Introduction to Computer Networks

Fairness of Bandwidth Allocation (§6.3.1)

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Topic

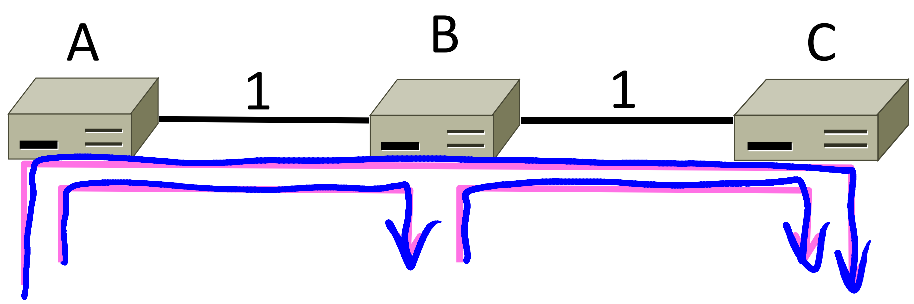
- What's a "fair" bandwidth allocation?
  - The max-min fair allocation

Recall

- We want a good bandwidth allocation to be fair and efficient
  - Now we learn what fair means
- Caveat: in practice, efficiency is more important than fairness

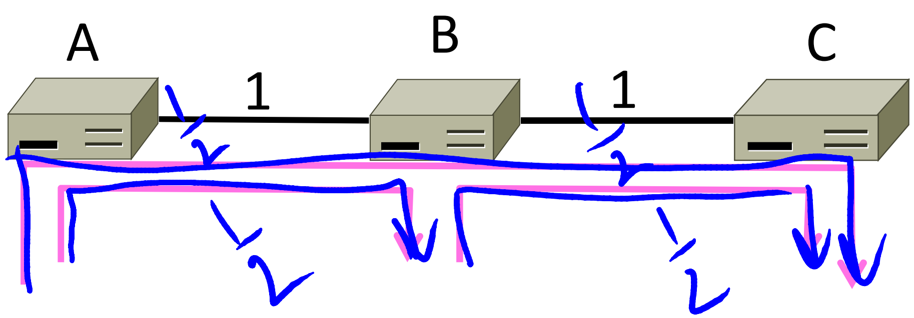
Efficiency vs. Fairness

- Cannot always have both!
  - Example network with traffic A→B, B→C and A→C
  - How much traffic can we carry?



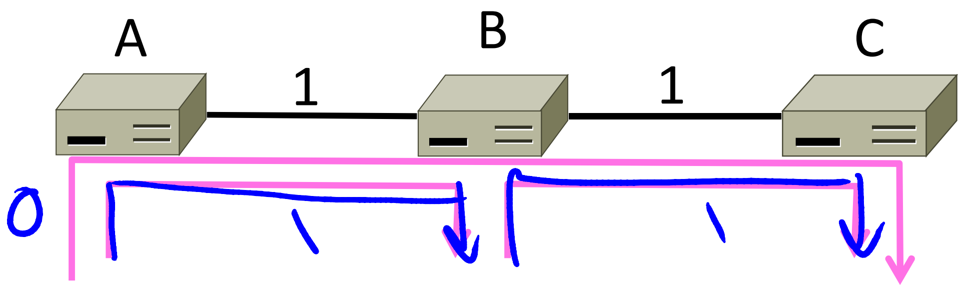
Efficiency vs. Fairness (2)

- If we care about fairness:
  - Give equal bandwidth to each flow
  - A→B: ½ unit, B→C: ½, and A→C, ½
  - Total traffic carried is 1 ½ units



Efficiency vs. Fairness (3)

- If we care about efficiency:
  - Maximize total traffic in network
  - A→B: 1 unit, B→C: 1, and A→C, 0
  - Total traffic rises to 2 units!

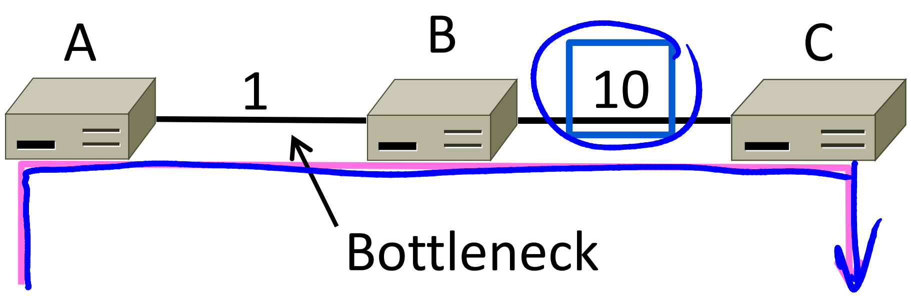


The Slippery Notion of Fairness

- Why is "equal per flow" fair anyway?
  - A→C uses more network resources (two links) than A→B or B→C
  - Host A sends two flows, B sends one
- Not productive to seek exact fairness
  - More important to avoid starvation
  - "Equal per flow" is good enough

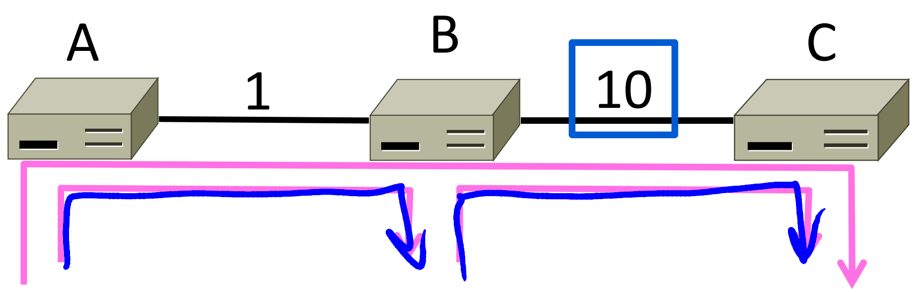
Generalizing "Equal per Flow"

- Bottleneck for a flow of traffic is the link that limits its bandwidth
  - Where congestion occurs for the flow
  - For A→C, link A–B is the bottleneck



Generalizing "Equal per Flow" (2)

- Flows may have different bottlenecks
  - For A→C, link A–B is the bottleneck
  - For B→C, link B–C is the bottleneck
  - Can no longer divide links equally …



Max-Min Fairness

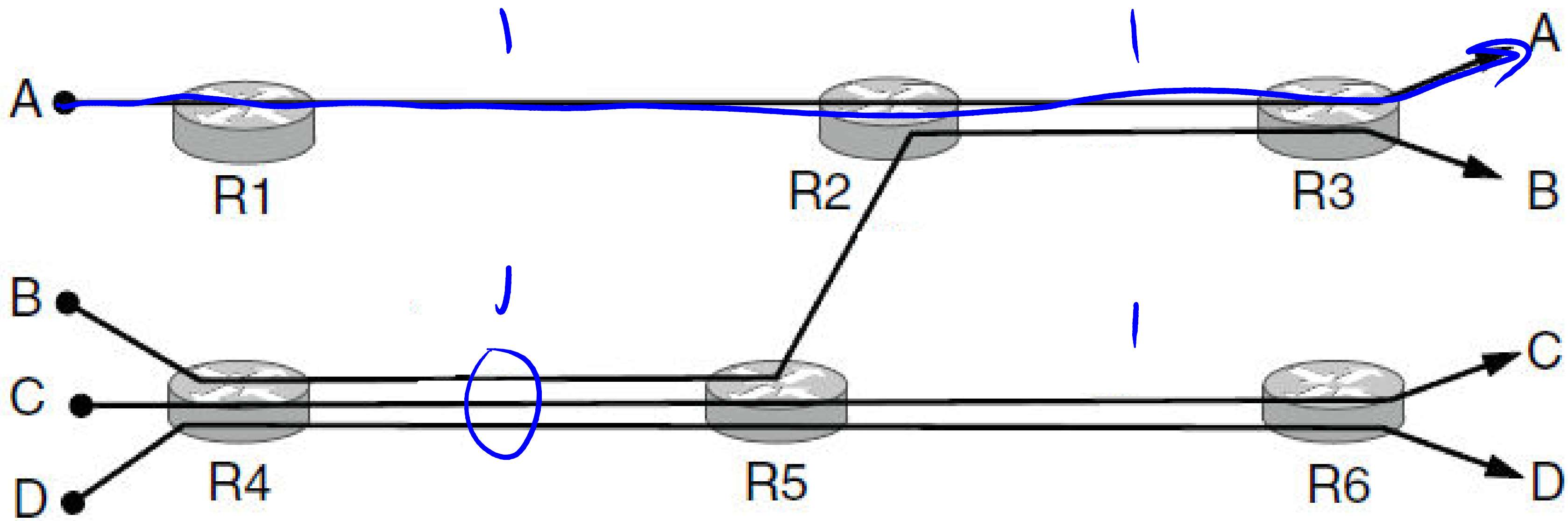
- Intuitively, flows bottlenecked on a link get an equal share of that link
- Max-min fair allocation is one that:
  - Increasing the rate of one flow will decrease the rate of a smaller flow
  - This "maximizes the minimum" flow

Max-Min Fairness (2)

- To find it given a network, imagine "pouring water into the network"
  1. Start with all flows at rate 0
  2. Increase the flows until there is a new bottleneck in the network
  3. Hold fixed the rate of the flows that are bottlenecked
  4. Go to step 2 for any remaining flows

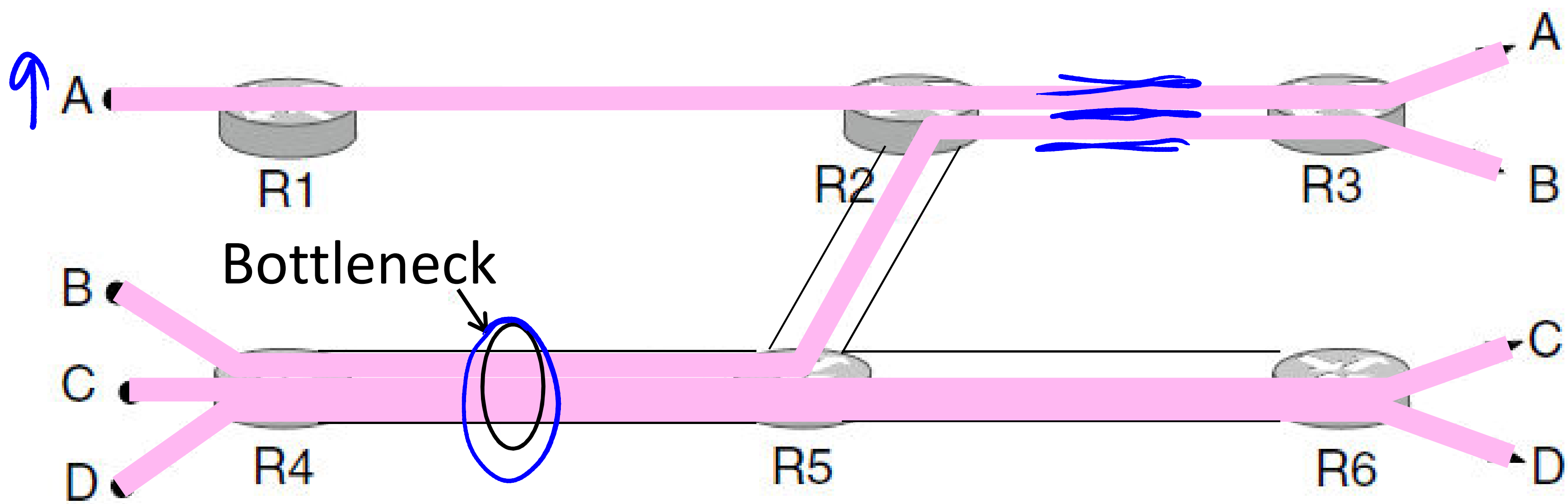
Max-Min Example

- Example: network with 4 flows, links equal bandwidth
  - What is the max-min fair allocation?



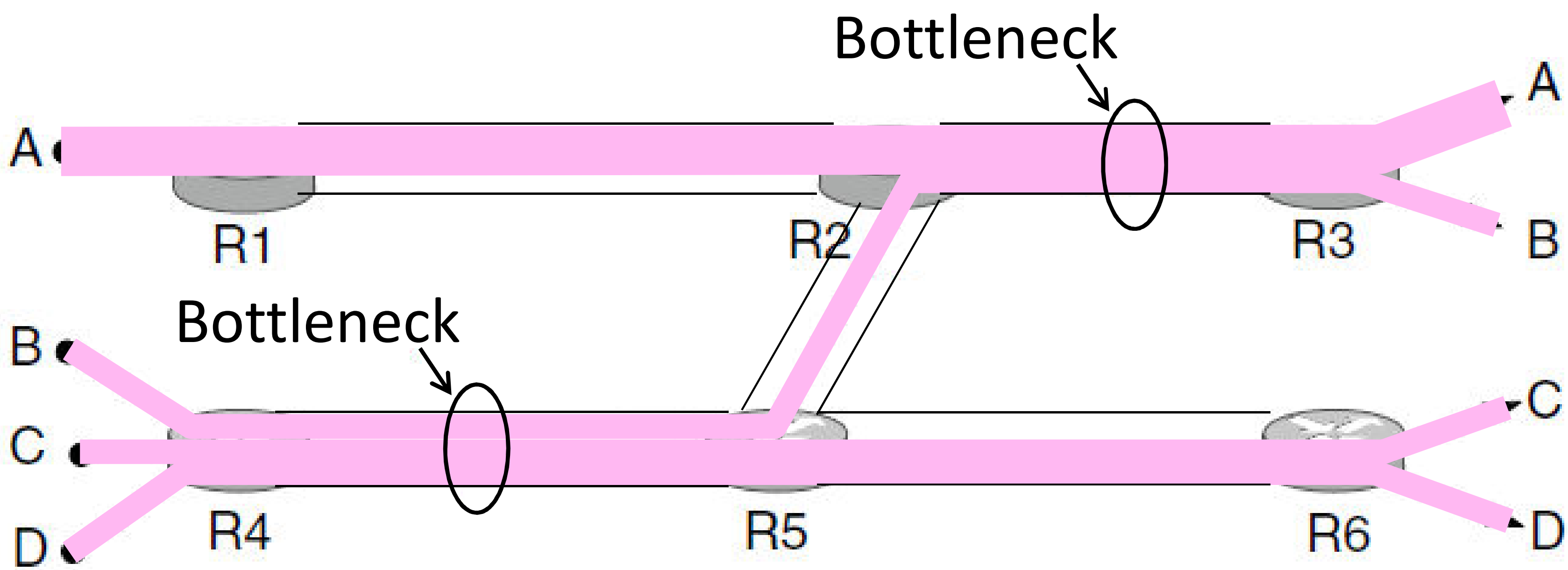
Max-Min Example (2)

- When rate=1/3, flows B, C, and D bottleneck R4—R5
  - Fix B, C, and D, continue to increase A

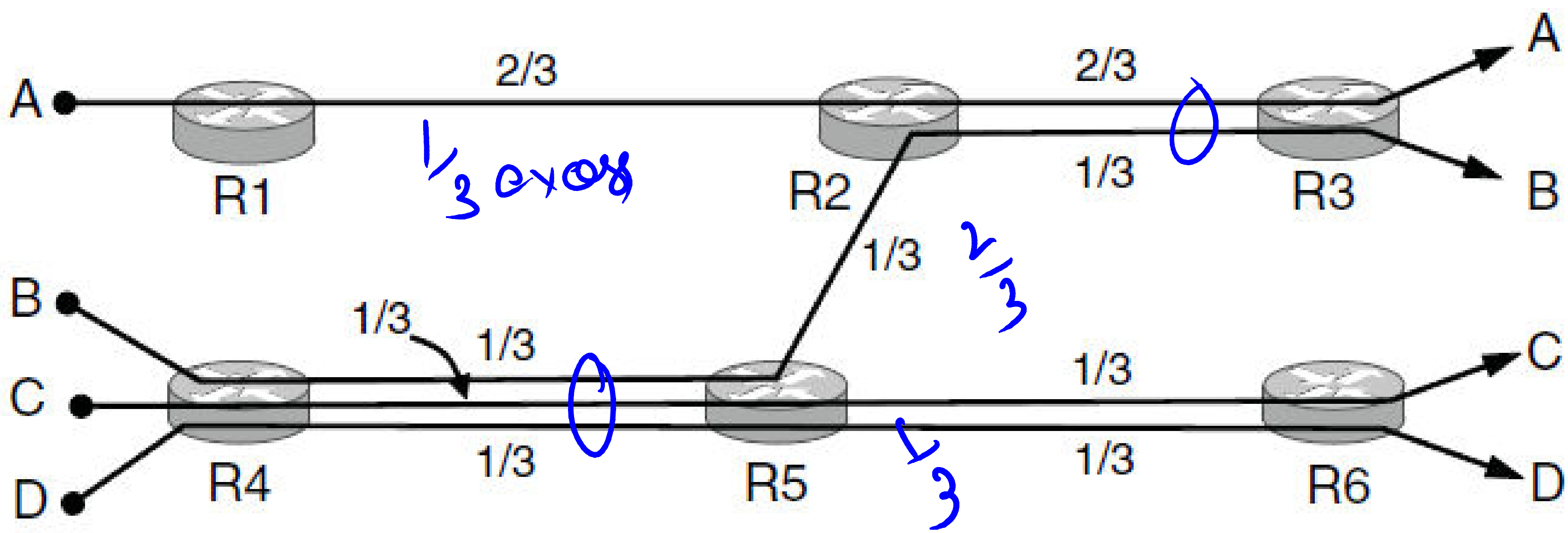


Max-Min Example (3)

- When rate=2/3, flow A bottlenecks R2—R3. Done.

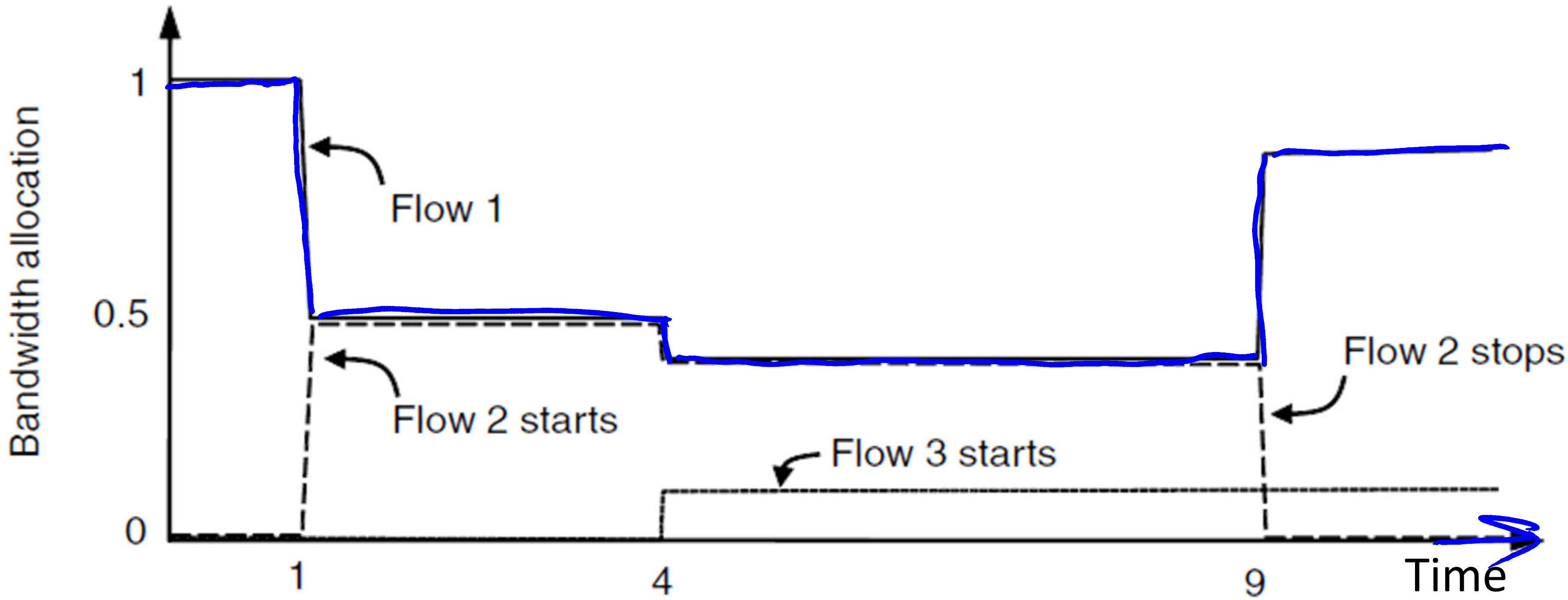


Max-Min Example (4)

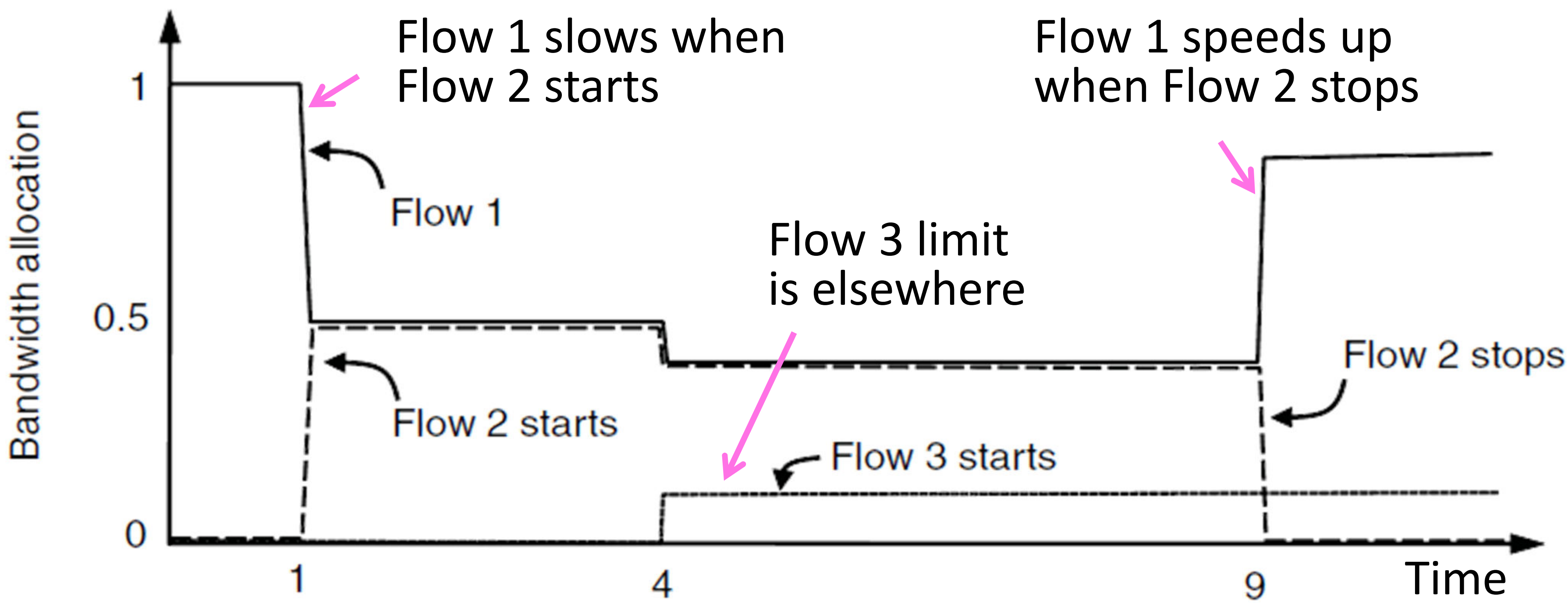
- End with A=2/3, B, C, D=1/3, and R2—R3, R4—R5 full
  - Other links have extra capacity that can't be used
- 

Adapting over Time

- Allocation changes as flows start and stop



Adapting over Time (2)



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