Ruckus
Simply Better Wireless.

white paper

Redefining WLAN Economics with Smart Mesh Networking

SMART RF, 802.11N AND SELF-OPTIMIZING SMART MESH NETWORKING OPEN DOORS TO A NEW WORLD OF UBIQUITOUS, PLUGGABLE WIRELESS LANS.

With the proliferation of WiFi-embedded laptops and handsets, Wireless LANs (WLANs) are becoming an integral part of enterprise networks. However, organizations with ubiquitous WLAN coverage are still in the minority. The reality is that businesses are still struggling with the complexity and cost of installing and managing large-scale WLANs.

A WLAN deployment typically entails a lengthy planning process involving complex RF design and labor-intensive cabling. Worse, the work is not over after the network is deployed. With more users, new devices, multimedia applications, ongoing moves/adds/changes and the dynamic nature of the RF environment, it is necessary to survey the WLAN and make adjustments from time to time to restore optimal performance and coverage.

During the process, if the need to add or relocate Wi-Fi access points (APs) arises, availability of Ethernet to the desired coverage areas may become a showstopper. Often, the cost of installing new cables dwarfs that of the WLAN equipment, especially when it interferes with everyday business.

Wi-Fi meshing is a potential solution to this problem. An enterprise mesh WLAN is made up of a group of cooperating APs, only some of which are directly attached to an Ethernet cable. The APs form a wireless topology to route client traffic between any member of the mesh, and the wired network. Meshing greatly reduces or eliminates WLAN cabling costs and delays as well as AP placement constraints. But despite these compelling benefits, most enterprises have not overcome their concerns over the performance, reliability, and complexity of mesh WLANs to take advantage of it on a broad scale.

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Mesh WLANs for the Enterprise – Why Not?

Ideally, a mesh WLAN is self-forming, self-optimizing and self healing, much like a router network; but unlike a router network, mesh WLANs must cope with two uniquely challenging variables - interference and media sharing - that have largely contributed to its uncertain viability in the enterprise.

Shared Media Mesh – Not Enough Capacity

A packet consumes bandwidth at every hop along a mesh path. Because Wi-Fi is a shared medium, it creates a delay for others contending for bandwidth in the same frequency channel.

Each hop a packet traverses within the contention domain exponentially depletes the network's capacity, and significantly limits the scale of mesh WLANs.

An obvious solution is to add bandwidth by deploying multi-radio APs. For example, a 2.4GHz radio can be dedicated to client access while a second 5GHz radio is used for backhauling. In this scenario, all of the mesh backhauls would still be subject to contention. Of course, APs with more than two radios can be deployed to further partition the backhaul links using different 5 GHz channels.

Mesh Meets Interference – Flaky and Flakier?

Regardless of meshing, enterprises have been frustrated with the limited range and unpredictable performance of WLANs. Meshing only compounds the problem — more APs are involved in completing a client transmission, more traffic competes for wireless bandwidth and there is higher exposure to the possibility of interference. Moreover, any problem with the mesh has potentially far-reaching impact, making reliability an ever more critical requirement.

While hop count and capacity limitations can be mitigated, interference, which reduces performance at the very least and at its worst, destabilizes the entire mesh, is much more difficult to detect and contain. Interference is not a binary phenomenon. Detection algorithms that rely primarily on SNR (Signal to Noise Ratio) statistics reported by Wi-Fi chipsets are often flawed.

For example, most chipsets cannot distinguish between a strong signal, and nearby interference, caused by the simultaneous transmissions of another client at close range.

Even when the AP senses interference, the typical response is to lower the data rate which results in reduced throughput or connection loss. Other interference mitigation techniques like re-routing the mesh, or changing the APs' power and channel settings, require disruptive actions across multiple nodes.

Conventional APs also have a proclivity to create "self interference" where adjacent APs create noise for each other because they use omni-directional antennas that consistently radiate in all directions. The risk of self interference is particularly high in a mesh WLAN where adjacent APs are likely to be placed in close range to achieve maximum backhaul data rates.

Mesh and WLAN — Too Complex

It is practically impossible to manually design a mesh WLAN that achieves optimal hop count, backhaul speeds, interference protection, resilience and load distribution at the same time. RF tools for mesh are rare, if they exist at all. In any case, static tools are helpless in the face of real time RF changes.

Beyond the design and installation phase, maintenance tasks for a mesh WLAN abound. Network topology needs to be monitored and tuned; coverage holes need to be plugged; access and backhaul capacities need to be balanced; and site surveys must be conducted periodically to ensure optimal performance.

Introducing Smart Wi-Fi

Recent developments in the Wi-Fi world have dramatically improved the viability of wireless meshing in the enterprise. The combination of IEEE 802.11n and Ruckus Wireless Smart Wi-Fi technology provides, for the first time, an opportunity to enable a high performance WLAN mesh that is dependable and yet simple to deploy and operate.

What is Smart Wi-Fi?

Smart Wi-Fi is a patented innovation that allows an AP to steer Wi-Fi signals farther, faster, and more reliably. It features three components: Smart antenna arrays, Smart RF routing software, and SmartCast™ (see separate white paper entitled: "Delivering the 802.11n Promise with Smart Wi-Fi").

A smart antenna array is an antenna structure made up of many directional antenna elements that can be selected individually or in combination to optimize each packet transmission. For example, elements with a particular directionality can be selected to focus transmit energy toward the receiver, or reject interference from the opposite direction. A small antenna package with just a dozen well placed elements can generate literally thousands of unique antenna patterns offering unprecedented diversity.

Smart RF routing software controls the Smart antenna array by continually learning the environment and re-configuring the antenna array to select the best antenna pattern. By adapting the antenna configuration for each client and each packet, if necessary, a Smart Wi-Fi AP is able to avoid interference in real time and consistently operate with maximum performing parameters, such as the highest data rates and the most efficient RF channels, while minimizing retransmissions. This means higher, more stable performance in challenging locations, more dependable connectivity, better coverage, fewer dead spots and higher network reliability.

SmartCast software is designed to optimize the system's performance of shared media WLANs. It allocates fair air time among clients operating at different speeds, schedules access based on traffic type and/or client priorities, and is capable of rate-limiting bandwidth on a per user basis to prevent any transmitter from monopolizing the shared bandwidth.

Smart Wi-Fi over 802.11n

802.11n is a new IEEE standard that dramatically improves performance and range over older 802.11 standards.

802.11n exploits new techniques such as spatial multiplexing, channel bonding, frame aggregation, and block acknowledgement to deliver a theoretical capacity up to eleven times higher than the previous 54 Mbps maximum. However, the key to obtaining the promised performance of 802.11n lies in the 802.11n system's ability to take advantage of these new techniques. In particular, spatial multiplexing only works over de-correlated multipaths, and channel-bonding requires the simultaneous availability of two clean, adjacent channels. Both benefit from an agile antenna system capable of finding suitable conditions in the environment, and adapting transmissions in real time to take advantage of them (see separate white paper entitled: "Delivering the 802.11n Promise with Smart Wi-Fi").

Most of today's 802.11n systems deploy static omni-directional antennas with no control over how signals propagate. Smart Wi-Fi, on the other hand, unleashes the power of 802.11n by adapting the signal path to take advantage of spatial multiplexing and channel bonding. With per-client traffic queuing and scheduling, Smart Wi-Fi also maximizes the use of frame aggregation and block acknowledgement techniques.

Figure 1 shows the performance difference between two 802.11n access points, one with Smart Wi-Fi and one without.

Enter Smart Mesh Networking

The Ruckus Smart Mesh Networking technology extends Smart Wi-Fi's benefits across a high performance, self-organizing, self-optimizing, self-healing 802.11n mesh backbone.

Smart Mesh Networking overcomes the performance, reliability and manageability objections that have stymied enterprise Mesh WLAN deployments.

Smart Mesh Networking Performance

An 802.11n Smart Mesh Networking provides 300 Mbps of access and backhaul capacity and reduces the packet delay per mesh hop by as much as five times over an equivalent 802.11g/a mesh. Backwards compatible with existing Wi-Fi devices, a 4-hop 802.11n Smart Mesh Networking backbone is able to deliver better or equivalent throughput than a wired 802.11g WLAN even for the legacy clients. 802.11n clients will further derive a two- to eight-fold increase in throughput (see Figure 2). Now, enterprises can take advantage of the benefits of unwiring their APs without compromising user performance.

Regardless of 802.11n's inherent capacity boost, the robustness and agility of Smart Wi-Fi is more important than ever in a mesh. The directionality of the embedded smart antenna array gives Smart Wi-Fi APs 50% more range (at a given throughput) over conventional 802.11n APs, so fewer of them are required to cover a given area. This in turn reduces hop count and backhaul traffic load, further enhancing system performance.

Confronted with interference, conventional APs either drop packets or respond by lowering the transmit data rate, which reduces system throughput.

Smart Wi-Fi has the unique option of finding a signal path that avoids the interference, thereby preventing packet loss and preserving the higher transmit rate. Should it fail to find a quality signal path (see Figure 4c), auto-topology software in the downstream Smart Wi-Fi APs will reroute their backhauls automatically when they detect a significant performance decrease in an upstream AP.

Smart Mesh Networking Reliability

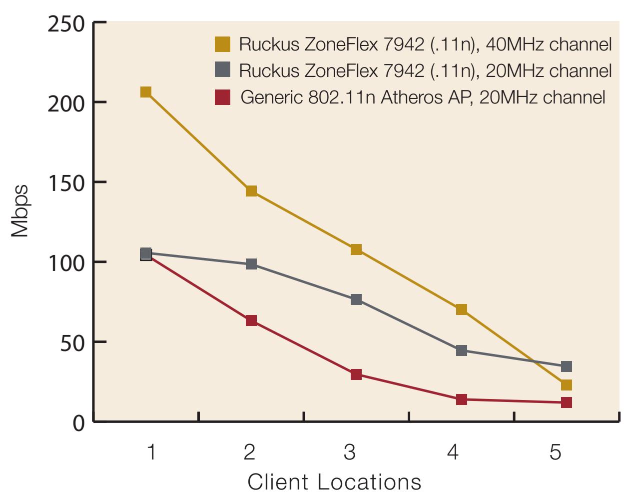
Achieving a high peak throughput is important, but a more critical priority for the mesh WLAN is to maintain its throughput reliably, and consistently across the coverage area. Interference is frequently the culprit for instability, dropped connections and performance fluctuations in a mesh WLAN.

Smart Wi-Fi technology is inherently interference robust. More importantly for a wireless mesh, Smart Wi-Fi APs make better "neighbors" than conventional APs. The Smart antenna array focuses transmit energy toward the intended recipient, but only for the duration of a transmission, typically a packet time. This minimizes the probability of self interference in the mesh, allowing adjacent Smart Wi-Fi APs to be placed at optimal distance to achieve the highest backhaul performance.

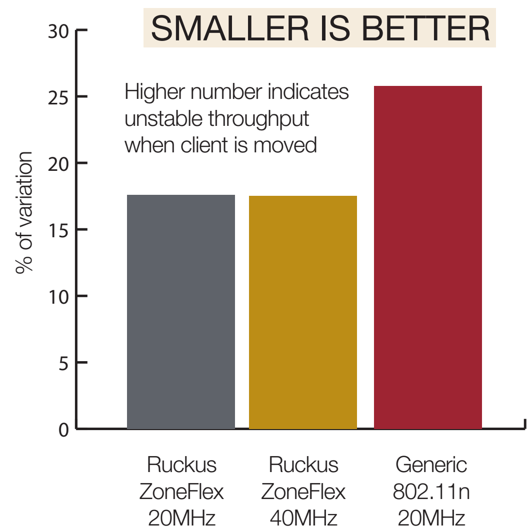
In the event of a Smart Wi-Fi AP impairment, or a sustained wave of severe interference, Smart Mesh Networking automatically reroutes and self heals (see Sidebar on Smart Mesh Networking auto-topology).

Figure 1: Ruckus 802.11n with Smart Wi-Fi versus Generic Atheros 802.11n Reference Design

802.11n Performance at Range



Thoughput Variabilities When Client is Rotated 90°, 180°,270° and 360°



United States building; ~3000 sq ft; 2-stories; wood construction (AP located near Location 1)

Location 1	5 ft	same room line-of-sight
Location 2	26 ft	passes through 1 interior wall
Location 3	35 ft	upstairs, passes through 2 interior walls plus floor material
Location 4	41 ft	passes through 2 interior walls, bathroom (with pipes and mirror), 1 exterior wall
Location 5	43 ft	passes through 3 interior walls plus floor material

Test method: UDP echo throughputs measured at millisecond intervals continuously for two minutes per location, per rotation.

In addition, SmartCast maintains traffic priority throughout the mesh, guaranteeing that VoIP traffic from a client downstream will not be affected by data traffic at an upstream Smart Wi-Fi AP, for example. It also allows the administrator to give the backhaul links priority over client access, as well as rate limit the clients, to ensure that no one would deliberately or inadvertently destabilize the network.

Smart Mesh Networking Simplicity

Designed for enterprises with limited RF-expertise and IT resources, Smart Mesh Networking simplifies deployment and operations by automating design, configuration, optimization and maintenance tasks whenever possible.

Smart Wi-Fi minimizes the need for comprehensive site surveys, RF design, and specialized installers. Because Smart Wi-Fi self-optimizes, performance is minimally affected by the Smart Wi-Fi AP's physical orientation, unlike conventional APs. The embedded smart antenna array obviates the need to manually tune the antenna's orientation and prevents unintentional interference.

In Smart Mesh Networking, there is no need to identify precisely where Smart Wi-Fi APs should be placed relative to one another to maximize backhaul speeds and minimize interference. The extended range of the Smart antenna system implemented on both ends of a backhaul link, means that more frequent than not, Smart Wi-Fi APs within a building can establish a high speed backhaul to the root AP directly or over a minimum number of hops.

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Figure 2: Throughput Comparison of 802.11n SmartMesh versus 802.11g Wired APs

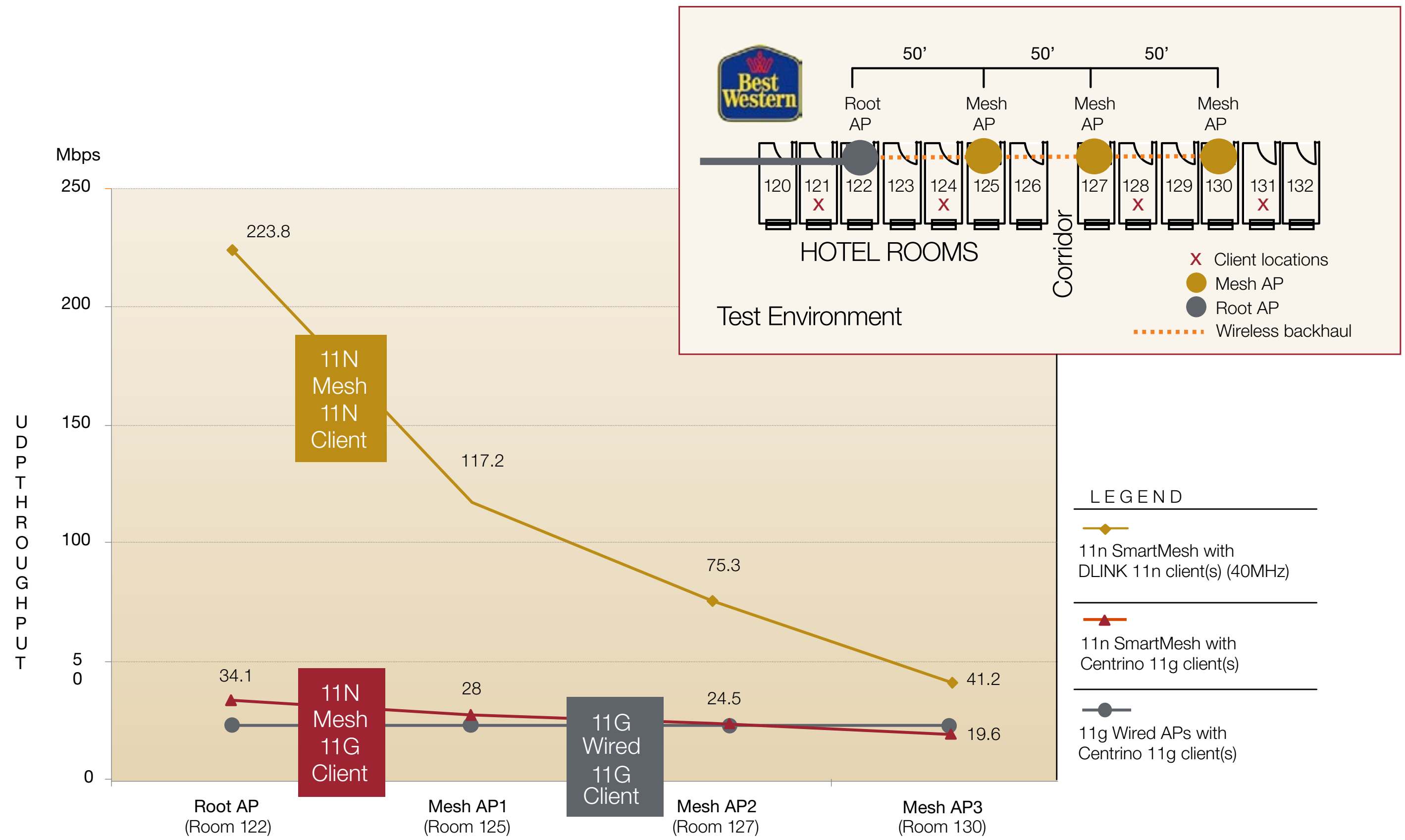
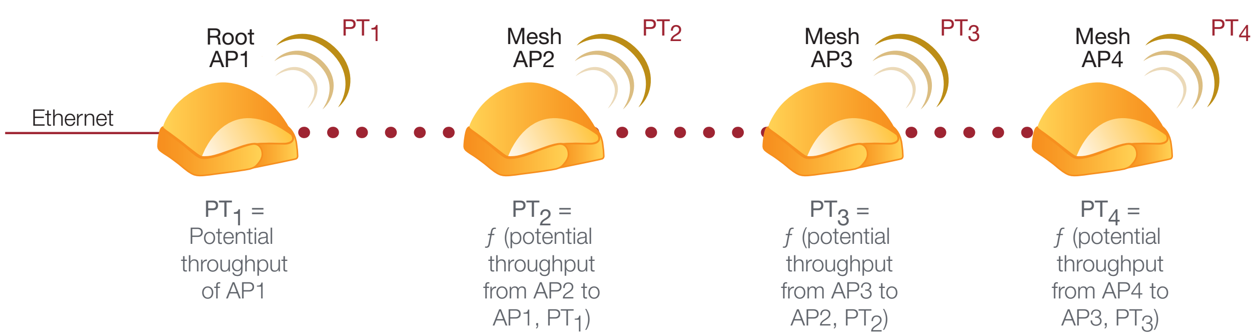


Figure 3: Smart Mesh Networking potential throughput metric



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Auto-topology software forms the best possible topology and optimizes it over time, based on real-time potential throughput metrics across all possible mesh paths. No manual intervention is necessary.

Smart Mesh Networking configuration and provisioning is literally plug-and-play. There is no need to configure each and every Smart Wi-Fi AP separately.

For ongoing operations, Smart Mesh Networking provides visibility into the network topology on a floor plan map view, allowing administrators to understand where there might be coverage holes, single points of failure or performance bottlenecks. Detailed statistics and logs offer topology, usage and other information needed for ongoing support, maintenance and capacity planning.

Smart Mesh Networking Economics

The powerful combination of Smart Wi-Fi, 802.11n, and Smart Mesh Networking empowers the enterprise for the first time, to remove the physical, technological, and economic obstacles that have prevented them from deploying WLANs ubiquitously.

Smart Mesh Networking gives enterprises the ability to install, maintain and expand the WLAN without lengthy, expert-labor-intensive RF planning; eliminate or at least minimize the installation of new Ethernet cabling; deploy fewer APs for any given coverage area; and operate the network with minimum expert staffing and user complaints.

All of these benefits translate into a total cost of ownership model that makes Smart Wi-Fi Wireless LANs unquestionably compelling to the enterprise.

SIDEBAR: SmartMesh Auto Topology

All sophisticated enterprise WLAN mesh systems provide some form of automatic topology formation, optimization, and redundancy functions. The topology algorithms are commonly based on hop-count, link capacity, and/or SNR (Signal to Noise Ratio), all of which are flawed if the goal were to achieve the best possible performing mesh WLAN.

Signal strength statistics such as SNR reported by the Wi-Fi chipsets are not always reliable. More often than not, Wi-Fi chipsets are unable to distinguish between strong interference generated by another transmitter in close proximity, and a strong signal.

The link capacity in a wireless mesh changes from moment to moment based on real time RF conditions, such as interference, as well as the processing load of the AP.

Hop count by itself does not dictate a path's performance. For example, a single hop mesh path operating at a 5 Mbps data rate serving 50 downstream clients is not necessarily better than a two hop path capable of 10 Mbps at each hop, that has only 5 downstream clients.

For Smart Mesh Networking, auto-topology is designed to select a path between every node, and a root AP that is most likely to deliver the highest performance at a given time. The function is distributed, allowing each Smart Wi-Fi AP to independently select its upstream path.

With each beacon, a Smart Wi-Fi AP advertises its real time Potential Throughput (PT). PT takes into consideration the potential throughput to its upstream AP and the potential throughput of its upstream AP (see Figure 3). When a Smart Wi-Fi AP joins the network, it establishes a secure backhaul connection with the best performing upstream AP based on all the PT advertisements, computes its own PT metric, and starts advertising itself.

Each Smart Wi-Fi AP continues to monitor the advertisements from all the potential upstream APs. In the event of a backhaul failure or significant performance impairment, the AP will re-route its backhaul to the current best performing upstream AP (see Figures 4a, 4b and 4c).

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Figure 4a: Smart Mesh Networking self-organizes

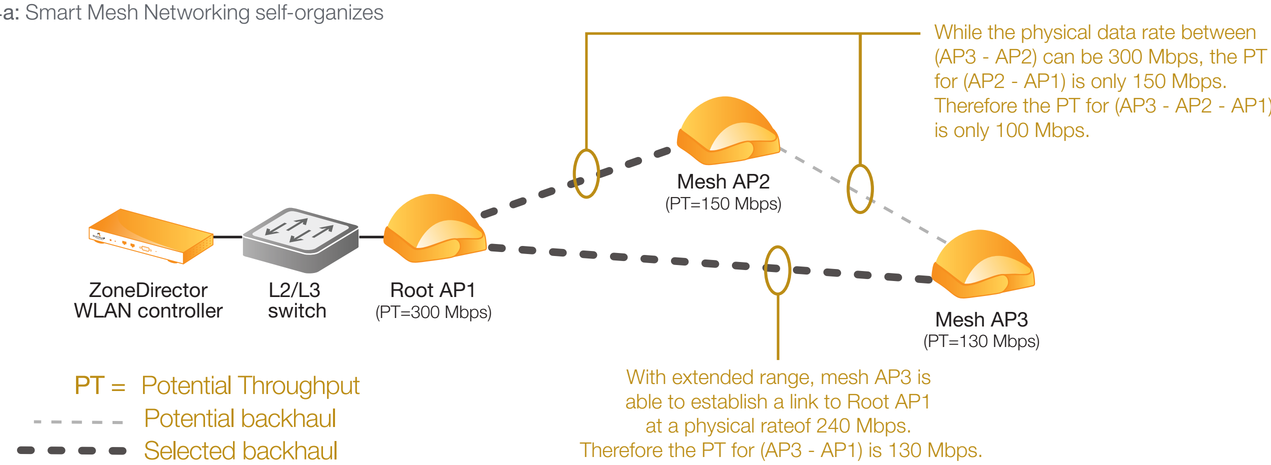

Figure 4b: Smart Mesh Networking self-optimizes

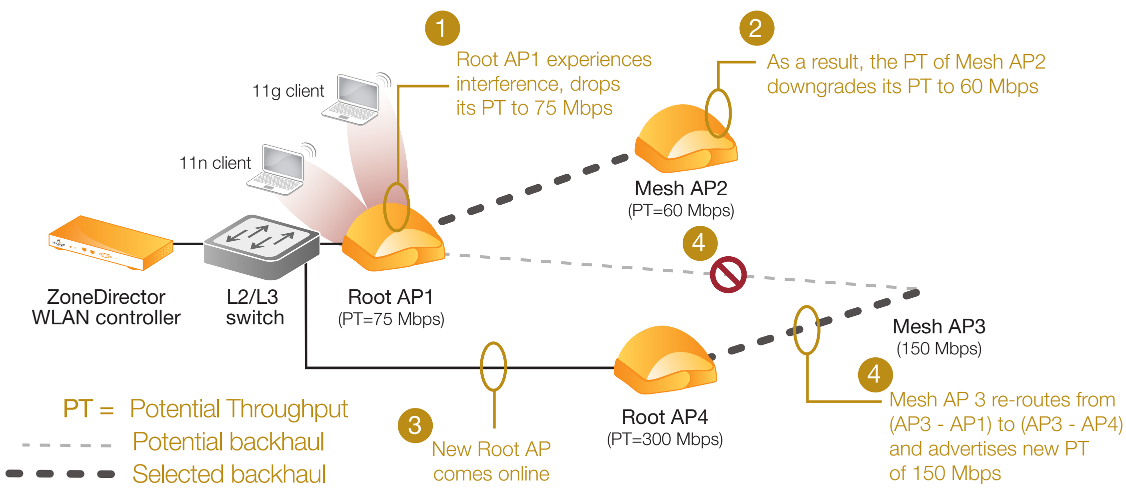

Figure 4c: Smart Mesh Networking self-heals

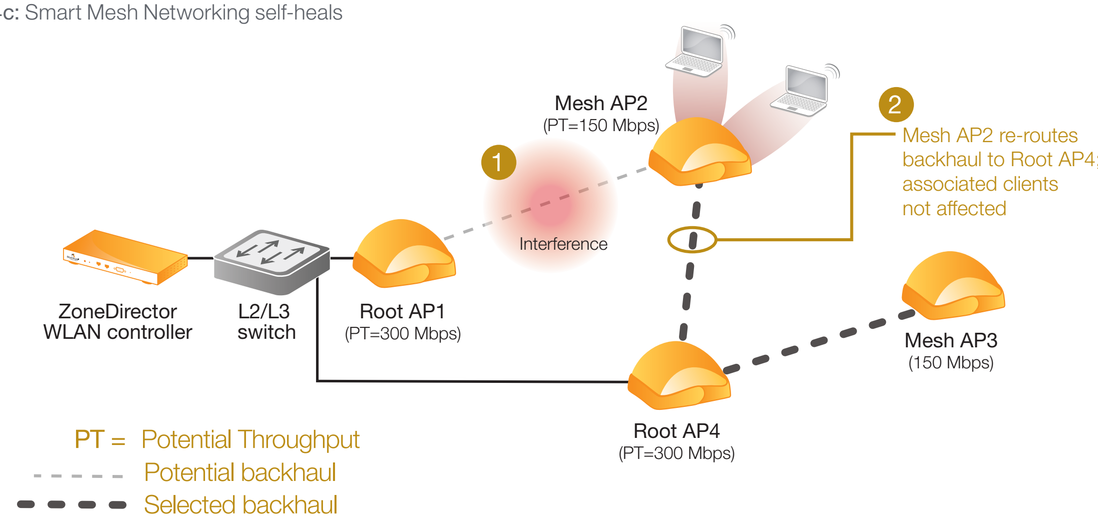

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TABLE 1: Legacy 802.11g vs. Smart Mesh Networking 802.11n

	Legacy 802.11a/g Wired WLAN	Ruckus 802.11n Smart Mesh Networking
RF planning and design	$5,000, 1 day	$500, 1 hour
Configuration and installation	2.5 business days	5 hours
WLAN Controller	$14,395	$4,000
Wired access points	$17,475 (25 802.11a/g APs x $699)	$3,495 (5 802.11n APs x $799)
Mesh access points	0	$6,990 (10 802.11n APs x $799)
Ethernet drops	$5,000 (25 drops x $200)	$1,000 (5 drops x $200)
Maintenance and post-installation	1.5 Days	0 Days
Total Cost of Ownership	$41,870 5 Business Days	$16,985 0.5 Business Days

An ROI Example

Legacy wired 802.11g WLAN vs. 802.11n Smart Mesh Networking

In the past, installing an 802.11g WLAN with equipment from a leading enterprise networking supplier that covers a 500-user, 50,000 square-foot office takes one week and more than $40,000 in capital and labor expenditure. With 802.11n Smart Mesh Networking, the same deployment takes less than a day and costs approximately $17,000.

Furthermore, the compelling economics of Smart Mesh Networking can be realized without compromising performance. Figure 2 demonstrates that by deploying an 802.11n Smart Mesh Networking backbone, the throughput of the meshed WLAN for legacy 802.11g clients is equivalent or better than that of an Ethernet connected 802.11g WLAN, even across 2-3 wireless hops.

When client devices eventually migrate to 802.11n, the same Smart Mesh Networking backbone would still be able to deliver more than 40 Mbps of client throughput even at three hops from the root AP.

Summary

Advances in signal path control and RF signal routing coupled with higher speed 802.11 technology, such as 802.11n, are creating new opportunities to redefine the economics of wireless LAN deployment.

Highly desirable to enterprise IT managers, wireless meshing in the enterprise had failed to take hold due to poor performance, signal instability and deployment complexity.

The advent of Smart Wi-Fi now enables a robust and high-performance wireless meshing network, that can adapt to changes in the Wi-Fi environment to ensure highly reliable, far-reaching backbone connections between mesh nodes.

Combined with 802.11n, Smart Mesh Networking now offers enterprises the ability to deploy a wireless LAN at half the cost, in half the time, and with three times the performance of traditional "wired" 802.11g networks.

Smart Mesh Networking creates a highly resilient wireless backbone that obviates the need to run Ethernet cables to every access point. Each Smart Wi-Fi AP integrates patented BeamFlex™ beam steering technologies. This minimizes wireless hops between mesh nodes, to deliver high performance, and ensures unprecedented resilience over wireless backhaul links.

Ruckus® Simply Better Wireless.

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