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STTP Compatible
Point on Wave Compression

IEEE 2664-2024 (STTP)

sttp IEEE 2664
Streaming Telemetry Transport Protocol

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Streaming Telemetry Transport Protocol

- US DOE Project
- Intrinsically reduces losses and latency compared to frame-based protocols
- Allows the safe co-mingling of phasor data with other operational data network traffic
- Detailed metadata exchanged as part of protocol
- Includes lossless compression to reduce bandwidth utilization
- Security-first design with strong authentication and option for encryption

STTP Compression Algorithm: TSCC

- IEEE 2664 Standard (STTP) includes a compression algorithm:
  - Time Series Special Compression (TSCC)
- Tuned for Synchrophasor Data and Streaming Data
- Algorithm uses multiple algorithms for different time-series elements, with special focus on “Value”:
  - ID
  - Time
  - Value (differential / 7-bit encoding / last result cache / zero handling)
  - Quality

TSSC Testing with Point of Wave

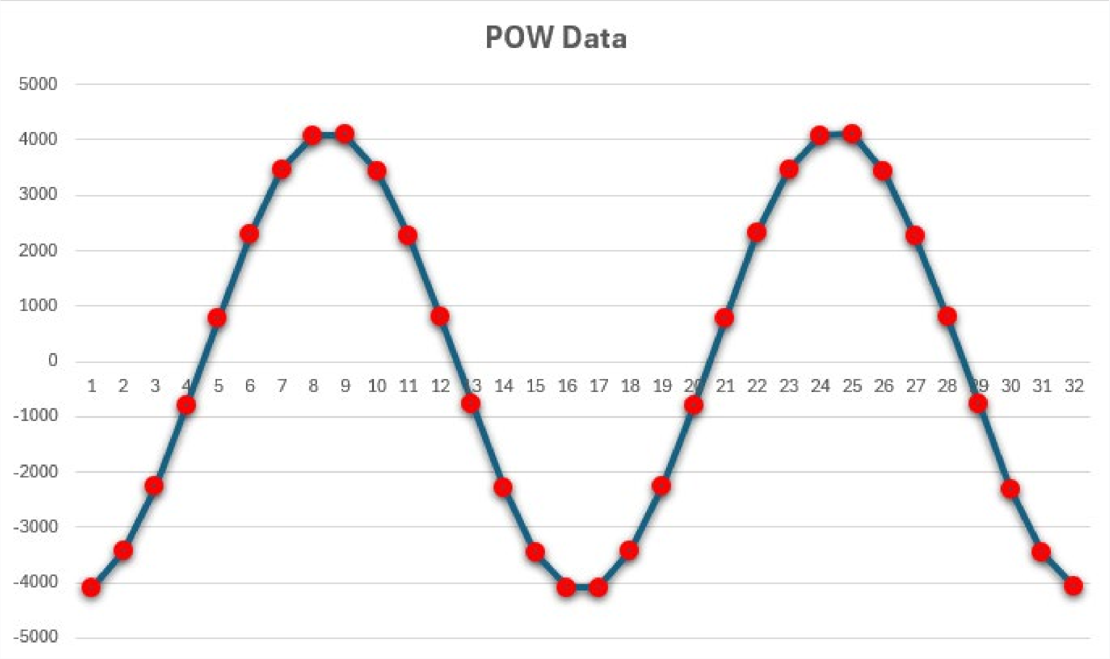
- During last NASPI meeting, a question came up about use of STTP TSSC for POW data
  - So, we collected some POW sample data and ran some tests
- Compression is very good for streaming phasor data
  - Low latency, low CPU impact, and fast
- Tests with streaming audio data also compressed well
  - Streaming signals at 44100 Hz data compressed well
- TSSC was expected to perform well with point on wave data…
  - Test data was recorded at 960Hz

It did not…

Why? Rate of Change

- TSSC performs well for data sets where there is a slow gradient of change:
  - This works well for phasor data (30/60Hz)
  - This works well for audio data (44100Hz)
- What makes 960Hz special?
  - Within 16 measurements, you move through 360 degrees →

WARNING: Curves Ahead!



Lots of experimentation ensued…

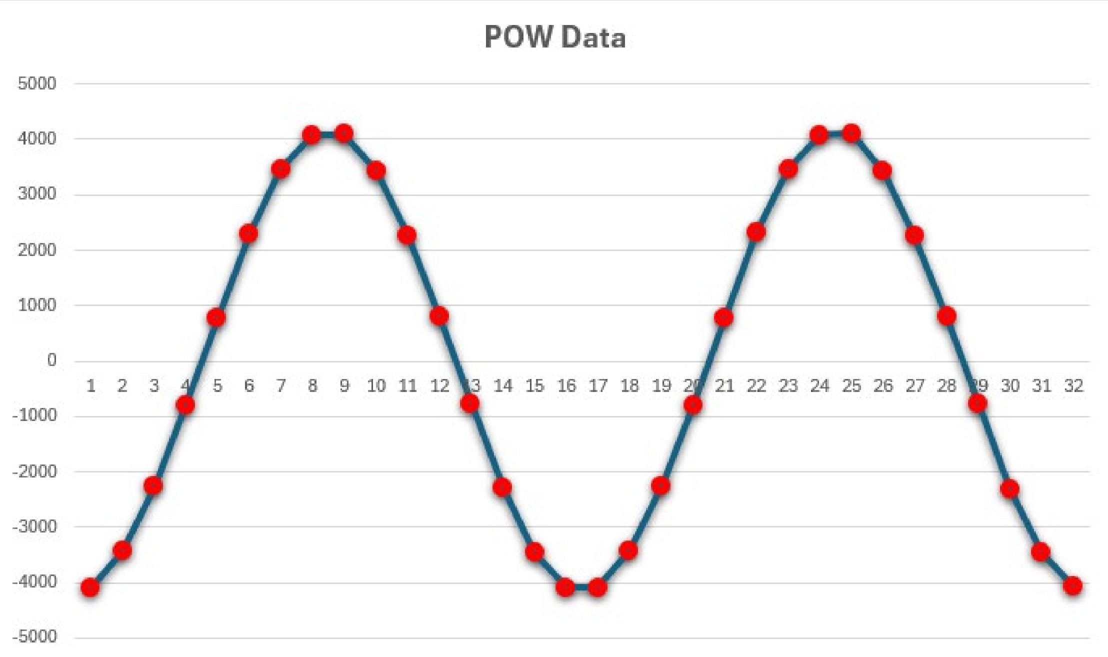
- After playing around with many compression techniques, you find that standard compression algorithms work fairly well.
- Of all the common players, LZMA (a.k.a. 7-zip) seemed to do the best job.
  - For a 5.6GB POW file representing a full day of data, 7-zip would reduce size by 65.6% (34.44% compression ratio)
- In terms of compression, we felt like this ratio could be improved, especially by understanding the sinusoidal nature of the data – something LZMA would not “assume”
- An idea: match the curve, producing small residuals, should be able to compress based on small values

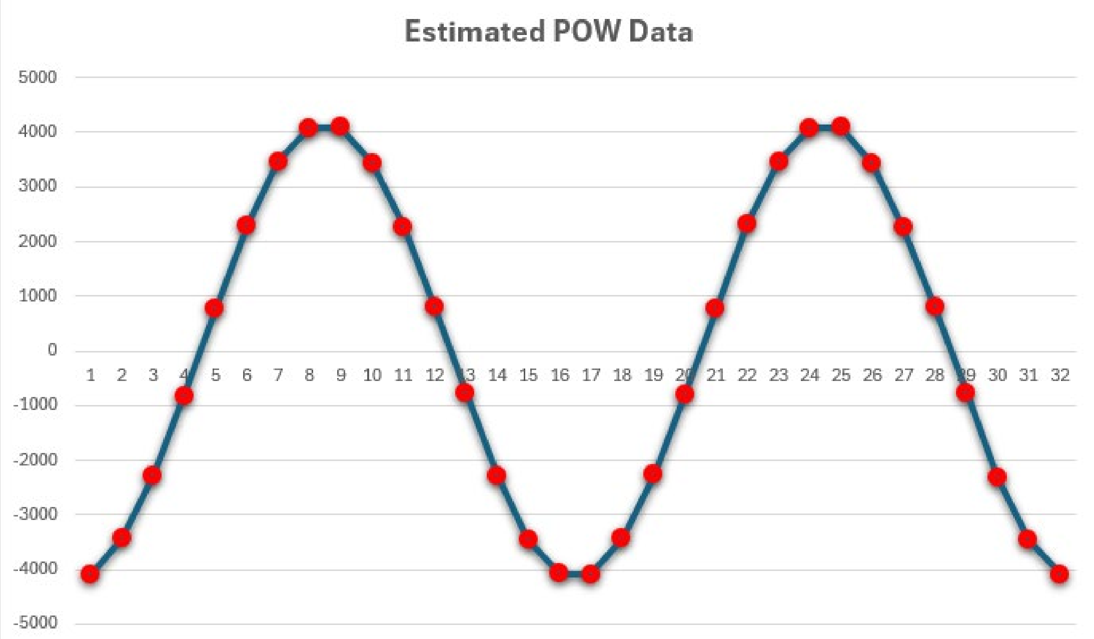
Trying to match the curve…

- Started with a goal of trying to emulate the source curve as close as possible, using Excel as a test bed
- Tried lots of frequency estimators with simple sine wave:
  - Zero crossing / FFT / and just assuming fixed 60hz
- For several sample files, narrowed in on the following solution
  - NOTE: *This was based on empirical work and intuition, not some mathematical hypothesis, which may produce better results*
- Emulating the POW curves with harmonic estimation, narrowing in on the 8th harmonic – simply because it produced the best match to original curve
  - For available data sources, anything higher or lower did not do as well

Getting as close as possible

-4076	-4080.34
-4088	-4092.92
-3436	-3436.72
-2274	-2285.47
-814	-822.08
770	761.8105
2306	2305.189
3468	3460.816
4082	4081.503
4097	4094.488
3437	3436.564
2257	2268.652
806	811.8743
-760	-759.954
-2302	-2301.64
-3469	-3468.84
-4087	-4082.08
-4093	-4090.85
-3423	-3430.22
-2260	-2268.38
-811	-814.821
779	771.1554
2314	2309.681
3471	3465.27
4076	4078.375
4103	4097.442
3421	3427.474
2254	2254.339
799	801.5861
-782	-771.874
-2315	-2309.46





Tiny residuals – *we can compress*!

Measured	Predicted	Residual
-4076	-4080.3429	4
-4088	-4092.9206	5
-3436	-3436.7209	1
-2274	-2285.4707	11
-814	-822.07975	8
770	761.810509	8
2306	2305.1895	1
3468	3460.81555	7
4082	4081.50316	0
4097	4094.48761	3
3437	3436.56381	0
2257	2268.65189	-12
806	811.874317	-6
-760	-759.95442	0
-2302	-2301.641	0
-3469	-3468.8422	0
-4087	-4082.0751	-5
-4093	-4090.8462	-2
-3423	-3430.219	7
-2260	-2268.3752	8
-811	-814.82135	4
779	771.155417	8
2314	2309.68149	4
3471	3465.26997	6
4076	4078.37499	-2
4103	4097.44182	6
3421	3427.47357	-6
2254	2254.33865	0
799	801.58615	-3
-782	-771.87386	-10
-2315	-2309.455	-6

- Very small residuals allows for interesting compression options
- For one, if most values are in the range of -8 to +8, then you can compress the value into 3-bits, saving a bit as a marker. So, 4-bits, i.e., a “nibble” – in other words, can fit two values into one byte
- From 3-bits, you can then move up to 7-bits and then 13-bits and finally, full value, with a marker
- In testing most values fell within either the 3-bit to 7-bit range, which meant good compression

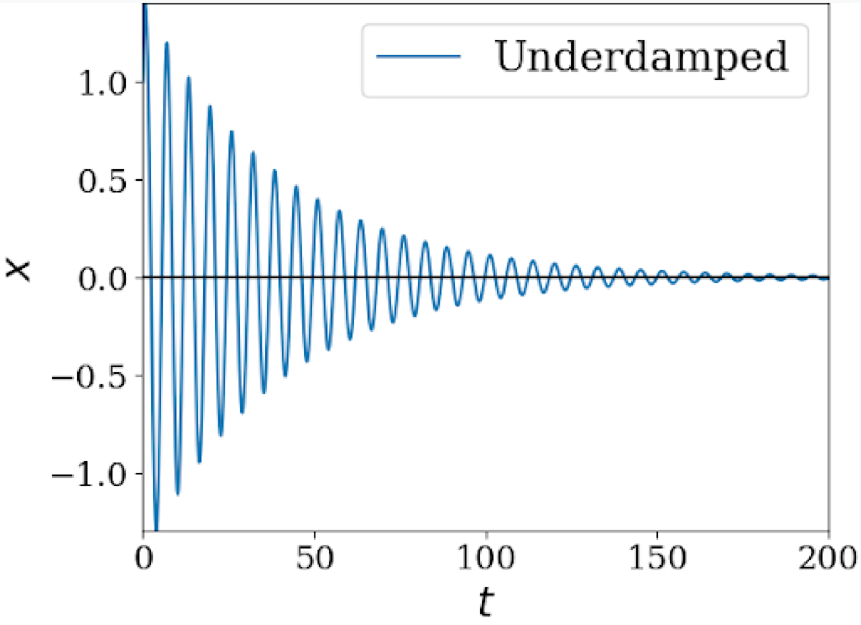
Harmonic Differential Compression

- For the current implementation, some default parameters (all configurable):
  - Harmonic count: 8
  - Supplemental compression algorithm: LZMA
  - Buffer size: 64K
  - Window size: 2 cycles
  - Frequency estimation: Fixed (options for zero crossing / FFT)
  - Target compression ratio: 26%
- Optimizations:
  - Caching of calculated omegas – reduces calls to trig functions
  - 3/7/13-bit encoding

Everything is peaches and cream…

Until it's not…

- Pretty, predictable curves aren't always so pretty
- Sometimes they get angry and noisy
- So, you need a "plan B" for compression in these cases
  - As previously tested, LZMA is a good "general choice" for compression
- When things don't compress well, e.g., less than a target of 26%, use a common compression algorithm, e.g., LZMA



Some results… *~25% compression ratio*

- *Note*: excludes results that used around 100% supplemental compression
- Smaller compression ratios values are better:

Example 1:
Encoded Size: 39.82 megabytes / 158 megabytes (**25.17%**)
Supplemental Compression: 1,028 / 1,265 (81.26%)

Example 2:
Encoded Size: 39.47 megabytes / 158 megabytes (**24.95%**)
Supplemental Compression: 319 / 1,265 (25.22%)

Example 3:
Encoded Size: 36.25 megabytes / 158 megabytes (**22.91%**)
Supplemental Compression: 436 / 1,265 (34.47%)

Example 4:
Encoded Size: 40.01 megabytes / 158 megabytes (**25.29%**)
Supplemental Compression: 0 / 1,265 (0.00%)

Example 5:
Encoded Size: 40.21 megabytes / 158 megabytes (**25.42%**)
Supplemental Compression: 0 / 1,265 (0.00%)

Example 6:
Encoded Size: 40 megabytes / 158 megabytes (**25.29%**)
Supplemental Compression: 598 / 1,265 (47.27%)

Example 7:
Encoded Size: 39.76 megabytes / 158 megabytes (**25.13%**)
Supplemental Compression: 518 / 1,265 (40.95%)

Example 8:
Encoded Size: 39.58 megabytes / 158 megabytes (**25.02%**)
Supplemental Compression: 0 / 1,265 (0.00%)

Example 9:
Encoded Size: 40.36 megabytes / 158 megabytes (**25.51%**)
Supplemental Compression: 0 / 1,265 (0.00%)

Example 10:
Encoded Size: 40.13 megabytes / 158 megabytes (**25.37%**)
Supplemental Compression: 0 / 1,265 (0.00%)

Conclusions

- For a sinusoidal inputs, results were better than LZMA alone
- For wave forms that don’t “fit”, LZMA produced better results
- The current implementation operates by using both, again, when ratio is less than (configurable) 26%, use LZMA
- ***Some math may go a long way at producing better results!***

- ***Pros***:
  - Good compression, ~25%
  - Suitable for streaming compression, e.g., STTP
  - Reduces bandwidth for streaming and file transfers in reduced bandwidth environments, e.g., sub-station

- ***Cons***:
  - CPU costs are high – lots of calculation required – so better suited for single value streams
  - More compression would be better, more work to be done on improving algorithm results