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# Real Time Tool to Characterize Power System Communication Delays

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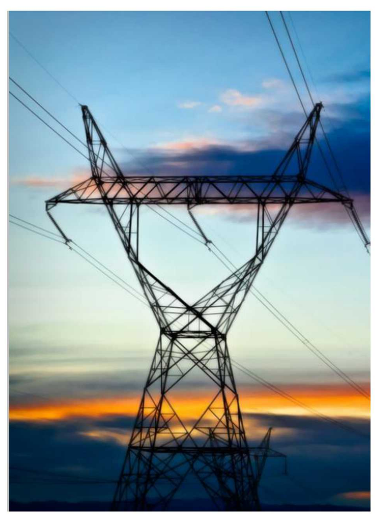

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## Introduction

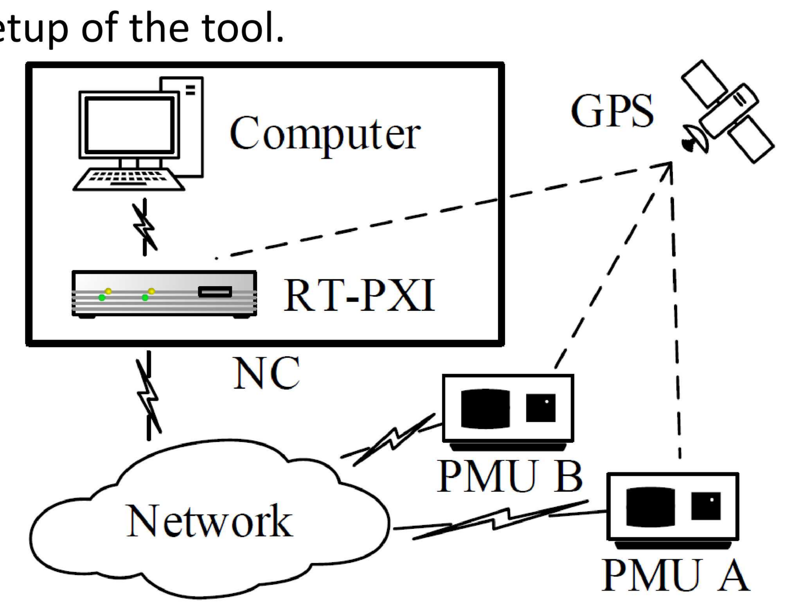
- Synchrophasor Measurement Units (PMUs) collect high resolution power systems data
- Synchrophasor data includes highly accurate time stamps
- Synchrophasor data is used in numerous real time (RT) applications
- Delays can adversely affect RT use of this data
- Packet losses can adversely affect synchrophasor data availability
- Accurately characterizing the delays and data loss can be valuable in RT systems.

The real-time (RT) tool includes:

- Recording Time Received of incoming synchrophasor packets
- Support for UDP and TCP streams
- Alignment and analysis of received packets
- Statistical summary on the measured delay
- Statistical summary on missing packets
- Mirroring data to other devices with recorded time of re-send

## Tool Implementation

This Network characterizer tool (NC) is implemented on a RT National Instrument PXI and a computer. The graphic below shows the general setup of the tool.

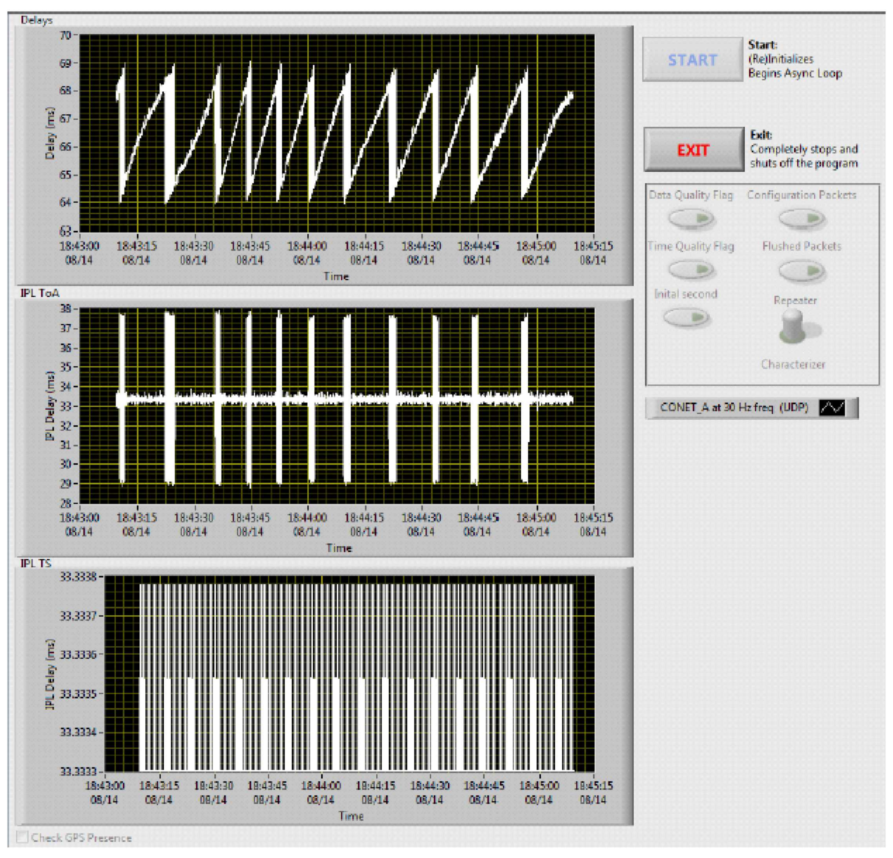



The screenshot to the right shows the user interface running on the computer. The Interface shows the delays of each packet ($T_{Del}$) and the Inter-Packet Latencies ($IPL$)

$$T_{Del} = T_{arrived} - T_{PMU\ Timestamp}$$

$$IPL_{arrive} = T^{k+1}_{arrived} - T^{k}_{arrived}$$

$$IPL_{PMU} = T^{k+1}_{PMU\ Timestamp} - T^{k}_{PMU\ Timestamp}$$

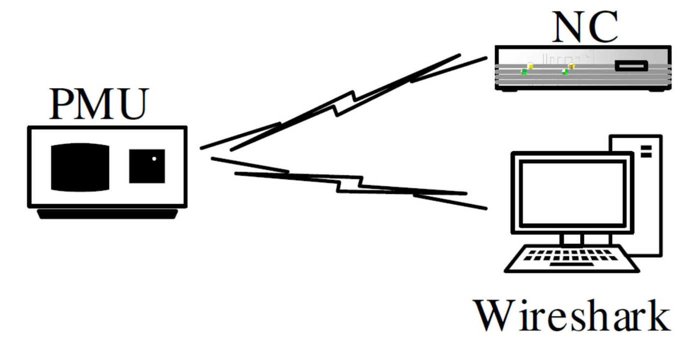


The RT PXI is connected to a GPS clock, which allows the NC to accurately timestamp the time of arrival of any synchrophasor data packet.
If desired the RT-PXI can also repeat packets to other devices and accurately record the time at which the packet is send to the network to analyze network delays

## Test Setup

The network used in this work is a simple dedicated Local Area Network containing the NC, a PMU and a computer running WS.

The PMU was set up to stream the data to WS and the NC simultaneously.




A Number of comparisons of the delays measured by the NC against the delays measured by Wireshark (WS) were done.

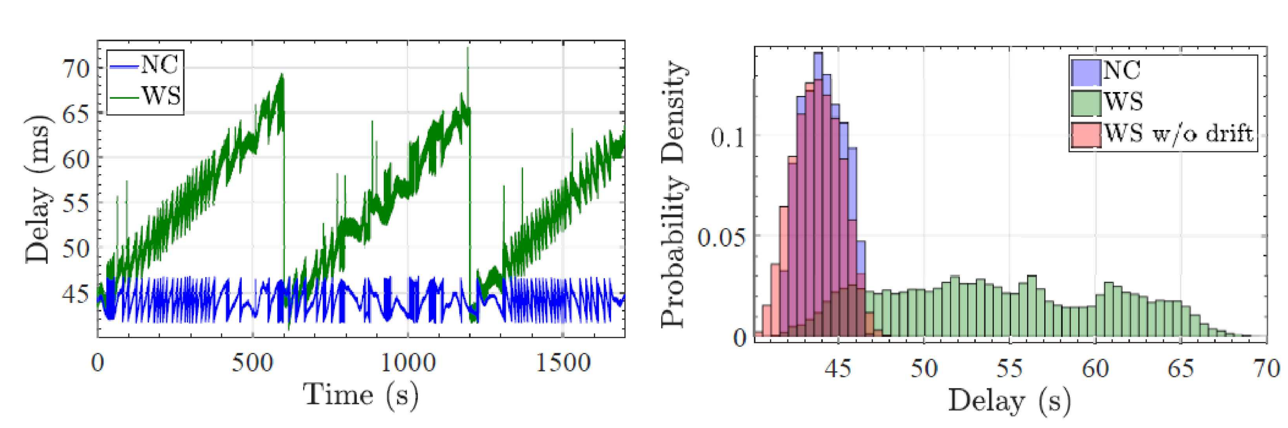
The 4 Scenarios described in this paper are

- PMU recording at 30 $fps$ connected through UDP
- PMU recording at 60 $fps$ connected through UDP
- PMU recording at 30 $fps$ connected through TCP
- PMU recording at 60 $fps$ connected through TCP

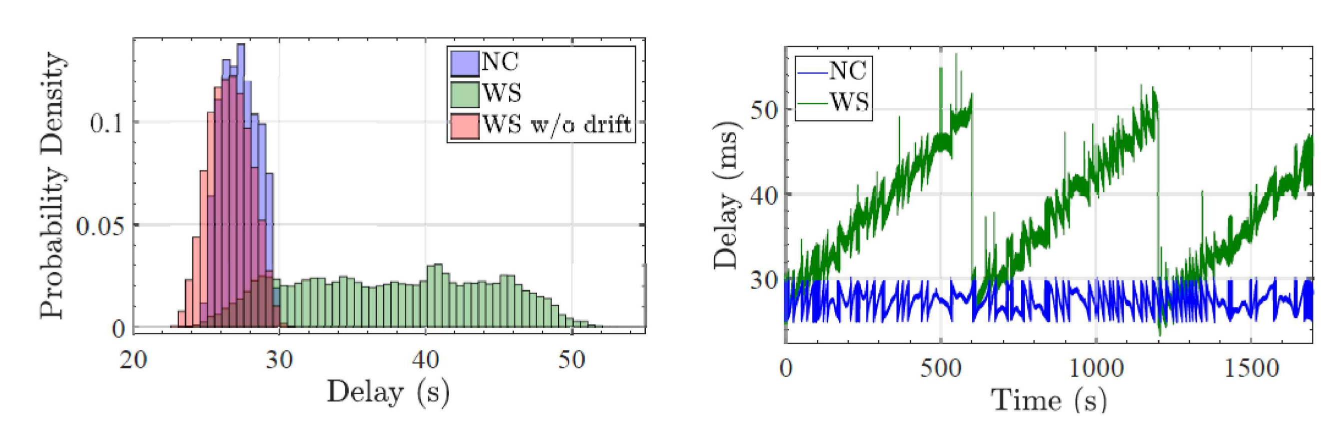
Additional test cases are included in [1]

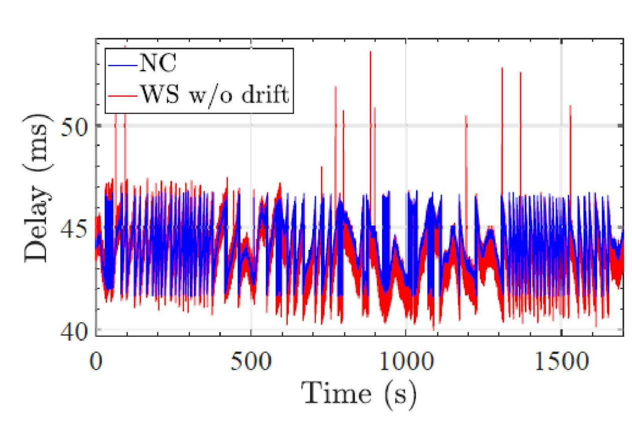
## Results

**30 $fps$ UDP Results**

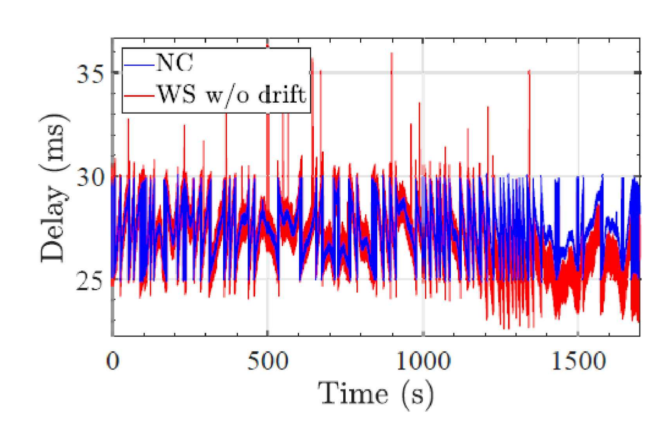



**60 $fps$ UDP Results**

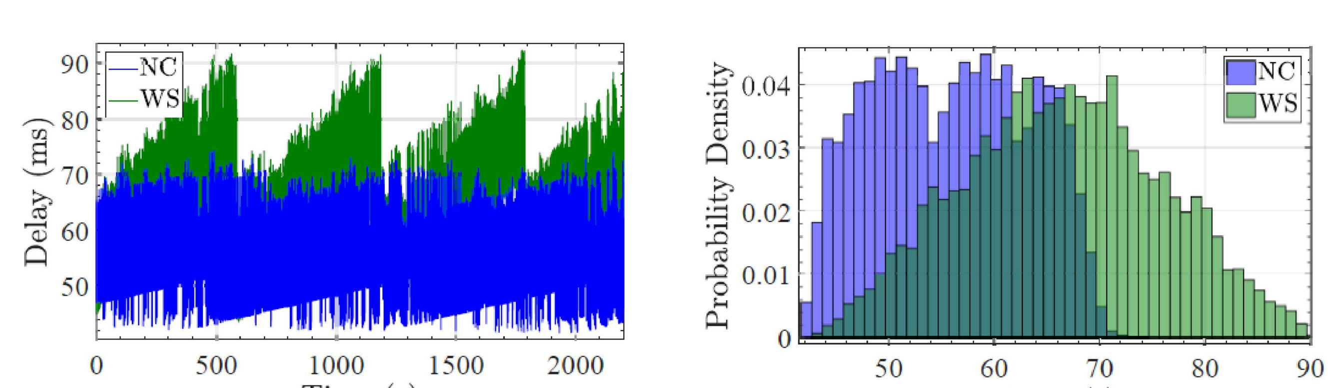


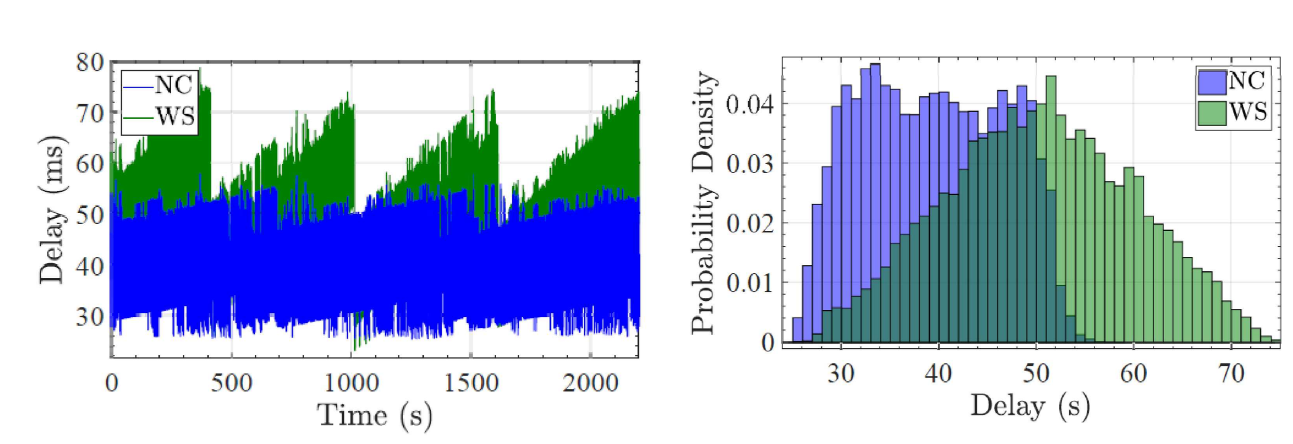

- The results indicate that the NC measures the delays significantly more accurate than WS.
- The repeating "saw tooth" pattern in the WS results is due to the computers local clock drifting and re-synchronizing with the GPS clock every 10 minutes
- Determining the drift of the clock allows the removal of this effect, however, the probability distribution of the delays measured by WS after removing the drift still shows more variation.




**30 $fps$ TCP Results**




**60 $fps$ TCP Results**




A similar pattern can be found in the WS results when using TCP. However, the delays vary significantly more when using TCP. Due to the increased variation it is difficult to estimate and remove the drift of the local clock used by WS.

## Conclusions

- A tool to measure synchrophasor latencies was developed and a comparison of the NC tool against a traditional network characterizer was completed.
- The proposed tool is capable of determining synchrophasor delays more accurately.
- Synchrophasor delay is dependent on:
  - Measurement frequency of the PMU.
  - Network Transport Protocol selected.

## References

[1] C. Lackner, F. Wilches-Bernal, B. J. Pierre, and D. A. Schoenwald, "*A Tool to Characterize Power System Communication Networks with Synchrophasor Data*", submitted to *IEEE Power and Energy Technology Systems Journal*, 2018.

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