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

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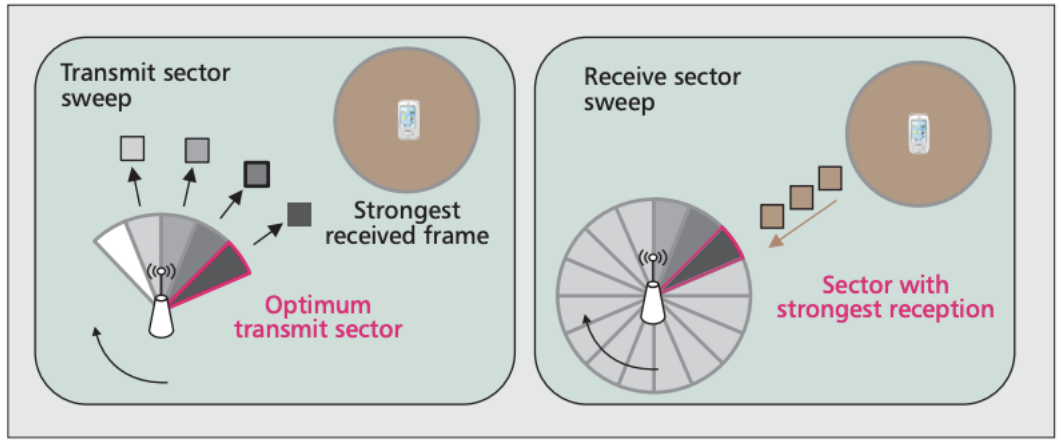
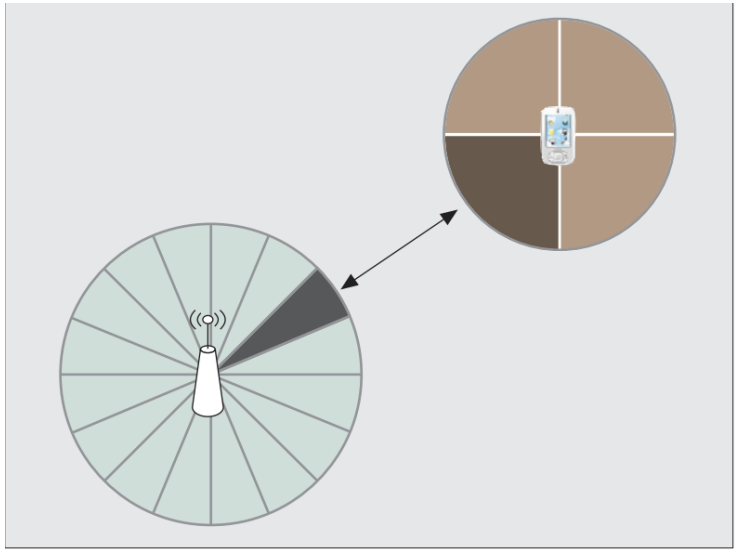
Agenda

- 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

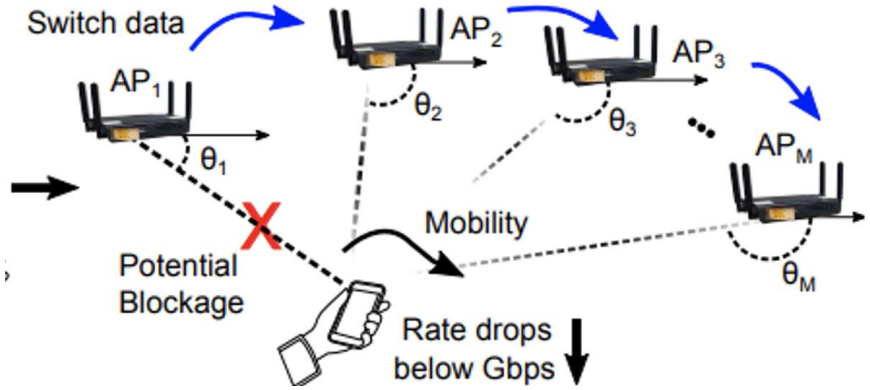


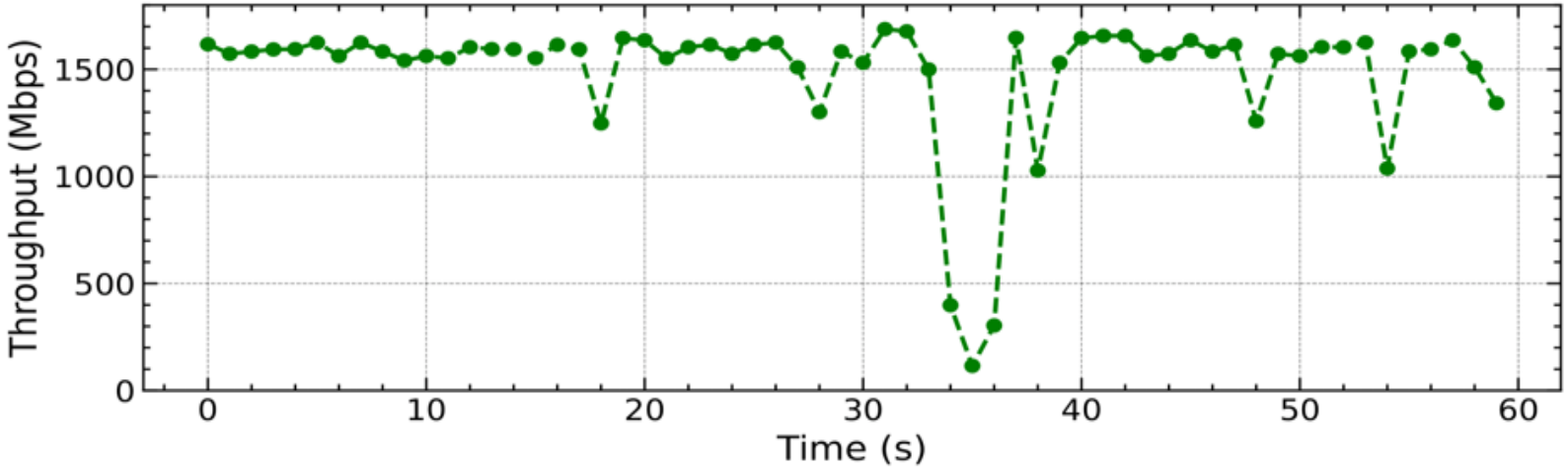


Nitsche, Thomas, Carlos Cordeiro, Adriana B. Flores, Edward W. Knightly, Eldad Perahia, and Joerg C. Widmer. "*IEEE 802.11 ad: directional 60 GHz communication for multi-Gigabit-per-second Wi-Fi*." *IEEE Communications Magazine* 52, 2014.

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

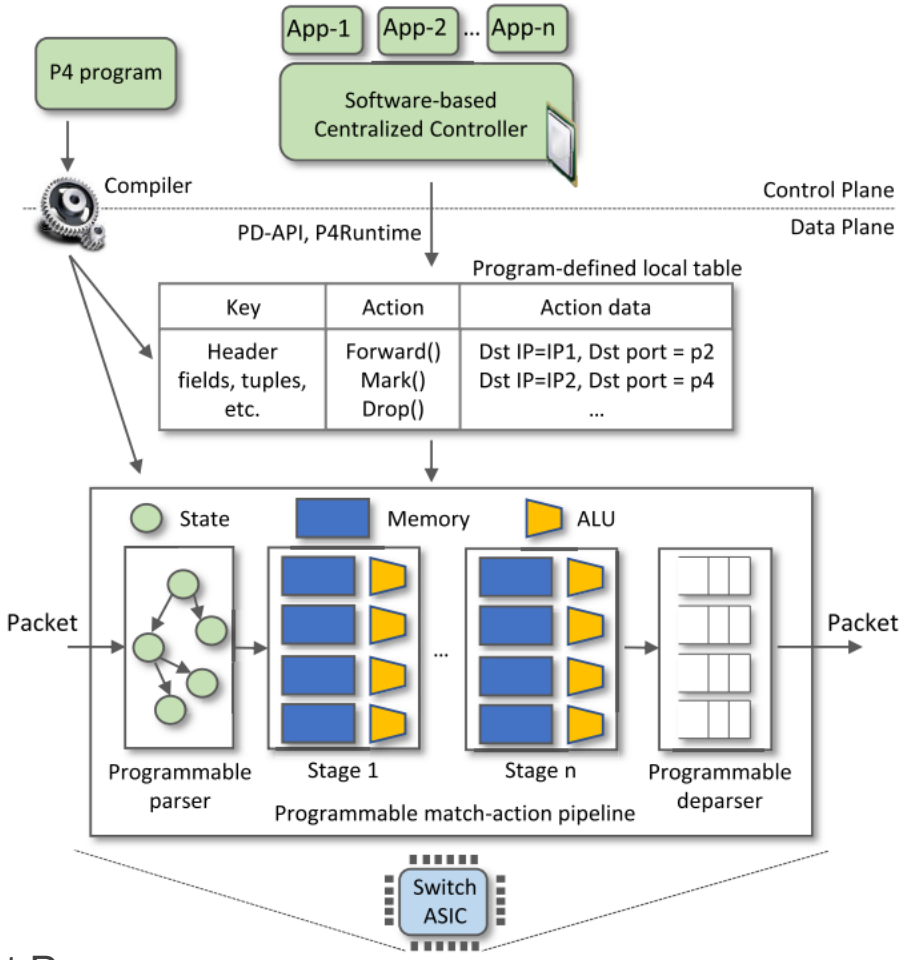




Sur, Sanjib, Ioannis Pefkianakis, Xinyu Zhang, and Kyu-Han Kim. "Towards scalable and ubiquitous millimeter-wave wireless networks." In Proceedings of the 24th Annual International Conference on Mobile Computing and Networking, 2018.

P4 Programmable Switches

- P4[1] 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

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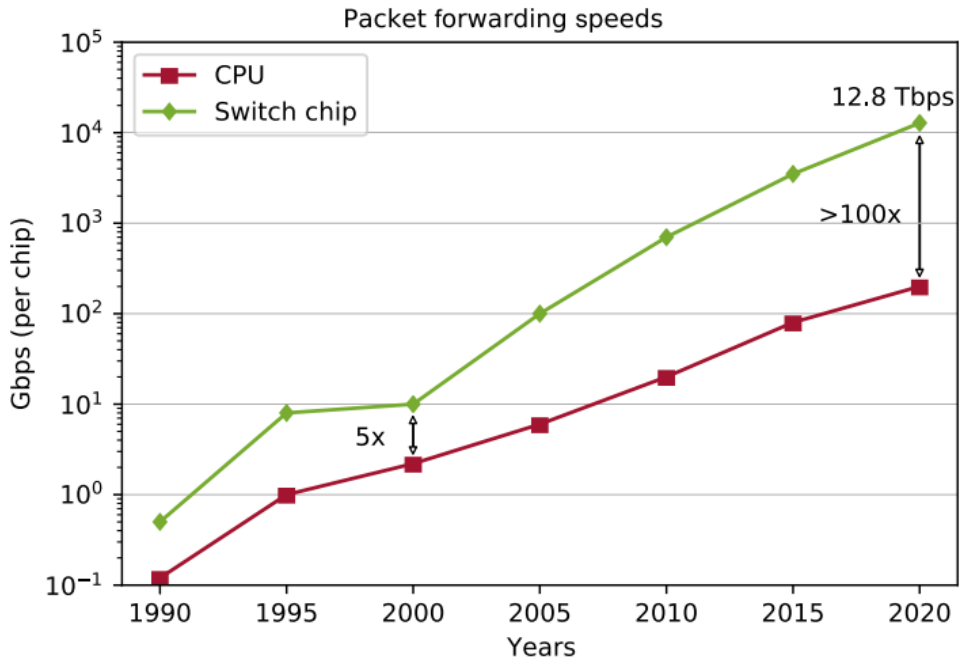

Reproduced from N. McKeown. Creating an End-to-End Programming Model for Packet Forwarding. Available: **https://www.youtube.com/watch?v=fiBuao6YZI0&t=4216s**

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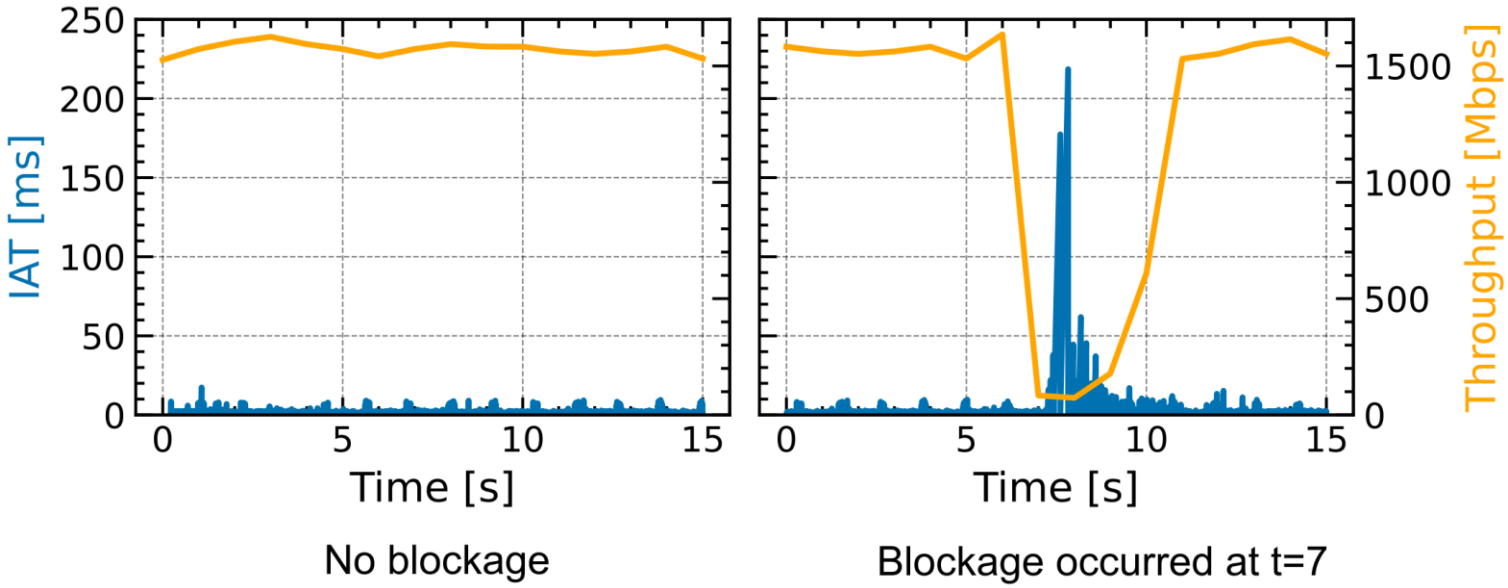
```
136  /*************************************************************************
137  ********************** P A R S E R  ***********************************
138  *************************************************************************/
139
140      state parse_ethernet {
141          packet.extract(hdr.ethernet);
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

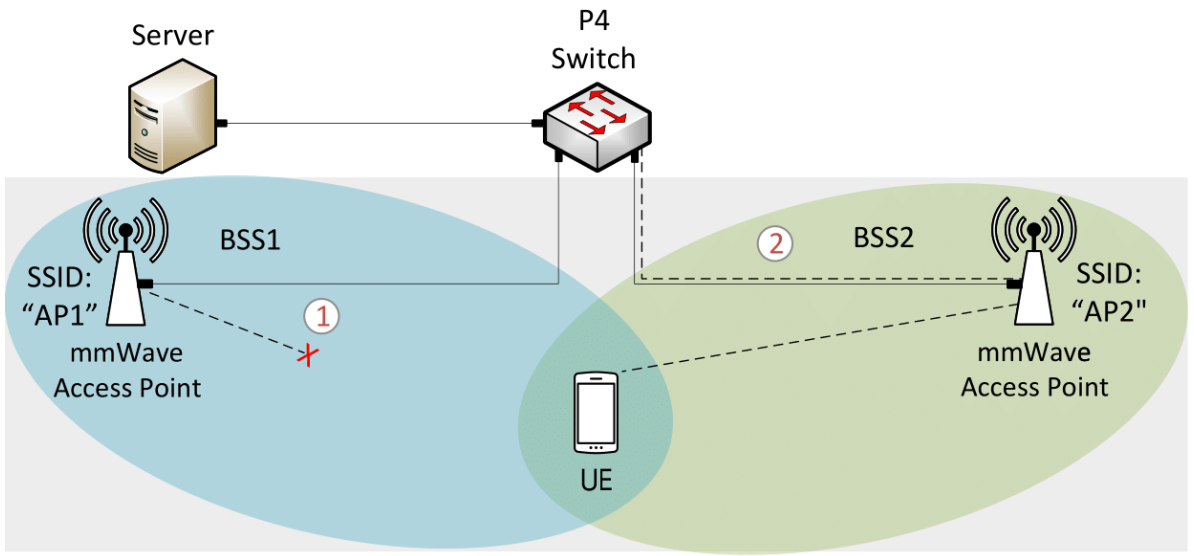
Motivation

- 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



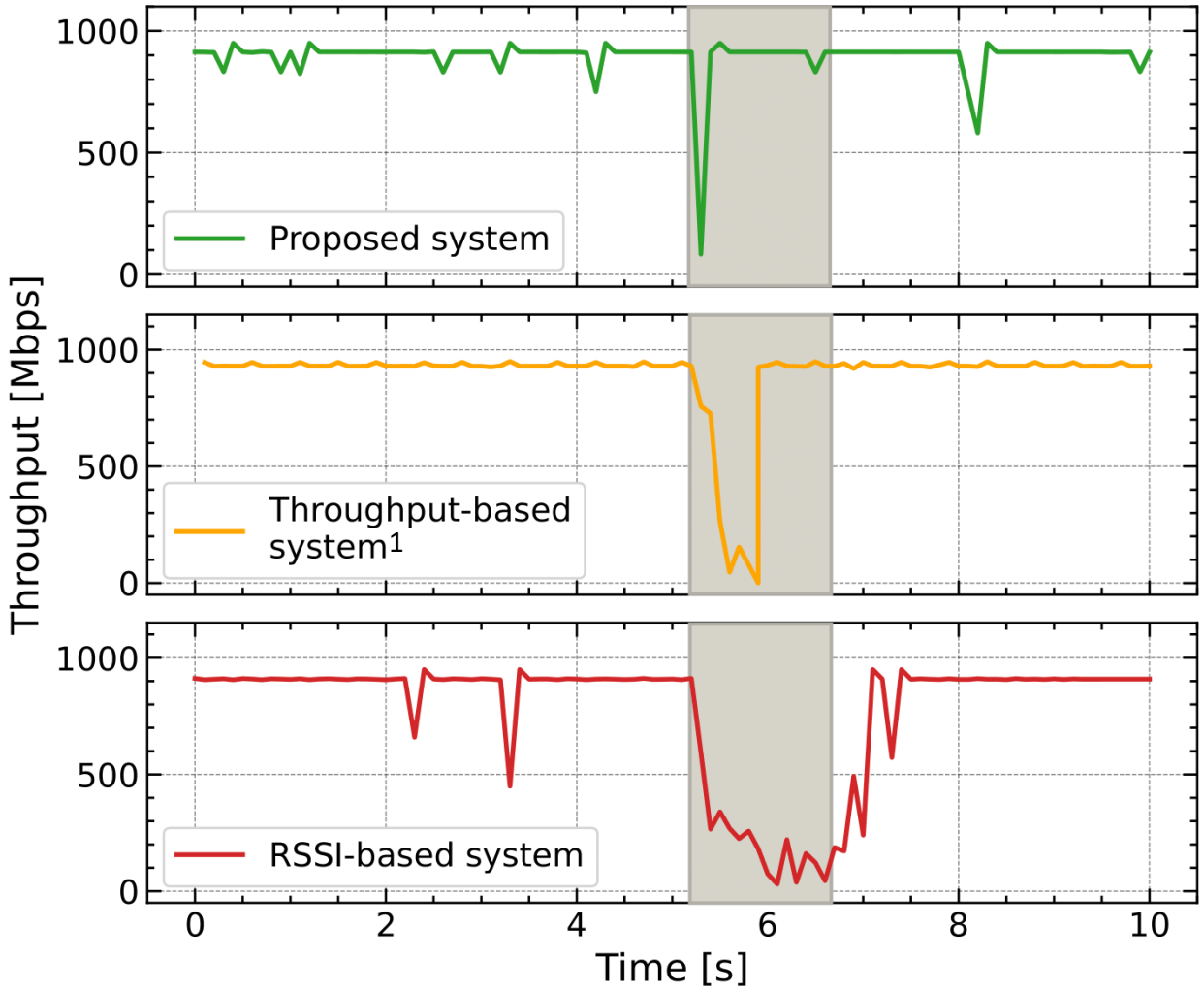
Proposed System

- 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



Results: Recovery Speed

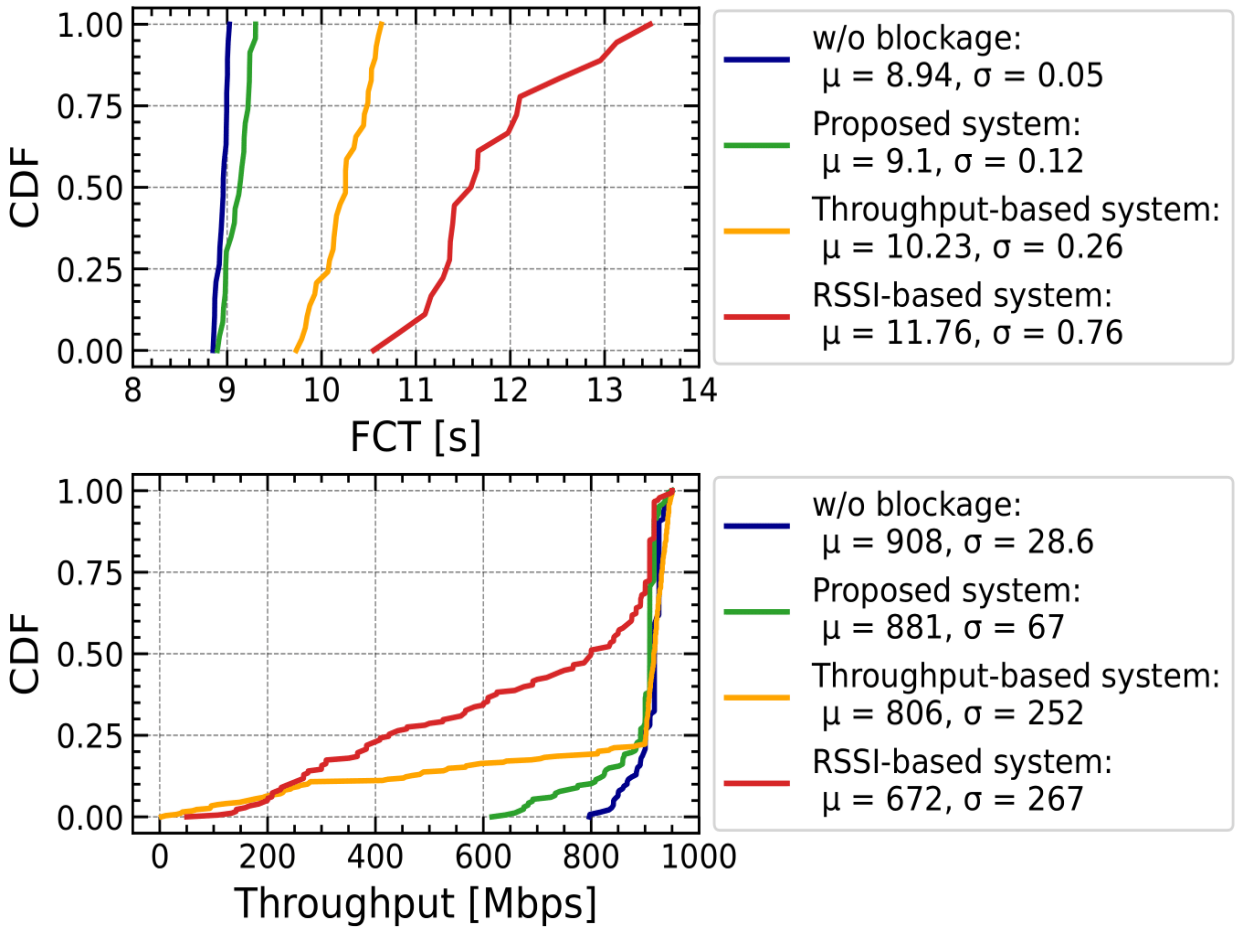
- The recovery speed from blockage was evaluated
- The line of sight (LOS) was blocked for 2 seconds
- The proposed system required around 160 milliseconds to fully recover from the blockage



[1]Y. Oguma et. al. “Implementation and evaluation of reactive base station selection for human blockage in mmWave communications,” Asia-Pacific Conference on Communications (APCC), 2015

Results: Flow Completion Time

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



Contributions

- 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 utilizing information from end devices

Limitations

- 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

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For additional information, please refer to
http://ce.sc.edu/cyberinfra/

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