



# Enhancing Blockage Detection and Handover on 60 GHz Networks with P4 Programmable Data Planes

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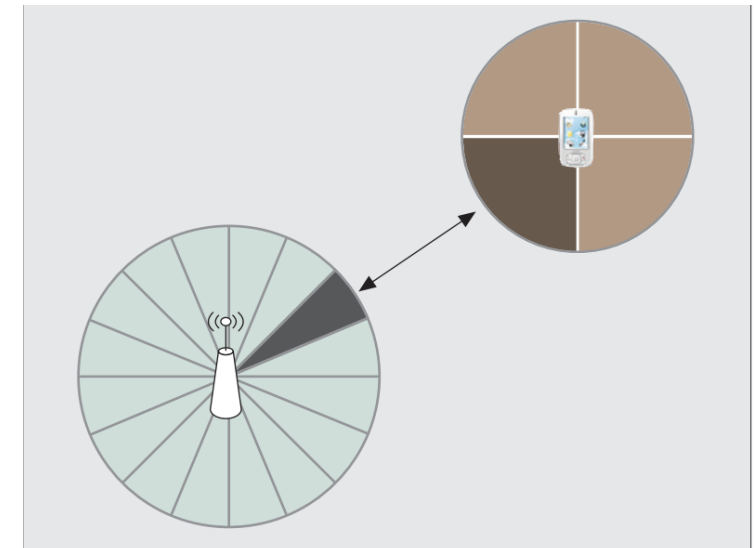
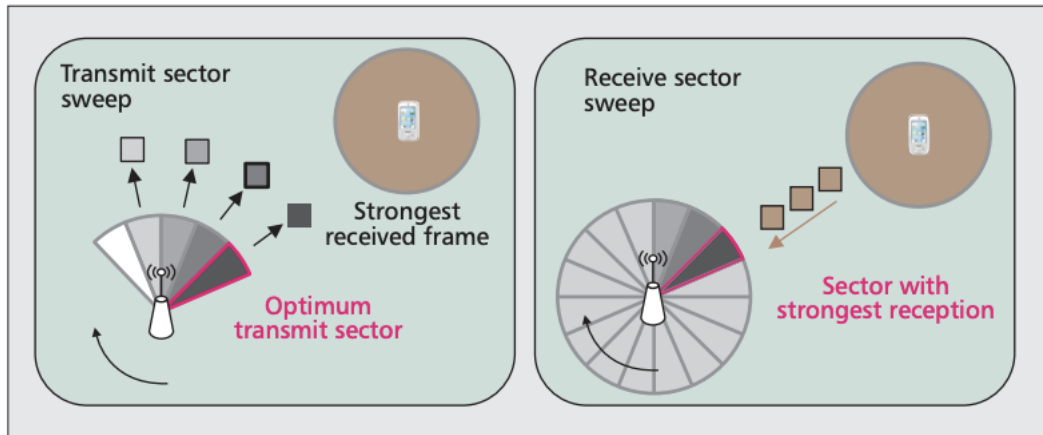
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# Agenda

- mmWave and the Blockage Problem
- P4 Programmable Switches
- Motivation
- Results and Evaluations
- Contributions
- Limitations

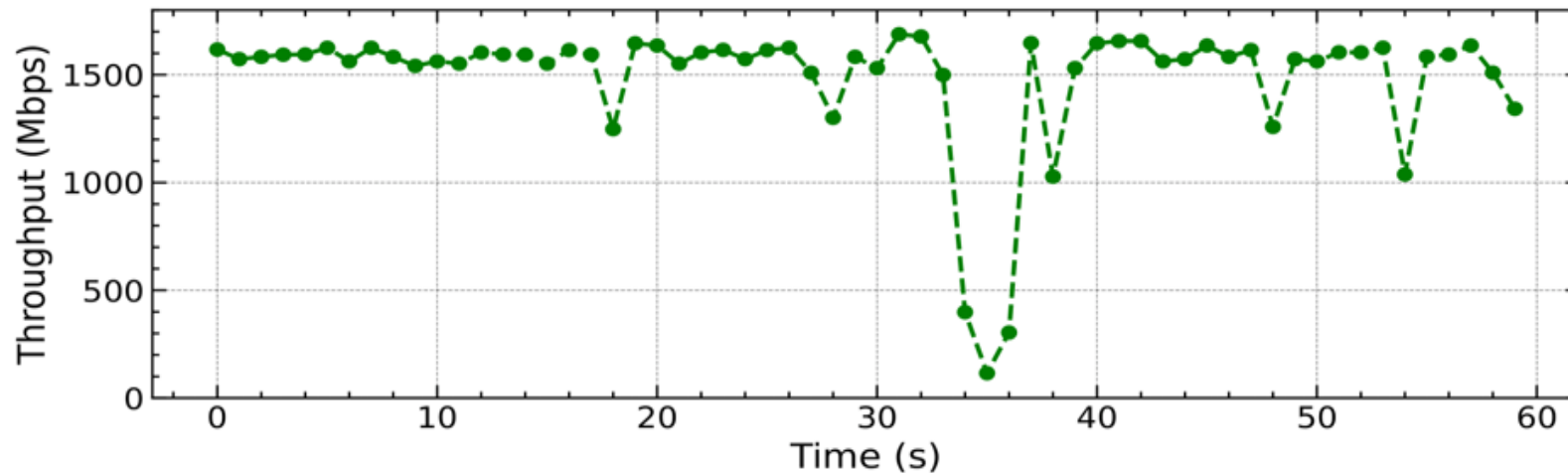
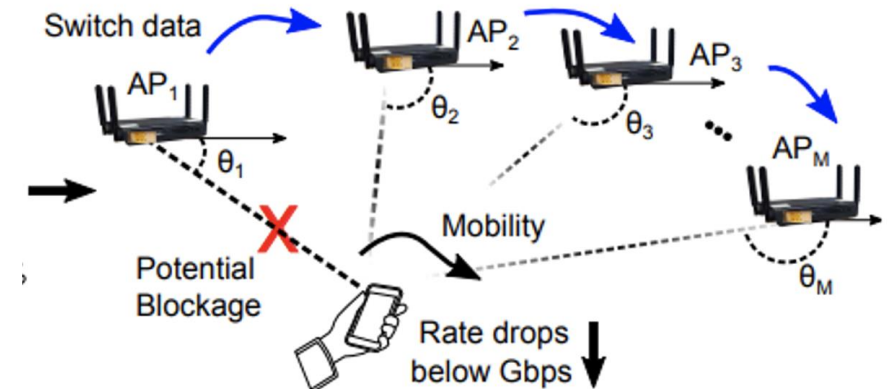
# mmWave

- Refers to the band of frequencies between 30 GHz and 300 GHz
- Uses the unlicensed spectrum (e.g., 60GHz)
- Offers significant bandwidth advantages and enables high-speed data transmission
- Uses the beamforming technique to overcome the limitations of limited range and signal attenuation



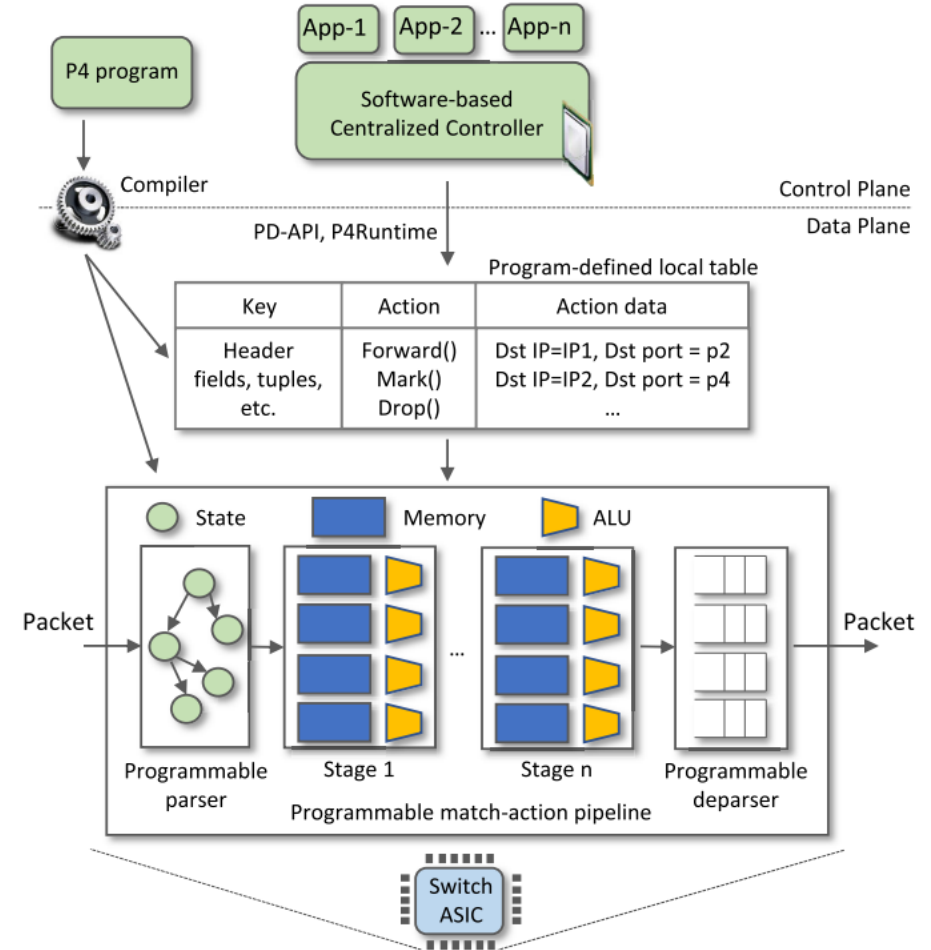
# Blockage Problem

- mmWave signals heavily rely on line-of-sight communication
- Obstacles like buildings and objects can block or weaken the signal
- Reduced coverage and potential signal loss are observed when line-of-sight is obstructed



# P4 Programmable Switches

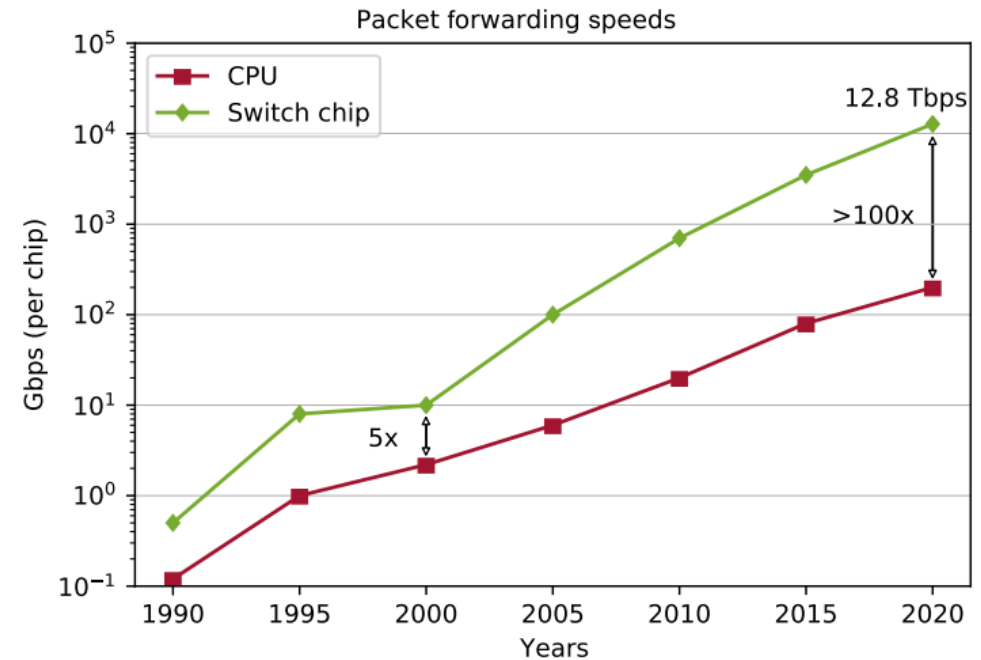
- P4<sup>1</sup> programmable switches permit a programmer to program the data plane
  - Define and parse new protocols
  - Customize packet processing functions
  - Measure events occurring in the data plane with high precision
  - Offload applications to the data plane



1. P4 stands for stands for Programming Protocol-independent Packet Processors

# P4 Programmable Switches

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Reproduced from N. McKeown. Creating an End-to-End Programming Model for Packet Forwarding. Available: <https://www.youtube.com/watch?v=fiBuao6YZI0&t=4216s>

# P4 Programmable Switches

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```
136 /*****  
137 ***** P A R S E R *****/  
138 *****/  
139  
140 state parse_ethernet {  
141     packet.extract(hdr.ethernet);  
142     transition select(hdr.ethernet.etherType) {  
143         TYPE_IPV4: parse_ipv4;  
144         default: accept;  
145     }  
146 }  
147  
148 state parse_ipv4 {  
149     packet.extract(hdr.ipv4);  
150     verify(hdr.ipv4.ihl >= 5, error.IPHeaderTooShort);  
151     transition select(hdr.ipv4.ihl) {  
152         5 : accept;  
153         default : parse_ipv4_option;  
154     }  
155 }
```

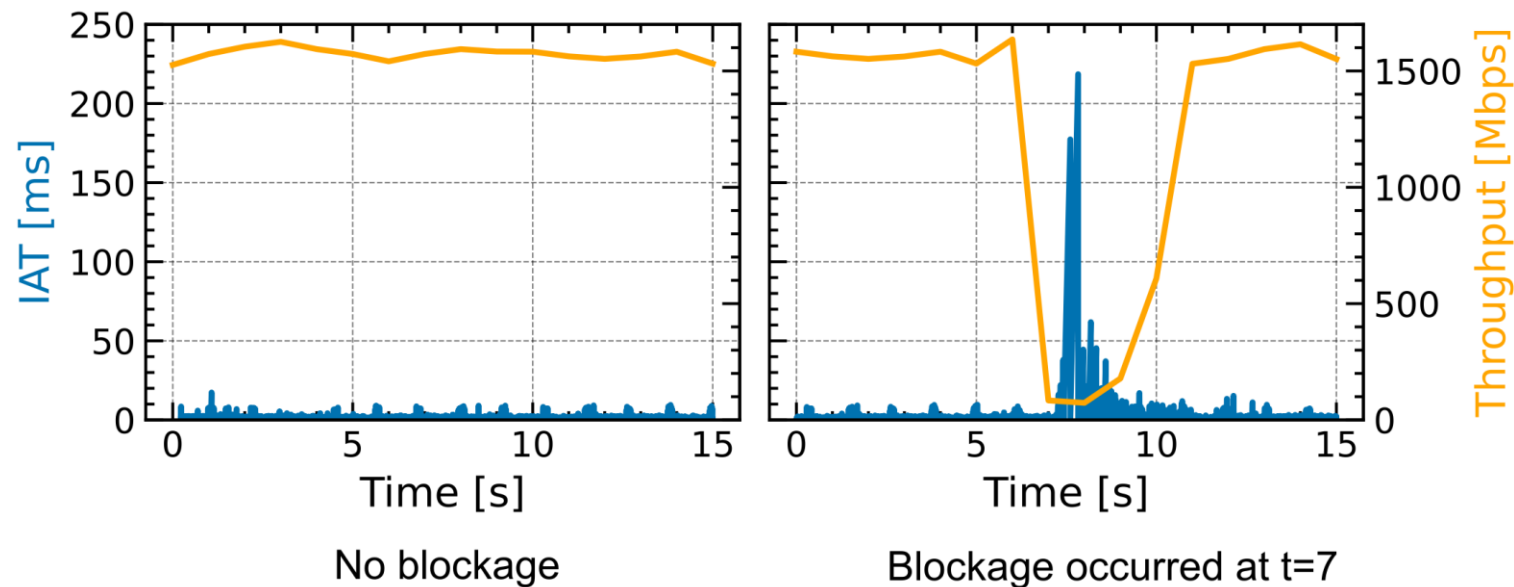
P4 code



Programmable chip

# Motivation

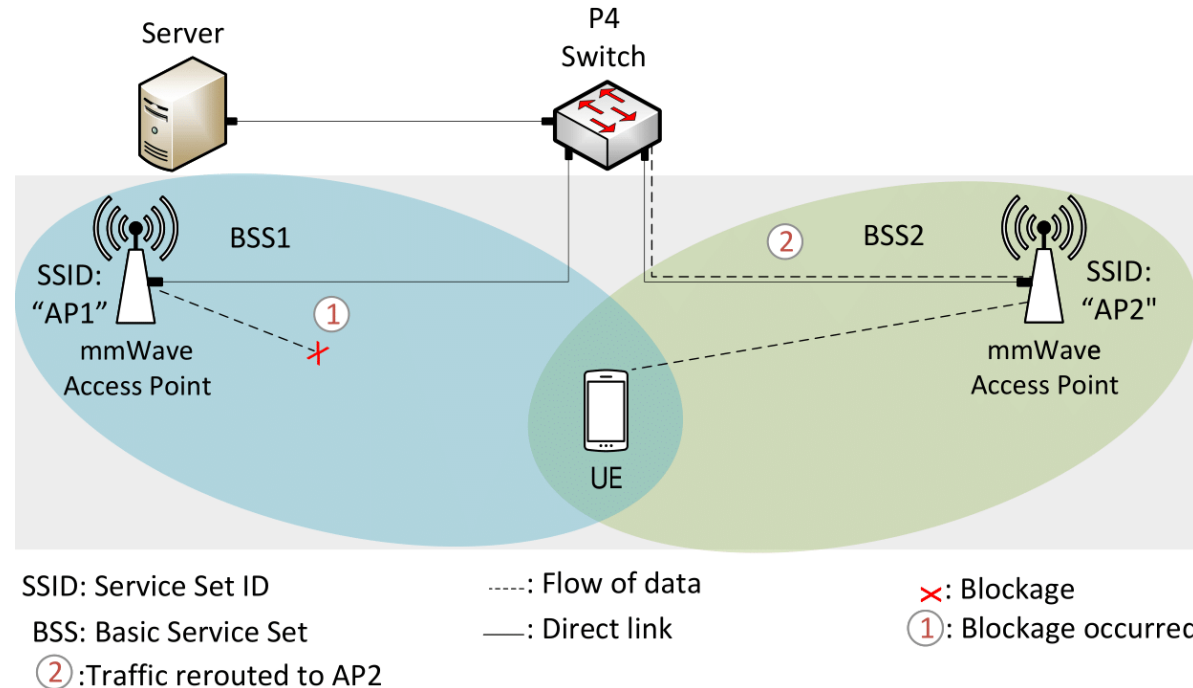
- The performance of a mmWave connection significantly degrades upon blockage
- Solutions rely on handover connections from the current (blocked) access point to an alternative (non-blocked) access point
- Upon blockage, the inter-arrival time (IAT) of the packets increases by multiple folds
- The increase in the IAT provides a clear indication of the blockage



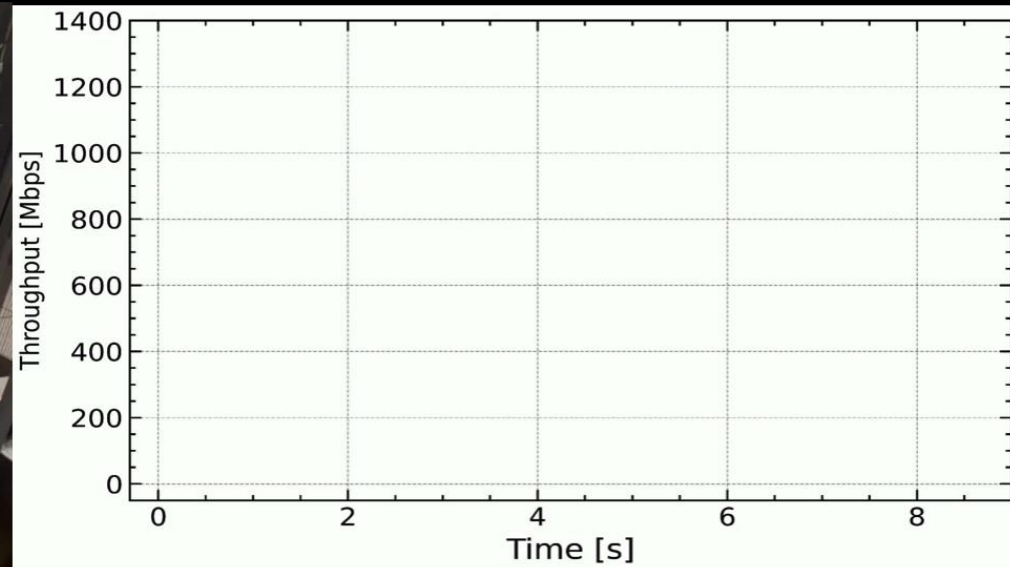


# Proposed System

- The system leverages programmable switches to monitor the inter-arrival time (IAT) of the packets
- Using the measurements, the programmable switch detects the blockage and then notifies the end user to handover
- The system was implemented and tested on a Tofino hardware switch and off-the-shelf mmWave-compatible devices

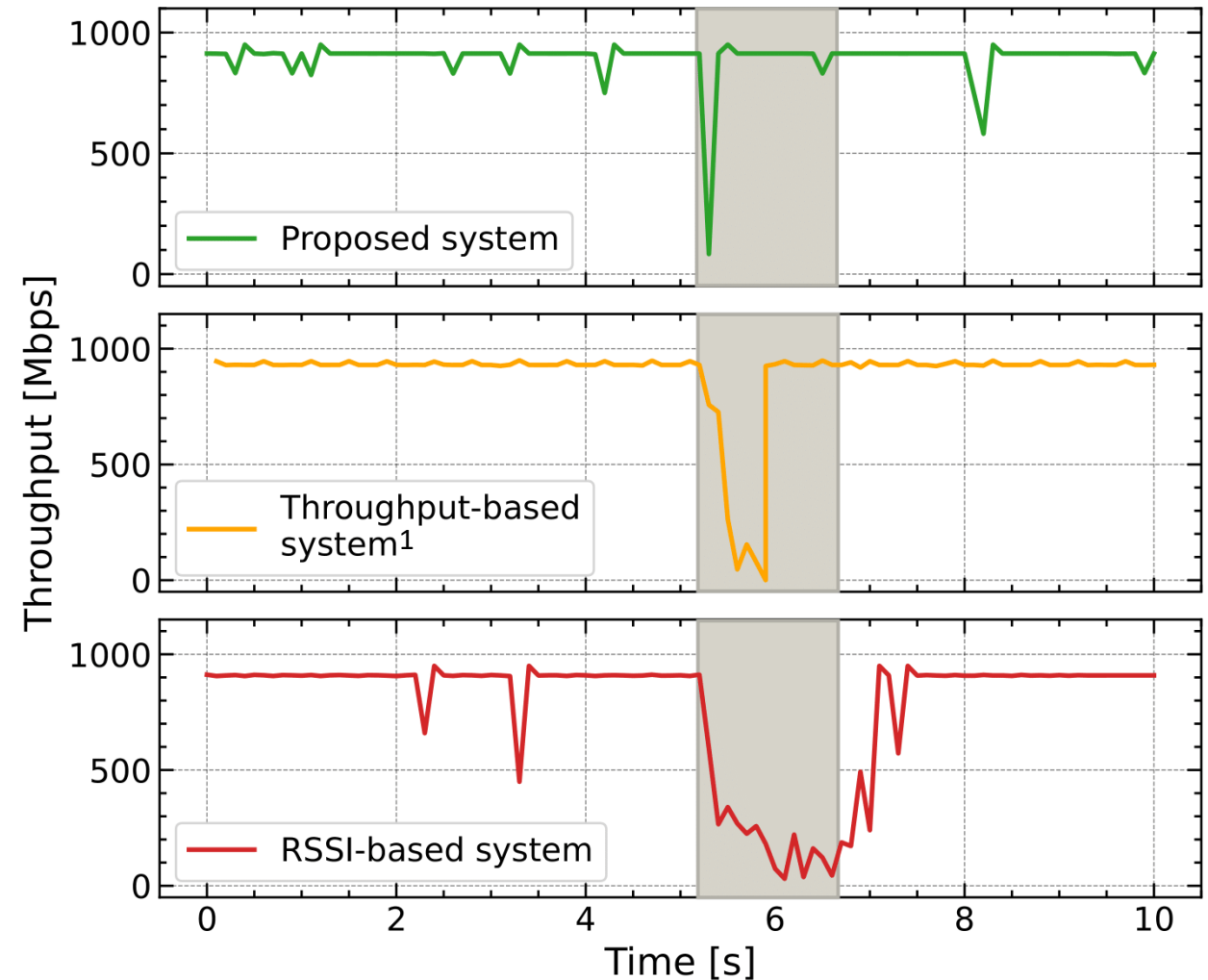


# Proposed System



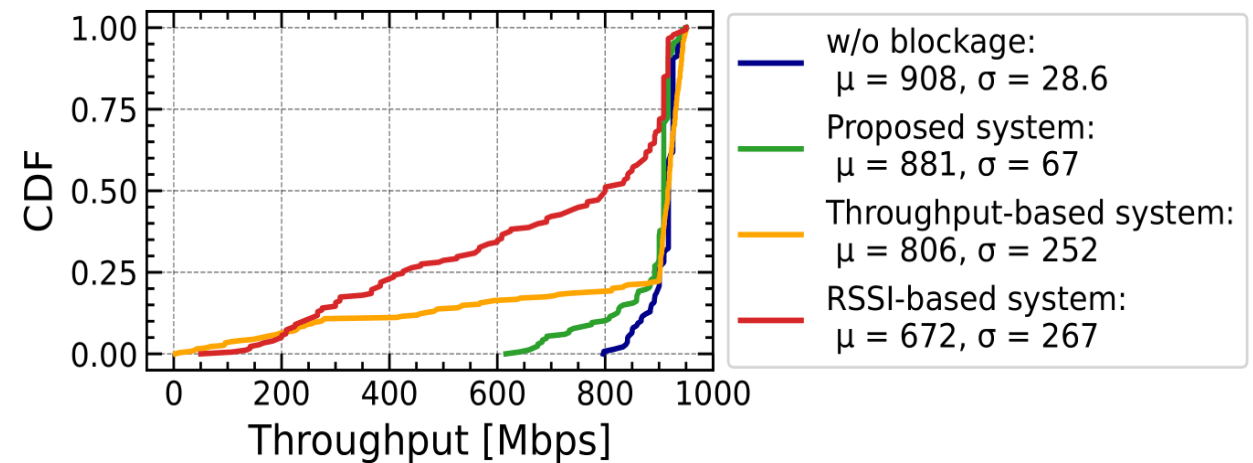
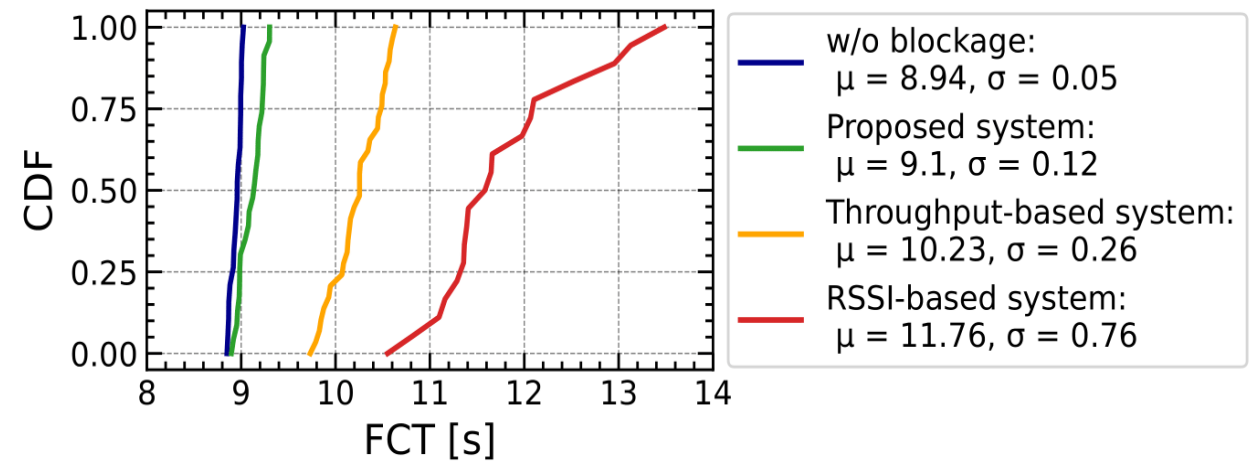
# Results: Recovery Speed

- In clear LOS, the average IAT is 7 microseconds (us)
- 93.3% of IATs are less than 1 us
- The recovery speed from blockage was evaluated
- The line of sight (LOS) was blocked for 2 seconds
- The proposed system required around 160 milliseconds to fully recover from the blockage



# Results: Flow Completion Time

- The flow completion time (FCT) of a 1-gigabyte flow was evaluated in four scenarios
- Four scenarios, each repeated 50 times
- The LOS was blocked for 2 seconds
- The FCT of the proposed system is close to the scenario w/o blockage



# Contributions

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- Leveraging PDP switches to compute the packet's IAT and detect mmWave blockage on a per-packet basis
- Conducting evaluations on a testbed composed of real devices, including a PDP switch, mmWave access points, and a mobile device operating in the 60 GHz band
- Detecting the blockage and initiating handover before the throughput degrades from the blockage
- Proposing a solution to the handover decision problem without modifying end devices
- Future work aims at extending the system to select the best alternative non-blocked access point by using information from end devices



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# Limitations

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- Using the 2.4 GHz channel to exchange control messages between the UE and the PDP switch:
  - The UE should get an implicit notification to perform handover
  - The alternative access point has a clear LOS
  - Additional input from the UE can be used to solve the access point selection problem
- The server is assumed to continuously send back-to-back traffic