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Telecommunication Interconnection Services-Linking Local and Wide Area Information Systems

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The bandwidth requirements for emerging information system applications such as client/server transaction processing, image and graphics transmission as well as distributed database systems are very different from those used in earlier applications. These modern applications all process large volumes of data, transmit intermittent high speed bursts and are intolerant of long delays. To satisfy the requirements of these applications, the capacity management system for local and wide area interconnection services must offer access to high bandwidth on demand, direct connectivity to all other points in the network as well as consumption only of bandwidth actually needed. There are a variety of network services available from the Telecommunication Networking Service Providers (Telcos) which can be used to fill these rolls in different situations. This paper addresses the various advantages and disadvantages, costs and benefits as well as performance and operational characteristics of the various interconnection services necessary to support modern information system applications.

1 Introduction

In recent years both local and wide area networks have been characterized by rapid changes in their underlying technology as well as the scope and variety of information system applications that they have been designed to support.

Local Area Networks (LANs) have been dominated by Ethernet and Token Ring systems for the underlying architectures. Further, very widespread use has been made of bridges and routers for interconnection while hubs, switches and new wiring technologies have revolutionised departmental LAN systems. Substantial development has occurred at the upper layers of the LAN architecture with systems such as TCP/IP (together with FTP, TELNET, NFS and SNMP), Novell/Netware and Windows NT now being commonplace.

Wide Area Networks (WANs) also have been subject to great changes. It was not too long ago when 9600 bps links interconnecting host and terminal clusters were considered to be a moderately high speed and 64 Kbps an expensive upper limit. Nowadays, 64 Kbps is only a very basic speed. 100 Mbps LANs running 100 BASE-T and 100 VGany-LAN protocols, 100 Mbps FDDI LAN interconnection systems and now 155 Mbps ATM systems as a basis for multimedia application communication are all in use or planned. Bandwidth needs are expanding much faster than the capacity of Telcos to meet them. Within the next few years a standard corporate desktop workstation is likely to offer 100 Mbps data transfer rates and will run NT Windows or some other icon-driven interface along with the heavy bandwidth demands associated with multimedia applications. Today's public networks would be hard pushed to meet these requirements.

Thus any considerations in the interconnection of local and wide area networks has to take these changing technologies and application requirements into consideration. In the past, LAN interconnections were often only required for the purposes of exchanging electronic mail - an information system application which only places very moderate demands upon the interconnecting network. Nowadays with distributed server and modern client/server architectures, it is quite acceptable for the interconnecting network to have to support on-line real time colour graphics, multimedia and voice applications. This places high demands upon the speed and reliability of the interconnecting network.

The bandwidth requirements for these interconnections often varies greatly with time and it is necessary that the interconnecting network be cost effective. For example it would be most inefficient to use a dedicated 2 Mbps interconnecting link when the application only required such a capacity for 30 minutes per day. Thus flexible bandwidth allocation systems have become imperative in order to meet today's competitive requirements.

It has been generally accepted that Digital Data Services (DDS) are suitable for dedicated LAN-to-LAN interconnection but the time varying and bursty nature of traffic now makes this option less attractive. On the other hand, Packet Switching Services suffer from speed limitations as well as difficulties in budgeting monthly time and volume charges.

Frame Relay is now starting to supersede Digital Data and Packet Switching Services. It is a new option designed to meet time varying bandwidth requirements. However DDS will continue to be most effective where high volumes of data are transmitted on a regular basis, where the continuity of connection is important, or where point-to-point services are also required.

ISDN is seen as complementary to Digital Data, Packet Switching and related services although in a number of situations many of these services overlap. ISDN's strength lies in the support for applications which require high volume data transfer with short holding times. However the volume related tariffs are tied to trunk-call charges and, as such, suffer from similar budgeting problems for network managers as does Packet Switching.

Figure 1 shows where these various services lie in the bandwidth utilization/line speed spectrum covering both switched and dedicated services (Note that the line speed axis is a logarithmic one). It can be seen that overlap with other services does exist and in some situations it may be difficult to choose between the alternatives. In the following section each of these services are discussed in further detail.

2 Digital Data Network Services

There are three types of services in this category. Most Telcos offer conventional Digital Data Service (DDS) that provides a managed network of point-to-point and multi-drop services at speeds ranging from 2400 bps to 128 Kbps [Diginet, 1995]. Secondly, the Wideband DDS is also a managed network offering point-to-point connections in multiples (1 - 30) of 64 Kbps - often referred to as Fractional T1 service. Thirdly the Megalink Service is an unmanaged network offering point-to-point 2 Mbps connections.

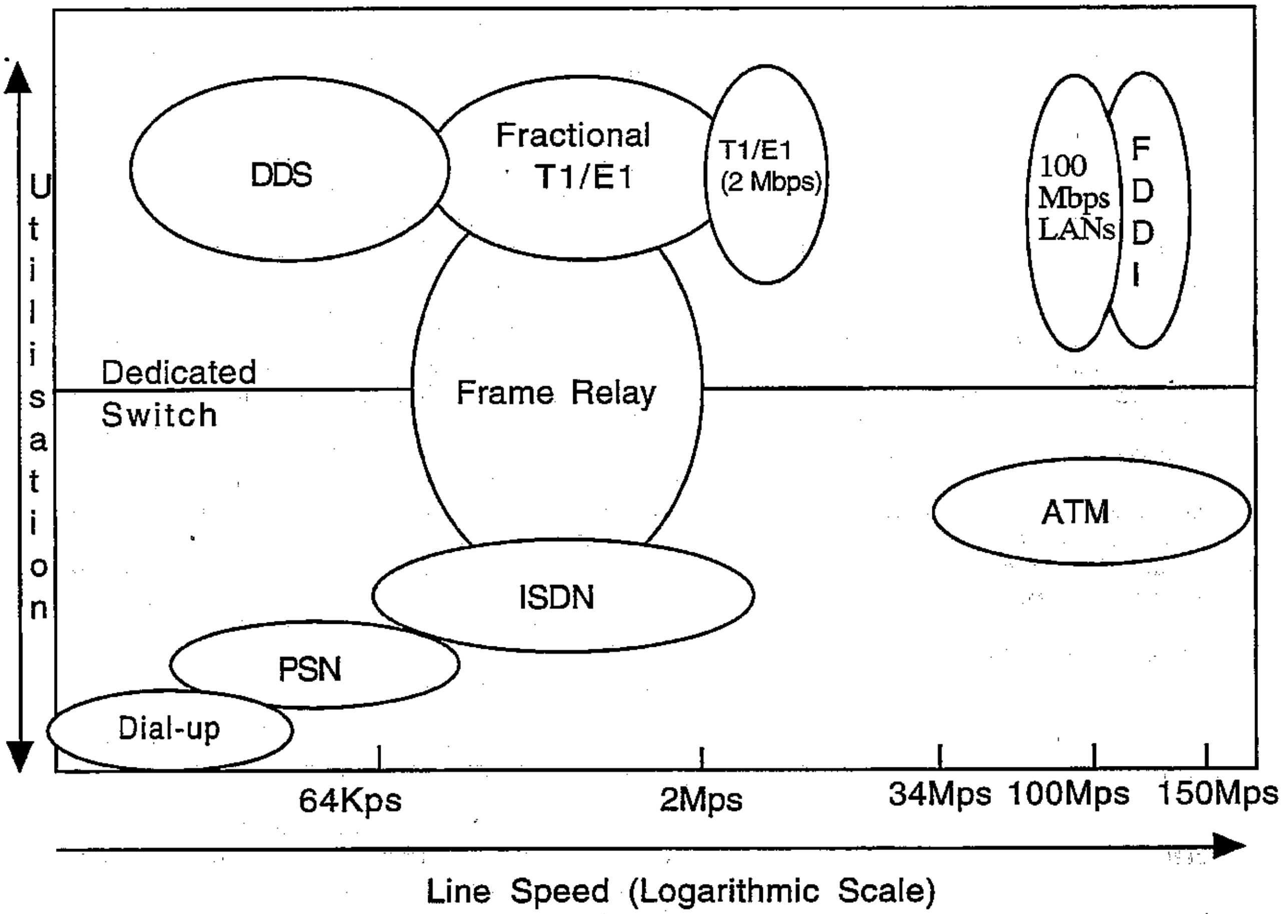

Figure 1 Positioning of Local and Wide Area Network Interconnection Services

The key characteristic of all of these three types of DDS is dedicated connection, which for certain applications, is desirable while for others it is not. DDS are excellent for private networks where the traffic can be managed over a 24 hour period. In general the inflexibility of bandwidth allocation associated with the DDS services has encouraged the use Frame Relay services.

DDS point-to-point links have been used most satisfactorily for many years although it is also fair to note that the high end of the multiple 64 Kbps spectrum has been extremely expensive and this has discouraged a number of companies from moving more quickly into the implementation of distributed applications. At the lower end of the spectrum 64 Kbps links have been used by some companies where reasonable data transfer volumes have justified the cost. Alternatively X.25 packet switching, and more recently, ISDN links at a similar speed often turned out to be expensive because of the significant connection and volume charges.

Today it is simply becoming too expensive to provide for the maximum bandwidth demands on a continuous basis. This requirement for a more cost effective elastic bandwidth allocation system has led to the development of Frame Relay to be discussed in a later section.

The interconnections to the DDS for both point-to-point and multipoint connections are shown in Figure 2.

The respective advantages and disadvantages are as follows:

Advantages

* Existing network service with virtually world-wide coverage
* Can be used for point-to-point and multi-point service at virtually any desired speed
* Managed network with excellent reconfiguration facilities
* Supports multiplexed services (eg LAN-to-LAN data along with voice and other multimedia services)

Disadvantages

* High cost for dedicated circuits for which overall utilization is often very low
* DDS is based upon Layer 1 architectures - all supporting protocols must be provided on an end-to-end basis
* All end point interface speeds must be the same

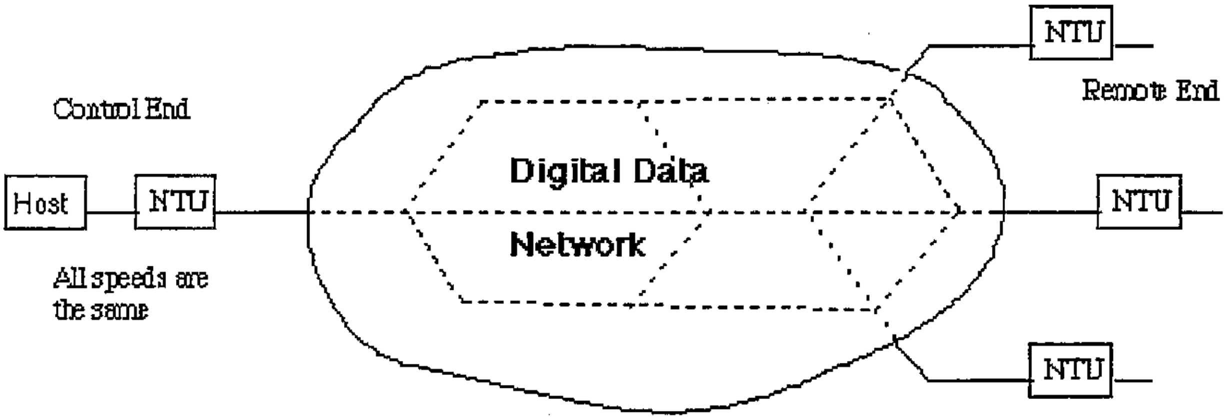

Figure 2 Equipment Interconnection to the Digital Data Network

3 Packet Switching

Packet Switching is a highly efficient, reliable and flexible method of transmitting data. Most communication resulting from information system applications consists of short bursts of data with intervening spaces which are often of longer duration than the data bursts. Packet Switching takes advantage of this by interleaving (multiplexing) bursts of data from many different users so that maximum use can be made of the communications links. This interleaving is achieved by assembling the bursts of data into packets, each containing address and control information as well as the users' data. These packets are then switched between users, hence the term "Packet Switching". The process is strictly one of "Statistical Time Division Multiplexing" (STDM) and there are many similarities between a Packet Switching Network (PSN) and a private STDM network.

Packets are assembled and disassembled either by the subscriber's equipment, or by a Packet Assembly/Disassembly (PAD) facility which forms part of the PSN interface. In either case, the process is almost instantaneous and data is transmitted as an uninterrupted stream.

The widespread use of PSNs throughout the world together with international agreement on the use of the X.25 Packet Switching protocol makes computer-to-computer communication relatively fast and simple [Telepac, 1995]. With public PSNs, users pay monthly rentals as well as time and volume usage charges. In cases where large enterprises are transmitting vast volumes of data between interconnected LANs, or for certain security measures, it may be cost justified to set up a private PSN. This requires an organization to manage its own switches as well as digital connecting links. The PSN concept is shown in Figure 3.

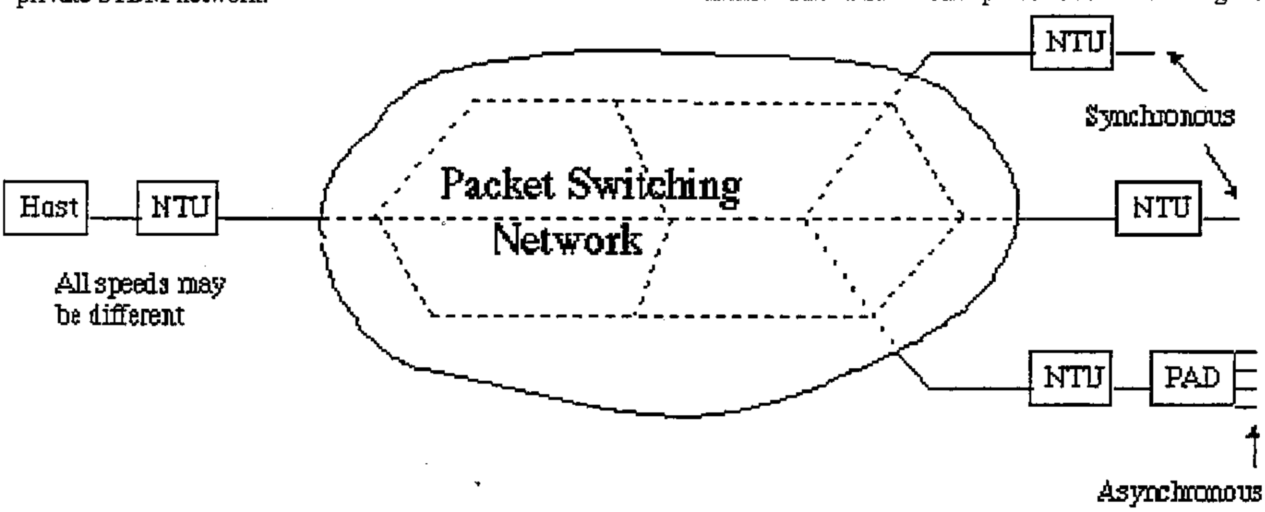

Figure 3 Equipment Interconnections to the Packet Switching Network

Packet Switching is applicable to information system communication in particular circumstances which can be seen from the following list of advantages and disadvantages:

Advantages
* Existing network service with world-wide coverage
* By use of Closed User Security Groups it is possible to derive a Virtual Private Network (VPN) for private use from the public network
* PSNs are Layer 3 architectures and therefore support a wide range of optional user facilities
* The protocols offer full end-to-end integrity
* Managed network
* Network speeds may vary at each end-point interface

Disadvantages
* Time and volume charge for the public network may make overall interconnection costs high
* Installation of a private PSN is likely to be expensive
* Maximum interconnection speed is currently 64 (or occasionally 128 Kbps)

* Overhead associated with inter-node integrity is often unnecessary with modem digital networks

4 Frame Relay

Frame Relay was launched late in 1990 in the US [AT&T, 1992] and progressively over the last two years in the Asia-Pacific region. Those promoting it have acclaimed it as an ideal for information system applications which require interconnected LANs[1] thus resulting in cost savings over the use of private leased DDS particularly as a consequence of its elastic bandwidth. In very general terms it seems that at best, network costs can be reduced by around 50% and at the worst it performs no differently to conventional X.25 networks. What is clear, however, is that very careful design and application tuning is required if the best is to be obtained from a Frame Relay service.

In some ways Frame Relay is of more significance to the Telcos than the user since 64 Kbps - 2 Mbps point-to-point links have been widely available for many years. However, the provision of such bandwidth on a continuous basis is uneconomical for many applications and a more flexible or elastic ("rubber") bandwidth system was needed. In most implementations of a public Frame Relay service it is easy to budget for the communication charges since these are based upon fixed costs such as the access rate and the CIR (Committed Information Rate) for each virtual circuit in the interconnected mesh.

Frame Relay is appropriate for major sites and networks requiring bursty traffic flow between interconnected LANs. It is relatively cheap to implement on existing hardware - sometimes it merely requires a software upgrade to the existing X.21 interface on a bridge or router. However it may also need to be seen as an interim solution until ATM is fully developed.

The important differences between Frame Relay and X.25 Packet Switching, are firstly more efficient use of digital bandwidth leading to higher data rates, and secondly the absence of error checking. Frame Relay's proponents argue that error checking at this level is not required, both because the error rates on modern digital leased lines are much lower than on the analogue lines X.25 was designed to use, and because error checking can still be implemented at a higher level by the system end-points.

The Frame Relay interface is thus designed to be simple, fast and efficient and is optimised for reliable, digital communications lines. With today's low error rates, it is unnecessary and inefficient to manage acknowledgments and retransmissions at each segment of the network. If a frame is corrupted or lost, it is not retransmitted within the network as acknowledgments and retransmissions are all handled by the end-systems.

Without this overhead, Frame Relay is able to run at very high speeds up to 2 Mbps in today's specification with higher speeds up to 34 Mbps (E3) and 45 Mbps (T3) demonstrated by vendors.

[1] A recent survey indicated that 81% of frame relay's use was directed at LAN-to-LAN communication. Another 15% was directed at terminal to host interconnection with the remaining 4% being used for host-to-host communication.

4.1 Virtual Circuits

In principle the Frame Relay standard allows use of either Permanent or Switched Virtual Circuits (PVCs or SVCs). Virtual circuits in the Frame Relay context are used for connectivity and addressing. All traffic for a particular virtual circuit uses the same path through the network. However, virtual circuits consume no resources when they are not active, but can (in principle) instantaneously carry up to 2 Mbps of traffic.

The protocols for dynamically setting up SVCs are still under development as they are more complicated than those used for PVCs although SVCs will inevitably be required for international Frame Relay services. Today, Frame Relay with PVCs allows any single device to communicate with hundreds of other devices directly by way of a single access port.

Once frames enter the Frame Relay network they are forwarded along the PVC according to the connection identifier specified in the two bytes at the front of the frame. Data transmitted on a particular PVC is statistically multiplexed onto network trunks along with data from other users in a similar manner to X.25 Packet Switching. Since this statistical multiplexing process involves variable store-and-forward delays, the throughput for individual transactions will be variable and usually less than the access rate. (See Figure 4).

4.2 CIR (Committed Information Rate)

Nodes in a Frame Relay network are linked by PVCs each with a Committed Information Rate (CIR) which defines the bandwidth guaranteed to be available to the connection although the maximum amount of bandwidth can be much higher if network capacity is available. This does not mean that excess bandwidth is always available as the network can only supply bandwidth up to the access rate of the connection to the network. If the network is congested, the bursts may not make it through the network and data can be discarded.

Commonly the CIR can be set to a minimum value of 8 Kbps and then increased in blocks of 4 Kbps. However this depends very much upon the equipment supplier and network operator.

The *advantages* of Frame Relay are:

* Higher network throughput capacity
* Flexible bandwidth
* Protocol transparency
* Reduced network delay
* Potential cost savings

The main *disadvantages* of Frame Relay are:

* Error protection must be provided at a higher level in the architecture
* Not suitable as a multimedia transport network
* Difficult to tune network (eg CIR, PVCs, access port speed)
* Wide variation in vendors implementation of congestion control systems
* Difficult to obtain accurate traffic profiles

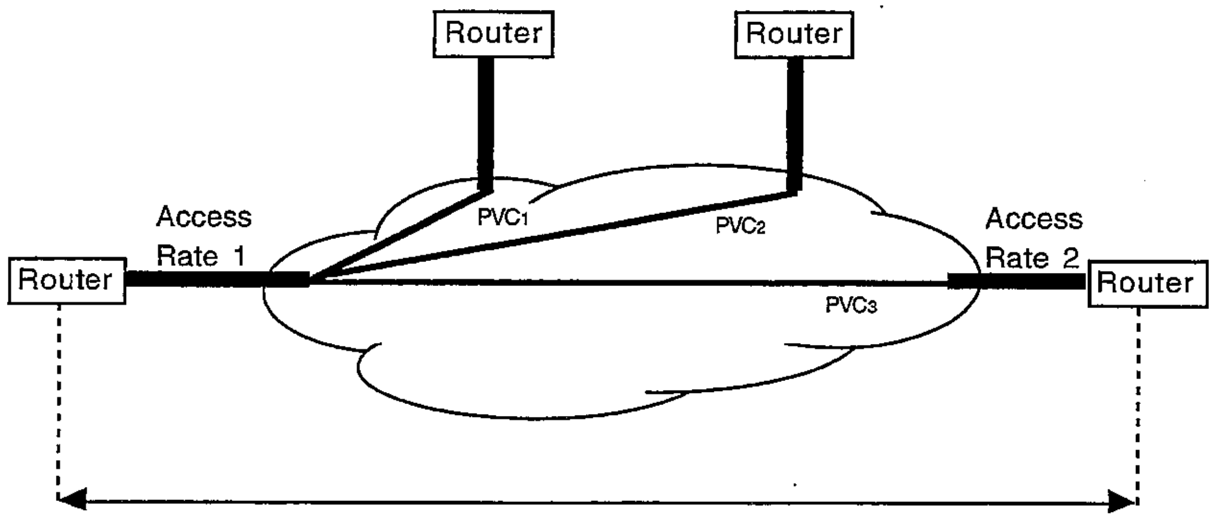

Figure 4 Frame Relay Interconnection Using PVCs

5 Integrated Services Digital Network (ISDN)

Since its inception nearly two decades ago, interest and expectation for ISDN has developed and died away on two previous occasions. The first occurred in the early 1980's and resulted from a push by the telephone companies (as they were then called) to implement ISDN as a means of consolidating network resources and achieving savings in operating costs. Because the telephone companies attempted to "go it alone", without the understanding and support of the equipment vendors and end users, this attempt failed.

The second push for ISDN built up after 1985, and arose from a number of trials, again initiated by the telephone companies, which sought to implement proprietary versions of ISDN interface standards, often supported by vendors. This failed to gain a significant presence for ISDN, because the end users had not been included in the development process.

Now ISDN has built up to a third wave of expectation, with the involvement of the Telcos [ISDN, 1995], terminal equipment manufacturers and end users. Unlike the previous two attempts this third effort has been much more successful.

However many consider that ISDN is "too little too late". Undoubtedly the speeds originally envisaged for ISDN are particularly undramatic by today's standards, especially with modern error correcting compression modems pushing towards the 64 Kbps mark - the basic B channel speed of ISDN.

The Telcos do not intend that ISDN encourage large scale movement away from other network services. Its fundamental ability lies in providing *high volume data transfer* capability, where *short holding times* are common.

ISDN provides both *Basic Rate* and *Primary Rate* interfaces. Basic Rate access is delivered as two, 64 Kbps channels. Primary Rate Access is capable of delivering up to 30 channels each at 64 Kbps. Both Basic and Primary Rate links support circuit switched connections, where the user dials up a distant site on an as required basis via a number of 64 Kbps channels.

ISDN has been defined variously as an *architecture*, a *technology*, a *network* and a *service*. It is most suitable for users needing to transmit large quantities of data between information system applications on an intermittent basis. Its potential is expected to develop in areas such as interactive file transfer, image transmission and as a backup service for critical, leased data circuits.

The various advantages and disadvantages of ISDN as an information system interconnection service can therefore be listed as follows:

Advantages

* Dial-up service on an "as required" basis
* Provides a multiple 64 Kbps interconnection service
* By virtue of its switched circuit capability, the flexibility of ISDN enables the establishment of an efficient interconnection of network when data transmission is required on a relatively infrequent basis.

Disadvantages

* High costs will result from long holding times, long distances and high volumes of data transfer

6 Fibre Distributed Data Interface (FDDI)

A substantial growth has occurred in the number of LANs which require to be inter-connected within the local environment - building, campus, factory - in order to support an integrated enterprise. Bridges form an appropriate interconnection methodology for two or three LAN segments or hubs normally by way of a backbone, cascaded or star topology. However fundamental limitations occur in that the backbone speed remains the same as the basic hub or bus speed. A high speed information highway is required to interconnect the various LAN segments and this needs to operate at a speed at least an order of magnitude greater than the departmental LAN speed.

FDDI is filling an important role for the support of distributed information system applications in this environment [Reardon, 1992]. The standards were rapidly developed and the availability of marketable products quickly followed. FDDI was conceived in the 1980s, and it was specifically designed to be used as the technology of the 1990s, viz fibre optic transmission, very large scale integration chips (VLSI), together with efficient, 'lightweight' software protocols. It was also the first practical networking architecture that became supported by multiple vendors and had consistent standards defined from the outset. It is now questionable as to whether this technology will be replaced with ATM in the second half of this decade.

Equally importantly, the real life solutions and products actually became available slightly ahead of user's needs, rather than lagging behind them, which has too often been the case with networking in the past (for example - the early implementations of ISDN).

From the user viewpoint, FDDI also came at a time when the limitations of existing LAN implementations were starting to constrain business effectiveness generally and the ability to exploit new high performance client/server systems and multimedia applications in particular.

As in all areas, there are always competing alternatives and FDDI is not the only way of meeting these needs. But overall, FDDI is a significant interworking networking technology for LAN-to-LAN communication with practical potential and momentum behind it.

The *advantages* as well as some of the applications which can be supported by FDDI are:

* Fibre based technology
* FDDI provides a backbone 'LAN of LANs' linking up different communities of users across sites such as factories, airports, universities and business complexes previously supported only by disparate LANs
* High rise buildings being cabled for FDDI in the vertical risers thus acting as a backbone for individual horizontal LANs which in turn support individual floors and departments
* Concentration of lower speed devices and bridging of LANs from different vendors onto an FDDI network for connectivity and multi-protocol interconnection benefits
* Direct dual attachment of high performance devices (eg CAD/CAM, high resolution colour graphics and other multimedia devices) onto the backbone network because of the speed and performance it provides
* Provides support for new high bandwidth information system applications such as medical imaging, engineering graphics and document image processing
* Mature standards including network management systems

Disadvantages

* The high cost of FDDI concentration and interface equipment
* The uncertainty as to whether ATM technology will replace the need for FDDI

7 Asynchronous Transfer Mode (ATM)

Probably no other technology has drawn so much attention as ATM has in recent times. Significant developments are now occurring in the Fast Packet Switching and Broadband-ISDN areas. These various technologies all come under the general umbrella of what is called "ATM technology". There has been substantial media hype in recent times and ATM looks set to make a major impact on high speed networking and as an a transport system for distributed information system applications. The ATM protocol is transparent to both the local and wide area networking environment thus obviating much of the protocol conversion commonly found in existing equipment interfaces between local and wide area networks.

One of the fundamental principles of ATM is to offer the end user a large variety of communication services through a single access point to the network - with each service potentially requiring a different bit-rate. Thus a technique was needed to switch delay-sensitive information such as video or voice as well as information flows that are more bursty and have widely variable bit-rates such as might be commonly found with LAN-to-LAN communication [Vetter, 1995].

ATM meets these requirements. It is a hybrid technique that combines the simplicity and very high bit-rates possible with circuit switching (currently used largely for voice or video transmission) with the flexibility of X.25 Packet Switching Systems which are commonly used for many information system applications.

In ATM, the basic unit of data transfer is called the cell. This appears as a packet having a fixed length with a header (including routing information used by the network) as well as an information field. The fixed format of the two fields assures that the processing can be carried out by simple high speed switching hardware, thus enabling faster processing speeds than are possible with traditional variable length packet-based networks such as X.25 Packet Switching and Frame Relay Systems.

ATM is certainly the buzz word of this decade appearing to be all things to all people. It is ideal for local, national, international, private and public networks; scalable speeds; for isochronous (real-time) and bursty traffic; for constant and variable bit-rate devices; for voice, video, imaging, and data; and it is capable of integrating these into one international broadband switched network of the future. What more could one want?

Frame Relay, in comparison, is positioned at the lower end of the ATM spectrum (up to 2 Mbps) but it uses variable length frames and only supports conventional computer data transfer and not multimedia applications which undoubtedly will be increasingly required in the future. Further, ATM is an architecture that supports multimedia communication at 155 Mbps and in many ways it replaces the need for 100 Mbps FDDI. However FDDI is widely available and in common use now - in spite of its high costs - while ATM is an unproven technology.

For future *wide* area information system networking requirements, Figure 5 shows how an ATM network will operate by providing a cell relay service to existing network architectures such as Frame Relay, X.25 and ISDN.

For future *local* area information system networking requirements, ATM switches will interconnect to hubs and other switches that will form the distribution point for existing and future LANs. Figure 6 shows a hub that has an interface for existing Ethernet and Token Ring legacy networks but also has an ATM interface for ATM capable workstations of the future. In addition, a local routing function will be provided in conjunction with, or in addition to the hub. Switched networks will therefore build upon the LANs and backbone routers now in place. ATM hubs and routers will link LANs and established connections to enterprise wide networks while ATM switches will connect departmental hubs and routers in order to form the basis of these new enterprise networks.

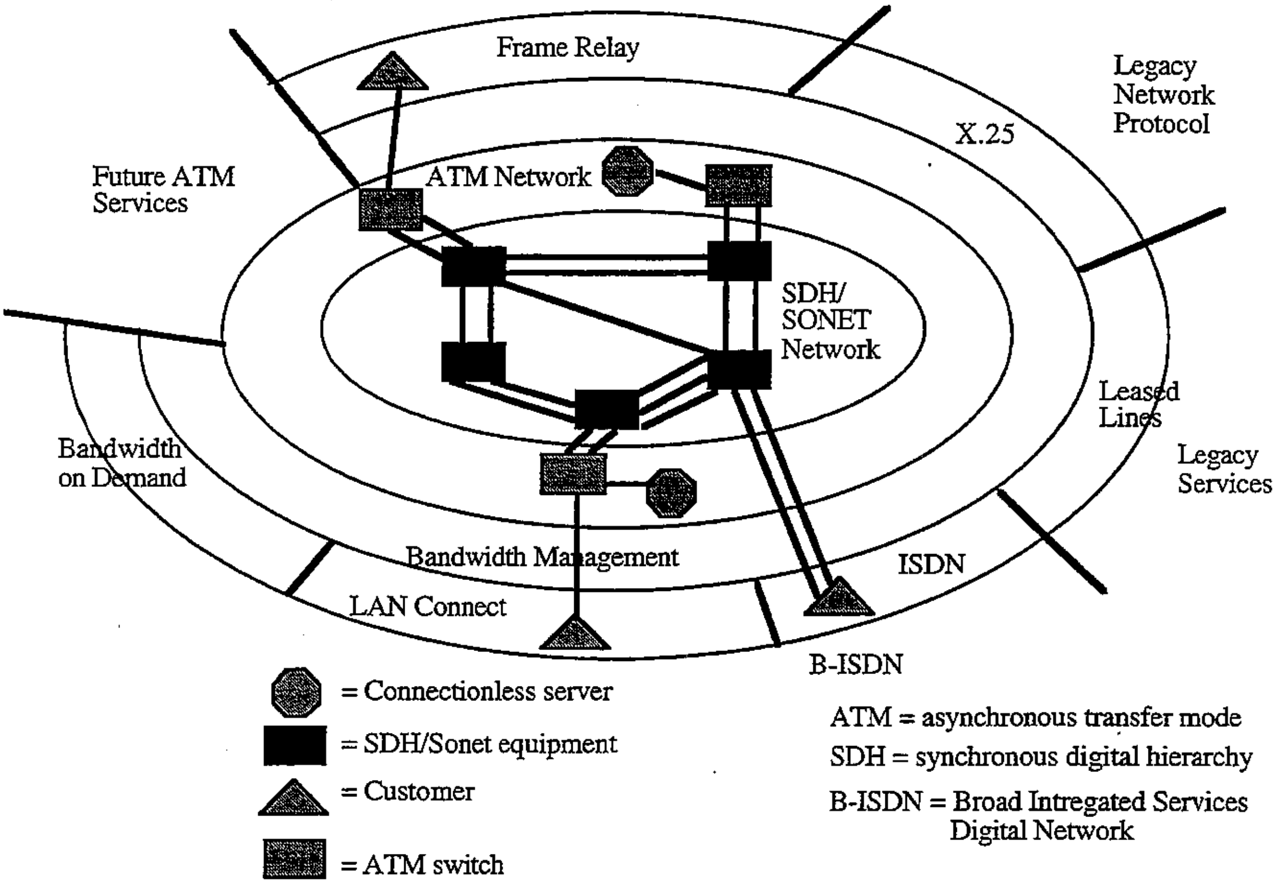

Figure 5 The ATM Network Comprising Switching, Bandwidth Management and Networking Services

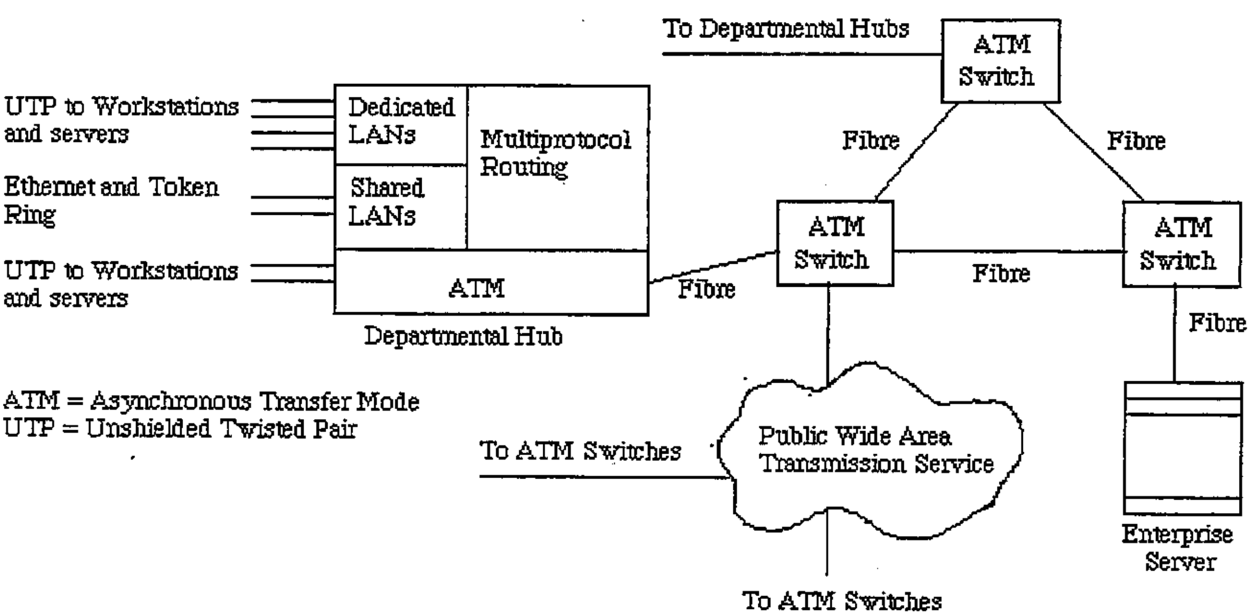

Figure 6 Departmental ATM Hub and Connection to the ATM Network

8 Example of Interconnection Options

The choice of interconnection services is necessarily arbitrary since it will be based upon a specific configuration and even more specific traffic statistics. Nevertheless it can be seen from the following example how the costs and benefits discussed in the previous section can be applied to this practical example.

The following example shows three interconnected LANs in three different cities. The routers at the interface at each of these LANs can be assumed to be capable of supporting any of the interfaces for DDS (X.21), Packet Switching (X.25), Frame Relay (X.21 + Software) and ISDN (I.430, I.440, I.450). It is further assumed that file and transaction processing capabilities are required between clients and servers in any pair of the three locations. In the example which follows it is further assumed that one 64 Kbps channel is required in order to support file transfer and basic client/server online transaction processing with adequate performance characteristics.

In the case of the DDS and Frame Relay no time or volume charges apply. However for DDS there is a cost component for distance in addition to the normal access charges. Thus the cost of a DDS service is dependant on both access speed and location. In the case of ISDN time charges apply while with Packet Switching both time and volume charges must be calculated. For this calculation the file transfer calculations are based upon a twice daily 10 Mbyte file transfer while the online transaction processing calculations are based upon 50 calls per day consisting of 4 segments (1 segment = 64 bytes) in and 50 segments (1 screen) out. The call holding time is 3 minutes per call.

For the purpose of this example, all calculations are in Singapore dollars. Installation and set-up charges for each service are not included in these calculations.

Digital Data Service

In this case three point-to-point circuits are required each incurring an access charge. In addition one Step E and two Step D transmission charges apply (These Step charges vary considerably amongst different Telcos).

Access	6 x $650	$3900
Transmission	2 x Step D @ $1820	
	1 x Step E @ $2260	$5900
Total monthly charges		**$9800**

Frame Relay

Three access points are required to the Frame Relay network, each at 64 Kbps. The CIR selected for each PVC between each pair of points is 16 Kbps.

Access	3 x $1250	$3750
CIR	6 PVCs @ $140	$840
Total monthly charges		**$4590**

Integrated Services Digital Network

Three access connections are needed to the ISDN network. A single B channel at 64 Kbps will be required. In addition, normal trunk-call charges apply for the connection time. These connection charges form a dominant part of the overall cost.

Access	3 x $167	$500

Time based upon an average trunk-call charge of $1.00/minute

2 x 10 Mbyte @ 64 Kbps = 41.6 minutes	
41.6 x 30 x $1.00	$1248
Online Transactions 50 calls/day @ 3 minute per call	
50 x 3 x 30 x $1.00	$4500
Total monthly charges	**$6248**

Packet Switching Network

Three connections are required to the PSN at each city.

Access	3 x $860	$2580
PVC charge @ $53	6 x $53	$318
Volume charge @ $.50/kilosegment		
File transfer	2 x 10 Mbytes/64,000 = 312.5 kilosegments	
	312.5 x 30 x $.5	$4688
Online Transactions	50 calls/day and 54 segments transferred	
	(50 x 54 x 30 x $.5)/1000	$40
Total monthly charges		**$7626**

From the above calculations it can be seen that the ISDN charges are highly subject to call duration while Packet Switching charges are highly subject to the volume of data transferred. This accounts for the high costs associated with online transaction processing for ISDN as well as the high costs associated with file transfer for Packet Switching. In the case of the DDS and Frame Relay networks no such time or volume related charges are incurred. In Figure 7 the costs for all five network types are shown relative to increasing transaction volumes.

This calculation is based upon an arbitrary network and the figures supplied by one Telco. Clearly the important issue here is not the absolute value of these calculations but rather the shape of the graphs and how the overall cost parameters are dependant upon factors such as connect time, volume (M bytes/day) and trunk call charges.

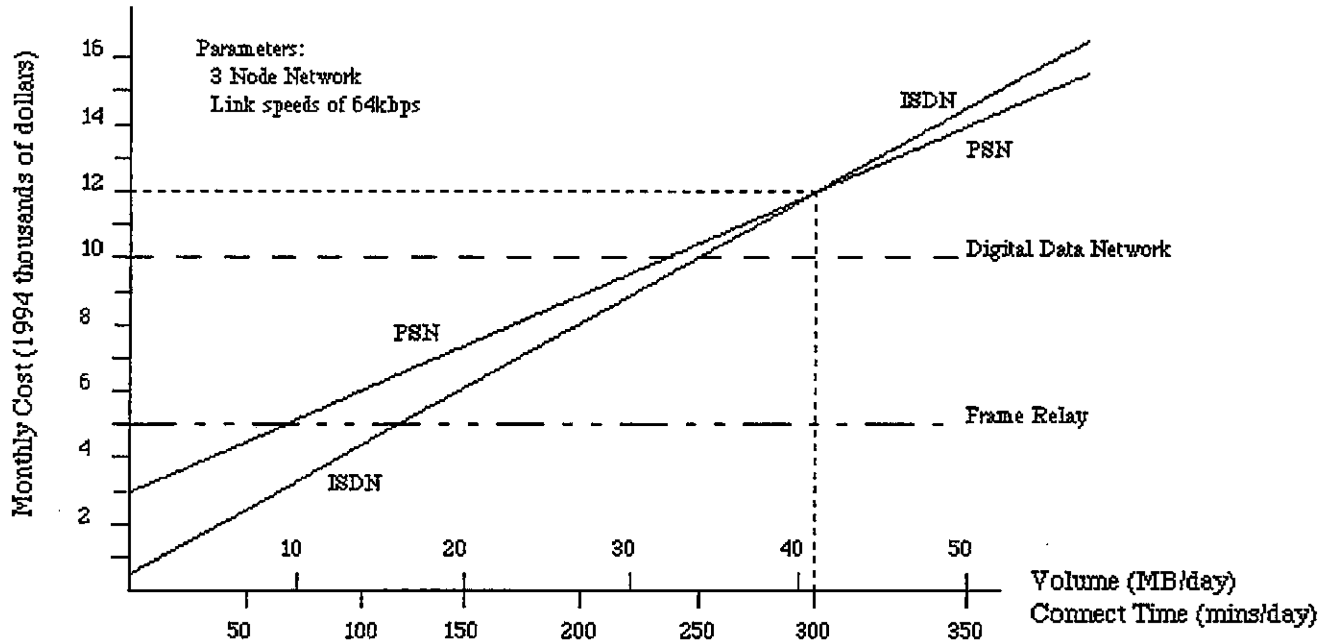

Figure 7 Cost Structure for Various Network Services Relative to Traffic Volumes

9 Cost/Benefit, Performance and Operational Issues

From the discussions in the preceding sections it can be seen that there are many factors to be considered in the selection of local and wide area interconnection services necessary to support modern distributed information system applications.

The nature of these applications to be supported play a big part in this choice. The issue is further complicated by the fact that a choice of network service based upon one set of applications may not turn out to be appropriate as additional applications are added. For example, applications which require real-time networking such as voice systems may not operate well over a Frame Relay service.

For cost effective communications, some form of elastic bandwidth is essential. Almost all applications make time varying bandwidth demands and in most cases it is simply too expensive to provide this maximum bandwidth on a continuous basis.

The costs of these various network services are constantly changing. Sometimes these changes reflect the real costs of providing the service, although that can vary as more users choose to use a particular service. More often than not, price changes have more to do with attracting customers to use (or not use) a particular Telco's service or to keep competitors out of the race, than for any real consideration for the customer. Further, these network providers often market bundled services under names that do not make it clear what technological solution is being used and thus making it difficult for the customer to make objective evaluations. These issues make for difficult financial planning problems for network managers.

The DDS has been the traditional method for private network point-to-point and multipoint networking requirements. Although their widespread use will continue, in many situations there are now more cost effective options tailored to customers' applications requirements.

Packet Switching is unlikely to be a serious contender for widespread LAN-to-LAN communication in the long term. Although it is a very robust reliable and widespread data network, the protocols were not designed for developing high bandwidth applications and modern fully digital networks. Also, as with ISDN, the volume dependant costs make budgeting difficult for network managers.

Frame Relay is positioned to be a more attractive LAN-to-LAN and LAN-to-WAN service now. It solves many of the problems associated with cost efficiency and it is suitable for the many existing information system applications. It has grown out of experience in the use of Digital Data and Packet Switching Services, streamlining the protocol to reflect modern digital switching networks. For the next few years Frame Relay will provide a wide area networking service at speeds up to 2 Mbps which will be adequate for the majority of applications.

FDDI can be considered to be in a separate category for it really only has application within the local environment and thus does not incur real volume related costs in the same way as wide area networking services do.

A remarkable degree of interest is being focused on ATM at the present time and it is very likely to be a significant force in the choice of networking services in the near future. The ATM Forum, which specifies many of the ATM implementation and operational standards, now has 550 member companies.

Multimedia applications require such a service while at the same time the ATM service needs multimedia applications to survive. Either way the picture looks rosy. There are a number of issues to be resolved before ATM can become a viable service. Although vendor implementations of ATM are on the market they do not yet interwork satisfactorily which is not surprising considering many of the interworking standards were only finally ratified by the ATM Forum late in 1994.

Another difficult with ATM is that much of the media attention has been upon the ATM protocol itself with considerably less attention on the information system application drivers. Undoubtedly multimedia will play a significant role in these information system applications, but much work and further clarification will be necessary in order to avoid the same mistakes as occurred with ISDN - a clever protocol suite looking for useful applications.

10 References

AT&T Frame Relay Knowledge Base, Release 2.0, 1992, AT&T Data Communication Services, 55 Corporate Drive, Brightwater NJ 08807

DigiNet, National Private Digital Network Service, Facilities and Charges, Singapore Telecoms, 1995

ISDN (Integrated Services Digital Network), Facilities and Charges, Singapore Telecoms, 1995

Reardon, R. (editor), FDDI Networking - Concepts Standards and Practice, IBC Technical Services, 1992, ISBN 1-85271-177-9

Telepac, Packet Switching Service, Facilities and Charges, Singapore Telecoms, 1995

Vetter, R.J., ATM Concepts, Architectures and Protocols, Communications of the ACM, Vol 38 No. 2, February, 1995