OPTIMISING TCP BUFFERS FOR SATELLITE COMMUNICATION LINKS

Presentation by Alexander Khouri

Based on ‘*Striking a Balance Between Bufferbloat and TCP Queue Oscillation in Satellite Input Buffers*’, by Ulrich Speidel & Lei Quan

AGENDA:

- ► Network Performance Metrics
- ► Satellite Data Links
- ► Transmission Control Protocol (TCP)
- ► Link Buffers
- ► Network Traffic Experiment

Types of Network Delays

- **Transmission Delay**
  → *Time routers take to push bits into a link*
- **Propagation Delay**
  → *Time signals take to travel physical distance*
- **Queueing Delay**
  → *Time packets spend in link buffers*

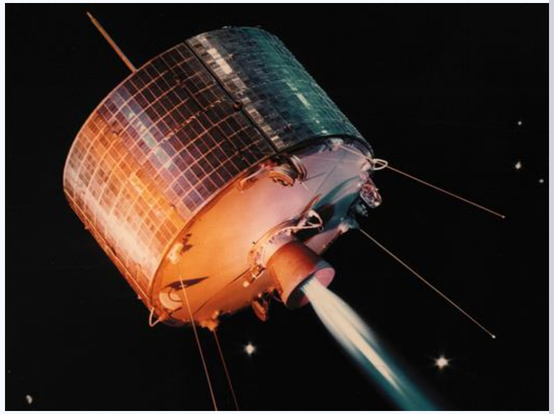
Bandwidth Delay Product (BDP)

- Defines the maximum amount of transmitted data that can exist inside a communication link
- Generally used for defining router buffer sizes

BDP = Bandwidth (bits/second) x Round-Trip Time (seconds)

Geostationary Earth Orbit (GEO) Satellites

- Altitude = ~36,000km
- Orbital Period = 1 day
- One satellite required for continuous link
- Large propagation delay



Syncom 1

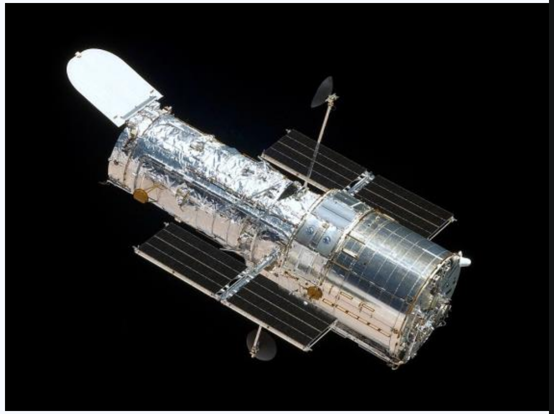
Medium Earth Orbit (MEO) Satellites

- Altitude = 2,000-36,000km
- Orbital Period = 2-24 hours
- Several satellites required for continuous link
- Medium propagation delay

GPS Block III

Low Earth Orbit (LEO) Satellites

- Altitude = <2,000km
- Orbital Period = <2 hours
- Many satellites required for continuous link
- Low(?) propagation delay

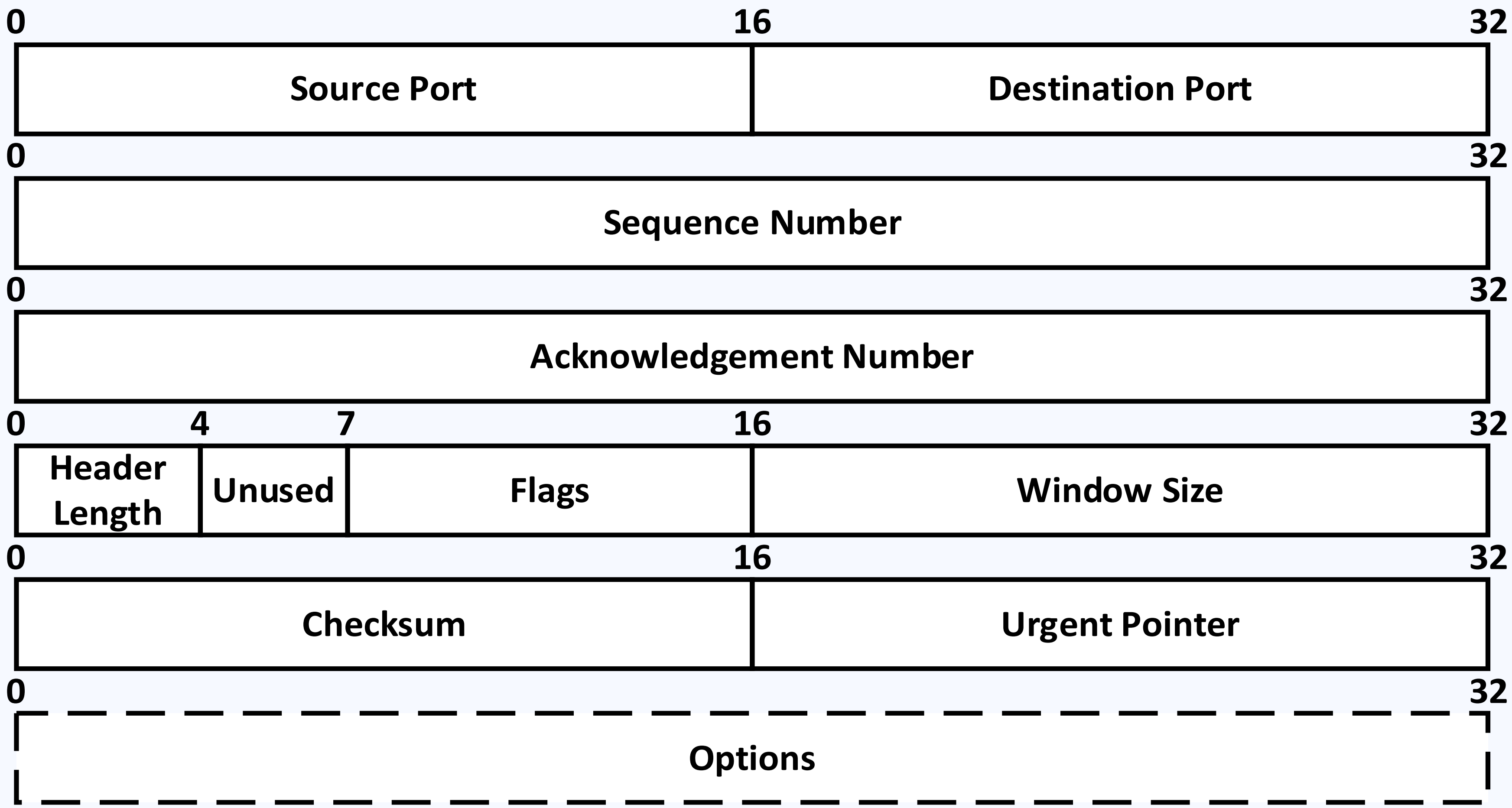


Hubble Telescope

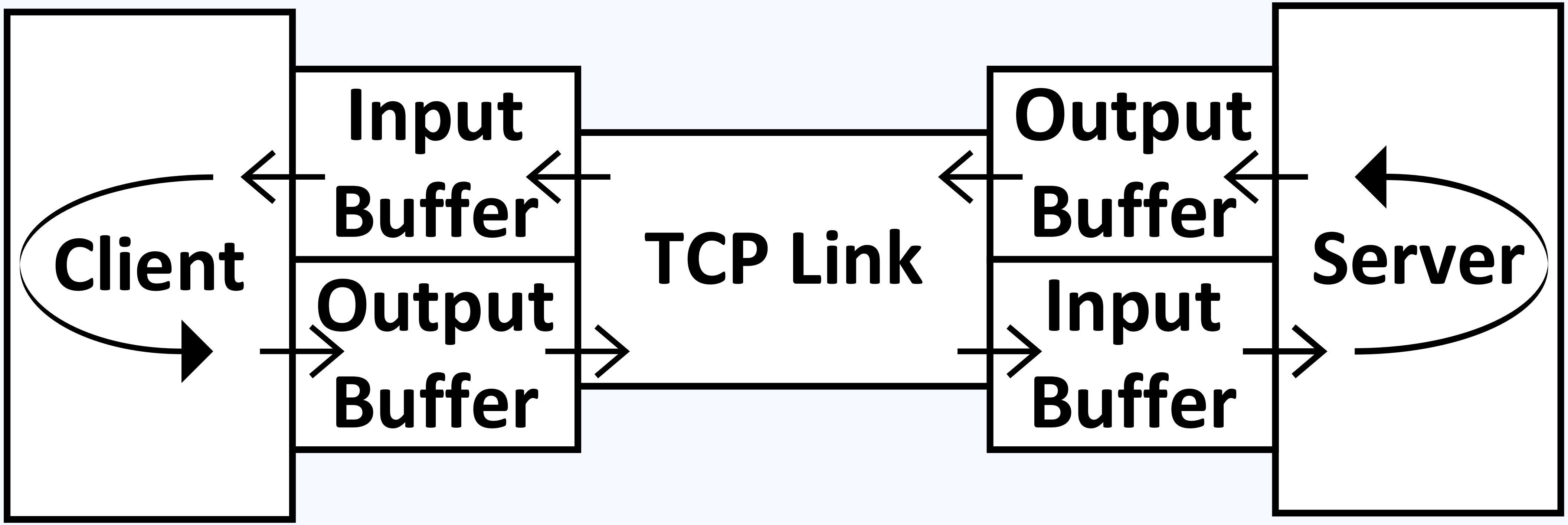
Transmission Control Protocol (TCP)

- Initiates connections via 3-way handshake
- Recipients acknowledge packets by sending ‘ACKs’
  - → *Lost packets are retransmitted*
  - → *Many dropped packets = Network congestion*
- Sends groups of packets in ‘windows’
  - → *Window sizes are adjusted to prevent congestion*

TCP Header


0
16
32
Source Port
Destination Port
0
32
Sequence Number
0
32
Acknowledgement Number
0
4
7
16
32
Header Length
Unused
Flags
Window Size
0
16
32
Checksum
Urgent Pointer
0
32
Options

Input/Output Buffers



Input/Output Buffers

- Output is buffered while sender waits for ACKs

  → *This causes transmission delays*

- Input is buffered while receiver processes packets

  → *This causes queueing delays*

  → *Larger buffer = Longer queueing delays*

  → *Smaller buffer = Receiver drops more packets*

  = More propagation delays

Buffer Management Algorithms

- Early buffers used simple First-In First-Out (FIFO) algorithms

  → *PROBLEM: Dense data channels occupy large buffer space, blocking smaller channels*

  → *SOLUTION: Randomly drop incoming packets with increasing probability as buffer fills i.e. 'Random Early Drop' (RED)*

  → *NEW PROBLEM: Many packets get dropped if buffers don't get emptied*

Bufferbloat vs Queue Oscillation

- Bufferbloat = Routers failing to clear input buffers

  → *Causes many packets to be dropped, which creates more propagation delays*

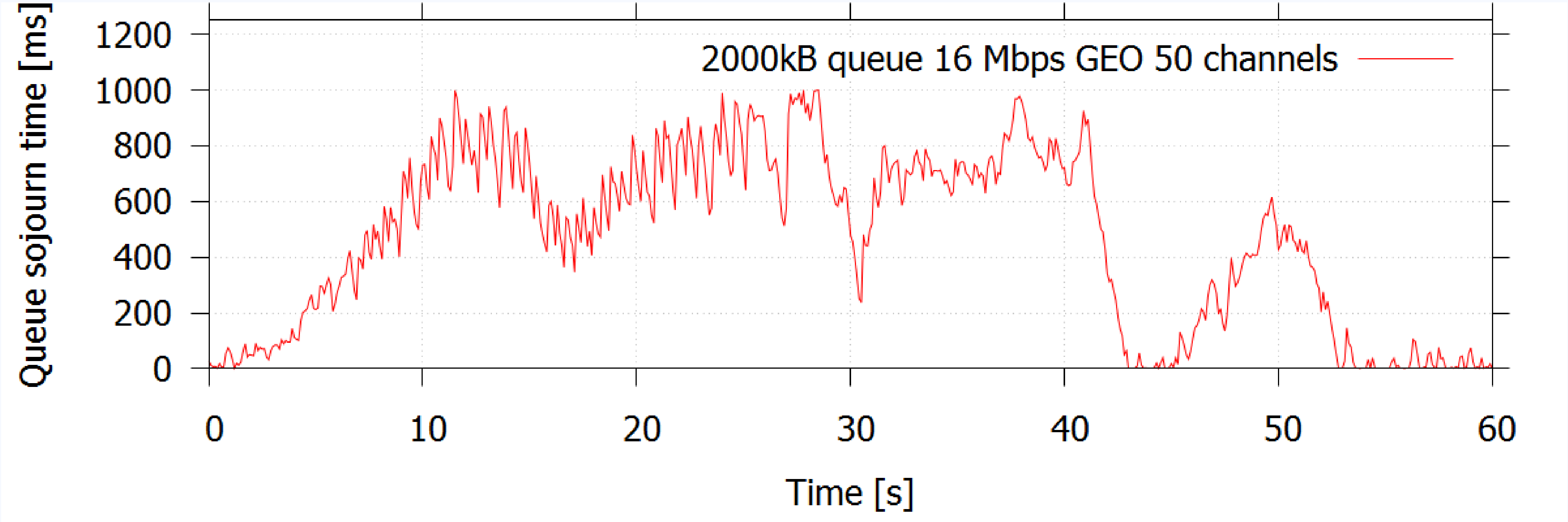
  → *Larger buffers take longer to clear*

- Queue Oscillation = Regular buffer clearing

  → *Still drops packets, but reduces queueing delays*

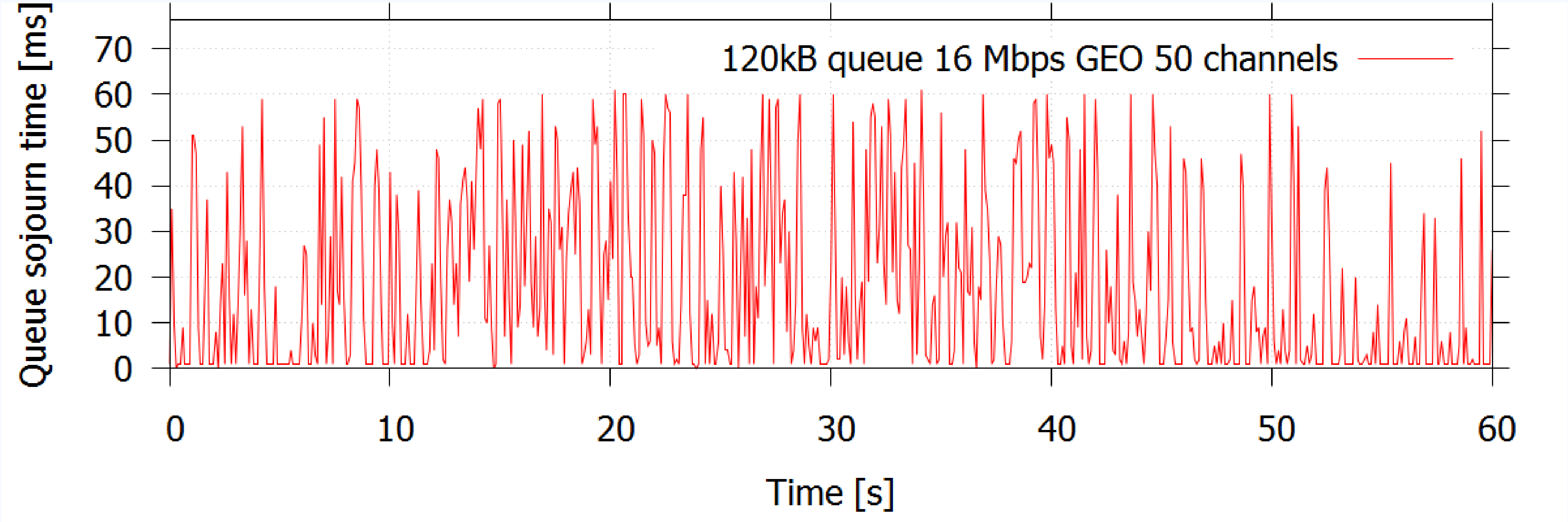
  → *Smaller buffers are easier to clear*

Large Buffers vs Small Buffers



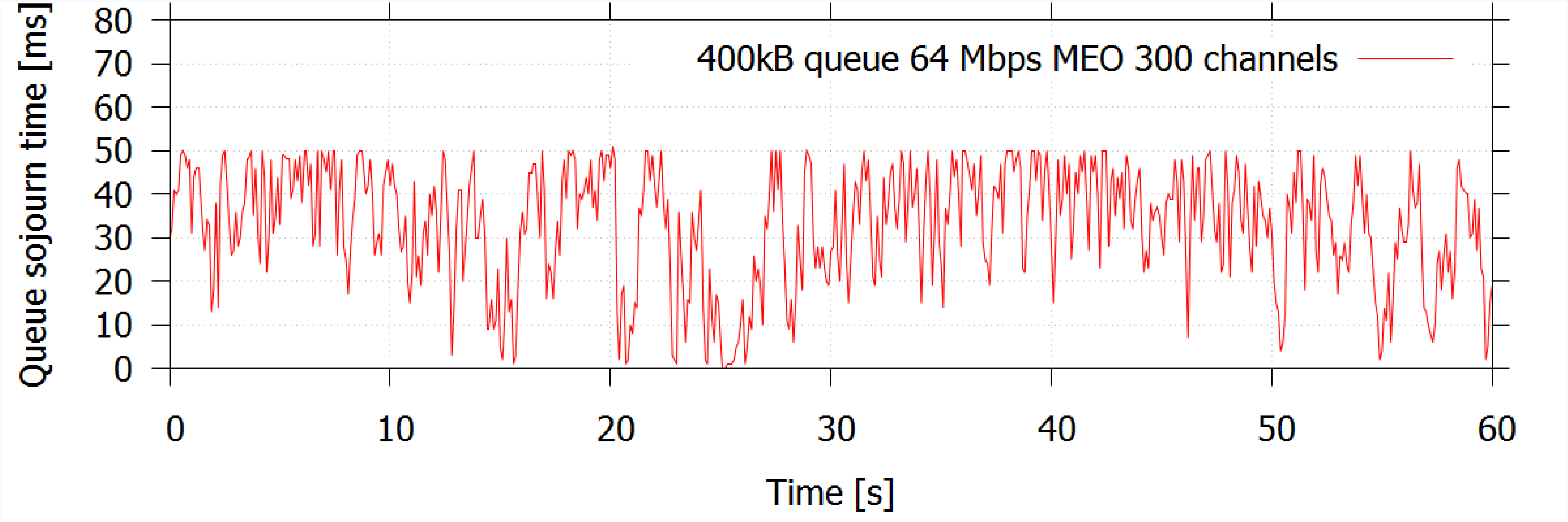
Queue sojourn time for a simulated 16Mbps GEO link using a 2MB buffer, transferring 40MB of TCP data through 50 channels over a 60 second period.

Large Buffers vs Small Buffers



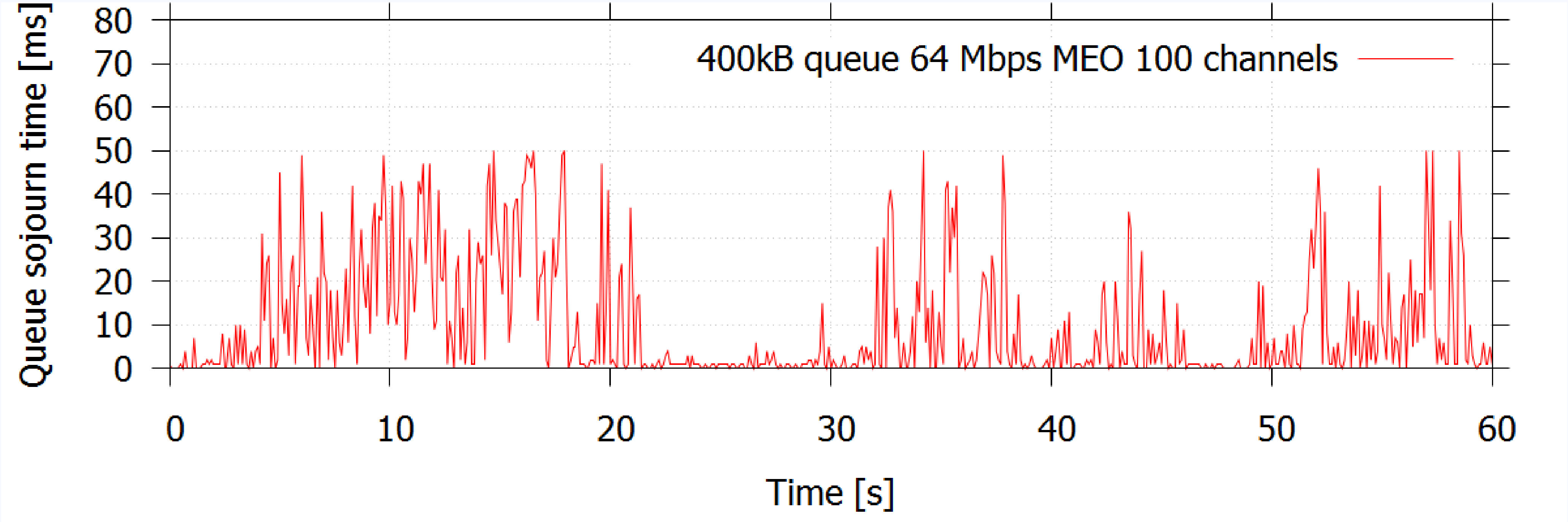
Queue sojourn time for a simulated 16Mbps GEO link using a 120kB buffer, transferring 40MB of TCP data through 50 channels over a 60 second period.

Many Channels vs Few Channels



Queue sojourn time for a simulated 64Mbps MEO link using a 400kB buffer, transferring 160MB of TCP data through 300 channels over a 60 second period.

Many Channels vs Few Channels



Queue sojourn time for a simulated 64Mbps MEO link using a 400kB buffer, transferring 160MB of TCP data through 100 channels over a 60 second period.

Conclusions

- Benefits of smaller buffers:
  - ➢ Buffers cleared more often
  - ➢ Shorter queueing delays
  - ➢ More consistent network performance
- Effects of more channels:
  - ➢ Buffers cleared less often
  - ➢ More queueing delays

SOLUTION:

$$Buffer = \frac{\mathrm{BDP}}{\sqrt{Channels}}$$

Questions?

References:

U. Speidel and L. Qian, "Striking a Balance between Bufferbloat and TCP Queue Oscillation in Satellite Input Buffers," *2018 IEEE Global Communications Conference (GLOBECOM)*, Abu Dhabi, United Arab Emirates, 2018, pp. 1-6, doi: 10.1109/GLOCOM.2018.8647662.

GeeksforGeeks, “Packet Switching and Delays in Computer Network,” *GeeksforGeeks*, August 12, 2019. [Online]. Available: https://www.geeksforgeeks.org/packet-switching-and-delays-in-computer-network. [Accessed August 27, 2020].

K. Boyini, “Packet Switching and Delays in Computer Network,” *Tutorials Point*, February 21, 2019. [Online]. Available: https://www.tutorialspoint.com/bandwidth-delay-product. [Accessed August 27, 2020].

H. Riebeek, “Catalog of Earth Satellite Orbits,” *The Earth Observatory*, September 4, 2009. [Online]. Available: https://earthobservatory.nasa.gov/features/OrbitsCatalog. [Accessed August 27, 2020].

References:

K. Boyini, “Packet Switching and Delays in Computer Network,” *Tutorials Point*, February 21, 2019. [Online]. Available: https://www.tutorialspoint.com/data_communication_computer_network/transmission_control_protocol. [Accessed August 27, 2020].

Braden, et al., “RFC 2309 - Recommendations on Queue Management and Congestion Avoidance in the Internet,” *Internet Engineering Task Force*, February, 1998. [Online]. Available: https://tools.ietf.org/html/rfc2309. [Accessed August 27, 2020].