AFDX® Tutorial

Avionics Databus Solutions

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

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www.aim-online.com

Right on Target

AFDX – Avionics Full Duplex Switched Ethernet

- 100Mbit/sec / 10Mbit/sec, 1GBit/sec implementations available from AIM !
- Built around commercial Ethernet (MAC, IP, UDP, SNMP) with provisions for deterministic behaviour
- Media is Copper, opt. Fibre Optic
- Three Types of Network elements
  - **End Systems (E/S)**
  - **Switches**
  - **Connections**
- 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 (public)

664P7-1 Aircraft Data Network, Part 7
Avionics Full-Duplex Switched Ethernet Network
PUBLISHED: 09-2009

664P2-2 Aircraft Data Network, Part 2
Ethernet Physical and Data Link Layer Specification
PUBLISHED: 01-2009

Topology

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

  Switch:

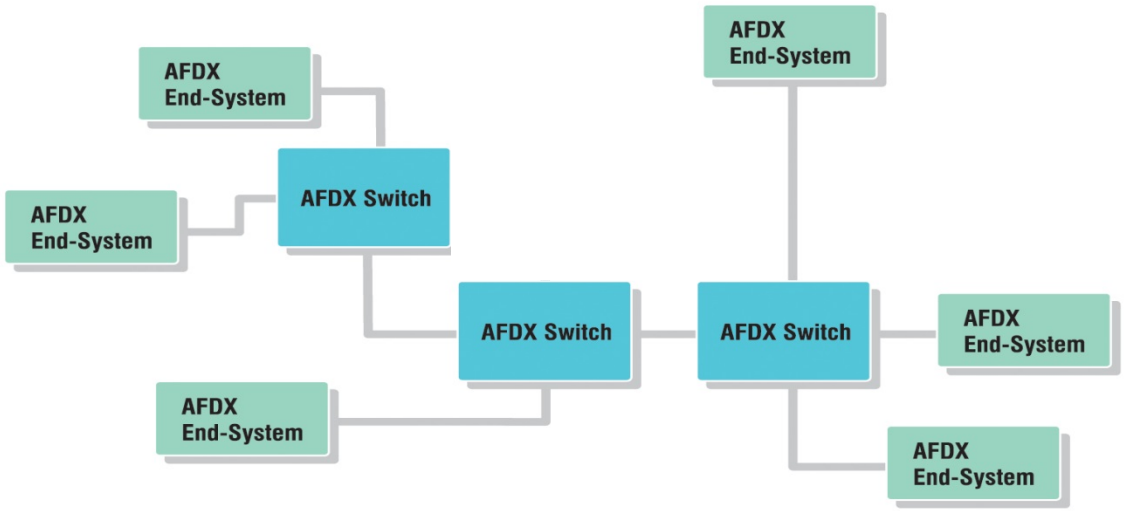
  A device which performs traffic policing and filtering, and forwards packets towards their destination End-Systems.

  End-System:

  A device whose applications access the network components to send or receive data from the network.

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

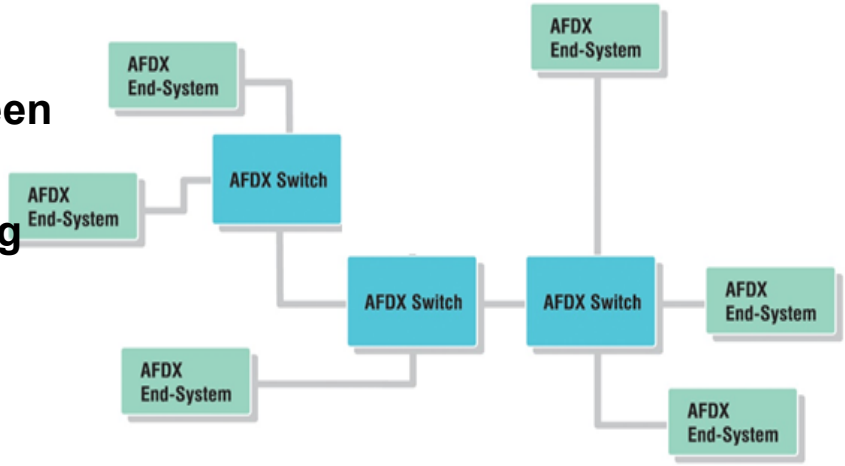
AFDX Network Topology



AFDX Network Topology

Communication Techniques

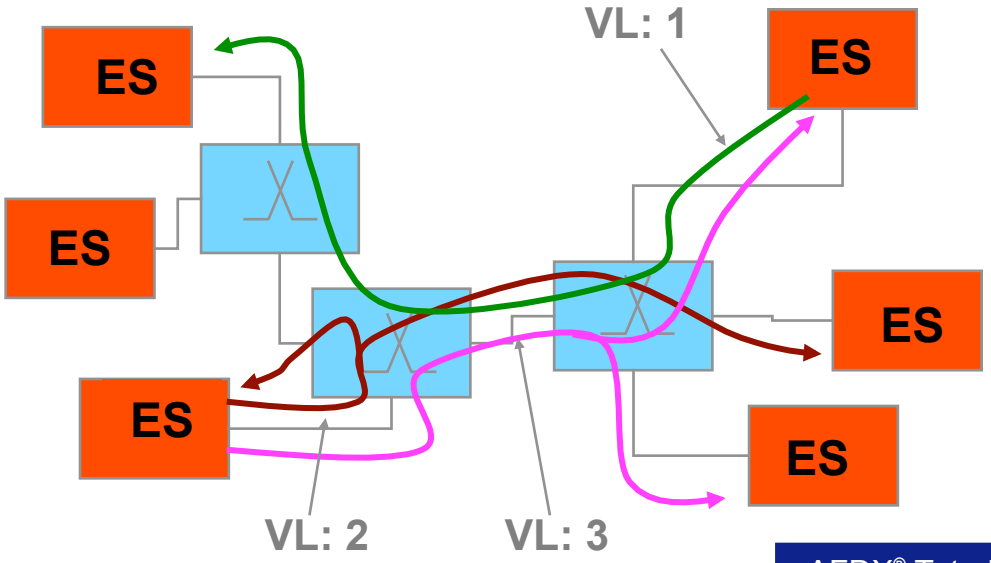
- AFDX Communication protocols have been derived from commercial standards
  - IEEE802.3 Ethernet MAC addressing
  - Internet Protocol IP
  - User Datagram Protocol UDP
  - SNMP
  - ICMP



- 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

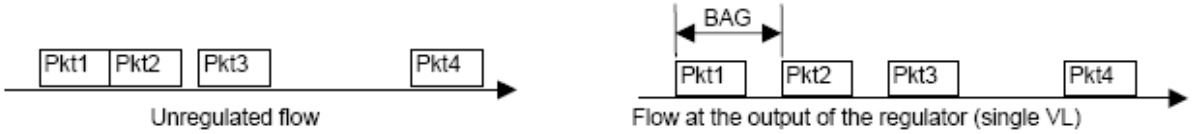
- An AFDX network can define up to 64k (2^{16}) VLs identified by a 16-Bit identifier in the MAC Destination Field of Ethernet Frame
- An AFDX End-Systems can support multiple VLs
- End-Systems perform Traffic shaping and Integrity Checking on each VL
- A Switch performs Traffic policing on each VL
-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

Virtual Link Parameters Overview

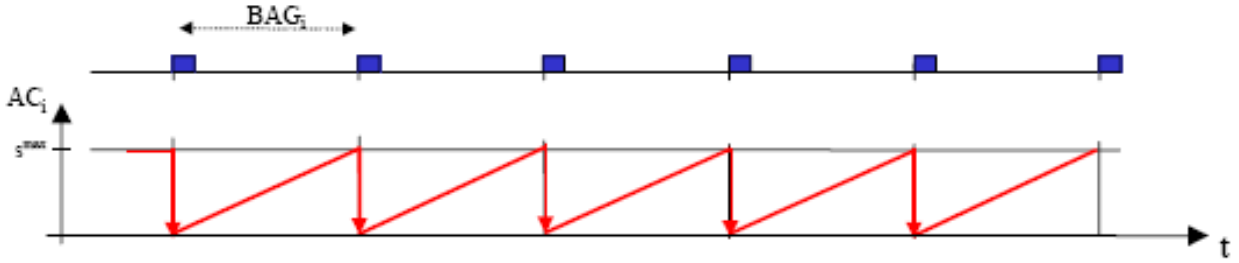
Parameter	E/S	Switch
BAG (Bandwidth allocation GAP)	Yes (Tx)	Yes
Frame Size	Yes (Tx)	Yes
max. allowed Jitter	Yes	Yes
No. of Sub-VLs	Yes (Tx)	No
Account Type	No	Yes
Priority	No	Yes
Network Selector	Yes	No
Skew Max.	Yes (Rx)	No

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)**



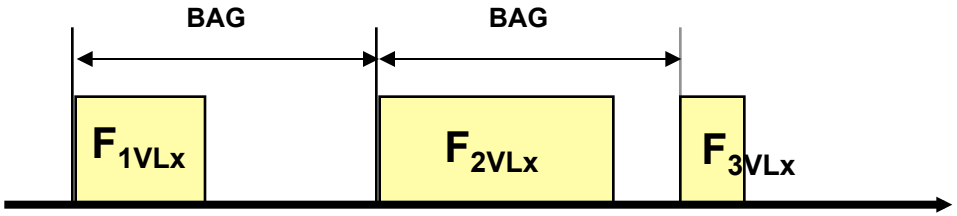
Source: ARINC SPECIFICATION 664P7

Virtual Link Parameters

- **Bandwidth Allocation Gap (continued):**
  - **Frames do not need to be transmitted exactly in multiples of the configured BAG**
  - **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)**
  - **BAG values are in milliseconds: 1, 2, 4, 8, 16, 32, 64, 128**

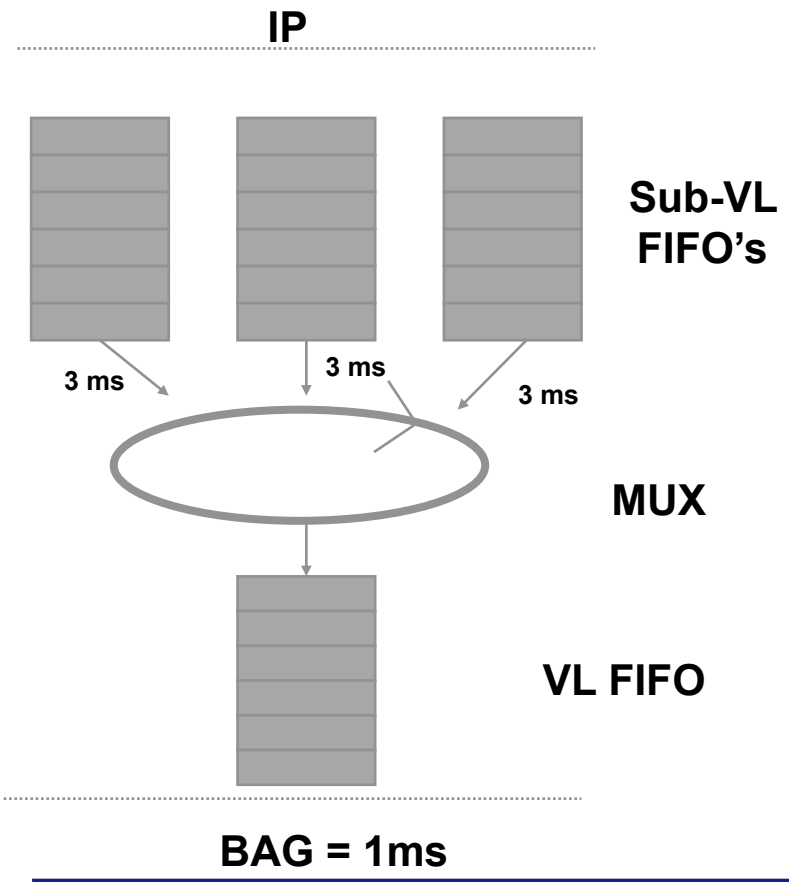
Virtual Link Parameters

- **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

- **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)

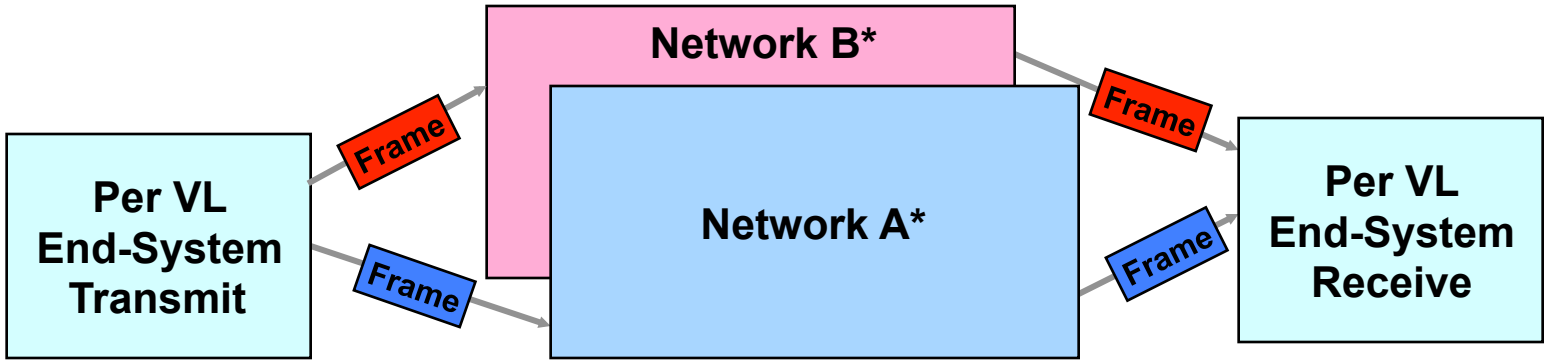


AFDX Integrity Checking

- 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!)



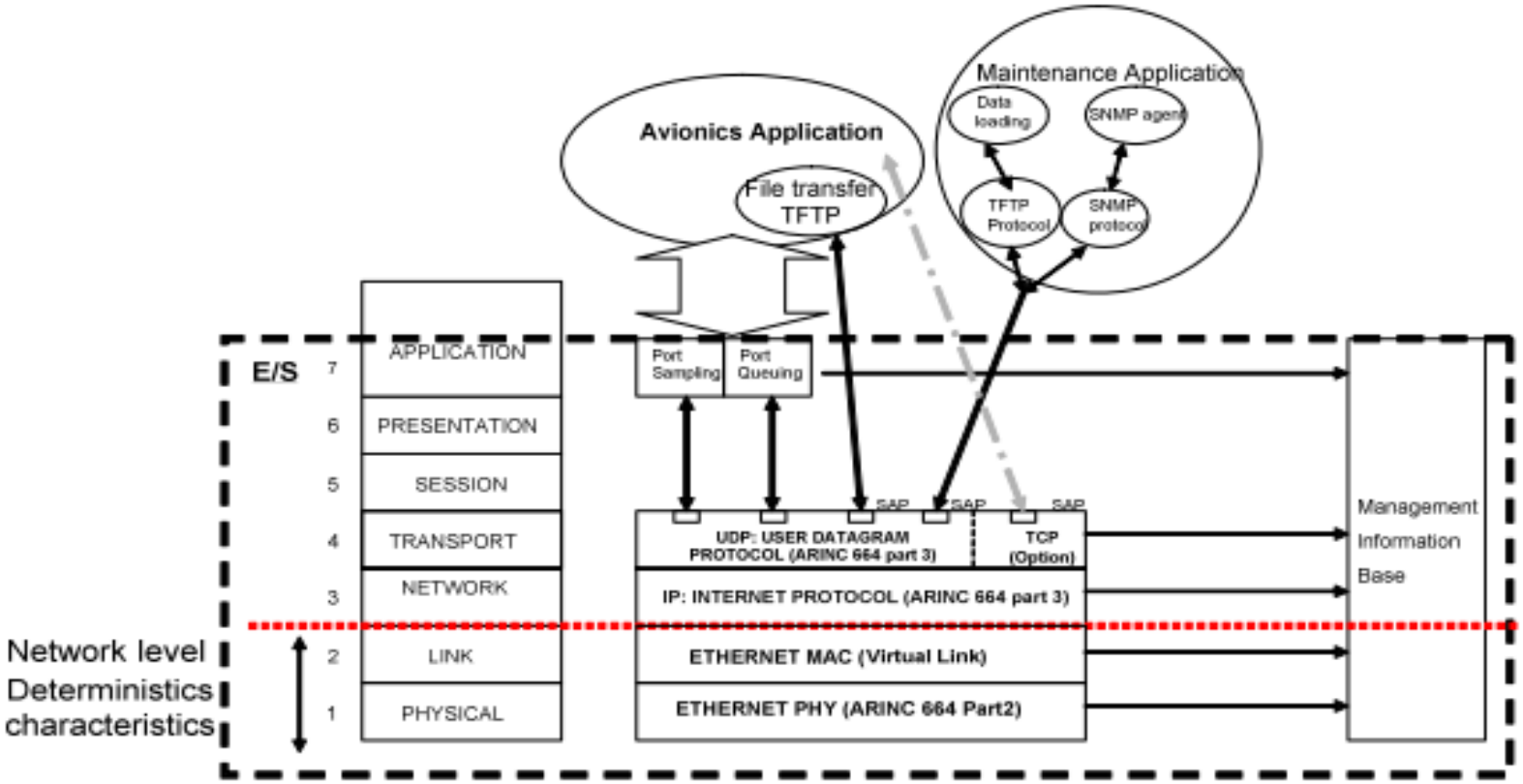
* The Networks are sometimes also called „Red“ and „Blue“

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, the “First Valid Frame wins” which requires provisions to support this algorithm e.g. the AFDX specific SN !

AFDX – Protocol Layers



Source: ARINC SPECIFICATION 664P7

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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)**
- **AFDX Switching is based on the MAC Destination Address (Layer 2)**
- **AFDX provisions for deterministic are implemented on Layer 2 only**

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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)

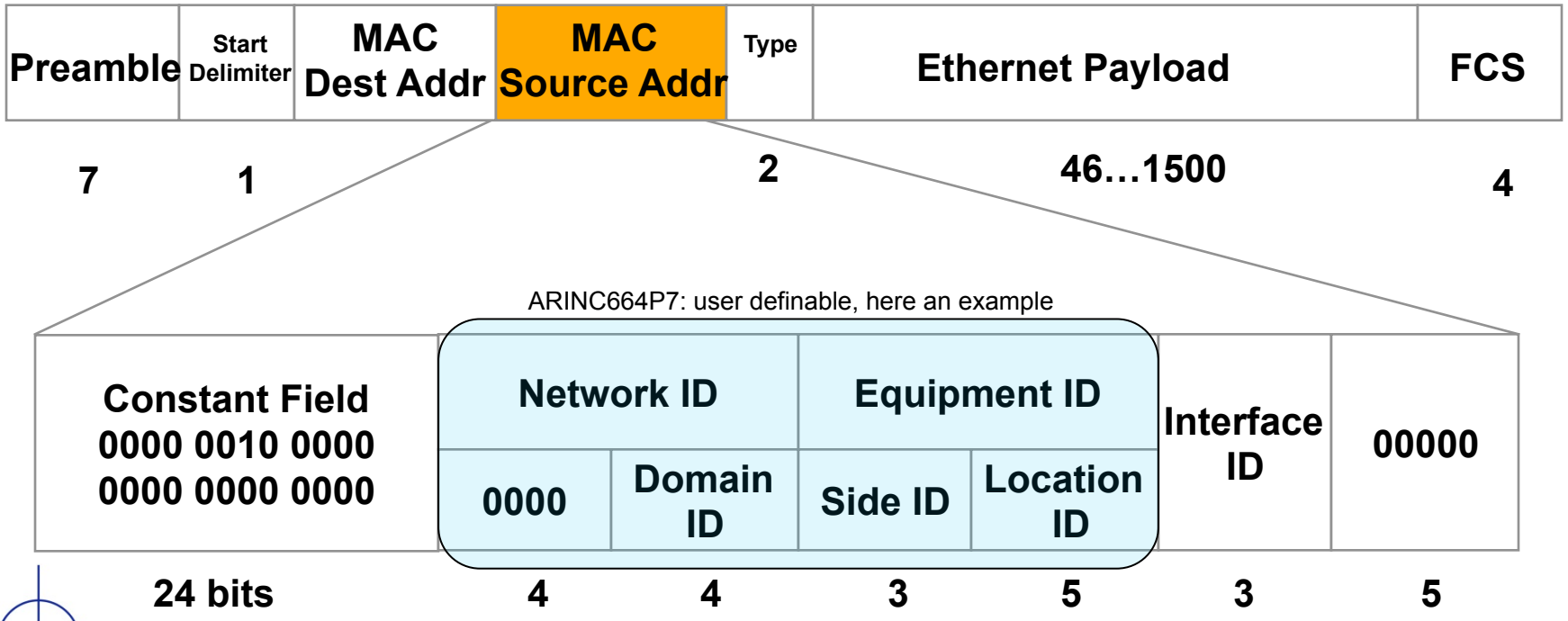
AFDX – MAC Layer 2

- 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

Preamble	Start Delimiter	User Programmable Frame Payload	FCS
7	1	1…1996	4

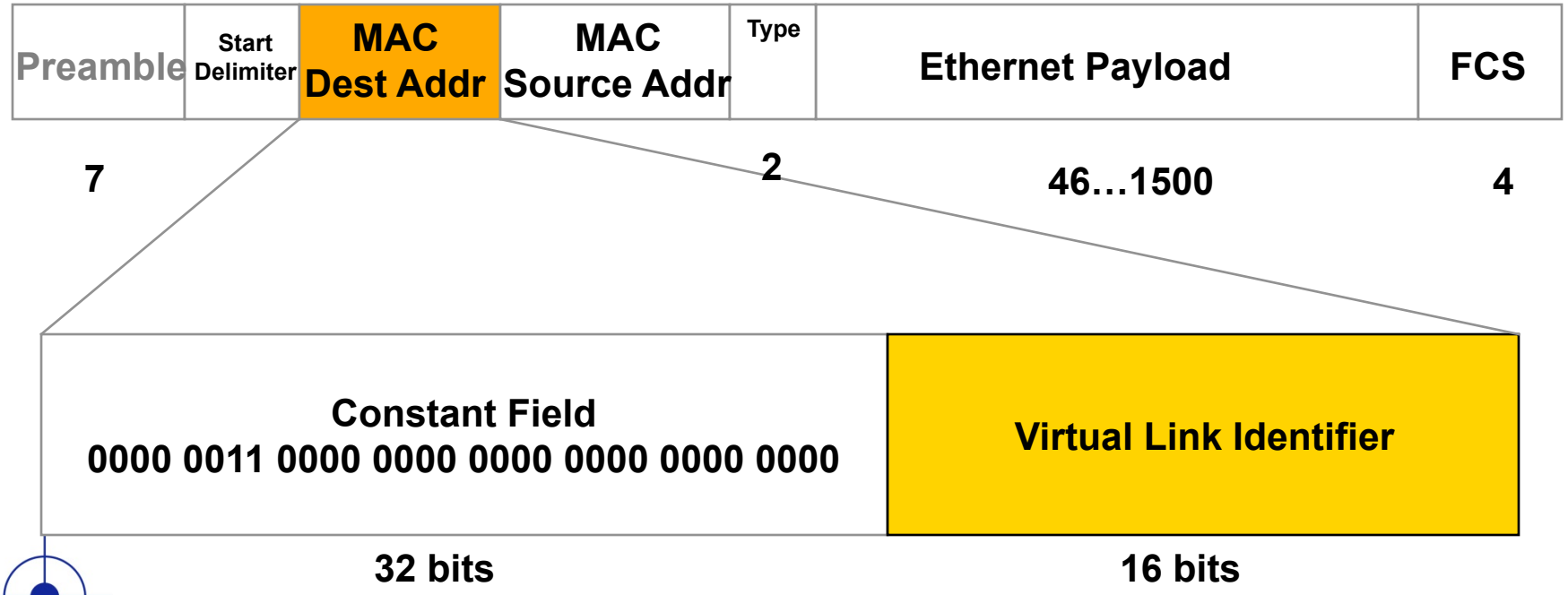
AFDX – MAC Layer Layer 2

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



AFDX – MAC Layer Layer 2

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



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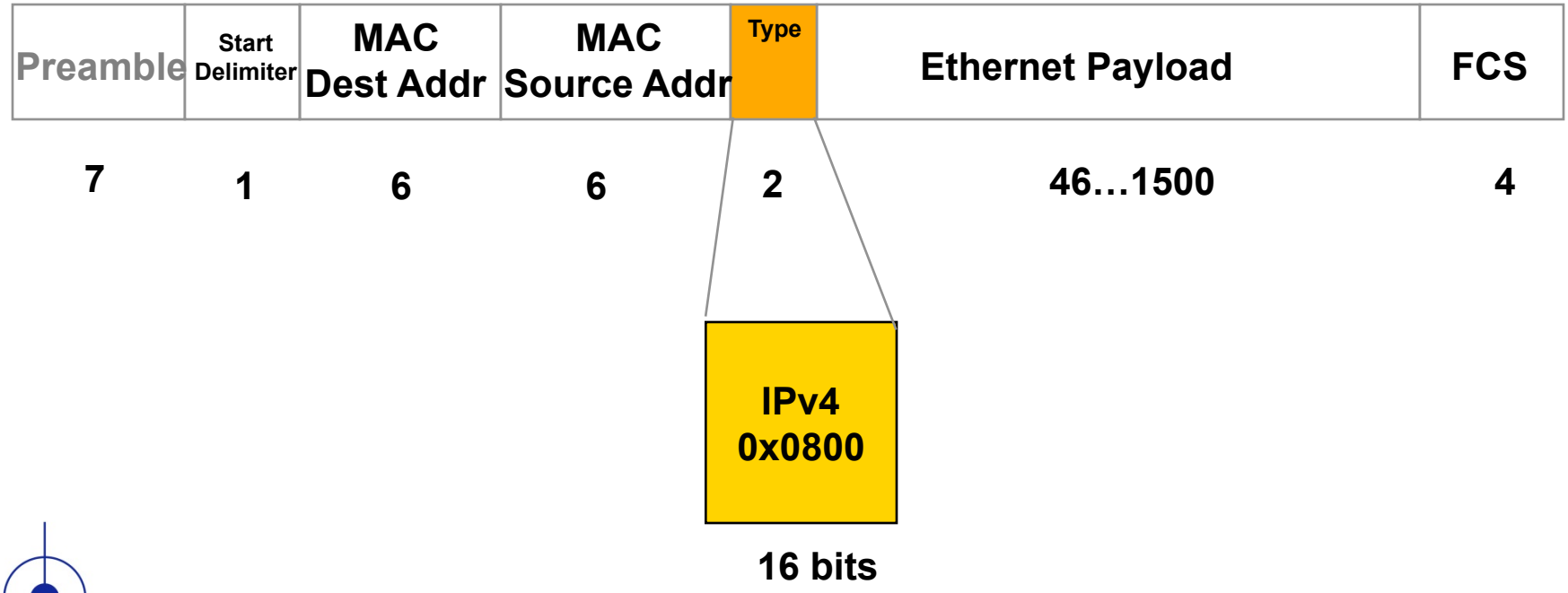
AFDX – MAC Layer Layer 2

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

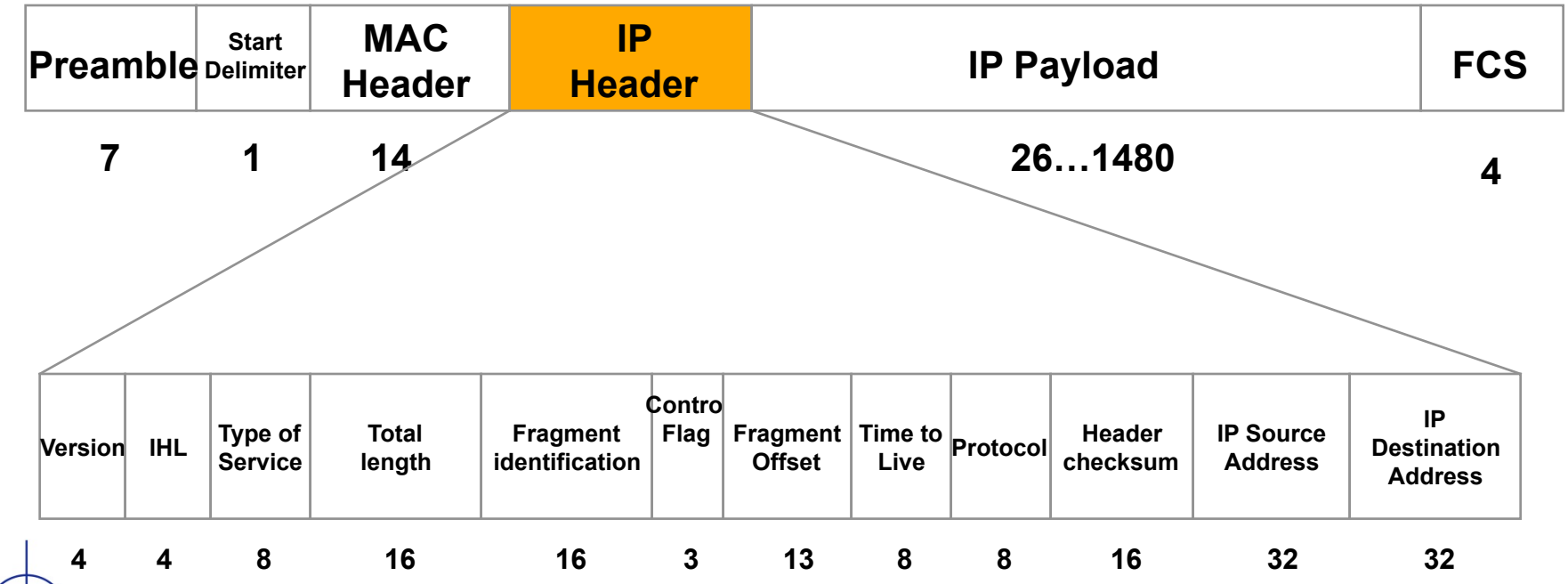


AFDX – MAC Layer Layer 2

- **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 !

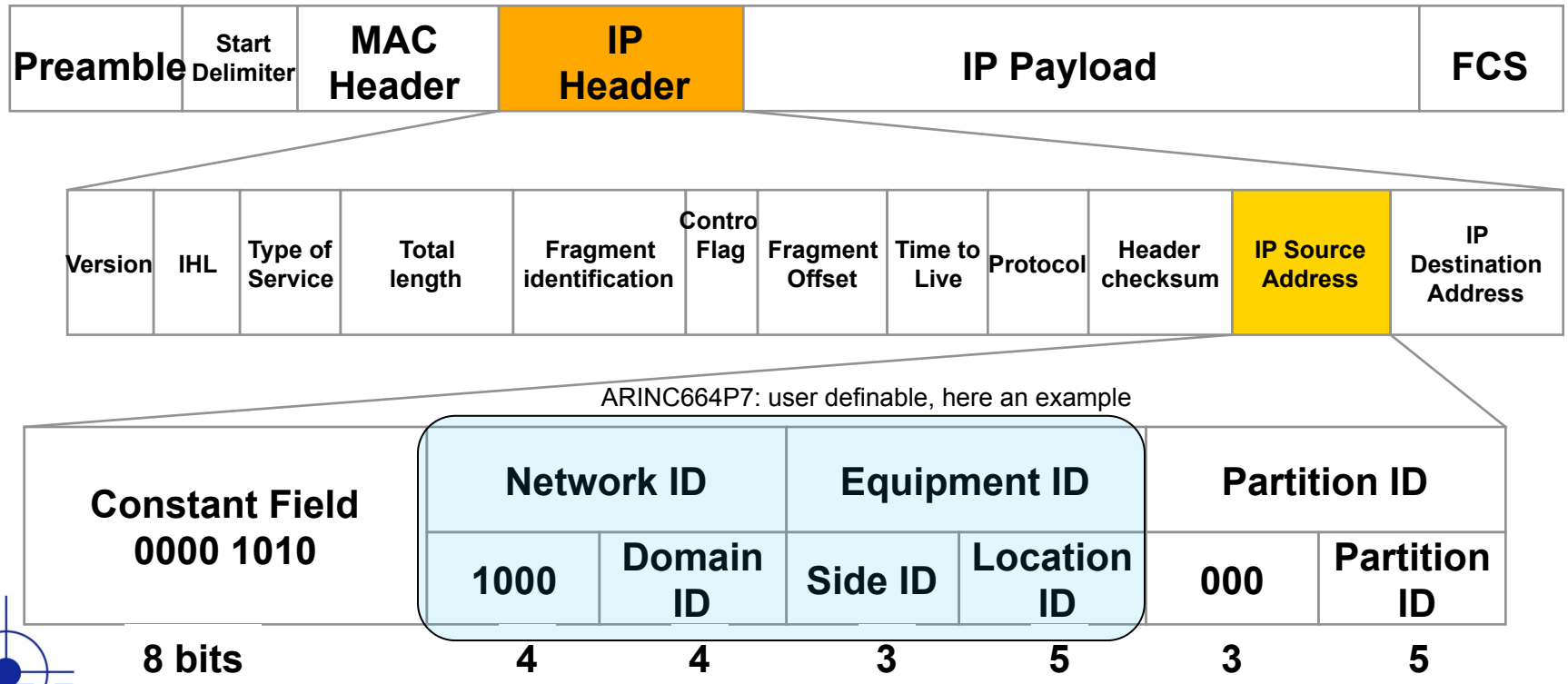
AFDX – IP (Internet Protocol) Layer 3

- **IPv4 Header**



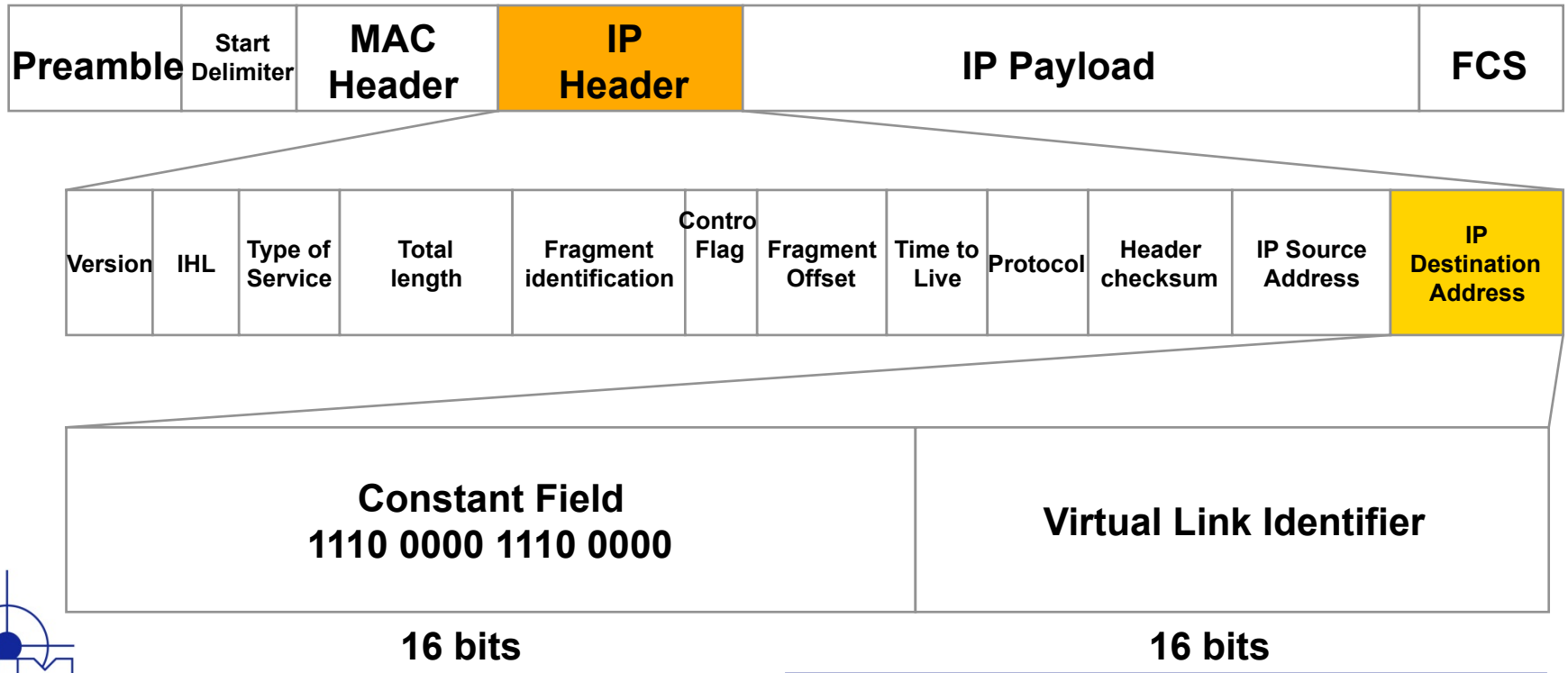
AFDX – IP (Internet Protocol) Layer 3

- **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)

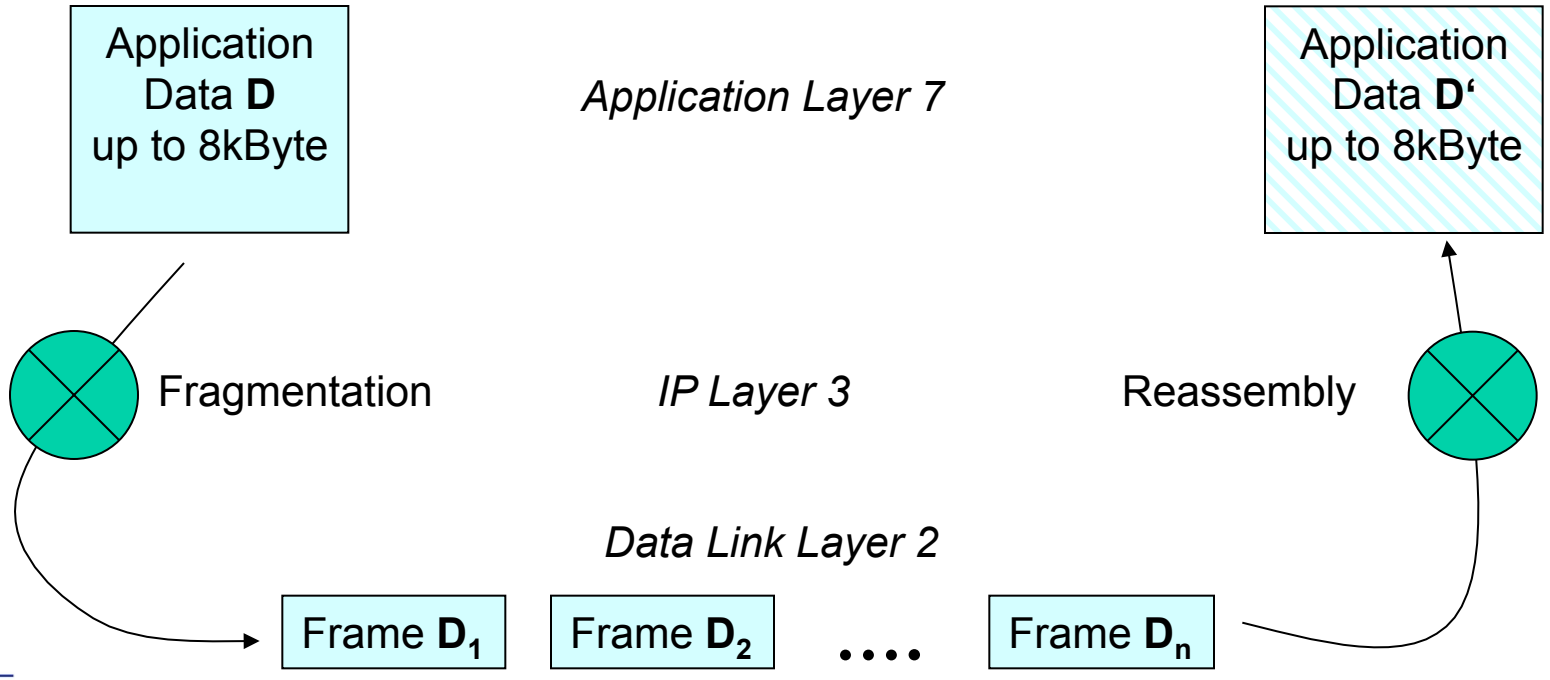
* a “receiver” e.g. means an application. In other words: data addressed to a unicast IP destination address shall be used by only one application, data addressed to a multicast IP destination address can be used by multiple applications in side the same End System. The Specifications are also using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

AFDX – IP (Internet Protocol) Layer 3

- **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

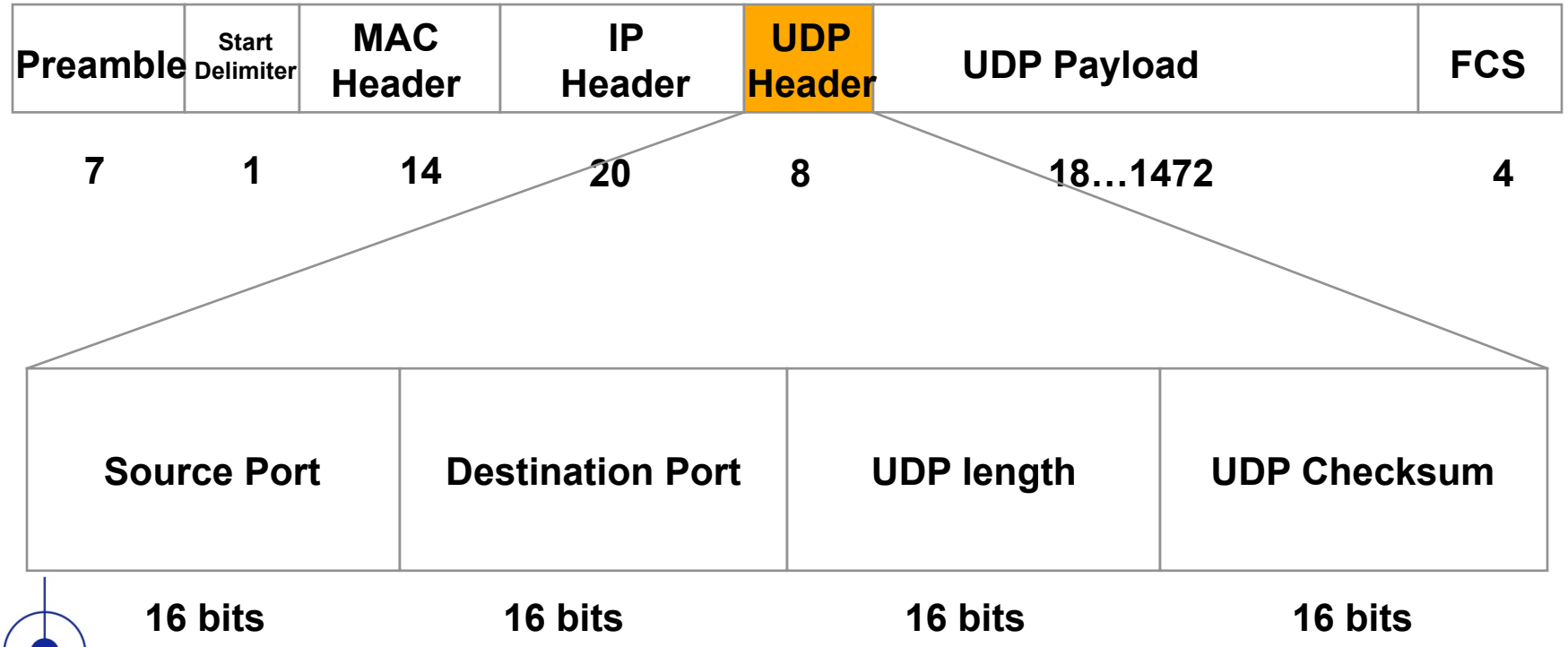
AFDX – IP (Internet Protocol) Layer 3

- **IP Fragmentation (simplified)**



AFDX – UDP (User Datagram Protocol) Layer 4

- **UDP Header**



AFDX UDP Protocol

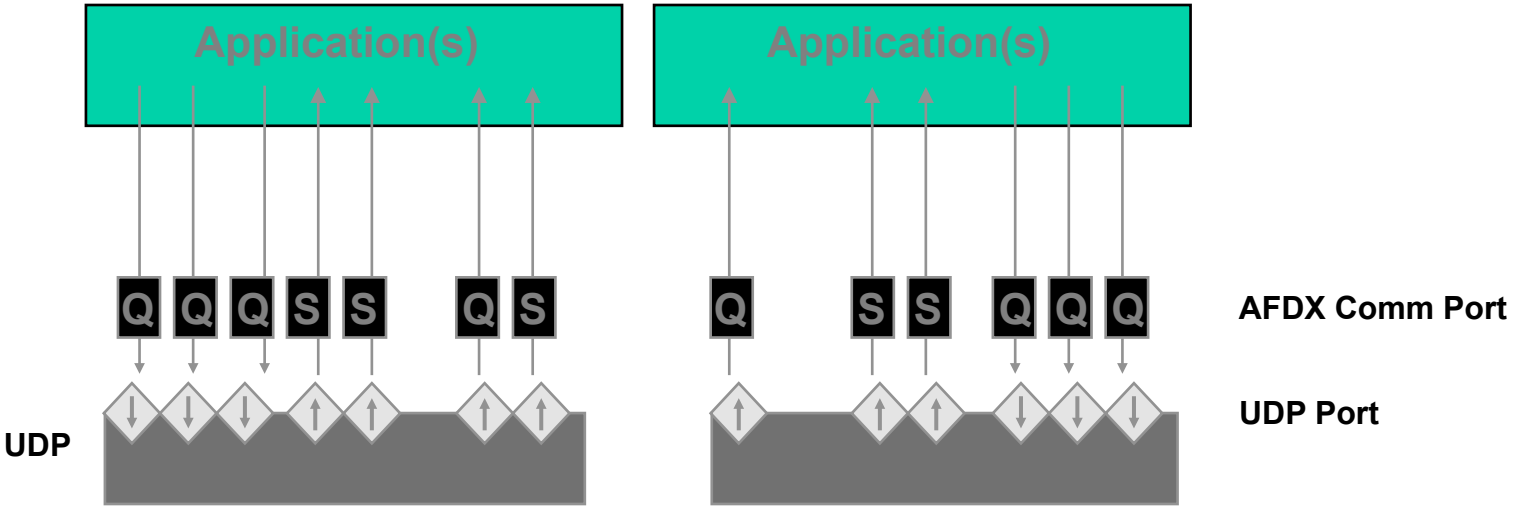
- **Applications send/receive "messages" through AFDX Comm(unication) Ports which are basically mapped to UDP Ports**

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

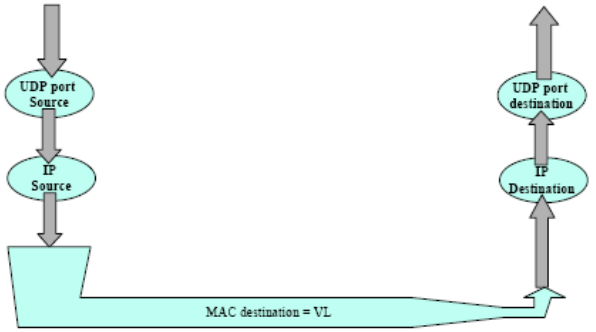


Source: ARINC SPECIFICATION 664P7

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***



Source: ARINC SPECIFICATION 664P7

- **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

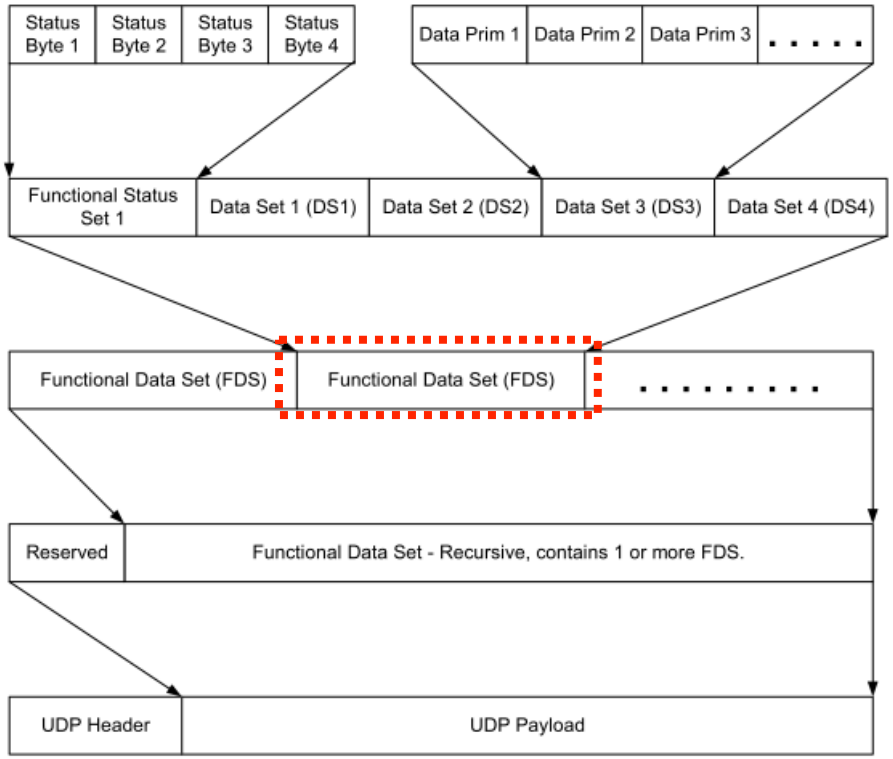
Preamble	Start Delimiter	MAC Header	IP Header	UDP Header	AFDX Payload	AFDX Sequence Number	FCS

- 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 Structuring

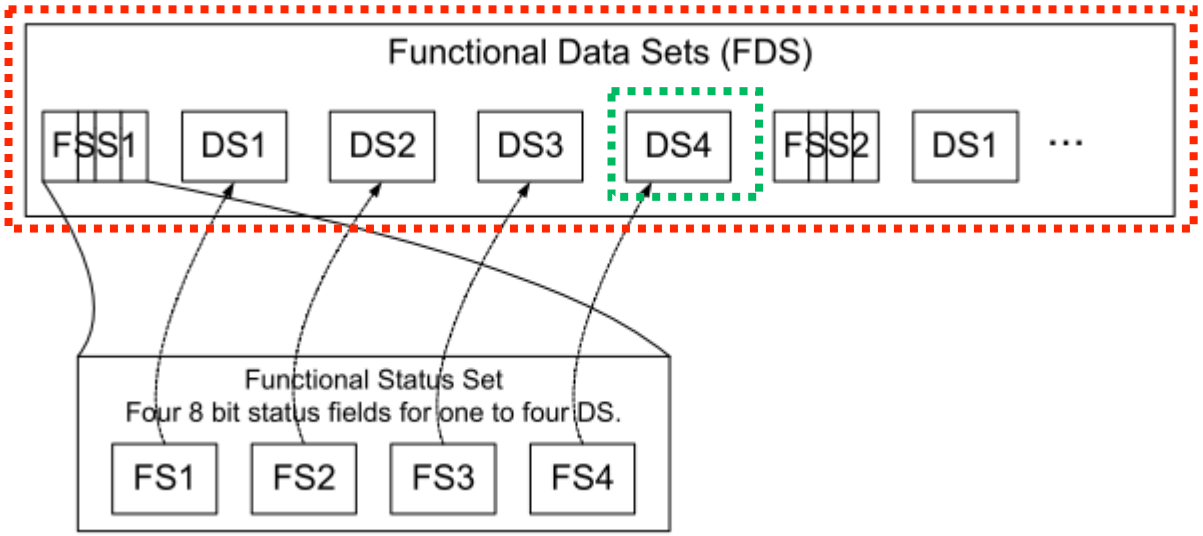
- **AFDX Payload for non-protocol based data is organized in so called Functional Data Sets (FDS)**



Source: ARINC SPECIFICATION 664P7

AFDX Payload Structuring

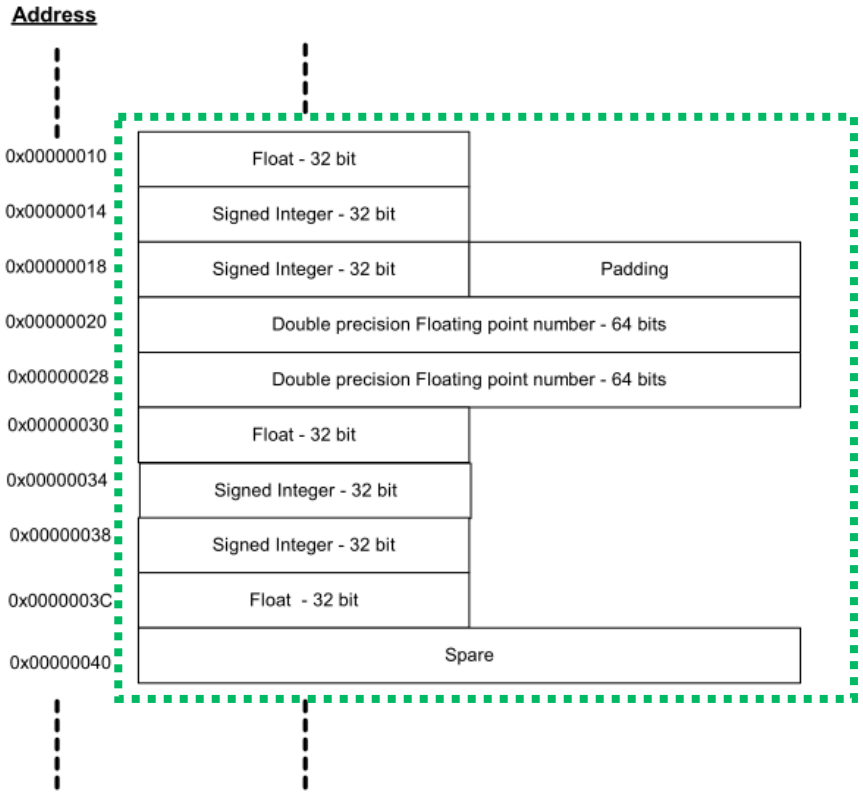
- **A Functional Data Set (FDS) is organized into Functional Status Set (FSS) and Data Sets (DS)**



Source: ARINC SPECIFICATION 664P7

AFDX Payload Structuring

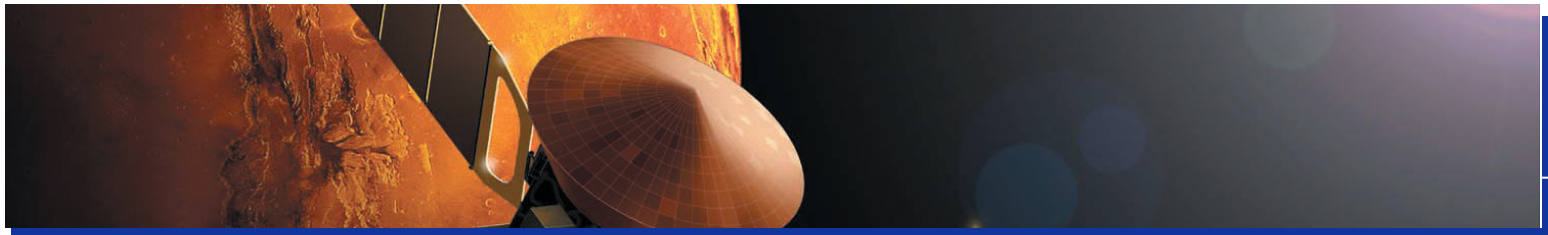
- **A Data Sets (DS) typically contains a Parameter (Datum) e.g. Float, Integer, Enumerated, Boolean, ……**



Source: ARINC SPECIFICATION 664P7

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



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Our Mission is your Success!

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