NATO STANDARD

AEP-77 VOLUME I

INTEROPERABLE COMMAND AND CONTROL DATA LINK FOR UNMANNED SYSTEMS (IC2DL) – TOP LEVEL DESCRIPTION

Edition A Version 1
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NORTH ATLANTIC TREATY ORGANIZATION

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NORTH ATLANTIC TREATY ORGANIZATION (NATO)

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NATO LETTER OF PROMULGATION

14 November 2016

1. The enclosed Allied Engineering Publication AEP-77 Volume I, Edition A, Version 1, INTEROPERABLE COMMAND AND CONTROL DATA LINK FOR UNMANNED SYSTEMS (IC2DL) TOP LEVEL DESCRIPTION, has been approved by the nations in the NATO NAVAL ARMAMENTS GROUP, is promulgated herewith. The agreement of nations to use this publication is recorded in STANAG 4660.

2. AEP-77 Volume I, Edition A, Version 1 is effective upon receipt.

3.

4. This publication is NATO UNCLASSIFIED and shall be handled in accordance with C-M(2002)60.

EDVARDAS MAZEIKIS,
Maj Gen, LTUAF
Director NATO Standardization Office

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RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS
Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Documents Database for the complete list of existing reservations.	

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RECORD OF SPECIFIC RESERVATIONS

[nation]	[detail of reservation]
BEL	This STANAG will be implemented for future systems and with a restriction on the use of the frequency band. In Belgium only the 4.4GHz - 5GHz can be implemented.

Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Documents Database for the complete list of existing reservations.

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The Allied Engineering Publication AEP-77, Interoperable Command and Control Data Link for Unmanned Systems (IC2DL), is made up of three volumes:

Volume I: IC2DL Top Level Description.

Volume II: IC2DL Physical Layer / Signal in Space Description.

Volume III: IC2DL Operational Physical Layer / Signal in Space Description.

To implement the technical definition and description of IC2DL all three volumes of AEP-77 are required.

This publication is Volume I: IC2DL Top Level Description and shall be handled in accordance with C-M(2002)60.

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CHAPTER 1 INTRODUCTION

1.1. AIM

1. The purpose of this AEP document is to define a standard Line Of Sight (LOS) Interoperable Command and Control Data Link (IC2DL) for Unmanned Systems that will facilitate and support NATO interoperability between heterogeneous Unmanned Systems (e.g. an Unmanned Aircraft (UA) from one system operated by a ground control system from another UA system (UAS)).

1.2. BACKGROUND

1. Data links provide connectivity between a remote controller and an unmanned aircraft. Pre-feasibility studies, including the NATO Industrial Advisory Group (NIAG) Study Group (SG) 53 Pre-Feasibility Study on Unmanned Air Vehicle (UAV) Systems Interoperability, concluded that a dual link architecture, consisting of a High Data Rate Data Link (HDRDL) and a high integrity Low Data Rate Data Link (LDRDL), are required to meet operational reliability, safety and Air Traffic Management (ATM) requirements for UAS operations in joint, coalition, and controlled air space operating environments.

2. The function of the HDRDL is to provide high rate imagery downlink capability for selected payloads, e.g. imagery, the associated telemetry if required, and a low rate command uplink for command and control of the air vehicle and its payload(s). The HDRDL provides short range video and telemetry broadcast to forces in the field for tactical situational awareness and is capable of conveying digital voice for Air Traffic Control (ATC) purposes. The UAS HDRDL requirement is supported by STANAG 7085 - Interoperable Data Links for Imaging Systems and this STANAG is the recommended NATO standard for the UAS high data rate data link.

3. For purposes of this AEP, low data rate is defined as less than 1 Mbits/sec. The objectives of the LDRDL are supported by this AEP description of the IC2DL.

1.3. IC2DL PURPOSE

1. The function of the IC2DL is to provide:

   a. A command and control (C2) uplink and telemetry downlink for multiple UAS;

   b. A limited narrow band sensor downlink for sensors such as EO/IR, ESM, and EW;

c. Digital voice communications for ATC purposes;

d. A network enabled capability to support communication with up to 5 active nodes.

1.4. SCOPE

1. The IC2DL specification described within this AEP document has been developed by defining three broad system characteristics: the transmission waveform description, network management process and the internal data link layer interfaces and communication protocols and message formats. The transmission waveform describes the frequency, pulse construction, and waveform properties for the data link carrier. The AEP was developed using ISO/IEC 7498, Open Systems Interconnection (OSI) model and the typical seven layers which describe the OSI model. The internal interfaces are the characteristics between the OSI layers defined in ISO/IEC 7498.

2. Specific configuration messages for IC2DL provided through external interfaces (e.g. UAS Control System (UCS)) are not included in this document and can be found in STANAG 4586 - Standard Interfaces of UAV Control System (UCS) for NATO UAV Interoperability.

3. IC2DL has been developed against a set of harmonised characteristics and requirements which are also captured within this document.

4. IC2DL is applicable to all UAS types and it is quite likely that a number of different Signals in Space (SiS) will be required to fulfil the mission and safety needs required for all UAS types. One IC2DL waveform is described with multiple SiS in this AEP. A SiS is defined as a unique combination of transmission characteristics that describes the over the air signal in space and time, for example:

- Single carrier / multi-carriers
- Modulation scheme and modulation order
- Spreading techniques
- Channel coding scheme and rate
- Interleaving scheme

1.5. INTEROPERABILITY APPROACH

1. To address potential interoperability concerns due to the presence of more than one Physical Layer (Layer 1) described in the AEP, the implementation of IC2DL shall be governed by the following:

- SiS 1-3 shall be **MANDATORY** and is referenced as SiS M in this document

- SiS 4 shall be **OPTIONAL** and is referenced as SiS O in this document

2. This means that a Nation wishing to implement STANAG 4660/AEP-77 must implement SiS M and SiS O is optional. As an example:

- Nation X wishes to use only SiS M - so Nation X will only implement the SiS M.
- Nation Y wishes to use SiS O - so Nation Y will have to implement both SiS M and SiS O.
- Nation X and Y are interoperable using SiS M.

1.6. DOCUMENT STRUCTURE

1. The structure of AEP-77 is split into three volumes:

Volume I: IC2DL Top Level Description (NATO UNCLASSIFIED);
Volume II: IC2DL Physical Layer and Signal in Space (SiS) description (NATO RESTRICTED);
Volume III: IC2DL Operational Physical Layer and SiS parameter values (NATO SECRET);

2. The AEP is structured in this way to cover the different classification levels (shown in brackets) of the information used to define IC2DL and all three volumes are required to define and implement an operational version of IC2DL.

3. This document is AEP-77 Volume I which defines the top level description of IC2DL. The document follows the outline described below:

- Chapter 1: Introduction
- Chapter 2: Overview
- Chapter 3: Reference Model
- Chapter 4: IC2DL Detailed Description
- Chapter 5: Reference Documents
- Chapter 6: Terms and Definitions

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CHAPTER 2 OVERVIEW

2.1. INTRODUCTION

1. UAS have become valuable assets in helping Joint Force Commanders (JFC) to meet a variety of theatre, operational and tactical objectives. The optimum synergy among the various national UASs deployed requires close co-ordination and the ability to quickly task available UAS assets, the ability to mutually control the air vehicles and their payloads, as well as rapid dissemination of the resultant information at different command echelons. This requires the employed UAS to have the communication data links that can reliably transmit the variety of data types to support UAS missions.

2. The following sections in this chapter provide the general description of IC2DL: the high level architecture and concept of operations. These concepts are then decomposed into the overall IC2DL system characteristics and requirements.

2.2. NETWORK

1. IC2DL has been developed to serve as a small communications network, which connects a set of nodes. A “node” can be a UAV platform, payload, or a controlling element. A controlling element can be a UAS control system (UCS), data processing / analysis facility, or a remote receiver. Each node may have different types of data associated with it: UAS command and control (including take-off and landing); mission command and control; or sensor data or voice. The specific data types to be transmitted by the data link are user/system specific, e.g. the user/system determines the data to be transmitted via the IC2DL.

2. A node can be Active or Passive. Active nodes transmit and receive data, while Passive nodes only receive data without acknowledgement. IC2DL shall have the capability to support up to five Active nodes. The IC2DL system has adopted a Time Division Multiple Access (TDMA) approach within its architecture. TDMA, coupled with system frequency and operating range restrictions, limits the number of active nodes. The IC2DL system will also perform basic network management functions, such as, system timing, data processing prioritization, node assignment, TDMA time allotments, and data mapping.

2.3. OPERATIONAL SCENARIOS

1. Several operational scenarios are presented which represent typical situations of IC2DL employment. Each scenario was constructed to demonstrate a different set of particular IC2DL characteristics (a user is not limited to use only these scenarios). The scenarios can be considered as Use Cases from which overall system

requirements can be decomposed and these characteristics will be summarized as system requirements and Information Exchange Requirements (IERs) later.

2.3.1. Use Case 1

1. In Figure 1: A typical concept of operations utilizing five nodes, the UCS is using a relay UAV to control the mission UAV, which is Beyond the Line Of Sight (BLOS) of the UCS. The mission UAV is relaying sensor data of the target back to users for analysis. The organization's Headquarters (HQ) requests sensor data and acknowledges receipt. Other organizational agencies are passively monitoring UAV transmissions and using the data for their own internal purposes. Simultaneously, the UCS is launching another UAV to relieve the mission UAV, currently on-station.

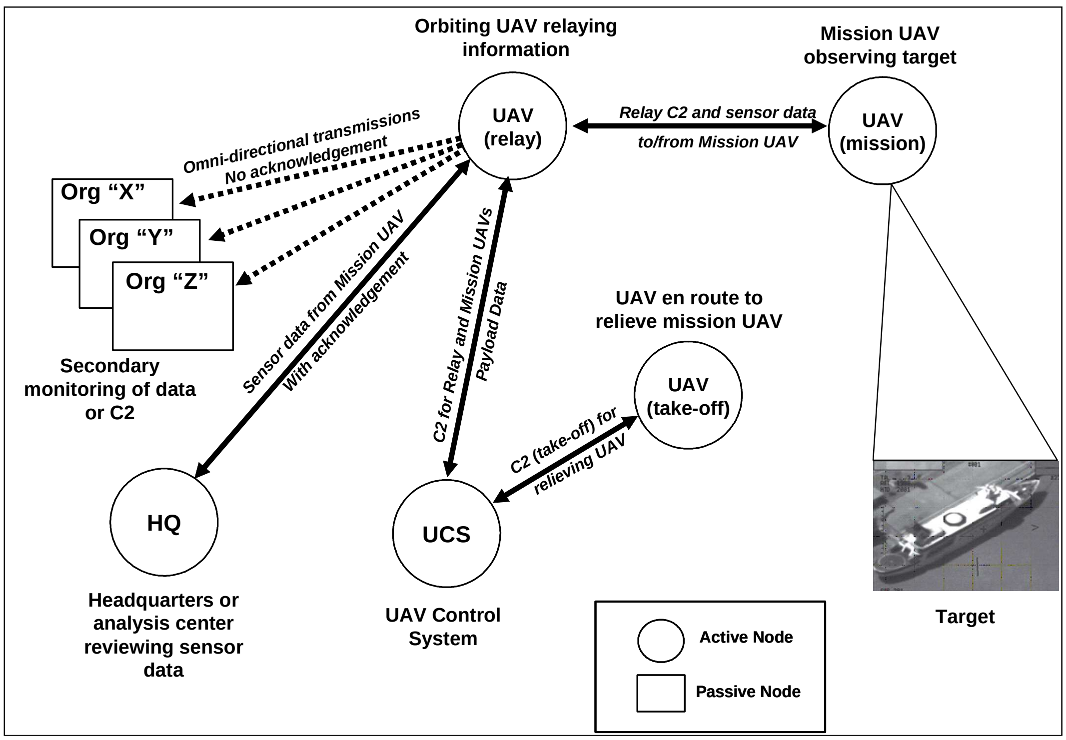

Figure 1: A typical concept of operations utilizing five nodes

2.3.2. Use Case 2

1. In Figure 2: Addition of fourth node to network, the mission UAV is providing sensor data to a user in the field. The UCS is also controlling the mission UAV. A new node is introduced into the network via a pre-negotiated procedure with the current UCS to assign node identification and TDMA time allocation (note: a "new" node could be a UAV or another UCS). Once the new UAV is accepted into the network, the current UCS assumes control of the new UAV. Periodically each UAV will broadcast its position/state data. This inter-UAV communication may be used for vehicle separation, coordination, or other tactical functions.

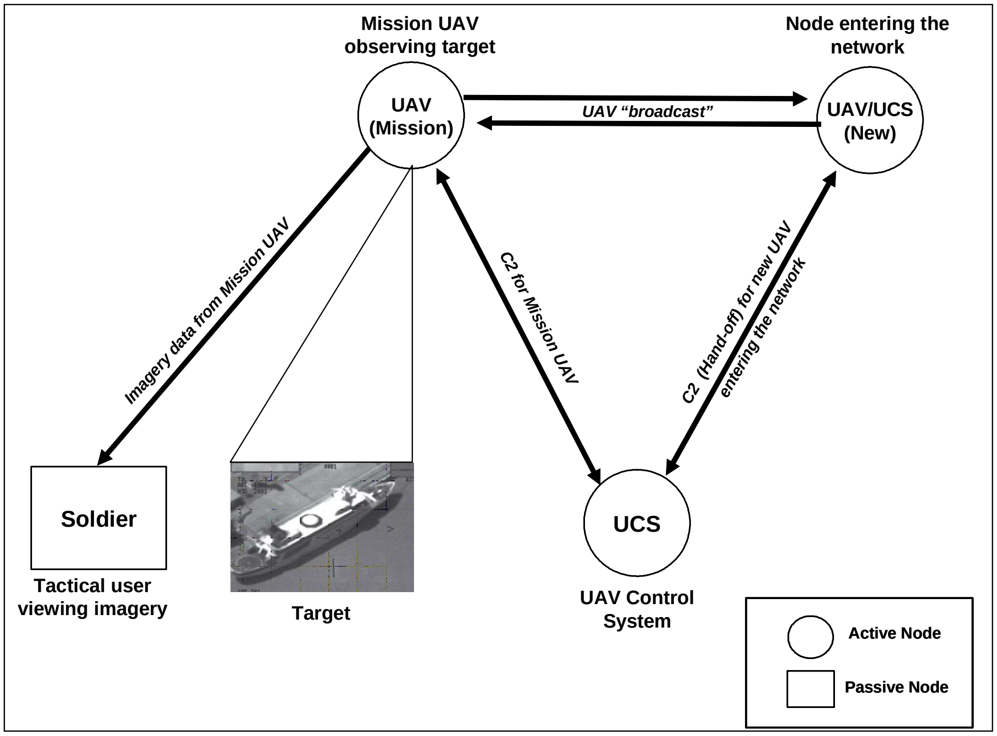

Figure 2: Addition of fourth node to network

2.3.3. Use Case 3

1. In Figure 3: UAV interoperating with an External Network, the mission UAV is flying in civilian controlled air space. The human operator at the UCS establishes and maintains voice communication with the local air traffic control authority to comply with civilian operating procedures. IC2DL will provide a digital voice interface between a ground station node and an air vehicle node's air traffic control radio. Simultaneously, an IC2DL node is serving as a gateway and the mission UAV is receiving sensor command and control from the user's net-centric environment. Although the net-centric environment may be vastly more complex than the IC2DL net, it still operates as a node with a TDMA allocation. The mission UAV may now transmit low data rate sensor information to the user's external network.

2. As there are only three "nodes" in use in Figure 3 the UCS could also be landing a second UAV and/or controlling a third UAV.

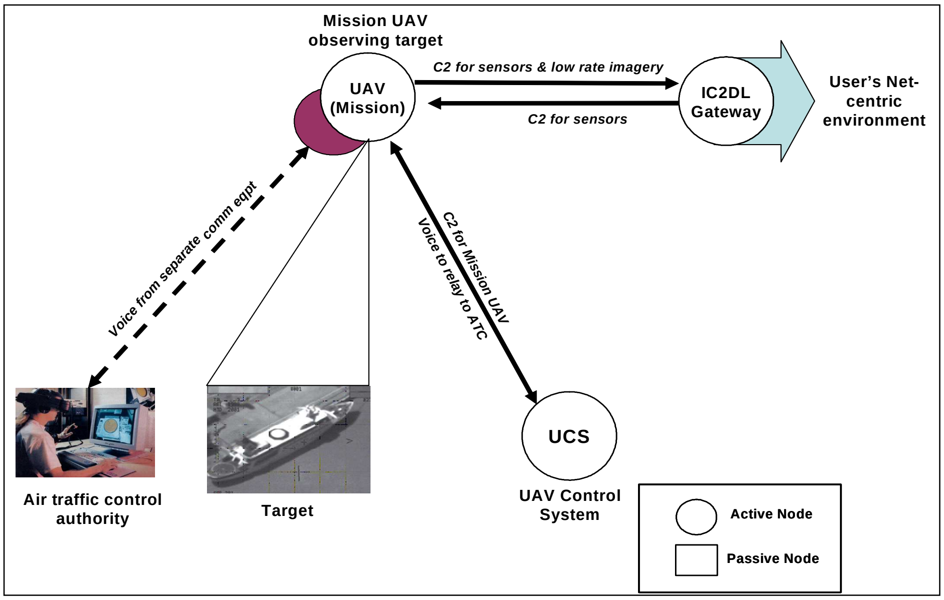

Figure 3: UAV interoperating with an External Network

2.3.4. Use Case 4

1. In Figure 4: Multiple IC2DL Networks in Simultaneous Operation, multiple networks are operating within one local area of operation. The underlying concept associated with this scenario is communications management. Several IC2DL networks can be operating simultaneously within one area of operations in which the assigned frequency allocations for each network may be limited. Under these conditions, frequencies will be allocated to UCS1 and UCS2 to preclude frequency interference among the networks.

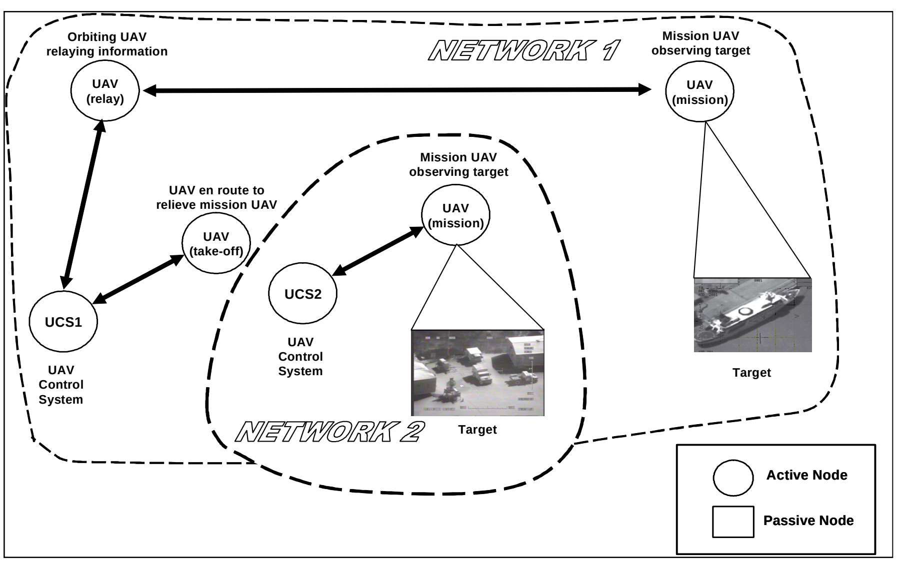

Figure 4: Multiple IC2DL Networks in Simultaneous Operation

2.4. IC2DL CHARACTERISTICS AND REQUIREMENTS

2.4.1. Top level characteristics

1. The top level characteristics for IC2DL are:

   a. Ability to support various types of UAS classes / categories.

   b. Convey, in near real-time, command and control data, telemetry status data, digital voice, and, bandwidth permitting, other user defined data during all phases of a mission including take-off and landing.

   c. Enable a UCS (an active node) to communicate near-simultaneously with a number of other active nodes (e.g. UASs, UCSs) within a network.

   d. Capability of adjacent networks to operate within the same operational area without interfering with each other.

   e. Network node configuration to be scalable from two to at least five active nodes.

   f. Capability to relay data between nodes to provide a BLOS capability (i.e. a one hop relay capability).

   g. Capability to support passive nodes (i.e. receive data without having to transmit).

   h. Provide high data link integrity – measure of link availability and quality of service.

   i. Operate in a multi-path environment and provide some measure of ECCM (EPM) capability (LPI, LPD, and anti-jam) – measures adopted need to be switchable (e.g. any frequency hopping or spread spectrum adopted measures should have an On/Off capability).

   j. Network to synchronize and operate without reliance on external timing/clocking source (e.g. no dependence on GPS-derived time).

   k. Network to synchronise and operate without node location (e.g. latitude and longitude node information accuracy not known).

   l. Network will have a single time master at any given time.

   m. Provisions for alternate timing master in the event of the loss of the current master under external control.

   n. Nodes joining the network are responsible for network synchronisation and selecting a non-interfering network assignment (in accordance with a pre-assigned network plan).

   o. Each node is responsible for reporting link status and detected faults to its locally connected computer (host).

   p. Capability to be tuned across a selected range of frequency bands.

q. Incorporate STANAG 4671 subpart H, Command and Control Data Link, requirements.

2.4.2. Information Exchange Requirements (IERs)

1. In addition to the above performance characteristics, IC2DL shall be able to exchange information between nodes, as contained in Table 2: IER Matrix.

2. The IERs describe the characteristics of the information or data that flows between nodes to support a particular operational condition. Table 2: IER Matrix lists the type of data and its characteristics for each node transfer. The column heading definitions for the matrix are described in Table 1: IER Matrix Column Heading Definitions.

Column Heading	Definition
Information Description	An operational task to be performed by IC2DL.
Type of Information	The type of data that is being transferred.
UJTL/NTA	Universal Joint Task List/Navy Task. Although these are drawn from US tactical definitions, it is meant to serve as a generalized high level task description reference for justifying the Information Description element.
Node-send	The IC2DL node sending the information.
Node-receive	The IC2DL node receiving the information.
Frequency	This refers to how often the data exchange takes place.
Data Rate	This refers to maximum rate for exchanging information between nodes.
Timeliness	This indicates how quickly the information response is to the first request.
Criticality	An indication to show whether or not the data exchange is critical.
Area	An indication to show if the Criticality is based on “Flight” or “Mission” success.

Table 1: IER Matrix Column Heading Definitions

3. The definition of each task description is listed in Table 3: Task Description Definitions.

Information Description	Type of Information	UJTL/ NTA	Nodes		Information Exchange Attributes				
			Send	Receive	Frequency	Data Rate	Timeliness	Criticality	Area
Command sensor	C2	TA 5.1/NTA 5.1.2	UCS	UAV	5-10Hz	5 kb/sec	30-100ms	Yes	Mission
Command UAV (tactical)	C2	TA 5.1/NTA 5.1.2	UCS	UAV	5-10Hz	5 kb/sec	<500ms	Yes	Flight
Command sensor	C2	TA 5.1/NTA 5.1.2	Net	UAV	5-10Hz	5 kb/sec	30-100ms	No	
Report UAV status (tactical)	C2	TA 5.1/NTA 5.1.2	Other A/C	UAV	5-10Hz	0.2 kb/sec	100ms	Yes	Flight
Command UAV (T/O & Land)	C2	TA 5.1/NTA 5.1.2	T/O & Land	UAV	20-25Hz	25 kb/sec	<30ms +/- 5ms	Yes	Flight
Report sensor status	C2	OP 2.2.1/NTA 2.2.1	UAV	Remote	5-10Hz	5 kb/sec	<1 sec	Yes	Mission
Report sensor status	C2	TA 5.1/NTA 5.1.2	UAV	UCS	5-10Hz	10 kb/sec	<1 sec	Yes	Mission
Report sensor status	C2	TA 5.1/NTA 5.1.2	UAV	Net	5-10Hz	5 kb/sec	<1 sec	No	
Report UAV status (T/O & Land)	C2	TA 5.1/NTA 5.1.2	UAV	T/O & Land	20-25Hz	25 kb/sec	<30ms +/- 5ms	Yes	Flight
Report UAV status (tactical)	C2	TA 5.1/NTA 5.1.2	UAV	UCS	5-10Hz	5 kb/sec	100ms	Yes	Flight
Report UAV status (tactical)	C2	TA 5.1/NTA 5.1.2	UAV	Other A/C	5-10Hz	0.2 kb/sec	100ms	Yes	Flight
Collect Sensor data	Sensor: EO, IR, SAR, ISAR, SIGINT	ST 2.2.1/NTA 2.2.3	UAV	UCS	On request	50 kb/sec	<5 sec	Yes	Mission
Collect Sensor data	Sensor: EO, IR, SAR, ISAR, SIGINT	ST 2.2.1/NTA 2.2.3	UAV	Net	On request	50 kb/sec	<5 sec	Yes	Mission
Collect Sensor data	Sensor: EO, IR, SAR, ISAR, SIGINT	OP 2.2.1/NTA 2.2.1	UAV	Remote	On request	50 kb/sec	<5 sec	Yes	Mission
Collect Sensor data	Sensor: EO, IR, SAR, ISAR, SIGINT	OP 2.2.1/NTA 2.2.1	UAV	Exploit Facility	On request	50 kb/sec	<5 sec	Yes	Mission
Relay voice (tactical)	Voice	OP 5.2/NTA 5.1.1.1.2.2	UCS	UAV	On request	5 kb/sec	<300ms	Yes	Flight
Relay voice (tactical)	Voice	OP 5.2/NTA 5.1.1.1.2.2	UAV	UAV	On request	5 kb/sec	<300ms	Yes	Flight

Table 2: IER Matrix

UJTL/ NTA	Title	Definition
OP 2.2.1	Collect Information on Operational Situation.	To obtain operationally significant information on enemy (and friendly) force strengths and vulnerabilities, threat operational doctrine, and forces (land, sea, and air and space). Threat includes threat allies, and, in military operations other than war, insurgents, terrorists, illegal drug traffickers, belligerents in peace support or peace enforcement situations, and other opponents. It also includes collecting information on the nature and characteristics of the area of interest, to include collecting battlefield damage assessment, munitions effects, medical assessments, and hazards, such as NBC contamination to conduct mission assessment. The nature and characteristics of the area include significant political, economic, industrial, geospatial (e.g., aeronautical, hydrographic, geodetic, topographic), demographic, medical, climatic, and cultural, as well as psychological profiles of the resident populations. This task includes collecting counterintelligence information to protect against espionage, other intelligence activities, sabotage, or assassinations conducted by or on behalf of foreign governments or elements thereof, foreign organizations or persons, or international terrorist activities.
OP 5.2	Assess Operational Situation.	To evaluate information received through reports or the personal observations of the commander (commander’s critical information requirements) on the general situation in the theatre of operation and conduct of the campaign or major operation. In particular, this activity includes deciding whether different actions are required from those that would result from the most recent orders issued. This includes evaluating operational requirements of subordinate task forces and components.
ST 2.2.1	Collect Information on Theatre Strategic Situation.	To obtain strategically significant information on enemy (and friendly) force strengths and vulnerabilities, threat operational doctrine, and forces. This task includes collecting critical information on threats to and status of inter/intra-theatre transportation infrastructures and PODs that could affect planning and execution of strategic airlift, sealift, and land movement. It also includes collecting information on the nature and characteristics of the area of interest. This task includes collecting battlefield damage assessment, munitions effects, medical assessments, and hazards such as NBC contamination, in order to conduct mission assessment. This task includes collecting counterintelligence information. The nature and characteristics of the area include significant political, economic, industrial, geospatial (e.g., aeronautical, hydrographic, geodetic, topographic), demographic, medical, climatic, and cultural, as well as psychological profiles of the resident populations. Threat from opposing coalitions includes allies and, in military operations other than war, threat includes insurgents, terrorists, illegal drug traffickers, belligerents in peacekeeping or peace enforcement situations, and other opponents.
TA 5.1	Acquire and Communicate Information and Maintain Status and Force Reporting.	As described opposite.
NTA 2.2.1	Collect Target Information.	To acquire information that supports the detection, identification, location, and operational profile of enemy targets in sufficient detail to permit attack by friendly weapons. The target acquisition system may be closed-loop (an inherent part of a weapons system) or open-loop (separate from the firing system but, nevertheless, part of the overall weapon system). Activities include searching for, detecting, and locating targets; and then tracking to include information such as range, bearing, altitude/depth, latitude/longitude, grid, and course and speed of the target. It also includes conducting post-attack Battle Damage Assessment (BDA) and identifying follow-on targets. This task includes optimizing the use of organic collection assets to provide Bomb Hit

		Assessment (BHA) ISO BDA for targeting cycle and re-strike assessment, in addition to Electronic Warfare Support (ES). (JP 2-0 Series, MCDP 2, MCWP 2-1, NDP 2, NWP 2-01)
NTA 2.2.3	Perform Tactical Reconnaissance and Surveillance.	To obtain, by various detection methods, information about the activities of an enemy or potential enemy or tactical area of operations. This task uses surveillance to systematically observe the area of operations by visual, aural, electronic, photographic, or other means. This includes development and execution of search plans. (JP 2-0 Series, MCDP 2, MCWP 2-1, NDP 2, NWP 2-01, NWP 3-01 Series, NWP 3-15 Series, NWP 3-21 Series)
NTA 5.1.1.1.2.2	Relay Communications.	To pass information which cannot reach its targeted audience directly. This includes the use of aircraft for tactical relay. (JP 3-0, 6-0, 6-02, NDP 6, NWP 6-01, 6-01.1)
NTA 5.1.2	Manage Means of Communicating Information	To direct, establish, or control the instruments used in sending or receiving information and to use various communication networks (visual, radio, wire and cable, and messenger) and modes (e.g., FM, multi-channel, RATT, CW, tactical satellite, data, facsimile) for obtaining or sending information. To operate these nets under various levels of emissions control (EMCON).

Table 3: Task Description Definitions

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2.4.3. Detailed Performance Requirements

1. Table 4: Detailed Performance Requirements lists specific performance requirements for IC2DL. These requirements were derived from the harmonized requirements[1] agreed by JCGUAS.

PARAMETER	REQUIREMENT
Bit Error Rate (BER)	10^{-8} (without encryption)
Link Availability	System Dependant(1)
Environmental Conditions	System Dependant
Operating Frequency Band	Located within the 1-5 GHz(2) range
Inter-node Speed (relative)	0 – 1320 knots
Waveform Inter-node Range	0.001-200NM
Reported Inter-node propagation time Accuracy	+/-200 nanoseconds
Data rate (network)	300 kbps (minimum capability)
Encryption	External to Data Link
LPI/LPD	To be achieved by spread spectrum(3)
Maximum Latency Launch and Recovery Air Vehicle C2 (non-L/R) Sensor C2 Voice	 50ms 1 second 150ms 30ms
Minimum Update rate supported for: Launch and Recovery Sensor C2	 25 Hz 10 Hz
Polarization	Vertical
Communication protocol Ground Data terminal (GDT) Air Data Terminal (ADT) Digital Voice/ATC (Military)	 IP/UDP IP/UDP For example AMBE 4.8 kb/sec
Multiple Access Communication	To be achieved by TDMA
External Timing Source	GPS/GNSS timing source not required.
Synchronisation Time	Less than 10 seconds
Antenna type and power output	System Dependent
Notes: (1) STANAG 4671 specifies overall link availability. (2) Waveform has to be capable of operating over this range. This does not mean that individual receiver-transmitters must operate over the full range. (3) The initial requirement captured in the harmonised requirement document has been revised to a more general description which reflects the variations due to the Signal-in-Space that can be adopted.	

Table 4: Detailed Performance Requirements

2. It should be noted that User Datagram Protocol (UDP) was chosen for the communication protocol because it is the preferred method for a connection-less

[1] The harmonized requirements for IC2DL are referenced in AC/141(JCGUAV)D(2008)0007 dated 15 October 2008 and agreed by NNAG JCGUAS through silence procedure 31 October 2008.

network. UDP also makes IC2DL compatible with STANAG 4586 systems. From an operational perspective, it is better to obtain “current” data, than to re-transmit and queue “stale” data.

2.4.4. Additional Assumptions

1. In addition to the requirements of Table 4, the following assumptions are included for the definition of the waveform:

a. The total usable bandwidth allocated to UAV Command and Control service under Line Of Sight (LOS) condition is in a range of 50 MHz, between 1 GHz and 5 GHz.

b. The minimum bandwidth required for the link to function is 1 MHz. This case corresponds to operation in fixed frequency.

c. The signal bandwidth at –30dB shall be in the order of 1MHz for SiS M and 5MHz for SiS O.

d. The channel spacing shall be in the range of 2MHz.

e. The useful node shall be situated at the maximum operational range (200NM) and the transmitter in the adjacent channel at the minimal separation distance of aeronautical platforms: 2NM. As the range ratio is 100, the adjacent channel power will be 40 dB greater than the desired signal.

f. The time spread of the different multi-paths can be as great as CHANNEL_LENGTH.

g. Network configuration and key management are outside the scope of this standard.

h. To achieve synchronisation in less than 10 seconds, time needs to be loaded with an accuracy of +/- 2 seconds with respect to the network time. If SiS O is being used and frequency hopping is not being used then time does not need to be loaded.

i. Phase noise, integrated from 100Hz to 10MHz shall be better than 5°RMS.

2.4.5. Frequency Sub-bands

1. In order to better explain how a STANAG 4660 data link can be designed within the operating frequency range of 1 GHz to 5 GHz, any or all of the following sub-bands could be implemented:

a. 1.164 – 1.375 GHz (L Band).

b. 2.025 – 2.400 GHz (S Band).

c. 4.400 – 5.000 GHz (C Band).

2.5. NOTIONAL IC2DL DESCRIPTION

2.5.1. Hardware Architecture

1. Figure 5: IC2DL Terminal Architecture illustrates an IC2DL terminal architecture. Under this architecture, all receivers "listen", while transmitters only transmit under designated, pre-assigned timeslots. Within IC2DL there are two functional components: the Digital Signal Processing section, which converts the incoming data into the proper digital stream and the RF section, which superimposes the data on the waveform carrier. There are two separate, logical classes of digital data:

a. Control and Status Information (CSI): This data is only for the local control of the terminal, such as ON/OFF, frequency settings, and terminal health reporting.

b. Application Data: This is the user data which is sent between Nodes. It is air vehicle and/or payload command, voice data to interface with Air Traffic Control, control and status and transmission of sensor data.

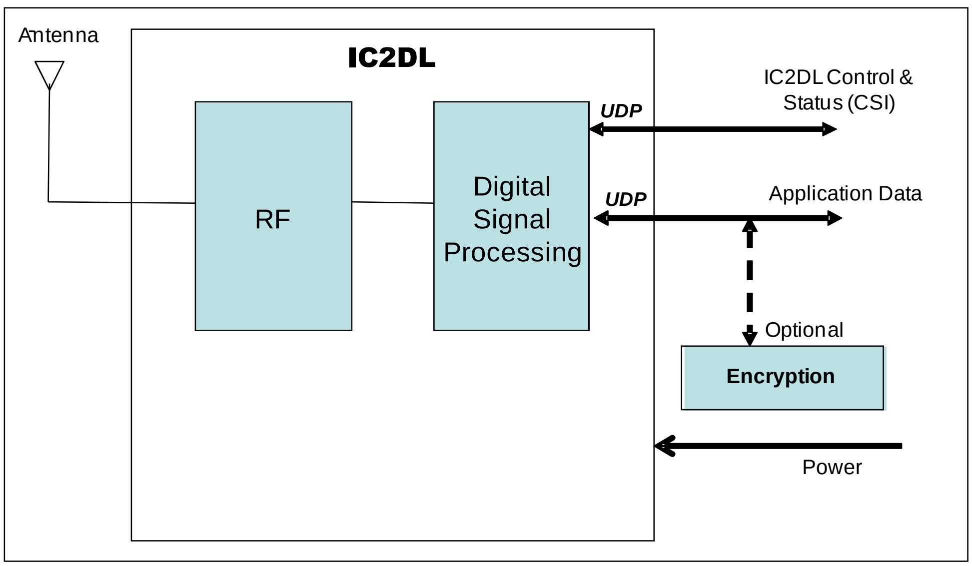

Figure 5: IC2DL Terminal Architecture

2. The architecture assumes that encryption is external to IC2DL and is optional.

3. The architecture assumes that the antenna is external to the IC2DL.

2.5.2. Network Circuits

1. The TDMA design allocates a fixed number of equal length timeslots per second. The terminal timeslot allocation is transparent to users of the IC2DL terminal.

A connection between two nodes is considered a virtual circuit. The virtual circuits are point-to-point resource allocations set up ahead of time or, in case of a joining node, set up dynamically. For each virtual circuit, bits are reserved. More bits means higher data rate for a virtual circuit. Fewer bits means lower data rate for a virtual circuit. The circuit possibilities depend on the network configuration. The common circuit possibilities include:

- Broadcast uplink and downlink
- Point to point (dedicated) uplink and downlink
- High throughput/Low latency circuits for take-off and landing

2. The implementation of circuits is described in Section 4.3.10.

2.6. DATA TYPES

1. The types of data that must be accommodated by the IC2DL are provided in Table 5: Required Data Types.

Data Type	Description	Protocol	Class
(1)	Command, control, and status (CCS) data used to control the sensor during the mission.	UDP data	Application
(2)	Command, control, and status (CCS) data used to control the air vehicle during the mission and navigation phases of flight.	UDP data	Application
(3)	Command, control, and status (CCS) data used to control the air vehicle during the take-off and landing phases of flight.	UDP data	Application
(4)	Digital voice to communicate between air vehicle controller and ground (Air Traffic Control) via the air vehicle.	UDP data	Application
(5)	User data.	UDP data	Application
(6)	Local command, control, and status (CCS) of the data link terminal	UDP data	CSI

Table 5: Required Data Types

2. The IC2DL system provides a form of Quality of Service (QoS) by allowing the user to assign up to four (4) priority levels for any of the Application data types.

CHAPTER 3 REFERENCE MODEL

3.1. BACKGROUND

1. The ISO/IEC basic reference model of OSI [ISO/IEC 7498-1] is used to define the architecture of the data link. Figure 6: Typical Seven Layer OSI Model depicts the typical seven layers which comprise the OSI model.

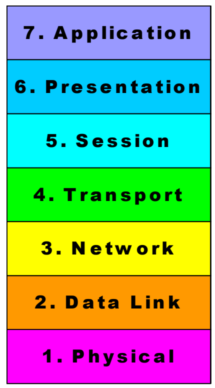

Figure 6: Typical Seven Layer OSI Model

3.2. IC2DL APPLICATION

3.2.1. OSI Tailoring

1. Although there are seven layers in the OSI model, not all of them need to be implemented. In the case of IC2DL several of the higher layers are null and two logical OSI stacks are used to utilize bandwidth more efficiently. In Figure 7: IC2DL Tailored OSI Reference Model, the UCS generates IP/UDP information in its OSI stack, which is then ported to the Control Data Terminal (CDT). The CDT processes the information and then transmits it to the Vehicle Data Terminal (VDT). The VDT then processes the information and ports it to the IP/UDP designated subsystem in the vehicle. In the transmit mode, IC2DL minimizes the IP/UDP headers before passing to the RF; in the receive mode, it reconstitutes the IP/UDP headers, based on the host provided data, before passing to the UCS or air vehicle.

2. While the IC2DL network is UDP/IP-based, it's assumed to be static in its configuration and could support up to the number of active nodes as defined in Section 2.2. The internal network connectivity tends to be point-to-point, where the UCS communicates with the nodes directly (and vice versa) without the necessity of routing the data via neighbouring node(s) through multiple hops (as in a standards-based IP-based network). The UCS is composed of core functionality, defined in STANAG 4586, with the capability to multiplex digital ATC voice communications. It is considered to

be the gateway for external communications networks (e.g. GIG, NIPRNET, SIPRNET, NSWan) into the IC2DL resources.

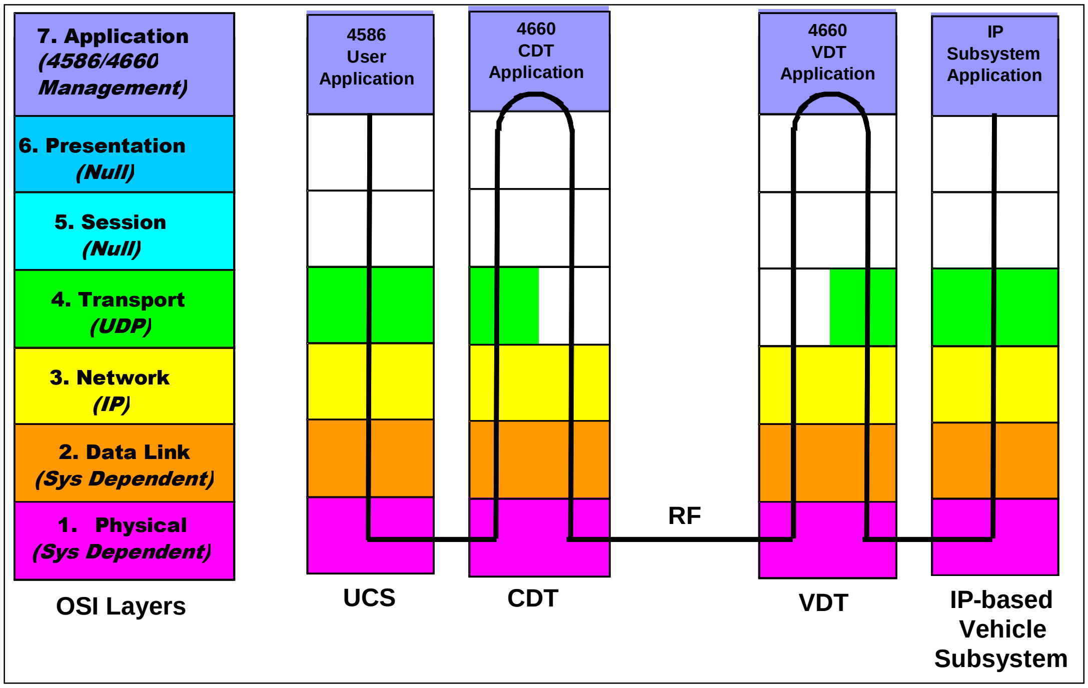

Figure 7: IC2DL Tailored OSI Reference Model

3.2.2. UDP Data (Application Data)

1. As shown in Figure 7, for uplink connection the UCS transmits command, control and status (CCS) data (including STANAG 4586 messages), digital voice, and/or sensor data, via UDP/IP to the CDT (e.g. Ethernet interface). The CDT processes the application data and transmits it in an efficient way that is optimized for IC2DL. Due to limited valuable over-the-air bandwidth, if the destination is IP based, only the minimal data is included in the transmissions over the air. Section 4.4 describes the scheme to manage TDMA slots and the associated data link/node ID, and appropriate IP addresses. This scheme includes an association “table” to ensure application data is transmitted to the correct destination or source /destination association. The “table” information is part of initial IC2DL network planning and each node is loaded with this information during initialization and only the updates to the “table” are transmitted over the air when a new node joins the network. With the messages defined in Section 4.4.4 and association “table”, the CDT places the correct data in the appropriate pre-assigned timeslot(s) for transmissions over the air to a receiving VDT.

2. As data arrives at the VDT interface, based on pre-assigned timeslot(s) in its configuration, the VDT Application retrieves data from the appropriate timeslot and processes and delivers it via UDP/IP (if the end destination is IP based) to the local avionics subsystem. If the end destination is non-IP based the VDT Application would

deliver the application data in a format compatible to the subsystem interface. For the down link connection, the avionics subsystem sends data to the VDT which has an Application that formats the received data and transmits it over the air on a pre-assigned timeslot. The CDT retrieves data from the appropriate pre-assigned timeslot and the CDT Application repackages the data based on the association table (including the necessary IP-based information) into UDP/IP/Ethernet format for delivery to the UCS.

3.2.3. Control and Status Information (CSI)

1. The CSI interface is IP based and provides the capability to control IC2DL locally by use of STANAG 4586 messages. The data terminal health status information is also reported through this interface. At a configurable time interval or on demand, the terminal health status is reported to the local control node. These status messages may be sent over the air to the UCS via the Application Data interface, dependent on the IC2DL configuration. In terms of Figure 7, this flow is mainly represented by having either of the IP-based messages sources terminating at their respective data terminal application layer.

3.2.4. Architecture Overview

1. IC2DL uses the OSI model and several of the higher layers are null. It also uses a Management Entity (ME) to utilize bandwidth more efficiently. As shown in Figure 8: Layered structure of the data link system in the transmit mode, the ME minimises the IP/UDP headers before passing to the RF; in the receive mode, the ME reconstitutes the IP/UDP headers, based on the host provided data, before passing to the UCS or air vehicle. The ME also sets the network configuration and the role for the participating nodes and is further defined in Section 4.3.2. Thus the Transport Layer (OSI layer 4) is absorbed into the Network Layer (OSI Layer 3) by the functions of the ME.

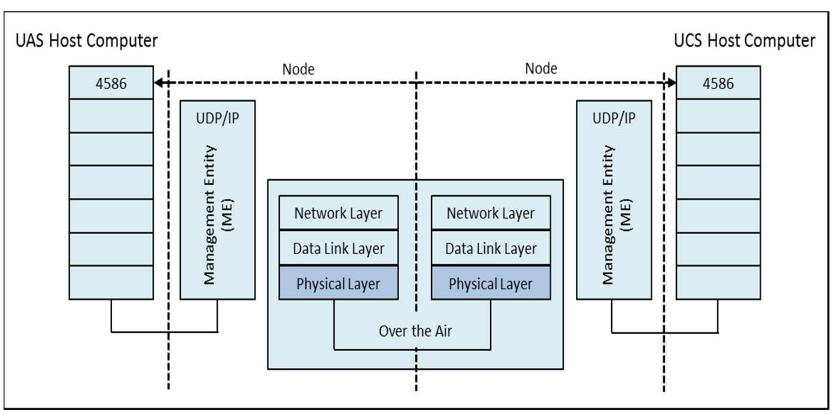

Figure 8: Layered structure of the data link system

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CHAPTER 4 IC2DL DETAILED DESCRIPTION

4.1. INTRODUCTION

1. This Chapter describes in detail the OSI Layers used by IC2DL.

4.2. PHYSICAL LAYER (LAYER 1)

1. See Volume II for the Physical Layer and Signal-in-Space description.

4.3. DATA LINK LAYER (LAYER 2)

1. The IC2DL data link layer is described and defined in the following sub-sections.

4.3.1. Data Link Layer Definition

1. The Data Link Layer for the IC2DL will be responsible for providing services to the IC2DL network layer. The Data Link layer's primary roles are: data encoding and decoding, and to provide a multiple access capability and mechanisms for multiple users to communicate to each other over a shared physical medium. The interfaces include control functions between the data link layer and the physical layer.

2. The Medium Access Control (MAC) functionality present in the traditional OSI Layer 2 is not implemented directly in the IC2DL Layer 2. The MAC layer functions, specifically addressing and channel access control mechanisms are contained in the Management Entity (ME), described below.

4.3.2. Management Entity Definition

1. Due to the TDMA nature of the radio network it is necessary to ensure changes to the configuration of the network are performed in a controlled manner. In order to achieve this, the concept of a ME is introduced into the radio architecture.

2. The ME is responsible for co-ordinating changes across several Layers of the IC2DL network in a robust manner. It is logical that the ME is therefore also responsible for local configuration changes to the terminal since the two are often closely linked.

3. The ME actually interfaces with several Layers of the tailored IC2DL OSI Model, as shown in Figure 9: Management Entity Functionality, and will be defined and discussed herein.

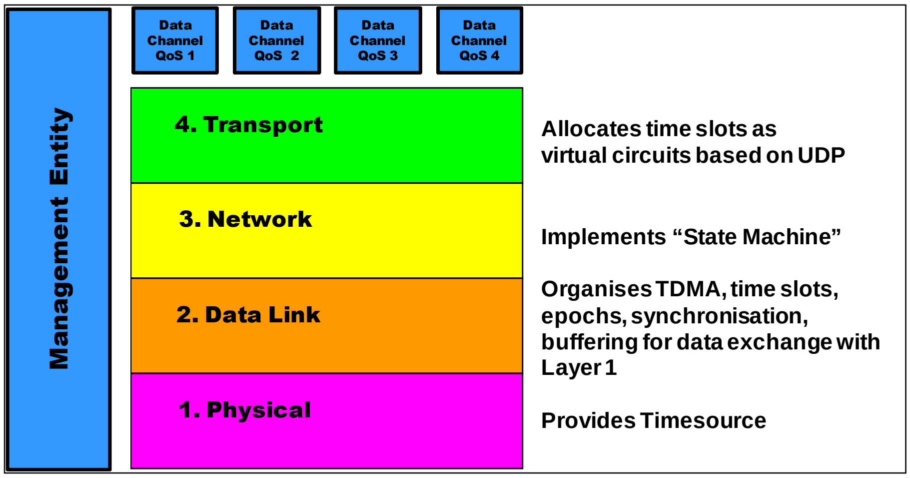


Figure 9: Management Entity Functionality

4. The functions of the ME are to:

- Manage the configuration of the nodes in terms of:
  - Slot assignments
  - Role assignment and modification (master, slave, relay, passive)
- Manage parameter settings:
  - Radio frequency, frequency hopping pattern
  - Spreading: code + on/off flag (per timeslot)
  - Maximum acceptable packet size
  - Transmit power control ("high" versus "low")
- Manage circuit mapping
  - Circuit to timeslot mapping
  - Node to circuit mapping
  - IP address/port to node mapping
- Manage Network topology
  - Nodes joining and leaving the network
  - Port numbers for applications to use
- Save, restore, and/or apply circuit profiles
- Node positions for range

4.3.3. Node Definitions

1. The IC2DL network provides near real time data communications between user terminal nodes on the same network. A Time-Domain Multiple Access (TDMA) technique is utilized to share the available time/frequency resource among the network participants. The Data Link layer provides a connectionless protocol for data and voice transfer, relying on the higher layers to account for any need of reliability over the IC2DL network.

2. Within the IC2DL TDMA approach, there are 3 different active types of nodes in the network: Master, Relay, and Slave.

3. The IC2DL network topology shall allow for:

a. one master node and up to 4 slave nodes (i.e. five active nodes in total);

b. one master node, one relay node and up to 3 slave nodes.

4. Two Slave nodes can communicate through a relay without the data going through the Master.

4.3.3.1. Master

1. The IC2DL network defines a Master node, which is responsible for transmitting Time Synchronisation Messages (TSM) periodically for synchronisation. There should only be a single Master node active at any given time. The Master is the time reference node for network synchronisation.

4.3.3.2. Relay

1. A Relay node is defined as a node used to relay messages across the network and also transmits TSMs periodically. The difference between a Relay and Master is that a Relay node synchronizes with the Master node.

4.3.3.3. Slave

1. The Slave nodes are neither the Master nor the Relay node and use the Master and/or Relay to synchronize and join the network.

4.3.3.4. Passive

1. A Passive node is not a Master, Relay or Slave node. A passive node uses the Master and/or Relay to synchronize but does not join the network. Passive nodes shall remain synchronised with a maximum shift equal to the propagation time to Master or Relay (see Section 4.3.11.3).

4.3.3.5. Node Interactions

1. Each node in the network is configured with a set of transmit and receive timeslots along with the necessary physical layer configuration parameters in order to allow synchronisation with either the Master node or the Relay node. The ability to synchronize with the Master or Relay node is necessary to support relaying capability where a node cannot receive from the Master, but can receive from the Relay node.

2. Once synchronized, a node, except for Passive nodes, is considered to be on the network and may have the ability to request and acquire timeslots on the network via the timeslot allocation mechanisms.

3. Each timeslot within the TDMA structure provides communication opportunities to multiplex air vehicle command, control and status, sensor command and control, user-defined data, and digital voice between the network nodes either directly or through a UAV relay. Timeslots will be allocated to network nodes depending on the configuration parameters programmed into the IC2DL nodes.

4. Figure 10: IC2DL TDMA Network with connectivity through an Airborne Relay illustrates as an example a TDMA network configuration involving an image transfer link from GCS to TAC Party via a relay UAV for range extension.

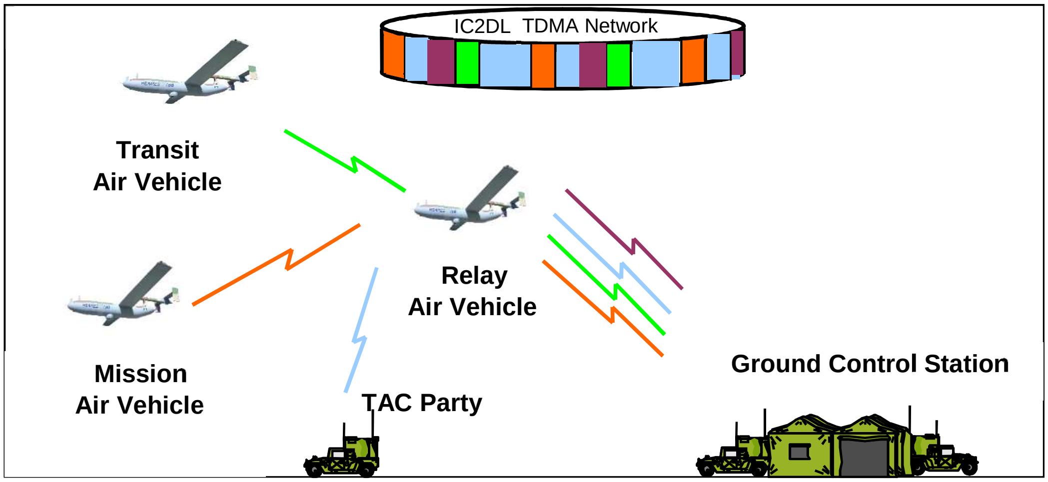


Figure 10: IC2DL TDMA Network with connectivity through an Airborne Relay

4.3.4. TDMA Timeslots

4.3.4.1. Programming Timeslot Activity

1. The IC2DL node shall allow programming of timeslot activity through the command and status interface.

2. Each node is synchronized to the designated IC2DL Master or Relay node through the network synchronisation process (see Section 4.3.11.3).

4.3.4.2. Timeslot Allocation

1. The IC2DL network timeslot allocation may be configured using STANAG 4586 messages and/or external private messages.

4.3.4.3. Timeslot Assignment Storage

1. The IC2DL node shall accept and store at least 3 independent timeslot assignment activity profiles in internal non-volatile memory with storage of timeslot activity assignments and an associated data input or output channel. Each profile shall include:

(1) circuit allocation to timeslot for each of the 94 timeslots defined as one epoch;
(2) circuit allocation between active nodes;
(3) data type and logical port allocation to circuit.

4.3.4.4. Transmit Timeslots

1. The IC2DL node shall be capable of transmission in every assigned timeslot opportunity, from none to all available timeslots. The maximum number of transmit timeslots is 94 (derived using 100 timeslots per epoch; minus 4 timeslots used for a Time Synchronisation Message (TSM) and minus 2 timeslots for Network Join).

2. The TSMs shall be transmitted at the first timeslot of the first four frames of an epoch. The TSMs shall be sent in ascending circuit definition order, as shown in Figure 11: TSM and Network Join Timeslot position.

3. The join timeslot shall be the first two timeslots of the fifth frame of the epoch. When a Relay node is active, TSMs are sent in alternate epochs by the Master node and the Relay node, as described in Section 4.3.11.4.

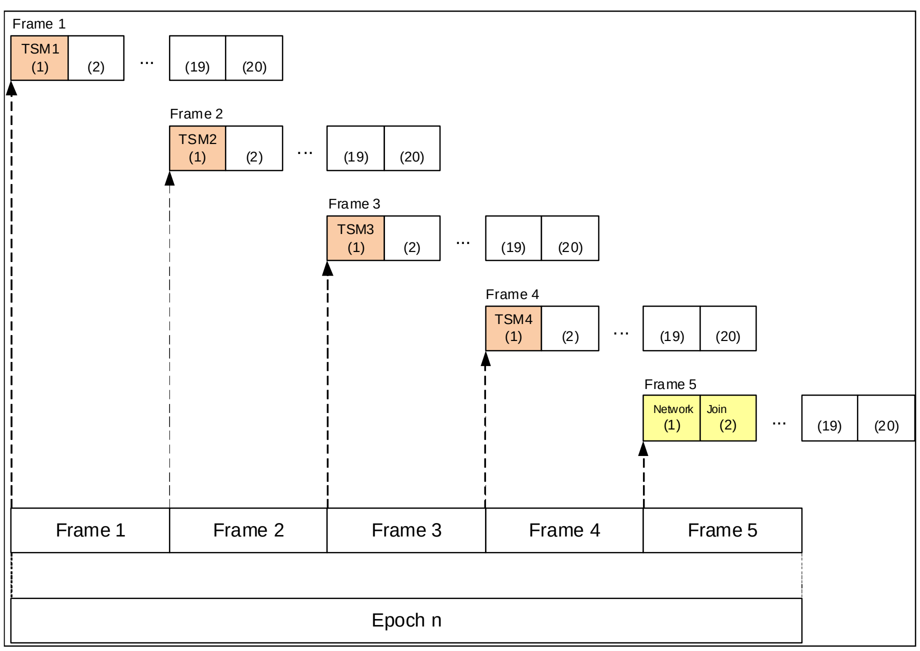


Figure 11: TSM and Network Join Timeslot position

4.3.4.5. Receive Timeslots

1. The IC2DL node shall be capable of reception in every assigned timeslot opportunity, from none to all available timeslots. The maximum number of receive timeslots is 94 (derived using 100 timeslots per epoch; minus 4 timeslots used for TSM and minus 2 timeslots for Network Join).

2. The TSMs are received at the first timeslot of the first four frames of an epoch. The TSMs will be received in ascending circuit definition order.

3. The join timeslot shall be the first two timeslots of the fifth frame of the epoch.

4.3.4.6. Unassigned Timeslots

1. The IC2DL node will ignore application data in unassigned timeslots.

4.3.5. Message Structures

1. There are seven message structures as shown in Table 6: Message Structures. The IC2DL data link layer uses a common message structure for voice/data messages and includes network state information. The use of different synchronisation messages provides robust synchronisation capabilities to the IC2DL network even when GPS/GNSS derived information is not available. The synchronisation messages also include timeslot and circuit assignment information for the entire network.

Message ID	Message Name	Description
01	Common Message Structure	
02	Time Synchronisation Message 1 (TSM)	Description of Circuits 1 – 4
03	Time Synchronisation Message 2 (TSM)	Description of Circuits 5 – 8
04	Time Synchronisation Message 3 (TSM)	Description of Circuits 9 – 12
05	Time Synchronisation Message 4 (TSM)	Description of Circuits 13 – 15
06	Time Synchronisation Response Message (TSR)	
07	Time Synchronisation Acknowledgement Message (TSA)	

Table 6: Message Structures

4.3.5.1. Time Synchronisation Message (TSM)

1. The TSM is described in Table 7: Time Synchronisation Message (TSM). Each node is defined by a node identification number (NID) and is discussed further in section 4.3.10.

Field Index	Field	Value(s)	# of Bits
01	Message ID	1-7	3

Field Index	Field	Value(s)	# of Bits
02	Epoch Number	0-1048575	20
03	Message Length	Fixed length for TSM (X bytes)	8
04	Master/Relay Flag	Master (0) or Relay (1)	1
05	NID 1 Status	4 values (unknown (00), slave (01), relay (10), master (11))	2
06	NID 2 Status	4 values (unknown (00), slave (01), relay (10), master (11))	2
07	NID 3 Status	4 values (unknown (00), slave (01), relay (10), master (11))	2
08	NID 4 Status	4 values (unknown (00), slave (01), relay (10), master (11))	2
09	NID 5 Status	4 values (unknown (00), slave (01), relay (10), master (11))	2
10	NID 1 Delay compensation	0-65535 (LSB = 100 ns)	16
11	NID 2 Delay compensation	0-65535 (LSB = 100 ns)	16
12	NID 3 Delay compensation	0-65535 (LSB = 100 ns)	16
13	NID 4 Delay compensation	0-65535 (LSB = 100 ns)	16
14	NID 5 Delay compensation	0-65535 (LSB = 100 ns)	16
15	Circuit Descriptions	Message ID #2 = Circuits 1..4 Message ID #3= Circuits 5..8 Message ID #4 = Circuits 9..12 Message ID #5= Circuits 13..15 (the most significant 26 bits are set to 0 as there is no circuit 16) Circuit description field takes the form: Source (3bits), relay NID (3bits), relay offset (5bits), dest1 (3bits), dest2 (3bits), dest3 (3bits), dest4 (3bits), SiS (3bits) With the most significant 26 bits representing the last circuit and the least significant 26 bits the first circuit in the sequence.	104
16	Circuit to Timeslot Allocation	Message ID #2 = Timeslots 1..25 Message ID #3 = Timeslots 26..50 Message ID #4 = Timeslots 51..75 Message ID #5 = Timeslots 76..100 25 4-bit values which is 1 for each timeslot defined as: 0000 = unassigned slot 0001 = slot assigned to circuit 1 0010 = slot assigned to circuit 2 0011 = slot assigned to circuit 3 … 1111 = slot assigned to circuit 15 Most significant nibble represents the highest timeslot and least significant nibble the first timeslot of the sequence.	100
17	Epoch Number of Master node change (the time the new configuration is to be applied)	0-1048575	20
18	New NID 1 Status	4 values (unknown (00), slave (01), relay (10), master (11))	2
19	New NID 2 Status	4 values (unknown (00), slave (01), relay (10), master (11))	2

Field Index	Field	Value(s)	# of Bits
20	New NID 3 Status	4 values (unknown (00), slave (01), relay (10), master (11))	2
21	New NID 4 Status	4 values (unknown (00), slave (01), relay (10), master (11))	2
22	New NID 5 Status	4 values (unknown (00), slave (01), relay (10), master (11))	2
23	Reserved		20
24	User Defined Field		8
25	Checksum		16
		Total Length	400

Table 7: Time Synchronisation Message (TSM)

2. On reception of the first transmission (TSM) from the Master the Slave must align the start of its timeslots to that time of reception.

3. On reception of a transmission (TSR) from the Slave at the Master, the Master measures the arrival time which is twice the propagation time. This propagation time is sent back (TSM) to the Slave in the Delay Compensation field.

4. The Slave shall then change its local time to compensate for this propagation delay. This synchronisation process is illustrated in Figure 17: Network Synchronisation.

4.3.5.2. Time Synchronisation Response (TSR) Message

1. Nodes shall use this TSR message to:

- Join a network and request allocation of timeslots
- Request additional allocation of timeslots
- Leave a network
- Relinquish timeslots.
- Adjust synchronisation (compensate delay propagation)

2. The TSR message is described in Table 8: Time Synchronisation Response (TSR).

Field Index	Field	Value(s)	# of Bits
01	Message ID	1-7	3
02	Message Length	Fixed length for TRS (X bytes)	8
03	Time stamp	20 MSB = epoch number 4 LSB = Message ID	24
04	Relay/Slave/Master Flag	Unknown (00), Slave (01); Relay (10); Master (11)	2
05	Relinquish/Join Flag	Join (000) Request (001) Leave (010) Relinquish (011) Synchronisation (100) Master change (101)	3
06	Relinquish Circuit ID	0-15 (Note: only use to relinquish)	4

Field Index	Field	Value(s)	# of Bits
07	Unique Identifier	0-65K Random number assigned to TSR message	16
08	Circuit Description	Source, relay NID, relay offset, dest1, dest2, dest3, dest4 (Note: only used on join request or reassigned circuit)	23
09	Timeslots Requested	Throughput requested per epoch in bytes : 0 - 91932 (Note: only used on join request)	17
10	Internode Quality Indicators	20 values of 12-bits each, 1 for each connection between two nodes Each internode quality value takes the form: Source (3 bits), Destination (3 bits), C/N in dB (6 bits, for -30dB to 33 dB), since the last TSR sent.	240
10	Reserved		20
11	User Defined Field		8
12	Checksum		16
		Total Length	384

Table 8: Time Synchronisation Response (TSR)

3. The Unique Identifier field uses a different random number for each individual TSR message. Since the Unique Identifier field is only meaningful to the node sending the TSR (and receiving the consequent TSA), there is not a problem if two nodes independently use the same random number in coincident TSR messages.

4. The Time Stamp field represents the time at which the TSM used for synchronisation has been sent by the Master. It is a copy of the epoch number and message ID sent in the TSM used for synchronisation. The 20 MSb represent the epoch number and the 4 LSb represent the message ID.

4.3.5.3. Time Synchronisation Acknowledgement (TSA) Message

1. The TSA message is described in Table 9: Time Synchronisation Acknowledgement (TSA).

Field Index	Field	Value(s)	# of Bits
01	Message ID	1-7	3
02	Message Length	Fixed length for TSM (X bytes)	8
03	Master Change Flag	No Change (00), Master Change(11)	2
04	Relay/Slave Flag	Slave (0) or Relay (1)	1
05	Join/Relinquish Response Flag	Join (01) or Relinquish (10) or Not-Join or Not-Relinquish (00) Response	2
06	Unique Identifier	0-65K Random number assigned to previous message (TSR)	16
07	Assigned NID	1-5 (Note: only used to join or reassigned circuit)	3
08	Assigned Circuit Description	Note: Only used on join request	23
09	Assigned Timeslots	Timeslots requested (100) (Note: only used on join request)	100
10	Master Change Flag		1
11	Reserved		17
12	User Defined Field		8

Field Index	Field	Value(s)	# of Bits
13	Checksum		16
		Total Length	200

Table 9: Time Synchronisation Acknowledgement (TSA)

4.3.5.4. Common Message Structure

1. The Common Message Structure (CMS) message is described in Table 10: Common Message Structure.

Field Index	Field	Value(s)	# of Bits
01	Message ID	1-7	3
02	Application Payload Length	0-16727	15
03	Circuit Number	1-16	4
04	NID Status	4 values (unknown (00), slave (01), relay (10), master (11))	2
05	Port 1	Port A := 00 Port B := 01 Port C := 10 Port D := 11	2
06	Port 1 Data Length		15
07	Port 1 Data Overrun		1
08	Port 1 Data	Aggregate data can't exceed payload length	
09	Port 2	Port A := 00 Port B := 01 Port C := 10 Port D := 11	2
10	Port 2 Data Length		15
11	Port 2 Data Overrun		1
12	Port 2 Data	Aggregate data can't exceed payload length	
13	Port 3	Port A := 00 Port B := 01 Port C := 10 Port D := 11	2
14	Port 3 Data Length		15
15	Port 3 Data Overrun		1
16	Port 3 Data	Aggregate data can't exceed payload length	
17	Port 4	Port A := 00 Port B := 01 Port C := 10 Port D := 11	2
18	Port 4 Data Length		15
19	Port 4 Data Overrun		1
20	Port 4 Data	Aggregate data can't exceed payload length	
21	Checksum		16
		Total Message Length	Dependent on SiS used

Table 10: Common Message Structure

4.3.6. Configuration

1. Network configuration is achieved using a coordinated combination of configuration messages (STANAG 4586 messages and/or external private messages), plus periodic TSMs.

2. A node must receive 4 TSMs in a coordinated manner and use these to configure itself correctly. The TSMs maintain the circuit to timeslot mapping.

4.3.7. Relay Transmit Timeslots

1. The IC2DL Relay node shall be capable of being assigned Relay-Transmit timeslots in every assigned timeslot opportunity and to re-transmit received Messages-to-Relay during those Relay-Transmit timeslots. The time spacing between the end of the receive timeslot when the Message-to-Relay has been received and the beginning of the Relay-Transmit timeslot when this Message-to-Relay is re-transmitted is referred as the Relay-offset. The Relay offset shall be a configurable setting (integer number of timeslots) and its minimum value shall be two timeslots.

4.3.8. Network Synchronisation Timeslots

1. The IC2DL node shall be capable transmitting or receiving Network synchronisation information in timeslots dedicated for network synchronisation. These timeslots are used by the Master and Relay nodes to transmit the TSM. See the Network Synchronisation Section 4.3.11.3 for detailed process.

4.3.9. Network Join Timeslots

1. The Network Join timeslots are composed of the first two slots of the fifth frame of an epoch. The nodes shall use the Network Join timeslots to send a TSR message to the Master or to the Relay.

2. The Master or the Relay node shall use the Network Join timeslot to send TSA messages to answer previous TSR, except when TSR is only used for synchronisation adjustment, which does not require any TSA from Relay or Master.

3. There is one available Network Join timeslot per epoch and this will be shared amongst all nodes in the network. The process for Network Join is defined in the Data Link States Section 4.3.11.

4. The Network Join timeslot will only occur once during an epoch. The use of the Network Join timeslot by two or more nodes simultaneously will result in collisions such that the message cannot be decoded by the receiver, so there will be a retransmission timer associated with the TSR message. When the TSR timer reaches 0, the node will perform a random back-off (up to X seconds) to avoid constant collisions by joining nodes. The back-off time ($T_{Back\text{-}off}$) will determine how many seconds to wait from the

original time to retransmit the TSR. $T_{Original}$ is the transmit timestamp for the TSR. $T_{Back-off}$ is given by:

$$T_{Back\text{-}off} = T_{Original} + RAND(X)$$

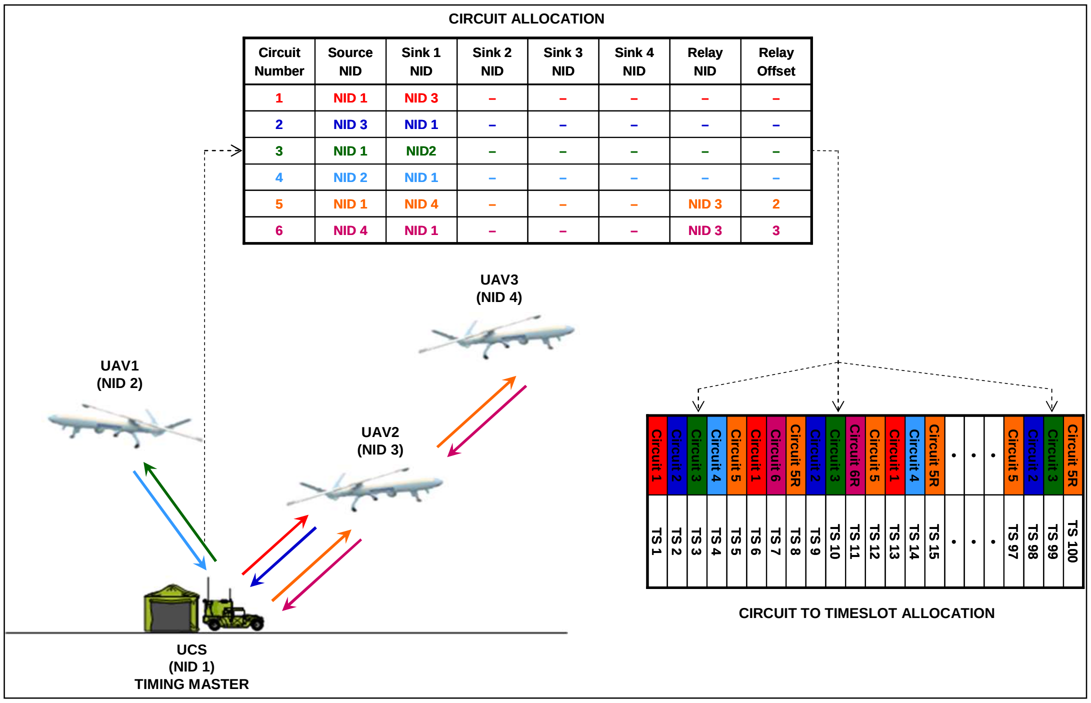
4.3.10. Circuits

1. A circuit defines the message route from source to destination node(s). If required, circuits can be passed through a relay node. Therefore, each circuit definition includes at a minimum: a SiS, the source node identification (NID) number, up to four sink NIDs, an optional relay NID and the associated relay offset. The relay offset defines the number of timeslots between the received message timeslot and the re-transmission timeslot to the destination node. For a relay circuit the SiS will be the same on both legs of the circuit.

2. IC2DL can support up to 15 different user defined circuits, which can be defined using a STANAG 4586 Message. Each defined circuit has to be assigned to both the source and destination NID(s). The circuits are then mapped to timeslots (e.g. using a STANAG 4586 message) and each circuit distribution is defined for an entire epoch (100 timeslots). Multiple messages are required to set up multiple circuits for a node. The content of this message is known by all nodes in the network. The combination of this message and the current timeslot number allows each local node to determine its activity in each timeslot (Transmit, Receive, or Idle). The content of the Circuit to Timeslot Allocation Message is continually repeated by the TSMs.

3. The user can alter the data rate of the different circuits by increasing or decreasing the number of timeslots allocated to particular circuits within an Epoch. The data rate is increased by allocating more timeslots to the particular circuit. Circuits including relays require two timeslots to communicate messages from the source NID to the final destination NID. The User must ensure that the relay offset timeslots are not allocated to other circuits. Six timeslots / epoch are reserved for Network Access.

4. As an example, Figure 12: Illustration of Circuit Implementation illustrates the content of the Circuit Allocation and the Circuit to Timeslot Allocation Messages. It shows a typical UAV scenario with one UCS (designated as the Master) and three UAVs. UAVs 1 and 2 are within range and LOS of the UCS node. UAV 3 is beyond range of the UCS but communicates in the network via UAV 2, which acts as the Relay node. All nodes in the network are identified by their unique NID number.



Circuit Number	Source NID	Sink 1 NID	Sink 2 NID	Sink 3 NID	Sink 4 NID	Relay NID	Relay Offset
1	NID 1	NID 3	–	–	–	–	–
2	NID 3	NID 1	–	–	–	–	–
3	NID 1	NID2	–	–	–	–	–
4	NID 2	NID 1	–	–	–	–	–
5	NID 1	NID 4	–	–	–	NID 3	2
6	NID 4	NID 1	–	–	–	NID 3	3

Figure 12: Illustration of Circuit Implementation

5. As illustrated in Figure 12, circuit 5 defines the relay from UCS to UAV 3 through UAV 2. Circuit 4 defines a point-to-point communication between UAV 1 (NID 2) and the UCS (NID 1) with no relay.

4.3.10.1. Circuit Latencies

1. The circuit allocations mechanism within the IC2DL network provides a flexible method for supporting different requirements for latency.

2. In a TDMA network the latency depends on timeslot allocation. The 30 msec latency for voice as defined in the requirements (see Table 4: Detailed Performance Requirements) can be met under the following assumptions:

- The latency is measured from the time the last bit of the messages for the timeslot is received at the input port of the transmitting node to the time this last bit is output from the receiving node.
- No relay configuration.
- Input data is synchronised with the TDMA.
- The processing time at the transmit and receive nodes is less than 18.6 msec for a timeslot of 11.4 msec.
- Figure 13: Latency Sequence Diagram gives an illustration of this maximum latency.

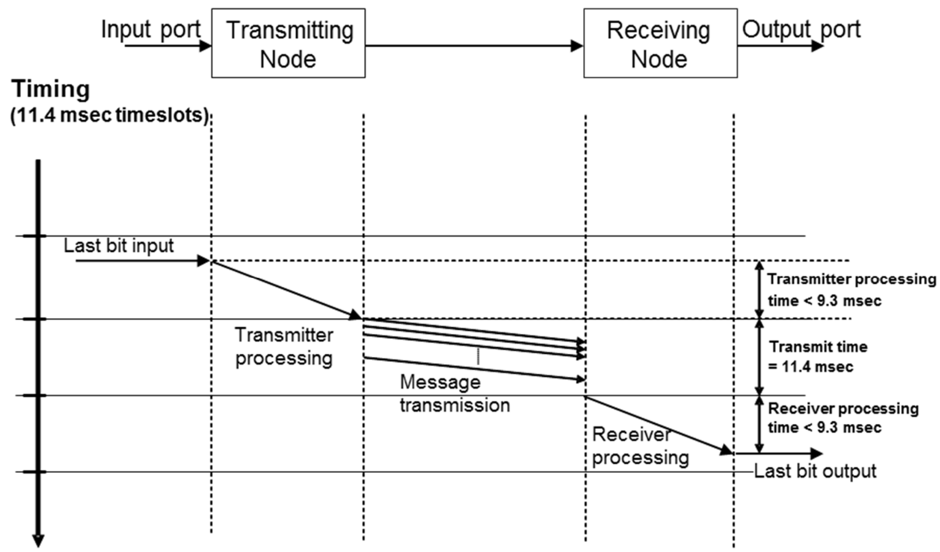


Figure 13: Latency Sequence Diagram

4.3.10.2. Circuit Throughput

1. The circuit allocations mechanism within the IC2DL network provides a flexible method for supporting different requirements for throughput.

2. The minimum throughput necessary for the IC2DL network is specified to account for the Data Link layer minimum possible timeslot size. The TSM is the largest of the mandatory messages defined for the IC2DL data link layer; therefore, the minimum throughput, in bits per second, for the IC2DL network is 94 timeslots (as defined in Section 4.3.4.4) times the TSM size.

4.3.10.3. Circuit Network Synchronisation Time

1. The Network synchronisation process is defined in Section 4.3.11.3. The total synchronisation time includes contributions from all applicable protocol layers.

4.3.11. Data Link States

1. The IC2DL data link layer performs various tasks to assure distributed multiple access control in a way that depends on the autonomous operation of each node. The operation of each node in the network will depend on the type of node. A node may initially be configured as a particular type (Master, Relay and Slave) and can transition to any other type.

2. The State Machine depicting the different states of an IC2DL node are specified in Figure 14: Node States (1), Figure 15: Node States (2) and Figure 16: Node States (3). The detailed state transition description is shown in Table 11: State Transition Description.

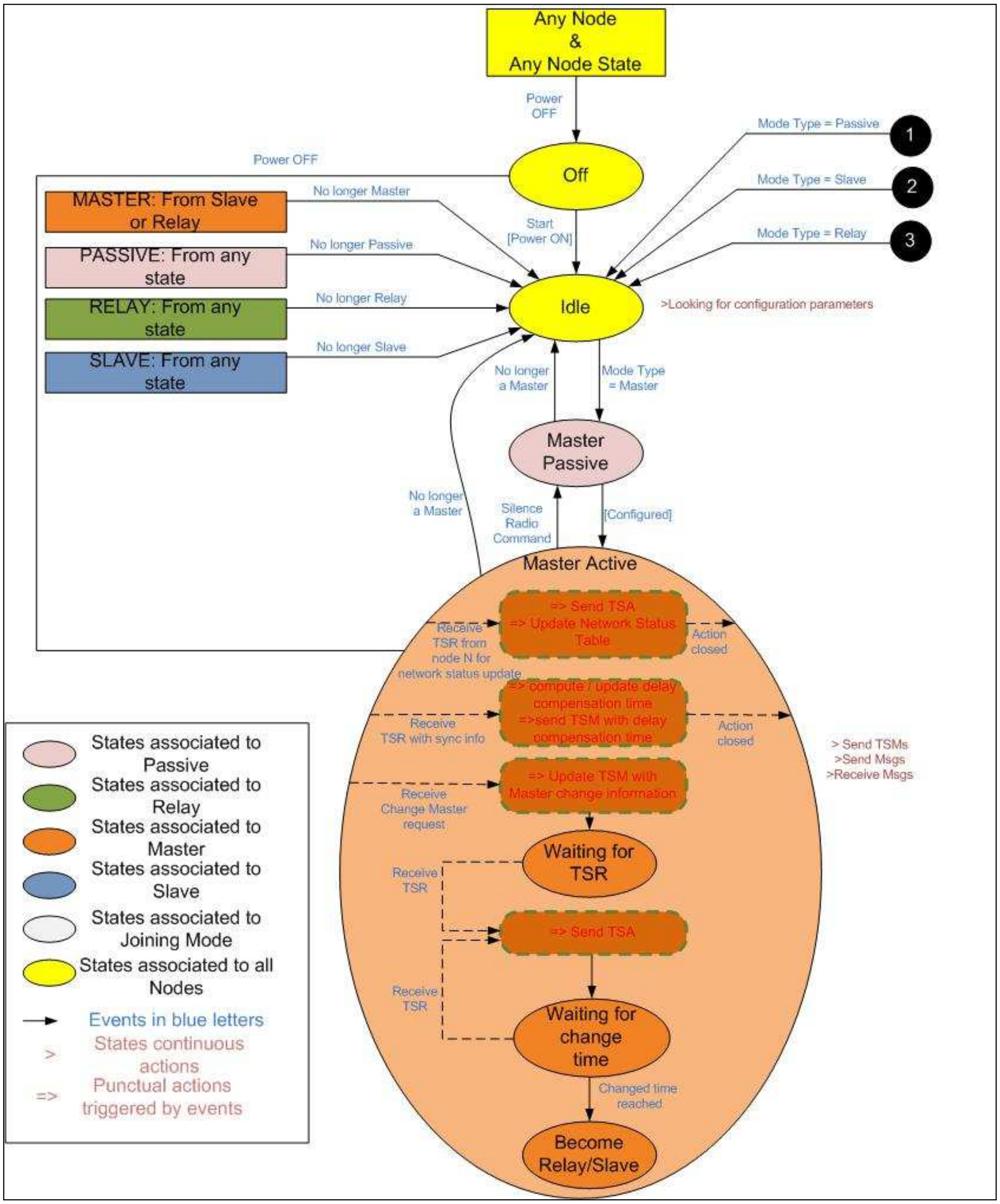


Figure 14: Node States (1)

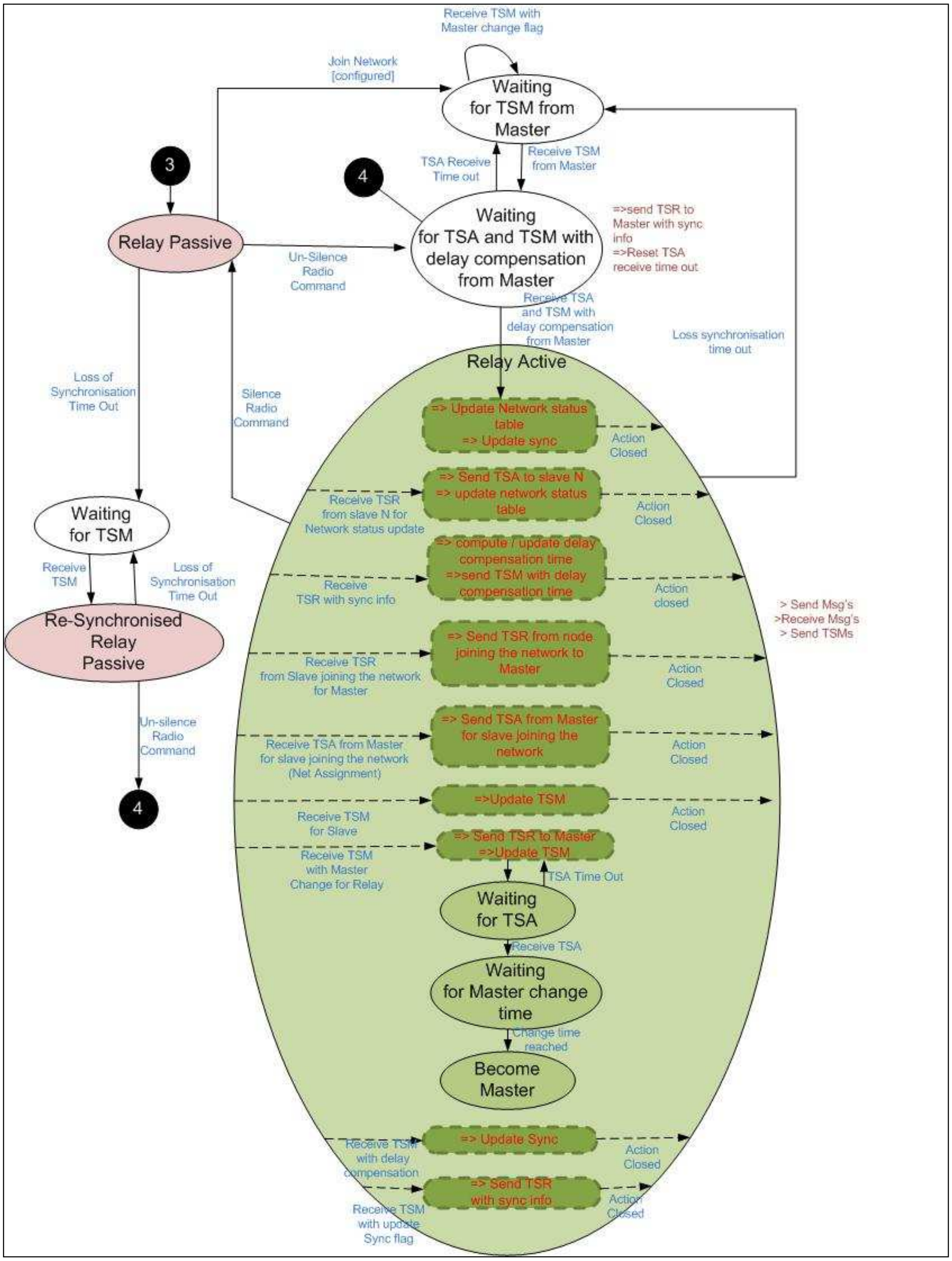


Figure 15: Node States (2)

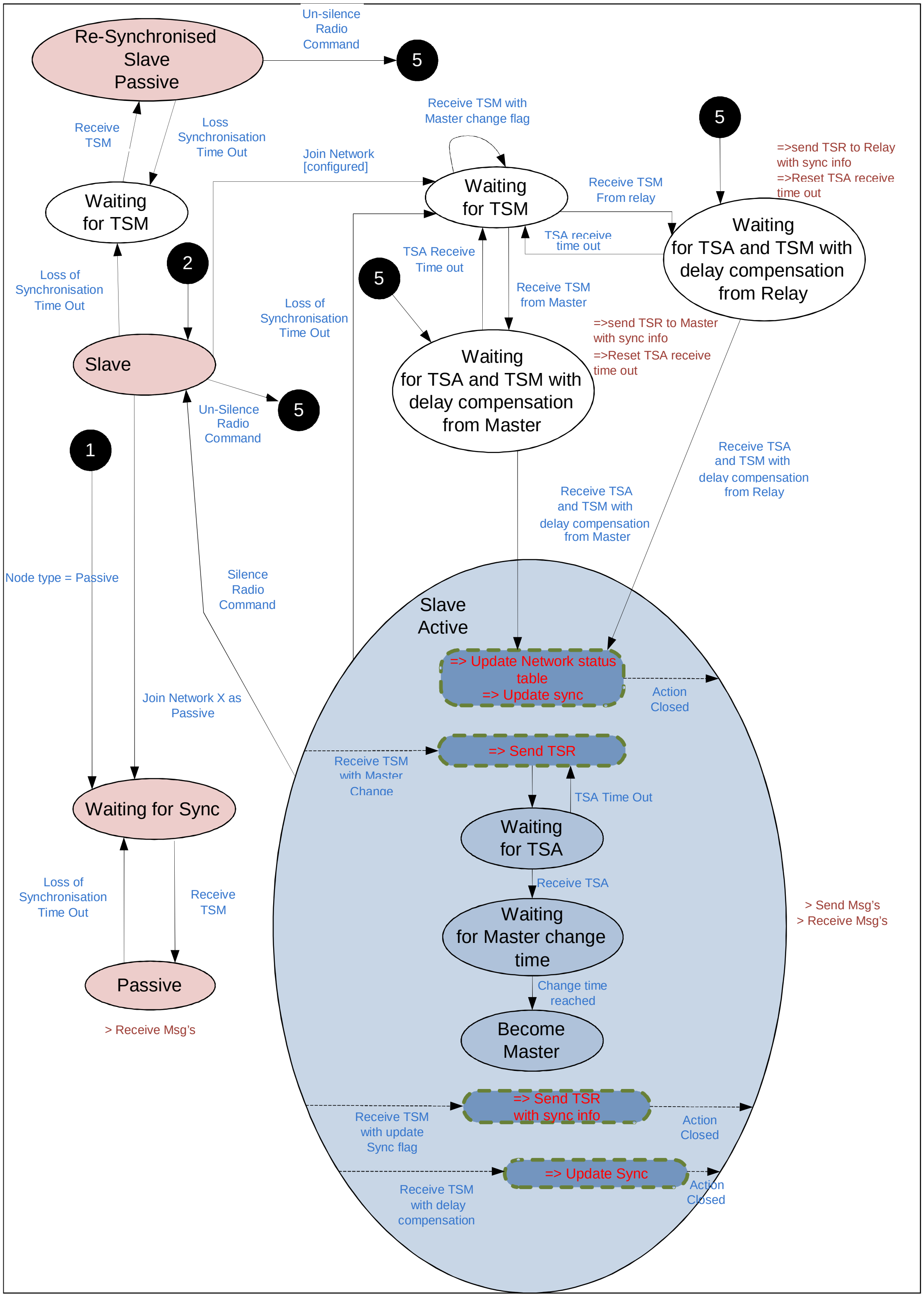


Figure 16: Node States (3)

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Current			Event	Resulting from event:		
Node type	**Node state**	**State continuous actions**		**Next Node Type**	**Next Node State**	**Actions**
NA	Off		Start (power on)	NA	Idle	
NA	Idle	Looking for configuration parameters		NA	Idle	
			Node Type = Master	Master	Passive	
			Node type = Relay	Relay	Passive	
			Node type = Slave	Slave	Passive	
			Node type = Passive	Passive	Waiting for Sync	
			Node type = Master	Master	Active	
			Node type = Relay	Relay	Waiting for TSM from Master	
			Node type = Slave	Slave	Waiting for TSM	
Master	Passive *Note: Network will be unavailable as no TSMs are sent*			Master	Passive	
			Receive configuration information	Master	Active	
	Active	Send TSMs Send Messages Receive Messages		Master	Active	
			Receive TSR from node N for network status update	Master	Active	Send TSA and Update Network Status Table
			Receive TSR with synchronisation information	Master	Active	Compute delay propagation and send next TSM with delay propagation information
			Receive "Silence Radio" command	Master	Passive	
Relay	Passive	Receive Messages		Relay	Passive	
			Receive configuration information	Relay	Waiting for TSM from Master	
			Un-silence Radio Command	Relay	Waiting for TSA and TSM with delay compensation from Master	Send TSR with synchronisation information to Master and reset TSA Receive Time Out
			Loss of Synchronisation Time Out	Relay	Waiting for TSM from Master	
		Receive Messages		Relay	Re-synchronised Relay Passive	

Current			Event	Resulting from event:		
Node type	Node state	State continuous actions		Next Node Type	Next Node State	Actions
	Re-synchronised Relay Passive		Un-silence radio command	Relay	Waiting for TSA and TSM with delay compensation from Master	Send TSR with synchronisation information to Master and reset TSA Receive Time Out
			Loss of Synchronisation Time Out	Relay	Waiting for TSM from Master	
	Waiting for TSM from Master		Receive TSM from Master	Relay	Waiting for TSA and TSM with delay compensation from Master	Send TSR with synchronisation information to Master and reset TSA Receive Time Out
			Receive TSM from Master with Master Change Flag Set	Relay	Waiting for TSM from Master	
			Receive TSM from Master	Relay	Re-synchronised Relay Passive	Receive Messages
	Waiting for TSA from Master		TSA Receive Time Out	Relay	Waiting for TSM from Master	
			Receive TSA and TSM with delay compensation from Master	Relay	Active	Update Network Status Table and update synchronisation
	Active	Send TSMs to Slave Send Messages		Relay	Active	
			Loss of Synchronisation Time Out	Relay	Waiting for TSM from Master	
			Receive TSR from Slave N yet in the network for network update	Relay	Active	Send TSA to Slave N and update Network Status Table
			Receive TSR with synchronisation information	Relay	Active	Compute delay propagation and send next TSM with delay propagation information
			Receive TSR from Slave joining network	Relay	Active	Relay received TSR from Slave joining Network to Master
			Receive TSA from Master for Slave joining network (Net Assignment)	Relay	Active	Relay received TSA from Master to Slave joining Network

Current			Event	Resulting from event:		
Node type	Node state	State continuous actions		Next Node Type	Next Node State	Actions
			Receive TSM with update synchronisation flag	Relay	Active	Send TSR with synchronisation information
			Receive TSM with delay compensation	Relay	Active	Update synchronisation
			Receive "Silence Radio" command	Relay	Passive	Receive Messages
Slave	Passive	Receive Messages		Slave	Passive	Receive Messages
			Receive configuration information	Slave	Waiting for TSM	
			Un-silence Radio Command	Slave	Waiting for TSA and TSM with delay compensation from Master/Relay	Send TSR with synchronisation information to Master/Relay and reset TSA Receive Time Out
			Loss of Synchronisation Time Out	Slave	Waiting for TSM	
	Re-synchronised Slave Passive	Receive Messages		Slave	Re-synchronised Slave Passive	
			Un-silence radio command	Slave	Waiting for TSA and TSM with delay compensation from Master/Relay	Send TSR with synchronisation information to Master/Relay and reset TSA Receive Time Out
			Loss of Synchronisation Time Out	Slave	Waiting for TSM	
	Waiting for TSM		Receive TSM from Master	Slave	Waiting for TSA and TSM with delay compensation from Master	Send TSR with synchronisation information to Master and reset TSA Receive Time Out
			Receive TSM from Relay	Slave	Waiting for TSA and TSM with delay compensation from Relay	Send TSR with synchronisation information to Relay and reset TSA Receive Time Out
			Receive TSM with Master Change Flag Set	Slave	Waiting for TSM	
			Receive TSM	Slave	Re-synchronised Slave Passive	
			TSA Receive Time Out	Slave	Waiting for TSM	

Current			Event	Resulting from event:		
Node type	Node state	State continuous actions		Next Node Type	Next Node State	Actions
	Waiting for TSA and TSM with delay compensation from Master		Receive TSA and TSM with delay compensation from Master	Slave	Active	Update Network Status Table and update synchronisation
	Waiting for TSA and TSM with delay compensation from Relay		TSA Receive Time Out	Slave	Waiting for TSM	
			Receive TSA and TSM with delay compensation from Relay	Slave	Active	Update Network Status Table and update synchronisation
	Active	Send Messages		Slave	Active	
			Loss of Synchronisation Time Out	Slave	Waiting for TSM	
			Receive "Silence Radio" command	Passive	Active	Receive Messages
			Receive TSM with delay compensation	Slave	Active	Update synchronisation
			Receive TSM with update synchronisation flag	Slave	Active	Send TSR with synchronisation information
Passive	Waiting for Sync		Receive TSM from Master or Relay	Passive	Active	Synchronize
	Active	Receive Messages		Slave	Active	
			Loss of Synchronisation Time Out	Slave	Waiting for TSM	
Any	Any		No longer Master, or No longer Relay, or No longer Slave, or No longer Passive	NA	Idle	
Any	Any		Power off	NA	Off	

Table 11: State Transition Description

4.3.11.1. Off

1. The OFF state is entered during a node power off.

4.3.11.2. Idle

1. The Idle state occurs after a node powers on and the Data Link layer software is initialized in the node. In the Idle state, the node is not keeping any active timers, not transmitting, and not receiving any data or voice.

2. Error messages will be issued to higher layer protocols if data or voice is attempted to be passed and this data or voice will be discarded.

3. In the Idle state, the node is awaiting the configuration.

4.3.11.3. Network Synchronisation

1. The network synchronisation process is defined to allow network synchronisation without any external timing such as GPS/GNSS. It is managed by the Layer 2 using both Layer 1 and Layer 2 information.

2. The Master node shall be the reference node for the network time synchronisation. All nodes of the network have their own system time managed by their platform. Layer 2 locally controls a platform time based on TDMA Epoch and slot number. Epoch 0 slot 0 is chosen as the 1st January 2010 00:00:00. All nodes of the network shall synchronise on the network time. A node is considered synchronised if its platform time is equal to the network time. The Master distributes its platform time in the network as network time. The Master is consequently always synchronised. Other active nodes (slaves and relay) shall be in three different synchronisation states: not synchronised, partially synchronised and fully synchronised. Passive nodes have only two different synchronisation states: not synchronised and partially synchronised.

3. The “not synchronised” state occurs when a node enters a network or it has lost synchronisation (see Section 4.3.11.8).). In that case, the node shall listen in an unslotted mode for a synchronisation message on a fixed frequency.

4. The “partially synchronised” state occurs just after receiving the first TSM in a non-synchronised state. In a partially synchronised state, the timeslot and frame timing of the synchronized node shall map the timeslot and frame timing of the reference node with a maximum shift equal to the propagation time, as depicted in Figure 17: Network Synchronisation.

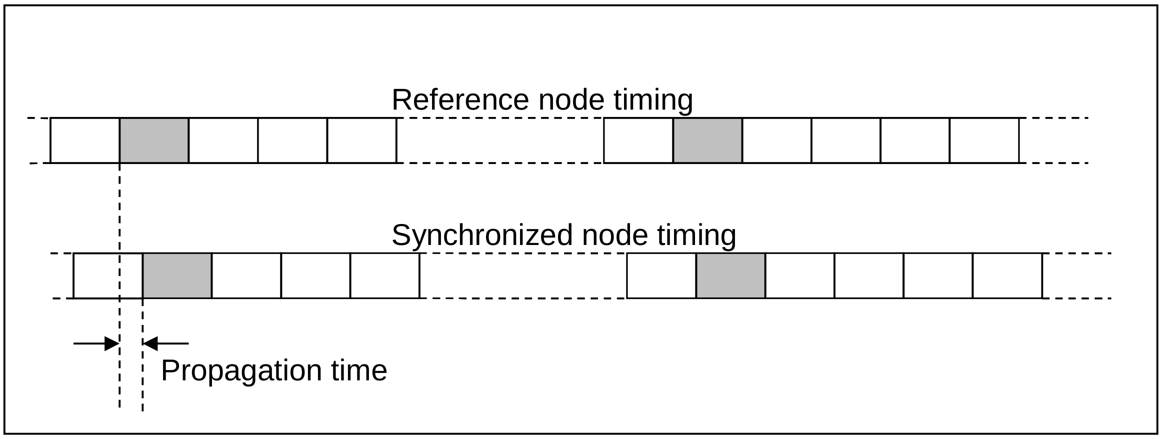

Figure 17: Network Synchronisation

5. In order to reach the "partially synchronised" state, the nodes shall use the time they receive a TSM, and the Message ID, Epoch Number, and Circuit Description contained in the TSM to synchronize their internal clock and map their timeslot and frame arrangement to the one of their reference node (Master or Relay).

6. The epoch number and Message ID shall be used to adjust the internal clock of the receiver to the one of the reference node (emitter of the TSM).

7. The Message ID shall be used to identify the frame within an epoch in which the TSM has been received (TSM 1 is transmitted in Frame 1 of an Epoch, TSM 2 is transmitted in Frame 2, TSM 3 is transmitted in Frame 3 and TSM 4 is transmitted in Frame 4 as described in Section 4.3.4.4.).

8. The Epoch Number shall be used to map the Epoch and Timeslot arrangement to the one of the reference node (Master or Relay).

9. The Circuit Description shall be used to determine if the node receiving the TSM is connected to the Master either directly or through a Relay.

10. The Relay node shall synchronize on the Master node. The Slave nodes shall synchronize on:

- The Master node if, according to the Circuit description, they have to connect directly with the Master node. The TSMs received from the Relay nodes shall then be ignored.
- The Relay node if, according to the circuit setting, they have to connect to the Master node through this Relay node. The TSMs received from the Master shall then be ignored.

11. The Passive nodes and Network Joining nodes shall synchronize on either the Master or the Relay upon best received TSMs.

12. TSMs shall be transmitted at the exact beginning of the Synchronisation timeslots. Synchronisation timeslots are the first timeslot of frames 1, 2, 3 and 4 of each Epoch.

13. When there is no Relay node in a network, the Master node shall use every Synchronisation timeslot to send TSMs.

14. When there is a Relay node in a network, the Master node shall use the Synchronisation timeslots of the even Epochs to send TSMs and the Relay node shall use the Synchronisation timeslots of the odd Epochs to send TSMs.

15. The "fully synchronised" state is required for communications from relay/slave to master. This state is consequently reserved for active nodes. Passive nodes remain synchronised to the reference node with a maximum shift equal to the propagation time.

16. As shown in Figure 18: Synchronisation Process, once partially synchronised, nodes send a TSR in the join timeslot, to join the network. This message is used by the emitter of the TSM (Master or Relay) to compute the propagation delay and includes this information in the next TSM. When receiving this second TSM, the receiver shall correct the synchronisation time with the received propagation compensation.

17. To remain in this state, even with clock drift the reference node (master or relay) activates the resynchronisation of the delay compensation for a given node by setting the delay compensation field of the considered node to -1. The considered node which receives this synchronisation message with its delay compensation equal to -1 shall send a TSR in the next join timeslot existing in the TDMA frame structure. The considered node includes in the message the time between the TSM reception and the response in TSR for the reference node to adjust the delay propagation clock. This resynchronisation shall be activated by the reference node regularly, in less than 1 min (see Figure 18).

18. For the highest accuracy, the TSM used for delay propagation shall be the 4th one of the Epoch to minimize the delay between TSM and TSR.

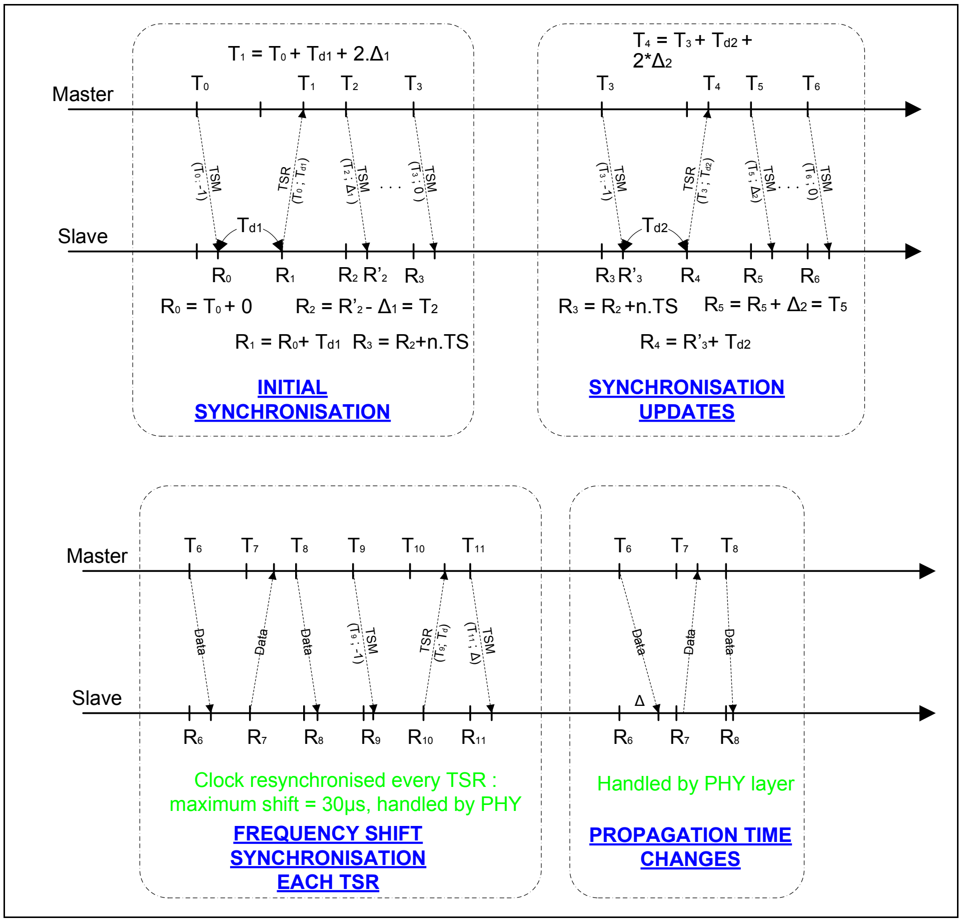

Figure 18: Synchronisation Process

4.3.11.4. Master Active State

1. The Master active state is only applicable to a Master node and only a single node in the network is able to be a Master node. Once in the active state, the Master node transmits TSM in the dedicated timeslots based on the network configuration.

4.3.11.5. Relay Active State

1. The Relay active state is only applicable to a relay node. Once in active Relay state, the Relay node transmits TSM in dedicated timeslots based on the network configuration.

4.3.11.6. Slave Active State

1. The Slave Active state is only applicable to slave nodes. Once a Slave node is synchronized to network and therefore in the Slave Active status, the Slave node will send data messages in assigned timeslots based on the network configuration.

4.3.11.7. Passive State

1. The Passive state is applicable to passive nodes, as well as to the other node types (Master, Relay, and Slave) when radio silence is commanded. Once in Passive state, the Passive node only receives in assigned timeslots based on the existing network configuration.

4.3.11.8. Loss of Synchronisation

1. Loss of synchronisation occurs for any active node that does not receive TSM within 1 minute. This event triggers multiple state transitions as specified in the state transition table and diagram above. A fixed limit was selected in order to allow safe reconfiguration of the network to occur; without this a node that still believes it is part of the network will not seek a new configuration that may have been implemented during a period of non-receipt of TSMs.

4.3.11.9. Join Network Process

1. The primary assumptions for the network join process are:

- That any joining node holds the necessary pieces of prerequisite information (see below).
- The desire to join the network is known at the application layer.

2. The information prerequisites are:

- Frequency configuration.
- Pseudorandom Number seed.
- Timing synchronisation, by receipt of one or more TSM messages from the network.

3. Network join procedure is predicated on synchronisation between the joining node and the IC2DL network, achieved by TSMs being received and understood by the joining node. TSMs are transmitted by the Network Timing Master node and also by a Relay node, if configured. Since a node may join the network from some (fairly) arbitrary geographical position, there is no guarantee that the joining node is, or could be manoeuvred to be, within range of the Network Timing Master node TSMs. Thus a mechanism is provided by which a nearby active node can be configured to act as a relay for the joining node. The necessary circuit reconfigurations must be applied before network join begins.

4. The procedure for joining onto a Relay is described in Figure 19: Message Sequence for Joining to a Relay, with messages being forwarded via the relay node. At the end of the example shown in Figure 19, the joining node is partially synchronised.

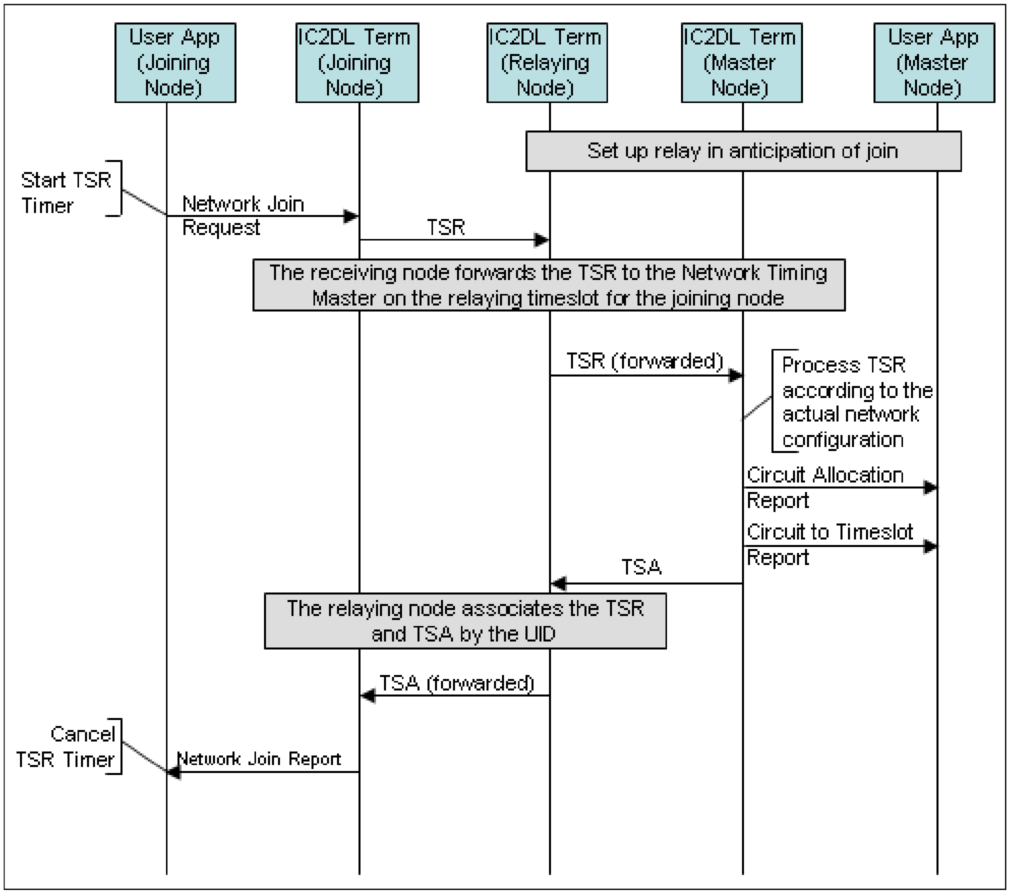

Figure 19: Message Sequence for Joining to a Relay

5. The random back-off technique is used to allow a joining node to retry the network join procedure if no TSA is received before TSR timer expiry. The intent of the random back-off time is to reduce the probability that two joining nodes re-transmit on the same network join timeslot in an epoch.

6. The Loss of Synchronisation procedure is invoked when a node does not receive a TSM for 1 minute.

4.3.11.10. Network Timing Master Reconfiguration Procedure

1. Due to the nature of the network, reconfiguration must be conducted in a co-ordinated manner. Changing the Network Timing Master requires particular attention since the loss of the Network Timing Master represents a loss of the network as shown in Figure 20: Master Change without TSR Loss and Figure 21: Master Change with TSR Loss.

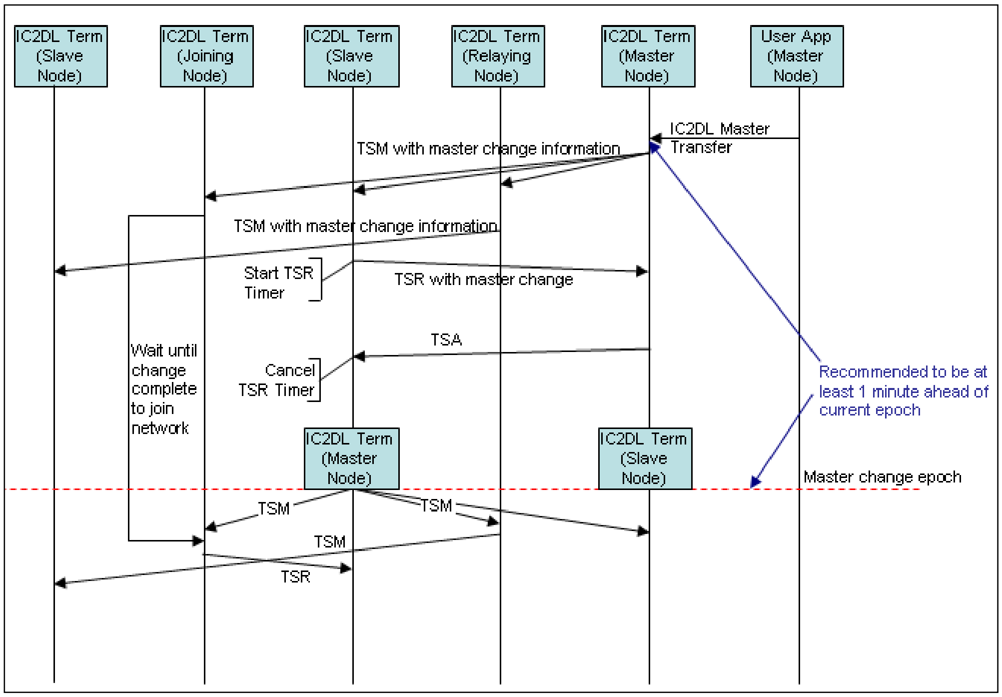

Figure 20: Master Change without TSR Loss

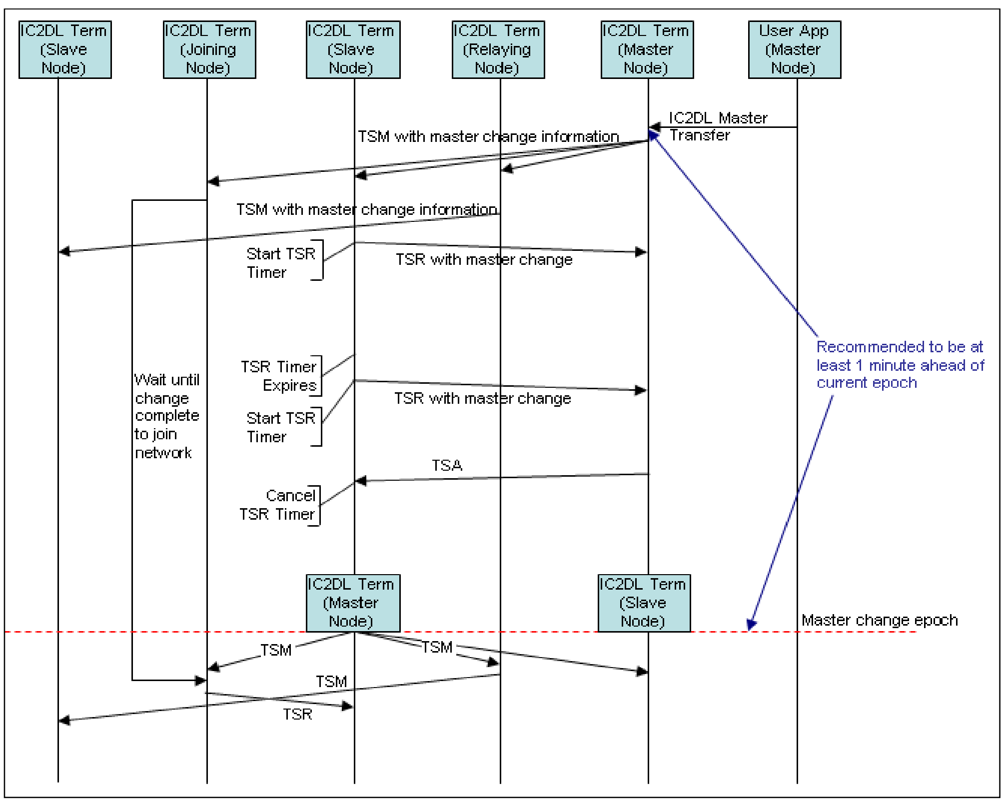

Figure 21: Master Change with TSR Loss

2. To do this in a controlled manner changes are propagated by the Network Timing Master. There are 2 likely scenarios for switching the Network Timing Master Node; one where the existing Master Node and the new Master Node are in direct communications and a second where the new Master Node is currently attached to a Relay Node. In both situations the existing Master Node must have information that the new Master Node has successfully received notification of the change. There are two further sub-variations of the scenario, one where the existing Network Timing Master is the same as the UCS and one where the UCS is not the existing Network Timing Master.

3. There are two situations that must be considered in terms of the timeline for reconfiguration:

a. IC2DL Network Timing Master is local to UCS, no Relay:

- UCS->IC2DL reconfigure Master
- IC2DL->TSM with new configuration table
- New Master node->TSR with request to become Master
- Existing Master node -> TSA with acknowledgement
- New Master instigates TSM transmission and existing Master ceases

b. IC2DL Network Timing Master is not local to UCS, no Relay:

- UCS->Current Master reconfigure Master
- Current Master ->IC2DL reconfigure Master
- IC2DL->TSM with new configuration table
- New Master node->TSR with request to become Master
- Existing Master node -> TSA with acknowledgement
- New Master instigates TSM transmission and existing Master ceases

4. It is important to note that a node attempting to join the network should wait until the master change procedure has been completed prior to requesting network resources; this is to simplify the process and also to ensure that TSR collisions do not occur that may hinder the master change.

5. It is recommended that when implementing the IC2DL terminal the epoch number used for a node change is set to the current epoch plus 1 minute or more. Although this is not an interoperability issue and implementers are in practice free to select an arbitrary time in the future a time of 1 minute aligns to the synchronisation time-out period, this also gives a large number of opportunities (~50) for the new master to handshake the change with the current timing master thus making the probability of failure small.

6. In the unlikely event that the Master change epoch is approached and the TSR/TSA handshaking sequence is not completed the current timing Master shall

revert the TSM back to the original state and the Master switch is abandoned. A cut-off of 10 seconds prior to the change epoch shall be implemented – by selecting 10 seconds both the current Master and new Master are able to gracefully revert back to their original states, the current Master shall not respond to any TSR received after the cut-off ensuring the change is not invoked.

7. In both cases, an external interface message is required to initiate the procedure. Such a message will be sent from an external application onto the Network Management Entity. This message will require two fields:

- The node ID of the new master.
- The state to which the current Master should move on relinquishing Master status (i.e. slave, relay or passive).

8. In order to allow for these interactions to occur in a safe manner, the TSM shall be altered to include future configuration information. This does not pose a problem as after the increase in size the TSM is still well below 528 bytes in length (the minimum IPV4 datagram size is 576 bytes that must be supported by all implementers - 528 bytes is the guaranteed minimum payload size after accounting for the headers as specified in STANAG 4586).

4.3.11.11. Active Time Tracking

1. To insure that their local timing remains synchronized with the network timing master, the Master activates regularly resynchronisation for each node (see Section 4.3.11.3).

4.3.12. Interface between Peer Layers

1. To support interoperability between nodes, the byte (bit) ordering shall be most significant byte (bit) first as illustrated in Figure 22: Byte Ordering.

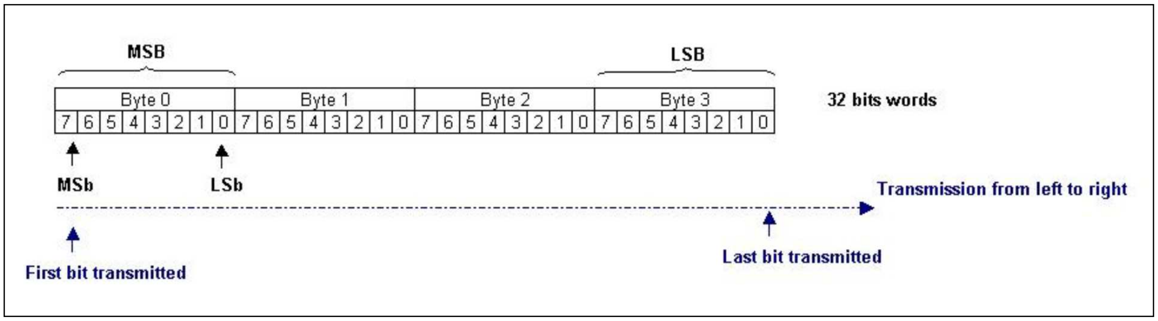

Figure 22: Byte Ordering

4.4. NETWORK LAYER (LAYER 3)

4.4.1. Overview

1. IC2DL does not send the UDP/IP addresses but simulates a UDP/IP data pipe, delivering UPD/IP frames from a source to destination node(s) as if on any other network. This is why the traditional Transport Layer (OSI Layer 4) is absorbed into Layer 3. The use of locally supplied UDP/IP addresses supplied by the data link, as set up by the host, allows for transparent transmission of UDP/IP through the data links. The actual data rate that can be supported by the data links is highly dependent on the host set up of the data links. The user defines the network connectivity and required transmission rates of data between nodes in the network and possible use of relays through STANAG 4586 Messages and/or external private messages.

2. Figure 23: Transmission of User Data illustrates the data transfer process for user data from one unit to another unit using the IC2DL.

4.4.2. Layer 3 Services

1. The services performed by the IC2DL Network Layer are:

- UDP ports presented to the Application layer
- Absorbs conventional “Transport Layer” function
- Simple connectionless approach from the application point of view but virtual circuits are used internally
- Provide priority based delivery of data
- Remove IP headers from incoming data
- Create IP headers on outgoing data
- Allocate packets to the right circuit
- Combine or split packets from different ports into timeslots
- Buffer data to be sent in upcoming timeslots. One buffer per timeslot, same size as the timeslot (TS)
- Drop data (bits) when the User tries to send too much data.

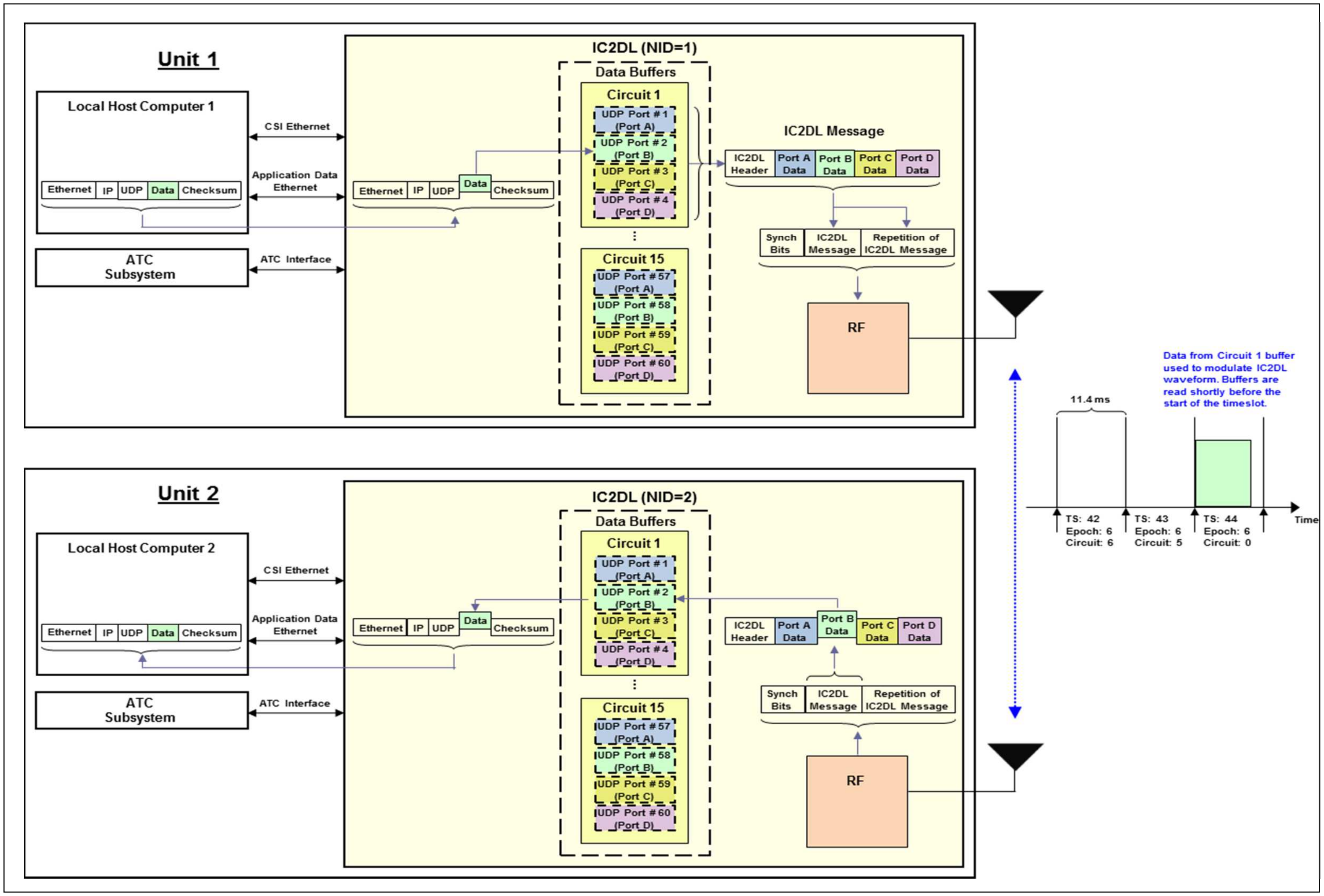

Figure 23: Transmission of User Data

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4.4.3. Implementation

1. The user has 15 separate circuits, each of which describes a data transfer route from a source node to destination node(s) using the IC2DL node identification number (NID).

2. The source node (e.g. node 1) host computer sends UDP/IP frames across the Data Ethernet to the local IC2DL (NID 1).

3. The local IC2DL node has a series of transmit data buffers that are used to store user UDP/IP payload data until it is transmitted in the next circuit opportunity. There are 15 groups of 4 data buffers, one group associated to each circuit type and 4 buffers per circuit type to store payloads for four separate user defined data types - Port A, Port B, Port C, and Port D.

4. Headers of incoming UDP/IP packets propagate up the UDP/IP stack to strip off the frame headers and footers, leaving just the data payload at the application layer. The frame headers and footers are discarded as the bandwidth of IC2DL is not sufficient to support transmission of complete UDP/IP packets.

5. The packet UDP port number is used to direct the incoming packet payload to the appropriate IC2DL transmit data buffer using the assigned port number, which like the circuit allocation is known by all nodes using the circuit. As an example, Table 12: Port Number Allocation Table Example illustrates the port number allocation, which provides a user defined one-to-one mapping between the incoming frame UDP port number and the associated data buffer (circuit + data type). The UDP port number to be used shall conform to Internet Assigned Numbers Authority (IANA).

UDP Port #	IC2DL Buffer
n1 (User Assigned)	Circuit 1, Port A, IP Address
n2 (User Assigned)	Circuit 1, Port B, IP Address
n3 (User Assigned)	Circuit 1, Port C, IP Address
n4 (User Assigned)	Circuit 1, Port D, IP Address
n5 (User Assigned)	Circuit 2, Port A, IP Address
. . .	. . .
n60 (User Assigned)	Circuit 15, Port D, IP Address

Table 12: Port Number Allocation Table Example

6. The example in Figure 23: Transmission of User Data shows the data payload of the incoming UDP/IP packet being directed by UDP port number and written to the Circuit 1, Port B buffers.

7. The IC2DL continuously writes incoming UDP/IP packet payloads to the data buffers dependent on the UDP port number.

8. Independent of this process is the TDMA timeslot timing. Shortly before a circuit transmission opportunity, the IC2DL reads the data buffers associated to that circuit and builds an IC2DL message combining the four data type blocks according to the predefined split defined in the circuit description. A network header is also included in the message. This message is used to modulate the IC2DL waveform, which is then sent on-air in the allocated timeslot.

9. Following transmission, the IC2DL sends UDP/IP 'transmission complete' messages to the local host computer, using each of the associated UDP port numbers, to inform the user that the buffers associated to that circuit are empty and the number of timeslots prior to the next transmission opportunity on that circuit.

10. Note that the IC2DL sends only the last data written to buffers prior to the circuit opportunity. The user is free to update the buffer as often as appropriate prior to transmit by appending data without overwriting existing data provided this does not overflow the buffer.

11. At the destination node(s) (e.g. node 2), the IC2DL waveform is received and processed. The receiving node writes the received data to the appropriate receive buffers based on the circuit number.

12. Each data component is encapsulated into its own reconstructed UDP/IP packet and sent to the local host computer using UDP port numbers derived from the Port Number Allocation Table.

13. IP packet reconstruction requires setting the IP address based on the host computer's IP assignment. As part of mission planning process, the IP address is uniquely specified for the node.

14. The checksum field shall be the 16 bit one's complement of the one's complement sum of all 16 bit words in the header.

4.4.4. Waveform Application Data Format

1. The application data contained in a timeslot shall use the format shown in Figure 24: Waveform Application Data Format.

App Len	Port	Qv	Port Len	Port Data	Jumb	Port	Qv	Port Len	Port Data	Jumb	Port	Qv	Port Len	Port Data	Jumb	Chk	Pad

Figure 24: Waveform Application Data Format

where:

Application length (***App Len***) is 2 bytes and is the number of bytes excluding both the ***App Len*** and ***Checksum*** (***Chk***)

Port is 7 bits which defines which of the three logical ports is associated with the ***Port Len*** and ***Port Data*** that directly follows.

0 = Port A
1 = Port B
2 = Port C
3 = Port D

Overrun (***Ov***) is a single bit that indicates that some of the port data was not sent.

Port Len is 2 bytes and is the number of bytes in ***Port Data***.

Port Data is the actual application data contained in the data link buffer.

Jumbo (***J***) is a single bit that indicates there is data to follow.

Chk includes all of the preceding bytes except for the ***App Len*** Bytes.

Pad N-bits of 0's in order to fill the maximum transmission unit (MTU).

2. If no data is present to send for a given logical port the ***Port***, ***Port Len***, ***Ov*** and ***Port Data*** will not be included in the Waveform Application Message. If data is present in the logical port the ***Port***, ***Port Len*** and ***Ov*** data must be placed in the Waveform Application Message, even if the actual port data must be dropped.

3. The order of the logical port data in the Waveform Application Message is determined by a STANAG 4586 Message and/or an external private message.

4. Once the Waveform Application Message is built, any logical port data that would not fit into the message shall be discarded and not buffered for later transmission unless jumbo buffers were enabled in which case it will follow in the next transmission for that circuit. The discarded data is to ensure timely delivery of application data and predictable latency at the expense of potential data loss.

4.4.5. IPv6 support

1. Although this AEP is written to provide a User Datagram Protocol (UDP) / Internet Protocol (IP) v4 interface to user applications, it shall also be able to support IPv6. A static (but reconfigurable) network is achieved by mapping addresses and port numbers to circuits and timeslots in the network.

2. IPv6 is a more sophisticated protocol than IPv4. This brings benefits to the user applications, which are not to be disregarded, but this brings a number of challenges to the prevailing approach to IP in the IC2DL network; specifically stripping and reconstitution of UDP/IP headers.

3. Firstly, IPv6 headers are significantly larger than IPv4 headers (320 bits vs. 160 bits minimum; both IP versions have optional header extensions). If stripping is not used, in other words the dynamic header fields are preserved across the air, then substantial extra information would need to be transmitted.

4. Secondly, IPv6 user applications may make use of IPv6 features in their designs – for example mobile IP routing, authentication information and encapsulated security information, all of which are present in the Extension header. Thus information loss in UDP/IPv6 will immediately remove that advantage.

5. In the definition given, there is a mechanism for indicating that a virtual circuit is carrying data on behalf of a UDP/IPv6 application (see Figure 25: Dual Stack for IPv4 and IPv6). However there is no mechanism for signalling the IPv6 header information which is lost on stripping.

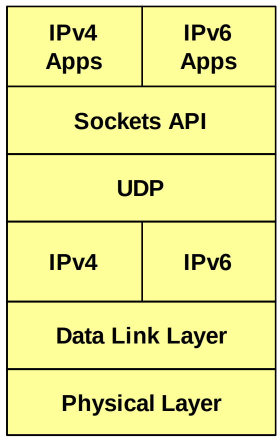

Figure 25: Dual Stack for IPv4 and IPv6

4.4.6. Segmentation and Reassembly of Large Messages

1. Section 4.4.4 presents the format of user data for presentation to the physical layer (Layer 1). The procedure for handling excess user data is given below:

> *"Once the waveform Application message is built, any logical port data that would not fit into the message shall be discarded and not buffered for later transmission. The discarded data is to ensure timely delivery of application data and predictable latency at the expense of potential data loss."*

2. However some of the messages carried through the IC2DL may be larger than the amount which can fit wholly within a single transmission timeslot (e.g. there is at least one STANAG 4586 message). Therefore a mechanism is required for segmenting and reassembling messages of this size.

3. When a jumbo payload is passed into the Network Layer it will be segmented. The first and second segments are buffered in the network layer. The first segment is flagged as having data to follow, and transmitted on the next available timeslot for the intended receiver. When this is received in the peer network layer, it is buffered in anticipation of a second segment. This is received by the peer network layer on the next receive timeslot. The receiver network layer then reassembles the payload and passes the whole payload to the peer application.

4. As an example:

- Node A is configured to transmit to node B on timeslots 2, 5, and 12.
- An application on node A sends a large payload.
- Assume the current timeslot is 3.
- Node A network layer segments the message and buffers the two parts.
- When timeslot 5 arrives, node A sends part 1 out on this timeslot with the Jumbo bit set.
- Node B receives this message segment and stores it (because part 1 is marked as being one of two segments)
- When timeslot 12 arrives, node A sends part 2 out on this timeslot with the Jumbo bit cleared.
- Node B receives this message and associates part 1 with part 2, reassembles the large payload and passes it on to its application layer.

Note:

- This scheme is limited to segmenting a large message into two segments. Segmentation into three or greater segments is not supported.
- Should either segment fail to arrive at the receiver in the next expected time slot, then the receiver would be unable to reassemble the payload correctly. In this case the jumbo payload is lost.

4.5. TRANSPORT LAYER (LAYER 4)

4.5.1. Overview

1. The traditional task of the Transport Layer is to provide guaranteed delivery of messages according to the service that is available through the subnet protocol. To do this, the layer responds to service requests from the Session layer (or Application layer) and issues service requests to the Network layer. As part of the Internet Protocol suite, this transport layer function is most commonly achieved by the connection oriented Transmission Control Protocol (TCP), which provides error recovery and flow control ensuring complete data transmission. The datagram-type transport or User Datagram Protocol (UDP) provides neither error recovery, nor flow control, leaving these functions to the application.

2. For IC2DL, only UDP is specified and required for timeliness of delivery. As described above, UDP is a very simple datagram service which does not provide the reliability and ordering guarantees that TCP does. Even though the datagrams may arrive out of order or go missing without notice, UDP processing is much faster without the overhead of analyzing and ensuring packet arrival.

4.5.2. Services Provided to the Application Layer

1. With UDP as the transport layer protocol, it provides a simple interface between the Network layer below and Application layer above. UDP provides no guarantees to the application layer for message delivery and the sender receives no acknowledgement of message delivery. The application layer, in this case, provides the necessary management of transmitted messages.

4.5.3. Functions

1. The transport layer function provided by IC2DL complies with RFC 768 which provides the details of UDP. It interoperates with TCP/IP-based networks external to the IC2DL network. However, within an IC2DL network, UDP messages and associated content are encapsulated and managed by the application functions to ensure efficient data transmissions over the air.

4.5.3.1. Addressing

1. To enable peer to peer communication to support various applications, UDP ports are defined and made available to IC2DL applications. The port field has 16 bits for a valid range of 0 through 65,535. Some of the ports are well-known and defined to support such intrinsic applications as SMTP, FTP, DNS, etc.

4.5.3.2. Management

1. The UDP header consists of only 4 fields; they are: source port, destination port, 16-bit length (of the entire datagram which includes header and payload data), and checksum (for error checking of the header and data). While UDP traffic is typically manageable in a well designed network, the potential of UDP messages overloading a network is possible due to network vulnerability, inadequate network architecture and design, etc. Congestion control mechanisms can be deployed to manage these possible network congestion scenarios.

4.6. SESSION LAYER (LAYER 5)

1. This Layer is null.

4.7. PRESENTATION LAYER (LAYER 6)

1. This Layer is null.

4.8. APPLICATION LAYER (LAYER 7)

1. For IC2DL the Application Layer function is provided by the Management Entity (ME) described in the data link layer section 4.3.

2. The ME communicates with the IC2DL service application within the local host computer (either at the UCS or UAV).

3. The ME manages the configuration of the IC2DL layers 1-4.

4. STANAG 4586 is not mandatory between the IC2DL terminal and the local host computer.

5. Transfer of application data between host computers connected to the data link are performed according to other standards selected by the host computer and would include STANAG 4586 for the AV and payload(s) operation.

6. The Data Link, Network and Transfer layers do not perform message acknowledgement between nodes. If confirmed receipt of data is required then the Application Layer of the local host computer will need to support this. For example STANAG 4586 messages exist to acknowledge receipt of received data when requested.

7. Figure 26: Relationship between ME, IC2DL service application and local host computer describes the relationship between ME and the IC2DL service application and the host computer.

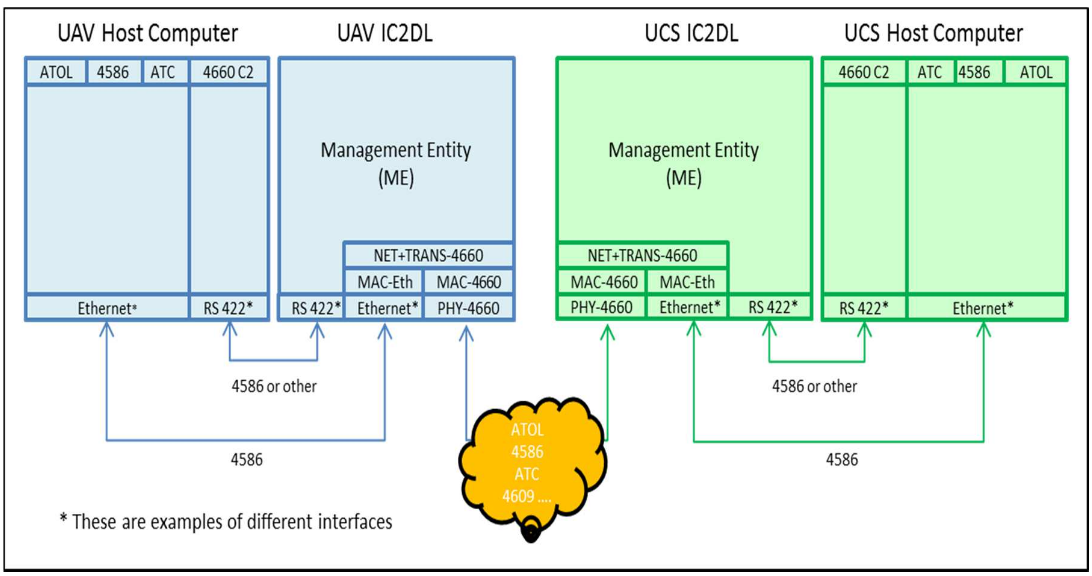

Figure 26: Relationship between ME, IC2DL service application and local host computer

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CHAPTER 5 REFERENCE DOCUMENTS

5.1. INTRODUCTION

1. The following Standardization Agreements (STANAGs), Military Standards (MIL-STDs), International Telecommunication Union (ITU) Recommendations and International Standards (ISs) contain provisions which, through references in this text, constitute provisions of this STANAG. At the time of publication, the editions indicated below were valid. All Recommendations and Standards are subject to revision, and parties to agreements based on this STANAG are encouraged to investigate the possibility of applying the most recent editions of the STANAGs, MIL-STDs, ITU Recommendations and ISs listed below. NATO maintains registers of currently valid STANAGs.

AAP-6 (V) modified version 02 – NATO Terms and Definitions
AEDP-2 – NATO ISR Interoperability Architecture
Baseline Specification for the High Integrity Data Link (HIDL) AC/141(PG/35)D/15
Comité Consultatif International Téléphonique et Télégraphique (CCITT) v.42bis – Modem standard for error correction and compression at speeds of 28.8 kbps
ECMA Script scripting language (ECMA Script 262)
Electronic Industry Association (EIA) RS-170
ETSI EN 302 245-2 V1.1.1 Electromagnetic compatibility and Radio spectrum Matters (ERM); Transmitting equipment for the Digital Radio Mondiale (DRM) broadcasting service.
File Transfer Protocol (FTP), IETF, RFC 959
Hypertext Transfer Protocol (HTTP) Version 1.1, IETF RFC 2616
ICAO document – Rules of the Air and Air Traffic Services, Doc 4444-RAC/501
Institute of Electrical and Electronics Engineers, Inc.(IEEE) Network Standards – 802
Internet Protocol (IP) (Ipv4 (RFC 791, 792, 919,922, 1112))
Ipv6 (RFC 2460-4, 2375, 2236)
ISO/Work Doc 9241-9 – Non-Keyboard Input Devices
ISO/CD 9241-13 – User Guidance
ISO/DIS 9241-14 – Menu Dialogues
ISO/CD 9241-16 – Direct Manipulation Dialogues
ISO/CD 13406-2 – Flat Panel Displays
International Organisation for Standardization/International Electrotechnical Commission ECMA Script Language Specification – ISO/IEC 16262
MIL-STD-2525B – Common Warfighting Symbology
MIL-STD-2401 – World Geodetic System – 84 (WGS – 84)
NATO C3 Technical Architecture (NC3TA) / Version 5.2 – June 8 – 2004 (All 5 volumes)
NATO Data Policy 2000 – 12.20-00
NIAG SG-53 – Pre-feasibility study on Unmanned Air Vehicle (UAV) Systems Interoperability (Phase 1) - NIAG-D(1998)0001 dated February 1998
NIAG SG-53 – Pre-feasibility study on Unmanned Air Vehicle (UAV) Systems Interoperability (Phase 2) - NIAG-D(1999)0001 dated March 1999

NIAG SG-101 – Pre-feasibility study on Interoperable Command and Control Data Link (IC2DL) - NIAG-D(2007)0023 dated August 2007
NIAG SG-140 – Pre-feasibility study on Tuneable UAS Interoperable Command and Control Data Link (IC2DL) - NIAG-D(2010)0018 dated November 2010
Network Time Protocol (V3), April 9, 1992, NTP (RFC-1305)
Society of Motion Picture and Television Engineers (SMPTE) 170 M
STANAG 3150 Uniform System of Supply Classification
STANAG 3151 Uniform System of Item Identification
STANAG 3809 Digital Terrain Elevation Data (DTED) Geographic Information Exchange Standard
STANAG 4250 NATO Reference Module for Open Systems Interconnection – Part 1 General Description
STANAG 4545 NATO Secondary Imagery Format
STANAG 4559 NATO Standard Image Library Interface (NSILI)
STANAG 4586, Edition 3 Standard Interfaces of UAV Control System (UCS) for NATO UAV Interoperability
STANAG 4607, NATO Ground Moving Target Indicator Format (NGMTIF) (pending ratification)
STANAG 4609 Edition 1, NATO Motion Imagery Standard
STANAG 4671 UAV System Airworthiness Requirements
STANAG 5500 NATO Message Text Formatting System (FORMETS) AdatP-3 Build 11
STANAG 7023 Air Reconnaissance Primary Imagery Data Standard
STANAG 7074 Digital Geographic Information Exchange Standard (DIGEST Version 1.2a)
STANAG 7085 Interoperable Data Links for Imaging Systems
STANAG 7149 NATO Message Catalogue (NMC) – APP 11– (Edition 1)
STDI-0002, National Imagery and Mapping Agency, “The Compendium of Controlled Extensions (CE) for the National Imagery Transmission Format (NITF)”, CMETAA Support Data Extension
Transport Control Protocol (TCP) (IETF STD 7) RFC 793 (TCP)
United States Message Text Format (USMTF)
User Datagram Protocol (UDP) (IEN 88, RFC 768, 1122)
Variable Message Format (VMF)

CHAPTER 6 TERMS AND DEFINITIONS

6.1. ACRONYMS

1. The following acronyms are used for the purpose of this AEP volume:

A	
A/C	Aircraft
ADT	Air Data Terminal
AEP	Allied Engineering Publication
App Len	Application Length
ATC	Air Traffic Control
ATM	Air Traffic Management
AV	Air Vehicle
B	
BER	Bit Error Rate
BDA	Battle Damage Assessment
BHA	Bomb Hit Assessment
BLOS	Beyond Line of Sight
C	
C2	Command and Control
CCS	Command, Control and Status
CDT	Control Data Terminal
Chk	Checksum
CMS	Common Message Structure
CSI	Control and Status Information
CUCS	Core UAV Control Station
D	
DNS	Domain Name Service
DRM	Digital Radio Mondiale
E	
ECCM	Electronic Counter Counter Measures
EMCON	Emissions Control
EO	Electro Optic
EPM	Electric Protective Measure
ESM	Electronic Support Measures
EW	Electronic Warfare
F	
FTP	File Transfer Protocol
G	
GCS	Ground Control Station
GDT	Ground Data Terminal
GHz	Gigahertz
GIG	Global Information Grid

GNSS	Global Navigation Satellite System
GPS	Global Positioning System
H	
HDRDL	High Data Rate Data Link
HQ	Headquarters
Hz	Hertz
I	
IC2DL	Interoperable Command and Control Data Link
IEC	International Enterprise Committee/International Electro Technical Commission
IER	Information Exchange Requirement
IP	Internet Protocol
IR	Infra-Red
ISAR	Inverse Synthetic Aperture Radar
ISO	International Organisation for Standardisation
ISs	International Standards
ITU	International Telecommunication Union
J	
JCGUAS	Joint Capability Group UAS
JFC	Joint Forces Command
K	
kbps	Kilo bits per second
L	
LDRDL	Low Data Rate High Integrity Data Link
LOS	Line of Sight
LPD	Low Probability of Detection
LPI	Low Probability of Intercept
LSb	Least Significant Bit
LSB	Least Significant Byte
M	
MAC	Media Access Control
ME	Management Entity
Mbits/sec	Megabits per second
MSb	Most Significant Bit
MSB	Most Significant Byte
MTU	Maximum Transmission Unit
msec	Millisecond
N	
NATO	North Atlantic Treaty Organization
NBC	Nuclear Biological & Chemical
NIAG	NATO Industrial Advisory Group
NID	Node Identification
NIPRNET	Non-classified Internet Protocol Router Network
NM	Nautical Mile
NSO	NATO Standardization Office
NSWan	NATO Secret WAN

NTA	Naval Task
O	
OSI	Open System Interconnection
Ov	Overrun
P	
Port Len	Port Length
Q	
QoS	Quality of Service
R	
RF	Radio Frequency
RFC	Requests For Comments
RMS	Route Mean Square
S	
SAR	Synthetic Aperture Radar
SIGINT	Signals Intelligence
SiS	Signal in Space
SiS M	Signal in Space Mandatory
SiS O	Signal in Space Optional
SMTP	Simple Message Transfer Protocol
STANAG	Standardization Agreement
T	
TAC	Tactical
TCP	Transmission Control Protocol
TDMA	Time Division Multiple Access
T/O	Take-Off
TRANSEC	Transmission Security
TS	Timeslot
TSA	Time Synchronisation Acknowledgement
TSM	Time Synchronisation Message
TSR	Time Synchronisation Response
U	
UA	Unmanned Aircraft
UAV	Unmanned Aerial Vehicle
UAS	Unmanned Aircraft System
UCS	UAS Control System
UDP	User Datagram Protocol
UJTL	Universal Joint Task List
V	
VDT	Vehicle Data Terminal
VSM	Vehicle Specific Module
W	
WAN	Wide Area Network
X	
Y	
Z	

6.2. TERMS AND DEFINITIONS

1. The following terms and definitions are used for the purpose of this STANAG/AEP.

Term	Definition
Air Reconnaissance	The collection of information of intelligence interest either by visual observation from the air or through the use of airborne sensors.
Air Traffic Control (ATC)	A service provided for the purposes of: a) preventing collisions between aircraft and in the manoeuvring area between aircraft and obstructions; and b) expediting and maintaining an orderly flow of air traffic.
Air Vehicle (AV)	The core platform consisting of all flight relevant subsystems but without payload and data link.
Aircraft Handover	The process of transferring control of aircraft from one controlling authority to another.
Alert	A signal or combination of signals that informs the aircrew of the existence of a warning, caution, or advisory condition, and may inform the aircrew of the nature of the warning, caution, or advisory condition.
Allied Data Publication – 3 (ADatP-3)	The NATO Message Text Formatting System (FORMETS) provides the rules, constructions and vocabulary for standardised CHARACTER-oriented MESSAGE TEXT FORMATS (MTF) that can be used in both manual and computer assisted operational environments. FORMETS is specified in Allied Data Publication Number 3 (ADatP-3).
Altitude	The vertical distance of a level, a point or an object considered as a point, measured from mean sea level. The terms most relevant to UAV operations are: **Absolute Altitude**: The height of an aircraft directly above the surface or terrain over which it is flying. **Critical Altitude**: The altitude beyond which an aircraft or air-breathing guided missile ceases to perform satisfactory. **True Altitude**: The height of an aircraft as measured from mean sea level.
Analysis	In intelligence usage, a step in the processing phase of the intelligence cycle in which information is subjected to review in order to identify significant facts for subsequent interpretation.
Automated Take-off and Landing	The ability of the AV to be launched with a single command once planning and pre-flight has been conducted and permission to launch has been granted. Includes releasing the AV from a securing device and flight of the AV to the first waypoint and the ability to land and secure the AV with a single command once the air vehicle has been stationed at a gate position no closer than 100 meters to the landing spot.

Byte	Eight bits.
Classification	The ability to determine unique characteristics about a contact, which allow the differentiation of military and commercial contacts and determination of contact class and type.
Command and Control	The exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of a mission.
Command Control Interface (CCI)	The interface between the UCS Core and the external C4I systems. It specifies the data requirements that should be adopted for communication between the UCS Core and all C4I end users through a common, standard interface.
Command and Control Information System	An integrated system comprised of doctrine, procedures, organizational structure, personnel, equipment, facilities and communications which provides authorities at all levels with timely and adequate data to plan, direct and control their activities.
Commonality	An item of an interchangeable nature which is in common use by two or more nations or services of a nation.
Communications Plan	The overarching plan which covers all communication aspects. Includes the Data Link Plan.
Compatibility	The suitability of products, processes or services for use together under specific conditions to fulfil relevant requirements without causing unacceptable interactions.
Component	In logistics, a part or combination of parts having a specific function, which can be installed or replaced only as an entity.
Compression	The ability to transmit the same amount of data in fewer bits. There are a variety of data compression techniques, but only a few have been standardized. The CCITT has defined a standard data compression technique for transmitting faxes (Group 3 standard) and a compression standard for data communications through modems (CCITT V.42*bis*). In addition, there are file compression formats, such as ARC and ZIP. Data compression is also widely used in backup utilities, spreadsheet applications, and database management systems. Certain types of data, such as bit-mapped graphics, can be compressed to a small fraction of their normal size.
Concept of Operations	A clear and concise statement of the line of action chosen by a commander in order to accomplish his mission.
Control Data Terminal (CDT)	The data link element consists of the air data terminal in the air vehicle and the control data terminal (CDT) that can be located either on the ground or in the air (e.g. Command and Control aircraft). Connectivity between the CDT and VDT is prerequisite for Level 2, 3, 4, and 5 interoperability.
Controlled Airspace	An airspace of defined dimensions within which ATC service is provided to controlled flights (e.g. flights within controlled airspace require approval by/coordination with the controlling authority, and certain manoeuvres may be prohibited or restricted, or require supervision).

Core UCS (CUCS)	Provides the UAV operator with the functionality to conduct all phases of a UAV mission. It shall support the requirements of the DLI, CCI, and HCI. Also provides a high resolution, computer generated, graphical user capability that enables a qualified UAV operator the ability to control different types of UAVs and payloads.
Countermeasures	That form of military science that, by the employment of devices and/or techniques, has as its objective the impairment of the operational effectiveness of enemy activity.
Data Communication	The transfer of information between functional units by means of data transmission according to a protocol.
Data Link	The means of connecting one location to another for the purpose of transmitting and receiving data.
Data Link Interface (DLI)	The interface between the Vehicle Specific Module (VSM) and the UCS core element. It provides for standard messages and formats to enable communication between a variety of air vehicles and NATO standardised control stations.
Data Link Plan	The details of the available link including the band and frequencies to be used. It is associated with waypoints within the route and the details of required actions made available for cueing the operator.
Electromagnetic Spectrum	The range of frequencies of electromagnetic radiation from zero to infinity.
Electronic Warfare (EW)	Military action to exploit the electromagnetic spectrum encompassing: the search for, interception and identification of electromagnetic emissions, the employment of electromagnetic energy, including directed energy, to reduce or prevent hostile use of the electromagnetic spectrum, and actions to ensure its effective use by friendly forces.
Emergency Recovery Plan	In case of failures such as data link loss, UAVs need to automatically carry out recovery actions referred to as Rules of Safety (ROS). The ROS are selected at the mission planning stage. The ROS differ according to the priority given to emergency action relative to that given to mission execution. Using the mission planning application the UCS operator selects the appropriate safety scenario (e.g. to define a pre-programmed recovery route).
Encoding	Converting information or data from a system, format or signal to another.
Exercise	A military manoeuvre or simulated wartime operation involving planning, preparation, and execution. It is carried out for the purpose of training and evaluation. It may be a combined, joint, or single Service exercise, depending on participating organizations.

Formatted Message Text	Words composed of several sets ordered in a specified sequence, each set characterized by an identifier and containing information of a specified type, coded and arranged in an ordered sequence of character fields in accordance with the NATO message text formatting rules. It is designed to permit both manual and automated handling and processing.
Frame	In photography, any single exposure contained within a continuous sequence of photographs.
Free Form Message Text	Words without prescribed format arrangements. It is intended for fast drafting as well as manual handling and processing.
Fusion	The blending of intelligence and/or information from multiple sources or agencies into a coherent picture. The origin of the initial individual items should then no longer be apparent.
Handover	The act of passing control of a UAV and/or a payload from one UCS to another UCS and/or transferring of data link control.
Human Computer Interface (HCI)	Definitions of the requirements of the functions and interactions that the UCS should allow the operator to perform. Will support any HCI requirements that are imposed on the CUCS by the Command and Control Interface (CCI) and Data Link Interface (DLI). Will also support any specific or unique CCI Specific Module (CCISM) or Vehicle Specific Module (VSM) display requirements.
Image	A two-dimensional rectangular array of pixels indexed by row and column.
Imagery	Collectively, the representations of objects reproduced electronically or by optical means on film, electronic display devices, or other media.
Imagery Exploitation	The cycle of processing and displaying, assembly into imagery packs, identification, interpretation, mensuration, information extraction, the preparation of reports (including annotated images) and the dissemination of information.
Integration	Refers to combining segments – not systems – and ensuring that the segments work correctly within the environment; do not adversely impact one another; and conform to standards. Integration does not imply interoperability. It only provides a level of assurance that the system will work as designed.
Intelligence	The product resulting from the processing of information concerning foreign nations, hostile or potentially hostile forces or elements, or areas of actual or potential operations. The term is also applied to the activity which results in the product and to the organizations engaged in such activity.
Interaction	A one or two-way exchange of data among two or more systems/sub-systems.

Interface	(1) A concept involving the definition of the interconnection between two equipment items or systems. The definition includes the type, quantity, and function of the interconnecting circuits and the type, form, and content of signals to be interchanged via those circuits. Mechanical details of plugs, sockets, and pin numbers, etc., may be included within the context of the definition. (2) A shared boundary, (e.g. the boundary between two subsystems or two devices). (3) A boundary or point common to two or more similar or dissimilar command and control systems, subsystems, or other entities against which or at which necessary information flow takes place. (4) A boundary or point common to two or more systems or other entities across which useful information flow takes place (It is implied that useful information flow requires the definition of the interconnection of the systems which enables them to interoperate). (5) The process of interrelating two or more dissimilar circuits or systems. (6) The point of interconnection between user terminal equipment and commercial communication-service facilities.
Interoperability	The ability of Alliance forces and, when appropriate, forces of Partner and other nations to train, exercise and operate effectively together in the execution of assigned missions and tasks.
Joint	Adjective used to describe activities, operations and organizations in which elements of at least two services participate.
Level of Interoperability (LOI)	Multiple levels of interoperability are feasible among different UASs. Maximum operational flexibility can be achieved if the UASs support the following levels of UAS interoperability: Level 1: Indirect receipt/transmission of UAV related payload data Level 2: Direct receipt of ISR/other data where “direct” covers reception of the UAV payload data by the UCS when it has direct communication with the UAV. Level 3: Control and monitoring of the UAV payload in addition to direct receipt of ISR/other data Level 4: Control and monitoring of the UAV, less launch and recovery Level 5: Control and monitoring of the UAV (Level 4), plus launch and recovery functions
Mission Plan	The route planning, payload planning, data link planning (including frequency planning), and UAV emergency recovery planning (rules of safety) for a A/V.
Meaconing	A system of receiving radio beacon signals and rebroadcasting them on the same frequency to confuse navigation. The meaconing stations cause inaccurate bearings to be obtained by aircraft or ground stations.

Metadata	Data about data. The term is normally understood to mean structured data about resources that can be used to help support resource description and discovery, the management of information resources (e.g., to record information about their location and acquisition), long-term preservation management of digital resources, and for help to preserve the context and authenticity of resources. Might be technical in nature, documenting how resources relate to particular software and hardware environments or for recording digitisation parameters. In short, any kind of standardised descriptive information about resources, including non-digital ones.
Mission Plan	The route planning, payload planning, data link planning (including frequency planning), and UAV emergency recovery planning (rules of safety) for a UAV flight.
Motion Imagery	A sequence of images, with metadata, which are managed as a discrete object in standard motion imagery format and displayed as a time sequence of images.
National Transmission Standards Committee (NTSC)	The first colour TV broadcast system was implemented in the United States in 1953. This was based on the NTSC standard. NTSC is used by many countries on the North American continent and in Asia including Japan. This U.S. video standard uses EIA RS-170 and SMPTE 170 M – 1994 formats. The standard applies to imagery with metadata in either closed caption overlays or encoded via closed caption. NTSC runs on 525 lines/frame and 30 frames/second with 2:1 interlace.
NATO ISR Interoperability Architecture (NIIA)	The architecture that defines the STANAGs used for ISR sensor system interoperability. This architecture is defined in AEDP-2.
NATO OSI Profile Strategy (NOSIP)	Interoperability strategy now merged into the NC3TA.
NATO Standardisation Agreement (NATO STANAG)	The record of an agreement among several or all the member nations to adopt like or similar military equipment, ammunition, supplies, and stores; and operational, logistic, and administrative procedures. National acceptance of a NATO Allied publication issued by the NATO Standardisation Office (NSO) may be recorded as a Standardisation Agreement.
NC3 Common Standards Profile (NCSP)	The minimum set of communication and information technology standards to be mandated for the acquisition of all NATO C3 systems.
NC3 Technical Architecture (NC3TA)	The technical, standards-related view of an overarching NC3 Architectural Framework.
Near Real Time	Pertaining to the timeliness of data or information which has been delayed by the time required for electronic communication and automatic data processing. This implies that there are no significant delays.
Network	(1) An interconnection of three or more communicating entities and (usually) one or more nodes. (2) A combination of passive or active electronic components that serves a given purpose.

Open Systems Interconnect Model	This model is defined in ISO/IEC 7498-1.
Passive	In surveillance, an adjective applied to actions or equipment which emits no energy capable of being detected.
Payload	UAV sensor(s), weapons, chaff, pamphlets, onboard systems, etc. carried onboard which are used to accomplish a specified mission.
Payload Plan	Details of the sensor to be used, or which sensors are to be loaded if multiple payloads are within the UAV capability. At specific points along a route there may be pre-planned sensor operations and the details of these have to be incorporated into the payload plan and associated with waypoints in the route. Available as hard copy for UAV payload loading and for display with or alongside the route plan, action cueing has to be incorporated either for the operator or the UAV depending on system sophistication. Includes payload configuration (e.g., payload type and lens size), payload imagery extraction (e.g., desired resolution), and operator commands for controlling both EO/IR and SAR payloads (e.g. zoom settings, depression angle, and focus).
Primary Data	Data directly received from the sensor.
Primary Imagery	Unexploited, original imagery data that has been derived directly from a sensor. Elementary processing may have been applied at the sensor, and the data stream may include auxiliary data.
Processed Imagery	Imagery that has been formatted into image pixel format, enhanced to remove detected anomalies and converted to a format appropriate for subsequent disposition.
Protocol	(1) [In general], A set of semantic and syntactic rules that determine the behaviour of functional units in achieving communication. For example, a data link protocol is the specification of methods whereby data communication over a data link is performed in terms of the particular transmission mode, control procedures, and recovery procedures. (2) In layered communication system architecture, a formal set of procedures are adopted to facilitate functional interoperation within the layered hierarchy. Note: protocols may govern portions of a network, types of service, or administrative procedures.
Real Time	Pertaining to the timeliness of data or information that has been delayed only by the time required for electronic communication. This implies that there are no noticeable delays.
Reconnaissance	A mission undertaken to obtain, by visual observation or other detection methods, information about the activities and resources of an enemy or potential enemy; or to secure data concerning the meteorological, hydrographic characteristics of a particular area.
Recovery	A mission which involves the return of an aircraft to base and includes the approach to the landing platform, and landing. If the Air Vehicle (AV) is to be stowed after flight, securing on deck and handling of the AV is also included.

Resolution	A measurement of the smallest detail which can be distinguished by a sensor system under specific conditions.
Route Plan	A set of waypoints for the UAV to follow, as well as general air vehicle commands for auxiliary systems (e.g. lights, IFF, de-icing, etc.) and emergency operation commands. Taxi or flight patterns may be incorporated into the route either as a series of sequenced waypoints or as 'seed' waypoints with range and bearing information, which, will depend on the sophistication of the UCS and UAV systems.
Secondary Imagery	Imagery and/or imagery products derived from primary imagery or from the further processing of secondary imagery.
Sensor	Equipment which detects, and may indicate, and/or record objects and activities by means of energy or particles emitted, reflected, or modified by objects.
Shall	Mandatory compliance.
Should	Recommended compliance.
Signal in Space (SiS)	Signal in Space is an unique combination of transmission characteristics that describes the over the air signal in space and time, for example: - Single carrier / multi-carriers - Modulation scheme and modulation order - Spreading techniques - Channel coding scheme and rate - Interleaving scheme
Signals Intelligence	The generic term used to describe communications intelligence and electronic intelligence when there is no requirement to differentiate between these two types of intelligence, or to represent fusion of the two.
Software	A set of computer programs, procedures and associated documentation concerned with the operation of a data processing system (e.g. compilers, library routines, manuals, and circuit diagrams).
STANAG	The NATO term derived from standardization agreement. See NATO Standardization Agreement.
Standardization	The development and implementation of concepts, doctrines, procedures and designs to achieve and maintain the required levels of compatibility, interchangeability or commonality in the operational, procedural, material, technical and administrative fields to attain interoperability.
Storage	a) The retention of data in any form, usually for the purpose of orderly retrieval and documentation. b) A device consisting of electronic, electrostatic or electrical hardware or other elements into which data may be entered, and from which data may be obtained.

Surveillance	The systematic observation of aerospace, surface or subsurface areas, places, persons, or things, by visual, aural, electronic, photographic, or other means.
System Architecture	Defines the physical connection, location and identification of the key nodes, circuits, networks, war fighting platforms, etc., associated with information exchange and specifies systems performance parameters. Constructed to satisfy operational architecture requirements per the standards defined in the technical architecture.
Target	a) A geographical area, complex, or installation planned for capture or destruction by military forces; b) In intelligence usage, a country, area, installation, agency, or person against which intelligence operations are directed.
Target Acquisition	The detection, identification, and location of a target in sufficient detail to permit the effective employment of weapons. Increasingly applied to reconnaissance as the object(s) of search and location activity, whether to provide intelligence data or to cue weapon systems directly.
Targeting	The ability to report the position (may include speed and direction) of a target detected with an AV payload. Target position is reported in terms of latitude and longitude (may include altitude) or in terms relative to a point. Target position information is sufficiently accurate to support weapon system fire control requirements.
Technical Architecture	A minimal set of rules governing the arrangement, interaction, and interdependence of the parts or elements whose purpose is to ensure that a conformant system satisfies a specific set of requirements. It identifies system services, interfaces, standards, and their relationships. It provides the framework, upon which engineering specifications can be derived, guiding the implementation of systems. Simply put, it is the “building codes and zoning laws” defining interface and interoperability standards, information technology, security, etc.
Tracking	Accurate location and updating of target positions (in terms of geographic co-ordinates) by radar, optical or other means.
TRANSEC	The application of security measures, in order to protect transmissions from interception and exploitation by means other than cryptanalysis.
Uninhabited Aerial Vehicle /Unmanned Aerial Vehicle (UAV)	A powered, aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or nonlethal payload.
Unmanned Aircraft System (UAS)	Includes the air vehicles, modular mission payloads, data links, launch and recovery equipment, mission planning and control stations, data exploitation stations and logistic support.

UAV Control System (UCS)	The functional set charged with control of the AV and interfacing with C4I, the UAV payload and UAV System operator(s). Includes all the UAV control systems and encompasses launch and recovery system.
United States Message Text Format (USMTF)	Fixed format, character-oriented messages which are man-readable and machine processable.
Variable Message Format (VMF)	Used between systems requiring variable bit-oriented messages.
Vehicle Specific Information	Information sent to or from the air vehicle that is not contained in the core, generic DLI message set.
Vehicle Data Terminal (VDT)	The data link element consists of the air data terminal in the air vehicle and the control data terminal (CDT). Connectivity between the CDT and VDT is prerequisite for Level 2, 3, 4, and 5 interoperability.
Vehicle Specific Module (VSM)	A function that resides between the DLI and the air vehicle subsystem. Facilitates compliance with this STANAG by acting as a bridge between standard DLI data formats, and protocols, and a specific air vehicle.
Video Imagery	A sequence of images, with metadata, which is collected as a timed sequence of images in standard motion imagery format, managed as a discrete object in standard motion imagery format, and displayed as a sequence of images. Video imagery is a subset of the class of motion imagery.
Warnings	An alert indicating a hazardous condition requiring immediate action to prevent loss of life, equipment damage, or failure of the mission.
Waypoint	A point on a UAV route which is defined by latitude/longitude. Altitude is usually defined.
Waypoint Control	Semi-autonomous or man-in-the-loop method of air vehicle control involving the use of defined points (latitude/longitude/altitude) to cause the UAV (air vehicle, sensor(s), weapons, dispensable payloads, onboard systems, etc.) to accomplish certain actions.

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