



Synchronized Measurements from Disparate Sources

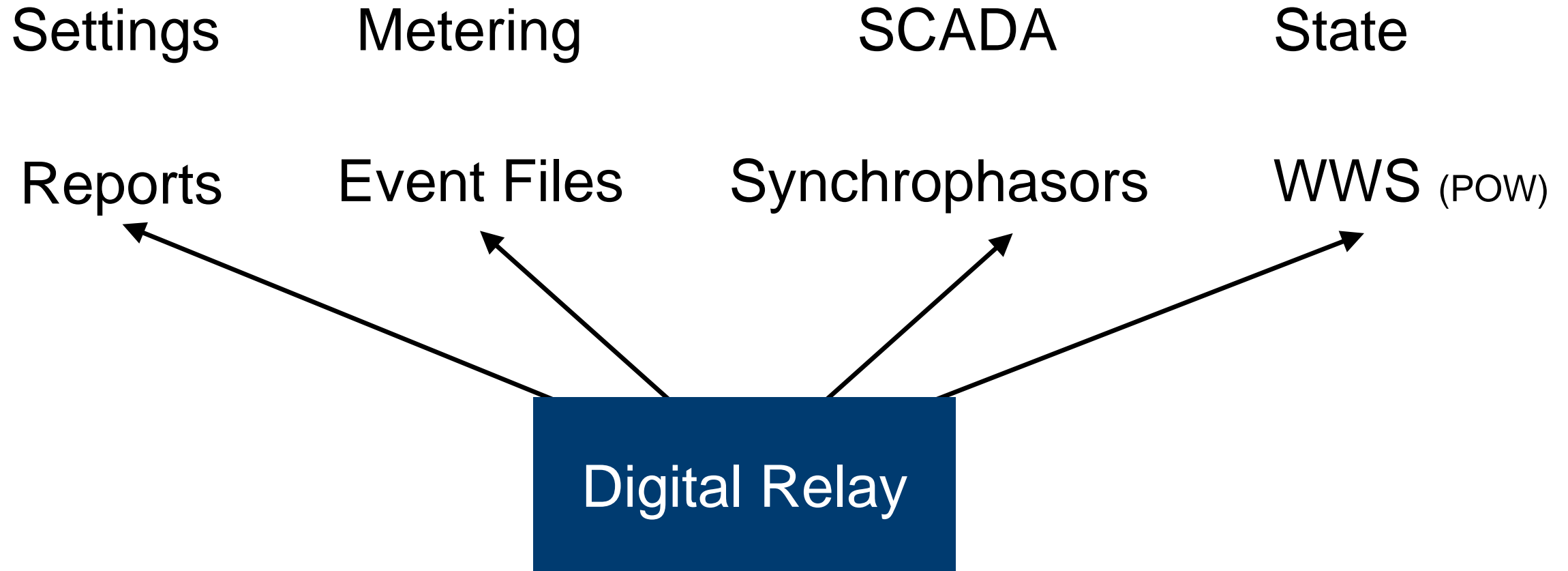
Dr. Greg Zweigle
NASPI Conference – October 30, 2019



Software solutions must focus on making
electric power system operations
safer, more reliable, more economical,

and simpler.

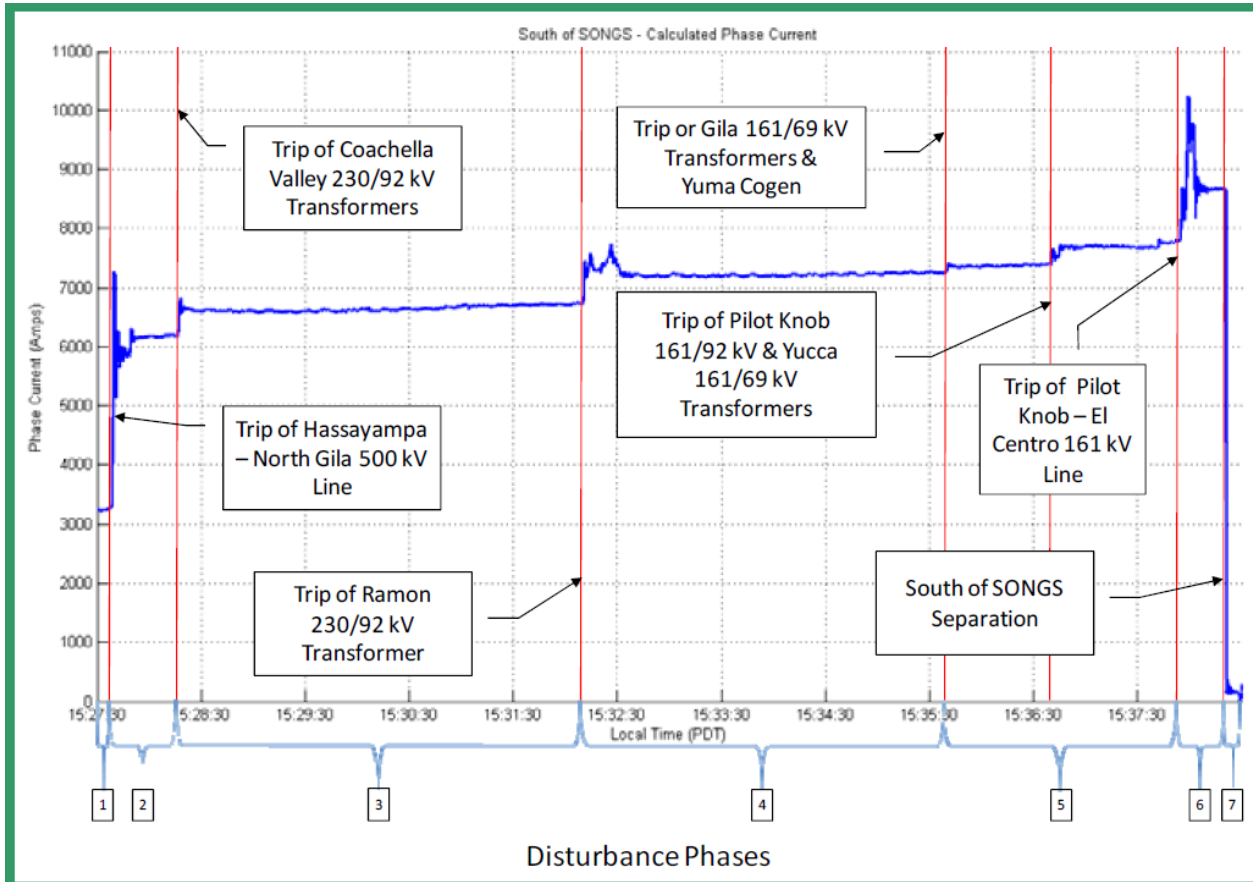
Modern Digital Relay Data Example



7,750 Relay Settings

- Protection (350 • 6 groups) 2,100
- Global 250
- Programming
 - Automation (100 • 10 blocks) 1,000
 - Protection (250 • 6 blocks) 1,500
- Communications / protocols 1,500
- Monitoring 1,000
- Aliasing 400

Why relay settings/state: “what is the *state* of the power system?”



or $Ae^{j\theta}$

Metering Data – More and more

- Fundamental 4 values per hour
- Harmonics x 4 bytes per value
- RMS x 24 hours per day
- Demand x 3 values (KWh, W, V)
- Energy x 1 million customers
- Winding
- Differential = 1 GB per day
- Thermal

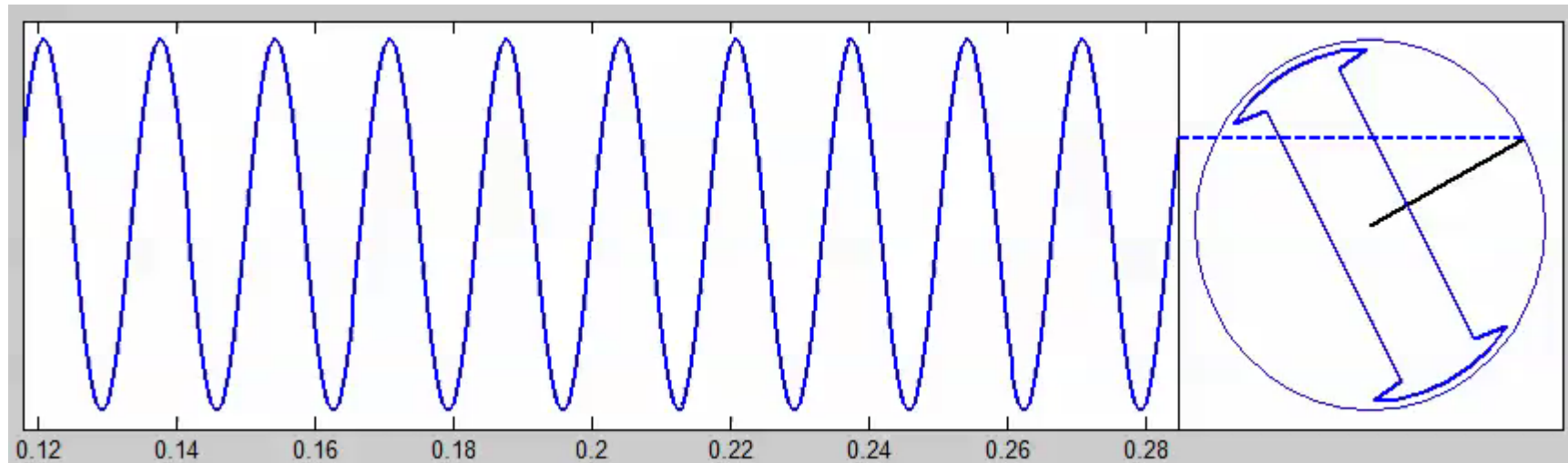
Quasi-Stationary Phasor Approximation

Limits both SCADA and Synchrophasors

$$x(t) = A \cos(\omega t + \theta) \rightarrow \bar{X} = Ae^{j\theta} \quad (1)$$

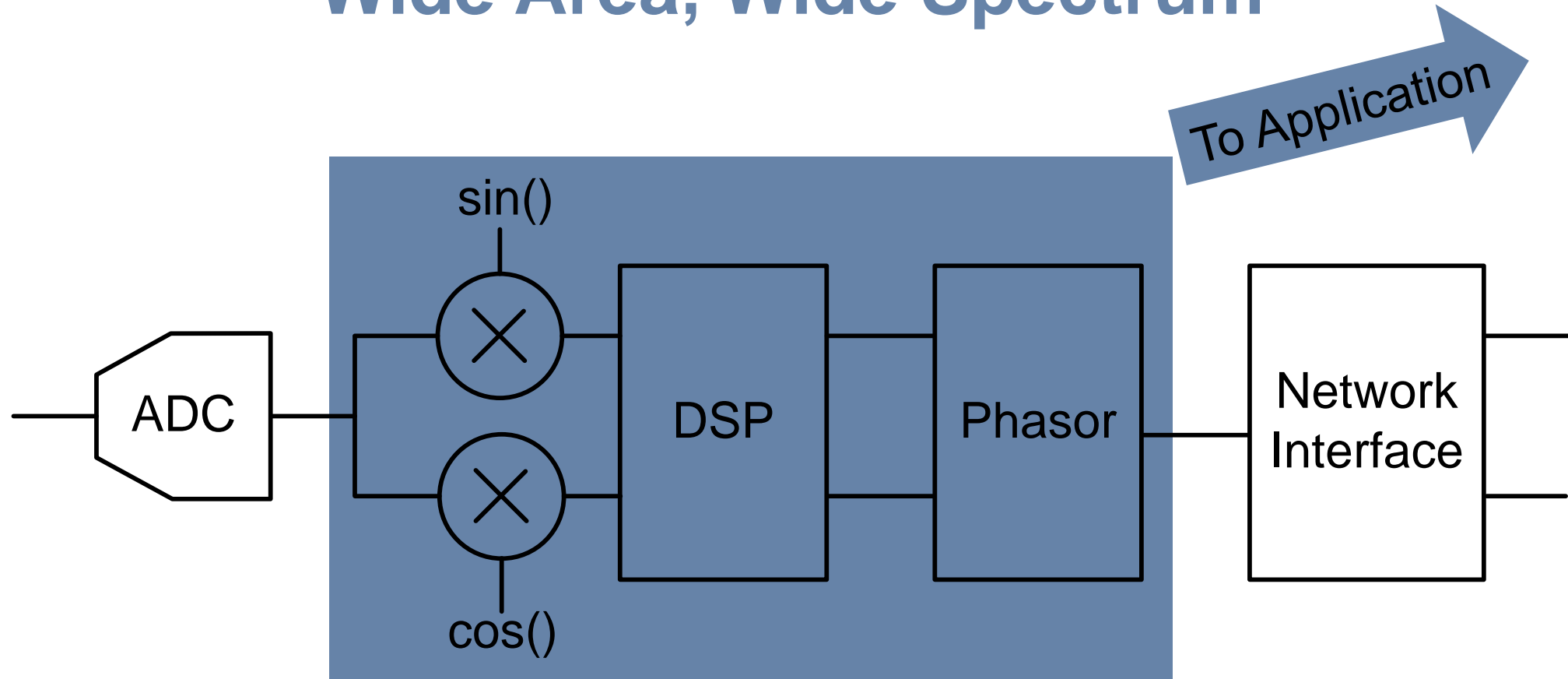
$$x(t) = A(t) \cos(\omega t + \theta(t)) \rightarrow \bar{X}(t) = A(t)e^{j\theta(t)} \quad (2)$$

$$x[KT_s] = A[KT_s] \cos(\omega KT_s + \theta[KT_s]) \rightarrow \bar{X}[KT_s] = A[KT_s]e^{j\theta[KT_s]} \quad (3)$$



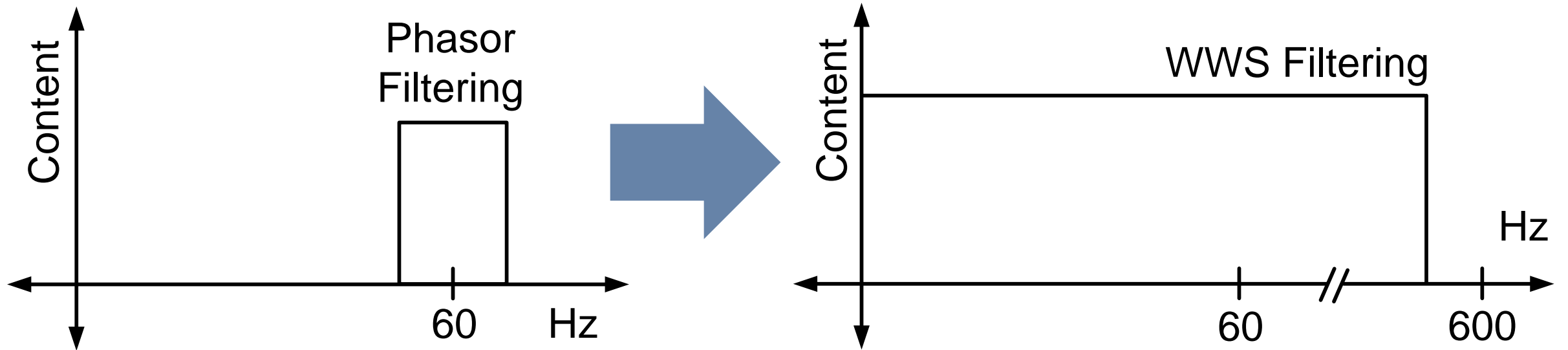
Moving Signal Processing to Applications

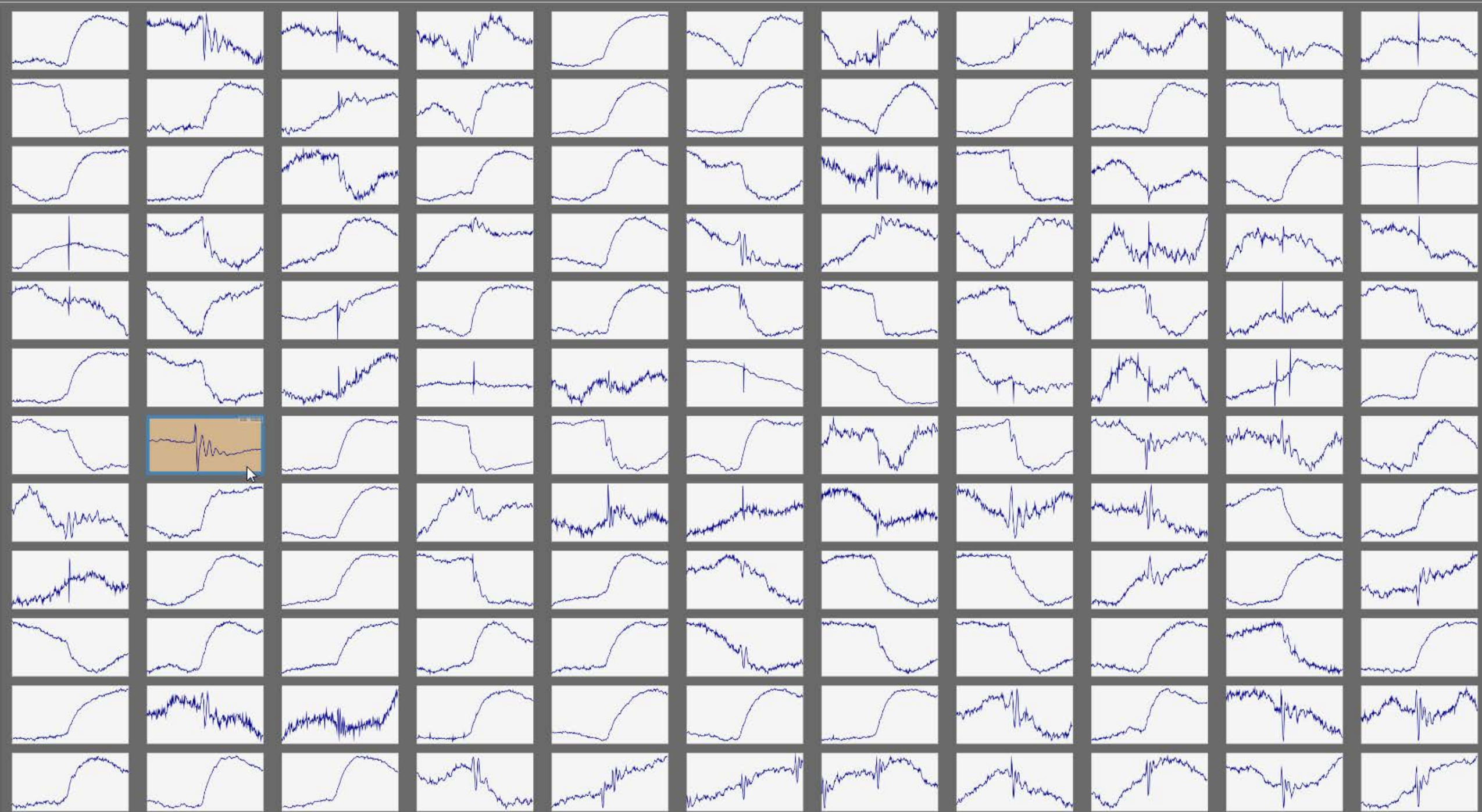
Wide Area, Wide Spectrum

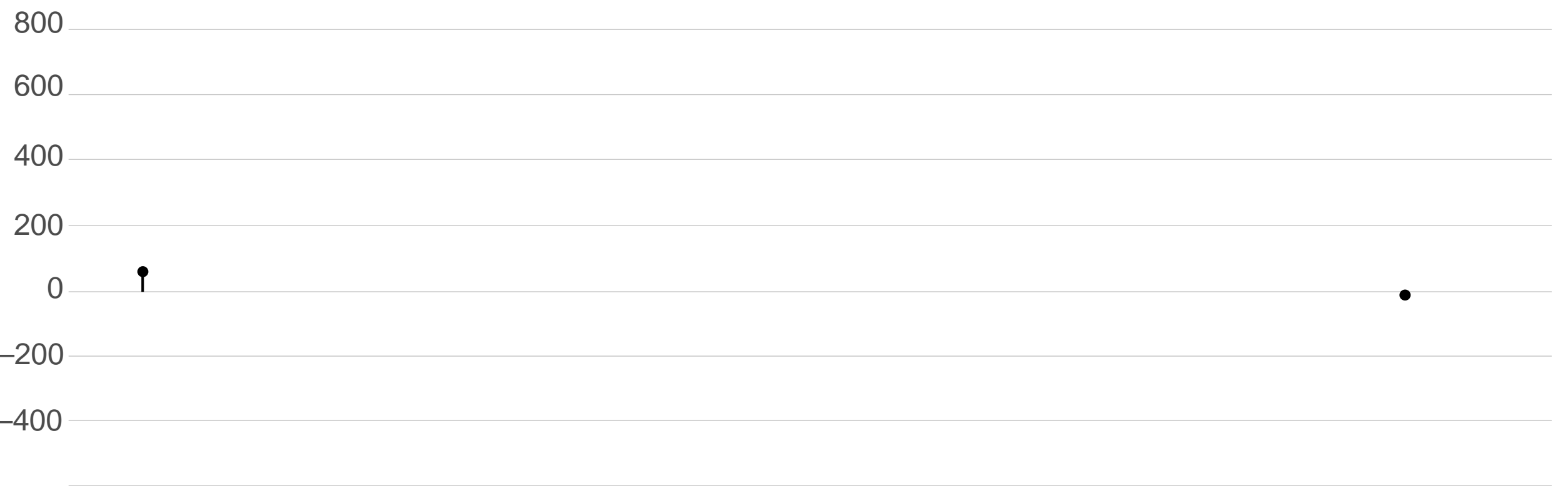


“A wide-area wide-spectrum big data system”, *IEEE Power and Energy Society General Meeting*, July 26 – 30, 2015.

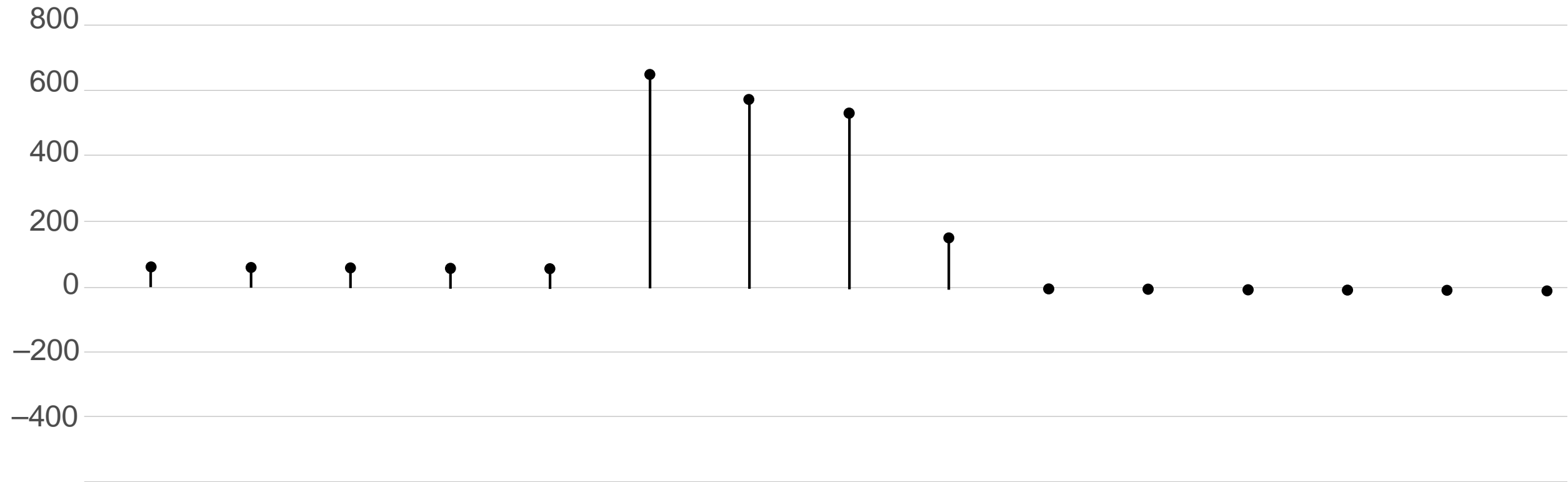
Analytics at Full Signal Bandwidth





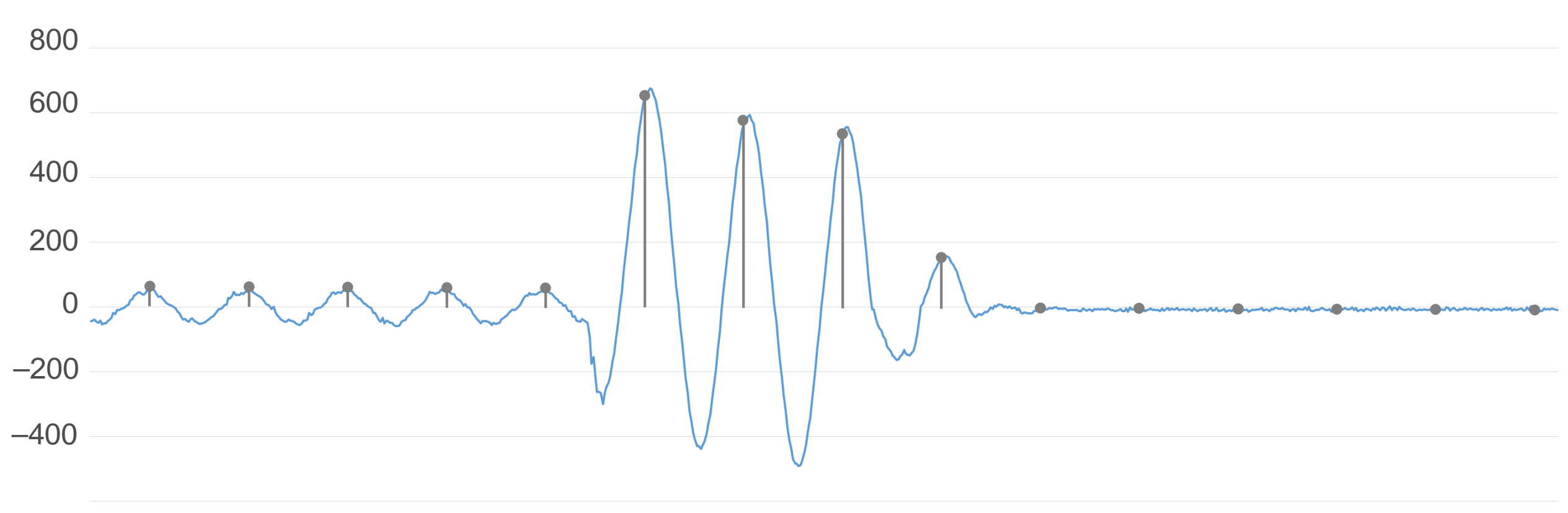


SCADA

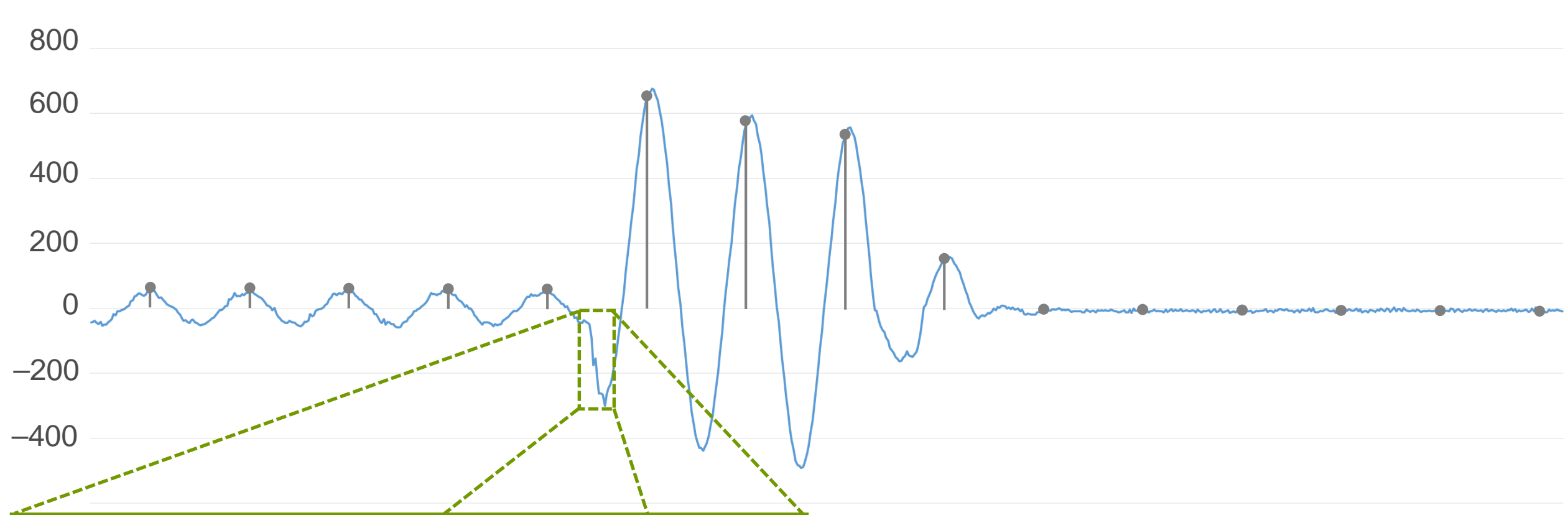


Synchrophasors* at tens of samples per second

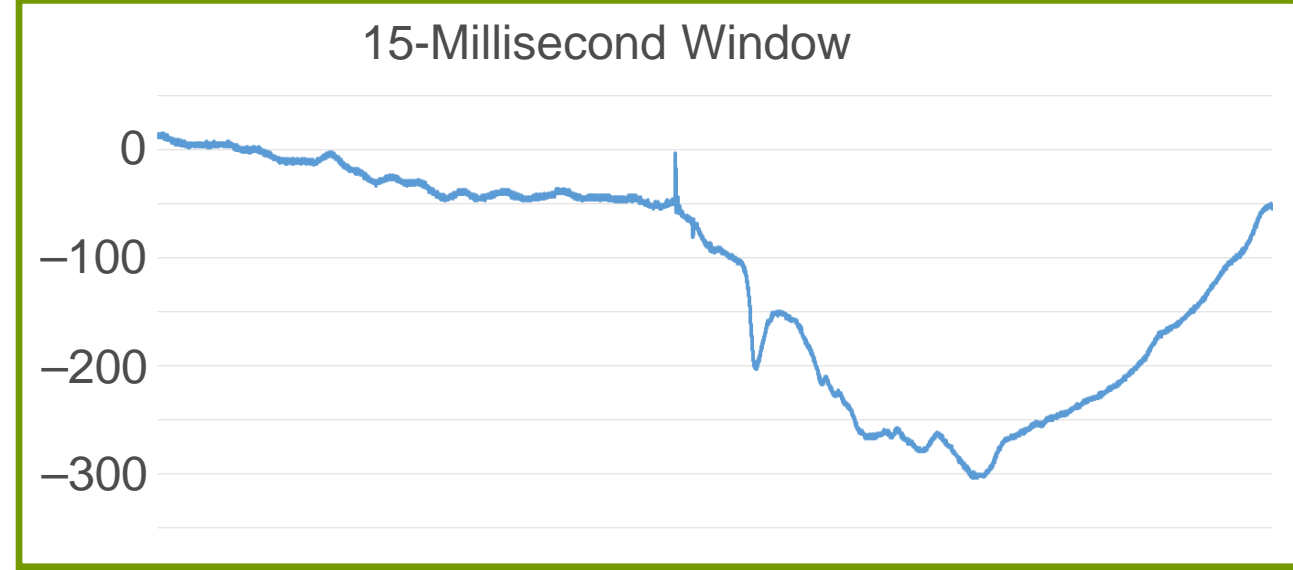
*qualitative



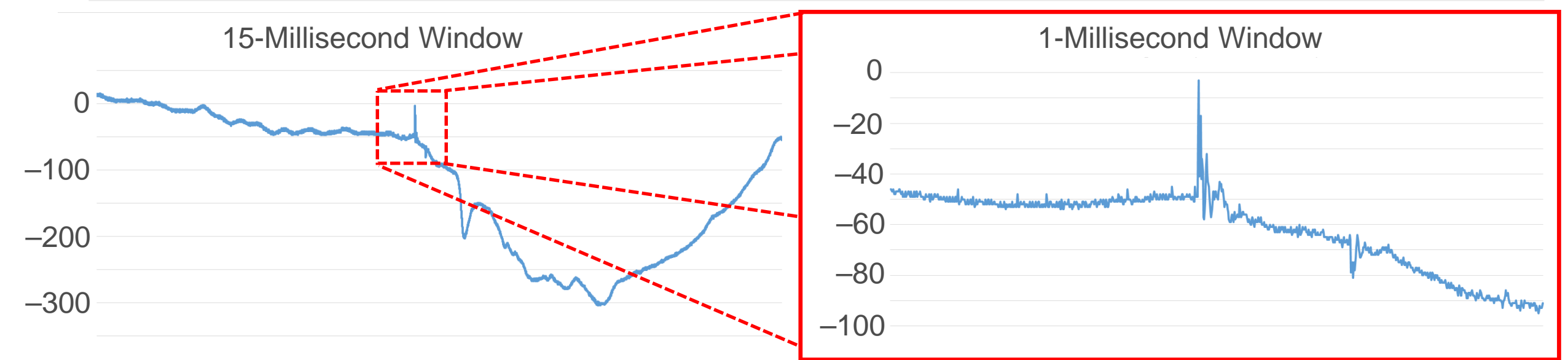
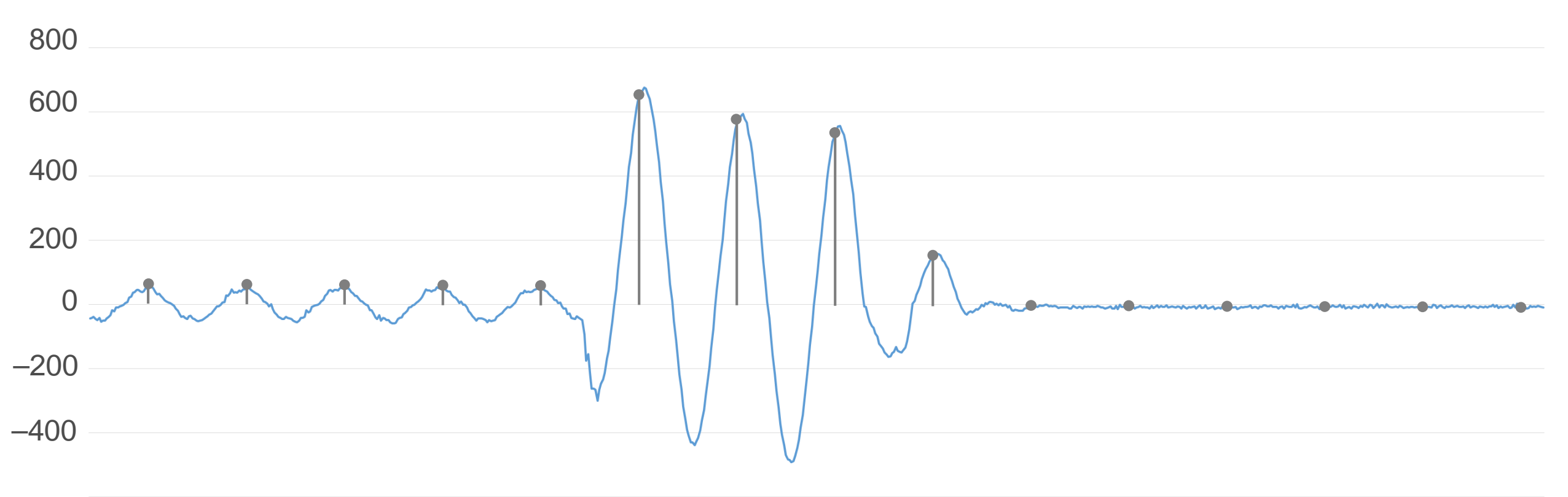
Wide-Area Wide Spectrum (WWS)



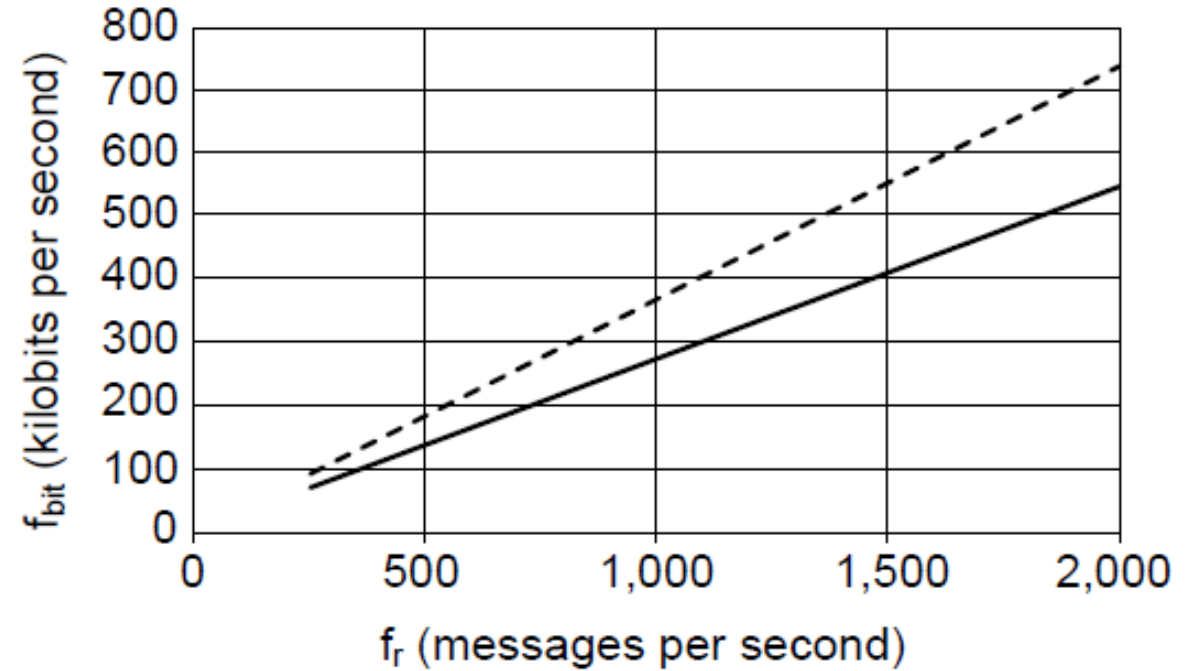
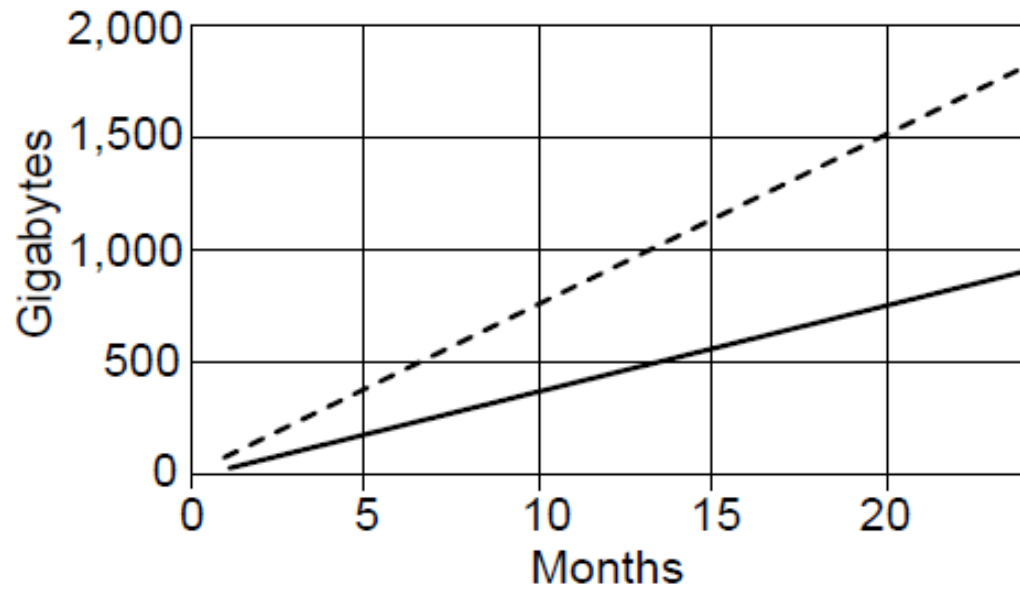
15-Millisecond Window



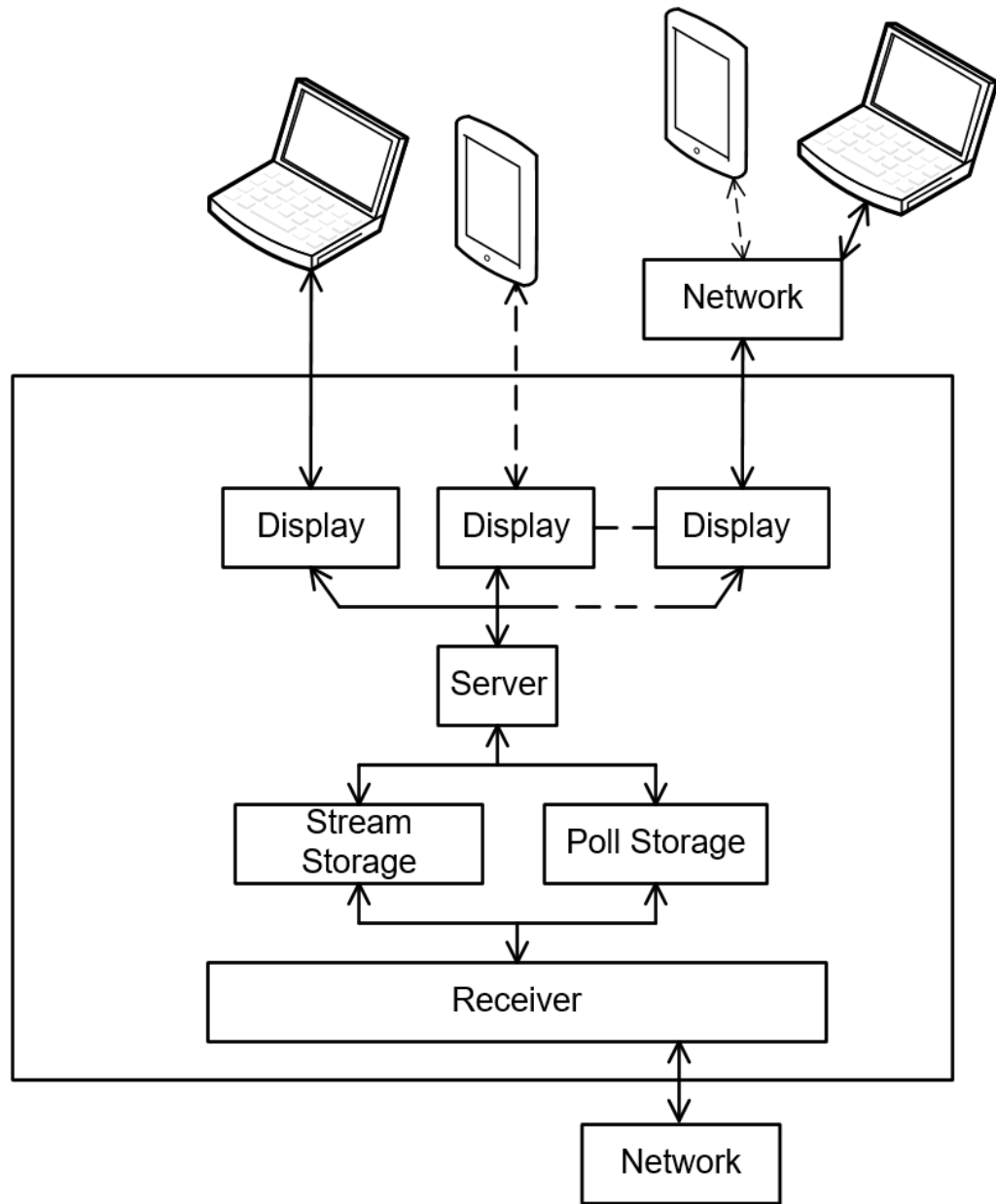
What is happening here....



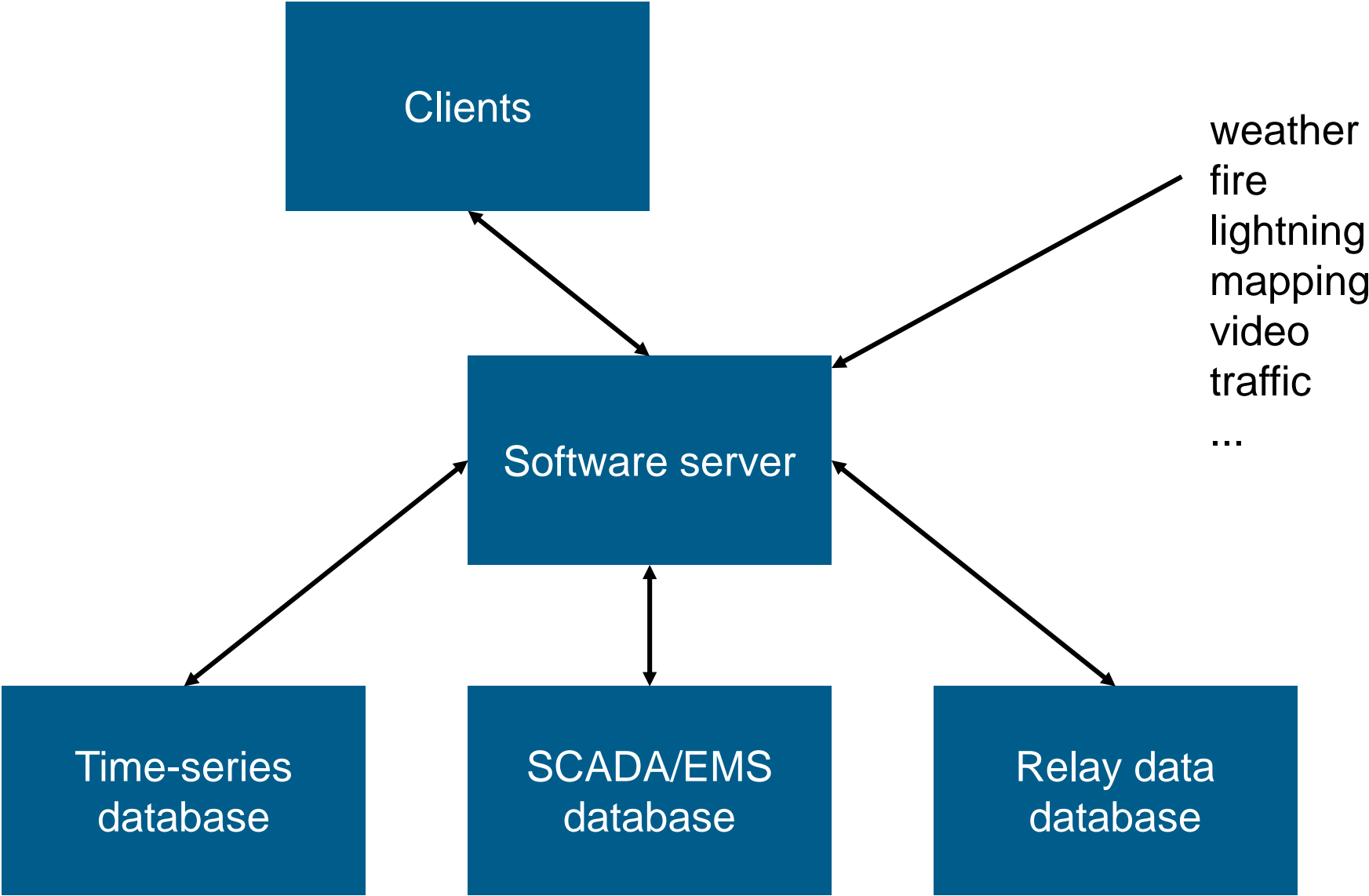
WWS Data Rates and Storage



Non-Streaming Point-On-Wave

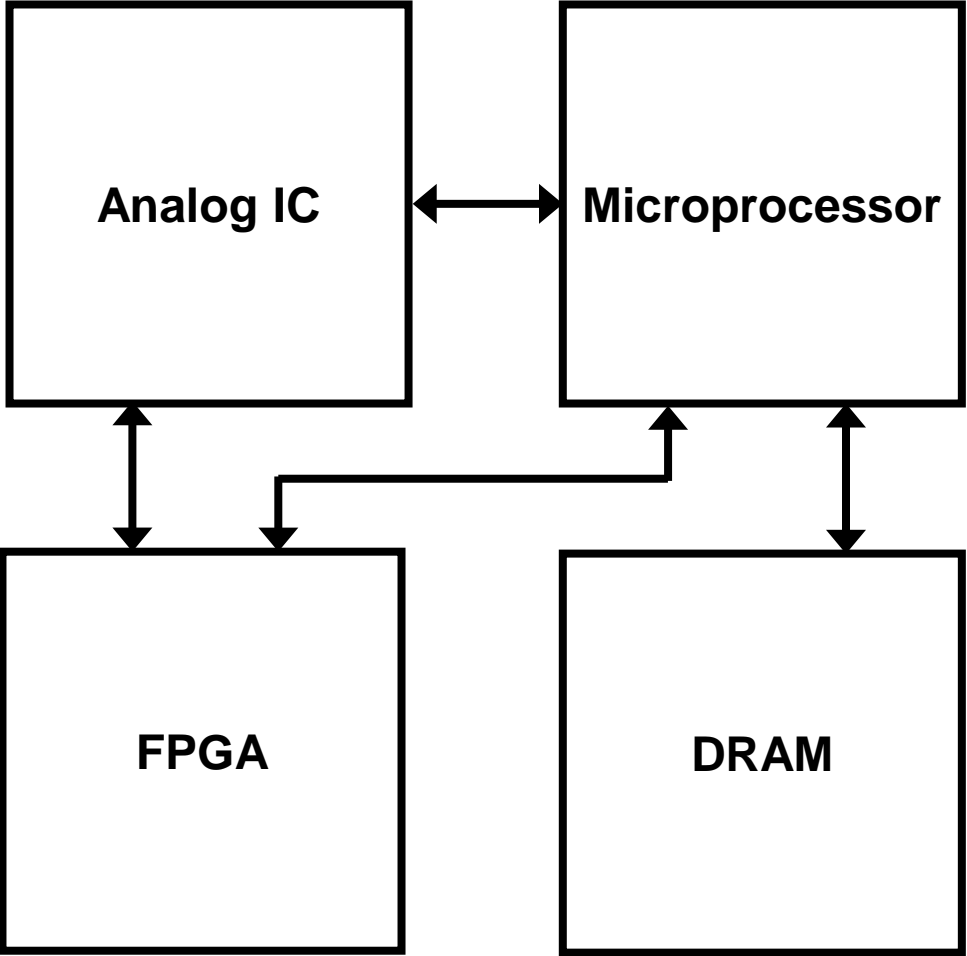


Data Source Architecture – Today

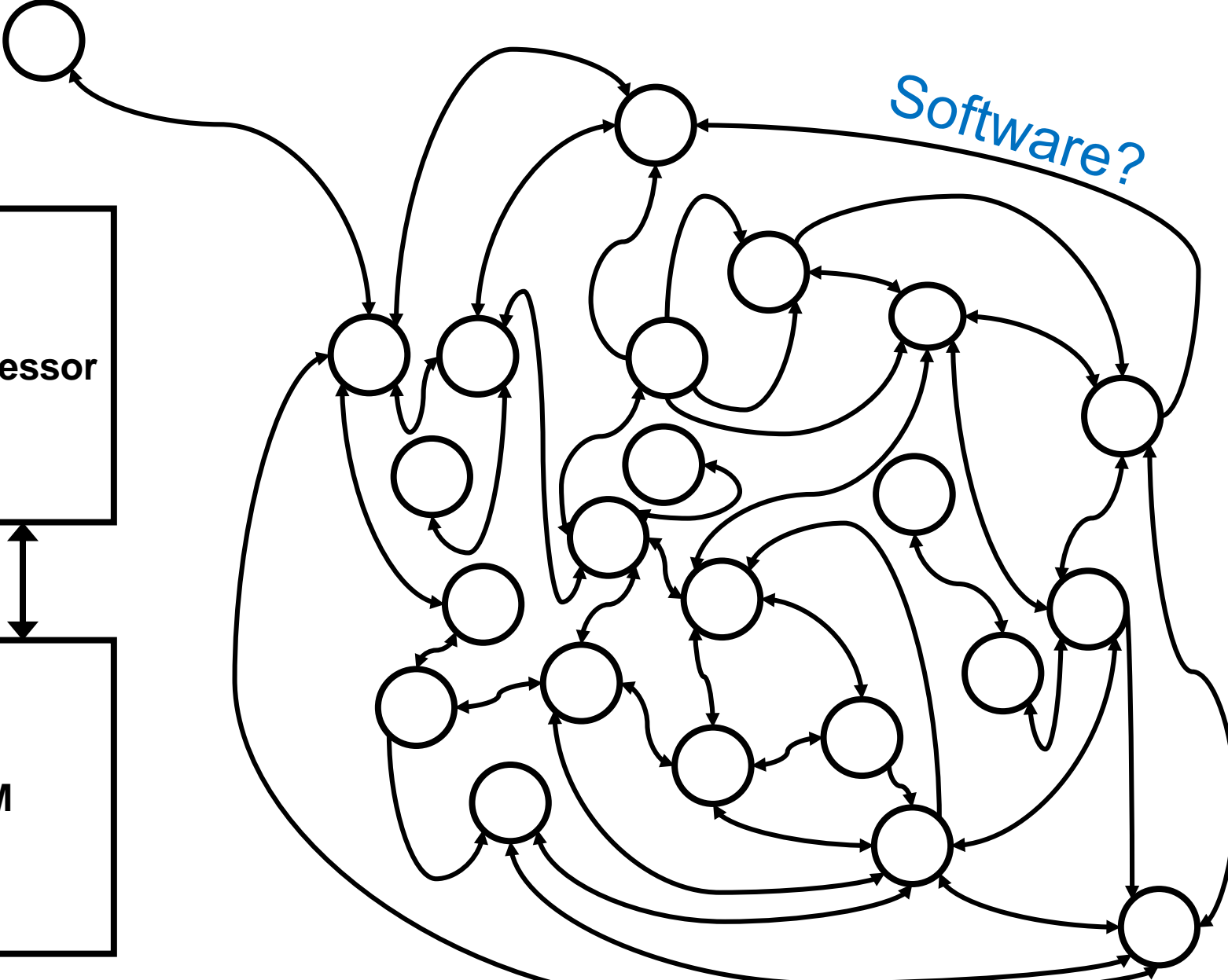


Why Can't Software Look Like Hardware?

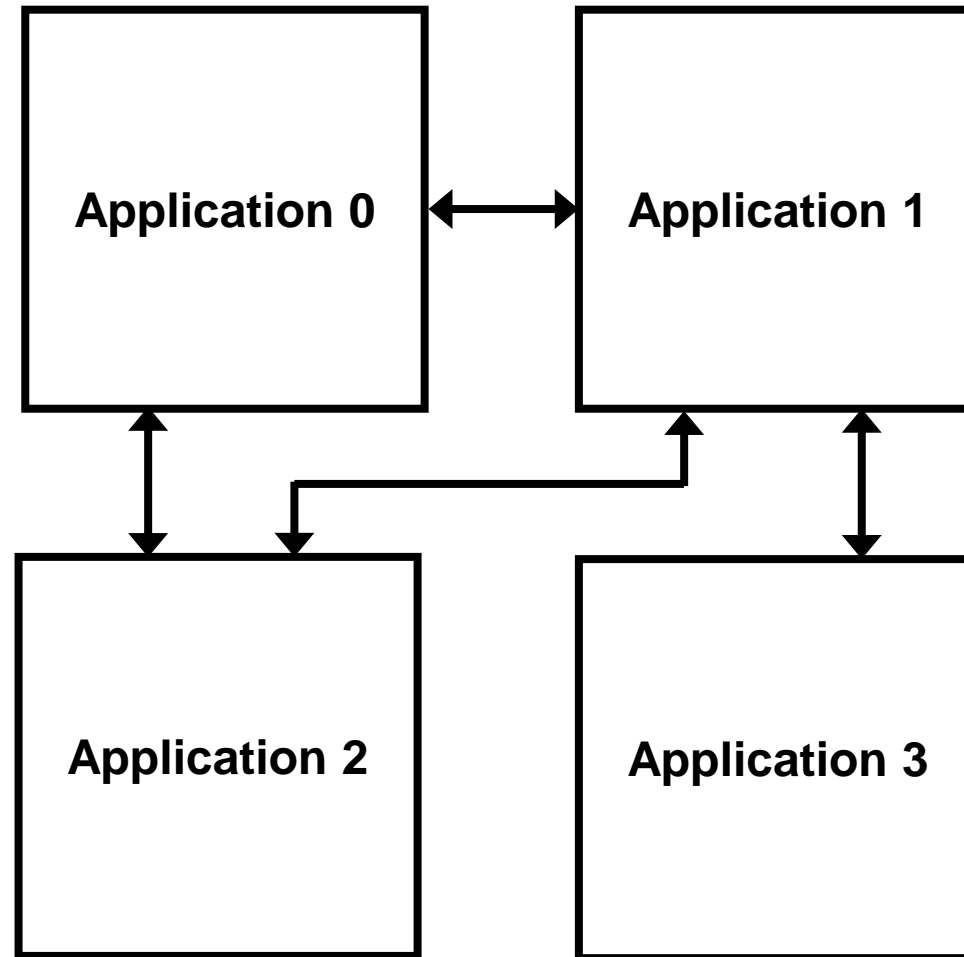
Hardware



Software?



Simplifying Connections to Disparate Sources



Containerized microservice (app-based) architecture