SAND2019-3937D

Real Time Tool to Characterize Power System Communication Delays

Christoph Lackner[1], Felipe Wilches-Bernal[2], Brian J. Pierre[2] and David A. Schoenwald[2]

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

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
- Replaying 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. Fig 1. shows the general setup of the tool

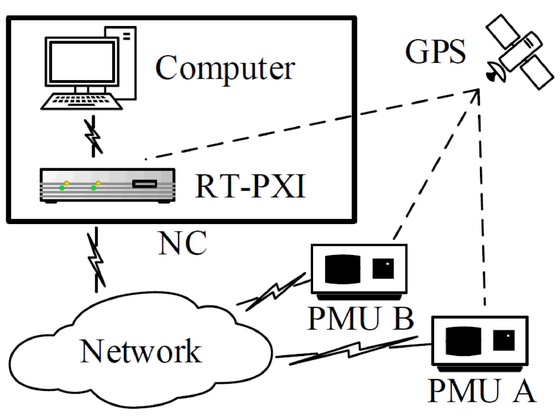
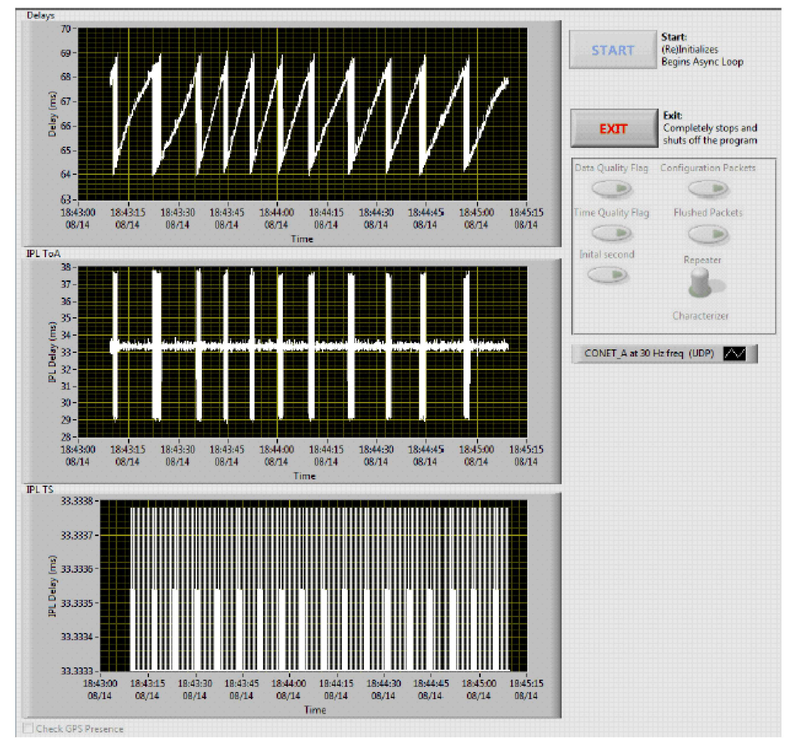


Fig. 2 shows the user interface running on the Computer. The Interface shows the delays of each packet (T_{Del}) and the Inter-Packet Latencies (IPL)

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

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

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



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.

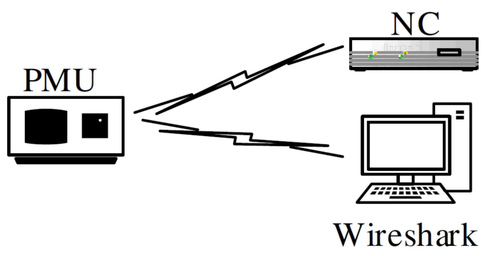
If desired the RT-PXI can also repeat packets to other devices and accurately record the time at which the packet is send to the network to analyze network delays

Test Setup

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

The 4 Scenarios used in this work 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

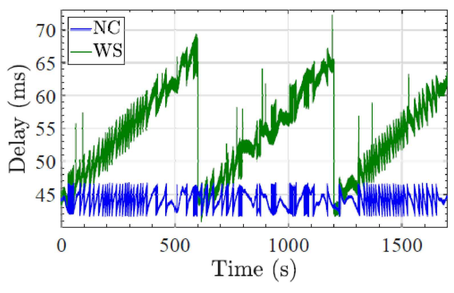


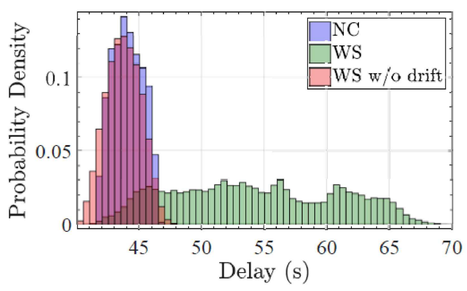
The network used in this work is a simple dedicated Local Area Network containing the NC, a PMU and a computer running WS.

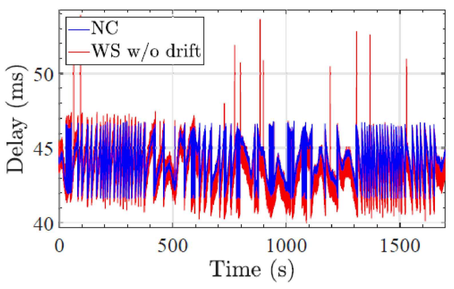
The PMU was set up to stream the data to WS and the NC simultaneously.

Results

30 fps UDP Results





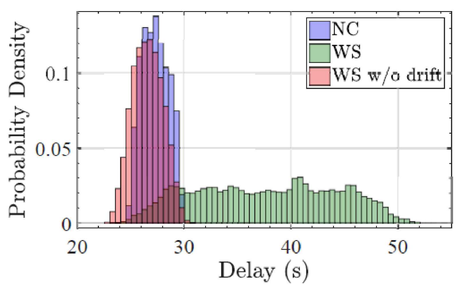


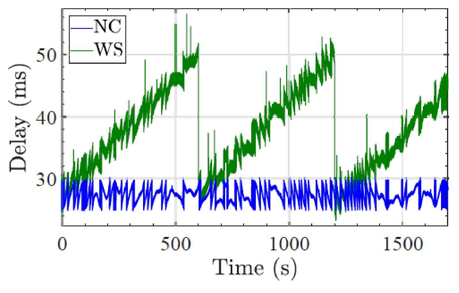
The results indicate that the NC measures the delays significantly more accurate than WS.

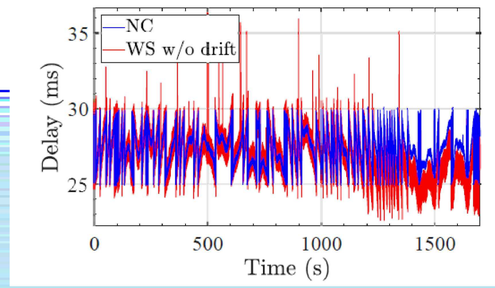
The repeating "saw tooth" pattern in the WS results is due to the computers local clock drifting and re-synchronizing with the GPS clock every 10 minutes

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.

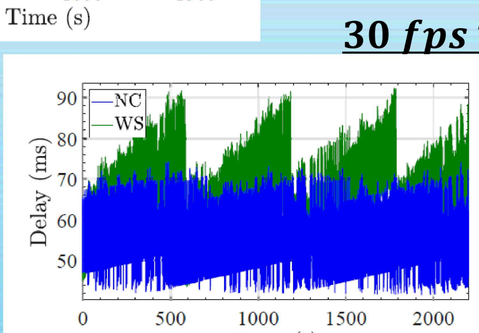
60 fps UDP Results

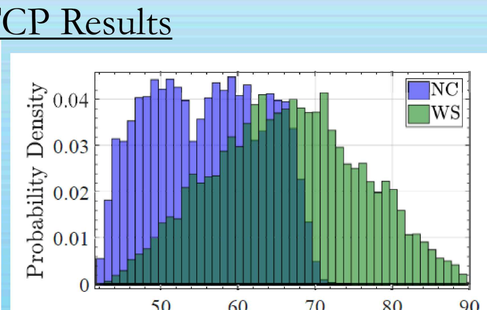




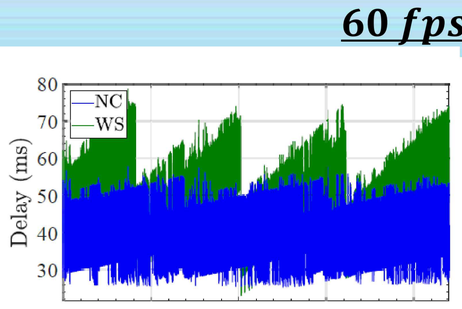


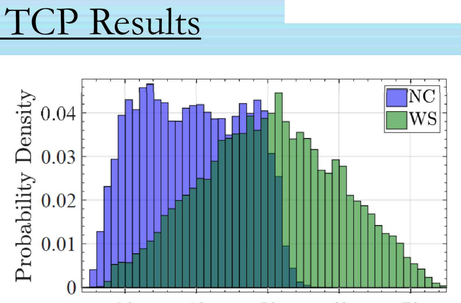
30 fps TCP Results





60 fps TCP Results





U.S. DEPARTMENT OF ENERGY
NNSA National Nuclear Security Administration

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.
SAND No. **SAND2018-10462 C**

The authors would like to thank Dr. Imre Gyuk, Director of Energy Storage Research, Office of Electricity Delivery and Energy Reliability for his funding and guidance on this research.

Sandia National Laboratories

[1] Rensselaer Polytechnic Institute [2] Sandia National Laboratories contact: lacknc@rpi.edu