Information Technology
Inside and Outside
- David Cyganski & John A. Orr

VII. Networks and the Internet

18. Telephone and Data Communications Networks

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18. Telephone and Data Communications Networks

- Objectives:
  - the two fundamental types of networks: circuit-based and packet-based networks;
  - the means by which **circuit-based networks** establish a path between two end points for communication;
  - the public switched telephone network (**PSTN**);
  - digital transmission systems (including **T1**) used on the PSTN;
  - the ways in which **packet-based networks** get data from transmitter to receiver without a dedicated path between the two terminals; and
  - some types of data communications protocols, including **Frame Relay** and **Asynchronous Transfer Mode(ATM)**.

18.1 Introduction

- Questions on the function of a network:
  - What **sort of information** is to be communicated?
  - Is the communication to be **one-way** or **two-way**?
  - Must the communication be **in real time**?
  - How many simultaneous users must the network handle?
  - Are all users to be connected in pairs (like a normal telephone call) or in some other arrangement?
  - Are the user-user connections permanent, or do they change frequently?
  - What is the typical period of time that a connection is maintained?

18.1 Introduction (2)

- **Telephone network** - communications connection:
  - **Two-Way:** Each party can speak to the other; that is, this is a system meant for conversation and not presentation or publication.
  - **Real-Time:** A delay in excess of about 1/3 of a second is disrupting to conversations, as it is a large enough a time period to be confused with vocal gestures (pause, doubt, surprise).
  - **Pair wise:** The conversation is an exchange between two people and not an open forum for anyone to join.
  - **Circuit Switched Connection:** Voice connections are set up and taken down frequently under control of the user (by dialing a number) as opposed to being permanent (in which case we would need a telephone in our house for each party to whom we ever intended to speak).

18.1 Introduction (3)

- A **cable television network**:
  - **One-Way:** The television programming provider sends its video product to your home and not vice versa.
  - **Not Real-Time:** As a viewer you don't really care or notice if the program you are watching is 10 seconds late or more. Because the communication is not two-way, there is no sense of delay, and hence the provider can use slow channels (satellites) or even manually mounted tape recordings to provide the video feed.
  - **One-to-Many:** The provider does not individually package and transmit TV shows to each user. A single launch of information is made of all the TV shows to all users. Users, of course, can independently select which information in the information stream to show on their screens.
  - **Permanent Connection:** The connections between the provider and the users are not switched or directed. As noted above, the same information is transmitted on one network to all viewers. When the viewers switch channels, they are only selecting what part of the information to view and are not altering what is being sent.

18.1 Introduction (4)

18.1.1 Circuit and Packet-Based Networks

- Two types of networks are:
  - ***Circuit-based networks*** are those in which a path is maintained between the users for the duration of the call; and
  - ***Packet-based networks*** are those in which individually addressed packets of information are sent into a communications system, and are individually forwarded until they reach the recipient.
- The **circuit-based network**
  - The **telephone** system: After a number has been dialed, a circuit is established. That is, a path has been created between your telephone and that of the person you called.
  - In the case of **cable television networks** (which are circuit-based) the provider drops the same messages into all the tubes.

18.1 Introduction (5)

18.1.1 Circuit and Packet-Based Networks✸✸

Circuit switching	Datagram packet switching	Virtual-circuit packet switching
Dedicated transmission path	No dedicated path	No dedicated path
Continuous transmission of data	Transmission of packets	Transmission of packets
Fast enough for interactive	Fast enough for interactive	Fast enough for interactive
Messages are not stored	Packets may be stored until delivered	Packets stored until delivered
The path is established for entire conversation	Route established for each packet	Route established for entire conversation
Call setup delay; negligible transmission delay	Packet transmission delay	Call setup delay; packet transmission delay
Busy signal if called party busy	Sender may be notified if packet not delivered	Sender notified of connection denial
Overload may block call setup; no delay for established calls	Overload increases packet delay	Overload may block call setup; increases packet delay
Electromechanical or computerized switching nodes	Small switching nodes	Small switching nodes
User responsible for message loss protection	Network may be responsible for individual packets	Network may be responsible for individual packets
Usually no speed or code conversion	Speed and code conversion	Speed and code conversion
Fixed bandwidth transmission	Dynamic use of bandwidth	Dynamic use of bandwidth
No overhead bits after call setup	Overhead bits in each packet	Overhead bits in each packet

18.1 Introduction (6)

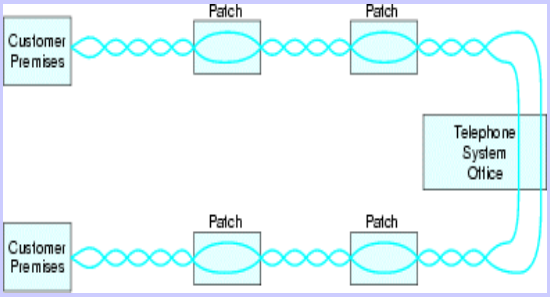
18.1.1 Circuit and Packet-Based Networks

- The **packet-based network**
  - the **postal** system: To send a packet of information (a letter) to someone, you must put an address on an envelope. Then, you drop the letter into a mailbox. This mailbox no longer acts like a tube following a single path to the destination. In fact, you can drop many messages with different addresses into the same mailbox and they will each be directed to the correct recipient, in stark contrast to the telephone example above.
  - In fact, not only do you not need a separate box for each possible recipient, you can actually use any mailbox you find on any street to send the same piece of mail.

18.2 Circuit-Based Networks

- ***circuit*** originally referred to **an unbroken pair of copper wires that connected one endpoint in a communications connection to the other endpoint**
- If ***N*** parties want to each be able to connect to any other party in the group,then **Nx(N-1)/2** wires need to be laid. So, the number of wires need is proportional to approximately the square of the number of parties in the group.

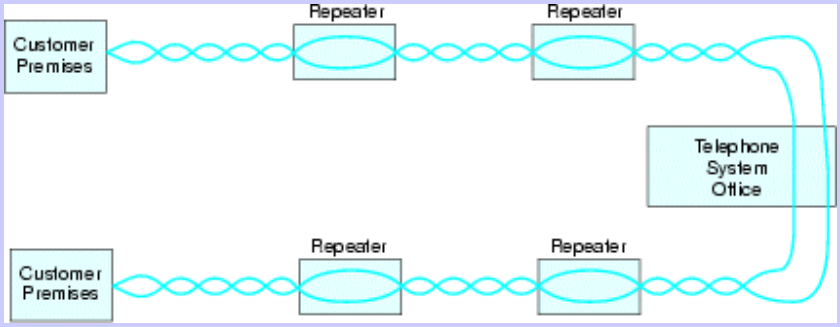
Figure 18.1: Uninterrupted permanent circuit created by connecting existing cable plant between two customer premises.



18.2 Circuit-Based Networks(2)

18.2.1 Telephone Circuits Are More than Just Wire

Figure 18.2: Permanent circuit using **repeaters** to achieve **greater bandwidth** and **reduced attenuation** of large signaling distances.



18.2 Circuit-Based Networks(3)

18.2.2 Public Switched Telephone Network Digital Services

- **PSTN** (Public Switched Telephone Network) has traditionally been in the business of providing temporary **circuit-based connections** on demand for **voice communications**.
- **Fiber-optic lines** connect many distant points in the PSTN with digital signaling speeds of **622 Mbps(OC-12)** from end to end
- The **telephone system for transport of data** at certain digital data speeds and formats that conform to **PSTN standard interfaces**.
- The service available to the user still presents all the features of the original circuit:
  - On arrangement with the PSTN it can be a permanent circuit.
  - It makes a fixed transmission data rate available at all times exclusively for that user.

18.2 Circuit-Based Networks(4)

18.2.2 Public Switched Telephone Network Digital Services(2)

- A customer can contract with the PSTN to provide a switched digital data circuit:
  - the time delay involved with call set-up and tear-down;
  - the possibility of getting a busy signal;
  - the possible higher cost than that of a dedicated circuit if the line is in use much of the time.

18.2.3 An Example of a Digital Transmission System: The T1 Carrier

- ***T1 carrier*** : the first and most popular digital permanent circuit services sold by the PSTN in North America.
  - sets of **24** simultaneous digitized phone conversations
  - pairs of copper wire over distances of up to approx. **50 miles**.
  - Repeaters were placed **6,000 feet** apart.
  - The overall bit rate is **1.544 Mbps** per channel.

18.2 Circuit-Based Networks(5)

18.2.3 An Example of a Digital Transmission System: The T1 Carrier(2)

- a **DS1 (Digital Services 1)** signal
- **T1** refers to both **the physical medium (the twisted pair cable)** and **the DS1 format of the digital data being used to move the data on that cable**.
  - **8,000 samples per second** quantized to **8 bits per sample**
  - **every 192 bits (24 voice channels x 8 bits) + 1 frame sync**
  - **193 bits x 8 samples/sec= 1.544 Mbps** are transmitted.

Table 18.1: The North American Digital Multiplex Hierarchy

Service Name	Bit Rate	Number of Voice Channels
DS1	1.544 Mbps	24 ch
DS2	6.312 Mbps	96 ch
DS3	44.736 Mbps	672 ch
DS4	274.176 Mbps	4032 ch

18.2 Circuit-Based Networks(6)

18.2.3 An Example of a Digital Transmission System: The T1 Carrier(3)

- the **North American and European (CCITT) standards** for digital transmission **over fiber-optic cables**.

Table 18.2: The North American Synchronous Optical Network (SONET) Hierarchy

North American Name	CCITT Name	Bit Rate
OC-1		51.84 Mbps
OC-3	STM-1	155.52 Mbps
OC-9	STM-3	466.56 Mbps
OC-12	STM-4	622.08 Mbps
OC-18	STM-6	933.12 Mbps
OC-24	STM-8	1244.16 Mbps
OC-36	STM-12	1866.24 Mbps
OC-48	STM-16	2488.32 Mbps

18.2 Circuit -Based Networks(7)

18.2.4 Integrated Services Digital Network (ISDN)

- In the **late 1980s**, the PSTN gave users **direct access to a switched digital service**.
- The service became widely available in a form that has been named **Integrated Services Digital Network,or ISDN**.
- **cost (high), data rate (not very high)** and **installation difficulties**
- will be **cheaper and/or faster** data transmission alternatives.
- **ISDN BRI (basic rate interface)** is available worldwide and offers a **192 kbps digital service** divided in a fashion that separates it into **one 16 kbps signaling** (call set-up, etc.) data streams and **two 64 kbps data streams** that can be used as two computer data streams, two digital phone streams, or one of each.
- The BRI service is often called the **2B+D service**,indicating that **two ``B'' channels** and **one ``D'' channel** are available on a single connection.

18.2 Circuit -Based Networks(8)

18.2.4 Integrated Services Digital Network (ISDN) (2)

- Users who need higher speed direct data access with control signaling (to exploit switched circuit access) can purchase a **T1 line** to support **the North American PRI (primary) service with 23B+D channels ➔ 23 64-kbps digital voice** or **data channels** and **1 signaling channel**.
- Together, **BRI and PRI ISDN services** are now commonly called ***Narrow Band ISDN***.
- Faster ***Broadband ISDN*** **or BISDN services** have been on the drawing boards for several years, and promise **eventually to deliver SONET hierarchy switched digital data services to users**. The ultimate goal of the telephone companies is to make BISDN the transport mechanism of choice for all data from bursty computer communications to continuous very high bandwidth television and future multimedia systems.

18.3 The Packet-Switched Connection

- a ***packet-switched*** delivery system:
  - permanent circuits from the endpoint to a local PSTN switch office;
  - the use of a packet interface protocol at the end points that transmits small packets of data encapsulated in a ``data envelope"containing the address of the sender and desired recipient of the data;
  - a packet ``node" at the local PSTN office that receives these packets, determines the route to another packet node that would bring the packet closer to the destination, and stores the packet until space on a shared permanent circuit to the next node becomes available, at which time it is forwarded; and
  - a small number of permanent circuits upon which the packets are transmitted among nodes.

18.3 The Packet-Switched Connection(2)

18.3.1 X.25 and the Virtual Circuit

- **In 1976** the **CCITT** (International Consultative Committee on telegraphy and Telephony) announced the definition of **a standard for packet-switched communications** known as **X.25**.
- X.25 provided the packet-switched capability for **multi point delivery of sporadic data** as described above via an approach that has come to be known as a ***virtual circuit***.
- A virtual circuit means that a path has been established (via some type of call set-up) between end points, but that path may not be uniquely dedicated to those users.
- A number of new **X.25 based network systems** arose that were not outgrowths of the telephone industry in response to the popularity of the X.25 virtual circuit packet service.
  ➔ as the **Public Data Networks (PDN).**
- The **maximum data rate** available via X.25 services at this time is about **64 kbps**.

18.3 The Packet-Switched Connection(3)

18.3.2 Wider Bandwidth Data Transmission: Frame Relay

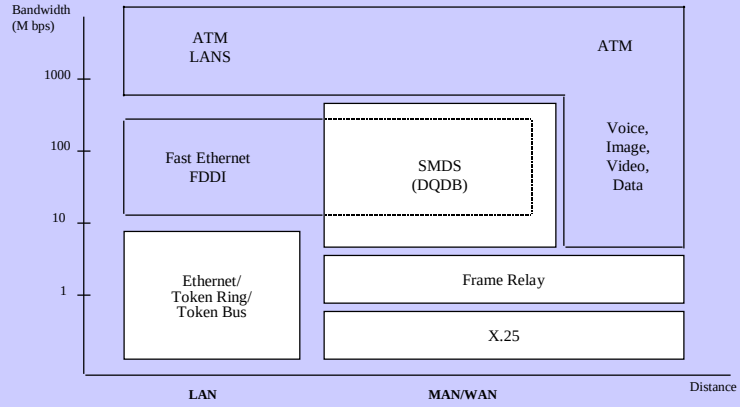
- Frame Relay is that, unlike in the X.25 service, there is no guarantee that a packet once sent will be delivered.
- Frame Relay services allow the end-users to apply their own strategies for replacing lost data and throttling data usage so as to make effective use of the service.
- In return, Frame Relay provides **up to 2 Mbps data rates at lower costs than X.25** for moving data **in virtual circuits**.
- **The higher speed and lower cost** associated with Frame Relay derives from the fact that in an X.25 circuit, **a great deal of processing must take place at every node in the network**.
  - **high-speed computers** must be employed **at each node**
  - **the amount of data** that can be handled is driven **by the availability, or lack thereof, of this computational power**

18.3 The Packet-Switched Connection(4)

18.3.3 Asynchronous Transfer Mode

- **on-demand movie** delivery services and **interactive high definition TV**→ High speed DSN required
- the key to moving packet-switched data more quickly is **simplification of the data handling at the network nodes**
- **ATM** further squeezes overhead out of the process of handling data streams by making the following additional concession:
  - Cell size=**53 bytes** with **48 bytes** devoted to **data** and **5 bytes** to **addressing and controlling the virtual circuit**.
  - the **small cell size** leads to a **lessening of the storage** needed in the **store-and-forward** architecture of the network.
- ATM-based virtual circuit packet transmission services for speeds up to OC-3 SONET, 155 Mbps
- Now available to the OC-12 SONET system, 622 Mbps
- New IC chips available to ATM data rates up to OC-96 SONET speeds of 5Gbps.

NETWORK PARADIGMS



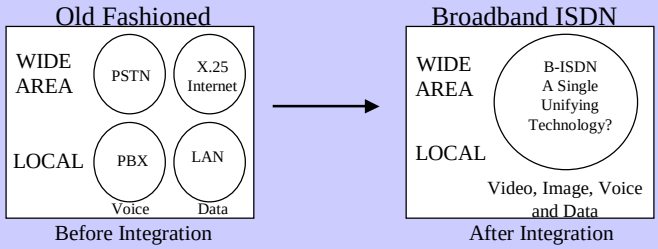
NETWORK PARADIGMS

	X.25	Frame Relay	Transparent LAN Service	SMDS	ATM
Standard body	ITU	ITU	IEEE	Bellcore IEEE 802.6	ITU
Service Type	Packet Switched	Packet Switched	Broadcast	Cell switched	Cell switched
PDU Type	LAPB	Core LAPD,LAP-F	802.3 or 5	802.6 Cell	ATM Cell
PDU Type	Variable Length	Variable Length	Variable Length	Fixed Length	Fixed Length
Switch Trunking	56 Kbps	1.5 Mbps	100 Mbps	45 Mbps	1.5-622 Mbps
Max. Packet Size	4 + 128 Bytes	8 + 1600 Bytes	802.5=21+4500 802.3=72+1500	16+9188 bytes	5+48 Bytes
Service Type	Connection-oriented	Connection-oriented	Connectionless	Connectionless	Connection-oriented
Implementation	Virtual circuit	Virtual circuit	Datagram	Datagram	VC/VP
Error Detection	CRC 16	CRC 16	CRC 32	CRC 16	CRC-8
Network Latency	High	Medium Low	Very Low	Very Low	Very Low

NETWORKING EVOLUTION

Traditionally

- Voice ⇨ Telephone networks
- Data ⇨ Computer networks and LAN
- Video Teleconference ⇨ Private computer networks
- TV ⇨ Broadcast radio or cable networks



Before Integration

After Integration