Understanding Broadband Wireless Access

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Intent

This document is intended to provide a brief description of broadband access systems, and a basic understanding of wireless technologies and their deployment for accessing and delivering broadband services to fixed[1] users

The information provided in this document is general in nature, and is based on the knowledge and experience of Industry Canada's Broadband Technology Resource Team (membership list in Appendix I). The information is intended to serve only as a guideline when planning the construction of a broadband system. Since wireless technologies are developing rapidly, readers should be aware that some of the information contained in this document will become outdated in time. The onus is on the reader to assess and validate any differences between the information in this document and other sources.

Although the focus of this document is wireless technologies, this should not be interpreted as a preference for wireless technologies over wireline technologies, i.e., coaxial cable (associated with internet over cable television distribution lines), DSL over twisted pair wire (associated with phone lines), or fibre optic cables.

[1] Fixed users - users who access broadband networks while stationary (not mobile), i.e. from their home, office, or while sitting in a library, airport or commercial building.

Introduction

What is broadband? Although the term "broadband" is widely used, it does not have a single definition. For the purpose of this paper, broadband refers to two-way access to a variety of services via a high speed connection to the public data network and/or the Internet. Wireless refers to the use of electromagnetic (radio) waves to carry telecommunications over part or all of a communication path.

As with the definition for broadband, there is no universally accepted minimum data transfer rate (the connection speed) for broadband. Certain services can, however, dictate the data transfer rate required for broadband. For instance, the Broadband Task Force[2] recognized that a data transfer rate of 1.544 Megabits per second[3] (Mbps) is suitable for full motion[4] videoconferencing, whereas for business applications the typical data rate for videoconferencing is 384 kilobits per second[5] (kbps). Companies offering residential high speed Internet access over phone or cable television lines in typically advertise a data transfer rate of one Mbps and up for downstream data (to the home) and 120 kbps and up for upstream data (away from the home).

Components of a Broadband Access System

The purpose of establishing a broadband access system is usually to connect individuals, business, and other organizations to the public data network so they may access the Internet, corporate or other private networks and services, and communicate with each other.

When establishing a broadband access system, there are a number of parts that must be considered:

- a point-of-presence (PoP), which is the location where a physical connection to the public data network can be established. Not all communities have a local PoP.
- a transport link refers to the technology that connects the data network at a PoP to a local distribution point.
- a local distribution point, also known as a hub, that permits local subscribers to simultaneously access the data network. A hub consists of a number of components.
- access links, that enable equipment at a subscriber's location to communicate with the hub, and;
- customer premise equipment (CPE) which is the physical device that connects a subscriber's computer equipment (whether a computer or a computer network) via the access link to the hub.

A further breakdown of the equipment and services, as well as the technology options, for each of the above is provide in the table below:

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[2] http://www.broadband.gc.ca/Broadband-document/english/table_content.htm

[3] (1) Megabit per second - the transfer of one million bits of data every second

[4] Full Motion Video - equivalent to television video with a frame rate of 30 frames per second reproducing smooth and continuous motion

[5] (1) Kilobit per second - the transfer of one thousand bits of data every second

<table>
<tr><th>Point-of-Presence</th><th>Transport Link Options</th><th>Hub Components</th><th>Access Link Options</th><th>Consumer premise equipment</th></tr>
<tr><td rowspan="2">Network Interface:
- fibre optic,
or
- electrical</td><td>Satellite</td><td rowspan="2">Servers</td><td>Wireless (radio)</td><td>Antenna/radio (RF modem)</td></tr>
<tr><td rowspan="3">Fibre optic cable</td><td>Coaxial cable (CableTV)</td><td>Cable modem</td></tr>
<tr><td rowspan="2">Routers</td><td rowspan="2">Twisted pair (DSL over phone lines)</td><td rowspan="2">DSL modem</td></tr>
<tr><td>Services:
Internet, e-mail, Web hosting, streaming media, video conferencing, private networks, telephony, etc.</td><td>Wireless (radio)</td><td rowspan="2">Services:
Internet, e-mail, Web hosting, streaming media, video conferencing, private networks, telephony, etc.</td><td>Fibre (fibre-to-the-home)</td><td>Fibre modem</td></tr>
</table>

The following deals mainly with wireless as a PoP-to-hub interconnect technology and a broadband (subscriber) access technology.

Why Wireless Broadband

Wireless technologies usually provide a competitive broadband access solution in areas with no communications infrastructure, or where the existing infrastructure can not be easily and economically upgraded. Wireless is suitable for harsh landscapes and lightly populated areas, but also can also be deployed to provide specialized services in urban areas. Wireless access technologies allow for direct connections between the subscriber and the access hub without the need for wire lines (whether fibre, coaxial cable or twisted pair cable). As an access technology, wireless can provide area coverage of approximately 5 to 15 km, but is also capable, when properly engineered, of reaching customers 20 to 30 km from a hub.

Wireless Radio Systems and Radiocommunication Considerations

A wireless broadband device consists of a radio unit with a data port, and either an integrated antenna (radio and antenna as a single unit) or an external antenna connected to the radio via a radio frequency (RF) cable. The purpose for integrating the antenna with the radio unit (commonly referred to as plug and play) is to permit a simple installation by subscribers. This results in a lower connection cost for both the operator and subscriber.

Currently, two typical configurations are used to deploy broadband wireless systems:

- a radio/antenna combination that communicates directly with another radio/antenna combination. This is called a point-to-point radio link. For point-to-point radio links, directional antennas are used, to focus the transmitted energy in the direction of the

receiver, and to focus the receive antenna in the direction of the transmit antenna.

- a radio/antenna combination at a hub that communicates simultaneously with many other radio/antenna combinations. This is referred to as a point-to-multipoint radio system. The antenna at a hub location of a point-to-multipoint radio system normally provides very broad coverage, whereas the antenna at the subscriber location may be directional (towards the hub).

It is possible to use more than one antenna at a hub site, both for point-to-multipoint coverage to serve nearby subscribers and for point-to-point links to connect distant subscribers.

Since the operation of the wireless transport link affects all subscribers' access to the data network simultaneously, the reliability on this link is critical. To ensure a high degree of reliability, the antennas at both ends of these links are normally designed for a clear line-of-site (LOS). The antenna support structures at both points must be tall enough to ensure the path between these antennas is not obstructed, e.g. by hills, trees, or buildings.

Until recently, point-to-multipoint radio systems were also designed so that all the antennas at the subscribers' premises had a clear LOS to the hub antenna, and vice versa. Advances in radio and antenna technology now permit reliable communication even if there isn't a clear line of sight between the antennas. These technologies are called non-line-of-sight (NLOS) and rely on the radio being able to decode a usable signal in the presence of multiple reflected signals. However, the coverage area of NLOS systems is quite limited when compared with LOS radio systems, typically 5 km or less.

An actual example illustrating the difference between a LOS link and one that would be considered NLOS can be found on the Peace River Internet Society web site[6].

Wireless technologies use the radio spectrum. The radio frequency spectrum is divided into a large number of frequency blocks; each block can have any number of uses. For example, most wireless local area networks operate in the frequency band from 2400-2483.5 MHz. Other devices that also operate in this band include cordless telephones and industrial (e.g. welders), scientific and medical devices. A listing of point-to-point and point-to-multipoint frequency bands that can be used for broadband wireless systems is available on Industry Canada's Broadband web site[7].

Unless wireless devices are specifically exempted, they must be licensed for use in Canada. Industry Canada issues two different types of licences: a site (radio) licence, or a spectrum licence. A site licence corresponds to the radio equipment specifications at a given location, whereas the spectrum licence corresponds to block of spectrum within an operating area. Devices that do not require a licence must be tested and certified to meet the standards listed in Radio Standard Specification (RSS) 210. If a certified wireless device (radio, antenna, or both) is modified, it must again be re-certified. RSS 210 is available on Industry Canada's

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[6] http://www.pris.bc.ca/home/hsi/, under LOCATION AVAILABILITY, select the link "Must have clear line of sight to a PriS Wireless Access Point"

[7] http://broadband.gc.ca/resources_e.asp - select the link **"**Broadband Spectrum Document**"**

Strategis web site[8]. The specific licensing and certification requirements for point-to-point and point-to-multipoint systems are identified in Standard Radio System Plans (SRSPs), Radio Standards Procedures (RSPs) and Radio Standards Specifications (RSSs) documents which correspond to the frequency band of operation[9]. For more information, refer to the above mentioned Broadband Spectrum Document under the columns *Source Document* and *Licensed or License Exempt*.

It is important to note that there are licence fees associated with holding a site licence or a spectrum licence. Licence fee are renewable yearly, unless a licence was obtained through a spectrum auction (initial payment covers multiple years) . Site licence fees correspond to the capacity (bit rate) of the radio equipment and number of frequencies used. The fees for spectrum licences are dependant on the frequency band, and other factors such as area of operation, the amount of radio spectrum, and the population within the area of operation. Licence fee are also posted on Industry Canada's Strategis web site. The fees associated with site licenses are listed in the Radiocommunication Regulations[10].

Radiocommunication Considerations

This section contains a brief description of various factors that affect the coverage and operation of a radio system.

Radio coverage typically decreases as frequency increases. Since the wavelength of a radio signal decreases with frequency, radio signals at higher frequencies are affected more by obstructions (such as trees, buildings, etc.) and atmospheric conditions (changes to humidity and temperature can effectively cause radio waves to bend; rain, snow, and fog can weaken radio signals at frequencies above 5 GHz).

Antennas directly affect coverage. The simplest antenna is called a monopole. A monopole antenna radiates a radio signal in all directions, producing a circular donut pattern. A typical monopole antenna is the antenna on a cellular radiotelephone. By modifying the characteristics of an antenna, it is possible to narrow the beam of the radio signal, effectively increasing the coverage distance within the narrow angle.

Coverage increases with an increase in transmitter power. A general rule is that as the power of a transmitter is quadrupled, the coverage radius is doubled. However, there are a number of factors that come into effect that limit the amount of power in a transmitter.

Antenna size decreases as frequency increases. The gain of an antenna is related to the ratio of the antenna size and the wavelength of a radio signal. As the frequency doubles, the gain of a given size of antenna (when tuned to the higher frequency) will quadruple.

Coverage increases with antenna height. Coverage, and hence, antenna height is an important

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[8] http://strategis.ic.gc.ca/SSG/sf01320e.html

[9] http://strategis.gc.ca/SSG/sf01841e.html

[10] http://strategis.ic.gc.ca/SSG/sf01265e.html

factor for point-to-point radio links that interconnect a hub to the data network, as well as for connecting distant subscribers.

Signal fading affects reliability. Depending on the frequency used, changes in atmospheric conditions can have a very large effect on radio signals. On a point-to-point radio link of 50 km, the radio path is usually designed to continue to operate even if the received radio signal fades by a factor of 10,000.

Signal multipath affects signal reception. As frequency increases, radio signals are more likely be reflected off surrounding flat surfaces. If there are delays between the direct and various reflected signals (referred to as "out of phase"), the signals may cancel out. New technologies, especially NLOS technologies, are designed to process both direct and reflected signals to ensure a usable signal. As well, new directional antenna designs permit antennas to focus in specific directions to lock onto the strongest signal, whether it is a direct or reflected signal.

Interference can affect the operation of wireless systems and devices. Interference normally occurs between two or more systems or devices that are operating on the same, or nearby, frequencies, within close proximity of each other. An indication interference is when a subscriber wireless device is not able to lock onto the signal from an its' intended hub. Solutions can be simple, such as changing the operating frequency (channel) at both the hub and subscriber (providing this is an easily accessible option) to installing (more) directional antennas at a limited number of locations. More costly solutions might include the re-location of hubs or the replacement of all wireless devices (hub and subscribers) with devices that operate in different frequency bands.

Data Networks and Standards

The purpose of this section is to explain common terms used to describe data networks and associated standards.

Personal Area Network (PAN)

A personal area network (PAN) is intended to enable communications between devices that are only a few feet apart (up to 10 metres). PANs include communications from: computer to computer or personal digital assistant; digital cell phone to vending machine, etc. Standards associated with wireless PANs include Bluetooth[11] and the related IEEE[12] 802.15.1 standard, the IEEE 802.15.3 standard for high data rate communication and the IEEE 802.15.4 standard for low data rate communication. More information on 802.15 is available on the IEEE web site[13].

Local Area Network (LAN)

A local area network (LAN) normally refers to communications between a group of computers and associated devices within 75 metres of each other. With the use of external antennas, the

[11] http://www.bluetooth.com/

[12] IEEE - Institute of Electrical and Electronics Engineers, Inc.

[13] http://grouper.ieee.org/groups/802/15/

range of wireless LANs can be extended to serve an area of 5 km in a point-to-multipoint point configuration and approximately 15 km in a point-to-point using various techniques. However, as the distance to subscribers increases, LAN equipment needs to be adjusted to allow for longer signal delays and to avoid communication collisions from "hidden nodes".

Wireless local area networks include IEEE's 802.11, 802.11b, 802.11a, and 802.11g compliant[14] and extended devices. These networks also include Wi-Fi[15] designated 802.11 devices certified to inter-operate with each other, regardless of manufacturer. Wireless LANs are well suited for consumers deploying these devices in their homes or office buildings. These networks are also gaining wide acceptance by service providers for broadband "hotspot" service, e.g. pay per use broadband wireless access in café's, airports, and hotels, to name a few. There have been some successful deployments of 802.11/Wi-Fi systems to provide broadband data services to small communities. However, theses systems normally have a limited number of subscribers and a reduced data transfer rate between the hub and subscribers, typically 128 kbps to 500 kbps. This helps overcome the limitations mentioned in the previous paragraph.

802.11 b and 802.11g devices operate in the frequency range 2400-2483.5 MHz, whereas 802.11a devices operate in the frequency range 5725-5825 MHz . These devices do not require a radio licences but must be certified for use in Canada. Certified devices are labelled to this effect.

Some wireless LAN equipment is based on proprietary technologies. In these cases, devices from one manufacturer will not normally interoperate with other manufacturers' devices (i.e. devices must be exactly the same to operate with each other).

Metropolitan Area Network (MAN)

Metropolitan Area Networks (MANs) are intended to provide much higher capacity and to a greater coverage area (up to 10 km) than LANs. In areas of high usage, wireless MAN operators can easily reduce the coverage from individual hub and install additional hubs to cover the intermediate areas. In this way, the MAN operator can increase the total capacity available to customers. Hubs are then interconnected using wireline or wireless radio links.

Although the IEEE has just recently developed and released the new 802.16 standard for MANs[16], most existing metropolitan area networks have been deployed using devices based on proprietary technologies. Although these proprietary technologies are similar to those used for 802.11, devices that belong to different manufacturers will generally not operate with one another.

Wide Area Network (WAN)

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[14] 802.11x - the Institute of Electrical and Electronics Engineers has developed a number of related 802.11 standards. For a brief description, refer to Appendix XXX.

[15] Wi-Fi - The Wi-Fi Alliance is an international association which certifies interoperability of wireless LAN products based on the IEEE 802.11 standard

[16] www.wirelessman.org

Wide area networks (WANs) are designed to provide high capacity data network access over large areas. In the past, wireless wide area networks required antennas at both the hub and subscriber location to have a clear line-of-site (commonly referred to as 1st generation technologies). Wireless WANs had to be carefully designed to maximize the coverage areas and subscriber antennas had to be mounted on towers to ensure a clear line of sight to the hub. As a result, the cost of 1st generation equipment was high. Although new NLOS technologies are developing quickly, their coverage still does not permit NLOS systems to provide the coverage needed for WANs.

Broadband Wireless Deployment Considerations

A common problem in the past with telecommunications and broadband systems has been the "build and they (customers) will come" approach. The following identifies various factors, within three main areas, that need to be carefully evaluated to ensure that a system and services implemented meet the needs of the intended community. The three areas are: a) assessing service requirements, b) ensuring the proposed technology is capable of addressing current and future community needs, and c) ensuring that all companies involved in various stages, up to and including deploying the broadband system, are capable of undertaking and completing the task.

A - Service Requirements

As mentioned, there are a wide range of factors that need to be considered when planning a broadband system. Identifying a service (coverage) area and understanding the environmental characteristics, as well as identifying subscribers and their service needs is the first step. Although the following contains a number of factors, the list should not be considered all inclusive.

Environmental Factors
- climate
- landscape
- vegetation
- man-made structures

Demographics
- population
- number and location of homes, business, and other (government, education, etc.) offices
- number of people/residence, business and government institutions
- number of computers per home/business
- hours of operation (e.g. weekdays 8 am - 4 pm for businesses)

Service Needs/Expectations
- services
  - data
  - voice
  - video
  - web hosting
  - e-mail
  - dedicated access, quality of service, etc.

    - network storage
  - technical support
    - (subscriber) capabilities
    - hardware/software
    - (hours of operation)
  - for wireless technologies, willingness to accept installation external antennas
  - affordable
    - price subscribers are willing to pay for different services

Finally, although more difficult to evaluate, one other factor to consider (in addition to subscribers) is the potential social and economic benefit to the community.

B - (Wireless) Technology Considerations

The next step is to identify the data network connect point (PoP), and suitable locations for the hub with regard to both the transport link and the access links (service area). Siting of the hub is important when deploying a wireless system, since it will affect coverage area, reliability (the ability to provide an always-on signal to subscribers), and the ability to use NLOS or LOS technologies to provide access to subscribers. For a wireless transport link, siting is even more crucial, since the reliability of this link affects all subscribers accessing the public data network. In addition, a hub site must be accessible (road access) and suitable for a building which contains electronic and radio equipment.

Once the data network interconnect point and potential hub locations are identified[17], it is important to identify and evaluate the various technologies available for the transport link and to provide subscriber access. This includes wire line technologies, as well as satellite technologies for the transport link. The technologies chosen must provide an affordable solution that addresses subscriber needs.

As mentioned, the technology that is selected must address subscribers needs. The following lists the main factors that should be evaluated to ensure a best fit at an affordable cost:

- overall system data transfer capacity and individual subscriber data transfer rates
- capable of delivering dedicated bandwidth as required by individual subscribers
- capable of addressing future capacity needs
- LOS or NLOS technology, or a combination of both
  - rated versus attainable coverage distances
- requirement for multiple hubs
- flexible and expandable to address future subscriber needs
  - adding or re-using radio channels
  - deploying directional antennas at hub(s) and at subscribes' premises
  - providing equitable access to all subscribers regardless of distance (near or far)

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[17] Prior to constructing radio towers, operators must ensure they receive aeronautical clearance for the radio tower, and assess the affects on the surrounding area. In this regards, Industry Canada has published two Client Procedures Circulars (CPC), CPC 2-0-2 titled Antenna Structure Clearance and CPC-2-0-03 titled Environmental Process, Radiofrequency Fields and Land-Use Consultation

from the hub, as well as during periods of low and high usage (i.e. the hub equipment may need to be adjustable to allow for longer delays for subscribers located far from the hub and avoid communication collisions from 'hidden nodes')
- capable of meeting the quality of service requirements, e.g. for streaming video and voice telephony services
- cost
  - hub equipment
  - subscriber equipment
- ease of installation and use of subscriber equipment (plug and play)
- security features

C - Technical Capability

Prior to entering into any agreement with companies to supply equipment and design and install a broadband system, it is prudent to evaluate the abilities and capabilities of those companies (final step). The following factors would apply whether or not an outside company will design and deploy the system:

- reputation of company
  - readily available products
  - number of successful installations
  - familiar with local (or similar) environment
- radiocommunication capabilities
  - designing and installing a wireless broadband system
    - hub
    - transport link
    - access system, including subscriber installations
    - training
  - offers timely support for troubleshooting deployments
- telecommunications capabilities
  - expertise with data networks and traffic modelling, both on the transport link and the subscriber access side
  - familiarity with hardware and software, and other service offerings (voice, video)
- maintenance and troubleshooting
  - capable of providing timely on-going technical and operational expertise
  - on-going, and timely, maintenance and troubleshooting of the transport link, the hub, and subscriber access links for which they are responsible
- readily available arrangements with other companies to address issues as they may arise

Future Developments

There are a number of areas where wireless technologies are advancing rapidly. Although only a few area are discussed below, there is no doubt that the cost of deploying and operating a network will decline, and the coverage area, capacity and capability of wireless will increase beyond what has been described in this document.

Technologies used in radios are becoming more sophisticated and robust (forgiving). These improvements are and will translate into higher data transfer rates, greater reuse of radio spectrum, and increases in coverage area (especially NLOS radio systems).

Advances in antennas will allow dynamic focussing, in real time, on the strongest signal from a subscriber premise, whether it is a direct or a reflected signal. An analogy to how this would work can be found on the International Engineering Consortium web site[18].

Although a standard(s) has yet to be developed, research has been undertaken in the area of rural area networks (RANs). RANs will eventually provide low cost access to areas of low population densities. They will likely operate in lower frequencies, with modulations and Media Access Protocols that allow NLOS transmission, and point-to-multipoint configurations over longer distances (up to 40 km) with total shared throughput in the range of 25 Mbps per channel[19].

Finally, in a traditional wireless network design (commonly referred to as a star configuration), every subscriber's wireless device communicates directly to a hub. In new mesh networks, subscriber devices can either communicate directly to a hub (access point), or via other subscribers' devices. In this way, the coverage of a mesh network can extend well beyond the traditional layout by connecting subscribers to each other. Also, the reliability increases for those subscribers whose equipment can communicate to the hub via more than one signal path. A number of companies are currently developing and testing mesh networks. A presentation on mesh networks can be found at the International Engineering Consortium web site[20].

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[18] http://www.iec.org/online/tutorials/smart_ant/topic01.html

[19] Communications Research Centre (CRC) R&D Program on Rural and Remote Broadband Access.

[20] http://www.iec.org/events/2002/natlwireless_nov/featured/tf2_beyer.pdf

Appendix I - Industry Canada Broadband Technology Team

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