Wireless Solutions for Reliable Distribution System Protection & Control

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Distribution Automation Applications
Distribution Automation Applications Requirements

- Speed
- Dependable and secure
- Interoperability
- Adequate Bandwidth
- Multiple protocol support
- Communications redundancy
- Reliable power source (battery back-up)
Independent/Peer-to-Peer FDIR

- Fault Detection Isolation and Restoration (FDIR)
- Independent/peer-to-peer messaging using IEC 61850 GOOSE
- Interoperability (non-proprietary)
- Speed of operation (seconds)
- Support for traditional DNP SCADA protocol for control, monitoring and metering
Centralized / Decentralized FDIR

- Communication to nearby substation or control center
- GOOSE can still be used for interoperability
- Speed of operation (seconds)
- Support for traditional DNP SCADA protocol for control, monitoring and metering

**Decentralized**

- Automation Controller at Nearby Substation
- Reduces complexity
- Configuration is easy to setup and maintain

**Centralized**

- Control Center
- Multiple / complex networks supported
- Multiple faults can be handled
- Large amounts of data/devices
- Load shedding
Distribution Automation with Distributed Energy Resources

- Automation Controller
- HMIs
- Inside the fence feeder relays
- Overhead Controllers
- Normally Open Switch
- Solar farm
- Padmount or DER MV gear protection

IEC 61850 MMS configuration & event data retrieval
Setting group change command
IEC 61850 GOOSE exchanges
Remote data retrieval (SCADA)
Microgrid Control System

- System integration of various DER assets
- Wide mix of protocols used (Modbus RTU, DNP, IEC 61850)
- Speed of operation (milliseconds to seconds)
Wireless Solutions & Architectures
## DA Applications: Field Area Network (FAN) Performance Requirements

<table>
<thead>
<tr>
<th>DA Applications</th>
<th>One-Way Network Latency Between IEDs</th>
<th>Network Reliability Requirement</th>
<th>Network Throughput Per IED</th>
<th>Cyber Security</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peer-to-Peer FDIR</td>
<td>&lt;100 msec</td>
<td>High</td>
<td>1's to 10's of Kbps</td>
<td>High</td>
</tr>
<tr>
<td>Centralized FDIR</td>
<td>&lt;200 msec</td>
<td>High</td>
<td>10's of Kbps</td>
<td>High</td>
</tr>
<tr>
<td>Decentralized FDIR</td>
<td>&lt;100 msec</td>
<td>High</td>
<td>10's of Kbps</td>
<td>High</td>
</tr>
<tr>
<td>DER Disconnect/Trip</td>
<td>&lt;100 msec</td>
<td>High</td>
<td>10's of Kbps</td>
<td>High</td>
</tr>
<tr>
<td>Microgrid Control System</td>
<td>&lt;100 msec</td>
<td>High</td>
<td>10's to 100's of Kbps</td>
<td>High</td>
</tr>
<tr>
<td>Microgrid Fast Load Shedding</td>
<td>&lt; 10 msec</td>
<td>High</td>
<td>10's to 100's of Kbps</td>
<td>High</td>
</tr>
<tr>
<td>Monitoring</td>
<td>1-2 seconds</td>
<td>Low</td>
<td>10's to 100's of Kbps</td>
<td>Low/Medium</td>
</tr>
<tr>
<td>Control</td>
<td>1-2 seconds</td>
<td>High</td>
<td>10's of Kbps</td>
<td>High</td>
</tr>
</tbody>
</table>

**Notes:**
- Network latency between relays is relatively subjective. Its budget is determined as part of a holistic automation scheme. Typical distribution recloser opening/closing may need to occur within seconds of fault detection.
- Effective network throughput per IED can impact latency.
### DA Applications: Choosing the Right RF Technology For the Application

<table>
<thead>
<tr>
<th>RF Technology</th>
<th>RF Band Ownership</th>
<th>Typical One-Way Latency</th>
<th>Available Throughput Per IED</th>
<th>CAPEX</th>
<th>OPEX</th>
<th>Typical Network Topology</th>
</tr>
</thead>
<tbody>
<tr>
<td>TV White Space</td>
<td>Unlicensed Public</td>
<td>10’s of msec</td>
<td>10’s of Mbps</td>
<td>High</td>
<td>Medium</td>
<td>P2P, P2MP, Mesh</td>
</tr>
<tr>
<td>900 MHz ISM Band</td>
<td>Unlicensed Public</td>
<td>10’s of msec</td>
<td>10’s of Kbps to Low 1000’s of Kbps</td>
<td>High</td>
<td>Medium</td>
<td>P2P, P2MP, Mesh</td>
</tr>
<tr>
<td>2.4 to 5.9 GHz ISM Band</td>
<td>Unlicensed Public</td>
<td>10’s of msec</td>
<td>1s to 10’s of Mbps</td>
<td>High</td>
<td>Medium</td>
<td>P2P, P2MP, Mesh</td>
</tr>
<tr>
<td>Narrowband 100, 200, 400, 900</td>
<td>Utility Owned</td>
<td>100’s of msec</td>
<td>10’s of Kbps</td>
<td>Higher</td>
<td>Medium</td>
<td>P2P, P2MP, Mesh</td>
</tr>
<tr>
<td>Upper A Block Wide Band 700 MHz</td>
<td>Utility Owned</td>
<td>10s to 100’s of msec</td>
<td>100’s of Kbps</td>
<td>Higher</td>
<td>Medium</td>
<td>P2P, P2MP, Mesh</td>
</tr>
<tr>
<td>CBRS 3.5-3.7GHz Band</td>
<td>Utility Owned Semi-Public</td>
<td>10’s of msec</td>
<td>10’s of Mbps</td>
<td>Higher</td>
<td>High</td>
<td>P2MP</td>
</tr>
<tr>
<td>Private LTE Bands</td>
<td>Utility Owned or Leased</td>
<td>10’s of msec</td>
<td>10’s of Mbps</td>
<td>Highest</td>
<td>High</td>
<td>P2MP</td>
</tr>
<tr>
<td>Public Cellular</td>
<td>Carrier Owned</td>
<td>10’s of msec</td>
<td>10’s of Mbps</td>
<td>Lowest</td>
<td>High</td>
<td>P2MP</td>
</tr>
</tbody>
</table>
DA Applications: Common FAN Network Topologies

**Point to Point**
- Simple topology
- Direct long-range communications possible
- Ideal for direct DER/DTT/DGT Applications
- Good for serial, IP, GOOSE

**Point to Multi-Point**
- Direct long-range communications possible
- Ideal for a Centralized or Decentralized FDIR
- Peer-to-Peer communications also possible via Access Point (AP)
- Can work well for Peer-to-Peer FDIR with attention to latency
- Good for serial, IP, GOOSE

**Mesh or Self-Healing Topologies**
- Radios automatically inter-connect based on proximity, line of sight, signal strengths
- Significantly shorter distance between radios, but higher overall network resiliency
- Long-range communications may require several intermediate hops (latency impact)
- Works well for peer-to-peer FDIR
- Good for serial, IP
- GOOSE may work if highly optimized broadband RF network is used
Improving Grid Reliability With FAN Network Design Considerations

- **Radio Device Ruggedness**: Compliant vs certified to substation-hardened standards
- **Radio Device Longevity**: High quality components & design → High MTBF
- **Number of Radio Uplinks/Modems**: Per Remote/IED: Single vs Dual
- **Number of Radio “Paths”**: Between remote and Base Station
- **Diversity of Radio Types/Options**
- **RF Band**: Licensed vs Unlicensed
- **Unlicensed Bands**: Media Access Control (MAC), bandwidth and interference mitigations
- **Cellular Uplink Redundancy**: Dual-SIM vs Dual Modems
Improving Grid Reliability With Network Security Considerations

- **Protect Data Transmission**
  - Encrypt everything at RF, IP and possibly application layers
  - Key Rotation Algorithms
  - Certificate Management

- **Protect Communication Devices**
  - Secure Boot: guard against hardware manipulations
  - Secure Firmware: guard against firmware manipulations
  - Secure CPU Processes: monitor CPU for unfamiliar/odd processes
  - Physical Security: GPS, alarm contacts, video security, etc.

- **Authorized Users and Data**
  - Users: authenticate and monitor authorized users network usage
  - Data: block all but known protocols, data types and data formats
  - Intrusion Detection: automatically monitor data traffic for odd patterns and report it
  - Intrusion Prevention: automatically block then report odd data patterns (i.e., malformed DNP3 SCADA packets)
Conclusions

Field Area Network technology choice, performance, availability and security play an integral role in improving reliable distribution protection & control operations:

• **Technology choice:** legacy narrowband technologies are holding steady, while broadband technologies such as private and public cellular have been picking up steam
• **Performance:** choices of topology, link speed, and RF technology impact latency and throughput performance of automation applications
• **Availability:** as FDIR, DERs, Microgrids increase in adoption and coordination complexity, improving network availability with multiple uplinks or backup paths becomes more important
• **Security:** adopting technologies recommended by NERC-CIP and other security standards bodies help protect the network and DA applications against intrusion and improve stability
Thank You

Questions?