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

Ali Mazloum*, Elie Kfoury*, Sanjib Sur*, Jorge Crichigno*, Nasir Ghani†
*University of South Carolina, United States
†University of South Florida, United States

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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\(^1\) 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
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=fiBua6YZI0&t=4216s
P4 Programmable Switches

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P4 code

```c
// PARSER

state parse_ethernet {
    packet.extract(hdr.ethernet);
    transition select(hdr.ethernet.etherType) {
        TYPE_IPV4: parse_ipv4;
        default: accept;
    }
}

state parse_ipv4 {
    packet.extract(hdr.ipv4);
    verify(hdr.ipv4.ihl > 5, error.IPHeaderTooShort);
    transition select(hdr.ipv4.ihl) {
        5: accept;
        default: parse_ipv4_option;
    }
}
```
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.

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

Email: jcrichigno@cec.sc.edu, amazloum@email.sc.edu