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The Effect of Adding Radios on 802.11g Network Throughput

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INTRODUCTION

The performance of the network is a common concern when mixing low-speed stations with high-performance networks. In reality the performance impact is dependent on the specific network setup and traffic patterns. A common misconception in Wi-Fi networking is that adding an 802.11b station to an 802.11b/g network will bring the whole network down to 802.11b rates.

This application note describes a low volume of "b" traffic will not show perceptible impact on a "g" network and it also uses a mathematical proof to describe the affect of adding a low-data transfer 802.11b station and various radios onto an 802.11b/g network. In many cases the addition of an 802.11b station is not more detrimental to the network than adding another 802.11g station. In addition, while its bandwidth may reduce, the operating rate of the original 802.11g station is not affected by adding an 802.11b radio.

This analysis assumes only basic distributed coordination function (DCF) between stations that all hardware supports in Infrastructure mode. More efficient methods like point co-ordination functions or hybrid co-ordination functions (added to IEEE 802.11-2007) are not utilized. Such optimizations can be used to reduce the impact of certain traffic.

MODELING PROFILES

To facilitate the analysis a model is created that accounted for the protocol variation allowed in the 802.11b/g specification. The intent was to account for the carrier detect, distributed coordination function and also the collision avoidance mechanisms built into the specifications. These variations impact the bandwidth available to stations on the network. The impact randomizes the maximum bandwidth available for any channel due to the variable hold-off that it implements. All analysis was assumed on the Infrastructure Basic Service Set (IBSS) networks.

Setting up the Model

The model starts with a control station on an 802.11b/g network. The control case has only the control station connected wirelessly on the network. The model determines the maximum bandwidth capability of the following:

- Single control station on the network
- Multiple stations on the same network

Analyzing the Model

Initially, an 802.11g station is considered on the air connected to an Access Point (AP). The bandwidth of the 802.11g control station is calculated in 802.11b/g mode (no protection), and then with the optional CTS-to-self mechanism of protection. The calculations are then made for the following conditions to determine the impact to the control station. The data is listed as the bandwidth of the control station under the following conditions:

- Additional 802.11g stations are added to the same network without CTS-to-self.
- Additional 802.11g stations are added to the same network with CTS-to-self enabled.
- Additional 802.11b stations are added to the control network (1500B packets).
- Additional low bandwidth 802.11b stations are added to the control network (500B packets).
- Additional low bandwidth 802.11b stations are added to the control network (100B packets).

The packet sizes are configured as: 802.11g devices to continuously send 1500 byte packets, 802.11b devices to continuously send 500 byte packets, and low bandwidth devices to continuously send 100 byte packets. This continuous traffic is not realistic for a deeply embedded device that sends small packets occasionally, but it shows worst case impact.

802.11 THEORY OF OPERATION

The 802.11 specification defines that mixed 802.11b and 802.11g or other radios on a network will communicate to other agents on the network at the best rate each can achieve for the link. 802.11 relies on a carrier sense and multiple access physical protocol with collision avoidance (CSMA/CA) to share the airspace with multiple stations. The protocol has multiple bandwidths of operation available and are generally delineated as follows:

- 802.11, 802.11b, 802.11b/g, and 802.11b/g/n - operates with a 2.4GHz carrier
- 802.11a - operates with 5Ghz carrier
- 802.11n - operates with 2.4GHz or 5GHz carrier.

The difference in notation of 802.11g and 802.11b/g indicates whether a station is in 802.11g mode or in its default b/g mode, which supports the operation in a network with 802.11b and 802.11g stations. While on a common carrier (either 2.4GHz or 5GHz) and protocol, various bandwidth radios are supportable and each will communicate at its own rate. This can be up to 11 Mbps for the 802.11b stations, and simultaneously up to 54 Mbps for the 802.11b/g stations.

The basic 802.11 MAC has an optional protection mechanisms such as Request-to-send (RTS) mechanism and Clear-to-send (CTS) mechanism. These mechanisms minimize the wasted transmissions due to collisions, but incurs slightly larger overhead cost for all the transmissions.

Apart from the two stations doing the RTS/CTS handshake, stations can invoke this protection mechanism by sending a CTS frame to themselves. This CTS-to-self is heard by other stations and provides for a contention free period for the station to communicate. This behavior is used in this analysis to model the impact of CTS to a g-only station network. It is assumed that in this analysis the access points will automatically invoke the CTS-to-self collision avoidance mechanism when 802.11b radios enter the network, which originally had the single control 802.11b/g radio operating in ‘g’ mode. Table 1 provides the impact of multiple stations on a control radio.

TABLE 1: IMPACT OF MULTIPLE STATIONS ON A G RADIO

G RADIOS	Station 1 Capacity/ Throughput (Mbps)	Station 2 Capacity/ Throughput (Mbps)	Station 3 Capacity/ Throughput (Mbps)	Station 4 Capacity/ Throughput (Mbps)
802.11g + other ‘g’ stations	31.0	16.8	11.5	8.8
802.11g + other ‘g’ stations with CTS-to-self	23.1	13.3	9.3	7.2
802.11g + other ‘b’ stations	23.1	14.5	9.3	5.9
802.11g + other ‘b’ stations (500b packets)	23.1	18.2	12.2	7.9
802.11g + other Microchip ‘b’ stations (100b packets)	23.1	17.3	11.5	7.4

Analyzing the Results

This section describes the impact of the multiple stations on a ‘g’ radio, as shown in Table 1. The values have a +/-5% variation due to the random nature of the protocol. Station 1 shows the bandwidth of the single 802.11b/g station running in 802.11g mode when it is on the network by itself. In all cases this 802.11g radio is attempting to transmit 1500 byte packets continuously. Thus, we are analyzing the impact to an 802.11g radio that is attempting a maximum bandwidth application like video transfer and are as listed:

- **802.11g + other ‘g’ stations**: shows the impact to the control station operating at 802.11g mode when other 802.11g stations are added. The additional 802.11g radios are also modeled to be continuously transmitting 1500 byte packets.
- **802.11g + other ‘g’ stations with CTS-to-self**: Shows the impact to the control 802.11g radio when it starts using CTS by itself, and also the impact to its maximum bandwidth capability when other 802.11g radios are added to the network using CTS-to-self protection.
- **802.11g + other ‘b’ stations**: Shows the impact to the control 802.11g radio when 802.11b radios are added to the network. These radios are continuously transmitting 1500 byte packets.
- **802.11g + other ‘b’ stations (500B packets)**: Shows the impact to the control 802.11g radio when 802.11b radios are added to the network that are transmitting 500B packets continuously.
- **802.11g + other Microchip ‘b’ stations (100B packets)**: Shows the impact to the control 802.11g radio when 802.11b radios are added that are continuously transmitting 100 byte packets.

in the preceding list, the first two points are the actual bandwidth capabilities of the control 802.11g radio. The data shows that the best an 802.11g network can achieve is 30 Mbps (+/-5%) of throughput without CTS-to-self protection and 23 Mbps (+/-5%) using CTS-to-self collision avoidance. The next critical illustration is that the 802.11g radio does not revert to 802.11b rates in the case when 802.11b radios are added to the network.

The control radio bandwidth of 30 Mbps halves when a second 802.11g radio is added to the network. This effect is rarely noted when comparing the impact of adding an 802.11b radio. When viewing the impact of adding an 802.11b radio (row 3) that is competing with the 802.11g radio to send the same type of high bandwidth data, the difference in impact is declining of about 2 Mbps versus an equivalent affect with an 802.11g competitor.

Interestingly, when an 802.11b competitor is not sending jumbo 1500 byte packets, its impact to the 802.11g control radio is less than adding a 802.11g radio. This is seen in row 4 where the 802.11b radio is sending 500 byte packets allowing the 802.11g radio more opportunities to compete for the medium. This effect does not improve with smaller packets for the 802.11b in this study because this analysis has each radio constantly seeking to send packets. Thus, in row 5 the 802.11b radio is reducing the number of times the control radio gets the medium because the 802.11b radio has more packet requests due to the smaller packet size.

For deeply embedded applications, a radio does not continuously transmit packets. Therefore, the impact to the network shown in the Table 1 will only be for the small periods of time that the embedded appliance is transmitting. When no data is transmitted, the control radio will revert to 23 Mbps. The control radio will revert to 30 Mbps if the 802.11b station disassociates from the AP and turns off. About 10 Mbps of bandwidth is required for uncompressed digital video, thus even when a deeply embedded radio gets on the medium it will not affect the required data transmission or the user experience of watching an HD streaming video with an 802.11g radio.

CONCLUSION

802.11 is a multiple access shared medium protocol. This means that as additional clients get on the medium the overall bandwidth is shared amongst all. This analysis has highlighted that adding an 802.11b radio to a network with an 802.11g radio will not bring all traffic down to 802.11b rates. It has also shown that adding any radio to a wireless network can affect the available bandwidth to other users on the network.

The primary impact on the network is determined by what various clients are trying to do, not what traffic rate they are at. This means that the best technical and most economical solution will consider the fit of the radio usage to the type of application desired. This allows optimization of cost and also for bandwidth sharing efficiency. For high bandwidth continuous transfers, high bandwidth radios should be used. For low bandwidth infrequent transfers, slow radios like 802.11b are appropriate and economical. The result is a better cost and power fit with deeply embedded applications, and also it does not impact the network greater than a high end radio.

The impact on the performance of the network can be managed through the intelligent configuration of packet size and how often the device accesses the network. In addition, applications with bursty ‘b’ traffic are easily implemented in the mixed environment due to longer intervals between network access. As seen in other studies, it is critical that the applications using the radios appropriately use the medium for their communications needs.

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REVISION HISTORY

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This is the initial release of the document.

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