The SecureMesh™ Wide Area Network -- Reliable & Flexible Wireless Mesh Communications for Distribution Automation

ABB APW 2011
CPS-152-1
TRILLIANT CASE STUDY ON DISTRIBUTION AUTOMATION

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• Business Case for DA

• DA Applications
  — Outage Management (Fault Detection, Isolation, Restoration)
  — Integrated Voltage Control
  — Asset Management
  — Substation Automation

• Communications Requirements for DA

• Trilliant’s SecureMesh Network
  — Integrated multi-tier network solution
  — Product & solution details
  — Customer deployments

• Solution Benefits
Utility business cases for DA typically show positive ROI, with or without combined AMI initiative.
Distribution Automation Applications

**Typical high-value applications with immediate positive ROI**

- **Outage Mgmt (Fault Location, Isolation and Restoration)**
  - Feeder reconfiguration
  - Switch & recloser automation

- **Integrated Volt/VAR Control (Conservation Voltage Reduction)**
  - Voltage monitoring
  - Capacitor bank control

- **Asset Management (e.g., Transformer Monitoring)**

- **Distribution Network Analysis**
  - Network state estimation (real time load calibration)
  - Load flow calculations
  - Short circuit calculations
  - Loss minimization
  - Load forecasting and capacity management
  - Comprehensive network model – energy diversion

- **Substation Automation**
  - Substation connectivity
  - SCADA support
  - Video surveillance
  - Mobile workforce applications

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Outside the Fence (apparatus on feeder circuit lines)

Inside the Fence (equipment within substations)
**Outage Management**

- **Objectives**
  - To detect fault conditions as quickly as possible
  - To communicate fault events to upstream & downstream switches and central head-end systems
  - To turn on/off protective switches/reclosers to prevent a major outage
  - To remotely restore power as quickly as possible to minimize outage

- **Requirements**
  - A remote controllable Smart Grid device
  - Low-latency communications
  - Support of DNP3 or IEC 61850 w/ GOOSE messaging
Integrated Volt/VAR Control

• Objectives
  — Measure voltage levels at end users
  — Allow control of load tap changers at substation feeders
  — Significant energy/cost savings are possible if today’s estimated voltage margins can be reduced

• Requirements
  — Voltage information from selected points in the grid (e.g., selected meters or sensors on grid apparatus)
  — Simultaneous monitoring of instantaneous voltage levels
  — Low-latency communications
  — Software applications (e.g., DMS) to integrate SCADA, sensor data, and meter data
  — Head-end control algorithms to optimize voltage regulation process
Substation Automation

- **Objectives**
  - Provide broadband communications to remote substations, especially those w/o any communications or currently requiring leased lines ($200~$600/month OPEX)
  - Eliminate truck rolls to gather data from substations without connectivity

- **Requirements**
  - Broadband connectivity
  - Support of SCADA, video surveillance, and/or mobile workforce apps
NIST Framework for Smart Grid

Communications are fundamental to enabling positive-ROI DA applications
Communications Requirements for DA

**DA imposes higher communications requirements than simple voice/data comms**

- **Capacity & latency**
  - Ability to support required traffic
  - Future proof – *ability to support future and/or new applications*

- **Standards support**
  - Support for SCADA, DNP3, and IEC 61850 w/ GOOSE messaging
  - Security

- **Coverage/availability**
  - Communications to remote substations
  - Communications distributed throughout distribution grid (e.g., to support voltage monitoring)

- **Reliability**
  - Network reliability – *fault tolerance*
  - Product reliability — *rugged product design, backup power, ease of deployment*
Communications Alternatives for DA

Cost & performance trade-offs will determine a utility’s decision

- **Wireline**
  - High bandwidth
  - Low latency
  - Potentially high deployment costs

- **Wireless**
  - Bandwidth and latency determined by technology/spectrum
  - Flexible deployment

- **Public network facilities**
  - Opex rather than capex
  - Availability/coverage determined by carrier

- **Private network facilities**
  - Capex rather than opex
  - Deployment and Quality of Service under utility control
Wireless Communications Considerations for DA

Deployment costs drive a utility’s decision to adopt wireless comms for DA

• **Public vs. private network**
  - Public networks (e.g., cellular): wide coverage, no infrastructure, high OPEX
  - Private network: under utility control, QoS, high CAPEX

• **Licensed vs. unlicensed spectrum**
  - Licensed: no interference, long range, $$ for spectrum license
  - Unlicensed: benefits of scale, wide vendor selection

• **Range vs. frequency band: greater range \(\rightarrow\) less equipment \(\rightarrow\) lower cost**
  - Determined by transmit power, antenna gains, receive sensitivity
  - Determined by frequency band
  - Determined by FCC regulations (Tx powers; licensed vs. unlicensed spectrum)
  - Determined by line-of-sight

• **Wireless network topologies**
  - Point-to-Point (P-P): potential longer range; limited coverage
  - Point-to-Multipoint (P-MP): wide coverage; single point of failure
  - Mesh: wide coverage; deployment flexibility; reliability
The SecureMesh™ Multi-Tier Communications Network

Secure, scalable, global standards-based architecture for future-proof Smart Grid networking

UnitySuite
Head-End Software
- data aggregation
- interface to a utility’s existing systems
- network and device management

SecureMesh WAN
(Wide Area Network)
- standards-based, high-capacity, low-latency wireless mesh technology
- AMI backhaul
- direct support of DA applications

SecureMesh NAN
(Neighborhood Area Network)
- standards-based, high data rate wireless mesh technology for AMI
- field-proven radio performance
- wide choice of meters

HAN
(Home Area Network)
various options to address the specific utility business model
The SecureMesh™ Wide Area Network (WAN)

**Scalable, broadband wireless mesh network technology**

- **5 GHz Wide Area Network**
  - Private network NAN backhaul
  - Direct support of Smart Grid devices

- **High-bandwidth, low-latency**
  - Adaptive air data rates from 6 to 54 Mbps
  - Low-latency (<10 ms/hop round-trip)

- **Open, standards-based design**
  - Layer 2 Ethernet framing
  - Standard chipsets

- **Scalable capacity/bandwidth**
  - Modular capacity injection
  - Bandwidth can be allocated as needed

- **Flexible topology, long range**
  - Easily deployed
  - Up to 10-mile range per hop
  - Multi-hop network bypasses obstacles

- **High reliability & availability**
  - Dynamic mesh routing
  - Self-healing

- **Proven in over 50 countries**

Representative SecureMesh WAN client devices
- Substation automation
- SCADA-over-IP
- Gridpoint monitoring
- IP-enabled or serial devices
## Summary of SecureMesh WAN Technology

**Scalable, broadband wireless mesh network technology**

<table>
<thead>
<tr>
<th>Architecture</th>
<th>multi-hop mesh point-to-multipoint TDMA network with synchronous dynamic beamswitching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Data Rate</td>
<td>• up to 54 Mbps (6, 9, 12, 18, 24, 36, 48, 54 Mbps)</td>
</tr>
<tr>
<td></td>
<td>• real-time adaptation based on link quality</td>
</tr>
<tr>
<td>Modulation</td>
<td>OFDM w/ adaptive modulation (BPSK, QPSK, 16-QAM, 64-QAM)</td>
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<tr>
<td></td>
<td>(orthogonal frequency division multiplexing)</td>
</tr>
<tr>
<td>Frequency Band</td>
<td>• 4.940 – 5.450 GHz (US: 4.94 - 4.99 GHz public safety; 5.25 – 5.35 GHz U-NII mid)</td>
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<td></td>
<td>• 5.470 – 5.725 GHz (US: 5.470 – 5.725 GHz U-NII worldwide)</td>
</tr>
<tr>
<td></td>
<td>• 5.725 – 6.075 GHz (US: 5.725 – 5.850 GHz U-NII upper/ISM)</td>
</tr>
<tr>
<td>Encryption</td>
<td>AES-128 (node-by-node link encryption)</td>
</tr>
<tr>
<td>Fault Tolerance</td>
<td>• intra-mesh dynamic routing (alternate paths to the supporting Gateway)</td>
</tr>
<tr>
<td></td>
<td>• all SecureMesh WAN devices maintain active backup paths</td>
</tr>
<tr>
<td></td>
<td>• fast switchover (seconds to &lt;1 min depending on fault scenario)</td>
</tr>
<tr>
<td></td>
<td>• inter-mesh dynamic routing (to alternate Gateways)</td>
</tr>
<tr>
<td></td>
<td>• switchover &lt; ~2 min</td>
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<tr>
<td></td>
<td>• “standby” Gateways are active (not idle), providing N-1 redundancy</td>
</tr>
<tr>
<td>Standards Compliance</td>
<td>• layer 2 Ethernet (IEEE 802.3) transport</td>
</tr>
<tr>
<td></td>
<td>• transparently supports IEC 61850, DNP3, TCP/IP (IPv4/v6), Modbus, ICCP, and other higher layer protocols for Smart Grid devices</td>
</tr>
</tbody>
</table>
# SecureMesh WAN Components

<table>
<thead>
<tr>
<th>Function</th>
<th>Gateway</th>
<th>Extender</th>
<th>Connector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity injection</td>
<td>Capacity injection (network takeout point)</td>
<td>• Coverage (network expansion)</td>
<td>• Network edge/endpoint</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ethernet drop for DA devices</td>
<td>• Ethernet drop for DA devices</td>
</tr>
<tr>
<td>Max Node-to-Node Range</td>
<td>~16 km / 10 miles (typically limited by terrain to ~8-11 km / 5-7 miles)</td>
<td>~12 km / ~7 miles</td>
<td></td>
</tr>
<tr>
<td>Additional Products</td>
<td></td>
<td><strong>Extender DualBand:</strong> Integrated Wi-Fi 802.11b/g access point</td>
<td><strong>Connector DualBand</strong> Integrated Wi-Fi 802.11b/g access point</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Extender Bridge:</strong> Integrated SecureMeshNAN access point</td>
<td></td>
</tr>
<tr>
<td>Battery Backup</td>
<td>• 8-hour backup power with SecureMesh Power Service Unit</td>
<td>• Backup provided by IED cabinet</td>
<td>• 27-hour backup power with ABB control cabinet</td>
</tr>
<tr>
<td></td>
<td>• 27-hour backup power with ABB control cabinet</td>
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UnitySuite™ NEMS Overview

- **Comprehensive Coverage**
  - Management capabilities at the network and device level
  - Standards-based SNMP MIBs

- **Over-the-air automatic provisioning & configuration**

- **Robust traffic management**
  - Traffic shaping and filtering
  - Traffic prioritization by VLAN and traffic type

- **Real-time fault alarms & event reporting**

- **Performance Monitoring**
  - Monitoring of network performance metrics
  - Configurable thresholds
  - Alerts can be forwarded to an existing management system (NMS, OMS, DMS)

- **Integration with Google Earth for network visualization**
  - Generate network maps based on NEMS data
  - Derive node locations using GPS functionality

- **Role-based Access Control for users/groups**
SecureMesh WAN Benefits for DA Applications

*Ideally suited for direct support of DA applications*

- **Long range mesh network: flexible topology with high reliability & availability**
  - Node-to-node distances up to 16 km/10 mi
  - Benefits of dynamic, self-healing mesh routing bypassing obstacles
- **High-bandwidth communications with Scalable capacity**
  - Throughput up to ~12 Mbps TCP/~20 Mbps UDP per Gateway, scalable with additional Gateways
  - Ideal for bandwidth-intensive protocols such as IEC 61850 or substation communications
  - Typical AMI data only take <4% of available bandwidth, leaving plenty for DA apps
- **Low-latency communications**
  - < ~8-10 ms per hop
  - Ideal for quick response of IEC 61850 GOOSE messaging, DNP3, Modbus
- **QoS and Network segmentation via private networking**
  - IEEE 802.1Q VLANs and/or IPsec VPNs
  - Traffic prioritization (3 priority levels)
  - Rate shaping (limited network capacity granted to any single device)
  - Multicast
- **Connectivity options**
  - Single Ethernet port supports multiple devices (w/ external router/switch)
  - Serial-to-Ethernet adapters provide serial interfaces (RS-232, RS-485)
  - Layer 2 Ethernet transport or IP encapsulation carries higher layer protocols: IEC 61850, DNP3...
Proven Interoperability

*Interoperability tested with industry-leading solutions*

- **COOPER Power Systems**
  - Yukon Feeder Automation platform
  - SMP 16/CP Intelligent Substation Gateway
  - Form 6 Recloser Control

- **GE**
  - D400 Substation Data Manager
  - XA/21 SCADA/Energy Mgmt System

- **SIEMENS**
  - 7SJ64 Smart IED Control HMI
  - 7SJ80 Smart IED
  - Vector OH switch

- **TELVENT**
  - Telvent Sage 2300 RTU

- **ABB**
  - DPU2000R Distribution Protection Unit
  - TPU2000R Advanced Transformer Protection Unit
  - PR 512 Circuit Breaker Protection for Primary distribution
  - PR 512 Circuit Breaker Protection for Secondary distribution
  - REF 543 Feeder Protection Terminal
  - REF 545 Feeder Protection Terminal
  - REF 550 Feeder Protection Terminal
  - REF 610 Feeder Protection
  - REF 615 Advanced Feeder Protection
  - REF 620 Advanced Feeder Protection
  - RET 630 Advanced Feeder Protection
  - REM 543 Motor Protection Relay
  - REM 545 Motor Protection Relay
  - REM 610 Motor Protection Relay
  - REM 615 Motor Protection Relay
  - REM 615 Motor Protection Relay
  - REC 501 Bay Control Terminal
  - REC 523 Bay Control Terminal
  - RER 620 Recloser IED
  - RET 541 Transformer Protection Terminal
  - RET 543 Transformer Protection Terminal
  - RET 545 Transformer Protection Terminal
  - RET 615 Transformer Protection Relay
  - RET 630 Transformer Protection Relay
  - RET 670 Transformer Protection Relay
  - SPAU 341 C Voltage Regulator Relay
Strong ABB-Trilliant partnership

Simulated ABB / SecureMesh WAN DA solution

Rigorous Testing Conducted by ABB Reveals that Trilliant’s SecureMesh Wide Area Network (WAN) Excels in Distribution Automation Applications

ABB-Trilliant Joint White Paper
Representative SecureMesh WAN DA Deployment

Control Center

- Safety
- Reliability
- Secure system
- Fully interoperable
- Easy to deploy
- Expandable

Substation A COM600 & SecureMesh Gateway (Primary)

Substation B COM600 & SecureMesh Gateway (Redundant)

ABB COM600

Recloser 1
Recloser 2 N.O.
Recloser 4
Recloser 3
Recloser 5

SecureMesh Extender
ABB PCD Recloser Controllers
ABB RER 620
SecureMesh Connectors
How does the SecureMesh WAN achieve such long range, high throughput, and low latency?
**Unique SecureMesh WAN Architecture**

**Deterministic access control combined with advanced antenna switching**

<table>
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<tr>
<th>Mesh Networking</th>
<th>Traffic Management</th>
<th>RF Management</th>
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<tbody>
<tr>
<td>Automatic Discovery</td>
<td>Dynamic QoS</td>
<td>Industry-leading SpectralReuse</td>
</tr>
<tr>
<td>Self-Optimized Routing</td>
<td>Scalable capacity</td>
<td>Self-Interference Mitigation</td>
</tr>
<tr>
<td>Dynamic Re-routing</td>
<td>Load Balancing</td>
<td>Non-Line-of-Sight Coverage</td>
</tr>
<tr>
<td>Self-healing failover</td>
<td>Traffic Prioritization</td>
<td>Adaptive Modulation</td>
</tr>
</tbody>
</table>

**Multi-hop Mesh Point-to-Multipoint TDMA Network**

**With Synchronous Dynamic Beamswitching Antenna Array**

**Advanced Beam-Switching Antenna Array**

**Time Division Duplex Transmission Control**

- Array of 8 high-gain sector antennas for 360° coverage
- High output radio with real-time beam switching to sector antennas
- Exceptional range performance and link stability
Dynamic TDMA w/ Beamswitching

- Sector Switching
  - Array of 8 high-gain sectorized antennas
  - Long range and high data rates
  - Operates under FCC P2P rules (up to 28.2 W EIRP)
  - Up to 16 km / 10 mi (limited by TDMA, not radio performance)
  - Up to 54 Mbps

- 8 separate sectorized 18 dBi antennas w/ 45° beamwidth

- High-speed antenna switching
  - Advanced antenna switching combined with deterministic access control
  - Switches high-power radio to 8-beam antenna array up to 10,000 times/second
  - Robust link performance
  - Efficient spectral reuse

- TDMA "bandwidth scheduler"
  - Distributed mesh-wide algorithm synchronizes transmissions for spectrum re-use
  - Coordinates dynamic high-capacity P2P links to mitigate self-interference
  - Deterministic low-latency/low-jitter TDMA protocol to support Smart Grid devices

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Patented dynamic and synchronized antenna switching

- Uniquely integrates backhaul, multi-hop relay, and access functionality
- Increases capacity through patented same-channel synchronization
- Increases coverage through innovative multi-hop extension