COMPUTER NETWORKS

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Transport Layer

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Principles of Congestion Control

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In this segment

- Principles of congestion control
- Causes/costs of congestion: scenario 1
- Causes/costs of congestion: scenario 2
- Causes/costs of congestion: scenario 3

Principles of congestion control

congestion:

- informally: "too many sources sending too much data too fast for *network* to handle"

- different from flow control!

- manifestations:
  - lost packets (buffer overflow at routers)
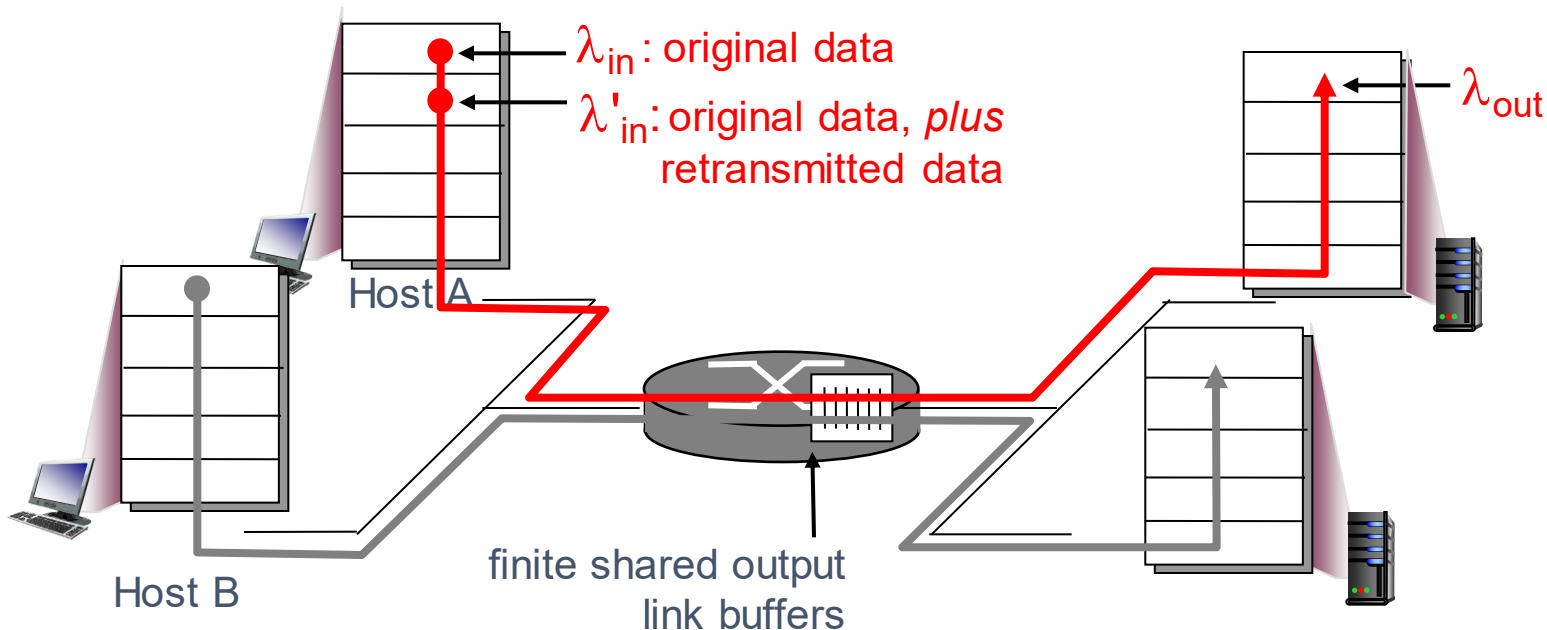 - long delays (queueing in router buffers)

- a top-10 problem!

Causes/costs of congestion: scenario 1

- two senders, two receivers

- one router, infinite buffers

- output link capacity: R

- no retransmission
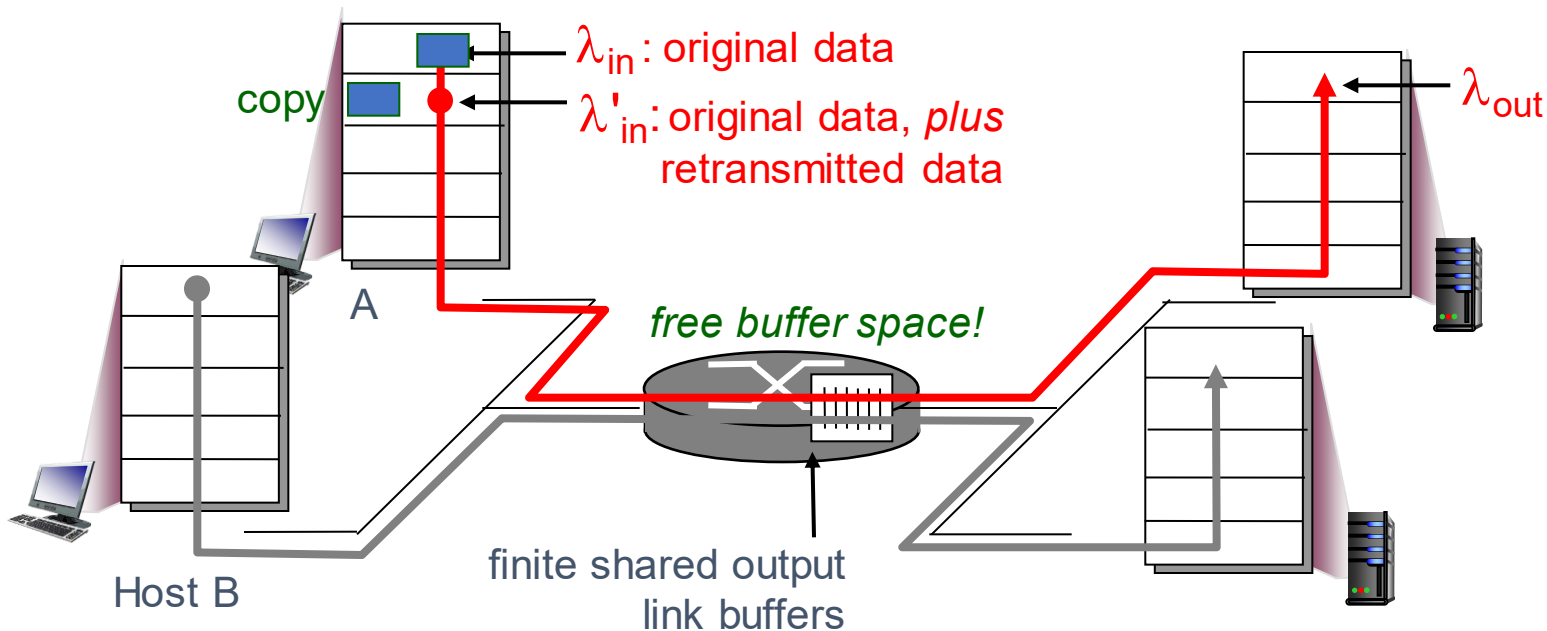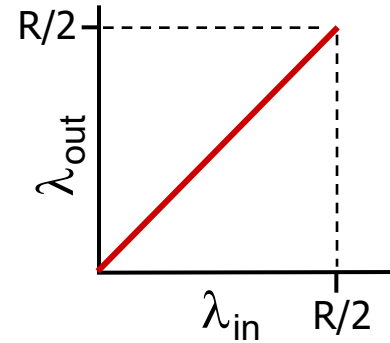
original data: λ_{in}

throughput: λ_{out}

Host A

unlimited shared output link buffers

Host B
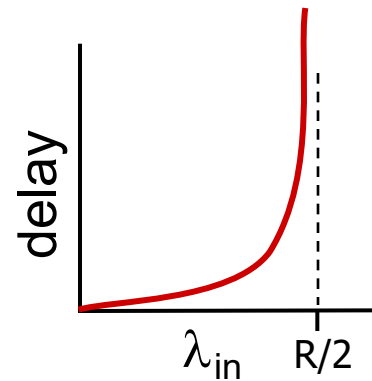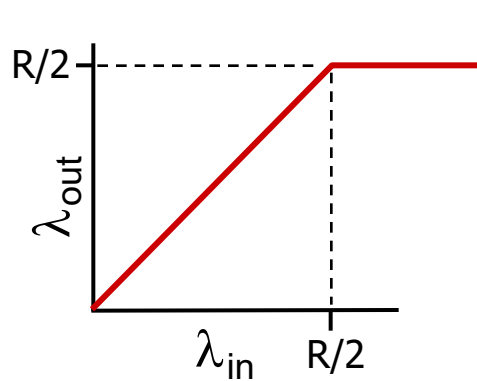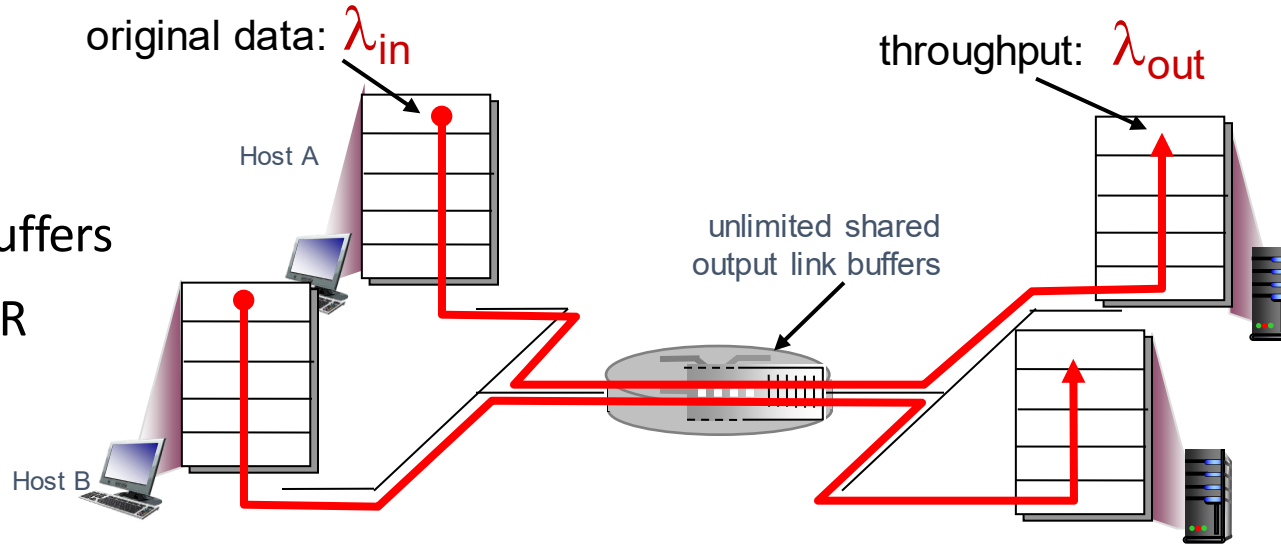
- maximum per-connection throughput: R/2

- large delays as arrival rate, λ_{in}, approaches capacity

Causes/costs of congestion: scenario 2

- one router, *finite* buffers

- sender retransmission of timed-out packet
  - application-layer input = application-layer output: $\lambda_{in} = \lambda_{out}$
  - transport-layer input includes *retransmissions* : $\lambda'_{in} \geq \lambda_{in}$

λ_{in} : original data

λ'_{in} : original data, *plus* retransmitted data

λ_{out}

Host A

Host B

finite shared output link buffers

Causes/costs of congestion: scenario 2

idealization: perfect knowledge

- sender sends only when router buffers available

λ_{in} : original data

λ'_{in} : original data, *plus* retransmitted data

λ_{out}

copy

A

Host B

free buffer space!

finite shared output link buffers

Causes/costs of congestion: scenario 2

Idealization: known loss

packets can be lost, dropped at router due to full buffers

- sender only resends if packet *known* to be lost

λ_{in} : original data

λ'_{in} : original data, *plus* retransmitted data

λ_{out}

copy

no buffer space!

A

Host B

Causes/costs of congestion: scenario 2

Idealization: known loss

packets can be lost,
dropped at router due to
full buffers

- sender only resends if
packet *known* to be lost

R/2

λ_{out}
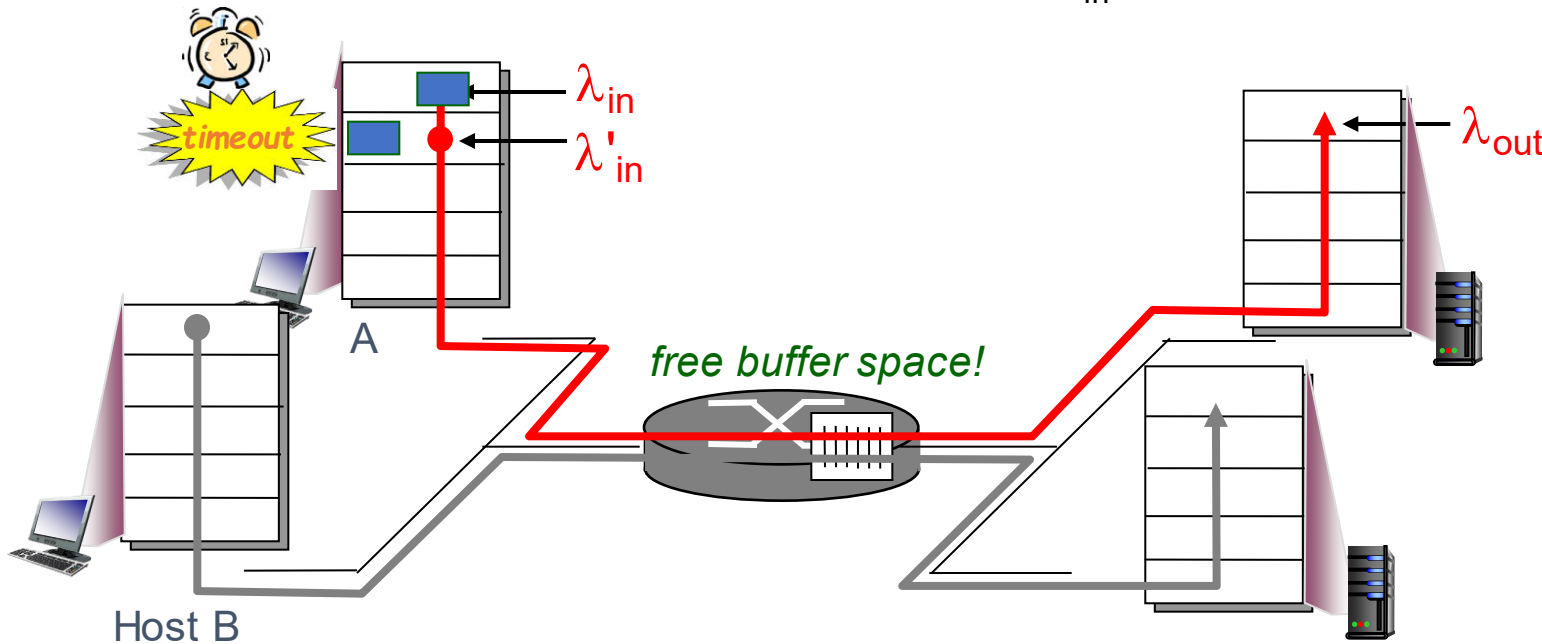
λ'_{in} R/2

when sending at R/2,
some packets are
retransmissions but
asymptotic goodput
is still R/2 (why?)

λ_{in} : original data

λ'_{in} : original data, *plus*
retransmitted data

λ_{out}

A

free buffer space!

Host B

10

Causes/costs of congestion: scenario 2

Realistic: duplicates

- packets can be lost, dropped at router due to full buffers

- sender times out prematurely, sending *two* copies, both of which are delivered

when sending at R/2, some packets are retransmissions including duplicated that are delivered!

λ_{out}

λ'_{in}

R/2

timeout

λ_{in}

λ'_{in}

A

λ_{out}

free buffer space!

Host B

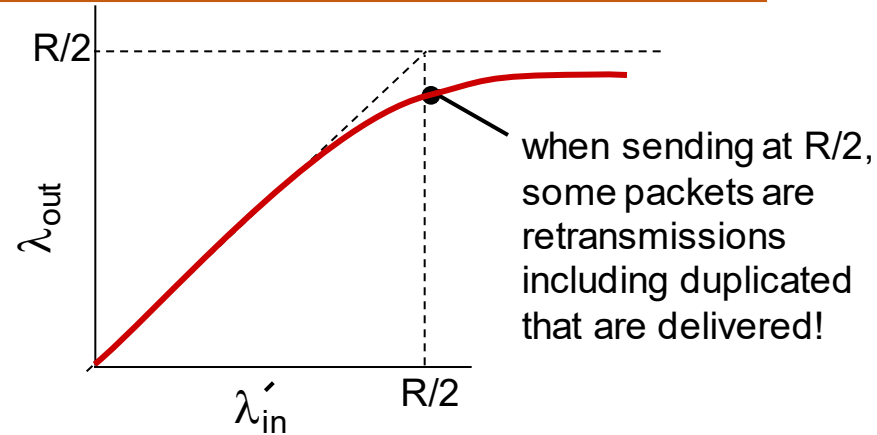## Causes/costs of congestion: scenario 2
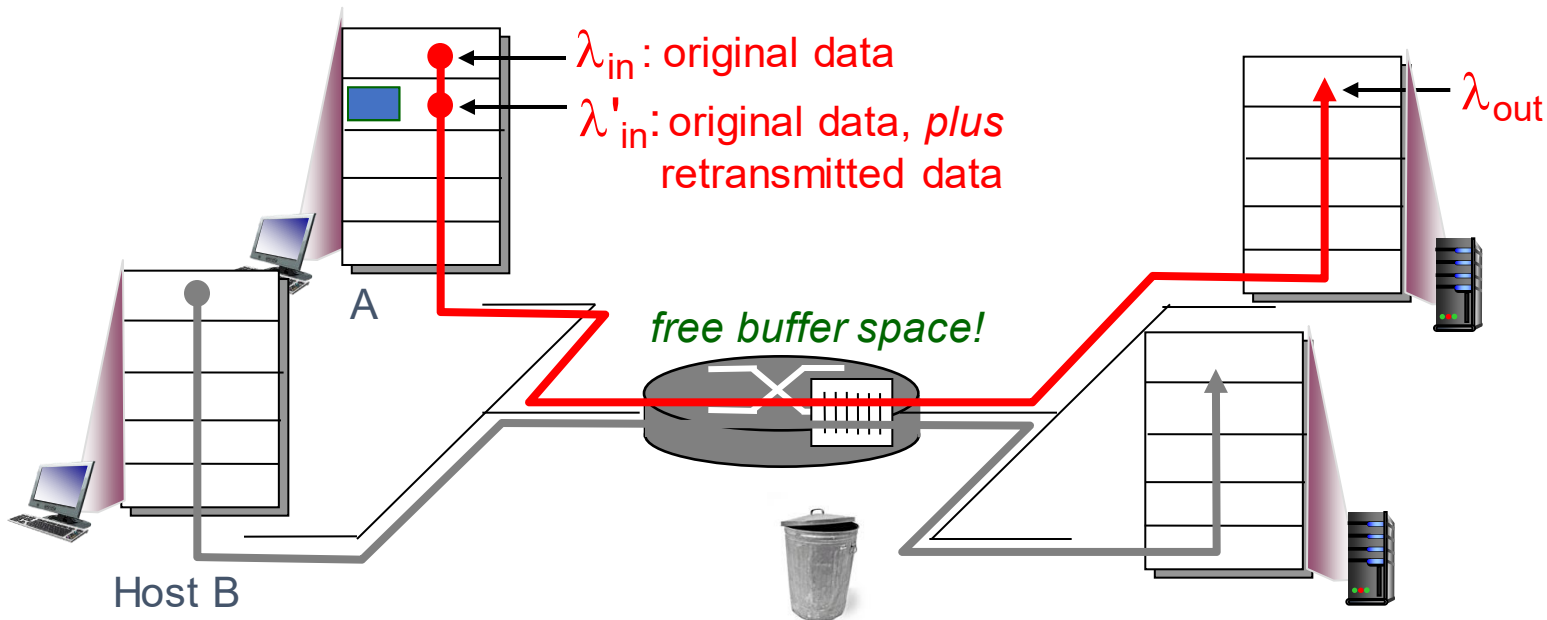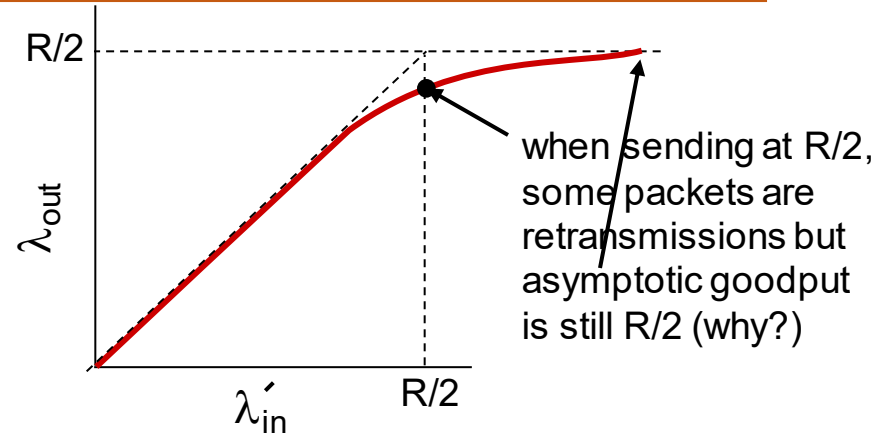
Realistic: duplicates

- packets can be lost, dropped at router due to full buffers
- sender times out prematurely, sending *two* copies, both of which are delivered

when sending at R/2, some packets are retransmissions including duplicated that are delivered!
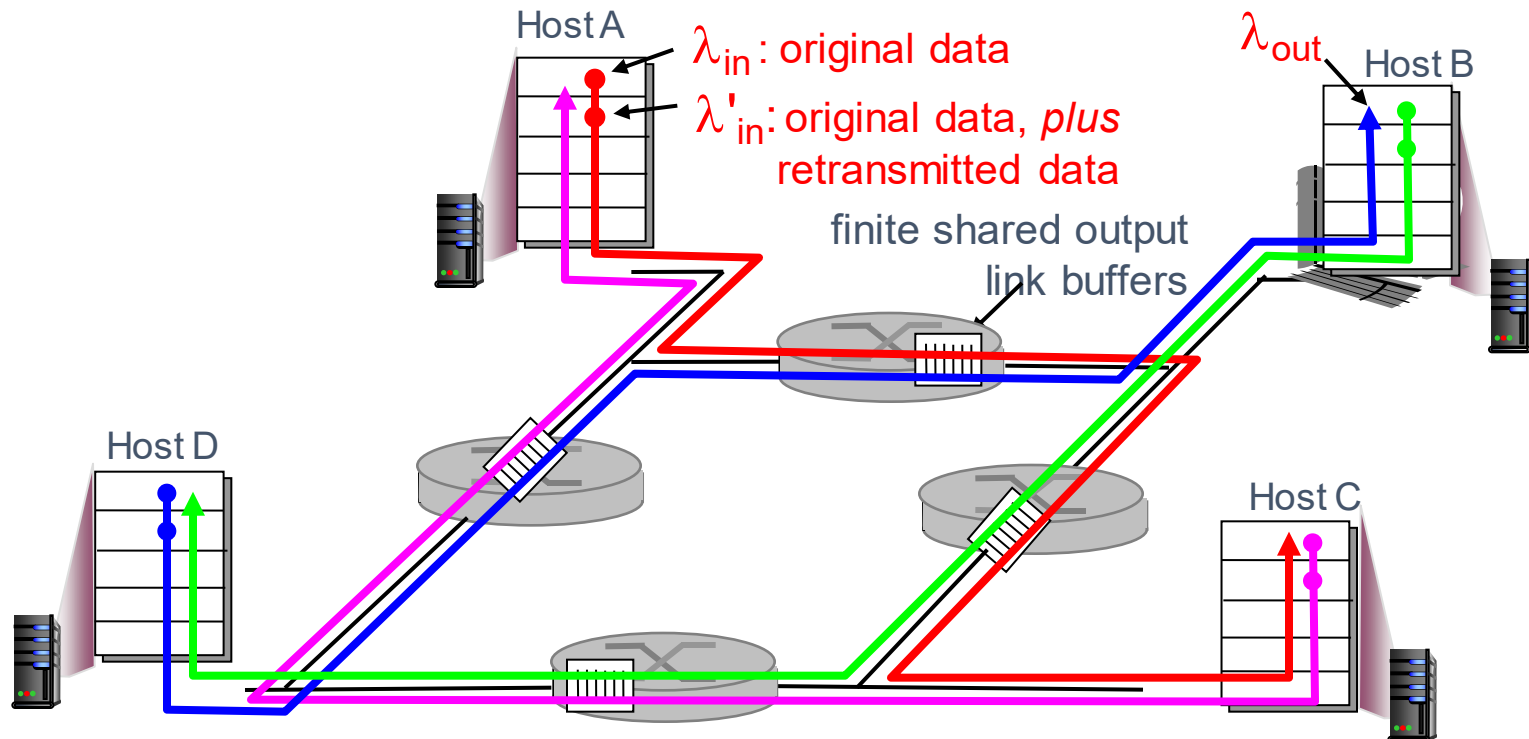
"costs" of congestion:

- more work (retrans) for given "goodput"
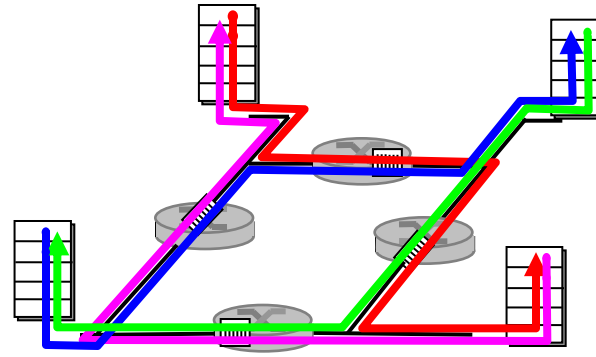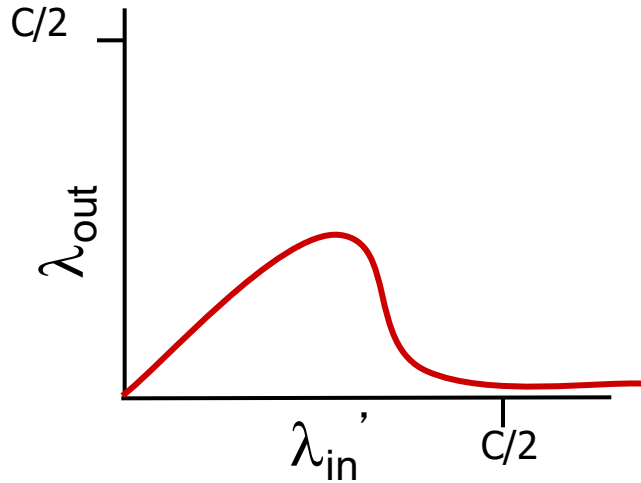- unneeded retransmissions: link carries multiple copies of pkt
  - decreasing goodput

Causes/costs of congestion: scenario 3

- four senders
- multihop paths
- timeout/retransmit

$\underline{Q}$: what happens as λ_{in} and λ_{in}' increase **?**

$\underline{A}$: as red λ_{in}' increases, all arriving blue pkts at upper queue are dropped, blue throughput $\rightarrow 0$

Host A

λ_{in} : original data

λ_{out} Host B

λ'_{in} : original data, *plus* retransmitted data

finite shared output link buffers

Host D

Host C

Causes/costs of congestion: scenario 3

another "cost" of congestion:

- when packet dropped, any "upstream transmission capacity used for that packet was wasted!

THANK YOU

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