THE NEW GENERATION SPACECRAFT DATA SIMULATOR TO TEST LEVEL ZERO PROCESSING SYSTEMS

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ABSTRACT

Over the last several years, the Data Systems Technology Division (DSTD) at Goddard Space Flight Center (GSFC) has developed software tools to generate simulated spacecraft data to support the development, test, and verification of prototype and production of its Very Large Scale Integration (VLSI) telemetry data systems. Recently, these data simulation tools have demonstrated their versatility and flexibility in the testing and deployment of several very high performance Level Zero Processing (LZP) systems. Because LZP involves the wide scale reordering of transmitted telemetry data, the data simulation tools were required to create a number of very large and complex simulated data sets to effectively test these high rate systems. These data sets simulated spacecraft with numerous instrument data sources downlinking out-of-sequence and errored data streams. Simulated data streams were encapsulated in Consultative Committee for Space Data Systems (CCSDS) packet and NASCOM data formats.

The knowledge and expertise gained in the development of the current simulation tools has been used to develop a new generation data simulation tool, known as the Simulated Telemetry Generation (STGEN) package. STGEN is a menu driven

software package running on UNIX platforms that can implement dynamic test scenarios with very fast turn around times from the data set design to the data set generation. The error options and locations in the telemetry data stream are fed via simple programs which are in turn script-driven . Scripts are used to manipulate packets, frames, and permit error insertion more easily and quickly . This paper first describes the STGEN software package and its test data design strategies . It then provides an example of STGEN 's first usage in the testing of systems to support EOS-AM spacecraft. Finally, a description of future planned improvements and uses of STGEN are provided.

KEY WORDS

CCSDS, spacecraft telemetry data simulator, level-zero processing.

INTRODUCTION

What is our general requirement for a test data generation tool? It must be versatile enough to simulate realistic data scenarios to exercise all the functionality of NASA ground telemetry systems in a reasonable amount of time . This means that the tool has to be easy to use, powerful enough to simulate the actual data scenarios, and easily extensible to incorporate new functions as testing needs change .

One guiding principle was followed in the development of Simulated Telemetry Generation (STGEN) package that helped accomplish many of these goals . This principle was to make simulated data generation roughly model the way that real data is generated on a spacecraft. STGEN was developed from a collection of object-like programs that mimicked spacecraft data handling subsystems . By piecing together a number of these programs through scripts, realistic data streams of any number of different spacecraft could be created . This approach has several additional advantages including the ability to easily add tests for new spacecraft data handling functions without major redevelopment.

As new spacecraft data handling functions evolve, new STGEN programs can be created. For example, a program exists that simulates the generation of protocol and 'pseudo-data' of an on-board instrument . The output of such a program is a sequence of Consultative Committee for Space Data Systems (CCSDS) packets . Several instances of these programs called from a script would feed a program that multiplexed packets and encapsulated them into frames . As new spacecraft functions drive the need for new testing of ground telemetry data system, new STGEN programs can be developed to model data handling subsystems.

Since STGEN was chartered to test NASA ground telemetry systems, it is at present script-driven to generate the various data products needed for testing . The data products used for testing the systems produced by the Data Systems Technology Division (DSTD), are CCSDS compliant frames and packets . There is a charter to test non-CCSDS data formats, and other data products which are at present partly being handled by previous simulators, and will eventually be incorporated in to the next generation of STGEN.

BACKGROUND

The CCSDS data formats are an internationally accepted set of protocols for the encapsulation and encoding of uplink and downlink spacecraft command and telemetry. These data protocols employ the concept of partitioning physical streams into multiple logical channels with one or more standard services prescribed for a given logical channel. These services accommodate large number of on-board sensors with a variety of data types including packet, voice, and video.

In the case of down-linked data, essentially raw sensor data is encapsulated in packets with a header which identifies the source of data, the type of data, the time when the reading was measured, and so on . The length of the packet is variable, and can be as small as 8 bytes or as large as 65536 bytes; however the size of the header is fixed . These packets can then be multiplexed with packets containing data from other sensors and encapsulated into fixed length frames . Frames are a higher level of encapsulation and are generally identified by a virtual channel which identifies the user services applied to the data . Virtual channels from different sources are then multiplexed to create a single physical channel . Figures 1-1 and 1-2 show the formation of the packet, multiplexed packet stream, frame, and the multiplexed frame stream generated on the spacecraft.

TESTING SCENARIO

The STGEN charter specifically calls for the design and generation of unique and complete data files that provide a complete solution for testing level-zero telemetry processing systems.

What does this charter entail ? The system tester has to develop a strategy to perform tests using a realistic data scenario that embodies the characteristics of the data.

- Test strategy: This specifies the functionality that has to be tested, and to what extent.

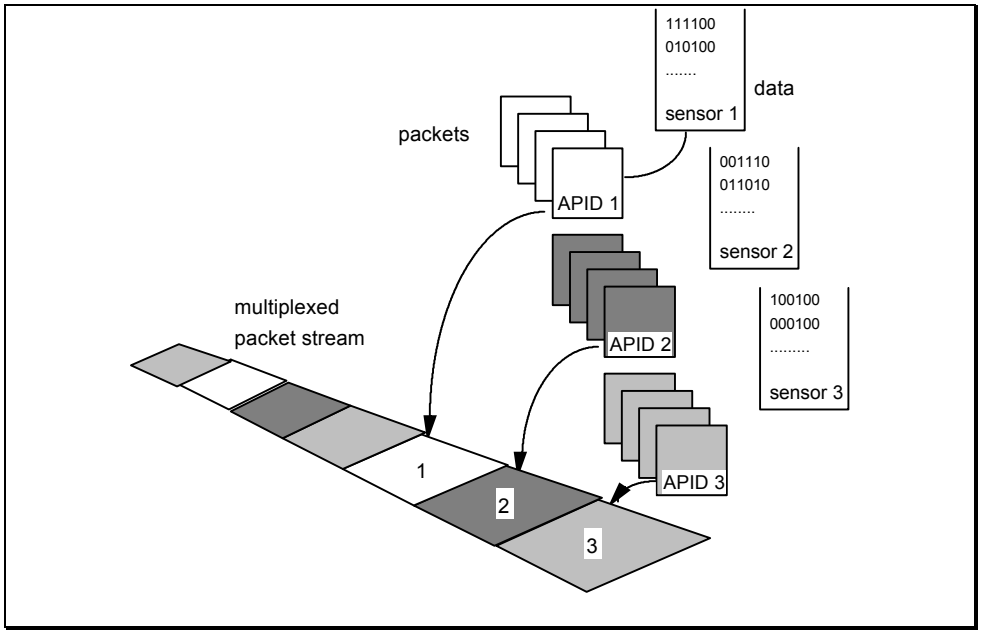

Figure 1-1 Packets and Multiplexed Packet Stream

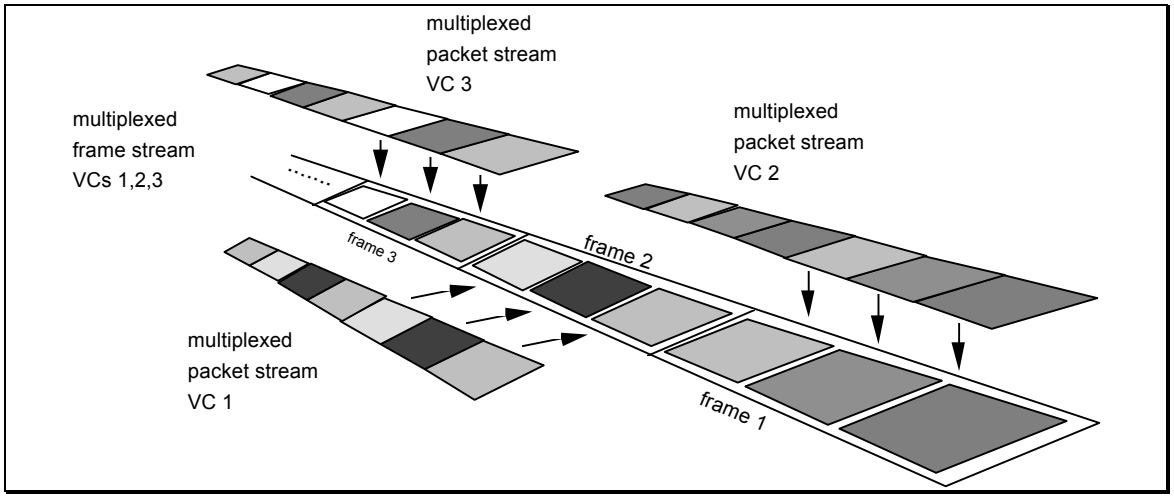

Figure 1-2 Multiplexed Frame Stream

- Data scenario: The data scenario replicates the order in which, and defines the content of the data downlinked or uplinked, and specifies as a minimum the following:
  - How many Data Units ?
  - How many Spacecraft Identities ?
  - How many Virtual Channels ?
  - How many Application Identities ?
  - Multiplexing scheme

- Data characteristics: This defines completely format and transmission characteristics of the data . A number of parameters have to be defined depending on the mission and include the following:

    - Highest level of encapsulation
    - Lowest level of encapsulation
    - Time code format
    - Sequencing format

To further demonstrate the versatility of STGEN, a typical testing scenario is described from the development of the testing strategy to a description of the final products from the simulator.

The following functions of a high speed VME-based level-zero processing telemetry system, used to capture and process CCSDS packetized telemetry from a low-earth orbit satellite were tested:

- Frame synchronization strategy
- Reed-Solomon decoding process
- Frame and packet processing functions
- Data product annotation process
- Data distribution process
- Packet input and output process
- On-board data simulation process

The format of the test data to be generated for testing the system are defined as follows.

> CCSDS Version 2 Frames, containing multiple Virtual Channel Identifiers (VCIDs) and multiple Spacecraft Identifiers (SCIDs), which are Reed-Solomon encoded, interleave level 4, frame length 1024 bytes with a 32-bit synchronization pattern.
>
> CCSDS Version 1 Packets with multiple Application Process Identifiers (APIDs) of sequence counts starting from 0, in 1 unit increments time code format, having the quicklook flag and checksum enabled with data patterns read in from external data pattern files.

The data scenario required these Version 2 frames to encapsulate forward ordered, sequential, Multiplexed Packet Data Units (MPDUs) consisting of CCSDS version 1 packets. The following specifications were levied on the test data:

- The minimum and maximum packets lengths are 64 and 775, from 62 sensors.
- The data is encapsulated in 8 VCs, where the VCIDs range from 35 - 52.
- The data is simulated from 3 spacecraft, where the SCIDs range from 21 - 26.
- The data stream size is 4 MBytes, and the downlink is simul ated at 50 Mbps.
- The minimum and maximum data rates per Virtual Channel (VC) are 0.72 and 21.5 Mbps.

The sources are identified by the APIDs, VCIDs, and SCID . However at the packet level, they are only identified by their APID, their respective packet sizes, and the total quantities encapsulated in the respective VC in the CADU stream . Each virtual channel stream has the packets multiplexed in a user-specified configuration . A specialized format can be used for any particular source . For example, the tester may want to have more than one occurrence of a particular APID with either a different packet length or on a different virtual channel . The assembly of the packet will define the length and naming convention of each packet in the data stream.

It may be necessary to ensure that the maximum packet data rates and/or virtual channel data rates for the system under test are not exceeded . To ensure that this does not occur, the maximum number of frames of a particular virtual channel that can be grouped together is calculated.

Once the test data has been designed, the next step in the process is to generate the data. The process comprises the following steps:

- Generate the individual packets
- List the order of multiplexing the packets within a virtual channel and generate the MPDU Data Stream File for each virtual channel
- Generate scripts to insert errors in the MPDU Data Stream File to simulate packet level errors in packets on a virtual channel basis
- List the order of multiplexing the VCDUs within th e data stream, and generate the Channel Access Data Unit (CADU) Data Stream File
- Generate scripts to insert errors in the CADU Data Stream File to simulate frame level errors in frames
- Reed-Solomon Encode the CADU Data Stream File creating CVCDUs within the CADUs

- Generate scripts to insert errors in the test data after Reed-Solomon encoding to simulate transmission errors.

For the data scenario the output products from STGEN are packets (or PDUs), packet streams (or MPDUs), and frames (CADUs) . At each stage the output products are uniquely identified and the name/s of the files passed on to the next level of encapsulation. Figure 1-3 shows the simulated telemetry data stream .

CONCLUSION

This package was used to successfully system test the 150 Mbps EOS-AM Front-End System. The test data simulated the high rate and low rate science and house-keeping data generated and downlinked from the EOS-AM spacecraft . Scripts were generated to insert frame and packet level errors in to the test data to fully exercise the error detection capabilities of the system.

STGEN is being upgraded to generate most formats of telemetry data currently being used. In addition, it will have the capability to meet the future standards for telemetry data. This package will be optimized to be even more flexible in that any field can be manipulated for format and content . The upgrades will also support 4800-bit NASCOM Block level data and forward link telecommand and control data . The concept of modeling spacecraft data handling will not only provide the capability to generate sensor data to be downlinked from the spacecraft, but also generate simulated control and response data exchanged between the spacecraft and the ground system . The tester could generate equipment-specific scripts to automatically respond to STGEN generated simulated command and control data.

The STGEN upgrade will also include an intuitive Graphical User Interface (GUI) which will minimize setting up the specification and description of the test data . The user will be able to select the type of data packet and specify all the fields both in size and content. The tester will also be able to specify the fields and describe the content of all the fields for the next level of encapsulation using the GUI .

STGEN has decreased the test generation time by a factor of five over previous methods used in the DSTD . Not only can the data be generated faster, but the data files can be viewed and corrected more easily and quickly . The upgraded version of the STGEN is expected to reduce the data generation time by a factor of 40 . The system will also generate a file that will provide a signature to the data being generated in terms of content, size, error description, and other accounting statistics .

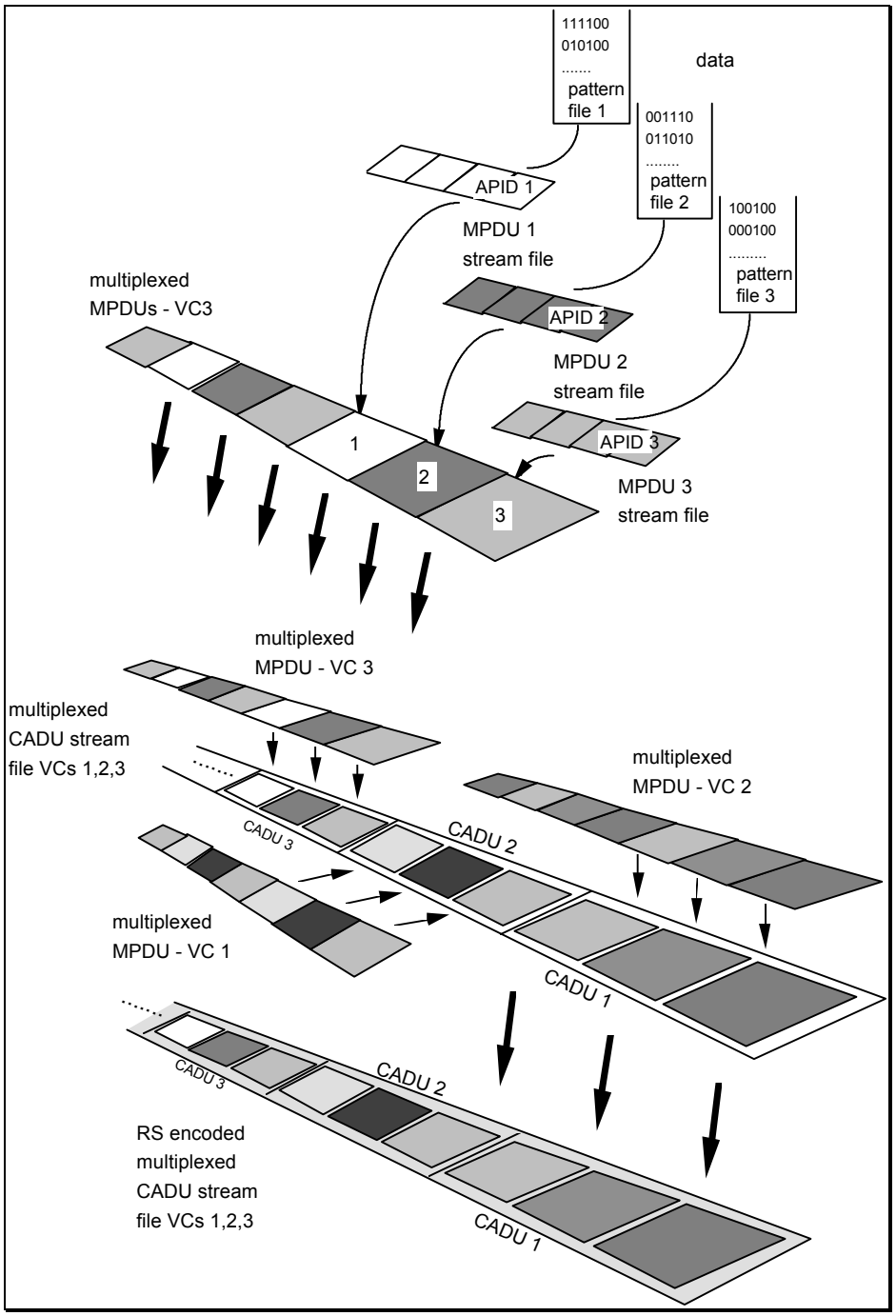

Figure 1-3 STGEN Simulated Test Data

To support automated test operations, STGEN will provide summaries of expected results for each test data file it generates .

The expected results will be stored in easily readable formats so that data verification tools can read them in for checking out test results . To ensure that the data scenario meets the expectation of the test case developer, STGEN will generate a 'pseudo-test

data file' whereby the expected results are printed out for the designed test data without actually generating the test data . This will enable the designer to make modifications to the data scenarios before actually generating the data.

NOMENCLATURE

APID	Application Identifier
CADU	Channel Access Data Unit
CCSDS	Consultative Committee for Space Data Systems
CVCDU	Coded Virtual Channel Data Unit
DSTD	Data Systems Technology Division
GSFC	Goddard Space Flight Center
GUI	Graphical User Interface
MPDU	Multiplexed Packet Data Units
PDU	Protocol Data Units
SCID	Spacecraft Identifier
STGEN	Spacecraft Telemetry Generation package
VC	Virtual Channel
VCDU	Virtual Channel Data Unit
VCID	Virtual Channel Identifier