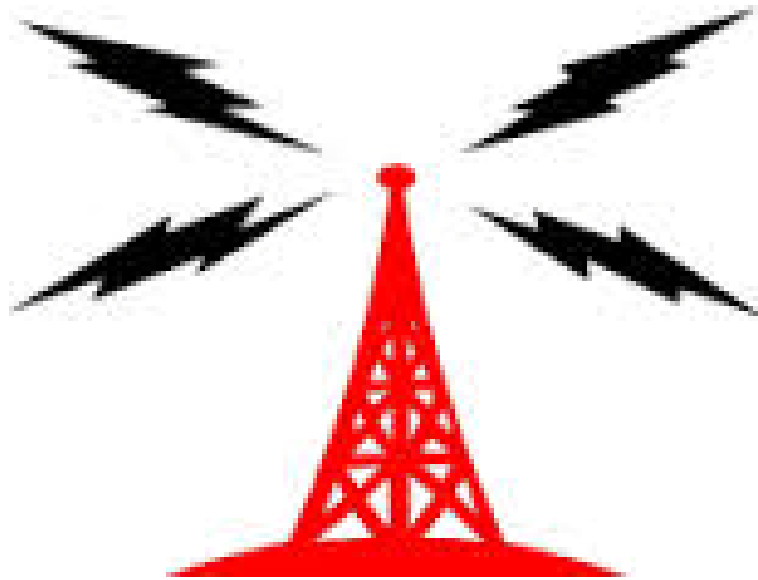


# High-availability/Low Latency Wireless Communication for Protection, Control, and SCADA applications



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imagination at work

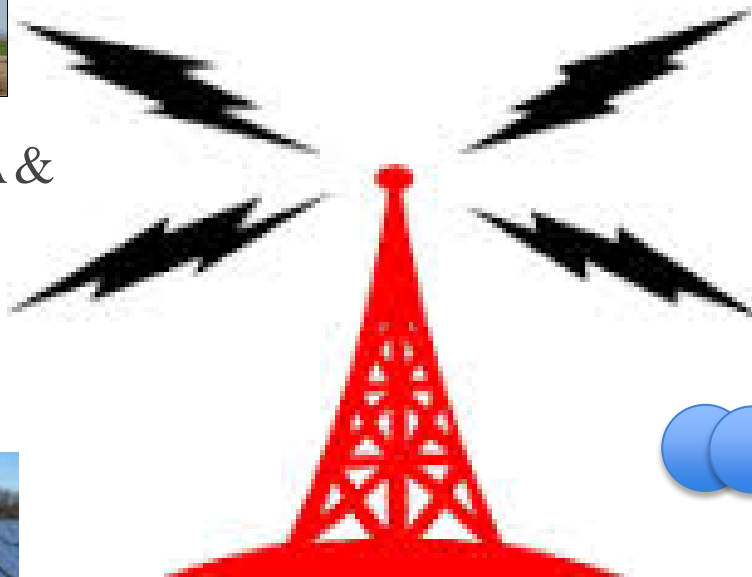
# Smart Grid Communication Applications and Requirements



Distribution SCADA &  
Asset Monitoring  
1-2 sec reporting



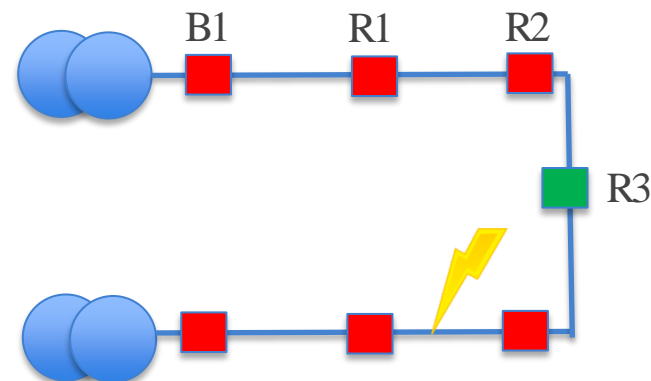
Capacitor Switching  
Several seconds



Distributed Energy / VPP  
Monitor & Control - secs  
100ms disconnect



Smart Home – DSM  
Seconds to minutes  
Future: 100s of ms...



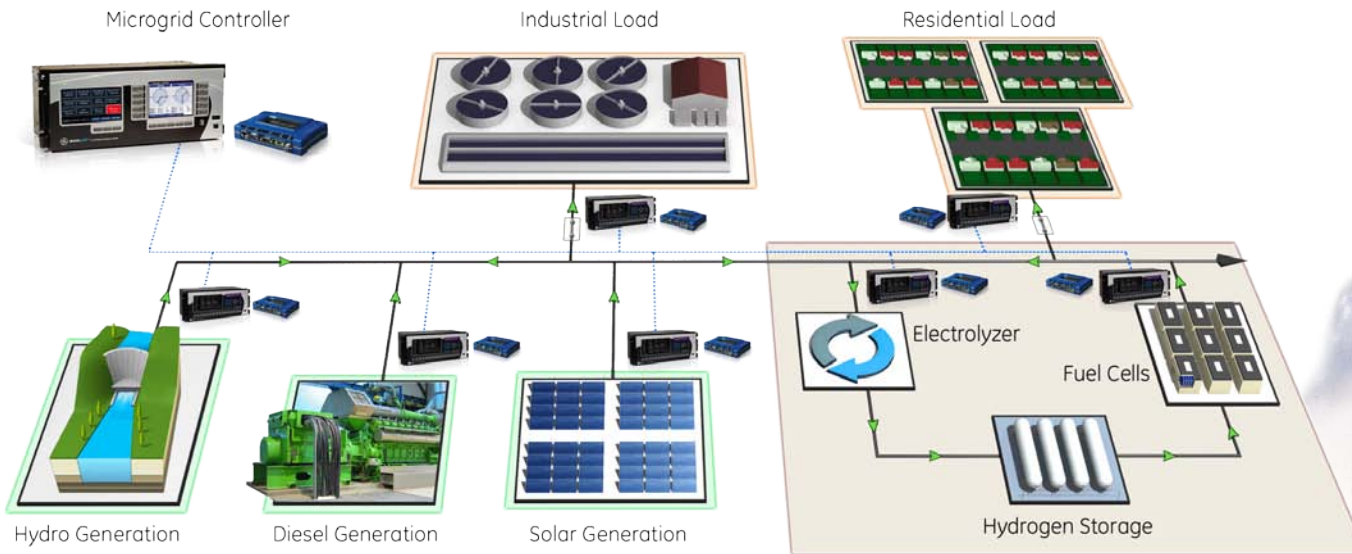
Dynamic Fault Isolation  
100 ms comm. time

# MicroGrid Control

Monitor the various Distributed Energy Resources - seconds

Execute Optimal Dispatch - seconds

Dynamically Balance Load and Generation - <100ms



All Applications Require Communications  
...with varying degree of performance

# Solution Requirements

Requirement	Functional Solution	Benefits
Route between NICs or VPN	Router	Flexible network design options
Bridge between NICs	Switch	Support of Layer 2 environments (GOOSE)
Secure server/client , Connection	IPSec VPN	Encrypt & tunnel between sites, meet NERC CIP requirements
Priority message delivery	Advanced QoS	Meet application SLA via deterministic networking
High Overall Availability	Redundancy	Improve High Availability and network up time
RS-232 Modbus, DNP, other	Serial Server	Connect into legacy install base
High Channel Availability	Multiple RFs	Choices of RF based on application and terrain

# RF Solution Space

ISM Band (Industrial, Scientific, and Medical)..Licensed bands an option

- Unlicensed 902 - 928 MHz – good penetration...other bands available
- 30 Mile radial range....Low Latency
- Possible interference....addressed through frequency hopping/blocking

Public 4G LTE, 3G (Verizon, ATT, etc.)

- Available infrastructure
- Operation expense
- SLAs not available

Private LTE (Band 26) – Licensed ...announced by Verizon & Motorola

- Large bandwidth (100Mb/sec)
- Needs infrastructure (some cost)
- Can be built more reliable than Public LTE

High Channel Availability Solution:  
Multiplicity of RF bands

# Unlicensed Radio Technology Requirements

- Hybrid solution of High-performance 900 MHz Frequency Hopping Spread Spectrum (FHSS) unlicensed radio and Digital Transmission System (DTS)
- Support for low-latency MAC layer transmission (for GOOSE) for low network latency (less than 5msec one-way) with a tunable dwell time
- Data Rates of 125Kbps, 250Kbps, 500Kbps, 1Mbps and **1.25Mbps...fixed or auto-select**
- Support networking features including bridging, routing, QoS (GOOSE priority), Firewalling and VPN tunneling
- NOTE: Sensitivity/range is dependent on modulation & terrain

# Radio Architecture



# Device Security:

- Logical Port Disable (e.g. HTTP, SSH, SNMP, etc.)
- Physical Port Disable
- Stateful Firewall
- Tamper Detect...Magnetometer
- Digitally Signed Firmware
- Secure Firmware Upgrade – via SFTP

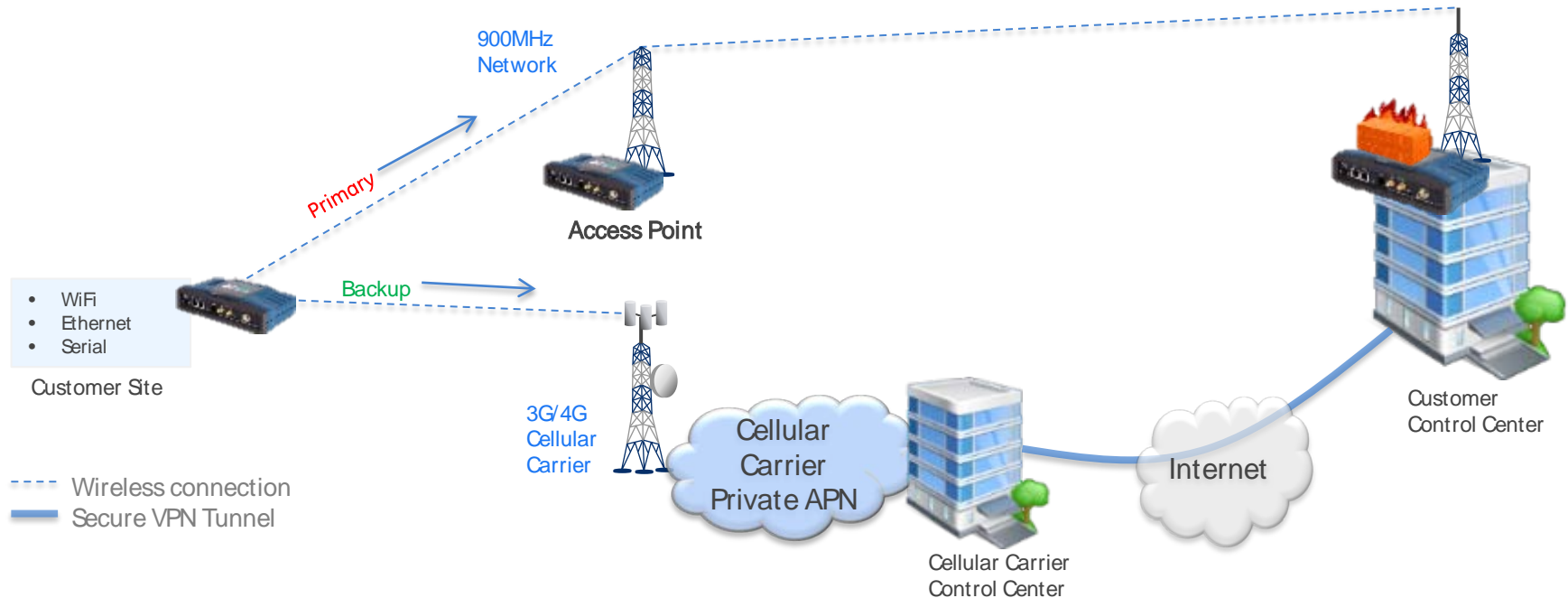




# Access and Monitoring Requirements

- User Accounts
  - RADIUS / AAA Log-in
- Role Based Access Control (RBAC) – 3 roles
- Secure Interface Protocols - HTTPS, SSH, SNMPv3, and NETCONF
- Audit and Logging (SNMP)
- Configuration Files and Restore Points

# Performance-Based Uplink Failover



- **Uplink Redundancy:** Any two interfaces (RF or wireline) can be placed in a virtual Bond interface with one as a primary and the other as a backup. Failover can be triggered on:
  - ✓ Primary interface going down (Loss of Signal/Status Down etc..)
  - ✓ X number of packet loss on primary link
  - ✓ Latency/performance degradation on primary link
- **L3 Route Failover:** can also operate at Layer 3 by activating a backup static route in case the Radio device at the end of the primary path becomes unreachable or has a degraded performance
- Cellular network availability could be further improved by utilizing M2M MVNOs that specialize in multi-carrier failover solutions



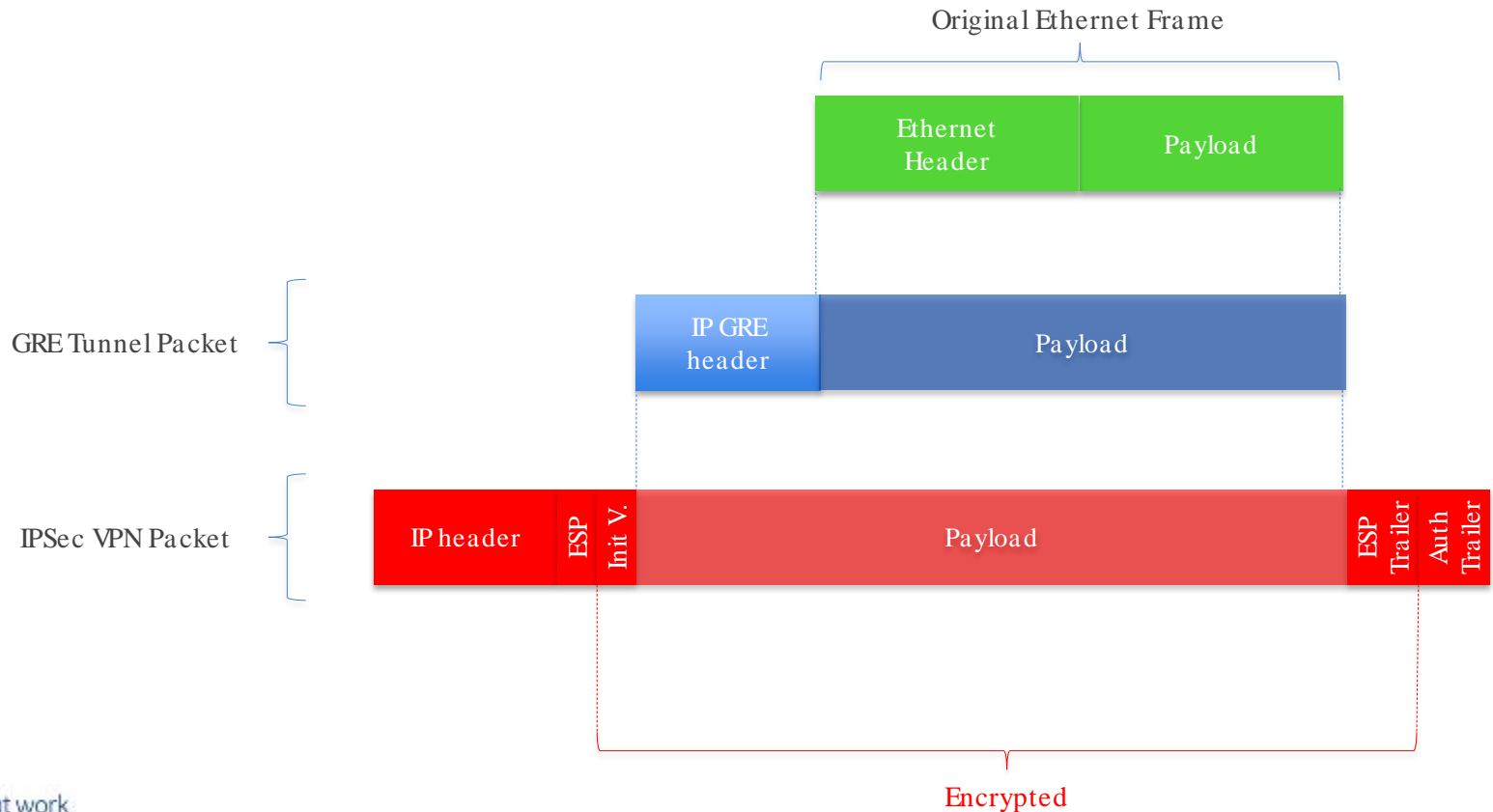
# Quality of Service (QoS)

- Quality of service (QoS) – enables classification of incoming traffic and subsequent prioritization of outgoing traffic
- Useful during congestion...
- Priority can be set via:
  - Ethertype (e.g. – IEC GOOSE)
  - 802.1a tag
  - UDP/TCP Port number

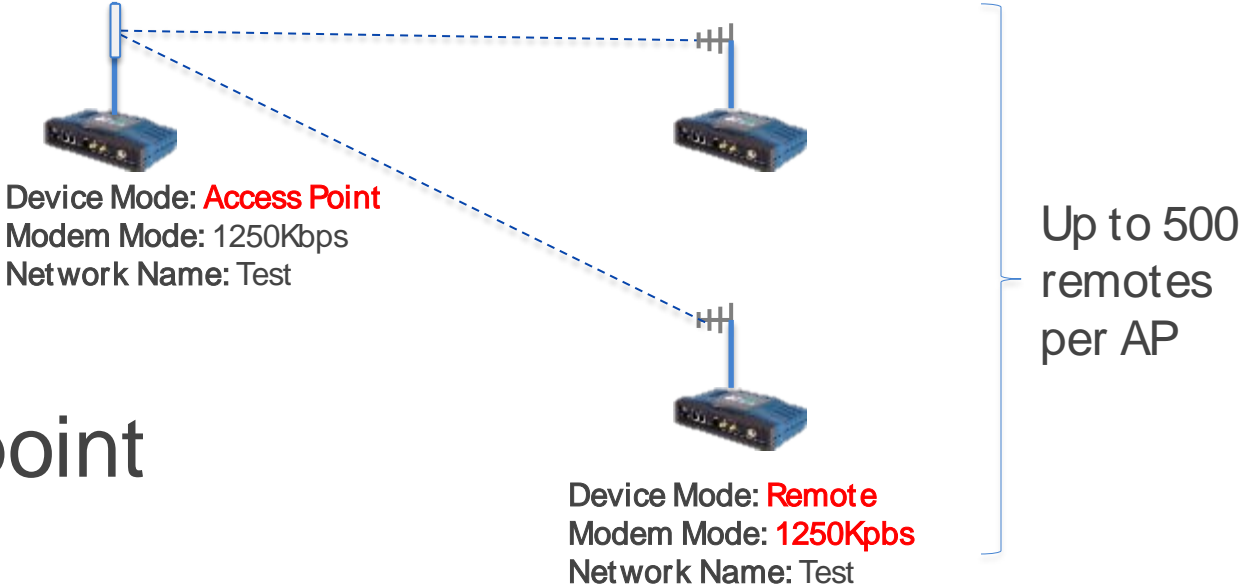


# IEC GOOSE over Generic Routing Encapsulation (GRE) via IPSec VPN Tunnel

- L2 GOOSE over GRE over IPSec creates an encrypted point to point Layer 2 VPN. The end networks see each others as if they're on the same "switch"...loss of Multicast property of GOOSE
- Packet Format for IPSec Tunnel Mode:



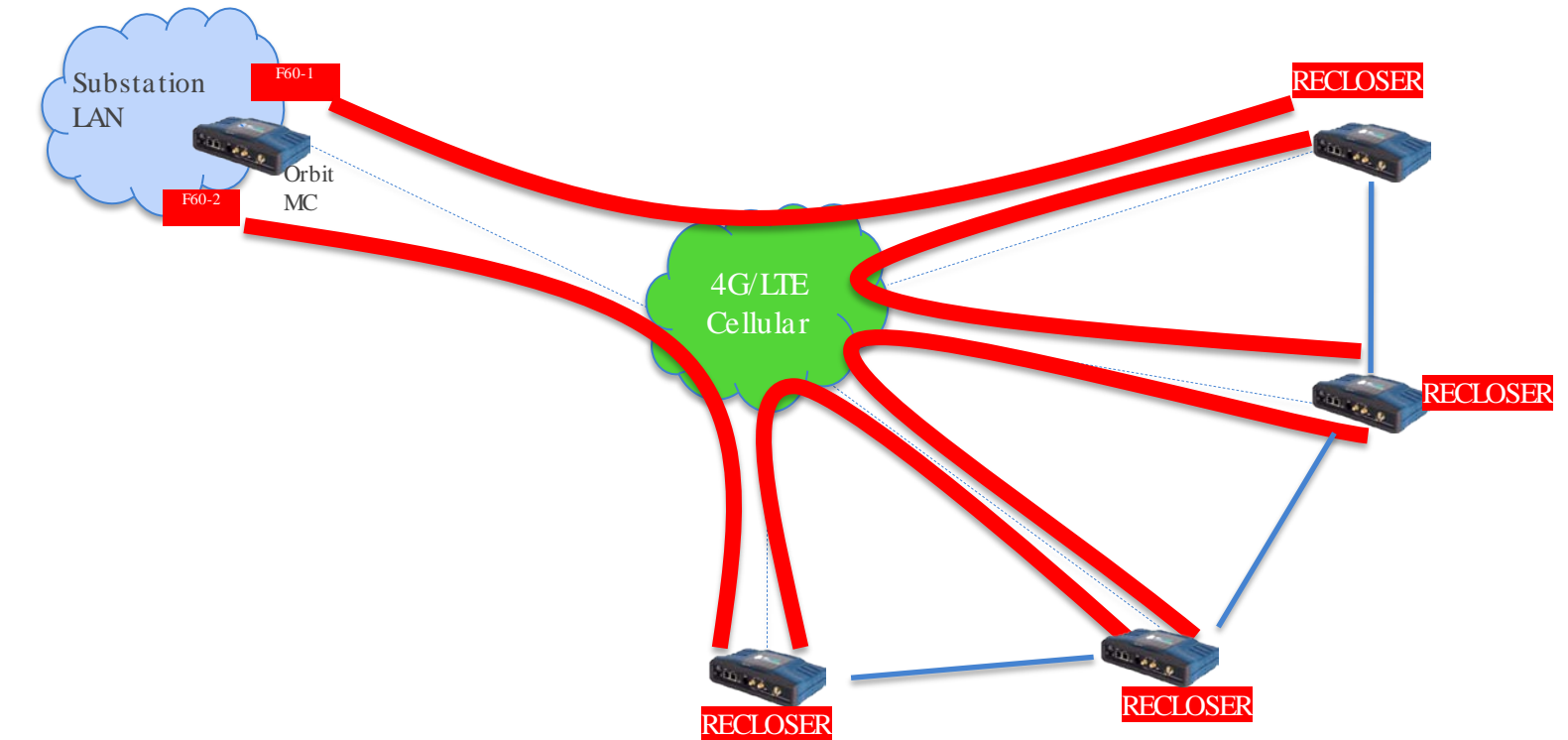
# 900MHz Topologies: Simple Point-to-Point



to Multipoint

Works with GOOSE Multicast

# IEC61850 GOOSE over ISM/LTE for DA/DG Protection Communication Architectures

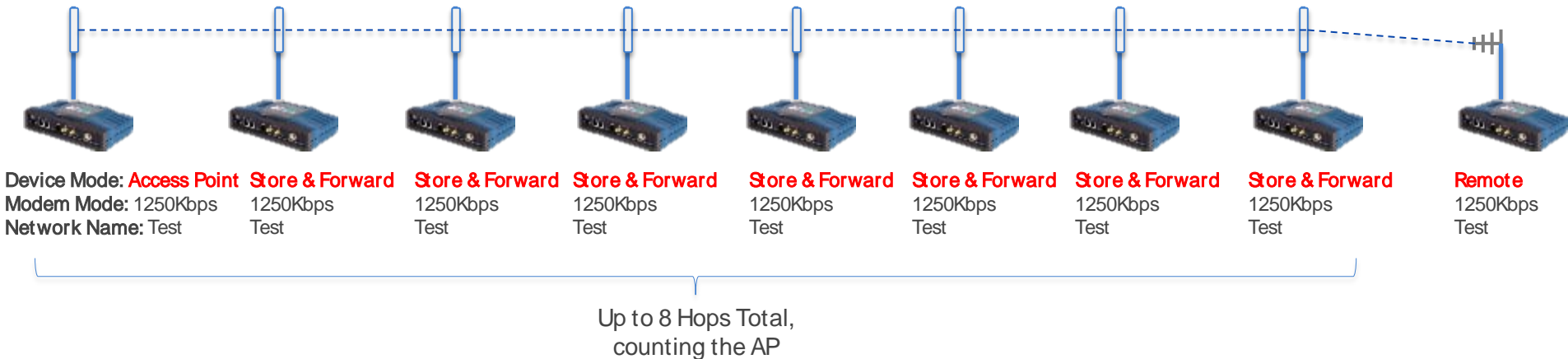


- ..... Cellular Uplink
- GOOSE over GRE through IPsec VPN LTE Tunnel
- GOOSE over GRE through IPsec VPN ISM Tunnel

# GOOSE Test Configuration & Performance Results

- Layer 2 GRE tunneling capabilities, - able to encapsulate an entire IEC61850 GOOSE frame inside of an IP packet, and tunnel it securely using an IPSec VPN over a cellular network.
- LTE Performance
  - Congested network (Distributech): <85ms
  - Un-congested network (Dallas suburb): <35ms
- 900 MHz Performance: <5ms....consistently

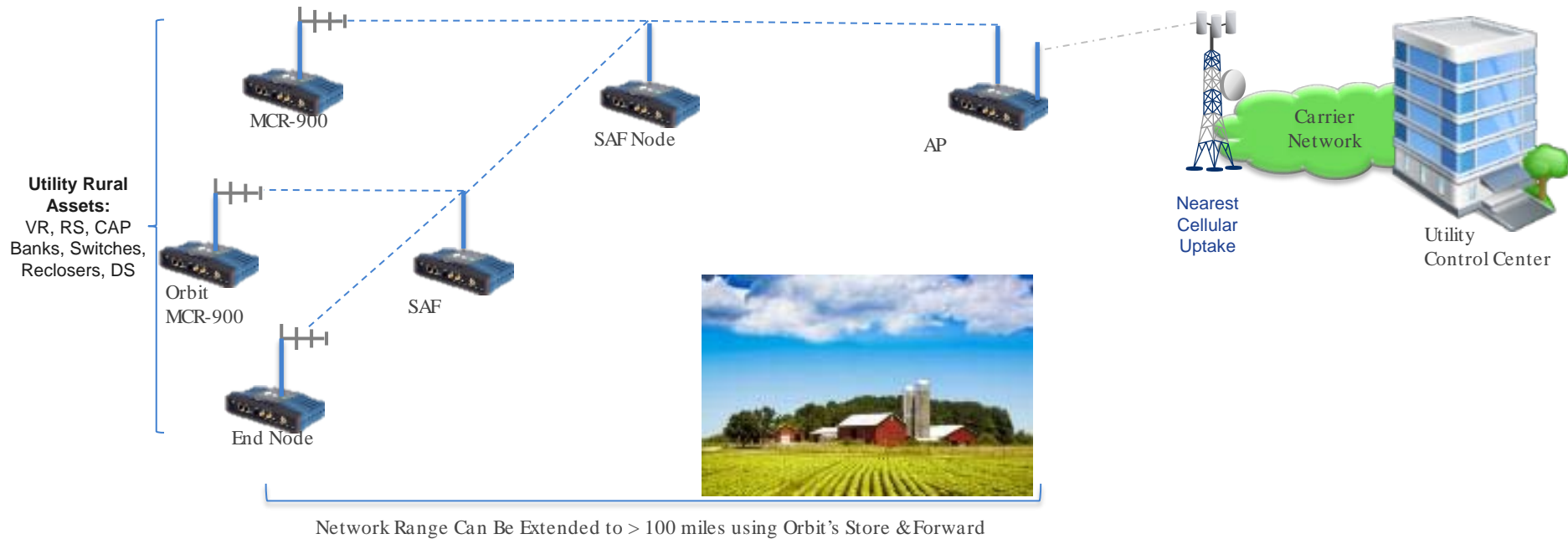
# 900MHz Topologies: Simple Store & Forward



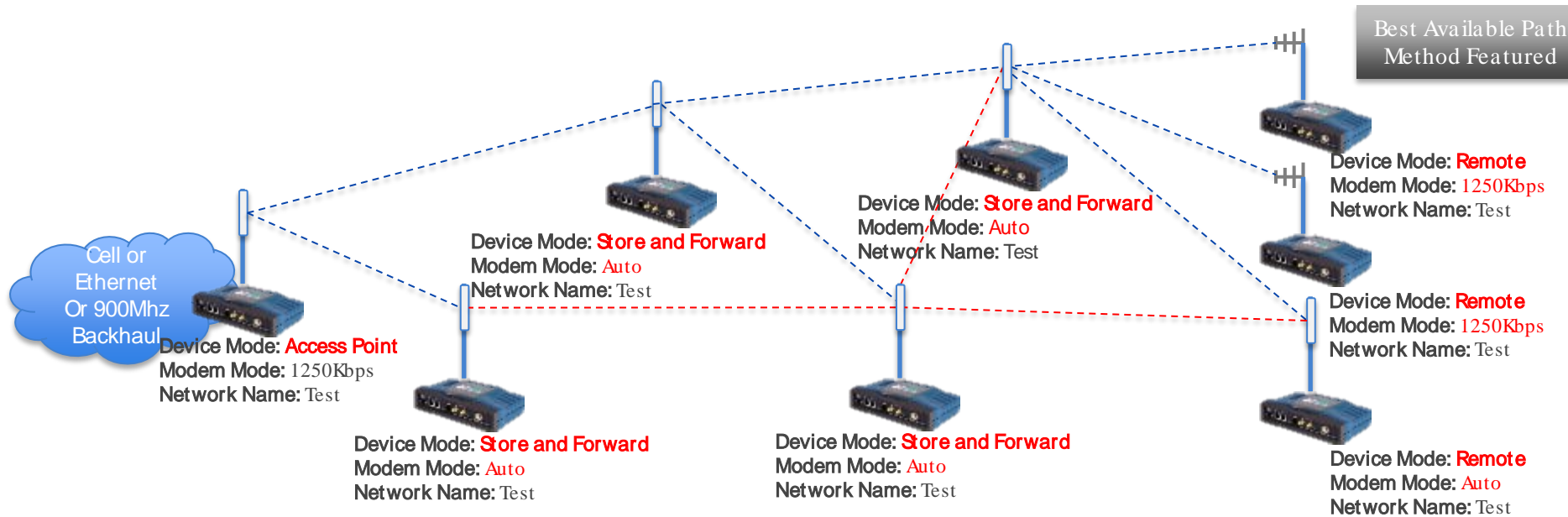
Can address long-haul / complex terrain issues



# Automation of Rural Distribution Assets/ SCADA



# 900MHz Topologies: Self-Healing Secure Mesh



## Mesh Configuration

- Two methods of self healing:

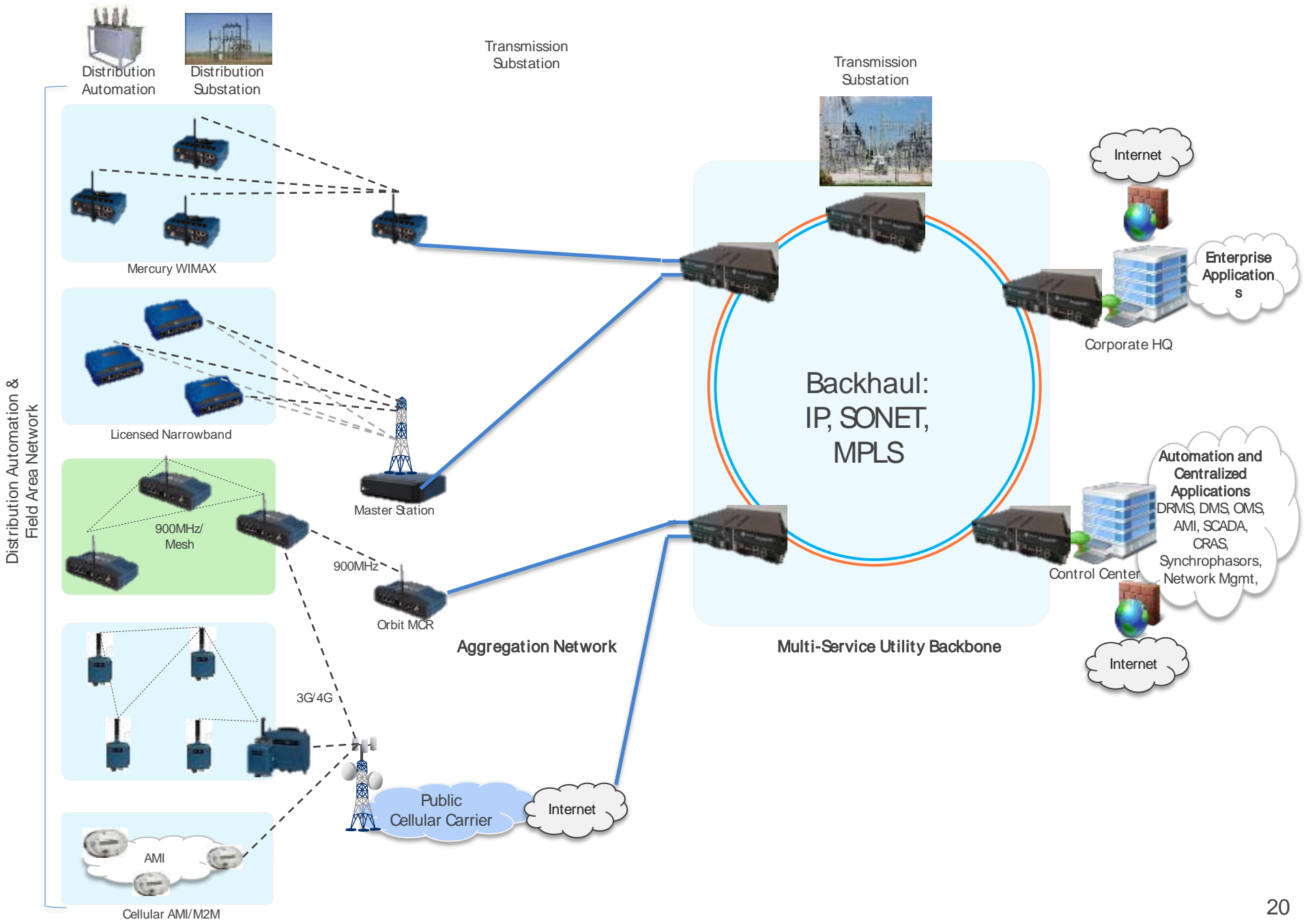
- Best Available Path:** Featured above, if SAF and REMOTE modem modes are set to AUTO, upon power up each would scan channels looking for upstream SAF or AP nodes, and would run analytics to pick the path based on the most optimum paths. This calculation may take one and up to a few minutes depending on the size of the network. Upon synchronization, the algorithm runs again only when the signal to AP/SAF weakens or is lost.
- First Available Path:** If a Remote or SAF's modem mode is set to a specific mode (e.g. 1250Kbps), they will synchronize to the first available/seen synchronization node (AP or SAF), despite the fact that it may not be the most optimum path. This mode is fast, and may bring the network up in seconds.

# Mobile Substation SCADA...auto-connect



Auto-switch to “best” carrier

# Large Scale Networking Solutions For Utilities



# Summary

- The combination of Traditional and Cellular technologies can provide a high-availability solution for critical communication requirements
- Multiple radio topologies are possible
- Very-low latency in the ISM band has been achieved
- GOOSE runs well over Wireless...