Position Paper

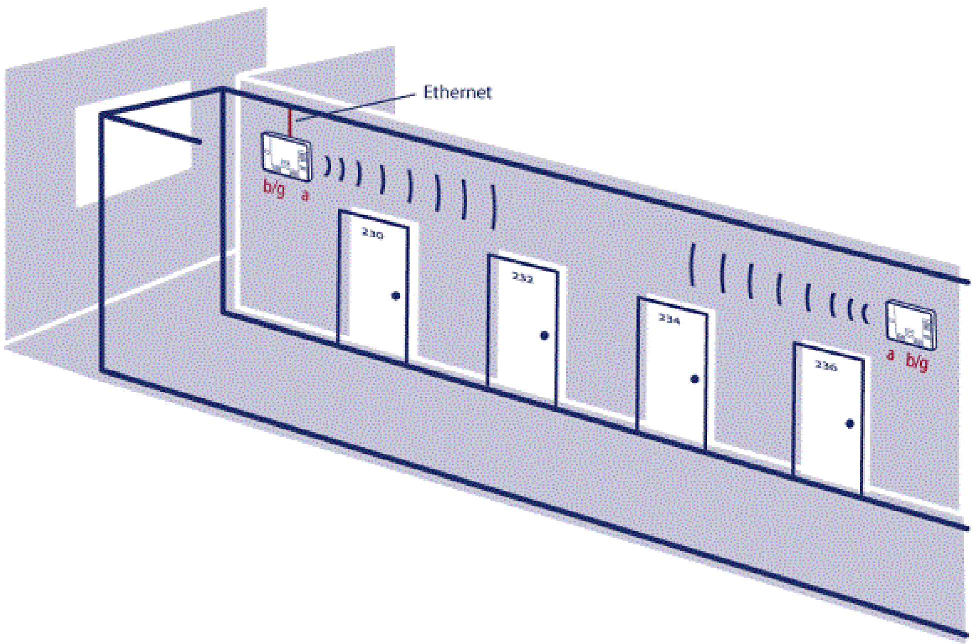
MESH TECHNOLOGY PRIMER

The Evolution of Wi-Fi: From Hot Spots to Hot Zones to Municipal Networks

Wi-Fi technology has experienced unprecedented growth for both consumer and enterprise use in a very short time. The first IEEE 802.11b based products became available in 1999. Not long after that, the first wireless LAN hot spot was borne. With the freedom of wireless becoming available at very low prices, the desire to have anytime, anywhere connectivity in places where it was never before possible quickly grew. Soon, businesses from coffee shops to hotels and airports were putting Wi-Fi access points up for their guests to use.

It also quickly became apparent that for many of these installations, easy connectivity to a wired network was not always possible for all access points. These types of venues were never designed for large scale connectivity to a network. Dragging cable to create connectivity negated the low cost promise of Wi-Fi. Ethernet cable runs can easily cost $1000 or more per access point – in many cases, two to three times the cost of the access point itself.

Fortunately, IEEE had considered this situation when they ratified the original 802.11 protocol. Within 802.11, the Wireless Distribution System (WDS) allows an access point to connect to another access point via the wireless medium. So, one access point that did not have wireline network access could gain connectivity via another access point that did have it.



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This solution works well for small numbers of access points. It has been employed widely in airports, hotels, and enterprises where Wi-Fi connectivity is needed, but where the cost of bringing Ethernet cabling into a jetway, lobby or outdoor campus is prohibitive.

However, as the cost of access points continued to decline, and embedded Wi-Fi clients became almost ubiquitous in laptops, a new type of Wi-Fi deployment began to emerge. No longer satisfied with just connecting in disparate cafes or hotels, several visionary cities began deploying Wi-Fi outdoors in business and suburban areas in an effort to attract business and tourism, and to close the digital divide. But with this step forward, another challenge surfaced. While WDS is excellent for connecting a small number of access points where direct network connectivity is not possible, its limitations become readily apparent if the situation is reversed – that is, if the *majority* of the access points *will not* connect directly to the wired infrastructure.

Metro Scale Wi-Fi Deployment Demands a Solution Utilizing Mesh Technology

Examining the details of deploying a broad scale municipal Wi-Fi network quickly reveals multiple reasons for limiting the amount of direct network connectivity needed for each access point. As Wi-Fi access points typically have a range of 1000 to 2000 feet outdoors, depending on the density of buildings, foliage and other obstacles, they must be placed fairly frequently to create pervasive coverage. Ten to twenty access points per square mile is a good average estimate for many suburban cities. The higher the access point is placed, the better its range will be, so desirable mounting sites include utility poles, water towers and the tops of city buildings. Existing network connectivity at these types of sites is highly unlikely. And, the cost of providing network connectivity to these sites is MUCH higher than pulling cable inside of a building.

Municipal network connectivity alternatives include DSL, leased lines such as a T1/E1, or wireless backhaul. The first two alternatives will cause a recurring monthly charge, typically reaching $600 to $800 per month for T1 connectivity. Wireless backhaul is often the lowest cost infrastructure solution, as it eliminates recurring monthly charges. Wireless multipoint backhaul solutions such as the Proxim Tsunami MP.11 family typically deliver a breakeven point versus leased lines within 12 to 18 months. However, this solution requires line of site from the central base station to the subscriber station – a condition that may not be easily met for all access points. So, it's extremely desirable from a cost perspective to be able to limit the number of access points that need direct network connectivity.

WDS could initially seem like an adequate solution to the problem of connecting access points together via radio. However, with ten to twenty access points needed per square mile, and many cities wanting to cover many tens of square miles, WDS won't scale well because each access point's WDS connection must be set manually. For example, a direct physical connection to the access point using WDS must be made to configure the IP address and the root access point. Further, there is no option to set up a secondary root access point if the first connection should fail for any reason. This risks clients being unable to connect to the network if an access point fails, with no remote remedy possible. Only a site visit entailing a direct connection to the access point will be able to correct the problem. With this situation, it is unlikely a municipality would feel comfortable relying on the network for any city business, and especially not for emergency services.

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Easy Outdoor Wi-Fi Network Deployment Using ORiNOCO Mesh Creation Protocol™

The desire for municipal Wi-Fi networks creates a requirement for self-forming and self-healing access point networks to eliminate the need for direct network connectivity to each access point, and to mitigate downtime in the event interference of access point failure occurs in a portion of the network.

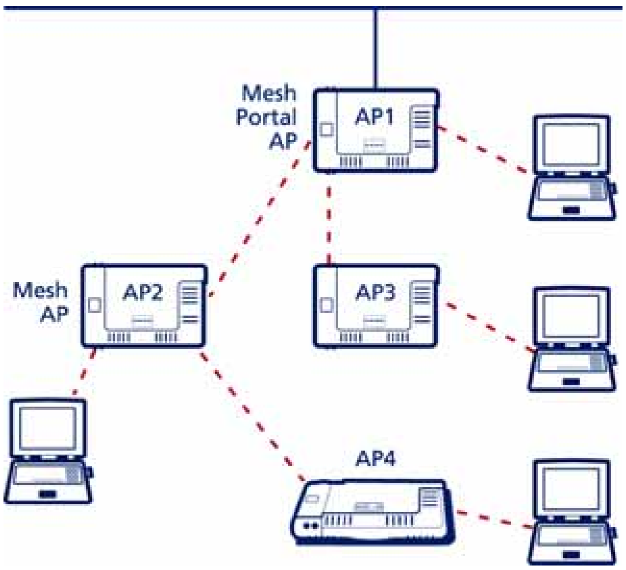
To solve these problems, Proxim has developed the ORiNOCO Mesh Creation Protocol™ (OMCP), an efficient, dynamic, low overhead method for access points to automatically form networks and optimize network efficiency. The ORiNOCO Mesh Creation Protocol provides:

- self-organizing network both at installation and when new Wi-Fi coverage areas are added
- self-healing in the event of interference or equipment failure
- ongoing dynamic recalculation of network efficiency and automatic network connection updates as needed
- low overhead to conserve bandwidth for application traffic
- highest levels of security – between clients and access points, and across the mesh network
- definable user group communities to maximize ROI by providing a single, secure infrastructure for different constituencies

Mesh Network Terminology

Standardization of mesh networking protocols is underway in the IEEE within Task Groups. Proxim employs the same terminology as IEEE to lessen confusion.

- Mesh AP – no wireline connection to the backbone
- Adjacent mesh APs – those APs without a wireline connection to the backbone that are able to connect to a mesh AP
- Station – an 802.11 client
- Hop – a term used to describe how far away from the wireline network a client is; defined by passing through a mesh AP



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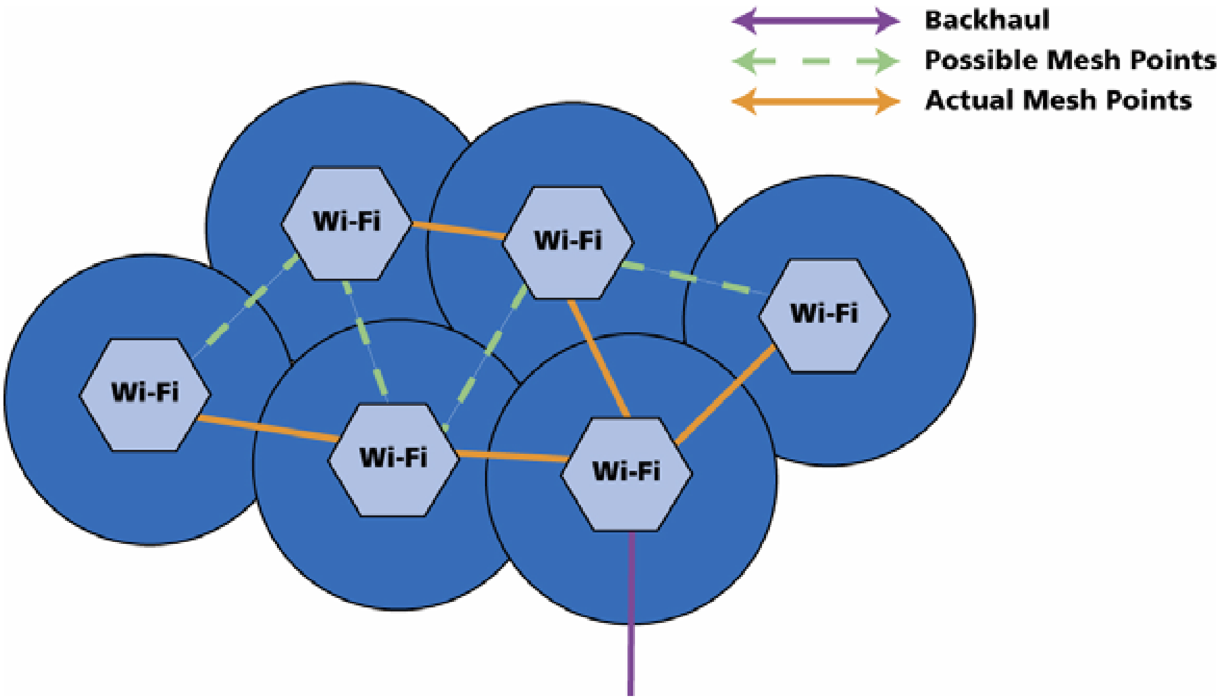
A Self-Forming, Self-Healing Network

The formation of a Proxim ORiNOCO mesh network begins as soon as the Wi-Fi cell is turned on. Wi-Fi cells that do not sense they have a direct network connection begin an automatic discovery process using standard 802.11 beacon and probe request responses. APs with the same SSID discover each other and create a table of all other APs within range. Secure links to the other mesh APs are created using secure AES encryption and authentication.

Proxim's OMCP then determines the most efficient path through the mesh, taking into account traffic load, link speed, signal strength, number of hops and other parameters. Based on this calculation, specific routes from each mesh AP to mesh portal APs [those directly connected to the network infrastructure] are set up.



As additional Wi-Fi cells are added to increase coverage or capacity, Proxim's OMCP will automatically recalculate all paths and update routes as necessary, and connect in the new devices. Automatic network organization ensures that time-consuming field configuration is not necessary. APs are simply plugged in, and within minutes are operating as part of the network.

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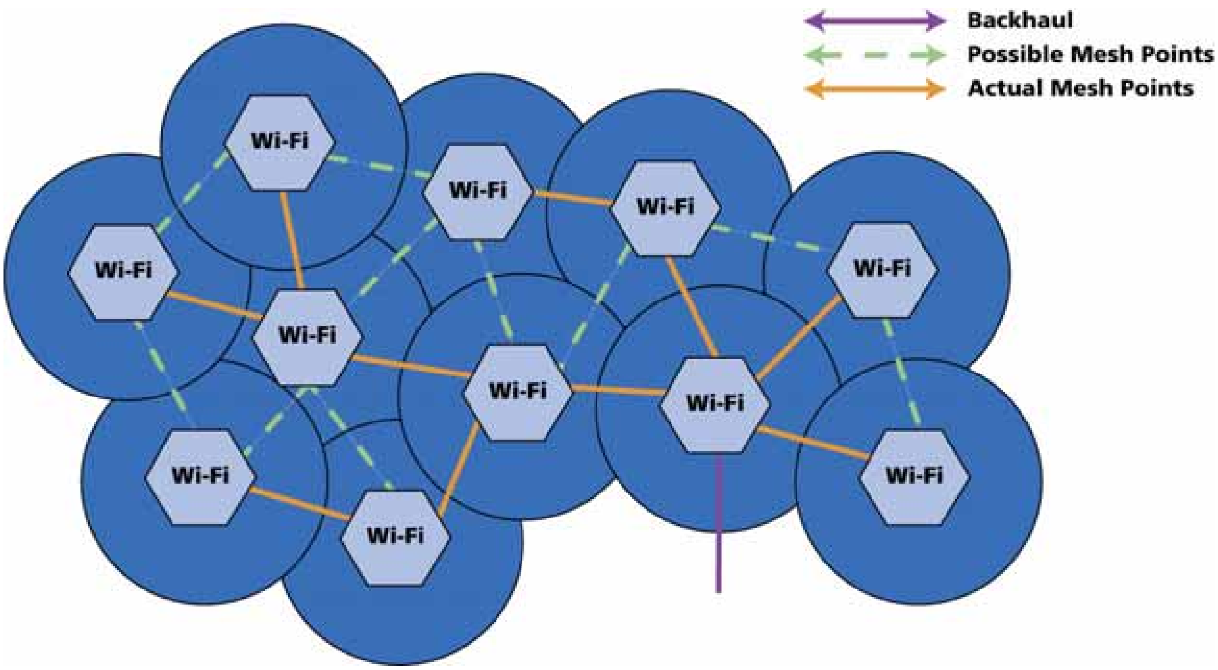

The ORiNOCO Mesh Creation Protocol is always dynamically calculating path efficiency for all possible routes. Each mesh AP secures a connection to all possible adjacent mesh APs. However, only one link is allowed to be open. Securing each possible connection in advance allows almost instantaneous path updates. The dynamic nature of OMCP is continuously checking for changes in the topology and environment. Changes in the network such as –

- link failure
- traffic load
- signal strength
- link speed

– will immediately be taken into account, and a new route will be created if necessary. As all links are pre-configured, the new path is simply unblocked, and traffic immediately begins to flow through the new route.

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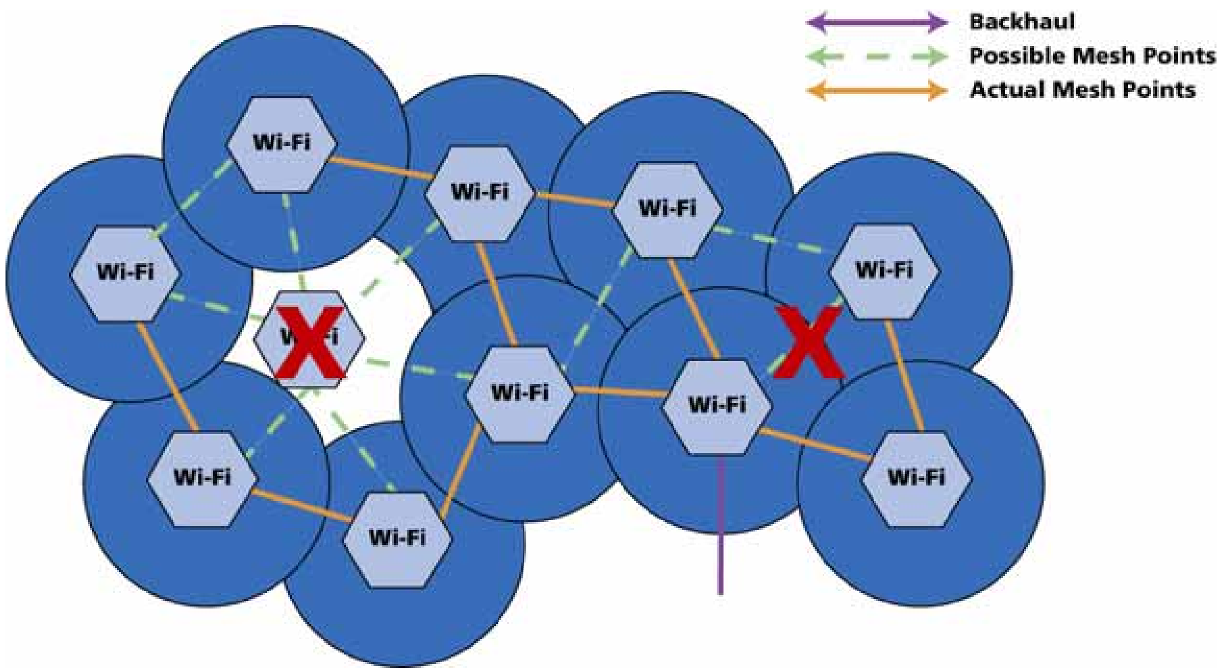

With self-healing properties as described, the mesh network now becomes suitable for municipal business as well as public safety applications, where high availability is critical.

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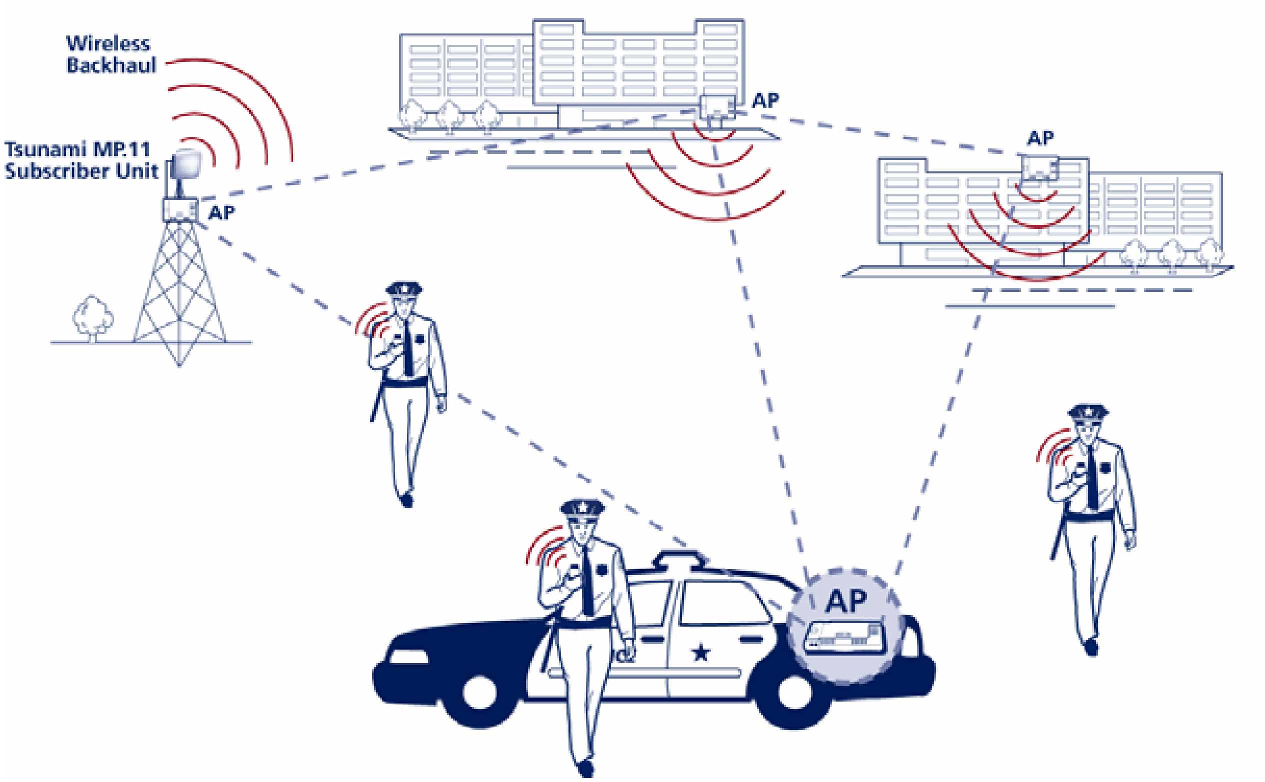
Mobility in the Mesh Network

One striking implication of the way Proxim's ORiNOCO Mesh Creation Protocol is implemented is that mobility of both Wi-Fi clients and the AP infrastructure can be achieved with excellent results. Clients can roam seamlessly among all APs just as with any non-meshing AP network. Security methods can include any combination of WEP, WPA, WPA2 or a VPN overlay, with no reauthentication required as the client roams among APs.[1]

In addition, mesh APs can also be mobile. This is highly desirable for public safety applications where, during an incident, emergency response officials need to remain connected to the network, but must exit their vehicle and move within the incident area. In this case, a mesh AP in the vehicle can provide local connectivity to Wi-Fi clients, enabling stronger signal strength, and thus better performance. Clients will have a better connection to a closer AP than an AP that may be mounted on top of a building or utility pole. As the need arises, the vehicle can move to different areas of the incident all while maintaining connectivity to the network.



[1] Assumes APs are all on the same subnet. For solutions where the APs must exist on different subnets, Proxim recommends IPUnplugged to provide seamless roaming across subnets with no disruption and no client software.

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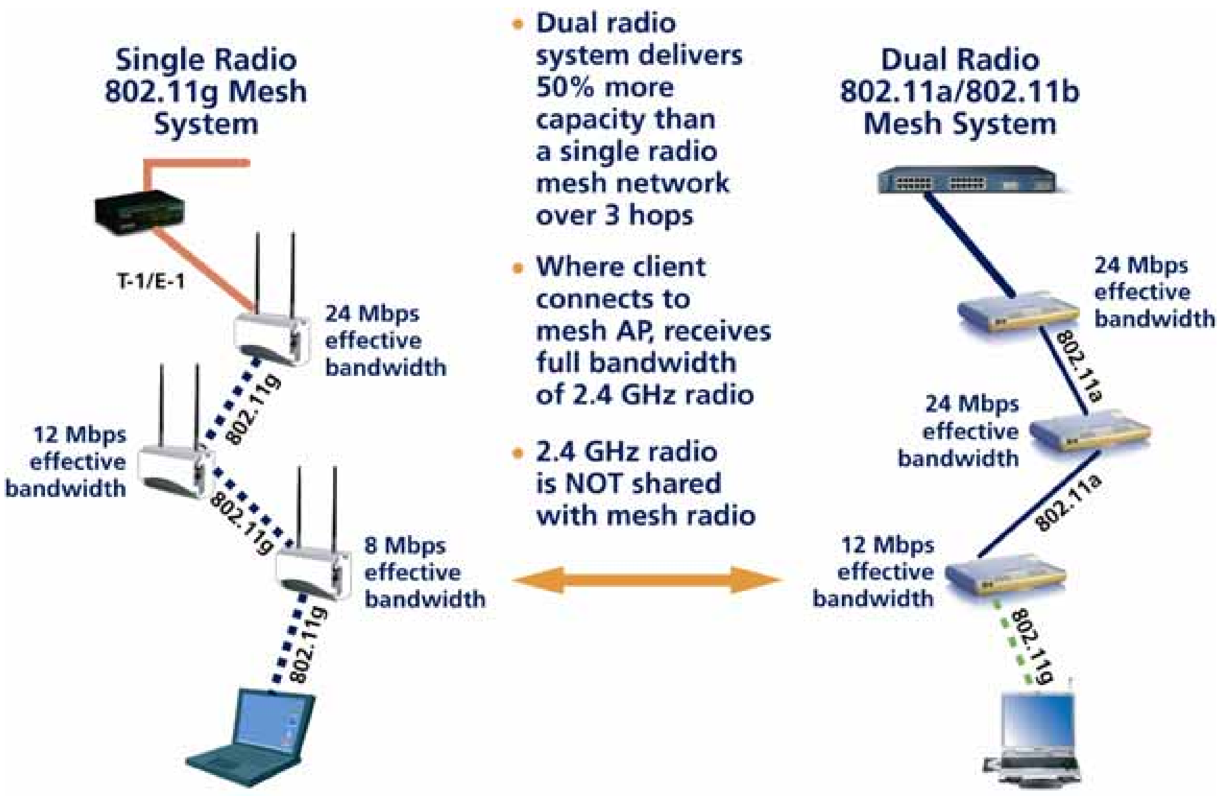
Dual Radio Meshing Delivers Superior Performance

While Proxim's ORiNOCO Mesh Creation Protocol could apply to a single radio Wi-Fi cell, Proxim's municipal network solution employs a dual radio Wi-Fi cell because of significant performance advantages realized with this approach. The Proxim solution utilizes a dual radio Wi-Fi cell with separate 2.4 GHz and 5 GHz radios. A separate 5 GHz radio used for meshing allows client traffic to be separated for highest performance. In a single radio mesh solution, the client traffic and mesh links share the same radio, which means that all traffic is on the same channel. This effectively cuts the mesh network performance by two-thirds at a minimum.[2]



With the Proxim solution, the 5 GHz radio can be dedicated to the mesh network, leaving client traffic to the 2.4 GHz radio. This means that a standard three-channel 802.11b or 802.11b/g network can be built out maximizing system performance.

[2] IEEE 802.11 spectrum in the 2.4 and 5 GHz bands is divided into channels. In the 2.4 GHz band where 802.11b and 802.11g operate, there are thirteen channels, with three of these being non-overlapping. For two 802.11 devices to communicate, they must be on the same channel. Bandwidth is added to a network by using all three non-overlapping channels. Hence, if a single channel is used for the entire network, the total system throughput is only one-third of what is possible. For 802.11b operation, this means that instead of having an aggregate over-the-air performance of 33 Mbps, only 11 Mbps is available.

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RF Aware for Superior Network Resiliency

Because Proxim's system is a dual radio solution, RF aware technology has been incorporated to enhance client performance. This technology automatically adjusts each AP's channel and power settings as needed.

For example, in the event of an AP failure, Proxim's OMCP will self-heal the network by automatically creating new meshing routes. But, it will also use auto-channel and power leveling to minimize any coverage gaps and prevent adjacent APs from using the same channel, which would reduce system throughput. In addition, this capability provides automatic RF recalculations as new nodes are added, eliminating the troublesome step of having to reconfigure channels and power levels on the already deployed APs.

Intelligent Traffic Balancing

Proxim's solution also offers active client load balancing. In the event of a heavily loaded AP, such as could occur during an emergency response situation, the Proxim ORiNOCO AP-4000M wireless LAN will actively seek to move clients to more lightly loaded APs, creating a more equitable distribution of traffic. Load balancing is independent of client type, does not require special client software, and takes into account both the traffic level on the AP and the number of currently associated clients.

Pre-Standards Based

Proxim's OMCP is based on existing IEEE standards where applicable, such as 802.11i and AES for security. In addition, Proxim is closely following the progress of the IEEE task group assigned to mesh, [802.11 TGs] and is delivering a pre-standards solution today.

Summary

Proxim's ORiNOCO Mesh Creation Protocol is a dynamic, low overhead solution that addresses the major challenges of deploying Wi-Fi cells outdoors for municipal broadband networks. We've applied significant innovation to solve the issues of self-formation and self-healing that are required for a resilient metro scale Wi-Fi network. Built on the decade-long foundation of invention and innovation within the Proxim ORiNOCO product line, Proxim's OMCP is the first truly robust metro scale Wi-Fi solution available for today's municipalities who are solving the challenges of the digital divide, protecting public safety, and developing new revenue bases.

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