WHITE
PAPER

Defining the Smart Grid WAN

Meeting distribution networking requirements for long range, high capacity, and low costs

Introduction

The key value of any wireless network is its ability to deliver the necessary capacity over an area of coverage at a cost commensurate with the value provided.

The impediment to achieving this rather simple goal is RF signal attenuation, which imposes constraints when balancing the contradictory objectives of close proximity (to enhance capacity) and long range (to extend coverage and lower costs). For example, a base station on a tower provides high capacity to subscribers in close proximity but capacity lessens over distance. To resolve capacity degradation, another base station can be optimally situated to provide better proximity and increase capacity but at a significant increase in costs.

The best way to summarize the mutual exclusivity of close proximity and long range is the expression:

"Cost, Coverage, and Capacity: Pick Any Two"

Any wireless deployment, therefore, is typically defined by these limitations:

1. Low cost and long range, but with low capacity
2. Low cost and high capacity, but only at short range
3. Long range and high capacity, but at a high cost

These tenets hold true for any wireless network and become increasingly important for the wide area network (WAN) tier of any Smart Grid network deployment. To build a WAN solution specifically for the utility networks, Trilliant developed a patented broadband wireless WAN system that helps overcome these limitations. Although still bound by the physics of RF signal attenuation, Trilliant has been able to provide breakthrough economics to utilities by extending coverage and improving capacity through an innovative wireless architecture called the SecureMesh™ WAN.

SecureMesh WAN – Defining the Smart Grid WAN

To confront the seemingly impossible goals of high capacity, long range, and low cost, Trilliant developed SecureMesh™ WAN, a patented synchronous switching broadband wireless system. This system dynamically aligns high-gain directional antennas to create dynamic point-to-point links throughout an entire network of interconnected base stations.

With this architecture, every base station is still able to cover 360° through eight individual 45° antennas. Each base station is a mesh node that dynamically switches between an array of high-gain (18 dBi) antennas to provide long-range point-to-point links to other mesh base stations. By dynamically interconnecting base stations with point-to-point links, SecureMesh WAN can enable multi-hop wireless networking, with each base station functioning as a "relay" to extend the total coverage area. Therefore, with dynamic antenna switching, each base station integrates a point-to-point backhaul and multi-hop mesh relay within a single system to extend range and keep costs low.

Note, however, that SecureMesh WAN does not simply repeat the signal, since that is an inefficient and wasteful use of spectral capacity. Instead, SecureMesh WAN coordinates and synchronizes

transmissions to maximize network-wide capacity. By allowing multiple simultaneous narrow-beam transmissions, SecureMesh WAN mitigates self-interference and leverages spatial diversity to maximize spectrum reuse, resulting in efficient capacity utilization throughout the entire spectrum.

Coverage Extension

To extend the coverage served by each mesh node, SecureMesh WAN uses a combination of high-gain directional antennas and multi-hop relaying at every base station in the network. High-gain directional antennas are, of course, one of the best methods to increase range since it increases the link budget for both transmit and receive. They also enable many of the advanced SecureMesh WAN features such as spectral reuse and self-interference mitigation.

- **Long Range Point-to-Point Backhaul Links**
  At synchronized time slots, each and every SecureMesh WAN node dynamically switches to the optimal high-gain antenna for transmission coordination. Since each backhaul link has a directional 18 dBi antenna at each end, the SecureMesh WAN nodes leverage 36 dBi of gain to provide a line-of-sight (LOS) link of up to 10 miles/16 km. These links can also support non-line-of-sight (NLOS) through OFDM modulation. The ranges of NLOS links vary, of course, depending on the type and amount of obstructions.

- **Mesh Networking Range Extension**
  Through the multi-hop relaying capability, each base station acts as a mesh node as well. This allows the coverage range to extend over multiple hops, with each “hop” extending range by up to 10 miles/16 km as indicated earlier. With multi-hop relay capabilities, the reach from a central site is no longer limited to a single base station; instead, the reach from the tower can be greatly extended through a series of interconnected mesh nodes – a 5-hops network can cover a radius up to 50 miles.

- **Coverage Fill-in by Routing Around Obstructions**
  Extending coverage is not just about pushing out the boundary of a coverage cell – coverage extension also applies to filling in coverage holes. Since SecureMesh WAN provide mesh networking relay capabilities, remote base stations can be routed around obstructions to easily reach and fill-in any holes in coverage.

Capacity Efficiencies

SecureMesh WAN is specifically designed to make the most efficient use of available spectrum over an entire mesh network. When the entire mesh of directional links is viewed as a whole, the SecureMesh WAN protocol enables multiple links to transmit using the same frequency with limited self-interference through a distributed synchronous protocol. This enables optimal spectrum reuse throughout an entire coverage region to increase the total “goodput” per second of airtime.

- **OFDM with Adaptive Modulation**
  All SecureMesh WAN links use OFDM to provide the best ability to close high-modulation rate links, even in NLOS environments. The links are constantly monitored and modulation rates periodically adapt to any changes in the wireless environment to ensure optimal performance.

- **Spatial Spectral Reuse**
  One of the main benefits of the mesh-wide coordinated transmission pattern is the idea of “spatial spectral reuse”. Since SecureMesh WAN coordinates all of the dynamic directional links, multiple simultaneous transmissions occur on the same frequency, effectively reusing the spectrum throughout the entire coverage region.

- **High Modulation Rates**
  Since SecureMesh WAN mesh nodes all provide point-to-point backhaul, they can easily be deployed in close proximity to subscribers. This allows the ability to convert “cell edge” low-

modulation links to high-modulation links through better proximity. With this capability, the network-wide average modulation rate increases and optimizes the "goodput" by enabling more frequent higher-throughout transmissions throughout the network.

- **Self-Interference Mitigation**
  As a result of dynamically switching directional antennas and synchronizing the reuse of the spectrum, SecureMesh WAN uses spatial diversity to effectively mitigate self-interference, resulting in further improving modulation rates and overall spectral efficiency.

- **Linear Capacity Scalability through Spectral Layering**
  Optimizing the spectral efficiency of a single frequency enables the use of alternative frequencies to linearly scale capacity. "Layering" alternate frequencies throughout the coverage region makes maximum use of available spectrum.

Breakthrough Economics

Through the technical advantages of greater coverage range and more efficient spectrum utilization, a large amount of bandwidth can be propagated from a single centralized injection point. When combined the other SecureMesh WAN features, this leads to significant economic advantages.

- **Mesh Coverage Extension Reduces Towers Costs**
  Mesh backhaul greatly increases the coverage radius of a single capacity injection point (SecureMesh WAN Gateway), thereby reducing the number of fiber sites required to provide broadband services over a given coverage area. Reducing the number of fiber sites required directly lowers lease costs as well as the number of leased or microwave backhaul connections required for each site.

- **Integrated Backhaul, Mesh, and Base Station Reduces Capital Costs**
  The unique integration of a point-to-point backhaul, a multi-hop mesh relay, and a point-to-multipoint base station leads to a significant reduction in network capital costs. Since these distinct functions are not discrete products, there are no additional costs because they are simply integrated into a single networking system. The ability to reuse the radio for different functions by dynamically switching directional antennas lowers the overall costs of deploying broadband wireless.

- **Automatic Discovery and Automatic Antenna Pointing Reduces Operating Costs**
  The ability of SecureMesh WAN to automatically discover all nodes and dynamically and automatically point directional antennas leads to a dramatically decrease in operating expenses. There is no manual antenna pointing required, regardless of whether the links are point-to-point, relay, or point-to-multipoint. SecureMesh WAN automatically discovers all nodes and automatically configures each and every link, which reduces the operational cost associated with deploying an advanced broadband wireless network. This minimizes the "hands-on" operational expertise and reduces the overall time to deploy.

Additional Benefits Derived from SecureMesh WAN

In addition to all of the aforementioned benefits, the SecureMesh WAN architecture also provides additional features that provide benefits to wireless operators.

- **Best-Path Routing, Dynamic Rerouting, and Self-Healing Failover**
  SecureMesh WAN has the ability to determine if multiple routes are available and to choose the optimal path. In addition, if modulation rates change or the network configuration changes, the mesh of interconnected point-to-point backhaul links can automatically and dynamically adapt. This optimizes throughput and can provide self-healing capabilities in case of failures.

- **Latency Guarantees**
  Since SecureMesh WAN is a synchronized protocol, it can provide low latency, low jitter, and

guarantees for latency-sensitive traffic such as VoIP.

- **Optional Wi-Fi Access**
  SecureMesh WAN also provides the ability of each mesh node to integrated Wi-Fi access points. All SecureMesh WAN mesh nodes are available with Wi-Fi access points (APs) at 2.4 and 4.9 GHz.

- **"Ethernet In/Ethernet Out"**
  Each SecureMesh WAN network is a full Layer 2 network, which results in "Ethernet In/Ethernet Out" across the network. This Layer 2 architecture supports virtual LANs (VLANs) to support a full range of higher level protocols including IPv4, IPv6, ANSI C12, DNP3, and Modbus.

- **Frequency Flexibility**
  Each high-gain directional antenna support a range of frequencies from 4.940-6.075 GHz. This allows each node to provide frequency flexibility and give Smart Grid operators the ability to change to new frequencies as required.

Summary

Although all wireless products are bound by the laws of physics, innovations solutions can help alleviate some of the fundamental constraints. The SecureMesh WAN leverages high-gain directional antennas to increase range and capacity, but through its patented method of dynamic antennas switching, still provides the cost advantages associated with simple omnidirectional mesh systems.

To learn more about Trilliant's multi-tier Smart Grid architecture, visit our online library at http://info.trilliantinc.com/library.

Trilliant

1100 Island Drive Redwood City, CA 94065
T 650-204-5050 F 650-508-8096
www.trilliantinc.com