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White Paper

Trends in broadband wireless

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Abstract

Wireless cable solutions enable cable operators to efficiently extend the reach of their high-speed data network into consumer, business or campus environments. These capabilities open opportunities for operators to grow revenue by providing services to both consumers and businesses — one of the key underpinnings for the strategic competition of MSOs with telcos and other service provider sectors.

But technologies are changing rapidly, and business strategies of cable operators are developing quickly, as was indicated by the cable industry's investment of more than $2.4US billion in spectrum for WiMAX deployment at the FCC auction last August. In this paper, we will explain recent developments in cellular, WiFi and WiMAX, and their implications for the cable industry. This paper will provide an update on the multiple wireless technologies available and the appropriate uses for each. It looks at trends in the technologies, applications and business models made possible with wireless deployments.

Included will be an overview of the following:

- 2G and 3G cellular standards and their evolution.
- The WiFi opportunity — Wireless Mesh and WiFi access point solutions can enable cable operators to deliver wireless broadband in, among other opportunities, municipal WiFi deployments.
- WiMAX — WiMAX (Worldwide Interoperability for Microwave Access) can deliver high-speed, broadband fixed and mobile services wirelessly to large areas with much less infrastructure than is needed today. We will look at the different flavors of WiMAX and the potential this technology presents for cable operators.
- Spectrum Acquisition and the Competitive Landscape — The latest developments here, following last year's FCC auction. What are the implications for cable operators in competition with telcos and satellite providers?
- Fixed Mobile Convergence — The demand for broadband services offered over both wireline and wireless networks (utilizing 3G/cellular, Wireless LAN and WiMAX technologies) is increasing, and operators need a solution that can reach across these domains to provide transparent service delivery.
- IP Multimedia Subsystem (IMS) — Enables cable operators to dramatically transform both the end-user communications experience and their own business models.

Introduction

Cable operators are recognizing the business opportunity wireless technology could enable, specifically by leveraging emerging wireless technologies to offer new broadband services to their subscribers. The mobile nature of these services — as well as the productivity and cost efficiencies they enable — has led to increasing subscriber demand for wireless broadband access. In addition, wireless broadband presents an opportunity to reach out to the enterprise, including small and medium-sized businesses (the SMB market) which in some cases may not currently have broadband access.

Almost two years ago we presented a paper at the SCTE Conference on Emerging Technologies which talked about a vision of a seamless wired line/wireless network. The industry buzzword has become "Internet Everywhere".

That paper tried to predict "The Wireless Cable World in 2010". But I'm afraid we looked a little too far out. As is often the case, real events have outpaced our ability to predict them. The proliferation of WiFi Mesh networks, and early buzz around WiMAX, plus developments in 3G and 4G wireless, all are worthy of another look.

For example, if pure investment and spectrum ownership are any indication, the FCC auction of August 2006 launched the consortium of cable companies known as SpectrumCo. as a major player in broadband wireless. Competition has a tendency to speed things up.

Today's wireless alternatives can become confusing. WiFi Mesh, WiMAX, 3G, 4G. We all hear the terms but their meaning is not always clear. General usage often blurs the technical facts behind the terminology.

Wireless comes of age

Over the past few years there has been a tremendous growth in the availability of wireless broadband services. Today it is not uncommon for subscribers to access the broadband network using wireless technology inside the home or office and from many points in between. The technology is in place to deliver the broadband mobile data, voice and video services both consumers and enterprises are demanding.

The expectations of today's users — and the ability of providers to meet them — would have been beyond reach even a few years ago. In addition to new broadband 3G and 4G cellular technologies, advancements in WiFi and WiMAX technologies will offer additional choices for the consumers looking for mobile broadband services.

Competitive factors almost dictate that cable operators enter the wireless market now. With phone companies now aggressively building fiber-to-the-home (FTTH) and fiber-to-the-curb (FTTC) networks to deliver high-capacity broadband services, including digital video and high-definition TV (HDTV), cable operators need new, advanced services to stay ahead of the competition. And wireless offerings certainly meet that need.

First- and second-generation (2G) cellular: a brief look back

Public cell phone testing began in the late 1970s, with the first trial taking place in Chicago, followed not long afterwards in Washington, D.C. and Baltimore (from Motorola and American Radio). In 1983, Ameritech offered the first analog cell service in the Chicago area. By 1987, there were over one million subscribers and frequencies were becoming overcrowded — a new technology was needed.

This overcrowding was addressed quickly through new cellular standards. 1988 was an important year for cellular wireless technology — the Cellular Technology Industry Association (CTIA) was developed to set standards for cellular phone providers. In 1991 the TDMA (Time Division Multiple Access) standard was created; since then, CDMA (Code Division Multiple Access) and GSM (Global System for Mobile Communications) standards have been developed. TDMA and CDMA are widely used in the United States; GSM has become the standard in Europe.

Wireless standards

TDMA IS-136 (Time Division Multiple Access) is an update to the original TDMA standard IS-54. This standard divides frequencies into time slots with each phone user having access to one time slot at regular intervals. TDMA IS-136 exists in North America at both the 800 MHz and 1900 MHz bands.

CDMA IS-95 (Code Division Multiple Access) is based on a form of spread spectrum technology that assigns voice signals digital codes within the same broad spectrum. CDMA exists at both the 800 MHz and 1900 MHz bands. Since the first introduction of IS-95 in the early 90s, CDMA has become one of the leading technology choices for digital wireless cellular communication. In the late 90s came the next generation of CDMA called CDMA2000 1X, which improved upon IS-95 by adding faster power control to reduce the variability of the received signal strength in slow to moderate fading conditions, thereby effectively doubling the subscriber density per radio carrier. 1X technology also enabled operators to offer up to 307-kbps packet data speeds.

GSM (Global System for Mobile Communications) is based on an improved version of TDMA technology. GSM engineers decided to use wider 200 kHz channels instead of the 30 kHz channels that TDMA used, and instead of having only three slots like TDMA, GSM channels had eight slots. GSM is currently the only one of the three technologies that provides data services such as email, fax, Internet browsing and intranet/LAN wireless access; and it's also the only service that permits users to place a call from either North America or Europe. From 1995 to 2000, GSM went through several technology evolutions — all aimed at achieving the higher speeds needed to support higher-bandwidth data requirements. GSM evolved first to GPRS (General Packet Radio Service), then to EDGE, and most recently to UMTS (Universal Mobile Telecommunications System).

Enabling wireless technologies: antennas and multiplexing

To continue the evolution of wireless technologies, the wireless industry must constantly address the challenges associated with achieving the next gains in capacity, coverage, and spectral and power efficiencies.

A new antenna processing technique called multiple-input multiple-output (MIMO) with a modulation scheme called orthogonal frequency division multiplexing (OFDM) is beginning to show promise. In spectral efficiency and capacity circles, the OFDM-MIMO combo is a blockbuster, with the potential to lay the foundation for the data rate and capacity gains that will be needed for years to come.

The first application of OFDM-MIMO is in the WiMAX technology solution. OFDM-MIMO is also being considered as an access technology for the evolution of both CDMA and UMTS networks. The 3GPP2 (Third Generation Partnership Project 2) standards bodies are discussing the incorporation of OFDM-MIMO in the evolution of 1xEV-DO/EV-DO RevA networks. In addition, the 3GPP (Third Generation Partnership Project) is considering the OFDM-MIMO evolution of HSDPA/HSUPA networks.

MIMO

MIMO is a radio air interface technology that can carry up to five times more data traffic than today's networks. This works by creating multiple parallel data streams between the multiple transmit and receive antennas, and by exploiting the multi-path phenomenon to differentiate among the multiple parallel signal paths between MIMO antennas. In this way, MIMO technology achieves a multi-fold user throughput gain and multiple aggregated network capacity increase compared to the current third-generation (3G) macro-cellular networks.

The basic proposition of MIMO technology is that the throughput will increase M-fold for the configuration of M transmit antennas and N receive antennas (in general N>M) compared to conventional single-input single-output (SISO) transmission with the same total transmit power and same bandwidth.

To handle the diverse deployment scenarios inherent in a radio environment, several MIMO modes are typically employed and adaptively used based on real-time radio propagation conditions and quality of service (QoS) requirements. For instance:

- Transmit diversity mode, typically space time transmit diversity (STTD), is used to improve channel quality by increasing the robustness of transmission and reducing the packet error rate
- Spatial multiplexing mode, which creates several parallel independent transmission streams, is used to increase throughput

OFDM

OFDM is a scalable modulation technique that uses many subcarriers, or tones, to carry a signal. OFDM signaling consists of a large set of spaced subcarriers (with no mutual interference) to perform parallel data transmission in the frequency domain.

The major merit of OFDM is that it eliminates the multi-path channel-induced self-interference that occurs with high-speed data transmission over the wireless channel and which can limit transmission speed and spectrum efficiency. Moreover, OFDM eliminates self-interference without requiring equalization at the receiver, thereby dramatically reducing complexity

Figure 1. MIMO: Multiple-Input Multiple-Output

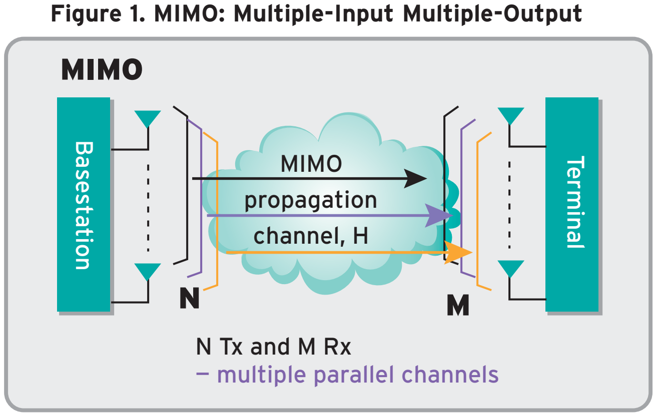
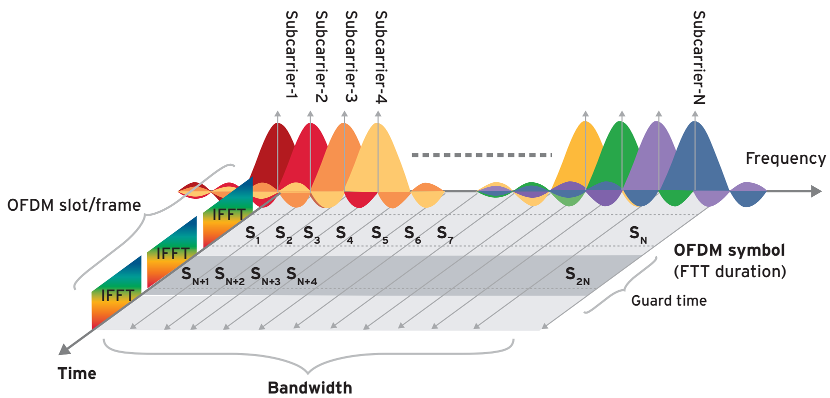


Figure 2. OFDM technology



without performance loss. As well, OFDM allows the coding modulation to be adapted to match the radio channel quality in both time and frequency, thereby achieving optimal transmission.

OFDM's self-interference-free property is ideally suited for MIMO transmission. The orthogonality among the subcarriers ensures that the MIMO transmission format is preserved at each subcarrier at the receiver without any cross-interference, making the MIMO signal reception a simple extension of basic OFDM signals. In addition, the OFDM signal allows the use of frequency domain orthogonal pilots to facilitate the MIMO channel estimation at the receiver.

When used in combination, OFDM and MIMO offer the best solution for making more efficient use of the spectrum and boosting throughput, which also leads to significantly reduced operating costs and a better end-user experience.

3G wireless technologies

Having achieved reasonably high packet data speeds, the next focus was to enable service providers with a technology to not only drive additional business but also generate new revenue streams.

In North America and Asia, the lead today is being taken by the Third Generation Partnership Project 2, commonly known as 3GPP2. This is a collaborative telecommunications specification-setting project comprising the Association of Radio Industries and Businesses (ARIB) – Japan, China Communications Standards Association (CCSA) – China, Telecommunications Industry Association (TIA) – USA, Telecommunications Technology Association (TTA) – Korea, and Telecommunication Technology Committee (TTC) – Japan. Last August, 3GPP2 announced several significant milestones in defining the 3G standard CDMA2000.

CDMA evolution

Moving towards an all-IP packet data network and the need to support significantly higher packet data rates resulted in the introduction of CDMA2000 1xEV-DO. It is one of the fastest mobile wireless networks currently deployed in the world with its first release –1xEV-DO Rev 0, supporting up to 2.4 Mbps and 153 kbps in forward and reverse link respectively. A newer version, CDMA EV-DO Revision A, allows operators to serve more customers on the same spectrum while delivering VoIP and other advanced multimedia services.

CDMA2000 is the most widely deployed 3G technology, with 162 operators in 72 countries, including 38 CDMA2000 1x-EV-DO systems, serving more than 250 million subscribers. Counting 2G cdmaOne™ subscribers, there are more than 300 million CDMA users worldwide. CDMA2000 has become the technology of choice for cdmaOne, TDMA, analog and greenfield operators, and is deployed in the 450, 800, 1700, 1900 and 2100 MHz bands. Nearly 1,250 CDMA2000 devices from more than 80 suppliers have been introduced to the market, including 280 1xEV-DO devices.

The latest news is Ultra Mobile Broadband, or UMB, which the CDMA Development Group has chosen as its go-to-market term for the set of standards supported by EV-DO Revision C, the latest proposed evolution of CDMA2000. UMB is lining up for 2Q 2007 standard finalization and a commercial introduction some time in 2009. By the way, UMB has a theoretical limit of 28 Mbps.

GSM evolution

UMTS providers are migrating to High Speed Downlink Packet Access (HSDPA), which provides a shared high-speed data pipe — similar to 1xEV-DO. When shared among many users, HSDPA provides users with download speeds of several hundred kilobits per second. HSDPA provides an average throughput of 800 kbps and even 1.5 Mbps in the field, thanks to high peak data rates of 3.6 Mbps for a Category 6 Mobile and up to 14.4 Mbps for a Category 10 Mobile — many times greater than is possible with today's commercially deployed UMTS networks. In addition, HSDPA provides lower latency with round trip delays of 70 ms — enabling great interactive applications like multi-user gaming, as well as faster and better quality video and audio services, and the ability to support twice as many wireless data users per cell site.

The WiFi revolution

While cellular technology was taking decades to find its way into the mass consumer market, a new revolution has been taking shape over the past five years. Wireless fidelity (WiFi) refers to specifications developed by the IEEE to standardize an over-the-air interface between a wireless base station and a client. These specifications are part of the 802.11 group.

802.11 specifications:

- 802.11 — Applies to wireless LANs and provides 1 or 2 Mbps transmission in the 2.4 GHz band using either frequency hopping spread spectrum (FHSS) or direct sequence spread spectrum (DSSS).
- 802.11a — An extension to 802.11 that applies to wireless LANs and provides up to 54 Mbps in the 5 GHz band. 802.11a uses an orthogonal frequency division multiplexing encoding scheme rather than FHSS or DSSS.
- 802.11b — An extension to 802.11 that applies to wireless LANS and provides 11 Mbps transmission (with a fallback to 5.5, 2 and 1 Mbps) in the 2.4 GHz band. 802.11b uses only DSSS. 802.11b was a 1999 ratification to the original 802.11 standard, allowing wireless functionality comparable to Ethernet.
- 802.11g — Applies to wireless LANs and provides up to 54 Mbps 2.4 GHz band. It is backward compatible with the 802.11b specification.
- 80211.n — 802.11n builds upon previous 802.11 standards by adding MIMO (multiple-input multiple-output). MIMO uses multiple transmitter and receiver antennas to allow for increased data throughput through spatial multiplexing and increased range by exploiting the spatial diversity.

Figure 3. 802.11 standards evolution

802.11 standards				
	802.11a	802.11b	802.11g	802.11n
Standard approved	July 1999	July 1999	June 2003	Not ratified
Data rate	54 Mbps	11 Mbps	54 Mbps	200+ Mbps
Throughput	25 Mbps	5 Mbps	25 Mbps (Pure g)	100+ Mbps
Modulation	OFDM	DSSS or CCK	DSSS or CCK or OFDM	DSSS or CCK or OFDM
RF band	5 GHz	2.4 GHz	2.4 GHz	2.4 GHz or 5 GHz
Number of spatial streams	1	1	1	1, 2, 3 or 4
Channel width	20 MHz	20 MHz	20 MHz	20 or 40 MHz

The WiFi standards have become prevalent quickly around the world for simple reasons: deployment is inexpensive and easy (it can be managed by non-technical users), it opens up a range of mobility and has become quite reliable. It is not uncommon for users with no experience to install a WiFi home network in just minutes. Once complete, that individual is able to roam within the coverage area, generally approximately 300 feet. Upon installation, a homeowner is able to move within the coverage area while maintaining a connection to the high-speed network.

All of this is accomplished over unlicensed, open frequency spectrum. These have been set aside for unrestricted consumer use. As WiFi security continues to improve, the promise of open airwaves will be borne out: inexpensive, secure connectivity to the high-speed network. While homeowners have been installing their own (and often unprotected) WiFi networks for years, a recent trend is for the installation of public 'hot zones,' blanketing whole cities or regions with WiFi coverage.

With the advent of WiFi, consumers have come to realize there is a way to get wireless Internet that didn't necessarily require phone companies at all. Inexpensive WiFi packages are available at mass retailers, and tens of millions are sold annually. Deployment is happening more quickly in the home than in business due to lingering security concerns; home users are willing to take the security risk to enjoy wireless broadband service. While individual consumers may have been the first to leverage this technology, we are beginning to see the deployment of citywide public municipal networks.

Today there are thousands of open-access hotspots across the country, located everywhere from Starbucks and airports to city parks. According to a hotspots directory at jwire.com, there are 141,644 free and paid WiFi hotspots in 132 countries — over 49,000 in the U.S. alone.

The rise in the number of U.S. hotspots has been quite dramatic and this trend is expected to continue for the foreseeable future. This will certainly be the case if governmental entities become involved in the deployments. This is happening today for the following reasons:

- Provide a public service to all citizens (low-cost access)
- Emergency services applications
- Attract businesses to coverage area

Although these "municipal" and other public WiFi deployments can represent competition to cable operators making a wireless play, they also represent an opportunity to work with the government entity and leverage existing cable plant.

Advances in WiFi technology

Wireless Mesh

Significant advances in the WiFi space are occurring with lightning speed. Wireless Mesh — a breakthrough decentralized network architecture that provides a high-speed and low-cost solution for coverage across a wider community — is now available. This enables inexpensive WiFi coverage for areas such as a large campus or urban downtown center, and does not require access to the wired network at every access point. Instead, wireless connections between the access points themselves provide the backhaul until eventual termination onto the wired network.

Mesh networks, with ad hoc networking and peer-to-peer communications technologies, enable individual WLAN networks to be networked, increasing coverage for users. Coming soon we will see inter-working between wide-area cellular networks and WLANs — an important step toward convergence.

Scenarios well-suited to wireless Mesh deployments include:

- Campus environments (enterprises and universities), manufacturing, shopping centers, airports, sporting venues and special events
- Military operations, disaster recovery, temporary installations, public safety
- Municipalities, including downtown cores, residential areas and parks
- Carrier managed service in public areas or residential communities

Benefits of Wireless Mesh

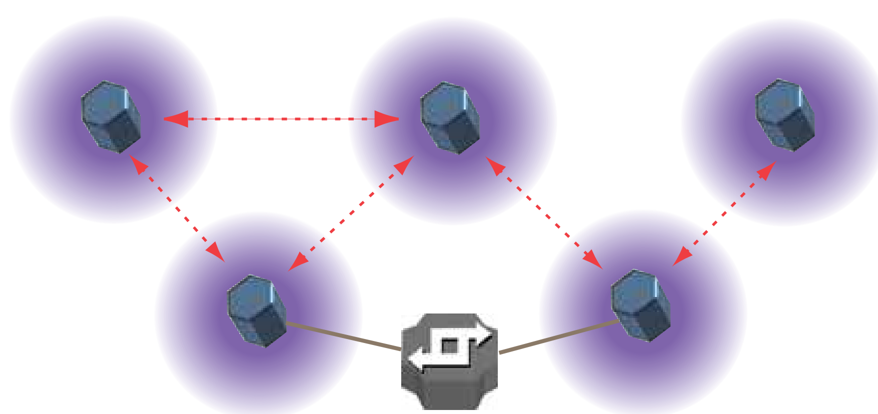
- Provides a value-added entry into the high-speed wireless packet and data business
  - Utilizes 802.11 technology — the interface of choice for high-speed wireless packet data
- Offers high-speed wireless packet data access across a wider coverage area
  - Today's cellular systems don't provide the bandwidth available in WLANs
  - Today's isolated hotspot 802.11 deployments don't satisfy user desire for ubiquitous access or for mobility
  - Emergence of small-form factor terminals with 802.11 wireless interfaces means impending demand for adding mobility to WLAN packet data services
- Minimizes cost of capital, installation and commissioning
  - Utilizes low-cost 802.11 technology
  - Uses wireless links for backhaul to eliminate costs associated with installation of wired interconnect
  - Auto-configuration algorithms in Wireless Access Point eliminate costs associated with engineering and organization of the wireless backhaul network
- Minimizes cost of operations
  - Uses wireless links for backhaul to eliminate costs associated with ongoing leasing of facilities
  - Auto-configuration, self-organizing and self-healing are intrinsic to the Wireless Mesh Network solution
  - Centralized OAM&P minimizes staffing requirements
- Highly flexible in terms of capacity, coverage and availability
  - Increasing capacity, coverage and/or availability simply means deploying more Wireless Access Points
  - Wireless Access Points may be deployed indoors or outdoors

Brief overview of Mesh technology

The Wireless Mesh Network makes outdoor WiFi viable and is designed to enable a new revenue opportunity for service providers or to enable enterprises to extend their private WLANs to outdoor areas. Mesh networks feature two main elements — Wireless Access Points and Wireless Gateways.

The Wireless Access Points (WAPs) perform client access and traffic distribution functions. The Wireless Access Point can connect to the network via a wired Ethernet connection or wireless

Figure 4. Wireless Mesh Network



transit link with other WAPs. Wireless Gateways logically connect the Mesh network IP Subnet(s) to the enterprise's wired network, or the service provider's distribution network, and are responsible for routing, Mesh transit link security, stateful firewalling and wireless user mobility. A benefit of the Mesh network architecture is that each wired access point can share its Ethernet connection among the meshed WAPs. Additional wired APs can be added to provide resiliency, or to improve throughput by decreasing the number of transit link hops to the wired network. Locations where wiring is possible are typically limited, representing the most restrictive planning parameter in any installation. Flexible Mesh backhaul options can overcome this restriction and can greatly expand deployment opportunities, reach and the service potential of the Mesh network.

The technology supports seamless roaming between access points. Auto-discovery, auto-configuration and self-healing capabilities simplify installation. The Mesh is "self-healing", meaning it reconfigures itself automatically if some access points are disabled. The network continues to function even if pieces are destroyed.

Some Mesh network technical considerations

Interference mitigation — The most destructive phenomenon for wireless networks is interference. Dual radio designs use different spectrums for transit and access to enable high-density deployments without the self-interfering limitations of single-radio designs. Access points can be enabled to survey RF characteristics, share information with neighbors and negotiate the transit link channel configuration that delivers the best signal and data rates. Smart antenna technology can intelligently control multiple integrated directional antennas and establishes transit link beams that don't interfere with non-targeted neighbors.

Security — Expansive Mesh networks rely on transit and backhaul links that traverse public spaces, creating an opportunity for hackers to intercept transmissions. IPSec security for transit links — a method derived from VPN technology — goes beyond the standards-based WEP/WPA/WPA2 access link security and addresses this transit link threat. When the secure tunnel terminates on the wireless gateway, a stateful firewall can filter authorized traffic to the wired network and ensures that control systems are inaccessible to mobile users.

Scalability — An Adaptive Mesh Management Protocol allows operators to add capacity by simply adding another Mesh access point into the targeted coverage zone. New WAPs can auto-discover their neighbors, negotiate the cleanest channels, and establish and maintain optimized routes.

What is "municipal wireless"?

A growing list of towns, cities and counties have launched or are planning municipal wireless initiatives — based on Mesh technology — for their community. Operators are being invited to address the requirements for these municipal wireless opportunities as many municipalities are adopting the public/private business model. Municipalities may offer asset rights — such as the use of streetlights for wireless access points — to the service provider at a very low cost or free as well as participate as an anchor tenant. A private-sector service provider, in turn, owns, operates and maintains the network and acts as both the retailer and wholesaler of an open access network. This presents great service and revenue opportunities for cable operators, who can leverage existing cable plant.

Growth in this area has been phenomenal. According to muniwireless.com, as of December 2006 a total of 312 government entities had either deployed or were planning to deploy municipal WiFi. Nearly half, 149, say they are "planning deployments," compared to 34 in July 2005. *(http://www.muniwireless.com/reports/docs/Dec-29-2006summary.pdf)*

An IDC forecast, U.S. Municipal Wireless 2006-2010, reported that vendors "are seeing three to eight RFPs coming out a week."

The following are some services that can be targeted — possibly by cable operators — to the government entity itself.

Emergency Services

Because of its reliable, secure coverage of a local area, Wireless Mesh is an excellent option for delivering mobile high-speed communications in emergency situations. The Mesh is "self-healing", meaning it reconfigures itself automatically if some access points are disabled. And, if a Wireless Mesh Network doesn't already exist in an area, it can be installed within hours, or at most a day, after an event like a hurricane, tornado or any kind of disaster.

If Homeland Security or the Federal Emergency Management Agency (FEMA) in the U.S needs to respond to a disaster where communications have been destroyed as it was during 9/11 in New York City, a Wireless Mesh Network can be deployed very quickly. Even if electricity isn't available, each Wireless Mesh access point can be powered through small solar panels and/or batteries.

Automated Meter Reading

Target municipal utilities with productivity-improving and new revenue-generating opportunities. With AMR, utility meters are read remotely with RF technology and backhauled over your municipal wireless network. This virtually eliminates operational costs, provides multiple accurate reads per day and provides the ability to offer customer services that are tied to frequent reads. This application can also cut meter-reading costs from $2.00 per read to less than $0.10.

Digital Video Surveillance

Target municipal public safety organizations by supporting their digital video surveillance initiatives. By carrying this video traffic over your municipal wireless network, enable communities to increase the level of security, while reducing the overall operational expenses associated with maintaining on-site personnel.

RFID and Sensor solutions

Target government entities and businesses to help them track and monitor their mobile assets throughout the city, and generate messages and alarms to other devices like a customer message board. Deployments have shown savings for these organizations as much as $4,500 per unit per year due to increased asset utilization, route optimization and fuel savings. Position your municipal wireless network as a key enabler for asset tracking.

What's hot? WiMAX.

With the first certified WiMAX products now over a year old — they were announced in January 2006 — WiMAX (Worldwide Interoperability for Microwave Access) is here. Aimed at metropolitan area networks (MANs), WiMAX will deliver broadband multimedia data ubiquitously over wireless links at several times the speed of traditional circuit-switched wireless systems, and over a far greater coverage area than today's WiFi technology.

Where WiFi enables affordable broadband Internet access within short-range "hotspots," at distances measured in tens of meters, WiMAX is designed to deliver the same access, at similar costs, but across tens of kilometers — and ultimately, with greater performance and higher speeds. In short, where WiFi provides high bandwidth but not distance, and current cellular systems provide distance but not high bandwidth, WiMAX will provide both. However, by providing reach and bandwidth enhancements, WiMAX is not a replacement for WiFi, but is more of a complement to it. As the promise of WiMAX unfolds to become a truly widespread consumer mobile broadband service, the concept of "Internet Everywhere" will take on a whole new meaning.

WiMAX enables wireless broadband access anywhere, anytime, on virtually any device. WiMAX offers unrivalled scope for services, as it can provide both fixed and mobile access over the same wireless interface. WiMAX (802.16e) bridges broadband access at home and in the office, allowing end users to take the Internet with them everywhere they go, making the device of tomorrow as connected as the cellular phone of today.

The two types of WiMAX: Fixed and Mobile

There are two versions of WiMAX. Fixed WiMAX supports fixed and nomadic services and can operate in the 3.5 GHz and 5.8 GHz band. Mobile WiMAX supports fixed, portable and mobile services and can operate in multiple frequencies below 3.7 GHz. Mobile WiMAX is expected to become the dominant version of WiMAX as it supports both fixed and mobile services and operates in a wider range of frequencies. However, Fixed WiMAX enjoys a time-to-market advantage, as certified products are already available, which gives it an initial advantage. While the choice of technology depends mostly on the services selected and the operator's focus and market, WiMAX is typically better suited to providing high capacity in areas with dense demand for either fixed or mobile access (e.g. urban areas) or to provide fixed access in more sparsely populated areas or where wired access technologies are not available.

WiMAX standards

With the introduction of WiMAX systems based on IEEE 802.16e, the increased capacity will enable higher-speed links for "last mile" connections. This increased capacity will also enable the introduction of new Ethernet-based data services for consumers and small to medium enterprises (e.g., transparent LAN services). In addition, IEEE 802.16e will enable a new set of high-speed nomadic and mobile data services, bringing a WiFi-like broadband experience to consumers over a wide metropolitan area.

The strength of WiMAX is not due to a single technological innovation, but rather to the confluence of multiple technology and market factors that gives it an advantage over other technologies.

Technical characteristics of IEEE 802.16e are as follows:

- Nomadic and mobile operation with wide area coverage or fixed/hotspot applications
- OFDMA in time division duplex (TDD) and frequency division duplex (FDD) operations

- Scalable OFDM/OFDMA with carrier requirements from 1.25 MHz to 20 MHz bandwidth
- Flexible frequency reuse pattern, including 1 and n (n>1)
- Fast link adaptation and modulation/coding
- High-efficiency coding and error correction schemes
- Multiple dimension of diversity
- MIMO (multiple-input multiple-output) technology MIMO also exists in 802.16-2004, although with fewer enhancements

Based on these technical characteristics, consequent maximum spectral efficiencies in an interference-limited environment are to be 6 and 2 [bps/Hz/cell (sector)] for downlink and uplink, respectively, and the spectral efficiencies at the cell edge are expected to be 2 and 1 [bps/Hz/cell (sector)] for downlink and uplink, respectively.

Potential WiMAX applications and target markets

The widespread appeal of WiMAX systems lies in the fact that the technology can be applied to a host of different applications offered by a range of different providers — from traditional wireless cellular operators to cable operators and new WiMAX entrants.

For instance, for the fixed wireless WiMAX version — IEEE 802.16-2004 — the primary value lies in the replacement of wired T1/E1 or DSL circuits for the "last mile" connection between end-user devices or premises and the high-speed transport network. Potential applications include:

- Wireless backhaul for WLAN hotzone and hotspot traffic
- Broadband access for small to medium enterprises, as an alternative to frame relay or circuit services (T1/E1)
- Cell site (GSM, UMTS, CDMA BTS) backhaul, when used in conjunction with circuit emulation services
- Consumer broadband services in rural and other underserved markets

WiMAX supports VoIP and we expect that VoIP services will become an important revenue stream for WiMAX operators, especially in emerging markets where the fixed and mobile phone charges are still very high.

WiMAX will give users uninterrupted, untethered access to a rich variety of high-bandwidth services — such as networked gaming, streamed digital music, TV and other entertainment services, videoconferencing, video surveillance and real-time dissemination of a variety of information — not only around homes, offices, coffee shops and even schools, but also as users roam in rural, suburban and metropolitan areas.

WiMAX 802.16e delivers significant improvements in speed, throughput and capacity that will enable Real-Time Services and bandwidth-intensive applications and services such as streaming music and video, video surveillance, voice over IP (VoIP) and video conferencing. Cellular operators, wireline carriers, cable operators, greenfield operators, government agencies and other new entrants will deploy WiMAX-based networks to offer Wireless Broadband Access.

The Cable industry invests in spectrum for WiMAX

As cable operators evaluate the range of technologies available to them to deliver broadband services to their customers, WiMAX is gaining support because it offers cable operators an evolutionary step in wireless access and can be used for a number of applications, including "last mile" broadband connections, hotspots, backhaul and high-speed connectivity.

The proof is that they have recently been investing heavily in spectrum licenses. In August 2006, the FCC held a Wireless Spectrum auction, putting 1,122 licenses in the 1710-1755 MHz and 2110-2155 MHz (AWS) bands up for bid. Spectrum in this band can be used by licensees, including cable operators, to deploy WiMAX.

After an intense bidding process, SpectrumCo., a consortium of cable operators including Comcast, Time Warner Cable, Cox and Advance/Newhouse along with Sprint/Nextel, won licenses in the auction. Comcast emerged as the majority stakeholder in the consortium with a 52 percent stake, and Sprint/Nextel emerged as the minority stakeholder with a 5 percent stake and no voting rights.

SpectrumCo.'s participation in the auction was significant because this marked the first time cable operators aggressively pursued wireless assets with bids totaling $2.4 billion. In fact, SpectrumCo.'s bid was the third highest behind T-Mobile at $4.2 billion and Verizon at $2.8 billion. T-Mobile currently has no 3G network in place, placing it at a disadvantage versus the competition. Verizon, on the other hand, has a 3G network, but only bid on spectrum that was only of key strategic value, and it paid the second-highest dollar amount for only 13 licenses.

Other cable operators, including Cablevision Systems and Dolan Family Holdings LLC, also participated aggressively in the auction's early rounds, but needed to drop out of the bidding in mid-August after competitors such as Verizon, T-Mobile and SpectrumCo.

topped its offers for market licenses in the New York metro area. However, experts predict Cablevision could bounce back from this setback by striking a deal with SpectrumCo. to share the New York spectrum with Time Warner. Time will only tell.

CableOne won licenses in 30 metro or regional markets at a price of about $22 million and Bend Broadband won two licenses in Oregon for approximately $540,000.

The SpectrumCo. cable companies account for approximately 58 percent of the cable customers in the U.S. Clearly they are planning to use this new wireless spectrum to offer new services that will help them compete more aggressively for subscriber dollars.

With wireless spectrum, cable operators will have more options for bundling voice, broadband, TV and wireless/mobile services into a "quadruple play" offering for consumers. Some cable operators within the consortium already have wireless offerings through a partnership with Sprint/Nextel. This partnership allows them to add wireless service to their existing triple-play bundles. But, despite bidding with Sprint/Nextel on this spectrum, many think this is a move by cable operators to hedge their bets in case their partnership with Sprint/Nextel does not pan out. With spectrum, cable operators could offer their own cell phone service outside of the Sprint/Nextel partnership if needed. This is like having an insurance policy on their joint venture.

Market consensus is the consortium will use spectrum cautiously, while continuing to make the most of their ties to Sprint/Nextel, as these cable operators will not want to forsake their current cash flow for a rush into the unknown territory of direct wireless deployments.

The wireless world is very different from the wired world, and a transition for them could be difficult. This way, cable operators will move to quadruple play, while maintaining a focus on creating shareholder value. The addition of wireless services, along with the roll-out of business services for the small and medium-size business market, will provide both a growth avenue and a better defense against competition.

WiMAX certification and product availability

WiMAX certification is the first step towards the commercialization of products. It has been introduced to ensure the interoperability of equipment from different vendors. During the WiMAX Forum certification testing, vendors have to show that their equipment can successfully operate within a network with equipment from multiple vendors. While all new certified products have to be backward compatible, new features are constantly added to the certification test cases, to ensure that WiMAX retains its technological edge and can support a rich set of applications and devices.

WiMAX vs. 3GPP2 cellular

With the addition of MIMO antenna technology (which was selected by the WiMAX industry for the IEEE 802.16-2005 standard), WiMAX will deliver up to five times the efficiency of today's 3G cellular networks for wireless data. This means broadband providers can deliver five times the speed, or serve five times as many customers, or buy one fifth of the spectrum, leading to lower costs and higher revenue.

WiMAX is well equipped to compete not only with existing wireless technologies, but also with evolving wireless technologies like 3G. For even though 3GPP and 3GPP2, which are responsible for drafting 3G specifications, are now adopting an approach similar to that taken by WiMAX, the new equipment will not be commercially available for several years to come. This will result in an increase in time to market, with 3G equipment supporting several key WiMAX capabilities two or three years later. Figure 3 shows the evolution of 3G technologies and WiMAX. The IP Multimedia Subsystem (IMS) is already supported by both and will be crucial in facilitating the interworking of the two types of technology. 3G is also moving towards OFDMA multiplexing and an all-IP core, but Mobile WiMAX will already support both. MIMO will be supported in WiMAX while 3G technologies will have to wait at least until 2010.

Market forecasts

The technological and market advantages of WiMAX translate into an attractive opportunity for service providers to offer advanced services like personal broadband, along with fixed and mobile access. To new entrants and fixed operators, WiMAX offers the opportunity to enter the mobile broadband market, which to date is controlled by mobile operators which have not been very successful or aggressive at promoting high-bandwidth applications.

Senza Fili Consulting has conducted an extensive demand-driven forecast of WiMAX adoption worldwide over the next five years that illustrates the market potential of WiMAX. We expect that there will be 15.4 million subscribers by 2010, contributing to service revenues in excess of US$16 billion. The forecast includes both Fixed and Mobile WiMAX, with Mobile WiMAX including both fixed and mobile access. In practice, the distinction between fixed and mobile subscribers will become increasingly tenuous, as mobile and fixed access will be combined in personal broadband service offerings.

The growth trend shows an early dominance of Fixed WiMAX, which benefits from its early market introduction. In subsequent years, Fixed WiMAX will continue to grow in niche markets, but by 2010 Mobile WiMAX will have grown to outpace Fixed WiMAX and to capture 57 percent of subscribers. The introduction of Mobile WiMAX equipment in the market in 2007 is followed by initial trials of the technology in 2007 and early 2008. As with every new wireless technology, a multi-year cycle is needed to complete technology and commercial trials and to initiate the commercial rollout. For Mobile WiMAX, this cycle will take place in the next five years. Wider commercial rollouts from 2010 onwards will lead to even stronger growth from that point.

Bringing it all together — IMS and Fixed Mobile Convergence

Fixed Mobile Convergence (FMC) has become a hot topic recently as cable operators address the opportunity to seamlessly deliver services and information through a variety of networks to residential and enterprise customers. Traditionally, operators have offered services bundled as the Triple Play, including video, voice and data. By leveraging new technology to add the element of mobility to create a Quadruple Play, operators will be able to deliver on the burgeoning demand for access to information from wherever a subscriber is, and using whatever device is most convenient — including the PC, TV, PDA and the ubiquitous cell phone.

As this demand for broadband services offered over both wireline and wireless networks (utilizing 3G/cellular, Wireless LAN and WiMAX technologies) increases, cable operators need a solution that can reach across these domains to provide transparent service delivery. There are several key reasons for this, including:

- Subscribers are going from one domain to another in real life; operators need to provide a superior end-user experience and convenience whereever they are, on the same device or different devices.
- Operators need the fastest road to revenue — services which can be delivered across access types mean a faster ramp to an engaged community of interest.
- In the past, network connectivity was the key to accessing services; it was the key to “owning” the subscriber. To maintain this ownership, service providers now need to offer innovative multimedia services that operate seamlessly across access and device types. In the new world, subscribers will have complete control over their communications. Network operators must provide subscriber-centric services independently from the type of network and device being used. Regardless of the access mechanism — DOCSIS, fixed wireline or mobile — there will be a transformation from an “access-centric” architecture to a “subscriber-centric” architecture.

The critical element to deliver these services transparently is the IP Multimedia Subsystem (IMS) and the derivative PacketCable 2.0 specifications, which enables cable operators to dramatically transform both the end-user communications experience and their own business models. IMS is a standardized service delivery architecture based on Session Initiation Protocol (SIP) that equips service providers to deliver a far richer service experience via a fully converged network across both wireline and wireless access.

While IMS/PC2 provides the access and service-agnostic platform for rapid and cost-effective services delivery, it does not provide the same services infrastructure as existing cellular networks today. Business realities require that IMS/PC2 provide evolutionary capabilities to seamlessly evolve from today’s services infrastructure to the new service delivery paradigm.

Cable operators in North America and Western Europe have spent the last 10 years building an impressive portfolio of full-duplex broadband networks. IMS and Fixed Mobile Convergence will enable them to exploit these investments to deliver a truly seamless broadband experience to customers wherever they are.

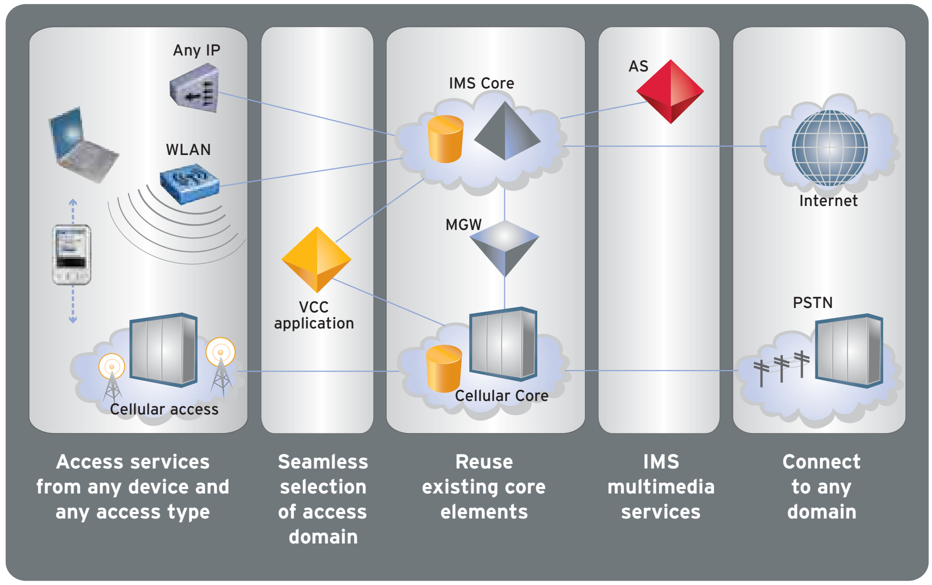
The WiMAX market opportunity

In the U.S., approximately 1.5 cellular subscriptions exist within every household currently being served by the cable operators. Simple math shows that incremental revenue per year is in the billions of dollars if even a relatively small percentage of users adopt the new service offering. Further, studies have shown the subscriber stickiness to the Quadruple Play service provider is greatly increased.

But, to adequately address the convenience aspect of the offer, services must work seamlessly inside and outside of the home environment. Just as there is one device, there must also be one phone number, one user identity, one voice mail account, one instant message identity, one address book, one bill, a consistent human-machine interface, and consistent operation which does not require the user to be aware of his/her current connectivity arrangement.

Fixed Mobile Convergence is a battle for subscriber ownership and there will be many different business models employed to achieve the objective. Roaming relationships between concatenated coverage areas and carriers are a staple of the cellular industry. Cable companies will of necessity be required to establish similar business relationships to existing cellular operators. These roaming relationships could take on many forms and will range from loosely to tightly coupled.

Figure 5. IMS — Voice Call Continuity



Technical challenges

The challenge for the technologists is to build the networks, products and capabilities that enable these business objectives to be realizable in the shortest amount of time.

The four service types of voice, video, data and mobility have long history in vertically-integrated networks and market-specific application definition and deployment. While these networks have performed well for the specific business originally designed for, they do not integrate easily when pushed to exist beyond the existing business boundaries.

The IMS/PC2 architecture

CableLabs® is nearing completion of the PacketCable™ 2.0 specifications, which are based in large part on the multi-industry standard IP Multimedia Subsystems (IMS), yet with cable-specific enhancements. The IMS/PC2 specifications are the foundation of this new approach to use the latest in technologies, evolve from existing services and to enable new business models. IMS/PC2 provides for the horizontal layering of the network with the service core being based upon IETF SIP signaling protocols and extending this protocol into a system-level implementation which is open and standardized globally. Openness and the ability for multi-vendor selection are of paramount importance to the realization of the business objectives.

IMS/PC2 provides the first step in the complex technology path towards full Fixed Mobile Convergence. It normalizes the network aspects by providing a SIP-based service core which is common across all service types. Further, it normalizes the interfaces to the applications environment, which enables a “plug-n-play” deployment of new applications as they are built. Applications no longer need to be access-aware or vertically integrated. Further, the realization of a service core with normalized interfaces will provide massively scalable deployments in linear increments, thus making network evolution very business-wise realizable.

Using IMS/PC2, application functionality can be delivered to the end user via any IP-enabled access network such as DOCSIS, WiFi, WiMAX or DSL. Applications such as presence, push-to-talk and content delivery can also be delivered to the end user independent of the access network type or the geographic and business domain boundaries. Applications development and deployment are greatly simplified, ensuring rapid introduction of new services in a very cost-effective manner. IMS/PC2 will do for the communications networks what JAVA™ and the Java Virtual Machine have done for the computing industry.

The IMS/PC2 architecture provides a consistent end-user representation to all applications and access network types. This provides the ability for:

- Single user identity and single sign-on
- A common approach to Authentication, Authorization and Accounting
- Ubiquitous service delivery so that services work consistently and reliably across any network
- Application servers to retrieve subscriber information dynamically and independent of where the application servers are placed within the network

- Flexibility in the deployment options available to the operator as hybrid centralized-decentralized models can be supported
- Geographic independence as the network components no longer need to be collocated with the access technology or subscriber base
- Multiple alternative business relationships with other carriers and third-party application providers
- PacketCable 2.0 specifications which will expand and enhance the IMS specifications include:
  - PacketCable Multi-Media (PCMM) compliance
  - Evolution of existing PacketCable 1.X services and networking elements
  - NAT/FW traversal
  - Multiple approaches to end-user and device security

The strategy of the specification work is to provide extensions to the existing specifications to ensure global multi-vendor standards that will interoperate with other network operators in other business domains. This again addresses the fundamental business drive to be able to flexibly support the current and evolving business models.

Getting to convergence standards

In backbone networks, FMC is driven mainly by the universal migration to an all-IP network, in which many of the core subsystems are identical across fixed and mobile networks. The general acceptance of the principle of layered networks, and the adoption by ITU NGN standards-setters of key related mobile standards, especially IMS, is a key.

Three approaches to FMC

There are currently three primary approaches in the industry to delivering a converged seamless service: Unlicensed Mobile Access (UMA), VoIP Extension and IMS-VCC (Voice Call Continuity).

UMA

UMA provides GSM services over WLAN radio with built-in roaming and handover between WLAN and GSM. While UMA may be appealing to GSM operators, there are a few drawbacks with this approach:

- It applies only to GSM operators.
- It doesn't provide any new end-user services, only connectivity to legacy services.
- It doesn't leverage SIP-compliant terminals, which are likely to be implemented on all WLAN-compatible terminals in the long term.

VoIP Extension

Several service providers offer downloadable clients for dual-mode handsets that extend the end user's subscription to the handset. Once out of WLAN coverage, though, the end user is back to normal cellular service. The advantages are a very low cost to the end user, an easy-to-install overlay solution and the ability to add multimedia services. A large and problematic drawback is that there is no opportunity to provide roaming to cellular service — so you have a converged device but not a converged service as part of an enhanced service portfolio. It is thus a step toward convergence but not true convergence.

IMS-VCC

Voice Call Continuity, currently under development in 3GPP R7, extends an IMS network to cellular coverage and addresses handover. It provides seamless voice call continuity between the cellular domain and any IP-connectivity access networks that support VoIP. It is the most comprehensive of converged service approaches in that it can work between any cellular technology (GSM, UMTS, CDMA) and any VoIP-capable wireless access. IMS-VCC provides for the use of a single phone number (or SIP identity) as well as handover between WLAN and cellular. It also provides key advantages.

Voice Call Continuity

VCC is the approach being adopted by the IMS/PC2 specification bodies. IMS-VCC provides seamless voice call continuity between the cellular circuit switched domain (CS) and any IP Connectivity Access Networks (IP-CANs) that supports VoIP, in particular WLAN. Therefore IMS-VCC provides a comprehensive converged service as it can work between any cellular technology (GSM, UMTS, CDMA) and any VoIP-capable wireless access (WLAN, WiMAX, 3GPP Rel-7/Rel-8 Evolved Access System).

The basic principal of VCC is that all calls and services are anchored within the IMS/PC2 domain for both incoming and outgoing call types. This ensures that seamlessness of service delivery and perception by the end user are achievable and that handoff from one domain to the other is performed in a robust and controlled fashion. Further, this approach maintains the integrity and the value proposition of the IMS/PC2 architecture in that it applies to any access network and does not inhibit the usage by the subscriber of any applications which have been deployed and subscribed to.

IMS-VCC uses the IMS network that is being adopted as the converged service architecture of choice across multiple IP-CANs to provide rich SIP-based multimedia applications. Some deployment of IMS networks began as early as 2005. However, up until 3GPP Rel-6, IMS does not provide seamless mobility with the cellular CS domain but only interworking capabilities (the capability to make a call from a SIP endpoint to the CS domain and vice-versa). IMS-VCC enhances IMS by adding the mobility (roaming and handover) function with the cellular CS domain. To enable active call handover between the two domains, all IMS-VCC user voice calls are anchored within the IMS domain, whether they are originated in the CS domain or in the IP-CAN (e.g. WLAN) domain, or whether there is IP-CAN connectivity or not.

Conclusion

From a broadband connectivity perspective, we see that everywhere the consumer goes there will probably be wireless broadband service available. This service comes via many different technologies — WiFi, WiMAX, HSDPA/HSUPA, 1xEV-DO — but the common denominators are that the wireless broadband connectivity is very fast, ubiquitously available and competitively priced — maybe even free.

A customer's identity will not be wrapped up in one device like today's cell phone. Customers will have many devices. Conversely, service providers will try to "own" the subscriber, not myriad individual services.

WiFi hotspots — free and paid — will continue to proliferate, as will municipal networks based on Mesh WiFi technology.

We expect that there will be 15.4 million WiMAX subscribers by 2010, contributing to service revenues in excess of US$16 billion. Available bandwidth on WiMAX services will continue to climb through application of antenna (MIMO) and multiplexing (OFDM) technologies. These technologies will be applied to cellular and WiFi as well.

Through the IP Multimedia Subsystem (IMS) infrastructure and Fixed Mobile Convergence, the consumer will have constant access to mobile broadband connectivity. The services used by the mobile consumer will sometimes ride over a cable operator's network and many times will not. We believe the most successful cable operators will be those who have evolved their services to transcend the many access methods the consumers will have at their fingertips. The Voice Call Continuity component brings "ease of use" to the bundle and makes multiple networks transparent to the customer — all delivering a positive user experience. In the end, we believe the user experience is what will differentiate the cable operators from their competitors.

Speaker Bio

Cortland Wolfe is Director of Business Development at Nortel where he has enjoyed 23 years of transforming the latest and greatest technologies into real-world applications for the cable industry.

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References

- *Fixed Mobile Convergence (FMC): The Opportunity and Realization*, Russ Coffin, Nortel Cable Solutions Group, Cable Tech Expo 2006
- *The Emergence of WiMAX*, Monica Paolini, Senza Fili Consulting, 2006
- *The Wireless Cable World in 2010*, Cortland Wolfe, SCTE 2006 Conference on Emerging Technologies
- 802.11 specifications from Webopedia.com
- MIMO and OFDM references from the Nortel Technical Journal, July 2005
- *WiMAX In the Cable Market*, Tom Buttermore, Nortel GM, Global Cable Solutions, at www.convergeddiigest.com
- WiFi hotspot statistics from: www.jwire.com
- Government wireless statistics from: www.muniwireless.com/reports/docs/Dec-29-2006summary.pdf

Acronym glossary

2G	Second Generation
3G	Third Generation
3GPP	The Third Generation Partnership Project
3GPP2	The Third Generation Partnership Project Two
AES	Advanced Encryption Standard
ARQ	Automatic Repeat Request
BF	BeamForming
CE	Consumer Electronics
CPE	Customer Premises Equipment
ETSI	European Telecommunications Standards Institute
EV-DO	CDMA EVolution Data Optimized
FDD	Frequency Division Duplex
HiperMAN	High Performance Radio Metropolitan Area Network
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
HSUPA	High Speed Uplink Packet Access
IEEE	Institute of Electrical and Electronics Engineers
IMS	IP Multimedia Subsystem
IP	Internet Protocol
LAN	Local Area Network
LTE	Long Term Evolution
MAN	Metropolitan Area Network
MIMO	Multiple Input Multiple Output
OFDM	Orthogonal Frequency Division Multiplex
OFDMA	Orthogonal Frequency Division Multiple Access
PCI	Peripheral Component Interconnect
PCMCIA	Personal Computer Memory Card International Association
PDA	Personal Digital Assistant
QoS	Quality of Service
SAE	System Architecture Evolution
SISO	Single Input Single Output
SOFDMA	Scalable Orthogonal Frequency Division Multiple Access
TDD	Time Division Duplex
VoIP	Voice over Internet Protocol
WAN	Wide Area Network
WCDMA	Wideband CDMA
WiMAX	Worldwide Interoperability for Microwave Access

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