CIS 457 - Data Communications

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Images taken from Kurose and Ross book

Circuit vs Packet Switching

Hosts must have some way of sharing network resources, especially link capacity

Circuit switching and packet switching are two methods to share network resources

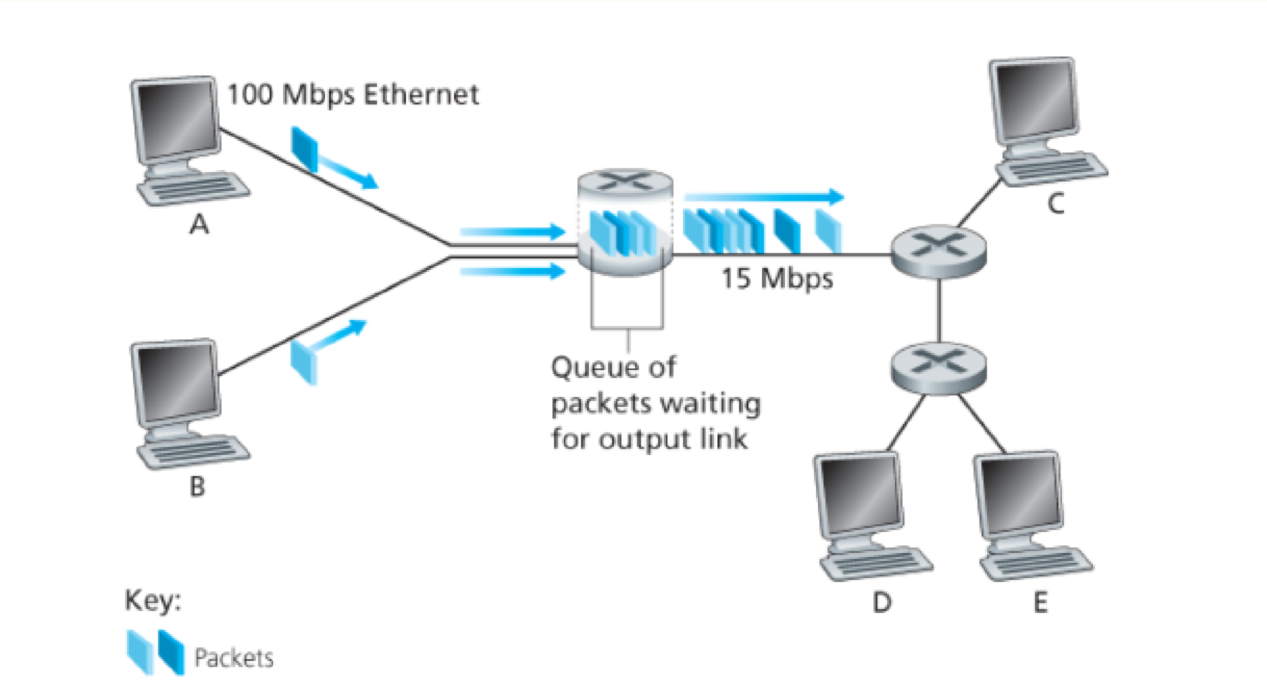
Packet switching is used in internet, but also important to understand circuit switching so we know *why* packet switching is efficient

Packet switching is process of moving packets through network as described so far

Hosts all send packets into network, possibly at same time

Packets arrive at routers and are dealt with in order, sometimes resulting in queuing delays

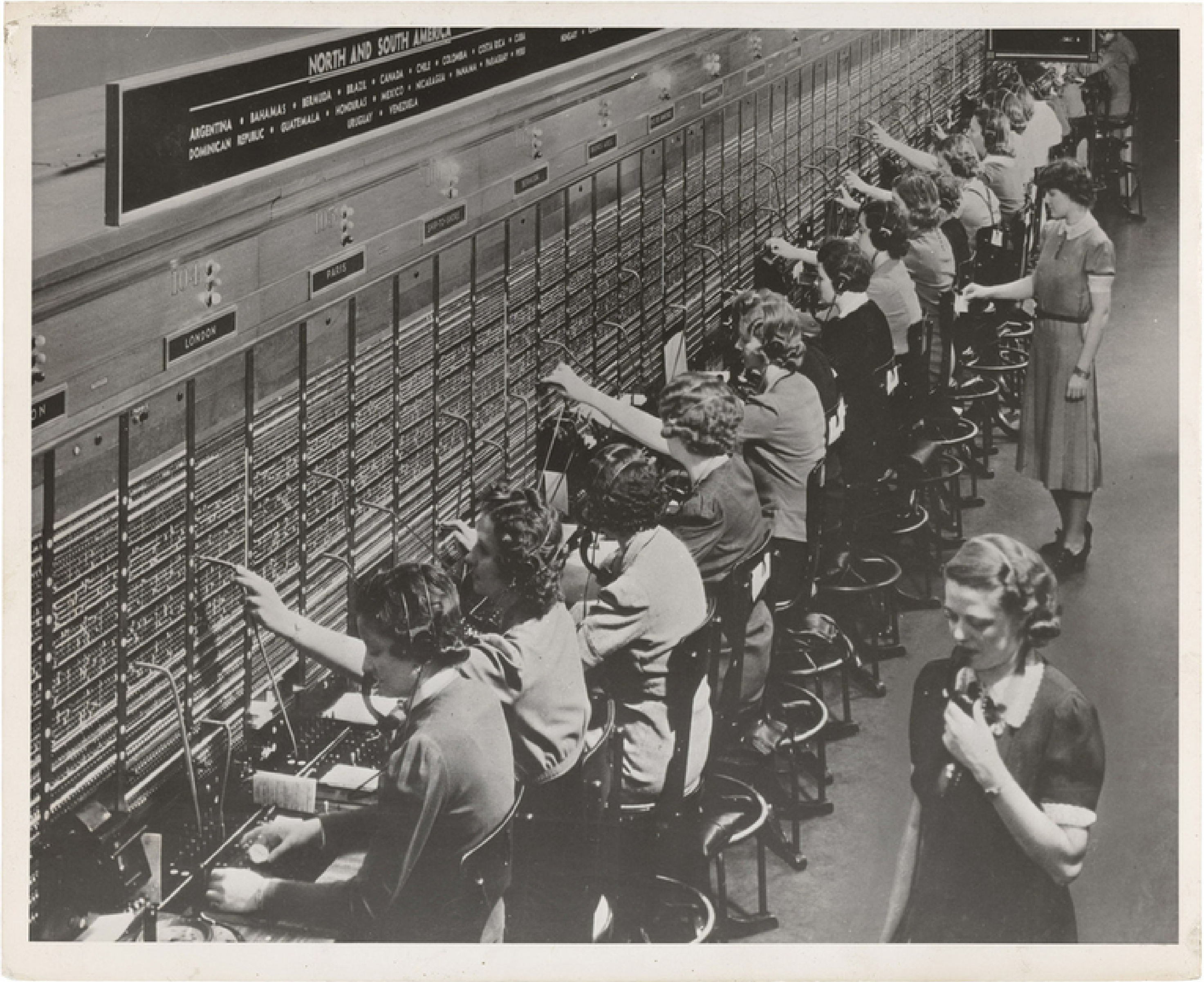
Sharing of link capacity occurs **on demand**


100 Mbps Ethernet
A
B
C
15 Mbps
Queue of packets waiting for output link
D
E
Key:
Packets

In circuit switching, resources (esp. transmission rate) reserved for connection during entire communication

Similar to reservation at restaurant: notify network communication will happen, and packets will not need to wait at router

Terminology comes from telephony, where such an end-to-end connection known as *circuit*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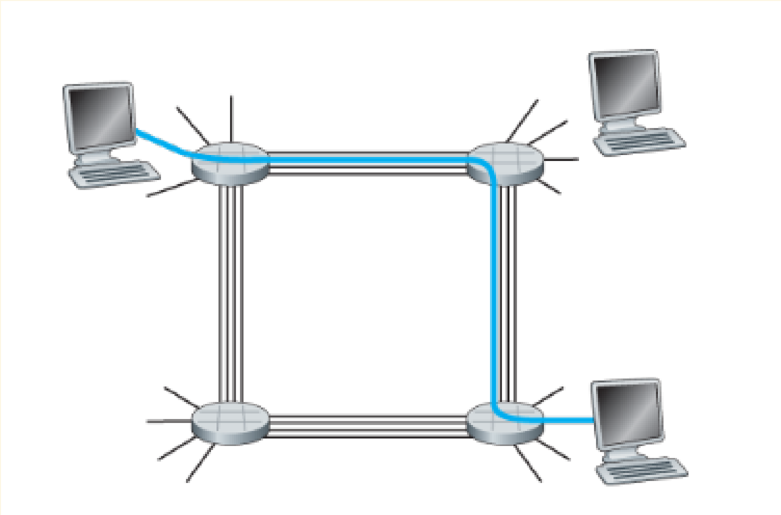
In computer network, establishing circuit means reserving constant transmission rate

Do not reserve entire links -- reserve fraction of each link's capacity

Provides guaranteed rate for sender



Each link supports up to four simultaneous connections

Split between connections not generally physical -- we see later how link transmission rate is apportioned

End-to-end connection established by network *before* communication between hosts occurs

In this example, each connection would get 1/4 of link capacity

In contrast, packet switching

- does not involve reservations
- can result in queuing delays

More complete comparison later

How is link capacity actually split up?

Refer to division of link as **multiplexing**

We see this term elsewhere in this course and other CS classes -- generally refers to controlling use of shared medium

Two types of multiplexing in circuit-switched networks:

- Frequency-division multiplexing (FDM)
- Time-division multiplexing (TDM)

In FDM, frequency divided among connections

For example, telephone networks split frequencies into 4kHz bands

Similarly, FM radio splits airwaves into frequency bands and each radio station gets certain frequency band

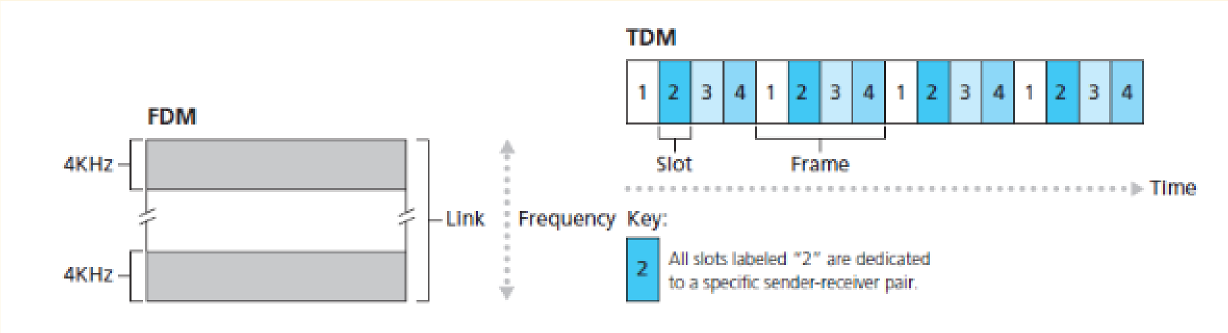
Amount granted to each connection is its **bandwidth**

Frequency division

In TDM

- time split into frames of fixed duration (e.g., 1 second)
- each frame split into some constant number of slots
- one slot per frame allocated to each connection

During each of its slots, given connection has sole use of entire link capacity


TDM
1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4
Slot
Frame
Time
FDM
4KHz
4KHz
Link
Frequency
Key:
2
All slots labeled "2" are dedicated
to a specific sender-receiver pair.

Bandwidth guarantees provided by circuit switching are very appealing to certain applications, such as video streaming

Major downside is less efficient use of resources due to **silent periods**

Consider phone call where both parties are silent for a time -- no data is transferred, but transmission resources cannot be used by other connections

Also, establishing circuits is itself not trivial task

In contrast, packet switching has unpredictable delays, which is not ideal for real-time applications

However, packet switching allows better sharing of link capacity compared to circuit switching

Packet-switched networks are simpler and less costly to set up

To see why packet-switching has better utilization, consider an example

Users are sharing 1 Mbps link

Each user alternates between sending data at 100 kbps and sitting idly

Each user active (i.e., sending) just 10% of time

Circuit-switched network must allocate 100 kbps for *each* user *at all times*

For example, split time into 1 second frames and each frame into 10 slots

Such a network could handle 10 users at once, with each guaranteed 100 kbps transmission rate

Next, assume same 1 Mbps network is packet-switched

If network had 35 users, each of which obeys same rules as before (sending 10% of time), probability of 11 or more sending at once approximately

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P(senders > 10) = 0.0004
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If number of senders <= 10, arrival rate of data at router will be <= 1 Mbps, so essentially no delay (just like circuit switched)

If number of senders > 10, queue (and delay) grow until rate drops

Because probability was tiny, can generally assume number of senders will not be above 10, meaning network gets same performance as circuit-switched network with more than 3 times number of users (35 vs 10)

Consider second example with same link capacity

Network has 10 users, 9 of which sit idle

1 user has "bursty" behavior and sends 1,000 1,000-bit packets once in a while, and is otherwise quiet

Under TDM with 10 slots per frame, each client gets 100 kbps (= 1 Mbps/10)

Sending 1,000 1,000-bit packets requires 10 time slots, which occur for 1/10 second over 10 seconds

For other 9/10 second (which is 90% of time), router is idle and no transmission capacity is used

In packet switching, if no other traffic present, sender uses full link capacity, reducing time to 1 second

To sum up, circuit switching pre-allocates transmission capacity regardless of demand

Allocated but unneeded capacity wasted

Packet switching allocates link usage on demand

Capacity shared only among users who have packets in transmit at a given time, so no transmission capacity wasted

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