ATHEROS® COMMUNICATIONS

White Paper

Super G

Maximizing Wireless Performance

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Executive Summary

Wireless networking applications and services require an infrastructure that enables high bandwidth performance, ubiquitous coverage and robust delivery capability for WLAN products. While each market segment may have different application drivers and needs, all require these underlying infrastructure performance characteristics. In the home/SOHO arena, these needs are driven by the desire to transmit multimedia content, support multiple devices beyond the PC and distribute broadband content throughout a variety of structures. In an enterprise environment, application drivers include large scale backups, video and VoIP conferencing, and numbers of users that are orders of magnitude higher than home/SOHO. It is therefore critical that today's WLAN infrastructure constantly strives to meet and exceed standard bandwidth capabilities.

The critical WLAN infrastructure performance requirements fall into a couple of key areas that determine the quality of the wireless solution:

- Throughput—for bandwidth intensive applications and growing volume of users; need "wired" speeds
- Coverage—for connectivity at long range and in all corners of the home, office, enterprise, or hot spot

These requirements must also be addressed in a way that is easy for the user and/or administrator of the network to utilize and support. Atheros' Super G technology was designed to provide the highest possible throughput:

- Data rates of 108 Mbps
- More than double the throughput of today's standard offerings
- Typical end user throughput exceeding 60 Mbps

It is a portfolio of components that additively increase end user throughput to support the needs of today's WLAN applications. It was also designed to intelligently engage based on application need while adapting to its environment and has the further effect of greater throughput at longer range. It is able to maintain standards compliance while providing these unique benefits individually to those STAs and APs on a given network that can support this technology. Moving forward, it will continue to evolve to support emerging bandwidth hungry applications.

NOTE: Super G capabilities apply to 5 GHz as well as 2.4 GHz (Super AG).

Table 1-1 summarizes Super G's four independent features and benefits, which are described in detail later in this white paper. Benefits of all features include:

- Transparent operation with no user intervention required
- Enabled devices still remain standards-interoperable

Table 1-1. **Super G Feature Summary**

Feature	Characteristics	Benefit
Bursting	■ More data frames per given time period ■ Standards-based ■ Relevant to STA	■ Increase throughput via overhead reduction ■ 802.11e subset ■ Advantage applies to any AP
Compression	■ Real-time hardware data compression ■ Standards-based (Lempel Ziv)	■ Increased data throughput using compressed frames ■ No impact on host processor
Fast Frames	■ Utilizes frame aggregation and timing modifications	■ Increases throughput by transmitting more data per frame
Dynamic Turbo	■ Similar to trunking techniques used in Fast Ethernet networks, utilizes dual channels to “double” transmission rates ■ Analyzes environment and adjusts bandwidth utilization accordingly	■ Maximizes bandwidth using multiple channels ■ Environment-aware

Performance Needs of Wireless Networking Applications

Wireless networking applications continue to push the limits of standards-based throughput. Regardless of the medium or market segment, bandwidth hunger has historically been a constant for network applications. Further, the rapid adoption of WLAN among consumers and enterprise users spawns new networking applications that compound the need for increased bandwidth availability. Add to this the increasing number of wireless-enabled device types and the never-ending quest for bandwidth begins. This situation requires timely solutions over and above existing standards to keep pace with demand.

Home/SOHO

As shown in Figure 1-1, the need for bandwidth is nowhere more apparent than in the home. Many factors drive this, including:

- Desire by broadband providers to deliver value added services to home users. Cable broadband service providers deliver upwards of 3 Mbps with the capability of 30 Mbps to each home. Future requirements may include 1 High Definition video stream (20 Mbps), 2 MPEG2 streams (2-10 Mbps each), and 1 data channel (1 Mbps) to each home. Add in multiple VoIP lines and this easily exceeds standard 802.11a/g capabilities today for wireless distribution throughout the home!

- Emerging wireless-enabled digital consumer electronic devices. Among these are digital video recorders, DVD players, audio players, advanced cable/satellite set top boxes, flat panel televisions/monitors, and web tablets. All are poised for rapid growth and beg for connectivity to share high bandwidth audio/video content.

- The PC serves as a repository for data files, pictures, videos, mp3, etc. With multiple PCs desiring access to hefty files and the need to back up large amounts of digital content, rapid transmissions with "wire-like" speeds are critical.

This scenario is not uncommon. The wireless network must support the coexistence of multiple high bandwidth streams leveraging the same router/AP.

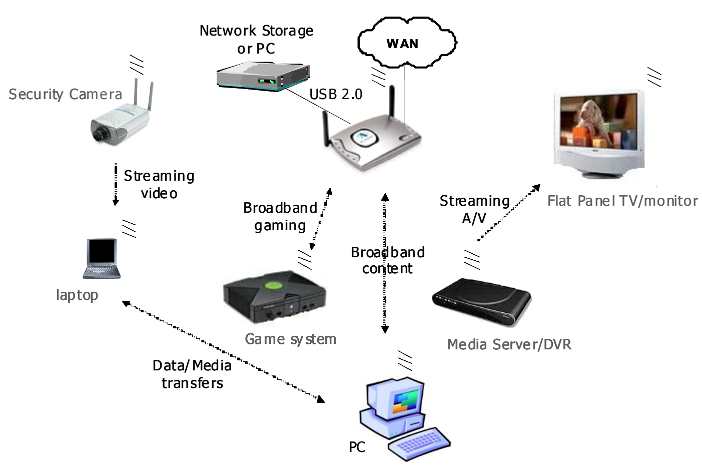


Figure 1-1. **Increasing Home Bandwidth Requirements**

Enterprise

Increasing adoption of WLAN within the corporate arena requires additional bandwidth support, particularly from APs. Figure 1-2 shows the factors driving enterprise bandwidth:

- Unlike the Home/SOHO environment, the ratio of stations to APs is decreasing rather than increasing due to increased deployment of APs in corporate settings and a mandated limit on the number of stations that can associate to an AP. This requirement ensures that stations can realize full bandwidth performance from a given AP, so it is critical that current APs can support the maximum bandwidth possible.
- Applications such as VoIP and video webcasting are much less forgiving to collisions from “best effort” traffic and other network anomalies. Excess bandwidth availability for these applications can address these issues effectively, especially in the absence of a standardized QoS mechanism.
- Escalating file sharing demands, such as large-scale backups and file transfers of growing amounts of media, require sustained “wire-like” speeds to be feasible.

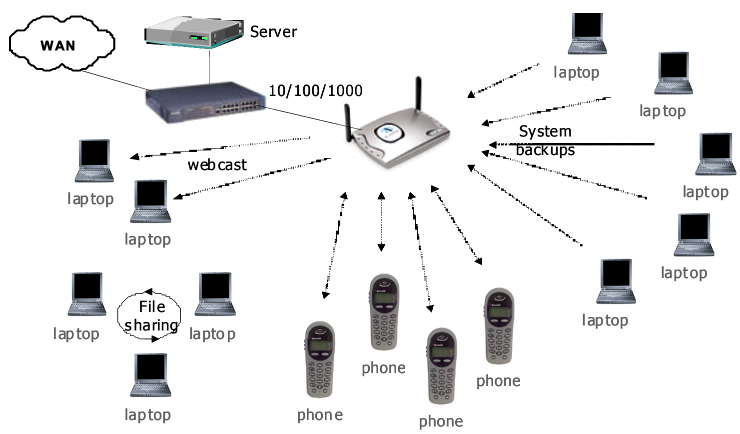


Figure 1-2. **Rising Enterprise Bandwidth Requirements**

Resulting Performance Requirements Common to Segments

- **Highest Possible Throughput**. This is the key WLAN networking requirement for today's applications. Emerging multimedia applications provided by consumer electronics and/or broadband providers must leverage the most bandwidth attainable. Existing PC based platforms must realize the best possible performance for “best effort” applications such as file transfers while maintaining standards compliance, especially as an increasing number of users share bandwidth.
- **Ease of Use**. Throughput enhancements allow standard devices to maintain communication while those STAs and APs take advantage of additional capabilities.
- **Seamless Upgrade**. As advances in throughput capabilities are realized, ideally these enhancements can be applied to existing hardware.
- **Environmental Awareness.** Ideally, the implementation has built-in intelligence to detect adjacent networks and adjust bandwidth allocation schemes accordingly.

Super G: Addresses High Bandwidth Requirements

Atheros' Super G is a series of intelligent mechanisms that engage when additional bandwidth is available and/or needed. It increases the actual end user throughput of an 802.11a/b/g network. These features include (1) bursting, (2) compression, (3) fast frames, and (4) Dynamic Turbo. These four capabilities operate independently to enhance the throughput of a network in different ways as follows:

- Atheros' Super G portfolio of bandwidth enhancements begins with the frame **bursting** mechanisms. This technique allows a transmitting device to send multiple frames in a "burst" rather than pause after each one. In other words, more information is transmitted during each transmission opportunity for a given station before that station defers access. Benefits of bursting are available to any station capable of this regardless of the associated AP.

- Super G further provides throughput benefits through **fast frames**. While bursting increases the number of frames transmitted in a given transmission opportunity, fast frames allows for more information per frame to be transmitted. Rather than restrict frames to the standard size, the frame size can be negotiated between a transmitter and receiver, thus maximizing efficiency via less overhead. This requires an AP that supports fast frames.

- In addition, link-level hardware **compression** more efficiently utilizes the wireless connection to further maximize bandwidth. This compression is implemented on a per frame basis and affects only data frames. The concept is similar to that used in common data file compression utilities such as WinZip. This also requires an AP that supports compression.

- Finally, **Dynamic Turbo** can dynamically provide a significant boost in bandwidth capability when required by very demanding applications. Without modification from the user, Dynamic Turbo can activate and double the realized bandwidth by leveraging 2 channels as one.

The user level TCP/IP performance of a Super G system is always significantly better than designs that only implement one performance feature, such as bursting-only, though actual performance will vary according to the type of data transmitted (IP data, video, voice, etc.), manufacturer-specific customizations, and the network environment. Super G is supported in chipsets that are fully interoperable with other 802.11a, b, or g products, and the user has the optional capability to enable or disable Super G features in the GUI. The features operate transparently to the user, the network, and the operating system, providing increased throughput in an on-demand basis. A wireless node can communicate on a link-by-link basis with both products that support and that do not support these features. Figure 1-3 displays how these features form the building blocks for a superior performance solution.

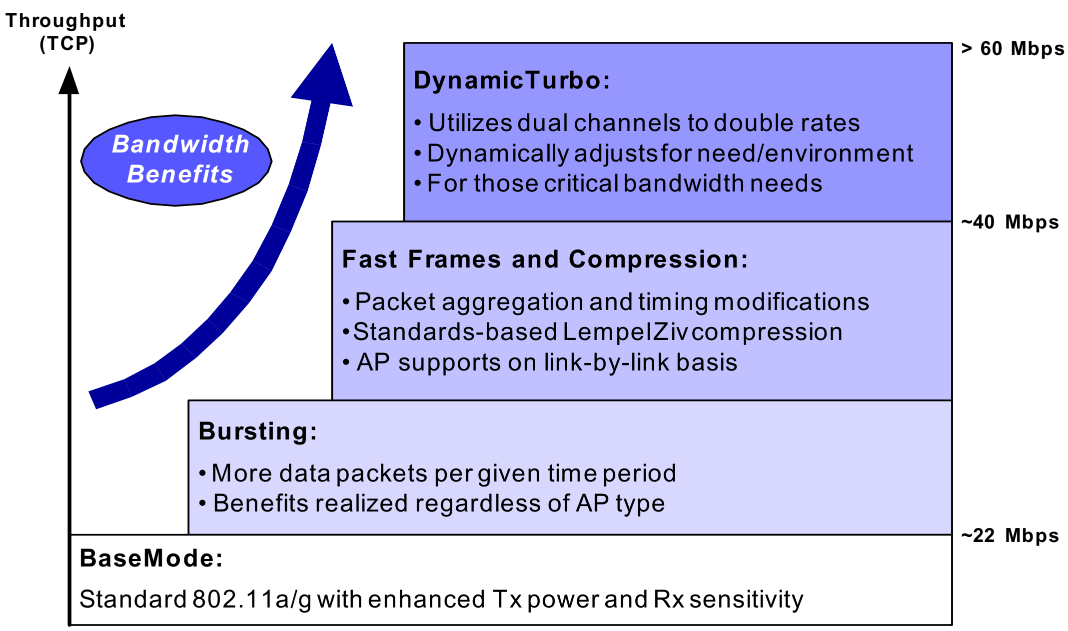


Figure 1-3. **Super G Technology Suite**

In base mode, Atheros' RF transmit power and high receive sensitivity capabilities translate to industry best range and throughput performance. Bursting offers incremental throughput performance for each capable station on the network. Stepping up to a Super G enabled AP provides the fast frames and compression features that bring the end user throughput up to approximately 40 Mbps. For essential high bandwidth needs, the Dynamic Turbo capability intelligently engages providing end user throughput performance exceeding 60 Mbps!

In Figure 2-7 on page 15 and Figure 2-8 on page 16, performance results are exhibited for Super G versus competitive offerings in both home and office environments. As shown in the benchmarks, Super G more than doubles throughput over standard offerings in these typical environments.

Super G Key Features

Atheros' Super G portfolio of performance enhancements enables networks to achieve best-in-class bandwidth while maintaining support for existing standards. Each component provides an incremental bandwidth benefit to the station and network.

Bursting

Frame bursting is a transmission technique supported by the draft 802.11e QoS specification. The advantage of frame bursting is that it can increase throughput when communicating with 802.11a, 802.11b, and 802.11g standards-compliant devices. Frame bursting increases the throughput of any 802.11a, 802.11b, or 802.11g link by reducing the overhead associated with the wireless transmission. This results in the ability to support higher data throughput in both homogeneous and mixed networks. As shown in Figure 1-4 on page 9, standard transmissions are separated by a time period (DIFS: distributed interframe space) during which all products must contend for airtime to transmit their data. After successfully transmitting one frame, products then contend for the airtime again. In a burst transmission, products contend for the airtime once before sending a series of data frames in quick succession. The overhead of contending for airtime and dead time between frame transmissions is reduced (SIFS: short interframe space).

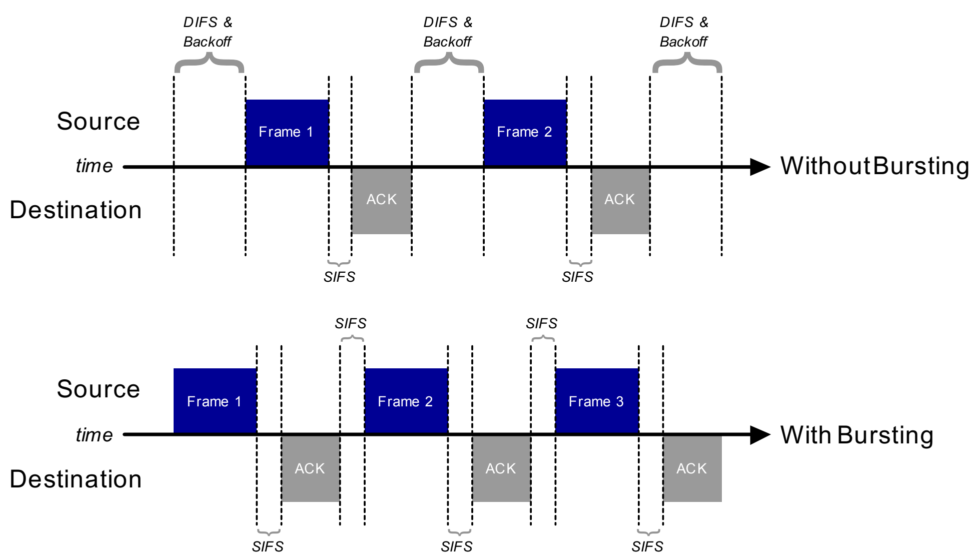


Figure 1-4. **Burst Timing**

All Atheros chipsets support the accelerated timing necessary to burst transmissions, and can receive all burst transmissions. If communicating with a product that fails to acknowledge a burst transmission, the Atheros design will fall back to non-burst mode on a link by link basis.

The dynamic frame bursting implementation in Atheros chipsets was designed to support the eDCF and WME QoS capabilities within the draft 802.11e standard. This Atheros implementation permits greater efficiency. The net result of this feature is higher throughput for more users in the network. For example, dynamic frame bursting is important whenever there is more than one station on a network. If there are at least two stations both near and far from an AP, the far station will transmit at a lower data rate, and thus consume more airtime than the nearby station. By bursting multiple frames, the far station will consume the majority of airtime and thus starve the faster, nearby station of their ability to communicate with the AP. However, the Atheros frame bursting technique provides for limits on the airtime used to transmit frames. Nearby stations will burst more frames than the far station since the time per frame is shorter. Since the nearby station transmits a larger number of frames while consuming much less airtime, Atheros' dynamic bursting technique increases the overall system capacity and performance of the network.

Compression

A complete hardware data compression engine is embedded in all Atheros 802.11b/g and 802.11a/b/g chipsets. This hardware engine operates in real-time to enhance throughput for many types of network traffic without affecting any of the algorithms used in the data transmission or framing techniques.

Atheros' hardware data compression engine implements the standards-based Lempel Ziv algorithm that is used in popular programs such as Pkzip, Winzip, and MS Windows operating system. This engine compresses prior to transmission and decompresses after reception. The obvious effect is to increase the data throughput of the compressed link, just as throughput is increased when a zipped file is attached to an email. The less obvious effect is that, because an Atheros compressed link requires less airtime to transmit each frame, the effective throughput of other links in the network is increased because they now have more airtime available.

Fast Frames

Fast Frames enhance data throughput by increasing the number of bits sent per data frame via bundling two data frames into a single wireless LAN frame, thereby eliminating the extra wireless network overhead associated with sending the second frame as shown in Figure 1-5. Typically, frames transmitted over the wireless medium are bridged to or from Ethernet, and therefore are generally restricted to the maximum Ethernet size of 1500 bytes. Fast Frames operate by changing the algorithms that determine how the actual data frame is structured, and their effect is additive to the frame bursting effect. Once Fast Frames have been negotiated over a specific AP-station link, both the AP and station can send wireless frames of 3000 bytes to the corresponding peer. Note that most others' bursting implementations do not provide for fast frames while the Atheros solution offers this added benefit.

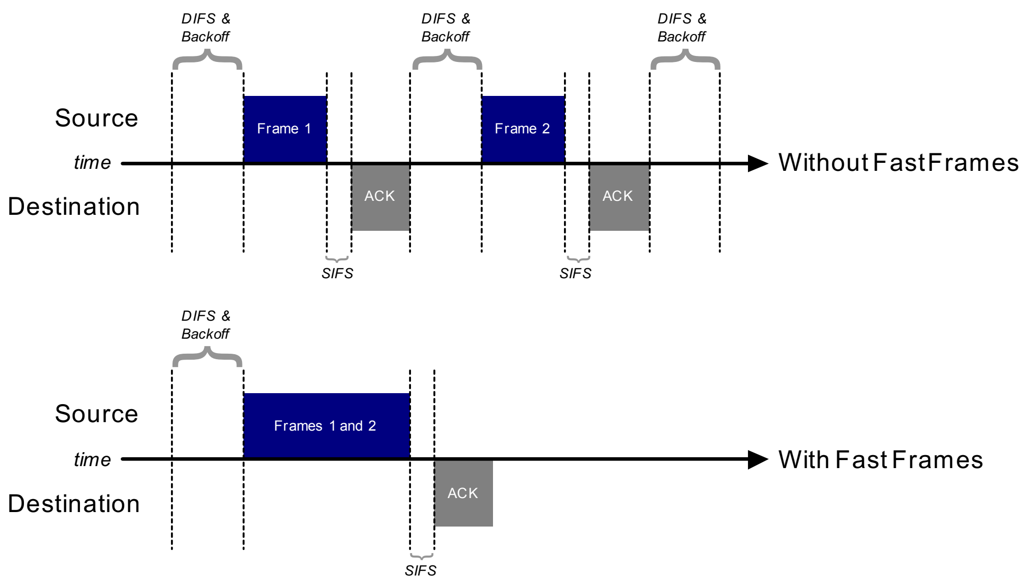


Figure 1-5. **Less Overhead with Fast Frames**

The Fast Frames technique is also based on the 802.11e draft standard. As with bursting, Fast Frames may not be supported by all third party hardware, but it is based on the technologies specified within the 802.11e draft. Because Fast Frames functions within existing timing parameters on a link by link basis and does not interfere with frame spacing, timing, or contention window parameters, this technique scales better to more networks than bursting alone.

Dynamic Turbo

The Atheros designs also feature a multi-channel capability that doubles the effect of all other enhancements and increases the range of a data link at any given data rate by adapting the way in which radio spectrum is used. This is called Dynamic Turbo.

The Atheros Dynamic Turbo capability operates by using the spectrum offered by two radio channels to transmit data, just as 10/100/1000 Ethernet trunking techniques use two or more wires to increase overall bandwidth. The data rate doubling is the most obvious effect of using multiple radio channels. An additional result of this capability is an increase in the effective range of a network. This comes about because the data rate of wireless networks decreases the further a station is from the AP, until at a certain distance the station no longer has sufficient bandwidth. For example, a 36Mbps link is only possible at a much shorter range than an 18 Mbps link. With the multichannel capability, the station can now achieve, for example, a 36 Mbps link available at the longer 18 Mbps link distance and a 12 Mbps link at the longer 6Mbps link distance. By providing an optional capability that uses multiple radio channels simultaneously, Atheros can both double the data rates offered by any single radio channel techniques and increase the effective range of a network.

Dynamic Turbo is engaged based on network traffic “demand” and environmental conditions. Atheros-enabled access points switch dynamically to this high-performance mode when an associated station requires the greater bandwidth based on the sustained throughput between the AP-station pair. The system periodically returns to base mode to allow third party stations to join the network. If any third party stations are associated to the AP, it will not enter this high-performance mode. The AP dynamically reconfigures itself for multi-channel and single-channel modes, freeing the user from any intervention.

Under typical usage conditions, Dynamic Turbo will have no significant impact on third party wireless networks or devices (see Figure 2-9 on page 17 and Figure 2-10 on page 18). Further, if network traffic is detected on adjacent channels in close proximity to a network operating in Dynamic Turbo mode, the AP will dynamically reconfigure for single-channel mode maintaining the performance benefits of the other Super G features, while allowing networks nearby to operate unimpeded (see Figure 2-11 on page 19).

Dynamic Turbo is enabled only when devices are operating on channels that would allow this greater bandwidth. In 2.4 GHz, there is one Turbo channel at 2437 MHz (channel 6). For 5 GHz, there are three Turbo channels in the lower UNII band as shown in Figure 1-6. There are another two Turbo channels in the upper UNII band (centered at 5765 and 5805 MHz).

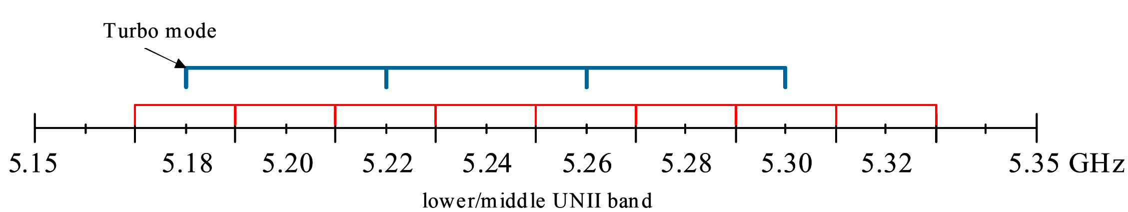


Figure 1-6. **Channels Centered at 5200, 5240, & 5280 MHz for lower UNII**

Conclusion

With the rapid emergence of bandwidth consuming applications for WLAN, existing standards-only schemes fall short. The Super G enhancements are designed to provide the optimal bandwidth performance possible for 802.11a/b/g networks with TCP/IP throughput exceeding 60 Mbps. Its modular approach allows individual stations and AP's to take advantage of those enhancements on a link-by-link basis, even in mixed networks with third party devices. Super G is designed to support today's applications while ensuring that today's networks can support emerging multimedia applications as well.

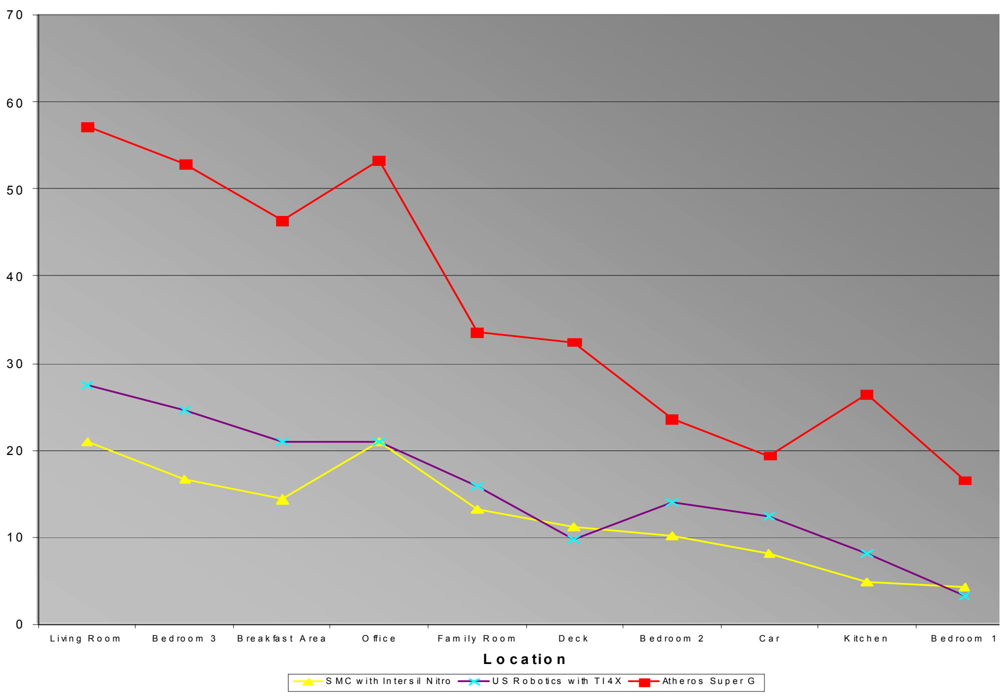
Super G is the premier standards-based performance solution:

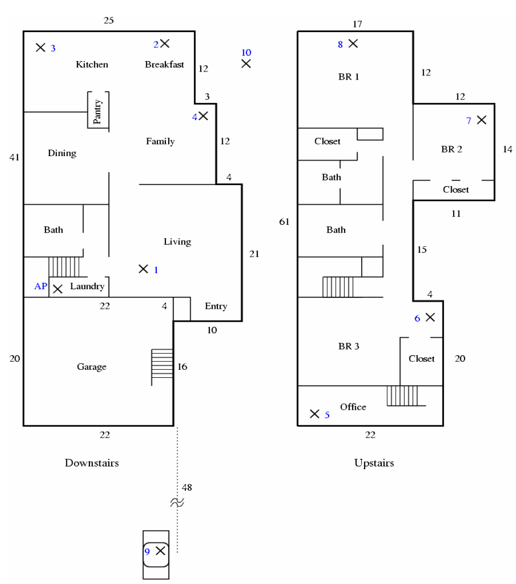
- Exceptional throughput for considerable bandwidth requirements: 108 Mbps data rates with typical end user throughput exceeding 60 Mbps
- Backward compatibility with 802.11a, b, g, and third party products
- APs capable of supporting diverse station types simultaneously
- Dynamically operates; freeing the user from added configuration
- Co-location enhancements provide environment-aware operation

In addition, Super G is designed to provide a foundation for future enhancements that build on upcoming standards such as 802.11n. It is fully compatible with IEEE and Wi-Fi Alliance standards and will evolve with next generation 802.11 standards.

Performance Benchmarks

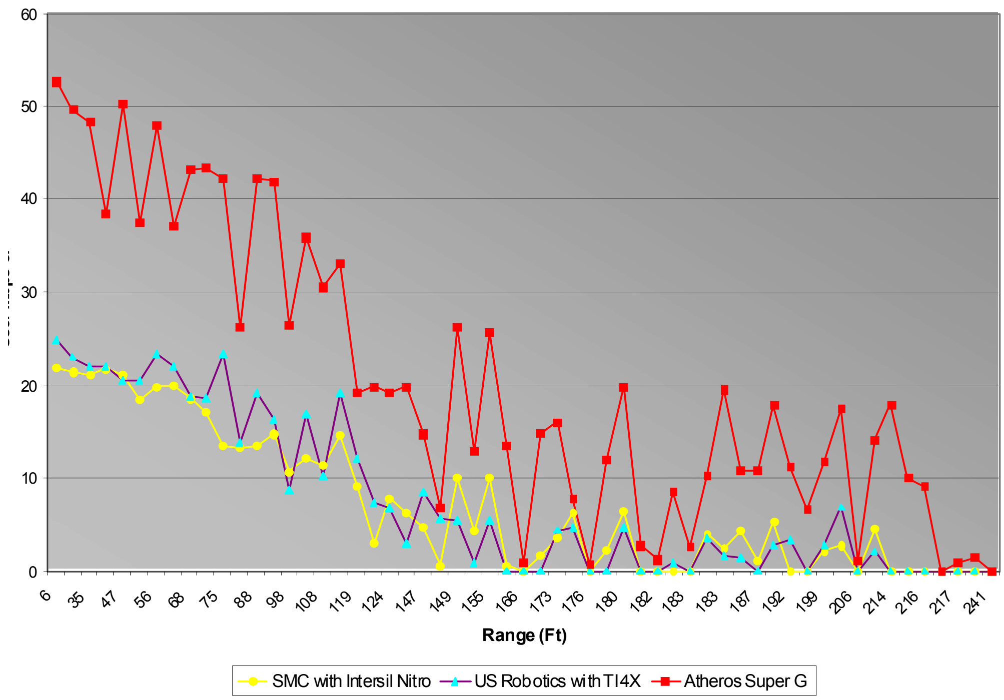
Figure 2-7. **Home Field Trials vs. Competitors**





- **Super G more than doubles throughput over standard 802.11a/g in a typical home**
- **Test locations throughout home are marked with an "x" at left**

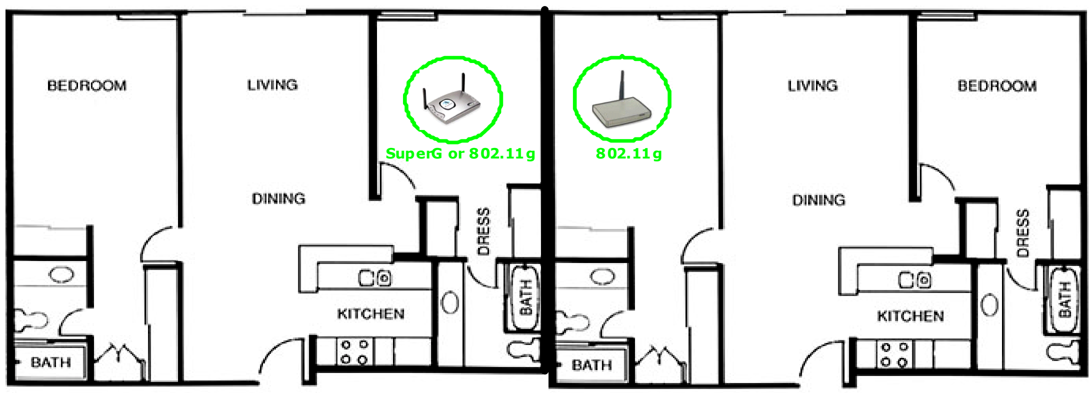
Figure 2-8. **Office Field Trials vs. Competitors**

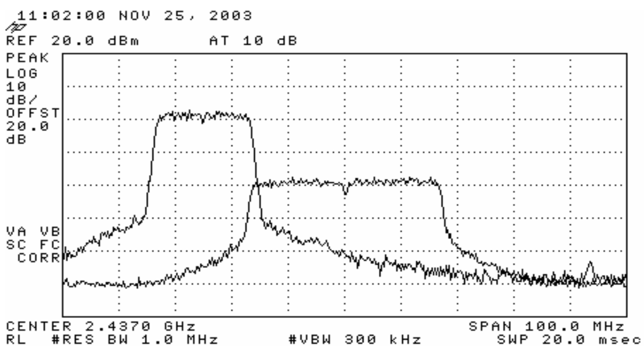


• **Super G more than doubles throughput over standard 802.11a/g in enterprise applications**

• **Test locations throughout office are numbered at left**

Figure 2-9. **In Typical Usage Scenarios, There Is No Need for Dynamic Turbo to Disengage Due to Attenuation via Walls**



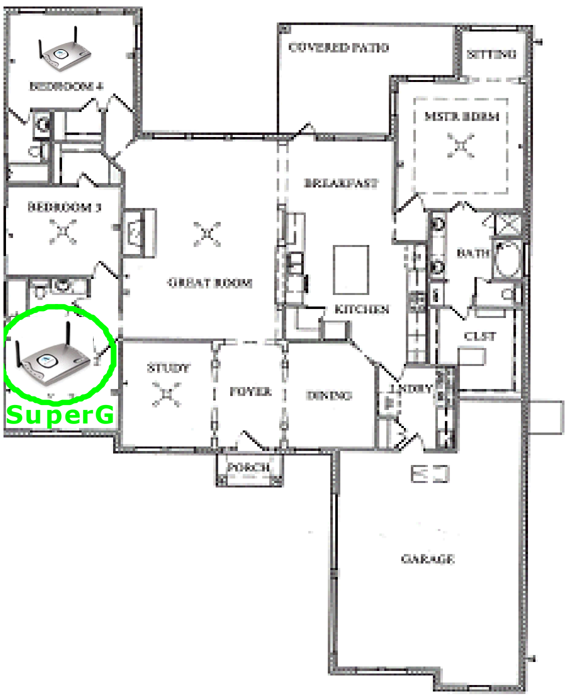


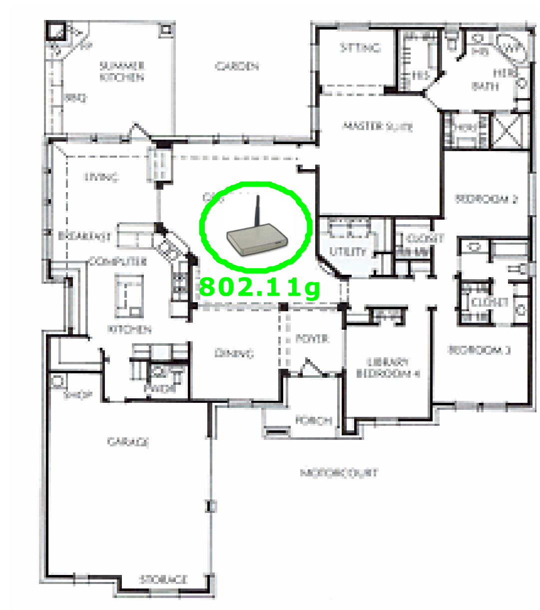
Source: Elliott Laboratories, Inc. 12/03

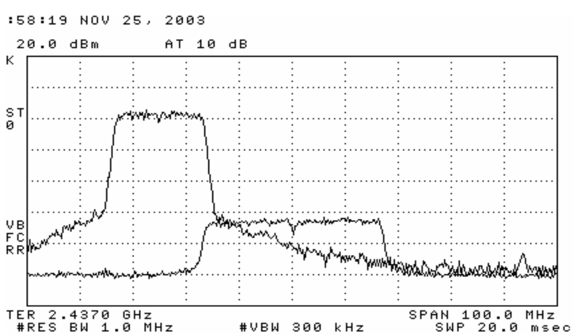
- Actual apartment test results show that both the Super G and standard 802.11g networks can fully support concurrent video streams
- Third-party testing conducted independently at Elliot Laboratories shows that only 16 dB of attenuation significantly reduces interference from SuperG

(At left is transmit spectrum of third party 802.11g on channel 1 and SuperG centered on channel 6 with 16dB attenuation - no significant spectral overlap)

Figure 2-10. **In a Single Family Home, Interference From Dynamic Turbo Is Even Less Likely Due to the Physical Separation and Exterior Walls**







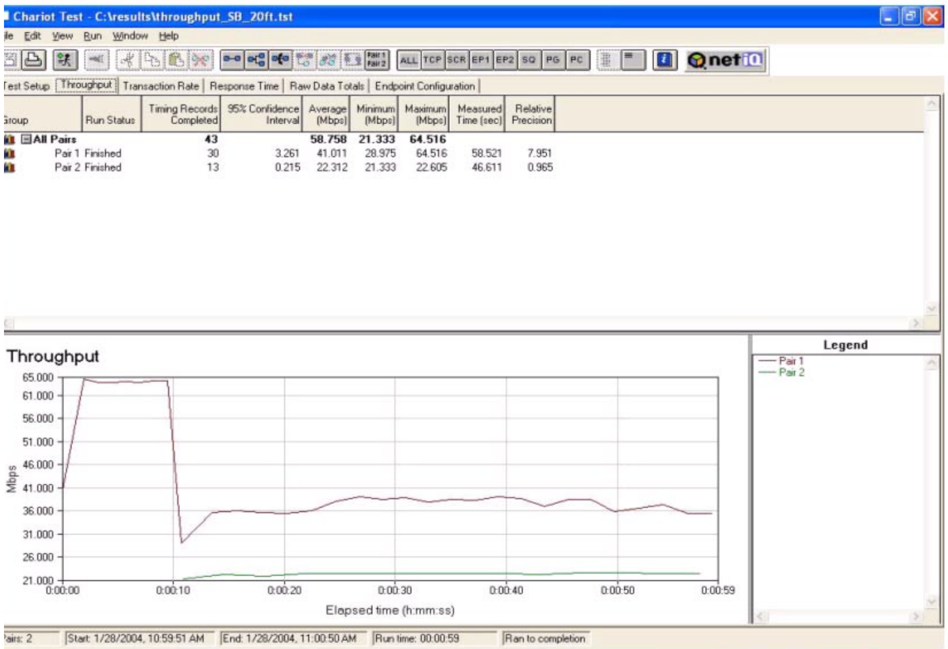
ource: Elliott Laboratories, Inc. 12/03

- Third-party testing conducted independently at Elliott Laboratories shows that only 30 dB of attenuation eliminates all interference from SuperG signals

- In real world scenarios, closely located networks will not experience any interference from a SuperG network

(At left is transmit spectrum of thir party 802.11g on channel 1 and SuperG centered on channel 6 with 30dB attenuation - no spectral overlap)

Figure 2-11. **Super G Network with 802.11g Introduced Into the Environment at 20 Foot Distance In Open Air**



In the absence of closely located network activity, Atheros Super G products provide over 60 Mbps of TCP throughput (pair 1)

- When third party traffic is introduced on a network in close proximity, the Super G Dynamic Turbo mechanism is immediately disengaged (pair 1) and the third party devices operate unaffected by Super G, maintaining their standard level of throughput (pair 2)
- Super G maintains a 2X throughput advantage even after Dynamic Turbo disengages (pair 1)

Related Elliott Laboratories papers:

- FCC Part 15, Subpart C (15.247) DTS Specifications for an Intentional Radiator on the Atheros Communications Model: Super G (December 2003)
- Adjacent Channel Coexistence Study for an Intentional Radiator on Atheros Communications Model: Super G (February 2004)

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