Communication Networks

Chapter 6 – Switching Technology
Overview

1. Switching in General
2. Circuit / Line Switching
   a) Space Division Multiplex
   b) Time Division Multiplex
3. Store & Forward
   a) Message Switching
   b) Packet Switching
      i. Virtual Circuit / Virtual Connection
      ii. Datagram
Example of a Telecommunication Network (Repetition)
1. Switching in General

Task of Switching

• Extension of point-to-point links to multi-hop communication
• Provision of communication paths through the network between two end devices
• Worldwide reachability → different network providers involved
• Probably different priorities, e.g. emergency calls
• Adaptivity to changing characteristics on the network:
  ▪ occasional failures
  ▪ varying load situations
  ▪ mobile devices
• Globally unique addresses required
Switching and Signaling

Switching:
- Provides a temporary communication path through the communication network on demand
- Involves both end systems and a chain of switching systems
- Can be realized both connection-oriented and connectionless

Signaling:
- Comprises information for switching
  - for connection setup
  - for management purpose
- Starts at the requesting end systems, traverses all involved switching systems and ends at the called end system
- Is (usually) implemented in a separate protocol stack
Connection-oriented and Connectionless Communication

• **Connection-oriented Communication**
  - Connection has to be established before data can be transferred
  - End node address only required during connection establishment, later on only the connection needs to be identified
  - High complexity – especially for the intermediate nodes → *connection context*
  - Quality of service can be guaranteed by reserving resources in the network

• **Connectionless Communication**
  - No context in the switches / routers
  - No guarantee for quality of service
  - Low complexity (“Shoot and pray”)

1. Switching in General
1. Switching in General

Routing

• Relevant for partly meshed networks
  ▪ Probably several paths to the destination
  ▪ Different metrics for the paths
  ▪ Applications and/or users might have different requirements

• Goal:
  Finding the *optimal* path to the given destination
  ▪ Proactive or reactive routing
  ▪ Both for connection-oriented and connectionless communication
  ▪ Mainly done in the network layer
  ▪ Basis: given metrics
Circuit Switching / Line Switching

- Originally developed for public telephone networks
- Connection is established over an end-to-end physical channel between end users
- Physical channel dedicated to a single connection
- Physical channel is on physical layer only and does not include any buffers
- Delay is only depending on the propagation delay of the physical signals and hence on the length of the channel itself
- Delivery is ordered
- Number of parallel connections limited by number of channels
2. Circuit Switching

Circuit Switching Scheme

Subscriber Line  Long Distance Line  Subscriber Line

End Systems  Local Exchange  Long-haul Exchange  Local Exchange

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PSTN Office Classification Hierarchy

2. Circuit Switching

The Beginning of Circuit Switching

• Caller turned the crank.
• In the central office, a flip fell down.
• The operator asked who the caller wanted to talk to.
• She plugged the according lines.
• When the talk was over, the operator had to disconnect the phones again.
Evolution of Circuit Switching

• At the beginning, the network was created using analog voice connections through manual switchboards.

• As a next step, automated telephone exchanges replaced most switchboards.

• Later digital switch technologies were used.

• Most switches now use digital circuits between exchanges, with analog two-wire circuits still used to connect to most telephones.
Circuit Switching based on SDMA

- Crosspoints on crossbars are used for connection establishment

- Example:
  - $m$ incoming lines
  - $n$ outgoing lines
  - Here, incoming line 1 is connected to outgoing line 2
Circuit Switching based on TDMA

- Incoming line is connected with the outgoing line only for a short time (time slot).
- A scheduler is responsible for setting the corresponding crosspoint.
Time-Division Multiplexing (TDM) I

Buffer 1
Buffer 2
Buffer 3
Buffer 4

Buffers for each Slot

Incoming Multiplexed Line

Cyclic Input

125µs-Period

Scheduler

Control addresses
(Buffer ID)

3
1
4
2

Outgoing Multiplexed Line

Random output

125µs-Period
Time-Division Multiplexing (TDM) II

Multiplexing

Demultiplexing

Frame

Time Slot

2.b Circuit Switching based on Time Division Multiple Access
3. Store and Forward

Store and Forward

• Firstly used in telegram switching.
• Switching systems equipped with buffer.
• No engaged lines, but data might have to wait or might get lost if there is no buffer available.
• Incoming data is stored in the buffer until the desired outgoing line is free.
• Since several data portions from different sources might be waiting for transmission, they can be re-ordered (e. g. according to priority).
• For two data portions sent after each other, there is no fix timing.
• Sender and receiver do not have to work at the same speed.
Switching Network

End System (User)

Switching System

End System (User)

LL = Local Loop
IL = Internal Data Link
3. Store and Forward

Data Link

- Communication from buffer to buffer
- Data link consists of
  - Sender buffer
  - Physical link
  - Receiver buffer
- Communication is finished, when the data frame has been completely received, checked against errors and stored in the receiver buffer
Model of a Switching Network
Store and Forward: Advantages and Disadvantages

Advantages

• Single link shared by multiple senders and receivers
• No occupied links
• Different data rates at sender and receiver possible
• Establishment of packet-priority systems
• Charging by the volume of data (number of packets) transmitted rather than connection time

Disadvantages

• Variable, unforeseeable transmission delays caused by packet processing and packet queues at packet switches
• Variable packet sizes leading to longer packet processing times at packet switches
• Overhead data in packets leading to lower data transmission efficiency and throughput than in circuit-switched networks
Message Switching

• Definition “Message”:

- a self-contained object of communication
  - variable length
  - depending of the contained information
  - message might be too long to be transferred in one data frame only
3.a Message Switching

Segmenting Messages

- Partitioning the message (layer 3) into several data frames (layer 2)
- According to the layer 2 entity, data frames might have a minimum length, which has to be achieved by padding
Segmenting over Several Data Links

• According to the characteristics of the layer 2 entities, data frames may have different sizes on different data links:

1, 2, 3, 4: Data frames on the according data link
3.a Message Switching

Segmenting and Reassembling

- Segmenting and reassembling the layer 3 message to consider the maximum frame size of different data links

PCI = Protocol Control Information of the according layer
SDU = Service Data Unit of the according layer
Message Switching Principle

• The message has to be completely received and reassembled before it can be transmitted over the next data link.

• A message consists of

  - message header
    - source and destination address
    - message type
    - message length
    - priority
    - timing information (e.g. sending time)

  - message body
    - user information to be transferred
Packet Switching

• Layer 3 deals with packets that
  ▪ have a maximum length
  ▪ might have a fixed length
• Packets are quite short
  ▪ layer 3 packet completely fits into a layer 2 frame
• Each packet contains
  ▪ control information in a header especially for packet forwarding
  ▪ user data, possibly part of a larger message
• Packets are received, buffered (until the outgoing link is free to send) and forwarded to the next node
Packet Forwarding

- Packets are forwarded independently of each other
- No reassembling needed in the forwarding nodes
  - Most important difference to message switching
- Temporal overlap of the packets results in shorter throughput times compared to message switching

According to Stallings (2014)

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Packet Switching Alternatives

• **Connection-oriented:**
  - Virtual Connection / Virtual Circuit
    - Permanent Virtual Circuit (PVC)
    - Switched Virtual Circuit (SVC)

• **Connectionless:**
  - Datagram Switching
Characteristics of Virtual Connections

- Bidirectional fixed transmission path (full duplex)
- Virtual Connection established between two connection end points in the data terminating equipment of sender and receiver
  - routing decision only once at connection setup
  - packets carry connection identifiers instead of full addresses
- Virtual Connection can comprise several switches
- Permanent Virtual Connection/Circuit
  - established for a longer time
  - comparable to a leased line
- Switched Virtual Connection/Circuit
  - established on demand
  - establishment must precede data exchange phase
  - comparable to Circuit Switching
Establishment of a Virtual Connection

- During establishment phase, a path is defined for all packets belonging to the virtual circuit.
- Thus, all packets are forwarded over the same path.
- Switches need to store information about all active virtual circuits.
Datagram Switching

- Datagrams are packets that contain complete addresses
  - source address
  - destination address
- No connection establishment (and release) required
- Datagram switches do not need to store information about ongoing communication associations
- Routing decision is done separately for each datagram
- **Advantages**
  - Information transfer is quicker (no connection establishment!)
  - Network resources can be better utilized
- **Disadvantages**
  - Quality of service cannot be guaranteed
  - Reordering of datagrams is possible
Process of Datagram Switching

- Each datagram may have its own path
- No reservation of resources possible
Overview of the Different Switching Technologies

Switching Technology

Circuit Switching
- Space Multiplex
- Time Multiplex

Store and Forward
- Packet Switching
- Message Switching

Virtual Circuit
- permanent
- switched

Data-gram
References


