Best Source Selectors and Measuring the Improvements

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Abstract: After years of tracing the evolution and solutions to finding the best data, I learned that it isn't best source selection that we all want. What we need is best data selection.

Keywords: bit error rate, best source selection, best data selection, variable error rates

1. Introduction

In today's wide ranging and long duration test environments, aircraft typically traverse many different geographical areas. The RF coverage of each area is the responsibility of any number of managerial departments and/or architectural approaches and capabilities. Yesterday's environment allowed postmission processing to bring data sets together under one file set while today, the resources and mission demands require a real-time solution. There is just no time to postprocess—the need is NOW.

2. The Evolution of Solutions

Over the past years, Best Source Selection technology has evolved tremendously. In the early days, the man-machine interface was a human watching indicators and moving patch cables from one source to another. It then evolved to some level of automation by switching sources based on receiver AGC. This was better, but still offered large data gaps.

The next, or third generation, level of automation was to switch sources based on decom status. Certainly, this third level of Best Source Selector advanced the goal of "perfect data." However, this still induced data gaps and even erroneous data due to the inherent latency that exists between streams coming from different physical locations and via vastly different architectures.

With today's different architectures and hardware solutions, the user may find one source arriving via direct RF link, a second arriving from a remote location with data buffered through ATM or IP connections, and a third directly arriving via fiber optics. This is a difficult concept to grasp so consider the following example. First, look at the data structures (both input and output) in Figure 1. In this example, as is typically the case, the output is to be processed at the central data center for classic real-time display and archiving. With a third generation "decom-only" approach to best source selection, the example and its impact is offered (Frame 1 is shaded for ease of identification).

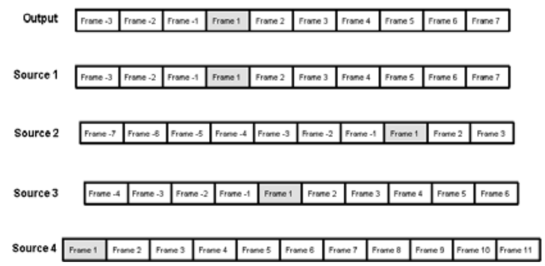

Figure 1

For starting conditions it is assumed that all four input sources are in lock and that data is being output. The output, which is shown at the top for ease of diagramming, is outputting data from Source 1 as it is in lock, but the analysis that follows is applicable for any condition.

You can see in Figure 1 that (as a starting point) we assume Stream 1 is in lock, and the output (at the top) matches Stream 1 (just under the OUTPUT link) because it is in lock and making 100% of the output contribution.

Now, refer to Figure 2.

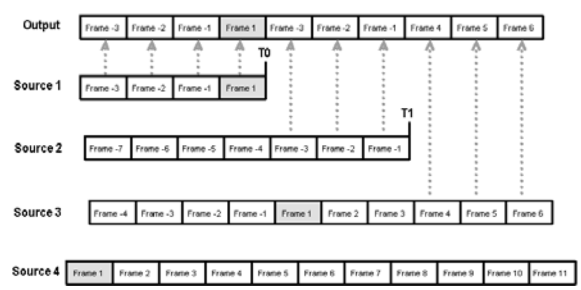

Figure 2

At time T_0, stream 1 drops out of lock and stops contributing to the decom-only Best Source Selector (BSS) function. The decom-only BSS then switches to steam 2, and its output continues uninterrupted. However, the result at the output is that Frame -3 is put into the Frame 2 position, Frame -2 is put into the Frame 3 position, etc.

At T_1, stream 2 drops out of lock and the decom-only BSS switches to stream 3. Now, Frame 4 is put into Frame 5's position and so on. The corruption continues and naturally, drop-outs occur whenever latency exists between data sources (as can easily be seen in Source 4). Compounding this corruption are the natural bit errors that occur in real-time telemetry. In this example, if at T_1 the data from Source 3, Frame 4 has bit errors in the data set, it is passed through as "perfect data" because this is just a best source selector. Even though the same data set (Frame 4) in Source 4 could be perfect, this true good data is tossed away.

Therefore, third generation decom-only BSS solutions promote poor data integrity by allowing:

- Corruption of the output data set by not addressing time skew
- Data gaps that become enlarged due to the resync data loss with each dropout.
- Ignoring of perfect data that can exist in another noncontributing data source will be ignored.
- Possesses no ability to handle either static or dynamic time skews of data sources.

3. The Ultimate Need

The ideal Best Source Selector isn't a Best Source Selector … because it's not the best "source" you want, but the best "data". Therefore, the solution is actually a Best Data Selector (BDS). As shown in Figure 3, it should provide:

- Traditional front-end decommutation
- Dynamic buffering with delay variability to align, in time, the incoming data sources.
- Algorithms to watch across "N" data sources and, on a bit-by-bit or word-by-word basis, provide output data that is truly best data, not just best source.

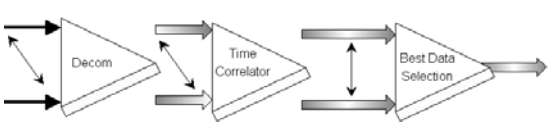

Figure 3

Wyle Laboratories Telemetry and Data Systems (TDS) has developed the next generation product—the Best Data Selector (BDS), which corrects the deficiencies of the decom-only BSS.

4. Decommutation

TDS has been building decommutation hardware and software for many years. The first stage of the BDS uses that decom technology and supports:

- Operation to 30 Mbps
- Sync patterns to 64 bits with programmable masks
- No restrictions on word sizes
- Frame sizes to 33,554,432 bits

This technology has been available to users for many years but now it is a part of a larger solution.

5. Dynamic Buffering

With the TDS BDS solution, the next stage after decommutation is to implement a dynamic buffer that first aligns by frame sync (a time skew correlator) and then examines all of the word values to find the proper alignment between data sources.

As an example, take the following four streams of data as shown in Figure 4.

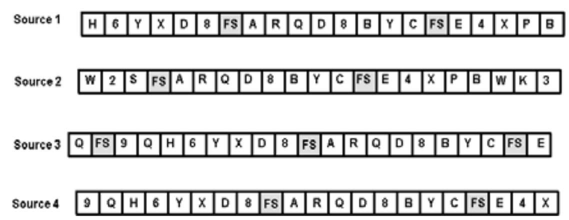

Figure 4

In Figure 3 (assuming all streams are in lock), you can see that the data is coming in but with offsets in the time relationships (caused by factors such as satellite links, telecommunications delays, etc.). The BDS brings in all of this data (up to ten buffers worth) and searches the data to find the best alignment of data. In Source 1, is the first frame sync aligned with the **first** frame sync of Source 2, or is it aligned with the **second** frame sync? In real-time, the BDS examines the word contents of each stream and quickly finds the best alignment as shown in Figure 5.

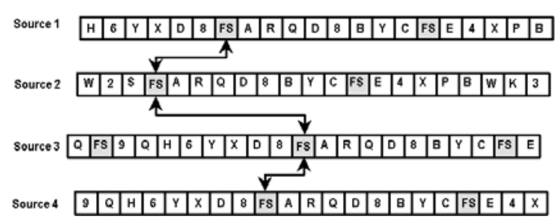

Figure 5

In Figure 5, you can see that alignment has been found between the streams and that each time offset has been realized. Once found, however, it does not stop. The BDS time skew correlator function is dynamic, independently monitoring each incoming data stream and watching for total word alignment so that any change in path delay is instantly addressed by TDS's BDS.

6. Not Just Best Source, but Best Data

When the time skew has been factored out, the Best Data Selector has the ability to select the preferred output based on individual needs. Preference can be given to a particular stream number, a stream that has been in lock the longest, a stream that was in lock last, or to get the best data, selected from all of the streams on a word-by-word or bit-by-bit basis.

When selecting on a bit-by-bit basis, the BDS takes the time-aligned data sets, strips across all words, finds the most common word and bit values, and outputs the result that occurs the most often, dynamically shifting from word correlation to bit correlation, depending on the level of data corruption it must address.

In Figure 6, you can see that the first word (Word 1 after the frame sync) has candidate values of A and B (A and B represent a sequence of bits – not real values). Since A occurs three times (streams 1, 3, and 4) out of the four possibilities, the most common bit values are output (that being A). Then words 2, 3, and 4 have no dispute because they are all the same in all time-aligned data sources. The same "voting" occurs again in time slot position 4. The bit values of D occur more often and the value of D is output.

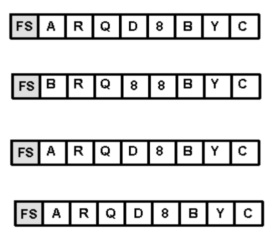

Figure 6Figure 7

This continues through all the data sets, words, and streams. The final data example is shown in Figure 7 with its output resultant table.

Word	Value	Votes?	Output
1	A B	3 1	A
2	R	4	R
3	Q	4	Q
4	D 8	3 1	D
5	8	4	8
6	B Z	3 1	B
7	Y	4	Y
8	C W	3 1	C

Figure 7

This voting mechanism occurs for each bit and word in the defined frame (typically a minor frame but within definitions you can define it to be a major frame) and outputs the bits that are present the most often in each particular time slot.

7. The Best Data Source Product

There are various manufacturers of Best Source Selectors and Best Data Selectors (BDS). Wyle Laboratories Telemetry and Data Products is one of the manufacturers of BSS and BDS technologies.

The Best Data Selector from Wyle Laboratories, Telemetry and Data Systems provides multiple iterations of the BDS time correlation and bit-voting applications within each product such that multiple input-to-output-pairings are available for implementation. The ability to run multiple iterations of the BDS allows a configuration of say six input ports and three output ports to run every possible combination and configuration—6 to 1, 4 to 1, 2 to 1, three sets of 2 to 1, dual 3 to 1's, etc.—all without any impact or dependencies between the iterations.

7.1 The Main Menu

This menu is the top level GUI for a four-stream BDS. (See Figure 8.) It easily and graphically shows the status of each incoming stream, the frequency of selection, the amount of correlation obtained within the stream data, and the amount of time correlation that was required. Pop-up menus reflect system set-up parameters from frame sync pattern to data selection criteria.

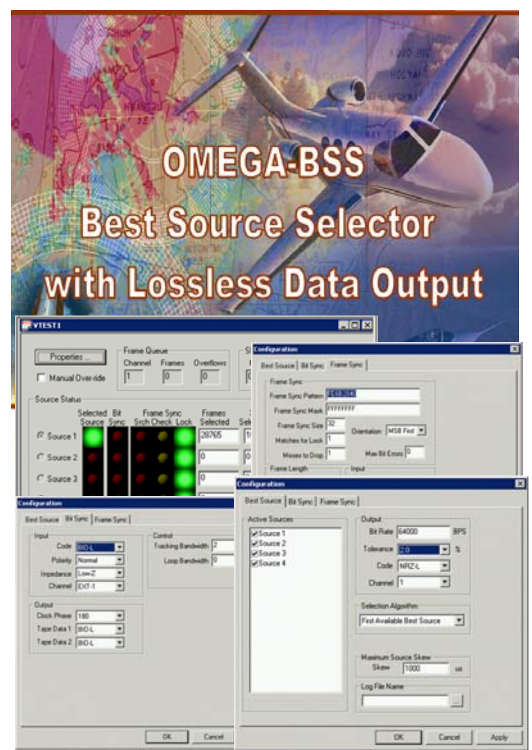

Figure 8

7.2 Test and Measurement:

The next question in outlining improvements in real-time data selectivity is testability and demonstrating quantitative results. A best source selector paper was presented during the 2004 ITC. In it, one government range showed strip chart products that graphed frame sync dropouts both with and without their BSS, and it showed a lessening of errors. Yes, it was visually appealing, but in reality, all it represented was a statistical sampling of frame sync bits within a minor frame (say, 30 bits out of 2000). There were no hard numbers.

To gain an understanding of the steps required to present measurable data, think of this simple diagram shown in Figure 9:

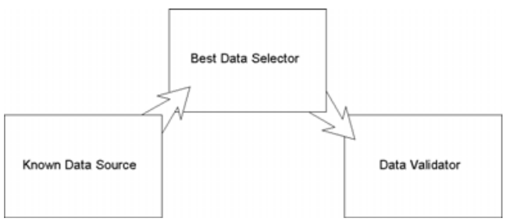

Figure 9

At the left, some set of known data must exist. It is ‘piped’ into the BDS where each stream of data is examined, compared, and then output. At the right is the data validation component that independently decides if the data matches the known data sets from the original source on the left.

To control this paradigm for demonstration purposes, the only independent data validation instrument the user should trust is a bit error detector. Therefore, to use a bit error rate test (BERT) as the validation stage, the known data sources should be bit error patterns of known data quality – preferably with differing data qualities.

To support this, engineers first used the TDS PCI All-in-One card (a 50 Mbps bit sync, decom, and time decoder) to capture a 2047 pattern from a Fireberd test unit. Software engineers then wrote custom software to randomly invert a bit based on the bit error rate (BER) desired (every 1,000 bits for 1 x 10^{-3}, every 10,000 bit for 1 x 10^{-4}, every 100,000 bits for 1 x 10^{-5}, and every 1,000,000 for 1 x 10^{-6}).

Figure 10 shows the sequence above but with the hardware and data quality assignments:

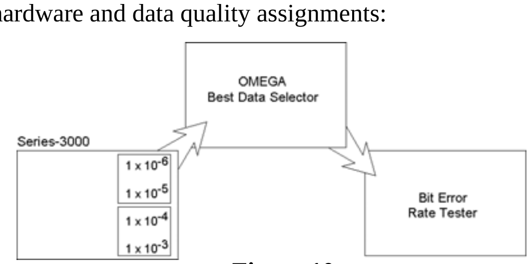

Figure 10

With this flow, the data to the left is generated from two dual-stream PSIM simulators. It is input into the OMEGA Best Data Selector and the single stream output is fed into a third party BERT.

The BERT allows verification of the four error rates (1 x 10^{-3}, 1 x 10^{-4}, 1 x 10^{-5}, and 1 x 10^{-6}), and can then examine the reconstructed output to measure the total link improvement.

With a Best Source Selector, the input to the BERT can only be as good as the best output from the sources. For example, if four 1 x 10^{-4} sources are provided, the ‘selector’ can only output data of 1 x 10^{-4} quality. However, with a best DATA selector, the bit voting and alignment allows the output to be of higher quality then any of the individual inputs.

8. Conclusion

It isn’t best <u>source</u> selection that you want; it’s best <u>data</u> selection that you need.

9. Acknowledgements

My appreciation goes to Jerry Mudd and to Felix Rivera for their tireless efforts on the development of the BSS test hardware.

10. Acronyms and Abbreviations

AGC	automatic gain control
ATM	asynchronous transfer mode
BDS	Best Data Selector
BER	bit error rate
BERT	bet error rate test
bit sync	bit synchronizer
BSS	Best Source Selector
decom	decommutator
GUI	graphical user interface
IP	Internet protocol
Mbps	megabits per second
resync	resychronize
RF	radio frequency
TDS	Telemetry and Data Systems