CS 3640: Introduction to Networks and Their Applications

Fall 2023, Lecture 3: Circuit switching

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You should have…

- Nearly completed Assignment 1 .

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Today's class

1. Recap

2. Circuit switching

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Recap: Internet design principles

- What are the four layers of the Internet’s 4-layer model? What does each layer accomplish?
- How has “layering” helped with the development of the Internet?
- What is the end-to-end principle? How does it complement the principle of layering?
- What is the impact of the end-to-end principle on the Internet’s design?
- When does violating the end-to-end principle make sense?
- What is fate-sharing? How does it apply to the Internet’s design?

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Recap: Building blocks of the Internet

- What are the types/hierarchy of networks/devices that make the Internet? Can you give examples of each?

- **Discuss: Why do phone and cable companies dominate the ISP (access network) landscape?**

Today's class

1.

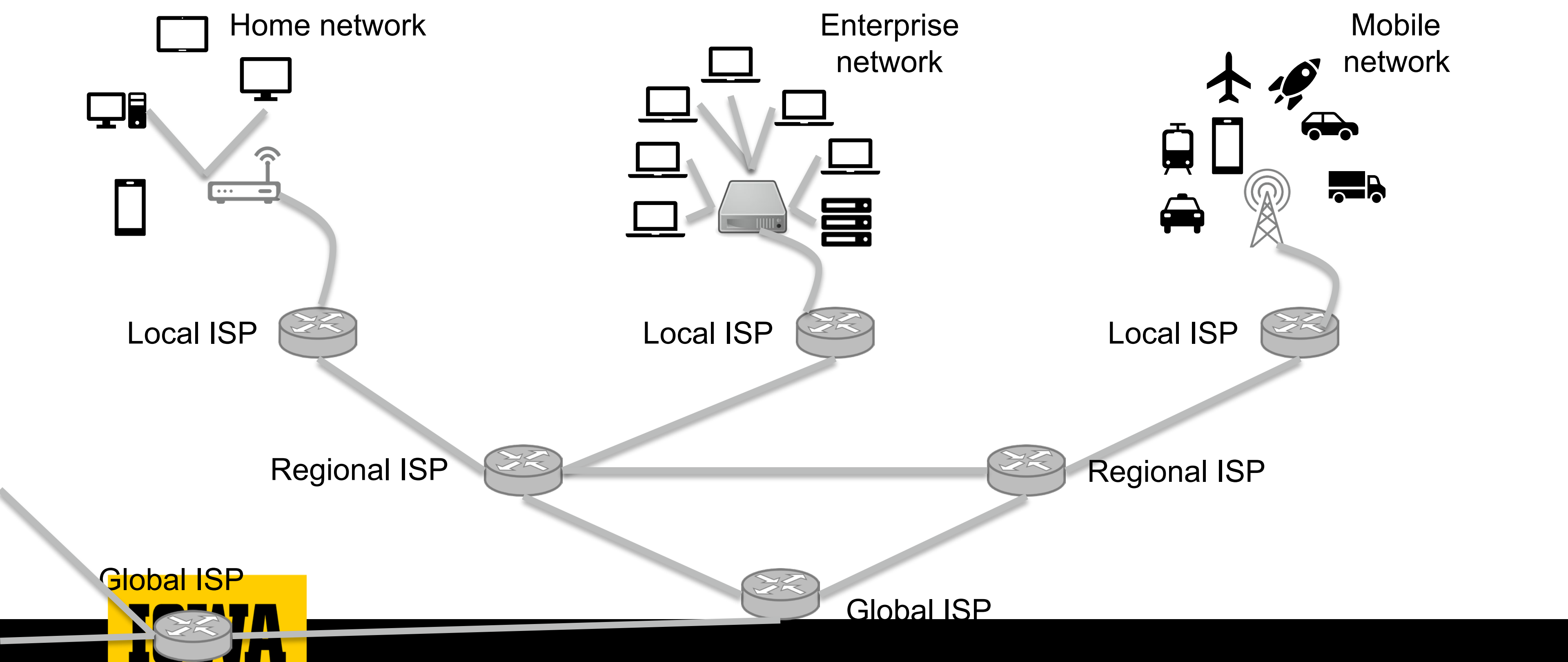
Recap

2.

Circuit switching

Another look at the network core

- This is the core infrastructure of the Internet
  - The core is where your local ISP connects to other “larger” ISPs. The larger ISPs do the same. Eventually, we end up with a large hierarchical network of networks – the Internet.

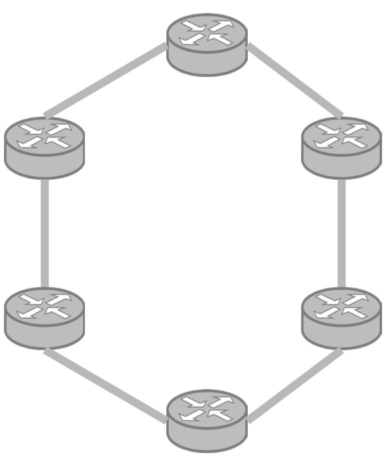


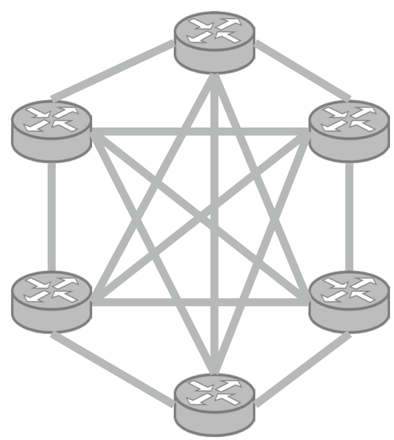
What should the network core look like?

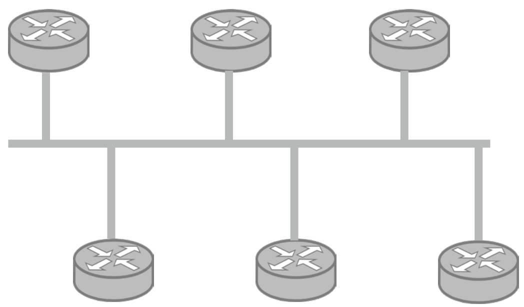
- This is where the magic happens. It consists of thousands of routers that enable scalability and connect billions of end -points with each other.

- How should all these routers be connected to each other?

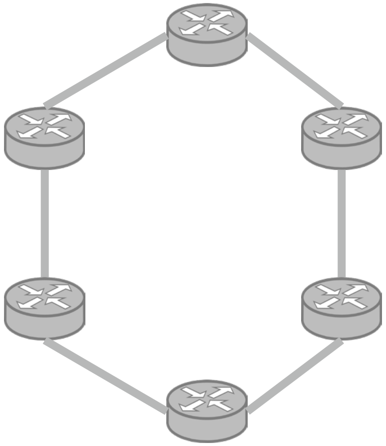
Discuss: Which one is better? Why?



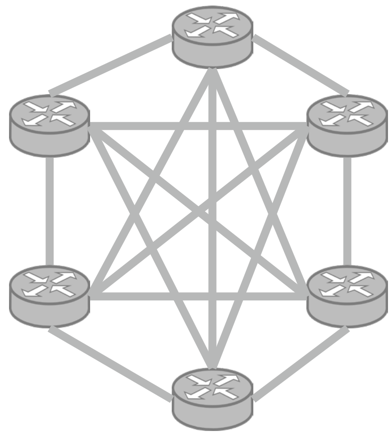




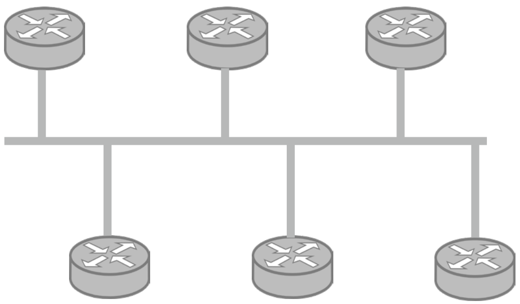
What should the network core look like?



+ Cheap. O(n) links
- Capacity (1/n)
- Resilience (limit: 1 link)



+ High resilience (limit: n-1)
+ Capacity (1)
- Expensive! $O(n^2)$ links.



+ Cheap. O(n) links
- Capacity (1/n)
- Resilience (limit: 1 link)

Factors to consider

- Resilience (#links that need to fail to fracture the network),
- Cost (not too many links), and
- Capacity (not too few links).

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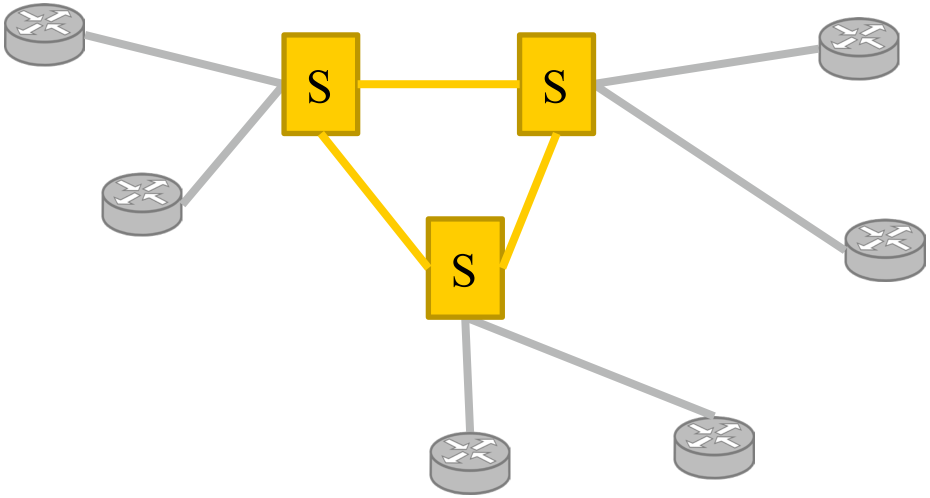
Finding a compromise with switches

Idea: Add another “non-routing” layer to group and interconnect routers.

Routers vs. switches

- Routers operate at the network layer (they make routing decisions)
- Switches operate at the link layer (they put data on the right wire)



Fully connected switches.
- High resilience.

Adding another layer above routers.
- $O(m^2)$ links.
- (m/n) average capacity.

m (#switches) << n (#networks/routers)

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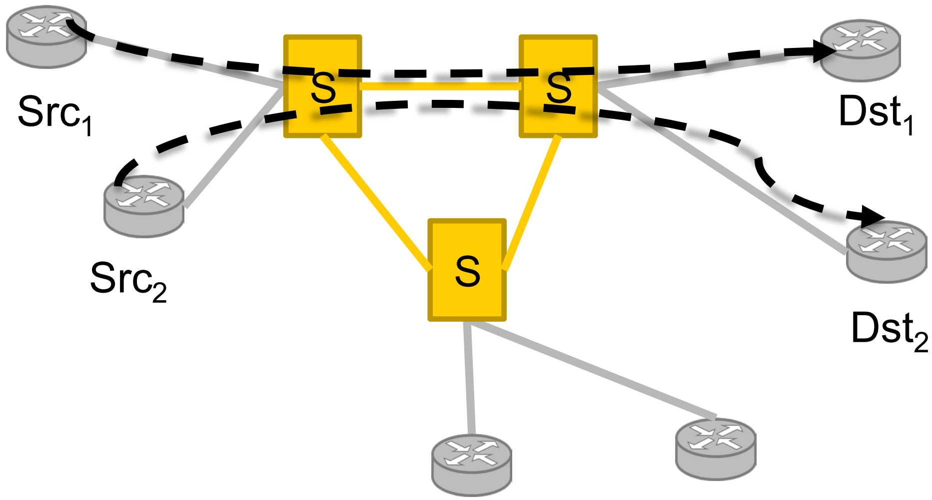
Switching and link sharing

- Switching basically allows multiple devices (routers at the core) to share a single link.
  - New problem: How should they share the link?



Method 1: Make a reservation

- Reserve the maximum bandwidth you will need ahead of time.
- Reservation-based sharing.

Method 2: Just hope for the best

- Just send packets when you must.
- On-demand sharing.

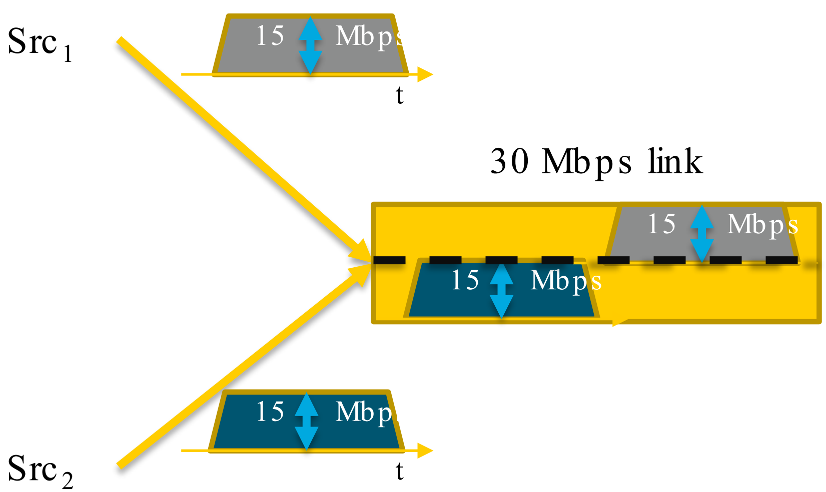
Discuss: Which is better?

Think about the end-to-end principle

Switching and link sharing

Scenario:

- Bandwidth of link: 30 Mbps.
- Src_1 needs 15 Mbps at peak and Src_2 needs 15 Mbps at peak. They peak at different times.
  - Both sources can send at maximum rate regardless of method.



Method 1: Make a reservation

- Reserve the maximum bandwidth you will need ahead of time.
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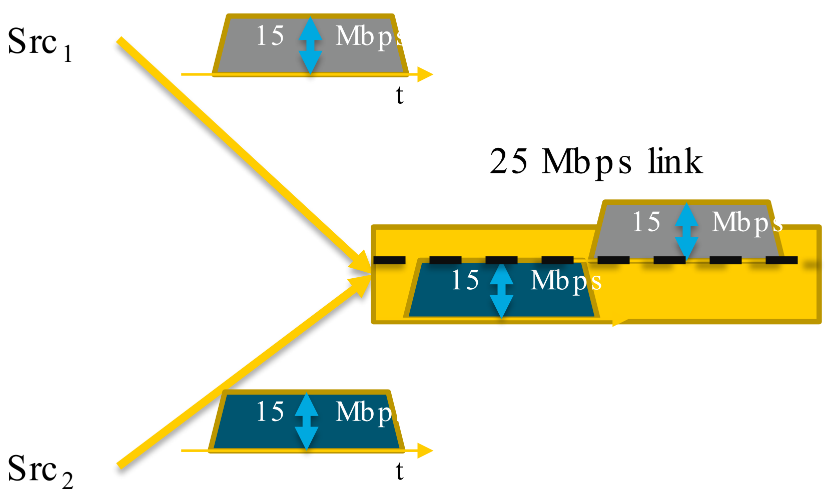
Method 2: Just hope for the best

- Just send packets when you must.
- On-demand sharing.

Switching and link sharing

Scenario:

- Bandwidth of link: 25 Mbps.
- Src_1 needs 15 Mbps at peak and Src_2 needs 15 Mbps at peak. They peak at different times.



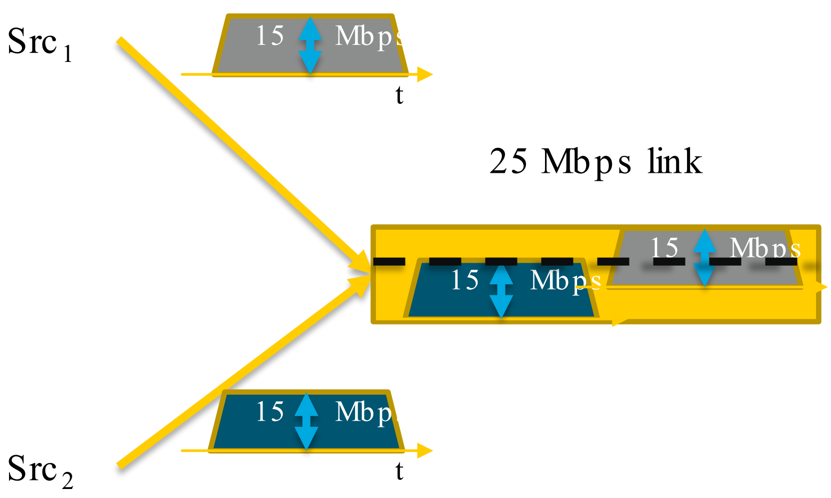
Method 1: Make a reservation

- If we allow peak rate reservation, we turn away Src_1.
- If we allow equal reservation, we underserve both sources (12.5Mbps capacity/15Mbps source). Results in lag (reliable transport) or high packet loss (unreliable transport).

Switching and link sharing

Scenario:

- Bandwidth of link: 25 Mbps.
- Src_1 needs 15 Mbps at peak and Src_2 needs 15 Mbps at peak. They peak at different times.



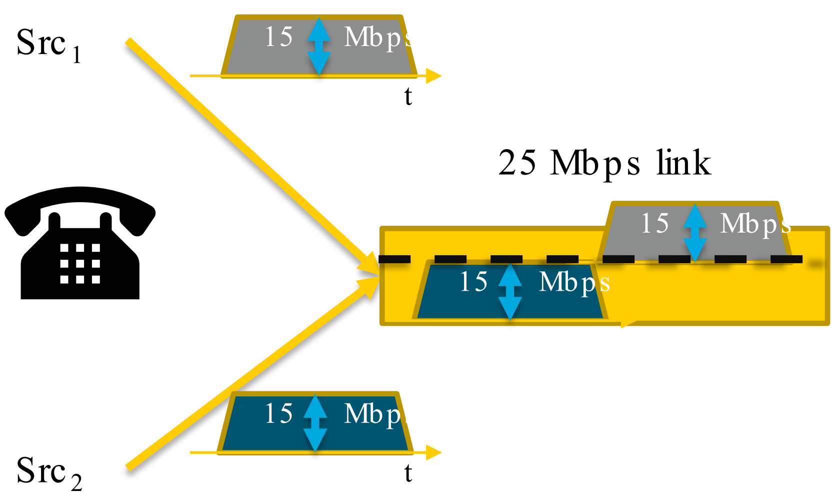
Method 2: Hope for the best

- Everything works out just fine!

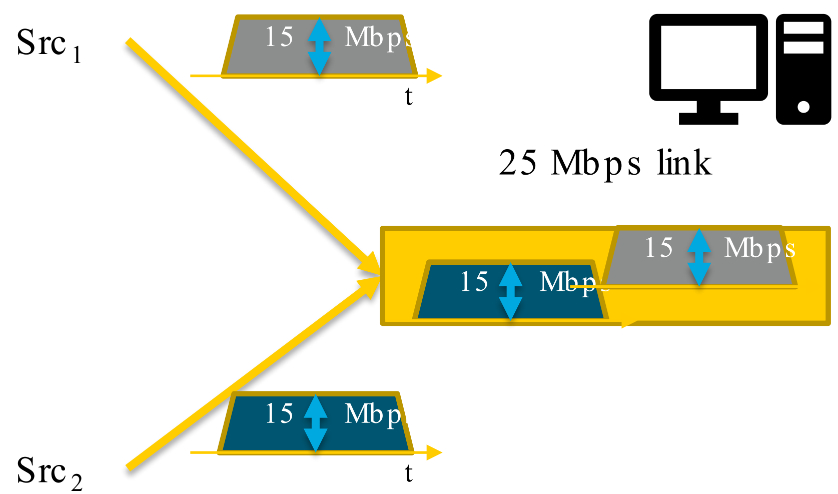
Switching and link sharing

Which is better?

- Bursty applications prefer on-demand sharing.
  - (peak rate/avg rate) is high, less predictable.
- Smooth applications prefer reservation-based sharing.
  - (peak rate/avg rate) is low, more predictable.
- **Discuss: Which one is better for the Web? Which one is better for phones?**



Reservation-based link sharing

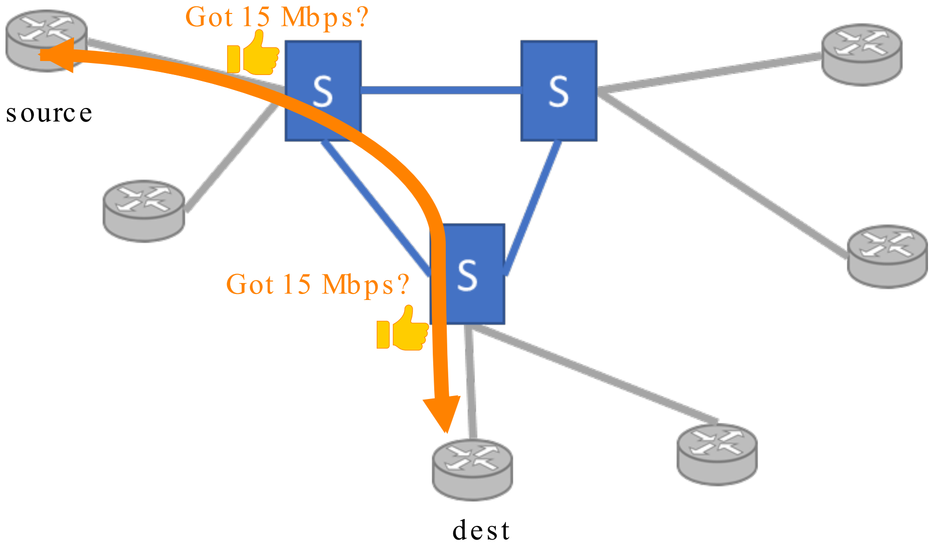


On-demand link sharing

How is reservation-based sharing implemented?

Circuit Switching.

- **Phase I: Circuit request and establishment.**
  - Each switch reserves the requested bandwidth and forwards the request to the next one.
  - Confirmation sent to source back via reserved bandwidth.
- Phase II: Data transfer.
- Phase III: Circuit teardown.



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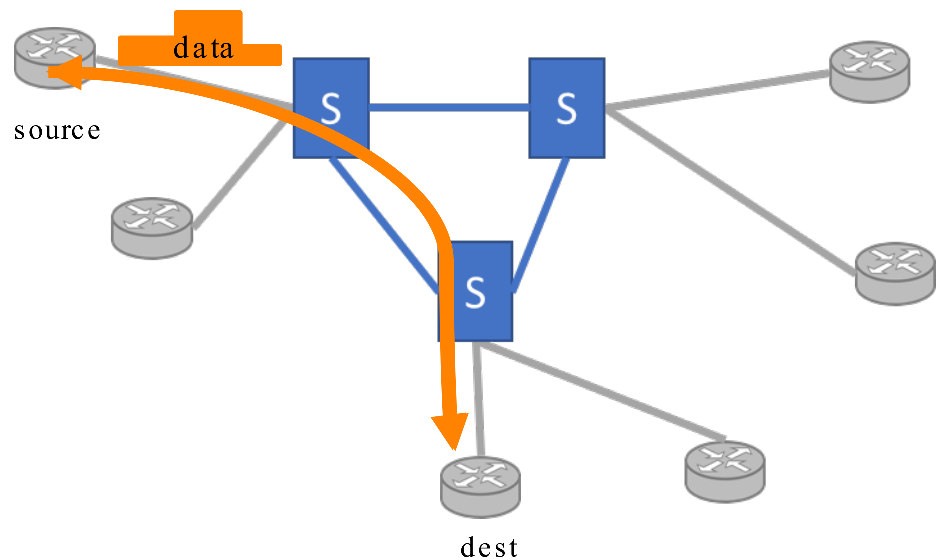
How is reservation-based sharing implemented?

Circuit Switching.

- Phase I: Circuit request and establishment.
- **Phase II: Data transfer.**
  - Transfer data using the established circuit
- Phase III: Circuit teardown.



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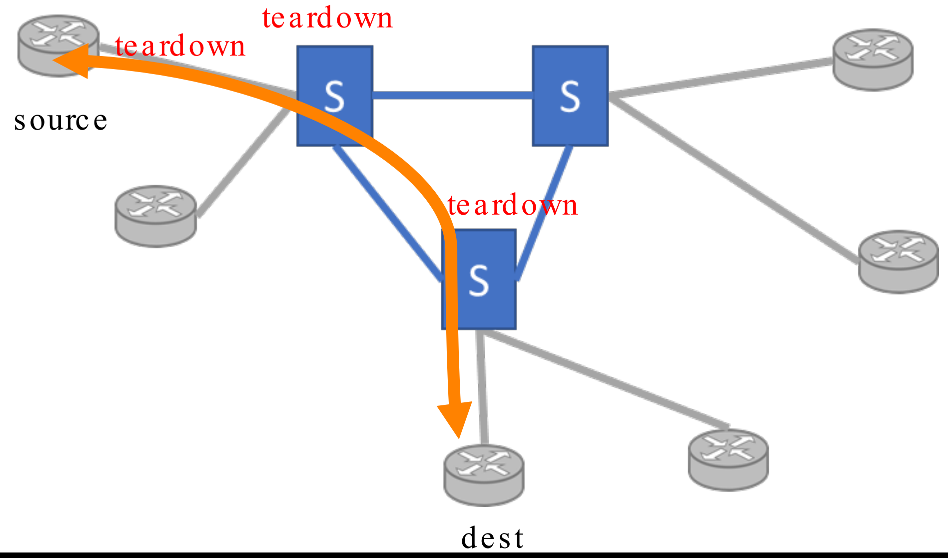
How is reservation-based sharing implemented?

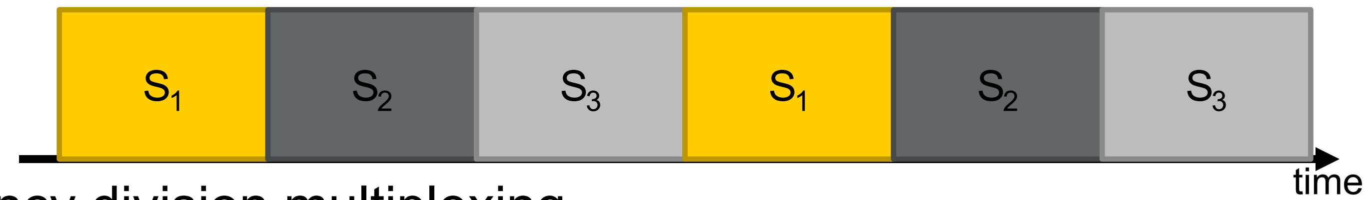
Circuit Switching.

- Phase I: Circuit request and establishment.
- Phase II: Data transfer.
- **Phase III: Circuit teardown.**
    - A teardown request is sent via the circuit.
    - After the confirmation is sent from the destination, each switch deletes the reservation.

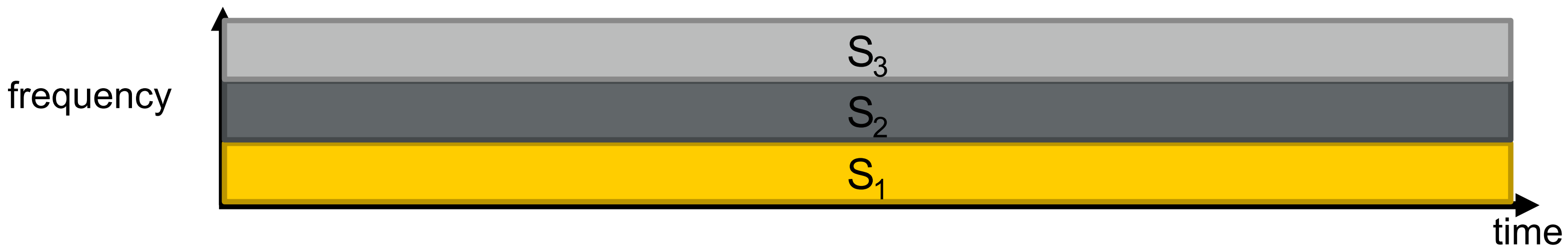


What does a “reservation” look like?

- Time division multiplexing
  - Splitting time between each source.



- Frequency division multiplexing
  - Split the link frequencies between each source.



Where have you seen frequency division multiplexing before?
Wi-Fi routers. 2.4GHz vs 5GHz.
Trade-offs: The higher the frequency, the lower the range.
The higher the frequency, the higher the bandwidth (more data/source or more sources).
But if you have only a few devices, do you really need to spend more $$$ for a 5GHz router?

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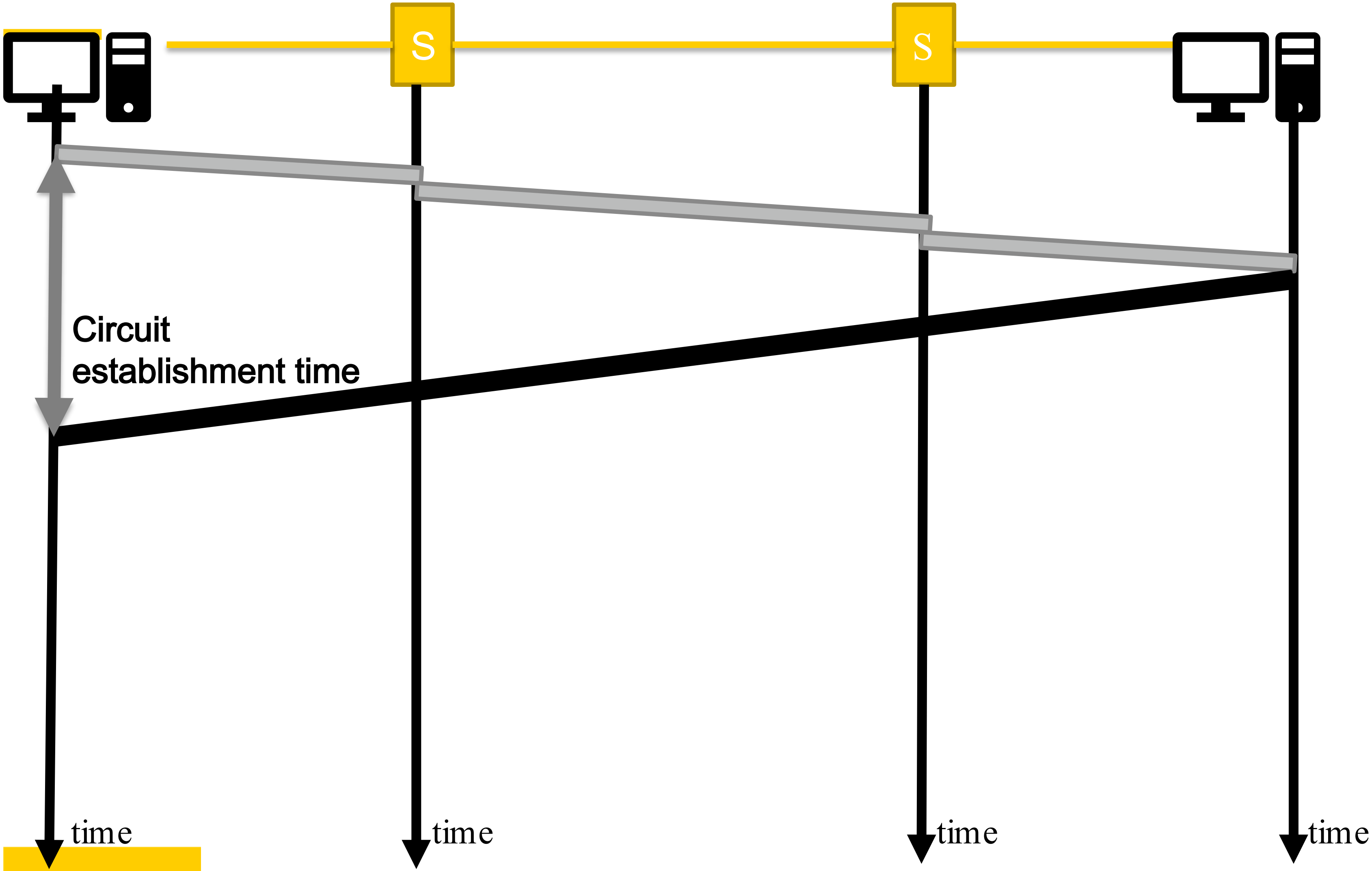
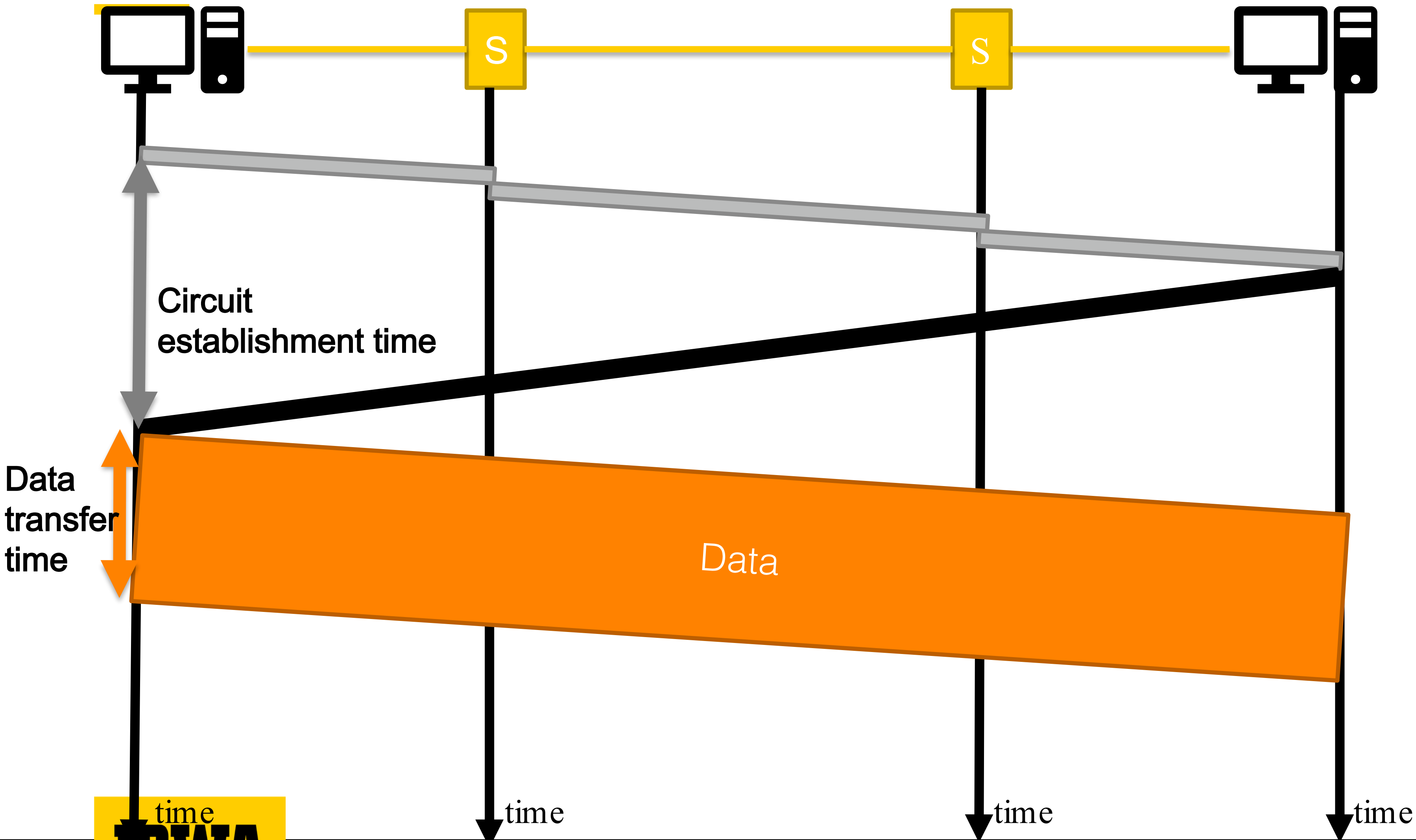
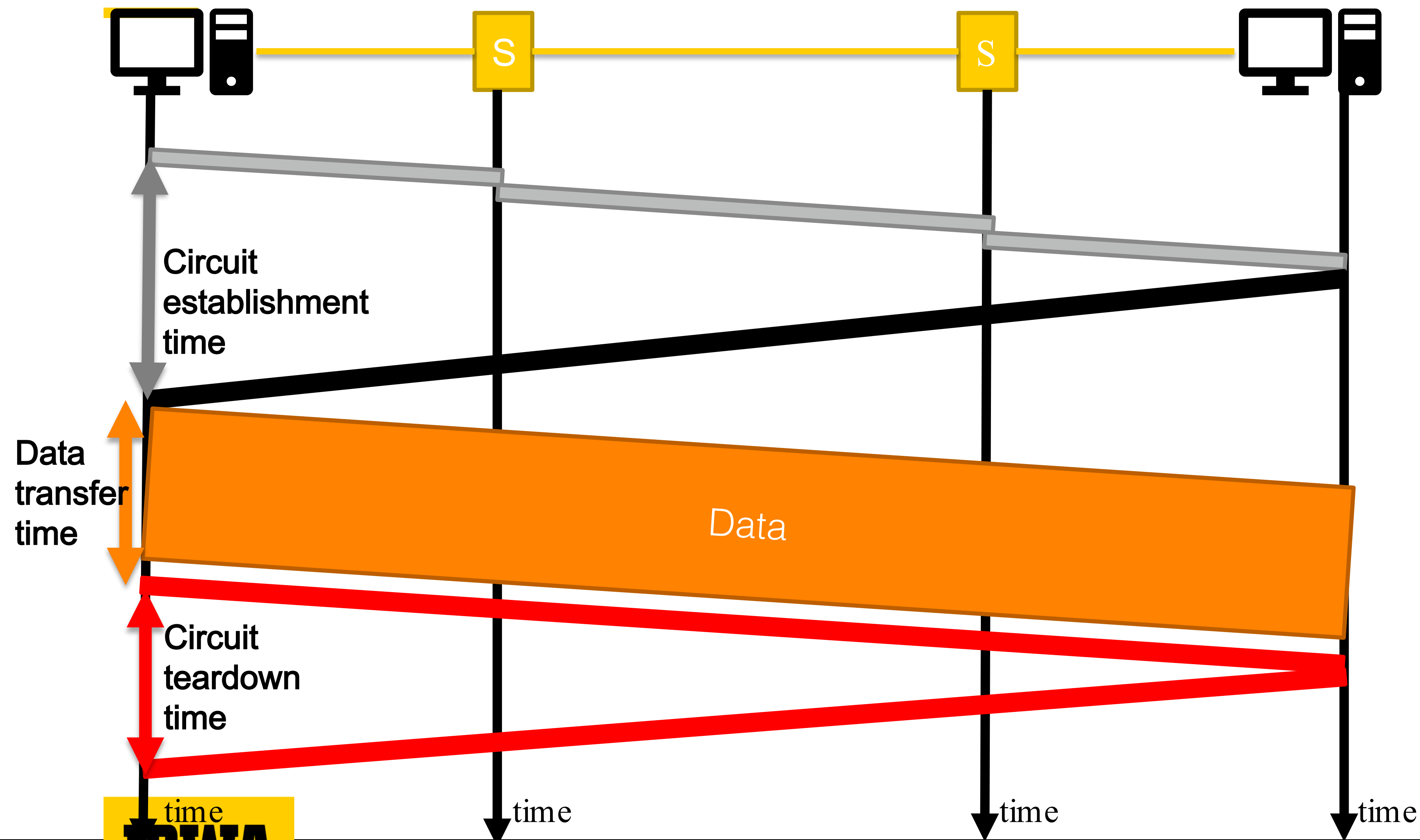
Performance and efficiency of circuit switching



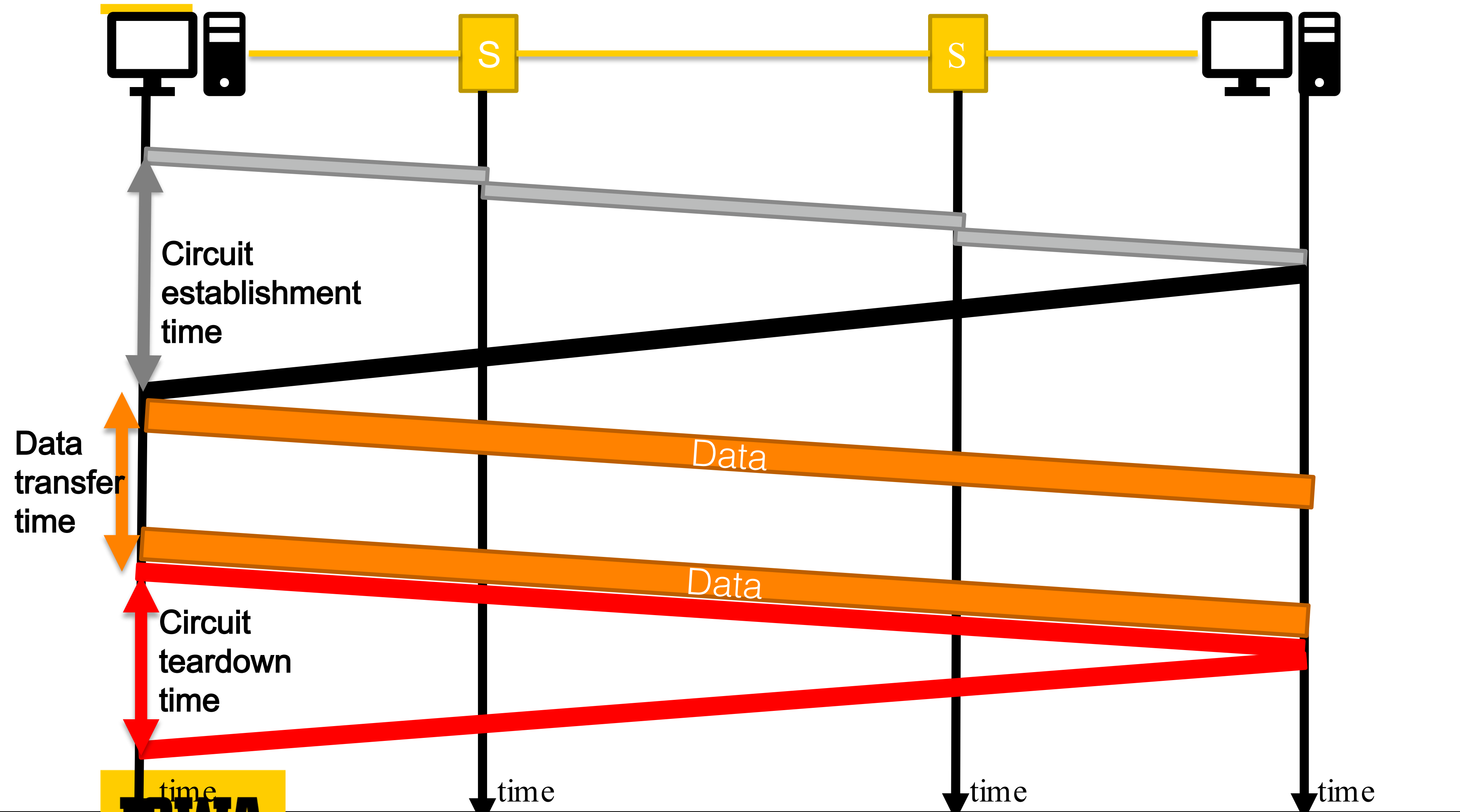
Performance and efficiency of circuit switching



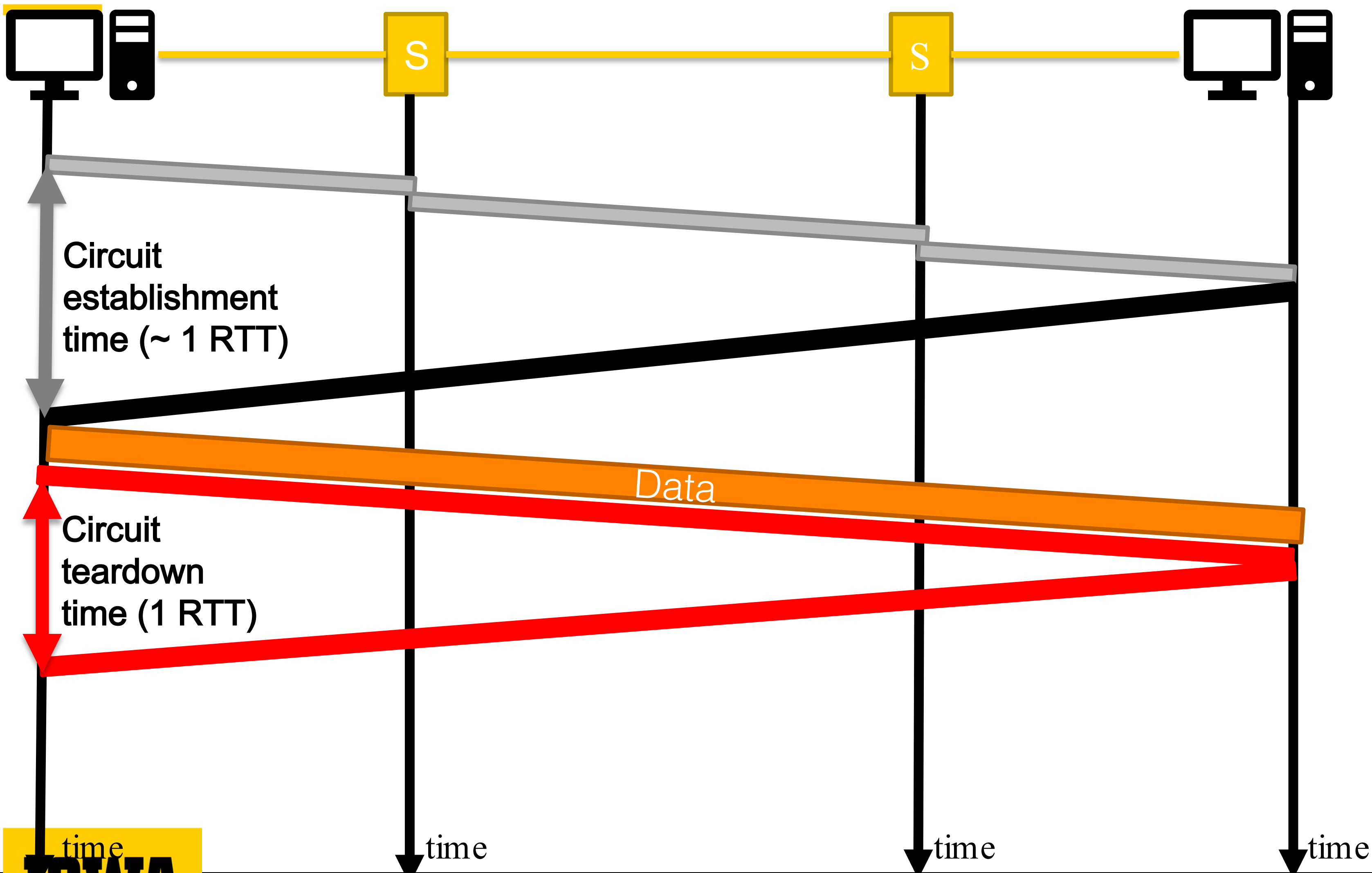
Performance and efficiency of circuit switching



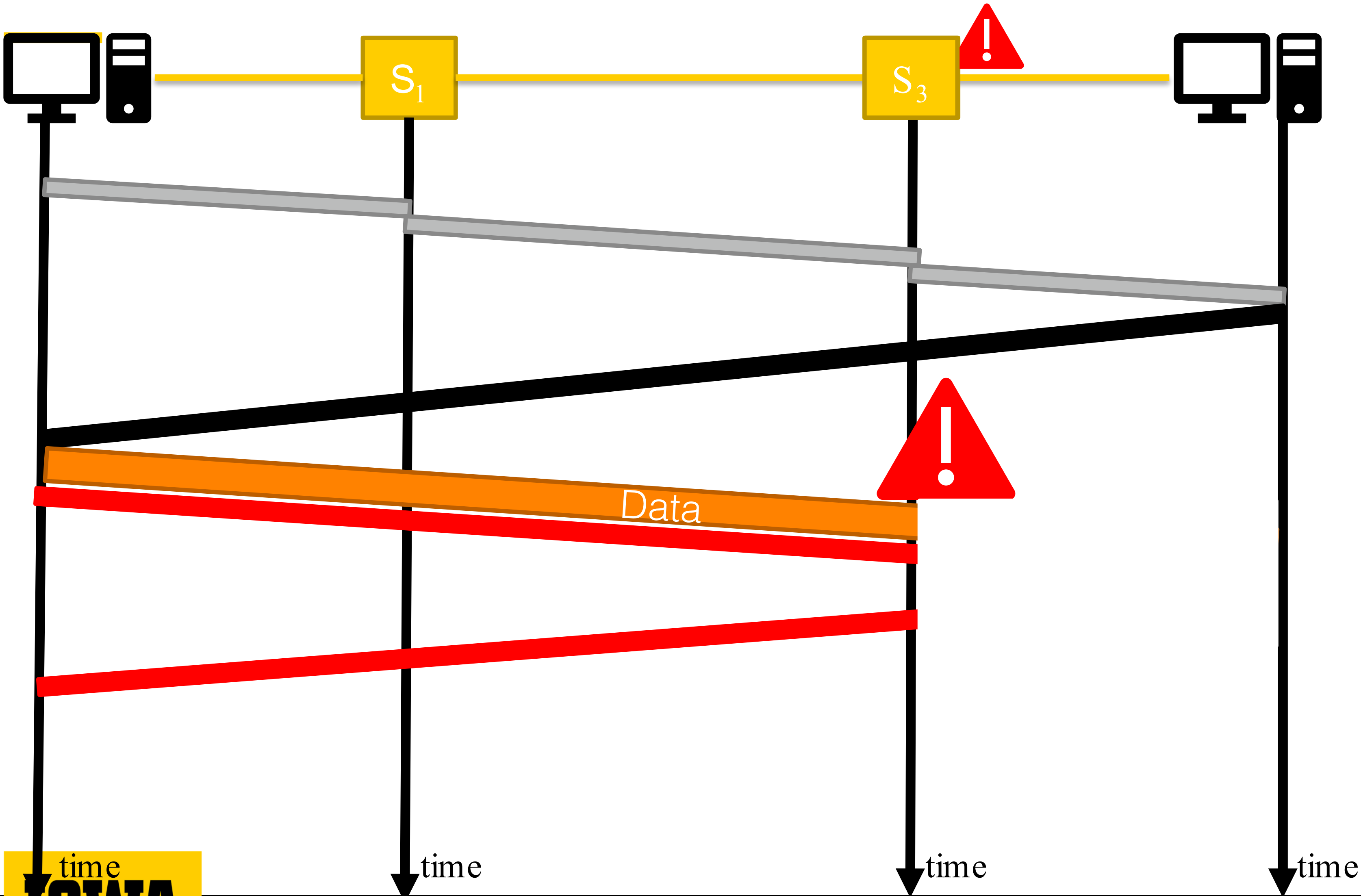
Why is bursty traffic bad in circuit switched networks?



Overhead of circuit switched networks



Failure in circuit switched networks



Summary of circuit switching

- Circuit switching is how reservation -based link sharing is implemented.
  - Reserves peak resources end -to-end (from source to destination).
  - All packets take the same route from source to destination.

- What types of traffic does it handle well?
  - Smooth and predictable traffic.
  - Good for old phone systems.

- What makes it unsuitable for the Internet?
  - Very inefficient for bursty traffic.
  - Failure cost is high. (switch/link failure = circuit failure)