# BROADBAND TERRESTRIAL WIRELESS TECHNOLOGY

# FOR SCHOOL CONNECTIVITY

13 May 1999

*Prepared For:*

Industry Canada
Information Highway Applications Branch

*Prepared By:*

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**xwave solutions** Document No. I121-12-001 Version 01

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| **Approvals** | **Signature** | **Date** |
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Broadband Terrestrial Wireless Technology
for School Connectivity

Version 01 #I121-12-001

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for School Connectivity

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# 1 OVERVIEW

SchoolNet, established in 1993 to promote the effective use of information technology to connect all of Canada's schools and libraries to the Internet, has a mandate to connect every classroom in Canada by March 31, 2001.

Industry Canada has suggested using **broadband terrestrial wireless technology** for connectivity as a viable option for education purposes. Wireless technology is also sometimes called **spectrum technology** in a broader sense, or **radio communications**. These latter two terms include satellite based spectrum technology whereas in this paper we expound on non-satellite based broadband wireless technology. The purpose of this paper is to briefly:

1. Provide some background information to the Canadian education community about broadband terrestrial wireless technology;
2. Describe the various technologies and services; and
3. Outline the potential costs and the range of costs involved when evaluating the various broadband terrestrial wireless technology options.

It is assumed that the audience has little or no knowledge of spectrum technologies and that the audience has some knowledge about the Internet, and applications such as broadcast video and video conferencing.

Any cost estimates provided are based on publicly available information at the time of writing this paper.

## 2 INTRODUCTION TO SPECTRUM TECHNOLOGY

As mentioned in the overview, broadband terrestrial wireless technology is a subset of spectrum technology. The following section introduces spectrum technology concepts and information that is applied to broadband terrestrial wireless systems.

### 2.1 What is Spectrum Technology?

**Electromagnetic radiation** encompasses radio waves, microwaves, infrared light, visible light, x-rays, gamma-rays and more. **Electromagnetic spectrum** is a label given to different kinds of electromagnetic radiation. Unlike electrons, electromagnetic radiation does not require a physical medium to be transmitted, such as a wire. Electromagnetic radiation travels through space and behaves similarly to a wave in that it reflects and refracts off objects.

Electromagnetic radiation can also be absorbed. The absorption of electromagnetic radiation by materials depends on the material as well as the frequency of the radiation. This is an important consideration when installing systems that need to operate within a building (where walls and bodies can absorb signals) as well as systems that need to operate outdoors (where objects such as trees, or rain can absorb signals).

Spectrum technology is technology that employs the use of the **electromagnetic spectrum** to transmit information.

#### 2.1.1 Basics - Electromagnetic Spectrum

The electromagnetic spectrum is composed of various types of radio waves: microwaves, infrared light, visible light, just to name a few. These waves travel in straight lines. There is a relationship between the energy, wavelength and frequency of a wave. The associated energy of the wave lowers as the frequency decreases and the wavelength elongates.

In the world of telecommunications, wavelength or frequency typically characterizes electromagnetic spectrum.

#### 2.1.2 Radio Waves

Radio waves are part of the electromagnetic spectrum. This portion of the spectrum, which is characterized by frequencies in the range of 10 kHz to 100 GHz, is often termed as the **Radio Frequency** or **RF** spectrum. The terminology of radio waves and microwaves are used interchangeably in the field of communications.

Radio waves have a longer wavelength than visible light. They have lower energy, and are at a lower frequency. Figure 2-1 illustrates a typical RF spectrum, a subset of the electromagnetic spectrum.

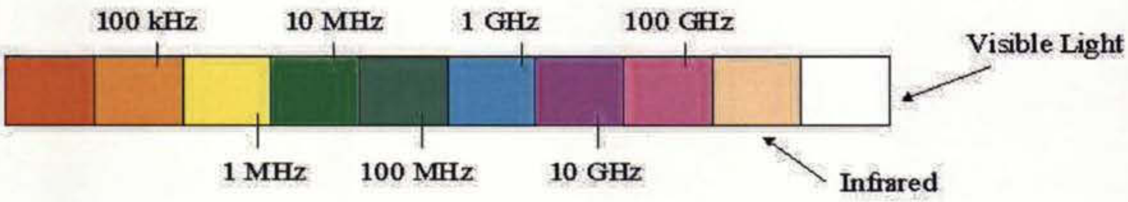


**Figure 2-1 Radio Spectrum Illustration**

The shorter wavelength, higher energy visible light can be seen on the far right-hand side of Figure 2-1.

The Radio Spectrum has been divided into **bands**. For instance, the L-Band typically goes from 1 GHz – 1.6 GHz. The word 'typically' is used because the assignment of band names such as 'L-Band' do not strictly correspond to a given set of frequencies. For instance, someone else might define 'L-band' as being from 900MHz to 1.5 GHz.

Some of these bands are used by radio broadcast stations, some of these bands are used for national security purposes, some of them are use by amateur radio hobbyists, and some of these bands are used by both microwave and satellite communications. Table 2-1 presents some of the bands in the radio spectrum and associated frequencies and wavelengths.

**Table 2-1 Frequency, Corresponding Bands and Wavelength[1]**

| Frequency (GHz) | Range of Wavelength (cm) | Band |
|---|---|---|
| 1-2 | 30-15 | L |
| 2-4 | 15-7.5 | S |
| 4-8 | 7.5-3.75 | C |
| 8-12 | 3.75-2.4 | X |
| 12-40 | 2.4-0.75 | K |

There are certain bands that are of particular interest when considering broadband terrestrial wireless services. These bands are L-band, S-band, and K-band. The systems that will be discussed in this paper are as follows: ISM (Industrial, Scientific and Medical) based systems

[1] http://www.jpl.nasa.gov/basics/bsf6-4.htm

(900MHz, 2.4 GHz, 5.8 GHz), Subscriber Radio Systems (1.4 GHz), Multipoint Communications Systems (2.5 GHz), Fixed Access Systems (3.4 GHz), Microwave (18-22 GHz), and Local Multipoint Communication Systems (24/38 GHz). Table 2-2 shows where the systems fit into the band structure.

**Table 2-2 Frequency and Associated Bands Discussed in This Paper[2]**

| Frequency (GHz) | Range of Wavelength (cm) | Band | Systems |
|---|---|---|---|
| 0.9-2 | 33-15 | L | ISM, Subscriber Radio Systems |
| 2-4 | 15-7.5 | S | ISM, MCS, Fixed Access Systems |
| 4-8 | 7.5-3.75 | C | ISM |
| 8-12 | 3.75-2.4 | X | Low capacity MCS |
| 12-40 | 2.4-0.75 | K | MCS, Fixed Services, LMCS |

All of these systems are technically classified as **microwave** systems; microwaves are radio waves that vary from approximately 1 millimeter to 30 centimeters in length.

### 2.1.3 Line-of-Sight

"Line-of-Sight" is an important term referred to at various points in this paper. It means being able to draw a straight line from one point (point A) to another point (point B) without obstructions

An obstruction can be a hill, a building, a tree, a moving object passing through the line-of-sight, and at times even certain weather conditions can cause obstructions. Obstructions may or may not be an issue depending on the characteristic of the electromagnetic wave. Different frequencies have different characteristics, just as different kinds of liquids have different characteristics (e.g. the viscosity of molasses is different than that for water) and this will cause them to behave differently under certain conditions.

Lower frequencies are better at penetrating obstructions or objects such as walls, or trees and require less power when operating under extreme rainy weather conditions. Higher frequencies require more power to penetrate objects and because of this, obstructions such as tree foliage may be problematic at higher frequencies.

[2] http://www.jpl.nasa.gov/basics/bsf6-4.htm

### 2.1.4 Channels

Industry Canada assigns spectrum based on service providers meeting licensing requirements and fees. Individual service providers will often then divide the spectrum into channels for particular purposes, much like cable TV is divided into channels with particular programs.

Channels can be characterized by their direction (i.e. Forward Link, Return Link), by their power, bandwidth and various other technical terms and definitions that help to ensure performance for the particular application.

The following sections explain the meaning of Forward Link, Return (Reverse) Link, Power, Bandwidth, and the relationships to propagation.

#### 2.1.4.1 Forward Link and Return Link

The terms '**Forward Link**' (also known as the Forward Channel) and '**Return Link**' (also commonly referred to as the reverse link or reverse channel) are important in the vocabulary of spectrum technologies. Forward Link designates the path from the base station to the user terminal (see Figure 2-2). Return Link designates the path from the user terminal to the base station.

Typically for Internet applications, there is more demand for the Forward Link than the Return Link. That means that the user is receiving more information (in the form of graphics, text, documents etc.) than they are sending (typically commands, or requests).

For a broadcast video, the demand is almost entirely on the Forward Link (asymmetrical) unless it is an 'on-demand' type service where the user sends a request for a particular video/broadcast and then prepares to receive that broadcast. For two-way video conferencing, the demand is symmetrical requiring equal resources on the Forward Link as the Return Link.

Therefore, a channel can be referred to and designed as symmetrical or asymmetrical. This characteristic of the channel will depend on the applications to be supported. Typically, spectrum technologies for education applications will be asymmetrical with the Forward Link providing more capacity than the Return link.

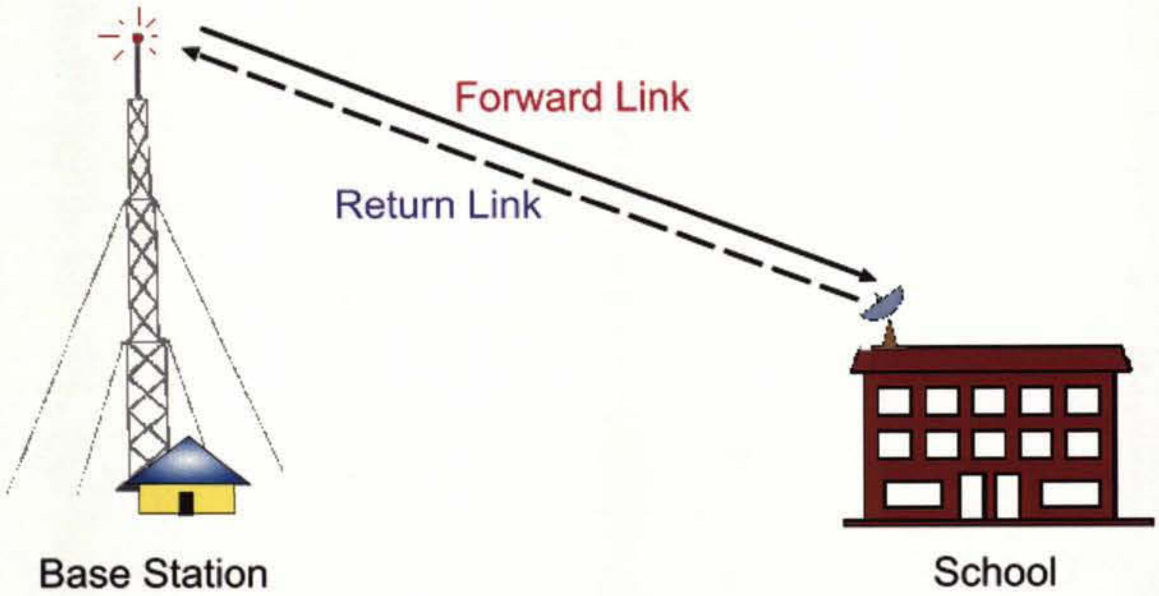


**Figure 2-2 Forward Link and Return Link Illustrating an Asymmetrical Channel**

#### 2.1.4.2 Power, Bandwidth and Propagation

Besides the wavelength and frequency of a radio wave, there are two other characteristics that are key when people discuss communications: **power** and **bandwidth**.

Power refers to the amount of energy used to transmit the wave. The more energy used to transmit a wave, the longer distance (also called **propagation**) the wave can travel.

Bandwidth refers to the width of spectrum that can be transmitted on a particular channel. It is the equivalent to the size of pipe in a water transportation situation. The larger the pipe, the greater the capacity to transport water. It is similar for spectrum technologies. The larger the bandwidth, the greater the capacity to transport information.

Bandwidth influences the capacity for a channel to carry information (e.g. more bandwidth, the more data that can be carried). For instance, 1 GHz of bandwidth has more capacity to transport information than 6 kHz. Using LMCS technology which will be discussed later, 1 GHz of bandwidth is roughly equivalent to 1 Gbps, (1,000 Mbps).

Power and bandwidth for any transmission are governed by rules and regulations set out by Industry Canada. Power is limited primarily for interference and safety reasons.

Although there are several factors besides power that affect propagation (the distance a wave can travel), the following diagram (Figure 2-3) illustrates the relationship between frequency, the distance a wave can travel (propagation), and the availability of spectrum. Although propagation can be measured, the relationship below is illustrative only. Industry Canada governs spectrum and therefore its availability is only illustrated below.

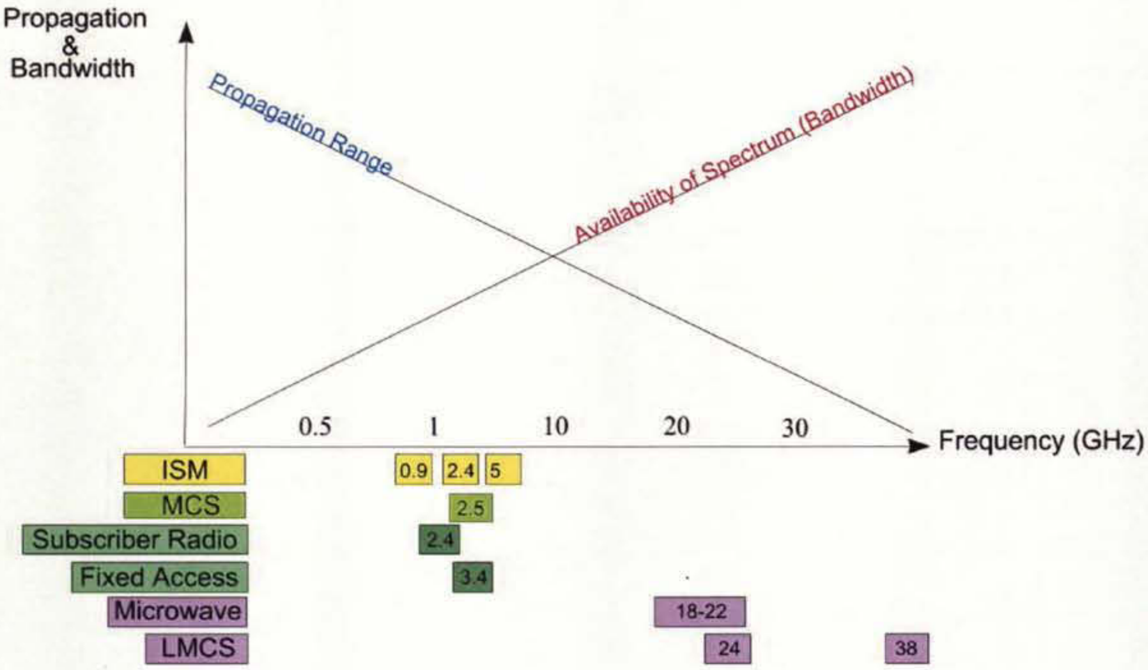


**Figure 2-3 Spectrum Availability and Propagation as a Function of Frequency**

In Figure 2-3, as the frequency increases, more bandwidth is available for bandwidth hungry applications. Bandwidth hungry applications are those applications that require a larger pipe in order to transmit the required information. Another item to note from the figure is that as the frequency increases, the propagation or ability for the wavelength to travel a given distance, decreases. This is because shorter wavelengths or higher frequencies require more power in order to travel the equivalent distance of a lower frequency given the same power.

### 2.1.5 General Applications and Bandwidth Requirements

There exist many kinds of different media; voice, small messaging (e.g. paging), CD quality sound, video, and data are the main kinds of media that we commonly experience in our everyday lives. Different media require different amounts of bandwidth because of the amount of information inherent in that media that needs to be transmitted. For instance, CD-quality sound has greater bandwidth requirements than voice. Video has even greater bandwidth requirements than CD-quality sound.

The diagram below (Figure 2-4) illustrates the approximate bandwidth requirements for different media.

| | |
|---|---|
| Voice | 6 kHz |
| AM | 10 kHz |
| FM | 200 kHz |
| CD | **Depends on compression techniques being used, but typically FM or higher is 'CD-quality'.** |
| Video | 6 MHz |
| Internet | **Depends on media being transported e.g. text, voice, images, sound, etc.** |

**Figure 2-4 Typical Bandwidth Requirements for Various Media Applications**

Power, modulation techniques (the type of technology used), frequency and various other engineering design parameters influence the relationship between bandwidth (the width of spectrum used) and throughput (measured in bits per second. In subsequent sections when the types of wireless technologies are discussed, an indication of this relationship will also be provided. For instance, with LMCS, typically one can achieve approximately 1 Mbps for every 1 MHz.

**Wideband** systems can typically deliver multiple voice channels, facsimile services, high-speed data and video-conferencing. Typically, they refer to any system that can deliver a data throughput from 64 kbps to 1.5 Mbps. **Broadband** tends to imply something that is larger than Wideband in terms of bandwidth. The terms wideband and broadband however, are often used interchangeably.

Broadband terrestrial wireless systems can be used to:

- access the Internet;
- broadcast educational programs;
- facilitate administrative business processes between the schools and/or school board;
- provide remote access for individual special needs students; and/or
- have collaborative work/materials for both students and teachers across the country.

There are two main areas where broadband terrestrial wireless systems can be deployed in the educational sector:

1. Within the school to interconnect workstations on a Local Area Network (LAN); and/or
2. Between schools or between the schools and a school board depending on if a particular school or the school board is being used as a hub because it has access to a high-speed wireline or wireless connection to the service provider.

These options can be seen in Figure 2-5.

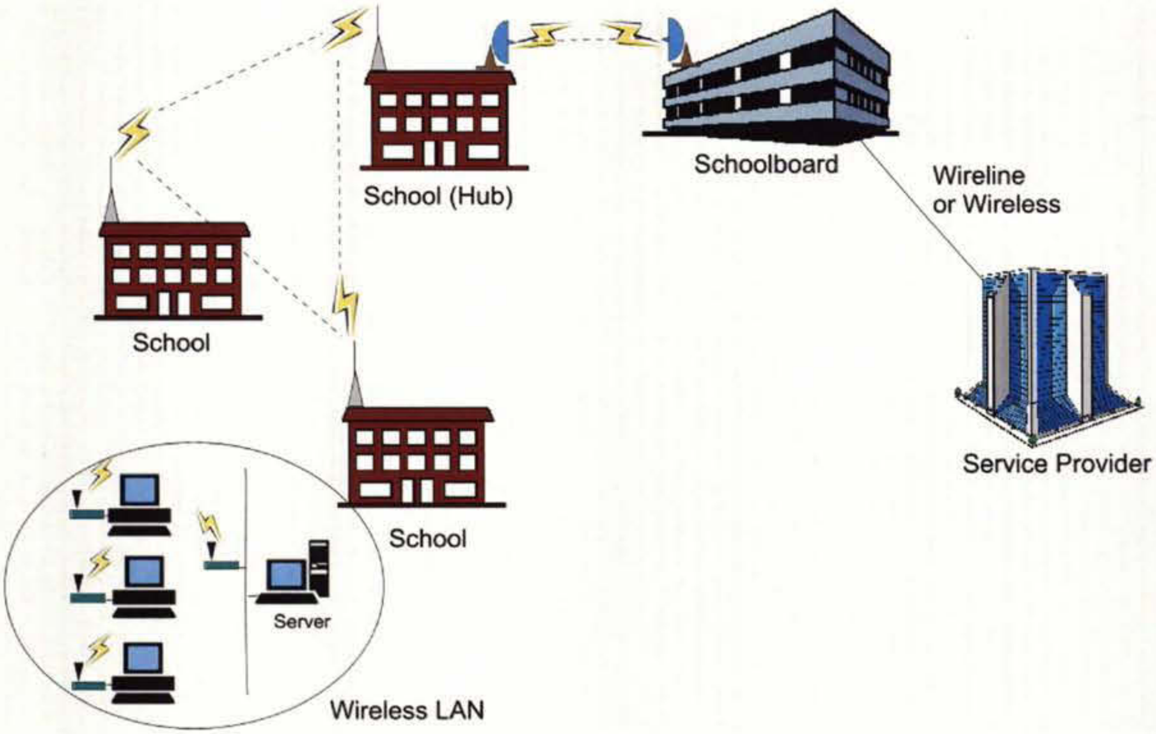


**Figure 2-5 Typical Spectrum Technology Options Applied to Education**

## 2.2 When Should I Use Wireless Technology?

Wireless technologies provide several advantages over wireline technologies. Some of these advantages include generally a faster time to market, lower infrastructure costs, and higher portability.

Nortel estimates that the cost of copper local loops in North America ranges from $1200 to $1300 per residence. When the terrain is difficult or the population density is low, the cost of copper can climb as high as $5000. As new neighbourhoods are developed the cost advantages of spectrum technologies will soon outweigh the wireline technologies.

The gap in costs between spectrum technology and wireline technologies is smaller every year. Numerous broadband satellite options will be on the horizon with 5 major players planning satellite broadband deployment over the next couple of years.

There are a number of situations when you might want to consider wireless technologies over wireline technologies:

1. **When quick deployment is important or when in a state of flux:**
   Wireless technologies are relatively fast to deploy. If you are considering a change in buildings and/or locations, or you are in a state of flux (e.g. fluctuating classroom sizes resulting in heavy use of portables) wireless technology is generally faster and less costly to deploy than wireline;

2. **When bridging schools across a short distance:**
   If there is a desire to interconnect schools across short distances (1-10 km) before going to a wireline technology, then spectrum technology may provide significant cost savings. (e.g. a school board are another school may be acting as a hub before going to wireline or a higher-speed wireless connection to the service provider);

3. **When rural or remote:**
   A rural site is defined here as a site that has limited access to high speed wireline services. A remote site is defined here as a site that has no current access to high speed wireline services and is not likely to in the near future.

   There are situations when rural sites might see considerable cost and performance savings when deploying a wireless system. For instance, a group of schools may opt to select one as the hub if one is closer than the others to a wireline option. The other schools may communicate wirelessly (e.g. via MCS) to the hub forming an inter-school network from which access to Internet and other services can be provided.

   In a remote situation where there is less likely to be a group of schools within reasonable proximity of each other, other facilities/organizations (e.g. community centre, band office) could share access in a wireless network. From there, the hub could communicate over satellite to a location where wireline can be accessed.

4. **When considering backup connectivity:**
   There may be rare situations when reliability is an issue and wireline is the cheaper technology to deploy operationally (e.g. a school board to service provider connectivity where the school board is acting as a hub). In these situations, wireless will offer reliable backup connectivity.

## 2.3 Who Owns Radio Spectrum?

The radio frequency spectrum is a publicly owned commodity and a limited national resource. Industry Canada is the designated federal government body responsible for ensuring that radio spectrum is used in the best interests of the nation (general public, private and public organizations). The use of spectrum is granted in the form of a radio license or radio authorization in accordance with specified policies, regulations, and procedures[3].

Figure 2-6 below provides an illustration of how spectrum is nationally administered and the relationships to the international community.

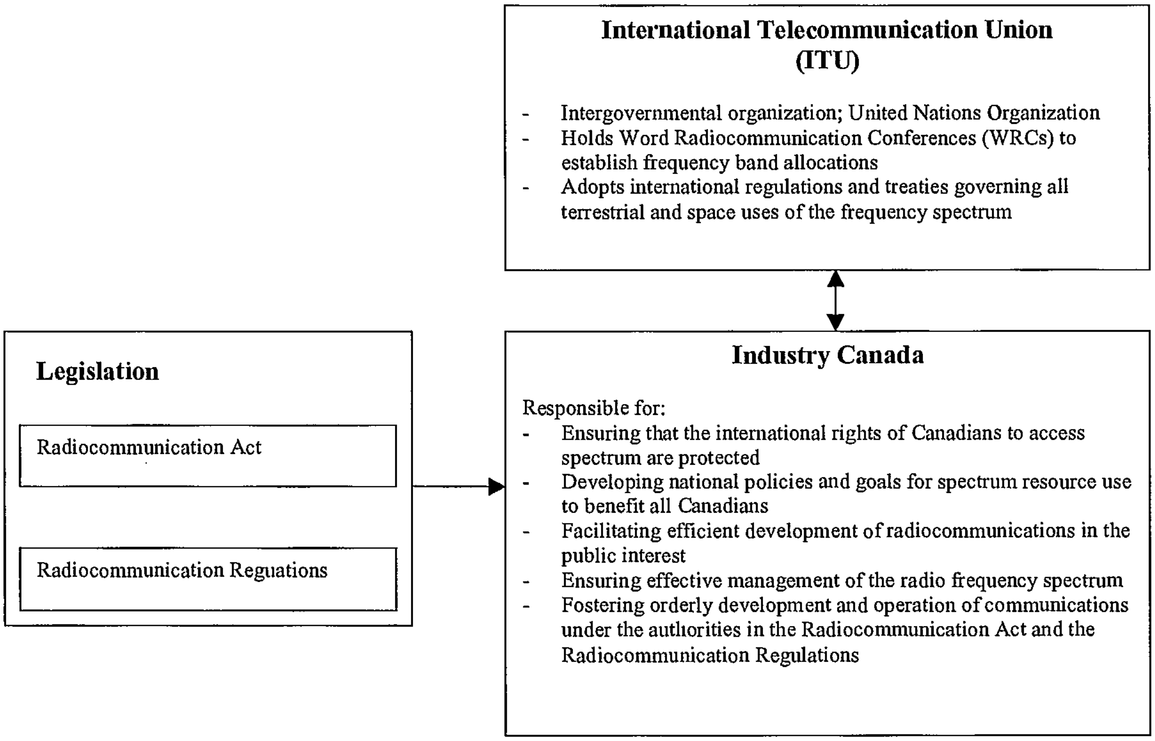


**Figure 2-6 The National Administration of Radio Spectrum**

There are some areas of the radio spectrum that are licensed, and other areas that are not licensed. Nevertheless, any equipment that is sold, whether for licensed or unlicensed bands, must be approved by Industry Canada to ensure its compliance with frequency, power, and bandwidth requirements.

In general, license-exempt (unlicensed) applications have low power emissions. Unlicensed means that anyone who has approved equipment can access the same frequencies that you are accessing. The implications are:

[3] Melnyk, Max. *Broadband Wireless Access Networks for Public Services*, Paper to the Public Interest Advocacy Centre (PIAC), June 4, 1998, p.3.

a) Users depending on equipment in unlicensed bands need to necessarily be concerned about interference from other unlicensed equipment that is nearby and operating in that same band;

b) Low power emissions may alleviate interference issues from more distance users but at the same time unlicensed bands may not be suitable for some applications where transmission is required for greater distances.

### 2.3.1 How Are Radio Licenses Granted?

Granting of spectrum (or radio licensing) has historically been on a "first-come, first-served" basis. It then moved to a staged comparative hearing process when there was an issue with availability of spectrum. Now radio spectrum is moving towards becoming a 'commodity' like any other. There is now a widespread trend in the governments of various jurisdictions to use auctions as a means of assigning spectrum, whereby they realize significant revenues from private companies for this commodity.

### 2.3.2 What Bands Are Suitable for Education Application Purposes?

There are several bands that are suitable for education purposes. However, Industry Canada doesn't necessarily provide licensing for an entire band (with the exception of the ISM band which actually spans a couple of bands), but for blocks of frequencies within bands. Any frequency block that has the capability of providing Wideband or Broadband Service may be suitable depending on the throughput requirements of the school.

The following classifications may be considered for Wideband or Broadband Service: 1.4 GHz (Subscriber Radio Systems), 2.5 GHz (Multipoint Communications Systems), 3.4 GHz (Fixed Access Systems), and 24/38 GHz (Broadband Access Systems – also known as Local Multipoint Communication Systems).

The various technologies and capabilities in these bands are discussed in Section 3.

## 3 ARCHITECTURAL OVERVIEW OF BROADBAND WIRELESS TERRESTRIAL TECHNOLOGIES OPTIONS AND COSTS

This section describes the various wireless technologies that are appropriate for **wideband** or **broadband** applications. These technologies are divided into appropriate applications for wireless LANs used within buildings, and broadband wireless technologies for external point-to-point, or point-to-multipoint applications.

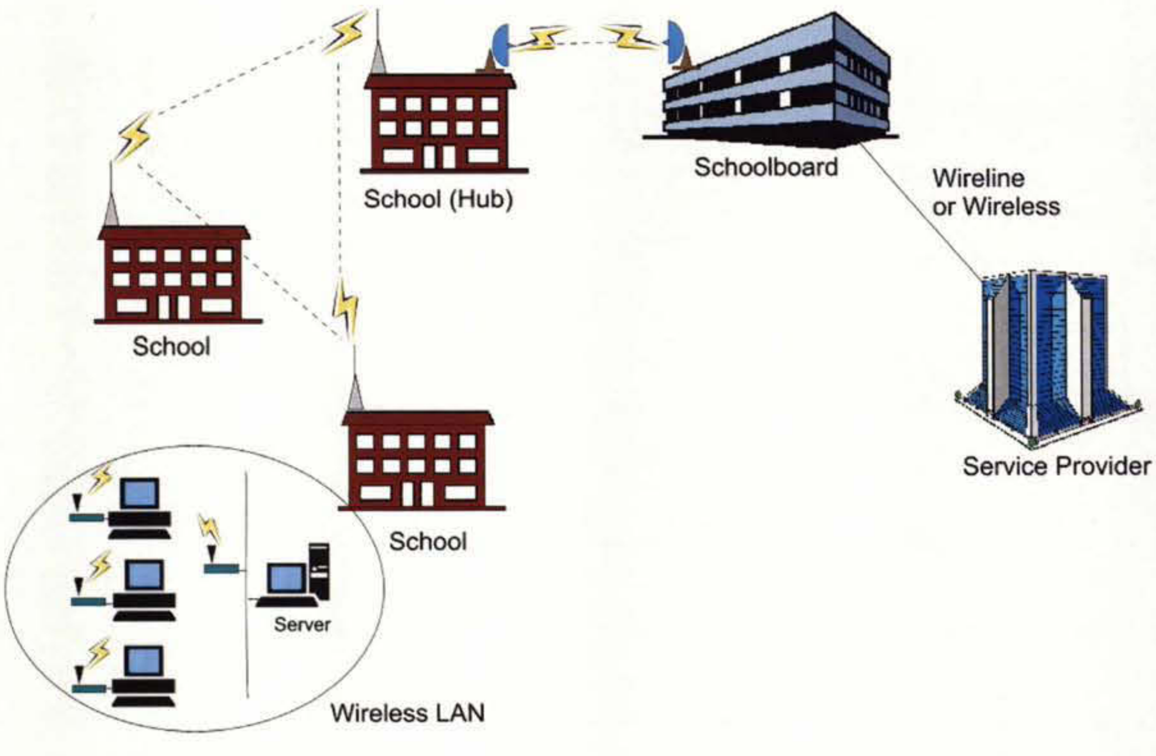


**Figure 3-1 Architectural Overview of Broadband Terrestrial Wireless Technologies Applications**

### 3.1 Wireless LAN Technologies

The term "wireless LAN technologies" refers to wireless technologies deployed within a building in support of a Local Area Network (LAN). It also sometimes refers to wireless technologies deployed between buildings in support of a LAN (e.g. ethernet bridges) or in an outdoor LAN application similar to what might be seen on a campus with roaming users.

Wireless devices can be used to connect computers and other devices together at high speeds in a LAN configuration instead of running cable between these devices.

This particular technology can be especially useful in a situation where cable is difficult to run because of the building structure, age, movement of equipment and/or classrooms.

### 3.1.1 General Architecture and Access

There are two basic types of wireless LAN networks that can be created:

1. Peer-to-peer
2. Client and Access Point.

#### 3.1.1.1 Peer-to-Peer

A peer-to-peer network is one where two or more computers are set-up in an independent network whenever they are in range of each other. They require no administration. They would be able to share only each other's resources. Typically, a wireless peer-to-peer transceiver can have a range of anywhere from under a 100 feet to approximately 300 feet.

A transceiver is the combination of both a receiver as well as a transmitter. The receiver receives the signal from the antenna and converts it from an analog signal to baseband. A transmitter receives a baseband signal and modulates the digital signal to an analog signal for transmission. The equipment in a peer-to-peer network typically comes with the transceiver and antenna as a single unit. However, in other types of networks especially for outdoor transmission, the transceiver is generally a separate unit from the antenna in order to provide flexibility for different antenna types as well as installation considerations such as the distance between the transceiver and antenna.

In order to set-up a peer-to-peer network, the following components are shown in Figure 3-2. The components of this kind of network are: a wireless transceiver and antenna, networking software, cable connection to the client, networking card (e.g. ISA, PCMCIA, parallel port) to support the connection to the wireless transceiver.

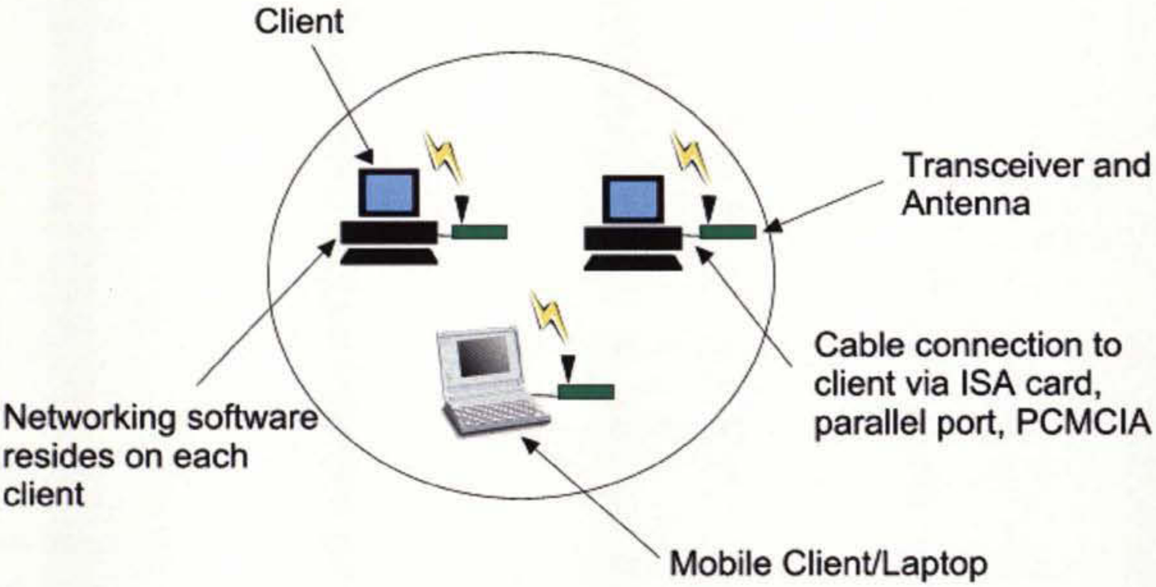


**Figure 3-2 Peer-to-Peer Network**

#### 3.1.1.2 Access Points and Extension Points

Another kind of wireless LAN architecture is one that has an **access point**. An access point is typically connected to the wired network, providing access to server resources and other wired and wireless clients on the network (see Figure 3-3). Access points have a range of approximately 500 feet indoors, and approximately 1000 feet outdoors.

Typically, an access point is connected to the wired LAN just as a PC would be connected to the LAN depending on what type of LAN it is. For instance, if the LAN is a 10baseT, then the access point would be connected via an RJ45 connector and would be seen by the LAN as a PC. However, the wireless units would view the access point as a hub.

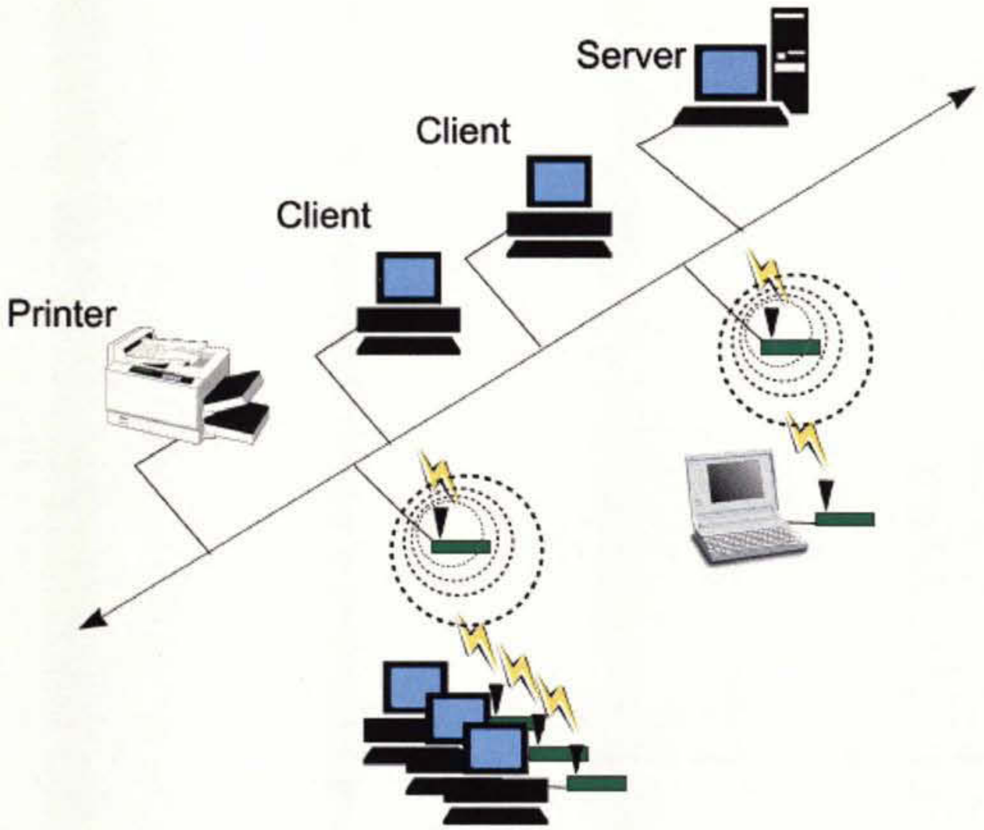


**Figure 3-3 Wired and Wireless Network Integrated Through Access Points**

The positioning of access cells (coverage area of one particular access point) is important so as to ensure that clients can roam in a designated area without losing contact with the network.

An extension point is like an access point however it is not connected to the network via wire. An extension point extends the range of the network by relaying signals from a client to an access point or to another extension point.

### 3.1.1.3 Antennas

There are basically two types of antennas for wireless LANs: directional and omni-directional. Directional antennas are applicable when there is a need to bridge two LAN networks from two schools, where those schools are separated by a very short distance (e.g. 1-2 kilometers). This may enable the schools to share resources on their networks or provide access from one school to another acting as a hub with a high-speed connection to the service provider.

An omni-directional antenna is typically used when roaming is required. The actual antenna can be in the form of a rod much like a car or cellular phone antenna, or it may be a 'patch' style antenna with the form factor of a large hockey-puck.

### 3.1.2 Summary and Typical Costs

The components of a wireless LAN network are:

- Workstations;
- Radio transceiver and antenna per work station;
- Cabling from the radio transceiver to the network interface card inside the workstation;
- Servers for resource management (e.g. file server, print server, etc.);
- Access point transceivers;
- Access point transceiver cabling; and
- Networking software.

The costs for radio transceivers/antennas vary from $150 to $2,000 US depending on the required bandwidth and network type or configuration (e.g. access point or extension vs. client transceiver). Equipping a client workstation for wireless connectivity is the lower end of the price range while an access point or extension point is represented at the higher end of the price range.

Capital costs for wireless systems equipment are typically higher than capital costs for wired systems equipment. However, the longer term operational/administrative and cabling costs associated with wired systems may result in a less expensive solution overall with a wireless system.

Wireless LAN systems from different vendors may not be interoperable (e.g. between clients, and access points, or clients and extension points) for several reasons. The first is that different vendors may be using different frequencies (e.g. one vendor may use 900 MHz whereas the other may use 2.4 GHz). Another reason is that even if vendors use the same frequency they may be using different technologies.

There are two basic technologies that are used for wireless LANs:

- Spread Spectrum technology at 900 MHz and 2.4 GHz in the ISM band; the two primary types of spread spectrum are Direct Sequence Spread Spectrum (DSSS), and Frequency Hopping Spread Spectrum (FHSS);
- Infrared light.

Even if vendors, however, are using the same technology and the same frequency, they may have proprietary implementations of the technology. These technologies, costs and bandwidth provided are discussed in the subsequent sections.

## 3.2 External Broadband Terrestrial Wireless Technology

### 3.2.1 General Access and Architecture

There are several types of external broadband terrestrial based wireless technology that are available today, or in the very near future (e.g. next 6 months) and may be suitable for education applications: ISM based technologies, point-to-point and point-to-multipoint fixed access technologies, LMCS, MCS, and subscriber radio systems.

As was shown in Figure 2-5, these technologies can be applied in the following configurations:

1. point-to-point between schools
2. point-to-multipoint between the school board and the schools (the school board could be acting as a service provider or a location from which to centralize communications and go over wireline to a service provider)
3. point-to-point between a school board and a service provider.

There are a number of general components that make up the architecture of broadband terrestrial based wireless system. One of the two key pieces in this architecture that will be of concern to schools are the base station and the customer premise equipment (CPE).

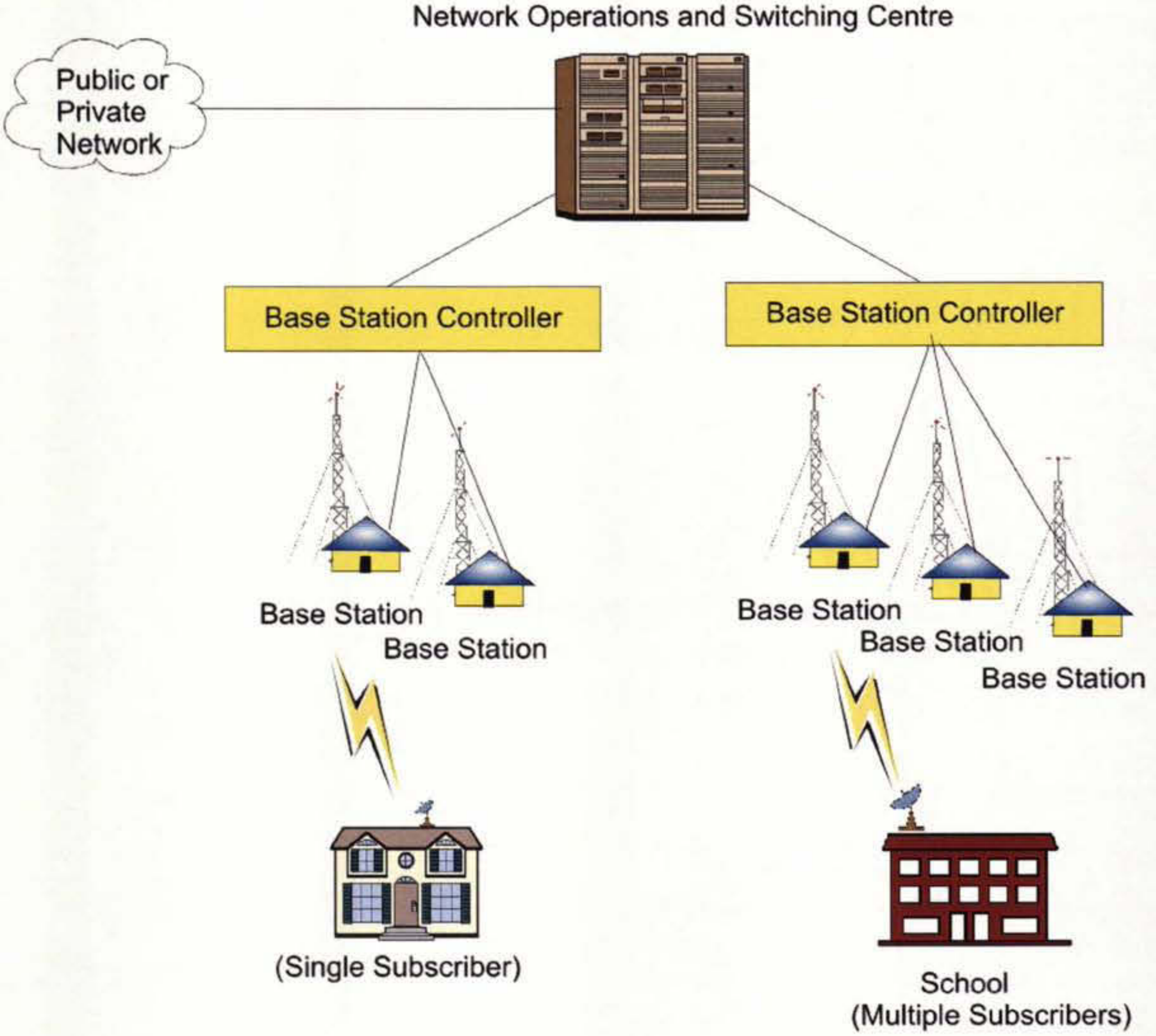


**Figure 3-4 General Architecture of External Broadband Terrestrial Wireless Networks**

The base station is typically located on a very high point in order to avoid interference and/or provide line-or-sight to another point. At times, the service provider may opt to use the school as a base station particularly if it offers one of the highest points in the area.

The CPE (customer premise equipment – the equipment that sits at the school or school board) includes all of the equipment that sits on the customer premises. It is generally comprised of:

- RF equipment (transmitters, receivers, antennas for transmission and reception);
- down conversion and up conversion equipment for conversion from RF to baseband and vice versa; and
- a network interface card to interface to the customer's network.

In some of these systems, the network interface card (NIC), down conversion and up conversion equipment are combined into a single unit. In this case, the NIC is the first piece of equipment at the end of the antenna cable, prior to interfacing with the customer network. The NIC might be connected to a router or brouter (combination of bridge and router) depending on the network configuration (Figure 3-5). The antenna may be mounted on the school roof, or on a separately constructed tower depending on the location of the school, the base station, and the geography of the area.

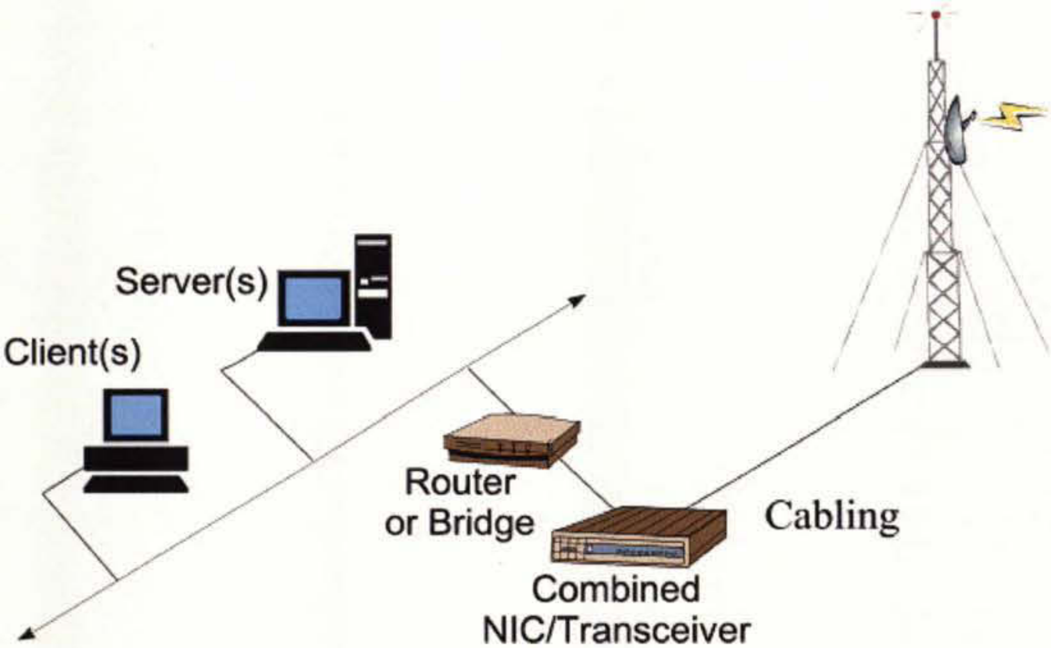


**Figure 3-5 General Configuration of Customer Premise Equipment**

**Installation**

Installation is an area of risk for all wireless networks that is mitigated or almost eliminated when the network is designed by system integration professionals and performed by properly trained technicians. Sometimes it is required that antennas at the customer premise and at base stations are 75-90 feet above ground.

Prior to installation, it is advisable that studies be done to understand potential interference problems due to other equipment (e.g. customer related or from other companies/organizations in the area), land profiles (e.g. trees, hills, etc.), and weather characteristics (e.g. particularly wet region, snow belt, etc.). Most of the time these issues can be overcome through proper design and network configuration.

### 3.2.2 Summary and Typical Costs

There are equipment, operational, and structural costs that need to be considered both at the owner's site as well as at the user's site. In a school application, the school may be both the owner and user, or the school board or service provider may be the owner and individual schools may be users.

Costs will vary for schools that are remote or rural vs. schools that are urban. Rural and remote schools may find that they need to be 'owners' and thus expend more resources on infrastructure due to the lack of options and service providers available. In urban locations, service providers are more likely to be considered as the 'owners' and absorb infrastructure costs because of their ability to offer the service to other businesses and/or residential locations.

Both owners and users need to consider operational costs. Operational costs are not provided here. For owners, these operational costs include maintenance on base stations and towers, staff office equipment, salaries, administration for program purposes, network management, interconnection costs, switching, backhaul and program delivery charges. For users, operational costs may typically include some staff office equipment for network management and maintenance, salaries, and program delivery charges.

The following costs are approximate only.[4] These costs do not include engineering costs (network architecture and site planning), license or auction fees, environmental and municipal costs or taxes.

**Table 3-1 Owner's Site Approximate Costs**

| Equipment | Approximate Price Range ($US per unit/location) |
|---|---|
| Land for Buildings and Tower | (dependent on location) |
| Transmitters/Receivers (TVRO Receiver) | $20,000 |
| Building | $30k-$50k |
| Towers | Up to $200,000 (dependent on height – Manitoba Education Research Learning Information Network MCS network most expensive tower was less than $20,000 CDN) |
| Antennas | $20,000 |
| Power/Emergency Power | $20,000 |
| Downconverters | $10,000 |
| Microwave Combiners | $5,000 |
| Channel Selectors | $10,000 |
| Digital Converters | $50,000 |
| Broadband Amplifier | $15,000 |

[4] Melnyk, Max. *Broadband Wireless Access Networks for Public Services*, Paper to the Public Interest Advocacy Centre (PIAC), June 4, 1998.

**Table 3-2 User's Site Approximate Costs**

| Equipment | Approximate Price Range ($US per unit/location) |
|---|---|
| Antenna/Downconverter | $150-$2500[5] |
| Datacombiner/Switch | $300 |

A datacombiner and/or switch may be required to combine or switch data streams to be transmitted from different sources. For instance, there may be an application where two separate networks in the school require the full available bandwidth for different periods. In this situation, a switch would provide control of the full bandwidth to the network. Or, there may be a situation where it is desirable to combine a data stream with a video stream, or two data streams, in which case a datacombiner or other type of combiner would be required.

[5] The $2500 per unit comes from LMCS approximate NIC costs. The NIC for MAXLink consists of what is traditionally understood as the network interface card as well as downconverter and upconverter.

# 4 TYPES OF WIRELESS LAN AND EXTERNAL WIRELESS TECHNOLOGIES

The following sections overview the specific types of technology offering for Wireless LANs and External Wireless Technologies.

A discussion of the ISM band is presented first and its application in both wireless LANs and external broadband wireless technologies is then presented.

## 4.1 Industrial, Scientific and Medical (ISM) Band

The ISM band is designated as an unlicensed band by Industry Canada, and regulated in that equipment must meet certain design requirements and regulations.

There are both indoor and outdoor applications of unlicensed bands at 900 MHz, 2.4 GHz, 5.0 GHz and 24 GHz. The chart below (Table 4-1) shows particular blocks of unlicensed frequencies.

**Table 4-1 Chart of Unlicensed Frequencies at 900 MHz, 2.4 GHz, and 5.0 GHz**

| Band | Unlicensed Frequencies |
|---|---|
| 900 MHz | 902 - 928 MHz |
| 2.4 GHz | 2400 - 2500 MHz |
| 5.0 GHz | 5725 - 5875 MHz |
| 24 GHz | 24 – 24.25 GHz |

The following table (Table 4-2) illustrates the propagation or maximum transmission range and data rates for various indoor and outdoor equipment in these bands.

**Table 4-2 Chart of Approximate Transmission Range and Approximate Data Rates in Unlicensed Bands for Some Existing Equipment**

| Frequency | Maximum Transmission Range | | Data Rate |
|---|---|---|---|
| | **Indoor** | **Outdoor** | |
| 900 MHz:<br>902 - 928 MHz | ~240m | ~16 km | Up to 2 Mbps |
| 2.4 GHz<br>2400 - 2500 MHz | ~200m | ~40 km | 2 Mbps, 3 Mbps, 4 Mbps, 10 Mbps |
| 5.8 GHz<br>5725 - 5875 MHz | ~36 m to 80 m | ~50 km (2 Mbps)<br>~100 m (10 Mbps)<br>~1-10 km (20 Mbps) | 2 Mbps to 20 Mbps |
| 24 GHz | TBD | TBD | TBD |

Transmission ranges and data rates are related to the regulated power requirements, and the various antenna configurations and design configurations provided by the vendors.

Applications for the ISM band include:

- Wireless LANs (typical)
- Point-to-point or point-to-multipoint links for connectivity between schools (e.g. WAN) and/or buildings (point-to-point links between schools is not as common an application due to possible interference issues)

The primary two technologies deployed over ISM are implementations (proprietary and otherwise) of spread spectrum and frequency hopping. These technologies are described in more detail in Section 3.1.

Infrared is not an ISM band technology. However, it can also be used for wireless LAN and point-to-point applications and is described in Section 3.1 as well.

### 4.1.1 ISM Band and Interface

ISM is an unlicensed band. Therefore, it may be subject to interference as certain sub-bands within the band become crowded by other unlicensed users. For this and other reasons, the 5.8 GHz sub-band has been made available. Currently, there are few vendors that have RF equipment for the 5.8 GHz band.

There are a number of items that will affect or limit interference such as power levels, antenna direction (whether omni-directional, or directional), transmitter heights, geography, etc. Application requirements need to be carefully matched with an appropriate design and feasibility, followed by professional installment.

### 4.1.2 Spread Spectrum ISM Band Technologies

#### 4.1.2.1 Direct Sequence Spread Spectrum (DSSS) Technologies

Over the last couple of years, several flavors of Direct Sequence Spread Spectrum (DSSS) have evolved; most of these are proprietary. DSSS has been implemented in several types of wireless applications at licensed and unlicensed frequencies.

Direct Sequence Spread Spectrum (DSSS) is a technique of modulating a signal such that it appears as noise in the frequency domain. Basically, this is accomplished by generating a redundant bit pattern for each bit to be transmitted according to a "pseudonoise" (PN) code. This has the effect of spreading the signal across a larger bandwidth.

Spread spectrum signals in general can not be easily detected or correctly decoded without knowing the exact way it was coded. And because the signal is 'spread' across a larger bandwidth, lower power levels are required to transmit the signal compared with other technologies.

Section 4.1.2.3 explains the typical bandwidth and licensing requirements of spread spectrum in an internal LAN application. Section 4.1.2.4 describes a small subset of the many equipment providers that offer DSSS wireless LAN technologies.

#### 4.1.2.2 Frequency Hopping Spread Spectrum (FHSS) Technologies

Spread Spectrum techniques are susceptible to what are called 'near-far' effects. Normally this 'near-far' effect is compensated for by controlling the transmitted power. Frequency hopping is a spread spectrum technique that reduces this susceptibility by hopping or changing transmitted frequencies in a pattern known by the transmitter and receiver across a bandwidth that is larger than the bandwidth required to normally transmit the information.

Frequency hopping spread spectrum techniques tend to provide for higher system capacity (number of units per channel), better interference immunity, and lower power consumption. The tradeoff is that a faster processor is required for the hardware.

##### 4.1.2.2.1 2.4 GHz ISM Band Standards: IEEE 802.11 and OpenAir 2.4

There are two primary standards for wireless LANs at 2.4 GHz: the IEEE 802.11 and the OpenAir 2.4 standard.

**IEEE 802.11**

The IEEE 802.11 defines physical characteristics of wireless systems using diffused infrared, DSSS, and FHSS. The goal of the IEEE 802.11 standard is to define interoperability and standards for wireless devices using the same physical medium (e.g. interoperability between diffused infrared system to another diffused infrared system, and not between a diffused infrared system and a DSSS system).

In the IEEE 802.11 standard, because it is not yet completed, there are a few key areas that are not addressed that prevent multi-vendor interoperability. They are as follows:

- The standard does not address how clients can be handed-off as the roam from one Access Point to another Access Point

- It does not map data framing or specify the data framing to be used by an Access Point
- There is no conformance test suite to ensure IEEE 802.11 compliance

**OpenAir 2.4**
In 1996, the Wireless LAN Interoperability Forum (WLI Forum) was created by several vendors to address the issue of multi-vendor interoperability of wireless LAN products and provide test suites in order to ensure this interoperability. This standard is called the OpenAir 2.4 standard, and is based on FHSS technology operating at the 2.4 GHz ISM band.

There are five key areas that define interoperability for wireless LANs. These five key areas are presented as follows:

- Data communication
- Roaming
- Security
- Configuration; and
- Coexistence.

Each of these areas are defined in the OpenAir Standard.

#### 4.1.2.3 Bandwidth, Coverage and Licensing

Most commercially available internal LAN spectrum technologies are unlicensed in the ISM bands. The most commonly used frequency is 900 MHz and 2.4 GHz.

Coverage is often a function of the antenna type, placement, and building construction. Coverage and/or range provided is most often specified for an open office or factory type environment. Therefore, the coverage and/or range may change significantly from the specification when operating in a school environment.

The potential of interference exists if two units attempt to access the same frequency at the same time. There are design rules set up by Industry Canada (and the FCC in the US) to ensure that the chance of interference is reduced. Frequency Hopping Spread Spectrum (FHSS) is more resistant to interference than DSSS. However, DSSS tends to offer better performance.

#### 4.1.2.4 Product Providers and Costs

Another resource for a listing of manufacturers for both external and internal LAN equipment is http://hydra.carleton.ca/info/wlan.html.

#### 4.1.2.4.1 AIRONET Wireless Communications

Aironet Wireless Communications Inc. designs and manufactures wireless LAN products using its own proprietary spread spectrum technologies. It designs and manufactures wireless access points, wireless client adapters, and wireless bridges.

**ARLAN 600 Series**
Aironet has a product series called the ARLAN 600 series that supports peer-to-peer networking, or interfaces with Ethernet, token ring, or LocalTalk networks through access points. It supports a direct connection to these networks via ISA, MCA, or PCMCIA (PC cards) client adapters. These adapters cards include the interface to the PC bus architecture, transceiver and antenna within one or two separate pieces of hardware. This technology is supported at 900 MHz (DSSS) or 2.4 GHz (DSSS) providing a throughput of up to 2 Mbps per channel in a range of approximately 3,000 feet indoors, or approximately 6 miles in a line-of-sight outdoor configuration for the wireless bridge.

**ARLAN 2000 and 3000 Series**
Aironet also carries an ARLAN 2000 series in support of long range high data rate Ethernet bridge supporting 4 Mbps data rates for up to 6 miles.

Aironet has a new product series called the ARLAN 3000 series that interfaces with a PC via a PCMCIA card. It is a FHSS technology at 2.4 GHz supporting a bandwidth of up to 2 Mbps per channel. There is optional ISA or serial bus interface support.

The FHSS products are appropriate for standard PC cards (PCMCMIA) where laptops are used and mobile roaming needs to be supported. This roaming is supported on Aironet's patented ARLAN Microcellular Architecture. The typical supported cell range is up to 500 feet indoors (line-of-sight) and up to 1000 feet outdoors (line-of-sight),

**Pricing**
The ARLAN 600 series prices (http://www.nortech.com/aironet/airprice.htm) run from approximately $2000 US for an access point to $700 US for a client adapter card. The ARLAN 2000 series costs approximately $3900 US. The ARLAN 3000 series prices run from approximately $1900 US for an access point to approximately $700 US for a client adapter card. The ARLAN 3000 series prices (see Section 4.1.2.4.1) run from approximately $1900 US for an access point to approximately $700 US for a client adapter card.

Web Site: http://www.nortech.com/aironet/introair.htm

#### 4.1.2.4.2 Lucent Technologies WaveLAN Solutions

Bell Laboratories and Lucent Technologies Wireless Communications and Networking Division (WCND) developed WaveLAN wireless LAN products (available in Canada). These products operate in the 2.4 GHz ISM band using DSSS and FHSS technologies.

WaveLAN product series offers:

- Client adapter cards (PCMCIA, ISA, IEEE 802.11 compliant PC Card and ISA cards)
- Ethernet and Serial Converter (Ethernet 10Base-T (RJ45) and RS232 serial port to WaveLAN wireless IEEE 802.11 converter)
- Access Points
- Wireless Bridges for Ethernet networks
- Fixed Wireless Point-to-Point Links
- Point-to-Point Bridges

The WaveLAN IEEE 802.11 compliant radios (DSSS) provide 2 Mbps data rate in a range of approximately 400m indoors and 16 km outdoors. The WaveLAN high-speed point-to-point bridges (FHSS) provide line-of-sight distances of over 32 km in a single hop and data rate of 3.2 Mbps and user data throughput of 2.2 Mbps.

**Pricing**
WaveLAN/IEEE PC cards are available for approximately $300 US, and the WaveLAN/IEEE ISA cards are available for $400 US.

Web site: http://www.wavelan.com and http://www.lucent.com

#### 4.1.2.4.3 Proxim Inc.

Proxim has developed several spread spectrum technologies at both the 900 MHz ISM and 2.4 GHz ISM bands (not yet certified for use in Canada).

Recommended by PC Magazine as one of the preferred vendors of peer-to-peer connection, the RangeLAN1 operates at 242 kbps up to 500 feet indoors, and the RangeLAN2 operates at 1.6 Mbps (2.4 GHz) for 300 to 500 feet indoors, and up to 800 feet outdoors.

The RangeLAN1 interfaces via an ISA, MCA, or PCMCIA card to the computer and via the parallel port adapter. The RangeLAN2 supports ISA, PCMCIA and a direct connection to the Ethernet.

Their 2.4 GHz kit is expandable to 10 nodes . The ISA card has a street price of $150 US, the ISA-bus Land adapter is $149 US list price, and the PC Card LAN adapter runs at $199 US street price. The cordless Ethernet bridge is $399 and the V.90 modem is $299. It is reported to provide effective Internet sharing at 1.6 Mbps throughput and 150 foot range indoors.

**RangeLAN2 Products**
Proxim's RangeLAN2 products are FCC certified FHSS technology and comply with the OpenAir® wireless LAN standard set by the Wireless LAN Interoperability Forum (WLI Forum). They operate at 1.6 Mbps and offer 15 independent channels (number of channels dependent on individual country regulations) for a total network bandwidth of approximately 24 Mbps.

**RangeLAN802 Products**
Proxim's RangeLAN802 products are similar to the RangeLAN2 products except that they operate at 2 Mbps, and offer IEEE 802.11 compatibility

Proxim's web site offers and interactive network designer to help a user design the appropriate wireless LAN using their products (http://www.proxim.com/products/designer/index.shtml).

Web Site: http://www.proxim.com/

#### 4.1.2.4.4 Wi-Lan Inc.

Wi-Lan utilizes two proprietary flavors of spread spectrum technology that it as patented called Multi-code Direct Sequence Spread Spectrum and Wide-Band Orthogonal Frequency Division Multiplexing which allows multiple simultaneous radio transmissions. It is Industry Canada as well as FCC approved. Their products include wireless Ethernet bridges and wireless modems.

**Wireless Bridges**
Wi-Lan's wireless bridges use a proprietary version of DSSS at the 900 MHz and 2.4 GHz ISM bands. Depending on the model, data rates will go from 1.5 Mbps to 4.5 Mbps. The 2.4 GHz models support multichannel access. If three channels are used for the highest data rate product, then the largest supported throughput is approximately 13.5 Mbps.

**Wireless Modems**
Wi-Lan's wireless modems use a proprietary version of DSSS at the 900 MHz and 2.4 GHz ISM bands as well, with some models having the capability to switch to FHSS in high interference situations. They interface to the PC via a standard RS232 port, offering synchronous as well as asynchronous modes of operation. Depending on the model and mode of operation (DSSS vs. FHSS), baud rates vary from 9600 bps to 38,400 bps.

Wi-LAN's solution has various coverage areas and ranges depending on network configuration, installation set-up, and equipment.

Web Site: http://www.wi-lan.com

#### 4.1.2.5 Future Considerations

Wireless LAN development in the 5 GHz and 17 GHz range has been in the research and development stage. A draft standard [has been created and named the ETSI HiperLan family. Both bands are unlicensed in the US (5 GHz is unlicensed in Canada) and offer throughputs of approximately 20 Mbps in a range of 10 to 100 m.

#### 4.1.2.6 Case Studies

##### 4.1.2.6.1 Lucent Technologies and OCRI Implementation for the Ottawa Area School Boards

The Ottawa Centre for Research and Innovation (OCRI) has been working with school boards in the Ottawa area to implement wireless LANs within the schools. They have set up a pilot project using 2 Mbps WaveLAN technology by Lucent Technologies. The original project was to cover all 4 school boards in the area, however, because of the demand for a 10 Mbps technology, they are currently undertaking a pilot study with the 2 Mbps technology at St. Patrick's and Confederation high schools until the 10 Mbps technology is available.

Each computer can be equipped for wireless communication at about $450 CDN per unit. Access points are called 'Wavepoints'. Confederation high school will be covered with 3 wavepoints at approximately $1500 per point.

The application is not Internet. The network is set-up for specific activities such as science labs, and administration applications for activities such as monitoring students in the hallways.

One of the incentives for Confederation to go wireless is that the school is changing locations in the near future. With the wireless technology, they would not lose their investment.

##### 4.1.2.6.2 Proxim Framingham State College (US) Case Study

Framingham State College in Massachusetts, US is a teacher's college that has partnered with Proxim to offer their students a remote Internet access laptop program on campus. They configured the network as a pilot for other colleges and K-12 institutions to learn about and experience the wireless LAN technology.

"Each student is loaned a laptop equipped with a Proxim RangeLAN2 PC card, creating a durable, light-weight, long-lasting mobile education tool. Framingham State College has installed 10 Proxim RangeLAN2 access points, providing for enough coverage in and around many campus buildings spanning 17.6 acres. By using a laptop and a RangeLAN2 PC card, college students can access the college network and the Internet from the library, most classroom buildings, some of the resident halls, and even the front lawn of the campus."[6]

#### 4.1.2.6.3 Wi-Lan and the Peel District School Board Case Study

On April 7, 1999, the Peel District School Board announced the purchase of 50 wireless Ethernet bridges from Wi-LAN Inc.

The Peel District School Board is one of Canada's largest public school systems covering 776 km and serving 104,000 students. Wi-LAN is providing the capability to supply students with high-speed bandwidth for Internet access and the ability to access centrally located on-live databases containing encyclopedias, newspapers and magazines.

The Peel District School Board begun their search when they recognized the needed a less expensive means to connect their typical school network of 150-450 computers and up to 2,200 students. In their search, they identified that the cost of a T1 service for the region's secondary schools would have required a $20,000/month budget. As a final alternative, the board decided to pursue spectrum technologies.

Wi-LAN helped create this high-speed backbone by using a series of towers and antennas on the roof of each school. They erected a 75' tower on the top of the central 'hub' at Robert J. Lee Public school that enabled students from the more distant Mayfield Public School to connect wirelessly to the Internet. At 3 Mbps, twice the speed of a T1 line, the Wi-LAN bridges will also benefit teachers and administrators by enabling access to leading edge service as future applications such as videoconferencing and distance learning. [15]

## 4.2 Infrared Technologies

### 4.2.1 Overview

Infrared light is grouped under a term called optical communications – which means using light waves for wireless communications. It is somewhere between the visible light spectrum and

[6] http://www.proxim.com/about/pressroom/1999pr/framing.shtml

microwaves (see Figure 2-1). A line-of-sight is required between transmitters and receivers since infrared signals will not penetrate walls or windows.

Although the line-of-sight requirement may dissuade usage, infrared has an inherent advantage in that it is not susceptible to interference such as the spread spectrum techniques. All new notebook computers are equipped with infrared interfaces for direct connection to desktop PCs, docking stations, and wired LANs.

Infrared technologies can be categorized into two basic implementations: directed and nondirected. Directed infrared is capable of transmitting data several miles because it uses a tightly focused beam. This is ideal for bridging LANs between schools where line-of-sight can be ensured. However, the performance can be affected by weather conditions.

In nondirected infrared systems, the beam is not as focused and bounces off objects such as walls and ceilings. There are two subcategories: line-of-sight or diffuse. Line-of-sight generally offers better performance. Diffuse links rely on bouncing off reflective surfaces. However, because energy is lost, performance of line-of-sight systems tend to exceed that of diffuse links.

### 4.2.2 Bandwidth and Licensing

Infrared light is not regulated, with the exception of power limitations for eye safety. Bandwidths of up to 10 Mbps for Ethernet and 16 Mbps for token ring are not uncommon for up to 6 km for interbuilding type communications. The performance potential is much larger and has been demonstrated in systems at 50 Mbps and 100 Mbps.

### 4.2.3 Product Providers and Costs

#### 4.2.3.1 Infrared Communications Systems Inc.

Infrared Communications Systems Inc. has a product line called SkyNet[7] that delivers infrared networking.

The SkyNet 500 and 600 series provide Fast Ethernet and Fiber Distributed Data Interface (FDDI) at 100 Mbps 'last-mile' connectivity. Equipment can be purchased and configured for distance from 250m to 4 km.

[7] SkyNet is a trademark of Infrared Communications Systems Inc.

The SkyNet 800 series provides 155 Mbps connectivity for Asynchronous Transfer Mode (ATM) networks. Equipment can be purchased and configured for distance from 250m to 4 km.

Both of these series are for line-of-sight operations.

Web Site: http://infraredsystems.net/start.htm

## 4.3 LMCS Technologies

### 4.3.1 Overview

Local Multipoint Communication System (LMCS) is a type of wireless cable system that requires line-of-sight (antennas must be in 'line-of-sight' to each other). It is also known as a 'last-mile' technology. The construction, installation, and maintenance costs of the last section of the communication link from a central office to the subscriber accounts for a large percentage of the total costs[8]. LMCS offers a means to significantly reduce these costs.

Local Multipoint Communication System (LMCS) (known as Local Multipoint Distribution Services (LMDS) in the US) is classified as a 'local' or 'last-mile' broadband, fixed wireless service and operates in the 28 GHz spectrum transmitting voice, video, and data. It is 'local' in that the typical cell sizes are 5 km due to the relatively short distance that the signal can travel. It is also known as a 'dense urban' service as result. It is a type of 'last-mile' technology that may be a viable alternative for schools.

The costs for obtaining licenses and setting up base stations can be substantial. These costs are incurred by the Service provider. The incremental investment is in the subscriber additions – the customer premises equipment (CPE) at the school. These costs include the installation of a receiving antenna, Network Interface Card (NIC) that is often comprised of a signal down and upconverter and all of the appropriate protocol stacks for network communications.

Some of the advantages of LMCS are its ability to combine multi-media delivery and multiple access. LMCS technology can translate 1 GHz of spectrum into approximately 1 Gbps of digital pipeline. Assuming 1 GHz of spectrum, an application or cell that is entirely video could provide up to 288 channels of digital broadcast quality and on-demand services.

This pipeline can be divided between the forward link and return link in accordance with the applications or requirements of the school or schools within a 2.5-5 km radius of the base station.

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[8] Some reports claim that it is almost 50% of the total capital outlay. See "Wireless Local Loop Technology: Motivations and Alternatives", Alan Jacobsen, Diva Communications. http://www.diva.com/wpwll.htm.

This radius from the base station is called a 'cell'. LMCS uses a technique similar to cellular in reusing spectrum This means that the same set a frequencies can be reused in each cell. An example LMCS application could provide a forward link throughput of approximately 100 Mbps and a return link of 1.544 Mbps (the equivalent of one T1). Within the cell, 9 different schools could each operate with a bandwidth of 100 Mbps in the forward link and 1.544 Mbps in the return link.

One of the concerns about LMCS is its operation under various weather conditions. Microwaves react with water molecules. For this reason, weather can cause interference issues with LMDS/LMCS because of their short wave-length and for this reason the antenna size and power requirements need to be carefully designed and correctly deployed for the city and area in which the unit is being installed. The potential weather related technical issues with LMCS have been overcome through engineering design and installation.

### 4.3.2 Bandwidth and Licensing

Industry Canada has allocated two (2) 500 MHz blocks in 66 designated areas covering 193 communities for LMCS licensing at 28 GHz.

Industry Canada collects service fees from service providers offering LMCS at the 28 GHz. These annual service fees are set at $0.50 per household per 500 MHz block. So for instance, the city of Toronto has a service fee of $807,202 versus Ottawa that has a service fee of $169,147.

Due to changes in the market place, Industry Canada has considered opening competition up in the 24 GHz, 28 GHz, and 38 GHz bands for exclusive (one player only) and share (shared resources among competing players) spectrum resources. These resources will be closely aligned to the US. Thus, the remaining service areas and blocks will be auctioned off in the second quarter of 1999. Auctioned licenses will have a 10 year term.

There are three companies in Canada of have been successful in obtaining LMCS licenses[9]:

- Digital Vision Communications (MaxLink Communications Inc.)
- CellularVision Canada Ltd. (Western International Communications Ltd.)
- RegionalVision Ltd.

Each one of these companies is operating in a separate area (e.g. they are not competing directly). A list of the areas in which they are operating can be found on the Industry Canada web site http:// spectrum.ic.gc.ca/lmcs/engdoc/success.html .

[9] http://spectrum.ic.gc.ca/lmcs/engdoc/success.html

### 4.3.3 Service Providers and Cost

This section provides an overview of companies that currently posses LMCS licenses in Canada.

Since Canadian service providers are not yet offering commercially available systems, there is no officially available information on hardware or service costs..

There are three service providers across Canada currently holding the LMCS licenses: RegionalVision Inc., Western International Communications Ltd., and MaxLink Communications Inc. These companies were not in commercial service at the time of writing this paper. As much information as possible in the time frame has been gathered and presented here. It is advised however that these service providers are consulted of the availability of commercial service in the geographical region of interest.

#### 4.3.3.1 RegionalVision Inc.

RegionalVision Inc. is one of three service providers currently holding LMCS licenses. Contact information is provided below.

Contact Information:
RegionalVision Inc.
10th Floor, 50 Burnhamthorpe Road West
Mississauga, ON L5B 3C2

#### 4.3.3.2 Western International Communications Ltd. (CellularVision Canada Ltd.)

Western International Communications Ltd. (CellularVision Canada Ltd.) is the second of three service providers currently holding LMCS licenses.

CellularVision recently sold its US LMDS spectrum and subscription television service to focus solely on Internet networking solutions. It offers a service in the US called 'SPEED' (http://www.cellularvision.com/) based on spread spectrum LMDS technology. This service uses a normal telephone line for the return link and spectrum technology in the forward link. The antenna is a 6 inch antenna which can be positioned in front of any window.

Equipment:
Speed Internal PCI Modem
Speedus.com Antenna
Coaxial cable between the modem and antenna
Speedus.com software
Netscape Navigator Speedus Edition

The residential monthly charge is $60 US per month for 6000 minutes (100 hours) of high-speed access, and unlimited dial-up access, 1 email address, 10 MB of personal web space. The modem is $350 and the on-site installation for the modem and antenna is $150 US. It is currently only available in New York city boroughs of Manhattan, Brooklyn, and Queens.

The business account charge is $85 US per month which includes unlimited high speed downstream, a dial-up account, 1 email address (additional email addresses are $3.00 per email address).

There is a 'SPEED enterprise service for networks for a network installation as opposed to a 'one-off' or single computer access. This service can be accessed for a monthly charge of $85 US, $25 US per screen and requires an Enterprise Router for $2000 US, and router installation for $500 US.

WIC is a subsidiary of CellularVision and will begin building its network in Toronto in 1997. This service or test network was deployed using 5 km cells. WIC has ordered $450 Million work of equipment from Newbridge and Alcatel.

WIC is focusing on point-to-point dedicated access, interactive multimedia service, and broadcast digital entertainment programming.

Contact Information:
CellularVision Canada Ltd.
1960-505 Burrard St.
Vancouver, B.C. V7X 1M6

WIC Connexus
Fax: (416) 232-9800

#### 4.3.3.3 Maxlink Communications Inc. (Digital Vision Communications)

MaxLink Communications Inc. is the third service provider that won a 28 GHz LMCS license for two (2) 500 MHz blocks of spectrum in 33 cities. Currently they have a test network set-up in Ottawa, Ontario and Hull, Quebec consisting of 3 cells. Each cell's base station serves approximately 2.5 km, with each cell divided into 4 sectors with the same frequencies reused in each sector. Fiber is run between the base stations and tied in with the Public Switched Telephone Network (PSTN).

MaxLink has the following technology and service partners:

- Newbridge Networks Corporation who provide the overall LMCS and ATM network elements

- Vienna Systems who provide hardware, software, and technical support for Voice over IP
- Sun Microsystems who provide equipment and services supporting Internet and Intranet applications
- UUNet who provide Internet connectivity

With these partners, MaxLink will provide the following services: Standard Telephony, IP Telephony, High Speed Internet Access, Web Video, Security Surveillance, Television, Multimedia conferencing.

At the time of writing this paper, MaxLink could not provide pricing, however it is anticipated that the customer premise equipment could cost under $4000 depending on the configuration. Service pricing will be available by early Q3 of 1999.

MaxLink has ordered $400 Million worth of equipment from Newbridge.

Contact Information:
MaxLink Communications Inc.
145 King Street West
Suite #202
Toronto, Ontario
M5H 1J8

Tel: (416) 777-9192 x.230
Toll Free: 1-888-388-9444
Fax: (416) 777-9011
http://www.maxlink.net

## 4.4 MCS Technologies

### 4.4.1 Overview

Multipoint Communication System (MCS) is also known as Multichannel Multipoint Distribution Service (MMDS) in the US. It is known as a suburban/rural technology and is similar to LMCS, but is able to travel longer distances (approximately 15-20 km radius) and has been commercially available for over 6 years.

Historically MCS has been used for one-way distribution of video services. In rural Manitoba, it was used for high schools to provide video teaching with audio conferencing back to the instructor. However, as it became increasingly important to offer rural populations more options with respect to education, resourcing issues arose and a mandate came about to replicate classrooms with interactive 2-way audio and video conferencing across 34 locations.

The Manitoba Education Research Learning Information Network (MERLIN) is an organization within the Manitoba Education and Training whose mandate is to coordinate the use of technology for learning across Manitoba. MERLIN placed a request for proposal (RFP) and chose MCS as most closely meeting its requirements. The MCS they implemented comes in two basic configurations:

- Analog; and
- Hybrid analog and digital.

The analog configurations often have a digital carrier for data. The hybrid analog and digital configurations final distribution is via analog.

#### 4.4.2 Bandwidth and Licensing

There are a number of advantages of the digital configuration with respect to bandwidth. Each analog video channel requires 6 MHz of bandwidth. MERLIN's digital system provides a 5:1 compression which means that they can then have 1.544 Mbps for video, and 512 kbps for data. The technology and network configuration can be evolved to be entirely data, however, the capital costs for data transmission equipment are significantly higher than for analog transmission equipment.

Most of the MCS applications in Manitoba are for point-to-point links to the hubsite. MCS is a licensed band with 16 channels supported at 2.5 GHz.

#### 4.4.3 Service Providers and Costs

MCS implementation requires an engineering firm with a background in similar implementations. Feasibility studies need to be completed for the links in their respective geographical areas. Towers need to be built and network loading conditions accessed. Most of the problems experienced with MCS may be in the integration with existing networks.

A list of potential service providers or systems integrators that can provide MCS services can be obtained from MERLIN at info@merlin.mb.ca, or itv@merlin.mb.ca.

## 4.5 Fixed Access Systems (3.4 GHz, 18-22 GHz)

### 4.5.1 Overview

Fixed Access Systems (microwave licensed technologies) are suitable for point-to-point links where a link needs to be provided directly between two schools.

Multipoint connections can also be supported however this requires the appropriate network bridges and can be very difficult to debug due to the distances involved.

The equipment costs of wireless links of this type can vary from under $3,000 US to $10,000 US depending on performance. Network bridges, with ethernet or token ring interfaces are typically in the $5,000 to $8,000 US range.

In this scenario, no network service provider. Sometimes, the license may be held by the network integrator or supplier of the equipment.

### 4.5.2 Bandwidth

Typically the bandwidth that can be provided with microwave licensed technologies is on the order of 5 Mbps to 10 Mbps.

### 4.5.3 Equipment Providers and Costs

#### 4.5.3.1 Microwave Radio Corporation

MRC has various products using an interface to a digital line. Operating 22 GHz in a licensed band, it operates up to 8.4 Mbps and 10 miles.

#### 4.5.3.2 Motorola (Wireless Data Group)

There are three products supported by the Motorola Wireless Data Group that may be suitable for point-to-point communications: Altair, VistaPoint, and VistaPoint LR. With an interface over an Ethernet Link, these 18 GHz microwave products provide 5.3 Mbps of data. VistaPoint operates at a distance of 500 feet, and the VistaPoint LR operates less than 4,000 feet.

One of the advantages with this product is that Motorola holds the license and grants use to user, preventing the user from having to get involved with yearly licensing requirements. In fact, in the US Motorola has obtained licenses for 18 GHz operation in metropolitan areas with populations over 30,000.

### 4.6 Subscriber Radio Systems (1.4 GHz)

The intention of Subscriber Radio Systems was to provide cost efficient deployment of voice telephony systems in rural areas. Subscriber Radio System basic network components are similar to those of LMCS or cellular networks. The Network Operations and switching centre interfaces with the PSTN on one side, and base station controllers on the other. The base station controllers carry some of the network operations responsibilities and control access to the various base stations typically over land line connections. The base stations provide connectivity access to schools, or individual homes.

Generally, subscriber radio systems that are intended for rural voice telephony do not have suitable bandwidths to support Internet or multi-media traffic.

## 5 ABBREVIATIONS

| | |
|---|---|
| AMPS | Advanced Mobile Phone Service |
| ATM | Asynchronous Transfer Mode |
| CDMA | Code Division Multiple Access |
| CDN | Canadian |
| CPE | Customer Premise Equipment |
| DSSS | Direct Sequence Spread Spectrum |
| EISA | Extended Industry Standard Architecture |
| FDDI | Fiber Distributed Data Interface |
| GHz | Giga Hertz ($10^9$ Hertz) |
| IEEE | Institute of Electrical and Electronic Engineering |
| ISA | Industry Standard Architecture |
| ISM | Industrial, Scientific and Medical |
| ISM band | Industrial, Scientific and Medical band |
| ISO | International Standards Organization |
| ISP | Internet Service Provider |
| IP | Internet Protocol |
| LAN | Local Area Network |
| LMCS | Local Multipoint Communication System |
| LMDS | Local Multipoint Distribution Service |
| Mbps | Mega bits per second ($10^6$ bps) |
| MCA | Micro Channel Architecture |
| MCS | Multipoint Communication System |
| MERLIN | Manitoba Education Research Learning Information Network |
| MMDS | Multipoint Multichannel Distribution Service |
| NIC | Network Interface Card |
| OCRI | Ottawa Centre for Research and Innovation |
| PCI | Peripheral Component Interface |
| PCMCIA | Personal Computer Memory Card International Association |
| PSTN | Public Switched Telephone Network |
| RF | Radio Frequency |
| RFP | Request For Proposal |
| TBD | To Be Determined indicating information not attainable at the time of writing this paper |
| US | United States |
| WAN | Wide Area Network |

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