2019

BROADBAND GUIDELINES

Technical Unit

National Telecommunications Regulatory Commission

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1.0 INTRODUCTION

The power of Internet has brought greater awareness, skills and resources, helping markets reach to a diverse global audience. Broadband provides the opportunity to do things differently, to achieve better outcome for people, countries and to ensure continuous growth of economy and social development. The proliferation of the broadband enables growth of Information and Communication Technologies (ICT), content, applications and services which may help Saint Lucia and in part the Caribbean to become a truly competitive knowledge-based economy and leverage citizens to become healthier, better educated and more engaged in their community & society.

Internet and Broadband access are widely recognized as catalysts for economic and social development of a country. Availability of broadband services at affordable price can contribute to higher Gross Domestic Product (GDP)[1] for growth rates, provide for a larger & more qualified labor force and increased working efficiency. There is a correlation between the broadband adoption rate and the GDP for various countries. Providing broadband access to citizens, communities and public institutions is one of the strategic objectives for governments worldwide. As per the report of World Bank[2], a 10-percentage increase in broadband penetration accounted for 1.38 percentage increase in per capita GDP growth in developing economies. This is much higher than the impact of mobile telephony growth on GDP. The report also indicates that across all telecom services, the positive effect on GDP is higher in developing countries (Saint Lucia) than in developed countries. In case of broadband this impact is about 15% more in developing countries than in developed countries.

Convergence and popularity of IP networks is leading to Next Generation Networks (NGN) worldwide. Provision of various services over IP network reduces capex and opex and provides competitive advantage in highly competitive market. A robust broadband network will be necessary to support all types of services; especially bandwidth intensive applications. As the bandwidth requirement is inversely proportional to the literacy level of user, the rural areas will require much higher bandwidth than their urban counterparts. In UK, British Telecom (BT) who pioneered NGN implementation realized that success of NGN implementation is dependent on availability of high speed access network. Accordingly, it has reviewed its plan for implementation of its project 21CN and higher emphasis is being given for upgradation of copper access network to fibre network to support growing demand for super-fast broadband services.

[1] It should be noted that this document focuses on technical guidelines. Research on Economic and Social developments are not included within this document. However as mentioned above various studies have revealed, expected growth of these two elements once broadband and the QoS of broadband is upgraded.
[2] IC4D 2009: Extending Reach and Increasing Impact

2.0 TYPES OF BROADBAND

2.1 Digital Subscriber Line (DSL):

DSL is a wireline transmission technology that transmits data faster over traditional copper telephone lines already installed to homes and businesses. DSL-based broadband provides transmission speeds ranging from several hundred Kbps to millions of bits per second (Mbps). The availability and speed of your DSL service may depend on the distance from your home or business to the closest telephone company facility.

2.1.1 Types of DSL Transmission Technologies:

Asymmetrical Digital Subscriber Line (ADSL) – Used primarily by residential customers, such as Internet surfers, who receive a lot of data (download) but do not send much (upload). ADSL typically provides faster speed in the downstream direction than the upstream direction. ADSL allows faster downstream data transmission over the same line used to provide voice service, without disrupting regular telephone calls on that line.

Symmetrical Digital Subscriber Line (SDSL) – Used typically by businesses for services such as video conferencing, which need significant bandwidth both upstream and downstream.

2.2 Cable Modem

Cable modem service enables cable operators to provide broadband using the same coaxial cables that deliver pictures and sound to your TV set.

Most cable modems are external devices that have two connections: one to the cable wall outlet, the other to a computer. They provide transmission speeds of 1.5 Mbps or more.

Subscribers can access their cable modem service by simply turning on their computers, without dialing-up an ISP. You can still watch cable TV while using it. Transmission speeds vary depending on the type of cable modem, cable network, and traffic load. Speeds are comparable to DSL.

2.3 Fiber Optic

Fiber optic technology converts electrical signals carrying data to light and sends the light through transparent glass fibers about the diameter of a human hair. Fiber transmits data at speeds far exceeding current DSL or cable modem speeds, typically by tens or even hundreds of Mbps. The actual speed you experience will vary depending on a variety of factors, such as how close to your computer the service provider brings the fiber and how the service provider configures the service, including the amount of bandwidth used. The same fiber providing your broadband can also simultaneously deliver voice (VoIP) and video services, including video-on-demand.

Telecommunications providers sometimes offer fiber broadband in limited areas and have announced plans to expand their fiber networks and offer bundled voice, Internet access, and video services.

Variations of the technology run the fiber all the way to the customer's home or business, to the curb outside, or to a location somewhere between the provider's facilities and the customer.

2.4 Wireless Broadband

Wireless broadband connects a home or business to the Internet using a radio link between the customer's location and the service provider's facility. Wireless broadband can be mobile or fixed.

Wireless technologies using longer-range directional equipment provide broadband service in remote or sparsely populated areas where DSL or cable modem service would be costly to provide. Speeds are generally comparable to DSL and cable modem. An external antenna is usually required.

Internet access services offered over fixed networks allow consumers to access the Internet from a fixed point while stationary and often require a direct line-of-sight between the wireless transmitter and receiver. These services have been offered using both licensed spectrum and unlicensed devices. For example, thousands of small Wireless Internet Services Providers (WISPs) provide such wireless broadband at speeds of around one Mbps using unlicensed devices, often in rural areas not served by cable or wireline broadband networks.

2.5 Wireless Local Area Networks (WLANs)

Provide wireless broadband access over shorter distances and are often used to extend the reach of a "last-mile" wireline or fixed wireless broadband connection within a home, building, or campus environment. Wi-Fi networks use unlicensed devices and can be designed for private access within a home or business, or be used for public Internet access at "hot spots" such as restaurants, coffee shops, hotels, airports, convention centers, and city parks.

2.6 Mobile Wireless Broadband

Services are also becoming available from mobile telephone service providers and others. These services are generally appropriate for highly-mobile customers and require a special PC card with a built-in antenna that plugs into a user's laptop computer. Generally, they provide lower speeds, in the range of several hundred Kbps.

2.7 Satellite

Just as satellites orbiting the earth provide necessary links for telephone and television service, they can also provide links for broadband. Satellite broadband is another form of wireless broadband, and is also useful for serving remote or sparsely populated areas.

Downstream and upstream speeds for satellite broadband depend on several factors, including the provider and service package purchased, the consumer's line of sight to the orbiting satellite, and the weather. Typically, a consumer can expect to receive (download) at a speed of about 500 Kbps and send (upload) at a speed of about 80 Kbps. These speeds may be slower than DSL and cable modem, but they are about 10 times faster than the download speed with dial-up Internet access. Service can be disrupted in extreme weather conditions.

2.8 Broadband Over Powerline (BPL)

BPL is the delivery of broadband over the existing low- and medium-voltage electric power distribution network. BPL speeds are comparable to DSL and cable modem speeds. BPL can be provided to homes using existing electrical connections and outlets. BPL is an emerging technology that is available in very limited areas. It has significant potential because power lines are installed virtually everywhere, alleviating the need to build new broadband facilities for every customer.

3.0 TECHNOLOGICAL DRIVERS

Liberalization and competition in the telecommunications market have brought new and innovative technologies in the market. The convergence of technologies and ubiquitous use of IP networks will increase broadband use. The distinction of medium for existing services such as voice, data or video, will blur with increased adoption of convergence. The move towards IP based services will make broadband technology integral part of our life as users will try to reap the full benefits of convergence.

The capabilities of smart phones bundled with pre-loaded features and inbuilt applications permit access to new domains using Internet access. Data cards and Wireless Broadband CPEs facilitate availability of broadband anytime, anywhere further fueling wireless broadband demand.

Technological innovation permits new ways of creating, distributing, preserving, sharing and accessing digital content. As economies move to become more knowledge-intensive, information-rich activities will increase; new content will be created, collected, managed, processed, stored, delivered, and accessed. This spread will contribute to further innovation, growth and enhanced utilization of broadband.

4.0 ARCHITECTURE

4.1 DSL and Cable Modem Networks

4.1.1 Digital Subscriber Line

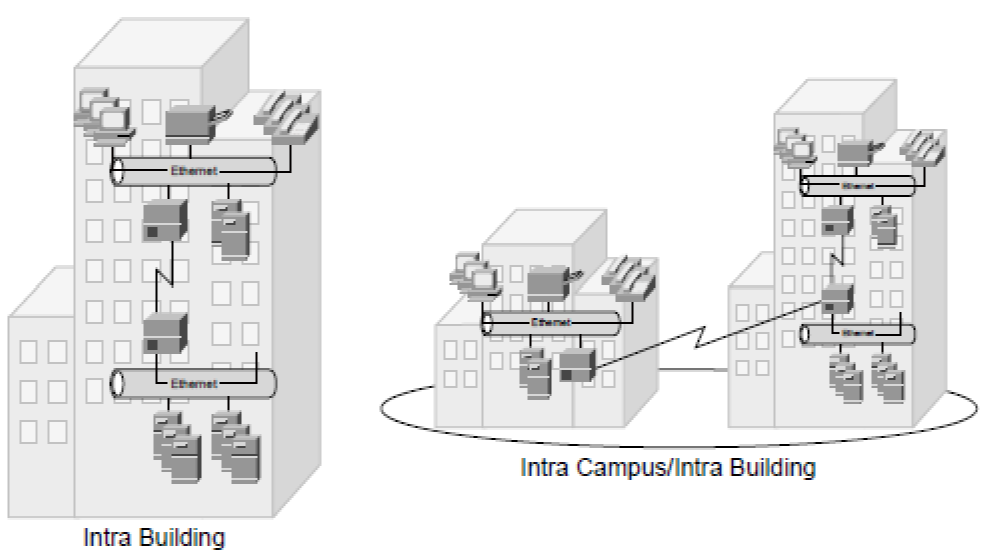
Digital subscriber line (DSL) technology is a modem technology using existing twisted pair telephone lines to carry high-bandwidth applications, such as multimedia and video. The term xDSL covers a number of DSL technologies, such as Asymmetrical Digital Subscriber Line (ADSL), Symmetrical Digital Subscriber Line (SDSL), Hi-Speed Digital Subscriber Line (HDSL), HDSL-2 (HDSLv2), ITU DSL standard (G.SHDSL), ISDN Digital Subscriber Line (IDSL), and Very-High-Data-Rate Digital Subscriber Line (VDSL).

xDSL services are dedicated point-to-point network access over twisted-pair copper wire on the local loop (last mile) between a network service provider's (NSP) central office (CO) and the customer site. xDSL also can be deployed in intra-building and intra-campus environments, as illustrated in Figure 1.

xDSL offers two chief benefits over dial-up service:
• Dial-up service is limited to 53.3 Kbps, whereas xDSL service can enable up to 6.122 Mbps.

• Dial-up service is initiated "on-demand" by the end-user, but xDSL service is a dedicated connection, meaning that it is "always on."

Figure 1
Intra Building and Intra-Campus/Intra Building

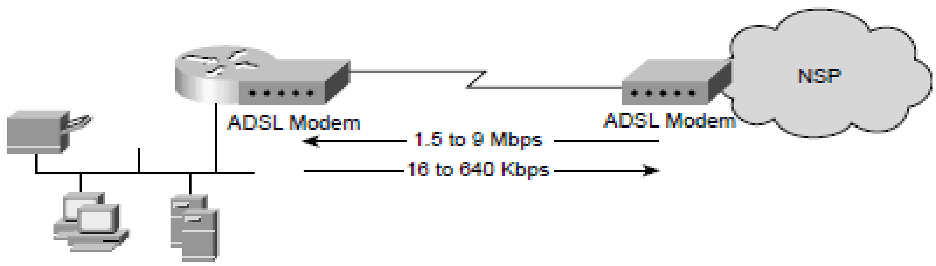


ADSL is often deployed in the small office/home office (SOHO) environment and is the traditional DSL service for residential deployment. The asymmetry is ideal in these environments because the majority of upstream bandwidth is consumed by Internet requests; for example, users navigating through web sites. These upstream requests are small compared to the downstream response, such as the web site fulfilling the user's request.

4.1.2 ADSL

ADSL technology makes more bandwidth available downstream, from a NSP central office (CO) to the customer site, than it makes available upstream, from the customer site to the CO. Figure 2 illustrates an example of an ADSL connection.

Figure 2
ADSL Connection



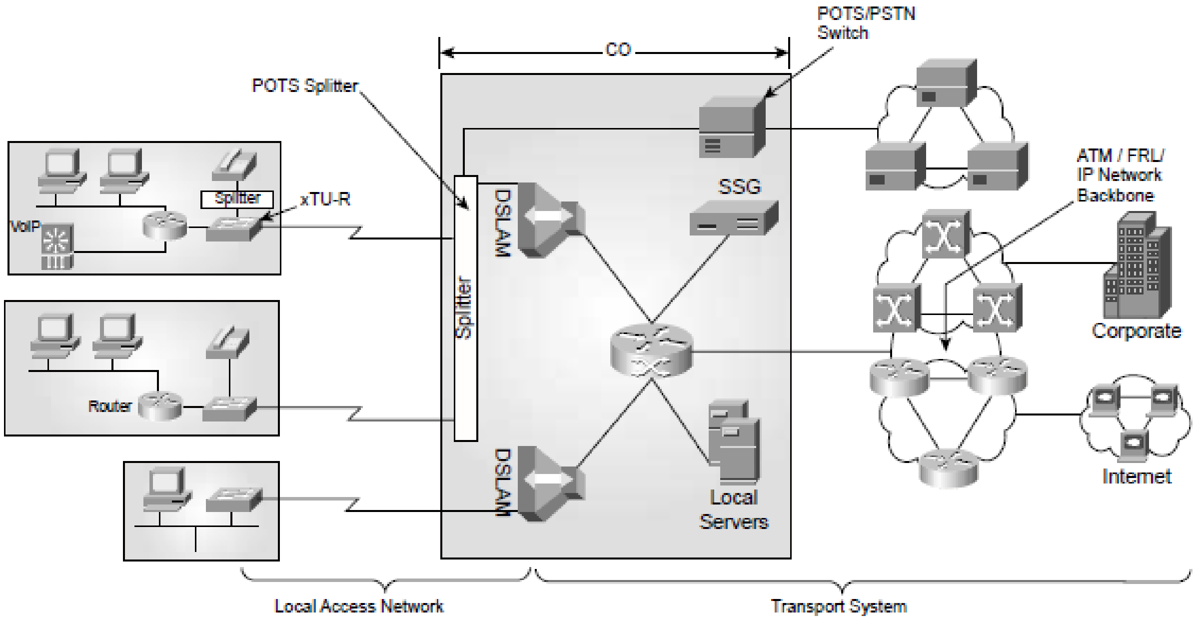
The asymmetry of ADSL, combined with always-on access (which eliminates call setup), makes ADSL another solution for Internet/intranet surfing, video-on-demand, and remote LAN access because users of these applications often download more data than they upload.

4.1.3 ADSL Architecture

ADSL circuits connect ADSL modems on each end of a twisted-pair telephone line, creating three data channels:

• A high-speed downstream channel—Ranges from 1.5 to 9 Mbps.
• A low-speed upstream channel—Ranges from 16 to 640 Kbps.
• A basic telephone service channel—The basic telephone service channel is split off from the digital modem by filters or plain old telephone service (POTS) splitters, providing uninterrupted basic telephone service.

Figure 3



ADSL architecture is made up of the following components:

• Transport System—Provides the carrier backbone transmission interface for the DSLAM system. This device can provide service specific interfaces such as T1/E1, T3/E3, OC-1/3, and STS-1/3.
• Local Access Network—Uses the local carrier Inter-CO network as a foundation, providing connectivity between multiple service providers and multiple services users, often with Frame Relay or ATM switches.
• Digital Subscriber Line Access Multiplexer (DSLAM)—Concentrates data traffic from multiple DSL loops onto the backbone network for connection to the rest of the network.
• DSL Transceiver Unit-Remote (xTU-R)—The customer site equipment for service connection to the DSL loop.
• POTS Splitters—Optional device at both CO and service user locations, enabling the copper loop to be used for simultaneous DSL and transmission and single line telephone service. POTS splitters come in two configurations:
— Single splitter version for mounting at the residence
— Multiple splitter version for mass termination at the CO

POTS splitters are either passive or active. Active splitters require an external power source, and passive splitters require no power and often have a higher mean time between failure (MTBF) than the active splitter. Passive splitters enable lifeline services, such as 911, in the event of a DSLAM or xTU-R power loss; active splitters require backup power.

ADSL Data Rates
Downstream bandwidth depends on a number of factors:

• Length of the copper line
• Wire gauge of the copper line
• Presence of bridged taps
• Presence of cross-coupled interference

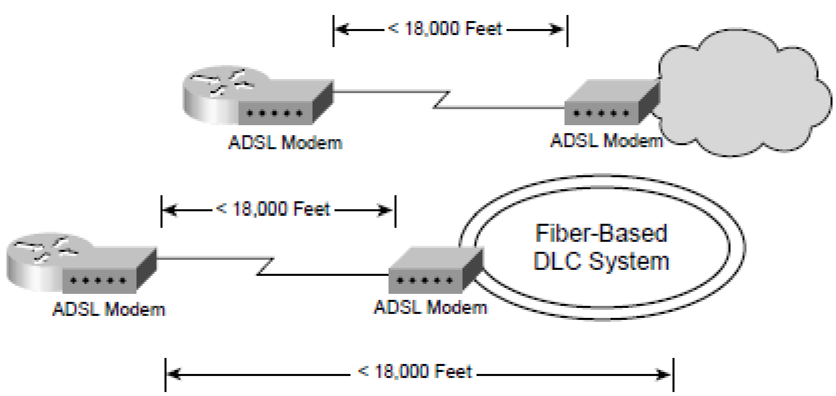
Line attenuation increases with line length and frequency, and decreases as wire diameter increases. Ignoring bridged taps, ADSL performs as shown in Table 1.

Table 1
ADSL Rates (Ignoring Bridged Taps)

Rate (Mbps)	Wire Gauge (AWG)	Distance (feet)	Wire Size (mm)	Distance (km)
1.5 or 2	24	18,000	0.5	5.5
1.5 or 2	26	15,000	0.4	4.6
6.1	24	12,000	0.5	3.7
6.1	26	9000	0.4	2.7

Customer sites beyond the previously listed distances can be reached with fiber-based digital loop carrier (DLC) systems, as illustrated in Figure 7-4.

Figure 4
ADSL with and Without Fiber-based DLC



4.1.4 Other xDSL Technologies

There are several xDSL implementations in addition to ADSL. These are as follows:

• Single-lined digital subscriber line (SDSL)—A rate-adaptive version of Hi-speed digital subscriber line (HDSL) which like HDSL is symmetric. SDSL enables equal bandwidth downstream from a network service provider CO to the customer site as upstream from the customer site to the CO. SDSL supports data only (maximum of 1.544 Mbps) on a single line and does not support analog calls.

• High-data-rate digital subscriber line (HDSL)—Developed by Bellcore, high bitrate DSL (HDSL)/T1/E1 technologies have been standardized by ANSI in the United States and by ETSI in Europe. HDSL is a more cost-efficient method of installing T1 service to a customer site than traditional dedicated DS1 service.
• HDSL 2—Standard enabling symmetric service at T1 speeds using a single-wire pair rather than the two pairs of HDSL service. HDSL-2 also was developed as a standard by which different vendors' equipment can interoperate.
• G.SHDSL (ITU HDSL Standard)—A standards-based, multirate version of HDSL-2, which offers symmetrical service.
• Integrated Services Digital Network (ISDN) digital subscriber line (IDSL)—A cross between ISDN and xDSL, using a single-wire pair to transmit full-duplex data at 128 kbps.
• Very-high-data-rate Digital Subscriber Line (VDSL)—Transmits high-speed data over short reaches of twisted-pair copper telephone lines, with a range of speeds depending on actual line length. The maximum downstream rate under consideration is between 51 and 55 Mbps over lines up to 1000 feet (300 m). Downstream speeds as low as 13 Mbps over lengths beyond 4000 feet (1500 m) also are in consideration.

4.2.1 Cable Access Technologies

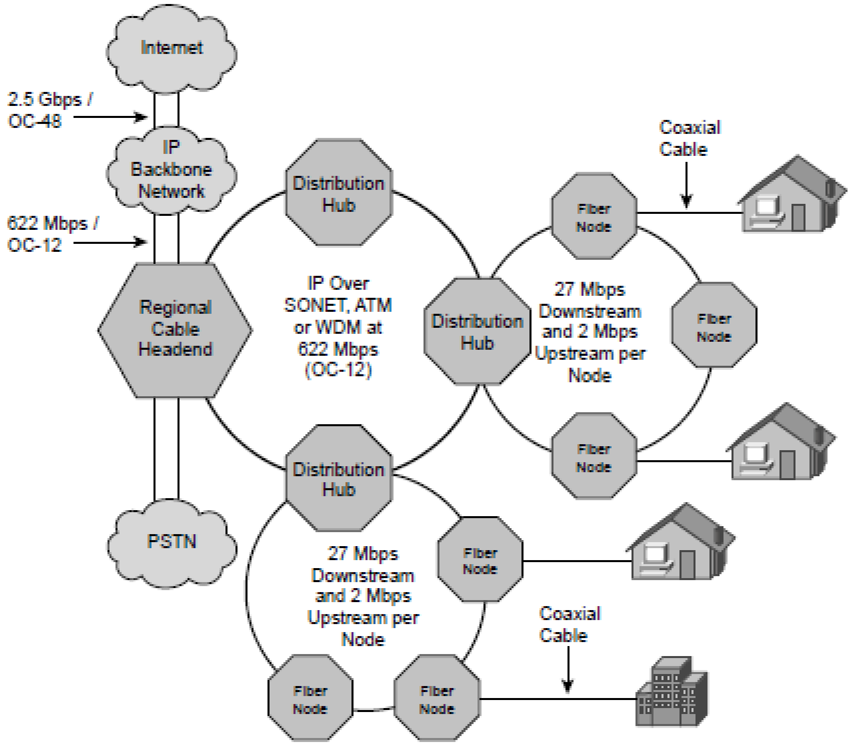
Cable television (CATV) is a unidirectional medium carrying broadcast analog video channels to the most customers possible at the lowest possible cost to the CATV service provider.

4.2 Cable Access Architecture

To deliver data services over a cable network, one television channel (50 to 750 MHz range) is allocated for downstream traffic to homes and another channel (5 to 42 MHz band) is used to carry upstream signals.

Figure 5 illustrates the architecture of a cable access network for both CATV and cable modem services.

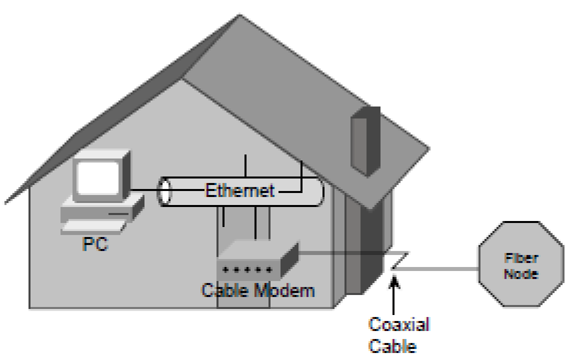
Figure 5
Cable Access Architecture



The following list details the cable access network architecture:

• Residential and business end-users are connected to fiber nodes by coaxial cables. Users attach to this cable through an Ethernet network interface card (NIC) installed in the PC, in turn connected to a cable modem, as illustrated in the Figure 6.

Figure 6
Cable Modem Access



•The fiber nodes house the Cable Modem Termination System (CMTS) at the head-end, communicating with the cable modems at the end-user premise. This communication creates a LAN connection between the end-user and the cable modem service provider.
• Most cable modems are external hardware devices connecting to a PC through a standard 10Base-T Ethernet card or Universal Serial Bus (USB) connection.
• These fiber nodes are connected by fiber rings (such as SONET) to the distribution hubs, which are in turn connected by fiber rings to a regional cable head-end.
• The cable head-end then forwards the traffic to the appropriate network—the PSTN for VoIP applications and the public Internet for all other IP traffic.

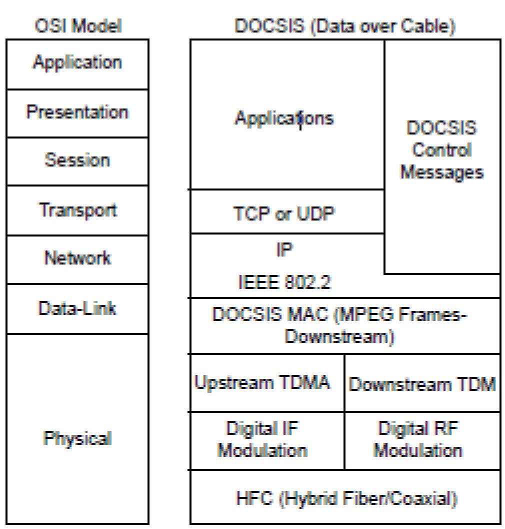
A single downstream 6 MHz television channel can carry up to 27 Mbps of downstream data throughput from the cable head-end; upstream channels can deliver 500 Kbps to 10 Mbps from home and business end-users. This upstream and downstream bandwidth is shared by other data subscribers connected to the same cable network segment, which is often 500 to 2000 homes on a modern network.

An individual cable modem subscriber can reach speeds from 500 Kbps to 1.5 Mbps or more, depending on the network architecture (for example, oversubscription ratio) and traffic load.

4.3 DOCSIS Standards, Signaling Protocols, and Applications

Data Over Cable Service Interface Specification (DOCSIS) is a set of standards for transferring data by CATV and cable modems. The DOCSIS interface specifications enable multivendor interoperability for transporting Internet Protocol (IP) traffic. The DOCSIS layers are compared with the OSI Reference Model layers in Figure 7.

Figure 7
OSI Layers and DOCSIS Layers



The following list details the correlation between the OSI Reference Model and the DOCSIS standard:

• TCP/IP support:
— IP services at the network layer (OSI Layer 3)
— TCP/UDP services at the transport layer (OSI Layer 4)
• Data-link layer:
— Logical Link Control (LLC) sublayer conforming to Ethernet standards
— Link security sublayer for basic privacy, authorization, and authentication
— Media Access Control (MAC) sublayer supporting variable-length protocol data units (PDU)
• Physical (PHY) layer comprised of the following:
— Downstream convergence layer conforming to MPEG-2
— Physical Media Dependent (PMD) sublayer for downstream and upstream data transmission; through Time Division Multiplexing (TDM).

Table 2
DSL Service Summary

DSL Type	Description	Data Rate Downstream; Upstream	Distance Limit	Application
ADSL	Asymmetric digital subscriber line	1.544 to 6.1 Mbps downstream; 16 to 640 Kbps upstream	1.544 Mbps at 18,000 feet; 2.048 Mbps at 16,000 feet; 6.312 Mbps at 12,000 feet; 8.448 Mbps at 9,000 feet	Used for Internet and web access, motion video, video on demand, remote LAN access.
HDSL	High-data-rate digital subscriber line	1.544 Mbps duplex on two twisted-pair lines; 2.048 Mbps duplex on three twisted-pair lines	12,000 feet on 24-gauge wire	T1/E1 service between server and phone company or within a company; WAN, LAN, server access.
SDSL	Single-line digital subscriber line	1.544 Mbps duplex (U.S. and Canada); 2.048 Mbps (Europe) on a single duplex line downstream and upstream	12,000 feet on 24-gauge wire	Same as for HDSL but requiring only one line of twisted-pair.
VDSL	Very-high digital subscriber line	12.9 to 52.8 Mbps downstream; 1.5 to 2.3 Mbps upstream; 1.6 Mbps to 2.3 Mbps downstream	4500 feet at 12.96 Mbps; 3000 feet at 25.82 Mbps; 1000 feet at 51.84 Mbps	ATM networks; Fiber to the Neighborhood.

5.0 FIBRE OPTICS

5.1 General Guidelines

The following contains information on the placement of fiber optic cables in various indoor and outdoor environments. In general, fiber optic cable can be installed with many of the same techniques used with conventional copper cables. Basic guidelines that can be applied to any type of cable installation are as follows:

- Conduct a thorough site survey prior to cable placement.
- Develop a cable pulling plan.
- Follow proper procedures.
- Do not exceed cable minimum bend radius.
- Do not exceed cable maximum recommended load.
- Document the installation.

5.2 Conduct a Site Survey

The purpose of a site survey is to recognize circumstances or locations in need of special attention. For example, physical hazards such as high temperatures or operating machinery should be noted and the cable route planned accordingly. If the fiber optic cable has metallic components, it should be kept clear of power cables. Additionally, building code regulations must be considered. If there are questions regarding local building codes or regulations, they should be addressed to the authority having jurisdiction, such as the fire marshal or city building inspector.

5.3 Develop a Cable Pulling Plan

A cable pulling plan should communicate the considerations noted during the site survey to the installation team. This includes the logistics of cable let-off/pulling equipment, the location of intermediate access points, splice locations and the specific responsibilities of each member of the installation team.

5.4 Follow Proper Procedures

Because fibers are sensitive to moisture, the cable end should be covered with an end cap, heavy tape or equivalent at all times. The let-off reel must never be left unattended during a pull because excess or difficult pulls, center-pull or back feeding techniques may be employed.

5.5 Do Not Exceed Cable Minimum Bend Radius

Every cable has an installation minimum bend radius value. During cable placement it is important that the cable not be bent to a smaller radius. After the cable has been installed, and the pulling tension removed, the cable may be bent to a radius no smaller than the long term application bend radius specification.

The minimum bend radii values still apply if the cable is bent more than 90 degrees. It is permissible for fiber optic cable to be wrapped or coiled as long as the minimum bend radius constraints are not violated.

5.6 Do Not Exceed Cable Maximum Recommended Load

While fiber optic cables are typically stronger than copper cables, it is still important that the cable maximum pulling tension not be exceeded during any phase of cable installation. In general, most cables designed for outdoor use have a strength rating of at least 2700 N. Fiber optic cables also have a maximum recommended load value for long term application. After cable placement is complete the residual tension on the cable should be less than this value. For vertical installations, it is recommended that the cable be clamped at frequent intervals to prevent the cable weight from exceeding the maximum recommended long term load. The clamping intervals should be sufficient to prevent cable movement as well as to provide weight support.

5.7 Leave Extra Cable

A common practice is to leave extra cable at the beginning and at the end of the cable run. Also, extra cable should be placed at strategic points such as junction boxes, splice cases and cable vaults. Extra cable is useful should cable repair or mid-span entry be required.

5.8 Document the Installation

Good record keeping is essential. This will help to ensure that the cable plant is installed correctly and that future trouble shooting and upgrading will be simplified. All fiber optic cables have a unique lot number shown on the shipping spool. It is important that this number be recorded. Cable pre- and post- installation test data should be recorded in an orderly and logical fashion.

5.9 Pulled Installations

In order to effectively pull cable without damaging the fiber, it is necessary to identify the strength material and fiber location within the cable. Then, use the method of attachment that pulls most directly on the strength material—without stressing the fiber. As a general rule, it is best to install cable prior to connector attachment. After connectors have been attached, it becomes more difficult to protect the fiber from inadvertent stress. If a pull is to be made entirely in one direction, connectors may be pre-installed on one end, leaving the other end for pulling. If the cable must be installed with connectors attached, every practical means must be taken to protect the connectorized end from damage or stress. Cushioned enclosures should be used to protect connectors during pulling.

The leading end of the cable should be sealed to prevent intrusion of water or other foreign material while pulling. Bi-directional pulls are possible by laying the cable into large "figure-8"-shaped loops on the ground, from where it can feed from both ends. For ease of cable installation, the area of the cable divided by the area of the duct or conduit should be less than 53% per a single cable. Permissible area to be occupied for 2 cables is 31%, for 3 or more cables it is 40%.

5.10 Direct Attachment

Strength member is tied directly to the pulling fixture. The cable end must be sealed to prevent intrusion of moisture while pulling.

With direct attachment, cable strength material is tied directly to the pulling fixture. Conventional cable tools may be used. Loose fiberglass threads are not suitable for direct attachment because they may break if knotted. Fiberglass epoxy rods are too rigid to tie, but may be secured to the pulling fixture by using tight clamping plates or screws.

5.11 Indirect Attachment

Pulling forces are distributed over the outer cable structure.

With indirect attachment, pulling forces are distributed over the outer portion of the cable structure. If cable strength materials are located directly beneath the jacket, this method will produce the least amount of stress on the fiber.

A popular type of pulling fixture for indirect attachment is the "Chinese Basket" or "Kellems Grip".

The Kellems Grip is usually reliable for cables of 1/4" diameter or more. Large pulling forces are possible with a Kellems Grip if the grip's diameter and length are properly matched to cable characteristics. A Kellem Grip should spread pulling forces over a 1m length of cable. For small cables, prestretching and taping the Kellems Grip to the cable helps to assure even pulling.

5.12 Cable Lubricants

Many lubricants are available for lowering friction forces. These include greases, waxes, clay slurries and water-based gels. Fiber optic jacket materials are compatible with most of these. For new conduit, lubrication of the conduit before pulling is suggested—particularly if there are several bends.

5.13 Air Plenums, Trays, Raceways

Installation procedures for open placement of fiber optic cables are the same as for electrical cables. Care should be taken to avoid sudden, excessive force so as not to violate tensile load and radius limits. Sharp bending and scraping at entrances and covers should be avoided.

5.14 Direct Burial

Outdoor cables may be buried directly in the ground. Environmental hazards include freezing water, crushing forces from rocky soil, ground disruption from construction, and rodents.

Burying the cable 90 to 120 cm deep may help prevent most of these hazards. Direct plow-in installation requires a cable capable of withstanding uneven pulling forces. Loose tube cables are best suited for these types of installations. Double jacketing, gel filling, metal sheathing and (CST)armoring are used as water barriers. Use of double jacketed armored cables can sometimes be avoided by burying polyethylene pipe to form a simple conduit. The pipe makes a smooth passageway and may be curved to allow easy access at manholes and other pull points. Cables may be subsequently replaced without digging.

5.15 Cable Storage

It is frequently required to store cables prior to installation. Temperature ranges for cable storage are listed in the corresponding catalog- or datasheet pages. It is recommended that cable ends be sealed to prevent intrusion of moisture. Polyethylene pipe can be used as a simple conduit. This allows use of less expensive cables in direct burial applications.

5.2 Cable Preparation

The following is a general description of cable preparation and termination procedures.

5.2.1 Jacket Removal

The procedure for stripping fiber optic cables is very similar to electronic cables. However, care should be taken not to cut into the layer of aramid directly beneath the jacket. This would either reduce the pull strength of the cable, or weaken the connection. For this reason, if a blade must be used, a cut which does not completely penetrate the jacket can be made. This will weaken it sufficiently and allow the jacket to be peeled. Most cables utilize a ripcord capable of tearing the outer sheath.

5.2.2 Cutting and Trimming Aramid

Aramid can be easily cut with sharp scissors if the threads are confined in movement so that cutting pressure can be applied. Ceramic scissors may also be used.

5.2.3 Steel and Fiberglass Epoxy Rod Members

Temperature stabilized cables of both loose and tight buffer constructions often have steel or fiberglass epoxy rods. Use of heavy-duty cutters is recommended for these hard materials.

5.2.4 Buffer Tube Trimming

Buffer tubes are made of plastic materials with various characteristics of hardness and flexibility. Buffer tubes are both flexible and strong, but may be trimmed easily. The simplest way is to score one side of the buffer tube firmly with a razor blade, then bend the tube sharply away from the score mark. The broken-off piece is then pulled straight off, leaving the fiber intact. A stripping tool which barely cuts through the tube is also satisfactory. If it is intended to cut through both the buffer tube and the fiber, use diagonal cutters and cut through cleanly.

5.2.5 Breakout Element Trimming

Breakout subunit element jackets are most easily removed by a stripping tool which cuts circumferencially. The jacket may then be pulled straight off, exposing the aramid.

5.3 Fiber Preparation

5.3.1 Fiber Stripping

Optical fibers must be stripped of buffer coatings to allow a close fit within precision connectors. (Note: always wear safety glasses or goggles when working directly with fibers.)

Buffer coatings are usually removed mechanically with sharp blades or calibrated stripping tools. In any type of mechanical stripping, the key is to avoid nicking the fiber.

(Note: Dispose of broken pieces of fiber by placing them on a piece of tape. Glass fibers are difficult to see and may not be felt until through the skin. Eyes should not be rubbed while working with fibers.)

5.4 Splicing Optical Fibers

Preparation of fibers for splicing is very similar to the process described under connectorization. After jacket materials, strength members and buffer tubes have been cut to the appropriate lengths, the fiber buffer coatings must be removed.

5.4.1 Cleaving

After the buffer coatings have been removed, fibers must be cleaved in preparation for splicing. Cleaving is a method of breaking a fiber in such a way as to create a smooth, square end on the fiber.

5.4.2 Principles of Cleaving

Glass is typically strong until a flaw occurs and creates a region of high stress under pressure. The first step in the cleaving process is to create a slight flaw or "scribe" in the outer surface of the fiber.

Optical fibers can be scribed with a sharp blade of hard material such as a diamond, ruby, sapphire or tungsten carbide. The scribe is made by lightly touching the cleaned fiber, at a right angle, on the desired cleave point with a scribing tool. Only the lightest pressure is required to produce a scribe if the blade is sharp. NOTE: DO NOT USE A SAWING MOTION. A crude or slanted scribe will produce shattered or scalloped end surfaces.

After the scribe is made, a straight pull will produce the cleanest break. If bending accompanies pulling, a square break is less likely, especially with large fibers. Dispose of broken fiber pieces by placing them on a piece of tape. ALWAYS WEAR SAFETY GLASSES WHEN WORKING WITH OPTICAL FIBERS.

The level of quality required for a given cleave depends on the application. For fusion splicing, mechanical splicing and some connectors systems, cleaves must be nearly perfect. Some connector and splicing systems use cleaving to produce the final end surface on the fiber (no subsequent grinding or polishing). However, for quick continuity checks with a flashlight, less than perfect cleaves may be acceptable. A 30x to 50x hand microscope is useful for quick checks of cleave quality. Cleaving tools are available in inexpensive hand models or more sophisticated mechanized tools.

5.4.3 Splicing Methods

There are two basic types of splices: Fusion and Mechanical.

5.4.3.1 Fusion Splicing

Fusion splices are made by positioning cleaned, cleaved fiber ends between two electrodes and applying an electric arc to fuse the ends together. A perfusion arc is applied to the fiber while the ends are still separated to vaporize volatile materials which could cause bubbles. Final precise alignment is done by moving fiber ends together until there is slight pressure between end surfaces.

An ideal fusion cycle is short and uses a ramped or gradually increasing arc current. A short, ramped cycle is considered least likely to produce excessive thermal stress in fibers. Cold temperatures require increased time and arc current.

Experienced operators consistently produce fusion splices with losses less than 0.2 dB per splice and averaging 0.3 dB on multimode fibers. Sophisticated fusion splicing systems for single-mode fibers produce typical splice losses of 0.05 to 0.1dB.

5.4.3.2 Mechanical Splicing

Mechanical splicing systems position fiber ends closely in retaining and aligning assemblies. Focusing and collimating lenses may be used to control and concentrate light that would otherwise escape. Index matching gels, fluids and adhesives are used to form a continuous optical path between fibers and reduce reflection losses.

5.4.4 Testing

5.4.4.1 The Flashlight Test

A simple continuity test for short-to-medium length fiber optic links is to shine a flashlight into a cleaved or connectorized link and observe if light comes out of the other end. On short lengths, it may be necessary to cleave only the end where the flashlight injects light into the fiber. This simple check can be made on cable lengths of up to a 1,5km and more. If cable ends are outdoors, sunlight may be used. NOTE: on longer lengths, the light observed at the opposite end may appear red in color. This is normal and is caused by the filtering of light within the fiber.

CAUTION: NEVER LOOK DIRECTLY INTO A FIBER CONNECTED TO LIGHT LAUNCHING EQUIPMENT. THIS CAN CAUSE PERMANENT EYE DAMAGE.

5.4.4.2The Optical Time Domain Reflectometer (OTDR)

OTDRs are typically used to measure distance and attenuation over the entire fiber link. They are also used to identify specific points along the link where losses occur, such as splices. An OTDR is an optical radar which measures time of travel and the return strength of a short pulse of light launched into an optical fiber. Small reflections occur throughout the fiber, becoming weaker as power levels drop with distance. At major breaks, large reflections occur and appear as strong peaks on an oscilloscope. Testing of short and medium distance fiber optic systems seldom requires an OTDR. In smaller systems, optical power meter tests are faster and more useful.

5.4.4.3 Magnifying Glasses and Microscopes

Because the naked eye cannot detect scratches or defects in optical fibers, use of magnification equipment is required. For most routine inspections, and ordinary battery-powered illuminated microscope of 30x to 100x can produce satisfactory results. Some microscopes are available with special adapters specifically designed for use with fiber optic connectors.

6.0 BROADBAND OVER POWER LINES

Broadband over Power Line (BPL) is a term used to identify technologies, equipment, applications and services intended at providing end users with communications means over existing power lines. BPL is also referred to the transmission of high-speed data over the electricity power line to provide communications service such as voice, video and data. The concept of transmitting signals over power lines has been around for many years and has been used by power companies to transmit data signals at low frequencies and low speed. In the year 2005, a new generation chipset at 200 Mbps was made commercially available offering enhanced performance of this technology. This development has made it possible for data to be transmitted at a much high speed.

6.1 General Requirement for Operational of BPL Physical Network Layer

Network Overview The system architecture should consist of the backhaul data network that connects the BPL network to the telecommunications network, and the BPL network which overlays the electricity distribution network.

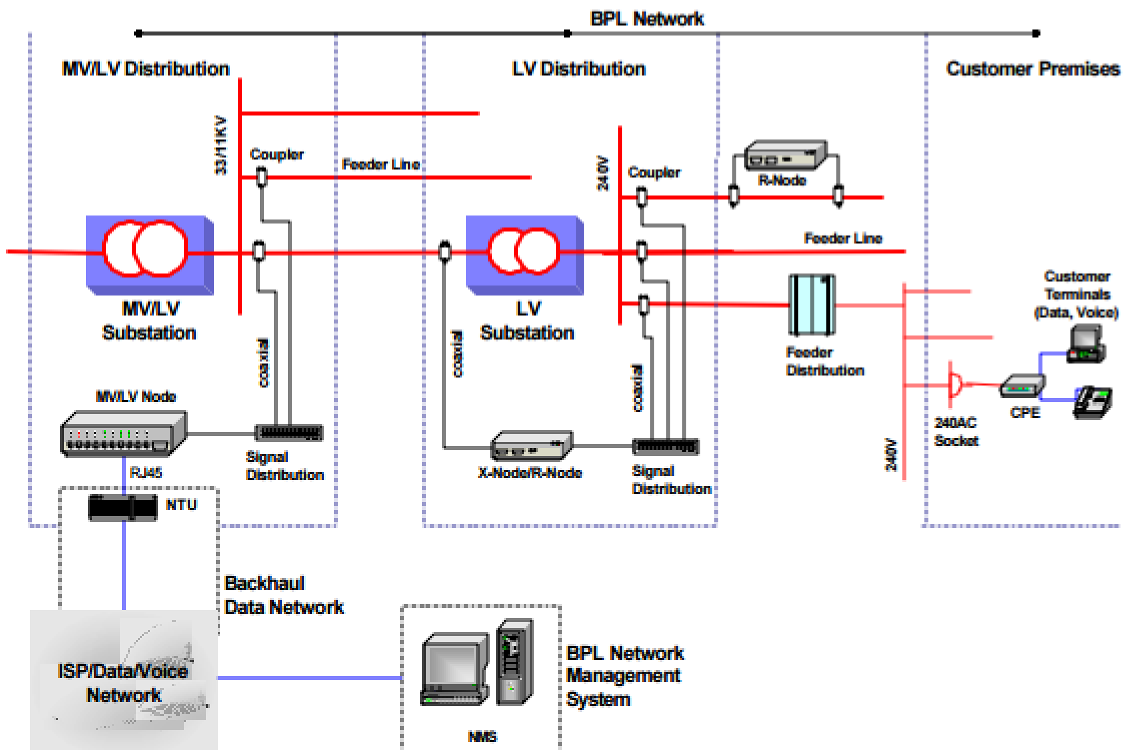


Figure 1: BPL Network Overview

Backhaul Data Network The backhaul data network is the telecommunications backbone to which the BPL-empowered distribution system is connected via high-speed data link.

BPL Network:

a. The BPL network is integrated with the electricity distribution system and is utilizing the electric power lines for broadband access communications.

b. The BPL system should have Network Management System (NMS) as parts of the network.

c. The BPL system should only be deployed on the MV and LV distribution systems.

BPL Physical Network Layer Components A number of electronic devices (or nodes) are deployed at various points in the electricity distribution network to overlay a communications network on the electric power lines. These devices are characterized as "Physical Network Layer components" and are designed to accomplish specific tasks along the BPL network. The list of nodes includes:

6.2 Medium/Low Voltage Node (MV/LV-Node):

The Medium/Low Voltage Node (MV/LV-Node) is a device that converts the normal IP-based communication signal to other signal appropriate for transmission over the electric power lines. It should be capable to support a variety of interfaces and functions, such as;

a. Backhaul connections to the telecommunications backbone.

b. BPL signals aggregation for transmission over the MV/LV feeder lines.

c. BPL local network management that provides various functions such as sub-elements configurations, controlling and monitoring, error correction and security.

Due to safety reason, the MV/LV-Node interface to the electric power lines should not be designed to directly connect to the electric power lines, instead, a coupling device either inductive or capacitive should be used. The connection between the MV-Node and coupling unit is generally by means of a coaxial cable.

A standard data interface ports (RJ-45) should be made available for connection to the telecommunications backhaul equipment.

6.3 Transformer Node (X-Node)

The Transformer Node (X -Node) is a device, which is installed in the transformer room and can provide two functions;

a. to transfer (i.e., by-passing the transformer) communication signals between MV and LV lines; and

b. as a repeater along the MV lines.

6.4 Repeater Node (R-Node)

The Repeater Node (R-Node) is a device, which is installed along the electric power lines (external or internal types) and is used to provide greater reach on long lines or lines with high attenuation so that the end-to-end communication quality is maintained. In some cases, the R-Node is a modified X-Node.

6.5 Customer Premises Equipment (CPE)

The Customer Premises Equipment (CPE) contains a BPL interface to the LV line, terminates and converts the BPL signal back to the normal IP based. The CPE should be modular in construction to allow a variety of other interfaces for in-home services. These will include support for an in-home data network and for telephony services with standard (RJ-11) analogue telephone ports.

6.6 Couplers

Couplers provide the means to transmit on and receive the communication signals from the electric power line. There are two methods for coupling the signal to the power line - capacitive and inductive coupling.

a. Capacitive coupler – The usage of capacitive coupler for the overhead MV and LV lines is preferred. For indoor applications, one should be mindful that the installation takes into consideration the issues related to the Malaysian electrical environment.

b. Inductive coupler – This is a passive-type coupler that can be installed without interrupting the supply across the electric power lines. It should operate in overhead, pad mounted and underground scenarios and is capable of withstanding high voltage level, weather elements, external elements and surges due to lightning and switching.

6.7 Line Conditioning Devices

Line conditioning devices are placed on both the MV and LV distribution lines and are responsible for the sectionalizing of the electricity distribution network. In all cases these devices should be designed to be active in the communications frequency band and not in the electricity frequency band. The functionality of the devices is to pass or block the signal as appropriate.

6.8 Electromagnetic Compatibility and Interference Requirements

6.8.1 General

The BPL equipment should have features to perform efficiently under the electrical environment and they should be Electromagnetic Compatible (EMC) to work with surrounding equipment and immune to the Electromagnetic Interferences/Radiations (EMI).

6.8.2 EMI Requirement for BPL Installation

a. The radiated emission limits for BPL installation should follow the Federal Communications Commission (FCC) Part 15 § 15.209 using a QP detector, specified as follows:

Frequency	Bandwidth	Radiated emission limits
1 to 30 MHz	9 kHz	30 µV/m (29.59 dBµV/m) at 30 meters
30 to 88 MHz	120 kHz	100 µV/m (40 dBµV/m) at 3 meters

b. The radiated emission should be measured as recommended in FCC Part 15, 15.31, 15.33 & 15.35.

6.8.3 Security Requirement

General Security of the BPL system should be mandatory to ensure reliability of the BPL system itself and the existing electricity services quality. Due to the criticalness of electricity services and to abide the national regulations on the electrical energy quality of service, priority of service should be given to electricity in any case.

For deployment of BPL system, two security measures should be adopted;

a. Security to the electricity distribution system and services.
b. Security to the BPL system.

7.0 End user

7.1 Broadband Speed Guide

The table below compares typical online activities with the minimum download speed (Megabits per second, or Mbps) needed for adequate performance for each application. Additional speed may enhance performance. Speeds are based on running one activity at a time.

Activity	Minimum Download Speed (Mbps)
General Usage	
General Browsing and Email	1
Streaming Online Radio	Less than 0.5
VoIP Calls	Less than 0.5
Student	5 - 25
Telecommuting	5 - 25
File Downloading	10
Social Media	1
Watching Video	
Streaming Standard Definition Video	3 - 4
Streaming High Definition (HD) Video	5 - 8
Streaming Ultra HD 4K Video	25
Video Conferencing	
Standard Personal Video Call (e.g., Skype)	1
HD Personal Video Call (e.g., Skype)	1.5
HD Video Teleconferencing	6
Gaming	
Game Console Connecting to the Internet	3
Online Multiplayer	4

7.2 Net Neutrality

The Commission is of the view that all content should be treated equal and users should not be charged or discriminated based on content, website, platform, application, type of attached equipment of method of communication. The Commission has conducted its own investigation into ISP providers after users complained of certain OTT services being blocked. The investigation revealed the offending providers, who were then approached by the Commission. After which all OTT services were in proper operation.

8.0 LTE (Long Term Evolution)

8.1 LTE – The De facto Mobile Access Standard

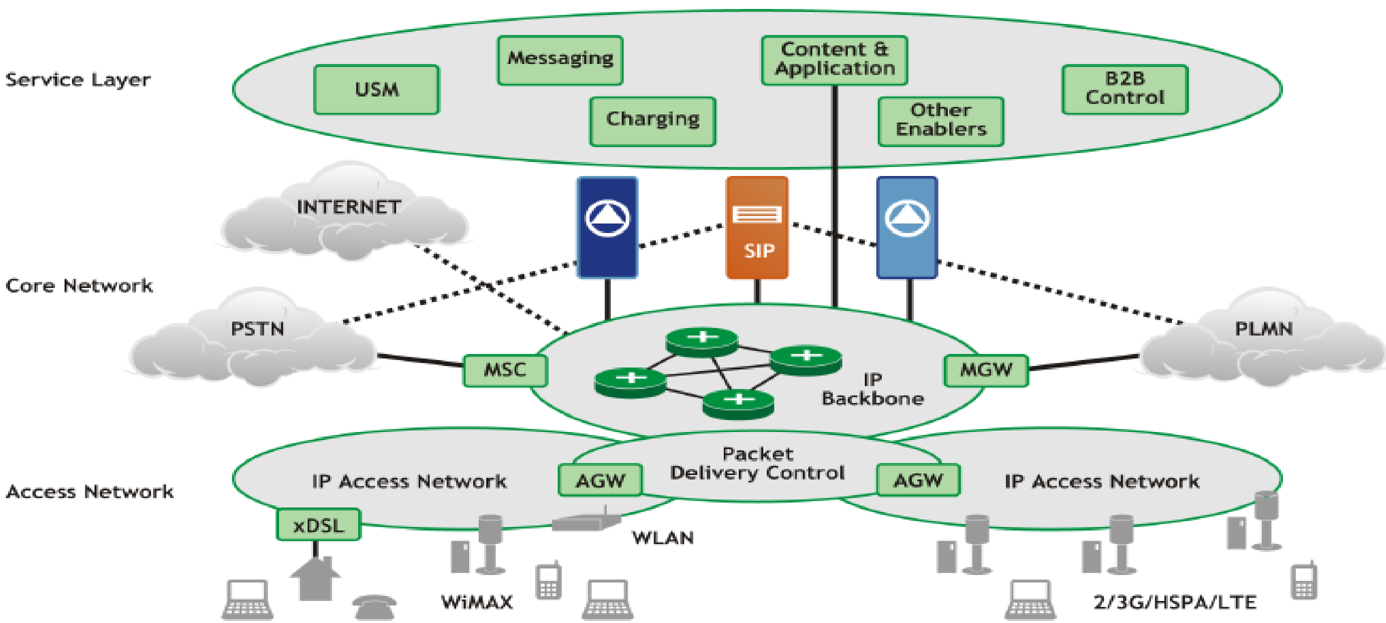


Figure 1 LTE supports the Next Generation Network by providing mobile access to an all-IP core.

Traditionally, operators have built multiple networks such as fixed telephone networks, cable TV networks, cellular telephone networks and data networks to provide fixed and mobile services to customers. The Next Generation Network (NGN) provides a flat all-IP core that interconnects multiple access technologies and provides a consistent and reliable user experience regardless of the access method, allowing the merging of these multiple access technologies into a single network. The NGN core will provide Quality of Service (QoS) support and a wide variety of applications and services. The NGN access network will provide mobility and routing management and ensure that the core sees any mobile network simply as another IP network. Mobile handover between access types will be seamless as the IP access network controls security, authentication, and billing for each of the access technologies.

LTE is the first access technology designed explicitly for the NGN, and is set to become the de-facto NGN mobile access network standard. It is designed to provide an always-on mobile data experience comparable to wired networks.

- LTE Release 8 supports peak data rates of up to 300 Mbps on the downlink and 75 Mbps on the uplink with a 20 MHz channel and 4x4 MIMO. A more common configuration of 20 MHz and 2x2 MIMO supports peak rates of 150 Mbps on the downlink and 50 Mbps on the uplink.
- LTE Advanced (Release 10) supports peak data rates of up to 1200 Mbps on the downlink and 600 Mbps on the uplink using both Carrier Aggregation (CA) and higher-order MIMO.
- LTE provides flexible duplex methods including both Frequency Division Duplex (FDD) and Time Division Duplex (TDD). This allows LTE technology to fit within either existing or new carrier spectrum allocations.
- LTE Rel. 8 supports scalable RF channel bandwidths from 1.4 MHz to 20 MHz.
- LTE Advanced supports CA with up to five 20 MHz carriers for a total of 100 MHz operating bandwidth.
- LTE interoperates with CDMA2000, W-CDMA and GSM systems. Multimode wireless devices support handover to and from these other systems.
- LTE provides a mechanism to interoperate in a limited fashion with other access technologies such as Wi-Fi (802.11)

8.2 OFDMA

The downlink LTE air interface is based on Orthogonal Frequency Domain Multiplexing Access (OFDMA), a multi-carrier scheme that allocates radio resources to multiple users based on frequency (subcarriers) and time (symbols) using Orthogonal Frequency Division Multiplexing (OFDM). For LTE, OFDM subcarriers are typically spaced at 15 kHz and modulated with QPSK, 16-QAM, or 64-QAM modulation.

OFDMA allows a network to flexibly assign bandwidth to a user based on bandwidth needs and the user’s data plan. Unassigned subcarriers are switched off, thus reducing power consumption and interference. OFDMA uses OFDM; however, it is the scheduling and assignment of radio resources that makes OFDMA distinctive. The OFDM diagram in Figure 2 shows a scenario where the subcarriers assigned to a set of users are static for a period of time. In the OFDMA diagram, multiple users flexibly share the subcarriers, with differing bandwidth available to different users at different times.

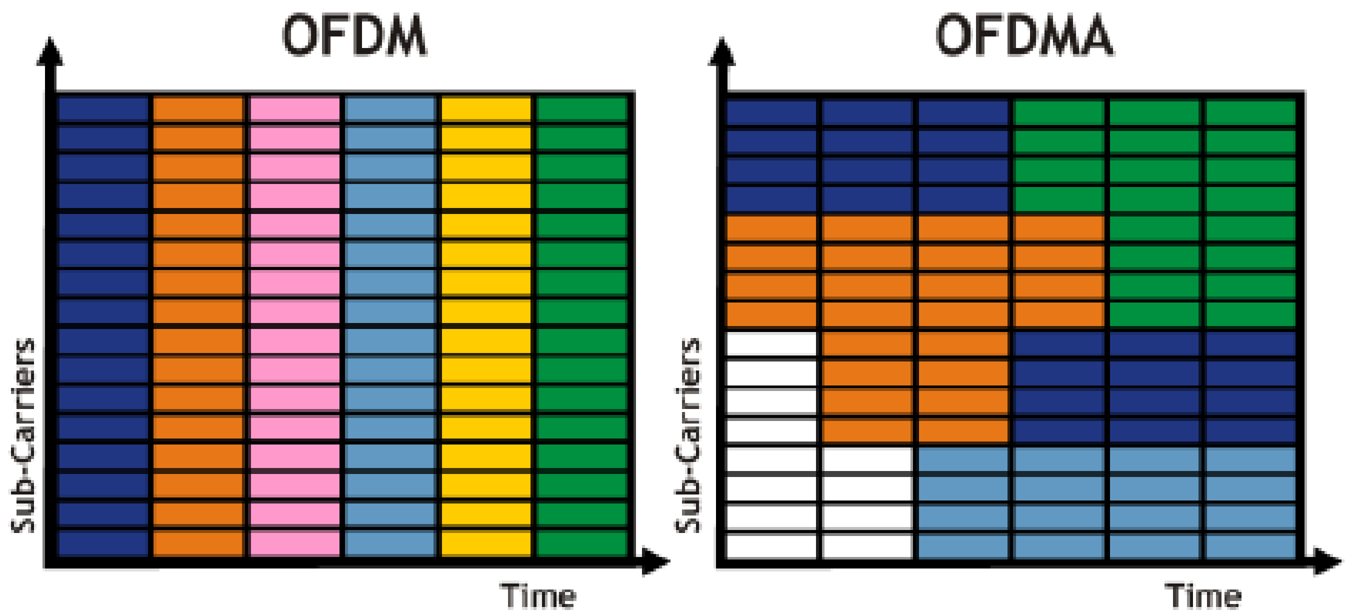


Figure 2 OFDM vs. OFDMA. Each color represents a burst of user data. In a given period, OFDMA allows users to share the available bandwidth.

8.3 SC-FDMA

In the uplink, LTE uses a pre-coded version of OFDM called Single Carrier Frequency Domain Multiple Access (SC-FDMA). SC-FDMA is used in place of OFDMA due to several factors, including the high current requirements for OFDMA-based power amplifiers and correspondingly short battery life. Lower Peak-to-Average Power Ratio for SC-FDMA-based power amplifiers results in extended battery life along with improved uplink performance.

In SC-FDMA, data is spread across multiple subcarriers.

This differs from OFDMA, where each subcarrier transports unique data. The need for a complex receiver makes SC- FDMA unacceptable for the downlink due to size and processing power limitations in a wireless device.

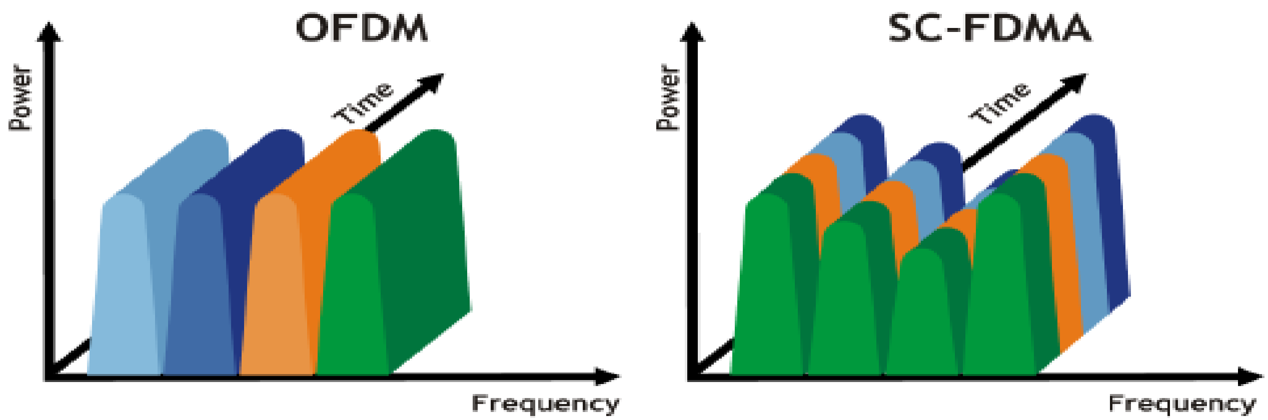
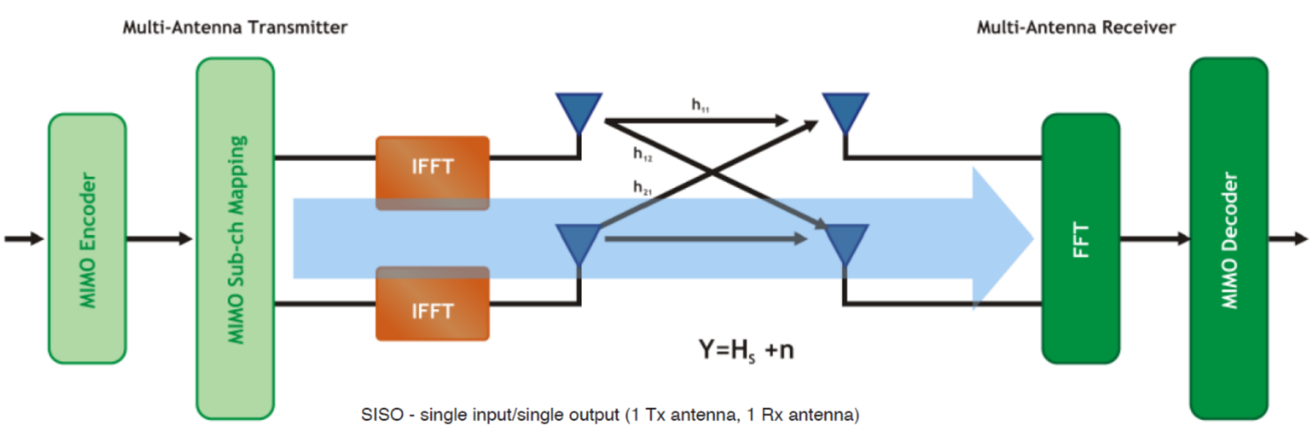


Figure 3 In OFDM, each frequency component carries unique information. In SC-FDMA, the information is spread across multiple subcarriers.

8.4 MIMO

Most modern wireless communication techniques use MIMO to increase the data rate to a user as well as to provide better coverage at the cell edge. Various techniques are available, including transmission of separate data streams from each antenna (spatial multiplexing), transmission of identical streams of data from each antenna (transmit diversity), reception on multiple antennas (receive diversity), and various combinations thereof. These techniques can be generalized as Single Input Single Output (SISO), Single Input Multiple Output (SIMO), Multiple Input Single Output (MISO), and Multiple Input Multiple Output (MIMO) as shown in figure 4.



SISO - single input/single output (1 Tx antenna, 1 Rx antenna)
SIMO - single input/multiple output (1 Tx antenna, multiple Rx antenna)
MISO - multiple input, single output (multiple Tx antenna, 1 Rx antenna)
MIMO - multiple input/multiple output (multiple TX antenna, multiple Rx antenna)

Figure 4 MIMO

For LTE Rel. 8, downlink MIMO configurations from SISO to 2x2 and 4x4 MIMO are supported, and the MIMO configuration changes dynamically based on measurement reports from the wireless device. For LTE Advanced, MIMO configurations up to 8x8 in the downlink and 4x4 in the uplink are supported in combination with Carrier Aggregation (CA), which uses multiple carriers.

For LTE Rel. 8, when a user is close to a base station and propagation conditions are optimal, 2x2 MIMO may be used with a high data rate to the wireless device. When a user is at a cell edge, one or both of the diversity modes may be used to increase the Signal to Interference plus Noise Ratio (SINR).

8.5 Adaptive Modulation/Coding (AMC) and Spatial Multiplexing

Adaptive Modulation and Coding (AMC) refers to the ability of the network to dynamically set the modulation type and coding rate based on the current RF channel conditions, which are determined by Call Quality Indicator (CQI) measurement reports from the wireless device and re-transmission attempts from the HARQ (Hybrid Automatic Repeat Request) acknowledgement/re-transmission process. In addition to AMC, the MIMO mode can be dynamically set to Transmit Diversity or one of several Spatial Multiplex modes. This is based on additional channel conditions reported by the LTE device using the Rank Indicator (RI).

The modulation used to transport data on each subcarrier can be QPSK, 16-QAM, or 64- QAM.. In the QPSK case, there are four possible symbol states, and each symbol carries two bits of information. In 16-QAM, there are 16 symbol states, with each symbol carrying 4 bits of information. Lastly, in 64-QAM, there are 64 symbol states, and each symbol carries 6 bits. Higher-order modulation is more sensitive to poor channel conditions than lower-order modulation because the detector in the receiver must resolve smaller amplitude and phase differences as the constellation becomes more dense. Based on this, the network would set the modulation to a lower order if poor channel conditions are reported by the wireless device.

Coding refers to various error-correction methodologies that add extra bits to the data stream to allow for error detection and correction. Specified as fractions, Code Rates specify the number of data bits in the numerator and the total number of bits in the denominator. Thus if the Code Rate is 1/3, protection bits are added so one bit of data is sent as three bits. If errors are reported by the wireless device, the network would increase the error correction to compensate.

8.6 eMBMS

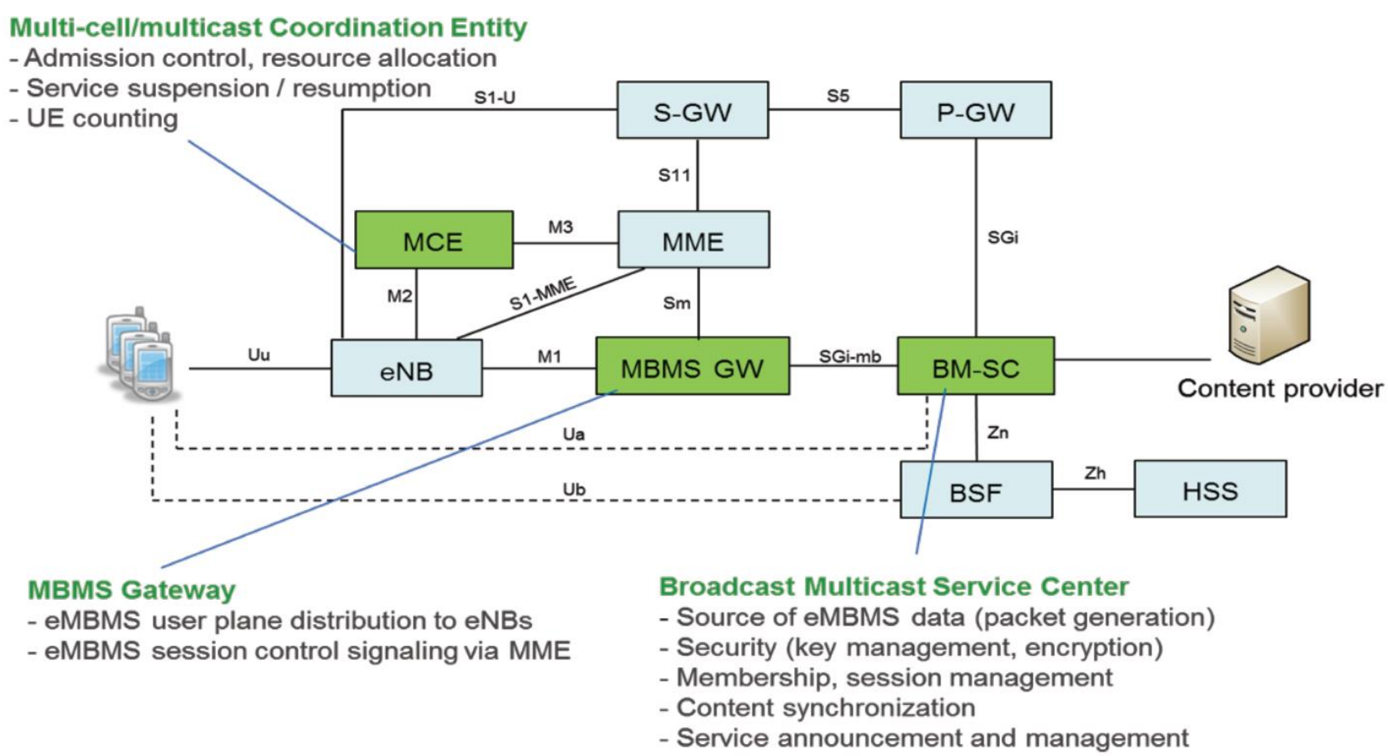
Operators need solutions allowing them to decrease network traffic while continuing to provide a similar level of service to customers. One of these solutions is MBMS/eMBMS.

Multimedia Broadcast Multicast Services (MBMS) is a point-to-multipoint transmission method in 3GPP networks. It is designed to provide efficient delivery of broadcast and multicast services, mainly multimedia but also other streaming services such as software updates, both within a cell as well as within the core network. Broadcast transmissions can be done both in a single cell and across multiple cells in a synchronised way so that the UE can receive the broadcast signal from many receivers (and combine it which improves signal robustness). It can then also move within the range of the MBMS access network while staying tuned to the signal and without the need of being explicitly handed over between cells, which reduces signalling overhead.

eMBMS (enhanced Multimedia Broadcast Multicast Services) is the LTE version of MBMS. eMBMS is part of Release 9, and is designed to work for both FDD and TDD LTE. eMBMS provides functionality similar to other broadcast technologies such as DVB-H/T/SH, DMB or former MediaFLO, but has some advantages over these technologies, such as no additional infrastructure required, and no additional spectrum required.

For security purposes eMBMS-related signaling also uses the BSF (Bootstrapping Server Function) and the HSS (Home Subscriber Server). The BSF is used for HTTP Digest AKA (Authentication and Key Agreement); the BSF also performs key derivation and provides the keys to the BM-SC, which distributes the keys and uses them for data encryption.

To improve the transport efficiency the IP Multicast shall be used for the eMBMS payload distribution in the backbone network between the MBMS-GW and the eNBs that have joined the IP Multicast Group. Synchronization information (SYNC) is required between the BM-SC and eNB for the purpose of multi-cell operation, as all eNBs need to send exactly the same data with the same settings (MCS, mapping to physical layer) at exactly the same time.



8.6.1 eMBMS Logical Architecture

eMBMS reuses existing LTE, Core Network and Internet Protocols. There are two types of services available over eMBMS:

Download, based on FLUTE (File Delivery over Unidirectional Transport) with the option of file repair over unicast bearers.

Streaming, based on DASH (Dynamic Adaptive Streaming over HTTP) for content stream formatting. The FEC (Forward Error Correction) is used in eMBMS transport protocols, allowing to correct some of the bit errors that can happen on the radio interface. Due to the unidirectional nature of eMBMS streams other low-latency correction schemes are not available as they would require feedback from the receiver. However, the file download service enables P2M file repair based on feedback from UEs over unicast bearers.

8.7 LTE NETWORK COMPONENTS

Major LTE Network Elements and Functions

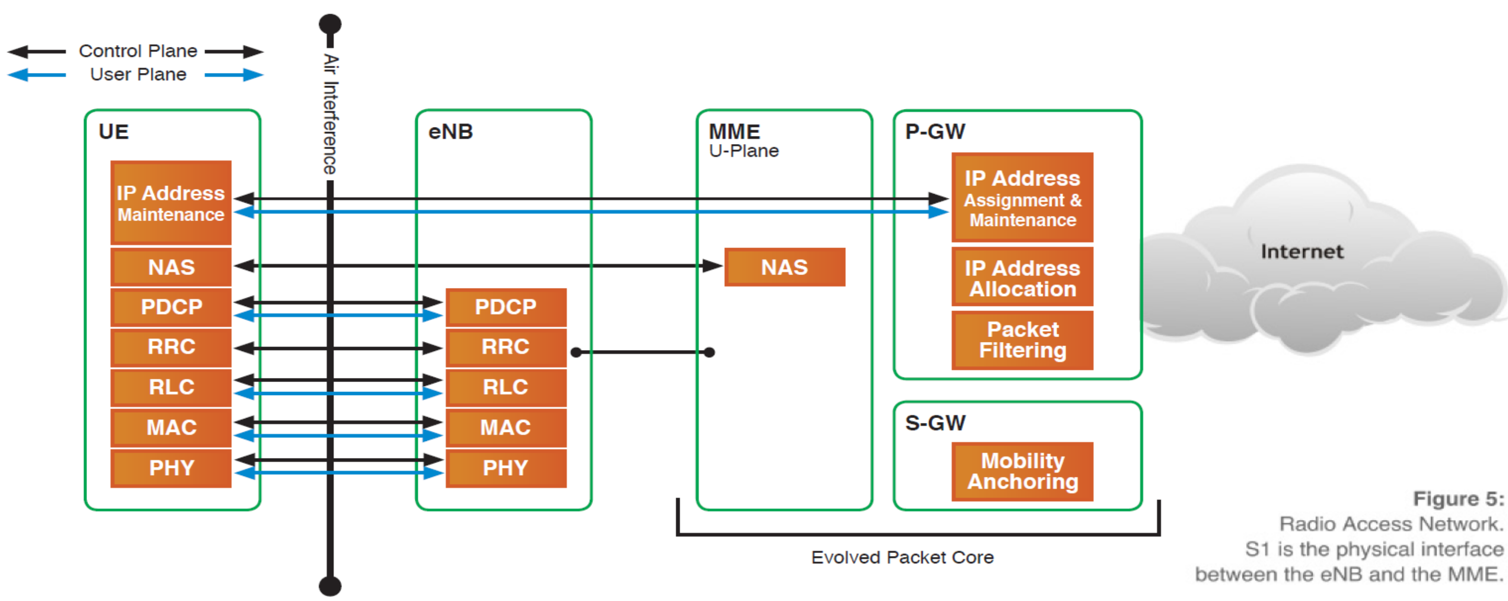


Figure 5:
Radio Access Network.
S1 is the physical interface between the eNB and the MME.

8.7.1 User Equipment (UE)

- Access device for user.
- Provides measurements that indicate channel conditions to the network.
- Includes the UICC (SIM card).

8.7.2 Evolved Node B (eNB)

- Hosts the PHYsical (PHY), Medium Access Control (MAC), Radio Link Control (RLC), and Packet Data Convergence Protocol (PDCP) layers.
- Controls user-plane header-compression and encryption.
- Provides Radio Resource Control (RRC) functionality for the control plane.
- Radio Resource Management-admission control, scheduling, enforcement of negotiated uplink QoS, cell information broadcast, ciphering/deciphering of user and control plane data, and compression and decompression of downlink and uplink user-plane packet headers.

8.7.3 PDN Gateway (P-GW)

- Provides connectivity between the UE and external packet data networks (PDNs) by being the point of egress and ingress for UE traffic (A UE may have simultaneous connectivity with more than one P-GW for accessing multiple PDNs).
- Performs policy enforcement, packet filtering for each user, charging support, lawful Interception, and packet screening.
- Acts as the anchor for mobility between 3GPP and non-3GPP technologies such as Wi-Fi and 3GPP2 (CDMA2000 1xRTTand EV-DO).

8.7.4 Mobility Management Entity (MME)

- Acts as the key control node for the LTE network.
- Responsible for idle mode UE tracking and paging procedures.
- Controls bearer activation/deactivation process.
- Selects the Serving Gateway (S-GW) for a UE at initial attachment and at the time of intra-LTE handover.
- Authenticates the user by interacting with the Home Subscriber Server (HSS).
- Serves as the termination point for the Non-Access Stratum (NAS) signaling. NAS signaling is responsible for generation and allocation of temporary identities to UEs and checks the authorization of the UE to camp on the system.
- Serves as the termination point for ciphering and integrity protection for NAS signaling.
- Handles security key management.
- Provides control plane function for mobility between LTE and other access networks.

8.7.5 Serving Gateway (S-GW)

- Routes and forwards user data packets.

- Acts as the mobility anchor for the user plane during inter-eNB handovers and as the anchor for mobility between LTE and other 3GPP technologies.
- Terminates the downlink data path for idle state UEs and triggers paging when DL data arrives for the UE.
- Manages and stores UE contexts, e.g. parameters of the IP bearer service and network internal routing information.

8.8 EPS Data Bearers and IP Access

The services provided by an LTE network are IP services, and are accessed by the UE via the PDN Gateway; the data is carried on data bearers. While a complete discussion of all the aspects of a data bearer is beyond the scope of this guide, there are some aspects that are useful to understand. Data bearers are connections between the UE and the P-GW and they sit “higher” than the radio bearers as shown in Figure 5.

In an LTE network deployment, there may be multiple PDN Gateways present. Each will be used for different services, depending on how the operator has designed their network. A simple way to think about this is that one P-GW could be used for access to the public internet and another could be used for access to operator provided services (such as VoLTE). Proper testing of a UE requires the network simulator to be capable of simulating the proper P-GW configuration as defined in either the industry test plan or the operator Carrier Acceptance Test Plan.

There are two types of data bearers in LTE: Default and Dedicated. The Default Bearer is set up as part of the initial connection between the UE and the P-GW; Dedicated Bearers may be set up and torn down as needed. Different services require different levels of performance, which introduces the concept of Quality of Service. The QoS Class Identifier (QCI) is used to communicate the different levels of service during the setup of the Data Bearer. The Table below (Figure 5.1) is taken from 3GPP TS 23.203 and shows the different types of QoS available for Data Bearers.

QCI	Resource Type	Priority	Packet Delay Budget	Packet Error Loss Rate	Example Services
1	Guaranteed Bit Rate	2	100 ms	A	Conversational Voice
2		4	150 ms	B	Conversational Video (Live Streaming)
3		3	50 ms	B	Real Time Gaming
4		5	300 ms	C	Non-Conversational Video (Buffered Streaming)
5	Non-Guaranteed Bit Rate	1	100 ms	C	IMS Signaling
6		6	300 ms	C	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
7		7	100 ms	B	Voice, Video (Live Streaming), Interactive Gaming
8		8	300 ms	C	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
9		9	300 ms	C	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)

Figure 5.1 Table showing the different types of QoS available for Data Bearers

8.9 FRAME STRUCTURES

In LTE, downlink and uplink transmissions are organized into frames that are 10 milliseconds (ms) long. A frame is divided into 10 subframes that are 1 ms each, and a subframe is divided into 2 slots that are 0.5 ms each. Each slot contains 7 symbols, where Ts (Sample Time) is the amount of time dedicated to each OFDM sample, and is the basic unit of time for LTE. Ts is defined as Ts = 1/(15000 x 2048) seconds or about 32.6 nanoseconds. The frame, subframe, and slot structure for LTE is illustrated in Figure 6.

Two frame types are defined for LTE: Type 1, used in Frequency Division Duplexing (FDD) and Type 2, used in Time Division Duplexing (TDD). Type 1 frames consist of 20 slots with slot duration of 0.5 ms as discussed previously. Type 2 frames contain two half frames, where at least one of the half frames contains a special subframe carrying three fields of switch information including Downlink Pilot Time Slot (DwPTS), Guard Period (GP) and Uplink Pilot Time Slot (UpPTS). If the switch time is 10 ms, the switch information occurs only in subframe one. If the switch time is 5 ms, the switch information occurs in both half frames, first in subframe one, and again in subframe six. Subframes 0 and 5 and DwPTS are always reserved for downlink transmission. UpPTS and the subframe immediately following UpPTS are reserved for uplink transmission. Other subframes can be used for either uplink or downlink. Frame Type 2 is illustrated in Figure

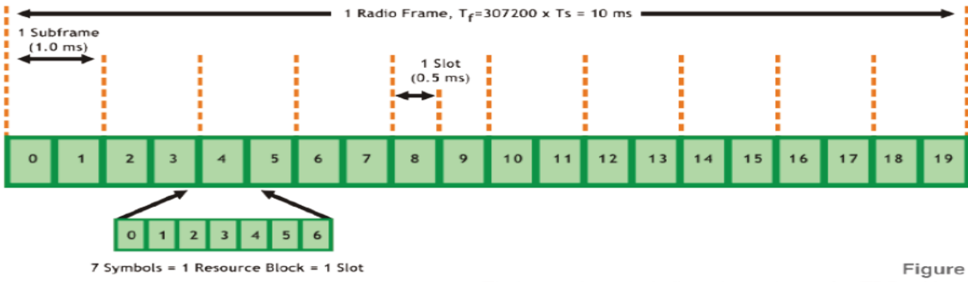


Figure 6: Type 1 Frame Type.
Timing and symbol allocations shown for FDD with normal cyclic prefix (CP).

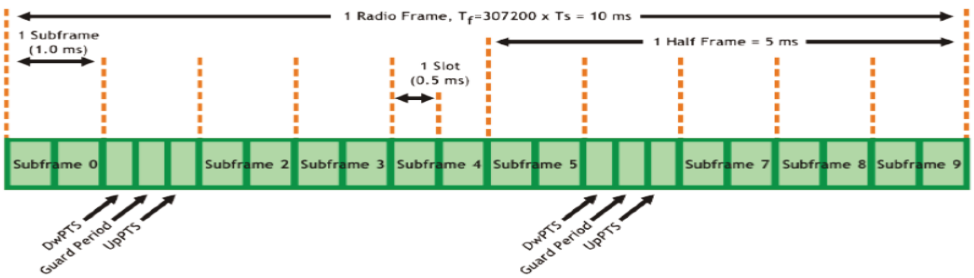


Figure 7: Type 2 frame type. Special fields are shown in Subframes 1 and 6.
Guard period separates the Downlink and Uplink. This TDD example represents a 5 ms switch point.
A 10 ms switch point would not have the special fields in subframe 6.

8.10 LTE Frame Structure and Bandwidth Concepts

As explained previously, in LTE, 10 one ms subframes comprise a 10 ms frame, two 0.5 ms slots comprise a one ms subframe, and 7 symbols comprize a 0.5 ms slot. Moving from this time-domain viewpoint to one taking into account both time and frequency aspects, the smallest modulation structure in LTE is one symbol in time vs. one Resource Element (RE).

Resource Elements are further aggregated into dimensions of 7 symbols by 12 subcarriers. The number of symbols in a RB depends on the Cyclic Prefix (CP) in use. When a normal CP is used, the RB contains seven symbols. When an extended CP is used due to extreme delay spread or multimedia broadcast modes, the RB contains six symbols. Figure 8 shows the relationship between a slot, symbols and Resource Blocks. NDLRB is the symbol used to indicate the maximum number of downlink Resource Blocks for a given bandwidth.

Physically, channel bandwidth is the width of the channel in frequency as measured from the lowest channel edge to the highest channel edge. Inunpaired spectrum, channel bandwidth is simply the width of the channel in frequency. In paired spectrum, channel bandwidth is the width of the uplink or downlink in frequency (typically the same for LTE, although asymmetric bandwidths are allowed for LTE Advanced).

The number of RBs that can fit within a channel varies proportionally to the bandwidth of the channel. Logically, as the channel bandwidth increases, the number of RBs can increase. The Transmission Bandwidth Configuration is the maximum number of Resource Blocks that can fit within the channel bandwidth with some guard band. For a channel with the maximum channel bandwidth of 20 MHz (for LTE Rel. 8), 100 RBs can fit within this bandwidth.

Spectrum allocations are managed by local regulatory agencies such as auction or other similar means. The spectrum allocated may be paired spectrum for use with FDD communications, or unpaired spectrum for use with TDD communications.

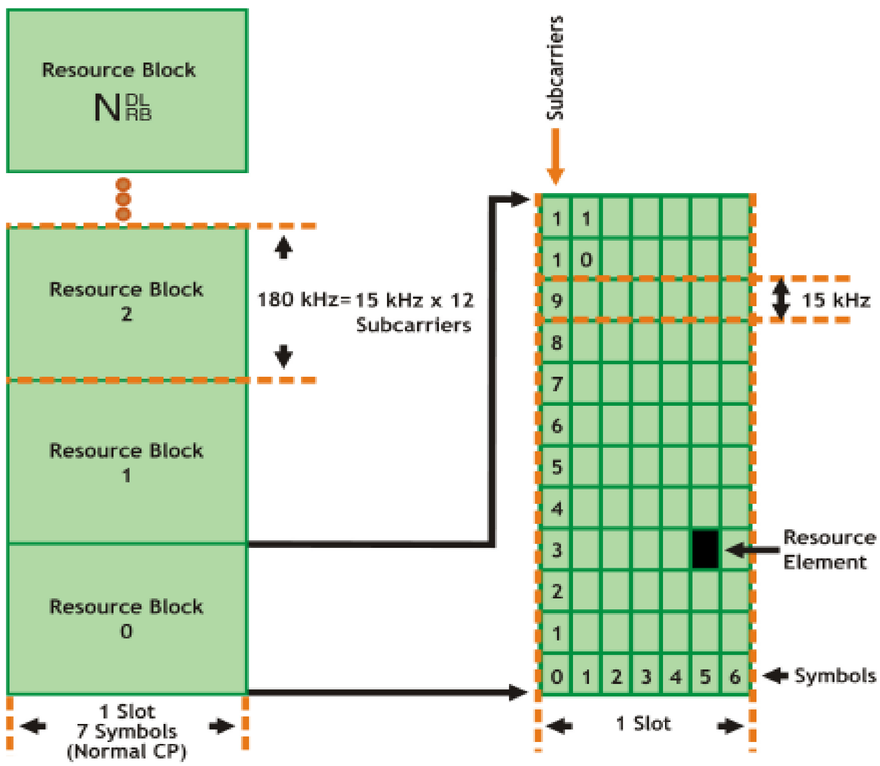


Figure 8: Relationship between a slot, symbols and Resource Blocks. N_{RB}^{DL} is the symbol used to indicate the maximum number of downlink Resource Blocks for a given bandwidth.

8.11 PHYSICAL CHANNELS & SIGNALS

8.11.1 LTE Downlink Channels and Signals

The LTE frame is defined in terms of physical channels and physical signals, which are positioned by the LTE standard at specific positions in the frame in terms of subcarriers and symbols, respectively. Channels are defined as carrying information receivedfrom higher layers. Signals are defined asoriginating at the physical layer. The next sections will review the functions of these physical layer channels and signals as well as their positioning in the frame structure.

8.11.2 Downlink Physical Channels

Physical Downlink Shared Channel (PDSCH)

Used to transport user data, the PDSCH is designed for high data rates. Modulation options include QPSK, 16-QAM, and 64-QAM. Spatial multiplexing is exclusive to the PDSCH. The RBs associated with this channel are shared among users.

Physical Broadcast Channel (PBCH)

The PBCH is used to send cell-specific system identification and access control parameters every 4th frame (40 ms). The PBCH uses QPSK modulation.

Physical Control Format Indicator Channel (PCFICH)

The PCFICH is used to inform the wireless device how many OFDM symbols will be used for the PDCCH in a subframe. The PCFICH uses QPSK modulation.

Physical Downlink Control Channel (PDCCH)

The PDCCH is used to transmit uplink and downlink resource scheduling allocations to the wireless devices. The PDCCH maps onto resource elements in up to the first three OFDM symbols of the first slot of a subframe and uses QPSK modulation. The value of the PCFICH indicates the number of symbols used for the PDCCH.

Physical Multicast Channel (PMCH)

The PMCH carries multimedia broadcast information and, like the PDSCH, has multiple options for modulation including QPSK, 16-QAM, or 64-QAM. Multicast information can be sent to multiple wireless devices simultaneously.

Physical Hybrid ARQ Indicator Channel (PHICH)

PHICH carries ACK/NACKs in response to uplink transmissions in order to request retransmission or confirm the receipt of blocks of data. ACKs and NACKs are part of the HARQ mechanism.

Reference Signal (RS)

Wireless devices use the RS for downlink channel estimation. They allow the wireless device to effectively demodulate the downlink signal.

RS's are the product of a two-dimensional orthogonal sequence and a two-dimensional pseudo-random sequence. There are three different sequences available for the orthogonal sequence and 170 possible sequences for the pseudorandom number (PRN), resulting in 510 possible RS sequences. The RS uses the first and fifth symbols under normal Cyclic Prefix (CP) operation, and the first and fourth symbols for extended CP operation; the location of the RS on the subcarriers varies.

Primary and Secondary Synchronization Signal (P-SS and S-SS)

Wireless devices use the Primary Synchronization Signal (P-SS) for timing and frequency acquisition during cell search. The P-SS carries part of the cell ID and provides slot timing synchronization. It is transmitted on 62 of the reserved 72 subcarriers (6 Resource Blocks) around DC on symbol 6 in slot 0 and 10 and uses one of three Zadoff-Chu sequences.

Wireless devices use the Secondary Synchronization Signal (S-SS) in cell search. It provides frame timing synchronization and the remainder of the cell ID, and is transmitted on 62 of the reserved 72 subcarriers (6 Resource Blocks) around DC on symbol 5 in slot 0 and 10. The S-SS uses two 31-bit binary sequences and BPSK modulation.

8.11.3 LTE Uplink Channels and Signals

Physical Uplink Control Channel (PUCCH)

The PUCCH carries uplink control information and is never transmitted simultaneously with PUSCH data. PUCCH conveys control information including Channel Quality Indication (CQI), ACK/NACK responses of the UE to the HARQ mechanism, and uplink scheduling requests.

Physical Uplink Shared Channel (PUSCH)

Uplink user data is carried by the PUSCH. Resources for the PUSCH are allocated on a sub-frame basis by the UL scheduler. Subcarriers are allocated in units of RB's, and may be hopped from sub-frame to sub-frame. The PUSCH may employ QPSK, 16-QAM, or 64-QAM modulation.

Physical Random Access Channel (PRACH)

The PRACH carries the random access preamble and coordinates and transports random requests for service from UE's. The PRACH channel transmits access requests (bursts) when a wireless device desires to access the LTE network (call origination or paging response).

Uplink Reference Signal

There are two variants of the UL reference signal. The demodulation reference signal facilitates coherent demodulation, and is transmitted in the fourth SC-FDMA symbol of the slot. A sounding reference signal is also used to facilitate frequency-dependent scheduling. Both variants of the UL reference signal use Constant Amplitude Zero Autocorrelation (CAZAC) sequences.

8.12 LTE Bands, Channel Bandwidths and Frequency Allocations

LTE Operating Bands indicates the carrier frequency to be used. Not all LTE frequency bands support all bandwidths. The chart includes both FDD and TDD bands.

LTE FDD/TDD Bands

3GPP TS 36.101-1 V10.3.0 (2011-06) Table 5.5-1E-UTRA operating bands			
E-UTRA Operating Band	Uplink (UL) Operating Band BS Receive / UE Transmit	Downlink (DL) Operating Band BS Transmit	Duplex Mode
	$F_{UL\ low}$ - $F_{UL\ High}$	$F_{DL\ low}$ - $F_{DL\ High}$	
1	1920 MHz - 1980 MHz	2110 MHz - 2170 MHz	FDD
2	1850 MHz - 1910 MHz	1930 MHz - 1990 MHz	FDD
3	1710 MHz - 1785 MHz	1805 MHz - 1880 MHz	FDD
4	1710 MHz - 1755 MHz	2110 MHz - 2155 MHz	FDD
5	824 MHz - 849 MHz	869 MHz - 894 MHz	FDD
6*	830 MHz - 840 MHz	875 MHz - 885 MHz	FDD
7	2500 MHz - 2570 MHz	2620 MHz - 2690 MHz	FDD
8	880 MHz - 915 MHz	925 MHz - 960 MHz	FDD
9	1749.9 MHz - 1784.9 MHz	1844.9 MHz - 1879.9 MHz	FDD
10	1710 MHz - 1770 MHz	2110 MHz - 2170 MHz	FDD
11	1427.9 MHz - 1447.9 MHz	1475.9 MHz - 1495.9 MHz	FDD
12	698 MHz - 716 MHz	728 MHz - 746 MHz	FDD
13	777 MHz - 787 MHz	746 MHz - 756 MHz	FDD
14	788 MHz - 798 MHz	758 MHz - 768 MHz	FDD
15	Reserved	Reserved	FDD
16	Reserved	Reserved	FDD
17	704 MHz - 716 MHz	734 MHz - 746 MHz	FDD
18	815 MHz - 830 MHz	860 MHz - 875 MHz	FDD
19	830 MHz - 845 MHz	875 MHz - 890 MHz	FDD
20	832 MHz - 862 MHz	791 MHz - 821 MHz	FDD
21	1447.9 MHz - 1462.9 MHz	1495.9 MHz - 1510.9 MHz	FDD
22			
23	2000 MHz - 2020 MHz	2180 MHz - 2200 MHz	FDD
24	1626.5 MHz - 1660.5 MHz	1525 MHz - 1559 MHz	FDD
25	1850 MHz - 1915 MHz	1930 MHz - 1995 MHz	FDD
33	1900 MHz - 1920 MHz	1900 MHz - 1920 MHz	TDD
34	2010 MHz - 2025 MHz	2010 MHz - 2025 MHz	TDD
35	1850 MHz - 1910 MHz	1850 MHz - 1910 MHz	TDD
36	1930 MHz - 1990 MHz	1930 MHz - 1990 MHz	TDD
37	1910 MHz - 1930 MHz	1910 MHz - 1930 MHz	TDD
38	2570 MHz - 2620 MHz	2570 MHz - 2620 MHz	TDD
39	1880 MHz - 1920 MHz	1880 MHz - 1920 MHz	TDD
40	2300 MHz - 2400 MHz	2300 MHz - 2400 MHz	TDD
41	2496 MHz - 2690 MHz	2496 MHz - 2690 MHz	TDD
42	3400 MHz - 3600 MHz	3400 MHz - 3600 MHz	TDD
43	3600 MHz - 3800 MHz	3600 MHz - 3800 MHz	TDD

Note: Band 6 is not applicable

Figure 13: Bands and Channel Bandwidths.

8.13 PHYSICAL CHANNELS & SIGNALS - Technology Additions to LTE for LTE Advanced

LTE Advanced is designed to be backwards compatible with LTE Rel. 8 and 9. Based on this target, LTE Advanced has “advanced” in 3 key areas including Carrier Aggregation, advanced MIMO techniques, and enhancements in the uplink.

Carrier Aggregation (CA) - In LTE Advanced, multiple carriers can be used together to increase throughput in the downlink and/or uplink. Up to 5 Component Carriers (CCs) can be used together with a maximum bandwidth of 100 MHz (5 x 20 MHz). Contiguous and non-contiguous CCs are allowed, and possible combinations include inter-band contiguous, inter-band non-contiguous, and intra-band. Due to the wide variety of possible bands involved in CA, three band combinations scenarios have been standardized in Release 10 including:

Band 40 contiguous Band 1 & 5 inter-band Band 3 & 8 inter-band

Advanced MIMO - LTE Advanced allows for increases in number of antennas on both the transmit and receive sides, as well as the potential for higher throughput from multiple spatial streams. Four to eight antennas can be used on the transmit side in the downlink, with the baseline configuration being 4x4. Peak rates of 1200 MB/s can be reached with an 8x8 configuration and optimum propagation conditions. One to four antennas can be used on the transmit side in the uplink, with the baseline configuration being 2x2. Peak rates of 600 MB/s can be reached with a 4x4 configuration and optimum propagation conditions.

New LTE device categories 6, 7, and 8 have been created for LTE Advanced to reflect the use of CA and Advanced MIMO as shown in Figure 14.

Enhanced Uplink - Two basic enhancements have been made to the uplink for LTE Advanced. First, LTE Rel. 8 was designed such that an LTE device would never use the PUCCH unless it had no data to send, and would normally combine control and data information into the PUSCH. This has been optimized in LTE Advanced, and sending of information on the PUCCH and PUSCH have been decoupled.

LTE Rel. 8 and SC-FDMA modulation was also designed such that data could be sent on the PUSCH only in contiguous subcarriers. While this was not optimal, transmission of data on non-contiguous subcarriers is now allowed for LTE Advanced.

Category	Peak Rate Mbps		Modulation		RF Bandwidth	Downlink MIMO	
	Downlink	Uplink	Downlink	Uplink	Downlink	2 Streams	4 Streams
1	10	5	QPSK, 16QAM, 64QAM	QPSK, 16QAM	20 Mhz	NA	NA
2	50	25	QPSK, 16QAM, 64QAM	QPSK, 16QAM	20 Mhz	X	NA
3	100	50	QPSK, 16QAM, 64QAM	QPSK, 16QAM	20 Mhz	X	NA
4	150	50	QPSK, 16QAM, 64QAM	QPSK, 16QAM	20 Mhz	X	NA
5	300	75	QPSK, 16QAM, 64QAM	QPSK, 16QAM, 64QAM	20 Mhz	X	X
6	300	50	QPSK, 16QAM, 64QAM	QPSK, 16QAM	20-40 Mhz	X	X
7	300	150	QPSK, 16QAM, 64QAM	QPSK, 16QAM	20-40 Mhz	X	X
8*	1200	600	QPSK, 16QAM, 64QAM	QPSK, 16QAM, 64QAM	20-40 Mhz	X	X

*Category 8 supports 8 streams

Figure 14: LTE UE Categories

9.0 GLOSSARY

Broadband: a high-capacity transmission technique using a wide range of frequencies, which enables a large number of messages to be communicated simultaneously.

eMBMS: LTE Broadcast (eMBMS) enables the same content to be delivered to a large number of users at the same time, resulting in a more efficient use of network resources when compared to each user receiving the same content individually.

Long Term Evolution: is a standard for 4G wireless broadband technology that offers increased network capacity and speed to mobile device users. LTE offers higher peak data transfer rates -- up to 100 Mbps downstream and 30 Mbps upstream.

MIMO: In radio, multiple-input and multiple-output, or MIMO, is a method for multiplying the capacity of a radio link using multiple transmission and receiving antennas to exploit multipath propagation.

Net neutrality: is the principle that Internet service providers treat all data on the Internet equally, and not discriminate or charge differently by user, content, website, platform, application, type of attached equipment, or method of communication. For instance, under these principles, internet service providers are unable to intentionally block, slow down or charge money for specific websites and online content. This is sometimes enforced through government mandate. These regulations can be referred to as "common carrier" regulations. This does not block all abilities that Internet service providers have to impact their customer's services. Opt-in/opt-out services exist on the end user side, and filtering can be done on a local basis, as in the filtration of sensitive material for minors. Net neutrality regulations exist only to protect against misuse.

Next-Generation Network (NGN): a packet-based network which can provide services including Telecommunication Services and is able to make use of multiple broadband, quality of Service-enabled transport technologies and in which service-related functions are independent from underlying transport-related technologies.

OFDMA: Orthogonal frequency-division multiple access (OFDMA) is a multi-user version of the popular orthogonal frequency-division multiplexing (OFDM) digital modulation scheme. Multiple access is achieved in OFDMA by assigning subsets of subcarriers to individual users.

SC-FDMA: Single-carrier FDMA (SC-FDMA) is a frequency-division multiple access scheme. It is also called linearly pre-coded OFDMA (LP-OFDMA). Like other multiple access schemes (TDMA, FDMA, CDMA, OFDMA), it deals with the assignment of multiple users to a shared communication resource.

Synchronous Optical Networking (SONET): SONET and Synchronous Digital Hierarchy (SDH) are standardized protocols that transfer multiple digital bit streams synchronously over optical fiber using lasers or highly coherent light from light-emitting diodes (LEDs). At low transmission rates data, can also be transferred via an electrical interface. The method was developed to replace the plesiochronous digital hierarchy (PDH) system for transporting large amounts of telephone calls and data traffic over the same fiber without synchronization problems.

Video on demand (display) (VOD): are systems which allow users to select and watch/listen to video or audio content such as movies and TV shows when they choose to, rather than having to watch at a specific broadcast time, which was the prevalent approach with over-the-air broadcasting during much of the 20th century.

10.0 ACRONYMS

ADSL: Asymmetrical Digital Subscriber Line
ATM: Asynchronous Transfer Mode
BPL: Broadband over Powerline
CATV: Cable Television
CPE: Customer Premise Equipment
CMTS: Cable Modem Termination System
CO: Central Office
DLC: Digital Loop Carrier
DOCSIS: Data Over Cable Service Interface Specification
DSL: Digital Subscriber Line
DSLAM: Digital Subscriber Line Access Multiplexer
eMBMS: Multimedia Broadcast Multicast Service
GDP: Gross Domestic Product
HDSL: Hi-Speed Digital Subscriber
ICT: Information and Communication Technologies
IP: Internet Protocol
ISDN: Integrated Services Digital Network
ISP: Internet Service Provider
Kbps: Kilo Bites Per Second
LTE: Long Term Evolution
Mbps: Mega Bites Per Second
MIMO: multiple-input and multiple-output
MISO: multiple-input and Single-output
NIC: Network Interface Card
NGN: Next Generation Networks
NSP: Network Service Provider
OFDMA: Orthogonal Frequency Domain Multiplexing Access
OSI: Open System Interconnection
PC: Parallel Communication
PDH: Plesiochronous Digital Hierarchy
POTS: Plain Old Telephone Service
PSTN: Public Service Telecommunications Network
TCP: Transmission Control Protocol
SC-FDMA: Single Carrier Frequency Domain Multiple Access
SDSL: Symmetrical Digital Subscriber Line
SDH: Synchronous Digital Hierarchy
SIMO: Single-input and multiple-output
SOHO: Small Office/Home Office
VDSL: Very High Data Rate Digital Subscriber Line
VOIP: Voice over IP
WISP: Wireless Internet Services Providers