RANGE COMMANDER'S COUNCIL (RCC) TELECOMMUNICATIONS AND TIMING GROUP (TTG) UPDATE ON TM OVER IP STANDARD DEVELOPMENT

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ABSTRACT

The RCC TTG initiated task TT-49 to generate a standard for the transport of serial streaming telemetry (TM) over the Internet Protocol (IP). An ad hoc committee was activated comprised of Range and vendor participation to develop this standard. This paper will address the progress of the standard, the use of commercial standards, and the benefits to the ranges. The early meetings focused on developing the packet structure; the preliminary results will be presented along with the latest status on the RCC approval cycle.

KEY WORDS

Telemetry, Networks, Internet Protocol, Timing, IRIG 106

INTRODUCTION

The Range Commander's Council (RCC) Telecommunications and Timing Group (TTG) initiated an effort to standardize the transport of Inter-Range Instrumentation Group (IRIG) 106 Chapter 4 streaming telemetry over an Ethernet/Internet Protocol (IP) infrastructure. This paper describes the motivations for developing the standard, the boundaries of the standard, the challenges of the standard, and the standard currently being submitted for final approval.

Motivation for Telemetry Over IP (TMoIP)

IP technology is emerging as the packet technology of choice for a range of networking uses, from traditional data applications to real-time applications such as voice and video transport. With the maturation of IP solutions, it is envisioned that the developments supporting the transport of voice and video streams over IP networks can be employed to enable the transport of

TM streams over IP networks. The proliferation of IP networking results in increased performance and lower cost of equipment as economies of technical and manufacturing scale occur. Using these products in the Ground Network allows the user to exploit these economies to provide more powerful implementations at lower cost.

Another benefit of TMoIP comes in the form of operational support. Since IP is very widespread, the skill set of the operators becomes less specialized to support one more capability over the ubiquitous IP network. A technician trained in IP technology can be trained on TM as a new service and support the mission in a relatively short amount of time. This approach addresses perhaps the single biggest issue facing range managers today: the turnover of qualified people supporting the mission.

Challenges for TMoIP

A number of technical challenges must be addressed in the TMoIP implementation before the advantages of IP network integration can be obtained.

Downlink data may originate from a variety of sources: the launch vehicle, the payload, aircraft, ship, or weapon platform. Downlink data requirements are fairly common across DoD services and mission requirements (planes, missiles, rockets, ships, tanks, etc.) in that it is usually a serial stream, with the timing source typically implemented using an on-board oscillator.

Downlink data is handled in several ways. Many operations require the recording of data at the receiving site to preserve information at the earliest ground based opportunity to ensure all data is available; others record at the data processing equipment location. Many missions support on-board recording for post-flight and only use the ground based recording in case the on-board copy is corrupted or worse. During the real-time test there is typically no time or available bandwidth for re-transmission on errors.

Difficulties arise when transmitting this type of data across a network with different timing characteristics than that of the source TM stream. This has been the challenge with TM since the beginning of real-time mission support. The isochronous nature of the TM stream using the on-board oscillator can be exacerbated by a number of causes that can impact timing, including Doppler and multi-path effects. Given the critical nature of the timing information contained in the source TM stream, it is important that the TMoIP solution address the requirement to accurately and reliably transport and regenerate the source TM timing across the network.

The requirement for delay is very subjective. Most users will say “as fast as possible” without being able to quantify. Typically, the most stringent requirement on delay is either voice or range safety. Standard Range Safety requirements state that from an event on the vehicle to the time the flight termination system (FTS) command is received at the vehicle shall not exceed 1 second, not counting 3 seconds allotted for human processing. That often translates into a requirements allocation of 100 milliseconds (msec) or less for the transmission of data from the receiving station to the data processing building. In the case of voice, audio embedded in the TM stream is often used to communicate with the test personnel as a hot-microphone. If the TM is delayed, an uncomfortable pause is noticed in the conversation and echo must be removed when the UHF/VHF radio is used on the ground. As echo cancellers can be used for the delay, the uncomfortable pause is the driving factor and requires a delay not to exceed 100 msec.

Path delay control mechanisms provide alignment of TM streams in the following scenarios:

- A single TM stream enters the network at different points and is received at a single site. Due to the differential path delays, the multiple receive streams must be re-aligned.
- A number of TM streams enter the network at different points and are received at a single site. Again, due to the different path delays, these streams must be aligned so that the data corresponds in time.
- A number of TM streams of diverse rates enter the network and are received at a single site. Due to the differential delays introduced by packetizing each stream, the streams must be aligned to enable the data points to correspond in time.

Potentially the biggest issue with providing a successful TMoIP solution is that IP is a best effort service without guaranteed service delivery. The goal of the TMoIP is to enable the use of Quality of Service (QoS) mechanisms that are available in Commercial-Off-The-Shelf (COTS) network equipment. Providing guidance for the provision of effective QoS is an important part of the TMoIP solution.

TELEMETRY SYSTEM OVERVIEW

Telemetry is the method of getting data from vehicles during operational launches, test missions, and a variety of other applications. The elements of a generic TM system are shown in Figure 1.

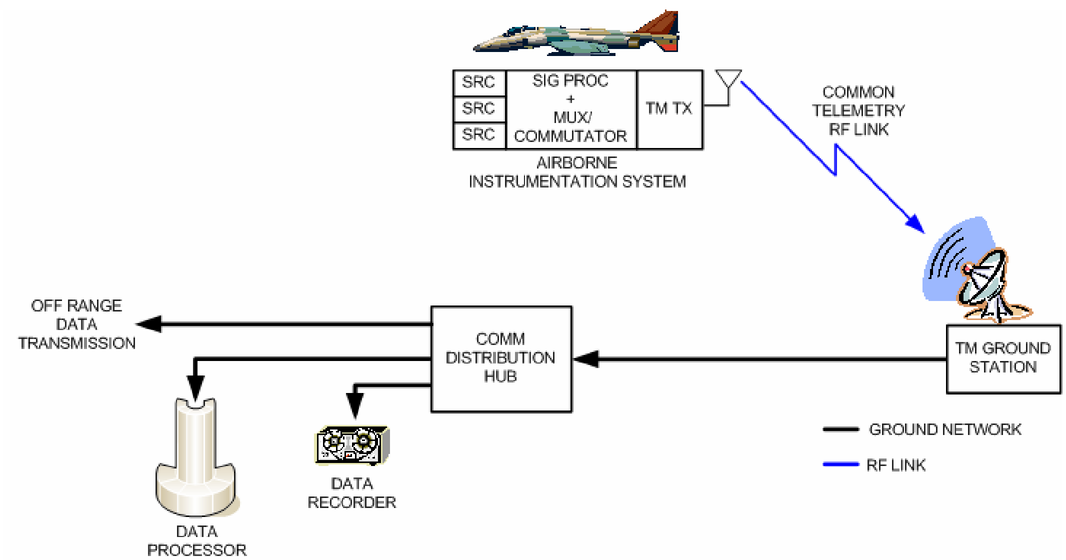

Figure 1 -- Reference Telemetry System

The five segments of a TM system are:

1. Airborne Instrumentation System
2. RF Link
3. TM Ground Station
4. Ground Network
5. Communications Distribution Hub and End Users

The overall goal is to get information that characterizes the operation of the vehicle to the engineers and end users who need it. If any one of these segments does not function correctly, the data will not be available when required.

Ground Network

The focus of this standard is to address the transmission of data over the Ground Network. The Ground Network provides distribution of the TM streams from the TM Ground Station to destinations that require the TM stream for analysis, storage, and monitoring.

The TM Ground Station is connected to the Communications Distribution Hub. The function of the Communications Distribution Hub is to forward the TM streams to the required end stations. The end stations can provide recording capability (Data Recorder), analysis and post-processing (Data Processor) or they can be off range locations (Off Range Data Transmission).

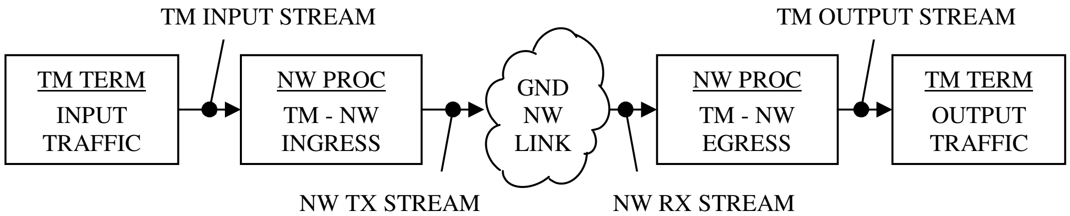

Figure 2 -- Ground Network Functional Blocks

A model for the Ground Network function is shown in Figure 2. There are three basic functional blocks associated with the Ground Network that participate in TM stream transport: the TM Terminal, the Network Processor, and the Ground Network Link.

TM Terminal (TM TERM)

The TM Terminal functional block provides connectivity to the native TM stream. At the network ingress, the TM Terminal block provides the TM Input Stream to the Network Processor block for transport via the Ground Network. At the network egress, the Network Processor receives the Network Rx Stream, generates the TM Output stream and sends it to the TM Terminal.

Network Processor (NW PROC)

The Network Processor provides different functionality depending upon its location relative to the Ground Network. At the ingress to the Ground Network, the Network Processor receives the TM Input Stream and provides the required formatting and adaptation to enable transport over the Ground Network Link. The end result of the Network Processor is the Network Tx Stream.

At the Ground Network Link egress, the Network Processor receives the Network Rx stream and performs the inverse formatting process to recover the TM stream. An additional important function of the Network Processor at the Ground Network Link egress is to recover the TM clock information such that the TM Output Stream has timing characteristics identical to the TM Input Stream.

Ground Network Link (GND NW LINK)
The Ground Network Link provides the actual transport that carries the Network Stream between locations. The goal of the Network Processor and Ground Network Link is to provide seamless transport for the TM stream. Ideally, the TM Output Stream should be identical to the TM Input stream except for the delay introduced by the transport process. The Ground Network has evolved over time from proprietary dark fiber and Time Division Multiplexing solutions, to **Asynchronous Transfer Mode** (ATM)-based solutions with limited interoperability, and finally to the emerging IP-based solution.

Asynchronous Transfer Mode is a protocol where data traffic is formatted into fixed length (48 data bytes + 5 bytes of header) packets for transmission through the network. ATM lends itself well to the transport of TM streams due to the following properties:

1. Through the Circuit Emulation mechanism, ATM supports transport of streaming serial or time division multiplexing (TDM) streams
2. The small fixed packet size produces minimal cell jitter
3. ATM supports built-in QoS mechanisms to ensure timely packet delivery

Internet Protocol (IP) traffic is formatted into variable-length packets, referred to as datagrams, but in contrast to the ATM protocol, the packet size can vary from 64 to 1536 bytes.

The goal of this standard is to provide a set of standard mechanisms to enable the transport of native TM streams over an IP-based network. Collectively, these mechanisms define the TMoIP implementation. The scope of this effort is the Ground Network segment of a total TM system, with the objective to identify the required functionality in the Network Processor and Ground Network segments to provide efficient and reliable delivery of TM streams over IP networks.

Overview of the TMoIP Document

The goal of this effort is to provide specifications and guidance for the Ground Network function, that includes the TM terminal, Network Processor, and Ground Network subsystems of a TM range network. The intention is to make use of existing standards wherever possible. The TMoIP solution addresses the following elements of the Ground Network (see Figure 2).

TM Terminal
The scope of this effort is to define the range of TM stream types to be supported, including the characteristics associated with Layer 1 (Physical Layer) of the Open Standard Interconnect (OSI) model.

Network Processor
The Network Processor furnishes the bulk of the TMoIP solution, and consists of the interface to the TM Terminal, the TM stream processing, and the interface to the Ground Network. The scope of this effort is to define the requirements for the Network Processor associated with OSI Layers 7 through 1.

Ground Network

The Ground Network provides IP network connectivity and transport of the TM-bearing IP traffic. It includes the network end equipment, typically an IP switch or router, and the interconnecting network.

TMoIP PAYLOAD CONSTRUCTION

The standard describes the TMoIP payload details. A payload structure is defined in that it provides sufficient flexibility to allow the user to optimize for payload efficiency and different network topologies, yet provides inter-working capability between different vendors. The TMoIP solution addresses the requirement to accurately and reliably regenerate the source TM timing at the network receiver by including objective specifications for the performance of the clock regeneration function. The TMoIP solution recommends mechanisms to control path delay, as well as the capability to provide the alignment of TM streams.

The standard defines management elements to enable status reporting, configuration, and integration with the end equipment that, with the TM Terminal, comprises the Ground Network.

High Level Requirements

For a full understanding of the TMoIP requirements, the major user operational requirements are summarized below. These high level requirements drive each of the detailed specification requirements. The TMoIP solution must solve the following operational problems:

- Accurately and reliably transport and regenerate the source TM data and timing across the network.
- Support an Encode/Decode latency of 100 msecs from the receiving station to the data processing location (including transmission time).
- Enable the use of QoS mechanisms that are available in COTS network equipment..
- Support additional management via out of band protocols such as Simple Network Management Protocol (SNMP).

OSI Layered Approach

The OSI protocols are a family of information exchange standards. The OSI model describes seven layers of interconnection: the physical layer, the data link layer, the network layer, the transport layer, the session layer, the presentation layer, and the application layer.

For purposes of defining the TMoIP payload, the TMoIP interface standard identifies the interface requirements as they relate to the OSI protocol layers for the TM Terminal and NW Processor functional blocks that were defined in Figure 2.

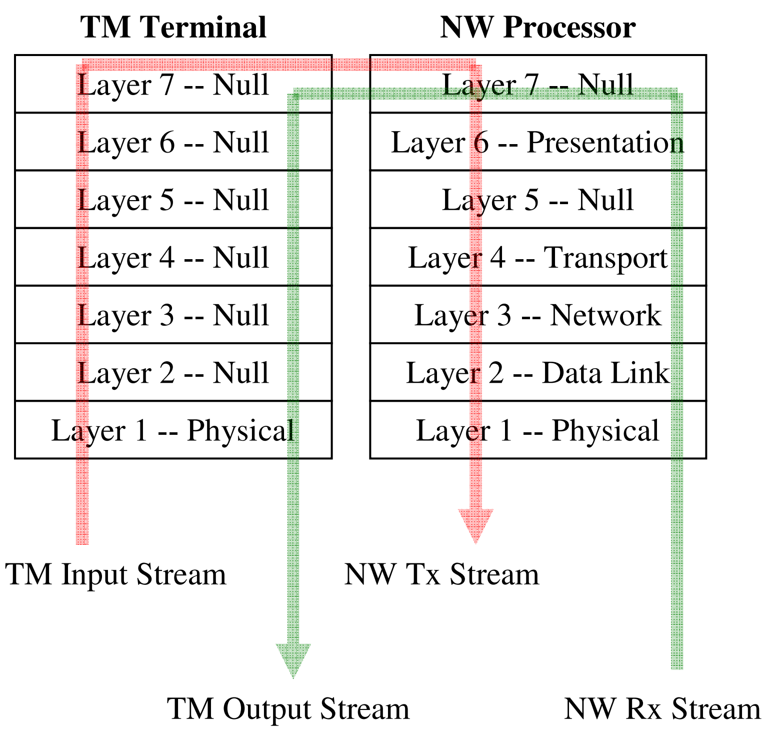

Figure 3 -- OSI Layers for TM Terminal and NW Processor

Figure 3 describes the OSI layer structure for the TM Terminal and NW Processor functions for the TMoIP data plane. A red line traces the path of a source TM stream (TM Input Stream) from Layer 1 of the TM Terminal to the Network Processor where ultimately the Network Tx Stream is produced for transport via the IP network. Conversely, the green line is the path of the IP traffic (NW Rx Stream) through the Network Processor to the TM Terminal, where it finally appears as the TM Output Stream.

The TM Terminal implements a single layer in the OSI model, Layer 1, with Layers 2 through 7 null layers. The Network Processor implements Layer 6 and Layers 4 through 1 of the OSI model, with Layers 5 and 7 null layers.

TMoIP Control Word

The TMoIP Control Word, shown in Figure 4, is pre-pended to the raw packet payload and supports the following functions:

- Detection of packet loss or packets out of ordering

- Ability to identify failures in local TM interface
- Fault signaling capability across the network

RES	L	R	M	RES	LEN	SEQ NUMBER

Figure 4 -- TMoIP Control Word

The TMoIP Control Word fields are defined in Table 1 below:

Table 1 -- TMoIP Control Word

Field	**Bits**	**Description**
RES	4	Reserved, code to "0000"
L	1	Local Defect Alarm, indicates local circuit fault in the TM stream
R	1	Remote Defect Alarm, indicates remote circuit fault in the TM stream
M	2	Local Defect Alarm Modifier
RES	2	Reserved
LEN	6	If non-zero, LEN indicates TMoIP Payload Length, defined as the TMoIP Control Word + Raw Packet Payload If zero, LEN indicates TMoIP Payload Length greater than 63 bytes. In this case the TMoIP payload length is determined via length fields in lower protocol layers.
SEQ NUMBER	16	Sequence Number

TMoIP Packet Design Summary

The TMoIP packet layout is shown in Figure 5 below. Each protocol layer adds overhead information to the TMoIP payload, resulting in the final TMoIP packet configuration. This packet structure is based on Internet Engineering Task Force (IETF) draft document draft-ietf-pwe3-tdmoip.

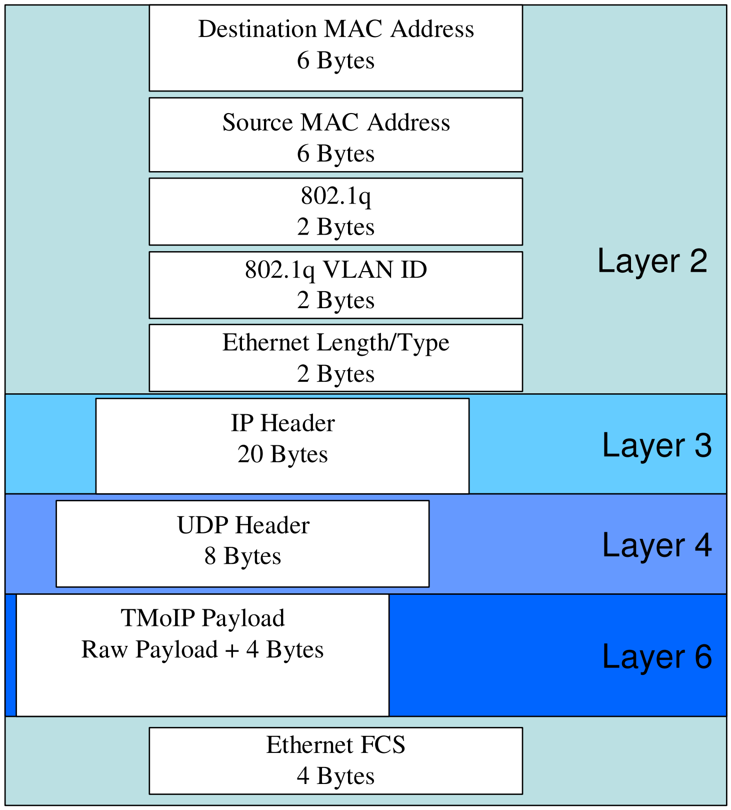

Figure 5 -- TMoIP Packet Layout

The field descriptions for the TMoIP packet are summarized in Table 1 below.

Table 1 -- TMoIP Packet Summary				
Field	**Description**		**Len**	**P/C/F** [1]
Ethernet Dest Addr	Identifies station(s) to receive frame		6	P
Ethernet Src Addr	Identifies station that originated frame		6	C
802.1q Length/Type	VLAN tag length/type		2	F = 0x8100
VLAN Tag Ctl Info	Bit	Description	2	
	0 - 2	User Priority Field		P
	3	Canonical Format Indicator (CFI)		F = 0
	4 - 15	VLAN Identifier (VID)		P
Length/Type			2	F = 0x0800
IP Header	Byte	Description		
	1	Version + IP header length	1	F = 0x45
20 Bytes Total	2	TOS	1	P
	3 – 4	Total length of IP packet	2	C
	5 – 6	16 bit ID	2	C/F
	7 – 8	Flags + Fragment Offset	2	F
	9	TTL	1	F/P
	10	Protocol (UDP)	1	F = 0x11
	11- 12	IP Header checksum	2	C
	13 – 16	Source IP address	4	P
	17 – 20	Destination IP address	4	P
UDP Header	Byte	Description		
	1 - 2	Source Port	2	F/P
8 Bytes Total	3 - 4	Destination Port	2	F/P
	5 – 6	UDP Length	2	C
	7 - 8	UDP Checksum	2	C
Payload	TMoIP Control Word		4	C
	TM Raw Packet Data		Note 2	C
Ethernet FCS	Ethernet Frame Check Sequence		4	C

Notes: 1. P = Programmable by user
2. C = Calculated or placed in packet without user intervention
3. F = Fixed

The following packet constraints have been identified:

1. Ethernet PDU maximum size 1518 bytes
2. Total packet overhead for Layer 2, Layer 3 and Layer 4 is 46 bytes without 802.1q tagging support, and 50 bytes with 802.1 tagging support.

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