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# ABB Protective Relay School Webinar Series

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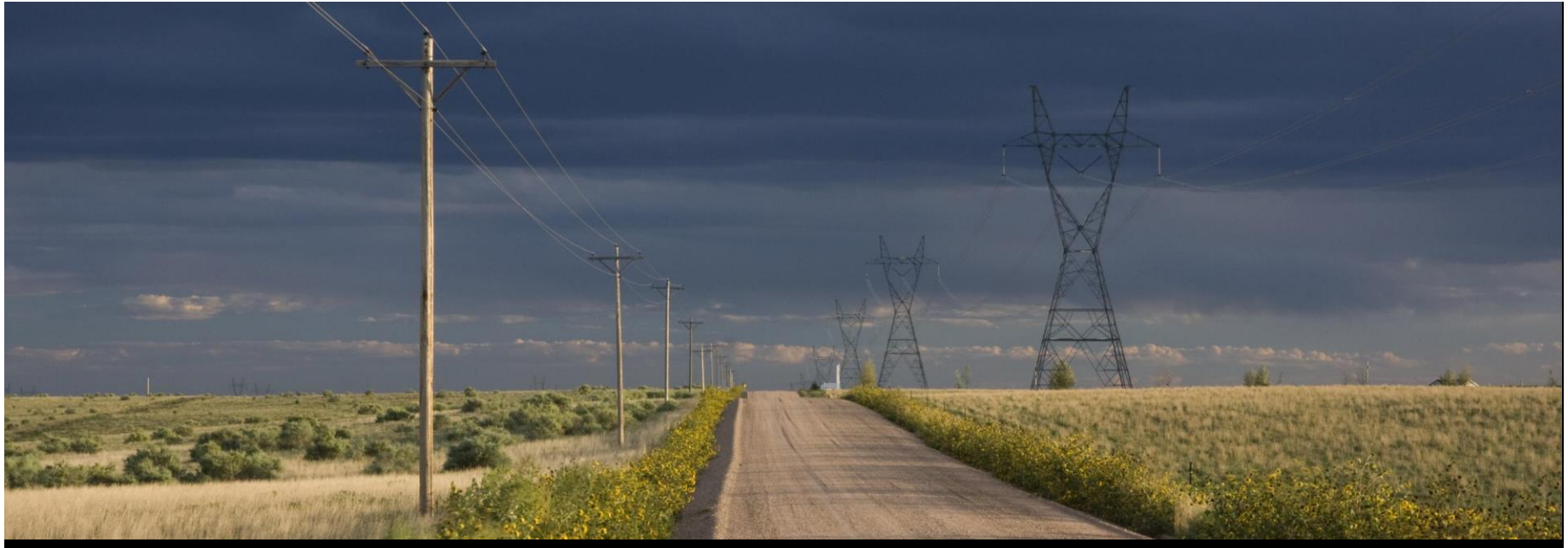

ABB Protective Relay School Webinar Series

# Tropos - Utility networking solution

Adam Guglielmo

July 2014

# Presenter

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# Learning objectives

- **Understand the ABB Tropos wireless networking solution, the value it provides, and the applications it supports in the utility network**
- **Review application examples and case studies of where the Tropos solution fits and is already being deployed**
- **Compare and contrast the ABB Tropos solution with other wireless and communication technology being marketed into the utility market today**

# ABB Wireless Communication Systems

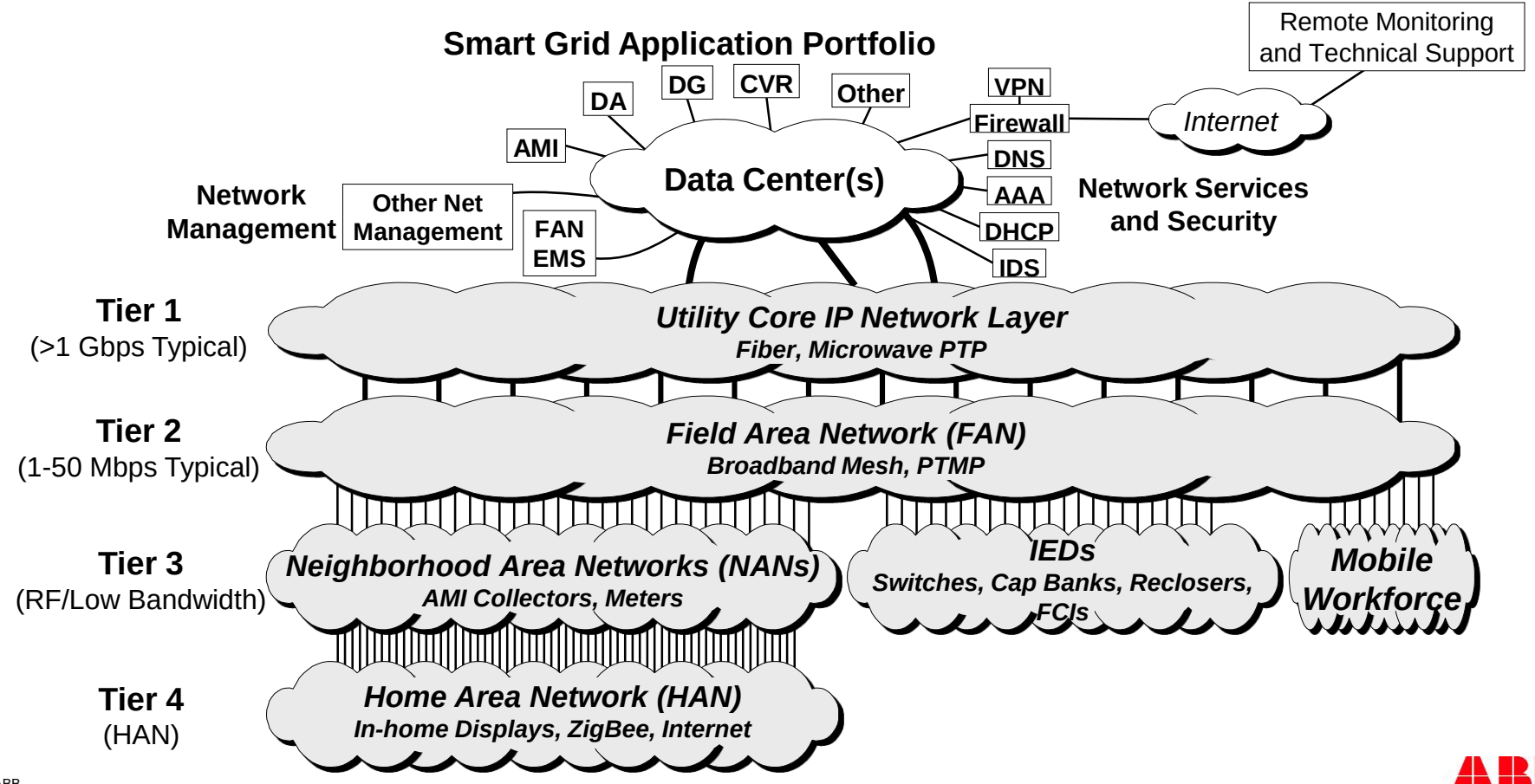
## The trusted choice for networking mission critical applications


- Market leader in private, outdoor, wireless mesh networking
  - 1,000 customer, 50 countries
  - 70,000+ routers shipped
  - 50 patents
- Why customers choose Tropos
  - Tropos works where others failed
  - High network availability
  - Embedded defense-in-depth security
  - IP simplifies application deployment
  - ABB delivers successful projects

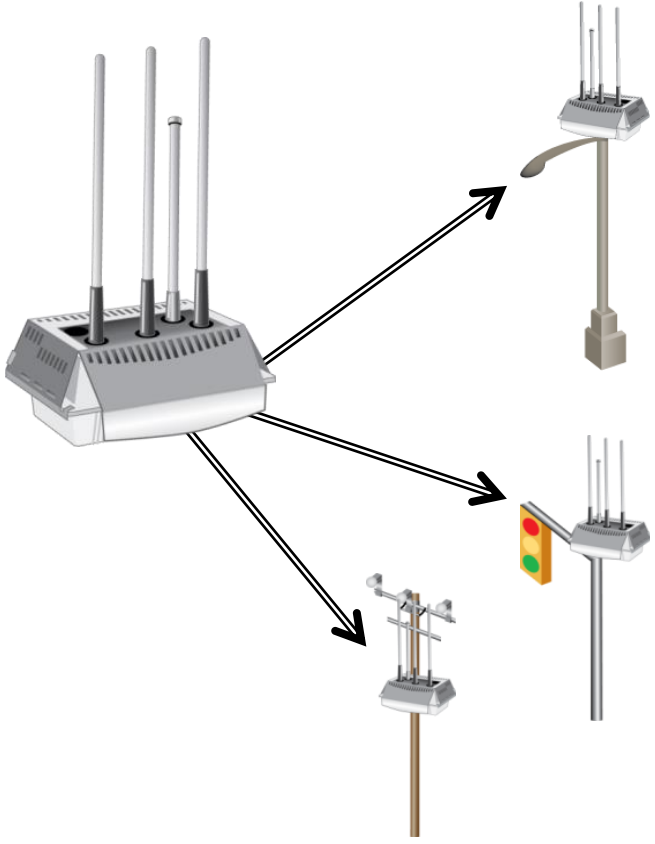
# What Tropos provides


- A high-performance wireless IP network communication system
  - Cost effective
  - Standards-based
  - Rugged and reliable
  - Secure
  - IP eases application rollout
- Scalable from a small, single application network to large, multi-application system
- Wide range of fixed and mobile routers
  - Unlicensed and licensed spectrum
  - AC and DC power
  - Internal and external battery backup
  - Ethernet and serial connections
- Support during and after deployment

# Tropos distribution area networks
## Fill gap between core network and field apparatus

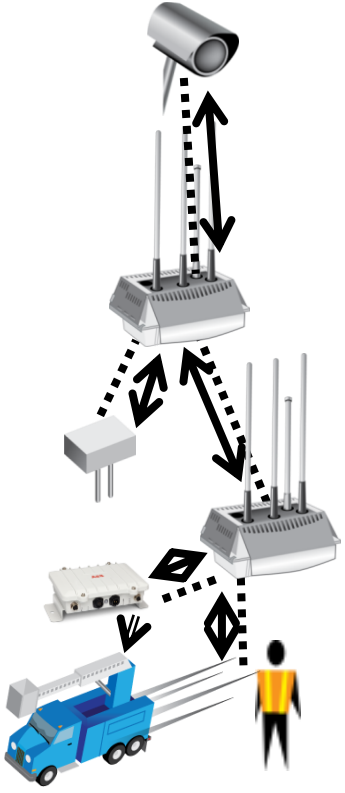


# Tropos mesh routers attach to street fixtures



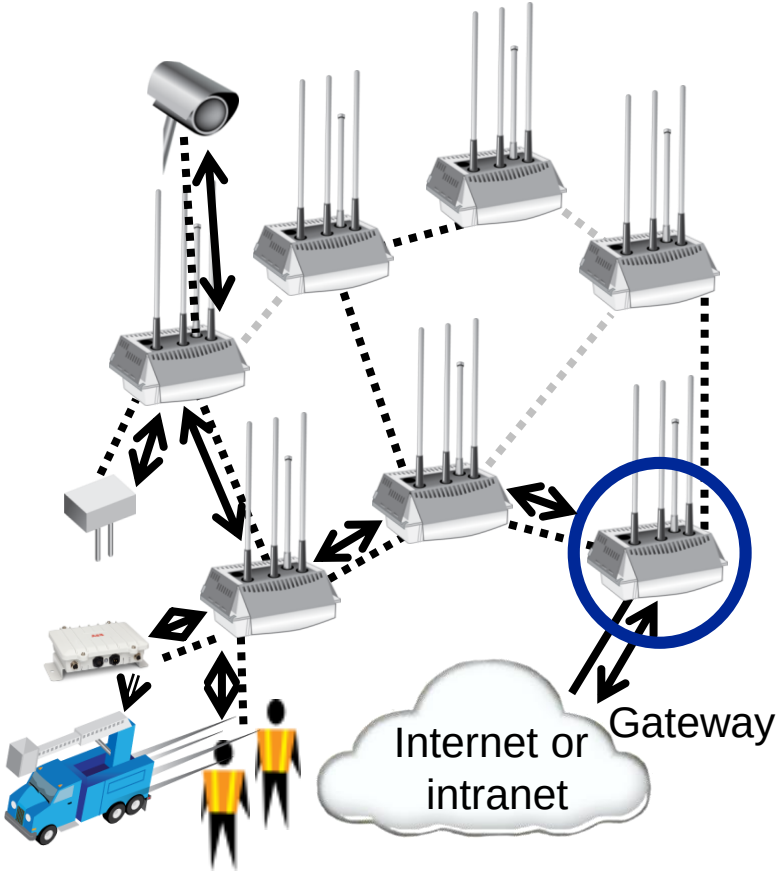
- Each router is the size of a take-out container
- Tropos mesh routers attach to street lights, traffic signals, utility poles, etc.
- Routers are very rugged and use little power
- Number of fixed routers per square or linear mile (kilometer) varies from light to heavy mesh, depending on topography and application

# Routers provide communications for many applications
## Secure, high-speed, low-latency



- Routers provide secure broadband wireless connections to nearby infrastructure, people and vehicles
- One network supports many applications and user groups
- Routers support industry standard security
  - AES encryption
  - Integrated firewall
  - Integrated IPsec VPN

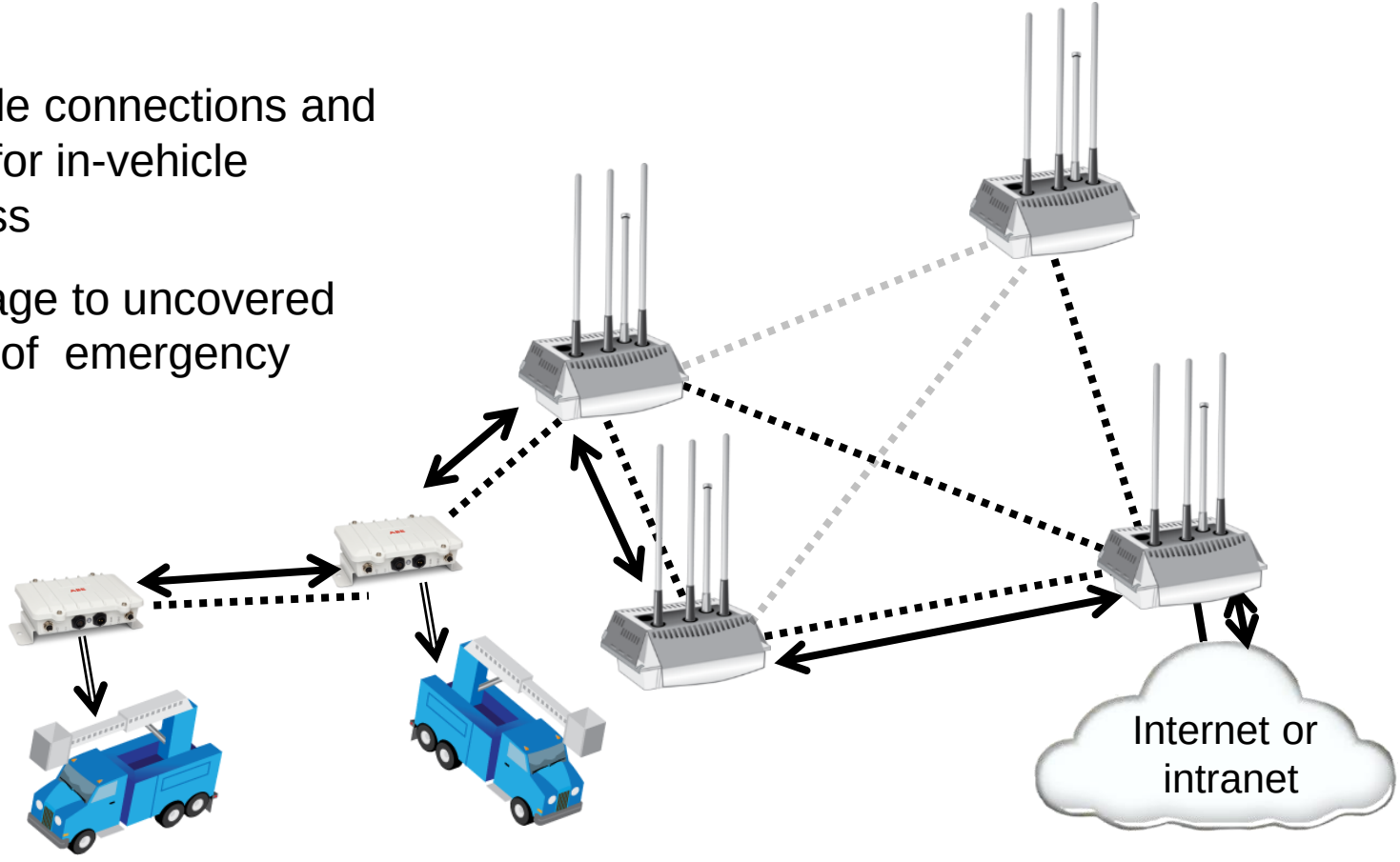
# Routers form a reliable mesh network
## Relay traffic to/from Internet or intranet




- Routers relay traffic between clients and gateway to Internet or intranet
  - 2.4 and 5 GHz mesh links supported
- Redundant wireless links provide high reliability

# Mobile routers enhance coverage

- Provide reliable connections and fast handoffs for in-vehicle network access
- Extend coverage to uncovered areas in case of  emergency



# Why Tropos wins
## Customers trust Tropos

- Meet unique needs of large, outdoor, mission-critical networks
- Many applications delivered over one network
- High performance
  - High throughput + low latency + large volumes of data
- High system availability
- Rugged hardware
- Proven scalability in multiple dimensions
- Enterprise-class security
- Visibility, management and mapping of large coverage areas and thousands of routers
- Legacy device integration
- Over 50% of our wins are “rescue missions”

# Tropos – networking for utilities
## Broadband enables smarter grid applications

Distribution
Automation & Control

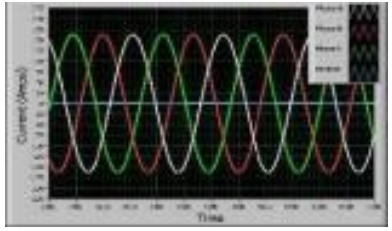
Automated
Metering

Renewables
Integration

Field Data
Applications


Demand
Response

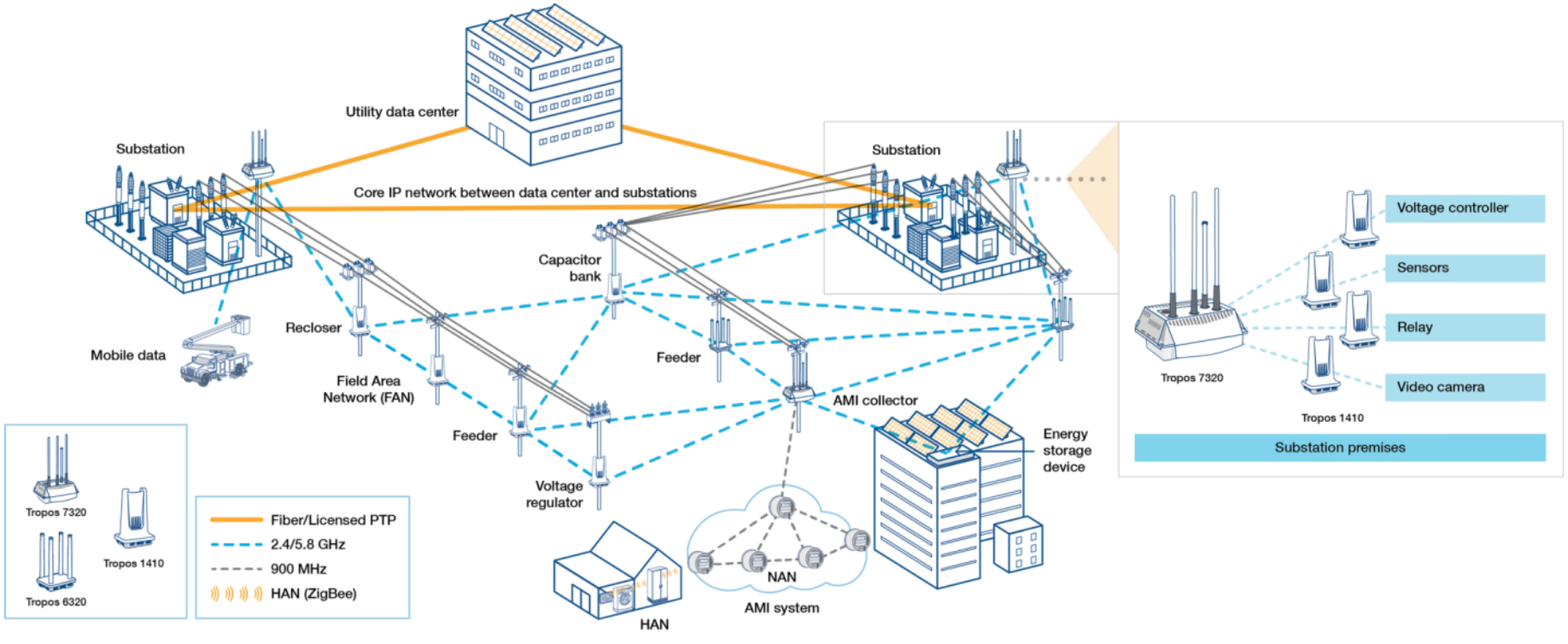
Outage
Management



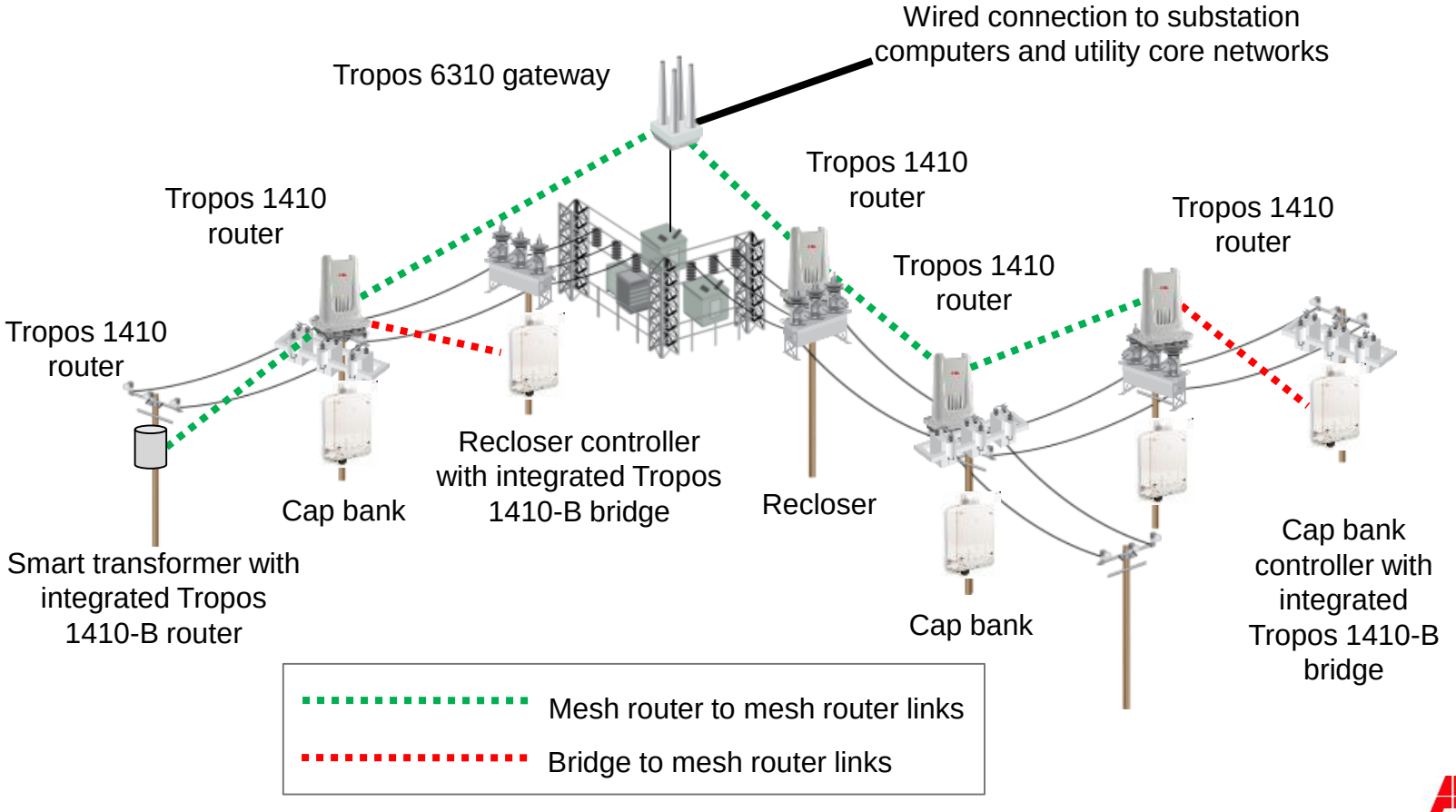
Power
Quality &
Planning

PHEV Integration

# Tropos network architecture for a utility
## Applicable to distribution feeders and substations



# Distribution feeder communications



# DA applications

- Basic automation
- Dynamic feeder reconfiguration
- Conservation voltage reduction
- Volt / VAR control
- Transformer monitoring

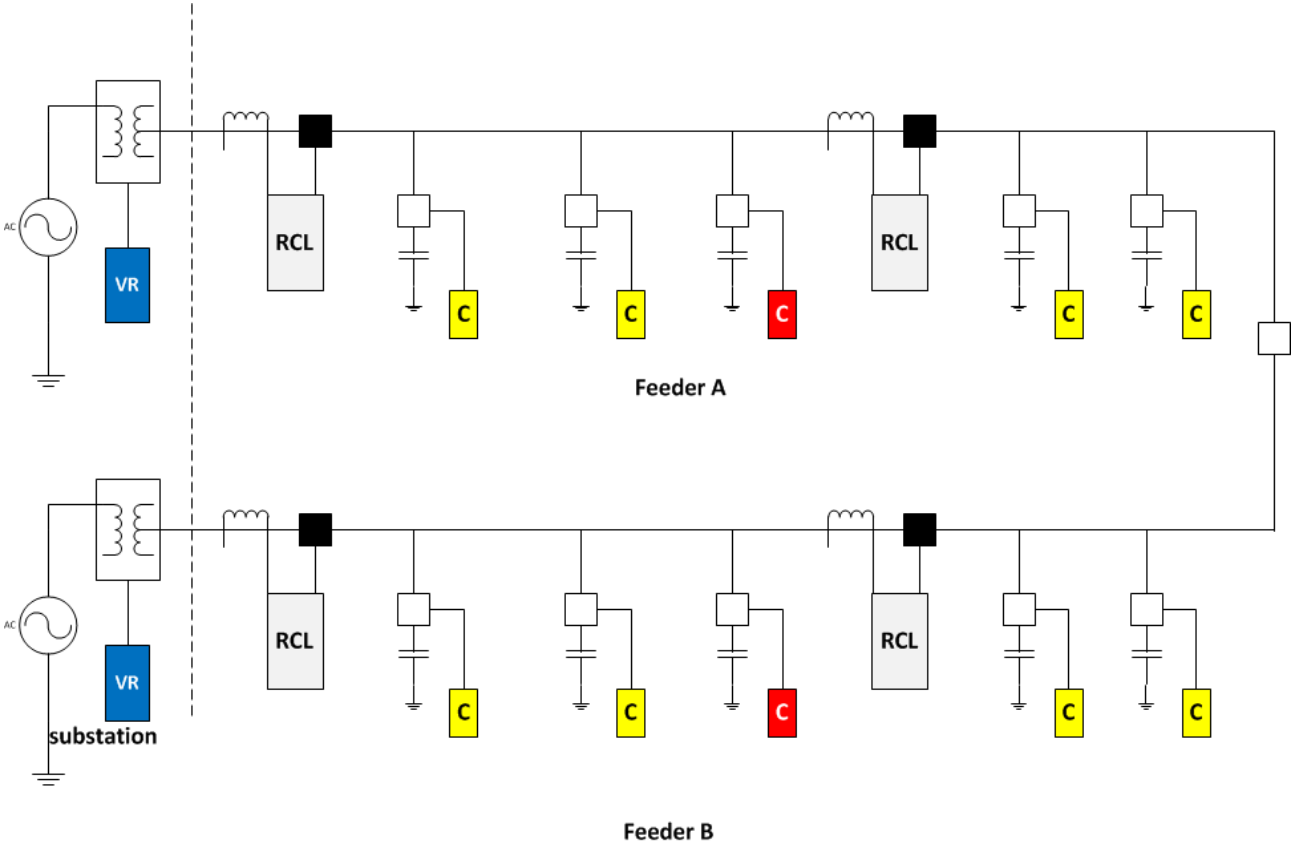
# Basic automation
## Remote sensing and control

- Simple measurements
- Outage and restoration reporting
- Predictive and preventive maintenance
- Cap bank neutral current monitoring

# Dynamic feeder reconfiguration

- Outage minimization
  - Isolation of outages
  - Redirection of power
- Distributed generation
  - Shift loads from one source to another

# Dynamic feeder reconfiguration

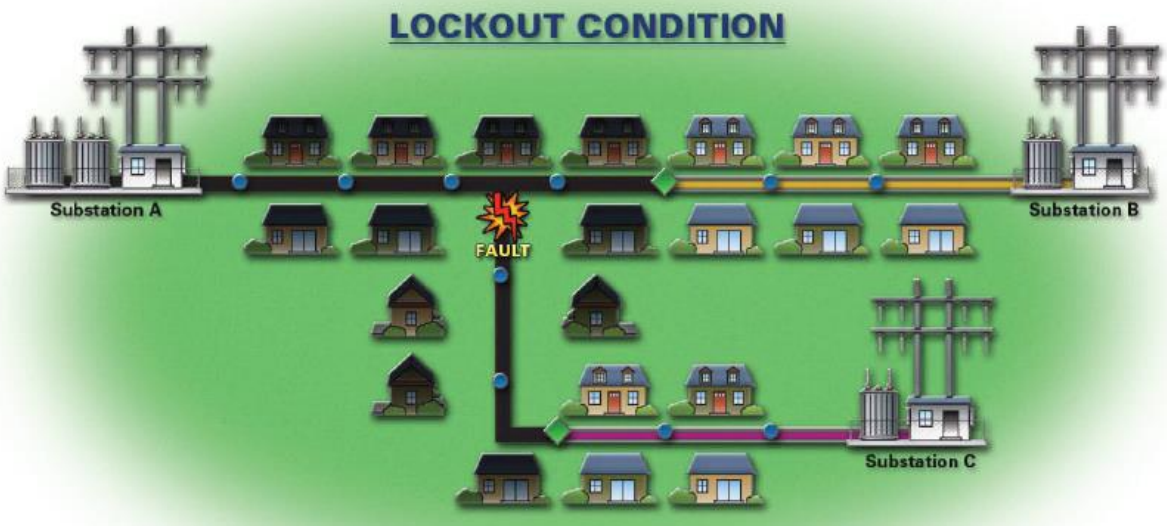


# Outage restoration example
## All customers have power


Source: Avista

# Outage restoration example

## Customers between Substation A and tie points lose power




Source: Avista

# Outage restoration example

## Power restored from Substation A to switch nearest fault


Source: Avista

# Outage restoration example

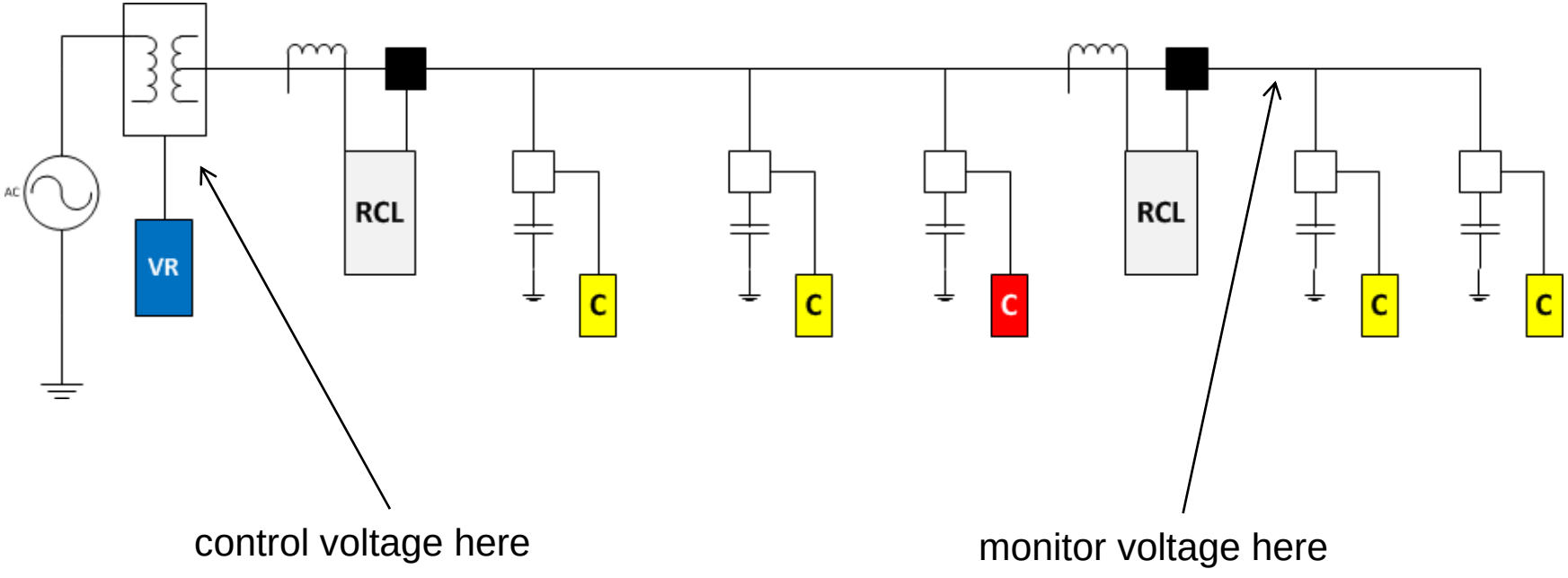
## Power restored from Substations B and C to switches nearest fault


Source: Avista

# Conservation voltage reduction

- Monitor line voltage to ensure minimum allowable voltage delivered to last customer
- Control voltage at the regulator
  - Usually in substation
  - Can be down the feeder
- Minimizes power delivered into the line minimizing cost to the utility
- Concern over constant-power loads
  - Current increases as voltage decreases causing additional drop on the line

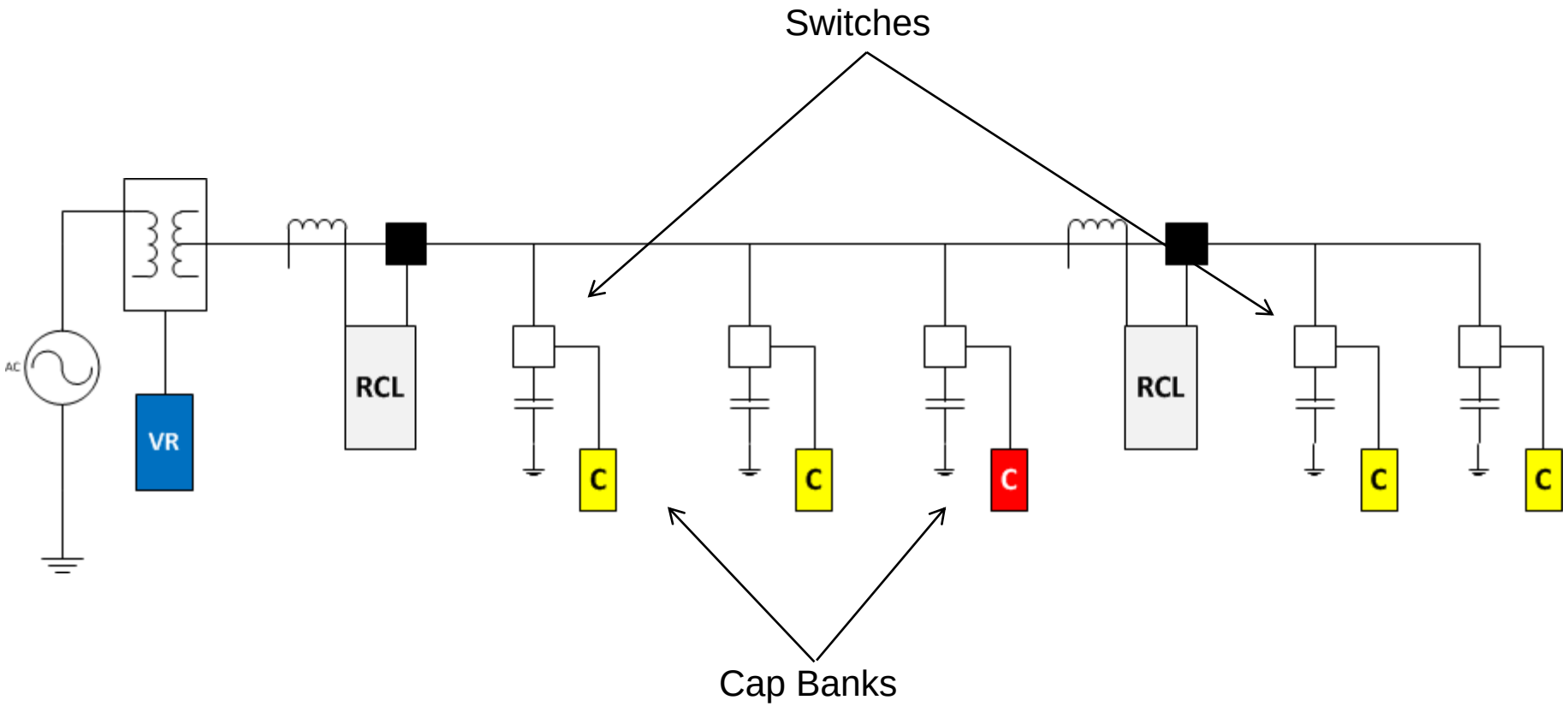
# Conservation voltage reduction
## Sub title



# Volt/VAR control
## Sub title

- Why: reactive loads decrease the efficiency of the network
- Objective: maintain power factor as close to unity as possible
  - Minimize power to the network
  - Minimize cost
- How: install capacitor banks at locations along the distribution feeder
  - Need to be switched to avoid leading power factor when load is resistive
  - Typical method is time-based switching
  - More effective method is measurement-based switching

# Volt/VAR control



# Transformer monitoring

## Applications

- transformer health monitoring
- transformer load monitoring
- power quality monitoring
- outage management
- theft monitoring

| | |
|---|---|
| functionality | ▪ measure and report temperature, voltage, current, oil level |
| requirements | ▪ high (seconds to minutes) latency<br>▪ 10-100 kbps throughput<br>▪ head end application support<br>  ▪ SCADA, EMS, DMS, Yukon |
| benefits | ▪ predictive, preventive maintenance<br>▪ energy theft detection<br>▪ improved asset management<br>▪ improved reliability |
| communications | ▪ almost none installed, but sensors and communications being considered |
| Tropos solutions | ▪ Tropos 1410-B integrated into sensor-equipped communicating transformer |

# Wireless in substations
## What's the business case?

- Wireless not generally consider to be a great fit for substations
- If building a new substation, most likely going to put fiber in the ground (or cable trays)
- Wireless networks serving feeders might terminate at fiber switch ports in substation but few other uses
- Game changer – the need for utilities to retrofit existing substations with automation capabilities

# Main factor driving wireless in substations
## Desire to avoid trenching in substation yards

- However as utilities look to add automation to existing substations, wired connections are not as readily available as many had assumed
- Going back and deploying fiber or fiber trays within existing substations is an expensive proposition
  - Trenching costs
  - Drilling holes in control cabinets
  - Safety considerations
- For substation retrofits, wireless is a great fit

# A closer look at trenching costs
## Digging in the substation yard

**Costs for a 200 foot long 1' x 1' trench**

- Mobilization = $5,000
- Excavation equipment = $9,600
  - $400/hr = $400 * 24 hrs (assumes all work done in a day)
- Backfilling equipment = $4,800
  - $200/hr * 24 hrs (assumes no machine compaction is required and manual compaction will suffice) $200 * 24 hrs = $4800
- Labor = $8,400
  - 2 laborers at $100/hr and 1 supervisor at $150/hr rate * 24 hrs
- Conduit and Misc = $6,000
- Demobilization = $3,000
- 15-20% contractor margin

**= total cost of $42,000-$44,000**

# A closer look at trenching costs

## Many factors have a significant impact on cost

**Total Cost of $42,000 -$44,000**

**Can easily rise into $100,000 to $150,000 range.**

**Aware of one real world example where trenching for three devices cost $256,000!**

- Location (state regulations, geography, labor costs)
- Other work contractor is asked to do on site (more work might mean lower per foot cost)
- Grading requirement on site
- Amount of hand excavation required due to obstructions
- Availability of reliable small contractors
  - Big contractors won't do work – mobilization/de-mobilization alone >$50,000)
- Safety training for working on energized substation
- Additional trenches to reach all equipment
- Drilling out holes in control cabinets/re-weatherproofing

# Compare to cost of wireless
# Tropos wireless for substation automation

- Much lower cost for a wireless solution
  - Assuming 18 IEDs in the substation which need to be connected (6 feeders with 3 x single phase regulators)
  - Cost of Tropos solution approximately $20,000 including ongoing support, network management system, and a day or two of professional services
    - Compared to the low-end of our trenching cost range, a wireless system ~50% of trenching cost alone
    - At high-end of range for trenching, a wireless system would be 10-20% of trenching cost alone
- There a lot fewer cost variables with wireless – a network of the same size will cost roughly the same to install in any substation
- Time to deploy is going to be faster as permitting, grading, safety considerations, etc., will not be as much of an issue

# Distribution Level Solution

Ethernet
Fiber

***Entire Min-Sub or Large pad-mount can be controlled, protected, metering and monitored with a switch, 1 REC device, 1 RTU, and Tropos communications!***

Control Center

Local control

Remote Control

**AFS65 switch**

**Tropos 3320 radio**

802.11a/b/g/n

Cyber Security


**RTU 540CID11 gateway**

Integrated I/Os
DNP3.0, IEC61850
HMI with trends, events, alarms, etc.

**REC670 relay**

Integrated IEC61850

# Transmission Level Substation Solution
## Substation Monitoring with Wireless Infrastructure

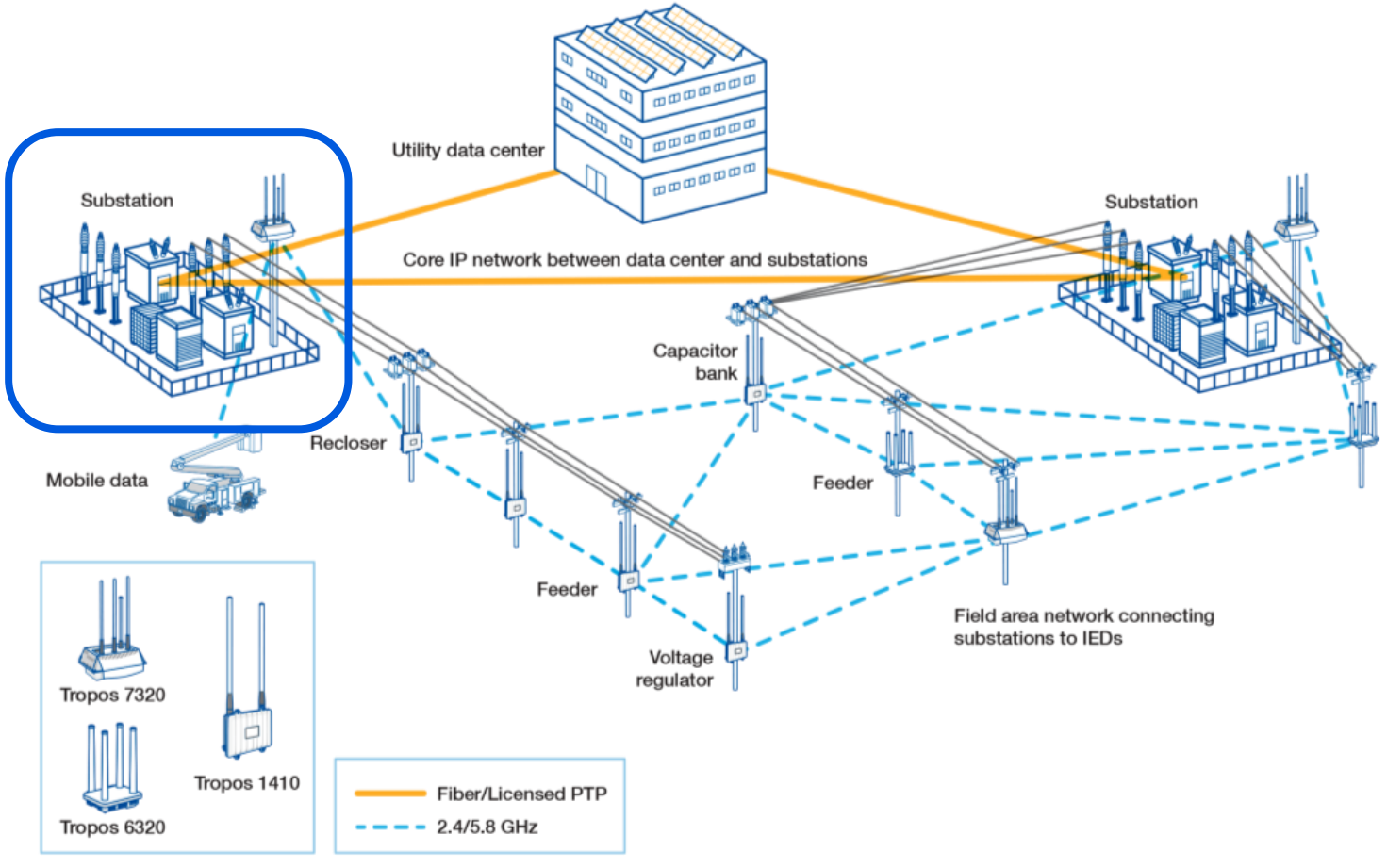
**What is it?**

- Complete ABB solution including communication

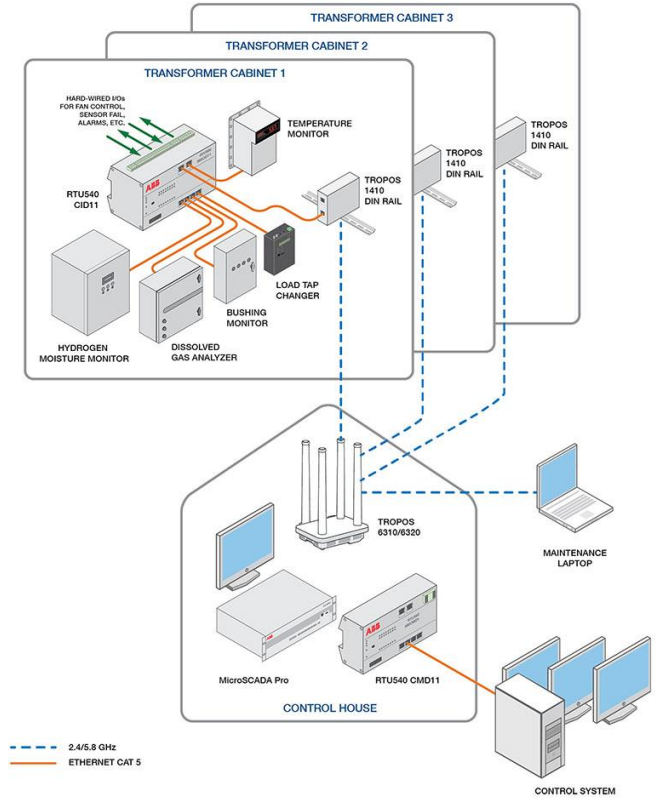
**What problems does it solve?**

- Reduction of several interfaces to a single one with one software tool across the whole network providing
  - Full system diagnosis and management
  - Logging, trending, alarms, web-based HMI
  - Time stamping
- Cost-effective and extensible wireless communication access to devices in the substation
- Managing the data that comes with increased monitoring and turn it into knowledge
- Ensure Cyber Security implementation across the entire solution supporting our customers to meet their NERC-CIP requirements and more

# Transmission Level Substation Solution
## Substation Wireless Monitoring Infrastructure



# Transmission Level Substation Solution
## Substation Wireless Monitoring Infrastructure

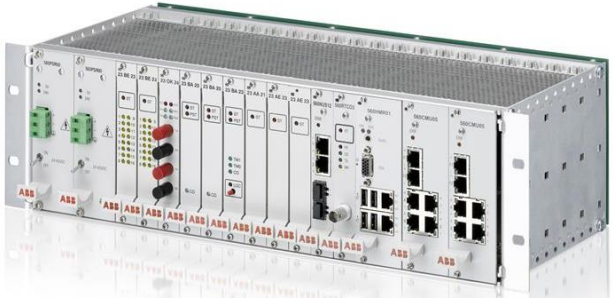



- Remote data collection from transformer monitoring devices (e.g. temperature, hydrogen-moisture, tap position) via RTU540 (hard-wired / serial / Ethernet)
- Wireless communication back to the control room via Tropos 1410
- Reception of transformer data at control room via Tropos 6320 sitting outside
- Communication from the control room to network control center via RTU540
- Dashboard turns data into knowledge with MicroSCADA Pro

# Benefits

- Open platform (future proof investment) and fully integrated solution
- Native IEC 61850 and DNP3 implementation ready to use – now or later with no additional costs
- Standard design can be used over and over again
- No trenching costs to pull communication cables while adding automation to existing substations
- SCADA consolidated dashboard overview with a drill-down option
- Consolidation of multiple substation functions into one platform including HMI, alarm annunciator, and expansion to advanced applications like Volt/VAR control, feeder re-configuration, and many more

# RTU500 series offering



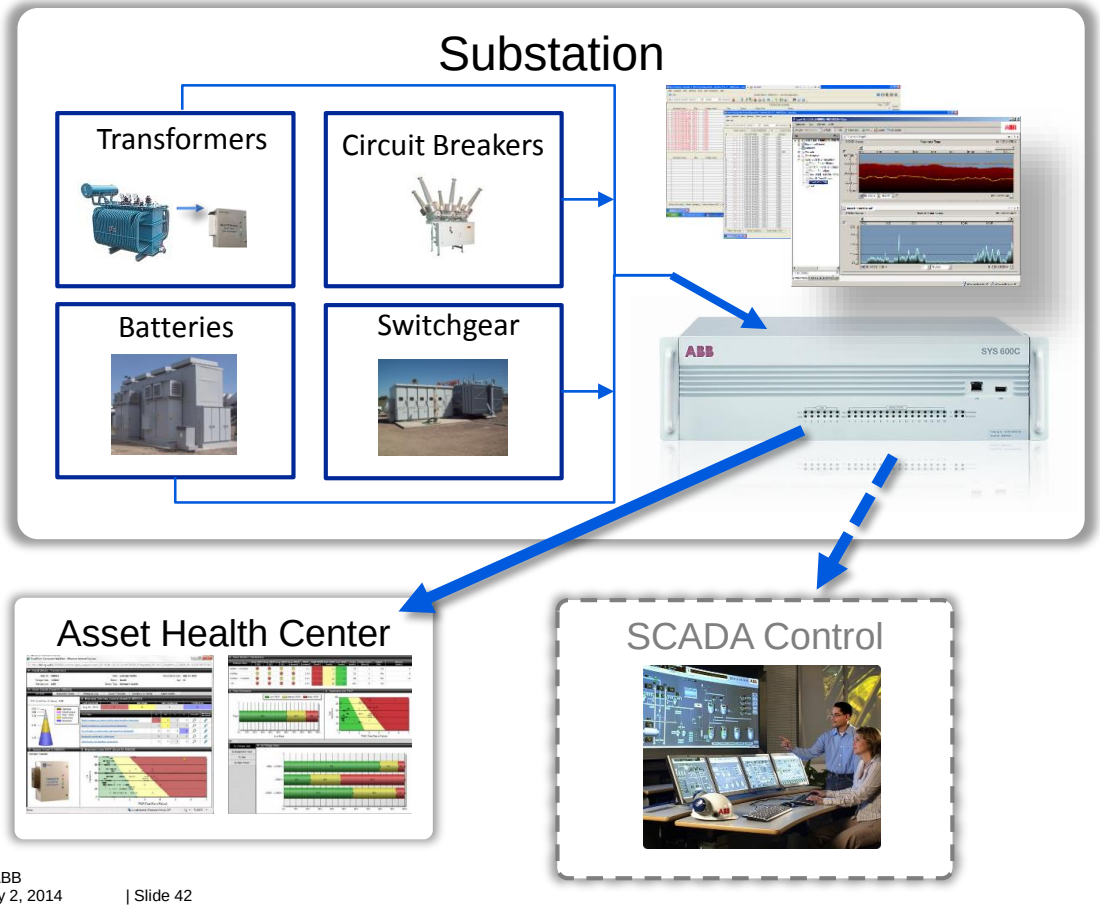

- RTU560 product line
  - 19” rack-based RTU, scalable, modular platform with redundancy concept
- RTU540 product line
  - DIN rail RTU, compact, rugged, metal housing
- RTU520 product line
  - DIN rail RTU, space-and cost-efficient solution, plastic housing

# Tropos wireless mesh networks offering



- Tropos 1410
  - Automation *end-point / edge router*
  - Available in ruggedized, weatherized or DIN rail mounted “indoor” version
  - Wired Ethernet or serial connections
  - Supports automation protocols including DNP3 and IEC 61850 as well as terminal server capability
- Tropos 6310/6320
  - Single (2.4 GHz) and dual-radio (2.4 GHz and 5 GHz) versions
  - Two wired Ethernet connections (backhaul and wired device)
  - Small, lightweight form factor
- Tropos 7320
  - Dual-radio (2.4 GHz & 5 GHz)
  - Optional internal battery backup
  - Modular antennas
  - IEEE 1613 for substation installations

# MicroSCADA Pro offering
## De-centralized Asset Health Repository



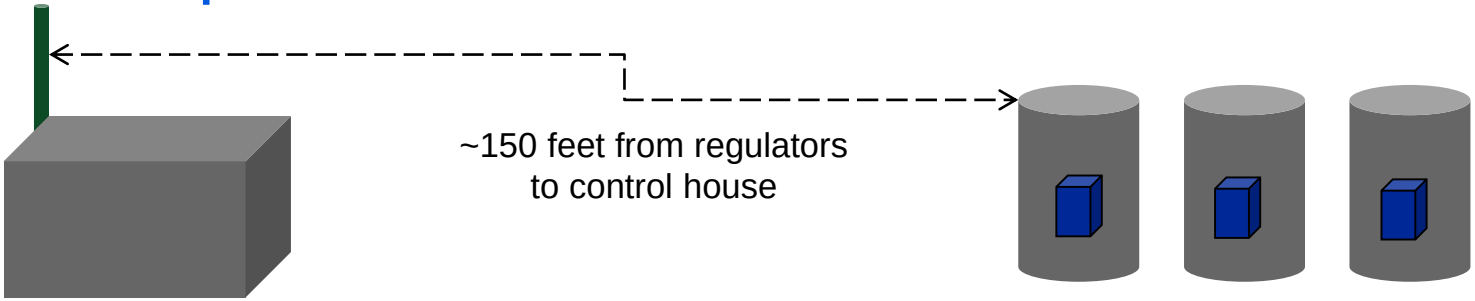

- Ruggedized solid-state substation server
- Local Operator's user interface
  - Asset health dashboard
  - Alarms/Events

- One platform for multiple substation automation applications:
  - HMI
  - SCADA Gateway
  - Alarm Annunciator
  - Advanced applications (Volt/Var Control, Fault Location, Isolation & Restoration)

# Example #1
## Substation automation with integrated communications

- Starting automate substations with SCADA (specifically voltage regulators)
- Communication requirements
  - Access to control panels without pulling any communications cables
  - No holes drilled in regulator cabinets as this would increase both installation time and costs
  - Access to controls from anywhere within the substation
    - Check or change settings, update firmware and control regulators from safe distance
    - Readily available monitoring, data logging, power quality, and condition-based maintenance information
  - Support for  proper cyber security standards

# Voltage regulator controller opportunity
## Substation pilot architecture




- Tropos 1410 wireless bridges installed in each regulator cabinet
  - Antennas were selected to provide enough signal strength when mounted inside the cabinets
  - Throughput still more than 1 Mbps
  - Output of radios configured so that it's strong to operate within the substation, but is not visible outside the fence
  - SSID of network is hidden
- Ethernet used to connect regulator controllers and Tropos wireless bridges
- Wireless bridges communicate to a Tropos wireless gateway mounted outside the control house
- Gateway connects to Layer 2 switch in the control house via Ethernet
  - Layer 2 switch also connects to an automation control unit
- L2 switch provides optical isolation and allows other devices in substation access to wireless network and substation computer
  - Protocol used is DNP3 over TCP/IP
- Can also access individual controls over the wireless network

# Example #2
## Substation transformer gas monitor sensors

- Utility had gas monitors that they require readings from a few times a day
- Doing lifecycle monitoring and management as lead time on replacement transformers is approximately two years
- The substation itself has fiber connectivity (backhaul) but the utility stated it was too difficult and too expensive to install fiber within the substation yard
- Previously each gas monitor was connected via a Sierra Wireless cellular modem
  - Field communications manager wanted to reduce cellular communication costs
  - For the pilot, cellular cards with a Tropos 1410 which connect to a gateway at the control house
  - Still backhauling via cellular out of the substation
- Cut cell modem requirement, reducing operating expenses

# Substation wireless enables applications beyond automation

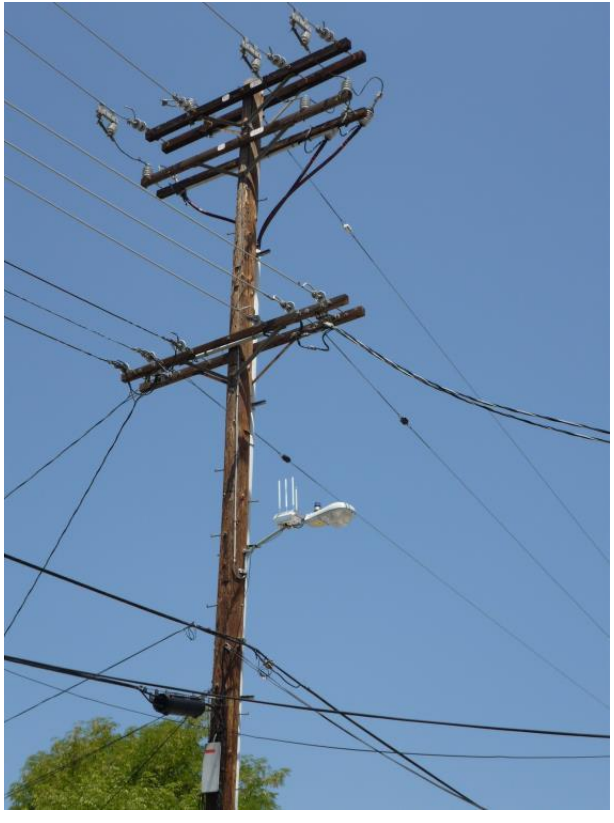
- Security applications can use the wireless network to support video surveillance cameras and intrusion sensors
- Transformer monitoring via the wireless network using smart transformers or gas sensors mounted near conventional transformers
- Mobile workforce applications enabled by connecting field workers' laptops, tablets and handhelds to the substation's wireless network

# Tropos utility customers


## Current Customer Applications

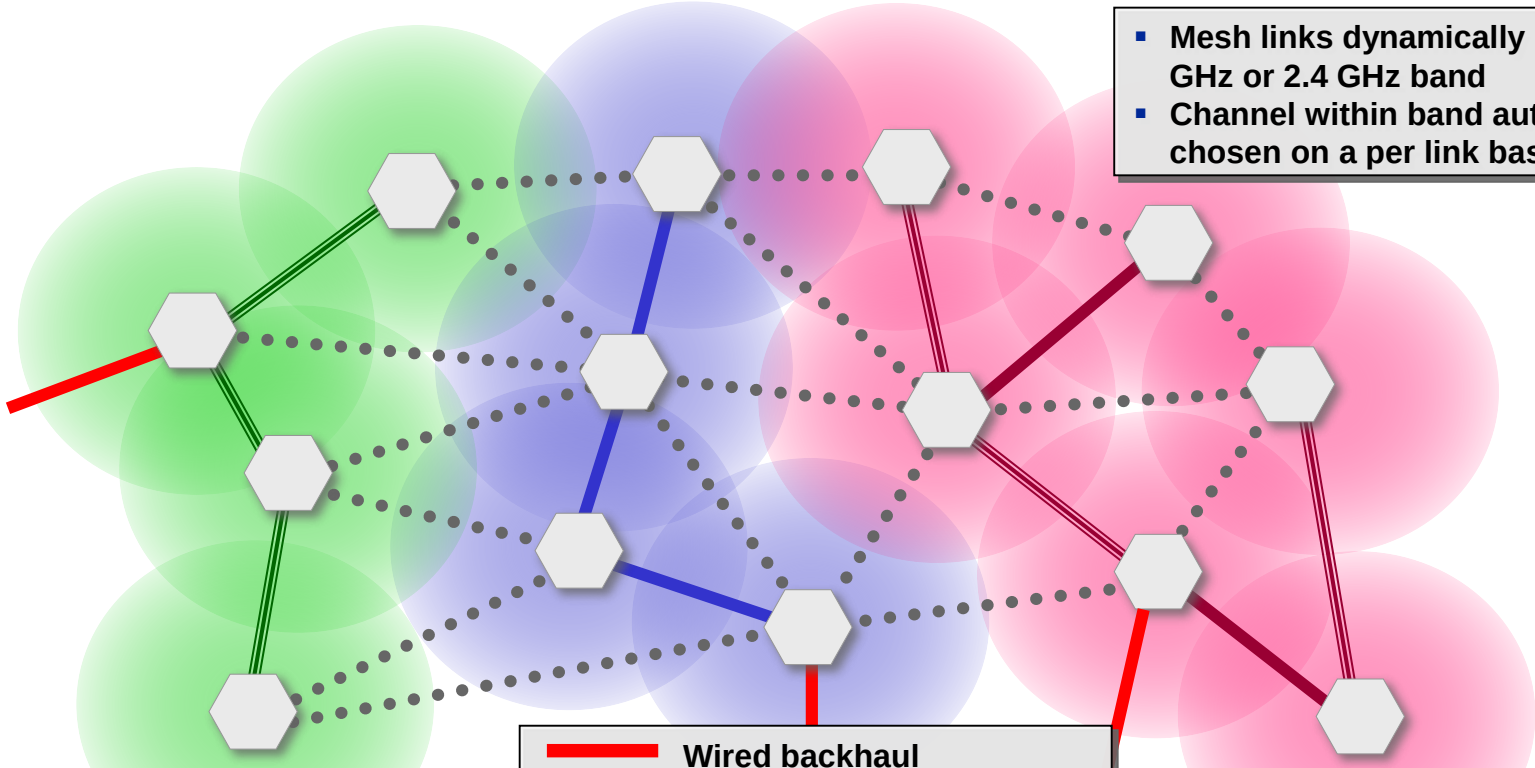
- AMR/AMI
- Voltage optimization
- Demand management
- Distribution automation
- SCADA
- Mobile utility workers
- Substation security
- Video security

# Tropos mesh networks for smarter grids



- Smarter grids increase the reliability and efficiency of power delivery while enabling energy conservation and reducing carbon footprint
- Networks enables valuable applications
  - Distribution automation
  - Substation automation
  - Automated metering infrastructure
  - Renewables and EV integration
- Tropos networks meet the stringent requirements of all smart grid applications
  - High system availability in harsh environments
  - >10 Mbps throughput at each node, <1ms per hop latency, multi-application support
  - Enterprise-class security
- Customers with networks in production include ADWEA, Avista, Burbank, DTE Energy, Glendale, Naperville, Rock Hill, Silicon Valley Power

# Tropos mesh software creates robust, high performance networks



- Mesh links dynamically choose 5 GHz or 2.4 GHz band
- Channel within band automatically chosen on a per link basis

2.4 GHz Link
5.X GHz Link

Wired backhaul
Optimal routing paths
Backup links

# Smart grid communication challenges

## Communicate with thousands of endpoints in large geographic areas

- Reliability of connections
- Network capacity headroom to enable future applications
  - AMI networks deliver sufficient capacity for meter reading but not other smart grid applications
  - Some utilities select an AMI network without considering future application and network needs
- Low latency to support automation applications
- Support multiple applications with QoS, security and traffic segmentation
- Scalable to large number of devices covering large geographic areas
- Cost-effective
- Easy interoperability with edge devices, avoid stranded assets
- Cyber security threats are real and will continue to evolve over time

# Selecting a network communications strategy

## Traditional approach

- Network per project
  - Build/pay as you go
- SCADA
- AMI
- Distribution automation
- Field data applications,…

## Strategic approach

- Layered communications architecture
- Supports for current plus future smart grid apps
- Minimizes incremental spend for additional field applications

# Network requirements increase with time

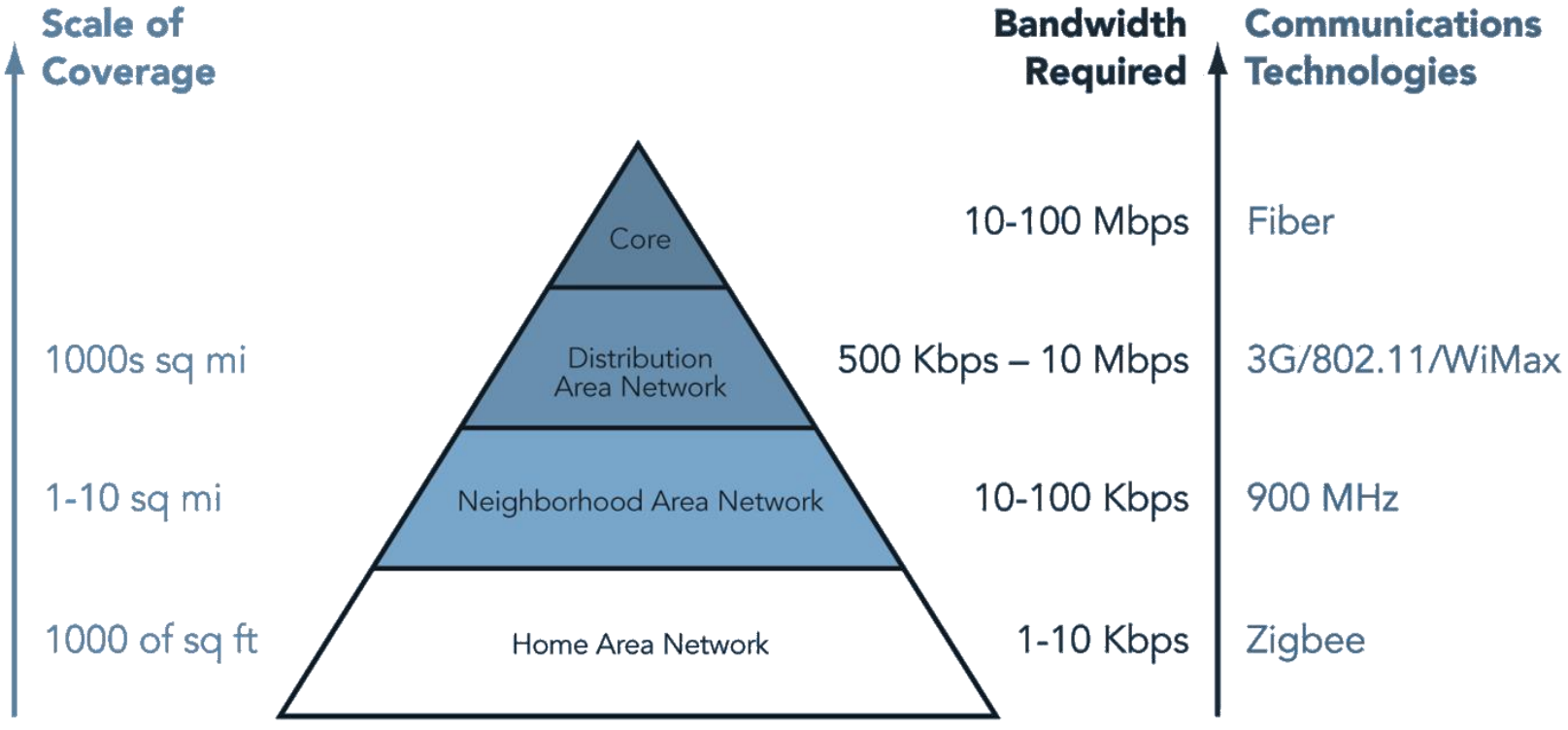
## Must provide Mbps of bandwidth and sub 20 ms latency

| Application | Latency | Bandwidth |
|---|---|---|
| Reclosers | 10s msec | <56 kbps |
| Capacitor Bank | 100s msec | <56 kbps |
| RTU | 1000s msec | 56 kbps |
| Motor Operated Disconnect | 1000s msec | <56 kbps |
| Line Regulator | 100s msec | <56 kbps |
| Advanced Metering | 100s msec | 56 kbps |
| IDR | 100s msec | <56 kbps |
| Demand Mgmt | 100s msec | <56 kbps |
| MWM Voice | 100s msec | <56 kbps |
| MWM Data | 100s msec | 1000's kbps |
| Aggregate | 10s msec | 1000's kbps |

Source: From IBM Presentation for the UTC on the Utility of the Future

- Other applications representing higher traffic include
  - Substation video
  - PHEV integration
  - Mobile GIS
  - AVL
  - and more in the future

# Higher levels require more aggregate bandwidth
## Same as enterprise networks



# Keys to successful smarter grid networks

- Standards-based
  - TCP/IP, 802.11, 802.3 Ethernet, 802.1x….
- High bandwidth & low latency
  - > 10 Mbps throughput at each node, < 1 ms latency per hop
- Resilient
  - Self organizing mesh, high system availability
- Secure
  - Multi-layer/multi-application model and standards compliant
- Manageable
- Scalable to cover small areas to thousands of square miles

# Tropos product line

- Wireless IP broadband mesh routers
  - Highly resilient, high capacity routers for covering broad distribution areas
  - Fixed and mobile models
  - Tropos Mesh OS – embedded operating system optimized for outdoor wireless broadband environments
- Directional radio products
  - High capacity, long range PTP and PTMP solutions
  - Used as backhaul for mesh networks and for communications directly to end points
- Centralized network management
  - Network management system with open APIs
  - Configure, manage, and monitor thousands nodes
- Support, maintenance, professional services

# Tropos mesh routers





- Reliable, resilient, tough
  - Self-organizing, fully redundant mesh
  - Can deliver >99.999% system availability
  - -40ºC to 55ºC operating range
  - IP67 weather tight (NEMA 6)
  - Optional battery backup
  - 165 mph wind survivability
  - Lightning, power surge, EMC protected
  - Salt fog rust resistance per ASTM B117
- Secure
  - VPN and firewall in every device
  - US government certified (FIPS 140-2)
- Manageable
  - Monitoring, configuration, upgrades, fault management, security
- Multiple applications
  - High bandwidth: >10 Mbps, low latency: <1 ms per hop
  - Virtual LANs with separate address spaces, security policies and QoS policies

# Tropos mesh routers
## Built for outdoor and difficult environments



- Radios designed and built in-house
- Support for 802.11a/b/g/n
- Superior receive sensitivity
- Precision ceramic filters eliminate near-band signals from other radio systems
- Telecom-grade surge and lightning protection
- Tuned for maximum rate at long distances, not just short-range performance
- Ruggedized and weatherized (IP67)

# Tropos 7320 mesh router


- Dual-radio (2.4 GHz & 5 GHz)
  - Two wired Ethernet connections
  - 30 W PoE sourcing capability, 12/24/48 VDC
  - Optional internal battery backup
  - Flexible input power options
    - AC powered version: 100 – 480 VAC
    - DC powered version: 12 – 60 VAC
  - Modular antennas
  - Supports all Tropos Mesh OS software features available in other Tropos routers
- Next generation wireless
  - Supports 802.11a/b/g/n clients
  - Maximal Ratio Combining (MRC) receiver for 2.4 GHz radio
  - Enhances rate-at-range
  - Increases mesh capacity
- IEEE 1613 for substation installations

# Tropos 63x0 mesh router

- Single (2.4 GHz) and dual-radio (2.4 GHz and 5 GHz) versions
  - Two wired Ethernet connections (backhaul and wired device support)
  - Powered by PoE
  - Supports all Tropos Mesh OS software features available in other Tropos routers
- Next generation wireless
  - Compatibility with 802.11b/g/a/n clients
  - Maximal Ratio Combining (MRC) receiver for 2.4 GHz radio
  - Enhances rate-at-range
  - Increases mesh capacity
- Small, lightweight form factor
  - Reduces weight and wind loading concerns on mounting assets
  - Skyline gray radome

# Tropos 1410 automation bridge & router
## Hardened cost-effective end point


- Wireless mesh router and bridge
  - Configurable via software load
- Available in ruggedized, weatherized enclosures or as an embeddable module
- 802.11b/g/n with 2x2 MIMO
- Integrated firewall and IPsec VPN
- Wired Ethernet or serial connection to field automation devices
- Supports automation protocols including DNP3 and IEC 61850 as well as terminal server capability
  - Facilitates integration of field automation devices

# Tropos directional radio systems

- Applications
  - Mesh cluster backhaul
  - Direct communication to fixed assets
  - Broadband communications to facilities
  - Cost effective in rural environments
- Features
  - PTP and PTMP modes on same hardware
  - 3.3-3.8GHz and 4.9-5.8GHz operation
  - High capacity and low latency
    - PTP: up to 90 Mbps, PTMP: up to 48 Mbps
    - PTP: <2 ms, PTMP: 3-5 ms
  - Secure
    - FIPS 140-2 certified, AES encryption
  - Manageable
    - Upgrades, configuration, performance monitoring, and fault management using Tropos Control
  - Multi-application
    - Application-based QoS
    - Traffic segregation using VLANs

# Tropos 4310 mobile mesh router

- Meshing capability optimized for mobility
  - Extends the mesh infrastructure
  - Fast roaming (100ms handoff)
- Trunk or dash-mounted with external antennas
  - Optional GPS
- Each vehicle is a mobile, high-powered hot zone
  - Connect Wi-Fi devices in or around the vehicle
  - Connect in-vehicle Ethernet devices
- Fully manageable by Tropos Control
  - Bulk upgrade and provisioning
  - Performance and fault monitoring
  - Location tracking on Google Maps or with AVL server
- Extends IPSec tunneling security to the vehicle (mobile VPN)

# Tropos Control
## Carrier-class network management


- Management designed for wireless networks
- Scalable thousands of devices
- Performance management to avoid outages
- Fast identification and correction of network faults
- Identify and isolate client device issues
- Asset management

# Tropos advantages

- Standards-based
- Resilient, high-availability architecture
- High performance
  - > 10 Mbps throughput at each node
  - < 1 ms latency per hop
- Multi-layer security
- One network for many applications
  - Application-based Quality of Service (QoS)
  - Application traffic segmentation
- Ease of operations and management
- Scalable to economically cover small areas to thousands of square miles

# Thank you for your participation

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