TIA STANDARD

Project 25

Fixed Station Interface

Messages and Procedures

TIA-102.BAHA

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TELECOMMUNICATIONS INDUSTRY ASSOCIATION

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association with the Electronic Industries Alliance

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FOREWORD

(This foreword is not part of this standard.)

This document has been submitted to APCO/NASTD/FED by the Telecommunications Industry Association (TIA), as provided for in a Memorandum of Understanding (MOU) dated December, 1993. That MOU provides that APCO/NASTD/FED will devise a Common System Standard for digital public safety communications (the Standard), and that TIA shall provide technical assistance in the development of documentation for the Standard. This document has been developed by TR8.19 (Wireline Interfaces) with inputs from the APCO Project 25 Interface Committee (APIC), the APIC Fixed Station Interface Task Group, and TIA Industry members. This document is being published to provide technical information on the emerging digital techniques for Land Mobile Radio Service.

This document defines a Conventional Fixed Station Interface (CFSI) for Project 25. The CFSI is the interface between a conventional fixed station, which is defined in this document as a functional component of a Fixed Station Subsystem, and a Conventional Fixed Station Host (CFSH). A CFSH is defined in this document as a functional component of either an RF Subsystem (RFSS) or a Console Subsystem. For the purposes of this document the CFSI is defined as a specialization of the generic Project 25 Fixed Station Interface (FSI) described in TSB-102-A. Future related standardization efforts are planned to develop new TIA standards defining protocols for a Trunked Fixed Station Interface for Project 25. In addition, future associated standardization efforts are planned to develop new TIA standards defining compliance tests (e.g., measurement methods, performance recommendations, and interoperability tests) for the Project 25 Fixed Station Interface protocols defined in this and future related standards.

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[*] Use of the trademark identified in this standard is not an endorsement by TIA.

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1 Scope

This document defines a Conventional Fixed Station Interface (CFSI). The CFSI is the interface between a conventional fixed station, which is defined in this document as a functional component of a Fixed Station Subsystem, and a Conventional Fixed Station Host (CFSH). A CFSH is defined in this document as a functional component of either an RF Subsystem (RFSS) or a Console Subsystem.[1] Clause 6 describes these elements and their relationship to each other. For the purposes of this scope statement, a fixed station may be either an "analog fixed station" or a "digital fixed station". An "analog fixed station" supports conventional FM RF resources or their equivalent. A "digital fixed station" supports the P25 Common Air Interface (CAI) for P25 conventional systems (see [8]).

This document fully describes the CFSI including its architecture (clause 6), and protocols (clauses 7 and 8). Clause 7 describes a basic analog audio and control interface, while clause 8 describes a more capable Internet Protocol (IP) (see [1]) based digital interface. This interface has been designed to work with IPv4. Use of this interface with IPv6 is for further study.

The functional scope of the CFSI as described herein comprises the following CFSI Analog and CFSI Digital Interface provisions.

The CFSI Analog Interface provides:

1. Transport of clear audio between a fixed station and its host[2] providing capabilities for full-duplex, half-duplex and simplex communications at the discretion of the fixed station.

2. Transport of E&M control signaling between a fixed station and its host to provide a simple "Push-to-talk" and "COR" capability.

3. Transport of Tone Remote Control (TRC) control signaling from a host to a fixed station to provide a variety of control functions including transmit channel control, squelch control, monitor control, clear/secure controls, analog/digital mode controls, etc.

4. A primitive "Intercom" capability allowing for the transport of audio between the fixed station and its host without initiating an RF transmission.

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[1] For the purposes of this document the CFSI is defined as a specialization of the generic Project 25 Fixed Station Interface (FSI) described in TSB102-A (see [19]).
[2] Throughout this document the terms "Host" or "host" refer to the CFSH as defined in this document.

The CFSI Digital Interface provides:

1. IP based capabilities equivalent to those provided via the Analog Interface.

2. Transport of encrypted audio between a digital fixed station and its host.

3. Transport of Caller-ID information between a digital fixed station and its host. This includes Unit ID from field units to consoles, and “Console ID” from consoles to field units.

4. Transport of Talk-group information between a digital fixed station and its host.

5. Transport of NAC code information between a digital fixed station and its host.

6. Transport of Emergency Alert messages from the digital fixed station to its host.

7. Transport of Emergency indications along with the voice stream between the digital fixed station and its host.

8. Transport of Received voter identification from the digital fixed station to its host.

9. Advanced Control of the Fixed Station by its host including the disabling of all squelch (monitor function).

10. A standard option to transport intercom audio to and from the fixed station location.

2 Document Organization

This document defines the Conventional Fixed Station Interface (CFSI) for Project 25 systems.

The document is organized into eight clauses that are structured as follows:

- Clause 1 provides a general description of the CFSI, including identification of key user requirements;
- Clause 2 identifies the document organization and structure;
- Clause 3 identifies the normative and informative references;
- Clause 4 defines key terms;
- Clause 5 provides a list of acronyms and abbreviations;
- Clause 6 defines the CFSI architecture;
- Clause 7 defines the CFSI analog interface;
- Clause 8 defines the CFSI digital interface.

3 References

The following documents contain provisions which, through reference herein, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. ANSI and TIA maintain registers of currently valid national standards maintained by them.

3.1 Normative References

[1] RFC 791, *Internet Protocol,* IETF, September 1981.

[2] TIA-603-C, *Land Mobile FM or PM – Communications Equipment – Measurement and Performance Standards*, TIA, August 2004.

[3] GR-506-CORE Issue 1 Rev 1, *LSSGR: Signaling for Analog Interfaces*, Telcordia, November 1996.

[4] TIA/EIA/IS-968, *Technical Requirements for Connection of Terminal Equipment To the Telephone Network*, Global Engineering Documents, Englewood CO, July 2001. (This is the privatization of FCC Title 47 CFR Part 68.)

[5] RFC 1884, *IP Version 6 Addressing Architecture*, IETF, December 1995.

[6] RFC 768, *User Datagram Protocol*, IETF, August 1980.

[7] RFC 3550, *RTP: A Transport Protocol for Real-Time Applications*, IETF, July 2003.

[8] TIA/EIA-102.BAAA, *Project 25 FDMA Common Air Interface*, TIA, May 1998.

[9] TIA/EIA-102.AABC, *Project 25 Trunking Control Channel Messages*, TIA, May 2000.

[10] TIA-102.AABF-A, *Project 25 Link Control Word Formats and Messages*, TIA, December 2004.

[11] TIA/EIA-102.BABA, *Project 25 Vocoder Description*, TIA, May 1998.

[12] ITU-T Recommendation G.711, *Pulse Code Modulation (PCM) Of Voice Frequencies*, International Telecommunication Union, 1993.

[13] RFC 2598, *An Expedited Forwarding PHB*, IETF, June 1999.

3.2 Informative References

[14] TSB102.AABG, *APCO Project 25 Conventional Control Messages*, TIA, July 1996.

[15] RFC 793, *Transmission Control Protocol,* IETF, September 1981.

[16] RFC 2475, *An Architecture for Differentiated Services*, IETF, December 1998.

[17] TSB102.BACC, *APCO Project 25 Inter-RF Subsystem Interface Overview*, TIA, December 2003.

[18] RFC 3551, *RTP Profile for Audio and Video Conferences with Minimal Control,* IETF, July 2003.

[19] TSB102-A, *APCO Project 25 System and Standards Definition*, TIA, November 1995.

[20] TSB102.AABD, *Project 25 Trunking Procedures*, TIA, October 1997.

4 Definitions

Base Station ....Equipment within a fixed station subsystem that performs at least the Base Radio functions of power amplifier (PA), RF front-end, modulation and demodulation. It may perform other fixed station subsystem functions also. It is normally connected to a console or RFSS through a Fixed Station Interface.

Block Payload ....The actual data contained in the block. The block data may be voice, control words, low speed data, etc.

Block Payload, Type Block PT .....A number which describes the basic payload type as defined by the IETF (when E bit is set to 0) or, it may be a profile specific type (when E bit is set to 1). In this specification, E = 1.

Block Type ....A block identifier used to indicate what type of data is contained in the block, such as CAI voice, IMBE only, link control word, encryption sync word, etc.

CAI (Common Air Interface) ....A radio to radio signal path defined in terms of access method, modulation scheme, vocoding method, channel data rate, and channel data format.

Console ....A device used by a dispatcher to communicate with radios in the field. These range from simple devices that resemble telephones to advanced touch screen computer based systems that control multiple transmitters and can patch multiple call groups together.

Fixed Data Network......................A network of fixed computer equipment for wide-area data communications.

Fixed Station ....RF equipment which is generally in a fixed location. It transmits the outbound path of the common air interface and receives the inbound path of the common air interface. It may also transmit or receive conventional FM. A fixed station may include a fixed station interface, and be configured as one or more base stations or repeaters and may include additional functionalities such as voters and distribution functions.

IMBE .... Improved Multi-Band Excitation. A low data rate Voice codec developed by Digital Voice Systems, Inc. (DVSI) used by P25 systems.

Mobile .... A Subscriber Unit intended for vehicular operation.

Portable .... A Subscriber Unit intended for hand-held operation.

Repeater .... Equipment within a fixed station subsystem that performs at least the radio functions of power amplifier (PA), RF front-end, modulation and demodulation. It may include a limited number of functions such as NAC detection, CTCSS/DCS detection to enable repeater functions etc. It need not include a connection to a console or RFSS through a Fixed Station interface.

RTP Header .... The part of the RTP header which includes the following information: version (V), padding (P), extension (X), CSRC count (CC) {when inserted by a mixer}, marker (M), payload type (PT), sequence number, timestamp, SSRC, and CSRC.

Tone Remote Control................... A legacy method of controlling fixed station functions using in-band tones over analog bearers.

Wildcard .... TRC functions that can be used for generic purposes via the terminating fixed station. Equipment that support Wildcard functions can use these to control additional fixed station functions or to control equipment external to the fixed station – for example start and stop of power generators.

5 Abbreviations and Acronyms

ACK..Acknowledgement
AFSI ....Analog Fixed Station Interface
ANSI...American National Standards Institute
CAI ....P25 Common Air Interface
CDCSS..Continuous Digital Controlled Squelch System
CFM ....Conventional FM
CFSH ....Conventional Fixed Station Host
CFSI..Conventional Fixed Station Interface
COR ....Carrier On Relay
CS ....Connected State
CTCSS ....Continuous Tone Controlled Squelch System
DARPA..Defense Advanced Research Projects Agency
DFSI ....Digital Fixed Station Interface
DSCP ....Differentiated Services Code Point
DUID ....Digital Unit IDentification
DVSI...Digital Voice Systems Inc.
E&M ....Ear & Mouth Signaling
EIA ....Electronics Industry Association
FDMA..Frequency Division Multiple Access
FM...Frequency Modulation
FS..Fixed Station
FSSI ....Fixed Station Subsystem Interface
FT..Frame Type
HLGT...High-level Guard Tone
IANA..Internet Assigned Numbers Authority
ICMP ....Internet Control Message Protocol
ID...IDentification
IETF ....Internet Engineering Task Force
IMBE™ ....Improved Multi-band Excitation
IP...Internet Protocol

LLGT .... Low-level Guard Tone
LSB .... Least Significant Byte
mA .... milliamp
MFID .... ManuFacturer IDentification
MSB .... Most Significant Byte
msec .... millisecond
N/A.. Not Applicable
NAC .... Network Access Code
NAK .... Negative Acknowledgement
OSI.. Open Systems Interconnection
P25 .... Project 25
PA .... Power Amplifier
PID.. Protocol IDentifier
PTT .... Push-to-talk
RF .... Radio Frequency
RFC .... Request for Comments
RFSS .... RF Subsystem
RTCP .... Real-time Transport Control Protocol
RTP... Real-time Transport Protocol
SBC .... Single Block Control
SF .... Super Frame
sec .... second
SSRC... Synchronization SouRCe
TCP... Transport Control Protocol
TIA .... Telecommunications Industry Association
TRC .... Tone Remote Control
UDP .... User Datagram Protocol
VC... Voice Conveyance

NOTE: Abbreviations for specific fields of the RTP, UDP and IP protocols can be found in the relevant references.

6 CFSI Architecture

This section describes the architecture of the Conventional Fixed Station Interface (CFSI) and is primarily informative in nature. Normative statements contained herein, however, are intended to be a part of this specification.

6.1 Core CFSI Functions

6.1.1 Conventional Analog Fixed Stations

Conventional Analog Fixed Stations provide mobile-to-mobile and mobile-to-console communications compliant with TIA/EIA 603 (see [2]). Conventional stations may “repeat” audio from their inbound channel to their outbound channel, or may only forward audio received from the fixed equipment.

Conventional Analog Fixed Stations may provide CTCSS or CDCSS squelch capabilities, or may be set to pass all received audio. Consoles are typically able to control the squelch characteristics, transmit and receive frequencies, and repeat mode of conventional stations.

Conventional Analog Fixed Stations may use either the Analog or Digital Fixed Station Interface.

6.1.2 Conventional Digital Fixed Stations

Conventional Digital Fixed Stations provide similar capabilities to those provided by analog fixed stations, but they use the P25 CAI rather than a TIA/EIA 603 air interface. Instead of CTCSS and CDCSS squelch, the Conventional Digital Fixed Stations provide squelch mechanisms based on Network Access Code (NAC) and talk-group. Digital Fixed Stations may also operate clear or encrypted.

> *NOTE*: The digital fixed station interface does not control secure mode and only exerts limited control over the squelch mode.

Conventional Digital Fixed Stations may use either the Analog or Digital Fixed Station Interface.

6.1.3 Mixed Mode Fixed Stations

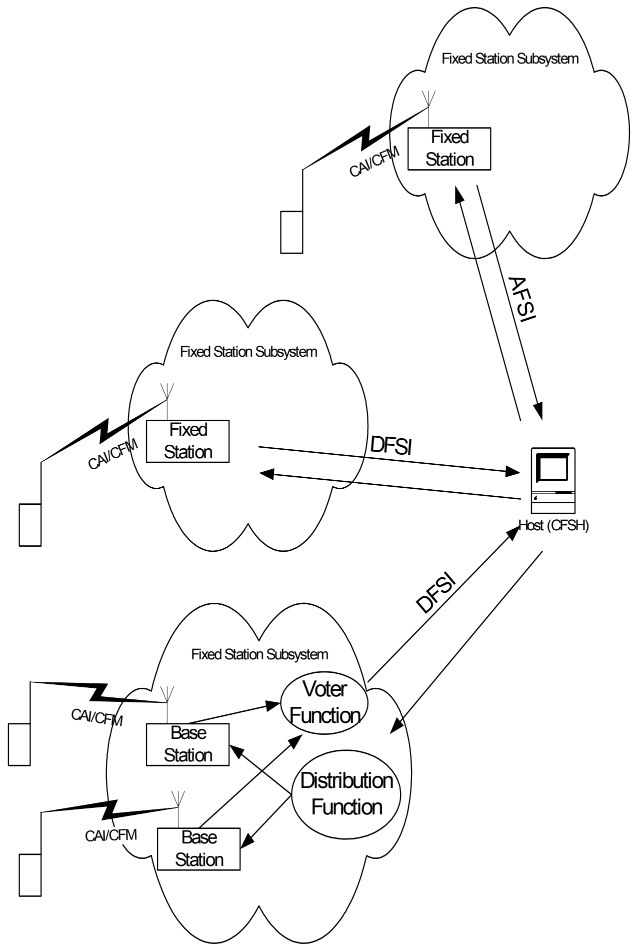
Certain fixed stations may provide both analog and digital modes. These stations also typically support console controls to switch between modes.

Mixed Mode Fixed Stations may use either the Analog or Digital Fixed Station Interface.

6.2 CFSI System Architecture and Overview

Figure 1 illustrates the architecture and context of the conventional FSI. Within the subsystem "cloud", the interconnection of the elements is manufacturer specific and not described in this specification.

Figure 1 – CFSI System Architecture



Outside of the cloud, however, each fixed station is connected via either an Analog Fixed Station Interface (AFSI) or a Digital Fixed Station Interface (DFSI) to one host, which may be either a Console Subsystem (of which a console is a functional element) or an RFSS. Any host may support a multiplicity of fixed station interfaces of any variety. The analog FSI supports only the simple model of a conventional FM (CFM) station. In contrast, the Digital FSI supports more complex models appropriate to the P25 CAI.

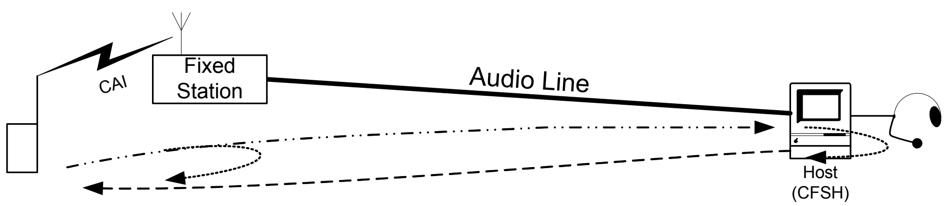
> *NOTE*: Unless otherwise indicated, for the purposes of this document "host" or "Host" refers to a Conventional Fixed Station Host (CFSH) as defined in this document.

Each fixed station supports one inbound and one outbound audio stream at any particular time. The composition of the stream is determined by the source. This architecture should not be construed as prohibiting multi-drop consoles, particularly in the analog case. Additional operator positions are transparent to the interface as they reside behind the abstraction presented by the CFSH.

6.2.1 Analog Fixed Station Interface

The analog fixed station interface models an analog station as a single fixed station connected via a 2 or 4 wire audio interface with 1 or 2 additional optional control signals to a single host. Control may be provided using the optional E&M (COR/PTT) signalling on the control signals, or through in-band tones. Figure 2 illustrates the conventional Analog Fixed Station Interface (AFSI).

Figure 2 – Conventional Analog Fixed Station Interface



Audio from the Host is sent to the fixed station where it is transmitted to subscriber units. Likewise, audio received by the fixed station from subscribers is transmitted to the host. Two repeat modes may be supported:

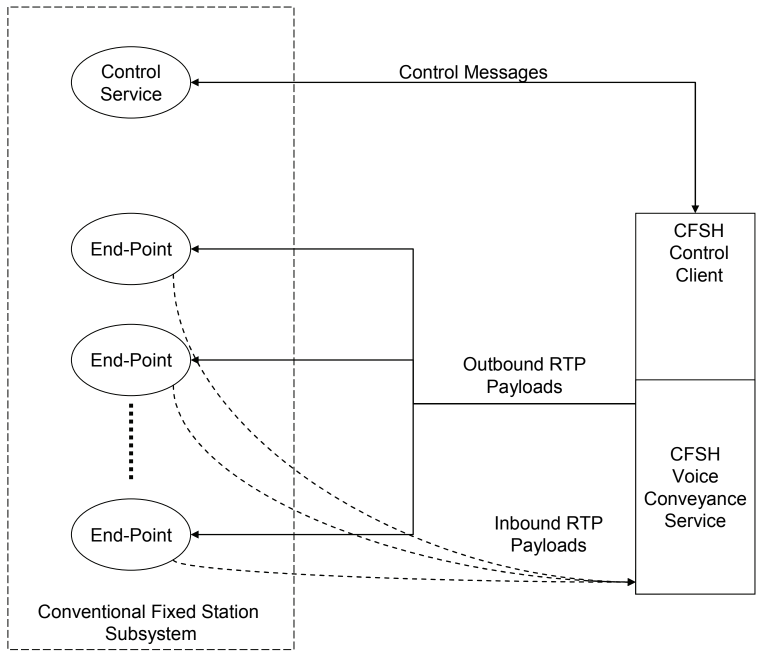
1. The fixed station may be configured to retransmit on the outbound air interface the voice stream it is receiving via the inbound air interface. This configuration would be overridden by a transmission from the CFSH.

2. If the connection is full-duplex, the CFSH may optionally send the audio received from the fixed station back to the fixed station for retransmission so that other subscriber units can hear.

6.2.2 Digital Fixed Station Interface

The Digital Fixed Station Interface employs Internet protocols to provide connectivity between a conventional fixed station host (CFSH) and a fixed station. The DFSI has two parts, a Control Service and a Voice Conveyance Service. The control service is modeled as a point-to-point connection between the host and a fixed station control service. The Voice Conveyance service is modeled as a point to multi-point connection between a host and one or more end-points sharing a single destination IP address and port, but with potentially different source IP addresses and ports. Thus a CFSH sends RTP based voice packets to a single address, but may receive them from different addresses. This arrangement is illustrated in Figure 3.

Figure 3 – Conventional Digital Fixed Station Interface



6.2.2.1 Control Service

The control service is concerned with providing control functions analogous to those provided by the analog fixed station interface, and with establishing and maintaining connectivity with the fixed station. The fixed station service is provided at a well-known UDP port and the host port is variable. The well-known fixed station control service port has a default value specified in 8.2, but may be programmable on a station-by-station basis.

The control service is also responsible for:

1. Control of the fixed station by its host including squelch disable.
2. Transport of emergency alert and other conventional control messages from the fixed station to its host.

6.2.2.2 Voice Conveyance Service

The voice conveyance service is concerned with the passing of RTP payloads between the host and the fixed station. Depending on the air interface supported by the fixed station, the RTP payload may carry either Common Air Interface voice (encoded with IMBE and potentially encrypted) or waveform coded voice. Both the CFSH and the Fixed Station learn the UDP/RTP ports to be used for the Voice

Conveyance Service upon connectivity establishment by the control service. As with the Analog Fixed Station Interface, two repeat modes may be supported.

1. The fixed station may be configured to retransmit on the outbound air interface the voice stream it is receiving via the inbound air interface. This configuration would be overridden by a transmission from the CFSH.

2. The CFSH may optionally send the audio received from the fixed station back to the fixed station for retransmission so that other subscriber units can hear.

The voice conveyance service is responsible for:

1. Transport of full-duplex clear audio between the fixed station and its host.
2. Conveyance of PTT signaling between the fixed station and its host.
3. Providing intercom capabilities between the fixed station and its host.
4. Transport of encrypted audio between the fixed station and its host.
5. Transport of Caller-ID information between the fixed station and its host.
6. Transport of Talk-group information between the fixed station and its host.
7. Transport of NAC code information between the fixed station and its host.
8. Transport of Emergency Call indicators between the fixed station and its host.
9. Transport of voter identification from the fixed station to its host.

7 CFSI Analog Interface

There shall be Standard Options allowing control of the Fixed Station (FS) using legacy analog circuits. Both E & M and Tone Remote Control analog circuits shall be available as Standard Options.

7.1 E & M

The intent of this requirement is to be compatible with E & M interfaces used in legacy, pre-P25 analog fixed stations.

The circuit shall be comprised of these signal pairs:

- A “Transmit” pair to convey analog audio to the Fixed Station transmitter.
- A “Receive” pair to convey analog audio from the Fixed Station receiver.
- An “E” pair to control the RF transmission of audio on the Transmit pair via the Fixed Station.
- An “M” pair to indicate the presence of signal being received by the Fixed Station. Use of the M-pair by the Host is optional.

The FS shall accept an audio signal range of –30 dBm to +10 dBm on the transmit audio pair. Over this range the transmitter shall be capable of providing full perceived audio modulation in either analog or digital RF modes. When receiving full perceived audio modulation the FS shall be capable of generating to the receive audio pair an audio signal range that encompasses –30 dBm to the maximum limit permitted by leased circuit compliance (e.g. FCC Part 68).

> *NOTE*: Some legacy analog equipment use signal levels on the audio pairs as high as +10 dBm to compensate for long line losses. However, +10 dBm levels may conflict with present compliance requirements.

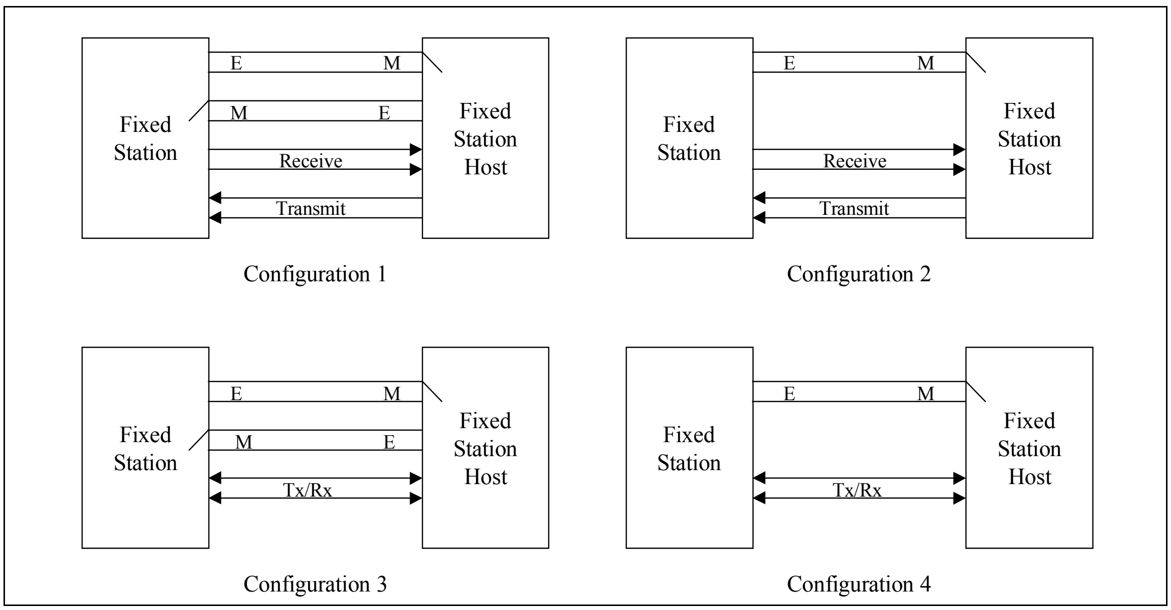
The E & M pairs are allowed to support E & M telephony standards as outlined in Section 9 of Telcordia GR-506 (see [3]), However, the following configuration shall be available to the installer ensuring support of legacy equipment. The E-pair shall have a configuration that expects the Host end to provide a dry contact closure while RF transmission of the audio on the Transmit pair is desired. The M-pair shall have a configuration that provides a dry contact closure while a compatible RF carrier is being received. The E & M pairs shall work over a range of 5 to 150 mA current with 50 ohm maximum contact resistance while the contacts are closed, and 10 to 60 Vdc with 5 megohm minimum resistance while the contacts are open. The E-pair shall limit its current to this range.

The electrical characteristics of the signal pairs shall comply with the applicable requirements of Section 4 of TIA/EIA-IS-968 (see [4]). TIA/EIA-IS-968 is the basis for US Government 47 CFR Part 68 (FCC Part 68).

The Transmit and Receive pairs shall be capable of being combined on a single pair which may be simplex, rather than full duplex.

Figure 4 shows the possible E & M interface configurations. In configurations which use a combined Transmit and Receive pair in a simplex mode, Transmit (FS E-pair active) shall have priority over Receive and shall silence Receive pair audio and shall make the FS M-pair inactive for the duration of the FS E-pair activation.

Figure 4 – Possible E&M Interface Configurations



7.2 Tone Remote Control

The intent of this requirement is to be compatible with Tone Remote Control (TRC) interfaces used in legacy, pre-P25 analog fixed stations.

The circuit shall be comprised of these signal pairs:

- A “Transmit” pair to convey analog audio to the Fixed Station transmitter, and to convey in-band control tones to the Fixed Station.
- A “Receive” pair to convey analog audio from the Fixed Station receiver.

The electrical characteristics of the signal pairs shall comply with the applicable requirements of Section 4 of TIA/EIA-IS-968 (see [4]). TIA/EIA-IS-968 is the basis for US Government 47 CFR Part 68 (FCC Part 68).

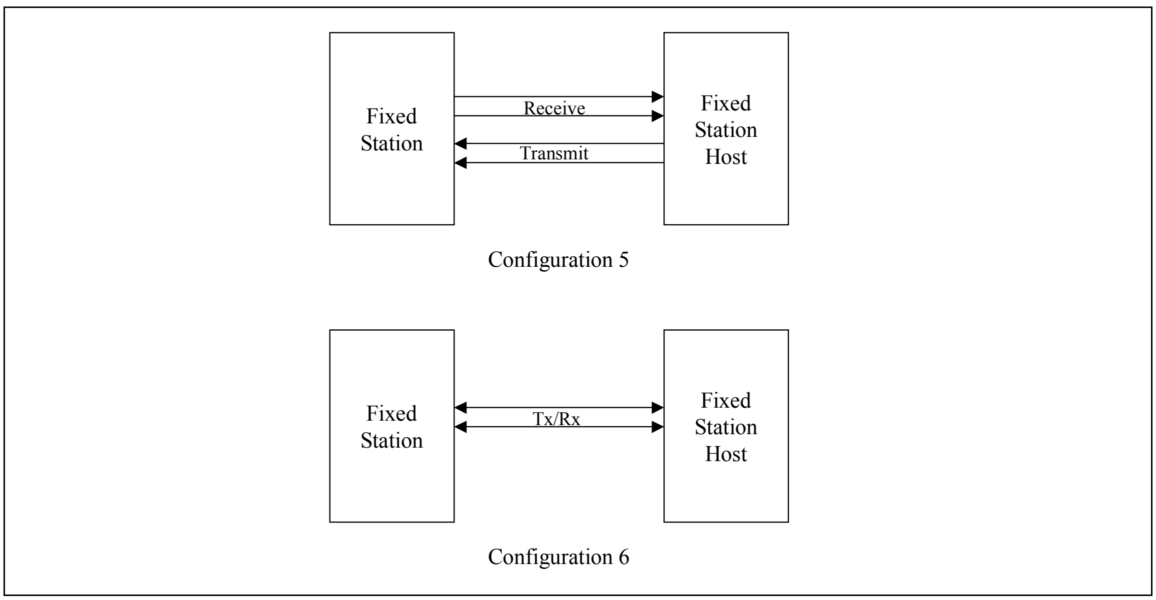
7.2.1 Simplex Wireline Interface for Configuration 6

The Transmit and Receive pairs shall be capable of being combined on a single pair which may be simplex, rather than full duplex.

Figure 5 shows the possible TRC interface configurations. In configurations which use a combined Transmit and Receive pair in a simplex mode, the Fixed Station shall be able to decode an incoming TRC sequence even while Receive audio is present. If the TRC sequence is a transmit sequence the Fixed Station shall mute any Receive audio on the audio pair for the duration of the transmission.

> *NOTE*: When using a 2-wire, simplex interface it is not possible for a console to take-over repeat audio.

Figure 5 – Possible TRC Interface Configurations

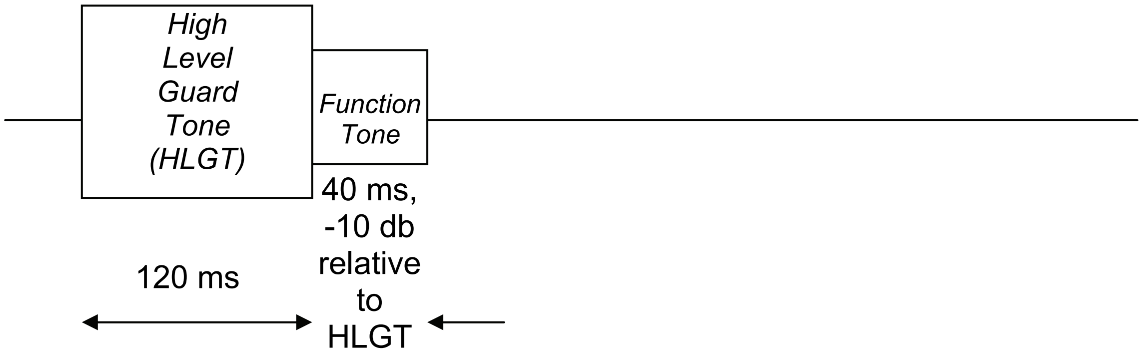


In addition to audio, the Transmit pair shall contain in-band TRC tones described in the sections that follow.

7.2.2 Non-Transmit Sequence

Figure 6 shows a TRC sequence that is used to control the Fixed Station without causing speech transmission over the RF channel. The sequence begins with a burst of High Level Guard Tone (HLGT) followed by a burst of Function Tone.

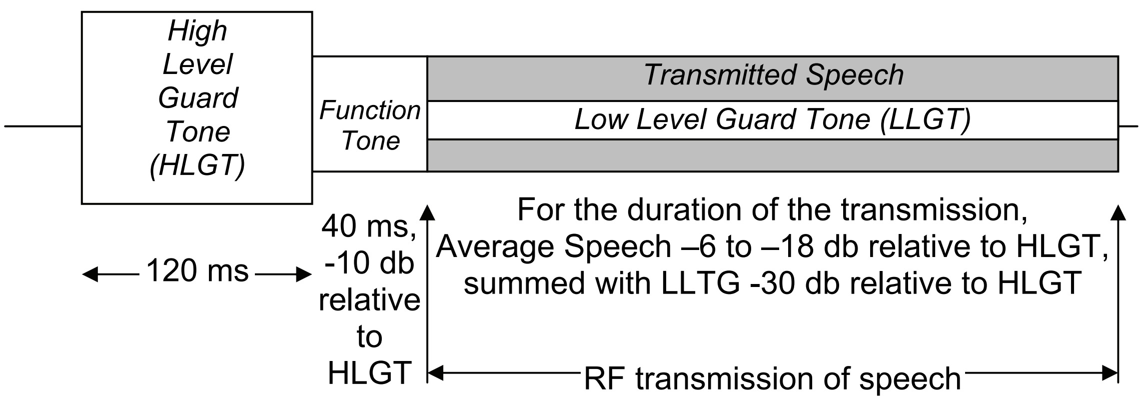
Figure 6 – Non-Transmit TRC Sequence



7.2.3 Transmit Sequence

Figure 7 shows a TRC sequence that is used to control a Fixed Station RF transmission. The sequence begins with a burst of High Level Guard Tone (HLGT) followed by a burst of Function Tone, followed by Low Level Guard Tone (LLGT) summed with transmit speech and is present for the duration of the speech transmission.

Figure 7 – Transmit TRC Sequence



7.2.4 Guard Tones

The duration of the High Level Guard Tone (HLGT) shall be nominally 120 milliseconds. The Low Level Guard Tone (LLGT) shall be nominally 30 db below HLGT and shall be summed with the speech intended for transmission. The LLGT should be filtered out prior to audio modulation of the RF transmission. The duration of the LLGT shall be for the duration of the speech transmission. The tone frequency used for the HLGT and LLGT shall be the same, and shall be one of the following field selectable values: 2100 Hz, 2175 Hz or 2325 Hz, with 2175 Hz being the default. The Guard Tone detector of the Fixed Station shall recognize the tone as valid within 10 Hz of the selected Guard Tone, and shall consider invalid tones 20 Hz or more from the selected Guard Tone. The Transmit pair of the FS shall be capable of accepting a HLGT range of –30 dBm to +10 dBm.

NOTE: The Host equipment generating the Guard Tone should maintain a tolerance of +/- 5 Hz. Some legacy analog host equipment use signal levels on the audio pairs as high as +10 dBm to compensate for long line losses. However, +10 dBm levels may conflict with present compliance requirements (e.g. FCC Part 68).

7.2.5 Function Tone

The duration of the Function Tone shall be nominally 40 milliseconds and shall be nominally 10 db below HLGT. The possible Function Tones shall be among the 15 tones listed Table 1. Table 2 outlines the functions that shall be supported by the FS and the recommended Functions Tone to be used for each of those functions. Table 1 shows six recommended mappings of Function Tones, one or more of which are generally compatible with legacy Host equipment. Manufacturers may optionally support additional Function Tones and may support additional features controlled by any of the Function Tones. However, when the Fixed Station is configured to support features listed in Table 1, it shall be possible to use the Function Tones designated in the Tables 1 and 2 to control those features.

Table 1 – TRC Function Tones vs. Possible FS Functions

Tone (Hz)	Simple Keying Command	Keying[a]	Function[a]	Function[b]	Wild Card	Other
None			Intercom			
2050			Monitor without receive code[b,e]	Monitor without receive code[b,e]		
1950	Xmit on selected channel[a], mode[c,d] and/or code[b,d]	Xmit on chan 1 [d]	Select chan 1			
1850	Xmit on channel[a] 1 without code[b,d]	Xmit on chan 2 [d]	Select chan 2			
1750		Xmit on chan 7 [d]	Select chan 7	Select code E	Second receiver Off	Receiver maximum squelch
1650		Xmit on chan 8 [d]	Select chan 8	Select code F	Second receiver On	Receiver minimum squelch
1550				Select code G	Repeat Off	
1450				Select code H	Repeat On	
1350		Xmit on chan 3 [d]	Select chan 3	Select code A	Wildcard 1 On	Select Digital RF Mode[c]
1250		Xmit on chan 4 [d]	Select chan 4	Select code B	Wildcard 1 Off	Select Analog RF Mode[c]
1150		Xmit on chan 5 [d]	Select chan 5	Select code C	Wildcard 2 On	Select Coded Speech
1050		Xmit on chan 6 [d]	Select chan 6	Select code D	Wildcard 2 Off	Select Clear Speech
950						Special
850						Special
750						Special
650						Special

Table Notes:
a – “Channels” may be either conventional frequencies, or talk groups.

b – “Codes” may be either analog CTCSS/DCS (subaudible squelch), or digital NAC.
c – Although the interface may be analog, the RF mode may be either analog or digital.
d – Individual channel parameters may include default code, secure mode (coded/clear) and RF mode (analog/digital) settings. Unless the channel parameters include default codes and modes, the transmission shall use the previously selected code, secure mode and RF mode.
e – Monitor (listen to all channel traffic without regard to code) is canceled by any Transmit or Channel Selection TRC sequence.

Table 2 – Possible FS Functions vs. TRC Function Tones

Function	TRC Sequence Type	Function Tone (Hz)
Intercom	None	None
Monitor without receive code[b,e]	Non-Transmit	2050
Transmit on selected channel[a], mode[c,d] and/or code[b,d]	Transmit	1950
Transmit on channel 1 [d]	Transmit	1950
Transmit on channel[a] 1 without code[b,d]	Transmit	1850
Transmit on channel 2 [d]	Transmit	1850
Transmit on channel 3 [d]	Transmit	1350
Transmit on channel 4 [d]	Transmit	1250
Transmit on channel 5 [d]	Transmit	1150
Transmit on channel 6 [d]	Transmit	1050
Transmit on channel 7 [d]	Transmit	1750
Transmit on channel 8 [d]	Transmit	1650
Select channel 1	Non-Transmit	1950
Select channel 2	Non-Transmit	1850
Select channel 3	Non-Transmit	1350
Select channel 4	Non-Transmit	1250
Select channel 5	Non-Transmit	1150
Select channel 6	Non-Transmit	1050
Select channel 7	Non-Transmit	1750
Select channel 8	Non-Transmit	1650
Select code A	Non-Transmit	1350
Select code B	Non-Transmit	1250
Select code C	Non-Transmit	1150
Select code D	Non-Transmit	1050
Select code E	Non-Transmit	1750
Select code F	Non-Transmit	1650

Table 2 – Possible FS Functions vs. TRC Function Tones (concluded)

Function	TRC Sequence Type	Function Tone (Hz)
Select code G	Non-Transmit	1550
Select code H	Non-Transmit	1450
Select Digital RF Mode[c]	Non-Transmit	1350
Select Analog RF Mode[c]	Non-Transmit	1250
Select Coded Speech	Non-Transmit	1150
Select Clear Speech	Non-Transmit	1050
Repeat On	Non-Transmit	1450
Repeat Off	Non-Transmit	1550
Second receiver On	Non-Transmit	1650
Second receiver Off	Non-Transmit	1750
Receiver maximum squelch	Non-Transmit	1750
Receiver minimum squelch	Non-Transmit	1650
Wildcard 1 On	Non-Transmit	1350
Wildcard 1 Off	Non-Transmit	1250
Wildcard 2 On	Non-Transmit	1150
Wildcard 2 Off	Non-Transmit	1050
Special	Transmit or Non-Transmit	950
Special	Transmit or Non-Transmit	850
Special	Transmit or Non-Transmit	750
Special	Transmit or Non-Transmit	650

7.2.6 Speech

Speech intended for RF transmission by the Fixed Station shall be summed with LLGT, and shall have an average level that is –6 to –18 db below HLGT.

> *NOTE*: The Host equipment generating the tones should also filter the Guard Tone frequency from the speech prior to summing with the speech with the LLGT otherwise phase coincidence may cause apparent gaps in the presence of the LLGT resulting in unintentionally dropping the RF transmission. It may be desirable to be able to adjust the speech level relative to the tone levels within the Fixed Station to ensure greatest compatibility with legacy Host equipment.

7.2.7 Sequence Off Time

Following either type of TRC sequence there shall be a minimum of 300 ms before another TRC sequence is sent.

7.3 Intercom

It shall be possible, as a Standard Option, to send speech between the Host and the Fixed Station without any accompanying TRC sequence or E & M-pair keying. This may be used for intercom purposes only, rather than to transmit RF.

8 CFSI Digital Interface

Note that except for the definition of the control messages (see 8.3), throughout this description, the conventions of Appendix B of RFC791 (see [1]) are used, that is, for multi-byte fields, information is transmitted most significant byte first and bit 0 represents the most significant bit of each byte. In 8.3, bytes are transmitted in the order described, and bit 0 represents the least significant bit of each byte.

8.1 Internet Protocol Overview

The Internet architecture layers (see Figure 8 for a mapping to the OSI model) are used to construct the Digital Fixed Station Interface (DFSI) protocol stack (illustrated in Figure 9). The non-proprietary protocols that make up the Internet protocol suite have become widely implemented standards because of the success of the Internet, and are supported by the widest variety of network equipment vendors. This allows the networks to connect DFSI equipment to be built with common off the shelf equipment, either by a user organization or a specialist network provider. Because the Internet architecture layers were developed much earlier than the Open Systems Interconnection (OSI) model they can only be roughly mapped to it (see Figure 8).

Figure 8 – Internet Architecture Layers and the OSI Layers

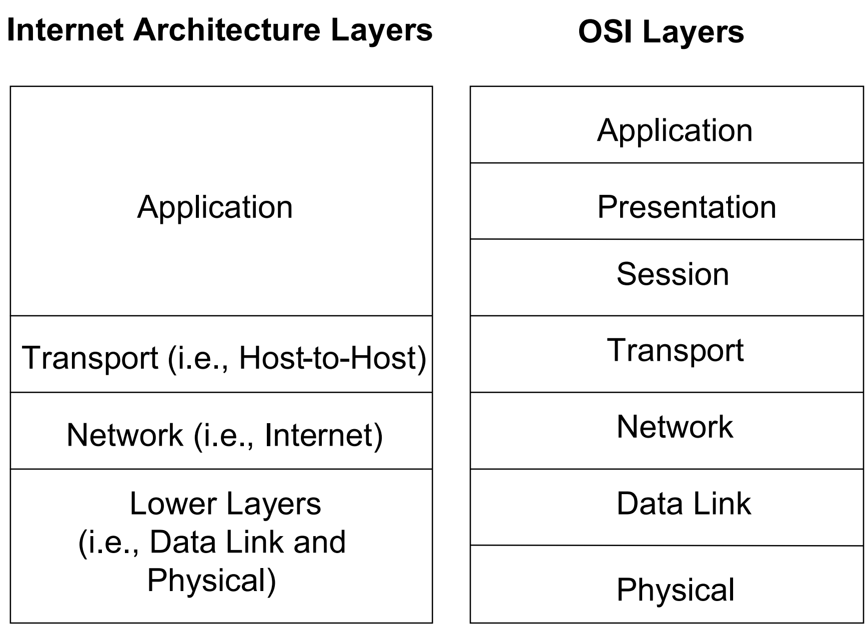
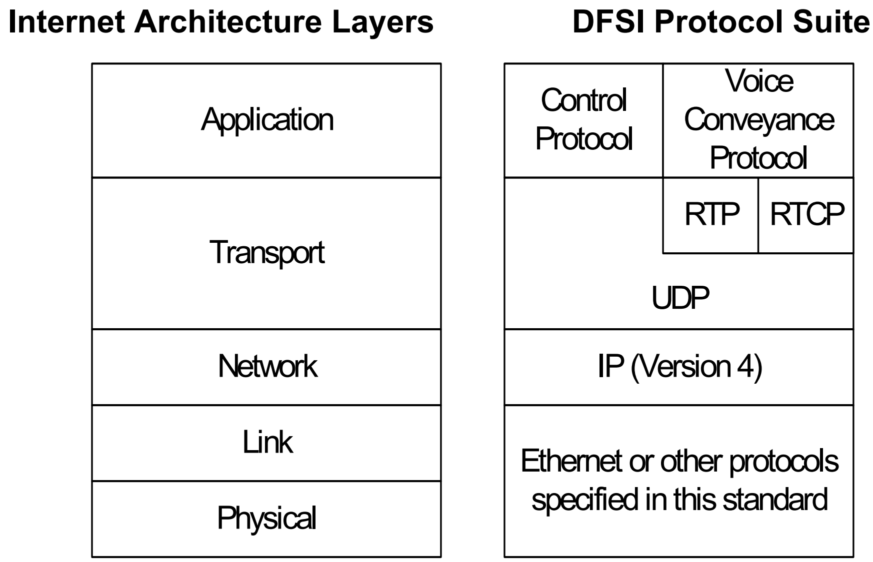


Figure 9 – DFSI Internet Protocol Suite



The following sections describe each of the layers of the Digital FSI (DFSI) Internet Protocol Suite, through the Transport Layer.

8.1.1 DFSI Lower Layers

These layers correspond to the physical and data link layers of the OSI layers. The Internet protocols, designed to be hardware independent, do not cover these lowest two OSI layers. As a result, the protocols of the Internet suite are widely used to connect heterogeneous systems.

The following specific lower layer requirements apply to the Digital Fixed Station Interface:

- Equipment conforming to DFSI shall offer the option of Ethernet 100 Base-T with a RJ-45 connector as the physical and data link layers.

- Equipment may offer any industry standard physical and link layer protocols that support the internet protocol, in addition to Ethernet 100 Base-T.

The network carrying the DFSI may change data link and physical protocols.

8.1.2 Network Layer

This layer corresponds to the OSI network layer, supporting routing of the packets through the network from the source host to the destination host or hosts. At this layer of the Internet, the main protocol is the Internet Protocol (IP). In addition, there are several control protocols.

IP is a connectionless packet protocol. Packets are groups of information transmitted as a unit to and from the upper layer protocols on sending and receiving hosts, and delivered from the sending to the receiving host over interconnected systems. Each IP packet includes an IP header that includes source and destination IP addresses.

There are two styles of IP address, unicast addresses allow packets to be routed to a single, particular host. Multicast addresses allow packets to be routed to an arbitrary collection of hosts. IP multicast offers a convenient mechanism to distribute data or voice to multiple hosts which suppliers of fixed station subsystems may use to implement the distribution function shown in Figure 1. Equipment conforming to the DFSI shall support unicast IP addresses. CFSH equipment conforming to the DFSI shall be able to send to IP multicast addresses.

There are two versions of the Internet protocol currently in use, IPv4 (see [1]) and IPv6 (see [5]). The equipment conforming to the DFSI shall support IPv4. This interface has been designed to work with IPv4. Use of this interface with IPv6 is for further study.

8.1.3 Transport Layer

This layer corresponds roughly to the OSI transport layer. Protocols at this layer communicate with peer processes in other hosts or networked devices. Two key host-to-host protocols at this layer are the User Datagram Protocol (UDP) (see [6]) and Transmission Control Protocol (TCP) (see [15]).

TCP is not well-suited to real-time applications, and it can not be used with IP multicast, whereas UDP is a simple connectionless datagram protocol. Therefore, TCP is not used in the DFSI.

8.1.3.1 RTP

The main feature that UDP provides is multiplexing of application protocols using the mechanism of port numbers which, along with an integrity checksum, are the only contents of the UDP header.

UDP does not provide "reliable" transport, there are no mechanisms to recover from lost packets or prevent packets form being delivered out of order. To regain some of the transport layer facilities that are not provided in UDP without incurring the penalties of TCP, the Real-time Transport Protocol (RTP) (see [7]) is often used. RTP provides detection of lost packets and out-of-order packets.

8.1.3.2 Requirement

Equipment conforming to the DFSI shall transport the control service over UDP only. Equipment conforming to the DFSI shall transport the voice conveyance Service over RTP on UDP.

8.1.3.3 RTCP Considerations

The Real-time Transport Control Protocol (RTCP) is a companion to RTP. Equipment may send RTCP reports as described in RFC 3550 (see [7]), but shall not depend on other equipment sending such reports.

8.1.4 Transport and Network Layer Parameters

The following sub-clauses specify the values of transport and network layer parameters for the DFSI.

8.1.4.1 IP Address

In accordance with 8.2, the IP addresses of the fixed station are configured in the host and the IP address of the host is learned by the fixed station. Specific addresses for both unicast and multicast operation are at the discretion of infrastructure designers.

8.1.4.2 DSCP Value

So that Differentiated Service enabled network equipment as described in RFC 2475 (see [16]) can give this traffic appropriate handling, equipment using this interface should set the Differentiated Services Code Point (DSCP) field of the IP headers as in Table 3.

Table 3 – DSCP Values

Voice Traffic	101110	Expedited forwarding (EF).
Control Traffic	100010	Assured forwarding class 4 Low drop

More details of expedited forwarding can be found in RFC 2598 (see [13]).

8.1.4.3 UDP Port Number

In accordance with 8.2, the UDP ports of the fixed station are configured in the host, and the fixed station learns the ports of the host. Specified port assignments are at the discretion of system designers.

8.1.4.4 RTP Padding Flag P

Implementers should set this to the appropriate value according to RFC 3550 (see [7]).

8.1.4.5 RTP Header Extension Flag X

Payload independent header extension is not used by the DFSI so X = 0.

8.1.4.6 RTP Payload Type

This interface shall use the dynamic payload type; type 100 (decimal).

8.1.4.7 RTP Marker Bit

The marker bit of the RTP header shall be set to 0.

8.1.4.8 RTP Time Stamp

In accordance with typical sampling rates used by voice codecs, 8 kHz shall be used as the clock rate for the timestamp.

8.1.4.9 CSRC

Radio networks rather than combining all signals in a conference bridge typically use techniques such as voting so that only one input voice stream contributes to the transmitted voice stream. There is therefore no need for a list of contributing synchronization sources. Therefore there shall be no Contributing Source (CSRC) list in DFSI RTP packets.

8.1.4.10 SSRC

Synchronization Sources (SSRCs) are selected by the host and assigned to the fixed stations through the connection protocol as described in 8.3.

8.2 DFSI Configuration Items

The following must be preconfigured as indicated in Table 4.

Table 4 – Configuration Items for the DFSI

Configuration Item	Entity[3]	Purpose	Default Value
Fixed Station Control IP Address	B	IP Address at which the fixed station subsystem supplies the Control Service. This shall be a unicast IP address.	N/A
Fixed Station Voice IP Address	B	IP Address at which the fixed station subsystem receives. outbound voice conveyance service traffic. This may a unicast or multicast IP address. It may be the same as or differ from the Fixed Station Control IP Address.	None
Fixed Station Control Port	B	UDP Port at which the fixed station supplies the Control Service.	7000
Fixed Station Voice Conveyance Port	S	UDP Port at which RTP traffic is conveyed to the fixed station. Provisioned in Connection Establishment Response.	None
Fixed Station RTCP Voice Conveyance port	S	UDP port at which RTCP traffic may be conveyed. Note that RTCP traffic is not required in the DFSI.	None
Host IP Address	H	The IP Address of the Host. This shall be a unicast IP address.	None
Control Retry Timer	B	Retry period for control messages.	500 msec
Control Attempt Limit	B	Maximum number of attempts for control messages.	3
Connectivity Tx Timer	B	Periodicity of control heartbeats	5 sec
Connectivity Loss Limit	B	Maximum number of heartbeat losses to allow.	2
FS Heartbeat Period	H	Periodicity of Fixed Station Heartbeats. This value is provisioned to the fixed station in the “Establish Connection” message.	30 sec

[3] H = Host, S = Fixed Station, B = Both

Table 4 – Configuration Items (concluded)

Configuration Item	Entity	Purpose	Default Value
Host Heartbeat Period	H	Periodicity of Host Heartbeats. This value is provisioned to the fixed station in the “Establish Connection” message.	30 sec
Voter Reporting Period	S	Periodicity of voter reports.	10 sec

8.3 DFSI Control Service

8.3.1 Control Messages

Table 5 summarizes the Control Service message set.

Table 5 – Control Service Message Set Mnemonics

Mnemonic	Message ID	Meaning/Purpose
FSC_CONNECT	0	Establish a connection with a Fixed Station
FSC_HEARTBEAT	1	Heartbeat/Connectivity Maintenance
FSC_ACK	2	Control Service Acknowledgement
FSC_SBC	3	Single Block Control
FSC_MAN_EXT	4	Manufacturer Extension
FSC_SEL_CHAN	5	Channel Selection Command
FSC_SEL_RPT	6	Repeat Mode Selection
FSC_SEL_SQUELCH	7	Squelch Mode Selection
FSC_REPORT_SEL	8	Report Selected Modes
FSC_DISCONNECT	9	Detach Control Service

All messages have a Message ID and Message version field. And all messages except Heartbeat and Acknowledgement have a Message Correlation Tag. The Message ID and Message version fields are fixed values determined by this specification. The Correlation Tag shall be selected by the source of the message and echoed back in its acknowledgement. Retries of any message shall be indistinguishable from the original message.

8.3.1.1 Establish Connection

The Establish Connection command may be sent by the host to establish a connection with the fixed station. It can only be sent by the host. Figure 10 illustrates data for the establish connection command.

Figure 10 – Data for the Establish Connection Command

Octet		
0	Message ID	FSC_CONNECT
1	Message Version	1
2	Message Correlation Tag	
3	VC Base Port (MSB)	Bits 8-15
4	VC Base Port (LSB)	Bits 0-7
5	VC SSRC (MSB)	Bits 24-31
6	VC SSRC (Next MS bits)	Bits 16-23
7	VC SSRC (Next MS bits)	Bits 8-15
8	VC SSRC (LSB)	Bits 0-7
9	FS Heartbeat Period	
10	Host Heartbeat Period	
Bit	7 6 5 4 3 2 1 0	

VC Base Port = The host Voice Conveyance RTP Port. By rule, the RTCP port (unused but reserved) is ((VC Base Port) + 1).

VC SSRC – The SSRC identifier to be used by the fixed station on all RTP transmissions sent to the host. VC SSRC shall be selected by the host to be unique in the context of the host at any particular time.

FS Heartbeat Period – The period at which the fixed station should send FSC_HEARTBEAT messages to the host control port. The FS Heartbeat Period is in units of seconds and is restricted to the range 5 to 255.

Host Heartbeat Period – The period at which the host will send FSC_HEARTBEAT messages to the fixed station control port. The Host Heartbeat Period is in units of seconds and is restricted to the range 5 to 255.

The response data for this command shall be as shown in Figure 11.

Figure 11 – Response Data for the Connection Command

Octet									
Octet 0	Response Version								1
1	FS VC Base Port (MSB)								Bits 8-15
2	FS VC Base Port (MSB)								Bits 8-15
Bit	7	6	5	4	3	2	1	0	

FS VC Base Port = The fixed station Voice Conveyance RTP Port. By rule, the RTCP port (unused but reserved) is ((FS VC Base Port) + 1).

8.3.1.2 Control Service Heartbeat

Figure 12 illustrates the Control Service Heartbeat message. This message is sent periodically by both the fixed station and the CFSH to establish and maintain connectivity of the control server and client.

Figure 12 – Message for Control Service Heartbeat

Octet		
Octet 0	Heartbeat Message ID	FSC_HEARTBEAT
1	Message Version	1

8.3.1.3 Control Service Acknowledgement

The Control Service Acknowledgement is used by both the client and the server to positively or negatively acknowledge the receipt of a control service message. It contains the identifying information of the message being acknowledged along with an ACK/NAK code and optional response data. Figure 13 illustrates the control service acknowledgement message.

Figure 13 – Message for Control Service Acknowledgement

Octet 0	Message ID	FSC_ACK
1	Message Version	1
2	Acknowledged Message ID	From msg being ack'd.
3	Acknowledged Message Version	From msg being ack'd.
4	Acknowledged Message Correlation Tag	From msg being ack'd.
5	Response code	
6	Response Data Length	
7+	Response Data	
Bit	7 6 5 4 3 2 1 0	

Table 6 summarizes the ACK/NAK code values.

Table 6 – ACK/NAK Code Values

ACK/NAK Code	Mnemonic	Meaning
0	CONTROL_ACK	General Acknowledgement
1	CONTROL_NAK	Unspecified Negative Acknowledgement
2	CONTROL_NAK_CONNECTED	The server is connected to some other host
3	CONTROL_NAK_M_UNSUPP	Unsupported Manufacturer specific message.
4	CONTROL_NAK_V_UNSUPP	Unsupported Message Version
5	CONTROL_NAK_F_UNSUPP	Unsupported Function
6	CONTROL_NAK_PARMS	Bad or Unsupported Command Parameters
7	CONTROL_NAK_BUSY	The fixed station subsystem is currently busy with a function that is incompatible with the requested action.

The content of the Response Data is specified with the message definition given in 8.3.1.4-10.

8.3.1.4 Single Block Control Message

The single block control message is used to convey conventional control messages as specified in TSB102.AABG (see [14]) and TIA/EIA-102.AABC (see [9]) between a fixed station and its host. Emergency Alert is one possible single block control message. Either the fixed station or its host may send it. Figure 14 illustrates the message for single block control.

Figure 14 – Message for Single Block Control

Octet	7	6	5	4	3	2	1	0	
0	Message ID								FSC_SBC
1	Message Version								1
2	Message Correlation Tag								
3	Reserved		Opcode						
4..12	Content								

Opcode = Control Message Opcode from TIA/EIA-102.AABC (see [9]).

Content = Bytes 1-9 of the corresponding single block control message from TIA/EIA-102.AABC (see [9]).

The Acknowledgement for this command shall have no response data (Response Data Length = 0).

8.3.1.5 Manufacturer Extension Message

The Manufacturer Extension Message may be used by manufacturers to provide value added and experimental extensions to the protocol. Either the fixed station or its host may send it. Figure 15 illustrates the message for manufacturer extension.

Figure 15 – Message for Manufacturer Extension

Octet	7	6	5	4	3	2	1	0	
0	Message ID								FSC_MAN_EXT
1	Message Version								1
2	Message Correlation Tag								
3	MFID								
4+	Manufacturer Specific Data								

The response data for a supported manufacturer extension will be specified by the manufacturer making the extension.

The Acknowledgements for unsupported manufacturer extensions shall have no response data (Response Data Length = 0).

8.3.1.6 Channel Selection Command

The Channel Selection command may be used by the host to select a particular RF channel for receive operations. Only the host may send the Channel Selection Command. Figure 16 illustrates the command for channel selection.

Figure 16 – Command for Channel Selection

Octet	Field (Bits 7–0)	Value
0	Message ID	FSC_SEL_CHAN
1	Message Version	1
2	Message Correlation Tag	
3	Receive Channel Number	
4	Transmit Channel Number	

Receive Channel Number = Channel number for receive operations. The specific meaning of the Channel Number parameter may be manufacturer specific.

Transmit Channel Number – Channel Number for transmit operations. The specific meaning of the Channel Number parameter may be manufacturer specific.

The Acknowledgement for this command shall have no response data (Response Data Length = 0).

8.3.1.7 Repeat Mode Selection Command

The Repeat Mode selection shall allow a host to select between the repeat and non-repeat modes of a fixed station. Only the host may send the Repeat Mode Selection command. Figure 17 illustrates the command for repeat mode selection.

Figure 17 – Command for Repeat Mode Selection

Octet	Field (Bits 7–0)	Value
0	Message ID	FSC_SEL_RPT
1	Message Version	1
2	Message Correlation Tag	
3	Repeat Mode	

Repeat Mode	=	0, Do Not repeat inbound audio on outbound channel;
	=	1, Repeat inbound audio;
	=	otherwise, illegal.

The Acknowledgement for this command shall have no response data (Response Data Length = 0).

8.3.1.8 Squelch Control Message

The Squelch control message is used by the host to select the Squelch mode of the fixed station. Monitor mode defeats all Squelch processing. The existing Squelch is restored by selecting monitor mode off. Figure 18 illustrates the message for Squelch control.

Figure 18 – Message for Squelch Control

Octet	Field	
0	Message ID	FSC_SEL_SQUELCH
1	Message Version	1
2	Message Correlation Tag	
3	Squelch Mode	
Bit	7 6 5 4 3 2 1 0	

Squelch Mode	Squelch Mode Value
Monitor off	0
Monitor on	1

The Acknowledgement for this command shall have no response data (Response Data Length = 0).

Note that Squelch type and Squelch parameters are set by configuration of the fixed station.

8.3.1.9 Report Selections

The Report Selections command may be sent by the host to cause the fixed station to report settings defined in the DFSI. It may only be sent by the host. Figure 19 illustrates the command for report selections.

Figure 19 – Command for Report Selections

Octet	Field	
0	Message ID	FSC_REPORT_SEL
1	Message Version	1
2	Message Correlation Tag	
Bit	7 6 5 4 3 2 1 0	

The positive acknowledgements of the Report Selections command shall contain the response data shown in Figure 20.

Figure 20 – Response Data for Report Selections

Octet	Field (Bit 7 … 0)	Value
0	Report Version	1
1	Repeat Mode Selection	
2	Receive Channel Selection	
3	Transmit Channel Selection	
4	Squelch Mode	

Repeat Mode Selection = 0, Do not repeat inbound audio;
= 1, Repeat inbound audio.

Receive Channel Selection = Numeric representation of the selected channel.

Transmit Channel Selection = Numeric representation of the selected channel.

Squelch Mode – See 8.3.1.8.

8.3.1.10 Detach

The detach command shall allow a host to tear down the connection with the fixed station in an orderly way. Only the host may send the Detach command. Figure 21 illustrates the command for detach connection.

Figure 21 – Command for Detach Connection

Octet	Field (Bit 7 … 0)	Value
0	Message ID	FSC_DETACH
1	Message Version	1
2	Message Correlation Tag	

The Acknowledgement for this command shall have no response data (Response Data Length = 0).

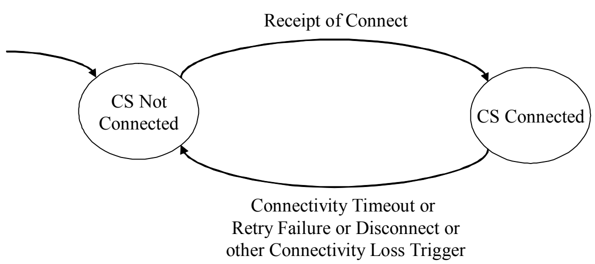
8.3.2 Control Service Procedures

8.3.2.1 Control Service Operational Description

Note that all state models represented in this section are for the purpose of describing the DFSI protocol and should not be construed as requiring or suggesting any particular implementation.

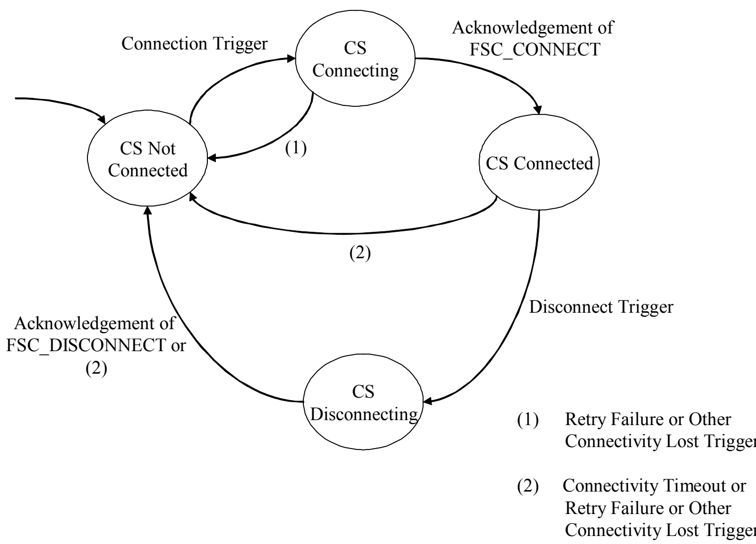
The state model for the fixed station control service is shown in Figure 22. In the *CS Not Connected* state, the fixed station operates in whatever configuration was last provided by a host. Emergency alerts received by the FS while in the *CS Not Connected* state must be dealt with in accordance with local policy and manufacturer implementations. The FS transitions to the *CS Connected* state upon receipt of an FSC_CONNECT message. In the *CS Connected* state, the fixed station is able to respond to control messages and forward Emergency Alerts to the host. Failure to receive an acknowledgement (Retry Failure), the lack of a heartbeat for a sufficient period of time (Connectivity Timeout), the receipt of a FSC_DISCONNECT message, or other implementation specific connectivity loss triggers (such as the receipt of a ICMP Port Not Found notification) cause a transition back to the *CS Not Connected* state.

Figure 22 – FS Control Service State Model



The host side of the control service protocol is similar to the fixed station side, and is illustrated in Figure 23. Upon receipt of an implementation specific connection trigger, the CFSH sends FSC_CONNECT and enters the *CS Connecting* state. Upon receipt of an acknowledgement to FSC_CONNECT, the host proceeds to the connected state wherein FSC_HEARTBEATS and other messages may be sent. As with the fixed station, failure of the retransmission protocol or connectivity protocol can cause a transition to the *CS Not Connected* state. Furthermore, the host can initiate a control disconnection by sending FSC_DISCONNECT and transitioning to the *CS Disconnecting* state. In this case, receipt of the acknowledgement to the FSC_DISCONNECT (or a connectivity or retry failure) causes the transition to *CS Not Connected.*

Figure 23 – Host Control Client State Model



8.3.2.2 Control Procedures

The following control procedures are subject to the following general requirements:

1. While in the *CS Not Connected* state, the fixed station shall silently discard all messages except for FSC_CONNECT and FSC_DISCONNECT.

2. While in the *CS Not Connected* state, the host shall silently discard all messages. As described previously, air interface messages received while in the *CS Not Connected* state must be processed in accordance with local policy and specific manufacturer implementations.

3. While in the *CS Connecting* state, the host shall silently discard all messages except for FSC_ACK.

4. While in the *CS Not Connected* state, neither the fixed station nor the host shall send any messages to the other, with the exception of FSC_ACK in response to a FSC_DISCONNECT that might occur due to a dropped FSC_ACK.

5. While in the *CS Connecting* state, the host shall only send FSC_CONNECT messages.

6. FSC_ACK shall always be sent to the IP address and UDP port contained in the message being acknowledged.

7. The host shall send all messages except for FSC_ACK to the pre-configured UDP control port of the fixed station.

8. The fixed station shall send heartbeat messages to the IP address and UDP port derived from the FSC_CONNECT message that initiated the connection.

9. Subject to these restrictions and those in the following procedures, the host may send any control message defined in 8.3.1.

10. Subject to these restrictions and the following procedures, the fixed station may only send FSC_HEARTBEAT, FSC_ACK, FSC_MAN_EXT, and FSC_SBC messages to the host.

8.3.2.3 Retry Protocol

With the exception of the Heartbeat and Acknowledgement messages, all control service messages shall be sent using the following retransmission protocol. Within the following description, “sender” refers to the host or fixed station sending the message, and “receiver” refers to the host or fixed station receiving the message.

1. Upon receiving a trigger for the transmission of a message, the sender shall:
    a. Choose a correlation tag, format the message, and send it to the control service port of the receiver.
    b. Start a retransmission timer with the value ControlRetryTimer.
    c. Reset a retransmission counter to zero.

2. Upon expiration of the retransmission timer, the sender shall:
    a. Increment the retransmission counter.
    b. If the value of the retransmission counter is equal to ControlAttemptLimit, the retry protocol has failed. The sender shall
        i. If the connectivity procedures of 8.3.2.4.3 and 8.3.2.4.4 are active, it shall discontinue connectivity procedures as described therein and revert to the *CS Not Connected* state.
        ii. The sender shall implement recovery procedures in accordance with local policy.
    c. If the value of the retransmission counter is less than ControlAttemptLimit, the sender shall reset the retransmission counter to the value ControlRetryTimer and resend the message.

3. Upon receipt of an acknowledgement, the sender shall:
    a. If the Acknowledged Message Id, Acknowledged Message Version, and Acknowledged Message Correlation Tag match those of an outstanding message, the sender shall:
        i. Cancel the retransmission timer of the outstanding message.
        ii. Perform further processing on the reply in accordance with local policy.

    b. Otherwise, the sender shall silently discard the acknowledgement.

4. Upon receiving a message other than a heartbeat or acknowledgement, the receiver shall:
    a. If the receiver is a fixed station that is currently connected to a host, and the IP address or UDP port of the sender do not match those of the host, the receiver shall reply with FSC_ACK with the ACK/NAK code set to CONTROL_NAK_CONNECTED and no response data.
    b. Otherwise, if the received message is FSC_MAN_EXT and the receiver does not support the message, the receiver shall reply with FSC_ACK with the ACK/NAK code set to CONTROL_NAK_M_UNSUPPORTED and no response data.

c. Otherwise, if the received message is a known command with an unsupported message version, the receiver shall reply with FSC_ACK with the ACK/NAK code set to CONTROL_NAK_V_UNSUPP.

d. Otherwise, the receiver shall perform message specific processing as specified in 8.3.2.5.

8.3.2.4 Connectivity Procedures

8.3.2.4.1 Connection Establishment Procedures

1. Upon detecting a connectivity trigger while in the *CS Not Connected* state, the host shall:
    a. Transition to the *CS Connecting* state.
    b. Send the FSC_CONNECT message to the Fixed Station, applying the retransmission protocol of 8.3.2.3.

2. Upon receipt of the acknowledgement of FSC_CONNECT, the host shall enter the *CS Connected* state, and initiate connectivity maintenance procedures as described in 8.3.2.4.3.

3. Upon failure of the retransmission protocol, or upon receipt of some other implementation specific connectivity lost indication, the host shall transition to the *CS Not Connected* state.

4. Upon receipt of FSC_CONNECT in the *CS Not Connected* state, the fixed station shall:

    a. Reply with FSC_ACK with the CONTROL_ACK response code.
    b. Transition to the *CS Connected* state, initiate connectivity maintenance procedures as described in 8.3.2.4.4, and allow Voice Conveyance services to operate using the SSRC contained within the FSC_CONNECT message as the SRC identifier for the RTP protocol.

5. Upon receipt of FSC_CONNECT in the *CS Connected* state, the fixed station shall reply with FSC_ACK message with the CONTROL_ACK response code if and only if the FSC_CONNECT message originated at the same IP address and UDP port as the FSC_CONNECT that caused the transition into the *CS Connected* state. Otherwise, the fixed station shall respond with the FSC_ACK with the CONTROL_NAK_CONNECTED response code.

8.3.2.4.2 Connection Detachment Procedures

1. Upon detecting a connectivity trigger in the *CS Not Connected* state, the host shall:
    a. Transition to the *CS Connecting* state.
    b. Send the FSC_CONNECT message to the Fixed Station, applying the retransmission protocol of 8.3.2.3.

2. Upon receiving the FSC_DISCONNECT message in the *CS Not Connected* state, the fixed station shall respond with FSC_ACK with a response code of CONTROL_ACK.

3. Upon receiving a FSC_DISCONNECT message in the *CS Connected* state, the fixed station shall:

    a. Reply with FSC_ACK with a status code of CONTROL_NAK_CONNECTED if the IP address and port of the sender of the FSC_DISCONNECT do not match those of the sender of the FSC_CONNECT that caused the transition into *CS Connected.*
    b. Otherwise,
        i. Reply with FSC_ACK with a status code of CONTROL_ACK and,
        ii. The fixed station shall terminate connectivity procedures as described in 8.3.2.4.4.

8.3.2.4.3 Host Connectivity Maintenance Procedures

1. To establish connectivity maintenance procedures, the host shall:
    a. Start a connectivity timer with the value ConnectivityTxTimer.
    b. Reset a connectivity counter to zero.

2. To discontinue (terminate) connectivity maintenance procedures, the host shall:
    a. Cancel the connectivity timer.
    b. Reset the connectivity counter to zero.
    c. Discontinue all pending retransmission procedures.
    d. Discontinue the transmission and any and all packets on the Voice Conveyance service.

3. A host that receives a heartbeat message in the *CS Connected* state shall perform the following if and only if the heartbeat originates from the expected IP address and UDP port:
    a. Reset the connectivity counter to zero.
    b. Otherwise, it shall silently discard the message.

4. Upon receiving a heartbeat message in the any other state, the host shall silently discard the message.

5. Upon expiration of the ConnectivityTxTimer, the host shall:
    a. Increment the connectivity counter.
    b. If the connectivity counter is greater than ConnectivityLossLimit, connectivity has been lost. The host shall enter the *CS Not Connected* state and take recovery actions in accordance with local policy.
    c. Otherwise, the host shall:
        i. Send a heartbeat to the fixed station.
        ii. Restart the connectivity timer with the value ConnectivityTxTimer.

8.3.2.4.4 Fixed Station Connectivity Maintenance Procedures

1. To initiate connectivity maintenance procedures, the fixed station shall:
    a. Reset a connectivity counter to zero.
    b. Start a connectivity timer with the value FSConnectivityTxTimer.

2. To discontinue (terminate) connectivity maintenance procedures, the fixed station shall:
    a. Cancel the connectivity timer.
    b. Reset the connectivity counter to zero.
    c. Cancel any pending retransmission procedures.
    d. Discontinue the sending of any and all RTP packets via the Voice Conveyance Service.

3. Upon receipt of a Heartbeat message, in the *CS Not Connected* state, the fixed station shall silently discard the message.

4. Upon receipt of a FSC_HEARTBEAT in the *CS Connected* state, the fixed station shall:
    a. If and only if the IP address and port of the message match those from the most recent successful FSC_CONNECT message, the fixed station shall:
        i. Reset a connectivity counter to zero.
        ii. Start a connectivity timer with the value FSConnectivityTxTimer.
    b. Otherwise, the fixed station shall silently discard the FSC_HEARTBEAT message.

5. Upon expiration of the connectivity timer, the fixed station shall:
    a. Increment the connectivity counter.
    b. If the connectivity counter is equal to FSConnectivityLossLimit, the connection has been lost. The fixed station shall revert to the *CS Not Connected* state.
    c. Otherwise, the fixed station shall transmit a heartbeat to its host.

8.3.2.5 Other Procedures

The following procedures related to actions performed following the validation of a message as described in 8.3.2.3. Each of these procedures results in the generation of an FSC_ACK message.

8.3.2.5.1 Single Block Control Message Procedure

The following procedure applies when a host receives a valid FSC_SBC command from a fixed station:

1. If the host does not support the Single Block Control message contained in the command:
    a. The host shall reply with FSC_ACK with the ACK/NAK code set to CONTROL_NAK_F_UNSUPP.

    b. Upon receiving the FSC_ACK, the fixed station shall take such steps as may be required by its air interface and local policy.

2. Otherwise, the host:
    a. Shall reply with FSC_ACK with the ACK/NAK code set to CONTROL_ACK and shall take such actions as may be required by the received message and local policy.

    b. In the event that the Single Block Control (SBC) message requires a response, the host shall formulate a Single Block Control message response (recommended to be implemented in accordance with the requirements of TSB102.AABG (see [14])), and shall transmit an appropriate FSC_SBC to the fixed station.

The following procedure applies when a fixed station receives a valid FSC_SBC command from its host:

1. If the fixed station does not support the Single Block Control message contained in the command:

    a. The fixed station shall reply with FSC_ACK with the ACK/NAK code set to CONTROL_NAK_F_UNSUPP and the response data length set to zero.
    b. Upon receiving the FSC_ACK, the host shall take such steps as may be required by the host's air interface and local policy.
2. If the fixed station subsystem is transmitting a voice stream on the outbound CAI at the time that it receives the FSC_SBC from the CFSH:
    a. The fixed station shall reply with an FSC_ACK with the ACK/NAK code set to CONTROL_NAK_BUSY.
    b. The fixed station should discard the FSC_SBC.

3. Otherwise, the fixed station shall respond with FSC_ACK with the ACK/NAK code set to CONTROL_ACK and shall further transmit the corresponding conventional message via the outbound air interface.

8.3.2.5.2 Manufacturer Extension Procedure

Processing of the FSC_MAN_EXT shall be manufacturer specific, but shall always result in the generation of FSC_ACK with an ACK/NAK code of CONTROL_ACK if the command was successfully executed, and an ACK/NAK code with some other value if the command was not successfully executed.

If a FSC_MAN_EXT is received that the receiver does not support, it shall send an acknowledgement with a NAK of CONTROL_NAK_M_UNSUPP and no response data.

8.3.2.5.3 Channel Selection Command Procedure

Upon receipt of a valid FSC_SEL_CHAN command, the fixed station subsystem:

- Shall reply with FSC_ACK with an ACK/NAK code of CONTROL_NAK_PARMS if the Channel Number parameter is illegal.
- Shall reply with FSC_ACK with an ACK/NAK code set to CONTROL_NAK_BUSY and discard the FSC_SEL_CHAN command, if the fixed station subsystem is currently transmitting voice.

Otherwise, it shall set the receive channel selection as indicated by the command and reply with FSC_ACK with and ACK/NAK code of CONTROL_ACK. In both cases, the Response Data Length of FSC_ACK shall be zero.

8.3.2.5.4 Repeat Mode Selection Procedure

Upon receipt of a valid FSC_SEL_RPT command, the fixed station shall begin operating in the selected mode and reply with FSC_ACK with and ACK/NAK code of CONTROL_ACK. The Response Data Length of FSC_ACK shall be zero.

8.3.2.5.5 Squelch Control Procedure

Upon receipt of a valid Squelch Control command, the fixed station shall reply with FSC_ACK with an ACK/NAK code of CONTROL_NAK_PARMS if it does not support the selected mode in its current operating mode. Otherwise, it shall begin operating in the selected mode FSC_ACK with and ACK/NAK code of CONTROL_ACK. In both cases, the Response Data Length of FSC_ACK shall be zero.

8.3.2.5.6 Report Selections Procedure

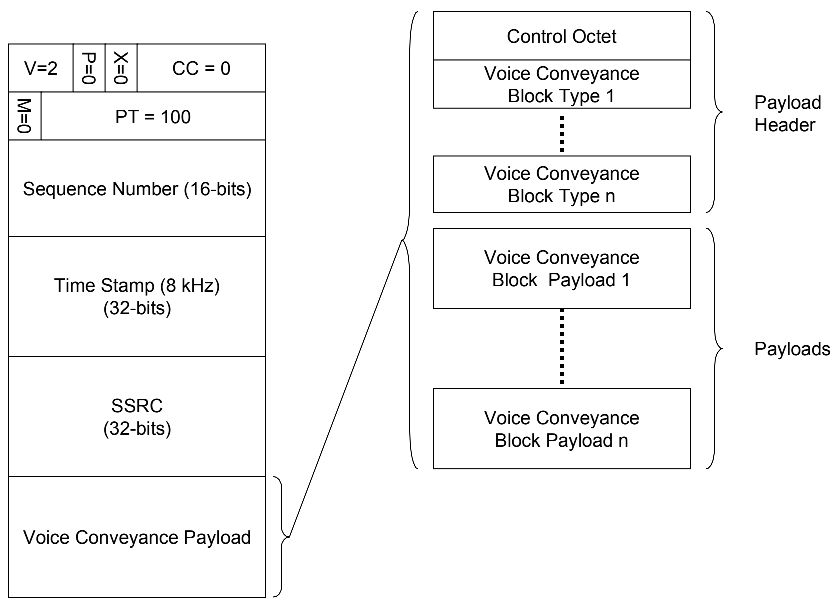
Upon receipt of a valid FSC_REPORT_SEL command, the fixed station shall reply with FSC_ACK with an ACK/NAK code of CONTROL_ACK. The Response Data of the FSC_ACK shall be as indicated in 8.3.1.9.

8.4 DFSI Voice Conveyance Service

8.4.1 Structure of Voice Conveyance Payload

The Voice Conveyance Payload shall consist of a payload header followed by blocks of data (Voice Conveyance Payload) as illustrated in Figure 24. The blocks of data carry P25 voice, signaling that is carried with voice on the P25 CAI and analog transparent audio. The Voice Conveyance Payload header shall indicate which of these blocks are present in the packet.

Figure 24 – Overview of DFSI Voice Conveyance Packet



8.4.1.1 Voice Conveyance Payload Header

The P25 RTP payload allows compact (often called compressed) and verbose (often called un-compressed) forms of the Voice Conveyance Payload header. This revision of the fixed station interface shall support the compact form (indicated by the C bit = 1, see below). Indicator bits are retained to allow for future support of the verbose form.

The Voice Conveyance Payload header shall consist of a control octet which indicates the number of Voice Conveyance blocks and one or more octets that indicate the types of blocks in the remainder of the payload as illustrated in Figure 25.

Figure 25 – DFSI Voice Conveyance Payload Header

Control Octet	1st Block Type	…..	Nth Block Type

8.4.1.1.1 Payload Header Control Octet.

The payload header control octet shall contain 4 fields as illustrated in Figure 26.

Figure 26 – Control Octet

0 0	1	2	3	4	5	6	7
S	C	Block Header Count					

The bits of the control octet are defined as follows:

S – Signal bit. Has no special meaning for the DFSI. Any value may be sent. Receivers should ignore this flag.

C – Compact. Indicates the compact payload header.

C =0 Shall be reserved for future use with the verbose payload header.

C =1 Compact block header shall be used in this revision of the fixed station Interface.

Block Header Count – The number of Block Types header bytes following the control octet. This is also the number of payloads in the packet.

8.4.1.1.2 Voice Block Types

Following the payload header control octet there are one or more Block type octets. The block types are followed by the block payloads. Figure 27 illustrates the structure of payload header and information blocks.

Figure 27 – Structure of Payload Header and Information Blocks

Control Octet	Block Type for Block Payload 1	…..	Block Type for Block Payload N	Block Payload 1	…..	Block Payload N

The block type octet is split into two fields, illustrated in Figure 28.

Figure 28 – Format of Block Type Field

0 0	1 2 3 4 5 6 7
E	Block PT

E Indicates whether Block PT is a standard IANA defined RTP payload type or a P25 specific payload.

E = 0 Shall mean that block PT indicates a standard IANA defined RTP payload is encapsulated in this Voice Conveyance Block Payload. The standard IANA defined RTP payload types supported in this revision of the fixed station interface shall be: 0, μ law PCM audio. This encoding scheme is described in RFC 3551 (see [18]). The guidelines described in reference [18] are followed except that the payload is encapsulated in a Voice Conveyance Block Payload.

E = 1 Shall mean that the block PT indicates a block type specific to the voice conveyance payload. The block types supported by this version of the DFSI are defined in 8.3.2.

Block PT indicates the type of the corresponding payload. For E=0, Block PT shall be 0, indicating μ law PCM audio. For E=1, Block PT may take on the following values:

0 – CAI Voice
6 – Voice Header Part 1
7 – Voice Header Part 2
9 – Start of Stream
10 – End of Stream
12 – Voter Report
13 – Voter Control
14 – TX Key Acknowledge
63-127 – Manufacturer Specific

In addition, the following values are reserved.

1 – Reserved for Packet Type
2 – Reserved for Link Control Word
3 – Reserved for Encryption Sync
4 – Reserved for Low Speed Data
5 – Reserved for Header Word
8 – Reserved
11 – Reserved for PTT Control Word
15-62 – Reserved for future expansion

The details of the P25 specific RTP Payloads are defined in 8.4.2

8.4.2 Voice Conveyance RTP Payload, Block PTs

In addition to the IETF defined Block PT type 0, μ law PCM audio (used with E=0), several more block types are needed by a dispatch radio system. These are indicated with an E bit of 1. This provides for up to 128 additional Block Payload Types (Block PTs). Only a few Block PTs, described in the next sections, are required for the DFSI.

All of the following specific types are designated as the Block PT. Designation excludes the E bit.

The value of the block type will be equal to 128 + Block PT.

8.4.2.1 Block with PT= 0 – CAI Voice

Blocks with this PT shall contain the P25 Common Air Interface (CAI) Improved Multiband Excitation (IMBE) voice codec data along with additional data that is paired with a particular voice frame on the P25 CAI (see [8]).

The IMBE data is divided into 8 decoded message vectors (U0-U7) as described in TIA/EIA-102.BABA (see [11]). The message vectors U0-U6 have been decoded (error correction code removed). Vector U7 is unprotected on the CAI.

All CAI frames shall contain these 14 octets. Figure 29 illustrates the common fields for CAI blocks.

Figure 29 – Common Fields for CAI Blocks

<table>
<tr><td>0</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>3</td><td></td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td></tr>
<tr><td colspan="8">Frame Type</td><td colspan="12">U0 (b11-0)</td><td colspan="12">U1 (b11-0)</td></tr>
<tr><td colspan="12">U2 (b11-0)</td><td colspan="12">U3 (b11-0)</td><td colspan="8">U4 (b10-3)</td></tr>
<tr><td colspan="3">U4</td><td colspan="11">U5(b10-0)</td><td colspan="11">U6(b10-0)</td><td colspan="7">U7 (b6-0)</td></tr>
<tr><td colspan="3">Et</td><td colspan="3">Er</td><td>M</td><td>L</td><td>E4</td><td colspan="3">E1</td><td colspan="2">SF</td><td colspan="2">B</td><td colspan="16"></td></tr>
</table>

A frame type field indicates which frame in a P25 super frame this block carries. This is necessary because different pieces of additional signaling are carried with each frame. The frame type field is composed of a Protocol Identifier (PID) and Frame Type (FT).

The first (high order) 3 bits of the field shall constitute the PID. The next 5 bits signify a frame type associated with that protocol identifier. For this revision of the fixed station interface PID = 3 shall be supported. Frame type shall have a range of 1 to 18 decimal or 1 to 12 hexadecimal. Hence the combined octet PID/FT shall have a range of 61 to 73 in hexadecimal notation.

The composition of the blocks with each PID/FT shall be as follows in Table 7.

Table 7 – CAI Frame Types

Name	PID/FT	Description
IMBEFRAME1	$62	IMBE Voice 1
IMBEFRAME2	$63	IMBE Voice 2
IMBEFRAME3	$64	IMBE Voice 3 + Link Control
IMBEFRAME4	$65	IMBE Voice 4 + Link Control
IMBEFRAME5	$66	IMBE Voice 5 + Link Control
IMBEFRAME6	$67	IMBE Voice 6 + Link Control
IMBEFRAME7	$68	IMBE Voice 7 + Link Control
IMBEFRAME8	$69	IMBE Voice 8 + Link Control
IMBEFRAME9	$6A	IMBE Voice 9 + Low Speed Data
IMBEFRAME10	$6B	IMBE Voice 10
IMBEFRAME11	$6C	IMBE Voice 11
IMBEFRAME12	$6D	IMBE Voice 12 + Encryption Sync
IMBEFRAME13	$6E	IMBE Voice 13 + Encryption Sync
IMBEFRAME14	$6F	IMBE Voice 14 + Encryption Sync
IMBEFRAME15	$70	IMBE Voice 15 + Encryption Sync
IMBEFRAME16	$71	IMBE Voice 16 + Encryption Sync
IMBEFRAME17	$72	IMBE Voice 17 + Encryption Sync
IMBEFRAME18	$73	IMBE Voice 18 + Low Speed Data

The report count fields shall reflect the number of decoding errors detected when the over the air frame was recovered at a receiver and the error correcting code (Golay or Hamming) was decoded. These may be used for error mitigation when the voice is decoded. If the number of errors detected is greater than can be indicated in the report field, the field shall be set to the maximum value.

Et shall be the total number of errors detected in the frame. This shall be the parameter ε_T described by equation 95 in TIA/EIA-102.BABA (see [11]) and limited to a maximum value of 7.

Er is a scaled version of ε_R described in equation 96 of reference [11]. Er shall be equal to 400 x ε_R rounded down to the nearest integer and limited to a maximum of 7.

M is the mute frame flag. When M is set to 1 and L set to 1 the frame should be muted. When M is reset to 0 and L set to 1 the previous frame should be repeated. The criteria for deciding that a frame should be muted are described in section 7.8 of reference [11].

L is the lost frame flag. When L is set to 1, it indicates a bad frame that should be muted or the previous frame repeated. The criteria for deciding that a frame should be muted or repeated are described in sections 7.7 and 7.8 of reference [11].

E4 shall be the number of errors detected in vector U4, limited to a maximum of 1.
E1 shall be the number of errors detected in vector U1, limited to a maximum of 7.
SF indicates a 2-bit free running super frame counter that is incremented on the first frame of each super frame. For this issue of the fixed station interface, this behavior is to maintain consistency with the ISSI.
B indicates the busy status field as defined in TIA/EIA-102.BAAA (see [8]).

In addition to the above 14 octets present on all IMBE frames, each of the following frame types specifies zero or more additional bytes that are appended to the end of the frame.

8.4.2.1.1 CAI Frames 1, 2, 10, and 11.

CAI Frames 1, 2, 10 and 11 have frame type fields $62, $63, $6B, $6C respectively. These frames shall contain only the basic14 octets with no additional data. Figure 30 illustrates the format for CAI Frames 1, 2, 10, and 11.

Figure 30 – Format for CAI Frames 1, 2, 10, and 11

<table>
<tr><td colspan="10">0</td><td colspan="10">1</td><td colspan="10">2</td><td colspan="2">3</td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td></tr>
<tr><td colspan="8">Frame Type</td><td colspan="12">U0 (b11-0)</td><td colspan="12">U1 (b11-0)</td></tr>
<tr><td colspan="12">U2 (b11-0)</td><td colspan="12">U3 (b11-0)</td><td colspan="8">U4 (b10-3)</td></tr>
<tr><td colspan="3">U4</td><td colspan="11">U5(b10-0)</td><td colspan="11">U6(b10-0)</td><td colspan="7">U7 (b6-0)</td></tr>
<tr><td colspan="3">Et</td><td colspan="3">Er</td><td>M</td><td>L</td><td>E4</td><td colspan="3">E1</td><td colspan="2">SF</td><td colspan="2">B</td></tr>
</table>

8.4.2.1.2 CAI Frames 3 to 8 with Link Control Data

CAI frames 3 to 8 have frame type fields $64 – $69 respectively. They include an additional 4 bytes to carry Link Control data.

The Link Control field of a block shall carry four of the 24 RS encoded 6-bit link control code words as described in section 5.5 of TIA/EIA-102.BAAA (see [8]). Refer to TIA-102.AABF-A (see [10]) for detailed discussions of Link Control definitions.

The link control field shall contain code words:

0, 1, 2, and 3 for CAI frame 3;
4, 5, 6, and 7 for CAI frame 4;
8, 9, 10, and 11 for CAI frame 5;
12, 13, 14, and 15 for CAI frame 6;
16, 17, 18, and 19 for CAI frame 7; or
20, 21, 2,2 and 23 for CAI frame 8.

The STATUS field is defined as follows:

$$\text{STATUS} = \quad ST3 * 3^3 + ST2 * 3^2 + ST1 * 3^1 + ST0 * 3^0$$

Where
STn=error status of LCn
STn=0 means no errors
STn=1 means 1 error
STn=2 means erasure

Again, the “R” bits are reserved. Figure 31 illustrates the CAI block with a link control word field.

Figure 31 – CAI block with Link Control Word Field

<table>
<tr><td colspan="10">0</td><td colspan="10">1</td><td colspan="10">2</td><td colspan="2">3</td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td></tr>
<tr><td colspan="8">Frame Type</td><td colspan="12">U0 (b11-0)</td><td colspan="12">U1 (b11-0)</td></tr>
<tr><td colspan="12">U2 (b11-0)</td><td colspan="12">U3 (b11-0)</td><td colspan="8">U4 (b10-3)</td></tr>
<tr><td colspan="3">U4</td><td colspan="11">U5(b10-0)</td><td colspan="11">U6(b10-0)</td><td colspan="7">U7 (b6-0)</td></tr>
<tr><td colspan="3">Et</td><td colspan="3">Er</td><td>M</td><td>L</td><td>E4</td><td colspan="3">E1</td><td colspan="2">SF</td><td colspan="2">B</td><td colspan="6">LC0,4,8...</td><td colspan="6">LC1,5,9...</td><td colspan="4">LC2,6, 10...</td></tr>
<tr><td colspan="2"></td><td colspan="6">LC3,7,11...</td><td>R</td><td colspan="7">Status (b6-0)</td></tr>
</table>

8.4.2.1.3 CAI Frame 9 and 18 with Low Speed Data.

Frames 9 and 18 have Frame Type fields of $6A and $73 respectively. This field of a block shall contain two octets of low speed data, as described in section 5.6 of TIA/EIA-102.BAAA (see [8]), either:

Octets 0 and 1 (CAI frame 9) or
Octets 2 and 3 (CAI frame 18).

The low speed data is accompanied by two 2-bit status words to indicate the number of errors decoded at the receiver. The binary values of this field are defined as follows:

00 = no errors

01 = 1 error

02 = 2 errors

03 = erasure – indicates that the decoder detected an uncorrectable combinations of errors in the code word.

Si – Status Bit S0 (CAI Frame 9), Status Bit S2 (CAI Frame 18)
Sj – Status Bit S1 (CAI Frame 9), Status Bit S3 (CAI Frame 18)

Figure 32 illustrates the CAI block with a low speed data field.

Figure 32 – CAI Block with a Low Speed Data Field

<table>
<tr><td colspan="10">0</td><td colspan="10">1</td><td colspan="10">2</td><td colspan="2">3</td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td></tr>
<tr><td colspan="8">Frame Type</td><td colspan="12">U0 (b11-0)</td><td colspan="12">U1 (b11-0)</td></tr>
<tr><td colspan="12">U2 (b11-0)</td><td colspan="12">U3 (b11-0)</td><td colspan="8">U4 (b10-3)</td></tr>
<tr><td colspan="3">U4</td><td colspan="11">U5(b10-0)</td><td colspan="11">U6(b10-0)</td><td colspan="7">U7 (b6-0)</td></tr>
<tr><td colspan="3">Et</td><td colspan="3">Er</td><td>M</td><td>L</td><td>E4</td><td colspan="3">E1</td><td colspan="2">SF</td><td colspan="2">B</td><td colspan="8">LSD (0 or 2)</td><td colspan="8">LSD (1 or 3)</td></tr>
<tr><td colspan="4">Reserved</td><td colspan="2">S_i</td><td colspan="2">S_j</td></tr>
</table>

8.4.2.1.4 CAI Frames 12 to 17 with Encryption Sync

Frames 12 to 17 have Frame Type fields of $6D to $72 respectively and carry four of the 24 RS encoded 6-bit encryption sync code words described in section 5.4 of TIA/EIA-102.BAAA (see [8]). The encryption sync field contains code words:

0,1,2 and 3 for Frame 12;
4, 5, 6 and 7 for Frame 13;
8, 9, 10 and 11 for Frame 14;
12, 13, 14 and 15 for Frame 15;
16, 17, 18 and 19 for Frame 16; or
20, 21, 22 and 23 for Frame 17.

The 7-bit status field indicates the number of bit errors detected when the over the air Hamming code was decoded.

The STATUS field is defined as follows:

STATUS $= ST3 * 3^3 + ST2 * 3^2 + ST1 * 3^1 + ST0 * 3^0$
Where:
STn=error status of ESn
STn=0 means no errors
STn=1 means 1 error
STn=2 means erasure

Figure 33 illustrates the CAI block with encryption sync field.

Figure 33 – CAI Blocks with Encryption Sync Field

<table>
<tr><td>0</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>3</td><td></td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td></tr>
<tr><td colspan="8">Frame Type</td><td colspan="12">U0 (b11-0)</td><td colspan="12">U1 (b11-0)</td></tr>
<tr><td colspan="12">U2 (b11-0)</td><td colspan="12">U3 (b11-0)</td><td colspan="8">U4 (b10-3)</td></tr>
<tr><td colspan="3">U4</td><td colspan="11">U5(b10-0)</td><td colspan="11">U6(b10-0)</td><td colspan="7">U7 (b6-0)</td></tr>
<tr><td colspan="3">Et</td><td colspan="3">Er</td><td>M</td><td>L</td><td>E4</td><td colspan="3">E1</td><td colspan="2">SF</td><td colspan="2">B</td><td colspan="6">ES0,4,8...</td><td colspan="6">ES1,5,9...</td><td colspan="4">ES2,6,10…</td></tr>
<tr><td colspan="2"></td><td colspan="6">ES3,7,11...</td><td>r</td><td colspan="7">Status (b6-0)</td></tr>
</table>

8.4.2.2 Block with PT = 1 – Packet Type

Blocks of this type are not supported for this version of the fixed station interface.

8.4.2.3 Block with PT = 2 – Link control word

Blocks of this type are not supported for this version of the fixed station interface.

8.4.2.4 Block with PT = 3 – Encryption sync word

Blocks of this type are not supported for this version of the fixed station interface.

8.4.2.5 Block with PT = 4 – Low speed data

Blocks of this type are not supported for this version of the fixed station interface.

8.4.2.6 Block with PT = 5 – Header word

Blocks of this type are not supported for this version of the fixed station interface.

8.4.2.7 Block with PT = 6 – Voice Header Part 1

Blocks of this type are sent at the start of a P25 voice stream. The contents shall be the information bits of the first 18 Header Data Unit Golay code words on the air interface.

If the fixed station subsystem receives a P25 voice stream from the air interface without a header data unit (such as due to an RF fade) it may send this voice stream on the fixed station interface with out any voice header blocks. In this case the receiver of the DFSI voice stream may extract the header data from the link control and encryption sync words carried with the P25 voice stream.

The block also contains 3-bit status fields for each of the code words to indicate the number of errors detected in decoding the Golay code. The 3-bit status fields are split, with the two most significant bits sharing the same byte as the associated code word and the least significant bit lumped into one of three other bytes with the LSB's from other code words.

Fixed stations shall transmit within a Header code data unit on the air interface, the contents of a block of this type received on the DFSI.

For more details of the header fields see TIA/EIA-102.BAAA (see [8]).

The frame type for a block with this PT shall be $60.

Figure 34 illustrates the first part of the CAI voice header.

Figure 34 – CAI Voice Header Part 1

<table>
<tr><td colspan="10">0</td><td colspan="10">1</td><td colspan="10">2</td><td colspan="2">3</td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td></tr>
<tr><td colspan="8">Frame Type = $60</td><td colspan="2">S0</td><td colspan="6">G0</td><td colspan="2">S1</td><td colspan="6">G1</td><td colspan="2">S2</td><td colspan="6">G2</td></tr>
<tr><td colspan="2">S3</td><td colspan="6">G3</td><td colspan="2">S4</td><td colspan="6">G4</td><td colspan="2">S5</td><td colspan="6">G5</td><td colspan="2">S6</td><td colspan="6">G6</td></tr>
<tr><td colspan="2">S7</td><td colspan="6">G7</td><td colspan="2">S8</td><td colspan="6">G8</td><td colspan="2">S9</td><td colspan="6">G9</td><td colspan="2">S10</td><td colspan="6">G10</td></tr>
<tr><td colspan="2">S11</td><td colspan="6">G11</td><td colspan="2">S12</td><td colspan="6">G12</td><td colspan="2">S13</td><td colspan="6">G13</td><td colspan="2">S14</td><td colspan="6">G14</td></tr>
<tr><td colspan="2">S15</td><td colspan="6">G15</td><td colspan="2">S16</td><td colspan="6">G16</td><td colspan="2">S17</td><td colspan="6">G17</td><td colspan="6">Reserved</td><td>S17</td><td>S16</td></tr>
<tr><td colspan="16">S15...S0</td></tr>
</table>

8.4.2.8 Block with PT = 7 – Voice Header Part 2

Blocks of this type are sent following the Block with PT = 6 – Voice Header Part 1. The contents shall be the information bits of the last 18 Header Data Unit Golay code words on the air interface.

If the fixed station subsystem receives a P25 voice stream from the air interface without a header data unit (such as due to an RF fade) it may send this voice stream on the fixed station interface with out any voice header blocks. In this case the receiver of the FSI voice stream may extract the header data from the link control and encryption sync words carried with the P25 voice stream. It also contains 3-bit status fields for each of the code words to indicate the number of errors detected in decoding the Golay code. The 3-bit status fields are split, with the two most significant bits sharing the same byte as the associated code word and the least significant bit lumped into one of three other bytes with the LSB's from other code words.

Fixed stations shall transmit within a Header code data unit on the air interface, the contents of a block of this type received on the fixed station interface.

For more details of the header fields see TIA/EIA-102.BAAA (see [8]).

The frame type for blocks with this PT shall be $61.

Figure 35 illustrates the second part of the CAI voice header.

Figure 35 – CAI Voice Header Part 2

Bits 0–7		Bits 8–9	Bits 10–15	Bits 16–17	Bits 18–23	Bits 24–25	Bits 26–29	Bit 30	Bit 31
Frame Type = $61		S18	G18	S19	G19	S20	G20		
S21	G21	S22	G22	S23	G23	S24	G24		
S25	G25	S26	G26	S27	G27	S28	G28		
S29	G29	S30	G30	S31	G31	S32	G32		
S33	G33	S34	G34	S35	G35	Reserved		S35	S34
S33...S18									

8.4.2.9 Block with PT = 9 – Start of Stream

Fixed stations shall be capable of sending blocks of this type on the fixed station interface. It shall contain the NID of the first data unit that the fixed station receives in a stream.

This block explicitly identifies the start of a stream.

> NID – Comprised of the NAC and DUID. See TIA/EIA-102.BAAA (see [8]) for details.
> Err Cnt – 4-bit count of the number of errors detected in the NID.

Figure 36 illustrates the start of stream block.

Figure 36 – Start of Stream Block

Bits 0–15	Bits 16–19	Bits 20–23
NID	Reserve	Err Cnt

8.4.2.10 Block with PT = 10 – End of Stream

Fixed stations shall send a block of this type when they detect the end of a voice stream on the air interface. This packet type explicitly identifies the end of a stream. No data apart from the RTP block header is defined.

8.4.2.11 Block with PT = 11 – PTT Control Word

Blocks of this type are not supported for this version of the fixed station interface.

8.4.2.12 Block with PT = 12 – Voter Report

This block is provided so that the fixed station subsystem can report the receiver status for each receiver. If multiple receivers are reported, multiple blocks may be included in one packet. Voter Reports are only sent on the inbound DFSI. Figure 37 illustrates the voter report block.

Figure 37 – Voter Report Block

0										1					
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5
Receiver Number								D	Receiver Status						

Receiver number 0 is reserved for use in Block with PT = 13 – Voter Control. Receiver numbers 1 to 255 indicate the receiver that the report is for. Mapping of the receiver number to receiver names and physical location are determined by equipment configuration parameters.

D indicates if this receiver is Disabled.

D=0 means that the receiver is not disabled.

D=1 means that this receiver is inhibited because of a DISABLE command for this number (or all receivers) or a SELECT command for another receiver number.

Table 8 shows receiver status voter report code meanings. .

Table 8 – Receiver Status Voter Report Codes

Code	Mnemonic	Meaning
0	NO_SIGNAL	No usable signal is being received by this receiver.
1	SELECTED	This receiver is currently selected. The audio being sent originates from this receiver.
2	GOOD_P25	A P25 signal with the correct NAC being received by this receiver. This receiver is not currently selected by the voter.
3	GOOD_FM	An FM signal with the correct sub-audible signal (if applicable) is being received by this receiver. This receiver is not currently selected.
4	BAD_P25	A P25 signal is being received by this receiver but the NAC does not match the desired NAC.

Table 8 – Receiver Status Voter Report Codes (concluded)

Code	Mnemonic	Meaning
5	BAD_FM	An analog FM signal is being received by this receiver but the desired sub-audible signal has not been detected.
6	NOT_EQUIPPED	No receiver is equipped for this number.
7	FAILED	The receiver with this number has failed.

8.4.2.13 Block with PT = 13 – Voter Control

Voter control blocks are sent on the outbound fixed station interface. Figure 38 illustrates the voter control block.

Figure 38 – Voter Control Block

0										1					
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5
Receiver Number								Command							

Receiver number = 0 indicates that this command applies to all receivers. Receiver numbers 1 to 255 indicate the receiver that this command relates to. The receiver number used here shall be same as the receiver number used for the same physical receiver in Block with PT = 12 – Voter Report.

Table 9 shows the meanings of the voter control command.

Table 9 – Voter Control Command

Code	Mnemonic	Meaning
0	REPORT	Send the status of this receiver now.
1	NORMAL	Forward speech from the receiver that has the best signal. This command cancels any SELECT or DISABLE command. Receiver number is not relevant to this command. Receiver number = 0 should be used with this command.
2	SELECT	Forward this receiver’s speech regardless of how good the signal is. This command disables all other receivers. This command can not be used with Receiver Number = 0.
3	DISABLE	Don't forward this receiver’s speech regardless of how good it is.

8.4.2.14 Block with PT = 14 Tx Key Acknowledge

This is sent on the inbound path indicating to the CSFH that the fixed station has started transmitting on the CAI. No data apart from the RTP block header is defined.

8.4.2.15 Block PT = 63 to 127 – Manufacturer specific data

These packet types are provided so individual manufacturers can carry additional proprietary data within a stream. Equipment conforming to this standard may include such blocks however they must follow any standard blocks which are sent in the same packet.

Equipment conforming to this standard shall ignore blocks of these types whose MFID they do not understand. However equipment conforming to this standard shall appropriately process any standard blocks which precede a manufacturer specific block in the same packet.

The length field specifies the number of octets in this block following the length field. Beyond the mandatory P25 manufacturer's identification (MFID) field and the length, the format of the internals of this packet are left open for any use. Manufacturers are encouraged to propose packet types, which may be of general use, to the TIA for inclusion in this profile. Figure 39 illustrates the format for manufacturer customizations.

Figure 39 – Format for Manufacturer Customizations

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---------------+---------------+-------------------------------+
|     MFID      |    Length     | Manufacturer specified format...
+---------------+---------------+-------------------------------+
```

8.4.3 Voice Conveyance Service Procedures

8.4.3.1 Connection of the Voice Conveyance Service.

8.4.3.1.1 Not Connected State

When the control service for a CFSH – Fixed Station Subsystem pair is in the not-connected state the voice conveyance service for that CFSH – Fixed Station Subsystem pair shall also be in the not connected state.

No voice conveyance packets are exchanged between a CFSH – Fixed Station Subsystem pair when they are in the not connected state.

The process of entering and leaving the connected state is described in 8.3.

8.4.3.1.2 Connected State

When the control service for a CFSH – Fixed Station Subsystem pair is in the connected state the voice conveyance service for that pair shall also be in the connected state.

The process of entering and leaving the connected state is described in 8.3.

When a CFSH – Fixed Station Subsystem pair are in the connected state they shall exchange voice conveyance packets according to the following procedures described in 8.4.3.2 through 8.4.3.7.

The setting of IP addresses, SSRC and UDP port number are described in 8.3.

8.4.3.2 Voting Control

The fixed station subsystem shall send an update of its state whenever its state changes. It shall send a report of its new state when it receives a voter control command. The fixed station subsystem shall also send periodic reports of its status. This allows for any reports which were missed when it changed state.

The Fixed Station Subsystem shall send a Block with PT = 12 – Voter Report for each receiver in the subsystem at least as often as specified by the vote report interval configuration parameter.

The fixed station subsystem shall send a Block with PT = 12 – Voter Report for the specified receiver (or all receivers if receiver number = 0) when it receives a Block with PT = 13 – Voter Control.

The fixed station subsystem shall send a Block with PT = 12 – Voter Report when the indicated receiver's status changes.

The fixed station subsystem shall begin forwarding voice traffic from the receiver with the best signal when it receives a Block with PT = 13 – Voter Control with the command NORMAL. The method for determining the best signal is up to the manufacturer of the comparator / voter.

The fixed station subsystem shall forward all voice traffic from the specified receiver and stop forwarding voice traffic from all other receivers when it receives a Block with PT = 13 – Voter Control with command SELECT.

The fixed station subsystem shall stop forwarding voice packets from the specified receiver (or all receivers if the receiver number = 0) when it receives a Block with PT = 13 – Voter Control with command DISABLE.

If the fixed station subsystem receives a Block with PT = 13 – Voter Control specifying a receiver number that does not exist for that fixed station subsystem it shall send a Block with PT = 12 – Voter Report specifying that receiver number with status NOT_EQUIPPED, unless the specified receiver number was 0.

8.4.3.3 Starting Voice Transfer

8.4.3.3.1 Start of Stream

When initiation of voice transfer across the CAI is required, a packet shall be sent containing a Block with PT = 9 – Start of Stream.

If the voice transfer is an analog transparent stream this packet should also contain a block of type 0 as described in 8.4.3.6, Transport of Analog Transparent Voice.

On the outbound path, each packet sent following the start of stream shall include a Block with PT = 9 – Start of Stream until a Block with PT = 14 Tx Key Acknowledge has been received on the inbound path.

These packets may also include voice stream blocks even though a Block with PT = 14 Tx Key Acknowledge has not yet been received. The receipt of the Block with PT = 14 Tx Key Acknowledge should not delay the transmission of speech. The Block with PT = 14 Tx Key Acknowledge is provided so that the human operator of a console may be given an indication that the fixed station was successfully keyed.

8.4.3.3.1.1 NAC

If the CFSH intends the fixed station subsystem to use a locally configured NAC on the outbound CAI, the CFSH shall set the value of NAC to $F7E.

If the CFSH intends the fixed station subsystem to use a specific NAC on the outbound air interface, the specific NAC shall be sent in the packet. This specific NAC shall not be $F7E or $F7F.

If the NAC in the start of stream message on the outbound DFSI is not $F7E the fixed station shall use this NAC on the outbound CAI.

If the NAC in the start of stream message on the outbound DFSI is $F7E the fixed station shall use a locally configured NAC on the outbound CAI.

On the inbound fixed station interface the fixed station subsystem shall insert the NAC received on the inbound CAI.

8.4.3.3.1.2 DUID

The DUID shall be either %0000 (header data unit), %0101 (LDU1) or %1010 (LDU2).

If the stream starts with a Block with PT = 5 – Header word the DUID shall be %0000 (header data unit).

DUID %0101 (LDU1) or %1010 (LDU2) may be sent when the header of a voice stream received on the CAI is missed and the LDU is the first decodable data has been received.

8.4.3.3.1.3 Err Cnt

On the in bound fixed station interface the “Err Cnt” field of a Block with PT = 9 – Start of Stream, shall be the number of errors a detected in the NID received on the CAI.

8.4.3.3.1.4 Super Frame Counter

P25 voice streams include a super frame count. Senders shall reset their super frame counter to zero when they start a stream.

8.4.3.3.2 Acknowledging Start of Stream

When a fixed station subsystem receives an outbound packet containing a start of stream message it shall key the transmitter. When the transmitter is successfully keyed the fixed station subsystem shall send an inbound packet containing Block with PT = 14 Tx Key Acknowledge.

Once the transmitter is successfully keyed, the fixed station subsystem shall send a Block with PT = 14 Tx Key Acknowledge in response to every start of stream that it receives.

The CFSH sends outbound DFSI packets across the CAI.

8.4.3.3.3 Intercom Traffic

If an outbound voice stream starts without a Block with PT = 9 – Start of Stream the fixed station subsystem shall not key its transmitter but route the audio to its intercom facility if equipped.

Audio from the fixed stations intercom facility, if equipped, is routed to the inbound path of the DFSI. The inbound voice stream audio from the intercom is differentiated from the audio originating on the CAI since it starts without a Block with PT = 9 – Start of Stream. It is expected that the users talking from the fixed station will identify themselves verbally. Verbal identification may be supplemented by the use of specific talk groups or P25 source address if the option to transfer intercom traffic as a P25 voice stream is being used.

Equipment implementing the DFSI shall support the transfer of intercom audio in analog transparent (G.711) mode.

As a standard option Intercom traffic may alternatively be transferred as a P25 voice stream. This option would require that the fixed station includes a vocoder.

8.4.3.4 The Header Packets

When a P25 voice stream is received from the CAI the header shall be sent on the DFSI as two fragments. This reduces delay since the first part of the header may be sent across the network before the entire header has been received on the CAI.

DFSI equipment sending an analog transparent stream shall not send any header packets. DFSI equipment that missed the header on the in-bound CAI should not send any header packets.

8.4.3.4.1 Sending Voice Headers on the Fixed Station Interface.

DFSI equipment shall send the first part of the P25 header in a packet containing a single Block with PT = 6 – Voice Header Part 1. As soon as the remainder of the header is received on the CAI, equipment shall send the second part of the header in a packet containing a single Block with PT = 7 – Voice Header Part 2.

Figure 40 illustrates the start of stream message sequence for outbound voice, and Figure 41 illustrates the start of stream message sequence with the first ACK lost.

Figure 40 – Start of Stream Message Sequence – Outbound Voice

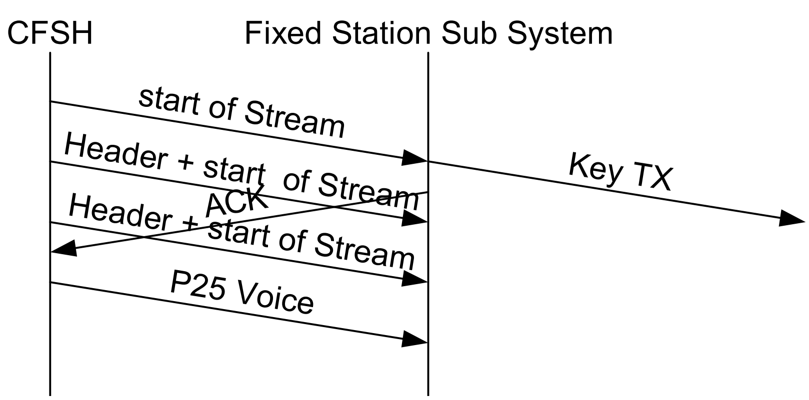
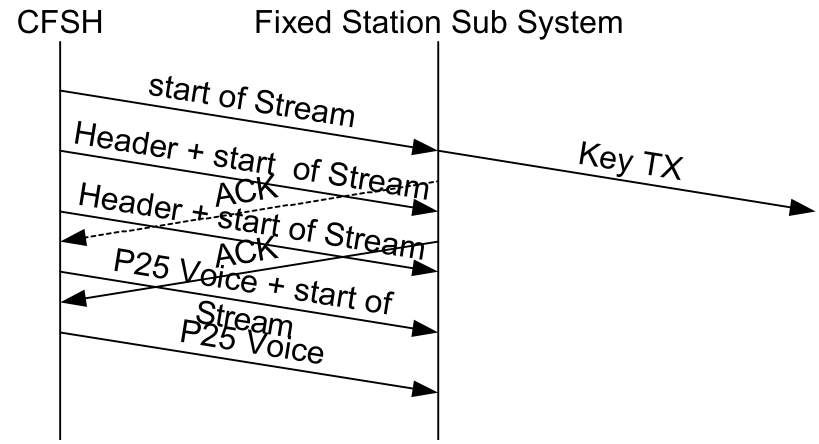


Figure 41 – Start of Stream with the First ACK Lost



8.4.3.5 Transferring Voice

8.4.3.5.1 P25 IMBE Voice

Each frame of P25 voice to be sent on the fixed station shall be encapsulated as described in 8.4.2.1 Block with PT= 0 – CAI Voice. This shall be combined with any other blocks that need to be sent at the same time in an RTP packet. Each RTP packet may contain 1, 2, or 3 Block with PT= 0 – CAI Voice.

On the inbound path error correction is performed on the voice frames received from the CAI and the error counts are added to the error control fields of the block.

8.4.3.5.2 Super Frame Counter

Before sending a CAI frame type $62 (IMBE voice 1) senders shall increment their super frame counter by 1. Senders shall insert the current value of their super frame counter in the SF field.

8.4.3.5.3 B Status Field

The Fixed station subsystem shall set the status symbols transmitted on the CAI to match the B field of the last status symbol received on the inbound CAI. The CFSH shall set the B field in the Block with PT= 0 – CAI Voice packets to match the status symbol desired on the outbound CAI.

8.4.3.6 Transport of Analog Transparent Voice

Analog transparent voice is a voice band signal typically sent to or from an analog FM RF transmitter or receiver. The fixed station is transparent to this base band signal and does not attempt to extract any meaning from it. In the receive direction the signal is demodulated, sampled and encoded. In the transmit direction it is decoded and modulated. Often this may be simply voice but it may include in band signaling between the analog subscriber units and the CSFH.

When in analog transparent mode DFSI equipment shall encode the analog audio signal using the μ law PCM scheme described in ITU-T Recommendation G.711 (see [12]). Every 20 ms 160 PCM samples are assembled into a analog transparent voice packet consisting of a block of type 0 E=0 PCMU. The format of this block is described in RFC 3551 (see [18]).

Figure 42 shows an example of the packet with analog transparent data block type.

Figure 42 – Packet with Analog Transparent Data

<table>
<tr><td>0</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>3</td><td></td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>0</td><td>1</td></tr>
<tr><td colspan="2">V=0</td><td>0</td><td>0</td><td colspan="4">CC=0</td><td>0</td><td colspan="7">PT=100</td><td colspan="16">Sequence Number</td></tr>
<tr><td colspan="32">Times Stamp</td></tr>
<tr><td colspan="32">SSRC</td></tr>
<tr><td rowspan="2">S = 1</td><td rowspan="2">C = 1</td><td colspan="6" rowspan="2">Block Header Count = 1</td><td colspan="8">Block Type 1 = 0</td><td colspan="16" rowspan="2">2 PCM Sample</td></tr>
<tr><td>E = 0</td><td colspan="7">Block PT=0 (PCM audio)</td></tr>
<tr><td colspan="32">156 PCM Samples</td></tr>
<tr><td colspan="16">2 PCM Samples</td><td colspan="16"></td></tr>
</table>

8.4.3.7 Terminating a Voice Stream

When equipment implementing the DFSI determines that a voice stream has ended it shall send four packets with a single Block with PT = 10 – End of Stream spaced 100 ms apart. If a new voice stream starts before all the end of stream packets have been sent, the remaining end of stream packets need not be sent and the new voice stream may be started immediately.

When a fixed station receives an end of stream packet it should de-key its transmitter. If a fixed station receives no voice packets for longer than a manufacturer specified timeout (typically 4 seconds) it should de-key its transmitter.

Figure 43 illustrates the end-of-stream process and Figure 44 illustrates the end-of-stream time-out.

Figure 43 – End of Stream

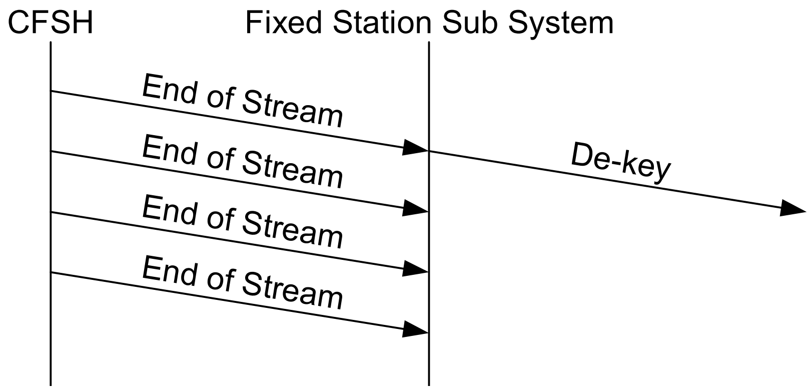
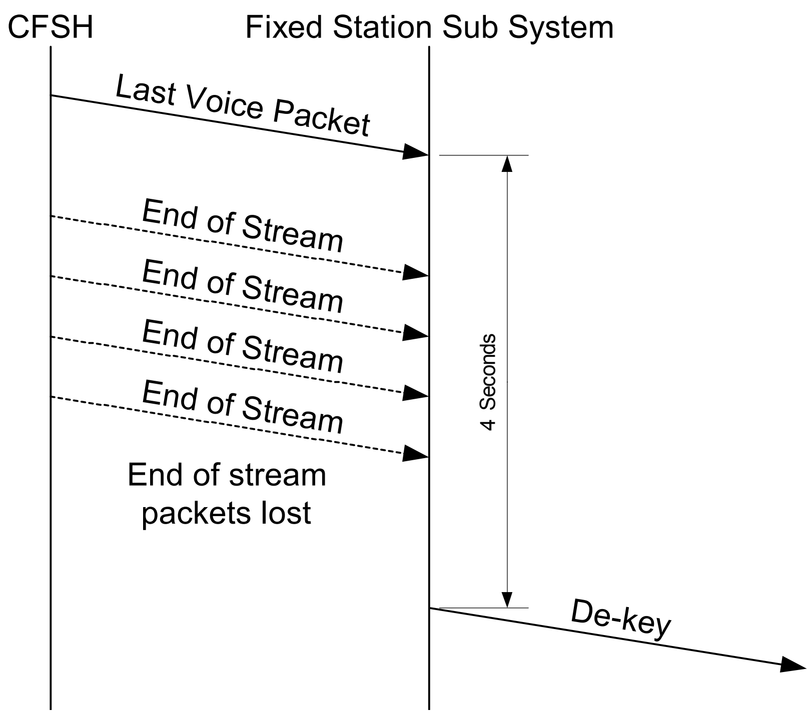


Figure 44 – End of Stream Time Out



- End -

TIA