Using Synchrophasor Data to Determine Disturbance Location

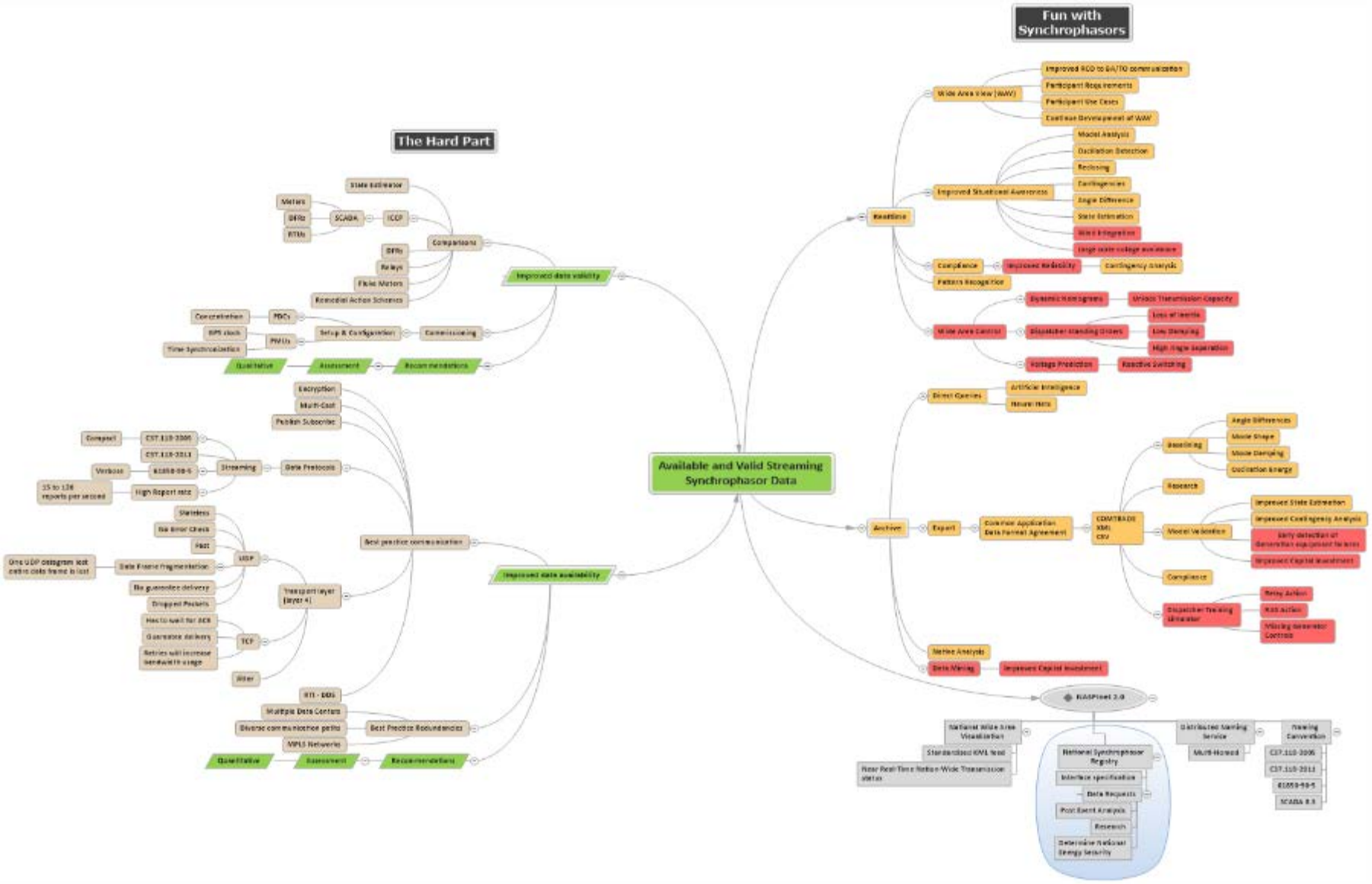
NASPI Work Group Mtg. Joint Panel Session
October 24, 2018

Data and Network Management Task Team
D&NMTT

Phun with Phasors
Dead On Arrival without the Data

Smart Grid

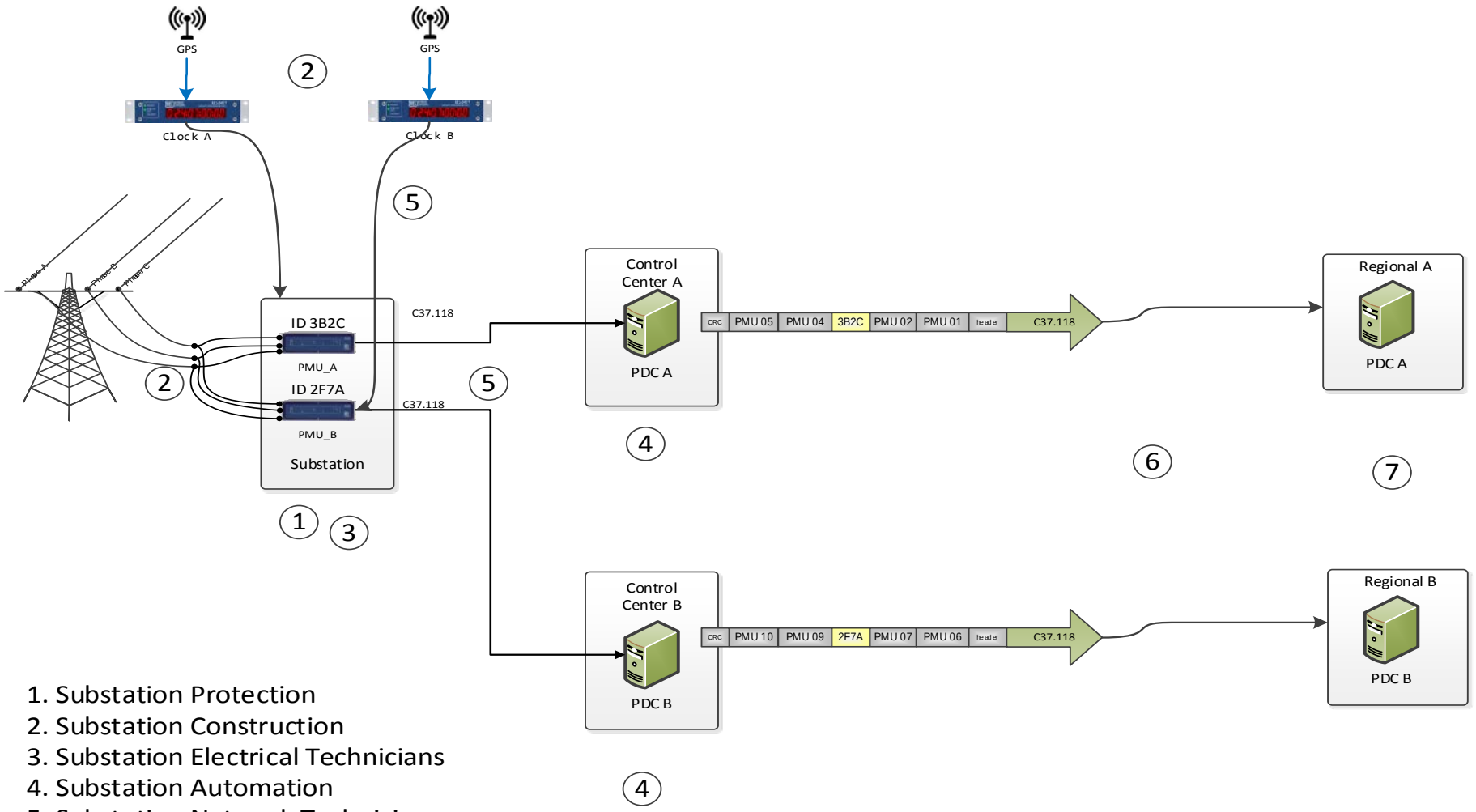
The term Smart Grid has been around for some time now, although the meaning has shifted over the years. In its earliest usage, it was applied to systems that made use of data to perform power quality studies and post event analysis. More recently, the term has come to mean using data to implement a "self-healing" grid. Self-healing is another term that has multiple definitions from standard protection relays and breakers to distribution level Fault Location, Isolation, and Service Restoration (FLISR). There are multiple definitions of what constitutes a Smart Grid, but ***the common denominator is that they all rely on data***.


Available and Valid Streaming Synchrophasor Data
The Hard Part
Improved data validity
Improved data availability
Best practice communication
Best Practice Redundancies
Fun with Synchrophasors
Baseline
Archive
Direct Queries
Improved RCO to BA/TO communication
Wide Area View (WAV)
Participant Requirements
Participant Use Cases
Continue Development of WAV
Improved Situational Awareness
Model Analysis
Oscillation Detection
Reviewing
Contingencies
Angle Difference
State Estimation
Wind Integration
Large-scale outage assistance
Compliance
Improves Reliability
Contingency Analysis
Pattern Recognition
Wide Area Control
Dynamic Nomograms
Unlock Transmission Capacity
Loss of Inertia
Low Damping
High Angle Separation
Voltage Prediction
Reactive Switching
Artificial Intelligence
Neural Nets
Export
Common Application Data Format Agreement
COMTRADE
XML
CSV
Baselining
Angle Differences
Mode Shape
Mode Damping
Oscillation Energy
Research
Model Validation
Improves State Estimation
Improves Contingency Analysis
Early detection of Generation equipment failures
Improves Capital Investment
Compliance
Dispatcher Training Simulator
Relay Action
Unit action
Missing Generator Controls
Native Analysis
Data Mining
Improves Capital Investment
PhasorPoint 2.0
National Wide Area Visualization
Standardized KML feed
Near Real-Time Nation-Wide Transmission status
National Synchrophasor Registry
Interface specification
Data Requests
Post Event Analysis
Research
Determine National Energy Security
Distributed Naming Service
Multi-Homed
Naming Convention
C37.118-2005
C37.118-2011
61850-90-5
SCADA 8.5
State Estimator
Meters
DFRs
RTUs
SCADA
ICCP
Comparisons
DFRs
Relays
Fixed Meters
Remedial Action Schemes
Commissioning
Concentrators
PDCs
GPS clock
PMUs
Time Synchronization
Setup & Configuration
Qualitative
Assessment
Recommendations
Encryption
Multi-Cast
Publish Subscribe
Data Protocols
Compact
C37.118-2005
C37.118-2011
Streaming
Verbose
61850-90-5
High Report rate
10 to 120 reports per second
Stateless
No Error Check
Fast
UDP
One UDP datagram lost entire data frame is lost
Data Frame fragmentation
No guarantee delivery
Dropped Packets
Transport layer (layer 4)
How to wait for ACK
Guarantee delivery
Retries will increase bandwidth usage
TCP
Jitter
RTI - DDS
Multiple Data Centers
Diverse communication paths
MPLS Networks
Qualitative
Assessment
Recommendations

Problem Overview

- Synchrophasor communication failures between the PMUs that measure the values and applications that use the measured values manifest as data availability issues. There is a need for continuous utility resource support to maintain communications between the PMUs and the systems that rely on the data
- Key Points
  - **Data Quality: Accuracy and Availability**
  - Measurement accuracy is determined entirely by the PMU.
  - Without maintenance procedures and policies, the deployed infrastructure fails. Availability decreases.
  - Use data tracker applications to track data availability to aid network and equipment troubleshooting.
  - Notification Systems and Support Groups are essential to maintaining Synchrophasor communication availability

Many business groups required to make it all work



1. Substation Protection
2. Substation Construction
3. Substation Electrical Technicians
4. Substation Automation
5. Substation Network Technicians
6. WAN Communications Technicians
7. IT (Corporate and Operations)

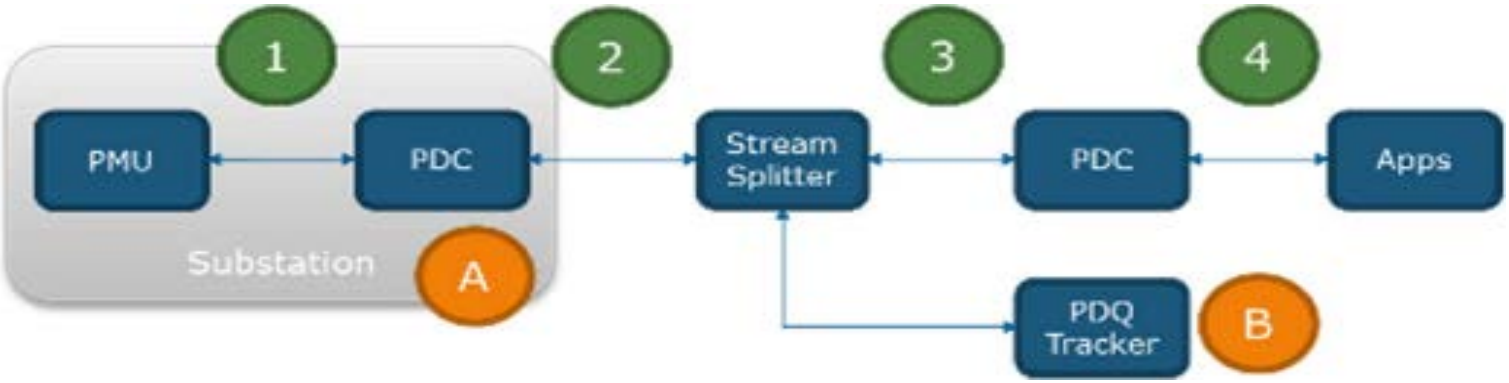
Determine the value of the Data

- Work with the end users of the data to develop availability SLAs, including acceptable dropouts and latency
  - Protection and Control
  - Linear State Estimation
  - Situational awareness
  - Post event analysis including (NERC PRC-002-2)
  - Baselining
- See Frank Tuffner's paper
  - PMU_Application_Data_Requirements_2015_March_20160425ver.docx

Create tools an policies to monitor availability

- Avoid sorting a report by PMU or Signal name
- Sort by error condition, or at least have the report interactive e.g. spreadsheet
- Dashboards give status at a glance
- Something to indicate warnings
- Need to show history
- Automated detailed analysis helps the network engineers
- Use the synchrophasor timestamp to help isolate issues
- The more specific a report the better to aid determining responsibility and issue

Understand your architecture



- The PDC can “hide” data availability problems
- Availability issues at location 1 appear as data errors at location 2
- Availability issues at location 2 are unchanged at location 3 but appear as data errors at location 4
- Availability issues at location 2 cause all the PMUs reporting to PDC A to have the same availability issues as seen by PDC B or the PDQTracker.

Understand the terminology

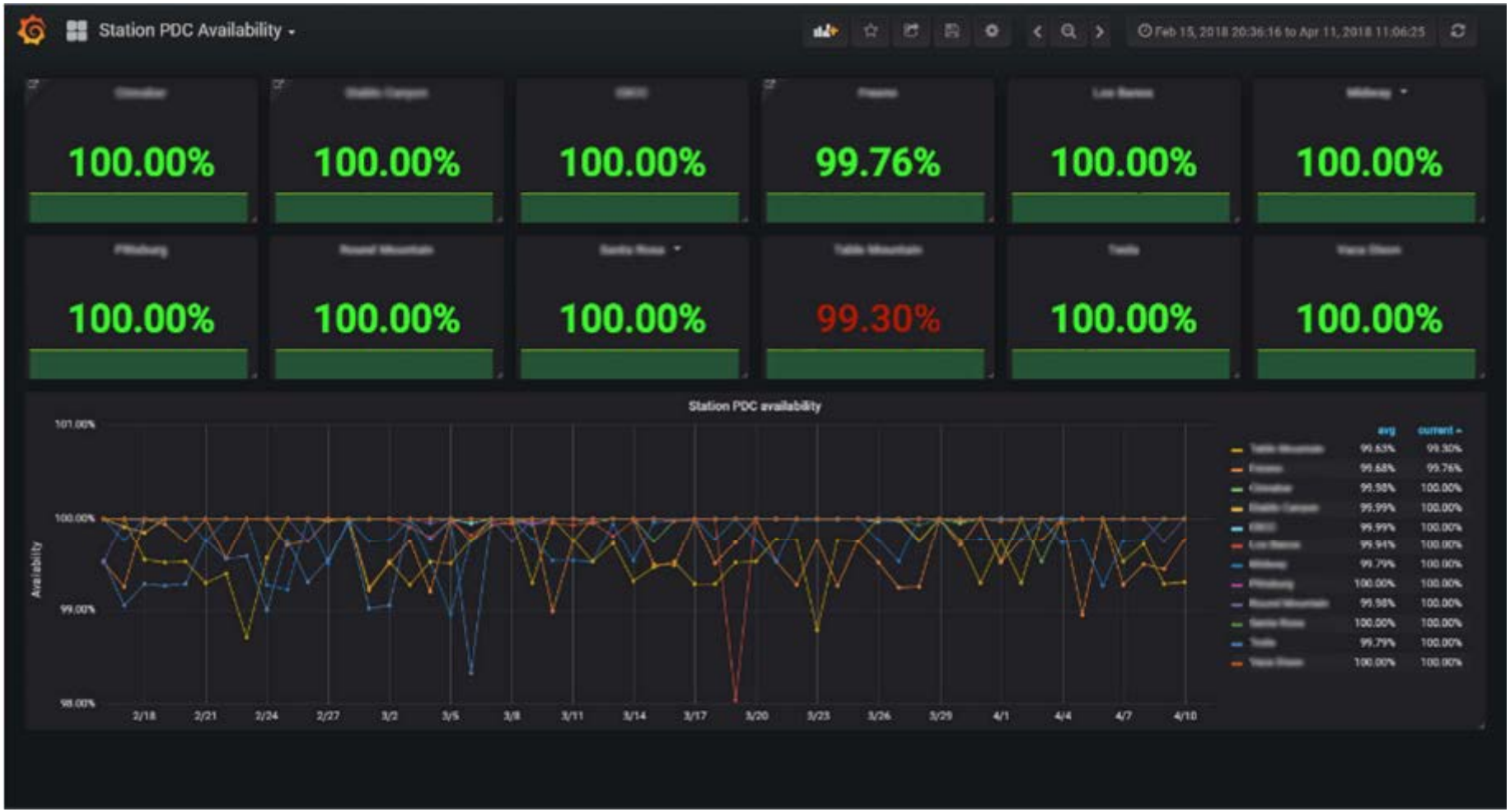
- Don’t use the term Packet when you mean Data Frame
- The term packet means a low level formatted unit of data on the network, it is not a C37.118 or 61850-90-5 data frame
- Invalid Data Flag
- Invalid Data flag as part of the C37.118 spec means nothing to the network engineer, understand how that flag gets set and what it means
- Time Error
- Some PDCs will set the time error bit when data does not arrive in time window this can cause confusion, understand how your vendor’s PDC operates
- Data does not arrive late – late is equivalent to never

Use the unique qualities of Synchrophasor data

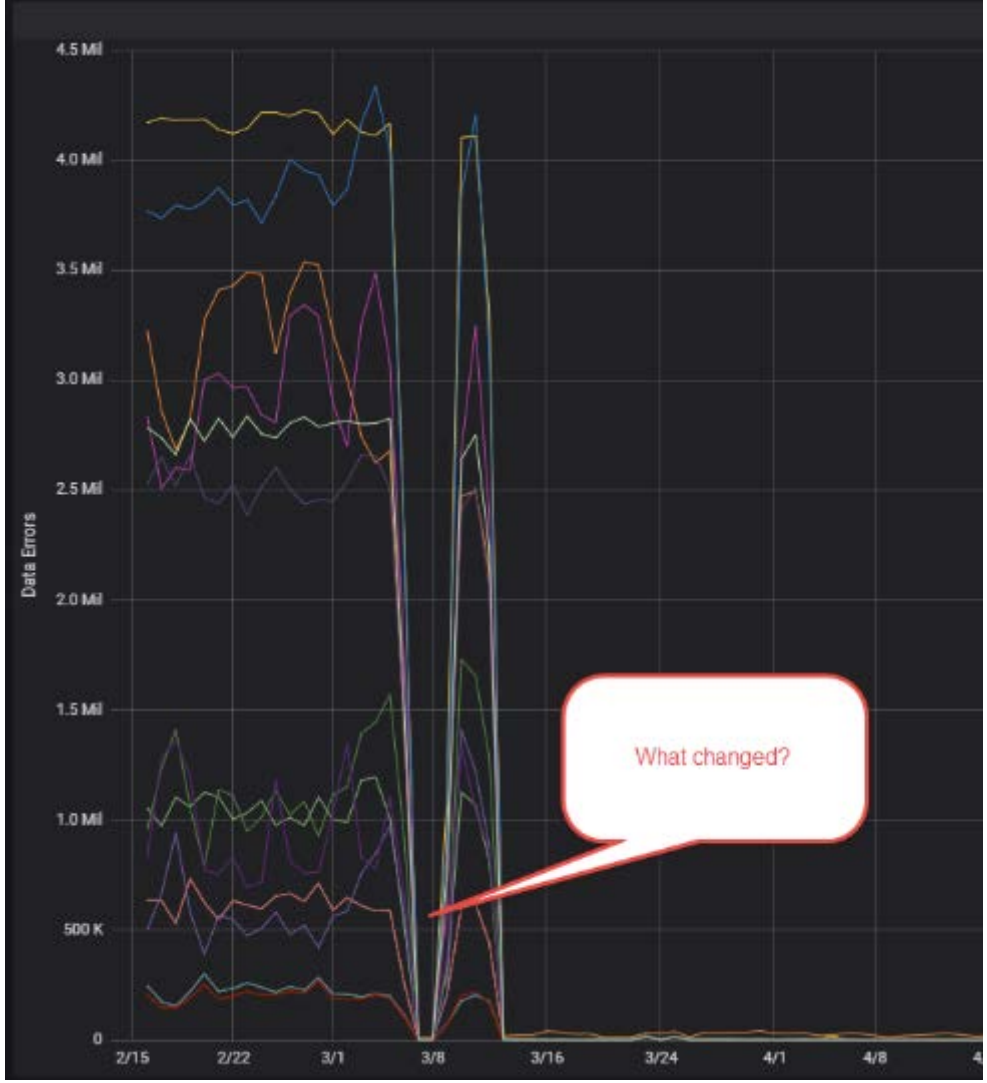
- These features when used in reporting can significantly reduce root cause analysis

- Accurate time stamp
- Fixed data rate

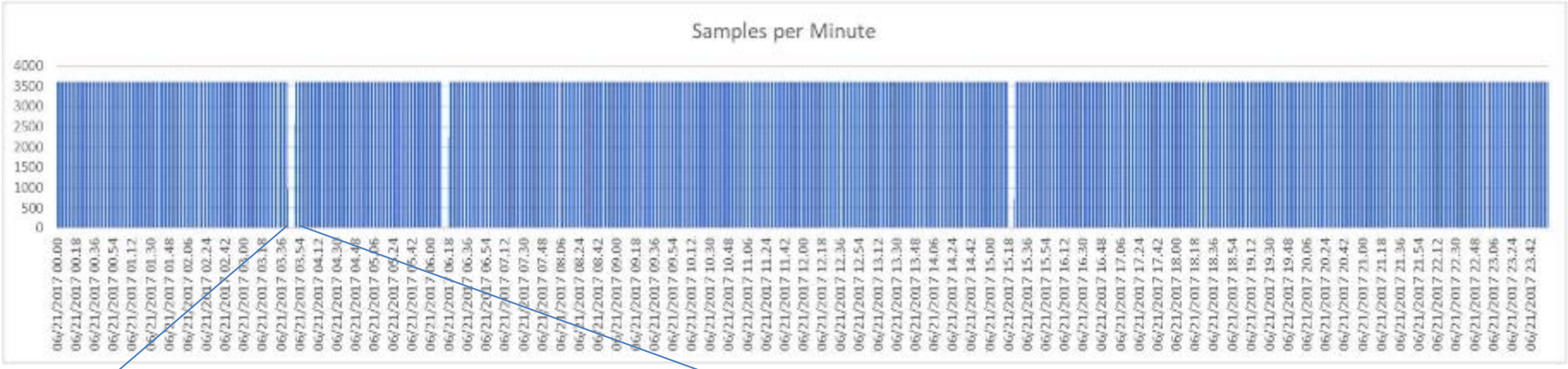
- Dashboards give quick at a glance status

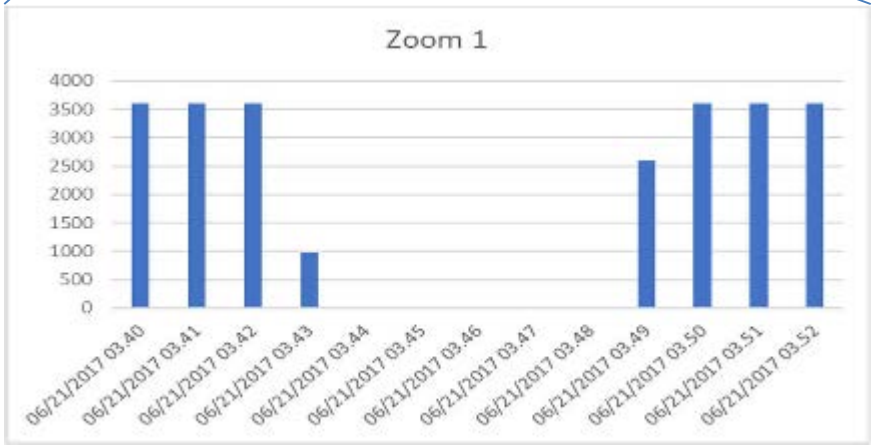


TCP/IP does not guarantee 100% delivery



Data errors indicate communication issues between station PMU and station PDC



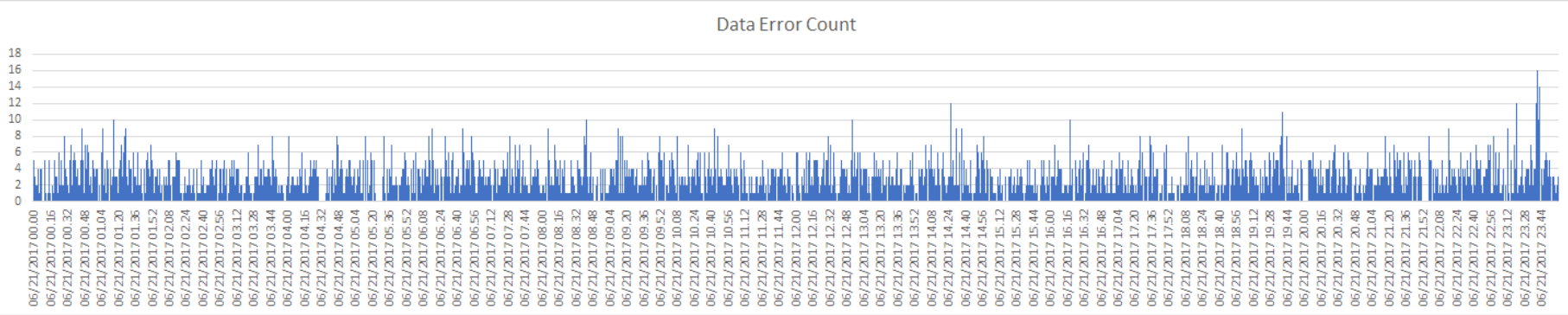


- **Counting how many samples arrive every minute can help trouble shooting**
- **In this case it could indicate router issues or some timed process overloading the network**

Data Dropouts Substation PDC to Control Center PDC

Typical of TCP/IP communication issues

PMU to PDC communication errors as seen on the output of the PDC

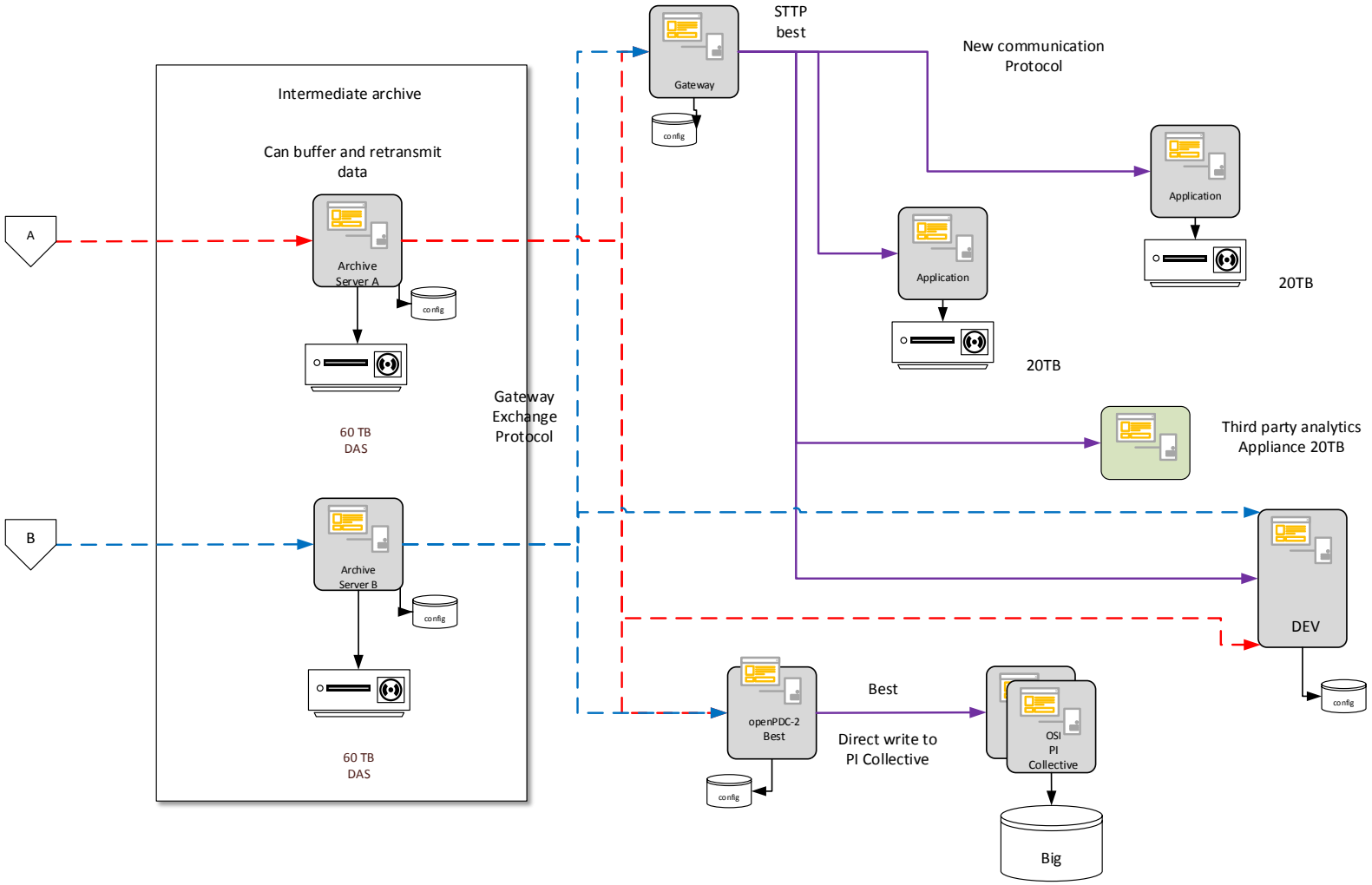


Spread out over entire day (4407 data errors)

Typical of UDP communication issues

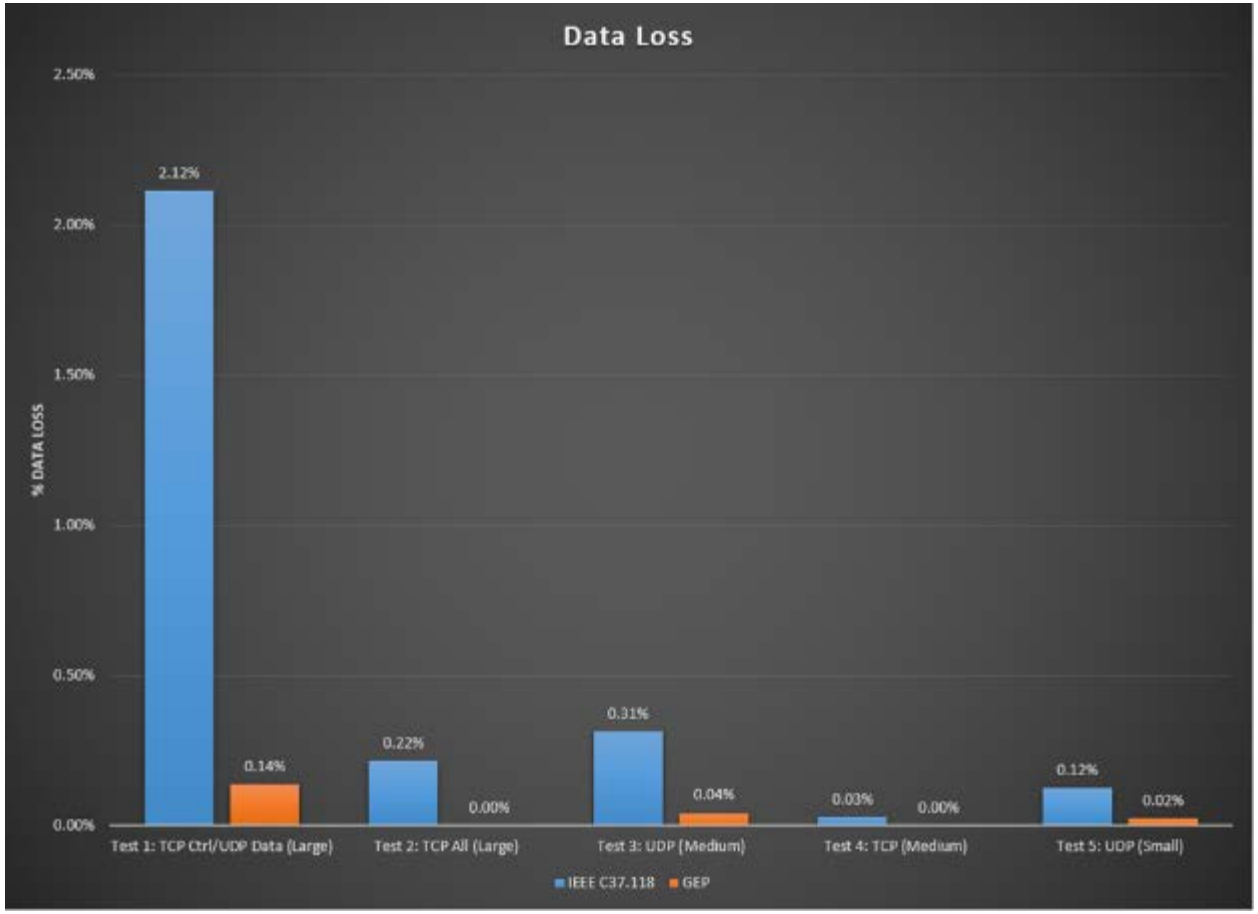
Data Archive

- Check to determine if Dan Trudnowski is in the room
- Determine data archive use case
- Determine Cost / Benefit for compression
- Leave at least one signal per PMU uncompressed e.g. frequency
- Consider using multiple archive strategies


Intermediate archive
Can buffer and retransmit data
A
B
Archive Server A
config
60 TB DAS
Archive Server B
config
60 TB DAS
Gateway Exchange Protocol
Gateway
config
STTP best
New communication Protocol
Application
20TB
Application
20TB
Third party analytics Appliance 20TB
DEV
config
openPDC-2 Best
config
Best
Direct write to PI Collective
OSI PI Collective
Big

Communication Protocols

- IEEE C37.118.2 and 61850-90-5 both suffer from the same issue, large data frames
- Vendor support is highest for C37.118
- TCP/IP cannot always deliver 100% of data frames
- UDP typically will drop 0.2% but has lower impact on bandwidth
- Sending data frames twice over UDP does not improve availability and can actually make it worse in some cases
- New protocols like Gateway Exchange Protocol (GEP) and Streaming Telemetry Transport Protocol (STTP)

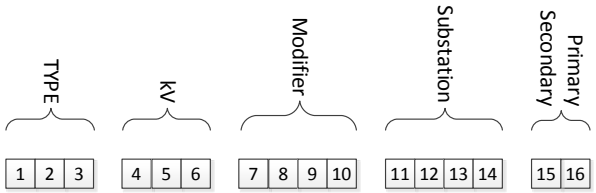


GEP test results from PRSP DOE funded project.
Phasor Gateway Results full paper

IEEE C37.118 data loss is highest for a UDP data channel. In the chart above, it is shown that the data loss percentage varies proportionally with frame size. Note that even when using TCP, data losses were seen with IEEE C37.118 – this TCP loss was at the application layer where phasor data had not arrived within the specified wait-time window.
The issues with IEEE C37.118 scaling are apparent in this graphic. In the “Medium” test case, representative of a large Transmission Operator, losses are manageable using UDP and can be avoided completely with TCP using either IEEE C37.118 or GEP. However, in the “Large” test case, IEEE C37.118 losses could be viewed as being at unacceptable levels at over 2%.

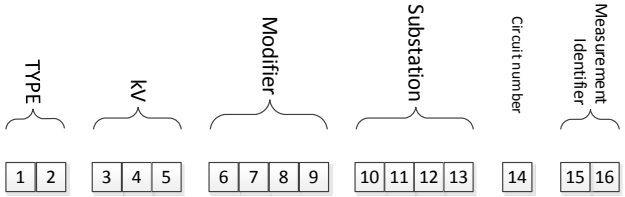
Naming convention

- While not technically either Data Archive or Networking issue using a naming convention can significantly improve data use
- PMU and Signal names require different organization for use inside a utility vs. use by an RC or ISO
- It is important to develop a naming convention and use it as early as possible
- Original naming conventions were simple because deployment was typically bus voltage and line current will have to revisit as other equipment is monitored with PMUs e.g. SynCon



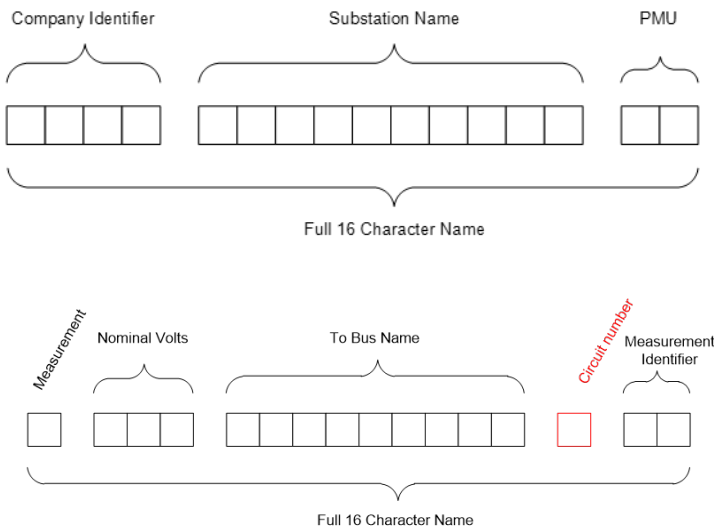
PMU Naming Convention

Utility



Signal Naming Convention

RC or ISO



Conclusion

- For synchrophasor based applications to be successful the data must be available at rates new to utilities
- Involve all the necessary lines of business at the utility early in the process
- Develop tools so you are able to be as precise as possible when explaining issues to network techs
- A network tech once told me “You can talk about us, but you can’t talk without us”