Data Communications & Computer Networks

Chapter 9

Circuit and Packet Switching

Fall 2008

Agenda

- Preface
- Circuit Switching
- Softswitching
- Packet Switching
- Home Exercises

Key points – Circuit switching

- Circuit switching is used in public telephone networks and is the basis for private networks built on leased-lines.
- Circuit switching was developed to handle voice traffic but also digital data (although inefficient)
- With circuit switching a dedicated path is established between two stations for communication
- Switching and transmission resources within the network are reserved for the exclusive use of the circuit for the duration of the connection
- The connection is transparent: once it is established, it appears to attached devices as if there were a direct connection

Key points – Packet switching

- Packet switching was designed to provide a more efficient facility than circuit-switching for bursty data traffic
- With packet switching, a station transmits data in small blocks, called packets
- Each packet contains some portion of the user data plus control info needed for proper functioning of the network
- A key element of packet-switching networks is whether the internal operation is datagram or virtual circuit (VC).
  - With internal VCs, a route is defined between two endpoints and all packets for that VC follow the same route
  - With internal diagrams, each packet is treated independently, and packets intended for the same destination may follow different routes
- Examples of packet switching networks are X.25, Frame Relay, ATM and IP.

Preface

Preface

- Previous lectures described how info can be encoded and transmitted over a communication link
- Now, we turn to broader discussion of networks, which can be used to interconnect many devices and in particular with traditional approaches to wide area network design: circuit and packet switching
- Since the invention of the telephone, circuit switching has been the dominant technology for voice communications
- Packet switching has been researched since 1970s and it is one of the few effective technologies for long-distance data communications
- Packet-switching networks consist of a distributed collection of packet-switching nodes
  - Causes time delay
  - Overhead involved (status info)
- As a result packet-switching networks can never perform "perfectly" and many algorithms are used to cope with the time delay and overhead penalties of network operation

Switching Networks

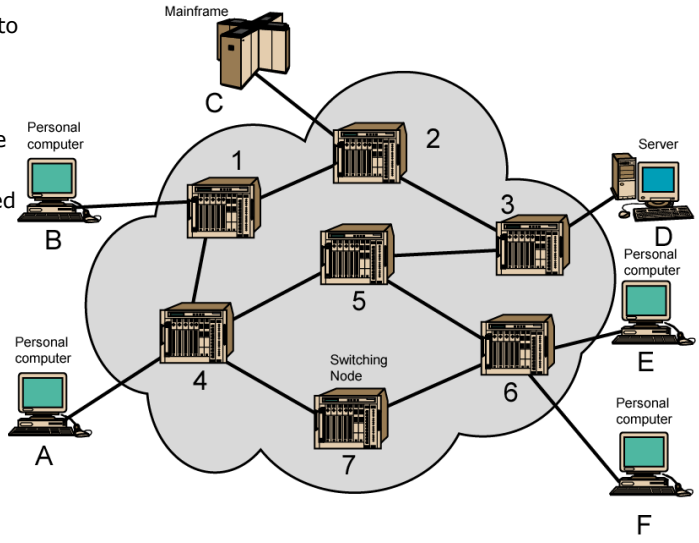
- Long distance transmission is typically done over a network of switched nodes
- Nodes not concerned with content of data
  - Their purpose is to provide a switching facility that will move data from node to node until they reach their destination
- End devices are stations
  - Computers, terminals, phones, etc.
- A collection of nodes and connections is a communications network
- Data routed by being switched from node to node

Nodes

- Nodes may connect to other nodes only, or to stations and other nodes
- Node to node links are usually multiplexed (using TDM or FDM)
- Network is usually partially connected
  - Some redundant connections are desirable for reliability
- Two different switching technologies
  - Circuit switching
  - Packet switching

Simple Switched Network

- Nodes connected to one another by transmission links
- Each station attaches to a node
- The collection of nodes is a switched communication network



Circuit Switching

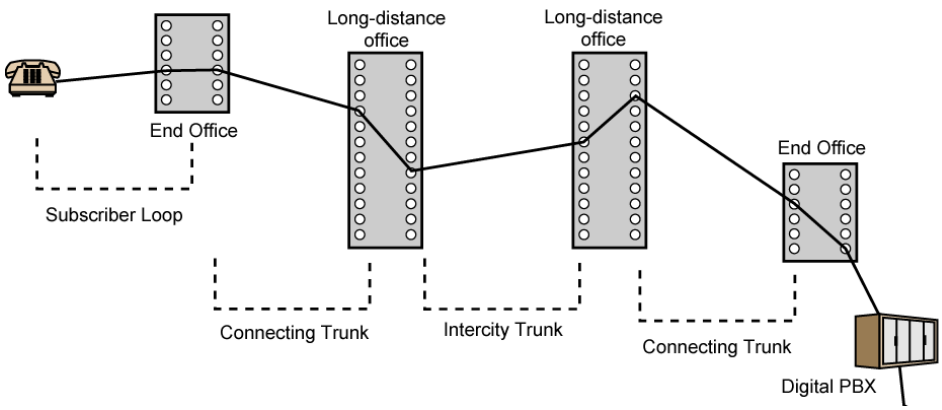
Circuit Switching

- Dedicated communication path between two stations
- Path is a connected sequence of links between network nodes
- On each physical link, a logical channel is dedicated to the connection
- Communication via circuit switching involves three phases:
  - Circuit Establishment
  - Data Transfer
  - Circuit Disconnect
- Connection path must be established before data transmission begins
- Nodes must have switching capacity and channel capacity to establish connection
- Switches must have intelligence to work out routing

Circuit Switching - Applications

- Circuit switching is inefficient
  - Channel capacity dedicated for duration of connection
  - If no data, capacity wasted
- Set up (connection) takes time
- Once connected, transfer is transparent to the users
  - Info is transmitted at a fixed data rate with no delay (except for the propagation delay)
- Developed for voice traffic (phone)
  - may also be used for data traffic via modem
- Private Branch Exchange (PBX) interconnection
  - Interconnection of telephones within a building or office

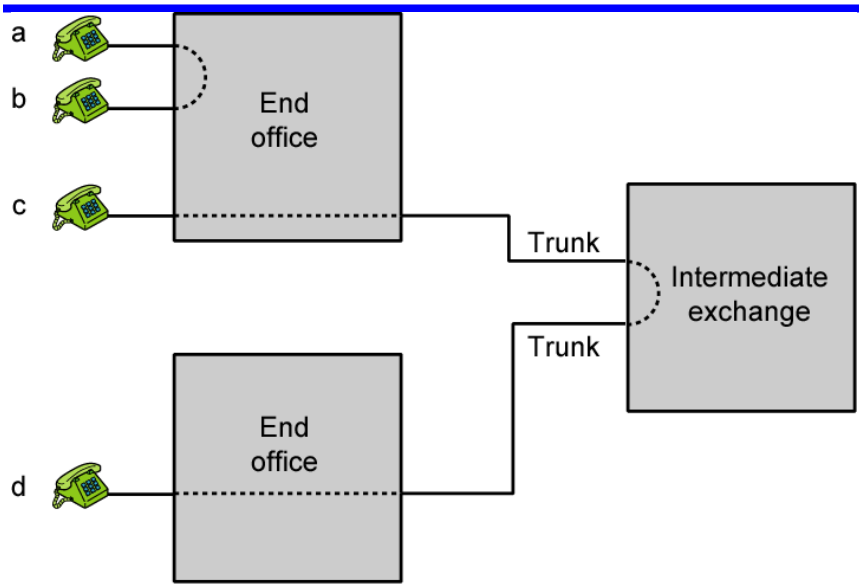
Public Switched Telephone Network (PSTN)



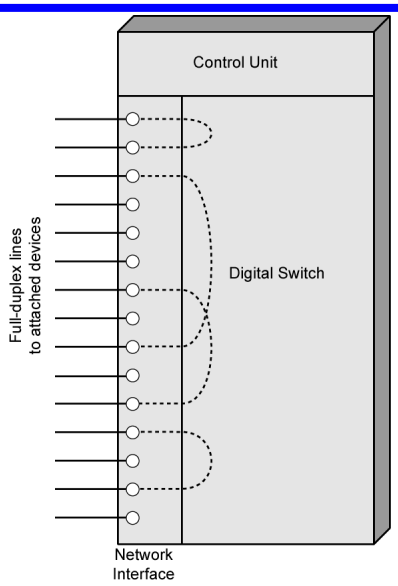
Telecoms Components

- **Subscriber**
  - Devices attached to network
- **Subscriber line**
  - Link between subscriber and the network
    - Also called Local Loop or Subscriber loop
  - Few km up to few tens of km
- **Exchange**
  - Switching centers in the network
  - End office or Local Exchange (class 5) supports subscribers
- **Trunks**
  - Branches between exchanges
  - Multiplexed

Circuit Establishment



Circuit Switch Elements



Circuit Switching Concepts

- **Digital Switch**
  - Provides transparent signal path between devices
- **Network Interface**
  - Represents functions and hardware needed to connect digital devices (eg data processing devices, digital telephones) to the network
- **Control Unit**
  - Establishes connections
    - Generally on demand
    - Handles and acknowledges requests
    - Determines if destination is free
    - Constructs the path
  - Maintains connection
  - Disconnects

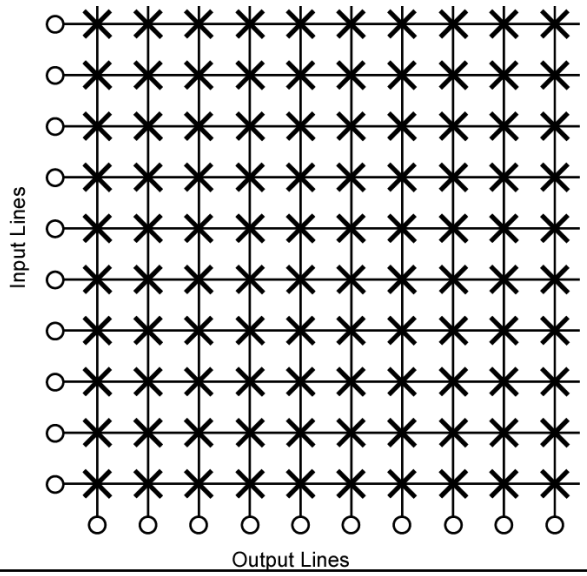
Blocking or Non-blocking

- An important characteristic of a circuit-switching device is whether it is blocking or nonblocking
- Blocking occurs when
  - the network is unable to connect stations because all paths are in use
  - A blocking network allows this
  - Used on voice systems
    - Short duration calls
- Non-blocking network
  - Permits all stations to connect (in pairs) at once
  - Used for some data connections

Space Division Switching

- Developed for analog environment
- Signal paths are physically separated from one another (divided in space)
- Basic building block of the switch is a metallic cross-point that can be enabled and disabled by a control unit
- Crossbar switch
  - Limitations
    - Number of crosspoints grows as square of number of stations (costly for a large switch)
    - Loss of crosspoint prevents connection
    - Inefficient use of crosspoints
      - All stations connected, only a few crosspoints are in use
    - Single-stage crossbar matrix is non-blocking i.e. a path is always available to connect an input to an output
  - To overcome these limitations, multiple-stage switches are used

Space Division Switch



Multistage Switch

- Reduced number of crosspoints
  - —This increases crossbar utilization
- More than one path through network
  - —Increases reliability
- More complex control
- May be blocking

Time Division Switching

- Modern digital systems rely on intelligent control of space and time division elements
- Use digital time division techniques to set up and maintain virtual circuits
- Partition low speed bit stream into pieces that share higher speed stream

Control Signaling Functions

- In a circuit-switched network, control signals are the means by which the network is managed and by which calls are established, maintained and terminated
- Functions of control signaling are:
  - Audible communication with subscriber (dial tone, ringing tone)
  - Transmission of dialed number
  - Call cannot be completed indication
  - Call ended indication
  - Signal to ring phone
  - Billing info
  - Equipment and trunk status info
  - Diagnostic info
  - Control of specialist equipment

Control Signal Sequence

- Consider a typical phone connection sequence from one line to another in the same central office
  - Prior to the call, both phones not in use (on hook)
  - Subscriber lifts receiver (off hook)
  - End office switch signaled
  - Switch responds with dial tone
  - Caller dials number
  - If target not busy, sends ringer signal to target subscriber
  - Feedback to caller
    - Ringing tone, engaged tone, unobtainable
  - Target accepts call by lifting receiver
  - Switch terminates ringing signal and ringing tone
  - Switch establishes connection
  - Connection release when source subscriber hangs up

Switch to Switch Signaling

- When the called subscriber is attached to a different switch than the calling subscriber, the following switch-to-switch trunk signaling functions are required:
  - —Originating switch seizes an idle interswitch trunk
  - —Sends off hook signal on trunk, requesting digit register at target switch (for address)
  - —Terminating switch sends off hook followed by on hook to show register ready
  - —Originating switch sends address

Location of Signaling

- Signaling between subscriber to network
  - —Depends on subscriber device and switch
- Signaling within the network
  - —Management of subscriber calls and network
  - —more complex

In Channel Signaling

- Use same channel for signaling and call
  - Requires no additional transmission facilities
- Inband signaling
  - Uses same frequencies as voice signal
  - Can go anywhere a voice signal can
  - Impossible to set up a call on a faulty speech path
- Out of band signaling
  - Voice signals do not use full 4kHz bandwidth
  - Narrow signal band within 4kHz used for control
  - Can be sent whether or not voice signals are present
  - Need extra electronics
  - Slower signal rate (narrow bandwidth)

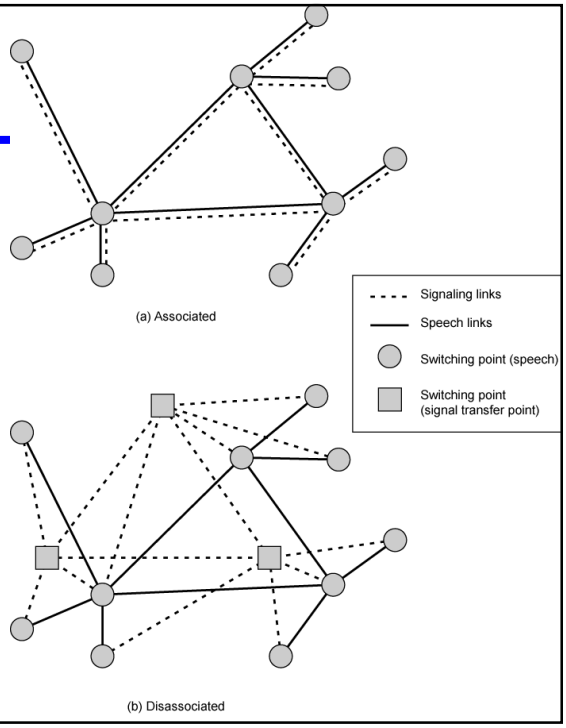
Drawbacks of In Channel Signaling

- Limited transfer rate
- Delay between entering address (dialing) and connection
- Overcome by use of common channel signaling

Common Channel Signaling

- Control signals carried over paths independent of voice channel
- One control signal channel can carry signals for a number of subscriber channels
- Common control channel for these subscriber lines
- Associated Mode
  - Common channel closely tracks interswitch trunks
- Disassociated Mode
  - Additional nodes (signal transfer points)
  - Effectively two separate networks

Common Channel Signaling Modes



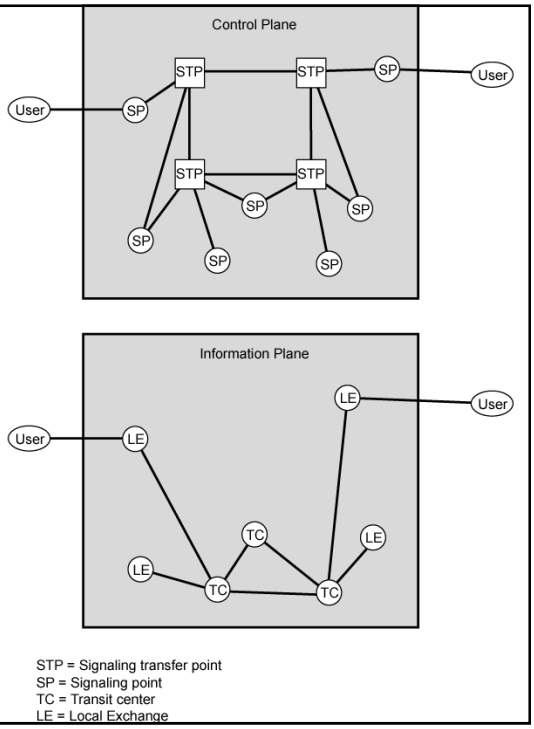
Signaling System Number 7 (SS7)

- Common channel signaling scheme
- Specifically designed to be used in ISDNs
- Purpose of SS7 is to provide a standardized common channel signaling system with the following characteristics:
  - —Optimized for 64k digital channel network
  - —Call control, remote control, management and maintenance
  - —Reliable means of transfer of info in sequence
  - —Will operate over analog and below 64k
  - —Point to point terrestrial and satellite links

SS7 Signaling Network Elements

- Signaling point (SP)
  - —Any point in the network capable of handling SS7 control message
- Signal transfer point (STP)
  - —A signaling point capable of routing control messages
- Control plane
  - —Responsible for establishing and managing connections
- Information plane
  - —Once a connection is set up, info is transferred in the information plane

Transfer Points



Signaling Network Structures

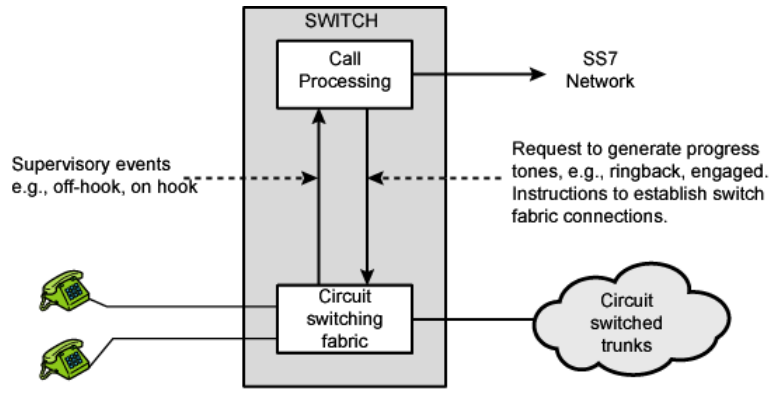
- The following parameters influence the decision concerning the design of the network and the number of levels to be implemented:
- STP capacities
  - Number of signaling links that can be handled
  - Message transfer time
  - Throughput capacity
- Network performance
  - Number of SPs
  - Signaling delays
- Availability and reliability
  - Ability of network to provide services in the face of STP failures

Softswitching

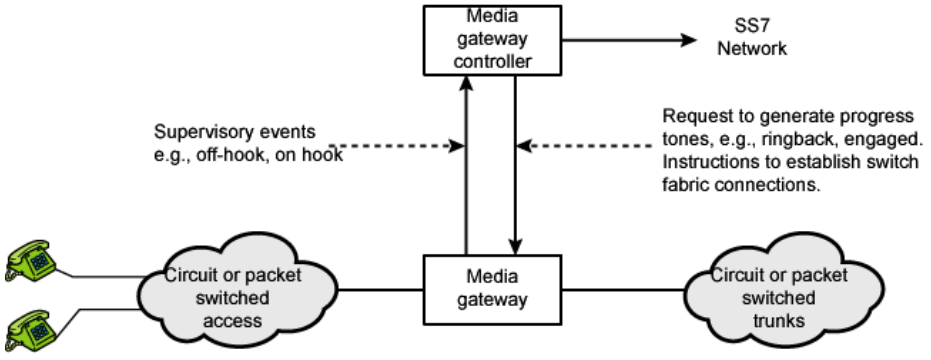
Softswitch Architecture

- General purpose computer running software to make it a smart phone switch
- Lower costs
- Greater functionality
  - Packetizing of digitized voice data
  - Allowing Voice over IP (VoIP)
- Most complex part of telephone network switch is software controlling call process
  - Call routing
  - Call processing logic
  - Typically running on proprietary processor
- Separate call processing from hardware function of switch
- Physical switching done by **Media Gateway (MG)**
- Call processing done by **Media Gateway Controller (MGC)**

Traditional Circuit Switching



Softswitch



Packet Switching

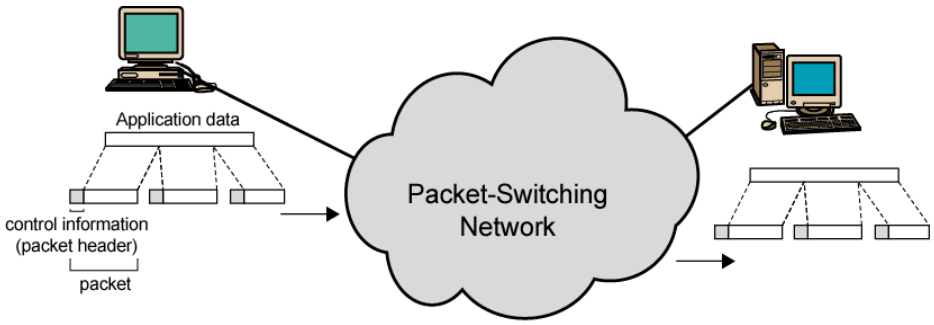
Packet Switching Principles

- Circuit switching designed for voice
  - —Key characteristic is that resources within the network are dedicated to a particular call
  - —Much of the time a data connection is idle
    - inefficient
  - —Data rate is fixed
    - Both ends must operate at the same rate, this limiting the utility of the network in interconnecting a variety of computers
- Packet switching networks address above problems

Basic Operation of packet switching networks

- Data transmitted in small packets
  - —Typically 1000 octets (bytes)
  - —Longer messages split into series of packets
  - —Each packet contains a portion of user data plus some control info
- Control info
  - —Includes routing (addressing) info
- At each node packets are received, stored briefly (buffered) and past on to the next node
  - —Store and forward

Use of Packets



Advantages of packet-switched over circuit-switched networks

- Line efficiency is greater, because
  - Single node to node link can be shared by many packets over time
  - Packets queued and transmitted as fast as possible
- Data rate conversion can be performed
  - Each station connects to the local node at its own speed
  - Nodes buffer data if required to equalize rates
- Packets are accepted even when network is busy
  - Delivery may slow down
- Priorities can be used
  - Transmit higher-priority packets first, so as to experience less delay

Switching Technique

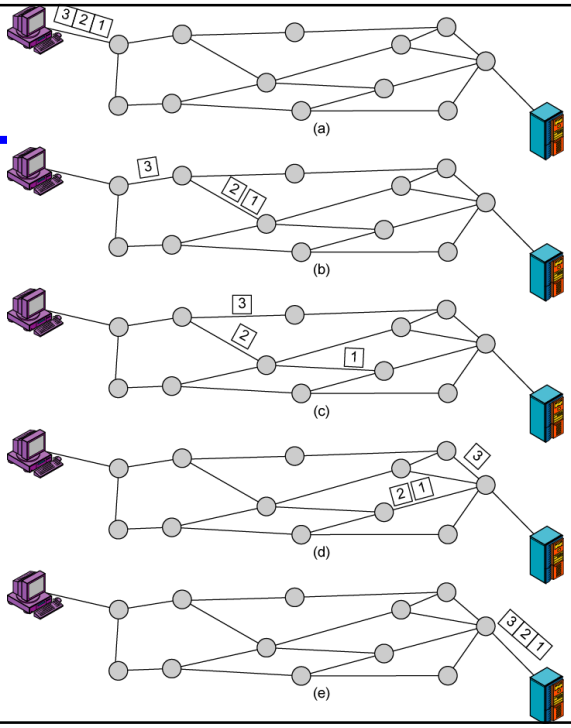
- Station breaks long message into packets
- Packets sent one at a time to the network
- Packets handled in two ways
  - Datagram
  - Virtual circuit

Datagram

- Each packet treated independently
- Packets can take any practical route
- Packets may arrive out of order
- Packets may go missing
- Up to receiver to re-order packets and recover from missing packets

Datagram Diagram

- Each node chooses the next node on a packet's path taking into account info received from neighboring nodes on traffic, line failures, etc
- Packets with same destination address do not follow the same route (c) and may arrive out of order at the exit node
- Exit node restores packets to their original order before delivering them to the destination

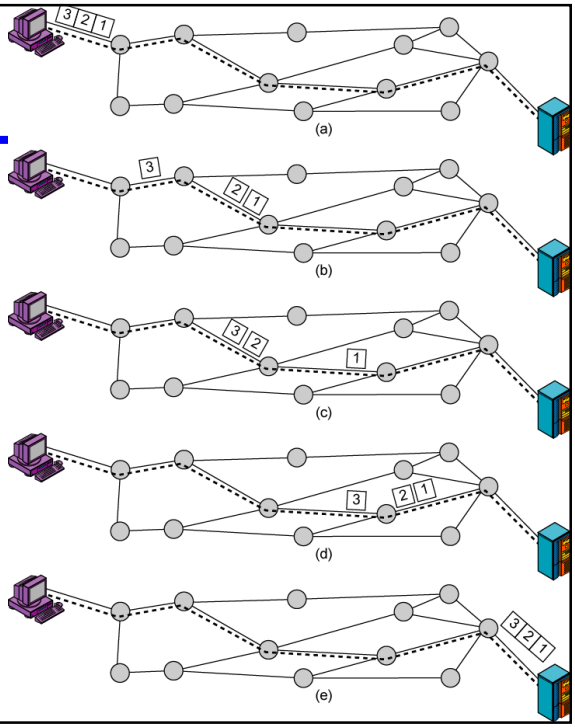


Virtual Circuit

- Preplanned route established before any packets sent
- Once route is established, all the packets between the two communicating parties follow the same route through the network
- Call request and call accept packets establish connection (handshake)
- Each packet contains a Virtual Circuit Identifier (VCI) instead of destination address
- No routing decisions required for each packet
- Clear request to drop circuit
- Not a dedicated path

Virtual Circuit Diagram

- A preplaned route is established before any packets are sent
- Once route is established, all the packets follow same route



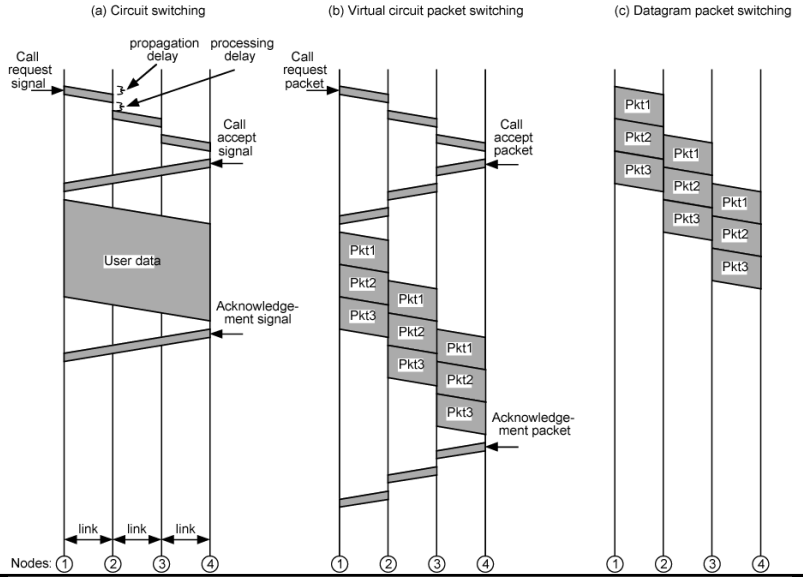
Virtual Circuits vs Datagrams

- **Virtual circuits**
  - —Network can provide sequencing and error control
  - —Packets are forwarded more quickly
    - No routing decisions to make
  - —Less reliable
    - Loss of a node looses all circuits through that node
- **Datagrams**
  - —No call setup phase
    - Better if few packets
  - —More flexible
    - Routing can be used to avoid congested parts of the network

Circuit vs Packet Switching

- **Performance**
  - —**Propagation delay**
    - Time taken for a signal to propagate from one node to the next (generally negligible)
  - —**Transmission time**
    - Time taken for a transmitter to send out a block of data
    - Eg it takes 1 sec to transmit a 10.000 block of data onto a 10kbps line
  - —**Node delay**
    - Time taken for a node to perform necessary processing as it switches data

Event Timing



Required Reading

- Stallings Chapter 10
- ITU-T web site
- Telephone company web sites

Home Exercises

Review questions

- Why is it useful to have more than one possible path through a network for each pair of stations?
- What are the four generic architectural components of a PSTN? Define each term.
- What is the principle application that has driven the design of circuit-switched networks?
- What is the difference between in-channel and common channel signaling?
- What are the drawbacks of in-channel signaling?
- What are the advantages of packet switching compared to circuit switching?
- What is the principle difference in the architecture of a softswitch compared to that of a traditional circuit switch?
- Explain the difference between datagram and virtual circuit operation.