EPFL

L17: The Link Layer & Ethernet

CS202 - Computer Systems

Two kinds of packet switches

- Link-layer packet switches (switches): implement physical and link layer
- Network-layer packet switches (routers): implement physical, link, and network layer

A note on terminology:

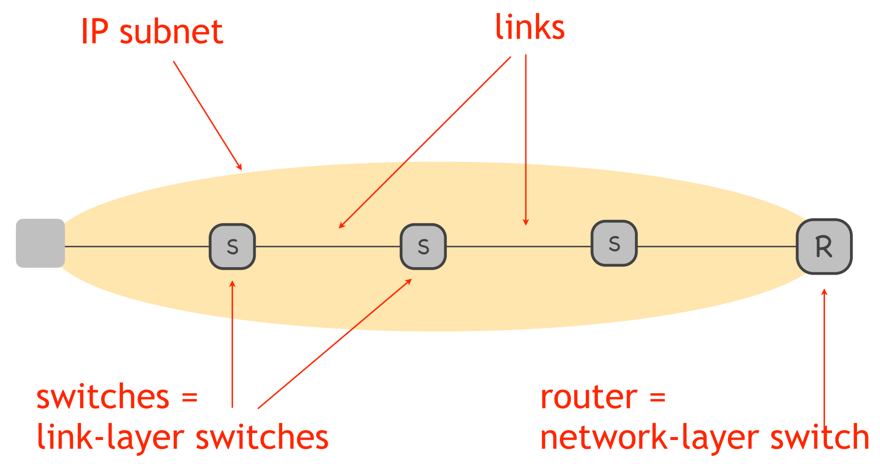
- When I say “switch” (without explaining what type of switch), I will mean link-layer switch. When I say “router,” I will mean network-layer switch.

Link vs. network layer

- Link layer: takes each packet from one end of one link to the other end
- Network layer: takes each packet from one end of the network to the other end

We will start by comparing the link and network layers:
- The role of the link layer is to take one packet from one end of *one link* to the other end.
- The role of the network layer is to take a packet from one end of *the network* to the other end.

Let’s see what this means in more detail.



Consider a single IP subnet (the yellow ellipsis).

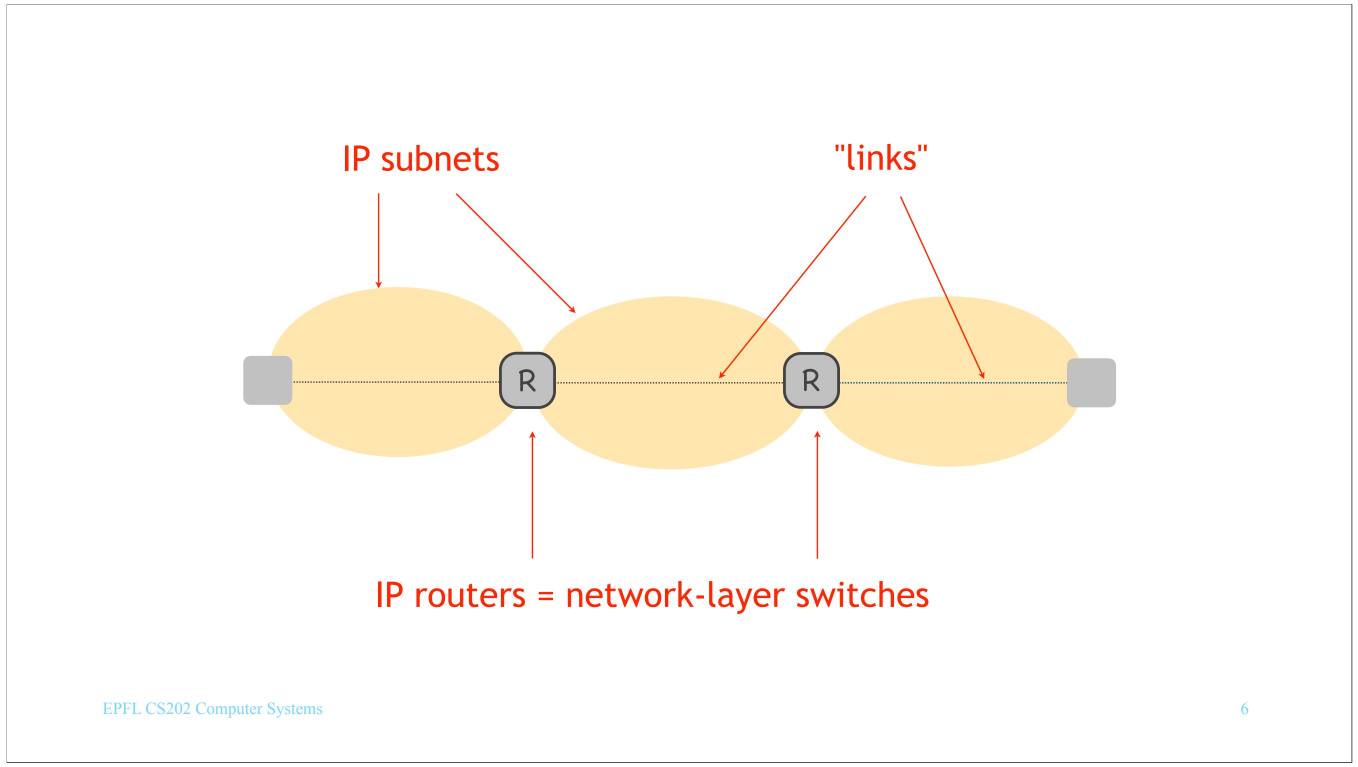
An IP subnet is a network, which has end-systems and routers at its boundaries, which are interconnected by link-layer switches.

From the point of view of an IP subnet:

- The role of the link layer is to take a packet across a single physical link.
- The role of the network layer is to take a packet across the entire network, i.e., the entire IP subnet (e.g., from the green end-system on the left to router R).

IP subnet point of view

- Link layer: takes packet from
  one end of one physical link to the other end
- Network layer: takes packet from
  one end of the IP subnet to the other end



Consider the Internet.

The Internet is a network of IP subnets, i.e., a network of networks (hence the name “Inter-network” or Internet).

From the point of view of the Internet, a “link” is a path segment across a single IP subnet.

So, from the point of view of the Internet:

- The role of the link layer is to take a packet across a single “link,” i.e., a single IP subnet.
- The role of the network layer is to take a packet across the entire network, i.e., the Internet.

Internet point of view

- Link layer: takes packet from
  one end of one IP subnet to the other end

- Network layer: takes packet from
  one end of the Internet to the other end

The "link layer"

- Link layer of an IP subnet: takes packet from one end of one physical link to the other end
- Link layer of the Internet = network layer of an IP subnet: takes packet from one end of one IP subnet to the other end

So, when we say "link layer," we could mean one of two things: …

When people, in general, say "link layer," they typically conflate the two, i.e., they refer to both of these things together.

The "link layer"

- Link layer of an IP subnet: takes packet from one end of one physical link to the other end
- Link layer of the Internet =
network layer of an IP subnet: takes packet from one end of one IP subnet to the other end

We will first discuss briefly the link layer of an IP subnet.

Link-layer services

- Error detection
  - *receiver detects and drops corrupted packets*
  - *relies on checksums*
- Reliable data delivery
  - *sender/receiver detect corruption and loss, and try to recover*
  - *relies on checksums, ACKs, retransmissions, …*
  - *only for error-prone links, typically wireless*

This link layer may offer an “error detection” service.
Meaning that the two devices an the ends of a physical link participate in a protocol to detect and drop corrupted packets.
They can do this by relying on checksums (like UDP and TCP).

This link layer may also offer a “reliable data delivery” service.
Meaning that the two devices at the ends of a physical link participate in a protocol to detect and recover from corruption and loss.
They can do this by relying on timeouts, ACKs, retransmissions… (like TCP).
This service it typically offered for error-prone links, e.g., wireless links.

Btw, when I say “receiver” on this slide, I mean a device that sits at the end of a physical link, which could be an end-system, a switch, or a router.

Similarly, when I say “sender,” I mean a device that sits at the beginning of a physical link.

Link-layer services

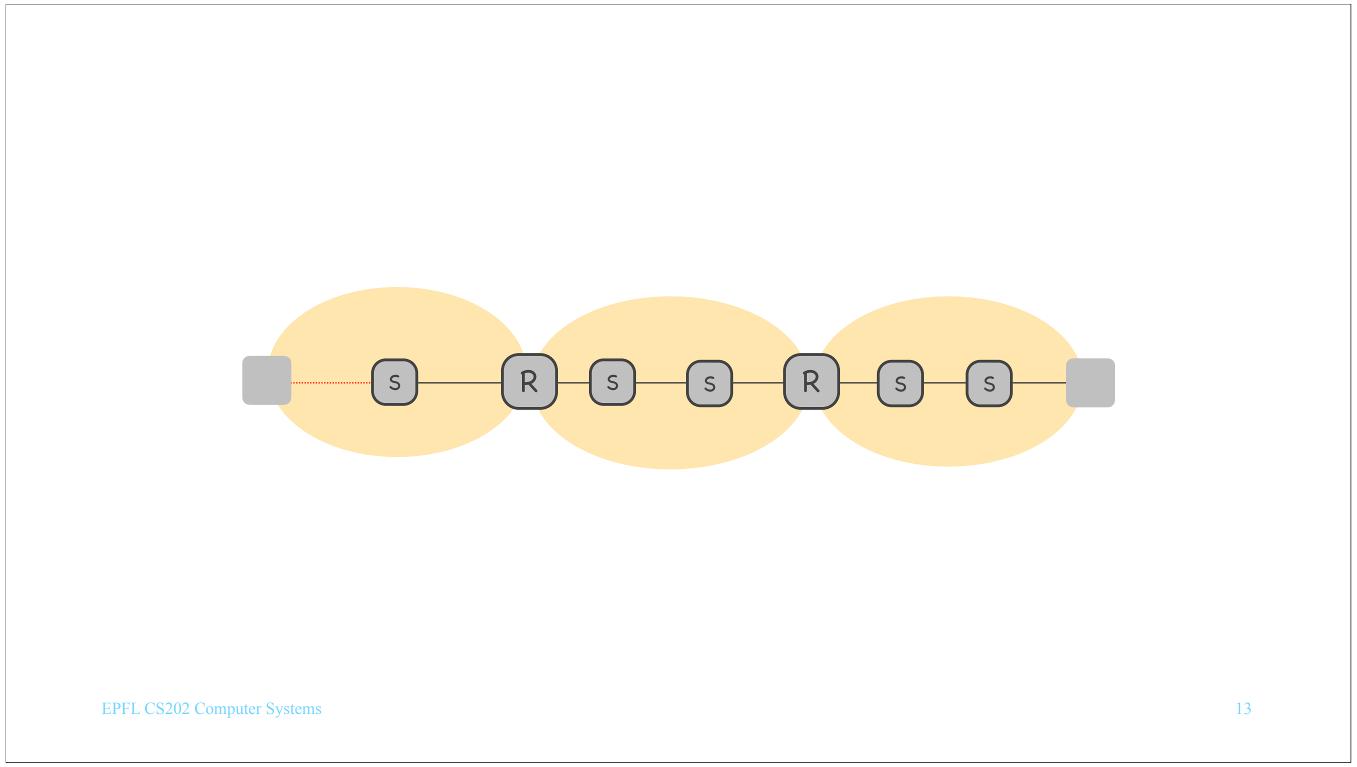
- Medium access control (MAC)
  - *sender manages access to shared medium (typically wireless link)*
  - *listens for ongoing transmissions or “collisions"*
  - *backs off and retries later*

This link layer may also offer a “Medium Access Control” (MAC) service.
This is useful when multiple links share the same physical medium (e.g., multiple wireless links share the same wireless environment).
In this scenario, when a sender transmits, it needs to detect whether someone else transmitted at the same time, in which case it cancels the transmission and “backs off,” meaning it retries later.

Why reliable data delivery at the link layer?
The transport layer does that anyway.

Why provide reliable data delivery at the link layer when TCP can provide it at the transport layer?

Differently said: If the network between Alice and Bob loses or corrupts packets, Alice and Bob can typically recover using TCP. Why provide recovery from loss and corruption also at the link layer?



Because it is a useful performance optimization:

Consider the topology shown above, where two end-systems communicate over a long sequence of physical links.

Suppose the first link is a wireless link that suffers from occasional “glitches,” i.e., short time intervals of heavy packet loss.

Suppose the source end-system sends a sequence of segments to the destination end-system during such a glitch, and they all get lost on the wireless link.

Think about how TCP recovers from such loss:
- The source end-system times out waiting for ACKs.
- It resets its congestion window to 1 MSS and retransmits the oldest unacknowledged segment.
- When it receives an ACK for this segment, it increases the congestion window to 2 MSS’s, retransmits the next two segments, and so on.

Two important points:
- The source end-system must wait for a TCP timeout before acting.
- The throughput from the source to the destination end-system drops significantly.

Now suppose the wireless link provides reliable data delivery (at the link layer). This means that the two devices at the ends of the wireless link (the source end-system and the first switch) try to **locally** recover from any packet loss that occurs on the wireless link.

Think about what happens:
- The link-layer part of the source end-system times out waiting for ACKs from the (link-layer part of the) first switch and retransmits the lost packets

(using some congestion-control algorithm that we have not discussed).
- The transport-layer part of the source end-system (the TCP code running at the source end-system) does not perceive any packet loss, so it does not timeout and does not reset its congestion window.

So: The link layer around the specific problematic link recovers quickly from the loss, hence TCP does not perceive the loss. This means no TCP timeout and no TCP congestion-window reset, hence higher throughput from the source to the destination end-system.

The “link layer”

- Link layer of an IP subnet: takes packet from one end of one physical link to the other end
- Link layer of the Internet:
  network layer of an IP subnet: takes packet from one end of one IP subnet to the other end

The rest of the lecture is dedicated to the link layer of the Internet,
i.e., how to get packets from one end of an IP subnet to the other.

There exist many different types of IP subnets, but we will discuss only the most popular one: Ethernet.