Circuit Switching
&
Packet Switching

Lecture 7

Building large networks

- A network is a set of connected devices.
- When ever we have multiple devices, we have the problem of how to connect them!
  - Point-to-point (mesh or star topology): impossible for large networks.
  - Multipoint (bus topology): does not work for large network since the distances between devices and the total number of devices increase beyond the capacity of the media and equipments.

Switching is the solution

- A switched network consists of a series of interlinked nodes, called switches.

- Switches are devices capable of making temporary connections between any two or more devices connected to the switch.

Switched Network

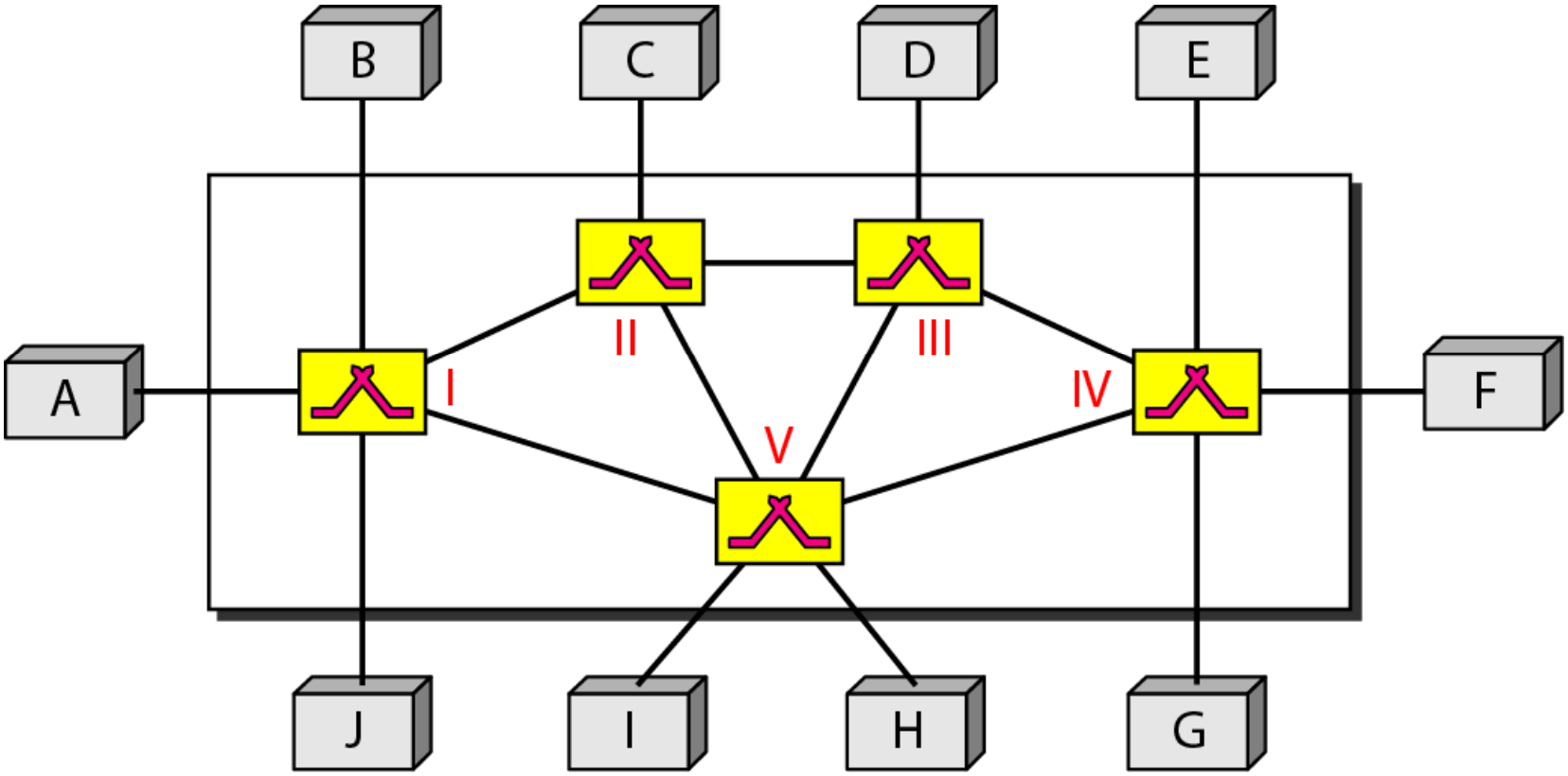


Figure: Switched network

Taxonomy of switched networks

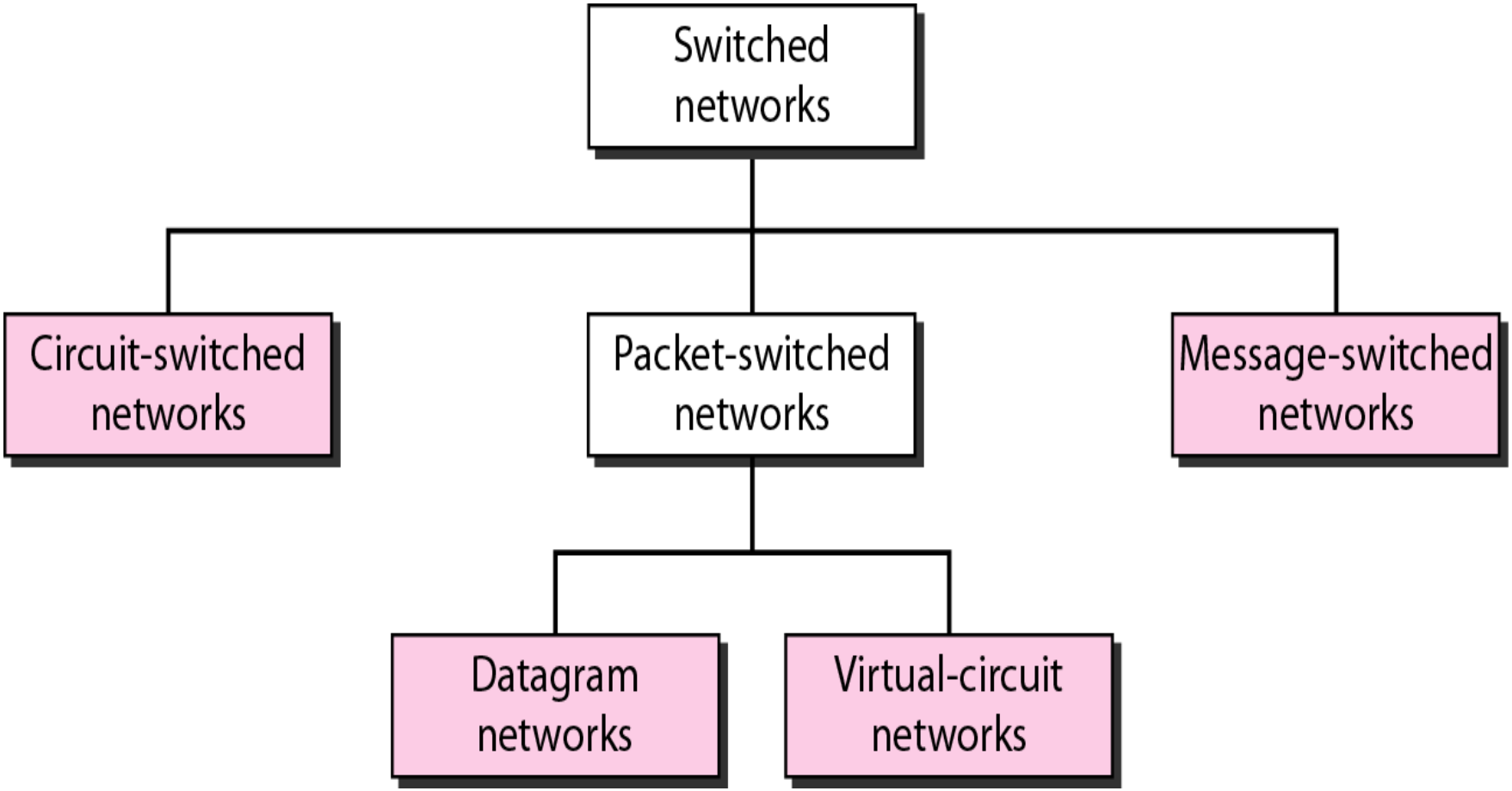


Figure: Taxonomy of switched networks

Circuit-Switched Networks

A circuit-switched network consists of a set of ***switches*** *connected by* ***physical links****.*

A ***connection*** *between two stations is a* ***dedicated path*** *made of one or more* ***links****.*

However, each connection uses only one ***dedicated channel*** *on each* ***link****. Each* ***link*** *is normally divided into* ***n*** *channels by using* ***FDM*** *or* ***TDM****.*

Phases in CSN (connection- oriented)

- **Setup phase**: In ***fig 3,*** the **end systems (A & M)** are directly **connected to a switch.**

  When ***end system A*** needs to **communicate** with ***end system M, sys. A*** requests a **connection** to ***M*** that must be **accepted** by all **switches as well as** by ***M*** itself. (this is called).

- **Data transfer phase**: A circuit (channel) is **reserved** on each **link**, and the **combination** of circuits/channels defines the **dedicated path.** After the **dedicated path** made of connected circuits/channels is established, **data transfer** can take place.

- **Connection end phase**: After all data have been transferred and any of the end systems A or B discard the connection, all the dedicated circuits/channels are released to be used by another connection.

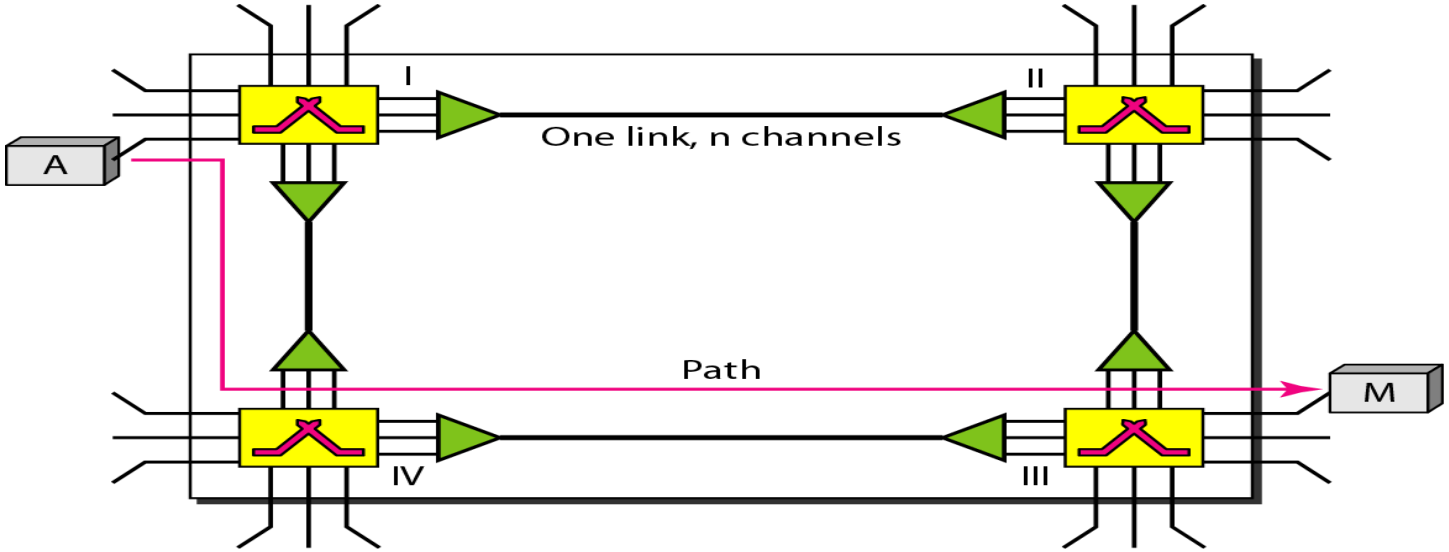


Figure : A trivial circuit-switched network

Circuit Switching

- Must have **switching capacity** and **channel capacity** to establish connection.
- Must have **intelligence** to work out **routing**.

- **Important aspects of Circuit Switching:**
  - Channel capacity is **dedicated** for the whole duration of connection.
  - If no data to transfer, **capacity is wasted.**
  - **Set up (connection)** takes time.
  - **Once connected,** transfer is **transparent.**
  - Developed for **voice traffic (phone).**

- **Examples:**
  - Telephone networks.
  - ISDN (Integrated Services Digital Networks).

Timing in Circuit Switching

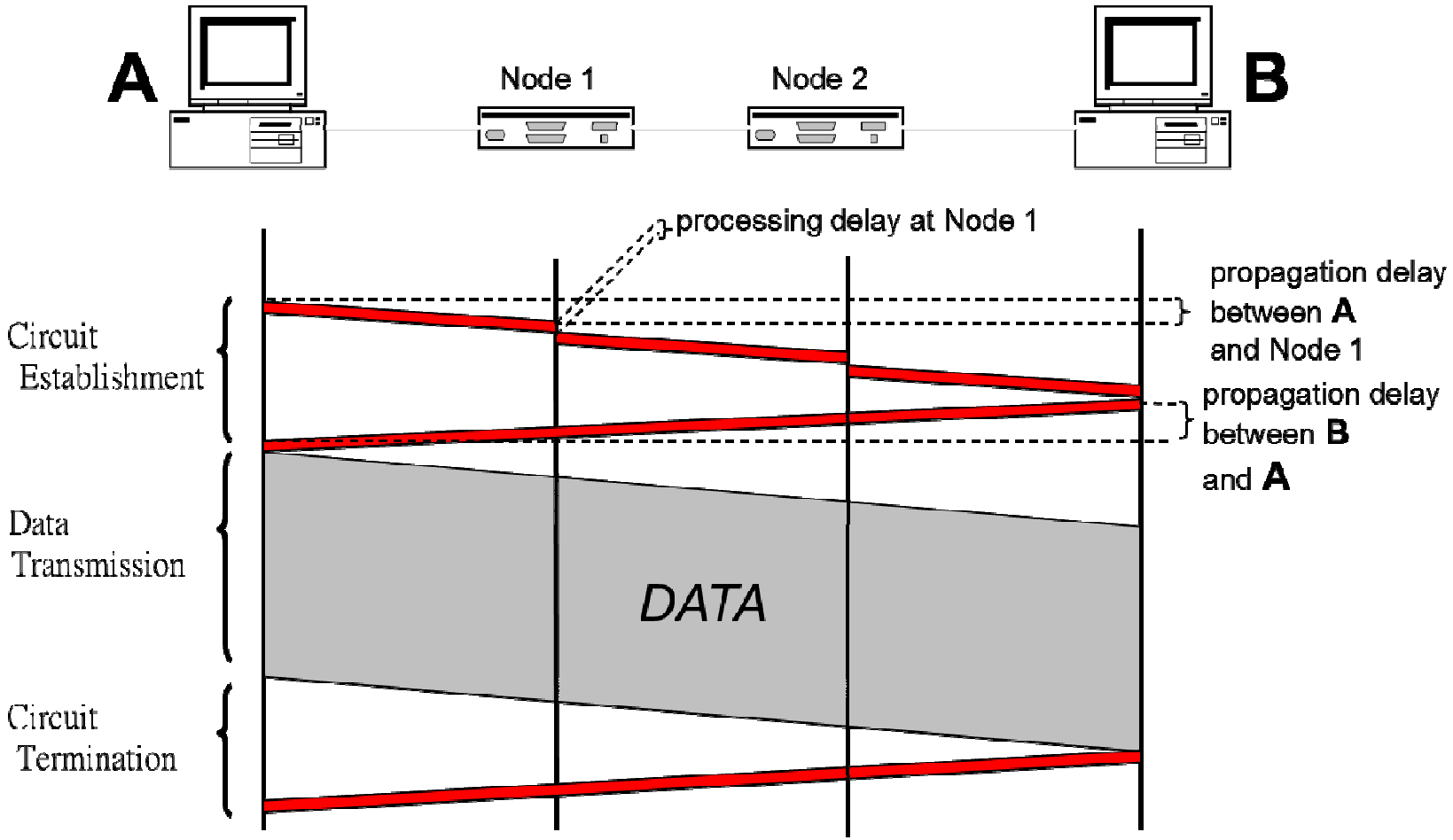


Figure : Timing in Circuit Switching

Circuit Switching
Advantages and Disadvantages

- **Advantages:**
  - Fixed delays.
  - Guaranteed continuous delivery.

- **Disadvantages:**
  - Channel capacity is **dedicated** for the duration of connection.
  - When there is no data to transfer, circuits remain idle, so capacity is **wasted**.
  - **Connection setup** takes time. So **not economical for short message**.
  - Developed for **voice traffic** (64 Kbps).
  - **Difficult** to support **variable data rates**.

Public Circuit Switched Network

Circuit switching was developed to handle voice traffic but is now also used for data traffic. A public telecommunications network can be described using four generic ***architectural components:***

- **Subscribers:** The devices that attach to the network, typically telephones, but the percentage of data traffic increases year by year.
- **Subscriber line:** The link between the subscriber and the network, also referred to as the *subscriber loop* or *local loop*, mostly using twisted-pair wire.
- **Exchanges:** The switching centers in the network. A switching center that directly supports subscribers is known as an end office.

Trunks: The branches between exchanges. Trunks carry multiple voice-frequency circuits using either FDM or synchronous TDM

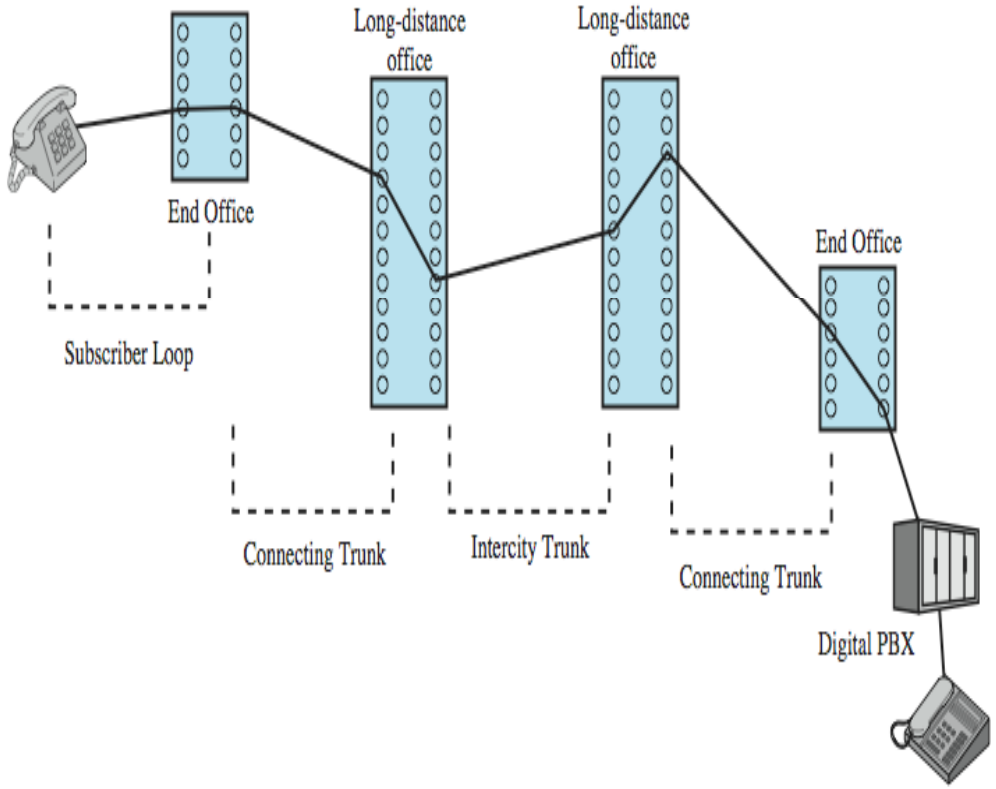


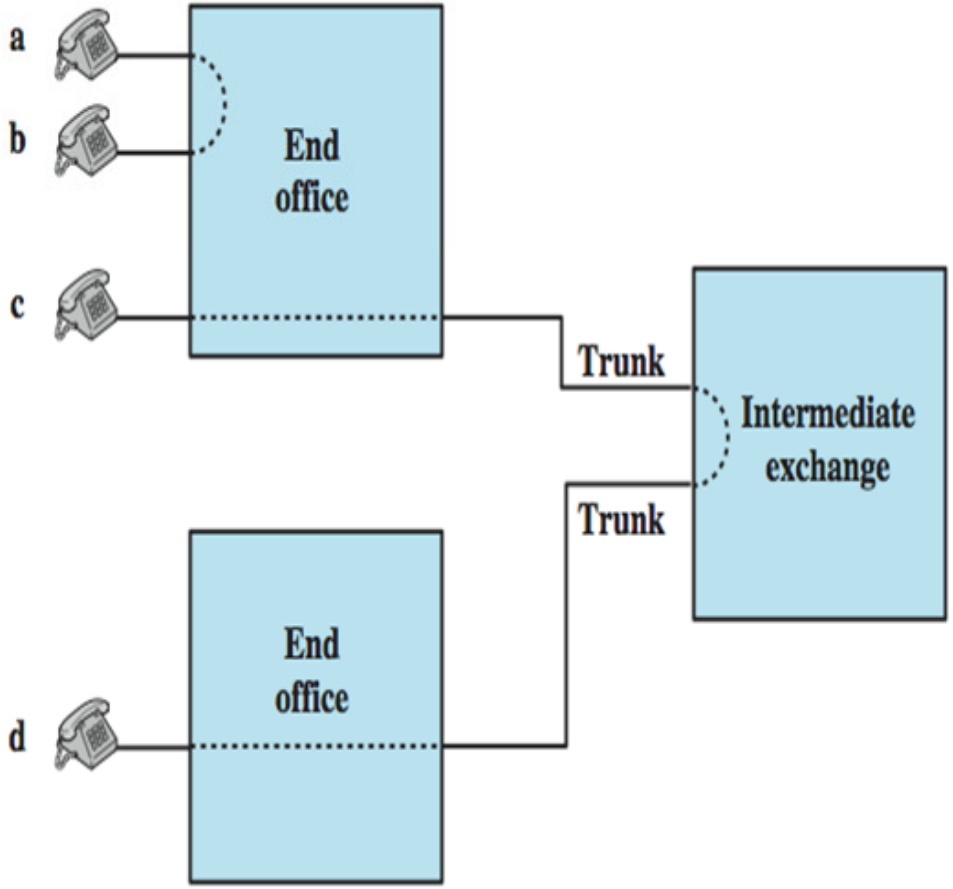
Figure : **Public Circuit Switched Network**

Circuit Establishment

Subscribers connect directly to an **end office**, which switches traffic between subscribers and between a subscriber and other exchanges. The other exchanges are responsible for ***routing*** and ***switching*** traffic between **end offices**.

➢ *In the figure*, a connection is established between lines ***a*** and ***b*** by simply setting up the connection through the **end office.**

➢ The connection between ***c*** and ***d*** is more complex. In c's end office, a connection is established between line ***c*** and one channel on a ***TDM trunk*** to the **intermediate switch**. In the intermediate switch, that channel is connected to a channel on a ***TDM trunk*** to ***d***'s **end office**. In that **end office**, the channel is connected to *line* ***d***.



Digital Circuit Switching Elements and Concepts

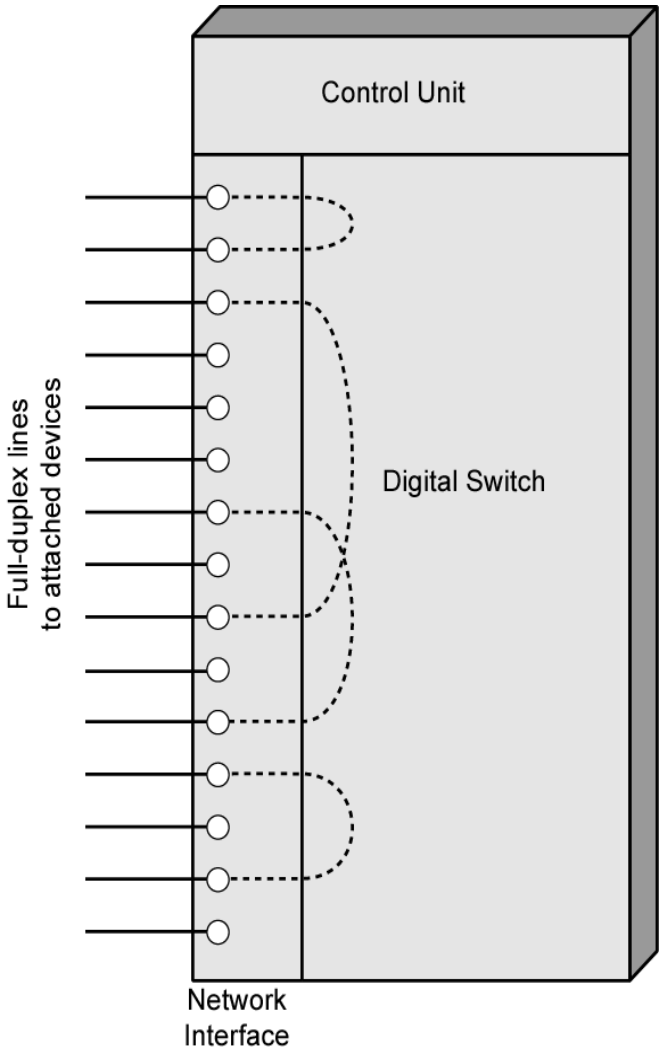


Figure : Circuit Switching Elements and Concepts

- **Digital Switch:**
  - To provide a transparent signal path between any pair of attached devices.
  - Typically, the connection must allow **full-duplex transmission**

- **Network Interface**
  - Represents the functions and hardware needed to connect digital devices, such as *data processing devices* and *digital telephones*, to the network.
  - Analog telephones can also be attached if the network interface contains the logic for converting to digital signals

- **Control Unit:**
  - ***Establish connections:***
    - ✓ Generally on demand.
    - ✓ **Handle** and **acknowledge** requests.
    - ✓ Determine if destination is free.
    - ✓ **Construct** circuit/channel path.
  - ***Maintain connection***
  - ***Disconnect***

Packet Switching

Packet Switching

- Data are sent as **formatted bit-sequences,** so-called **packets.**

- Packets have the following structure:

  - Header and Trailer carry **control information** (e.g., **destination address, check sum**)

- **Each packet** is passed through the network from **node to node** along some path **(Routing).**

- At **each node** the **entire packet** is **received, stored briefly** (buffered), and then **forwarded** to the **next node** (Store-and-Forward Networks)

- Typically **no capacity** is **allocated** for packets.

Packet Switching
Advantages

- **Some important aspects of Packet Switching:**
  - **Single node to node link** can be **shared** by **many** end users **simultaneously.**
  - Packets are **queued and transmitted** as fast as possible.
  - Packets are **accepted** even when network is **busy.**
    - ✓ Delivery may slow down.
  - Priorities can be used.

Circuit vs. Packet switching

Circuit switching	***Packet switching***
Fixed delay	**Variable** delay
Very **inefficient** use of connection capacity	Much more **efficient** use of connection capacity
When overloaded, unable to make connection at all	Can almost always connect, but may be with long delays
Both ends of connection must use **same data rate**	Data-rate conversion is easy
Expensive for **variable data rate**.	Economical.

Circuit vs. Packet switching

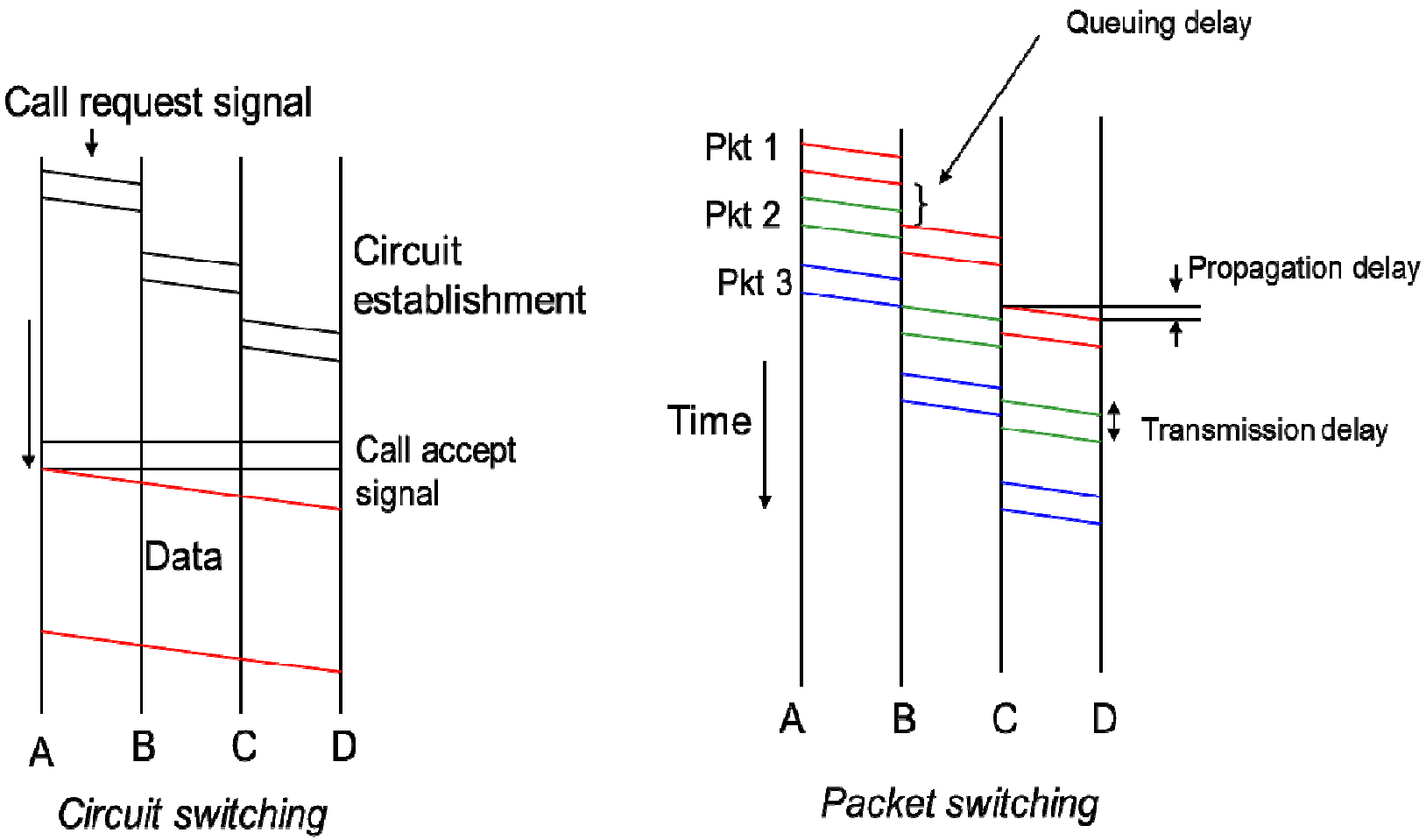


Figure 7: Circuit vs. Packet switching

Packet 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 packet switching

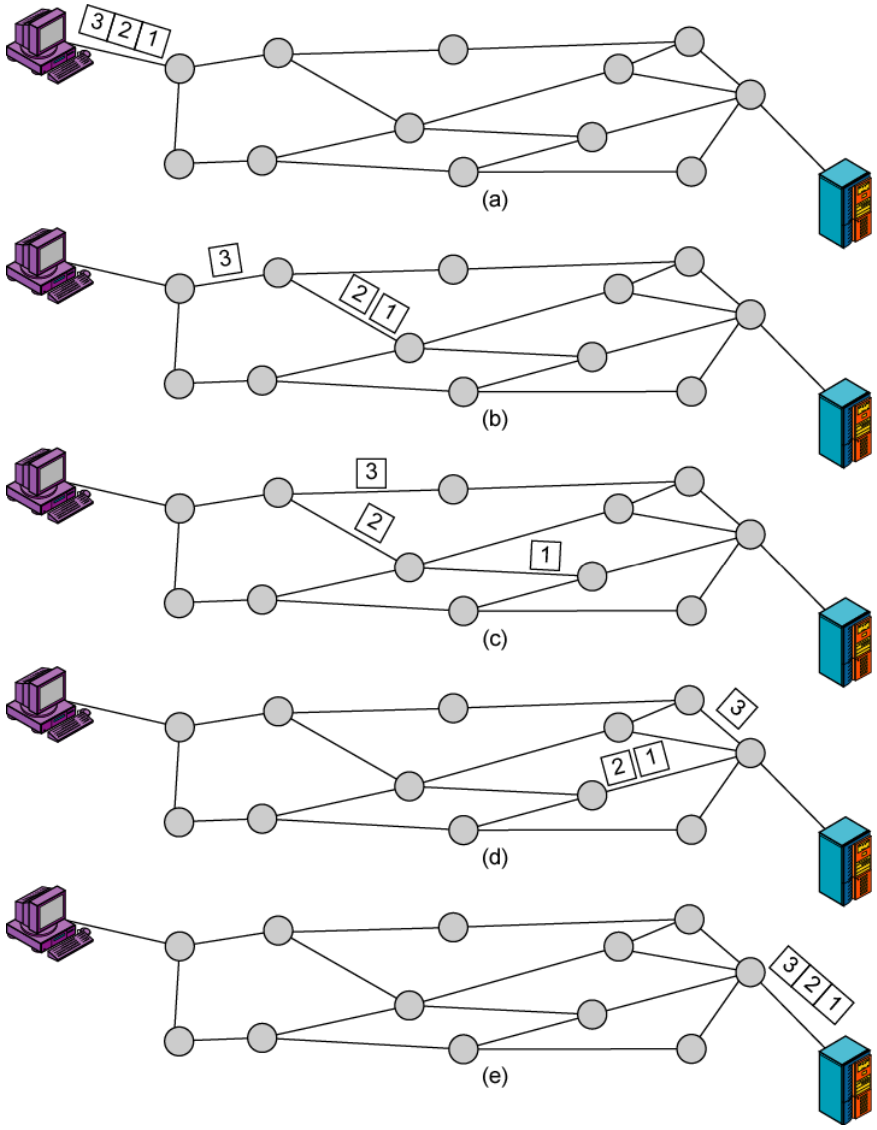


Figure 8: Datagram Packet switching

- **Each packet is independently switched.**
  - each packet header contains destination address.
- **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**
- **E.g., IP (The Internet Protocol)**

Timing of Datagram Packet Switching

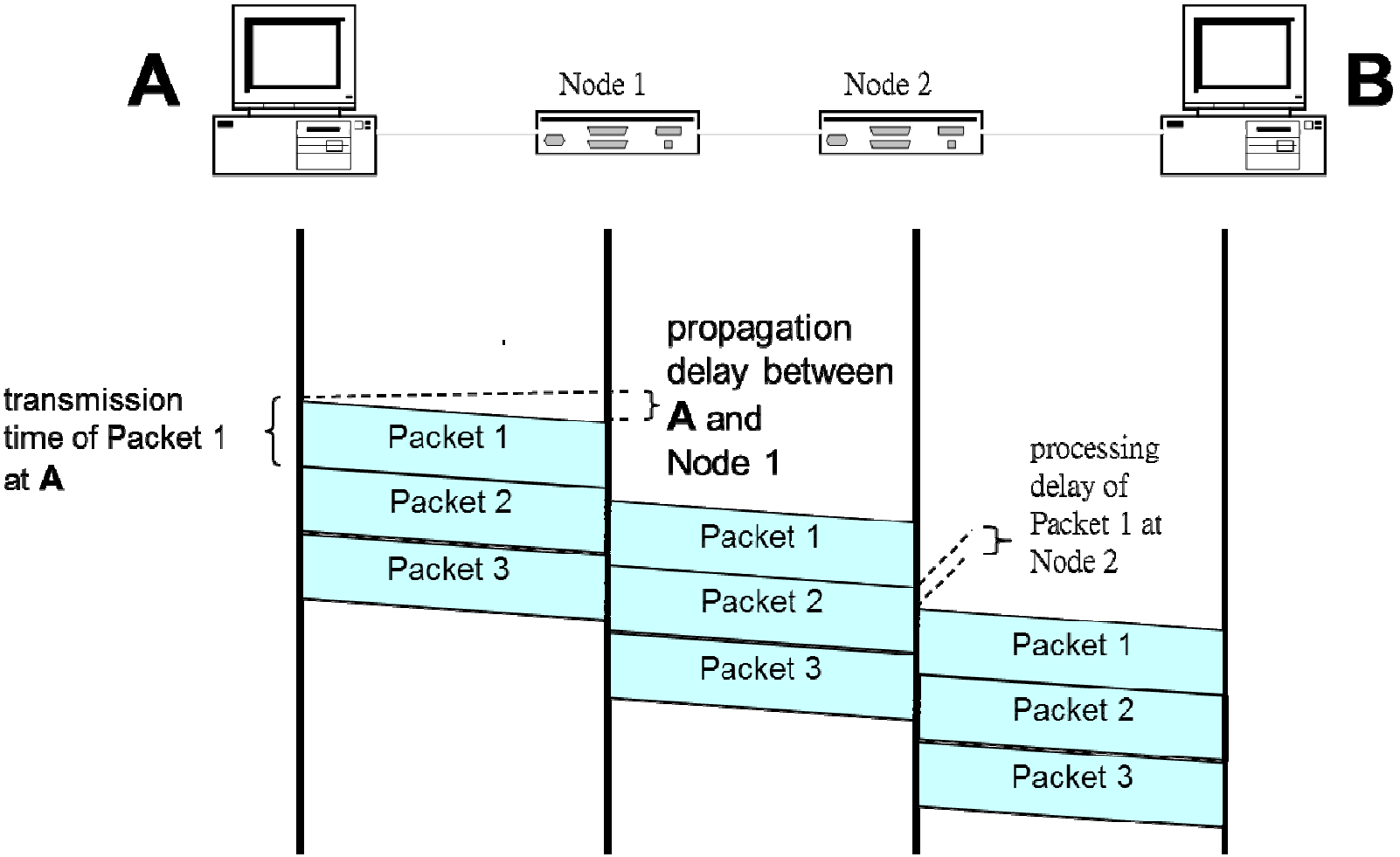


Figure 9: Timing of Datagram Packet switching

Virtual-Circuit Packet Switching

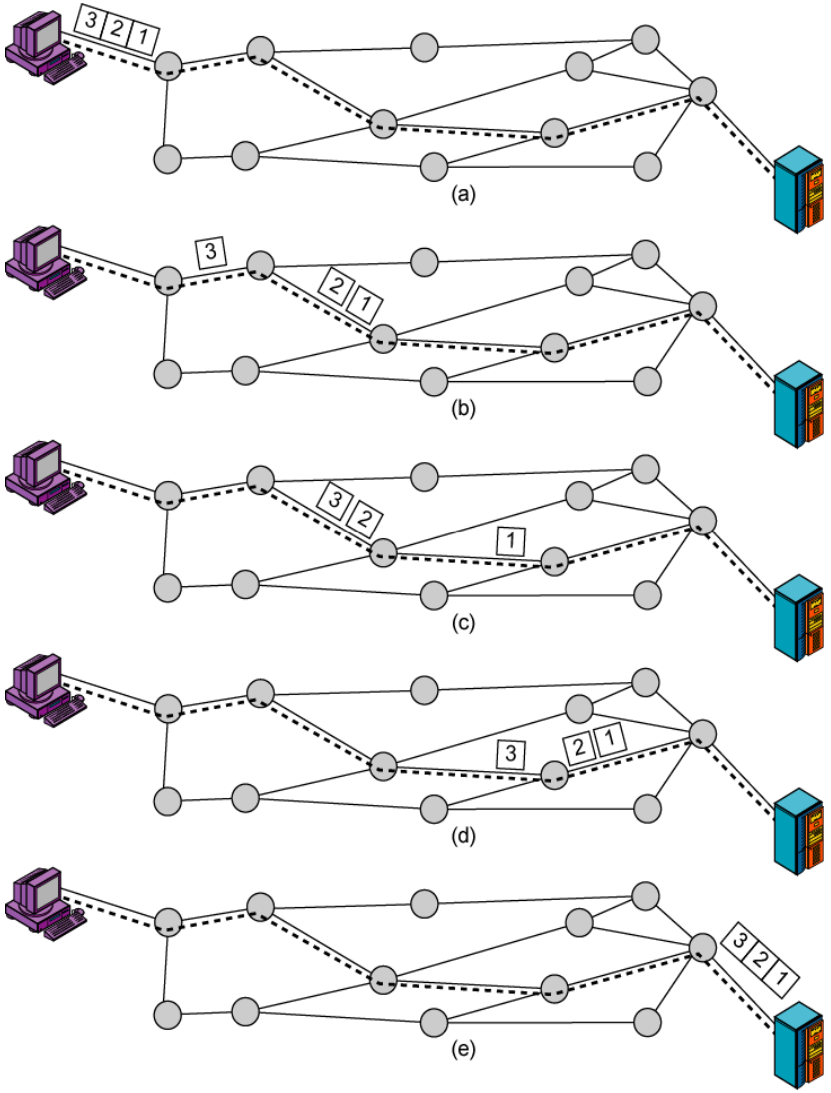


Figure 10: Virtual-Circuit Packet switching

- Preplanned route established before any packets sent
- Call request and call accept packets establish connection (handshake)
- Each packet contains a virtual circuit identifier instead of destination address
- No routing decisions required for each packet
- Clear request to drop circuit
- Not a dedicated path
- E.g., ATM (Asynchronous transfer mode)

Timing of Virtual-Circuit Packet Switching

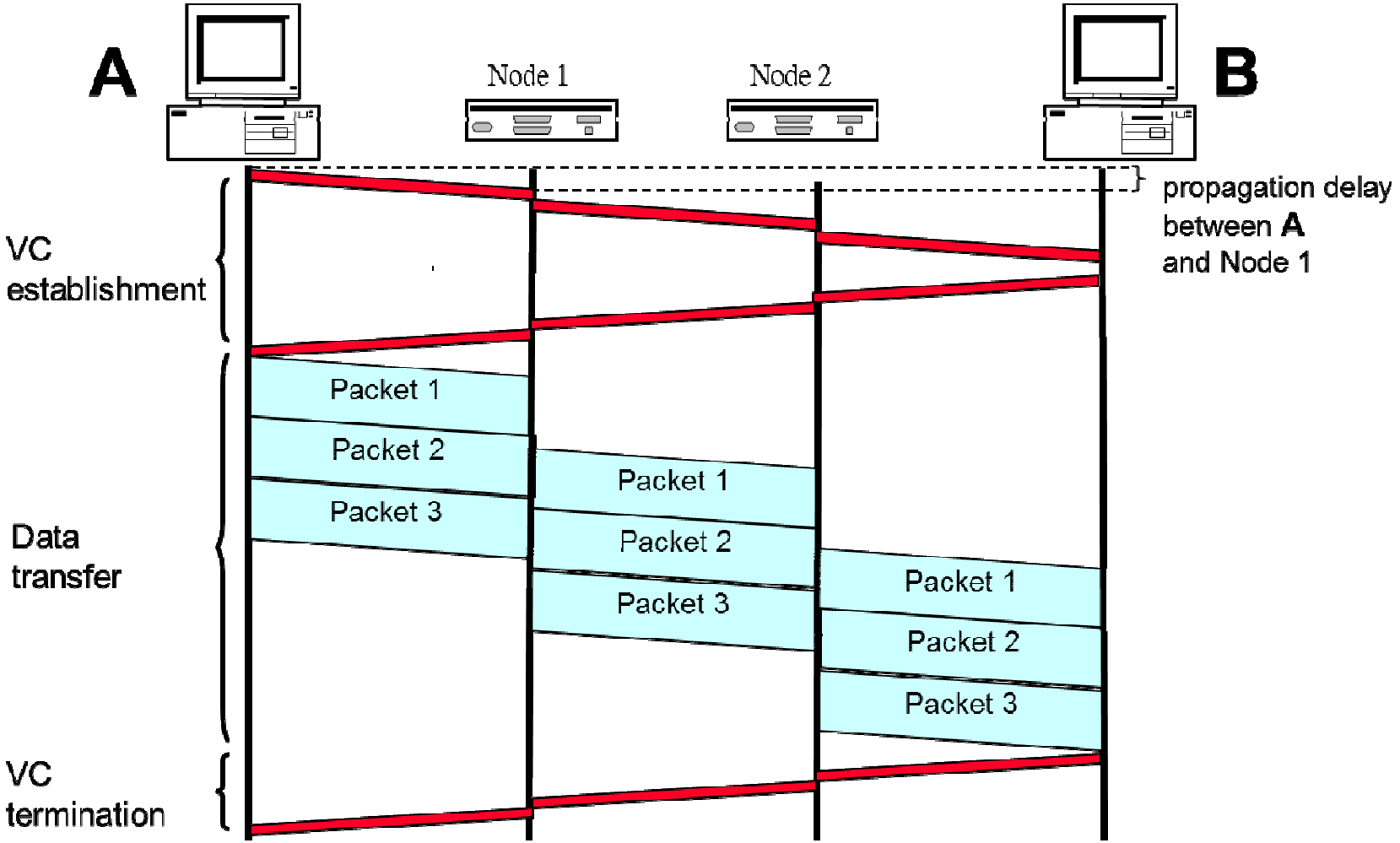


Figure 11: Timing of Virtual-Circuit Packet switching

Datagram vs. Virtual-Circuits Packet Switching

Datagram	***Virtual circuits***
☒ No sequencing for the packets	☒ Network can provide sequencing and error control
☒ No call setup phase	☒ Call set up phase is required before data transmission
☒ Good for non real time data transmission	☒ Good for real time data transmission
☒ Variable delay	☒ Fixed delay
☒ Routing decision needed for each packet	☒ No routing decisions needed
☒ More reliable as data loss is minimal	☒ Less reliable as data loss takes place in case of high traffic
☒ Routing can be used to avoid congested parts of the network	☒ Loss of a node looses all circuits through that node

END