iNET 101

From an Instrumentation Engineer’s Perspective

The Why of iNET

1. Bandwidth needs are increasing and available spectrum is decreasing
2. The need for two-way communication has become even more important to address #1
3. With #2 comes the ability to address new scenarios and be more efficient in testing
4. Configuration and management become more difficult and require automation and declarative setup

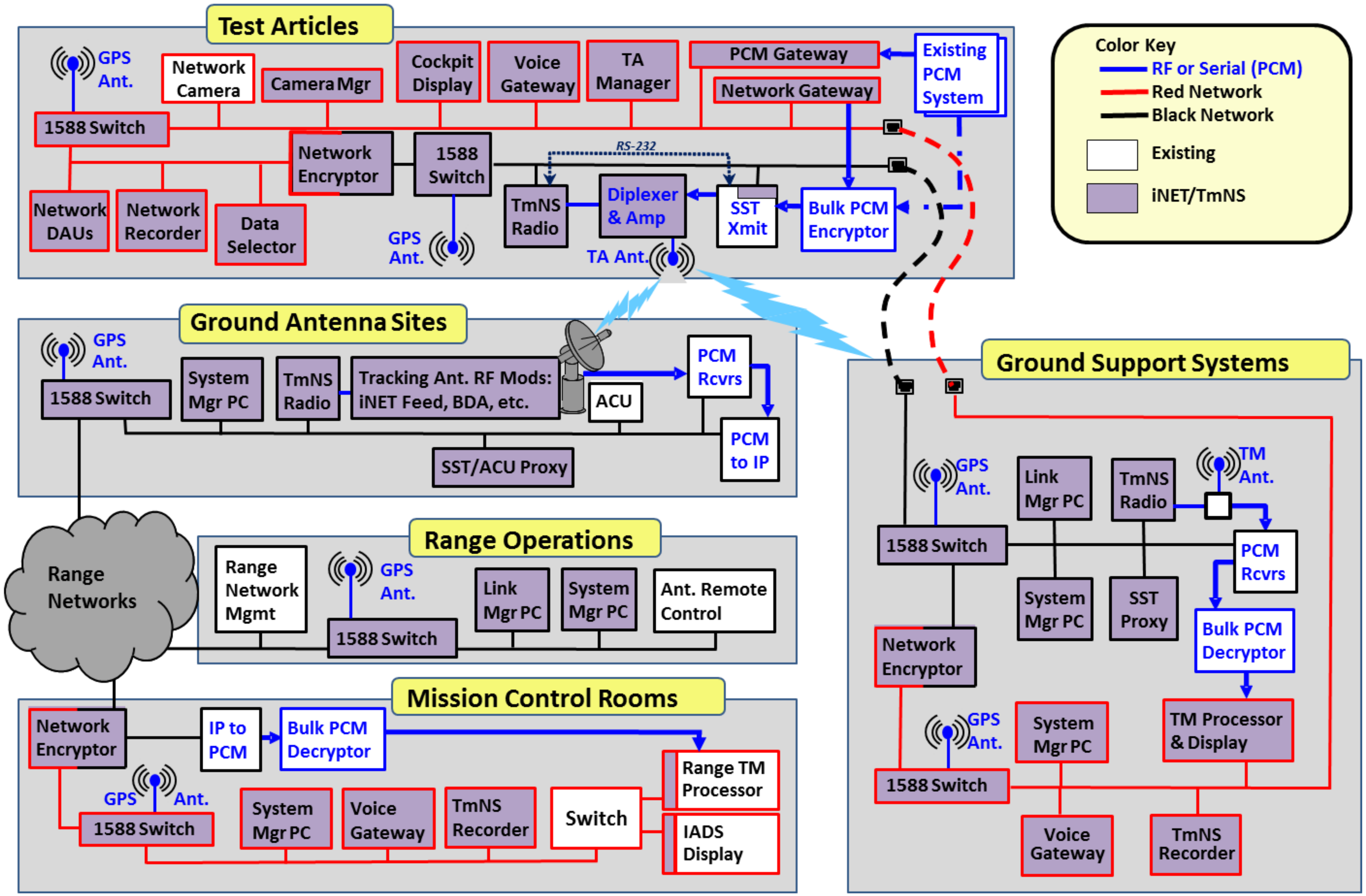
Source Documents

- iNET Needs Discernment document – 19 May 2004
  - The iNET study results will lead to a CTEIP Development Project that will develop needed technology, mature the TmNS, and lead to its deployment at MRTFB sites throughout DoD.
- iNET 53 Scenarios – 5 May 2007
  - Scenario 1: Fetch Data from Test Article on Demand (Aircraft)
  - Scenario 2: Access Additional Data on the Test Article Inter-Maneuver (Aircraft)
  - Scenario 3: Control Instrumentation on the Test Article Remotely (Aircraft)
  - Scenario 5: Reconfigure Transmitted Telemetry Information During a Test (Aircraft)

Key Features

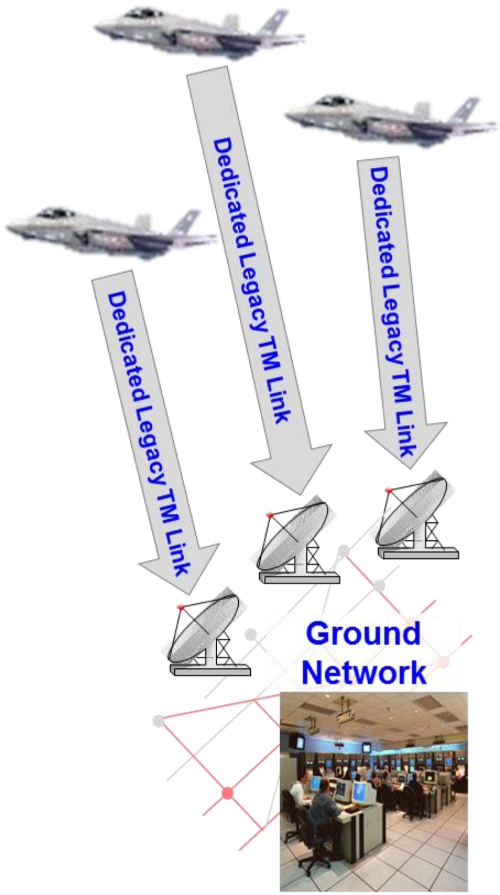
- Bidirectional Communications
    - Real-time access to Test Article (TA) Measurements
    - PCM Backfill
    - Real-time Command and Control of TA Equipment
- Dynamic Spectrum Sharing
- Quality of Service
- Fully Interconnected System
- Over-the-Horizon Telemetry

System Overview



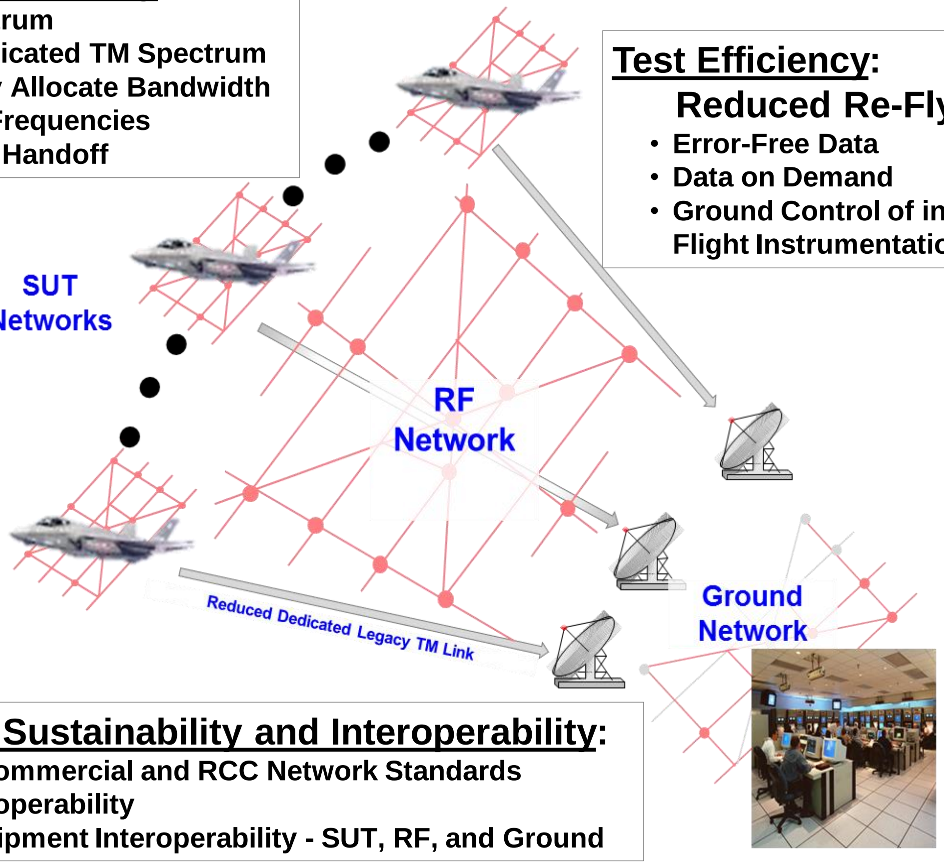
iNET Impacts

Current Telemetry Paradigm



iNET Telemetry Paradigm

Spectrum Efficiency:
- Share Spectrum
- Reduce Dedicated TM Spectrum
- Dynamically Allocate Bandwidth
- Control Tx Frequencies
- Inter-Range Handoff



Test Efficiency:

Reduced Re-Fly
- Error-Free Data
- Data on Demand
- Ground Control of in-Flight Instrumentation

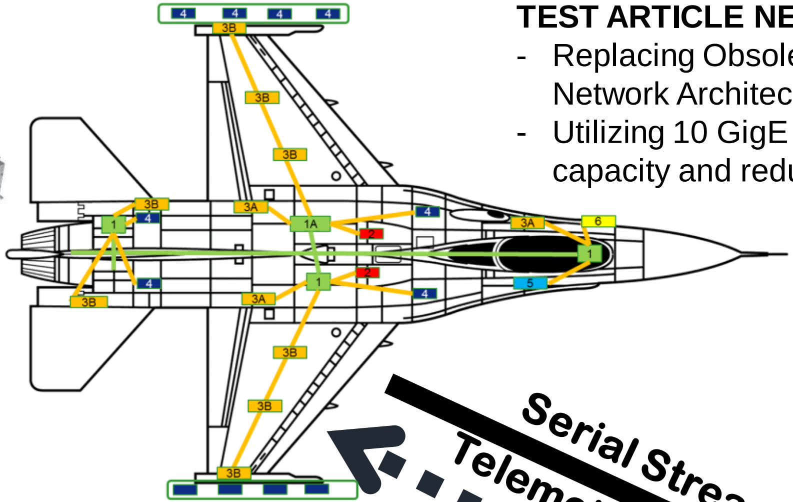
Long Term Sustainability and Interoperability:
- Based on Commercial and RCC Network Standards
- Range Interoperability
- Vendor Equipment Interoperability - SUT, RF, and Ground

iNET Represents a Major Shift in the Telemetry Paradigm

Moving Real-Time Test Data into the Networking Age

Real-Time Mission Support Upgrades

”Any Data, Any Time, Any Where”

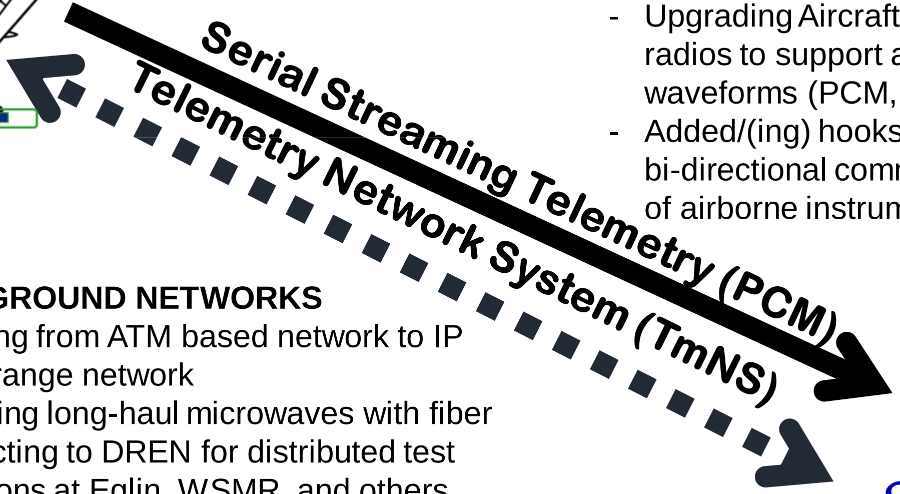


TEST ARTICLE NETWORKED INSTRUMENTATION

- Replacing Obsolete CAIS Instrumentation Architecture with Network Architecture
- Utilizing 10 GigE Backbone and 1 GigE Legs to increase capacity and reduce wiring

TELEMETRY

- Upgraded (412 TW) / Upgrading (SW Ranges) to L/S/C Band capable ground antennas
- Upgrading Aircraft and Ground radios to support all of the ARTM waveforms (PCM, SOQPSK, CPM)
- Added/(ing) hooks to support future bi-directional command and control of airborne instrumentation system



MISSION CONTROL ROOMS

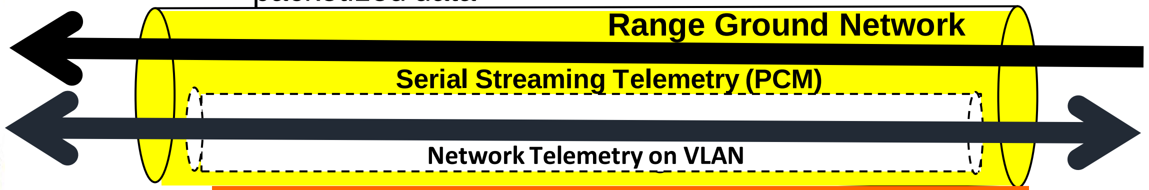
- Upgrading the MCR architecture to a modular design that enables future flexibility by adding/swapping modules
- Minimizes specialized hardware dependencies
- Supports distributed operations from ground up
- Integrates simulations and stimulation into the MCR

RANGE GROUND NETWORKS

- Migrating from ATM based network to IP based range network
- Replacing long-haul microwaves with fiber
- Connecting to DREN for distributed test operations at Eglin, WSMR, and others
- Migrating voice, video and data to packetized data

Ground Station

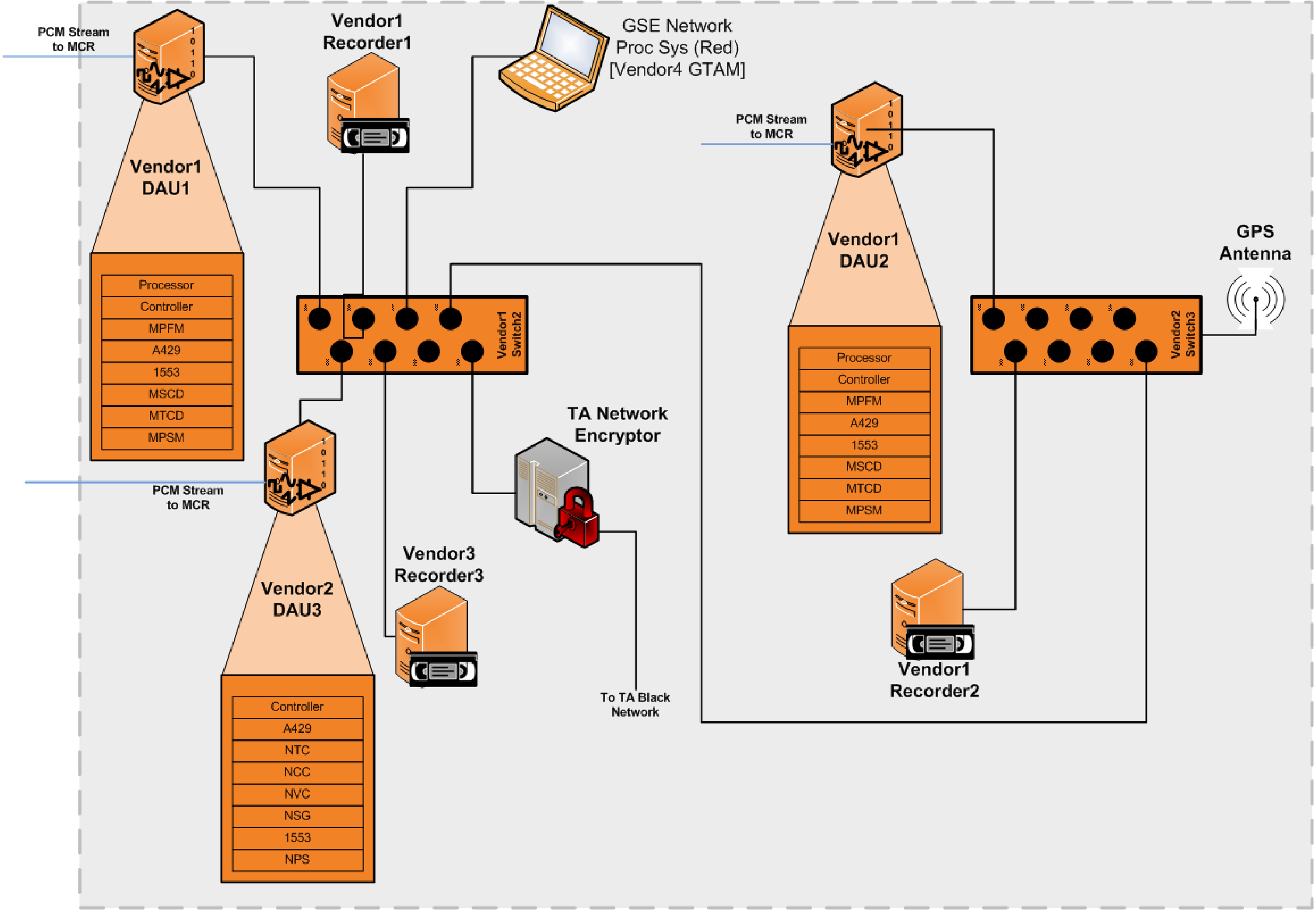
Control Room



Leveraging iNET, I&M and SRF

What to care about

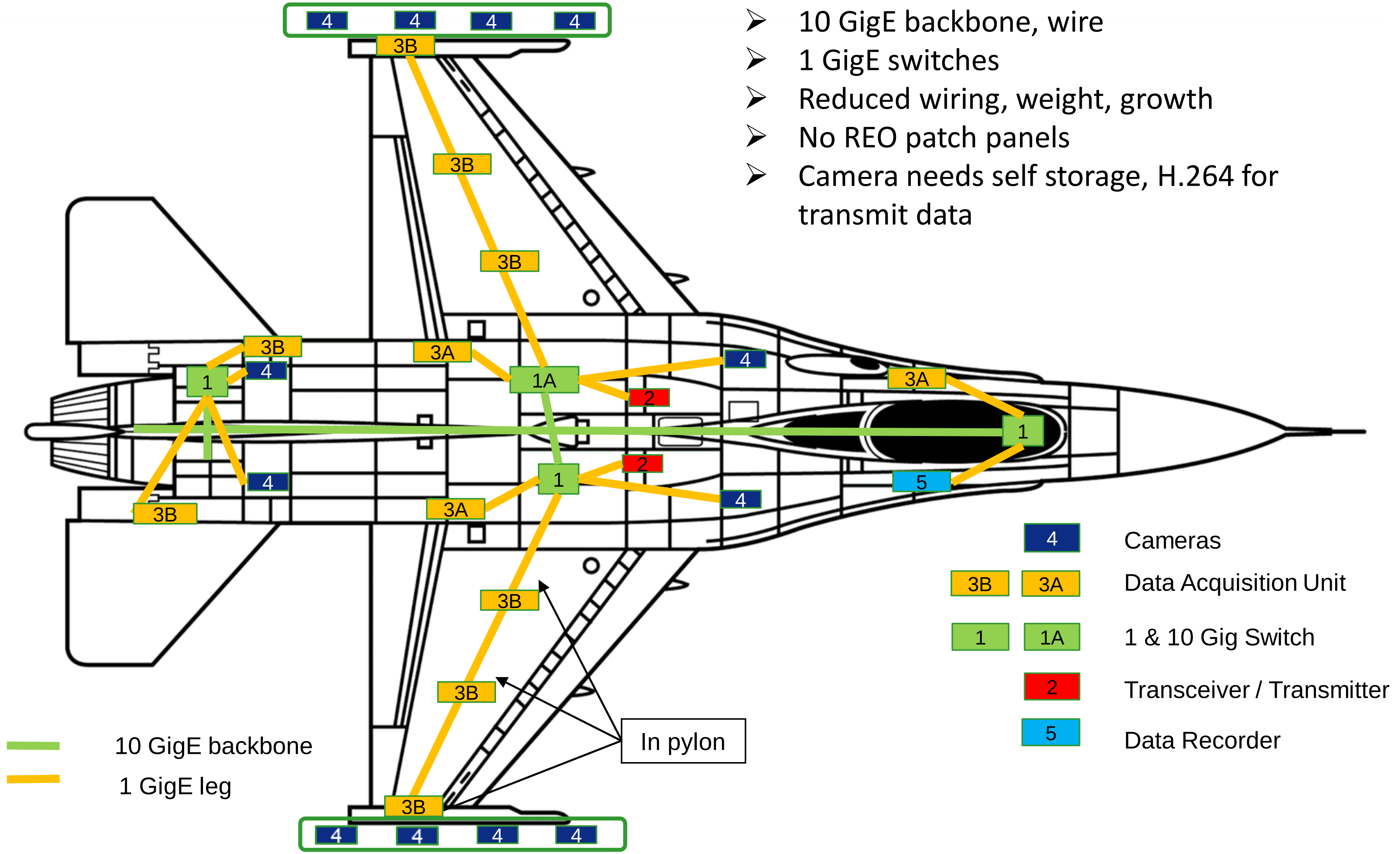
1. What an on-aircraft system looks like from a wiring and component perspective
2. What does one do to program this new system
3. What is involved from a testing and troubleshooting perspective
4. What new skills will an instrumentation engineer / tech need in order to design / build / install / checkout / troubleshoot an Ethernet-based system
5. What is IEEE 1588 time and how is it different from IRIG time


PCM Stream to MCR
Vendor1 DAU1
Processor
Controller
MPFM
A429
1553
MSCD
MTCD
MPSM
Vendor1 Recorder1
GSE Network Proc Sys (Red) [Vendor4 GTAM]
PCM Stream to MCR
Vendor1 DAU2
Processor
Controller
MPFM
A429
1553
MSCD
MTCD
MPSM
GPS Antenna
Vendor1 Switch2
Vendor2 Switch3
TA Network Encryptor
PCM Stream to MCR
Vendor2 DAU3
Controller
A429
NTC
NCC
NVC
NSG
1553
NPS
Vendor3 Recorder3
To TA Black Network
Vendor1 Recorder2

High Level iNET Architecture
Edwards I&M Project (CANIS FY17-25)

Common Airborne Network Instrumentation Solutions

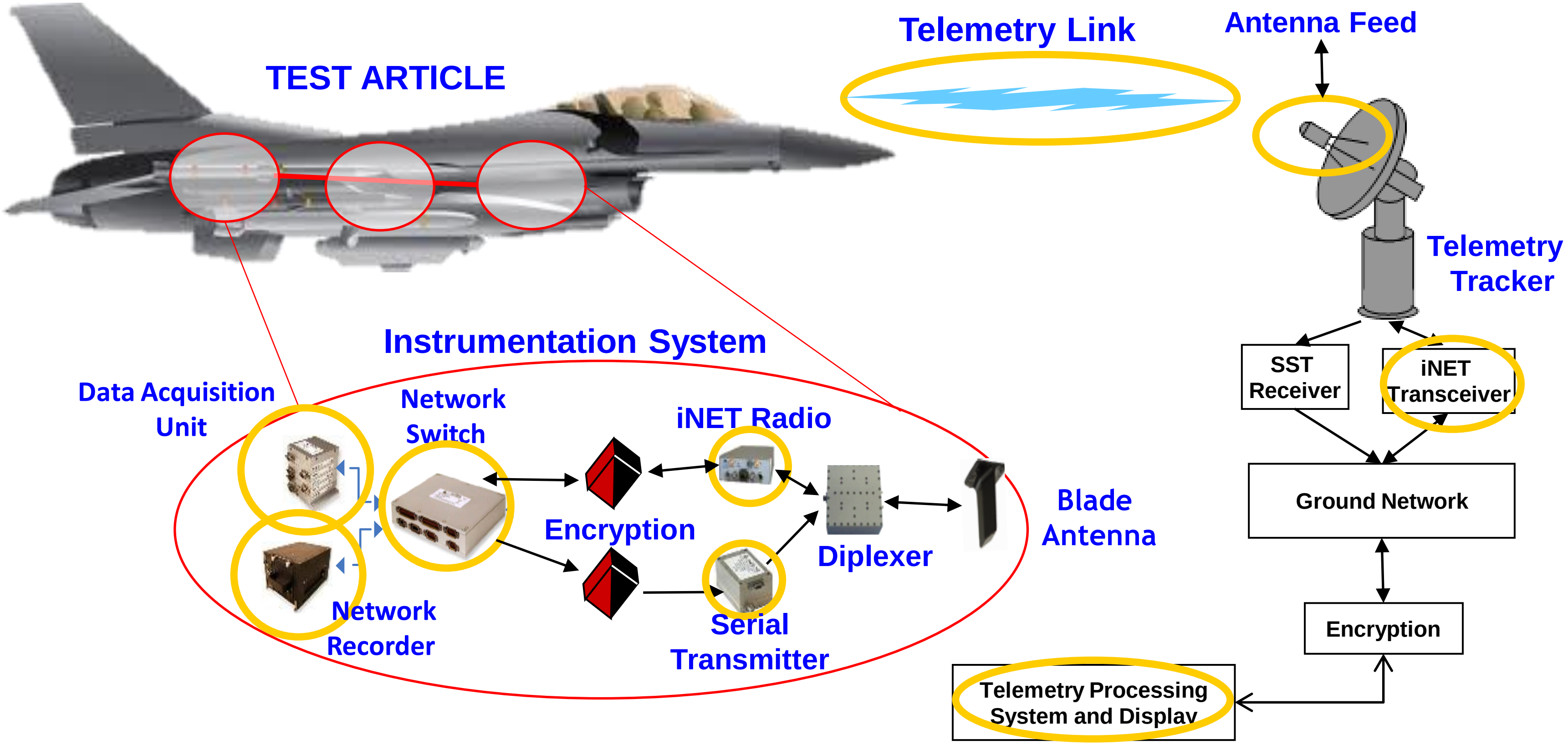
- 10 GigE backbone, wire
- 1 GigE switches
- Reduced wiring, weight, growth
- No REO patch panels
- Camera needs self storage, H.264 for transmit data



High Level iNET Subsystems

Network Enabled Instrumentation
Network Enabled Ground Stations
Mission Control Rooms
Ground Support Equipment

Modified or Developed Components



IRIG 106-17 Chapters 21 – 28

- 21 – Introduction
- 22 – Network-Based Protocol Suite
- 23 – Metadata Configuration
- 24 – Message Formats
- 25 – Management Resources
- 26 – TmNSDataMessage Transfer Protocol
- 27 – Radio Frequency (RF) Network Access Layer
- 28 – RF Network Management

TmNS = Telemetry Network Standard

- From Chapter 21.2.1
  - The TmNS defines interfaces, data delivery protocols, configuration files, and command and control concepts. These are standardized so as to support interoperability across components (and vendors) within a particular TmNS-defined network.
  - The TmNS is composed of sets of components that are modeled after network appliances typically found on the Internet. Each TmNS-compliant component implements certain TmNS interfaces (as applicable), thus providing multi-vendor interoperability.

Interfaces

- Management – MDL (XML), SNMP and Web Browser
- Time – IEEE 1588
- Data Delivery
  - LTC – UDP
  - RC - TCP
- RF Network

Data Delivery

- Latency/Throughput Critical: used to deliver test data when latency or throughput constraints are more important than reliability constraints (real-time). The underlying technologies supporting this delivery protocol are User Datagram Protocol, Internet Group Management Protocol, and IP multicasting.
- Reliability Critical: used to deliver test data when reliability constraints are more important than latency or throughput constraints (reliable). The underlying technologies supporting this delivery protocol are TCP and Real Time Streaming Protocol.

Definitions

- TmNS Data Message – A container/envelop for holding data for transport/delivery of measurement data, bus data, etc.
- End Node – A network device that produces and/or consumes TmNS Data Messages
- Network Device – A device that merely propagates TmNS Data Messages (i.e. router, switch, etc.)
- Network Recorder – An End Node that records TmNS Data Messages and Produces/replays TmNS Data Messages on demand
- Network Gateway – An End Node that receives TmNS Data Messages and produces PCM data
- PCM Gateway – An End Node that receives PCM data and produces TmNS Data Messages
- TLV – Type / Length / Value

Basic TA Components

	Capability	Component(s)
Test Article	Data acquisition	Network DAU
	On-board recording	TA Network Recorder
	Network data transport and IEEE 1588 time synchronization	TA Switch
	Configure and monitor status of devices	*Test gear used for setup, configuration, and monitoring status (e.g. laptop with System Manager). This gear is removed prior to test.*
Test Article	Data acquisition	Network DAU
	On-board recording	TA Network Recorder
	Network data transport and IEEE 1588 time synchronization	TA Switch
	Voice communications	TA Network Voice Gateway
	Encryption	TA Network Encryptor
	Bidirectional Telemetry	TA Radio

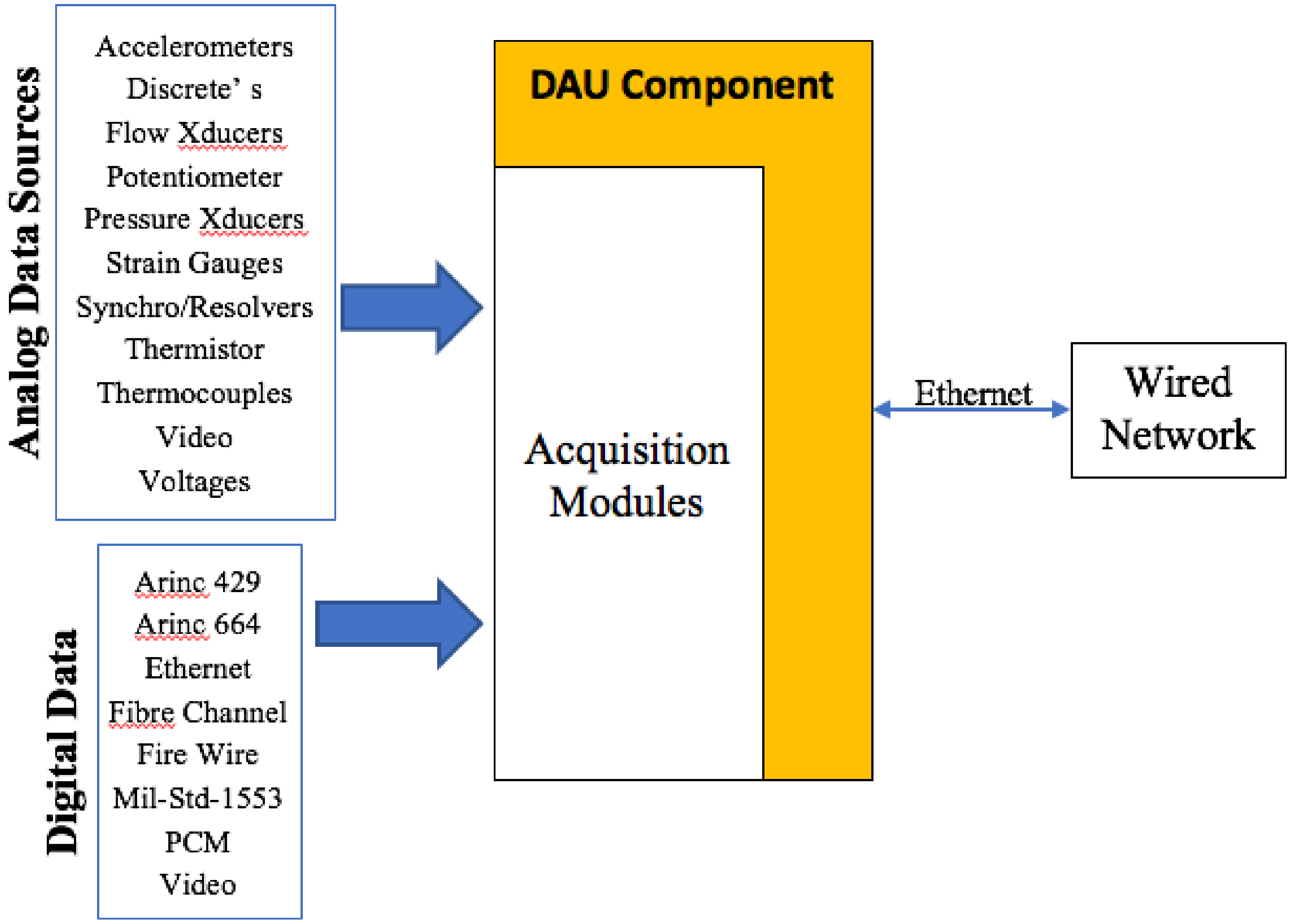
TA Subsystem Component Types

Component	Role	Functionality Description	Command and Control Plane
Network DAU	Acquire, time stamp, and publish data	Acquires and time tags analog and bus measurements. Transmits data in TmNS Data Messages (multicast, unicast delivery).	Red Network
TmNS Recorder	Record and store data	Records TmNS Data Messages. Deliver requested data upon receipt of a request.	Red Network
1588 Switch	Forward data, support IEEE-1588 timing capabilities, support multicast data delivery	Switches packets, provides IGMP snooping capabilities, supports IEEE-1588 network time distribution (e.g. time master, transparency capabilities).	Red and Black Network

TA Subsystem Component Types (continued)

Voice Gateway	Provide Voice over IP (VoIP) services to support voice communications with other VoIP systems (other TA, ground control room, etc.)	Provide voice services over the network by adapting between voice and Voice over IP (VoIP) network traffic.	Red Network
PCM Gateway	Convert serial PCM stream to TmNS Data Messages	The PCM Gateway accepts an RS-232/422 serial PCM stream, decommutates it, and then reproduces the test data in TmNS Data Messages onto the TmNS network.	Red Network
Network Gateway	Convert TmNS Data Messages to a serial PCM stream	The Network Gateway provides the capability to move data from the TmNS network to the SST data stream. It receives TmNS Data Messages utilizing both the RC and LTC delivery protocols and also supports IEEE 1588-2008 for precise time alignment of TmNS Data Message timestamps with the PCM frame timing.	Red Network

The DAU



Analog Data Sources
Accelerometers
Discrete' s
Flow Xducers
Potentiometer
Pressure Xducers
Strain Gauges
Synchro/Resolvers
Thermistor
Thermocouples
Video
Voltages
Digital Data
Arinc 429
Arinc 664
Ethernet
Fibre Channel
Fire Wire
Mil-Std-1553
PCM
Video
DAU Component
Acquisition Modules
Ethernet
Wired Network

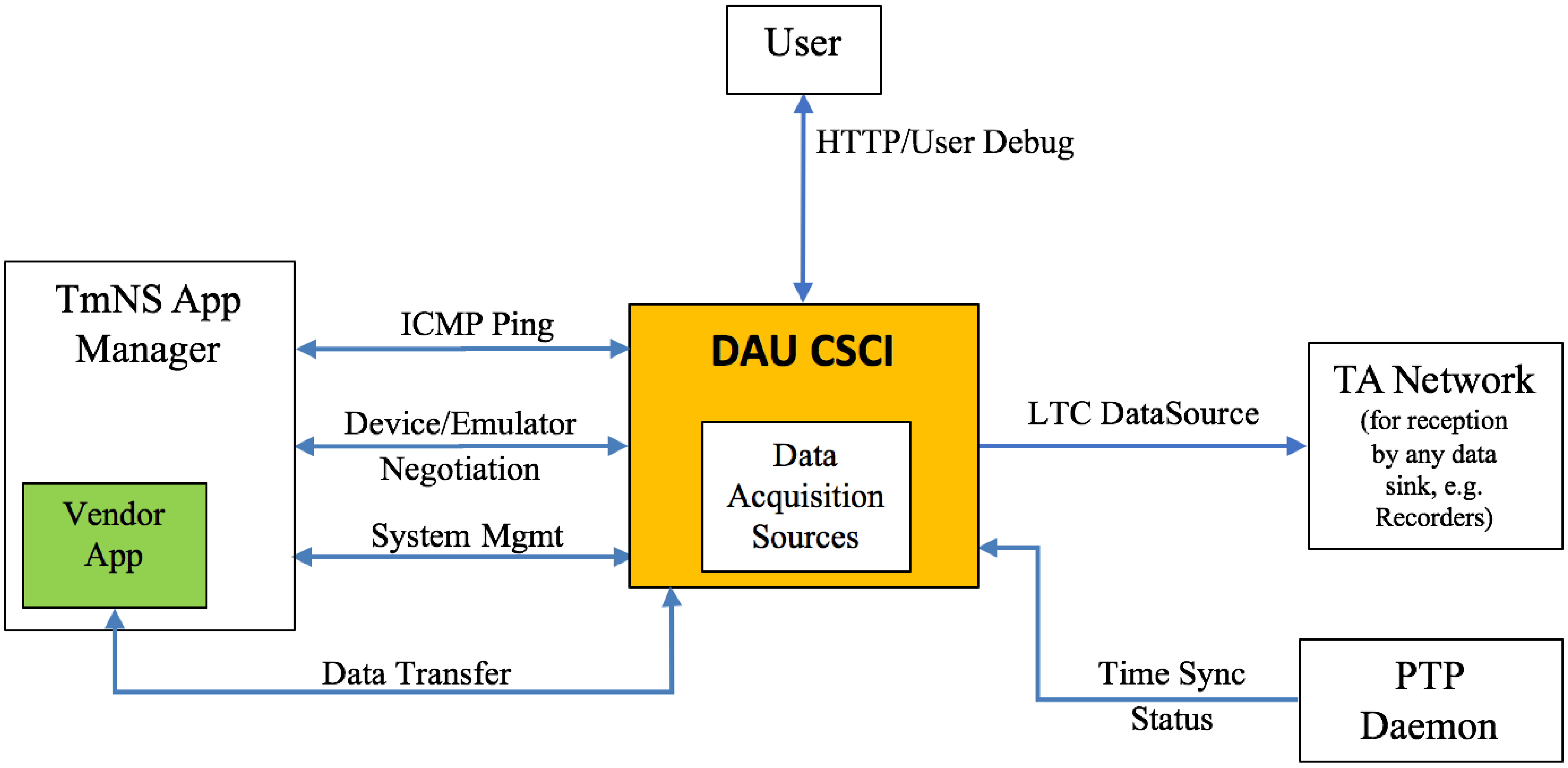
DAU Requirements

- Acquire Data
  - This function shall collect data from the various DAU inputs (Acquisition Source Input) and convert it to a digital form appropriate for use as an input to the Host the Embedded TA DAU function (Data Acquisition Input). The specific requirements of this function will depend on the particular electrical and protocol characteristics of the TA Acquisition Source that it connects to.
  - The Acquire Data function will also respond to Calibration Mode Control input from the Host the Network DAU function by substituting in the selected internal calibration source in place of the data from the TA Acquisition Source.
- Process Time Messages
  - This function shall implement the requirements of an IEEE 1588-2008 (Precision Time Protocol - PTP) slave. This function shall process IEEE 1588-2008 messages and update the local system clock in an incremental fashion to slowly move toward the correct time as specified by the IEEE 1588-2008 messages.

DAU Software Requirements

- The Network DAU software implements the capabilities required to support the Latency/Throughput Critical (LTC) delivery requirements as defined in Chapter 26, Section 26.3.1. The DAU is an EndNode that acquires data and publishes the data via TmNSDataMessages onto the network. The TmNSDataMessage structure is defined in Chapter 24.2*. The Network DAU also requires an IEEE 1588-2008 slave clock for precise time synchronization for message timestamping. The Network DAU is manageable via SNMP through the management resources defined in Chapter 25, is configurable using an MDL Instance Document in accordance with the MDL Schema defined in Chapter 23, conforms to DiffServ, supports LTCDataSource functionality, and implements an IEEE 1588-2008 slave clock. The DAU CSCI consumes data from various acquisition sources for a particular DAU as assembled based on the test mission requirements. The specific requirements for acquisition sources are heavily dependent on the supplier's catalog of acquisition modules. The MDL has the expressive language to configure these acquisition sources such that the capabilities/features are retained in a Network DAU implementation.

DAU Logical Interfaces

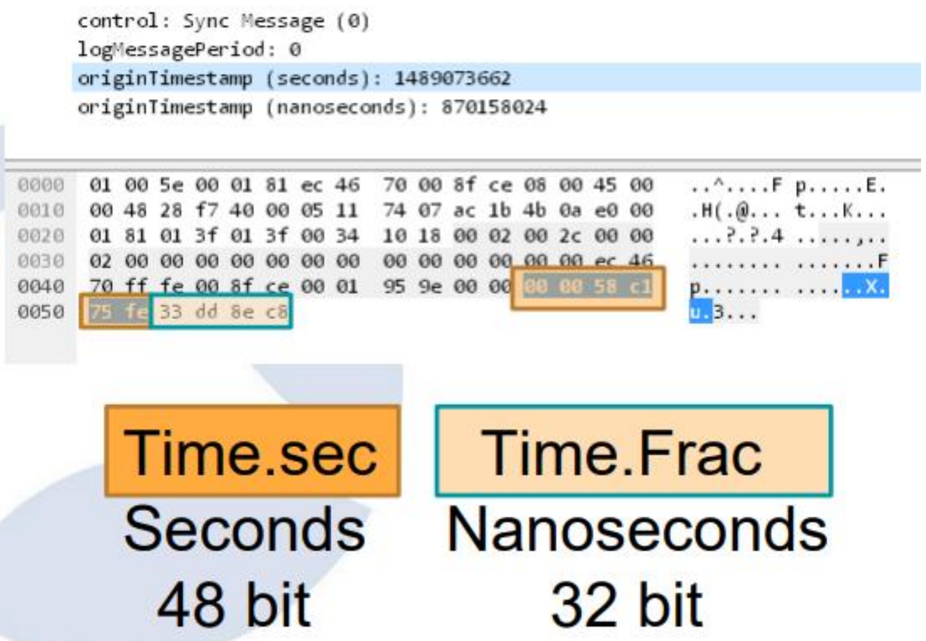


IEEE 1588-2008 Precision Time Protocol (PTP)

- Sub-microsecond synchronization of real-time clocks in components of a networked distributed measurement and control system
- Key point is synchronization so that each node on the network operates on the same time clock
- Every node must support a real-time clock
- Data Acquisition Units (DAUs) time tag measurements at the source and send that along with the data
- GPS used to synchronize GrandMaster Clocks and serves as the common time reference

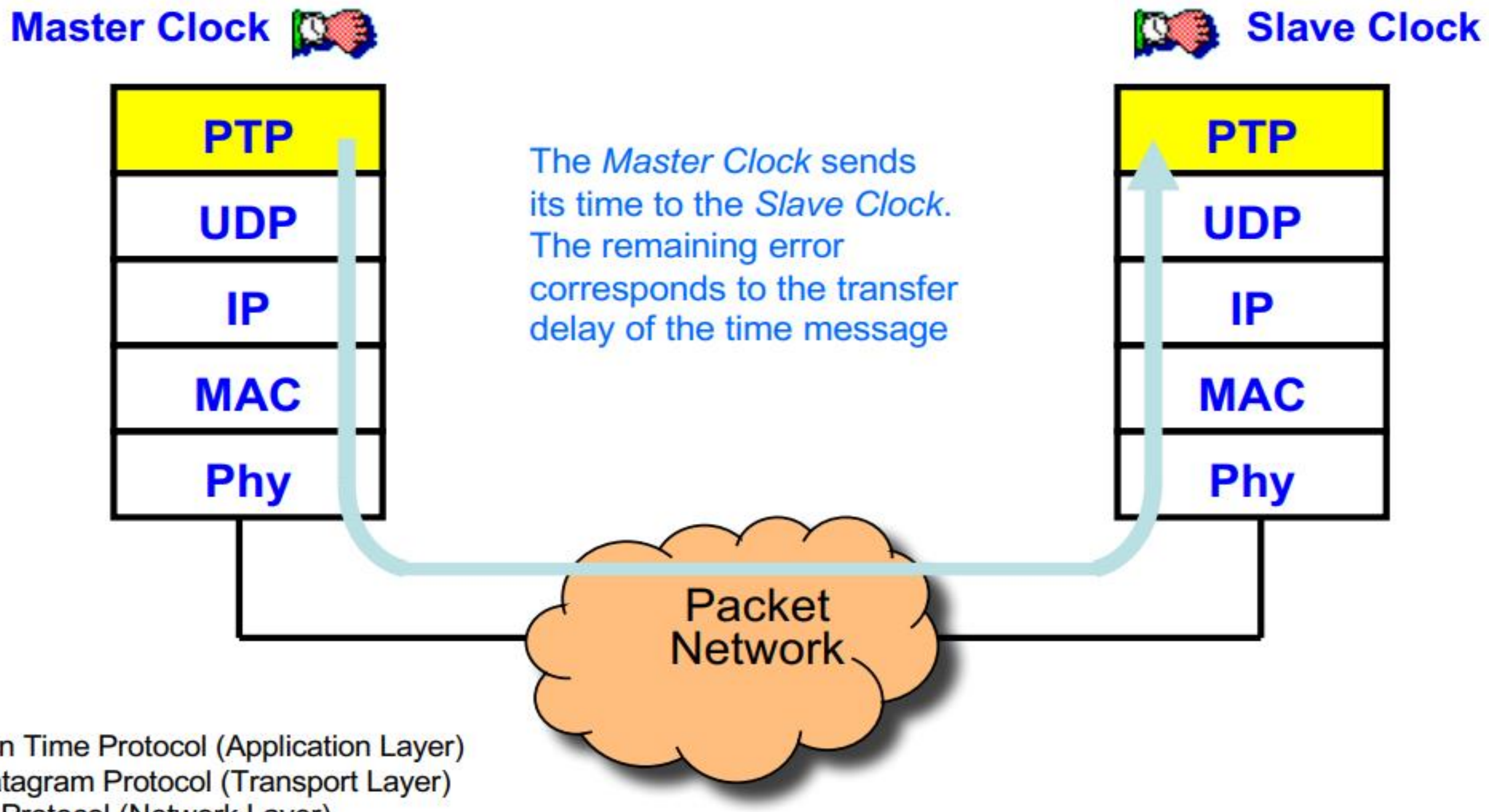
PTP Timestamps

- PTP use 80 bit-Timestamps
  - They consist of a 48-bit part for seconds and a 32-bit part for nanosecond
  - The time scale rolls over every 2^{48} seconds (8.925.512 years)
  - Theoretical resolution of 2^{32} nanoseconds
  - Timescale from TAI
    - also alternative timescale possible



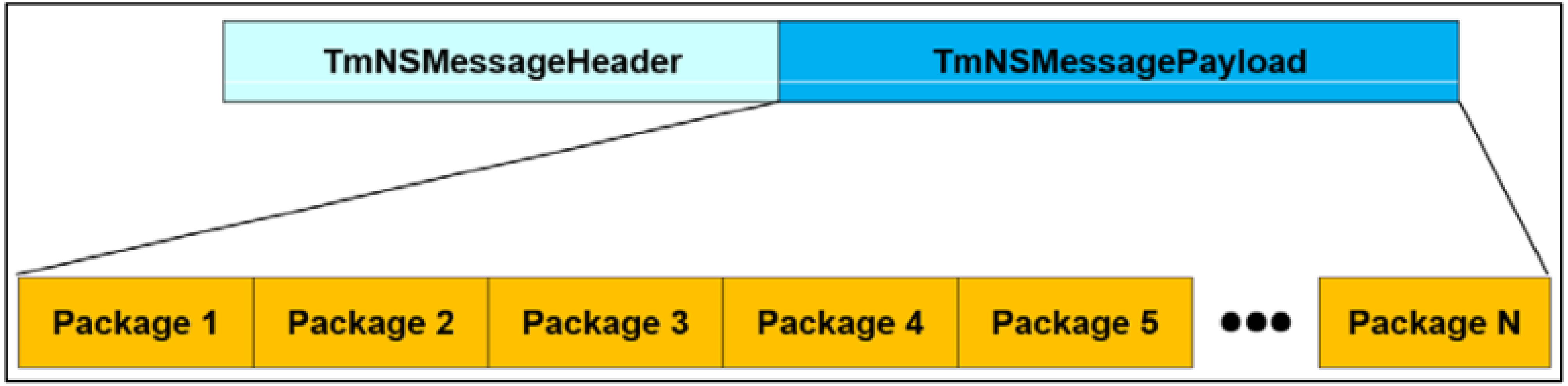
- IRIG 106 Chapter 11 Defines IEEE-1588 time as a 64-bit quantity with two 32-bit values for seconds and nanoseconds

Basic Operation of 1588 Clock Adjustment

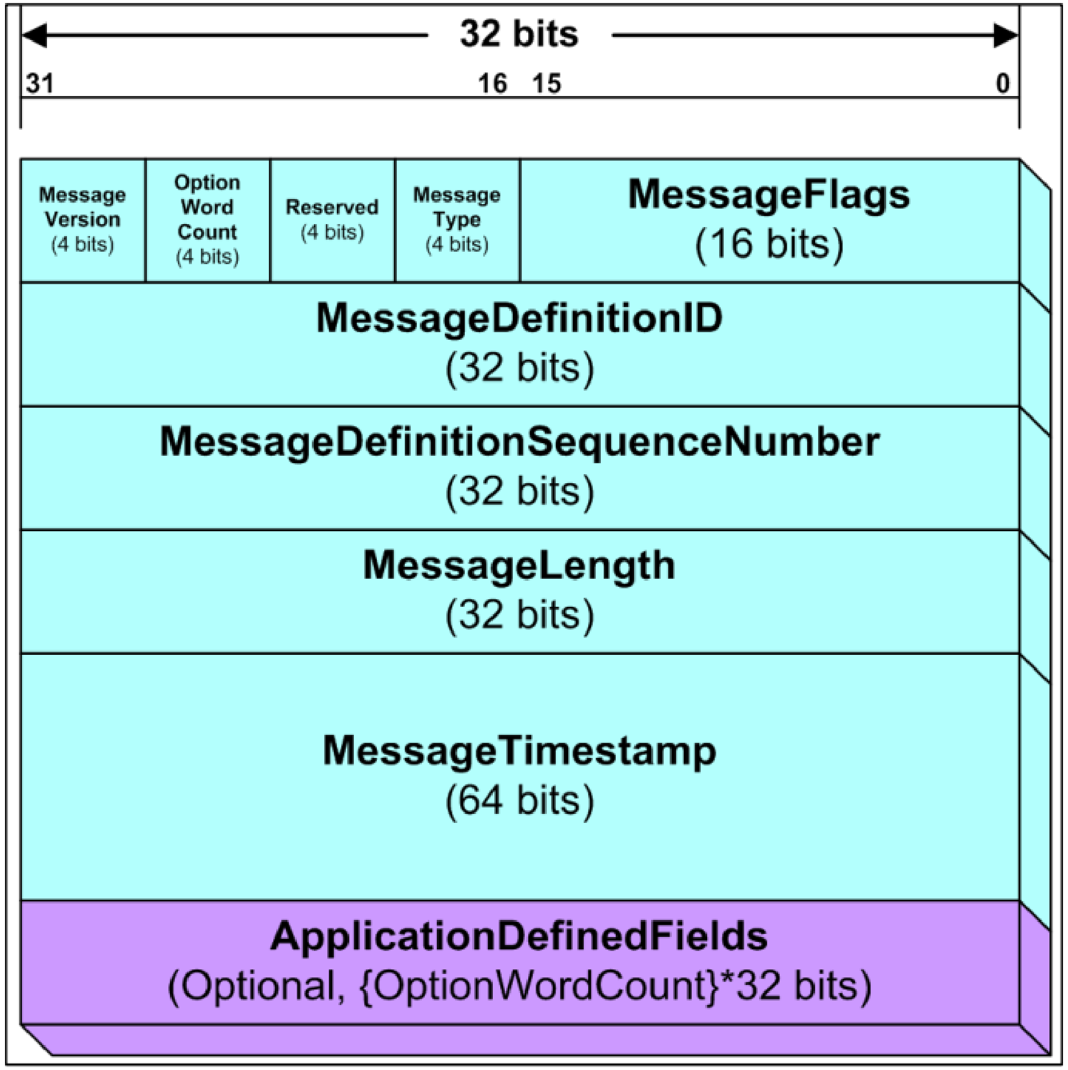


PTP : Precision Time Protocol (Application Layer)
UDP : User Datagram Protocol (Transport Layer)
IP : Internet Protocol (Network Layer)
MAC : Media Access Control
Phy : Physical Layer

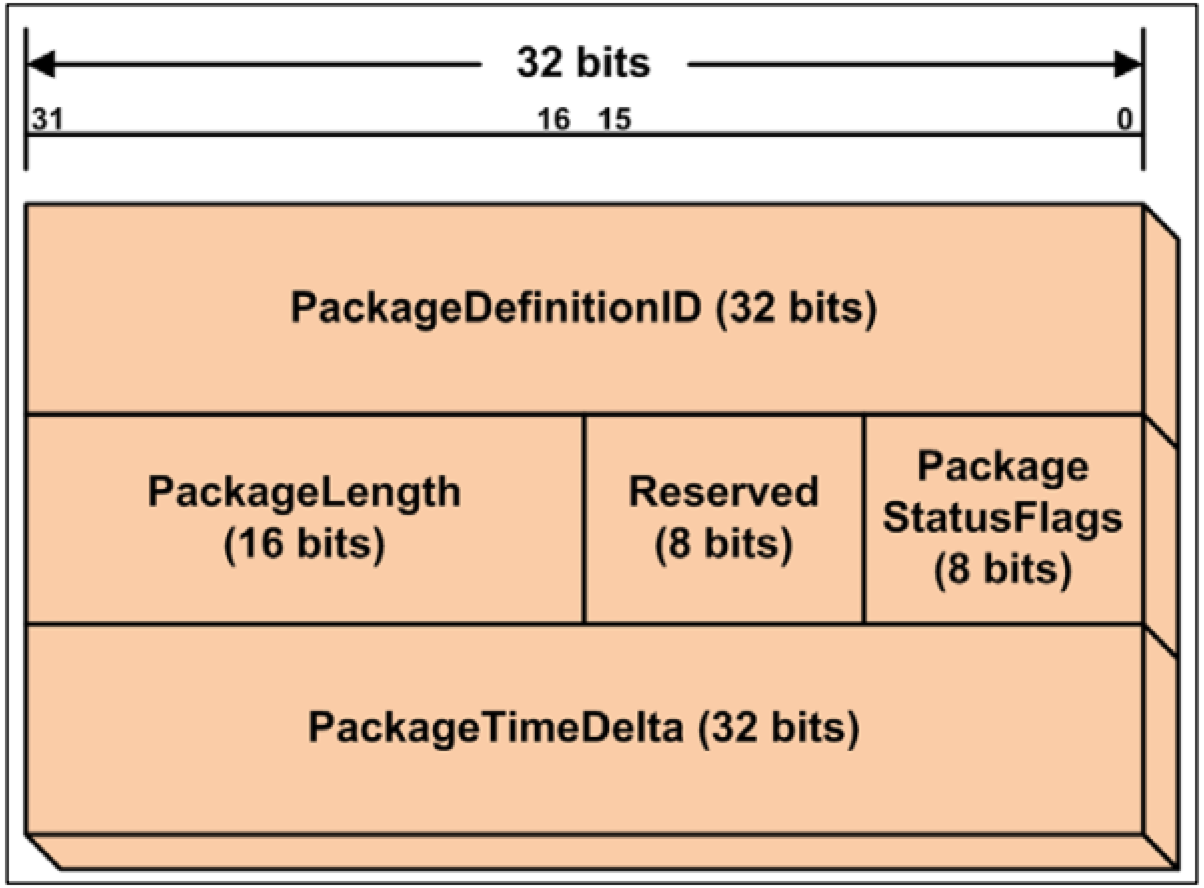
TmNS Message Structure



TmNS Message Header Structure



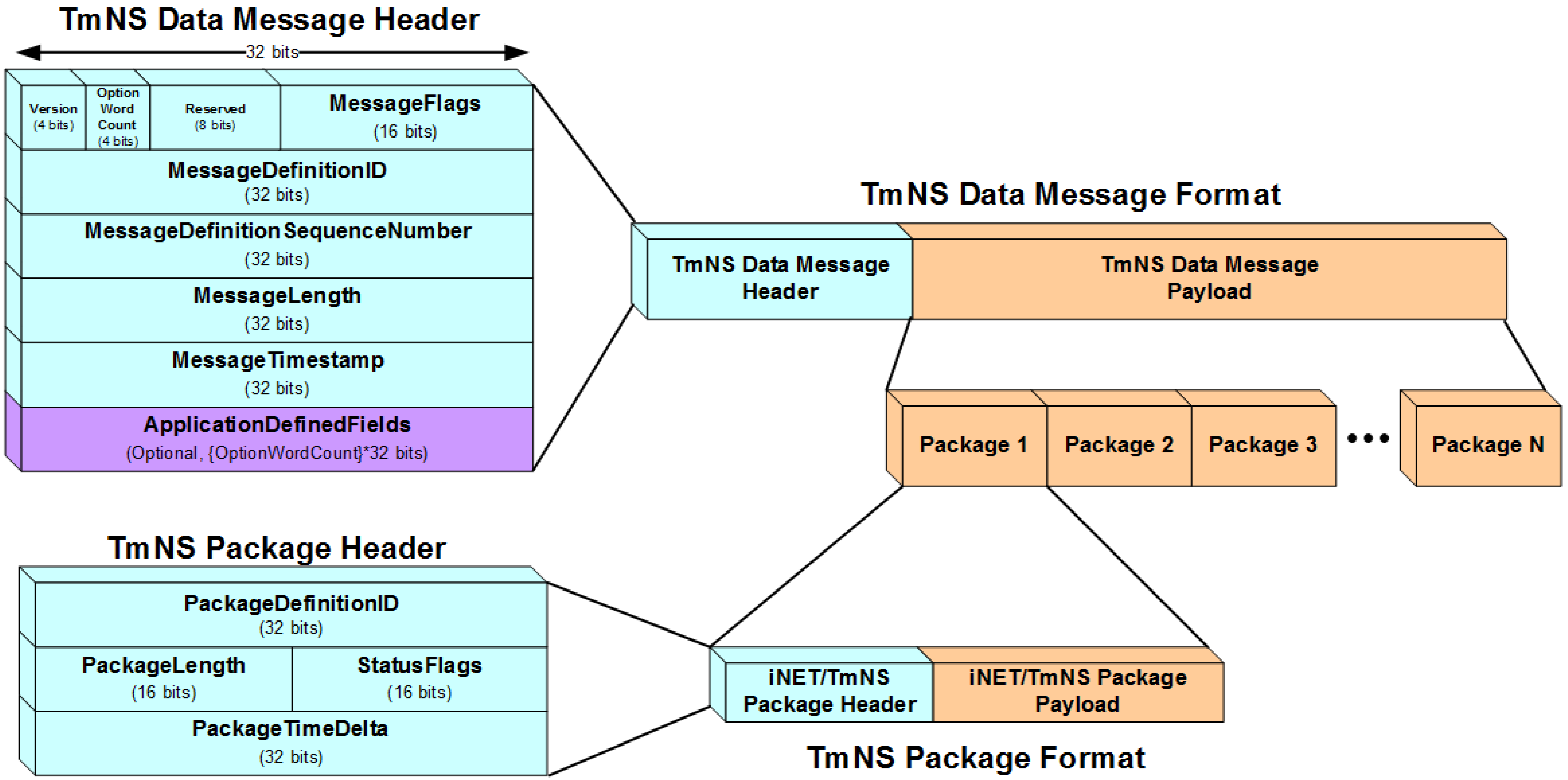
Package Header



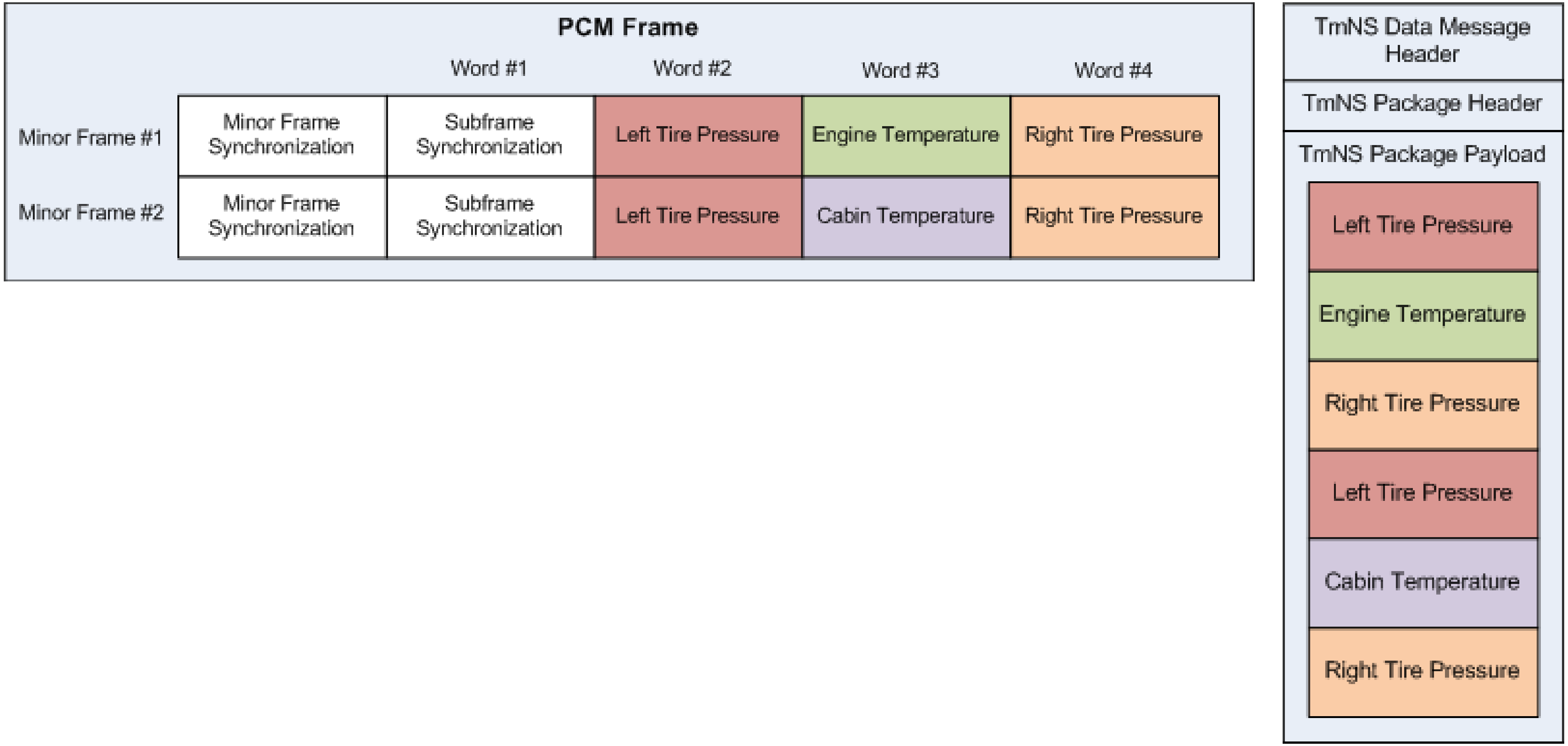
Package details

- Each Package shall include either a PackageHeader, a PackagePayload, or both.
- The PackageTimeDelta field shall provide the Package base time relative to the MessageTimestamp field in the TmNSDataMessageHeader. The value in the field shall be a non-negative integer that represents nanosecond resolution in the range of 0 to 232 – 1.

TmNS Messages carry Packages



PCM frame to TmNS Package



Multicast Data Delivery

- Motivation: efficient point-to-many conversation
  - Source from unique IP address
  - Destination to unique qroup as in 224.1.1.1, 224.0.0.1 – 239.255.255.255
- Designed for datagram (UDP) packets
- Consumers must subscribe to join a multicast group
- Uses setup protocol for routers (across subnet boundaries)
- Scales well (inter-networking) using IGMP snooping

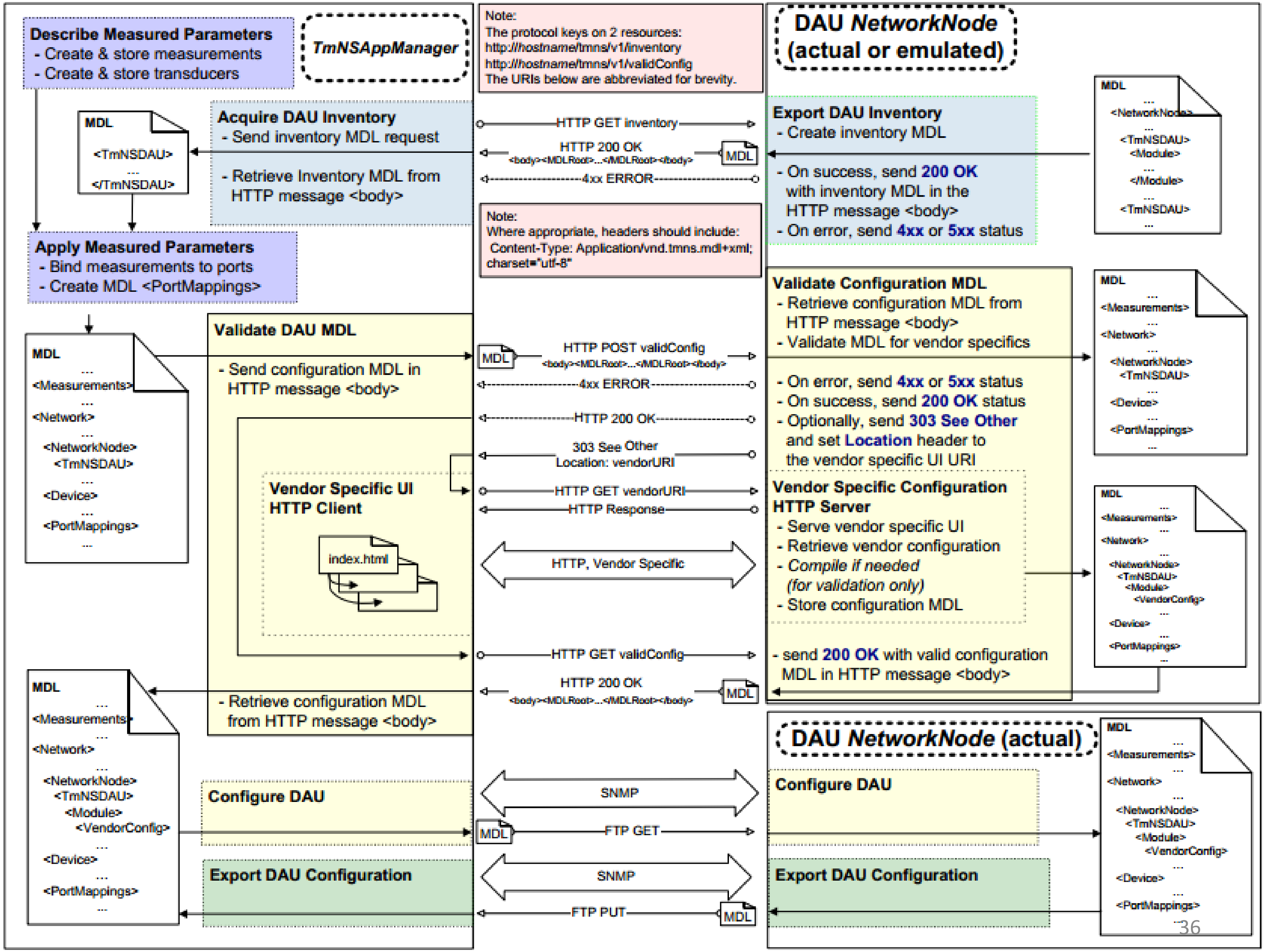
Device Configuration (section *25.4.3.1.1*)

- The *TMA* Configuration Protocol is a sequence of steps executed between a *TmNSApp* manager and a target *TMA* to configure the target *TMA* using an MDL instance document.
    1. The *TmNSApp* manager sets the **tmnsTmaCommon:tmnsTmaCommonConfiguration:configurationURI** resource on the target *TMA* to the location of the configuration file.
    2. The *TmNSApp* manager sets the **tmnsTmaCommon:tmnsTmaCommonConfiguration:configure** resource on the target *TMA* to “true”. Once a *TmNSApp* manager has set the **tmnsTmaCommon:tmnsTmaCommonConfiguration:configure** resource to “true”, any attempt by the *TmNSApp* manager to change the resource’s value shall be ignored until the target *TMA* has set the resource’s value to “false”.

Device management

- *25.4.3.1.2 Configuration Error Handling*
  - The *TMA* shall attempt to restore the previous configuration prior to the initiating of the configure attempt.
  - **configurationVersion** set to empty string, **tmaStateString** set to "unconfigured"
- *25.4.3.2.1 Export Configuration File Protocol for TMAs*
  - A successfully exported MDL instance document from a *TMA* shall be capable of reconfiguring the original *TMA* into the configuration state at the time of the export process.
- *25.4.3.2.2 Export Log File Protocol for TMAs*

From Chapter 25 TmNS Configuration Negotiation Protocol Diagram



Questions?