Tutorial on Networking for Digital Substations

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Agenda

- Performance requirements
- Good Practices
- Conclusion
Digital Substation

Network (SCADA / Station Bus)

- PTP
- GOOSE
- MMS

Relay
BCU
DFR
Relay
BCU
Relay
Relay
Relay

Bay 1
Bay 2
Bay 3
Bay 4
Bay 5
Bay 6
Bay 7
Bay 8

MU
MU
MU
MU
MU
MU
MU
MU

RIO
RIO
RIO
RIO
RIO
RIO
RIO
RIO

Network (Process Bus)

- GOOSE
- SV
- PTP
Digital Substation messages

- **GOOSE** messaging – status and control flags between devices

- **Sampled Values (SV)** messaging – instantaneous samples of current and voltage published by merging units (MUs) to other IEDs

- **IEEE 1588 (PTP)** messaging – highly accurate time synchronization over packet-based networks

<table>
<thead>
<tr>
<th>Message</th>
<th>Steady State</th>
<th>Burst</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOOSE</td>
<td>~1 Kb/s</td>
<td>~1 Mb/s</td>
</tr>
<tr>
<td>SV (Protection)</td>
<td>~5 Mb/s (50 Hz), ~6 Mb/s (60 Hz)</td>
<td>-NA-</td>
</tr>
<tr>
<td>SV (Metering)</td>
<td>~10 Mb/s (50 Hz), ~12 Mb/s (60 Hz)</td>
<td>-NA-</td>
</tr>
<tr>
<td>PTP</td>
<td>~1 Kb/s</td>
<td>-NA-</td>
</tr>
</tbody>
</table>
# Digital Substation messages Latency Requirements

<table>
<thead>
<tr>
<th>Message</th>
<th>Max. Delay (ns)</th>
<th>Bandwidth</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOOSE (Trip)</td>
<td>3</td>
<td>Low</td>
<td>Protection</td>
</tr>
<tr>
<td>GOOSE (other)</td>
<td>10 to 100</td>
<td>Low</td>
<td>Protection</td>
</tr>
<tr>
<td>Sampled Values</td>
<td>4</td>
<td>High</td>
<td>Process Bus</td>
</tr>
<tr>
<td>PTP</td>
<td>-</td>
<td>Low</td>
<td>General Phasors, SVs</td>
</tr>
<tr>
<td>MMS (low speed)</td>
<td>&lt; 100</td>
<td>Low</td>
<td>Control</td>
</tr>
<tr>
<td>MMS (med speed)</td>
<td>&lt; 500</td>
<td>Low</td>
<td>Control</td>
</tr>
</tbody>
</table>

As per IEC 61850-90-4
Selection of Network Devices

- Substation Hardened, Dual Power Supply, Watchdog contact
- Number and Type of Ethernet ports: Don’t forget to include spare ports
- Port Speed, Bandwidth: Trunk Ports, Edge ports Bandwidth req might be different
- Layer 2 Functionalities: MAC, VLAN, ACL for traffic segregation
- PTP: Transparent clock (1-step or 2-step)
- Redundancy: PRP, HSR, RSTP, RedBox etc.

Other features:
- SNMP for monitoring
- IGMP for PMU/ R-GOOSE application
- L3 features
- Cybersecurity etc.
Good Practices
Keep Sender and Receiver as close as possible

- Minimize Latency
- Minimize Bandwidth requirements on Trunk Ports
- Avoid Loss of packets during congestion
Redundancy of Network RSTP
Issues with Large Network:

- Bigger the ring, bigger are the chances of having more than single failure
- All the IEDs need to support all the data flow
A MAC address is given to a network adapter when it is manufactured. It is hardwired or hard-coded onto your computer's network interface card (NIC) and is unique to it.

A MAC Address Table is used to define the aging time of learned MAC addresses, their mode of operation, whitelisting and blacklisting devices according to their right to access subnetworks.
Network Traffic Segregation

- **Static MAC Filtering**

<table>
<thead>
<tr>
<th>Delete</th>
<th>VLAN ID</th>
<th>MAC Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>01-0C-CD-01-00-02</td>
<td></td>
</tr>
</tbody>
</table>

  **Port Members**

- **Dynamic MAC Filtering** using GMRP etc.

- **IED A: GOOSE Publisher**

- **IED B: GOOSE Subscriber**

<table>
<thead>
<tr>
<th>SETTING</th>
<th>PARAMETER</th>
</tr>
</thead>
<tbody>
<tr>
<td>TxGOOSE1 Mode</td>
<td>GOOSE</td>
</tr>
<tr>
<td>TxGOOSE1 CoB name</td>
<td>L90_CoB</td>
</tr>
<tr>
<td>TxGOOSE1 GoID</td>
<td>L90_GoO</td>
</tr>
<tr>
<td>TxGOOSE1 Dataset</td>
<td>T6DataSet</td>
</tr>
<tr>
<td>TxGOOSE1 DST MAC</td>
<td>01-0C-CD-01-00-02</td>
</tr>
<tr>
<td>TxGOOSE1 VLAN Priority</td>
<td>4</td>
</tr>
<tr>
<td>TxGOOSE1 VLAN ID</td>
<td>2</td>
</tr>
</tbody>
</table>

**IED A: GOOSE Publishing Parameters**
Virtual LAN technology allows logical separation of the physical network.
Network Traffic Segregation

VLAN

IED A: GOOSE Publisher

IED B: GOOSE Subscriber

IED A: GOOSE Publishing Parameters
Access Control Lists

- Block or allow whole types of traffic based on EtherType
  - Can explicitly block or allow GOOSE, SV, PTP on any ports
  - Deny all other traffic by default
Quality of Service (QoS) Prioritizing Traffic

<table>
<thead>
<tr>
<th>Message</th>
<th>Priority in network</th>
<th>QoS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTP</td>
<td>Medium</td>
<td>4</td>
</tr>
<tr>
<td>Sampled Values</td>
<td>Medium</td>
<td>4</td>
</tr>
<tr>
<td>GOOSE (control)</td>
<td>High</td>
<td>5</td>
</tr>
<tr>
<td>GOOSE (trip)</td>
<td>Highest</td>
<td>6</td>
</tr>
<tr>
<td>MMS and TCP/IP comms</td>
<td>Low</td>
<td>0</td>
</tr>
</tbody>
</table>
Network FAT

• What a FAT is:
  • Off-site commissioning of the substation network
  • Performed with software simulators / test equipment
  • Tested in a controlled scenario

• What a FAT does:
  • Reduce commissioning time
  • Reduces installation time
  • On-site work is verifying communications cable connections
Summary

• Our substation networks don’t change frequently
  • Traffic flows are consistent and predictable
  • Network requirements only change with capital projects

• Simple, standard networking tools cover our needs
  • Link speed to provide bandwidth
  • Traffic shaping through VLANs, MAC address filtering, Access Control Lists
  • QoS, traffic shaping to address latency
  • Network topology (RSTP, PRP, HSR) provides reliability

• First step is good project engineering
Thank You

Questions?