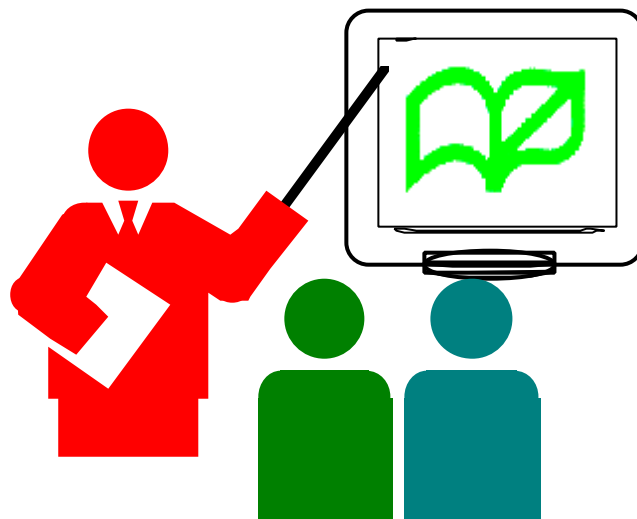


Information Technology in Education Project

Wireless Networking in Schools

(RM04/2002)



Information Technology Education Resource Centre
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Education Department
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1. Background

At present, all schools have their local area network (LAN) in place for teaching and learning. However, in many occasions, the school LAN only covers a limited number of classrooms and special rooms. Many schools may need a wireless network as an ad hoc connection for some school activities. This ad hoc wireless networking should support the conduction of teaching, learning, or testing sessions at places beyond the reach of the current school network, such as the school hall or playground.

This document will introduce and compare the basic technologies and characteristics of different kinds of wireless networking and the related end-user devices.

2. Overview of Wireless Technologies

In general, the following technologies can be used for wireless networking implementation.

Wireless Local Area Network (WLAN) technology

This refers to the use of mobile networking devices as an extension/replacement of wired LAN. The data transmission rate of WLAN is relatively fast, comparable to the wired network. Details of the WLAN technology are given in **Annex A.1**. The industrial standards of the WLAN technology, including the de facto standard of IEEE 802.11b, are also discussed there.

Wireless Personal Area Network (WPAN) technology

WPAN refers to point-to-point communication in a confined short-range area without using cable. In a WPAN, users can use portable devices such as PDA (Personal Digital Assistant) and mobile phone to access the network resources or to exchange data. The data transfer rate and distance coverage for WPAN application is relatively low. Cable replacement technologies, such as *Bluetooth* or *Infrared*, are commonly used in WPAN. More details on these cable replacement technologies can be found in **Annex A.2**.

Wireless Wide Area Network (WWAN) technology

The network coverage of WWAN is the greatest but the data transfer rate for WWAN is slower than WLAN and WPAN. In WWAN, end-user devices are often connected through public networks. For mobile WAN technologies, *GSM* (Global System for Mobile Communications) and *GPRS* (General Packet Radio Service) are currently available in Hong Kong. *3G* (3rd Generation Mobile Service) currently implemented in Japan, may be available in Hong Kong sometime later. More details on WWAN are given in **Annex A.3**.




3. Comparison of wireless technologies

The general features of different kinds of wireless technologies are summarized below:

Table 1 Comparison of different kinds of wireless technologies

	WLAN	WPAN (Bluetooth)	WPAN (Infrared)	WWAN
Maximum Distance Covered	100 m	10 m	1 m	Miles
Peak Data Transfer Rate (bps)	- 11 M (802.11b / HomeRF) - 54 M (802.11a)	721 K	- 115 K for Serial Infrared (SIR) - 4 M for Fast Infrared (FIR)	- 14.4 K (GSM) - 114 K (GPRS) - 384K to 2M (3G)
Cost	- Startup Cost: High - Recurrent Cost: Low	- Startup Cost: High/Low <input checked="" type="checkbox"/> - Recurrent Cost: Low	- Startup Cost: Low - Recurrent Cost: Low	- Startup Cost: Low (Internet access) - Recurrent Cost: High
Hardware availability	- High popularity (802.11) - Limited Popularity (HomeRF 1.0) - Not Available (802.11a / HomeRF 2.0)	Limited popularity	High popularity	- High popularity (GSM) - Limited popularity (GPRS) - Not Available (3G)
Devices Supported	Desktop PC, Notebook computer, WinCE PDA	Notebook computer, PDA (Palm & WinCE)	Notebook computer, PDA (Palm & WinCE)	Notebook computer, PDA (Palm & WinCE)
Maximum concurrent connections	Range from 5 to 30 users per access point, depending on premises condition	7 slaves per master	1 to 1 connection	Unlimited (Internet access) Or Depends on modem pool size (GSM) Or Service providers' provision (GPRS)
Communication	Point-to-Point and Point- to-multipoint	Point-to-Point and Point- to-multipoint	Point to point	Point-to-Point and Point- to-multipoint
Application	LAN	WPAN / Cable replacement	WPAN / Cable replacement	WAN

For devices with built-in Bluetooth features to support communication in one-to-one fashion, the setup cost would be low. But for multipoint network setup with devices not having built-in Bluetooth feature, the setup cost would be high.

<p>Example products</p>	<p>3Com AirConnect Access Point, PCMCIA card, PCI card</p> 	 <p>3Com® Wireless Bluetooth™ PC Card</p>	<p>Infrared-port on notebook computer, PDA or mobile phone</p>	 <p>Novatel Wireless PC Card for GSM /GPRS</p>
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In considering different kinds of wireless technologies, the following factors are important for choosing the right technology:

Data Transfer Rate

WLAN bears the highest data transfer rate among the three technologies. The peak data transfer rate of WLAN (11Mbps for 802.11b) is comparable to the 10Mbps wired Ethernet network, though slower than the more common 100Mbps Fast Ethernet network.

Distance Coverage

WWAN spreads the widest area as it is WAN in nature. WPAN has the shortest distance coverage among three technologies.

Cost

The startup costs for WLAN and multipoint Bluetooth are relatively high due to the requirements in installing a number of access points and client connection devices. In WWAN, the recurrent cost would be high for using the public network instead of local network. For WWAN for some remote site, extra startup cost may be involved. Please refer to **Annex A.3.3** for further information.

Popularity

For WLAN, 802.11b is the de facto standard with lots of products and solutions available on the market. For WPAN, Bluetooth is growing rapidly, while IrDA infrared has already been supported and implemented in most computer devices. For WWAN, GSM is the common default network in Hong Kong while GPRS is becoming popular.

There are a number of WLAN standards on the market. Features of three major technologies are given below:

Table 2.0 Comparison of different WLAN technologies

	802.11a	802.11b	HomeRF
Peak Data Transfer Rate (bps)	54 M	11 M	- 1.6 M (HomeRF 1.0) - 10 M (HomeRF 2.0)
Frequency	5 GHz	2.4 GHz	2.4 GHz
Maximum Distance Covered [☒]	100 m	100 m	100 m
Hardware Availability	Products start to be released	High popularity	- Low Popularity (HomeRF 1.0) - Products start to be released (HomeRF 2.0)
Voice Channel supported	No	No	Yes
Major Vendors Backing	Proxim	Apple, Dell, Cisco, Intel, Lucent, Proxim	Proxim, Motorola, Siemens, Intel

4. Comparison of wireless user-end devices

To access the wireless network, schools may use either notebook computer or PDA as the end-user devices. Both devices are designed for mobile computing and can be implemented with the different wireless technologies. Schools may choose between the notebook computer solution and the PDA solution according to their requirements.

(a) Notebook

Wireless networked notebook computers work similar to the networked desktop or notebook computers. For instance, it can run client-server applications, thin client applications as well as web-based applications. Implementation of notebook computers with different wireless technologies is summarized below:

WLAN	<ul style="list-style-type: none"> ● Install each notebook computer with a WLAN PC card. ● Connect the WLAN Access Point to the school network.
WPAN	<ul style="list-style-type: none"> ● Some notebook computers come with built-in Bluetooth ports. If there is no built-in Bluetooth port, install the notebook computer with a Bluetooth PC card. ● Connect the Bluetooth hubs to the school network for multipoint configuration.
WWAN	<ul style="list-style-type: none"> ● Install the GPRS/GSM PC card to the notebook computer. ● Subscribe a mobile data service from a service provider.

[☒] To achieve the maximum distance coverage, the data transfer rate would drop accordingly.

(b) PDA

There are two major types of PDAs, namely Pocket PC and Palm PDA. Pocket PCs are PDAs using Window CE operating system while Palm PDAs are PDAs using Palm operating system. Both can be used as the end-user devices. At present, the local network access capability of Pocket PC is considered higher than that of Palm PDA. Hence, Pocket PC would be more suitable for wireless network implementation.[☐]

Pocket PC connects to most servers using standard Internet protocols like web browsing, e-mail and file exchange services. It can also run a terminal client software to connect to a terminal server. Implementation of Pocket PC with different wireless technologies is summarized below:

WLAN	<ul style="list-style-type: none"> ● Install each Pocket PC with a WLAN PC card. ● Connect the WLAN Access Point to the school network.
WPAN	<ul style="list-style-type: none"> ● Some PDAs come with built-in Bluetooth ports. If there is no built-in Bluetooth port, install the PDA with a Bluetooth PC card. ● Connect the Bluetooth hubs to the school network for multipoint configuration.
WWAN	<ul style="list-style-type: none"> ● Install the GPRS/GSM PC card to the Pocket PC. ● Subscribe a mobile data service from a service provider.

4.1 Considerations in choosing the device

Apparently, the main differences between notebook computer and Pocket PC are on the size and weight. However, the following factors are equally worthy to be considered:

(I) Applications availability, development and support

Similar to the desktop computer, notebook computer can run most application packages. Also, different desktop operating systems can be implemented and run on the notebook computer.

In Pocket PC, the applications will be limited and must be specially designed for the Windows CE system. Desktop applications cannot be run in the PDAs unless they have Window-CE versions. Comparing with the abundant software titles in Windows 9x/NT/2000 platforms, there are much less software titles in Windows CE platform.

Most notebook computers are running on the Windows platform. There are many professionals on the market who can carry out Windows applications development and support. However, as PDA is running on specific platforms, it may be less easy to get skilled persons for applications development and support.

[☐] For the new version of Windows CE, Windows CE .net, there is built-in support for wireless technology such as Bluetooth and 802.11.

(II) Battery Life

It is necessary for the end-user devices to have sufficient power supply in the course of operation. Additional battery packs may be needed for the notebook computers to allow continuous operation. The battery of notebook computer is replaceable. However, the battery of PDA usually cannot be replaced, except some latest Pocket PC models. The PDA has to use the PDA cradle for battery charging.

(III) Display

The small display of PDA may limit its applications. For instance, most of the Internet web pages are not designed for Windows CE. Using PDA may need to scroll extensively, up or down and left or right to view the whole screen. This may also happen when PDA is used as a thin client to access the resulting display from terminal server. However, some applications which are specially designed for PDA, would cater for the small display problem.

(IV) Input

Notebook computer comes with a keyboard or a trackball as input device. However, PDA relies on point-and-click action as input. Point-and-click is an appropriate input method for small devices but it may not be good for fast text input. Also, the input method may limit the applications of PDA. For example, in a test/examination session running on PDA, multiple-choice type questions would be preferred rather than the essay type questions.

5. Recommendation

Wireless technologies

If schools want to use a wireless network ***to access the network resources on their school LAN within their premises***, WLAN technologies would be more appropriate. Among the WLAN standards, 802.11b would be a favorable choice because:

- *High bandwidth* (max. 11Mbps) – the 802.11b products provide similar data transfer rate as wired Ethernet.
- *Long distance coverage* (maximum 100 meter) – the signal can penetrate walls or other obstacles to extend the network coverage across classrooms.
- *Popular* – there are plenty of 802.11b products on the market, as 802.11b is the de facto standard of WLAN technology.
- *Cost* – the prices of 802.11b products are dropping as more vendors are entering into the market.
- *Upgradability* – with a large user base of 802.11b products, the future wireless products or standards would cater for the upgradability and compatibility with the 802.11b devices.

End-user devices

In choosing the end-user devices, PDA could be considered if portability and simple operation are the major concerns. However, it is necessary to have sufficient vendors and personnel to provide development and on-going support of the PDA applications.

On the other hand, to attain the highest compatibility with the existing systems, notebook solution should be the choice. The applications and network resources can be easily run on the notebook computers.

Emerging technologies

The above recommendation should be reviewed from time to time because of the fast development in wireless technologies. Some emerging technologies are in the pipeline, for instance, the new DECT (**D**igital **E**nhanced **C**ordless **T**elecommunications) with longer distance and 20Mbps data transfer rate, and the Advanced Infrared with support range of 10 meters and 4Mbps data transfer rate.

Also, the IEEE 802.11g wireless standard may be approved in the beginning of 2003. 802.11g will be backward compatible with 802.11b. The 802.11g products will operate at 2.4GHz frequency at data transfer rate of 54Mbps. Success of the new technologies will depend on the adoption of technologies by hardware manufacturers, however.

Annex A – Wireless Technologies

A.1 Wireless LAN (WLAN)

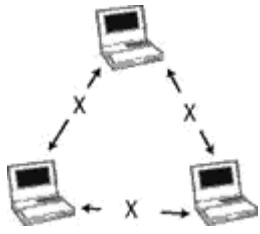
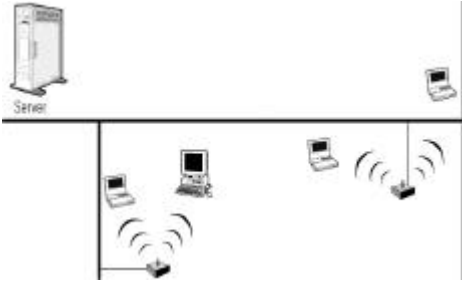
Wireless LAN (WLAN) is a network technology that allows the connection of computers in local area network without wire or cable. It can be implemented as an extension to, or as an alternative for, a wired LAN within a premise. The technology may use electromagnetic waves such as radio frequency, microwave or infrared for communications; either point-to-point connection or multiple points access with roaming.

A.1.1 Wireless LAN Configuration

A typical WLAN consists of the following components:

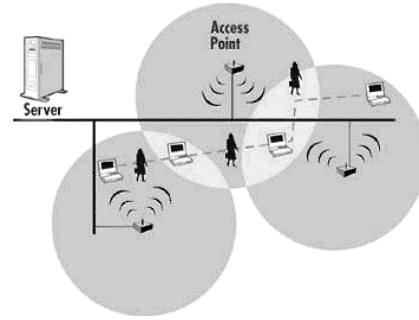
- **Access point:** it is both a transmitting and a receiving device for wireless networking. You can imagine that it is the 'hub' for wireless devices. A single access point can support several computers each with a Wireless LAN adapter. It can be connected to the wired network through a fixed location, e.g. a data node point.
- **WLAN adapter:** it is implemented as PC card in notebook computers, or use ISA or PCI adapters in desktop computers, or add-on card in the hand-held devices. The nature of the wireless connection is transparent to the network operating system. Two computers with WLAN adapter can communicate with each other.

Here are the general configurations of WLAN:

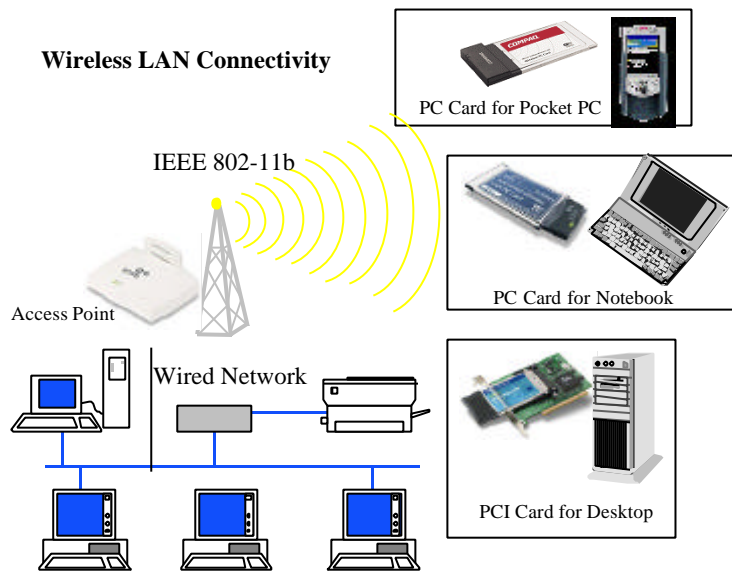
<p>Peer-to-Peer</p> <p>This is the most basic configuration. Two or more PCs equipped with wireless adapter cards can set up an independent network</p>	
<p>Extension of wired LAN</p> <p>Installation of access point can extend or replace a wired LAN.</p>	

Roaming

In this setup, clients can move seamlessly among a cluster of access points. The coverage of network can be extended.



Sources of diagrams: Wireless LAN Alliance (WLANA)



A.1.2 Wireless Technology Standards

There are 3 types of Wireless LAN using radio frequency as transmit media. They are evolved from the 802.11 wireless LAN specifications.


(1) IEEE 802.11b

802.11b is currently the de facto standard of WLAN. The market for 802.11b wireless LAN is getting bigger. There are many 802.11b devices for desktop, notebooks computer and PDA on the market. The popularity drives the price of most 802.11b products down to a reasonable level. The price of the Access point is now ranging from HKD\$2,000 to \$4,000 and the adapter is around HKD\$800 to \$1200.

Here are the features of 802.11b:

<i>Frequency:</i>	2.4GHz
<i>Data Transfer Rate *:</i>	Maximum 11 Mbps
<i>Estimated Distance Coverage:</i>	Open areas – 305m Closed areas – 76 to 122 m

**As interference or signal weakening may occur, the data transfer rate would drop at fixed intervals to 5.5Mbps, then 2Mbps and finally down to 1Mbps. So most devices would support four different data transfer rates, namely 11Mbps, 5.5Mbps, 2Mbps and 1Mbps, depending on the environment.*

You may find the Wireless Fidelity (Wi-Fi) logo  on most 802.11b products. The Wi-Fi interoperability certification from the Wireless Ethernet Compatibility Alliance (WECA) guarantees interoperability and compatibility between different 802.11b products. Hence, products with Wi-Fi logo should work with each other.

(2) HomeRF

HomeRF is the standard used in the home networking environment. It is a kind of hybrid standard including 6 voice channels based on the Digital Enhanced Cordless Telecommunications (DECT) standard and the 802.11 wireless-Ethernet specification for data communications. So HomeRF is implemented in a number of home appliances, including cordless phone, home wireless networking devices.

The current available HomeRF 1.0 products support a data transfer rate at 1.6Mbps. Later version such as the HomeRF 2.0 is capable of supporting 10Mbps. It is expected that future HomeRF version will support 20Mbps. It should be noted that HomeRF and Wi-Fi are not compatible with each other. Also, they would not interfere with each other in the same premises.

Here are the features of HomeRF 2.0:

<i>Frequency:</i>	2.4GHz
<i>Data Transfer Rate *:</i>	Maximum 10 Mbps
<i>Distance Coverage:</i>	Similar to 802.11b

**As interference or signal weakening may occur, the data transfer rate of the devices would drop back to 5Mbps, then 1.6Mbps and finally down to 0.8Mbps. So usually the devices would support 10Mbps, 5Mbps, 1.6Mbps and 0.8Mbps, depending on the environment.*

At present, the prices of HomeRF 1.0 products are lower than those of Wi-Fi. As more 802.11b products are being released with lower price tag, the price of HomeRF and 802.11b could be comparable in near future.

(3) IEEE 802.11a

IEEE 802.11a may become the next generation of enterprise-class wireless LAN technology. It supports peak 54 Mbps data transfer rate. Since it operates in the 5-GHz band, there will be less interference issues comparing with the 2.4 GHz products. However, at 5GHz operating frequency, 802.11a is only licensed for usage in North America at this moment.

For 802.11a and 802.11b products, their signals travel in different frequency bands, so that there will be no interfere among them. However, the two technologies are not interoperable.

Here are the features of 802.11a:

<i>Frequency:</i>	5 GHz
<i>Data transfer Rate *:</i>	Maximum 54 Mbps
<i>Distance Coverage:</i>	Will cover significantly shorter distance than 802.11b. Maybe from 6 to 25 m.

**As interference or signal weakening may occur, the data transfer rate of the devices would drop back to lower rate like 48Mbps, 36Mbps, 24Mbps, 12Mbps and 6Mbps.*

For interoperability, Wi-Fi5 would be the name for interoperability certification from the Wireless Ethernet Compatibility Alliance (WECA) for 802.11a products, just like Wi-Fi in 802.11b.

At this moment, the 802.11a products have just started to ship by companies such as Proxim and Atheros. It is expected that more 802.11a products will come out soon.

A.1.3 Considerations on 802.11b implementation

- In choosing the 802.11b products without the Wi-Fi certification, schools are recommended to consult the contractors/vendors for the compatibility of the devices between different brands.
- The environment is one of the factors may affect the data transfer rate and distance coverage of wireless network. Also, the overall throughput of the network depends on the number of concurrent network connections as well as the number of access points. Hence, school is advised to have a field test of the system to evaluate the performance.
- Attention should be paid when the wireless network spreads across more than one classroom. Tests should be conducted to review the interference of the wireless devices between classrooms. On the other hand, the accessibility of clients between classrooms has to be tested. Also, the requirement of roaming should be identified.

A.2 Wireless Personal Area Network (WPAN) technologies

WPAN is a confined short-range network. The applications usually involve "cable replacement" technologies on a point-to-point networking basis. Users could use their mobile devices like PDA, notebook computer or even mobile phone to access the resources on network. For instance, they can print a document from the PDA using the network printer without attaching to the network. Also, they may make use of the network to synchronize data between the mobile devices.

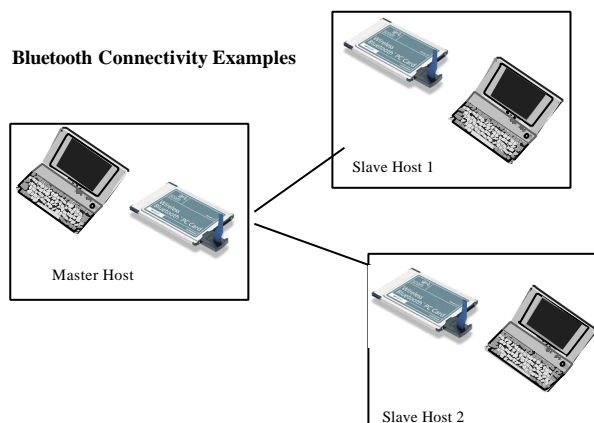
A.2.1 Bluetooth

The Bluetooth wireless technology is a "cable replacement" design that supports (i) point-to-point, and (ii) point-to-multipoint connections. It aims for the "personal device" market with small, less expensive and battery supplied devices like mobile phone and PDA without using IP addresses.

For multipoint configuration, up to seven 'slave' devices can be set to communicate with a 'master' radio in one device. Bluetooth has two levels of defined power; a lower power level that covers a shorter personal area within a room, and a higher power level that can cover a medium range, such as home area. Here is an overview of Bluetooth specifications:

<i>Frequency:</i>	2.4 GHz
<i>Data transfer Rate:</i>	Maximum 721 Kbps for Bluetooth 1.0 Maximum 10Mbps for the proposed Bluetooth 2.0
<i>Distance Coverage:</i>	10 m

The current version of Bluetooth, 1.0, operates at about 700Kbps. The next generation, Bluetooth 2.0, will be operated at speed up to 10Mbps. However, currently there is not much detail on Bluetooth 2.0.



Technically, Bluetooth technology can be implemented as a wireless LAN using Bluetooth access point. However, Bluetooth technology is somewhat limited for this kind of application, primarily because it was not designed for LAN.

The Bluetooth specification will serve as the foundation for IEEE 802.15.1 WPAN standard. The IEEE 802.15.1 will be fully compatible with Bluetooth v1.1. Such arrangement will promote the use of Bluetooth technology. It is expected that there will be more Bluetooth products to be released.

A.2.2 Infrared

Similar to Bluetooth technology, infrared is another point-to-point communication design which is mostly used in cable replacement. Infrared applications have already incorporated into our daily life, such as TV remote control, wireless mouse and keyboard. A number of mobile phone devices also come with built-in infrared ports.

Many PDAs like Palm and Pocket PC are using this technology to exchange data between hosts. In notebook computer, infrared port is almost a mandatory feature. A standard known as IrDA (Infrared Data Association) is available on the market for devices to communicate using infrared light pulses. IrDA is so popular that most devices support the standard. For IrDA-1.1, the maximum speed is 115Kbps in SIR (Serial InfraRed) mode. In addition, the speed can be increased up to 4Mbps in FIR (Fast InfraRed) mode and 16Mbps in VFIR (Very Fast InfraRed) mode.

However, due to the following constraints, infrared technology may not be suitable as a wireless solution for a classroom environment:

- short distance range (1 meter)
- requirement of line-of-sight operation
- narrow working angle cone (30 degree) between devices
- single user mode operation

A.3 Wireless Wide Area Network (WWAN) technologies

Apart from the above-mentioned technologies, we can use PDAs or notebook computers for wireless connection through the public mobile network. In this case, communications between devices go through the public mobile network rather than the school local network.

This approach may be more suitable for accessing the remote servers, such as web servers on Internet. For accessing the network resources in schools, modem pool in school or special arrangement from mobile service providers may be required.

A.3.1 WWAN standards

Currently, GSM (Global System for Mobile Communications) is the most widely used public mobile network in Hong Kong. The peak transfer rate of GSM network is 14.4 Kbps. For the new GPRS (General Packet Radio Service) network, or 2.5G network,

the maximum data transfer rate is 114 Kbps[☒]. In the coming 3G mobile network (3rd Generation), the network will support 384Kbps for users in motion and 2Mbps for stationary users. However, it should be noted that the transmission rate in the mobile networks would depend on the provision of the mobile network service providers.

A.3.2 Features of WWAN

There are some special features of WWAN that are worth to be mentioned.

- *Internet ready (not applicable for GSM)*

GPRS and the future 3G network allow users to remain permanently connected to the network. This "always on" feature can help the users immediately access to the network. Such feature would not increase the phone bill since GPRS or 3G will charge the usage on data volume rather than on airtime.

- *Free from local network infrastructure*

For Internet access, WWAN will rely on the public mobile network. There is no requirement on school's own network. Hence, WWAN for Internet access can be implemented in school without a local area network.

- *Number of clients support*

In WLAN, the number of nodes to be supported per access point is limited. In WPAN technologies, it mainly supports the peer-to-peer mode of networking. For WWAN, there is virtually no limit on adding clients to accessing Internet via mobile network. The public mobile network can cater for large population of users. However, for remote accessing the school LAN resources, the number of users to be supported would depend on the size of the modem pool or service level of the public mobile network service providers.

- *Long data range*

Unlike WLAN and WPAN technologies, WWAN can be used anywhere in the city without limiting to the school areas. This is in fact the benefit of using WAN.

- *Service provider dependent*

The network performance would depend on the service level of the public mobile network service provider. School has nearly no control on the performance when comparing with the operation in a school LAN.

As the WWAN technology is still at the infant stage, the bandwidth, cost and availability of devices may not be ideal for LAN resources access. However, it could be a good alternative for Internet access in schools.

[☒] *Note: The 114Kbps rate of GPRS is difficult to achieve: all the 8 timeslots have to be allocated to a single user excluding the voice capability. In real situation, the mobile station hardware or client devices on the market can only support up to 4 timeslots, that is, 53.6 Kbps. In addition, as some bandwidths would be reserved for voice, the effective data transfer rate of GPRS ranges only from 20Kbps to 50Kbps.*

A.3.3 Cost factors for remote access setup in WWAN

	Method	Cost factors
GSM	Modem Pool (at school)	<ul style="list-style-type: none"> ● Modems and fixed phone lines installation and acquisition costs. ● Maintenance cost of modem pool plus monthly phone lines charge.
GPRS	GPRS connection <input type="checkbox"/> (at service provider)	<ul style="list-style-type: none"> ● Fixed connection cost linking the GPRS network to school LAN. ● Maintenance and service charge from GPRS service provider (e.g. network configuration and agent installation)

In GPRS network, special remote access services have to be provided by the mobile network service provider.