Congestion Control

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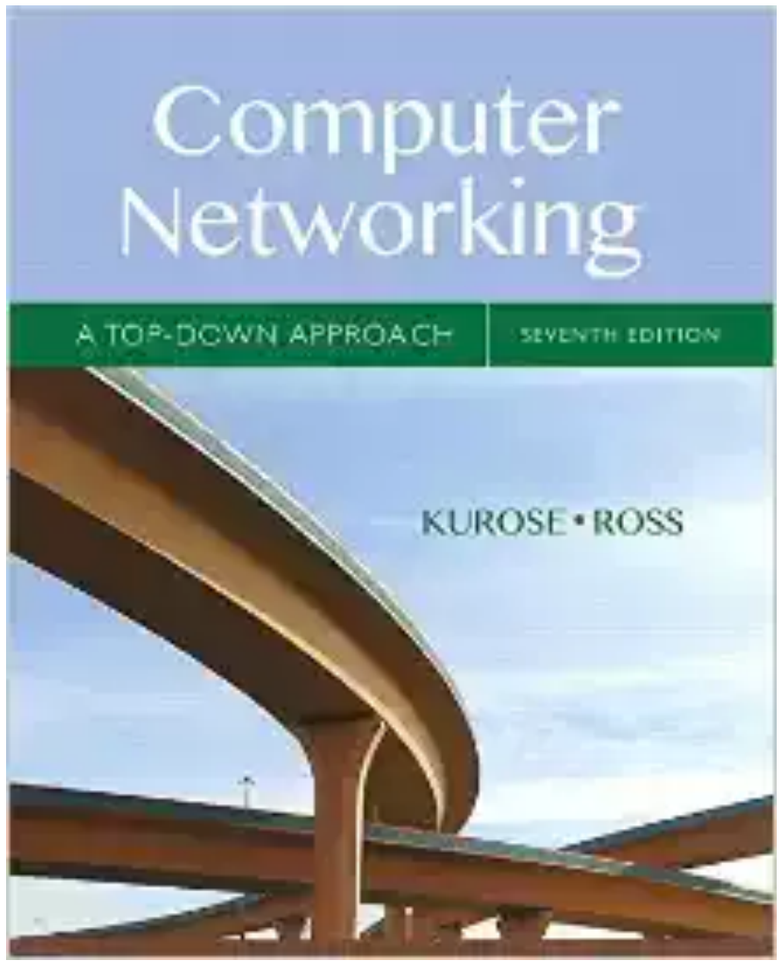
"Well, we busted outa class, had to get away from those fools,
We learned more from a three minute record than we ever learned in school."

These slides are more-or-less directly from the slide set developed by Jim Kurose and Keith Ross for their book "Computer Networking: A Top Down Approach, 5th edition".

The slides have been lightly adapted for Mark Allman's EECS 325/425 Computer Networks class at Case Western Reserve University.

Reading Along …



- 3.6: Principles of Congestion Control

Congestion Control

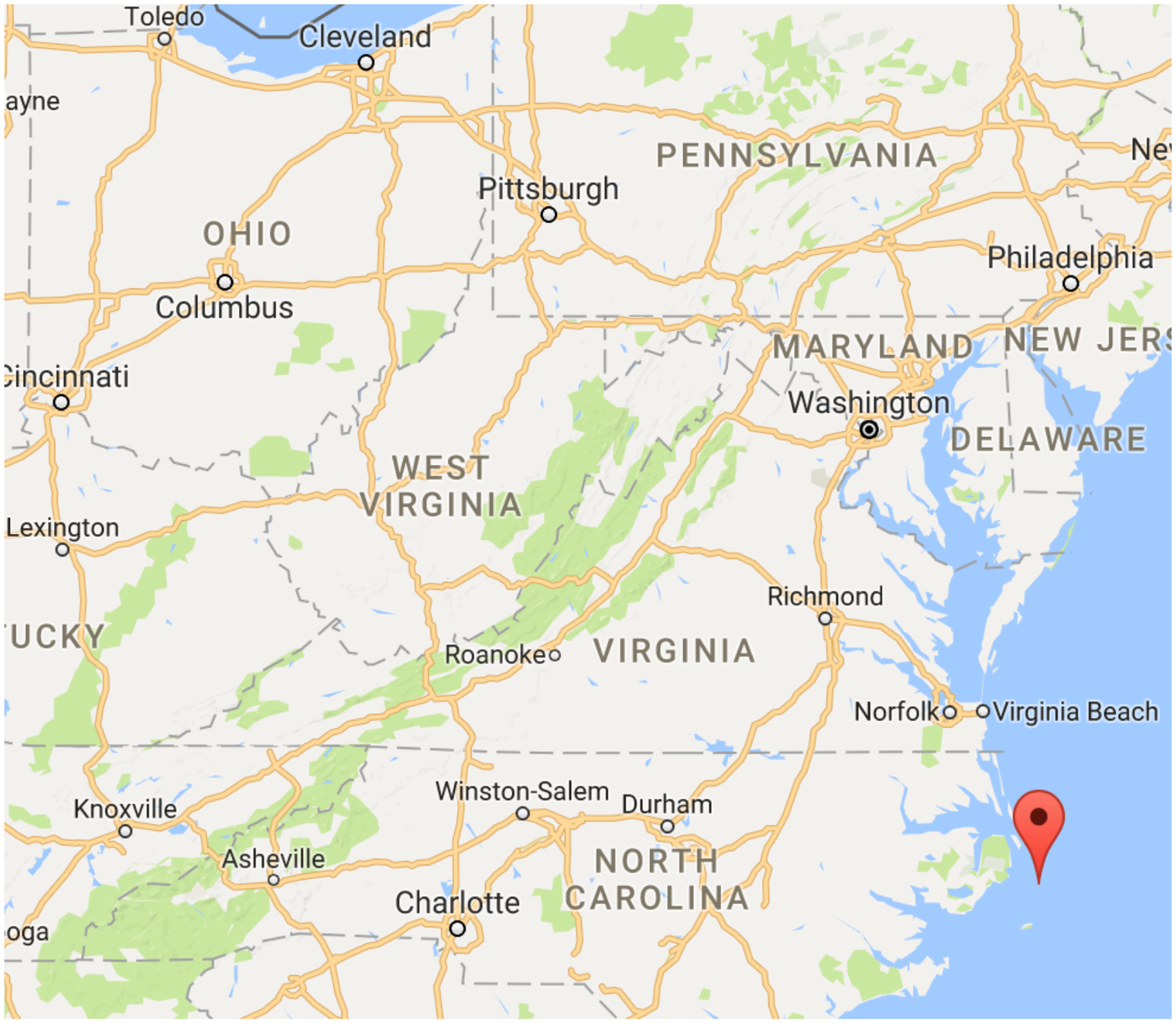
Congestion Control

- What is "congestion"?

Congestion Control

- What is "congestion"?
- Why does it need "controlled"?

Congestion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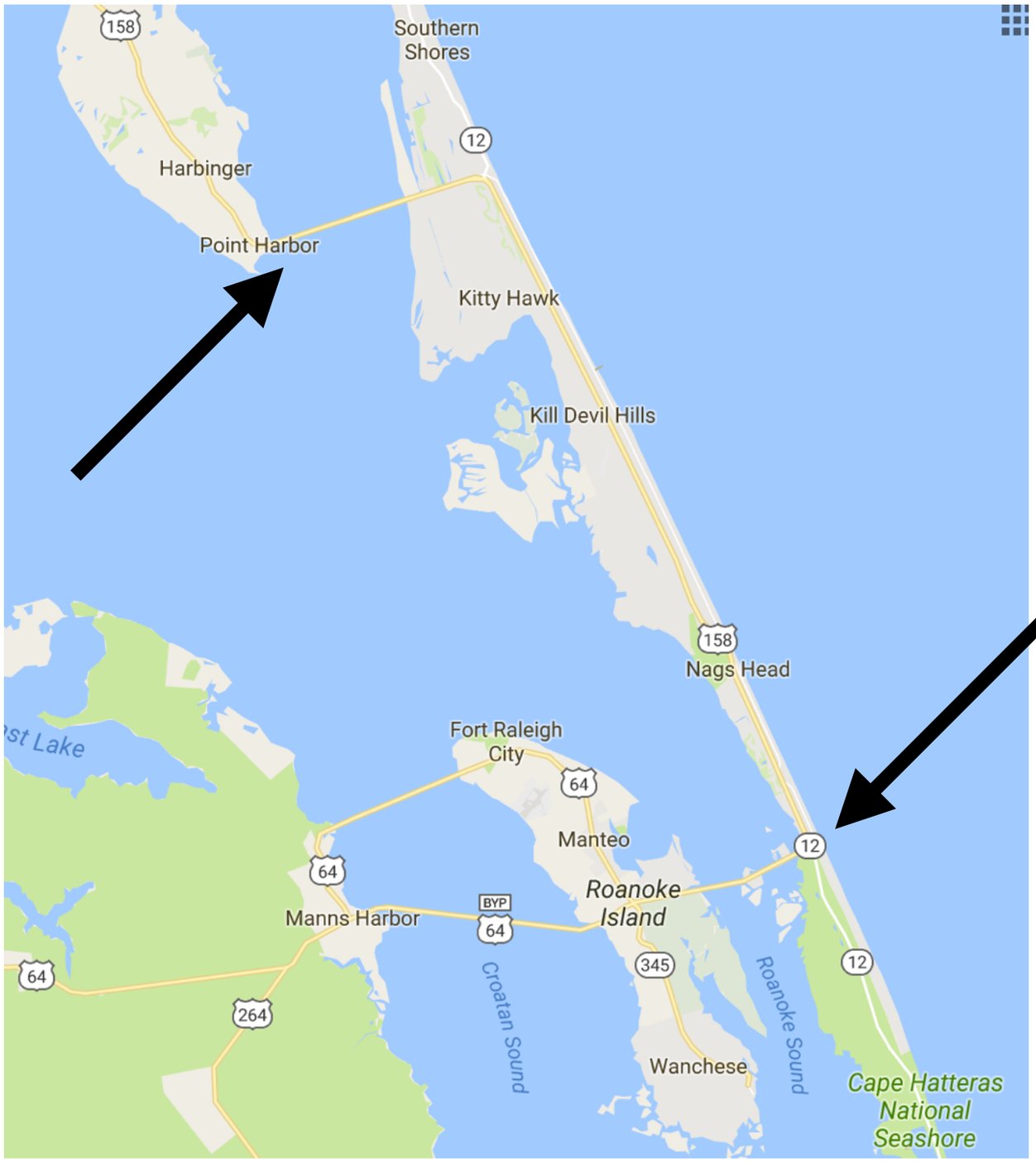
Congestion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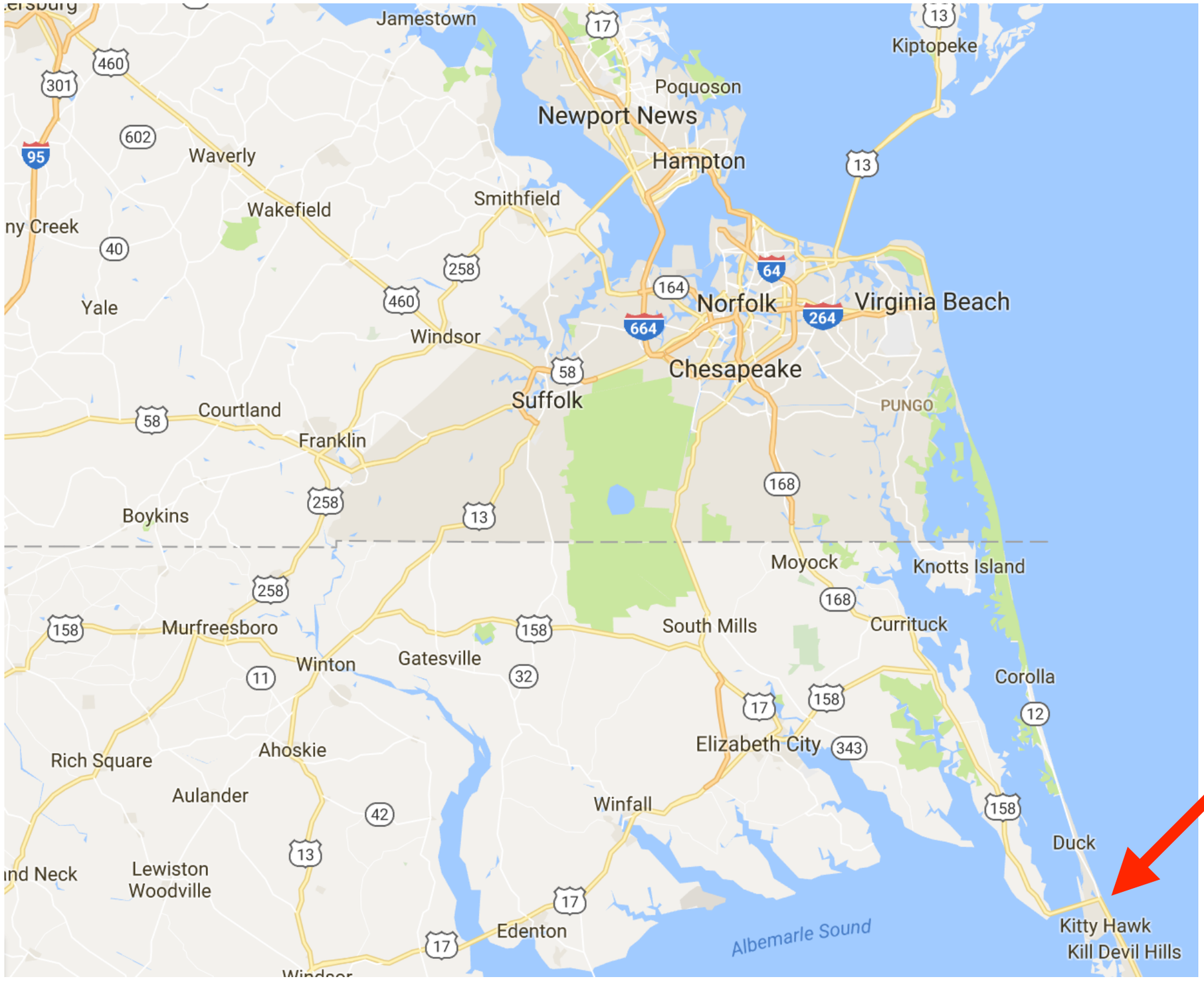
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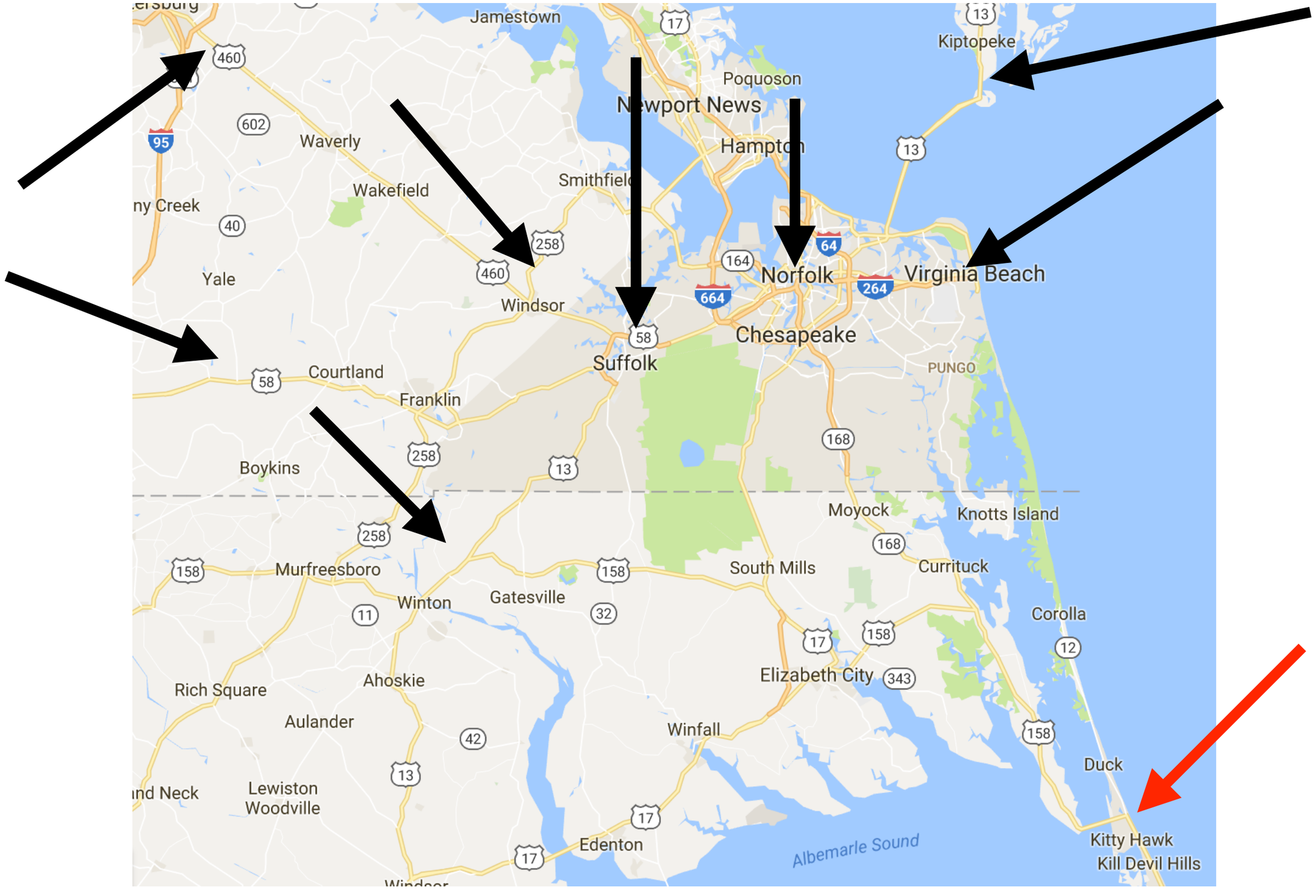
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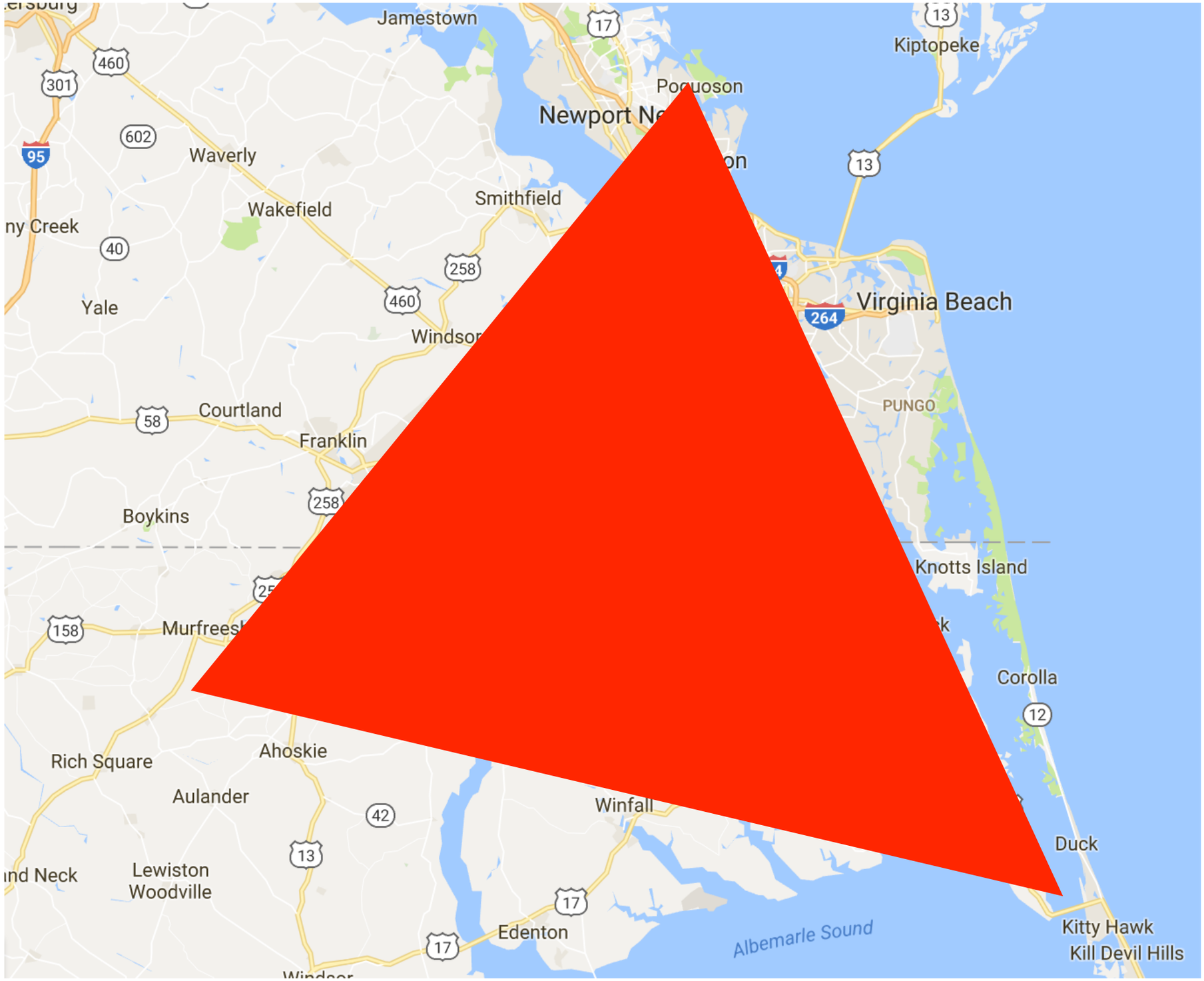
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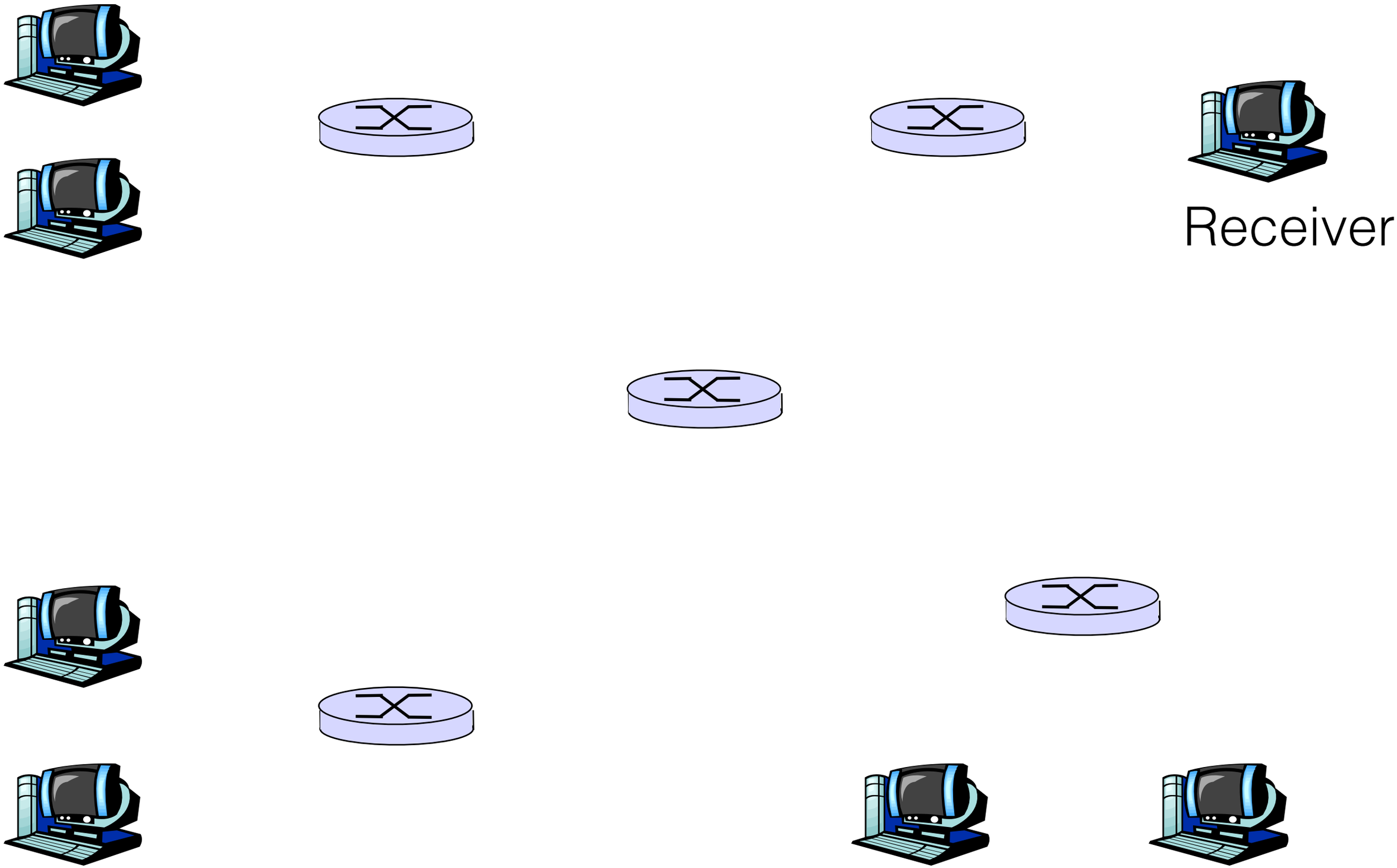
Worth the Effort!

A Networking Example



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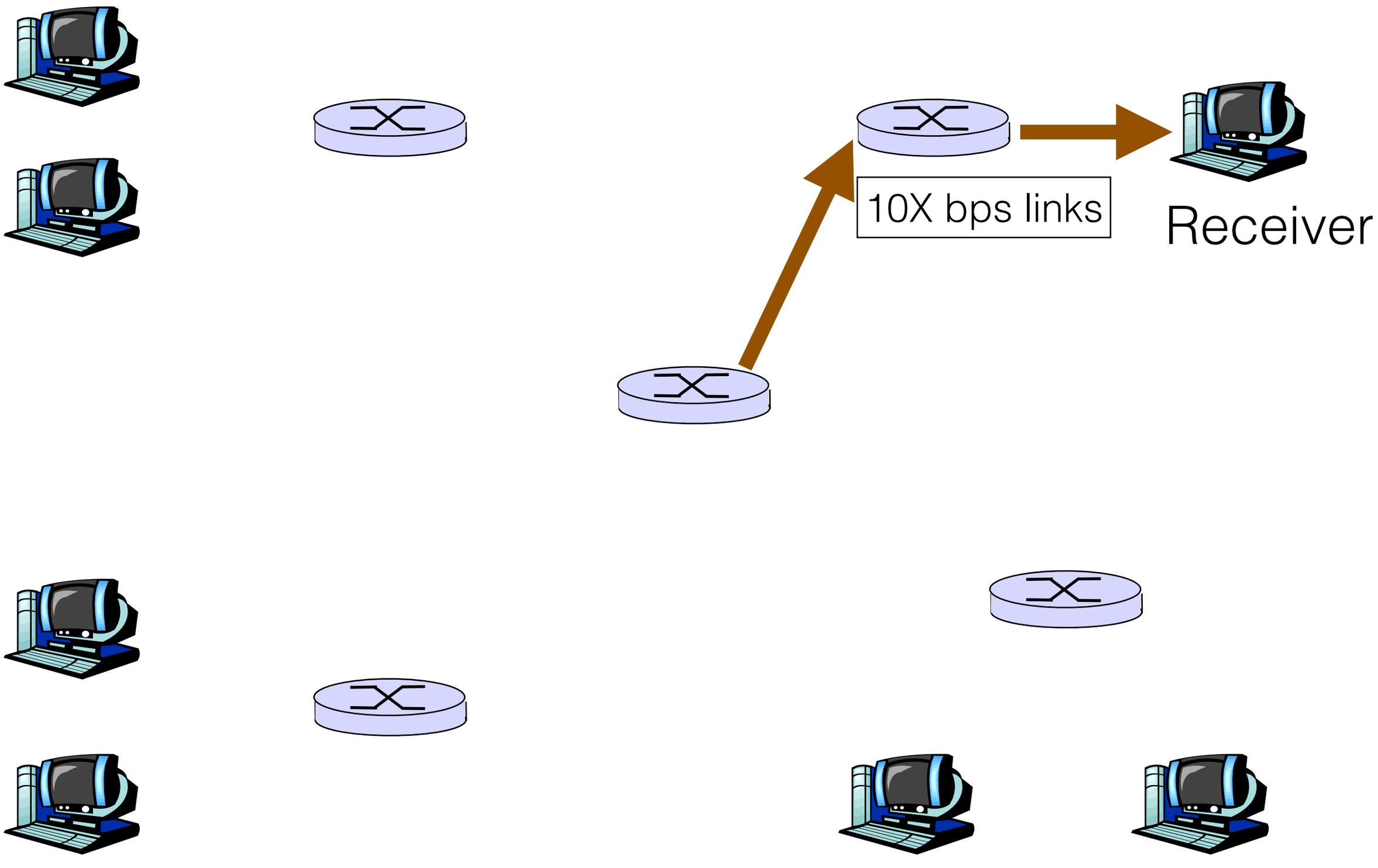

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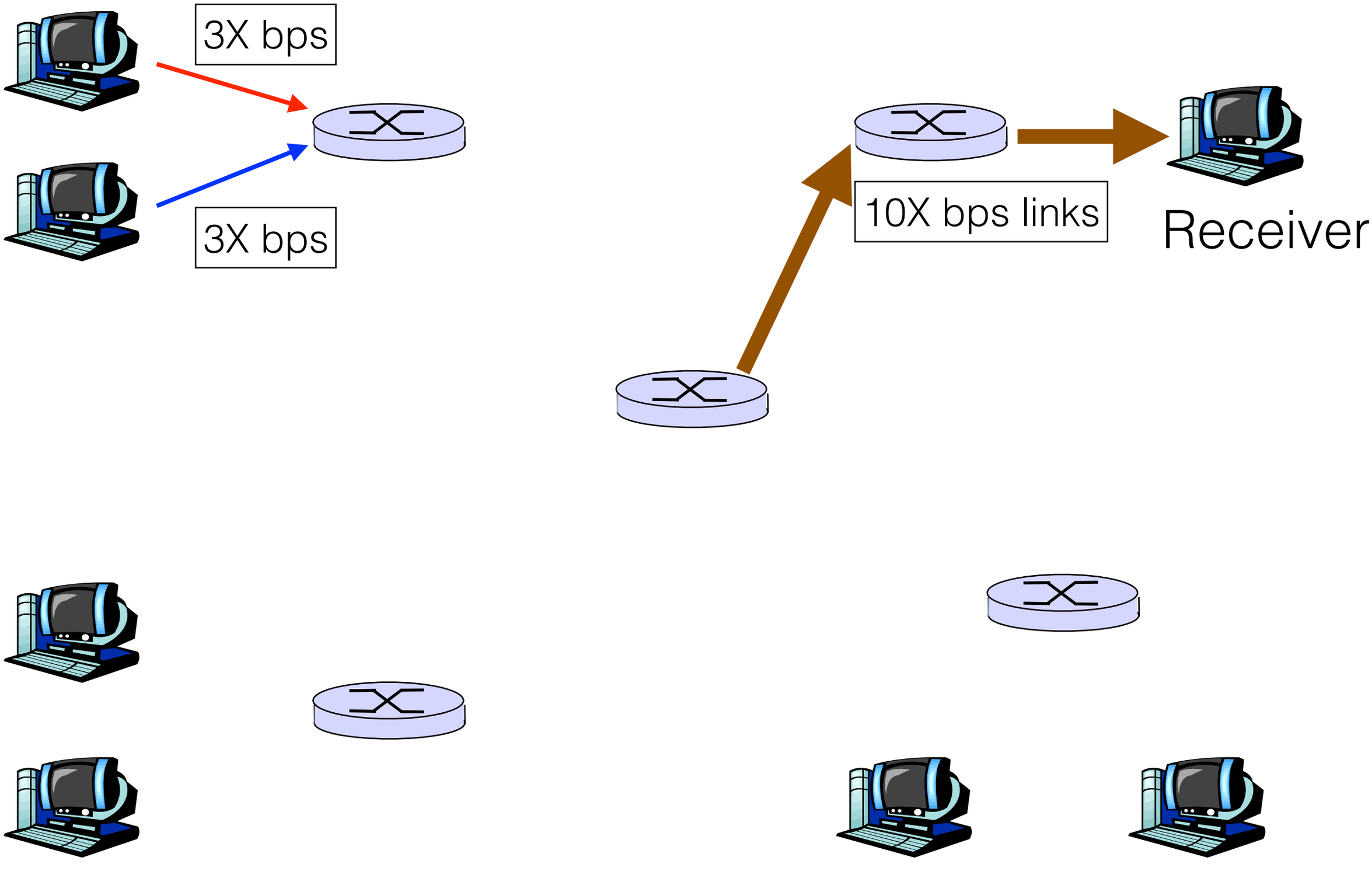

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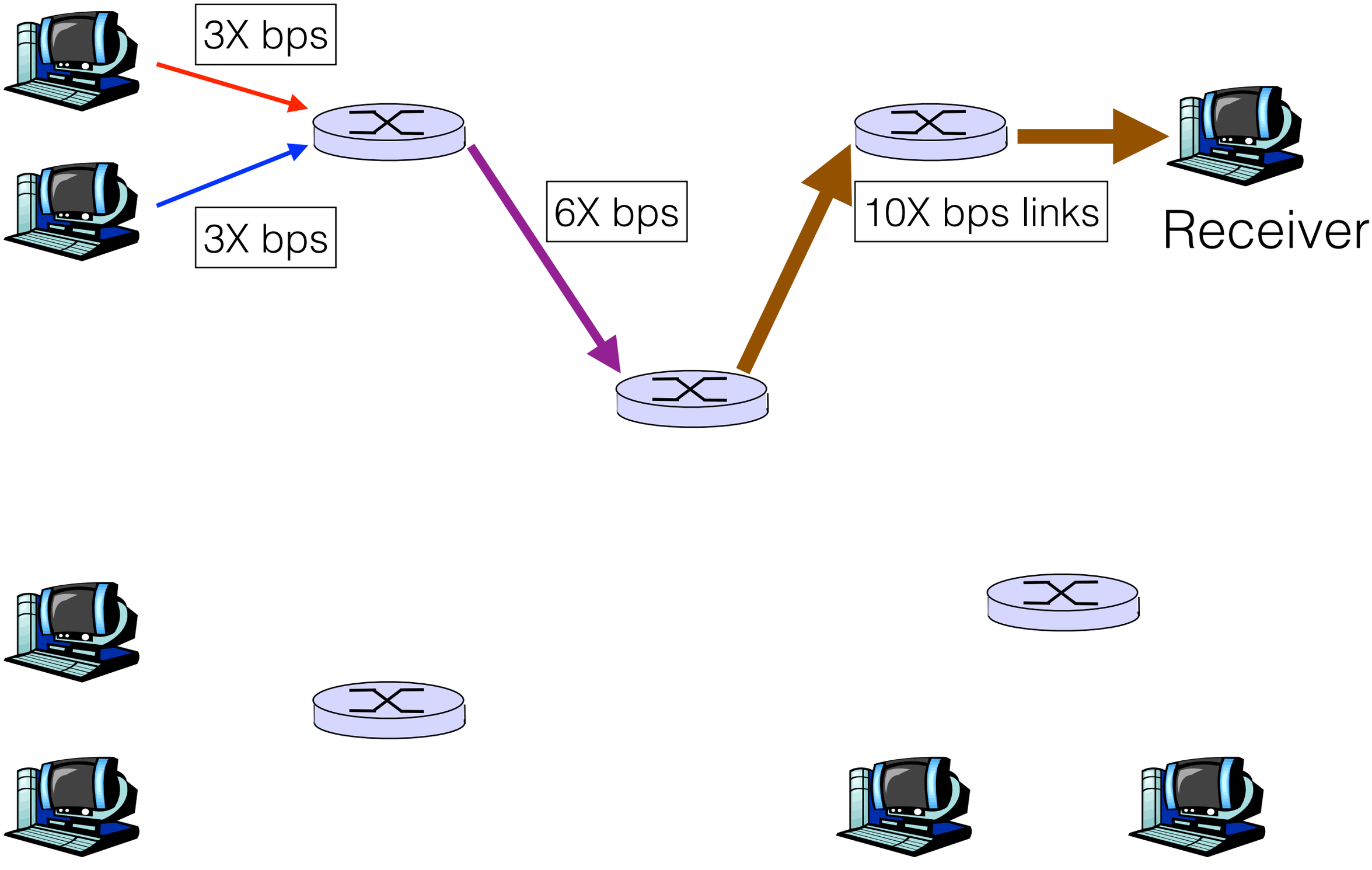

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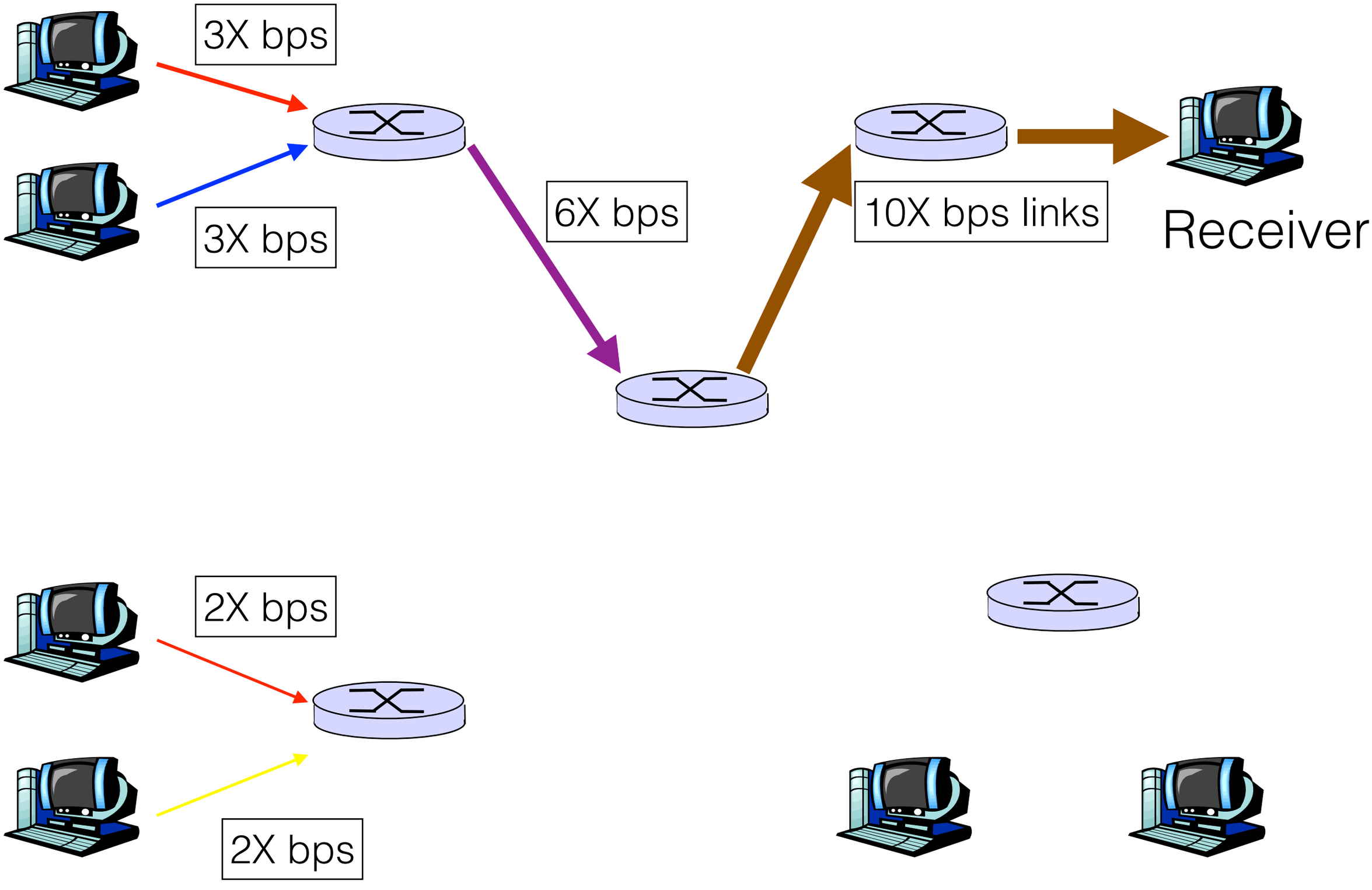

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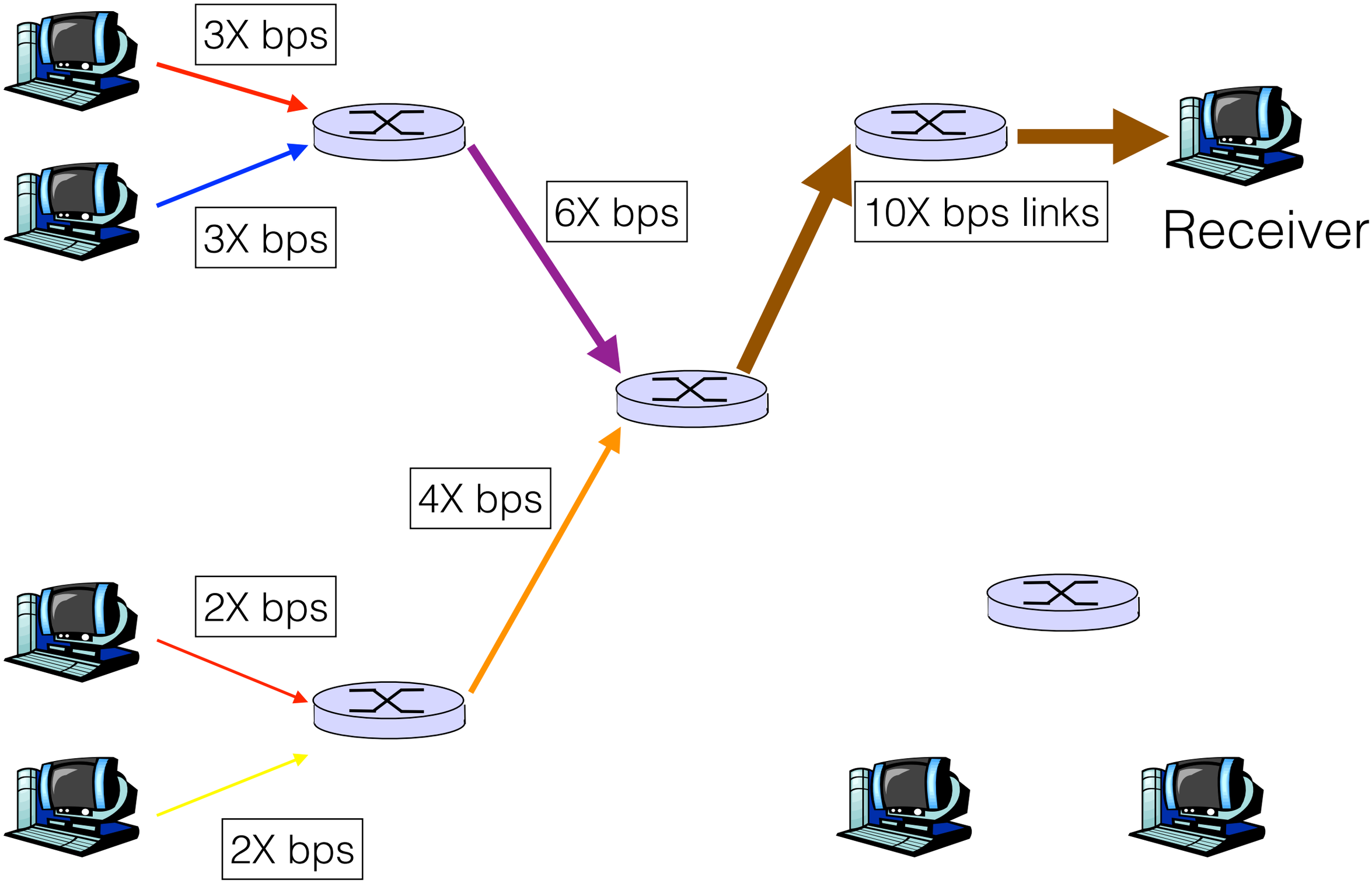

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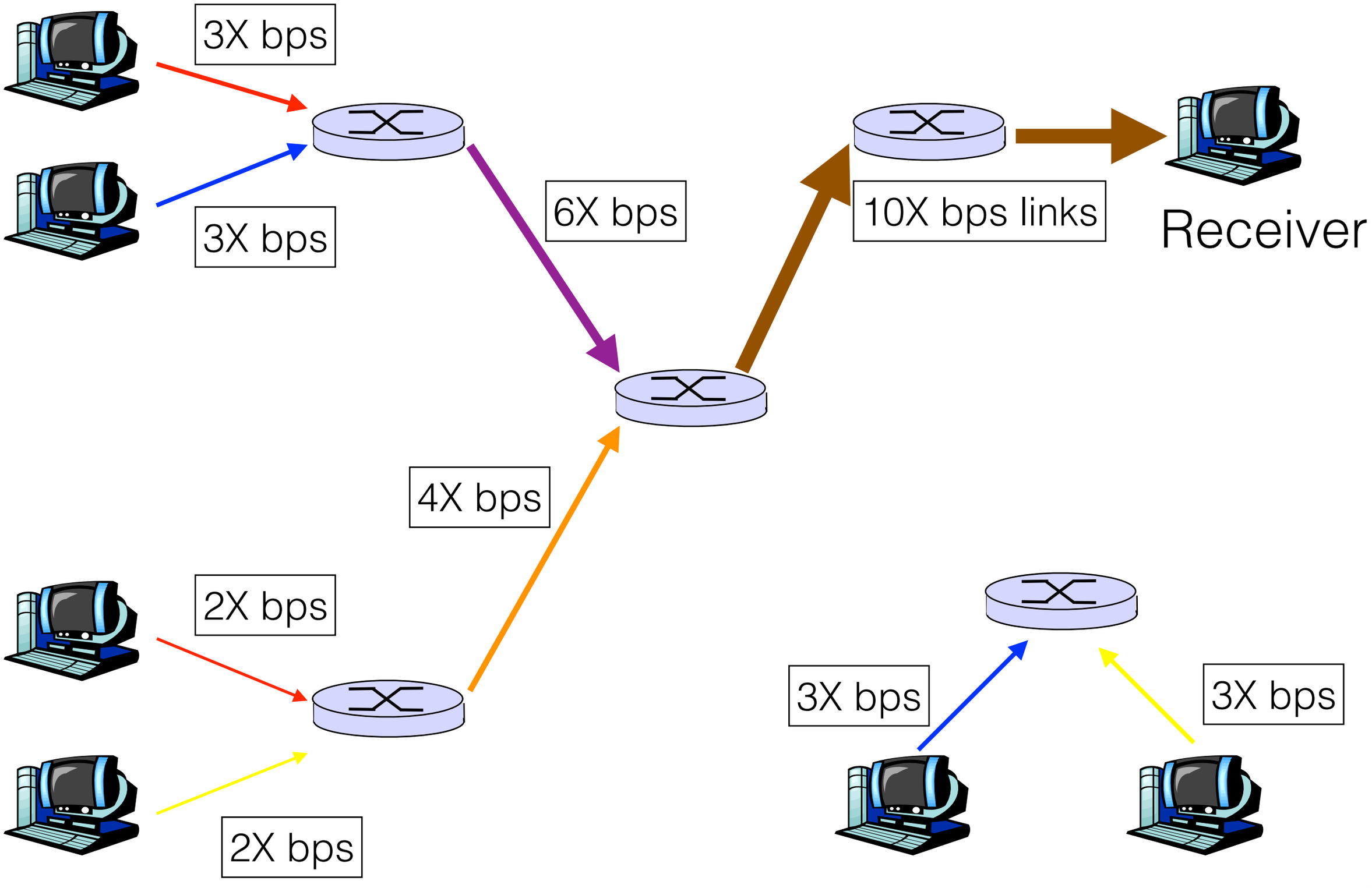

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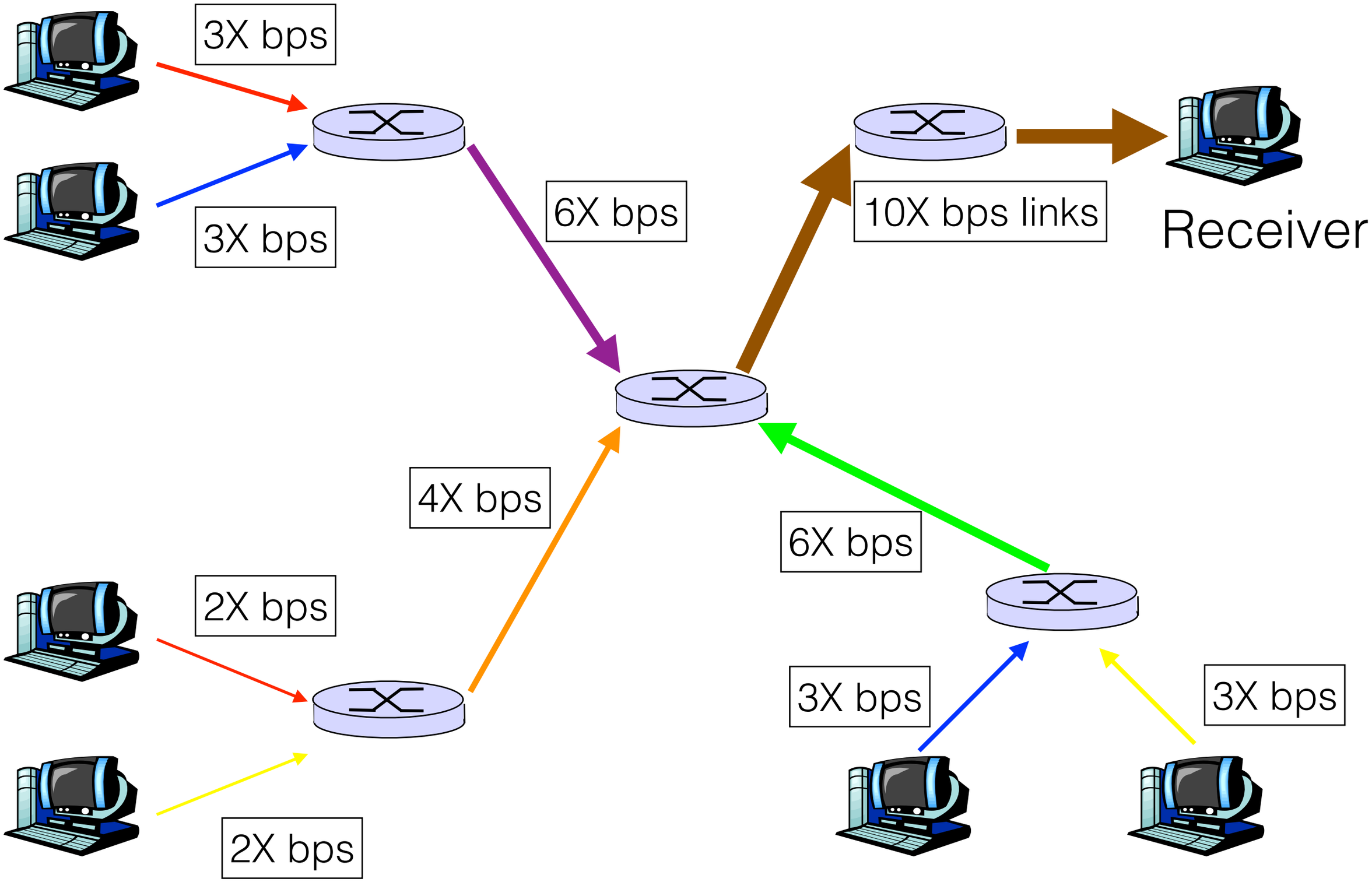

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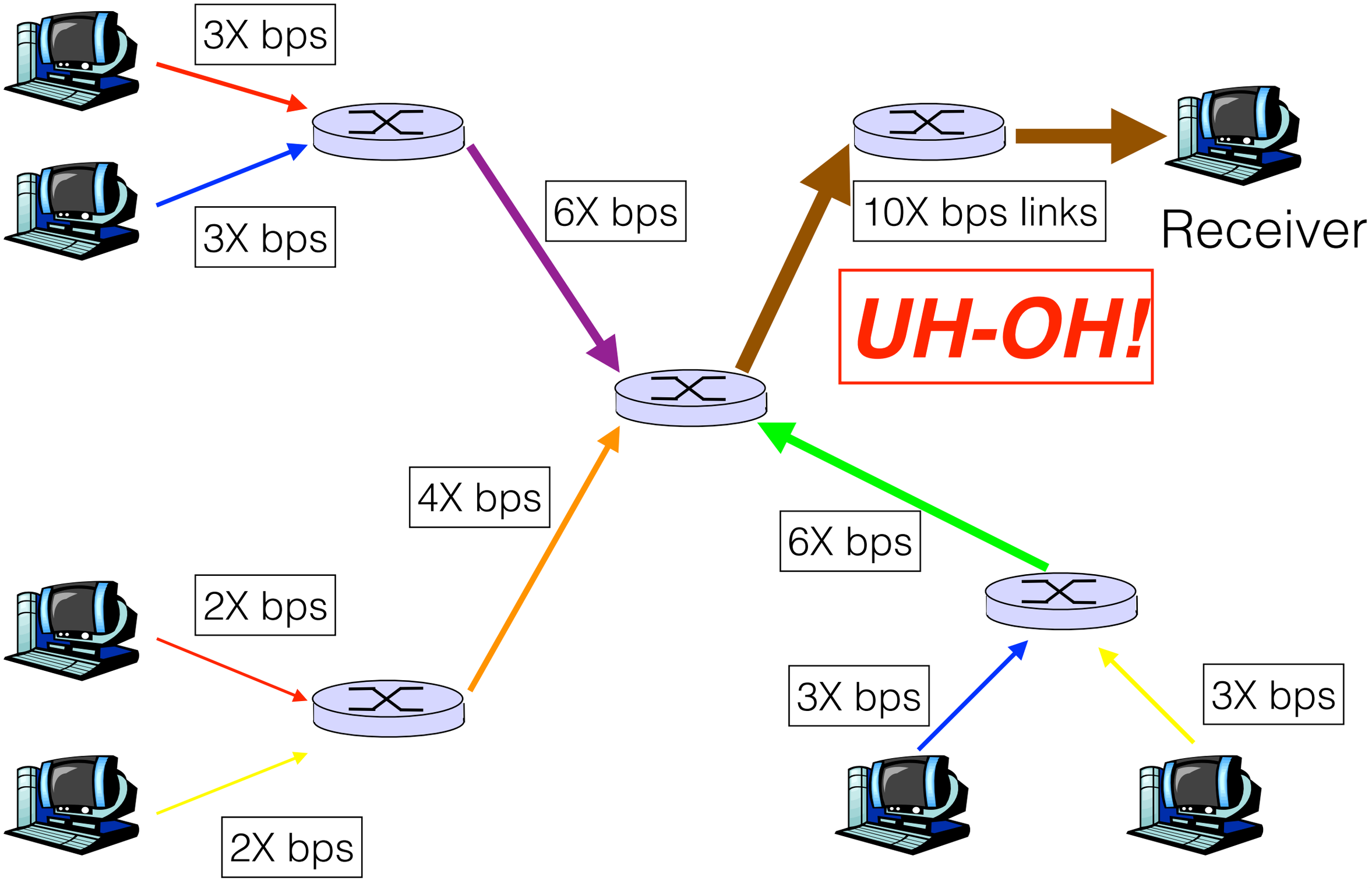

Principles of Congestion Control

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  - long delays (queueing in router buffers)
- a top-10 problem!

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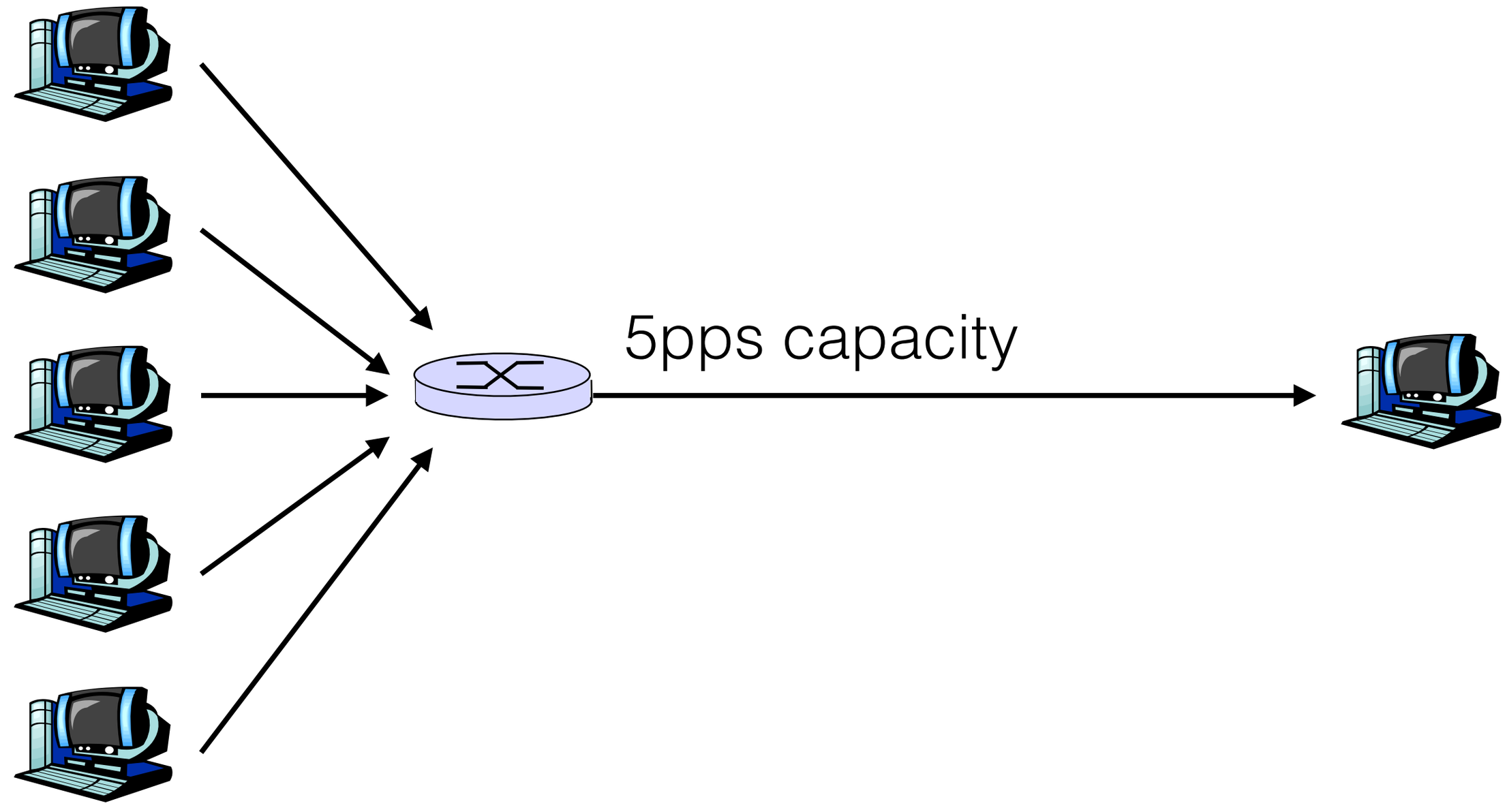
- but, are these annoyance or fundamental issues?!
  - left unchecked congestion can lead to "collapse" whereby a network expends scarce resources on packets that will ultimately be dropped
    - i.e., accomplish little—if any—meaningful work

Congestion: Single Bottleneck



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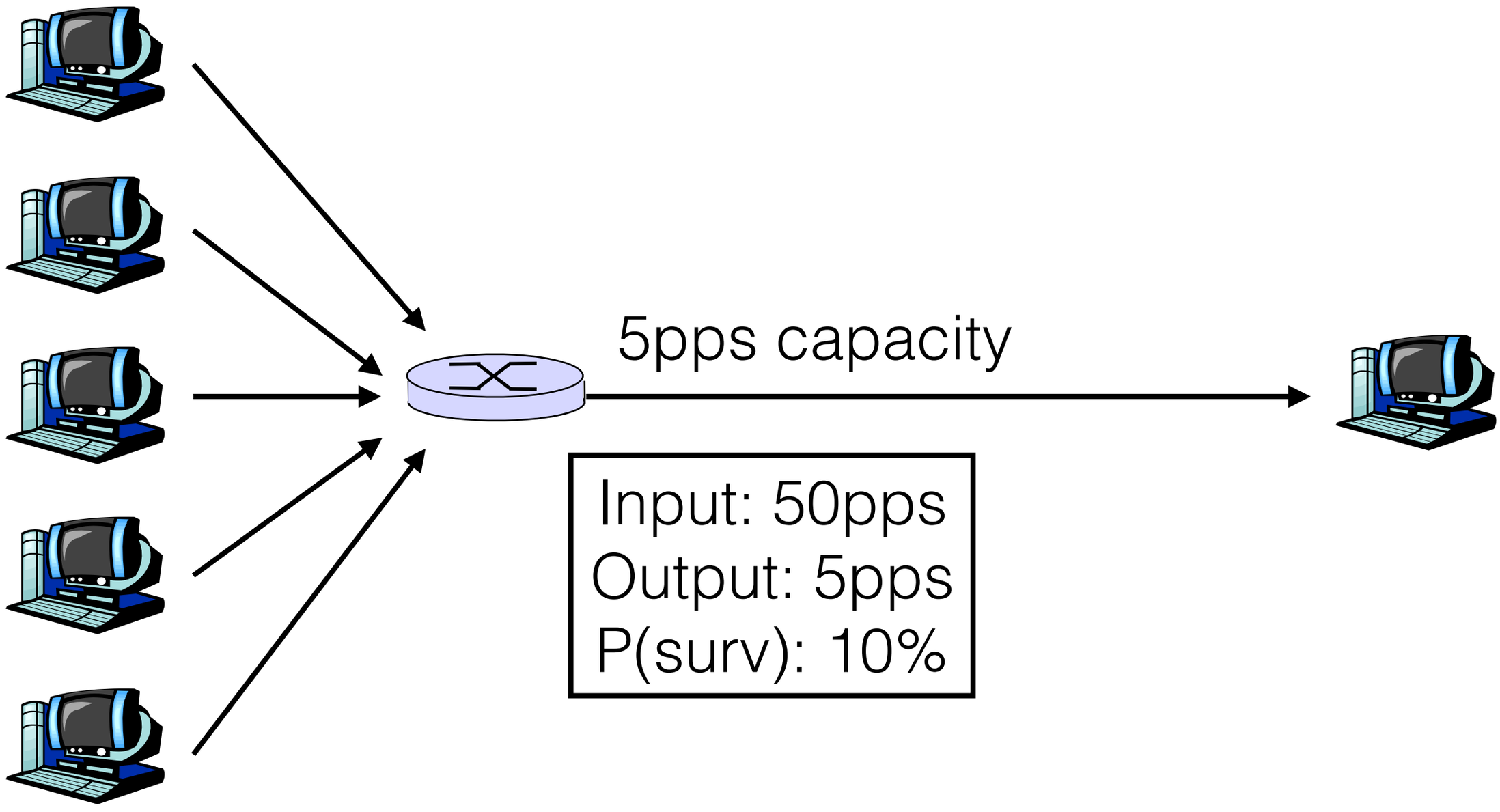
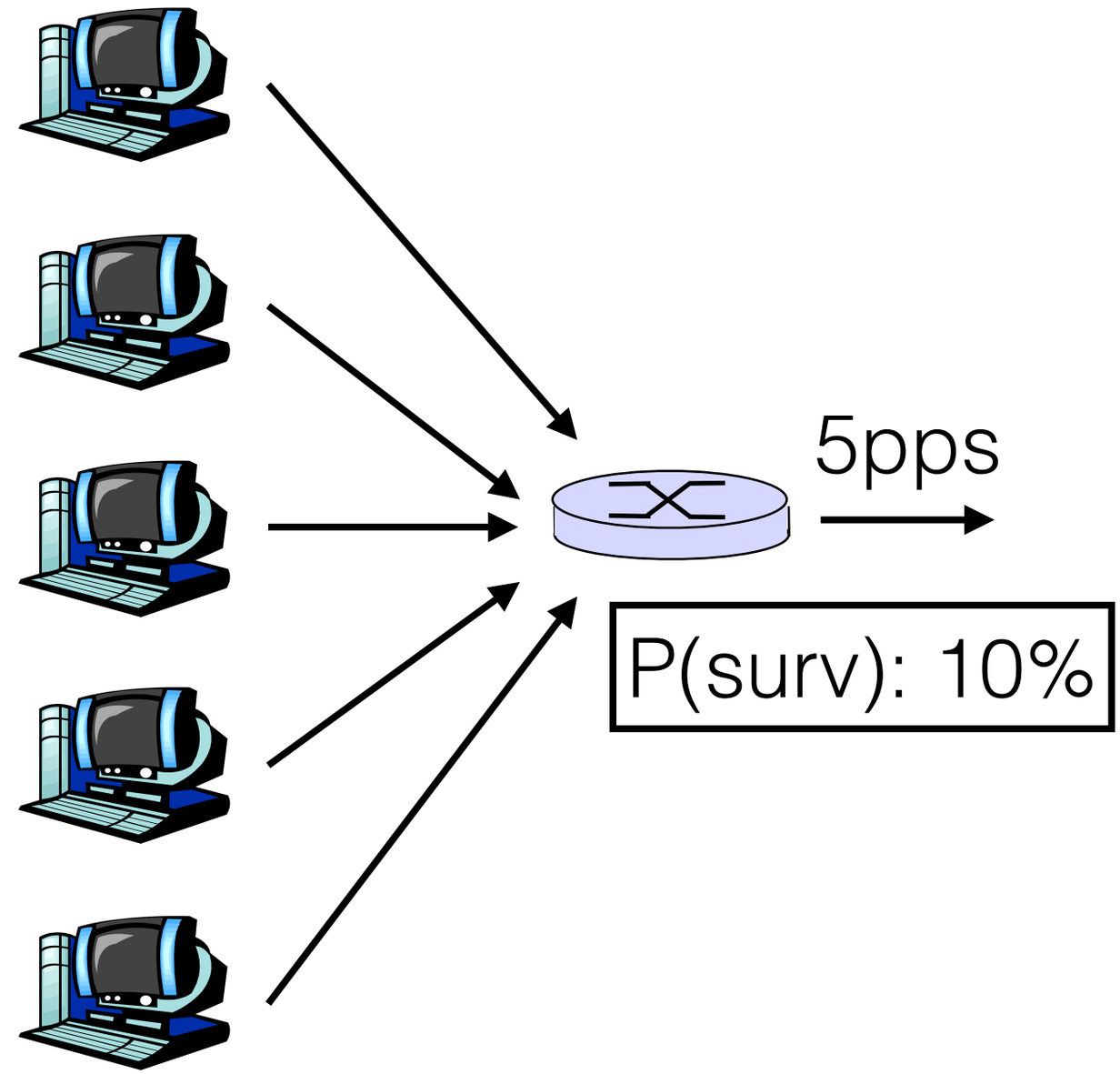


Congestion: Multiple Bottlenecks



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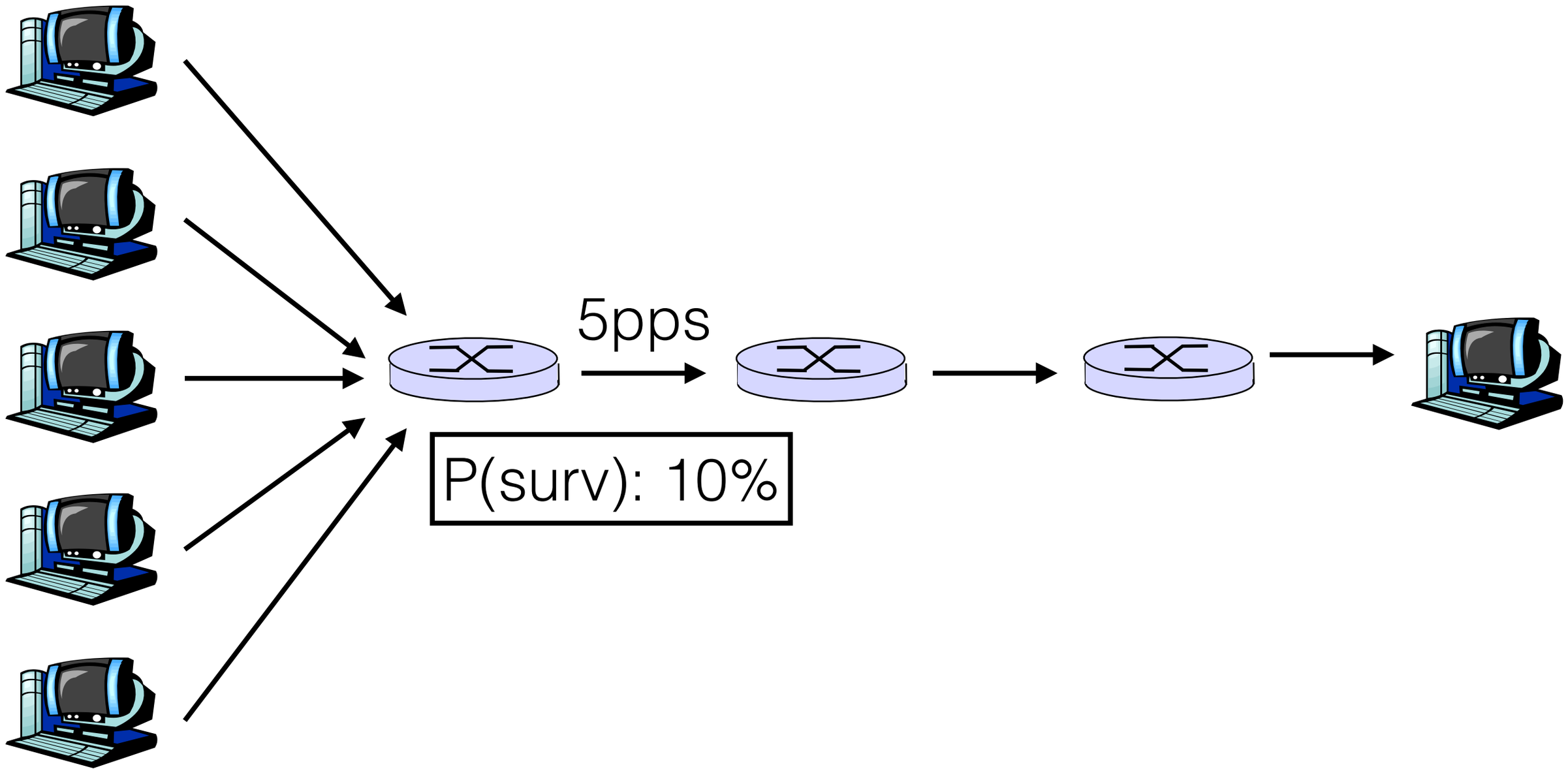

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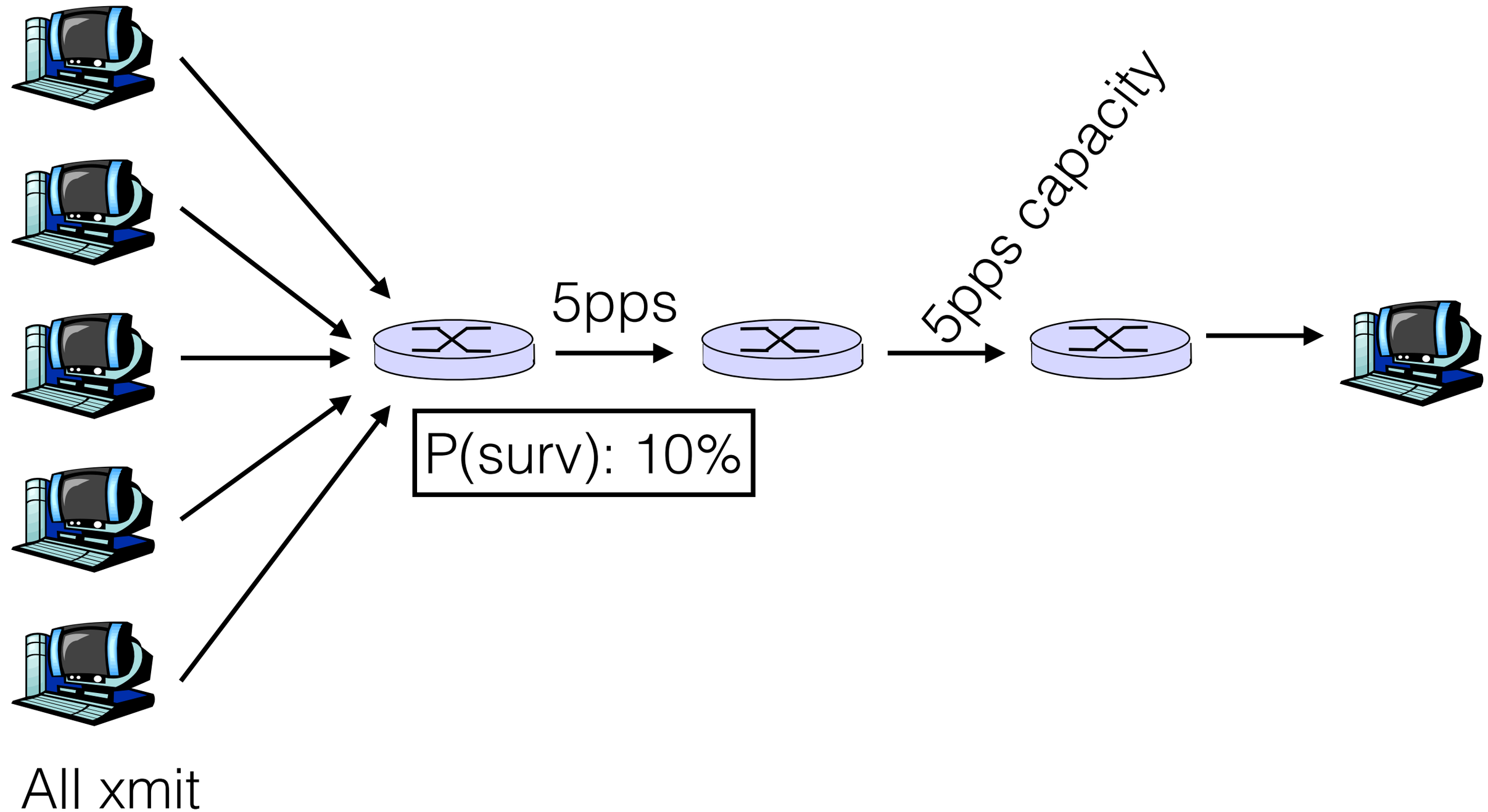

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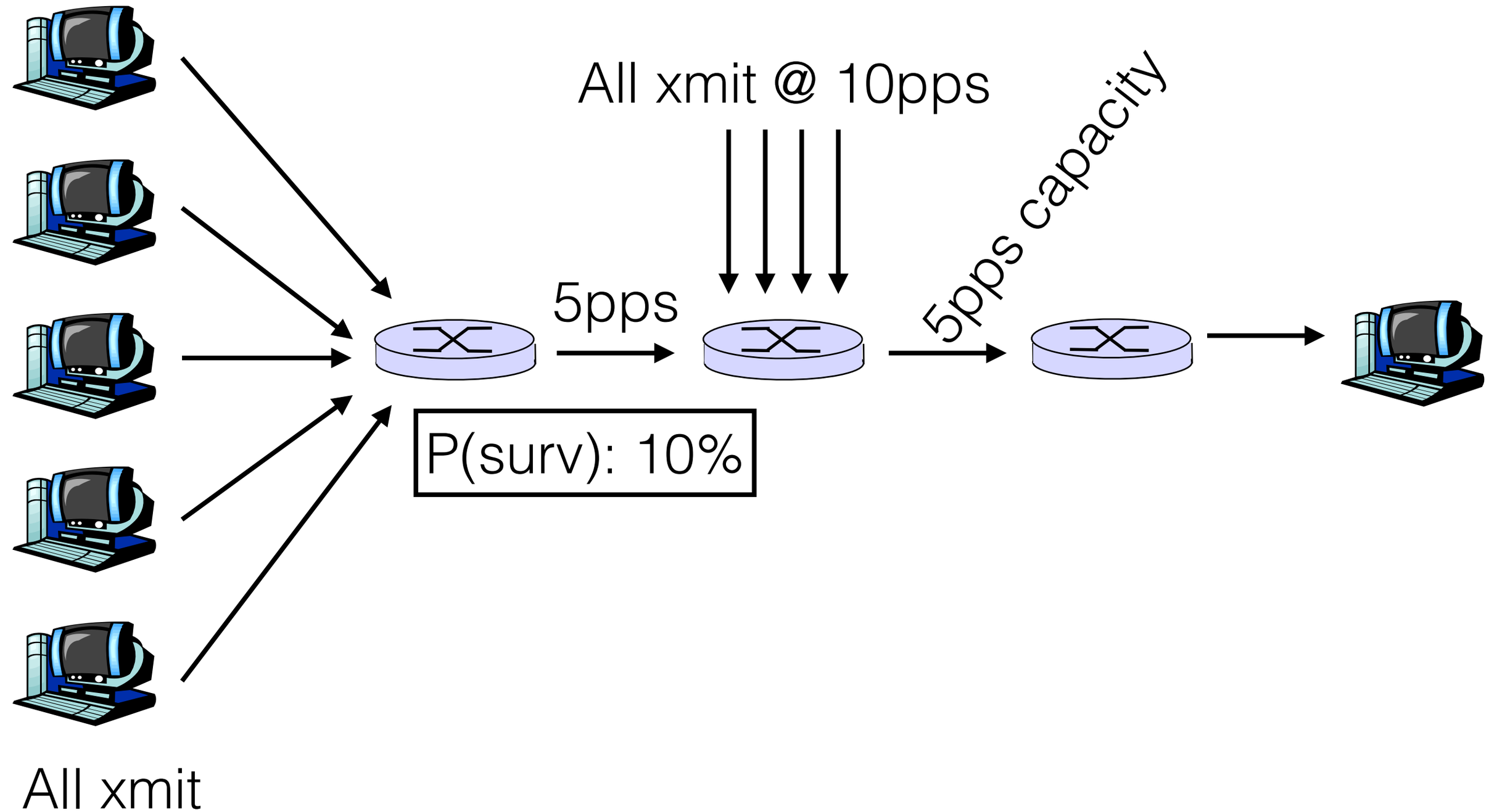

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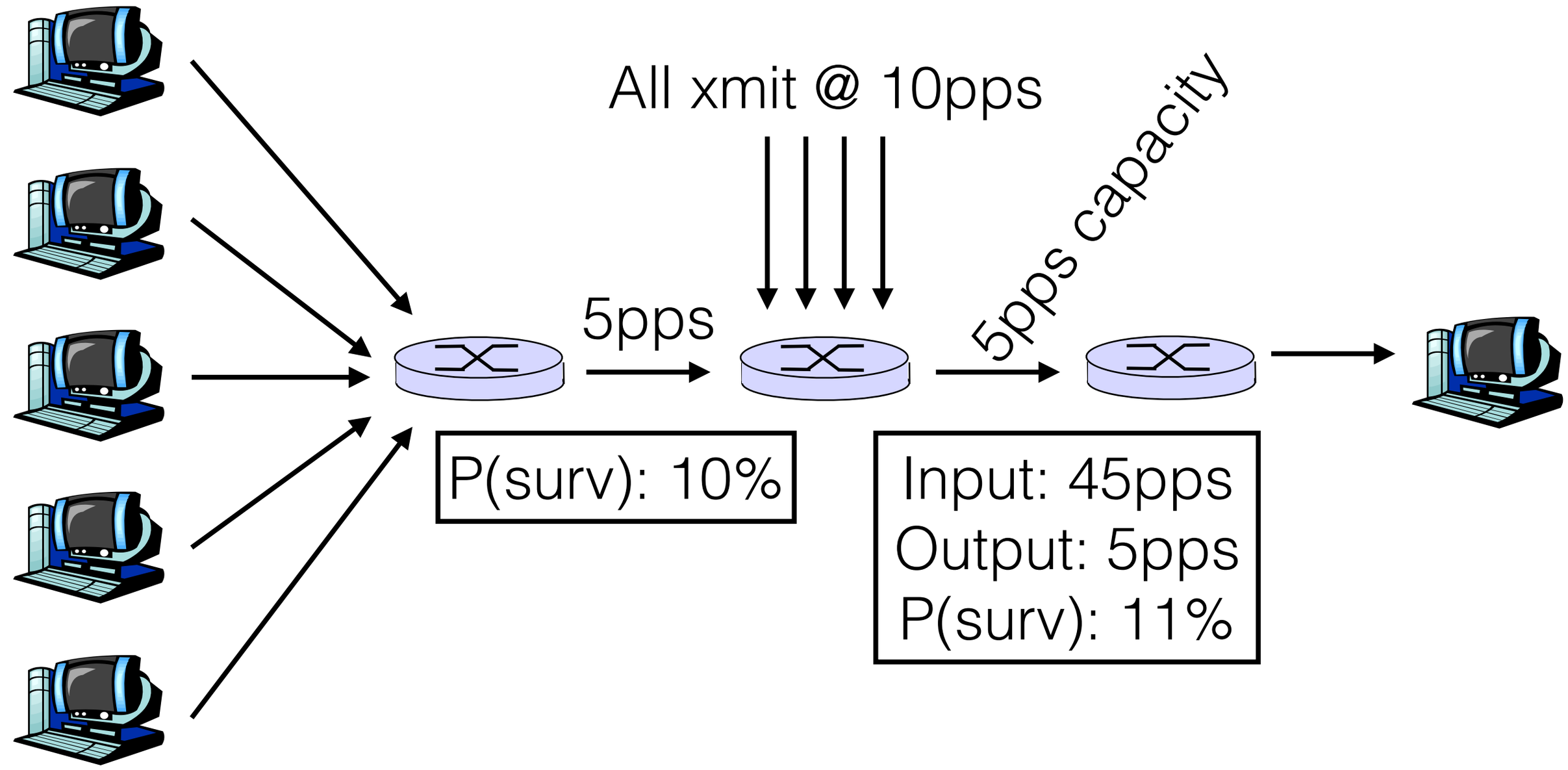

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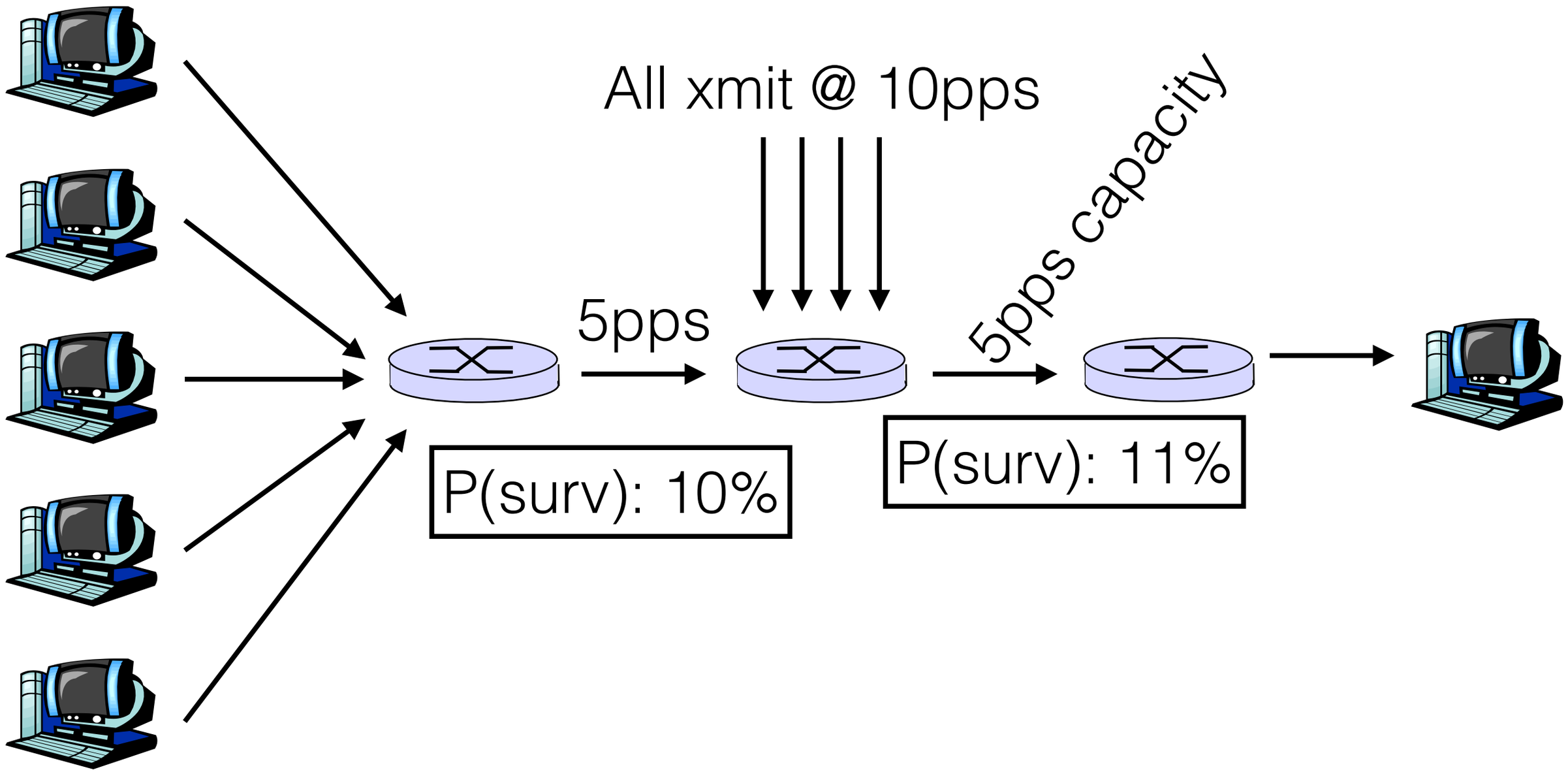

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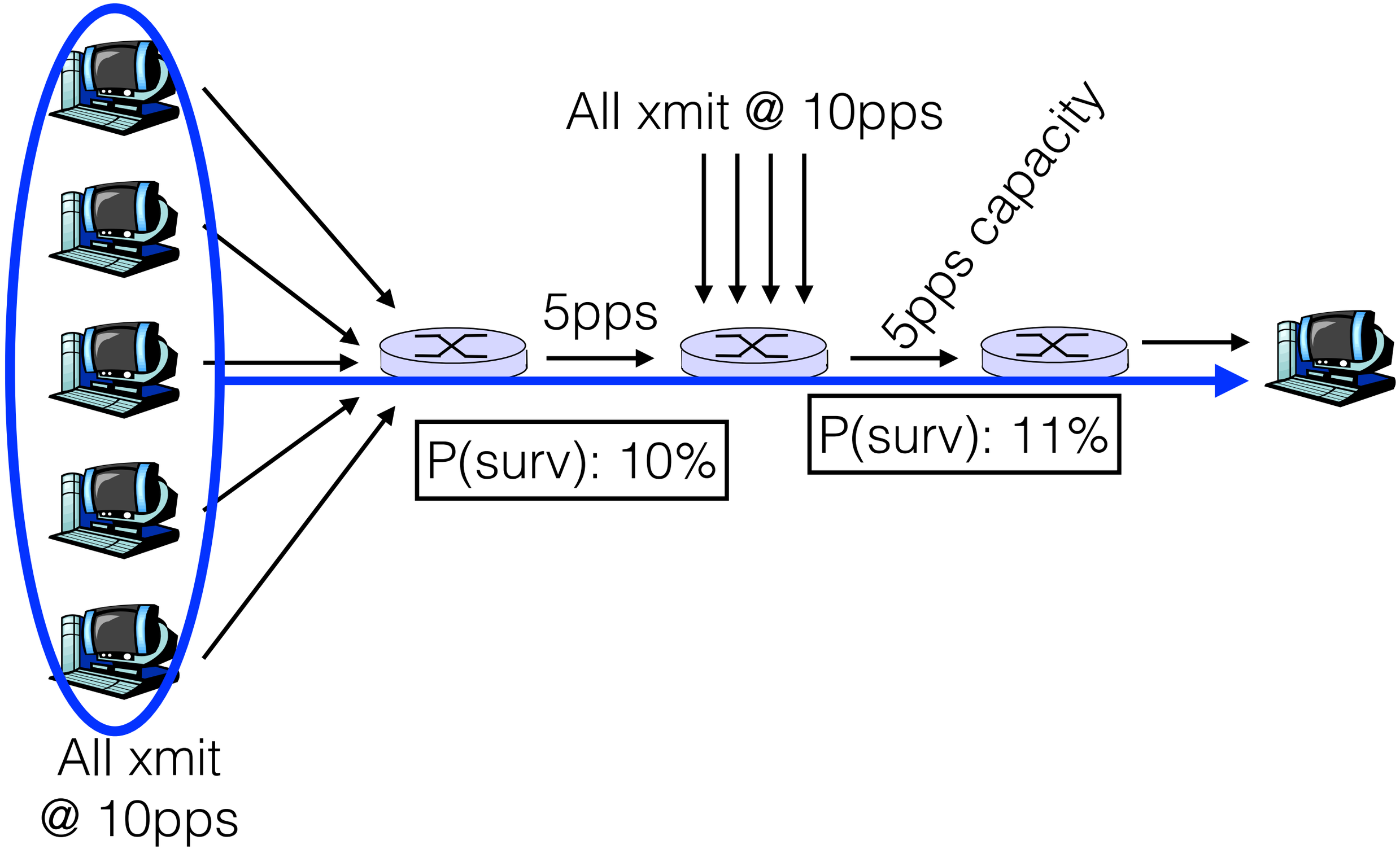

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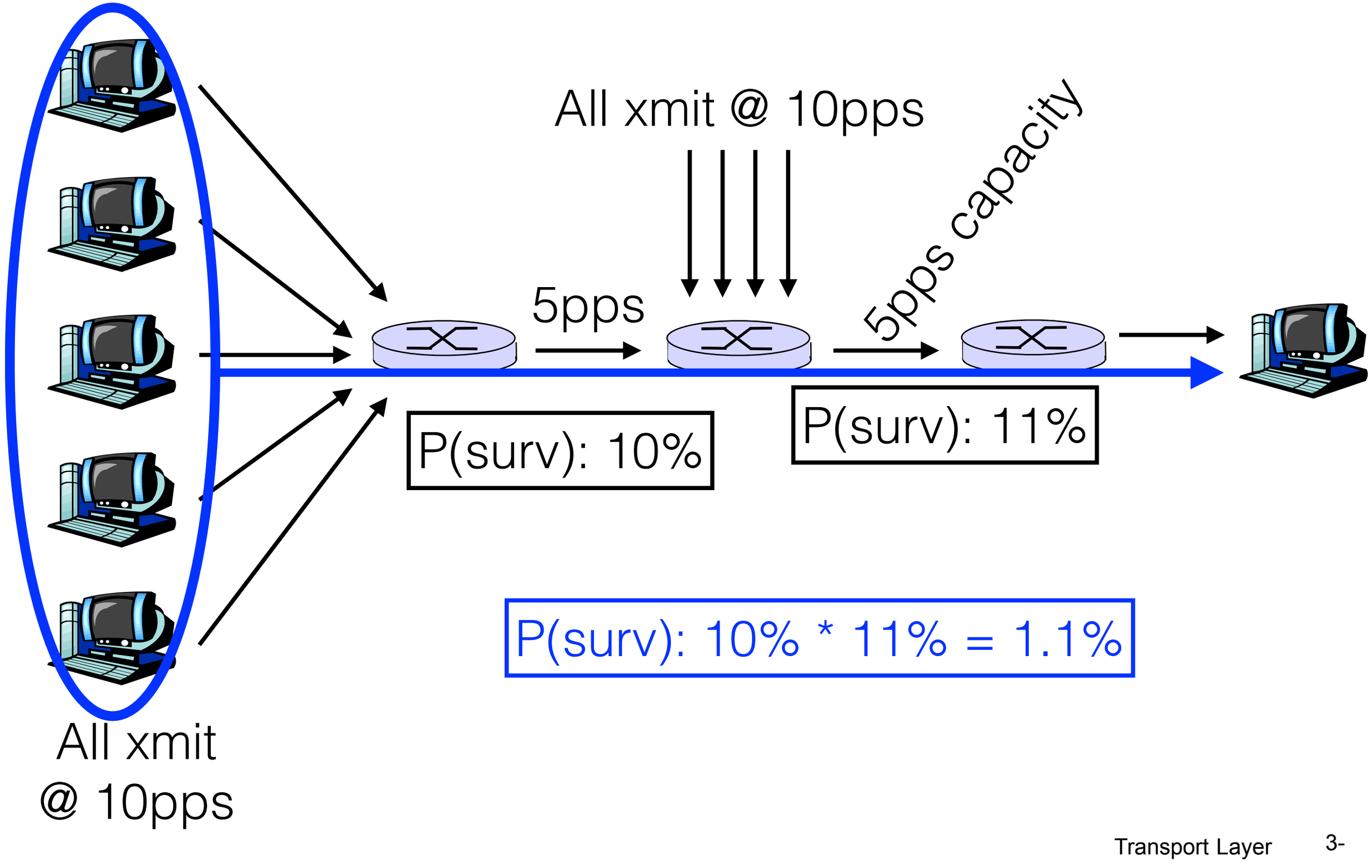

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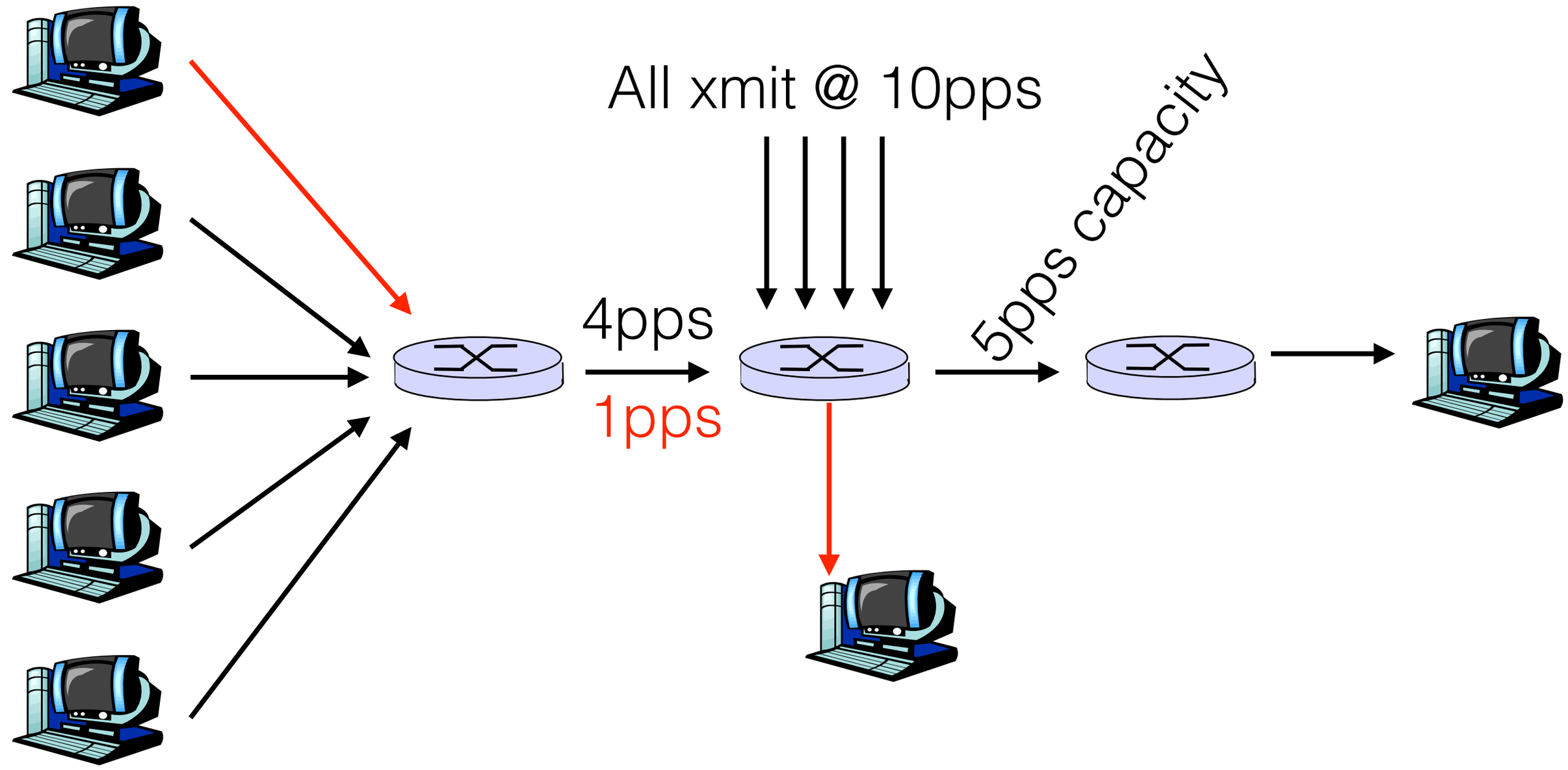

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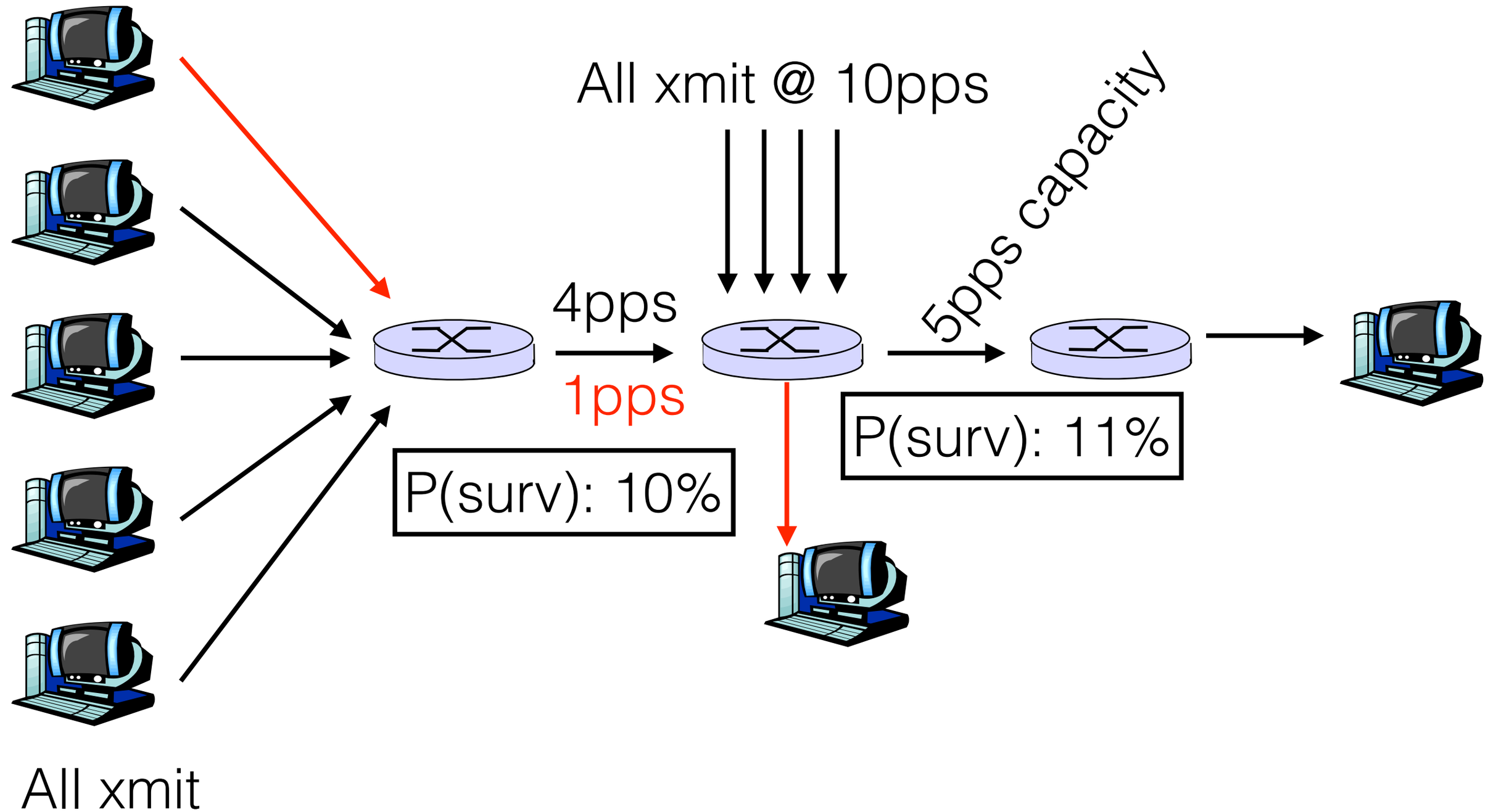

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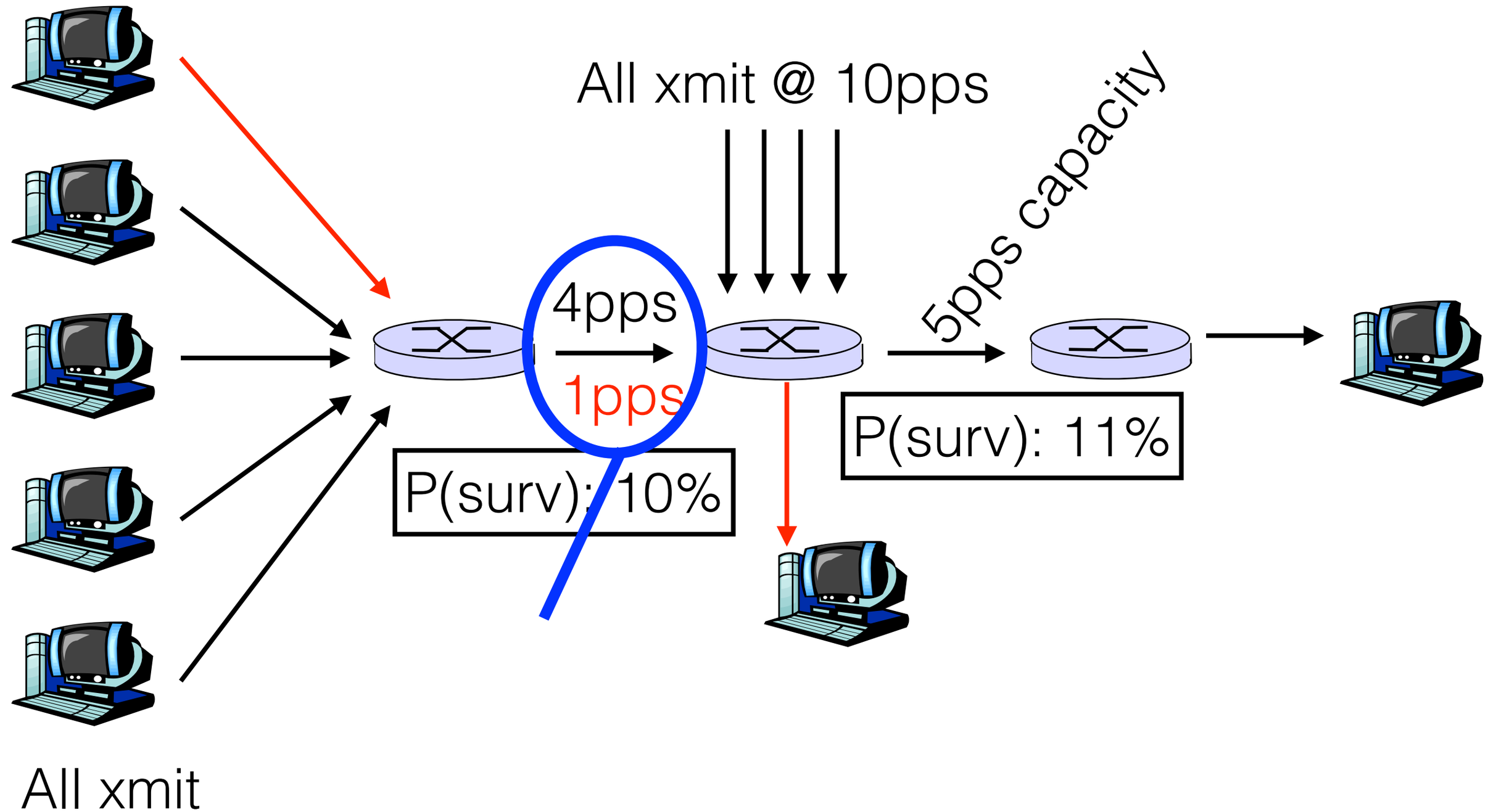

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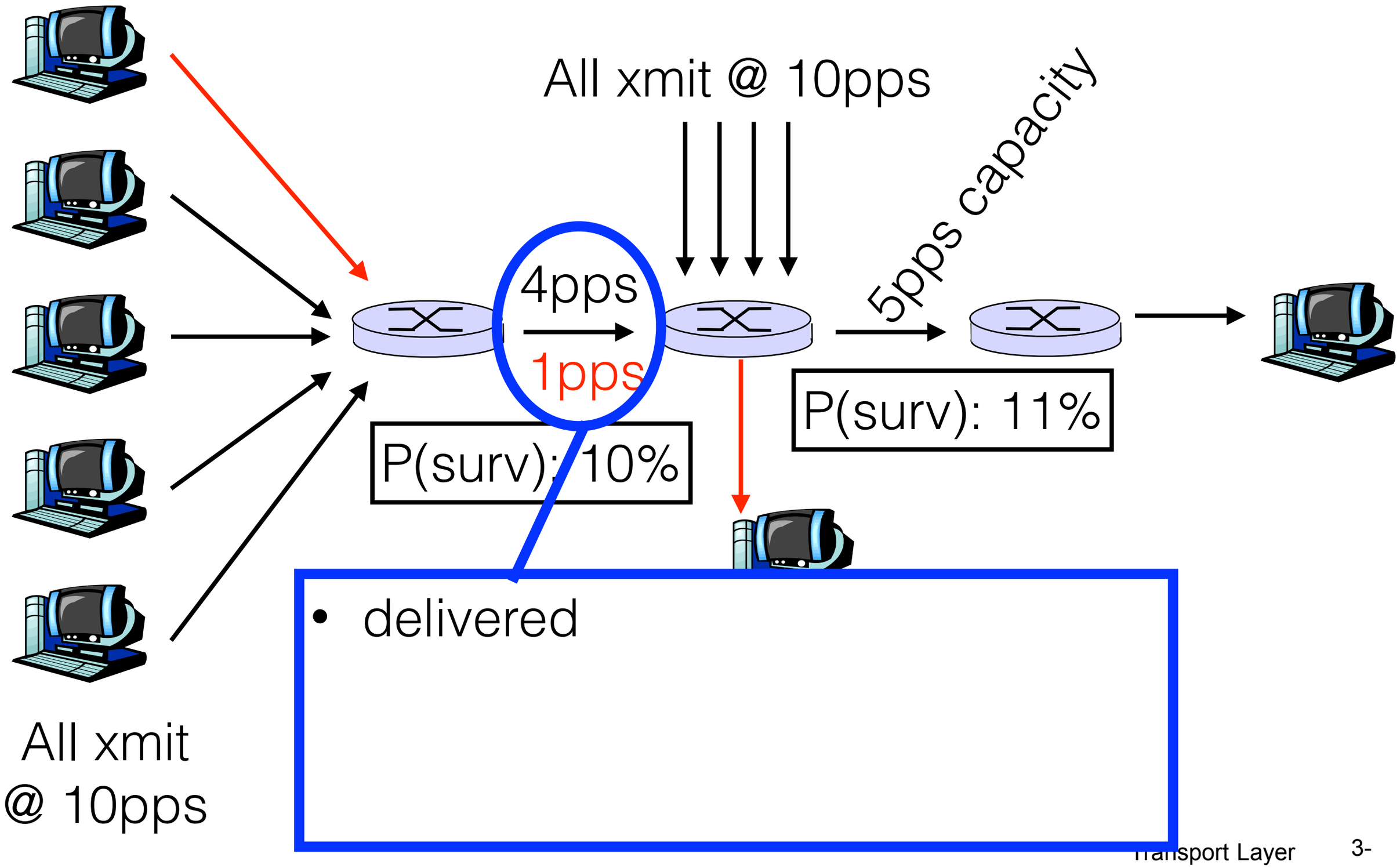

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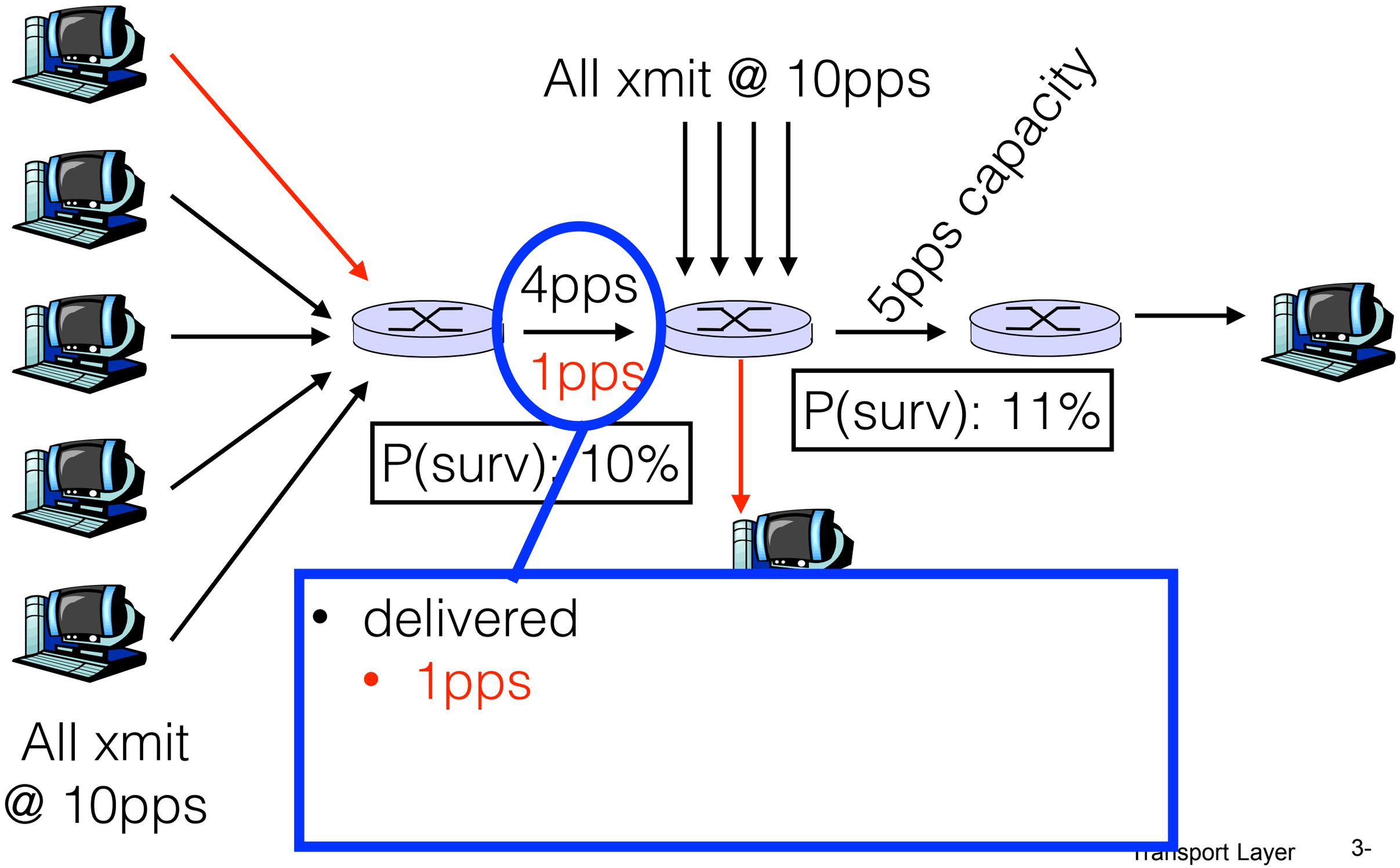

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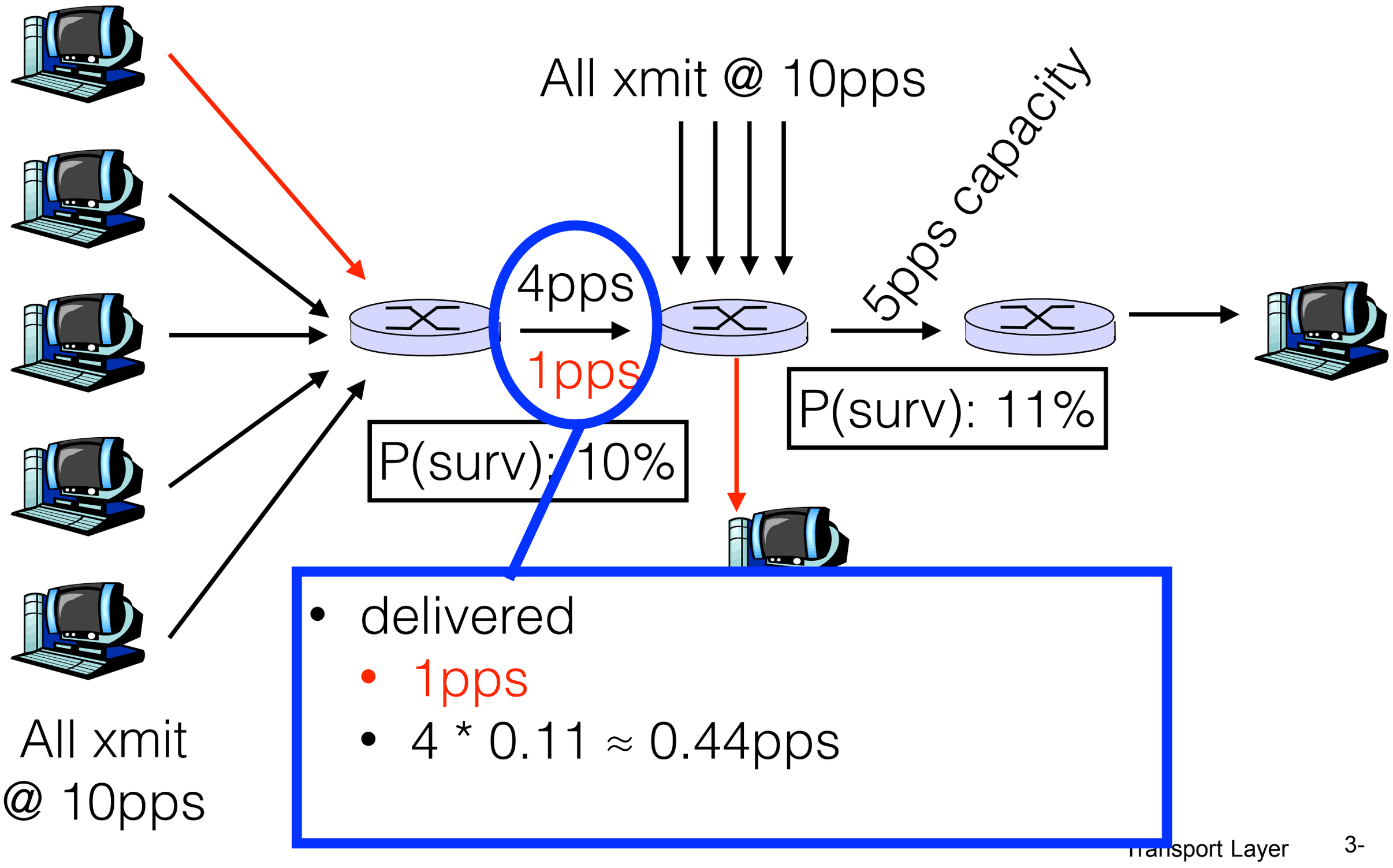

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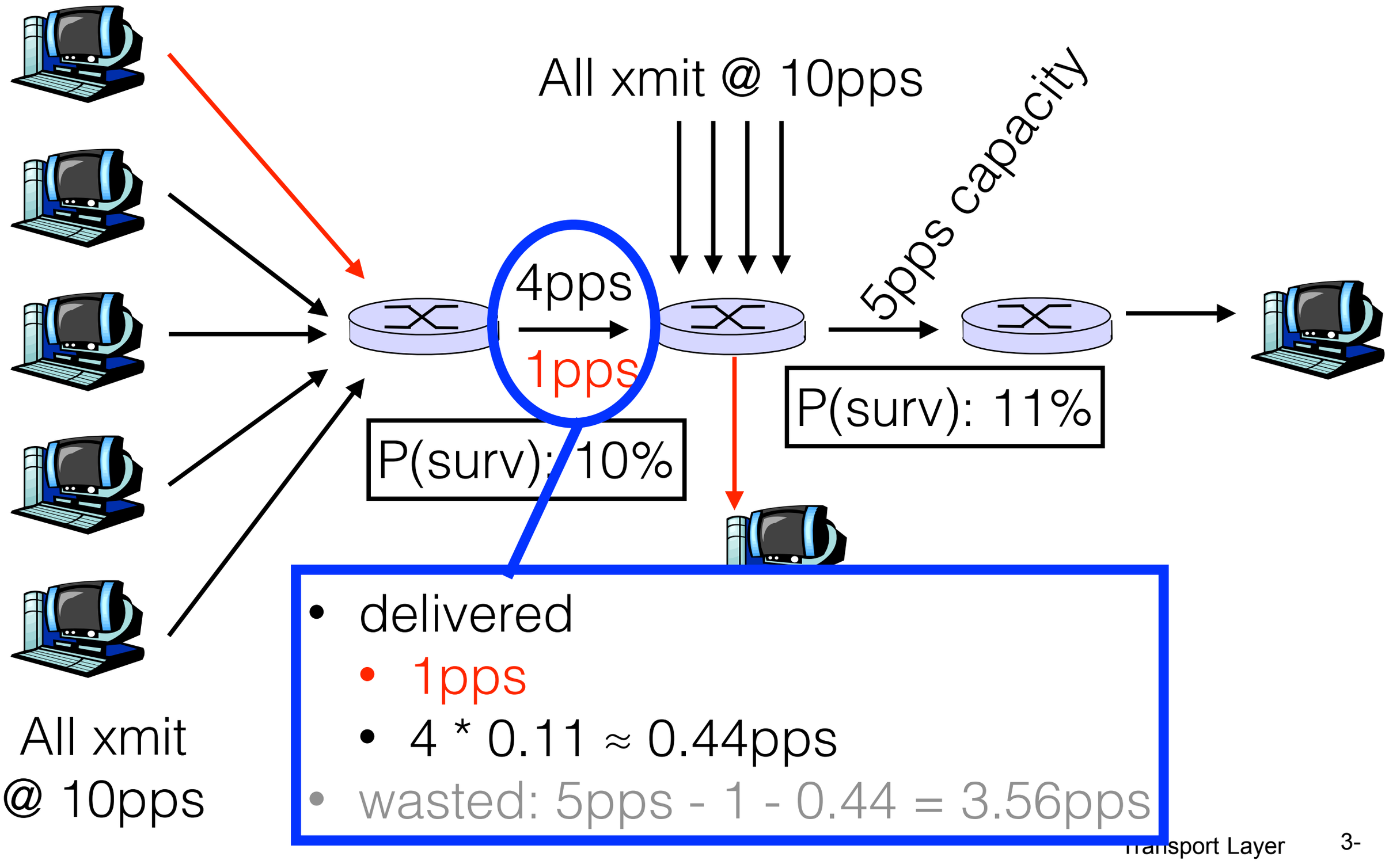
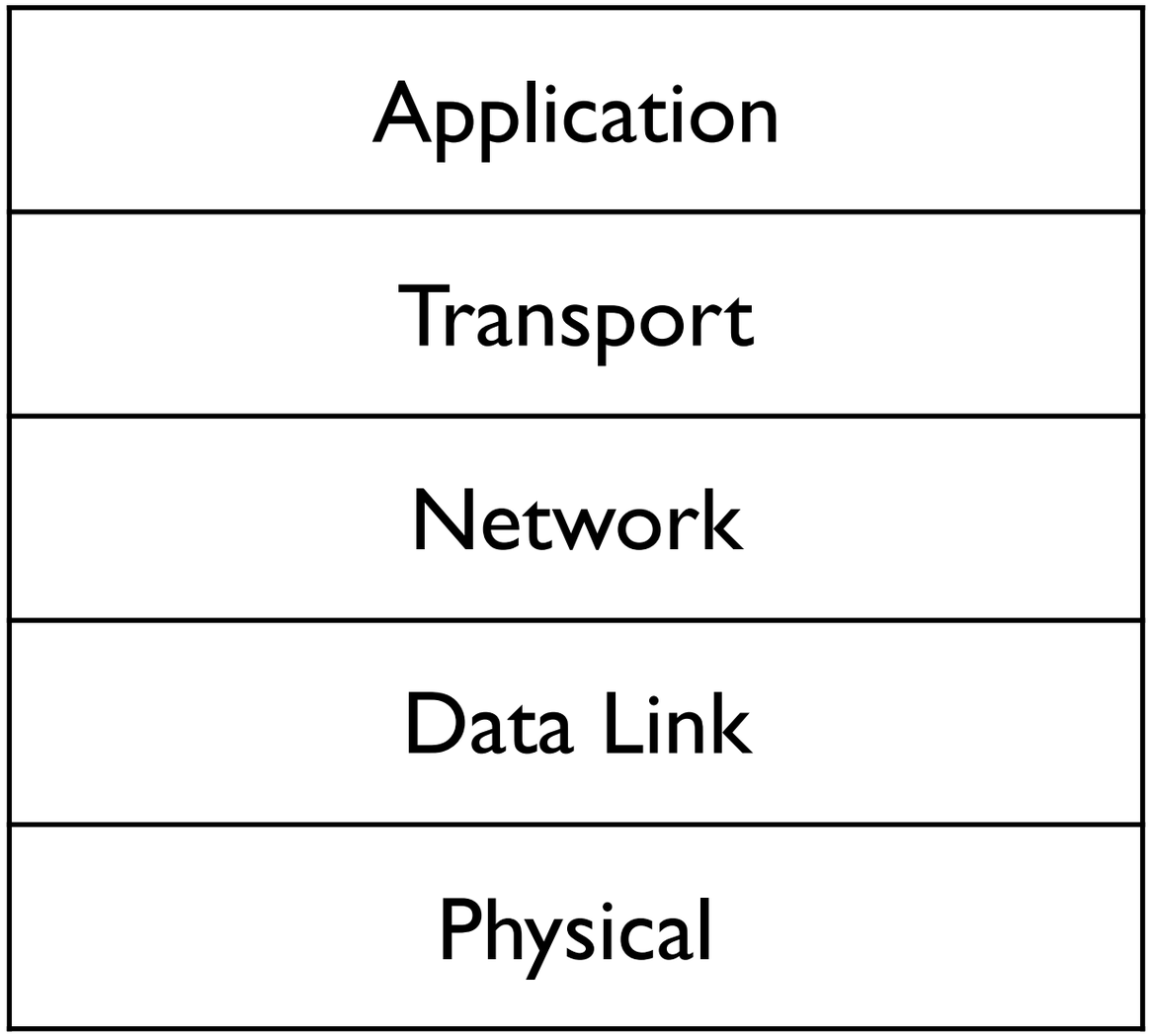


Approaches towards congestion control

Approaches towards congestion control



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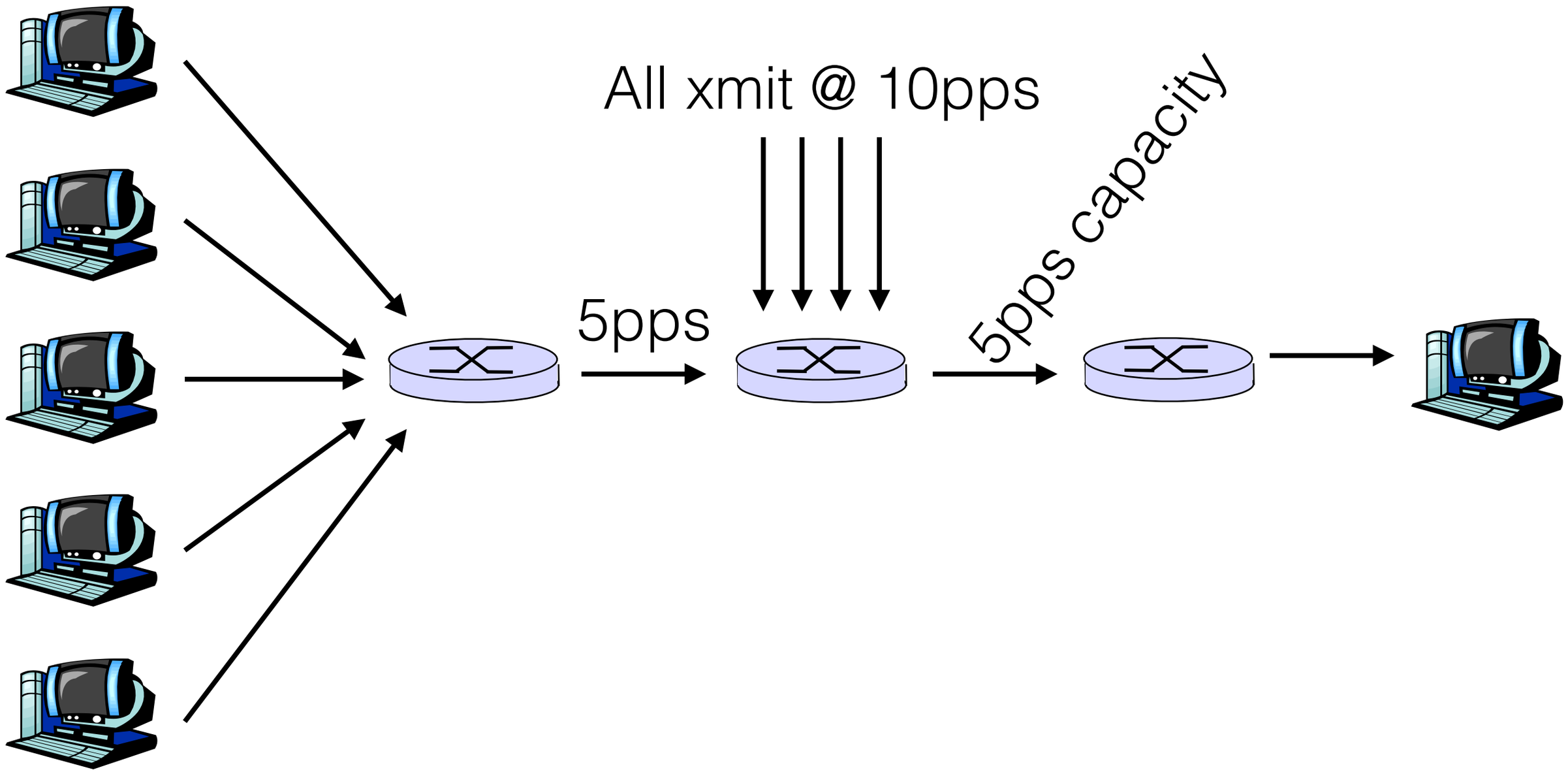

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- "tragedy of the commons" problem

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- congestion inferred from end-system observed loss, delay
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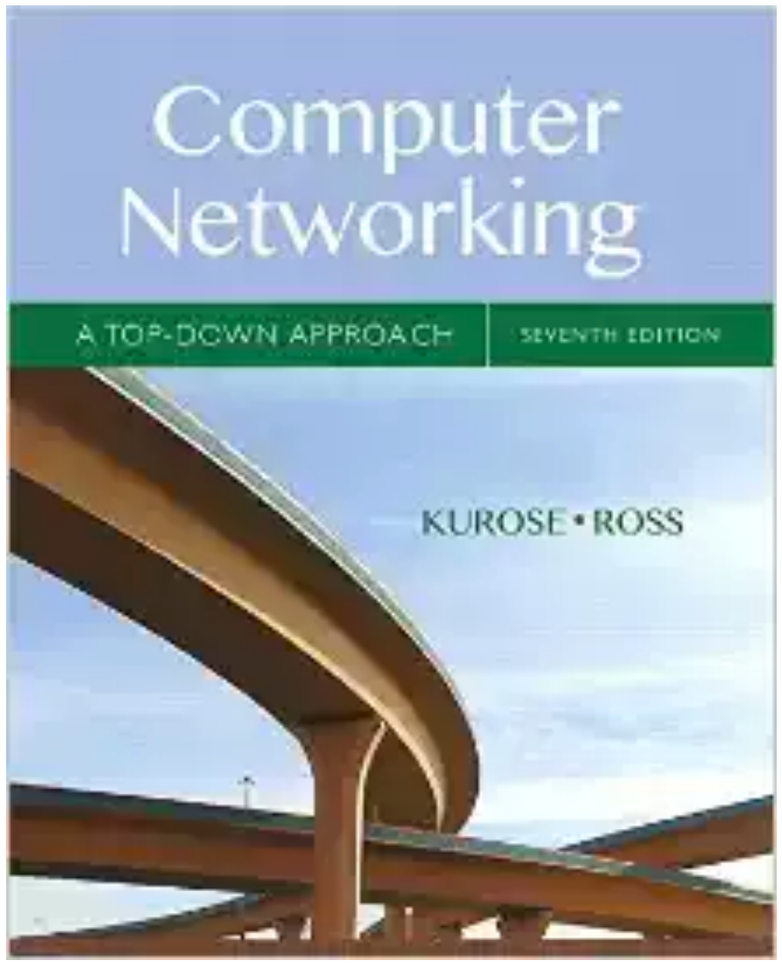
network-assisted congestion control:

- routers provide feedback to end systems
  - single bit indicating congestion (SNA, DECbit, TCP/IP ECN, ATM)
  - explicit rate sender should send at

Reading Along …



- 3.7: TCP Congestion Control

TCP Congestion Control

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- RFCs 3390, 3517, 3782, 5681, etc.

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  - cwnd is sender state and not transmitted to the receiver

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- Assume loss means the network is congested
  - not always a good assumption

TCP Congestion Control

- Additive increase, multiplicative decrease (AIMD)
  - when no congestion detected, increase the rate (cwnd) linearly
  - when congestion detected, decrease the rate (cwnd) by half

TCP Congestion Control: details

- sender limits transmission:

LastByteSent-LastByteAcked

≤ cwnd

- roughly,

$$\text{rate} = \frac{\text{cwnd}}{\text{RTT}} \text{ Bytes/sec}$$

- **cwnd** is dynamic, function of perceived network congestion

How does sender perceive congestion?

- loss event = timeout or 3 duplicate acks

Getting Started

- OK, so, send at most cwnd bytes

- But, how do we get started?

TCP Slow Start

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- when connection begins, increase rate exponentially until first loss event:
  - initially **cwnd** = 1 MSS
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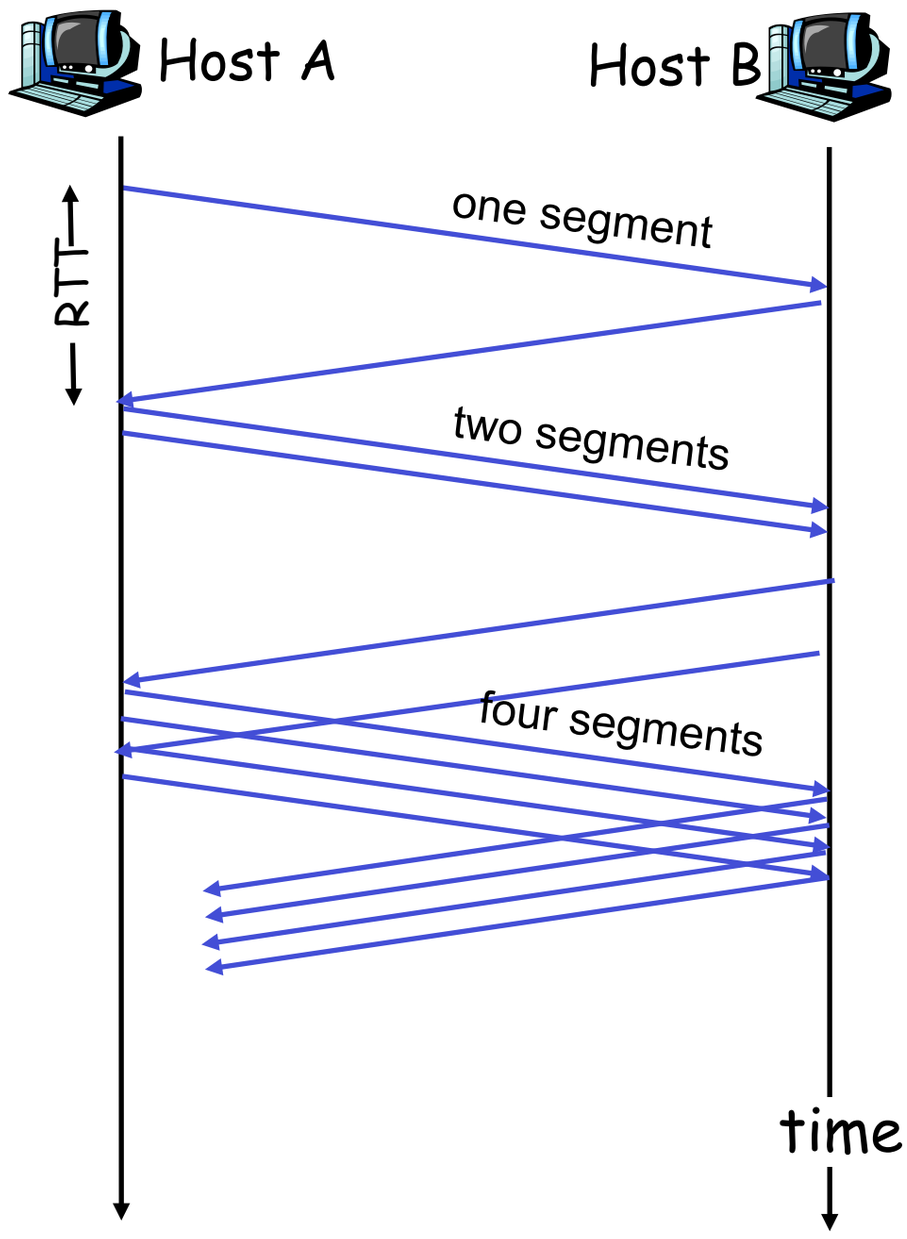

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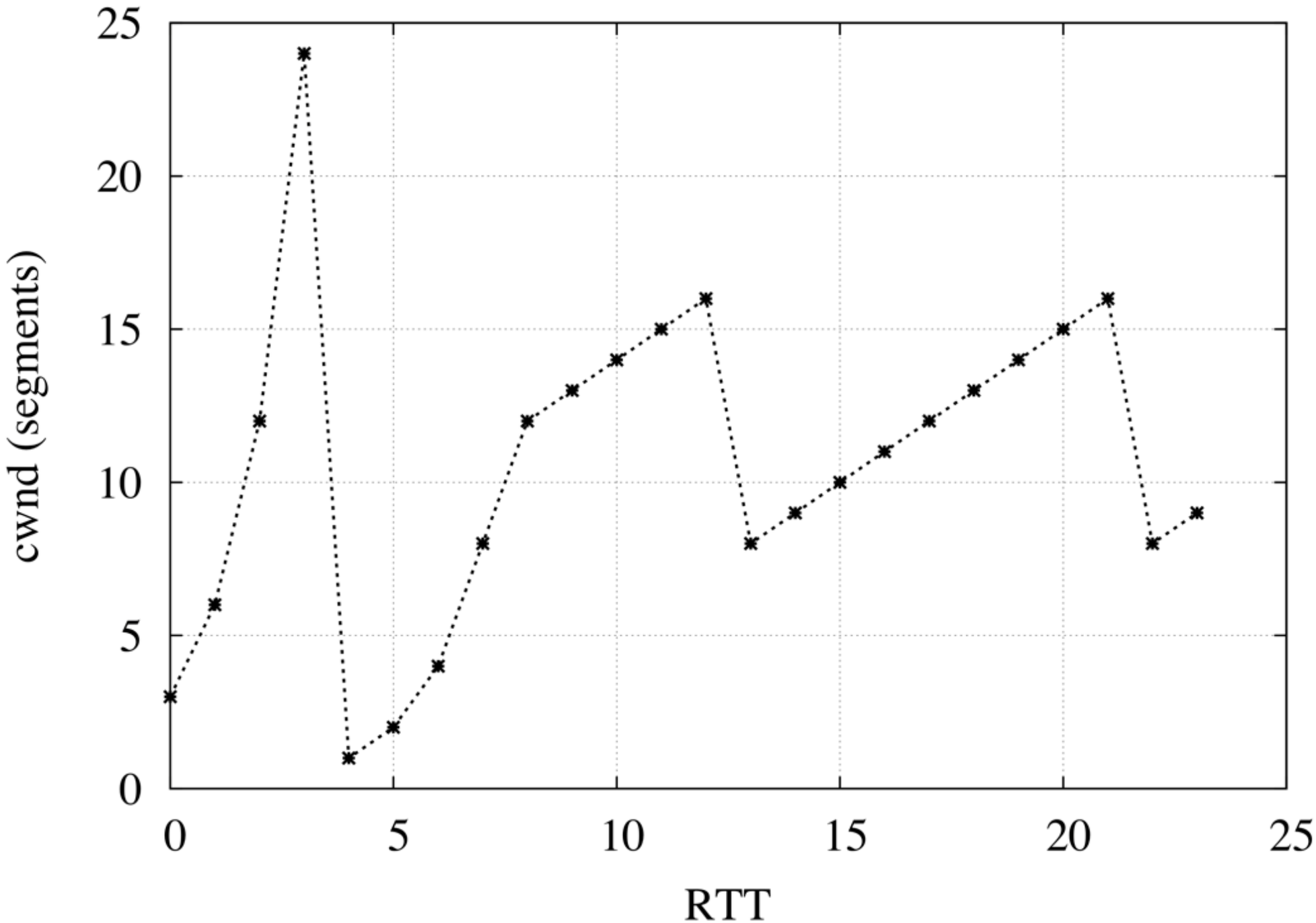
Philosophy:

- 3 dup ACKs indicates network capable of delivering some segments
- timeout indicates a "more alarming" congestion scenario

Congestion Window Evolution



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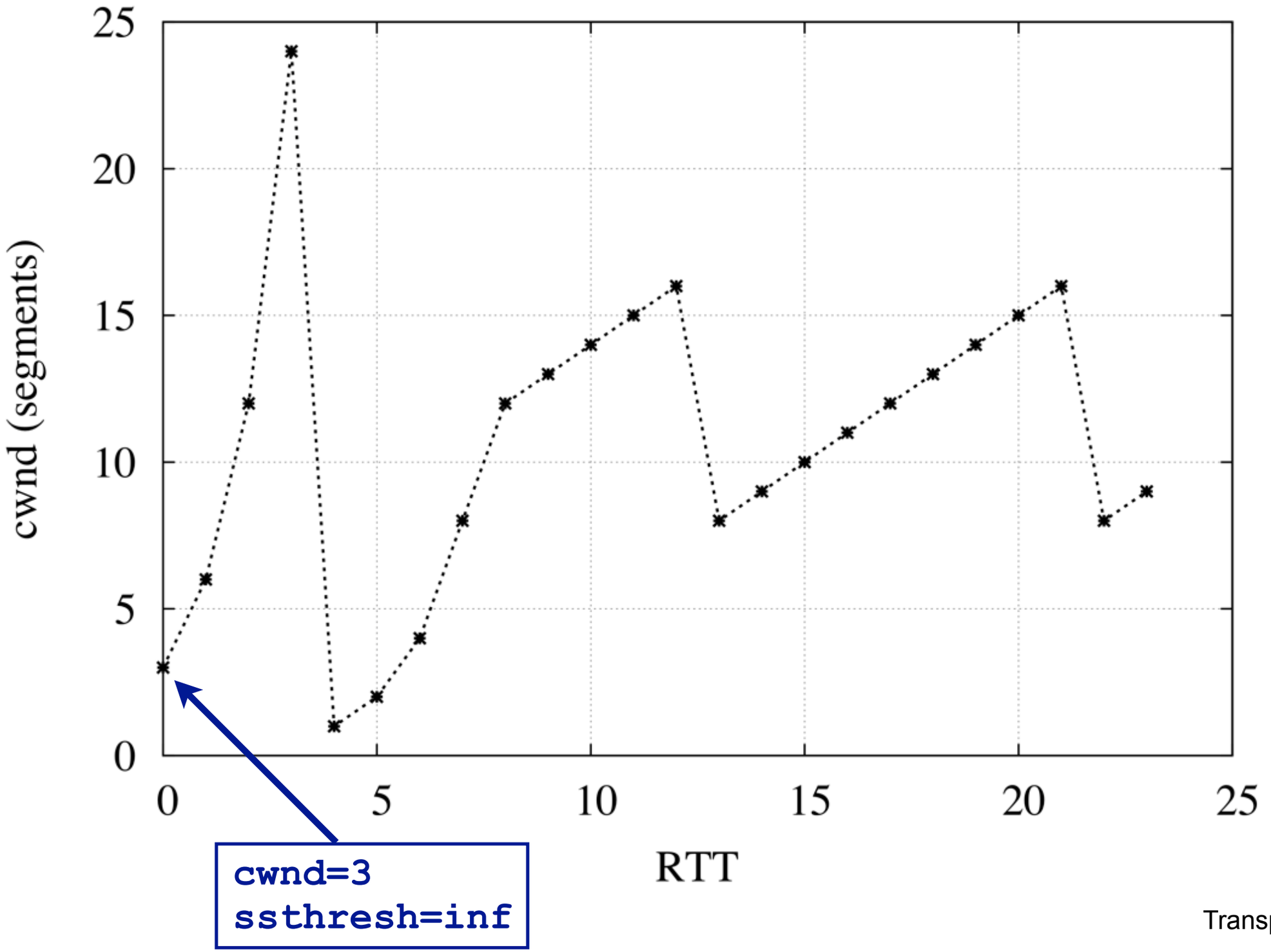

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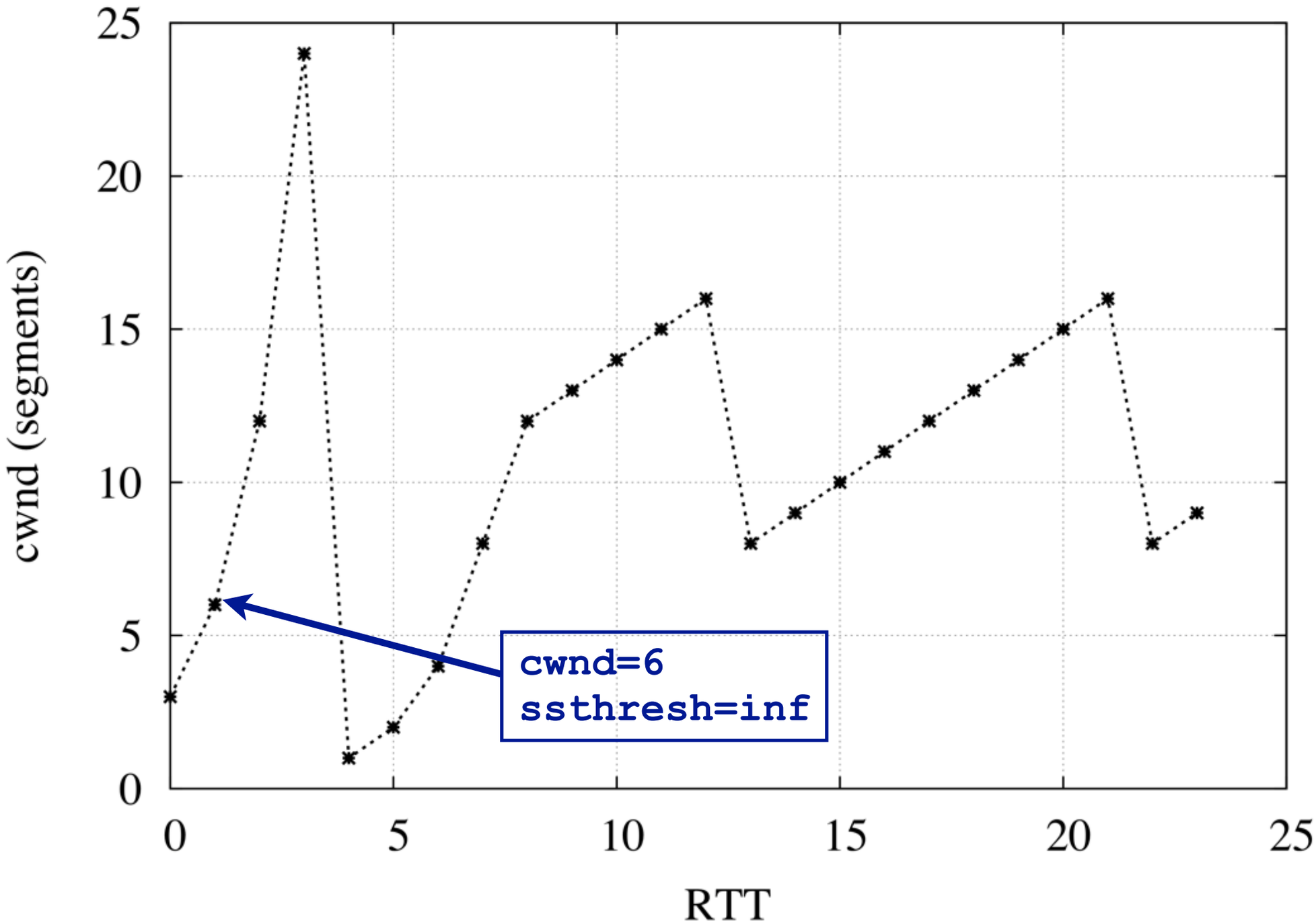

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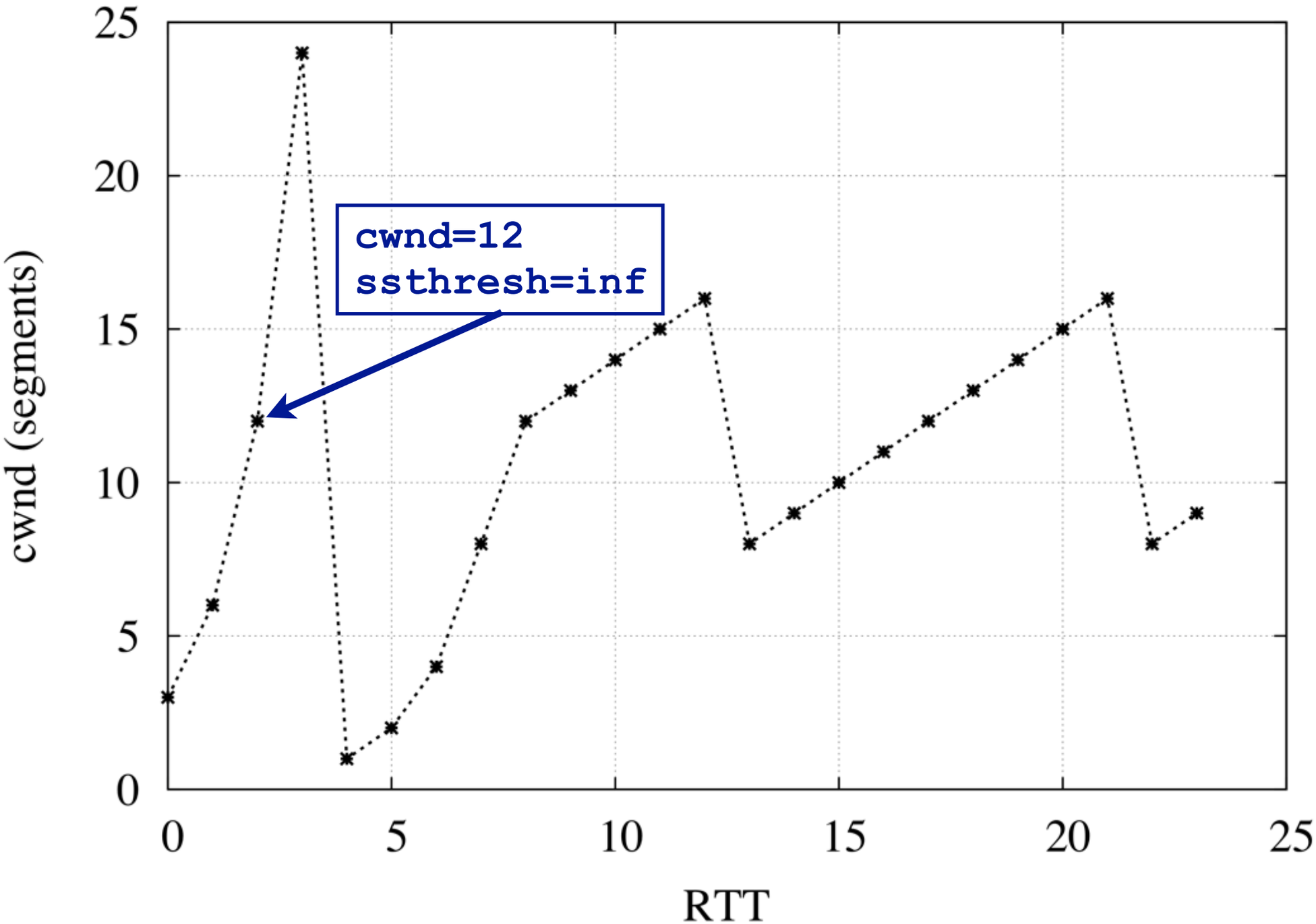

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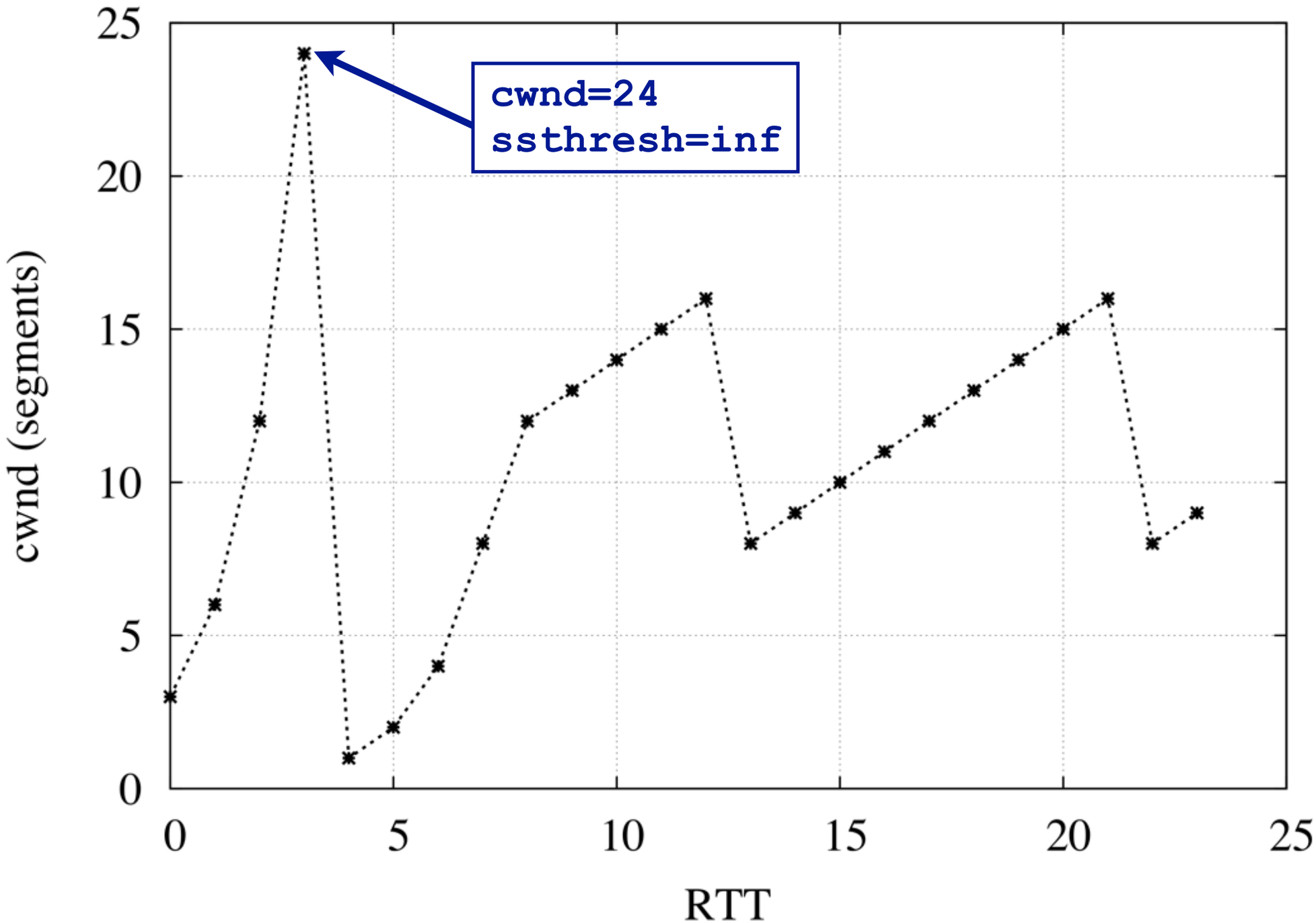

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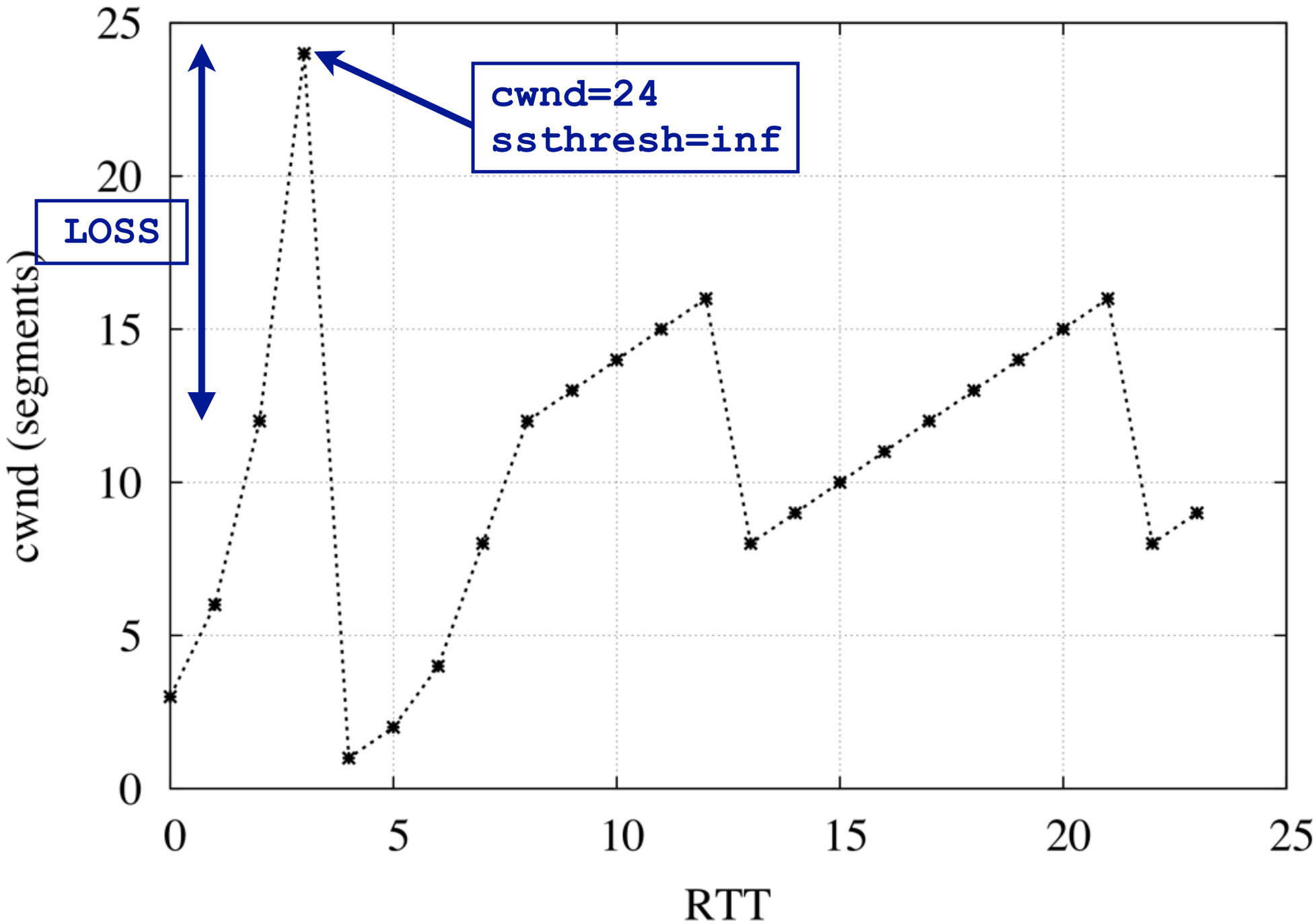

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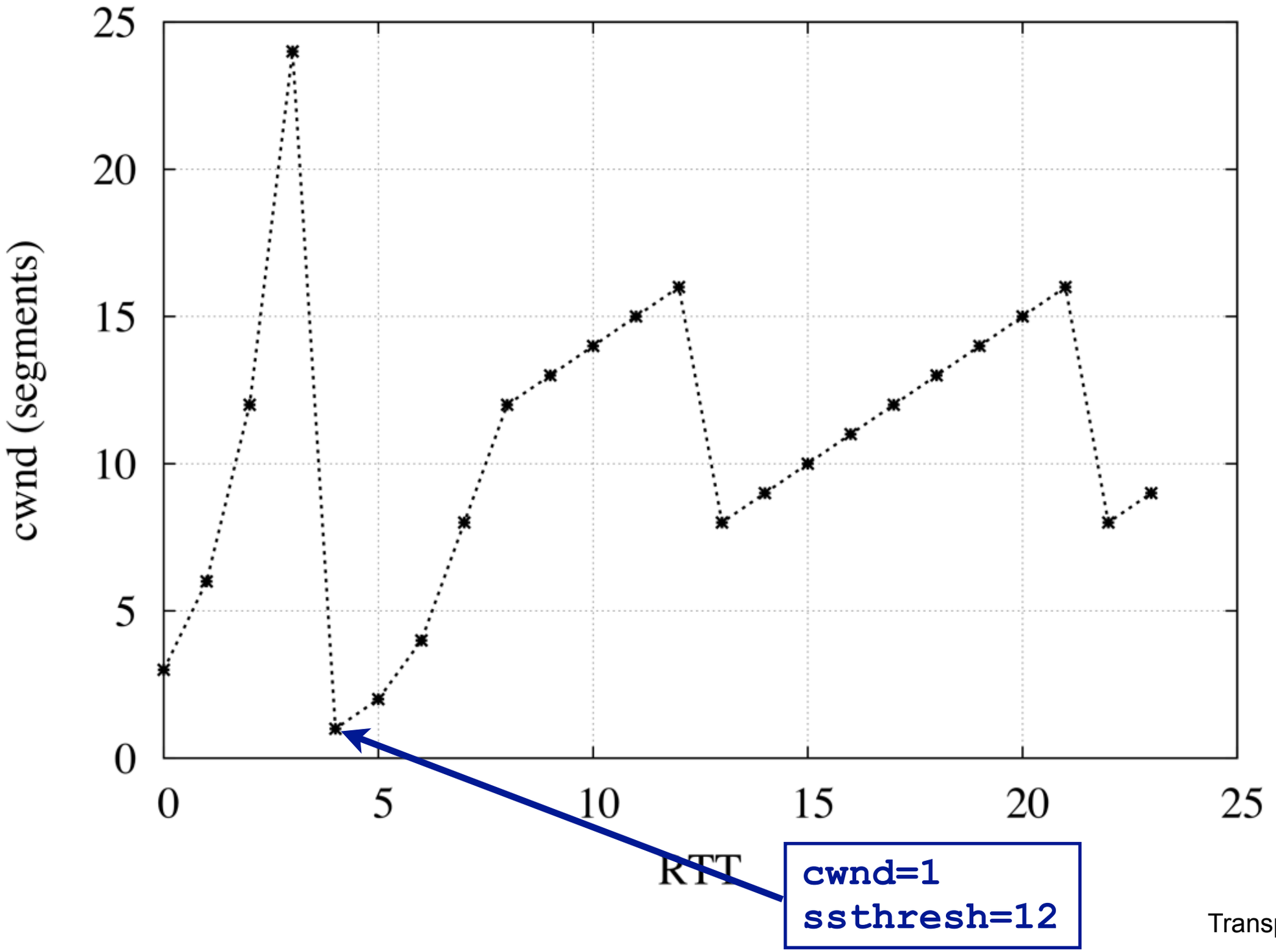

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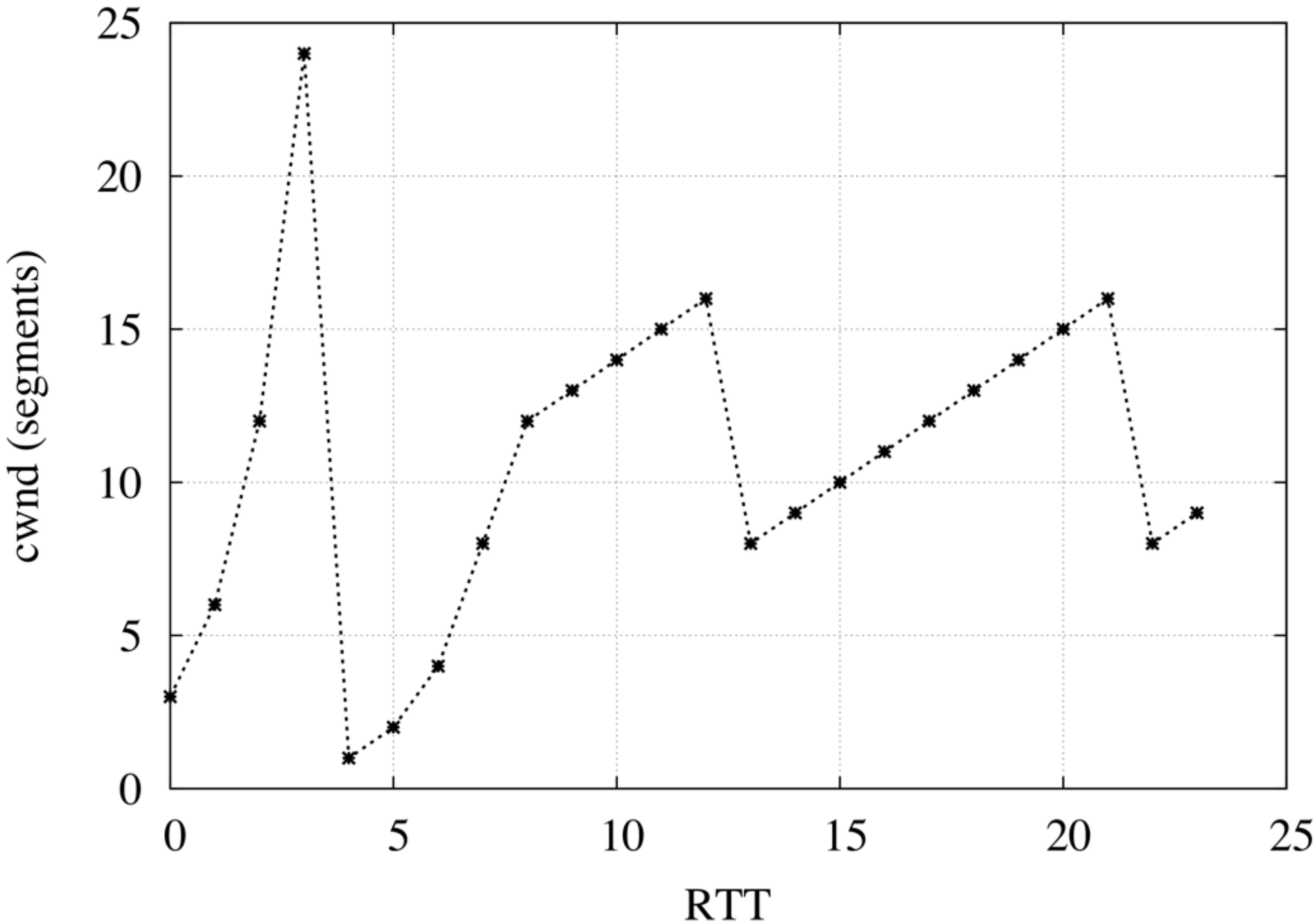

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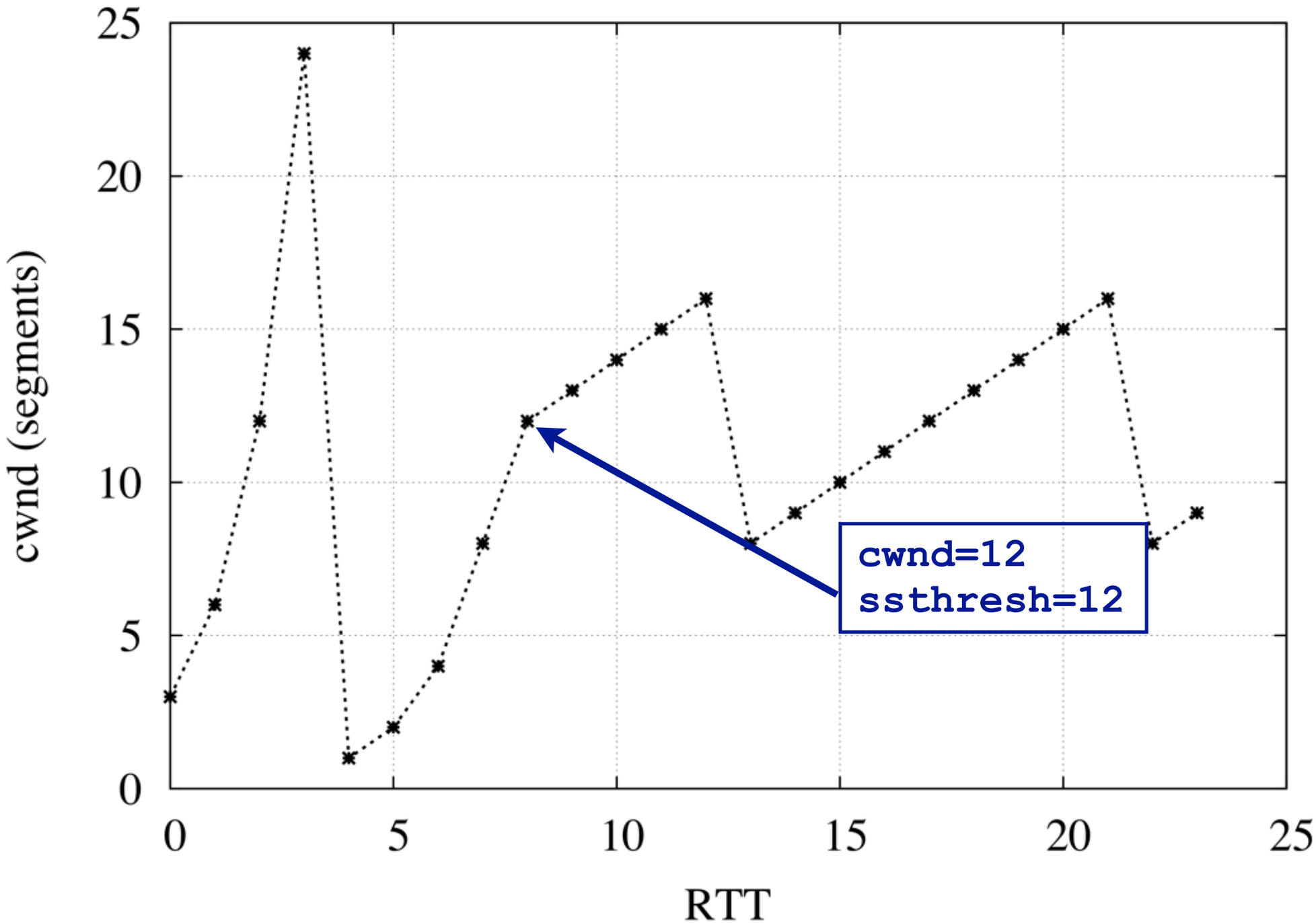

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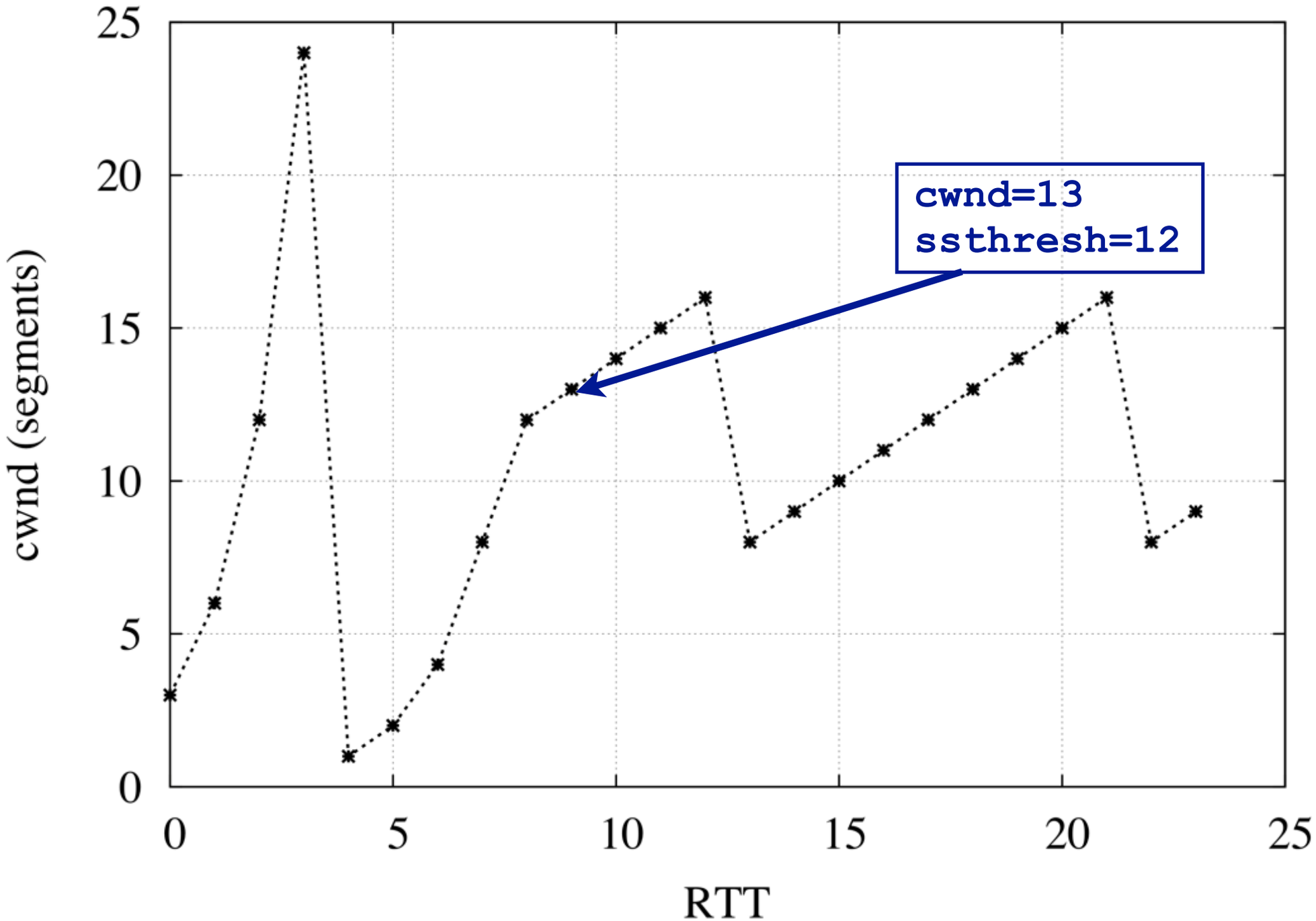

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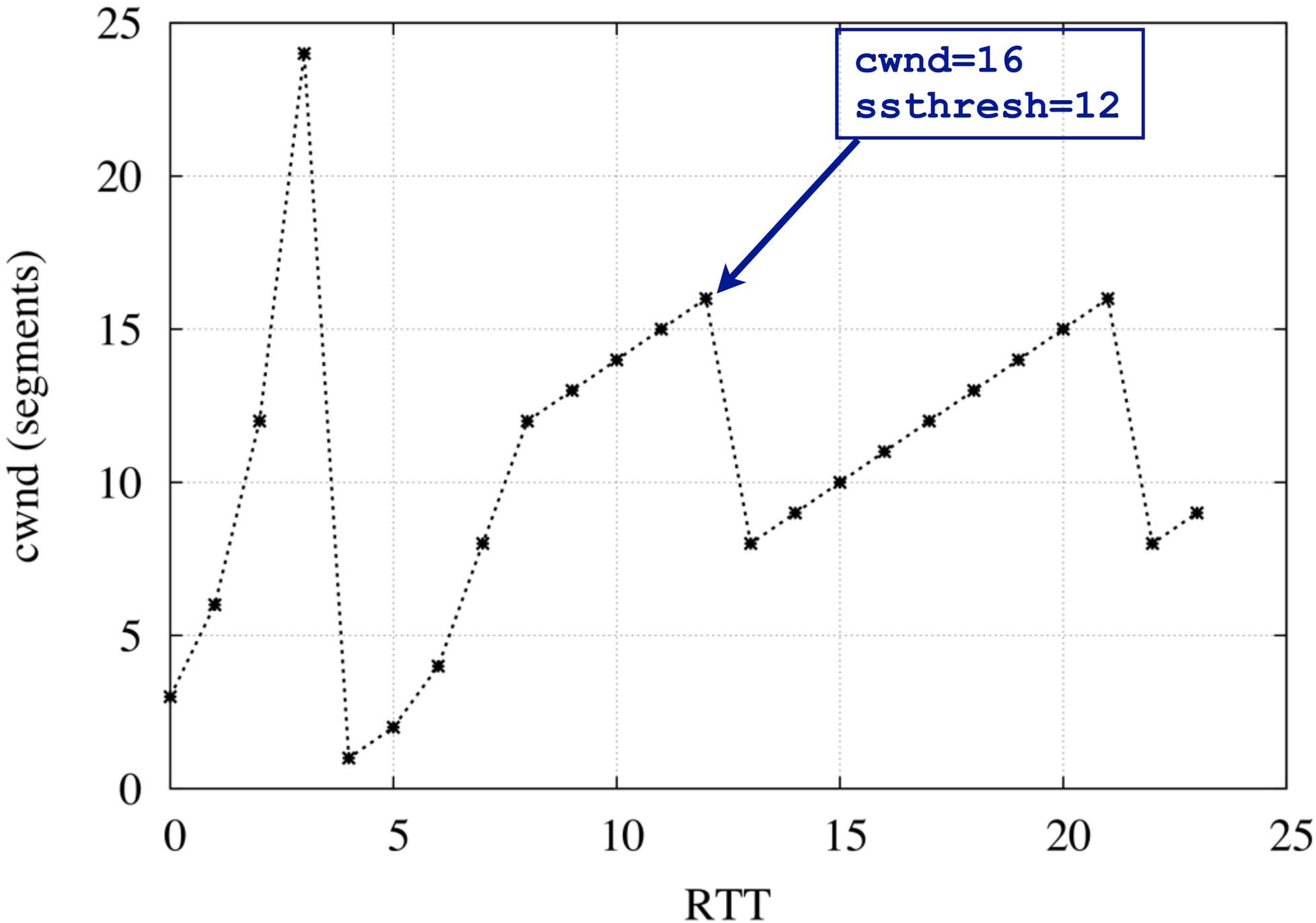

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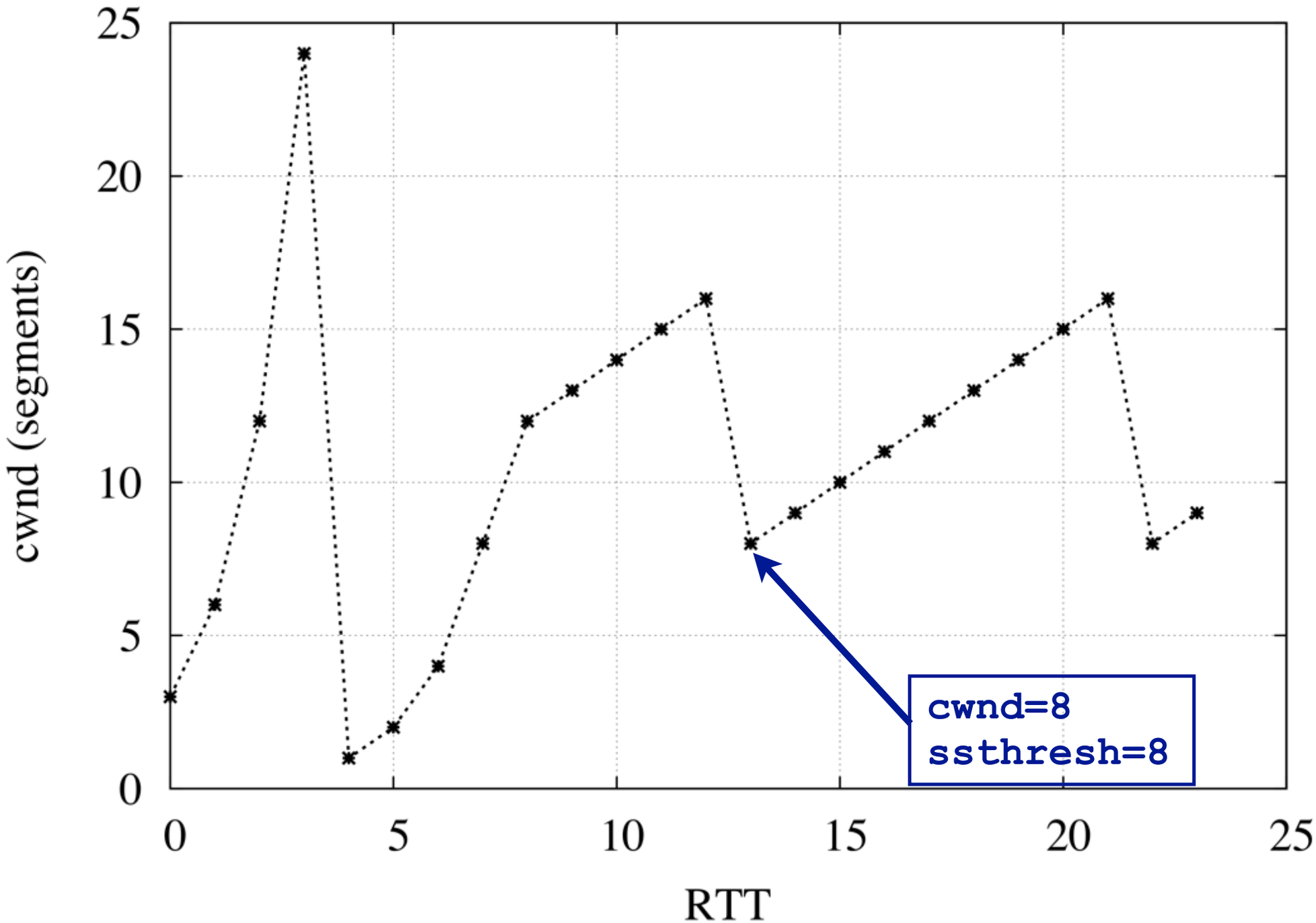

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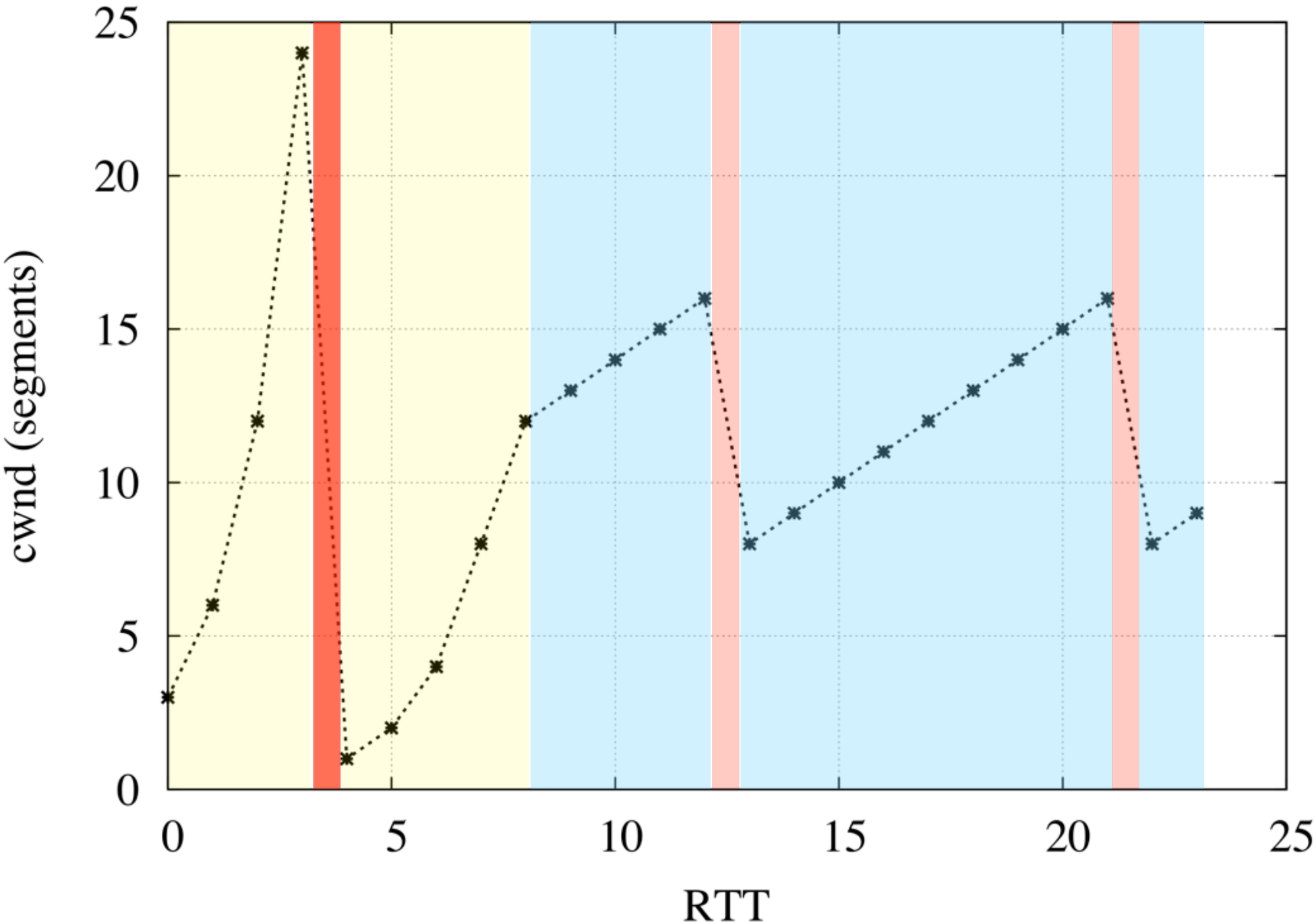

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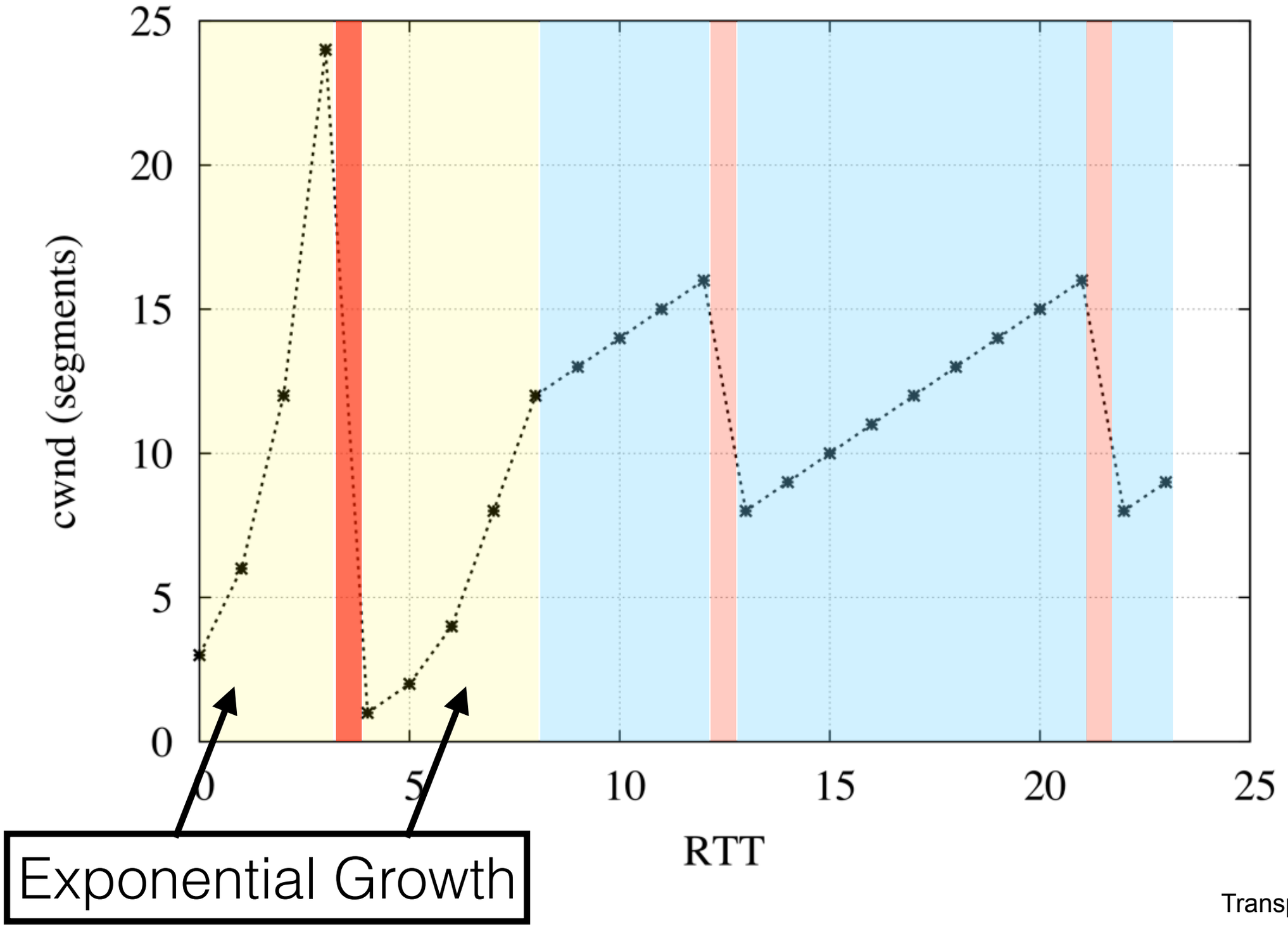

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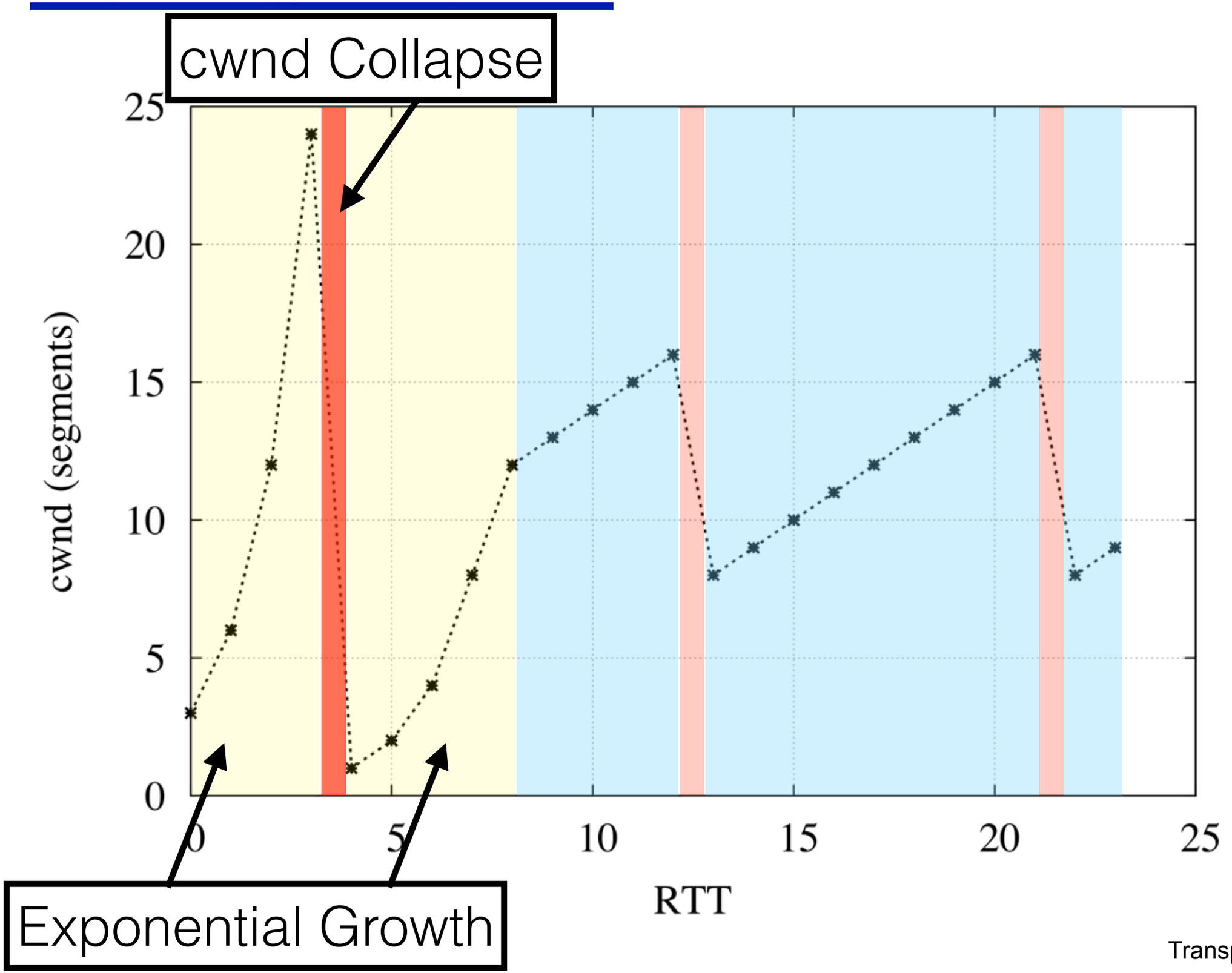

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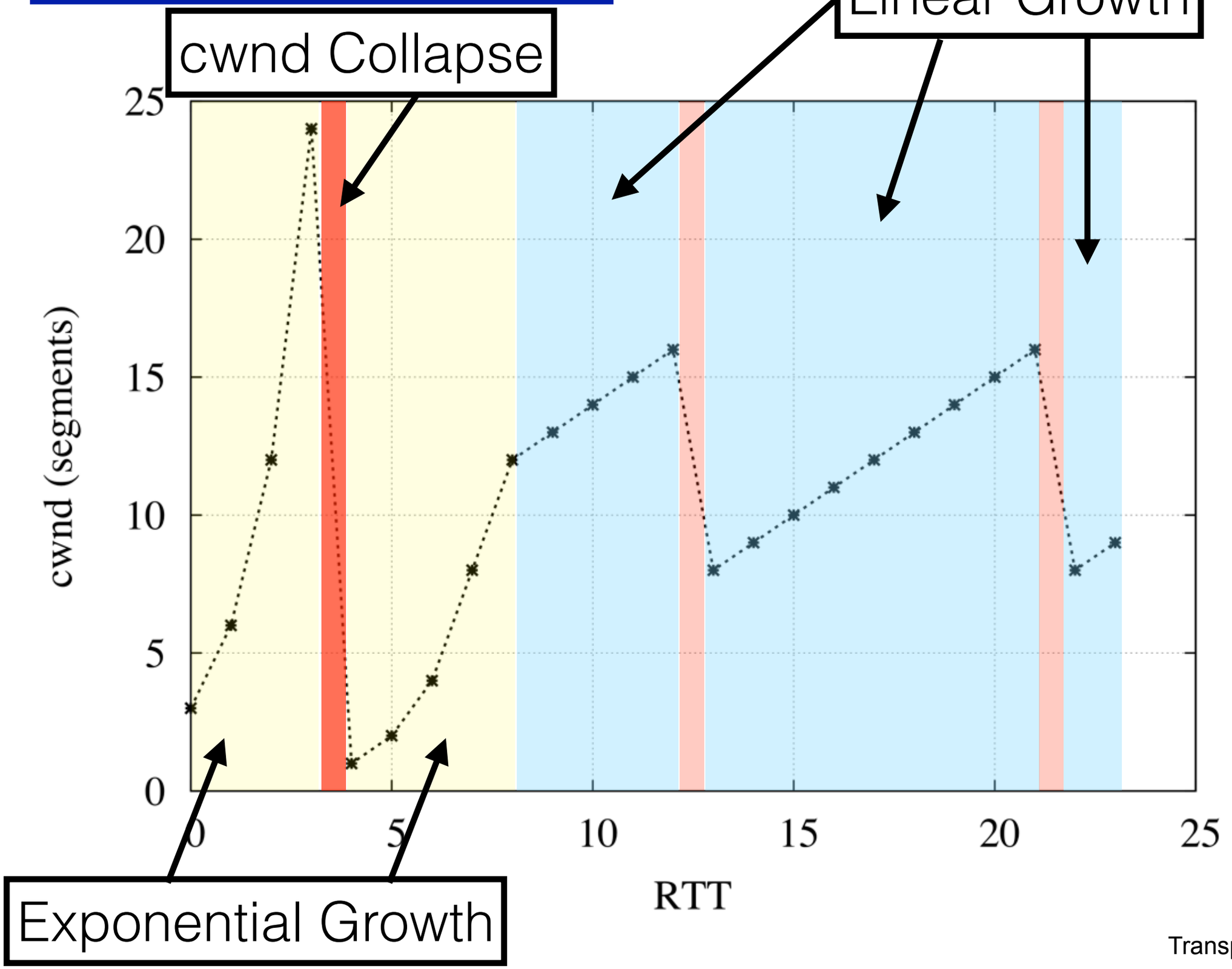

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