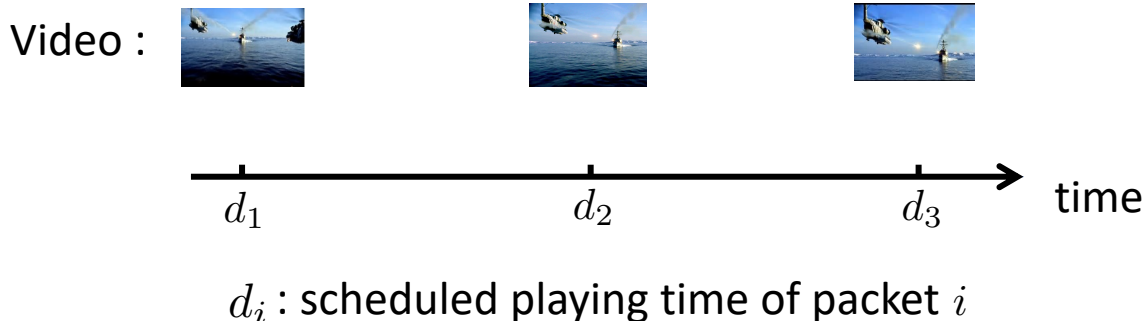


Low Latency Queuing Control in Extendable Mobile Ad-hoc Network Emulator (EMANE)

Present by Shaoyi Li

Background of our Research

- Network latency is any kind of delay that happens in data communication over a network, including jitter, delay, etc.
- **Example:** Jitter probability in video streaming
 - Suppose a video has just started to stream.
 - Every packet must be delivered before its scheduled playing time (e.g., 10 mins after starting); otherwise, a *jitter event* occurs
 - Hence, *jitter event = being late after scheduled playing time (deadline or due date)*
 - Users suffer annoying freezes
- How to minimize the probability of jitter events?



Answer: Packet-Level Queueing Control

- The key lies in **finding the right order to send packets.**

Theorem: [Sun-Shroff-Koksal'16,17, Bedewy-Sun-Shroff'19,19-2]

Which packet to send first? Depends on which **delay metric to minimize**

Jitter probability (lateness): Earliest Due Date (**EDD**) First

Average delay: Shortest Remaining Processing Time (**SRPT**) First

Maximum delay: First-Come, First-Served (**FCFS**)

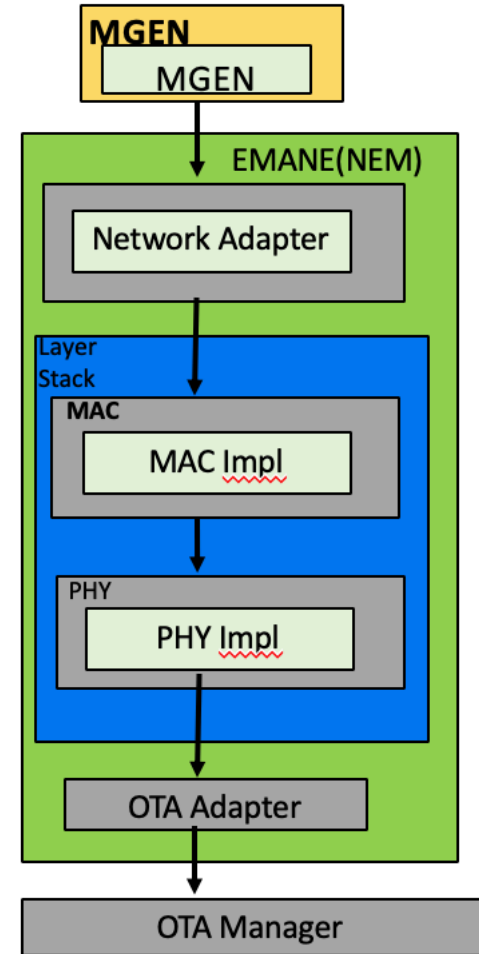
Age of Information (AoI): Last-Generated, First-Served (**LGFS**)

How to evaluate the policy performance in delay control?

- **Hardware field test:** Expensive and hard to control
- **Software solutions**
 - **Simulators:** Network Simulator version 2/3 (**NS2/NS3**) is not real-time.
 - **Emulators:** 1) Common Open Research Emulator (**CORE**) only simulates upper three OSI layers not including MAC layer queue module.
2) Extendable Mobile Ad-hoc Network Emulator (**EMANE**) emulates MAC and PHY layer.

EMANE Architecture

- **Multi-Generator (MGEN)**
 - Emulates upper three OSI layers
 - Generates UDP IP traffic flows
- **EMANE**
 - Describes Network Emulation Modules (NEMs)
 - Reads the traffic flow through API
 - Emulates MAC and PHY layer
 - TDMA radio module
 - Collect data into log file



Network Emulation Modules (NEMs)

EMANE Installation

- EMANE provides a separate network IP stacks to implement independent NEMs. This virtualization is most often implemented using Linux Containers (LXCs).
- **Operating system:** Linux in Ubuntu 14.04
- Complicated Installation
 - Ubuntu 14.04 on Oracle VM VirtualBox 5.02
 - More than 30 pre-built packages
 - 7 pluggable applications
 - 10 radios and 10 nodes addresses configuration
- One lost step in installation causes system running problems
 - User installation guide: **2 weeks → 30 minutes**
 - FAQ manual shared in lab for future use

Assigning Due Time to Packet generated from MGEN

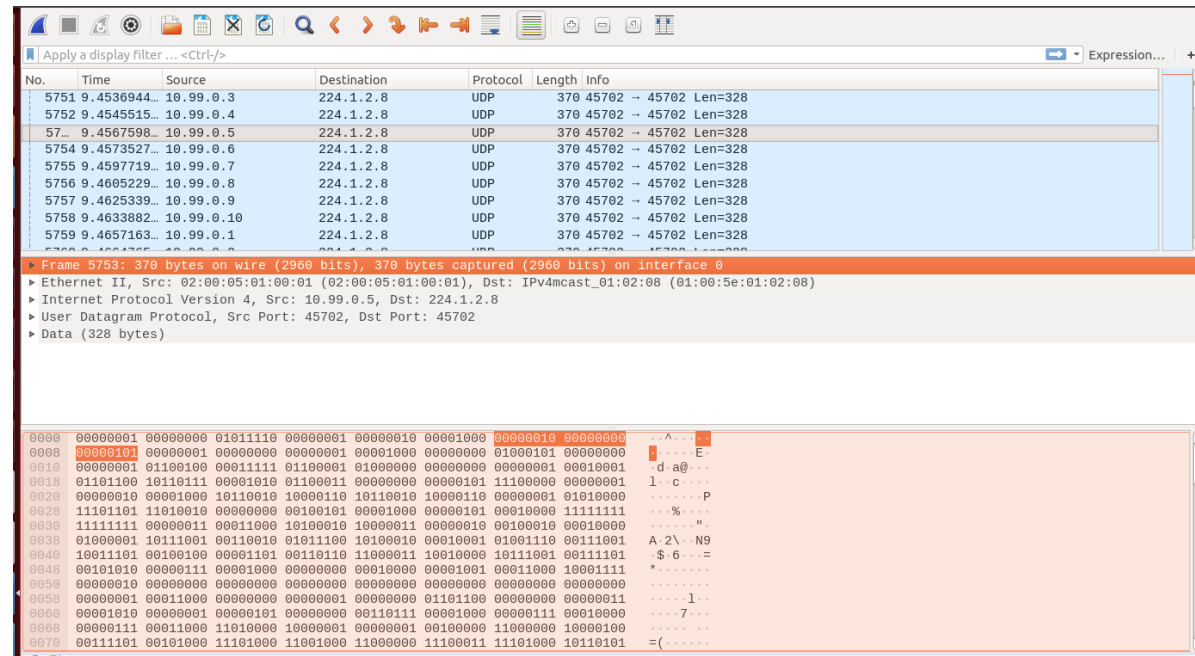
MGEN output packet format

IP Header	UDP Header	MGEN message data payload	Data payload
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- MGEN output packet contains **four** parts
 - **UDP** and **IP header**
 - **MGEN message data payload** for event message read at destination
 - **Packet Data payload**
- Due time assignment for each packet
 - Parameters are defined in MGEN script using command line
 - Defines **absolute** due time in **hexadecimal**
- Difficulties in locating due time in packet data
 - Data stream is transmitted in **network bytes order (big-endian)**
 - Not aware of the locations of due time in 512 kB packet

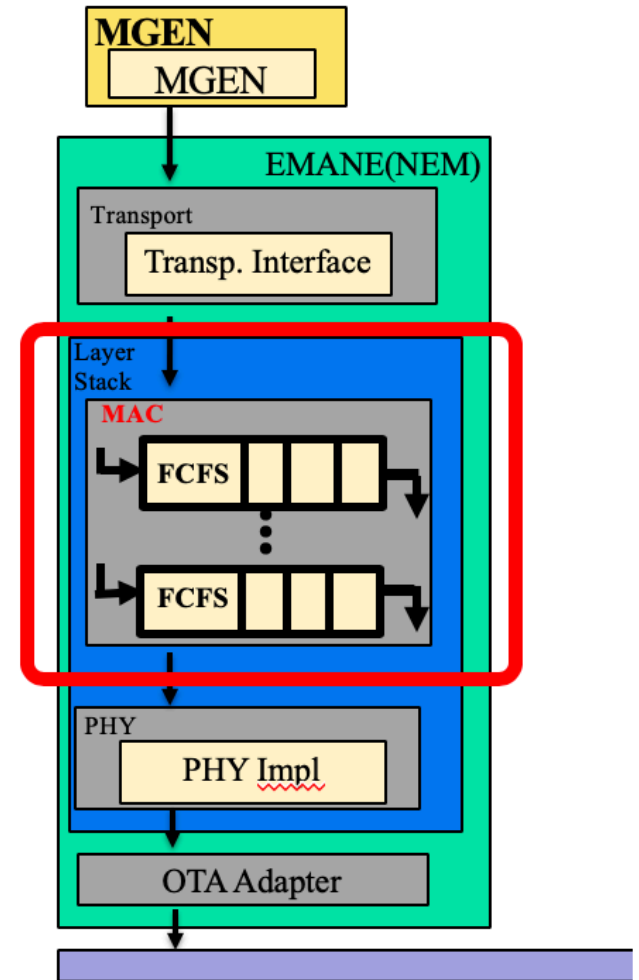
Locate Data Payload in Packets from MGEN

- Using Wireshark tool to parse packet data
 - Automatic data collection and data interpretation tool avoids manual operation errors.
 - Locate the due time in a 512kB packet accurately.



MAC Layer Queue Module in EMANE

- Queue module in EMANE MAC layer
 - FCFS queue discipline
 - 5 priority queues with levels 0-4
 - Queue module uses DSCP (first 6 bits in TOS field in IP header) as packet priority.
 - We set all packets' priority as 0 in MGEN, the queue is locked to level 0
- Dropping the oldest packet when enqueue operation occurs on a queue which is at its maximum size = 255 packets.



Low Complexity Queue Scheduling Module

- EDD policy as an Example
 - Use “list” data structure in standard C++
 - Insert at right position upon Enqueue
 - Packets always ordered in their due dates
 - **Lower computational complexity $O(n)$ than bubble sorting $O(n^2)$**

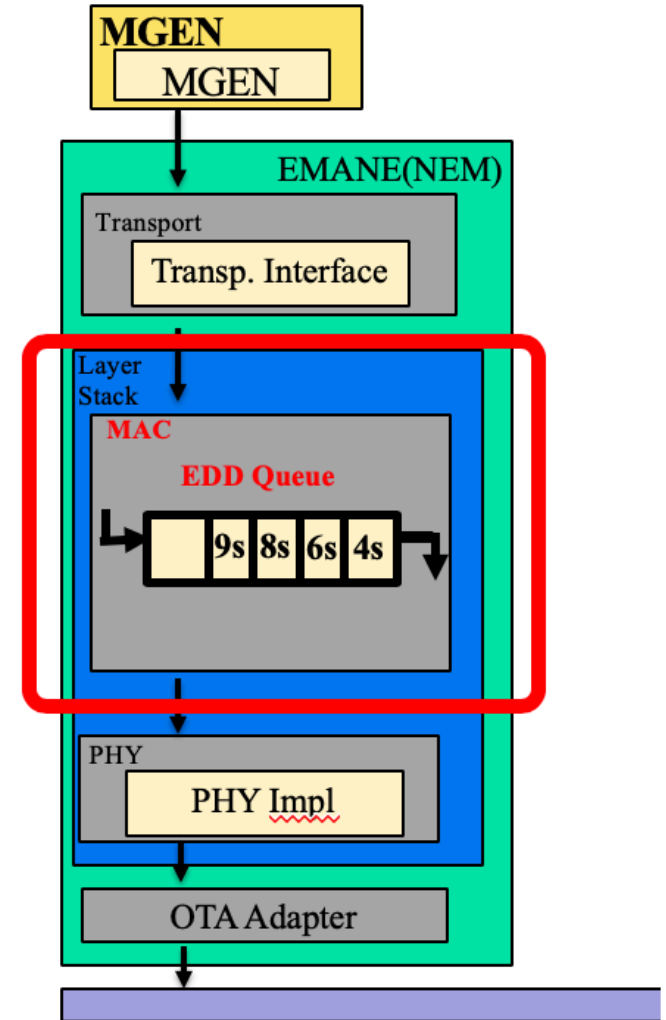
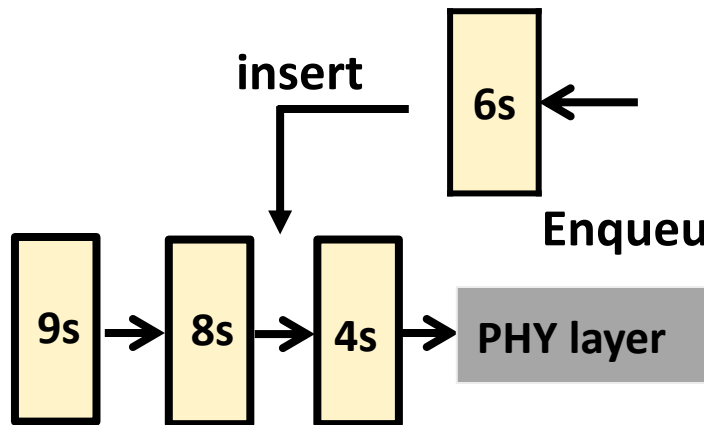
Due date = 6 seconds

insert

6s

Enqueue

Data structure:
list



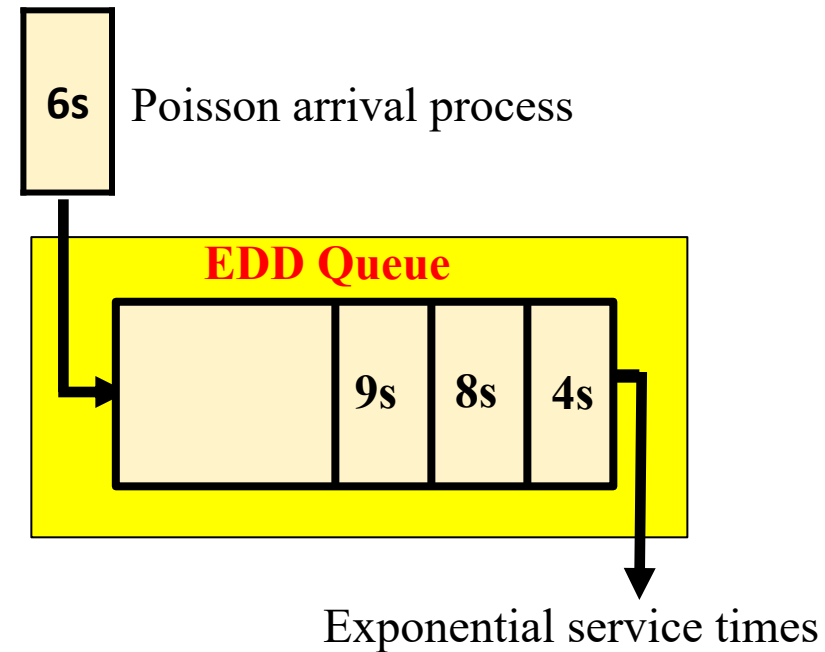
Queue Module Development

- Difficulties in EMANE module development
 - EMANE is a large-scale emulator with **long compilation time**, usually longer than 15mins per time.
 - Modules in EMANE are highly coupled, one error or bug in syntax causes **butterfly effect**.
 - **No debug mode** to trace packet in module and parse critical packet data, such as packet sequence number or due time, etc.
- Queue debugging in EMANE is time-consuming
 - Print key variables in log file → Long log file, including all events information.
 - Large quantity print operations run out memory → Event information is lost in log file.
 - Bugs → Log file not generated, stuck for a long time.
- No efficient debug and development method in current research.
- **Solution: Code migration**

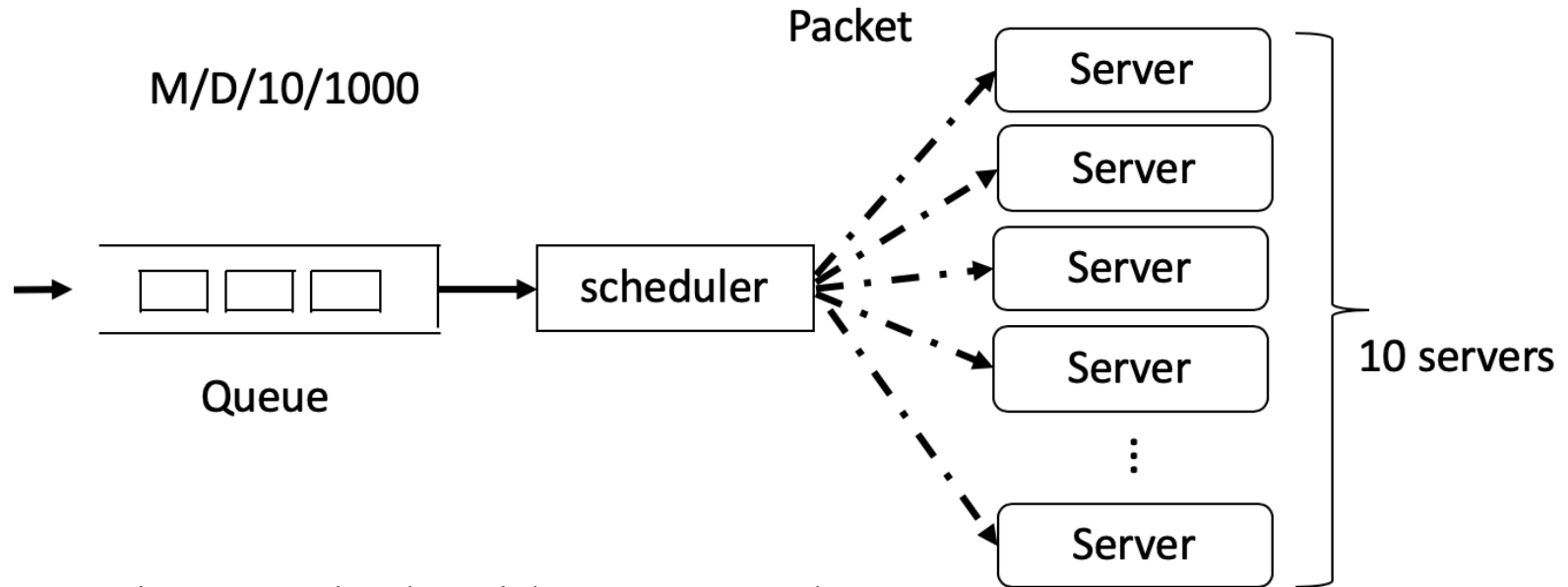
Improve Development and Debugging Efficiency

- We design an independent queue module in Xcode
 - Migrate the related modules from EMANE into Xcode
 - Simplify EMANE queue module: Delete packet fragmentation, because the default TDMA slot bytes limit is further larger than the packet size.
- We build a debugging environment outside of EMANE
 - Higher layer → Poisson arrivals
 - lower layer → Exp service times
 - Migrate back to EMANE after debugging, match our module interfaces with EMANE's module.
 - Significantly reduce debugging time

Debugging Environment
outside of EMANE:



Queuing System Introduction

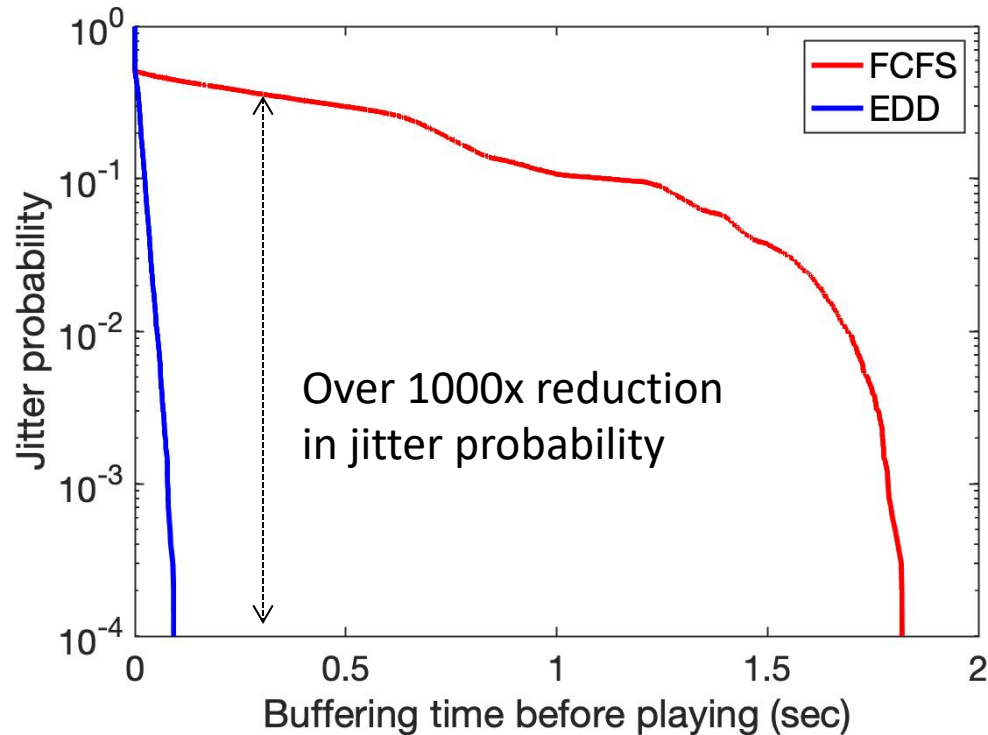


- Poisson arrivals with 10000 packets
- Deterministic service process
- 10 users
- Queue size = 1000
 - Tradeoff between queuing delay and queue overfilling
- Single queue with FCFS and EDD policy

Simulation Data Pre-Process

- EMANE log file records all the events happening in system which are printed with words and data, MATLAB can't read it directly.
 - Design a Python keywords crawler to extract useful data into text files.
- EMANE does dequeue operation even the queue is empty which generates worthless data.
 - Set flag in dequeued packet from an empty queue and not collect these wrong data.

Jitter probability of Video Stream

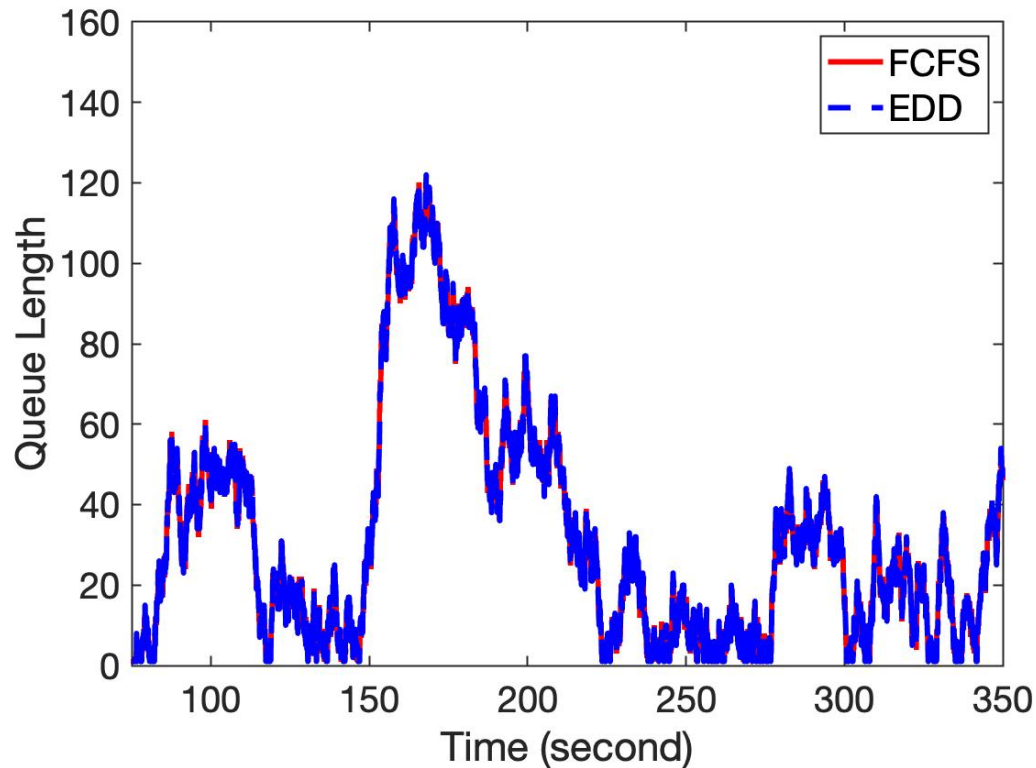


$$\lambda = 64 \text{ packets/second}$$

Over 1000x reduction in jitter probability!

Why? in current EMANE module, some packets that need to be sent immediately are sent several seconds later.

Queue Length (Average Delay)



$\lambda = 64$ packets/second

Packet reordering does not affect average delay

Conclusions

- Summarize the installation steps into a guide which makes the installation **efficient** and **accurate**.
- Use **MGEN** to configure the emulation parameters, and locate packet data payload using Wireshark.
- Design an **independent low complexity** EDD queue module matching EMANE system with C++ standard data structure **List**.
- Propose an efficient **debug** and **software development** method for EMANE.
- EDD policy overwhelms FCFS policy by **1000x jitter probability reduction** without affecting **average delay**.

Future Work

- Multiple delay objectives in different flows
 - Expand one flow to several flows with various policies
 - Resolve priority conflicts among different flows
- Implement EDD queue module in Multi-hop network
 - Network topology changes.
 - The first node perform as a bridge.