CT 1502
Planning and Design of Communication Networks

Circuit Switching Networks

Chapter 3

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Outlines

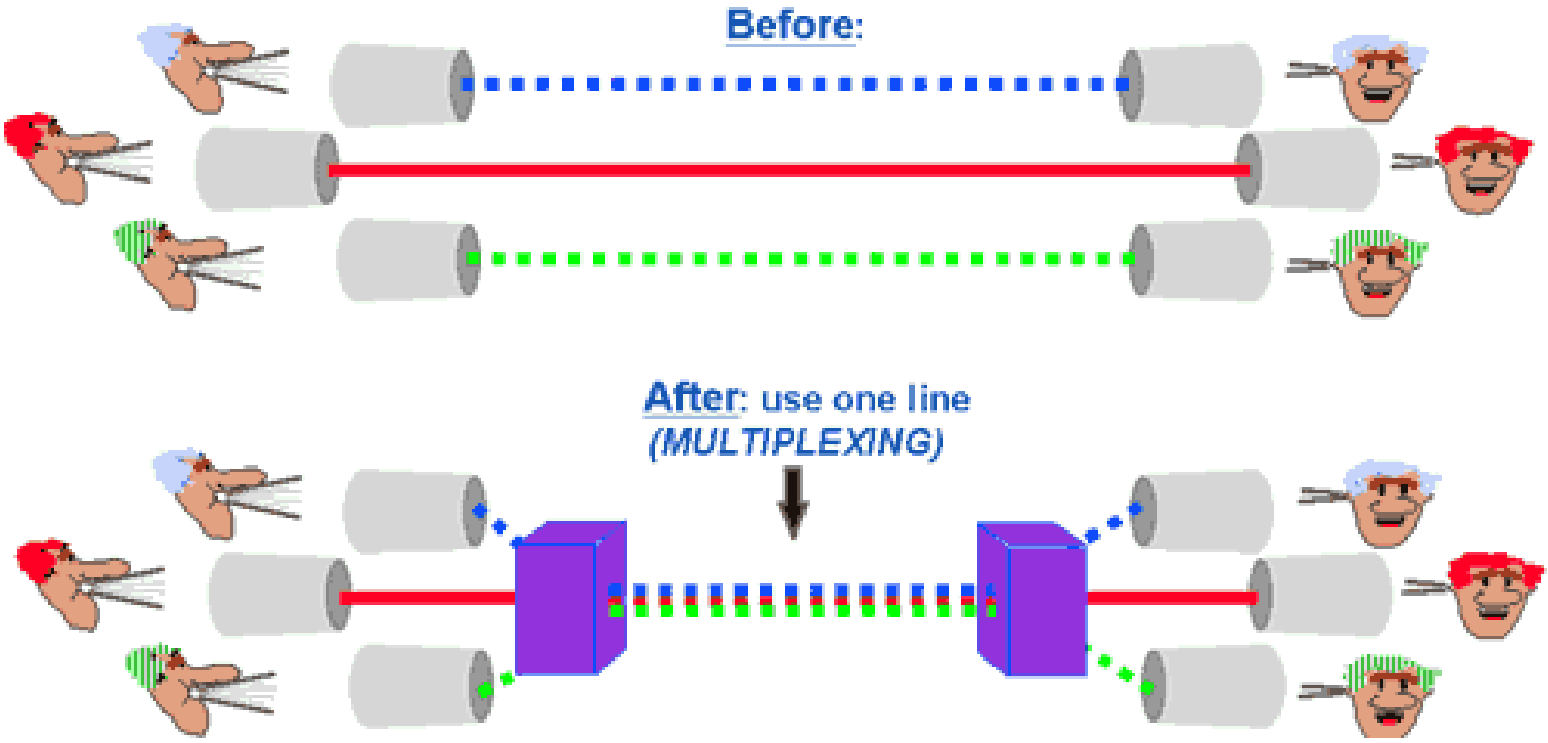
- Circuit Switching Principles and Benefits
- Principles of Sharing
- Circuit Switching Networks Architecture
- Analysis of circuit switching network
- Examples

Circuit Switching Principles and Benefits

- **Principles of Sharing:** designing technical architecture that provides communications over wired and wireless channels between variety distance points in order to “share” resources.

- Network engineering aims to design and develop these “sharing” ways to achieve its objectives.

Circuit Switching Principles and Benefits

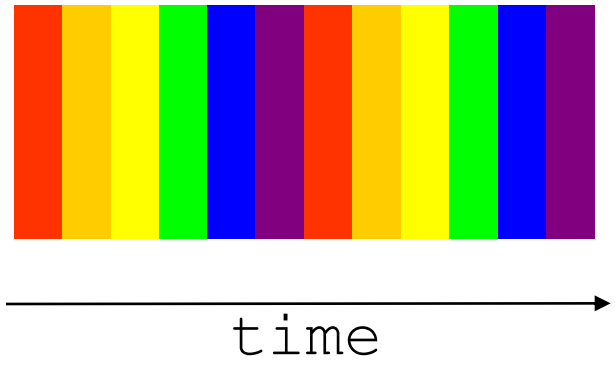


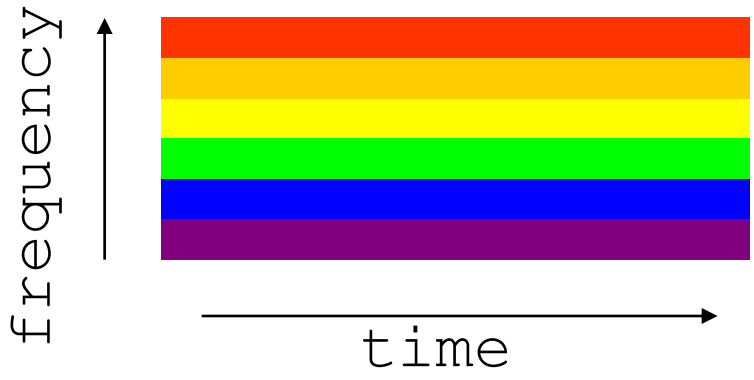
Main purpose is Sharing the channel

Circuit Switching Principles and Benefits

- **Principles of Sharing**
  - **Fixed Sharing:**
    - Frequency Division Multiplexing(FDM)
    - Time Division Multiplexing(TDM)
  - **Dynamic Division:**
    - more efficient, less expensive.

Fixed sharing





Principles of Fixed Division: *Frequency*

- **Frequency Bandwidth:** the difference in hertz between the highest frequency the signal uses and the lowest frequency it uses.
- **Multiplexing:** to refer to the combination of information streams from multiple sources for transmission over a ***shared medium.***

Principles of Fixed Division: *Frequency*

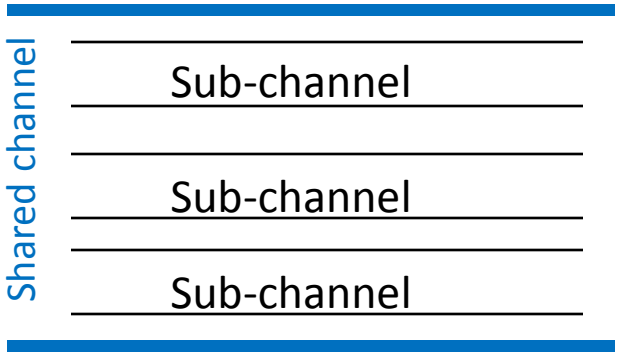
- **Frequency Division Multiplexing(FDM):** Divide the frequency spectrum into logical channels and assign each information flow one logical channel

$$N = F / f$$

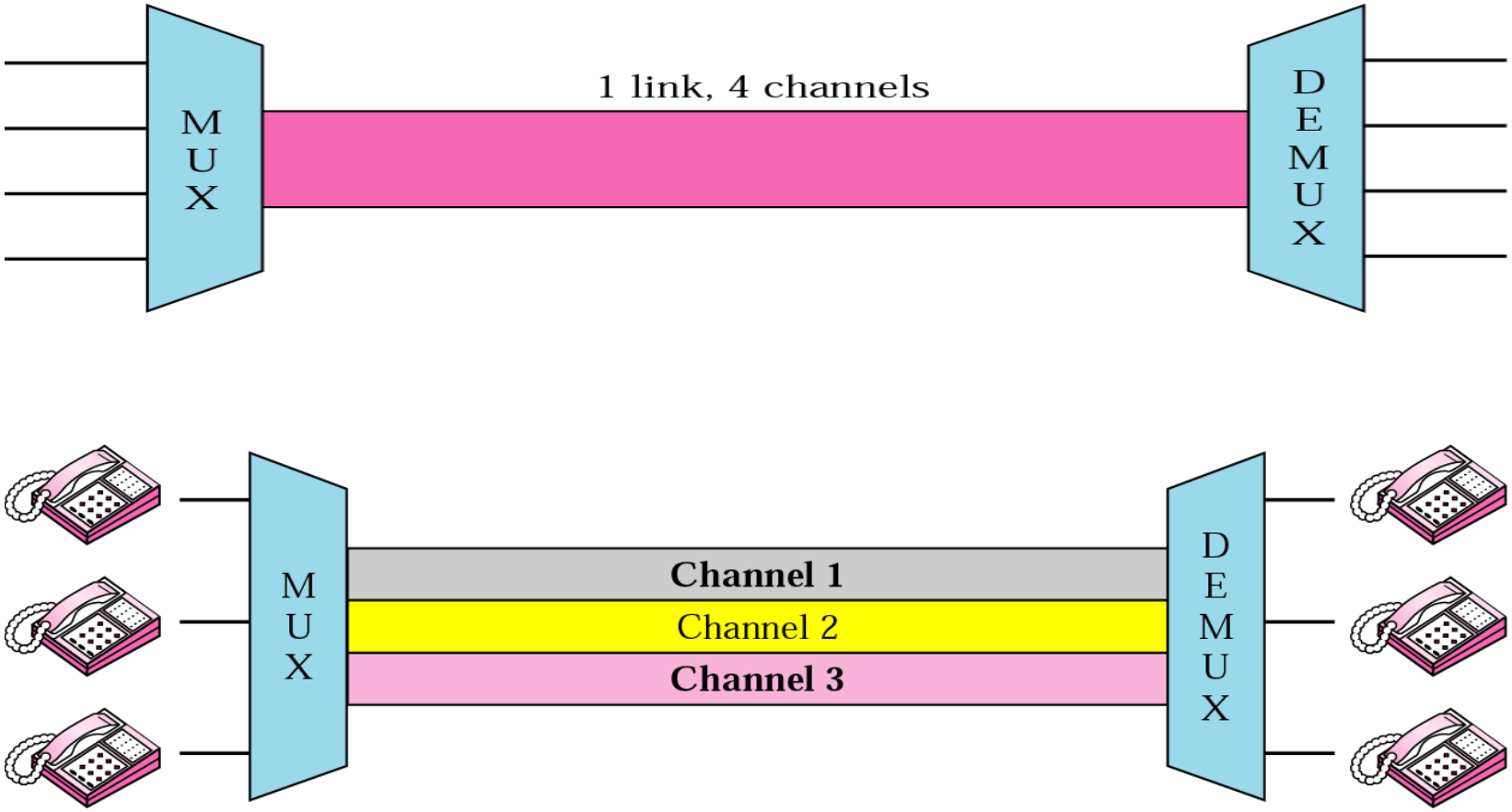
N: number of sub-channel

F: frequency bandwidth of shared medium(channel)

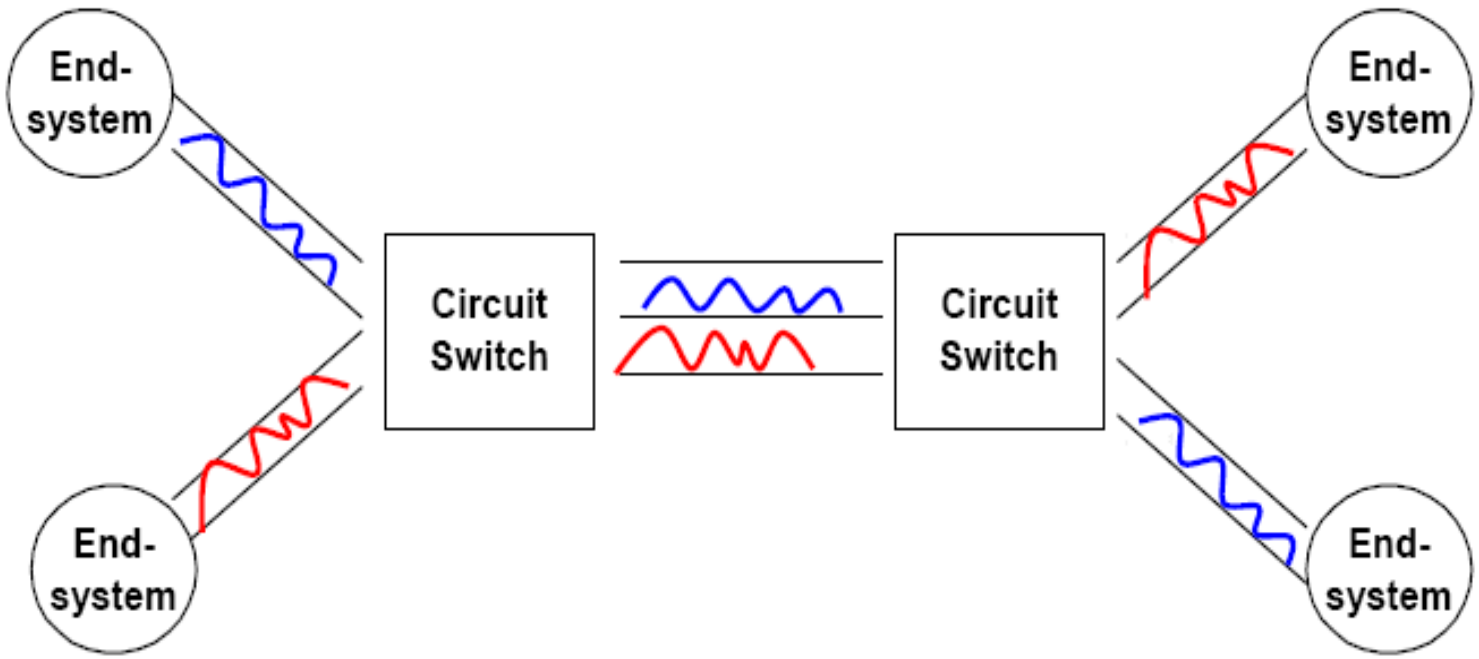
f: frequency of sub-bandwidth



Frequency Division Multiplexer(FDM)



Frequency Division Multiplexer(FDM)



- A circuit switch bundles (multiplexes) multiple voice calls on a high bandwidth link

Example (Frequency Division Multiplexer)

- Five channels, each with a 100-KHz bandwidth, are to be multiplexed together. What is the minimum bandwidth of the link if there is a need for a guard band of 10 KHz between the channels to prevent interference?

Answer :

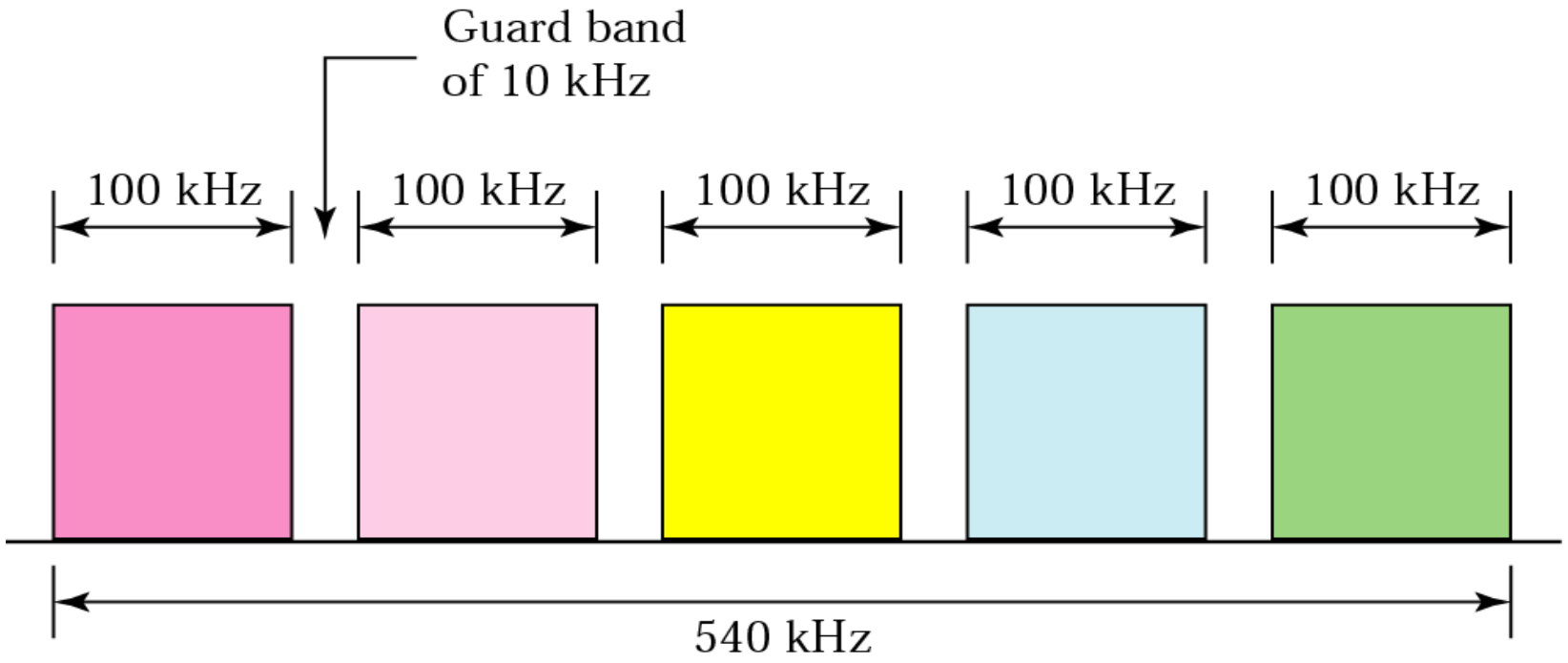
•For five channels, we need at least four guard bands. This means that the required bandwidth is at least

$$N=F/f \Rightarrow F= N \cdot f$$

$$5 \times 100 + 4 \times 10 = 540 \text{ KHz},$$

as shown next slide

Example (Frequency Division Multiplexer)

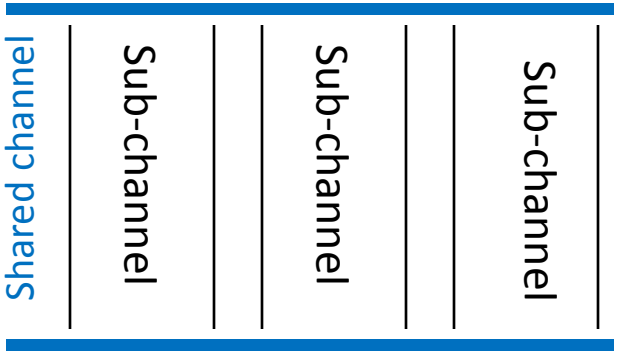


Principles of Fixed Division: *Time*

- **Time Division Multiplexing(TDM):** is a digital process that allows several connections to share the high bandwidth of a link .Each connection occupies(يشغل) a portion of time in the link

  – multiplexing in time simply means transmitting an item from one source, then transmitting an item from another source, and so on
  – TDM is a digital multiplexing technique for combining several low-rate channels into one high-rate one.

Principles of Fixed Division: *Time*



N = T / s

N: number of sub-channel
T: time frame of shared medium(channel)
S**:** time slots

Time Division Multiplexer(TDM)

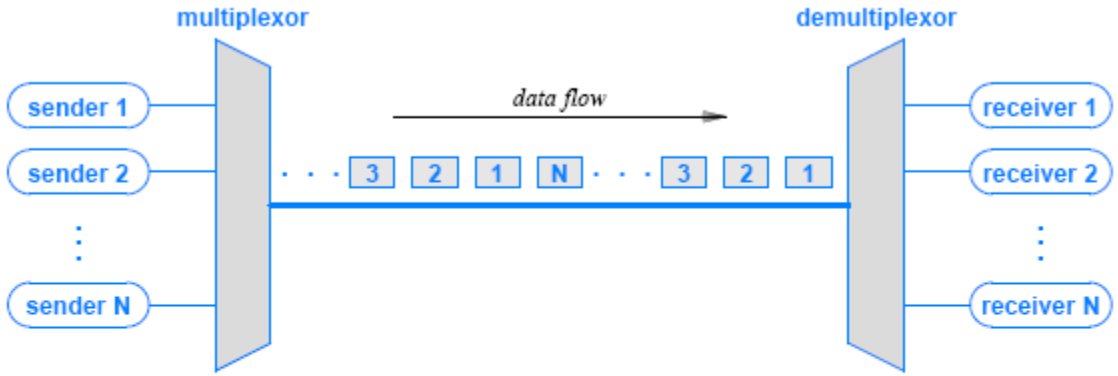
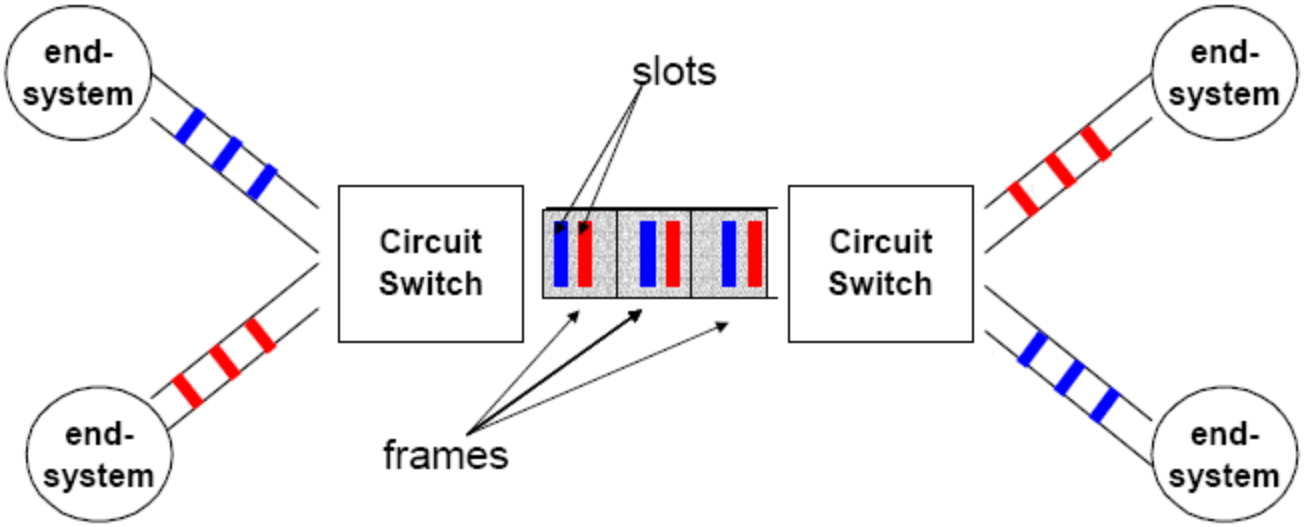


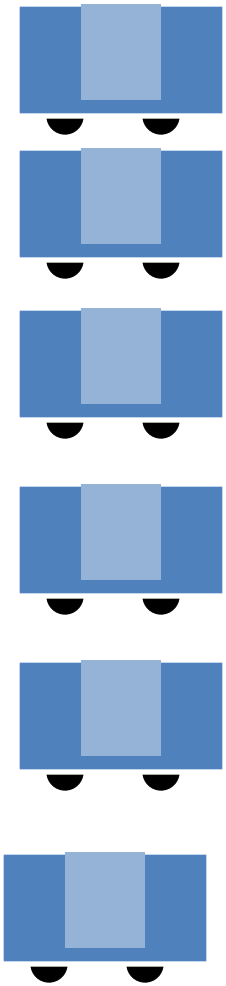
Figure 11.8 Illustration of the Time Division Multiplexing (TDM) concept with items from multiple sources sent over a shared medium.

Time Division Multiplexer(TDM)

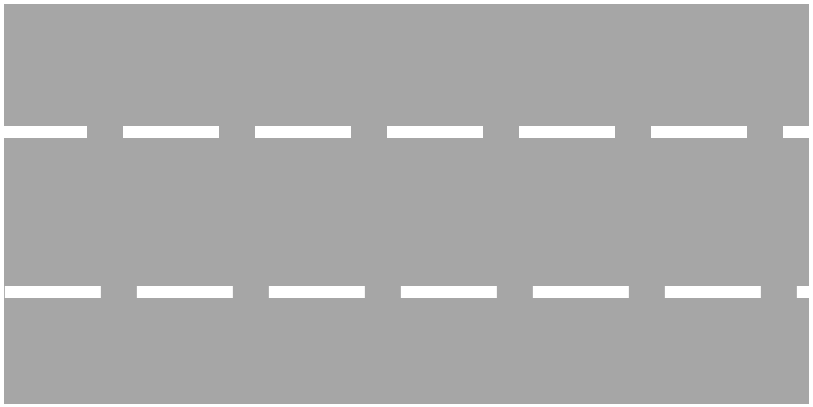


- Time is divided into frames of fixed length
- Each frame has a fixed number of constant-sized “slots”
- Each circuit obtains one or more “slots” per frame

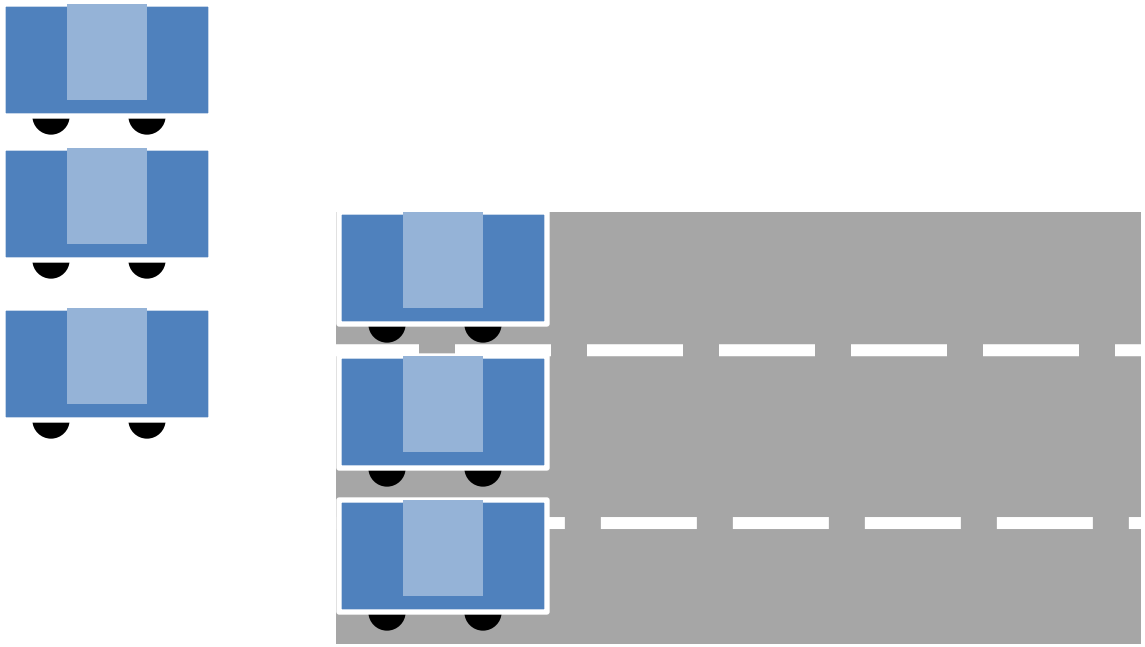
Time Division Multiplexer(TDM)



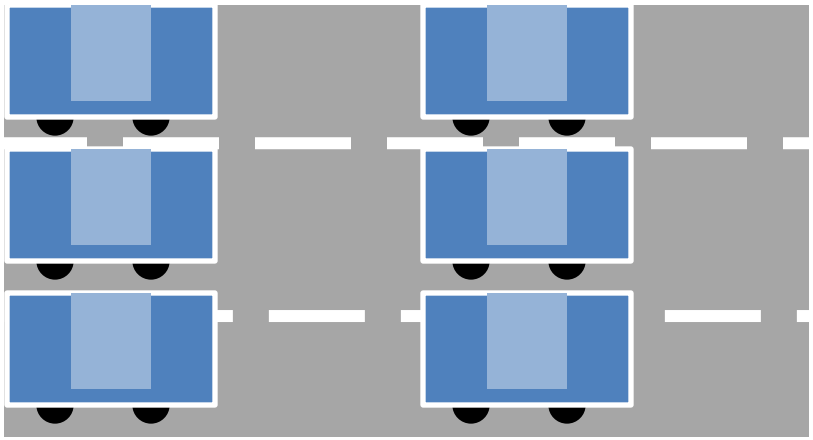
- Can all cars move at the same time?



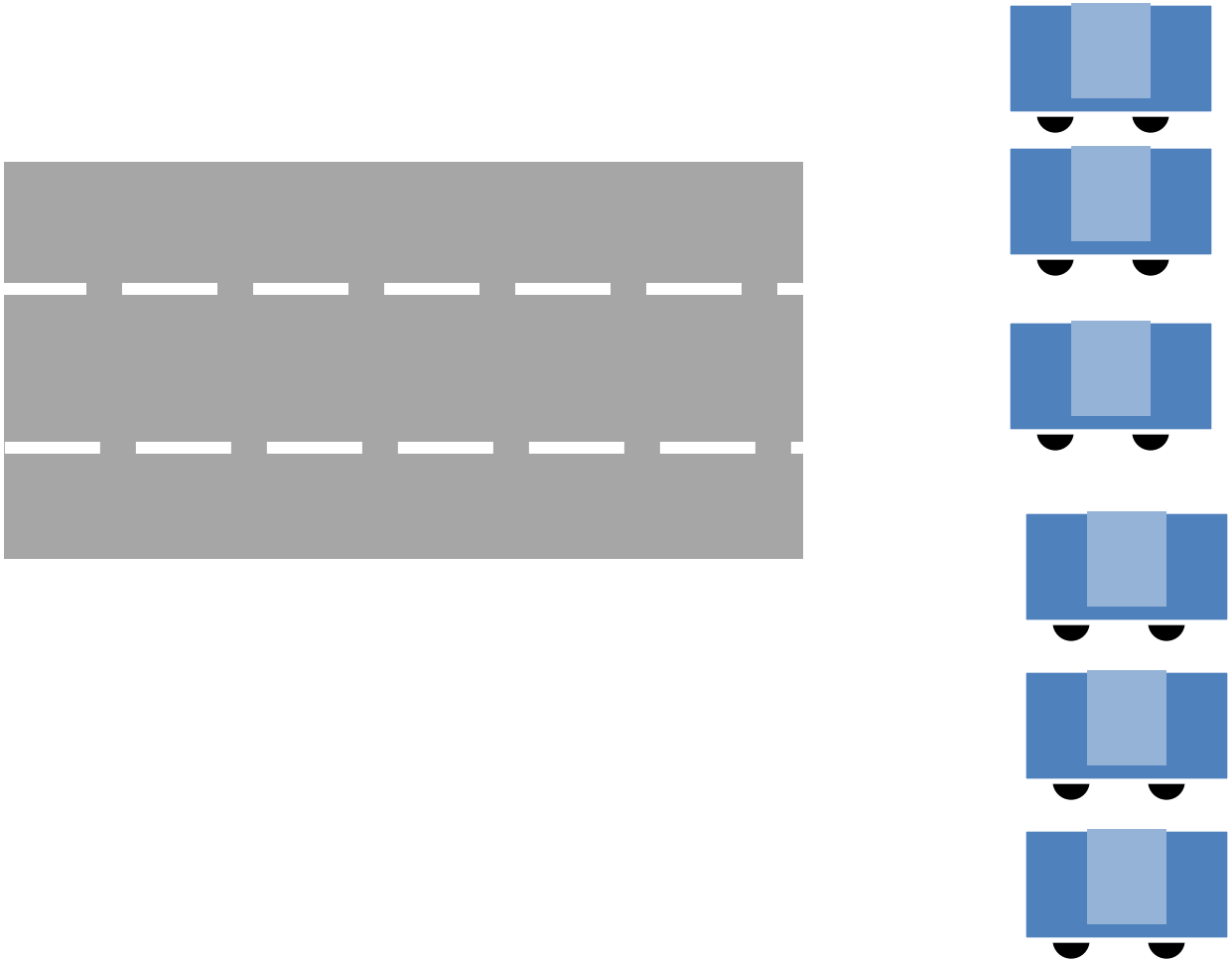
Time Division Multiplexer(TDM)



Time Division Multiplexer

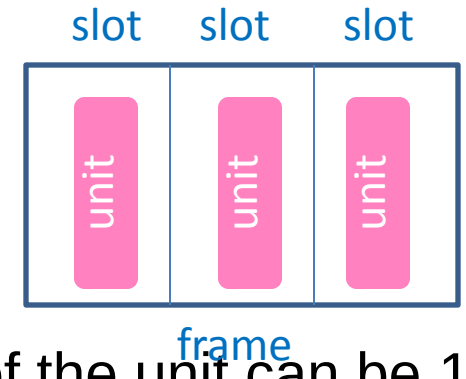


Time Division Multiplexer



Time Division Multiplexer(TDM)

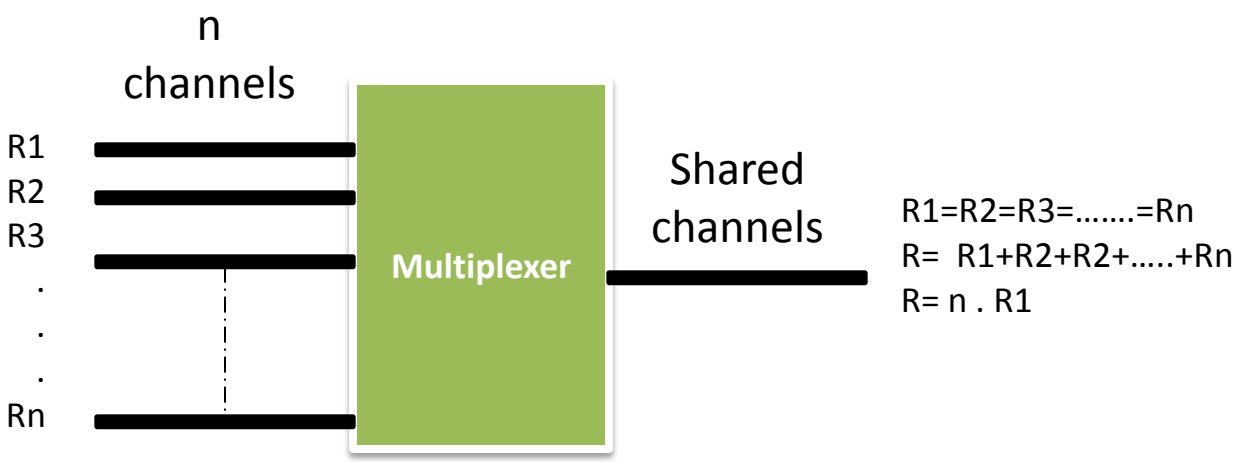
- The data flow(تدفق البيانات) of each connection is divided into units(وحدات) , and the link combines one unit of each connection to make a frame.



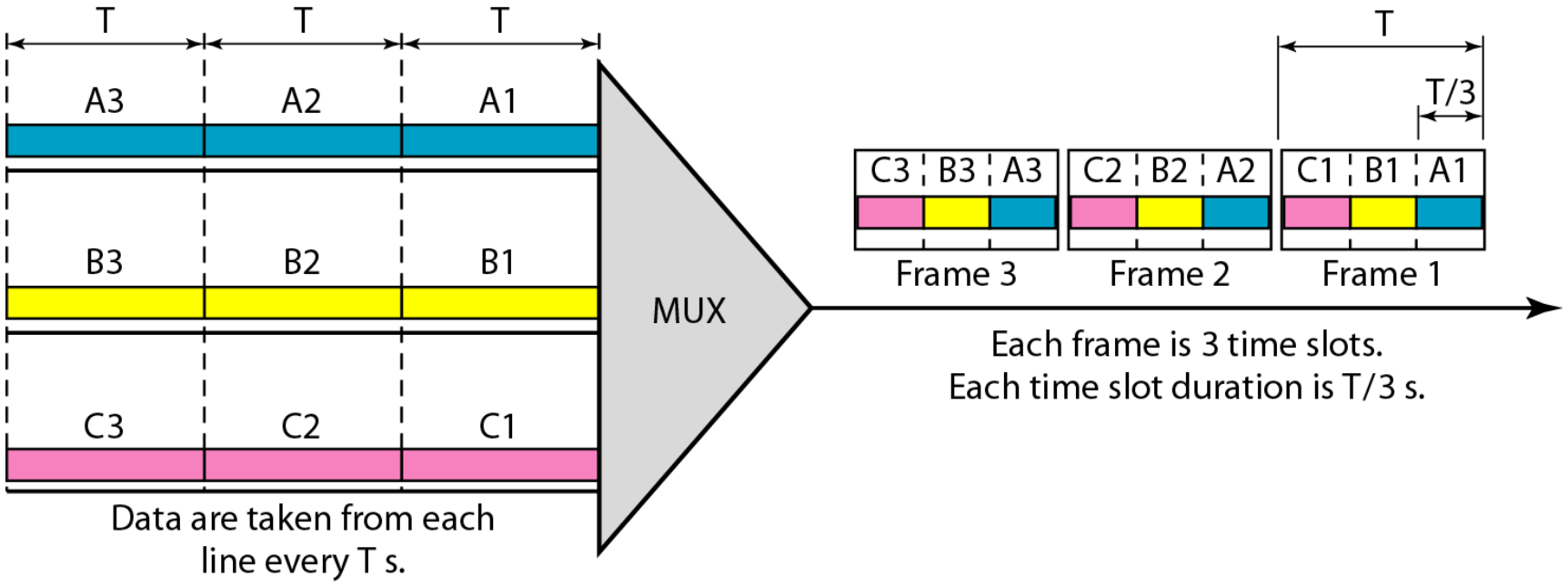
- The size of the unit can be 1 bit or several bits.
- For n input connections , a frame is organized into a minimum of n time slots (num of connections = num of slots)

Time Division Multiplexer(TDM)

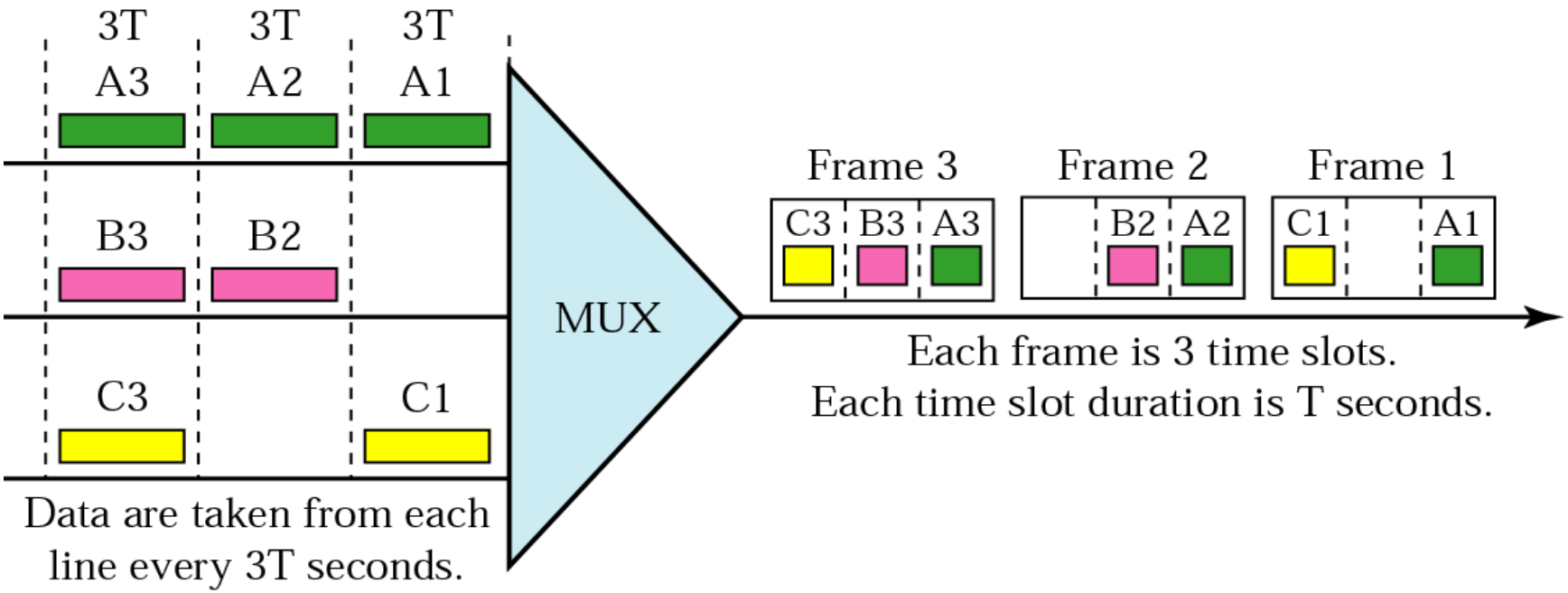
- Note
- In TDM , the data rate of the link that carries data from n connections must be n times the data rate of a connection to guarantee the flow of data.



Time Division Multiplexer



Time Division Multiplexer



Example (Time Division Multiplexer)

- Four 1-Kbps connections are multiplexed together. A unit is 1 bit.
- Find
  - (1) the duration of 1 bit before multiplexing
  - (2) the transmission rate of the link
  - (3) the duration of a time slot
  - (4) the duration of a frame

Example (Time Division Multiplexer)

Answer:

We can answer the questions as follows:

1. The duration of 1 bit is 1/1 Kbps, or 0.001 s (1 ms).
2. The rate of the link is 4 Kbps.
3. The duration of each time slot 0.001/4 s or $25*10^{-5}$ s or 0.25 ms
4. The duration of a frame 1 ms.

Dynamic Division

- **Dynamic division:** allow the user to use channel to transmit data only when he need to.
- In fixed division multiplexer Number of users "X" is equal to number of channels "N"

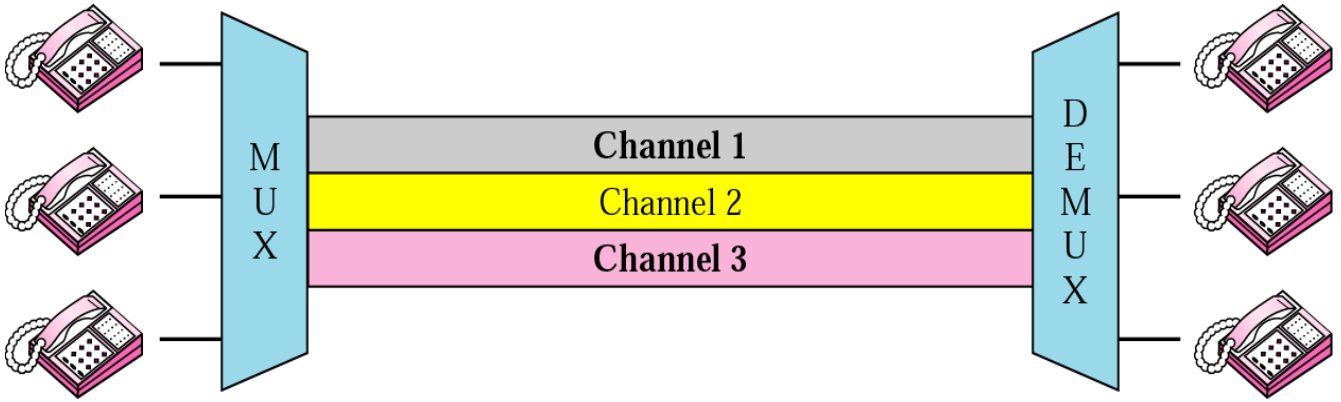
$$X=N$$

- In Dynamic division

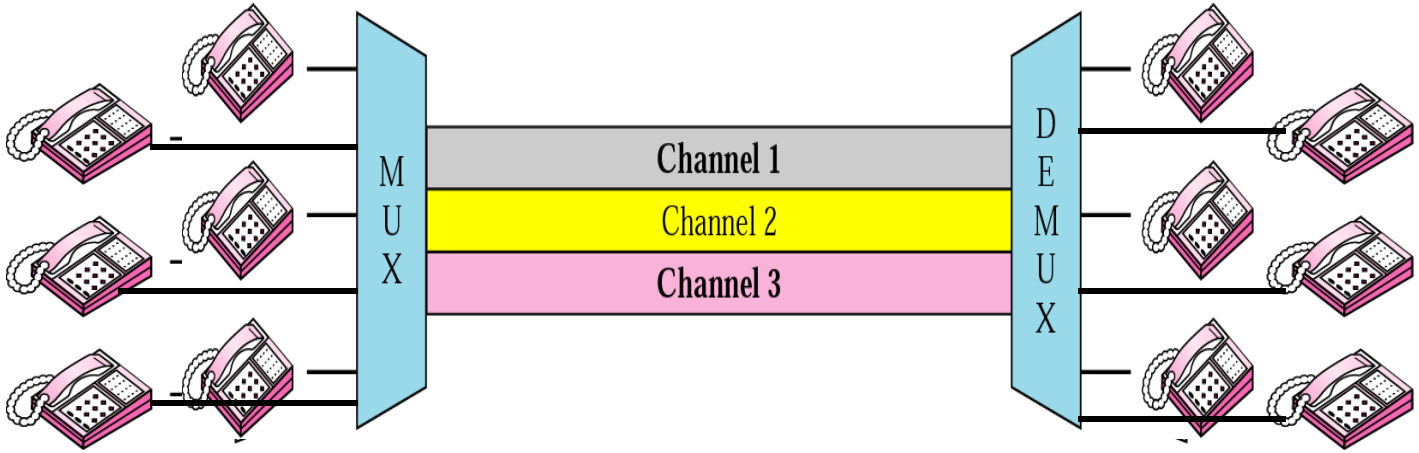
$$X>N$$

Dynamic Division

- User request a channel(call)
- Circuit switch reserve a sub-channel for that user to use
- After user done, the same channel can be reserved for other user
- In case all channels busy, and some user request one, the circuit switch "reject"(رفض) the call, that refer as "congestion" (اختناق)



Fixed division



Dynamic Division

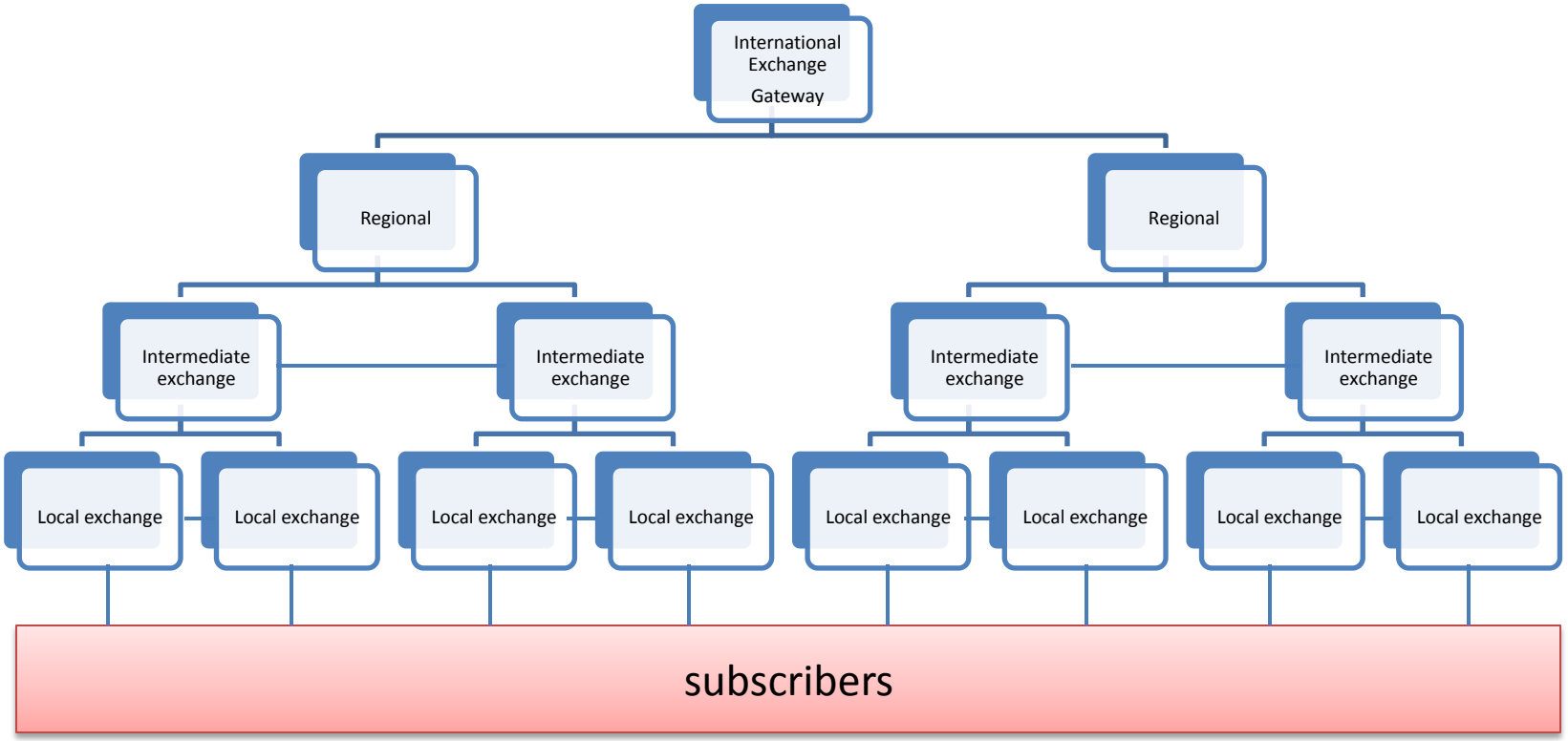
Circuit Switching Networks Architecture

- **Fixed Telephone Networks**
- **Mobile Telephone Networks**

Fixed Telephone Networks

- Telephone networks take a hierarchy structure (شكلاً هرمياً), the base is users' connections "Local Exchanges"(المقاسم المحلية) what form the local telephone network
- The hierarchy summit is the "International Exchanges"(لدولية)

Fixed Telephone Networks



Fixed Telephone Networks

- Characteristics:
  - Reliability
  - Readiness
  - Dial
  - Connecting
  - Continuation
  - Ending

Mobile Telephone Networks

- Relies on circuit switching concept
- Cellular phones using wireless communication channels
- Connection circuit connect mobile users to the nearest cellular mobile network station
- One call needs 2 communication channels,

one for sending, the other for receiving

Mobile Telephone Networks

- Mobile telephone networks can serve large

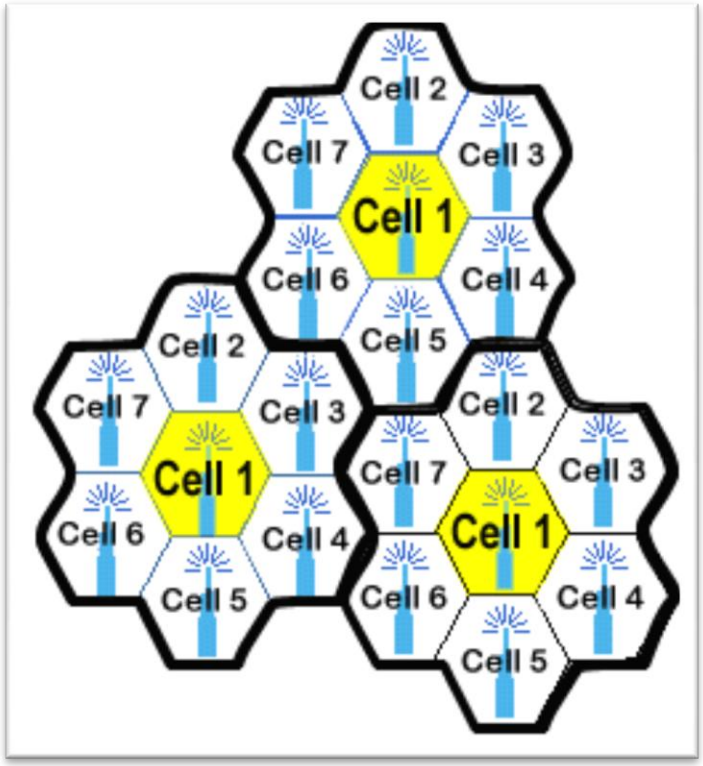
  number of subscribers at the same time as long as calls are “geographical isolated” (عزل جغرافي) to prevent signals “interference”(تداخل الاشارات)

How Mobile Telephone Networks

- re-usage of frequencies of wireless channels
  - Reuse of limited wireless frequencies to serve the most users as possible
- since mobile telephone relies on “circuit switching”, it’s requires:
  - Dividing frequencies into “clusters”(مجموعات).
  - For a frequency set used in one cell, can not be used in neighboring cells, but they can be used in distant cells
  - “Geographical isolated” is mandatory for reusing frequencies to avoid interference.

Frequency Reuse

- assigning to each cell a group of channels used within a small geographic area.
- Cells are assigned a group of channels that is completely different from neighboring cells.
- The coverage area of cells is called the “footprint”.
- This footprint is limited by a boundary so that the same group of channels can be used in different cells that are far enough away from each other so that their frequencies do not interfere.



Circuit Switching Networks Performance

- Tree factors to define Network

  Performance:

  1. Use Demand
  2. Network Capacity
  3. Performance Measure

Use Demands

- How many requests?
  - Requests are “random”(عشوائية)
  - Sometimes high, sometimes l
  - Calculate “traffic” (الحركة)

- How long it takes to serve?
  - Duration of service is “random”
  - Long duration, short duration

Use Demands

- Incoming calls:
  - Calculate R: how many calls in one unit of time
  - $R = \frac{\text{calls}}{\text{time unit}}$
- Call duration:
  - Calculate "call duration average" D
  - $D = \frac{\text{time unit}}{\text{call}}$

Use Demands

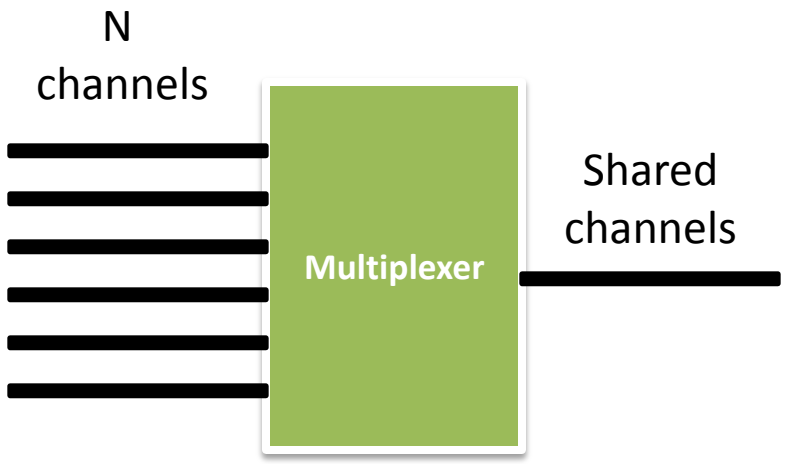
- Time unit:
  - The time unit used in circuit switching networks is:”Hour”
  - Performance studies perform on “Busy Hour”
  - Busy Hour : is the highest traffic hour in a day
  - Service Providers offer discount on some day hours to reduce the busy hour load.

Use Demands

- Traffic load:
  - **A = R [calls / hour] . D [hours / call]**
  - A: traffic load that measuring with “Erlang”
  - One Erlang is the usage of a channel within one hour

Network Capacity

- N: how many channels can be served



Performance Measure

- How many rejected calls (Congestion) of total calls.

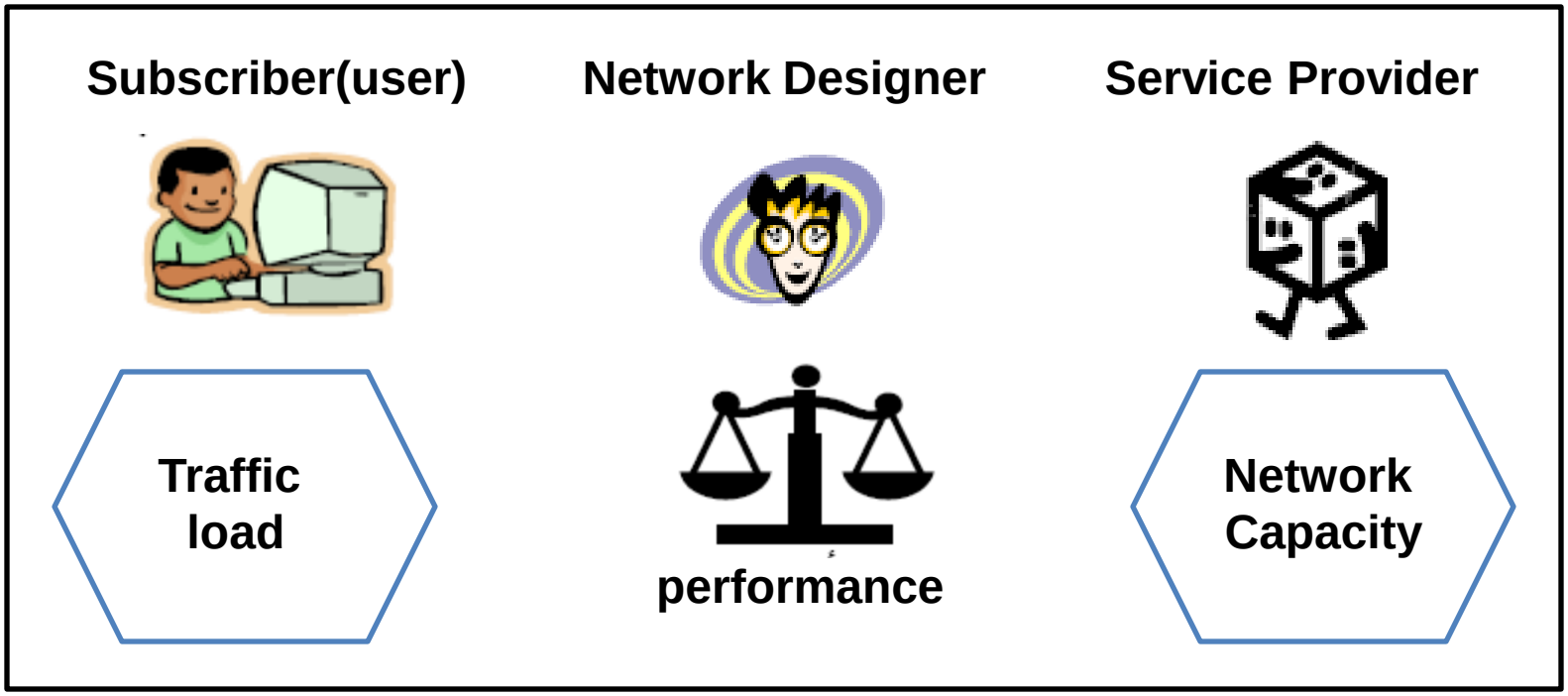
$$B = \frac{A^N / N!}{\sum_{i=0}^{i=N} (A^i / i!)}$$

- Rejected Traffic Load: **J = B . A**
- Carried (Services) Traffic: ***K = (1-B) . A = A – J***
- Average Channel Occupancy(معدل شغل القناة): ***q = K / N***
- ***q:*** is service provider's benefits

Performance Measure

- Service providers tend to raise the traffic load in order to raise benefits (رفع الأرباح)
- That lead to raise “congestion” which lead to unpleasant subscribers (عدم رضى العميل) and make them to look for other service provider
- Since the service provider willing to satisfy customers, he should balance the traffic load and the benefits.

Computing Performance Measure



Load traffic and Network Capacity Balance

To be continued…