

CS4450

Computer Networks: Architecture and Protocols

Lecture 2

Sharing Networks: “Packets” and “Flows”

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Goal of Today's Lecture

- Learn about:
 - Two important performance metrics:
 - Bandwidth
 - Delay
 - Why are these important?
 - Two ways of sharing networks:
 - Circuit switching
 - Packet switching
 - **Why do current networks use packet switching?**

But first, Recap from last lecture

Recap: what is a computer network?

A set of network elements connected together, that implement a set of protocols for the purpose of sharing resources at the end hosts

- **Three important components:**

- **Core infrastructure:**

- A set of network elements connected together

- **Protocols:**

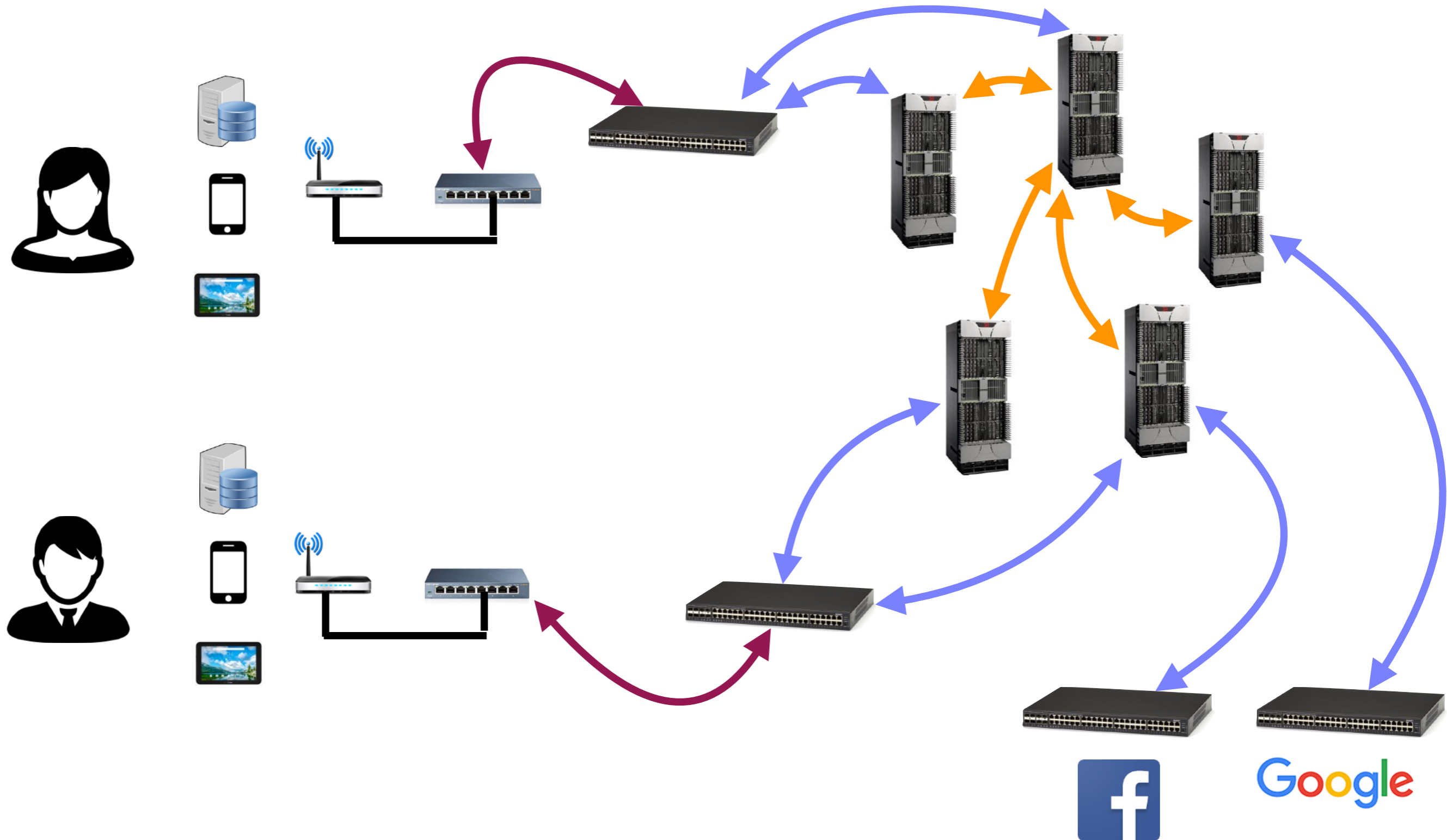
- Needed to use the network

- **Purpose:**

- Sharing resources at the end hosts (computing devices)

What is a computer network?

A set of network elements connected together, that implement a set of protocols for the purpose of sharing resources at the end hosts



Recap: what do computer networks look like?

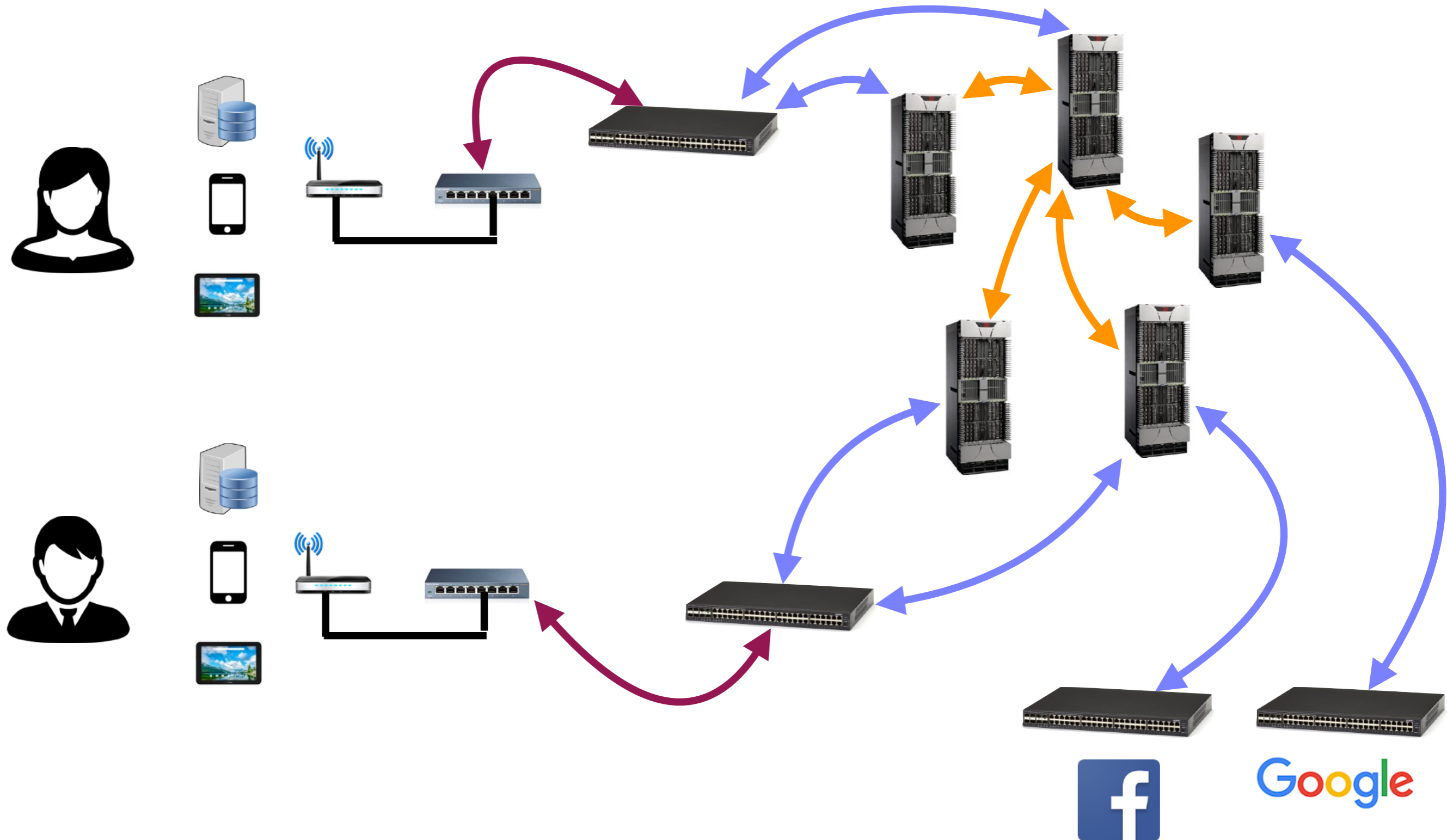
Three Basic components

- **End hosts:** they send/receive packets
- **Switches/Routers:** they forward packets
- **Links:** connect end hosts to switches, and switches to each other

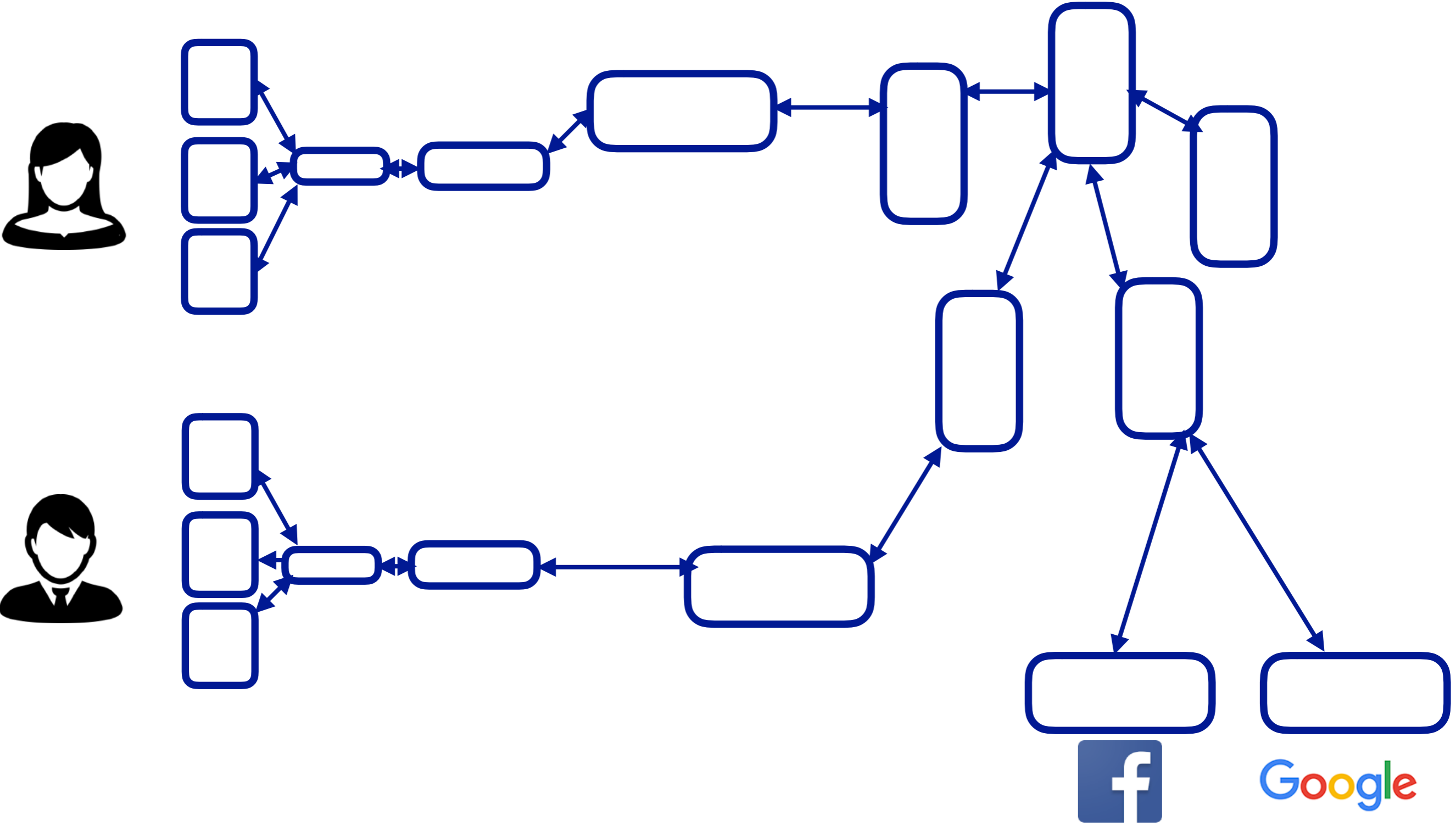
Lets make the picture simpler for today's lecture

What is a computer network?

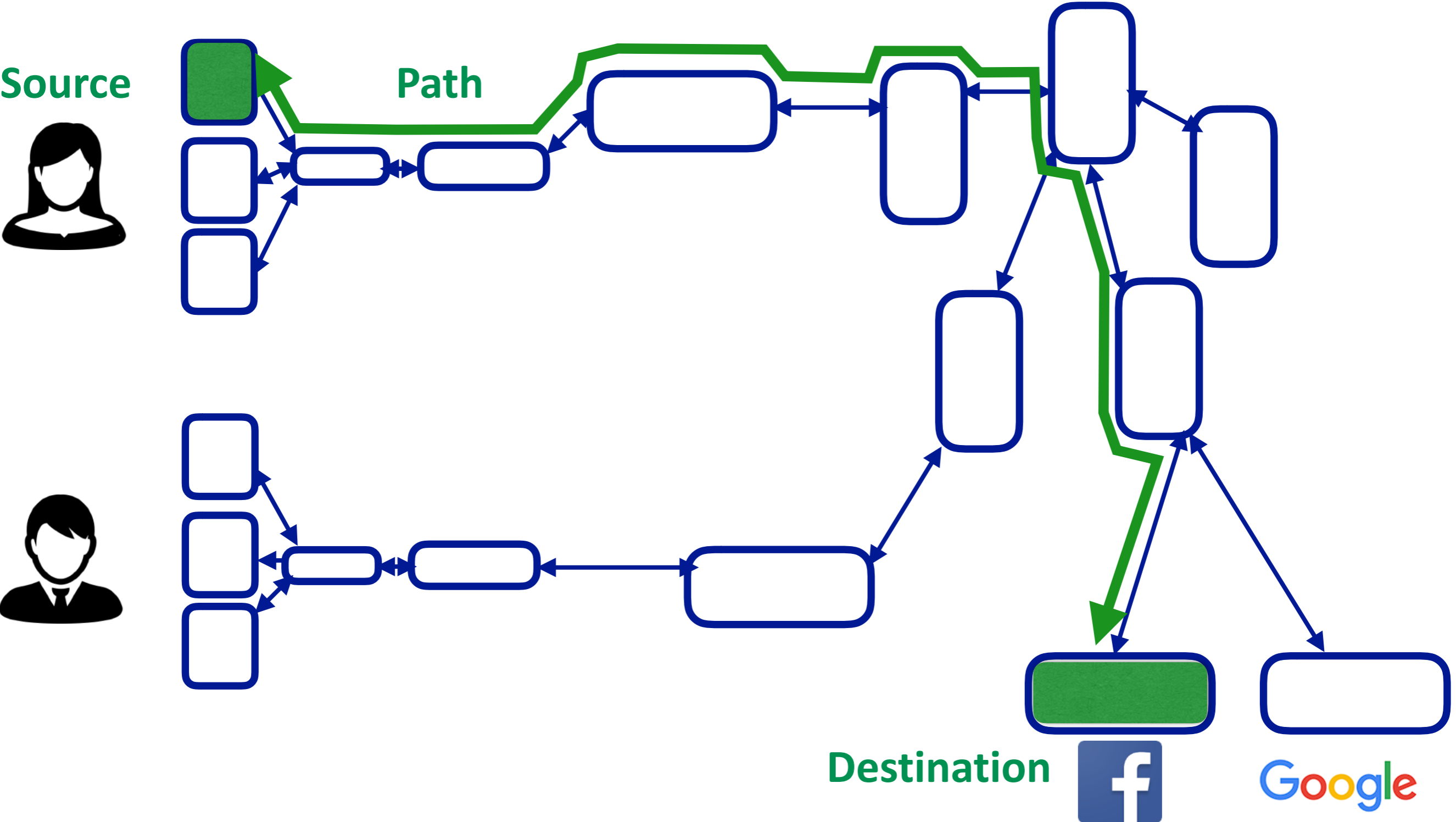
A set of network elements connected together, that implement a set of protocols for the purpose of sharing resources at the end hosts



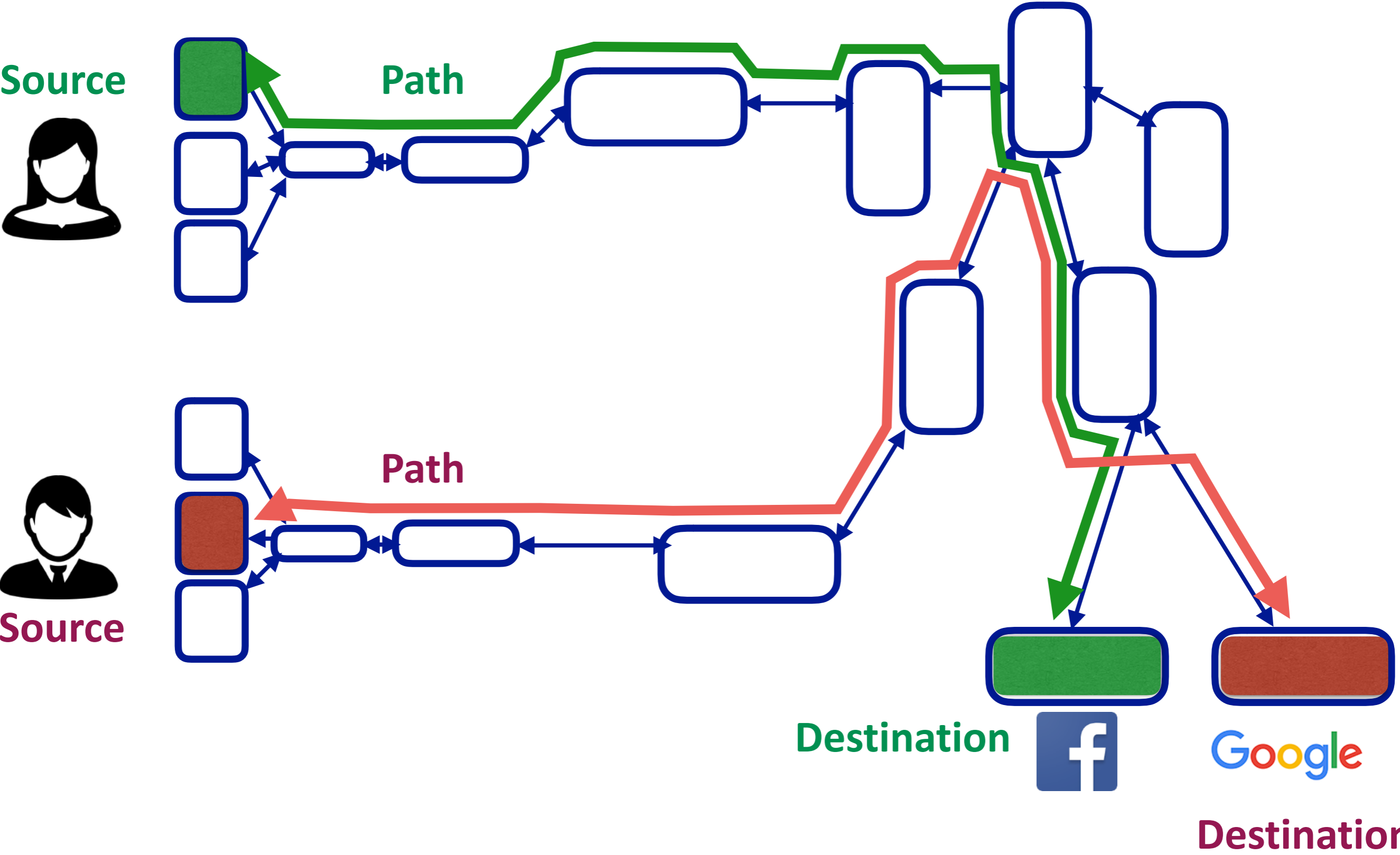
A computer network can be abstractly represented as a graph



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A computer network can be abstractly represented as a graph



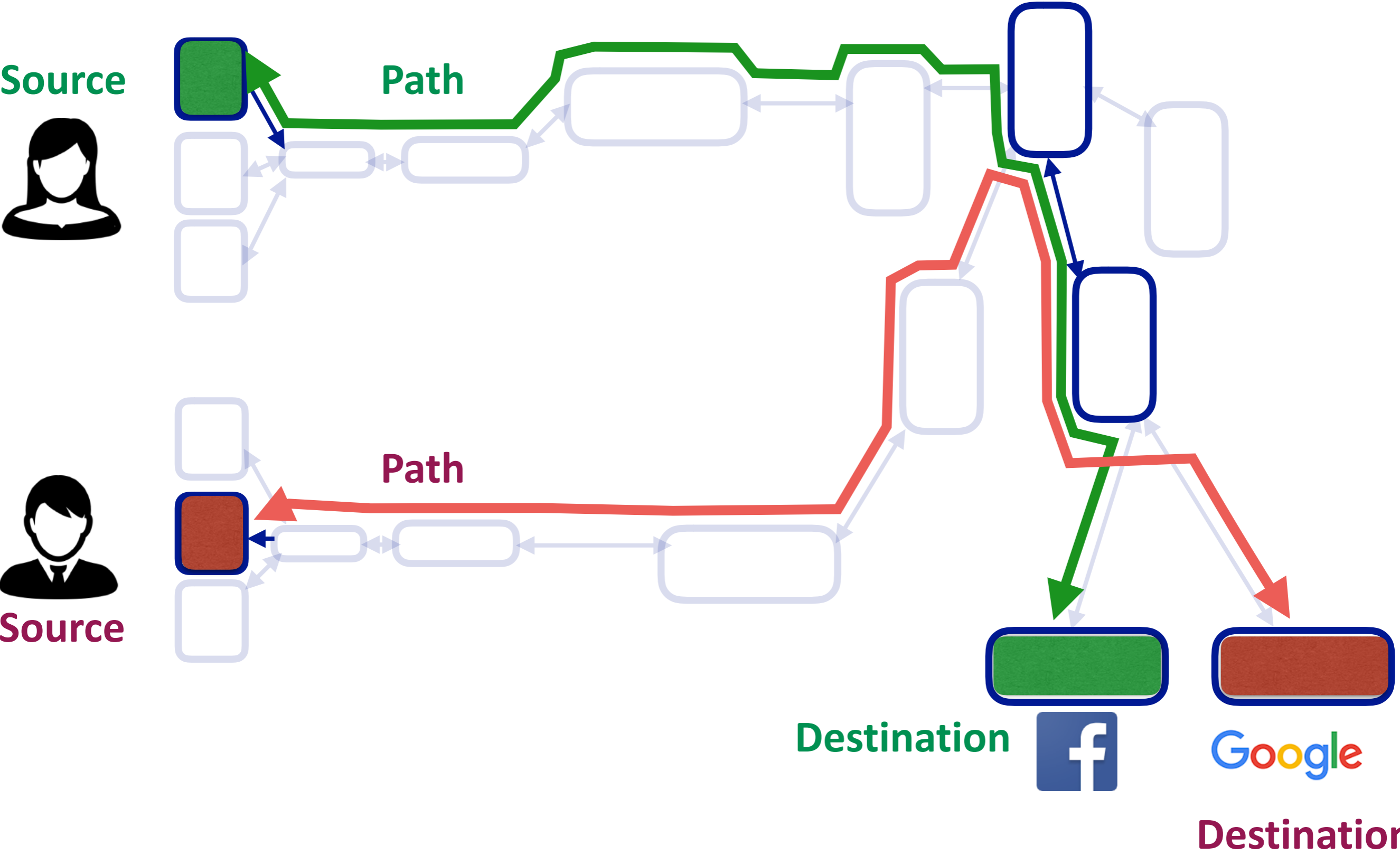
Many mechanisms!

- **Locating the destination:** Naming, addressing
- **Finding a path to the destination:** Routing
- **Sending data to the destination:** Forwarding
- **Failures, reliability, etc.:** Distributed routing and congestion control

Will take the entire course to learn these:

one thing at a time :-)

Today's focus: sharing the network (graph)



Today's lecture: sharing computer networks

1. What does network sharing mean?
2. What are the performance metrics?
3. What are the various mechanisms for sharing networks?
4. **Why “packets” and “flows”?**
5. **Understanding bandwidth and latency for packets**

What does network sharing mean?

The problem of sharing networks

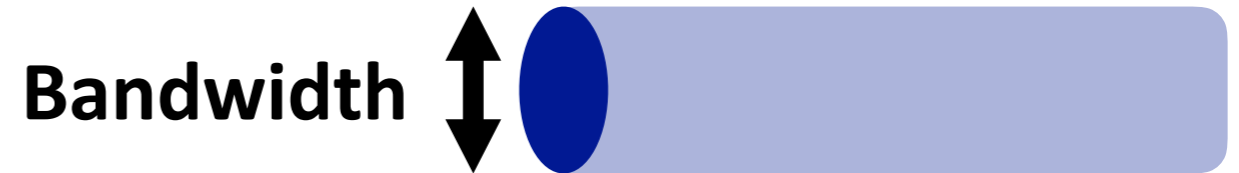
- Must support many “users” at the same time
- Each user wants to use the network (send and receive data)
- Limited resources
- **Fundamental question:**
 - **How does network decide which resource to allocate to which user at any given point of time?**

What are the performance metrics?

Performance metrics in computer networks!

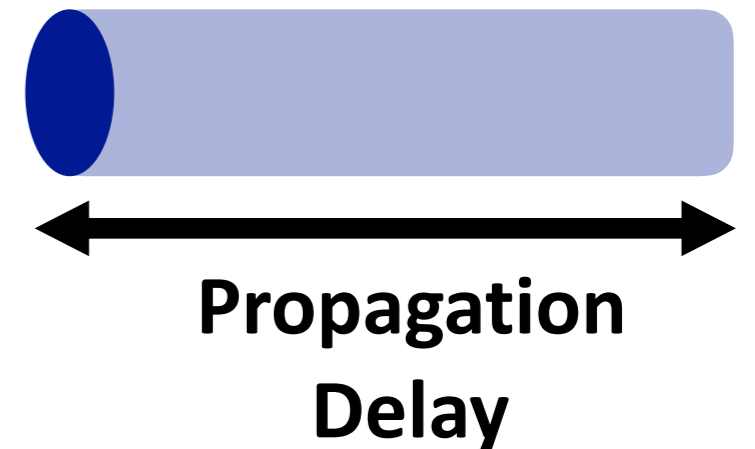
- **Bandwidth:** Number of bits sent per unit time (bits per second, or bps)

- Depends on
 - Hardware
 - Network traffic conditions
 -



- **Propagation delay:** Time for one bit to move through the link (seconds)

- Depends on
 - Hardware
 - Network traffic conditions
 - How large is the unit?
 -



- **Many other performance metrics (reliability, etc.)**

- We will come back to other metrics later ...

What are the various mechanisms for sharing networks?

Two approaches to sharing networks

- **First: Reservations**

- Reserve bandwidth needed in advance
- Set up circuits and send data over that circuit
 - No need for packets
- Must reserve for peak bandwidth

- Peak bandwidth?

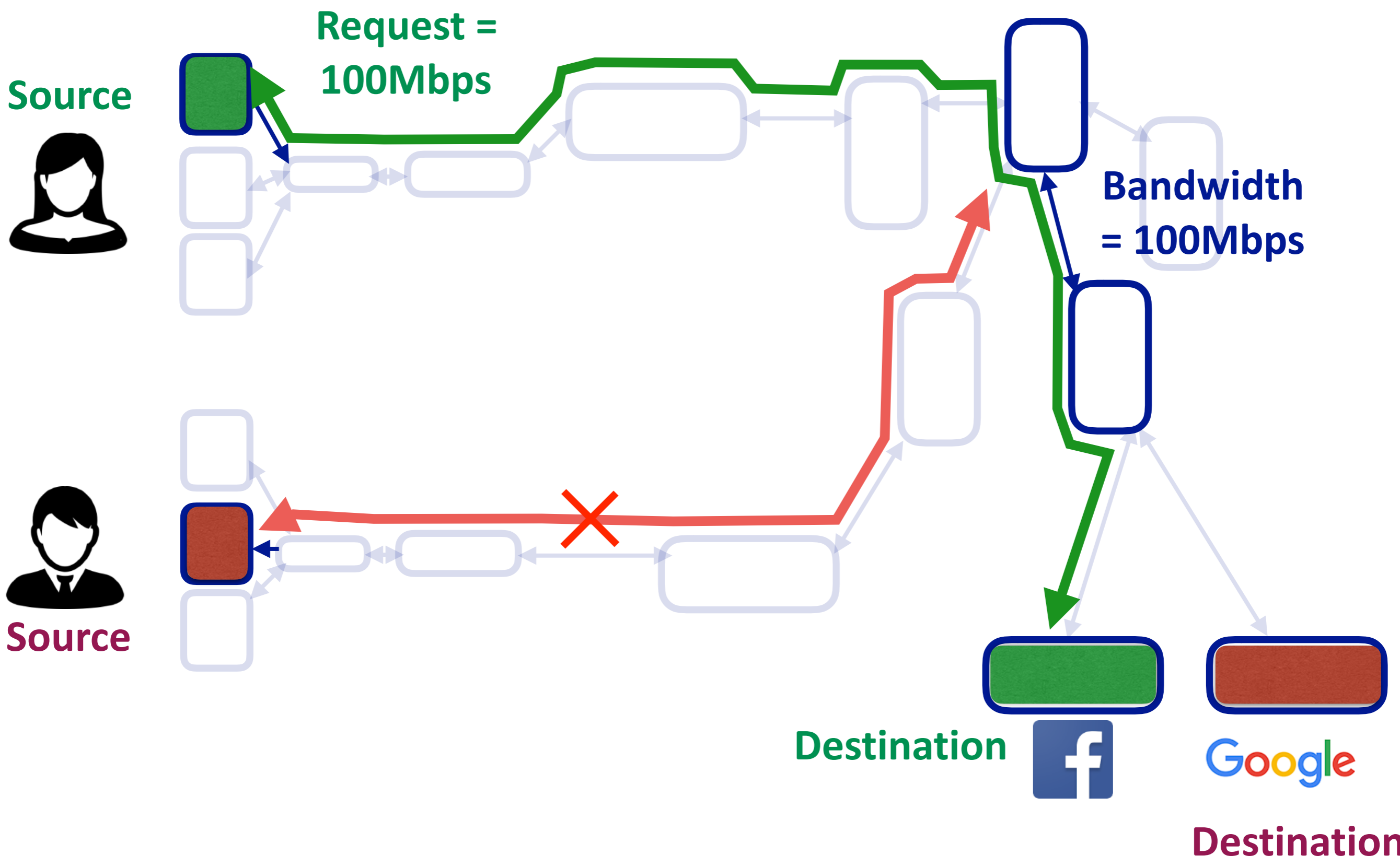
- Applications may generate data at rate varying over time
- 100MB in first second
- 10MB in second second ...
- Reservations must be made for “peak”

Circuit switching: Implementing reservations since ...

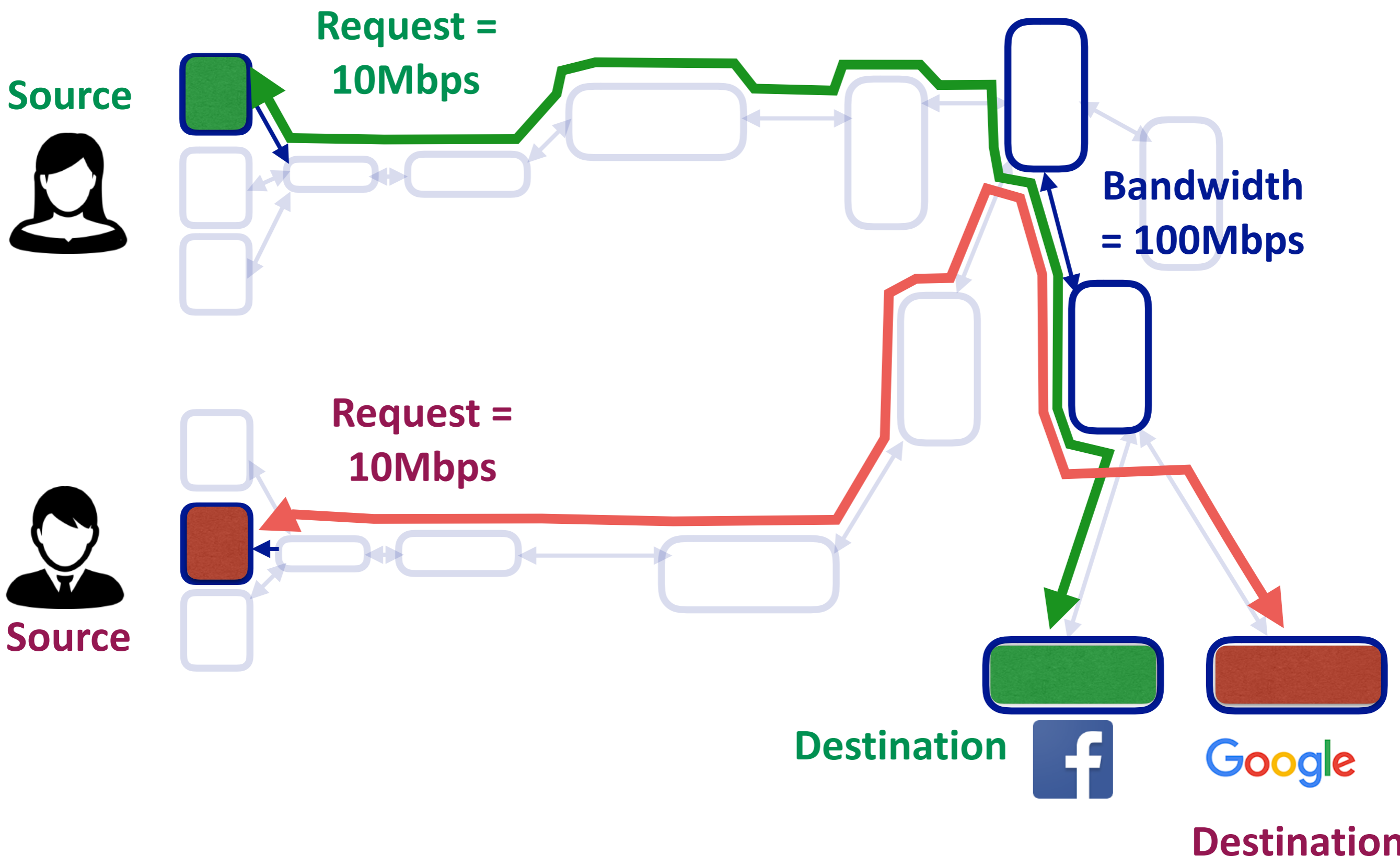
Telephone networks

- One of the many approaches to implementing reservations
- **Mechanism:**
 - Source sends a reservation request for peak demand to destination
 - Switches/routers establish a “circuit”
 - Source sends data
 - Source sends a “teardown circuit” message

Circuit switching: an example (red request fails)



Circuit switching: another example (red request succeeds)



Circuit switching and failures

- Circuit is established
- **Link fails along path (!!!!!!!)**
 - First time we have seen failures making our life complicated.
 - Remember this moment.
 - Its gonna happen, over and over again.
- Must establish new circuit

Circuit switching doesn't route around failures!!

Circuit switching summary

- **Goods:**

- Predictable performance
- Reliable delivery
- Simple forwarding mechanism

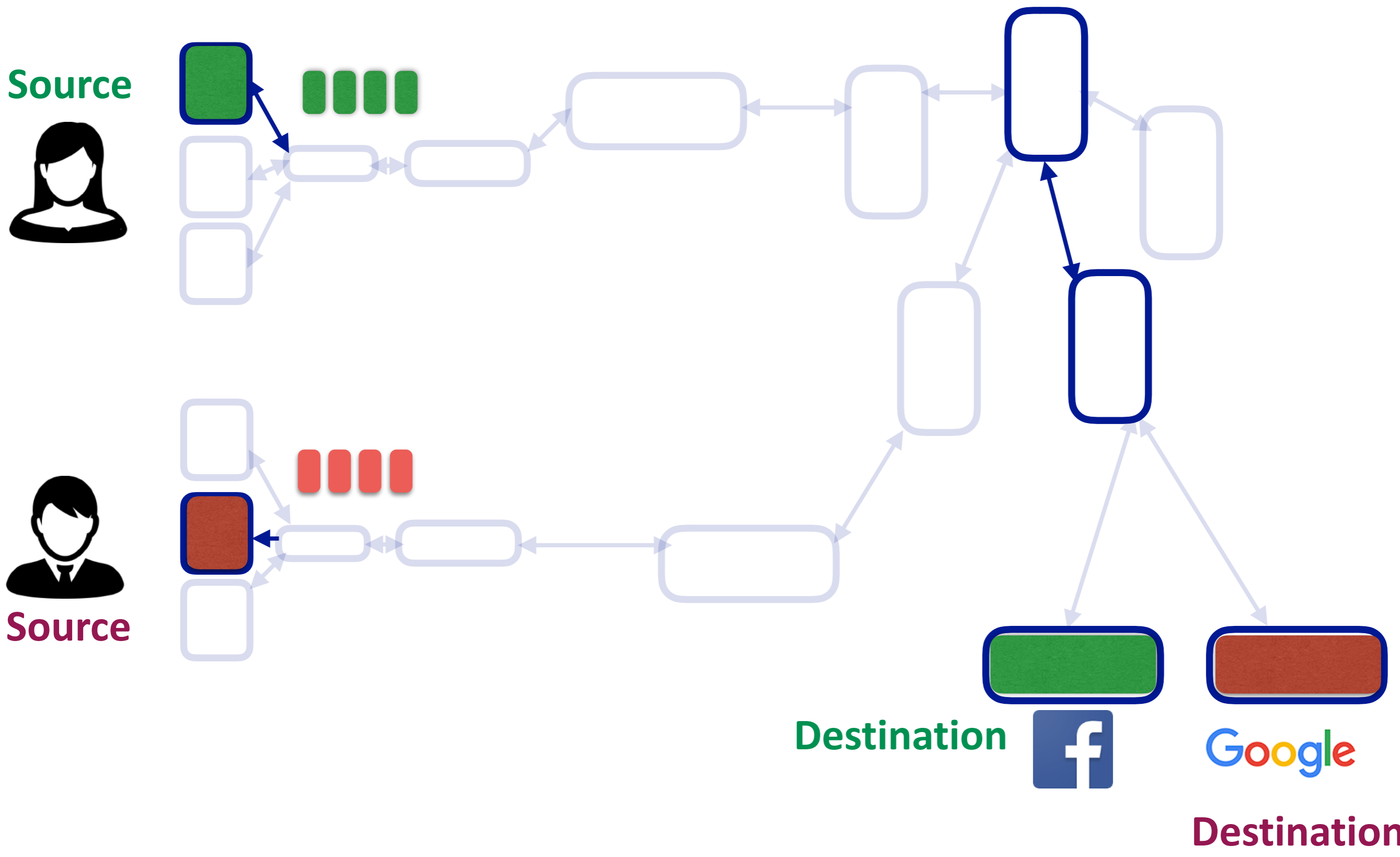
- **Not-so-goods**

- Resource underutilization
- Blocked connections
- Connection set up overheads
- Per-connection state in switches (scalability problem)

Two approaches to sharing networks

- **Second: On demand (also known as “best effort”)**
 - **Designed specifically for the Internet**
 - Break data into packets
 - Send packets when you have them
 - Hope for the best ...

Packet switching: an example



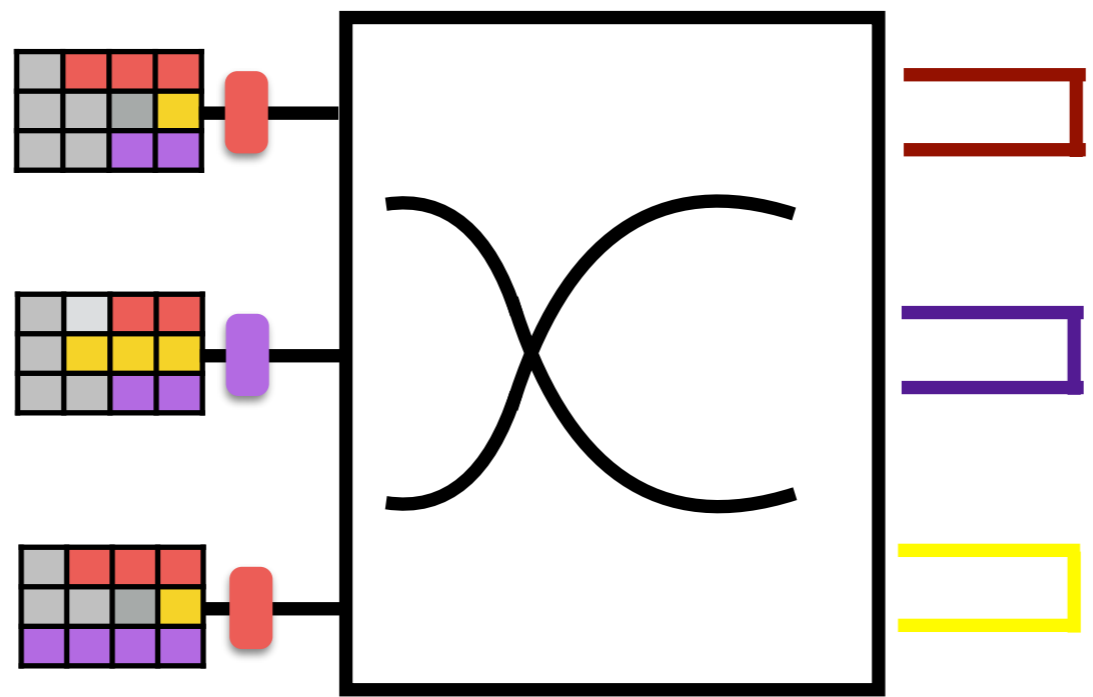
Packets

- **Packets carry data (are bag of bits):**
 - Header: meaningful to network (and network stack)
 - can be multiple headers
 - Body: meaningful only to application
 - More discussion in next lecture
- **Body can be bits in a file, image, whatever**
 - can have its own application “header”
- **What information goes in the header?**

What must headers contain to enable network functionality?

- **Packets must describe where it should be sent**
 - Requires an address for the destination host
 - can be multiple headers
- **Packets must describe where its coming from**
 - why?
 - Acknowledgments, etc.
- **Thats the only way a router/switch can know what to do with the packet**

Packet switching: what does a switch look like



Packet switching summary

- **Goods:**

- No resource underutilization
 - A source can send more if others don't use resources
- No blocked connection problem
- No per-connection state
- No set-up cost

- **Not-so-goods:**

- Unpredictable performance
- High latency
- Packet header overhead

Circuits vs packets

- Pros for circuits:
 - Better application performance (reserved bandwidth)
 - More predictable and understandable (w/o failures)
- Pros for packets:
 - Better efficiency
 - Simpler switches
 - Easier recovery from failures
 - Faster startup to first packet delivered

Summary of network sharing

Statistical multiplexing

- **Statistical multiplexing:** combining demands to share resources efficiently
- Long history in computer science
 - Processes on an OS (vs every process has own core)
 - Cloud computing (vs every one has own datacenter)
- Based on the premise that:
 - **Peak of aggregate load is \ll aggregate of peak load**
- Therefore, it is better to share resources than to strictly partition them ...

Two approaches to sharing networks

Both embody statistical multiplexing

- Reservation: sharing at connection level
 - Resources shared between connections currently in system
 - Reserve the peak demand for a flow
- On-demand: sharing at packet level
 - Resources shared between packets currently in system
 - Resources given out on packet-by-packet basis
 - No reservation of resources

Understanding delay/latency

Packet Delay/Latency

- Consists of four components
 - Link properties:
 - Transmission delay
 - Propagation delay
 - Traffic matrix and switch internals
 - Processing delay
 - Queueing delay
- First, consider transmission, propagation delays
- Then queueing delay
- Ignore processing delays

Transmission delay

- How long does it take to push all the bits of a packet into a link?
- Packet size / Transmission rate of the link
- Example:
 - Packet size = 1000Byte
 - Rate = 100Mbps
 - $1000 * 8 / 100 * 1024 * 1024$ seconds

Propagation delay

- How long does it take to move one bit from one end of a link to the other?
- Link length / Propagation speed of link
 - Propagation speed \sim some fraction of speed of light
- Example:
 - Length = 30,000 meters
 - Delay = $30 \times 1000 / 3 \times 100,000,000$ second = 100us

Group Exercise 2:

How long does it take for a *packet* on a link?

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How long does it take for a *packet* on a link?

Constraints:

- Packet size = 1000Byte
- Rate = 100Mbps
- Length = 30,000m

