Telemetry Best Source Selection at White Sands Missile Range

Richard (Ray) Engler
Johanna Kirby
Telemetry Data Center
System Engineering Branch
White Sands Missile Range, New Mexico

Keywords: Telemetry, Best Source Selector, Corrrelator, WSMR

Abstract:

Over the last year, the Telemetry Data Center at White Sands Missile Range has conducted extensive comparative testing between its' 20 year old Best Source Selector and several "off the shelf" selectors currently available. This paper explores the concerns involved in the process of selecting a new Best Source Selector and examines the inherent problems and differences associated with the old and new selectors.

Introduction

Telemetry Best Source Selection is a vital step of signal processing in many mission applications at White Sands Missile Range (WSMR). The Telemetry Data Center (TDC) at WSMR serves as the primary hub for a large array of telemetry sites. During operations, these telemetry sites are used to acquire a single/multiple object(s) as it flies over the range. The resultant telemetry streams are relayed to the TDC for real-time signal processing, providing data for flight safety, project personnel, go/no go indications and flight analysis. The Best Source Selector is intended to determine which of the telemetry streams tracking the test object(s) provide the best quality data at any given time.

The BSS

For many years, the TDC has employed a Best Source Selector (BSS) that essentially switches between input data streams. The BSS can be operated in either manual or auto mode. In the manual mode (fig 1), input data streams are selected by physically exercising a multiple-input / single-output switch.

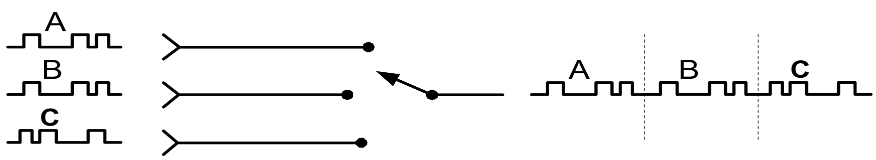

Figure 1 - Physical Best Source Selector

In auto mode (fig. 2), the switch process is based upon frame synchronization history and the duration of sync lock. Decommutators (decoms) are used to check the sync patterns of incoming telemetry streams. The BSS monitors each decom's sync lock status. A "locked" condition causes the decom to output a digital value of "1" to the BSS.

The BSS uses a counter to determine which of the input data streams had been "locked" the longest. Whenever an input stream loses lock, i.e. takes a "hit" to its sync pattern, its' counter is reset to zero. The best source output stream is analogous to a physical connection to the input stream with the longest contiguous "locked" condition.

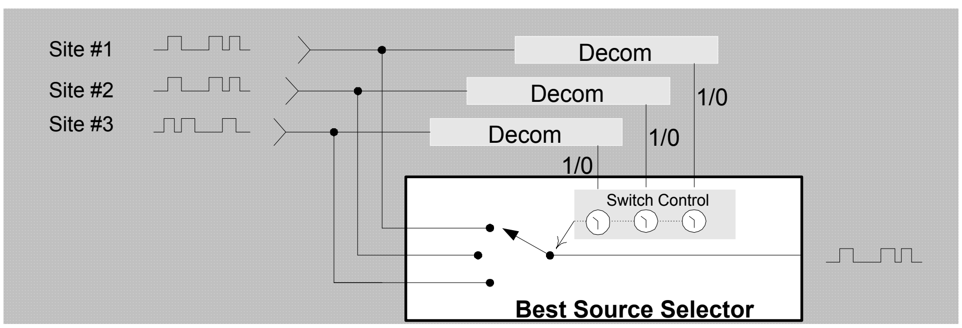

Figure 2 - Best Source Selector

BSS Drawbacks

The BSS has been in operation at TDC for about 20 years. Our BSS system was designed and built "in house" at TDC, and has worked exceptionally well. However, there are multiple problems inherent to the BSS that has made the search for a better system necessary.

1. The BSS inherently introduces corruption into the best source output stream. Since the BSS is analogous to a physical multiple-input/single-output switch, the best source output data stream takes a "hit" whenever a switch occurs between input streams. This occurs because the switch is not synchronous. As a result, the BSS output stream often contains more data drops than individual input streams.

2. Switching between input data streams is inherently vulnerable to latency problems. Since telemetry sites are strategically scattered throughout WSMR, there is a resultant.

time delay associated with each incoming stream The length of each delay, or data latency, is different for each site
Therefore, as the BSS switches between streams, the resultant output stream appears to jump forward or backward in time, depending upon the site selected (fig 3).

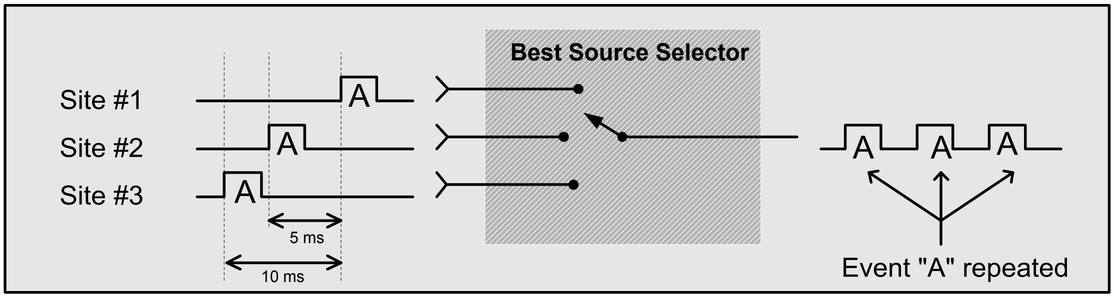

Figure 3 - Data Stream Latency

The physical switching characteristic of the BSS, combined with the effects of inherent data latency can cause the same event to appear twice on one Best Source Stream. It can also cause events to disappear completely.

3. The BSS switches only analog data. For many years, telemetry data at WSMR was relayed primarily in analog format, i.e. bipolar Pulse Code Modulation (PCM) without clock. "Off the air" data streams could be fed into Bit Synchronizers (Bit Syncs) at the receiving site. The data component was then transferred to the TDC as Pre-D. Once in the TDC, PCM input data streams were bit-synced to provide a clock component to the data prior to the decommutator processing. Sometimes, signals were bit synced twice.

In 2002, WSMR telemetry upgraded from an analog based data transfer system to a digital TTL (Transistor /Transistor Logic) based system. In this system, "off the air" data streams are bit synced only once, at the receiving telemetry site. Input data streams are transmitted to the TDC as data/clock pairs in TTL format. In the TDC, data/clock pair signals are fed directly into decoms for processing. The TTL based system eliminated the need for bit syncs in the TDC, dramatically improved data quality and system reliability.

The BSS however, was not well suited to handle the TTL data/clock format. It was designed in an analog environment, and had no provisions for switching data/clock pairs. Since the BSS had no clock switching capability, TTL data/clock signals required conversion to analog PCM to allow for best source selection. The best source PCM stream was then reconverted to TTL data/clock format for signal processing. The cumbersome procedure effectively constrained performance benefits that were achieved by the TTL based system.

In addition, the BSS was designed to operate on input voltages levels of 1 to 2 volts, while TTL voltage levels can reach 5v. Using TTL voltage levels in the BSS caused the circuits to be overdriven, resulting in degradation of the best source output stream and a decrease in the overall bit rate that the BSS could handle.

4. The BSS was limited by the speed of data it could process. Testing showed significant data deterioration at 10Mbits/sec. The current BSS would was not sufficient to process the high bit rates that are expected in the near future.

5. The BSS was designed and built at WSMR; hence there are no "commercial off the shelf" (COTS) equivalents, and only a limited number of units available. Repairs had to be performed in house and documentation was old and inaccurate.

6. The widespread adoption of mux/demux systems in telemetry relay systems forced the TDC to abandon the BSS.

Breaking with Tradition

Finding an acceptable Best Source Selection replacement turned out to be a much more difficult challenge than was originally anticipated. We started by setting the following criteria:

Target Requirements:

1. **The new method had to be "at least" the minimum equivalent of the old method.**
2. **The unit must switch digital signals (i.e. data/clock pairs).**
3. **The unit must employ COTS, upgradeable technology.**
4. **The unit must address the issue of data latency.**
5. **Best source data streams should improve data quality or be "cleaner" than original streams**
6. **The unit must have initial data rate requirements of 15M with 20M available in the near future.**
7. **The unit had to be reliable enough for use in a real-time setting.**
8. **The unit must integrate seamlessly into our existing processing system.**

The primary concern in the selection process was to acquire a system that was, at the very least, a current version of the BSS. The option to rebuild and upgrade the old system was attractive; however, it would require a large investment of manpower hours plus equipment costs. Industry did have several COTS switchers available, but we were unfamiliar with their operation and capabilities. With a limited budget and time frame in which to find a suitable replacement, it was decided to explore both commercial and in house solutions.

The "In House" Effort

Initially our "in house" efforts of designing a replacement for the best source system looked promising. Suggested solutions included a software based switching unit, a hybrid system that coupled the BSS with a digital switch, and a complete rebuild of the BSS. All of these designs worked by physically switching between input data streams to form an output best source stream; therefore they also had many of the same deficiencies associated with the BSS. Latency issues were not addressed, and we were unable produce a best source stream that was superior to individual input streams

Additionally, all of the "in house" plans were dependant upon a large bank of external decoms, which provided sync lock status for the BSS technique. These plans were abandoned when we discovered, during regular equipment testing, that most of these decoms had become unusable. Due to the age and the cost associated with the repair, we decided to retire these decoms. The replacement cost of the decoms effectively ended our "in-house" solution effort.

The "Out House" Effort

Our first look at COTS switchers was somewhat disappointing. Only a few companies were actively building switchers, and these units did not meet our preconceived expectations of "what the vendor switcher should be". Although we looked at several units, none proved acceptable. Models that we tested were either unreliable enough for real-time operations, or neglected to address our latency issues. On the plus side, the venders we contacted provided ideas that we had not explored, had working systems available, and were willing to collaborate with us in fabricating a system that met our requirements. The decision was made to issue a white paper on two advanced best source selection concepts. The white paper was forwarded to any commercial TM vendor that expressed interest. After an extensive collaborative effort with several manufactures, we purchased the most promising switcher available. The purchase included an agreement with the vendor to pursue tailoring the unit to custom fit our requirements.

The CSS

The COTS Best Source Selector that best suited our needs was the Correlating Source Selector (CSS). The CSS approached best source selecting from a different direction. Rather than using a switch approach, the CSS employs a correlator to build best source composite stream. The correlation process works by aligning and comparing input data streams. The best source output is a composite data stream derived from components of the input data streams.

Alignment of data streams is accomplished by ramping the clock rate, (bit rate) of streams with latency. Shorter latency data streams are delayed until longer latency streams "catch up". The best source output stream also exhibits a varying bit rate to due buffering and alignment compensation for the input streams. Although there is an overall system latency increase or penalty, it does resolves the latency issues. The varying bit rate does, however hold the potential of complicating the digital recording of the output stream.

Once aligned, the correlator composites input data streams bit-by-bit using a majority rule basis (fig. 4).

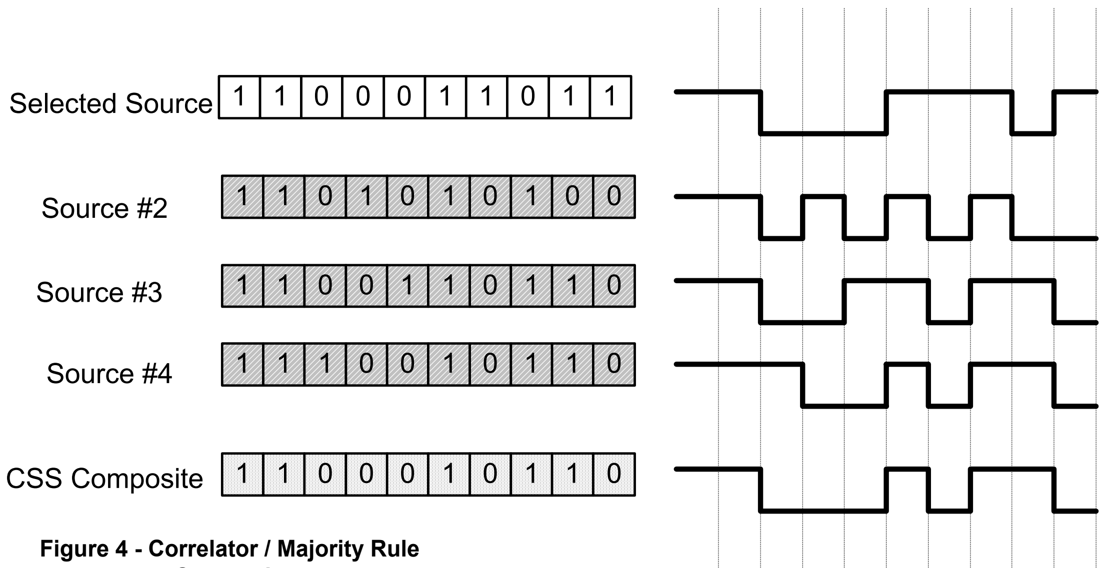

Figure 4 - Correlator / Majority Rule Composite

The resulting best source output is a unique composite stream and is potentially cleaner than source data streams. In order for correlation to occur, there must be at least three useable input data streams. In situations with less than three input data streams, the CSS falls back into a frame sync history select method of best source selection.

The CSS is interfaced via a personal computer (PC) through a network connection and software controlled with an Internet browser. Our CSS chassis came equipped with 8 input/output decom cards, scaleable into Best Source switchers of 2 or more inputs; thus allowing multiple best sourcing to done in a single box. The CSS switches TTL data/clock signals pairs, and can currently handle data streams up to 20M.

BSS vs CSS

Before the CSS could be used in actual operations, the system required extensive testing to determine if it actually perform as claimed and was reliable enough to use in a real-rime configuration. To conduct the testing, the CSS was installed in parallel with the BSS. This allowed side-by-side comparison testing of the two units and provided a piggyback configuration for the CSS during missions operations.

Operation of the CSS was not nearly as user friendly as the BSS. The BSS was hard wired to almost run by itself, requiring only the input of data streams and remote loading of external decoms. Although interfacing to the CSS was straightforward, configuration loads are complicated and contained several software bugs. Even though the CSS was PC controlled, it initially did not have the capability of loading or saving setup files. It was necessary to manually load the CSS for each application.

System status for the BSS consisted of red, yellow and green light emitting diodes (LED) located directly on the unit. Remote panels could be hard wired into the system for additional monitoring. The BSS also provided a status monitor voltage, which corresponded to the currently selected best source site. The CSS relies on an Internet browser to provide system control and operation status. Although the browser provides a low cost software interface; it can be slow, cumbersome, and accounts for most of CSS system issues. Status pages are easy to use and employ red, yellow, blue and green indicators. The CSS offers a hierarchical or weighted switching scheme and allows channels to be selected or deselected in real time. Additional remote monitoring of the CSS is accomplished by connecting PCs to the system network.

CSS Testing

Multiple Bit Error Rate (BER) test streams were used to evaluate the performance of the CSS. The BER box supplied 4 independent data streams simultaneously to both the CSS and BSS systems. The BER box allowed us to vary signal quality and data rates of individual input data streams and evaluate the effectiveness of each switcher under a wide range of situations. During testing, “Sync lock” status indications from all input and output signals were recorded on strip chart recorders (Fig. 5).

This chart represents a typical test scenario. It depicts 1 data stream with zero errors (BER 2) and 3 streams experiencing varying error rates. In this case, the BSS outperformed the CSS. Since the BSS is a selector, which changes data streams only upon a drop in data, the BSS output remained continuously connected to the data source with zero errors. Of particular interest is the CSS output. Notice that the CSS output is noisier or comparable to several of the input streams. The correlator majority rule process likely causes this.

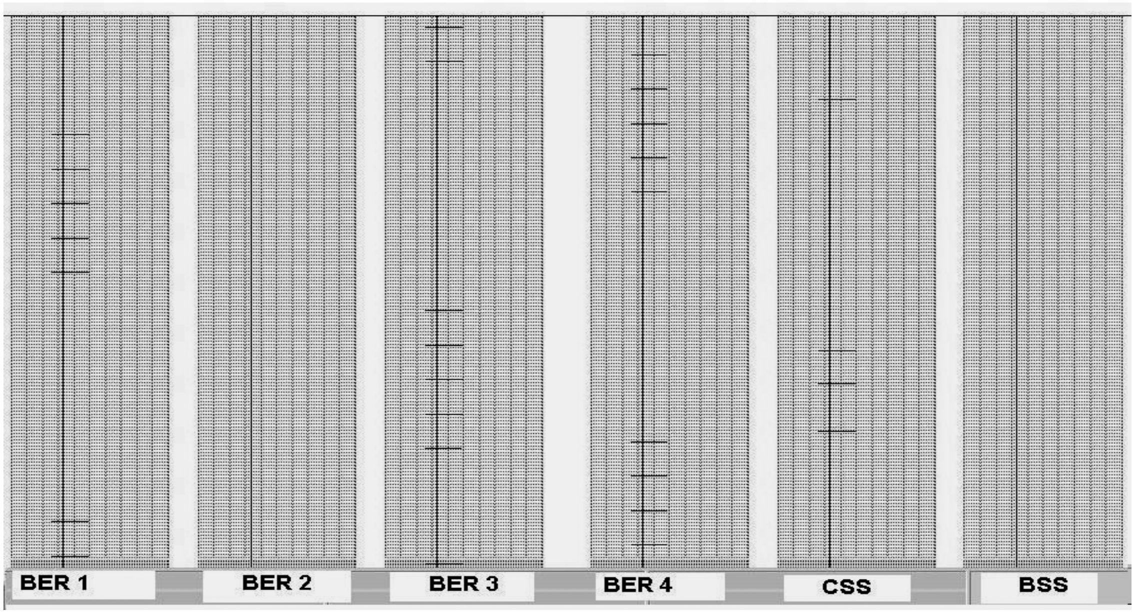

Figure 5 - Strip Chart plot of Sync lock status

Although this scenario is possible, it is highly unlikely a data stream with zero drops would occur during an actual mission or operation.

The next chart depicts a typical real-time scenario in which all input data streams are of relatively good quality (threshold or above), each experiencing approximately 1 error per 10,000 bits. (Fig. 6).

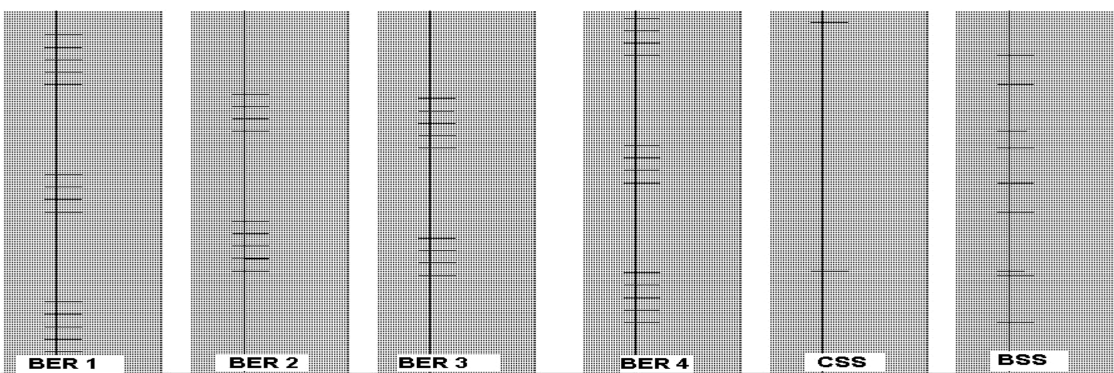

Figure 6 - Strip Chart plot of Sync lock status

This case insures that the BSS will switch input streams. Whenever the BSS switches, it corrupts the resultant output stream as it switches from stream to stream. The BSS switching characteristic becomes apparent by comparing the BSS output stream with the input streams. The CSS, which actually builds a new output stream, exhibiting relatively few data drops, producing an output data stream that is superior in data quality when compared to each of the input streams.

By examining the charts, it can be concluded that each switching system has it's advantages, depending upon the quality of the input data streams. If at least one input stream is very clean, the BSS can produce very good results. However, if the input data qualities are dissimilar, the CSS is the winner. In these tests, the BER signals being generated are not truly randomly distributed, but essentially equivalent. It should be understood that actual mission data differs somewhat from stream to stream.

Future Considerations

A future application for the CSS includes encrypted data source selection, improved software interface for system control, multiple outputs of best source stream in multiple data formats, binary frame sync status outputs of all input channels and increased data rates (up to 30M).

Conclusion

After extensive tests of the CSS and the BSS, TDC has tentatively designated the CSS as the primary switching system. During this time, the manufacturers of the CSS have provided excellent support; diligently working to upgrade the system and resolved issues of concern.

Overall, the CSS has proved that it can consistently produce a best source output that is superior in quality when compared to its inputs. It addresses input data latency issues, is easily upgradeable, and allows for customized switching setups. Only time and several hundred real-time missions will determine whether the CSS will remain as our primary switching system.

Related Papers:

White Paper — Real Time Multiple Source Compositing
Juan Guadiana, guadianaj@wsmr.army.mil

Acknowledgements:

Juan Guadiana — Telemetry Data Center, White Sands Missile Range
Johanna Kirby — Telemetry Data Center, White Sands Missile Range
Preston Hauk, Steve Proudlock — NetAcquire Corporation

Special thanks for the hard working and dedicated professionals at White Sands Missile Range Telemetry Data Center. Without their help and support this work could not have been possible.

Author Bio:

Richard (Ray) Engler is a full time husband and father currently living in Las Cruces NM. In his spare time, he works at the Telemetry Data Center at White Sands Missile Range. He has been a member of the White Sands Team for 20 years.

> *"I'm so far over the hill, I'm on the bottom of the other side."*
> *Wiley Burp*

Johanna Kirby is a resident of Las Cruces and has worked in various software and hardware positions at White Sands Missile Range. She has been part of the Telemetry Data Center family for the majority of her career. She has been a member of the White Sands Team for 16 years.