WAN (Wide Area Network)

1. Switch Communications Network

Beyond LAN, data is transmitted from source to destination via a network of intermediate switching nodes, aka **Switched Communication Network**.
This network is made of many **nodes**, aka the switching devices that receive and forward data. A node can be a **switching node**, i.e. it only focuses on moving data, or a normal node.
A normal node has many **stations**, aka end devices such as computer, terminal, etc. connected to it, to send and receive data.
Node-Station link is usually point-to-point link.
Node-Node link is usually multiplexed, either FDM (Frequency Division Multiplexing) or TDM (Time Division Multiplexing).

There are 2 different technologies used in WAN:

1. Circuit Switching
2. Packet Switching

1.1. Circuit Switching

Derived from **public telephone network**, Circuit Switching connects 2 nodes/stations by a dedicated path. It takes some time to negotiate & establish the connection before the transmission can happen, and requires disconnection when done, `Establish -> Transfer -> Disconnect`. It can be inefficient as the dedicated path takes up dedicated channel capacity during the connection, and the capacity might be wasted if no data is transmitted.

- **Usage**: it is not always used in 100%, even in voice call, might be worse for client-server terminal connection, inefficient for digital transmission.
- **Performance**: Delay prior to connection establishment, but transparent and no transmission delay nor variation in delay (both are requirements of voice traffic) afterward.
- **Application**: Public Telephone Network, PBX (to interconnect telephones within a building), private network, data switch.
- **Characteristic**: *Blocking* or *Non-Blocking*
    - Blocking: only 1 connection between 2 stations at a time, use all paths, **for voice systems**.
    - Non-Blocking: all stations can connect at the same time, **more suitable for data connection**.

1.1.1. Circuit Switch Node

Consists of has 3 parts:

- the **Digital Switch** provides transparent signal path and support full-duplex transmission.
- **Network Interface** faces the digital devices (computer)
- and **Control Unit** to establish, maintain or terminate the connection.

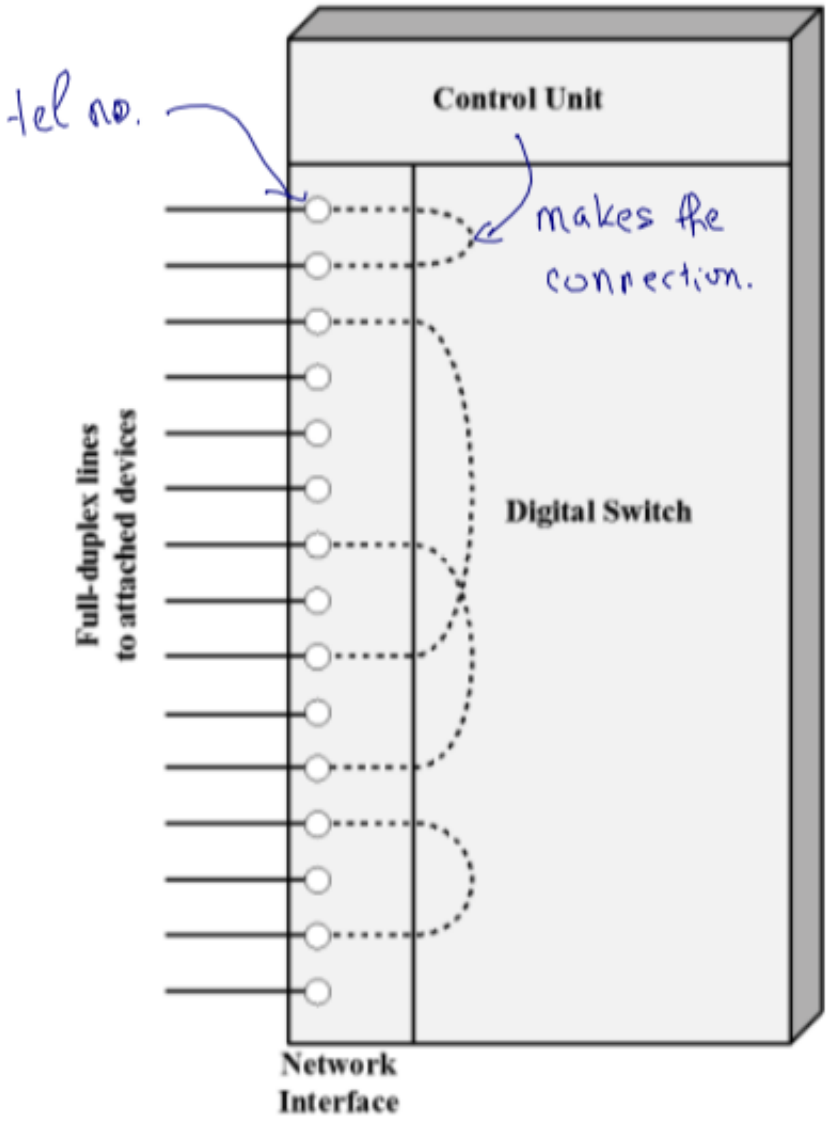


Figure 9.4 Elements of a Circuit-Switch Node

1.1.2. Space Division Switching

> Space Division Switch is a switch in which signal paths are physically separate from one another (divided in space). Each connection requires the establishment of a physical path through the switch dedicatedly between 2 end points. Basic building block is a metallic crosspoint or semiconductor gate.

Single Stage Switch or Crossbar Switch

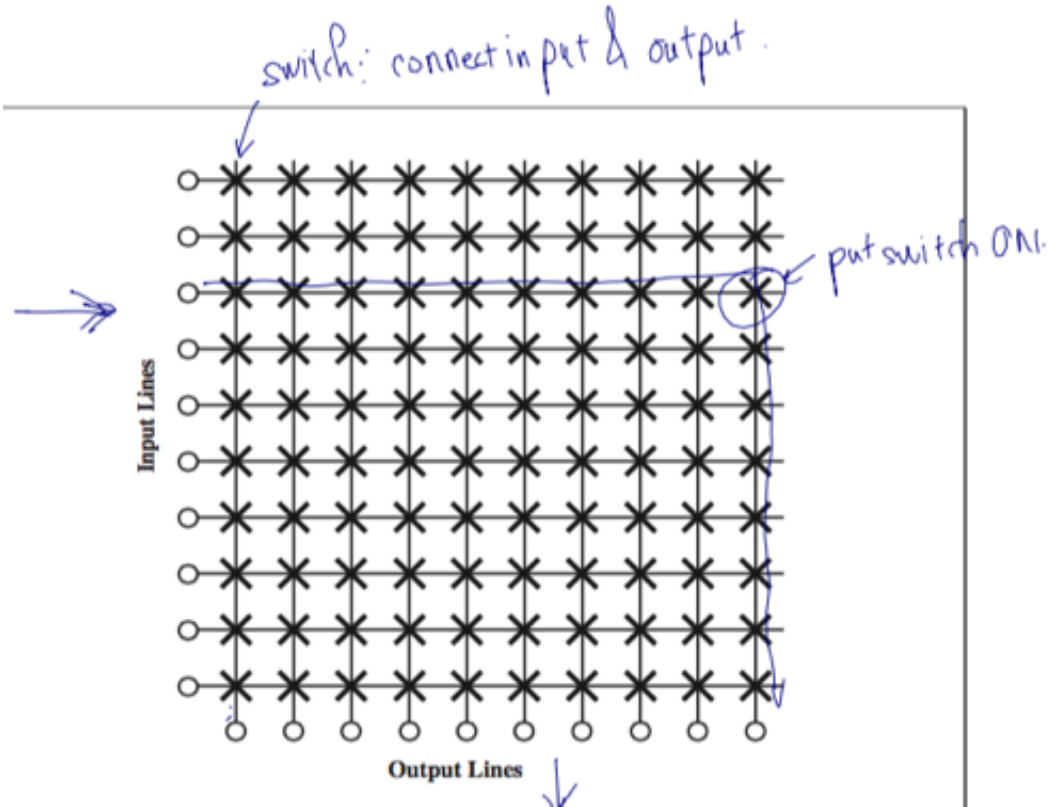


Figure 9.5 Space-Division Switch

Multi-stage Switch

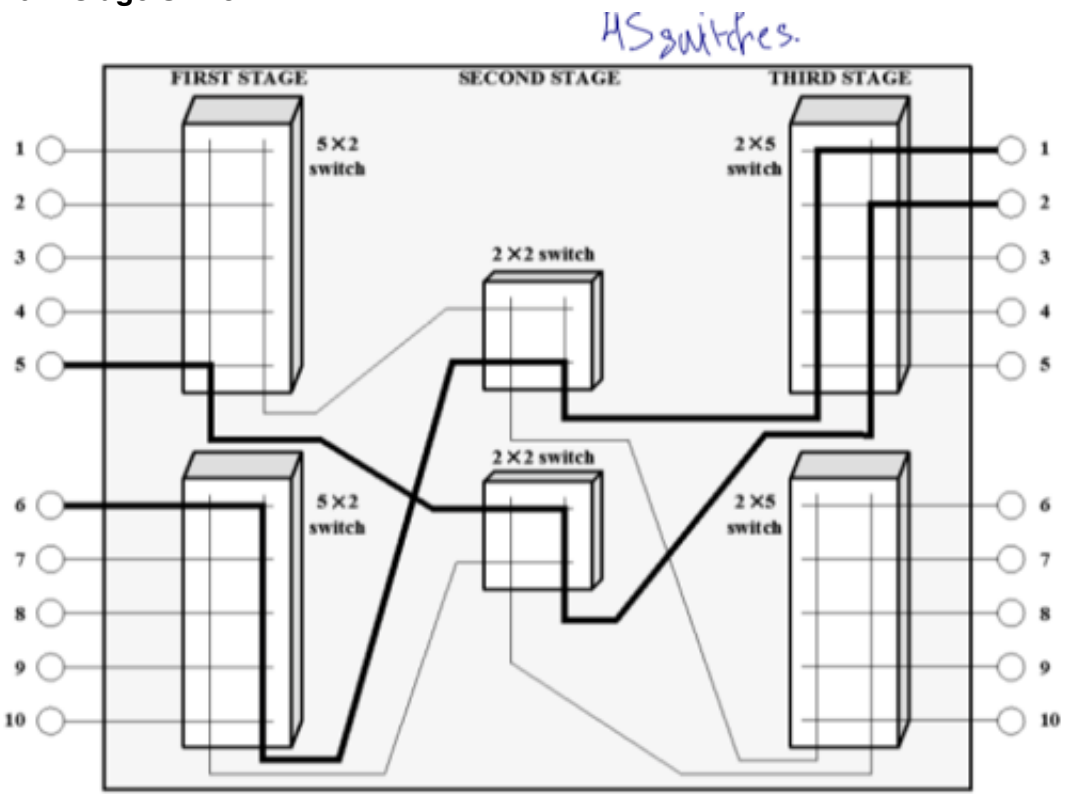


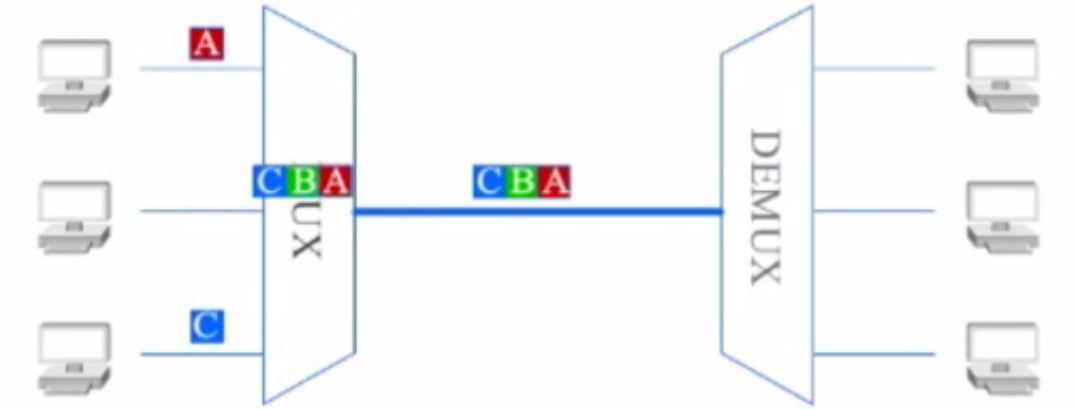
Figure 9.6 Three-Stage Space-Division Switch

Compare 2 types of space division switch.

	Single Stage (Crossbar) Switch	Multi-Stage Switch
Advantages	• simple • non-blocking scheme, everyone can talk to each other	lesser/smaller switches –> efficient in cost & hw maintenance
Disadvantages	• list of switch grows huge, difficult to maintain • SPOF (if a switch fail, comm can't be made)	Maybe blocking, i.e. there is a max of number of connection can be established at the same time

1.1.3. Time Division Switching

This switch uses the TDM technique, to partition different lower-speed bit streams into chunks for sharing a higher speed stream.
Example of a synchronous TDM, it uses TSI mechanism (Time-Slot Interchange).



TSI is simple and effective, but the number of connections is limited by the amount of latency it can tolerate, so people use multiple TSI to carry a portion of the traffic and improve the latency.

1.1.4. SoftSwitch

A general-purpose computer running specialized software is used as a smart phone switch.
SoftSwitch costs less and has more functions than traditional circuit switches, very popular for VOIP approach.

1.2. Packet Switching

Packet Switching is designed for data transmission, which breaks the big packet into smaller ones, containing user data and control info (for routing purposes). Packet Switching has several advantages over Circuit

Switching:

- **Line efficiency**, single line shared by multiple packets
- it supports **data-rate conversion** so different stations using different data rates can exchange data.
- Packets are accepted & **buffered when network is busy** (which is rejected in Circuit Switching)
- **Prioritization** can be implemented.

There are 2 switching techniques:

1. **Packet Datagram**: each packet is independent from each other. Datagram is primitive thus flexible, no establishment setup. Packet can go on different routes, thus more flexible in case one node is down, and arrive out of sequence.
2. **Virtual Circuit**: similar to Circuit Switching, a preplanned route is setup for transferring packets (thus taking more time for establishment). No routing decision is required afterward thus packets are fwded more quickly. It's less reliable as if one or more node in the route is down. Used in ATM, point-2-point connection. For long message, this is more preferrable.

Example:

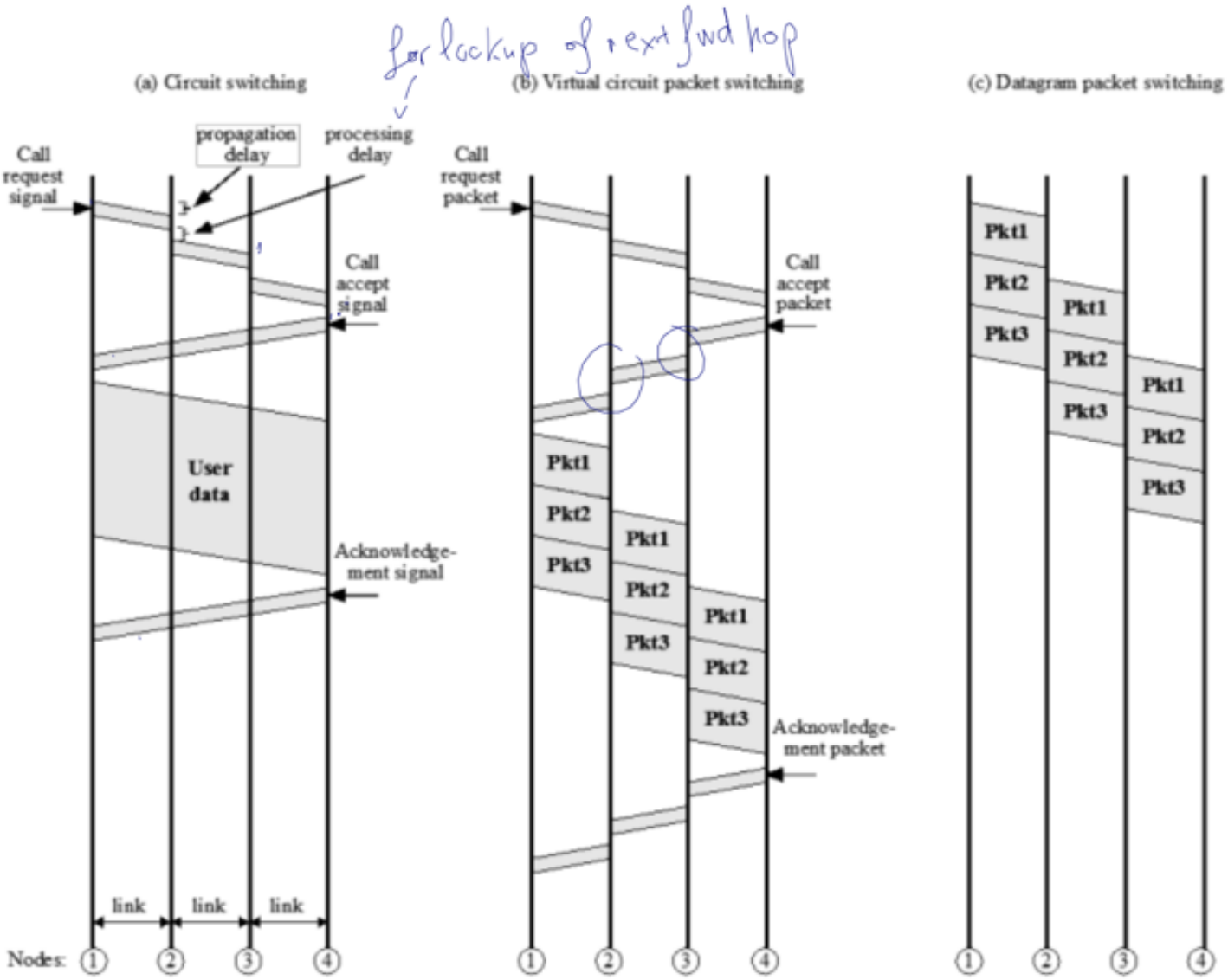


Figure 9.15 Event Timing for Circuit Switching and Packet Switching

1.3. Comparison of Communication Switching Techniques (Important)

Circuit Switching	Datagram Packet Switching	Virtual circuit Packet switching
Dedicate transmission path	No dedicate path	No dedicate path
Continuous transmission of data	Transmission of packets	Transmission of packets
Fast enough for interactive	Fast enough for interactive	Fast enough for interactive
Message 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 packet sequences
Usually no speed or code conversion	Speed and code conversion	Speed and code conversion
Fixed bandwidth	Dynamic use of bandwidth	Dynamic use of bandwidth
No overhead bits after call setup	Overhead bits in each packet	Overhead bits in each packet

1.4. ATM (Asynchronous Transfer Mode)

ATM is a switching and MUX technology that breaks packet into small, fixed-length packets called cells, to obtain the **performance of circuit-switching network**, and **flexibility and efficiency of a packet-switching network**, mostly used in DSL implementation.