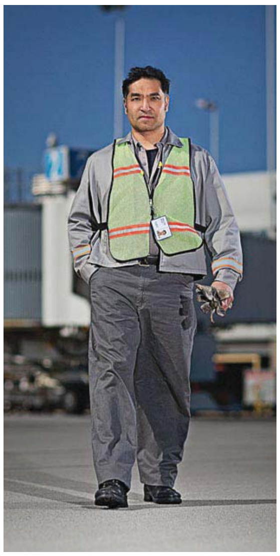
POSITION PAPER

802.11n in the Outdoor Environment

How Motorola is transforming outdoor mesh networks to leverage full "n" advantages

Municipalities and large enterprise customers are deploying mesh networks to provide wireless broadband connections across cities or within campus environments. Today, these networks support many different types of applications, including video surveillance, meter reading and traffic control, and have demonstrated mesh networks' ability to deliver a compelling return on investment as well as enable new services.



Many current mesh network deployments are based on WiFi technology, the common term for wireless services meeting the IEEE 802.11 standards. Up to now, the best available data speeds leveraging 802.11a, –b or –g standards reach burst data rates of 54 Mbps. However, over the past year, the promise and subsequent arrival of 802.11n technology has generated a substantial amount of industry discussion and debate. Adoption of 802.11n WiFi in both the enterprise and consumer markets is quickly gaining ground, with many customers upgrading older indoor networks to meet new 'next generation' standards. These new high capacity networks promise to deliver substantial cost savings in not only infrastructure and operations, but also in end-user productivity and efficiency gains.

The use of 802.11n in outdoor network deployments has raised some interesting questions. Based on current network configurations and emerging ROI models, the potential benefits are dramatic. However, the specific capabilities of 802.11n as applied to outdoor networks differ significantly from common indoor network configurations. Network planners and operators must understand the technology enhancements 802.11n brings along with the unique environmental challenges inherent to outdoor deployments in order to leverage the full advantages of "n" technology.

This paper will focus on the key 802.11n technology enhancements, specific product design considerations for 802.11n mesh access points, and how to maximize the benefits of 802.11n technology in outdoor networks.

Key Technical Enhancements

IEEE 802.11n is the next generation standard for WiFi-based technology, promising high data rates, longer range and more reliable coverage than 802.11a/b/g networks. In order to achieve optimized gains in an outdoor network, the technology will have to account for unique environmental considerations. As with earlier 802.11a/b/g deployments, 802.11n technology was originally designed for indoor hot spots. Performance expectations have been derived from in-building access points that take advantage of very short reflective signals bouncing around a room or building, as well as a wide RF channel with little interference.

The following 802.11n properties will be explored, offering a perspective on their benefits or limitations in an outdoor network:

Multiple Input Multiple Output (MIMO)

The 802.11n technology standard offers a variety of physical layer diversity mechanisms for achieving higher throughput and improved packet reception capability. Each 802.11n radio can have multiple transmit antennas and paths. Multiple spatial data streams can be transmitted at the same time, on the same channel, but by different antennas. The data streams can be combined from multiple receivers using advanced signal processing. When discussing 802.11n or MIMO networks, three numbers are typically referenced – the first is the number of transmit antennas, the second is the number of receive antennas and the third is the number of spatial streams. For example, a 3x3:2 system has three transmit signals, three receive signals and two spatial streams.

Cyclic Shift Diversity (CSD)

Transmitting from a single antenna can lead to areas with unexpectedly poor coverage. This coverage "null" or deep fade can be caused by interference, multi-path errors or general obstructions. 802.11n allows for multiple transmitting antennas, with each broadcasting the same data with slight delays. The most effective systems will use multiple antenna polarities to send out different versions of the same signal. The client devices will hear different signals strongest in different parts of the coverage area, and use the best available signal for communications. This results in more uniform coverage and generally higher data rates throughout the coverage area.

Maximal Ratio Combining (MRC)

In public access and municipal networks, client coverage is often limited by the uplink connection of the client to the access point. Network clients typically include low powered devices – smart phones, laptops, and PDAs – limited by the strength of their transmitting radios due to size, cost and battery life. MRC utilizes multiple receive

antennas to reconstruct signals, thereby reducing error probabilities and re-transmissions, allowing clients to be "heard" better.

Spatial Multiplexing

Spatial Multiplexing allows data to be split and transmitted via two independent data streams using spatial separation of signals by antennas, effectively doubling the throughput of a wireless channel. Using different signals mitigates interference and improves throughput. However, the capability to send parallel data streams depends on the environment. Indoor 802.11n gains from Spatial Multiplexing use multi-path from the building walls to achieve a very high spatial separation when the signals arrive at the receiver out of phase. However, in outdoor environments it is difficult to create enough separation among the antenna signals to provide parallel data streams to support Spatial Multiplexing.

2. Channel Bonding

802.11n introduces two different channel bandwidths: 20 MHz and 40 MHz. By combining two adjacent 20 MHz channels into a single 40 MHz channel, 802.11n doubles the available data rate. Channel bonding is most effective in the 5 GHz frequency given the greater number of available channels. 5 GHz has 24 non-overlapping channels separated by 20 MHz. This allows up to 12 non-overlapping 40 MHz channels. The 2.4 GHz frequency has only 3 non-overlapping 20 MHz channels. Therefore, bonding two 20 MHz channels uses two thirds of the total frequency capacity in the 2.4 MHz spectrum.

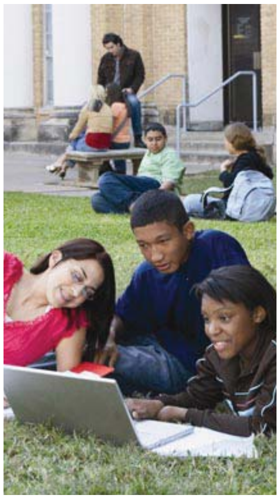
3. Frame Aggregation

802.11n provides an option of combining multiple data frames ready for transmission into an aggregate frame. This helps channel contention and backhaul delays by transmitting the aggregated frame in a single transmission on the channel.

The User Benefits of 802.11n Technology

The key advantages offered by 802.11n lie equally in the high bandwidth applications it enables as well as the vastly improved network performance it delivers. The latest applications require higher data rates, reliable links and predictable performance to realize their full potential. Video, for example, is having a profound effect on the way people communicate and consume information and has a dramatic impact on public access network infrastructure needs and performance. It is estimated that video is now approximately one-quarter of all consumer Internet traffic. In addition, video is a critical capability in public safety, transportation and industrial markets, with real-time surveillance being the primary driver. MIMO technology as well as frame aggregation are beneficial in enabling the transmission of superior video quality. MIMO enables faster download capabilities, reduced interference and enhanced connectivity while frame aggregation ensures content is combined to support streaming video.

Municipalities stand to benefit greatly from investing in a joint 802.11n network, allowing multiple departments – public safety, public works, department of transportation, etc. – to share access and associated costs. A key technology of 802.11n, Spatial Multiplexing, can effectively double the throughput of a wireless channel; allowing more applications



from multiple departments to run simultaneously. Additionally, channel bonding increases the performance of the network. Network users are not required to upgrade legacy 802.11a/b/g clients to new 802.11n clients, as 802.11n networks are backwards compatible with 802.11a/b/g clients. Some aspects of 802.11 technology, such as multi-antenna MRC, can benefit legacy 802.11 a/b/g client performance as well.

The number of devices required to cover an area and the overall cost to deploy a network are important criteria as CIOs and IT managers calculate their potential return on the network and total cost of ownership. Increasing the transmit power will lower the number of access points required per square mile and will decrease deployment as well as ongoing operational costs. Additionally, designing networks for multiple uses enables costs to be shared among many different departments over the long-term.

Maximizing 802.11n Benefits Outdoors

As highlighted in the technology enhancement descriptions above, achieving the full benefit of 802.11n requires a number of elements working together to reach the high data rates and capacities promised by 11n technology. As a result, network designers and planners must consider the network as well as the capabilities of the access points that will be deployed. Without such understanding, the investment in an 802.11n network may yield only minor improvements over 802.11a/b/g offerings.

There are three primary benefits network designers want to achieve:

1. Better Client Coverage

Today, the number of access points required in a network is largely determined by the ability of the network access points to "hear" the client devices. Better uplinks from clients will reduce the number of nodes required, which reduces not only the equipment costs but site acquisition, installation and ongoing maintenance costs. A network with fewer nodes is easier to deploy and maintain.

2. Stronger Mesh Layer Connections

If better client coverage allows for fewer access points to create the same coverage, then the connections between the nodes – the mesh itself – needs to support the same separation. Without advancements in the mesh layer technology, the mesh nodes will have to be deployed at the same density as they are today, so there is little to no gain from better client connections. The mesh layer has to be capable of the same separation enabled by strong client connections.

3. Higher Mesh Capacity

The data rate offered to 11n subscriber units can be outstanding – it's possible to provide a 100 Mbps connection or more to a client. But the fastest client connection is worth nothing unless the mesh layer of the network can provide the same or greater speed connection back to the wired network. Network designers know that the true 'capacity' of their network is determined at the mesh layer, and harnessing the power of 11n connections between nodes is critically important.

Motorola's Mesh Solution for the Outdoor 802.11n Market

Motorola developed specific technology for our next generation 802.11n access point, the AP 7181. This technology was designed from the ground up to meet the needs of wide area networks, supporting high capacity video and highway-speed mobility.

RF Antenna Design

Motorola designed an antenna system that takes advantage of polarization diversity to increase the probability for parallel data paths in an outdoor environment. This enables the access point to achieve higher data rates (up to 300 Mbps) in 802.11n. Getting the second data stream to support the high throughput can only be realized through high transmit power and a smart antenna design. Most wireless 802.11n access points today transmit using vertical dipole antennas (sticks). These antennas use only vertically polarized transmissions, effectively limiting the access point to a single spatial stream. Motorola's solution uses both vertical and horizontal polarizations to deliver higher data rates and greater range compared to a system that uses only a single polarization. The MRC algorithm in the AP 7181 optimally combines signals with different polarizations. The system can use the dual polarizations to lower interference from other networks or to deliver parallel streams in an outdoor environment.

Ideally each radio in the access point would have multiple transmit and receive antennas, with both vertical and horizontal polarization. With three radios, and three antennas per radio, there could potentially be nine antennas sticking out of the node. Motorola has developed a way to combine 24 antennas, using no external dipole sticks.

High Transmit Power Radios

Indoor access points are limited to 100 mWatts compared to outdoor units that are allowed to transmit as high as 1 watt. The FCC has recognized that outdoor networks require increased power levels in order for access points to effectively support backhaul links over increased distances. Higher radio transmit power enables stronger client connections and stronger mesh connections, which result in more consistent and faster data speeds. An access point with a transmit power of 100 mWatts (20 dBm) will offer only 10 percent of the power of an access point with a transmit power of 1 watt (30 dBm). Lower power access points can require two to four times the number of nodes to cover a given geographical area.

Manufacturing radios that transmit clean signals at high power rates is difficult. Developing radios that transmit clean signals at high data rates and high power is even more challenging. Most vendors will trade data rates for power – the highest power outputs are only seen at the very lowest data rates. Motorola has developed new radios for the AP 7181 that maintain high power transmissions even at the highest data rates. This enables the full benefits of strong connections, especially in meshing layer communications.

Introducing Motorola's Next Generation Platform, AP 7181

Motorola developed the AP 7181 to harness the full capabilities of 802.11n technology. Leveraging its ADEPT (ADvanced Element Panel Technology) state-of-the-art antenna technology, AP 7181 achieves maximum data rates by delivering a reliable dual data stream in an outdoor environment. The integrated ADEPT antenna system overcomes the limitations of multiple antenna sticks in a typical 11n access point. This improved antenna system takes advantage of polarization diversity and increases the probability of parallel data paths enabling multiple spatial data streams – a key design factor for enabling the higher data rates in 802.11n. ADEPT implements a 3X3 MIMO solution that ensures Spatial Multiplexing and high data rates while providing a full omni-directional pattern at maximum power levels.

Paired with Motorola's new high-powered radios, the access point offers maximum coverage, throughput and network capacity to support network demands for years to come. Figures 1 and 2 compare the performance of multiple stick antennas to Motorola's ADEPT design.

Figure 1 Traditional OMNI Sticks Antennas

Figure 1 depicts traditional OMNI stick-based access points resulting in a "self shadowing" coverage pattern, where nearby antennas shade or notch the desired omni-directional antenna pattern leading to unpredictable coverage holes.

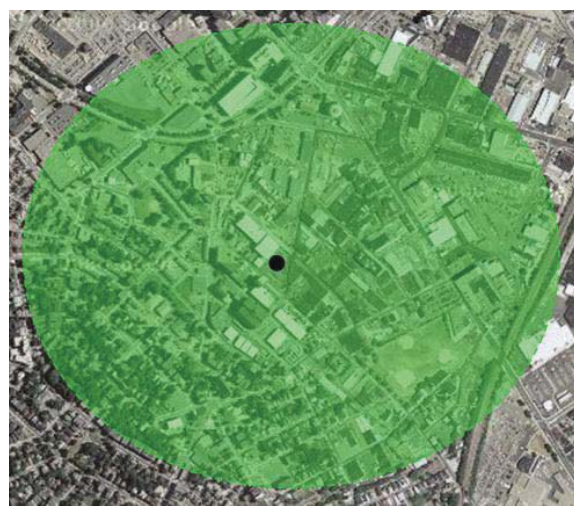


Figure 2 Motorola's ADEPT Antennas

Figure 2 highlights Motorola's ADEPT system, which provides true omni-directional coverage for predictable deployments and reliable connections.

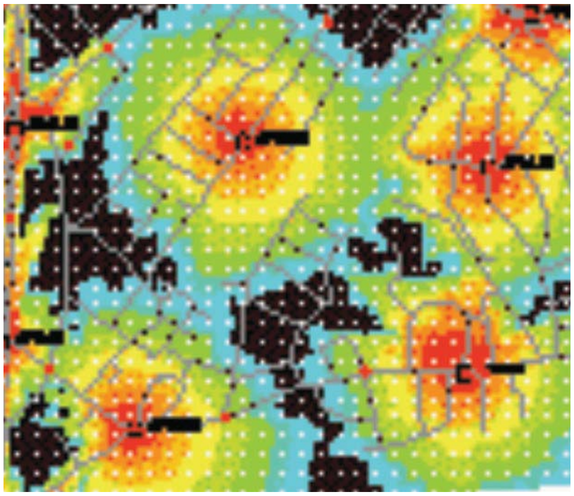


Figure 3 802.11g System Coverage

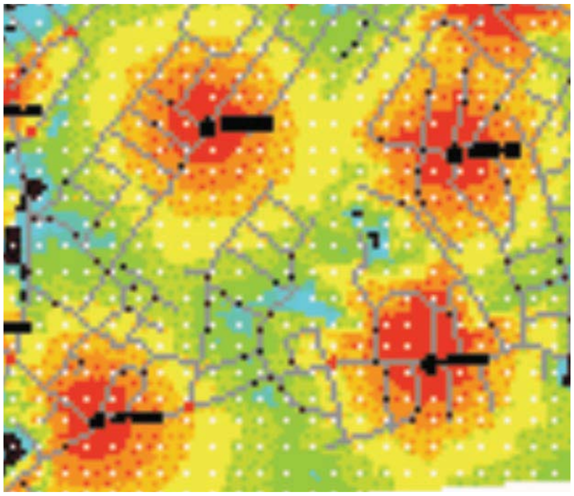


Figure 4 Motorola 802.11n System Coverage

Figures 3 and 4 show relative coverage for 802.11g and Motorola's outdoor 802.11n solution. The dark areas in the coverage map depict areas with no usable signal strength. Even when legacy 802.11g access points are deployed closer to each other, some areas are left with no coverage. Network designs completed with sophisticated planning tools, such as Motorola's One Point Wireless Suite, reveal that 802.11g systems require 52 percent more access points to cover the same area compared to Motorola's outdoor 802.11n technology.

A Whole New View of Outdoor Wireless

Technology evolves rapidly in the wireless space. In 2009, many of the WiFi-enabled clients sold will feature 802.11n-capable radios. Demand for 802.11n networks will continue to grow as private, enterprise and public network operators look to protect their IT investments for refresh and expansion to new applications with greater range, simplified deployments and AP's that provide highly reliable, predictable coverage and optimize the performance of legacy devices.

Successful 802.11n deployments will require an in-depth understanding of the outdoor wireless environment, and advanced RF design tools to ensure long-term network performance, reliability and cost effectiveness. The expertise and ability to manage indoor and outdoor integrated communications networks is also a critical capability with the capacity that 802.11n technology brings.

As with any new innovation, the full adoption of MIMO and 802.11n technology will take time and bring a whole new tier of products and applications to market that will fundamentally change the way we work and communicate. Motorola intends to lead that innovation with products that reflect superior design and engineering, deliver reliable performance at a lower cost, exceed customer expectations and deliver rapid ROI.

About Motorola Wireless Broadband

Motorola's comprehensive portfolio of reliable and cost-effective wireless broadband solutions together with our WLAN solutions provide and extend coverage both indoors and outdoors. The Motorola Wireless Broadband portfolio offers high-speed Point-to-Point, Point-to-Multipoint, Mesh, Wi-Fi and WiMAX networks that support data, voice and video communications, enabling a broad range of fixed and mobile applications for public and private systems. With Motorola's innovative software solutions, customers can design, deploy and manage a broadband network, maximizing uptime and reliability while lowering installation costs.

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