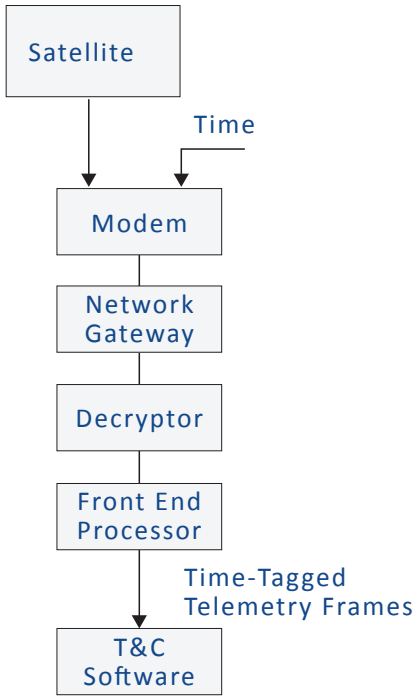
Part 1 - Introduction and Telemetry Flow

Introduction

Time-tagging of satellite telemetry assigns a timestamp to each minor frame or transfer frame. Depending on the accuracy requirements, a range of techniques can be used to correlate time with each telemetry frame.

Mission control center software uses the ground arrival time of downlink telemetry to archive telemetry measurands, detect missing frames, support anomaly resolution, and in some cases, calculate the on-orbit time for the telemetry points. Most satellite systems embed on-orbit time within the downlink data, and this time information is used for the payload and state-of-heath processing.

Depending on the operational use and required accuracy, the time-tagging of satellite telemetry can range from simple to sophisticated. Simple schemes assign a time to when the decrypted and synchronized telemetry frame is received by the T&C software. More sophisticated methods assign a timestamp that matches the ground arrival time of the frame's first bit with microsecond precision.



Telemetry Flow

The flow of telemetry data from spacecraft to T&C software follows a path with multiple processing steps, transport protocols, and format conversions. Understanding each of these helps with understanding telemetry time-tagging.

Telemetry data originates on the spacecraft, and the telemetry frames that contain this data are contiguous and of a fixed length, with each frame having a synchronization pattern at the beginning. The telemetry may be encrypted and then modulated for RF transmission.

The RF signal is received by a ground antenna where it is frequency converted and output to the modem. The modem demodulates the signal and bit synchronizes the data stream to recover the telemetry data bits.

Key issue -- If the downlink is encrypted, the modem has no ability to detect where each frame starts/ends in the steady stream of bits. The modem outputs the telemetry data in network packets at regular intervals or as a bit stream that is then formatted into network packets. These network packets pass over a wide area network to the control center. Here the data is passed through a decryptor and then to the front end processor (FEP).

With the data now decrypted, the FEP performs frame synchronization for each frame. These frames, along with their time-tag are passed in network packets to the T&C software.

Part 2 - Time-Tagging Basics

Simple Time-Tagging

A simple approach to time-tagging is sufficient for many satellite systems. The system time of the FEP Is synchronized to NTP (Network Time Protocol) and assigns the time to each minor frame as they are synchronized and sent to the T&C software. This timestamp is the time associated with the frame being processed. It does not represent the ground arrival time, that might be 1-2 seconds earlier in time.

The time tag does provide an accurate way to assign a relative time to each telemetry frame and to the telemetry measurands as they are repeatedly received in subsequent frames.

Legacy Time-Tagging

Many legacy systems transport the IRIG time data stream from the antenna site with the serial telemetry data. These streams are multiplexed together and then demultiplexed at the control center with some degree of time-data correlation. Time-data correlation means that the regenerated data streams and IRIG time data streams have the same time relationship to each other as when they were first multiplexed.

The IRIG time stream is sent to the FEP in parallel with the telemetry data flowing through the decryptor and then to the FEP's frame synchronizer. The IRIG time stream is decoded in the FEP and used as the time source for time-tagging the telemetry frames.

This time-tagging approach more closely approximates the ground arrival time, although it is skewed in time by the processing delay and jitter associated with the decryption and frame synchronization. The deterministic delays can be removed in the ground processing software.

Time Sources

The two most commonly used time sources are IRIG-B and NTP.

IRIG stands for Inter-Range Instrumentation Group and the IRIG standard defines various time formats for transferring timing information. IRIG-B is a format often used in legacy satellite ground systems. IRIG-B time generators are synchronized to the GPS timing signal, allowing them to effectively be synchronized across multiple physical locations. The IRIG-B output is an amplitude-modulated signal that must be decoded by an IRIG Time Processor in the FEP. The IRIG signal provides an accurate indicator at one second intervals, and the FEP's Time Processor runs a high stability internal oscillator and synchronizes its internal time counters to this time hack to provide sub-microsecond accuracies.

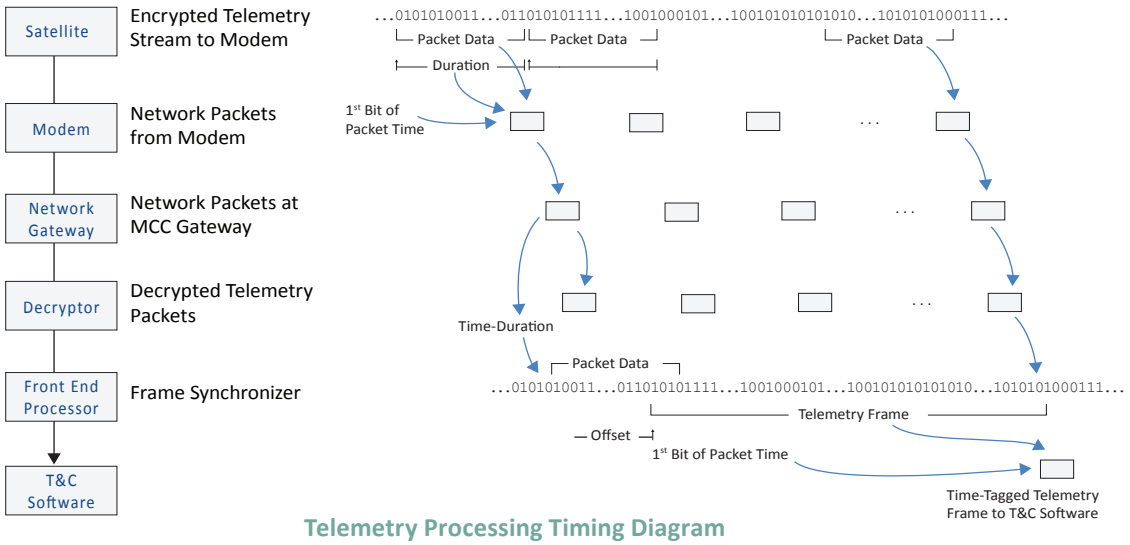
NTP is the acronym for Network Time Protocol. NTP enables clock synchronization between computer systems on a common network, synchronizing their system clocks to Coordinated Universal Time (UTC). NTP enables the various servers in the satellite ground system to maintain their system time to within a few milliseconds of each other.

Part 3 - Precision Time-Tagging

High Precision, High Accuracy Time-Tagging

Modern ground architectures may require a very precise timestamp, taking out the skew and jitter associated with transport and processing delay. The time-tagging approach must determine the exact arrival time at the remote antenna site of the leading edge of the first bit of each telemetry frame.

The modem outputs snippets of the telemetry data in packets and provides a precise timestamp for the first bit in each telemetry packet and the duration of the data in that packet. This time and duration information traverses the ground network in the same packet as the telemetry data snippet.



Telemetry Processing Timing Diagram

The network packets arrive at the control center after transport across the WAN. The Network Gateway accounts for the WAN delay, jitter in the packet arrival rate, and the potential for lost packets needing to be re-transmitted.

At the control center, the network gateway decouples the 1st bit time and packet duration information from the telemetry data. The telemetry data is decrypted and then re-joined in the FEP with the timing information thanks to synchronization between the Network Gateway and FEP.

As part of the frame synchronization process, the FEP interpolates between two time-stamps to determine the offset, and therefore, the time that corresponds to the first bit of the actual telemetry frame. This time-stamp is then sent with the telemetry frame to the T&C software.

Note that time-tag accuracies on the order of 50 microseconds and frame-to-frame variation of less than 1 microsecond can be achieved with this approach.

Can we help? AMERGINT's expertise is available to assist in your systems engineering and design

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