Delays, throughput, packet and circuit switching

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Outline

- Packet and Circuit Switching
- Delays
- Throughput

Packet and Circuit Switching

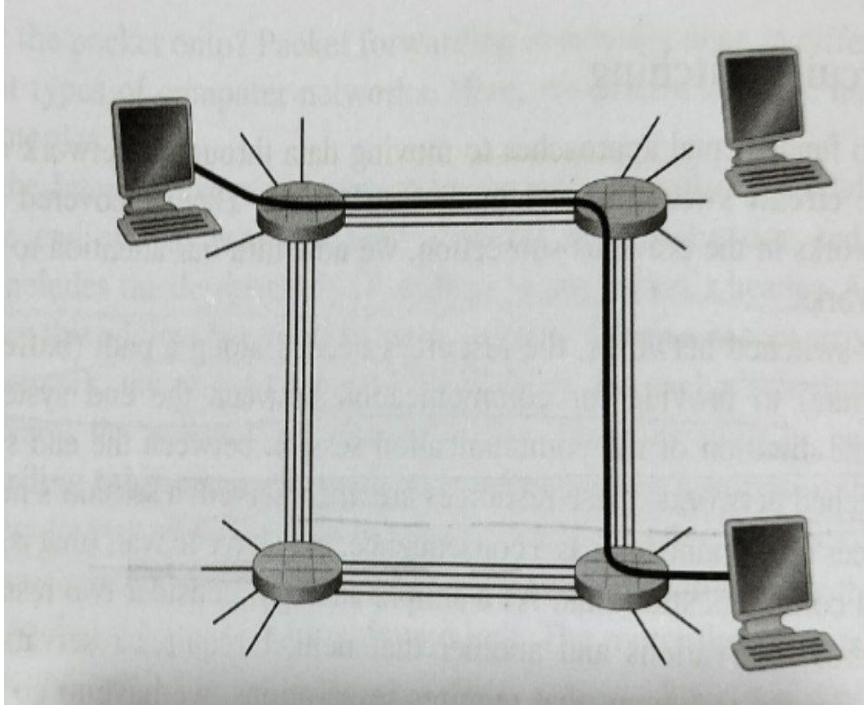
Packet Switching

- The hosts send messages
- The messages are separated into smaller parts, the **packets**
- The packets passes through routers and switches to reach their destination
- Store-and-forward transmission
    - routing table
- The packets are transmitted via communication links
    - packet size= L bits, link’s data rate= R
        - time for transmission= L/R seconds

Circuit Switching (1/2)

- Traditional phone networks
- Resource allocation throughout the duration of communication
- **Circuit**: establishment and maintenance of the connection
- Stable and guaranteed data rate

Circuit Switching (1/2)

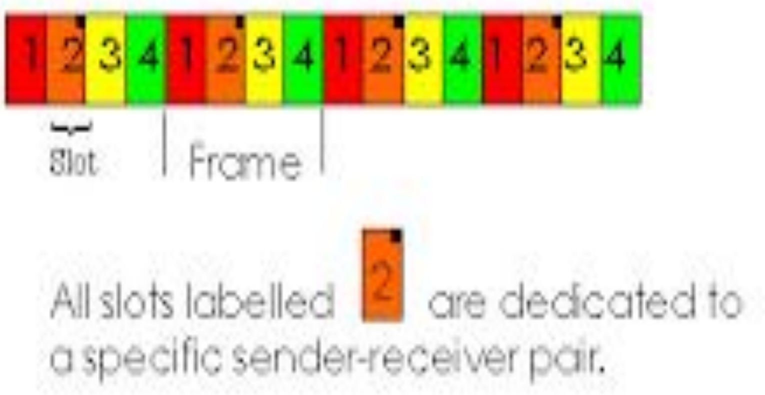


- Each link has 4 circuits => 4 simultaneous connections
- End-to-end connection
  - 2nd circuit of the 1st link
  - 1st circuit of the 2nd link
- Each circuit has ¼ of the link’s bandwidth
  - 1 Mbps link -> 250 kbps each circuit

Circuit Switching: FMD

- The frequency spectrum is shared between the connections (circuits)
- Each connection uses one frequency band throughout the entire communication
    - Radio stations are shared the frequency spectrum 88-108 MHz
    - Each station transmits to a specified smaller band (e.g. 87.2 MHz)

Circuit Switching: TDM



- The time is divided into frames of equal durations
- Each frame is divided into timeslots (slots)
- Each connection gets one slot per frame
- **Date rate**= frames’ data rate* bits per slot
  - **frames’ data rate**= 8.000 frames/sec, **bits per slot**= 8 bits
  - **data rate**= 8.000*8= 64 kbps

Packet vs Circuit Switching

Packet

- Resources are reserved on demand
- Not suitable for real time application, due to unexpected delays
- Better bandwidth sharing
- Simpler, more efficient
- Best effort

Circuit

- Resource allocation throughout the duration of communication
- The link is allocated during idle times
- Increased overhead and cost
- Bandwidth guarantees

Example 1 (1/2)

- link's data rate= 1 Mbps
- Each user send data only 10% of the time with rate 100 kbps
- Circuit switching, TDM, 1 frame/sec, 10 slots of 100ms
- Each user uses 1 slot per frame
    - Max number of users?
        - Answer
            - link's data rate/user's data rate= 1Mbps/100kbps= 10 users
    - What is the probability that a user is active?
        - Answer
            - p=0,1

Example 1 (2/2)

- link's data rate= 1 Mbps
- Each user send data only 10% of the time with rate 100 kbps
- Circuit switching, TDM, 1 frame/sec, 10 slots of 100ms
- Each user uses 1 slot per frame
    - If there are 35 users (N=35), what is the probability that 11 users transmit simultaneously? (hint binomial distribution)
        - [Answer]
            - $P(X=k)= (N\ k)*p^{k}*(1-p)^{N-k}$, where $(N\ k)=N!/k!*(N-K)$
            - $P(X=11)= (35\ 11)*0.1^{11}*0.9^{(35-11)}= 35!/11!*(35-11)!*0.1^{11}*0.9^{24}= 35!/11!*24!*0.1^{11}*0.9^{24}=$ 0,00033

Example 2 (1/2)

- 10 users (1 active 9 idle)
- The active user sends 1000 packets of 1000 bits
- link’s data rate= 1 Mbps
- Each user send data only 10% of the time with rate 100 kbps
- Circuit switching, TDM, 1 frame/sec, 10 slots/frame, 1000 bits/slot, 10 slots of 100ms
    - How much time is needed for a user to send all its data, using the TDM set up above?
        - Answer
            - It sends 1000 packets* 1000 bits= 10^6 bits=1 Mbits, sends 1000 bits per slot, one slot per frame
            - (data)/(bits per slot) = 10^6/1000= 1000 slots are needed
            - (time per slot)*(number of slots)=10.000ms= 100s

Example 2 (2/2)

- 10 users (1 active 9 idle)
- The active user sends 1000 packets of 1000 bits
- link's data rate= 1 Mbps
- Each user send data only 10% of the time with rate 100 kbps
- Circuit switching, TDM, 1 frame/sec, 10 slots/frame, 1000 bits/slot
  - How much time is needed for a user to send all its data, using packet switching?
    - Answer
      - It sends 1000 packets* 1000 bits= 10^6 bits=1 Mbits
      - The active user can send data with data rate 1Mbps since no one uses the link the same time

Delays

Types of Delays

- Processing delay
- Queue delay
- Transmission delay
- Propagation delay

Types of Delays: Processing delay

- The time required to:
  - Examine the header of the packet
  - Determine the output interface

Types of Delays: Queue delay

- The buffer that the packets wait to transmit
- If the queue of a router is empty and any other packet is transmitted the same time then the queue delay is 0

Types of Delays: Transmission delay

- The time required for all the bits of the packet to be pushed to the link from the router

Types of Delays: Propagation delay

- The time required for one bit to reach the next router
- distance between two routers/speed of light

End to End delay

- Consider:
  - N-1 routers between source and destination host
  - No network congestion -> queue delay= 0
  - d_{proc}: processing delay
  - d_{prop}: propagation delay
  - transmission rate= R bits/sec, L: packet size => d_{trans}= L/R
  - End-to-end delay:
    - $d_{end\text{-}end} = N(d_{proc}+d_{prop}+d_{trans})$

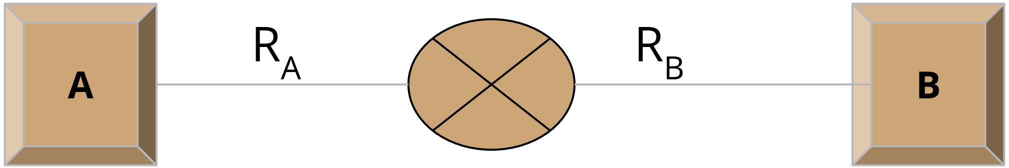
Throughput

Throughput

- Transfer a large file from host A to B
- The throughput is the speed in bits/sec that B receives the file

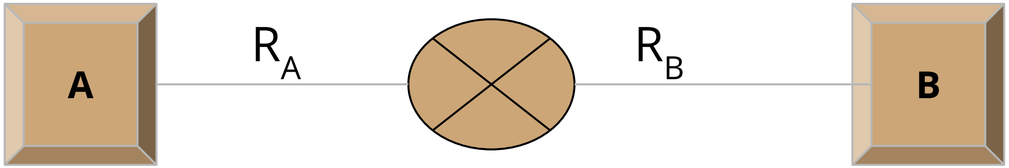
Throughput

- Consider that the data flow only from A to B
- The host A cannot transmit data with rate greater than R_A
- The router cannot transmit data with rate greater than R_B
- If R_A<R_B then the bits that sends the host A via router, reach the host B with speed R_A so the end to end throughput is R_B
- If R_A>R_B then the router will not be able to forward data as fast as it receives it and the end to end throughput is R_A



Example

- file size= 32 Mbits
- R_A= 2 Mbps, R_B= 1Mbps
- **time**= file size/throughput= 32 Mbits/min{R_A,R_B}= $32*10^6$ bits/$1*10^6$ bits/sec= 32 sec



Thank You