Home Networking Requirements and Associated Whitecap™2 Benchmark Tests White Paper

INTRODUCTION

1. Purpose of this Document

Home networking is a new category, and many of the technologies being used for it have simply migrated from the data-centric enterprise world. The metrics used to evaluate these products have also followed them from the enterprise market, and the focus is on measuring data transmissions such as file transfer speeds. However, home users have a different set of requirements than enterprise users, and products originally designed for the enterprise environment do not satisfy these requirements. These requirements fall into three key dimensions that serve to characterize the "goodness" of a home networking solution:

- **Multimedia and Quality of Service (QoS) Support** - for distributing high fidelity content (e.g., streaming audio, video, etc.)
- **Reliability** - for sustained operation and resistance to adverse environmental conditions and common household interferers (e.g., microwave ovens, cordless phones)
- **Ease of Use** - for setting up and operating the network

Given these unique requirements for home networking products, there is a need to rethink the approach for evaluating them. In this document, Cirrus Logic presents a new approach and provides the results of the evaluation for the Whitecap™2 Network Protocol. The suggested tests are conducted with Cirrus Logic-enabled solutions utilizing Whitecap2's multimedia and QoS extensions to the IEEE 802.11b wireless standard, compared against wireless networking solutions based solely on the 802.11b standard. Companion documents are available that provide the evaluation methodology and tool kit to duplicate testing. It is worth noting that, contrary to enterprise-originated technology migrating to the home, Cirrus Logic's technology was designed specifically to address the key dimensions of home networking requirements outlined above. As the standards evolve towards a full multimedia (MM) capable solution, Whitecap2 provides the best migration platform towards 802.11e while supporting today's home networking requirements, including interoperability with Wi-Fi (802.11b).

2. Highlights

Two wireless networking technologies with the same raw speed can have very different performance and operating characteristics.

- Whitecap2 provides superior throughput to support distribution of high fidelity content, such as high bit-rate MPEG2 (used in DVD titles and DVR video). Whitecap2 manages the transmission of such content at a higher bit-rate threshold and with higher quality due to the Dynamic Stream Support architecture, while transmission in a data-oriented network (802.11b) faces pervasive skips and pauses.

- Whitecap2 Dynamic Stream Support includes Contention-Free Access (a slotted architecture), which provides the ability to efficiently utilize and allocate available bandwidth in a predictable and efficient fashion, allowing simultaneous video and audio streams among multiple nodes; something a traditional CSMA (collision based) 802.11b network cannot support.
- A Peer-to-Peer (Mesh) Topology creates a network where devices communicate directly with each other. Traffic is not routed through a single coordinator, which would reduce throughput.
- Whitecap2 is specifically tailored for the home with ease of use (Coordinator Redundancy, Open Enrollment) and robustness/reliability (Channel Agility, FEC) features integrated. Features such as Channel Agility and Forward Error Correction (FEC) are imperative to support time-sensitive content such as video and audio in a harsh home environment.
- Whitecap2 provides the infrastructure to preserve Parameterized QoS for service providers, and a smooth migration platform towards the 802.11e implementation providing the performance to support current and emerging digital content types.

3. Networking Perspectives: Home Networking vs. Enterprise Networking

Home networking differs from enterprise networking in a variety of ways that greatly influence the ultimate success of provided solutions. These differences include:

Technical Expertise:

- There is minimal networking knowledge in the home, as opposed to a dedicated network administrator in the enterprise environment.

Application Usage Model:

- Enterprise networking has typically focused on printer and file sharing among PCs, while applications driving the need for networking in the home are more entertainment focused and more likely tied to service provider offerings - multimedia content distribution, broadband connection sharing, gaming, etc.

Cost Sensitivity:

- There is more cost sensitivity in the home environment with home users as well as consumer electronics companies, broadband service and equipment providers.

Device Support:

- The enterprise environment consists of PCs and printers while the home environment is being bombarded with an assortment of digital devices that could potentially enjoy the benefits of a network: PCs, TV's, set top boxes, web pads, digital video recorders (DVRs), etc.

Structural Variables:

- A standard home typically sits on a ¼ acre lot, with wallboard walls, wooden frames, and multiple smaller rooms, while the enterprise typically consists of much larger structures, more open spaces, roaming over wider areas, and mandated locations for electronic equipment. The home is an "unmanaged" environment in the sense that there is no control over equipment location in the home. Deployment in an enterprise environment is planned for best performance.

Environmental Factors:

- Specifically regarding wireless transmissions, the home can be a much harsher environment with appliances such as cordless phones, microwaves, and metal ceiling fans that are much less common in the enterprise environment.

4. Resulting Home Network Infrastructure Requirements

Given the unique characteristics of home networking outlined above, it is not realistic to expect an enterprise solution to fill the needs of the home network. In order to meet the needs of the home, a home network solution must address the following requirements:

Multimedia/Quality of Service Support:

- High net throughput for supporting high fidelity content, such as video transmission
- Efficient bandwidth allocation/usage to support multiple simultaneous content streams (also known as Traffic Category in the IEEE 802.11 Specifications)
- Support for isochronous streams (video, audio, voice)
- Predictable latencies to allow bandwidth allocation to be managed effectively
- Peer-to-peer communications - any device should be able to send and receive from any other at full performance levels

Ease of Use, Reliability, Robustness:

- Easy installation and maintenance with minimal user intervention
- Avoidance of in-band interferers
- Uncorrupted transmissions (no re-transmitting content) to support isochronous streams
- Security to prevent unauthorized access and protect content
- Network coverage throughout all parts of the home

Scalability:

- Firmware upgrade to support new network features and/or services
- Consistently high performance as additional devices are added
- Price/performance value for the consumer

Standards Compliance:

- Wi-Fi (802.11b) compliant-interoperability with other Wi-Fi devices/networks
- Forward interoperability path for compliance with 802.11e

TESTS

1. Testing Methodologies

It is important that results are measured qualitatively as well as quantitatively. Traditional network measurements focus on simple file transfer throughput, while a home network must support additional applications such as video with a higher value placed on them by the user. Entertainment applications (multimedia) demand a high level of quality for the experience to be a positive one for the user - transmission of less than flawless video and audio (freezing or skipped frames/notes) is easily detectable and cause for rejection of a product, while a barely perceptible delay in a print command or file transfer is virtually immaterial. Consumers have invested in high performance standalone devices, and they will not accept performance compromises to network them. These qualitative aspects - the real drivers of experience satisfaction - must be measured when gauging the ability of a network to meet the consumer's requirements.

Broadband Internet access is widely acknowledged as the strongest driver of home networking - the desire to share the connection amongst 2 or more computers. The most likely configuration for a home network will be 2 or more computers sharing a broadband connection. It is becoming increasingly common for other devices, such as web pads, digital set tops, DVRs and MP3/audio players to be added to a home network. Scalability - the ability to support additional nodes and services, well beyond a simple point-to-point PC-to-PC network - is an important capability for home networking technologies in such an emerging industry. Tests were therefore performed in configurations that included more than point-to-point situations.

Testing was done using dual protocols: UDP, which best supports multimedia streams, and TCP, which more commonly supports file transfer tasks. The Ganymede Chariot tool was used for the quantitative measurements, while qualitative measurements consisted of observations of video/audio quality. Detailed descriptions and illustrations of test configurations can be found in Cirrus Logic's "Wireless Adapter Test Kit" description and diagram documents.

Multimedia/QoS infrastructure support tests

The following tests provide an indication of the ability to distribute and support high rate multimedia streams.

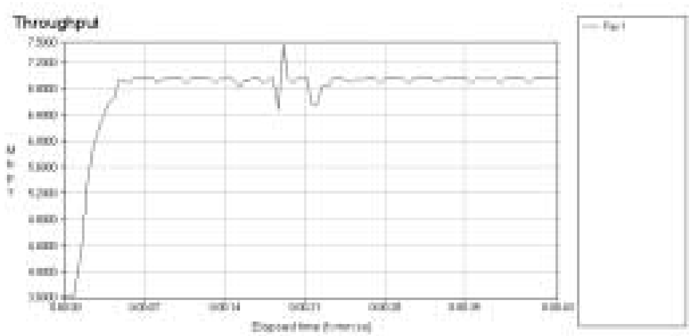
Case 1) Total UDP/TCP Throughput:

UDP and TCP are two common protocols used to transmit content in a networking environment. UDP is typically used for multimedia, while TCP is used for other types of data. The average UDP throughput is measured between two Windows 98 PCs at an ideal distance (~10 ft. apart) indicating the maximum bandwidth support capability. The total TCP throughput for multiple streams is measured, indicating the maximum download distribution capability. Also, the qualitative MPEG stream tests the maximum rate stream that will play flawlessly from a user perspective.

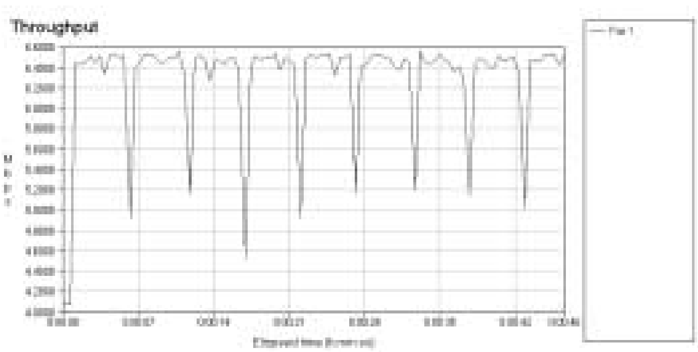
Test	Leading 802.11 Solution	Whitecap2
Quantitative		
1) UDP Chariot result	6.0 Mbps average (6.2 peak)	**6.7 Mbps average (8.1 peak)**
2) Aggregate Chariot TCP result	5.3 Mbps average	**5.2 Mbps average**
Qualitative		
3)"Pull" MPEG stream (UDP)	4 Mbps stream	**6 Mbps stream**

Higher throughput support on UDP translates to more multimedia streams and/or higher quality streams supported. Cirrus Logic technology is able to provide higher usable UDP throughput due to its low overhead contention-free architecture and delayed acknowledgements, while providing comparable TCP throughput for more ordinary data transfers.

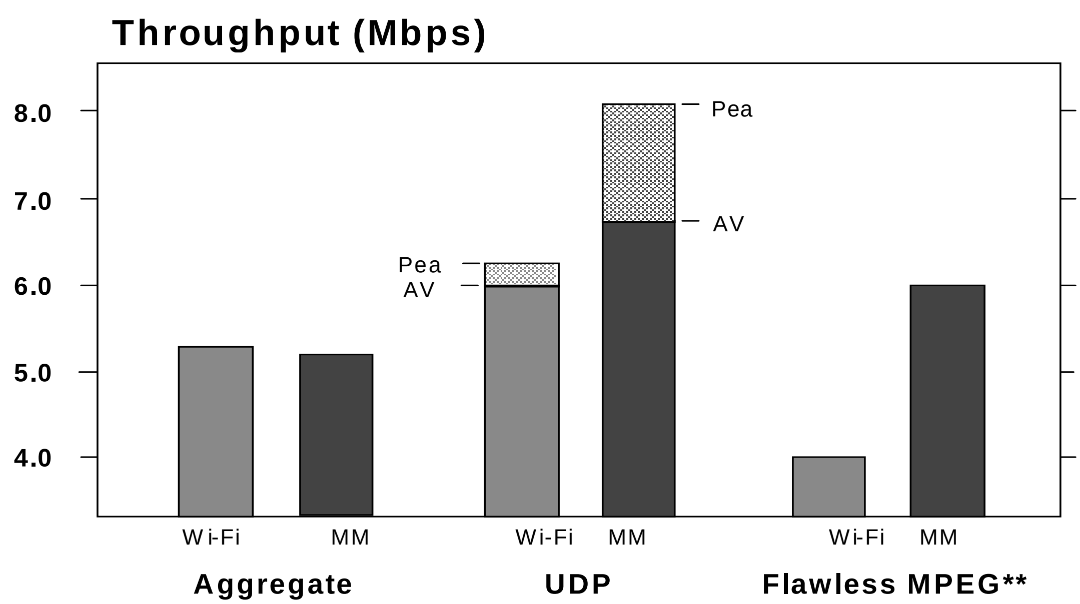
The throughput discrepancy is also graphically illustrated below:



Slotted architecture (Dynamic Stream Support) provides superior usable throughput (~7Mbps) and lower overhead vs. Wi-Fi (both ad hoc and AP)



Average Wi-Fi mode throughput is ~6Mbps in ad hoc mode (shown), and degrades by ~50% when in AP mode



Notes: * Throughput measured between Windows 98 PC's using Ganymede Chariot Test Suite
** Flawless MPEG is maximum single stream that will play without stutter or pauses

Case 2) Enhanced TCP Support:

A typical PC user's experience is modeled through two tests: 1) copying a file using the standard Windows copy methods (drag and drop), 2) playing a video stream using a standard Windows media player. Most PC applications use TCP to transmit data which can severely hinder system performance (due to TCP acknowledgement overhead) if not addressed (as shown below).

Test	**Leading 802.11 Solution**	**Whitecap2**
Quantitative		
4) Timed 30 MB File pull in Windows 98 (PC to PC)	53 seconds	**54 seconds**
Qualitative		
5) Pull MPEG stream in Windows 98 (TCP)	1.5 Mbps MPEGs	**6 Mbps MPEGs**

The higher rates for video (MPEG) transmission reflect a better user experience when streaming content to the user PC. Again, a higher rate provides superior quality and/or additional streams. The Cirrus Logic system is tuned to maximize performance on multimedia transmission while providing equal TCP performance for activities such as file transfers.

Case 3) Peer-to-Peer (Mesh) Topology vs. Access Point Infrastructure:

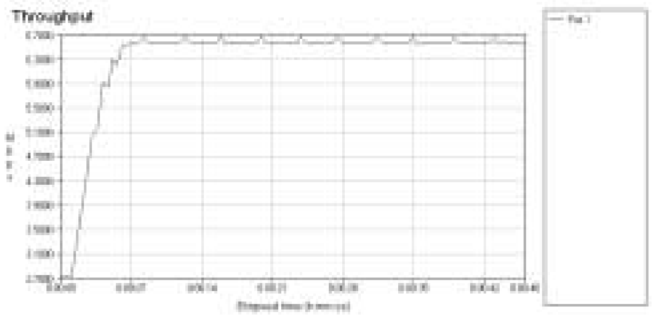
802.11's access point infrastructure requires the "access point" (Ethernet bridge with additional services) to manage network activity among all nodes. The resulting inefficiencies are revealed when compared to a peer-to-peer topology. Whitecap2's Peer-to-Peer Topology does not require an access point to coordinate traffic for other nodes on the network. Each node can transmit directly to the corresponding destination node. The resulting discrepancy in performance between the two systems can be compared by testing UDP and TCP throughput among PC's on the network as well as streaming multimedia between PC's. The 802.11 access point's existence introduces overhead into the system which severely degrades overall performance among the other nodes, unlike Whitecap2's Peer-to-Peer Topology.

Test	Leading 802.11 Solution	Whitecap2
Quantitative		
6) TCP & UDP results among PC’s with 802.11 AP or Cirrus Logic Ethernet bridge powered on	UDP: 3.0 Mbps TCP: 2.2 Mbps	UDP: 6.3 Mbps TCP: 3.7 Mbps
Qualitative		
7) Stream UDP between PC’s with 802.11 AP or Cirrus Logic Ethernet bridge powered on	2.5 Mbps	6 Mbps

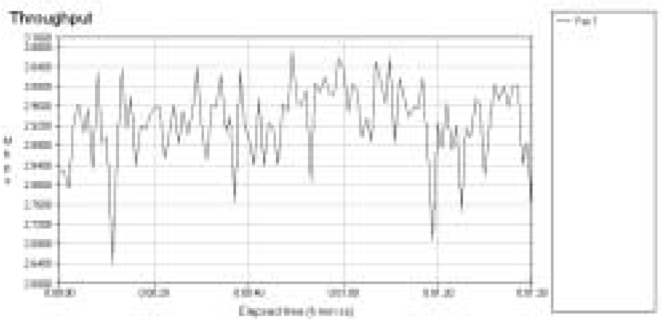
The 802.11 system has a 50% decrease in UDP performance and a 55% decrease in TCP performance (relative to no access point running), while Whitecap2's Peer-to-Peer Topology has no performance issues when the corresponding Ethernet bridge is active. 802.11's performance decrease is undesirable, especial-

ly given the fact that sharing a broadband connection will utilize an Ethernet bridge or "access point" device.

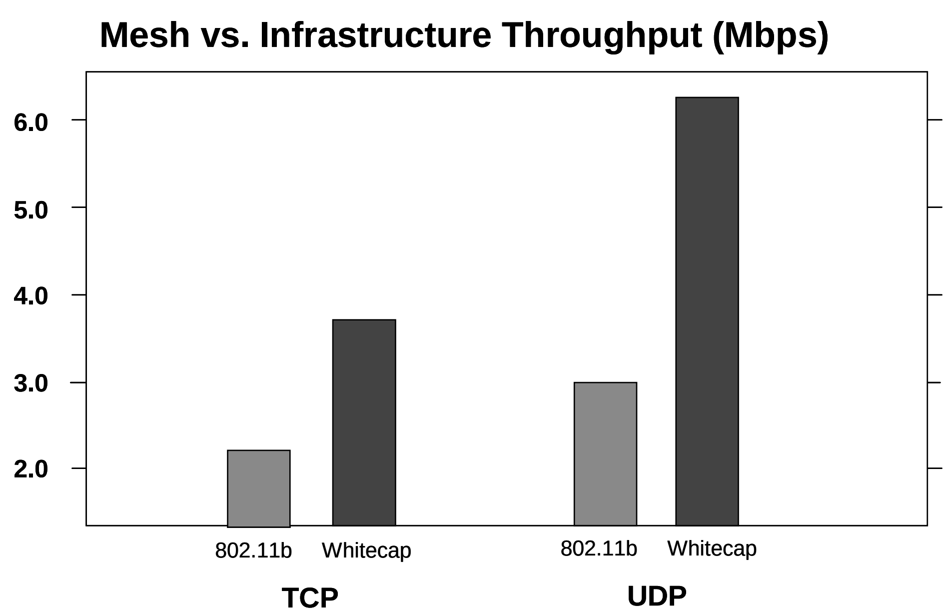
The peer-to-peer vs. access point discrepancy is also graphically illustrated below:



Whitecap2 maintains consistent bandwidth allocation and throughput with a contentionless architecture (superior utilization of usable throughput)



802.11 system cannot consistently maintain bandwidth required to flawlessly stream higher rate MPEG video or multiple low rate streams



Notes: Throughput measured between two Windows 98 PC's using Ganymede Chariot Test Suite in a multi-node network that includes an Ethernet Bridge or an Access Point

Case 4) Bandwidth Utilization:

Network management tools indicate the available bandwidth on the network. We can test how much of this is actually used by transmitting video files and comparing the highest rates that will flawlessly play vs. the measured bandwidth available. This provides an indication of utilization efficiency on the network.

Test	Leading 802.11 Solution	Whitecap2
Quantitative/ Qualitative		
9) Compare UDP Chariot results to qualitative experience	Chariot indicates 6 Mbps available for UDP; qualitative 802.11 test can only play 4.0 Mbps MPEG (67 % of available bandwidth utilized).	**Chariot indicates 6.7 Mbps available for UDP; qualitative Cirrus Logic test can play 6.0 Mbps MPEG (90 % of available bandwidth utilized).**

The 802.11 utilization of 67% vs. Cirrus Logic's 90% reveals wasted bandwidth on the 802.11 system. Whitecap2's Dynamic Stream Support architecture ensures that streams are consistently allocated virtually all of the bandwidth available.

Case 5) Bandwidth Allocation:

Simulating UDP and TCP traffic and noting the percentage of bandwidth allocated to each stream can reveal bandwidth allocation capabilities. We can then transmit actual video simultaneously with a data file transfer and note how the networks perform. This aspect of traffic management is critical for providing basic QoS, meaning streams that require higher allocated bandwidth receive it, while simple data transfers can coexist without interfering. Additionally, testing multiple lower rate video streams (1.1 Mbps) reveals contention problems when multiple nodes attempt to transmit simultaneously on an 802.11 system.

Test	Leading 802.11 Solution	Whitecap2
Quantitative/Qualitative		
10) Establish a qualitative test to match Chariot expectation for bandwidth allocation	Chariot allocates 3.7 Mbps for UDP and 1.9 Mbps for TCP on a 2 node 802.11 system for simultaneous streams. Therefore, a 3 Mbps UDP stream should play with a file push, but does not; video stutters.	**Chariot allocates 6.0 Mbps for UDP and .5 Mbps for TCP on a 2 node Whitecap system for simultaneous streams. Therefore, a 5 Mbps UDP stream should work flawlessly with a file push. It does.**
11) Multiple Stream contention	4 nodes all transmitting/ receiving 1.1 Mbps MPEG stream has numerous stutters and pauses rendering all streams unacceptable.	**The Whitecap system can support 4 nodes transmitting/receiving 1.1 Mbps streams.**

Bandwidth allocation in CSMA networks is much less efficient as indicated above. The Whitecap2 Dynamic Stream Support system allocates the bulk of the bandwidth for the UDP stream; each stream is allocated what it needs, providing basic QoS. Collision effects of CSMA can also be observed when streaming multiple low rate streams, which cannot co-exist flawlessly in 802.11. Whitecap2's contention-free architecture eliminates collisions and ensures that each node is provided a turn to transmit.

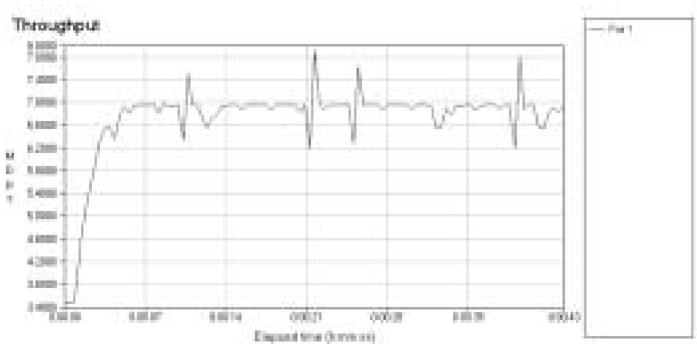
Reliability and Robustness includes interference immunity and long operating range

Case 6) Microwave Interference:

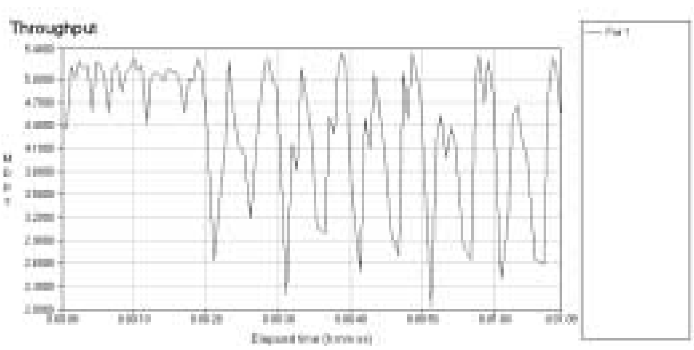
Network throughput measurements can be taken when an interferer, such as a microwave oven, is present. 802.11 networks without any type of forward error correction (FEC) are severely degraded, resulting in lower throughput measurements and lower rates for flawless streams.

Test	Leading 802.11 Solution	Whitecap2
Quantitative		
12) Chariot UDP results with microwave on	802.11 UDP throughput dropped from 6 Mbps to 4.4 Mbps	Whitecap avg UDP throughput did not drop from the original 6.6 Mbps
Qualitative		
13) Stream UDP video with microwave on	Only 3.0 Mbps will play without stutters (down from 4.0 Mbps)	Can still play 6.0 Mbps

Whitecap2's forward error correction (FEC) corrects corrupted packets during transmission, so throughput is not affected by noise in the RF channel. (Note: tests were executed on adjacent channels to microwave)The FEC discrepancy is also graphically illustrated below:



Whitecap2 average throughput is not affected by RF interference generated by microwaves (adjacent channels)



802.11 experiences severe degradation (>30% worse average throughput than without interference)

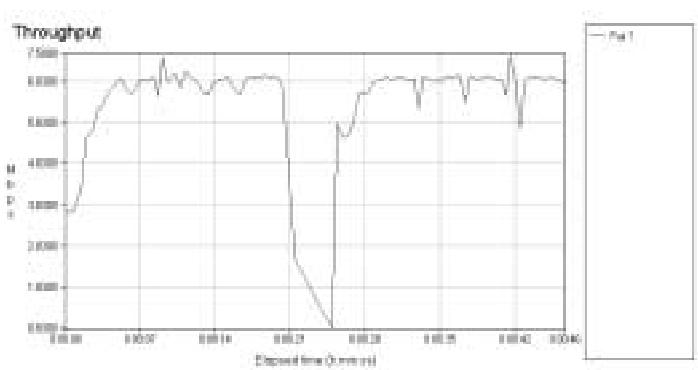
Case 7) Cordless Phone Interference (Broken Connection):

Other interferers in the home can be even harsher, and completely corrupt the channel rendering it unusable. To test this we can stream a 1.1 Mbps video between 2 nodes. In this case, an 802.11 system must be completely shut down and brought back up on another channel, where the Whitecap network can continue the transmission by automatically changing channels.

Test	Leading 802.11 Solution	Whitecap2
Qualitative		
14) Stream TCP or UDP video with 2.4 Ghz phone transmitting	1.1 Mbps clip freezes when interferer introduced; system must be restarted	**1.1 Mbps clip plays with no impact (channel changes when interferer introduced)**

Clearly, the inability to dynamically change channels to avoid interference poses some major performance challenges for 802.11. Assuming the unlikely case where the home user would even have knowledge of distinct channels for operation, the user would be required to manually change the channel through the 802.11 access point. Whitecap's ability to automatically change the network channel when a catastrophic interferer is present frees the user from intervention and preserves the multimedia experience enjoyed by the user.

The channel agility discrepancy is also graphically illustrated below:



Whitecap2 system detects interference on channel, switches channels, and resumes application

802.11b test could not complete (test application aborted due to lost connection)

Case 8) Long Range Coverage:

It is critical that the entire house can be covered by the network solution at the maximum bandwidth. Therefore, we duplicate some of the same UDP and TCP tests at 150 feet that were done in test 1. In many 802.11 solutions, the signal is weaker at longer distances, which results in reduced bandwidth.

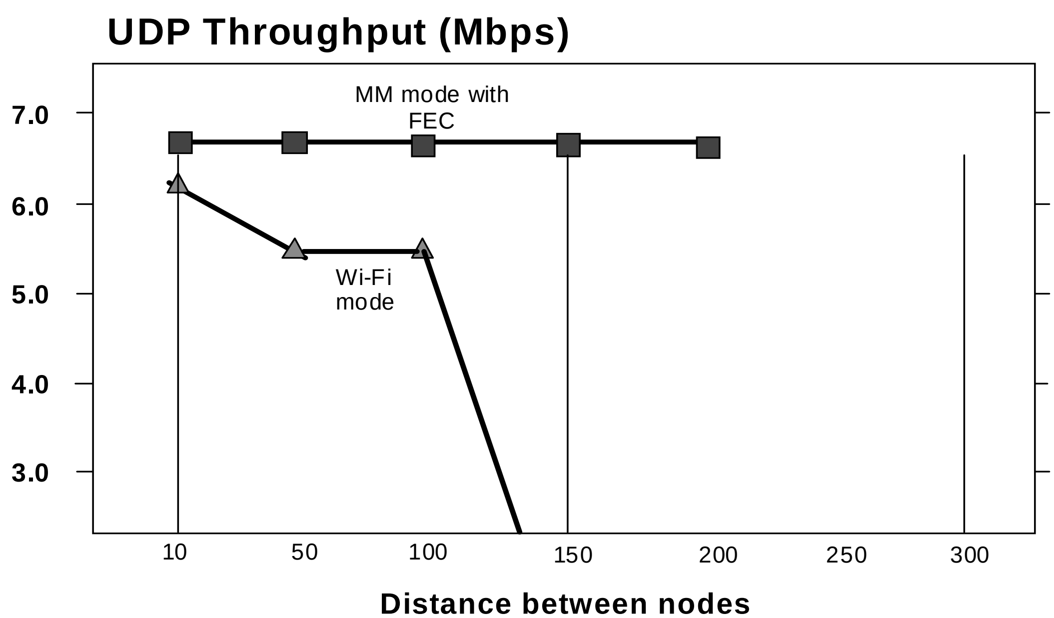
Test	Leading 802.11 Solution	Whitecap2
Quantitative		
15) Chariot UDP and TCP results at ~150 ft vs. 10 ft (2 node system)	802.11 UDP throughput dropped from 6 Mbps to ~4.6 Mbps 802.11 TCP throughput dropped from 5 Mbps to ~1.9 Mbps	**UDP stays at 6.6 Mbps** **TCP stays at 3.8 Mbps**
Qualitative		
16) Stream UDP MPEG at ~150 ft vs. 10 ft (2 node system)	3.0 Mbps was highest rate that would stream successfully (vs. 4.0 Mbps at 10 ft)	**Can still play 6 Mbps video**

Whitecap2's FEC capability, antenna gain, and receiver sensitivity all contribute to the built in fade margin which allows the system to perform equally well in both of the following scenarios:

- through obstructions at longer distances in the home
- short range line-of-sight configurations

Basic 802.11 systems do not have these built in capabilities.

The range coverage discrepancy is also graphically illustrated below:



Notes: Throughput measured between two Windows 98 PC's using Ganymede Chariot Test Suite.

CIRRUS LOGIC TECHNOLOGY OVERVIEW

1. Whitecap2 Solution Uniquely Addresses Home Networking Needs

A key element of Cirrus Logic's technology portfolio is the Whitecap2 network protocol. Whitecap2 is designed for the requirements of the full spectrum of multimedia content including data, voice, audio, and video, while also providing industry-standard Wi-Fi (IEEE 802.11b) interoperability. Whitecap2 efficiently manages a network of heterogeneous devices and digital content. Some of these key features are outlined below. Further details can be found in the Whitecap2 Whitepaper and Whitecap2 product brief.

Complete Multimedia Support

Dynamic stream support adjusts slots based on needs of each node on the network, avoiding wasted bandwidth and preserving overall bandwidth for other nodes, which translates into higher usable throughput.

- Dynamic Stream Support's superior throughput allows the highest quality video transmission. The architecture and packet structures have been designed to minimize the overhead for network access and housekeeping.
- Superior throughput is also aided by Whitecap2's Delayed Acknowledgements, which improve the payload efficiency and minimize overhead for network access and housekeeping by deferring acknowledgement packets, thus increasing the bandwidth available for multimedia transport.
- Dynamic Stream Support also utilizes available bandwidth more efficiently than traditional 802.11 networks. This is vital as more devices and streams are added to the network.
- Dynamic Stream Support provides dynamic bandwidth allocation and management supporting coexistence of multiple streams in an efficient manner. There are no collisions as in a CSMA network and each stream receives its required bandwidth - no more, no less. This allows multiple streams and combinations of video and data streams to coexist.
- Whitecap2's host platform driver extensions enhance traditional TCP application performance in the typical home usage scenarios ("pulling" content such as video). These software extensions have enhanced the performance of Whitecap2. The implementation allows TCP applications to reach performance levels approaching that of UDP services when "pulling" content from another machine.
- Whitecap2's Peer-to-Peer (Mesh) Topology allows devices to communicate directly with each other without the need to transmit through an access point (AP). This provides superior performance among nodes on the network vs. the 802.11 AP infrastructure.

Reliable Wireless Delivery

- Video and audio streams cannot be retransmitted since a few dropped frames can severely diminish the quality and user experience. Forward Error Correction (FEC) recovers data "on the fly" and effectively increases the usable throughput. In unpredictable environments such as homes, this ensures consistent, quality performance.
- Whitecap2's Channel Agility feature can identify and switch network operation to the channel with the lowest packet error rate. If the connection between coordinator and client(s) is broken, or the coordinator deems the bit error rate to be too high, the entire network will change channels.
- Structures have varying degrees of RF path loss based on the layout (number of walls) as well as the

construction material (wood, concrete, etc.). Indoor path losses are much worse than outdoor. Whitecap2's FEC feature provides a significant advantage which translates to increased range.

- Security is also important in the home network. To avoid unauthorized access, the Whitecap2 protocol follows a strict authentication procedure before a connection is granted. Each Whitecap2 network is identified by a unique 16-bit subnet ID. The subnet ID is a field in the Whitecap2 protocol header and is unique to a specific network. Packets with the incorrect subnet ID authentication are dropped and denied access to all devices on the network. The Whitecap2 protocol subnet ID provides reliable security by exercising security on a packet-by-packet basis. In addition, 40-bit WEP encryption is available to provide privacy equivalent to wired networks.

Ease of Use

- Whitecap2's Coordinator Redundancy prevents a single point of failure and allows continued operation even if the coordinator node within the network fails or is turned off, unlike 802.11 systems running in AP mode. Whitecap2's coordinator is able to identify alternate coordinators on the network, which can take over in the event the coordinator is shut down. This is automatic and executed seamlessly to the end user.
- Open Enrollment allows "faceless" devices with no input mechanism, such as Ethernet bridges or access points, to be authenticated over the air from any authorized node on the network. The user can choose to grant or deny access based on the device.
- Whitecap2's Channel Agility feature described earlier also benefits the user from an ease of use perspective. The user is not required to find and select the best channel.
- Firmware Update is available for Whitecap nodes and allows users to install future firmware enhancements and upgrades. Upgrades ensure scalability with new services and reduce device obsolescence. For "faceless" devices, firmware updates can be done over the air.

Foundation infrastructure for future services & 802.11e implementations

Effective bandwidth management and a contention-free architecture are key components for providing future services that support multiple media streams in the home. The Whitecap2 protocol has already in place the "hooks" necessary to support an 802.11e implementation with respect to multimedia content. Some of the potential features/implementations that leverage the Whitecap2 infrastructure are listed below:

- Parameterized QoS Implementations - Allocation of network resources for each stream is based on bandwidth, latency, and jitter requirements. This approach offers significant improvement over priority-based QoS mechanisms that do not provide deterministic allocation of resources and related guarantees.
- Priority Services - High priority traffic (video, voice) is differentiated from low priority data (file transfers, print jobs) by decoding packet fields. Priority Services can be supported in a parameterized QoS implementation.
- Multicast - Reduces the required bandwidth to support sharing media streams by allowing traffic to be sent only once to the clients receiving the media stream (rather than to each individually).
- Co-location - Closely located subnets on the same channel can gracefully share the available bandwidth if they must operate on the same channel.

THIRD PARTY REVIEWS CONFIRM WHITECAP 802.11 EXTENSION BENEFITS

1. Network World (January 2001)

"…Wow, was it (Whitecap) ever better…(on 802.11) the video tripped along in a way that'd make you boo and throw popcorn at the screen…clearly, vanilla 802.11b isn't ready to deliver entertainment applications…Whitecap is just what you want in the home…"

2. PC Magazine (May 2001)

"…Whitecap technology is likely to be a key component in the new 802.11e standard currently in the proposal stage…the Panasonic gateway and wireless cards work exactly as promised, with reasonably easy setup…"

3. ZDNET (May 2001)

"Whitecap technology has advantages over 802.11b standard…it (Panasonic gateway with Whitecap) worked flawlessly. We took the wireless notebook everywhere in the house, both upstairs and down, and we received nary a hiccup…you could say that Whitecap is actually the superior technology. What makes Whitecap a compelling wireless solution is that it is "smarter" than 802.11b, meaning it uses its available bandwidth better. For example, if two computers are on a network and one is sharing a bunch of Word docs and the other is streaming video or mp3 files, Whitecap is able to allot the appropriate amount of bandwidth to each session. An 802.11b wireless network, on the other hand, pretty much allots the same amount of bandwidth for everything that's being transferred. This isn't an issue when the only things being transferred are small packets of data, but you might encounter a bottleneck while attempting to stream multimedia files…we found in our transfer tests that Whitecap actually handles streaming media better than 802.11b…"

4. PC World (July 2001)

"Panasonic's special PC card is the first to use the Cirrus Logic Whitecap technology for making 802.11b more multimedia-friendly. We tested the system by streaming DVD (MPEG2) and MPEG1 videos between two computers located on different floors of a duplex condominium. First we used a standard 802.11b network, and then we repeated the operation using the Panasonic network. Next, we attempted the same transfers while simultaneously copying a 50MB file folder from one PC to the other. Streaming over the non-Whitecap network yielded rather low-grade DVD, and that quality deteriorated further when directory copying occurred in the background; the copying took about 9 minutes. In contrast, DVD quality on the Panasonic system was good…"

5. CNET (June 2001)

"…The (Panasonic) Concourse connects with desktop and notebook PCs via Ethernet cables, existing phone lines, or wirelessly. This all-in-one wonder can also connect via all three modes simultaneously…The wireless option (Whitecap) is the easiest network interface to install and use…"