Container Security Sensor Data Transmission in a Power-Limited Application

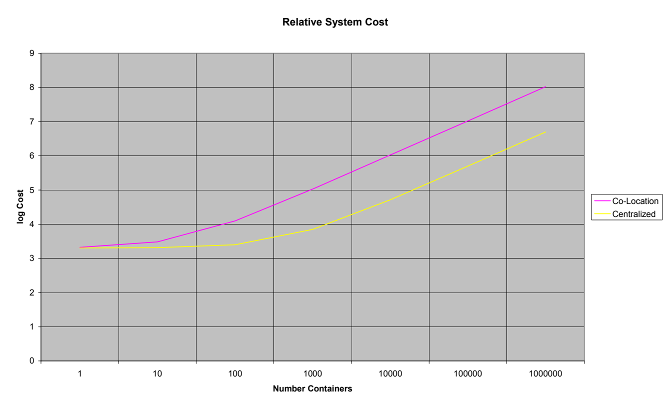
David Erickson
iControl, Inc.

1 Sensor Data Evaluation

iControl in cooperation with Nevada Nanotech Systems (NNTS), makers of a Micro-Electro-Mechanical Systems (MEMS) technology sensor for container security, conducted an integrated sensor production and data transmission test. Data from the sensor represented (a) explosive chemicals, (b) biological agent and (c) total ion content (TIC) of subject molecules (ethanol, formaldehyde and ammonia). This integration test evaluated the power budget implications of local processing and communications bandwidth budgets.

In working with NNTS, iControl sought to identify the individual and system power costs associated with various architectures: (a) co-located sensor data processing, (b) simplified pre-screen sensor data processing and (c) centralized data processing.

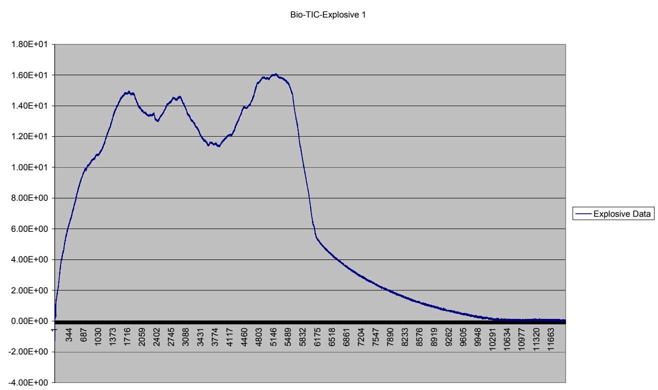
Co-locating sensor processing with each sensor simplifies the amount of transmitted data and alarm. The transmitted signal may be reduced to “nominal” or “alarm” or perhaps a level of detection from 0 to 100%. But while co-location reduces the communications bandwidth burden, the computational burden imposes upon the container power budget.



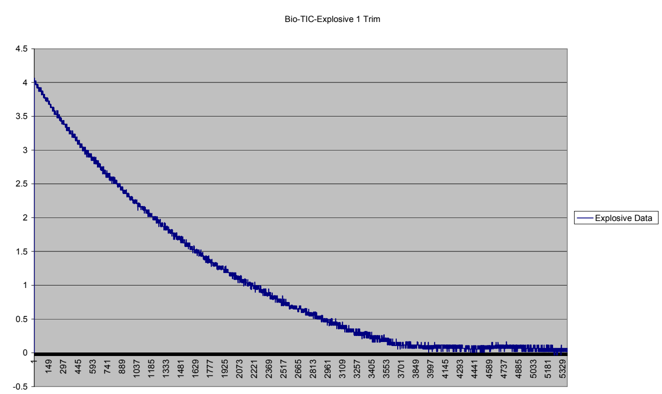
Centralized processing minimizes the container power consumption. But raw sensor data may require significantly more communications bandwidth, and bandwidth also implies power consumption.

The integration test establishes early that raw MEMS sensor data is significantly large and therefore must be considered as part of the system design. The second objective is to explore solutions to reducing the transmission bandwidth without imposing a computational burden.

1.1 Data Selection

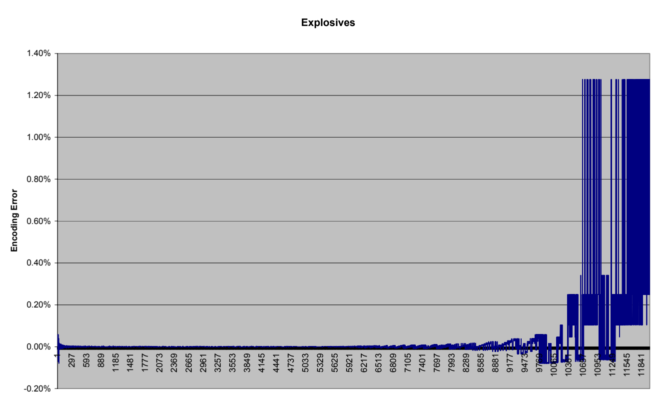


The next plot of 12,000 samples identifies the presence of explosives. Without discussing the proprietary nature of the sample data, the key data can be selected from the right-most 5300 data points—the left-most points having minimal explosive signature information. Applying a window filter to the data further increases precision by reducing dynamic range (maximum is 4.00 instead of 16.00). Conversely, a compressed data stream can accurately represent reduced dynamic range.



The window filter applied to this data by the communications package provides a 56% reduction in bandwidth. The reduction in dynamic range further reduces the data requirements by 75% for a cumulative processing gain of 89%. The transmission power required to send the raw data is reduced to just 11% by using window filters in the container communications package.

1.2 Data Compression



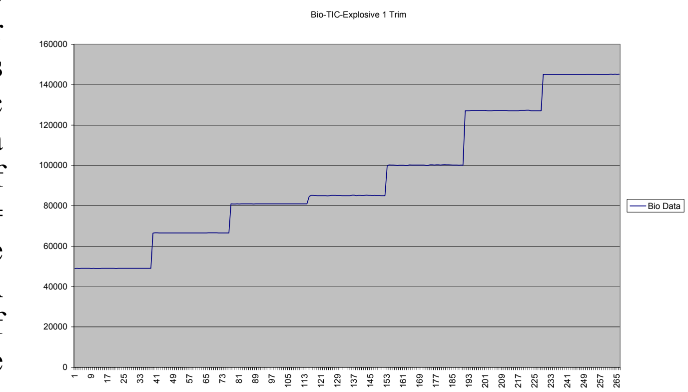
Reviewing the previous plot, the data stream is a bandwidth-limited series of a single variable appropriate for data compression. A simple algorithm specifies the difference between adjacent points—delta tracking—providing significant reduction in communicated data or bandwidth or transmission power.

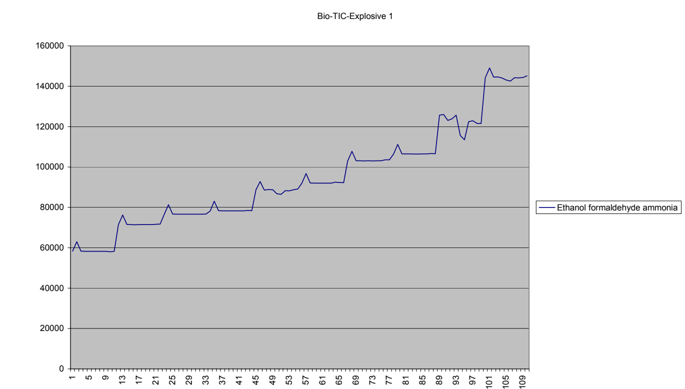
Analyzing the windowed data, the maximum change is 2.5% of the total dynamic range, a factor of 40 processing gain over the uncompressed data. Combined with the window gains, the total gain exceeds 99.7%.

Therefore, the 12,000 16-bit fixed-point numbers produced by the single sensor can be compressed to fewer than 100 transmitted bytes with less than 1.3% loss of data precision. A 1.3% coding error is within the inherent error bounds of the sensor data.

1.3 Data Representation

The biological analogs and organic compounds produce MEMS sensor signatures with far fewer samples but a significantly greater dynamic range. When the samples indicate a series of quantum values, a series of each point of discontinuity (x = time, y = value) may provide the most efficient communication. A review of the full spectrum of sensor data will aid in assessing the best data compression techniques.





2 Conclusion

MEMS sensor data for the Container Security Initiative may produce a large amount of data. Judicious application of simple information processing algorithms results in a dramatic reduction in transmission bandwidth. Employing these algorithms enables the system to simultaneously minimize the container's computational and transmission power requirements.