mmWave for Future Public Safety Communications

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December 12, 2017

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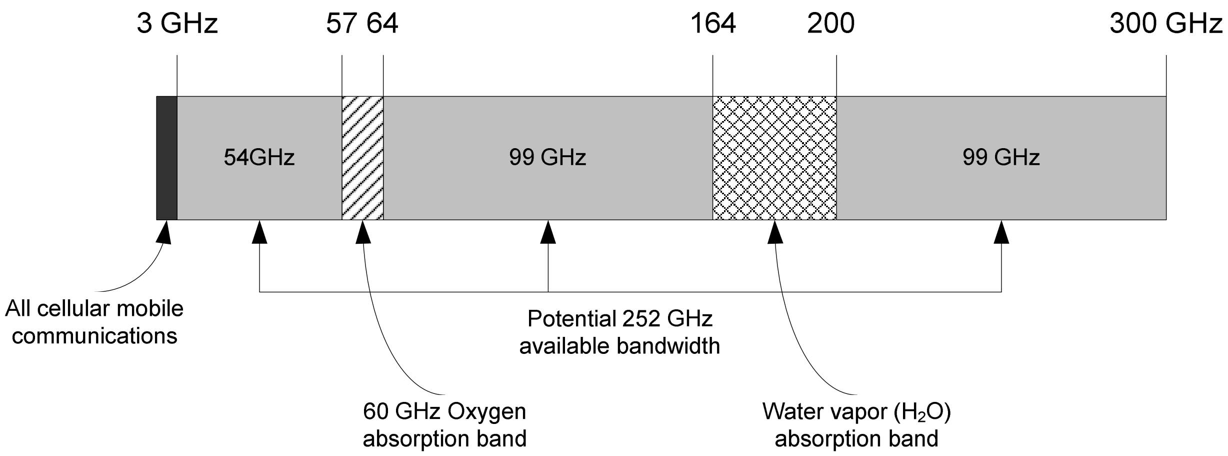
Outline

- Introduction
- PSC requirements
- Open challenges above 6 GHz
- Wildfire use case
- Conclusions

mmWave communications

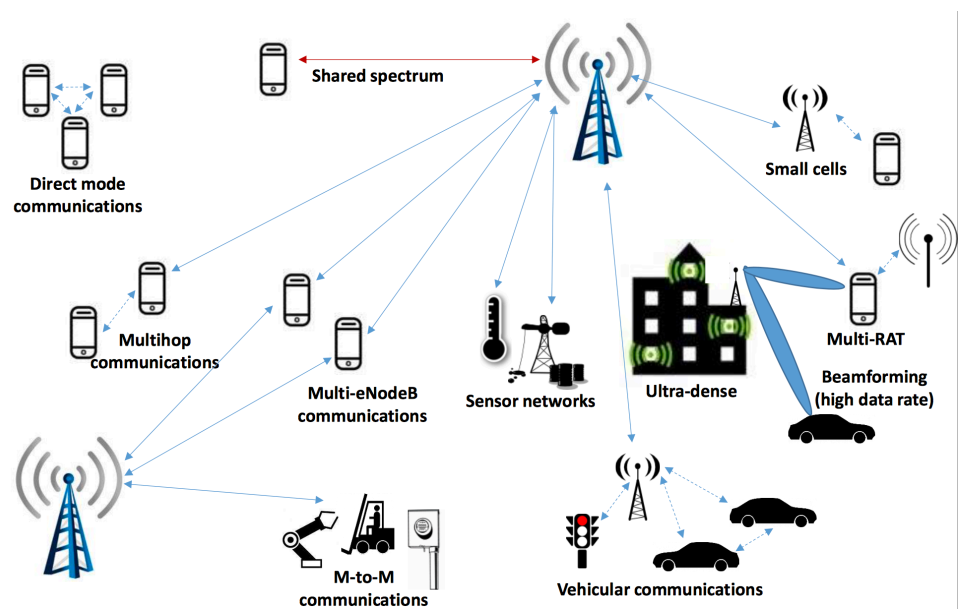
- Potentials
  - Bandwidth
  - Large arrays in small space



3GPP New Radio will support mmWave

PSC and mmWave

- Real-time *high quality* video
- AR/VR content
- Different kind of sensors (e.g., LIDAR)
- Low latency communications



Tracy McElvaney, “*5G: From a Public Safety Perspective*,” 2015

PSC requirements

- Support to command and control hierarchy
- Interactive/non interactive
- Data and voice transmissions
- Resilient and robust networks
- Low latency

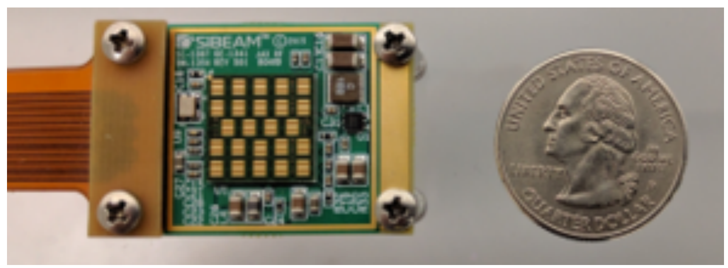
How can mmWaves meet these demands?

SAFECOM, US communications program of the Department of Homeland Security, “Public Safety Statements of Requirements for Communications and Interoperability Vols. I and II.”

mmWave limitations

- High propagation loss

Need to use directional transmission



Impact on PHY and MAC layer procedures

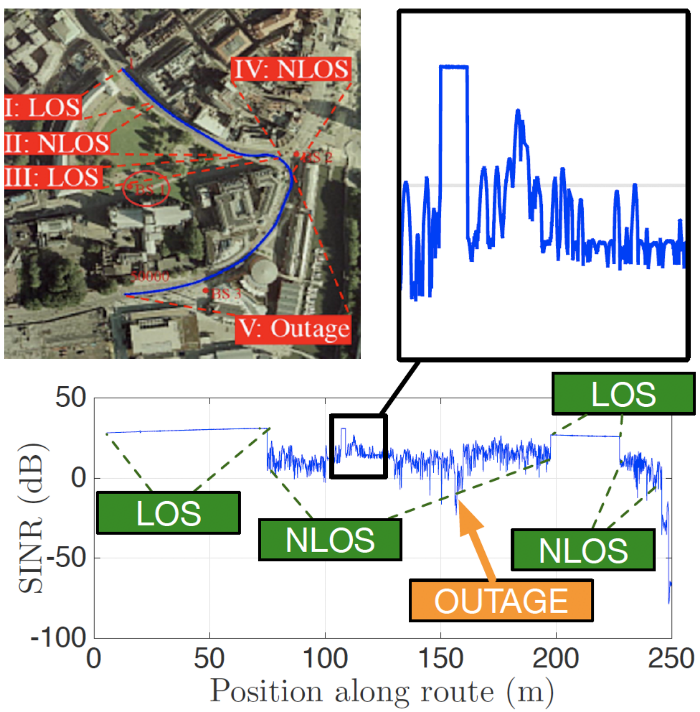
Challenges:

- Maintain alignment in dynamic scenarios
- Autonomous network discovery & reconfiguration

mmWave limitations

- High penetration loss – blockage

Fast variations of the channel quality



Challenges:

- How to get around obstacles
- Avoid losing connectivity

Challenges in PSC use cases

- Aerial/UAV and vehicular communication
  - Lack of measurements at mmWave frequencies
  - Sophisticated tracking
- Ad-hoc and resilient deployments
  - Frequent link adaptation/handovers
  - Suboptimal end-to-end performance
- Machine-type communications
  - Still unexplored

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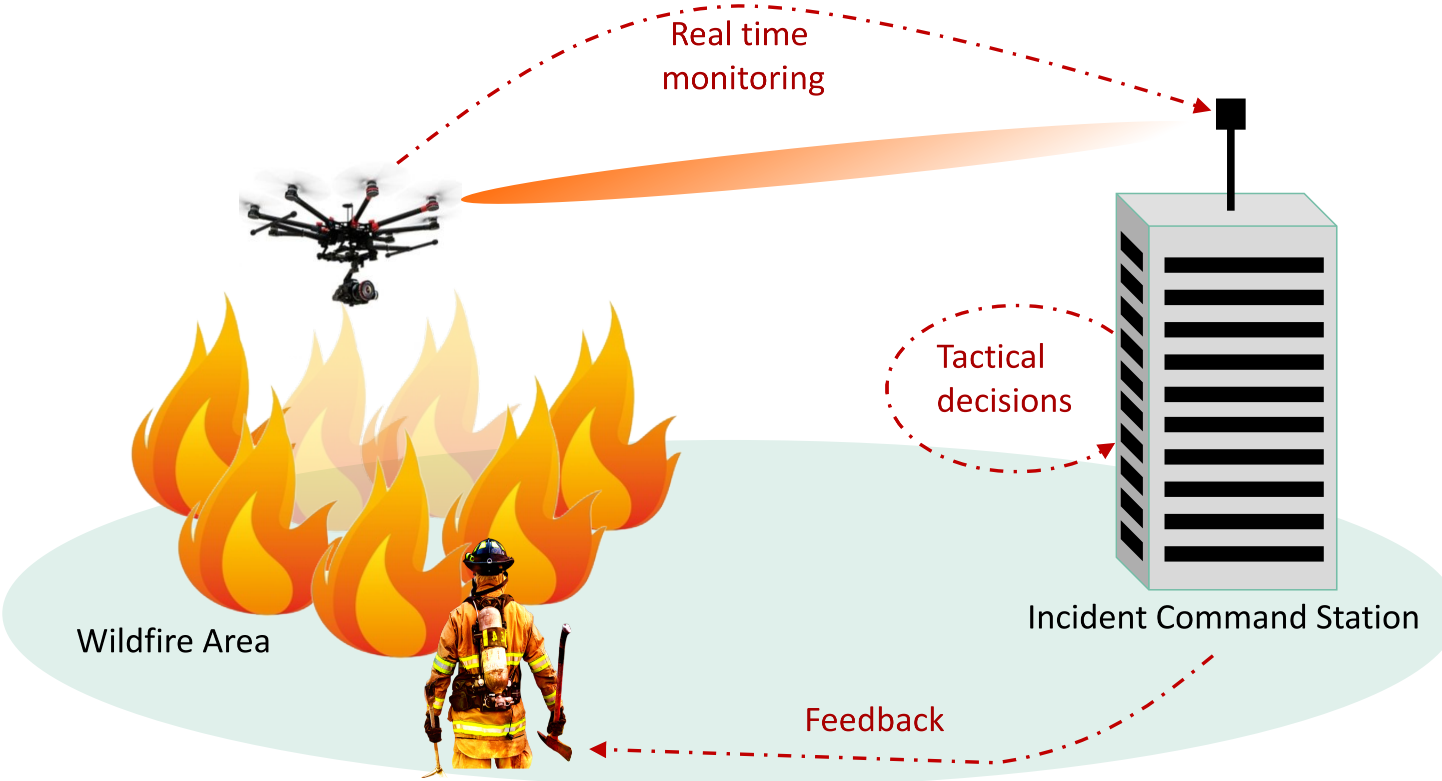
Example: wildfire scenario



Inspired by the Robotic Emergency Deployment team at the Austin Fire Department

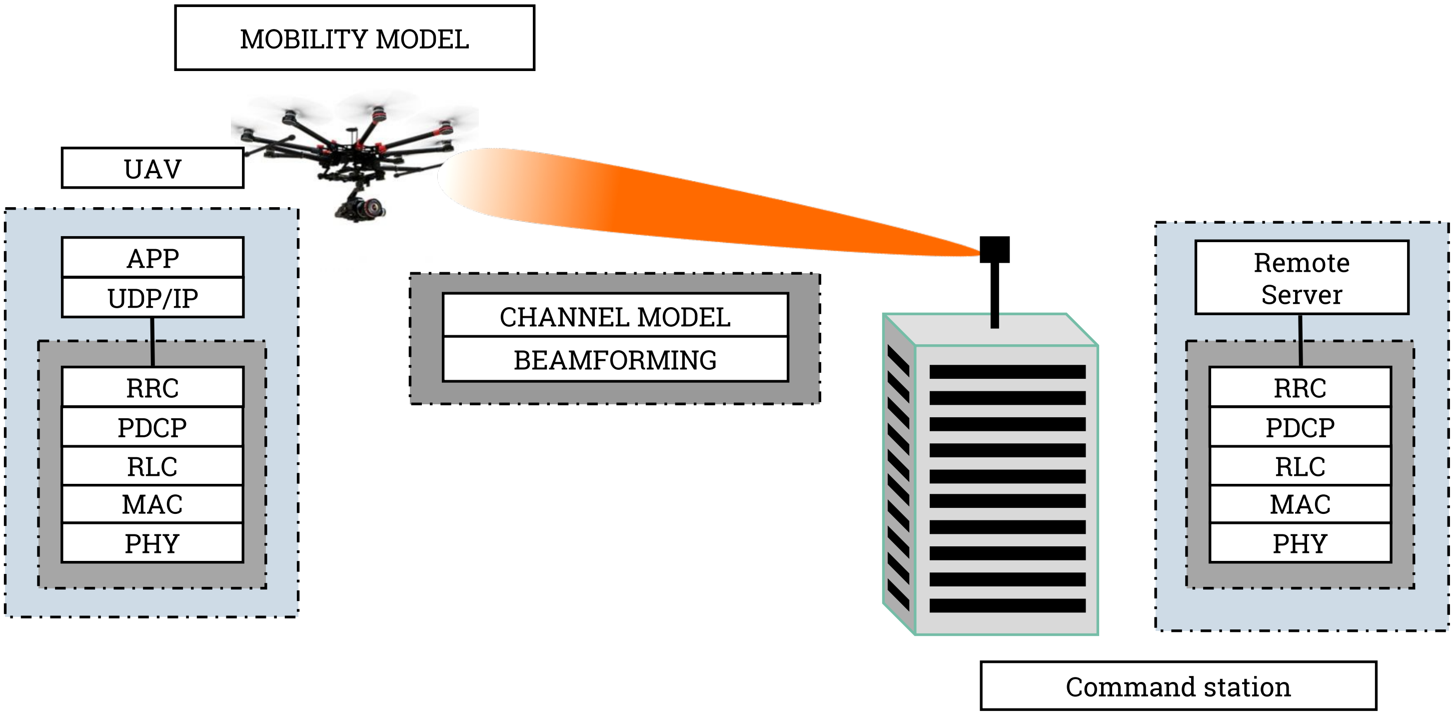
Wildfire reporting

- Current operations
  - Record video on SD card and physically send to command
  - Use low data rate links (3G/4G)
- Ideally
  - Use multiple high-resolution lenses for photos and videos
  - 360 degrees video content

⇒ mmWaves can provide a high data rate

Performance evaluation

- Based on ns-3 + LTE module
- End-to-end performance analysis

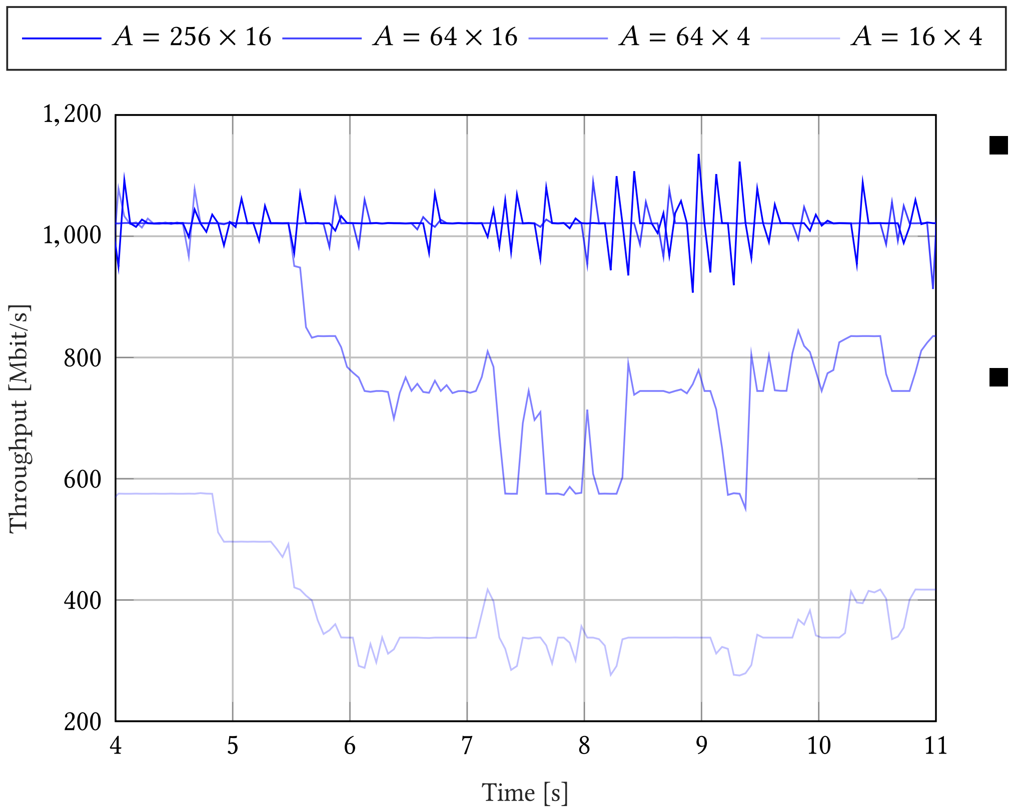


Performance evaluation

- Gauss-Markov mobility
  - 1.6 to 2.4 km IC – UAV distance
- Channel model
  - Free space pathloss
  - Single LOS ray
  - Doppler + shadowing
  - BF update every 5 ms

Parameter	Value
mmWave carrier frequency f_c	28 GHz
mmWave bandwidth	1 GHz
mmWave max PHY rate	3.2 Gbit/s
Beamforming vector update period	5 ms
Antenna combinations $A = N_{\text{eNB}} \times N_{\text{UE}}$	$\{16 \times 4,\ 64 \times 4,\ 64 \times 16,\ 256 \times 16\}$
Video source rate R	$\{1, 100, 1000\}$ Mbit/s
Transport protocol	UDP
Max UAV speed v	30 m/s
Wildfire - IC distance	$\{1.6, 2.4\}$ km
UAV height	30 m

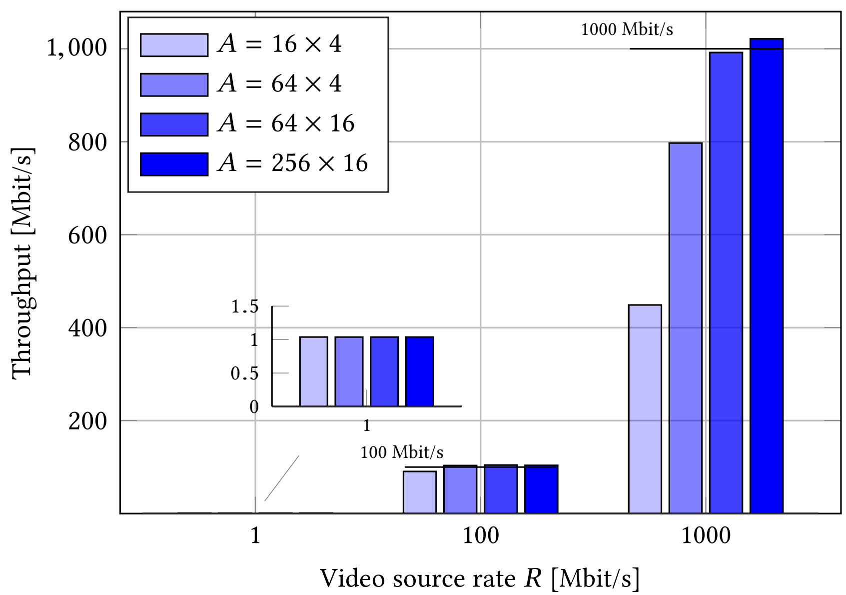
Throughput evolution

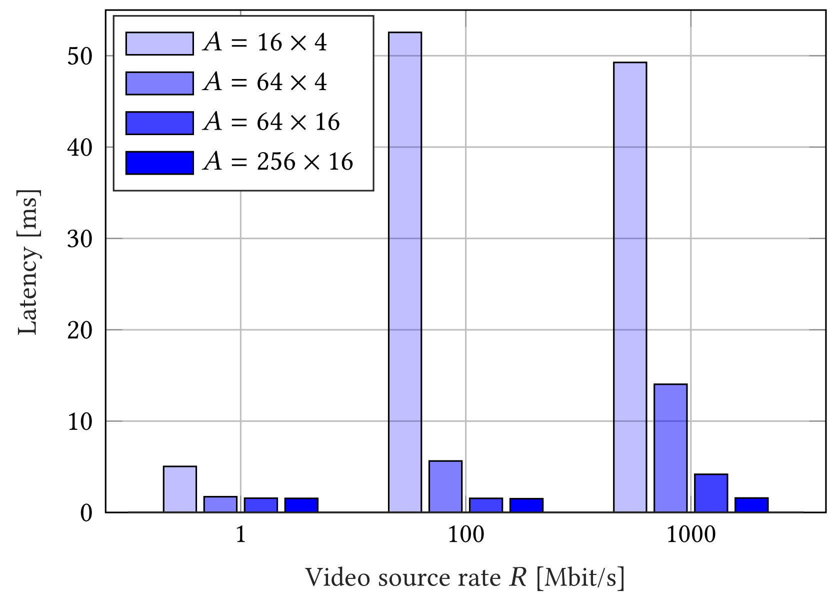


- Test antennas with different number of elements
- Suitable configurations are
  - 256 elements at IC, 16 at UAV
  - 64 elements at IC, 16 at UAV

Long-distance propagation only with BF gain

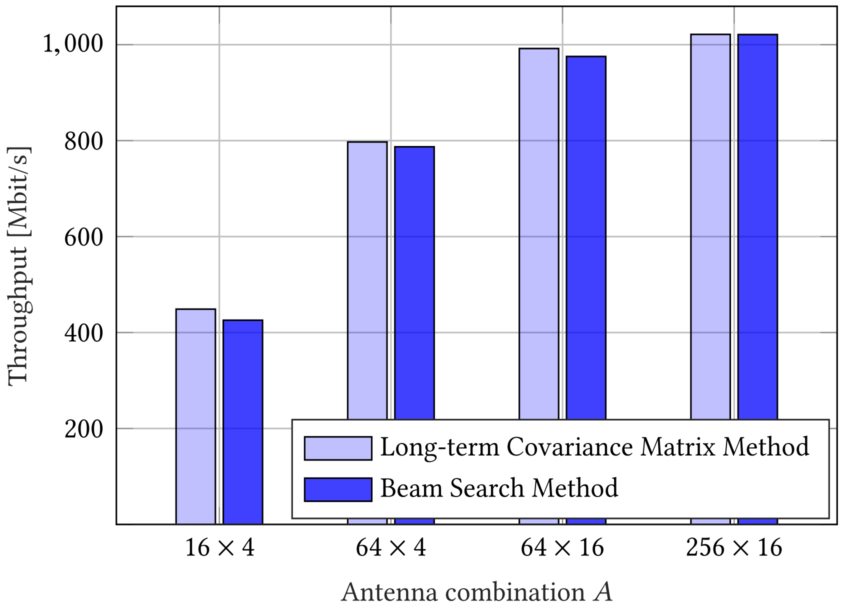
Throughput and latency

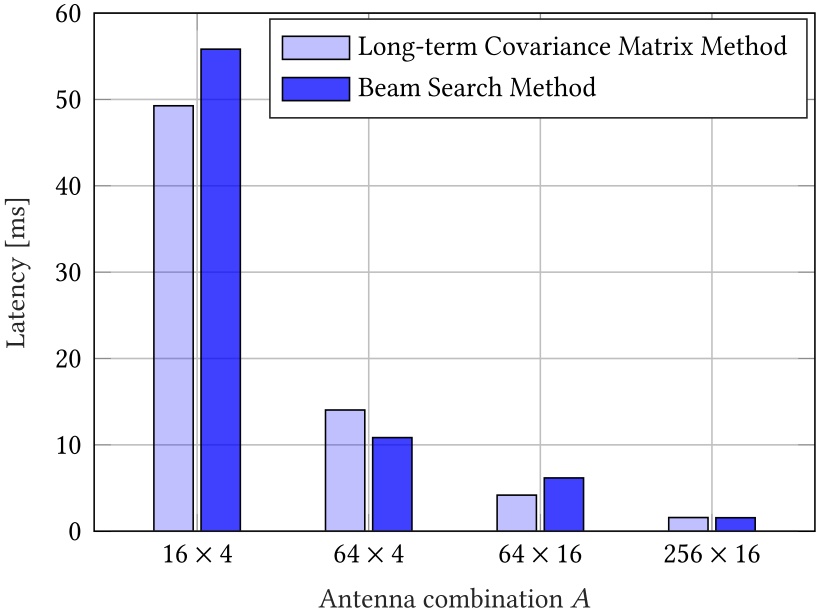




- Test different source rates
- Antennas with more elements increase the received power
  - Improve throughput
  - Reduce latency (fewer retransmissions)

Beamforming strategies





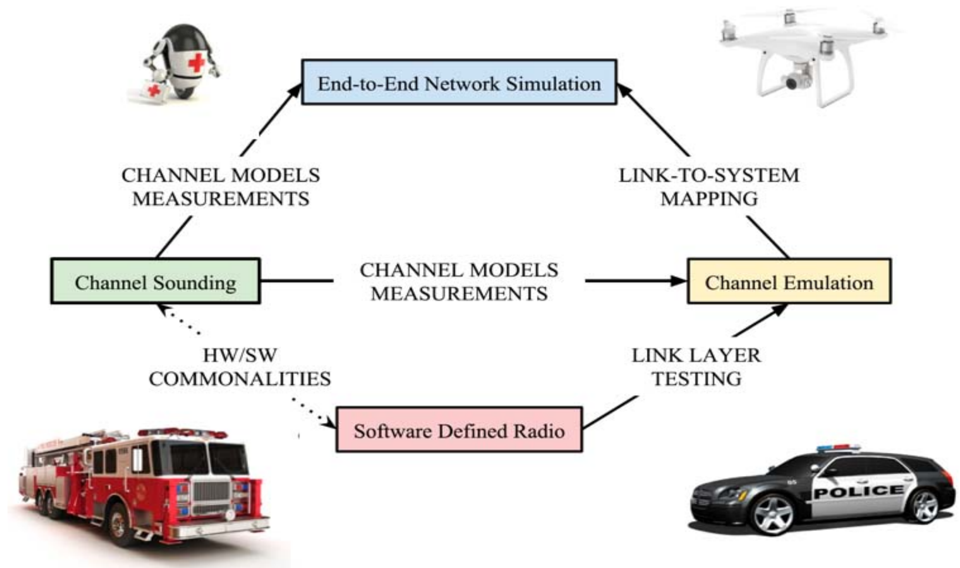
- Compare
  - Optimal beamforming (based on long-term covariance matrix)
  - Beam search with pre-defined beams

Conclusions

- mmWave can be an enabler of next-gen PSC
  - Wildfire use case
- Several challenges need to be addressed
  - Reliability?
  - Long-distance communication?
- Need for a research platform

End-to-end research platform for PSC over mmWave

NYU WIRELESS



- Measure dynamic directional channels in Public Safety (PS) scenarios.
- Prototyping new ultra-low latency MAC and synchronization algorithms likely to be used in the PS links.
- Provide the first scalable real-time emulation of complex mmWave channels in PS settings.
- Development and integration of PS specific scenarios in end-to-end mmWave network simulator.

Useful resources

- ns-3 mmWave module
  - https://github.com/nyuwireless-unipd/ns3-mmwave
- mmWave networking research @ UNIPD
  - http://mmwave.dei.unipd.it
- NYU Wireless
  - http://wireless.engineering.nyu.edu

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