AFDX® Workshop

Avionics Databus Solutions

- **Network Overview and Topology**
- **Virtual Link Concept**
- **Redundancy / Integrity Checking**
- **Protocol Layers**
- **Payload Organisation**

AFDX a registered trademark of Airbus Deutschland GmbH

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AFDX – Avionics Full Duplex Switched Ethernet

- 100Mbit/sec / 10Mbit/sec, first 1GBit/sec implementations available !
- Built around commercial Ethernet (MAC, IP, UDP, SNMP) with provisions for deterministic behaviour
- Media is Copper or Fibre Optic
- 3 Types of Network elements
  - **End Systems (E/S)**
  - **Switches**
  - **Links**
- Why AFDX?

  High Speed Commercial Ethernet with provisions for guaranteed Deterministic Timing and Redundancy required for Avionics applications

AFDX – Avionics Full Duplex Switched Ethernet

- related Standards (most important), www.arinc.com

AIRCRAFT DATA NETWORK
PART 7
AVIONICS FULL DUPLEX SWITCHED ETHERNET (AFDX) NETWORK
ARINC SPECIFICATION 664P7
PUBLISHED: June 27, 2005

AIRCRAFT DATA NETWORKS
PART 2
ETHERNET PHYSICAL AND DATA-LINK LAYER SPECIFICATION
ARINC SPECIFICATION 664
PUBLISHED: JUNE 10, 2003

AFDX – Avionics Full Duplex Switched Ethernet

- related Specifications (most important), AIRBUS proprietary

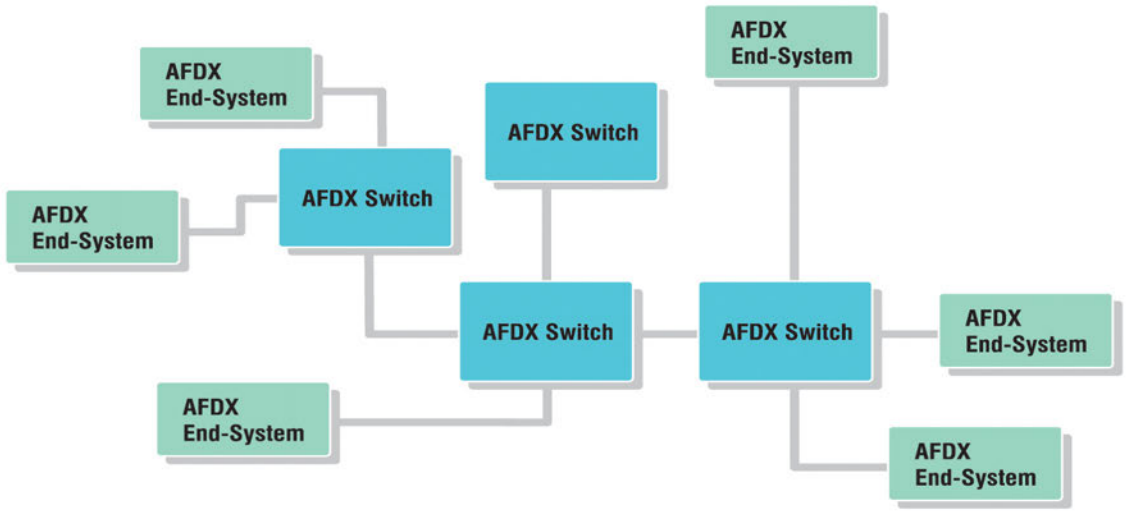
AFDX END SYSTEM DETAILED FUNCTIONAL SPECIFICATION
L42D1515045801

AFDX SWITCH DETAILED FUNCTIONAL SPECIFICATION
L42D1515051901

AFDX MESSAGE FORMATS DETAILED FUNCTIONAL SPECIFICATION
L42D1 515.1722/01

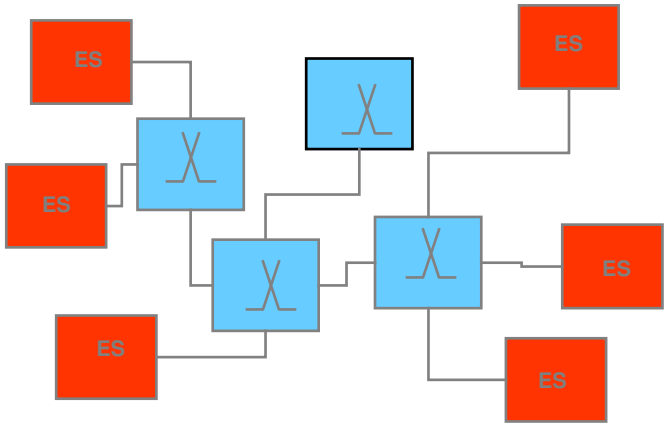
RULES FOR THE CONSTRUCTION OF AFDX MESSAGES
L42D1 515.0004/2002

AFDX Network Topology



AFDX Network Topology

Topology



- **AFDX is a network architecture**
- **There are two types of devices:**

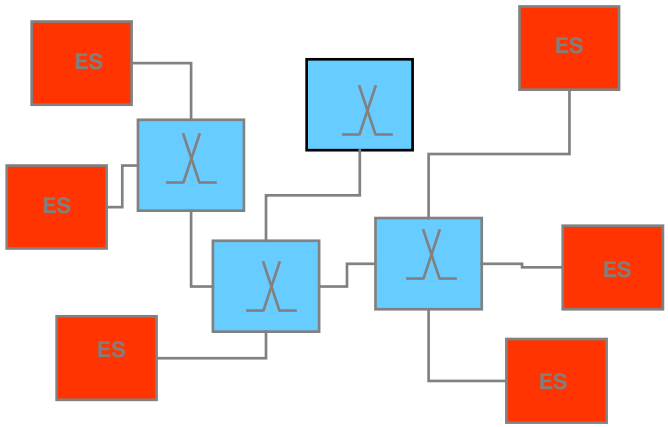
  ***Switch*: A device which performs traffic policing and filtering, and forwards packets towards their destination End-Systems.**

  ***End-System*: A device whose applications access the network components to send or receive data from the network.**

- **All connections are full duplex, 100Mbits/sec (no dedicated backbone bus for Inter-switch communications)**
- **Redundancy is achieved by duplication of the connections (wires) & Switches**

Communication Techniques

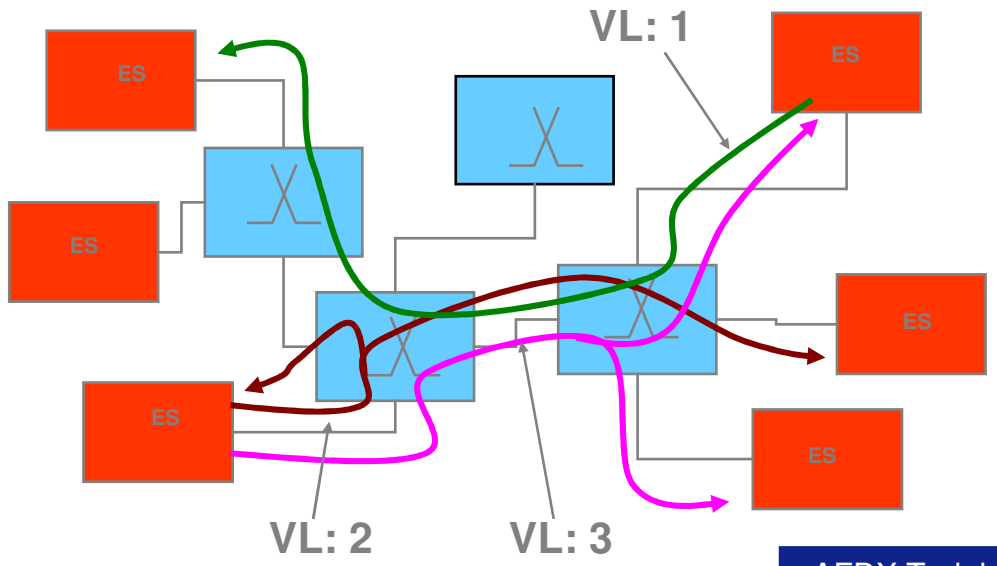
- **AFDX Communication protocols have been derived from commercial standards**
  - **IEEE802.3 Ethernet MAC addressing**
  - **Internet Protocol IP**
  - **User Datagram Protocol UDP**
  - **SNMP**
  - **ICMP**



- **Provisions have been added to ensure Deterministic Behaviour**
- **End-Systems perform traffic shaping which is enforced by Switches**
- **Switches perform traffic policing and static routing of frames**

Virtual Link (VL) Definition

- **End-Systems exchange Frames through Virtual Links (VLs)**
- **A Virtual Link defines a unidirectional (logical) connection from one source End-System to one or more destination End-Systems → "Uni- or Multicast" communication**



Virtual Link Definition

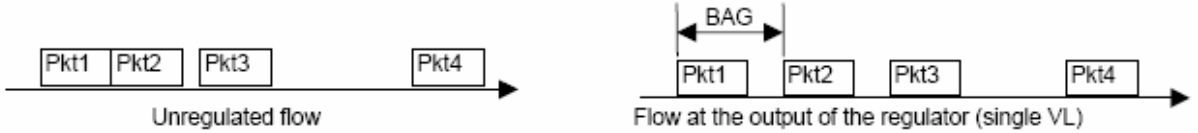
- An AFDX network can define up to 64k (2^{16}) VLs identified by a 16-Bit identifier in the MAC Destination Field of Ethernet Frame
- An AFDX End-Systems can support multiple VLs
- End-Systems perform Traffic shaping and Integrity Checking on each VL
- A Switch performs Traffic policing on each VL
- Traffic shaping and policing combined, offer the baseline for deterministic behaviour of the network

Virtual Link Parameters Overview

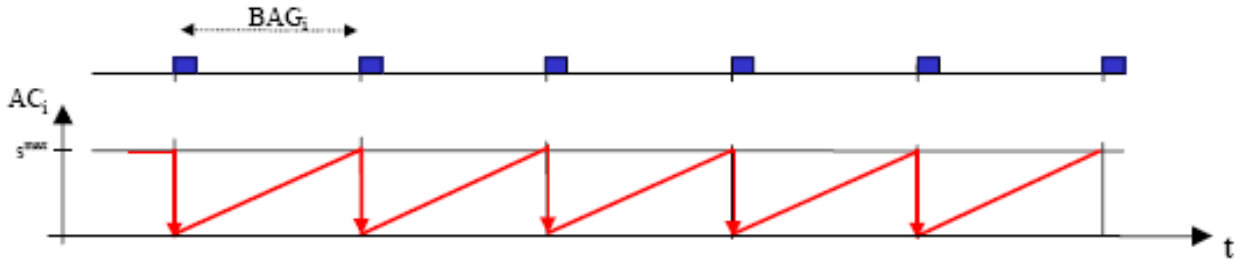
Parameter	E/S	Switch
BAG (Bandwidth allocation GAP)	Yes	Yes
Frame Size	Yes	Yes
max. allowed Jitter	Yes	Yes
No. of Sub-VLs	Yes	No
Account Type	No	Yes
Priority	No	Yes
Network Selector	Yes	No
Skew Max.	Yes	No

Virtual Link Parameters

- **Bandwidth Allocation Gap (BAG):**
  - **The End-System controls the transmission flow for each VL in accordance with the BAG (traffic shaping)**



  - **The Switch verifies the BAG (traffic policing)**



Virtual Link Parameters

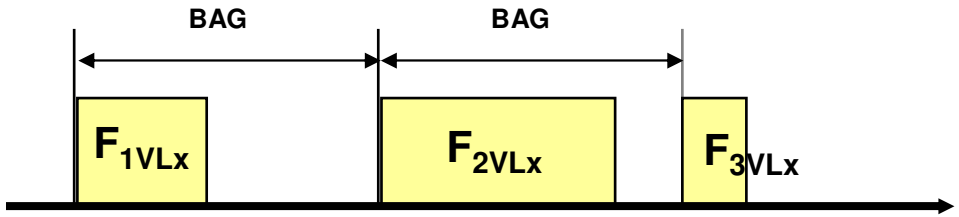
- **Bandwidth Allocation Gap (continued):**
  - **Frames do not need to be transmitted exactly in multiples of the configured BAG**
    Example: a "Sampling" service with 20ms rate on VL with 4ms BAG
    → every 20ms a valid frame appears on the network),
    → the Sampling Service uses < 100% of the VL bandwidth
  - **Frames on a VL can be transmitted slower than the BAG without impact on the Switching (see above)**
  - **if no data are available to send on a VL, no frames appear**
  - **Frames on a VL can be transmitted faster than the BAG with impact on the Switching (traffic policing)**
    (see at "Jitter" Parameter for details).

Virtual Link Parameters

- **Bandwidth Allocation Gap (continued):**
  - **BAG values are in milliseconds: 1, 2, 4, 8, 16, 32, 64, 128**
  - **Per VL a maximum of 1000/ BAG Frames per second can be transmitted.**

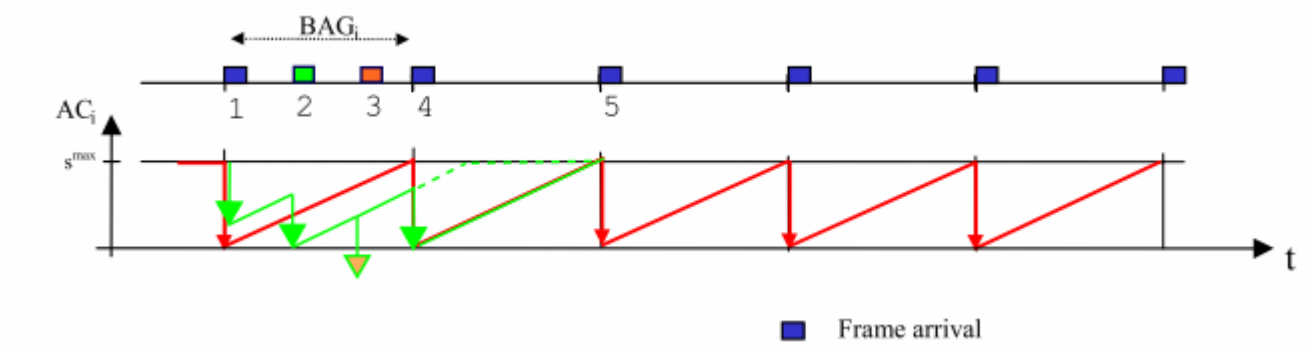
Virtual Link Parameters

- **Frame Size S_{max}:**
  - **each VL max. Frame Size S_{max} can be individually configured S_{max} = {64,….,1518}**
  - **Together with the BAG, the absolute (worst case) bandwidth consumption on an AFDX link can be calculated for a given VL**
  - **Frames on a VL can have different Frame sizes S: 64 <= S <= S_{max}**



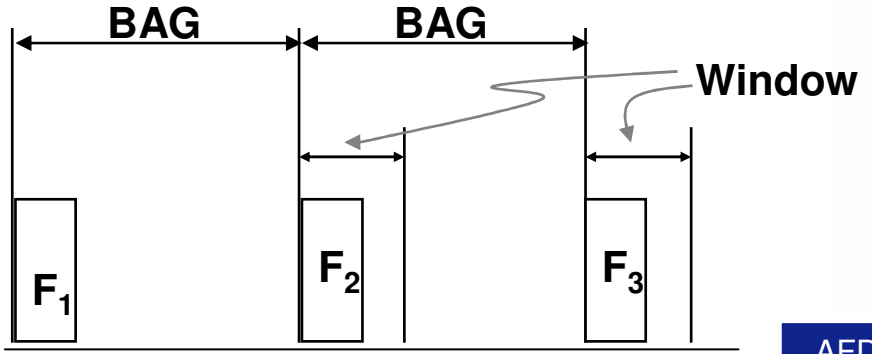
Virtual Link Parameters

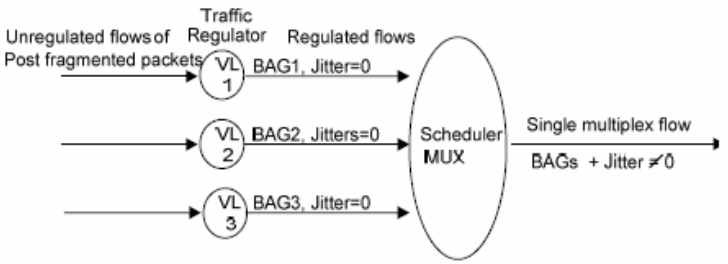
- **Frame Size (continued):**
  - **The End System has to maintain the Frame size for all transmitted frames with respect to the configured max. Frame Size for each VL e.g. IP Fragmentation**
  - **The Switch checks for the max. Frame Size and maintain its "Accounts" for handling the forwarding (e.g. Byte-based vs. Frame-based filtering)**



Virtual Link Parameters

- **Jitter (in General) :**
  - **The difference between the minimum and maximum time from when a source node sends a message to when the sink node receives the message.**
  - **Jitter is generally a function of the network design and multiplexing multiple VLs on one port as well as dependent on the Switch**
  - **For a VL, frames can appear on the link in a given time interval (Window) which is sized by the BAG and the maximum allowed jitter**

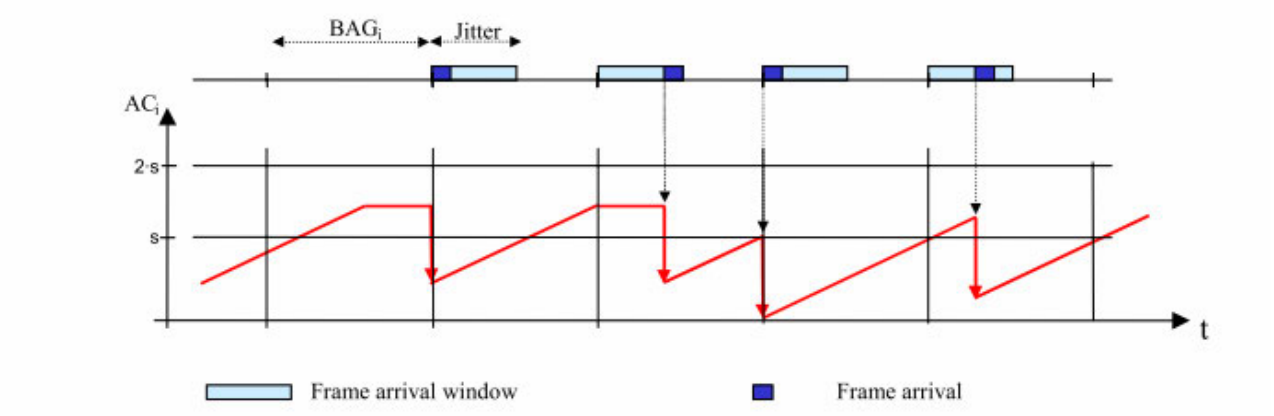




Virtual Link Parameters

- **maximum allowed Jitter:**
  - **The maximum allowed Jitter is configuration parameter of the Switch for maintaining the "Account" for each VL (→ traffic policing) Allowing a Jitter for a VL make the Switch more "tolerant" for frames appearing faster than the BAG by increasing the**

"Account" = $s_i^{max} \cdot \left(1 + \frac{J_{i,switch}}{BAG_i}\right)$ **(e.g. max. allowed Jitter 0.5ms, BAG 1ms → Smax * 1,5)**

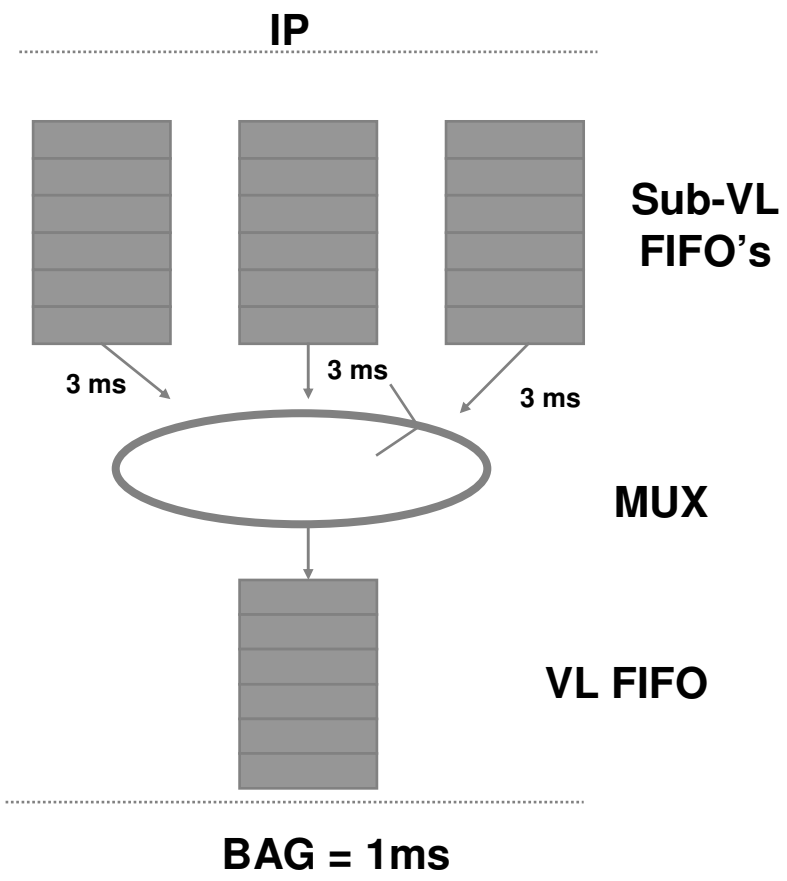


Virtual Link Parameters

- **maximum allowed Jitter (continued):**
  - **The End System has to maintain the traffic flow (→ traffic shaping) in order to achieve the Jitter <= max. allowed Jitter**

Virtual Link Parameters

- **Sub-VLs (E/S relevant only):**
  - Each VL may consist of up to 4 sub-VLs
  - There is a Round-Robin Scheduling of sub VL's
  - sub-VL assignment is not encoded in the frame → cannot be directly resolved (vs, VL)



Virtual Link Parameters

- **Account Type and Priority (Switch relevant only):**
  - **the Account Type defines if the Switch maintains individual Accounts for every VL or shared Accounts between multiple VLs**
  - **the Priority is a VL related configuration parameter of the Switch to group VLs in Low or High priority groups, with different internal handling of the forwarding**

Virtual Link Parameters

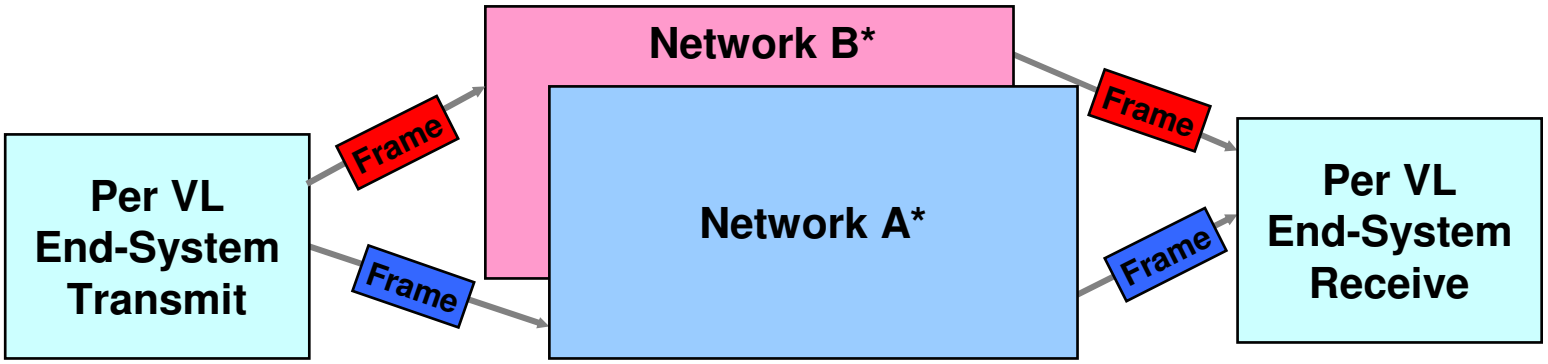
- **Network Selector and Skew Max (E/S relevant only):**
  - **These parameters are basically important in conjunction with the Redundancy Management (see following pages)**

AFDX Integrity Checking

- Integrity checking is done per VL and per Network
- Checking is based on Sequence Number (SN) and the so called “Maximum Consecutive Frames Lost”
  - The Sequence numbering is performed for each VL individually
- All Invalid Frames are discarded (e.g. with physical errors)

AFDX Redundancy Management

- The Ports, Links and Switches are duplicated for redundancy
  - Switch does not need know about redundancy (duplicated)
  - E/S needs to know about redundancy (not duplicated!)

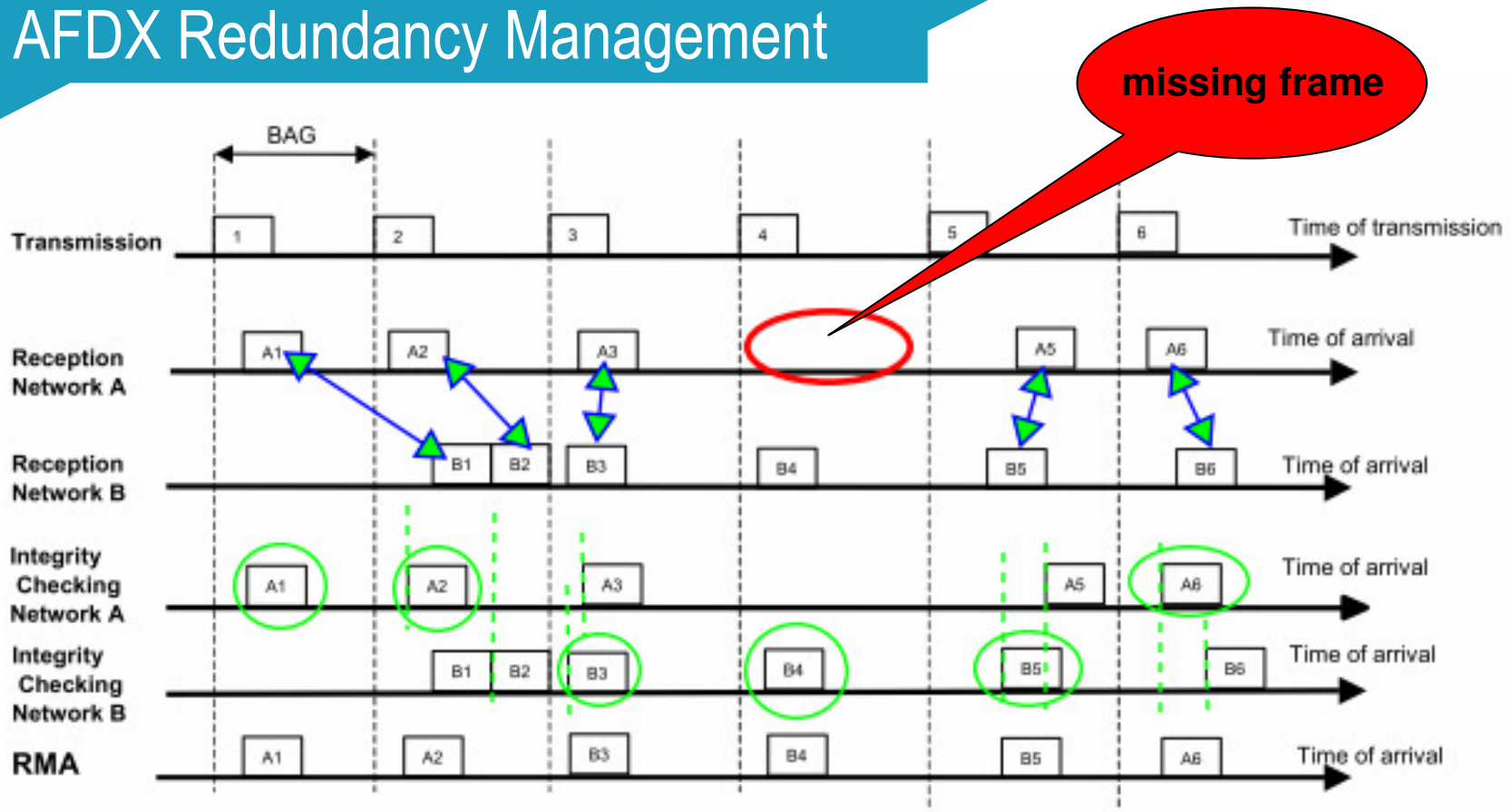


* The Networks are sometimes also called „Red“ and „Blue“

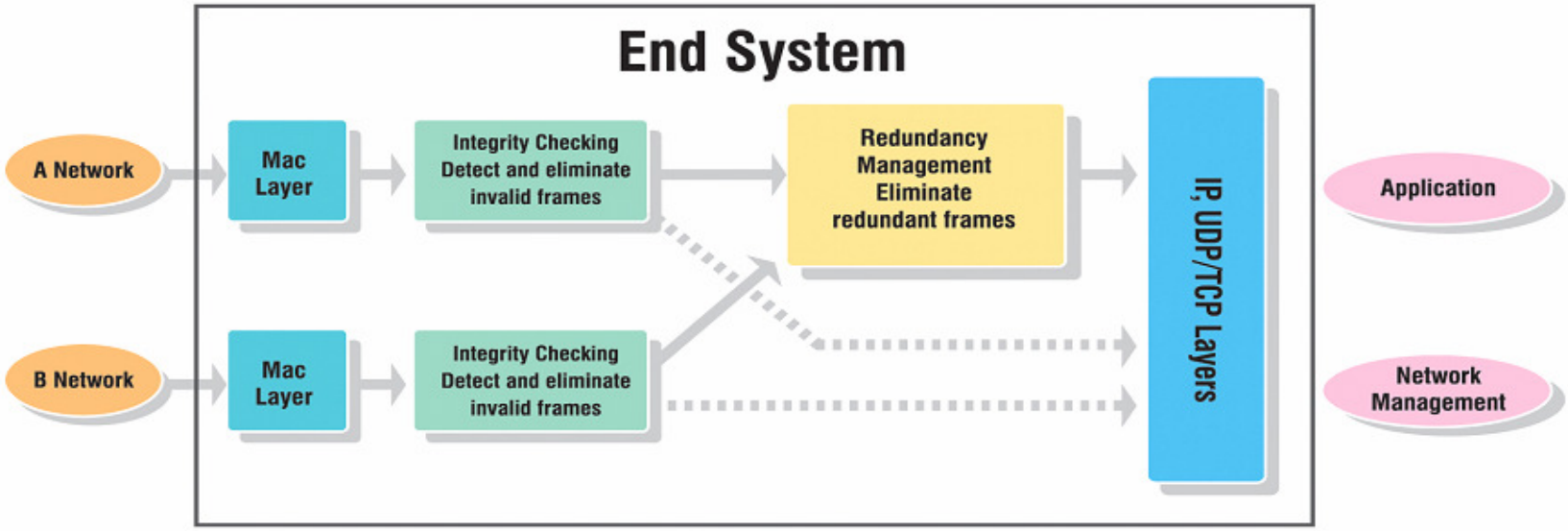
AFDX Redundancy Management

- Frames are concurrently transmitted over both networks (if VL is configured accordingly → Network Selector “A and B”, “A only” and “B only” may be also configured for VLs)
- on the Receiving End-System, “First Valid Frame wins” which requires provisions for this algorithm e.g. the SN

AFDX Redundancy Management



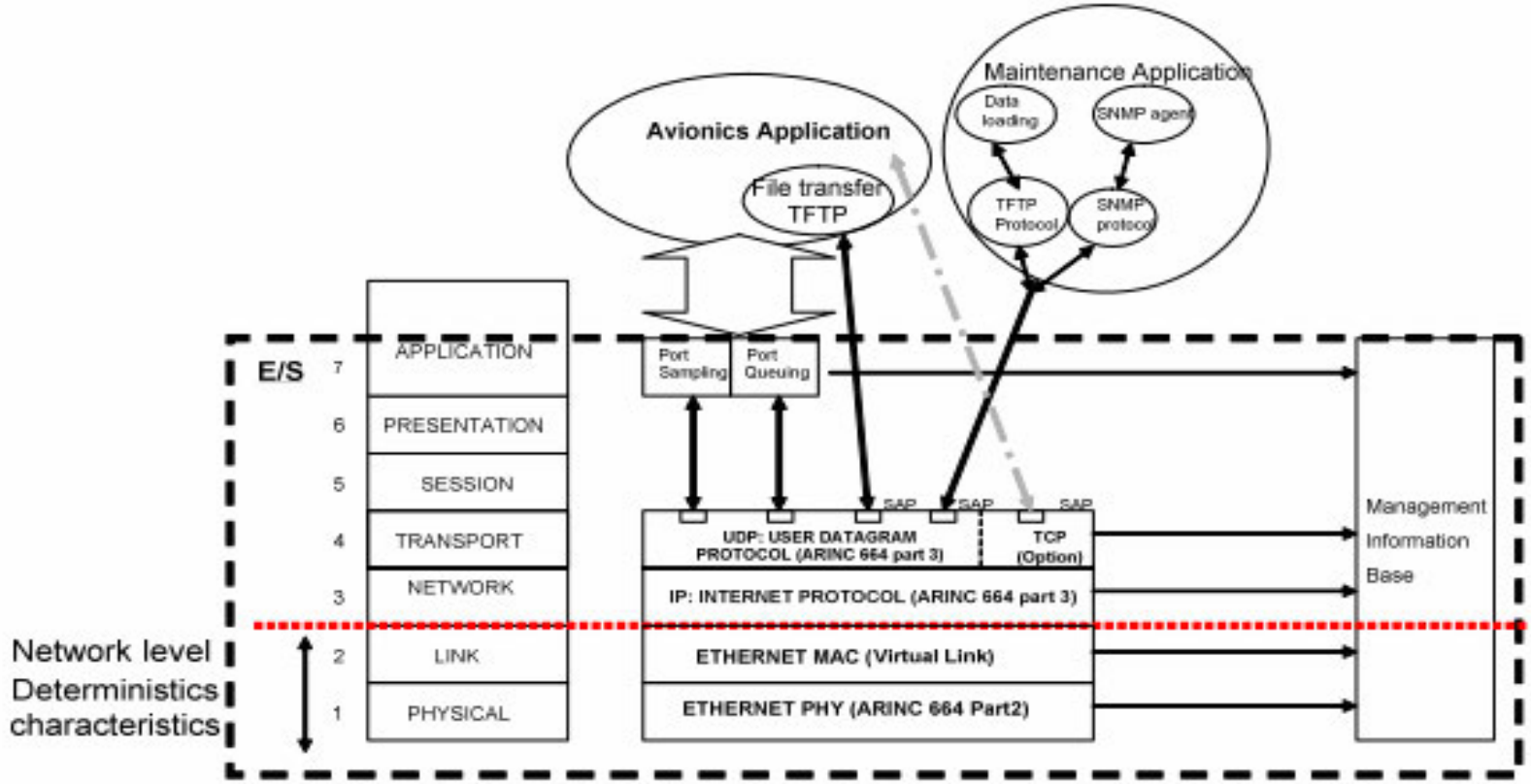
Redundancy Management & Integrity Checking



AFDX Protocol Layers

- **Avionics applications residing at End-Systems exchange messages via the services of the User Datagram Protocol Layer (*UDP*, Layer 4) with underlying Internet Protocol (*IP*, Layer 3)**
  - **The UDP Protocol is also the base for upper layer protocols for maintenance purposes (*SNMP* Simple Network Management Protocol) and File Transfer Services (*TFTP* Trivial File Transfer Protocol)**
  - **End Systems also have to support *ICMP* Internet Control Message Protocol based on *IP* protocol, but still residing in Layer 3. (known as "Ping command", "Echo Request/Reply" on ICMP)**
- **AFDX Switching is based on the MAC Destination Address (Layer 2)**
- **AFDX provisions for deterministic are implemented on Layer 2 only**

AFDX – Protocol Layers



AFDX Frame Structure

Preamble	Start Delimiter	MAC Header	IP Header	UDP Header	AFDX Payload	AFDX Sequence Number	FCS
7	1	12	22	8	17…1471	1	4

Frame Size: 64…1518 Bytes

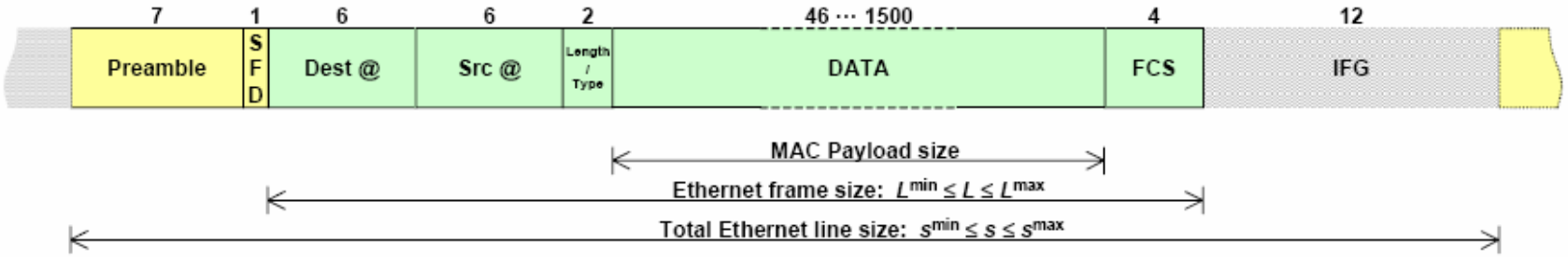
Preamble + Start Delimiter + InterFrame Gap: 20 Bytes

Duration of Minimum Frame: 6.72 usec (84 Bytes a 80ns)

Duration of Maximum Frame: 123.04 usec (1538 Bytes a 80ns)

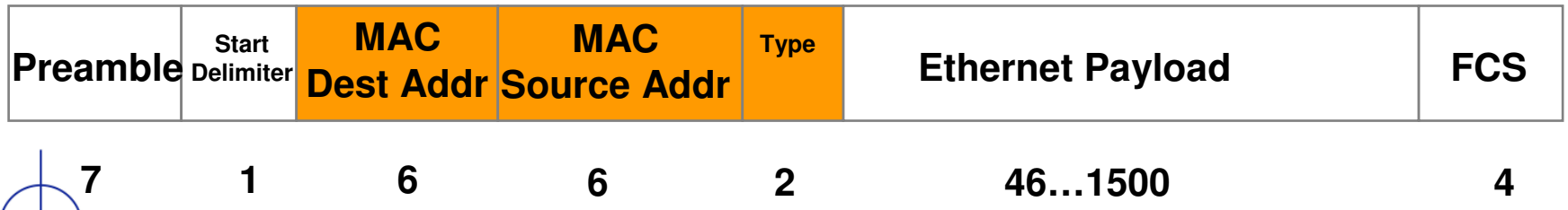
AFDX Frame Structure

- **Frame Size Terminology (Source: ARINC664)**



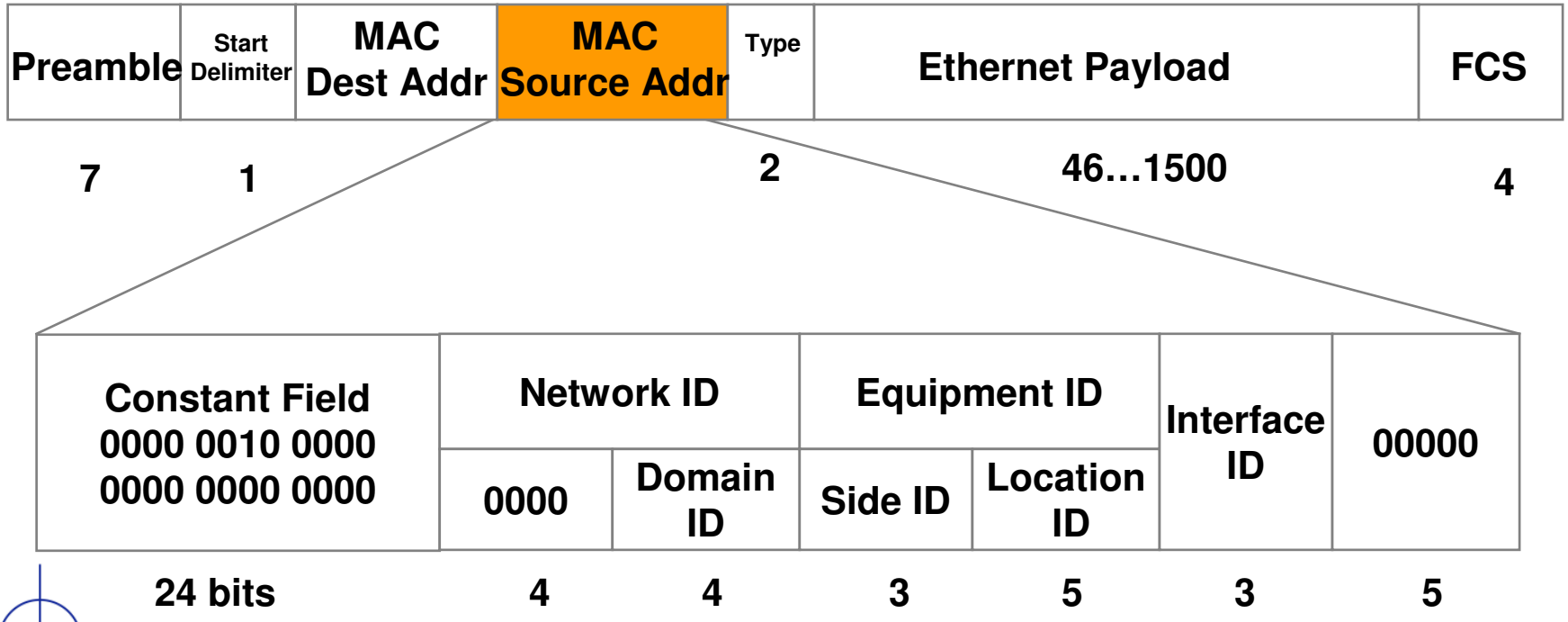
AFDX – MAC Layer 2

- MAC header comprises a Source and Destination Address, and a Type Field
- Each address is 48 bits wide
- The Destination Address identifies the Virtual Link
- The Source Address is (must be) a Unicast Address
- The Destination Address is (must be) a Multicast Address



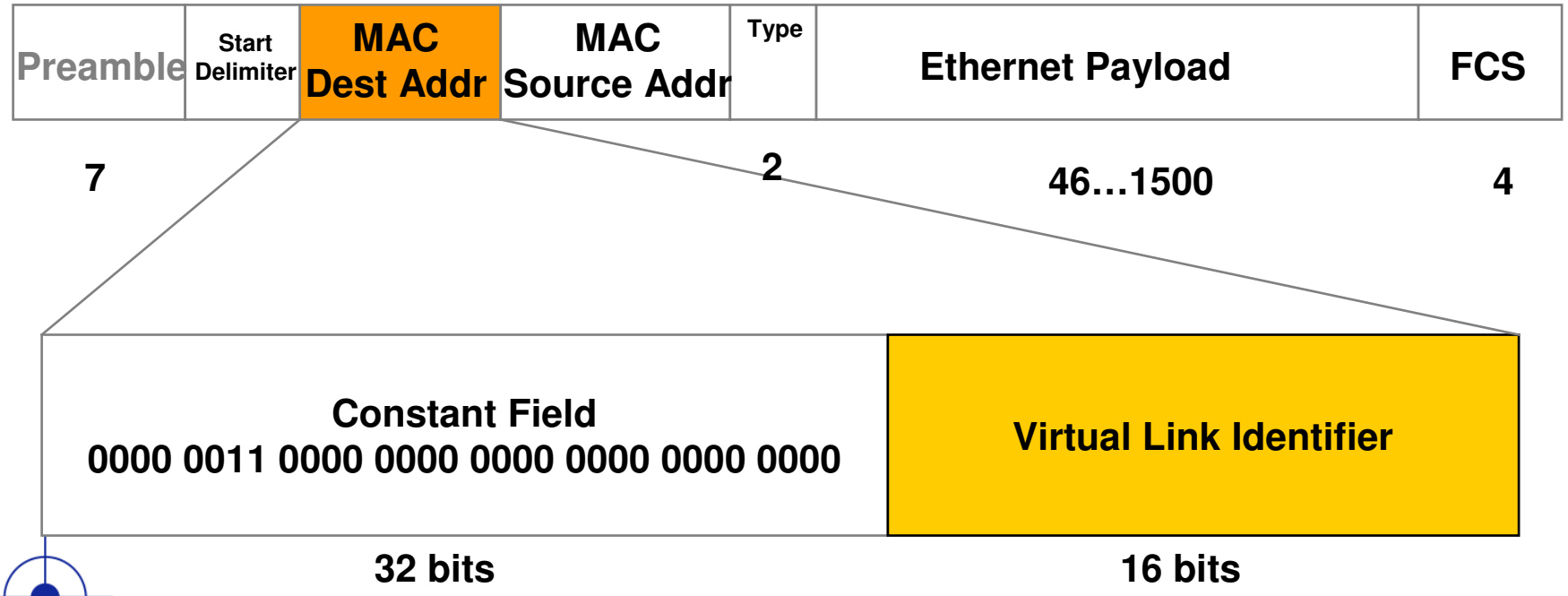
AFDX – MAC Layer Layer 2

- **MAC Source Address encodes the unique "Source" of the frame**



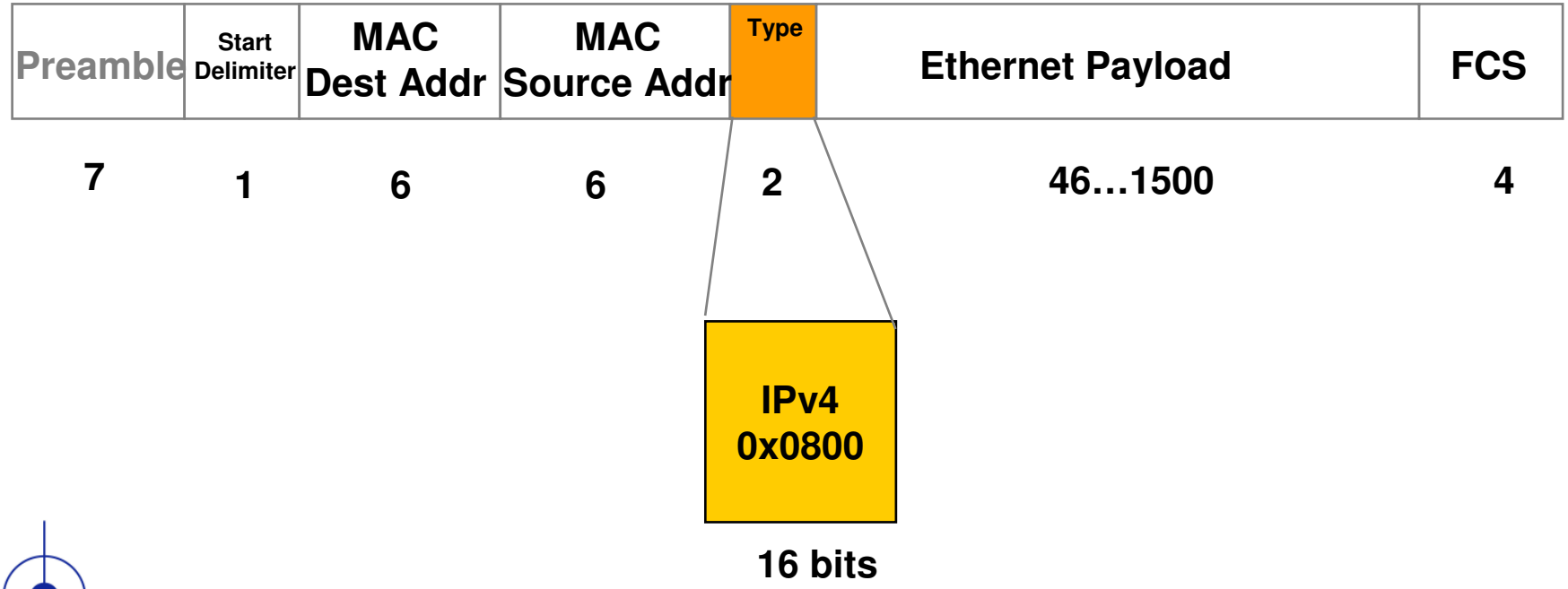
AFDX – MAC Layer Layer 2

- **MAC Destination Address identifies the Virtual Link**



AFDX – MAC Layer Layer 2

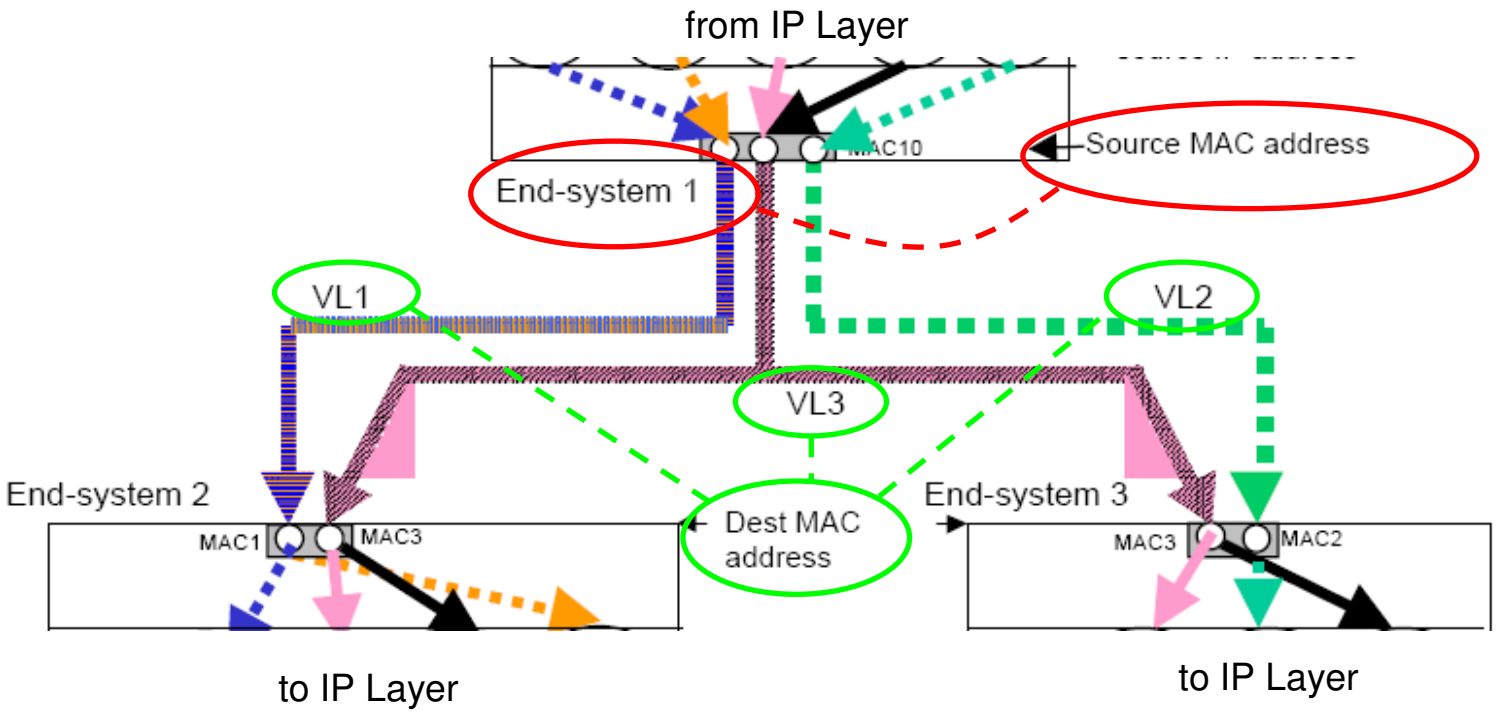
- **The IP Type Field defines IPv4 support only (today)**



AFDX – MAC Layer Layer 2

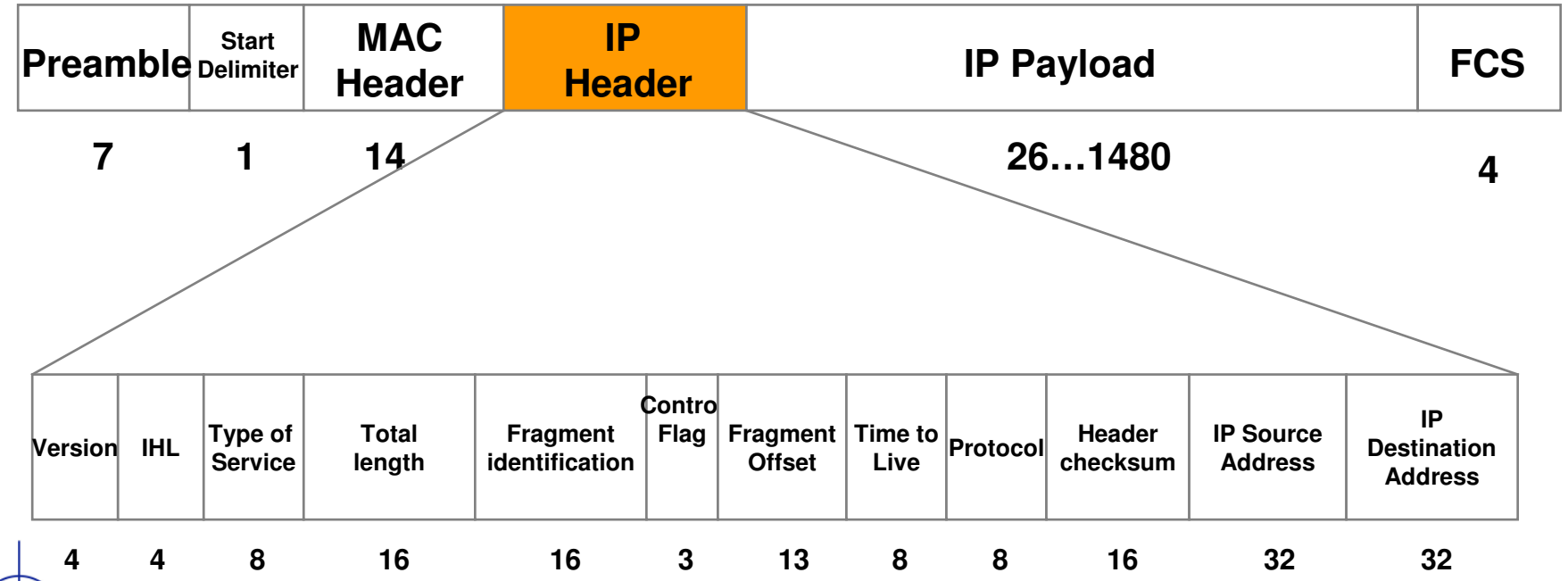
- **MAC Addressing**
  - The MAC Source address identifies a system wide unique source equipment (End System) → always “Unicast”
  - The MAC Destination address is always a “Multicast” address (No Broadcasts allowed !) and a receiving equipment can handle multiple MAC Destination addresses resp. VLs !

AFDX – MAC Layer Layer 2



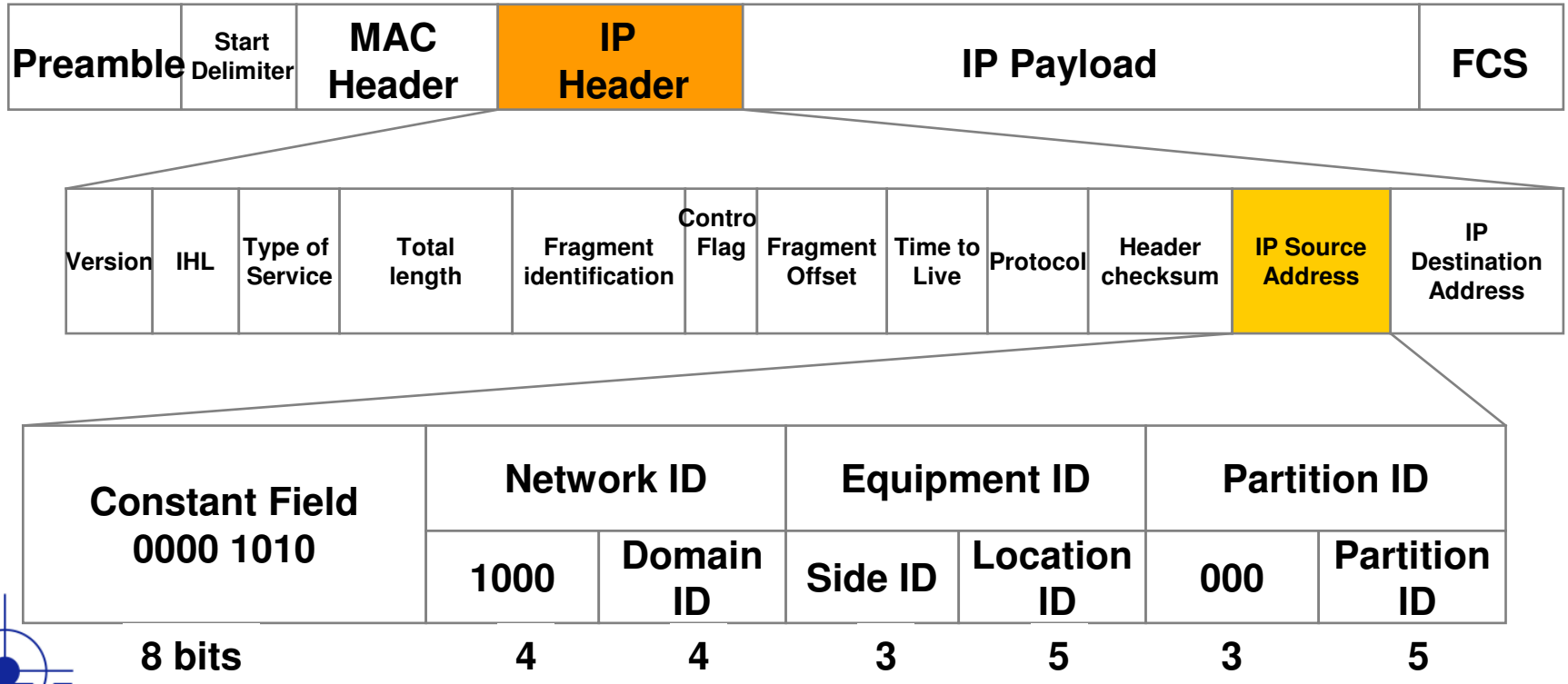
AFDX – IP (Internet Protocol) Layer 3

- **IPv4 Header**



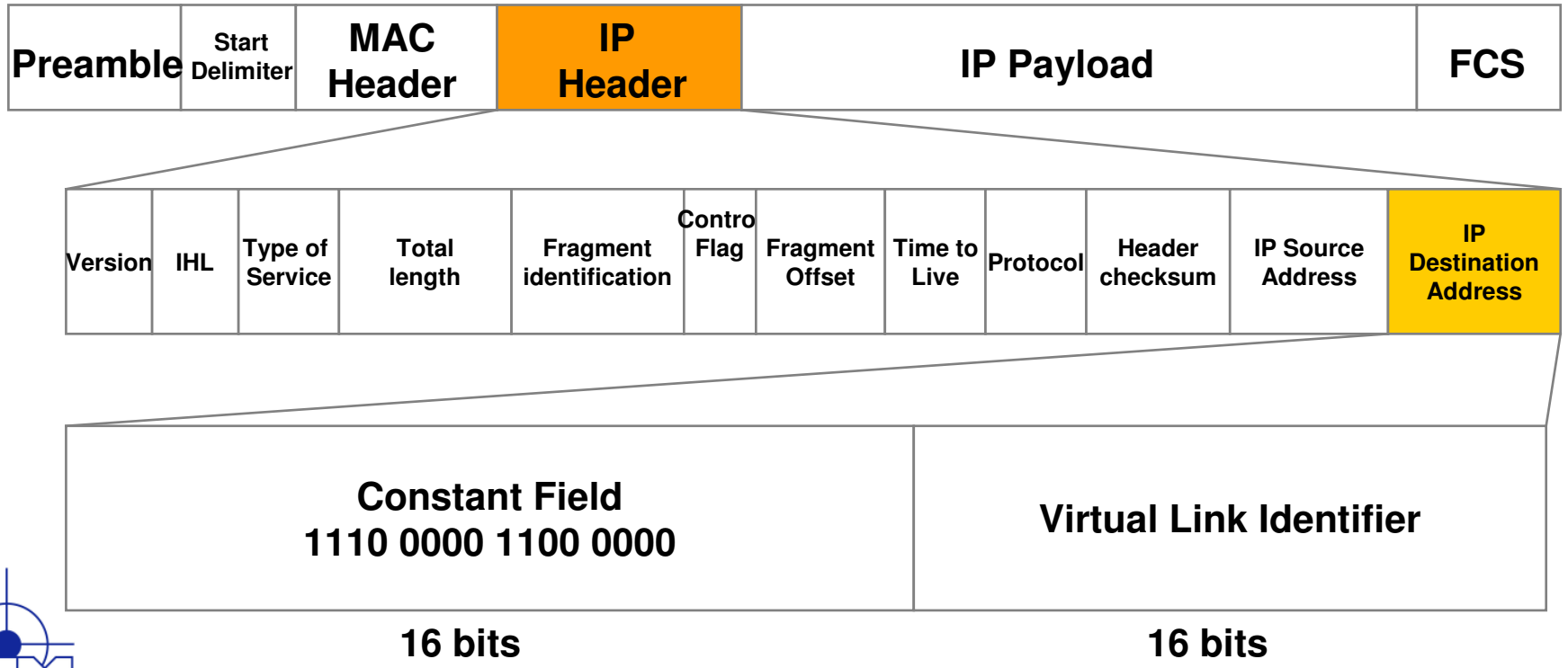
AFDX – IP (Internet Protocol) Layer 3

- **IP Unicast Source and Destination Address**



AFDX – IP (Internet Protocol) Layer 3

- **IP Multicast Destination Address**

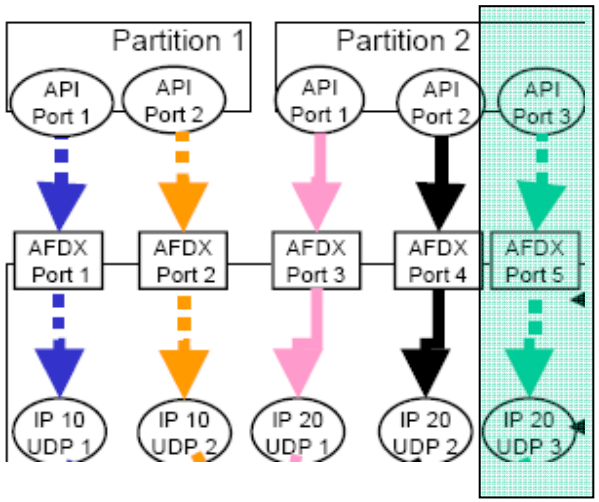


AFDX – IP (Internet Protocol) Layer 3

- **IP Addressing**
  - IP Source is always a Unicast Address, Class A Private IP (→ single source) Example: **10**.x.x.x
  - IP Destination either Multicast (→ multiple receivers* in a End System e.g. **224.224.**x.x) or Unicast (→ single receiver* in End System e.g. **10**.x.x.x)

* a “receiver” e.g. means an application. In other words: data addressed to a unicast IP destination address shall be used by only one application, data addressed to a multicast IP destination address can be used by multiple applications in side the same End System. The Specifications are also using the term “partition” in sense of an “application”.

AFDX – IP (Internet Protocol) Layer 3

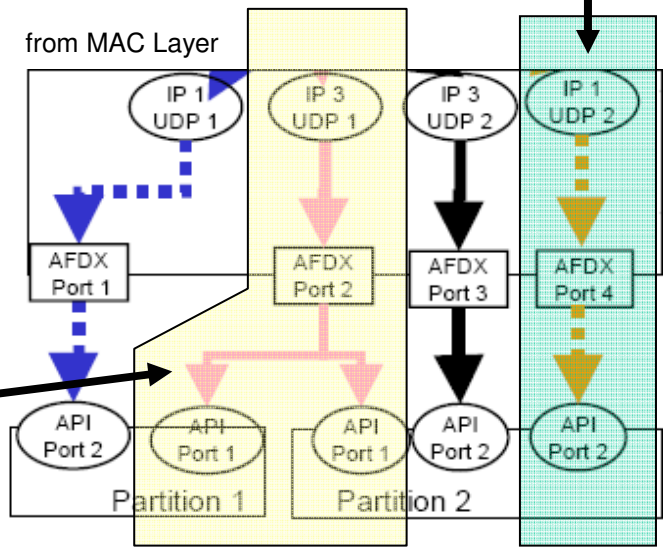


to MAC Layer

data source always Unicast

data destination Unicast

data destination Multicast



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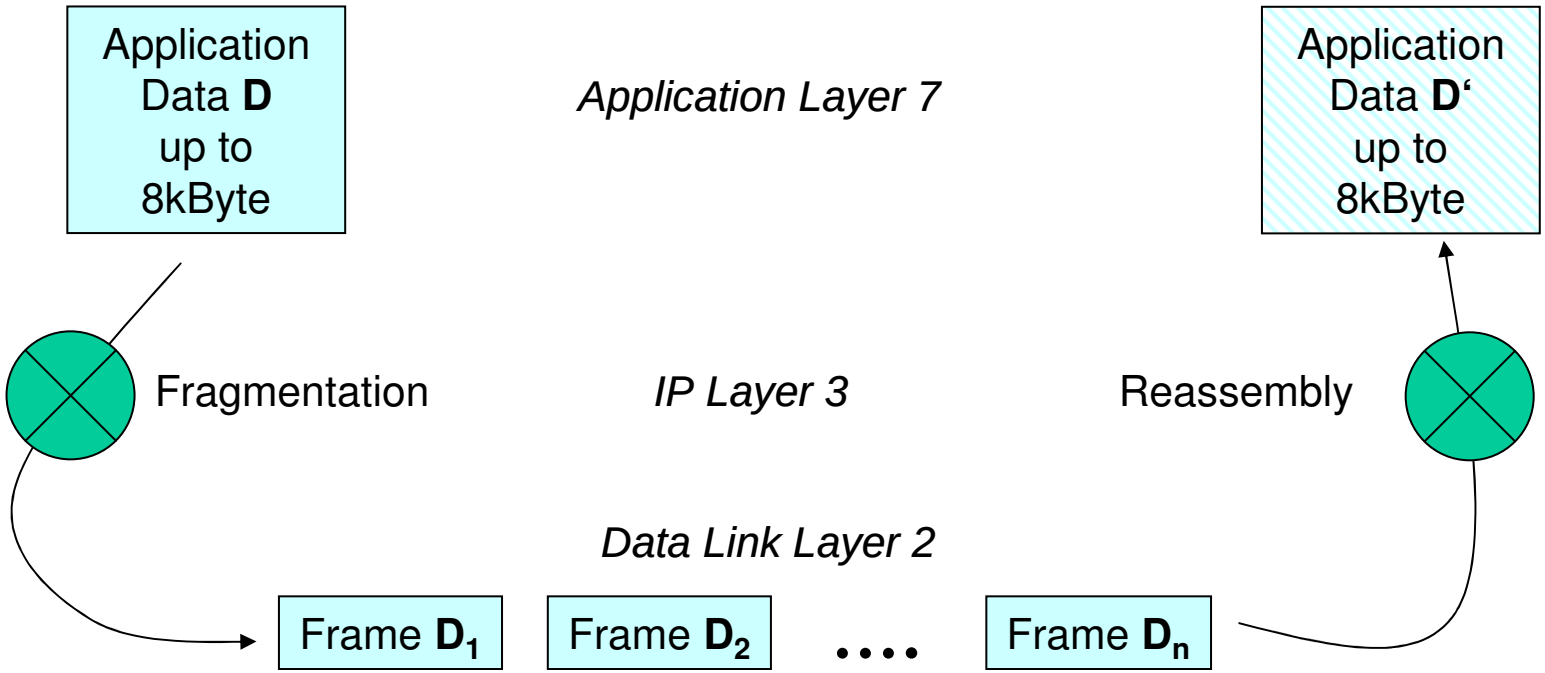
AFDX – IP (Internet Protocol) Layer 3

- **IP Fragmentation**
  - In the IP Layer message data (up to 8kByte for AFDX) are fragmented for transmission via multiple MAC Frames (if necessary)
  - Fragmentation is a standard functionality if the IP Layer (not AFDX specific), however for AFDX the fragments are expected always “in order”
  - IP Layer needs to respect the max. Frame size of associated VL !
  - on receiving side the IP **Reassembly** is the counterpart

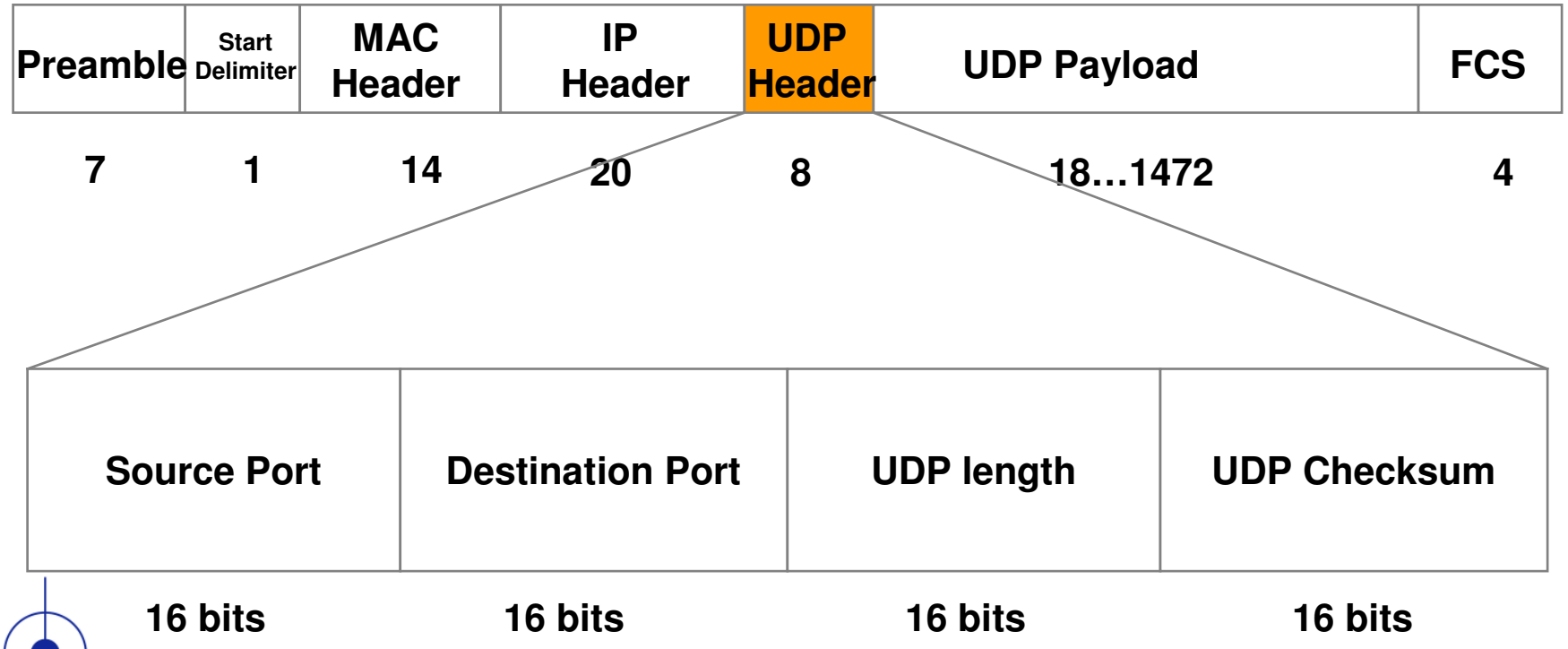
AFDX – IP (Internet Protocol) Layer 3

- **IP Fragmentation (simplified)**

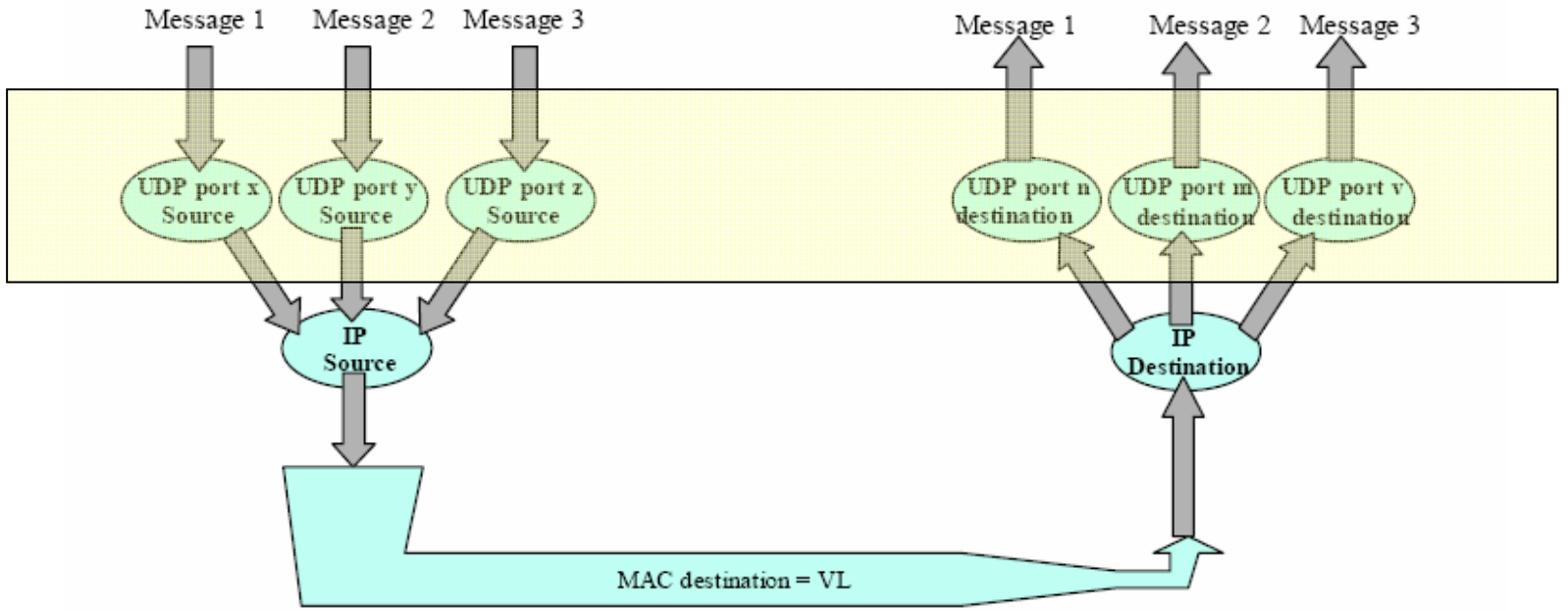


AFDX – UDP (User Datagram Protocol) Layer 4

- **UDP Header**



AFDX – UDP (User Datagram Protocol) Layer 4



AFDX UDP Protocol

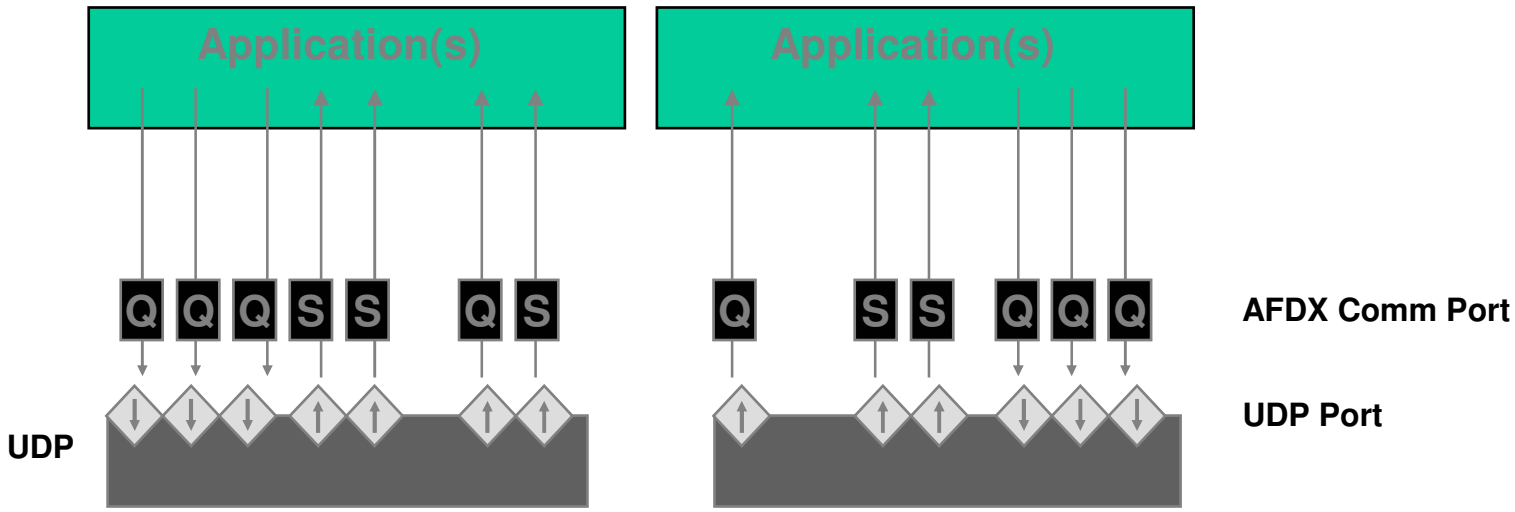
- **Applications send/receive "messages" through AFDX Comm(unication) Ports which are basically mapped to UDP Ports**

There are two types of AFDX Comm Ports which detailed characteristics are defined by the ARINC653 Standard (AVIONICS APPLICATION SOFTWARE STANDARD INTERFACE)

- **Queuing Ports - AFDX messages may be sent over several AFDX frames (fragmentation by IP layer dependent on the associated VL Max. frame size), no data is lost or overwritten. The max. amount of data handled per queuing port is 8kByte.**

- **Sampling Ports - AFDX messages are sent in one Frame, data may be lost or overwritten. The max. amount of data handled per sampling is limited by the associated VL max. Frame size.**

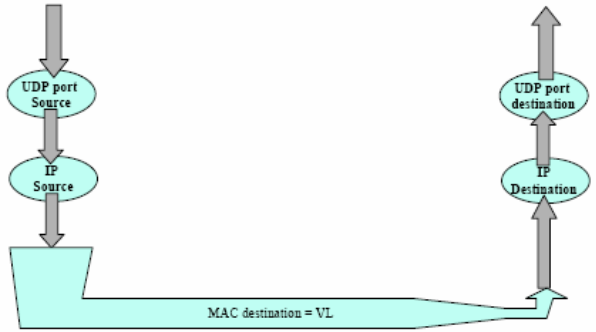
AFDX UDP Protocol



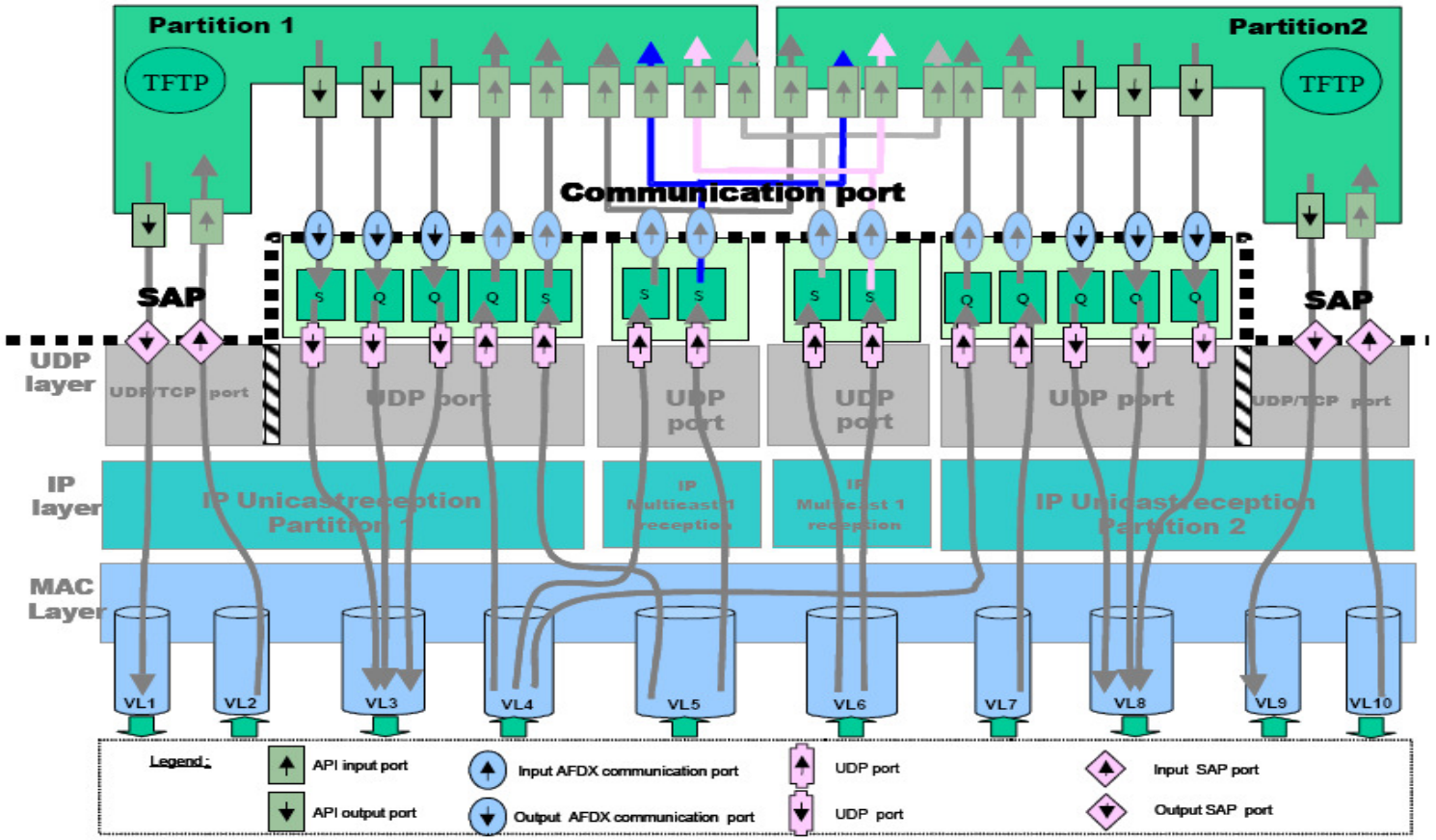
AFDX UDP Protocol

- **AFDX Comm Ports are typically associated with a "Quintuplet" consisting of**

  **** UDP Source Port Number***
  **** UDP Destination Port Number***
  **** IP Source Address***
  **** IP Destination Address***
  **** Virtual Link Number***



- **AFDX Comm Port types can be either Send or Receive ports**
- **Structuring of the AFDX Payload Data (=UDP Payload) defined in ARINC664 P7 and Airbus proprietary specifications.**
- **A special type of UDP Ports are called SAP (Service Access Point)**



AFDX Payload Summary

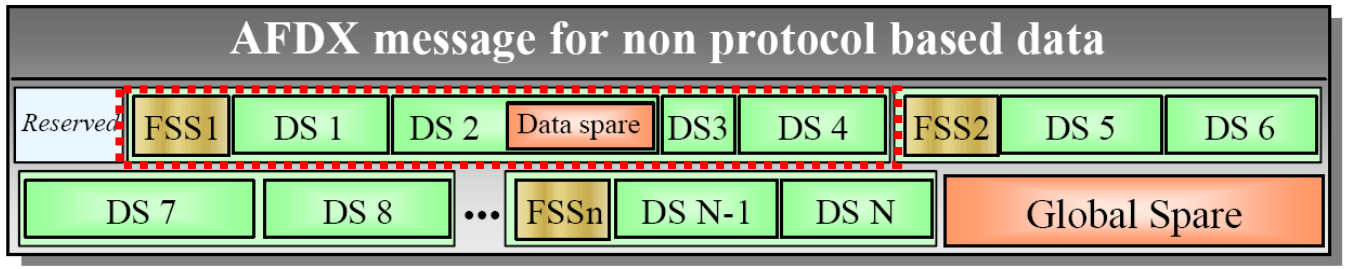
Preamble	Start Delimiter	MAC Header	IP Header	UDP Header	AFDX Payload	AFDX Sequence Number	FCS

- AFDX Payload is carried in one (Sampling and Queuing Ports) or multiple Frames (Queuing Ports) via UDP Protocol
- IP Fragmentation / Reassembly is used for transmission of up to 8 kByte payload data
- UDP Header only in first frame of fragmented a “message” !
  The Fragmentation Information is handled via IP Header

Preamble	Start Delimiter	MAC Header	IP Header	AFDX Payload	AFDX Sequence Number	FCS

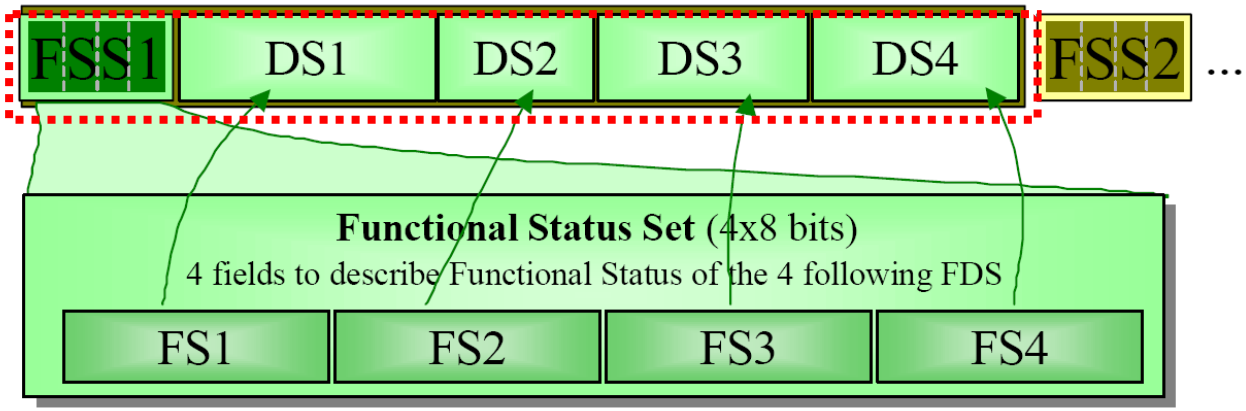
AFDX Payload

- **AFDX Payload for no-protocol based data is organized in so called Functional Data Sets (FDS)**



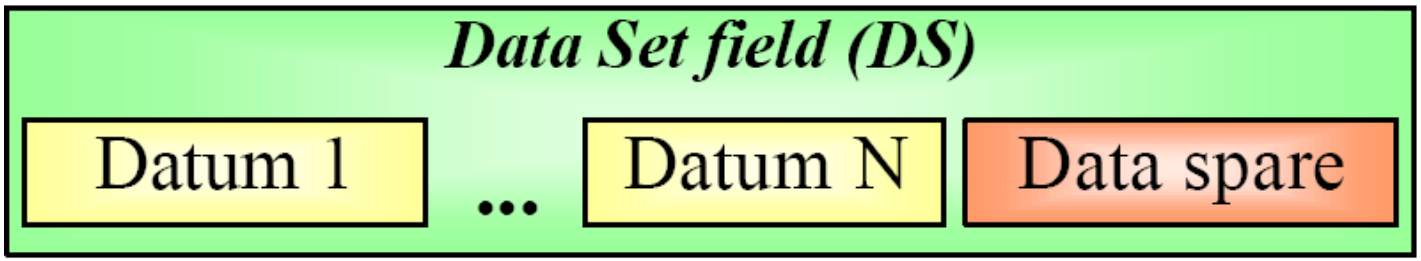
AFDX Payload

- **A Functional Data Set (FDS) is organized into Functional Status Set (FSS) and Data Sets (DS)**



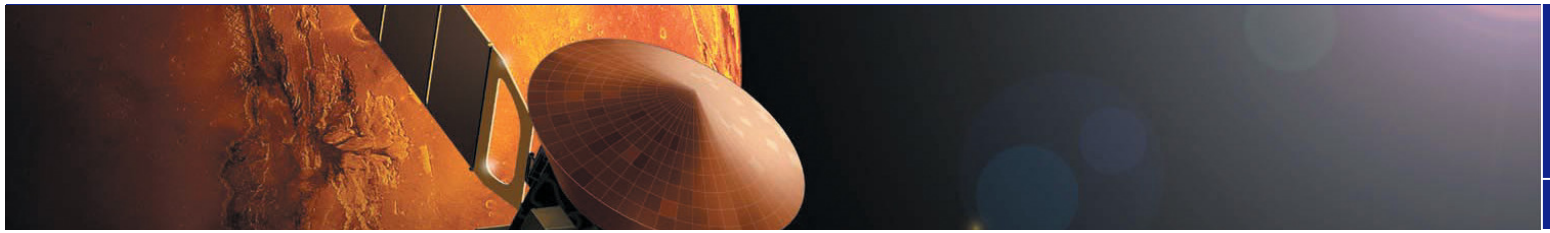
AFDX Payload

- **A Data Sets (DS) typically contains a Parameter (Datum) e.g. Float, Integer, Enumerated, Boolean, ……**



AFDX Glossary

AFDX	Avionics Full Duplex Switched Ethernet
E/S	End System
VL	Virtual Link
MAC	Media Access Control
IP	Internet Protocol
UDP	User Datagram Protocol
SAP	Service Access Point
TFTP	Trivial File Transfer Protocol
API	Application Programming Interface
OSI	Open Systems Interconnection
BAG	Bandwidth Allocation Gap
SNMP	Simple Network Management Protocol
MIB	Management Information Base
TCP	Transmission Control Protocol
SNMP	Simple Network Management Protocol
ICMP	Internet Control Message Protocol
ICD	Interface Control Document
NCD	Network Control Document
ISDB	Integrated Systems Data Base
ARINC	Aeronautical Radio Incorporated
RM	Redundany Management
IC	Integrity Checking



Right on Target

Our Mission is your Success!

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