

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

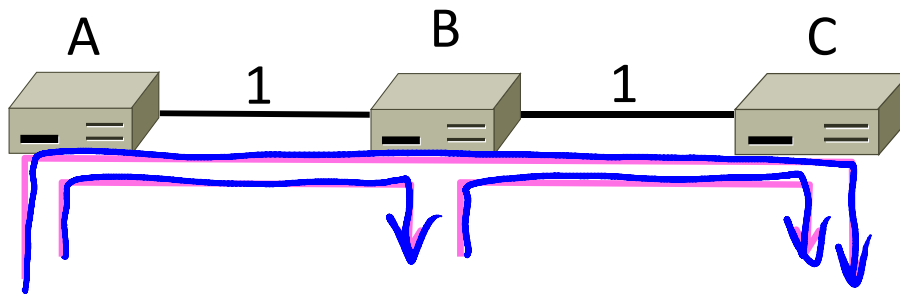


Recall

- 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

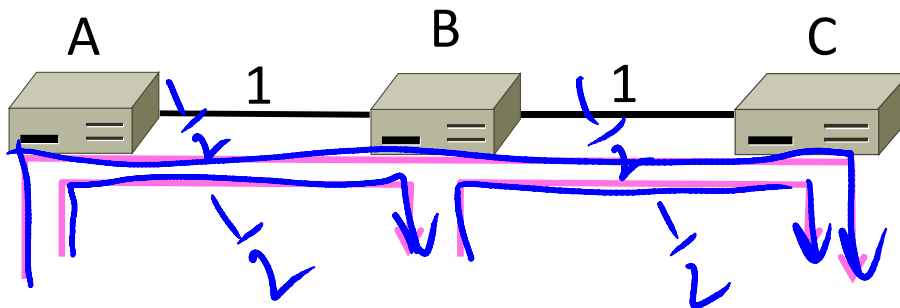
Efficiency vs. Fairness

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



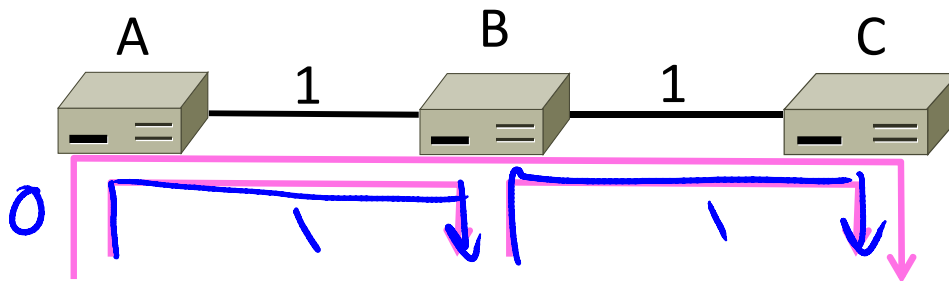
Efficiency vs. Fairness (2)

- If we care about fairness:
 - Give equal bandwidth to each flow
 - $A \rightarrow B$: $\frac{1}{2}$ unit, $B \rightarrow C$: $\frac{1}{2}$, and $A \rightarrow C$, $\frac{1}{2}$
 - Total traffic carried is $1 \frac{1}{2}$ units



Efficiency vs. Fairness (3)

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

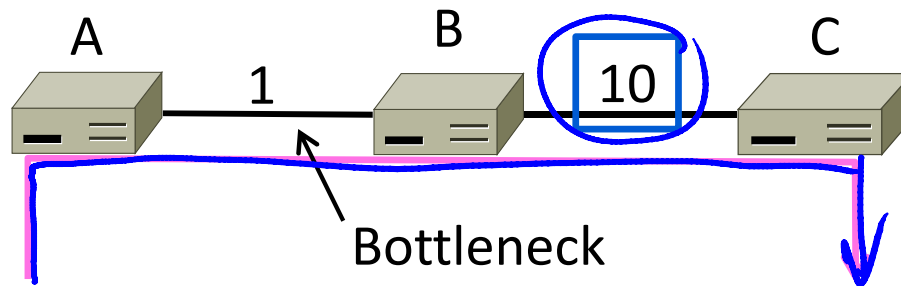


The Slippery Notion of Fairness

- 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

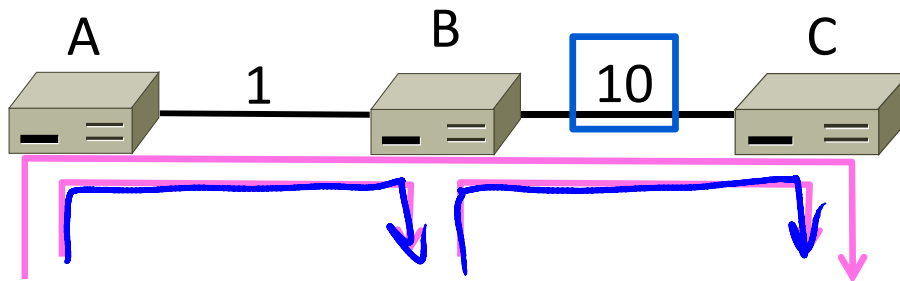
Generalizing “Equal per Flow”

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



Generalizing “Equal per Flow” (2)

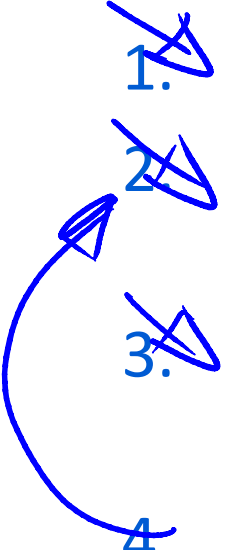
- Flows may have different bottlenecks
 - For $A \rightarrow C$, link $A-B$ is the bottleneck
 - For $B \rightarrow C$, link $B-C$ is the bottleneck
 - Can no longer divide links equally ...



Max-Min Fairness

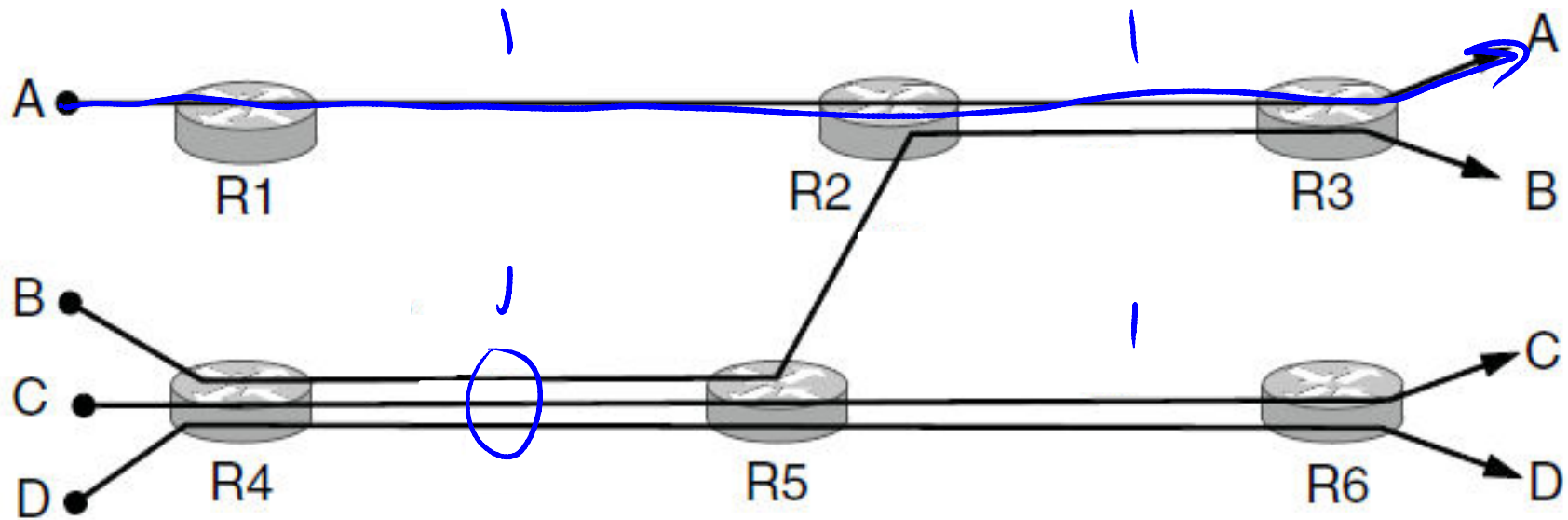
- Intuitively, flows bottlenecked on a link get an equal share of that link
- Max-min fair allocation is one that:
 - Increasing the rate of one flow will decrease the rate of a smaller flow
 - This “maximizes the minimum” flow

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
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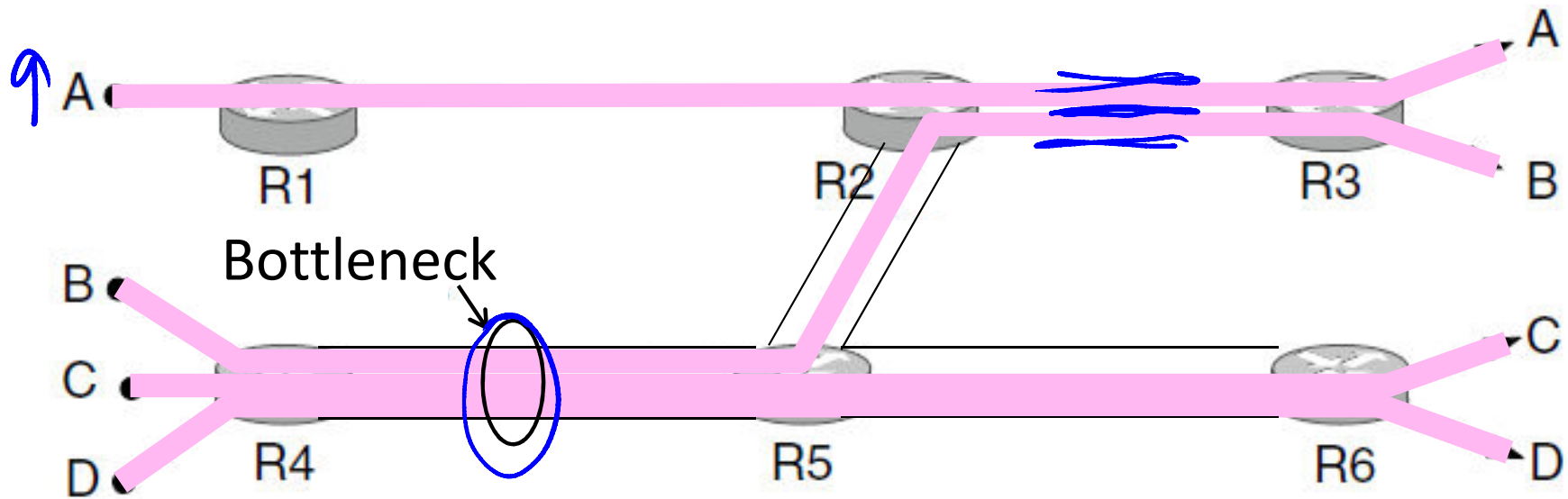
Max-Min Example

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



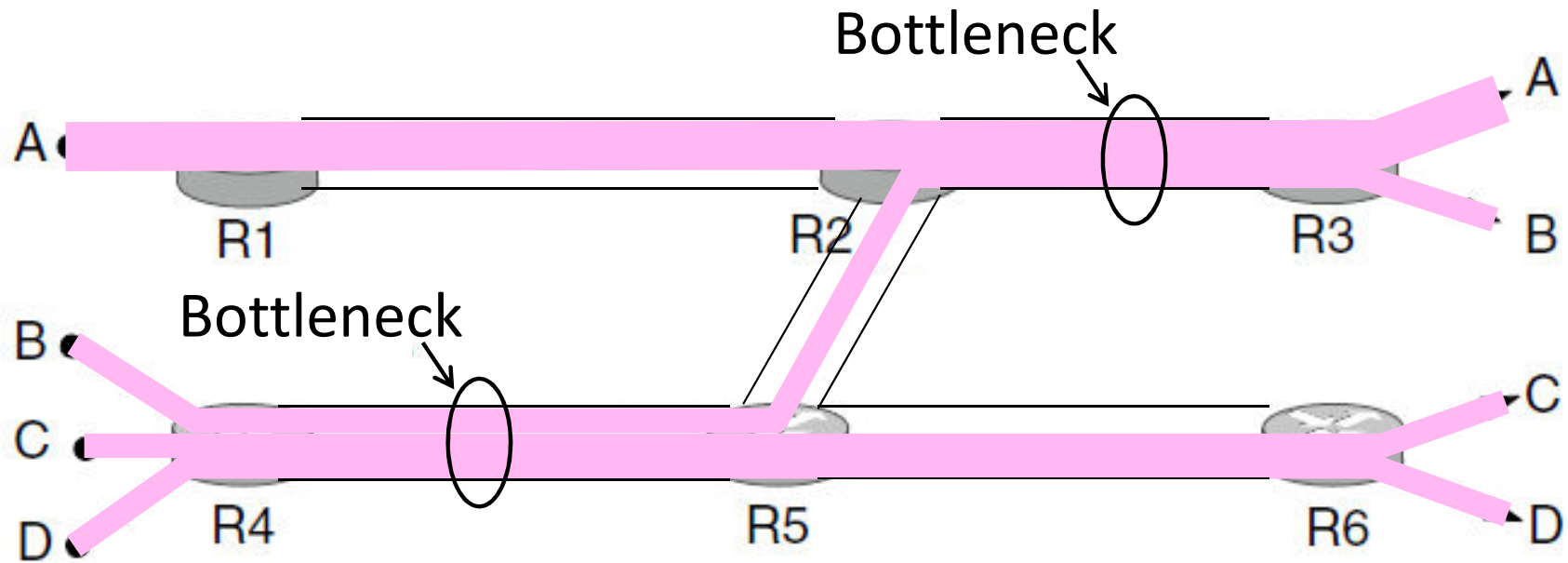
Max-Min Example (2)

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



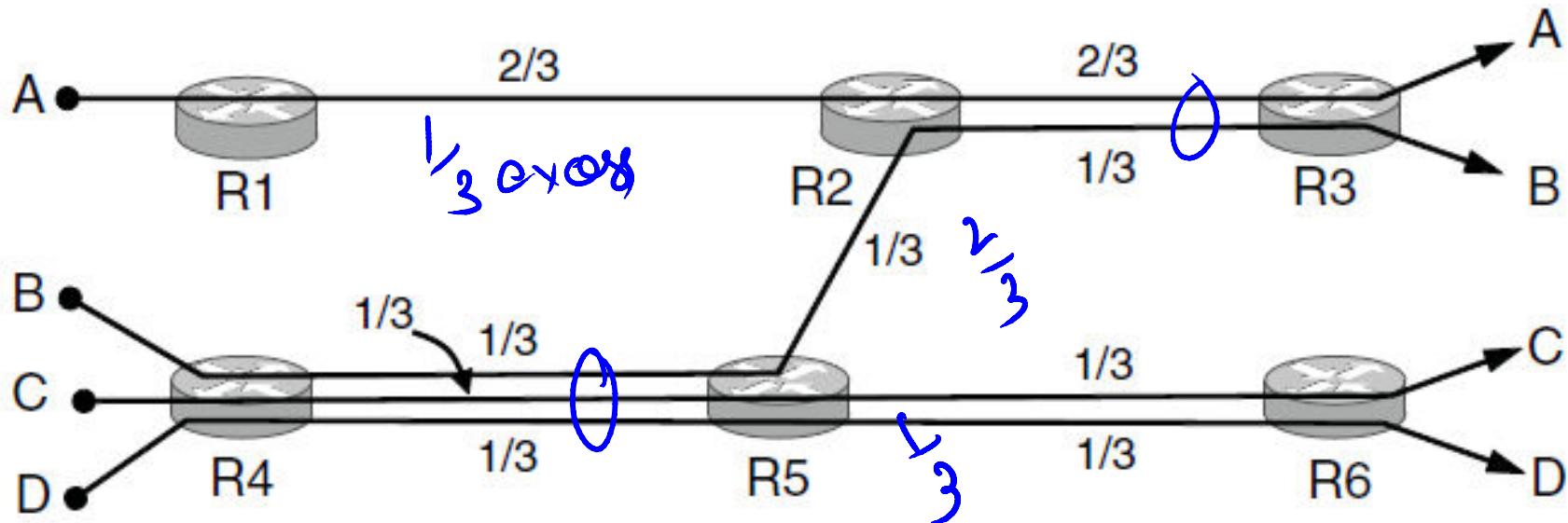
Max-Min Example (3)

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



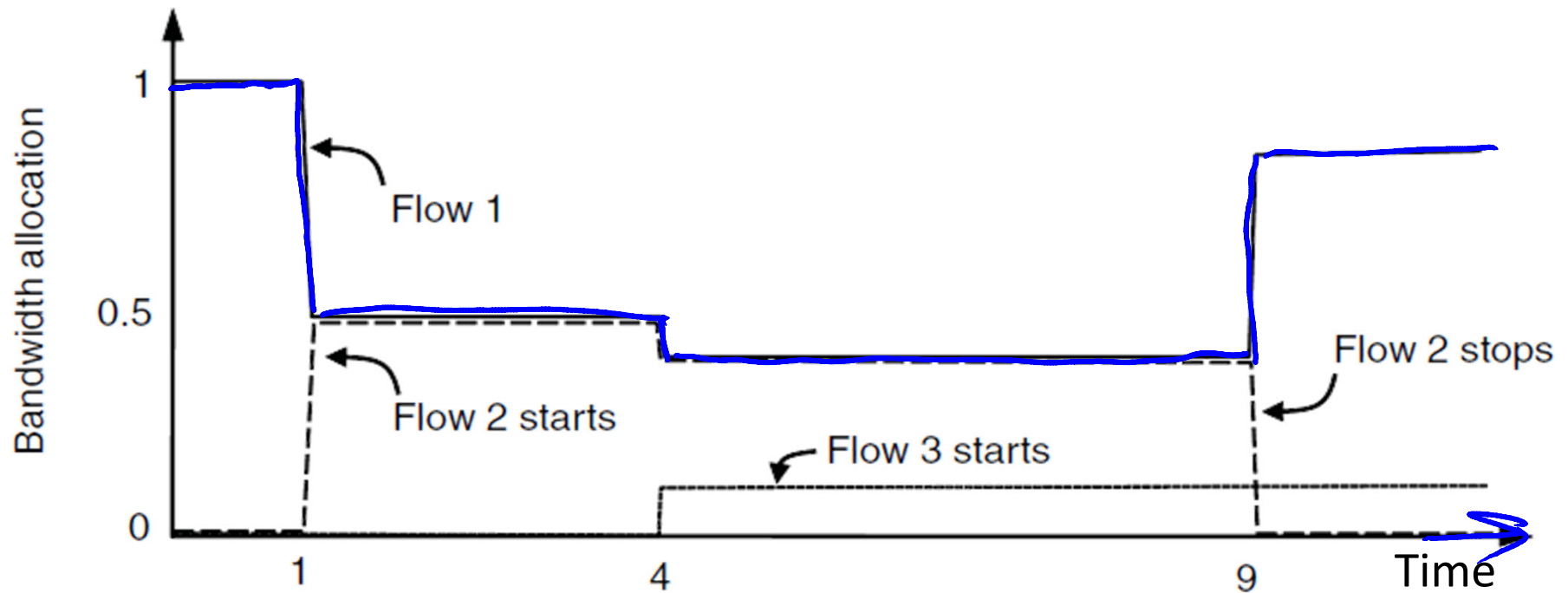
Max-Min Example (4)

- 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

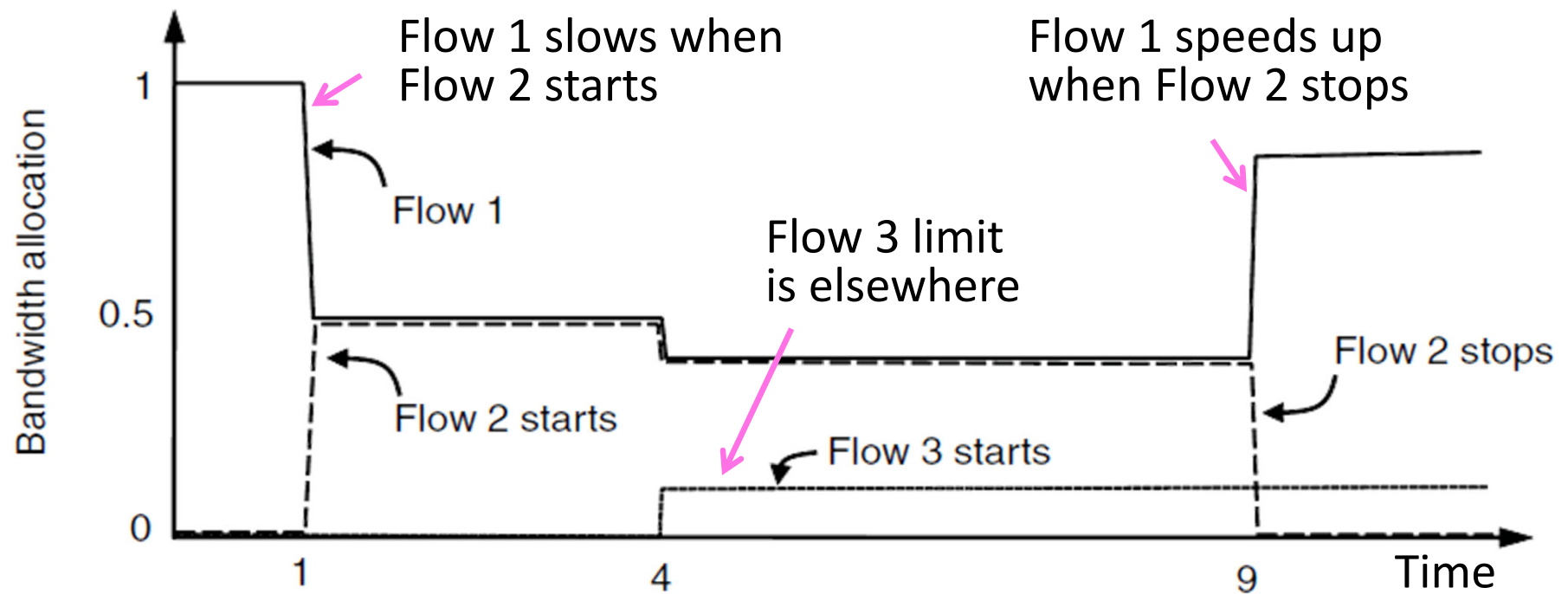


Adapting over Time

- Allocation changes as flows start and stop



Adapting over Time (2)



END

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