
Introduction to Computer Networking

Issued by

National Centre for Technology in Education (NCTE)



1.0 Introduction

This document includes information under the following main headings:

- Introduction to Networking
- Advantages of Networking
- Types of Networks
- Models of networking appropriate to schools
- NCTE recommendation to schools
- Some relevant terms.

For schools who require more background information relating to networking, other information links will be posted on the NCTE as required website at <http://www.ncte.ie/ICTAdviceSupport/AdviceSheets/>

1.1. Basic of Networking

A computer network consists of a collection of computers, printers and other equipment that is connected together so that they can communicate with each other (see Advice Sheet 17 on the ICT Planning for schools pack). Fig 1 gives an example of a network in a school comprising of a local area network or LAN connecting computers with each other, the internet, and various servers.

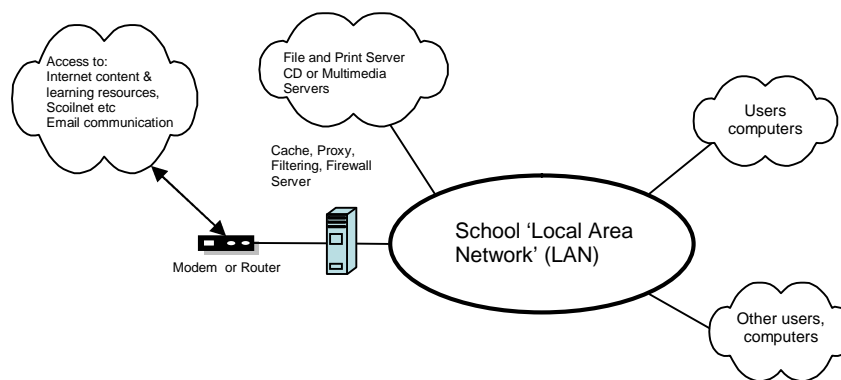


Fig 1: Representation of Network in a school.

Broadly speaking, there are two types of network configuration, peer-to-peer networks and client/server networks.

Peer-to-peer networks are more commonly implemented where less than ten computers are involved and where strict security is not necessary. All computers have the same status, hence the term 'peer', and they communicate with each other on an equal footing. Files, such as word processing or spreadsheet documents, can be shared across the network and all the computers on the network can share devices, such as printers or scanners, which are connected to any one computer.

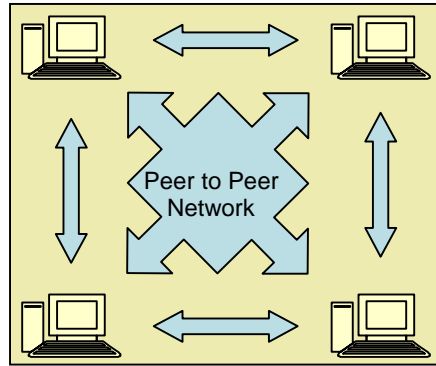


Fig 2: Peer to Peer Networking

Client/server networks are more suitable for larger networks. A central computer, or 'server', acts as the storage location for files and applications shared on the network. Usually the server is a higher than average performance computer. The server also controls the network access of the other computers which are referred to as the 'client' computers. Typically, teachers and students in a school will use the client computers for their work and only the network administrator (usually a designated staff member) will have access rights to the server.

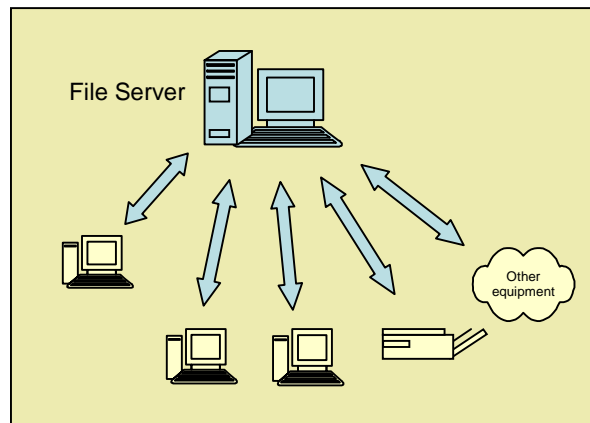


Fig 3: Client - Server Networking

Table 1 provides a summary comparison between Peer-to-Peer and Client/Server Networks.

Peer-to-Peer Networks vs Client/Server Networks	
Peer-to-Peer Networks	Client/Server Networks
• Easy to set up	• More difficult to set up
• Less expensive to install	• More expensive to install
• Can be implemented on a wide range of operating systems	• A variety of operating systems can be supported on the client computers, but the server needs to run an operating system that supports networking
• More time consuming to maintain the software being used (as computers must be managed individually)	• Less time consuming to maintain the software being used (as most of the maintenance is managed from the server)
• Very low levels of security supported or none at all. These can be very cumbersome to set up, depending on the operating system being used	• High levels of security are supported, all of which are controlled from the server. Such measures prevent the deletion of essential system files or the changing of settings
• Ideal for networks with less than 10 computers	• No limit to the number of computers that can be supported by the network
• Does not require a server	• Requires a server running a server operating system
• Demands a moderate level of skill to administer the network	• Demands that the network administrator has a high level of IT skills with a good working knowledge of a server operating system

Table 1: Peer-to-Peer Networks vs Client/Server Networks

Components of a Network

A computer network comprises the following components:

- A minimum of at least 2 computers
- Cables that connect the computers to each other, although wireless communication is becoming more common (see Advice Sheet 20 for more information)
- A network interface device on each computer (this is called a network interface card or NIC)
- A 'Switch' used to switch the data from one point to another. Hubs are outdated and are little used for new installations.
- Network operating system software

Structured Cabling

The two most popular types of structured network cabling are **twisted-pair** (also known as **10BaseT**) and **thin coax** (also known as **10Base2**). 10BaseT cabling looks like ordinary telephone wire, except that it has 8 wires inside instead of 4. Thin coax looks like the copper coaxial cabling that's often used to connect a Video Recorder to a TV.

10BaseT Cabling

When 10BaseT cabling is used, a strand of cabling is inserted between each computer and a hub. If you have 5 computers, you'll need 5 cables. Each cable cannot exceed 325 feet in length. Because the cables from all of the PCs converge at a common point, a 10BaseT network forms a **star configuration**.

Fig 4a shows a Cat5e cable, with a standard connector, known as an RJ-45 connector.

Fig 4b shows a standard Cat5e Wall Outlet socket which the cables are connected to.

Fig 4c shows a standard Cat5e Patch Panel Wall Outlet socket which is used to terminate the cables from various points in the school bank to a central point.

Fig 4d shows a wall mounted cabinet used to house and protect patch panel cables and connectors.



Fig 4a: Cat5e Cable and a close up of RJ-45 connector

Fig 4b: Cat5e Wall Outlets

Fig 4c: Cat5e Patch Panel

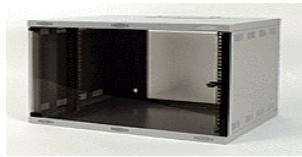


Fig4d: Wall Mounted Cabinet

10BaseT cabling is available in different grades or **categories**. Some grades, or "cats", are required for Fast Ethernet networks, while others are perfectly acceptable for standard 10Mbps networks--and less expensive, too. All new networks use a minimum of standard **unshielded twisted-pair (UTP) Category 5e** 10BaseT cabling because it offers a performance advantage over lower grades.

Network Interface Card (NIC)

A NIC (pronounced 'nick') is also known as a network card. It connects the computer to the cabling, which in turn links all of the computers on the network together. Each computer on a network must have a network card. Most modern network cards are 10/100 NICs and can operate at either 10Mbps or 100Mbps. Only NICs supporting a minimum of 100Mbps should be used in new installations schools. Computers with a wireless connection to a network also use a network card (see Advice Sheet 20 for more information on wireless networking).

Fig 5: Network Interface Cards (NICs)

Hub and Switch

A hub is a device used to connect a PC to the network. The function of a hub is to direct information around the network, facilitating communication between all connected devices. However in new installations switches should be used instead of hubs as they are more effective and provide better performance. A switch, which is often termed a 'smart hub'.

Switches and hubs are technologies or 'boxes' to which computers, printers, and other networking devices are connected. Switches are the more recent technology and the accepted way of building today's networks. With switching, each connection gets "dedicated bandwidth" and can operate at full speed. In contrast, a hub shares bandwidth across multiple connections such that activity from one PC or server can slow down the effective speed of other connections on the hub.

Now more affordable than ever, Dual-speed 10/100 autosensing switches are recommended for all school networks. Schools may want to consider upgrading any hub based networks with switches to improve network performance – ie speed of data on the network.

Fig 6a: An 8 port Hub

Fig 6b: 2 Examples of 24 port Switches

Wireless Networks

The term 'wireless network' refers to two or more computers communicating using standard network rules or protocols, but without the use of cabling to connect the computers together. Instead, the computers use wireless radio signals to send information from one to the other. A wireless local area network (WLAN) consists of two key components: an access point (also called a base station) and a wireless card. Information can be transmitted between these two components as long as they are fairly close together (up to 100 metres indoors or 350 metres outdoors).



Fig 7a: Wireless Access point or Wireless Basestation

Suppliers would need to visit the schools and conduct a site survey. This will determine the number of base stations you need and the best place(s) to locate them. A site survey will also enable each supplier to provide you with a detailed quote. It is important to contact a number of different suppliers as prices, equipment and opinions may vary. When the term 'wireless network' is used today, it usually refers to a wireless local area network or WLAN. A WLAN can be installed as the sole network in a school or building. However, it can also be used to extend an existing wired network to areas where wiring would be too difficult or too expensive to implement, or to areas located away from the main network or main building. Wireless networks can be configured to provide the same network functionality as wired networks, ranging from simple peer-to-peer configurations to large-scale networks accommodating hundreds of users.



Fig 7b: Desktop PC Wireless LAN card

Fig 7c: Laptop PC Wireless LAN card

What are the advantages and disadvantages of a Wireless LAN?

Wireless LANs have advantages and disadvantages when compared with wired LANs. A wireless LAN will make it simple to add or move workstations, and to install access points to provide connectivity in areas where it is difficult to lay cable. Temporary or semi-permanent buildings that are in range of an access point can be wirelessly connected to a LAN to give these buildings connectivity. Where computer labs are used in schools, the computers (laptops) could be put on a mobile cart and wheeled from classroom to classroom, providing they are in range of access points. Wired network points would be needed for each of the access points.

A WLAN has some specific advantages:

- It is easier to add or move workstations
- It is easier to provide connectivity in areas where it is difficult to lay cable
- Installation can be fast and easy and can eliminate the need to pull cable through walls and ceilings
- Access to the network can be from anywhere in the school within range of an access point
- Portable or semi-permanent buildings can be connected using a wireless LAN
- Where laptops are used, the 'computer suite' can be moved from classroom to classroom on mobile carts
- While the initial investment required for wireless LAN hardware can be similar to the cost of wired LAN hardware, installation expenses can be significantly lower
- Where a school is located on more than one site (such as on two sides of a road), it is possible with directional antennae, to avoid digging trenches under roads to connect the sites

- In historic buildings where traditional cabling would compromise the façade, a wireless LAN can avoid drilling holes in walls
- Long-term cost benefits can be found in dynamic environments requiring frequent moves and changes
- They allow the possibility of individual pupil allocation of wireless devices that move around the school with the pupil.

WLANs also have some disadvantages:

- As the number of computers using the network increases, the data transfer rate to each computer will decrease accordingly
- As standards change, it may be necessary to replace wireless cards and/or access points
- Lower wireless bandwidth means some applications such as video streaming will be more effective on a wired LAN
- Security is more difficult to guarantee, and requires configuration
- Devices will only operate at a limited distance from an access point, with the distance determined by the standard used and buildings and other obstacles between the access point and the user
- A wired LAN is most likely to be required to provide a backbone to the wireless LAN; a wireless LAN should be a supplement to a wired LAN and not a complete solution
- Long-term cost benefits are harder to achieve in static environments that require few moves and changes
- It is easier to make a wired network 'future proof' for high data transfer.

Wireless Network Components

There are certain parallels between the equipment used to build a WLAN and that used in a traditional wired LAN. Both networks require network interface cards or network adapter cards. A wireless LAN PC card, which contains an in-built antenna, is used to connect notebook computers to a wireless network. Usually, this is inserted into the relevant slot in the side of the notebook, but some may be internal to the notebook. Desktop computers can also connect to a wireless network if a wireless network card is inserted into one of its internal PCI slots.

In a wireless network, an 'access point' has a similar function to the hub in wired networks. It broadcasts and receives signals to and from the surrounding computers via their adapter card. It is also the point where a wireless network can be connected into an existing wired network.

The most obvious difference between wireless and wired networks, however, is that the latter uses some form of cable to connect computers together. A wireless network does not need cable to form a physical connection between computers.

Wireless Network Configurations

Wireless networks can be configured in an ad hoc/peer-to-peer arrangement or as a local area network.

Ad Hoc/Peer-to-Peer Configuration

This is the most basic wireless network configuration. It relies on the wireless network adapters installed in the computers that are communicating with each other. A computer within range of the transmitting computer can connect to it. However, if a number of computers are networked in this way, they must remain within range of each other. Even though this configuration has no real administration overhead, it should only be a consideration for very small installations.

Benefits and Educational Uses

The installation of cables is time consuming and expensive. The advantages of not doing so are apparent: the amount of work required and the time taken to complete it are significantly reduced the network is accessible in places where wiring would have been difficult or impossible with no cables linking computers together, cable-related faults and network downtime are minimised Where a wireless network is in place, teachers or students can have continuous access to the network, even as they move with their equipment from class to class.

The space over which a wireless network operates is not planar but spherical. Therefore, in a multi-level site, network access is available in rooms above or below the access point, without the need for additional infrastructure.

In a location within a school where network access is required occasionally, desktop computers fitted with wireless network cards can be placed on trolleys and moved from location to location. They can also be located in areas where group work is taking place. As they are connected to the network, documents and files can be shared, and access to the Internet is available, enhancing group project work.

As the range of the wireless network extends outside the building, students and teachers can use wireless devices to gather and record data outside, e.g., as part of a science experiment or individual performance data as part of a PE class.

Technical and Purchasing Considerations

Network interface cards for wireless networks are more expensive than their wired counterparts. The cost of the access points has also to be considered.

Wireless networks work at up to 54Mbps, whereas wired networks normally work at 100Mbps (Fast Ethernet). This data transmission rate is dependant on the number of users, the distance from the access point and the fabric of the building (metal structures in walls may have an impact). A wireless network will be noticeably slow when a group of users are transferring large files. This should be considered if multimedia applications are to be delivered over the network to a significant number of users.

As the range of the network may extend beyond the walls of the building, it can be accessed from outside. Consideration should be given to what security features the equipment provides to ensure that only valid users have access to the network and that data is protected.

1.2. Advantages of Networking schools

Speed.

Networks provide a very rapid method for sharing and transferring files. Without a network, files are shared by copying them to floppy disks, then carrying or sending the disks from one computer to another. This method of transferring files in this manner is very time-consuming.

Cost.

The network version of most software programs are available at considerable savings when compared to buying individually licensed copies. Besides monetary savings, sharing a program on a network allows for easier upgrading of the program. The changes have to be done only once, on the file server, instead of on all the individual workstations.

Centralized Software Management.

One of the greatest benefits of installing a network at a school is the fact that all of the software can be loaded on one computer (the file server). This eliminates that need to spend time and energy installing updates and tracking files on independent computers throughout the building.

Resource Sharing.

Sharing resources is another area in which a network exceeds stand-alone computers. Most schools cannot afford enough laser printers, fax machines, modems, scanners, and CD-ROM players for each computer. However, if these or similar peripherals are added to a network, they can be shared by many users.

Flexible Access.

School networks allow students to access their files from computers throughout the school. Students can begin an assignment in their classroom, save part of it on a public access area of the network, then go to the media center after school to finish their work. Students can also work cooperatively through the network.

Security.

Files and programs on a network can be designated as "copy inhibit," so that you do not have to worry about illegal copying of programs. Also, passwords can be established for specific directories to restrict access to authorized users.

Main challenges of installing a School Network

Costs

Although a network will generally save money over time, the initial costs can be substantial, and the installation may require the services of a technician.

Requires Administrative Time.

Proper maintenance of a network requires considerable time and expertise. Many schools have installed a network, only to find that they did not budget for the necessary administrative support.

File Server May Fail.

Although a file server is no more susceptible to failure than any other computer, when the file server "goes down," the entire network may come to a halt. When this happens, the entire school may lose access to necessary programs and files.

1.3. Networking Models: Towards a Networked School

This model shows a diagram of a networked school indicating the various types of networking models used. These include computer rooms, networked classrooms, networked specialist rooms for specific subjects. Mobile solutions are shown in the Resource room, the General Purpose room and Building # 2. Note: To improve readability only network points are shown, rather than cabling itself. Refer to Fig 8.

Main School Building

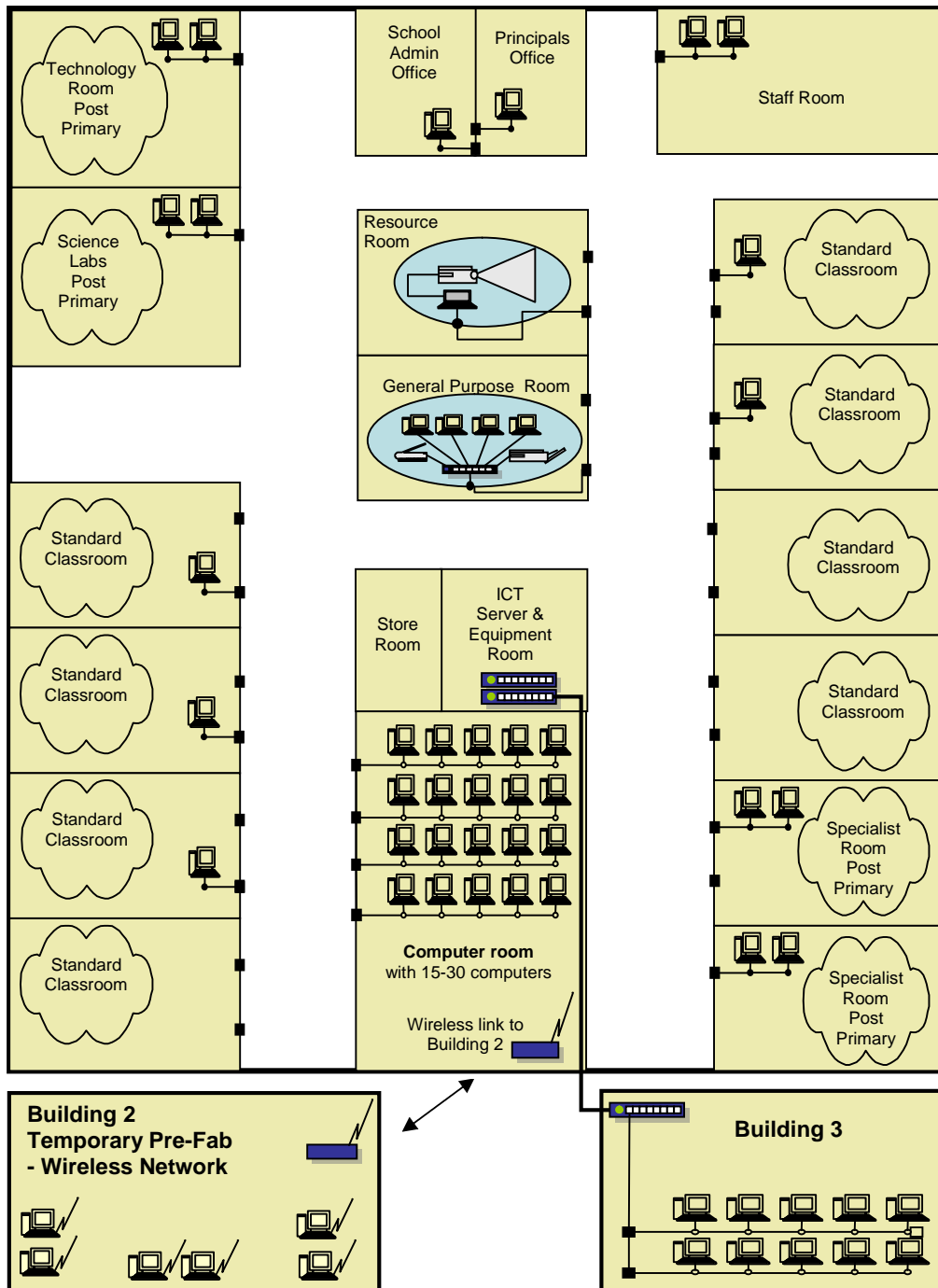


Fig 8: Representation of a Whole School Network Model

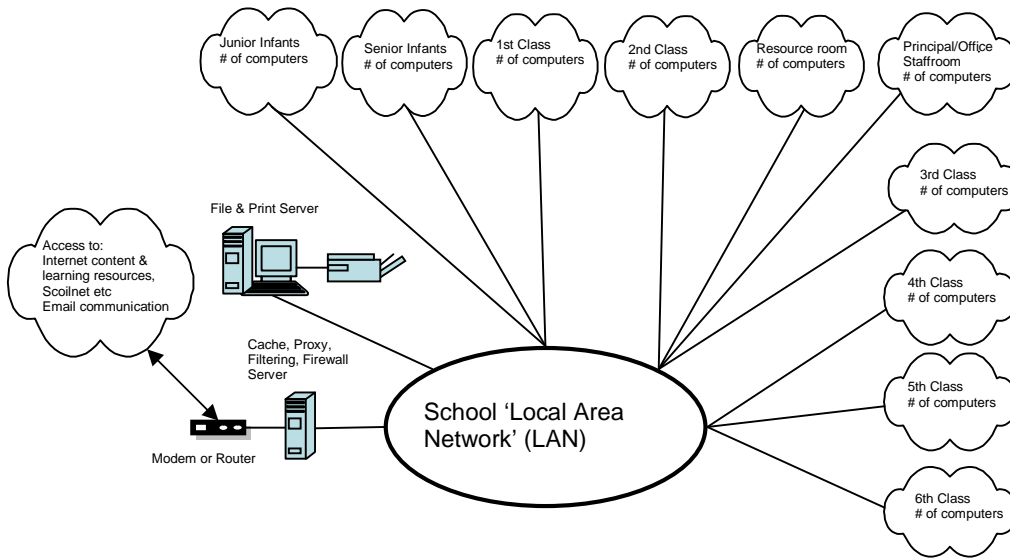


Fig 9: Typical Network Model for a Primary or Special school.

Figure 9 shows a model for a Primary or Special school. This includes connectivity to all classrooms back to a central network. The network connects to a File and Print Server. Internet access is handled via a modem or router, while internet Filtering , Proxy and Web Caching are all handled via a dedicated server.

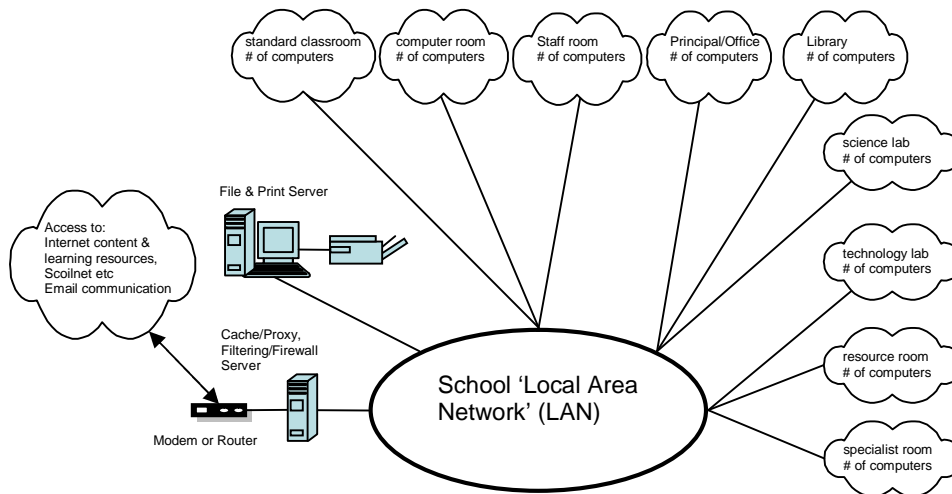


Fig 10: Typical Network Model for a Post Primary school.

Figure 10 shows a model for a Post Primary school. This includes connectivity to all classrooms back to a central network. The network connects to a File and Print Server. Internet access is handled via a modem or router, while internet Filtering , Proxy and Web Caching are all handled via a dedicated server.

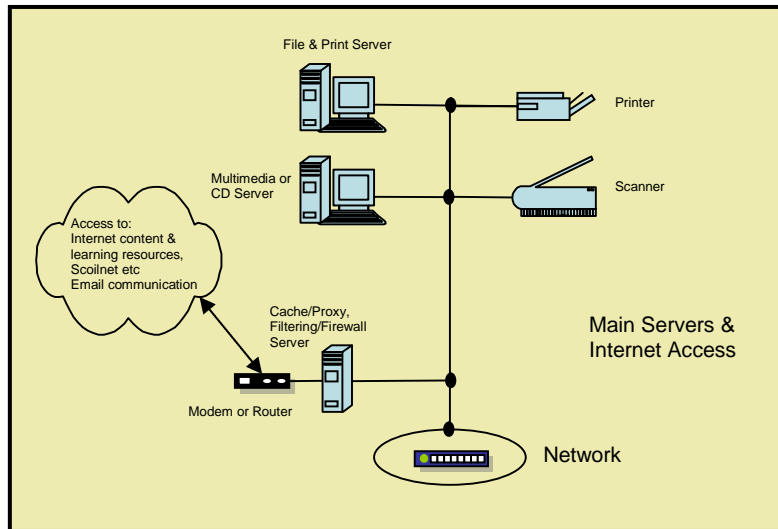


Fig 11: Server Functionality Model

Server Functionality

The network connects to a File and Print Server, Fig 11. The File server stores common files, The Print Server manages the different requests for printing. A Multimedia or CD server is used to store and distribute Multimedia - Sound, Video, Text , applications etc . Internet access is handled via a modem or router, while internet Filtering , Proxy and Web Caching are all handled via a dedicated server.

Example network configurations:

Models for Networking

First let's review some simple models where no networking exists and computers are used in standalone or ad-hoc mode. The following represent some simple models representing classrooms.

Model 1a: One computer in a classroom with its own private printer. It is recommended that schools with computers in this situation would network the classrooms in question as shown. Networking will more effectively make use of commonly shared resources such as file servers and school printers, internet , email etc. When a mobile PC or PC with projector is require in a room the network points are already present. In this scenario, there could be a single LAN-connected point for the teacher and an additional LAN connection to allow for a portable switch. Refer to diagram 12a

Model 1a

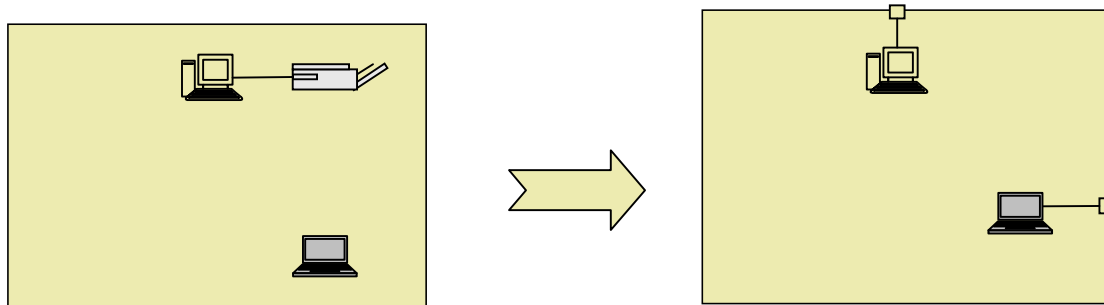


Fig 12a: From single PC to networked LAN Points

Model 1b: This scenario is similar to Model 1a, but where other equipment such as printers, scanners are used in ad-hoc and inefficient configuration. It is recommended that schools with computers in this situation would network the classrooms in question. Networking will more effectively make use of commonly shared resources such as scanners, printers, internet, email etc. In this scenario there may be a single LAN-connected point for the teacher and a limited number of LAN connection points throughout the room to allow students access to the school LAN. The connection points may be situated as required around the room depending upon class learning requirements and the availability of existing power outlets. Refer to diagram 12b

Model 1b:

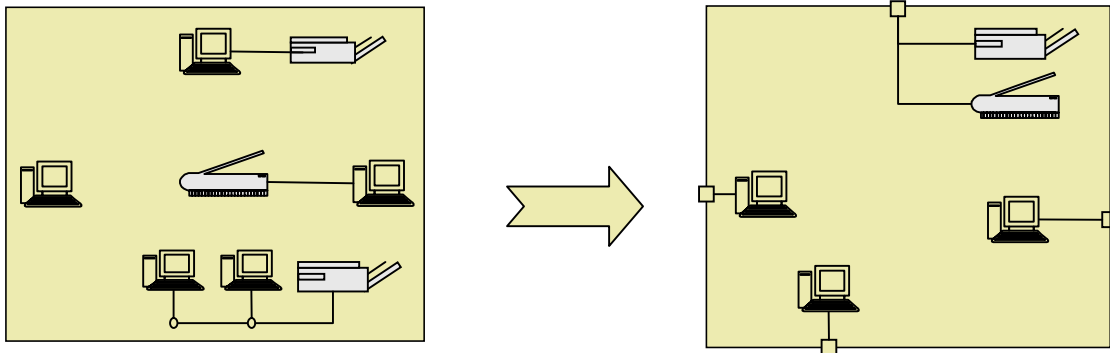


Fig 12b: Networking other commonly used equipment

Networked Computer Room

Model 1c: A non networked computer room or resource area with an ad-hoc and inefficient use of printers, scanners etc. Networking computer rooms is essential so that all PCs can access printers, the internet, email etc. This scenario represents a school computing room which can be timetabled for classes, and with each computer networked to the LAN. There may be a single LAN-connected presentation point for the teacher and LAN-connected computers throughout the classroom. Traditionally, ICT in Irish secondary schools has been concentrated in dedicated computer rooms. Primary schools have more varied deployment. From an administrative point of view, this setup is attractive. An entire class can be timetabled, avoiding problems of extra teachers for split classes. Refer to diagram 12c

Model 1c:

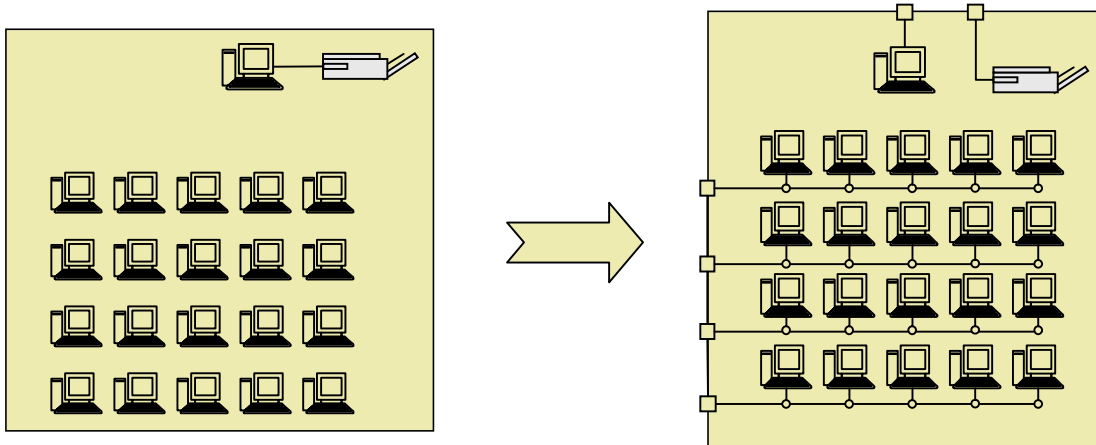


Fig 12c: Networked computer lab.

Media Bays (Ref Fig 13a)

Media bays, or data suites are clusters of perhaps four desktop computers, a scanner and a printer. Though self-sufficient in terms of peripherals, they would be connected to the main school network and have Internet access. This is one reason why they would be best sited in public areas around the school. These suites would be used by students in small groups or individually and could accommodate task-oriented activities and self-directed learning.

Advantages are easy access to staff and students alike, Utilise areas of school without losing classrooms
Public supervision

Disadvantages are Open access means security issues must be addressed .

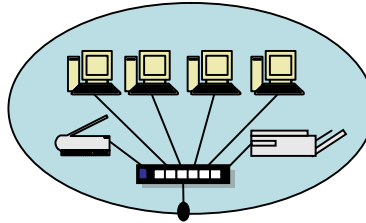


Fig 13a: Movable or mobile Media Bays

Laptop and data-projector (Ref Fig 13b)

A combination of laptop and data-projector is a highly effective teaching model where a teacher wants to provide the whole class with visual or multimedia content . It can be used in conjunction with an existing LAN point in the room for best effect.

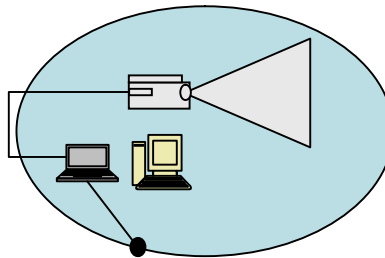


Fig 13b: Movable or mobile Laptop PC with Digital Projector

Wireless LAN (Ref Fig 13c)

This scenario has the capability to connect multiple computers to the school LAN without providing direct LAN connections. No LAN cabling is required for the classroom; instead all computers are radio linked to the LAN. Wireless LAN technology is relatively new and generally more expensive and more limited than cabled LANs. There is the potential, however, to save on extensive cabling work with this option.

Wireless connections allow a region to be connected to a network by radiowaves, which link a wireless card in the computer to a wireless access point. One should remember that the access point itself must be connected by cable to the main network.

Advantages

- Flexibility of machines - usually laptops - linked even if students break into small workgroups in different parts of room.
- Wireless networking means that large common areas such as canteens or libraries can be easily connected to the network.
- Less unplugging of cables into sockets reduces wear and tear

Disadvantages

- Wireless networking may prove much more expensive if wiring large numbers of machines close together.
- Wireless hubs data rates (typically 54 Mbps) are considerably less at present than their cable equivalent. Thus is unsuitable for high data volumes such as multimedia access by large numbers of machines.
- Manufacturers stated ranges of 100 - 300 metres is wildly optimistic. Ranges of less than 18 metres are not uncommon, Data rates drop off as distance increases.

While it is unlikely that wireless will replace data cables in the near future they do provide a flexibility that can be harnessed creatively.

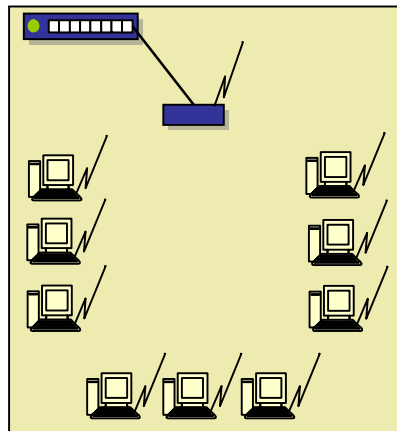


Fig 13c: Wireless LAN (WLAN)

2.1. Some Relevant Terms

MDF	Main Distribution Frame
IDF	Intermediate Distribution Frame
Broadband	Refers to a higher speed always on internet connection
Narrowband	Refers to speeds of up to 128kbps
Dial up	Refers to having to dial up the internet every time one goes online.
Always On	Refers to the nature of broadband, being 'always on' means a dial up is not required.
Download speed	The speed at which data is delivered to a school modem from the internet
Upload speed	The speed at which data is sent to the internet from a school modem.
ISP	Internet Service Provider
ISDN	Integrated Services Digital Network (64kbps single channel or 128kbps dual channel)
PSTN	Public Switched Telephone Network (refers to an ordinary telephone line)
ADSL	Asymmetric Digital Subscriber Loop
Mbps	Megabits per second (1,000,000 bits per second)
Kbps	Kilobits per second (1,000 bits per second)
Ethernet	Ethernet is a standard for transferring data over networks.
USB	Universal Serial Bus
Modem	A simple device used to access the internet
Router	A more technically advanced device used to access the internet