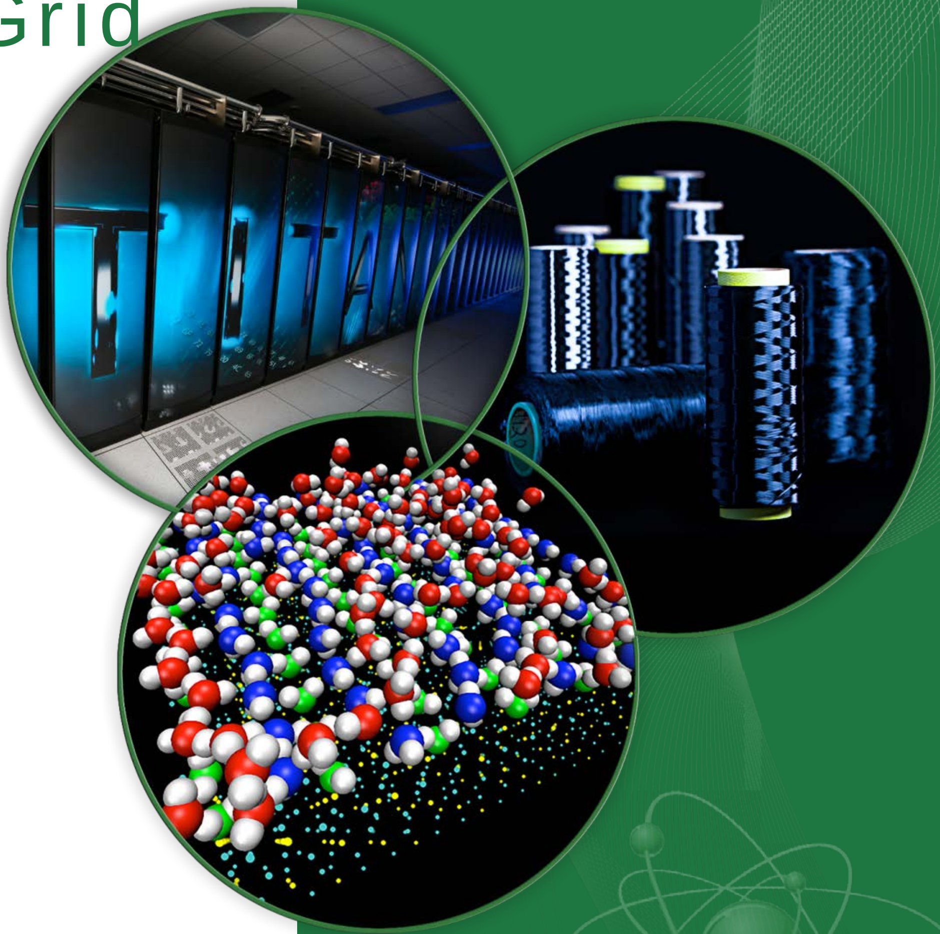
Is NTP A Suitable Timing Source For Grid Applications?



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March 23, 2017

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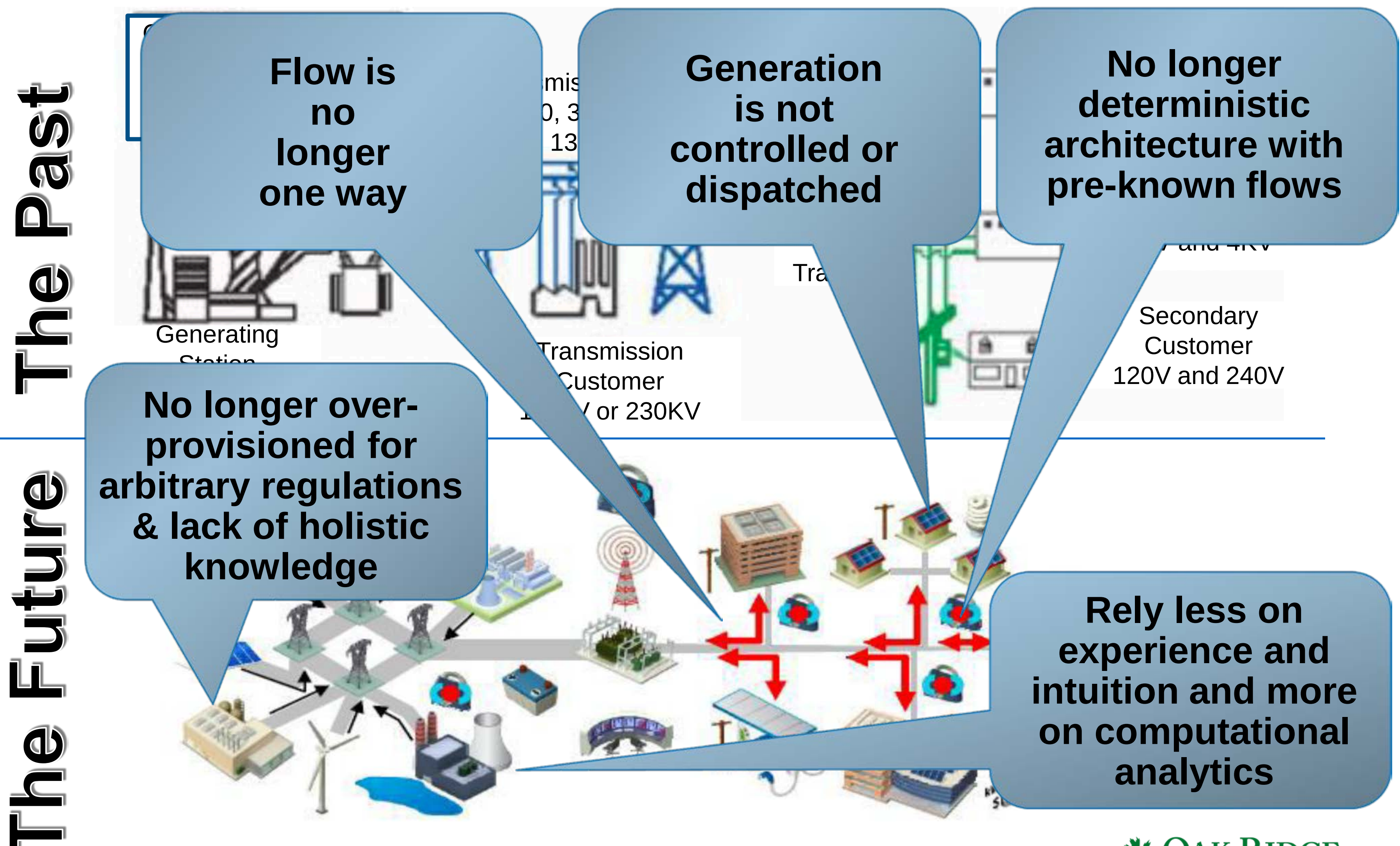
Outline

- Motivation
- Approach & Research
  - What is NTP & How Does It Work?
  - Strengths & Weaknesses
  - Applications
- Conclusion & Acknowledgements

The Need For Time Agreement

The Grid Is Becoming More Like A WAN



…And Situational Awareness of a Distributed WAN Demands Coordination

The Valley Falls, Rhode Island train wreck of the Providence and Worcester Railroad, August 12, 1853

The North American Electric Reliability Council cited a lack of situational awareness as a contributing factor leading to the 2003 blackout.

Among their recommendations was the installation of time-synchronized data recording and reporting devices.

- Cast a wide net – monitor & capture timestamped state as much as possible
- Analyze rapidly distilling critical info
- Retain all useful data with timestamps for future analysis

Better Time Agreement ➔ Better Understanding

- At 60 Hz nominal frequency, a 1 percent Total Vector Error (TVE) provides a timing error budget of 26 microseconds. Given there are other sources of errors, the TSTF has established a goal of 1 microsecond or better accuracy to UTC.

- According to some work by Zhao et al., angle error as low as ±0.1° can cause a failure, and an angle error of ±0.6° will have an even greater impact.[1]

- From a study of the Northeast Power Coordinating Council model, an angle error as small as ±0.15° is able to change the first responding PMU.

[1] Jiecheng Zhao, Jin Tan, Ling Wu, Lingwei Zhan, Yilu Liu, Jose R. Gracia, Paul D. Ewing. Impact of Measurement Error on Synchrophasor Applications. ORNL Technical Report

Okay, We Need Distributed Time Isn't That Easy in 2017?

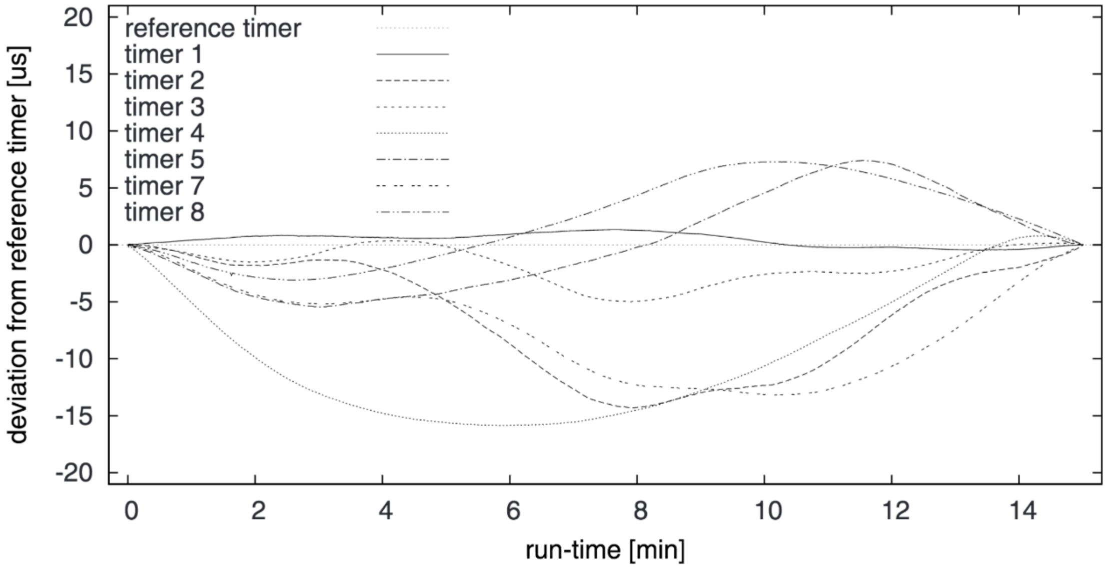


Figure 1: Frequency stability of 8 computer clocks.

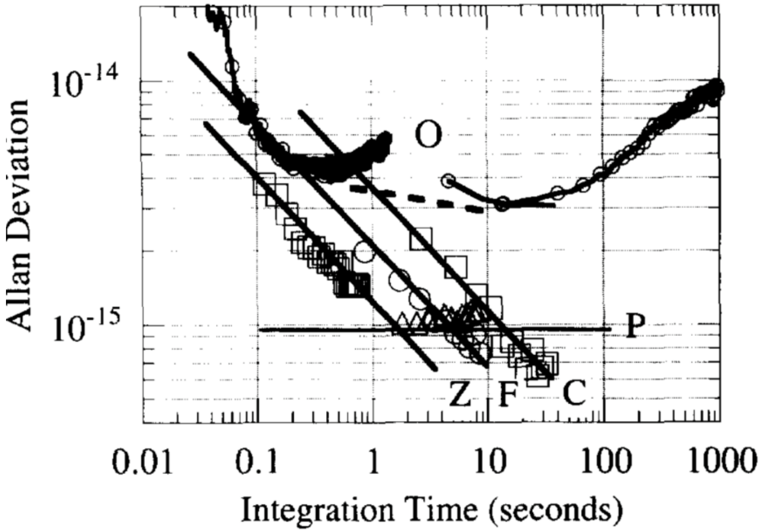


Figure 2: Frequency stability of 5 types of oscillators: (O) sapphire crystal; (Z) "zero-beat" servo; (F) frequency servo; (C) circular servo loop; (P) power servo controlled.

Figure 1 Source: Jens Doleschal, Andreas Knupfer, Matthias S Muller, and Wolfgang E Nagel. Internal timer synchronization for parallel event tracing. In European Parallel Virtual Machine/Message Passing Interface Users Group Meeting, pages 202–209. Springer, 2008.

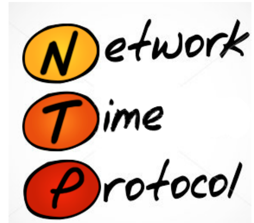
Figure 2 Source: Luiten, A. N., A. G. Mann, M. E. Costa, and D. G. Blair. "Power stabilized cryogenic sapphire oscillator." IEEE transactions on instrumentation and measurement 44, no. 2 (1995): 132-135.

The Usual Suspects of Timing

- Time Standards
  - UTC (common, includes leap seconds)
  - GMT
  - TAI
- Oscillators
  - Hold-over oscillators
  - Physical-layer signaling
  - CPU cycles since last reboot
- Clock sources capable of Communicating Time Info
  - Uni-directional broadcast (GPS, eLoran)
  - Bi-directional exchanges

Beyond GPS…

- NTP (ubiquitous)

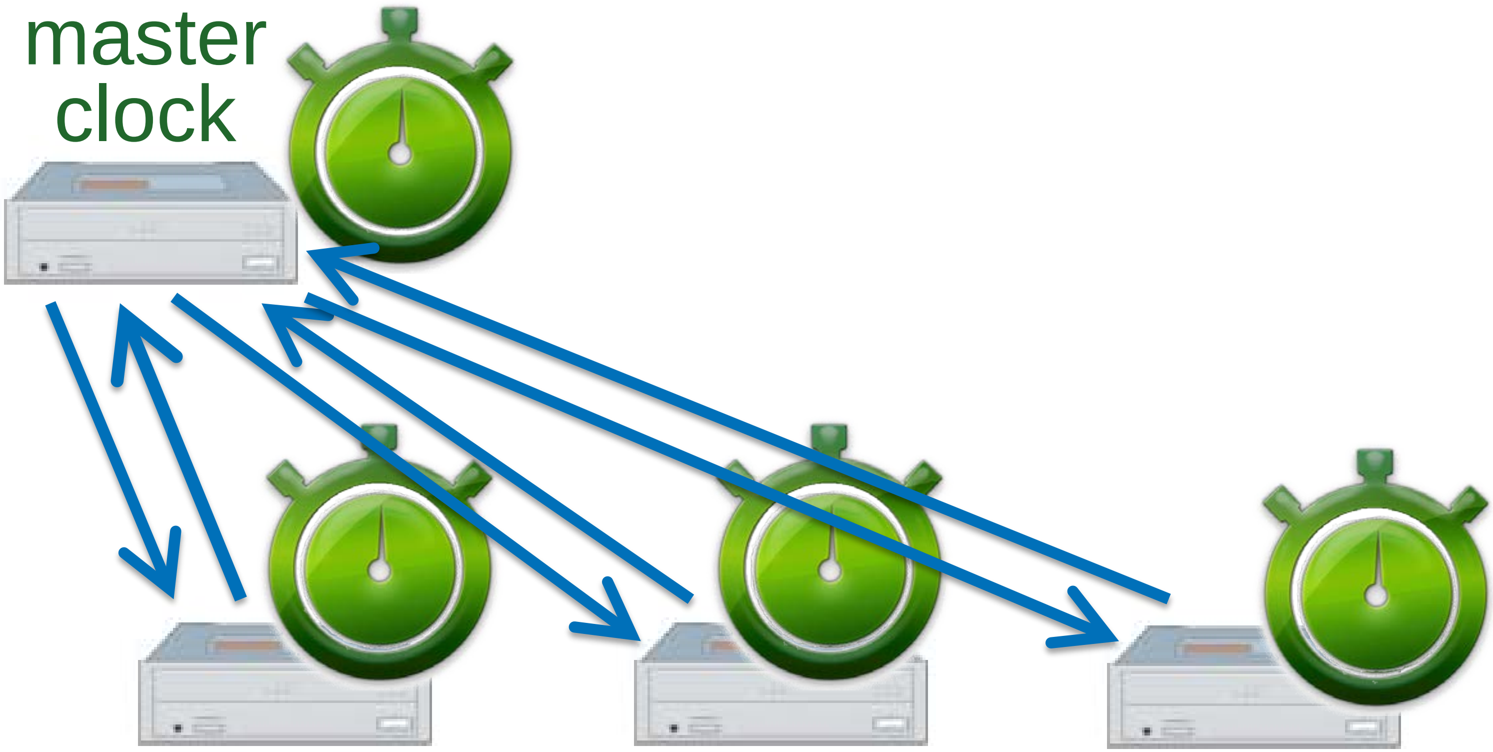


- PTP (more accurate up to about five routers/switches)

- TSN - a group of individuals defining standards in 802.1 for time sensitive networking (e.g. 802.1as is PTP)

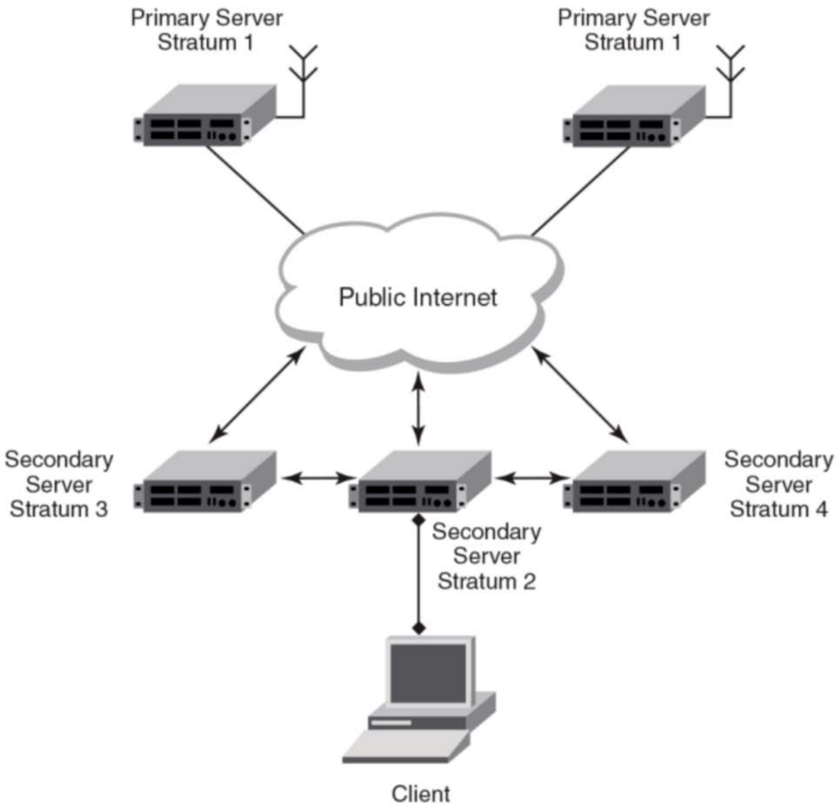
- Synchronous Ethernet (SyncE); subject to loops

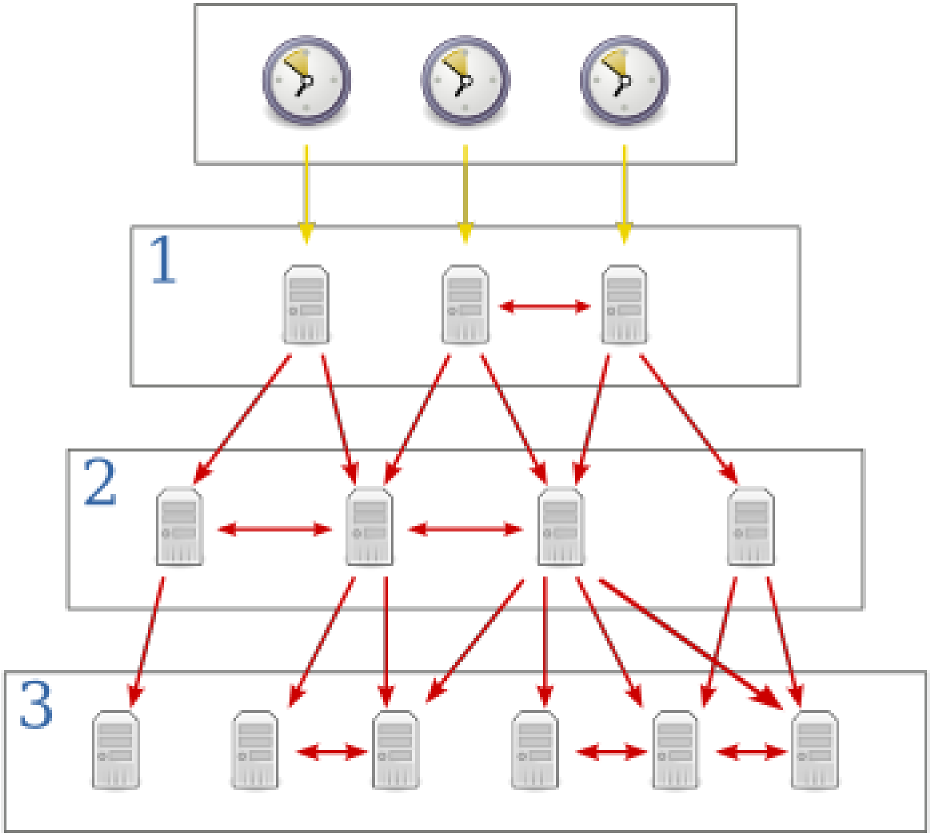
Basic Idea of a networked time source



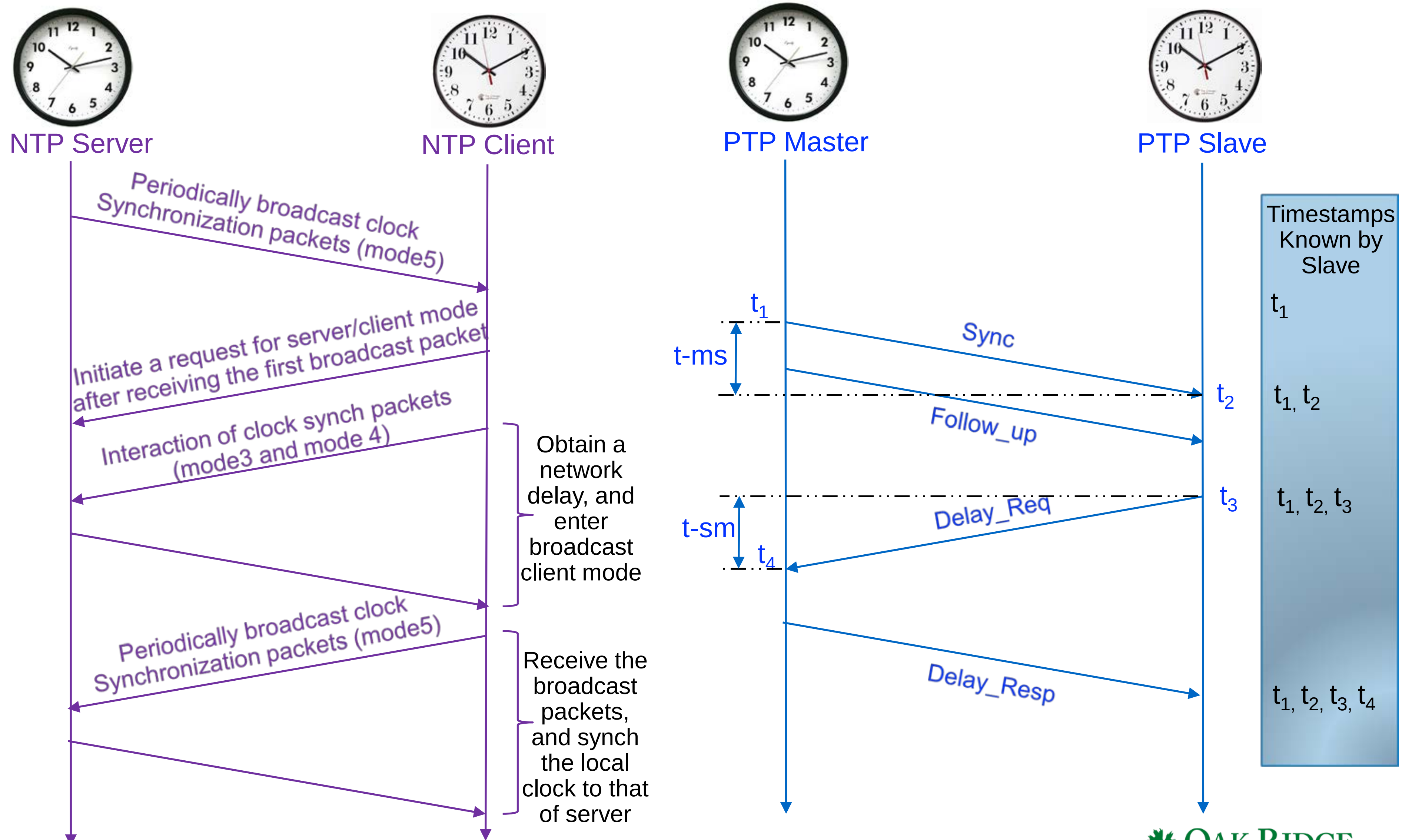
Distribution systems (e.g., NTP, GPS) typically do not know about local time zones or daylight saving time. A time server located anywhere in the world can provide synchronization to a client located anywhere else in the world.

An Overview of NTP





It's All In The Exchanges



Strengths & Weaknesses of NTP

Strengths

- Ease of implementation
- Cost
- Robustness

Weaknesses

- Accuracy (Difficult to account for message queuing)

What Happens If We Rely Solely on NTP?

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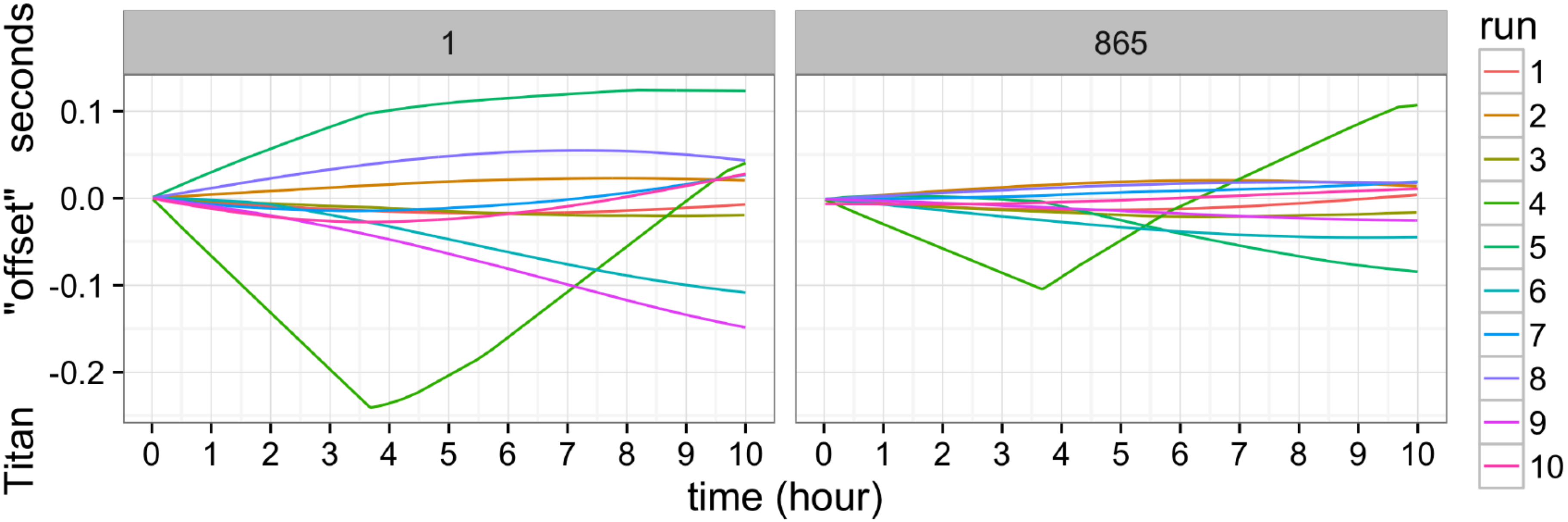
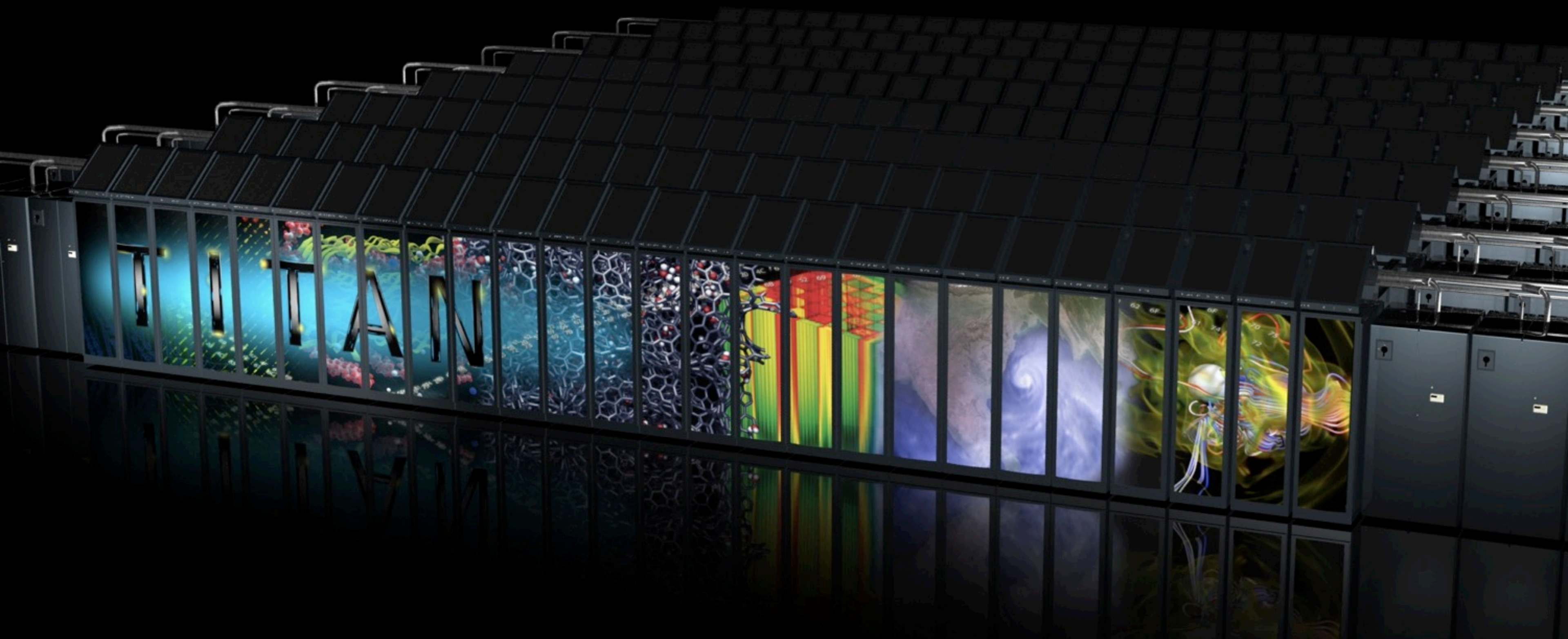


Recommendations & Conclusions

- If you have to deploy now, consider a combination of GPS backed by good hold-over oscillators and/or PTP
- Better yet, if you can wait – trust that something better will soon be available
- Do not consider NTP to be appropriate for distributed, dynamic control of power grid functions

Acknowledgements

This presentation gratefully used information and figures from the Electricity Advisory Committee; DOE's Grid Tech Team; the Office of Electricity Delivery and Energy Reliability (OE); the Office of Energy Efficiency and Renewable Energy (EERE); and the Office of Energy Policy and Systems Analysis (EPSA).



This research used resources of the Oak Ridge Leadership Computing Facility at the Oak Ridge National Laboratory, which is supported by the Office of Science of the U.S. Department of Energy under Contract No. DE-AC05-00OR22725.

Questions?

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Extra Viewgraphs