Tropos Mesh Architecture

Tropos offers the market leading IP-based outdoor wireless broadband infrastructure that can be cost-effectively used for one or multiple applications. Designed to deliver superior capacity, resiliency, security and scalability, the Tropos Mesh Architecture is decentralized and highly flexible. Distributed intelligence enables each Tropos Mesh Router to make coordinated routing and airtime management decisions in real time, maximizing bandwidth and system performance by eliminating the latency and overhead associated with a centralized architecture.

FEATURES AND BENEFITS

- 4G network delivers a rich user experience and supports latency-sensitive applications
- Standards-compliant IP solution ensures broad application support and future viability of network investments
- Resilient, highly-reliable architecture eliminates single points of failure by automatically rerouting traffic preventing downtime
- Multi-layer security protects network resources and data and enables multi-use
- Scalable approach supports seamless evolution from thin mesh networks to high-density deployments
- Seamless mobility and handoffs at vehicular speeds support mobile workforce applications

TROPOS networks

A Smarter Way to Build Outdoor Wireless Mesh Networks

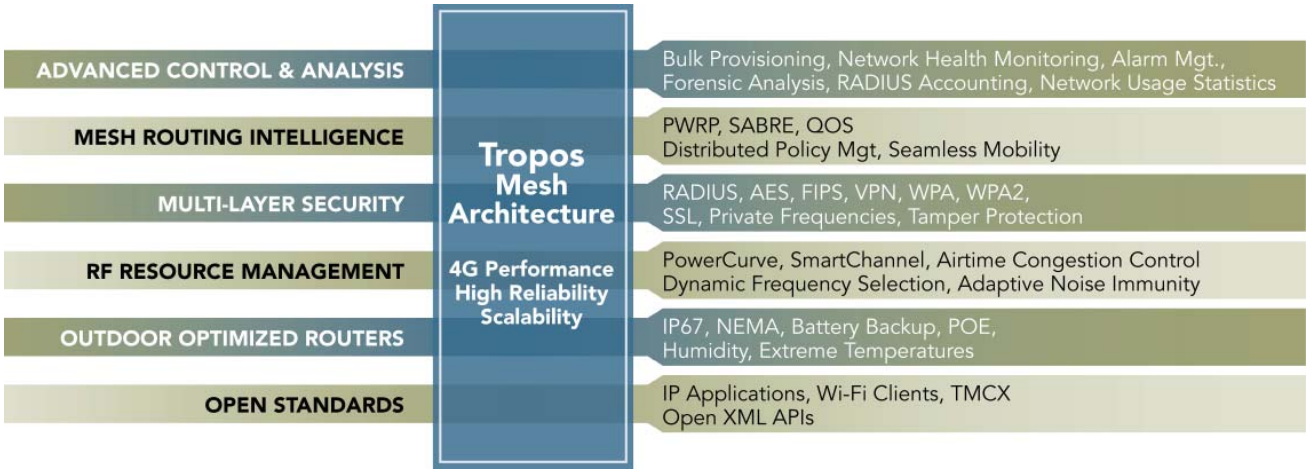
The flexible Tropos Mesh Architecture is ideal for creating metro-scale networks that support a broad range of applications, including public safety, transportation, utility meter reading, smart grid, and mobile access. The intelligent, distributed architecture employs patented algorithms that enable Tropos routers to maximize network performance by quickly adapting to changes in the RF environment.

Unlike architectures dependent on a centralized controller, all routing and transmission decisions in a mesh environment are made using the routers' on-board processing power, enabling them to take place in real time. Processing power grows proportionally as additional routers are added to the network, providing a scalable solution that does not require deployment of additional centralized resources. This intelligent, distributed approach enables the coordination of airtime and channel utilization to be accomplished entirely with information exchanged among neighboring routers, delivering a fast and responsive solution.

Similarly, the information needed by intelligent routers to compute optimal mesh routes can be obtained from members of its current and adjacent clusters. This decentralized approach also preserves bandwidth availability, because valuable resources are not consumed by network-wide exchanges of data between routers and centralized resources. The distributed intelligence of the Tropos Mesh Architecture enables networks to be scaled to arbitrarily large sizes while minimizing routing and control overhead at a fixed level.

The standards-compliant, IP-based Tropos Mesh Architecture supports the widest range of network applications, protecting against limitations imposed by proprietary systems and ensuring the future viability of infrastructure investments. All Tropos mesh routers, including single- and multi-radio models and mobile nodes, are interoperable because of the routing software's ability to assign any interface or frequency band to either mesh traffic or client access. Networks can be incrementally expanded from small areas to a multi-thousand router deployment, or upgraded to support bandwidth-intensive applications, without requiring any of the original infrastructure to be replaced.

The collection and analysis of management data is also facilitated by the intelligence of the distributed Tropos Mesh Architecture. Data is collected and preprocessed at the network edge, delivering real-time insight into network and client activity, granular monitoring of performance statistics, and rich diagnostic data on network behavior. The intelligent pre-processing of management data helps conserve system bandwidth, and maximizes the storage and processing resources of the Tropos Control management system by preventing excessive floods of management traffic.



Mesh Routing Intelligence

Designed and optimized for operation in dynamic outdoor environments, the Tropos mesh routers provide 4G levels of performance through a self-configuring, self-healing distributed mesh architecture. By combining patented RF resource management algorithms with standards-based radio technologies operating in unlicensed frequency bands, the Tropos architecture delivers a scalable, resilient solution for deploying broadband wireless metro mesh networks.

The distributed Tropos Mesh Architecture provides a highly-reliable, fault-tolerant network infrastructure that is capable of routing around interference and congestion bottlenecks. Unlike network architectures that are dependent on a central controller, the Tropos Mesh Architecture can easily recover from the loss of any network component without suffering costly downtime. Each router within the resilient, self-healing architecture continually monitors its environment for potential ways to optimize the network. If a problem occurs with either a gateway or node router, the mesh automatically and seamlessly reconfigures itself to keep the network up and running. When the router is brought back online, the network quickly reconfigures to it's optimum configuration.

The distributed Tropos Mesh Architecture is flexible and well-suited for deployments of any size. Organizations can start with a low-density mesh to support low band width applications such as AMR/AMI (Automated Meter Reading/Advanced Metering Infrastructure), and migrate over time to denser installations of Tropos mesh routers, leveraging and extending their original hardware investment. Regardless of cluster size, the infrastructure can be scaled to cover hundreds of square miles while keeping routing overheads to less than 5% of the available airtime. This stands in marked contrast to controller-based architectures where the volume of control traffic increases with the size of the network.

The cornerstone of the Tropos Mesh Architecture is the Predictive Wireless Routing Protocol (PWRP), a patented routing algorithm created to maximize the performance and resiliency of wireless mesh networks. PWRP is a dynamic wireless-aware routing protocol that allows mesh routers to perform end-to-end measurements of path quality, and use these measurements to make routing decisions that result in the highest end-to-end throughputs. PWRP allows the mesh routers to self-organize into a redundant and resilient mesh topology and to adapt to network events to prevent service interruptions. The result is a high-availability architecture with the ability to maximize performance by dynamically responding to changes in the RF environment in real time.

Flexible Dual-Radio Routers and Policy-Based Routing Enhance Network Performance

Tropos is unique in enabling both radios of a dual-radio router to be used for either mesh connections or client access, thereby significantly increasing the reliability and capacity of multi-band networks and minimizing overall system cost. Dual-mode routers increase mesh capacity by opportunistically choosing 4.9/5.8 GHz links whenever possible. In areas where line-of-sight is restricted, the 2.4 GHz radio provides a reliable, long-range connection. Because the 4.9/5.8 GHz radio is also available for client access, data traffic can be offloaded effectively from the 2.4 GHz spectrum.

In order to achieve the potential of dual-frequency networks, Tropos developed Spectrum and Application Based Routing Engine (SABRE), a patent-pending algorithm that integrates seamlessly with PWRP. SABRE intelligently manages multiple unlicensed and/or licensed frequencies, offering unique benefits. It provides sophisticated policy-based routing that can be used to segment data traffic across frequency bands. For example, network access for client devices can be segmented to use the licensed 4.9 GHz band for video surveillance, while making the unlicensed 2.4 GHz frequency available for other applications. SABRE enables IT managers to enforce policies that shift prioritized traffic from a licensed to an unlicensed network, while simultaneously preventing the unlicensed network users from accessing the resources of the licensed network.

Seamless Mobility

Tropos' intelligent distributed networks can be quickly extended through the use of mobile routers. Mobile mesh routers were originally designed to provide police and fire vehicles with wireless broadband connectivity, taking advantage of PWRP's unique abilities to dynamically establish optimum routes that deliver seamless coverage. Single- and dual-band mobile routers are available, providing access to both unlicensed and licensed public safety frequencies. Both designs are capable of supporting transparent handoffs at speeds of up to 80 mph. In addition, each of the mobile nodes extends connectivity to client devices in and around the vehicle, creating a tactical response zone in almost any location.

Wi-Fi clients traversing a Tropos network experience seamless roaming whether they are walking or in a vehicle traveling at high speeds. Tropos' patented low-latency handoff algorithms are able to track mobile clients on very short time scales, ensuring that latency sensitive voice connections, VPN sessions, and data transfers are maintained without disruption. This is accomplished without the need for any client software, and 802.11-compliant devices of all types are supported. Transparent handoffs ensure that clients are not dropped from the network as their connection shifts from router to router.

Network Security

An essential element of the Tropos Mesh Architecture is security. Wireless networks are inherently more vulnerable than traditional wired infrastructures, making multi-layered security an essential component of the Tropos architecture.

- Network access control protects the network from unauthorized users through WPA2 authentication, MAC address control lists, SSID suppression, per-VLAN security for multi-use networks, and packet filtering firewalls by IP address, protocol, TCP/UDP port, and VPN credential authentication
- Network resource protection is achieved via software alarms for intrusion, address, protocol, and TCP port filtering, and VPN filtering
- Hardware security is achieved via tamper-evident enclosures. Tropos routers are FIPS 140-2 certified and meet the requirements of NERC CIP 002-009
- Endpoint and wireless client protection is implemented through configuration of multiple VLANs and WPA2 authentication, evil twin detection, and peer-to-peer blocking
- Secure end-to-end transmission is ensured through end-to-end VPN support, WPA2 encryption for client links, AES encryption for mesh links, and support for multiple VLANs
- Secure configuration, operation, and management is achieved through SSL security to restrict unauthorized access to control functions:
  - Access to the Tropos Control server from wireless clients can be disallowed
  - Tropos Control also supports tiered access and auditing of authorized administrative users and transactions.
  - Management traffic from Tropos Control to individual routers is protected using end-to-end AES encryption within the mesh

RF Resource Management

Tropos has developed a suite of algorithms for efficient RF spectrum management and optimal spatial frequency reuse. PWRP uses these patent-pending algorithms to continuously and dynamically optimize the use of available spectrum via automatic channel selection, adaptive data rate selection, automatic transmit power adjustment, and adaptive noise immunity (ANI). Efficient RF spectrum management provides the optimum balance between higher bit rates and fewer retries to maximize performance. The algorithms highlighted in this section provide dynamic interference rejection, help maximize network capacity, support efficient concurrent operation in multiple channels, and select optimum data rates to maximize performance in constantly changing RF environments.

PowerCurve

PowerCurve maximizes network capacity and performance by optimizing power and rate parameters on a per-link, per-packet basis. This advanced, distributed algorithm dynamically increases or decreases transmit power levels to maximize the number of wireless links that can operate concurrently. Unlike systems where transmit power is configured as a static setting, PowerCurve dynamically monitors and adjusts power and rate. This fluid approach to managing transmit power and data rates increases aggregate network throughput, and is enabled by the distributed architecture.

SmartChannel

Designed to optimize performance in both single- and dual-radio networks, this distributed algorithm continually samples available channels to analyze link performance and interference trends. Channel decision logic is integrated into PWRP routing algorithms so that the quality of end-to-end paths across the network are assessed and the optimum path selected. In dual-radio routers, fine-grained channel plans are implemented within individual clusters to optimize each cell for client coverage and spectral reuse. SmartChannel's network analysis is non-disruptive to user traffic and sessions, and it optimizes capacity and reliability by predicting channels that are least likely to experience interference.

Airtime Congestion Control

Airtime Congestion Control (ACC) is designed to provide consistent performance for large numbers of users, even under extreme load conditions. The algorithm addresses a well-known shortcoming of the 802.11 MAC, where network capacity decreases as the amount of traffic attempted to be transferred increases beyond a certain threshold. ACC is a rate-limiting algorithm, but because it only activates when total airtime utilization is about to cause a capacity meltdown its implementation results in a net increase in throughput. When airtime utilization is low, ACC is completely inactive and clients are allowed to pass traffic without restriction. Only when a router approaches saturation are nearby routers alerted to conserve airtime. This is not done by capping throughput, but by allocating airtime on a per-client basis. ACC activates only when performance-impacting congestion is detected and returns to a monitoring state once the congestion condition has eased.

Adaptive Noise Immunity

Adaptive Noise Immunity (ANI) adjusts chip-level packet detection parameters in real time to minimize false detection events and maximize receiver sensitivity. Outdoor environments differ significantly from indoor environments in the variety and strength of interference sources, and dynamic detection parameter adjustment is critical to maintaining high performance. Tropos ANI algorithms have been developed through real-world testing and refined to perform in challenging interference environments where other devices stall, reset, or lose sensitivity.

Advanced Management and Analysis

Tropos Control provides a comprehensive management system capable of streamlining the deployment, optimization, maintenance, and control of metro-scale networks. Tropos Control is designed to deliver system-level monitoring and management of Tropos mesh networks, as well as provide device management services for all routers within the Tropos infrastructure. System-wide software updates and bulk provisioning can be achieved via a single command from the management station, streamlining a potentially time-consuming operation. A centralized alarm manager provides real-time visibility into the status of network elements. The intuitive web-based interface allows networks to be managed from any computer. The powerful, standards-compliant software solution improves the efficiency of IT personnel by simplifying complex tasks such as network health monitoring, mesh performance analysis, and system optimization.

From the central management console, IT personnel are able to view the network as a single entity and perform a wide range of critical analytics, including alarm configuration and monitoring, accounting, data mining and statistical capture, trend analysis, and drill-down monitoring of client connectivity. The combination of data collection at the edge and powerful analytic services at the core deliver rich network usage statistics and detailed visibility into network operation, far beyond the levels made possible by conventional element management systems.

Outdoor-Optimized Mesh Routers

Designed for mission-critical operation in the widest possible range of environmental conditions, Tropos mesh routers are housed in a rugged enclosure that can be deployed into almost any operating environment. Typical mounting locations for routers within metro deployments include streetlights, traffic lights, utility poles, and buildings, as well as trunks and vehicle interiors for mobile routers. Tropos routers are resistant to vibration, corrosion, high winds, extreme temperatures, snow, and ice, and are fully compliant with IP67 specifications for dust, humidity, and immersion.

Tropos routers also provide other key features for installation into metro environments, including options for battery backup, NEMA compliant photo-electric power taps, and the ability to support a wide variety of peripherals (such as video cameras) by providing Power over Ethernet (PoE).

Open Standards

Designed to provide both broad application support and investment protection, the Tropos Mesh Architecture delivers support for all IP-based solutions and 802.11a/b/g/n-compliant client devices. Developed using open standards, the Tropos architecture is based on standards-compliant radio chipsets, and protects against restrictions imposed by proprietary, closed systems with limited application and client support.

Tropos is committed to providing a flexible, standards-based environment and is a leader in the development of open standards within the wireless broadband industry. By introducing the Tropos Metro Compliant Extensions (TMCX) as an open standard to assist in the development of more efficient algorithms, Tropos is actively engaged in assisting client hardware vendors in maximizing the performance of client devices. TMCX addresses key issues that are central to maximizing the performance and reliability of both fixed and mobile client devices connecting to a metro-scale broadband wireless network.

The underlying Tropos Mesh Architecture is radio-agnostic and can readily be adapted to other standards-based radio technologies such as Mobile WiMAX or 900 MHz. Tropos continues to participate in standards bodies that are engaged in the development of wireless protocols, including IEEE 802.11 and IEEE 802.16.

TROPOS networks

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