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27 July 1995
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7 MAY 1993

# MILITARY STANDARD

## INTEROPERABILITY STANDARD FOR DIGITAL MESSAGE TRANSFER DEVICE SUBSYSTEMS

AMSC N/A

AREA TCSS

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# FOREWORD

This document specifies the lower layer (Physical through Intranet) protocol for interoperability of command, control, communications, computers, and intelligence ($C^4I$) systems over combat net radio (CNR) on the battlefield. This protocol provides the necessary information required to pass digital data via CNR on the battlefield. The Internet and Transport protocol required for seamless communications with different network media is provided in MIL-STD-2045-14502-1.

This MIL-STD shall be used for all inter-and intra-Department of Defense (DoD) digital message transfer devices (DMTDs) and $C^4I$ systems that exchange information with DMTDs. The MIL-STD contains technical parameters for the data communications protocols that support DMTD interoperability. It provides mandatory system standards for planning, engineering, procuring, and using DMTDs in tactical digital communications systems.

When approved, this standard shall be used by the Office of the Secretary of Defense, the military departments, the Joint Chiefs of Staff, the unified and specified commands, DoD agencies and DoD field activities in accordance with DoD Instruction 5000.2, dated 23 February 1991.

Beneficial comments (specific recommendations, additions, deletions) and any pertinent data that may be of use in improving this MIL-STD should be addressed to:

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Fort Monmouth, New Jersey 07703-5613

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# 1. SCOPE

1.1 Purpose. This MIL-STD promulgates the minimum essential technical parameters in the form of mandatory system standards and optional design objectives for interoperability and compatibility among DMTDs, and between DMTDs and applicable $C^4I$ systems. These technical parameters are based on the data communications protocol standards specified herein to ensure interoperability.

1.2 Scope. This MIL-STD identifies the procedures, protocols, and parameters to be applied in specifications for DMTDs and $C^4I$ systems that exchange information with DMTDs. This MIL-STD addresses the communications protocols and procedures for the exchange of information among DMTDs, among $C^4I$ systems, and between DMTDs and $C^4I$ systems participating in inter- and intra-Service tactical networks. The material is presented in the context of the Open Systems Interconnection (OSI), as documented in national and international standards.

1.3 Application guidance. This MIL-STD applies to the design and development of new equipment and systems, and to the retrofit of existing equipment and systems.

1.4 System standards and design. The parameters and other requirements specified in this MIL-STD are mandatory system standards if the word shall is used in connection with the parameter value or requirement under consideration. Non-mandatory design objectives are indicated in parentheses after a standardized parameter value or by the word should in connection with the parameter value or requirement under consideration.

1.5 Tailoring. This MIL-STD is a compilation of selected options derived from military, commercial, and federal standards.

## 2. APPLICABLE DOCUMENTS

### 2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this MIL-STD to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the current issue of the DoD Index of Specifications and Standards (DoDISS) and supplements thereto, cited in the solicitation (see 6.2).

STANDARDS

FEDERAL

| | |
|---|---|
| FED-STD-1037 | Glossary of Telecommunication Terms |

MILITARY

| | |
|---|---|
| MIL-STD-188-100 (Series) | Common Long Haul and Tactical Communications System Technical Standards |
| MIL-STD-188-110 | Equipment Technical Design Standards for Common Long Haul/Tactical Data Modems |
| MIL-STD-188-114 | Electrical Characteristics of Digital Interface Circuits |
| MIL-STD-188-200 | System Design and Engineering Standards for Tactical Communications |
| MIL-STD-2045-14502-1 | Information Technology DoD Standardized Transport Profile -- Internet Transport Profile for DoD Communications. -- Part 1: Transport and Internet Services |

[Unless otherwise indicated, copies of federal and military standards are available from the Naval Publications and Forms Center, ATTN: NPODS, 5801 Tabor Avenue, Philadelphia, PA, 19120-5099.]

2.1.2 Other Government documents, drawings, and publications. None.

2.2 Non-Government documents. The following documents form a part of this MIL-STD to the extent specified herein. Unless otherwise specified, the issues of the documents that are DoD-adopted are those listed in the issue of the DoDISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DoDISS are the issues of the documents cited in the solicitation (see 6.2).

**INTERNATIONAL ORGANIZATION for STANDARDIZATION (ISO)**

ISO 3309 — Information Processing Systems -- Data Communication -- High-level Data Link Control Procedures -- Frame Structure.

ISO 7498 — Information Processing Systems -- Open Systems Interconnection -- Basic Reference Model.

ISO 7498 AD I — Information Processing Systems -- Open System Interconnection -- Basic Reference Model -- Addendum 1: Connectionless-mode transmission.

ISO 8802.2 — Information Processing Systems -- Local Area Networks -- Part 2: Logical Link Control.

ISO 8802-2/DAM 2 — Information Technology -- Local Area Networks -- Logical Link Control -- Amendment 2: Acknowledged Connectionless-mode Service and Protocol, Type 3 Operation.

ISO 8885 — Information Processing Systems -- Data Communications -- High-level Data Link Control Procedures -- General Purpose XID Frame Information Field Content and Format.

[ISO standards are available from the American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.]

**International Telecommunications Union (ITU)**

Formerly known as International Telephone and Telegraph Consultative Committee (CCITT)

CCITT V.10 — Electrical Characteristics for Unbalanced Double-Current Interchange Circuits for General Use with Integrated Circuit Equipment in the Field of Data Communications.

CCITT V.33 — 14,400 Bits Per Second Modem Standardized for Use on Point-to-Point 4-wire Leased Telephone-Type Circuits.

CCITT V.36 — Modems for Synchronous Data Transmission Using 60-108 kHz Group Band Circuits.

CCITT X.21 Interface Between Data Terminal Equipment (DTE) and Data Circuit-Terminating Equipment (DCE) for Synchronous Operation on Public Data Networks

[CCITT standards are available from Omnicom, 115 Park Street, South East, Vienna, VA 22180]

2.3 Order of precedence. In the event of a conflict between the text of this MIL-STD and the references cited herein, the text of this MIL-STD takes precedence. Nothing in this MIL-STD, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

# 3. DEFINITIONS

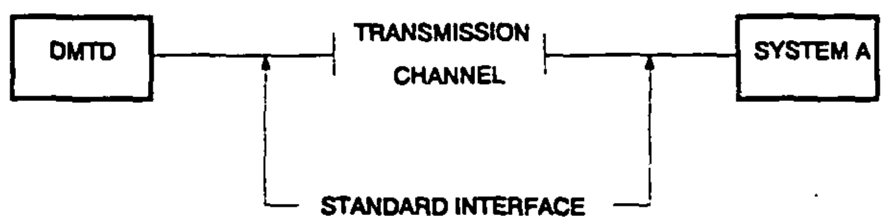
3.1 Definitions of terms. Definitions of terms used in this MIL-STD are specified in FED-STD-1037.

3.2 Abbreviations and acronyms. Abbreviations and acronyms used in this MIL-STD are defined in Appendix A. Those listed in the current edition of FED-STD-1037 have been included for the convenience of the reader.

# 4. GENERAL REQUIREMENTS

4.1 Digital message transfer device. A DMTD is a portable data terminal device with limited message generation and processing capability. DMTDs are used for remote access to automated $C^4I$ systems and to other DMTDs. The environment encompasses point-to-point, point-to-multipoint, relay and broadcast transfer of information over data communications links.

4.2 Interoperability. Interoperability of DMTDs and associated $C^4I$ systems shall be achieved by implementing the standard interface for DMTD subsystems (see Figure 1) specified in this MIL-STD. This standard defines the layered protocols for the transmission of single or multiple segment messages over broadcast radio subnetworks and point-to-point links. It provides the minimum essential data communications parameters and protocol stack required to communicate with other data terminal devices. These communications parameters and protocols will facilitate functional interoperability among DMTDs, and between DMTDs and applicable $C^4I$ systems within the layered framework described below. Electrical and mechanical design parameters are design-dependent and are outside the scope of this MIL-STD. Interoperability considerations for terminal designers and systems engineers are addressed in 6.3.




NOTES:

1. DMTD and System A (where system A can be another DMTD or a C4I system) may include modems, line drivers, error control algorithms, encryption devices, control units, and other devices as required to comply with this MIL-STD.
2. The transmission channel may include single and multichannel transmission equipment.

FIGURE 1. Standard interface for DMTD subsystems.

4.3 Framework. The communications and procedural protocols used in DMTD equipment shall support the layers of the functional reference model depicted in Figure 2. The DMTD functional reference model in Figure 2 is based on the ISO 7498 OSI seven-layer model and is for reference only. Figure 2 contains the framework that is used in this MIL-STD for defining the protocols required to exchange information among DMTD subsystems, and between DMTD subsystems and applicable $C^4I$ systems. Figure 3 illustrates a representative time epoch of the basic frame structure supported by the DMTD subsystem. This standard describes the protocols at the following OSI layers:

1. Physical Layer

2. Data Link Layer
   a. Network Access Control
   b. Link Level Control

3. Network Layer (Intranet Layer)

It assumes MIL-STD-2045-14502-1 is implemented at the Network Layer and the Transport Layer. Based upon this assumption, a Segmentation/Reassembly protocol and procedures for multi-addressing using the Internet protocol (IP) option are described in MIL-STD-2045-14502-1.

| |
|---|
| Application Layer * |
| Presentation Layer * |
| Session Layer * |
| Transport Layer * |
| Network Layer |
| Data Link Layer |
| Physical Layer |

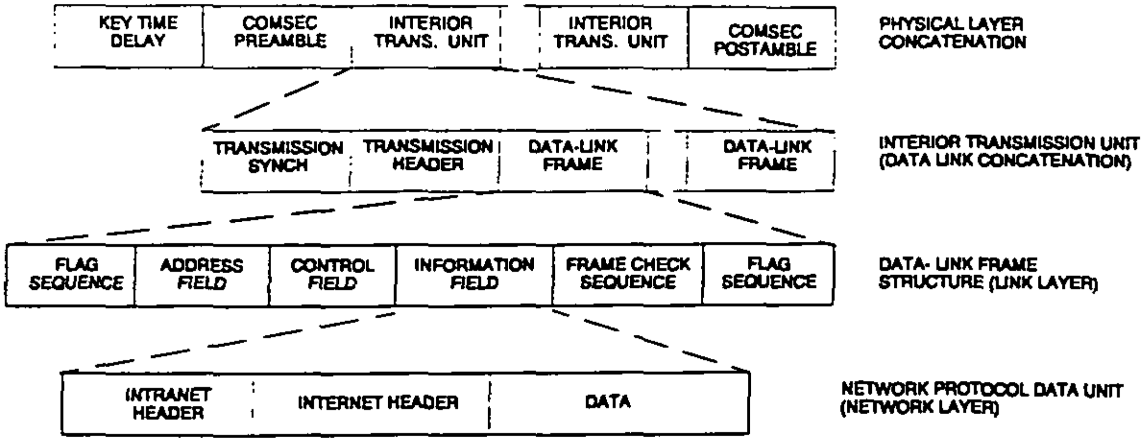
* NOTE: These layers are not addressed in this standard

Figure 2. DMTD functional reference model.

4.4 DMTD capabilities. The waveform and the protocols necessary to ensure end-to-end interoperability at the interface shall support the following capabilities:

a. Transmission in a half-duplex mode over radio, wire-line, and satellite links;

b. Link encryption;




NOTE:

The Network Protocol Data Unit may include an Internet Header in addition to the required Intranet Header. This standard does not specify requirements for the Internet Header.

Figure 3. Basic structure of DMTD protocol data units at the standard interface.

c. Point-to-point, multipoint, relay or broadcast connectivity between stations;

d. Asynchronous balanced mode of operation between two or more stations;

e. Network access control for network access management and collision avoidance;

f. Transport of bit-oriented or free-text (character-oriented) messages for information exchange in a variable message format over the link;

g. User data exchange using single or multiple frame packets;

h. Addressing conventions that support single, multiple, and global station broadcast addressing, as well as routing and relay;

i. Error control, for maintaining data integrity over the link, including frame check sequence (FCS), forward error correction (FEC), and time-dispersal coding (TDC);

j. Data-link frame acknowledgment, intranet frame acknowledgement and end-to-end, segment acknowledgement at the transport layer;

k. Intranet relay at the network layer; and

l. Topology update capability for the intranet.

# 5. DETAILED REQUIREMENTS

5.1 Physical layer. The physical layer shall provide the control functions required to activate, maintain, and deactivate the connections between communications systems. This standard does not address the electrical or mechanical functions normally associated with physical layer protocols.

5.1.1 Transmission channel interfaces. The transmission channel interfaces specified below define the transmission envelope characteristics (signal waveform, transmission rates, and operating mode) authorized at the standard interface between a DMTD and the transmission channel. The transmission channel may consist of wireline, satellite, or radio links.

5.1.1.1 Non-return-to-zero interface. This interface shall be used primarily with digital transmission equipment. A non-return-to zero (NRZ) signal waveform shall be used for this interface.

5.1.1.1.1 Waveform. The NRZ unbalanced and balanced waveforms shall conform to paragraphs 5.1.1.7 and 5.2.1.7, respectively, of MIL-STD-188-114A.

5.1.1.1.2 Transmission rates. The output transmission rates of the NRZ interface shall be the following bit rates: 75, 150, 300, 600, 1200, 2400, 4800, 9600, and 16000 bits per second (bps).

5.1.1.1.3 Operating mode. The NRZ interface shall support half-duplex transmission.

5.1.1.2 Frequency-shift keying interface for voice frequency channels. This interface may be used. It is primarily associated with analog single-channel [3-kilohertz (Khz)] radio equipment. The frequency-shift keying (FSK) data modem characteristics shall conform to paragraph 5.2.2 of MIL-STD-188-110.

5.1.1.2.1 Waveform. The FSK modulation waveform shall conform to paragraph 5.2.2.1 of MIL-STD-188-110. The characteristic frequencies, in hertz (Hz), for transmission rates of 600 bps or less, and 1200 bps, shall be as shown in Table I.

5.1.1.2.2 Transmission rates. Output transmission rates of the FSK interface shall be the following bit rates: 75, 150, 300, 600, and 1200 bps.

5.1.1.2.3 Operating mode. The FSK interface shall support half-duplex transmission.

Table I. Characteristic frequencies of frequency-shift keying interface for voice frequency channels.

| PARAMETER | CHARACTERISTIC FREQUENCY (Hz) | |
|---|---|---|
| | 600 bps or less | 1200 bps |
| Mark Frequency | 1300 | 1300 |
| Space Frequency | 1700 | 2100 |

5.1.1.3 Frequency-shift keying interface for single-channel radio. This interface, used within DoD, may also be used for North Atlantic Treaty Organization (NATO) single-channel radio applications. The FSK interface data modem characteristics shall conform to paragraph 5.1 of MIL-STD-188-110.

5.1.1.3.1 Waveform. The FSK modulation waveform shall conform to paragraphs 5.1.1 and 5.1.2 of MIL-STD-188-110. The characteristic frequencies are specified in Table II.

Table II. Characteristic frequencies of frequency-shift keying interface for single-channel radio.

| PARAMETER | CHARACTERISTIC FREQUENCY (Hz) |
|---|---|
| Mark Frequency | 1575 |
| Space Frequency | 2425 |

5.1.1.3.2 Transmission rates. Output transmission rates of the single-channel FSK interface shall be the following bit rates: 75, 150, 300, 600, and 1200 bps.

5.1.1.3.3 Operating mode. The single-channel FSK interface shall support half-duplex transmission.

5.1.1.4 Conditioned diphase (CDP) interface. This interface may be used. It is primarily associated with wideband wireline equipment.

5.1.1.4.1 Waveform. The CDP modulation waveform shall conform to paragraph 5.4.1.4 of MIL-STD-188-200. The unbalanced and balanced signal waveform shall conform to paragraphs 5.1.1.7 and 5.2.1.7, respectively, of MIL-STD-188-114.

5.1.1.4.2 Transmission rates. The output transmission rate of the CDP interface shall be 16 and 32 kilobits per second (kbps).

5.1.1.4.3 Operating mode. The CDP interface shall support half-duplex transmission.

5.1.1.5 Differential phase-shift keying interface for voice frequency channels. This interface may be used. It is primarily associated with analog (nominal 4-Khz voice frequency) wireline and radio equipment. Differential phase-shift keying (DPSK) modulation data modem (2400 bps) and phase-shift keying (PSK) modulation data modem (1200 bps) characteristics shall conform to the applicable requirements of MIL-STD-188-110.

5.1.1.5.1 Waveform. The DPSK modulation waveform shall conform to Appendix A of MIL-STD-188-110. The PSK modulation waveform shall conform to paragraph 5.3 of MIL-STD-188-110.

5.1.1.5.2 Transmission rates. The output transmission rate of the DPSK and PSK interfaces shall be 2400 and 1200 bps, respectively.

5.1.1.5.3 Operating mode. The DPSK and PSK interfaces shall support half-duplex transmission.

5.1.1.6 Packet mode interface. This interface shall use a modified CCITT X.21 half-duplex synchronous interface for transferring digital data across the interface between data terminal equipment (DTE) and data circuit-terminating equipment (DCE). The packet interface shall be a modified CCITT X.21 interface with a CCITT V.10 electrical circuit between a DTE (DMTD or $C^4I$ system) and the DCE.

5.1.1.6.1 Waveform. The electrical characteristics of the packet mode interface shall be identical to CCITT V.10 for interfaces to voice band modems.

5.1.1.6.2 Transmission rates. The DTE device shall be required to accept signal timing from the DCE (radio) at 16 Kbps. The DTE shall be required to synchronize to the DCE signal timing and accept data at the supplied signaling timing rate. In the packet mode, the radio provides signal timing to support 16 Kbps data transfers between the radio and the DTE.

5.1.1.6.3 Operating mode. The packet mode interface shall support half-duplex transmission.

5.1.1.7 Amplitude Shifting Keying (ASK). This interface may be used. It is used primarily with analog voice grade radios to transmit digital data.

5.1.1.7.1 Waveform. The ASK waveform is a band limited NRZ waveform with average white Gaussian noise added to it. The ASK signal shall be a bipolar signal nominally centered around ground. However due to the radio automatic gain control performance, the ASK signal may have a direct current (DC) component.

The ASK signal-to-noise ratio shall be in the range of 0 to 12 decibels (dB). The ASK signal shall be demodulated using a optimal bit synchronizer with a bit error rate performance of 1.5 dB from theoretical.

5.1.1.7.2 Transmission rates. The output transmission rates of the ASK interface shall be the following bit rates: 2400, 4800, 9600 and 16000 bits per second.

5.1.1.7.3 Operating mode. The ASK interfaces shall support half-duplex transmission.

## 5.2 Physical-layer protocol

5.2.1 Physical-layer protocol data unit. The transmission frame shall be the basic protocol data unit (PDU) of the physical layer and shall be as shown in Figure 4. Figure 4a presents the transmission frame structure for traditional COMSEC (backward-compatible mode). Traditional COMSEC is used in this MIL-STD to denote systems with the COMSEC equipment placed external to the DMTD. Figure 4b presents the transmission frame structure with COMSEC embedded in the DMTD (embedded mode). Figure 4c presents the transmission frame structure without COMSEC.

| COMSEC PREAMBLE | TRANSMISSION SYNCHRONIZATION | DATA FIELD | COMSEC POSTAMBLE |
|---|---|---|---|

Figure 4a. Transmission frame structure with external COMSEC.

| TRANSMISSION SYNCHRONIZATION WITH COMSEC MESSAGE INDICATOR | DATA FIELD | COMSEC POSTAMBLE |
|---|---|---|

Figure 4b. Transmission frame structure with embedded COMSEC.

| TRANSMISSION SYNCHRONIZATION | DATA FIELD |
|---|---|

Figure 4c. Transmission frame structure without COMSEC.

Figure 4. Transmission frame structure.

5.2.1.1 Communications security preamble and postamble. These fields are present when link encryption is used. The COMSEC preamble field shall be used to achieve cryptographic synchronization over the link. The COMSEC postamble field shall be used to provide an end-of-transmission flag to the COMSEC equipment at the receiving station. These fields and the COMSEC synchronization process are described in Appendix D.

5.2.1.2. Transmission synchronization field. The structure of the transmission synchronization field is dependent on the mode of operation. The three modes are Asynchronous for use with DCEs that present modulated data without a clock, Synchronous for use with DCEs that present a clock and data interface and Packet for use with DCEs that require no frame synchronization. The structures for Asynchronous and Synchronous modes are shown in Figure 5. The structure for the Packet Mode is described in 5.2.1.2.3.

5.2.1.2.1 Asynchronous mode transmission synchronization field. The Asynchronous Transmission Synchronization field shall be composed of the following:

a) Bit Synchronization
b) Robust Frame Synchronization (Optional)
c) Robust Frame Format (Optional)
d) Frame Synchronization (Conditional)
e) Message Indicator (embedded COMSEC only)
f) Transmission Word Count

5.2.1.2.1.1 Bit synchronization subfield. This subfield shall be used to provide the receiver a signal for achieving bit synchronization. Bit synchronization is used only in Asynchronous Mode with embedded COMSEC and no COMSEC. The duration of the bit synchronization subfield shall be a variable time from 0 to 10 seconds in 10 millisecond increments. For asynchronous transmission, the minimum bit synchronization subfield shall be a 64 bit pattern that consists of alternating ones and zeros, beginning with a one.

5.2.1.2.1.2 Robust frame synchronization subfield. This subfield shall consist of the fixed 64-bit synchronization pattern shown in Figure 6. After the Bit Synchronization Subfield is recognized, the receiver shall correlate for the synchronization pattern. A pattern shall be detected if 13 or fewer bits are in error with non-inverted or inverted data. If the correlation detects an inverted synchronization pattern, all received data shall be inverted before any other received processing is performed. After the synchronization pattern is detected, the frame format subfield shall be decoded to determine what physical level processing is required for data reception. If the robust frame synchronization pattern shown in Figure 6 is used, the frame synchronization pattern described in 5.2.1.2.1.5 shall not be used. If the frame synchronization subfield described in 5.2.1.2.1.5 is detected before the robust frame synchronization

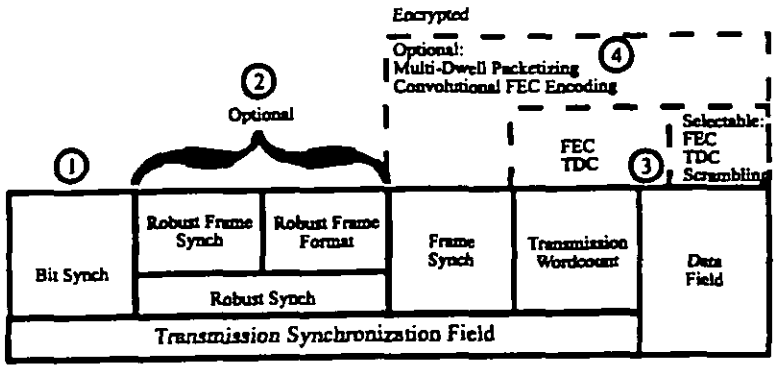



Figure 5a. With External COMSEC or No COMSEC

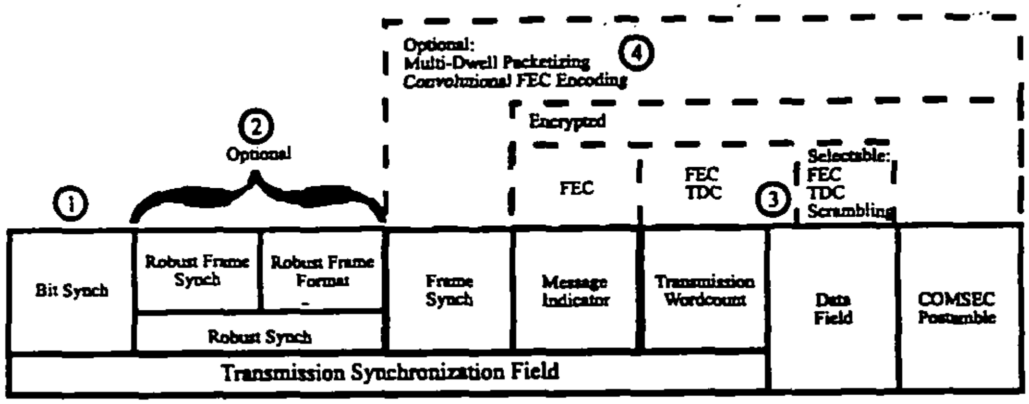



Figure 5b. With Embedded COMSEC

NOTES

1. Bit Synch is used only in Asynchronous Mode with Embedded COMSEC and No COMSEC.
2. Optional Robust Frame Synch is available only in Asynchronous Mode. When Robust Frame Synch is used, Frame Synch shall not be used.
3. Golay FEC/TDC are applied to the Transmission Wordcount, Message indicator and Transmission Header fields in Asynchronous and Synchronous Modes. (The Transmission Header is the leading portion of the data field as described in 5.3.1.)
4. Optional Multi-Dwell Packetizing and Convolutional FEC Encoding are available only in Asynchronous Mode.

Figure 5. Transmission synchronization field.

subfield, the receiver shall assume the optional robust processing is not requested for this transmission.

| LSB | MSB |
|---|---|
| 0100100111001100111011011011111100000010011011010101111000111000 | |

Figure 6. Robust frame synchronization subfield.

5.2.1.2.1.3 Robust frame format subfield. The robust frame format subfield is a seven bit field which specifies the format of the transmitted frame. The robust frame format subfield shall be formatted with multi-dwell majority vote 3 out of 5 Bose-Chaudhari-Hocquenghem (BCH) (15, 7) coding and no scrambling or convolutional encoding. The bits are defined in Tables III, IV and V.

Table III. Robust frame format.

| Bit(s) | Fields |
|---|---|
| 0 (LSB) | Multi-Dwell Flag |
| 1 | Scrambling Flag |
| 2, 3, 4 | Multi-Dwell Transmission Format |
| | |
| 5,6 | Convolutional Coding Constraint Length |

Table IV. Multi-dwell transmission format.

| | |
|---|---|
| 000 | Single BCH(15,7) word<br>32 BIT SOP<br>11 64-bit segments per packet |
| 001 | Majority Vote 2 out of 3 BCH(15,7) word<br>64 BIT SOP<br>11 64-bit segments per packet |
| 010 | Majority Vote 3 out of 5 BCH(15,7) word<br>64 BIT SOP<br>13 64-bit segments per packet |
| 011 | Majority Vote 3 out of 5 BCH(15,7) word<br>64 BIT SOP<br>6 64-bit segments per packet |

Table V. Convolutional coding constraint length codes.

| | |
|---|---|
| 00 | Constraint Length 3 |
| 01 | Constraint Length 5 |
| 10 | Constraint Length 7 |
| 11 | Convolutional Coding Disabled |

5.2.1.2.1.4 Multi-dwell protocol. The multi-dwell protocol provides the capability to transmit data over frequency hopping radios without internal buffering. The multi-dwell protocol is described in Appendix J.

a. The multi-dwell start of packet (SOP) header size and segment count redundancy are configured depending upon the channel environment and are not changed on a per transmission basis.

b. The upper layer indicates the size of the transmission in the PL-Unitdata Request data length. The physical layer shall use the data length information to determine the most efficient multi-dwell parameters to use for data transmission. The optional multi-dwell segment count may be used by the upper layer to override the automatic determination of the multi-dwell transmission parameters made by the physical layer. For a multi-dwell reception, the upper layer will use the timing of the transition of the PL-Status Indication Network Activity from "busy with data" to "clear" to indicate the time of reception of the last bit of data.

5.2.1.2.1.5 Frame synchronization subfield. This subfield shall consist of the fixed 64-bit synchronization pattern shown in Figure 7. After the bit synchronization field is recognized, the

| LSB | MSB |
|---|---|
| 0110010011110010111100101001011010010000010111101010110111011001 | |

Figure 7. Frame synchronization pattern.

receiver shall correlate for the frame synchronization pattern. A pattern shall be detected if 13 or fewer bits are in error with non-inverted or inverted data. If the correlation detects an inverted frame synchronization pattern, all received data shall be inverted before any other received processing is performed. If the robust frame synchronization pattern shown in Figure 6 is used, the frame synchronization pattern shown in Figure 7 shall not be used.

5.2.1.2.1.6 Message indicator. The message indicator field is contained within the transmission synchronization field only when COMSEC is embedded in the host. The message indicator field is defined in Appendix D (D5.1.1.3 and D5.2.3). Golay forward error correction (FEC) is applied to the TWC, Message Indicator (with embedded COMSEC) and Transmission Header in Asynchronous and Synchronous Modes.

5.2.1.2.1.7 Transmission word-count (TWC) subfield. The TWC is a 12-bit value calculated by the transmitting station to inform the receiving station of the number of 16-bit words (after any appropriate FEC encoding, TDC fill or zero bit insertion) that form the data field(s) of the transmission frame. The maximum TWC is 4095 ($2^{12}$-1). The value provided by the 12 information bits is binary-encoded. The maximum number of words is dependent on the maximum number of bits allowed in the data field of a transmission frame. It is possible that the number of bits in the data field will not be evenly divisible by 16. In that case, the word count shall be rounded to the next higher integer. TDC is applied to the TWC and Transmission Header in Asynchronous and Synchronous Modes. Golay FEC is applied to the TWC, Message Indicator (with embedded COMSEC) and Transmission Header in Asynchronous and Synchronous Modes.

5.2.1.2.2 Synchronous Mode Transmission Synchronization field. The Synchronous Transmission Synchronization field shall be composed of the following:

a) Frame Synchronization
b) Message Indicator
c) TWC

5.2.1.2.2.1 Frame Synchronization subfield. The Synchronous Mode Frame Synchronization subfield is the same as the Asynchronous Mode Frame Synchronization subfield defined in 5.2.1.2.1.5.

5.2.1.2.2.2 Message Indicator. The format of the Synchronous Mode Message Indicator field is the same as for the Asynchronous Mode Message Indicator field defined in 5.2.1.2.1.6.

5.2.1.2.2.3 Transmission Word Count. The Synchronous Mode TWC format is the same as the Asynchronous Mode TWC defined in 5.2.1.2.1.7.

5.2.1.2.3 Packet Mode Transmission Synchronization field. This field consists of at least 4 HDLC flags corresponding to the following bit pattern shown in Figure 8.

| LSB | MSB |
|---|---|
| 01111110011111100111111001111110 | |

Figure 8. Packet Mode Transmission Synchronization Field.

5.2.1.3 Data field. The data field shall contain the string of bits created by the data-link layer following the procedures for framing, zero bit insertion, concatenation, FEC, TDC, and scrambling. FEC, TDC and Scrambling are not applied when Packet Mode is used.

5.2.2 Keytime delay. Keytime delay (KT) is an element of the transmission equipment and one of the many variables that must be considered for some of the network access control schemes. KT is defined in Appendix C (C3.1.2).

5.2.3 Net access control related indications.

a. The net busy information is conveyed to the upper layer protocol (data link) through a status indication. Upon detection of a net busy, the net busy indicator shall be set. The net busy sensing indicator shall be reset when neither digital data nor voice is detected by the net busy sensing function. Appendix C (C3.1.1) describes the net busy sensing function.

b. The net access control algorithm described in Appendix C needs the transmitter to know when the last bit of data is transmitted, and the receiver to know when the last bit of data is received. The upper layer will use the timing of the transition of the PL-Status Indication Network Activity parameter from "busy with data" to "clear" to indicate the time of reception of the last bit of data. The upper layer shall use the timing of the transition of the PL-Status Indication Transmission Status parameter from "in process" to "transmission complete/idle" to indicate the time of transmission of the last bit of data

5.2.4 Physical-layer to upper-layer interactions. At least three primitives are used to pass information for the sending and receiving of data across the upper layer boundary.

a. Requests for transmission of data are sent by the upper layer, using the physical layer (PL) Unitdata Request primitive with the following parameter:

PL-Unitdata Request
- Data/Data length
- FEC/TDC/Scrambling
  - No FEC, No TDC, No Scrambling
  - No FEC, No TDC, Scrambling
  - FEC, No TDC, No Scrambling
  - FEC, No TDC, Scrambling
  - FEC, TDC, No Scrambling
  - FEC, TDC, Scrambling
- Multi-dwell segment count
  - 6 segments per packet
  - 11 segments per packet
  - 13 segments per packet

b. Indication of data received is provided to the upper layer through the Unitdata Indication primitive with the following parameter:

PL-Unitdata Indication
- Data/Data length
- FEC/TDC/Scrambling
  - No FEC, No TDC, No Scrambling
  - No FEC, No TDC, Scrambling
  - FEC, No TDC, No Scrambling
  - FEC, No TDC, Scrambling
  - FEC, TDC, No Scrambling
  - FEC, TDC, Scrambling
- Multi-dwell segment count
  - 6 segments per packet
  - 11 segments per packet
  - 13 segments per packet

c. Net activity status information is provided to the upper layer through a Status Indication with the following parameters:

PL-Status Indication
- Net activity
  - net clear
  - net busy
  - busy with/data
  - busy with/voice
- Transmission Status
  - transmit complete/idle
  - in-process
  - transmit aborted

5.3 Data-link layer. The data-link layer shall provide the control functions to ensure the transfer of information over established physical paths, to provide framing requirements for data, and to provide for error control. Zero bit insertion is applied to the Transmission Header and Data Link Frame.

5.3.1 Transmission Header. The Transmission Header is sent before each data field transmission. The Transmission Header consists of a two octet Transmission Information field, a 32-bit FCS, in accordance with paragraph 5.3.4.2.5, and is bounded by Flags in accordance with paragraph 5.3.4.2.1. The Transmission Information field contains Selection bits and a Transmission Queue subfield which indicates the transmitting station queue length. The Transmission Header format is shown in Figure 9. Golay FEC and TDC are applied to the entire Transmission Header (except when the Packet Mode Interface described in paragraph 5.1.1.6 is used at the Physical Layer), including leading and trailing flags, Message Indicator (with embedded COMSEC) and TWC. The TWC, Message Indicator and transmission header shall have Golay FEC applied when operating in the Asynchronous and Synchronous modes. TDC (7x24) bit interleaving shall be applied in unison with the FEC on the TWC and transmission header. The data shall be formatted into a TDC block composed of seven (7) 24-bit Golay (24,12) codewords in a manner analogous to 5.3.14.3. There are 168 FEC-encoded bits with this TDC.

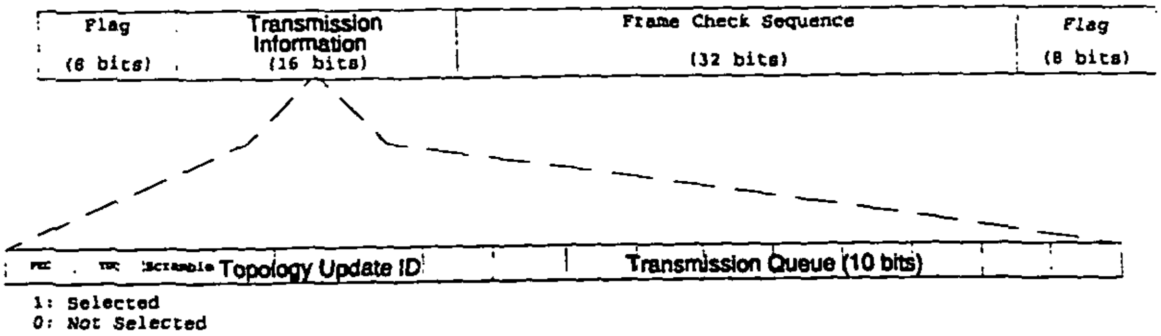



Figure 9. Transmission Header.

5.3.1.1 Selection bits. The first three bits of the Transmission Information field selects FEC, TDC and Scrambling, respectively, on or off for the remainder of the physical layer data field. A zero indicates "off" and a one indicates "on" in these bit positions. Regardless of the setting of these three bits, Golay FEC/TDC is applied and Scrambling is not applied to the entire Transmission Header. Scrambling, if used, shall be applied before any FEC and TDC is applied. FEC, TDC and scrambling are not applied when the Packet Mode Interface described in paragraph 5.1.1.6 is used at the Physical Layer.

5.3.1.2 Topology Update Identifier. This subfield shall contain the least significant three bits of the Topology Update ID used in the most recent Topology Update message (see 5.4.1.2). If no Topology Update messages have been sent, this subfield shall be all zeros.

5.3.1.3 Transmission queue subfield. This subfield is used to support the radio embedded net access delay (RE-NAD) process and the deterministic adaptable priority net access delay (DAP-NAD) process. The entire field is 10-bits long with the first two bits ('T'-bits) indicating how the rest of the subfield is interpreted. The format of the transmission queue subfield is shown in Figure 10.

5.3.1.3.1 T-bits. The two left-most bits in the transmission queue subfield are the T-bits. The bit sequence interpretations are indicated in Figure 10. The transmission queue subfield has a variable format depending on which of the following uses are intended:

a. T-bits = 00 The transmission queue subfield does not contain information and is ignored.

b. T-bits = 01 The transmission queue subfield is used in conjunction with RE-NAD. This subfield contains queue precedence (in bit positions 2-3) and queue length (bit positions 4-7). Bit positions 8 and 9 are spare and ignored.

c. T-bits = 10 The transmission queue subfield is used in conjunction with DAP-NAD. This subfield contains Data Link Precedence (in bit positions 2 and 3) and First Subscriber Number (in bit positions 4-9).

d. T-bits =11 This bit sequence is INVALID and shall be ignored. Data link frame(s) after this header shall be processed normally.

T-Bits

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | Transmission Queue Subfield Ignored | | | | | | | |
| 0 | 1 | Queue Prec. | | Queue Length | | | | spare | |
| 1 | 0 | Data Link Prec. | | First Subscriber Number | | | | | |
| 1 | 1 | Invalid/Ignored | | | | | | | |

Figure 10. Transmission queue subfield formats

5.3.1.3.2 Queue precedence. The queue precedence component indicates the highest precedence level of information type frames in the queue. The precedence levels and bit sequences are:

| | |
|---|---|
| Urgent | 00 |
| Priority | 01 |
| Routine | 10 |
| Reserved | 11 |

5.3.1.3.3 Queue length. The queue length component indicates the number of concatenated frame sequences required to transmit all of the highest priority messages in the transmission queue at the time the transmission was created. This number may be used by receiving station to calculate the average network member's queue length. This average is used in calculation of the continuous scheduler for the Radio Embedded channel access procedure (C3.4.4).

5.3.1.3.4 Data link precedence. This subfield consists of two bits and contains a value that indicates the highest priority of any message that is contained in the physical frame. It shall contain the value 0 if an urgent message is in the frame, 1 if a priority but no urgent message is in the frame and 2 if neither an urgent nor priority message is in the frame. The variable NP in the equations defined in Appendix C (C3.4.5.2) is either set equal to the contents of this field or to 0 for the next net access period depending upon the service desired. For higher throughput with only limited regard to message priority, the variable NP is set to the contents of the Data Link precedence field of the most recent reception. To ensure faster access by higher priority information, NP is set equal to the lowest value in any of the frames. The bit coding for Data Link precedence is shown below in Table VI. Undefined precedence values shall be handled as routine.

Table VI. Bit Coding for Data Link Precedence.

| Bit Pattern | Data Link Precedence |
|---|---|
| 00 | urgent |
| 01 | priority |
| 10 | routine |
| 11 | undefined |

5.3.1.3.5 First subscriber number. This subfield consists of 6 bits and designates the number of the subscriber that is to have the first net access opportunity at the next net access period (the one immediately following this transmission). The number of the subscriber that has the first net access opportunity is the variable FSN in the equations defined in Appendix C (C3.4.5.2). Bit coding for First subscriber number is shown in Table VII.

Table VII. Bit Coding for First Subscriber Number.

| Bit Code | First Subscriber Number |
|---|---|
| 000000 | Illegal |
| 000001 - 111111 | Station 1 - 63 |

5.3.2 Net access control. The presence of multiple subscribers on a single communications net requires a method of controlling the transmission opportunities for each subscriber. To minimize conflicts, the net busy sensing function and net access control (NAC) procedures regulate transmission opportunities for all participants on the net. Random - Net Access Delay (R-NAD), Hybrid - Net Access Delay (H-NAD), Prioritized - Net Access Delay (P-NAD), Radio Embedded Net Access Delay (RE-NAD) and Deterministic Adaptable Priority - Net Access Delay (DAP-NAD) shall be implemented as the authorized NAC procedures at this interface. Appendix C defines the NAC parameters for R-NAD, H-NAD, P-NAD, DAP-NAD, and RE-NAD.

5.3.2.1 Scheduler. When the net access is embedded in the radio, a scheduler may be implemented in the DTE or communications processor to organize radio access throughout the network. The scheduler is used to provide a random distribution of timing for channel requests. When a station has data to transmit, it shall calculate the scheduler timer as indicated in Appendix C (C3.4.4.1). When this timer expires, the link layer shall first determine that the previous frame concatenation was transmitted by the physical layer. If the frame concatenation was not transmitted, the link layer shall request its transmission. If a higher precedence individual frame becomes available for transmission, the concatenated frames shall be re-built to include the higher precedence frame. If the previous frame concatenation was transmitted, the link layer shall build a new frame concatenation. This frame concatenation shall then be passed to the physical layer for transmission. Both randomized and immediate scheduler modes are specified in Appendix C (C3.4.4.1.1 and C3.4.4.1.5, respectively).

5.3.3 Types of procedures. Four types of operation for data communication between systems are defined to provide basic connectionless and connection mode operations:

Type 1 - Unacknowledged Connectionless Operation
Type 2 - Connection-mode Operation
Type 3 - Acknowledged Connectionless Operation
Type 4 - Decoupled Acknowledged Connectionless Operation

Types and services 1 through 3 are based on ISO 8802-2. The Type 1 connectionless operations are mandatory for implementation in all systems. The Type 2 connection mode is optional for this interface. The Type 4 connectionless mode (decoupled ACK) is optional.

5.3.3.1 Type 1 operation. For the purpose of this protocol, Type 1 operation will designate both of the ISO 8802-2 connectionless operations (acknowledged and unacknowledged).

5.3.3.2 Type 2 operation. With Type 2 operation, a data-link connection shall be established between two systems prior to any exchange of information bearing PDUs. For efficiency at system startup, connections may be assumed to exist with all other stations in the network; and the system may depend on information transfer phase procedures to resolve error conditions. The connection normally shall remain open until a station leaves the net. The normal communications cycle between Type 2 systems shall consist of transferring PDUs from the source to the destination, and acknowledging receipt of these PDUs in the opposite direction.

5.3.3.3 Type 3 Operation. For the purpose of this protocol, Type 3 operation is included in Type 1 operation.

5.3.3.4 Type 4 operation. With Type 4 operation, acknowledgements are decoupled from the original Decoupled Information Acknowledgment (DIA) PDU, and DIA PDUs contain a non-modulus identification number assigned by the originator.

5.3.4 Data-link frame. The data-link frame shall be the basic protocol data unit (PDU) of the link layer. The transmission header is not a PDU.

5.3.4.1 Types of frames. Three types of frames convey data over the data-link: an unnumbered frame (U PDUs), an information frame (I PDUs) and a supervisory frame (S PDUs).

5.3.4.1.1 Unnumbered frame. The U PDUs shall be used for Type 1, Type 2 and Type 4 operations. They provide connectionless information transfer for Types 1 and 4 operations. PDUs provide acknowledgment, and station identification/status information for Type 1 operations. They also provide data-link control functions for Type 1 through 4 operations.

5.3.4.1.2 Information frame. The I PDUs are used for information transfer in Type 2 operations only. They convey user data or message traffic across a link. The I PDUs are not used in Type 1 operations.

5.3.4.1.3 Supervisory frame. The S PDUs are optional and are used for data-link supervisory control functions and to acknowledge received I PDUs in Type 2 operations. Additionally, the Type 4 Decoupled Receive Ready (DRR) response S PDU is used to acknowledge Type 4 DIA PDUs. The S PDUs are not used in Type 1 operations.

5.3.4.2 Data-link frame structure. The basic elements of the data-link frame shall be the opening flag sequence, the address field, the control field, the information field, the FCS, and the closing flag sequence. Each Type 1, Type 2 and Type 4 data-link frame shall be structured as shown in the data link frame portion of Figure 11.

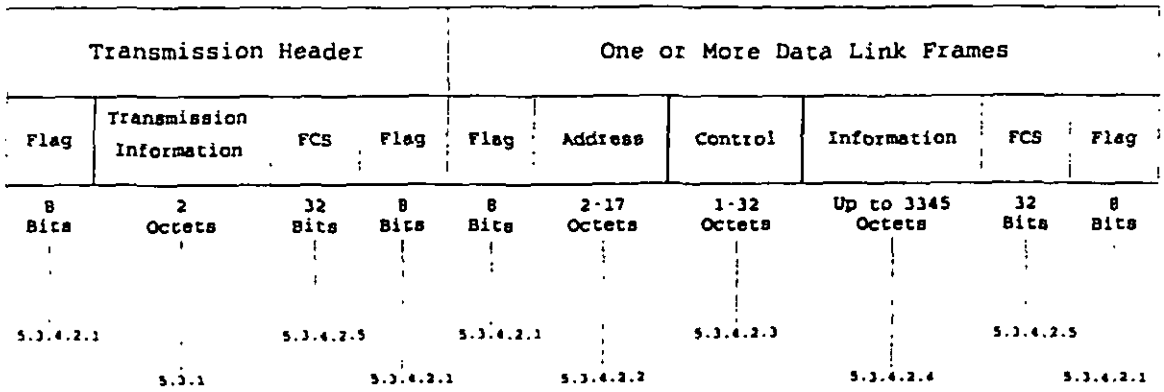



Figure 11. Data Link Frame Structure and Placement.

5.3.4.2.1 Flag sequence. All frames shall start and end with the 8-bit flag sequence of one 0 bit, six 1 bits, and one 0 bit (01111110). The flag shall be used for data-link frame synchronization.

5.3.4.2.2 Address fields. These fields shall identify the link addresses of the source and destinations.

5.3.4.2.2.1 Address format. Each address in the address fields shall consist of a single octet. The source address octet shall consist of a command/response (C/R) designation bit [the least significant bit (LSB)] followed by a 7-bit address representing the source. Each destination octet shall consist of an extension bit (the LSB) followed by the 7-bit destination address. The destination address uses a modification of the High-Level Data-link Control (HDLC) extended addressing format. The destination address shall be extended by setting the extension bit of a destination address octet to 0, indicating that the following octet is another destination address. The destination address field shall be terminated by an octet that has the extension bit set to 1. The destination address field shall be extendible from 1 address octet to 16 address octets. The format of the address fields shall be as shown in Figure 12.

5.3.4.2.2.2 Addressing convention. The following addressing conventions shall be implemented in the 7 address bits of each address octet. Address allocations, as shown in Figure 13, are divided among five address types: individual, group, global, special, and reserved.

NOTE: Source and destination addresses are assigned by an administrative authority.

| LSB | | | | | | | MSB | |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| 0/1 | X | X | X | X | X | X | X | SOURCE Octet (1 = response; 0 = command) |
| 0 | X | X | X | X | X | X | X | DESTINATION 1 Octet |
| . | | . . | | | | | | |
| . | | . . | | | | | | |
| . | | . . | | | | | | |
| 1 | X | X | X | X | X | X | X | DESTINATION M Octet where M ≤ 16 |

Figure 12. Extended address field format.

| LSB | | | | | | | MSB | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 127 | Global Multicast Address |
| X | X | X | X | X | X | 1 | 1 | 96-126 | Group Multicast Addresses |
| X | X | X | X | X | X | X | X | 3-95 | Individual Addresses |
| X | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | Special (Net Control) Address |
| X | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | Special (Net Entry) Address |
| X | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Reserved Address |

Figure 13. Address allocation.

5.3.4.2.2.2.1 Source and destination.

5.3.4.2.2.2.1.1 Source address. The source address is either an individual or special (Net Control or Net Entry) address and is always the first address. Its legal values range from 1 to 95. The source address has two parts: the C/R designation bit (bit 1, LSB) and the actual 7-bit address value. The C/R designation bit shall be set to 0 for commands and 1 for responses.

5.3.4.2.2.2.1.2 Destination address(es). The second through seventeenth address bytes are labeled destination addresses, which may be global, group, individual, or special addresses. Each destination address is contained in an 8-bit field, which has two parts: the extension bit (bit 1, LSB) and the actual 7-

bit address value. An extension bit set to 0 indicates that 1 or more addresses follow. An extension bit set to 1 indicates the last address of the address string has been reached.

5.3.4.2.2.2.2 Types of addresses. The following paragraphs describe the five types of addresses and how they shall be used.

5.3.4.2.2.2.2.1 Reserved address. Address 0 is labeled a reserved address. A station receiving a value of 0 in the destination address field shall ignore the address and continue processing any remaining addresses.

5.3.4.2.2.2.2.2 Special addresses. Addresses 1 and 2 are labeled special addresses. These addresses are provided as net control and unit entry addresses for units entering a new net without knowledge of actual addresses being used. Special addresses are used as described in Appendix E (E4.1.2).

5.3.4.2.2.2.2.3 Individual addresses. Individual addresses uniquely identify a single station on a broadcast subnetwork. Individual addresses shall be assigned within the address range 3 to 95. Stations shall be capable of sending and receiving 1 to 16 individual destination addresses in a single data-link frame. Sending stations shall not use any individual address more than once in a data link frame. When individual address(es) are present, a receiving station shall receive all addresses, search for its unique individual address, and follow the media access procedures described in Appendix C.

5.3.4.2.2.2.2.4 Group multicast addresses. Group multicast addressing, used when broadcasting messages to multiple (but not all) stations on a broadcast subnetwork, may be implemented. The valid address range shall be 96 to 126. Assignment of membership to (or deletion from) a group is outside the scope of this protocol. While the use of link group multicast addresses is optional, all stations shall be capable of recognizing received group addresses. If a receiving station does not implement group addressing procedures, it shall still process all received addresses, but ignore the group addresses (that is, recognize range 96 to 126 as group addresses). When group addressing is implemented, a station shall be capable of sending and receiving 1 to 16 destination group addresses. Coupled data link acknowledgment of group multicast addresses using the F-bit shall not be allowed. An uncoupled TEST response PDU with its F-bit set to zero shall be sent in response to a TEST command PDU addressed to a group multicast address when the receiving station is a member of the specified group.

5.3.4.2.2.2.2.5 Individual and multicast addresses mixed. A station that optionally implements multicast (group and global) addressing shall also be capable of sending and receiving both multicast and individual addresses "mixed" in a destination address subfield. Only one type of multicast (group or global) shall be mixed in a destination address subfield. All stations shall be capable of receiving mixed addresses. The total number of destination addresses shall not exceed 16. If both multicast and individual addresses are mixed, only the individual addresses are acknowledged when indicated. Multicast addresses shall not be acknowledged. In addition, individual addresses shall precede multicast addresses. The reception and acknowledgment procedures stated in this paragraph shall be valid even for stations that do not implement multicast addressing procedures.

5.3.4.2.2.2.2.6 Global multicast addressing. Global multicast addressing, used when broadcasting messages to all systems on a broadcast subnetwork, shall be implemented through the unique bit pattern 1111111 (127). If the global address is used, it shall be the only multicast destination address, but individual addresses are allowed with the global address. All broadcast stations shall be capable of receiving and sending this address, and all stations will process the information contained within the frame. Data-link acknowledgment of the global address shall not be allowed, except for the TEST Response PDU. Coupled data link acknowledgment of the global address using the F-bit shall not be allowed. An uncoupled TEST response PDU with its F-bit set to zero shall be sent in response to a TEST command PDU addressed to the global address.

5.3.4.2.2.3 Mapping. A link address is a point of attachment to a broadcast network. The upper-layer protocol is responsible for mapping one or more upper-layer addresses to a data-link address. Multiple upper-layer addresses may map to one or more group or individual addresses.

5.3.4.2.3 Control field. The control field indicates the type of PDU and the response requirements and connection information about the PDU being transmitted over the data link. A summary of the formats and bit patterns (showing LSB as the left most bit) for Types 1, 2 and 4 is shown in Tables VIII, IX and X, respectively. Figure 14 illustrates the data-link PDU control field formats.

5.3.4.2.3.1 Type 1 operations. For Type 1 operations, the control field is an 8-bit pattern designating 1 of 5 types of U PDUs. The URR and URNR PDUs are used to indicate overall station status.

5.3.4.2.3.2 Type 2 operations. The Type 2 control field is a 16-bit pattern for I PDUs and S PDUs and includes sequence numbers. The Type 2 U PDUs have an 8-bit pattern. The Type 2 control field shall be repeated if more than one destination address is present. Each destination address field shall have a corresponding control field. Each of the corresponding control fields (when repeated) shall be identical except for the P/F bit and sequence numbers. The Unnumbered Receive Ready (URR) and Unnumbered Receive Not Ready (URNR) PDUs with single control field are used to indicate overall station status. The RR and RNR are used to indicate station status for Type 2 operations only.

5.3.4.2.3.3 Type 4 operations. The Type 4 control field is a 16-bit pattern for U PDUs and S PDUs, and includes identification numbers. The control field distinguishes between a DIA PDU with a frame identification number and four S PDUs used in a connectionless environment with decoupled acknowledgements. The URR and URNR with single octet control field are used to indicate overall station status. The DRR and Decoupled Receive Not Ready (DRNR) PDUs are used to indicate station status for Type 4 operations only.

Table VIII. Type 1 PDU formats.

| COMMANDS/ RESPONSES | ADDRESS FIELD | CONTROL FIELD The left-most bit is the least significant bit. | INFORMATION FIELD |
|---|---|---|---|
| XID PDU | | | |
| EXCHANGE IDENTIFICATION (XID) COMMAND MESSAGE | Contains source address and up to 16 individual addresses, group address, special net entry address, special net controller address, or the global address. | Variable Bit pattern = 1111X101<br><br>(X represents the P/F bit settings) | This field follows the ISO 8885 format for XID commands and responses. It is used to supply or request link management information. Appendix E details the information field structure. |
| EXCHANGE IDENTIFICATION (XID) RESPONSE MESSAGE | Contains source address and address of the sender of the command message. | Bit pattern = 1111X101 | |
| UI PDU | | | |
| ACKNOWLEDGMENT REQUIRED | Contains the source address and up to 16 individual, group or global link addresses of agencies for which the message is intended. | Bit pattern = 11001000 identifies this frame as a UI PDU requiring acknowledgment. | Contains data from the upper protocol layer. |
| ACKNOWLEDGMENT NOT REQUIRED | Contains the source address and up to 16 destination (group, global and/or individual mixed) addresses of agencies for which the message is intended. | Bit pattern = 11000000 identifies this frame as a UI PDU not requiring acknowledgment. | Contains data from the upper protocol layer. |

Table VIII. Type 1 PDU formats (Concluded).

| COMMANDS/ RESPONSES | ADDRESS FIELD | CONTROL FIELD The left-most bit is the least significant bit. | INFORMATION FIELD |
|---|---|---|---|
| Status PDU | | | |
| UNNUMBERED RECEIVE READY (URR) COMMAND | Contains source address, and individual, group, or global addresses. | Bit pattern = 11000100 indicating receive ready command. | No information field allowed. |
| UNNUMBERED RECEIVE READY (URR) RESPONSE | Contains source address and the address contained in the source subfield of a received UI PDU, which this frame acknowledges. | Bit pattern = 11001100 indicating last UI PDU is acknowledged. | No information field allowed. |
| UNNUMBERED RECEIVE NOT READY (URNR) COMMAND | Contains source address and individual, group, or global addresses of agencies that are to stop transmitting I and UI PDUs to the agency generating this frame. | Bit pattern = 11010000 indicating receive not ready command. | No information field allowed. |
| UNNUMBERED RECEIVE NOT READY (URNR) RESPONSE | Contains source address and destination to which this response is being sent. | Bit pattern = 11011000 indicating receive not ready response. | No information field allowed. |
| TEST COMMAND | Contains source address and the individual, group, or global address of agencies that are to respond. | Bit pattern = 1100X111 | Information field optional. |
| TEST RESPONSE | Contains source address and destination to which this response is being sent. | Bit pattern = 1100X111 | Information field optional. |

Table IX. Type 2 PDU formats.

| COMMANDS/ RESPONSES | ADDRESS FIELD | CONTROL FIELD The left-most bit is the least significant bit. | INFORMATION FIELD |
|---|---|---|---|
| U PDUs | | | |
| UNNUMBERED ACKNOWLEDGMENT (UA) RESPONSE | Contains source address and up to 16 individual link addresses of stations to receive this PDU. | Bit pattern = 1100X110 | No information field allowed. |
| SET ASYNCHRONOUS BALANCED MODE EXTENDED (SABME) COMMAND | Contains source address and up to 16 individual link addresses of stations to receive this PDU. | Bit pattern = 1111X100 | No information field allowed. |
| RESET (RSET) COMMAND | Contains source address and up to 16 individual link addresses of stations to receive this PDU. | Bit pattern = 11111001 | No information field allowed. |
| FRAME REJECT (FRMR) RESPONSE | Contains source address and up to 16 individual link addresses of stations to receive this PDU. | Bit pattern = 1110X001 | See Figure 19. |
| DISCONNECT MODE (DM) RESPONSE | Contains source address and up to 16 individual link addresses of stations to receive this PDU. | Bit pattern = 1111X000 | No information field allowed. |
| DISCONNECT (DISC) COMMAND | Contains source address and up to 16 individual destination addresses. | Bit pattern = 1100X010 | No information field allowed. |
| I PDU | | | |
| ACKNOWLEDGMENT OR OTHER APPROPRIATE RESPONSE REQUIRED | Contains source address and up to 16 individual and/or group or global addresses of agencies for which the message is intended. | Bit pattern = 0SSSSSSSXRRRRRRR. Identifies this frame as an I PDU. | Contains data from the upper layer protocol. |

Table IX. Type 2 PDU formats (Concluded).

| COMMANDS/ RESPONSES | ADDRESS FIELD | CONTROL FIELD The left-most bit is the least significant bit. | INFORMATION FIELD |
|---|---|---|---|
| S PDUs | | | |
| RECEIVE READY (RR) COMMAND | Contains source address and up to 16 individual addresses. | Bit pattern = 10000000XRRRRRRR, indicating receive ready command. | No information field allowed. |
| RECEIVE READY (RR) RESPONSE | Contains source address and up to 16 individual link addresses of stations to receive this PDU. | Bit pattern = 10000000XRRRRRRR, indicating last I PDU is acknowledged. | No information field allowed. |
| RECEIVE NOT READY (RNR) COMMAND | Contains source address and up to 16 individual link addresses of stations to receive this PDU. | Bit pattern = 10100000XRRRRRRR, indicating receive not ready command. | No information field allowed. |
| RECEIVE NOT READY (RNR) RESPONSE | Contains source address and up to 16-individual link addresses of stations to receive this PDU. | Bit pattern = 10100000XRRRRRRR, indicating receive not ready. | No information field allowed. |
| SELECTIVE REJECT (SREJ) COMMAND AND RESPONSE | Contains source address and up to 16 individual link addresses of stations to receive this PDU. | Bit pattern = 10110000XRRRRRRR. | No information field allowed. |
| REJECT (REJ) COMMAND AND RESPONSE | Contains source address and up to 16 individual link addresses of stations to receive this PDU. | Bit pattern = 10010000XRRRRRRR. | No information field allowed. |

(X represents the P/F bit setting, S represents send sequence number, and R represents receive sequence number.)

Table X. Type 4 PDU Formats

| COMMANDS/ RESPONSES | ADDRESS FIELD | CONTROL FIELD The left-most bit is the least significant bit. | INFORMATION FIELD |
|---|---|---|---|
| U PDUs | | Bit pattern - | |
| DIA ACK Req'd | Contains source address and up to 16 individual and/or group or global link addresses for which the message is intended. | 110101LL<-ID #-> L-bits are used to indicate PDU precedence | Contains data from the upper layer protocol. |
| S PDU | | | |
| DRR resp | Contains source address and individual address for the originator of the DIA PDU which this PDU ACKs. | 100010LL<-ID #-> L-bits are used to indicate precedence of PDU being ACK'd. The ID no. is that of the DIA PDU being ACK'd. | No information field allowed |
| DRR cmd | Contains source address and individual and/or group or global addresses | 1000100000000000 indicates a station is ready to receive DIA PDUs. | No information field allowed |
| DRNR resp | Contains source address and individual address for the originator of the DIA PDU, which this PDU acknowledges | 101010LL<-ID #-> indicates a station is not ready to receive DIA PDUs due to a busy condition. L-bits are used to indicate precedence of PDU being ACK'd. The ID no. is that of the DIA PDU being ACK'd. | No information field allowed |
| DRNR cmd | Contains source address and individual and/or group or global addresses | 1010100000000000 indicates a station is not ready to receive DIA PDUs due to a busy condition. | No information field allowed |

| | | 1 (LSB) | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 through 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| INFORMATION TRANSFER COMMAND RESPONSE (I PDU) | Type 2 | 0 | N(S) | | | | | | | P/F | N(R) |
| SUPERVISORY COMMANDS/RESPONSES (S PDUs) | Type 2 | 1 | 0 | S | S | Z | Z | Z | Z | P/F | N(R) |
| | Type 4 | 1 | 0 | S | S | 1 | 0 | L | L | | ID Number |
| UNNUMBERED COMMANDS/RESPONSES (U PDUs) | Types 1 & 2 | 1 | 1 | M | M | P/F | M | M | M | | |
| | Type 4 | 1 | 1 | 0 | 1 | 0 | 1 | L | L | | ID Number |

Figure 14. Data-link PDU control field formats.

Note:

The left-most bit is the first bit delivered to and received from the physical layer.

N(S) = Transmitter send sequence number (Bit 2 = LSB)
N(R) = Transmitter receive sequence number (Bit 10 = LSB)
S = Supervisory Function bit
M = Modifier function bit
Z = Reserved and set to zero
P/F = Poll bit - command PDU transmissions
Final bit - response PDU transmissions
(1 = Poll/Final)
L = Level of precedence
1 1 = reserved
1 0 = routine
0 1 = priority
0 0 - urgent

5.3.4.2.3.4 Poll/final bit. The Poll/final (P/F) bit serves a function in both command and response PDUs. In command PDUs, the P/F bit is referred to as the P-bit. In response PDUs, it is referred to as the F-bit. The P-bit set to 1 shall be used to solicit a response PDU, with the F-bit set to 1. On a data link, only 1 Type 2 PDU and/or Type 1 PDU with a P-bit set to 1 shall be outstanding in a given direction at a given time. Before a station issues another PDU with the P-bit set to 1 to a particular destination, it shall have received a response PDU from that remote station with the F-bit set to 1 or have timed out waiting for that response PDU. The P/F bit is not implemented in Type 4 operations.

5.3.4.2.3.5 Sequence numbers. Sequence numbers are used only with Type 2 I and S PDUs. The Type 2 I and S PDUs shall contain sequence numbers. The sequence numbers shall be in the range of 0-127.

5.3.4.2.3.6 Identification numbers. Identification numbers are used only with Type 4 DIA PDUs and DRR/DRNR S PDUs. The Type 4 DIA and DRR/DRNR response S PDUs shall contain an identification number. The identification number is used to identify each DIA PDU and permit decoupled acknowledgements in a connectionless environment. The identification numbers shall be in the range of 1-255.

5.3.4.2.3.7 Precedence. The two level-of-precedence bits (L-bits) are used only in the control field of Type 4 PDUs. In the DIA PDU, the L-bits indicate the precedence of the data in the information field. In the DRR response S PDU, the L-bits are used to indicate the precedence of the DIA PDU information being acknowledged. The data link precedence values and their appropriate mappings to IP precedence levels are indicated in 5.3.16.

5.3.4.2.4 Information field. The information field may be present in either the I, UI, DIA, FRMR, TEST, or XID PDU. The length of the information field shall be a multiple of 8 bits, not to exceed 3345 octets. If the data is not a multiple of 8 bits, 1 to 7 fill bits (0) shall be added to meet this requirement. The maximum information field size defaults to 3345 octets. A smaller size may be established at initialization through local system information or using the XID PDUs. Contents of the information fields of the FRMR, TEST, and XID PDUs are described in 5.3.6.2.3.6 and 5.3.6.1.5, and in Appendix E, respectively.

5.3.4.2.5 Frame check sequence. For error detection, all frames shall include a 32-bit FCS prior to the closing flag sequence. The contents of the address, control, and information fields are included in the FCS calculation. Excluded from the FCS calculation are the 0's inserted by the 0-bit insertion algorithm. The formula for calculating the FCS, which is the 1's complement (inversion) of the remainder of a modulo-2 division process, employs the generator polynomial, P(X), having the form

$$P(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^{8} + x^{7} + x^{5} + x^{4} + x^{2} + x + 1$$

FCS generation shall be in accordance with the paragraph entitled "32-bit Frame Checking Sequence" in ISO 3309, and implemented in a manner that provides a unique remainder when a frame is received without bit errors incurred during transmission. If the FCS of a received frame proves the frame to be invalid, the frame shall be discarded.

5.3.4.3 Data-link PDU construction. The data-link procedures that affect data-link PDU construction include (a) order-of-bit transmission and 0-bit insertion, discussed below; and (b) FEC and TDC, discussed in 5.3.14.

5.3.4.3.1 Order-of-bit transmission. The order-of-bit transmission function specifies the sequence in which bits are ordered by the data-link layer for transmission by the physical layer. The Information Field shall be transmitted LSB of each octet first. The flag and control fields shall be transmitted LSB first. For the FCS, the most significant bit (MSB) shall be transmitted first. For the address field, the source address octet is transmitted first and the destination address octet(s) are transmitted in order. The LSB of each address octet is transmitted first. The information field octets shall be transmitted in the same order as received from the upper layers, LSB of each octet first.

5.3.4.3.2 Zero-bit insertion algorithm. The occurrence of a spurious flag sequence within a frame or Transmission Header shall be prevented by employing a 0-bit insertion algorithm. After the entire frame has been constructed, the transmitter shall always insert a 0 bit after the appearance of five 1's in the frame (with the exception of the flag fields). After detection of an opening flag sequence, the receiver shall search for a pattern of five 1's. When the pattern of five 1's appears, the sixth bit shall be examined. If the sixth bit is a 0, the 5 bits shall be passed as data, and the 0 shall be deleted. If the sixth bit is a 1, the receiver shall inspect the seventh bit. If the seventh bit is a 0, a flag sequence has been received. If the seventh bit is a 1, an invalid message has been received and should be discarded.

5.3.5 Operational parameters. The various parameters associated with the control field formats are described in the following sections.

5.3.5.1 Type 1 operational parameters. The only parameter that exists in Type 1 operation is the P/F bit. The Poll (P) bit set to 1 shall be used to solicit (poll) an immediate correspondent response PDU with the Final (F) bit set to 1 from the addressed station. The response with F-bit set to 1 shall be transmitted in accordance with the response hold delay (RHD) procedures defined in Appendix C (C3.2).

5.3.5.2 Type 2 operational parameters. The various parameters associated with the control field formats in Type 2 operation are described in 5.3.5.2.1 to 5.3.5.2.3.2.

5.3.5.2.1 Modulus. Each I PDU shall be sequentially numbered with a numeric value between 0 and MODULUS minus ONE (where MODULUS is the modulus of the sequence numbers). MODULUS shall equal 128 for the Type 2 control field format. The sequence numbers shall cycle through the entire range. The maximum number of sequentially numbered I PDUs that may be outstanding (that is, unacknowledged) in a given direction of a data-link connection at any given time shall never exceed one less than the modulus of the sequence numbers. This restriction shall prevent any ambiguity in the association of sent I PDUs with sequence numbers during normal operation and error recovery action.

5.3.5.2.2 PDU-state variables and sequence numbers. A station shall maintain a send-state variable, V(S), for the I PDUs it sends and a receive-state variable, V(R), for the I PDUs it receives on each data-link connection. The operation of V(S) shall be independent of the operation of V(R).

5.3.5.2.2.1 Send-state variable V(S). The V(S) shall denote the sequence number of the next in-sequence I PDU to be sent on a specific data-link connection. The V(S) shall take on a value between 0 and MODULUS minus ONE. The value of V(S) shall be incremented by one with each successive I PDU transmission on the associated data-link connection, but shall not exceed receive sequence number N(R) of the last received PDU by more than MODULUS minus ONE.

5.3.5.2.2.2 Send-sequence number N(S). Only I PDUs shall contain N(S), the send sequence number of the sent PDU. Prior to sending an I PDU, the value of N(S) shall be set equal to the value of the V(S) for that data-link connection.

5.3.5.2.2.3 Receive-state variable V(R). The V(R) shall denote the sequence number of the next in-sequence I PDU to be received on a specific data-link connection. The V(R) shall take on a value between 0 and MODULUS minus ONE. The value of the V(R) associated with a specific data-link connection shall be incremented by one whenever an error-free I PDU is received whose N(S) equals the value of the V(R) for the data-link connection.

5.3.5.2.2.4 Receive sequence number N(R). All I and S PDUs shall contain N(R), the expected sequence number of the next received I PDU on the specified data-link connection. Prior to sending an I or S PDU, the value of N(R) shall be set equal to the current value of the associated V(R) for that data-link connection. N(R) shall indicate that the station sending the N(R) has received correctly all I PDUs numbered up through N(R)-1 on the specified data-link connection.

5.3.5.2.3 Poll/final (P/F) bit. The P/F bit shall serve a function in Type 2 operation in both command and response PDUs. In command PDUs the P/F bit shall be referred to as the P-bit. In response PDUs it shall be referred to as the F-bit. P/F bit exchange provides a distinct C/R linkage that is useful during both normal operation and recovery situations.

5.3.5.2.3.1 Poll-bit functions. A command PDU with the P-bit set to 1 shall be used to solicit (poll) a response PDU with the F-bit set to 1 from the addressed station on a data-link connection. Only one Type 2 PDU with a P-bit set to 1 shall be outstanding in a given direction at a given time on the data-link connection between any specified pair of stations. Before a station issues another PDU on the same data-link connection with the P-bit set to 1, the station shall have received a response PDU with the F-bit set to 1 from the addressed station. If no valid response PDU is received within a system-defined P-bit timer time-out period, the resending of a command PDU with the P-bit set to 1 shall be permitted for error recovery purposes.

5.3.5.2.3.2 Final-bit functions. The F-bit set to 1 shall be used to acknowledge the receipt of a command PDU with the P-bit set to 1. Following the receipt of a command PDU with the P-bit set to 1, the station shall send a response PDU with the F-bit set to 1 on the appropriate data-link connection at the first possible opportunity. First possible opportunity is defined as transmitting the frame ahead of other frames at the next network access opportunity. The response PDU shall be assigned an URGENT priority. The station shall be permitted to send appropriate response PDUs with the F-bit set to 0 at any net access opportunity without the need for a command PDU.

5.3.5.3 Type 4 operational parameters. The two parameters associated with the control field formats in Type 4 operation are precedence described in 5.3.4.2.3.7 and Identification number.

5.3.5.3.1 Identification number. The Identification number field is used in conjunction with the originator's station address to identify the PDU. The station's identification number is assigned just prior to the initial transmission of the PDU. This number is not changed on link layer retransmission of the PDU. Each station shall keep a number for originating PDUs. Duplicate frame identification numbers from the same originator shall be prevented from being forwarded through the network.

5.3.6 Commands and responses. This section defines the commands and associated responses. Definitions of the set of commands and responses for each of the control field formats for Type 1, Type 2 and Type 4 operations, respectively, are contained in 5.3.6.1, 5.3.6.2 and 5.3.6.3. The C/R bit, the LSB of the source address field, is used to distinguish between commands and responses. The following discussion of commands and responses assumes that the C/R bit has been properly decoded. A single multi-addressed frame shall not contain different PDU types nor contain the same individual address more than once. The control field for all addresses in a single multi-addressed frame shall be the same except for the P/F bit and sequence number. Some of the commands described in the following paragraphs require a response at the earliest opportunity. Response PDUs requiring "earliest opportunity" transmission shall be queued ahead of all other PDUs, except those queued for "first possible opportunity" for transmission during the next network access opportunity. The response PDU shall assume the priority level of the highest PDU queued or the mid (PRIORITY) level, whichever is greater. The Type 4 DRR response PDU shall assume the precedence of the DIA frame it is acknowledging.

5.3.6.1 Type 1 operation commands and responses. Type 1 commands and responses are all U PDUs. The U PDU encodings for Type 1 operations are listed in Figure 15.

FIRST CONTROL FIELD BIT DELIVERED TO/RECEIVED FROM THE PHYSICAL LAYER ↓

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Bit Position |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | P/F | 0 | 0 | 0 | UI Command |
| 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | URR Command |
| 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | URR Response |
| 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | URNR Command |
| 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | URNR Response |
| 1 | 1 | 1 | 1 | P/F | 1 | 0 | 1 | XID Command/Response |
| 1 | 1 | 0 | 0 | P/F | 1 | 1 | 1 | Test Command/Response |

Figure 15. Type 1 operation control-field bit assignments.

5.3.6.1.1 Unnumbered information command. The unnumbered information PDU (UI PDU) shall be used to send information to one or more stations. The P-bit of the control field of the UI PDU is used by the transmitter to request that individually addressed receiver(s) acknowledge receipt of the transmitted UI PDU or to specify that an acknowledgment is not required. The UI PDU shall be addressed to individual, group, or global addresses. The source address shall be the individual address of the transmitting station.

5.3.6.1.2 Unnumbered receive-ready command. The unnumbered receive-ready (URR) command PDU shall be transmitted to one or more stations to indicate that the sending station is ready to receive I, DIA and UI PDUs. The URR PDU shall be addressed to individual, group, or global addresses. The source address shall be the individual address of the transmitting station.

5.3.6.1.3 Unnumbered receive-not-ready command. The unnumbered receive-not-ready (URNR) command PDU shall be transmitted to one or more stations to indicate that the sending station is busy and cannot receive I, DIA or UI PDUs. The URNR PDU shall be addressed to individual, group, or global addresses. The source address shall be the individual address of the transmitting station.

5.3.6.1.4 Exchange identification command. The exchange identification (XID) command PDU shall be used to request the link parameters and to announce a station's presence on or departure from the network. The XID command PDU with the P-bit set to 1 shall cause the destination station to respond with an XID response PDU, with the F-bit set to 1 and containing no information, after the appropriate RHD period (see C3.2). The XID command with appropriate information field (Join Accept or Join Reject) shall be provided by NETCON at the earliest possible opportunity following transmission of the XID response. The XID Join Request command PDU, with the P-bit set to 0, shall cause the destination station to respond with an appropriate XID response (Join Accept or Join Reject) PDU, with the F-bit set to 0, at the earliest possible opportunity. The information field of an XID PDU shall consist of an 8-bit XID format identifier field plus the group identifier fields described in Appendix E. The XID command PDU shall be addressed to either an up to 16 individual, global, or special net control addresses. The source address may be an individual address or the special (net entry or net control) address.

5.3.6.1.5 Test command. The test command (TEST) shall be used to cause the destination station to respond with the TEST response at the earliest opportunity, thus performing a basic test of the transmission path. An information field is optional with the TEST command PDU. It may contain any bit pattern, but is limited to a maximum length of 128 octets. If present, however, the received information field shall be returned, if possible, by the addressed station in the TEST response PDU. The TEST command, with the P-bit set to 1, shall cause the individually addressed destination station(s) to respond with a TEST response PDU (with no information field), with the F-bit set to 1, after the appropriate RHD period (see C3.2). The TEST command, with the P-bit set to 0 shall cause each destination station (including members of group and global addresses) to respond with a TEST response (with information field) with the F-bit set to 0 at the earliest possible opportunity. Group and global addresses do not reply to a TEST command with the P-bit set to 1. The TEST command PDU shall be addressed to an individual and/or group or global destination addresses. The source address shall be an individual address.

5.3.6.1.6 Unnumbered receive-ready response. The URR response shall be used to reply to a UI command that requested an acknowledgment (P-bit set to 1). The URR response shall be the first PDU sent by the receiving station upon receiving a UI command after the appropriate RHD period (see C3.2). The source and destination shall be individual addresses.

5.3.6.1.7 Exchange identification response. An appropriate XID response shall be used to reply to an XID command. The XID response PDU (with no information field) shall be used to reply to an XID command (Join Request, Join Accept, Join Reject, Hello or Goodbye) that has the P-bit set to 1. The XID command with the appropriate information field (Join Accept or Join Reject) shall be provided at the earliest opportunity following transmission of the XID response. The XID response PDU shall be the first PDU sent by the receiving station upon receiving an XID command PDU, after the appropriate RHD period (see C3.2). The response to an XID Join Request command that has the P-bit set to 0 shall be the XID Join Accept or Join Reject response with the F-bit set to zero. No response is provided to an XID Join Accept or Join Reject response that has the P-bit set to 0. The contents of the XID response information field is described in Appendix E (Tables E-3 through E-7). The source address shall be an individual or special (net entry or net control) address. The destination address shall be an individual or the special (net entry or net control) address. After receiving a response to an XID Join Request with the destination address equal to the net entry address, compare the unique identifier with the unique identifier in the Join Request. If they are not the same, ignore the response to the XID Join Request.

5.3.6.1.8 Test response. The TEST response, with F-bit set to 1, without an information field shall be used by individual addressees to reply to the TEST command with the P-bit set to 1. The TEST response shall be the first PDU sent by the receiving station upon receiving a TEST command PDU, after the appropriate RHD period (see C3.2). Group and global addressees do not reply to TEST command with P-bit set to 1. The TEST response, with F-bit set to 0, shall be used by all addressees (individual, group and global) tc reply to the TEST command with the P-bit set to 0 at the earliest opportunity. If an information field was present in the TEST command PDU that had the P-bit set to 0, the TEST response PDU shall contain the same information field contents. If the station cannot accept the information field of the TEST command, a TEST response without an information field may be returned. The source and destination addresses shall be an individual or net control address.

5.3.6.1.9 Unnumbered receive-not-ready response. The URNR response PDU shall be used to reply to a UI command with the P-bit set to 1, if the UI command cannot be processed due to a busy condition. If used, the URNR response shall be the first PDU transmitted by the receiving station, upon receiving a UI command, after the appropriate RHD period (see C3.2). The URNR response shall have the F-bit set to 1 and shall be addressed to the source of the UI command.

5.3.6.2 Type 2 operation commands and responses. Type 2 commands and responses consist of I, S, and U PDUs.

5.3.6.2.1 Information-transfer-format command and response. The function of the information (I) command and response shall be to transfer sequentially numbered PDUs that contain an information field across a data-link connection. Send and receive sequence numbers associated with group and global addresses shall be set to zero by the transmitter and ignored by the receiver and are not acknowledged. The encoding of the I PDU control field for Type 2 operation shall be as listed in Figure 16.

| FIRST CONTROL FIELD BIT DELIVERED TO/RECEIVED FROM THE PHYSICAL LAYER ↓ | | | |
|---|---|---|---|
| 1 | 2 3 4 5 6 7 8 | 9 | 10 11 12 13 14 15 16 |
| 0 | N(S) | P/F | N(R) |
| INFORMATION TRANSFER FORMAT | SEND SEQUENCE NUMBER (0-127) | COMMAND (POLL) RESPONSE (FINAL) | RECEIVE SEQUENCE NUMBER (0-127) |

Figure 16. Information-transfer-format control field bits.

The I PDU control field shall contain two sequence number subfields: N(S), which shall indicate the sequence number associated with the I PDU; and N(R), which shall indicate the sequence number (as of the time the PDU is sent) of the next expected I PDU to be received, and, consequently, shall indicate that the I PDUs numbered up through N(R)-1 have been received correctly.

5.3.6.2.2 Supervisory-format commands and responses. Supervisory (S) PDUs shall be used to perform numbered supervisory functions such as acknowledgments, temporary suspension of information transfer, or error recovery. S PDUs shall not contain an information field and, therefore, shall not increment the send-state variable at the sender or the receive-state variable at the receiver. Encoding of the S PDU control field for Type 2 operation shall be as shown in Figure 17. An S PDU shall contain an N(R), which shall indicate, at the time of sending, the sequence number of the next expected I PDU to be received. This shall acknowledge that all I PDUs numbered up through N(R)-1 have been received correctly, except in the case of the selective reject (SREJ) PDU. The use of N(R) in the SREJ PDU is explained in 5.3.6.2.2.4.

5.3.6.2.2.1 Receive-ready (RR) command and response. The RR PDU shall be used by a station to indicate it is ready to receive I PDUs. I PDUs numbered up through N(R)-1 shall be considered as acknowledged.

FIRST CONTROL FIELD BIT DELIVERED TO/RECEIVED FROM THE PHYSICAL LAYER

| 1 2 | 3 4 | 5 6 7 8 | 9 | 10 11 12 13 14 15 16 |
|---|---|---|---|---|
| 1 0 | S S | X X X X | P/F | N(R) |
| SUPER-VISORY FORMAT | | RESERVED SET TO 0 | COMMAND (POLL) RESPONSE (FINAL) | RECEIVE SEQUENCE NUMBER (0-127) |

| COMMANDS | SS | RESPONSES |
|---|---|---|
| RECEIVE READY (RR) | 00 | RECEIVE READY (RR) |
| REJECT (REJ) | 01 | REJECT (REJ) |
| RECEIVE NOT READY (RNR) | 10 | RECEIVE NOT READY (RNR) |
| SELECTIVE REJECT (SREJ) | 11 | SELECTIVE REJECT (SREJ) |

Figure 17. Supervisory-format control field bits.

5.3.6.2.2.2 Reject (REJ) command and response. The REJ PDU shall be used by a station to request the resending of I PDUs, starting with the PDU numbered N(R). I PDUs numbered up through N(R)-1 shall be considered as acknowledged. It shall be possible to send additional I PDUs awaiting initial sending after the resent I PDUs. With respect to each direction of sending on a data-link connection, only one "sent REJ" condition shall be established at any given time. The "sent REJ" condition shall be cleared upon receipt of an I PDU with an N(S) equal to the N(R) of the REJ PDU. The "sent REJ" condition may be reset in accordance with procedures described in 5.3.7.2.5.4. Receipt of a REJ PDU shall indicate the clearance of a busy condition except as noted in 5.3.7.2.5.8.

5.3.6.2.2.3 Receive-not-ready (RNR) command and response. The RNR PDU shall be used by a station to indicate a busy condition (a temporary inability to accept subsequent I PDUs). I PDUs numbered up through N(R)-1 shall be considered as acknowledged. I PDUs numbered N(R) and any subsequent I PDUs received shall not be considered as acknowledged; the acceptance status of these PDUs shall be indicated in subsequent exchanges.

5.3.6.2.2.4 Selective-reject (SREJ) command and response. The selective reject PDU is used by a station to request retransmission of the single I PDU numbered N(R). If the P-bit in the SREJ PDU is set to 1, then I PDUs numbered up to N(R)-1 shall be considered acknowledged. If the P-bit is set to 0, then the N(R) of the SREJ PDU does not indicate acknowledgment of any I PDUs. Each SREJ exception condition shall be cleared (reset) upon receipt of an I PDU with an N(S) equal to the N(R) of the SREJ PDU. A data station may transmit one or more SREJ PDUs, each containing a different N(R) with the P-bit set to 0, before one or more earlier SREJ exception conditions have been cleared. I PDUs that have been transmitted following the I PDU designated by the SREJ PDU shall not be retransmitted as the result of receiving the SREJ PDU. Additional I PDUs awaiting initial transmission may be transmitted following the retransmission of the specific I PDU requested by the SREJ PDU. The SREJ is used to recover from receipt of frames with various types of errors, including sequence number errors due to lost frames and FCS errors.

5.3.6.2.3 Unnumbered-format commands and responses. Unnumbered (U) commands and responses shall be used in Type 2 operations to extend the number of data-link connection control functions. The U PDUs shall not increment the state variables on the data-link connection at either the sending or the receiving station. Encoding of the U PDU control field shall be as shown in Figure 18.

FIRST CONTROL FIELD BIT DELIVERED TO/RECEIVED FROM THE PHYSICAL LAYER

↓

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | P | 1 | 0 | 0 | SABME Command |
| 1 | 1 | 0 | 0 | P | 0 | 1 | 0 | DISC Command |
| 1 | 1 | 1 | 1 | P | 0 | 0 | 1 | RSET Command |
| 1 | 1 | 0 | 0 | F | 1 | 1 | 0 | UA Response |
| 1 | 1 | 1 | 1 | F | 0 | 0 | 0 | DM Response |
| 1 | 1 | 1 | 0 | F | 0 | 0 | 1 | FRMR Response |

Figure 18. Unnumbered-format control field bits.

5.3.6.2.3.1 Set Asynchronous balanced mode extended (SABME) command. The SABME command PDU shall be used to establish a data-link connection to the destination station in the asynchronous balanced mode (ABM). No information shall be permitted with the SABME command PDU. The destination station shall confirm receipt of the SABME command PDU by sending a UA response PDU on that data-link connection at the earliest opportunity. Upon acceptance of the SABME command PDU, the destination station send- and receive-state variables shall be set to 0. If the UA response PDU is received correctly, then the initiating station shall also assume the asynchronous balanced mode with its corresponding send- and receive-state variables set to 0. Previously sent I PDUs that are unacknowledged when this command is executed shall remain unacknowledged. Whether or not a station resends the contents of the information field of unacknowledged outstanding I PDUs shall be decided at a higher layer.

5.3.6.2.3.2 Disconnect (DISC) command. The DISC command PDU shall be used to terminate an asynchronous balanced mode previously set by a SABME command PDU. It shall be used to inform the destination station that the source station is suspending operation of the data-link connection and the destination station should assume the logically disconnected mode. No information field shall be permitted with the DISC command PDU. Prior to executing the command, the destination station shall confirm the acceptance of the DISC command PDU by sending a UA response PDU on that data-link connection. Previously sent I PDUs that are unacknowledged when this command is executed shall remain unacknowledged. Whether or not a station resends the contents of the information field of unacknowledged outstanding I PDUs shall be decided at a higher layer.

5.3.6.2.3.3 Reset (RSET) command. The RSET command PDU shall be used by a station in an operational mode to reset the V(R) in the addressed station. No information field is permitted with the RSET command PDU. The addressed station shall confirm acceptance of the RSET command by transmitting a UA response PDU at the earliest opportunity. Upon acceptance of this command, the V(R) of the addressed station shall be set to 0. If the UA response PDU is received correctly, the initializing station shall reset its V(S) to 0.

5.3.6.2.3.4 Unnumbered acknowledgment (UA) response. The UA response PDU shall be used by a station on a data-link connection to acknowledge receipt and acceptance of the SABME, DISC, and RSET command PDUs. These received command PDUs shall not be executed until the UA response PDU is sent. No information field shall be permitted with the UA response PDU.

5.3.6.2.3.5 Disconnect mode (DM) response. The DM response PDU shall be used to report status indicating that the station is logically disconnected from the data-link connection and is in asynchronous disconnected mode (ADM). No information field shall be permitted with the DM response PDU.

5.3.6.2.3.6 Frame reject (FRMR) response. The FRMR response PDU shall be used by the station in the ABM to report that one of the following conditions, which is not correctable by resending the identical PDU, resulted from the receipt of a PDU from the remote station:

a. The receipt of a command PDU or a response PDU that is invalid or not implemented. Below are three examples of invalid PDUs:

   (1) the receipt of an S or U PDU with an information field that is not permitted,
   (2) the receipt of an unsolicited F-bit set to 1, and
   (3) the receipt of an unexpected UA response PDU.

b. The receipt of an I PDU with an information field that exceeded the established maximum information field length that can be accommodated by the receiving station for that data-link connection.

c. The receipt of an invalid N(R) from the remote station. An invalid N(R) shall be defined as one that signifies an I PDU that has previously been sent and acknowledged, or one that signifies an I PDU that has not been sent and is not the next sequential I PDU waiting to be sent.

d. The receipt of an invalid N(S) from the remote station. An invalid N(S) shall be defined as an N(S) that is greater than or equal to the last sent N(R)+ k, where k is the maximum number of outstanding I PDUs. The parameter k is the window size indicated in the XID PDU.

The responding station shall send the FRMR response PDU at the earliest opportunity. An information field shall be returned with the FRMR response PDU to provide the reason for the PDU rejection. The information field shall contain the fields shown in Figure 19. The station receiving the FRMR response PDU shall be responsible for initiating the appropriate mode setting or resetting corrective action by initializing one or both directions of transmission on the data-link connection, using the SABME, RSET or and DISC command PDUs, as applicable.

5.3.6.3 <u>Type 4 operation commands and responses</u>. The Type 4 commands and responses consist of U and S PDUs.

5.3.6.3.1 <u>Unnumbered information transfer format commands</u>. The function of the Type 4 unnumbered information with decoupled acknowledgement (DIA) commands shall be to transfer PDUs that contain an identification number and an information field across a connectionless link. The encoding of the PDU control field for Type 4 operation shall be as listed in Figure 20.

5.3.6.3.1.1 <u>DIA PDU acknowledgement</u>. Transmitted DIA PDUs are acknowledged by a Type 4 DRR response S PDU with the same precedence from the receiving stations, except for the following cases:

1) The receiving station is a global or group multicast addressee only.

2) The receiving station's link address is not in the destination address field.
3) The response mode parameter is set to no.

| FIRST CONTROL FIELD BIT DELIVERED TO/RECEIVED FROM THE PHYSICAL LAYER ↓ | | | | | | |
|---|---|---|---|---|---|---|
| 1----------16 | 17 | 18--24 | 25 | 26--32 | 33--36 | 37-40 |
| REJECTED PDU CONTROL FIELD | 0 | V(S) | C/R | V(R) | WXYZ | V000 |

Figure 19. FRMR information field format.

Notes to Figure 19:

a. Rejected PDU control field shall be the control field of the received PDU that caused the FRMR exception condition on the data-link connection. When the rejected PDU is a U PDU, the control field of the rejected PDU shall be positioned in bit positions 1-8, with 9-16 set to 0.

b. V(S) shall be the current send-state variable value for this data-link connection at the rejecting station (bit 18 = low-order bit).

c. C/R set to 1 shall indicate that the PDU causing the FRMR was a response PDU, and C/R set to 0 shall indicate that the PDU causing the FRMR was a command PDU.

d. V(R) shall be the current receive-state variable value for this data-link connection at the rejecting station (bit 26 = low-order bit).

e. W set to 1 shall indicate that the control field received and returned in bits 1 through 16 was invalid or not implemented. Examples of invalid PDU are defined as:

   (1) the receipt of an S or U PDU with an information field that is not permitted,
   (2) the receipt of an unsolicited F-bit set to 1, and
   (3) the receipt of an unexpected UA response PDU.

f. X set to 1 shall indicate that the control field received and returned in bits 1 through 16 was considered invalid because the PDU contained an information field that is not permitted with this command or response. Bit W shall be set to 1 in conjunction with this bit.

g. Y set to 1 shall indicate that the information field received exceeded the established maximum information field length which can be accommodated by the rejecting station on that data-link connection.

h. Z set to 1 shall indicate that the control field received and returned in bits 1 through 16 contained an invalid N(R).

i. V set to 1 shall indicate that the control field received and returned in bits 1 through 16 contained an invalid N(S). Bit W shall be set to 1 in conjunction with this bit.

| FIRST CONTROL BIT DELIVERED TO/RECEIVED FROM THE PHYSICAL LAYER ↓ | | |
|---|---|---|
| PDU Identifier | L-bits | PDU Identification No. |
| 1 2 3 4 5 6 | 7 8 | 9 10 11 12 13 14 15 16 |
| 1 1 0 1 0 1 | L L | <---ID Number---> |

Figure 20. Type 4 DIA PDU Control field bit assignments.

5.3.6.3.2 Supervisory format commands and response. The S PDUs shall be used to convey link acknowledgement of a DIA PDU and whether or not a station is ready to receive Type 4 PDUs. The S PDU has a single destination address. For the command DRR and DRNR S PDUs the destination address is the global address and does not acknowledge DIA PDUs. These S PDUs are used to indicate Type 4 receive status. The response DRR S PDU contains a single destination address, that of the originator of the DIA PDU being acknowledged. The command S PDU level of precedence shall be set to the highest precedence while response S PDUs shall use the precedence of the DIA PDU which they are acknowledging. The encoding of the S PDU control field for Type 4 operation shall be as listed in Figure 21.

| FIRST CONTROL BIT DELIVERED TO/RECEIVED FROM THE PHYSICAL LAYER ↓ | | |
|---|---|---|
| PDU Identifier | L-bits | PDU Identification No. |
| 1 2 3 4 5 6 | 7 8 | 9 10 11 12 13 14 15 16 |
| 1 0 0 0 1 0 | 0 0 | 0 0 0 0 0 0 0 0<br>DRR Command |
| 1 0 0 0 1 0 | L L | <---ID Number---><br>DRR Response |
| 1 0 1 0 1 0 | 0 0 | 0 0 0 0 0 0 0 0<br>DRNR Command |
| 1 0 1 0 1 0 | L L | <---ID Number---><br>DRNR Response |

Figure 21. Type 4 S PDU Control field bit assignments.

5.3.7 Description of procedures by type. The procedures for each operation type are described in 5.3.7.1, 5.3.7.2 and 5.3.7.3

(and their subparagraphs). The three types of procedures can coexist on the same network.

5.3.7.1 Description of Type 1 procedures. The procedures associated with Type 1 operation are described in 5.3.7.1 through 5.3.7.1.5.11.

5.3.7.1.1 Modes of operation. In Type 1 operation, no modes of operation are defined. A station using Type 1 procedures shall support the entire procedure set whenever it is operational on the network.

5.3.7.1.2 Procedure for addressing. The address fields shall be used to indicate the source and destinations of the transmitted PDU. The first bit in the source address field shall be used to identify whether a command or a response is contained in the PDU. Individual, group, special, and global addressing shall be supported for destination addresses in command PDUs. The source address field shall contain an individual or special address.

5.3.7.1.3 Procedure for using the P/F bit. The station receiving a UI, XID, or TEST command PDU with the P-bit set to 1 shall send an appropriate response PDU with the F-bit set to 1.

5.3.7.1.4 Procedures for logical data-link set-up and disconnection. Type 1 operation does not require any prior data-link connection establishment (set-up), and hence no data-link disconnection. Once the service access point has been enabled within the station, information may be sent to, or received from, a remote station also participating in Type 1 operation.

5.3.7.1.5 Procedures for information transfer.

5.3.7.1.5.1 Sending UI command PDUs. Information transfer from an initiating station to a responding station shall be accomplished by sending the UI command PDU. When a sending station sends a UI command PDU with the P-bit set to 1, it shall start an acknowledgment timer for that transmission and initialize the internal transmission count variable to zero. If all expected URR or URNR response PDUs are not received before the timer runs out, the sending station shall resend the UI command PDU, increment the internal transmission count variable, and restart the acknowledgment timer. Prior to resending the UI command PDU, the group and global addresses shall be removed as well as individual addresses from which an acknowledgment (URR or URNR) was received. If a URR response PDU is still not received, this resending procedure shall be repeated until the value of the internal transmission count variable is equal to the value of the logical link parameter N4, as described in 5.3.8.1.1c, at which time an acknowledgment failure status shall be reported to the data-link user. An internal transmission count shall be maintained for each UI information exchange (where P-bit = 1) between a pair of sending and receiving stations. Both the acknowledgment timer and the internal transmission count, for that exchange, shall not affect the information exchange with other receiving stations. If a URNR response PDU is received in response to a UI command with the P-bit set to 1, the receiving station shall designate the sending station as busy. The retransmission of the UI command shall follow the rules for the busy condition. Transmission of UI commands to that station shall be discontinued until the busy state is cleared. UI PDUs that have the P-bit set to 0 are not acknowledged nor retransmitted.

5.3.7.1.5.2 Receiving UI command PDUs. Reception of the UI command PDU with P-bit set to 0 shall not be acknowledged. A station shall acknowledge the receipt of a valid UI command PDU, which has the P-bit set to 1 and contains the station individual address, by sending a URR response PDU to the originator of the command UI PDU. If the receiving station is unable to accept UI PDUs due to a busy condition, it shall respond with a URNR response PDU.

5.3.7.1.5.3 Sending URR response PDUs. A URR response PDU, with the F-bit set to 1, shall be sent only upon receipt of a UI command PDU, with the P-bit set to 1. The URR response PDU shall be sent to the originator of the associated UI command PDU.

5.3.7.1.5.4 Sending URNR response PDUs. A URNR response PDU, with the F-bit set to 1, may be sent by the remote station to advise the originator of the associated UI command PDU that it is experiencing a busy condition and is unable to accept UI PDUs.

5.3.7.1.5.5 Receiving UI acknowledgment. After sending a UI command PDU with the P-bit set to 1, the sending station shall expect to receive an acknowledgment in the form of a URR response PDU from the station to which the command PDU was sent. Upon receiving such a response PDU, the station shall stop the acknowledgment timer associated with the transmission for which the acknowledgment was received and reset the associated internal transmission count to zero. If the response was a URNR response PDU, the sending station will stop sending UI, I, and DIA PDUs to that remote station until a URR command PDU is received or the busy-state timer expires, indicating termination of the busy condition.

5.3.7.1.5.6 Sending URNR command PDUs. A URNR command PDU, with the P-bit set to 0, may be sent at any time to indicate a busy condition.

5.3.7.1.5.7 Receiving URNR command PDUs. Receipt of the URNR indicates that the sending station is busy and no additional I, UI or DIA PDUs should be sent until the sending station regains its ability to receive messages. The URNR command PDU does not contain any acknowledgment information.

5.3.7.1.5.8 Sending URR command PDUs. A URR command PDU, with the P-bit set to 0, may be sent by a station at any time to indicate the regaining of its ability to receive messages.

5.3.7.1.5.9 Receiving URR command PDUs. The receipt of the URR command PDU cancels the prior receipt of a URNR and indicates that the sending station is now operational.

5.3.7.1.5.10 Using XID command and response PDUs. XID procedures are as defined in 5.3.6.1.4 and 5.3.6.1.7, and are described in Appendix E.

5.3.7.1.5.11 Using TEST command and response PDUs. The TEST function provides a facility to conduct loop-back tests of the station-to-station transmission path. The TEST function may be initiated within the data-link layer by any authorized station within the data-link layer. Successful completion of a test started by sending a TEST command PDU with the P-bit set consists of receiving a TEST response PDU with the F-bit set and containing no data from each individual or special addressee. Successful completion of a test started by sending a TEST command PDU without the P-bit set consists of receiving a TEST response PDU without the F-bit set and containing the identical data from each individual, special, group or global addressee. The length of the information field is variable from 0 to 128 octets. Any TEST command PDU received in error shall be discarded and no response PDU sent. In the event of a test failure, it shall be the responsibility of the TEST function initiator to determine any future actions.

5.3.7.2 Description of Type 2 procedures. The procedures associated with Type 2 operation are described in 5.3.7.2.1 through 5.3.7.2.8.

5.3.7.2.1 Modes. Two modes of operation are defined for Type 2 operation: an operational mode and a non-operational mode.

5.3.7.2.1.1 Operational mode. The operational mode shall be the ABM. ABM is a balanced operational mode in which a data-link connection has been established between two stations. Either station shall be able to send commands at any time and initiate response transmissions without receiving explicit permission from the other station. Such an asynchronous transmission shall contain one or more PDUs that shall be used for information transfer and to indicate status changes in the station (for example, the number of the next expected I PDU; transition from a ready to a busy condition, or vice versa; occurrence of an exception condition). A station in ABM receiving a DISC command PDU shall respond with the UA response PDU if it is capable of executing the command. ABM consists of a data-link connection phase, an information transfer phase, a data-link resetting phase, and a data-link disconnection phase.

5.3.7.2.1.2 Non-operational mode. The non-operational mode shall be the ADM. ADM differs from ABM in that the data-link connection is logically disconnected from the physical medium such that no information (user data) shall be sent or accepted. ADM is defined to prevent a data-link connection from appearing on the physical medium in a fully operational mode during unusual situations or exception conditions. Such operation could cause a sequence number mismatch between stations or a station's uncertainty of the status of the other station. A data-link connection shall be system-predefined as to the conditions that cause it to assume ADM. Below are three examples of possible conditions, in addition to receiving a DISC command PDU, that shall cause a data-link connection to enter ADM:

a. the power is turned on,
b. the data-link layer logic is manually reset, or
c. the data-link connection is manually switched from a local (home) condition to the connected-on-the-data-link (on-line) condition.

A station on a data-link connection in ADM shall be required to monitor transmissions received from its physical layer to accept and respond to one of the mode-setting command PDUs (SABME, DISC), or to send a DM response PDU at a medium access opportunity, when required. In addition, since the station has the ability to send command PDUs at any time, the station may send an appropriate mode-setting command PDU. A station in ADM receiving a DISC command PDU or any I or S PDU shall respond with the DM response PDU. A station in ADM shall not establish a FRMR exception condition. ADM consists of a data-link disconnected phase.

5.3.7.2.2 Procedure for addressing. The address fields for a PDU shall be used to indicate the individual source and up to 16 destinations. The first bit in the source address field shall be used to identify whether a command or response is contained in the PDU. A single data-link connection can be established between any two stations on the network.

5.3.7.2.3 Procedures for using the P/F bit. An individually addressed station receiving a command PDU (SABME, DISC, RR, RNR, REJ, or I) with the P-bit set to 1 shall send a response PDU with the F-bit set to 1. The response PDU returned by a station to a RSET, SABME or DISC command PDU with the P-bit set to 1 shall be a UA or DM response PDU with the F-bit set to 1. The response PDU returned by a station to an I, RR, or REJ command PDU with the P-bit set to 1 shall be an I, RR, REJ, RNR, DM, or FRMR response PDU with the F-bit set to 1. The response PDU returned by a station to an RNR command PDU with the P-bit set to 1 shall be an RR, REJ, RNR, DM, or FRMR response PDU with the F-bit set to 1. The response PDU returned by a station to a SREJ with the P-bit set to one shall be the requested I-Frame (response) with the F-bit set to one.

NOTE: The P-bit is usable by the station in conjunction with the timer recovery condition. (See 5.3.7.2.5.11)

5.3.7.2.4 Procedures for data-link set-up and disconnection.

5.3.7.2.4.1 Data-link connection phase. Either station shall be able to take the initiative to initialize the data-link connection.

5.3.7.2.4.1.1 Initiator action. When the station wishes to initialize the link, it shall send the SABME command PDU to one or more individual addresses and start the acknowledgment timer(s). Upon receipt of the UA response PDU, the station shall reset both the V(S) and V(R) to 0 for the corresponding data-link connection, shall stop the acknowledgment timer and shall enter the information transfer phase. When receiving the DM response PDU, the station that originated the SABME command PDU shall stop the acknowledgment timers for that link, shall not enter the information transfer phase for that station, and shall report to the higher layer for appropriate action. Should any acknowledgment timer run out before receiving all UA or DM response PDUs, the station shall resend the SABME command PDU, after deleting the address and control fields corresponding to the received UAs or DMs, and restart the acknowledgment timers. After resending the SABME command PDU N2 times, the station shall stop sending the SABME command PDU and shall report to the higher layer for the appropriate error recovery action to initiate. The value of N2 is defined in 5.3.8.1.2.d. Other Type 2 PDUs received (commands and responses) while attempting to connect shall be ignored by the station.

5.3.7.2.4.1.2 Respondent action. When a SABME command PDU is received, and the connection is desired, the station shall return a UA response PDU to the remote station, set both the V(S) and V(R) to 0 for the corresponding data-link connection, and enter the information transfer phase. The return of the UA response PDU shall take precedence over any other response PDU that may be pending at the station for that data-link connection. It shall be possible to follow the UA response PDU with additional PDUs, if pending. If the connection is not desired, the station shall return a DM response PDU to the remote station and remain in the link disconnected mode. For a description of the actions to be followed upon receipt of a SABME or DISC command PDU, see 5.3.7.2.4.4.

5.3.7.2.4.2 Information transfer phase. After having sent the UA response PDU to an SABME command PDU or having received the UA response PDU to a sent SABME command PDU, the station shall accept and send I and S PDUs according to the procedures described in 5.3.7.2.5. When receiving an SABME command PDU while in the information transfer phase, the station shall conform to the resetting procedure described in 5.3.7.2.6. When receiving an RSET command PDU while in the information transfer phase, the station shall conform to the resetting procedure described in 5.3.7.2.7.

5.3.7.2.4.3 Data-link disconnection phase. During the information transfer phase, either station shall be able to initiate disconnecting of the data-link connection by sending a DISC command PDU and starting the acknowledgment timer (see 5.3.8.1.2.a). When receiving a DISC command PDU, the station shall return a UA response PDU and enter the data-link disconnected phase. The return of the UA response PDU shall take precedence over any other response PDU that may be pending at the station for that data-link connection. Upon receipt of the UA or DM response PDU from a remote station, the station shall stop its acknowledgment timer for that link, and enter the link disconnected mode. Should the acknowledgment timer run out before receiving the UA or DM response PDU for a particular link, the station shall send another DISC command PDU and restart the acknowledgment timer. After sending the DISC command PDU N2 times, the sending station shall stop sending the DISC command PDU, shall enter the data-link disconnected phase, and shall report to the higher layer for the appropriate error recovery action. The value of N2 is defined in 5.3.8.1.2.d.

5.3.7.2.4.4 Data-link disconnected phase. After having received a DISC command PDU from the remote station and returned a UA response PDU, or having received the UA response PDU to a sent DISC command PDU, the station shall enter the data-link disconnected phase. In the disconnected phase, the station shall react to the receipt of an SABME command PDU, as described in 5.3.7.2.4.1, and shall send a DM response PDU in answer to a received DISC command PDU. When receiving any other Type 2 command, I or S PDU, the station in the disconnected phase shall send a DM response PDU. In the disconnected phase, the station shall be able to initiate a data-link connection.

5.3.7.2.4.5 Contention of unnumbered mode-setting command PDUs. A contention situation on a data-link connection shall be resolved in the following way: If the sent and received mode-setting command PDUs are the same, each station shall send the UA response PDU at the earliest opportunity. Each station shall enter the indicated phase either after receiving the UA response PDU, or after its acknowledgment timer expires. If the sent and received mode-setting command PDUs are different, each station shall enter the data-link disconnected phase and shall issue a DM response PDU at the earliest opportunity.

5.3.7.2.5 Procedures for information transfer. The procedures that apply to the transfer of I PDUs in each direction on a data-link connection during the information transfer phase are described in 5.3 7.2.5.1 through 5.3.7.2.5.11. When used, the term number one higher is in reference to a continuously repeated sequence series, that is, 127 is 1 higher than 126, and 0 is 1 higher than 127 for the modulo-128 series.

5.3.7.2.5.1 Sending I PDUs. When the station has an I PDU to send (that is, an I PDU not already sent), it shall send the I PDU with an N(S) equal to its current V(S) and an N(R) equal to its current V(R) for that data-link connection. At the end of sending the I PDU, the station shall increment its V(S) by 1. If the acknowledgment timer is not running at the time that an I PDU is sent, the acknowledgment timer shall be started. If the data-link connection V(S) is equal to the last value of N(R) received plus k (where k is the maximum number of outstanding I PDUs; see 5.3.8.1.2.e), the station shall not send any new I PDUs on that data-link connection, but shall be able to resend an I PDU as described in 5.3.7.2.5.6 or 5.3.7.2.5.9. The RR command is sent to a destination station when the *k* value at the originating station reaches half of the *k* value for that connection. The destination station shall respond with a RR Response with the N(R) indicating the last received I PDU. When a local station on a data-link connection is in the busy condition, the station shall still be able to send I PDUs, provided that the remote station on this data-link connection is not also busy. When the station is in the FRMR exception condition for a particular data-link connection, it shall stop transmitting I PDUs on that data-link connection.

5.3.7.2.5.2 Receiving an I PDU. When the station is not in a busy condition and receives an I PDU whose N(S) is equal to its V(R), the station shall accept the information field of this PDU, increment by 1 its V(R), and act as follows:

a. If an I PDU is available to be sent, the station shall be able to act as in 5.3.7.2.5.1 and acknowledge the received I PDU by setting N(R) in the control field of the next sent I PDU to the value of its V(R). The station shall also be able to acknowledge the received I PDU by sending an RR PDU with the N(R) equal to the value of its V(R).

b. If no I PDU is available to be sent by the station, then the station shall either:

   (1) send an RR PDU with the N(R) equal to the value of its V(R) at the earliest opportunity; or

   (2) if the received PDU was not a command PDU with the P-bit set to 1, wait for some period of time bounded by the probability of the remote acknowledgment timer expiration, for either an I PDU to become available for transmission or to accumulate additional I PDUs to be acknowledged in a single RR PDU, subject to window size constraints.

c. If receipt of the I PDU caused the station to go into the busy condition with regard to any subsequent I PDUs, the station shall send an RNR PDU with the N(R) equal to the value of its V(R). If I PDUs are available to send, the station shall be able to send them (as in 5.3.7.2.5.1) prior to or following the sending of the RNR PDU.

When the station is in a busy condition, the station shall be able to ignore the information field contained in any received I PDU on that data-link connection. (See 5.3.7.2.5.10.)

5.3.7.2.5.3 Receiving incorrect PDUs. When the station receives an invalid PDU or a PDU with an incorrect source address, the entire PDU shall be discarded. If an incorrect destination address is received, disregard that address field and continue processing the PDU.

5.3.7.2.5.4 Receiving out-of-sequence PDUs. When the station receives one or more I PDUs whose N(S)s are not in the expected sequence, that is, not equal to the current V(R) but is within the receive window, the station shall respond by sending a REJ or a SREJ PDU as described in either 5.3.7.2.5.4.1 or 5.3.7.2.5.2.

5.3.7.2.5.4.1 Reject response. When an I PDU has been received out-of-sequence and more than one frame is missing, the station may discard the information field of the I PDU and send a REJ PDU with the N(R) set to the value of V(R). The station shall then discard the information field of all I PDUs until the expected I PDU is correctly received. When receiving the expected I PDU, the station shall acknowledge the PDU, as described in 5.3.7.2.5.2. The station shall use the N(R) and P-bit indications in the discarded I PDU. On a given data-link connection, only one "sent REJ" exception condition from a given station to another given station shall be established at a time. A REJ and SREJ exception condition cannot be active at the same time. A "sent REJ" condition shall be cleared when the requested I PDU is received. The "sent REJ" condition shall be able to be reset when a reject timer time-out function runs out. When the station perceives by reject timer time-out that the requested I PDU will not be received, because either the requested I PDU or the REJ PDU was in error or lost, the station shall be able to resend the REJ PDU up to N2 times to reestablish the "sent REJ" condition. The value of N2 is defined in 5.3.8.1.2.d.

5.3.7.2.5.4.2 Selective reject response. When an I PDU has been received and not more than one frame is missing, the station may retain the information field of the out-of-sequence I PDUs and send a SREJ PDU for the missing I PDU. A station may transmit one or more SREJ PDUs, each containing a different N(R) with the P-bit set to 0. However, a SREJ PDU shall not be transmitted if an earlier REJ condition has not been cleared. When the station perceives by the reject timer time-out that the requested I PDU will not be received, because either the requested I PDU or the SREJ PDU was in error or lost, the station shall be able to resend all outstanding SREJ PDUs in order to reestablish the "sent SREJ" condition up to N2 times.

5.3.7.2.5.5 Receiving acknowledgment. When correctly receiving an I or S PDU, even in the busy condition (see 5.3.7.2.5.10), the receiving station shall consider the N(R) contained in this PDU as an acknowledgment for all the I PDUs it has sent on this data-link connection with an N(S) up to and including the received N(R) minus one. The station shall reset the acknowledgment timer when it correctly receives an I or Type 2 S PDU with the N(R) higher than the last received N(R) (actually acknowledging some I PDUs). If the timer has been reset and there are outstanding I PDUs still unacknowledged on this data-link connection, the station shall restart the acknowledgment timer. If the timer then runs out, the station shall follow the procedures in 5.3.7.2.5.11 with respect to the unacknowledged I PDUs.

5.3.7.2.5.6 Receiving an SREJ PDU. If the received transmission is an SREJ command or response PDU, the I PDU corresponding to the N(R) being rejected shall be retransmitted.

5.3.7.2.5.7 Receiving an RSET PDU. Upon receipt of the RSET command PDU, the receiving station shall reply with a UA response PDU and shall then set its V(R) to 0 for the initiating station.

5.3.7.2.5.8 Receiving an REJ PDU. When receiving an REJ PDU, the station shall set its V(S) to the N(R) received in the REJ PDU control field. The station shall resend the corresponding I PDU as soon as it is available. If other unacknowledged I PDUs had already been sent on that data-link connection following the one indicated in the REJ PDU, then those I PDUs shall be resent by the station following the resending of the requested I PDU. If retransmission beginning with a particular PDU occurs while waiting acknowledgment (see 5.3.7.2.5.11) and an REJ PDU is received, which would also start retransmission with the same I PDU [as identified by the N(R) in the REJ PDU], the retransmission resulting from the REJ PDU shall be inhibited.

5.3.7.2.5.9 Receiving an RNR PDU. A station receiving an RNR PDU shall stop sending I PDUs on the indicated data-link connection at the earliest possible time and shall start the busy-state timer, if not already running. When the busy-state timer runs out, the station shall follow the procedure described in 5.3.7.2.5.11. In any case, the station shall not send any other I PDUs on that data-link connection before receiving an RR or REJ PDU, or before receiving an I response PDU with the F-bit set to 1, or before the completion of a resetting procedure on that data-link connection.

5.3.7.2.5.10 Station-busy condition. A station shall enter the busy condition on a data-link connection when it is temporarily unable to receive or continue to receive I PDUs due to internal constraints; for example, receive buffering limitations. When the station enters the busy condition, it shall send an RNR PDU at the first possible opportunity. It shall be possible to send I PDUs waiting to be sent on that data-link connection prior to or following the sending of the RNR PDU. The station may send a URNR command PDU to the global address after the RNR PDU. While in the busy condition, the station shall accept and process supervisory PDUs and return an RNR response PDU with the F-bit set to 1 if it receives an S or I command PDU with the P-bit set to 1 on the affected data-link connection. To indicate the clearance of a busy condition on a data-link connection, the station shall send an I response PDU with the F-bit set to 1 if a P-bit set to 1 is outstanding, an REJ response PDU, or an RR response PDU on the data-link connection with N(R) set to the current V(R), depending on whether or not the station discarded information fields of correctly received I PDUs. The station may then send a URR command PDU to the global address. Additionally, the sending of a SABME command PDU or a UA response PDU shall indicate the clearance of a busy condition at the sending station on a data-link connection.

5.3.7.2.5.11 Waiting acknowledgment. The station maintains an internal retransmission count variable for each data-link connection, which shall be set to 0 when the station receives or sends a UA response PDU to a SABME command PDU, when the station receives an RNR PDU, or when the station correctly receives an I or S PDU with the N(R) higher than the last received N(R) (actually acknowledging some outstanding I PDUs). If the acknowledgment timer, busy-state timer, or the P-bit timer runs out, the station on this data-link connection shall enter the timer recovery condition and add 1 to its retransmission count variable. The station shall then start the P-bit timer and send an S command PDU with the P-bit set to 1. The timer recovery condition shall be cleared on the data-link connection when the station receives a valid I or S PDU from the remote station with the F-bit set to 1. If, while in the timer recovery condition, the station correctly receives a valid I or S PDU with:

a. the F-bit set to 1 and the N(R) within the range from the last value of N(R) received to the current V(S) inclusive, the station shall clear the timer recovery condition, set its V(S) to the received N(R), stop the P-bit timer, and resend any unacknowledged PDUs; or

b. the P/F bit set to 0 and the N(R) within the range from the last value of N(R) received to the current V(S) inclusive, the station shall not clear the timer recovery condition but shall treat the N(R) value received as an acknowledgment for the indicated previously transmitted I PDUs. (See 5.3.7.2.5.5.)

If the P-bit timer runs out in the timer recovery condition, the station shall add 1 to its retransmission count variable. If the retransmission count variable is less than N2, the station shall resend an S PDU with the P-bit set to 1 and restart its P-bit timer. If the retransmission count variable is equal to N2, the station shall initiate a resetting procedure, by sending a SABME command PDU, as described in 5.3.7.2.6. N2 is a system parameter defined in 5.3.8.1.2.d.

5.3.7.2.6 Procedures for mode resetting. The resetting phase is used to initialize both directions of information transfer according to the procedure described in 5.3.7.2.6.1 through 5.3.7.2.6.3. The resetting phase shall apply only during ABM. Either station shall be able to initiate a resetting of both directions by sending a SABME command PDU and starting its acknowledgment timer.

5.3.7.2.6.1 Receiver action. After receiving a SABME command PDU, the station shall return one of two types of responses, at the earliest opportunity:

a. a UA response PDU and reset its V(S) and V(R) to 0 to reset the data-link connection, or

b. a DM response PDU if the data-link connection is to be terminated.

The return of the UA or DM response PDU shall take precedence over any other response PDU for that data-link connection that may be pending at the station. It shall be possible to follow the UA PDU with additional PDUs, if pending.

5.3.7.2.6.2 Initiator action. If the UA PDU is received correctly by the initiating station, it shall reset its V(S) and V(R) to 0 and stop its acknowledgment timer. This shall also clear all exception conditions that might be present at either of the stations involved in the reset. The exchange shall also indicate clearance of any busy condition that may have been present at either station involved in the reset. If a DM response PDU is received, the station shall enter the data-link disconnected phase, shall stop its acknowledgment timer, and shall report to the higher layer for appropriate action. If the acknowledgment timer runs out before a UA or DM response PDU is received, the SABME command PDU shall be resent and the acknowledgment timer shall be started. After the timer runs out N2 times, the sending station shall stop sending the SABME command PDU, shall report to the higher layer for the appropriate error recovery actions to initiate, and shall enter the ADM. The value of N2 is defined in 5.3.8.1.2.e. Other Type 2 PDUs, with the exception of the SABME and DISC command PDUs, received by the station before completion of the reset procedure shall be discarded.

5.3.7.2.6.3 Resetting with the FRMR PDU. Under certain FRMR exception conditions (listed in 5.3.7.2.8), it shall be possible for the initiating station, by sending an FRMR response PDU, to ask the remote station to reset the data-link connection. Upon receiving the FRMR response PDU (even during a FRMR exception condition), the remote station shall either initiate a resetting procedure, by sending a SABME or RSET command PDU, or initiate a disconnect procedure, by sending a DISC command PDU. After sending an FRMR response PDU, the initiating station shall enter the FRMR exception condition. The FRMR exception condition shall be cleared when the station receives or sends a SABME or DISC command PDU, DM response PDU or RSET command PDU. Any other Type 2 command PDU received while in the FRMR exception condition shall cause the station to resend the FRMR response PDU with the same information field as originally sent. In the FRMR exception condition, additional I PDUs shall not be sent, and received I and S PDUs shall be discarded by the station. It shall be possible for the station to start its acknowledgment timer on the sending of the FRMR response PDU. If the timer runs out before the reception of a SABME or DISC command PDU from the remote station, it shall be possible for the station to resend the FRMR response PDU and restart its acknowledgment timer. After the acknowledgment timer has run out N2 times, the station shall reset the data-link connection by sending a SABME command PDU. The value of N2 is defined in 5.3.8.1.2.e. When an additional FRMR response PDU is sent while the acknowledgment timer is running, the timer shall not be reset or restarted.

5.3.7.2.7 Procedures for sequence number resetting. This resetting procedure, employing the RSET command, is used to reinitialize the receive-state variable V(R) in the addressed station and the send-state variable V(S) in the local station. The addressed station shall confirm acceptance of the RSET command by transmission of a UA response at the earliest opportunity. Upon acceptance of this command, the addressed station V(R) shall be set to 0. If the UA response is received correctly, the initializing station shall reset its V(S) to 0. The RSET command shall reset all PDU rejection conditions in the addressed station, except for an invalid N(R) sequence number condition which the addressed station has reported by a FRMR. The RSET command may be sent by the station that detects an invalid N(R) to clear such a frame rejection condition in place of sending a FRMR frame. To clear an invalid N(R) frame rejection condition with an RSET command, the RSET command shall be transmitted by the station that detects the invalid N(R). When the RSET command is transmitted, the responsibility for all unacknowledged I PDUs reverts to a higher level. Whether the content of the information field of such acknowledged I PDUs is reassigned for transmission or not is decided at a higher level.

5.3.7.2.8 FRMR exception conditions. The station shall request a resetting procedure by sending an FRMR response PDU, as described in 5.3.7.2.6, after receiving, during the information transfer phase, a PDU with one of the conditions identified in 5.3.6.2.3.6. The coding of the information field of the FRMR response PDU that is sent is given in 5.3.6.2.3.6. The other station shall initiate a resetting procedure by sending a SABME or RSET command PDU, as described in 5.3.7.2.6, after receiving the FRMR response PDU.

5.3.7.3 Description of Type 4 procedures. The procedures associated with Type 4 operation are described in 5.3.7.3.1 through 5.3.7.3.5.3.

5.3.7.3.1 Modes of operation. In Type 4 operation, no modes of operation are defined. A station using Type 4 procedures shall support the entire set whenever it is operational on the network.

5.3.7.3.2 Procedures for addressing. The address field shall be used to indicate the source and destinations of the transmitted PDU. The first bit in the source address shall be used to identify whether a command or a response is contained in the PDU. Individual, group, and global addressing shall be supported for the destination addresses in command PDUs. The source address shall contain an individual address.

5.3.7.3.3 Procedure for using the P/F bit. The P/F bit is not implemented in Type 4 operation.

5.3.7.3.4 Procedures for logical data-link set-up and disconnection. Type 4 operation does not require any prior data link set-up and disconnection. Link initialization procedures are not required for Type 4 operation. All stations shall advance to the Information Transfer State.

5.3.7.3.5 Procedures for information transfer.

5.3.7.3.5.1 Sending DIA command frames. The DIA PDU may either be a new PDU from the local user, or a retransmission of a DIA PDU which was not acknowledged within the period determined by the T1 parameter. DIA PDUs are retransmitted up to N2 times, where N2 is as specified by the station parameters.

5.3.7.3.5.2 Receive not ready procedure.

5.3.7.3.5.2.1 Sending a DRNR command PDU. A station may generate and transmit a DRNR command PDU if its Response Mode is enabled and it receives a DIA PDU which it cannot accept because its receive buffers are full. A station shall generate a DRNR command PDU when directed by the management function (e.g., operator). The DRNR command S PDU does not acknowledge a DIA PDU. The station may send a URNR command PDU to the global address after the DRNR PDU.

5.3.7.3.5.2.2 Receiving a DRNR command PDU. Upon receipt of a DRNR PDU a station shall inhibit transmission of DIA PDUs to the station which originated the DRNR command by updating the station status table to reflect this busy condition. The DRNR PDU shall not change the Response Mode status of a station. Any PDUs in the Retransmission queue addressed to the busy station shall be modified to delete (null) the busy station from the destination address list. Normal transmissions of DIA PDUs to that station shall resume upon receipt of a DRR command from the station.

5.3.7.3.5.2.3 Sending a DRNR response PDU. A station shall generate and transmit a DRNR response PDU after it has sent a DRNR command PDU (if its Response Mode is enabled) while it is processing frames in its receive queues in the busy condition. A DRNR response acknowledges the DIA PDU indicated in the PDU identification number field while reinforcing the station's busy condition.

5.3.7.3.5.2.4 Receiving a DRNR response PDU. Upon receipt of a DRNR response PDU, a station shall search the destination addresses associated with the identification number in the DRNR response PDU. The response PDU originator's address shall be deleted from the destination address field (if it is still there) of the DIA being acknowledged.

5.3.7.3.5.3 Receive ready procedures.

5.3.7.3.5.3.1 Sending a DRR PDU. A station shall generate and transmit a DRR PDU if its Response Mode is enabled and one of the following conditions exist.

a. The station is no longer busy and had previously sent a DRNR command PDU.

b. The station received a DIA PDU from a transmitting station which requires acknowledgement.

c. As directed by the user interface.

5.3.7.3.5.3.1.1 Sending a DRR command PDU. The DRR command PDU is generated and transmitted by a station to indicate the end of a Type 4 busy/buffer full condition. The DRR command PDU is addressed to the global address (ALL ONES). The DRR command S PDU does not acknowledge DIA PDUs. The DRR command PDU only changes the busy status to DRR. This frame does not change the Response Mode status. The station may send a URR command PDU to the global address after the DRR PDU.

5.3.7.3.5.3.1.2 Sending a DRR response PDU. The DRR response PDU is generated and transmitted by a station whose Response Mode is enabled to acknowledge the acceptance of a DIA PDU, and is addressed to the originator of the DIA PDU. The DIA PDU which is being acknowledged is indicated by the PDU identification number.

5.3.7.3.5.3.2 Receiving a DRR response PDU. Upon receipt of a DRR response PDU a station shall search the destination addresses associated with the identification number in the DRR response

PDU. The DRR response PDU originator's address shall be deleted from the destination address field of the DIA being acknowledged.

5.3.8 Data-link initialization. The XID command and response messages, formatted as shown in Table VIII and described in Appendix E, are used to establish and control link parameters. The join network request message contains the link operating parameters such as keytime delay, subscriber rank, and net access method. Initialization is caused by an operator or system request. The Join Request is sent to the default network control (NETCON) destination address, which shall be the station assigned to perform NETCON station responsibilities. The NETCON station verifies link parameters and provides values for missing or incorrect parameters to ensure that the new station will not disrupt the net. The NETCON station will reply with either a Join Reject or Join Accept PDU. If the initializing station receives a Join Reject PDU, it should not attempt any link activity until the correct parameters have been obtained.

NOTE: Link initialization may also occur without an XID PDU exchange. Prearrangement by timing, voice, written plans, or orders provides the operator with the necessary frequency, link address, data rate, and other parameters to enter a net and establish a link. With the prearranged information, an operator may begin link activity on the net and initialization is assumed when the new station senses the net and transmits its first message.

5.3.8.1 List of data-link parameters. This MIL-STD defines a number of data-link parameters for which the system-by-system range of values are determined at network establishment. The maximum number of octets in the information field of a UI, I or DIA PDU is an adjustable data-link parameter in the range of 708 - 3345. The definitions of additional parameters for the three types of operation are summarized in 5.3.8.1.1 through 5.3.8.1.3.

5.3.8.1.1 Type 1 logical data-link parameters. The logical data-link parameters for Type 1 operation shall be as follows:

a. Acknowledgment timer. The acknowledgment timer is a data-link parameter that shall define the timeout period (TP) during which the sending station shall expect an acknowledgment from a specific destination station. The acknowledgment timer should not be activated until the corresponding PDU has been transmitted. TP shall take into account any delay introduced by the physical sublayer. The value of TP is described in Appendix C (C3.3).

b. Busy-state timer. The busy-state timer is a data-link parameter that defines the time interval following receipt of the URNR command PDU during which the station shall wait for the other station to clear the busy condition. Default value is 120 seconds.

c. Maximum number of transmissions, N4. N4 is a data-link parameter that indicates the maximum number of times that an UI, TEST or XID command PDU is retransmitted by a station trying to accomplish a successful information exchange. Normally, N4 is set large enough to overcome the loss of a PDU due to link error conditions. The maximum number of times that a PDU is retransmitted following the expiration of the acknowledgement timer is established at protocol initialization. This value is in the range of 0 through 5 and defaults to 2. The retransmission of PDUs may be over-ridden by the Response Mode parameter, which is described in 5.3.11.2.

d. Minimum number of octets in a PDU. The minimum-length valid data-link PDU shall contain 2 flags, 2 addresses, one 8-bit control field, and the FCS. The minimum number of octets in a valid data-link PDU shall be 9.

5.3.8.1.2 Type 2 data-link parameters. The data-link connection parameters for Type 2 operation shall be as follows:

a. Acknowledgment timer. The acknowledgment timer is a data-link connection parameter that shall define the time interval during which the station shall expect to receive acknowledgment to one or more outstanding I PDUs or an expected response to a sent U command PDU. The acknowledgment timer should not be activated until the corresponding PDU has been transmitted. Time values are established at protocol initialization and are in the range of 10 to 1800 seconds in one second increments. Default is 120 seconds.

b. P-bit timer. The P-bit timer is a data-link connection parameter that defines the time interval during which the station shall expect to receive a frame with the F-bit set to 1 in response to a sent Type 2 command with the P-bit set to 1. The P-bit timer should not be activated until the corresponding PDU has been transmitted. Time values are established at protocol initialization and are in the range of 10 to 60 seconds in increments of 1 second. Default is 10 seconds.

c. Reject timer. The reject (REJ) timer is a data-link connection parameter that defines the time interval during which the station shall expect to receive a reply to a sent REJ or SREJ PDU. The reject timer value shall be equal to or less than twice the acknowledgment timer. The reject timer should not be activated until the corresponding PDU has been transmitted.

d. Maximum number of transmissions, N2. N2 is a data-link connection parameter that indicates the maximum number of times that a PDU (including the S command PDU that is sent as a result of the acknowledgement P-bit or reject timer expiring) is sent, following the running out of the acknowledgment timer, the P-bit timer, or the reject timer. The maximum number of times that a PDU is retransmitted following the expiration of the timers is established at protocol initialization. This value is in the range of 0 through 5 and defaults to 2. The retransmission of PDUs may be overridden by the Response Mode parameter, which is described in 5.3.11.2.

e. Maximum number of outstanding I PDUs, *k*. The maximum number (k) of sequentially numbered I PDUs that the station may have outstanding (that is, unacknowledged) at any given time is a data-link connection parameter, which shall never exceed 127. A lower value for *k* may be established.

f. Minimum number of octets in a PDU. A minimal-length valid data-link connection PDU shall contain exactly 2 flags, 2 address fields, 1 control field, and the FCS. Thus, the minimum number of octets in a valid data-link connection PDU shall be 9 or 10, depending on whether the PDU is a U PDU, or an I or S PDU, respectively.

5.3.8.1.3 Type 4 data-link parameters. The logical data-link parameters for Type 4 operation shall be as follows:

a. Acknowledgement (T1) Timer. The T1 timer is the maximum time a station shall wait for an acknowledgement of a transmitted DIA PDU before that PDU is retransmitted. The value of T1 shall be in the range of 5-120 seconds in increments of 0.2 seconds. Each DIA PDU transmitted shall be assigned a T1 timer. When the T1 timer expires for DIA PDU, that DIA PDU shall be retransmitted in the next transmission opportunity for that precedence, assuming the N2 count has not been reached. DIA PDUs with only one destination will be discarded if the destination replied with a DRNR or DRR response PDU. If the DIA PDU is multi-addressed, the receive station is removed (nulled) from the destination address field. This timer shall be paused whenever the net is busy with voice. This timer is resumed when voice transmission has completed.

b. Maximum number of transmission attempts, N2. The N2 parameter shall indicate the maximum number of attempts to complete the successful transmission of a DIA PDU. The value of N2 shall be the maximum retransmit value (range = 0-5).

c. K maximum number of outstanding DIA frames. The value of K indicates the maximum number of DIA PDUs that a station may have outstanding (awaiting acknowledgement) at any given time. The value of K ranges from 5 - 20 DIA PDUs.

5.3.9 Frame transfer. After the station has joined the net, it can begin to send frames. The data-link layer shall request the transmission of a frame by issuing a Unitdata request to the physical layer.

5.3.9.1 PDU transmission. The data-link layer initiates transmission by building a transmission unit and passing it to the physical layer. The elements of a transmission unit include one transmission header (see 5.3.1), one or more PDUs (see data-link concatenation, below), the additional bits resulting from the operations of zero-bit-insertion, optional FEC encoding, optional TDC and optional scrambling. To request transmission, a PL unitdata request is issued by the data-link layer protocol after a transmission unit has been constructed. PDUs shall be queued for transmission in such a manner that the highest priority PDUs are transmitted before lower priority PDUs. If a prioritized net access scheme is active, the priority access level used shall be the priority of the PDU that is to be transmitted next. Transmission units of the same priority shall be in first-in first-out order. Type 2 I PDUs for a particular connection shall be transmitted in the order of their sequence numbers. Any PDUs may be concatenated at the data-link layer or physical layer except Type 1 PDUs with the P bit set to 1.

5.3.9.2 Data-link concatenation. The sending station may concatenate any PDUs, except Type 1 PDUs that require the TP timer (P bit set to 1), by using one or two flags to separate each PDU. The combined length of the concatenated PDUs, before 0-bit insertion, may not exceed the established maximum PDU size for a single PDU (see 5.3.8.1.1.d). The PDUs are concatenated after the 0-bit insertion algorithm is applied. FEC, with or without TDC, and scrambling are optionally applied before the transmission unit is passed to the physical layer in a PL-unitdata request. Data-link concatenation to add another interior data frame shall not be performed if the resulting frame would take longer to transmit than the maximum transmit time allowed for the network. Data-link concatenation is shown in Figure 22.

5.3.9.3 Physical-layer concatenation. Physical layer concatenation does not apply when Packet Mode is used. More than one PDU may be passed to the physical layer with no additional bits between frames. The time to transmit the combined length of the transmission frame, shall not exceed the maximum transmit time allowed for the network. The physical layer shall transmit each transmission unit following the complete physical layer procedures, with no additional bits between frames. Physical layer concatenation is shown in Figure 23.

5.3.9.4 PDU transmissions. Both data link layer and physical layer concatenation may be used to build a single transmission frame. All types of operation PDUs, except Type 1 PDUs with the P-bit set may be concatenated within the same single transmission frame. PDUs are placed in the appropriate priority-level queue, with each level queue using a single first-in first-out order. If the first PDU in the highest priority level queue (or only

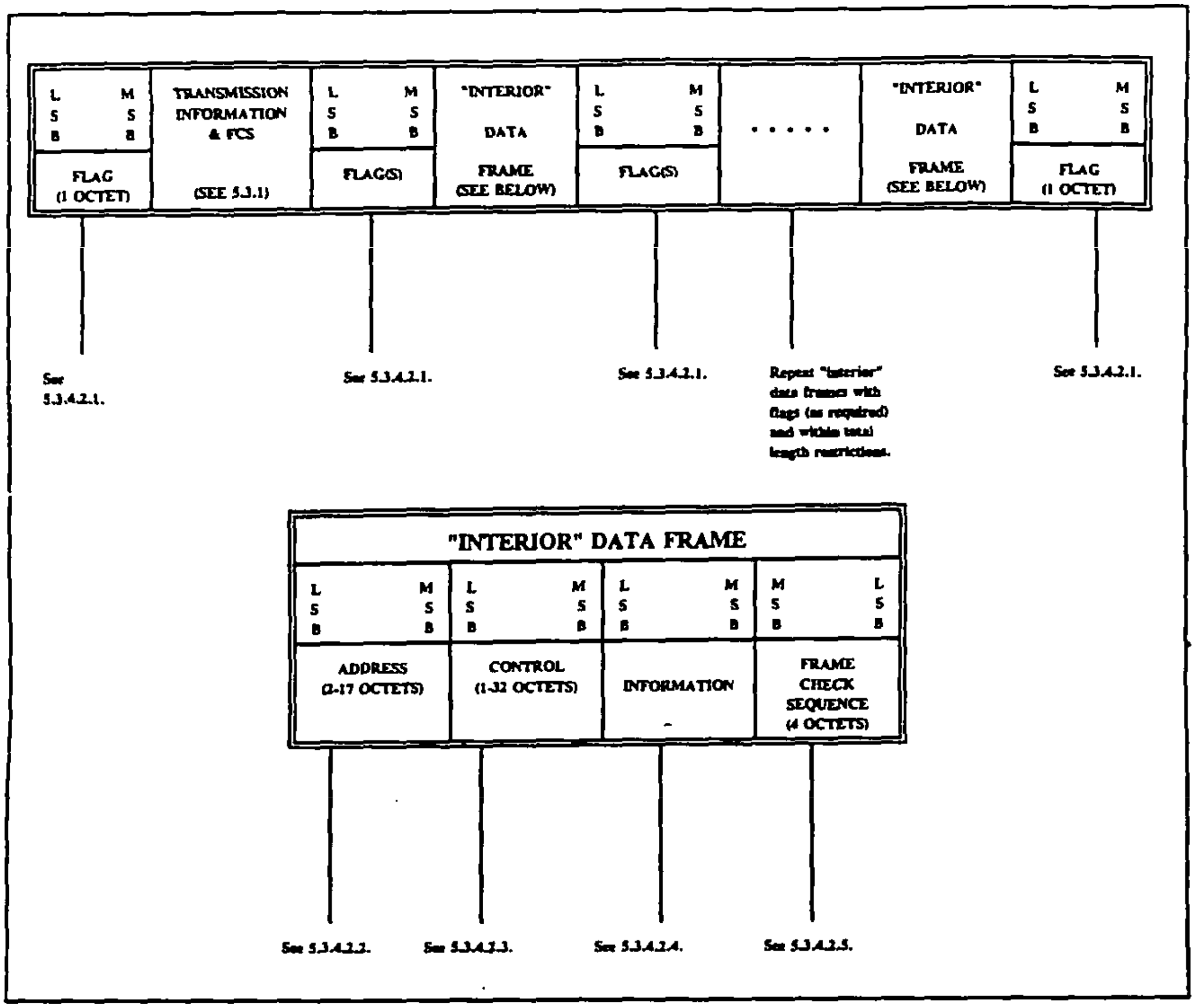



Figure 22. Data-link concatenation.

queue) may be concatenated, then other PDUs may be concatenated with that PDU even if a PDU that does not allow concatenation is queued ahead of them. The PDU that did not allow concatenation shall be at the head of its appropriate queue for the next net access period. If the first PDU in the highest priority level queue (or only queue) does not allow concatenation, it shall be the only PDU transmitted in that net access period.

5.3.10 Flow control. Flow control provides the capability of reducing the allowed input rate of information to prevent congestion to the point where normal operation may become impossible. The control-field sequence numbers are available for this service.

5.3.10.1 Type 1 flow control. Type 1 transmissions can be acknowledged or unacknowledged. Acknowledged and unacknowledged

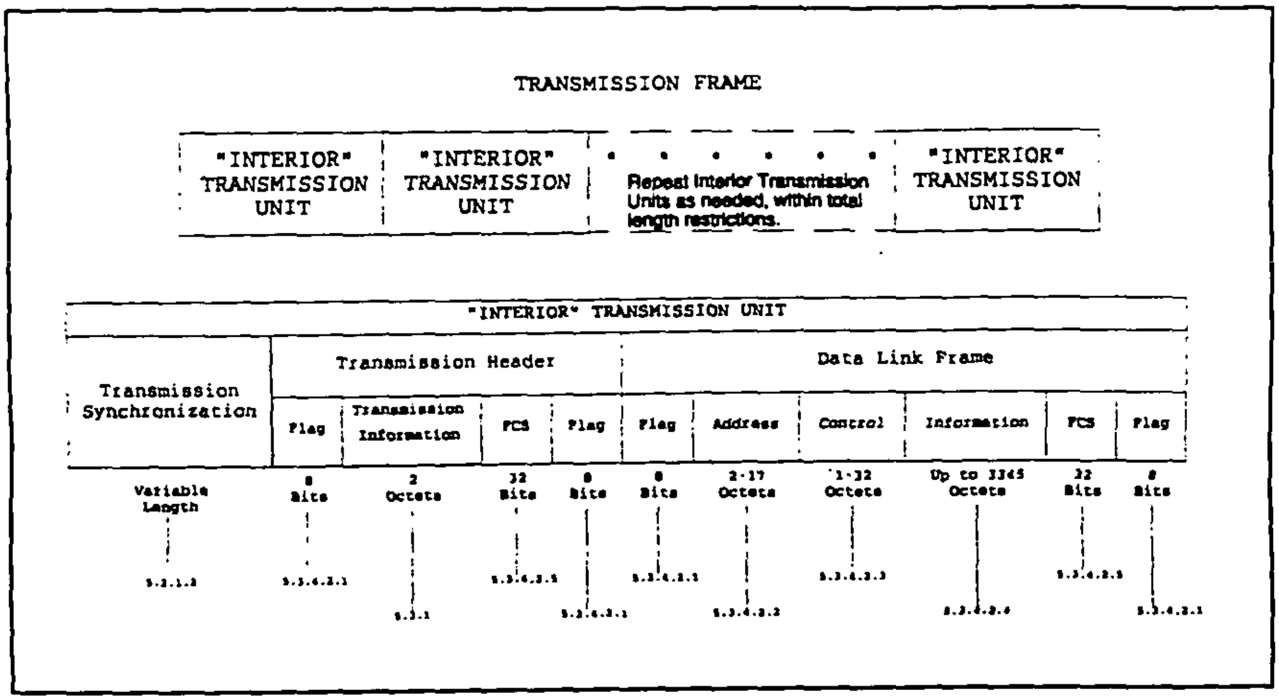



Figure 23. Physical-layer concatenation

operations can perform flow control using URR and URNR messages. These messages announce the station's ability to accept incoming frames.

5.3.10.2 Type 2 flow control. The send and receive sequence numbers, N(S) and N(R), are used in conjunction with the send- and receive-state variables, V(S) and V(R), to control data flow. Flow control is implemented by the window method. The window defines the maximum number of undelivered frames a given user may have outstanding. The maximum number (*k*) of sequentially numbered I PDUs that may be outstanding (that is, unacknowledged) at any given time is a data-link connection parameter, which shall never exceed 127. The incremental updating of N(R) acts as the positive acknowledgment of transmitted frames up to, but not including, that frame number. The window flow-control mechanism requires that the highest sequence number transmitted by the user be less than the sum of the last received N(R) plus *k*. Window size (*k*) is a feature that is agreed upon by the users at initialization. The larger the window, the greater the traffic loading a given user places on a single channel.

5.3.10.3 Type 4 flow control. Type 4 flow control is performed using DRR and DRNR messages. These messages indicate a station's ability to accept incoming DIA frames. In addition, a window method is used to define the maximum number of frames a given station may have outstanding. The maximum number of DIA PDUs that may be outstanding (unacknowledged) at any given time is the Type 4 *k* parameter.

5.3.11 Acknowledgment and response. All UI, DIA, TEST, XID or I PDUs that require an acknowledgment shall be acknowledged except for the following cases:

a. the control field of the received PDU specifies that no acknowledgment is required,

b. the response mode (described in 5.3.11.2), has been set to Off,

c. the receiving station is a group (including global) addressee only,

d. the receiving station's individual address is not in the address field, or

e. the PDU is invalid.

5.3.11.1 Acknowledgment. Acknowledgments are applicable for both Type 1, Type 2 and Type 4 operations.

5.3.11.1.1 Type 1 acknowledgment. Each PDU, with the P-bit set to 1, shall be acknowledged before another PDU is transmitted. This is defined as a coupled acknowledgment. All UI, TEST, and XID command PDUs that have the P-bit set to 1 shall be acknowledged. The RHD procedures (see C3.2) shall be followed by all stations on the network to allow each responding station an interval in which they can transmit their acknowledgment.

5.3.11.1.2 Type 2 acknowledgment. Type 2 PDUs that require acknowledgment shall activate the acknowledgment timer. Type 2 also uses P and F-bit procedures for acknowledgments, but these P and F-bit procedures do not involve coupled acknowledgments. The Type 2 operation does not use the RHD timer, which allows receiving stations to send their acknowledgments during the current net access period. All acknowledgments are transmitted in another net access period. An I PDU acknowledgment does not necessarily correspond on a one-to-one basis with the I PDU and does not necessarily apply to the immediately preceding I PDU.

5.3.11.1.3 Type 4 acknowledgment. The DIA PDU shall activate the acknowledgment timer. The Type 4 operation does not use the RHD timer. All acknowledgments are sent in another channel access period. All DIA PDUs are independently acknowledged.

5.3.11.2 Response mode. The protocol shall allow an operator to initiate Response mode as an override feature that, when invoked, prevents any transmission (including retransmission) without explicit permission from the operator. As a security feature, the operator shall be able to turn off automatic transmissions but still continue to receive. Normal protocol exchanges shall occur when the response mode is ON. Only the operator can initiate a transmission when the Response mode is OFF. The

Response mode shall override the Maximum Number of Transmissions data-link parameters. The default value of the Response mode is ON. If the Response mode is OFF during Type 2 operations, the flow control mechanism and retransmission timers in the remote system will eventually cause the connection to be lost. While response mode is OFF for the destination, DL-Unitdata Indications will be serviced as Type 1 operations without acknowledgement.

5.3.12 Invalid frame. A frame is invalid if it has one or more of the following characteristics:

a. not bounded by a beginning and ending flag,

b. too short,

c. too long,

d. has an invalid address or control field, and

e. has an FCS error.

A frame is too short if it contains less than 9 bytes. A frame is too long if it exceeds the maximum PDU length as described in 5.3.8.1.1.d for Type 1, 5.3.8.1.2.f for Type 2 and 5.3.8.1.3.c for Type 4. Any invalid frame shall be discarded.

5.3.13 Retransmission. The data-link layer will retransmit a command frame waiting for a response. The default number of retransmissions is 2, but the data-link layer protocol may be initialized to automatically retransmit 0 to 5 times. If the response mode is OFF, no automatic retransmissions shall be made.

5.3.14 Error detection and correction. FEC coding alone, or FEC coding in unison with TDC, may be used to provide error detection and correction (EDC) capabilities to compensate for errors induced during transmission. If selected, the FEC process shall be used to encode the data-link frame of 5.3.4. If selected, the TDC process shall be applied to the FEC-encoded data-link frame and to the fill bits. Three modes of EDC shall be supported: FEC OFF, FEC ON with TDC, and FEC ON without TDC (NOTE: FEC ON without TDC may be used when the transmission channel provides the TDC capability). The EDC modes are selectable.

5.3.14.1 Forward-error-correction coding. When FEC is selected, the Golay (24,12) cyclic block code, described in detail in Appendix F, shall be used for FEC. The generator polynomial to obtain the 11 check bits shall be

$$g(x) = x^{11} + x^{10} + x^6 + x^5 + x^4 + x^2 + 1$$

where

$$g(x) \text{ is a factor of } x^{23} + 1$$

5.3.14.2 Forward-error-correction preprocessing. When FEC is selected, data bits shall be divided into a sequence of 12-bit segments for Golay encoding. The total number of segments shall be an integral number. If the data bits do not divide into an integral number of segments, fill bits, consisting of 1 to 11 0's, shall be added at the end to form an integral number of segments. Coupled acknowledgments of Type 1 URNR frames shall be duplicated, including the beginning and ending flag, when FEC and TDC are selected. This provides a station with two opportunities to receive an error-free frame. The duplicated copy shall always start at the exact midpoint of the TDC Block.

5.3.14.3 Time-dispersive coding. TDC bit interleaving may be selected in unison with FEC. When TDC is selected, data shall be formatted into a sequence of TDC blocks composed of sixteen 24-bit Golay (24, 12) codewords (that is, there are 384 FEC-encoded bits per TDC block). Each TDC block shall contain a total of 16 FEC codewords. If the last TDC block of a message contains less than 16 FEC codewords, fill codewords shall be added to complete the TDC block. These 24-bit fill codewords shall be created by Golay-encoding an alternating sequence of 12-bit data words, with the first word composed of 12 ones followed by a word composed of 12 zeros. The fill codewords shall alternate until the TDC block is filled. The TDC block shall be structured into a 16 x 24 matrix (the Golay codewords appear as rows), as shown in Figure 24.

| | | | | |
|---|---|---|---|---|
| $A_1$ | $A_2$ | | $A_{23}$ | $A_{24}$ |
| $A_{25}$ | $A_{26}$ | | $A_{47}$ | $A_{48}$ |
| $A_{49}$ | $A_{50}$ | | $A_{71}$ | $A_{72}$ |
| | | | | |
| $A_{361}$ | $A_{362}$ | | $A_{383}$ | $A_{384}$ |

**Golay Codeword in each row**
**$A_1$, $A_2$, $A_3$, . . . . , $A_{24}$**

Figure 24. 16 x 24 matrix before interleaving.

($A_1$ through $A_{24}$ are the bits of the first Golay codeword. $A_{25}$ is the first bit of the second Golay codeword). Each TDC block matrix shall be rotated to form a 24 x 16 matrix. The Golay codewords now appear as columns, as shown in Figure 25. The TDC block is transmitted row by row with the LSB ($A_1$) of the first row first. At the receiver, the TDC-encoded bit stream shall be structured into a 24 x 16 matrix. Each received TDC block matrix shall be rotated to form the original 16 x 24 matrix, as shown in Figure 24. The TDC decoder at the receiver shall perform the inverse of the TDC encoding process.

| | | | | |
|---|---|---|---|---|
| $A_1$ | $A_{25}$ | | $A_{337}$ | $A_{361}$ |
| $A_2$ | $A_{26}$ | | $A_{338}$ | $A_{362}$ |
| $A_3$ | $A_{27}$ | | $A_{339}$ | $A_{363}$ |
| | | | | |
| $A_{24}$ | $A_{48}$ | | $A_{360}$ | $A_{384}$ |

Golay codeword in each column
Transmit sequence: row by row
$A_1$, $A_{25}$, . . . . , $A_{337}$, $A_{361}$

Figure 25. Transmitter's 24 x 16 matrix after interleaving.

5.3.15 Data scrambling. Data scrambling must be performed if the transmission medium does not have a DC response and there is the possibility that "long" strings of NRZ ones or zeros are transmitted. Long is a relative term that is dependent on the data rate, the low frequency channel cutoff frequency, and the channel signal-to-noise ratio (S/N), since at low S/N there is less margin for DC drift.

At the Data Link layer, the Transmission Header selects a CCITT V.36 scrambler, which includes a randomizer function as well as a pseudo-noise (PN) generator. It is applied inside the FEC (that is, before FEC is applied).

If a CCITT V.36 scrambler is used, and it is outside of the FEC (applied after the FEC on transmission), bit errors at the receiver will be extended. In a high bit error rate environment this extension will become catastrophic. For that reason a CCITT V.33 scrambler, which uses a PN generator but not a randomizer, is specified for use at the Physical layer (as part of the multi-dwell protocol; see J3.3). In both cases, there is a very small probability that the interleaving for the Data Link layer scrambler or the fixed PN sequence for the Physical layer scrambler may do more harm than good. Therefore, they are individually selectable. Both scramblers should not be used at the same time.

5.3.16 Link layer interactions. The data-link layer interacts with both the next higher and next lower layer to pass or receive information regarding services requested or performed. Three primitives are used to pass information for the sending and receiving of data across the upper layer boundary.

a. Requests for transmission of data are sent by the upper layer, using the data-link layer (DL) unitdata request primitive, with the following parameters:

DL-Unitdata Request
- Destination(s)
- Source
- Topology Update ID
- *Quality of Service*
  - Precedence (Urgent/Priority/Routine)
  - Throughput Requested (Normal/High)
  - Delay Requested (Normal/Low)
  - Reliability Requested (Normal/High)
- Data/Data Length

b. Indications are provided to the upper layer through the DL-Unitdata Indication and DL-Unitdata Status Indication primitives with the following parameters:

DL-Unitdata Indication
- Destination(s)
- Source
- Topology Update ID
- Data/Data Length

DL Status Indication
- Acknowledgment Failure
- Connection Status

c. Descriptions of the above parameters follow:

(1) The destination(s) can be 1 to 16 individual or multicast (including global) addresses.

(2) The source address is the individual address of the outgoing link.

(3) Topology Update ID, in a DL-Unitdata Request, shall contain the most recent Topology Update ID sent from the upper layer. Topology Update ID, in a DL-Unitdata Indication, shall contain the Topology Update Identifier field from the Transmission Header.

(4) Quality of Service parameters are used to determine the service provided by the data-link layer.

(a) Precedence parameters are used by the prioritized transmission scheme and are used to order outgoing queues. The precedence levels available to the network will be mapped into three levels (urgent, priority, and routine) in the data-link layer. Precedence levels in the network layer shall be mapped as shown in Table XI.

Table XI. Network Layer to Data Link Layer Precedence Mapping.

| Network Precedence | Data-Link Precedence |
|---|---|
| Critic/ECP<br>Flash Override<br>Flash<br>Network Control (NETCON)<br>Internet Control | URGENT |
| IMMEDIATE<br>PRIORITY | PRIORITY |
| ROUTINE | ROUTINE |

(b) Reliability requested parameter is used to indicate if a reliable type of service is requested.

(c) Throughput parameter is used to indicate if a high throughput type of service is requested.

(d) Delay parameter is used to indicate if a low delay type of service is requested.

(5) Data/Data Length is the block of data exchanged between the data-link layer and its upper layer user, and an indication of the data's length.

(6) Acknowledgment Failure is an indicator to inform the upper layer if a data-link acknowledgment was not received from the remote station when reliability was requested in a Unitdata Request.

(7) Connection Status is an indicator to inform the upper layer if a Type 2 connection has been established, reset or disconnected.

5.4 Network layer.

5.4.1. Intranet Protocol. The Intranet layer, layer 3a, has been dedicated to routing intranet packets between a source and possibly multiple destinations within the same radio network. The intranet layer also accommodates the exchange of topology and connectivity information.

5.4.1.1 Intranet header. Figure 26 defines the Intranet header. For Intranet relaying and message types 1, 2 and 3, the entire header shall be used. Otherwise, only the Version Number, Message Type, Intranet Header Length and Type of Service shall be used.

| LSB 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| VERSION NUMBER | | | | MESSAGE TYPE | | | |
| INTRANET HEADER LENGTH | | | | | | | |
| TYPE OF SERVICE | | | | | | | |
| MESSAGE IDENTIFICATION NUMBER | | | | | | | |
| MAX. HOP COUNT | | | | SPARE | | | |
| ORIGINATOR ADDRESS | | | | | | | |
| DESTINATION/RELAY STATUS BYTE 1 | | | | | | | |
| DESTINATION/RELAY ADDRESS 1 | | | | | | | |
| DESTINATION/RELAY STATUS BYTE 2 | | | | | | | |
| DESTINATION/RELAY ADDRESS 2 | | | | | | | |
| . | | | | | | | |
| . | | | | | | | |
| . | | | | | | | |
| DESTINATION/RELAY STATUS BYTE N | | | | | | | |
| DESTINATION/RELAY ADDRESS N | | | | | | | |

Figure 26. Intranet Header

5.4.1.1.1. Version. The version number shall indicate which version of the intranet protocol is being used. The current value is 0.

5.4.1.1.2. Message Type. The message type is a number 0 to 15 which indicates the type of data in the data field of the intranet layer packet. Table XII lists all the valid message types. Since the message type field in the intranet header is always present in information frames of any link layer type, it is used to determine what type of data is borne by the information frame.

Table XII. Intranet Message Types

| | |
|---|---|
| 0 | Reserved |
| 1 | Intranet Acknowledgment |
| 2 | Topology Update |
| 3 | Topology Update Request |
| 4 | IP Packets |
| 5 | ARP/RARP |
| 6 to 15 | Spare |

5.4.1.1.3. Intranet Header Length. The Header Length shall be the number of octets in the intranet header only. The minimum length is 3 octets.

5.4.1.1.4. Type of Service. The Type of Service (TOS) field in the intranet header is modeled exactly upon, and copied from, the IP TOS field. The TOS is subdivided according to Figure 27.

| LSB 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| PRECEDENCE | | | D | T | R | X | X |

Figure 27. TOS Field

The 3 bits of precedence are defined in 5.4.3.4.3. The remaining bits are as specified in MIL-STD-2045-14502-1.

5.4.1.1.5. Message Identification Number. The message identification number shall be a number, 0-255, assigned by the originating hosts. Together with the originator address it uniquely identifies each packet being relayed.

5.4.1.1.6. Maximum Hop Count. The maximum hop-count shall be the maximum number of times this intranet packet can be relayed on the radio net. A hop is defined as a single link between two adjacent nodes. This number is set by the source host and is decremented each time a device receives the intranet header. If the maximum hop count is decremented to 0, the intranet packet shall not be forwarded any further, however it shall be processed locally if applicable.

5.4.1.1.7. Destination/Relay Status Byte. The Destination/Relay Status Byte (see Figure 28) shall provide intranet routing information for each destination and/or relay address. In addition, this octet also selects end to end intranet acknowledgments.

| LSB 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Distance | | | REL | S/D | | DES | ACK |

Figure 28. Destination/Relay Status Byte

5.4.1.1.7.1. Distance. The distance subfield specifies how many hops a relay address is away from the originator node. For final destination addresses which are not relayers, the distance field gives the number hops from the originator node to the destination node.

5.4.1.1.7.2. REL. The REL bit when set indicates that the given node will participate in relaying.

5.4.1.1.7.3. S/D. The S/D bits indicate the type of relaying to be performed. The relay types are defined in Table XIII. The value of 0 indicates source directed relay defined in Appendix I.

Table XIII. Relay Types

| | |
|---|---|
| 0 | Source Directed Relay |
| 1 | Spare |
| 2 | Spare |
| 3 | Spare |

5.4.1.1.7.4. DES. When the DES bit is set, the following address is at least one of the destinations for the packet. The following address may also be a next hop relay for another destination.

5.4.1.1.7.5. ACK. The ACK bit when set requests end to end intranet acknowledgments for the associated node only. The procedure for end-to-end (ETE) intranet acknowledgment follows.

5.4.1.1.7.5.1 Receiving ETE Intranet ACK. When a node receives an Intranet Packet with the ACK bit set, it shall return an Intranet Acknowledgment packet at the first possible opportunity. The Intranet Acknowledgment packet shall have the same Message Identification Number as the received Intranet Packet. The path specified in the Intranet Acknowledgment packet shall be the reverse path specified in the received Intranet Packet. The Intranet Acknowledgment packet shall specify exactly one destination, namely the originator of the received Intranet Packet.

5.4.1.1.7.5.2 ETE Intranet ACK Timeout. When a node sends an intranet packet with the ACK bit set, it shall start its ETE acknowledgement timer. The ETE acknowledgment timer is an intranet parameter that defines the period within which a sending station shall expect an acknowledgment from the destination(s). The value of the ETE acknowledgment timer shall be a fixed factor plus a factor proportional to the number of hops required for all destinations to receive the packet. The default value for the fixed factor shall be 20 seconds. The default value for the proportional factor shall be twice the value of the data link layer acknowledgment timer, multiplied by the number of hops to the furthest destination. The maximum value for the ETE Intranet Acknowledgment Timer shall be 10 minutes (600 seconds).

5.4.1.1.7.5.3 Receiving an Intranet Acknowledgment Packet. When an Intranet Acknowledgment Packet is received, that destination shall be removed from the list of destinations from which an acknowledgment is required. When all destinations have acknowledged, no further action is taken at the Intranet Layer.

5.4.1.1.7.5.4 Expiration of the ETE Intranet ACK Timer. When the ETE acknowledgment timer expires, the sending station shall retry the transmission of the Intranet packet. The number of retries shall be a value between 1 and 4, with a default of 2. Each retransmission may use a new path to each unacknowledging destination. If only one path exists to a destination, that path shall be used until either the acknowledgement is received or the maximum number of Intranet retransmissions is exhausted.

The retransmitted packet shall have a recreated Intranet Header with the same Type of Service field and Message Identification Number. The Intranet Header shall be recreated to specify the new path to the destination. This recreated Intranet Header shall not specify paths to nodes that have already acknowledged the message. This recreated Intranet Header shall not specify paths to nodes from which an acknowledgment is not required. This recreated Intranet Header shall include paths to all nodes from which an acknowledgment is required, but from which an acknowledgment has not yet been received.

5.4.1.1.8. Originator Address. The originator address shall be the link layer address of the originating node.

5.4.1.1.9. Destination/Relay Address. The intranet destination/relay address shall be the 7-bit link layer address. It is either the destination address for an intranet packet or the relay address. The extension bit (LSB) is available for use by relaying procedures.

5.4.1.2. Topology Update. Connectivity and topology information of the intranet is essential for a node to initiate and/or perform intranet relay. Each node on the radio network needs to determine what nodes are on the network and whether they are 1 or more hops away. This information can be partially determined passively by listening to a node's traffic at layers 3a and 2 and/or actively by exchanging topology information. The topology update data structure, defined in Figure 29, has been provided for nodes in the intranetwork to exchange topology and connectivity information. Appendix B specifies the procedure for exchanging topology information between nodes.

5.4.1.2.1. Topology Update Length. The Topology Update Length field is the length in octets of topology update data. Topology Update Length shall not exceed the MTU minus 8 octets.

5.4.1.2.2. Topology Update ID. The Topology Update ID is a number from 0 to 255. Together with the originator's link layer

| LSB 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Topology Update Length | | | | | | | |
| Topology Update ID | | | | | | | |
| Node 1 Address | | | | | | | |
| Node 1 Status Byte | | | | | | | |
| Node 1 Predecessor Address | | | | | | | |
| Node 2 Address | | | | | | | |
| Node 2 Status Byte | | | | | | | |
| Node 2 Predecessor Address | | | | | | | |
| ... | | | | | | | |
| Node N Address | | | | | | | |
| Node N Status Byte | | | | | | | |
| Node N Predecessor Address | | | | | | | |

Figure 29. Topology Update Data Structure.

address, the Topology Update ID uniquely identifies each topology update generated by the originating node. This number is incremented by 1 every time a topology update is generated. The Topology Update ID for the first topology update generated shall be 1.

5.4.1.2.3. Node Address. The Node Address is the link layer address of node in the intranet.

5.4.1.2.4. Node Status Byte. The ith Node Status Byte characterizes the link between originator host (the host whose address appears in the originator address of the intranet header) and the ith node whose address immediately follows the Node Status Byte as defined in Figure 30.

| LSB 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| LINK QUALITY | | | HOP LENGTH | | | NR | QUIET |

Figure 30. Node Status Byte

5.4.1.2.4.1 Link Quality. The Link Quality subfield for the ith node provides an assessment of the link quality between the ith node predecessor and the ith node. The Link Quality is set to 0 if the quality of a link is unknown. Increasing Link Quality value infers a poorer link. Table XIV lists the Link Quality values.

5.4.1.2.4.2. Hop Length. The Hop Length subfield defined in Table XV indicates the distance in hops from the source to the given node. Hop Length = 1 means the node can be reached directly by the source - no relays are required. A hop length of 0 indicates that the source may know that node should be on the network but does not know where it is.

Table XIV. Topology LINK QUALITY Values

| Link Quality | Description |
|---|---|
| 0 | Unknown |
| 1 | Best Link |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | Worst Link |

Table XV. Hop Length Values

| Hops | Description |
|---|---|
| 0 | Unknown |
| 1 | 0 Relays required |
| 2 | 1 relays required |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | 6 or more relays required |

5.4.1.2.4.3. NR. The NR bit when set to 1 indicates that the node is not participating as a relayer.

5.4.1.2.4.4. Quiet. The Quiet bit, when set, indicates the node is either in quiet mode or going into quiet mode and cannot transmit any traffic.

5.4.1.2.5. Node Predecessor Address. Each node maintains intranet topology as spanning tree rooted at itself. For the ith node in the spanning tree, the Node Predecessor Address is the link layer address of the node one branch up from the ith node in the spanning tree. The predecessor for all nodes within 1 hop of the originator node, which is the root of the spanning tree is the originator node. The predecessor for all nodes n hops away is a node which is n-1 hops away from the originator and that can talk directly with the node n hops away. If the ith node has not been integrated into the source node's spanning tree, the Node Predecessor Address for the ith node should be set to: 0.

5.4.1.3 Topology Update Request Message. The Topology Update Request message, Intranet Relay Message Type 3, consists of the Intranet Header with one originator and one destination address. No Information field is permitted. The maximum hop count and distance field shall be set to 1. The Relay, S/D, and ACK bit shall be always zero. The DES bit shall be always 1. The destination address shall be the link layer address of the node to which this request has been made.

5.4.1.4 Intranet Layer Interactions. The Intranet Layer (Layer 3A) interacts with both the next higher layer and next lower layer to pass or receive information regarding services requested or performed. Three primitives are used to pass information for the sending and receiving of data across the upper layer boundary.

a. Requests for transmission of data are sent by the upper layer, using the Intranet layer (IL) Unitdata Request primitive, with the following parameters:

IL-Unitdata Request Destination(s)
Source
Quality of Service
Precedence
Throughput (Normal/High)
Delay (Normal/Low)
Reliability (Normal/High)
Data/Data Length

b. Indications are provided to the upper layer when data is received through the IL-Unitdata Indication primitive, with the following parameters:

IL-Unitdata Indication Destination(s)
Source
Data/Data Length

IL-Status Indication Acknowledgment failure
Connection Status/failure

c. Descriptions of the above parameters follow:

(1) The destination can be 1 to 16 individual or data-link layer multicast (including global) addresses.

(2) The source address is the data link layer individual address of the outgoing link.

(3) Quality-of-service parameters are used in determining the service provided by the Intranet layer. Quality of service parameters are identical to those at the data link layer, described in 5.3.16c(3).

(4) Data/Data Length is the block of data exchanged between the Intranet layer and its upper layer (i.e., IP) user, and an indication of the data's length.

(5) Acknowledgment Failure is an indicator to inform the upper layer if an Intranet acknowledgment was not received from the remote station when reliability was requested in an IL-Unitdata Request.

(6) Connection is an indicator to inform the upper layer if a Type 2 connection has been established or disconnected.

5.4.2. Subnetwork Dependent Convergence Function (SNDCF). The International Organization for Standards description of the network layer defines a subnetwork dependent convergence layer, between the intranet and internet layers. The layer performs the necessary functions to assure that IP expected services are provided within a particular subnetwork type. The functions required to converge IP services within a MIL-STD-188-220 subnet-work (layers 3a and below) services are: (1) determine the complete list of IP final destinations within the subnetwork; (2) determine the associated subnetwork address(es) for each IP address; and (3) determine the subnetwork type of service requirements (reliability, throughput, delay and precedence). The preceding information is contained in the IP header. If the IP protocol implementation does not provide the required information through an inter-layer interaction, the SNDCF must examine the IP header fields to "learn" the destinations and type of service. The SNDCF is only active for an IL-Unitdata request from the IP. The convergence functions for a MIL-STD-188-220 subnetwork using the Selective Directive Broadcast protocol described in MIL-STD-2045-14502-1 are described below.

5.4.2.1 Determine Destination Function. The Determine Destination function obtains final destination information from the IP header. The IP destination address field of the IP header is examined first. If the address in that field is an individual address, broadcast address (all 1's), or multicast address (Class D), the Determine Destination function is complete and it passes the single IP address to the Address Mapping Function. If the IP destination address is a directed broadcast address, (all ones in the host portion of the IP address only) the network portion of the IP address (NET ID) is compared to the local NET ID, the single IP directed broadcast address is passed to the Address Mapping function and the Determine Destination function is complete. If the NET ID portion of the directed broadcast IP address is the same as the local NET ID, the Determine Destination function examines the IP option field for the presence of the multi-address IP option (selective directed broadcast). If the option is present, the list of individual IP addresses contained in the option is passed to the Address Mapping function. If the option is not present, the IP directed broadcast address is passed to the Address Mapping function.

5.4.2.2. Address Mapping Function. The SNDCF Address Mapping function is provided one or more addresses from the Determine Destinations function. The Address Mapping function determines the data link address(es) associated with an IP address. The Address Mapping function accesses an information base to determine the data link layer address associated with an IP address. IP broadcast (all 1's) addresses and directed broadcast addresses for the local subnetwork are mapped to the data link global address.

5.4.2.3 Type of Service Function. The SNDCF Type of Service function obtains the IP service requirements from the IP Type of Service header field. The values in the field are provided to the Intranet Layer protocol.

5.4.2.4 Intranet Send Request. After the SNDCF layer performs all of its functions, it issues an IL-Unitdata Request that includes the list of data link addresses and the Type of Service data.

# 6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Subject term (key word) listing. The follow key words and phrases apply to this MIL-STD.

Data Communications Protocol
Digital Message Transfer Device
Error Detection and Correction
Interoperability
Open Systems Interconnection
Packets
Radio
Relay
Segmentation
Variable Message Format

6.2 Issue of the DoD index of specifications and standards. When this MIL-STD is used in procurement, the applicable issue of the DoDISS must be cited in the solicitation.

6.3 Interoperability considerations. This section addresses some of the aspects that terminal designers and systems engineers must consider when applying MIL-STD-188-220 in their communications system designs. The proper integration of MIL-STD-188-220 into the total system design will ensure the interoperability of stations that exchange information over a data communications link consisting of a DMTD, a transmission channel, and a DMTD or C4I system.

6.3.1 Transmission channel. For the purpose of this MIL-STD, the transmission channel (from the transmitter to the receiver) is considered transparent to the DMTD subsystem. However, the transmission channel must be interoperable within itself. The transmission channel may be secured or non-secured, using such media as line-of-sight (LOS) radio, high frequency (HF) radio, wireline, and SATCOM.

6.3.2 Physical interface. The specifics of the physical interface for connecting DMTDs to the equipment that implements the transmission channel are beyond the scope of this MIL-STD. The actual physical connections will depend on the interface characteristics required by the particular transmission equipment. These unique physical interface characteristics may be defined in the equipment specifications or in technical interface specifications. Therefore, the requirements for the electrical features (such as data, clock, and control) and mechanical features (such as connectors, pin assignments, and cable) of the connection between the DMTD and the associated transmission channel equipment is left to the equipment designer. The data signaling format (that is, NRZ, FSK, CDP) is specified in this MIL-STD at the standard interface, because it is an interoperability parameter. The design philosophy is that what appears at the input end of the transmission channel must be the same at the output end.

6.3.2.1 SINCGARS SIP R/T interface.

6.3.2.1.1 CSMA net access. The DTE (DMTD or C4I system) interacts with the DCE via an X.21 data interface and an External Control Interface. When the precedence level of the transmission changes, the DTE shall set the precedence level of for the new transmission via the External Control interface. This precedence level will correspond to the frame with the highest precedence value within the series of concatenated frames.

6.3.2.1.2 Net busy sensing and receive status. The presence of multiple stations on a single random access communications net requires voice/data *Net Busy Sensing* and the use of net access control to reduce the possibility of data collisions on the net. The combined Data and Voice Nets require cooperation between the DTE (DMTD or C4I system) and the DCE.

The DCE indicates the presence of receive data and voice via the X.21 Indication line "I" signal. A precise determination of the net status is obtained via the X.21 DTE Receive line "R" signal in combination with the "I" signal:

I = ON and R = Flags -> Data being received

I = ON and R = 1's -> Voice operation

I = OFF and R = 1's -> Idle/Transmission Completed

I = OFF and R = Flags -> Data being transmitted

The transmission of data takes effect by driving the X.21 Control line "C" (push-to-talk) and DTE Transmit line "T", as follows:

Verify I = OFF and R = 1's, then assert C = ON and send flags T = Flags

Verify I = OFF and R = Flags, then transmit data T = Data

Upon transmit completion, assert C = OFF and send T = 1's

6.3.3 COMSEC interoperability. The COMSEC function provides a link encryption capability. In the traditional COMSEC mode of operation, the COMSEC function (normally implemented in ancillary equipment) is considered part of the transmission channel. In the embedded COMSEC mode, the COMSEC function is an integral part of the DMTD subsystem.

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# APPENDIX A

# ABBREVIATIONS AND ACRONYMS

## A1. General

A1.1 Scope. This appendix contains a list of abbreviations and acronyms pertinent to MIL-STD-188-220.

A1.2 Application. This appendix is not a mandatory part of MIL-STD-188-220. The information contained herein is intended for guidance only.

## A2. Applicable documents.

This section is not applicable to this Appendix.

## A3. Abbreviations and acronyms.

| | |
|---|---|
| (n) | repeatability factor |
| ABM | asynchronous balanced mode |
| ACK | acknowledgment acronyms pertinent to |
| ADM | asynchronous disconnected mode |
| ASK | Amplitude Shift Keying |
| BCH | Bose-Chaudhari-Hocquenghem |
| bps | bit(s) per second |
| C/R | command/response |
| C4I | command, control, communications, computers, and intelligence |
| CCITT | International Telephone and Telegraph Consultative Committee |
| CDP | conditioned diphase |
| CMD | command |
| COMSEC | communications security |
| CSMA | Carrier Sensed Multiple Access |
| D | RE-NAD Damping coefficient |
| d/c | don't care |

| | |
|---|---|
| DAP-NAD | Deterministic Adaptive Prioritized - Network Access Delay |
| dB | decibel |
| DC | direct current |
| DCE | data circuit-terminating equipment |
| DES | destination |
| DIA | unnumbered information (PDU) with decoupled acknowledgement |
| DISC | disconnect |
| DL | data-link layer |
| DM | disconnect mode |
| DMTD | digital message transfer device |
| DoD | Department of Defense |
| DoDISS | Department of Defense Index of Specifications and Standards |
| DPSK | differential phase-shift keying |
| DRNR | Decoupled Acknowledgement Receive Not Ready |
| DRR | Decoupled Acknowledgement Receive Ready |
| DTE | data terminal equipment |
| ECP | engineering change proposal |
| EDC | error detection and correction |
| ETE | end-to-end |
| F | final |
| FCS | frame check sequence |
| FEC | forward error correction |
| FED-STD | federal standard |
| FH | frequency hopping |
| FIPS | federal information processing standard |

| | |
|---|---|
| FRMR | frame reject |
| FSK | frequency-shift keying |
| H-NAD | hybrid net access delay |
| HDLC | high-level data link control |
| HF | high frequency |
| HLEN | header length |
| HRT | hop recovery time |
| Hz | hertz |
| I PDU | information PDU |
| IAB | Internet Architecture Board |
| IANA | Internet Assigned Number Authority |
| IHL | internet header length |
| IL | intranet layer |
| IP | internet protocol |
| ISN | initial sequence number |
| ISO | International Organization for Standardization |
| JIEO | Joint Interoperability and Engineering Organization |
| kbps | kilobit(s) per second |
| KG | key generator |
| kHz | kilohertz |
| KT | keytime delay |
| LOS | line of sight |
| LSB | least significant bit |
| MI | message indicator |
| MIL-STD | military standard |
| MMTU | minimum MTU size |

| | |
|---|---|
| MSB | most significant bit |
| MSS | maximum segment size |
| MTU | maximum transmission unit |
| N(R) | receive sequence number |
| N(S) | send-sequence number |
| NAC | net access control |
| NAD | net access delay |
| NATO | North Atlantic Treaty Organization |
| NB | narrowband |
| NETCON | network control |
| NP | network protocol |
| NPDU | network protocol data unit |
| NRZ | non-return-to-zero |
| NS | number of stations |
| OSI | Open Systems Interconnection |
| OTAR | over-the-air rekeying |
| P | poll; RE-NAD Partition coefficient |
| P/F | poll/final |
| P-NAD | priority - network access delay |
| PDU | protocol data unit |
| PL | physical layer |
| PN | pseudo-noise |
| PSK | phase-shift keying |
| QT | quiet timer |
| R/C | receipt/compliance |
| R-NAD | random net-access delay |
| RE-NAD | Radio Embedded - Network Access Delay |

| | |
|---|---|
| REJ | reject |
| REL | relay |
| RF | radio frequency |
| RFC | request for comment |
| RHD | response hold delay |
| RNR | receive not ready |
| RR | receive ready |
| RSET | reset |
| R/T | radio/transmitter |
| S/N | signal-to-noise ratio |
| S-PDU | supervisory PDU |
| SABME | set asynchronous balanced mode extended |
| SATCOM | satellite communications |
| SC | single channel |
| SH | segmentation/reassembly header size |
| SINCGARS | Single Channel Ground and Airborne Radio System |
| SIP | system improvement program |
| SOP | start of packet |
| SP | subscriber precedence |
| SREJ | selective reject |
| ST | satellite time delay |
| STD | standard |
| T | RE-NAD Topology coefficient |
| Tc | continuous scheduler interval timer |
| TCP | Transmission Control Protocol |
| TDC | time-dispersive coding |
| TIDP | technical interface design plan |

| | |
|---|---|
| TL | traffic load |
| TOS | type of service |
| TP | timeout period |
| TTL | time to live |
| TWC | transmission word count |
| U PDU | unnumbered PDU |
| UA | unnumbered acknowledgment |
| UDP | user datagram protocol |
| UI | unnumbered information |
| ULP | upper layer protocol |
| URNR | unnumbered receive not ready |
| URR | unnumbered receive ready |
| V(R) | receive-state variable |
| V(S) | send-state variable |
| VER | version |
| VMF | variable message format |
| WB | wideband |
| XID | exchange identification |

APPENDIX B

INTRANET TOPOLOGY UPDATE

B1. General.

B1.1. Scope. This appendix describes a procedure for active intranet topology updates. The intranet is defined as all processors and CNRs within a single transmission channel.

B1.2. Application. This appendix is a mandatory part of MIL-STD-188-220. The information contained herein is intended for compliance.

B2. Applicable Documents. This section is not applicable to this appendix.

B3. Problem Overview. Figure B-1 shows a sample extended CNR network. Each node labeled A through H is considered to be a radio with an associated communication processor. The dotted ovals indicate subsets of connectivity. Figure B-2 is a link diagram of the sample network. (The link between nodes B and D is not shown; the link is temporarily unusable due to line-of-sight obstruction, distance or other physical phenomena.) Assuming the nodes know nothing about neighbor nodes that are more than 1 hop away, they need to exchange connectivity information. The topology update packet is used to exchange topology information to build up a more complete view of the intranet's topology at every node.

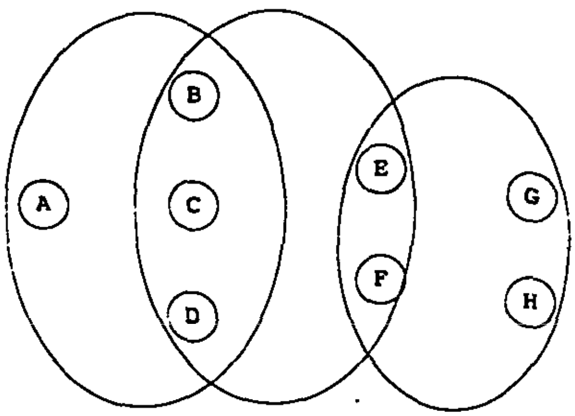


Figure B-1. Sample Intranet

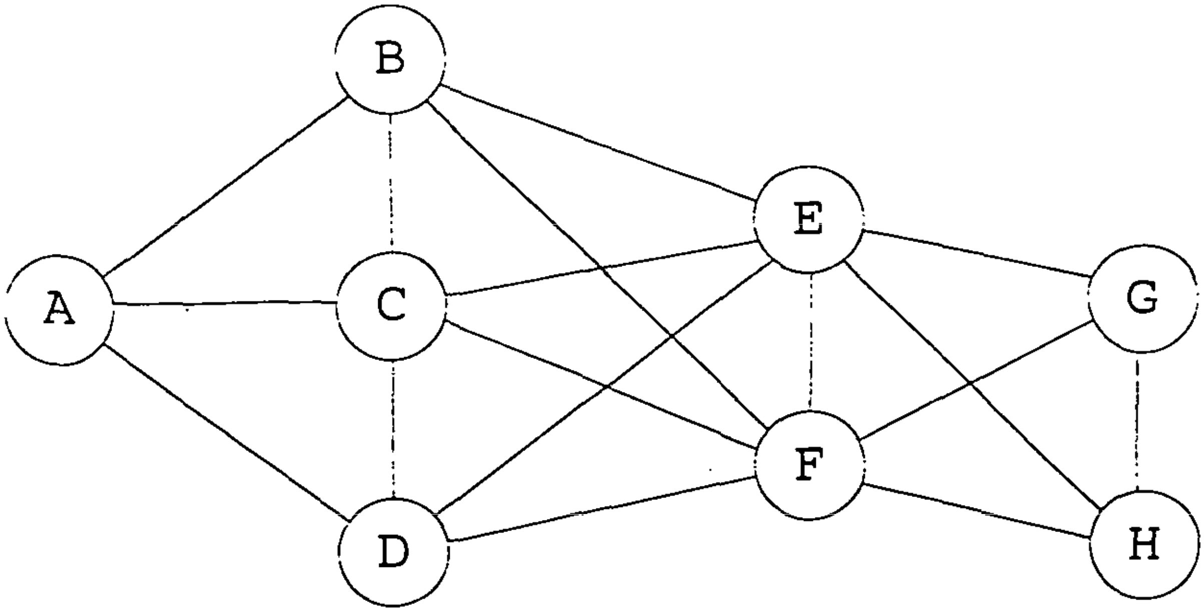


Figure B-2. Link Diagram of Sample Network

B3.1. Spanning Trees. Each node should store topology information as a spanning tree graph. Figure B-3 shows the spanning tree for nodes A and C prior to the exchange of any topology information. Similar graphs would exist for all other nodes. The graphs clearly show that all nodes are one hop away.

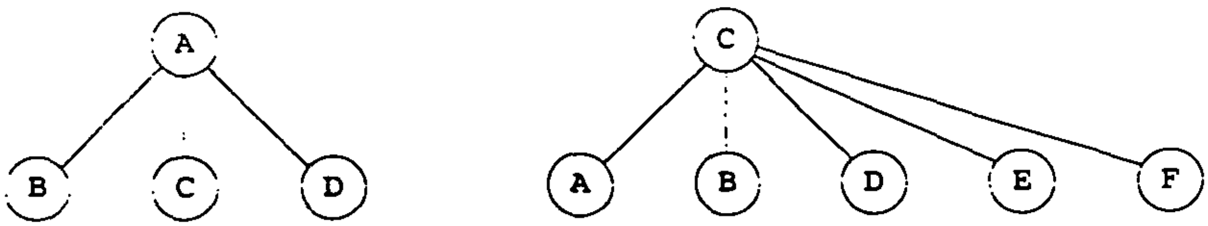


Figure B-3. Spanning Tree for Nodes A and C

## B4. Topology Updates

B4.1. Exchanging Spanning Trees. After node C broadcasts its topology information to all nodes one hop away, all neighbor nodes integrate C's spanning tree into their own. Node A would integrate the graph for Node C into its spanning tree as shown in Figure B-4.

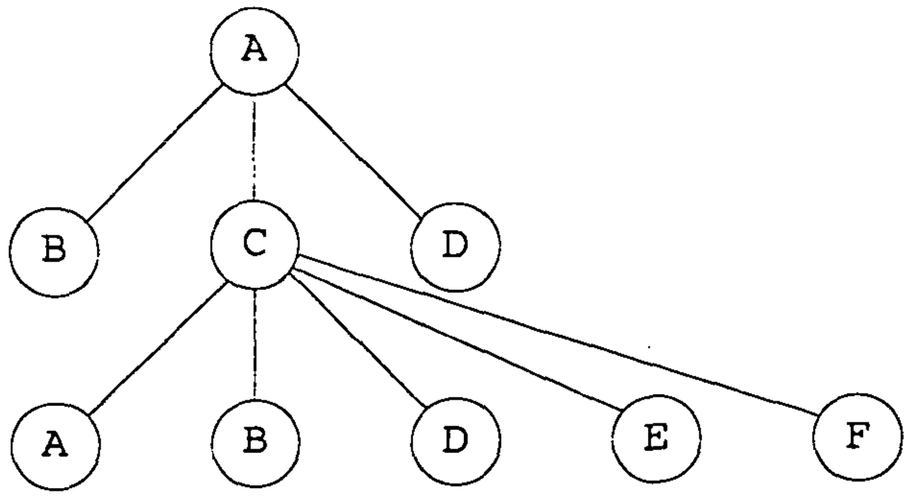


Figure B-4. Concatenated Spanning Tree for Node A

Before the spanning tree is saved, Node A prunes any successive instances of itself and subsequent successors. For instance, in Figure B-4, the link from A to C is the same as the link from C to A; therefore, the link from C to A is removed.

B4.2. Topology Tables. The topology table for A is shown in Table B-1. It assumes no nodes are in quiet mode, all nodes can participate in relay, and all links have a cost of 1. The actual link layer addresses for the nodes would be placed into the table in place of the symbols A, B, C, etc. The extension bit in the address octet would always be set to 0 for topology updates.

Table B-1. Topology Table for Node A.

| Node Address | Node Ancestor | Hops | Cost | NR | Quiet |
|---|---|---|---|---|---|
| B | A | 1 | 1 | 0 | 0 |
| C | A | 1 | 1 | 0 | 0 |
| D | A | 1 | 1 | 0 | 0 |
| B | C | 2 | 1 | 0 | 0 |
| D | C | 2 | 1 | 0 | 0 |
| E | C | 2 | 1 | 0 | 0 |
| F | C | 2 | 1 | 0 | 0 |

There are two entries for node B indicating that there are two paths from A to B. This table can be immediately copied to the respective fields of a topology update packet. The ancestor address is not included in the topology update packet for neighbor nodes because the ancestor is, by definition, the originator node.

B4.3. Sparse Spanning Trees. Exchanging full spanning tree graphs provides full topology information; however, the amount of data in the spanning tree gets very large, especially for fully connected nets. The number of links in a fully connected net = $n(n-1)/2$. To reduce the number of branches in the spanning tree, paths to duplicate nodes on the tree are pruned. Only the shortest paths to the node are retained. In the above example the path from C to B and C to D would be pruned yielding the sparse spanning tree in Figure B-5 and Table B-2. If two or more branches have the same end nodes and the same length (in number of hops), they are all retained. The number of retained branches may be limited in large radio networks to again limit the size of the update packets.

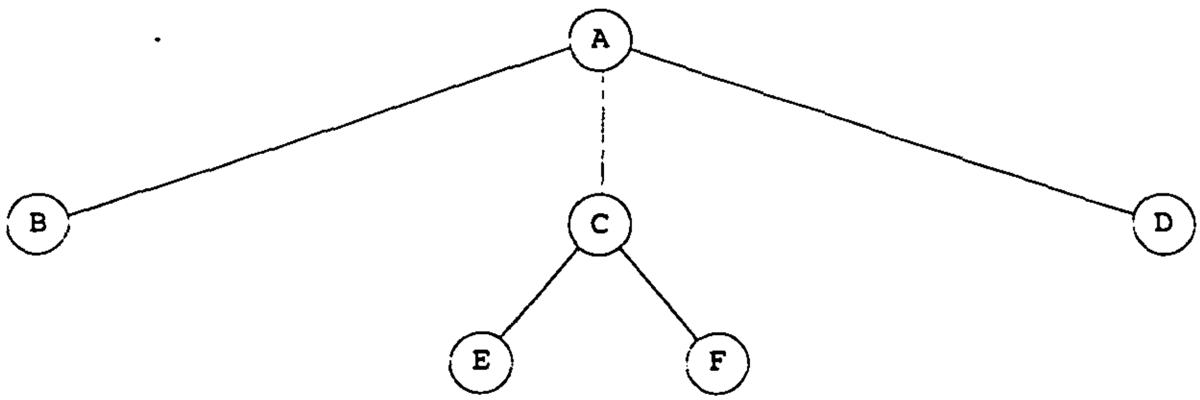


Figure B-5. Sparse Spanning Tree for Node A

Table B-2. Sparse Spanning Tree for Node A.

| Node Address | Node Ancestor | Hops | Cost | NR | Quiet |
|---|---|---|---|---|---|
| B | A | 1 | 1 | 0 | 0 |
| C | A | 1 | 1 | 0 | 0 |
| D | A | 1 | 1 | 0 | 0 |
| E | C | 2 | 1 | 0 | 0 |
| F | C | 2 | 1 | 0 | 0 |

The final spanning tree for Node A, after all the nodes exchange their sparse spanning trees, is shown in Figure B-6 and Table B-3.

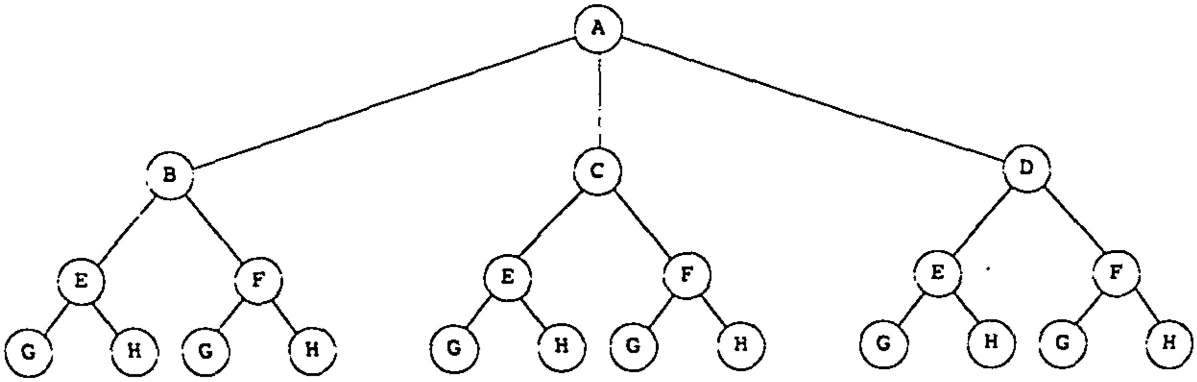


Figure B-6. Final Spanning Tree for Node A

Table B-3. Final Spanning Tree for Node A.

| Node Address | Node Predecessor | Hops | Cost | NR | Quiet |
|---|---|---|---|---|---|
| B | A | 1 | 1 | 0 | 0 |
| C | A | 1 | 1 | 0 | 0 |
| D | A | 1 | 1 | 0 | 0 |
| E | B | 2 | 1 | 0 | 0 |
| F | B | 2 | 1 | 0 | 0 |
| E | C | 2 | 1 | 0 | 0 |
| F | C | 2 | 1 | 0 | 0 |
| E | D | 2 | 1 | 0 | 0 |
| F | D | 2 | 1 | 0 | 0 |
| G | E | 3 | 1 | 0 | 0 |
| H | E | 3 | 1 | 0 | 0 |
| G | F | 3 | 1 | 0 | 0 |
| H | F | 3 | 1 | 0 | 0 |

B4.4. Rules For Exchanging Topology Updates. Topology update packets are transmitted exclusively using a global multicast address.

B4.4.1. Topology updates are triggered for node I by the following:

a) Node I detects a failed link

b) Node I detects a new or recovered link

c) Node I detects a change in the quality of a link - applicable only if link costs are used.

d) Node I receives a topology update from another node which modifies its sparse spanning tree.

e) Node I changes its response mode status and wishes to announce this change.

f) Node I changes its relay capability status.

g) Node I receives a topology update request.

B4.4.2. Optimally, topology updates should be concatenated with other traffic for queuing by the link layer. Topology Update Messages are sent to the global multicast address using Type 1 Unnumbered Information Frames which are not acknowledged. The precedence of the Topology Update Request is user configurable.

B4.4.3. If no other traffic is queued by the link layer, the updates should be transmitted no more often than once every MIN_UPDATE_PER. MIN_UPDATE_PER is measured in minutes and is set by the network administrator when the nodes are configured. The network administrator can disable topology update transmission by setting MIN_UPDATE_PER to zero. Update packets are superseded by newer packets if they have not been queued at the link layer.

B4.5. Non-Relayers. Nodes wishing to be non-relayers must add a separate entry into the sparse spanning table and update packets with NODE ADDRESS and NODE ANCESTOR set to their own address and the NR bit set to 1. Non-relayer nodes remain in the sparse spanning trees; however, they must not have any subsequent branches. Their entries in the spanning table must have the NR bit set to 1.

B4.6. Quiet Nodes. Nodes in the quiet state may appear in the sparse spanning tables and in update packets with the **QUIET** bit set to 1; however, they must not have any subsequent branches in the spanning tree. Nodes wishing to announce that they are entering quiet mode must add a separate entry into the sparse spanning table and update packets with **NODE ADDRESS** and NODE **PREDECESSOR ANCESTOR** set to their own address and the **QUIET** bit set to 1.

B4.7. Topology Update Request Messages. The Topology Update Request Message is triggered whenever there is a mismatch between the topology update ID received from a station and the value that had been stored previously. The Topology Update Request Message will use Type 1 Unnumbered Information frame which is not acknowledged and is addressed to a specific station. The precedence of the Topology Update Request Message is user-configurable. The Topology Update Request Message may be sent no more often than MIN_UPDATE_PER/2. This constant allows up to two requests to be sent to a node while the node is waiting for the MIN_UPDATE_PER timer to expire.

# APPENDIX C

# NET ACCESS CONTROL ALGORITHM

C1. General.

C1.1. Scope. This appendix describes the net access control (NAC) algorithm to be used in the DMTD.

C1.2. Application. This appendix is a mandatory part of MIL-STD-188-220. The information contained herein is intended for guidance only.

C2. Applicable documents. This section is not applicable to this appendix.

C3. Net access control. The NAC protocol shall be used to detect the presence of active transmissions on a multiple-subscriber-access communications network and shall provide a means to preclude data transmissions from conflicting on the network. The stations shall implement the following four basic subfunctions:

a. net busy sensing

b. response hold delay (RHD)

c. timeout period (TP)

d. net access delay (NAD)

C3.1. Net busy sensing function. The net busy function is used to establish the presence of a data or voice signal at the receiving station due to activity on the net. Net busy sensing for a data signal shall be provided. Net busy sensing for a voice signal may be provided.

C3.1.1. Data net busy sensing. Net busy due to a data transmission shall be detected within a time period B which is related to the bit rate n, for all networks. For digital NRZ modulations, B shall be less than or equal to (32/n) seconds after the first valid data bit is delivered to the station by the communication media. For other modulations, B shall be less than or equal to (64/n) seconds after the first valid data bit is delivered to the station. Upon detection of data net busy, the data-link net busy indicator shall be set. Setting the data-link net busy sensing indicator shall inhibit all message transmissions, including coupled response messages. The data-link net busy sensing indicator shall be reset upon indication from the physical layer that neither voice nor digital data is being detected by the station.

C3.1.2. Voice net busy sensing. Net busy due to a voice transmission may be detected. If voice transmissions are not detected, this function shall report that the net is never busy due to a voice transmission. Upon detection of voice net busy, the data-link net busy indicator shall be set. Setting the data-link net busy sensing indicator shall inhibit all message transmissions, including coupled response messages. The data-link net busy sensing indicator shall be reset upon indication from the physical layer that neither voice nor digital data is being detected by the station.

C3.1.3. Net busy detect time. The time required to detect data net busy shall be the same for all stations on the network. This Net_Busy_Detect_Time is a key factor in achieving both throughput and speed of service. Where a communication media provides capabilities to detect data net busy more quickly than given by the formula below, the use of these capabilities is strongly encouraged. In these cases, Net_Busy_Detect_Time can be set to reflect the capabilities of the media. Where the communication media does not provide special capabilities or these capabilities cannot be used by all stations on the network, the station shall examine received data to detect data net busy. In these cases, the maximum time allowed to detect data net busy shall be given by the formula:

Net_Busy_Detect_Time = (KT + C + B + ST)

where:

KT = the value of the keytime delay
C = the CRYPTO device preamble transmission time
B = the time to detect data net busy
ST = the satellite interface delay time

NOTE: Parameters necessary to compute KT, C, B, and ST are initialized locally or learned using the XID messages described in Appendix E. Net_Busy_Detect_Time can also be learned using the XID messages described in Appendix E.

C3.2. Response hold delay. An $RHD_0$ period and an individual RHD value are calculated to determine the time that an addressed receiving station delays before sending a Type 1 response PDU upon receiving a Type 1 command PDU (UI, TEST & XID) requesting acknowledgment (that is, P-bit set to 1 and addressed to the station's individual or special address). The RHD controls net access and the NAD algorithm is suspended during this period. An RHD period is the amount of time required for a single station to respond. The individual RHD is the time at which a particular station accesses the network. If the scheduler is running, immediate scheduling should be used for Type 1 Acknowledgement. The individual RHD value to be used shall be determined by the position of the receiving station's individual or special address in the PDU destination portion of the address field. The value of all non-integer variables (that is, KT, E, S, T, and C) in the RHD equations are rounded to the nearest millisecond. The calculated values for $RHD_i$, TP, and NAD are rounded to the nearest millisecond. The RHD time shall start at the precise instant that the last bit of valid data for a frame requiring a coupled acknowledgement from this station is delivered to the station by the communication media.

a. Each RHD period shall depend on five factors: the keytime delay; the currently selected transmission rate; the time for equipment turnaround; the time to transmit the crypto device preamble and postamble; and the time to transmit one response Type 1 PDU including zero bit insertion (80 bits if the FEC/TDC function is not selected), or one FEC-coded response Type 1 PDU (168 bits), or one FEC/TDC block (384 bits if the FEC/TDC function is selected). All stations on a subnet shall use the same values in calculating RHD.

b. One $RHD_0$ period shall be calculated by the following formula:

$$RHD_0 = KT + E + T + S$$

where:

*KT* = Keytime delay, which is defined as the time interval from the start of a transmission event (such as an operation of a push-to-talk activation of a transmit command) to the start of the bit synchronization field. KT compensates for the transmission equipment (radio and COMSEC) start up time to allow an end-to-end radio link to be established. The KT range shall be 0 to 5.6 seconds in millisecond increments. The KT parameter shall be the same value for all stations on the net. The minimum selectable value shall be the time required by the station experiencing the longest equipment delay time.

The term *E* shall be the sum of the following time elements:

(1) The equipment turnaround time that is equal to the time to change from transmit to receive state, or the carrier drop-out time, whichever is greater.

(2) The amount of time from when the host delivers the last bit of data to the transmission channel until the transmission channel delivers that same last bit of data to all receiving stations not more than one hop away. This time is in addition to satellite delay timer (ST).

(3) The additional transmission time that is required by the cryptographic function. (See Appendix D-1 or D-2).

(4) The satellite delay time (ST) parameter that is required when determining NAD. The ST range shall be 0 to 2.0 seconds in millisecond increments when satellite transmission is used. A delay time of 0.0 seconds shall be used when satellite transmission is not used. The default time for satellite transmissions is 2.0 seconds. The ST parameter shall be the same value for all stations on the net.

The term *S* shall be the sum of the times required to transmit a Type 1 response PDU (see C3.2a), Transmission Synchronization (see 5.2.1.2) and the Transmission Header (see 5.3.1).

The term T is a tolerance term that compensates for the maximum deviation of other parameters. This term shall be selectable within a range of 0.0 to 0.5 seconds in millisecond increments, with 0.05 second as its default value.

c. The individual addressed station's response hold delay (RHDi) shall be calculated by

$$RHD_i = (i - 1) \times RHD_0 + E - C$$

The variable i (where $1 \leq i \leq 16$) is the individual station's position in the destination portion of the address field.

The term C is the cryptographic device preamble time. The preamble transmission time required by the cryptographic function may vary, depending on factors such as the COMSEC approach (external or embedded), equipment, and transmission rate. The value can range nominally from 0.30 to 25 seconds for traditional COMSEC; from 0.36 to 1.6 seconds for narrow-band COMSEC, and from 0.02 to 4.0 seconds for embedded COMSEC (as specified in the standard).

The values for KT, C, E, S, and T can be initialized locally or learned, using the XID messages described in Appendix E.

C3.3 <u>Timeout period</u>. TP is the time all stations shall wait before they can schedule the NAD. During this window of time, the transmitting station shall wait to receive the anticipated response frame(s), if any, from all the addressed stations. TP shall equal (E - C) if no immediate Type 1 response (TEST, URNR, URR or XID) is expected (that is, P-bit set to 0). TP shall be computed after the station's equipment configuration has been established. If the equipment configuration is modified, TP shall be recomputed using the new parameters. The TP variable settings shall be the same for all stations on a subnet. A retransmission shall be executed whenever TP has been exceeded without acknowledgments having been received from all individual and special destinations. Prior to retransmission, the address field of the frame shall be modified automatically to delete the destination station(s) that previously acknowledged the frame. If EDC is enabled, it is possible for the receiving stations to begin the NAD at different times as a result of the error correction processing time. To ensure that the receiving stations begin their NADs at the same time, the error correction processing time shall be subtracted from the calculated TP. Operationally, TP shall be used as follows:

a. Upon termination of a message transmission that requires an immediate response, the transmitting station shall set the TP timer. If the transmitting station does not receive all the expected responses (TEST, URR, URNR, or XID) within TP, and if the number of transmissions is less than the Maximum Number of Transmissions data link parameter, the station shall automatically go into the retransmission sequence. If any other frame is received when a response-type frame (TEST, URR, URNR, or XID) is expected, procedures for the newly received frame type shall be followed and the TP procedures established for the previous UI, TEST or XID frame shall be discarded.

b. The TP shall be calculated by all stations on the net/link as follows. The value of all non-integer variables (that is, $RHD_0$, E, and C) in the TP equation are rounded to the nearest one-thousandth. The calculated value of TP is rounded to the nearest millisecond.

$$TP = j \times (RHD_0) + E - C$$

where:

j = The total number of destination individual link addresses for this transmitted frame

TP = (E - C) if no link acknowledgment has been requested

Note: $RHD_0$, E, and C were previously described.

The TP time at a receiving station shall start at the precise instant that the last bit of valid data for the last frame in a possibly concatenated transmission is delivered to the station by the communication media. The TP time at a transmitting station shall start at the precise instant that the last bit of valid data for the last frame in a possibly concatenated transmission is delivered to the communication media by the station. When operating with a communication media that introduces a significant delay, other than that addressed by Satellite Time, between the starting time for TPs at transmitting and receiving stations (e.g., SINCGARS radios 153 millisecond throughput delay in frequency hopping mode), the transmitting station shall add this delay time to its TP so that all stations on the network will complete their TP timers at the same instant.

C3.4 Net access delay. NAD is defined as the time a station with a message to send shall wait to send a frame after the TP timer has expired. NAD discipline is based on an infinite sequence of "slots" that begin when the TP timer has expired. Slots are defined to be long enough so that all stations on the net will detect a station transmitting at the beginning of a slot prior to the beginning of the next slot. All transmissions, except the coupled acknowledgements, shall begin at the start of the next NAD slot.

There are five schemes for calculating NAD. The five schemes are defined below. Four schemes (R-NAD, P-NAD, H-NAD AND DAP-NAD) compute a value F for each station on the net. This F value is the number of the NAD slot that each station will transmit whenever it has any information to send.

The random net access delay (R-NAD) scheme provides all stations with an equal chance to access the network. The prioritized net access delay (P-NAD) scheme ensures the highest precedence station with the highest priority message will access the net first. In the case of RE-NAD, net access delay is computed by the radio. With RE-NAD the DTE (DMTD or C4I system) does not compute net access delay but does schedule channel access opportunities at which an access attempt can be initiated by the DTE. DAP-NAD, like P-NAD, ensures the highest priority message will access the net first. It does not ensure first access by highest precedence station however. The hybrid net access delay (H-NAD) scheme combines random access with the preferential access by frame priority. The random and hybrid schemes might result in a collision (the same NAD value for two stations). The P-NAD and DAP-NAD schemes always produce a unique NAD value for each station. In all of the NAD schemes, if the TP timer is active, the stations with frames to transmit shall wait for the TP timer to expire before the NAD is started. If the TP timer is not active, the station shall calculate its NAD using the proper NAD scheme for the network. Each NAD scheme produces a set of allowed access periods. The net may be accessed only at the beginning of one of those periods. If a station using P-NAD, DAP-NAD or H-NAD is waiting for its NAD time and a higher priority frame becomes available for transmission, the station may shorten its NAD time to a time it would have computed if it had computed its original NAD time using the new, higher frame priority. Below are the frame reception and transmission procedures:

a. A station shall analyze a received frame to determine if a TP timer must be set. After the frame check sequence has been verified, the address and control fields are analyzed. If the received frame is either an XID, UI, or TEST frame and the poll bit is set to 1, then a TP timer is set. Any other pending frames for transmission shall be placed on hold. If the received frame was not an XID, UI, or TEST frame with the poll bit set,a NAD value shall be computed and initiated after the TP timer expires. An R-NAD or H-NAD value shall be calculated and initiated if the net busy status is clear. DAP-NAD values need to be recalculated after each transmission. The values of all non-integer variables (that is, KT, C, ST, and B) in the NAD equation are rounded to the nearest millisecond. The calculated value of NAD is rounded to the nearest millisecond.

b. If a station does not have a frame to transmit, it shall compute a NAD time using routine priority for its calculations. If the NAD time arrives before a frame becomes available to transmit or frame(s) are not yet encoded for transmission, the station shall compute and use a new NAD time. The starting time for the new NAD shall be the same as the starting time for the NAD that was just completed. The F value used in computing the NAD shall be the sum of the F value used in the NAD just completed, plus a value dependent on the NAD in effect.

   1) For P-NAD this value shall be (NS + 1). This creates another group of NAD slots for all stations on the network. Adding this value at all stations preserves the algorithmic collision prevention property of P-NAD.
   2) For R-NAD this value shall be [(3/4) * NS + 1]. Adding the same constant value at all stations preserves the random property of R-NAD.
   3) For H-NAD this value shall be 1 if the station has an urgent or priority frame to transmit and (Routine MAX + 1 - Routine MIN) if a station has only a routine frame(s) or no frame(s) to transmit. The value 1 preserves the intent of H-NAD that is to grant preferential net access to stations with urgent or priority frames to send. The value (Routine MAX + 1 - Routine MIN) preserves the random property of H-NAD for stations with only routine frames to send.
   4) For RE-NAD, F is not used.
   5) For DAP-NAD this value shall be (NS). This creates another group of NAD slots for all stations on the network. Adding this value at all stations preserves the algorithmic collision prevention property of DAP-NAD.

c. All stations on the net shall continue to sense the link for data or voice net busy and shall withhold transmission until the appropriate NAD period has expired. NAD shall be calculated using the formula:

NAD = F * Net_Busy_Detect_Time

where Net_Busy_Detect_Time is as defined in C3.1.3.

C3.4.1 Random net access delay. The R-NAD calculation method shall ensure that each station has an equal chance of accessing the network. The random nature also may provide a resolution if an access conflict occurs. Each attempt to access the net potentially can use a NAD value different from the station's previous value. The integer value of F shall be obtained from a pseudorandom number generator. The range of the pseudorandom number depends on the number of stations (NS) in the network. F shall be an integer value (truncated) in a range between 0 and (3/4)NS. NS can be learned through the XID join exchange, or fixed by a system parameter established at initialization.

C3.4.2 Prioritized net access delay. The P-NAD calculation method shall ensure that the net access precedence order assigned to subscribers is preserved. Each station shall calculate three unique P-NAD values, one for each of the three frame precedence levels. The integer value of F shall be calculated as:

F = SP + MP + IS

where:

SP = the station priority:
SP = (subscriber rank -1) for the initial transmission;
and SP = 0 for subsequent transmissions.

MP = the message precedence:
MP = 0 for all urgent messages;
MP = (NS + 1) for all priority messages;
and MP = 2 x (NS + 1) for all routine messages,
where NS is the number of subscribers on the network.

IS = the initial/subsequent factor:
IS = 0 for the initial transmission, and
IS = NS for subsequent transmissions.

Only one station on the net uses the subsequent factor. That is the station that transmitted last on the net. However, transmissions of coupled Type 1 acknowledgments do not count as transmissions for the purpose of determining which station transmitted last.

C3.4.3 Hybrid net access delay. The H-NAD calculation method ensures that net access delay times are shorter for higher priority frames, while maintaining equal access chances for all stations. Each priority level has a distinct range of pseudo-random F values determined by the number of stations in the subnetwork, the network percentage of the particular priority level frames, and the traffic load. The integer value of F shall be calculated as

F = MIN + RAND * (MAX - MIN)

where:

MAX and MIN are integer values defining the ranges:

RAND = pseudorandom number in the range 0.0 to 1.0

Urgent_MIN = 0, for urgent frames

Urgent_MAX = USIZE + 1, for urgent frames

Priority_MIN = Urgent_MAX + 1, for priority frames

Priority_MAX = Priority_MIN + PSIZE + 1, for priority frames

Routine_MIN = Priority_MAX + 1, for routine frames

Routine_MAX = Routine_MIN + RSIZE + 1, for routine frames

USIZE = the additional number of random numbers generated for urgent frames

PSIZE = the additional number of random numbers generated for priority frames

RSIZE = the additional number of random numbers generated for routine frames

where the minimum MIN/MAX range size is 2.

The additional range sizes (xSIZE) are integers based on the percent of frames expected at a specific priority level (%priority_level) and the number of stations adjusted (ADJ_NS) by the expected traffic load (TL). NS, %priority_level, and TL, may be input using the XID frames or by initialization input. xSIZE is rounded to the nearest non-negative integer.

USIZE = %U * ADJ_NS, %U = percentage of urgent frames (default 25%)

PSIZE = %P * ADJ_NS, %P = percentage of priority frames (default 25%)

RSIZE = %R * ADJ_NS, %R = percentage of routine frames or 100% - (%U + %P) (default 50%)

where the adjusted number of stations increases if the expected TL is heavy and decreases if the traffic load is light. The minimum random number range at each of the three priority levels is 2, so 6 stations are subtracted from the adjusted number of stations.

ADJ_NS = INTEGER (NS * TL) -6 or = 1 (whichever is greater)

where:

| | | |
|---|---|---|
| TL | = 1.2 | Heavy Traffic Load |
| | = 1.0 | Normal Traffic Load |
| | = 0.8 | Light Traffic Load |

C3.4.4. Radio embedded network access delay (RE-NAD).

C3.4.4.1. RE-NAD media access. The radio embedded network access delay (RE-NAD) DTE data link layer uses a 1-persistent channel access protocol between the DTE (DMTD or C4I system) and DCE. When the continuous scheduler interval timer (Tc) expires and the previous series of concatenated frames was successfully transmitted, a new series of frames is sent to the physical layer. If there is a pending series of concatenated frames, its transmission is requested again. It should be noted that the physical layer holds the series of concatenated frames when channel access has been denied. If channel access was denied a new Tc timer is calculated and channel access for transmission of the pending series of concatenated frames is requested when the new Tc timer expires. If a higher precedence individual frame becomes available for transmission, the concatenated frames shall be re-built to include the higher precedence frame.

For the Type 1 acknowledgment, the RE-NAD portions in both DTE and DCE are suspended and channel access is controlled by the RHD and TP processes. The RE-NAD algorithm is resumed following expiration of the TP timer.

C3.4.4.1.1. Random schedule interval. In order to achieve high performance radio net communication, efficient channel access and multi-level precedence, a 1-persistence RE-NAD algorithm is implemented in the DTE. This algorithm uses the "continuous scheduler" concept to provide a random distribution of timing for channel access via the Tc interval timer. The Tc interval timer is the sum of a fixed interval and a random interval. Toffset is the fixed interval. The fixed interval is dependent on the local station's recent use of the channel and is described more fully in C3.4.4.1.2. The random interval is dependent on network population, network connectivity, traffic load and the local station's recent use of the channel;. It is discussed in C3.4.4.1.3 and C3.4.4.1.4.

The value of Tc is recalculated periodically from the expression:

Tc = Toffset + uniform_random(schedint)

The record of transmit traffic load at the local station is updated after every transmission attempt by the local station, which modifies the value of Toffset. Thus, TC is to be updated after every local transmission attempt.

C3.4.4.1.2. Calculation of the scheduler offset. The parameter "Toffset" in C3.4.4.1.1 is a function of the average transmit duration. A transmission is composed of unnumbered, supervisory and information frames. Combinations of these frames are concatenated into a series of frames for transmission. Toffset is calculated as follows:

Toffset = 2 * average transmit duration of the series of concatenated frames
Toffset = 2 * Ttrans     1.0 <= Toffset <= 10 seconds

where Ttrans = Average concatenated frame transmit duration

The average transmit duration of a series of concatenated frames is determined from the knowledge of the average length of the series of frames in bits divided by the effective on the air information transfer rate. The average length of the series of concatenated frames is computed based on the length of the last four series of concatenated frames transmitted by the local station. Toffset is bounded by 1.0 to throttle the channel by not allowing a station continuous access to the channel. The maximum of 10 seconds places an upper bound on the amount of time a station must wait between channel access attempts when long messages on a low rate channel are used. Toffset is to be updated after every transmission by the local station.

If the scheduler expires and there are no PDUs to transmit, the number of bits equal to one half the effective on the air information transfer rate (bps) will be entered into the record containing the last four transmissions. The value of Ttrans will default to 0.5 second. This will allow the Toffset parameter to default to 1 second during extended periods of inactivity.

C3.4.4.1.3. Calculation of the scheduler random parameter. The parameter schedint depends on queue lengths and average concatenated frame transmit duration as follows:

schedint = Fsched * Ttrans, min <= schedint <= max

where:

Ttrans = Average concatenated frame transmit duration.
Fsched = Scheduling Factor.
min = 3 seconds; max = 20 seconds.

schedint shall be recomputed after every transmission by the DTE.

C3.4.4.1.4. Calculation of the scheduling factor. The scheduling factor, Fsched, is based on three other factors: 1) the Partition Factor, Fpart, 2) the Topology Factor, Ftop, and 3) the Load Factor, Fload as follows:

Fsched = ( ( T*Ftop) (Fload) )/( (P*Fpart) + D )

such that min<=Fsched<=max

where:

| | FH | SC |
|---|---|---|
| T = | 1 | 2 |
| P = | 3 | 3 |
| D = | 7 | 7 |
| min = | 1 | 1 |
| max = | 20 | 20 |

and

FH = Frequency Hopping Mode
SC = Single Channel Mode
T = Topology Coefficient
P = Partition Coefficient
D = Damping Coefficient

Fload and Fsched are recomputed after every transmission attempt by the local station. Fpart and Ftop are computed after a topology update is generated or received. The T, P and D coefficients represent a compromise between high throughput and low delay, while promoting channel stability. The increase in coefficient T for single channel mode is compensating for the hidden terminal effect in multi-hop fixed frequency networks. The minimum value of 1 second has a throttling effect on the amount of time a station must wait between channel access attempts in a heavily congested, large network with multiple relayers.

C3.4.4.1.4.1. Calculation of the Partition Factor. The Partition Factor is computed in a fully distributed manner by each node in the net. Partition Factor takes into account the one-hop connectivities experienced by each node in the net and is a measure of the connectivity between a node's neighbors. When a node's neighbors are strongly interconnected, i.e., the neighbors can hear each other, traffic will be routed directly between neighbors without a need for the node in question to relay the traffic. However, when a node's neighbors are weakly interconnected, for example the neighbors cannot hear each other, the node in question will see an increase in traffic due to relaying between neighbors.

The Partition Factor takes values between 1 for a strongly connected network and 7 for a weakly connected network. In the case of a higher partition factor the channel access scheduling interval is decreased, (the scheduling rate is increased), at the node doing the calculation, to meet the need for a higher percentage of the channel capacity to handle increased relay traffic. The Partition Factor for a non-relay node is set to 1 without executing the following algorithm.

Partition Factor is computed after a topology change is detected.

ALGORITHM: Calculation of the Partition Factor, Fpart, at node j.

1. Set the number of neighbors to zero, set the number of broken links to zero.

2. For each node i in the network, if there is a one hop link from i to j then:

2a. Increment the number of neighbors.

2b. For each node k in the network, if there is a one hop link from k to j and there is no one hop link from i to k then increment the number of broken links.

3. max links = # of neighbors * (# of neighbors -1)

4. If max links less than 1 then max links = 1.

5. Fpart = broken links * 6 / max links.

6. Fpart = Fpart + 1.

7. FINISH.

The constant 6 in algorithm step 5 establishes a set of 7 different levels of expected relaying. Nodes that are expected to do a significant amount of relaying (because their neighbors are not strongly connected) will receive the value 7 for Fpart, which shortens their scheduling interval per the algorithm in C3.4.4.1.4. Nodes that are not expected to do a significant amount of relaying (because their neighbors are fully connected, thus reducing the amount of relaying required and providing a number of nodes to share relaying responsibilities) will receive the value 1. This lengthens their scheduling interval Nodes whose neighbors are neither strongly nor weakly connected are assigned a value between 1 and 7, exclusive, that depends on the degree of connectivity between the node's neighbors. This provides a total range of 7 values to bias a node's scheduler, depending upon the degree of relaying that a node is expected to do.

C3.4.4.1.4.2. Calculation of the Topology Factor. The Topology Factor is computed in a fully distributed manner by each node in the net. This algorithm computes the ratio of the number of nodes that are one and two hops away from the node doing the computation, to the number of neighbors of the node doing the computation. Since this is computed at each node in a fully distributed manner, this enables each node to evaluate its own situation in the network with respect to competition for the shared channel. A node with a high ratio of nodes within two hops to number of neighbors should use a longer scheduling interval due to the fact that neighbor nodes will have to handle the relaying traffic between the node under consideration and all other nodes in the net. Also, neighbor nodes will experience a higher ratio of receive collisions since the node in question and the nodes two hops away are "hidden" from each other and thus cannot cooperate well in the channel access process.

Topology Factor takes values from 3 for a low ratio of nodes within two hops to neighbors, and 40 for a high ratio of nodes two hops to neighbors. In cases of higher Topology Factor values it is desirable to use a longer channel access scheduling interval to reduce the occurrence of channel access contention and collisions.

Topology Factor is computed after a topology change is detected.

ALGORITHM: Calculation of Topology Factor, Ftop, for node j

1. Set "number of neighbors" to zero.

2. Set "hearing within two hops" to zero.

3. For each node i in the net, if there is a one hop link from unit i to unit j then

3a. Increment the number of neighbors.

3b. Hearing within two hops = hearing within two hops + (number of neighbors of unit i) - 1. (don't count unit j).

4. If the number of neighbors is zero then set Ftop = 10. Go to step 10.

5. Hearing within 2 hops = hearing within 2 hops + # of neighbors.

6. Hearing within 2 hops = (hearing within 2 hops * 6)/4.

7. Ftop = hearing within two hops/number of neighbors.

8. If Ftop is less than 3 then Ftop = 3.

9. If Ftop is greater than 40 then Ftop = 40.

10. FINISH.

The constants 6 and 4 in algorithm step 6, and the constant 10 in algorithm step 4 are the default values which, when used in the Fsched equation (see C3.4.4.1.4), restrict the channel access opportunities to a stable region offering good throughput and delay characteristics. The constants 6 and 4 in algorithm step 6 throttle the scheduler as the number of nodes increases, which preserves throughput. The values 6 and 4 give more range when using integer division than the values 3 and 2, respectively.

C3.4.4.1.4.3. Calculation of the Load Factor. The Load Factor is computed in a fully distributed manner by every node in the net. In the transmission header, one byte is dedicated to transmitting the number of messages at the highest priority level remaining in the information frame queue. The four most significant bits (MSB) indicate the level of the highest priority message. The three least significant bits (LSB) indicate the number of frame concatenation's required to transmit all of the messages at the above priority level. The four LSB are quantized as shown in Table C-1.

Table C-1. Calculation of the Load Factor

| Number of Concatenated Frames Required | Bit Pattern |
|---|---|
| 0.0 | 0 0 0 0 |
| 0.0 (exclusive) - 0.5 (inclusive) | 0 0 0 1 |
| 0.5 (exclusive) - 1.0 (inclusive) | 0 0 1 0 |
| 1.0 (exclusive) - 2.0 (inclusive) | 0 0 1 1 |
| 2.0 (exclusive) - 3.0 (inclusive) | 0 1 0 0 |
| 3.0 (exclusive) - 4.0 (inclusive) | 0 1 0 1 |
| 4.0 (exclusive) - 5.0 (inclusive) | 0 1 1 0 |
| > 5.0 | 0 1 1 1 |

The Load Factor takes on values such that 1.0 < Fload < 18.0. The minimum value of 1.0 places an upper limit on the speed of the scheduler per the Fsched equation in C3.4.4.1.4. The value of 18.0 provides a useful range for adaptation of the scheduler due to differing traffic loads, and is divisible by 2 and 3, resulting in integer ranges for the three different precedence values. Higher values of the Load Factor indicate that the node has shorter queues of equal or lesser priority. In cases of high load factor, it is desirable to increase the scheduling interval to give neighboring nodes with higher priority or longer queues of equal priority more opportunities to transmit. The Load Factor is calculated after every expiration of the scheduler, prior to calculation of the next expiration.

ALGORITHM: Calculation of the Load Factor, Fload.

1. Determine the number of unique neighboring node priority levels broadcast by all the nodes including this one. This data is taken from the last transmission received from each neighboring node.

2. Divide the interval 0.0 to 18.0 into equal segments, one per unique announced priority level. The first segment (0.0 to 9.0 for two levels) is allocated to the highest priority traffic. Define the Segment Offset as the lower bound of the chosen segment. For two precedence levels, the Segment Offset is 0.0 for the highest precedence and 9.0 for the Lowest Precedence. Define the Segment width equal to 18.0/Number of precedence levels. For all three precedence levels, each precedence level has a segment width of 6.0

3. Each segment is subdivided into n unique levels where n is the number of unique quantized concatenated frame lengths reported by the neighboring nodes and the node doing the computation. In the case of only one length, all nodes use the midpoint of the segment. In the case of multiple lengths, these lengths are ordered from longest to shortest (1 -> n). In the following computation of Load Factor, a node would use a value of m determined by its position in that ordering. All nodes with the longest quantized length use the value 1, while those with the shortest use the value n for variable m in the following equation:

   Load Factor = Segment offset + (Segment width*m)/(n+1)

   Segment Offset is the Lower bound of the segment chosen by precedence level from step 2.

   Segment Width is the maximum Load Factor (18) divided by the number of unique precedence levels

   n is the number of unique quantized queue lengths.

   m is this nodes positioning within the ordering of quantized queue lengths.

Table C-2. Calculation of the Load Factor -- Example 1

| Node Number | Highest Precedence | Quantized Queue Length | Load Factor |
|---|---|---|---|
| 1 | Routine | 0 0 0 1 | 12.0 |
| 2 | Routine | 0 0 0 1 | 12.0 |
| 3 | Routine | 0 0 1 1 | 6.0 |
| 4 | Routine | 0 0 1 1 | 6.0 |

All nodes compute the load factor in the following manner.

1. There is only 1 unique priority level (Routine).

2. The Segment is determined to encompass the whole range 0->18.

3. The Segment Offset is the lower bound (0).

4. The Segment Width is the entire range (18).

5. Two unique Quantized Queue Lengths are noted. The value of n is set to 2.

6. The unique Quantized Queue Lengths are ordered from longest to shortest (3,1).

7a. Nodes 1 and 2 note that their positioning in this sequence is 2 and set m to 2.

7b. Nodes 3 and 4 note that their positioning in this sequence is first and set m to 1.

8a. Nodes 1 and 2 compute their load factor from the equation.

Load_Factor = Segment Offset + (Segment Width*m)/(n+1)
= 0 +(18 * 2)/(2+1)=12

8b. Likewise, Nodes 3 and 4 do the Load Factor computation.

Load_Factor = 0 + (18 * 1)/(2+1)=6

Table C-3. Calculation of the Load Factor -- Example 2

| Node Number | Highest Precedence | Quantized Queue Length | Load Factor |
|---|---|---|---|
| 1 | Routine | 0 0 0 1 | 13.5 |
| 2 | Routine | 0 0 0 1 | 13.5 |
| 3 | Urgent | 0 0 1 0 | 6.0 |
| 4 | Urgent | 0 0 1 1 | 3.0 |

All nodes compute the load factor in the following manner.

1. There are two unique precedence levels (Urgent and Routine).

2. The load Factor Range is divided into two segments 0-9, 9-18. The segment 0-9 is reserved for Urgent, while the segment 9-18 is reserved for Routine.

3. The Segment Offset is the lower bound of the segment. The Segment Offset is 0 for Urgent and 9 for Routine.

4. The Segment Width for both precedence levels is the entire range (0->18) divided by the number of precedence levels. Segment Width = 18/2 = 9.

Nodes 1, 2 perform the following computations:

5. There is only one Quantized Queue Length. Thus, n is equal to 1 and since there is only 1 length both nodes and 2 use the first position in the sequence and set m to 1.

6. Load Factor = Segment Offset + (Segment Width*m)/(N+1)
   = 9 +(9 * 1)/(1+1)=13.5

Nodes 3,4 perform the following computations.

7. The unique Quantized Queue Lengths are ordered from longest to shortest (3,2). There are two unique lengths which sets the value of n to 2.

8. Node 3 has a length of 2 which occupies position 2 in the ordering of step 7. Because is occupies position 2, the value of m is set to 2.

   Load_Factor = Segment Offset + (Segment Width*m)/(n+1)
   = 0 +(9 * 2)/(2+1)=6

Node 4 has length of 3 which occupies position 1 in the ordering of step 7. Node 4 sets it's value of m to 1.

Load_Factor = Segment Offset + (Segment Width*m)/(N+1)
= 0 +(9 * 1)/(2+1)=3

C3.4.4.1.5 Immediate mode scheduling. The average scheduling interval of the continuous scheduler is a factor in determining intranetwork end-to-end delay. In a lightly loaded net the average end-to-end delay will not be less than the average scheduling interval. In large nets this contributes to unnecessarily large end-to-end delay under conditions of low input load.

This situation is corrected by use of "immediate mode" scheduling under certain specific conditions.

The problem mentioned above is most obvious in large nets under conditions of light load. The Topology Factor incorporates net size in computing the scheduling interval increases as net size increases. However, in large nets under conditions of light input load channel utilization is low, yet end-to-end will be unnecessarily large due to the average scheduling interval of the continuous scheduler.

This situation is corrected using "immediate mode" scheduling as follows:

1. If the message is Type 1 and requires a coupled acknowledgment, set Tc to 0.0 seconds and initiate an immediate channel access attempt. If the DCE is busy, implement the 1-persistent DTE-DC channel access protocol and transmit when the busy period ends. All stations receiving this transmission will suspend their Tc timers and observe the Type 1 timing for coupled acknowledgements.

2. If the scheduler expires and there are no concatenated frames awaiting transmission, set Immediate Mode true. Compute and start the next random interval of the continuous scheduler (Tc).

3. When an information PDU arrives for transmission and Immediate Mode is true, compute a scheduling interval as follows:

   Tc = 100 msec

   When this is done, Immediate Mode is reset to false. The previously scheduled Tc is to be canceled. The 100 msec allows an opportunity for messages which have been segmented/fragmented/received to be piggy-backed into the same series of concatenated frames. This increases efficiency without imposing delay.

4. When the scheduler expires due either to the Tc scheduled as a result of the immediate mode operation or due to normal continuous operation, and I-frame(s), S-frame(s), U-frame(s) or a frame concatenation are pending, perform concatenated frame processing as normally is done. Compute and start the next random interval of the continuous scheduler (Tc) in the normal manner.

5. The Tc interval timer set as a result of immediate mode operation is to be suspended and resumed for voice operation as is done for continuous mode operation.

C3.4.4.2 RE-NAD net access. When the precedence level of the transmission changes, the DTE shall set the precedence level of the new transmission. This precedence level will correspond to the frame with the highest precedence value within the series of concatenated frames.

C3.4.4.3 Net busy sensing and receive status. The presence of multiple stations on a single random access communications net requires voice/data Net Busy Sensing and the use of net access control to reduce the possibility of data collisions on the net. The combined Data and Voice Nets require cooperation between the DTE (DMTD or C4I system) and the DCE.

The DCE indicates the presence of receive data and voice by signalling the following conditions:

Data being received,
Voice operation,
Idle/Transmission completed,
Data being transmitted.

The transmission of data by the DTE is allowed only in the Idle/Transmission completed state.

C3.4.5 Deterministic Adaptable Priority-Net Access Delay (DAP-NAD). DAP NAD is a method of generating Net Access Delays to control net accesses which provides every subscriber with an equal opportunity (when considering multiple access periods and equal message priorities) to use a radio/wireline net. It is deterministic in that every subscriber has an opportunity to access the net and given the device, network, and protocol parameter settings, the maximum time for net access can be calculated.

The mechanism for providing equal net access is to give the first "access opportunity" (the time at which a subscriber may transmit a message if one is available) to a different subscriber at each "net access period" (the time between message transmissions when all subscribers are determining when to transmit) and to give later access opportunities to all other subscribers in sequence. Each subscriber is assigned a Subscriber Rank that is in the range of 1 to the Number of Subscribers (NS in the equations that follow). During the first net access period, subscriber number 1 is given the first access opportunity, subscriber number 2 is given the second access opportunity, subscriber number 3 the third access opportunity, etc. After the last subscriber has been given an access opportunity, subscriber number 1 is again given an access opportunity, followed by subscriber number 2, etc. This continues until a subscriber transmits a message. The subscriber that transmits the message shall place the number of the next higher subscriber in the First Subscriber Number subfield of the Transmission Header. The very next access period (the first DAP-NAD time slot following the message transmission) is reserved, such that any node can interrupt the network in case the network priority is lower than the precedence of the message they have to transmit. This reserved slot is only used when the network is in Priority or Routine mode. All nodes having messages to transmit with a precedence that is greater than the current network priority would transmit a short Urgent control frame in the reserved slot. Upon receipt of this Urgent control frame or detection of a net busy condition during the reserved slot, all receiving nodes would assume that the network priority had gone to Urgent and act accordingly. In this manner, transmissions in the reserved slot would serve to interrupt the operation of a network operating at Priority or Routine causing it to elevate to Urgent mode. The next station authorized to access the network is the First Station Number specified in the Transmission Header of the transmission that occurred before reverting to Urgent mode. Each subscriber calculates different NAD times for each net access period. There are three net priority modes; urgent, priority and routine. The reserved slot is not provided when the network is in the Urgent mode. The calculation of the NAD times are discussed in the following paragraphs.

a. Net in Urgent Mode. The first NS number of access opportunities of a net access period are reserved for subscribers that have an urgent message awaiting transmission. Those subscribers that do not have any urgent messages awaiting transmission must wait for at least the NS+1 access opportunity before they can transmit. The next NS number of access opportunities of the net access period are reserved for subscribers that have a priority (or an urgent if one has become available since the previous access opportunity) message awaiting transmission. Those subscribers that have only routine messages awaiting transmission must wait for at least the 2NS+1 access opportunity before transmitting. Those subscribers that have any messages awaiting transmission, regardless of priority, by the 2NS+1 access opportunity can transmit when their calculated access opportunity arrives.

b. Net in Priority Mode. The first NS number of access opportunities are reserved for subscribers that have an urgent or priority message awaiting transmission. Those subscribers that only have routine messages awaiting transmission must wait for at least NS+1 access opportunity before they can transmit. Those subscribers that have any messages, regardless of priority, awaiting transmission by the NS+1 access opportunity can transmit when their calculated access opportunity arrives. The very first net access period following completion of the transmission while in Priority mode shall be reserved for any station with an Urgent message to notify all other subscribers to revert back to Urgent network mode. The subscriber with the station number matching the First Subscriber Number in the Transmission Header of the transmission completed just before the reserved slot shall have the first net access opportunity. The network shall remain in the Urgent mode until all station have had an opportunity to access the network.

c. Net in Routine Mode. No access modes are reserved. Any subscriber that has a message, regardless of priority, can transmit when their calculated access opportunity arrives. The very first net access period following completion of the transmission shall be reserved for any station with an Urgent or Priority message to cause the network to go to Urgent mode. If no station transmit during the reserved slot, the network remains in the mode designated by the Data Link Precedence field in the Transmission Header provided by the last station accessing the network. Routine mode remains in effect until a message is transmitted.

C3.4.5.1. DAP-NAD Information Field. To allow for rapid recovery (resynchronization) to the DAP-NAD mechanism when messages are not received correctly due to noise, etc., and to provide subscribers information about the priority of a message, a DAP-NAD Information Field has been added to the Transmission Header. This field defines the next access opportunity. This field is present in all physical frames. This field contains the First Subscriber Number subfield which contains the number of the subscriber that is to have the first net access opportunity at the next net access period (the one immediately following this transmission). The number of the subscriber that has the first net access opportunity is the variable FSN in the equations below. The DAP-NAD Information Field also contains the Data Link Precedence subfield which indicates the highest priority of any message that is contained in the physical frame. It shall contain the value 0 if an urgent message is in the frame, 1 if a priority but no urgent message is in the frame and 2 if neither an urgent or priority message is in the frame. The Type 1 acknowledgment sent in response to a transmission will use the same Data Link Precedence and First Subscriber Number as used in the original message to which the acknowledgment applies. The variable NP in the equations below shall be set equal to the content of this subfield for the next net access period. If the transmission contained multiple frames, the variable NP is set equal to the highest value in any of the frames. If net busy is detected in the reserved net access period, the network reverts to the Urgent mode regardless of the setting in the Data Link Precedence subfield.

C3.4.5.2 DAP-NAD Equations. A sequence of NADs for each net access period is generated. A subscriber may transmit a message(s) when the time following the Timeout Period equals any one of the terms (NAD values) in the sequence. Equation 1 is used by each subscriber to calculate its DAP-NADs.

(1) $NAD_n = F_n$ Net_Busy_Detect_Time for n=1 to ∞

$NAD_n$ is the nth term in the sequence of NADs that are associated with a subscriber during a net access period. Each term ($NAD_1$, $NAD_2$, $NAD_3$, etc.) is a point in time (a delay following the Timeout Period) at which a subscriber may begin transmitting. If a subscriber does not begin transmitting at one term (e.g. $NAD_2$), it must wait until at least the next term (e.g. $NAD_3$) before it can begin transmitting. For the DAP-NAD method, the values of the terms calculated by a subscriber will be different than the values of the terms that are calculated by all of the other subscribers (no two subscribers will have terms with the same values). Also, the values of the terms calculated by a subscriber for one net access period will be different than the values of the terms calculated by that subscriber for the next net access period. $F_n$ is nth term in a sequence of factors that when multiplied by Net_Busy_Detect_Time yields the nth NAD term. $F_n$ is an integer calculated per equation 2.

(2) $F_n = F_1 + (n-1)NS$ for n=1 to ∞

$F_n$ is the nth term in a sequence of factors. $F_1$ is the first term in the sequence and is the base from which all the other terms are calculated. It is calculated per equation 3. NS is the number of subscribers on the net and is the common difference between the terms of the sequence. The variable n is an integer and has a range of 1 to infinity.

(3) $F_1 = F_{min} + P \times NS$

$F_1$ is the first term in the sequence of factors. The first term that a subscriber can have is the minimum factor ($F_{min}$) plus an offset determined by priority of messages awaiting transmission. $F_{min}$ is calculated using equation 4. P is the factor that accounts for message priority. It is calculated using equation 5.

(4) $F_{min}$ = SN - FSN if SN ≥ FSN, else $F_{min}$ = NS+SN-FSN

$F_{min}$ is the minimum possible factor that a subscriber could have if message priority and network priority mode were ignored. SN is the number of the subscriber. It is an integer, has a range of 1 to NS, and is assigned at communications initialization. FSN is the number of the subscriber that has the first net access opportunity for the present net access period. It is set equal to the value received in the DAP-NAD information field of the Transmission Header of the last transmission on the net.

(5) P = MP - NP if MP ≥ NP. else P = 0

P is the factor that accounts for priority of messages awaiting transmission. It is used to generate the offset to add to $F_{min}$ to generate $F_1$. MP is a variable indicating the highest priority of any messages awaiting transmission. It shall have a value of 0 if there are any urgent messages awaiting transmission, the value 1 if there are any priority messages and no urgent messages awaiting transmission, and the value 2 if there are no urgent or priority messages awaiting transmission. NP is a variable indicating the highest priority of any messages contained in the last transmission on the network. It shall have the value 0 if an urgent message was in the last transmission, 1 if a priority but no urgent message was in the last transmission, and 2 if neither an urgent or priority message was in the last transmission.

C3.4.5.3 Initial Condition State. The above DAP-NAD operations and equations only apply to subscribers after they are on-line and have received a message. A subscriber that has just come on line and has not yet received a message is not in synchronism with other subscribers (this subscriber has not yet started any timers and if it had, they would not have been started at the same time as other subscribers' timers). These subscribers shall be considered to be in the initial condition state. Regardless of what causes a subscriber to be in the initial condition state, transmissions must be delayed by at least the time specified by equation 6 while in that state.

(6) INAD = TP + 3 x NS Net_Busy_Detect_Time

INAD (Initial condition state Net Access Delay) is the minimum time that a subscriber must delay transmission of a message after it has become capable of receiving and transmitting messages, but no more than 20 seconds. The TP in the equation shall be a worst case TP, i.e., as if there had just been a Type 1 message on the net that required acknowledgment and was addressed to 16 subscribers on the net.

C3.5. Voice/data net sharing. A station may support this protocol on a network where both voice and data transmissions are allowed to occur. When operating in a mixed voice and data network, voice and data net sharing shall operate in the following manner:

a. A receive operation shall be considered a voice reception unless a valid synchronization pattern (bit synchronization, frame synchronization or robust frame synchronization) is identified within 128 bit times (2 frame synchronization times) after the first valid bit delivered to the station by the communication media. A receive operation that is less than 0.75 seconds in length shall be considered a noise burst instead of a voice reception.

b. The net shall be synchronized based on RHD and TP timers, which are driven only by data transmissions and receptions. Voice receptions and noise bursts shall not be used for resynchronizing net timers.

c. A station shall not transmit during a noise burst or a voice reception. After completion of a voice reception, a station shall wait at least (E-C) milliseconds before initiating transmission.

d. After completion of a voice reception, operation of the P-NAD net access scheme shall be reinitiated if P-NAD is being used. P-NAD consists of a sequence of NAD slot groups. Within each NAD slot group there is one NAD slot assigned to each station and one slot assigned to the station that transmitted last. After a voice reception is completed, the current, partially-completed NAD slot group and the next complete NAD slot group shall be used only by stations with urgent-precedence data transmissions. The NAD slot group after these groups shall be used only by stations with urgent-precedence or priority-precedence data transmissions. Subsequent NAD slot groups may be used by any station. This preserves the intent of P-NAD, which is to deterministically avoid collisions and to ensure that high-precedence traffic is always transmitted first.

e. Media access control timers shall not be suspended or resumed as a result of voice receptions.

f. Data link protocol timers shall be suspended and resumed as a result of voice receptions.

g. Relative priorities of voice and data on the net shall be adjusted by selectively enabling or disabling physical and/or data link concatenation for a station.

Concatenation may be disabled to give priority to voice and may be enabled to give priority to data.

APPENDIX D

COMMUNICATIONS SECURITY STANDARDS

D1. General.

D1.1 Scope. This appendix describes the COMSEC interoperability parameters for the DMTD subsystem. It defines the technical requirements for backward-compatible (traditional) and forward-compatible (embedded) interface modes. See classified Appendix D-2 for additional information.

D1.2 Application. This appendix is a mandatory part of this MIL-STD. The information contained herein is intended for compliance.

D1.3 Interoperability. This appendix cannot guarantee the DMTD user end-to-end interoperability. The selection of COMSEC and signaling is a function of communications media. Traditional COMSEC equipment is specific to communications media and may not be compatible due to signaling differences. The systems integrators and systems planners must ensure that compatible media and signaling are chosen if interoperability is desired. This COMSEC specification will provide for interoperability of the underlying encryption algorithm.

D2. Applicable Documents

a. (U) ON431125 WINDSTER Cryptographic Standards
b. (U) DS-68 INDICATOR Cryptographic Standards

D3. Definitions. Refer to Appendix A.

D4. General Requirements. The backward-compatible mode applies when link encryption for DMTD subsystems is provided by external COMSEC devices. These external COMSEC devices may be standalone equipment (such as the VINSON and KG-84) or communications equipment with embedded COMSEC (such as SINCGARS). The forward-compatible mode shall apply for all future DMTD subsystems that will embed COMSEC within the DMTD. The backward-compatible mode may also be emulated using embedded COMSEC devices.

D5. Detailed Requirements

D5.1 Traditional COMSEC transmission frame. The traditional COMSEC transmission frame shall be composed of the following components, as shown in Figure D-1. Figure D-1 provides additional detail to Figure 4a.

a) COMSEC Bit Synchronization

b) COMSEC Frame Synchronization

c) Message Indicator

d) Transmission Synchronization (see 5.2.1.2).

e) Data Field (including Transmission Header)

f) COMSEC Postamble

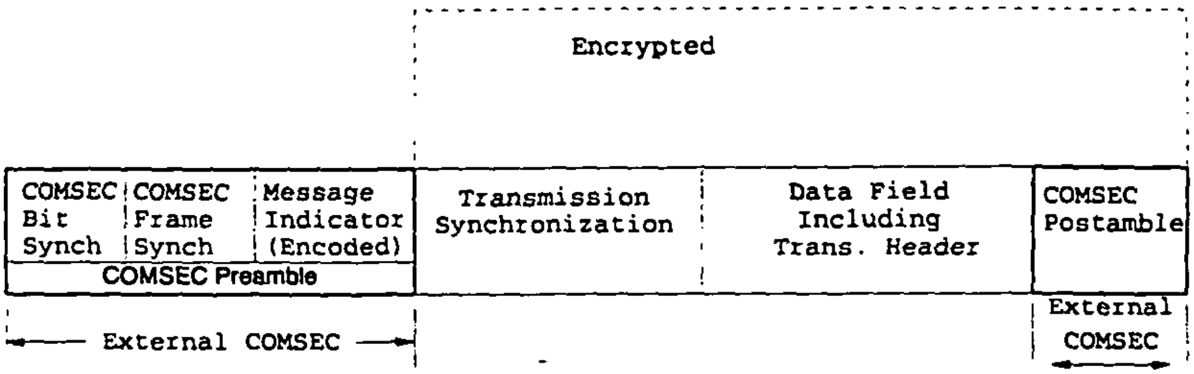


Figure D-1. Traditional COMSEC transmission frame structure.

D5.1.1 COMSEC synchronization field. The COMSEC synchronization field shall consist of three components: a COMSEC bit synchronization subfield, a COMSEC frame synchronization subfield, and a Message Indicator (MI) subfield. This field is used to achieve cryptographic synchronization over the link.

D5.1.1.1 COMSEC bit synchronization subfield. This subfield shall be used to provide a signal for achieving bit synchronization and for indicating activity on a data link to the receiver. The duration of the bit synchronization field shall be selectable from 200 milliseconds to 1.5 seconds. The bit synchronization subfield shall consist of the data-rate clock signal for the duration of the subfield.

D5.1.1.2 COMSEC frame synchronization subfield. This subfield shall be used to provide a framing signal indicating the start of the encoded MI to the receiving station. This subfield shall be 465 bits long, consisting of 31 Phi-encoded bits, as shown in Figure D-2. Figure D-2 provides additional detail to Figure 4b. The Phi patterns are a method of redundantly encoding data bits. A logical 1 data bit shall be encoded as Phi(1)= 111101011001000, and logical 0 data bit shall be encoded as Phi(0)= 000010100110111. A simple majority voting process may be performed at the receiver to decode the Phi-encoded frame pattern to its original format.

| LSB | MSB |
|---|---|
| 11111111111111111111111111111110 | |

Figure D-2. COMSEC frame synchronization pattern for Phi encoding.

D5.1.1.3 Message Indicator subfield. This subfield shall contain the COMSEC-provided MI, a stream of random bits that are redundantly encoded using Phi patterns. Cryptographic synchronization is achieved when the receiver acquires the correct MI.

D5.1.2 Transmission synchronization field. This field, consisting of the bit synchronization subfield, optional robust frame synchronization subfield, optional robust frame format subfield, frame synchronization subfield and the TWC subfield, shall be as defined in 5.2.1.2.

D5.1.3 Data field. This field, including Transmission Header as defined in 5.3.1, shall be as defined in 5.2.1.3.

D5.1.4 COMSEC postamble field. This field shall be used to provide an end-of-transmission flag to the COMSEC at the receiving station. This will be automatically performed by the COMSEC key generator. Refer to 0N431125, WINDSTER Cryptographic Standards, or DS-68, INDICTOR Cryptographic Standards, as appropriate.

D5.1.5 COMSEC algorithm. The COMSEC algorithm shall be backward-compatible with VINSON and SINCGARS equipment. Refer to 0N431125, WINDSTER Cryptographic Standards.

D5.1.6 COMSEC modes of operation. The COMSEC shall be operated in Mode A. The rekey functions shall be performed through the use of KY-57 rekeys for backward compatibility. Refer to 0N431125, WINDSTER Cryptographic Standards.

D5.2 Embedded COMSEC transmission frame. The embedded COMSEC transmission frame shall be composed of the following components, as shown in Figure D-3.

a. Bit synchronization

b. Robust Frame synchronization

c. Robust Frame Format

d. Frame Synchronization

e. Message Indicator

f. Transmission word count

g. Data Field

h. COMSEC Postamble

| | | | | Encrypted | | |
|---|---|---|---|---|---|---|
| Bit Synch | Robust Synch. | Frame Synch. | Message Indicator | Transmission Wordcount | Data Field & T.H. | COMSEC Postamble |
| Transmission Synchronization | | | | | | |

Figure D-3. Embedded COMSEC transmission frame structure.

D5.2.1 Bit synchronization field. This field shall be used to provide a signal for achieving bit synchronization for the message as well as the COMSEC, and for indicating activity on a data link to the receiver. The duration of the bit synchronization field shall be as defined in 5.2.1.2.1.1.

D5.2.2 Frame synchronization field. This field shall be either the Robust Frame Synchronization field defined in 5.2.1.2.1.2 or the Frame Synchronization field defined in 5.2.1.2.1.5. In either case frame synchronization is to be provided for both the message frame and the COMSEC. When the Robust Frame Synchronization field is used, the Robust Frame Format field defined in 5.2.1.2.1.3 also shall be used. The Robust Frame Format field shall not be used when the Robust Frame Synchronization field is not used.

D5.2.3 Message Indicator field. This field shall contain the MI, a stream of random data that shall be encoded using Golay, as defined in 5.3.14.1. Cryptographic synchronization is achieved when the receiver acquires the correct MI. The COMSEC shall provide the MI bits. For backward compatibility, these MI bits must be redundantly encoded using Phi patterns, as described in D5.1.1.

D5.2.4 Transmission word-count field. This field shall be as defined in 5.2.1.2.1.7.

D5.2.5 Data field. This field, including Transmission Header as defined in 5.3.1, shall be as defined in 5.2.1.3.

D5.2.6 COMSEC postamble field. This field shall be used to provide an end-of-transmission flag to the COMSEC at the receiving station. The flag shall be a cryptographic function and may be used by the data terminal as an end-of-message flag as well.

D5.2.7 COMSEC algorithm. Refer to 0N431125, WINDSTER Cryptographic Standards.

D5.2.8 COMSEC modes of operation. COMSEC shall be operated in Mode A for all applications. The rekey functions will be performed through the use of KY-57 rekeys for backward-compatibility and will be performed through over-the-air-rekeying (OTAR) techniques for forward compatibility. Rekey signaling for OTAR must be supplied by the host equipment. Refer to 0N431125, WINDSTER Cryptographic Standards.

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# APPENDIX E

# DATA-LINK MANAGEMENT PROCESSES

## E1. General.

E1.1 Scope. This appendix describes the management processes associated with the data-link layer.

E1.2 Application. This appendix is a mandatory part of MIL-STD-188-220. The information contained herein is intended for compliance.

## E2. Applicable documents.

ISO 8885, General Purpose XID Frame Information Field Content and Format.

## E3. Exchange identification frame.

The XID Frame Format is used to request or disseminate data-link information. The XID format shall be in accordance with ISO 8885. At initialization time, a station can request link operating parameters that may be unknown. The XID user message types have been designed to provide management capabilities at the link layer. However, they are not required if all the stations on the net have been configured with link addresses and operating parameters prior to initialization.

E3.1 XID format. The XID PDU shall consist of an originator address, destination address, control field, and an information field. The information field of the XID PDU is comprised of the format identifier, group identifier, and a MIL-STD-188-220 defined message. The format identifier is in the first octet of the information field and indicates that the XID frame is in accordance with ISO 8885. The group identifier shall indicate that a MIL-STD-188-220 defined message follows. The MIL-STD-188-220 defined message occupies the remaining portion of the information field. Table E-1 shows the XID format. All XID frames contain the MIL-STD-188-220 defined group identifier that is designated by the value 255 (the value for user data in ISO 8885). One of the five MIL-STD-188-220 messages, listed in Table E-2 and defined in Tables E-3 through E-7, follow the group identifier field.

E3.2 XID command/response messages. XID command messages (Join Request, Join Accept, Join Reject, Hello, and Goodbye) shall have the C/R bit in the source address set to 0 in the Originator Address field. The XID response messages (Join Accept and Join Reject) shall have the C/R bit set to 1.

Table E-1. MIL-STD-188-220 XID Format.

| BYTE NUMBER | FIELD NAME | L S B M S B | VALUE |
|---|---|---|---|
| 1 | ORIGINATOR ADDRESS | XXXXXXXX | 3 to 95; 1 may also be used for message 20; 2 may be used for messages 21-22 |
| 2 | DESTINATION ADDRESS | XXXXXXXX | 3 to 95; 1 allowed in messages 21-22; 2 allowed in message 20; individual, group, global and NETCON addresses for messages 23-24 |
| 3 | CONTROL FIELD | 1111X101 | XID FRAME |
| 4 | FORMAT IDENTIFIER | 01000001 | 130 General-Purpose |
| 5 | GROUP IDENTIFIER | 11111111 | 255 |

E3.3 XID poll/final bit. The XID command P = 1 (Join Request) shall cause the destination station to respond with an XID Response PDU with F = 1 (the response PDU does not contain data). The XID command message P = 1 with data in the parameter fields (Join Accept or Join Reject) shall be provided at the earliest opportunity following the XID Response. The response to an XID Join Request with P = 0 shall be a Join Accept or Join Reject with F = 0. No response is provided to an XID Join Accept, Join Reject, Hello or Goodbye with P = 0.

E4. Parameters to Negotiate. The parameters to negotiate for MIL-STD-188-220 are specified and located in the user data subfield of the XID frame. When the field size exceeds one octet, octets are transmitted from the most significant octet to the least significant octet.

E4.1 MIL-STD-188-220 parameters. MIL-STD-188-220 specific initialization parameters are contained in the user data subfield of the XID Join messages (Request, Accept, and Reject). A new station's link address if not preassigned, shall be assigned by NETCON. An originator of the Join Request may use a special net entry link address of 1 that has been reserved for temporary use by a station requesting link address assignment. To request information, a parameter field will contain all 1s, that indicates information is being requested.

E4.1.1 Link management messages. Table E-2 lists five XID link management messages. Three messages are used in the procedure for a station to request or verify the network operating parameters. At initialization, a station can send the Join Request message, and the NETCON station will either accept or reject the request to join. The Hello message allows an initiating station to announce its link address. The goodbye message is issued to notify that a station is leaving the net. Table E-1 shows the XID frame format that precedes the user data subfield. The user data subfield of each message is presented in Tables E-3 through E-7.

Table E-2. Link Management Messages.

| MESSAGE NUMBER | TITLE | DESCRIPTION |
|---|---|---|
| 20 | Join Request | Request operating parameters assignment, validation, or both |
| 21 | Join Accept | Accepts the Join Request |
| 22 | Join Reject | Rejects the Join Request with errors indicated |
| 23 | Hello | Announces link address for an initiating station |
| 24 | Goodbye | Announces that initiating station is leaving the network. |

Table E-3. Join Request Message.

| BYTE NUMBER | FIELD IDENTIFICATION | FIELD SIZE (BITS) | VALUE |
|---|---|---|---|
| 1 | Message Number: Identifies specific message content. | 8 | 20 |
| 2 | Unique Identifier: Identifies the unit station to be initialized. | 32 | identifier of the unit. |
| 6 | Group Address: Bit map that identifies the group address(es) that the station is part of. | 32 | LSB = 96,<br>MSB-1 = 126 |
| 10 | Link Address: Identifies the link address of the station to be initialized. | 8 | 255 = requesting<br>3 to 95 = actual link addresses |
| 11 | Station Class: The type of service provided by the station. | 8 | 255 = requesting<br>1 = Type 1<br>2 = Types 1 and 2<br>3 = Types 1 and 4<br>4 = Types 1, 2 and 4 |
| 12 | Robust Frame Format: Identifies a 7 bit field which specifies the format of the transmitted frame. | 8 | 255 = requesting, Robust Frame Format as defined in MIL-STD-188-220( ) Table III. |
| 13 | EDC Mode: The FEC, TDC and Scrambling guidance for use in building transmission headers. | 8 | 255 = requesting,<br>0=No FEC, No TDC, No Scrambling,<br>1=No FEC, No TDC, Scrambling,<br>2=FEC, No TDC, No Scrambling,<br>3=FEC, No TDC, Scrambling,<br>4=FEC, TDC, No Scrambling<br>5=FEC, TDC, Scrambling |
| 14 | Net Busy Detect Time: The amount of time to detect net busy after push-to-talk has been initiated. | 16 | 65535=requested from 0 in 1 msec increments |
| 16 | Equipment Preamble Time: The amount of time that a station must wait from the push-to-talk until it can transmit. | 16 | 65535=requested from 0 in 1 msec increments |
| 18 | Key Time: Equipment dependent delay time (KT) used in net access delay time calculations. | 16 | 0 - 5600 in 1 msec increments |

Table E-3. Join Request Message. (continued)

| BYTE NUMBER | FIELD IDENTIFICATION | FIELD SIZE (BITS) | VALUE |
|---|---|---|---|
| 20 | Equipment Postamble Time: (includes COMSEC Preamble Time)The amount of time from the release of the push-to-talk until the end of transmission. | 16 | from 0 in 1 msec increments |
| 22 | Carrier Dropout Time: The maximum amount of time required for an R/T to transition from the transmit state to the receive state. | 16 | from 0 in 1 msec increments |
| 24 | Equipment Lag Time: The amount of time from when the host provides the first bit of data until that bit is transmitted. | 16 | 65535=requested from 0 in 1 msec increments |
| 26 | Tolerance Time: The factor T used to compensate for the variance of the other variables in the RHD formula. | 16 | 65535=requested 0 - 500 msec in 1 msec increments |
| 28 | Processing Time: The amount of error correction processing time required to be added to the transmitter's TP calculation. | 8 | 255 = requested 0 - 100 msec in 1 msec increments |
| 29 | NAD Method: The type of net access delay scheme to be used to access the net. | 8 | 255 = requested 0=R-NAD, 1=P-NAD, 2=H-NAD, 3=DAP-NAD 4=RE-NAD |
| 30 | Subscriber Rank: Identifies the comparative ranking of stations on the net. | 8 | 255 = requested 0=unused, 1 - 95 actual values |
| 31 | Number Of Stations: Indicates the number of stations participating on the net. Used in NAD calculations. | 8 | 255 = requested 2 - 95 stations on the net |

Table E-3. Join Request Message. (continued)

| BYTE NUMBER | FIELD IDENTIFICATION | FIELD SIZE (BITS) | VALUE |
|---|---|---|---|
| 32 | Urgent Percent: The percentage of urgent (%U) frames expected in an average 24-hour period. Used in the H-NAD calculation. | 8 | 255 = requested 0 - 100% |
| 33 | Priority Percent: The percentage of priority (%P) frames expected in an average 24-hour period. Used in the H-NAD calculation. | 8 | 255 = requested 0 - 100% |
| 34 | Traffic Load: The amount of net traffic expected. | 8 | 255 = requested 0=normal, 1=heavy, 2=light |
| 35 | Max Transmit Seconds: The maximum amount of time a transmitter is allowed on the net. | 8 | 255 = requested 1 - 254 seconds |
| 36 | Physical Concatenation: Indicates if concatenation is allowed at the physical layer. | 8 | 255 = either OK 0=off, 1=on |
| 37 | Data Link Concatenation: Indicates if concatenation is allowed at the data link layer. | 8 | 255 = either OK 0=off, 1=on |
| 38 | Max UI, DIA And I Info Bytes: Indicates the largest information field size allowed on the net. | 16 | 65535=requested 708 - 3345 bytes |
| 40 | Type 2 ACK Timer: The amount of time before a retrans-mission is sent. | 16 | 65535=requested 1 - 1800 seconds |
| 42 | Type 2 K Window: The maximum number of outstanding information frames allowed before a RR is required. | 8 | 255 = requested 1 - 127 acceptable range |
| 43 | Type 4 ACK Timer: The amount of time before a retrans-mission is sent. | 16 | 255 = requested 5 - 120 seconds |
| 45 | Type 4 K Window: The maximum number of outstanding information frames allowed before a DRR is required. | 8 | 255 = requested 5 - 20 frames |

Table E-3. Join Request Message. (continued)

| BYTE NUMBER | FIELD IDENTIFICATION | FIELD SIZE (BITS) | VALUE |
|---|---|---|---|
| 46 | Response Mode: Indicates whether a station should send out any transmissions. | 8 | 255 = requested<br>0=Always on,<br>1=off,<br>2=on but can select off |

Table E-4. Join Accept Message.

| BYTE NUMBER | FIELD IDENTIFICATION | FIELD SIZE (BITS) | VALUE |
|---|---|---|---|
| 1 | Message Number: Identifies specific message content. | 8 | 21 |
| 2 | Unique Identifier: Identifies the unit station to be initialized. | 32 | identifier of the unit. |
| 6 | Group Address: Bit map that identifies the group address(es) that the station is part of. | 32 | LSB = 96,<br>MSB-1 = 126 |
| 10 | Link Address: Identifies the link address of the station to be initialized. | 8 | 3 to 95 = actual link addresses |
| 11 | Station Class: The type of service provided by the station. | 8 | 1 = Type 1<br>2 = Types 1 and 2<br>3 = Types 1 and 4<br>4 = Types 1, 2 and 4 |
| 12 | Robust Frame Format: Identifies a 7 bit field which specifies the format of the transmitted frame. | 8 | Robust Frame Format as defined in MIL-STD-188-220( ) Table III. |
| 13 | EDC Mode: The FEC, TDC and Scrambling guidance for use in building transmission headers. | 8 | 0=No FEC, No TDC, No Scrambling,<br>1=No FEC, No TDC, Scrambling,<br>2=FEC, No TDC, No Scrambling,<br>3=FEC, No TDC, Scrambling,<br>4=FEC, TDC, No Scrambling<br>5=FEC, TDC, Scrambling |

Table E-4. Join Accept Message. (continued)

| BYTE NUMBER | FIELD IDENTIFICATION | FIELD SIZE (BITS) | VALUE |
|---|---|---|---|
| 14 | Net Busy Detect Time: The amount of time to detect net busy after push-to-talk has been initiated. | 16 | from 0 in 1 msec increments |
| 16 | Equipment Preamble Time: The amount of time that a station must wait from the push-to-talk until it can transmit. | 16 | from 0 in 1 msec increments |
| 18 | Key Time: Equipment dependent delay time (KT) used in net access delay time calculations. | 16 | 0 - 5600 in 1 msec increments |
| 20 | Equipment Postamble Time: (includes COMSEC Preamble Time)The amount of time from the release of the push-to-talk until the end of transmission. | 16 | from 0 in 1 msec increments |
| 22 | Carrier Dropout Time: The maximum amount of time required for an R/T to transition from the transmit state to the receive state. | 16 | from 0 in 1 msec increments |
| 24 | Equipment Lag Time: The amount of time from when the host provides the first bit of data until that bit is transmitted. | 16 | from 0 in 1 msec increments |
| 26 | Tolerance Time: The factor T used to compensate for the variance of the other variables in the RHD formula. | 16 | 0 - 500 msec in 1 msec increments |
| 28 | Processing Time: The amount of error correction processing time required to be added to the transmitter's TP calculation. | 8 | 0 - 100 msec in 1 msec increments |
| 29 | NAD Method: The type of net access delay scheme to be used to access the net. | 8 | 0=R-NAD, 1=P-NAD, 2=H-NAD, 3=DAP-NAD, 4=RE-NAD |

Table E-4. Join Accept Message. (continued)

| BYTE NUMBER | FIELD IDENTIFICATION | FIELD SIZE (BITS) | VALUE |
|---|---|---|---|
| 30 | Subscriber Rank: Identifies the comparative ranking of stations on the net. | 8 | 0=unused, 1 - 95 actual values |
| 31 | Number Of Stations: Indicates the number of stations participating on the net. Used in NAD calculations. | 8 | 2 - 95 stations on the net |
| 32 | Urgent Percent: The percentage of urgent (%U) frames expected in an average 24-hour period. Used in the H-NAD calculation. | 8 | 0 - 100% |
| 33 | Priority Percent: The percentage of priority (%P) frames expected in an average 24-hour period. Used in the H-NAD Calculation. | 8 | 0 - 100% |
| 34 | Traffic Load: The amount of net traffic expected. | 8 | 0=normal, 1=heavy, 2=light |
| 35 | Max Transmit Seconds: The maximum amount of time a transmitter is allowed on the net. | 8 | 1 - 254 seconds |
| 36 | Physical Concatenation: Indicates if concatenation is allowed at the physical layer. | 8 | 0=off, 1=on |
| 37 | Data Link Concatenation: Indicates if concatenation is allowed at the data link layer. | 8 | 0=off, 1=on |
| 38 | Max UI, DIA And I Info Bytes: Indicates the largest information field size allowed on the net. | 16 | 708 - 3345 bytes |
| 40 | Type 2 ACK Timer: The amount of time before a retransmission is sent. | 16 | 1 - 1800 seconds |
| 42 | Type 2 K Window: The maximum number of outstanding information frames allowed before a RR is required. | 8 | 1 - 127 acceptable range |

Table E-4. Join Accept Message. (continued)

| BYTE NUMBER | FIELD IDENTIFICATION | FIELD SIZE (BITS) | VALUE |
|---|---|---|---|
| 43 | Type 4 ACK Timer: The amount of time before a retransmission is sent. | 16 | 5 - 120 seconds |
| 45 | Type 4 K Window: The maximum number of outstanding information frames allowed before a DRR is required. | 8 | 5 - 20 frames |
| 46 | Response Mode: Indicates whether a station should send out any transmissions. | 8 | 0=Always on, 1=off, 2=on but can select off |

Table E-5. Join Reject Message.

| BYTE NUMBER | FIELD IDENTIFICATION | FIELD SIZE (BITS) | VALUE |
|---|---|---|---|
| 1 | Message Number: Identifies specific message content. | 8 | 22 |
| 2 | Unique Identifier: Identifies the unit station to be initialized. | 32 | identifier of the unit. |
| 6 | Group Address: Bit map that identifies the group address(es) that the station is part of. | 32 | LSB = 96, MSB-1 = 126 |
| 10 | Link Address: Identifies the link address of the station to be initialized. | 8 | 255 = unknown<br>3 to 95 = actual link addresses |
| 11 | Station Class: The type of service provided by the station. | 8 | 255 = unknown<br>1 = Type 1<br>2 = Types 1 and 2<br>3 = Types 1 and 4<br>4 = Types 1, 2 and 4 |
| 12 | Robust Frame Format: Identifies a 7 bit field which specifies the format of the transmitted frame. | 8 | 255 = unknown, Robust Frame Format as defined in MIL-STD-188-220( ) Table III. |

Table E-5. Join Reject Message. (continued)

| BYTE NUMBER | FIELD IDENTIFICATION | FIELD SIZE (BITS) | VALUE |
|---|---|---|---|
| 13 | EDC Mode: The FEC, TDC and Scrambling guidance for use in building transmission headers. | 8 | 255 = unknown, 0=No FEC, No TDC, No Scrambling, 1=No FEC, No TDC, Scrambling, 2=FEC, No TDC, No Scrambling, 3=FEC, No TDC, Scrambling, 4=FEC, TDC, No Scrambling 5=FEC, TDC, Scrambling |
| 14 | Net Busy Detect Time: The amount of time to detect net busy after push-to-talk has been initiated. | 16 | from 0 in 1 msec increments |
| 16 | Equipment Preamble Time: The amount of time that a station must wait from the push-to-talk until it can transmit. | 16 | from 0 in 1 msec increments |
| 18 | Key Time: Equipment dependent delay time (KT) used in net access delay time calculations. | 16 | 0 - 5600 in 1 msec increments |
| 20 | Equipment Postamble Time: (includes COMSEC Preamble Time)The amount of time from the release of the push-to-talk until the end of transmission. | 16 | from 0 in 1 msec increments |
| 22 | Carrier Dropout Time: The maximum amount of time required for an R/T to transition from the transmit state to the receive state. | 16 | from 0 in 1 msec increments |
| 24 | Equipment Lag Time: The amount of time from when the host provides the first bit of data until that bit is transmitted. | 16 | from 0 in 1 msec increments |

Table E-5. Join Reject Message. (continued)

| BYTE NUMBER | FIELD IDENTIFICATION | FIELD SIZE (BITS) | VALUE |
|---|---|---|---|
| 13 | EDC Mode: The FEC, TDC and Scrambling guidance for use in building transmission headers. | 8 | 255 = unknown,<br>0=No FEC, No TDC, No Scrambling,<br>1=No FEC, No TDC, Scrambling,<br>2=FEC, No TDC, No Scrambling,<br>3=FEC, No TDC, Scrambling,<br>4=FEC, TDC, No Scrambling<br>5=FEC, TDC, Scrambling |
| 14 | Net Busy Detect Time: The amount of time to detect net busy after push-to-talk has been initiated. | 16 | from 0 in 1 msec increments |
| 16 | Equipment Preamble Time: The amount of time that a station must wait from the push-to-talk until it can transmit. | 16 | from 0 in 1 msec increments |
| 18 | Key Time: Equipment dependent delay time (KT) used in net access delay time calculations. | 16 | 0 - 5600 in 1 msec increments |
| 20 | Equipment Postamble Time: (includes COMSEC Preamble Time)The amount of time from the release of the push-to-talk until the end of transmission. | 16 | from 0 in 1 msec increments |
| 26 | Tolerance Time: The factor T used to compensate for the variance of the other variables in the RHD formula. | 16 | 0 - 500 msec in 1 msec increments |
| 28 | Processing Time: The amount of error correction processing time required to be added to the transmitter's TP calculation. | 8 | 0 - 100 msec in 1 msec increments |

Table E-5. Join Reject Message. (continued)

| BYTE NUMBER | FIELD IDENTIFICATION | FIELD SIZE (BITS) | VALUE |
|---|---|---|---|
| 13 | EDC Mode: The FEC, TDC and Scrambling guidance for use in building transmission headers. | 8 | 255 = unknown, 0=No FEC, No TDC, No Scrambling, 1=No FEC, No TDC, Scrambling, 2=FEC, No TDC, No Scrambling, 3=FEC, No TDC, Scrambling, 4=FEC, TDC, No Scrambling 5=FEC, TDC, Scrambling |
| 14 | Net Busy Detect Time: The amount of time to detect net busy after push-to-talk has been initiated. | 16 | from 0 in 1 msec increments |
| 16 | Equipment Preamble Time: The amount of time that a station must wait from the push-to-talk until it can transmit. | 16 | from 0 in 1 msec increments |
| 18 | Key Time: Equipment dependent delay time (KT) used in net access delay time calculations. | 16 | 0 - 5600 in 1 msec increments |
| 20 | Equipment Postamble Time: (includes COMSEC Preamble Time)The amount of time from the release of the push-to-talk until the end of transmission. | 16 | from 0 in 1 msec increments |
| 29 | NAD Method: The type of net access delay scheme to be used to access the net. | 8 | 0=R-NAD, 1=P-NAD, 2=H-NAD, 3=DAP-NAD, 4=RE-NAD |
| 30 | Subscriber Rank: Identifies the comparative ranking of stations on the net. | 8 | 255 = unknown 0=unused, 1 - 95 actual values |
| 31 | Number Of Stations: Indicates the number of stations participating on the net. Used in NAD calculations. | 8 | 2 - 95 stations on the net |

Table E-5. Join Reject Message. (continued)

| BYTE NUMBER | FIELD IDENTIFICATION | FIELD SIZE (BITS) | VALUE |
|---|---|---|---|
| 13 | EDC Mode: The FEC, TDC and Scrambling guidance for use in building transmission headers. | 8 | 255 = unknown, 0=No FEC, No TDC, No Scrambling, 1=No FEC, No TDC, Scrambling, 2=FEC, No TDC, No Scrambling, 3=FEC, No TDC, Scrambling, 4=FEC, TDC, No Scrambling 5=FEC, TDC, Scrambling |
| 14 | Net Busy Detect Time: The amount of time to detect net busy after push-to-talk has been initiated. | 16 | from 0 in 1 msec increments |
| 16 | Equipment Preamble Time: The amount of time that a station must wait from the push-to-talk until it can transmit. | 16 | from 0 in 1 msec increments |
| 18 | Key Time: Equipment dependent delay time (KT) used in net access delay time calculations. | 16 | 0 - 5600 in 1 msec increments |
| 20 | Equipment Postamble Time: (includes COMSEC Preamble Time)The amount of time from the release of the push-to-talk until the end of transmission. | 16 | from 0 in 1 msec increments |
| 32 | Urgent Percent: The percentage of urgent (%U) frames expected in an average 24-hour period. Used in the H-NAD calculation. | 8 | 0 - 100% |
| 33 | Priority Percent: The percentage of priority (%P) frames expected in an average 24-hour period. Used in the H-NAD Calculation. | 8 | 0 - 100% |
| 34 | Traffic Load: The amount of net traffic expected. | 8 | 0=normal, 1=heavy, 2=light |

Table E-5. Join Reject Message. (continued)

| BYTE NUMBER | FIELD IDENTIFICATION | FIELD SIZE (BITS) | VALUE |
|---|---|---|---|
| 13 | EDC Mode: The FEC, TDC and Scrambling guidance for use in building transmission headers. | 8 | 255 = unknown, 0=No FEC, No TDC, No Scrambling, 1=No FEC, No TDC, Scrambling, 2=FEC, No TDC, No Scrambling, 3=FEC, No TDC, Scrambling, 4=FEC, TDC, No Scrambling 5=FEC, TDC, Scrambling |
| 14 | Net Busy Detect Time: The amount of time to detect net busy after push-to-talk has been initiated. | 16 | from 0 in 1 msec increments |
| 16 | Equipment Preamble Time: The amount of time that a station must wait from the push-to-talk until it can transmit. | 16 | from 0 in 1 msec increments |
| 18 | Key Time: Equipment dependent delay time (KT) used in net access delay time calculations. | 16 | 0 - 5600 in 1 msec increments |
| 20 | Equipment Postamble Time: (includes COMSEC Preamble Time)The amount of time from the release of the push-to-talk until the end of transmission. | 16 | from 0 in 1 msec increments |
| 35 | Max Transmit Seconds: The maximum amount of time a transmitter is allowed on the net. | 8 | 1 - 254 seconds |
| 36 | Physical Concatenation: Indicates if concatenation is allowed at the physical layer. | 8 | 0=off, 1=on |
| 37 | Data Link Concatenation: Indicates if concatenation is allowed at the data link layer. | 8 | 0=off, 1=on |

Table E-5. Join Reject Message. (continued)

| BYTE NUMBER | FIELD IDENTIFICATION | FIELD SIZE (BITS) | VALUE |
|---|---|---|---|
| 13 | EDC Mode: The FEC, TDC and Scrambling guidance for use in building transmission headers. | 8 | 255 = unknown,<br>0=No FEC, No TDC, No Scrambling,<br>1=No FEC, No TDC, Scrambling,<br>2=FEC, No TDC, No Scrambling,<br>3=FEC, No TDC, Scrambling,<br>4=FEC, TDC, No Scrambling<br>5=FEC, TDC, Scrambling |
| 14 | Net Busy Detect Time: The amount of time to detect net busy after push-to-talk has been initiated. | 16 | from 0 in 1 msec increments |
| 16 | Equipment Preamble Time: The amount of time that a station must wait from the push-to-talk until it can transmit. | 16 | from 0 in 1 msec increments |
| 18 | Key Time: Equipment dependent delay time (KT) used in net access delay time calculations. | 16 | 0 - 5600 in 1 msec increments |
| 20 | Equipment Postamble Time: (includes COMSEC Preamble Time)The amount of time from the release of the push-to-talk until the end of transmission. | 16 | from 0 in 1 msec increments |
| 38 | Max UI, DIA And I Info Bytes: Indicates the largest information field size allowed on the net. | 16 | 708 - 3345 bytes |
| 40 | Type 2 ACK Timer: The amount of time before a retransmission is sent. | 16 | 1 - 1800 seconds |
| 42 | Type 2 K Window: The maximum number of outstanding information frames allowed before a RR is required. | 8 | 1 - 127 acceptable range |
| 43 | Type 4 ACK Timer: The amount of time before a retransmission is sent. | 16 | 5 - 120 seconds |

Table E-5. Join Reject Message. (continued)

| BYTE NUMBER | FIELD IDENTIFICATION | FIELD SIZE (BITS) | VALUE |
|---|---|---|---|
| 13 | EDC Mode: The FEC, TDC and Scrambling guidance for use in building transmission headers. | 8 | 255 = unknown,<br>0=No FEC, No TDC, No Scrambling,<br>1=No FEC, No TDC, Scrambling,<br>2=FEC, No TDC, No Scrambling,<br>3=FEC, No TDC, Scrambling,<br>4=FEC, TDC, No Scrambling<br>5=FEC, TDC, Scrambling |
| 14 | Net Busy Detect Time: The amount of time to detect net busy after push-to-talk has been initiated. | 16 | from 0 in 1 msec increments |
| 16 | Equipment Preamble Time: The amount of time that a station must wait from the push-to-talk until it can transmit. | 16 | from 0 in 1 msec increments |
| 18 | Key Time: Equipment dependent delay time (KT) used in net access delay time calculations. | 16 | 0 - 5600 in 1 msec increments |
| 20 | Equipment Postamble Time: (includes COMSEC Preamble Time)The amount of time from the release of the push-to-talk until the end of transmission. | 16 | from 0 in 1 msec increments |
| 45 | Type 4 K Window: The maximum number of outstanding information frames allowed before a DRR is required. | 8 | 5 - 20 frames |
| 46 | Response Mode: Indicates whether a station should send out any transmissions. | 8 | 0=Always on,<br>1=off,<br>2=on but can select off |
| 47 | Error Indicator: A bit map to identify the field(s) that contained errors. | 32 | See Figure E-2 for bit-map meaning. |

Table E-6. Hello Message

| BYTE NUMBER | FIELD IDENTIFICATION | FIELD SIZE (BITS) | VALUE |
|---|---|---|---|
| 1 | Message Number: Identifies specific message content. | 8 | 23 |
| 2 | Unique Identifier: Identifies the unit station to be initialized | 32 | identifier of the unit |
| 6 | Group Address: Bit map that identifies the group address(es) that the station is part of. | 32 | LSB = 96<br>MSB-1 = 126 |

Table E-7. Goodbye Message.

| BYTE NUMBER | FIELD IDENTIFICATION | FIELD SIZE (BITS) | VALUE |
|---|---|---|---|
| 1 | Message Number: Identifies specific message content. | 8 | 24 |
| 2 | Unique Identifier: Identifies the unit station to be initialized. | 32 | identifier of the unit |
| 6 | Group Address: Bit map that identifies the group address(es) that the station | 32 | LSB = 96<br>MSB-1 = 126 |

E4.1.2 Join the network messages. Three messages are used to convey network operating parameters. The initializing station sends the request to join message, and the NETCON replies with either an accept or reject message. Figure E-1 shows a sample message exchange when the link address is to be assigned.

E4.1.2.1 Network control station. In a network that expects a station to request link operating parameters, one station must be designated the NETCON station. Only the NETCON will respond to those requests and therefore eliminate excessive response frames. The designation of the NETCON station will be done by a network authority. The data-link address 2 is a special address for the network control station. All stations can address the network control station by using that special address. The network control station may also be assigned an additional individual data-link address that it shall also recognize. All stations should be capable of performing the functions of NETCON. An operator command either at initialization or during normal operation times may inform the station of its NETCON responsibility.

E4.1.2.2 Message exchange sequence. The initializing station sends to the NETCON station an XID Join Request message, that may contain the known MIL-STD-188-220 parameters. MIL-STD-188-220 parameter fields that are left empty (a bit pattern of all 1s) indicate a request for NETCON to supply the parameters. The NETCON station compares the MIL-STD-188-220 parameter fields with current network operating parameters. If an error is found, a Join Reject message is sent, entering all of the correct parameters into the frame and marking the error field to indicate the corrected parameters. Figure E-2 shows the error field indicators. If there is no error, a Join Accept message is sent after entering the parameters for any empty MIL-STD-188-220 parameter fields.

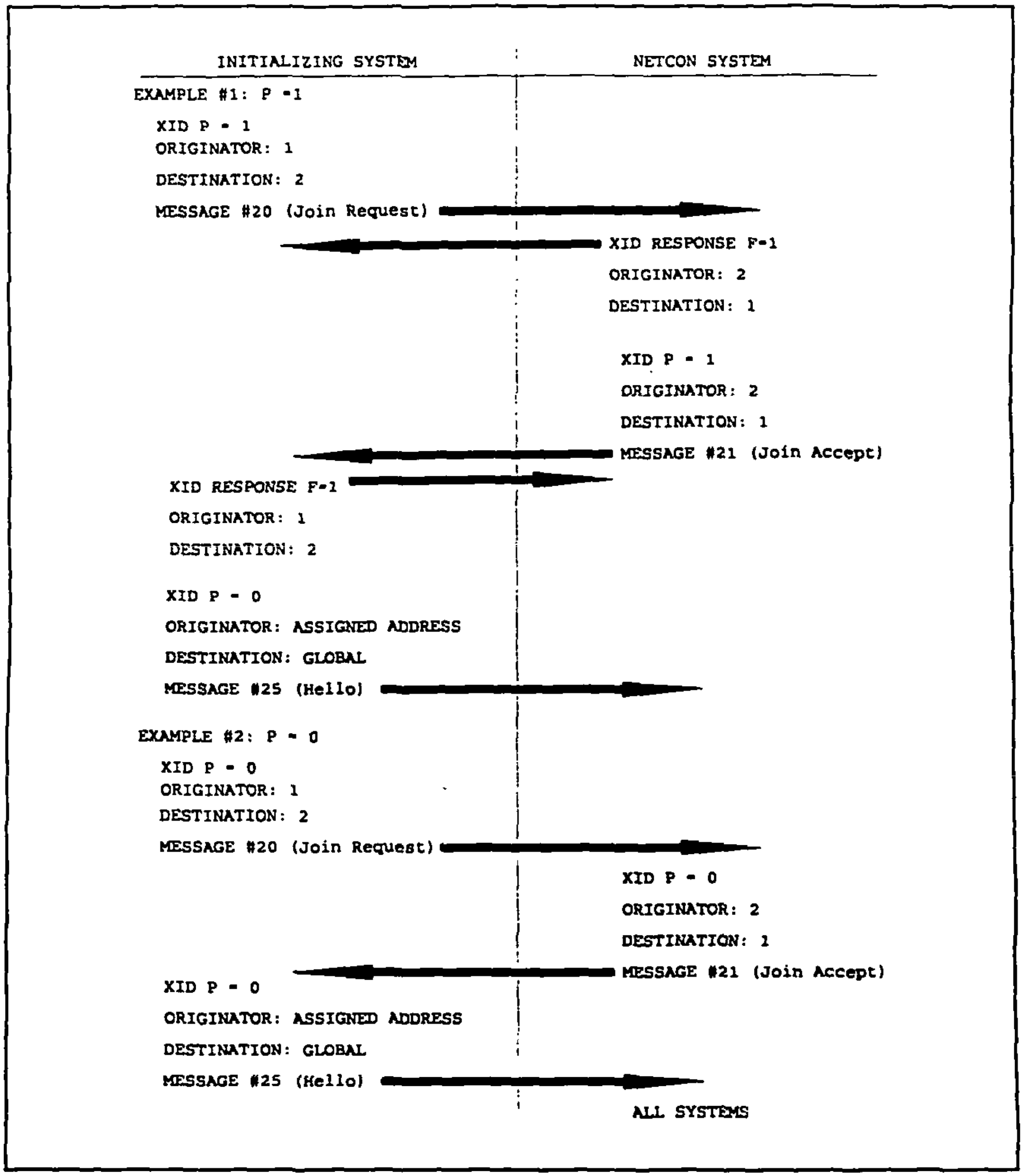



Figure E-1. Sample Message Exchange with Successful Link Address Assignment.

E4.1.3 Hello Message. This message is sent after the link operating parameters are known and the station is ready to enter the network. The message contains the link address of the station entering the network. Address tables within the receiving station are updated, if necessary, with the new address information. This message may be sent to up to 16 individual, group, global and special net controller addresses with or without the P bit set, following the address mixing rules of 5.3.4.2.2.2.2. The acknowledgement sent in response to an XID command shall be an XID response PDU with no information field.

E4.1.4 Goodbye Message. This message is sent by a station to notify the NETCON and other net subscribers that it is leaving the net. This message may be sent to up to 16 individual, group, global and special net controller addresses with or without the P bit set, following the address mixing rules of 5.3.4.2.2.2.2. The acknowledgement sent in response to an XID command shall be an XID response PDU. Address tables within the receiving station are updated, if necessary. If the NETCON receives this message, it shall update the appropriate internal tables.

When this message is received by a station that has an established Type 2 connection with the source station, the connection shall be immediately terminated.

E5. Net-access. The set of join messages makes it possible for a station to know little about the network configuration when it is initializing. This flexibility requires some special handling of the frames.

E5.1 Net-access delay method. MIL-STD-188-220 allows a network to choose among the net-access delay schemes defined in Appendix C (C3.4). Each station that operates on the net must use the same scheme. If the station does not know this information before initialization, the join network request message allows a station to learn the net access scheme. In the case that the net access scheme is unknown the random method will be used for the XID Join Request message.

| ERROR INDICATOR | | |
|---|---|---|
| LSB | 0 | Group Address |
| | 1 | Link Address |
| | 2 | Station Class |
| | 3 | Robust Frame Format |
| | 4 | EDC Mode |
| | 5 | Net Busy Detect Time |
| | 6 | Equipment Preamble Time |
| | 7 | Key Time |
| | 8 | Equipment Postamble Time |
| | 9 | Carrier Dropout Time |
| | 10 | Equipment Lag Time |
| | 11 | Tolerance Time |
| | 12 | Processing Time |
| | 13 | NAD Method |
| | 14 | Subscriber Rank |
| | 15 | Number of Stations |
| | 16 | Urgent Percent |
| | 17 | Priority Percent |
| | 18 | Traffic Load |
| | 19 | Max Transmit Seconds |
| | 20 | Physical Concatenation |
| | 21 | Data Link Concatenation |
| | 22 | Max UI, DIA And I Info Bytes |
| | 23 | Type 2 ACK Timer |
| | 24 | Type 2 K Window |
| | 25 | Type 4 ACK Timer |
| | 26 | Type 4 K Window |
| | 27 | Response Mode |
| MSB | 28 - 31 | Reserved |

The Error Indicator field is a 32-bit map identifying which field(s) are in error.
Bit = 0 indicates no error in defined field
Bit = 1 indicates error in defined field

Figure E-2. Error Indicators.

# APPENDIX F

# GOLAY CODING ALGORITHM

## F1. General.

F1.1 Scope. This appendix contains amplifying information in support of MIL-STD-188-220.

F1.2 Application. This appendix is not a mandatory part of MIL-STD-188-220. The information contained herein is intended for guidance only.

## F2. Applicable documents.

## F3. Forward error correction.

The FEC method requires the receiver to detect and automatically correct errors in a received block of information. Extended Golay (24, 12, 8) Coding is used to provide this error detection and correction in this standard. The number of errors the receiver can detect and correct depends on the coding method. The information bits (k) are separated into blocks that contain both information bits and code bits. The length of the block, including the information and code bits, is (n). The code is described as (n,k), where n is the length of the block and k is the number of information bits in the block.

## F4. Golay code.

The Golay code is a linear, block, perfect, and cyclic (23,12) code capable of correcting any combination of three or fewer errors in a block of 24 digits. The generator polynomial for this code is recast as polynomials higher order first

$$g(x) = x^{11} + x^{10} + x^6 + x^5 + x^4 + x^2 + 1$$

where g(x) is a factor of $x^{23} + 1$

F4.1 Half-rate and Extended Golay code. The half-rate Golay code (24,12, 7) is formed by adding a zero fill bit to the Golay (23, 12) code. Extended Golay is formed by adding an odd parity bit to the Golay (23,12) code. The (24,12, 8) code is preferable to the (23,12) because it has a code rate of exactly one-half. This code rate simplifies system timing.

F4.2 Golay code implementation. The Golay code may be implemented in either hardware or software. The hardware implementation uses shift-registers for encoding and decoding, as described in F4.2.1 and F4.2.2, respectively. The software implementation uses a generator matrix and conversion table, as described in F4.2.3.

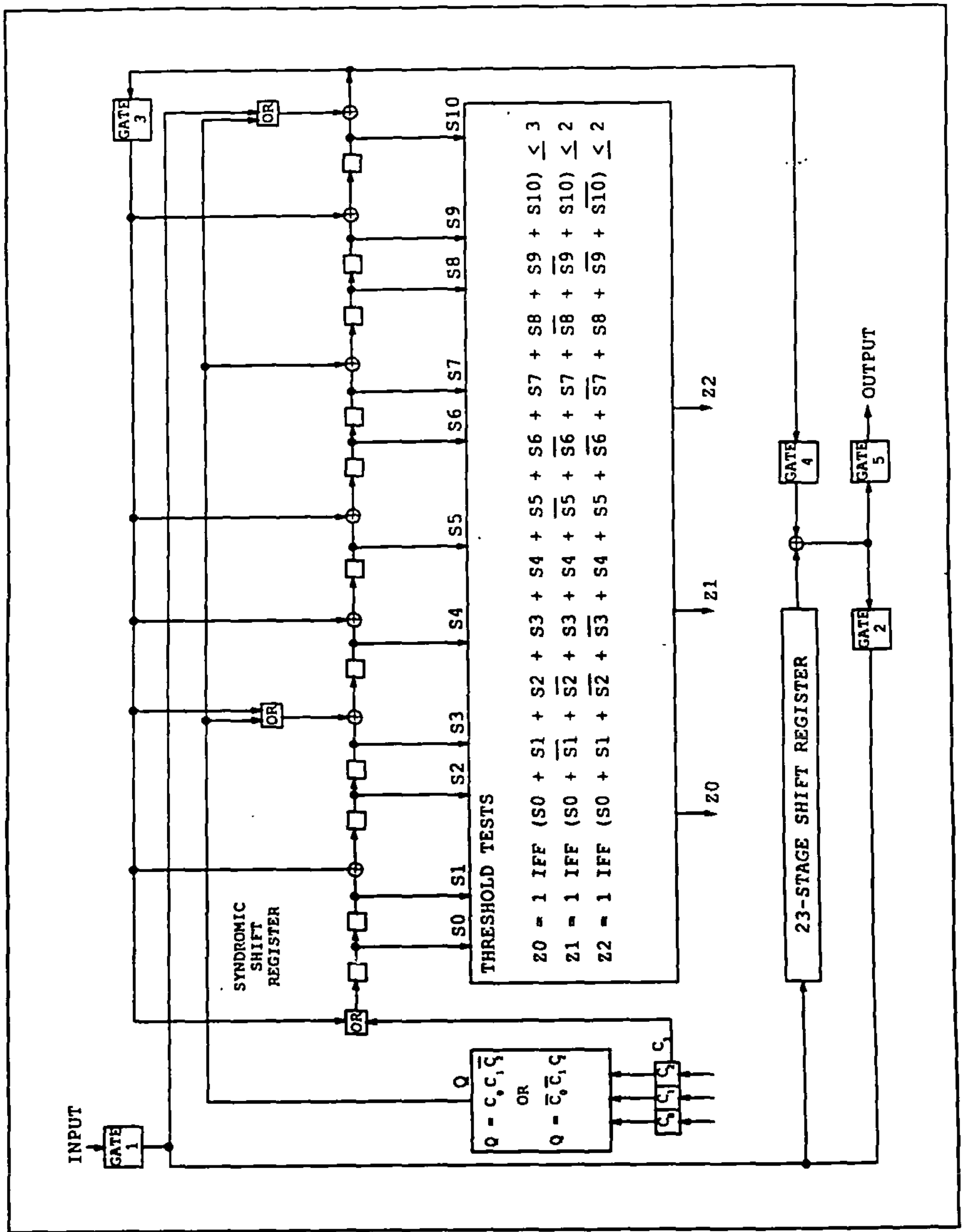
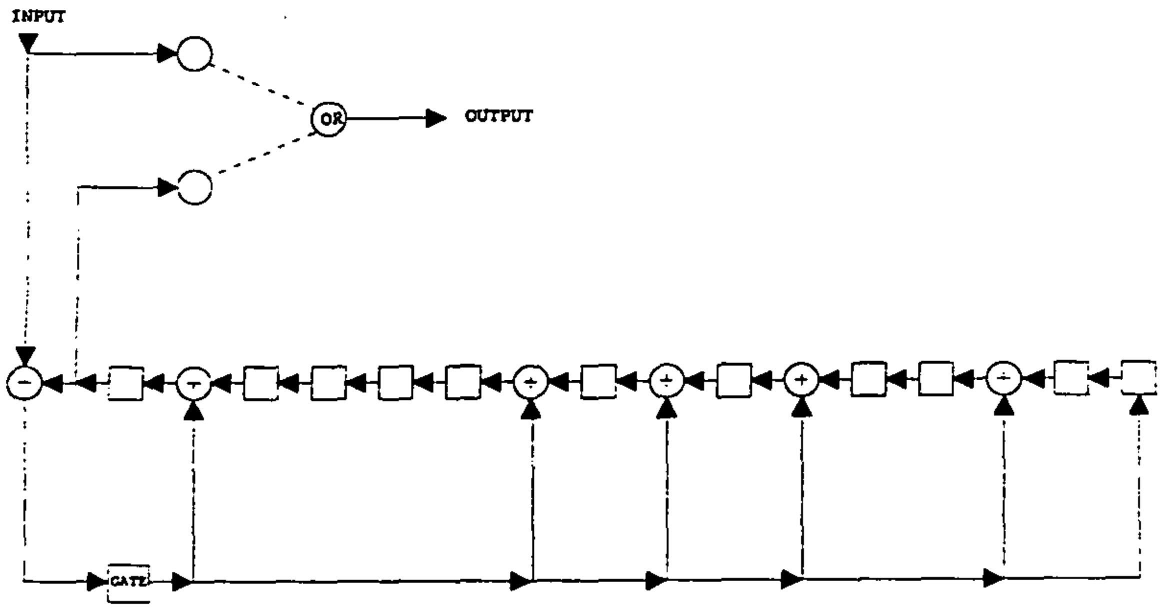



Figure F-2. Kasami error-trapping decoder for the (24, 12) Golay code.

F4.2.1 Hardware implementation. Golay code encoding can be performed with an 11-stage feedback shift register with feedback connections selected according to the coefficients of g(x). A shift register corresponding to the coefficients of g(x) is shown in Figure F-1. The k information bits are located at the beginning of the n symbol block code. With the gate open, the information bits are loaded into the shift register stages and simultaneously into the output channel. At this time the shift register contains the check symbols. With the gate closed, register contents are then shifted onto the output channel. The last n k symbols are the check symbols that form the whole codeword.




Encoder for $g(x) = 1 + x^2 + x^4 + x^5 + x^6 + x^{10} + x^{11}$

Figure F-1. Shift register encoding for the (23, 12) Golay code.

F4.2.2 Hardware decoding. The Golay code is decoded using a number of techniques such as the error-trapping process developed by T. Kasami. The Kasami error-trapping decoder for the Golay code is shown in Figure F-2. It works as follows:

1. Gates 1, 3, and 5 are opened, and gates 2 and 4 are closed. The received codeword r(x) is then shifted into both the 23-stage shift register and the syndrome register. At the same time, the previously corrected codeword is shifted out to the user. The syndrome

$$S(x) = S0 + S1x + . . . + S10x^{10}$$

is then formed and subjected to threshold tests.

2. Gates 1, 4, and 5 are closed and gate 2 is opened. Gate 3 remains open. The threshold tests occur in the following order:

   a. If Z0 is unity, then all the errors are confined to the 11 high-order positions of r(x), and S(x) matches the errors. Z0 opens gate 4 and closes gate 3. Contents of both the 23-stage shift register and the syndrome shift register are then shifted 11 times, and the errors are corrected. Then gate 4 is closed and the contents of the 23-stage shift register are shifted until the received codeword is in its original position. The decoder then goes to step 3 below.

   b. If Z1 is unity, the error pattern in S(x) is the same as the errors in the 11 high-order bits of the codeword r(x), and a single error exists at location x5. Gate 4 is opened and gate 3 is closed. The counter is preloaded with a count of 2, and both the syndrome shift register and the 23-stage shift register are shifted until the error in x5 is corrected. Then gate 4 is closed, and the contents of the 23-stage shift register are shifted until the received codeword is in its original position. The decoder then goes to step 3.

   c. If Z2 is unity, the error pattern in S(x) is the same as the errors in the 11 high-order bits of the codeword r(x), and there is a single error in location x6. The same steps are followed as in b (above) except that the counter is preloaded with a count of 3. The decoder then goes to step 3.

   d. If neither of the three thresholds is unity, the decoder goes directly to step 3.

3. Gates 1, 4, and 5 are closed, and gates 2 and 3 are opened. Contents of both the 23-stage shift register and the syndrome shift register are then shifted once to the right. The decoder then goes to step 2.

4. This action continues until step 3 has been executed 46 times. Then the decoder returns to step 1 to process the next received codeword.

The decoder always yields an output. The output is correct if there were 3 or fewer errors in the received codeword, and erroneous if there were more than 3 errors in the codeword.

F4.2.3 <u>Software implementation</u>. The transmitting DMTD shall generate the check bits using the following generator polynomial:

$$g(x) = x^{11} + x^{10} + x^{6} + x^{5} + x^{4} + x^{2} + 1$$

Note that using modulo 2 addition,

$$x^{23}+1 = (x^{11}+x^{10}+x^{6}+x^{5}+x^{4}+x^{2}+1)\ (x^{11}+x^{9}+x^{7}+x^{6}+x^{5}+x+1)\ (x+1)$$

The 11 check bits shall be as derived from the following generator matrix G:

$$
\begin{array}{r}
 \\
x^{11} \cdot g(x) = \\
x^{10} \cdot g(x) = \\
x^{9} \cdot g(x) + x^{11} \cdot g(x) = \\
x^{8} \cdot g(x) + x^{10} \cdot g(x) = \\
x^{7} \cdot g(x) + x^{9} \cdot g(x) = \\
(x^{6} + x^{8} + x^{11}) \cdot g(x) = \\
(x^{5} + x^{7} + x^{10}) \cdot g(x) = \\
(x^{4} + x^{6} + x^{8}) \cdot g(x) = \\
(x^{3} + x^{5} + x^{8} + x^{11}) \cdot g(x) = \\
(x^{2} + x^{4} + x^{7} + x^{10} + x^{11}) \cdot g(x) = \\
(x + x^{3} + x^{5} + x^{9} + x^{10} + x^{11}) \cdot g(x) = \\
(1 + x^{2} + x^{5} + x^{8} + x^{9} + x^{10} + x^{11}) \cdot g(x) =
\end{array}
\begin{array}{c}
x^{22} \ \ 21\ 20\ 19\ 18\ 17\ 16\ 15\ 14\ 13\ 12\ 11\ 10\ 9\ 8\ 7\ 6\ 5\ 4\ 3\ 2\ 1\ \ x^{0} \\
\left[\begin{array}{ccccccccccccccccccccccc}
1&1&0&0&0&1&1&1&0&1&0&1&0&0&0&0&0&0&0&0&0&0&0\\
0&1&1&0&0&0&1&1&1&0&1&0&1&0&0&0&0&0&0&0&0&0&0\\
1&1&1&1&0&1&1&0&1&0&0&0&0&1&0&0&0&0&0&0&0&0&0\\
0&1&1&1&1&0&1&1&0&1&0&0&0&0&1&0&0&0&0&0&0&0&0\\
0&0&1&1&1&1&0&1&1&0&1&0&0&0&0&1&0&0&0&0&0&0&0\\
1&1&0&1&1&0&0&1&1&0&0&0&0&0&0&0&1&0&0&0&0&0&0\\
0&1&1&0&1&1&0&0&1&1&0&0&0&0&0&0&0&1&0&0&0&0&0\\
0&0&1&1&0&1&1&0&0&1&1&0&0&0&0&0&0&0&1&0&0&0&0\\
1&1&0&1&1&1&0&0&0&1&1&0&0&0&0&0&0&0&0&1&0&0&0\\
1&0&1&0&1&0&0&1&0&1&1&0&0&0&0&0&0&0&0&0&1&0&0\\
1&0&0&1&0&0&1&1&1&1&1&0&0&0&0&0&0&0&0&0&0&1&0\\
1&0&0&0&1&1&1&0&1&0&1&0&0&0&0&0&0&0&0&0&0&0&1
\end{array}\right] = G \\
\underbrace{\qquad\qquad\qquad}_{\text{Parity}}\ \underbrace{\qquad\qquad\qquad}_{\text{Identity}}
\end{array}
$$

where the matrix contains the coefficients of the polynomials on the left. By interchanging the I and P columns to obtain matrix T, that is,

$$G = [P, I]_{(12 \times 23)} \;=\!> [I, P]_{(12 \times 23)} = T$$

$$T = \begin{bmatrix}
1&0&0&0&0&0&0&0&0&0&0&0&1&1&0&0&0&1&1&1&0&1&0 \\
0&1&0&0&0&0&0&0&0&0&0&0&0&1&1&0&0&0&1&1&1&0&1 \\
0&0&1&0&0&0&0&0&0&0&0&0&1&1&1&1&0&1&1&0&1&0&0 \\
0&0&0&1&0&0&0&0&0&0&0&0&0&1&1&1&1&0&1&1&0&1&0 \\
0&0&0&0&1&0&0&0&0&0&0&0&0&0&1&1&1&1&0&1&1&0&1 \\
0&0&0&0&0&1&0&0&0&0&0&0&1&1&0&1&1&0&0&1&1&0&0 \\
0&0&0&0&0&0&1&0&0&0&0&0&0&1&1&0&1&1&0&0&1&1&0 \\
0&0&0&0&0&0&0&1&0&0&0&0&0&0&1&1&0&1&1&0&0&1&1 \\
0&0&0&0&0&0&0&0&1&0&0&0&1&1&0&1&1&1&0&0&0&1&1 \\
0&0&0&0&0&0&0&0&0&1&0&0&1&0&1&0&1&0&0&1&0&1&1 \\
0&0&0&0&0&0&0&0&0&0&1&0&1&0&0&1&0&0&1&1&1&1&1 \\
0&0&0&0&0&0&0&0&0&0&0&1&1&0&0&0&1&1&1&0&1&0&1
\end{bmatrix}$$

I P

The transmission order and value of the code word bits can be obtained by matrix multiplication (modulo 2 addition without carry) as follows:

$$\underset{(1\times12)}{\left[ Ib_1 \ \text{INFO BITS} \ Ib_{12} \right]} \cdot \underset{(12\times23)}{\left[ I, P \right]} = \underset{(1\times23)}{\left[ \text{INFO BITS, CHECK BITS} \right]}$$

↑ FIRST BIT TRANSMITTED ↑ FIRST BIT TRANSMITTED

# APPENDIX G

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# APPENDIX H

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# APPENDIX I

## SOURCE DIRECTED RELAY

I1. General.

I1.1 Scope. This appendix describes a procedure for relaying packets across a CNR intranet using source directed routes. The intranet is defined as all processors and CNRs within a single transmission channel.

I1.2 Application. This appendix is a mandatory part of MIL-STD-188-220. The information contained herein is intended for compliance.

I2. Applicable Documents. None

I3. Problem Overview. Intranet relaying is required when nodes in a intranet need to communicate, but are not nearest neighbors capable of hearing one another's radio transmissions.

I4. Procedure.

I4.1 Forward Routing. Source Directed Relay provides a simple non-dynamic procedure for relaying a packet from an originator to one or more destinations. The source must calculate the path through the intranet network to reach each destination. These paths are based on the topology and connectivity table. The specific source directed route for each destination must be encoded into the intranet header. If the routes for two or more destinations share common links along the paths, the two paths should be merged together. As a result of this, the resulting paths should not have any common nodes.

The address of successive relayers, destinations, and their associated status bytes are placed in the intranet header in order of progressing through the spanning tree. Nodes which are one hop away and destinations only are placed into the Intranet Header first with their DES bit set to 1. The next entries into the Intranet Header are the relay paths which may include nodes which are relayers and destinations. Each relay path starting at the source is completed before another relay path with its origin at the source is begun. Within the status byte for each relayer the REL bit is set to 1 and S/D is set to 0. If the relayer is also a destination in addition to being a relayer, the DES bit is set to 1. If there are multiple destinations following a relayer, each of these destination addresses and their status bytes should be listed sequentially in the header after the relay node in the header. Within this group the extension bit within the destination/relay address field is 0 for destinations except the last destination whose extension bit is set to 1. All destinations have their DES bit set to 1.

All destinations in the relay path tha· are required to provide end-to-end intranet acknowledgements ha·/e set the ACK bit in their status bytes to 1. For all destinations, the **DISTANCE** field is set to the number of hops between the originator and the ultimate destination host for the relay. For nodes that perform relay and are not destinations for the given relay (**REL** bit set and **DES** unset), the **DISTANCE** field has no meaning.

I4.2 End-to-end Acknowledgements. End-to-end Acknowledgements are formed by the ith final destination nodes upon receipt of an intranet header with **ACK** bit set in **DESTINATION STATUS BYTE** for the ith destination. The **MESSAGE ID** for the packet to be acknowledged is retained. The message type is set to 1. The path between the originator node and the ith destination is reversed. All intermediate destinations are removed. The path will contain one originator, one destination, and the relayers. The **DES** bit in the status bytes for all relayers is set to 0, indicating they perform relay only. No data is carried with an end-to-end acknowledgement packet; just the intranet header.

I5. Examples. To illustrate Source Directed Relay procedures consider the sample network link diagram in Figure I-1 and final spanning tree in Figure I-2. Table I-1 gives specific addresses for the nodes labeled A, B, C, D, E, F, G and H. To maintain consistency with other sections of MIL-STD-188-220, the least significant bit (LSB) is presented to the left of the figures in this appendix.

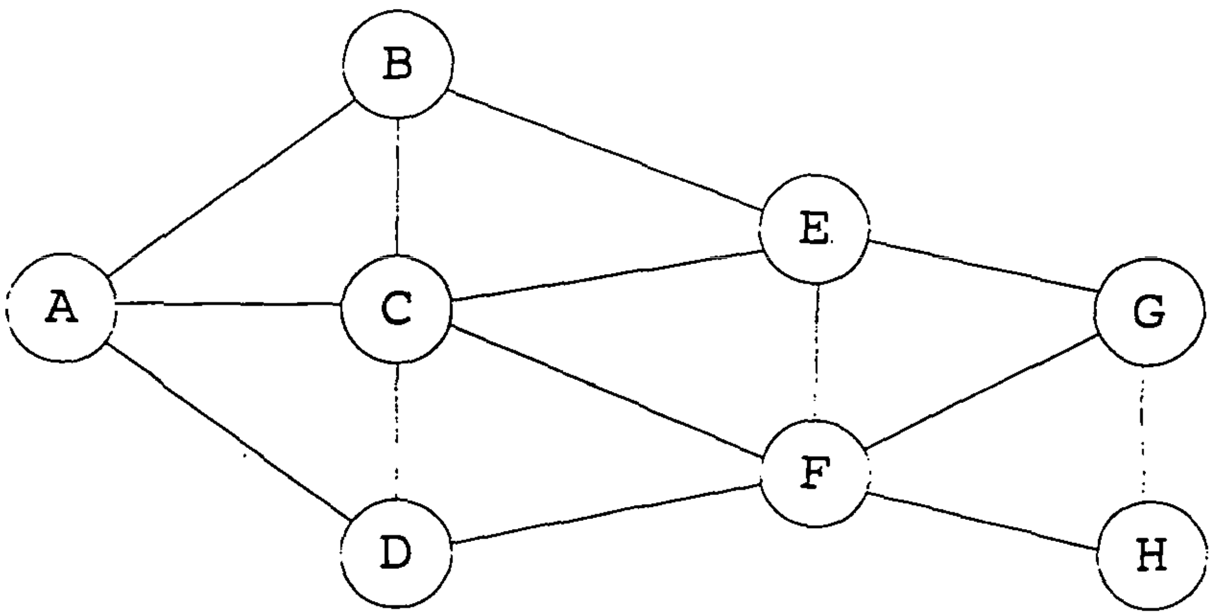



Figure I-1. Link Diagram of Sample Network

I5.1. EXAMPLE 1. Assume that node A has a packet bound for node G alone. Node A's Sparse Spanning Tree provides the following potential paths to Node G: A-B-E-G, A-C-E-G, A-C-F-G and A-D-F-G. Assuming that all paths have the same quality and cost, any path may be selected by Node A. In this example, path A-B-E-G is selected.

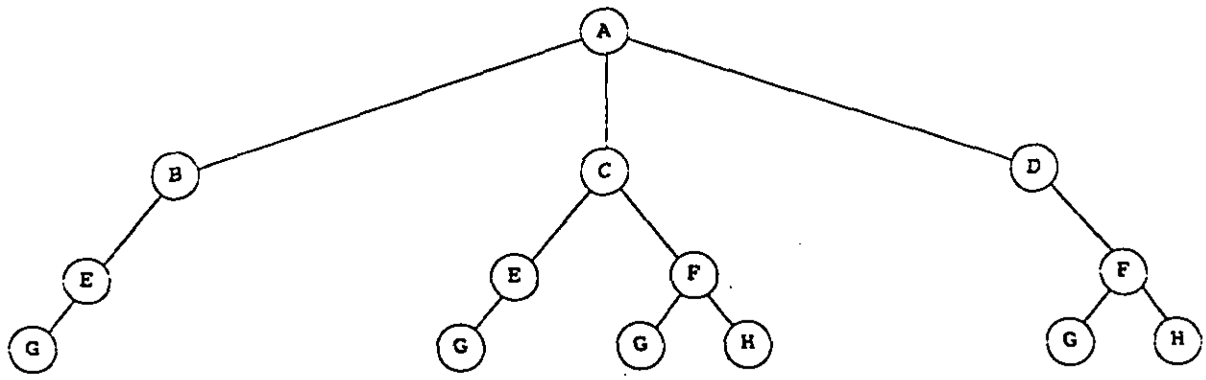



Figure I-2. Final Spanning Tree for Node A

Table I-1. Sample Node Addresses

| Node | LSB | | | | | | | MSB | Address |
|---|---|---|---|---|---|---|---|---|---|
| A | x | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 3 |
| B | x | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 4 |
| C | x | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 5 |
| D | x | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 6 |
| E | x | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 7 |
| F | x | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 8 |
| G | x | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 9 |
| H | x | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 10 |

The following values are assigned to the Intranet Header in example 1:

MESSAGE TYPE = 4 (IP Packet)
TYPE_OF_SERVICE = 0000 0000
MESSAGE_ID = 1
MAX_HOP_COUNT = 3 (Distance from node A to node G)
ORIGINATOR ADDRESS = 3 (node A)
STATUS BYTE 1 = 10010000 (DIS=1, REL=Yes, DES=No, ACK=No)
DESTINATION 1 = 4 (node B)
STATUS BYTE 2 = 01010000 (DIS=2, REL=Yes, DES=No, ACK=No)
DESTINATION 2 = 7 (node E)
STATUS BYTE 3 = 11000010 (DIS=3, REL=No, DES=Yes, ACK=No)
DESTINATION 3 = 9 (node G)
HEADER LENGTH = 12 octets

Figure I-3 shows the complete Intranet Header for example 1. Note that the LSB in all destination addresses is 0 except for the last destination address (node G).

| 0 LSB | 1 | 2 | 3 | 4 | 5 | 6 | 7 MSB |
|---|---|---|---|---|---|---|---|
| VERSION NUMBER | | | | MESSAGE TYPE | | | |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| INTRANET HEADER LENGTH | | | | | | | |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| TYPE OF SERVICE | | | | | | | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MESSAGE IDENTIFICATION NUMBER | | | | | | | |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAX HOP COUNT | | | | SPARE | | | |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| ORIGINATOR ADDRESS | | | | | | | |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 1 | | | | | | | |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY ADDRESS 1 | | | | | | | |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 2 | | | | | | | |
| 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY ADDRESS 2 | | | | | | | |
| 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 3 | | | | | | | |
| 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| DESTINATION/RELAY ADDRESS 3 | | | | | | | |
| 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |

Figure I-3. Example 1 Intranet Header

I5.2. EXAMPLE 2. Assume that node A has a packet bound for nodes G and H. Node A's Sparse Spanning Tree provides the following potential paths to nodes G and H: A-B-E-G, A-C-E-G, A-C-F-G, A-C-F-H, A-D-F-G, and A-D-F-H. Of these potential paths, the most economical choices are those that use node F for relaying: A-C-F-G, A-D-F-G, A-C-F-H, and A-D-F-H. Although paths A-B-E-G and A-C-E-G are viable paths to node G, they would unnecessarily increase processing at nodes B and E, and would increase the size of the Intranet Header in this example. In this example the selected paths are A-C-F-G and A-C-F-H.

The following values are assigned to the Intranet Header in example 2:

MESSAGE TYPE = 4 (IP Packet)
TYPE_OF_SERVICE = 0000 0000
MESSAGE_ID = 2
MAX_HOP_COUNT = 3 (Distance from node A to nodes G and H)
ORIGINATOR ADDRESS = 3 (node A)
STATUS BYTE 1 = 10010000 (DIS=1, REL=Yes, DES=No, ACK=No)
DESTINATION 1 = 4 (node C)
STATUS BYTE 2 = 01010000 (DIS=2, REL=Yes, DES=No, ACK=No)
DESTINATION 2 = 8 (node F)
STATUS BYTE 3 = 11000010 (DIS=3, REL=No, DES=Yes, ACK=No)
DESTINATION 3 = 9 (node G)
STATUS BYTE 4 = 11000010 (DIS=3, REL=No, DES=Yes, ACK=No)
DESTINATION 4 = 10 (node H)
HEADER LENGTH = 14 octets

Figure I-4 shows the complete Intranet Header for example 2. Note that the LSB in all destination addresses is 0 except for the last destination address (node H).

| 0 LSB | 1 | 2 | 3 | 4 | 5 | 6 | 7 MSB |
|---|---|---|---|---|---|---|---|
| VERSION NUMBER | | | | MESSAGE TYPE | | | |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| INTRANET HEADER LENGTH | | | | | | | |
| 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| TYPE OF SERVICE | | | | | | | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MESSAGE IDENTIFICATION NUMBER | | | | | | | |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAX HOP COUNT | | | | SPARE | | | |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| ORIGINATOR ADDRESS | | | | | | | |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 1 | | | | | | | |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY ADDRESS 1 | | | | | | | |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 2 | | | | | | | |
| 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY ADDRESS 2 | | | | | | | |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 3 | | | | | | | |
| 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| DESTINATION/RELAY ADDRESS 3 | | | | | | | |
| 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 4 | | | | | | | |
| 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| DESTINATION/RELAY ADDRESS 4 | | | | | | | |
| 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |

Figure I-4. Example 2 Intranet Header

I5.3. EXAMPLE 3. In the third example, node A wishes to deliver a packet to nodes D, E, F, G and H. In this case node A again would select the most economical path to each destination, taking into consideration the impacts on network traffic and Intranet header size. Table I-2 lists the potential and selected paths from node A to each of the intended destinations.

A similar process would be used to select economical paths to relay nodes, such as node C. The shortest path to the most distant nodes G and H are reviewed to determine whether the relay nodes C and F are also destinations. Note that node F is both a destination and a relay while node C is a relay node only.

Table I-2. Paths Used in Example 3.

| Destination Node | Potential Paths | Selected Path |
|---|---|---|
| D | A-D | A-D |
| E | A-B-E<br>A-C-E | A-C-E |
| F | A-C-F<br>A-D-F | A-C-F |
| G | A-B-E-G<br>A-C-E-G<br>A-C-F-G<br>A-D-F-G | A-C-F-G |
| H | A-C-F-H<br>A-D-F-H | A-C-F-H |

The following values are assigned to the Intranet Header in example 3:

MESSAGE TYPE = 4 (IP Packet)
TYPE_OF_SERVICE = 0000 0000
MESSAGE_ID = 3
MAX_HOP_COUNT = 3 (Distance from node A to nodes G and H)
ORIGINATOR ADDRESS = 3 (node A)
STATUS BYTE 1 = 10000010 (DIS=1, REL=No, DES=Yes, ACK=No)
DESTINATION 1 = 6 (node D)
STATUS BYTE 2 = 10010000 (DIS=1, REL=Yes, DES=No, ACK=No)
DESTINATION 2 = 5 (node C)
STATUS BYTE 3 = 01000010 (DIS=2, REL=No, DES=Yes, ACK=No)
DESTINATION 3 = 7 (node E)
STATUS BYTE 4 = 01010010 (DIS=2, REL=Yes, DES=Yes, ACK=No)
DESTINATION 4 = 8 (node F)
STATUS BYTE 5 = 11000010 (DIS=3, REL=No, DES=Yes, ACK=No)
DESTINATION 5 = 9 (node G)
STATUS BYTE 6 = 11000010 (DIS=3, REL=No, DES=Yes, ACK=No)
DESTINATION 6 = 10 (node H)
HEADER LENGTH = 18 octets

Figure I-5 shows the complete Intranet Header for example 3. Note that the LSB in all destination addresses is 0 except for the last destination address (node H).

| 0 LSB | 1 | 2 | 3 | 4 | 5 | 6 | 7 MSB |
|---|---|---|---|---|---|---|---|
| VERSION NUMBER | | | | MESSAGE TYPE | | | |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| INTRANET HEADER LENGTH | | | | | | | |
| 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| TYPE OF SERVICE | | | | | | | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MESSAGE IDENTIFICATION NUMBER | | | | | | | |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAX HOP COUNT | | | | SPARE | | | |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| ORIGINATOR ADDRESS | | | | | | | |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 1 | | | | | | | |
| 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| DESTINATION/RELAY ADDRESS 1 | | | | | | | |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 2 | | | | | | | |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY ADDRESS 2 | | | | | | | |
| 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 3 | | | | | | | |
| 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| DESTINATION/RELAY ADDRESS 3 | | | | | | | |
| 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 4 | | | | | | | |
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| DESTINATION/RELAY ADDRESS 4 | | | | | | | |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 5 | | | | | | | |
| 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| DESTINATION/RELAY ADDRESS 5 | | | | | | | |
| 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 6 | | | | | | | |
| 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| DESTINATION/RELAY ADDRESS 6 | | | | | | | |
| 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |

Figure I-5. Example 3 Intranet Header Created by Node A (Originator)

I5.4. RELAY PROCESSING. Although the separate examples 1,2,3 all have diverse paths, they would all require the same number data link information frames for delivery (one). The UI, I, or DIA frame would be transmitted to each destination simultaneously. Addressed destinations would perform the required data link layer processing described in 5.3 and pass the information field of the frame to the Intranet layer for further processing.

The Intranet header is scanned for the node's data link layer address. When found, the previous octet - the Destination/Relay Status byte - is inspected. If the Relay bit is not set and the destination bit is set, the data portion following the Intranet header is passed to the next higher protocol layer for further processing. If the Relay bit is set, Relay processing is required. If both the Relay bit and the Destination bit are set, Relay processing is performed before the passing data portion of the frame to the next higher protocol layer for further processing. Relay processing involves the following steps:

1. Scan forward until the relayer node sees it's own address.

2. Scan toward the end of the header looking for all nodes whose DES bit is set and whose distance is one hop greater than your own. Terminate the scan when a distance less than or equal to your own or the end of the header is found. Save the addresses.

3. While scanning forward until a hop distance less than or equal to your own is found, find all relay addresses that are one hop away from your address and save these addresses.

4. Remove all duplicate saved addresses and pass the remaining addresses to the data link layer to form a multi-addressed information frame containing the Intranet header and data.

The following sections discuss the relay processing at each of the downstream relayers in Example 3. There are two options when filling out the Intranet Header Address Field at the relay nodes. The relay nodes may copy the Address Field and place it into the relay packet intact or they may delete the addresses which have no impact on forwarding or return of a network layer acknowledgment. If the implementor chooses to leave the address field intact, the address field in Figure I-5 is used at every relayer. If the implementor chooses to compress the address field to save transmitted bytes, the following paragraphs dictate the method for compression. There is no interoperability problem regardless of which of these two methods are implemented.

I5.4.1 <u>RELAY PROCESSING AT NODE C.</u> Node C is a relay node, but not a destination node. Node C is responsible for relaying the information to nodes E F, G and H.

Node C assigns the following values to the Intranet Header in example 3:

MESSAGE TYPE = 4 (IP Packet)
TYPE_OF_SERVICE = 0000 0000
MESSAGE_ID = 3
MAX_HOP_COUNT = 2 (Original MAX_HOP_COUNT - 1)
ORIGINATOR ADDRESS = 3 (node A)
STATUS BYTE 1 = 10010000 (DIS=1, REL=Yes, Des=No, ACK=No)
DESTINATION 1 = 5 (node C)
STATUS BYTE 2 = 01000010 (DIS=2, REL=No, DES=Yes, ACK=No)
DESTINATION 2 = 7 (node E)
STATUS BYTE 3 = 01010010 (DIS=2, REL=Yes, DES=Yes, ACK=No)
DESTINATION 3 = 8 (node F)
STATUS BYTE 4 = 11000010 (DIS=3, REL=No, DES=Yes, ACK=No)
DESTINATION 4 = 9 (node G)
STATUS BYTE 5 = 11000010 (DIS=3, REL=No, DES=Yes, ACK=No)
DESTINATION 5 = 10 (node H)
HEADER LENGTH = 16 octets

Figure I-6 shows the complete Intranet Header created by Node C.

I5.4.2. RELAY PROCESSING AT NODE F. Node F is both a destination and a relayer with relay responsibilities to nodes G and H. Node F assigns the following values to the Intranet Header in example 3:

MESSAGE TYPE = 4 (IP Packet)
TYPE_OF_SERVICE = 0000 0000
MESSAGE_ID = 3
MAX_HOP_COUNT = 1 (Received MAX_HOP_COUNT - 1)
ORIGINATOR ADDRESS = 3 (node A)
STATUS BYTE 1 = 10010000 (DIS=1, REL=Yes, DES=No, ACK=No)
DESTINATION 1 = 5 (node C)
STATUS BYTE 2 = 01010010 (DIS=2, REL=Yes, DES=Yes, ACK=No)
STATUS BYTE 2 = 8 (node F)
STATUS BYTE 3 = 11000010 (DIS=3, REL=No, DES=Yes, ACK=No)
DESTINATION 3 = 9 (node G)
STATUS BYTE 4 = 11000010 (DIS=3, REL=No, DES=Yes, ACK=No)
DESTINATION 4 = 10 (node H)
HEADER LENGTH = 14 octets

Figure I-7 shows the complete Intranet Header created by Node F.

| 0 LSB | 1 | 2 | 3 | 4 | 5 | 6 | 7 MSB |
|---|---|---|---|---|---|---|---|
| VERSION NUMBER | | | | MESSAGE TYPE | | | |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| INTRANET HEADER LENGTH | | | | | | | |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| TYPE OF SERVICE | | | | | | | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MESSAGE IDENTIFICATION NUMBER | | | | | | | |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAX HOP COUNT | | | | SPARE | | | |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| ORIGINATOR ADDRESS | | | | | | | |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 1 | | | | | | | |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY ADDRESS 1 | | | | | | | |
| 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 2 | | | | | | | |
| 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| DESTINATION/RELAY ADDRESS 2 | | | | | | | |
| 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 3 | | | | | | | |
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| DESTINATION/RELAY ADDRESS 3 | | | | | | | |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 4 | | | | | | | |
| 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| DESTINATION/RELAY ADDRESS 4 | | | | | | | |
| 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 5 | | | | | | | |
| 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| DESTINATION/RELAY ADDRESS 5 | | | | | | | |
| 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |

Figure I-6. Example 3 Intranet Header for Node C (Relay Node)

| 0 LSB | 1 | 2 | 3 | 4 | 5 | 6 | 7 MSB |
|---|---|---|---|---|---|---|---|
| VERSION NUMBER | | | | MESSAGE TYPE | | | |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| INTRANET HEADER LENGTH | | | | | | | |
| 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| TYPE OF SERVICE | | | | | | | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MESSAGE IDENTIFICATION NUMBER | | | | | | | |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAX HOP COUNT | | | | SPARE | | | |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ORIGINATOR ADDRESS | | | | | | | |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 1 | | | | | | | |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY ADDRESS 1 | | | | | | | |
| 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 2 | | | | | | | |
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| DESTINATION/RELAY ADDRESS 2 | | | | | | | |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 3 | | | | | | | |
| 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| DESTINATION/RELAY ADDRESS 3 | | | | | | | |
| 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| DESTINATION/RELAY STATUS BYTE 4 | | | | | | | |
| 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| DESTINATION/RELAY ADDRESS 4 | | | | | | | |
| 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |

Figure I-7. Example 3 Intranet Header Created by Node F (Relay and Destination Node)

# APPENIDIX J

## ROBUST COMMUNICATIONS PROTOCOL

### J1. General

J1.1. Scope. This appendix describes the interoperability and technical requirements for the robust communications protocol for DMTD subsystems. This appendix applies only to HAVEQUICK II compatible systems that require interoperability with radios that do not have data buffering or synchronization capability.

J1.2 Application. This appendix is not a mandatory part of this MIL-STD. The information contained herein is intended for guidance only.

### J2. Applicable Documents. This section is not applicable to this appendix.

### J3. Introduction.

This physical layer protocol provides the additional processing to aid the transfer of secure and non-secure digital data when concatenated with the link processing of the MIL-STD-188-220 protocol. The additional processing of this protocol allows for a higher level protocol with an error correcting capability equal to rate 1/2 Golay to transfer a burst of data containing up to 67,200 data symbols with better than 90% probability of success in a single transmission, this being over an active ARC-164 link with a random bit error rate of 0.1 or less. The second goal of this physical protocol is for the required performance to be achieved entirely in software using current systems with modest processing capability.

J3.1 Physical Protocol Components. Three individually selectable processes are used to meet the performance requirement. The first is the application of rate 1/3 convolutional coding to combat high random bit error rates. The second is a provision for data scrambling. Scrambling at the physical layer is implemented simply as the multiplication of the transmit data with a pseudo random bit pattern. The third is a packetizing scheme that allows for the re-transmission of the data that was lost due to an ARC-164 frequency hop. The re-transmission is performed, and data recovered within the data burst and the data interruption is transparent to the higher level protocol. This packetizing scheme has been dubbed the Multi-Dwell protocol because it was formulated to allow a message to be transmitted over multiple ARC-164 hop dwells.

J3.2 Optional rate 1/3 convolutional coding. The transmitting convolutional encoder generates three output bits for each input information bit. Figure J-1 shows an example of the encoding process for a constraint length (K) of 3. The encoder consists of a shift register equal in length to the constraint length. The data to encode is shifted from left to right one bit at a time. After each shift, three output bits are generated using the G1, G2, and G3 polynomials. The three encoded output bits are generated in the G1, G2, G3 order. The G2 output shall be inverted to provide some data scrambling capability. The convolutional encoding shift register is initialized to a state of zero when a transmission is requested. The first output bits are generated when the shift register contains the first upper layer bit to transmit, followed by all zeros. Upon detection of the robust synchronization pattern, the Viterbi decoder is initialized to make use of the knowledge of the initial encoder shift register state.

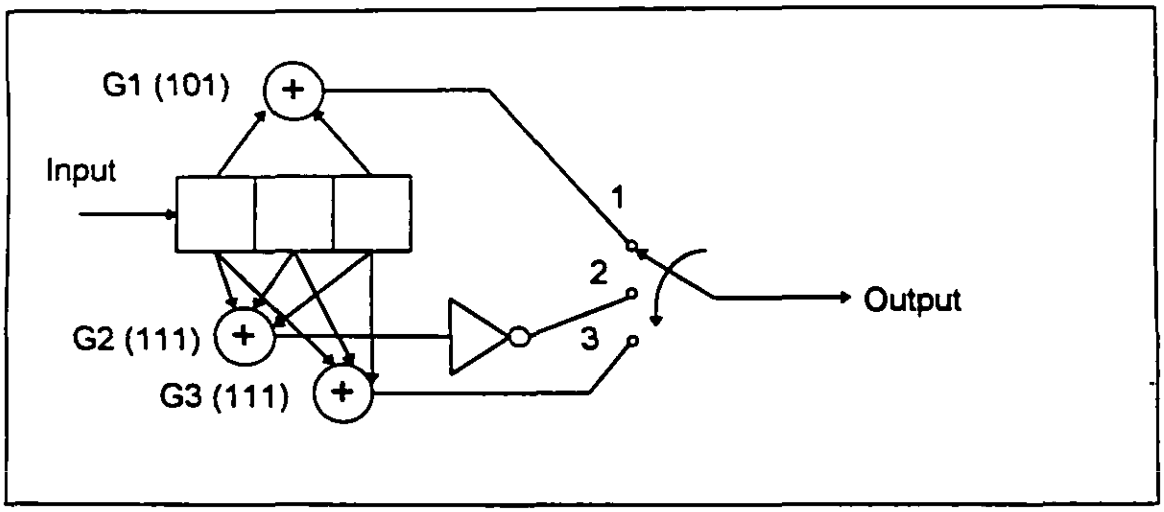



Figure J-1. Convolutional encoder with inverted G2 K=3.

Table J-1 lists the generator polynomials used for the three specified constraint lengths. The most significant bits of the octal representation of each polynomial are used for each polynomial.

Table J-1. Convolutional Coding Generator Polynomials (Octal).

| Constraint Length | G1 | G2 | G3 |
|---|---|---|---|
| 3 | 5 | 7 | 7 |
| 5 | 52 | 66 | 76 |
| 7 | 554 | 624 | 764 |

Figure J-2 shows the relative error correcting capability of rate 1/3 convolutional coding in a random error environment using the Viterbi decoding algorithm with hard decisions. The performance was achieved using a trace back buffer length of 16, 32, and 64 for constraint lengths 3, 5, and 7 respectively. If the demodulator and decoder are components of the same subsystem, soft decision information from the demodulator can be used to further enhance the performance.

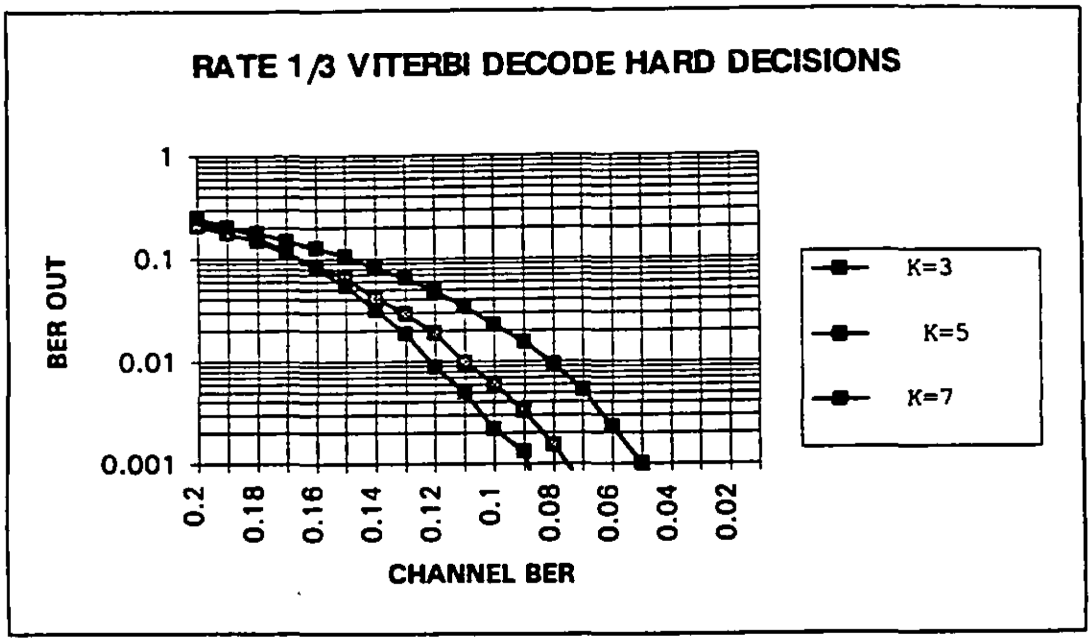



Figure J-2. Rate 1/3 Convolutional Coding Performance For Constraint Lengths 3, 5, and 7.

J3.3 Optional data scrambling. Physical layer data scrambling shall use the pseudo random bit generator specified in CCITT V.33 Annex A. The shift register shall be initialized to all zeros before the first bit of data is scrambled on transmission. On data reception, the descrambler shift register shall be initialized to zero before the first received data bit is descrambled. Figure J-3 shows the structure of the data scrambler and descrambler.

J3.4 Optional robust multi-dwell.

J3.4.1 Multi-dwell packet format. When the ARC-164 radio is in active mode, multi-dwell packetizing shall be enabled. The format of each multi-dwell packet is shown in Figure J-4. Each packet consists of a start of packet (SOP) pattern and a segment counter followed by 6, 11 or 13 64-bit data segments.

J3.4.2 Multi-dwell SOP field. The SOP pattern is a 32 or 64 bit long pattern used for multi-dwell packet detection. The maximum number of bits in error should be set to match the bit error rate environment. For normal operation, it is recommended that the maximum number of bits in error be set to 9 for a 64-bit pattern, and to 3 for a 32-bit pattern. The length of the SOP pattern shall be determined by bits three and four of the robust frame format.

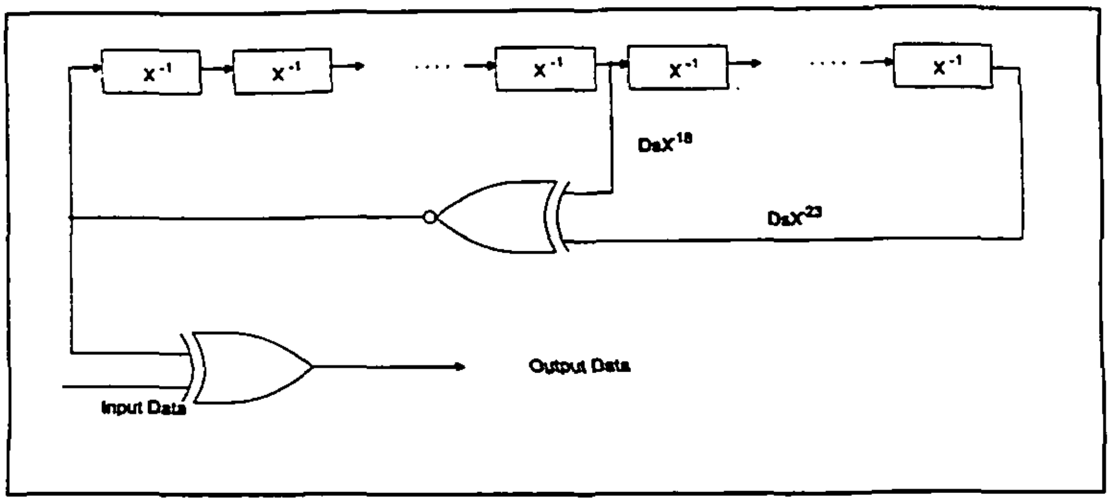



Figure J-3. Data Scrambler Structure.

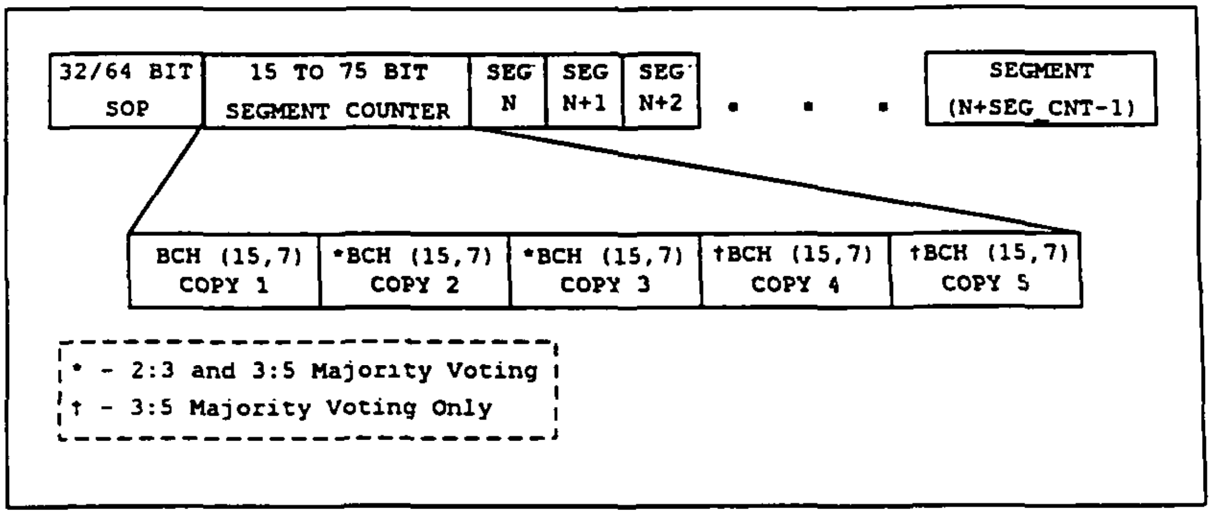



Figure J-4. Multi-Dwell Packet.

| LSB | MSB |
|---|---|
| 1010010011100010111100101000011010010000011111101010110011011101 | |

Figure J-5. Multi-dwell 64-bit SOP pattern.

| LSB | MSB |
|---|---|
| 00000011100100001001001110101110 | |

Figure J-6. Multi-dwell 32-bit SOP pattern.

J3.4.3 Multi-dwell segment count field. The segment counter is a modulo 64 count of the first segment in the packet. The six required bits shall be encoded as 1, 3, or 5 BCH (15,7) codewords depending on bits 2, 3 and 4 of the robust frame format. The six-bit segment counter shall occupy the 6 least significant bits of the seven-bit BCH data field. The most significant bit of the data field can optionally be used as an end of frame flag which, when set, indicates that data transmission is complete. A multi-dwell packet marked with an end of frame flag shall contain only the SOP pattern and the segment count field used to make the segment number of the last non-fill data segment transmitted.

J3.4.4 Multi-dwell data segments. Each multi-dwell packet shall contain 6 or 17 consecutive 64-bit data segments. Unless a channel interruption is detected during the transmission of the packet, each data segment shall contain the next 64 bits supplied by the data link layer for transmission. The last multi-dwell packet shall contain pad bits and segments as necessary to complete the packet. The transmitted pad data shall be an alternating one, zero sequence.

J3.4.5 Multi-dwell hop detection. The physical layer shall have the means of detecting or predicting communications link outages.

J3.4.6 Multi-dwell transmit processing. Data received from the data link layer for transmission shall be broken into 64 bit segments for transmission. The data shall be packetized as stated in J3.4.1. Packets shall be transmitted consecutively with the packet count subfield containing the count, modulo 64, of the first segment in the packet until a communications link outage is detected, at which time, the remainder of the data segments in the currently transmitted packet shall be filled with an alternating one/zero pattern. If the configurable hop recovery time (HRT), is greater than the time remaining to complete the transmission of the current packet, the alternating one/zero sequence shall be extended to the end of the HRT period. If a hop is detected during the multi-dwell packet synchronization field, or during the transmission of the first two segments, the entire packet shall be retransmitted. The first multi-dwell packet transmitted in a frame shall not contain the multi-dwell synchronization field. It is assumed that the segment count of the first packet is zero.

J3.4.6.1 Hop data recovery time period. A configurable variable called the hop recovery time (HRT) shall be used to determine if the fill data transmitted following a hop must be extended to ensure that the following multi-dwell synchronization field can be received. The HRT is defined as the time period from the beginning of the transmitting radio frequency synthesizer frequency hop to the time that the bit synchronizer connected to the receiving radio can reliably demodulate data. Because different hop detection/ prediction methods flag the hop at different times relative to the beginning of the transmitting radio frequency synthesizer frequency slew, the configured HRT shall be internally adjusted to insure that different DMTDs in a network can all use the same configurable HRT.

J3.4.6.2 Data transmitted after a hop. The multi-dwell packet transmitted directly following a communications link outage shall retransmit data starting with the 64-bit segment preceding the segment that was being transmitted when the hop was detected.

J3.4.6.3 Termination of transmission. After the final packet of the frame is transmitted, without a hop detected during a data segment containing actual data (not fill data), data transmission shall be terminated. To prevent receive delays caused by the receiver not being able to determine that the last data segment has been received, an optional truncated multi-dwell packet can be sent with the end of frame flag set. The segment count associated with the end of frame flag shall mark the last non-fill data segment transmitted.

J3.4.7 Multi-dwell receive processing. If the multi-dwell flag was set in the robust synchronization field, the receiver shall buffer the multi-dwell data packet. The segment count for the first multi-dwell packet in a frame shall be assumed to be 0. After the last packet bit is received, the receiver shall open the SOP correlator window. When the SOP pattern is recognized, the segment count is decoded using the combination of majority and BCH decoding specified in the robust synchronization field. After each new segment count is decoded, the buffered data for data segments lower in count than the new segment count are passed on to the next higher layer as received bits. The segments of the newly received packet are then buffered and held until it is verified that the buffered segments will not be re-transmitted.

J3.4.7.1 Receive end of frame detection. The data remaining in the multi-dwell receive data buffer shall be provided to the higher level protocol when an end of frame condition is detected. The end of frame condition may be determined by the data demodulator, the optional multi-dwell end of frame flag, or by a message from the higher level protocol indicating that message reception is complete.

J3.4.7.2 Optional soft decision information. When there is a very high link BER, a SOP pattern may not be recognized or the segment count may not be correctable. If fewer than three consecutive segment counts cannot be corrected the correct number of bits shall be supplied to the upper level protocol as to not cause a bit slip, and consequently, the loss of the remaining data in the frame. If convolutional coding is used with multi-dwell, it is suggested that soft decision information is supplied indicating the low quality of the received data resulting from a missed SOP pattern or an unrecoverable segment count.

J3.4.8 Multi-dwell majority logic overhead choice. The choice of the amount of multi-dwell majority voting (MV) overhead is dependent on the expected link BER. Table J-2 gives an estimate of the maximum random BER supported for a 90% probability of passing a single frame of length 1536 bits, 7680 bits, and 67,200 bits with no errors introduced due to multi-dwell processing.

Table J-2. Maximum Supported BER.

| Segment Count MV | 1536 | 7680 | 67,200 |
|---|---|---|---|
| 1 out of 1 | 0.055 | 0.03 | 0.016 |
| 2 out of 3 | 0.14 | 0.11 | 0.07 |
| 3 out of 5 | 0.2 | 0.14 | 0.12 |

J3.4.9 Multi-dwell overhead. The multi-dwell protocol introduces an overhead that shall be considered in the network timing calculations. The overhead is a function of the radio hop rate, the multi-dwell segment count majority voting choice, and the message length. Table J-3 gives the equation to calculate the actual worst case realized data rate for each hop rate and majority logic combination. The numbers in table J-3 were run with a hop recovery time of 15.625 ms, a maximum radio timing drift over a 1/2 hour period, an instantaneous data rate of 16000 bits/second. The actual efficiency will depend upon the exact implementation, therefore the numbers in Table J-3 should be used as a guide only. The six-segment multi-dwell packet shall be used for protocol acknowledgments and other single TDC block messages. The calculated realized data rate shall be used for the bit rate of all data encapsulated by the multi-dwell protocol.

Table J-3. Multi-dwell overhead.

| HOP RATE | Multi-dwell overhead calculation | | | |
|---|---|---|---|---|
| | MV 1:1, 11 segments | MV 2:3, 11 segments | MV 3:5, 13 segments | MV 3:5, 6 segments |
| 0 | $R/((0.3*10^{(-L*.00003)})+1.06)$ | $R/((0.3*10^{(-L*.00003)})+1.16)$ | $R/((0.2*10^{(-L*.00003)})+1.17)$ | $R/((0.1*10^{(-L*.00003)})+1.36)$ |
| 1 | $R/((0.6*10^{(-L*.00003)})+1.10)$ | $R/((0.6*10^{(-L*.00003)})+1.21)$ | $R/((.55*10^{(-L*.00003)})+1.23)$ | $R/((0.3*10^{(-L*.00003)})+1.40)$ |
| 2 | $R/((0.5*10^{(-L*.00003)})+1.15)$ | $R/((0.5*10^{(-L*.00003)})+1.27)$ | $R/((0.7*10^{(-L*.00003)})+1.30)$ | $R/((0.4*10^{(-L*.00005)})+1.48)$ |
| 3 | $R/((0.5*10^{(-L*.00003)})+1.20)$ | $R/((0.4*10^{(-L*.00002)})+1.36)$ | $R/((0.8*10^{(-L*.00003)})+1.29)$ | $R/((0.2*10^{(-L*.00003)})+1.56)$ |
| 4 | R/(1.45) | R/(1.51) | $R/((0.7*10^{(-L*.00002)})+1.46)$ | $R/((.07*10^{(-L*.00002)})+1.85)$ |
| ALL | R/(1.72) | R/(1.72) | R/(1.96) | R/(2.27) |

R = the instantaneous data rate
L = the number of bits to be transmitted

J3.4.9.1 Terminals lacking hop detection. The ALL case in Table J-3 is to show the efficiency of the multi-dwell protocol in systems where the hop cannot be detected due to hardware or software limitations. Since there is no hop timing information available, the DMTD shall assume that the radio will hop at every possible time slot. In these systems, it is assumed that timing synchronization with the radio will be made by the detection of the falling edge of the radio delayed push to talk (DPTT) signal provided by the ARC-164 radio.

J3.5 Robust Communications Protocol Network Timing. The use of the robust communications protocol requires the modification of the Appendix C type 1 network timing equations. The bit rate, transmit delays, and receive processing delays are modified by the robust protocol. For purposes of robust network timing two system bit rates are defined. The first is the channel bit rate which is represented as $n_c$. The second is the data link bit rate which is represented as $n_l$. As an example, if rate 1/3 convolutional coding is applied at the physical layer and the channel bit rate is 16 khz, the link bit rate would be 5.33 khz. In this example, an external cryptographic device would transmit the MI field at $n_c$ Hz and an internal cryptographic device would transmit the MI field at $n_l$ Hz. The multi-dwell reduction of $n_l$ is not deterministic but is bounded. The average multi-dwell $n_l$ is a function of the multi-dwell packet format, the timing of the DMTD transmit request in relation to the radio TRANSEC timing, and the number of bits to be transmitted. The following paragraphs address the required modifications to the Type 1 network timing equations.

J3.5.1 Net busy sensing function. Because net busy sensing is performed at the physical level, there are no modifications to the net busy sensing timing or methods when using the robust communications protocol.

$$Net\_Busy\_Detect\_Time = (KT + C + B + ST)$$

J3.5.1.1 Keytime delay (KT). The keytime delay is not effected by robust processing. However, when using a HAVEQUICK II radio, the actual keytime varies from transmission to transmission.

J3.5.1.1.1 Application guidance HAVEQUICK II link. The HAVEQUICK II TRANSEC timing and the DMTD network timing are not synchronized. To avoid the loss of critical data, such as the cryptographic synchronization and or the protocol SOM patterns, the DMTD transmission timing must be synchronized to the frequency hops. Generally, the radio provides a delayed push-to-talk (DPTT) signal which marks the beginning of a hop dwell with a guaranteed minimum duration. This minimum dwell period is sufficient to carry the synchronization field of an external cryptographic device or the robust frame synchronization field when an internal cryptographic device is used. The time from the DMTD transmit request to the assertion of the DPTT signal is, by definition, the key delay. For the purposes of network timing, the maximum delay between the DMTD transmit request and DPTT must be used as the key delay.

J3.5.1.2 CRYPTO device preamble transmission time (C). The crypto preamble transmission time is not effected by robust processing. Typically, this timing component is only applicable when using an external crypto device since the DMTD has no knowledge of data reception until the receiving crypto has successfully received the crypto preamble.

J3.5.1.3 Net busy detection time (B). The physical level bit synchronizing and SOM detection functions perform the detection of active data. There is no difference in the timing of this function when the robust SOM pattern precedes the protocol message synchronization pattern.

J3.5.1.4 Satellite interface delay (ST). The satellite interface delay is not effected by robust processing.

J3.5.2 Response hold delay. The additional transmission time required for the robust synchronization field and $n_1$ bit rate reductions add new terms to the response hold delay timing equations. Also additional receive processing delays impact the internal DMTD timing calculations.

$$RHD_0 = KT + E + T + S$$

J3.5.2.1 Keytime delay (KT). The usage of keytime delay for the calculation of RHD is not effected by the robust protocol.

J3.5.2.1.1 Application guidance HAVEQUICK II link. Because the keytime delay varies from transmission to transmission, the actual key delay will typically be less than the configured key delay. Also, the DMTD cannot delay the transmission of synchronization data until the end of the configured keytime delay period and maintain data synchronization with the radio hops. As a result, the transmitting DMTD cannot simply calculate the time from the DMTD transmit request to the transmission of the last message bit. A logical signal from the physical layer to the data link layer indicating the message completion time is required to insure that the transmitter and receiver(s) use the same reference point for the calculation of RHD and TP.

J3.5.2.2 Transmission processing delays (E). The equipment turnaround time and carrier drop-out time component of E are not changed by the robust protocol. The HAVEQUICK II radio introduces additional equipment turnaround time $ET_1$ and $ET_2$ as shown in Figure J-7. The transmit delay from the host to the transmission of data which is the host processor to DMTD interface delay, is not changed by the robust protocol. The additional transmission time that is required by the cryptographic function is not changed for an external crypto. For an internal crypto, the MI field will now be transmitted at the lower $n_1$. The satellite delay time is not changed by the robust protocol.

J3.5.2.3 Response transmission time (S). The response transmission time is changed by the robust protocol. A type 1 response PDU from the data link layer consists of the 64 bit message synchronization field, an optional imbedded MI field, the 168 bit word count and transmission header TDC block, and 384, 160, or 80 bits of acknowledgment data depending on the selectable use of EDC and TDC. The sum of these components are transmitted at the link data rate ($n_1$). In all response transmission cases, except for a secure external crypto transmission with rate 1/3 convolution coding enabled, the response is short enough that a multi-dwell transmission is not required. A multi-dwell transmission is required when using an external crypto and with the selection of rate 1/3 convolutional coding because the data may be interrupted by a frequency hop. Table J-4 gives the maximum number of bits that will be transmitted at the channel bit rate ($n_c$) for the link data sizes and multi-dwell SOP majority logic choices. These numbers are for the HOP ALL case, which is the worst case, and for the highest operational hop rate, hop rate 3. The 139 robust protocol header bits are included in Table J-4. The numbers in Table J-4 do not include the "wasted time" shown in Figure J-7.

J3.5.2.4 Tolerance (T). There is no required change in the tolerance calculation for the robust protocol.

J3.5.2.5 Individual response hold delay ($RHD_i$). The RHDi equation does not require modification for robust protocol implementation.

Table J-4. Multi-dwell response overhead.

| LINK BITS | multi-dwell external crypto response transmission time, HRT = 15.6 ms, 6 segments/packet | | | | | |
|---|---|---|---|---|---|---|
| | MV 1:1 FEC rate 1/3 | | MV 2:3 FEC rate 1/3 | | MV 3:5 FEC rate 1/3 | |
| | HOP RATE 3 | HOP ALL | HOP RATE 3 | HOP ALL | HOP RATE 3 | HOP ALL |
| 312 | $2047/n_c$ | $2047/n_c$ | $2109/n_c$ | $2604/n_c$ | $2139/n_c$ | $3139/n_c$ |
| 392 | $2047/n_c$ | $2478/n_c$ | $2109/n_c$ | $2604/n_c$ | $2139/n_c$ | $4143/n_c$ |
| 616 | $3047/n_c$ | $3478/n_c$ | $3109/n_c$ | $4602/n_c$ | $3139/n_c$ | $5189/n_c$ |

J3.5.2.6 Response transmission example. Figure J-7 shows an example of the timing of an acknowledgment when an external cryptographic device is used with the HAVEQUICK II radio. The keytime delay is shown as the period between the assertion of the DMTD transmit request and the radio DPTT signal. The falling edge of the DPTT signal marks the beginning of a long hop dwell that is long enough to contain the crypto preamble time. If an external crypto device was not used, this long dwell time would contain the entire acknowledgment. After the crypto has finished transmitting the MI field, the transmitting DMTD begins to supply data for transmission. Depending on the length of the COMSEC bit sync field, there may be time to transmit the acknowledgment or at least the robust synchronization field on the long dwell. Typically, the COMSEC bit synchronization time is not very accurate and may be long enough to push the MI field to the end of the guaranteed long dwell time. For this reason, the DMTD typically waits to start data transmission on the first hop dwell following the long guaranteed dwell. The end of the guaranteed hop dwell is marked by the possible hop label. The first bit of the robust SOM pattern is transmitted after the configured hop recovery time (HRT). During the transmission of the response, one or more hops may occur which will vary the transmission time of the acknowledgment. When the response transmission is complete, the DMTD de-asserts the transmit request signal. The radio will de-assert DPTT after a variable delay ($ET_1$) at a time synchronized with the hop sequence. After DPTT is de-asserted, the crypto transmits the postamble so that a hop will not occur during the transmission of the postamble. The radio RF output remains active for longer that is required for the transmission of the crypto postamble which is shown as the $ET_2$ time period.

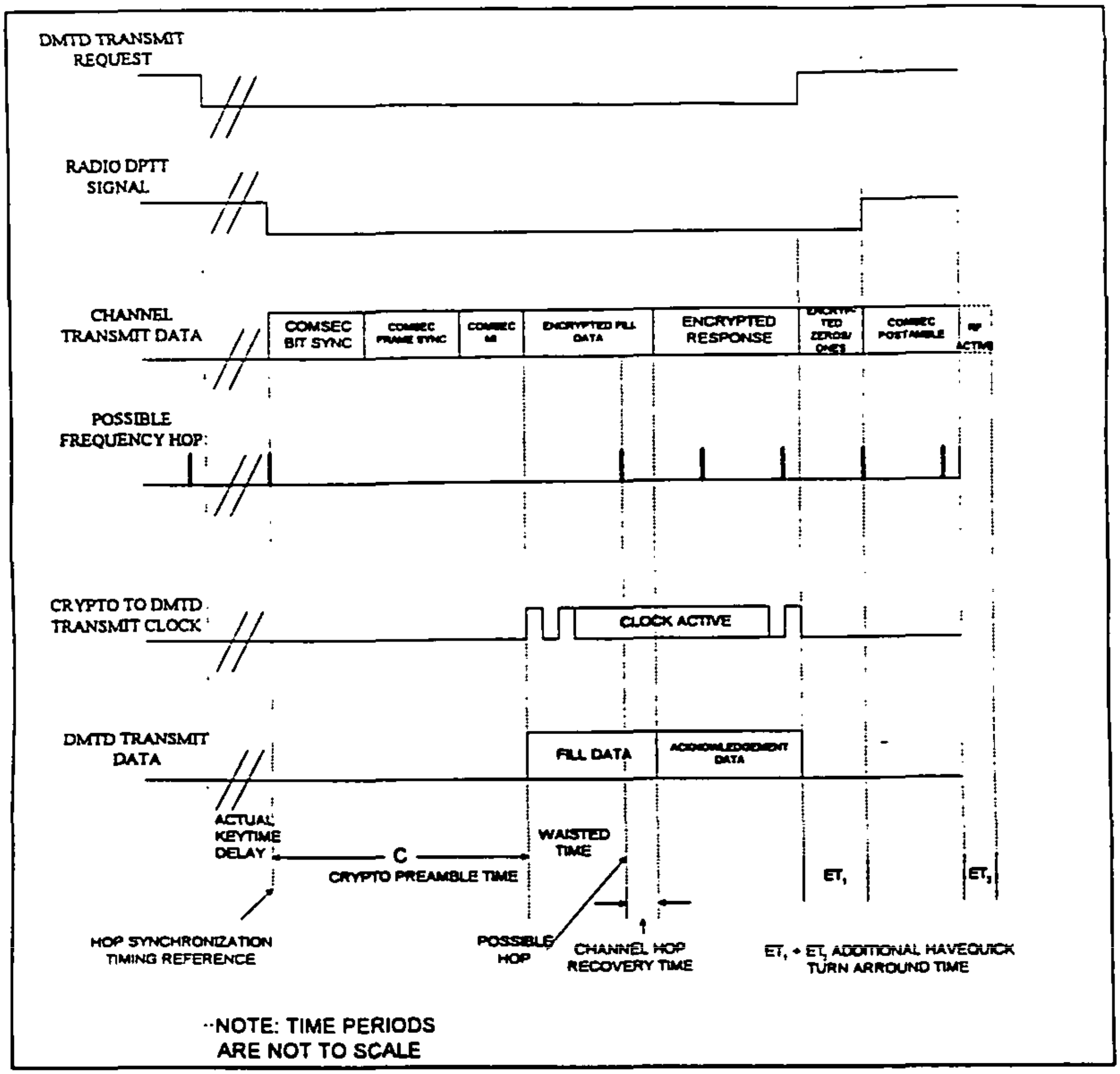



Figure J-7. HAVEQUICK II External Crypto Acknowledgment Transmission.

J3.5.2.7 Estimation of multi-dwell $n_1$. Figure J-8 shows an example of the $n_1$ data rate for a multi-dwell transmission with a channel data rate of 16 kb/s. This is the worst case data rate reduction which would be experienced with rate 1/3 convolutional coding, a 64 bit SOP pattern length, and 3 out of 5 majority logic decoding of the segment count field. The data rate shown Figure J-8 is the number of link bits to transmit divided by the number of channel bits transmitted times the $n_c$. Since rate 1/3 convolutional encoding is used in this example, the maximum link data rate achievable would be 5.33 khz. For short messages, the radio hop timing at the beginning of the transmission has a significant impact on the transmission efficiency. This example uses 13 segments per packet which is the recommended segment per packet count for long transmissions using 3 out of 5 majority logic. This figure and the equations given in Table J-3 are given as an aid for network throughput estimation and should not be used for network timing. The bit rate estimating equation used in Figure J-3 is:

$$\text{link rate} = \text{nc} / (0.5*10^{(-\text{link bits} * .00003)} + 1.301)$$

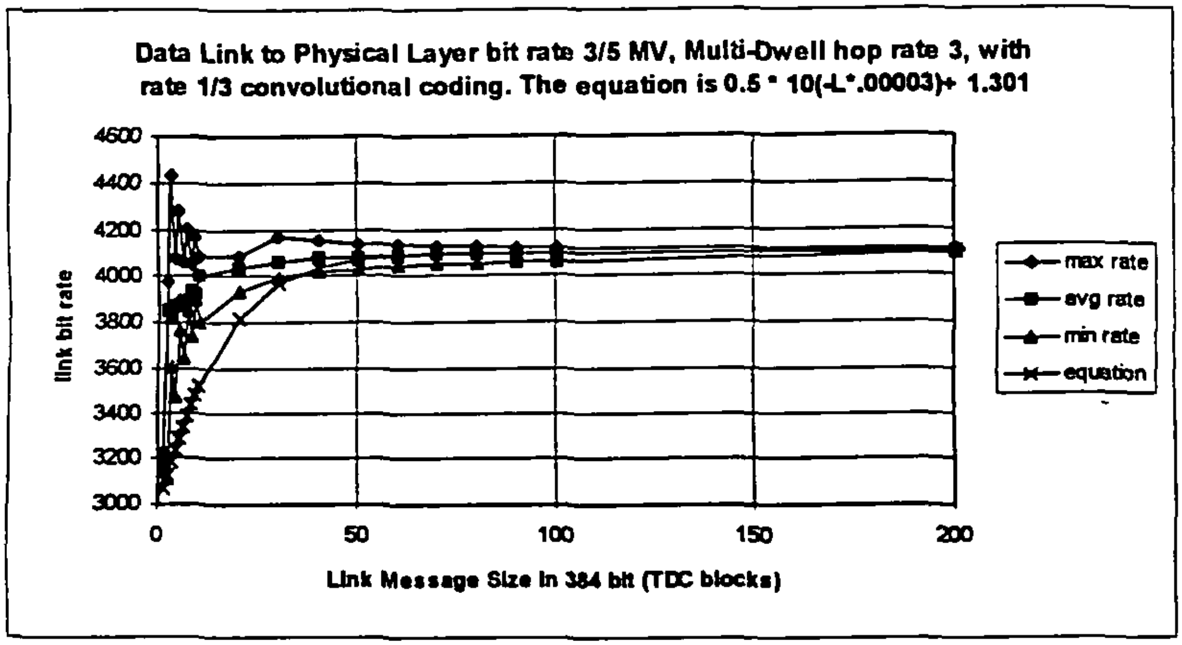



Figure J-8. Link Data Rate as a Function of Message Size.

J3.5.2.8 Receive Processing Delays. In order to calculate the reference point for the RHD and TP timers, the receiving DMTD must know the time of arrival of the last bit of the transmission. In order to do this, the data link layer normally determines the last bit of the transmission after decoding the word count and tags the arrival of the last data bit from the physical layer. The physical layer receive delays are dependent on the DMTD hardware and software implementation. The two delay components are processing delays and data pipeline delays. The processing delays are independent of the received data rate and the pipeline delays are dependent on the data rate. If the receive data rate is known, the data link layer can calculate the time of arrival of the last bit of the message by subtracting off the processing and pipeline delays. If the received data rate is not known, it is impossible to convert a pipeline delay from bits to seconds. The data rate of all non-multi-dwell transmissions is known to be either $n_c$ or $n_c/3$ dependent on the use of rate 1/3 convolutional coding. The received data rate of a multi-dwell transmission is not known. For or this reason, when a multi-dwell transmission is received, the physical layer must tag the time of arrival of the final multi-dwell bit. The physical layer can determine the time of arrival of the last bit by using the end of frame flag which is the most significant bit in the final multi-dwell segment count field.

The trace back buffer length of the Viterbi decoder introduces a known pipeline delay in the received data. The length of the trace back buffer is an implementation choice which is dependent on the Viterbi decoder architecture.

J3.5.3 Timeout period (TP). The timeout period is composed of terms that have already been defined.

J3.5.4 Network access delay (NAD). The network access delay is always an integer number times the Net_Busy_Detect_Time which has previously been defined.

J3.6 Summary. The physical layer robust protocol introduces additional transmit and receive delays due to the robust header and the convolutional decoding pipeline delays. Multi-dwell packetizing introduces a data rate reduction which varies widely for short transmissions. The HAVEQUICK II radio introduces variable delays in the keytime delay and the equipment turn-around time. To maintain network timing using the type 1 timing equations, the net busy sense timing and the response transmission time must be a known constant. In most cases, the response can be transmitted without using the multi-dwell packetizing algorithm. When the multi-dwell packetizing algorithm must be used to transmit a response, the worst case time to complete the transmission is used in the response transmission time component of the term E in RHD. The message transmission time is variable and is only required to be known at the end of the transmission. Two additional physical to data link signals are required to mark the time of the last transmitted bit for transmission, and the time of the last received bit for a reception.

# APPENDIX K

## BOSE - CHAUDHARI - HOCQUENGHEM (15, 7) CODING ALGORITHM

K1. General.

K1.1 Scope. This appendix describes a linear block cyclic code capable of correcting any combination of two or fewer errors in a block of 15 bits.

K1.2 Application. This appendix is a conditionally mandatory part of MIL-STD-188-220. It is mandatory for implementing Robust Frame Synchronization with Asynchronous mode operation (described in 5.2.1.2.1).

K2. Applicable documents. This section is not applicable to this appendix.

K3. BCH (15,7) code. The BCH (15,7) code is a linear, block, cyclic, BCH code capable of correcting any combination of two or fewer errors in a block of 15 bits. The generator polynomial for this code is

$$g(x) = 1 + X^4 + X^6 + X^7 + X^8$$

where $g(x)$ is a factor of $X^{15} + 1$

K3.1 Hardware encoding. BCH (15, 7) encoding can be performed with an 8 stage feedback shift register with feedback connections selected according to the coefficients of $g(x)$. A shift register corresponding to the coefficients of $g(x)$ is shown in Figure K-1.

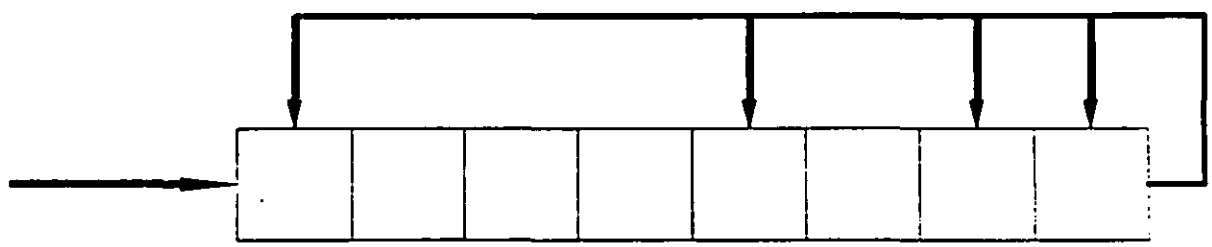
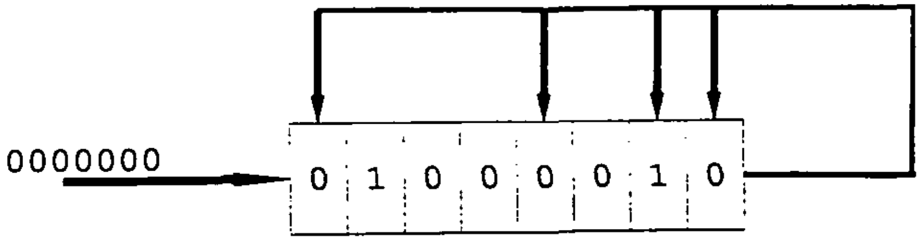


Figure K-1. Shift register encoder for the BCH (15,7) code.

Figure K-2 illustrates its operation by showing the encoding of the information vector (1000010) to form the code vector (10100101 | 01000010), where the parity check sequence is shown before the partition and the information sequence after. The information sequence with eight zeros after it (place holders for the parity bits to be calculated) is shifted into the register

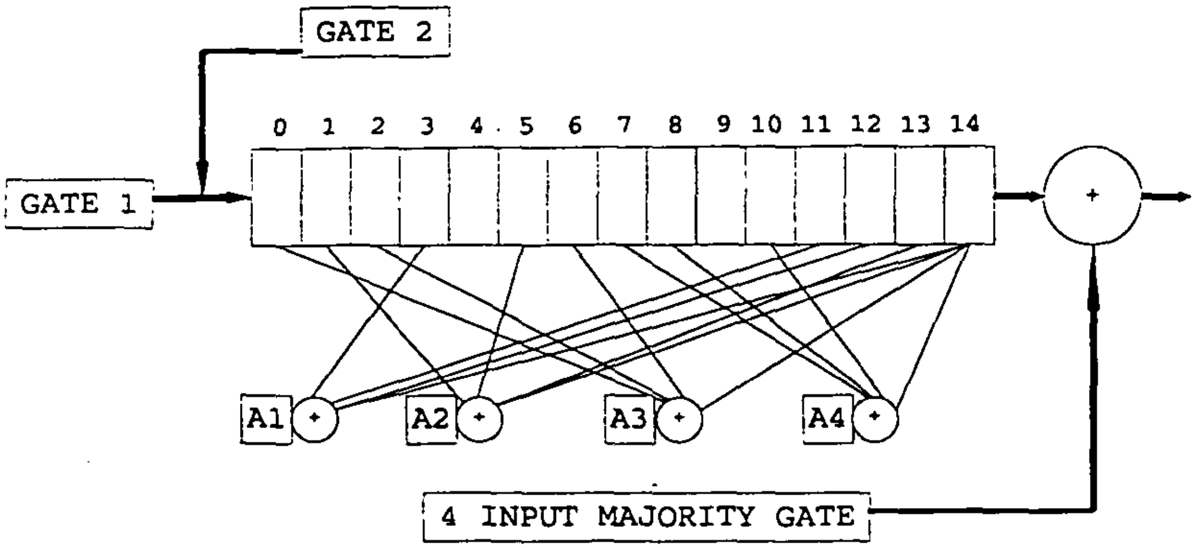



| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Shift | 000000 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| Feedback | | 0 | | | | 0 | | 0 | 0 | |
| Sum | 000000 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | |
| Shift | 00000 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Feedback | | 1 | | | | 1 | | 1 | 1 | |
| Sum | 00000 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | |
| Shift | 0000 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 |
| Feedback | | 1 | | | | 1 | | 1 | 1 | |
| Sum | 0000 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | |
| Shift | 000 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| Feedback | | 0 | | | | 0 | | 0 | 0 | |
| Sum | 000 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | |
| Shift | 00 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| Feedback | | 1 | | | | 1 | | 1 | 1 | |
| Sum | 00 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | |
| Shift | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 |
| Feedback | | 0 | | | | 0 | | 0 | 0 | |
| Sum | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | |
| Shift | | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| Feedback | | 1 | | | | 1 | | 1 | 1 | |
| Sum | | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | |

Figure K-2. Encoding example.

initially (it is really a fifteen bit shift register but only the last eight positions correspond to the coefficients of g(x) and contain feedback connections). The operation of the shift register consists of seven rounds of shift, feedback, and sum operations. The parity portion of the code vector can then be read out of the shift register as shown.

K3.2 Hardware/Software Decoding. Because of its special structure (it is completely orthogonalizable in one step), the BCH (15,7) code can be decoded very efficiently with a majority logic scheme which can be directly implemented in software or hardware. It is most easily described in terms of the shift register implementation shown in Figure K-3. With gate 2 open and gate 1 closed, the received block is read into the shift register. the output of the four modulo 2 summers is sampled by




| | | | | |
|---|---|---|---|---|
| A1 | 3 | 11 | 12 | 14 |
| A2 | 1 | 5 | 13 | 14 |
| A3 | 0 | 2 | 6 | 14 |
| A4 | 7 | 8 | 10 | 14 |

Figure K-3. BCH (15,7) majority logic decoding.

the majority gate and processed as follows: if a clear majority of the inputs are ones (three or more) then the output is one, otherwise (if two or fewer inputs are ones) the output is zero. This output is used to correct the last bit of the shift register. The corrected bit is output to the receiver and feedback through gate 2 as the register is right shifted. The process is now repeated thirteen times until the last bit is corrected.

K3.3 Software encoding. The BCH (15,7) code is most efficiently encoded in systematic form from the generator matrix shown in Figure K-4.

$$G = \left[\underbrace{\begin{matrix} 1 & 0 & 0 & 0 & 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 0 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 1 & 1 & 1 \end{matrix}}_{\text{Parity}} \middle| \underbrace{\begin{matrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{matrix}}_{\text{Identity}}\right]$$

Figure K-4. BCH (15, 7) generator matrix.

CONCLUDING MATERIAL

**Custodians:**

Army - CR
Navy - EC
Air Force - 90

**Review activities:**

Army - AM, SC, PT , AC, MI
Navy - MC, NC, TD , OM
Air Force - 02, 13, 17, 19,
29, 89, 93, 11, 18
DLA - DH
NSA - NS
ECAC - --
DMA - MP
DOT - OST
DIA - DIA

**Preparing Activity:**

DISA - DC

**Agent:**

N/A

(Project TCSS - 2200)

**International Interest:**

NATO

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# STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

## INSTRUCTIONS

1. The preparing activity must complete blocks 1,2, 3, and 8. In block 1, both the document number and revision letter should be given.
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
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| I RECOMMEND A CHANGE: | 1. DOCUMENT NUMBER MIL-STD-188-220A | 2. DOCUMENT DATE (YYMMDD) 950727 |
|---|---|---|

3. DOCUMENT TITLE Interoperability Standard for Digital Message Transfer Device Subsystems

4. NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)*

5. REASON FOR RECOMMENDATION

6. SUBMITTER

| a. NAME *(Last, First, Middle Initial)* | b. ORGANIZATION | |
|---|---|---|
| c. ADDRESS *(Include Zip Code)* | d. TELEPHONE *(Include Area Code)*<br>(1) Commercial<br>(2) DSN<br>*(If applicable)* | 7. DATE SUBMITTED *(YYMMDD)* |

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