White Paper

Xpress^{TM} Technology:
Maximizing Performance in 802.11 Wireless LANs

Wireless networks are proliferating at a rapid pace – and the number of notebooks, handheld computers and other devices equipped to connect to them is growing even faster. Wireless networking is a shared medium – so as more devices crop up to demand bandwidth, improving performance becomes critical. Frame bursting is an ideal way to improve performance because it reclaims some of the network's raw data rate for the clients on the network. Frame bursting is an extension of a feature in existing wireless networks, so it can improve overall network performance regardless of whether every node incorporates the feature. And because frame bursting is included in draft specifications for upcoming wireless LAN standards, it follows that all nodes will one day include the feature.

The purpose of this paper is to:

- Introduce frame bursting technology.
- Explain the benefits of a standards-based approach to improving wireless network performance.
- Introduce Broadcom's implementation of frame bursting, Xpress^{TM} Technology. Xpress Technology is compliant with draft specifications of two planned wireless industry standards.

Table of Contents

Introduction

The state of wireless LAN technology is evolving rapidly. The most common use for a wireless network today is to connect a single notebook computer to a broadband internet connection. Increasingly, though, wireless networks are handling a growing number of clients due to the boom in notebooks with embedded wireless capability.

Wireless is a shared medium. So the more clients on the network, the less bandwidth there is for any given client. This problem will only grow worse as the number of wireless-ready devices mushrooms beyond notebooks and handheld computers. In fact, half of all wireless LAN chip sets will enable something other than a PC by 2004.

In the enterprise, for example, voice-over-IP phone systems and cellular phones with wireless LAN capabilities will follow the proliferation of wireless-enabled notebooks. And for the home, retailers are planning to stock shelves with a wide range of wireless-enabled products, from notebooks, desktops, printers and media servers to MP3 players, digital cameras, camcorders, DVD players and digital TV displays.

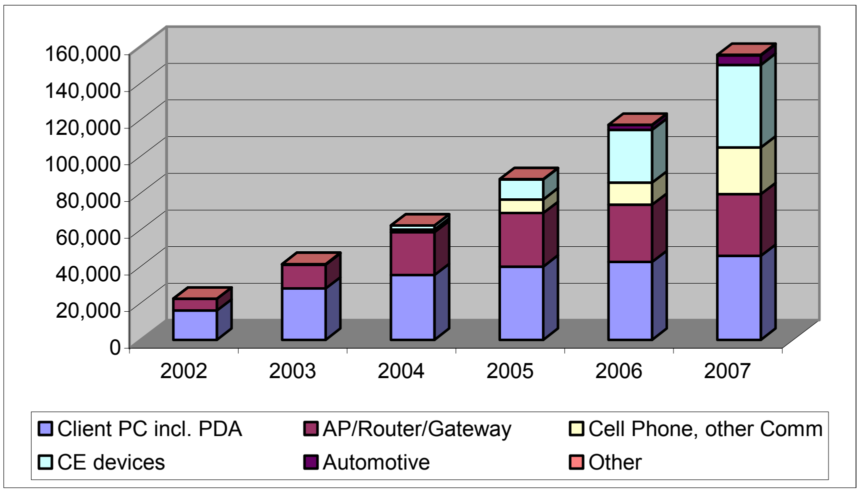


Figure 1. Wireless LAN chip sets shipped per year, by segment. Units in millions. Source: TechKnowledge Strategies, Inc.

As more and more devices vie for the limited bandwidth of the wireless network, wireless LAN suppliers must find ways to wring every ounce of performance out of their hardware. At the same time, they must ensure that their hardware will be compatible – not only with existing equipment, but also with gear that ships in the future.

The IEEE recently approved 802.11g as the newest mainstream wireless LAN standard. It offers a dramatic increase in performance for 2.4GHz wireless networks. Another technique, called frame bursting, is emerging to extract even more performance out of wireless networks. It is a standards-based approach that increases performance by making the network more efficient.

This white paper describes frame bursting, and illustrates how it increases throughput in a variety of wireless LAN scenarios, including pure 802.11b, 802.11a and 802.11g networks as well as mixed 802.11b/ 802.11g environments.

Frame Bursting: Improving Performance through Efficiency

Wireless LAN performance has been increasing over time. Specifically, the industry has pushed raw data rates from the 1Mbps and 2Mbps of the initial 802.11 standard to 11Mbps with 802.11b and up to 54Mbps with both 802.11g and 802.11a. Of course, effective throughput is lower than the raw data rates, due to associated overhead such as data framing protocol activity.

Due to the improved modulation techniques of 802.11a, 802.11b and 802.11g, individual frames – which are basically data packets prepared for wireless transmission – take less and less time to transmit, but overhead takes the same amount of time. An unfortunate byproduct of this phenomenon is that, with each new enhancement, overhead takes up a greater percentage of the available bandwidth. So while raw bandwidth has been climbing, efficiency – or the percent of raw bandwidth left for data – has been falling. To put another way, the available bandwidth for data is climbing more slowly than total bandwidth.

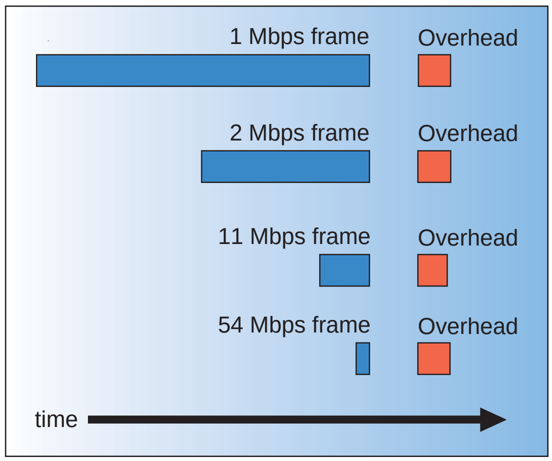


Figure 2. Overhead dominates faster date rates

Frame bursting is a straightforward technique that reclaims some of that lost bandwidth for data. The original 802.11 standard calls for a wireless device to wait a specified period between each frame it sends. The pauses give other devices opportunities to signal that they would like to send some data, as well. With frame bursting, the client that is sending data is allowed to send several frames in a row without pausing to allow others a chance to transmit.

Imagine a dinner table conversation where the person speaking paused after each word to give someone else a chance to start speaking. In this example, it's easy to see how the group could speed up the conversation considerably by pausing only after each sentence.

Figure 3 shows that overall network performance improves whether frame bursting is implemented in every client, or just a few

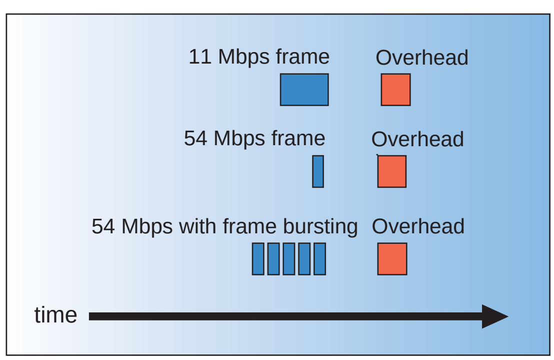


Figure 3. Frame bursting improves network efficiency

BROADCOM®

Standards-Based Approach

Frame bursting is a standards-based technology that is an extension of a feature in an early version of the 802.11 specification called fragment bursting. The technology is also included as an efficiency-improving component in drafts of the 802.11e specification, which focuses on quality-of-service issues such as prioritizing traffic for time-sensitive applications like streaming media. (In the draft 802.11e specification, the technology is actually referred to as continuation transmit opportunity, or CTXOP.) As well, industry leaders like Microsoft, Broadcom and others are defining a subset of the draft-802.11e specifications called Wireless Multimedia Enhancements, or WME. The framers of the forthcoming WME specification, which hope to bring their standard to market on a quicker timetable than 802.11e, have included frame bursting technology, as well.

Improving performance with a standard technique is preferable to proprietary alternatives, for several reasons. Proprietary solutions require that all nodes use the same technology in order to experience performance benefits, leaving products from other vendors unable to participate. In addition, there may be some risk associated with proprietary performance approaches, because the hardware may operate unpredictably in networks that otherwise conform to industry standards.

To understand how frame bursting improves efficiency by minimizing overhead, it is first helpful to understand the purpose of the overhead in 802.11 network traffic. As data is sent over airwaves, it is difficult to be sure that the information was received successfully. So after each data transmission, the recipient sends an acknowledgement, or ACK, after a specified delay, called a short inter-frame spacing, or SIFS. If the transmitting station doesn't receive the ACK, it assumes that the transmission was unsuccessful and resends the data. If it receives the ACK, it must then wait some time before initiating the next transmission. This delay is called distributed inter-frame spacing, or DIFS. In addition, there is some random back-off time added to allow another station to communicate if it has data to transmit.

With frame bursting technology, the transmitter is only required to insert a SIFS between the recipient station's ACK and the next data transmission. So the transmitter can send a string of multiple data frames more quickly. Frame bursting can be added to any wireless node, whether it is 802.11a, 802.11b or 802.11g. As well, any 802.11 node is capable of receiving bursted frames because of the fragment bursting technology built into the standard. So even in environments with non-bursting nodes, each node that adds frame bursting will increase the aggregate performance of the network.

WME

Wireless Multimedia Enhancements, or WME, is a grass-roots industry standard that was crafted to bring frame bursting and quality-of-service features to market faster.

The WME specification is actually a subset of the emerging 802.11e QoS standard now in the works. It is basically a collection of features in the 802.11e specification that suppliers are prepared to bring to market today.

Microsoft, Broadcom, Intel, Cisco, Intersil, Atheros, Agere, AMD, Texas Instruments and others are collaborating on WME. The group is soliciting the Wi-Fi Alliance, an industry association dedicated to promoting wireless LAN usage, to sponsor the WME standard. (The Wi-Fi Alliance is a logical sponsor for the standard, as it backed a similar effort earlier this year called WPA, which is a subset of the emerging 802.11i security standard.)

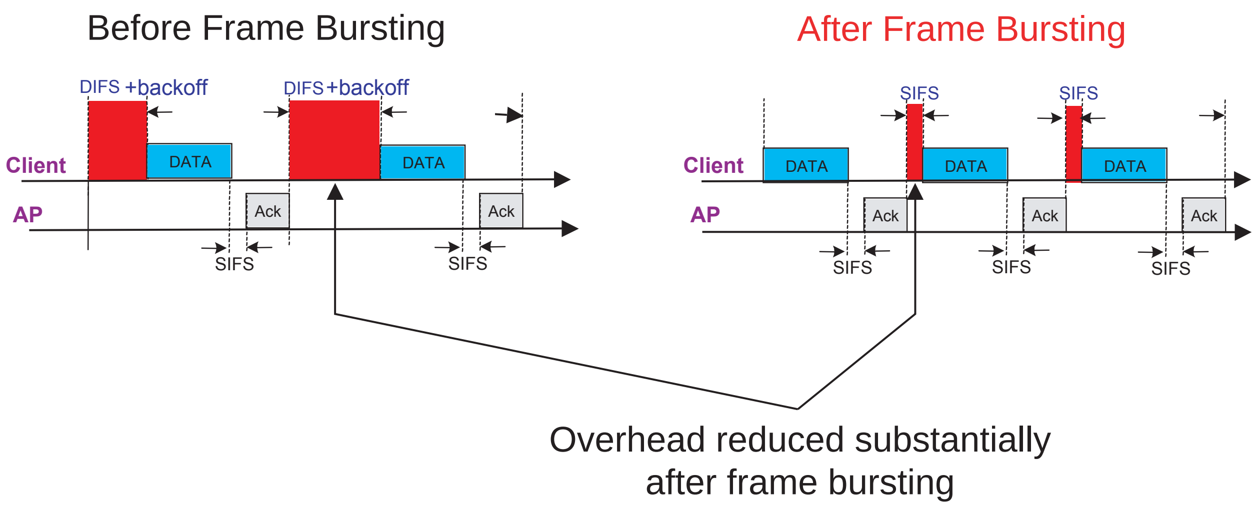


Figure 4. Data Transmission before and after frame bursting

Without the traditional back-off overhead in place after every data transmission, another client is unable to break in and transmit its own data. As a result, the potential exists under frame bursting for one node to monopolize the network with one long string of data transmissions. To prevent that, there are mechanisms in place that limit the number of consecutive frames a given node can burst before it must back off and give another station a chance to transmit.

The maximum number of bursted frames is based on the length of time that a slower node would take to send one frame and corresponding overhead. In theory, then, a slower node wouldn't be penalized by frame bursting because it wouldn't ever have to wait for a chance to transmit longer than it would take it to transmit one of its own frames.

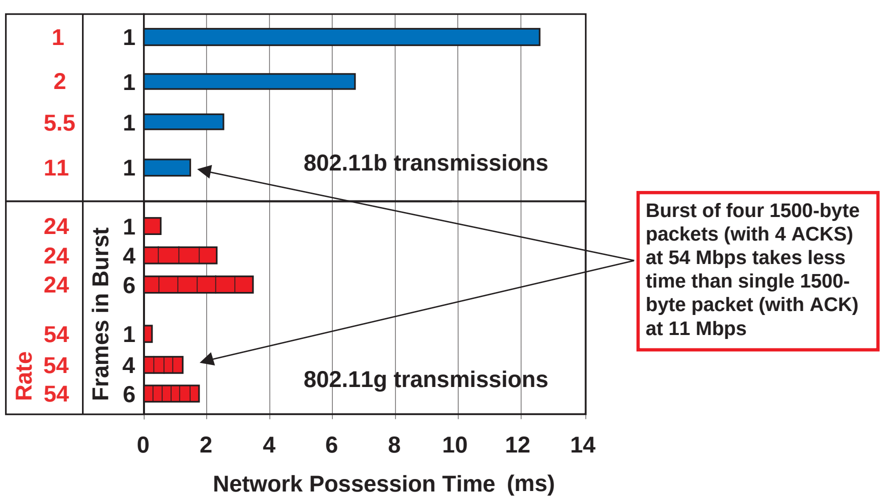


Figure 5. More frames delivered in the same time period

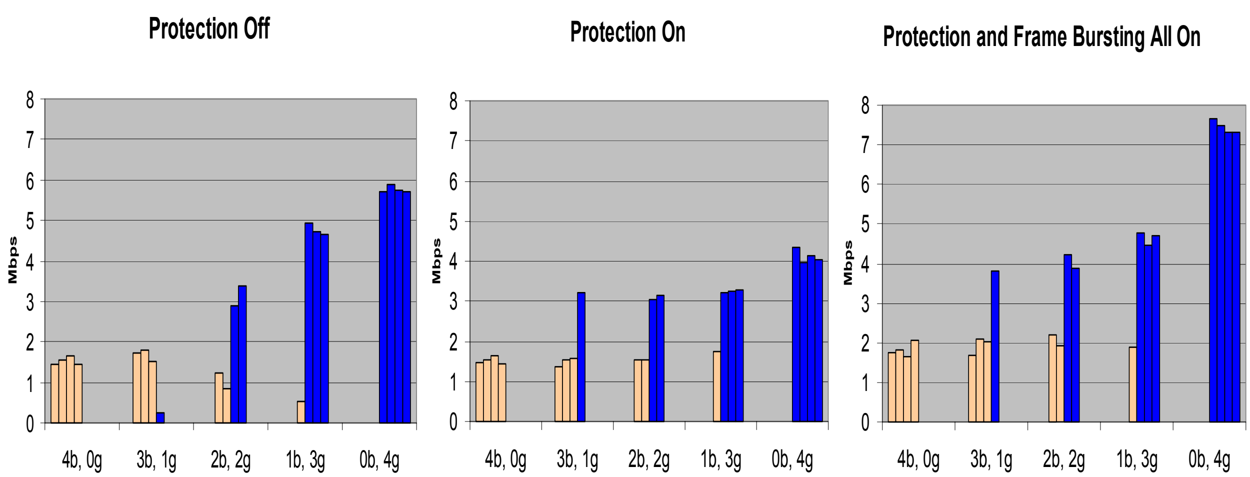
Frame Bursting in a Mixed-Mode Environment

As discussed above, standards-based frame bursting is an effective way to increase the effective throughput for a variety of wireless network configurations. But it makes the most difference in a mixed, 802.11b and 802.11g, environment because it frees up so much time for 802.11g nodes, which are capable of much faster data rates.

These mixed-mode environments require additional overhead to ensure that access to the wireless network is doled out equitably between 802.11b and 802.11g clients. In a mixed-mode environment, the 802.11g hardware recognizes 802.11b transmissions. But the reverse isn't true: an 802.11b client doesn't recognize when an 802.11g client is transmitting, and assumes that the airwaves are clear for it to send data. The result is failed transmissions, which can result in unfavorable performance for some clients.

The solution to this problem is what's known as protection mechanism. With protection mechanisms in place, 802.11g clients announce using 802.11b data rates that they will be transmitting on the channel for a period of time.

By pre-announcing data transmissions, the protection mechanism reduces data collisions. Testing reveals that overall network performance is allocated more fairly among the clients with protection enabled. And with both protection and frame bursting enabled, throughput is fast and allocated fairly.



Client configurations: 4- 802.11b clients, 0- 802.11g clients, 3- 802.11b clients, 1- 802.11g client, etc.

Figure 6. Throughput before and after protection and frame bursting: Protection brings predictability and fairness at the expense of throughput. Frame bursting restores and improves performance.

Remember that a wireless network is a shared medium, so the raw data rate is shared among all the clients. In a 54 Mbps network, for example, the aggregate throughput – or combined effective data rate after overhead – is less than 25 Mbps without frame bursting.

While protection results in predictable and equitable performance for 802.11g nodes, it is clear that frame bursting improves throughput for the overall network in most cases – some by more than 70 percent.

BROADCOM®

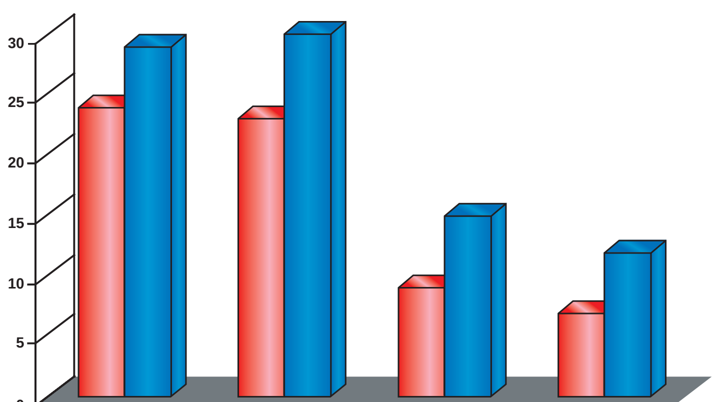
Xpress™ Technology: Frame Bursting from Broadcom

Broadcom is the first vendor to introduce standards-based frame bursting across all flavors of 802.11 technology and refers to this as Xpress™ Technology. It is a feature made available through Broadcom's OneDriver™ software and applies to the AirForce™ 802.11b, 802.11a/g and 54g™ product lines.

Xpress™ Technology implements the latest version of frame bursting in the 802.11e draft specification, and it is also found in the WME specification. Because the implementation is done entirely in software, any product that has shipped with Broadcom technology, including the industry leading 54g™ products, can be upgraded with a simple software download. Because it makes use of the fragment bursting technology found in the original 802.11 specification, the aggregate performance of any network with 802.11 compliant hardware will benefit from the addition of Xpress™ Technology to one or more of its nodes.

Broadcom has done extensive testing using Xpress™ technology to verify performance in both all-Broadcom technology environments and in networks with technology from other vendors. These results closely match simulated results from the complex mathematical model that Broadcom used to plan its implementation. In a homogenous technology environment, whether 802.11b, 802.11g or 802.11a, Xpress Technology can improve aggregate network performance by as much as 27 percent. In a mixed network, as end users will find migrating from 802.11b to 802.11g, aggregate network performance can increase by as much as 75 percent. In all cases tested, adding Xpress Technology to an 802.11 node improved the aggregate network performanc

.



	1 g-client bursting	2 g-clients' bursting	1 g-client, 1 b-client bursting	1 g-client bursting, 1 b-client non-bursting
Aggregate throughput without Xpress	24	23.5	9.3	6.9
Aggregate throughput with Xpress	29.5	29.9	14.9	12.1
	23% Aggregate Performance Improvement	27% Aggregate Performance Improvement	61% Aggregate Performance Improvement	75% Aggregate Performance Improvement

Figure 7. Throughput improvement with Xpress Technology

Measuring Network Performance with Synthetic Benchmarks

Industry benchmarks can be helpful tools for comparing network hardware. But because there are so many possible network configurations and data traffic patterns, synthetic benchmarks are not always the best predictors of in-the-field performance.

One of the most widely-used performance metrics in networking is called Chariot from NetIQ. The most commonly used test in the Chariot benchmarking suite simulates copying a large file repeatedly. While the test is a good indicator of available throughput, it is not necessarily a good predictor of everyday performance.

Real-world network traffic is sporadic, not constant. Users typically send and receive data infrequently and, for the most part, in relatively small amounts. A typical email, for example, is only a few thousand bytes. So if two clients are sending email, they may compete initially for access to the network. But the contention won't last long. There would be even less contention in a mixed network, as the 802.11g client would transmit the email and back off the network in one-fifth the time of its 802.11b counterpart.

Contention would be lower still in a network with frame bursting enabled.

So while Chariot may be a great tool for evaluating maximum throughput, it is clear that it does not necessarily represent how hardware will perform in the real world. When comparing products based on simulated benchmark tests, note that tests representing large crowded networks will demonstrate lower performance in benchmark tests, but real-world results will be greater.

Conclusions

Wireless networking is proliferating at a rapid pace. Over time, analysts forecast that wireless-enabled notebook computers and PDAs will be vying for time on networks with each other, as well as printers, cell phones, consumer electronics devices and a host of other products.

With all these demands on the wireless network, standards-based improvement to performance is paramount. The IEEE has recently approved the new mainstream 802.11g standard that enables 54 Mbps, 2.4 GHz wireless LANs. And frame bursting has emerged as a great way to improve performance by making the network more efficient. Frame bursting is a standards-based technology, so it improves performance for existing wireless installations as well as for new equipment. And because it is standards-based, frame bursting does not require the presence of proprietary hardware in the network for clients to experience the benefit.

Broadcom is introducing frame bursting as Xpress™ technology, and is making the feature available through its OneDriver ™ software. As a result, Xpress is becoming available for all of Broadcom's AirForce ™ wireless LAN product family. The improvement in performance is greatest for mixed 802.11b + 802.11g environments and is an ideal performance technology to be implemented as the industry transitions from 802.11b to 802.11g as the mainstream wireless LAN standard.

Because Xpress technology is standards-based frame bursting and it leverages existing standards, Xpress technology benefits more than just an individual user or device. Xpress truly warrants its name, because each node that introduces Xpress technology to the network also increases the aggregate performance of the network – maximizing performance of the 802.11 wireless LAN.

Broadcom Corporation

16215 Alton Parkway
P.O. Box 57013
Irvine, CA 92619-7013
Phone: 949-450-8700
FAX: 949-450-8710
www.broadcom.com
www.54g.org