Comparison of MeshNetworks Enabled Architecture (MEA®) and Quadrature Division Multiple Access (QDMA®) radio system with 802.11 based technology for Use in Wide Area Mobile Broadband Networks

As the need for cost-effective wide area mobile broadband communications continues to grow the question arises as to whether it is better to adopt earlier wireless technologies orginally designed for non-mobile, short range communications, or whether to use more recently developed technologies specifically designed for wide area mobile communications. This analysis specifically compares the differences in capabilities, functionality and performance between the use of 802.11 WLAN technology and MeshNetworks MEA/QDMA mobile broadband solutions

Introduction

As municipalities, law enforcement and homeland security agencies begin to deploy explore the deployment of broadband wireless networks, questions arise regarding the technology choices available and the differentiators between them. In particular, these agencies have asked MeshNetworks to compare and contrast its MEA/QDMA solution with both standard and meshed 802.11 based offerings.

This paper sets out to describe the similarities and the differences between these alternatives as well as providing some recommendations based on the agencies objectives, functionality desired and the role the network will play in daily and incident communications.

802.11 Radio Technology Overview

Designed to replace the wire between the LAN port in the wall and the desktop computer, the IEEE created the 802.11 wireless LAN standard as the logical extension of 802.3-based wired Ethernet networks. 802.11 specifies an *over the air* interface between a client and a base station or Access Point (AP), as well as an interface between two client devices. The original intent for this technology was to simplify physical connectivity between stationary users and wired LANs via a wireless protocol.

The network topology chosen was a typical wireless point to point (between clients) and point to multipoint architecture, (more commonly known as 'hub and spoke'), where one AP talks to multiple clients.

The 802.11 standard has evolved over the years, offering increased data modulation rates. However, the original and most popular version, 802.11b, is also the version used almost exclusively for outdoor deployments due to its generally better range and coverage. The ".b" standard utilizes a Direct Sequence Spread Spectrum (DSSS) modulation operating in the ISM II band of 2.4 GHz. There are 11 possible radio channels, though there are only three non-overlapping (i.e. non-interfering) available.

The maximum raw data rate is 11 Mbps, though in reality the best data throughput rate a user will see is around 5 Mbps even in an ideal scenario. Sustained throughput rates will be between 500Kbps and 2Mbps depending on range, interference conditions and number of users in an area. Finally 802.11b (in fact all versions of 802.11) operate via a single channel Medium Access Control (MAC) layer. This means that one radio channel is used for all users on an AP and that this channel also carriers all system overhead, signaling and user data payload within the same channel.

QDMA Radio Technology Overview

There are several similarities between the 802.11b and MeshNetworks' (QDMA) radio platform. Both are DSSS radios, operate in the 2.4GHz ISM band and provide wireless broadband data rates. However unlike 802.11 which was designed for a stationary indoor environment, QDMA was designed for a much more demanding application.

QDMA was born out of a DARPA project for battlefield communications. Requirements included end-to-end IP support, high-speed user mobility and optimization for use in a multi-hop meshed network architecture. The radio had to support a self-forming self-healing routing protocol and be optimized for a high data density (bits/Km^2). The system would also have to be capable of supporting real-time voice, data video and position location information under highly hostile physical and RF conditions.

To this end, the QDMA radio supports low latency, end to end IP connectivity for users traveling at speeds in excess of 250mph. It also supports raw burst data rates of up to 8Mbps, with the demonstrated capability of supporting throughput of 1.3Mbps at speeds of over 80 mph.

In addition to these basic capabilities, the QDMA radio has been specifically optimized to support highly scaleable, wide area mobile broadband meshed networks. As part of this optimization and in direct contrast to 802.11-based systems, the QDMA radio leverages a multi-channel Medium Access Control (MAC) architecture. This enables the overall wireless network and each individual radio to transmit and receive on four separate, non-interfering 20 MHz channels. One is designated as the control channel

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and carries the network signaling that coordinates user traffic, network management and position-location information between radios. The other three channels are dedicated to carrying user's data payload. Radios can select the best of the three data channel to use on a packet by packet basis. This allows different radio pairs to simultaneously communicate while in close proximity to each other, since each radio can dynamically select (and co-ordinate) the use of multiple data channels. This increases data transmission density and spectrum efficiency in the MEA network. The multi-channel operation of the MEA network also enables every radio to mitigate and proactively deal with local radio interference caused by MEA or other devices operating within the 2.4 GHz band.

Another differentiator between QDMA and 802.11 protocols is that QDMA incorporates position-location technology directly in the radio. By gathering time-of-flight and triangulation information from neighboring devices, location information can be mapped without the need for GPS equipment. Accurate location information is available within buildings, canyons and tunnels, places where GPS doesn't work.

Specific MEA/QDMA Advantages

High-Speed Mobility Support

Mobility has become an increasingly important requirement for wireless broadband access. The ability to deliver DSL-like speeds when using computing devices in fast moving vehicles is currently in high demand, yet no 802.11-based system can meet this requirement.

Though it is common to see the word "mobility' used with 802.11, the fact is that vendors are stretching definition of mobility to suit the limitations of the technology. 802.11 supports walking speed mobility fairly reliably, and up to 30 Mph under favorable conditions. Because of this, information regarding 802.11 based wide area networks mention "session persistence" and "roaming" between APs. This means that connectivity to the network is not maintained when driving between APs. However once you stop or slow to a crawl, the network will likely be able reconnect to the client device. Since the network is disconnected while the client is traveling using Voice over IP (VoIP) or sending/receiving data or video comes to a halt while the client is moving at driving speeds.

However MeshNetworks (and US defense agencies) specifically chose to utilize QDMA radio technology over 802.11 because QDMA was designed and optimized for high speed mobility. QDMA will maintain connectivity with clients moving at speeds of up to 250 Mph. The ability to maintain broadband links while at high speeds is why a MeshNetworks supplied solution is being used on racing cars in the Indy Racing League (IRL). To date it is the only solution to provide constant, always on, communications to and from the car over 100% of the track. Even in these harsh racing conditions, broadband data still flows at 230 Mph.

MeshNetworks support for high-speed mobility goes beyond its use of the QDMA radio. An important aspect of mobility (particularly in a meshed network architecture) is the ability to make ultra-fast routing decisions and end-to-end link selections. MEA's high performance routing engine operates at Layer 2 in the software stack (as opposed to Layer 3 or higher in competitive 802.11 based systems), which enables interaction directly with the radio interface at Layer 1. This permits a response to the changes in the RF environment, network topology, and congestion/interference conditions on a packet by packet basis.

The combination of the mobility optimized QDMA radio and MEA routing technology creates a wireless broadband system that offers continuous connectivity and smooth handoff between APs. In comparison, 802.11-based meshed systems offer neither high-speed connectivity nor smooth handoff between APs.

Robust Outdoor WAN Deployment

Real world deployments provide a harsh testing ground for wireless broadband technologies. Free space interference, Multipath and Raleigh fading are only a few of the conditions radios systems face in a wide area mobile data networks. It is important that the technology chosen for are capable of effectively dealing with so that they can deliver on promised performance and reliability.

The 2.4 GHz ISM band is unlicensed, so there is a risk of interference from other devices operating at these frequencies. To deal with this, MEA's multi-channel MAC enables the system to select from up to three available data channels. This enables any node in the network to deal with local interference, without impacting the overall performance of the network. MEA devices intelligently negotiate channels between themselves, to minimize both self-interference within the system, as well as interference caused by non-MEA devices.

High performance routing also plays a role mitigating interference in a MEA system. New routes can be instantly selected if interference or congestion lowers the availability of node or path through the network.

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Other conditions encountered in wide area outdoor deployments like Multipath and Raleigh fading cause RF conditions to change and resemble those of high speed mobility scenarios, even when users and nodes are stationary. Changes in the physical environment (such as a truck driving by, tree branches moving etc.) are common causes of these effects. 802.11has not been optimized to deal with these issues. Conversely, QDMA was built with these conditions in mind. The result is a highly robust radio link and network topology that provides better performance in harsh environments.

Optimized for Mobile Mesh Architecture

Two types of Meshed Networks exist today - fixed and mobile. These terms refer to the systems ability to support connectivity to users or other devices while they are in motion, typically at highway speeds or faster. Fixed meshes required the user to be stationary or moving very slowly. In many cases these systems do not support handoff between APs even at walking speeds.

Given its inherent limitations, 802.11 is typically used for fixed infrastructure meshed networks, between the stationery APs. Clients use standard Wi-Fi PC cards that do not directly support any meshing. These client cards communicate in a direct point-to-point manner with the Access Points. This lack of meshing capability at the client level has other implications that will be addressed in later parts of this document.

WiFi's single channel MAC also limits its efficiency in a mesh deployment. It is true that neighboring APs can be configured with different channels. Unfortunately, this will cause the client to drop its existing AP connection, rescan for the new channel and attempt to reconnect with the network as it moves into the coverage area of the next AP. This process can take from 10 seconds to 30 seconds each time. Given this, using multiple channels in wide area 802.11 based systems is rarely done. Yet a single shared channel drastically limits the number of simultaneous conversations that can occur. Supporting multiple simultaneous conversations is critical to the scalability and performance of a mesh network.

It is for this reason that the original QDMA specification was developed with a multi-channel MAC optimized for mesh network architecture. Multiple simultaneous conversations can occur between neighboring nodes since each pair can instantly select from three non-interfering bearer channels. The common control channel coordinates data channel assignment across neighboring user pairs, further increasing the performance of the wireless network.

Supports Infrastructure and Ad Hoc Meshing

Mesh networks can be further delineated in to those that only support meshing between APs (infrastructure meshing) and those that also empower client nodes to form meshed connections (ad hoc client meshing).

MEA technology supports both infrastructure and client meshing. MEA's infrastructure meshing creates a robust and scalable network, while client meshing enables end users to instantly form a broadband wireless network between each other – with or without the inclusion of network infrastructure. In fact, MeshNetworks Multi-Hopping® technology can turn every client device into a router/repeater. As users join the network they improve network coverage and increase network throughput. MEA networking is unique in that it supports "continuous meshing." That is, it supports simultaneous operation of infrastructure and client meshing while it also allows clients to move seamlessly between infrastructure-based and client-based peer-to-peer networks. Users such as first responders can instantly create a meshed broadband network at an incident, simply by turning their MEA radios. No preexisting or predeployed network infrastructure is required.

802.11 on the other hand has two distinct and separate modes of operation; infrastructure (used talking to APs) and ad hoc (talking to other clients). These are separate modes and can not both be activated at the same time, therefore 802.11 based systems can only operate in either infrastructure or ad hoc modes. No wide area meshed 802.11 based solution offers the ability to mesh clients or have them assist in enhancing the network infrastructure. Instant meshed broadband networks between clients are not supported. There are some meshed solutions that support client to client meshing, however these solutions do not support and infrastructure mode and are capable of only small ad hoc meshing groups.

Additional MEA Technology Highlights

MeshNetworks Scaleable Routing (MSR™)

At the heart of MeshNetworks high performance networking technology is an efficient and scalable routing protocol designed specifically for use in Multi-Hopping wireless mesh networks – the MeshNetworks Scalable Routing (MSR™) protocol. The MSR protocol is designed to work efficiently with or without centralized wireless infrastructure equipment (i.e. wired APs or stations), which enables nodes to seamlessly transition between infrastructure and client-based ad hoc networks.

MSR technology enables dynamic, self-forming, self-healing, Multi-Hopping routing between participating nodes in a MEA network. The MSR protocol is a hybrid routing approach that leverages proactive and reactive routing techniques via situation-aware networking. With this methodology, network topology dynamics, local RF conditions and degree of client mobility influence the routing metrics used on a moment by moment basis.

The MSR protocol is self-optimizing and delivers ultra-fast route convergence for mobile or RF hostile networks, while minimizing overhead on a per node and system wide basis. This unique technique reduces the flooding overhead and latency usually associated with the route discovery process of classical reactive protocols, as well as the high routing overhead usually associated with classical proactive protocols. The situation-aware routing algorithms used in the MSR protocol greatly enhance the scalability of the network, while supporting high mobility in real world, wide area networks. In addition, the algorithms used have been demonstrated to be free of routing loops in all topology and network conditions.

Adaptive Transmission Protocol (ATP™)

Many possible environmental conditions can interfere with data transmitted wirelessly. This is particularly true of broadband data in high speed mobility situations. Multipath, shadowing, fast fading and interference (both intentional and unintentional) can all cause excessive packet loss at the receiver.

To deal with these conditions, the transmitting node will be instructed to back down its data rate for a period of time. However, these adverse RF conditions can appear on a highly dynamic basis. If the data rate is decreased for longer than the condition exists, link reliability may be satisfactory, but throughput is not maximized. If the data rate is raised too quickly while the condition continues, the resulting packet loss can also lead to poor data throughput. The purpose of ATP services is to enable the MSR protocol to balance the requirements of a reliable transmission while assuring the highest data throughput rate possible on a packet by packet basis.

MeshNetworks Positioning System (MPS™)

MPS technology offers 3-D position, location and tracking capabilities without the use of GPS Satellites. MPS leverages patented position location and determination methods built into the QDMA radio, as well as sophisticated, but CPU efficient, heuristic processing. MPS enhanced products allow determination of your own position or the position of any other user. Position location information, accurate to within +/- 10 meters, is generated in less than one second at mobility speeds of up to 250 mph.

Since MPS doesn't rely on satellites, it works in both exterior and interior locations where GPS will not. Position location is determined utilizing sophisticated time of flight and triangulation information by using other devices in the network as reference points. These features are available in both infrastructure and ad hoc client networks. Unique and powerful applications for military, public safety, telematics and m-commerce applications can be built with MPS products and technologies.

A Word on Standards

No standards for meshed 802.11 networking exist today. However, MeshNetworks has been instrumental in the formation and activities of the new 802.11s mesh networking group at the IEEE. This group is tasked with creating an open standard for use with 802.11 radio systems. Until such time as the standard is ratified (2 to 4 years), there is no such thing as a standard 802.11-based mesh solution.

Several vendors are claiming they are "based on standards" which to some extent is true. However these vendors fail to point out that the only standard and interoperable equipment used in their solutions is the client PC card, a small part of the overall solution and system cost. None of the 802.11-based mesh systems on the market today can interoperate or work together. All mesh vendors APs and wireless routers are proprietary, hence the drive for an IEEE standard.

In the same regard MEA is a proprietary technology. However, it is based on industry standard IP protocol for transparent support of new and existing internet-ready devices or applications.

In addition to the IEEE, MeshNetworks is heavily involved with the IETF and TIA in helping to move towards standards for meshed networks.

Conclusion

802.11 has revolutionized wireless networking in the last few years and has removed the need for wires to the desktop in most LAN settings. While 802.11 is a highly popular consumer and enterprise networking solution, it has inherent limitations that cripple its performance in wide area broadband applications. 802.11 has proven itself to be more suitable to "hot spot" deployments than to full coverage metro area deployments. These limitations are further exposed when 802.11 is used in a mobile mesh network. Nonetheless, several vendors are attempting to use 802.11 as the basis for a meshed wide area solution. Unfortunately, none of these systems are interoperable with each other.

As a response to this and other issues, the IEEE has formed the 802.11s working group to address the proliferations of proprietary 802.11 mesh solutions on the market. The focus of the group appears to be on developing solutions for home and enterprise applications, since wide area and mobile broadband networking are being taken up by separate groups outside of 802.11, namely the 802.16 and 802.20 groups.

MeshNetworks' MEA and QDMA technologies where originally developed to address the needs of a battlefield communications system. Each component and technology has been designed and optimized for mobile broadband delivery via a meshed network architecture. The result is a flexible and robust wireless solution for mission critical communications. MEA currently powers the world's largest mobile mesh networks in a variety of market segments, including public safety, public transportation, and municipal governments. Based on industry standard IP, MEA can support today's and tomorrows internet ready devices and applications.

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