Tropos Technology Overview

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TROPOS networks
Metro-Scale Mesh Networking Defined™

Agenda

- Introduction
- Tropos MetroMesh™ Architecture
- Tropos MetroMesh OS
  - Predictive Wireless Routing Protocol
  - Virtual Network Infrastructure
  - Metro-Scale Roaming
  - Multi-Layered Security
- Tropos Control Element Manager
- Purpose-Built MetroMesh Platforms
- Summary

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Tropos Networks

- Proven leader in delivering systems to build truly ubiquitous, metro-scale, Wi-Fi mesh networks
- Innovative and patented MetroMesh architecture
  - Tropos MetroMesh OS
  - Tropos Control EM
  - Purpose-built platforms
- Hot spots?
  - **Way too small**
- Hot zones?
  - **Think bigger!**

Tropos Unwires the Entire City

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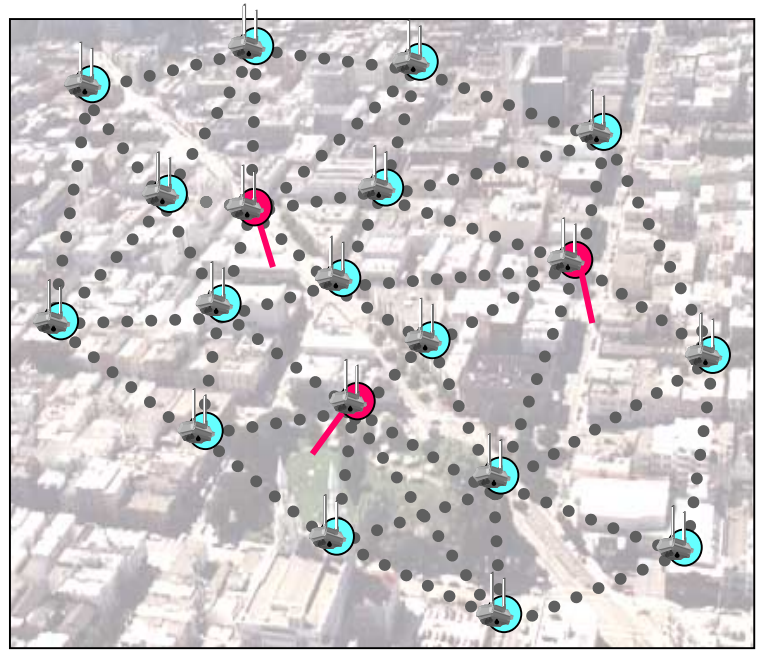
Anatomy of a Wireless Mesh

- Mesh units talk to each other wirelessly
  - Most are totally wireless (**nodes**) and only need a power connection
  - They use Internet Protocol (IP) to share the spectrum bandwidth
    - The same way 100 users can share a 2 Mbps E-1 line



- Typically, only 10-20% of mesh units are **gateways** to the wired network
  - Their precise location in the mesh can be determined by backhaul availability
  - Nodes can be reconfigured as gateways as subscriber capacity needs increase

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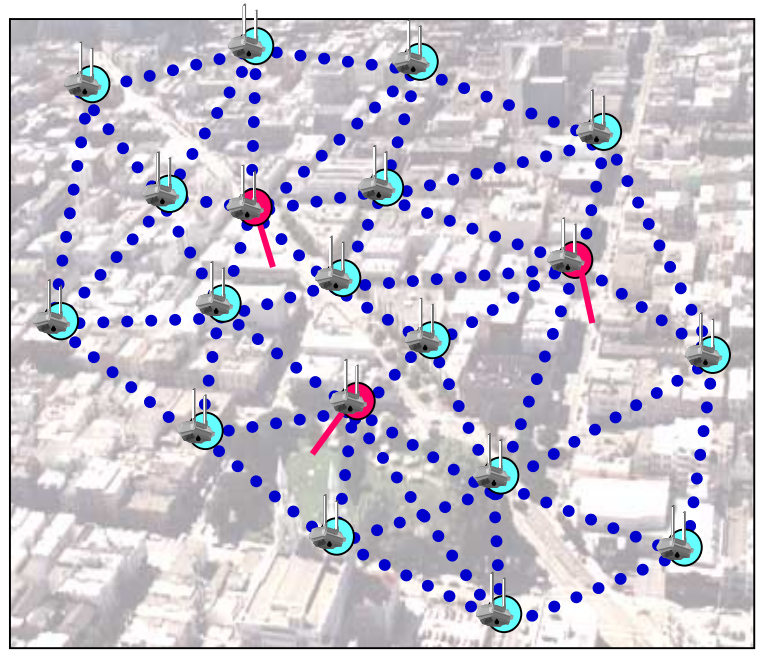
Anatomy of a Wireless Mesh

- Movement of data through the mesh must be managed by a true **mesh routing protocol**
  - Throughput-optimized for wireless
    - Based on measured wireless data throughput (not shortest path/ spanning tree)
  - Dynamic, to cope with the changing RF environment
    - Multi-path fading
    - Interference
  - With seamless roaming throughout the coverage area
    - Operates as a single, contiguous hot zone
    - Preserving authentication and security throughout



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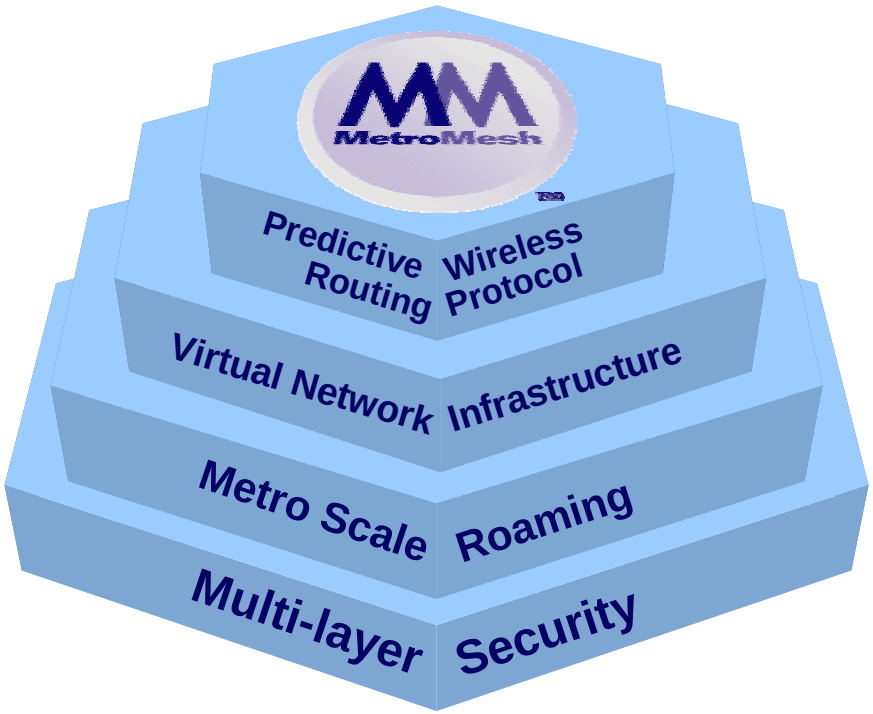
Tropos MetroMesh™ OS



- **Predictive Wireless Routing Protocol**
  - High throughput, self-configuring, self-healing, scalable networks
- **Virtual Network Infrastructure**
  - Multiple user groups sharing the same infrastructure
  - QoS-ensured user and application priorities
- **Metro-Scale Roaming**
  - Full transparent roaming throughout the coverage area
    - Node to node, subnet to subnet
  - Maintains TCP sessions and all authentication connections
- **Multi-Layer Security**
  - Supports multi-layered, high security models
  - Appropriate policies for each user group

The Core of a High Performance, Reliable, Scalable Wireless Infrastructure

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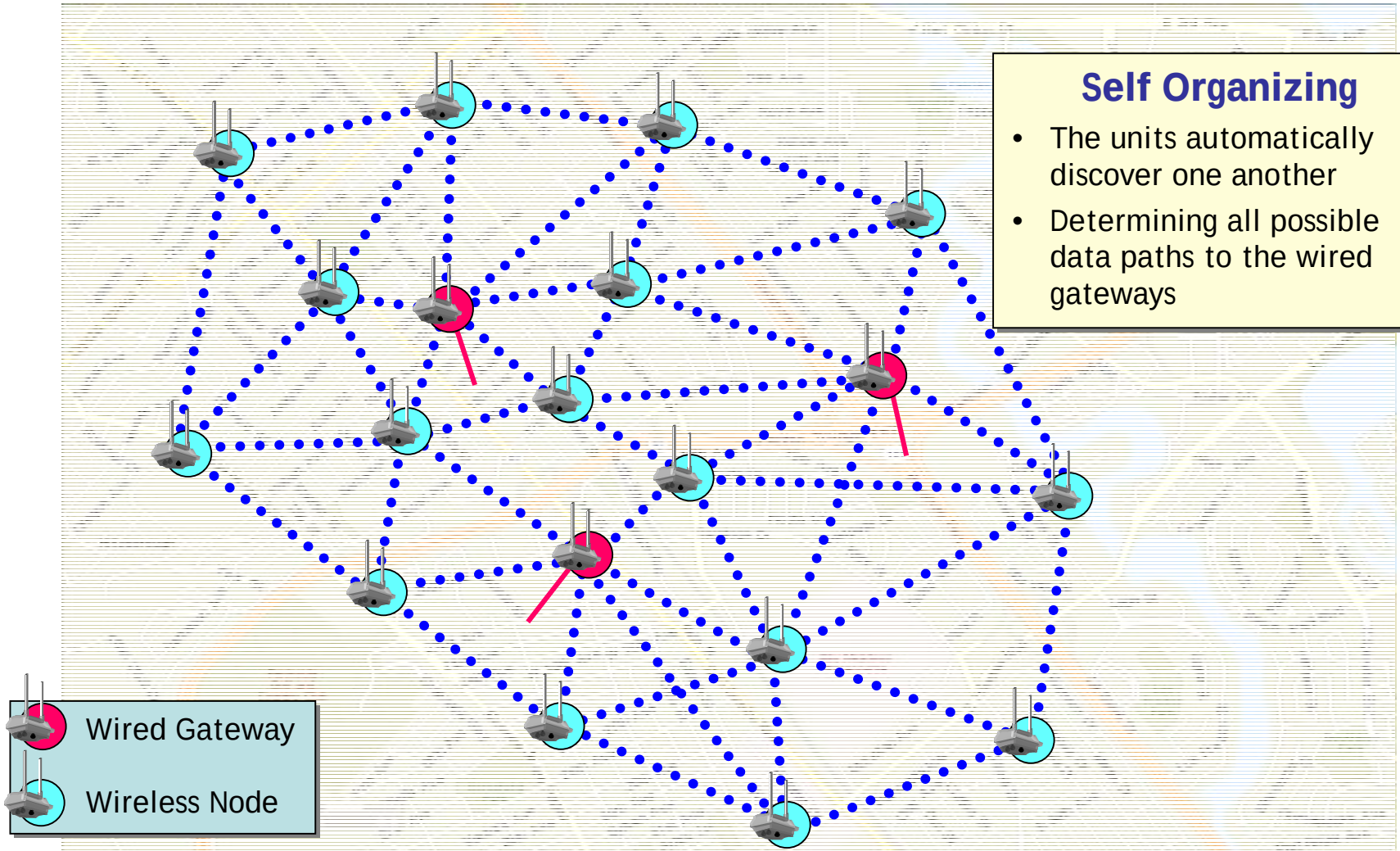
Predictive Wireless Routing Protocol



Self Organizing

- The units automatically discover one another
- Determining all possible data paths to the wired gateways

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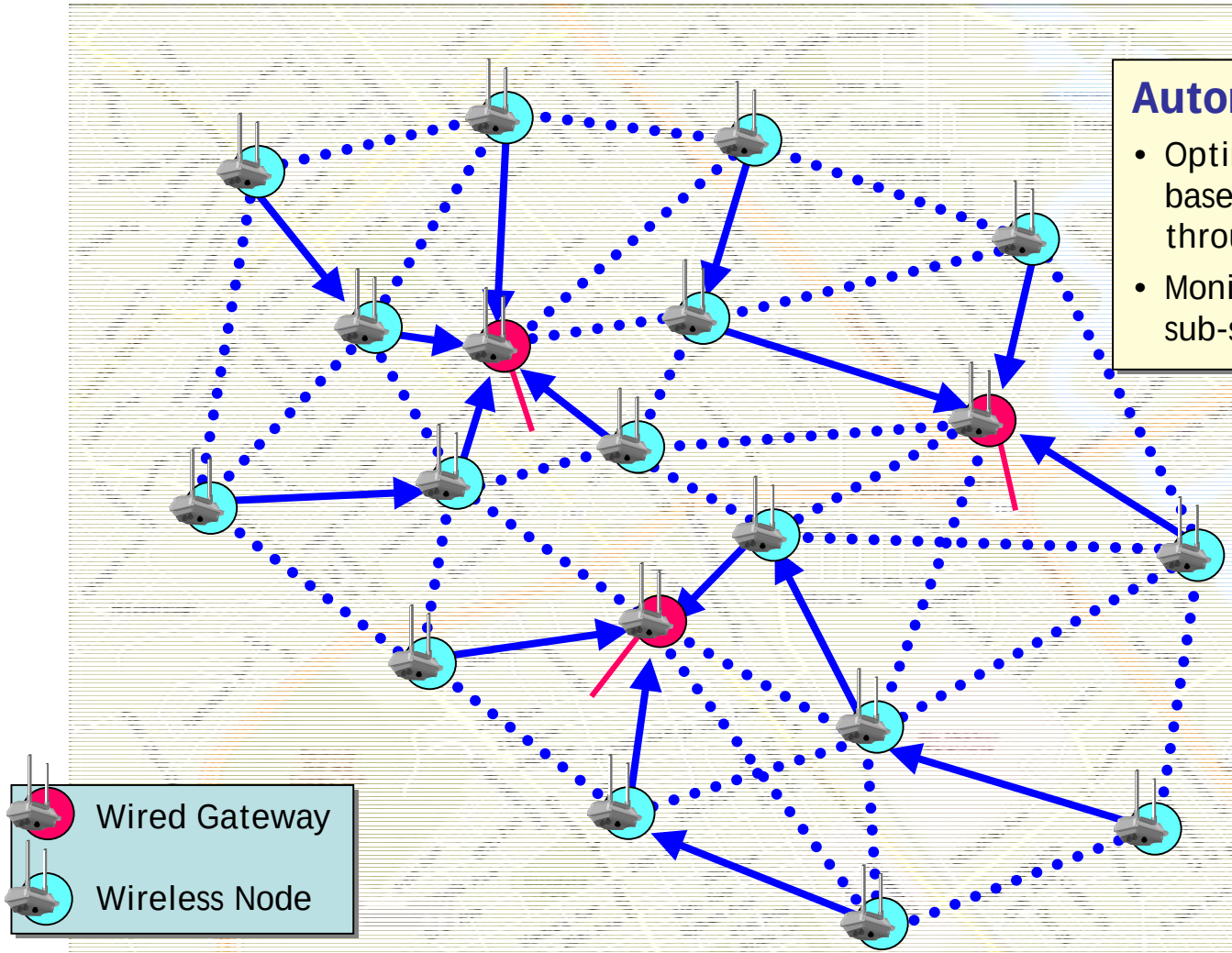
Predictive Wireless Routing Protocol



Automatic Configuration

- Optimum data routes set up based on best end-to-end throughput
- Monitored and maintained on sub-second basis

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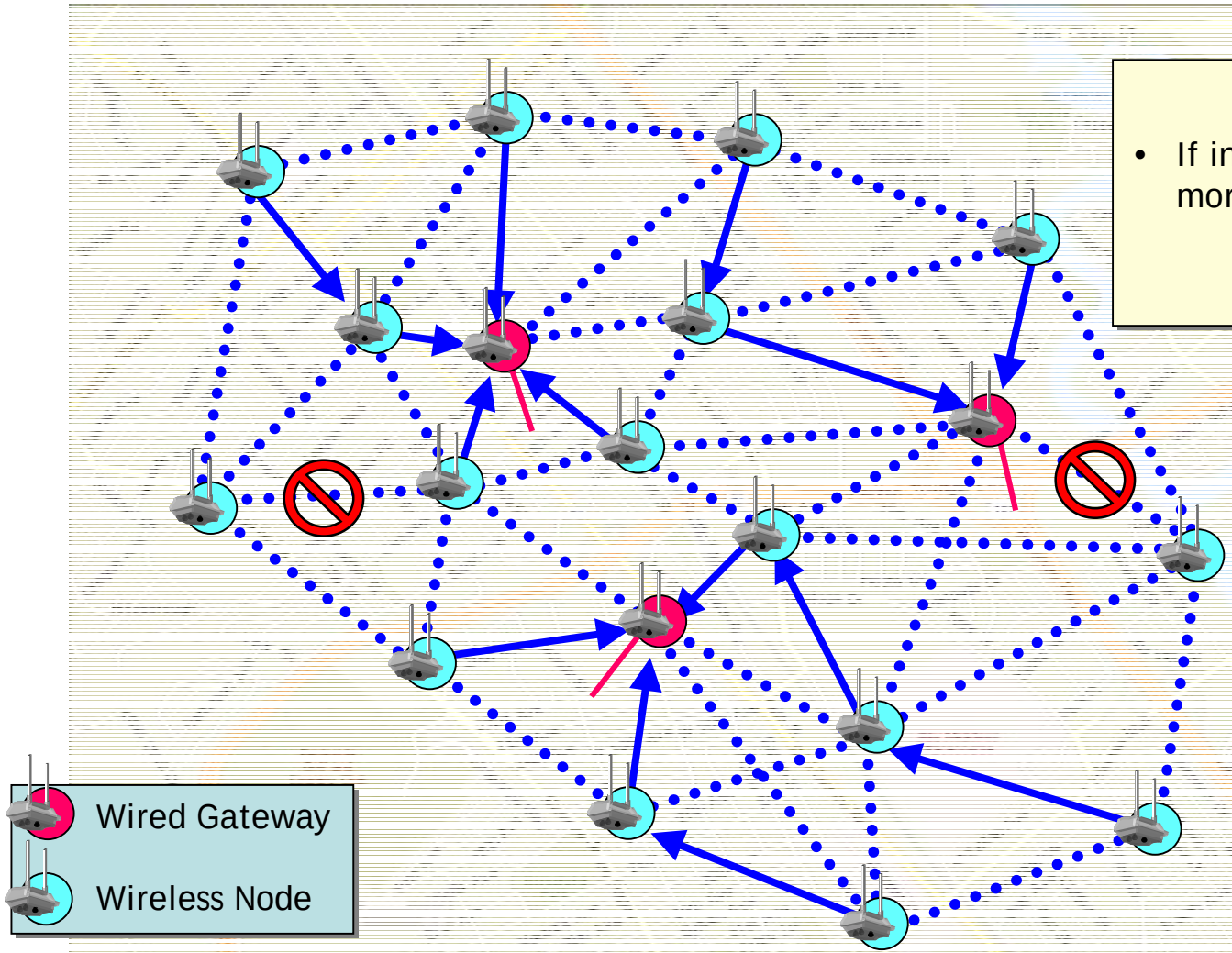
Predictive Wireless Routing Protocol



Self Healing

- If interference causes one or more links to be interrupted…

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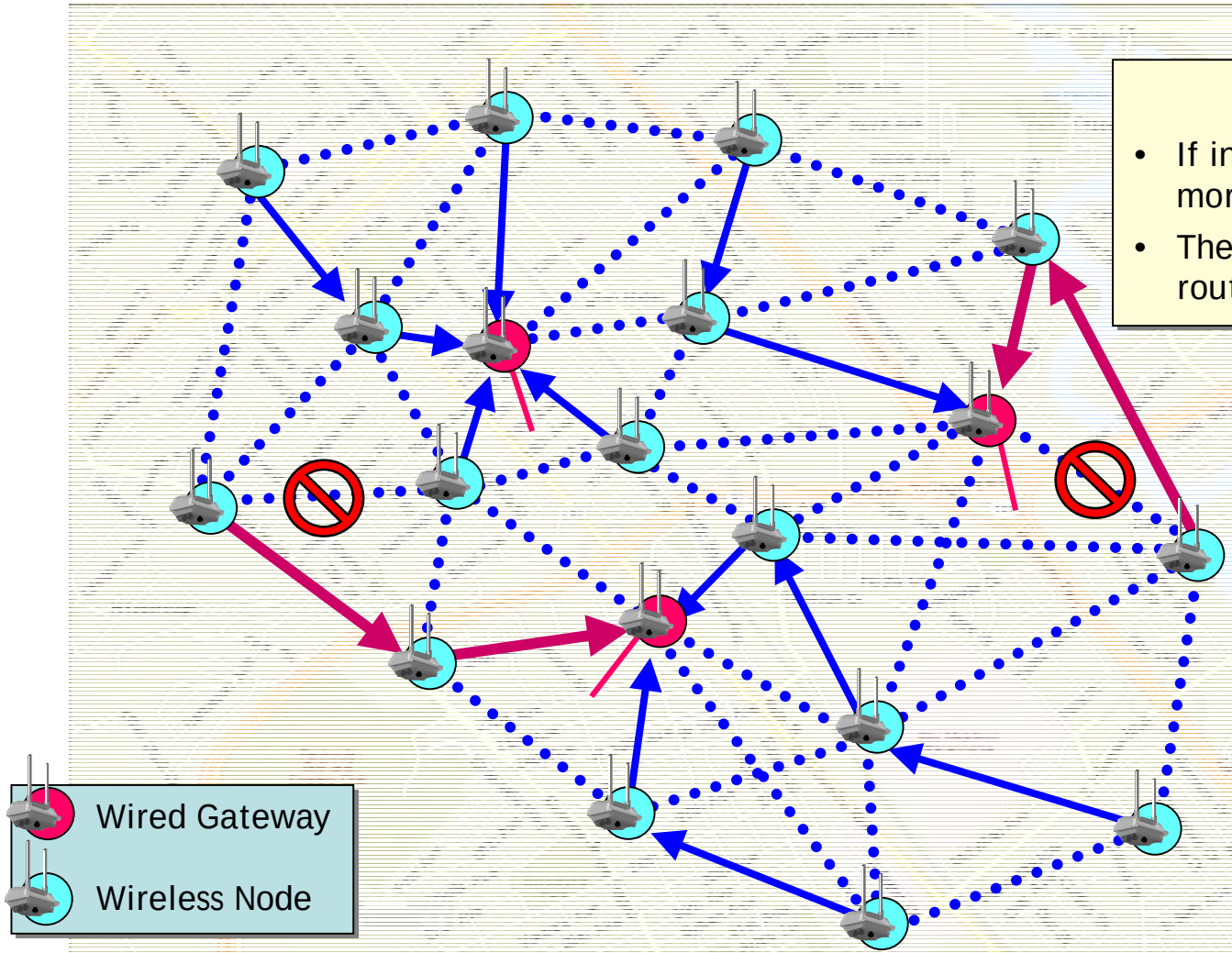
Predictive Wireless Routing Protocol



Self Healing

- If interference causes one or more links to be interrupted…
- The network automatically routes around the obstructions

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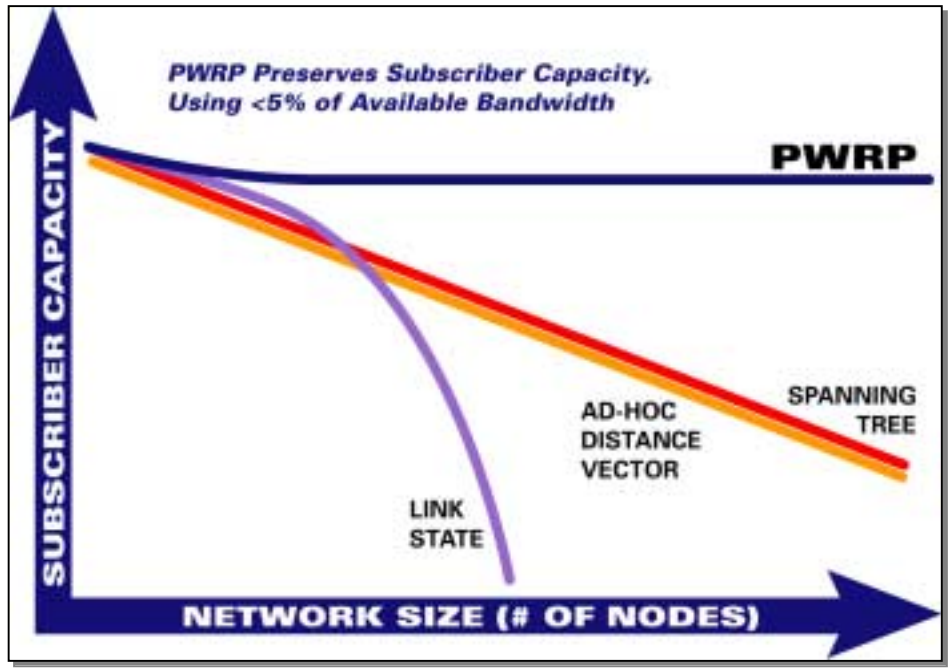
PWRP: Unlimited Scalability

Metro-Scale Means Big Networks

- Hundreds or thousands of nodes are required to cover metro areas
- Protocol overhead for legacy mesh algorithms grows as the network grows
  - As much as 20 Mbps in a 2,000 node city-wide network
  - Consumes almost all available throughput of 802.11g network



PWRP Overhead Remains Flat at <5% of Network Bandwidth

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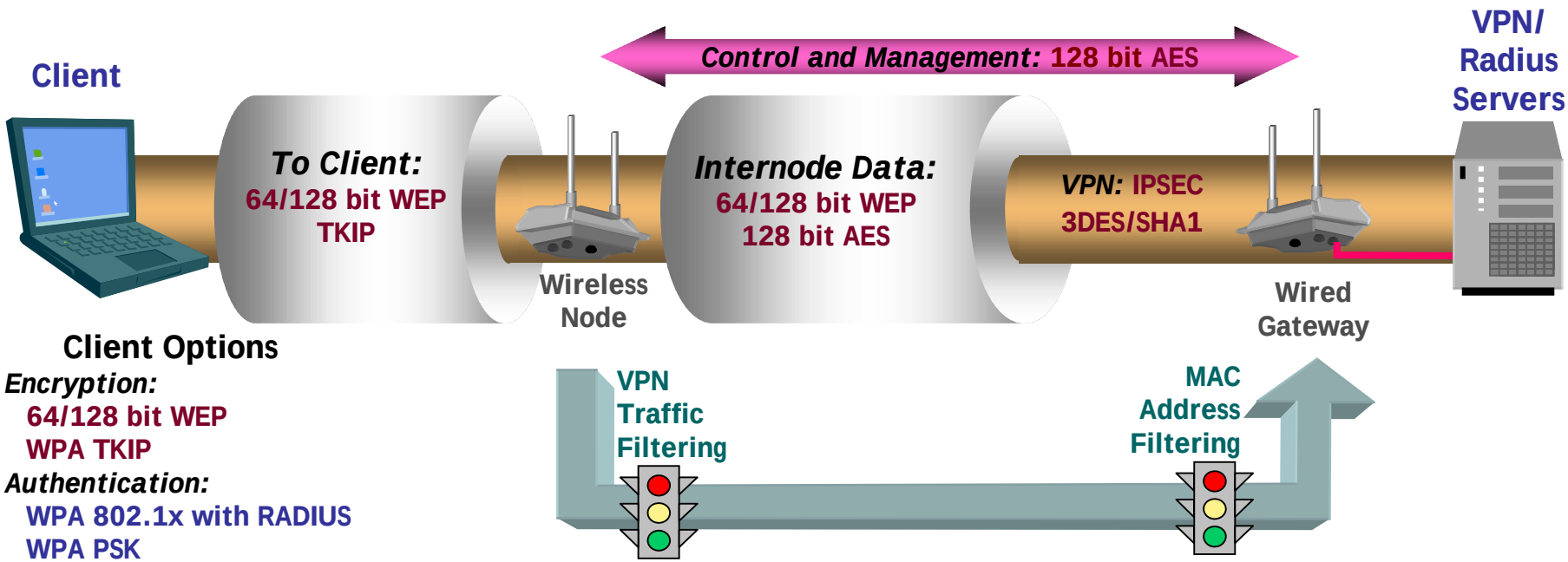
Multi-Layer Security



Client Options

Encryption:

- 64/128 bit WEP
- WPA TKIP

Authentication:

- WPA 802.1x with RADIUS
- WPA PSK

802.11b/g Wireless Network

VPN Tunnel

Tropos Control and Management

Wired Network

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Virtual Network Infrastructure

- Virtual wireless networks over a single infrastructure
  - Multiple ESSID support
  - VLAN tags by ESSID
  - VLAN tags by IP address
- Advanced industry-standard security options *for each virtual network*
  - 802.1x WPA support
  - AES encryption for all internode traffic
- Quality of Service
  - Priority and bandwidth control by user group (IP range)
  - Priority and bandwidth control by application (port)

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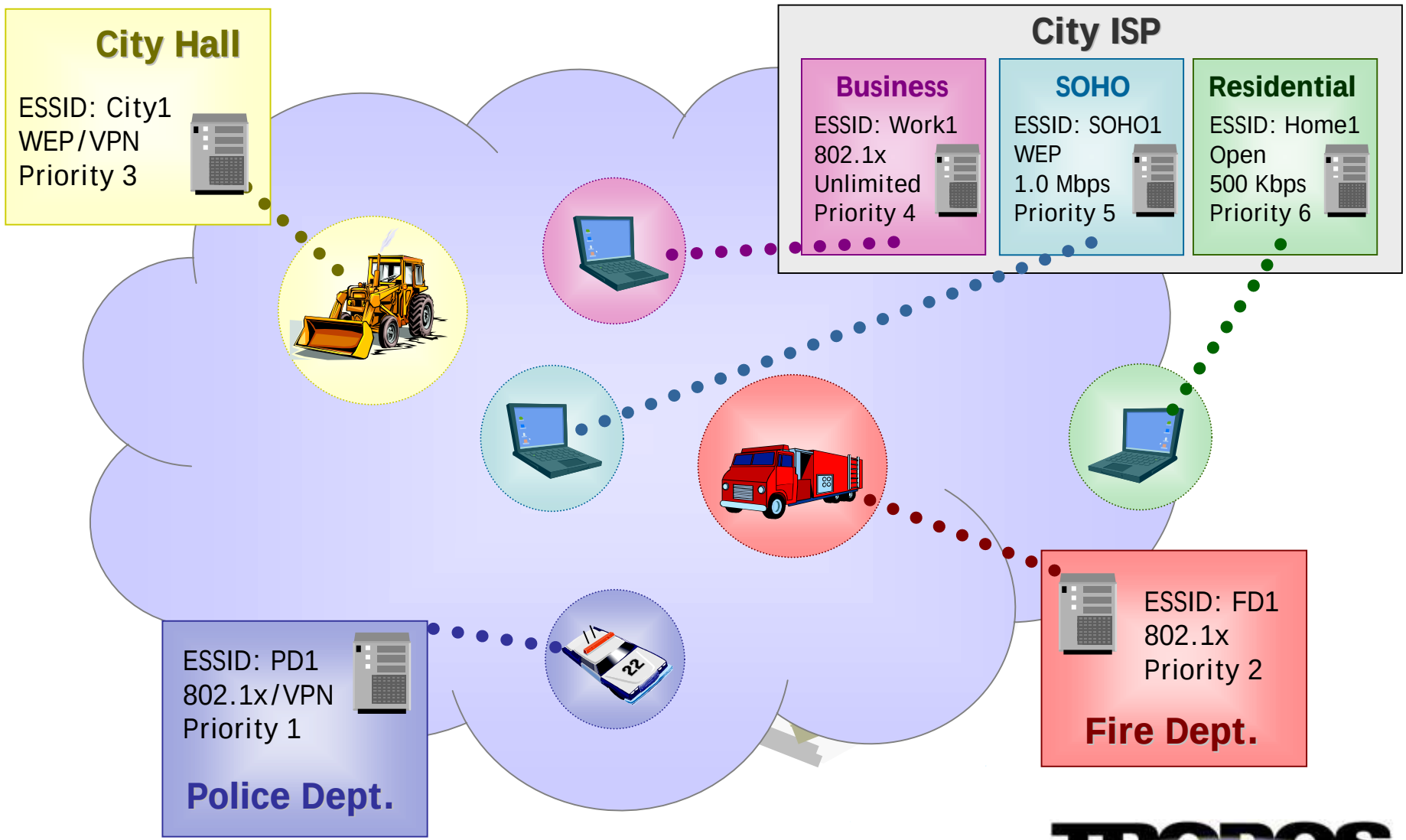
Multiple ESSID and VLAN Support



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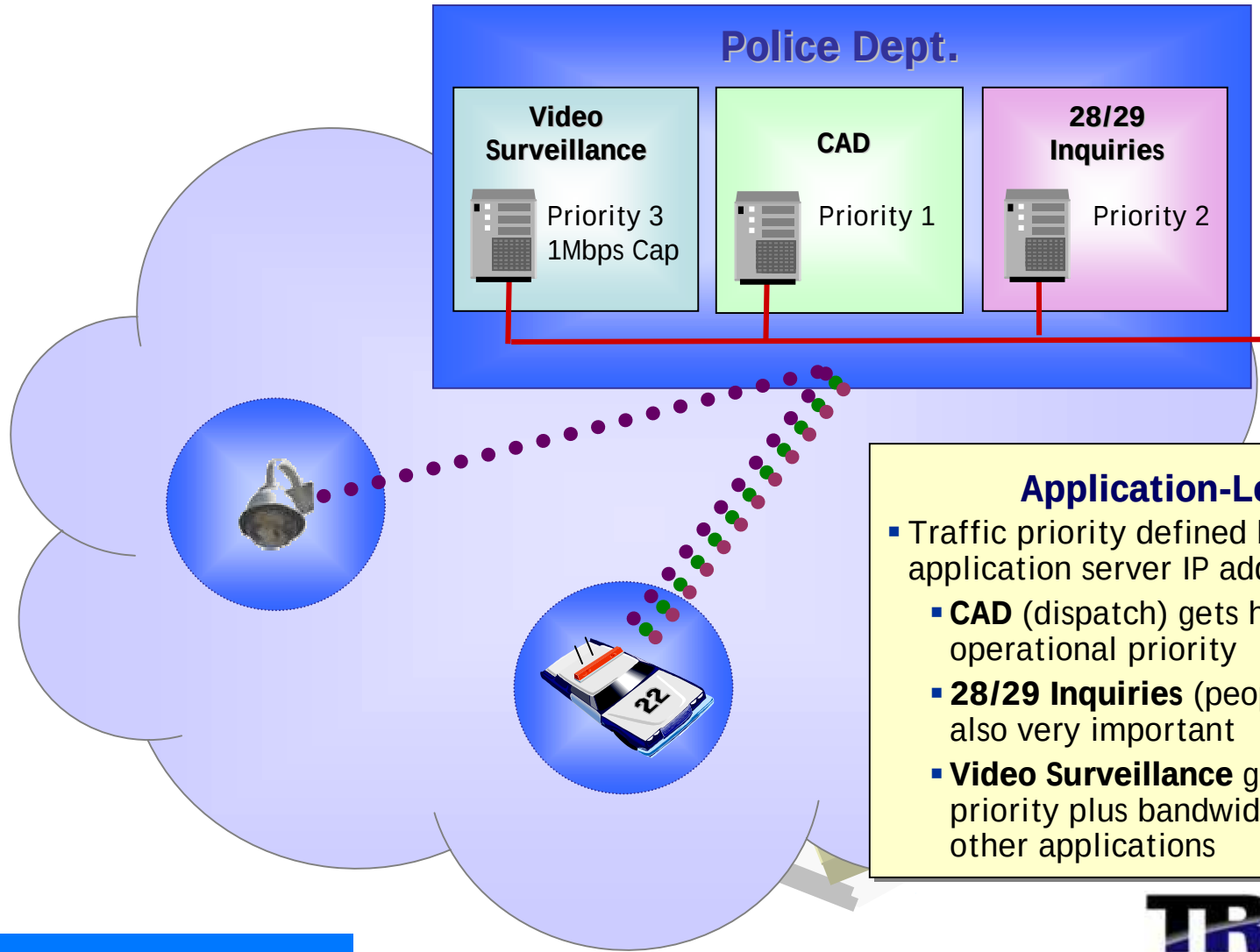
Application Prioritization



Application-Level QoS

- Traffic priority defined by port or application server IP address
  - **CAD** (dispatch) gets highest operational priority
  - **28/29 Inquiries** (people and vehicles) also very important
  - **Video Surveillance** gets high traffic priority plus bandwidth cap to protect other applications

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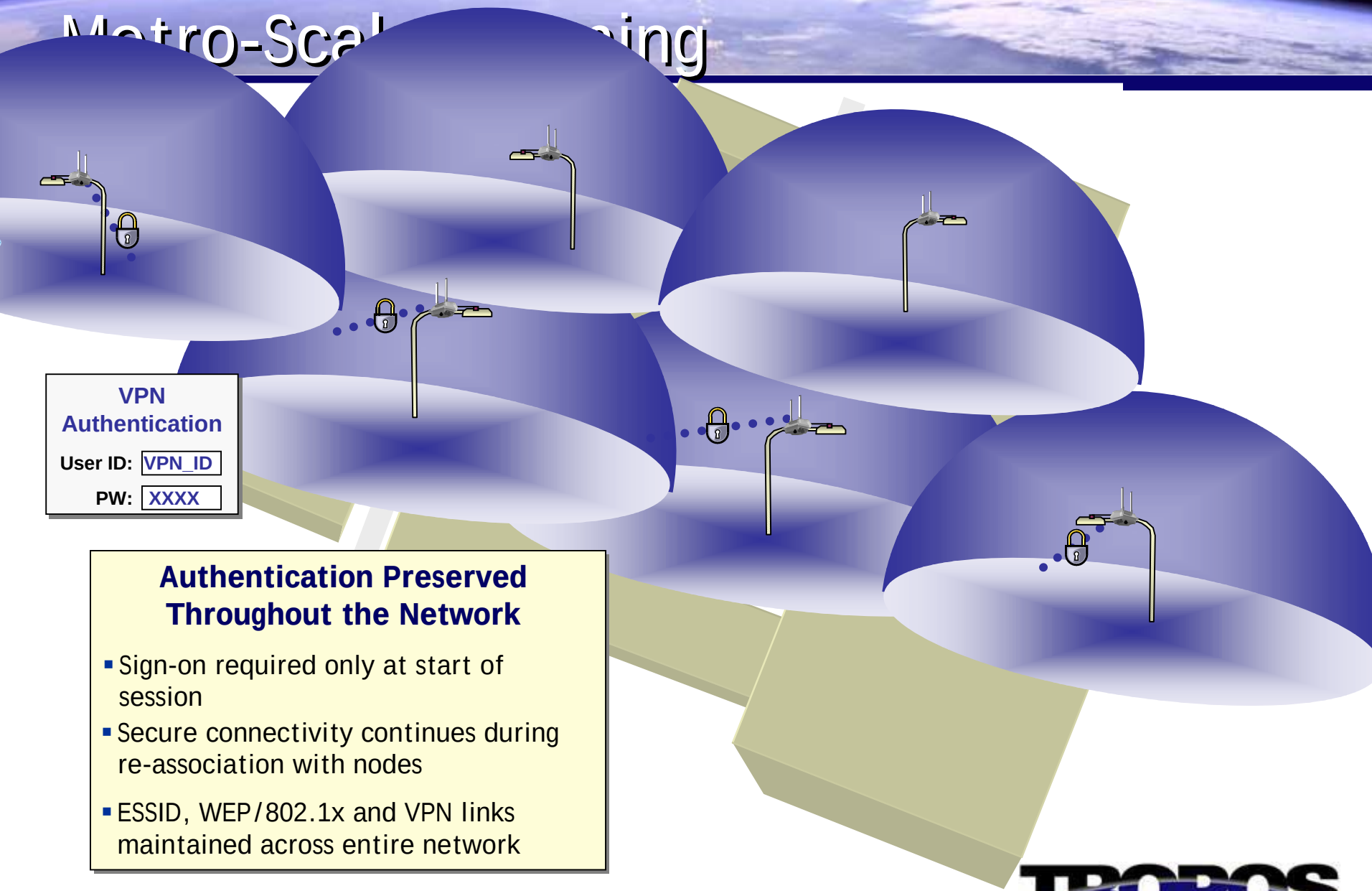
Metro-Scale [illegible]ing



Authentication Preserved Throughout the Network

- Sign-on required only at start of session
- Secure connectivity continues during re-association with nodes
- ESSID, WEP/802.1x and VPN links maintained across entire network

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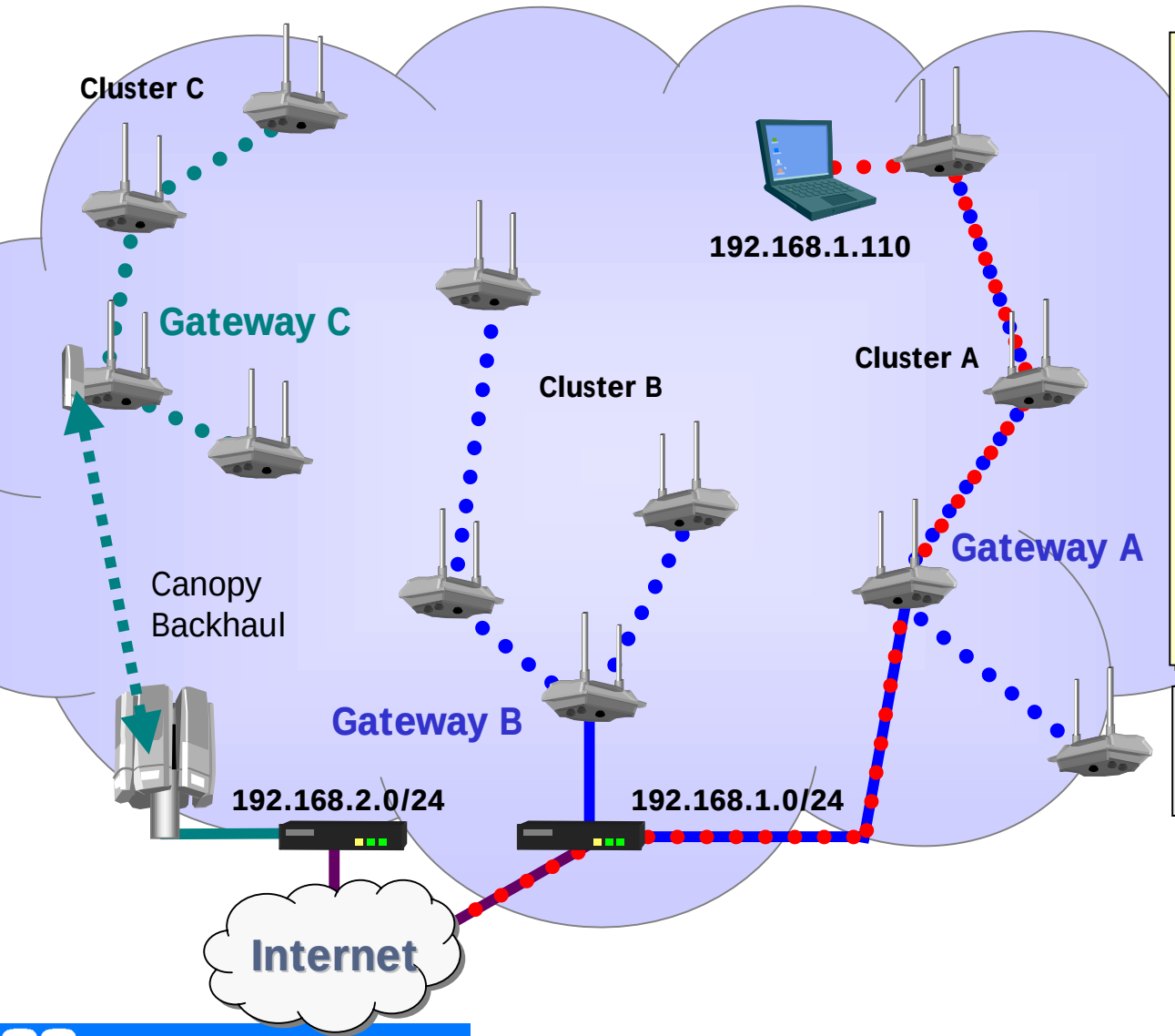
Metro-Scale Roaming



Client Connects in Cluster A

- IP address of client (192.168.1.110) is in subnet covering both wired and wireless interfaces of Gateway A and Gateway B
- Gateway A uses proxy-ARP to answer for client's packets from other devices, such as Default Router

IP Tunnel Traffic

TCP Session

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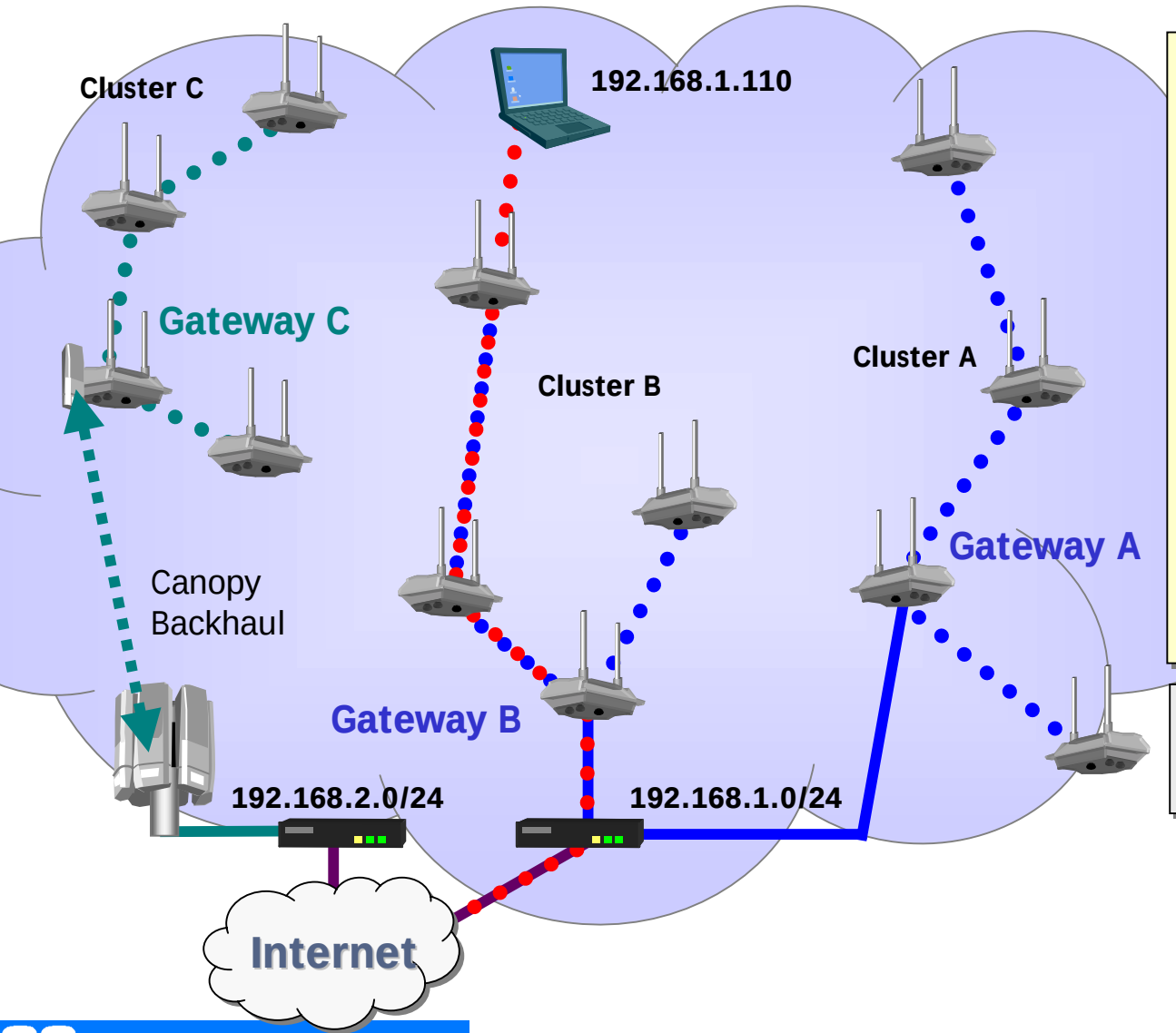
Metro-Scale Roaming



Client Roams to Cluster B

- IP address of client remains constant
- Client is registered in Gateway B's roaming database and deregistered in Gateway A's
  - Gateway B issues gratuitous ARP to clear ARP caches of other devices
  - Gateway B assumes proxy-ARP responsibility for client
- TCP sessions transparently preserved

IP Tunnel Traffic

TCP Session

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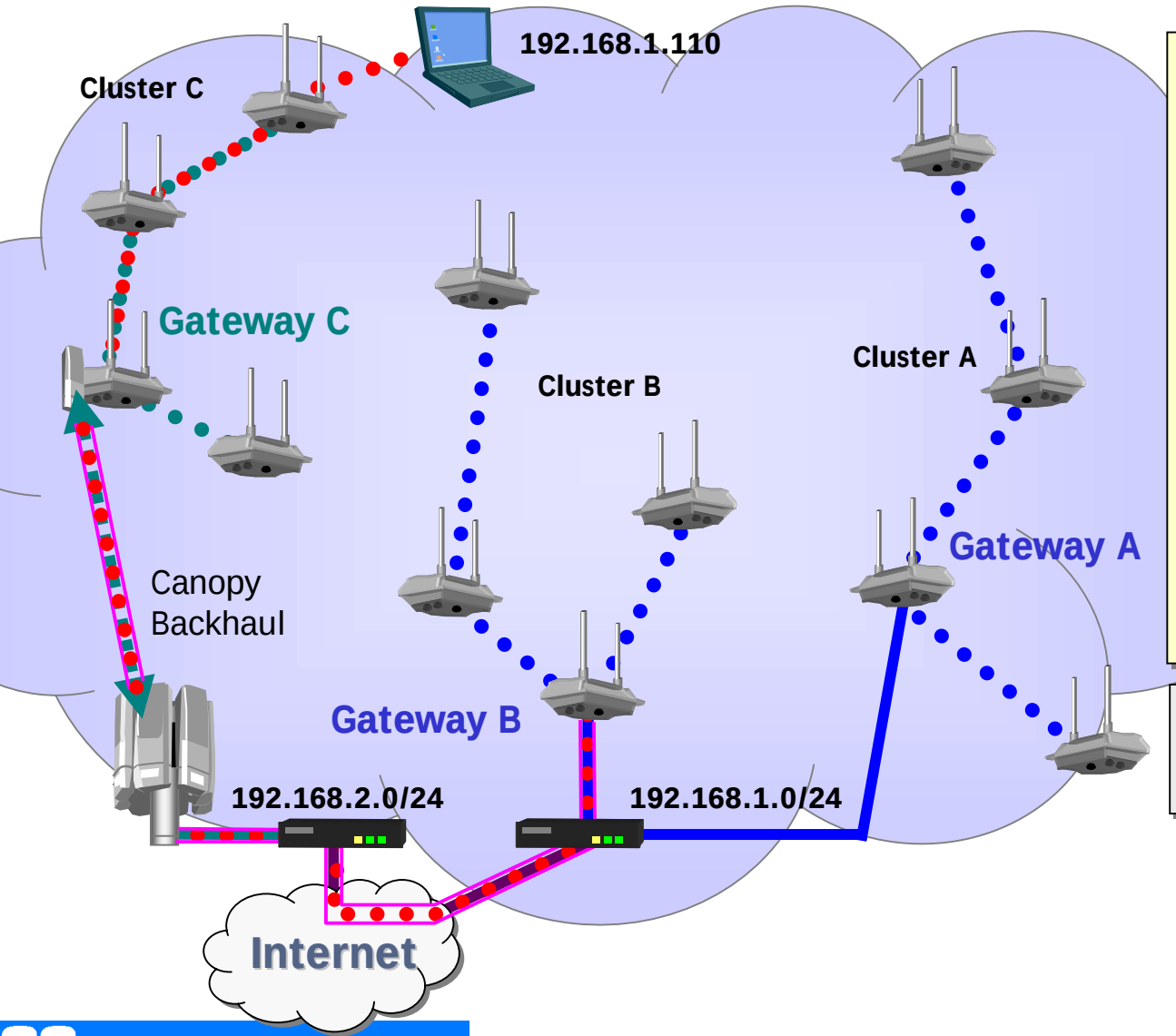
Metro-Scale Roaming



Client Roams to Cluster C

- IP address of client remains constant, even though its subnet changes
- Client is registered in Gateway C's roaming database
  - Looks up home gateway (B) from Gateway List
  - Gateway C opens IP tunnel to Gateway B
  - Client traffic forwarded through tunnel
- TCP sessions transparently preserved

IP Tunnel Traffic

TCP Session

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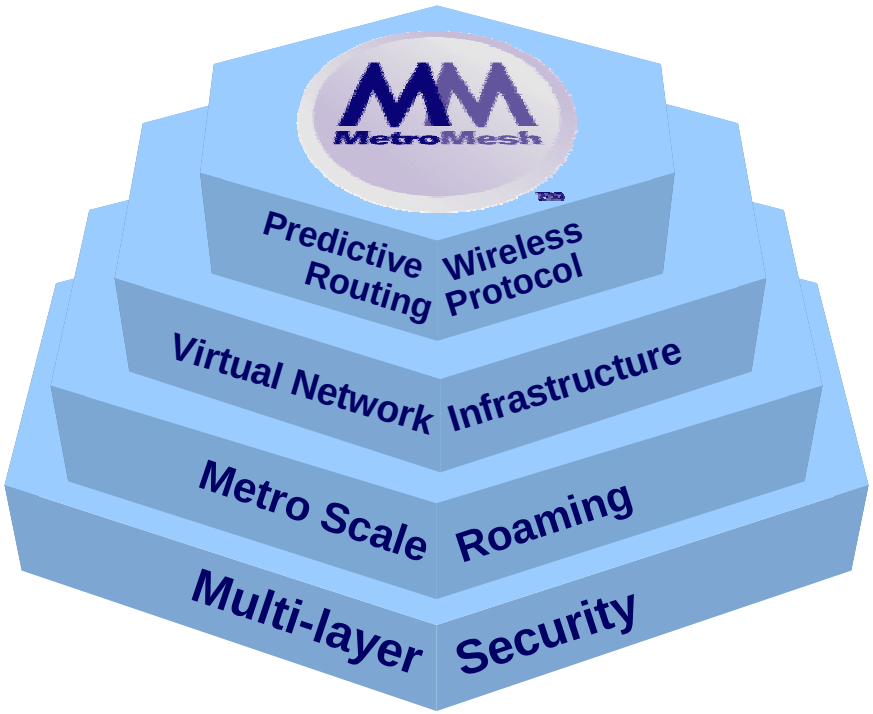
Tropos MetroMesh™ OS



- **Predictive Wireless Routing Protocol**
  - Self-organizing, self-healing, scalable
  - Industry best subscriber capacity
- **Virtual Network Infrastructure**
  - Leverage of city-wide infrastructure for the entire city enterprise
- **Metro-Scale Roaming**
  - Single sign-on and security preserved throughout the coverage area
- **Multi-Layer Security**
  - Highest, industry-standard security to the edge of the network
  - Independent options and policies for each enterprise user group

The Core of a High Performance, Reliable, Scalable Wireless Infrastructure

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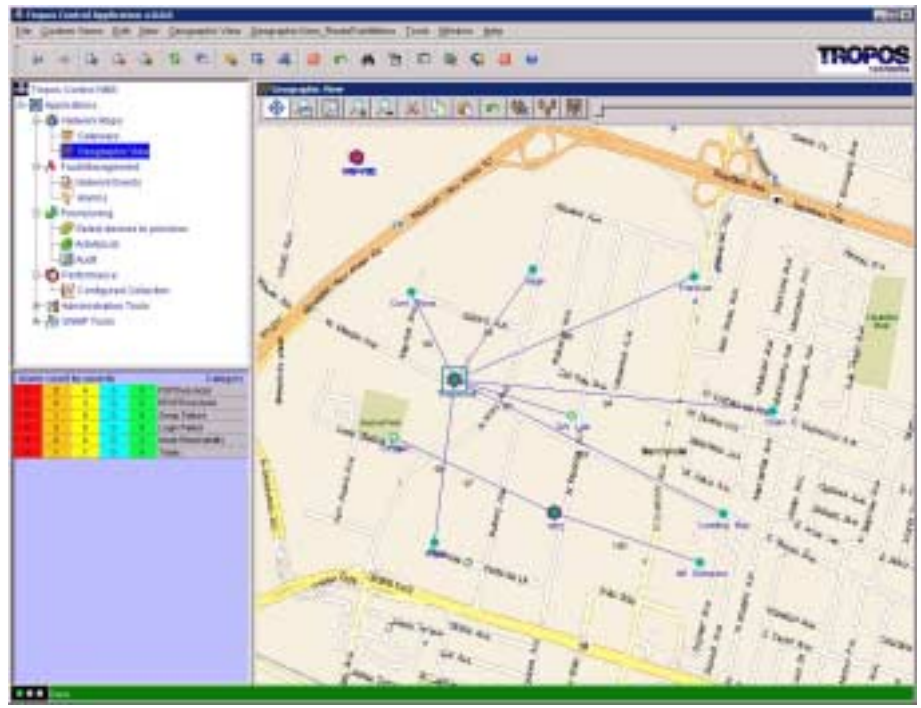
Tropos Control Element Manager

- Wireless-optimized network management
  - Metrics based on actual measured wireless performance
  - Over-the-air configuration and provisioning
  - Supports thousands of MetroMesh routers
- Centralized management of the entire network
  - Router configuration
  - Real-time network monitoring and control
  - Sophisticated fault monitoring and reporting
  - On-air software upgrades
- SNMP-compliant
  - Readily integrates into existing NOC infrastructure



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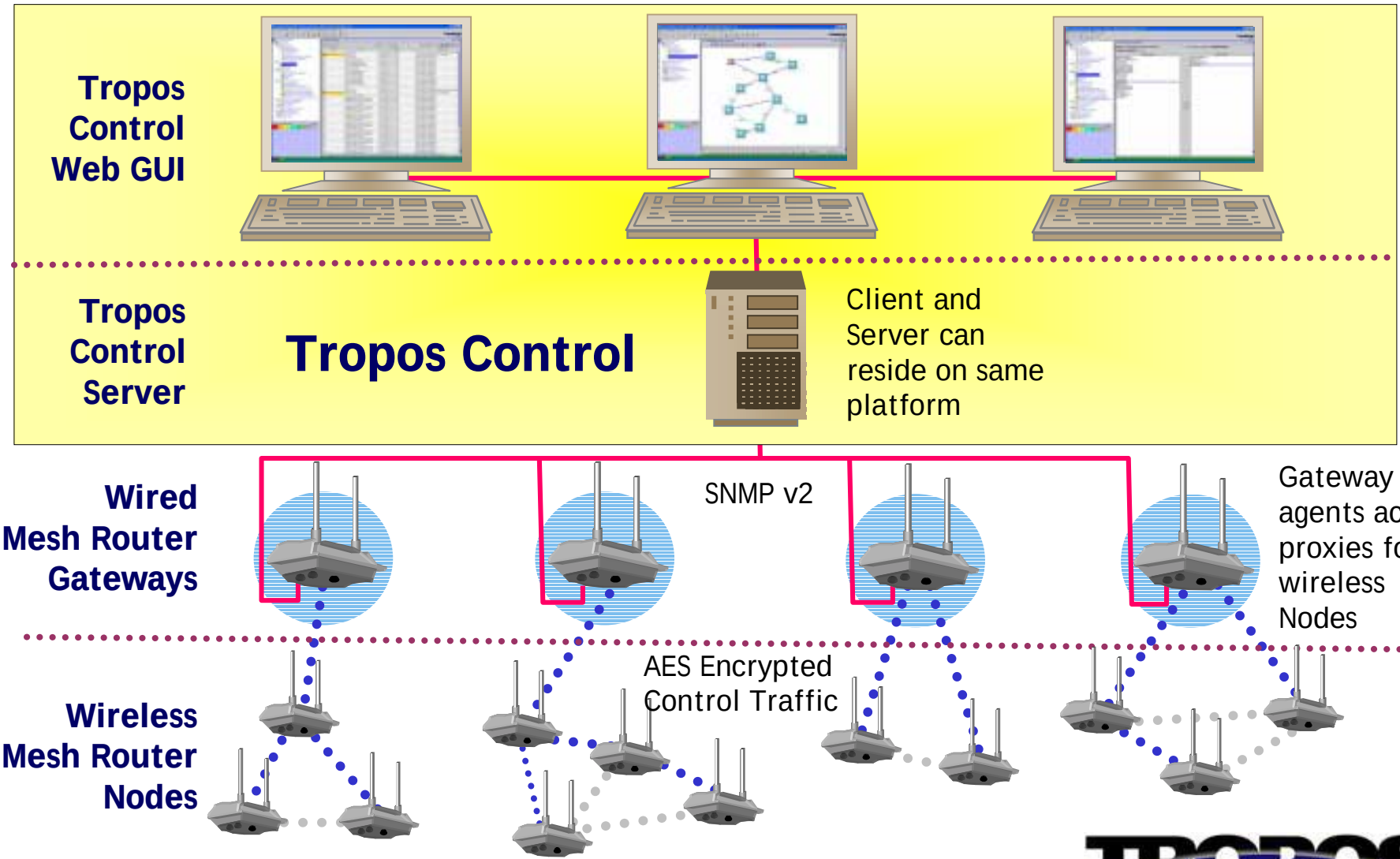
Tropos Control Architecture



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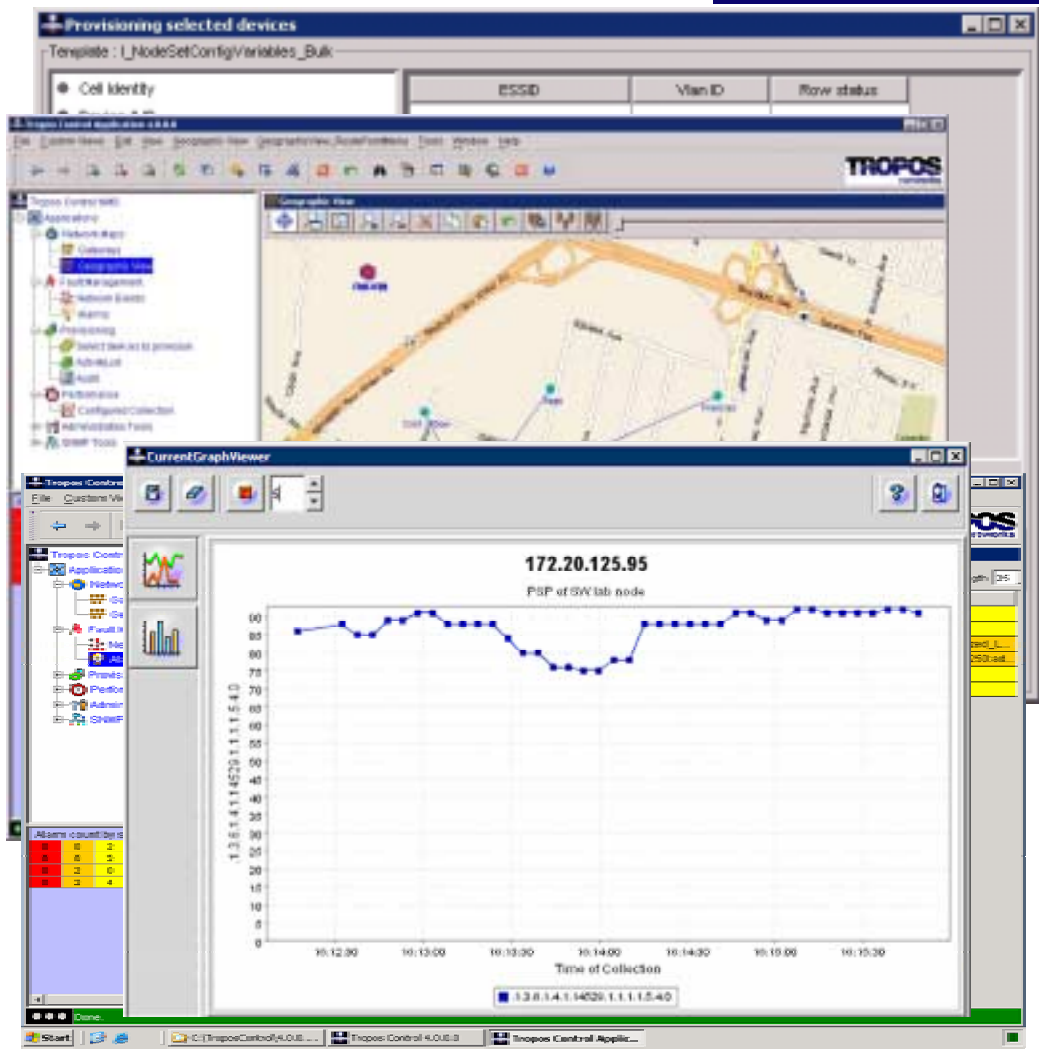
Deploy, Operate, Optimize

- System Deployment
  - Profile based management
  - Bulk provisioning
  - Software loading
  - Task scheduling
- System Operation
  - Alarm Manager
  - Event Browser
  - Fault correlation
- System Optimization
  - Performance thresholding
  - Extensive operational reporting



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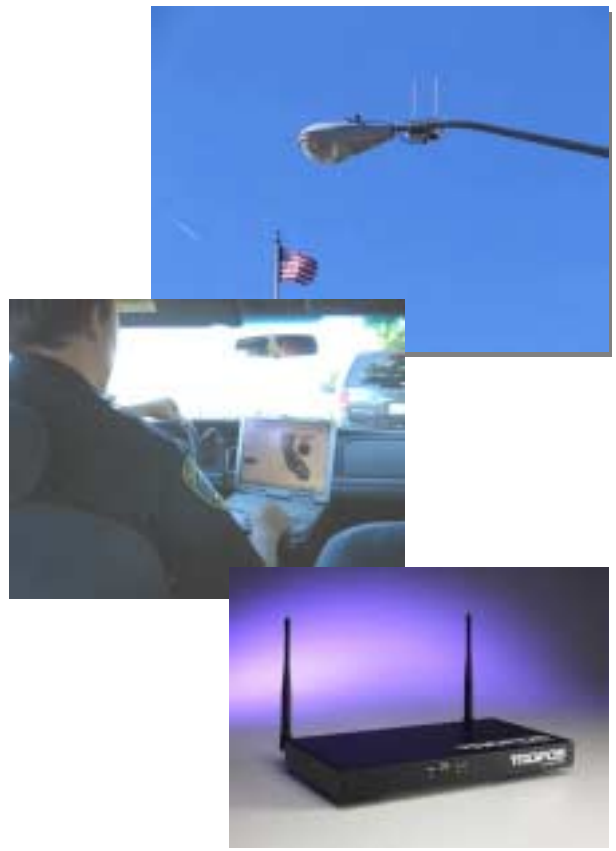
Purpose-Built MetroMesh Platform

The Most Efficient, Metro-Optimized Radio Technology

- The best throughput, with the first 802.11g mesh performance
- The best power output
- The best receive sensitivity (-100 dBm at 1 Mbps)

- **Tropos 5210 outdoor MetroMesh router**
  - Totally weathertight, hurricane resistant
  - Multiple power options, simple to install
- **Tropos 4210 mobile MetroMesh router**
  - Highest power, best receive sensitivity, best high speed roaming in-vehicle 802.11g client
  - Creates mesh-extending, tactical hot-zones
  - Delivers flexible deployment options through enhanced throughput and reduced node density
- **Tropos 3210 indoor MetroMesh router**
  - Brings the power of MetroMesh indoors



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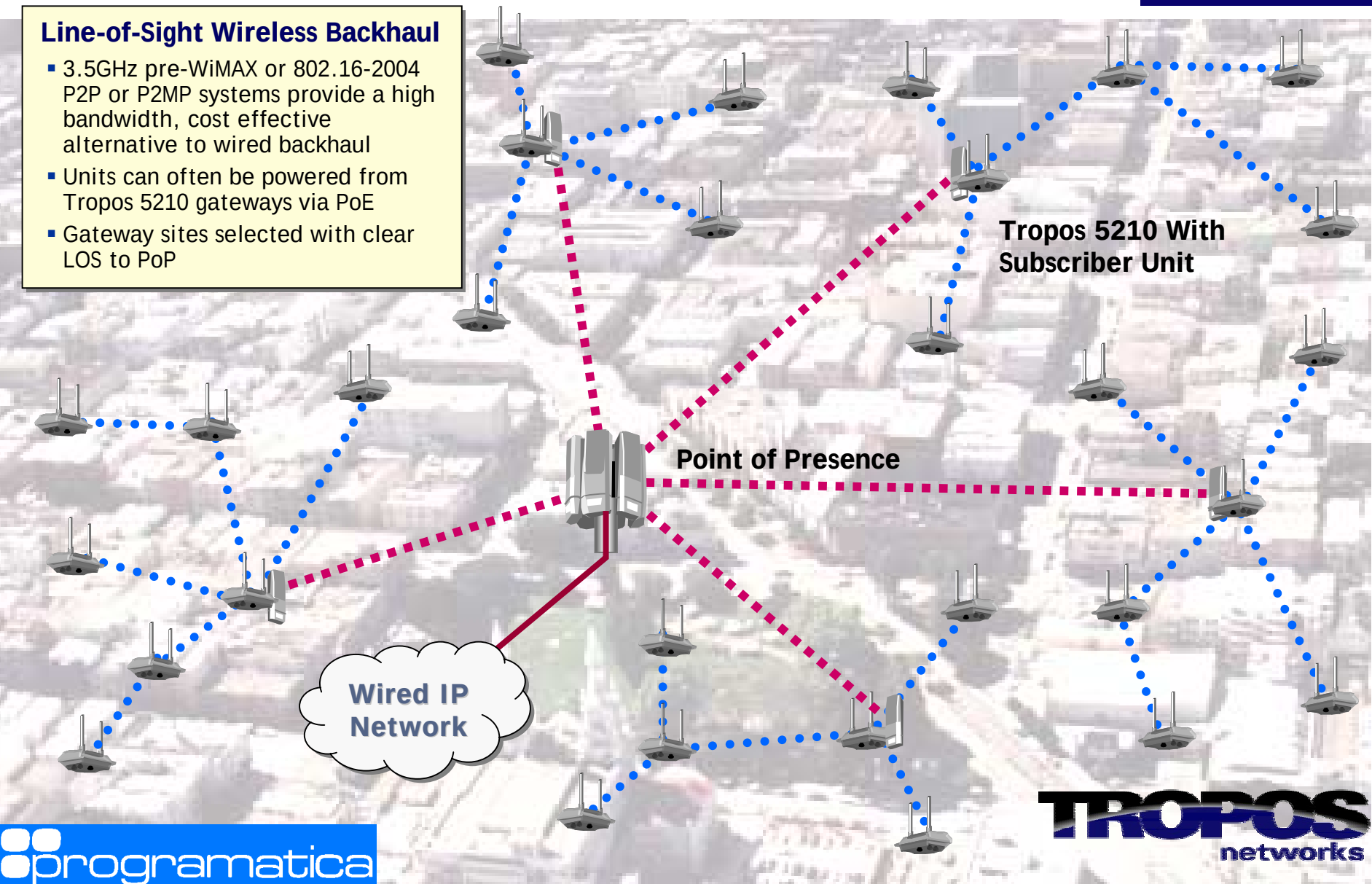
3.5GHz Wireless Provides Great Backhaul

Line-of-Sight Wireless Backhaul

- 3.5GHz pre-WiMAX or 802.16-2004 P2P or P2MP systems provide a high bandwidth, cost effective alternative to wired backhaul
- Units can often be powered from Tropos 5210 gateways via PoE
- Gateway sites selected with clear LOS to PoP



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Tropos Technology Summary

- **Tropos MetroMesh OS**
  - **Predictive Wireless Routing Protocol (PWRP)** for highest subscriber capacity, rapid deployment and unfettered scalability
  - Multiple private and public networks on a single wireless infrastructure
  - Secure roaming throughout the metro coverage area
  - Multi-layer security delivered to the edge of the wireless network
- **Tropos Control EM**
  - Wi-Fi optimized, SNMP-compliant element manager
- **Purpose-Built Platforms**
  - Carrier-grade indoor, outdoor and mobile MetroMesh routers

Metro-Scale Mesh Networking Defined™

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