Coexistence of MEA and 802.11b Networks

The number of RF devices operating in the second 2.4 GHz ISM band is growing rapidly. The increasingly widespread availability of devices such as 802.11b WLAN devices and Bluetooth Personal Area Networks raises concerns of how to maintain effective and reliable comunications as these technologies must gracefully coexist. MeshNetworks Enabled Architecture (MEA™) utilizes a unique multi-channel MAC protocol that makes efficient use of the second ISM band by dividing the spectrum into four separate channels. Each channel is used to route packets around high interference areas. Network operators who are concerned with interference can follow simple guidelines to maximize spectrum usage and enhance network performance.

Introduction

One of the most critical factors affecting the performance of wireless communications networks is the ability to operate in proximity to each other on the same frequency bands. This white paper will offer an explanation and supporting research results to demonstrate how MeshNetworks Enabled Architecture (MEA™) systems using MeshNetworks high performance Quadarature Division Multiple Access (QDMA®) mobile broadband radio technology and 802.11b systems can coexist while maintaining high levels of network performance.

The ISM Bands

The Industrial, Scientific and Medical (ISM) bands (900 - 928 MHz and 2.4000 - 2.4583 GHz) were set apart by the International Telecommunication Union for non-commercial use of the radio frequency spectrum. These bands are currently used for license-free digital communications applications. All MeshNetworks MEA/QDMA products operate in the second ISM band at 2.4 GHz. This band is also shared by 802.11b/g WLAN radios and Bluetooth based Personal Area Network (PAN) devices. In addition, the 2.4 GHz ISM band is the home for many narrowband radio devices such as cordless phones, wireless keyboards and infant monitors. It is essential that any radio operating in this crowded spectrum be able to gracefully coexist with other radios. In particular, a radio must be able to remain operational while exposed to other interfering devices.

Interference in the ISM Band

Interference occurs when two radios transmit at the same time within the same frequency spectrum. A receiving radio would then receive two signals; one desired and one undesired. If the energy of the undesired signal is much greater than the energy of the desired signal, then the receiving radio will experience interference and the transmission may fail. The interference experienced by a radio is, therefore, affected by three factors.

- First, the amount of frequency-overlap between the two transmitted signals will affect the interference levels.
- Secondly, the point in time at which the two signals are transmitted may result in time overlap and, hence, affect the interference levels.
- Thirdly, the energy of the desired signal relative to the energy of the undesired signal as seen by the receiver will affect the interference levels.

The effects of these various types of interference result in data packet collisions and eventually loss of data packets. When a data packet is lost, it must be retransmitted until it is successfully received. The need to retransmit data packets will affect the performance of the radio link and, ultimately, impact network latency, throughput and performance. The following section will introduce the QDMA multi-channel MAC and detail how a MEA system can mitigate the effects of interference by proactively avoiding areas of high interference.

The MEA/QDMA Channel

QDMA wireless technology incorporates a multi-channel MAC using four separate, non-overlapping channels. One channel is designated as the Control channel, and the remaining three channels are designated as Data channels. The Control channel coordinates all traffic between radios within a local region. The three data channels are used to send user data packets between radios.

Figure 1 illustrates the relative location of the Control channel and Data channels within the 2.4 GHz ISM band. Although the functional designation of any given channel can be configured by the MEA/QDMA network operator, the Control channel is typically placed at the high end of the ISM spectrum to minimize interference from popular 802.11b channels.

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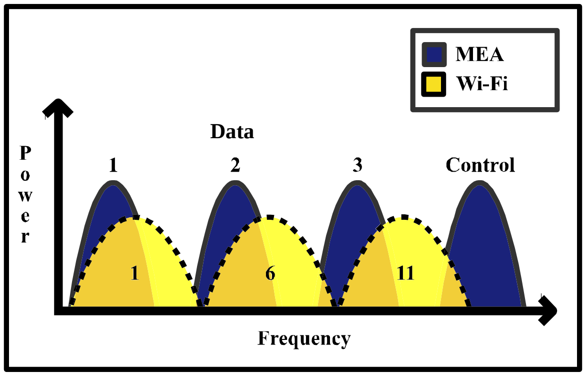

Figure 1. QDMA and 802.11b Channel Configuration

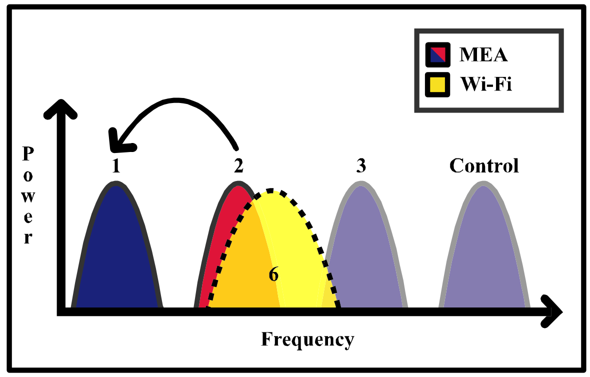

Figure 2. Dynamic Channel Allocation

Superimposed in Figure 1 are the most commonly used 802.11b/g channels. Notice that the presence of an 802.11b network will cause interference between the MEA network and the 802.11b/g network.

While an 802.11b/g radio is limited to operating within a given channel, the multi-channel QDMA radio in a MEA network has the option of using any Data channel for transmission. Intelligent real-time monitoring of the Control and Data channels allows a QDMA radio to employ Dynamic Channel Allocation (DCA) to select a Data channel, or "path", with the least interference. This allows data packets to be sent "around" areas of high congestion and interference. This ability to avoid interference allows a MEA/QDMA network to operate at a high level of performance even under severe conditions. Moreover, by avoiding problematic channel areas, the MEA/QDMA network also mitigates the impact on the collocated 802.11b/g network, hence, maintaining its network performance as well.

Figure 2 exemplifies how the DCA algorithm favors Data channel 1 over channel 2 because of the detected interference caused by the 802.11b/g network operating on channel 6. By avoiding Data channel 2, it is possible to maintain network performance in both networks.

A QDMA radio will adapt and select a data channel on a real-time basis based on local conditions. Therefore, it is possible for a widely deployed network to gracefully coexist with a number of 802.11b/g networks operating at various channel frequencies.

Interference in MEA/QDMA Networks

The effects of interference on the Control and Data channels serve to impede overall network performance. Although the types of interference are the same for both Control and Data channels, the effect on network performance differs slightly. Testing performed at MeshNetworks indicates that collocated MEA and 802.11b networks can both maintain a high level of network performance. Tests were structured so that there were high levels of frequency overlap between the two networks. This resulted in interference caused by frequency overlap as well as time overlap. The Packet Completion Rate (PCR) was used as a measure of success. The PCR is a measure of packet loss, so a high completion rate indicates a high network performance level.

Data Channel Collisions

Interference tests on the Data channel were conducted by measuring PCR on both a MEA/QDMA and 802.11b network. The 802.11b network was configured to operate on channel 1 so that maximum frequency overlap would occur with QDMA's channel 1. Figure 3 shows the frequency configurations and the frequency overlap between the MEA/QDMA and the 802.11b network.

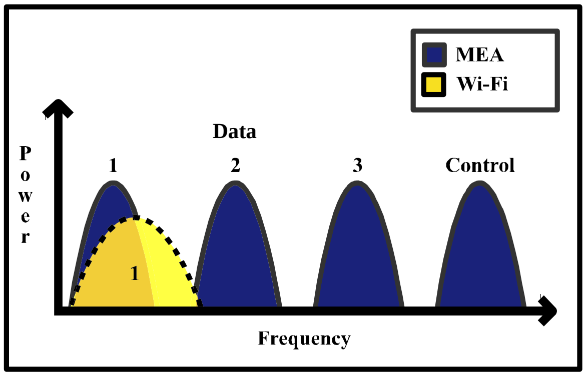

Figure 3. Data Channel Collisions

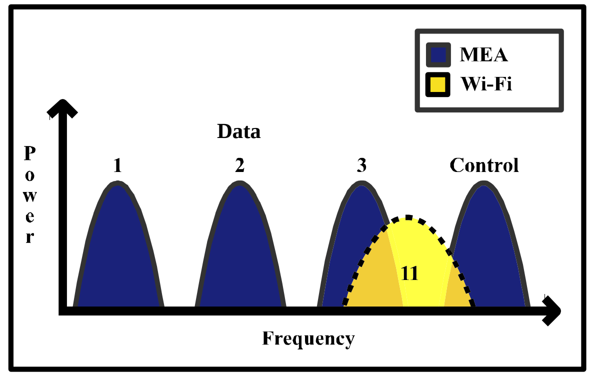

Figure 5. Control Channel Collisions

Figure 4 shows the Packet Completion Rate for varying levels of interference known as Signal to Interference Ratios (SIR). Clearly both networks operate at a near 100% packet completion rate for low interference levels (SIR > 20dB). Performance for both networks begins to drop at SIR levels of 20 dB. However, even at high interference levels (SIR = –20dB), the packet completion rate is still above 60% and both networks remain fully functional.

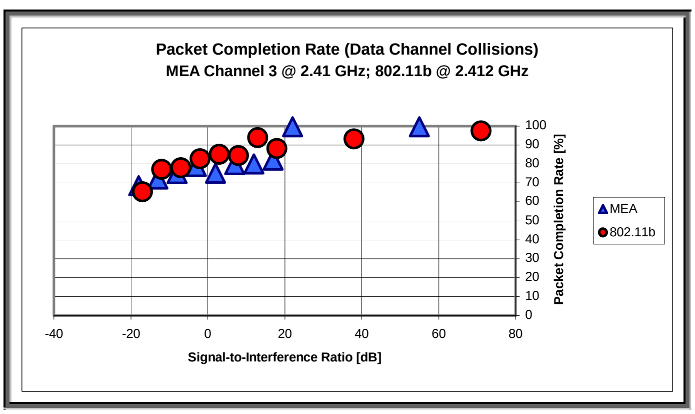

Figure 4. Packet Completion Rate (Data Channel Collisions)

Control Channel Collisions

Another common scenario is when a MEA/QDMA network is collocated with an 802.11b network operating on channel 11. This case results in partial frequency overlap between the 802.11b network and the QDMA Control channel. Figure 5 illustrates this scenario.

Figure 6 shows that each network operates with packet completion rates well above 90% at reasonable interference levels. As with the Data channel test, packet completion rates begin to drop as the SIR drops below 20 dB, and at severe interference levels, the packet completion rate for both networks approaches 50%. Although system performance is affected at severe interference levels, both networks remain fully functional.

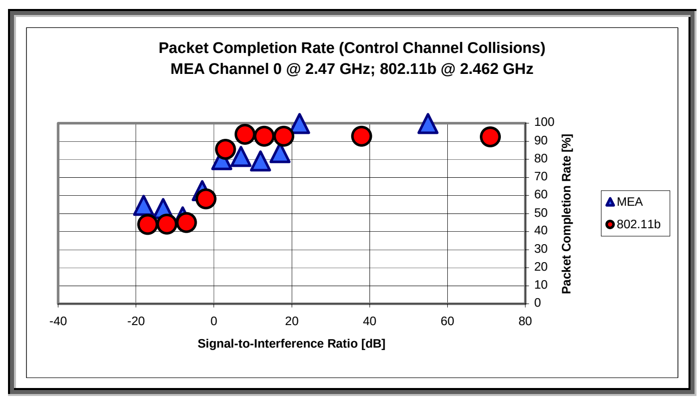

Figure 6. Packet Completion Rate (Control Channel Collisions)

Managing Network Interference

The previous section identified situations that resulted in packet loss and eventual system performance degradation. While both networks remain fully functional, MeshNetworks has developed network configuration and management methods to mitigate the negative impact of interference between networks.

Network performance will remain high if SIR levels are maintained at 10 dB or better. Three common methods of improving SIR levels are Dynamic Channel Allocation, Network Separation and Channel Blocking.

Dynamic Channel Allocation

The QDMA multi-channel MAC of a MEA radio operates on multiple channels. The MEA radio constantly monitors channel conditions. Therefore, intelligent decisions can be made in selecting which Data channel to use. By monitoring and being aware of the RF surroundings, DCA allows a QDMA radio to avoid data channels that are known to cause interference. Interference conditions are continuously monitored so that a Data channel may be immediately reused once it is determined that it no longer causes interference.

Physical Separation of Access Points

If interfering radios are sufficiently separated, then the undesired received interfering signal will contain a sufficiently small amount of energy. This small amount of energy is not sufficient to adversely affect the much stronger desired signal. As seen previously in Figures 4 and 6, an SIR level of 10 dB or better will yield packet completion rates well above 80%.

A simple equation based on free-space propagation can be used to provide an estimate of the signal-to-interference ratio, assuming that all radios transmit at the same power level.

$$SIR = 20 \times \log\left(\frac{d(STA, Noise\ source)}{d(STA, AP)}\right)$$

Here, *d(STA, noise source)* represents the distance from a client to an interfering source and *d(STA, AP)* represents the distance between a client and its access point.

As an example, if the access point is 20 feet away, then an SIR of 10 dB is maintained if the interfering source is located 65 feet away. By maintaining proper separation between QDMA and 802.11b/g access points, performance for both networks will remain near 100%.

Channel Blocking

In extreme circumstances, where interference levels are high due to access points being deployed in proximity to each other, it may not be possible to maintain the desired separation as demonstrated earlier. In this case, the MEA/QDMA network operator may choose to permanently block, or disable, a QDMA channel at the specific MEA/QDMA node that is exposed to very high levels of interference. Figure 7 illustrates this scenario.

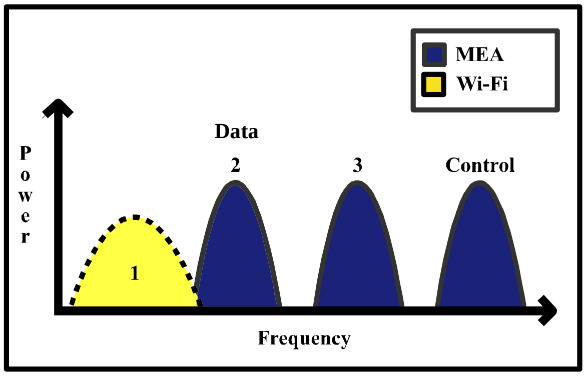

Figure 7. Channel Blocking

In this example, QDMA channel 1 is blocked for the node to avoid interference from 802.11b/g channel 1. The DCA algorithm will never request that MEA channel 1 be used for any data transfers to or from this node. Since there is no frequency overlap between the two networks, there will be no data packet collisions and both networks will operate at high packet completion rates. Note that all other nodes in the MEA/QDMA network can still use channel 1.

Conclusion

The MEA/QDMA Multi-channel MAC and channel blocking can be used together to handle interference in even the harshest of operating environments. DCA effectively bypasses the interfering networks and enables all networks (including surrounding 802.11b/g networks) to operate at a higher level of performance. By intelligently selecting or blocking channels, a QDMA based wireless network can maintain a high level of throughput and user access. These unique capabilities allow MEA/QDMA networks to be deployed in areas where multiple interfering 802.11b/g systems operate with little or no performance penalty.

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