# AT&T Developer Program

# Broadband Innovation

## Applications for New Broadband Networks

### White Paper

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# Revision History

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| August 17, 2008 | 1.0 | First release of this paper. |

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# 1. Introduction

This paper discusses developments in broadband networks including both wireline and wireless networks. Wireline topics include Digital Subscriber Line (DSL), Data Over Cable Service Interface Specification (DOCSIS), Passive Optical Networks (PONs), and Metro Ethernet. Wireless topics include High Speed Uplink Packet (HSUPA), High Speed Packet Access (HSPA) Evolution, 3GPP Long Term Evolution (LTE), as well as personal-area technologies such as Wireless USB (WUSB). The final section presents application development considerations for new broadband networks.

## 1.1 Audience

The target audience of this white paper is software developers, IT developers, architects, and managers developing and deploying applications for multiple types of broadband networks.

## 1.2 Contact Information

E-mail any comments or questions regarding this white paper via the AT&T Developer Program. Please reference the title of this paper in the message.

## 1.3 AT&T Resources

AT&T Developer Program: http://developer.att.com

Mobile Application Development: http://developer.att.com/mobiledevelopment

Network Technology:
http://developer.att.com/developer/index.jsp?page=toolsTechSection&id=7600074

3G: http://developer.att.com/3G

Device Information: http://developer.att.com/devicedetails

Mobile Middleware: http://developer.att.com/middleware

Wireless Reference Architecture Material: http://developer.att.com/WRA

Certified Application Catalog: http://developer.att.com/certifiedsolutionscatalog

devCentral Resource on Platforms and Operating Systems

## 1.4 Terms and Acronyms

The following table defines the acronyms used in this document.

***Table 1: Terms and Acronyms***

| Term or Acronym | Definition |
|---|---|
| | |
| 3GPP | Third Generation Partnership Project |
| API | Application Programming Interface |
| ATM | Asynchronous Transfer Mode |
| CDMA | Code Division Multiple Access |
| DOCSIS | Data Over Cable Service Interface Specification |
| DSL | Digital Subscriber Line |
| DVR | Digital Video Recorder |
| EDGE | Enhanced Data Rates for GSM Evolution |
| FTTN | Fiber to the Node |
| HD | High Definition |
| FMC | Fixed Mobile Convergence |
| HSDPA | High Speed Downlink Packet Access |
| HSPA | High Speed Packet Access |
| HSPA+ | HSPA Evolution |
| HSUPA | High Speed Uplink Packet Access |
| IMS | IP Multimedia Subsystem |
| IP | Internet Protocol |
| IPTV | IP Television |
| LTE | (3GPP) Long Term Evolution |
| MB-OFDM | Multi-band Orthogonal Frequency Division Multiplexing |
| Mbps | Megabits per second |
| MPLS | Multiprotocol Label Switching |
| OFDMA | Orthogonal Frequency Division Multiple Access |
| PAN | Personal-Area Network |
| PON | Passive Optical Network |
| QoS | Quality of Service |

| | |
|---|---|
| SDH | Synchronous Digital Hierarchy |
| SONET | Synchronous Optical Network |
| TDMA | Time Division Multiple Access |
| UMA | Unlicensed Mobile Access |
| UMTS | Universal Mobile Telecommunications System |
| USB | Universal Serial Bus |
| UWB | Ultra Wideband |
| WDM | Wave Division Multiplexing |
| WUSB | WUSB |
| | |

## 2. Introduction

The rate of innovation in broadband technologies continues at a rapid pace. Throughput rates that delighted users a decade now are unimaginably slow. Data content that once consisted of text-based terminal sessions has evolved into rich and graphical user interfaces, and now content increasingly consists of multimedia.

As network performance and capacity has increased, applications have become more sophisticated, enabling companies to work in a way in which geography becomes ever less a factor, and workers can be effective from anywhere. Consumers are also gaining enjoyment from these new capabilities with services such as VoIP telephony, IPTV, fast Internet connections, music and video downloads, and social networking.

Innovation has spanned both wireline and wireless networks. While wireline provides the greatest capacity and performance, wireless and mobile networks provide huge freedom for the consumption of services. The two are highly complementary.

### 2.1 Wireline and Wireless

There are a variety of networking technologies that provide enterprises and consumers with connectivity whether access to the Internet or on a site-to-site basis. Table 2 summarizes the most important of these including the approximate maximum downlink throughput you can obtain on these networks today, and comments about the future of these networks.

***Table 2: Capabilities of Today's Networks***

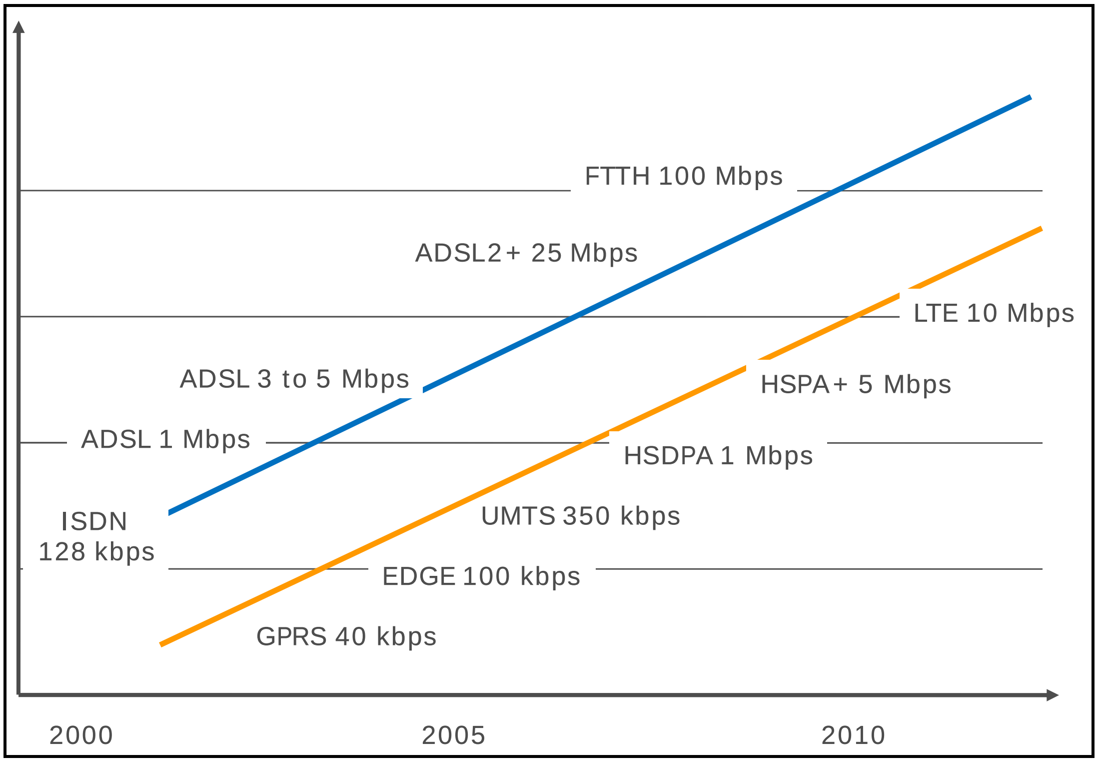
| Technology | Max Downlink<br>Today's Networks | Comments |
|---|---|---|
| DSL | 10 Mbps | 50 Mbps possible with VDSL2, leverages existing copper |
| Cable Modems | 16 Mbps | 50+ Mbps possible with DOCSIS 3.0 |
| Fiber to the Home | 50 Mbps | 100 Mbps and much higher rates possible but |

| Technology | Max Downlink<br>Today's Networks | Comments |
|---|---|---|
| | | expensive to deploy |
| Mobile Wireless | 5 Mbps | 100 Mbps+ capabilities in development |
| Fixed Wireless | 1 to 5 Mbps residential<br>10 to 100+ Mbps business | Multiple available technologies, bands, topologies |
| Metro Ethernet | 1 Gbps | 10 Gbps available soon |
| Backbone Networks | 40 Gbps links | 100 Gbps in development |

The throughput and capacity of wireline networks typically exceeds those of wireless networks. Keep in mind that one optical fiber has greater data capacity than the entire RF spectrum through 100 GHz. Wireless networks, however, provide much greater freedom in how users interact with applications and services. Wireline and wireless technologies are also highly interwoven with wireline networks providing the core for wireless networks.

Figure 1 shows the approximate evolution of wireline and wireless technologies based on throughputs that users might reasonably achieve. The blue line shows wireline technologies and the orange line shows wireless technologies. There has been an approximate 10 to 1 difference in wireline and wireless speeds over the years.

*Figure 1: Wireline and Wireless Throughput Evolution (User Throughputs)*




The next section discusses wireline technologies in greater detail, and the subsequent section covers wireless technology evolution.

# 3. Wireline Developments

There are many different wireline developments a paper like this could discuss, but the ones that are most significant include carrier transport networks, metro Ethernet, passive optical networks and DOCSIS. This section also briefly covers IPTV and AT&T's U-Verse service.

## 3.1 Carrier Transport Networks

There are two characteristics that define the improvements being made to carrier backbone networks. One is increased capacity, and the other is quality-of-service (QoS) combined with management. The combination results in more dependable and predictable services to customers. Other benefits include the ability for operators to host applications and to offer location transparency resulting in consistent services regardless of location.

High speed links in transport networks today operate over 10 Gbps or 40 Gbps fiber-optic links using Wave Division Multiplexing (WDM), a method that allows multiple channels in the same fiber. 100 Gbps capabilities are in development.

In the 1990s, the most widely used protocol for transporting voice and data was Asynchronous Transfer Mode (ATM). Even today, there are new networks deployed that use ATM. ATM commonly operates over fiber optic cable in combination with Synchronous Optical Network (SONET) or Synchronous Digital Hierarchy (SDH) protocols. ATM can transport a wide variety of protocols including TCP/IP or voice circuits.

This decade, the most common backbone network architecture is based on IP and Multiprotocol Label Switching (MPLS). MPLS enables operators to transport a wide variety of other protocols securely and with quality-of-service management. The MPLS protocols operate within the operator's domain over SONET/SDH or carrier Ethernet optical connections.

Customer networks do not need to support MPLS to take advantage of MPLS-based services. A version of MPLS, called Transport MPLS, incorporates additional features for transporting multiple traffic types. By isolating traffic, MPLS can be used to implement VPN functions.

There are also competing protocol developments such as Provider Backbone Transport (PBT), which is also called Provider Backbone Bridging-Traffic Engineering (PBB-TE), an Ethernet-oriented approach.

Figure 2 shows the typical protocols employed in some of today's new transport networks with fiber optical connections at the physical layer (wavelength division multiplexing), optical Ethernet as the layer two protocol, Transport MPLS as the layer 3 transport, and then the service networking layers, which are the customer traffic and can consist of protocols such as Ethernet, ATM or Frame Relay, which then carries the customer's IP or other traffic.

***Figure 2: Transport Networks***

| Traditional Approach | Emerging Approach | |
|---|---|---|
| IP, etc. | IP, etc. | Service Networking Layer 3 |
| Ethernet, ATM, Frame Relay | Ethernet, ATM, Frame Relay | Service Networking Layer 2 |
| SONET/SDH, OTN | Transport MPLS | Transport Networking Layer |
| SONET/SDH, OTN | Ethernet | Physical Medium Layer |
| Wavelength Division Multiplexing | | Photonic Layer |

**ATM: Asynchronous Transfer Mode**
**FR: Frame Relay**
**MPLS: Multiprotocol Label Switching**
**OTN: Optical Transport Network**
**SDH: Synchronous Digital Hierarchy**
**SONET: Synchronous Optical Network**

A common way that operators make their MPLS networks available to customers is as a metro Ethernet service, which is discussed next.

## 3.2 Metro Ethernet

Historically, network operators made wide-area network links available via leased line connections. A popular and more popular alternative beginning in the 1990s was Frame Relay, a switched service that emulated leased lines through what were called Permanent Virtual Circuits (PVCs). Frame Relay is still widely used today. A quickly emerging alternative for wide-area and metro-area connectivity is the use of Ethernet, referred to as metro Ethernet.

A metro Ethernet is an operator-provided, managed extension of localized Ethernet networks across wider areas operating as an access network for connectivity to other networks whether the Internet or as a private connection to other sites. Typical applications include data, VoIP and video.

Benefits to customers include being able to use well-understood and inexpensive Ethernet interfaces such as 100 BASE-TX or 1000 BASE-FX with IEEE 802.3z compatibility.

The operator transport network, as discussed in the previous section, is often IP/MPLS operating over Ethernet and used to transport customers' Ethernet frames. The result, as shown in Figure 2, is Ethernet over MPLS over Ethernet.

Typical speeds offered to customers range from 512 kbps to 1 Gbps, with 10 Gbps service expected in the near future.

Typical configurations include:

- Access
- Point to point
- Ethernet channel on a dedicated ring
- Point to multipoint
- Multipoint to multipoint (Virtual Private LAN Service)

Features include service-level agreements and monitoring.

## 3.3 MPLS VPN

Operators with MPLS networks (such as AT&T) can provide VPN functions across the MPLS network. This VPN approach is different from IPsec types of VPNs. The MPLS network uses traffic separation via route distinguishers to offer privacy, whereas IPsec VPNs rely on encryption. The MPLS operator also manages the equipment and VPN functions, whereas or IPsec approaches the end-user organization owns and manages the VPN equipment f. Finally, the

MPLS VPN operator can offer additional services such as traffic engineering to provide QoS, SLAs and classes of service. Such options are more limited with IPsec approaches which often rely on the public Internet for transport.

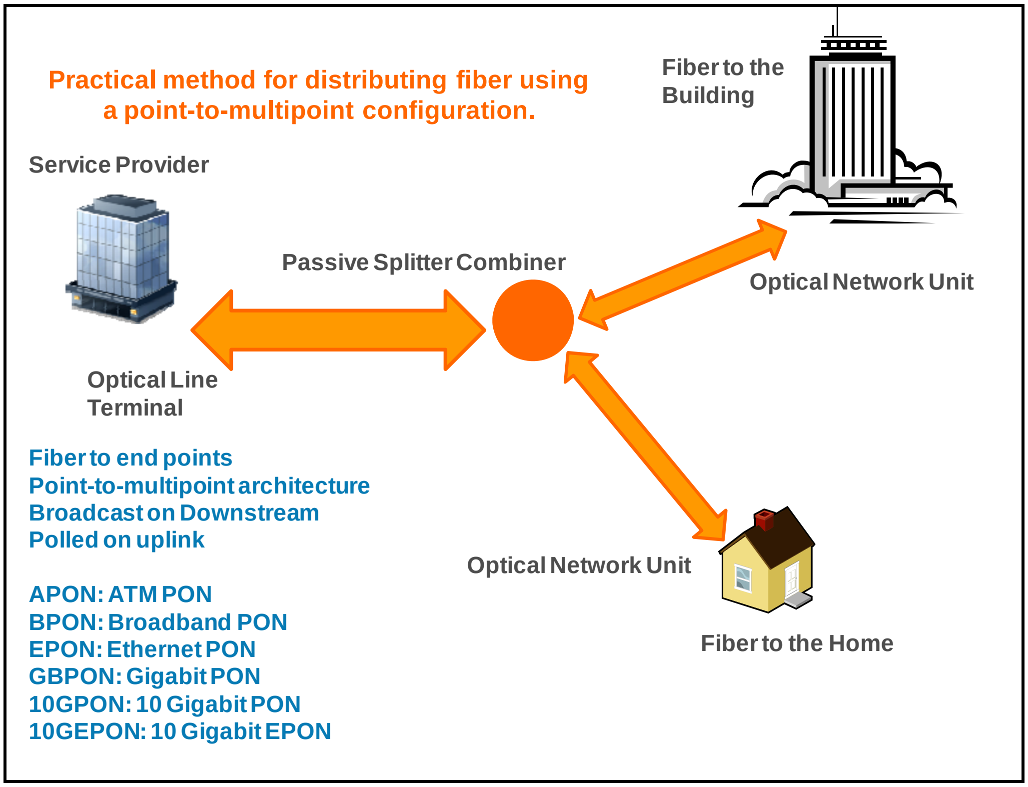
## 3.4 Passive Optical Networks

Passive optical networks (PONs) provide a means of cost-effectively deploying fiber-optical connections to multiple endpoints. The architecture is point to multipoint and is called “passive,” because the signal is split and combined using passive elements that do not require external power.

As summarized in Figure 3, there are multiple types of PONs, with the most common type being deployed today to serve residences and businesses called GPON, or Gigabit PON, which supports 2.488 gigabits per second (Gbps) of downstream bandwidth, and 1.244 Gbps of upstream bandwidth. In the future, 10GPON will support 10 Gbps of downstream service.

Actual data rates offered to customers are lower than these rates with 50 Mbps being a typical high-speed Internet speed for consumers and 100 Mbps for businesses.

*Figure 3: Passive Optical Network*




## 3.5 DOCSIS

Cable modems support data communications over coaxial cable through implementation of a standard called Data Over Cable Service Interface Specification. Currently deployed systems use DOCSIS version 1.x or 2.0, but new systems will soon start using DOCSIS 3.0, which enables higher speeds.

Table 3 shows the different DOCSIS versions and the maximum synchronization speed along with maximum usable speeds.

***Table 3: DOCSIS Versions and Throughput Capabilities - Max Sync (Max Usable)***

| DOCSIS Version | Downstream | Upstream |
|---|---|---|
| 1.x | 42.88 (38) Mbps/s | 10.24 (9) Mbps/s |

| DOCSIS Version | Downstream | Upstream |
|---|---|---|
| 2.0 | 42.88 (38) Mbps/s | 30.72 (27) Mbps/s |
| 3.0 4-channel | +171.52 (+152) Mbps/s | +122.88 (+108) Mbps/s |
| 3.0 8-channel | +343.04 (+304) Mbps/s | +122.88 (+108) Mbps/s |

Typical maximum cable rates available today are about 16 Mbps downstream and 2 Mbps upstream, but many typical subscriptions have downstream service of about 5 Mbps and upstream services of about 512 kbps. Services based on DOCSIS 3.0 will enable higher speeds—as high as 150 Mbps—although initial speeds will likely be lower such as 50 Mbps downstream.

## 3.6 IPTV and AT&T U-Verse

An increasingly popular application for wireline-based broadband networks is IPTV, a form of digital television that uses Internet Protocol. IPTV is often combined with complementary services such as video on demand, Internet access and VoIP. Customers can enjoy IPTV over a variety of broadband connections like DSL or fiber. Wireless connections are not feasible at this time due to high bandwidth and QoS requirements.

Unlike TV that uses coaxial cable wherein all the available channels are present on the cable, IPTV uses a multicasting approach in which only desired channels are sent over the Internet connection.

AT&T's U-Verse includes IPTV with High Definition (HD) capability and has the following characteristics.

- Based on fiber to the node (FTTN), then copper lines to customer locations.
- Backbone based on MPLS.
- H.264 (MPEG-4 AVC) video encoding.
- Set-top boxes that are IP multicast clients and include digital video recorder (DVR) capability.
- Internet service with maximum downstream rate of 10 Mbps and 1.56 Mbps upstream.

# 4. Wireless Broadband Developments

Persistent innovation is increasing the capabilities of wireless networks, both in the wide area and local area. This section discusses the 3GPP roadmap including planned enhancements for EDGE, HSPA and the next-generation LTE platform. There are also complementary developments that leverage wireless communications such as fixed mobile convergence (FMC) and femto cells. In the local area, capabilities are increasing with higher speed Wi-Fi, and new personal-area network technologies such as wireless USB.

## 4.1 3GPP Evolution

3GPP is the international organization developing the specifications for the Global System for Mobile Communications (GSM) family of technologies, which includes EDGE (Enhanced Data Rates for GSM Evolution), HSPA (High Speed Packet Access) and LTE (Long Term Evolution) .

The evolution follows three different radio-technology platforms:

1. **Time Division Multiple Access (TDMA):** Includes GSM and EDGE. These are 2G cellular networks.

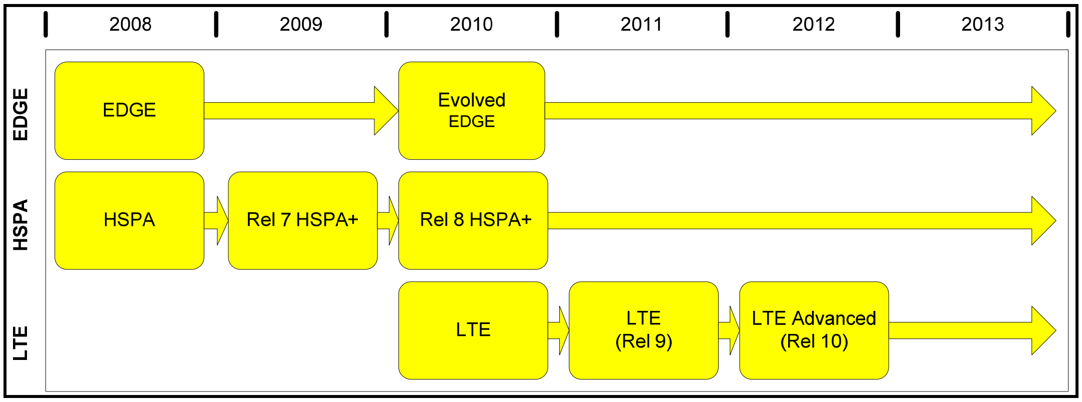
2. **Code Division Multiple Access (CDMA):** Includes Universal Mobile Telecommunications System (UMTS) and HSPA. These are 3G cellular networks.

3. **Orthogonal Frequency Division Multiple Access (OFDMA):** Includes LTE. Although OFDMA systems are referred to as 4G, this is not technically correct since there is no formal definition of 4G.

AT&T's Broadband Connect service is HSPA, a data service for UMTS.

Figure 4 shows a prediction for earliest deployments of future versions of these technologies including Evolved EDGE, HSPA Evolution (commonly called HSPA+) and LTE. The releases refer to 3GPP specification releases.

***Figure 4: Evolution of 3GPP Technologies (EDGE, HSPA, LTE)[1]***




The following sections discuss these specific technologies and their capabilities.

## 4.2 Evolved EDGE

EDGE is the most successful wireless-data technology ever deployed with networks supporting the technology worldwide. Although operators are deploying 3G globally, it is logical to keep evolving EDGE, because in many deployments, 3G is not available throughout the coverage area and, in some countries, operators have not yet deployed 3G.

Evolved EDGE includes a number of enhancements to improve data performance, will initially double throughputs, and may eventually quadruple data throughputs. Evolved EDGE networks will also have reduced latency.

Evolved EDGE includes innovations such as being able to receive data on two radio channels simultaneously and higher-order radio modulation. The result will be user-achievable data throughput rates of over 1 Mbps under good conditions.

## 4.3 HSUPA

Initial UMTS networks deployed early during this decade had maximum throughput rates of 384 kbps. With the addition of High Speed Downlink Packet Access, downlink speeds increased significantly. Now with High Speed Uplink Packet Access, uplink speeds are notably faster as well.

[1] Source: Rysavy Research. Note: Does not indicate any specific AT&T deployment.

HSUPA achieves higher throughputs by using:

- An enhanced dedicated physical channel.
- A short transmission time Interval,(as low as 2 msec.), which allows faster responses to changing radio conditions and error conditions.
- Fast scheduling at the Node B (base station), which allows the base station to efficiently allocate radio resources.
- Fast Hybrid ARQ (Automatic Repeat Request), which improves the efficiency of error processing.

The result is an 85% increase in overall cell throughput on the uplink with user rates that frequently exceed 1 Mbps.

AT&T has deployed HSUPA in much of its 3G coverage area. The combination of HSDPA and HSUPA is usually referred to as HSPA. AT&T has performed tests that have established the following typical HSPA throughput rates:

- **Downlink:** 700 kbps to 1.7 Mbps.
- **Uplink:** 500 kbps to 1.2 Mbps.

## 4.4 HSPA+

3GPP has specified a number of enhancements to HSPA to further increase capabilities with deployments expected over the next several years. Specific innovations include:

- Use of higher-order modulation (64 Quadrature Amplitude Modulation).
- Multiple Input Multiple Output (MIMO) in which separate antennas transmit and receive multiple, parallel data streams.
- Interference cancellation.
- Simultaneous operation over multiple radio carriers.
- Dual-carrier operation.

Resulting peak network data rates are as follows:

*Table 4: HSPA+ Downlink and Uplink Speeds Based on Configuration*

| Technology | DL (Mbps) | UL (Mbps) |
|---|---|---|
| Current systems | 14.4 | 5.76 |
| DL 64 QAM, UL 16 QAM | 21.1 | 11.5 |
| Addition of 2X2 MIMO | 42.2 | 11.5 |

With HSPA+, typical downlink user rates are likely to at least double the current HSPA throughput rates and could eventually exceed 5 Mbps. HSPA+ largely matches the capability of competing technologies such as WiMAX.

## 4.5 3GPP Long Term Evolution

LTE is an entirely new radio platform, with 2010 the first year that operators might actually deploy the technology. LTE is the overwhelming choice of GSM/UMTS operators for their next-generation platform. Even a number of CDMA operators are planning to migrate to LTE.

It is important to put LTE into a proper context. Even with initial deployments expected relatively soon, current 3G technologies will account for the greatest number of subscribers for many years, and it will be mid-next decade before there are a significant number of LTE subscribers. This parallels the migration from 2G to 3G in which, even today, there are more GSM than UMTS subscribers.

Some specific features of LTE include:

- Use of an Orthogonal Frequency Division Multiple Access (OFDMA) access method in the radio channel.
- Implementation of all services, including voice, in the IP domain.
- Scalable bandwidth up to 20 MHz, covering 1.25, 2.5, 5, 10, 15, and 20 MHz radio channels. This facilitates deployment in available bands.
- Support for both frequency-division and time-division duplex modes.
- Significantly reduced latency—to as low as 10 msec between user equipment and the base station, and less than 100 msec transition time from inactive to active.

- Use of MIMO.

Based on MIMO configuration, LTE achieves the following peak network rates.

***Table 5: LTE Downlink and Uplink Peak Speeds Based on Configuration***

| LTE Configuration | Downlink (Mbps)<br>Peak Data Rate | Uplink (Mbps)<br>Peak Data Rate |
|---|---|---|
| Using 2X2 MIMO in the Downlink and<br>16 QAM in the Uplink | 172.8 | 57.6 |
| Using 4X4 MIMO in the Downlink and<br>64 QAM in the Uplink | 326.4 | 86.4 |

Actual user throughput rates will be lower than the peak network rates and will depend on network configuration, width of radio channel used and other factors, but typical downlink throughput rates could easily exceed 10 Mbps.

## 4.6 WiMAX

WiMAX is a potential alternative to cellular technology for wide-area wireless networks. Like LTE, WiMAX uses OFDMA.

WiMAX is based on the IEEE 802.16 standard, which has the following versions:

- IEEE 802.16 for telecom backhaul
- IEEE 802.16-2004 for fixed, point to multi-point applications
- IEEE 802.16e-2005 for mobile communications
- IEEE 802.16 Release 1.5 for enhanced operation
- IEEE 802.16m future evolution

WiMAX will initially be deployed in 10 MHz radio channels using a time-division duplex mode. Throughput rates are potentially higher than HSPA, but no higher than HSPA+, and will be lower than for LTE networks.

## 4.7 Fixed Mobile Convergence

Fixed mobile convergence refers to the integration of mobile networks with those providing fixed service. This technology area is also referred to as Unified Communications.

The benefits to users of FMC include lower service costs, fewer phone numbers, better indoor coverage, and consistent service (e.g., voice mail) across multiple network types.

There are a number of enabling technologies for FMC:

- IP Multimedia Subsystem (IMS)
- Unlicensed Mobile Access (UMA)
- Femto cells

IMS is a platform being deployed by AT&T and many other operators to enable a common approach across multiple access networks for a wide variety of services including circuit-switched voice, VoIP, video, location information and messaging. IMS supports FMC. For example, it can provide for seamless hand-off for a voice call over a cellular connection to the call handled over a Wi-Fi network.

UMA is another approach for implementing FMC. Although simpler to implement and deploy than IMS, it is far more limited in scope of supported applications. It essentially tunnels GSM protocols over Wi-Fi connections. UMA-capable handsets can operate over either GSM or Wi-Fi connections. UMA requires handsets that implement UMA protocols and Wi-Fi.

Another FMC approach is with femto cells, discussed next.

## 4.8 Femto Cells

Femto cells are small, low cost-base stations that provide coverage in a residence or business location using a mobile operator's licensed frequency bands. The backhaul connection is via the user's existing Internet connection.

The advantage of a femto-cell approach compared to a dual-mode, Wi-Fi/cellular approach is that it works with all available handsets. Femto cells provide a number of benefits including:

- The ability to use the same handset for all telephony.
- Providing indoor coverage potentially better than a wide-area network through use of indoor access points (either femto cells or Wi-Fi based).
- Service pricing for voice and data that is expected to be more attractive when operating over the femto cell.
- Greater data capabilities than with the wide-area network since the entire radio channel is serving a single customer location.

Figure 5 shows the femto-cell coverage versus the wide-area coverage provided by the macro-cell network.

***Figure 5: Femto-Cell Coverage***

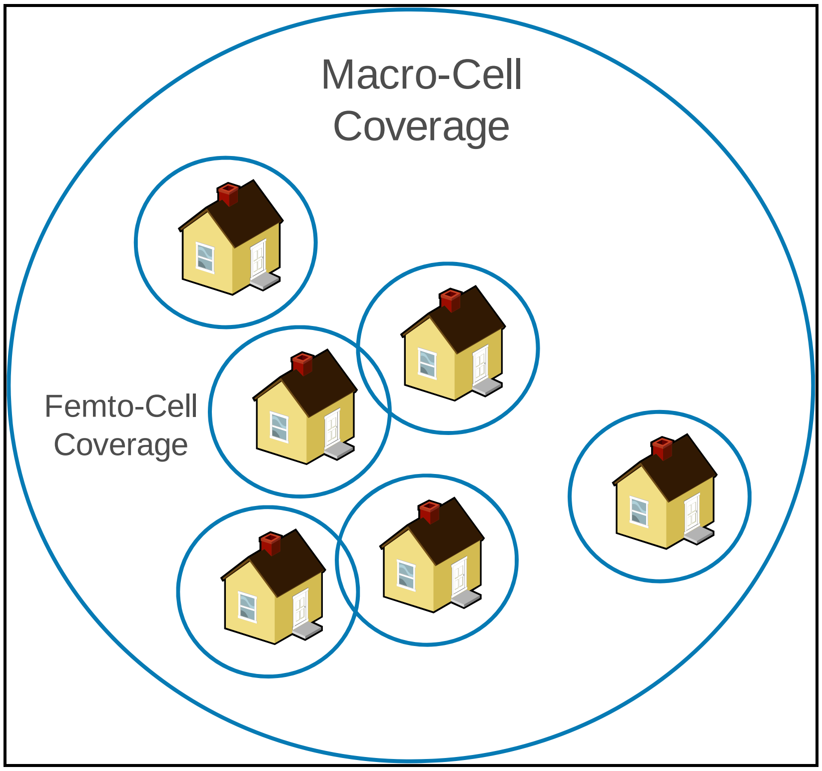
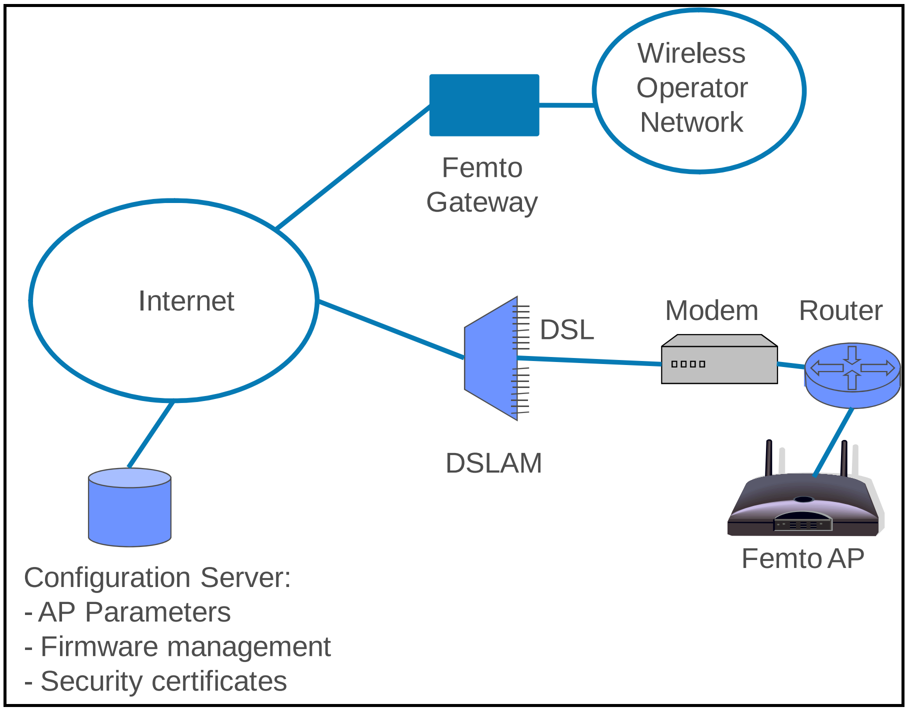



Figure 6 shows the femto-cell architecture, which consists of a femto-cell access point at the customer location, a configuration manager for configuring operating parameters for the femto access point, and a gateway to the wireless operator's network.

*Figure 6: Femto-Cell Architecture*




## 4.9 Wi-Fi

Wi-Fi has become an extremely successful, local-area networking technology. With IEEE 802.11n, users can obtain real throughput rates of about 100 Mbps, making Wi-Fi a viable alternative to Ethernet for many networking applications.

There are a number of handset devices that support Wi-Fi such as the AT&T Tilt and Apple iPhone 3G, as shown in Figure 7. For handsets, Wi-Fi is well suited for high-volume data transfers that might otherwise exceed users' data plans, and for applications such as VoIP that work best with very low latency connections.

Some operators, including AT&T, provide access to their Wi-Fi hotspot networks as part of their 3G data plans.

Via municipal Wi-Fi networks and a large network of Wi-Fi hotspots, Wi-Fi is becoming increasingly available in public areas. Coverage is generally localized, however, making Wi-Fi mainly complementary with wide-area wireless networks.

*Figure 7: Recent Popular Devices with Wi-Fi (AT&T Tilt, iPhone 3G)*

## 4.10 Personal-Area Networking Developments

Just as there has been continued innovation with wide-area and local-area wireless networks, there is comparable innovation in personal-area networking technology, often based on the same radio advances. Devices in the local area are increasingly interconnected including scanners, hard drives, printers, and consumer devices.

The best-known personal-area networking technology is Bluetooth, which has had the greatest success with headsets and hands-free applications in cars. Bluetooth also supports tethering facilitating the use of handsets as modems for computers. This is particularly attractive with AT&T's 3G service, which allows simultaneous voice and data. Bluetooth Enhanced Data Rate today supports 3 Mbps. In the future, Bluetooth capabilities will increase using either the IEEE 802.11 physical layer, and/or Ultra Wideband (UWB).

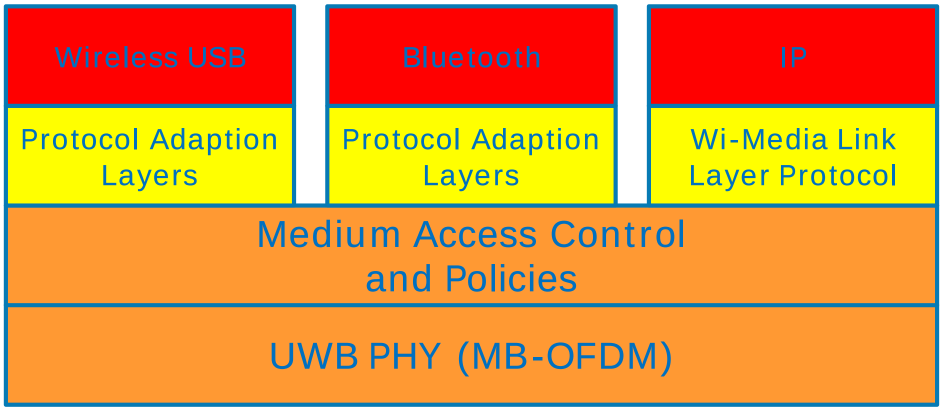
UWB is a radio technology that transmits at low power across extremely high bandwidths. Operating over small distances (e.g., inside a room), data rates up to 1 Gbps are feasible; although many devices will operate at throughput rates lower than this. Another advantage of UWB is operation at very low power such that products today consume only 1.25 to 2 mW per Mbps.

UWB is seeing market realization through an implementation called Multi-band Orthogonal Frequency Division Multiplexing (MB-OFDM), which is based on specifications managed by the WiMedia Alliance. Wireless USB (WUSB) uses

MB-OFDM and enables applications such as wireless docking of laptops. WUSB will also be an option for handsets in the future for applications such as multimedia synchronization.

Figure 8 shows the WiMedia protocols. Via protocol-adaption layers, different higher level protocols can take advantage of UWB connections, including WUSB, Bluetooth and IP protocol stacks.

***Figure 8: WiMedia Protocol Architecture***



# 5. Broadband Applications

In designing applications for new broadband networks, there are a number of considerations. Table 6 shows how much bandwidth common applications consume. Some of these values, such as basic high-speed Internet at 5 Mbps, are approximations.

The applications that consume the greatest bandwidth today are video oriented, whether video conferencing or high-definition TV.

***Table 6: Applications and Bandwidth***

| Application | Bandwidth |
|---|---|
| Internet Streaming Video | 1 Mbps |
| Standard Definition TV | 2 Mbps |
| Gaming | 2 Mbps |
| Video Conferencing | 3 Mbps |
| Distance Learning | 3 Mbps |
| Basic High-Speed Internet | 5 Mbps |
| Telecommuting | 5 Mbps |
| Multimedia Web interaction | 10 Mbps |
| High-Definition TV | 9 Mbps |
| Enterprise Applications | 1 to 10 Mbps |

The following sections discuss application considerations for HSPA, FMC, femto cells, Wi-Fi, multimode devices, UWB, multi-network management and optimization.

## 5.1 HSPA Applications

HSPA networks are on a trajectory to deliver ever increasing speeds with innovations such as HSUPA now becoming widely available and HSPA+ planned for the relatively near future. Users already experience throughput speeds of more than 1 Mbps in both downlink and uplinks making many new applications feasible. Moreover, 3G networks like HSPA have significantly reduced latency compared to prior wireless data technologies.

Applications that make sense for HSPA include:

- Most existing networking applications.
- Web-based applications.
- Multimedia.
- High volume download/upload.

No matter how fast wide-area, wireless networks become, however, there remain a number of items that differentiate them from wireline networks. These include.

- **Connection stability.** With a good signal and under stationary conditions, connections are generally stable. When mobile, however, connections may sometimes be lost. Applications may need to respond accordingly such as automatically reconnecting to servers.
- **Variation in connection speed.** Although today's 3G networks have high average speeds, there are speed variations due to varying signal quality and network loading from voice and data users. This situation will not change with new wireless networking technologies.
- **2G fallback.** 3G coverage does not extend to all areas and, in some areas, users will connect over 2G networks, such as EDGE, in which speeds of about 100 kbps are slower than 3G. Applications operating over wide coverage areas should accommodate these lower speeds.
- **5 GByte cap on unlimited plans.** Current high-volume pricing plans include a 5 GByte cap for monthly usage, which for many data applications is more than sufficient. Some applications, however, particularly higher-definition video, can quite easily consume this cap.
- **Mobile middleware for mobile applications.** Mobile middleware remains an effective solution for many applications, even over broadband networks, due to features such as data compression, security, policies that can manage which applications have access to a particular network, session management, and transparent roaming across multiple network types (e.g., 3G to Wi-Fi.)
- **No QoS.** Today's wireless broadband networks typically do not offer any QoS features through which applications can request items such as

minimum throughput or delay. Due to variations in speed and latency, applications such as VoIP may not operate reliably.

## 5.2 FMC and Femto Cells

As FMC solutions such as femto cells become available, there are a number of considerations for developers.

- **Seamless roaming with hand-off.** Users will be able to seamlessly move between femto and macro coverage areas maintaining voice and data sessions.
- **Service continuity.** For both voice and data, the services a subscriber has (e.g., RIM e-mail, IMS-based applications) should be equally available for both macro-cell and femto-cell access.
- **Higher average data throughput with lower latency.** Femto connections will on average yield higher throughputs at lower latency than wide-area connections. For some subscribers, speeds will be limited by their Internet connection, not their wireless connection.
- **Greater data capacity.** Caps on monthly data volume will likely either be higher or unlimited. Users' ISP policies, however, may also have volume restrictions.
- **Determining macro or femto network.** It may not be possible for the application to automatically detect whether it is in femto or wide-area coverage.

## 5.3 Wi-Fi

As more devices, particularly mobile phones, include support for Wi-Fi, application developers should consider how best to leverage this networking option.

Wi-Fi is well suited for the following situations:

- **High volume data transfer.** Higher speeds available with Wi-Fi make transfers of large amounts of data (e.g., video content) practical, especially with local servers.

- **Internet connection restrictions.** Though Wi-Fi supports very high throughput rates, in a home network or hotspot connection, throughputs may be limited by the wireline connection. Many hotspots use 1.5 Mbps T1 circuit connections limiting throughput to this rate.

- **Higher QoS.** Wi-Fi connections have lower latency than wide-area wireless connections making applications such as VoIP operate better. Moreover, there are QoS standards defined for Wi-Fi (e.g., IEEE 802.11e) that increasingly will allow applications to manage QoS for data sessions.

Ideally, mobile applications should monitor the network connection type and manage sessions accordingly.

## 5.4 High-Speed Personal-Area Networking

With personal-area networking technologies such as Bluetooth and Wireless USB, there are a number of ways applications can take advantage of these connections. Both mobile phones and laptop computers will benefit from higher speeds with the following types of possible usages:

- **High-speed tethering.** Faster PANs will be able to keep up with the ever-increasing speeds of HSPA (and later LTE),making it practical to use phones as modems.

- **Media synchronization.** Devices will be able to quickly exchange high volumes of multimedia files with desktops and local networks.

- **Wireless docking.** Phones and laptops will be able to wirelessly dock for access to peripherals such as displays, keyboards, mice, and external hard drives.

## 5.5 Multi Network Considerations

Increasingly, applications must work across multiple network types, including 2G, 3G, Wi-Fi and PANs. There are a number of ways that applications can accommodate heterogeneous network environments.

First, application developers should be aware that movement between 2G and 3G is seamless, with data sessions keeping the same IP address, and hand-offs from 2G to 3G or from 3G to 2G occurring automatically. This facilitates application development, although it does suggest that applications should work satisfactorily over either 2G or 3G connections.

If devices have Wi-Fi capability, then they can take advantage of potentially higher-speeds, especially if connecting to local servers. Device platforms provide connection management APIs with which applications can detect and manage connections. Alternatively, connections may be managed by users.

There are also mobile middleware products that implement policies that can control which applications have access to a particular network.

## 5.6 Application Optimization for Broadband

As networks become faster and have greater capacity, more networking applications work well. The need for optimization, however, does not go away, especially for applications used on a regular or intensive basis, or when mobile.

Optimization strategies include:

- **Design for lowest-common denominator connection type.** Designing for worst-case throughput and latency conditions means users will always have a good experience with the application.
- **Accommodate type of connection.** Applications should ideally adjust their behavior based on the connection type. For example, high-volume media transfers can be restricted to a PAN or LAN connection.
- **Design for latency.** Latency can affect applications as much as throughput, and although latency with HSPA is only about 100 msec and will go down in the future with HSPA+ and LTE, applications that engage in a large number of back-and-forth messages will not provide response times as good as those that coalesce transmissions.
- **Manage battery and power in small devices.** Network speeds are increasing faster than battery capability, and data communications is a large contributor to power consumption. Minimizing data transferred translates directly to improved battery life.
- **Leverage available bandwidth.** Although bandwidths may be high with new broadband networks, applications can still benefit greatly from more

powerful compression schemes. For example, MPEG4 only requires about half the number of bits to represent video as MPEG2.

- **Consider rich Internet technologies.** For Web applications, technologies such as AJAX, Adobe Flash, Google Gears, and others provide vibrant user experiences, and allow selective updates of display and interaction with local data resulting in responsive interfaces and efficient network utilization.

Developers can either optimize their own applications or look to third-party application frameworks, such as mobile middleware solutions, which incorporate optimization within their architectures.

## 6. Conclusion

There is tremendous innovation occurring in both wireline and wireless, broadband networking technologies. Although sometimes positioned as competitive, in most instances, wireline and wireless technologies are complementary, each best for certain scenarios and applications. Wireline technology developments are being driven by fiber-optic capacity and video applications, while wireless technologies are being driven by mobility and an increasing application scope enabled by higher throughputs and complementary services.

The 3GPP roadmap incorporates ongoing improvements in EDGE, HSPA and LTE, continually raising throughput rates, reducing latency and increasing capacity. Meanwhile, advances in local and personal-area technologies facilitate sophisticated device interaction, and simplify docking and synchronization procedures.

This paper presents technologies across an extended time horizon. Developers should be aware that next-generation technologies like LTE will not be available for several years, and it will be mid-next decade before they are prevalent. As HSUPA deployment in 2008 has demonstrated, however, there will be an ongoing series of enhancements enabling ever more powerful, mobile applications.

Many off-the-shelf networking applications will work extremely well over wireless connections. Applications that are network aware, however, and that are optimized for wireless networking will continue to provide users with the best experience.

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