CDMA2000 & Wi-Fi: Making a Business Case for Interoperability

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Executive Summary

The data capabilities of Wi-Fi and hot spot services are often compared to those of CDMA2000. The two technologies will co-exist successfully serving different purposes. CDMA2000 is ideally suited for mobile applications and road warriors while Wi-Fi is well suited for private networks such as enterprises, campuses and homes. Yet CDMA2000 operators are beginning to look at Wi-Fi to augment their networks in areas such as airports where data usage is expected to be high.

Wi-Fi could augment CDMA2000 systems in high traffic areas but it is not a substitute for high-speed wide area networks (WAN) technologies such as CDMA2000. The two systems will achieve similar speeds depending on the backhaul used by the hot spot operator. CDMA2000 1xEV-DO provides speeds comparable to a hot spot using a T1 backhaul (e.g., T-Mobile operated hot spots), and CDMA2000 1X provides speeds similar to a hot spot using a DSL backhaul (e.g., Cometa hot spots). This paper discusses the unique value proposition of CDMA2000 and the role Wi-Fi could play in a CDMA2000 network.

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Wi-Fi's Mixed Market Potential

According to recent studies by analyst firms such as Forrester Research and Strategy Analytics, the number of laptops with built-in Wi-Fi will grow from 24% in 2003 to at least 80%, or 141 million, by 2008. Meanwhile, the number of Wi-Fi hot-spots[1] in the United States are forecasted to grow from 3,020 at the end of 2002 to 12,080 in 2003 and more than 72,000 in 2007, according to the Yankee Group.

But measured in terms of the ability to provide a dependable, extensive mobile broadband service, that growth is less impressive. Take coverage, which traditionally is one of the key yardsticks that consumers and enterprises use when picking a wireless provider. With each hot spot covering, at best, a radius of less than 200 feet, 12,080 hot spots wouldn't provide seamless coverage of the borough of Manhattan, let alone the entire United States.

In June 2003, Singapore's MobileOne abandoned plans to supplement its 3G network with Wi-Fi because hot spot coverage wasn't extensive enough to meet customer needs during a four-month trial. "The business model does not appear to be

[1] A hot spot is a Wi-Fi access point.

workable, according to customer feedback, as users don't like having to stay within 50 to 100 meters of the hot spot," a MobileOne spokesman told Reuters.

Furthermore, the addressable Wi-Fi market will remain small compared to the size of the wireless industry. Even when the number of Wi-Fi laptops hits 141 million in 2008, that's still only about one-third of the number of cell phones sold industrywide in 2002.

Why Wi-Fi Isn't Necessarily Broadband

The articles and analyst reports that are bullish on Wi-Fi usually make this argument: Wi-Fi delivers 11 Mbps, which is significantly faster than 3G, so consumers and business users will opt for Wi-Fi wherever it's available. Assuming that data rates are a decisive factor – an assumption that overlooks factors such as coverage and security – also assumes that most hot spots deliver data rates faster than CDMA2000. But that's not necessarily the case.

If throughput really is that important to most consumers and business users, then Wi-Fi has little or no advantage over CDMA2000.

Take 802.11b, the most widely used type of Wi-Fi. Its theoretical maximum data rate is 11 Mbps, but with all Wi-Fi technologies, including 802.11b, at least half of the available bandwidth is consumed by radio overhead. To get the remaining throughput of about 5.5 Mbps, the user would have to be no more than a few feet from the access point (AP),[2] and the Wi-Fi provider would need to equip that AP with backhaul capable of delivering the full 5.5 Mbps.

Considering that the vast majority of public hot spots use, at best, a T-1 line for backhaul, the real-world throughput would be only about 1 Mbps.[3] Add in factors such as other users and a weak signal, and the throughput is cut to hundreds of kilobits per second.

By comparison, an optimized CDMA2000 1xEV-DO network can consistently deliver 500 kbps even when the user is a mile or more away from the cell site.[4] In better conditions, throughput may be over 1 Mbps, which is at least as fast, if not faster, than 802.11b. So if throughput really is that important to most consumers and business users, then Wi-Fi has little or no advantage over CDMA2000.

[2] As with all wireless technologies, Wi-Fi's ability to support high data rates diminishes as the signal weakens due to factors such as distance, interference and walls.
[3] Verizon Wireless is advertising its Wi-Fi service's peak data rates as 1.544 Mbps, or T-1 speeds.
[4] Monet Mobile Networks, which offers 1xEV-DO as an alternative to dial-up, cable and DSL, says that average speeds range from 300 kbps to 700 kbps.

Data Throughput Comparison

Wi-Fi			CDMA2000		
	Peak	Average		Peak	Average
T1-Based Service (T-Mobile)	11 Mbps	300 - 700 Kbps	1xEV-DO	2.4 Mbps	300 - 600 Kbps
DSL-based Service (Cometa)	384 Kbps	~100 Kbps	1X	144 Kbps	60 - 100 Kbps

Note: average throughput rates assume moderate network traffic

Barriers to Wi-Fi Deployment and User Adoption

The low cost of Wi-Fi infrastructure suggests that the service can be deployed quickly, easily and affordably. Although that assumption is correct to a certain extent, it also ignores several key issues, such as coverage, roaming, backhaul, interference and security, all of which affect deployment and user adoption.

To blanket 10 square kilometers, a Wi-Fi network would require roughly 650 APs. By comparison, nine CDMA2000 1xEV-DO cell sites could cover the same area.

Coverage

A single AP can cover, at best, a radius of only about 200 feet, so hundreds of APs are necessary to provide seamless coverage just in, say, a downtown.[5]

For example, Qualcomm has roughly 200 APs throughout its San Diego campus, yet Wi-Fi coverage is still spotty. To put that in perspective, 200 APs is roughly 15% of Boingo Wireless' total worldwide network.[6] So even though APs are relatively inexpensive, the cost of seamless coverage for just a campus or downtown quickly adds up. To blanket 10 square kilometers, a Wi-Fi network would require roughly 650 APs. By comparison, nine CDMA2000 1xEV-DO cell sites could cover the same area.

Roaming

Roaming is key to the success of any wireless technology that can't offer extensive, let alone ubiquitous, coverage from day one.[7] Although Wi-Fi aggregators and operators such as Boingo and Wayport have made significant progress toward expanding

[5] The access point density would have to be even higher if the Wi-Fi service also provided voice over IP because users would expect to be able to make calls in lunchrooms, smoking areas and other places where they normally wouldn't try to use their laptops.

[6] In December 2002, there were roughly 3,800 U.S. hot spots, according to MDR/In-Stat, which expects the total to hit at least 25,000 by the end of 2005. (By comparison, a single major CDMA operator typically has nearly 20,000 cell sites, each of which cover a mile or more rather than a few hundred feet.) Another recent estimate, by Allied Business Intelligence, puts the current number of hot spots worldwide at 28,000, growing to at least 160,000 by 2007.

[7] Cometa Network is a recent example of the challenge of quickly building an extensive Wi-Fi network. When the company launched in December 2002, it planned to deploy more than 25,000 hot spots by the end of 2003. But some media reports, such as www.unstrung.com/document.asp?doc_id=36594, say that as of early July, Cometa has deployed only 10 hot spots.

coverage through roaming agreements, for most users, logging on to another provider's hot spot usually means tinkering with their device settings or providing a credit card number.[8]

The catch is that a Wi-Fi provider can't simply partner with any hot spot operator in another area – assuming that another operator even covers that area – without first ensuring that the potential partner can meet certain guidelines, such as secure connections and detailed usage statistics for billing.

Backhaul

In most analyst reports and articles in the trade and mainstream press, the role of backhaul in Wi-Fi doesn't get the attention that it deserves. That's ironic because backhaul directly affects a topic that is always covered: data rates. Yet Wi-Fi's real-world data rates are at least half of their theoretical peak rates due to factors such as signal strength, interference and radio overhead. Backhaul can reduce the remaining throughput even further.[9]

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For example, some Wi-Fi operators recently have begun emphasizing that a T-1 provides backhaul for each of their APs. Meanwhile, small Wi-Fi operators, such as a coffee shop owner, typically use DSL or cable for backhaul – assuming that their ISP even allows commercial re-use.[10] At best, cable, DSL or a T-1 line is capable of providing far less than 2 Mbps, a rate that is reduced even more when multiple users share the same AP.

Backhaul can make or break the business case for a public Wi-Fi service. The average cost of a T-1 line is approximately $750 per month, which is too expensive for individual Wi-Fi operators to make a business case for, let alone justify giving away as part of a loss leader Wi-Fi service aimed at attracting more customers to a coffee shop or hotel. If the Wi-Fi service charges, say, $30 per month for unlimited use, each AP requires almost 25 subscribers just to pay for backhaul.[11] Few places have the population density necessary to have that many paying Wi-Fi users within range of each AP.

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[8] With Wi-Fi's security flaws, discussed below, constantly in the mainstream press, many users might balk at providing a credit card number over a connection that they feel is insecure.

[9] One convenient way to check the true speed of a Wi-Fi connection is to log onto a hot spot and then go to the Internet Connection Speedometer at http://promos.mcafee.com/speedometer.

[10] AT&T Broadband and Time Warner New York City are two examples of ISPs that have sent cease-and-desist letters to customers who use their broadband connections to provide free Wi-Fi to neighborhoods.

[11] In a May 2003 report, Forward Concepts expects revenue from each U.S. hot spot to average about $15,000 by 2007. That amount would more than pay for the cost of two T-1s per hot spot, but the bigger question is, how many hot spots will generate enough revenue to keep stand-alone Wi-Fi providers in business until 2007?

As noted ealier, the average cost of a T1 line is approximate $750. In comparison, the cost to offer backhaul for data on a CDMA2000 network is essentially free, as the expense is subsidized by the voice network's use of the connection. This provides CDMA2000 operators a huge advantage in offering data to their subscribers.

Another big issue is backhaul availability. In many places, weeks or months can pass between the time that a T-1 is ordered and when it's provisioned. That can delay an aggressive, widespread Wi-Fi rollout.

Interference

Wi-Fi uses unlicensed spectrum, so service can be launched more quickly and less expensively than if spectrum first has to be acquired.

But on the other hand, unlicensed spectrum means no regulatory recourse against interference. Worse, the most popular type of Wi-Fi, 802.11b, uses the crowded 2.4 GHz band, which already is home to a myriad of other technologies, including Bluetooth, cordless phones and microwave ovens.

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A technology that is inherently vulnerable to interference is difficult to market as more than a best-effort service. Without some basic QoS guarantees, a wireless service – Wi-Fi or otherwise – won't be attractive to business and enterprise users.

Mitigating interference can be difficult or impossible. For example, public Wi-Fi is still a relatively new service, so building owners have limited experience with the technology. As a result, it's rare to see a lease that includes provisions covering Wi-Fi, such as giving a leaseholder exclusive rights to offer Wi-Fi in all or part of a building. The exception is airports, where increased concerns about security have resulted in a trend toward leases that limit leaseholders' ability to install their own Wi-Fi networks.[12] Most airports now prefer or require a single Wi-Fi operator, which either becomes the exclusive provider for the facility or leases service to other providers.

Security

Most Wi-Fi APs and modems use the Wired Equivalent Privacy standard, which is very susceptible to hacking and eavesdropping. In June 2003, the Wi-Fi industry completed a new standard, Wi-Fi Protected Access (WPA), to plug security holes.

[12] As noted later, CDMA operators should seek to partner with Wi-Fi providers that have exclusive rights to key public places, such as airports, that are frequented by business users.

Many vendors say that they plan to offer software upgrades so that owners of newer APs and modems can add WPA, but anecdotal[13] and scientific evidence show that few users know or bother to turn on WEP.

Meanwhile, the Wi-Fi industry is working on 802.11i, which offers more security than WPA, but it's unclear when the technology will be commercially available. One thing is certain: 802.11i's architecture is so different from WEP and WPA that it can't be offered as a software upgrade. Instead, users will have to replace their equipment, potentially slowing adoption of 802.11i. CDMA is inherently much more secure than Wi-Fi. For example, it's immune to "wardriving," where a user with a Wi-Fi device can search for other nearby Wi-Fi users and capture their data traffic as it travels between their modem and the AP. CDMA also is a service that's offered only by large, established telecom providers, which are companies that recognize the importance of end-to-end security and know how to add it to their networks.

By offering a complementary Wi-Fi service, a CDMA operator can establish and strengthen relationships with more broadband users, particular enterprise customers.

The Business Case for Linking Wi-Fi and CDMA

Wi-Fi's significant limitations beg the question, why would a CDMA operator want to add Wi-Fi to its portfolio of high-speed data services?

One major reason is that Wi-Fi can be a convenient way to offload some high-bandwidth data, freeing the CDMA network to focus on delivering voice and high-speed data to users who are mobile. Another reason is that although the addressable Wi-Fi market is small compared to CDMA, it's still significant. By offering a complementary Wi-Fi service, a CDMA operator can establish and strengthen relationships with more broadband users, particularly enterprise customers.

To provide Wi-Fi services, a CDMA operator can partner with a Wi-Fi provider or, when possible, leverage a sister company that provides Wi-Fi service by reselling its service, just as a wireless division may get long distance from its sister division. The latter option often helps avoid some of the technical and business hurdles related to linking two disparate networks.

Wi-Fi providers can be divided into two types – operators and aggregators –

[13] In July 2003, security vendor AirDefense monitored Wi-Fi usage at Boston's major convention center. In two days, it identified 141 unencrypted APs, 149 eavesdropping attempts, 105 denial-of-service attacks and more than three dozen other security attacks. Worse, the users in this area during those two days should be more aware of Wi-Fi's security risks than the average consumer or business user: They were all attending the 802.11 Planet Expo trade show.

with the distinction based on whether they own the hot spots that they use to provide service. That distinction affects their ability to be an effective partner for mobile operators.

There is a wide variety of operators, ranging from the owner of a coffee shop with a single AP to regional and national operators such as Cometa Networks and Wayport. The common denominator is that operators own all or most of their hot spots, although they may supplement them through roaming agreements with aggregators or other operators.

By comparison, aggregators such as Boingo Wireless, GRIC Communications and iPass own few, if any, hot spots. Instead, using a "virtual operator" business model, they partner with Wi-Fi operators and resell their service to mobile operators, end users, or both.

Operators and aggregators can be attractive partners for CDMA operators because they reduce the time, cost and risk of launching a hot spot service. By partnering with Boingo, for example, a CDMA operator can offer its customers Wi-Fi service in more areas and more quickly than if it deployed its own hot spots or cut multiple deals with individual Wi-Fi operators. Established operators and aggregators also have a good understanding of a CDMA operator's needs, including authentication, backhaul, billing, roaming and QoS.

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Technical Options for Linking Wi-Fi and CDMA

There are multiple ways to link a CDMA network to one or more Wi-Fi networks in order to provide seamless broadband service. The choice depends on factors such as the operators' back-office systems and the types of users they're pursuing.

The linkage also can be divided into two areas: the network and the user device.

Network

Linking CDMA and Wi-Fi networks involves both business agreements and engineering. The business issues typically include negotiating service-level agreements and determining how much visibility each provider has into its partner's network for identifying and resolving problems. The key technical issues generally

involve billing and authentication, and they tend to be more challenging when the networks are owned by different companies rather than by different divisions of the same company.

The Wi-Fi provider must be able to authenticate the CDMA user, track his usage and then deliver that information in a format compatible with the CDMA operator's billing systems.[14] The hurdles may be political. For example, one CDMA operator said that it originally wanted to get the same information from its Wi-Fi partner's RADIUS AAA server that it was pulling from its server, but the partner couldn't deliver, so they had to compromise.

The hurdles also can be technical, such as a Wi-Fi partner that can't track usage by a certain criteria or can't deliver the usage information in a format that's compatible with the CDMA operator's billing system. Indeed, Cometa Networks has said that it plans to use a flexible, granular billing system as a way to differentiate itself from other Wi-Fi operators and make itself attractive to mobile operators.

Major Wi-Fi providers clearly recognize the importance of interoperability with 3G. Boingo Wireless, for example, is working with TSI Telecommunication Services on back-office systems to support roaming between 3G and Wi-Fi. In a July 2003 interview with Reuters, TSI's CEO said that three major mobile operators are testing the system, where features include better support for integrated billing.

At the same time, many mobile operators see integrated billing as a way to differentiate themselves and reduce costs, such as printing and mailing separate bills. For users, a single monthly bill for 3G and Wi-Fi is a convenience that could be one more barrier to churn.

Wireless industry standards bodies have done their part to enable 3G/Wi-Fi interoperability. One example is Mobile IP, which eases handoffs between disparate networks so that they're not noticeable to users or programs, such as e-mail, that balk when their IP connection changes. These technologies are particularly useful for a CDMA operator that targets vertical markets such as law enforcement, where a police cruiser may use Wi-Fi within a block of the station but then switch to 3G when it moves out of range.

[14] Ericsson is among several vendors whose GSM/Wi-Fi interoperability systems leverage the SIM for processes such as authentication. Although in theory CDMA could leverage the R-UIM for the same functions, many CDMA operators say that they prefer software-based solutions.

Dozens of infrastructure vendors, large and small, have launched or are developing network technology to support 3G/Wi-Fi interoperability and established security standards such as IPSec. For example, Lucent Technologies offers CDMA infrastructure that supports security features such as VPNs and handoffs between 3G and Wi-Fi regardless of where the data session originated.

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User Devices

The hardware and software necessary for users to alternate between CDMA and Wi-Fi varies by the type of device they use. For example, some users might have a dual-mode CDMA/Wi-Fi PC card modem for their laptops,[15] while others might have a laptop with built-in Wi-Fi and a separate CDMA PC card.

In both cases, the laptop, Tablet PC or PDA also will need software to manage the connection. One example is PCTEL's Segue client software, which the CDMA operator can configure to look for the CDMA network first and then fall back on Wi-Fi. Users with Windows XP laptops and Windows Mobile 2003 PDAs also benefit from those operating systems' ability to sense available networks, regardless of technology. Client software such as Segue can automatically switch users to CDMA as they move out of Wi-Fi coverage while maintaining services such as virtual private networks (VPNs). However, a growing consensus argues that seamless switching isn't necessary to attract users because in most cases, they'll be stationary while using their laptops rather than moving in and out of coverage at pedestrian or vehicular speeds.

Sprint PCS and Verizon Wireless are two examples of CDMA operators that offer Wi-Fi.

Examples of Commercial CDMA/Wi-Fi Services

Thanks to a wide variety of network and device solutions, linking CDMA2000 and Wi-Fi networks to provide a user-friendly broadband service is a viable option. Sprint PCS and Verizon Wireless are two examples of CDMA operators that offer Wi-Fi.

[15] Some CDMA operators say that dual-mode PC card modems are falling out of favor with operators and users. Indeed, the debut of Intel's Centrino chipset in March 2003 is the latest example of device vendors' preference for built-in Wi-Fi. Meanwhile, Qualcomm says that although it can easily add Wi-Fi to its CDMA chipsets, it hasn't because device vendors haven't asked for it due to no operator requests for hardware that combines CDMA and Wi-Fi.

Sprint PCS

In July 2003, Sprint PCS announced plans to offer Wi-Fi service in more than 2,100 U.S. locations by early 2004. The "PCS Wi-Fi Access" service will use a combination of hot spots owned and operated by Sprint and, via roaming agreements, with Wi-Fi operators such as Wayport, Airpath Wireless and Cometa Networks. The Sprint-owned hot spots will be in prime locations frequented by business users, including airports, convention centers and hotels.

PCS Wi-Fi Access leverages the company's existing PCS Connection Manager client software, which has been expanded to identify hot spots owned by Sprint or its roaming partners and automatically connect users.

Verizon Wireless

Verizon Wireless' parent company, Verizon Communications, offers several Wi-Fi services. In November 2002, Verizon Communications began offering turnkey Wi-Fi packages for small businesses that include design and installation. At the time, the company said that it was the first step in "an eventual nationwide rollout of wireless LAN services." In May 2003, Verizon Communications launched a hot spot service in New York city by adding Wi-Fi to its pay phones. Verizon Wireless could leverage Verizon Communications' Wi-Fi portfolio by reselling some or all of those services.

In August 2003, Verizon Wireless launched a Wi-Fi service by teaming with Wayport, a partnership that was originally announced in March 2003. Under the agreement, Verizon Wireless customers with Wi-Fi laptops and PDAs can get access from more than 500 Wayport hot spots across the United States.

To use the service, Verizon Wireless customers must supply their own Wi-Fi modem, such as one that's built into their laptop's motherboard or a PC card that plugs into a laptop or PDA. Although Verizon Wireless isn't selling Wi-Fi PC cards or CDMA2000/Wi-Fi PC cards, it does provide its Wi-Fi customers with free client software that automatically detects when they're within range of a Verizon Wireless hot spot.

Verizon Wireless is advertising the Wi-Fi service's peak data rates as 1.544 Mbps, or T-1 speeds. One key feature is single billing: Wi-Fi data, CDMA voice and CDMA data all appear on the same monthly bill.

Other Potential CDMA Services

Several other CDMA operators are in a good position to offer Wi-Fi. One example is KT Freetel of South Korea, whose sister company, NESPOT, offers an extensive hot spot service in public places such as subway stations. SK Telecom is another South Korean CDMA operator that is working to add Wi-Fi to its portfolio.

In December 2002, Bell Mobility's parent company, Bell Canada, began adding Wi-Fi to its payphones in Montreal and Toronto. In July 2003, the Bell AccessZone service was expanded to VIA Rail trains. If Bell AccessZone graduates from a trial to a commercial launch, Bell Mobility could leverage that investment by reselling it as part of a bundled CDMA/Wi-Fi service.

Conclusion: Wi-Fi and CDMA Are Complements, Not Competitors

Wi-Fi's impressive growth can't be denied. Businesses and consumers continue to adopt the technology, in homes, campuses and enterprises. Many CDMA2000 operators are investigating Wi-Fi and its potential benefits to augment their networks, yet the power of CDMA2000 should not be overlooked. Backhaul limitations on Wi-Fi hot spots do not allow the technology to offer significantly greater user experiences than CDMA2000 1xEV-DO. Wi-Fi's significant shortcomings are in key areas such as security and coverage, which means that it will remain a niche technology – albeit a useful one.