Software-defined mmWave Initial Access using GNU Radio

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Our Contribution

- **Expose control** of mmWave front-ends in GNU Radio
- Implement a flexible **initial access control loop**
- **Enabling high-level experiments**, e.g., beam management & initial access design trade-offs
Outline

- Motivation
- Implementation
- Experimental Results
- Conclusions
OTA Experiments < 6GHz
(SISO, omnidirectional antennas)

- **Distance** and **gain** play a huge role to set up the experiment

- Great for **broadcast** experiments
OTA Experiments > 6GHz
(using mmWave front-ends)

- Combine **flexibility** of SDRs with **directionality** of mmWave front-ends (InterDigital, Sivers, etc)
- Experiments **characterizing** equipment and medium
OTA Experiments > 6GHz
(using mmWave front-ends)

- Currently, **manual** beam steering for TX and RX to find each other

- Beyond distance and gain, now the **direction** also plays a huge role
Initial Access Procedure
Locate TX and RX before establishing communication

- Manual beam steering may be *impractical*
- Initial access **dynamically locates** TX and RX
- Proving the environment to find the **best beams**
- **MAC-level functionality** missing from GNU Radio
Current mmWave Front-ends

- Multi-element **phased-array antenna modules**
- RF chains for up/down converting from/to IF
- **Real-time control** over GPIO and/or SPI:
  - Transmission mode (TX, RX, TRX, off)
  - Gain (TX, RX)
  - Codebooks, a.k.a., beams (TX/RX direction)

InterDigital MHU

Sivers EVK
SofTwAre-defined Mmwave INitial Access (STAMINA)
Abstracting GPIO Control

- Different pins and ranges for the **same functionality**
- **Parameterization** to different models using config files
- Incorporating **hardware-specific** considerations
- Expose high-level abstraction as a **GNU Radio block**
Abstracting GPIO Control

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Initial Access Control Loop

- Iteratively **sweeping** over different beams
- Capturing the Received Signal Strength (RSS) from different directions
- Using the highest RSS to decide the **best beam pair** for data transmission
- Loop and adapt to changes
Realization in GNU Radio

- **Arbitrary** sweep sequences, beam durations, cadence of measurements
- Use blocks **standalone** or altogether
- **Asynch** messages to pass control information
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Development Setup

Hardware Components

Host PC + USRP X310 + mmWave Ctl

RX MHU

TX MHU
Development Setup

System Design

Host PC

Ctl Msqs
IQ Samples

NI USRP X310

Power & GPIO 
10 MHz REF
5.3 GHz IF

InterDigital M2T (mmWave Ctrl)

InterDigital MHU (mmWave RX)
28 GHz

Power & GPIO 
10 MHz REF
5.3 GHz IF

InterDigital MHU (mmWave TX)

NI

USRP X310
Experimental Results
Platform Validation

- Successfully controlled beams
- Observed different power levels according to orientation
Experimental Results
Exploring the Flexibility of the Platform

- Users can play with initial access parameters to obtain desired performance.

(a) Accuracy of the IA procedure to select the correct beam pair, known a priori by design.

(b) Average packet rate obtained when transmitting data after running the IA procedures.
This Isn't Even My Final Form...

- Still **work in progress**
- A couple things on our roadmap:
  - Replace async messages by something better
  - Mux between payload and known control frames

- **Contact**
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- **Source code available on GitHub** *(but you’ll need a front-end):*
  - https://github.com/CCI-NextG-Testbed/gr_stamina

- **CCI xG Testbed** *(we are open to collaborations!)*
  - https://cyberinitiative.org/xg-testbed.html
Join us **November 7-8th**

NSF IUCRC Next G Center Planning Workshop

@ VT Research Center, Arlington VA

Registration: wisper@cyberinitiative.org