

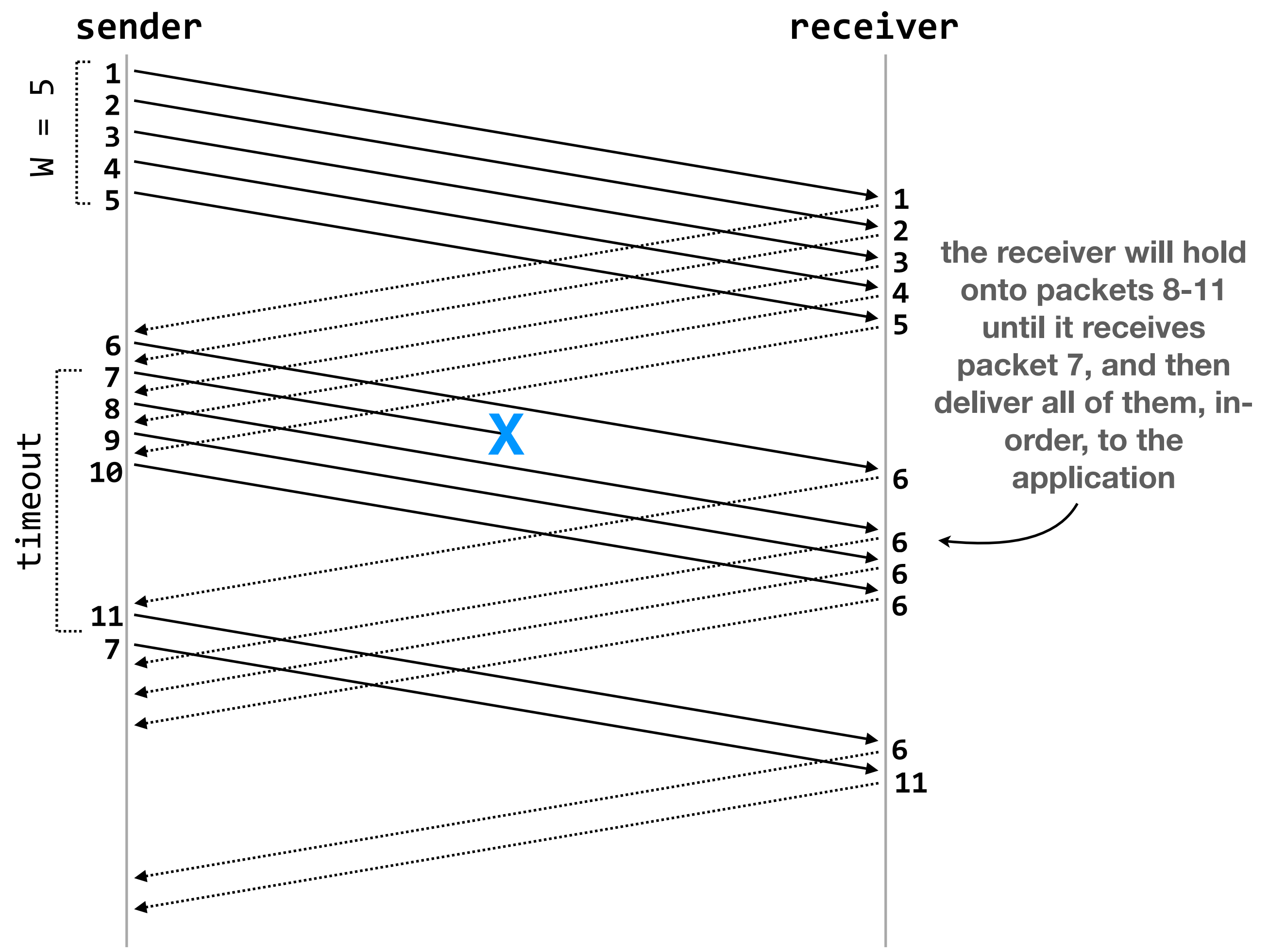
6.1800 Spring 2024

Lecture #12: In-network resource management

continuing to share a network, this time with help from switches

reliable transport protocols deliver each byte of data **exactly once, in-order**, to the receiving application

the sender is allowed to have W outstanding packets at once, but no more



sequence numbers: used to order the packets

acknowledgments (“ACKs”): used to confirm that a packet has been received

an ACK with sequence number k indicates that the receiver has received **all packets up to and including k**

timeouts: used to retransmit packets

note that the sender could also infer loss because it has received multiple ACKs with sequence number 6, but none with sequence number > 7 ; we’ll come back to that

this is known as a **sliding-window protocol**

the **window** of outstanding (un-ACKed) packets **slides** along the sequence number space

1970s:
ARPANet

1978: flexibility and
layering

early 80s: growth → change

late 80s: growth → problems

1993:
commercialization

hosts.txt

distance-vector
routing

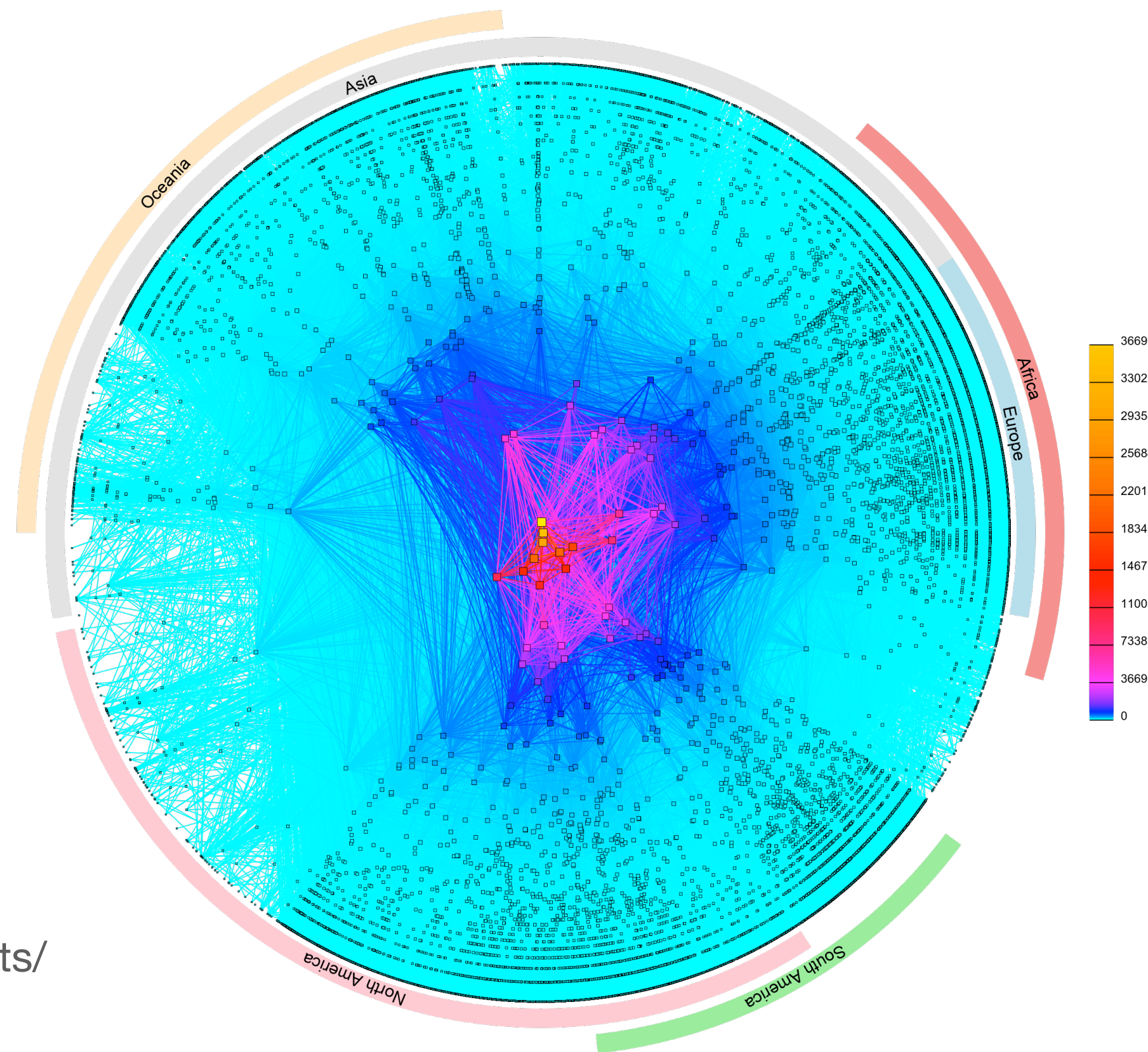
TCP, UDP

OSPF, EGP, DNS

congestion collapse
(which led to congestion control)

policy routing

CIDR



CAIDA's IPv4 AS Core,
January 2020

(<https://www.caida.org/projects/cartography/as-core/2020/>)

question: TCP congestion control doesn't react to congestion until after it's a problem; could we get senders to react before queues are full?

application

the things that actually generate traffic

transport

sharing the network, reliability (or not)

examples: TCP, UDP

network

naming, addressing, routing

examples: IP

link

communication between two directly-connected nodes

examples: ethernet, bluetooth, 802.11 (wifi)

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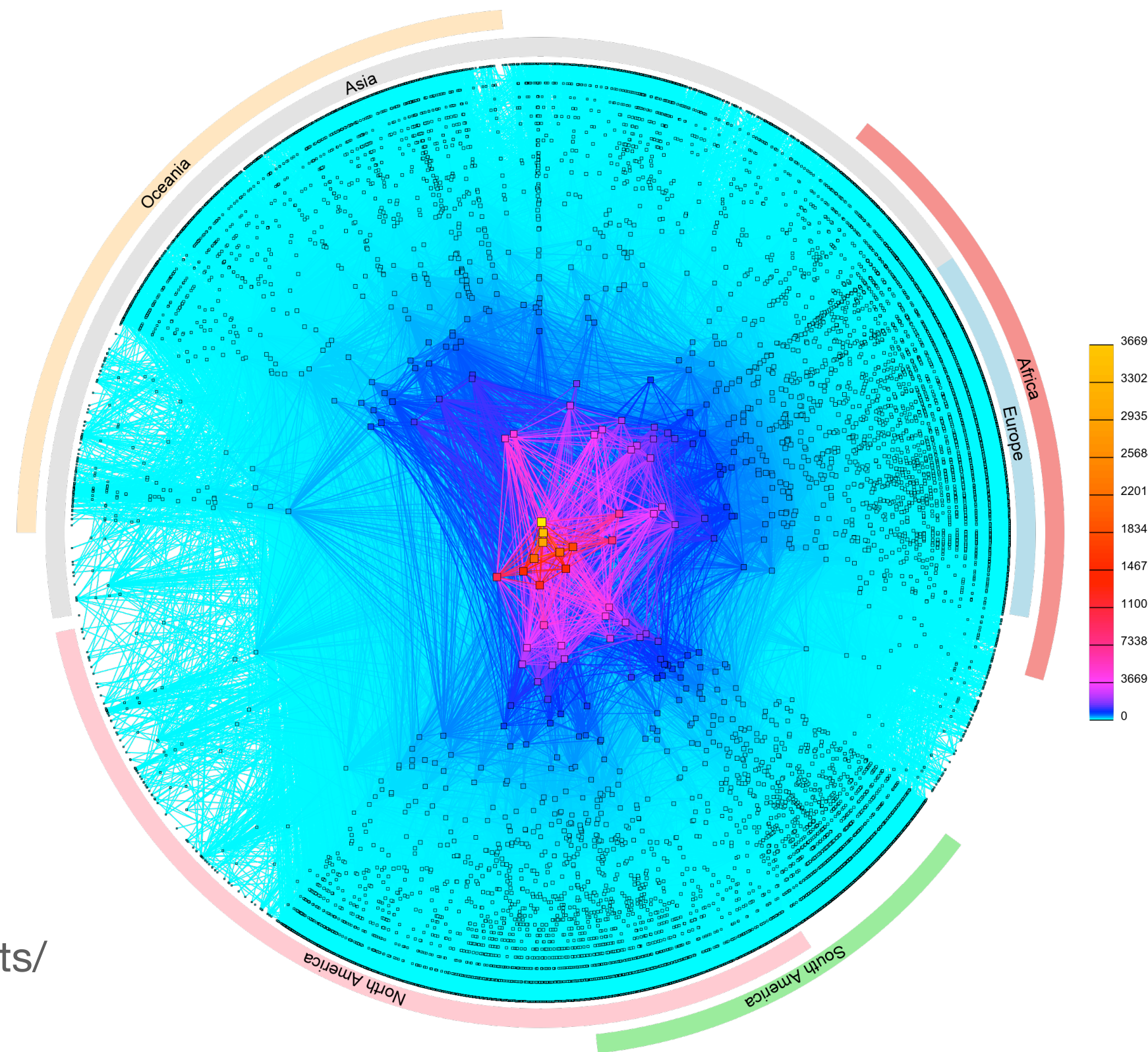
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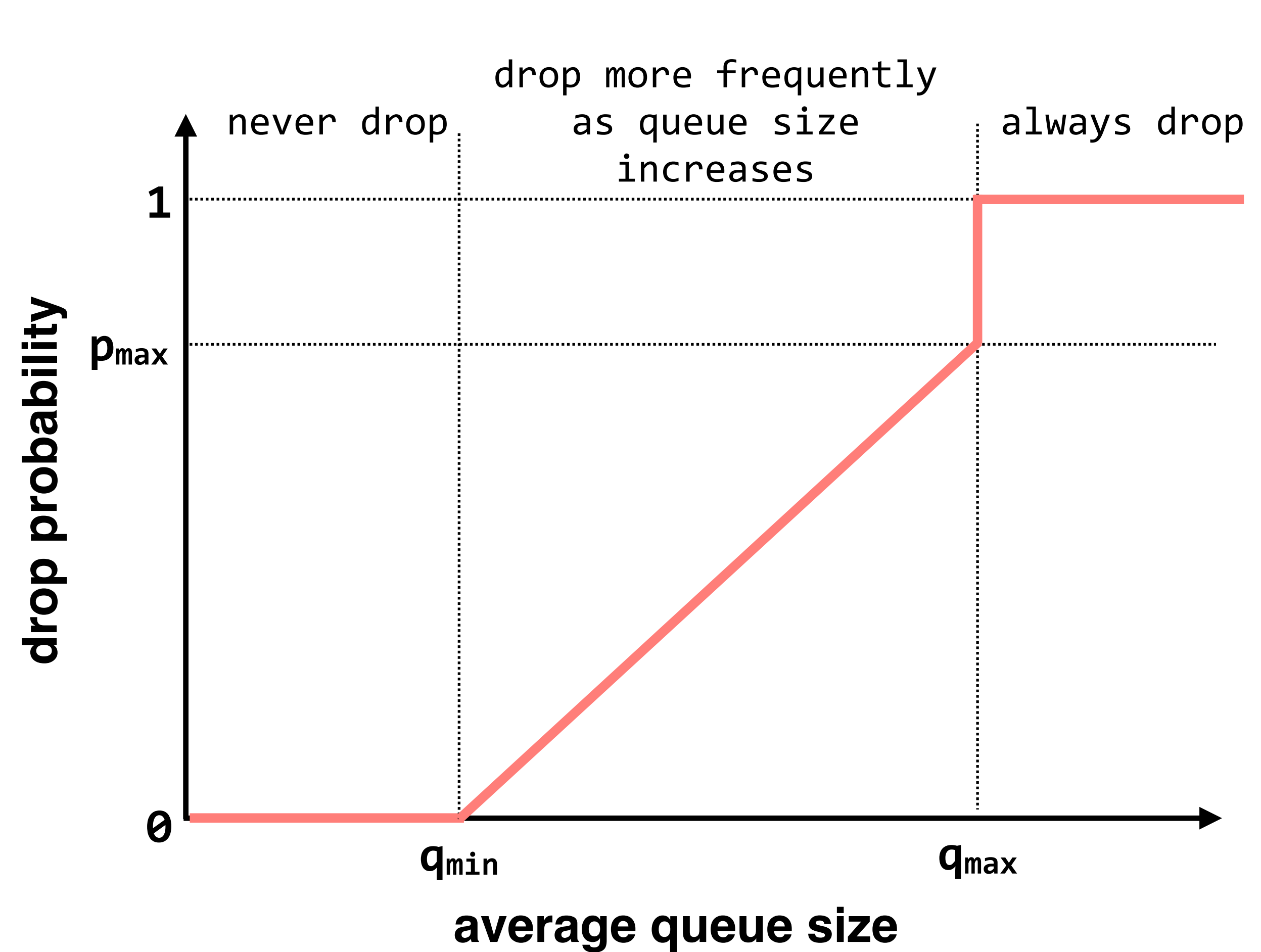
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queue management: given a queue, when should it drop packets?

droptail: drop packets only when the queue is full. simple, but leads to high delays and synchronizes flows.

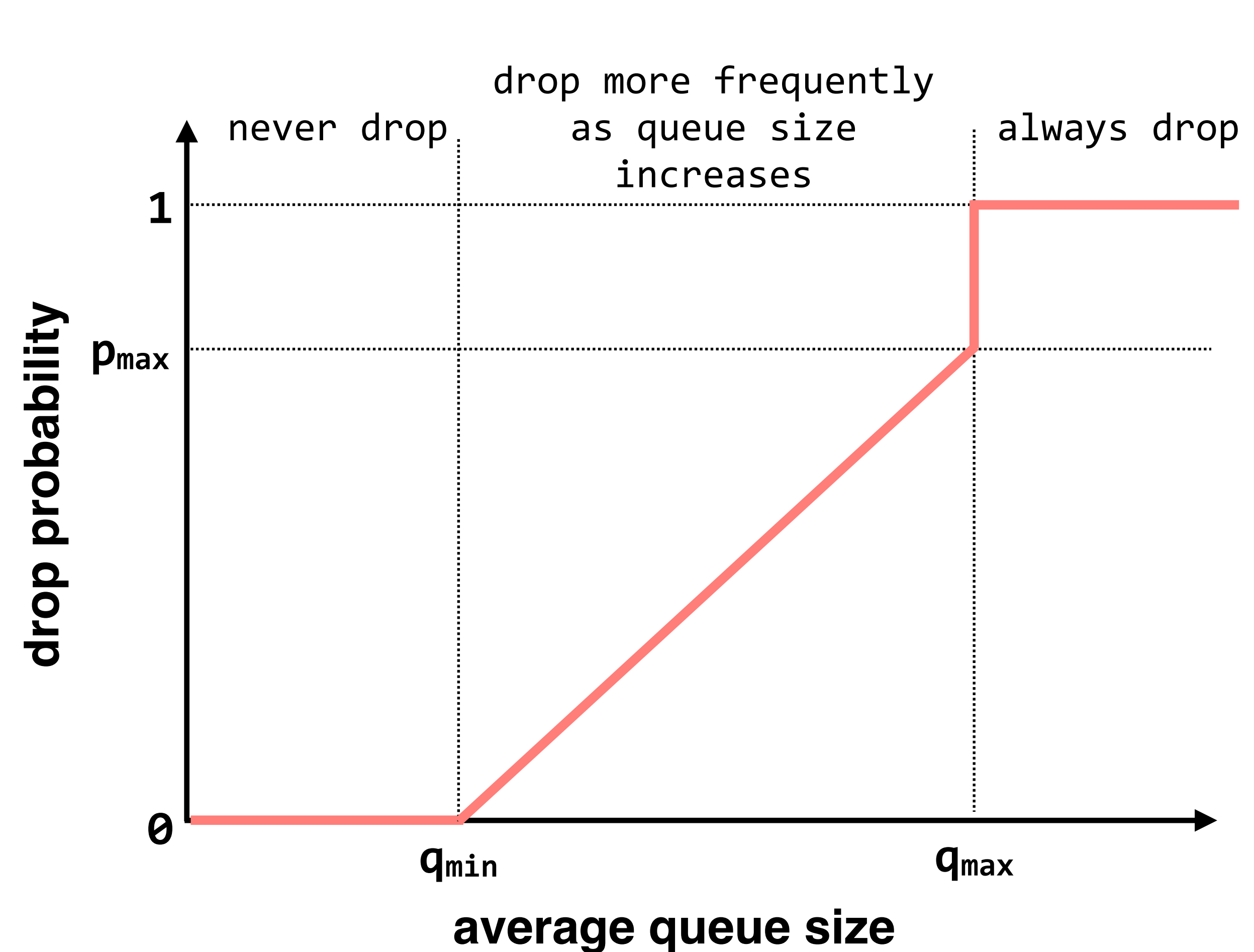
RED: drop packets before the queue is full, with increasing probability as the queue grows. prevents queue lengths from oscillating, decreases delay, flows don't synchronize.



queue management: given a queue, when should it drop (or mark) packets?

droptail: drop packets only when the queue is full. simple, but leads to high delays and synchronizes flows.

RED (drops) / ECN (marks): drop (or mark) packets before the queue is full: with increasing probability as the queue grows. prevents queue lengths from oscillating, decreases delay, flows don't synchronize. but complex and hard to pick parameters



as long as our switches are taking a more active role, let's see what else they can do

(we'll return to queue management later in the lecture)

delay-based scheduling: can we give latency guarantees for some types of traffic?

priority queueing: put latency-sensitive traffic in its own queue and serve that queue first (can extend this idea to multiple queues/types of traffic)

question: what could go wrong here?

delay-based scheduling: can we give latency guarantees for some types of traffic?

priority queueing: put latency-sensitive traffic in its own queue and serve that queue first. does *not* prevent the latency-sensitive traffic from “starving out” the other traffic (in other queues).

as long as our switches are taking a more active role, let's see what else they can do

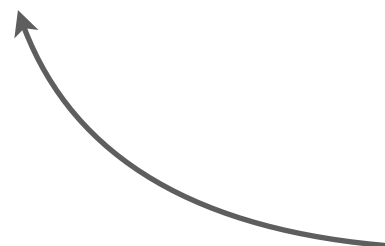
(we'll return to priority queueing later in the lecture)

bandwidth-based scheduling: can we allocate specific amounts of bandwidth to some traffic?

round robin: can't handle variable packet sizes (and in its most basic form doesn't allow us to weight traffic differently)

deficit round robin: handles variable packet sizes (even within the same queue), near-perfect fairness and low packet processing overhead

deficit round robin also doesn't require a mean packet size, which is another good thing



in each round:

for each queue q:

q.credit += q.quantum

while q.credit >= size of next packet p:
q.credit -= size of p
send p

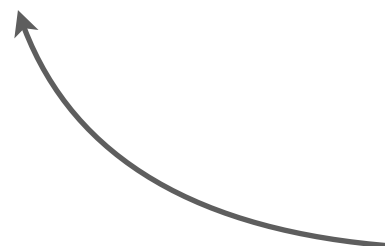
question: suppose one of our queues is empty for many rounds. should it accumulate credit while empty?

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in each round:

for each queue q:

if q is not empty:

q.credit += q.quantum

while q.credit >= size of next packet p:

q.credit -= size of p

send p

else:


q.credit = 0

now let's start revisiting some of our previous strategies

delay-based scheduling: can we give latency guarantees for some types of traffic?

priority queueing: put latency-sensitive traffic in its own queue and serve that queue first. does *not* prevent the latency-sensitive traffic from “starving out” the other traffic (in other queues).

can solve this problem by doing something similar to bandwidth-based scheduling across the two queues



in-network resource management

type of management	what does this type of management allow a switch to do	example protocols	how the protocol works	pros/cons?
Queue Management	signal congestion, potentially before queues are full	DropTail	drop packets when the queue is full	simple, but queues get full (among other problems)
		RED, ECN	drop or mark packets before the queue is full	can keep queues from filling up, but complicated
Delay-based Scheduling	prioritize latency-sensitive traffic	Priority Queueing	serve some queues before others	prioritized queues can starve out the others
Bandwidth-based Scheduling	enforce (weighted) fairness among different types of traffic	Round-robin	try to give each type of traffic an equal share of bandwidth	can't handle variable packet sizes
		Weighted Round-robin	round robin, but incorporate average packet size	average packet size hard to get
		Deficit Round-robin	round robin, but do a better job with packet sizes	honestly pretty good

we didn't cover weighted round-robin; this is just to give you a sense that there are algorithms that exist "between" round-robin and deficit round-robin

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is in-network resource management a good idea on the Internet?

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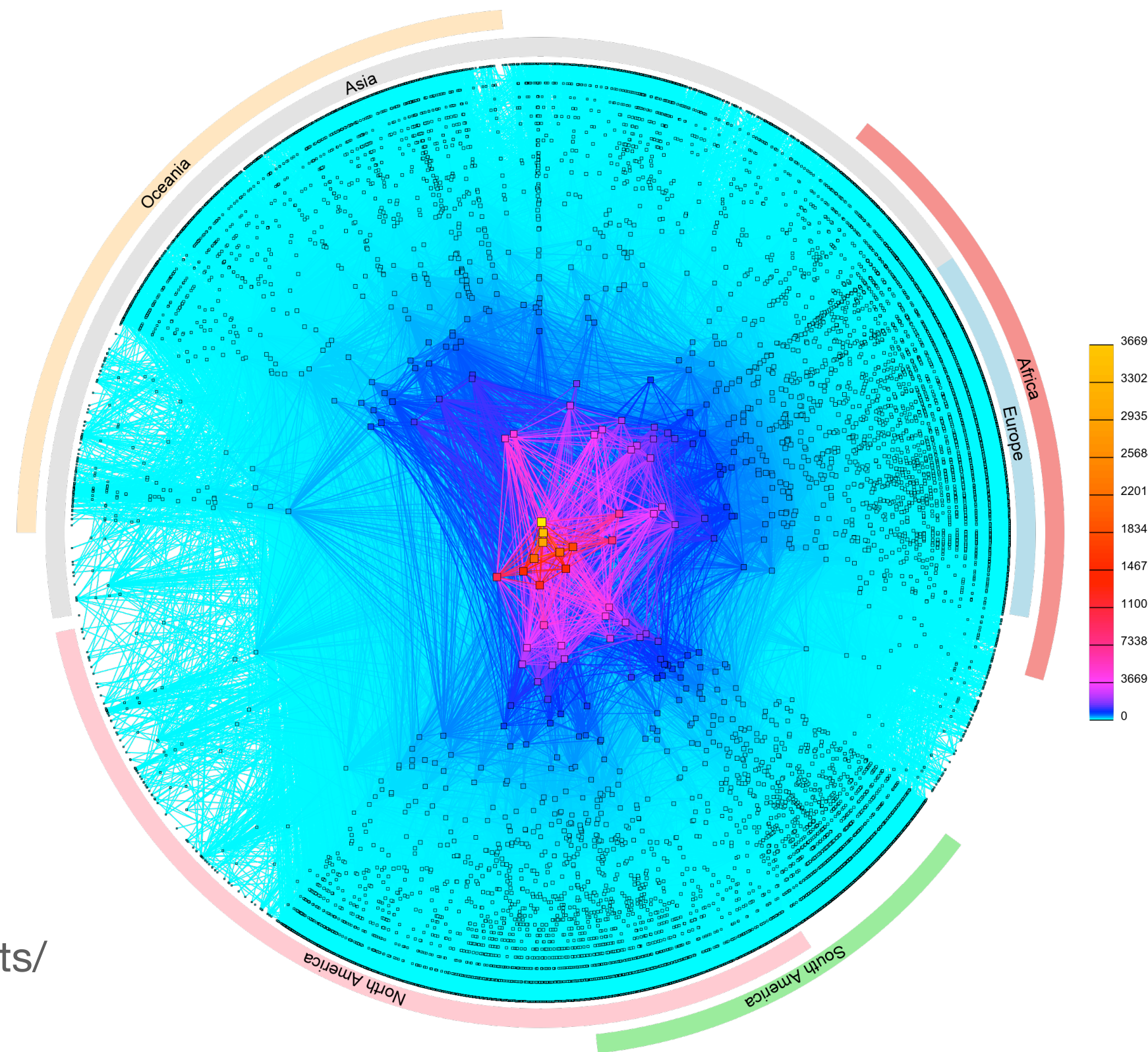
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Sally Floyd, Who Helped Things Run Smoothly Online, Dies at 69

In the early 1990s, Dr. Floyd was one of the inventors of Random Early Detection, which continues to play a vital role in the stability of the internet.



Sally Floyd. “Her work on congestion control,” a colleague said, helped keep the internet “working for everyone.” Carole Leita

6.1800 in the news

One byproduct of Dr. Floyd’s work reflected her passion for keeping things fair to all internet users. “Her work on congestion control was about keeping it working for everyone,” Dr. Kohler said. “For people with fast connections, and for people with slow connections.”

<https://www.nytimes.com/2019/09/04/science/sally-floyd-dead.html>