APPENDIX D*

# SELF-ORGANIZING TIME DIVISION MULTIPLE ACCESS

# VDL MODE 4

# STANDARDS AND RECOMMENDED PRACTICES

(4 April 1996)

# DRAFT

* This appendix is available in English only.

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# 1. DEFINITIONS AND SYSTEMS CAPABILITIES

## 1.1 Definitions

The following terms are used in this document as they are defined below:

*Accuracy*. The degree of conformance between the estimated or measured position and/or velocity and/or time of/at a platform and its true position and/or velocity and the true time.

*Aeronautical telecommunications network (ATN)*. An internetwork architecture that allows ground, air/ground, and avionic data subnetworks to interoperate by adopting common interface services and protocols based on the International Organization for Standardization Open Systems Interconnection Reference Model.

*Aircraft address*. A 24-bit binary number uniquely assigned to each aircraft carrying a Mode S transponder or other data link installation. This is effectively the address of the airframe and is distinct from other commonly used addresses such as the flight number or the tail number (*i.e.* registration number).

*Applications*. Specific use of systems that address particular user requirements. For the case of GNSS, applications are defined in terms of specific operational scenarios such as the support of en route navigation or low-visibility aircraft taxiing, etc.

*ATN router*. An intermediate system used to interconnect subnetworks conforming to the *Manual of the Aeronautical Telecommunication Network (ATN)* (Doc 9578).

*Augmentation of GNSS*. Augmentation is the technique of providing the system with input information, extra to that derived from the main constellation(s) in use, which provides additional range/pseudo-range inputs or corrections to, or enhancements of, existing pseudo-range inputs. This enables the system to provide a performance which is enhanced relative to that possible with the basic satellite information only.

*Automatic dependent surveillance-broadcast (ADS-B)*. A surveillance service based on aircraft self-determination of position/velocity/time (*e.g.* via GNSS) and automatic, periodic or aperiodic, broadcast of this information along with auxiliary data such as aircraft ID, communications control parameters, etc. ADS-B is intended to support multiple high-level applications and associated services such as cockpit display of traffic information (CDTI), traffic alert and collision avoidance functionality, enhanced traffic management in the air and on the ground, search and rescue support and others.

*Autotune function*. A function performed by the Link Management Entity. The Autotune Function allows an STDMA station to change transmit and receive frequencies without pilot intervention, subject to ground command or other operating criteria contained in an onboard database.

*Availability*. The availability of a navigation system is the percentage of time that the services of the system are within required performance limits. Availability is an indication of the ability of the system to provide usable service within the specified area of coverage. Signal availability is the percentage of time that navigational signals transmitted are available for use. Availability is a function of both the physical characteristics of the environment and the technical capabilities of the transmitter facilities.

*Control domain*. A 3D volume, including the surface, within which a ground station may exercise control. Actual exercise of such control is dependent on application requirements.

*Data circuit terminating equipment*. A peer entity of Data Terminating Equipment controlled by a data communications network.

*Data link entity*. A protocol state machine capable of setting up and managing a single data link connection.

*Data link sublayer*. A link over the Media Access Control sublayer.

*Data terminal equipment*. A digital data transmitter/receiver device.

*Differential*. Differential GNSS is an augmentation, the purpose of which is to determine position errors at one or more known locations and subsequently transmit derived information to other GNSS receivers in order to enhance the accuracy of the position estimate.

*Effective data rate*. The actual instantaneous data throughput realized after overheads imposed by bit stuffing and by any forward error correction encoding, but not retransmissions.

*Flight information service broadcast (FIS-B)*. A broadcast service providing, *inter alia*, national, regional and local weather data, terminal information, NOTAMS, RVR, Special Use Airspace (SUA) status, and auxiliary data.

*Internetworking protocol*. A protocol that transfers data packets between intermediate systems and end systems interconnected by subnetworks and that is supported by the routing protocols and addressing plan.

*International Organization for Standardization*. An international standards organization that has developed, among other standards, the Open Systems Interconnection Reference Model and protocol standards at various levels of the model.

*Geometric dilution of position (GDOP)*. In a multilateration system, the ratio of the standard deviation of the position error to the standard deviation of the measurement errors.

*Global navigation satellite system (GNSS)*. GNSS is a world-wide position, velocity and time determination system that includes one or more satellite constellations, receivers, and system integrity monitoring, augmented as necessary to support the required navigation performance for the actual phase of operation.

*Integrity*. The assurance that all functions of a system perform within operational limits.

*Link establishment*. The process by which an aircraft determines the communications environment, decides upon communications parameters, initializes any logical state machines within the protocol stack, and initiates communications and broadcasting. Also the process by which an aircraft and a ground system discover each other, determine to communicate with each other, decide upon the communication parameters, initialize any state machines and initiate communications.

*Link layer*. The layer that lies immediately above the physical layer in the Open Systems Interconnection protocol model. The link layer provides for the reliable transfer of information across the physical media. It is subdivided into the data link sublayer and the Media Access Control sublayer.

*Link management entity*. The AVLC-specific entity that lies immediately above the link layer and controls the operations of the data link service, the Media Access Control sublayer, and the physical layer.

*Media access control*. The sublayer that acquires the data path and controls the movement of bits over the data path.

*Nanosecond (nsec or ns)*. One billionth of a second.

*Network layer*. The layer that provides the upper layers with independence from the data transmission and routing functions used to connect systems. The network layer is responsible for routing and relaying functions both within any subnetwork and throughout the aeronautical internetworking domain.

*Open systems interconnection model*. A model (developed by the International Organization for Standardization) that provides a standard approach to data network design. This approach introduces modularity by dividing the complex sets of functions that comprise networking into seven more manageable, self-contained functional layers. By convention, these layers are usually depicted as a vertical stack.

*Physical layer*. The lowest level layer in the open systems interconnection protocol model. The physical layer is concerned with only the transmission of binary information over the physical medium (*e.g*. VHF radio).

*Quality of service*. The information relating to data transfer characteristics used by various communication protocols to achieve various levels of performance for network users.

*Receiver autonomous integrity monitoring (RAIM)*. A technique whereby a civil GNSS receiver/processor determines the integrity of the GNSS navigation signals without reference to sensors or non-DoD integrity systems other than the receiver itself. This determination is achieved by a consistency check among redundant pseudorange measurements.

*Self-organizing TDMA (STDMA)*. A multiple access scheme based on time-shared use of an RF channel employing: (1) discrete contiguous time slots as the fundamental shared resource; and (2) a set of operating protocols that allows users to mediate access to these time slots without reliance on a master control station.

*Selective availability (SA)*. A set of techniques for denying the full accuracy and selecting the level of positioning, velocity and time accuracy of GPS available to users of the Standard Positioning Service (L1 frequency) signal.

*Service primitives*. The status and control information that must be available to the receiving entity to properly process incoming information. A service primitive may contain parameters. If parameters exist, they describe information that is defined either as mandatory (M) or optional (O) for conformance to a particular communications standard.

*Service provider*. An entity at a layer that provides services to the layer above. These services are provided at service access points through the use of service primitives.

*Service user*. An entity at a layer that makes use of the services that are provided at Service Access Points by the layer below through the use of service primitives.

*Situational awareness*. An integrated understanding of factors that contribute to the operation of aircraft/vehicles under normal and abnormal conditions. Factors affecting situational awareness include spatial awareness, awareness of environment, aircraft/vehicle performance awareness, aircraft/vehicle systems awareness, and operator/crew/controller awareness.

*Subnetwork dependent convergence facility*. A facility that matches the characteristics and services of a particular subnetwork to those characteristics and services required by the internetwork facility.

*Subnetwork layer*. The layer that establishes, manages, and terminates connections across a subnetwork.

*T* . The baud period or 1/baud rate.

*Time division multiple access (TDMA)*. A multiple access scheme based on time-shared use of an RF channel employing: (1) discrete contiguous time slots as the fundamental shared resource; and (2) a set of operating protocols that allows users to interact with a master control station to mediate access to the channel.

*Traffic information service broadcast (TIS-B)*. A broadcast service providing correlated surveillance data for all traffic in a specified domain.

## 1.2 Acronyms and abbreviations

The following acronyms and abbreviations are used in this document as they are defined below:

| Acronym | Definition |
|---|---|
| A/A | air-to-air |
| A/C | aircraft |
| ACK | acknowledge(ment) |
| ADS-B | automatic dependent surveillance broadcast |
| A/G | air/ground |
| AGC | automatic gain control |
| AMCP | Aeronautical Mobile Communications Panel |
| AMS(R)S | aeronautical mobile-satellite (route) services |
| ATC | air traffic control |

| Acronym | Definition |
|---|---|
| ATN | aeronautical telecommunication network |
| AVLC | aviation VHF link control |
| AWGN | additive white gaussian noise |
| BCD | binary coded decimal |
| BER | bit error rate |
| BFR | block failure rate |
| CAA | civil aviation authority |
| CCIR | International Radio Consultative Committee, reorganized into the Radiocommunication Bureau (BR) of the ITU |
| CDMA | code division multiple access |
| CDTI | cockpit display of traffic information |
| CMD | command |
| C/R | command/response |
| CSC | common signalling channel |
| CSMA | carrier sense multiple access |
| CW | continuous wave |
| DCE | data circuit-terminating equipment |
| DISC | disconnect |
| DPDU | data link protocol data unit |
| DLS | data link service |
| DLSAP | data link service access point |
| DOC | designated operational coverage |
| DSB-AM | double sideband amplitude modulation |
| DTE | data terminal equipment |
| DTR | data transfer ready |
| FCS | frame check sequence |
| FEC | forward error correction |
| FIS-B | flight information service - broadcast |
| FRMR | frame reject |

| Acronym | Definition |
|---|---|
| GDOP | geometric dilution of precision |
| GI | group identification |
| GMSK | gaussian minimum shift keying |
| GNSS | global navigation satellite system |
| GSIF | ground station information frame |
| HDLC | high-level data link control |
| HIC | highest incoming channel |
| HO | handoff |
| HOC | highest outgoing channel |
| HTC | highest two-way channel |
| IATA | International Air Transport Association |
| ICAO | International Civil Aviation Organization |
| ID | identification (identifier) |
| Info | information |
| INIT | initialization |
| ISH | intermediate system hello |
| ISO | International Organization for Standardization |
| LCN | logical channel number |
| LCR | link connection refused |
| LIC | lowest incoming channel |
| LME | link management entity |
| LN | local negotiation |
| LOC | lowest outgoing channel |
| lsb | least significant bit |
| LTC | lowest two-way channel |
| LWS | local wait state |
| MAC | media access control |
| MIB | management information base |
| msb | most significant bit |

| Acronym | Definition |
|---|---|
| MSK | minimum shift keying |
| NPDU | network protocol data unit |
| NSAP | network service access point |
| OCP | outgoing connection pending |
| OSI | open systems interconnection |
| PDU | protocol data unit |
| PECT | peer entity contact table |
| P/F | poll/final |
| PI | parameter identifier |
| PN | pseudo noise |
| PPM | parts per million |
| Q-bit | qualifier bit |
| QOS | quality of service |
| RAIM | receiver autonomous integrity monitoring |
| REJ | reject |
| RF | radio frequency |
| rms | root mean square |
| RNR | response not ready |
| RR | receive ready |
| RSP | response |
| RWS | remote wait state |
| SA | selective availability |
| SARPs | Standards and Recommended Practices |
| SDU | service data unit |
| SNAcP | subnetwork access protocol |
| SNPA | subnetwork point of attachment |
| SNPDU | subnetwork protocol data unit |
| SNR | signal to noise ratio |
| SNS | subnetwork service |

| Acronym | Definition |
|---|---|
| SNSAP | subnetwork service access point |
| SQP | signal quality parameter |
| STDMA | self-organizing time division multiple access |
| SU | signal unit |
| SVC | switched virtual circuit |
| TBD | to be determined (flag for future value) |
| TBR | to be refined (flags for further refinement in the document) |
| TDMA | time division multiple access |
| TIS-B | traffic information service - broadcast |
| UA | unnumbered acknowledgment |
| UI | unnumbered information |
| UTC | universal co-ordinated time |
| VC | virtual circuit |
| VDL | VHF digital link |
| VHF | very high frequency |
| WAAS | wide area augmentation system |
| XID | exchange ID |
| XOR | exclusive OR |

## 1.3 Scope of document

The Standards and Recommended Practices (SARPs) for the self-organizing time division multiple access (STDMA), defined and referenced in this document, shall apply to aeronautical VHF digital communications systems providing the functions of a navigation/surveillance data link. These functions include, *inter alia*, local area GNSS augmentation, Automatic Dependent Surveillance Broadcast (ADS-B), Traffic Information Service Broadcast (TIS-B), Flight Information Service Broadcast (FIS-B), reception and processing functions associated with these broadcasts, and auxiliary point-to-point data exchange. ADS-B is expected to support applications such as Cockpit Display of Traffic Information (CDTI), Airborne Collision Avoidance, search and rescue (SAR) coordination, enhanced ATC operations and improved traffic management in the air and on the surface. STDMA equipment compliant with these SARPs will support two-way digital communications between airborne platforms and between aircraft and ground stations via the ATN.

### 1.3.1 Validation

Validation of these SARPs may be performed with suitably compliant equipment. However, prior to the wide availability of D8PSK radio equipment, elements of these SARPs relating to channel management and control, and STDMA-specific services, may be validated with radio equipment employing FM/GMSK modulation at a baud rate of 9.6 kbps. Use of such equipment requires adjustment of certain features of the data link standard defined herein, at the physical and data link layers. Where appropriate, suitable guidance is provided in these SARPs for such validation.

## 1.4 Radio channels and functional channels

### 1.4.1 Aircraft radio frequency range

#### 1.4.1.1 Transmit tuning range

An STDMA system radio shall be capable of tuning to any of the 760 25-kHz channels from 118.000 MHz through 136.975 MHz within 100 msec of the receipt of the command.

#### 1.4.1.2 Receive tuning range

An STDMA system radio shall be capable of tuning to any of the 1000 25-kHz channels from 108.000 MHz through 136.975 MHz. Aircraft radios shall be capable of tuning within 100 msec of the receipt of the command.

### 1.4.2 Ground radio frequency range

A ground radio shall be capable of operating on its assigned channel within the 108.000 - 136.975 MHz band.

*Note.− The difference in tuning ranges for aircraft radios, with respect to transmit operations versus receive operations, enables DGNSS uplink transmissions in a protected band (108-117.975 MHz). Aircraft radios may tune to these channels for receive operations, but are prevented from generating accidental transmissions.*

### 1.4.3 Common signalling channels

Frequencies [136.900] MHz and [136.950] MHz shall be used as worldwide Common Signalling Channels (CSC), as required to satisfy user communications objectives.

*Note.− Additional CSCs may be defined in a local domain, and notified to airborne users by broadcast from ground stations on the worldwide CSCs defined above.*

### 1.4.4 Validation of radio channels and functional channels

For validation, the requirements of Sections 1.4.1 and 1.4.2 shall be applied. If validation is performed with equipment fully-compliant with these SARPs, the requirements of Section 1.4.3 shall also be applied. If validation is performed with FM/GMSK radio equipment, validating Administrations shall specify appropriate CSCs.

### 1.5 System capabilities

The STDMA communications functions shall meet the general requirements in Sections 1.5.1 through 1.5.9.

#### 1.5.1 Coexistence

The STDMA system shall provide for interoperability with VHF Data Link services as defined in Sections 2 through 10. The level of radiated emissions in adjacent frequency channels shall be minimized, and shall conform to the limits specified in Section 2.3.1.2.

#### 1.5.2 ATN compatibility

The STDMA system shall provide physical layer, data link layer and subnetwork layer services within the ATN such that logical interoperability can be maintained at these layers.

#### 1.5.3 Data transparency

The STDMA system shall provide code-independent, byte-independent transfer of data.

#### 1.5.4 Broadcast

The STDMA system shall provide link layer broadcast services.

#### 1.5.5 Ground network transition

An STDMA-equipped aircraft shall transition between autonomous and control modes, and from one controlled network to another when circumstances dictate.

#### 1.5.6 Slaved synchronization

An STDMA aircraft radio shall provide the capability for slaved synchronization wherein estimates of antenna position, velocity and associated time are derived from ranging estimates relative to other STDMA ground and airborne stations in the vicinity. This capability shall be utilized whenever GNSS-derived estimates of position, velocity and time are unavailable, and sufficient other STDMA stations exist in the environment to enable such estimation.

#### 1.5.7 Real-time processing

STDMA stations shall process physical layer message headers in real time (*i.e.* during the current slot). The remainder of the message shall be processed prior to the completion of the message slot following the end of the message.

*Note.− The physical layer header must be processed during the current slot since the physical layer header of a User Burst contains the transmission length field, which is needed to determine end of message as well as the potential for the receiving station to access the subsequent slot, should such access be scheduled. Processing of the remainder of the message within one additional slot is intended to minimize buffering delays* *in the STDMA equipment, and avoid large queues of unprocessed messages that could exceed hardware memory capacity and thereby lead to loss of data.*

### 1.5.8 Differentiation of STDMA traffic and user traffic

The STDMA system shall differentiate between two types of traffic:

1. STDMA traffic, consisting of control traffic and STDMA-specific application data; and
2. other user traffic supporting ATN-compliant communications.

These forms of traffic shall be differentiated at the physical and data link layers. STDMA traffic shall be differentiated from user traffic through the use of a unique synchronization sequence and abbreviated physical and Data Link Sublayer (DLS) frames. An STDMA burst modulated with D8PSK is always contained within one access slot (9000 slots available per minute), and will be of a fixed length. A user burst may be of arbitrary length up to the maximum allowed by the encoding limitations of the transmission length parameter.

*Note.− A physical-layer packet containing STDMA-specific traffic (including control traffic) will be referred to as an "STDMA burst." A physical-layer packet containing other user traffic, such as ATN-compliant traffic, will be referred to as a "user burst."*

### 1.5.9 Validation of system capabilities

For validation, the requirements of Sections 1.5.2 and 1.5.7 shall be applied. If validation is performed with equipment fully-compliant with these SARPs, the requirements of Sections 1.5.1 and 1.5.8 shall also be applied. If validation is performed with FM/GMSK radio equipment, all traffic is STDMA-specific. Individual applications shall be differentiated through processing of the message type field contained in the message header. For FM/GMSK modulation, the channel shall be subdivided into 9000 slots/minute as for D8PSK modulation, but STDMA bursts require 4 access slots and shall be constrained to start in slots with (slot ID modulo 4) = 0 relative to start of frame.

## 2. PHYSICAL LAYER PROTOCOLS AND SERVICES

The airborne and ground terminals of the STDMA shall access the physical medium operating in simplex mode.

### 2.1 Functions

The physical layer shall provide the following functions:

1. Transceiver frequency control
2. Data reception by the transceiver
3. Data transmission by the transceiver
4. Notification services
5. Arrival time measurements

### 2.1.1 Transceiver frequency control

The STDMA physical layer shall set the transceiver frequency as commanded by the Link Management Entity (LME). Channel selection time shall be less than [5 msec].

*Note.− For validation with FM/GMSK, channel selection time shall be less than 10 msec.*

### 2.1.2 Data reception by transceiver

Signals received by the transceiver shall be decoded so that they may be accurately read at the higher layers.

### 2.1.3 Data transmission by transceiver

#### 2.1.3.1 Data encoding and transmission

The STDMA physical layer shall appropriately encode the data received from the data link layer and transmit it over the RF channel.

#### 2.1.3.2 Time of transmission

Transmission shall be "strobed" with start of RF transmission occurring no later than [1 usec ($10^{-6}$ seconds)] after the nominal start of a message slot.

*Note.− The strobe ensures that the transmitted message starts at the beginning of a message slot in the STDMA frame. Message slots are slaved to Universal Coordinated Time (UTC) as derived from GNSS or an equivalent standard. Time accuracies as derived from GNSS will be better than 0.5 usec (2σ).*

2.1.3.3 **Automatic transmitter shutdown**

On the STDMA common signaling channels defined in Section 1.4.3, the STDMA station shall automatically shut-down power to the final stage amplifier in the event that the transmitter remains "on" for more than 0.5 second. Reset to an operational mode shall require a manual operation. The transmitter shall be considered "on" if the output power delivered to the antenna port exceeds [-10 dBW].

*Note.− This concept of a "slow-blow fuse" is intended to protect the worldwide communal resource of the common signaling channels against so-called "stuck transmitters". STDMA operations on other channels will be protected by the standard 30-second shut-down required of all aeronautical VHF transmission equipment.*

2.1.4 **Notification services**

The operational parameters of the equipment shall be monitored at the physical layer. Signal quality analysis shall be performed on the demodulator evaluation process and on the receive evaluation process; this analysis shall be normalized between a scale of 0 and 15, where 0 to 3 is considered poor, 4 to 12 is adequate, and 13 to 15 is excellent.

*Note.− Processes that may be evaluated in the demodulator include BER, SNR, and timing jitter. Processes that may be evaluated in the receiver include received signal level and group delay.*

2.1.5 **Arrival time measurements**

The physical layer shall maintain an independent clock or frequency standard with stability greater than [$\Delta f/f = 10^{-7}$]. This clock or frequency standard shall be physically independent of any embedded GNSS subsystem. The arrival time of each training sequence, with arrival time referenced to this clock or frequency standard, and training sequence as defined in Section 2.2.3, shall be measured and made available as required to support secondary navigation functions of STDMA described in Section 10.3.2.

2.1.6 **Validation of Physical Layer Functions**

If validation is performed with equipment fully-compliant with these SARPs, the requirements of Sections 2.1.1 through 2.1.5 shall be applied. If validation is performed with FM/GMSK radio equipment, the physical layer shall conform to the standards of Sections 2.1.1 through 2.1.5 except as set forth below.

2.1.6.1 **Transceiver frequency control**

Channel selection time shall be less than 10 msec.

2.2 **Protocol definition**

2.2.1 **Modulation scheme**

The modulation scheme shall be differentially encoded 8 phase shift keying (D8PSK), using a raised cosine filter with $\alpha = 0.6$. The information to be transmitted shall be differentially encoded with 3 bits per symbol transmitted as changes in phase rather than absolute phase. The data stream to be transmitted shall be divided into groups of 3 consecutive data bits, low bit first. Zeros shall be padded to the end of the transmissions if needed for the final channel symbol.

### 2.2.1.1 Data encoding

A binary data stream entering a differential data encoder shall be converted into three separate binary streams X, Y, and Z so that bits 3n form X, bits 3n+1 form Y, and bits 3n+2 form Z. The triplet at time k ($X_k$, $Y_k$, $Z_k$) shall be converted to a change in phase as shown in Table 2-1, and the absolute phase $\phi_k$ is the accumulated series of $\Delta\phi_k$, that is

$$\phi_k = \phi_{k-1} + \Delta\phi_k$$

**Table 2-1: Mode 2 Data Encoding**

| $X_k$ | $Y_k$ | $Z_k$ | $\Delta\phi_k$ |
|---|---|---|---|
| 0 | 0 | 0 | $0\pi/4$ |
| 0 | 0 | 1 | $1\pi/4$ |
| 0 | 1 | 1 | $2\pi/4$ |
| 0 | 1 | 0 | $3\pi/4$ |
| 1 | 1 | 0 | $4\pi/4$ |
| 1 | 1 | 1 | $5\pi/4$ |
| 1 | 0 | 1 | $6\pi/4$ |
| 1 | 0 | 0 | $7\pi/4$ |

### 2.2.1.2 Transmitted signal form

The transmitted signal shall be $H(e^{j(2\pi ft + \phi(t))})$, where $H(\bullet)$ is a fully raised cosine filter with $\alpha = 0.6$. The spectral mask and phase tolerance mask for the D8PSK transmitter are described in Tables 2-2 and 2-3, respectively.

**Table 2-2: Spectral Mask for D8PSK Transmitter**

| Lower bound | | Upper bound | |
|---|---|---|---|
| Frequency (Hz) (deviation from channel center) | Attenuation (dBc) | Frequency (Hz) (deviation from channel center) | Attenuation (dBc) |
| 0 | -0.25 | 0 | 0.251700 |
| -0.25 | 2500 | 0.25 | |
| 3000 | -1 | 3900 | -1 |
| 3900 | -3 | 4900 | -3 |
| 4800 | -6 | 5800 | -6 |

| | | | |
|---|---|---|---|
| 5350 | -10 | 6650 | -10 |
| 6310 | -20 | 7910 | -20 |
| 6680 | -30 | 8680 | -30 |

**Table 2-3: Phase Tolerance Mask for D8PSK Transmitter**

| Lower bound | | Upper bound | |
|---|---|---|---|
| Frequency (Hz deviation from channel center) | Phase (degrees deviation from linear) | Frequency (Hz deviation from channel center) | Phase (degrees deviation from linear) |
| 0 | -1.8 | 0 | 1.8 |
| 5250 | -1.8 | 5250 | 1.8 |
| 5250 | -2.8 | 5250 | 2.8 |
| 6000 | -2.8 | 6000 | 2.8 |
| 6000 | -180 | 6000 | 180 |

### 2.2.2 Modulation rate

The symbol rate shall be 10500 symbols/sec ± 50 ppm, resulting in a nominal bit rate of 31500 bits/sec.

### 2.2.3 Training sequence

Data transmission begins with a demodulator training sequence consisting of two or five segments:

1. Transmitter power stabilization
2. Synchronization and ambiguity resolution
3. Reserved symbol (user burst only)
4. Transmission length (user burst only)
5. Header FEC (user burst only).

#### 2.2.3.1 Transmitter power stabilization

The first segment of the training sequence is the transmitter power stabilization, which shall consist of exactly three (3) symbols each representing 000. The transmitter shall be within 90% of the steady state power level by the end of the transmitter power stabilization segment.

*Note.– One function of STDMA is to provide a secondary navigation capability based on time-of-arrival measurements of the synchronization words defined in Section 2.3.3.2 below. These synchronization words occur immediately following the transmitter power stabilization interval in the level 1 frame. Any variation in the duration of the power stabilization interval would introduce large errors in the secondary navigation* *function. Thus, the transmitter power stabilization interval must be exactly three symbols long without variation*.

### 2.2.3.2 Synchronization and ambiguity resolution

The second segment of the training sequence shall consist of a unique word providing for synchronization and ambiguity resolution. The unique word shall also serve to differentiate between STDMA traffic and user traffic. The following sequences shall be used:

| | |
|---|---|
| [TBD] | STDMA burst |
| 000 001 011 101 000 010 110 101 010 100 011 111 110 111 100 001 | user burst |

and shall be transmitted from left to right.

*Note.− The synchronization sequence for an STDMA burst is [TBD]. It should be selected to have good autocorrelation properties and low cross correlation with the user burst sync sequence, as well as low cross-correlation with other synchronization sequences employed by the IVAD/VDL standard.*

### 2.2.3.3 Reserved symbol (user burst only)

For a user burst, the third segment of the training sequence shall consist of the single symbol representing 110 .

*Note.− This reserved symbol allows an STDMA station to differentiate an STDMA transmission from a VDL transmission. STDMA and VDL transmissions are likely to have differing protocol structures at higher layers of the ISO stack; a unique reserved symbol acts as a toggle to control higher-level processing in equipment that is compatible with both systems. VDL-only stations will reject STDMA transmissions due to the unexpected reserved symbol.*

### 2.2.3.4 Transmission length (user burst only)

To allow the receiver to determine the length of the final Reed-Solomon block of a user burst, the transmitter shall send a 17-bit word, from least significant bit (lsb) to most significant bit (msb), indicating the total number of bits of the Reed-Solomon encoded segment of the transmission.

### 2.2.3.5 Header FEC (user burst only)

To correct bit errors in the header of a user burst, a (25, 20) block code shall be computed over the reserved symbol and the transmission length segments and transmitted as the fifth segment. The encoder shall accept the header in the bit sequence that is being transmitted. The five parity bits that shall be transmitted shall be generated using the following equation:

$$p = iH^T$$

where p is the parity word, i is the reserved symbol/transmission length sequence, T is the matrix transpose function, and H is the parity matrix defined below:

$$H = \begin{bmatrix} 0&0&0&0&0&0&0&0&1&1&1&1&1&1&1&1&1&1&1&1 \\ 0&0&1&1&1&1&1&1&0&0&0&0&1&1&1&1&1&1&1&1 \\ 1&1&0&0&0&1&1&1&0&0&1&1&0&0&0&0&1&1&1&1 \\ 1&1&0&1&1&0&1&1&0&1&0&1&0&0&1&1&0&0&1&1 \\ 0&1&1&0&1&0&0&1&1&1&1&0&0&1&0&1&0&1&0&1 \end{bmatrix}$$

2.2.3.6 **Bit transmission order**

The five parity bits of the resultant vector product shall be transmitted from the left bit first.

2.2.4 **Forward error correction (user burst only)**

In order to improve the effective channel throughput by reducing the probability that a user burst must be discarded due to channel errors, FEC shall be applied after the training sequence, regardless of frame boundaries.

2.2.4.1 **FEC calculation**

The FEC coding shall be accomplished by means of a systematic Reed-Solomon (255,249) $2^8$-ary code capable of correcting up to three codeword symbol errors. The field defining the primitive polynomial of the code shall be as follows:

$$p(x) = (x^8 + x^7 + x^2 + x + 1)$$

The generator polynomial shall be as follows:

$$\prod_{i=120}^{250} (x - \alpha^i)$$

*Note.– The Reed-Solomon codes are described in the Recommendation for Space Data System Standards: Telemetry Channel Coding, by the Consultative Committee for Space Data Systems*

2.2.4.2 **PSDU lengths**

A user burst with transmission length longer than 1992 bits shall be split into blocks of 249 octets, with the last block being potentially less than 249 octets. The six parity check octets then shall be appended to the 249 octets of data to produce a block of 255 octets. These octets shall be converted into blocks low word first.

2.2.4.3 **Block codes**

Blocks less than 1992-bits long shall be coded according to the code in Table 2-4. Although the encoder and decoder shall fill the block with *zeros*, these *zeros* shall not be transmitted.

**Table 2-4: Block Coding Length**

| *Block Length* | *Code* |
|---|---|
| 0-16 bits | None |
| 17-240 bits | Reed-Solomon (251,249) $2^8$-ary 1 error correcting |
| 241-536 bits | Reed-Solomon (253,249) $2^8$-ary 2 error correcting |
| 537-1992 bits | Reed-Solomon (255,249) $2^8$-ary 3 error correcting |

2.2.4.4 **Single corrections**

For blocks intended to correct only one word, all six parity codeword symbols shall be generated, but only the first two shall be transmitted. The last four parity codeword symbols shall be treated as erasures at the decoder.

2.2.4.5 **Two-word corrections**

For blocks intended to correct two words, all six parity codeword symbols shall be generated, but only the first four shall be transmitted. The last two parity codeword symbols shall be treated as erasures at the decoder.

2.2.5 **Interleaving (user burst only)**

To improve the performance of the FEC, a word-based table-driven interleaver shall be used. The transmitter shall write the message to be transmitted (on which the FEC already has been computed) into a table (with 255 cells per row, with each cell containing an octet) by row and read the transmission by column. The receiver shall calculate the number of full rows and the size of the last row (which may be a partial row) and fill its table by column and read it out by rows, realizing that the number of rows per column may change while filling the table.

*Note.– The primary functions envisioned for STDMA involve message lengths less than 255 octets. For such messages, interleaving becomes a "null operation" with the output identical to the input.*

2.2.6 **Bit scrambling (user burst only)**

To aid in clock recovery, a Pseudo Noise (PN) scrambler with a 15-stage generator register shall be Exclusive ORed (XORed) with the transmitted data stream, starting with the message length segment of the training sequence. The scrambler and descrambler configurations shall be as shown in Figure 2-1. The polynomial for the h-register of the scrambler and descrambler shall be as follows:

$$1 + X + X^{15}$$

### 2.2.6.1 Scrambler functions

The scrambler and descrambler shall be clocked at the rate of one shift per bit, with the first scrambler bit in the frame unshifted. The initial status of the shift register, preset at the beginning of the transmission, shall be programmable to enable the scrambler to be used for encryption in the future. The default initial value of the h-register is 1101 0010 1011 001, with the left-most bit in the first stage of the h-register, as shown in Figure 2-1.

Figure 2-1: Scrambler and descrambler functional block diagram

### 2.2.7 Channel sensing

#### 2.2.7.1 Channel busy to idle detection

An STDMA station shall employ two means to determine the channel busy to idle transition

a) measurement of transmission length. When an STDMA burst training sequence has been detected, the STDMA station shall consider the channel idle at the end of the *a priori* end of message; and

b) measurement of received power. When an STDMA station receives on-channel power of at least -87 dBm for at least 5 msec, and no STDMA burst training sequence has been detected, then it shall consider the channel unoccupied if the received signal is attenuated to below -92 dBm for at least 0.9 msec.

*Note 1.− An STDMA station shall continue to search for valid synchronization sequences if it has determined the channel to be busy based solely on measurement of received power.*

*Note 2.− High efficiency requires that STDMA VDL stations "hand-off" the channel resource among themselves with minimum delay. Idle detection via the determination of transmission length supports this objective. Subsequent transmissions will also be limited by known reservations and possible resource allocations by ground stations (if present). The second technique, based on power measurements, is intended as a fail-safe mode when no valid training sequence has been detected.*

#### 2.2.7.2 Channel idle to busy detection

An STDMA station shall employ two means to determine the channel idle to busy transition at the physical layer. In addition, an STDMA station shall consider the channel occupied if it has received and processed a reservation for the current slot.

**Detection of the unique word**

Detection of the unique word shall be based upon correlation or matched-filter detection of an STDMA burst or user burst unique word (see Section 2.2.3.2) with a normalized detector output greater than [0.9].

**Measurement of channel power**

In the absence of correlation or matched-filter detection of the unique word (see Section 2.3.3.2), a VDL station shall consider the channel occupied within 1 msec after on-channel power rises to at least -90 dBm.

### 2.2.8 Receiver/transmitter interaction

#### 2.2.8.1 Receiver to transmitter turnaround time

A station shall begin the transmission of the transmitter power stabilization portion of the training sequence within 1 usec after nominal start of slot.

*Note.– This is consistent with, but more stringent than, the VDL SARPs. The tight specification of turnaround time is intended to support the secondary navigation function of STDMA, which requires that STDMA stations slave their transmissions closely to UTC time. The 1 usec tolerance in this parameter translates into a minimum range estimation error of 1000 feet for STDMA stations attempting to determine their position from the position reports and arrival times of STDMA messages.*

#### 2.2.8.2 Transmitter to receiver turnaround time

A station shall be capable of receiving and demodulating with nominal performance an incoming signal within 0.8 msec after completing a transmission.

### 2.2.9 Validation of the physical layer protocol definition

If validation is performed with equipment fully-compliant with these SARPs, the requirements of Sections 2.2.1 through 2.2.8 shall be applied. If validation is performed with FM/GMSK radio equipment, the physical layer shall conform to the standards set forth below.

#### 2.2.9.1 Modulation scheme

The modulation scheme shall be Frequency-Modulated Gaussian Minimum Shift Keying (FM-GMSK), which is a continuous-phase, frequency shift keying technique using two tones. The presence of the lower tone of a tone pair shall indicate a bit change from the previous bit. The presence of the higher tone shall indicate that there is no bit change. The phases of the two tones shall be chosen so that the minimum phase discontinuity occurs at the interface with the preceding bit and so that the amplitude of each tone is zero at the bit transition. The slope of the waveforms at the end of a bit cell shall be positive for a binary *one* and negative for a binary *zero*.

Phase coherence shall be maintained through the transmission media for successful decoding at the receiving end. The establishment of correct phase relationships shall be performed by the ground and airborne decoding hardware during the Continuous Wave (CW) tone segment of the training sequence.

2.2.9.2 **Modulation rate**

Binary *ones* and binary *zeros* shall be generated with a modulation index of 0.4, producing data transmission at a bit rate of 9600 bits/sec ± 50 ppm.

2.2.9.3 **Training sequence**

Data transmission shall begin with a 4.166 msec demodulator training sequence consisting of one segment: synchronization. This segment shall consist of exactly 5 bytes of alternating zeros and ones (010101...).

2.2.9.4 **Forward error correction**

Forward error correction shall not be applied to FM/GMSK modulated data.

2.2.9.5 **Interleaving**

Interleaving shall not be applied to FM/GMSK modulated data.

2.2.9.6 **Bit scrambling**

Bit scrambling shall not be applied to FM/GMSK modulated data.

2.2.9.7 **Channel sensing**

**Channel busy to idle detection**

No indication of packet length is provided by the physical layer packet header for FM/GMSK modulated data. For reception of such data, an STDMA station shall employ two means to determine the channel busy to idle transition

**Detection of the DLS end-of-frame flag**

The DLS sublayer shall provide an end-of-frame indication to the physical layer. See Section [3.3.4].

**Measurement of received power**

The channel busy to idle transition shall alternatively be determined as described in Section 2.2.7.1.

**Channel idle to busy detection**

For reception of FM/GMSK modulated data, an STDMA station shall consider the channel occupied within 1 msec after on-channel power rises to at least -90 dBm. In addition, an STDMA station shall consider the channel occupied if a reservation has been received and processed for the current slot.

### 2.2.9.8 Receiver/transmitter interaction

#### Receiver to transmitter turnaround time

A station shall begin the transmission of the FM/GMSK synchronization sequence within 1 usec after deciding to transmit.

#### Transmitter to receiver turnaround time

A station shall be capable of receiving and demodulating with nominal performance an incoming signal within 1 msec after completing a transmission.

# 3. LINK LAYER PROTOCOLS AND SERVICES

## 3.1 General information

The STDMA link layer shall be divided into three sublayers:

A Media Access Control (MAC) sublayer requiring the use of slotted TDMA

1. A Data Link Service (DLS) sublayer providing connection-oriented and broadcast services over the MAC sublayer
2. A Link Management Entity (LME) which establishes and maintains connections.

## 3.2 MAC sublayer

### 3.2.1 MAC services

#### 3.2.1.1 Multiple access

The MAC sublayer shall implement a slotted TDMA algorithm to allow all stations the opportunity to transmit while maximizing system throughput, minimizing transit delays, and minimizing collisions.

#### 3.2.1.2 Channel congestion

The MAC sublayer shall notify the LME sublayer whenever channel congestion is detected. Packets intended for transmission, which fail to be transmitted in the intended slot, shall be purged.

*Note.– Upon being informed that a message has been blocked, higher layers may choose to regenerate the same message or send a different message.*

### 3.2.2 MAC sublayer system parameters

MAC service system parameters shall be as described in Table 3-1, where 9000 slots = 1 frame = 1 minute.

*Note.– Individual messages may overlap slot boundaries, subject to the limitations imposed by the Maxlength parameter.*

**Table 3-1: MAC Service System Parameters**

| Symbol | Parameter Name | Minimum | Maximum | Default | Increment |
|---|---|---|---|---|---|
| M2 | Maxlength | 2 slots | 512 slots | [20 slots] | 2 slots |
| TM2 | Channel Busy Timer | 20 slots | 9000 slots | 1500 slots | 20 slots |
| BO | Busy_override | 0 | 1 | 0 | 1 |

#### 3.2.2.1 Maxlength M2 (maximum length of autonomous user burst)

The parameter M2 shall be the maximum length of a user burst transmitted without a resource request and reservation response from a ground station. The default value for M2 shall be [20 slots].

*Note.– Longer messages can be transmitted after segmentation. Ground stations can adjust this parameter in local airspace for selected users or all users.*

### 3.2.2.2 Timer TM2 (channel busy timer)

The TM2 timer shall be initialized to the maximum time that the STDMA station will wait after receiving a request to transmit from higher layers. If this timer expires, the channel shall be considered congested and the LME informed.

### 3.2.2.3 Busy_override BO (ignore channel congestion indication)

The *Busy_override* parameter BO is a logical switch (=0/1) that shall be used to control transmission on a congested channel. If BO=0, transmission shall be prevented on a busy channel. If BO=1, transmission shall be initiated in the indicated time slot regardless of channel activity.

*Note.– This parameter allows an STDMA station to access slots of distant users, as determined by higher layers of the protocol, under high traffic conditions.*

### 3.2.3 MAC sublayer procedures

The MAC sublayer shall receive a transmit packet and associated transmit slot ID(s) from higher layers. The MAC sublayer shall deliver the message packet to the physical layer. The MAC sublayer shall check for channel congestion at the physical layer (*e.g.* channel busy indication at start of slot). If the channel is free, or if the *Busy_override* parameter has been set (BO=1), it shall strobe the physical layer to initiate transmission of the packet at the appropriate time.

*Note 1.– Higher protocol layers must determine candidate slot(s) for transmission, based on slot reservations and possible resource assignment commands from ground stations (if present), and provide this information to the MAC sublayer along with the value of the associated Busy_override parameter BO. Since transmission must occur within 1 usec of start of slot, the physical layer and MAC sublayer must interact asynchronously with regard to channel congestion indications and transmission strobes (e.g. transmission strobe could be an AND gate with three inputs: (1) message ready for transmission; (2) indication from physical layer that channel idle OR BO=1; and (3) UTC time = start of slot).*

*Note 2.– The Busy_override parameter allows an STDMA station to transmit in a slot also accessed by a distant user (i.e. with high traffic conditions, an STDMA station that is unable to identify an unreserved time slot can select for its own use the time slot of the most distant user of which it is aware).*

### 3.2.4 MAC sublayer validation

For FM/GMSK modulation, the default value of the Maxlength parameter M2 shall be 40 slots. The frame structure shall retain a 1 minute frame with 9000 slots; however, access opportunities shall occur every fourth slot measured from start of frame (ie, slots 1, 5, 9, ..., 8997).

## 3.3 DLS sublayer

### 3.3.1 Protocol definition for STDMA bursts

#### 3.3.1.1 Services for STDMA bursts

**Connectionless services**

STDMA bursts shall only be used to support connectionless services.

**Frame Check Sequence (FCS) Processing**

On transmit and receive, the DLS sublayer shall calculate a Frame Check Sequence over the Message Type and Information fields of the DLS frame, per ISO 3309, and modulo-2 add it to the Source ID field.

**Station Identification**

The link layer header of STDMA bursts shall contain a source address.

**Address Uniqueness**

Each airborne and ground radio shall be assigned an address. For airborne users, this may be a 24-bit address such as the user's unique ICAO address, or some other 24-bit address designed to provide code compatibility with an ICAO address space, but offer anonymity.

**Bit stuffing**

For STDMA bursts, bit stuffing shall not be performed.

**Data transfer**

Data shall be transferred in the information subfield of the STDMA Burst DLS frame.

### 3.3.1.2 DLS protocol specification for STDMA bursts

The DLS frame format for STDMA bursts shall consist of the elements illustrated in Table 3-2.

**Table 3-2: DLS Frame format for STDMA bursts**

| Description | Octet # | Bit number | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| Source Address and CRC | 1 | $a_{24}$ | $a_{23}$ | $a_{22}$ | $a_{21}$ | $a_{20}$ | $a_{19}$ | $a_{18}$ | $a_{17}$ |
| | 2 | $a_{16}$ | $a_{15}$ | $a_{14}$ | $a_{13}$ | $a_{12}$ | $a_{11}$ | $a_{10}$ | $a_9$ |
| | 3 | $a_8$ | $a_7$ | $a_6$ | $a_5$ | $a_4$ | $a_3$ | $a_2$ | $a_1$ |
| Message Type | 4 | $t_7$ | $t_6$ | $t_5$ | $t_4$ | $t_3$ | $t_2$ | $t_1$ | $d_{92}$ |
| Information sub-field (92 bits) | 5 | $d_{91}$ | $d_{90}$ | $d_{89}$ | $d_{88}$ | $d_{87}$ | $d_{86}$ | $d_{85}$ | $d_{84}$ |
| | : | : | : | : | : | : | : | : | : |
| | 16 | $d_3$ | $d_2$ | $d_1$ | | | | | |

### 3.3.1.3 Library of STDMA messages

STDMA Bursts are listed and summarized in Table 3-3, and detailed in subsections below.

**Table 3-3: Library of STDMA Bursts**

| Type | Name | Functionality |
|---|---|---|
| 0 | User sync | Declares presence of user; provides unique ID, position report, slot reservations/access regime and sync capabilities. This burst type also serves as the network entry message. |
| 1 | Compressed Supervisory Frame | Provides ACK/NAK (Receiver Ready (RR) and Selective REJect (SREJ)) as alternative to ACK/NAK piggybacked on other user communications. Also provides capability for resource request. |
| 2 | ID request | Requests flight number or tail number associated with a specific 24-bit ICAO-unique ID, and aircraft router DTE address suffix. |
| 3 | ID report | Associates flight number or tail number with user's 24-bit ICAO-unique ID. Includes aircraft router DTE address suffix (supports establishment of SVC to aircraft router). |
| 4 | UTC time inquiry | Requests UTC time. |
| 5 | UTC time report | Transmits UTC time, if currently available/known. |
| 6 | Compressed Unnumbered INFO (UI) | Provides capability for efficient broadcast transmission of short messages (up to 80 bits of user data) in a single access slot. |

| | | |
|---|---|---|
| 32 | User sync (polled) | Declares presence of user in polled mode; provides unique ID, position report, slot reservations/access regime and sync capabilities. Adjacent 4 time slots may be accessed only by ground stations and airborne users under ground command. |
| 64 | Polling message | Autotune command which provides assigned frequency, time slot, time-out period and position reporting resolution. This message can be by a ground station at any time, in order to add a user to the controlled network on this frequency, or hand-off the user to a different network. |
| 65 | ACK | Acknowledgment (if not piggybacked on other user communications). |
| 66 | ID request | Requests flight number or tail number associated with a specific 24-bit ICAO-unique ID, and aircraft router DTE address suffix. |
| 69 | UTC time report | Transmits UTC time, if currently available/known. |
| 70 | Contention resolution | Identifies time slots where two or more autonomous users have apparently garbled their transmissions due to mutual interference |
| 71 | System configuration | Describes usage/allocation of slots on channel. Includes slots assigned to voice circuits if present, associated squelch window (if present), reserved slots, and random access slots. Describes functional allocation of slots, if a specific allocation is defined by a ground station (*e.g.* DGNSS, CDTI, etc.). |
| 72 | Directory of services | Describes generic functions and applications available on other VHF frequencies. |
| 73 | Reservation response | Responds to airborne user request for channel resources. Either signals actual reservation, or acknowledges receipt of resource request (*i.e.* reservation is pending). |
| 74 | Recovery flag | Informs aircraft that the ground station is in the link recovery state. |

**Messages transmitted from autonomous mobile stations**

**Burst Type 0: User Sync (Autonomous)**

The user sync burst is defined in Table 3-4. The information subfield of the DLS frame contains latitude and longitude, velocity, heading, altitude, time stamp of position report, climb/descend indicator, and communications control parameters. This information shall be provided by the Application layer, optionally processed through the presentation layer for encryption; see Sections 9 and 10.

*Note 1.– At the application layer, position and velocity data will be referenced to the time stamp, which will be the previous integer UTC second relative to the message slot supporting the message. Linear extrapolation from the current position and velocity data will be used to reference this information to the appropriate integer second.*

*Note 2.– In cases where the message slot start boundary exactly coincides with an integer UTC second, the time stamp shall be the current time. In all other cases, the time stamp shall be the previous integer UTC second. Thus, time stamping involves truncation of CURRENT TIME OF TRANSMISSION to the integer second.*

*Note 3.– If transmission is blocked at the physical layer (channel busy and BO=0), the link layer will purge the message and generate an appropriate indication to higher layers, which may regenerate the message or generate a new message; associated navigation data must be aligned with this implied timestamp by the application layer.*

*Note.– In the event that latitude and longitude is unknown (e.g. GNSS receiver temporarily blocked or inoperative), the application layer should fill lat/long fields with 1's. This will be interpreted as a flag by receiving stations that such data is unavailable, but that communications protocols are to be continued.*

**Burst Type 1: Compressed Supervisory Frame**

This message type provides for Receiver Ready (RR), Selective REJect (SREJ) and resource request functionality, as summarized in Table 3-5. Note that the number of slots requested will be constrained by the Maxlength parameter maintained at the MAC layer.

**Table 3-4: Burst Type 0: User Sync (Autonomous)**

| Message Parameter/Field | Field length (bits) | Format and interpretive notes |
|---|---|---|
| Mobile ID | 24 | ICAO ID overlaid with CRC (24 bits) |
| Message type | 7 | 0 (binary 0000000) |
| Latitude | 20 | resolution = 0.001 minutes (90°; north = positive) or 0.016 minutes depending on position resolution flag |
| Longitude | 20 | resolution = 0.001 minutes (180°; east = positive) or 0.032 minutes depending on position resolution flag |
| Speed | 11 | resolution = 2 kts (0 - 4095 kts) |
| Heading/direction | 11 | resolution = 0.2 degrees (0 - 359.8) |
| Position resolution flag | 1 | 0=low resolution (default); 1=high resolution |
| Altitude | 12 | resolution = 16 ft (4.876 m) (0 - 19.7 km) |
| Climb/descend indicator | 2 | 0 = maintaining altitude;<br>1= climbing; 2= descending;<br>3= GNSS altitude not determined (2D navigation) |
| GNSS Sync | 1 | 0= not GNSS time sync'd; 1= GNSS time sync |
| DGNSS | 1 | 0= GNSS navigation; 1= DGNSS navigation |
| Slot time-out counter | 2 | 0= last transmission in this time slot; 1= 1 minute left to change; 2= 2 minutes left to change; 3= 3 or more minutes left to change. |
| Slot offset | 8 | After slot time-out, entity with ID indicated at layer 2 will occupy slot offset this amount (±127 slots) from current slot. Value of 128 indicates new slot position will be greater than 127 slot positions from current position. |
| Spare | 3 | N/A |
| Total data length | 123 | |

**Table 3-5: Burst Type 1: Compressed Supervisory Frame**

| Message Parameter/Field | Field length (bits) | Format and interpretive notes |
|---|---|---|
| Mobile ID (Source addr) | 24 | ICAO ID overlaid with CRC (24 bits) |
| Message type | 7 | 1 (binary 0000001) |
| Ground station vs. aircraft destination station | 1 | 0 = aircraft; 1 = ground stationDestination address |
| 24 | Separate 24-bit address space for ground stations relative to mobile IDs | |
| Link control field | 8 | Supports RR and SREJ functionality |
| Number of slots requested | 9 | Supports resource request functionality (all zeros when no resource requested). Max value = 512. |
| Data priority for requested slots | 4 | |
| Voice request | 2 | |
| SREJ information | 24 | |
| [CRC-CCITT] | [16] | |
| Spare | [4] | |
| Total data length | 123 | |

**Burst Type 2: ID Request**

This message is intended to generate a response from one or several STDMA stations, so that a correlation can be made between ICAO-unique ID(s) and flight number(s) or tail number(s). The format shall be as specified in Table 3-6 below. An ID request can be addressed to a specific ICAO-unique user ID, or broadcast to all aircraft within [10 nmi] of a specified location.

**Table 3-6: Burst Type 2: ID Request**

| Message Parameter/Field | Field length (bits) | Format and interpretive notes |
|---|---|---|
| Mobile ID (Source addr) | 24 | ICAO ID overlaid with CRC (24 bits) |
| Message type | 7 | 2 (binary 0000010) |
| Destination address | 24 | ICAO-unique (24 bits) or BCST (all zeros) |
| Latitude* | 16 | Resolution = 0.256 minutes |
| Longitude* | 16 | Resolution = 0.512 minutes |
| Spare | 36 | |
| Total message length | 123 | |

*Lat/long fields are interpreted if and only if Destination Address is identically 0.

### Burst Type 3: ID Report

This message is a response to a Type 2. Consistent with paragraph 3.3.1.3, the STDMA station may generate a Type 3 ID report intended to correlate its ICAO-unique ID with its tail number or flight number. This may be useful as a prelude to voice communications or automatic data exchange to support future applications.

The Type 3 ID report shall consist of the transmitting station's 24-bit ICAO-unique ID, a 7-bit message type field and a 48 bit Mobile ID field encoding the tail number or flight number.

Table 3-7: Burst Type 3: ID Report

| Message Parameter/Field | Field length (bits) | Format and interpretive notes |
|---|---|---|
| Mobile ID (Source addr) | 24 | ICAO ID overlaid with CRC (24 bits) |
| Message type | 7 | 3 (binary 0000011) |
| Flight number or tail number | 48 | |
| Spare | 44 | |
| Total message length | 123 | |

### Burst Type 4: UTC Time Inquiry

Time inquiries can be used for synchronization in the event that GNSS or UTC time is unavailable (*e.g.* due to hardware malfunction). It shall consist of a destination ID associated with the entity from which time synchronization is desired, as indicated in Table 3-8 below.

**Table 3-8: Burst Type 4: UTC Time Inquiry**

| Message Parameter/Field | Field length (bits) | Format and interpretive notes |
|---|---|---|
| Mobile ID (Source addr) | 24 | ICAO ID overlaid with CRC (24 bits) |
| Message type | 7 | 4 (binary 0000100) |
| Destination address | 24 | |
| Position resolution request | 1 | 0 = low resolution (default);<br>1 = high resolution. |
| Spare | 67 | |
| Total message length | 123 | |

**Burst Type 5: UTC Time Report**

The reply to a time inquiry shall follow the format indicated in Table 3-9 below. Time shall be extrapolated to the start time of the message slot that will be used to transmit the message.

*Note 1.– The combination of time source location, UTC time and time slot ID provide sufficient information to support time synchronization.*

*Note 2.– This message type differs from the standard Type 0 sync message in the following ways: (1) speed and heading/direction are replaced with time and slot ID; (2) change of time slot information (TIME-OUT counter and OFFSET) is replaced with date.*

*Note 3.– In the event that a STDMA station is not synchronized to UTC time, all received time messages should be processed. Three consecutive time messages should agree before local time is updated (this prevents synchronization on an erroneous time message). However, the requirement for three time messages in agreement does not apply if the STDMA station generated the initial request for time.*

**Burst Type 6: Compressed Unnumbered Information (UI) Frame**

This burst provides for efficient broadcast transmission of short messages (up to 80 bits of user data) in a single access slot, as summarized in Table 3-10.

**Table 3-9: Burst Type 5: UTC Time Report**

| Message Parameter/Field | Field length (bits) | Format and interpretive notes |
|---|---|---|
| Mobile ID (Source addr) | 24 | ICAO ID overlaid with CRC (24 bits) |
| Message type | 7 | 5 (binary 0000101) |
| Latitude | 20 | resolution = 0.001 minutes (90°; north = positive) or 0.016 minutes depending on value of position resolution field |
| Longitude | 20 | resolution = 0.001 minutes (180°; east = positive) or 0.032 minutes depending on value of position resolution field |
| Position resolution field | 1 | Same as value contained in UTC Time Request message |
| UTC time (hours and minutes) | 11 | 5 bits for UTC hours (0-23); 6 bits for UTC minutes (0-59). |
| Time slot ID | 12 | Number of time slots since start of UTC second, defining slot ID used for this reply (slot ID = KX + this subfield, where K=number of slots per second for protocol mode of operation; and X=UTC seconds since start of UTC minute) |
| Altitude | 12 | resolution = 16 ft (4.876 m) (0 - 19.7 km) |
| Timestamp | 6 | UTC seconds from start of minute (0 - 59); 61 indicates time not available from this station; 63 indicates position is not available (*e.g.* GNSS receiver is not navigating) |
| Climb/descend indicator | 2 | 0 = maintaining altitude;<br>1= climbing; 2= descending;<br>3= GNSS altitude not determined (2D navigation) |
| GNSS Sync | 1 | 0= not GNSS time sync'd; 1= GNSS time sync |
| DGNSS | 1 | 0= GNSS navigation; 1= DGNSS navigation |
| UTC month and day | 9 | 4 bits for UTC month (1-12); 5 bits for UTC day (0-31) |
| Spare | 17 | |
| Total message length | 123 | |

**Table 3-10: Burst Type 6: Compressed Unnumbered Information (UI) Frame**

| Message Parameter/Field | Field length (bits) | Format and interpretive notes |
|---|---|---|
| Mobile ID (Source addr) | 24 | ICAO ID overlaid with CRC (24 bits) |
| Message type | 7 | 6 (binary 0000110) |
| Broadcast Service Access Point | 8 | |
| Spare | 1 | |
| Destination class | 3 | The broadcast address to which the message is broadcast. |
| User data | 80 | User-specified |
| Total message length | 123 | |

**Messages transmitted from ground-controlled mobile stations**

Certain control traffic associated with users operating under active ground control is identified by Control Burst message types between 32 and 63. Autonomous users are prevented from autonomously accessing slots within 4 positions of a slot occupied by a control burst with message type $\geq$ 32. However, any user can access any slot if commanded to do so by a ground station.

**Burst Type 32: User Sync (Polled)**

This message type is identical to Type 0 described in Paragraph 3.3.1.3, with the following exceptions: (1) message type = 32 (0100000); and (2) the TIME OFFSET field is replaced with an extended-length slot time-out counter (in minutes) defining the time-out interval commanded by the ground station (a one-shot position poll/response would be indicated by a 0 time-out). This message type is employed by a user under active ground control, when slot assignments, update rate, reporting resolution and other parameters are under specific control of the ground station. Type 0 messages are not transmitted by a station that is transmitting Type 32 messages.

**Messages transmitted from ground stations**

**Polling Message (Command)**

This command autotunes one STDMA station to a specified frequency, slot assignments, update interval, time-out interval, and position reporting resolution (used for setting lat/long resolution in Type 0 and 32 messages).

If FIRST ALLOCATED TIME SLOT > 9000, the identified user shall interpret the message as a command to enter pseudo-autonomous mode with the commanded update rate (*i.e.* mobile station selects reporting slots to approximate the commanded update interval consistent with other traffic on the channel). The identified mobile station shall respond with a Type 0 message (autonomous position report) in this mode.

If TIME-OUT COUNTER = 0, the identified user shall interpret the message as a one-shot poll and shall remain in autonomous mode after responding in the indicated timeslot.

**Table 3-11: Burst Type 64: Polling Command**

| Message Parameter/Field | Field length (bits) | Format and interpretive notes |
|---|---|---|
| Source ID | 24 | ICAO-unique ID with CRC |
| Message ID | 7 | 1000000 |
| Destination ID | 24 | ICAO-unique ID |
| First allocated time slot | 16 | numbered from start of frame (start of UTC minute) |
| Time increment | 16 | second time slot commanded = first allocated time slot + increment |
| Time-out counter | 4 | Number of minutes transmission (0 implies stop after this minute) |
| Radio channel | 4 | |
| Position report resolution flag | 1 | 0 = low res (default); 1 = high res |
| Spare | 27 | |
| Total message length | 123 | |

**Burst Type 65: Acknowledgment**

This message has identical structure to message type 1. However, only the RR and SREJ functionality is required; resource request functionality is not required for ground stations.

**Burst Type 66: ID Request**

This message has identical structure to message type 2.

**Burst Type 69: UTC Time Report**

This message has identical structure to message type 5.

**Burst Type 70: Contention Resolution**

This message type contains a source ID, message type and list of slot IDs which appeared garbled at the ground station. Each slot ID consumes 14 bits (*i.e.* to uniquely define one of 9000 slots per minute). One contention resolution message can identify 6 apparently garbled time slots.

**Burst Type 71: System Configuration**

This message type describes the usage and allocation of TDMA slots on the channel.

**Burst Type 72: Directory of Services**

Describes key functions available on other VHF frequencies.

**Table 3-12: Burst Type 71: System Configuration**

| Message Parameter/Field | Field length (bits) | Format and interpretive notes |
|---|---|---|
| Source ID | 24 | ICAO-unique ID with CRC |
| Message ID | 7 | 1000111 |
| Superframe length (measured in slots) | 13 | Defines typical update interval for synchronization and position reporting |
| Number of voice circuits | 3 | 0-4 voice circuits |
| Squelch window | 3 | |
| Reserved slots (measured from start of superframe) | 13 | 0-8190, or ALL |
| Services supported on this channel | 16 | interpreted as 16 separate YES/NO toggles for 16 potential services. |
| Adjacent frequency #1 | 11 | |
| Adjacent frequency #2 | 11 | |
| Adjacent frequency #3 | 11 | |
| Spare | 11 | |
| Total message length | 123 | |

**Table 3-13: Burst Type 72: Directory of Services**

| Message Parameter/Field | Field length (bits) | Format and interpretive notes |
|---|---|---|
| Source ID | 24 | ICAO-unique ID with CRC |
| Message ID | 7 | 1001000 |
| Adjacent frequency #1 | 11 | |
| Adjacent frequency #2 | 11 | |
| Adjacent frequency #3 | 11 | |
| Services supported on frequency # 1 | 16 | interpreted as 16 separate YES/NO toggles for 16 potential services. |
| Services supported on frequency # 2 | 16 | interpreted as 16 separate YES/NO toggles for 16 potential services. |
| Services supported on frequency # 3 | 16 | interpreted as 16 separate YES/NO toggles for 16 potential services. |
| Spare | 11 | |
| Total message length | 123 | |

Burst Type 73: Reservation Response

This message responds to one or two airborne users' requests for channel resources. It can signal actual reservations, or acknowledge receipt of resource requests. In the latter case, the actual reservation is assumed to be pending.

**Table 3-14: Burst Type 73: Reservation Response**

| Message Parameter/Field | Field length (bits) | Format and interpretive notes |
|---|---|---|
| Source ID | 24 | ICAO-unique ID with CRC |
| Message ID | 7 | 1001001 |
| Mobile user ID #1 | 24 | identifies source of reservation request |
| First reserved slot for Mobile user ID #1 | 14 | 0-9000. If greater than 9000, indicates reservation pending |
| Priority of reservation request being serviced (Mobile user ID#1) | 4 | Matches priority of reservation request. Allows multiple reservation requests to be pending at one time (one per priority level) |
| Mobile user ID #2 | 24 | identifies source of reservation request |
| First reserved slot for Mobile user ID #2 | 14 | 0-9000. If greater than 9000, indicates reservation pending |
| Priority of reservation request being serviced (Mobile user ID#2) | 4 | Matches priority of reservation request. |
| Spare | 8 | |
| Total message length | 123 | |

**Burst Type 74: Recovery Flag**

This message is used to inform aircraft that the ground station is in the link recovery state. This message invokes recovery procedures in the aircraft LME.

*Note.− This message is provided to maintain compatibility with IVAD VDL; it may be superceded by the standard VDL broadcast XID recovery mechanism.*

**Table 3-15: Burst Type 74: Recovery Flag**

| Message Parameter/Field | Field length (bits) | Format and interpretive notes |
|---|---|---|
| Source ID | 24 | ICAO-unique ID with CRC |
| Message ID | 7 | 1001010 |
| Spare | 92 | |
| Total message length | 123 | |

### 3.3.2 Protocol definition for user bursts

The DLS frame format for user bursts is illustrated in Table 3-16. The DLS protocol for User Bursts shall conform to the VDL SARPs Mode 2 except as described below.

#### 3.3.2.1 Broadcast services

An STDMA station shall transmit one and only one Broadcast Subnetwork Dependent Convergence Function (BSNDCF) packet in a UI (P=0) frame.

*Note.– Most STDMA functions are expected to be performed with unnumbered information (UI) frames.*

**Table 3-16: DLS Frame Format for User Bursts**

| Description | Octet # | Bit number | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| Flag | - | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| Destination address field | 1 | | | | | | | A/G | 0 |
| | 2 | | | | | | | | 0 |
| | 3 | | | | | | | | 0 |
| | 4 | | | | | | | | 0 |
| Source address field | 5 | | | | | | | C/R | 0 |
| | 6 | | | | | | | | 0 |
| | 7 | | | | | | | | 0 |
| | 8 | | | | | | | | 1 |
| Link control field | 9 | | | | P/F | | | | |
| Information | N-2 | | | | User | data | | | |
| Frame check sequence | N-1 | | | | | | | | |
| | N | | | | | | | | |
| Flag | - | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |

### 3.3.3 DLS parameters

The DLS sublayer timers and parameters for an STDMA station shall conform [to the VDL SARPs DLS sublayer timers and parameters for Mode 2, except as modified below.]

#### 3.3.3.1 T1 Timer (delay before retransmission)

If the value of the TD99 XID parameter (specifying the 99th percentile of expected transmit delay) is set to 0, the procedures of the VDL SARPs (Mode 2) shall be used. Otherwise, the T1 timer shall be set to the value of TD99.

#### 3.3.3.2 T2 Timer (delay before acknowledgement)

The T2 timer is not implemented in STDMA stations. The delay before internal initiation of an acknowledgement process shall be less than one slot (6.67 msec). Acknowledgements shall be piggybacked on pending transmissions, if possible.

#### 3.3.3.3 T4 Timer (maximum delay between transmissions)

The T4 timer is not implemented in STDMA stations. The equivalent function is provided by MAC-layer parameter specifying Type 0 Control Burst Update Interval.

#### 3.3.3.4 Parameter k (window size)

This parameter has the same meaning as in the VDL SARPs for Mode 2; it must be understood that "frame" in the context of parameter k refers to an outstanding DLS packet as opposed to an STDMA frame of 9000 access slots.

### 3.3.4 DLS procedures

DLS procedures shall [conform to VDL SARPs Mode 2 except as noted below.]

#### 3.3.4.1 Broadcast messages

Broadcast messages shall be processed.

#### 3.3.4.2 Transmit queue management

The transmit queue manager shall maintain three transmit queues, each in priority order: the two transmit queues specified in the VDL SARPs (supervisory and information) and a queue containing STDMA bursts. Where relevant, messages shall be tagged with a preplanned transmit slot (*e.g.* Type 0 STDMA Bursts) and associated Busy_override parameters (BO = 0/1). The transmit queue manager shall receive from the MAC sublayer a list of upcoming transmit opportunities, and shall schedule the pending communication events relative to this list. Scheduled DLS frames shall be passed to the MAC sublayer in their scheduled order along with an indication of the intended (starting) slot for transmission and BO status.

#### 3.3.4.3 Supervisory data

Supervisory data shall be piggybacked on pending communications where possible. If there is no pending communications activity, supervisory data shall be handled with compressed supervisory bursts.

### 3.3.5 Validation of DLS sublayer using FM/GMSK

#### 3.3.5.1 DLS sublayer services for FM/GMSK

DLS services for validation using FM/GMSK differ from those for D8PSK in the following respects.

**FCS generation and error detection**

The DLS sublayer shall calculate a Frame Check Sequence over the Information subfield of the DLS frame, per ISO 3309, and insert it in the appropriate subfield of the DLS frame. Errors in reception shall be detected in the link layer by the FCS per ISO 3309. If the computed FCS does not match the transmitted FCS, the frame shall be discarded.

**Determination of message type**

Message type shall be determined by the first byte of the information subfield indicated in Table 3-17.

**Station identification**

For validation using FM/GMSK, each airborne and ground radio shall be assigned an address. Source or destination address information shall be encoded following the 8-bit message type in the information subfield indicated in Table 3-17. Address subfields shall provide for a 48-bit address space as indicated in Section 3.3.5.2.2 and its subsections.

*Note.− The message type will determine whether the address information refers to source address, destination address or both. The 48-bit address space provides capability to support a 24-bit address such as an ICAO-unique address (or equivalent), or a flight number or tail number encoded as eight characters of 6-bit compressed ASCII. When using a 24-bit address, the address should be padded on the right with 24 1's.*

Bit stuffing

Bit stuffing/destuffing shall be performed.

User data

STDMA data is not differentiated from user data at the DLS sublayer when validation is performed using FM/GMSK. Only STDMA bursts are defined. User data may be transmitted as a free-text message using STDMA message type 32. ATN-compliant data transfer is not supported.

3.3.5.2 DLS sublayer protocol specification for FM/GMSK

Frame format

The DLS frame format for FM/GMSK shall be of variable length demarcated by frame flags, and shall consist of the elements illustrated in Table 3-17.

Table 3-17: DLS Frame format for STDMA/GMSK

| Description | Octet # | Bit number | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| Flag | - | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| HDLC address (extended start flag) | 1 | | | | | | | | |
| Information subfield | 2 to (N-2) | See Section 3.3.5.2.2 for a description of the message elements contained in this subfield, as a function of message type. | | | | | | | |
| Frame check sequence | (N-1) | | | | | | | | |
| | N | | | | | | | | |
| Flag | - | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |

**Library of STDMA bursts for validation with FM/GMSK**

STDMA bursts for validation with FM/GMSK are listed and summarized in Table 3-18 and detailed below. Messages with type fields < 64 shall be reserved for autonomous mobile users. Messages with type fields between 64 and 127 shall be reserved for mobile users operating under ground control. Messages with type fields ≥ 128 shall be reserved for fixed ground stations.

**Type 1: Autonomous Position Report**

The autonomous position report shall provide an unambiguous, fixed-resolution report of user position, velocity, altitude, turn indication, altitude change status, timestamp and communications status. Message fields are described in Table 3-19. On transmit, information for these fields shall be provided by the application layer, optionally processed through the presentation layer for encryption. On receive, information from these fields shall be provided to the presentation layer for optional processing and ultimate delivery to the application layer.

**Table 3-18: Summary of STDMA message types for validation with FM/GMSK**

| Type | Name | Function | Notes |
|---|---|---|---|
| 1 | Position report | Report position, velocity, status | |
| 2 | Encrypted position report | Report position, velocity, status | |
| 7 | Resource request | Allows airborne user to request channel resources on a dedicated-access basis (i.e. not random access) | |
| 32 | Message to mobile or base station | Free text for air-to-air or air/ground communication (addressed) | |
| 33 | ACK of received message | ACK of free text message | |
| 34 | Common message | Free text for air-to-air or air/ground communication (broadcast) | |
| 35 | ID request | Request flight number or tail number | |
| 36 | ID report | Associate flight number or tail number with ICAO-unique ID | |
| 62 | UTC time inquiry | Request UTC time | |
| 63 | Reply to time inquiry | Transmit current UTC time, if avail. | |
| 65 | Position report (polled) | Report position, velocity, status | |
| 66 | Encrypted position report (polled) | Report position, velocity, status | |
| 129 | Polling message | Autotune command (frequency, slot assignment(s), time-out interval | |
| 160 | Message to mobile or base station | Free text for ground-to-air communications (addressed) | |
| 161 | ACK of received message | ACK of received free-text message (addressed) | |
| 162 | Common message | Free text for ground-to-air communications (broadcast) | |
| 171 | DGNSS corrections - RTCM | Transmit differential GNSS corrections (RTCM V2.0 messages) | Any RTCM/SC-104 message |
| 172 | DGNSS corrections - RTCA | Transmit differential corrections (RTCA/DO-217, Appendix A) | Any RTCA/DO-217 message190 |
| 190 | UTC time inquiry | Request UTC time | |
| 191 | Reply to UTC time inquiry | Transmit current UTC time, if avail. | |
| 200 | Correlated surveillance picture | Transmit correlated surveillance picture (all mobiles known to gnd stn) | |
| 210 | Contention resolution | Identify slots with garbled messages | |
| 211 | Directory of services | Describe applications available on this frequency, and list other frequencies that are active in the airspace | |
| 212 | Reservation response | Respond to resource request | |

**Table 3-19: Autonomous position report**

| Message Parameter/Field | Field length (bits) | Format and interpretive notes |
|---|---|---|
| Message type | 8 | 00000001 |

| | | |
|---|---|---|
| Mobile ID | 48 | 8 characters of 6 bits each |
| Latitude | 24 | Resolution = 0.001 minutes (90°; north = positive) |
| Longitude | 25 | Resolution = 0.001 minutes (180°; east = positive) |
| Speed | 11 | Resolution = 2 kts (0 - 4095 kts) |
| Heading/direction | 12 | Resolution = 0.1 degrees (0 - 359.9) |
| Altitude | 12 | Resolution = 16 ft (4.876 m) (0 - 19.7 km) |
| Timestamp | 6 | UTC seconds from start of minute (0 - 59); 63 indicates GNSS receiver is not navigating |
| Climb/descend indicator | 2 | 0 = maintaining altitude; 1 = climbing; 2 = descending; 3 = GNSS altitude not determined (2D navigation) |
| GNSS Sync | 1 | 0 = not GNSS time sync'd; 1 = GNSS time sync |
| DGNSS | 1 | 0 = GNSS navigation; 1 = DGNSS navigation |
| Slot time-out counter | 2 | 0 = last transmission in this time slot; 1 = 1 minute left to change; 2 = 2 minutes left to change; 3 = 3 or more minutes left to change. |
| Time offset | 8 | After slot time-out, entity with ID indicated at layer 2 will occupy slot offset this amount (±127 slots) from current slot. Value of 128 indicates new slot position will be greater than 127 slot positions from current position. |
| Total message length | 160 | |

**Type 2: Encrypted position report**

This message type shall be structurally identical to Type 1 at the DLS sublayer and functionally identical to Type 1 at the application layer.

*Note.− Crypto is applied to the lat/long, speed, heading/direction, altitude and (a portion of the) timestamp subfield at the presentation layer.*

**Type 7: Resource request**

This message type provides a mechanism for an airborne (or ground-based) user to request dedicated-access channel resources for user communications. As indicated in Table 3-20, it shall include the ID of the airborne or ground-based mobile user, the ID of the ground station of which the request is made, the number of slots requested, and the priority of the intended communications. Note that short messages can be sent on an autonomous, random-access basis or a more robust dedicated access basis using this control message and the associated Reservation Response message described below. A long message (length greater than *Maxlength*) can be sent in a single packet if a resource has been specifically dedicated to the airborne user for this purpose; otherwise, a long message must be segmented for transmission.

**Table 3-20: Resource request**

| Message Parameter/Field | Field length (bits) | Format and interpretive notes |
|---|---|---|
| Message type | 8 | 00000111 |
| Source ID | 48 | 8 characters of 6 bits each. |
| Destination ID | 48 | 8 characters of 6 bits each. If ICAO-unique 24-bit address is used, it shall be encoded in upper 3 bytes. This information is manipulated and reformatted as required at the presentation and data link layer. Source ID is added at the data link layer in Mode 2 and Mode 3. |
| Number of slots requested | 12 | |
| Data priority | 4 | |
| Total message length | 120 | |

### Type 32: Message to mobile or base station

This is an addressed message to a specific intended recipient. Data shall be transmitted in the form of 6-bit packed ASCII characters. The text message shall be limited to 63 ASCII characters maximum following the message ID subfield. Should a longer text message be required, this can be achieved by transmitting several blocks and using the option bits. Note that multiple blocks can be transmitted in a single physical layer frame, up to the limit imposed by the Maxlength parameter defined in Section 3.2.2.1. Interpretation of specific subfields is defined in Table 3-21.

**Table 3-21: Point-to-point addressed message**

| Message Parameter/Field | Field length (bits) | Format and interpretive notes |
|---|---|---|
| Message type | 8 | 00100000 |
| Source ID | 48 | 8 characters of 6 bits each. |
| Destination ID | 48 | 8 characters of 6 bits each. If ICAO-unique 24-bit address is used, it shall be encoded in upper 3 bytes. This information is manipulated and reformatted as required at the presentation and data link layer. Source ID is added at the data link layer in Mode 2 and Mode 3. |
| Length/option | 8 | 2-bit option field (includes continuation flag); 6 bit length field defining number of 6-bit packed ASCII characters ($\leq$63) |
| Message data | 6N | N 6-bit packed ASCII characters |

Type 33: ACK of received message

This message acknowledges error-free receipt of a Type 32. It shall consist of an 8-bit message ID (=33), 48 bits transmitter ID (8 characters of 6 bits each), 48 bits receiver ID (8 characters of 6 bits each), and 2 bits status (set equal to the option field in the Type 32 message being acknowledged).

Type 34: Common message

This is similar to a Type 32, but with a broadcast destination address applied at the link layer. No acknowledgment is required.

Type 35: ID request

This message is intended to generate a response from one or several STDMA stations, so that a correlation can be made between ICAO-unique ID(s) and flight number(s) or tail number(s). The format is specified in Table 3-22 below. An ID request can be addressed to a specific ICAO-unique user ID, a specific flight number or tail number, or broadcast to all aircraft within [10 nmi] of a specified location.

**Table 3-22: ID request**

| Message Parameter/Field | Field length (bits) | Format and interpretive notes |
|---|---|---|
| Message type | 8 | 00100011 |
| Destination ID* | 48 | 24-bit ICAO ID or equivalent, 48-bit flight number or tail number (8 6-bit characters), or BCST (000....0) |
| Latitude** | 20 | High-order bits or NULL (000...0) |
| Longitude** | 20 | High-order bits or NULL (000...0) |
| Total message length | 72 | |

* ICAO ID is padded on the right with 1's. This sequence acts as a tag to differentiate 24-bit ICAO-unique ID's from 48-bit ASCII identifiers.

**Lat/long fields are interpreted if and only if Destination ID is identically 0.

**Type 36: ID report**

This message is a response to a Type 35. An STDMA station may generate a Type 36 ID report intended to correlate its ICAO-unique ID with its tail number or flight number. This may be useful as a prelude to voice communications or automatic data exchange to support future applications.

The Type 36 ID report consists of an 8 bit message type field followed by a 48 bit Mobile ID field. If the ID Request contained an ICAO ID, the Mobile ID field shall be stuffed with the tail number or flight number. If the ID Request contained a flight number or tail number, the Mobile ID field shall be stuffed with the ICAO ID.

**Type 62: UTC Time inquiry**

Time inquiries can be used for synchronization in the event that GNSS or UTC time is unavailable (e.g. due to hardware malfunction). It shall consist of a destination ID associated with the entity from which time synchronization is desired, as indicated in Table 3-23 below.

**Table 3-23: Subfield Definitions for UTC Time Inquiry**

| Message Parameter/Field | Field length (bits) | Format and interpretive notes |
|---|---|---|
| Message type | 8 | 00111110 |
| Source ID | 48 | 8 characters of 6 bits each. |
| Destination ID | 48 | 8 characters of 6 bits each. If ICAO-unique 24-bit address is used, it shall be encoded in upper 3 bytes and padded on the right with 1's. |
| Total message length | 104 | |

### Type 63: Reply to time inquiry

The reply to a time inquiry shall follow the format indicated in Table 3-24 below. Time shall be extrapolated to the start time of the message slot that will be used to transmit the message.

*Note 1.− The combination of time source location, UTC time and time slot ID provide sufficient information to support time synchronization.*

*Note 2.− This message type differs from the standard Type 1 position report in the following ways: (1) speed and heading/direction are replaced with time and slot ID; (2) change of time slot information (TIME-OUT counter and OFFSET) is replaced with date.*

*Note 3.− In the event that a STDMA station is not synchronized to UTC time, all received time messages should be processed. Three consecutive time messages should agree before local time is updated (this prevents synchronization on an erroneous time message). However, the requirement for three time messages in agreement does not apply if the STDMA station generated the initial request for time.*

Table 3-24: Reply to time inquiry

| Message Parameter/Field | Field length (bits) | Format and interpretive notes |
|---|---|---|
| Message type | 8 | 00111111 |
| Destination ID | 48 | 8 characters of 6 bits each. |
| Latitude | 24 | Resolution = 0.001 minutes (90°; north = positive). |
| Longitude | 25 | Resolution = 0.001 minutes (180°; east = positive). |
| UTC time (hours and minutes) | 11 | 5 bits for UTC hours (0-23); 6 bits for UTC minutes (0-59). |
| Time slot ID | 12 | Number of time slots since start of UTC second, defining slot ID used for this reply (slot ID = KX + this subfield, where K=number of slots per second (150); and X=UTC seconds since start of UTC minute). |
| Altitude | 12 | Resolution = 16 ft (4.876 m) (0 - 19.7 km). |
| Timestamp | 6 | UTC seconds from start of minute (0 - 59); 63 indicates GNSS receiver is not navigating. |
| Climb/descend indicator | 2 | 0 = maintaining altitude;<br>1= climbing;<br>2= descending;<br>3= GNSS altitude not determined (2D navigation). |
| GNSS Sync | 1 | 0= not GNSS time sync'd; 1= GNSS time sync. |
| DGNSS | 1 | 0= GNSS navigation; 1= DGNSS navigation. |
| UTC month and day | 9 | 4 bits for UTC month (1-12); 5 bits for UTC day (0-31). |
| Spare | 1 | N/A |
| Total message length | 160 | |

Type 65: Position report (polled)

Same overall format as Type 1, but transmitted from a ground-controlled mobile. TIME OFFSET subfield shall be replaced with an extended-length slot time-out counter (in minutes) defining the time-out interval commanded by the ground station.

*Note.– Should no new allocation to this STDMA station be made by the ground station, the mobile will cease transmit operations in the assigned slot when the time-out counter reaches 0, and will initiate operations in an autonomous mode.*

*Note.– The normal interpretation of the TIME OFFSET subfield is irrelevant in ground-controlled mode since the ground station makes all scheduling decisions.*

### Type 66: Encrypted position report (polled)

Same overall format as Type 2, but transmitted from a ground-controlled mobile. TIME OFFSET subfield is replaced with an extended-length slot time-out counter (in minutes) defining the time-out interval commanded by the ground station.

*Note 1.− Should no new allocation to this STDMA station be made by the ground station, the mobile will cease transmit operations in the assigned slot when the time-out counter reaches 0, and will initiate operations in an autonomous mode.*

*Note 2.− The normal interpretation of the TIME OFFSET subfield is irrelevant in ground-controlled mode since the ground station makes all scheduling decisions.*

### Type 129: Polling message

This message autotunes one or more STDMA stations to specified frequencies, slot ID(s), update intervals, and time-out interval(s). The format is indicated in Table 3-25.

If FIRST ALLOCATED TIME SLOT > 9000, the identified user shall interpret the message as a command to enter pseudo-autonomous mode with the commanded update rate (i.e. mobile station selects reporting slots to approximate the commanded update interval consistent with other traffic on the channel). Mobile shall respond with a Type 1 position report in this mode.

*Note.− The allocated binary polling ID is a short-term, compact ID assigned to the mobile by the ground station to support efficient polling operations.*

### Type 160: Message to mobile or other base station

Structure is identical to Message Type 32. Message type subfield = 10100000.

### Type 161: ACK of received message

Structure is identical to Message Type 33. Message type subfield = 10100001.

### Type 162: Common message

Structure is identical to Message Type 34. Message type subfield = 10100010.

### Type 171: DGNSS corrections - RTCM

The information subfield shall consist of one full message as defined in RTCM SC-104 V2.0.

*Note.− All DGNSS messages in the SC-104 standard are supported as subtypes of this message type. The message type field contained in the information subfield differentiates among separate functions.*

Table 3-25: Polling message format

| Message Parameter/Field | Field length (bits) | Format and Interpretive Notes |
|---|---|---|
| Message ID | 8 | 10000001 |

| | | |
|---|---|---|
| Source ID | 48 | 8 characters of 6 bits each. |
| Destination ID (mobile #1) | 48 | 8 characters of 6 bits each. If ICAO-unique 24-bit address is employed, it shall be encoded in the upper (most significant) 3 bytes. |
| Allocated binary polling ID | 16 | Used for subsequent addressing of mobiles in compact format |
| First allocated time slot | 16 | numbered from start of frame (start of UTC minute). |
| Time increment | 16 | second time slot commanded = first allocated time slot + increment. |
| Time-out counter | 4 | Number of minutes transmission (0 implies stop after this minute). |
| Radio channel | 4 | |
| Position report resolution flag* | 1 | 0=low res (default); 1=high res. |
| Total | 84 | |

*Not used.

### Type 172: DGNSS corrections - RTCA

The information subfield shall consist of one full message as defined in RTCA/DO-217 Appendix A.

*Note 1.– All DGNSS messages in the DO-217 standard are supported as subtypes of this message type. The message type field contained in the information subfield differentiates among separate functions.*

*Note 2.– Both Type 171 and Type 172 correction messages support DGNSS message subtype 2: Delta corrections. These are available as part of the relevant standards, but should never be transmitted. To conserve bandwidth, corrections are calculated on “old” ephemerides for the first 5 minutes following a change of navigation data from a spacecraft.*

*Note 3.– There are substantial differences between the RTCM and RTCA standards for DGNSS corrections. The RTCM standard has a more complete message set and supports a range of applications; however, its detailed performance characteristics make it inappropriate for critical phases of flight such as precision approach. The RTCA standard was specifically developed to support DGNSS Instrument Approach Procedures: Special Category I. STDMA flexibility is enhanced by providing support for both standards.*

### Type 190: UTC time inquiry

Identical to Message Type 62 at the application layer (with exception of Message ID, which is set to 10111110).

### Type 191: Reply to UTC time inquiry

Identical to Message Type 63 (with exception of Message ID, which is set to 10111111).

*Note.– Ground stations should schedule Type 191 messages at regular intervals to support time synchronization in the local airspace. With multiple ground stations performing this function (or one ground station plus several mobiles), STDMA stations unable to determine their own position via GNSS can develop a rough estimate of system time and vehicle location with sufficient accuracy to support channel access and en route position reporting.*

### Type 200: Correlated surveillance product

This message type reports the position/speed/heading of targets under track in a compact format suitable for CDTI applications. If the ground station has access to STDMA data only, this message will simply rebroadcast the incoming data suitably manipulated for compactness, and updated to a common time reference. If the ground station has access to a source of correlated surveillance data, this message may include target reports due to other surveillance systems such as Mode S squitter and ground-based radar.

Each target shall be represented by [56] bits in accordance with Table 3-26. IDs and other information are suppressed to conserve bandwidth.

*Note 1.– This message type can become lengthy in dense airspace, with frame overhead representing a small fraction of total message length.*

*Note 2.– The full surveillance picture may be divided into multiple layer 1 frames for transmission in order to avoid long periods of continuous channel occupancy. [30 - 50] target reports per message may represent a reasonable operating point.*

**Table 3-26: Data format for target report in correlated surveillance product**

| Information | Number of bits (all these values are tentative!) | Notes |
|---|---|---|
| Position | 34 | Combined latitude and longitude. Specific format TBD. Resolution on the order of 256-512 feet at the equator should be acceptable. |
| Speed | 7 | Encoding technique TBD. Probably use logarithmic scale. |
| Heading | 7 | Resolution = 3.2 degrees. |
| Altitude | 8 | Encoding technique TBD |
| Total per target | 56 | |

### Type 210: Contention resolution message

This message type contains a list of slot IDs which appeared garbled at the ground station. The message structure consists of a MESSAGE TYPE ID (11010010) followed by N slot IDs. Each slot ID consumes 14 bits (*i.e*. to define uniquely one of 9000 slots per minute).

*Note 1.− Garbling is a likely result of multiple access attempts in the same slot. However, on a ground-controlled channel, garbling due to multiple access attempts can occur only among uncontrolled users during network entry. This is a very low-probability event. Nevertheless, this message type is defined to quickly resolve the contention and allow the (two or more) contending users to select empty slots for declaration of network entry.*

*Note 2.− When multiple consecutive slots are garbled, a ground station may conserve throughput resources by indicating only every fourth slot.*

### Type 211: Directory of Services

Describes key functions available on other VHF frequencies.

Table 3-27: Type 72: Directory of Services

| Message Parameter/Field | Field length (bits) | Format and interpretive notes |
|---|---|---|
| Source ID | 48 | ICAO-unique ID with CRC |
| Message ID | 8 | 11010011 |
| Adjacent frequency #1 | 11 | |
| Adjacent frequency #2 | 11 | |
| Adjacent frequency #3 | 11 | |
| Services supported on frequency # 1 | 16 | interpreted as 16 separate YES/NO toggles for 16 potential services. |
| Services supported on frequency # 2 | 16 | interpreted as 16 separate YES/NO toggles for 16 potential services. |
| Services supported on frequency # 3 | 16 | interpreted as 16 separate YES/NO toggles for 16 potential services. |
| Total message length | 137 | |

Type 212: Reservation Response

This message responds to one or two airborne users' requests for channel resources. It can signal actual reservations, or acknowledge receipt of resource requests. In the latter case, the actual reservation is assumed to be pending.

Table 3-28: Type 73: Reservation Response

| Message Parameter/Field | Field length (bits) | Format and interpretive notes |
|---|---|---|
| Source ID | 48 | ICAO-unique ID with CRC |
| Message ID | 8 | 11010100 |
| Mobile user ID #1 | 24 | identifies source of reservation request |
| First reserved slot for Mobile user ID #1 | 14 | 0-9000. If greater than 9000, indicates reservation pending |
| Priority of reservation request being serviced (Mobile user ID#1) | 4 | Matches priority of reservation request. Allows multiple reservation requests to be pending at one time (one per priority level) |
| Mobile user ID #2 | 24 | identifies source of reservation request |
| First reserved slot for Mobile user ID #2 | 14 | 0-9000. If greater than 9000, indicates reservation pending |
| Priority of reservation request being serviced (Mobile user ID#2) | 4 | Matches priority of reservation request. |
| Total message length | 140 | |

### 3.4 Link management entity sublayer

The LME shall [conform to the VDL SARPs using the Mode 2 parameter values, except as described below.]

*Note.– The LME is required to support ATN, but is not required for STDMA-specific services.*

### 3.4.1 VDL private parameters

Bit 4 of Table 3-2 (Modulation scheme and bit rate) of the VDL SARPs shall be redefined as shown in Table 3-29.

Table 3-29. Expanded Modulation Scheme and Bit Rate

| Bit | Name | Encoding | |
|---|---|---|---|
| 4 | STDMA | 0 | (Not STDMA) |
| | | 1 | STDMA at 31500 bit/s |

### 3.4.2 STDMA private parameters

The naming convention and functional breakdown for STDMA private parameters shall conform to the VDL SARPs.

#### 3.4.2.1 General information private parameters

STDMA private parameter set identifier
The STDMA parameter set is identified by the ISO IA5 character capital 'S' encoded as per table 3-30. This parameter shall be included whenever any of the STDMA private parameters are to be sent. It shall be the first private parameter sent as per ISO 8885.

Table 3-30. STDMA Private Parameter Set Identifier Parameter Encoding

| Field | Bit Encoding | Notes |
|---|---|---|
| Parameter ID | 0 0 0 0 0 0 0 0 | Parameter set identifier |
| Parameter len | 0 0 0 0 0 0 0 1 | |
| Parameter val | 0 1 0 1 0 0 1 1 | Character S |

#### 3.4.2.2 Aircraft-initiated information private parameters

[TBD]

#### 3.4.2.3 Ground-initiated modification private parameters

M2 parameter
This parameter defines the value of M2 that an aircraft shall use, encoded as a 16-bit unsigned integer as per Table 3-31.

Table 3-31. M2 Parameter Encoding

| Field | Bit Encoding | Notes |
|---|---|---|
| Parameter ID | 0 1 0 0 0 0 0 0 | M2 parameter |
| Parameter len | 0 0 0 0 0 0 1 0 | |
| Parameter val | $n_{16}$ $n_{15}$ $n_{14}$ $n_{13}$ $n_{12}$ $n_{11}$ $n_{10}$ $n_9$ | |
| | $n_8$ $n_7$ $n_6$ $n_5$ $n_4$ $n_3$ $n_2$ $n_1$ | |

T5min parameter
This parameter defines the value of T5min that an aircraft shall use, encoded as a 16-bit unsigned integer as per Table 3-32.

Table 3-32. T5min Parameter Encoding

| Field | Bit Encoding | Notes |
|---|---|---|
| Parameter ID | 0 1 0 0 0 0 0 1 | T5min parameter |
| Parameter len | 0 0 0 0 0 0 1 0 | |
| Parameter val | $n_{16}$ $n_{15}$ $n_{14}$ $n_{13}$ $n_{12}$ $n_{11}$ $n_{10}$ $n_9$ | |
| | $n_8$ $n_7$ $n_6$ $n_5$ $n_4$ $n_3$ $n_2$ $n_1$ | |

TD99 parameter

This parameter defines the value of TD99 that an aircraft shall use, encoded as a 16-bit unsigned integer as per Table 3-33.

Table 3-33. TD99 Parameter Encoding

| Field | Bit Encoding | Notes |
|---|---|---|
| Parameter ID | 0 1 0 0 0 0 1 0 | TD99 parameter |
| Parameter len | 0 0 0 0 0 0 1 0 | |
| Parameter val | $n_{16}$ $n_{15}$ $n_{14}$ $n_{13}$ $n_{12}$ $n_{11}$ $n_{10}$ $n_9$ | |
| | $n_8$ $n_7$ $n_6$ $n_5$ $n_4$ $n_3$ $n_2$ $n_1$ | |

3.4.2.4 Ground-initiated information private parameters

**Short Broadcast Service Access Point (BSAP) availability**

This parameter, encoded per Table 3-34 and which may be repeated, shall state the availability of various one-octet BSAPs on a particular frequency. The mode subfield (m bits), encoded per Table 3-21 of the VDL SARPs, shall indicate the mode that the transmissions shall use. The frequency subfield (f bits), encoded as Integer[ (freq_in_MHz) * 100) - 10000], shall be the frequency that this parameter applies to. The BSAP subfield (b bits), encoded as a list of one or more 8-bit integers, shall be a list of BSAPs available on the designated frequency.

Table 3-34: Short BSAP Availability Parameter Encoding

| Field | Bit Position | Notes |
|---|---|---|
| Parameter ID | 1 1 0 0 0 0 0 0 | Short BSAP availability |
| Parameter len | $n_8$ $n_7$ $n_6$ $n_5$ $n_4$ $n_3$ $n_2$ $n_1$ | |
| Parameter val | $m_4$ $m_3$ $m_2$ $m_1$ $f_{12}$ $f_{11}$ $f_{10}$ $f_9$ | mode / frequency |
| | $f_8$ $f_7$ $f_6$ $f_5$ $f_4$ $f_3$ $f_2$ $f_1$ | |
| | $b_8$ $b_7$ $b_6$ $b_5$ $b_4$ $b_3$ $b_2$ $b_1$ | an available BSAP |

Long BSAP availability

This parameter, encoded per Table 3-29 and which may be repeated, shall state the availability of various two-octet BSAPs on a particular frequency. The mode subfield (m bits), encoded per Table 3-21 of the VDL SARPs, shall indicate the mode that the transmissions shall use. The frequency subfield (f bits), encoded as Integer[(freq_in_MHz) * 100) - 10000], shall be the frequency to which this parameter applies. The BSAP subfield (b bits), encoded as a list of one or more 16-bit integers per Table 3-35, shall be a list of BSAPs available on the designated frequency.

Table 3-35: Long BSAP Availability Parameter Encoding

| Field | Bit Position | Notes |
|---|---|---|
| Parameter ID | 1 1 0 0 0 0 0 1 | Long BSAP availability |
| Parameter len | $n_8$ $n_7$ $n_6$ $n_5$ $n_4$ $n_3$ $n_2$ $n_1$ | |
| Parameter val | $m_4$ $m_3$ $m_2$ $m_1$ $f_{12}$ $f_{11}$ $f_{10}$ $f_9$ | mode / frequency |
| | $f_8$ $f_7$ $f_6$ $f_5$ $f_4$ $f_3$ $f_2$ $f_1$ | an available BSAP |
| | $b_{16}$ $b_{15}$ $b_{14}$ $b_{13}$ $b_{12}$ $b_{11}$ $b_{10}$ $b_9$ | |
| | $b_8$ $b_7$ $b_6$ $b_5$ $b_4$ $b_3$ $b_2$ $b_1$ | |

3.4.3 LME timers and parameters

### 3.4.3.1 Procedures

The LME shall conform to the VDL SARPs, except that the aircraft location and ground location private parameters shall not be included in any XID.

# 4. SUBNETWORK LAYER PROTOCOLS AND SERVICES

The Subnetwork Layer provides for management of all frequency channels supporting STDMA operations. This requires the maintenance of databases, for each channel, containing reporting and reported entities and channel access utilization within the STDMA frame. Control messages exchanged by active STDMA stations, previously described in Section 3.3.1.3, are used to maintain these databases.

*Note.– The database(s) may be shared with the Application layer.*

## 4.1 Functions

### 4.1.1 Determine reporting rate and channel access parameters

The STDMA station shall determine its operating mode (autonomous versus ground-controlled) and channel access parameters, identified in Table 4-1, based on default parameters and ground command.

**Table 4-1: STDMA station reporting rate and channel access parameters**

| Operating Parameter | Default Value | Default Overrides |
|---|---|---|
| Autonomous/controlled (AUTO) | Autonomous | Ground command; station shall revert to autonomous mode if polling command "times out". |
| Update interval (R1_i) | 5 seconds | Ground command. Valid range is 1 to 60 seconds. Furthermore, an STDMA station can report at higher rate (using autonomous mode) if so required to support collision avoidance or other functional requirements specified at the Application layer. |
| Time-out period (TM3_i_max) | 5 minutes for position reporting activity; 0 for all other events | Ground command |

#### 4.1.1.1 Operating mode

Operating mode shall be considered a global parameter affecting operation on all channels. The default operating mode shall be AUTONOMOUS. An STDMA station can be commanded to operate in GROUND-CONTROLLED mode by a ground station (*i.e.* based on an autotune command). STDMA stations shall revert to AUTONOMOUS mode following time-out of ground-commanded reservations.

*Note.– This parameter is determined at the Subnetwork layer and mirrored at the Application layer. Any STDMA channel operated in GROUND-CONTROLLED mode implies the STDMA station as a whole shall be operated in GROUND-CONTROLLED mode.*

#### 4.1.1.2 Update interval for channel i

The parameter R1_i shall specify the nominal interval between Type 0 STDMA bursts on channel i. The default value is R1 maintained at the Application layer. The default value can be overridded by ground command.

#### 4.1.1.3 Maximum reservation hold time for channel i

For each slot reservation associated with a Type 0 STDMA burst, the TM3 timer shall be initialized to the minimum of: (1) the number of frames for which a slot reservation for a Type 1 message can be held; or (2) the number of frames for which the associated slot is free (*e.g.* unreserved by other users).

### 4.1.2 Maintain frame map of current and future reservations

The STDMA station shall maintain a frame map describing current and future reservations for each slot in the frame, on each monitored frequency supporting STDMA operations, based on best-available data received from the channel(s).

### 4.1.3 Select unused slots for transmit access

#### 4.1.3.1 Autonomous mode

Initial access

The STDMA station shall use any uniform selection process to select slots for transmission attempts. Slots available for selection shall be unreserved and shall be at least [4] slot positions from any slot currently in use, or reserved for use, by a ground station or a ground-controlled mobile station.

In the event that the slot pool is empty, the STDMA station shall employ an overflow selection technique as specified in paragraph 4.1.5.

Continued access

For planning of ongoing access associated with position reporting activity subsequent to the time-out interval, the STDMA station shall use any uniform selection process to select slots for ongoing transmission attempts. Slots available for selection shall include all slots projected to be unreserved following the time-out event, which are within 127 slot positions of the current slot, and which also satisfy the criteria defined above. If no slots are available satisfying these criteria, the STDMA station shall apply the initial access procedure described above.

#### 4.1.3.2 Ground-controlled mode

Nominal operations

The STDMA station shall attempt transmission in slots assigned to it by ground command, with operating parameters as assigned.

**Additional transmissions**

Additional transmissions shall be supported using autonomous operating protocols. Additional transmissions or transmission attempts may be generated due to unmodeled movement, identification of potential collision threats, or other communication requirements. For these additional, nonrepetitive transmissions, SLOT TIME-OUT shall be set to 0 and TIME OFFSET shall be set to 128.

*Note.– Algorithms that determine the need for additional transmissions due to unmodeled movement shall be sensitive to differing operational requirements associated with airborne and surface operations. If the STDMA station is aware that its supporting vehicle is operating on the surface, additional transmissions due to unmodeled movement should be generated only if the commanded position report update interval is longer than [10] seconds.*

4.1.4 **Receive channel congestion reports and blocked access reports from MAC layer**

The STDMA station shall receive and process appropriately reports of channel congestion and blocked transmission attempts generated by the MAC layer.

*Note.– Blocked transmission attempts will typically result in the intended message being purged at the link layer.*

4.1.5 **Automatic overflow protection**

The STDMA station shall incorporate automatic overflow protection mechanisms to ensure that all STDMA stations in an airspace receive a fairly apportioned fraction of the channel resource as system demand begins to approach system capacity. Two techniques shall be incorporated as part of the planning process for aperiodic communications, as well as continued/ongoing access after each timeout period:

1. *ADS-B transmissions*. The STDMA station shall estimate channel loading over the previous 60 second period. If channel loading is less than 90% (*i.e*. less than 90% of available slots filled), the update interval shall be the nominal update interval commanded by the ground, or otherwise specified for the frequency channel and airspace involved. If channel loading is between 90% and 100%, update interval shall be linearly adjusted such that an estimated loading of 100% would lead to an update interval = 1.5 x (nominal update interval).

2. *All transmissions*. If no empty or unreserved slots can be identified for access, the STDMA station shall determine the slot(s) accessed by the most distant user, and use those slots for access. Range determination shall be based on the ADS-B position reports broadcast by the users.

# 5. SNDCF

## 5.1 Introduction

The SNDCF shall support a connection-oriented interface and a broadcast interface to the ATN.

## 5.2 Connection-oriented SNDCF

The connection-oriented SNDCF shall conform to the VDL SARPs.

## 5.3 Broadcast SNDCF

The Broadcast SNDCF (BSNDCF) shall provide a mechanism for an ATN ES using CLTP and CLNP to efficiently communicate with multiple destination ESs.

*Note.– The four entities involved in sending a broadcast are designated the “sending ES,” “sending BSNDCF server,” “receiving BSNDCF server,” and “receiving ES.” The BSNDCF servers are A/G routers. The sending ES sends a “prebroadcast packet” to the sending BSNDCF server, which sends a “broadcast packet” to any receiving BSNDCF servers, which in turn send a “postbroadcast packet” to none, one, or more receiving ES. Each of the three packets has a different format, as described below. In some implementations, the sending ES and sending BSNDCF server (or the receiving BSNDCF server and receiving ES) are implemented in a single LRU; these implementations may not actually go through the process of converting the broadcast packet to the uncompressed CLTP/CLNP format.*

### 5.3.1 Packet formats

#### 5.3.1.1 Prebroadcast packet

The prebroadcast packet shall be a CLTP packet encapsulsated in a CLNP unitdata packet per Sections 6 and 7. The listed CLNP and CLTP fields shall conform to Table 5-2; unlisted fields shall be set as desired by the sending ES. The sending ES shall also include the Destination Class and Frequency CLTP parameters in the prebroadcast packet.

**Table 5-1: Prebroadcast packet fields**

| Field | Source |
|---|---|
| Destination NSAP | NSAP of CLTP process on sending BSNDCF server |
| Source NSAP | NSAP of CLTP process on sending ES |
| SP bit | 0 |
| MS bit | 0 |
| data unit identifier | shall not be included |
| segment offset | shall not be included |
| total length | shall not be includedDestination TSAP |
| [256] decimal | |
| Source TSAP | TSAP of application process on sending (and receiving) ES |

5.3.1.2 Broadcast packet

The sending BSNDCF server shall convert the prebroadcast packet to the broadcast packet. The broadcast packet format shall consist of a fixed part (per Table 5-2 and 5-3) and a variable part (per ISO 8473 and ISO 8602).

**Table 5-2: Broadcast packet short format**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| 0 | $v_2$ | $v_1$ | $n_3$ | $n_2$ | $n_1$ | $t_2$ | $t_1$ |
| $b_8$ | $b_7$ | $b_6$ | $b_5$ | $b_4$ | $b_3$ | $b_2$ | $b_1$ |
| CLNP options | | | | | | | |
| CLTP options | | | | | | | |
| CLTP user data | | | | | | | |

**Table 5-3: Broadcast packet long format**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| 1 | $v_2$ | $v_1$ | $n_3$ | $n_2$ | $n_1$ | $t_2$ | $t_1$ |
| $b_{16}$ | $b_{15}$ | $b_{14}$ | $b_{13}$ | $b_{12}$ | $b_{11}$ | $b_{10}$ | $b_9$ |
| $b_8$ | $b_7$ | $b_6$ | $b_5$ | $b_4$ | $b_3$ | $b_2$ | $b_1$ |
| CLNP options | | | | | | | |
| CLTP options | | | | | | | |
| CLTP user data | | | | | | | |

The fixed header shall consist of 5 subfields. The IPI subfield shall be [CD] hexadecimal. The version subfield (v bits) shall be a 2-bit integer specifying the version of the BSNDCF protocol. The CLNP option count subfield (n bits) shall be a 3-bit integer specifying the number of CLNP options that follow the fixed part of the header. The CLTP option count subfield (t bits) shall be a 2-bit integer specifying the number of CLTP options that follow the CLNP options. The BSAP subfield (b bits) shall be an 8-bit integer or 16-bit integer specifying the Broadcast Service Access Point (BSAP) of this packet. The CLNP and CLTP options which follow the fixed header may be any options except those regenerated by the receiving BSNDCF server. No field in the fixed portion of the CLNP or CLTP header shall be included in the broadcast packet. All CLNP and CLTP options may appear in the broadcast packet, except for the CLNP padding, QOS, segmentation, and priority parameters.

The maximum length of a broadcast packet on a transmission media shall be equal to the maximum length of a SNAcP packet on that media.

5.3.1.3 **Postbroadcast packet format**

The postbroadcast packet format shall be a CLTP packet encapsulated in a CLNP unitdata packet. The source NSAP shall be the NSAP of the receiving BSNDCF server, and the source TSAP shall be [256] decimal.

*Note.− The postbroadcast packet format conforms to the ISO standard; there are no extensions required.*

### 5.3.2 Procedures

The four entities involved in the transmission of a broadcast packet shall conform to the procedures defined in the ATN manual, ISO 8473, and ISO 8602, except as noted below.

#### 5.3.2.1 Sending ES

The sending ES shall create a prebroadcast packet including all mandatory parameters. If the application is generating periodic transmissions, then the sending ES shall also include the Next Report parameter.

#### 5.3.2.2 Sending BSNDCF server

The sending BSNDCF server shall create a broadcast packet from the prebroadcast packet via the following conversion. The short format shall be used if the source TSAP is a single octet; the long format shall be used if the source TSAP is two octets. The version shall be set to 0. The CLNP options (except for the QOS parameter and the source route parameter) shall be copied after the fixed header and the CLNP option count shall be set accordingly. The CLTP options (except for the parameters defined in Section 7 and the source and destination TSAPs) shall be copied after the CLNP options and the CLTP option count shall be set accordingly. The BSAP shall be set equal to the source TSAP.

The broadcast packet shall be transmitted to the requested destination class on all of the indicated frequencies. If the specified class is undefined for the requested frequency, the all stations class shall be used. If the r bit in the Next Report parameter is set and a packet from the same source NSAP and TSAP has not been transmitted, the old packet shall be deleted and replaced with the new packet.

Recommendation

In order to more efficiently use the RF channel, the sending BSNDCF server should use the Next Report parameter (when included) to reserve a future slot for periodic application.

Error reports

If a sending BSNDCF server does not have access to a requested frequency, then the packet shall be discarded; if the E/R CLNP bit is set, then a type 128 decimal Error Report shall be sent to the sending ES. If the requested destination class is not supported by the requested frequency, then the packet shall be sent to the all stations class; if the E/R CLNP bit is set, then a type 129 decimal Error Report shall be sent to the sending ES. If the packet is too large to fit in a single broadcast packet, then the packet shall be discarded; if the E/R CLNP bit is set, then a type 5 decimal Error Report shall be sent to the sending ES. If the prebroadcast packet does not contain the Frequency and Destination Class parameters, then the packet shall be discarded; if the E/R bit is set, then a type 1 decimal Error Report shall be sent to the sending ES. If a broadcast packet is replaced without being transmitted and the E/R bit is set, then a type 3 decimal Error Report shall be sent to the sending ES.

#### 5.3.2.3 Receiving BSNDCF server

A receiving BSNDCF server shall discard all received broadcasts with an IPI not equal to [CD] hexadecimal or a version not equal to 0.

*Note.− Transmissions with an IPI other than [CD] are, by definition, not a BSNDCF packet. They may be processed by the receiving station, but not by the receiving BSNDCF process.*

A receiving BSNDCF server shall maintain a list of delivery stations for every TSAP as defined in Table 5-4

*Note.− The maintenance of these tables in the various receiving BSNDCF servers may be either via manual configuration or a dynamic protocol. However, this is outside the scope of the SARPs.*

**Table 5-4: Postbroadcast Packet Parameters**

| Field | Value |
|---|---|
| CLNP IPI | As required by ATN Manual |
| length indicator | Computed |
| version/protocol ID extension | As required by ATN Manual |
| Lifetime | As requested by receiving ES |
| SP bit | 0 |
| MS bit | 0 |
| E/R bit | As requested by receiving ES |
| Type | As required by ATN Manual for UNITDATA packet (28 decimal) |
| Segment length | Computed |
| Header checksum | Computed if requested by receiving ES |
| Destination NSAP | Receiving ES NSAP |
| Source NSAP | Receiving BSNDCF server NSAP |
| QOS parameter | As requested by receiving ES |
| Priority | As requested by receiving ES |
| Security | From broadcast packet (if included) |
| Route recording | If included in broadcast packet (updated by sending and receiving BSNDCF servers) |
| Source routing | Included if requested by receiving ES |
| CLTP header Length Indicator | As computed |
| CLTP IPI | As required by the ATN Manual (40 hexadecimal) |
| Source TSAP | [256] decimal |
| Destination TSAP | From BSAP subfield of broadcast packet |
| User checksum | From broadcast packet (if included) |

*Note.– The only identification of the sending ES is via data included in the application data.*

After receiving a broadcast packet sent to its server class (*i.e.* a receiving BSNDCF server on the ground shall discard a packet sent to all aircraft), a receiving BSNDCF server shall create a CLTP/CLNP packet from the broadcast packet and the data specific for that TSAP. A receiving BSNDCF server shall discard a packet for which it has no configured receiving ESs.

5.3.2.4 Receiving ES

A receiving ES shall process the postbroadcast packet as per the ATN Manual.

# 6. NETWORK LAYER PROTOCOLS AND SERVICES

**The network layer protocol shall be CLNP as specified in the ATN Manual.**

# 7. TRANSPORT LAYER PROTOCOLS AND SERVICES

The transport layer shall ensure end-to-end delivery of user-specific application data.

## 7.1 Connection-oriented transport layer

The connection-oriented transport layer shall conform to the ATN manual.

## 7.2 Connectionless transport layer

The connectionless transport layer shall conform to the ATN manual, except for the new parameters defined below for use in broadcast services.

### 7.2.1 ATN-specific parameters

#### 7.2.1.1 Destination class

This parameter shall be the desired destination class that the sending BSNDCF server shall use. This parameter shall be as defined by Table 7-1 and encoded in Table 7-2.

Table 7-1: Defined Destination Classes

| Class | Description | Additional Data |
|---|---|---|
| 0 | All stations | No additional data |
| 1 | All airborne stations | No additional data |
| 2 | All ICAO ground stations | No additional data |
| 3 | All ground stations | No additional data |
| 4 | All ground stations of specified operator<br><br>(VHF-only) | $g_{22}\ g_{23}\ g_{24}\ g_{25}\ \ g_{26}\ g_{27}\ 0\ \ 0$<br>$g_{15}\ g_{16}\ g_{17}\ g_{18}\ \ g_{19}\ g_{20}\ g_{21}\ 0$<br>$g_{8}\ g_{9}\ g_{10}\ g_{11}\ \ g_{12}\ g_{13}\ g_{14}\ 0$<br>$g_{1}\ g_{2}\ g_{3}\ g_{4}\ \ g_{5}\ g_{6}\ g_{7}\ 0$ |
| 5-255 | Reserved | |

Table 7-2: Destination Class Parameter Encoding

| Field | Bit Position | Notes |
|---|---|---|
| Parameter ID | 0 0 0 0 0 0 0 0 | Destination class |
| Parameter len | $n_8\ n_7\ n_6\ n_5\ \ n_4\ n_3\ n_2\ n_1$ | |
| Parameter val | $c_8\ c_7\ c_6\ c_5\ \ c_4\ c_3\ c_2\ c_1$ | class |
| | $a_8\ a_7\ a_6\ a_5\ \ a_4\ a_3\ a_2\ a_1$ | additional data (optional) |

7.2.1.2 Frequency

This parameter, encoded per Table 7-3, shall be one or more frequencies on which the sending BSNDCF server shall transmit. The band subfield (b bits) shall determine which frequency band to transmit in. The frequency subfield (f bits) shall determine which frequency within that band. The band and frequency shall be determined per Table 7-4.

**Table 7-3: Band and Frequency Syntax**

| Band | Description | Encoding Example |
|---|---|---|
| 0 | VHF | Integer[(freq in MHz * 100) -10000]<br>136.975 MHz = 3697 decimal = E75 hex |
| 1 | Mode-S | TBD TBD |
| 2 | Satcom | TBD TBD |
| 3 | HF | TBD TBD |
| 4-15 | reserved | |

Table 7-4: Frequency Parameter Encoding

| Field | Bit Position | Notes |
|---|---|---|
| Parameter ID | 0 0 0 0 0 0 0 1 | Frequency |
| Parameter len | $n_8\ n_7\ n_6\ n_5\ \ n_4\ n_3\ n_2\ n_1$ | |
| Parameter val | $b_4\ b_3\ b_2\ b_1\ \ f_{12}\ f_{11}\ f_{10}\ f_9$ | band / frequency |
| | $f_8\ f_7\ f_6\ f_5\ \ f_4\ f_3\ f_2\ f_1$ | |

7.2.1.3 Next report

This parameter shall be included by a sending ES to inform the sending BSNDCF server of a future transmission. The sending ES shall include the time that this packet was generated, the time that the next packet will be generated, and options on handling this stream of packets. The two time fields shall specify the minutes (m bits), seconds (s bits), and thousandths of seconds (t bits) (relative to the current UTC hour). The maximum value of the minutes and seconds subfields shall be 59 decimal; the maximum value of the milliseconds subfield shall be 999 decimal. The sending BSNDCF server shall use the current generation time to compute the latency between the sending ES and the sending BSNDCF server.

The boolean Replace (r bit) bit in the Options subfield shall be set to 1 by the sending ES to cause the sending BSNDCF server to replace any as yet untransmitted packets (from the same source NSAP and TSAP) with the current packet; the r bit shall be set to 0 by the sending ES to cause the sending BSNDCF server to transmit all packets.

**Table 7-5: Next Report Parameter Encoding**

| Field | Bit Position | Notes |
|---|---|---|
| Parameter ID | 0 0 0 0 0 0 1 0 | Next report |
| Parameter len | 0 0 0 0 0 1 1 1 | |
| Parameter val | 0 0 $m_6$ $m_5$ $m_4$ $m_3$ $m_2$ $m_1$ | Generation time |
| | $s_6$ $s_5$ $s_4$ $s_3$ $s_2$ $s_1$ $t_{10}$ $t_9$ | |
| | $t_8$ $t_7$ $t_6$ $t_5$ $t_4$ $t_3$ $t_2$ $t_1$ | |
| | 0 0 $m_6$ $m_5$ $m_4$ $m_3$ $m_2$ $m_1$ | Next generation time |
| | $s_6$ $s_5$ $s_4$ $s_3$ $s_2$ $s_1$ $t_{10}$ $t_9$ | |
| | $t_8$ $t_7$ $t_6$ $t_5$ $t_4$ $t_3$ $t_2$ $t_1$ | |
| | 0 0 0 0 0 0 0 r | Options |

### 7.2.2 Transport Service Access Point (TSAP) Registration

Table 7-6 shall be the list of registered TSAPs.

**Table 7-6: Registered TSAPs**

| TSAP | Application |
|---|---|
| 0 | CLTP protocol |
| 1 | Navigation-Surveillance |
| 2-128 | Reserved for broadcast applications |
| 129-255 | Reserved |
| 256 | BSNDCF server |
| 257-16384 | Reserved |
| 16385-65535 | Spare |

## 8. SESSION LAYER PROTOCOLS AND SERVICES

The Session layer shall handle login, logout and billing for user-specific applications that may be defined.

*Note.− This layer is only required to support certain user-defined and user-specific applications. It is optional and may be omitted from STDMA-compliant hardware.*

## 9. PRESENTATION LAYER PROTOCOLS AND SERVICES

### 9.1 Functions

The presentation layer formats received data for use by the application layer, and also formats application layer data for delivery to lower layers for transmission over the RF channel. For encrypted message types, crypto is applied in the “lowest sublayer” of the presentation layer.

#### 9.1.1 Encryption and decryption

The presentation layer shall perform encryption and decryption for message types that contain encrypted position/velocity data (*e.g.* message types 2 and 66). Encryption/decryption shall be applied to the following message fields: latitude; longitude; speed; heading/direction; altitude; timestamp (first 4 bits only).

*Note.− Encryption/decryption is an optional function.*

# 10. APPLICATION LAYER PROTOCOLS AND SERVICES

## 10.1 General information

Application-layer service system parameters and functions required to support STDMA operations are noted below.

*Note.− The application layer is user and application specific, and may involve functionality beyond that required to support STDMA operations.*

## 10.2 Application layer service system parameters for STDMA

Application layer service system parameters are described in Table 10-1.

**Table 10-1: Application Layer Service System Parameters**

| Symbol | Parameter Name | Minimum | Maximum | Default | Increment |
|---|---|---|---|---|---|
| AUTO | Operating Mode (autonomous or ground-controlled) | N/A | N/A | Autonomous | N/A |
| TM3 | Reservation Hold Time | 1 frame | 16 frames | 4 frames | 1 frame |
| R1 | Sync Update Interval | 150 slots | 4500 slots | 1500 slots | 150 slots |
| R2 | Sync Stagger Range* | 1 slot | 255 slots | 255 slots | 2 slots |
| CSC_MAX | Number of CSCs | 1 | 4 | 2 | 1 |
| CSC_i | Channel ID of ith CSC (one per CSC) | [1] | [960] | TBD | 1 |

*The sync stagger range is assumed to be centered on the nominal update interval.

### 10.2.1 Operating mode (Autonomous/Ground-controlled)

This parameter is determined at the Subnetwork layer and mirrored at the Application layer. See Section 4.1.1.1 Any STDMA channel operated in GROUND-CONTROLLED mode implies the STDMA station as a whole shall be operated in GROUND-CONTROLLED mode.

### 10.2.2 TM3 (max reservation hold time)

The application layer shall maintain, and make available to the Subnetwork layer, the value of the maximum reservation hold time parameter TM3.

*Note 1.− In the absence of competing access attempts by other STDMA stations, as default behavior, an STDMA station will reserve slots for Type 0 STDMA bursts for TM3 frames. The max reservation hold time shall be zero frames for all other message types (i.e. STDMA stations may access the channel but may not reserve slots in future frames). After occupying a slot for TM3 frames (for a Type 0 STDMA bursts), the STDMA station will move to a new slot.*

*Note 2.− On any individual channel, TM3 may be overridden by a ground commanded TIMEOUT INTERVAL, which becomes the channel-specific maximum value associated with individual slot reservation timers defined at the Subnetwork layer.*

*Note 3.− STDMA stations pre-reserve slots for their future accesses as described in Section 4.1.3 and Section 4.1.5. Each slot reservation associated with a Type 0 STDMA burst requires a separate timer at the subnetwork layer since slot reservations may have different timeout intervals, and staggered start times, and therefore may time-out at different times. On a congested channel, it may not be possible to reserve a slot for the maximum time allowed by this parameter. In this case, users may be forced to shift reservations more frequently for some or all of their accesses.*

### 10.2.3 Sync burst update interval R1

The sync burst update interval parameter R1 shall describe the nominal update interval, measured in slots of ~6.67 msec duration (exactly 9000 slots per minute) of Type 0 STDMA bursts.

*Note.− The actual update intervals will be pseudorandom, staggered about this nominal value, as a function of parameter R2 described below. Furthermore, the value of R1 can be overridden on any particular channel by ground command. An STDMA station can report at a higher rate (in autonomous mode) if so required to support collision avoidance functionality.*

### 10.2.4 Sync stagger range R2

The sync stagger range parameter R2 shall describe the range of pseudorandom variation in slot positions containing Type 0 STDMA bursts for a given STDMA station. STDMA stations will attempt to stagger type 0 accesses over this range. The value of R2 can be overrided on any particular channel by ground command.

*Note.− In the event that channel congestion prevents an STDMA station from reserving a slot for a type 0 STDMA burst within this range about a nominal update point, it will make an attempt to access and reserve a slot outside this range as a newly-entering user (i.e. without pre-reservation).*

### 10.2.5 Number of common signalling channels CSC_MAX

The parameter CSC_MAX shall define the maximum number of CSCs in an airspace. The default value shall be 2. However, a ground station can reset this value based on local requirements.

### 10.2.6 Common signalling channel i, CSC_i

The parameter(s) CSC_i shall define the channels to be used as CSC(s). A ground station can reset these parameters based on local requirements.

## 10.3 Application Layer Functions for STDMA

### 10.3.1 Provide navigation function

The application layer shall acquire, possibly from an external interface: (1) current user platform latitude, (2) longitude, (3) speed, (4) heading/direction, (5) altitude and (6) time. This information, along with its quality and source, shall be provided to lower layers of the STDMA protocol stack as required to support timely generation of Type 0 STDMA bursts.

*Note.− This information may be processed through the Presentation layer for encryption, if required.*

### 10.3.2 Provide secondary navigation function

In the event that GNSS-based navigation is unavailable, the application layer shall estimate station position by generating UTC time inquiries as required, processing replies to UTC time inquiries, and processing position reports whose GNSSSYNC flags are SET (=1).

### 10.3.3 Determine required update rate for position reports

The application layer shall determine the required update rate for position reports based on currently-valid commands from a ground station (if present), default parameters and real-time kinematics relative to other reporting and reported entities in the airspace. An appropriate indication to the Subnetwork layer shall be provided.

### 10.3.4 Maintain database of reporting and reported entity positions and velocities

The STDMA station shall maintain a database of positions and velocities for all reporting and reported entities. The database shall as a minimum contain last reported position and velocity, and time of validity. Data on self-reporting entities, associated with a unique vehicle ID, shall be maintained for at least 30 minutes following the latest report. Capability shall exist to encode station IDs in terms of ICAO-unique 24-bit addresses as well as 48-bit compressed ASCII addresses (8 characters of 6 bits each). This database, or selected elements of this database, shall be made available to other application-layer functions, such as secondary navigation.

*Note.− The 30 minute memory requirement is intended to support search and rescue operations by retaining in the database of all receiving STDMA stations the last reported position of each aircraft for a reasonable period of time. This data may be requested by certain ground stations in order to support search and rescue operations.*

*Note.− Position data on reported entities (e.g. data contained in a correlated surveillance picture from the ground) need not be retained for 30 minutes.*

### 10.3.5 Determine ranges and range-ordered listing of STDMA stations in the airspace

The application layer shall determine the range to each STDMA station reporting on a channel to which the station is listening, and shall range-order the stations based on this determination. Appropriate results from this function shall be made available to the Subnetwork layer for purposes of slot selection.

*Note.− This function must be performed at the application layer since navigation data may be encrypted at lower layers.*

### 10.3.6 Response to ID request

Upon receipt of a Type 35 message, the STDMA station shall generate a Type 36 (ID report) if:

1. The Type 35 contained an ICAO-unique address corresponding to that of the STDMA station; or
2. The Type 35 contained a flight number or tail number corresponding to the STDMA station; or
3. The Type 35 contained a broadcast address, but the position indicator was within [10 nmi] of the STDMA station's position.

### 10.3.7 Check validity of information content

The STDMA station shall check the validity of the data content of position reporting messages received from other self-reporting STDMA stations. This shall be done by comparing current reported position and velocity to last reported position and velocity for the same declared vehicle ID. Position reports in the database shall be identifiable as validated vs. not validated.

*Note.− This application layer validation is required since the Type 0 STDMA Burst CRC check is overlaid with the transmit station ID. This can lead to error events which manifest as a valid report for a phantom user ID. The validation check will differentiate such events, and others, while still allowing associated applications (e.g. CDTI) to use each received report with caution appropriate to the application. For position reports from phantom users (i.e. due to channel errors), as well as the first position report from actual users, positions will be unvalidated. These may be displayed or otherwise processed as appropriate for the application. In the case of first-time reports from actual users, position and velocity data will be validated upon receipt of the second valid position report.*

*Note.− The validation check should be designed to accept takeoff and landing dynamics, as well as unexpected dynamics for users already in the data base (e.g. as associated with uncoordinated flight just prior to an accident, such as stalls, spins, powered dives, etc, subsequently requiring Search and Rescue operations). One possible way to implement such a check is to compare the previous and current position report to determine if a combination of [1g] accelerations, operating over the time interval between the two position reports, could have led to the position and velocity deltas reported by the user.*

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# SELF-ORGANIZING TIME DIVISION MULTIPLE ACCESS

## VDL MODE 4

## GUIDANCE MATERIAL

(4 April 1996)

# DRAFT

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1. **STDMA operations concept**

1.1 Time division multiple access (TDMA) is a multiple access scheme based on time-shared use of an RF channel employing:

a) discrete contiguous time slots as the fundamental shared resource; and

b) a set of operating protocols that allows users to interact with a master control station to mediate access to the channel. Self-organizing TDMA (STDMA) as described in this guidance material and the proposed ICAO Standards and Recommended Practices (SARPs) is defined as a multiple access scheme based on time-shared use of an RF channel employing:

1) discrete contiguous time slots as the fundamental shared resource; and

2) a set of operating protocols that allows users to mediate access to these time slots without reliance on a master control station.

1.1.1 The STDMA concept of operations is based on the following elements:

a) a global navigation satellite system (GNSS) receiver for the determination of user position and accurate system time. (The GNSS receiver and the STDMA airborne system will function in a degraded mode if the receiver is unavailable or inoperative.).

b) A TDMA frame structure with numerous slots of relatively short duration optimized for exchange of real-time air traffic management (ATM) information (e.g. ADS-B, differential global navigation satellite system (DGNSS), air traffic control (ATC) communications, etc.).

c) A self-organizing protocol for slot reservations that provides high system throughput and efficiency without reliance on external or master control stations.

d) A computer, part of every STDMA system, that maintains position/track data for all users detected, as well as their current and planned slot assignments, for use in supporting user requirements as well as controlling/mediating access to the channel.

e) Optional use of ground controllers/monitors to provide a feed to ground-based operations, as well as to control channel access more precisely and efficiently than is possible with the self-organizing protocol. When a ground station assigns users to specific slots, the affected users switch to position reports with message types that indicate they are under ground control. Users operating in autonomous mode are precluded from accessing slots within four slot positions of such a message; autonomous users currently operating in such a slot must vacate immediately and select a new slot. Thus, ground-based slot assignments automatically reserve additional capacity for new users to be placed under control.

f) A message library that is structured to permit certain system operating modes and parameters to be inferred by monitoring of the RF communication traffic. For example, the existence of a STDMA ground station can be inferred by detection of message types greater than sixty-three. Reservation fields allow each user to reserve new/ different time slots (unused in general) and announce these reservations to the entire community. Timeout fields specify future duration of slot reservations (including no time remaining).

g) A realtime operating system that allows the STDMA transponder to adjust its operation based on information received in the most recent slot. Guard time in the most recent slot, and synchronization time in the current slot, are used to process information and determine slots to be reserved.

## 1.2 Operating characteristics

1.2.1 All information communicated over the data link is transferred as messages identified either as a control burst or as a user burst. The message type indicates whether the message is transmitted from a base station or from a mobile unit. It also indicates if the communication is conducted in autonomous or controlled mode. The message type is also used when applying a priority schema to ensure that more urgent messages are transmitted before less urgent.

1.2.2 The autonomous mode of STDMA is based on the capability in each unit to organize its own access to the data link. This self-organizing mechanism ensures that transmissions take place in free time slots or in time slots used by other users which are of no interest to the own (and nearly) unit(s).

1.2.3 The main (master) frame in the STDMA system is one minute, i.e. the self organizing mechanism is based on the transmission of at least one position report each minute. It is anticipated that the maximum report rate is one position report once a second, i.e. maximum sixty position reports for a unit in one main frame. The main frame of one minute is divided into 9000 timeslots. Each time slot is accessible for receiving or transmitting by any user communicating on the data link. One position report will occupy one, two or four time slots depending on the transmission rate on the data link.

## 1.3 Channel operations

1.3.1 An STDMA channel, and the STDMA stations accessing that channel, can be operated in an autonomous or ground-directed mode.

### 1.3.1.1 Autonomous mode operations

1.3.1.1.1 In autonomous mode, each user's slot reservations periodically “time out” and new slots must be selected. Each user reports current time remaining for its slot reservations (in minutes), as well as intended new slots for future use. The intended new slots are determined by the same algorithm as the original slot assignments, although movement in the slot map is normally limited to shifts of less than 128 slot positions. If a transponder declares a slot reservation and subsequently detects another transponder with the same slot reservation, it makes a new selection immediately (i.e. the **last** transponder to declare a slot has priority). This has the effect of minimizing the probability of a packet collision, since one-way communication in either direction is sufficient to avoid the conflict. If no slots are available within 127 slot positions of the current slot, the transponder vacates with an indication that it is moving more than 127 positions, and “grabs” an unused (or distantly-used) slot. This situation is analogous to an initial system entry.

1.3.1.1.2 Under nominal conditions, the protocol described above permits each user to declare future intentions to switch slots multiple times before actually performing the slot change. Barring pathological error patterns on the link, this has the effect of virtually eliminating packet collisions.

1.3.1.2 **Controlled mode operations**

1.3.1.2.1 If an STDMA control station is present, it can broadcast differential global positioning system (DGPS) corrections, make slot assignments and rebroadcast position reports derived from other channels and possibly other systems (e.g. radar surveillance or Mode S squitter) Figure 1-1 illustrates a typical slot map in controlled mode. In this typical operational scenario, the controlling station has constructed a 2-second subframe by reserving slots at epochs of 300 slots to announce its own presence, provide differential corrections, and broadcast position reports for non-equipped targets (e.g. users detected by ground radar). Equipped users operating in controlled mode have been assigned time slots within the 2-second subframe (note that not all users are necessarily reporting every 2 seconds; isolated or stopped vehicles could be assigned as few as one or two slots per minute, essentially time-sharing slots over 2-second subframe epochs).

1.3.1.2.2 All the messages to the left of the sliding threshold in Figure 3-1 have message types greater than sixty-three, indicating control station transmissions or mobile reports from controlled users. These messages set off an exclusion zone for autonomous users. Autonomous users are not allowed to reserve, or access, slots within three positions of such messages. This provides a margin for contention-free build-up of the polling list (the controlling station can assign the unused slots, or assign mobile users to its own slots (such as DGPS), and slide the DGPS corrections data to the right. Note that the sliding boundary has been illustrated as “straight” for clarity, but could actually be in different locations in each 2-second subframe. The initial selection of a 2-second subframe is arbitrary, and the subframe size for operational systems may be different for each controlled environment and application domain. Any structure other than the 1 minute frame is chosen as a matter of convenience and, if present, is application-specific. Note that individual STDMA transponders can be assigned reporting rates that are either more or less frequent than the 2-second poll cycle, based on scheduling decisions made in the STDMA control station.

1.3.1.2.3 A control station will always monitor the STDMA signaling channel(s) as well as the channel it is controlling (if different from the common signaling channel).

**Figure 1-1: Conceptual Frame Structure in Ground-Controlled Mode**

1.3.1.2.4 A control station will periodically broadcast a surveillance picture derived from all appropriate sources available to it. Surveillance sources may include the ADS-B reports of STDMA stations themselves, and may also include ground-based data received from Mode S squitter monitors, radars, etc. The surveillance picture may be broadcast on (all) STDMA channels in operation in the local area. *(Note.− If multiple control stations are within radio line-of-sight of the affected airspace, ground co-ordination may take place to ensure that only one ground station broadcasts a surveillance picture on each channel. This co-ordination is not a requirement of the STDMA system).*[*]

1.3.1.2.5 A control station will autotune nearby mobile STDMA stations as required to ensure efficient and effective STDMA operations. STDMA stations entering the airspace while operating on the common

[*] Ground broadcast of a correlated surveillance picture, or product, offers a convenient way to deliver early benefits to ADS-B users in domestic airspace − especially terminal area airspace. In the absence of mandated equipage, mixed-fleet operations will exist for many years. Ground broadcast of a correlated surveillance picture gives early users the operational equivalent of full fleet equipage, without mandates. It also means that different classes of users can use different ADS-B systems (e.g. Mode S squitter for Part 121 operators and VHF STDMA for others); the ground surveillance system, part of the ATC infrastructure, takes as input all available surveillance data and generates a single high-integrity surveillance picture which can be rebroadcast on the STDMA system (and other systems) in compact form.

signaling channel may be autotuned to a special local channel. STDMA stations operating on the local channel, but leaving the area, may be autotuned to the common signaling channel. Autotune commands include direct-to-frequency, slot ID(s), timeout interval, protocol mode and reporting resolution (if appropriate). Thus, a STDMA station can switch frequencies without incurring a delay to develop a slot map on the new channel.

1.4 **Network Entry**

1.4.1 STDMA operations will take place on specific frequencies including the common signaling channels. An STDMA station can enter an established network on a particular channel in two ways:

a) **Autonomous mode**. In this mode, an STDMA station “listens” to a pre-defined channel(s) for a period of time, for example 1-2 minutes, to determine channel activity, other participating member IDs, current slot assignments and reported positions of other users, and possible existence of STDMA ground stations. During this time period, a “dynamic directory” of all members operating in the system is established. After building a frame map that includes activity status for all slots and reported positions for all users, the transponder selects for its own use a slot(s) that is unused and unreserved. It begins broadcasting basic position reports in this slot(s). If all slots are already in use or reserved, it selects a slot(s) associated with the most distant user and broadcasts in that. (Rationale: the most distant user is not relevant in the local domain.). Nearby users detect the new transmissions and add the user information to their slot maps and position data bases. All data transmitted over the data link will be continuously stored and updated in each and every STDMA transponder operating within radio range. This supports continued high-efficiency operation of the system as well as user applications such as CDTI, TCAS functionality, search and rescue operations (if implemented), etc. If an STDMA station operating in autonomous mode enters a zone in which a master STDMA station (e.g. a ground station) is asserting controlled operations on the channel, the master STDMA station may autotune the autonomous STDMA station to a specific slot assignment, and direct the unit's channel accessparameters. (e.g. update rate, radio channel, timeout period, and reporting resolution).

b) **Controlled mode**. In this mode, an STDMA station that has been operating in a controlled mode on one channel can be autotuned to a different channel and slot assignment by the controlling STDMA station. This allows for rapid contention-free network entry as an STDMA-equipped aircraft transitions from one airspace to another (e.g. high density terminal area airspace with STDMA operations on a special channel, to en-route airspace with STDMA operations on the common signaling channel).

1.5 **Slot contention resolution**

1.5.1 To minimize accidental transmission collisions, all users transmitting in autonomous mode periodically change their time slots for transmission. Each slot reservation is associated with a time-out interval, chosen individually and randomly, between 4 and 8 minutes long. At the beginning of a new main frame the time-out counter associated with this interval is decremented.

1.5.2 As old reservations time-out, STDMA stations attempt to select NEW slots for future synchronization and position reporting. Tentative reservations for future use are broadcast as part of the ongoing synchronization activity. This process gives all STDMA stations the information required to select and access slots with low probability of contention.

1.5.3 When changing time slots a time slot used by the own user during the previous main frame cannot be chosen for transmission in the next main frame. The time slot used has to change. Users attempt to select slots within 127 slot positions of their current slots; however, greater offsets can be employed if so required due to channel congestion.

1.5.4 In order to minimize the probability of slot contention with so-called “hidden transmitters,” STDMA stations employ a “politeness protocol” whereby a station will **change** its current and future reservations if it hears a competing reservation from another station.

## 1.6 Variable report rate

1.6.1 The current reporting defines the nominal increment. The reporting rate (nominal increment) is adjustable. Depending on the surrounding traffic situation the need for position information differs. When an aircraft is alone in an airspace there is no need for rapid reporting rates. In another situation with two aircraft on opposite headings or when two aircraft are closing there is a need for a very rapid reporting rate. The reporting rate can be changed by a manual order from the pilot or from the air traffic controller, or it could be changed by an adaptive process in the systems on board the aircraft or in the systems on the ground. An autonomous automatic adoption of report rate is recommended in an operational system.

1.6.2 The change of reporting rate is carried out in the same way regardless of how the decision was made and initiated. How the report rate should be adapted to a specific situation is more a philosophical and psychological issue.

1.6.3 A change of reporting rate is done in two consecutive main frames. In the first the necessary movements or terminations of presently used time slots are announced. In the second main frame the announced movements and terminations are done and, if necessary, new time slots are allocated. The easiest change is to change the reporting rate with a factor evenly divisible by two. When operating in controlled airspace, a ground station can command a higher update rate and make it effective in the current frame. In uncontrolled airspace (autonomous mode), under extreme circumstances, application-layer processes associated with an STDMA station may induce a higher reporting rate in the the current frame. These extra reports would be transmitted in slots that were apparently unused/unreserved by other stations, without the protection of a prior reservation.

1.6.4 The STDMA system is based on the assumption that all users transmit at least one position report in each main frame. However, it is possible to have a longer time than one minute between the position reports, but then the user has to enter the system as a “new” user for each transmission. Each position report also has to announce that the transmission is the last one in that main frame.

## 2. Spectrum management

### 2.1 Spectrum management

2.1.1 The proposed STDMA VDL system, like any RF communications, navigation, and surveillance (CNS) system, requires spectrum resources to function. VHF spectrum is increasingly congested. The STDMA operations concept is sensitive to this issue, as well as other needs of the spectrum management community, even as it satisfies the demands of the users. The STDMA system architecture allows for a basic functionality independent of ground infrastructure and with a limited set of common channels.

2.1.2 Figure 2-1 illustrates the proposed channel structure for STDMA VDL. A world-wide pair of common signaling channels provides for automatic dependent surveillance broadcast (ADS-B) in all airspaces up to and including the most dense projected environments (e.g. the LA Basin). These common signaling channels can also be used to transmit optional STDMA system management information (if desired by local authorities). In the proposed scheme, these common signaling channels should be allocated world-wide and would represent the common element of STDMA VDL operations. On an optional basis, subject to local and regional requirements and spectrum management constraints, additional channels may be allocated to functions such as DGNSS broadcast, aeronautical telecommunication network (ATN) or AOC. If allocated, these channels could be defined in an onboard data base, via ground broadcast of an STDMA services directory, or both.

**Figure 2-1. STDMA Resource assignment philosophy**

2.1.3 The proposed channel structure for STDMA allows for increasingly sophisticated functions with the addition of auxiliary channels and ground stations. It is suggested that two frequency channels in the 136.9 - 136.975 MHz band be allocated for ADS-B operations and a “directory of services.” Flight safety critical functions, such as DGNSS data link, weather updates, automatic terminal information service (ATIS), and correlated surveillance to support CDTI, can be supported on dedicated and protected channels in the 112 - 117.950 MHz band, if so required by national or regional policy. AOC and other data link applications can be supported in the VHF communications band. The system is flexible; indeed, from a technical standpoint, all operations and all functions might be supported on a single frequency channel until such time that fleet equipage reaches moderate levels.

2.1.4 For safety-critical applications, a full dual-redundant equipment suite may be required. For example, Category II/III precision approach operations may require dual-redundant avionics with receivers tuned to independent frequency channels (or independent time slots on the same channel).

2.1.5 The proposed frequency plan for STDMA VDL provides for spectrum efficiency for basic functions, operational and spectrum management flexibility for augmented functions, special protection for safety-critical functions, and compatibility with a range of increasingly sophisticated user avionics for flexible operations in all airspaces. It also allows each Provider State to set its own spectrum management policies for radio navigation and preserves the independence of data communications and navigation utilization of the RF resources.

## 2.2 Rationale for dual common signaling channels

### 2.2.1 Protocols for dual-channel use

2.2.1.1 The proposed STDMA VDL operations concept requires autonomous-mode STDMA stations to cycle among the available common signaling channels for purposes of communications link robustness. The aggregate update rate must satisfy the default or commanded requirement (e.g. 5 seconds). With two common signaling channels defined, a user operating at the default update rate would transmit once every 10 seconds on each frequency for an average update rate of once per 5 seconds when both frequencies are considered.* The user's single transmitter (minimum hardware configuration) alternates between the two frequencies, tuning automatically, while the two receivers monitor each channel full-time. A user with a single receiver (i.e. second receiver failed or reassigned to other functions) would monitor a single frequency and receive position reports from all STDMA users every 10 seconds.

### 2.2.2 ADS-B capacity with dual common signaling channels

2.2.2.1 The draft STDMA VDL SARPs offers 9000 separately addressable message slots per frequency channel per minute. With 2 frequency channels, this is 18,000 slots per minute or 1,500 slots every 5 seconds. The STDMA multi-access protocols have demonstrated better than 95 per cent channel efficiency in autonomous mode, in terms of slots accessed successfully without garble or blocking. Thus, a two-channel configuration can be projected to support more than 1,400 users simultaneously with updates every 5 seconds. This exceeds all projected requirements for airborne ADS-B even with full world-wide fleet equipage.

* In autonomous mode, the airborne STDMA station will select starting slots on each frequency channel to approximate a 5 second aggregate update rate; limited dither may exist and is actually desirable.

### 2.2.3 Far-term growth capacity

2.2.3.1 Four features are included to provide additional growth as required: (1) STDMA operating protocols are defined in general for N common signaling channels; (2) protocols are defined to automatically "throttle-back" the autonomous update rate as theoretical user carrying capacity is approached; (3) the STDMA slot selection protocols applied by each user automatically protect near-by operations at the expense of distant users; and (4) ground stations can always tailor the update rate of selected (or all) users to satisfy local requirements.

2.2.3.2 Item (1) implies that, if a third common signaling channel is added, users will automatically adjust by splitting their transmissions over all three channels. In this case, with a nominal update rate of once per 5 seconds, each user would appear on each channel roughly once every 15 seconds. Total system capacity would exceed 2,000 users. The concept generalizes to other nominal update rates and other values of N.*

2.2.3.3 Item (2) implies that the autonomous update rate will be "throttled-back" as perceived channel usage begins to exceed 90 per cent of theoretical capacity in a limited geographic domain. Update rates will be gracefully reduced consistent with the need to avoid channel congestion.

2.2.3.4 Item (3) implies that, if insufficient slots are available to support all required accesses, users will still transmit but will preferentially select slots associated with distant transmitters rather than near-by transmitters. Garble will occur, but in a controlled manner such that all users retain the benefit of ADS-B and cockpit display of traffic information (CDTI) in their respective local domains.

2.2.3.5 Item (4) implies that local or regional authorities are always able to "take control" of the system to mediate channel access, update rates, frequency assignments for transmission, etc., in order to match spectrum requirements with local operational requirements and spectrum constraints. For example, users can be commanded to operate with variable update rates (long update periods for remote users; short update periods for users in terminal areas, etc.), or on dedicated frequencies for special domains (e.g. terminal areas, approach corridors, surface operations, etc.).

### 2.2.4 Common signaling channel assignments in the 136.9 - 136.975 MHz band

2.2.4.1 The current concept relies on world-wide frequency assignments in the 136.9 - 136.975 MHz band reserved by ICAO for VHF data link. The baseline concept assumes two channel assignments in order to support autonomous operations in the most dense airspace (e.g. the LA Basin) at an average update rate of once per 5 seconds per aircraft. This could be viewed as excessive for most areas of the world, where peak instantaneous aircraft counts will remain low for the indefinite future. On the other hand, an architecture with dual channels everywhere simplifies user operations and spectrum co-ordination, and would not adversely affect spectrum utilization in those areas of the world with low density traffic requirements (i.e. in regions where aircraft counts are low, over-all spectrum requirements are also low and dual common signaling channels are acceptable). An alternative spectrum management philosophy with a single world-wide channel

* Users with two receive channels would perceive an average update rate of once per 7.5 seconds in this case; users would be free to add additional receive channels to restore a 5 second update, if they so desire.

would provide 5 second updates almost everywhere in the world without ground control; ground stations or additional frequency channels could be used in selected domains to satisfy exceptional requirements.

**2.3 Aeronautical radio navigation and other protected services**

2.3.1 The proposed draft SARPs for STDMA VDL specifies avionics receive capability in the 108 - 137 MHz band and avionics transmit capability in the 117.975 - 137 MHz band. The requirement for dual-receive/single transmit capability allows an STDMA airborne station to receive safety-critical transmissions in a protected band (108 - 117.95 MHz) while still performing all of its other STDMA-supported functions in the 117.975 - 137 MHz band. The integrity of these safety-critical transmissions is preserved since the airborne transmitter cannot tune to the protected band.

**2.4 Air carrier operations with situation awareness and incentives for early equipage for aircraft operators**

2.4.1 The STDMA VDL protocol permits ground-based ATC surveillance products to be broadcast in a timely and RF-protected manner to all STDMA-equipped users. Thus a co-ordinated airspace or surface environment picture that is fully equivalent to that available to the Air Traffic Controller can be received by all STDMA users and displayed on inexpensive display terminals or fed to EFIS Display -equipped aircraft. Air carriers with sophisticated equipment can safely view all aircraft within their sphere of interest even if aircraft within the operating environment are not suitably equipped (e.g. track data for these aircraft are broadcast from the ground for the benefit of all STDMA-equipped users). These sophisticated air carrier systems can perform CAS-like and flight profile analysis functions to manage and report the progress of a flight. The use of inexpensive displays and other hardware and software to monitor and view aircraft operations within the sphere of influence of equipped GA or other carrier aircraft will provide sufficient advisory information to make the pilot more aware of the situation around him. STDMA-based systems, as a technology that is based upon open systems concepts and that uses inexpensive CPU hardware and display components, will provide cost-sensitive users an incentive for early equipage of an interoperable CNS-compliant communication and navigation system.

**2.5 Operations under failure modes of avionics and satellite-based navigation services**

2.5.1 STDMA failure modes include ground controller failure and transponder navigation function failure.

2.5.2 If a control station fails catastrophically, such that it stops broadcasting or assigning slots, users will "time-out" automatically and resume operations in an autonomous mode. Steady-state throughput performance for ADS-B appears comparable for autonomous and ground-controlled modes; however, catastrophic ground station failure may lead to a temporary loss of capacity in high-density airspace. Data link services that depend on the existence of the ground station would also be lost (e.g. DGNSS broadcast, correlated surveillance and weather uploads, point-to-point circuits for ATC and AOC, etc. For applications where this loss of throughput is unacceptable, availability and continuity of function may be enhanced by providing redundant control stations.

2.5.3 If an STDMA transponder is unable to navigate and determine system time via GNSS, it can devolve to a lower-performance navigation capability by ranging from nearby STDMA stations. By using position reports that are themselves derived from a stable reference such as GNSS, a degraded transponder may generate an estimate of its two-dimensional position as well as system time. The position solution that results is less precise than desired, but retains sufficient accuracy to support en-route operations. The time solution will have sufficient accuracy to support channel access and position reporting (i.e. position error on the order of [1 km] and time error on the order of [1 usec]). A transponder estimating position and time in this manner sets the GPSSYNC bit to 0 to prevent other transponders from relying on its position reports in a similar manner

## 3. Descriptive notes, explanation of features, and optional elements

### 3.1 Failure modes associated with dual common channel strategy

3.1.1 With two common channels carrying all ADS-B traffic all the time, STDMA VDL is inherently robust in terms of unintentional interference on either channel. Loss of either channel, due to unintentional and unforeseen events, results in a graceful reduction of CDTI update rate for all users. The reduced update rate is still sufficient to satisfy situational awareness requirements in en-route airspace and possibly terminal area airspace.*

### 3.2 Embedded data base and directory of services

3.2.1 In a philosophical parallel to the ongoing development of GNSS receiver functionality, it is suggested that STDMA avionics contain a data base of frequency assignments and associated operations accessible to the equipment.** A trivial example of such a data base would be knowledge of the N common signaling channels allocated for ADS-B operations. If additional functions are to be supported on these channels, locally, regionally or world-wide, this information could be encoded as well. Regions with greater or fewer frequency assignments would be identified. Special purpose frequencies, such as those dedicated to DGNSS broadcast or AOC, would be identified along with the location and operating range of their associated ground stations.

3.2.2 It is further suggested that authorized ground stations broadcast a “directory of services” on the common signaling channels, defining those frequencies and associated operations available in a local domain. For example, a ground station in the vicinity of an airport might identify the existence of local DGNSS transmissions, weather, ATIS and CDTI information on a dedicated frequency(ies). This “pointer” would be broadcast on the common signaling channels at periodic intervals, thereby providing a redundant means of specifying available services to airborne users. The “directory of services” messages could be used to override on-board data base parameters in order to accommodate local changes in policy.

### 3.3 Ground based GNSS augmentation in the 108 - 117.950 MHz band

3.3.1 On a national or regional basis, it may be decided that DGNSS transmissions should be protected by use of frequency subbands unavailable to mobile transmitters. For example, RTCA/DO-217

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* Update rate requirements and CDTI requirements are not yet defined by ICAO; it is believed that 5 to 10 second updates are adequate.

** This data base could be updated at periodic intervals tied to the operational requirements of the aircraft.

specifies DGNSS transmissions in the 108-117.950 MHz band since this band is allocated to aeronautical radionavigation, and airborne transmission is excluded. STDMA operations can support this protection technique, with DGNSS transmissions in the protected band and knowledge of such channels pre-loaded in the onboard data base as well as broadcast in the directory of services on the common signaling channel. For Category II/III precision approach operations, redundancy requirements may lead to a need for a high rate broadcast on separate frequency channels or separate time slots of the same channel. Such operations are also consistent with STDMA.

## 3.4 ADS-B rebroadcast and CDTI broadcast

3.4.1 The STDMA operations concept provides for rebroadcast of ADS-B data and broadcast of a correlated surveillance product to support high-reliability cockpit display of traffic information (CDTI). These functions require a ground station. When a ground station is present, it can receive/demodulate/process all ADS-B reports and rebroadcast those reports on a dedicated local channel. This may have a marginal safety benefit since it can help mitigate the "hidden transmitter" problem, and can also allow the merging of ADS-B reports from multiple domains that may be operating on multiple frequency channels (e.g. en-route, terminal area, approach/departure corridors, surface operations, etc.). Approach/departure corridors and surface operations are particularly sensitive, since in these domains higher update rates on the order of 1 Hz may be required for some/all users.

3.4.2 An STDMA ground station can also act as the transmission point for a true correlated surveillance product composed of the optimal fusion of data from all surveillance assets available to the local or regional ATC authority. For example, en-route radar, terminal area radar, surface radar and ADS-B reports from STDMA as well as Mode S operations could be fused into a single correlated picture as part of the normal ATC/surveillance function of the airspace. This correlated picture could be transmitted to the STDMA ground station in parallel with its delivery to the normal ATC controller positions. At the STDMA ground station, it would be compressed for efficient transmission over the RF channel and broadcast on a specified frequency. An analysis of the LA Basin, with 1,100 aircraft reported once per 10 seconds (average), indicates that a full correlated picture can be transmitted. This indicates that DGNSS broadcast and full CDTI could be supported on a single protected frequency channel, possibly with sufficient resource remaining for weather updates and digital ATIS.

3.4.3 The large volume of CDTI data would be filtered onboard each STDMA-equipped aircraft subject to specific real-time operational requirements, yielding full situational awareness with high reliability. Full situational awareness would be provided without mandated equipage -- a key benefit of ground station-mediated operations. This offers a convenient transition path for STDMA users, providing early benefits for initial users and allowing each operator to tailor a purchase strategy based on company-specific requirements. Furthermore, individual users and operators could select their ADS-B technology of choice − STDMA, Mode S or other − and rely on the ground infrastructure to correlate all reports with primary and secondary radar surveillance. The ground processor, in conjunction with the ATC infrastructure, essentially buffers all STDMA users who choose early equipage, against delayed purchases by other users, as well as equipment failures on other aircraft. STDMA users with limited processing capability, no FMS, or other limitations could ignore the entire CDTI uplink by simply not demodulating the associated channel, or ignoring all messages with the message type ID associated with this function.

### 3.5 Navigation operations

3.5.1 In operation, each STDMA transponder determines its own GNSS-based position and time or receives this information from an external GNSS receiver. DGPS corrections can be applied if available from external sources or STDMA ground stations. GNSS position/velocity/time and other navigation and guidance information can be provided to external systems such as autopilots and displays.

3.5.2 If GNSS-derived navigation data is not available (e.g. due to equipment failure), an STDMA station can derive a coarse position fix by processing STDMA messages received from other STDMA stations. STDMA position reports give a station's position and velocity slaved to Universal Co-ordinated Time (UTC),. These position reports are transmitted in a frame structure that is also tied to UTC. An STDMA station can triangulate to determine its own position by calculating ranges to the declared positions of the other STDMA stations in the environment. It is also possible for an STDMA station to develop an estimate of UTC in order to support its own transmit activities. The ability to determine position and time from received STDMA position reports depends on the existence of sufficient other STDMA stations in the airspace or on the ground, which are themselves synchronized to UTC time and have sufficient positioning accuracy to act as a primary source of navigation.

#### 3.5.3 Domestic backup to GNSS

3.5.3.1 As a special case, the STDMA ground stations could provide a limited backup for GNSS. Ground stations are at surveyed locations; with the addition of atomic clocks (currently becoming available), a network of ground stations would provide, a navigation infrastructure that is independent of GNSS, and accurate to approximately 1 nmi (i.e. sufficiently accurate for en-route operations).

## 4. Potential applications

4.1 These STDMA VDL protocols are proposed as part of ICAO's implementation of a world-wide CNS architecture. In conjunction with other VDL protocols optimized for: (1) long aperiodic communications; and (2) combined voice and data communications, the STDMA VDL will permit definition and implementation of numerous air-ground VHF communication-based applications to support Air Traffic Service requirements. Several applications have already been defined and proposed for use in the near term, while others are yet to be properly quantified and reduced to a set of application level requirements. Air Traffic Service Communications (ATSC) based data applications that can be supported by the proposed STDMA VDL protocol are listed below:

### 4.2 Broadcast data applications

4.2.1 **Ground based GNSS augementation**. This application augments GNSS integrity, provides increased availability, and provides increased accuracy for local area GNSS operations.

4.2.2 **Satellite based augmentation**. This application augments GNSS integrity and provides increased availability for wide-area GNSS applications. Additionally, it permits local ground based VHF stations to operate as independent back-up time and navigation ranging sources in the event of primary avionics or satellite failure, and to provide supplementary coverage in areas where satellite based augmentation signal availability is not fully assured (extreme latitudes, and areas of poor satellite coverage).

4.2.3 **Automated dependent surveillance (ADS-B)**. The aircraft-based ADS-B application automatically broadcasts aircraft position, altitude, and vector information for use and display by other aircraft and by ground users.

4.2.4 **Flight information service broadcast (FIS-B)**. The ground-based FIS-B application broadcasts time-sensitive weather and supporting information to aircraft.

4.2.5 **Traffic information service-broadcast (TIS-B)**. The ground-based TIS-B application broadcasts a correlated surveillance product for the airspace. Surveillance data may be combined from primary and secondary radars, satellite-based ADS, ADS-B (STDMA and Mode S squitter) and other assets (e.g. surface surveillance radar for surface operations).

4.3 **Addressed data applications**

4.3.1 **Controller/Pilot Data Link Communications (CPDLC)**. The CPDLC application provides data communication (such as requests, clearances, and air-ground traffic flow information) between pilots and controllers, and their respective systems.

4.3.2 **Automatic Dependent Surveillance (ADS)**. The aircraft ADS application responds automatically to ground system requests for a variety of reports, including position and related weather information, either periodically or upon occurrence of a specified event.

4.3.3 **Flight Information Services (FIS)**. FIS applications involve collection, handling and dissemination of flight related information to and from designated users. Applications include the Traffic Information Service (TIS), FIS Request/Reply (FIS R/R), and FIS Down-Link (FIS D-L).

4.3.4 **Context Management (CM)**. The CM application provides the initial aircraft log-on to a ground system through the exchange of appropriate aircraft and ground system addresses (such as ATN transport address). CM can also be used to forward aircraft addresses to other ground systems.

4.3.5 The following table lists applications by mode (autonomous or controlled) of operation that can be supported by equipment compliant with these SARPs.

| Application | No control station available | Controlled or centrally managed station available |
|---|---|---|
| Automatic Dependent Surveillance - Broadcast | • | • |
| Automated hand-off for ATC comm<br>• autotune aircraft comm radio<br>• controller/controller hand-off in support of VHF analog voice | | • |
| Search and rescue<br>• ELT beacon<br>• Position report stored in all stations which received it | • | • |
| Differential GNSS uplink | | • |
| TCAS functionality (for low-end aircraft) | • | • |
| Flight services (file flight plans, amend, etc.) | | • |
| Weather services (uplink weather map; downlink local conditions) and FIS-B | | • |
| Traffic Information Service-Broadcast (TIS-B) | | • |
| Flight clearances | | • |
| Vectoring information | | • |
| AOC | | • |
| Surface surveillance | | • |
| Surface CDTI | • | • |
| Surface navigation | | • |
| Taxi guidance/clearances | | |
| Collision avoidance; conflict probing | • | |
| Air-to-air data exchange | • | |
| | • | |

Figure 4-1. Potential Applications of STDMA

### 4.4 Existing STDMA VDL to serve as the demonstration system

4.4.1 The current STDMA VDL system has been defined, developed, tested and operated for a number of years. It has demonstrated validity in large-scale tests and in controlled demonstrable environments. The data collected and results of these tests have been published for widespread review. Additional test data and conditions for operational acceptance can be immediately established and verified by the CAA/ICAO community to assess the system's viability. The SARPs are further enhancements to the current STDMA VDL concept and demonstrate the upward scaleability of the proposed STDMA VDL. The final implementation of STDMA defined in the SARPs will permit substitution of the AMCP approved D8PSK modulation scheme (Mode 2 of CSMA/VDL SARPs) in lieu of the current FM GMSK modulation. This change will permit the STDMA VDL system to operate at a data transmission rate of 31.5 kbits/sec (versus 9600 bits/sec under FM/GMSK) using the D8PSK modulation scheme. Compatibility of the two VDL SARPs at the physical layer, and portions of the data link layers are also maintained. Accordingly, the current STDMA systems will serve as the validation platform for the final AMCP approved STDMA. Operation and installation of the validation system will continue until AMCP accepted D8PSK-based modulation is fully verified and certified.

### 4.5 Supports gate-to-gate CNS/ATM data communications in "All-Weather" Operations

4.5.1 At the specific request of several Provider State CAAs, air carriers, and avionics and aircraft manufacturers, the proposed STDMA VDL SARPs have been enhanced to provide a communications architectural framework to permit STDMA to support all weather operations from VFR conditions up to and including Category I/II/III IMC and surface movement operations, in environments from sparse en-route to high density airspace.

### 4.6 Permit transition planning to enhance safety of flight, coexistence and interoperability with other existing data link technologies

4.6.1 Each VDL standard proposed to the international community has been optimized to enhance certain features and capabilities at the expense of others. The proposed STDMA VDL is compatible with these other standards, at the physical layer and selected sublayers of the data link layer, in selected modes of operation. This limited compatibility and interoperability suggests that common avionics can be developed with multiple modes of operation, providing user-desired mixes of functionality in a cost-effective package. Any new standard must be developed with a goal of interoperability and hardware compatibility.

## 5. Hardware concept for STDMA VDL

5.1 The basic hardware concept for STDMA avionics consists of a single frequency-agile transmitter and two frequency-agile receivers. This is illustrated in Figure 5-1. With a minimal avionics suite and in remote or low-density airspace, the two receivers would dwell on the common signaling channels and the transmitter would alternately tune between the two channels to transmit the user's ADS-B reports. The two receive channels would collect all ADS-B reports in range, yielding track updates for all nearby users at nominal 5 second epochs. If a ground station is present, a directory of services might also be received on the common signaling channels. The basic STDMA avionics suite, which includes one transmitter and two receivers, is sufficient to perform all STDMA-supported functions. However, this basic suite will force some users to accept tradeoffs among competing operational requirements. Thus, users may wish to expand the number of receiver and transmitter cards in the avionics package. Three or four receive channels and two transmit channels should be sufficient for all currently-identified functions.

5.2 If the user wishes to perform auxiliary functions, such as reception of DGNSS data link or AOC data transfer, one of the available receivers would be autotuned to the appropriate frequency channel. In a receive-only application, such as DGNSS data link, ATIS, weather updates, CDTI, etc., this is sufficient to support the intended function. In a receive/transmit application, the receiver may have to dwell for 1-2 minutes to collect slot usage information on the channel prior to data link transmission. Alternatively, if the user is operating under ground control, a transmission slot may have been pre-assigned by the ground station for the user's specific requirement. This would allow rapid autotuning and data transmission. Since most users will have low transmit duty cycles, a single transmitter is likely to be sufficient for virtually all operational scenarios. A second transmitter is required only in the event that a user anticipates high-priority communications where delays on the order of 10 msec are deemed unacceptable. For safety-critical applications, a full dual-redundant equipment suite may be required. For example, Category II/III precision approach operations may require dual-redundant avionics with receivers tuned to independent frequency channels (or independent time slots on the same channel).

**Figure 5-1. STDMA Hardware Concept**

### 5.3 Single avionics hardware and software architecture enhances safety of flight components and assists in flight certification procedures

5.3.1 The basic hardware concept for STDMA VDL avionics consists of a single frequency-agile transmitter and two frequency-agile receivers. With a minimal avionics suite and in remote or low-density airspace, the two receivers would dwell on the common signaling channels and the transmitter would alternately tune between the two channels to transmit the user's ADS-B reports.

5.3.2 The basic STDMA avionics suite is sufficient to perform all STDMA-supported functions. If the user wishes to perform auxiliary functions, such as reception of DGNSS data link or AOC data transfer, one of the receivers would be autotuned to the appropriate frequency channel. In a receive-only application, such as DGNSS data link, ATIS, weather updates, CDTI, etc., this is sufficient to support the intended function. Subject to operational requirements and cost tradeoffs by aircraft operators, additional receiver (and transmitter) cards could be purchased to enhance the operational availability of auxiliary functions. For safety-critical applications, a full dual-redundant equipment suite may be required. For example, Category II/III precision approach operations may require dual-redundant avionics with receivers tuned to independent frequency channels (or independent time slots on the same channel). Thus the certification issues associated with equipage of a wide variety of aircraft with varying levels of equipment sophistication will be greatly simplified through the implementation of single common hardware and software architecture that permits operations in the most favourable to the most demanding environment.

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