Open-Source Simulation Platform for Public Safety

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#PSCR2019

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***Please note, unless mentioned in reference to a NIST Publication, all information and data presented is preliminary/in-progress and subject to change**

Outline

Motivations

Step Number One

Step Number Two

The role of simulations

Modeling public safety scenarios

Step Number Three

Step Number Four

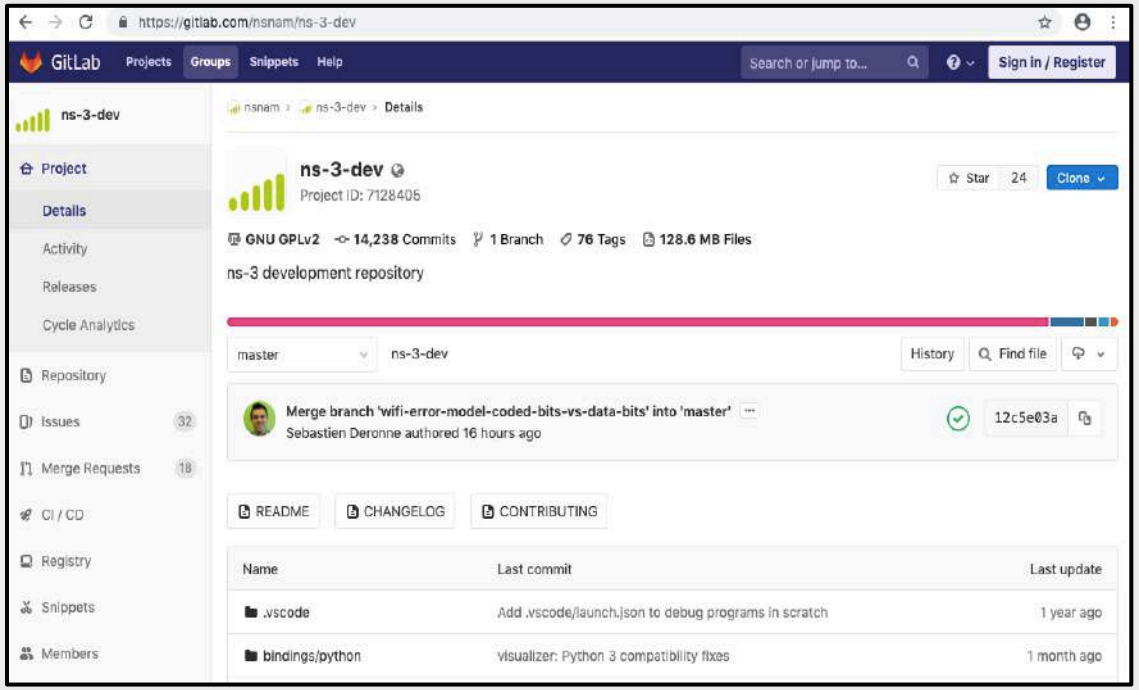
Case Study: high school shooting

Motivations

- **Develop widely accessible tools**
- **Leverage existing open source projects**
- **Leverage collaboration with other researchers**

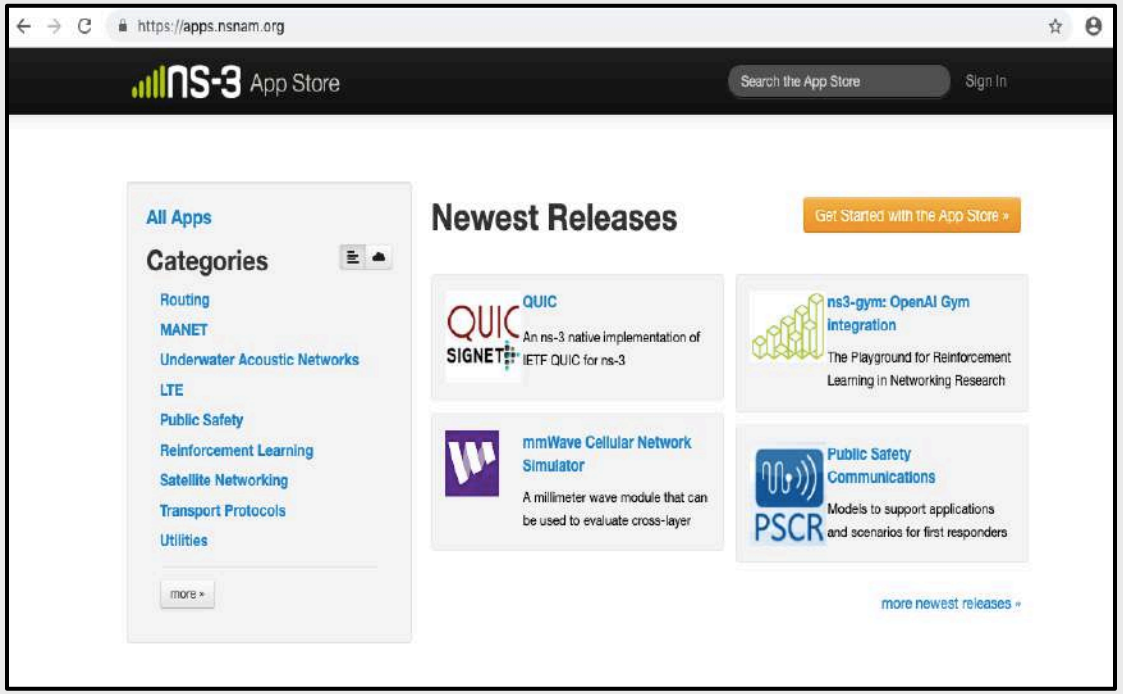
Dissemination

ns-3 extensions of common benefit are contributed back to the ns-3 mainline repository



https://gitlab.com/nsnam/ns-3-dev

The ns-3 PSC module is maintained as an extension in the ns-3 App Store



https://apps.nsnam.org

The Role of Simulations

Increasing realism
Increasing cost and complexity

Spreadsheets

- First-order assessment of throughput, capacity, performance, etc.

Simulations

- Varying levels of abstraction
- Can be large-scale
- Reproducible and easily shared

Testbeds

- Study actual implementation performance and limitations
- Typically small-scale scenarios

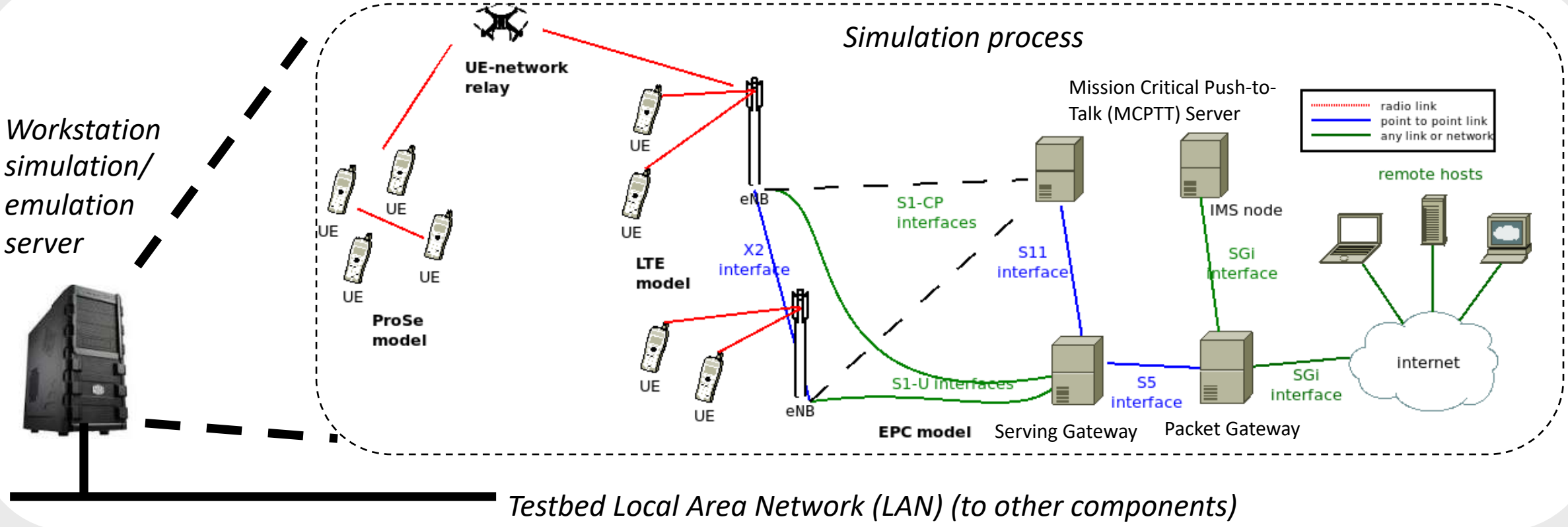
Live networks

- Highest realism but tests are very expensive (preparation time, personnel)

Can be combined!

Variations on Simulation

"Network-in-a-box" could be connected to a testbed Radio Access Network (RAN) or Evolved Packet Core (EPC)/IP Multimedia Subsystem (IMS) components



- **Typical use case is to run the entire process as a simulation**
- **Alternatively, when run in real-time mode, the simulation process can interact with internal Linux containers or with external testbed equipment**

Technical Approach

- **Build a reasonably complete set of public safety-oriented *models* and *example scenarios* to be further refined by future researchers**
- **Modeling choices should be driven by known or anticipated *research questions* that are amenable to simulation study**
- **Example research questions for simulation:**
  - **How does MCPTT-enabled core network performance differ from 'over-the-top' MCPTT deployment?**
  - **How do network capacity requirements change as a scenario evolves?**
  - **How to design a resource scheduler supporting a UE-to-network relay?**
  - **What are performance implications of different discovery pool size allocations?**

Major Components of a Simulation Scenario

Environment

Location, terrain, building information; Interference; propagation.

Technology

Infrastructure and user devices; Application models

Behavior

Human and machine drivers of network traffic; Mobility models

Measurements

Information to be provided by the output of the simulation.

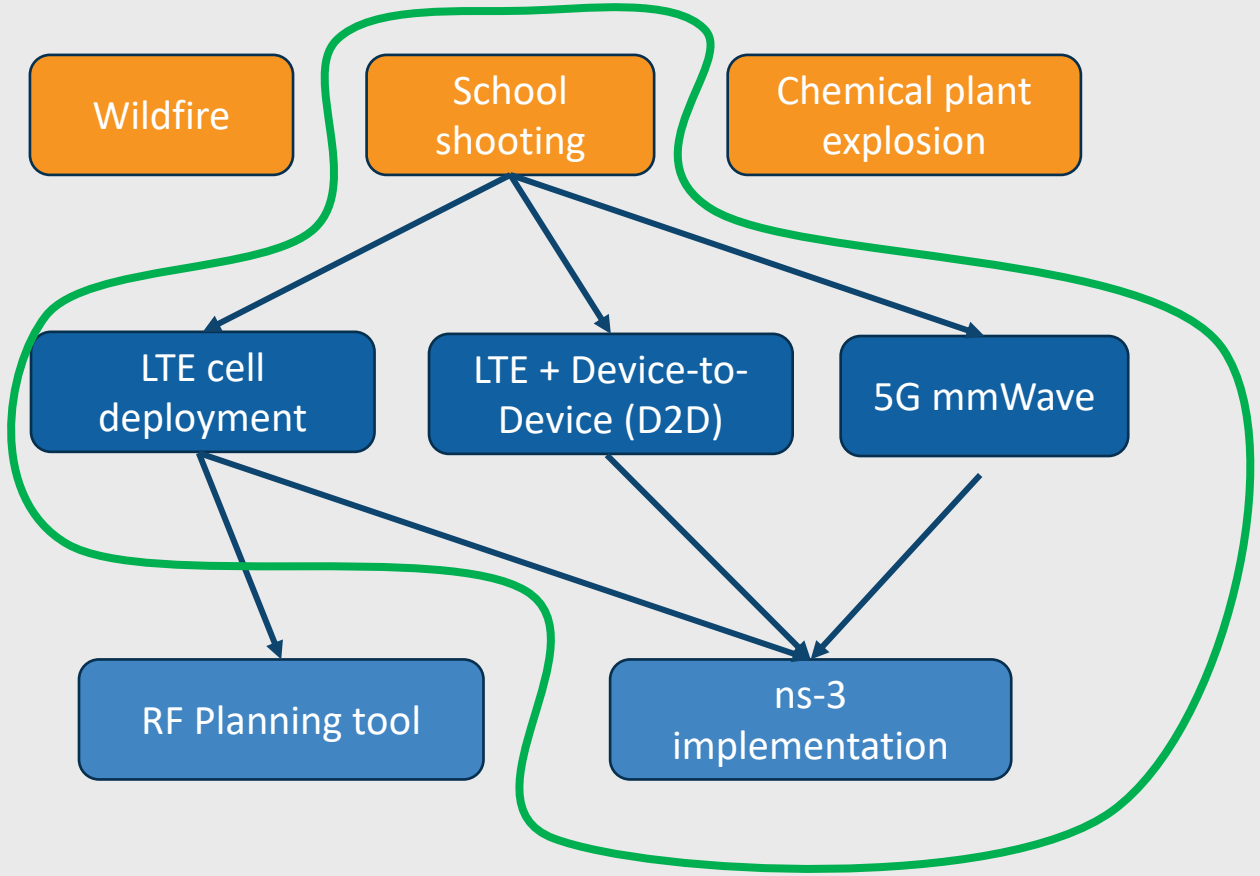
Modeling Public Safety Scenarios

Examples of incidents

Environment and Behavior

Technology

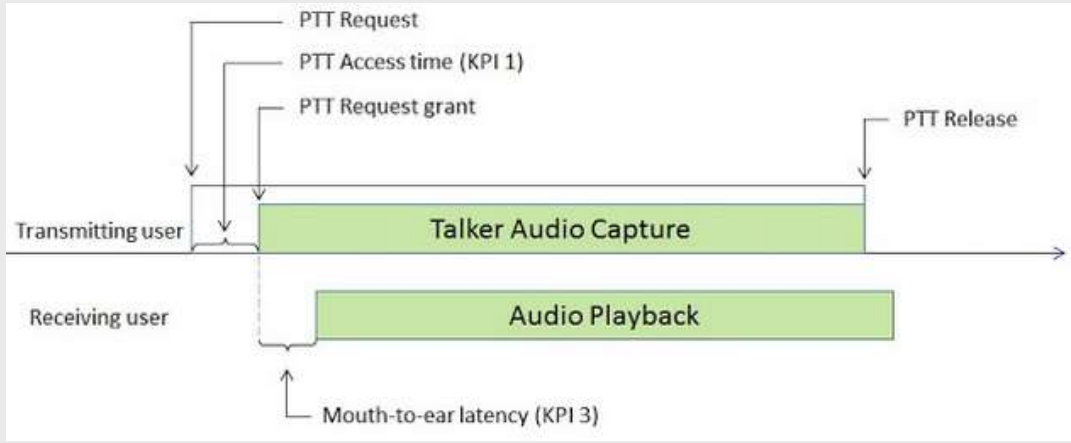
Measurements and Implementation



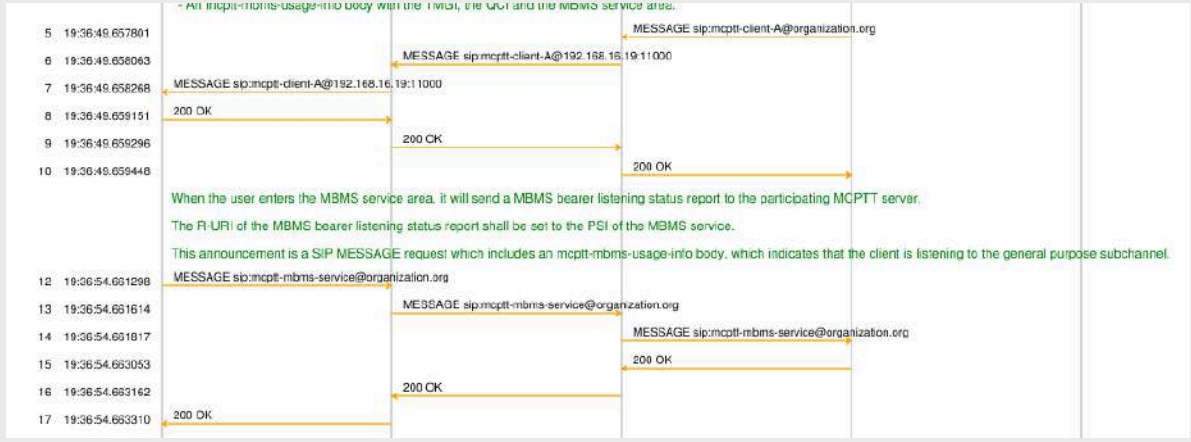
Improving Model Accuracy

MCPTT Application

- **Detailed study of key performance parameters (e.g. tail distributions of mouth-to-ear latency) require higher fidelity models of the LTE control plane and application (MCPTT) dynamics**



Examples of 3GPP Defined Key Performance Indicators (KPIs) for MCPTT (TS 22.179)



Examples of Session Initiation Protocol (SIP) messages exchanged during on network call setup (https://www.nemergent.com/traces/03/)

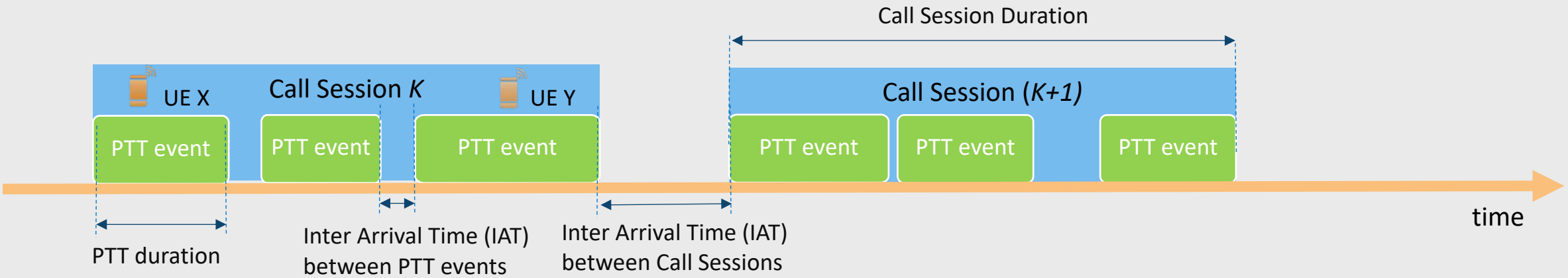
➔ Off-network implementation has been completed

➔ On-network implementation is on-going

Improving Model Accuracy

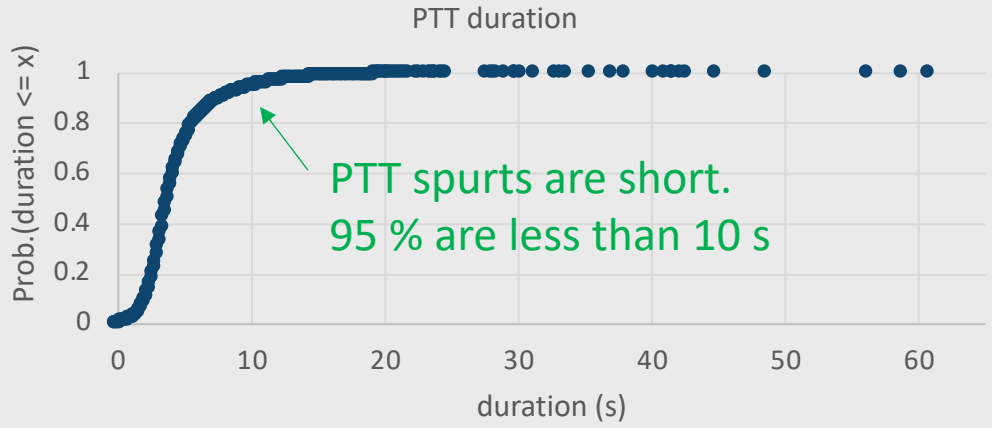
MCPTT Application Usage

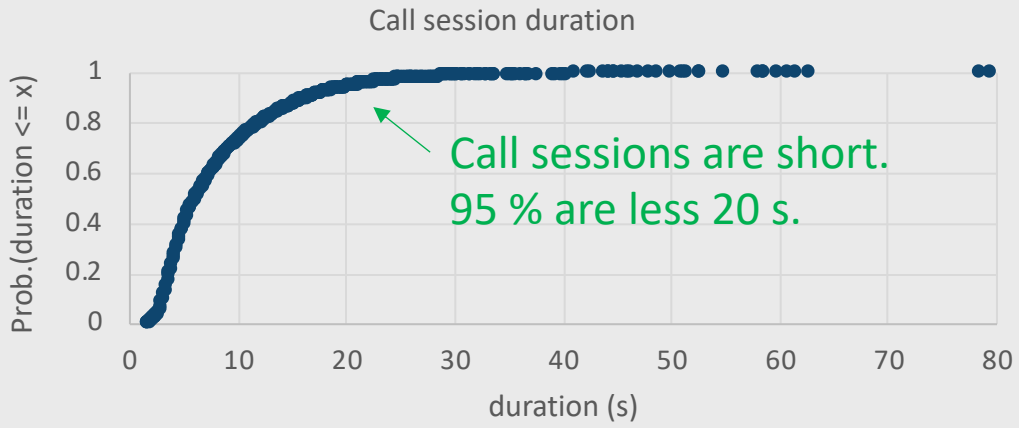
- **Using call logs from existing Land Mobile Radio (LMR)/P25 systems, we can derive models characterizing the application usage**
  - **Frequency and duration of first responders push-to-talk (PTT) spurts**
  - **Variations of activities during special events**

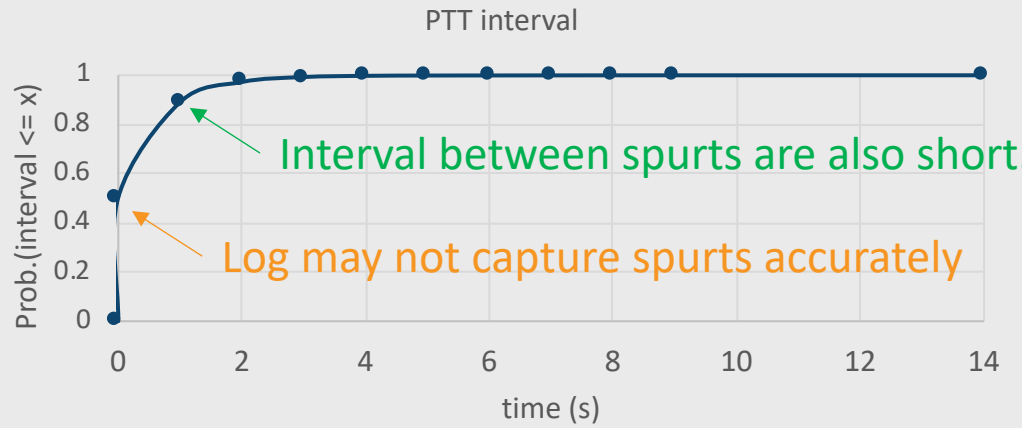


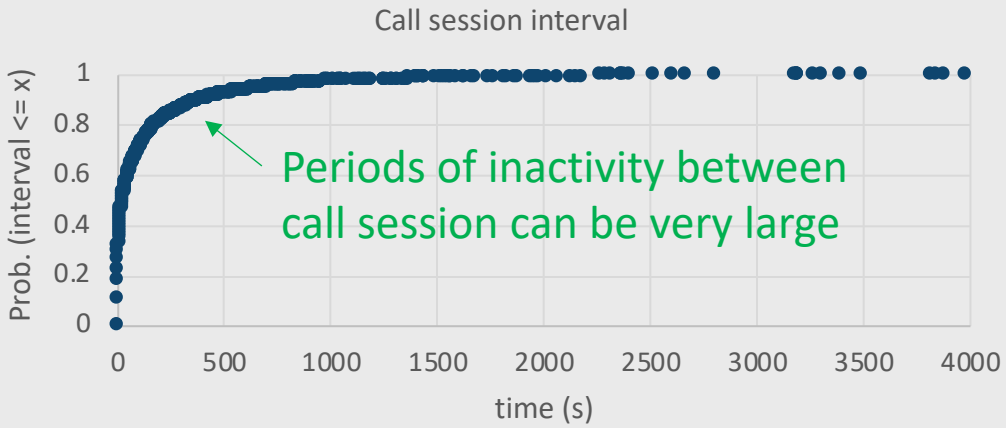
Improving Model Accuracy

MCPTT Application Usage – Example





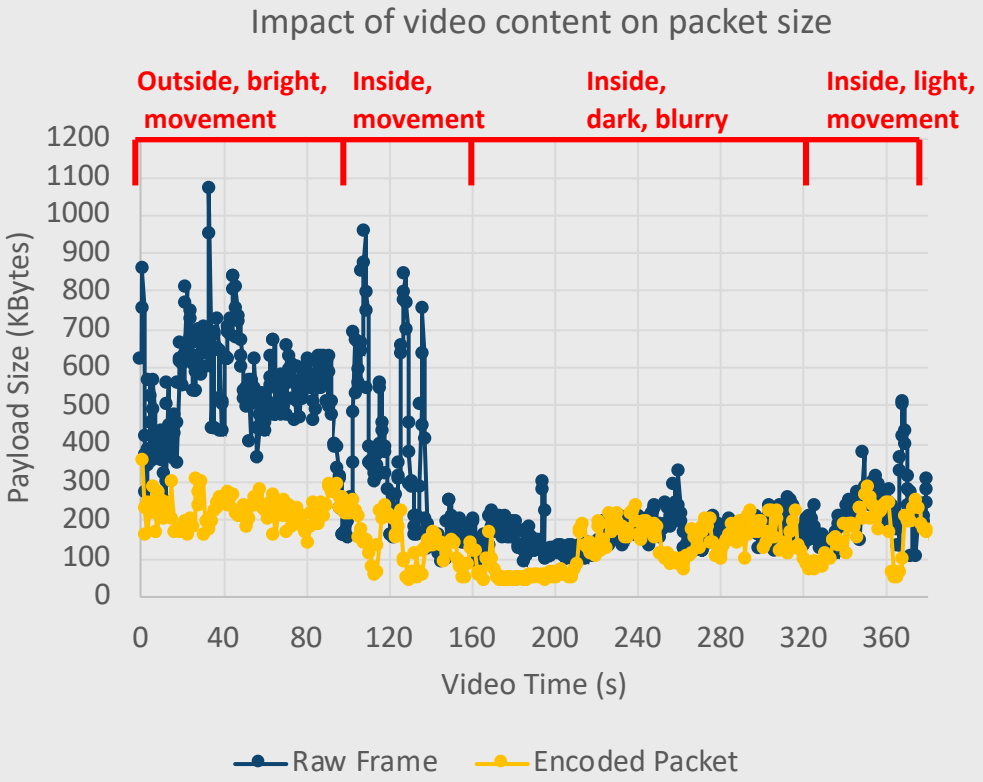




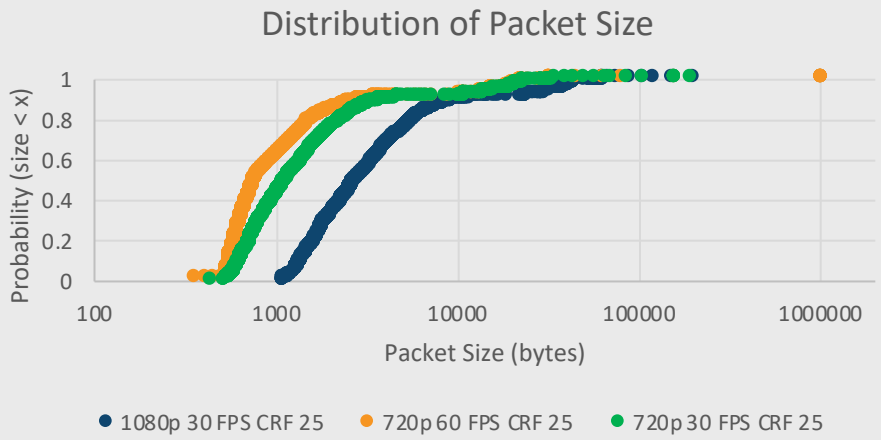
➔ PSCR geolocation project will be used to collect more accurate data and derive models for different locations, for both on network and direct mode

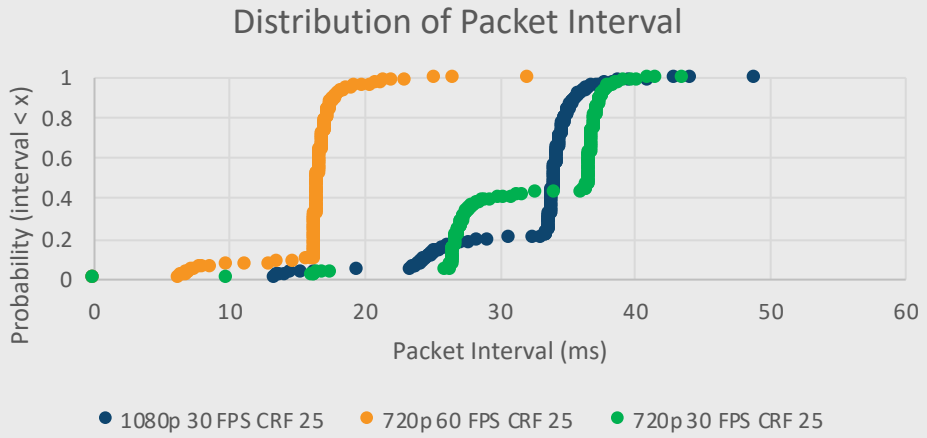
Improving Model Accuracy

Video Applications



Streaming protocol
Codec
Resolution
Frame rate

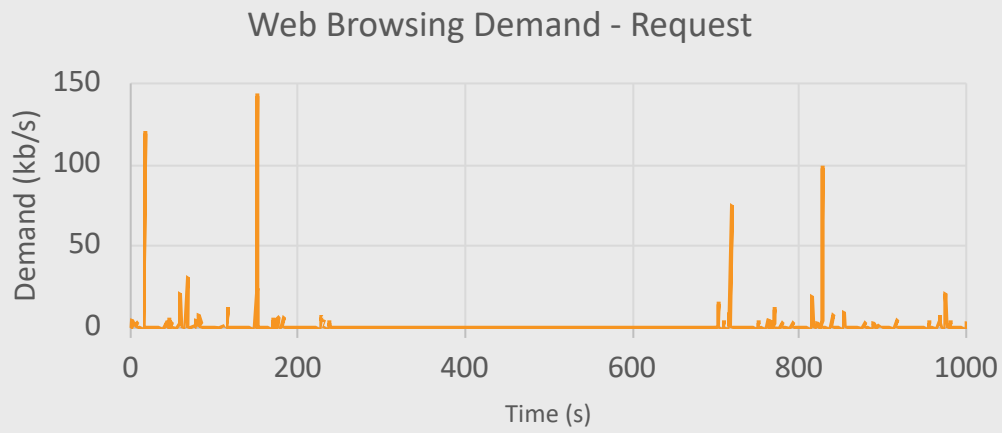


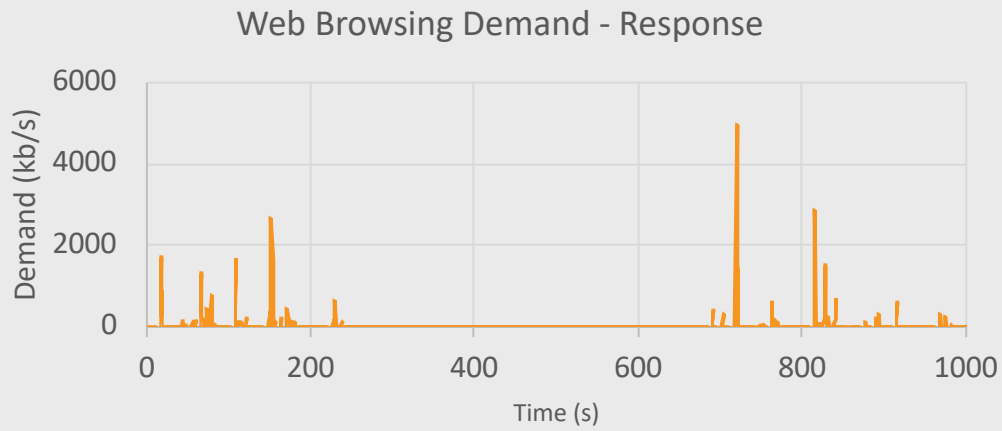


Improving Model Accuracy

HTTP Applications

- **PSCR implemented an ns-3 model based on Intel whitepaper “A New Traffic Model For Current User Web Browsing Behavior”.**
- **It implements request/response models taking into account the number of objects in the web pages (i.e. script, images, etc…)**
- **It also includes**
  - **Modeling of server response time**
  - **Implementation of client-side cache**
- **The model allows to collect various statistics**
  - **Connection establishment latency**
  - **Page loading time**

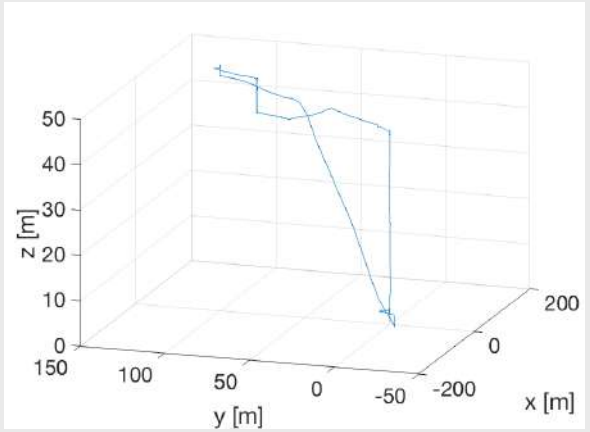




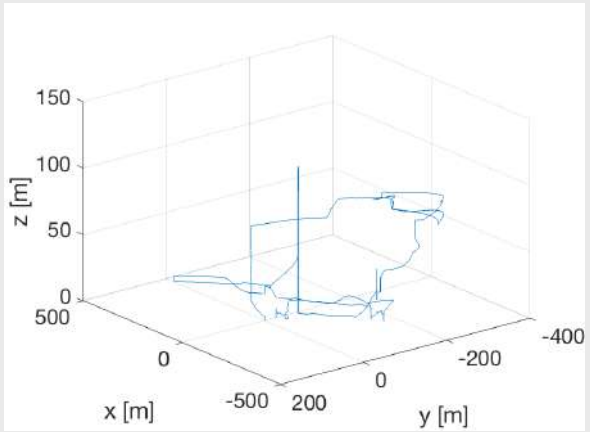
Improving Model Accuracy

Mobility Models

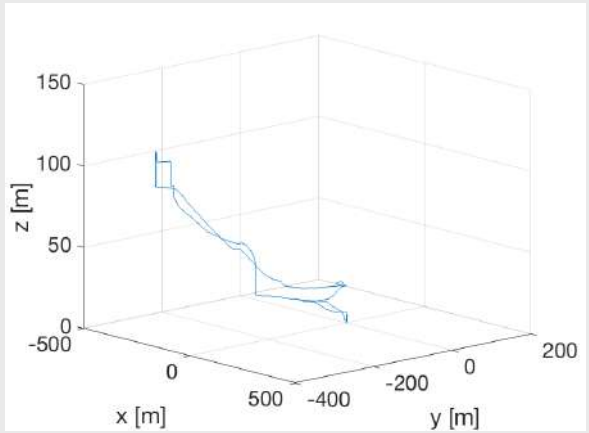
- **The mobility of the users in the simulation impacts, among others, the**
  - **Signal to Interference + Noise Ratio (SINR)**
  - **Throughput**
  - **Network procedures (e.g., handovers)**
- **Models can be improved using real traces**



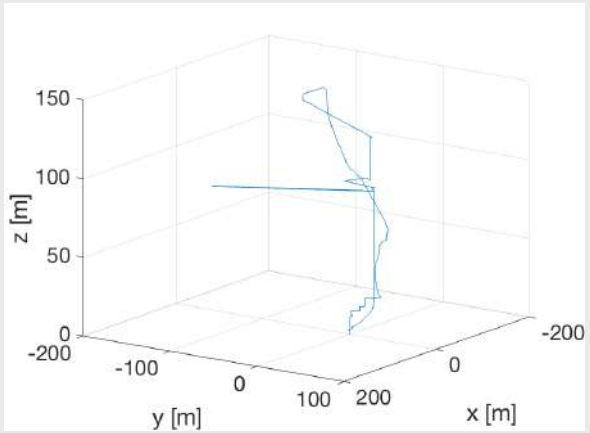
Crowd



Prescribed burn



Sonar



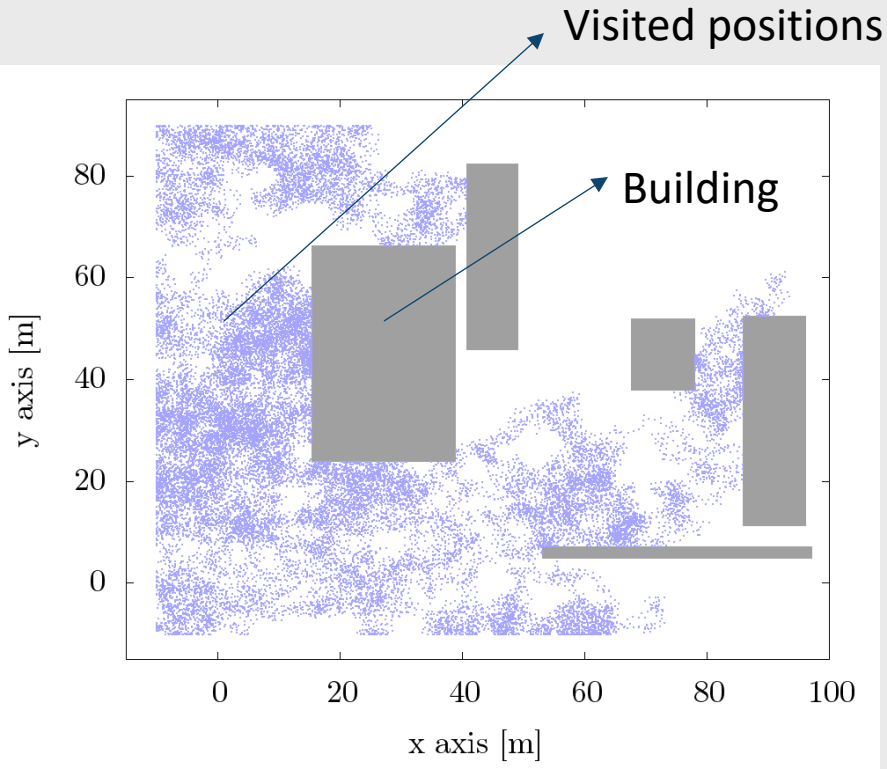
Missing person

Traces from Unmanned Aerial Vehicle (UAV) missions of the Austin Fire Department

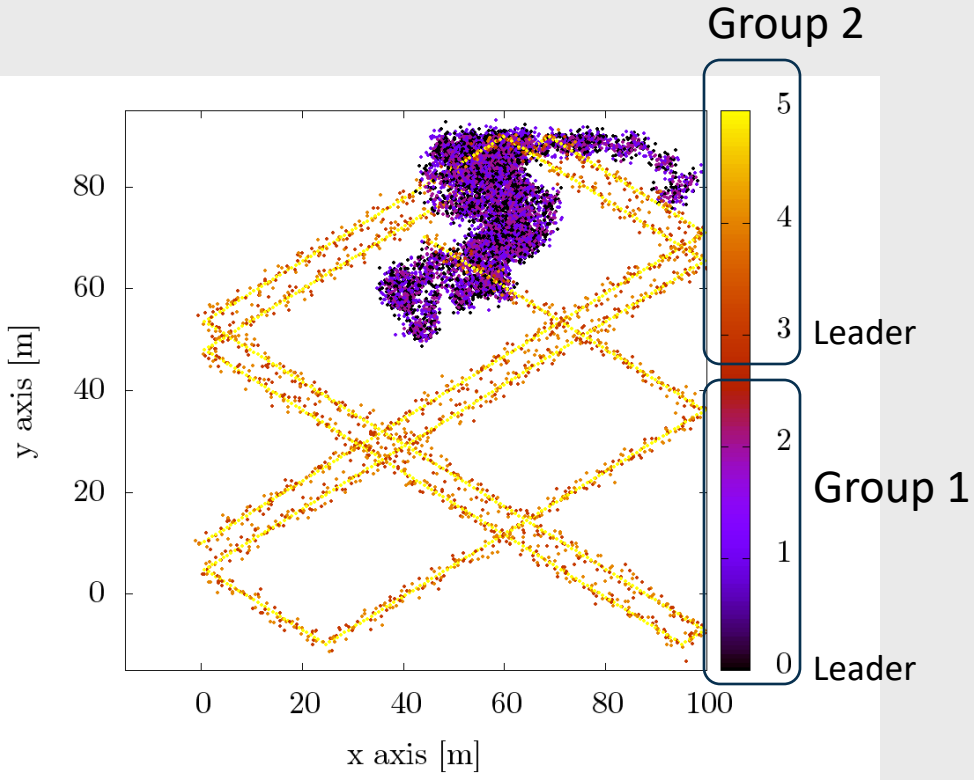
Improving Model Accuracy

Mobility Models

- **Synthetic models can also be improved to reflect reality**



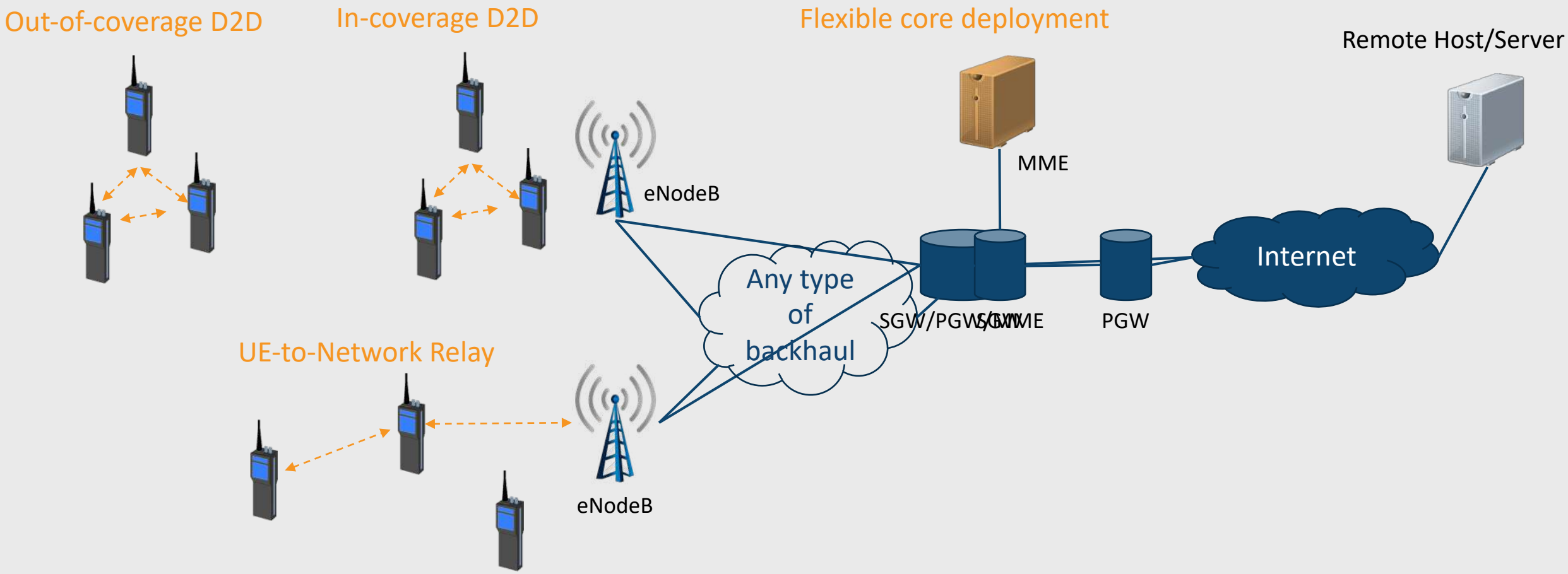
Random walk that avoids buildings and obstacles



Group mobility models

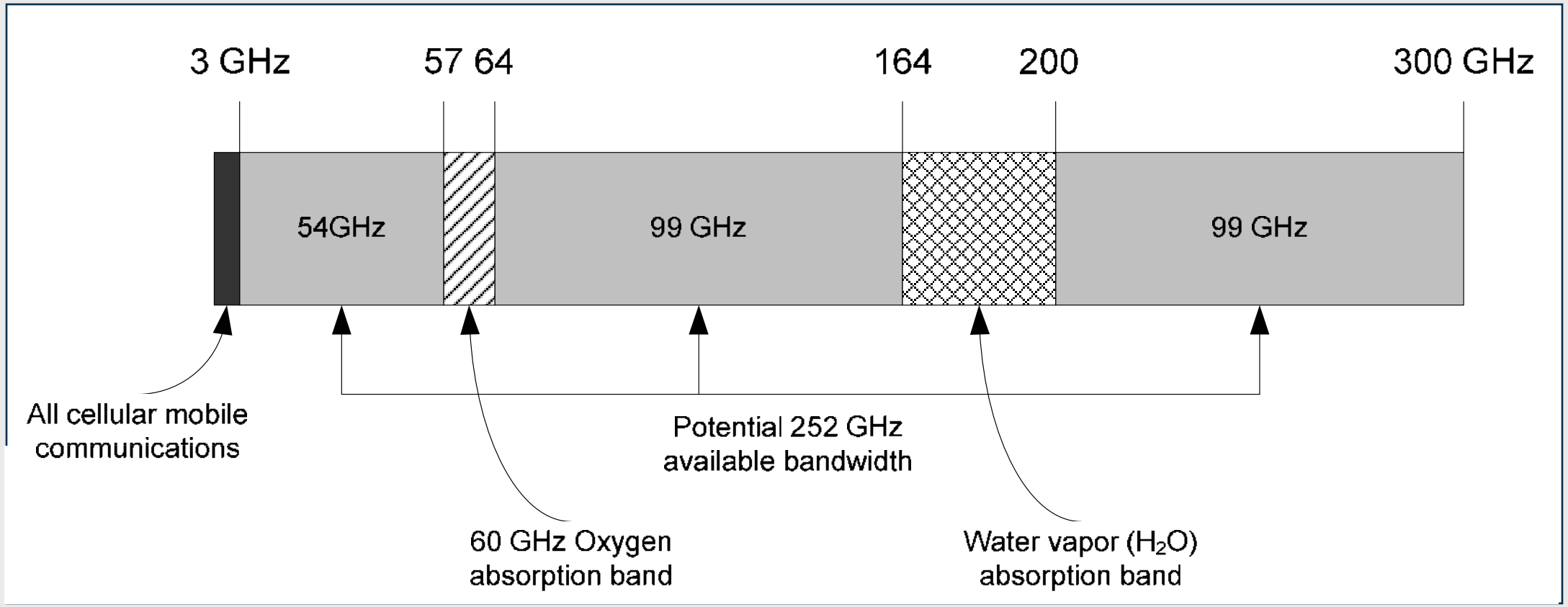
Improving Model Accuracy

LTE Technology



New Models

mmWave for PSC: The benefits of high bandwidth

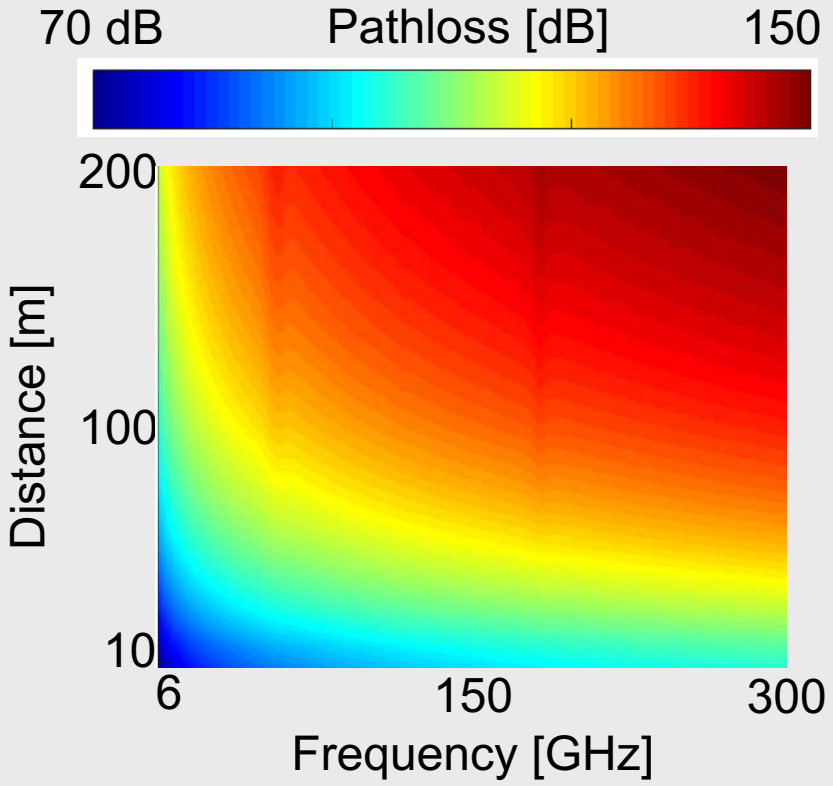


Z. Pi and F. Khan, "An introduction to millimeter-wave mobile broadband systems," in *IEEE Communications Magazine*, vol. 49, no. 6, pp. 101-107, June 2011.

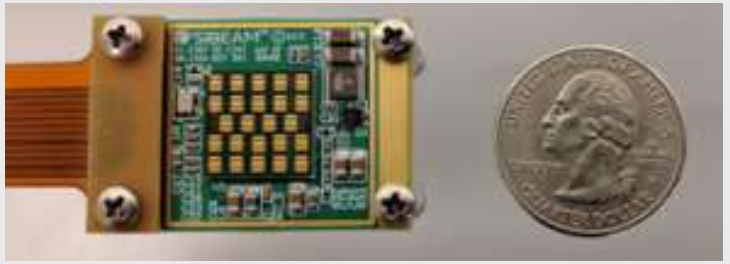
New Models

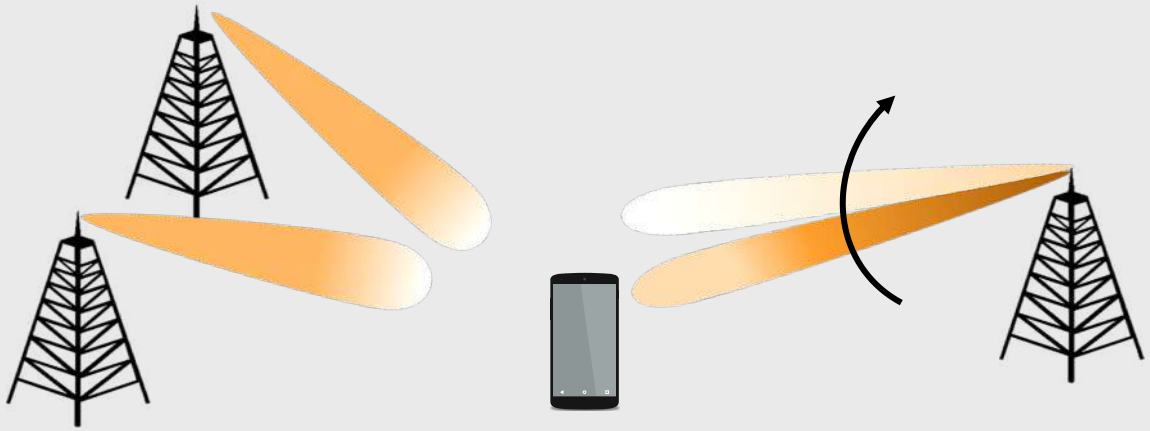
mmWave challenges of directionality and reliability

High Propagation Loss



Directionality

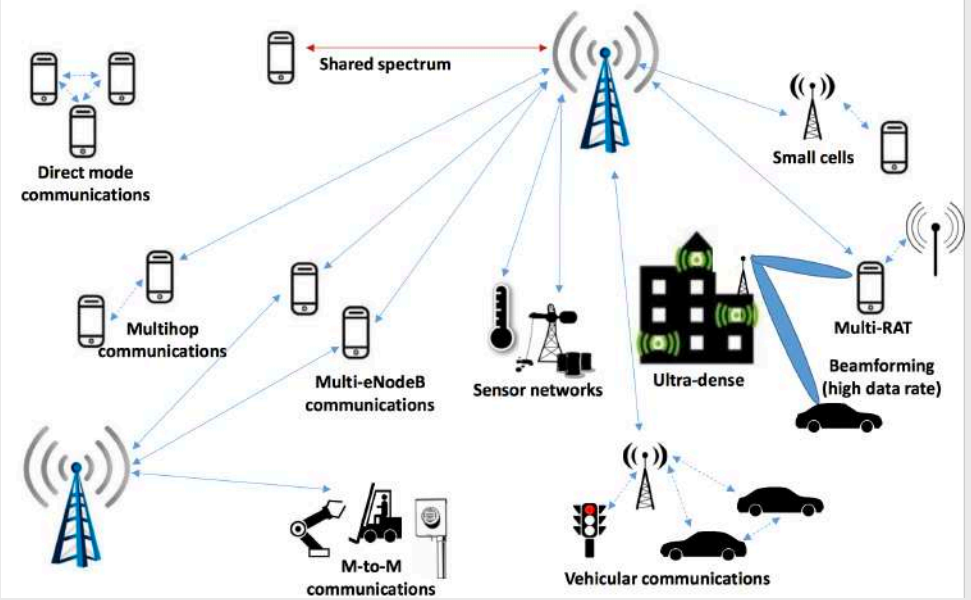




New Models

Use cases for mmWave in PSC

- **Real-time high quality video**
- **AR/VR content**
- **Different kind of sensors (e.g., LIDAR)**
- **Low latency communications**
- **Remote control**
- **Research areas**
  - **Channel sounding in PSC scenarios**
  - **Software defined radios for mmWaves experimentation**
  - ***End-to-end network simulation***



Tracy McElvaney, "5G: From a Public Safety Perspective," 2015

Performance Evaluation of Next-Gen Networks

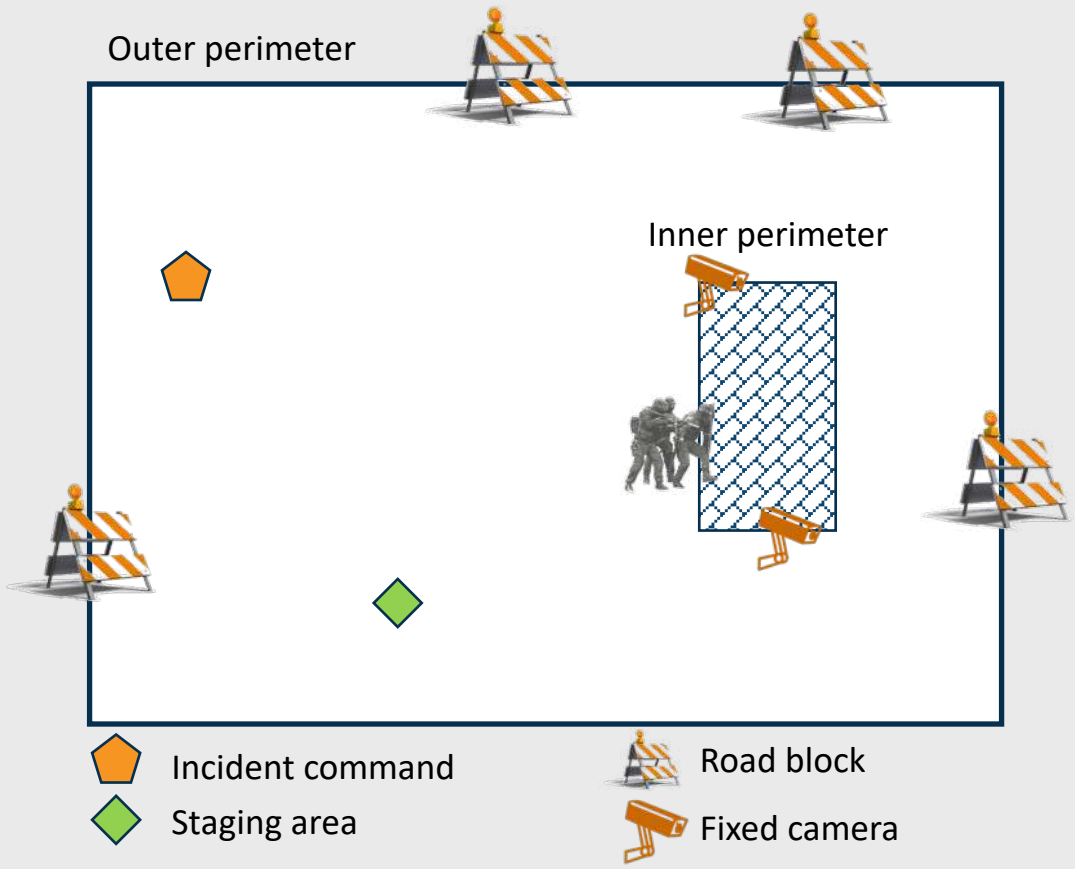
Same scenarios - Enhanced Communications

- **LTE Macro Cell Deployment**
- **LTE D2D and ProSe**
- **mmWave Communications**

High School Shooting Incident

Scenario overview

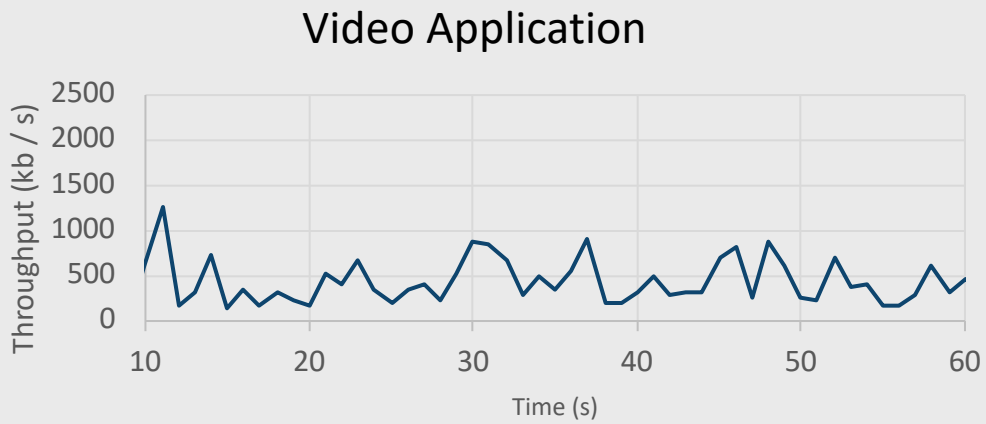
- **Report of an active shooter at a large high school and involves casualties**
- **More than 100 public safety responders representing:**
  - **Strike teams (SWAT)**
  - **Law Enforcement (for perimeter security)**
  - **Emergency Medical Service (EMS)**
  - **Firefighter**
  - **Incident Command / Unified Command (IC/UC)**
- **First responders use a mix of real-time streaming video, telemetry, biometrics, pre-plans, and other applications (more than 20 different applications in total)**

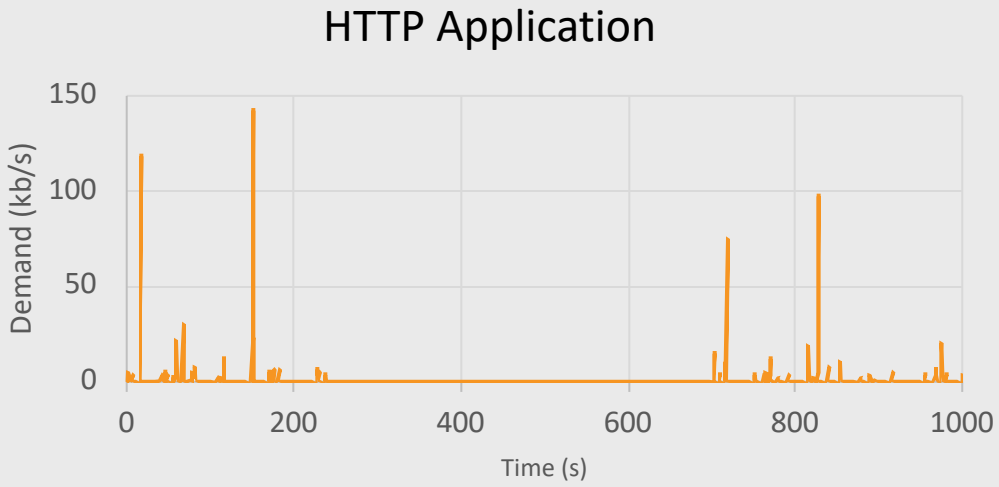


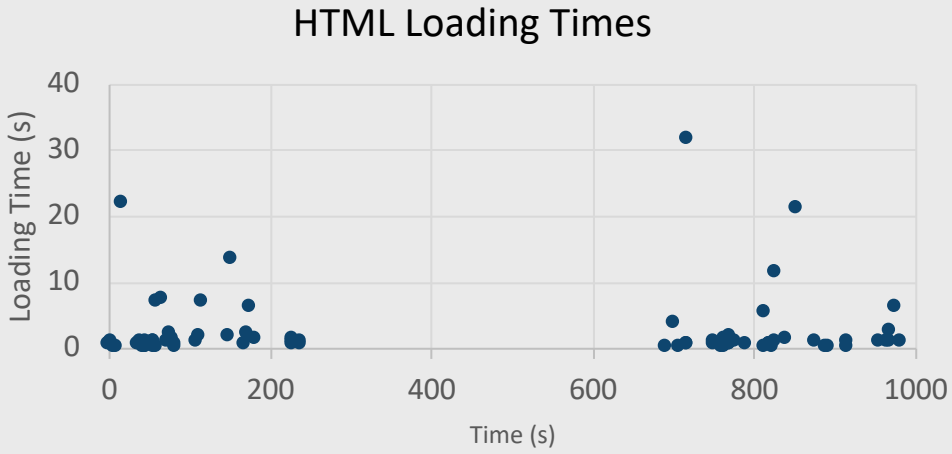
Note: scenario inspired by M. Navolio, "Minnesota Department of Public Safety, Public Safety Wireless Data Network Requirements Project Needs Assessment Report," May 27, 2011.

High School Shooting Incident

Evaluating Detailed Behaviors



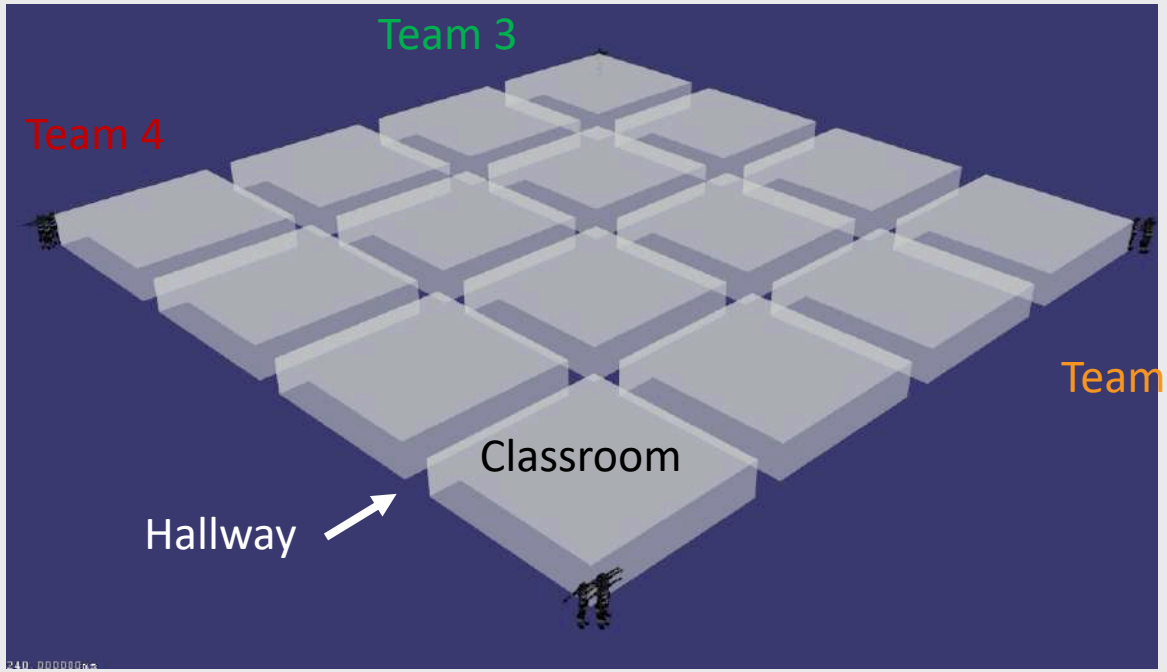




D2D in High School Shooting Scenario

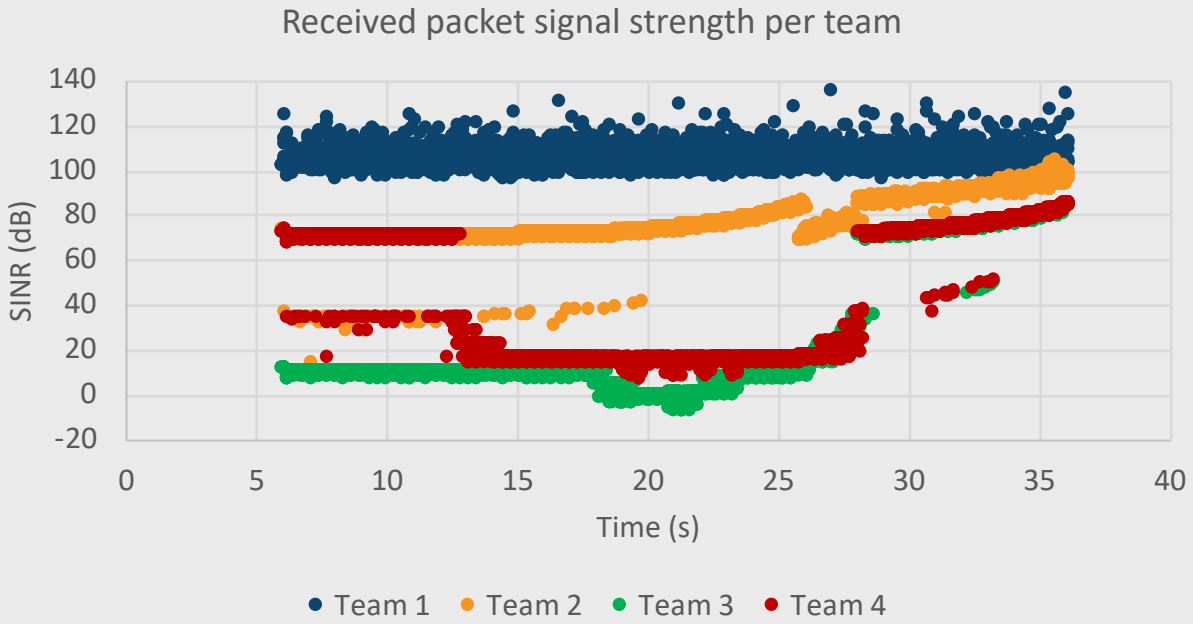
Scenario Description

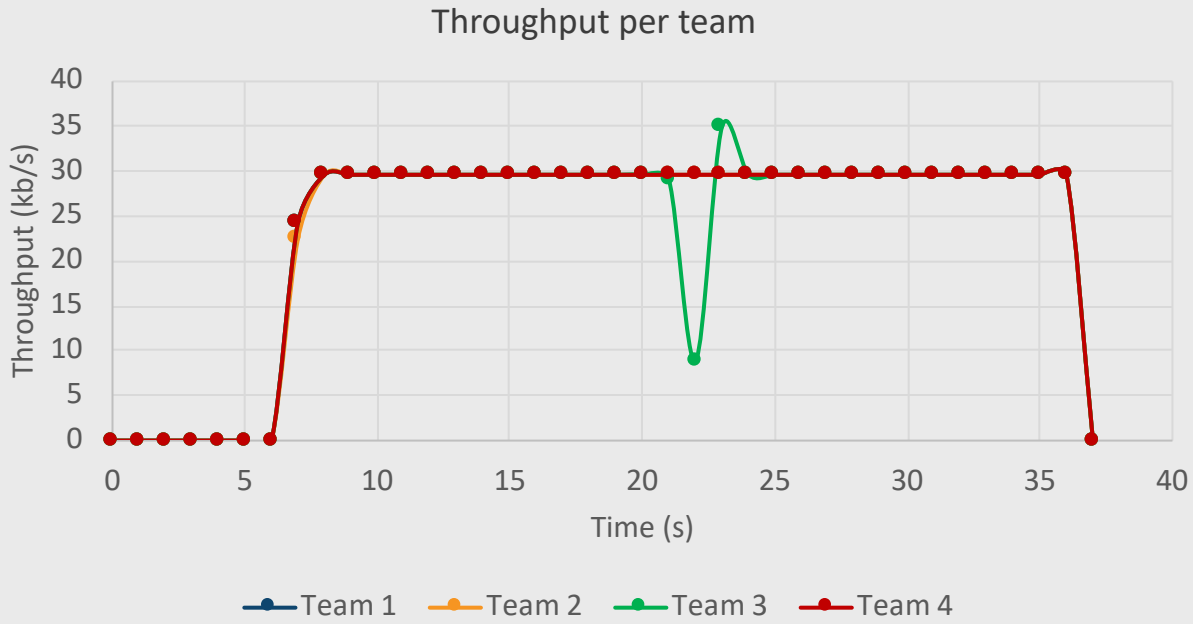
- **Focus on indoor use case**
  - **SWAT team strike in the building**
  - **Group mobility model**
  - **Coverage considerations**
- **4 SWAT teams**
  - **4 officers each**
- **Using MCPTT or video traffic over ProSe**



D2D in High School Shooting Scenario

Performance using MCPTT

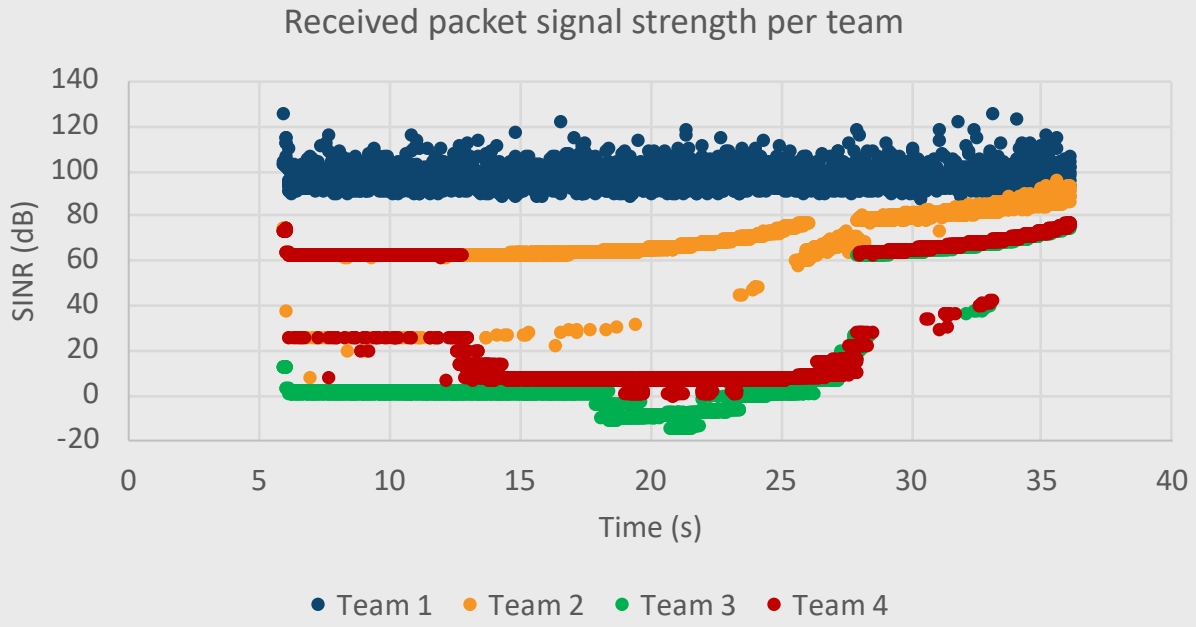


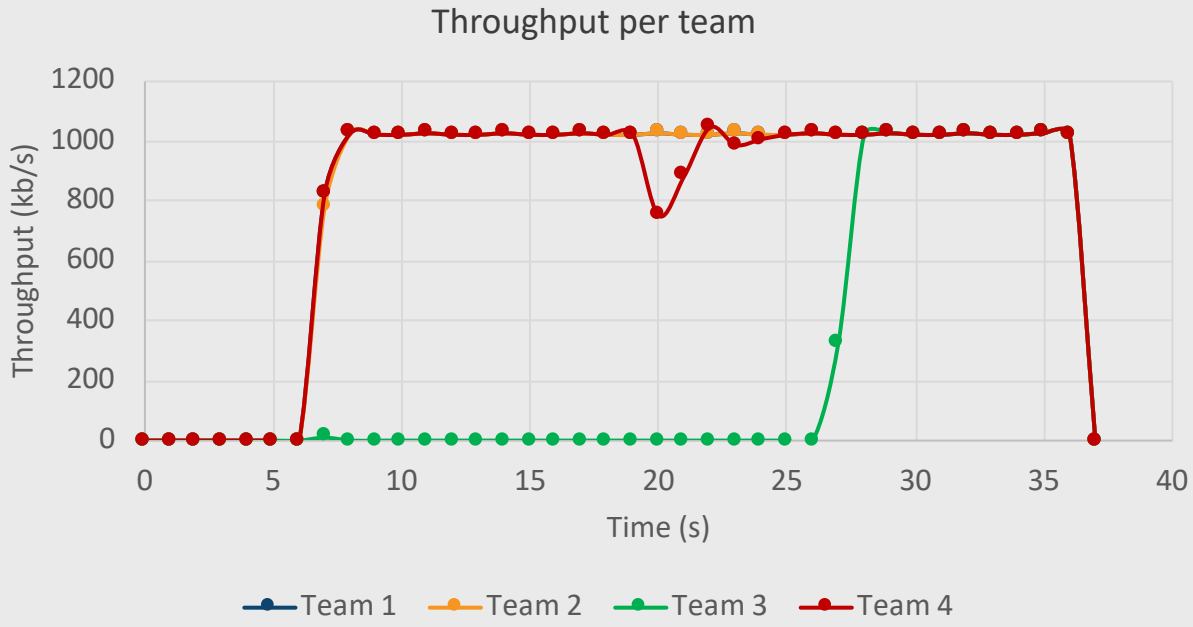


- **LTE Prose can provide indoor voice coverage for first responders**
- **Some degradation may occur due to obstacles**

D2D in High School Shooting Scenario

Performance using Video Traffic





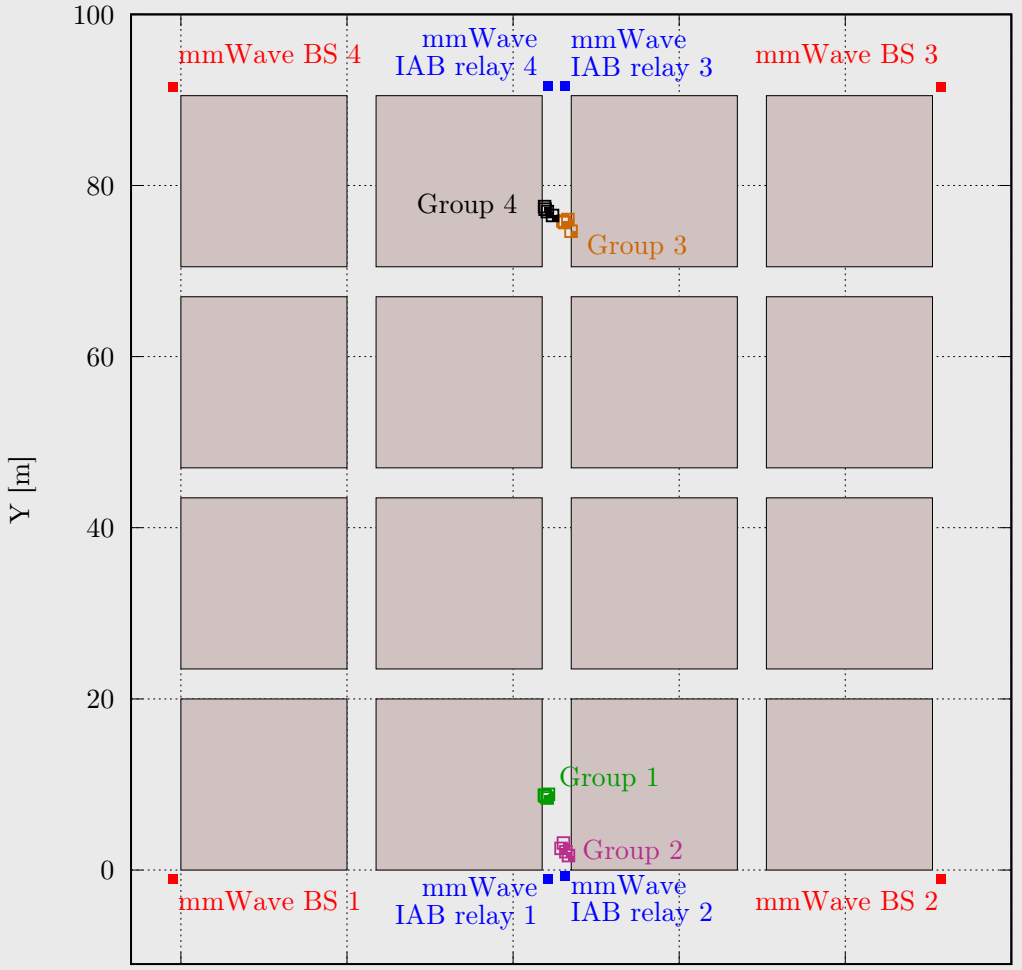
- **When considering higher data rates, LTE Prose provides limited coverage**

➔ Need to investigate other solutions

mmWave in High School Shooting Scenario

Develop a reference scenario and run a preliminary evaluation

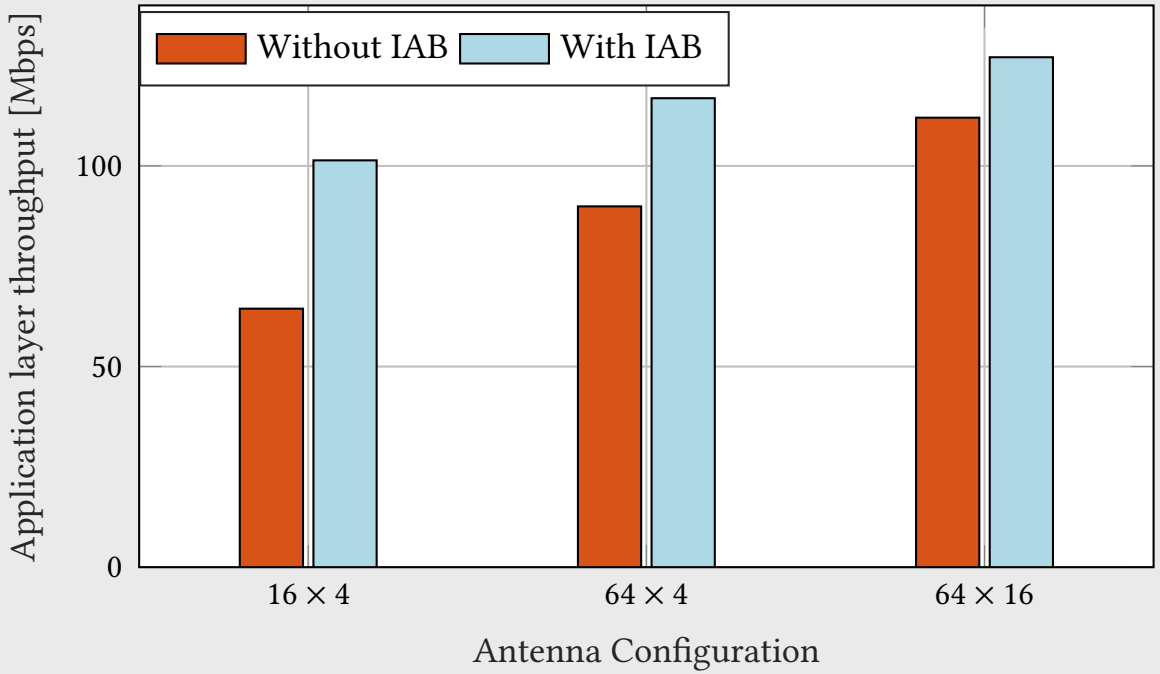
- Same scenario as for D2D
- 4 mmWave base stations at the corners (close to the accessible entrances)
- Mobile relays (IAB) or not
- Video streaming
  - Each officer streams video from head/body cam to IC station



mmWave in High School Shooting Scenario

Develop a reference scenario and run a preliminary evaluation

- **Mobile relays (IAB) or not**
- **Impact of different antenna arrays**
- **Metric: application layer throughput**



Take Aways

- **Realist public safety scenarios are complex**
  - **Can involves hundreds of users**
  - **Organization in units**
  - **Standard Operating Procedures (SOPs), i.e. less random events**
  - **Applications of first responders are different than commercial users**
- **Realistic inputs are needed**
- **Channel models for realistic and PS-specific environments (i.e. fire, smoke, crowd)**
- **Simulations can provide a performance assessment in scenarios where testbeds or real deployments are not feasible**
- **Simulators are becoming more capable of reporting QoE metrics**

Future Priorities

- Scenario development
  - Build collection of incidents
- Application models
- New technologies
  - 3GPP New Radio (NR)
  - NR Vehicle-to-Anything (V2X)
  - mmWave
  - Unmanned Aerial Vehicle (UAV)
- Measurement-based channel models

Contact Us

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https://github.com/usnistgov/psc-ns3
https://github.com/nyuwireless-unipd/ns3-mmwave
https://github.com/signetlabdei/mmwave-psc-scenarios
https://github.com/signetlabdei/ns3-mmwave-iab

ns-3 App Store https://apps.nsnam.org/

THANK YOU

#PSCR2019

Break for

Lunch

BACK AT

1:00PM