PSCR

2017
PUBLIC SAFETY BROADBAND STAKEHOLDER MEETING

Day 1
Monday, June 12

#PSCR2017

2017

PUBLIC SAFETY BROADBAND
STAKEHOLDER MEETING

Sue Swenson

FirstNet Chairwoman

Keynote Address

#PSCR2017

Disclaimer

Certain commercial entities, equipment, or materials may be identified in this document in order to describe an experimental procedure or concept adequately.

Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the entities, materials, or equipment are necessarily the best available for the purpose.

Acronym Glossary

- AF = Authentication Framework
- AMR-WB = Adaptive Multi-Rate Wideband
- API = Application Program Interface
- AR = Augmented Reality
- BIM = Building Information Model
- CEP = Circular Error Probable
- DDPS = Device-to-Device Systems for Public Safety
- DMO = Direct Mode Operations
- DOD = Department of Defense
- DSSS = Direct Sequence Spread Spectrum
- EMS = Emergency Medical Service
- EPC = Evolved Packet Core
- GCSE = Group Communication System Enablers
- IMU = Inertial Measurement Unit
- ISP = Internet Services Provider
- KPI = Key Performance Indicator
- LMR = Land Mobile Radio
- LTE = Long Term Evolution
- MCOP = Mission Critical Open Platform
- MCPTT = Mission Critical Push-to-Talk
- MCS = Modulation and Coding System
- MCV = Mission Critical Voice
- MOS = Mean Opinion Score
- NPSBN = Nationwide Public Safety Broadband Network
- NIST = National Institute of Standards and Technology
- OAI = Open Air Interface
- OTT = Over-the-Top Content
- P&T = Positioning and Timing
- PGW = PDN (Packet Data Network) Gateway
- PHY = Physical Layer of the OSI (Open Systems Interconnection)
- PNT = Position, Navigation, Timing
- PSC = Public Safety Communications
- PSCCH = Physical Sidelink Control Channel
- PRB = Physical Resource Block
- ProSe/PS = Proximity Services
- PS = Public Safety
- PSO = Public Safety Officers
- PSIAP = Public Safety Innovation Accelerator Grant Program
- PTT = Push-to-Talk
- Rej = Rejection
- RF = Radio Frequency
- RLF = Radio Link Failure
- SDR = Software-Defined Radio
- SGW = Satellite Gateway
- SLSSs = Sidelink Synchronization Signals
- SoC = System-on-a-Chip
- SWaP+C = Size, Weight, Power, and Cost
- SyncRef = Synchronization Reference
- VOR = VHF (Very High Frequency) Omni-directional Range
- VR = Virtual Reality
- UE = User Equipment
- UX = User Experience
- ZUPT = Zero Velocity Update

PSCR

Public Safety Mission Critical Voice

Latest research plans and results from PSCR

PSCR

2017

PUBLIC SAFETY BROADBAND
STAKEHOLDER MEETING

#PSCR2017

Speakers

- **Jeb Benson,** PSCR Technology Acceleration & External Research Group
- **Richard Rouil,** PSCR Modeling & Simulation
- **David Griffith,** PSCR Modeling & Simulation

PSCR

MCV Goals FY16-17

- **Evaluate out-of-coverage MCV communication**
- **Study QoS, Priority and Preemption mechanisms in order to serve MC applications**
- Accelerate R&D of MCPTT & DMO
- Lower barrier of entry for MCV research
- Build PS R&D ecosystem

Stay Tuned:
MCV/RPP Grant Program Panel

- **'Benchmarking' → Quality of experience**

PSCR

Out-of-Coverage Communication in LTE

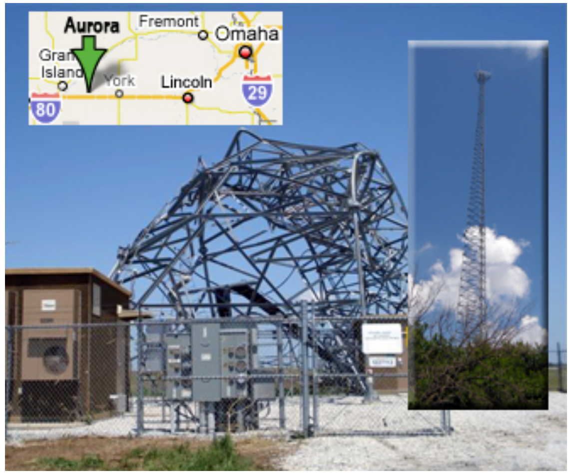
Richard Rouil and David Griffith
NIST/CTL/Wireless Networks Division
June 12, 2017

PSCR

2017
PUBLIC SAFETY BROADBAND
STAKEHOLDER MEETING

#PSCR2017

Motivations



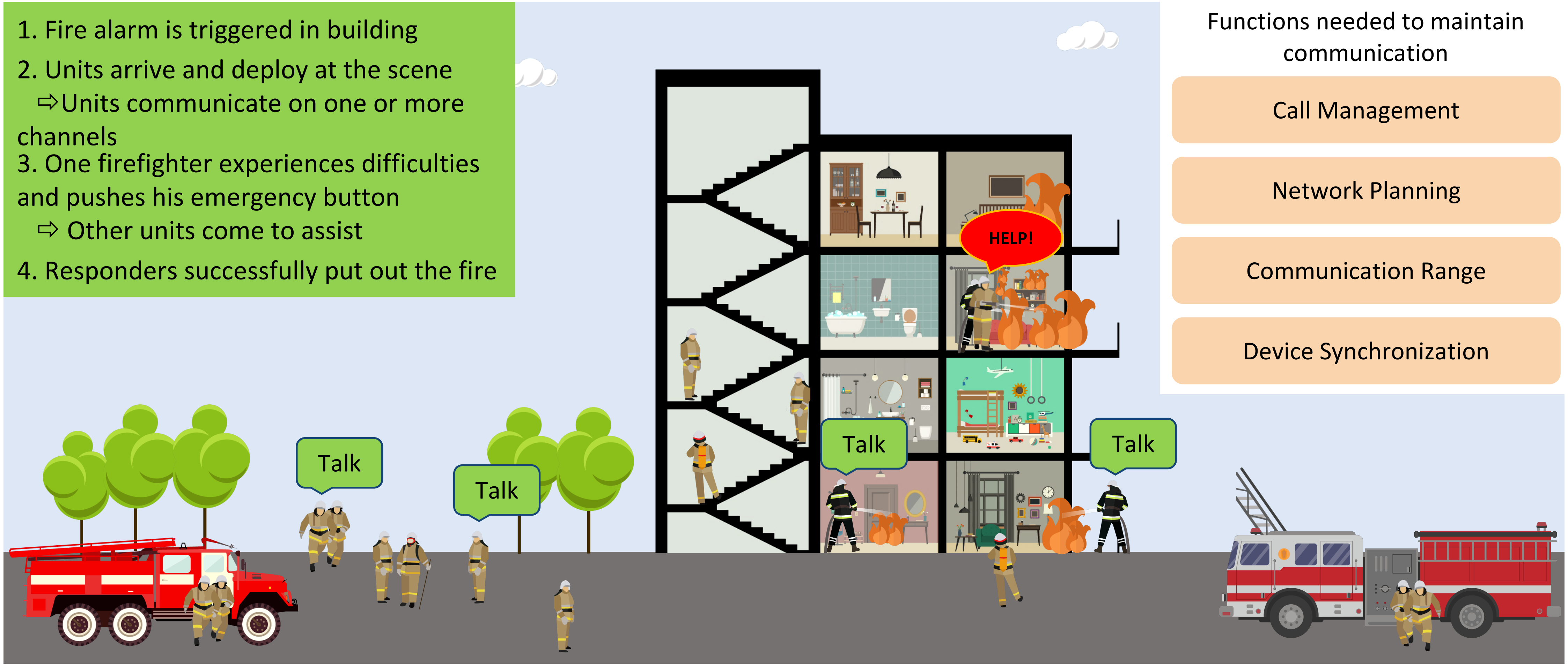
- First Responders have to communicate in challenging environments where the network infrastructure may be down or non-existent: “out-of-coverage scenario”
- The ability to have device to device (D2D*) communication when in “out-of-coverage” from cellular towers can be the difference between life and death

* D2D, sidelink, and proximity services are interchangeable terms in the remainder of the talk.

Sources:
https://media.defense.gov/2012/Jun/29/2000137943/-1/-1/0/120627-F-TQ740-256.JPG
https://www.dhs.gov/science-and-technology/wildland-fire-fighter-uniform-redesigned
http://wirelessestimator.com/content/articles/?pagename=Cell%20Site%20Tower%20News

Out-of-Coverage Scenario

1. Fire alarm is triggered in building
2. Units arrive and deploy at the scene
   ⇨Units communicate on one or more channels
3. One firefighter experiences difficulties and pushes his emergency button
   ⇨ Other units come to assist
4. Responders successfully put out the fire



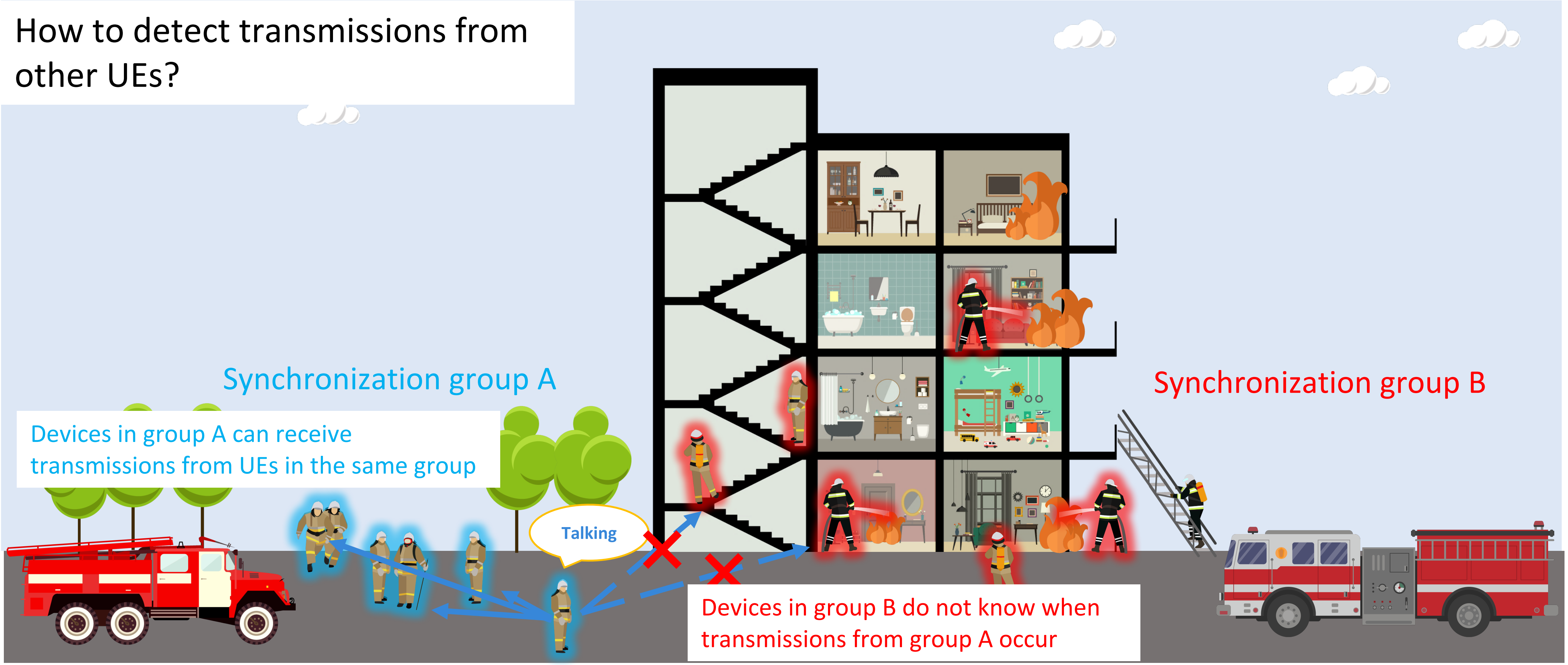
Functions needed to maintain communication

- Call Management
- Network Planning
- Communication Range
- Device Synchronization

PSCR

Device Synchronization

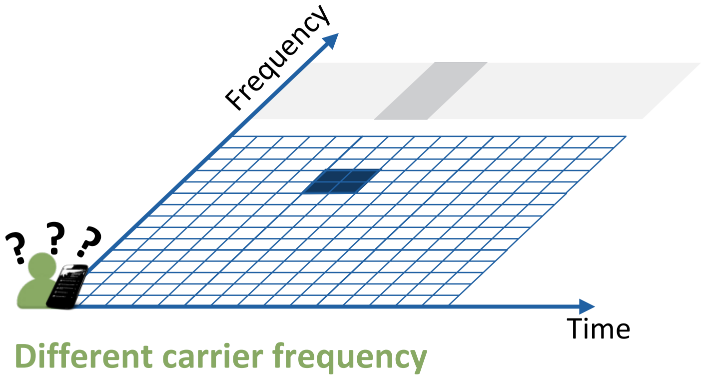
How to detect transmissions from other UEs?

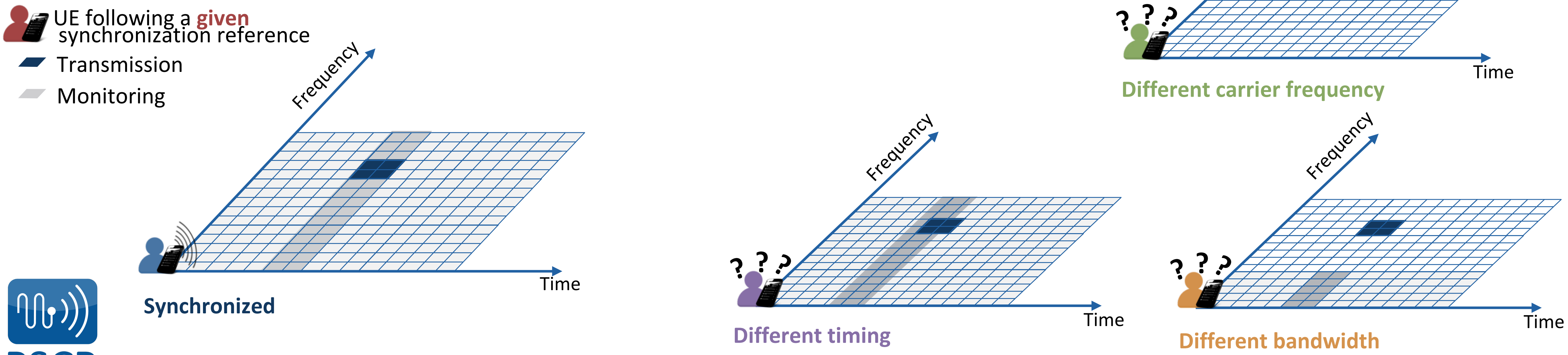


PSCR

Information Needed for Synchronization

- User Equipment (UEs) attempting to communicate need to be configured to transmit and monitor the same set of radio resources:
  - Timing (meeting analogy: time zone, 8 AM EDT vs 8 AM PST)
  - Carrier frequency (meeting analogy: room location)
  - Bandwidth (meeting analogy: room capacity)



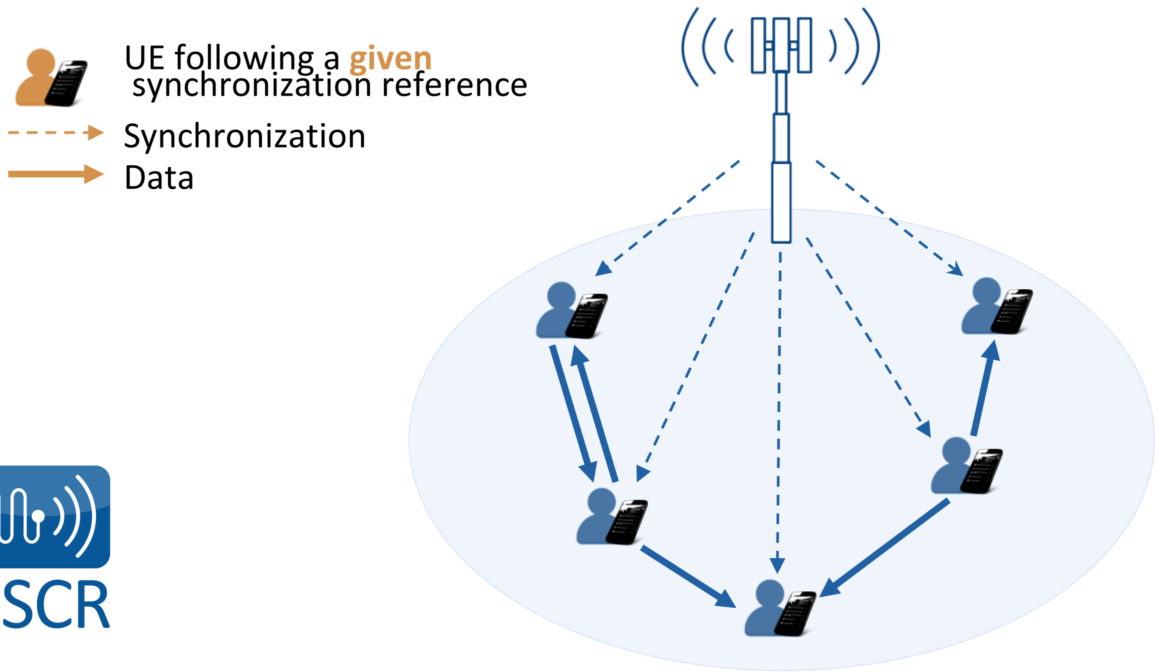


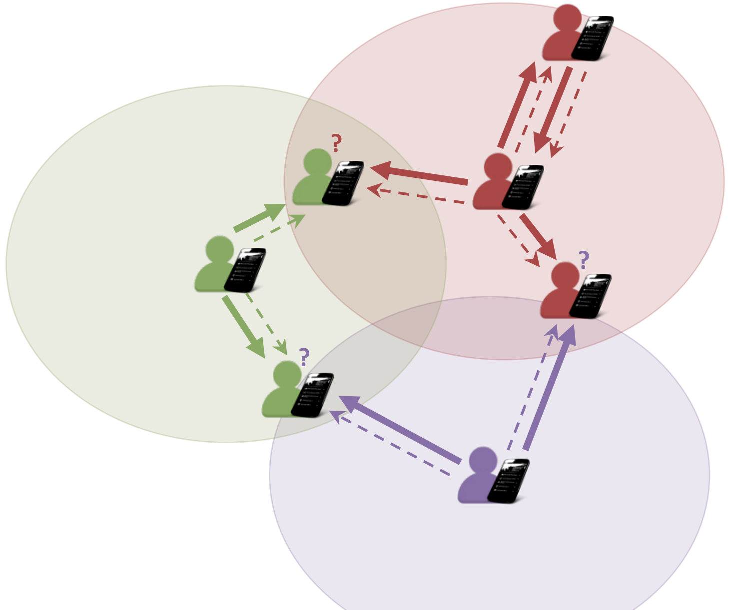
PSCR

In-Coverage vs. Out-of-Coverage Synchronization

- In-coverage synchronization is a centralized process
  - The eNodeB is the master node announcing the synchronization reference
  - Each UE within the eNodeB coverage synchronizes to that synchronization reference

- Out-of-coverage synchronization is a distributed process
  - Each UE announces its synchronization information only when transmitting data
  - Each UE may detect multiple synchronization references, and it synchronizes to the most suitable one
    - Impairing the communication with UEs following other synchronization references

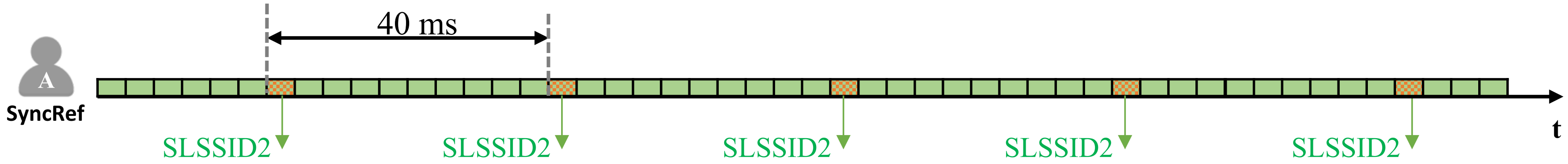




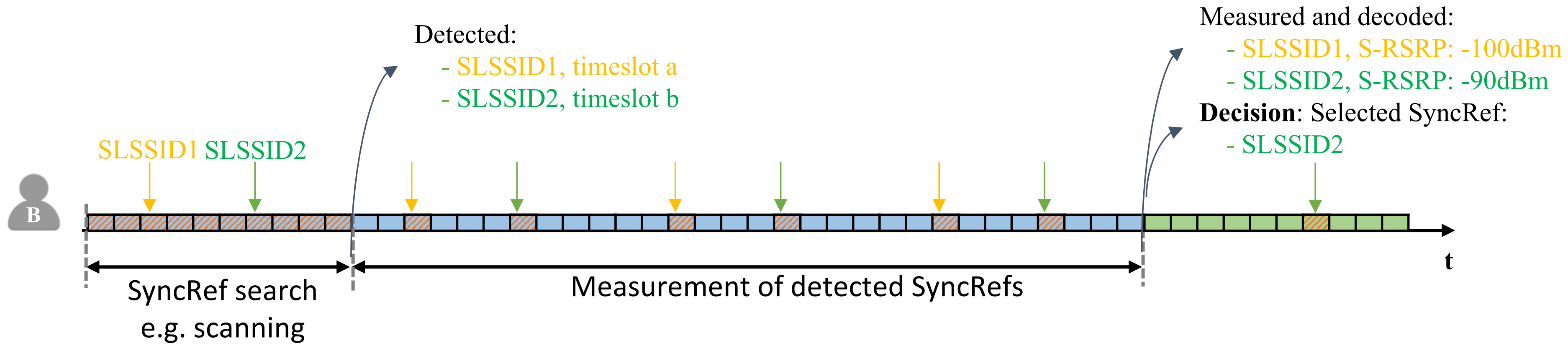
PSCR

Out-of-Coverage Synchronization

- A UE acting as a Synchronization Reference (SyncRef) sends Sidelink Synchronization Signals (SLSSs) every 40 ms



- Other UEs must detect and select the most suitable SyncRef and synchronize to it



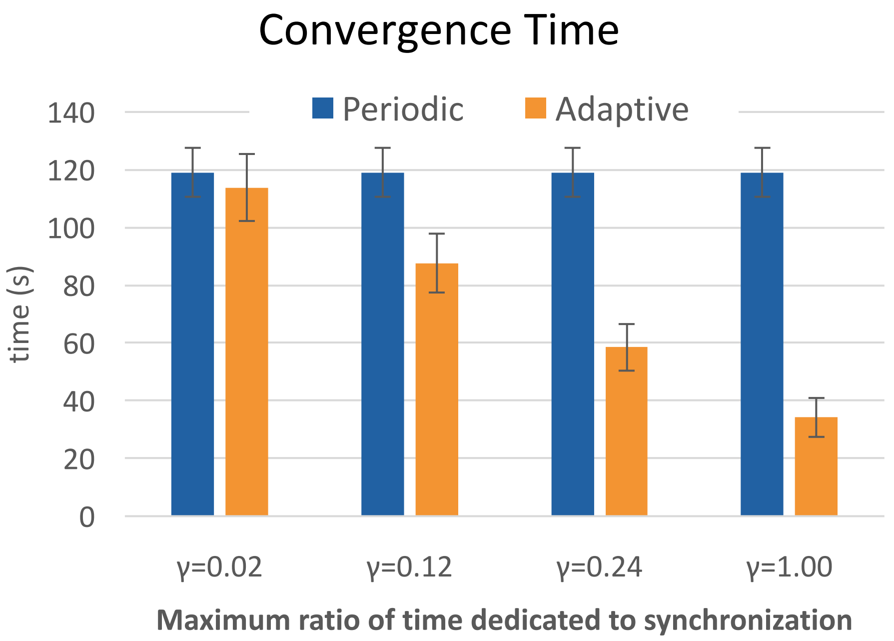
- Synchronization may lead to significant packet loss.

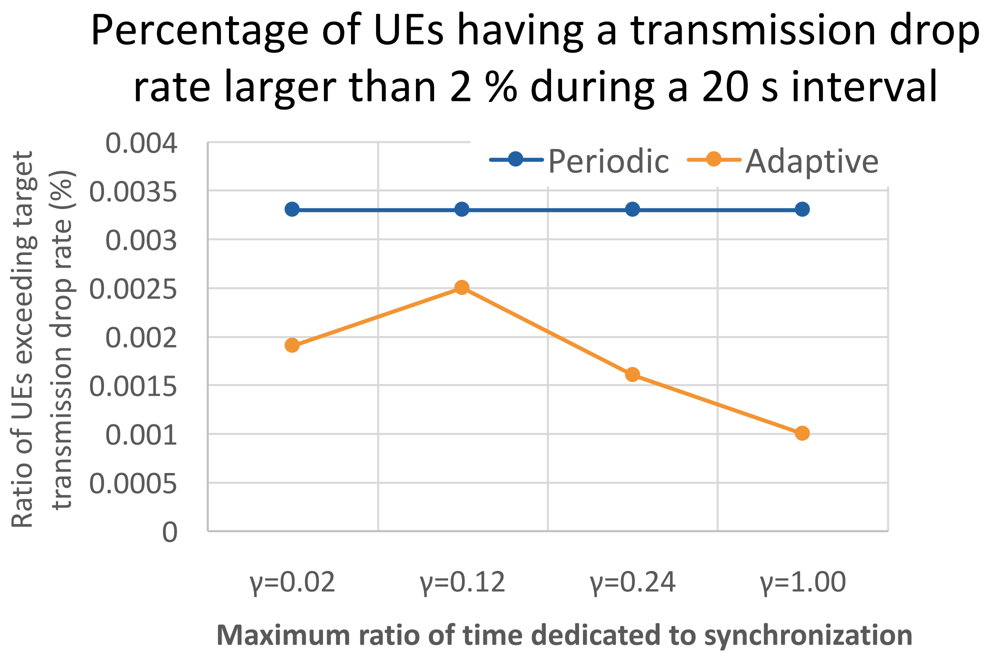
⇨How to perform synchronization while minimizing packet loss?

PSCR

Evaluating Synchronization

Configuration:
24 UEs: 12Tx and 12 Rx
On-Off traffic pattern





- Design and evaluate an adaptive algorithm to provide fast convergence to a synchronized state
  - Faster convergence time when the UE is allowed to spend more time in RX mode (higher γ value) performing synchronization
  - Reduced transmission drop rate

PSCR

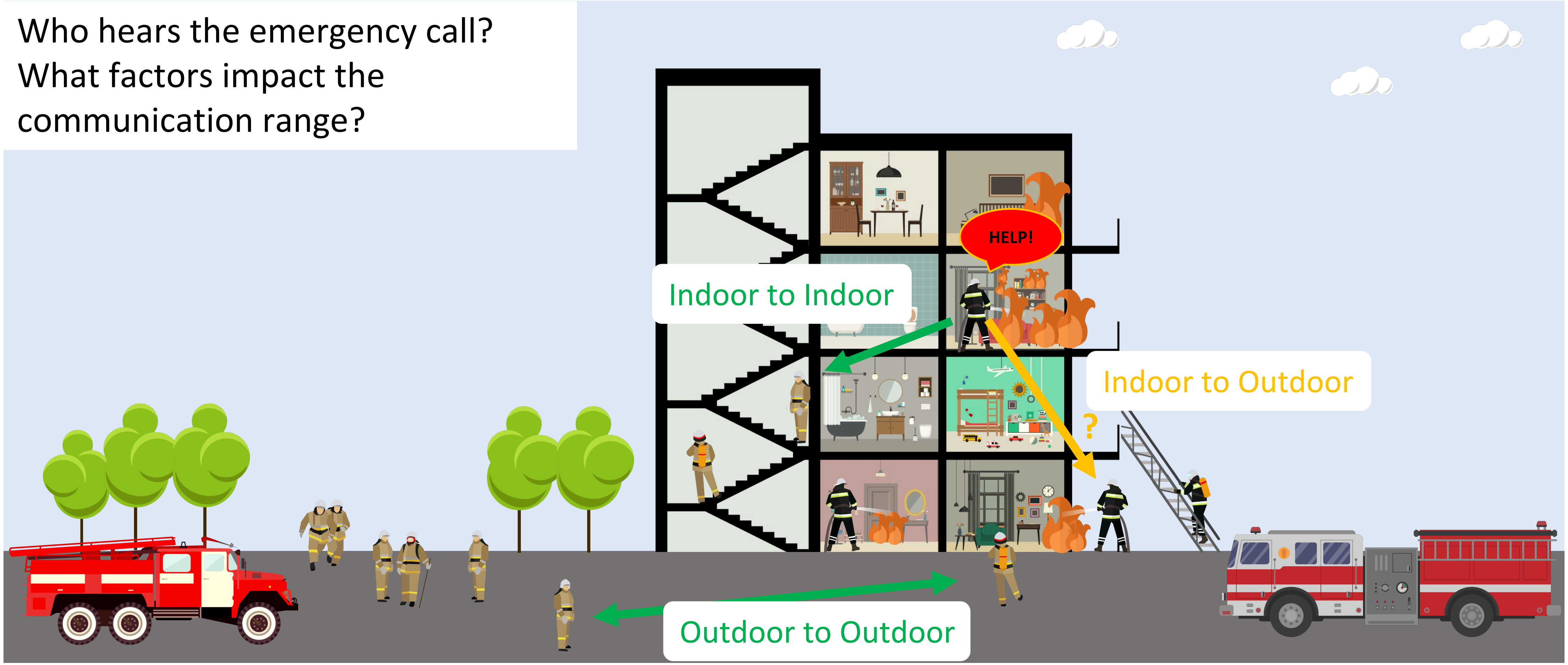
Synchronization: Next Steps

- Evaluate synchronization mechanisms in additional scenarios
  - Partial coverage
  - Relay nodes
- Develop algorithms to speed up synchronization for D2D Discovery service

PSCR

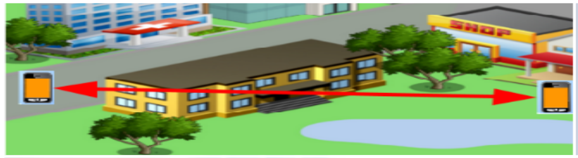
Communication Range

Who hears the emergency call? What factors impact the communication range?



PSCR

Environments

Environment		Model Used
Outdoor to Outdoor (O2O)		3GPP D2D Outdoor to Outdoor [1]
Outdoor to Indoor (O2I)		3GPP D2D Outdoor to Indoor [1]
Indoor to Indoor (I2I) Same Building		Distance Partitioned Model [2]
Indoor to Indoor (I2I) Different Building		3GPP D2D Indoor to Indoor [1]

[1] 3GPP TR 36.843 V12.0.1, "Technical Specification Group Radio Access Network: Study on LTE Device to Device Proximity Services: Radio Aspects (release 12)," 2014.
[2] D. Akerberg, "Properties of a TDMA PICO Cellular Office Communication System," in *Proc. of IEEE GLOBECOMM*, 1988.

PSCR

Resource Configuration

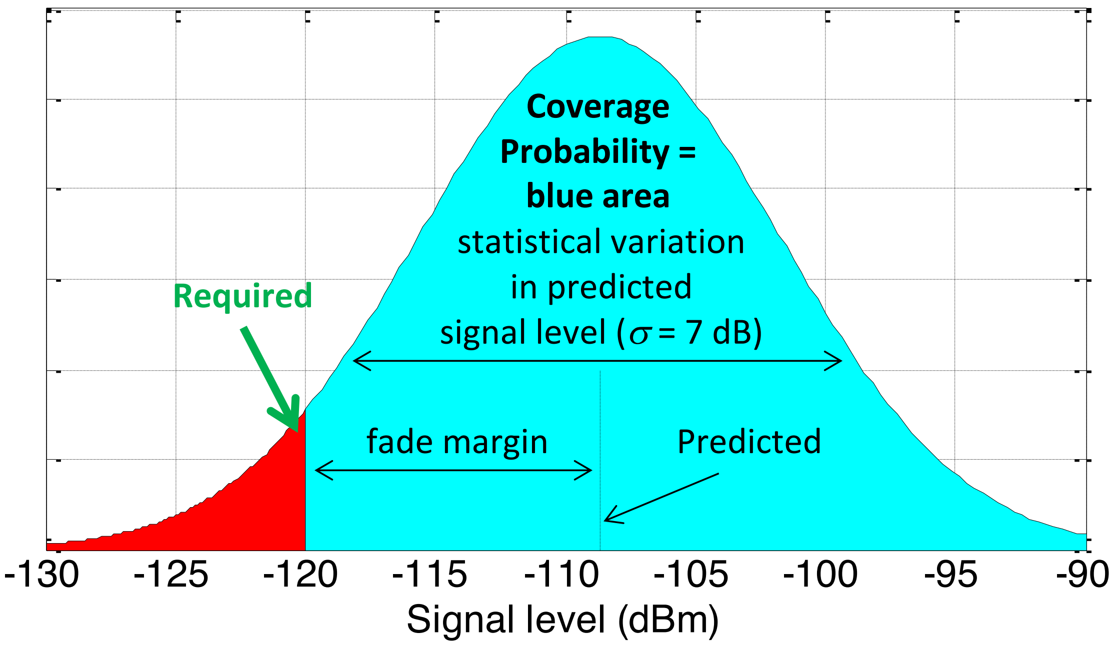
- Performance of the shared channel depends on the resource configurations, such as the Physical Resource Block (PRB) size and the Modulation and Coding Scheme (MCS) value
- Mandatory Adaptive Multi-Rate Wideband (AMR-WB) codec for Mission Critical Push To Talk (MCPTT) supports multiple configurations:
  - Few choices to support 12 kb/s rate with header compression* (assuming 25 % of subframes available for D2D), such as:
    - MCS 0 and 12 PRBs
    - MCS 5 and 4 PRBs
    - MCS 10 and 2 PRBs
    - MCS 18 and 1 PRBs

*Assumptions based on 3GPP 36.843 Study on LTE Device to Device Proximity Services

PSCR

Coverage Probability

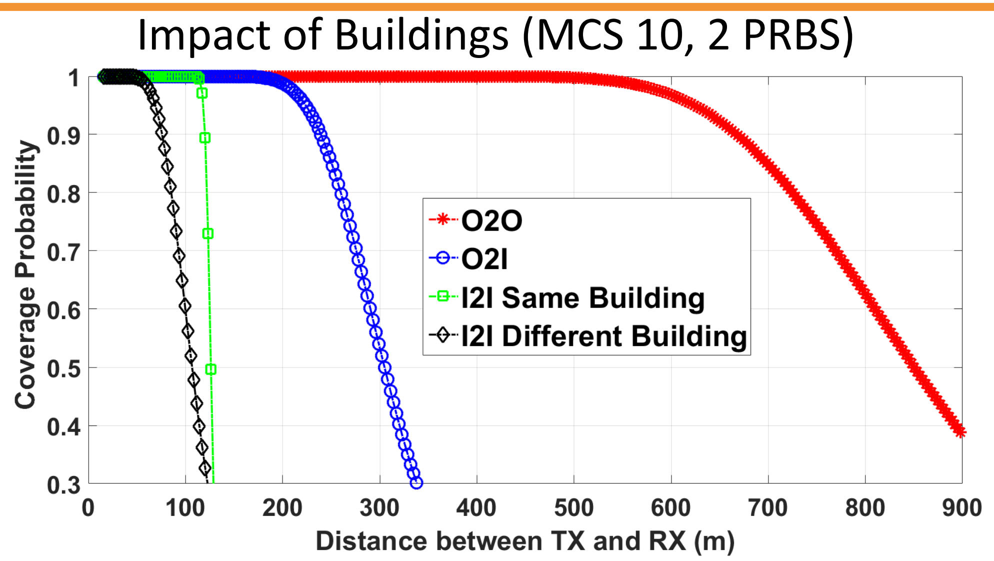
- The communication range is defined as the probability that the signal level at a given location is above the minimum required level
- The computation of the received signal power takes into account the following channel effects:
  - Path Loss
  - Shadowing
  - Small-scale fading
- For a given distance between transmitter (TX) and receiver (RX), combine both line-of-sight and non line-of-sight probabilities

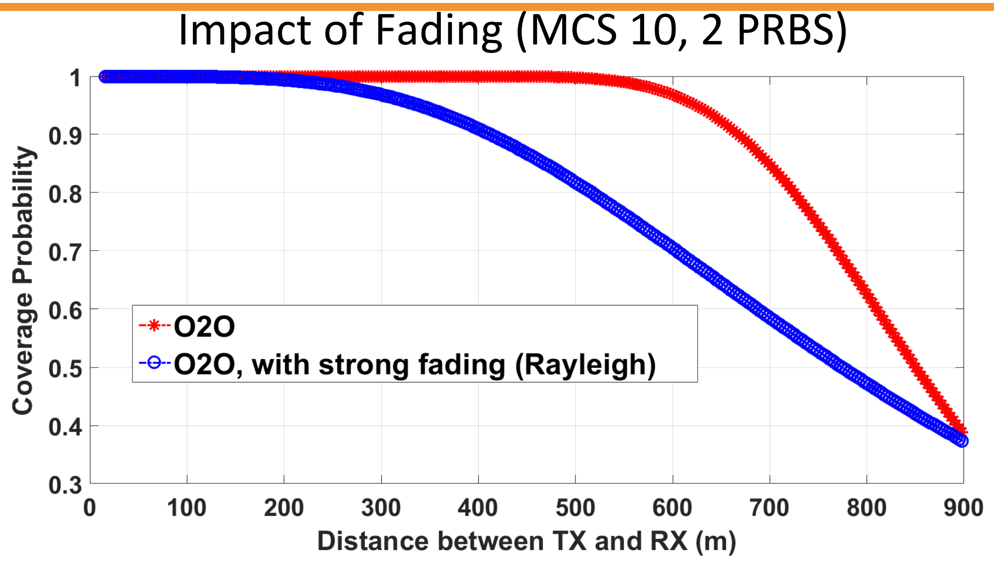


11.5 dB fade margin $\Rightarrow$ 95% coverage probability
7.3 dB fade margin $\Rightarrow$ 85% coverage probability

PSCR

Impact of Environment





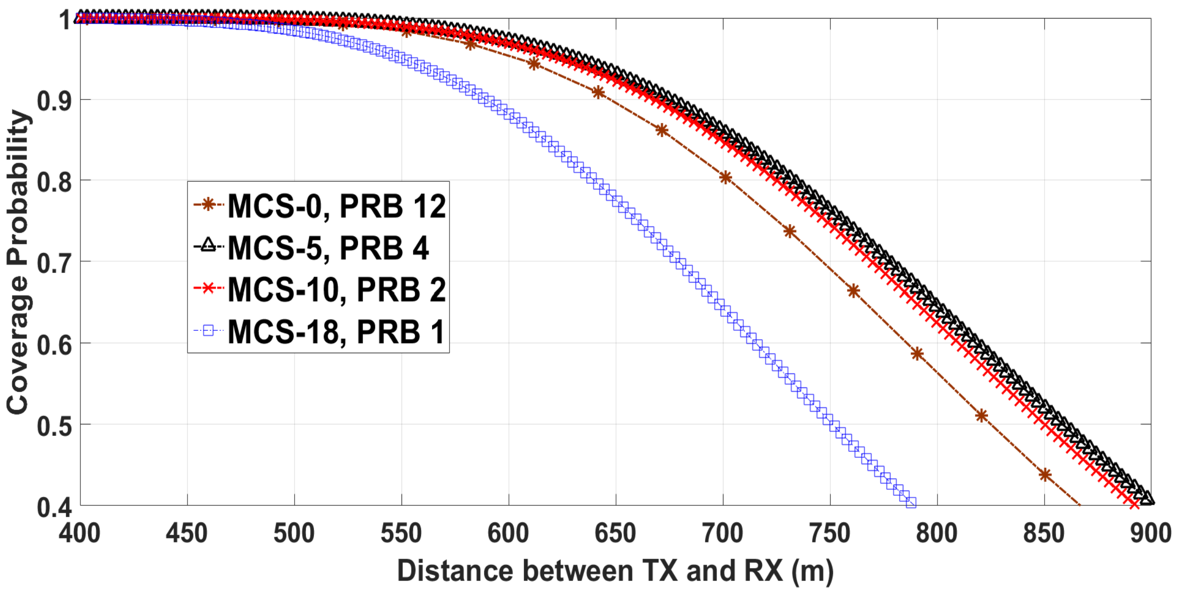
- Buildings significantly impact communication range, because of the penetration loss due to the building walls and floors
- Fading conditions can also reduce communication range
- As a result, we obtain an interval for the maximum communication range. For MCS 10 and 2 PRBs we have:

Coverage Probability	O2O (m)	O2I (m)	I2I Same Building (m)	I2I Different Building (m)
99%	221 - 364	88 – 131	83 - 106	22 - 30
95%	332 - 458	126 – 170	94 - 111	33 - 44
90%	411 - 537	150- 194	103 - 114	44 - 55

PSCR

Impact of Resource Configuration

Coverage probability vs. distance for O2O



Communication range for all configurations to achieve 95 % coverage probability (when fading is not considered)

Resource Configurations	O2O (m)	O2I (m)	I2I Same Building (m)	I2I Different Building (m)
MCS 0 / 12 PRBs	458	165	110	44
MCS 5 / 4 PRBs	474	170	112	45
MCS 10 / 2 PRBs	458	170	112	45
MCS 18 / 1 PRB	411	150	106	38

- With MCS 18, 16-QAM (Quadrature Amplitude Modulation) is used => significant higher Signal to Noise Ratio (SNR) margin is needed => lower coverage probability
- With 12 PRBs => significant thermal noise floor rises => lower coverage probability
- The results indicate that there is a trade-off

PSCR

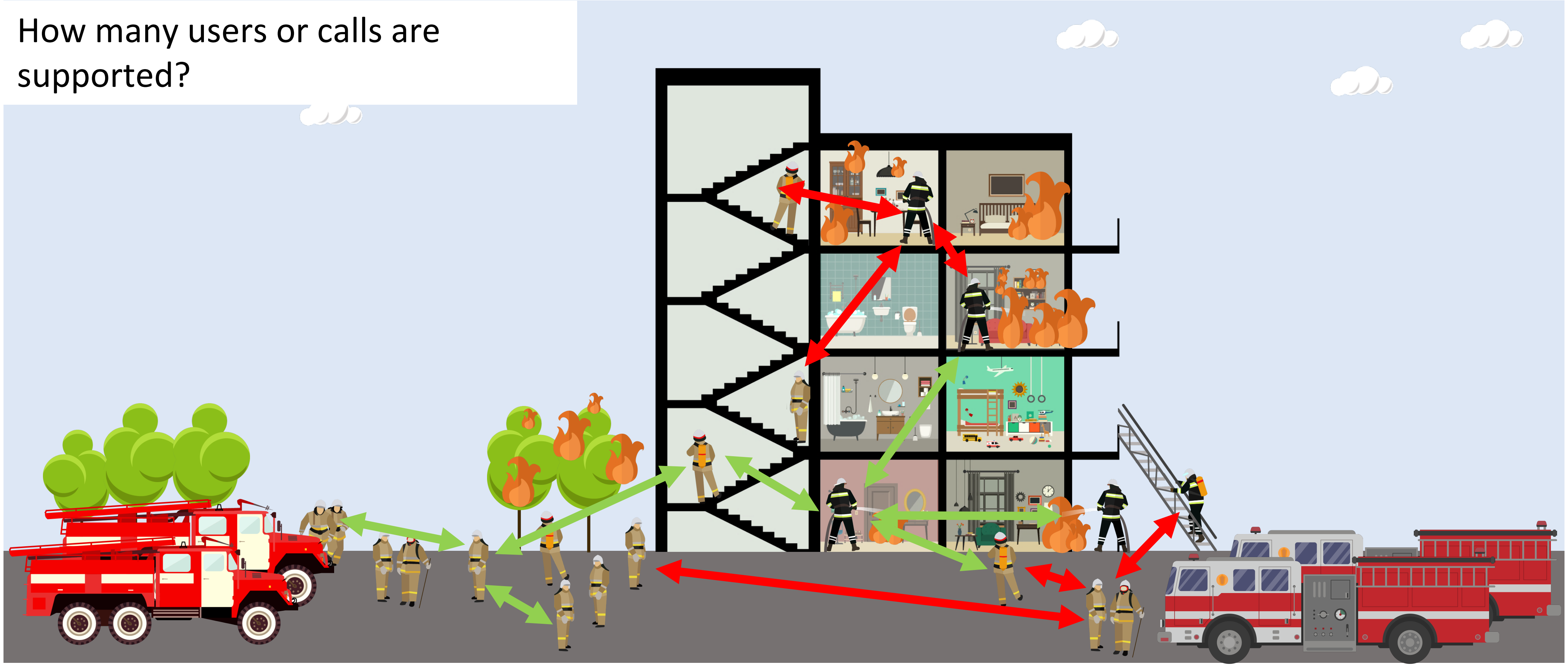
Communication Range: Next Steps

- Evaluate impact of additional system parameters
  - Transmission power
  - Different resource configurations for voice traffic
- Compute range for different audio coding rates
  - Study how to control codec rate to balance audio quality and reliability
- Consider interference from other transmitters
  - Evaluate the impact scheduling decisions

PSCR

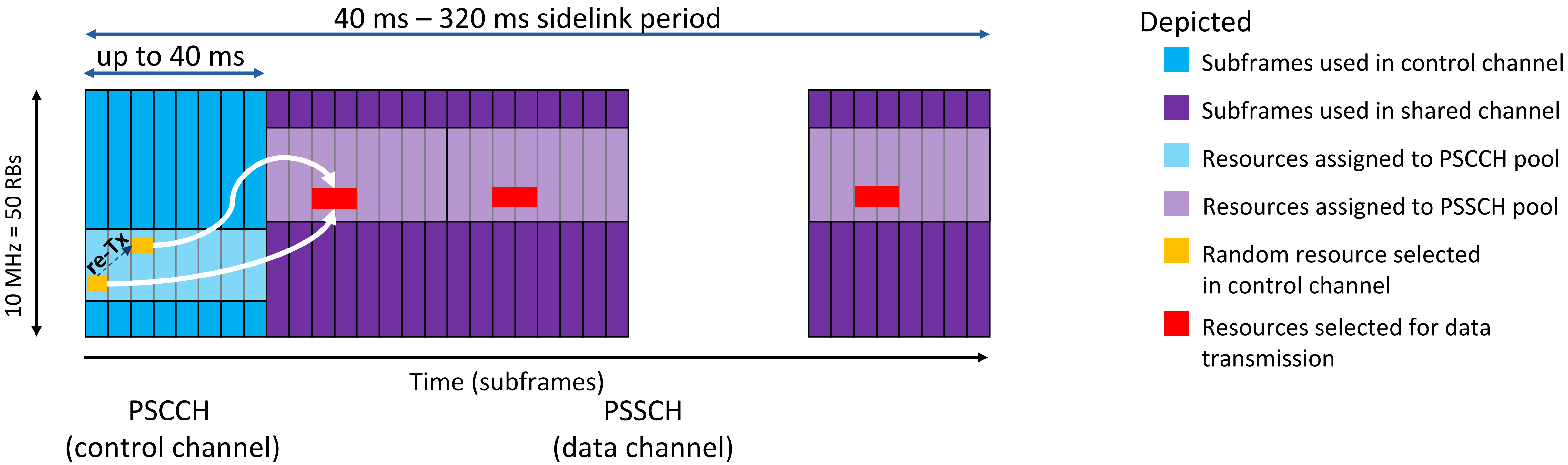
Network Planning

How many users or calls are supported?



PSCR

Resource Allocation in D2D



- **Transmitting UEs:** To transmit, a UE selects a **random resource** in the PSCCH pool to send a Control Information Message, indicating where and how the data will be transmitted in the PSSCH.
- **Listening UEs:** Each UE listens to the control channel to learn whether other UEs are going to transmit and what resources they will use

PSCR

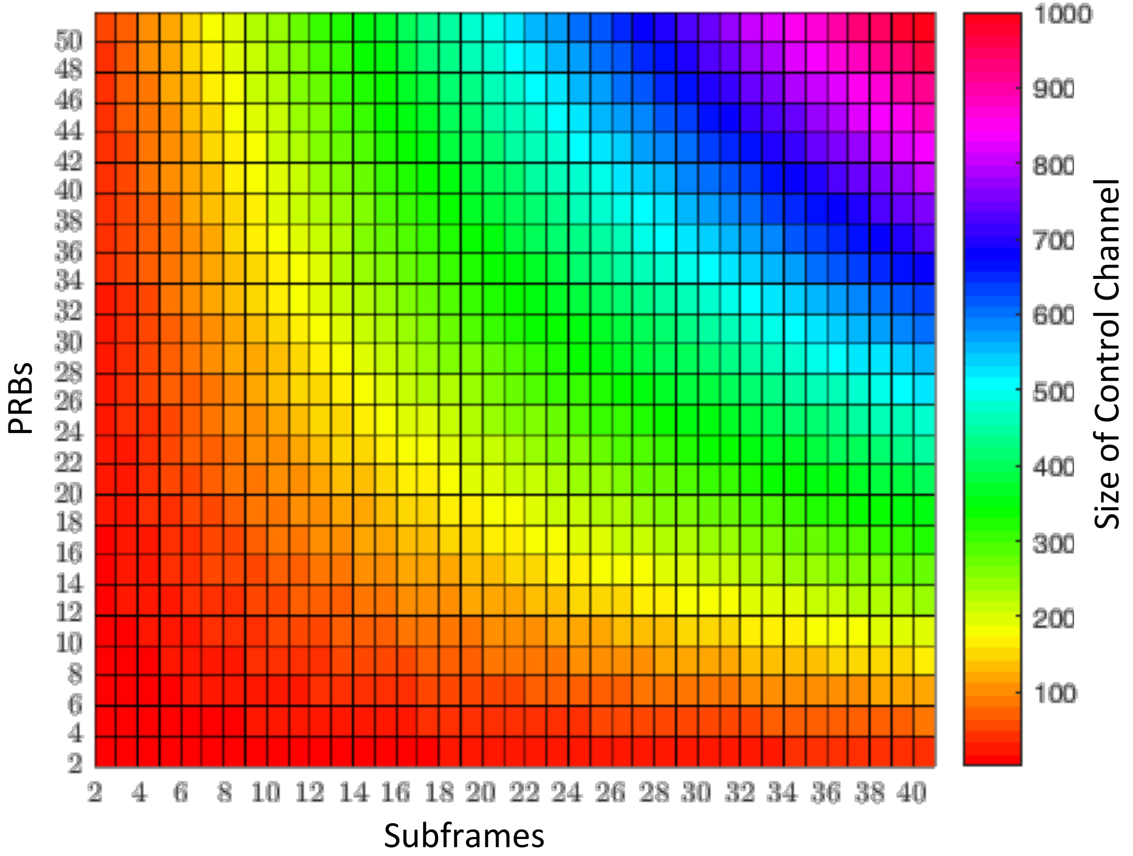
Factors to Consider in Network Planning

- Input
  - Usage scenario: number of devices using the same resources
  - Target performance levels
  - Protocol operation constraints
    - No coordination = message collisions
    - Half duplex devices cannot transmit and receive at the same time
    - Layer 1 groupcast communication
- Output
  - Pool size
    - Control and shared channel
  - MCS selection

PSCR

Control Channel Configuration

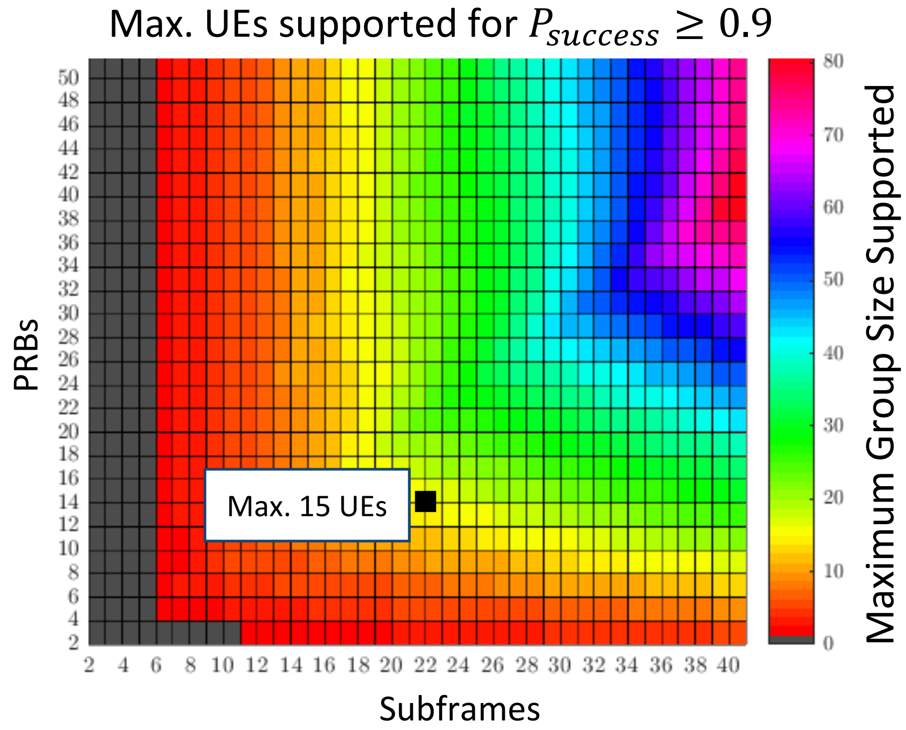
- There are 975 possible PSCCH pool configurations in a 10 MHz bandwidth for D2D communication over LTE setting.

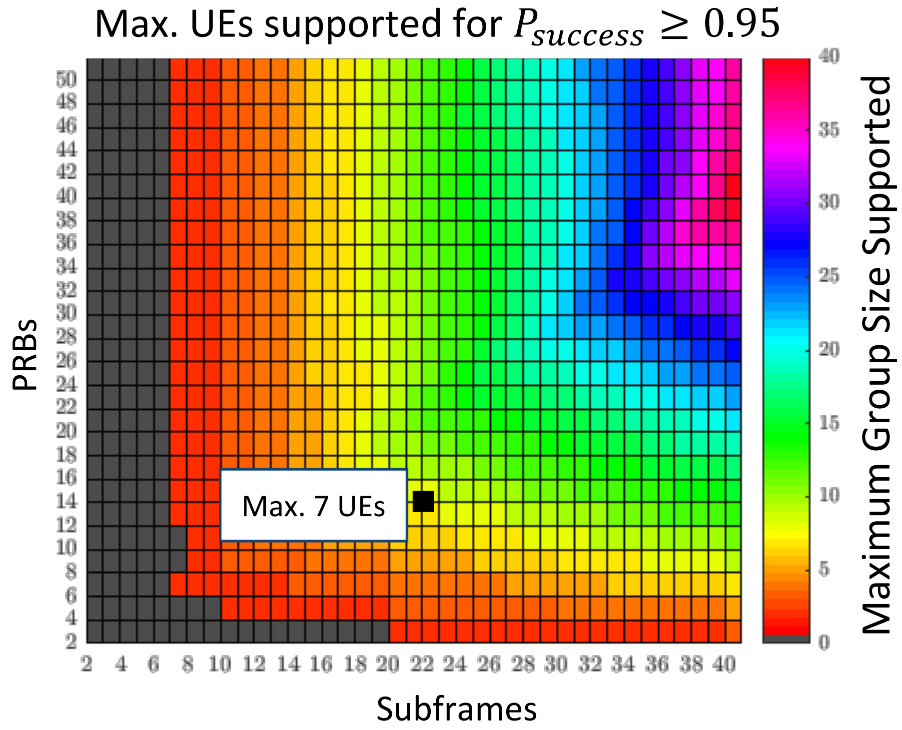


Which pool configuration

PSCR

Control Channel Performance Metric

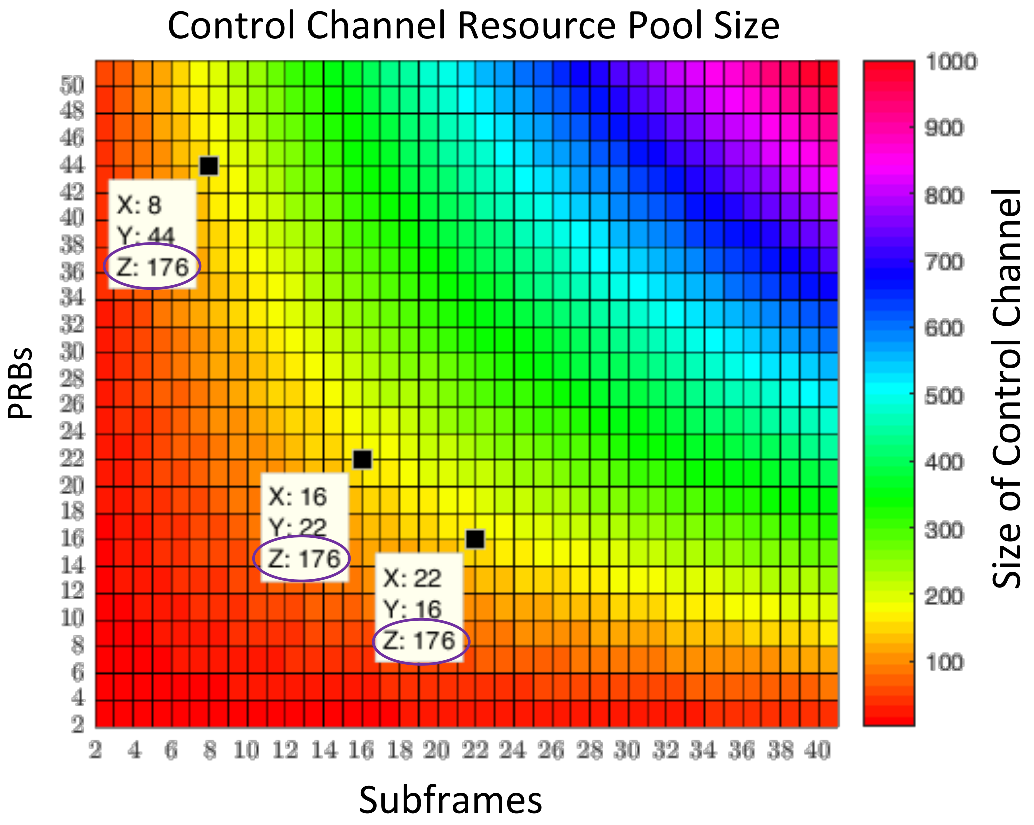


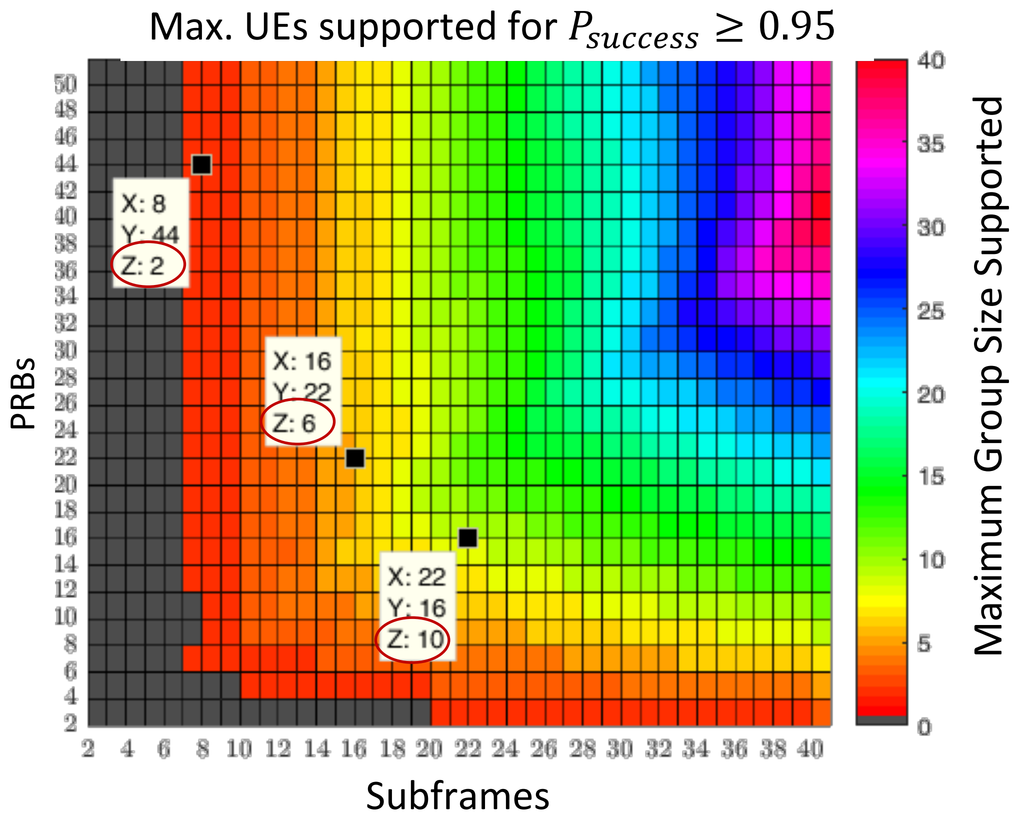


- Probability of a successful transmission is defined as:
  - For a group size N, $(N-1)$ UEs receive a transmitter message (assuming all UEs try to transmit at the same time)
- Calculate the largest group size supported by a pool configuration given a target success transmission ratio.
  - The higher the target success ratio, the smaller the group size
  - Some configurations do not support any group size

PSCR

Analysis of Control Channel Configuration

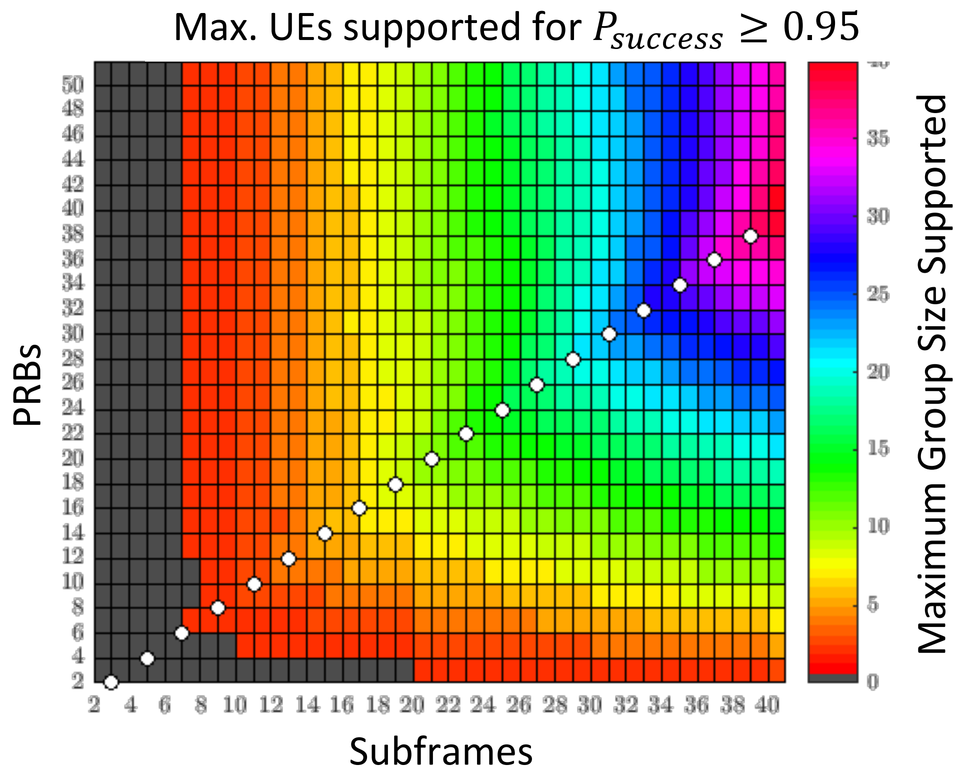




- Pool configurations with equal sizes have different Performance!
- Consider three configurations producing a pool of 176 resources (**Z** value on **left** graph)
  - The maximum number of UEs supported (**Z** value on **right** graph) is different due to the constraints associated with half duplex transmissions

PSCR

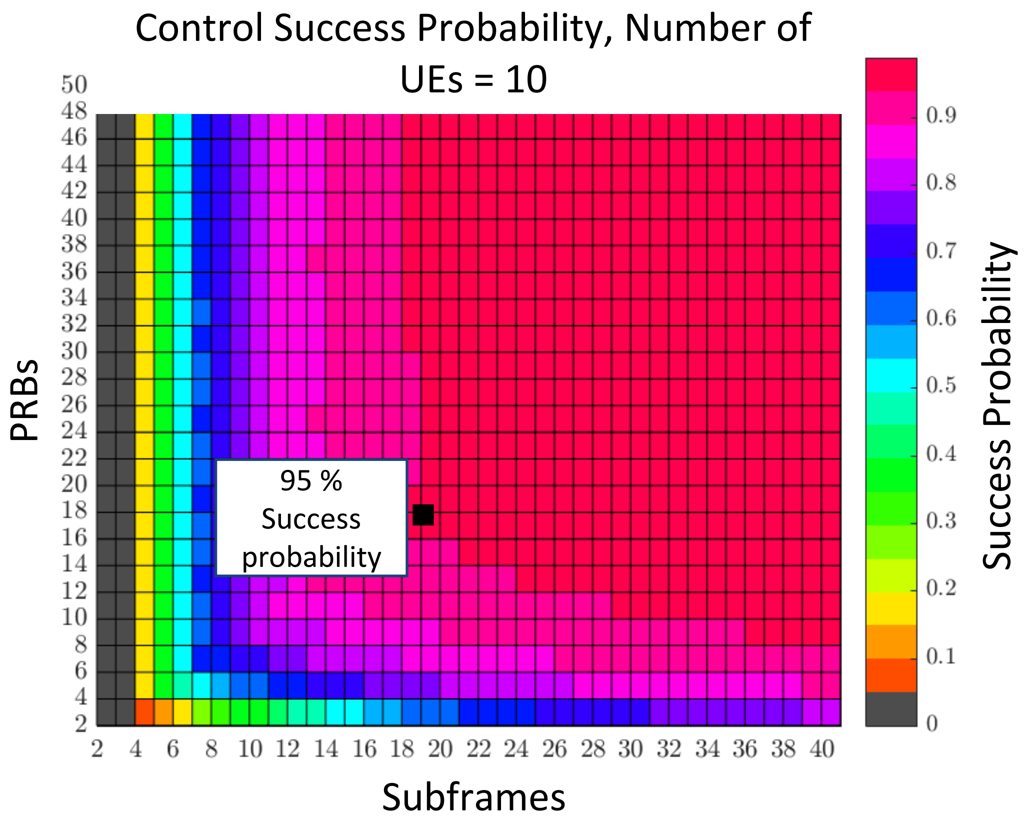
Optimal Control Channel Configuration

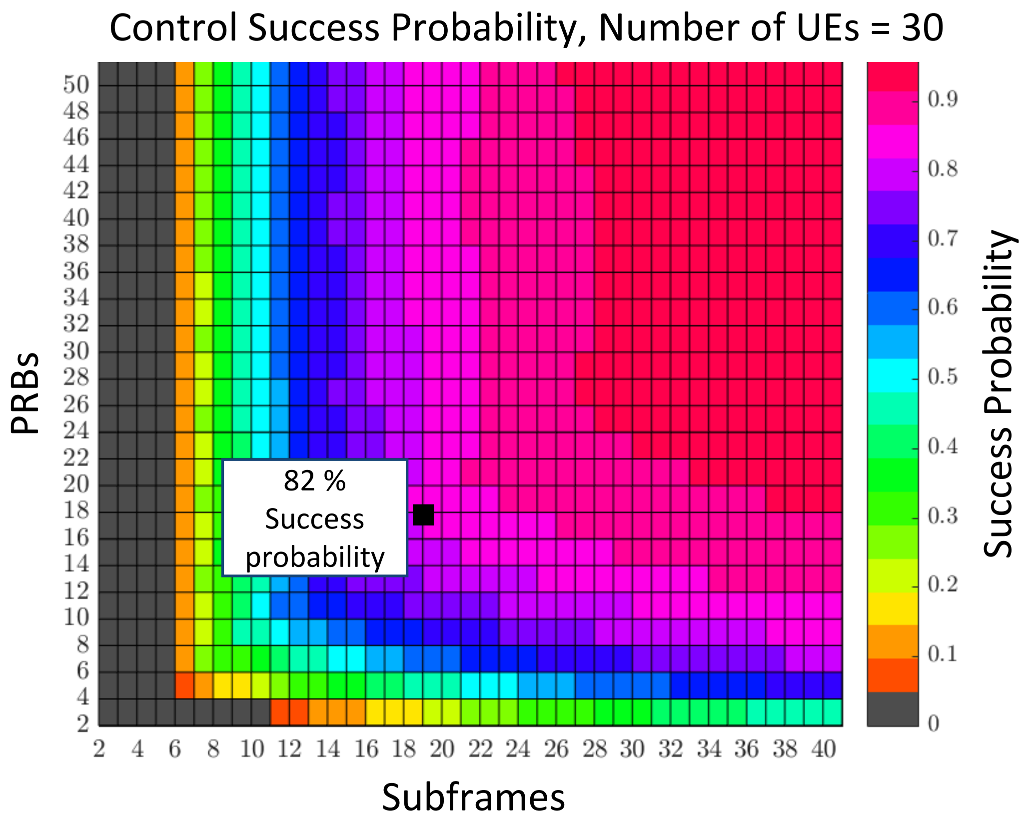


- The resource pools identified by white circles on the graph maximized the number of UEs supported for that pool size
- Those configurations eliminate the half-duplex effect
  - Performance are affected only by the probability of collisions

PSCR

Importance of Good Planning





- Another way to look at the metric is to see what the success probability is for a given number of UEs
  - If the resources were allocated assuming at most 10 responders in the group but 20 more arrive at the scene, the probability of success drops
  - May be acceptable if the probability that the event occurs is very low

PSCR

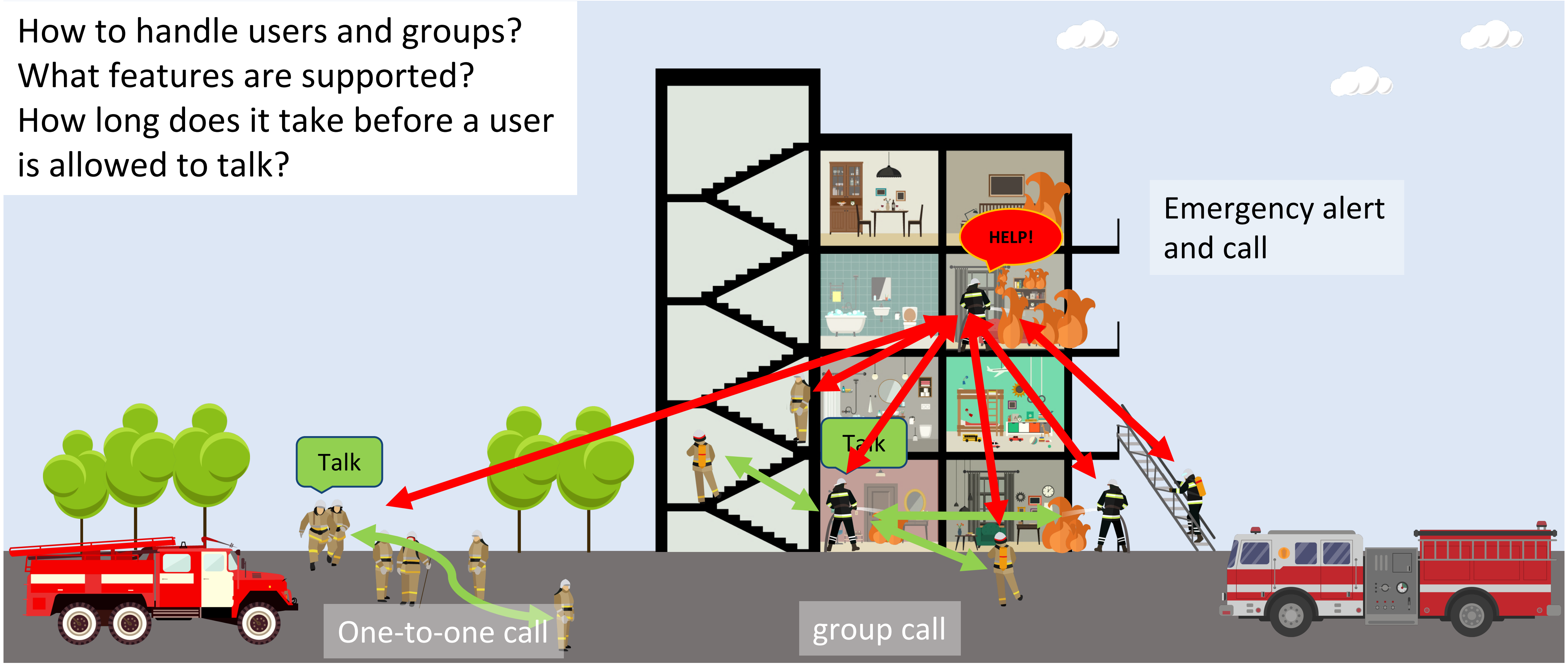
Network Planning: Next Steps

- Extend control channel analysis by modeling the data channel
- Study allocation schemes for partial and in coverage scenarios
- Research alternative resource selection algorithms
  - Impact of not using random selection
- Evaluate V2X capabilities and study applicability to MCV

PSCR

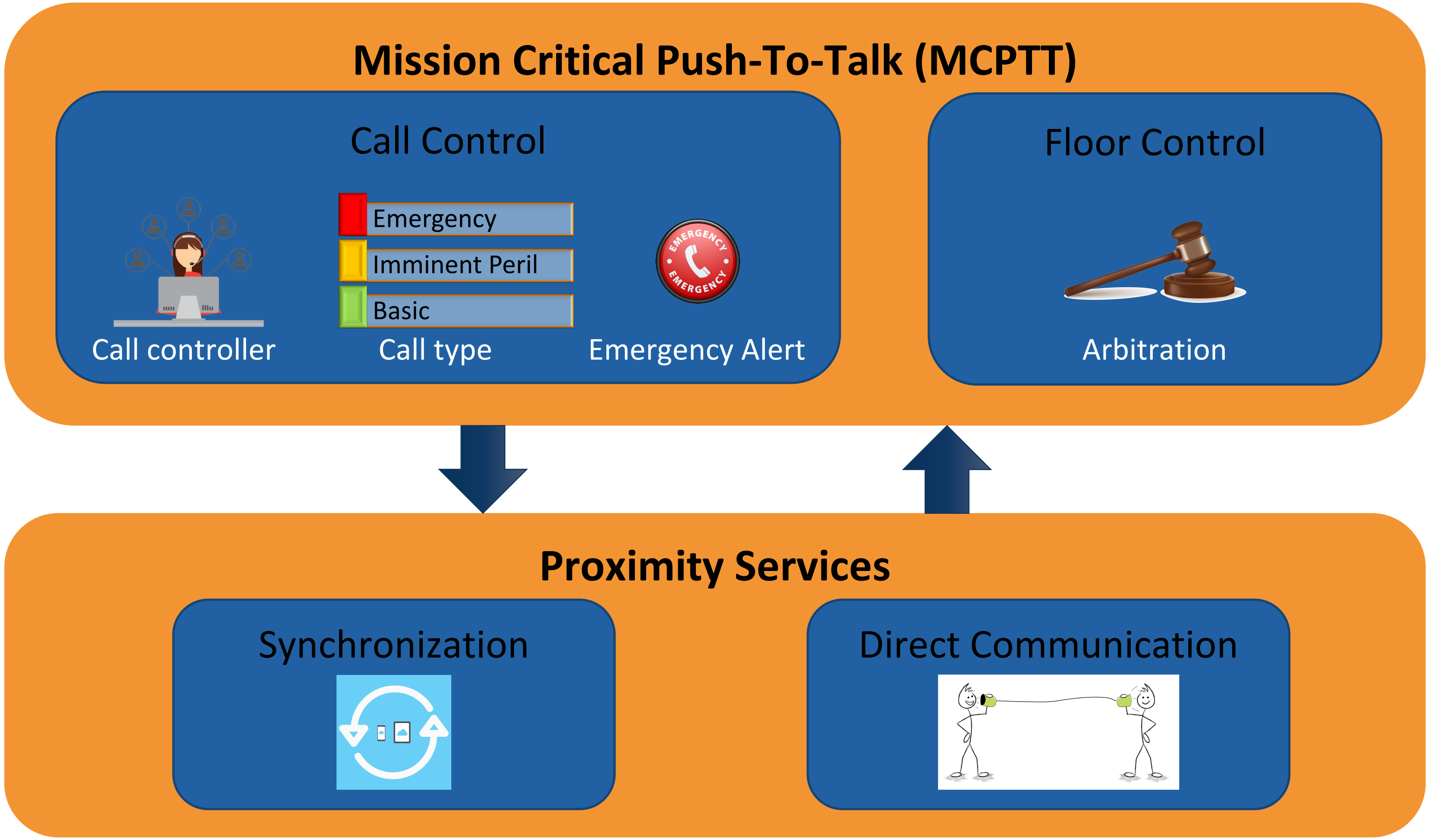
Call Management

How to handle users and groups?
What features are supported?
How long does it take before a user is allowed to talk?



PSCR

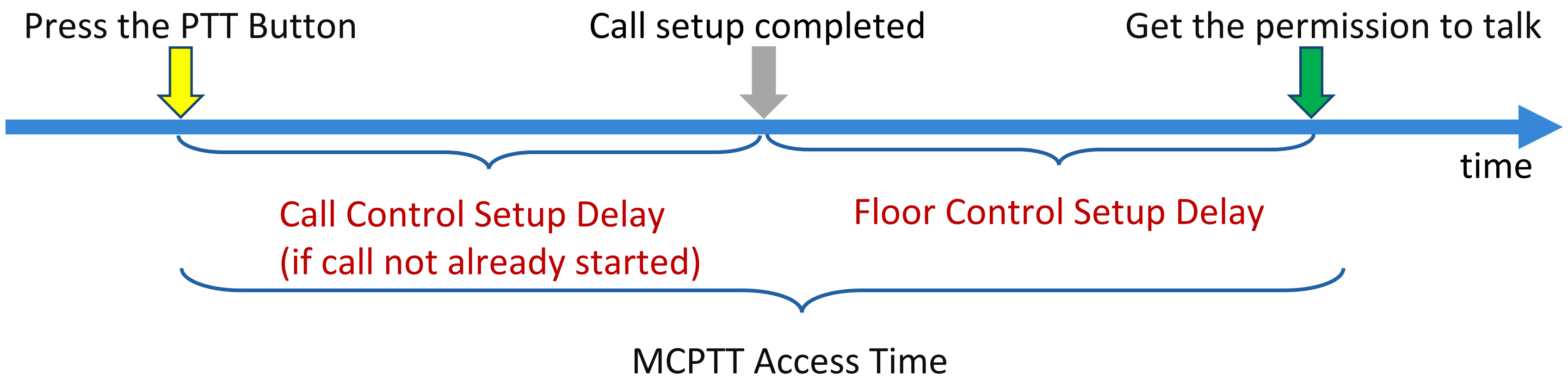
Out-of-Coverage Call Management



PSCR

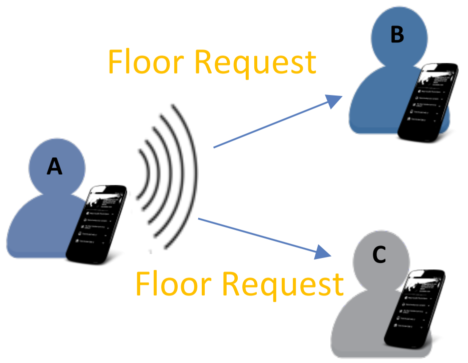
MCPTT Access Time Analysis

- Objectives
  - Predict delay performance for various possible scenarios
  - Obtain insights for enhancements/optimization
- Access Delay metric



PSCR

Floor Control Setup Procedure

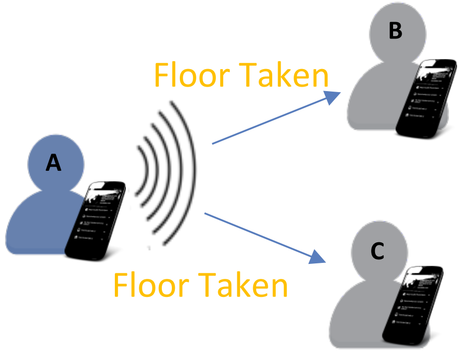


UE A wants to talk;

- Triggered by User pushing the PTT button;
- Send out **Floor Request** message;
- Retransmit **Floor Request** if needed;

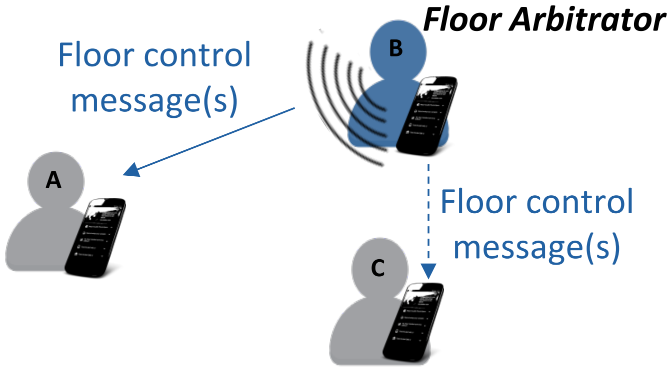
Case 1: No response

After several retransmissions of the **Floor Request** message, UE A takes the floor and sends a **Floor Taken** message.

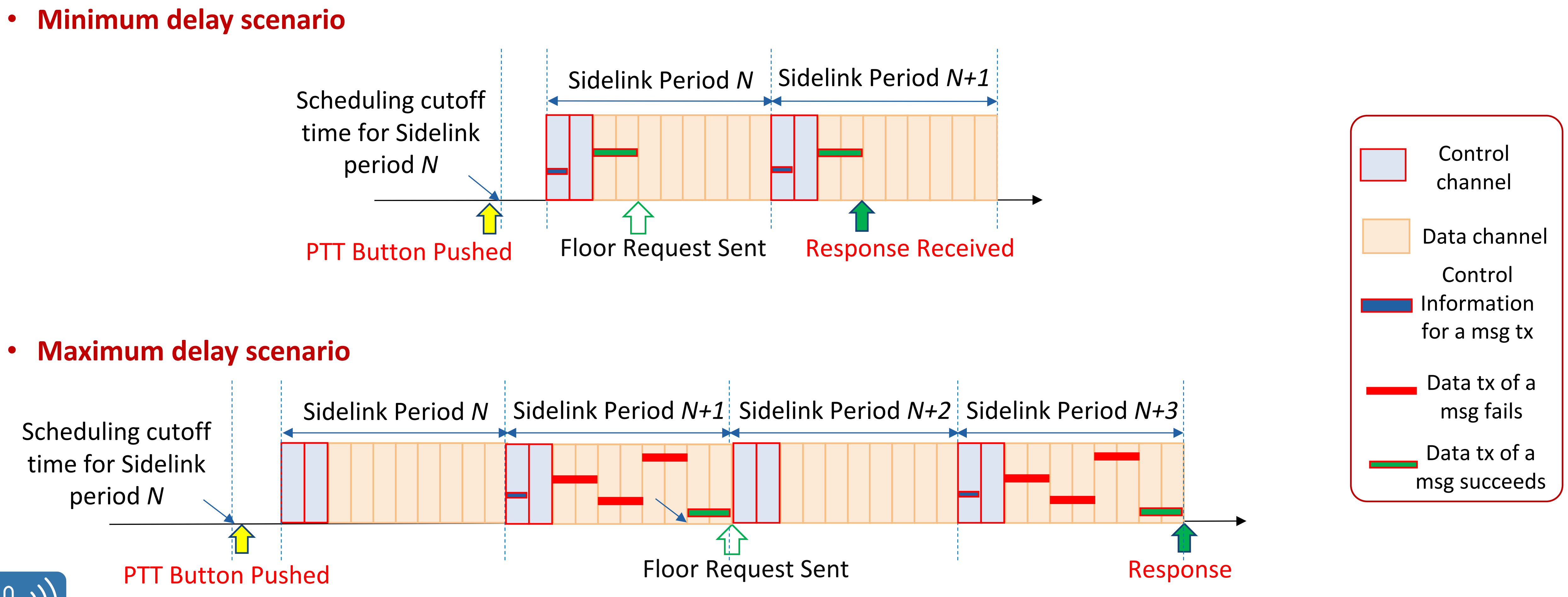


Case 2: The current floor arbitrator responds

Depending on configuration and priority, UE B decides to grant, deny, or queue the request from UE A and sends the appropriate floor control message.



Impact of Sidelink Configuration on MCPTT

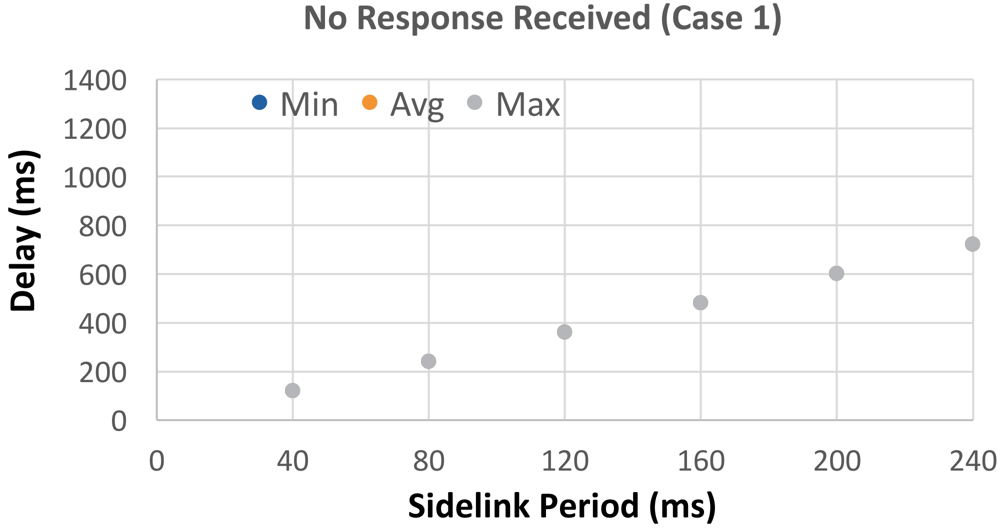


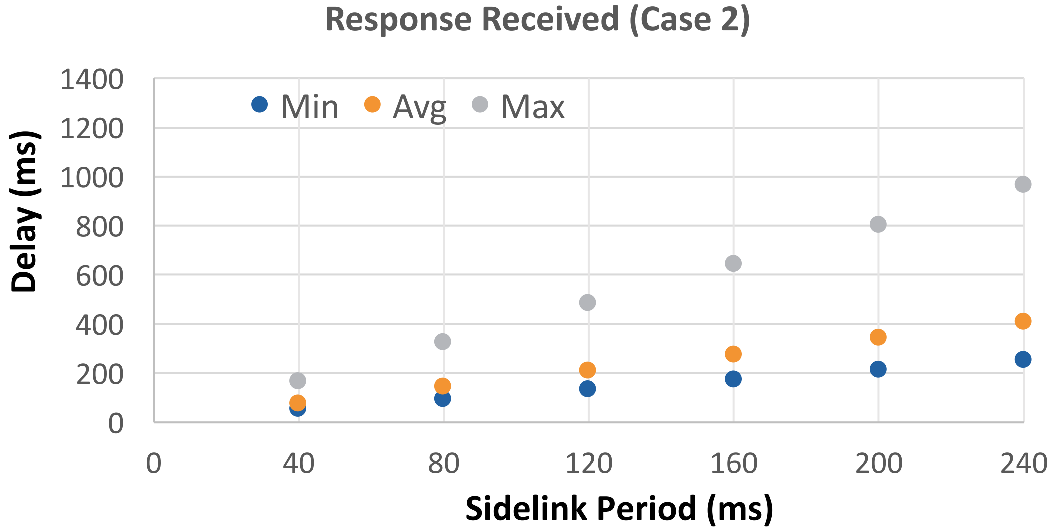
PSCR

Impact of Sidelink Configuration on Performance

Floor Control Setup Delay

(assumes packet success rates of 0.9 for the first three transmissions, success rate of 1 for the last transmission, and 8 ms control channel size)





- The larger the sidelink period, the longer the delay for both cases
- Delays in case 1 are simply caused by timer configuration (which by default is the same as the sidelink period) thus no variations between the Min and Max delays
- In case 2, the delays depend on the transmissions of both requests and response, thus more variations.
- While smaller sidelink periods lead to faster access time, they also restrict the size of the resource pools and increase overhead

PSCR

Findings on Access Time Analysis

- ProSe configuration impacts the performance of MCPTT
- MCPTT timers need to be adjusted to ProSe configuration
  - Premature expiration of certain timers may lead to undesirable consequences
    - Multiple group calls for the same group (that will eventually be merged)
    - Multiple arbitrators within one group call
  - Long timer values may lead to excessive access time
- Delays are affected by the number of active MCPTT clients in the area

PSCR

Call Management: Next Steps

- Develop PTT call models
- Complete study of call control setup delay analysis
- Further investigate multiple arbitrators scenarios
- Evaluate additional features
  - Call priority
  - Emergency alert
  - Call merging

PSCR

Summary

- We developed analytical and simulation tools to estimate and evaluate the performance of MCV when the UEs are out of coverage
- We defined performance metrics to characterize the performance of both ProSe and MCPTT application
  - Time required for UEs to synchronize with each other
  - Range for reliable communication in a given environment
  - Adequate resource allocation to meet target performance
  - Application performance with regards to access delays
- We expect our findings on device and resource configuration to support and improve first responders’ out-of-coverage communication

PSCR

Quick Recap of NIST D2D work

- Synchronization
  - Impact of timing on the ProSe synchronization function (CCNC 2017)
- Communication
  - LTE Uplink Performance with Interference from In-Band D2D Communications (WCNC 2015)
  - An LTE Device-to-Device module for ns-3 (WNS3 2016)
  - A Clustering-Based Device-to-Device Communication to Support Diverse Applications (RACS 2016)
  - Physical Sidelink Control Channel (PSCCH) in Mode 2: Performance Analysis (ICC 2017)
  - Implementation and Validation of an LTE D2D Model for ns-3 (WNS3 2017)
  - BLER Performance Evaluation of LTE Device-to-Device Communications (NISTIR 8157)
  - US DoC contribution C1-163707 (revision of C1-163265) on off-network floor control corrections, which has been agreed in CT1
- Discovery
  - Optimizing the UE Transmission Probability for D2D Direct Discovery (GLOBECOM 2016)
  - Group Discovery Time in D2D ProSe Networks (INFOCOM 2017)
  - A Novel Adaptive Transmission Algorithm for Device-to-Device Direct Discovery (IWCMC 2017)

PSCR

Public Safety Mission Critical Voice Quality of Experience

PSCR

2017

PUBLIC SAFETY BROADBAND STAKEHOLDER MEETING

#PSCR2017

Thesis

PUBLIC SAFETY mission critical voice should be understood in terms of quality of experience (QoE) rather than simply quality of service (QoS)

PSCR

QoE vs QoS

<u>QoS</u>

[1]*The totality of **characteristics of a telecommunications service** that bear on its ability to satisfy stated and implied needs of the user of the service*

<u>QoE</u>

[2]*Describes the degree of delight of the user of a service, influenced by **content**, **network**, **device**, **application**, **user expectations** and goals, and **context** of use*

QoE = QoS + a whole lot more

[1] ITU-T. Recommendation P.10/G.100 – Vocabulary for performance and quality of service – amendment 1: New appendix 1 – Definition of quality of experience (QoE), 2007.
[2]Fiedler, M., Kilkki, K., and Reichl, P. (eds), *From quality of service to quality of experience*. Dagstuhl Seminar Proceedings 09192, Dagstuhl, Germany, 2009.

PSCR

Why QoE? Example – video[1]

70% of customers who switch to a competitor do so because of poor service

#1 complaint – poor video service

How do you quantify video QoE?

PSCR

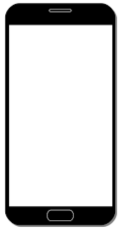
[1]https://networks.nokia.com/solutions/quality-of-experience-infographic

Why QoE? Example – video[1]

MOS	Excellent	Good	Fair	Poor	Bad
	5	4	3	2	1

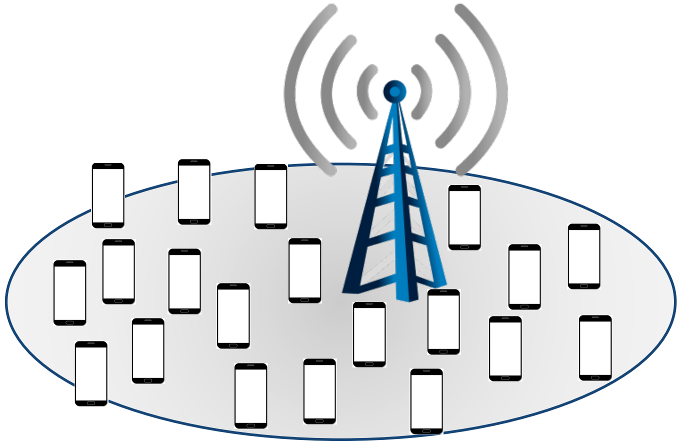
> 80% retention

> 75% abandonment

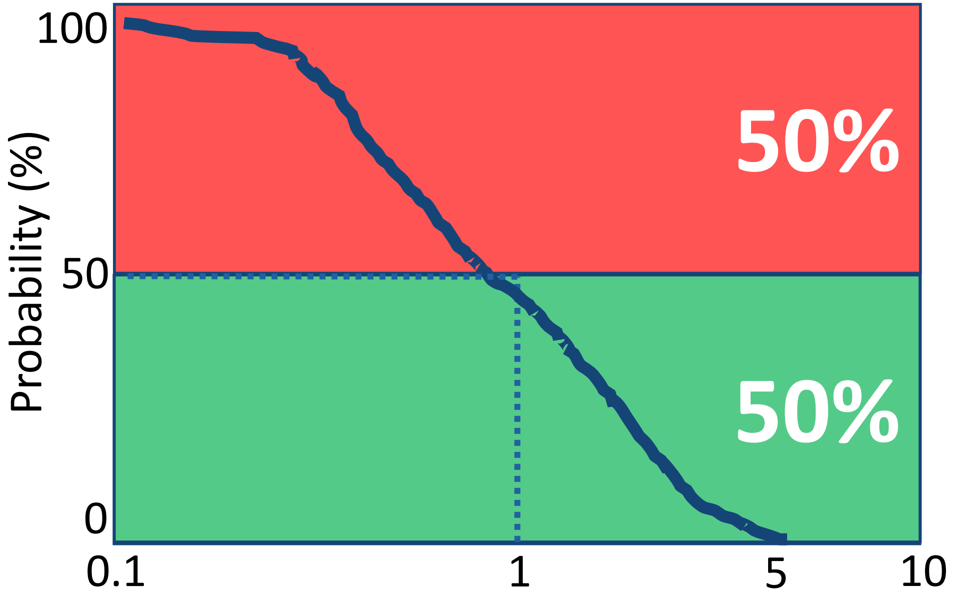


4 in.
1136 x 640

MOS	Mbps
5	1.8
4	1.1
3	0.6



20 active UE in cell



PSCR

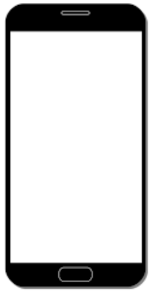
[1]https://networks.nokia.com/solutions/quality-of-experience-infographic

Why QoE? Example – video[1]

Excellent MOS = 5	Good MOS = 4	Fair MOS = 3	Poor MOS = 2	Bad MOS = 1

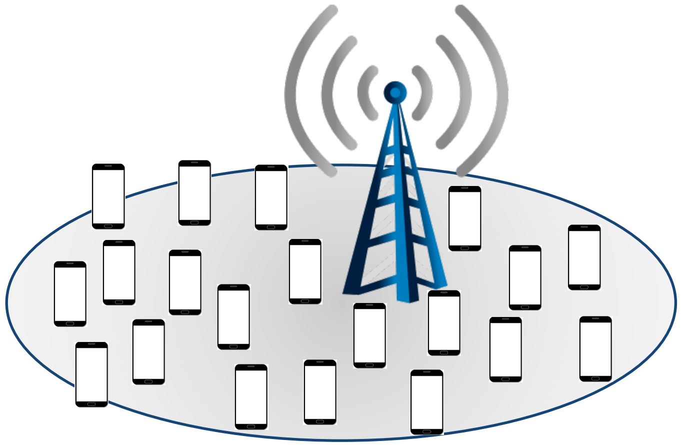
> 80% retention

> 75% abandonment

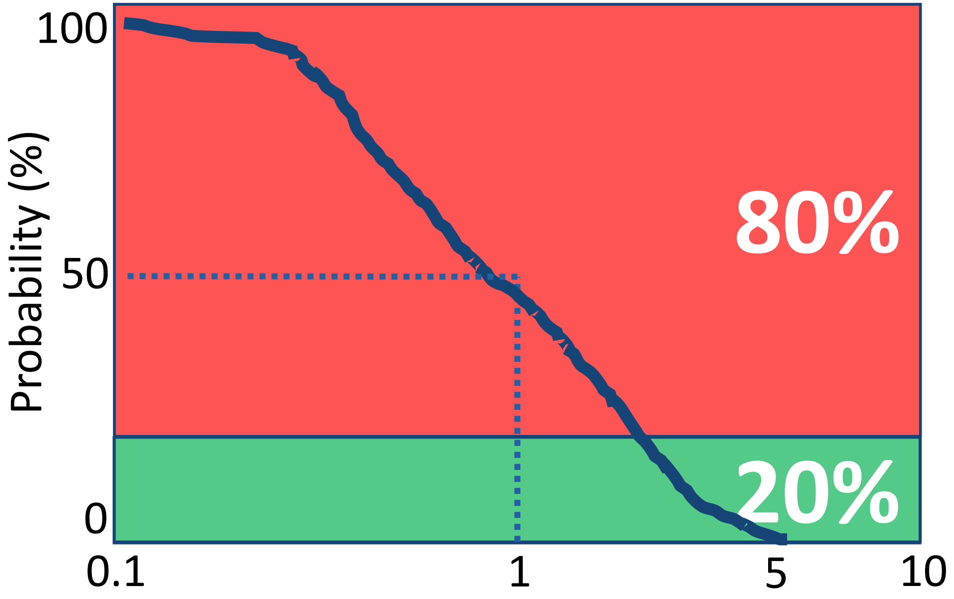


5 in.
1440 x 2560

MOS	Mbps
5	3.8
4	2.5
3	1.7



20 active UE in cell



[1]https://networks.nokia.com/solutions/quality-of-experience-infographic

Why QoE? Example – video[1]

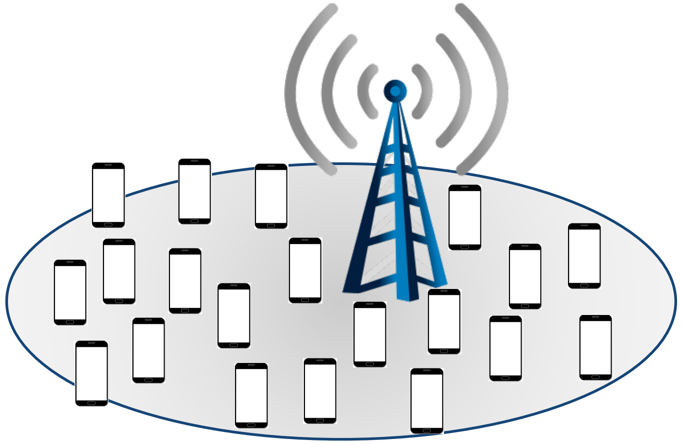
Excellent	Good	Fair	Poor	Bad
MOS = 5	MOS = 4	MOS = 3	MOS = 2	MOS = 1

> 80% retention

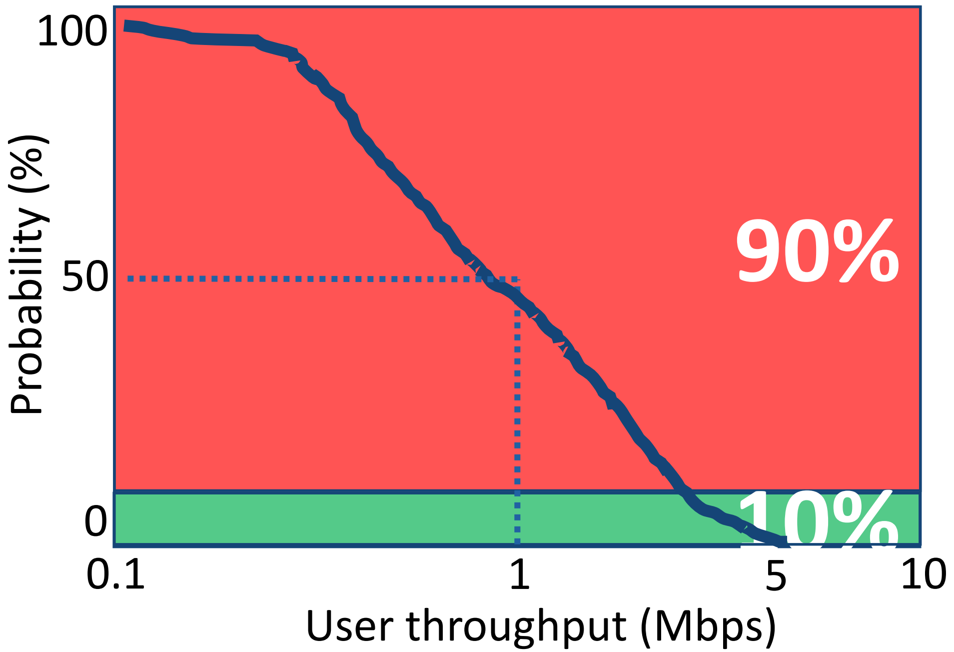
> 75% abandonment

9.7 in.
2048 x 1536

MOS	Mbps
5	5.5
4	3.8
3	2.5



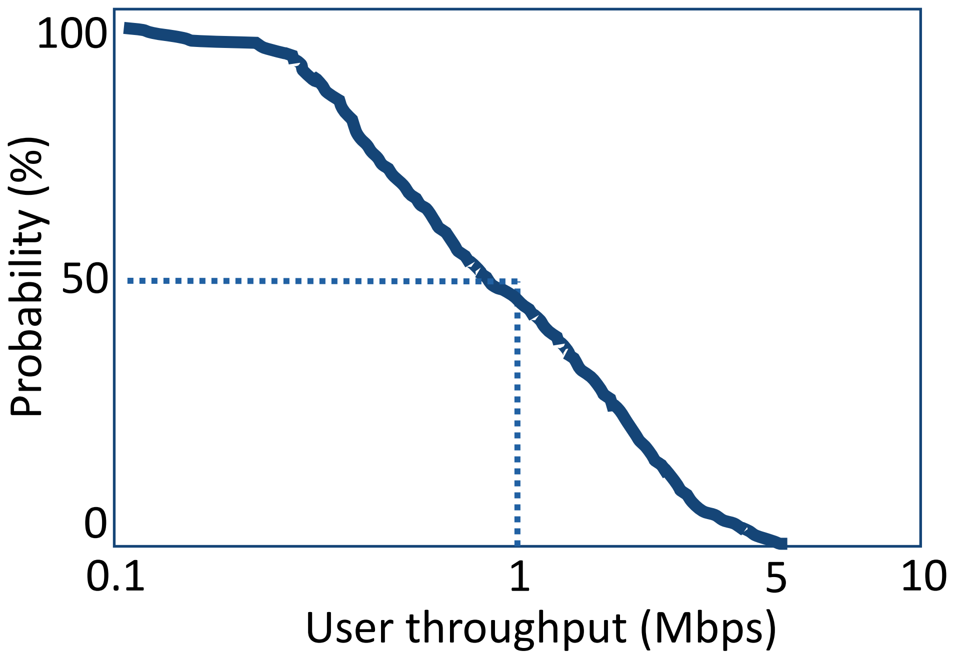
20 active UE in cell

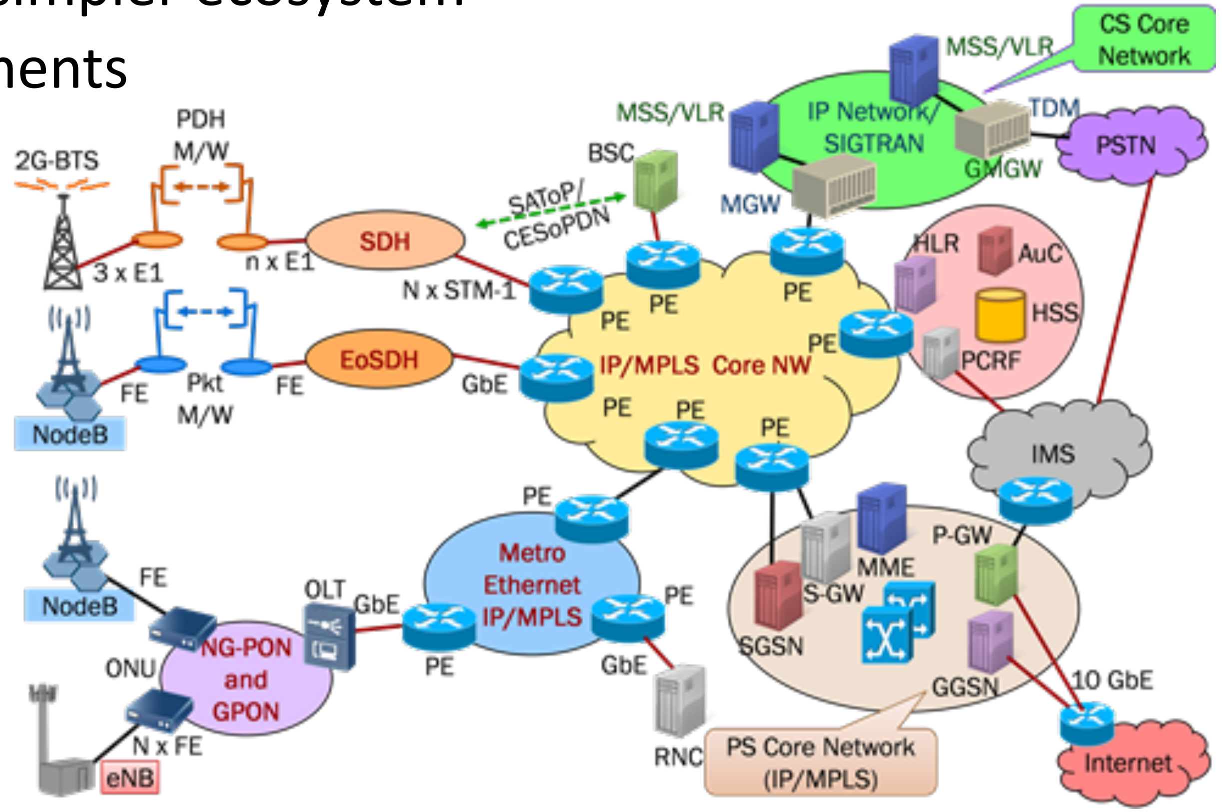


[1]https://networks.nokia.com/solutions/quality-of-experience-infographic

Why QoE for Carriers/ISPs?

- Traditional QoS is not fit for an era of complex networks, services, smart devices, and apps
  - Worked great in legacy networks and simpler ecosystem
  - Good for pinpointing network impairments

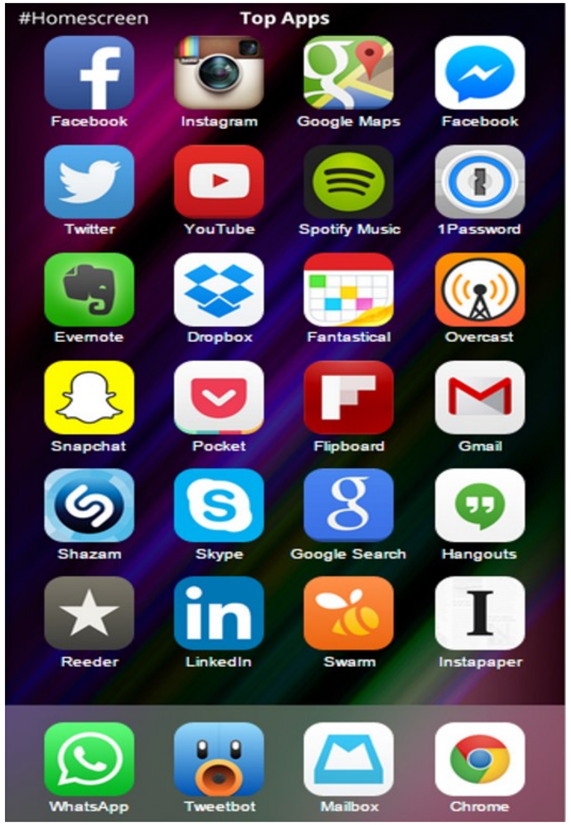




PSCR

Why QoE for Carriers/ISPs?

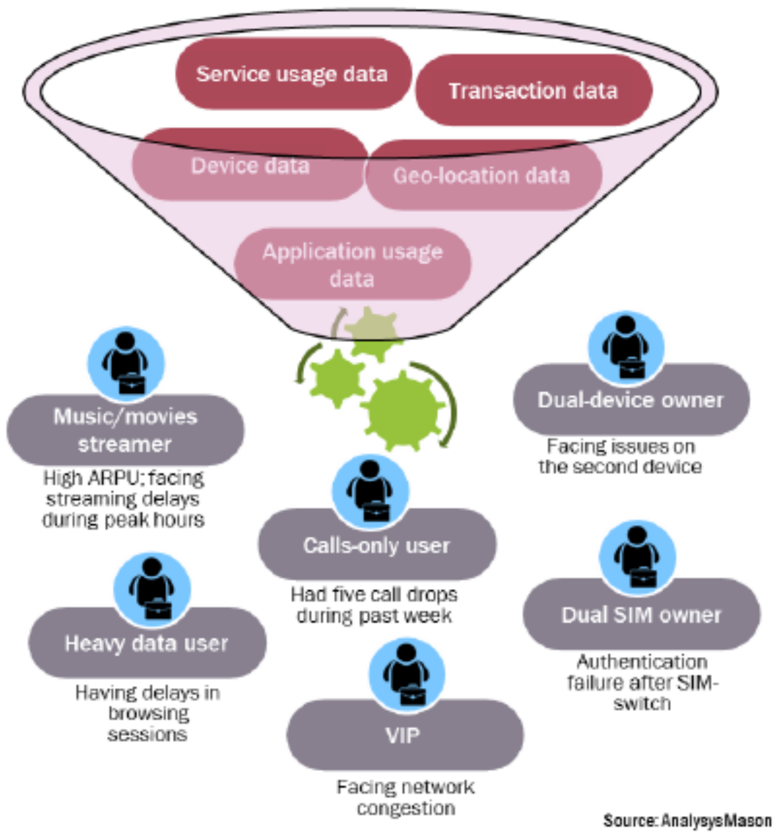
- Consumers are more loyal to device brand and apps than to ‘pipes’
- End-to-end quality depends on network, device, application
  - Diversification of the ‘value chain’
  - Third-party often provides the content service

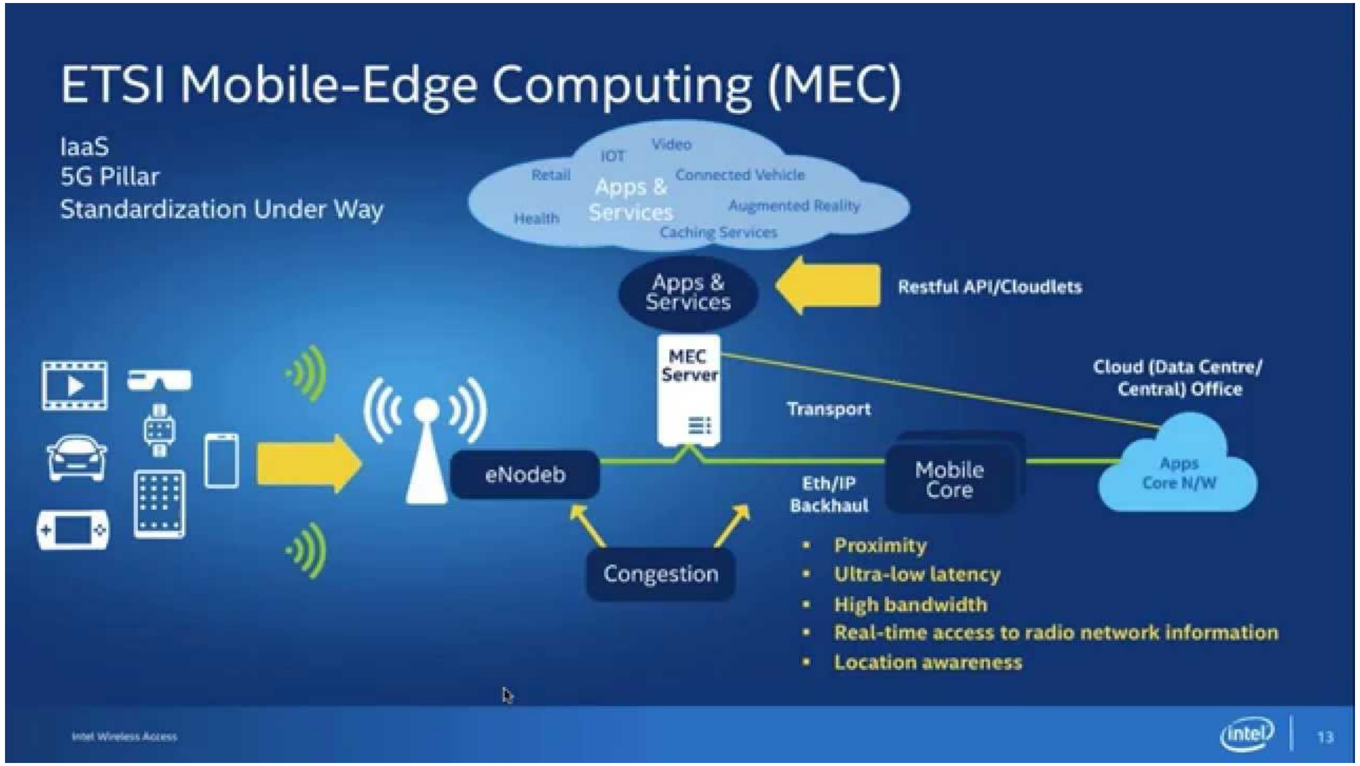


PSCR

Why QoE for Carriers/ISPs?

- QoE is the new key differentiator for customer retention
  - This is one factor driving edge computing and co-location





PSCR

Why QoE for Public Safety?

- QoE emerged to address multimedia. **MC communications and operations will be multimedia.**
- Public safety will increasingly use **complex networks, services, devices, and applications.**
  - MCV included
- First responders will have the most **demanding requirements** on mobile networks.
- Focus is **entirely on end-user** interaction and **service**, not the network(s).
- '~~Content is king~~'. PS requires **critical content in the right context.**
- **Nobody** has ever looked at MCV from a QoE perspective. Until…

PSCR

MCV Roundtable 2017 - Public Safety + Industry

Identify expectations and metrics that will enable us to understand, measure, monitor, and predict MCV QoE across LMR, LTE, and future technologies.

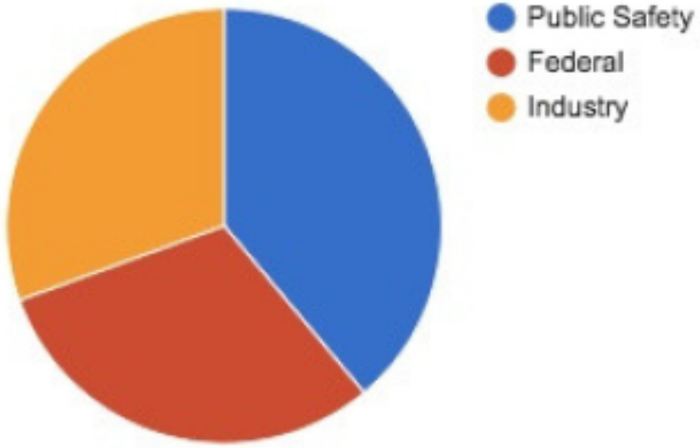
An overview of invited & attending organizations:

Federal:
- DHS S&T
- DHS OEC
- DOJ/NIJ
- FCC
- FirstNet
- NIST
- UK Home Office

Industry:
- AT&T
- Bittium
- Cobham Wireless
- EE
- Ericsson
- ESChat
- Harris Corp
- Kodiak
- Motorola Solutions
- Mutualink
- Nokia
- Samsung
- Sonim
- Spirent
- Verizon

Public Safety:
- Arvada Police
- CITIG
- City of Arvada
- City of Boise Fire
- City of Houston
- Denver Health
- Eagle County
- Grundy County 911
- NPSTC
- North Metro Fire
- PSAC
- State of Colorado
- Vail Police

Breakout of Roundtable Attendees



36 total non-PSCR attendees

PSCR

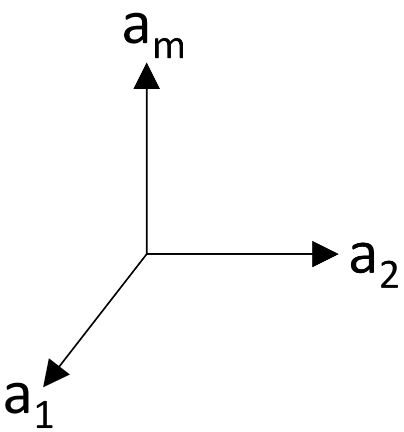
MCV Roundtable 2017 – Task & Outcomes

QoE Area	
Metrics	Situational factors
Environmental/ Structural factors	Technical factors

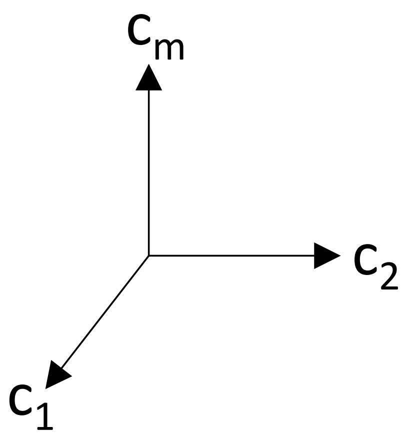
- Eight QoE areas were identified:
  - Access
  - Coverage
  - Intelligibility
  - Interoperability
  - Priority
  - Security
  - Situational awareness
  - Usability

- This is a **very** unique set
- Could argue some should be combined
- How to better organize the data?

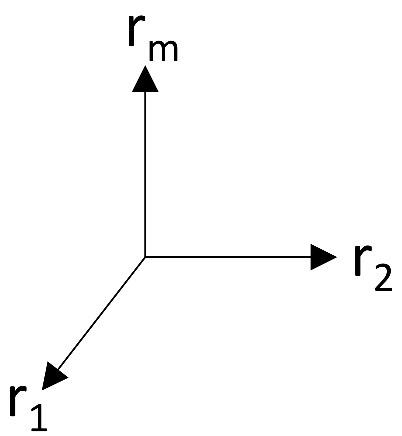
The ARCU Model[2] – Multidimensional



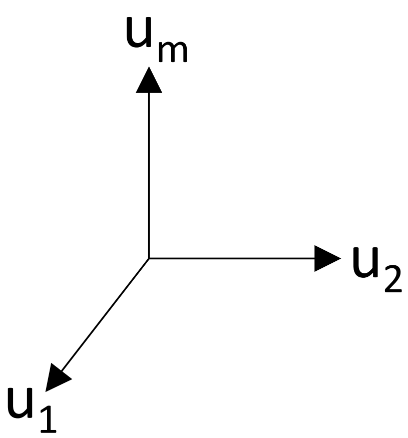
Application space: A
Application configuration related factors (e.g. encoding, resolution, frame rate)



Context space: C
Factors indicating the situation in which a service or application is being used (e.g. ambient conditions, location, time, task)



Resource space: R
Network/system factors related to resource characteristics and performance (e.g. bandwidth, packet loss, delay)

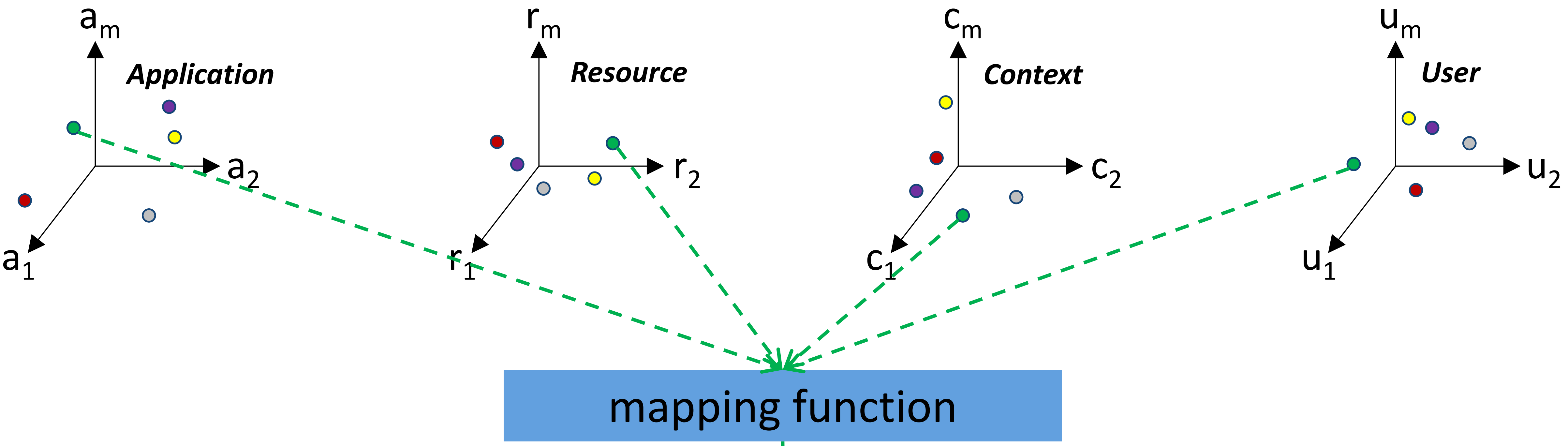


User space: U
Parameters related to specific user of a given service or application (e.g. user profile, preferences, prior experience, motivation)

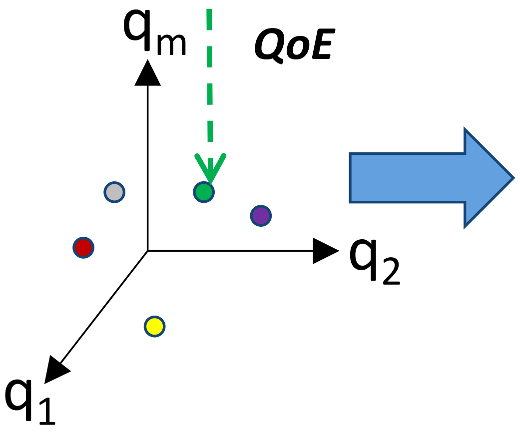
PSCR

[2]From: Skorin-Kapov, L. and Varela, M., ‘A multidimensional view of QoE: The ARCU model’. Proceedings of the 35th International Convention MIPRO, Opatija, Croatia, May 2012, pp. 662-666.

The ARCU Model[2] – Mapping to QoE



QoE space: Q
Quantitative and qualitative quality metrics (e.g. ease of use, efficiency, satisfaction, availability, comfort, utility)



$$QoE_{Integral} = f(w_1q_1, w_2q_2, \ldots, w_mq_m)$$

Quality of Experience Estimators in Networks (QuEEN)[3]

- Models in terms of hierarchy
- Divides user and context space further
  - Interface – technical, physical part of context space (type of device, screen size)
  - Context – non-technical part of context space (ambient light, mobility, stress level, cost)
  - Human – pscyho-physical aspects related to perceptual characteristics of users (audio sensitivity, perception of time)
  - User – aspects of humans as users of services or applications (motivation, expectation, level of expertise)

<table>
<tr><td rowspan="2">User</td><td>User</td></tr>
<tr><td>Human</td></tr>
<tr><td rowspan="2">Context</td><td>Context</td></tr>
<tr><td>Interface</td></tr>
<tr><td>Application</td><td>Application</td></tr>
<tr><td>Resource</td><td>Resource</td></tr>
<tr><td>ARCU spaces</td><td>QuEEN layered model</td></tr>
</table>

PSCR

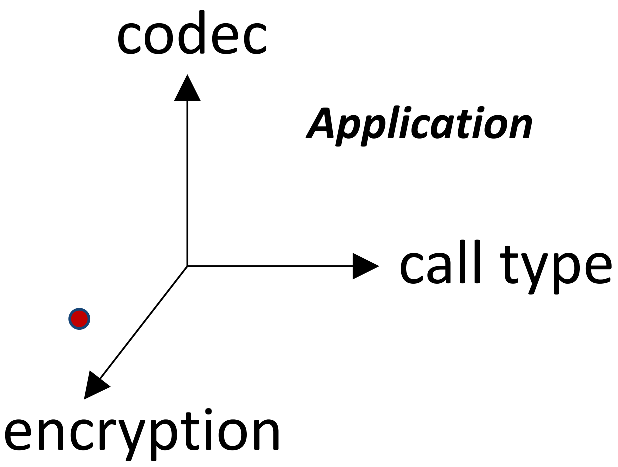
[3]From: Guyard, F., *et al.*, ‘Quality of experience estimators in networks’. In Mellouk, A. and Cuadra A. (eds.), *Quality of experience engineering for customer added value services: From evaluation to monitoring*. Iste/John Wiley & Sons, New York, 2014.

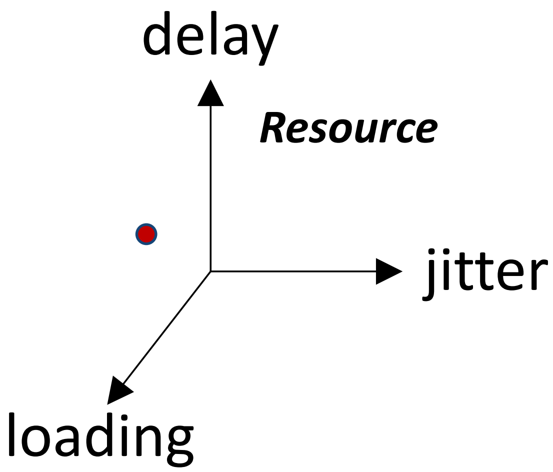
ARCU Model – MCV Roundtable

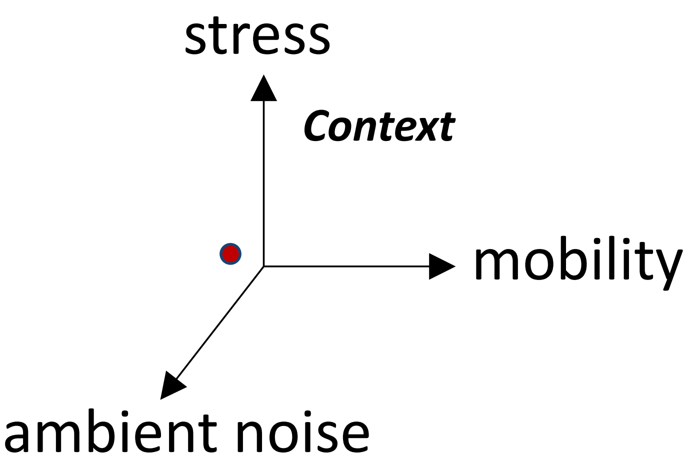
Service	Input dimensions				QoE dimensions
	(A) Application	(R) Resource	(C) Context	(U) User	
Mission critical voice	codec	bandwidth/throughput	Context:	User:	access & priority
	bit rate	active users (loading)	user mobility	experience	- access time
	frame rate	channels	location	proficiency	- mouth-to-ear
	error correction	error rate	task/activity	rank/position	- bonk rate
	echo cancellation	packet loss	time of day / shift	service/segment	- drop rate
	playout buffer size	end-to-end delay	stress level	expectation	- abandonment
	hang-time	jitter	ambient noise		
	call-type	loss burstiness	group size	Human:	intelligibility
	network status	QoS/bearer type	proximity	hearing sensitivity	- MOS-L/CQS/O
	override settings	unicast/broadcast	mutual aid	perception of duration	
	active applications	IRAT handovers			sit. awareness
	application type	interworking	Interface:		- talker ID
	encryption alg.		radio/device	*Additional QoE* ←	- location time-to-fix/acc.
	authentication			interoperability	
	power config.			coverage	- selectivity
	floor request			usability	security
	late call entry				- cover rate
	pre-emption				- event rate
	relay				

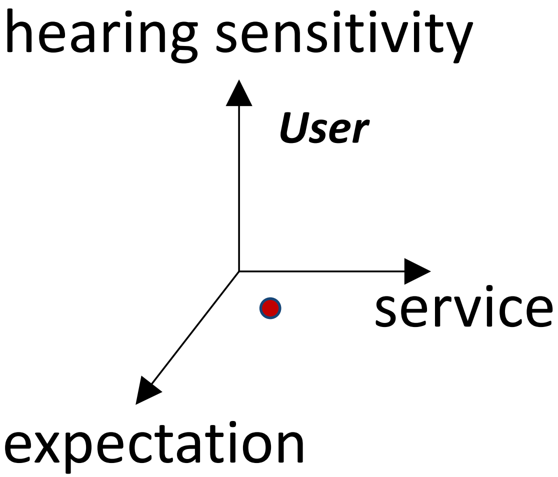
PSCR

Example: n = 1 users





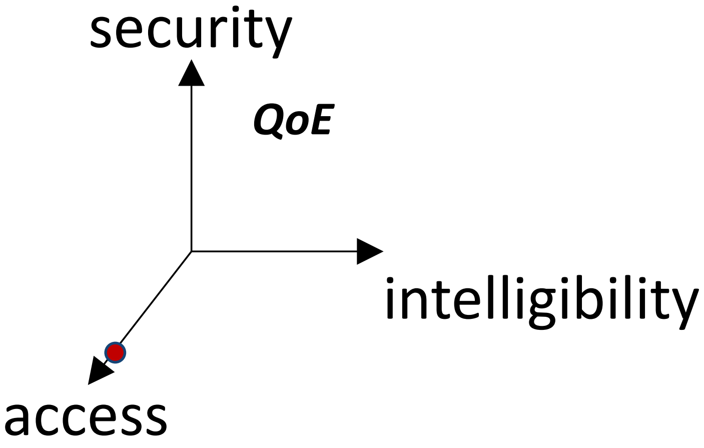




$m_a = m_r = m_c = m_u = 3$

$n = 1$ •

Regression, PCA, ML



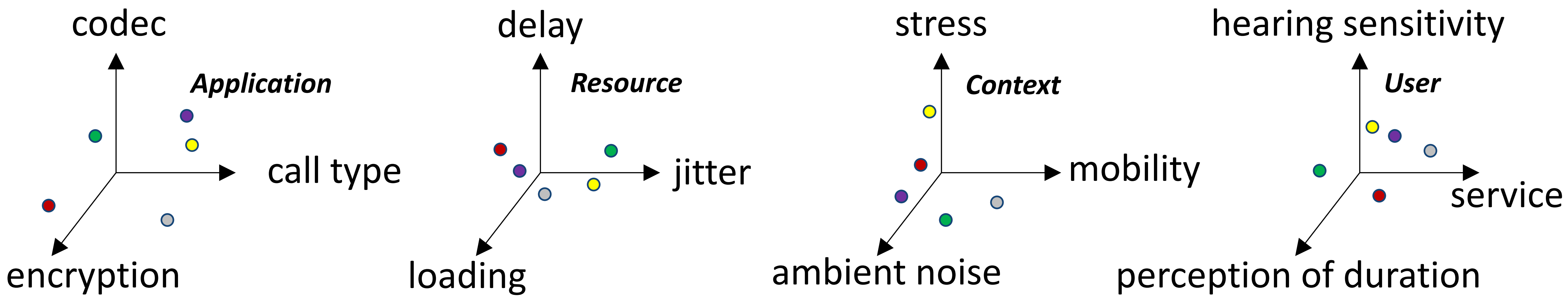
QoE = $w_1$access

+ $w_2$intelligibility + $w_3$security

PCA = principal components analysis

ML = machine learning

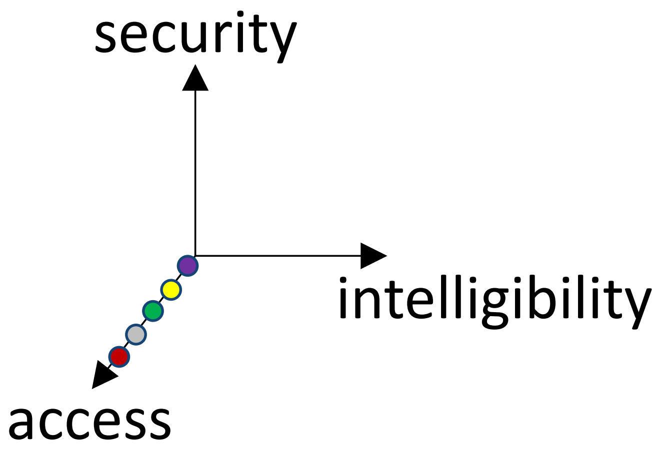
Example: n = 5 users



$m_a = m_r = m_c = m_u = 3$

$n = 5$

Regression, PCA, ML



QoE = $w_1$access

+ $w_2$intelligibility + $w_3$security

Set of w_n can be tailored by dept, region, domain, etc.

PSCR

Next steps

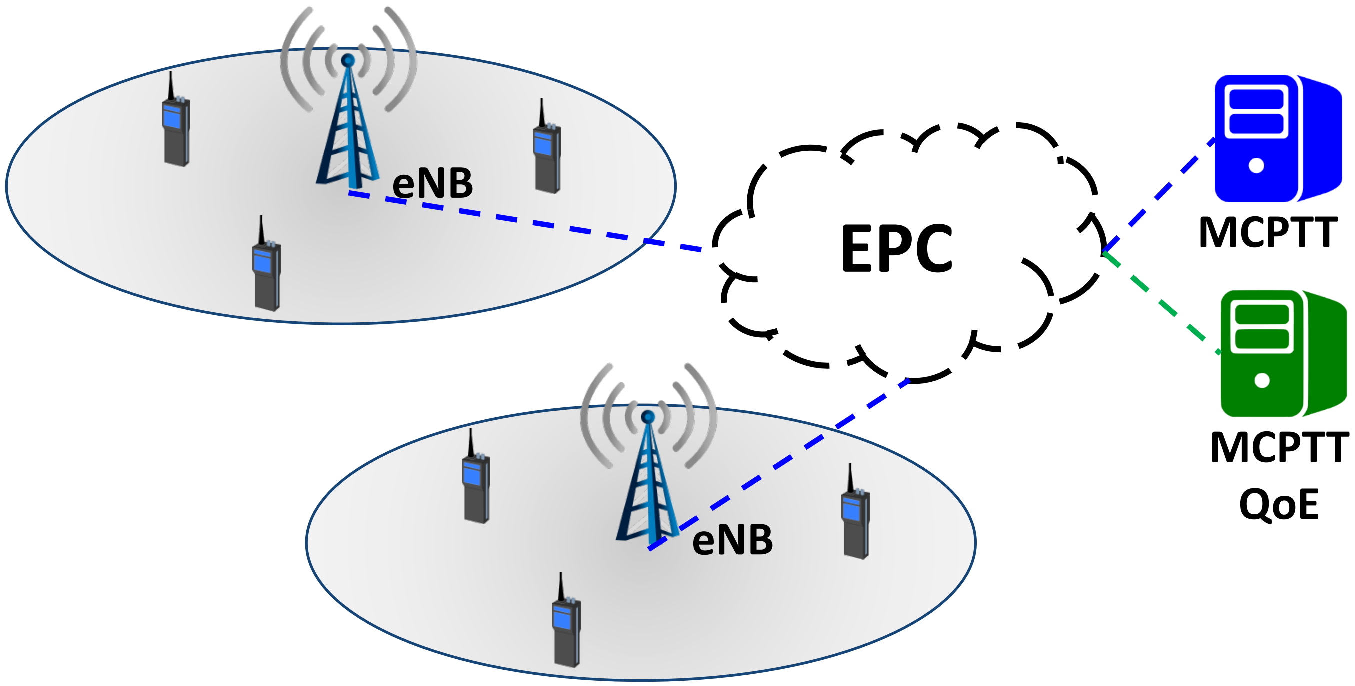
- Select first QoE dimension(s)
  - Objective factors to drive monitoring
- Down-select input dimensions to monitor/control
- Test methodology
  - Lab (black box) vs field/excercise
    - Lab – application, resource, user (mostly)
    - Field – context
- Sample size
- Timescale – session, incident, shift

Way to test context & user stress in lab?

PSCR

Future R&D

- QoE measure → monitor → predict
  - Evaluate common schedulers in terms of MCV QoE
    - QoE often achieved by over-provisioning
  - QoE-based scheduling
  - Passive vs. **active** monitoring

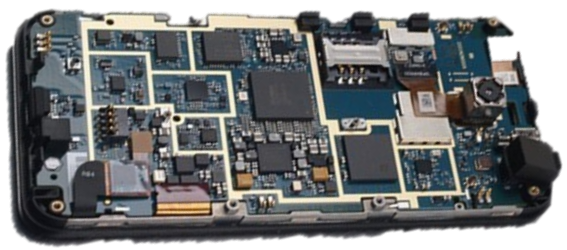


PSCR

Future R&D

- Android MCPTT QoE SDK/middleware
  - Could this work for direct mode?

Demo app	3rd party app	3rd party app
MCOP SDK		
MCOP HW/MW integration API		
ProSe	eMBMS	QoE
Vendor specific HW access		
Operating system		



From: Liberal, Fidel, ‘Mission Critical Open Platform (MCOP)’, PSIAP application.

PSCR

Takeaways

- QoE can be a powerful tool for service providers to understand MCV performance from the user's perspective
  - It's a win-win!
- Public Safety MCV is unique, and will be challenging area for QoE estimation
- PSCR will use a multi-dimensional approach to developing and testing various QoE areas
- The MCV framework can be expanded to include MC data and video
  - Will grow with network, e.g. 5G
- Future R&D could include methods for active QoE monitoring and QoE-based scheduling

PSCR

Advancing Mission Critical Voice Technologies Through PSCR's Innovation Accelerator Grant Program

PSCR

2017

PUBLIC SAFETY BROADBAND STAKEHOLDER MEETING

#PSCR2017

MCV Goals FY16-17

- Evaluate out-of-coverage MCV communication
- Study QoS, Priority and Preemption mechanisms in order to serve MC applications
- **Accelerate R&D of MCPTT & DMO**
- **Lower barrier of entry for MCV research**
- **Build PS R&D ecosystem**
- 'Benchmarking' → Quality of experience

PSCR

MCV/RPP Grant Awardees

The George Washington University

Harris Corporation

New York University

Software Radio Systems Limited

Sonim Technologies Inc

Universidad del Pays Vasco / Euskal Herriko Unibertsitatea

University of Southern California

University of Washington

Vencore Labs, Inc. dba Applied Communications Science

Presentations

Universidad del País Vasco / Euskal Herriko Unibertsitatea

Mission Critical Open Platform (MCOP)

Sonim Technologies, Inc.

End-to-End Mission Critical Push to Talk with Direct Mode Operation

Software Radio Systems Limited

OpenFirst

Vencore Labs, Inc. dba Applied Communications Science

Device-to-Device System for Public Safety (DDPS)

University of Washington

Modeling, Simulation and Performance Evaluation for Future Public Safety Networks

University of Southern California

Propagation Channel Models and System Performance for Device-to-Device Communications for Public Safety Applications

PSCR

Mission Critical Open Platform

Universidad del País Vasco / Euskal Herriko Unibertsitatea

PSCR

2017

PUBLIC SAFETY BROADBAND
STAKEHOLDER MEETING

#PSCR2017

Mission Critical Open Platform

MCOP

Fidel Liberal

fidel.liberal@ehu.eus

2017 Public Safety Broadband Stakeholder Meeting

PSCR

June 12-14, 2017
Marriott Rivercenter
San Antonio, TX

www.pscr.gov

TCCA Bittium EXPWAY

eman ta zabal zazu

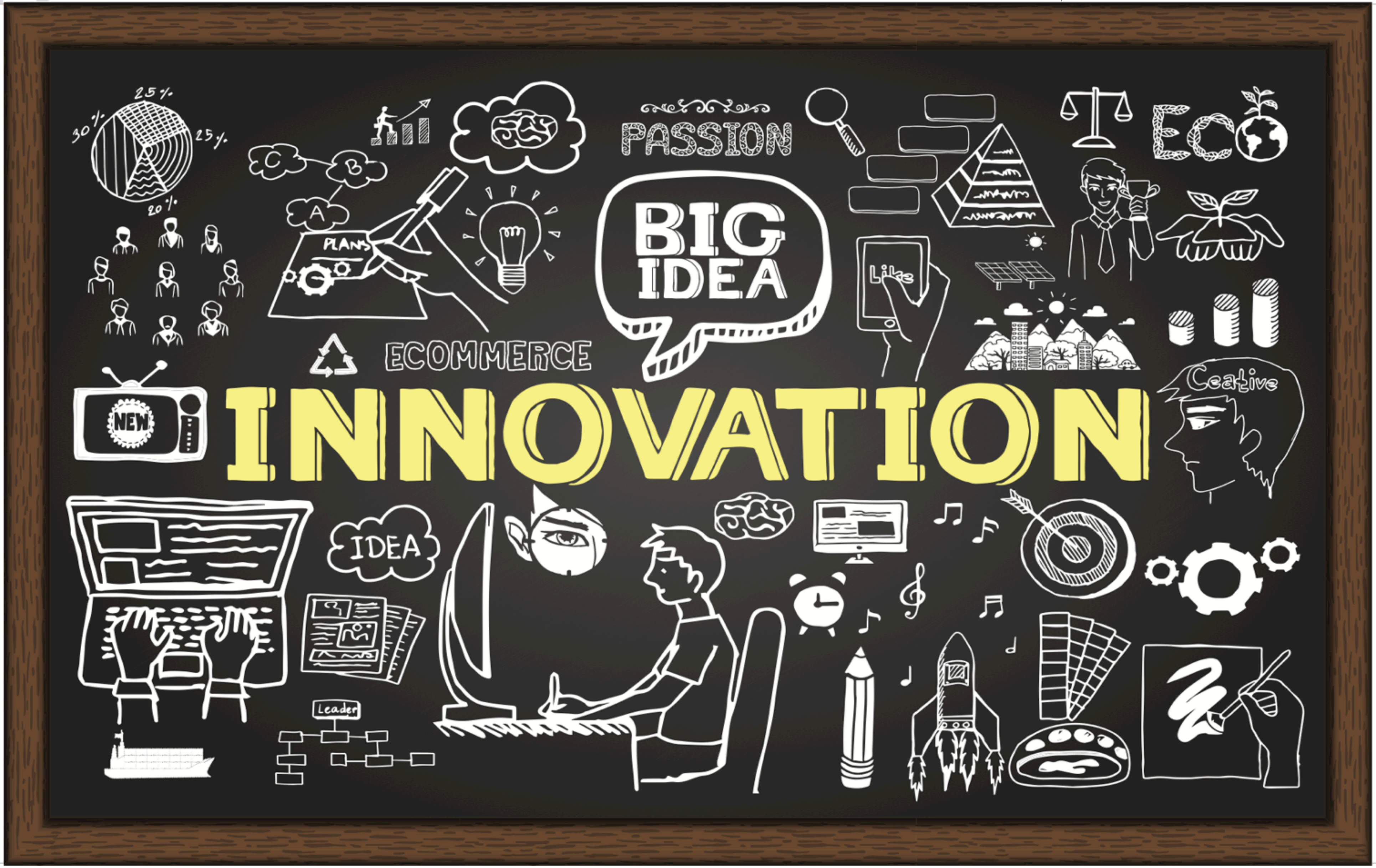
Universidad del País Vasco
Euskal Herriko Unibertsitatea

CAMPUS OF INTERNATIONAL EXCELLENCE

Outline

- Problem statement
- Project objectives
- MCOP approach
- Expected impact

eman ta zabal zazu


25%
30%
25%
20%
PLANS
PASSION
BIG IDEA
ECO
ECOMMERCE
NEW
INNOVATION
Ceative
IDEA
Leader

Problem statement

Classical Entry Barriers

~~Proprietary~~

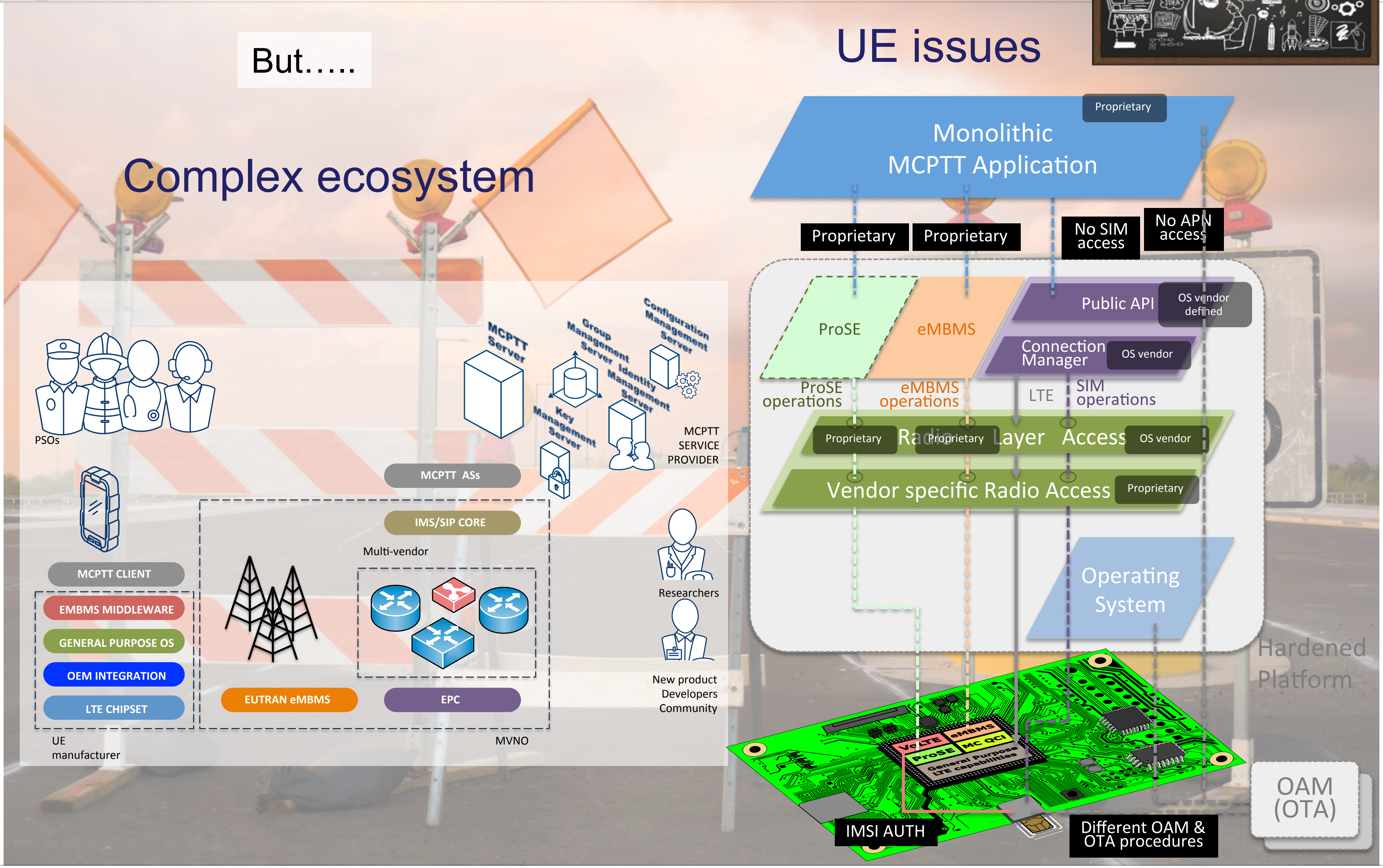
~~Niche Technologies~~

~~Expensive HW platforms~~

~~Lack of interoperability~~

VS.

Problem statement



MCOP project

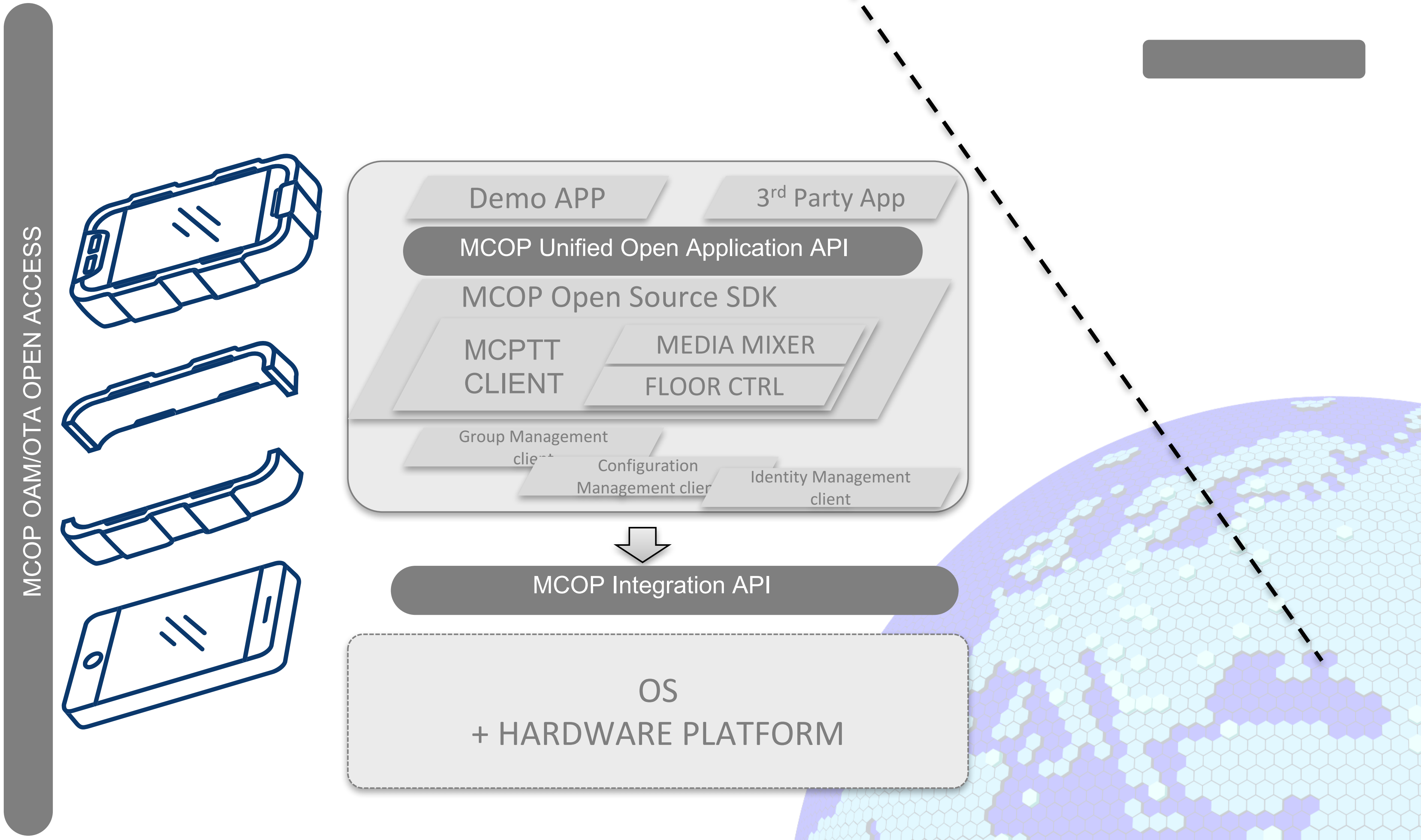
Mission
Critical
Open
Platform

Fostering innovation by targeting common needs of the industry

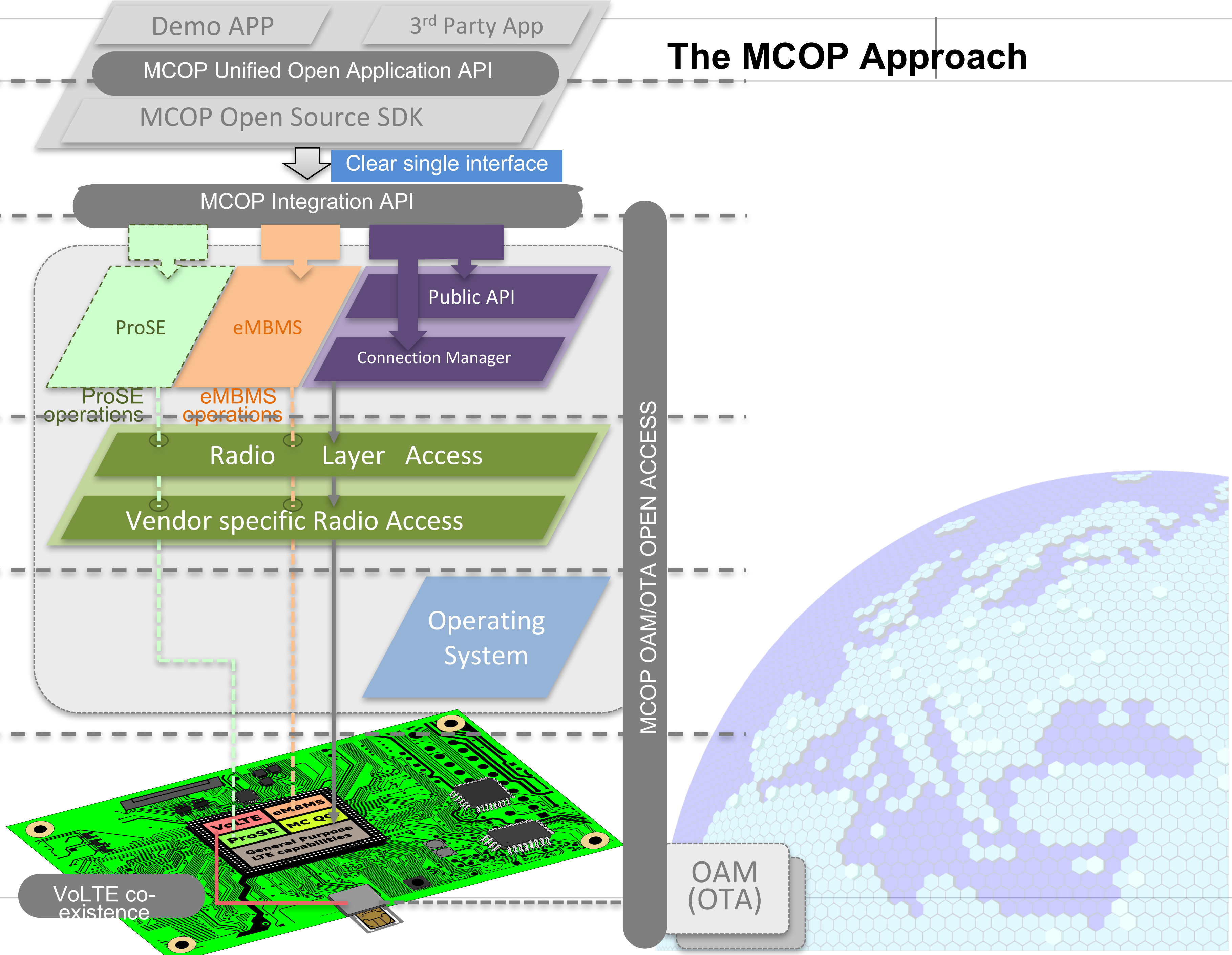
Traditional telco
Former OTT PTT solutions providers
Small integrators
PSOs' IT departments
Newcomers

- Gather and agree on common requirements for the platform from industry fora.
- Analyze architecture problems.
- Define an open platform including different level APIs.
- Validate the architecture and intermediate APIs.
- Deploy and maintain a sustainable live on-site and online testbed.
- Disseminate the results.

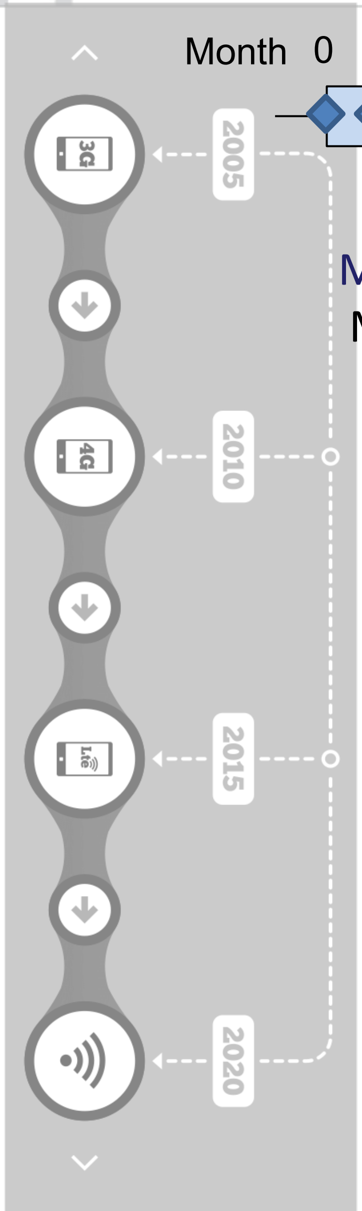
The MCOP Approach

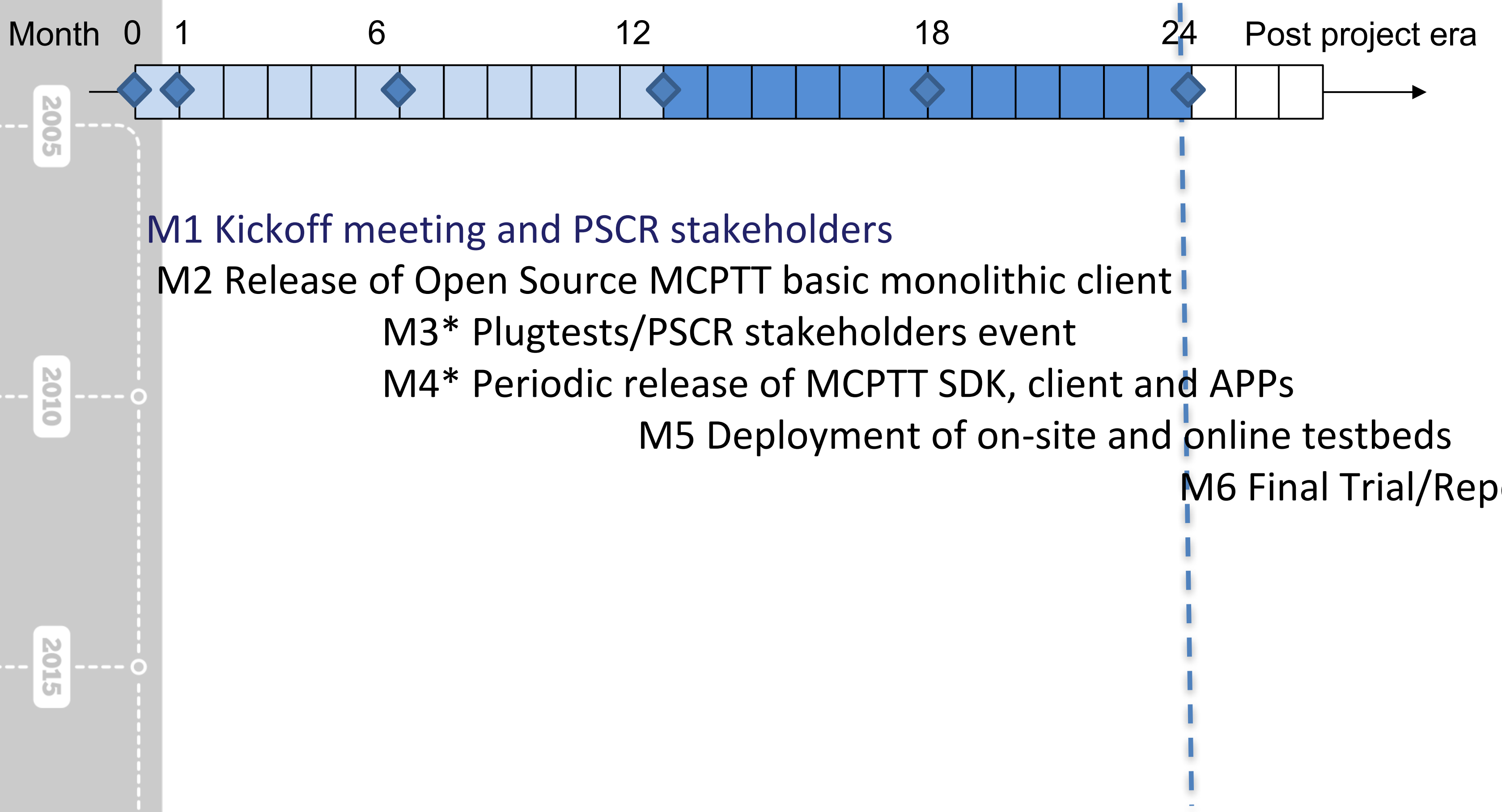


The MCOP Approach



Milestones





M1 Kickoff meeting and PSCR stakeholders

M2 Release of Open Source MCPTT basic monolithic client

M3* Plugtests/PSCR stakeholders event

M4* Periodic release of MCPTT SDK, client and APPs

M5 Deployment of on-site and online testbeds

M6 Final Trial/Report

- PSOs
  - Improve **MCPTT awareness** and encourage informed decisions/purchases
  - Easier and planned **product integration**
  - Avoid single **vendor independence**
  - Hands on **trial and training**
- MC Apps developers & new practitioners
  - **Open** community and standard troubleshooting platform
  - **Standardization**/normalization/certification/conformance testing
  - Shared knowledge, **reference implementation** and MC-grade **experimentation platform**
  - **Reduce production costs and open integration possibilities**
  - Un-tie APP level from specific HW platform

PSCR 2017 Public Safety Broadband Stakeholder Meeting
June 12-14, 2017
Marriott Rivercenter
San Antonio, TX
www.pscr.gov

Mission Critical Open Platform

MCOP

WE WANT YOUR FEEDBACK

TCCA

EXPWAY

Bittium

eman ta zabal zazu

Universidad del País Vasco

Euskal Herriko Unibertsitatea

CAMPUS OF INTERNATIONAL EXCELLENCE

Dr. Fidel Liberal
fidel.liberal@ehu.eus

End-to-End Mission Critical Push to Talk with Direct Mode Operation

Sonim Technologies, Inc.

PSCR

2017

PUBLIC SAFETY BROADBAND
STAKEHOLDER MEETING

#PSCR2017

PSCR – Stakeholder Meeting

Innovation Accelerator Grant Program

Advancing Mission Critical Voice Technologies

June 12th, 2017

sonim®
BUILT FOR LIFE™

Lead Organization

Sonim Technologies Inc.

Grant Partner

Nemergent Solutions SL, Spain

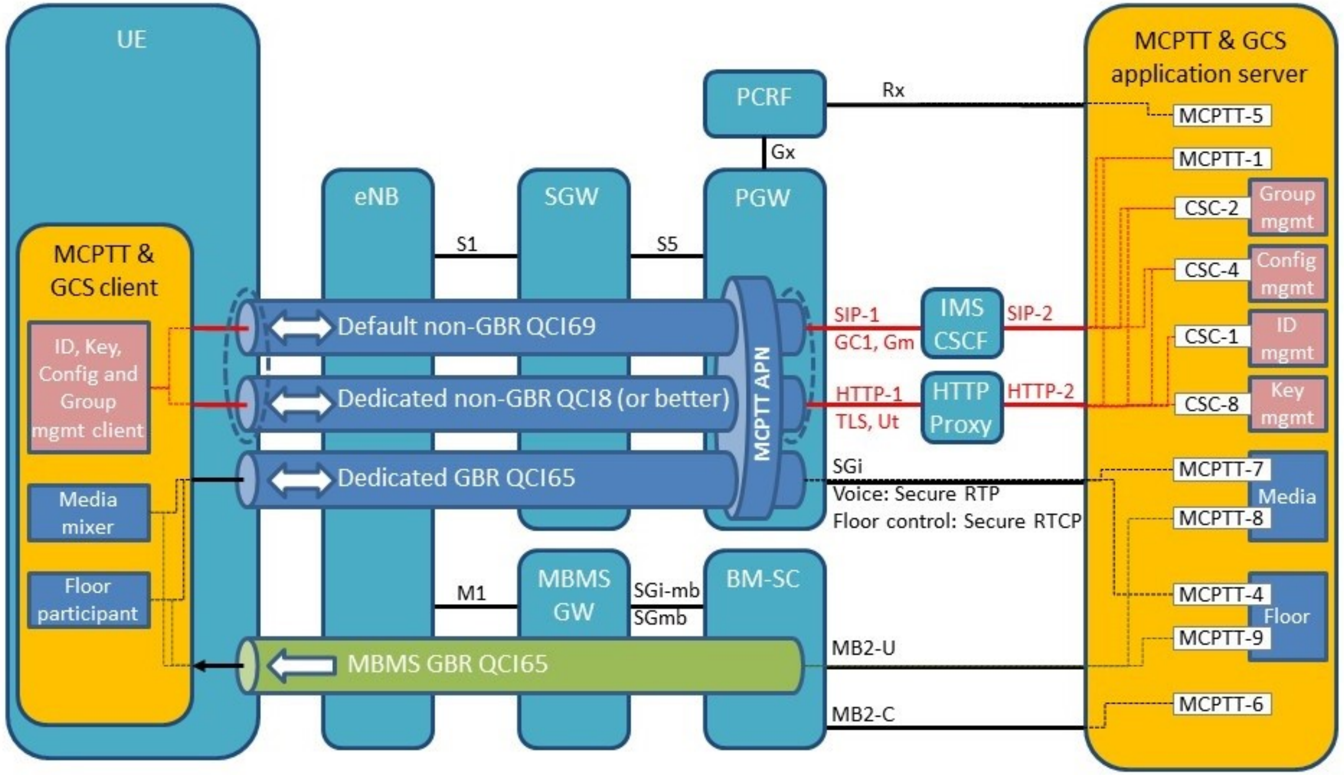
Public Safety Organization Partners

Atlantic City Police Department, New Jersey

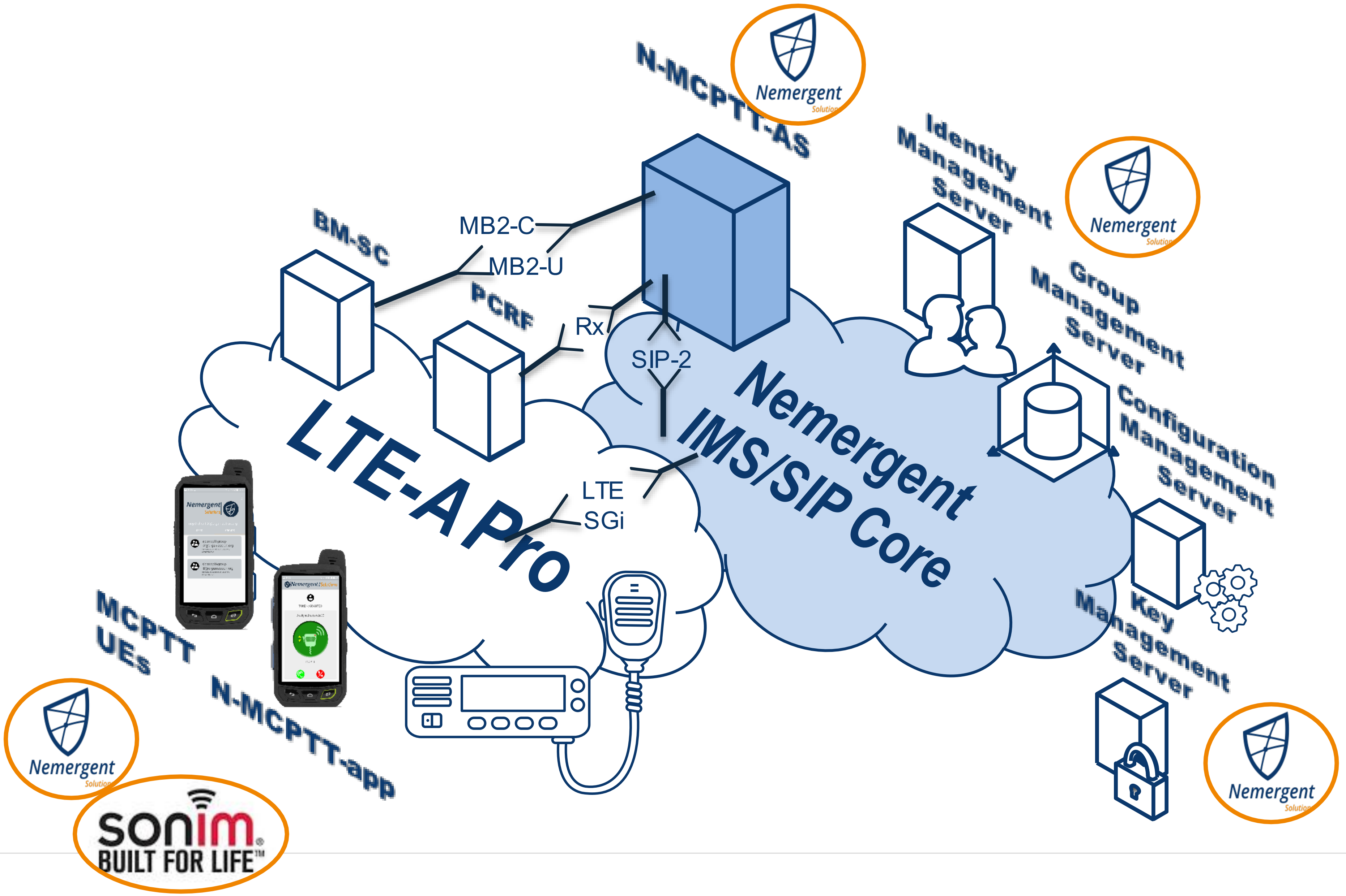
County of Fairfax, Virginia

The overall goals of the project are to:

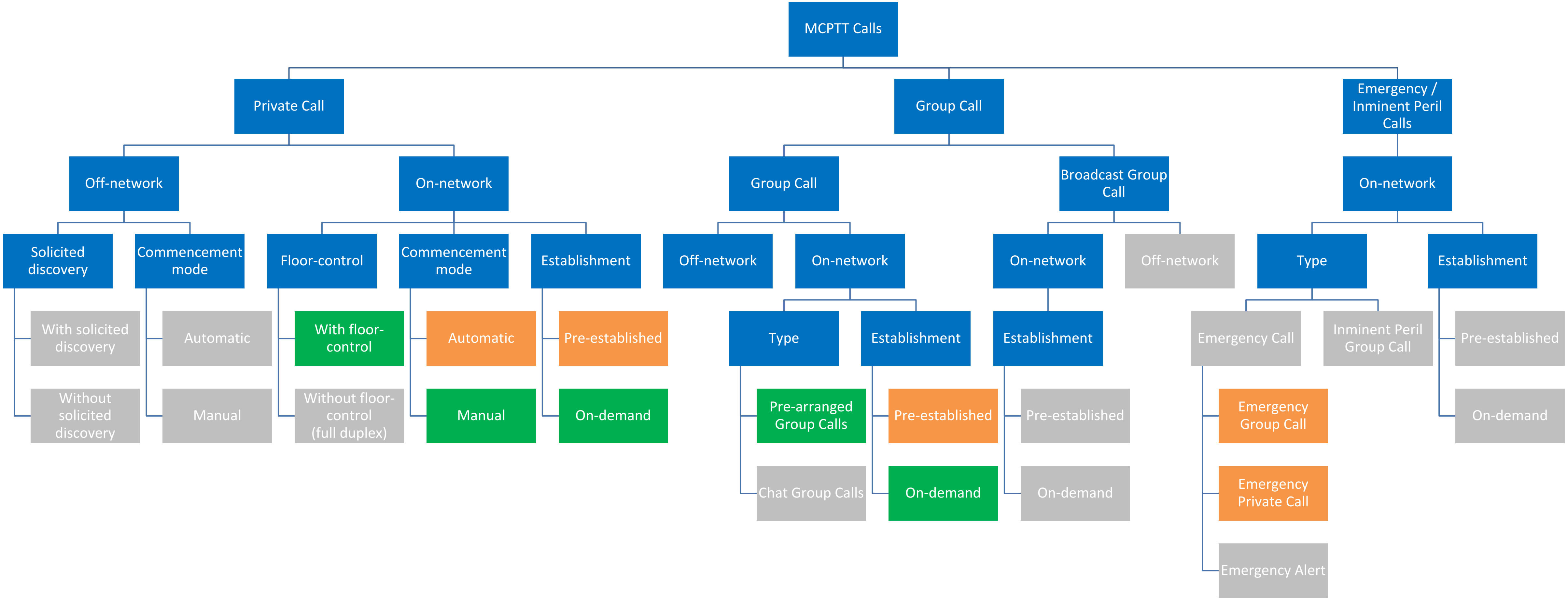
1. *Develop a 3GPP R13 compliant end-to-end MCPTT solution for demonstration purposes*
2. *Integrate Sonim APIs with Nemergent client application*
3. *Conduct field testing of the end-to-end solution with First Responder partners and demonstrate a true mission critical voice experience*
4. *Release 3GPP R13 compliant client solution as an open-source package for general use*



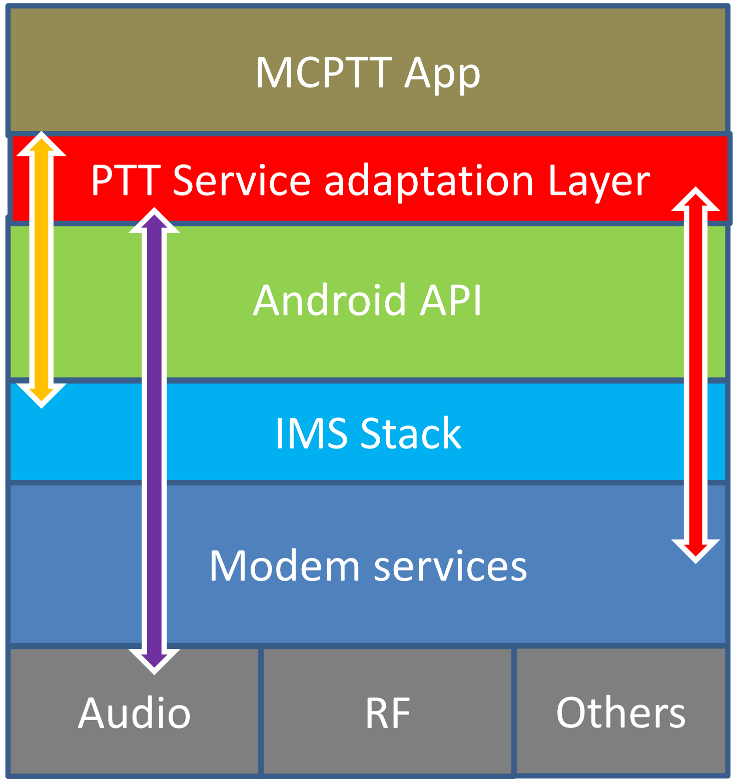
3GPP Release 13 MCPTT Architecture


N-MCPTT-AS
Nemergent
Identity Management Server
Nemergent
BM-SC
MB2-C
MB2-U
PCRF
Rx
SIP-2
Group Management Server
Configuration Management Server
Nemergent IMS/SIP Core
LTE-A Pro
LTE SGi
MCPTT UEs
N-MCPTT-app
Key Management Server
Nemergent
Nemergent
sonim BUILT FOR LIFE

Supported MCPTT Call Types



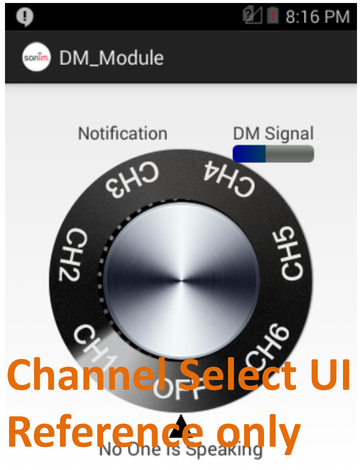
Key Contribution areas from Sonim –



1. MCPTT Service adaptation layer for android as reference implementation
2. Enhanced usability by improving key usage scenarios
3. Accessory integration for MCPTT e.g. Channel Select accessory
4. Performance metrics on reference Android device
5. Field testing and benchmark reporting

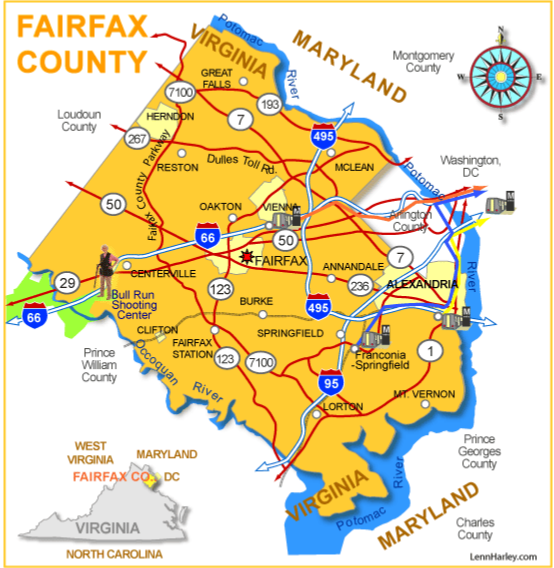
Examples of User Experience Focus in MCPTT Service Integration

- Integration of PTT button for all states of the device
- Common proposal for critical usage functions
- Enhanced usability aspects using a Channel Select Module
  - feasibility of supporting a similar UX as Radios
- KPI – benchmark performance proposals using reference implementation
  - measurements on live FirstNet environment when available
- Field tests to evaluate the performance and submit statistical usability information



Sonim will provide handsets with integrated MCPTT client:

- *20 handsets will be deployed to Fairfax County, VA and Atlantic City Police for field testing*
- *Sonim will provide onsite support of the field test efforts and collect user data for report generation*
- Nemergent will provide end-to-end MCPTT software support



Thank You

Robert Escalle – Vice President, Public Safety Market Segment
r.escalle@sonimtech.com

sonim®
BUILT FOR LIFE™

OpenFirst

Software Radio Systems Limited

PSCR

2017

PUBLIC SAFETY BROADBAND
STAKEHOLDER MEETING

#PSCR2017

OPENFirst

The Open-Source SDR LTE Platform for First Responders

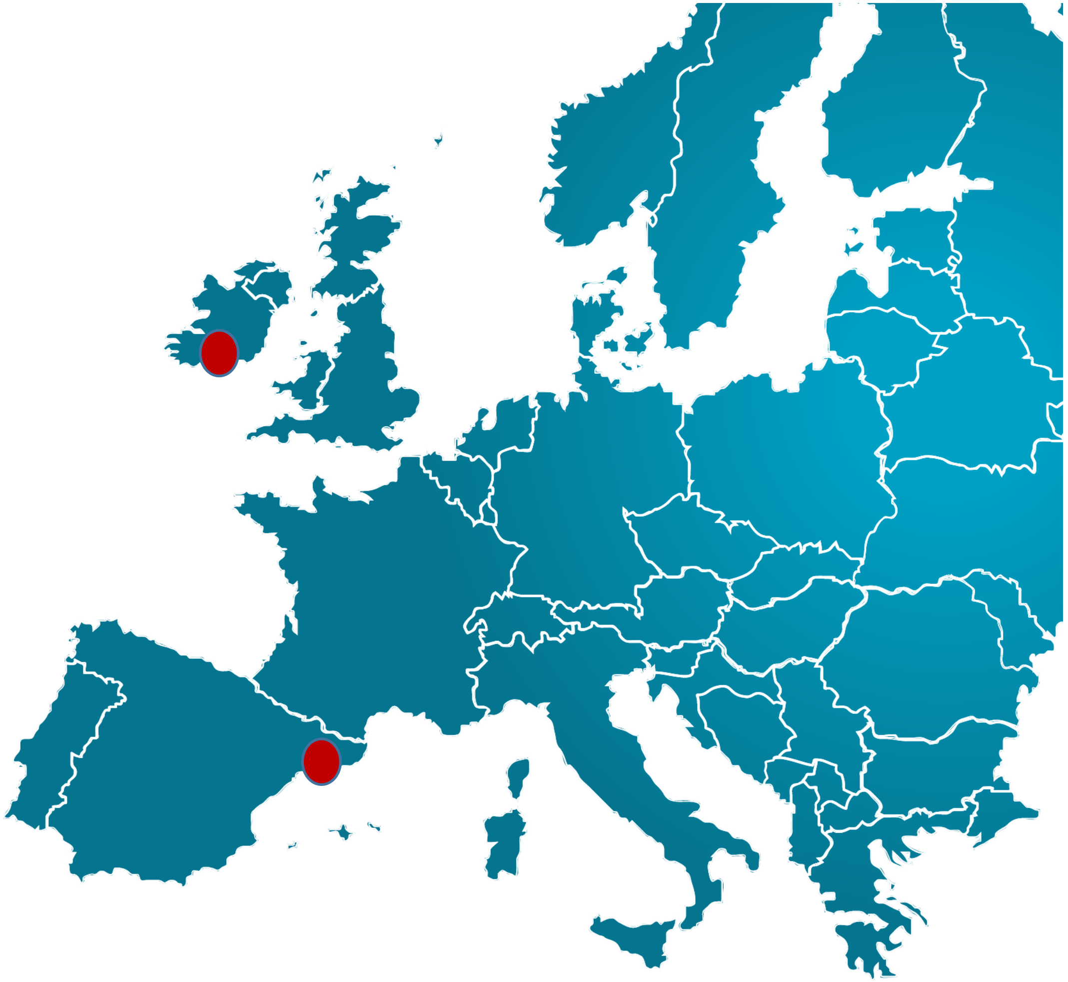
SOFTWARE RADIO SYSTEMS

Paul Sutton PhD
Director

Ismael Gomez PhD
Director

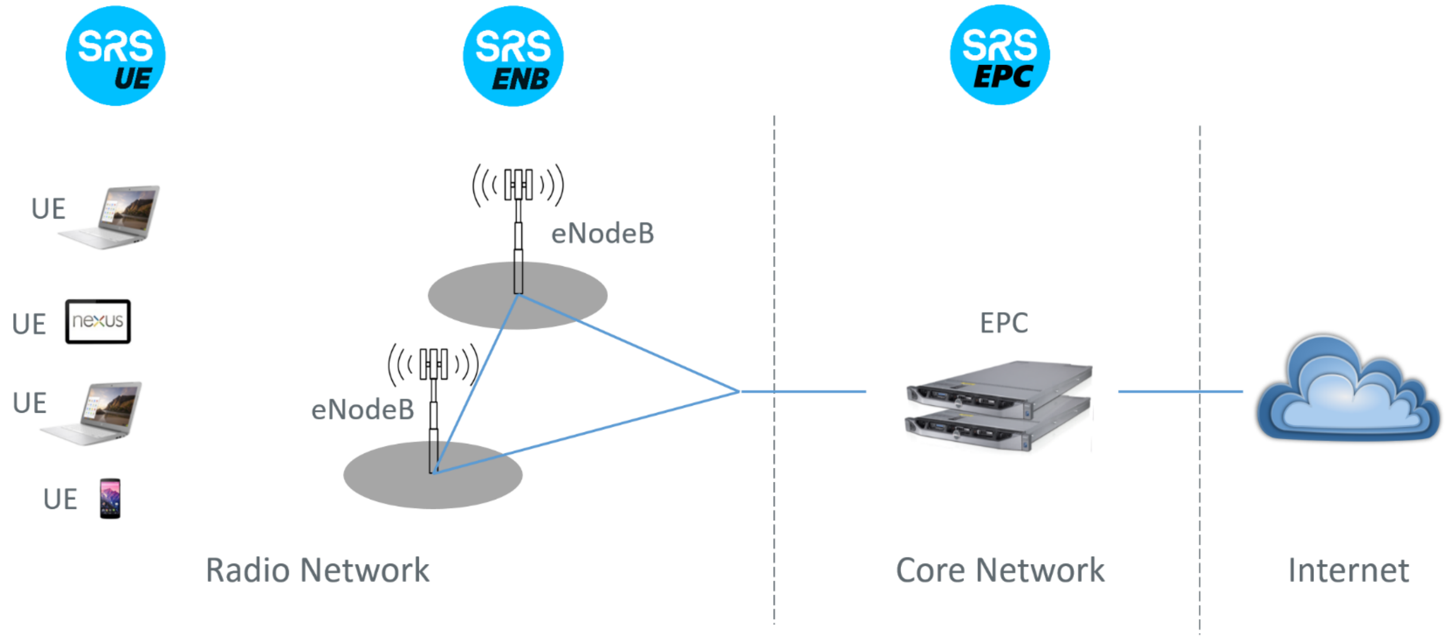
Andre Puschmann
Senior Engineer

Linda Doyle PhD
Director



SRS
SOFTWARE RADIO SYSTEMS

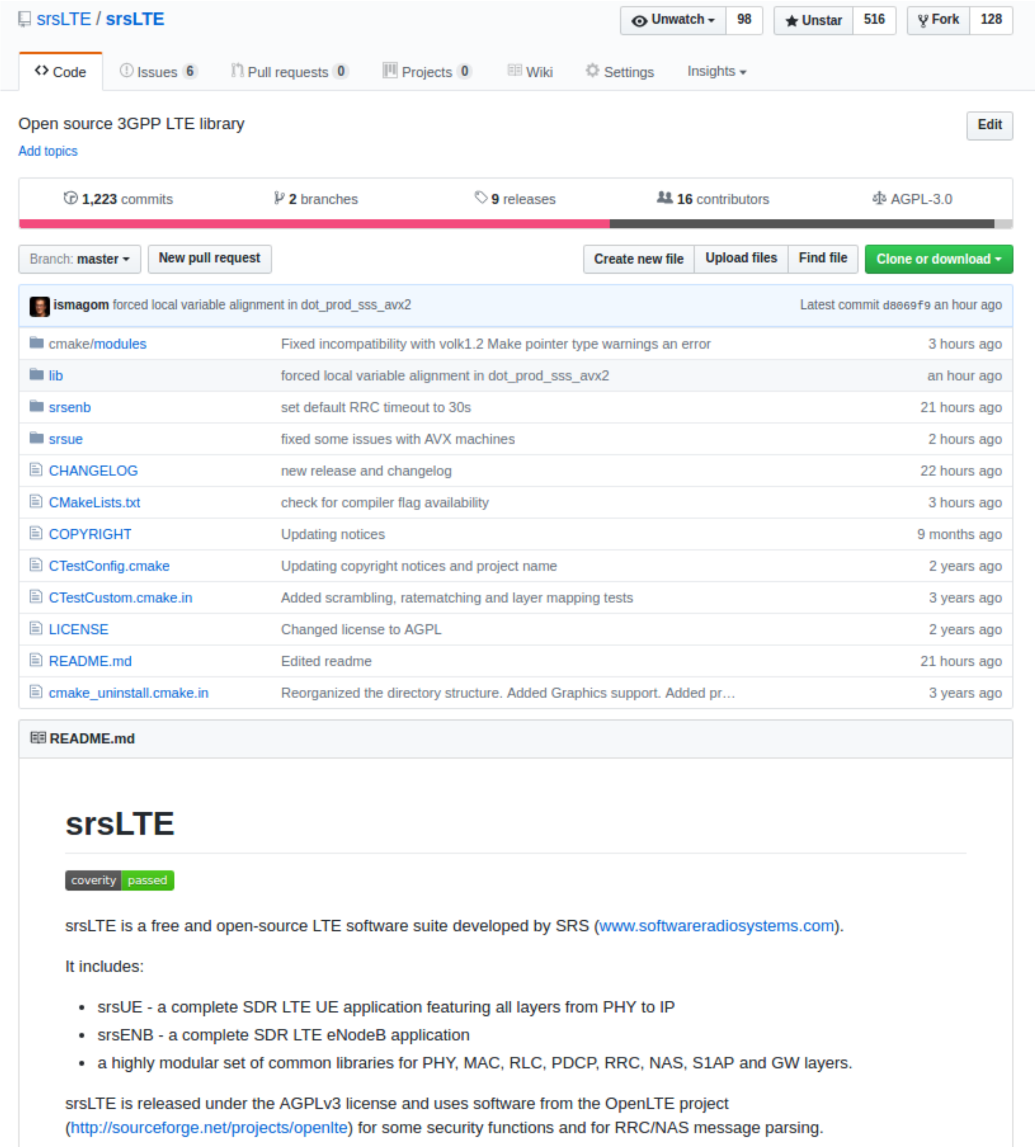
OPENFirst



- An open-source end-to-end LTE network platform for public safety research & development.
- A reference implementation of key LTE features for first responders.
- Enabling, supporting and growing the public safety broadband development ecosystem.
- Providing a commercialization path for public safety LTE using proven business models.
- Building upon the proven srsLTE suite of open-source libraries, tools and applications.

SRS SOFTWARE RADIO SYSTEMS

SRS
SOFTWARE RADIO SYSTEMS


srsLTE / srsLTE

Unwatch 98 | Unstar 516 | Fork 128

Code | Issues 6 | Pull requests 0 | Projects 0 | Wiki | Settings | Insights

Open source 3GPP LTE library

Add topics

1,223 commits | 2 branches | 9 releases | 16 contributors | AGPL-3.0

Branch: master | New pull request | Create new file | Upload files | Find file | Clone or download

ismagom forced local variable alignment in dot_prod_sss_avx2 — Latest commit d8069f9 an hour ago

cmake/modules	Fixed incompatibility with volk1.2 Make pointer type warnings an error	3 hours ago
lib	forced local variable alignment in dot_prod_sss_avx2	an hour ago
srsenb	set default RRC timeout to 30s	21 hours ago
srsue	fixed some issues with AVX machines	2 hours ago
CHANGELOG	new release and changelog	22 hours ago
CMakeLists.txt	check for compiler flag availability	3 hours ago
COPYRIGHT	Updating notices	9 months ago
CTestConfig.cmake	Updating copyright notices and project name	2 years ago
CTestCustom.cmake.in	Added scrambling, ratematching and layer mapping tests	3 years ago
LICENSE	Changed license to AGPL	2 years ago
README.md	Edited readme	21 hours ago
cmake_uninstall.cmake.in	Reorganized the directory structure. Added Graphics support. Added pr…	3 years ago

README.md

srsLTE

coverity passed

srsLTE is a free and open-source LTE software suite developed by SRS (www.softwareradiosystems.com).

It includes:

- srsUE - a complete SDR LTE UE application featuring all layers from PHY to IP
- srsENB - a complete SDR LTE eNodeB application
- a highly modular set of common libraries for PHY, MAC, RLC, PDCP, RRC, NAS, S1AP and GW layers.

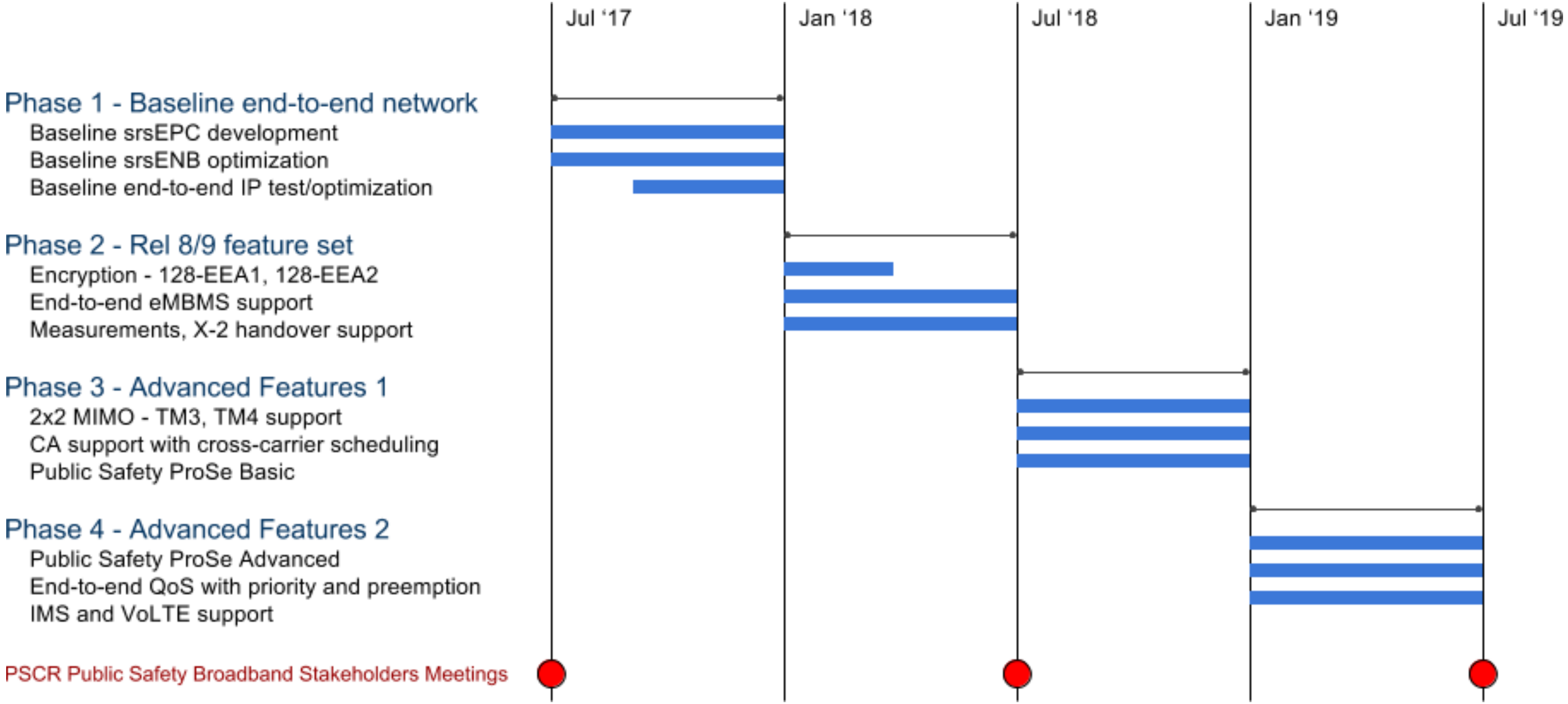
srsLTE is released under the AGPLv3 license and uses software from the OpenLTE project (http://sourceforge.net/projects/openlte) for some security functions and for RRC/NAS message parsing.

open source

- GNU Affero General Public License (AGPLv3)
- Ensuring dissemination of the technology
- Maximizing usability
- Safeguarding availability
- Guaranteeing sustainability

www.github.com/srslte

SOFTWARE RADIO SYSTEMS


Jul '17
Jan '18
Jul '18
Jan '19
Jul '19
Phase 1 - Baseline end-to-end network
Baseline srsEPC development
Baseline srsENB optimization
Baseline end-to-end IP test/optimization
Phase 2 - Rel 8/9 feature set
Encryption - 128-EEA1, 128-EEA2
End-to-end eMBMS support
Measurements, X-2 handover support
Phase 3 - Advanced Features 1
2x2 MIMO - TM3, TM4 support
CA support with cross-carrier scheduling
Public Safety ProSe Basic
Phase 4 - Advanced Features 2
Public Safety ProSe Advanced
End-to-end QoS with priority and preemption
IMS and VoLTE support
PSCR Public Safety Broadband Stakeholders Meetings

OPENFirst

SRS

SOFTWARE RADIO SYSTEMS

Device-to-Device System for Public Safety

Vencore Labs, Inc. dba Applied Communications Science

PSCR

2017

PUBLIC SAFETY BROADBAND
STAKEHOLDER MEETING

#PSCR2017

Public Safety Broadband Stake Holder Meeting at San Antonio (2017)

June 6, 2017

Vencore Labs Team: Richard Lau (co-PI), Tony Triolo (co-PI), Stephanie Demers, Heechang Kim

Partner: EURECOM: Prof. Raymond Knopp

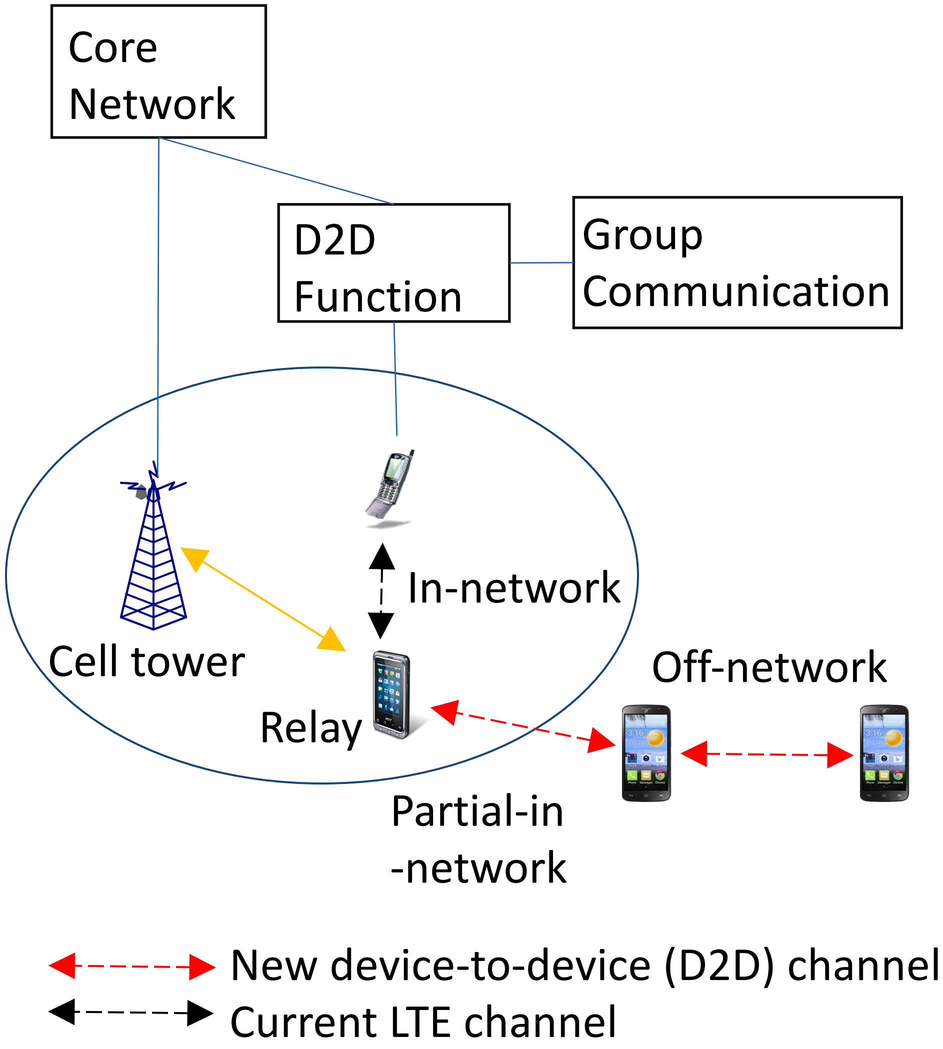
Device-to-Device System for Public Safety (DDPS)

2017-NIST-PSIAP-01

Contact: Dr. Richard C. Lau
Chief Scientist & Vencore Labs Fellow
Tel: (732) 898-8476
Email: clau@vencorelabs.com

VENCORE LABS

Problem Space & Stakeholders



Key Stakeholders:

- Law enforcement
- Firefighters
- Medical personnel
- Military organizations
- Volunteer groups

Key CONOPS for Public Safety:

- Fall back in the event of complete LTE network failure, e.g. natural disasters
- UE-UE communication within coverage
- UE-UE communication outside coverage
- Mixture of UE communication within and outside coverage

Key Services:

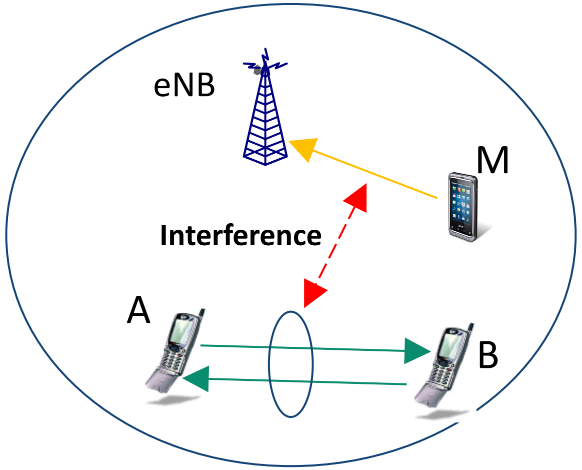
✓ Mission-Critical Voice
✓ 3GPP Proximity Service (ProSe)
✓ 1:1 and 1:many group communication
✓ Service continuity

Objectives of Vencore Labs DDPS Solution

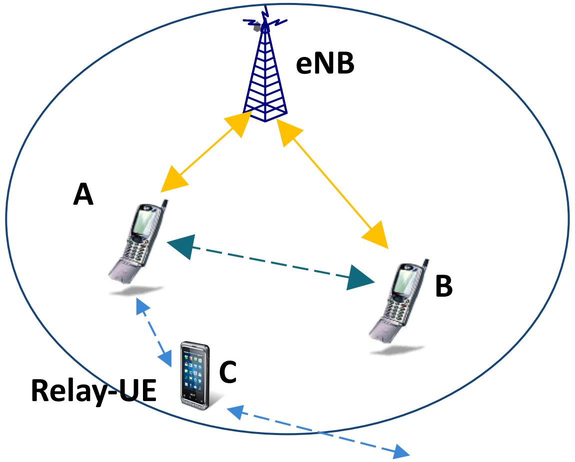
- Build complete ProSe stack for Mission Critical Voice.
- Extend the current OpenAirInterface^{TM}(OAI) implementation to include the access-stratum ProSe services, namely the LTE Sidelink (PC5) interface based on the Rel-14 3GPP specifications.
- Solve open issues related to UE discovery, resource allocation, time synchronization, and service continuity.
- Demonstrate ProSe solution on software defined radio platform.
- The device-to-device (D2D) stack will help create an ecosystem and will be provided to interested vendors for commercialization on a system-on-a-chip (SoC) platform.
- With appropriate NIST permissions, the software will be released back into the open source OAI community.

Vencore Labs DDPS Approach

- Build complete ProSe stack for Mission Critical Voice based on 3GPP standard and Open Source OAI and demonstrate in a hardware testbed.
- Design and implement new scheduling algorithms for autonomous resource allocation, which improves on current baseline ProSe specification to minimize collision probability.
- Design and implement novel multi-antenna-based synchronization techniques to achieve significant improvement in UE autonomous synchronization.
- Solve complex service continuity challenges for both on-network and off-network operations.



Interference



Service Continuity

Major Milestones

- Phase 1 (June 1, 2017 - May 31, 2018)
  - ***1.1 DDPS system architecture and interface design***
  - ***1.2 ProSe software design and implementation***
  - ***1.3 New resource allocation and synchronization algorithms***
  - ***1.4 ProSe system integration including UE, ProSe function, and E-UTRAN and EPC modifications***
  - ***1.5 General program management***
- Phase 2 (June 1, 2018 - May 31, 2019)
  - ***2.1 Service Continuity analysis, gap analysis, and solution to gaps***
  - ***2.2: ProSe software upgrade including UE-to-Network Relay***
  - ***2.3: ProSe software integration on SDR platform***
  - ***2.4: DDPS demonstration in open air field***
  - ***2.5: Transition Plan and program management***

Expected Impact

- Develop and integrate LTE D2D ProSe (PS) capabilities; demonstrate service continuity with respect to various interworking scenarios in field demonstrations, laying the foundation for wide-spread deployment of D2D PS service.
- Provide reliable communication capability within groups of first responders through the use of ProSe-based devices and support communication among different emergency responder groups.
- Solve challenging issues in cell tower failure disaster scenarios, including resource allocation in high interference environments, fast discovery, timing synchronization, and service continuity, in extreme disaster scenarios.
- Transition the DDPS technology to the Public Safety Broadband Program, and integrate it into emerging Public Safety networks, through design based on evolving 3GPP standards and open source implementations.
- With permission from NIST, integrate the DDPS OAI extension into the OpenAirInterface™ Software Alliance (OSA), a non-profit organization founded by EURECOM.

Modeling, Simulation and Performance Evaluation for Future Public Safety Networks

University of Washington

PSCR

2017

PUBLIC SAFETY BROADBAND STAKEHOLDER MEETING

#PSCR2017

Modeling, Simulation & Performance Evaluation for Future Public Safety Networks

U. Washington (Lead)
S. Roy (P.I., Integrated Systems Prof. Electrical Eng.)
T. Henderson & J. A. Ritcey (Co-PIs)

CTTC, Barcelona, Spain (Sub)
L. Giupponi (Sr. Researcher)

Partners/Transitions
City of Seattle; Communications Technology Lab (CTL), NIST

Public Safety Stakeholders Meeting

UNIVERSITY *of* WASHINGTON

June 2017

Project Overview

> Proposal responding to Topics

A (Mission Critical Voice) D (PSC Demand Models)

E (Research and Prototyping Platforms)

of the 2017 NIST-PSIAP-01 NOFO

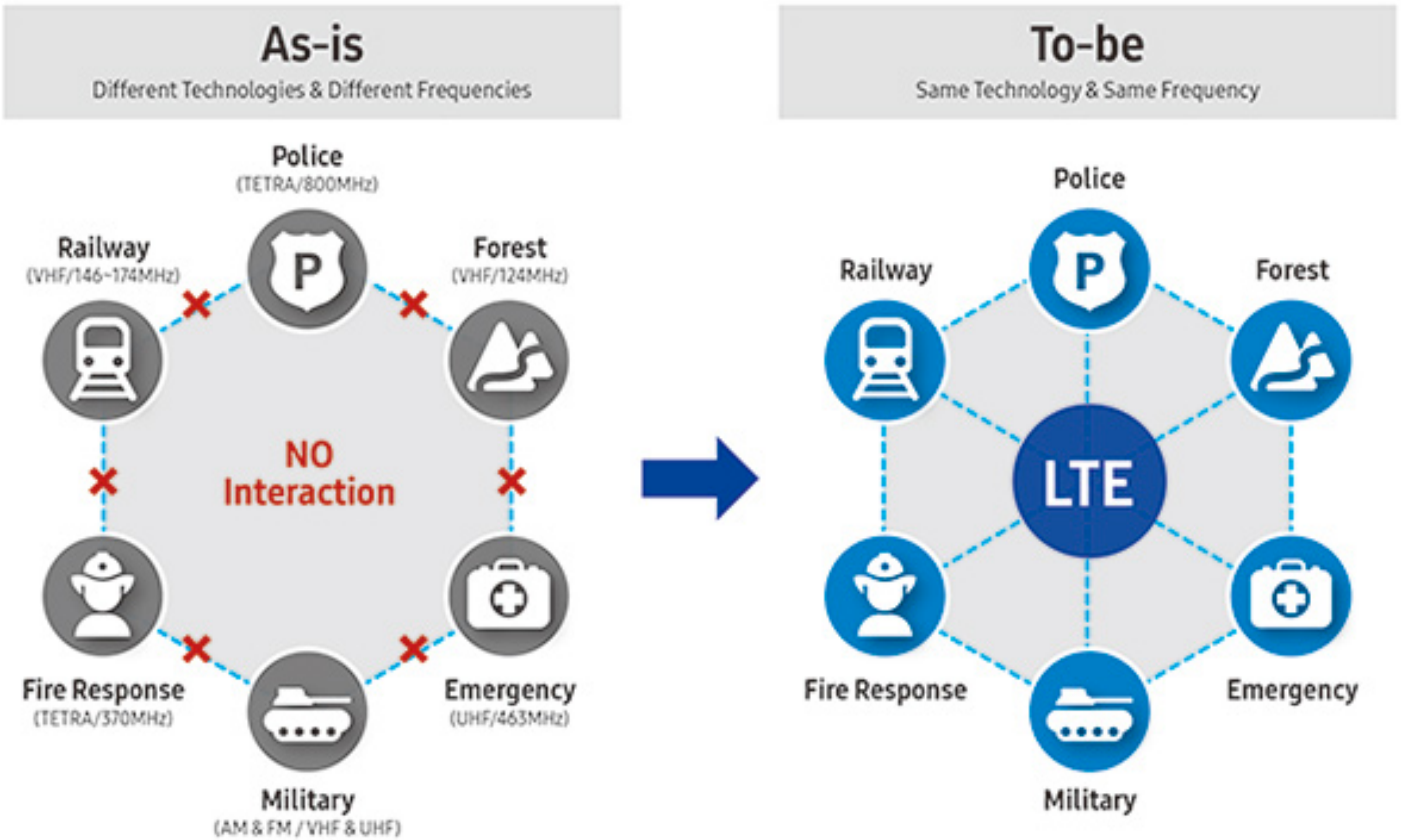
> <u>RD&E program</u>

1. PSCR Network Demand Modeling - to be coordinated with City of Seattle's public safety transition plans - current (P25 PTT) and future (broadband LTE)

2. Open Source (ns-3) simulation platform development & associated performance analysis:

   Packet Level Network Simulation for Mission Critical Voice/Data, D2D (Direct Mode) over LTE Networks - coordinate with NIST CTL

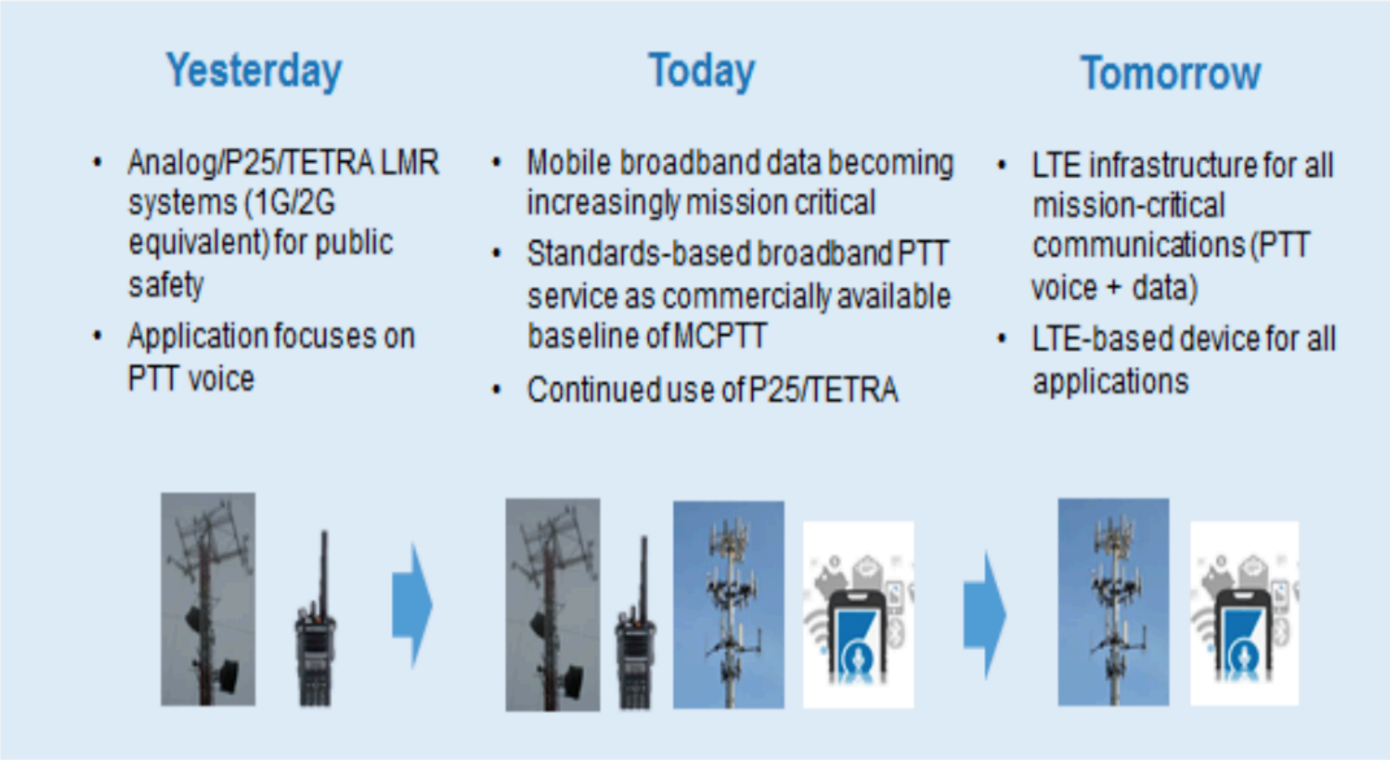
The Ideal Transition



Broadband LTE Advantages for MCPTT

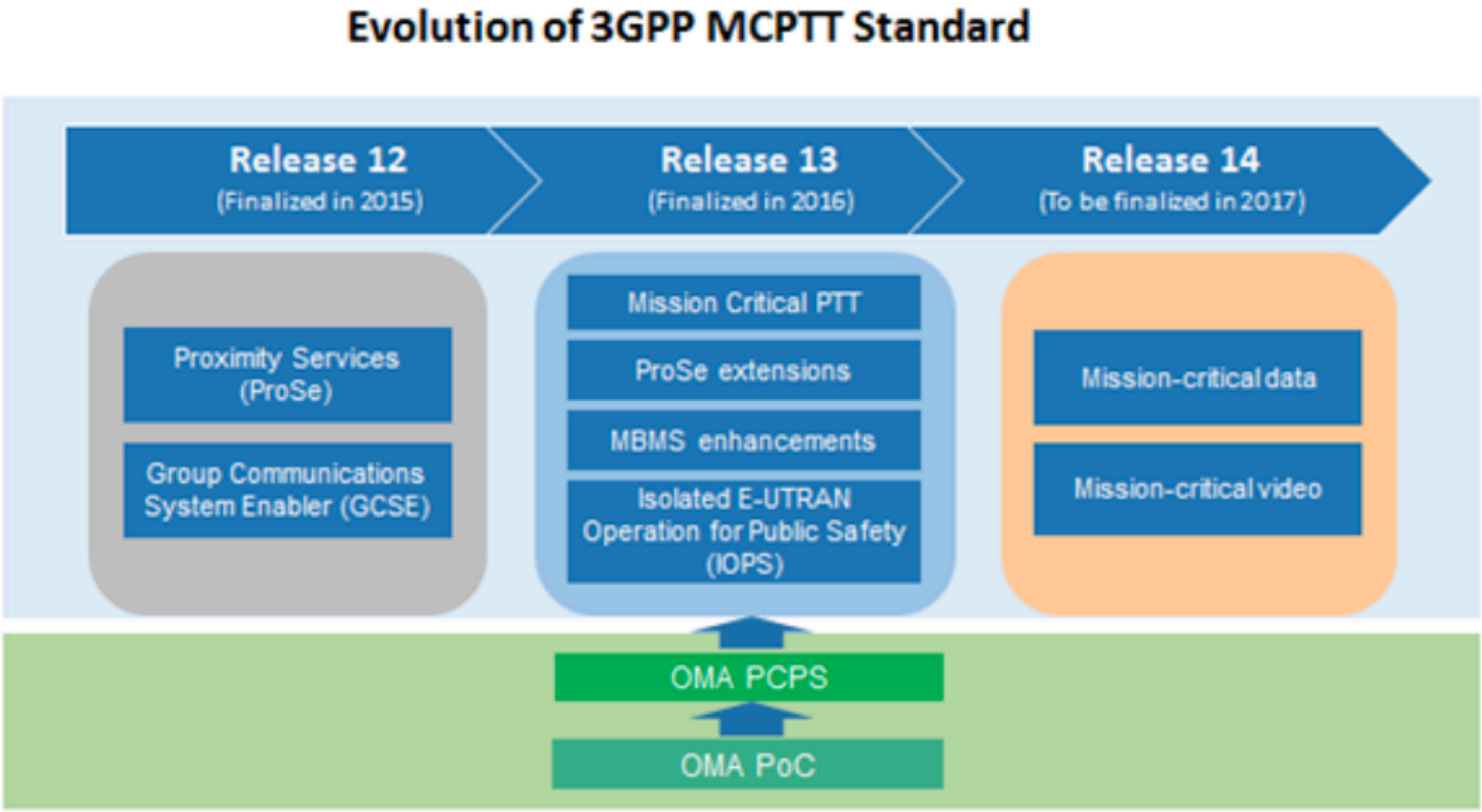
- ➢ Compared with legacy land mobile radio/private mobile radio systems (P25 and TETRA), MCPTT over LTE offers numerous advantages:
- A single device for all voice and data applications
- Integration of situational awareness and other PSC applications designed for LTE and devices running smartphone operating systems
- Cost savings/economy of scale
- Ubiquitous network coverage
- Capacity scalability
- Cross-agency interoperability
- Thriving ecosystem
- Continuous rapid innovations

From Narrowband Mission-critical Voice to Converged Broadband Mission-Critical Communications



Mission-critical push-to-talk (MCPTT) functionality is now part of the LTE Release 13 (March 2016) → MCPTT-capable equipment should be available for FirstNet c. 2018.

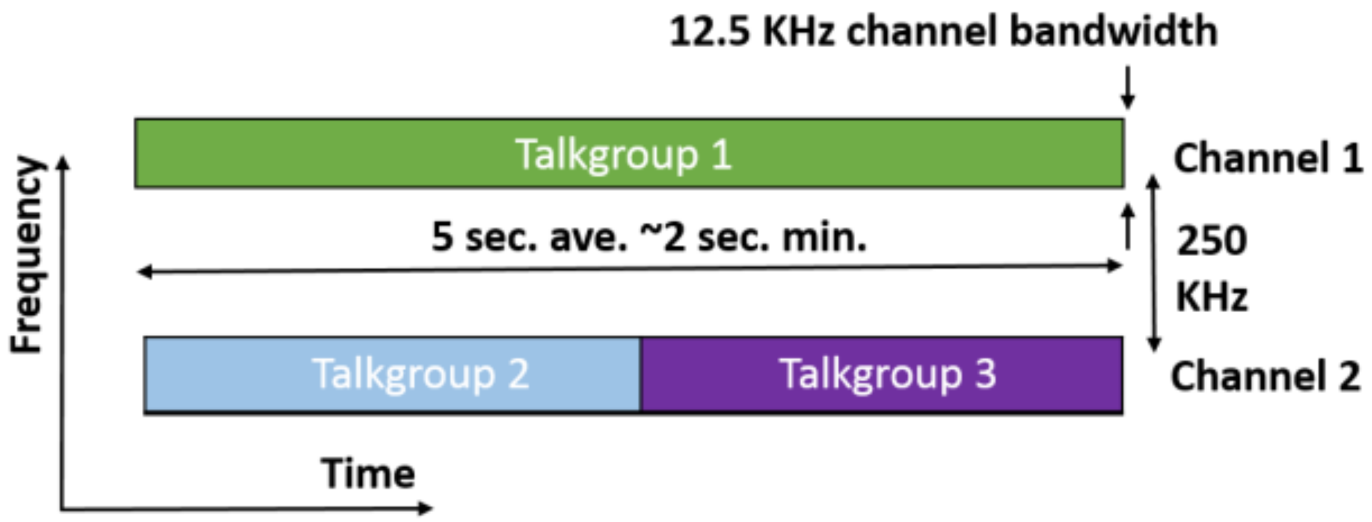
Supporting Broadband Technologies



Scenario Development: Demand Models for Network Provisioning

- **Emergency Scenario Models**
  - Spatial Scale
  - Temporal Scale
  - Responder Density/Scale

- **Probabilistic Models for Voice, Data, Video**
  - Call Holding Times
  - Call inter-arrivals
  - Talkgroup Statistics
  - Correlations/Distributions



Talk Groups in Modeling APCO 25 taken from "A Comparative Study of LMR and LTE-based PSC," SouthEastCon 2015

KEY QUESTION: WHEN is 10 MHz for Broadband LTE PSC Adequate ?

- Disagreements on the adequacy of 10 MHz for various public safety/emergency scenarios:

  - [1] estimated that 10 MHz is more-than-adequate (overprovision) for normal daily routines and for several emergency scenarios as described ; only for the `worst' case scenarios, 10 MHz is inadequate and priority roaming on 700 MHz cellular network will be needed (hence very occasional) → was the substantial basis for the 10 MHz allocation.

  - [2] rebuts that [1] seriously under-estimates traffic demand due to some methodological issues and predicts much more widespread roaming on a daily basis:
    - neglects emerging data (multimedia) traffic demands
    - lack of proper modeling of emergency events: e.g. multiple smaller events within the same cell area
    - Further, mechanisms for priority roaming on commercial LTE networks TBD
    - Cost of adequate LTE network site deployments to meet coverage (baseline capacity) requirements as mandated

[1] Peha et al. ``The Public Safety Nationwide Interoperable Broadband Network: A New Model for Capacity, Performance and Cost,'' FCC White Paper, Jun. 2010.

[2] Seybold, Rebuttal `` Public Safety LTE Network Testing,'' FCC Docket 06-229, Sep. 2011.

PSCR Network Simulation: Tools, Methods

> Need: Create PSCR-focused research and prototyping platforms (topic E)
- Packet-level network simulators to simulate end-to-end flow of application data through network scenarios

> Research aim: Enhance the open source ns-3 discrete-event network simulator to become a preferred simulation framework for public safety communications research (PSCR)

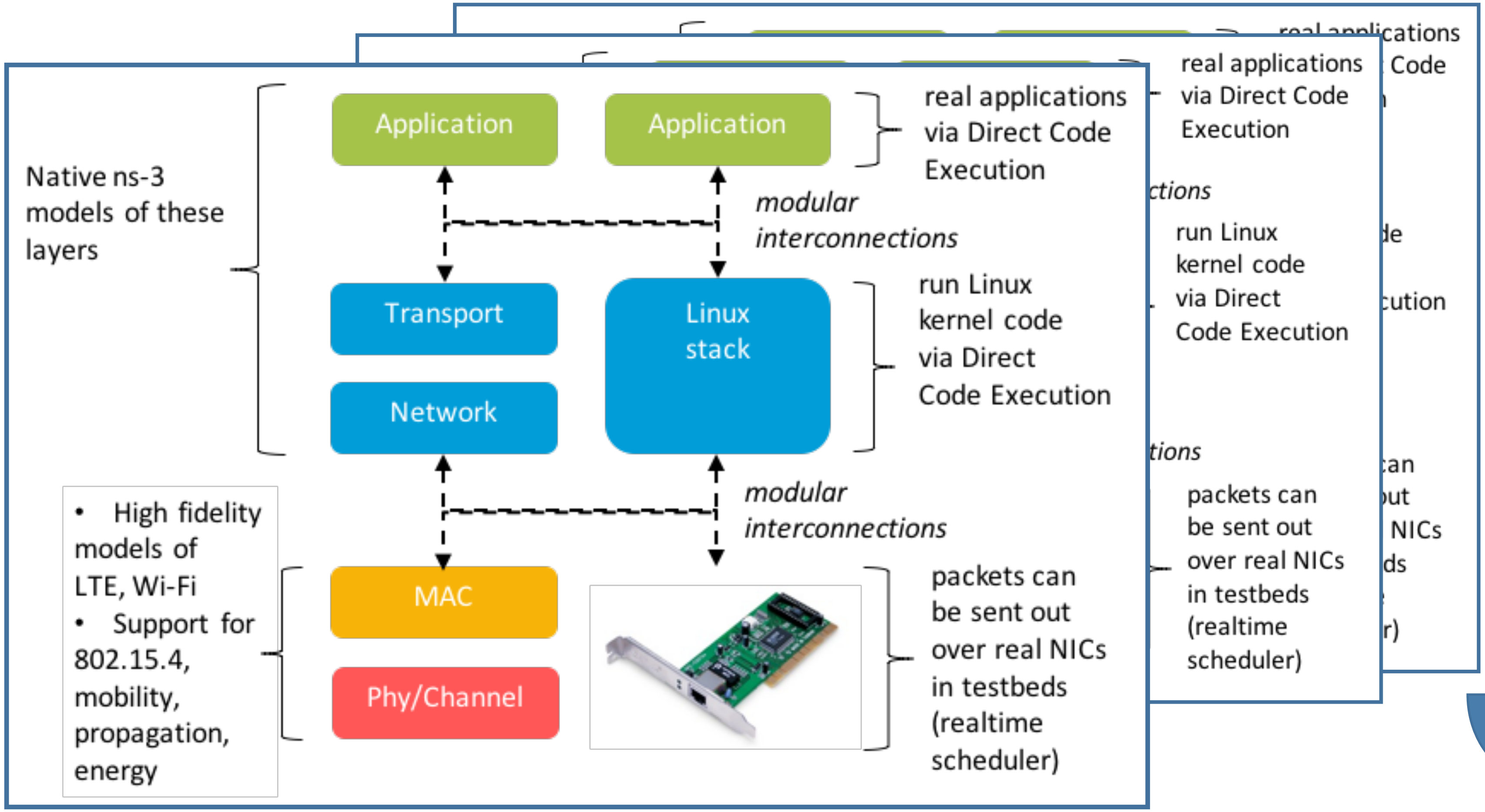
> Technical leads: Tom Henderson (Univ. of Washington) and Lorenza Giupponi (CTTC)

ns-3 overview

www.nsnam.org

> **THE leading open source**, **packet-level network simulator** oriented towards network research, featuring **a high-performance core** enabling **parallelization across a cluster** (for large scenarios), **ability to run real code**, and **interaction with testbeds**

Runs on a single machine



or partitioned across a cluster

ns-3 Work Summary

> Aim to take PSCR models for LTE Mobile Broadband and progress them to the state at which external researchers can use/extend them to use cases of interest

- Technical: Enhance LTE models for D2D, proximity services, group communications, and PSCR scenario support
- Access: Simulator is already freely available under GPLv2; propose the same for this effort
- Sustainability: Build a community-of-interest around PSCR module for ns-3, invest also in baseline LTE improvements

NIST CTL team already using ns-3, has built extensions for D2D models

- Richard Rouil et al. "Implementation and Validation of an LTE D2D Model for ns-3," *Proc. 2017 Workshop on ns-3*, June 2017

Legacy: (EU) LENA Project for LTE EPC Stack

> A Product-oriented simulator:

- Designed around an industrial API: the Small Cell Forum MAC Scheduler Interface Specification
- Allows testing of real code in the simulation
- Accurate model of the LTE/EPC protocol stack
- Specific Channel and PHY layer models for LTE macro and small cells

> Supports the evaluation of:

- Radio-level performance
- End-to-end QoE

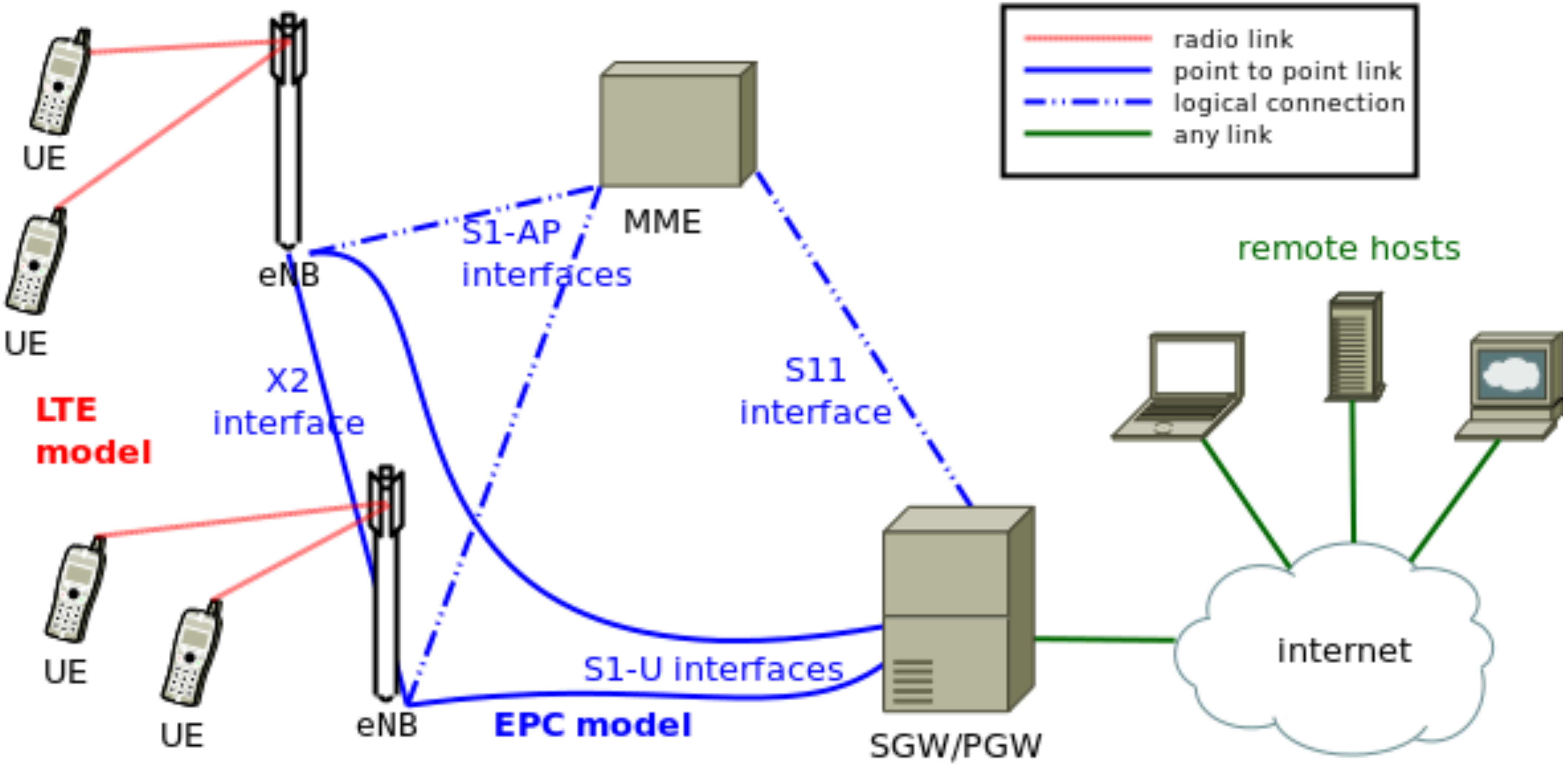
> Scalability requirements:

- Several 10s to a few 100s of eNBs
- Several 100s to a few 1000s of UEs

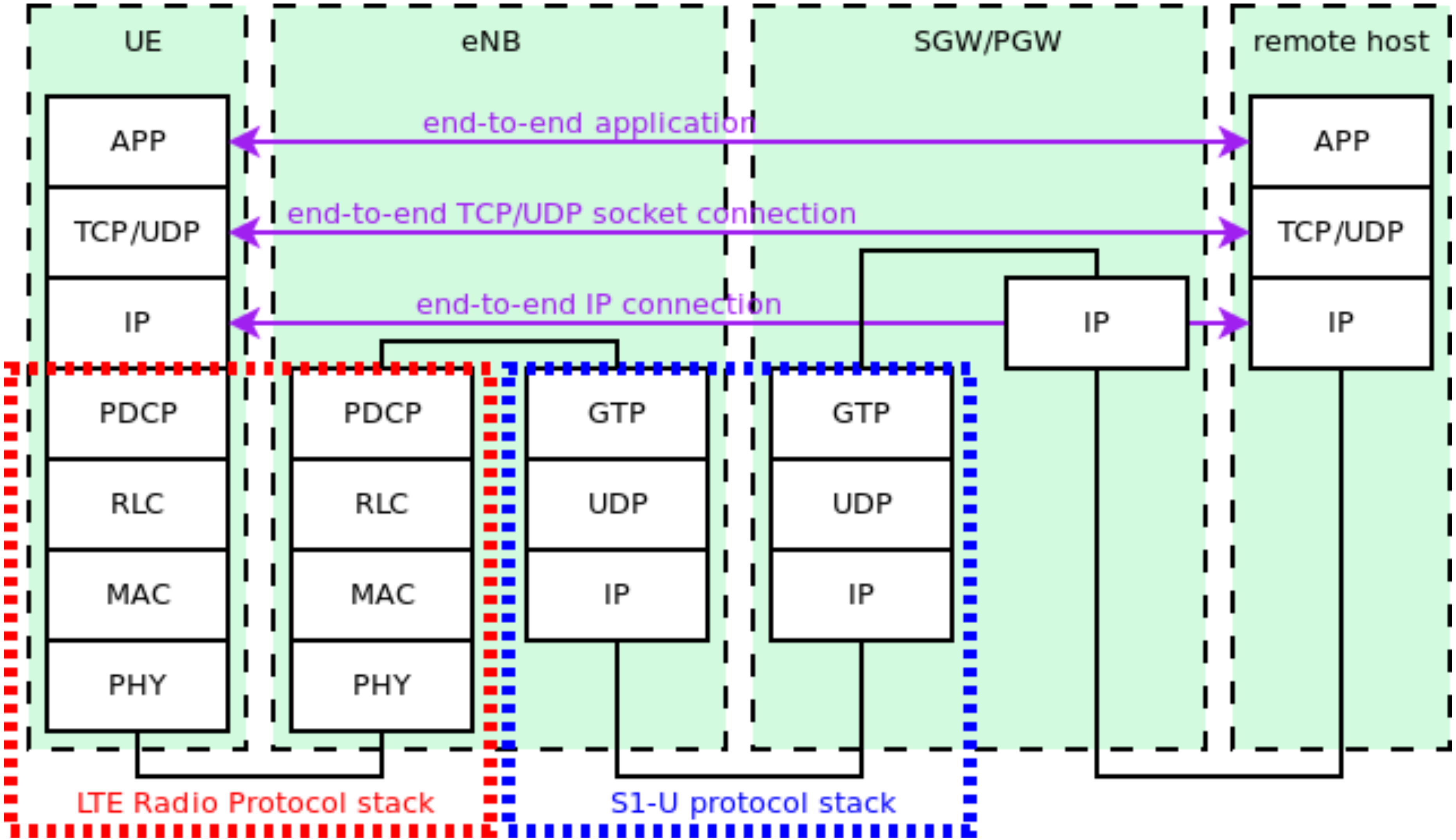
> Designed/developed at CTTC, Barcelona

http://networks.cttc.es/mobile-networks/software-tools/lena/
http://www.cttc.es/project/lte-epc-network-simulator/

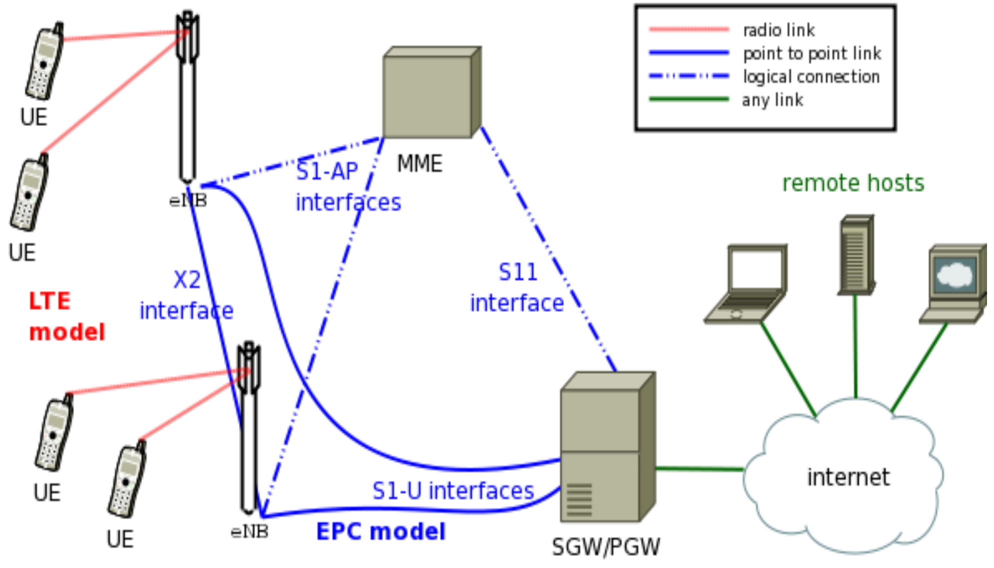
LENA Model Overview



End-to-End Data Plane Stack

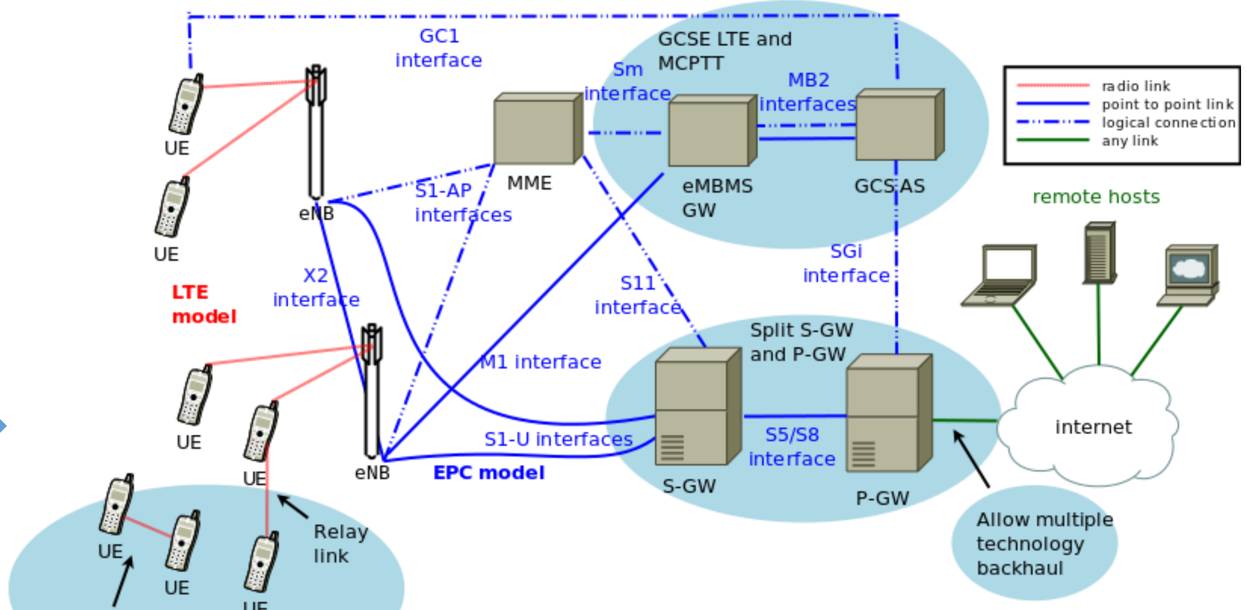


Development Plans for ns-3's PSCR Module



- Incorporate NIST D2D and ProSe models
- Add GSCE and MCPTT support
- Develop public safety scenarios
- Improve underlying LTE standards support

Existing ns-3 LTE support



Topic 3: ns-3 Models and Scenarios for PSCR

> D2D and Proximity Services support
- Include features inherently missing in LTE model: IDLE mode and management of RLF
- Improvement of current D2D model and inclusion of carrier aggregation.

> Group Communications Support and MCPTT
- Add modeling support for prioritized group calls through underlying GCSE LTE extensions, proximity services, location services, and applications.
- Provide APIs to allow users to define different scenarios to manage priority for group sessions across the set of public safety applications .

> Scenario support
- Deliver simulation support code, known in ns-3 terminology as "helper" code, to support selected, specific PSCR scenarios, and allow users to run one of a few canonical scenarios.

> LTE baseline improvements and scalability
- Investigation of simplied error models leading to comparable precision and reduced complexity, towards better runtime simulation performance.
- Improved backhaul models to support wireless and configurable backhauls.
- Upgrade EPC model to support SGW/PGW separation (currently not available)
  → support dynamic scenario setups for PSC networks, not required in operator planned networks.

Propagation Channel Models and System Performance for Device-to-Device Communications for Public Safety Applications

University of Southern California

PSCR

2017

PUBLIC SAFETY BROADBAND STAKEHOLDER MEETING

#PSCR2017

Propagation channel models and system performance for device-to-device communications for public safety application

Andreas F. Molisch (PI), Seun Sangodoyin

Wireless Devices and Systems (WiDeS) group

University of Southern California

Introduction

- Cellular (infrastructure-based) communications are not suitable for PSOs
  - Limited area coverage
  - bad outdoor-to-indoor coverage
    - breaks down when infrastructure destroyed (disaster scenario)

  -> device-to-device comm. is needed

- D2D communication is being developed in 3GPP (LTE-Direct)

  - 3GPP channel models not concentrating on PSO applications
    - reliability not major concern

- Key scenario of interest:

  - V2V communication (between emergency vehicles)
  - O2I communication (outdoor command post to firefight in a building)

Project objectives and technical approach (1)

- Build/modify channel sounder for measuring D2D channels that is
  - Portable
  - Multi-antenna
  - Capable of dynamic measurements

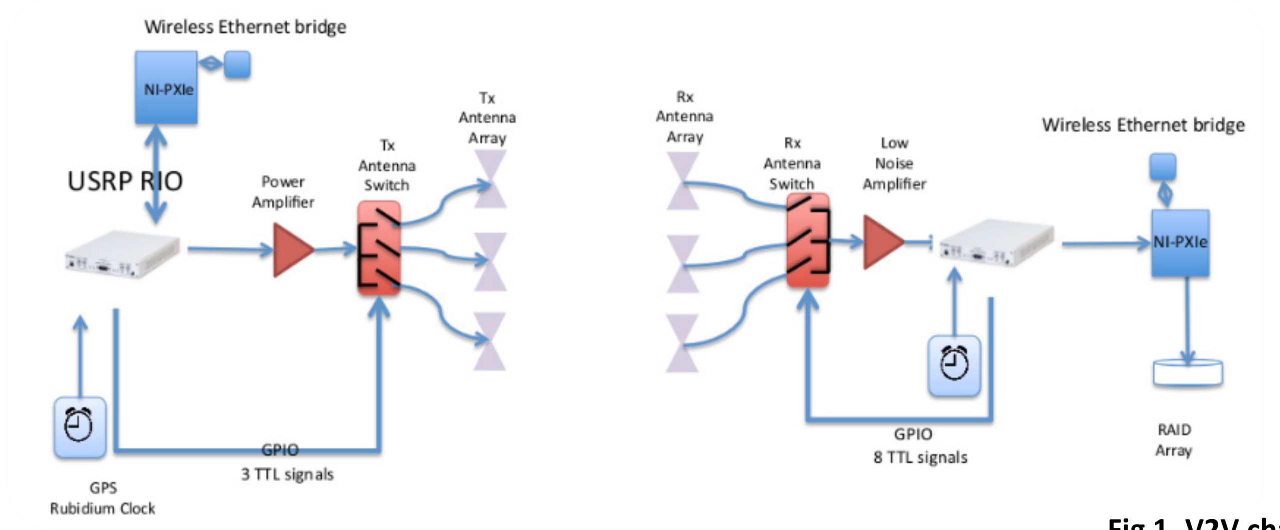


Fig 1. V2V channel sounder setup

State of the art: existing sounders either cannot do multi-antenna, or can only measure short burst

Project objectives and technical approach (2)

- Perform extensive measurement campaigns
  - -V2V channels
  - -I2O channels (outdoor to street level, indoor to ground or higher floor)

State of the art: only a few sample measurements exist at PSO frequencies

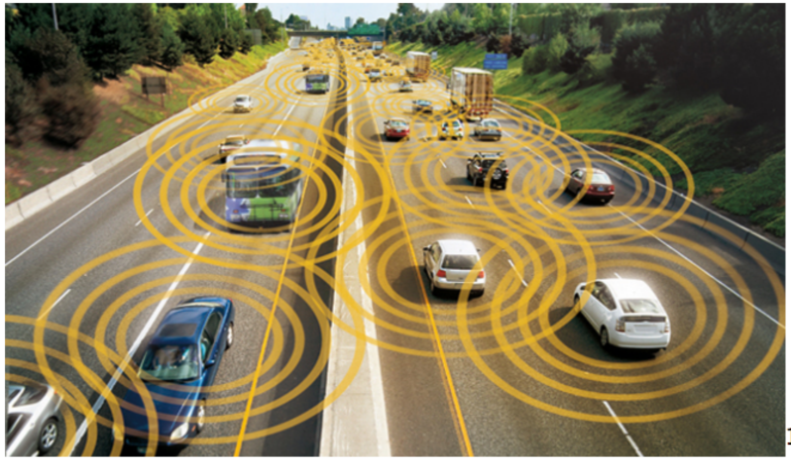
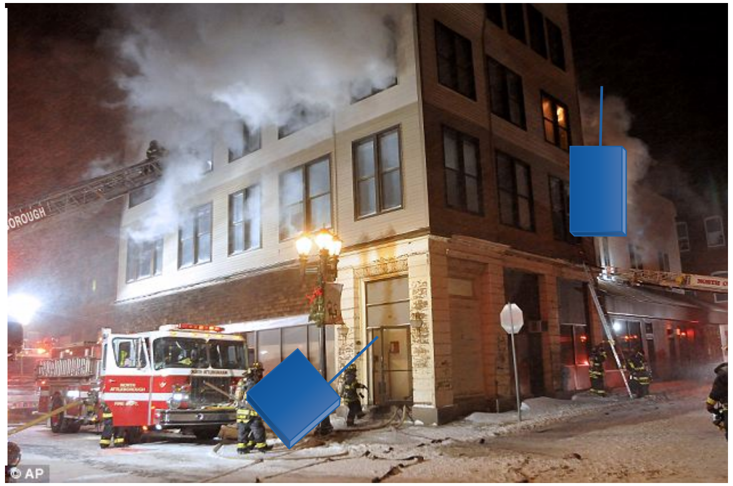

[1]

Fig 1. V2V Channels



Device 2

Device 1

Fig. 2 I2O channel

[1] (http://www.wired.com/images blogs/); dailymail.co.uk

Project objectives and technical approach (3)

- Evaluate measurement data with HRPE algorithm (4D RiMAX) and EKF

  -Extend 4D-RIMAX to handle the full-polarimetric case
  - Extend EKF algorithm to handle fast time-varying channels
  - Path tracking and clustering procedure

    State of the art: evaluation with Fourier resolution (order of magnitude worse than HRPE)

- Develop channel models for future system development

    State of the art: 3GPP channel models, which do not include non-stationarities, indoor-to-outdoor (high indoor to low outdoor) scenario, …

Project objectives and technical approach (4)

- Assess performance of LTE-Direct system

  - Use Matlab LTE-sidelink package to simulate D2D transceiver
  - Simulate with directly measured channels and developed GSCM model
  - Determine performance limitation (max. distance between devices)

    State of the art: no realistic performance assessment of LTE-Direct for PSO applications exists (as far as we know)

- Develop improvements for increasing reliability

  - Investigate antenna arrays applique as performance improvement
  - Modifications needs to be standards compliant

    State of the art: LTE-Direct is mainly single-antenna system

Expected Impact

- Provide realistic framework for testing D2D comm. for PSOs
- Allow benchmarking of standard and assess product offers to PSOs
- Suggestions for system improvements to meet reliability goals
- Develop channel models for future system development
- Provide channel measurement data that can be used by related projects

Indoor Location-Based Services for Public Safety

PSCR research plans and current findings

PSCR

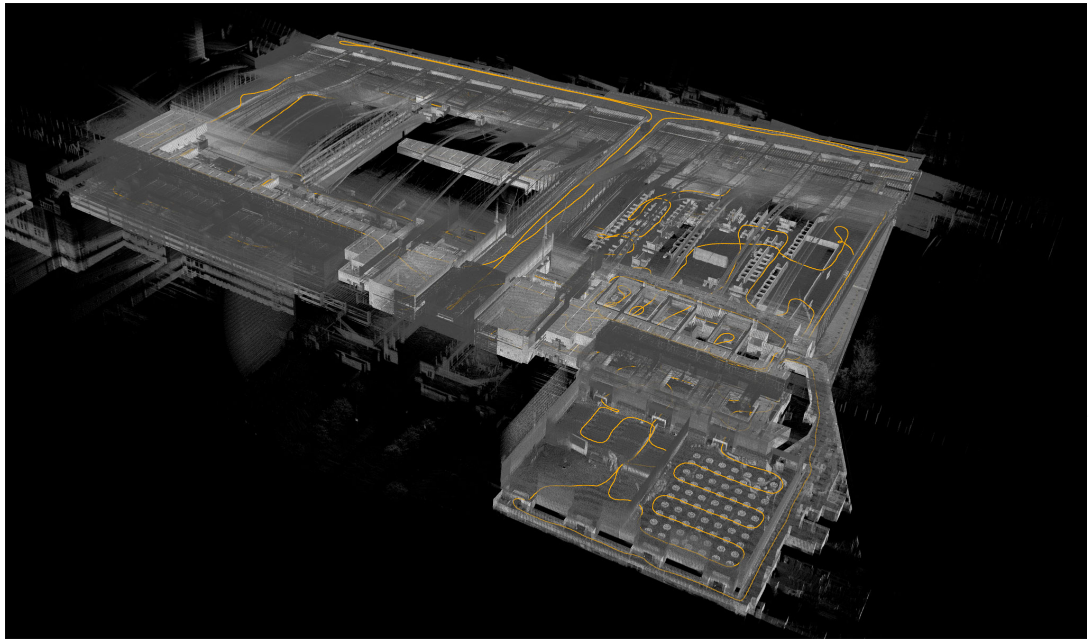
2017

PUBLIC SAFETY BROADBAND
STAKEHOLDER MEETING

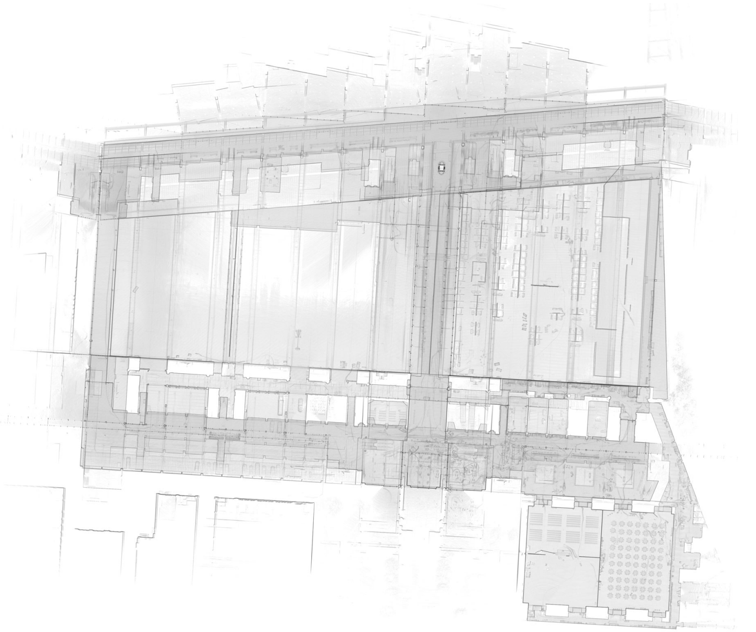
#PSCR2017

LBS Goals FY17-22

- Mapping
  - Accelerate indoor mapping & automated PS relevant feature identification technologies
  - Explore indoor map, building, location, and navigation data interoperability, distribution, and sharing through open standards



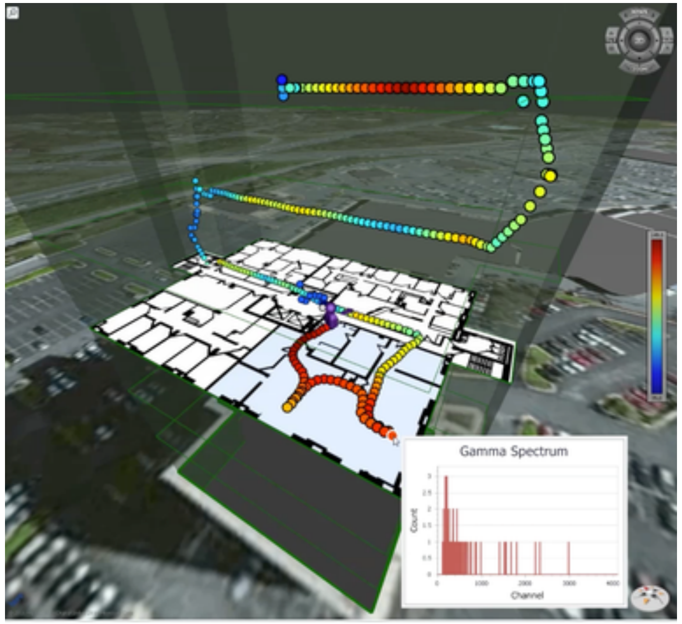
European Commission – Joint Research Centre



PSCR

LBS Goals FY17-22

- Indoor positioning
  - Rapidly accelerate indoor location tracking technologies purpose-built for PS
  - Develop robust indoor positioning measurement framework and reference measurement system

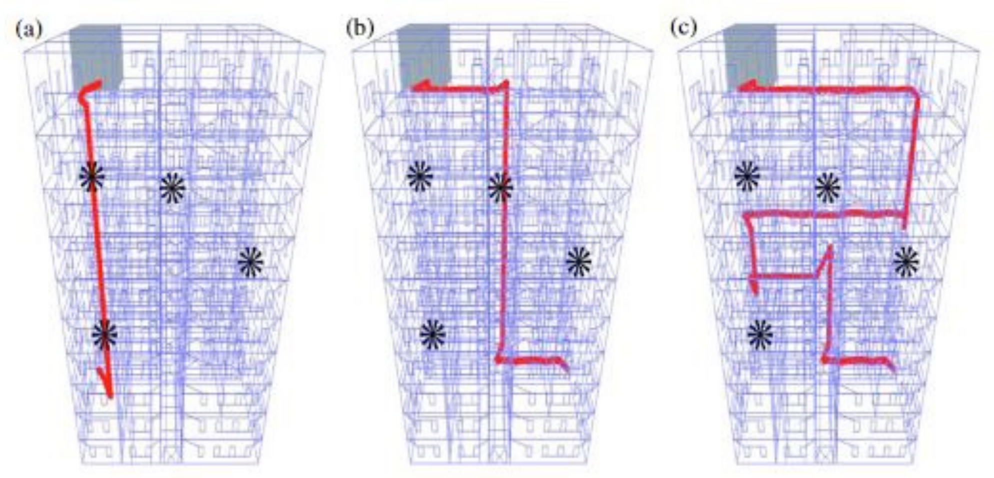


TRX Systems

PSCR

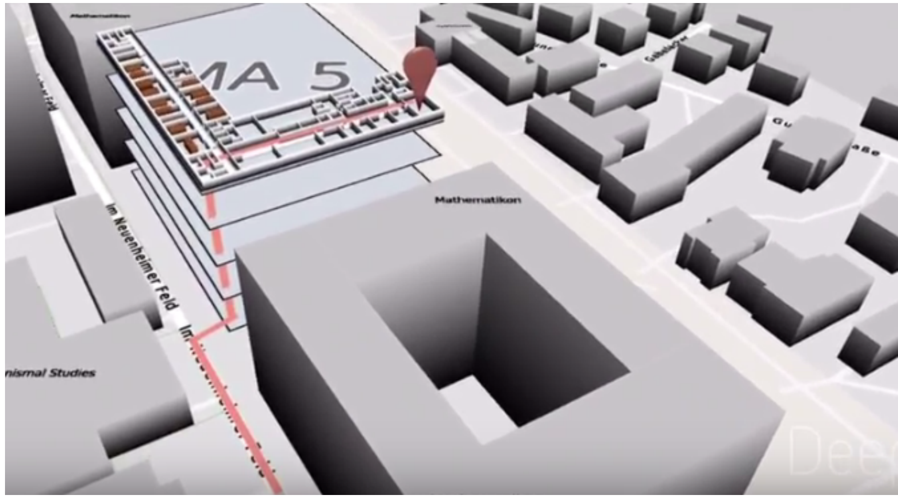
LBS Goals FY17-22

- Location-based services
  - Navigation algorithms for first responders
  - Navigation user interfaces



Univ. of the West of England

Accenture



DeepMap

PSCR

Other LBS Activities

LBS Discussion Forum

Tuesday 4:00pm – 5:00pm, Salon I

Two tracks:

- Operational needs/constraints (Jeb)
- Technical approaches (Dave/Fabio)

LBS/RS Grantee Panel

Wednesday 8:30am – 10:00am

PSCR

Speakers

David Howe – NIST Physical Measurement Laboratory

Fabio DaSilva – NIST Physical Measurement Laboratory

Alicia Evangelista, Brienne Engel – yet2

Location-Based Services Scouting

PSCR

June 12, 2017

3D Geolocation and LBS

PNT within an LTE Network

Presented by
David A Howe
NIST Physics Lab and Advanced Time and Frequency Research
Time and Frequency Division
Boulder, CO 80305
dhowe@nist.gov

PSCR

2017

PUBLIC SAFETY BROADBAND
STAKEHOLDER MEETING

Commercial companies may be mentioned. No endorsement is implied.

Session Definition of the Problem

- **Improve Location Based Services that work seamlessly across the country to save lives and protect our communities.**
- ***DoC Secretary of Commerce Wilbur Ross announced March 30 public-private partnership to create a nationwide public safety broadband network. FirstNet is an independent authority within the U.S. Department of Commerce that will sign a 25-year contract with the network provider to equip first responders with the latest technology, interoperability among firefighters, police officers and emergency personnel.***

PSCR

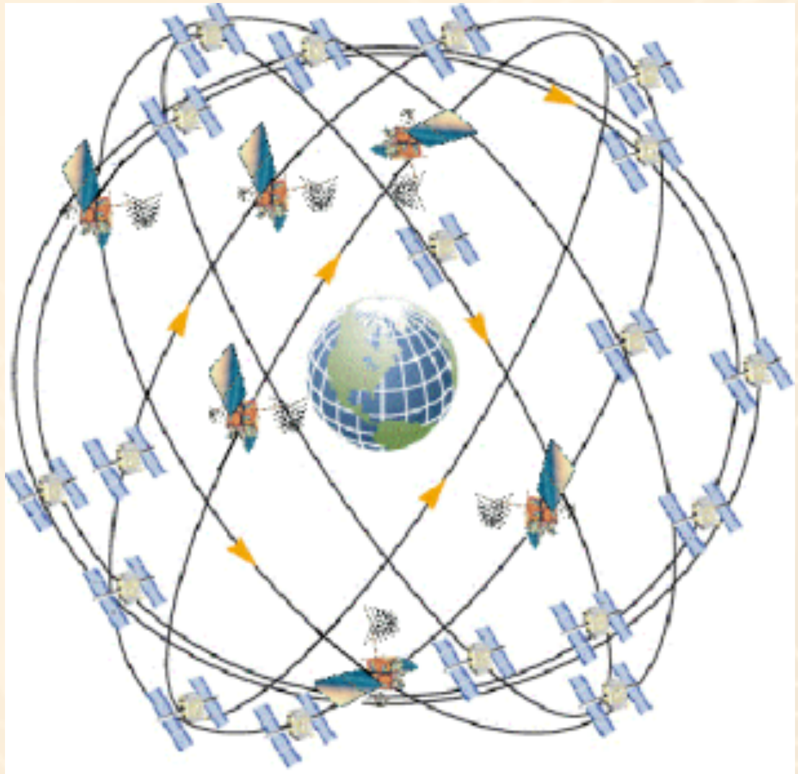
Outline

- ***Why*** **NIST's Physics Lab and Advanced Time and Frequency Research?**
- ***Baseline Set Of Requirements:*** **Shared *RF timing system* with *1 m, 3D* uncertainty in a urban building or high-rise *with 1-way comm's***
- ***Hyper-growth In Cots Smartphone Localization***
  - **Incentives and Applications of 3d Geolocation**
- ***Advanced Research Thrusts:***
  - ***3D Geolocation – High-accuracy, low-jitter User Clock***
  - ***Multipath Cancellation – Short vs. Long Distance***
    - ***Latest GPS Changes – >10 db Rej Of Interference And Multipath With M-code***
  - ***Indoor Mapping in Real Time***
  - ***Atomic Magnetometer Localization (in next talk)***
  - ***Quantum Technology for Geolocation***
- ***Summary***

PSCR

Why NIST Physics Lab and Advanced Time and Frequency Research

- **NIST Time and Frequency Metrology**
- **World-leading research** on Atomic Clocks, GPS Timekeeping, Quantum Sensing and Localization, U.S. Primary Time Standard and Time Scale (UTC), Alt-PNT (Position, Navigation, Timing), Synchronization, Military and Industrial Certified Measurements and Calibrations
- **Time standard** serving GPS, WWVB, ITS, Power Grid, SEC, NASA DSN, World Time-stability Standards
- **Government partners**: AF Space Command, ONR, DARPA, NSA, CIA, NRO, Alt-PNT
- **World-leading calibrations**, including certified stability, vibration and temperature sensitivity measurement
- **Legacy tech transfer to numerous** commercial instrument co's, eg., Keysight, Rhode, Anritsu, Microsemi, etc.
- **DoD partners**, eg., Raytheon, Lockheed, Northrup, etc



PSCR

Baseline Set of Requirements

- **Shared *RF timing system* with *1 m, 3D* real-time uncertainty in urban buildings or high-rises *with 1-way communications***

Shared –

Can be used with existing communications without interference

Radio-location system –

Example Techniques: OTDOA, FDOA, TOA, AOA, 4 sites

No reliance on UE two-way comms –

Example: GPS event-detection-location

1 m, 3D uncertainty, real-time (0.1 sec) –

High accuracy, no latency

Urban buildings or high-rises –

Unknown, cluttered, hazardous, risky

Minimize User Equipment (UE) complexity and power draw –

PSCR

Hyper-growth in Smartphone Capabilities

Enormous user market and cell providers can develop its own PNT, better performance than GPS and with large commercial profit-making incentives, competitive, not government owned.

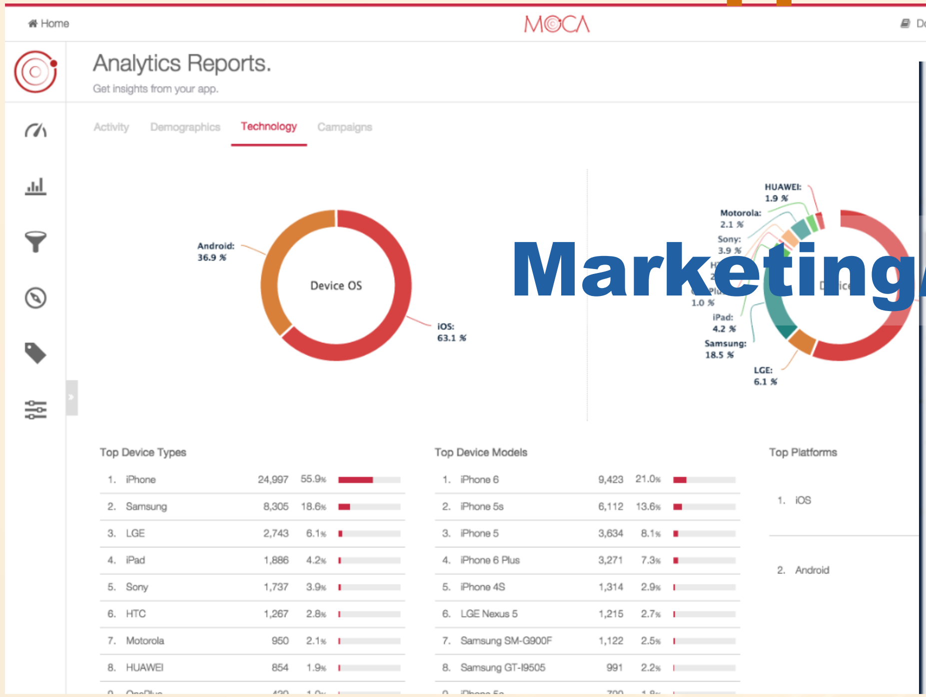
- Providers are experiencing exponential growth to more cell sites with low SWaP+C, more modulation modes, and more spectrum (mm wave)
- Cell providers know they can locate phones without GPS. Can providers outperform GPS?
  - **GPS limitations:** Large CEP, ZUPT (no tracking), and lag time
    - Because of enhanced 911 location based services (LBS) **there are a growing number of P and T solutions that are available as commercial products now, some in next slides**
    - These products are enabled largely by smart phone technology that is federally mandated to provide 911 LBS
    - **Cell-phone P and T is driven by profit and business incentives (usually digital solutions)**

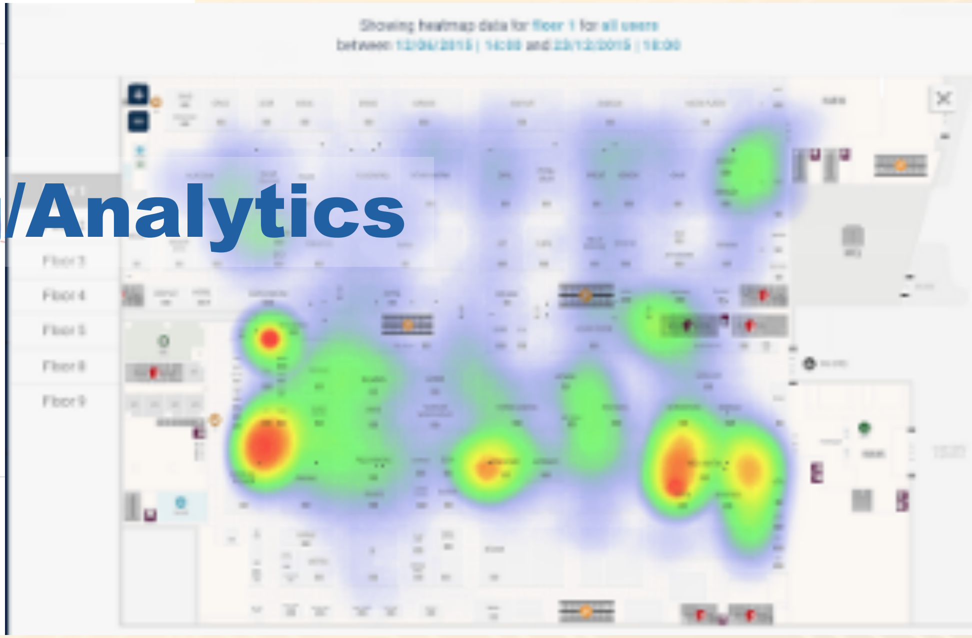
- ***Focus is on fast, accurate LBS specifically for Emergency Response***

PSCR

..but there are vast Business Incentives

Location Based Services (LBS)
Applications





Marketing/Analytics

PSCR

..but there are vast Business Incentives

Location Based Services (LBS)

Applications

Asset Tracking

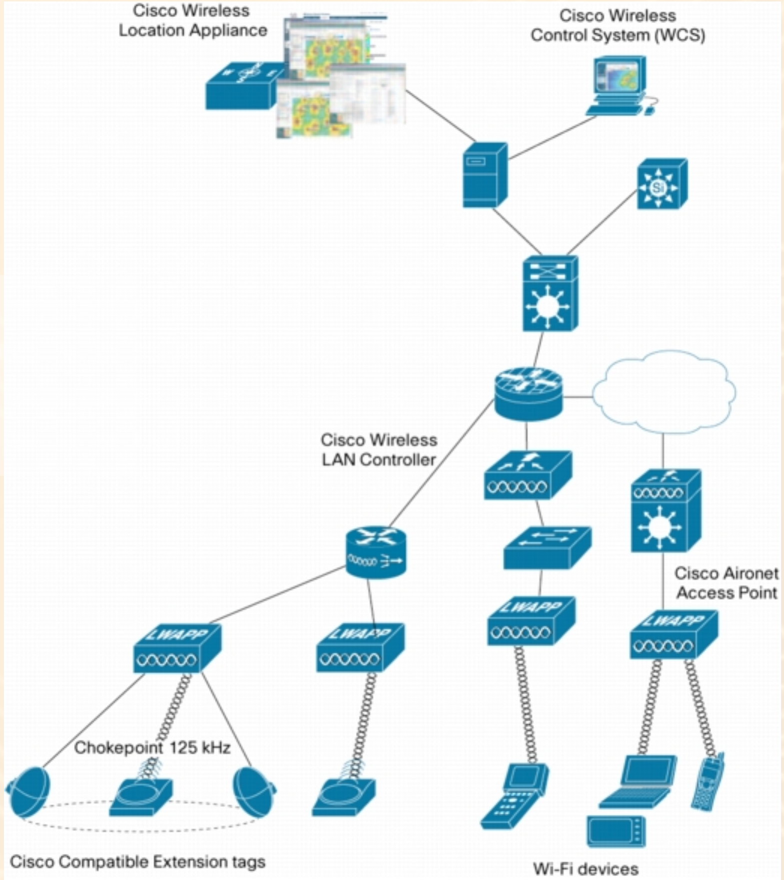
PSCR

..but there are vast Business Incentives

Location Based Services (LBS)

Applications

IoT Device Location

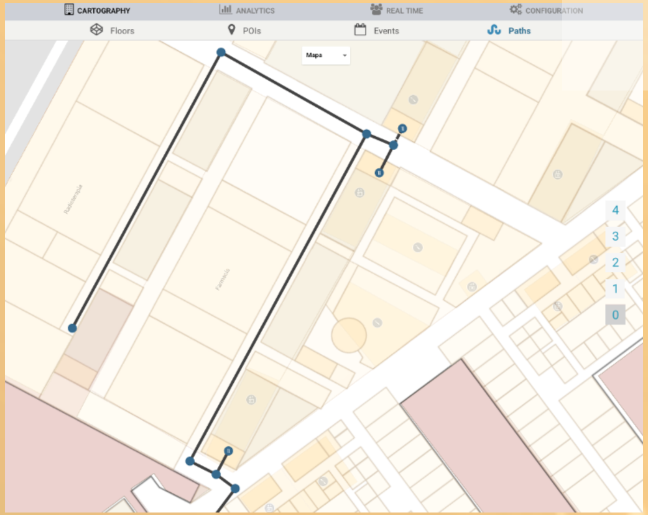


PSCR

..but there are vast Business Incentives

Location Based Services (LBS)
Applications

Site Navigation & Mapping

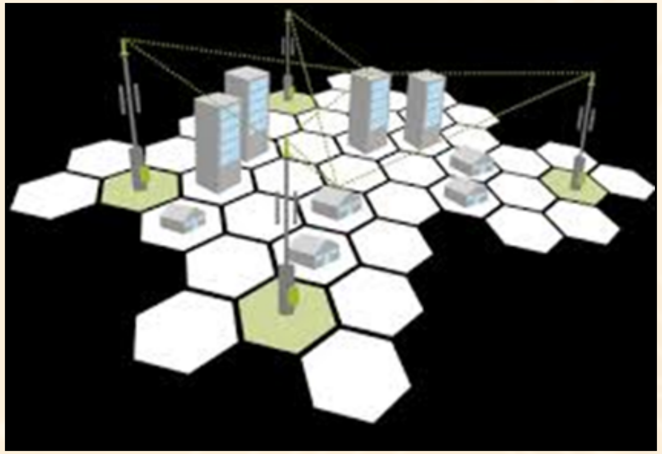


PSCR

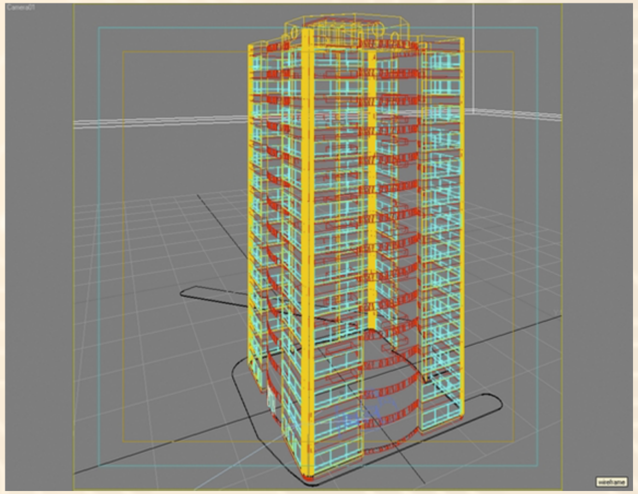
Four Research Thrusts for
Location Determination Using Timing

- **We consider several synchronized stations receiving pulses from a beacon or "tag" in the vicinity whose position is to be determined by time-differences of arrival at the receiver. A class of "triangulation" using timing.**
- **For the time being, these tags provide range $\mathbf{r}_A, \mathbf{r}_B, \mathbf{r}_C, \mathbf{r}_D, \ldots$, but this is not an essential restriction and will be removed later.**

Geolocation using low-jitter clock



Multipath Cancellation



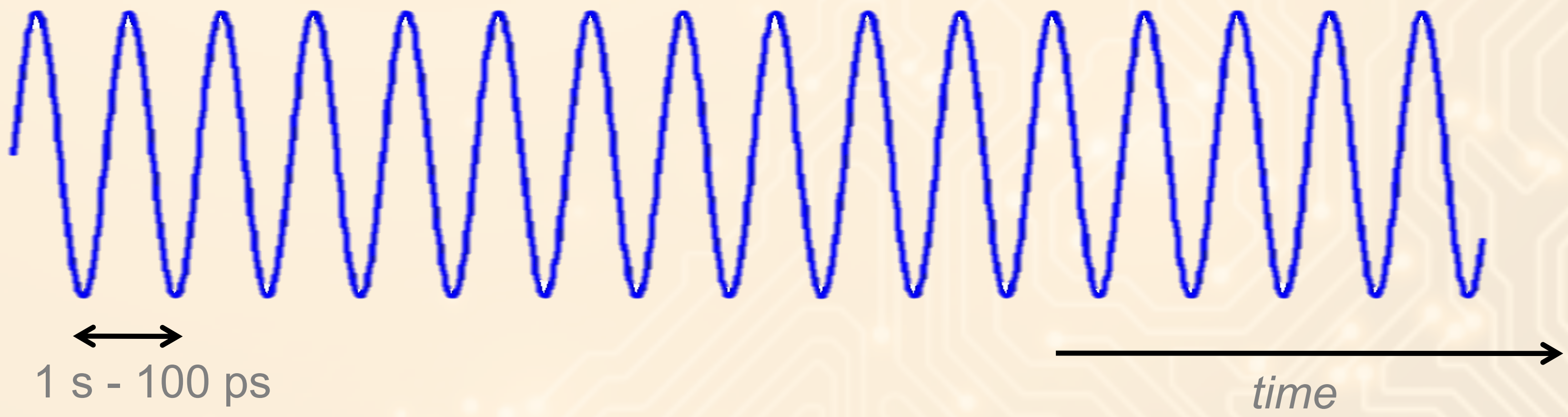
Indoor Mapping (real time)

PSCR

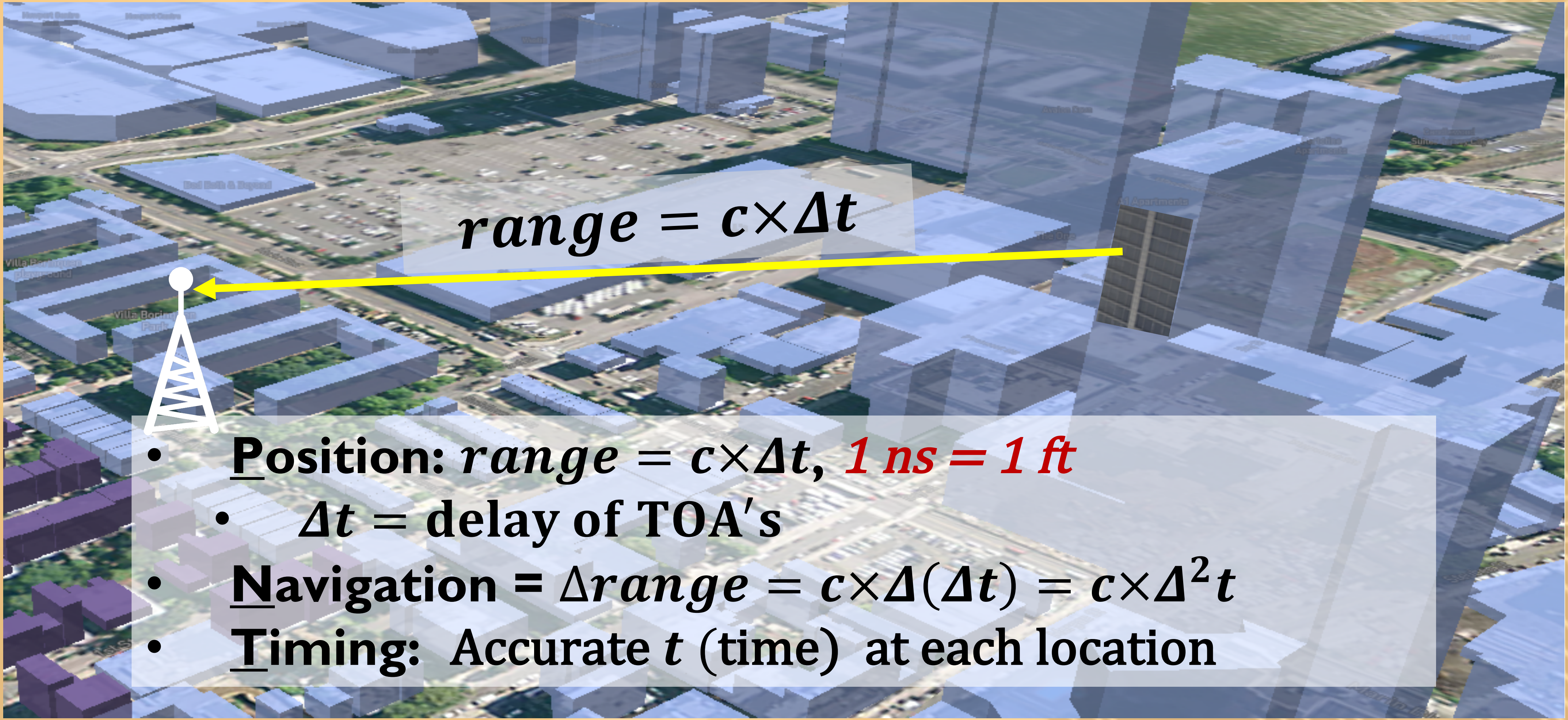
Timing

- **Characterization of the noise in the frequency of electromagnetic oscillators on time intervals from 10^{-10} s to several minutes**

$$V(t) = A\sin[2\pi f_0 t + \phi(t)]$$



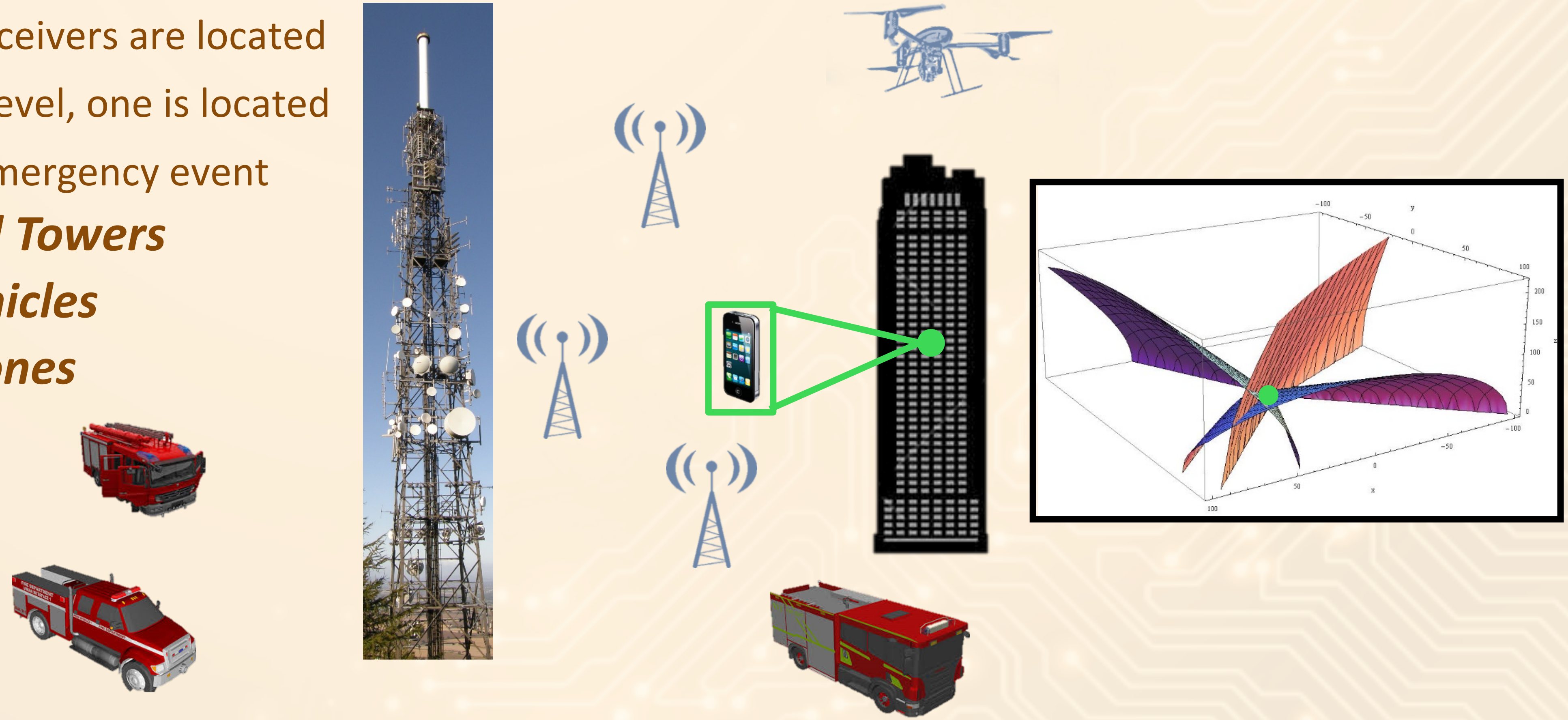
Research Thrust #1, Geolocation:
Long Range: First Responder Beacons To Receiver



- **Position:** $range = c \times \Delta t$, *1 ns = 1 ft*
  - Δt = delay of TOA's
- **Navigation** = $\Delta range = c \times \Delta(\Delta t) = c \times \Delta^2 t$
- **Timing:** Accurate t (time) at each location

For height, three independent OTDOA <u>range</u> measurements are required!

- ***Four receivers***
- Three receivers are located ground level, one is located above emergency event
  - ***Cell Towers***
  - ***Vehicles***
  - ***Drones***

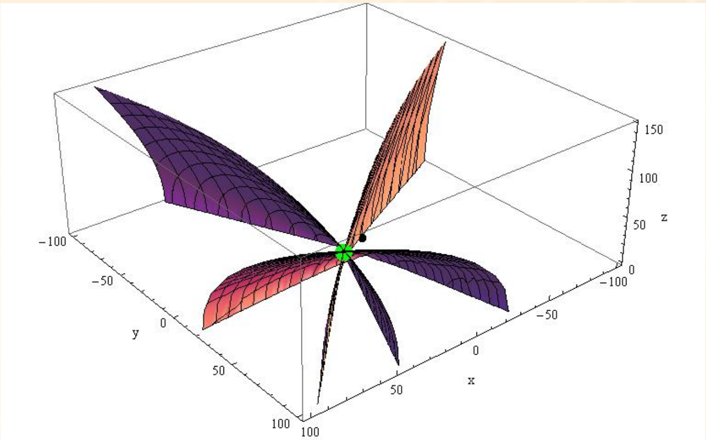


PSCR

Three range measurements are needed

- *Suppose there are three receivers and three time-differences are measured by the receivers*
- The solution is not unique because three independent measurements have not been made: this can be seen most easily from the equations:

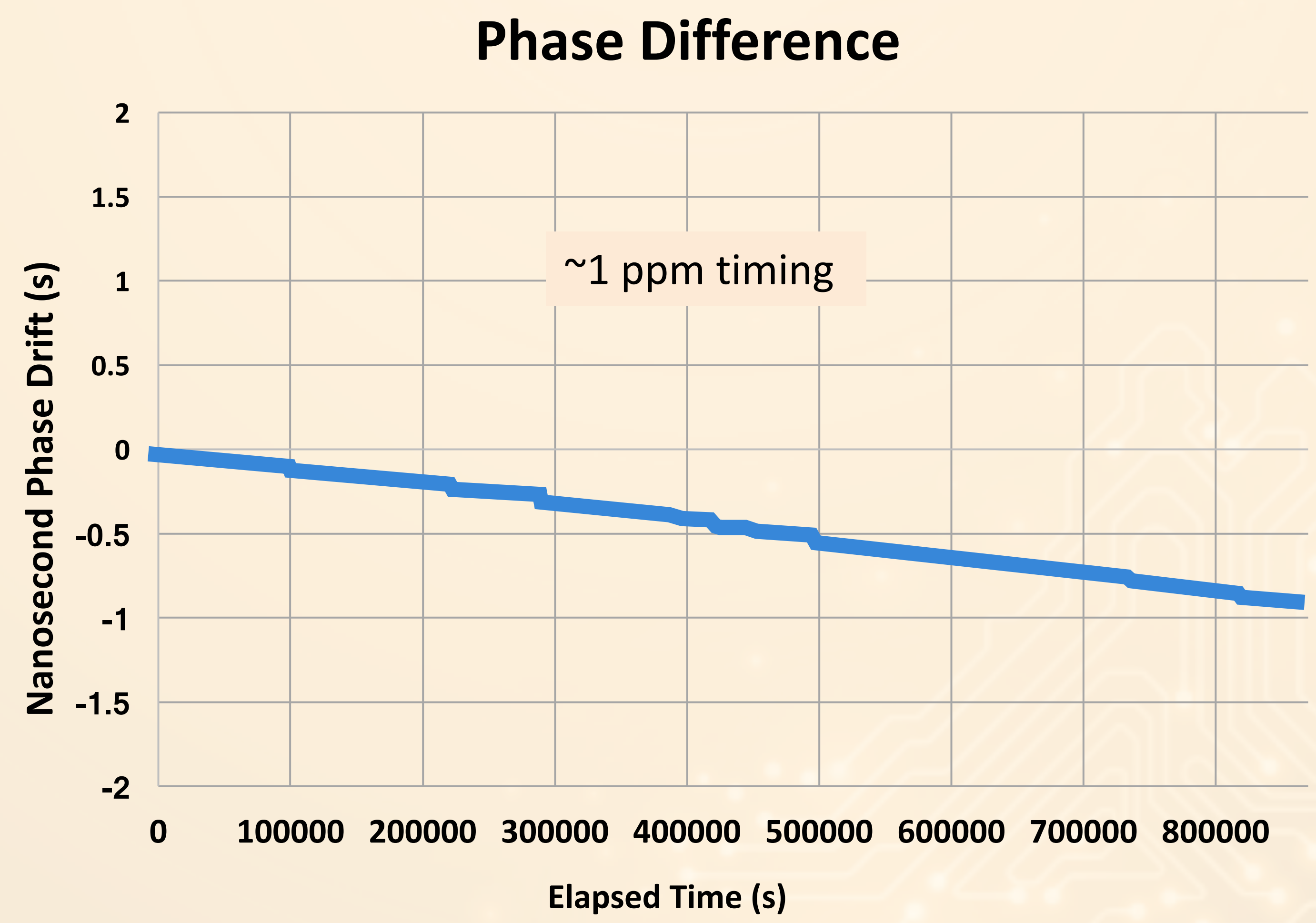
$$\left|\mathbf{r}-\mathbf{r}_A\right|-\left|\mathbf{r}-\mathbf{r}_B\right|=\tau_A-\tau_B=\tau_{AB};$$
$$\left|\mathbf{r}-\mathbf{r}_B\right|-\left|\mathbf{r}-\mathbf{r}_C\right|=\tau_B-\tau_C=\tau_{BC};$$
$$\left|\mathbf{r}-\mathbf{r}_C\right|-\left|\mathbf{r}-\mathbf{r}_A\right|=\tau_C-\tau_A=\tau_{CA}.$$



- The third equation is obtained by combining the first two, so is not independent

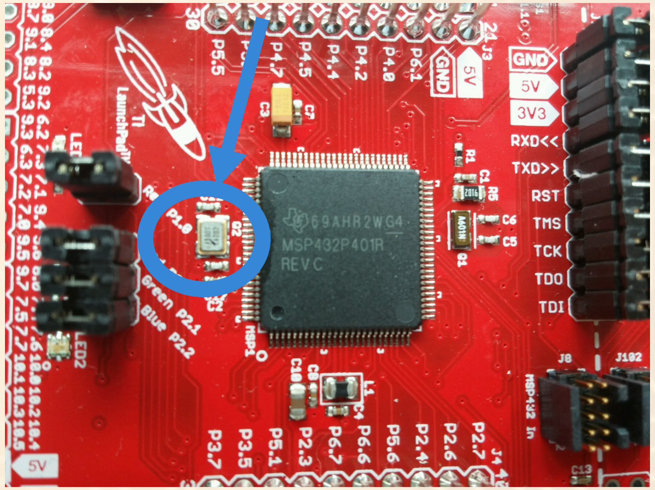
PSCR

Typical OTS Crystal Oscillator, needs constant synchronization



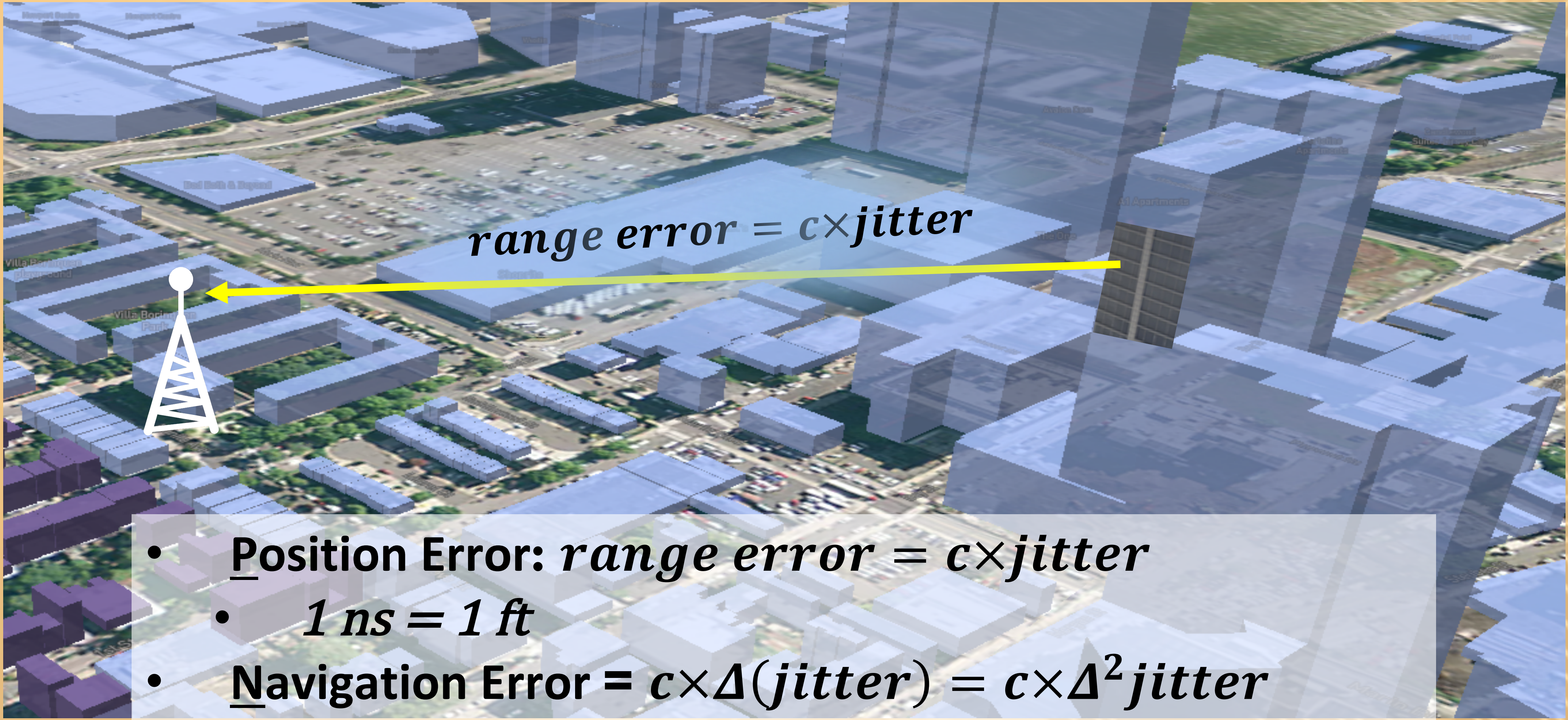
Crystal Oscillator

- Most accurate of four receivers
- High power consumption



PSCR

Range Error is dependent on *Clock Jitter*

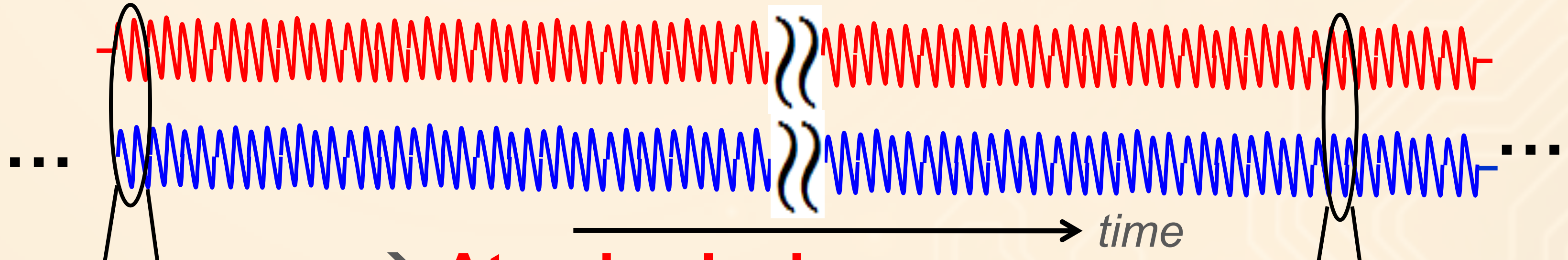


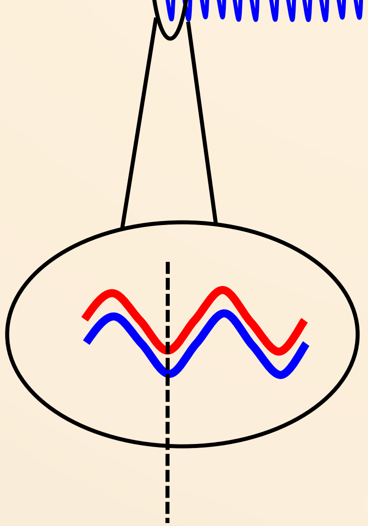
- Position Error: $range\ error = c\times jitter$
  - $1\ ns = 1\ ft$
- Navigation Error = $c\times\Delta(jitter) = c\times\Delta^2 jitter$

PSCR

Timing Jitter

- More *subtle frequency changes* are manifest and “jittering” of the electromagnetic wave over a measurement interval

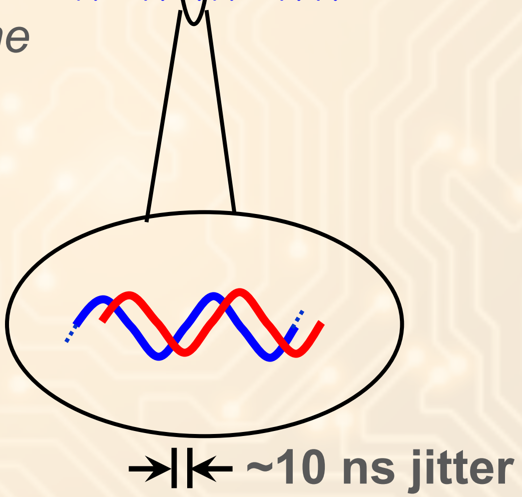




Signals time synchronized

→ **Atomic clocks** significantly improve multi-point timing for:

- ✓ ***High-resolution PNT-system***
- ✓ **Accuracy**
- ✓ **Increased data rates in communications systems**
- ✓ **High-resolution radar images**

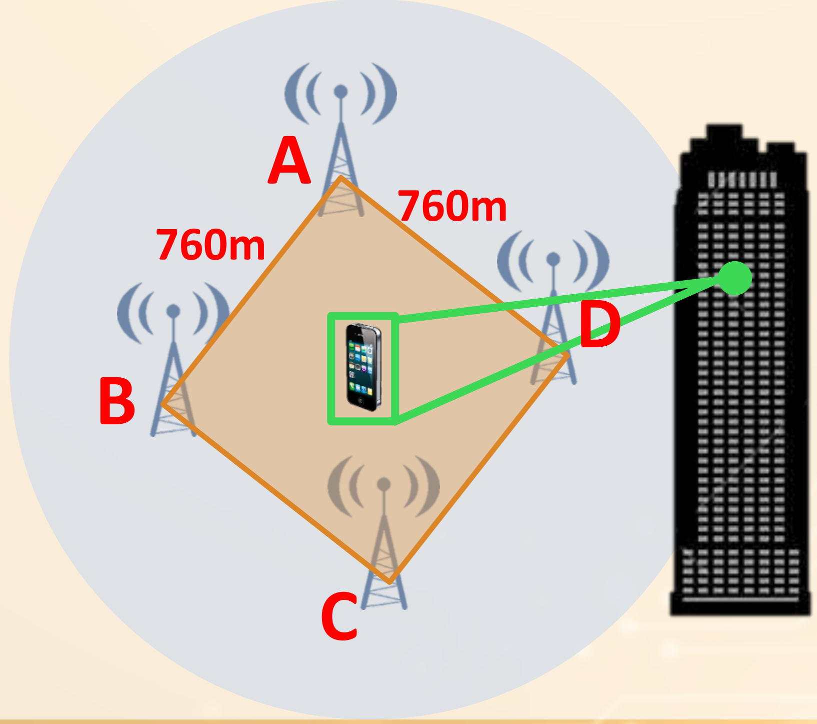


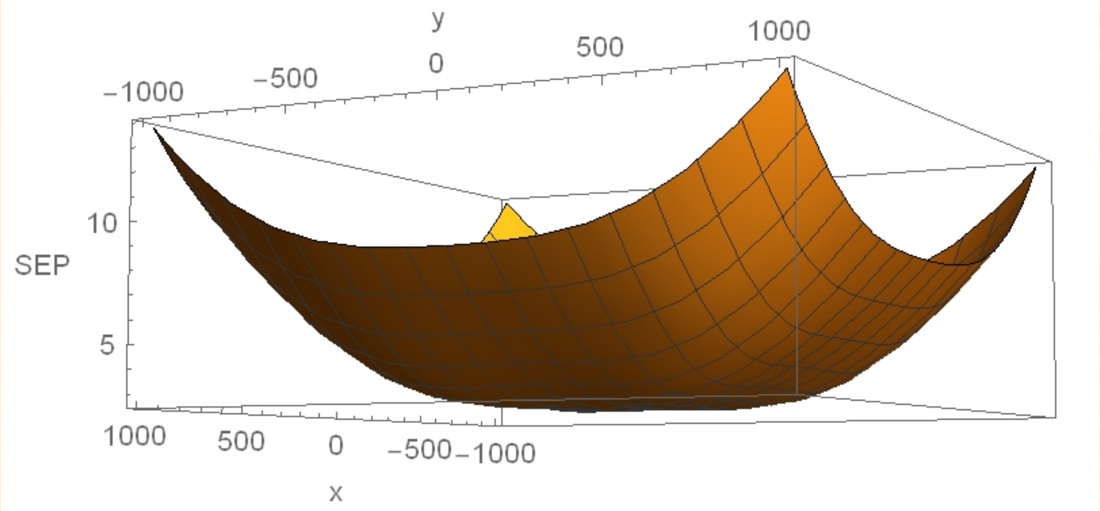
PSCR

The Error Map for best OTS oscillator

As an example of the computation of SEP, we have constructed the following example:

- Receivers are at the corners of a square of side 760 meters. The TAG has been placed at altitude 65 meters, and an uncertainty of 10 ns has been assumed. All four in-dependent time measurements are used, entailing an extension of the above theory to include non-square matrices. The SEP is plotted in the following graph (units are meters). (x,y) are the horizontal coordinates of the emitter position.

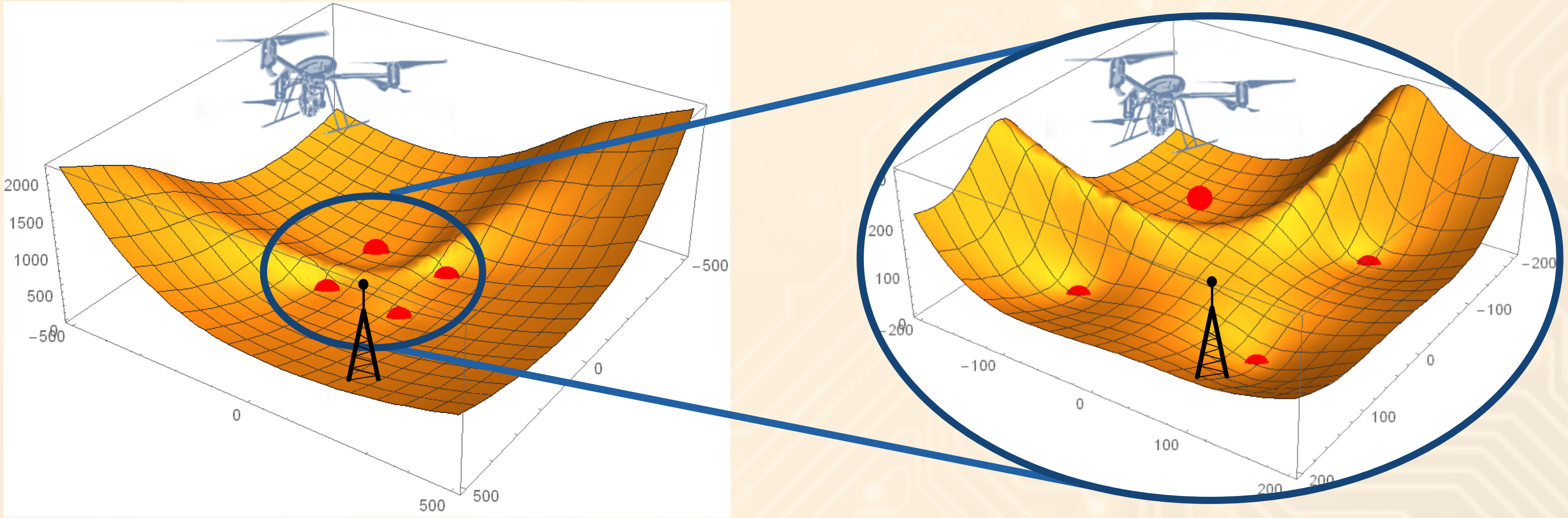




PSCR

Error map for practical configurations of receivers

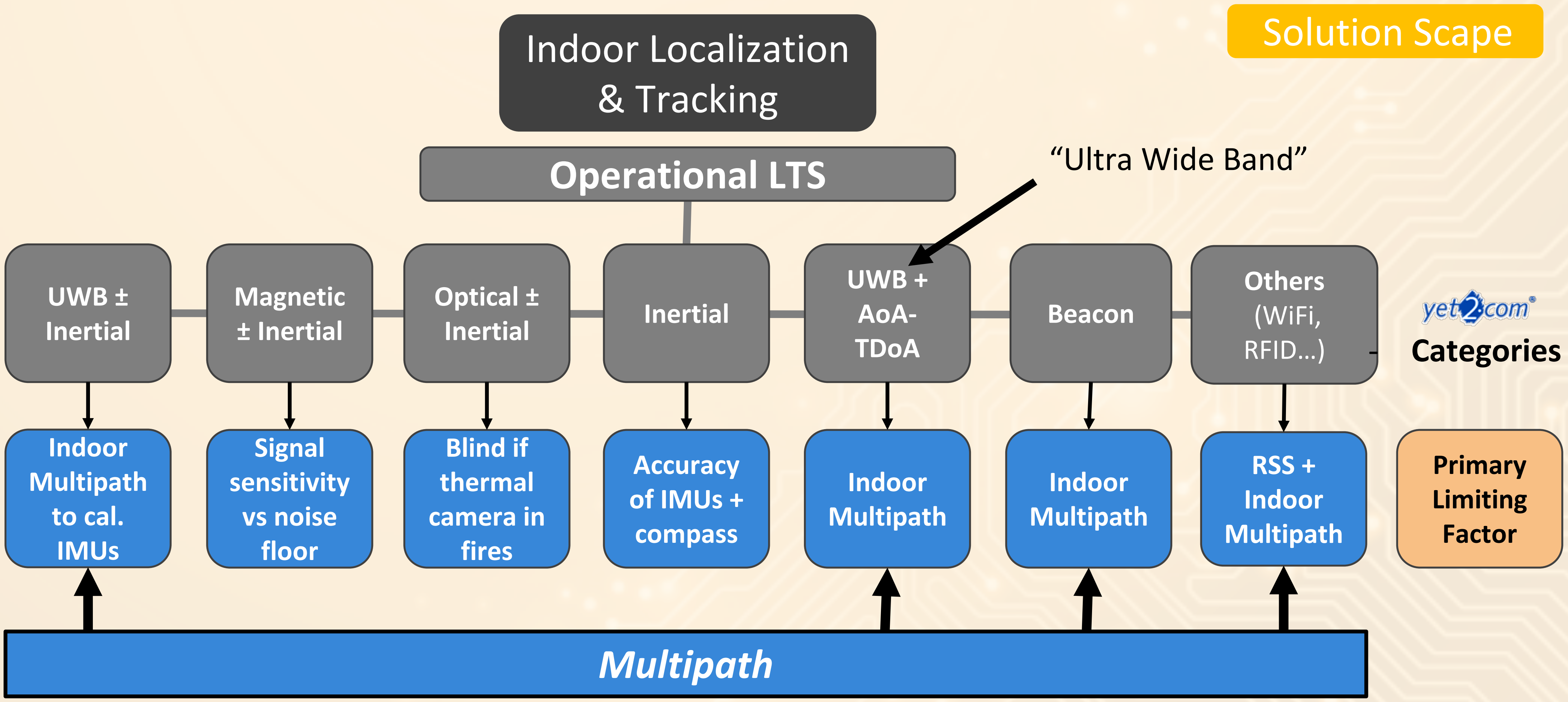
- Red dots are receivers, total area shown: 1000 m x 1000 m
- Receiver locations: square of size 200x200 meters; three on ground, one height 30 m, TAG height: 10 m



PSCR

Research Thrust #2, Multipath:

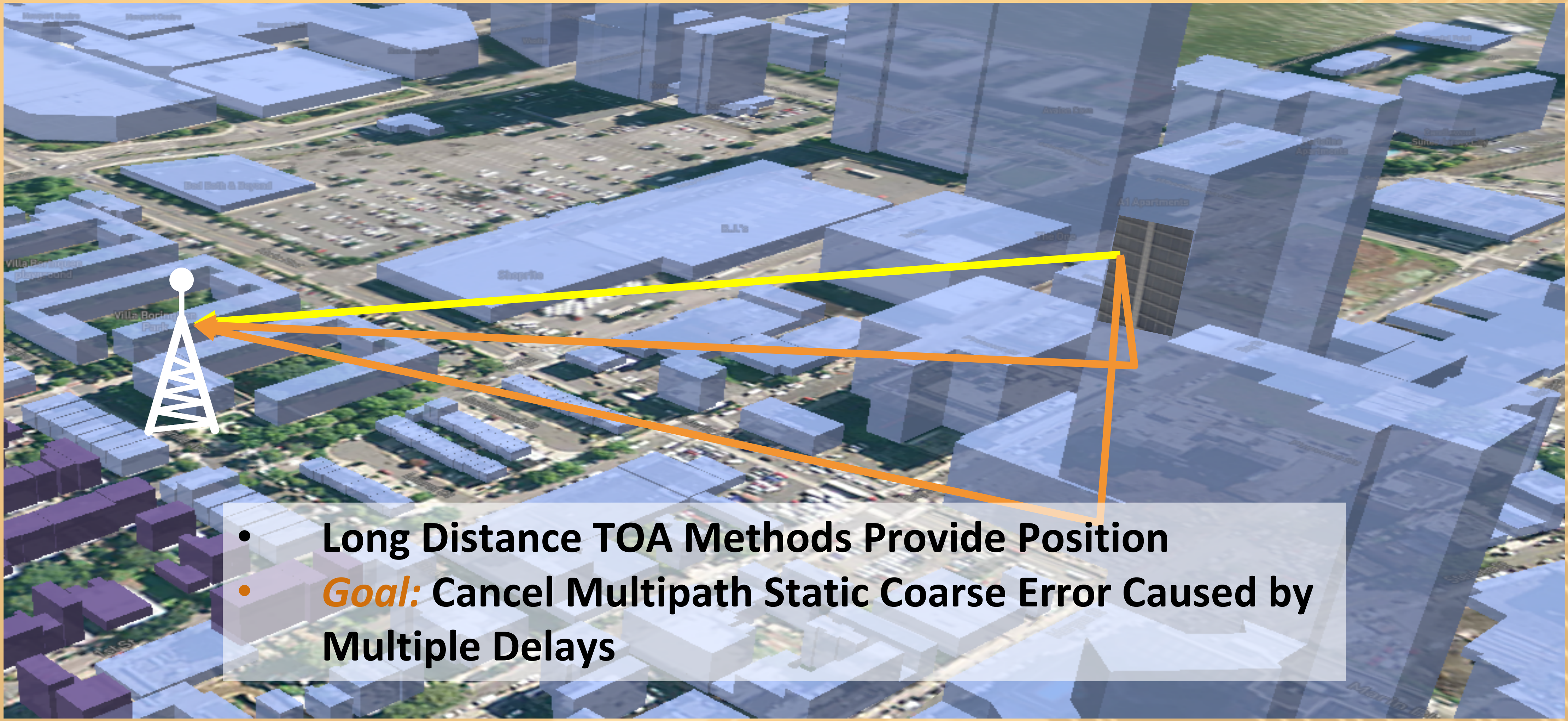
Multipath Impact



PSCR

What is Multipath?

Long Range Multipath is Self-interference



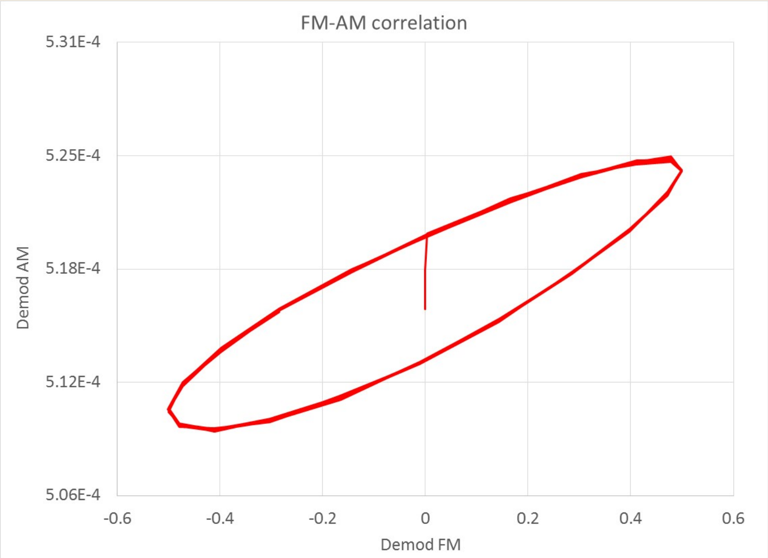
- Long Distance TOA Methods Provide Position
- *Goal:* Cancel Multipath Static Coarse Error Caused by Multiple Delays

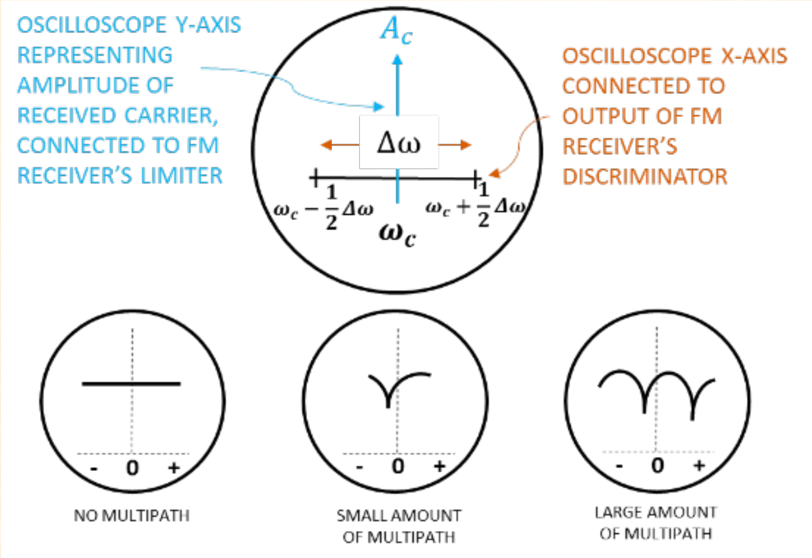
PSCR

NIST Advanced Research is focused on

AM-PM Correlation Method of Instantaneous Multipath Detection and Cancellation

- Instantaneous cancelation of multipath is based on detection of multipath's property of ***PM-to-AM conversion***, followed by feedforward correction. The technique requires that we recover the ***AM*** of the DSSS received signal, something which is not ordinarily done but is easy using a separate AM receiver or detector.



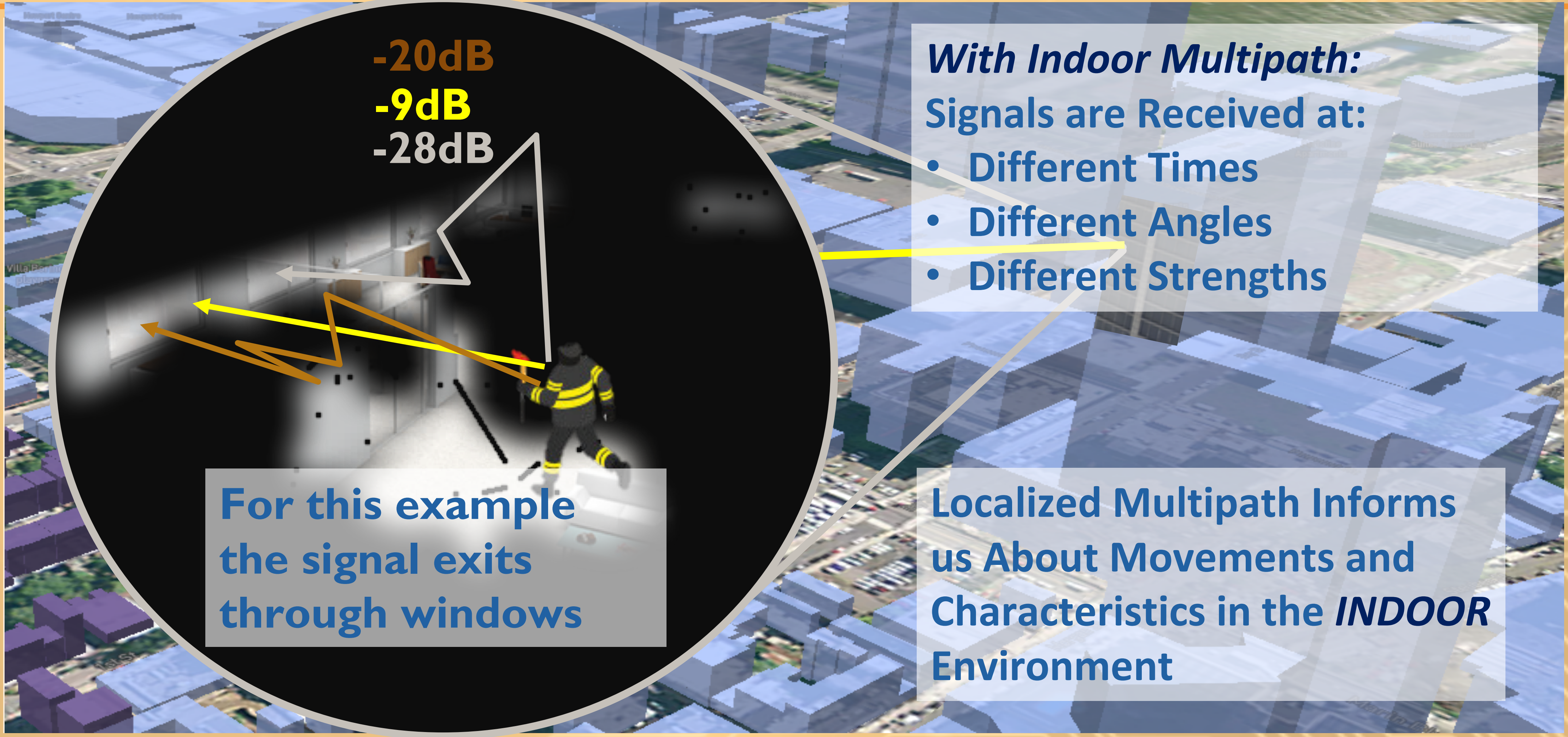


PSCR

After Cancellation of Long Range Multipath, we still have Indoor Short-range residuals

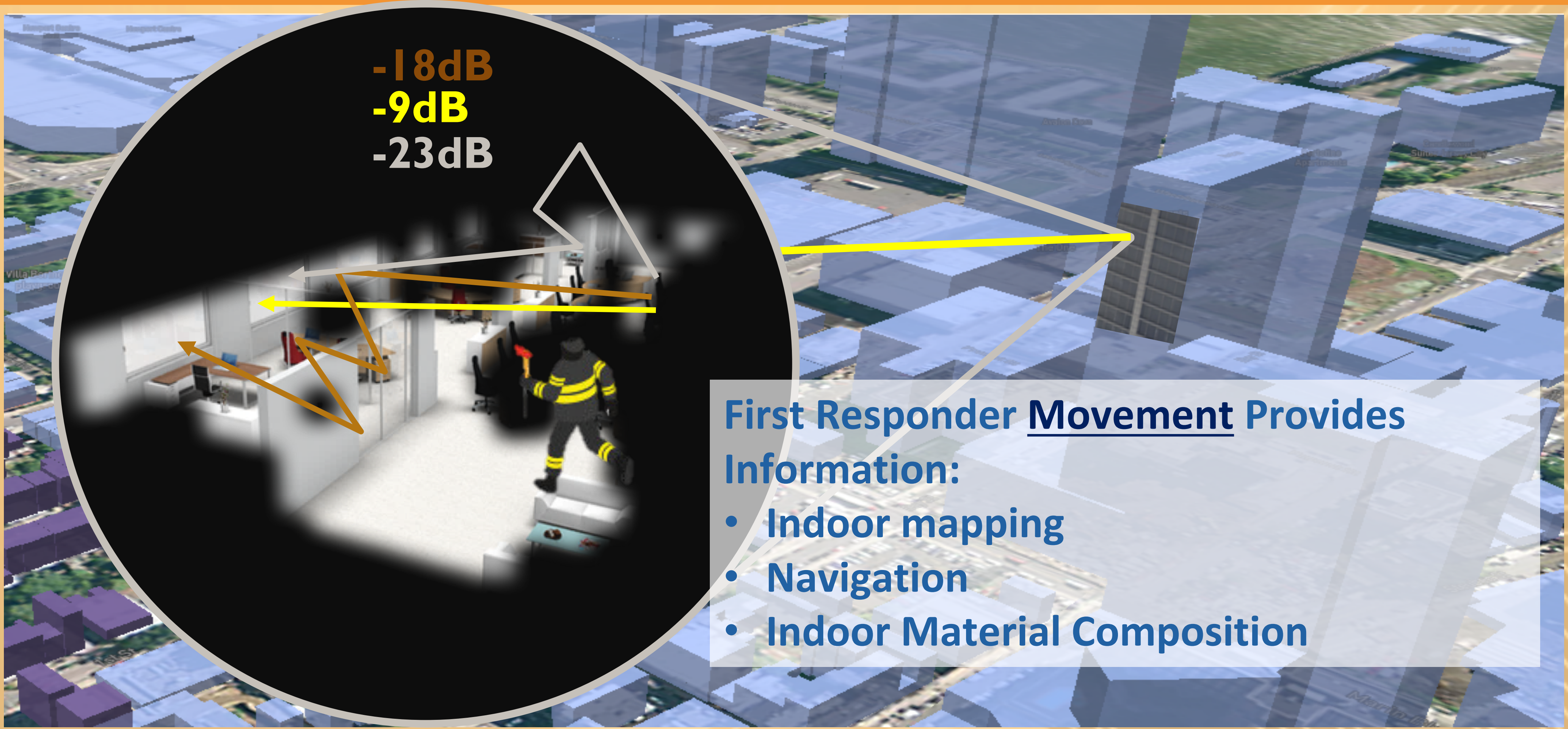
PSCR

Indoor Multipath



PSCR

Indoor Multipath



First Responder **Movement** Provides Information:

- Indoor mapping
- Navigation
- Indoor Material Composition

PSCR

Indoor Multipath

PSCR

Real-time Indoor Data

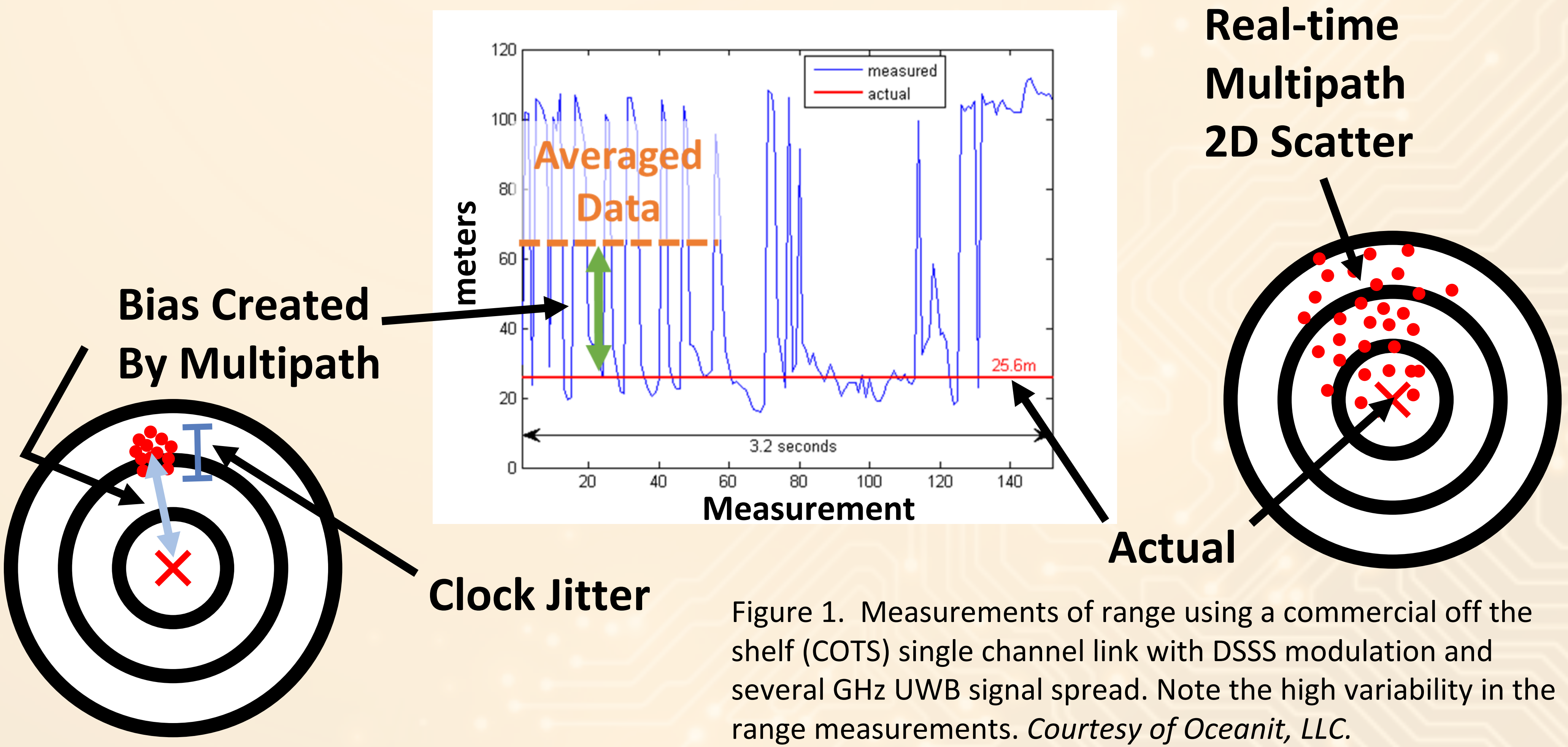


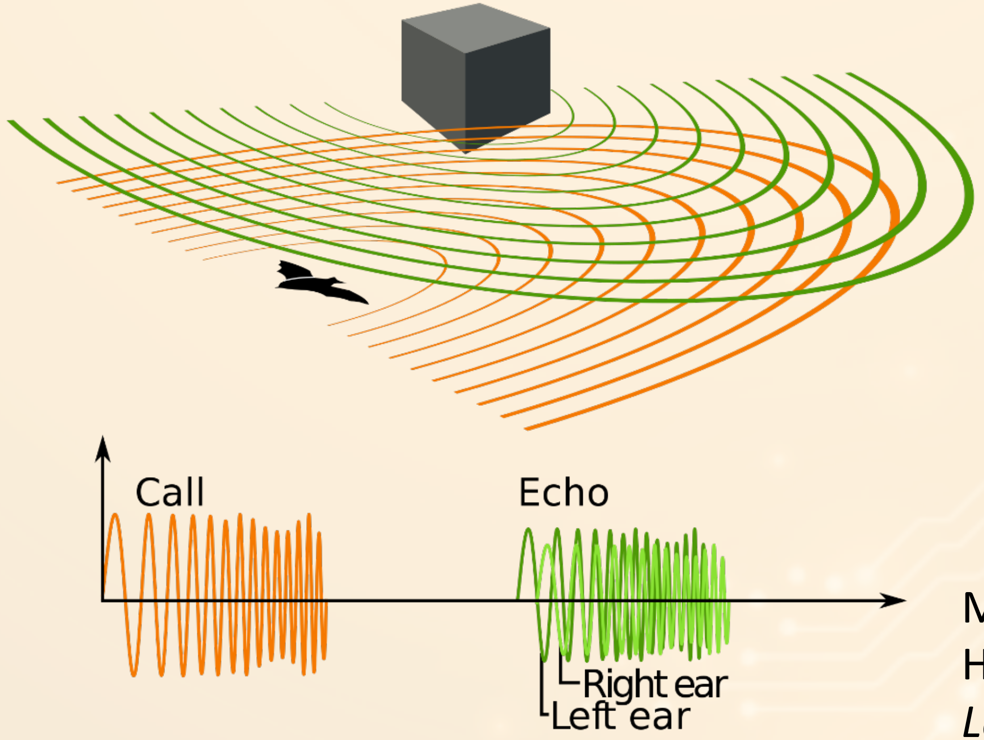
Figure 1. Measurements of range using a commercial off the shelf (COTS) single channel link with DSSS modulation and several GHz UWB signal spread. Note the high variability in the range measurements. *Courtesy of Oceanit, LLC.*

PSCR

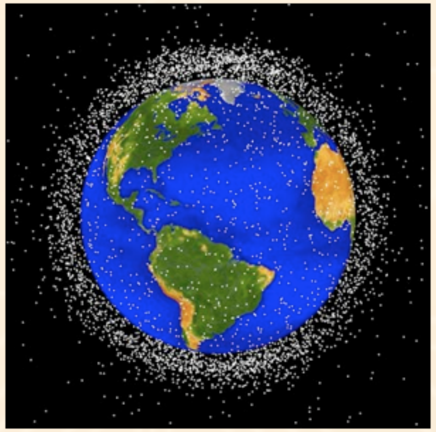
Research Thrust #3, Mapping:

Indoor-surroundings using AF to RF Sensing

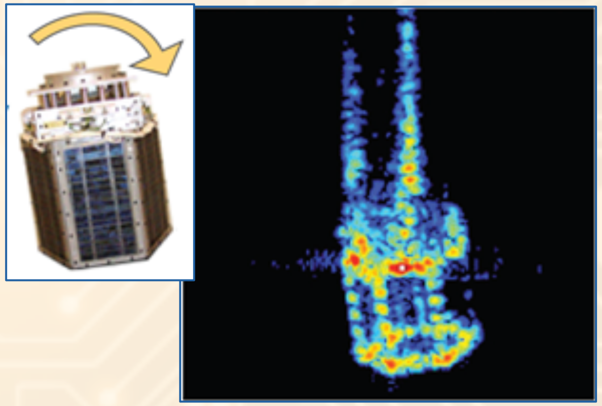
- Similar to Echolocation in bats, dolphins, porpoises (Chirped Sonar)
  - Echolocation in Bats and Dolphins 1st Edition by Jeanette A. Thomas (Editor), Cynthia F. Moss (Editor), Marianne Vater (Editor)



Hi-resolution Imaging



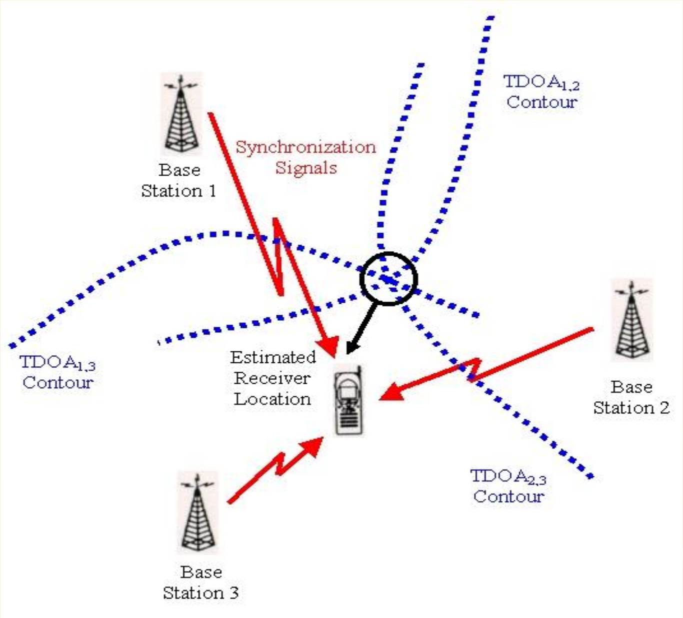
RF Chirped Radar



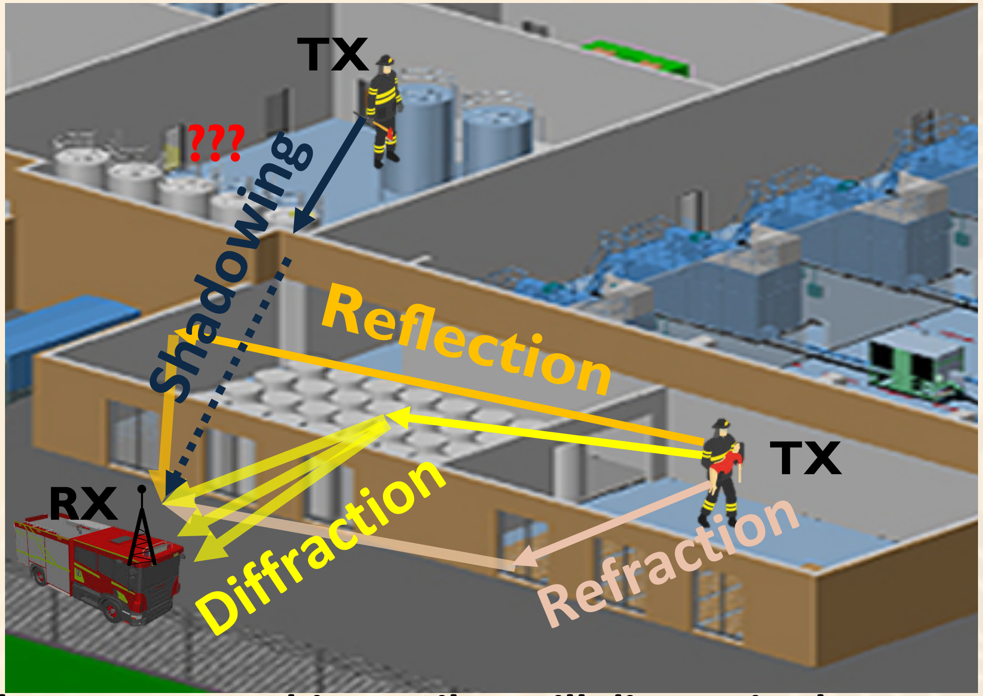
M.G. Czerwinski and J. M. Usoff, "Development of the Haystack Ultrawideband Satellite Imaging Radar," *Lincoln Laboratory Journal*, vol. 21, no. 1, 2014, pp. 28-44

Mapping of Indoor-surroundings using short-range "multipath"

- ***Impact of Long-range Multipath is substantially reduced with close proximity, accurate clocks and multipath correction***
- ***BUT Close-range Multipath properties inform about first-responder indoor environment***



Long Range: "triangulation" using timing.

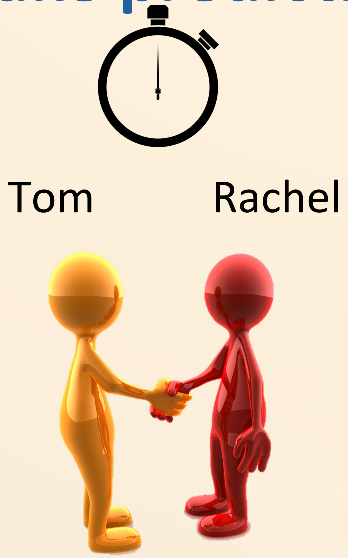


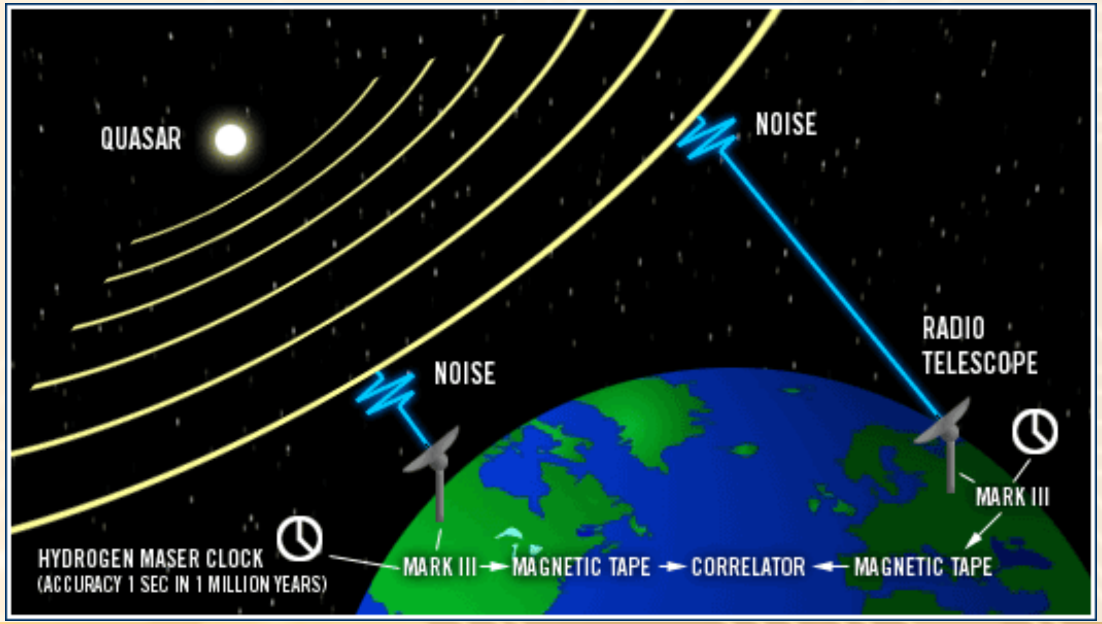
Short Range: Fabio DaSilva will discuss in the next talk
Come to our discussion panel and visit our booth

PSCR

Research Thrust #4, Quantum Sensing: Separated atomic clocks are "connected" by quantum consistency principles

- Precise geolocation using Relativity & atomic-clock motion
- Strange quantum theories and tests are evolving
- Like detecting a needle in a haystack, continental drift & earthquake prediction use Quantum Communications

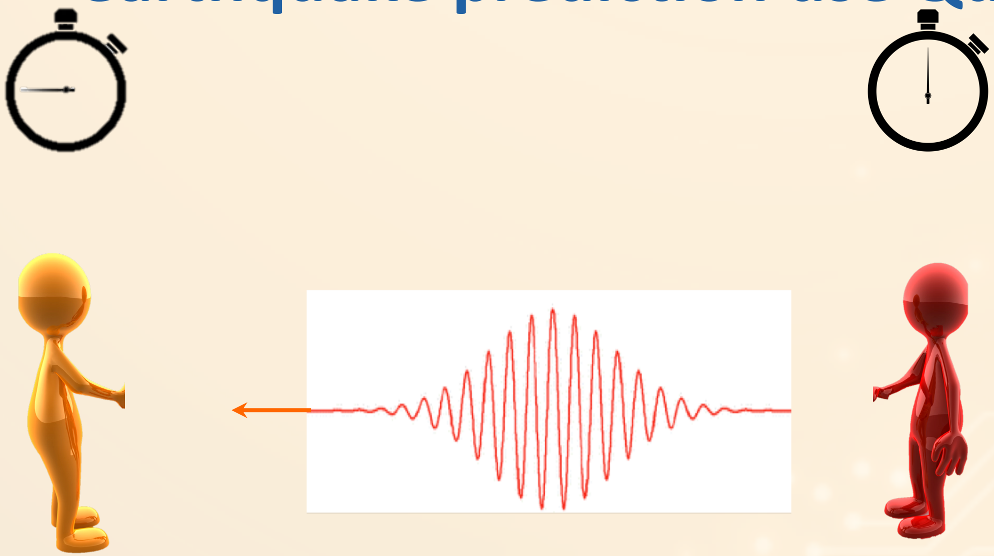


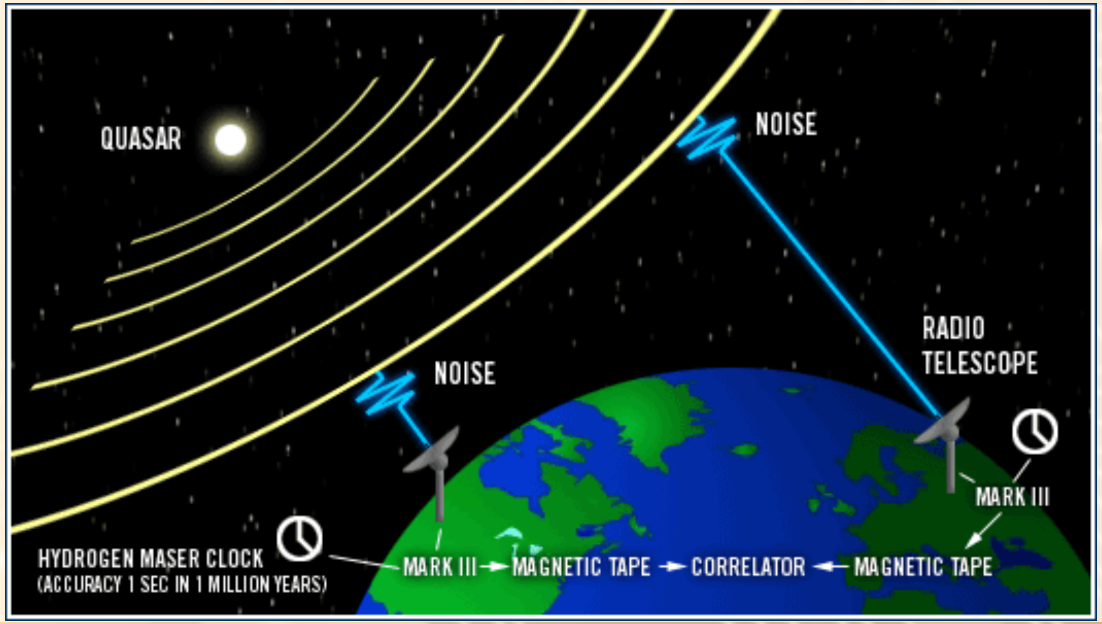


PSCR

Research Thrust #4, Quantum Sensing:
Separated atomic clocks are "connected" by quantum consistency principles

- Precise geolocation using Relativity & atomic-clock motion
- Strange quantum theories and tests are evolving
- Like detecting a needle in a haystack, continental drift & earthquake prediction use Quantum Communications





PSCR

Summary

NIST

- ***Advanced Research Thrusts:***
  3D Geolocation – High-accuracy, low-jitter User Clock
  Multipath Cancellation – Short vs. Long Distance
  Latest GPS Changes – >10 db Rej Of Interference And Multipath With M-code
  Indoor Mapping in Real Time
  Atomic Magnetometer Localization (in next talk)
  Quantum Technology for Geolocation

- ***Baseline Set Of Requirements:*** **Shared *RF timing system* with *1 m, 3D* uncertainty in an urban building or high-rise *with 1-way comm's***
- ***Hyper-growth In Cots Smartphone Localization***
  - **Incentives And Applications Of 3D Geolocation**

NIST Physics Lab and Advanced Time and Frequency Research

PSCR

Please save your questions until after this session ends

UWB Technical Risk Table
(risks are above zero, either low or high):

CATEGORY	RISK
• Sharing risk:	**Low** since UWB signals have a negligible effect at any bandwidth.
• Cost risk:	**Low** if meter-accuracy, **High** if mm-accuracy with atomic clocks in its infrastructure.
• Integration risk:	**Low** since it is independent of, i.e., does not interfere with established, current communications standards such as 4G LTE.
• Accuracy risk:	**Low** at meter-accuracy, bandwidth flexibility for use in open, multipath free space, **High** as buildings and other urban structures increase multipath.
• Efficiency risk:	**Low** for mission specific situations (firefighter in burning building), **High** for more generic uses.
• Develop. risk:	**Low** since it is based on well established technologies that are becoming COTS and on recent UWB LBS-related research and programs (eg., microPNT).
• Interference risk:	**Low,** can use noise-blanking very effectively (eg., lightning-overload blanking), **Low** even as tag pulses are orthogonal spread-spectrum.

Other

- **Public Safety implementation risk:** UNKNOWN.
- **Scaling risk:** x10 **Low**, x1000 **High**.

PSCR

Preliminary: TECHNICAL FACTORS OF POSITIONING HIERARCHY

- Received signal strengths (RSS)
  - *– low accuracy*
- Angle of arrival (AOA), less used Direction of arrival (DOA)
  - *– high relative GDOP, antenna-array size*
- Phase of arrival (POA)
  - *– phase ambiguity and sync*
- Observed phase difference of arrival (OPDA)
  - *– phase ambiguity*
- Time of arrival (TOA)
  - *– sync*
- Observed time difference of arrival (OTDOA)
  - *– minimum of 4 simultaneous receptions*
- Two-way time transfer (TWTT), also Round-trip time of flight (RTOF)
  - *– near simultaneous Tx and Rx, bandwidth*
- Proximity
  - *– well-known, fixed positions of dense grid of antennas*

PSCR

GPS Usage and Augmentation

GPS Usage Assessment:

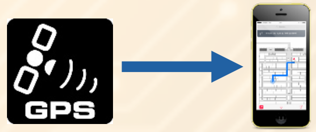
- Self driving cars – *no, GPS alone cannot be used to self-drive cars* – cars need navigation in the immediate surroundings, GPS is too slow for navigation/tracking
- Airline navigation, takeoff, and landing – *no, airlines use IMU's, VOR and altitude data*
- DOD uses GPS – *no, new systems must operate w/o GPS*
- Space satellites & vehicles – *no, GPS is not designed to work in space, but side-lobe ranging works to large extent*
- Locating individuals, tags – *no, can't distinguish between individuals with certainty if moving* (like firefighters and people who are ganged together)
    - *Doesn't work indoors or underground*
    - *No 3D, only 2D*
    - *CEP is too large*
- Used in cell phones – *no, GPS is too slow for navigation/tracking,* cell phones use compass and inertial sensors, WiFi database, cell tower and hotspots
    - Best for *calibration of sensors*, at ZUPT
    - *Terrain maps are used for driving*
    - *2D only, again for driving*
- Power grid: *GPS is used* because "it's there" *not because it's needed* – power industry uses an internal synch method or WWVB without GPS

PSCR

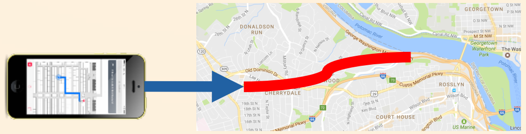
Diminishing GPS Usage

<u>Question: "What is the GPS duty cycle?"</u>

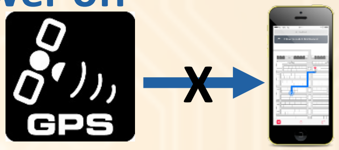
- At "ZUPT," GPS is needed once at cold startup, at time t_0, for a P&T search directly traceable to NGA and GPS-T, UTC(USNO)



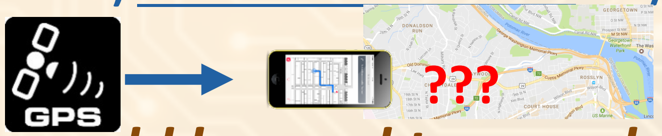
1. Fusion of sensors and terrain mapping does most navigating



1. GPS is not absolutely needed when receiver is not moved after power off
2. Last P-holdover is in memory and constant
3. GPS T-holdover is in UE clock and is unstable



- "How frequently is GPS needed or used?"
  - If *sensors* & *map* conflict, then at "ZUPT" UE reconnects to 1) <u>external P&T services and/or</u> 2)GPS for traceable cold start calibration



- *<u>Considering this, what P and T services are or could be used to complement GPS for enhancing LBS?</u>*

PSCR

PSCR

2017

PUBLIC SAFETY BROADBAND
STAKEHOLDER MEETING

Indoor Localization of First Responders

Fabio da Silva

NIST Physical Measurement Laboratory (PML)/PSCR

Outline

- Anatomy of an indoor location emergency
- Why is indoor location technically hard?
- First-principles approach
- Conclusions and future work

Anatomy of an indoor location emergency

- Timeline:
  - Notification @ 6:13 pm
  - Deployment @ 6:26 pm
  - Critical point @ 6:47 pm
- Conditions:
  - 6-story building
  - Practically no windows
  - Maze-like geometry

Source: Mark Harris, IEEE Spectrum, September 2013 p.30

PSCR

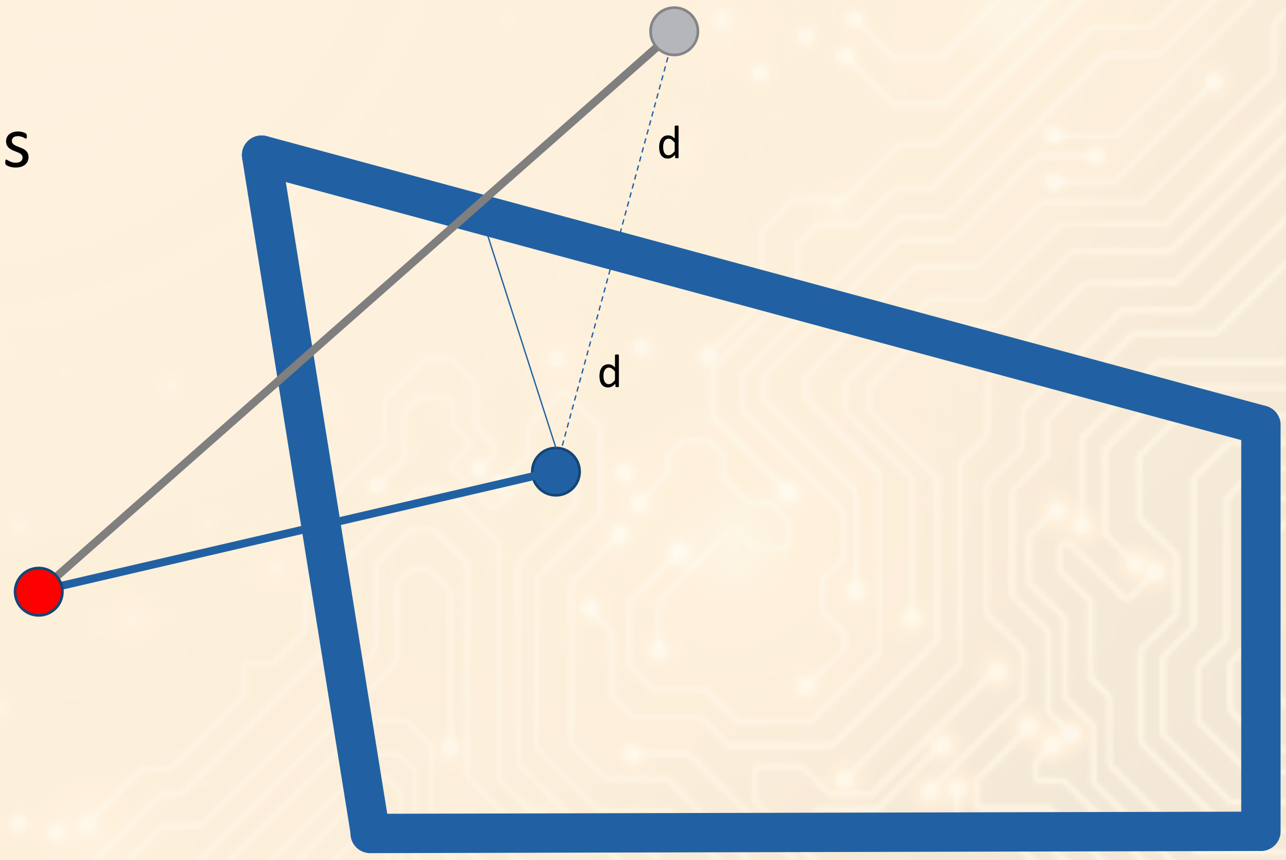
Why is indoor location technically hard?

- **[N**on] **L**ine **o**f **S**ight:
  - Multipath
  - Attenuation
  - Delay

PSCR

Multipath (reflection)

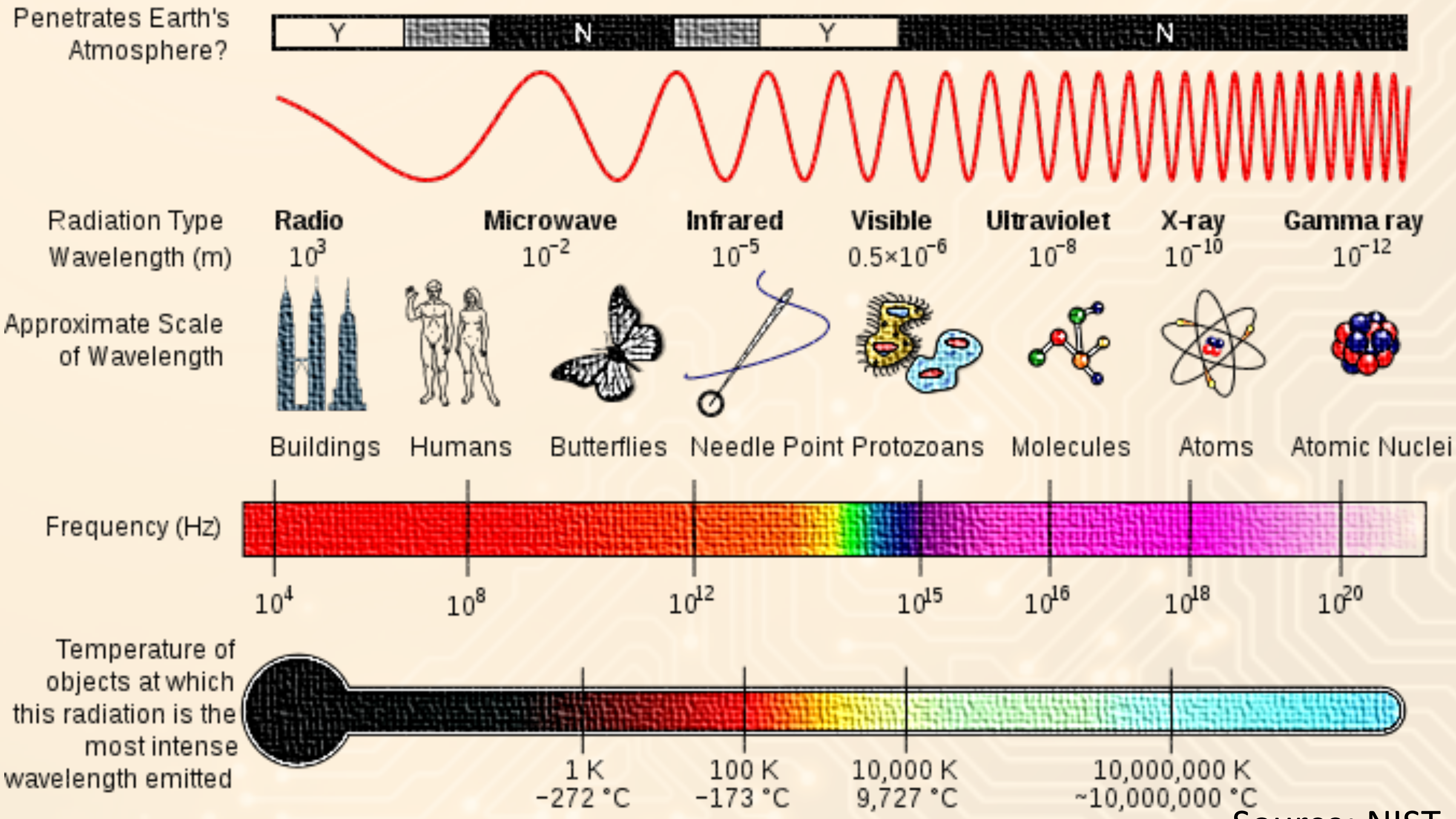
- Image source model
- Euclidian distance matrices
- Combinatorial time



Source: Ivan Dokmanić, PhD thesis (2015)

Attenuation (absorption)

- Skin effect

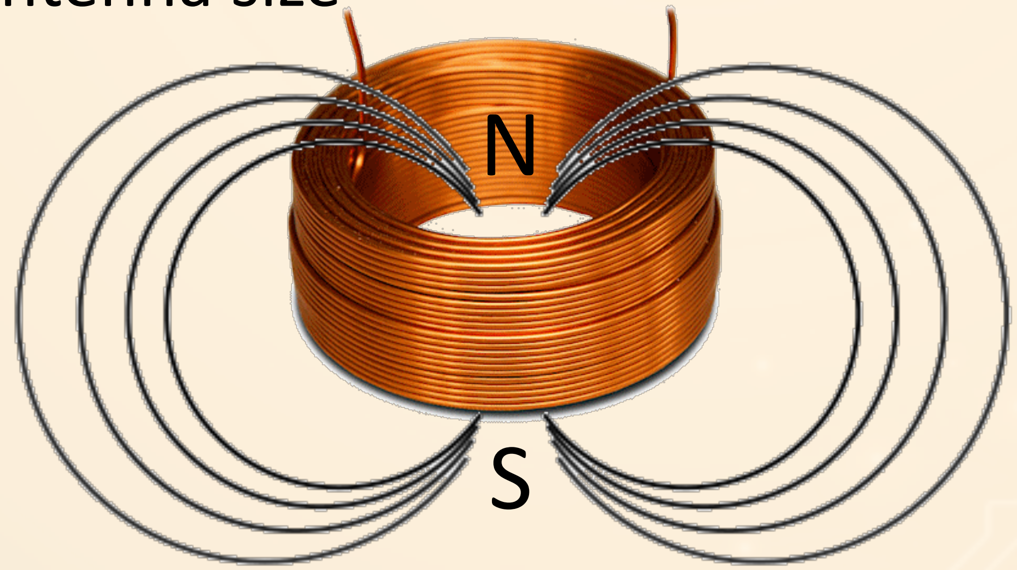


Source: NIST

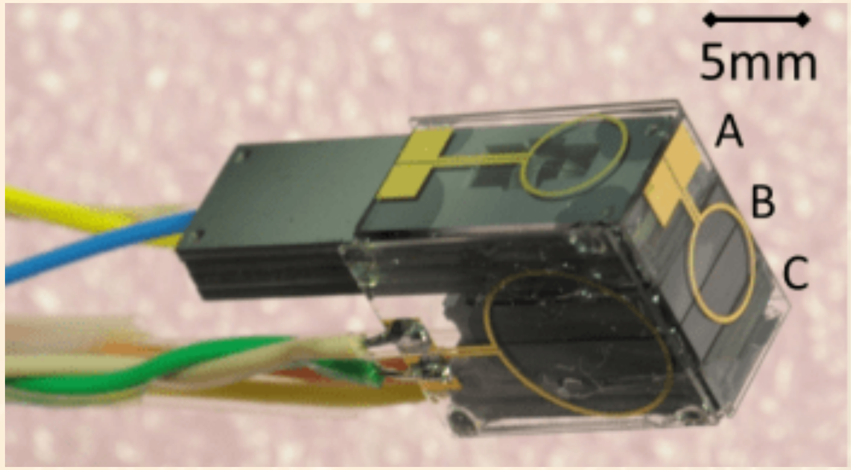
PSCR

Attenuation (absorption)

- Skin effect
- Antenna size



Transmitter



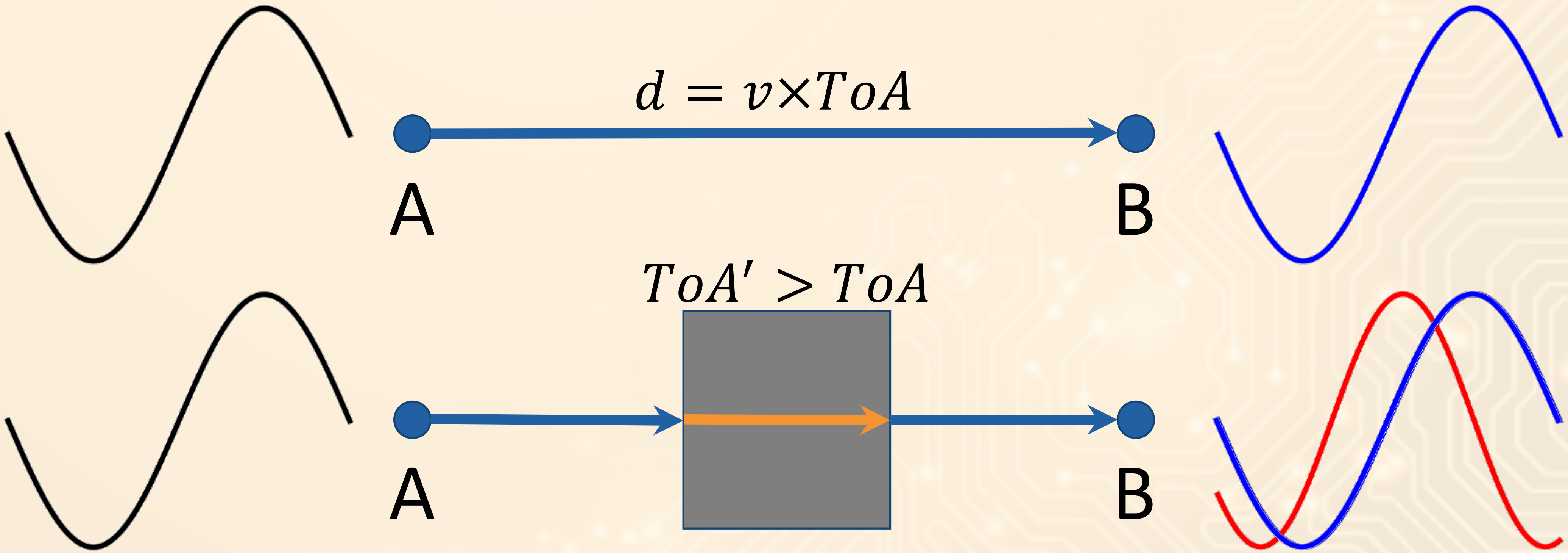
Receiver

Source: NIST

PSCR

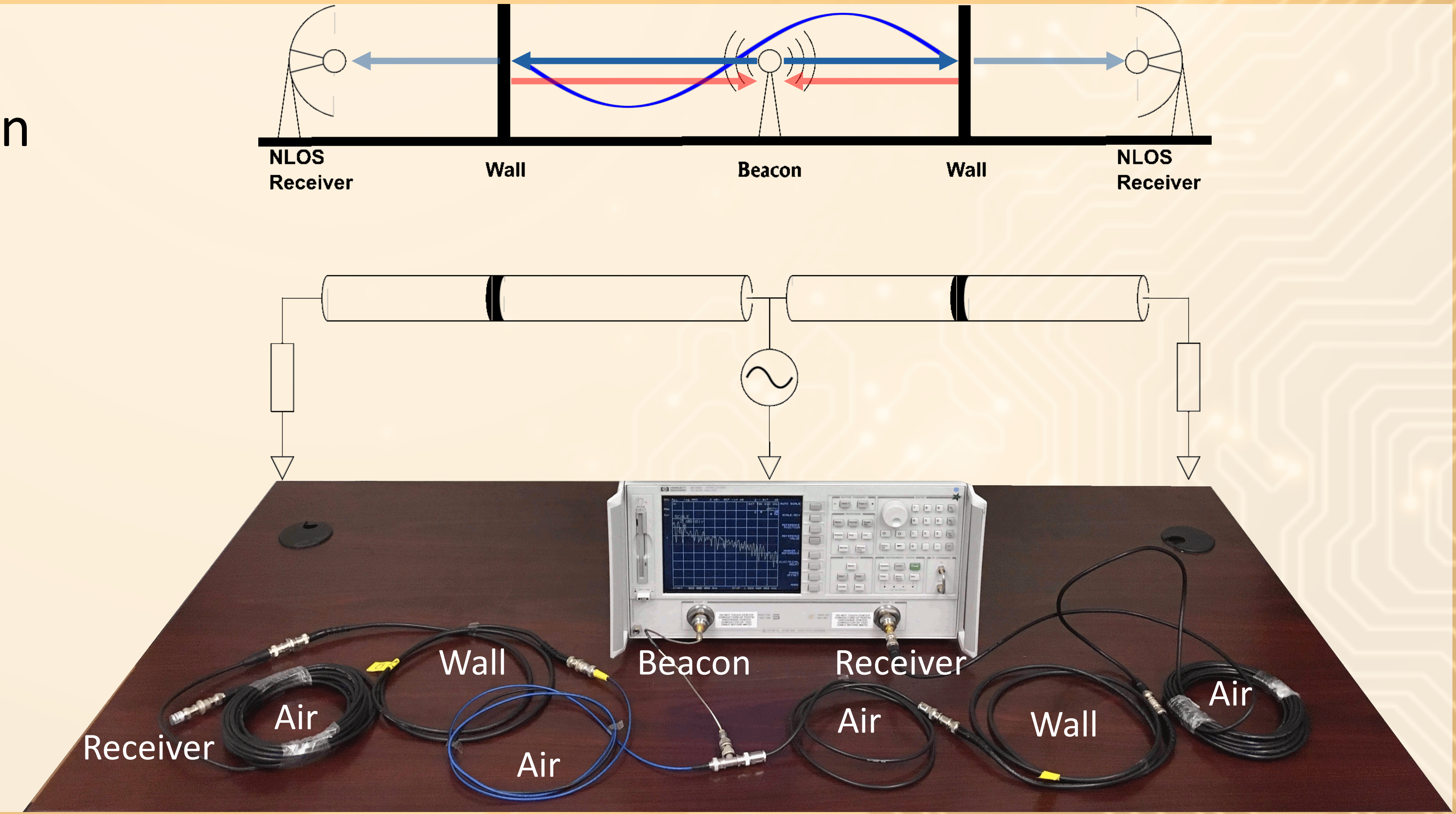
Delay (transmission)

- Index of refraction: n

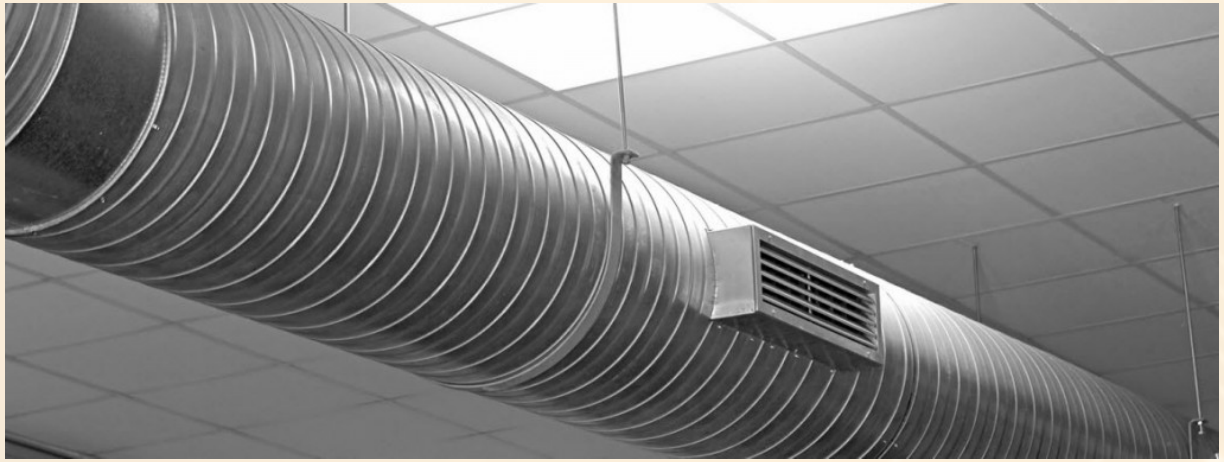


First principles approach

- Multipath
- Attenuation
- Delay

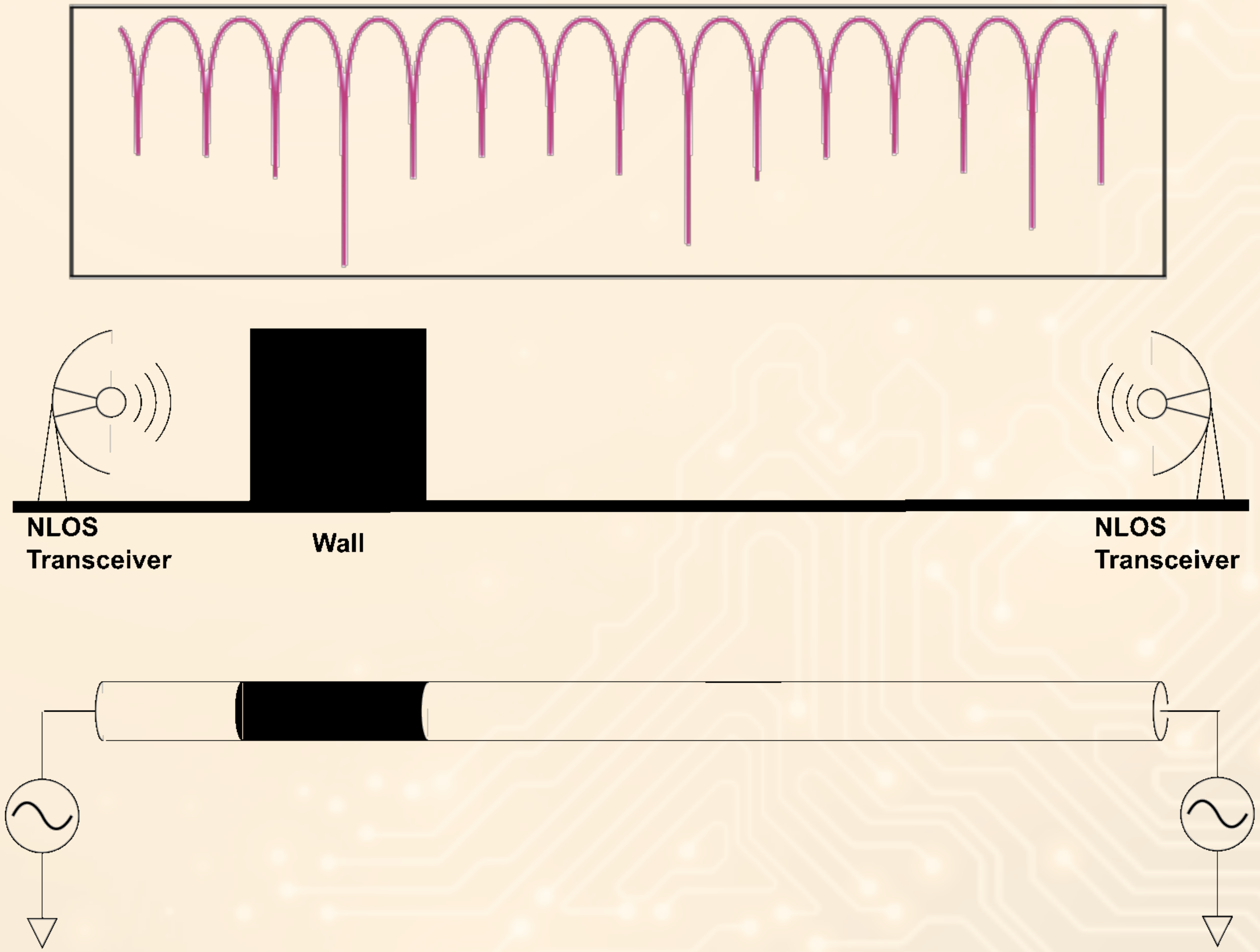


1D indoor location



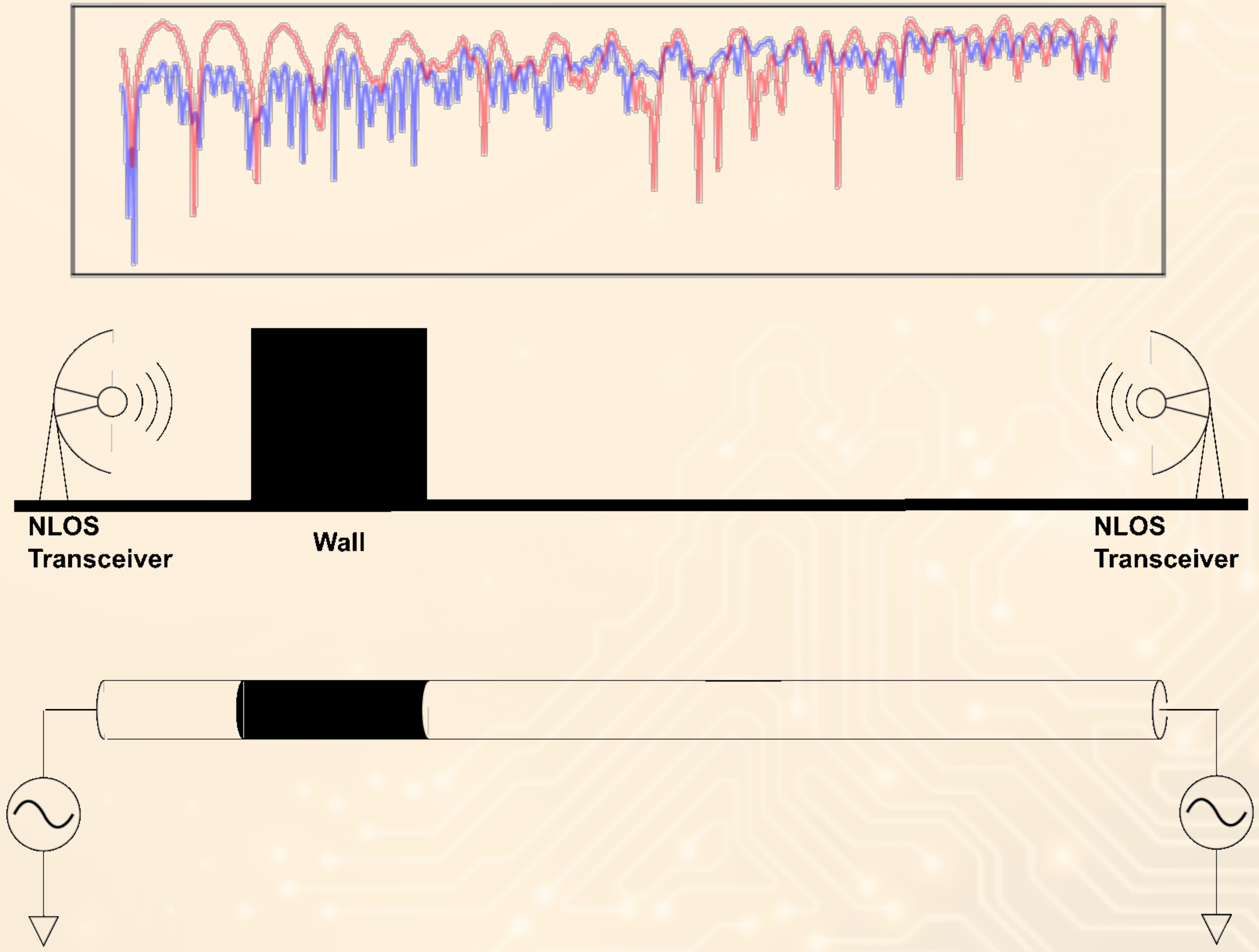
PSCR

1D Wall



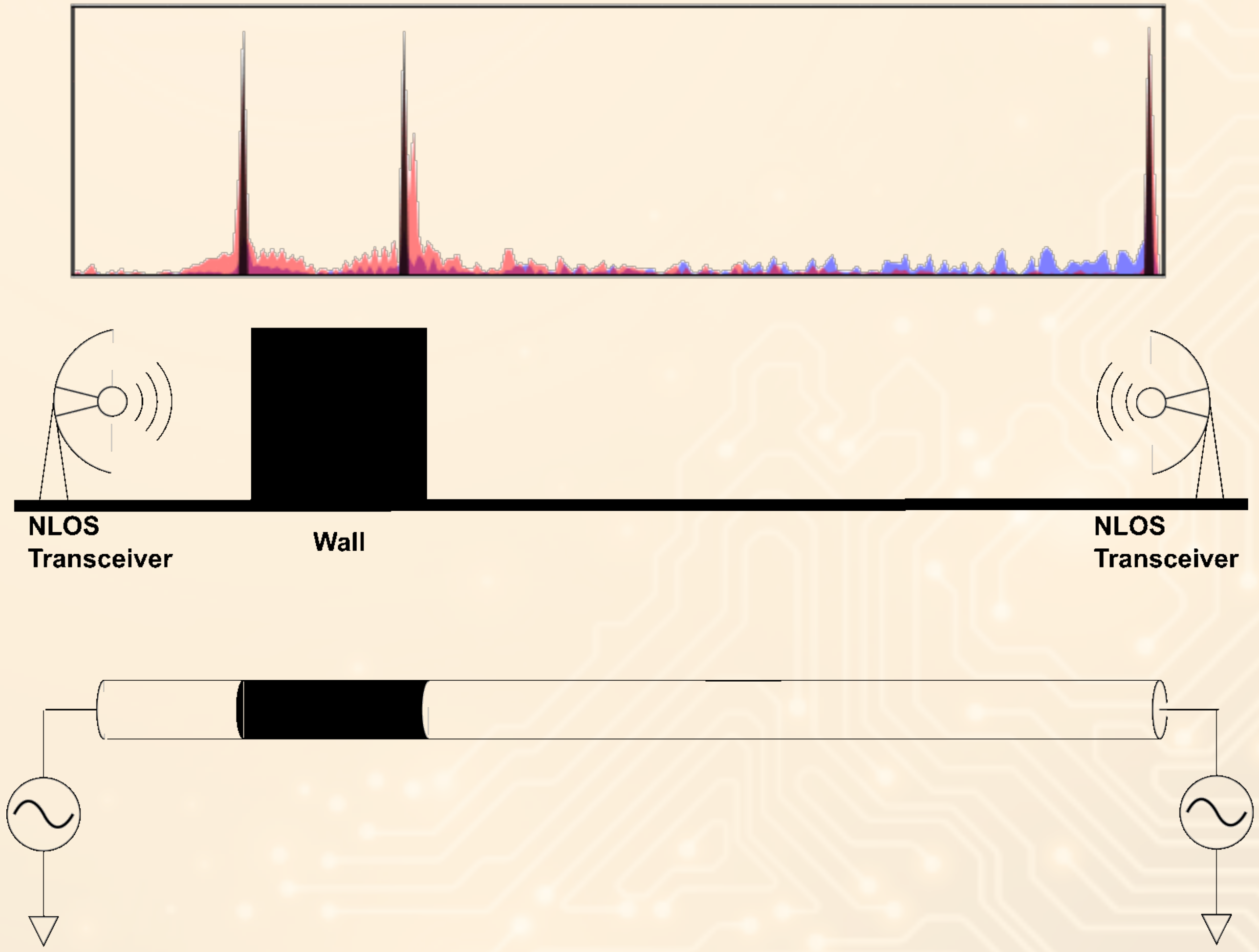
PSCR

1D Wall



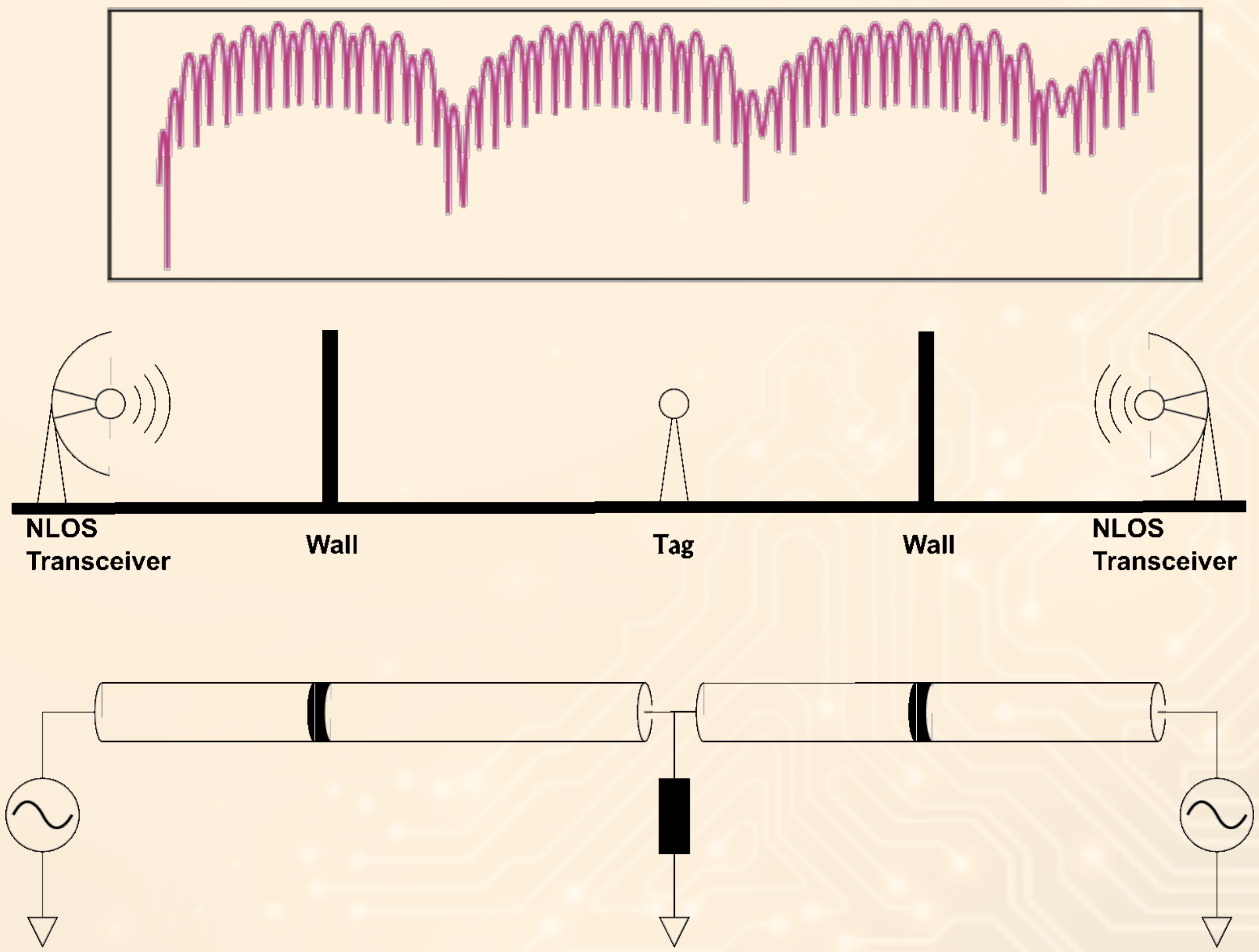
PSCR

1D Wall

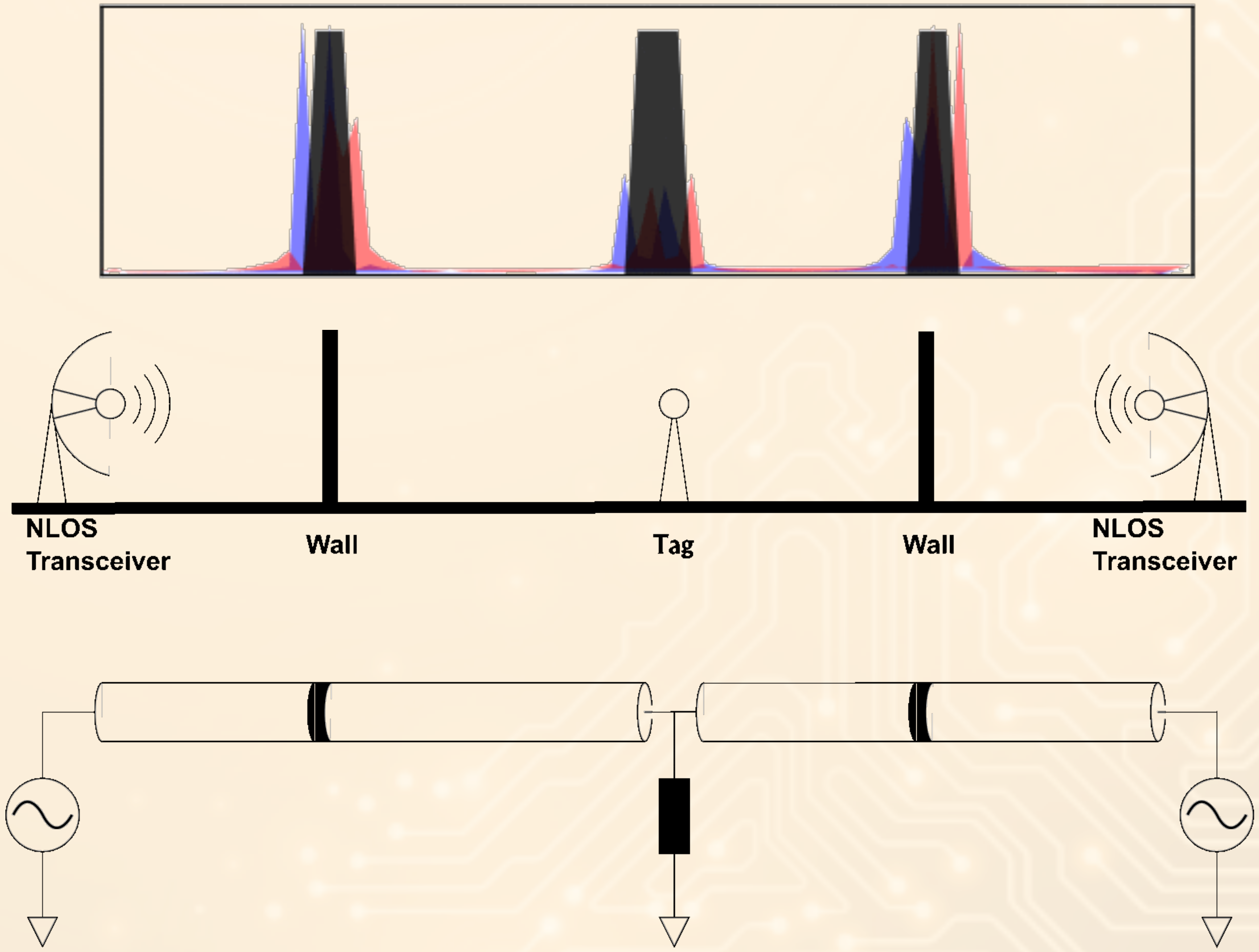


PSCR

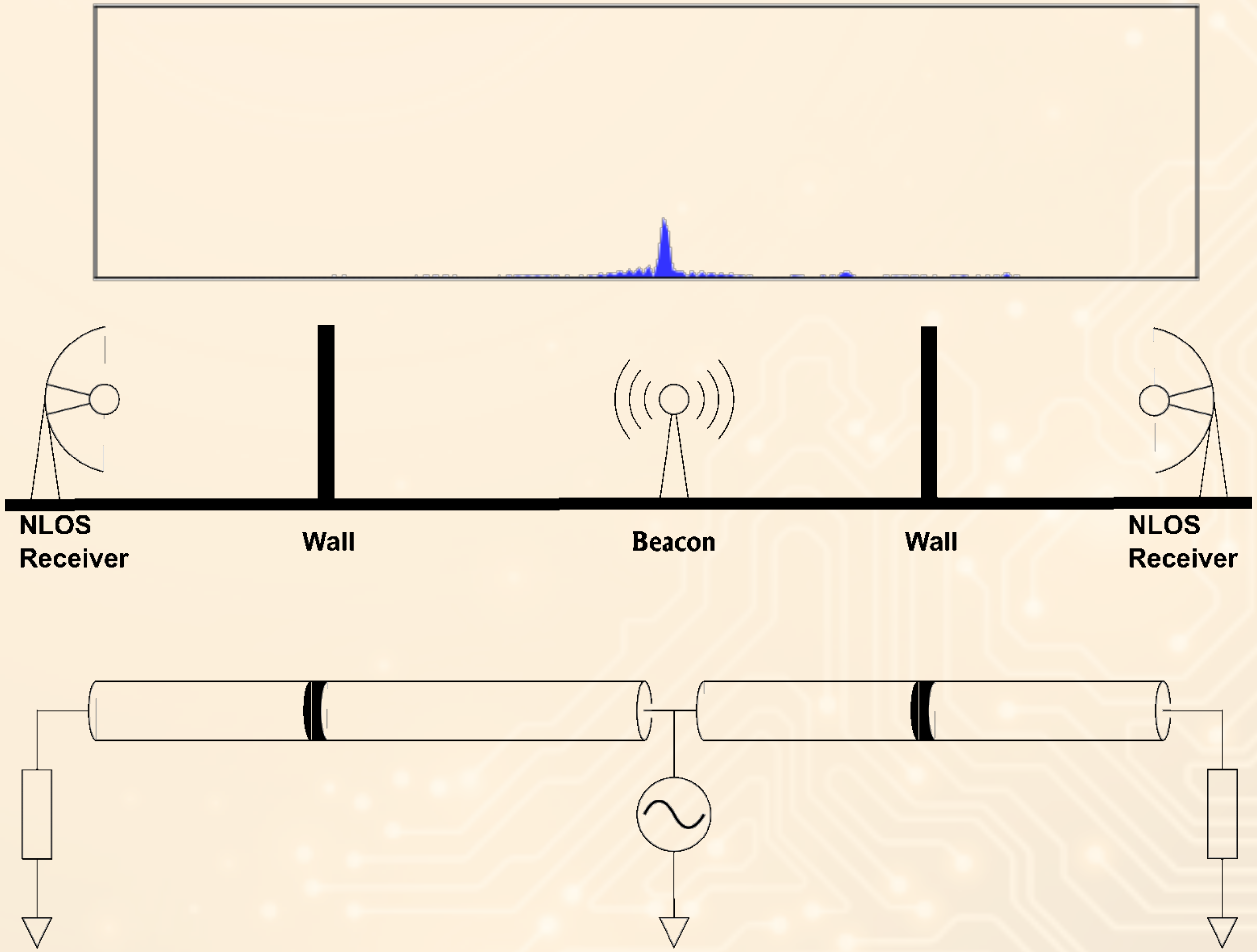
1D room with passive load



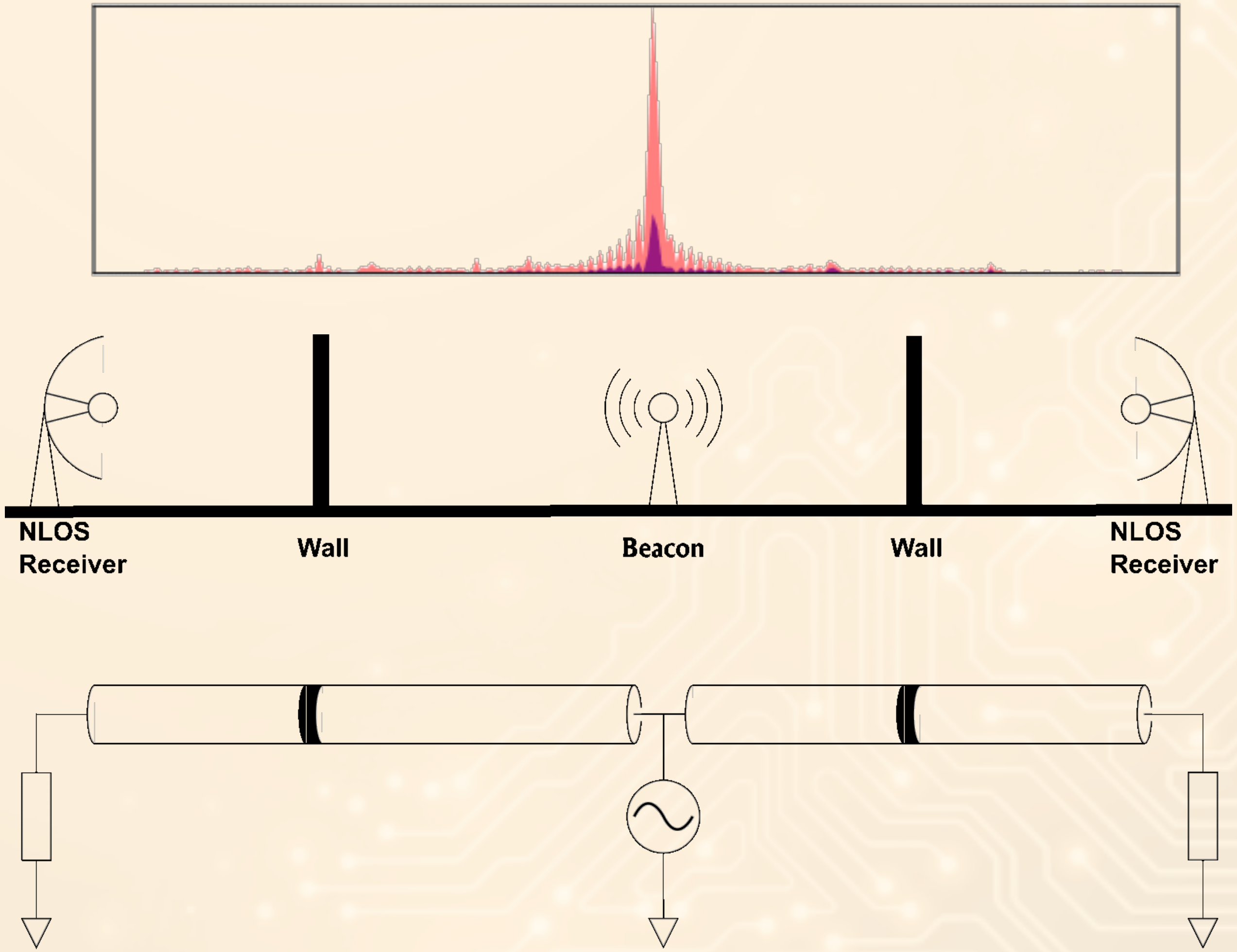
1D room with passive load



1D room with active load



1D room with active load



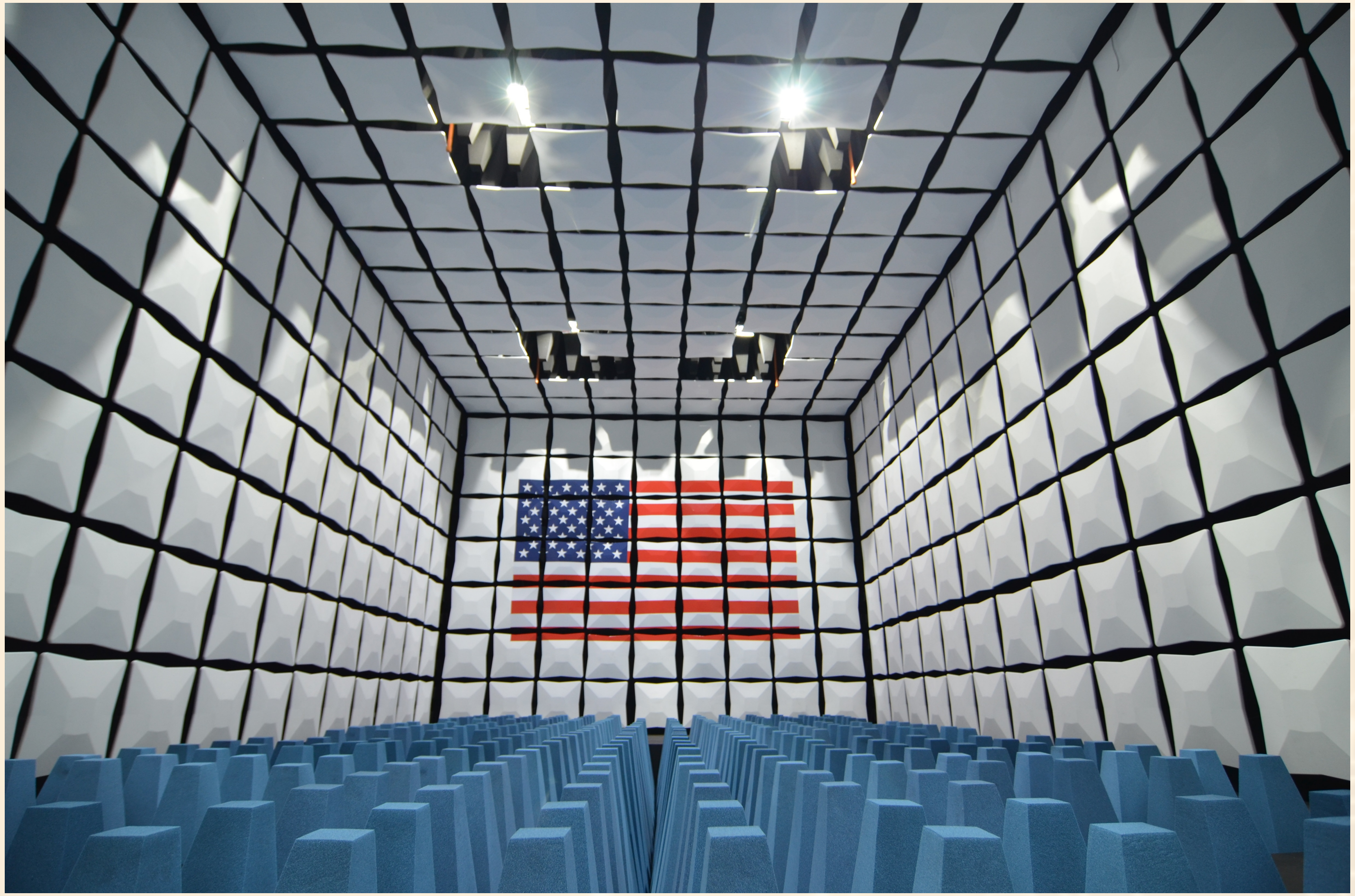
PSCR

Conclusions and Future Work

- Exploit multipath/attenuation/delay features of received signals
- Constraints and scenarios: passive vs active beacons
- 2D (in plane) and 3D (z-axis) analysis:
  - Polarization
  - Diffraction/refraction
- Measurements
  - Anechoic chamber
  - Real structures
  - Acoustics
  - 4G LTE infrastructure integration

PSCR

Conclusions and Future Work



PSCR

Conclusions and Future Work

PSCR

PSCR

2017

PUBLIC SAFETY BROADBAND
STAKEHOLDER MEETING

Acknowledgements

Matthew Kowalsky
Craig Nelson
Archita Hati
Vladislav Gerginov
Corey Barnes
David Howe (Group Leader)
Jason Coder (CTL)

NIST PSCR Stakeholder Meeting

Location Based Services Scouting

yet2

June 12, 2017

yet2 Mission

yet2: Helping you harness external opportunities to ignite innovation

- Full range of innovation services in technology scouting, start up/small company sourcing, OI Portal Management, out-licensing, and anonymous patent buying.
- Global technology & legacy venture networks, enabling us to connect those with technology needs to those with solutions.
- Vetted and experienced scouting experts.

Summary of TechNeeds

INDOOR MAPPING

Seeking new approaches for creating new indoor maps or compiling existing data into indoor maps.

INDOOR LOCALIZATION & TRACKING

Identifying the current limits of existing operational and reference Localization and Tracking Systems.

INDOOR NAVIGATION

Methods or technologies that enable indoor navigation of a first responder to a point of interest.

INDOOR MAPPING

SLAM, Map Access, Map Integration, Crowdsourcing and Incentivizing

SolutionScape

INDOOR MAPPING

- **Virtual Reality**
  - Cardiff University
- **2D to 3D Conversion**
  - GeoComm
- **Digitization of Maps**
  - AABSyS
  - CartoFusion Technologies
  - Project Atlas
  - Micello
- **Crowdsource Mapping**
  - Wuhan University
  - Nanyang Tech. Uni.
  - Inlocomaps
  - Locometric
  - SUNY Buffalo
  - Sensopia
- **SLAM**
  - GeoSLAM
  - NaviPack
  - Kaarta
  - Leica Geosystems
  - UC Berkeley
  - Indoor Reality
  - Scanse
  - Munich Uni. (TUM)
  - Viametris
  - TeraBee
  - University of Würzburg
- **Indoor/ Outdoor Maps**
  - Ubica2 Project
  - ESRI
  - Heidelberg Mobil
- **Feature Extraction/ Recognition**
  - ZenRobotics
  - Uber Technologies
  - York University
  - German Uni. of Cairo
  - UC Santa Barbara
  - TU Ilmenau
  - Aipoly
  - Cambridge University

Wuhan University

Wuhan, China.
Founded 1893.
http://www.lmars.whu.edu.cn/en/index.jsp

Technology Description

- Developing a method where indoor locations are measured through crowdsourcing via smartphone.
- User activities are defined into landmarks with both WiFi fingerprinting and activity type information.
- Landmarks can be clustered into nodes to define paths, features or map routes.

Comparative Value Proposition

Accuracy of 0.8 – 1.5 meters. A minimum of 3 reference points are required, and these can be obtained through GPS or WiFi fingerprinting.

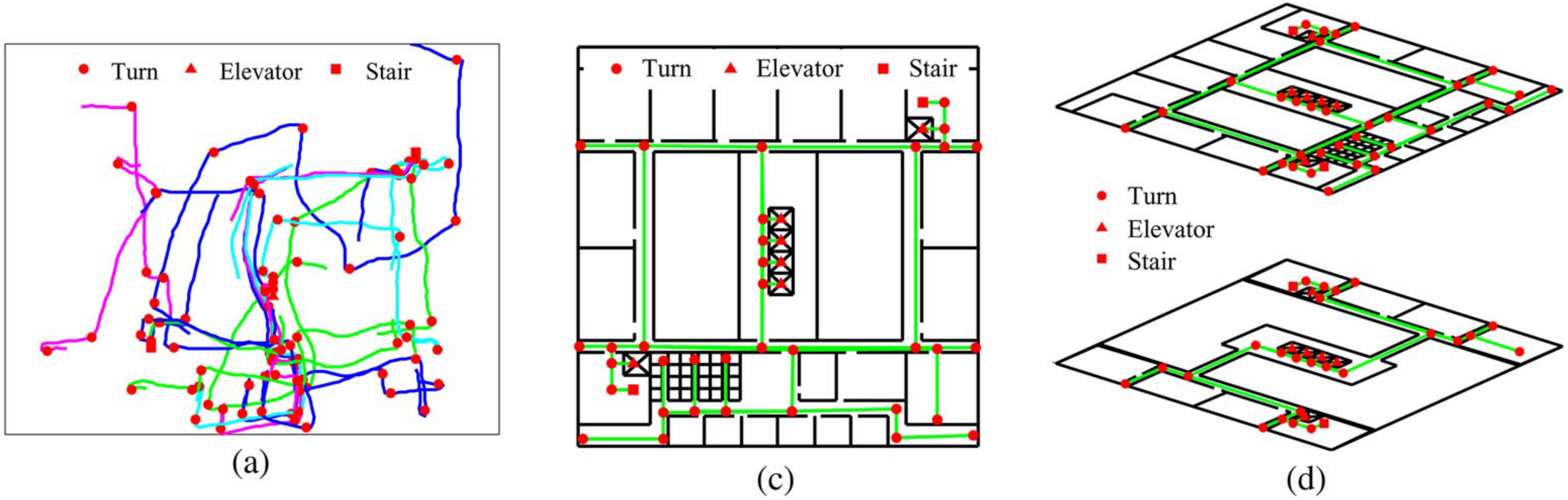


Fig. 9. Outcome of the mapping process. (a) Crowdsourcing trajectories; (c) mapping result of the 14th floor (2D); and (d) mapping result of the 13th and 14th floors (3D).

York University

Toronto, ON, Canada.
Founded 1959.
http://www.yorku.ca/gsohn/

Technology Description

- Methods to extract semantic information from raw laser-generated point clouds.
- Algorithms extract topological information (floor, above floor, ceiling level).
- The methods also use an additional algorithm for door detection, which differentiates between openings and doors.

Comparative Value Proposition

- Offers an alternative method to manually extracting doorway information from laser-generated raw point clouds.
- Initial incarnation of the algorithm has a false positive rate of 9.4 % and a positive detection rate of 71.9 %.

Figure 8. Door detection evaluation; greens indicate the successfully detected doors, while reds are missing, and oranges are false positives

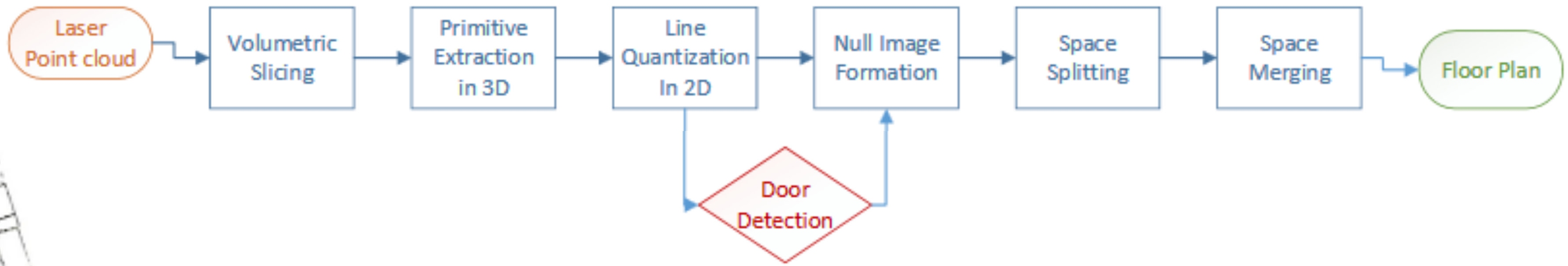


Figure 1. The overview of the method

Scanse

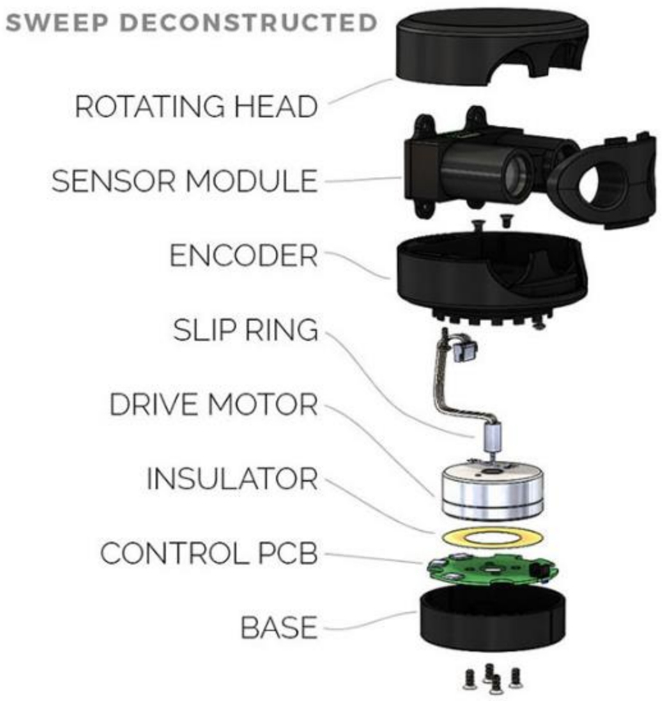
San Leandro, CA, USA.
Founded 2014.
http://scanse.io

Technology Description

- Sweep is a lightweight, 3D-printed LiDAR system.
- The LiDAR operates a 905 nm light source and captures 1000 samples/second with a 360° scanning angle.
- Sweep communicates to an external interface through a universal asynchronous receiver/transmitter (UART).

Comparative Value Proposition

- Compatible with operation from -10°C – 70°C at humidity levels up to 85% without icing or condensing.
- Scanning range of 0.1 m – 40 m with accuracy within 2% of measured distance. Scanning resolution of 1 cm.
- Priced at $349.00 (compared to $10K+ for competing LiDAR). Currently in pre-order, with orders to ship by end of Q2 2017.



INDOOR LOCALIZATION AND TRACKING

Beacons, WiFi, Inertial Sensors, UWB, Optical, Magnetic

SolutionScape

INDOOR LOCALIZATION AND TRACKING

OPERATIONAL							REFERENCE
UWB +/- Inertial	Magnetic +/- Inertial	Optical +/- Inertial	Inertial	UWB + AoA-TDoA	Beacon	Others (WiFi, RFID, etc.)	
TRX Systems	GiPTech	Swedish Defense Res. Agency	Navisens	Ubisense	Vital-Tech	Delft University	EVARILOS
Tyndall Nat'l Institute UCC	NASA JPL	WPI	Dune		Nextome	Locoslab	Campus Bio-Medico Univ. / REFIRE
KTH	IndoorAtlas	TH Wildau	Omnisense		NextNav	Nanyang University	
	Chinese Acad. of Sciences				Mist BLE Alliance	University of Illinois	
	CornerTurn					Campus Bio-Medico Univ. / RISING	
						University of Perugia	
						University of Southern CA	
						Focal Point Systems	
						BAE Systems	

GiPSTech

Rende, Italy
Founded in 2014
http://www.gipstech.com

Technology Description

- GiPSTech has developed a **geomagnetic-field localization and navigation system** for indoor locations (where GPS doesn't work).
- GiPSTech's technology works by crossing the **geomagnetic** signals of a smart phone. This involves combining **magnetic** fingerprinting and **inertial** analysis via gyroscope/accelerometer in a phone.
- Their technology is based on a **novel algorithm** that employs anomalies of the geomagnetic field to locate and track objects and users that are moving in indoor environments.
- GiPSTech has been able to implement their technology **using beacons** and are looking to **use Wi-Fi**.

Comparative Value Proposition

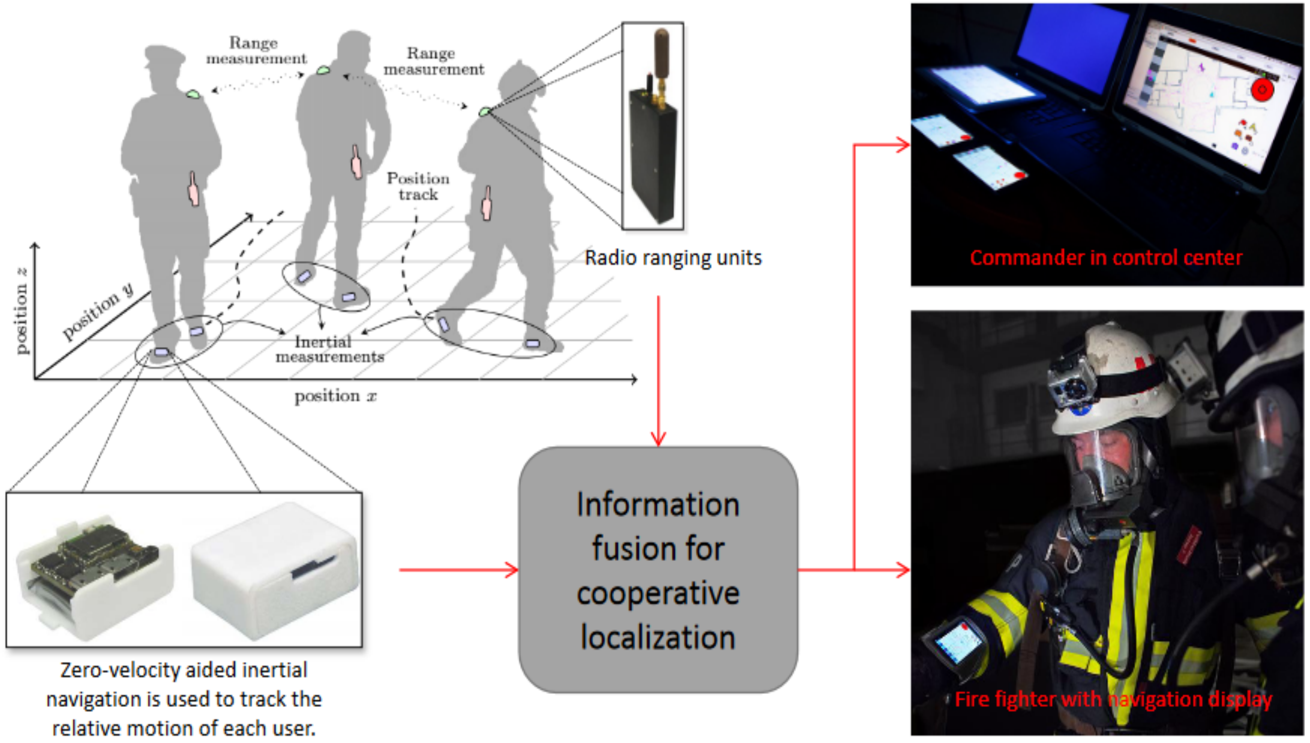
- Claim to reach a **1 meter precision.**
- **Novel algorithm** that seems to be unique (eg. compared to *IndoorAtlas*).
- **Not requiring costly infrastructure to be installed**, GiPStech allows inexpensive tracking of personal. Other technologies e.g. Bluetooth or beacon technologies all require hardware in place.

KTH Royal Institute of Technology

Stockholm, Sweden
Founded 1827
Journal Article

Technology Description

- The TOR (Tactical lOcatoR) system uses dual foot-mounted low-cost inertial sensors and RF(UWB)-based inter-agent ranging.
- Scenario-based tests were performed using fully-equipped firefighters mimicking a search operation in a partly smoke-filled environment. (Tests included realistic firefighter movements and inter-agent distances).



Comparative Value Proposition

- An infrastructure-free, real-time and cooperative localization system

- Initial results provide a position accuracy of about 2-4 m during realistic firefighter operations, with only two smoke diving firefighters and one supervising firefighter within range.

- Next: Early research stage. Upgrades of the TOR system are expected to improve the usability and position accuracy, and continued scenario-based testing will be performed.

REFIRE and RISING Projects

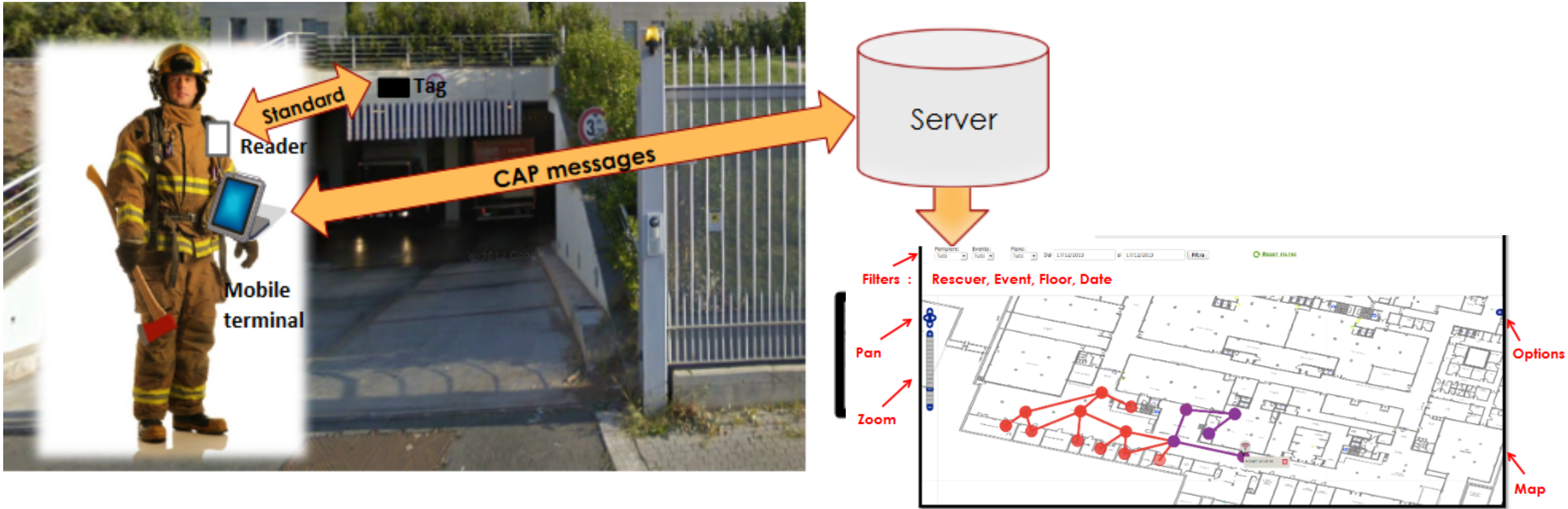
Rome, Italy
Established in 2012.

Technology Description

- The **REFIRE project** was initiated to develop standard communication and localization protocols for non-proprietary system interoperation for first responder applications.
- **The RISING project** was initiated to implement existing technologies for effective localization and communication services for indoor and deep-indoor emergencies. It is composed of deployable solutions exploiting low-cost, simple, highly standardized pre-installed landmarks.

Comparative Value Proposition

In 2014, REFIRE ended with the demonstration of the system based on a combination of inertial platforms and RFID technology. They demonstrated the feasibility of a system able to locate a rescuer inside a building with the accuracy of a few meters, without any drift or performance degradation caused by walked distance and time.



INDOOR NAVIGATION

Wayfinding, Haptics, HUDs, Route Planning, User Interfaces

SolutionScape

INDOOR NAVIGATION

INTERFACES

- **Haptics/ Auditory**
  - Yale University
  - Arizona State Uni.
  - Ducere Technologies
  - Georgia Inst. of Tech.
  - Accenture
  - A*STAR
- **Map Displays**
  - UC Berkeley
  - **Autonomous Navigation**
    - MIT Lincoln Lab
  - **Augmented Reality**
    - Insider Navigation
    - Overlay
- **Consumer Navigation**
  - Indoorway
  - Indoo.rs
  - Coppelis Digital Inno.
  - ROOMAPS
  - UTAD
  - IndoorSpirit

METHODS

- **Map-free Navigation**
  - University of Virginia
  - Norwegian Uni. of S&T
  - Meiji University
  - MIT-Robust Robotics
  - Zhejiang University
- **Wayfinding Algorithms**
  - AIONAV
  - Ghent University
  - Salzburg University
  - Liebniz University
  - University of Arkansas
  - University of Oklahoma
  - University of Illinois
  - Uni. of West of England
  - East China University
- **Routing Algorithms**
  - University of Cincinnati
  - HafenCity University
  - University of Melbourne

MIT Robust Robotics Group

Cambridge, MA, USA.
Founded in 1861.
http://groups.csail.mit.edu/rrg/index.php?n=Main.Research

Technology Description

- Partially Observable Markov Decision Processes (POMDPs)
- Planning with incomplete information
- Approximates high-dimensional probability distributions over states using low-dimensional representations
- Exponential Family Principal Component Analysis reduction technique removes majority of implausible beliefs for efficient planning with little loss in performance

Fig. 6: Experiment in which our planner (blue) reached its goal over 2x faster than baseline (red). Velocity profiles and trajectories for each planner are shown.

Comparative Value Proposition

- Minerva, the tour-guide robot in the Smithsonian Museum uses motion planning strategy balancing cost of motion with positional uncertainty to achieve goals
- Nursebot, a robot for assisting nurses and the elderly with daily activities, estimates and plans for a wide variety of human behaviors

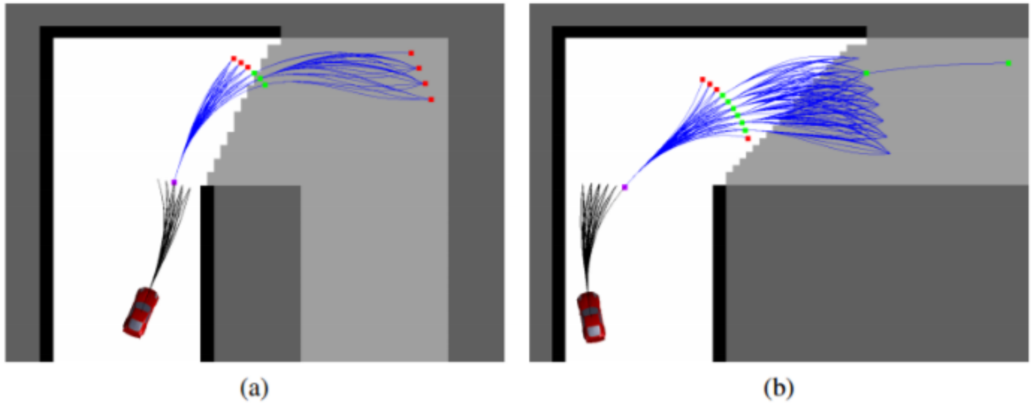


Fig. 3: Examples of "collision" (a) and "non-collision" (b) training events. One of the immediate actions (black) is chosen for labeling. The training planner determines whether the end of this action (purple dot) is an inevitable collision state with respect to the hidden map (shown in light gray). Feasible partial paths are shown in blue. Nodes successfully expanded by the training planner are green, and nodes for which no collision-free outgoing action exists are red. In (a), all partial paths dead-end (red nodes) before reaching the desired three-action horizon because the vehicle speed is too great to complete the turn given curvature and cuvature rate limits. In (b), the training planner successfully finds a sequence of three actions.

Univ. of the West of England

Bristol, UK.
Founded in 1972.
http://cuber.org.uk/

University of the West of England
BRISTOL

Emergency response in complex buildings

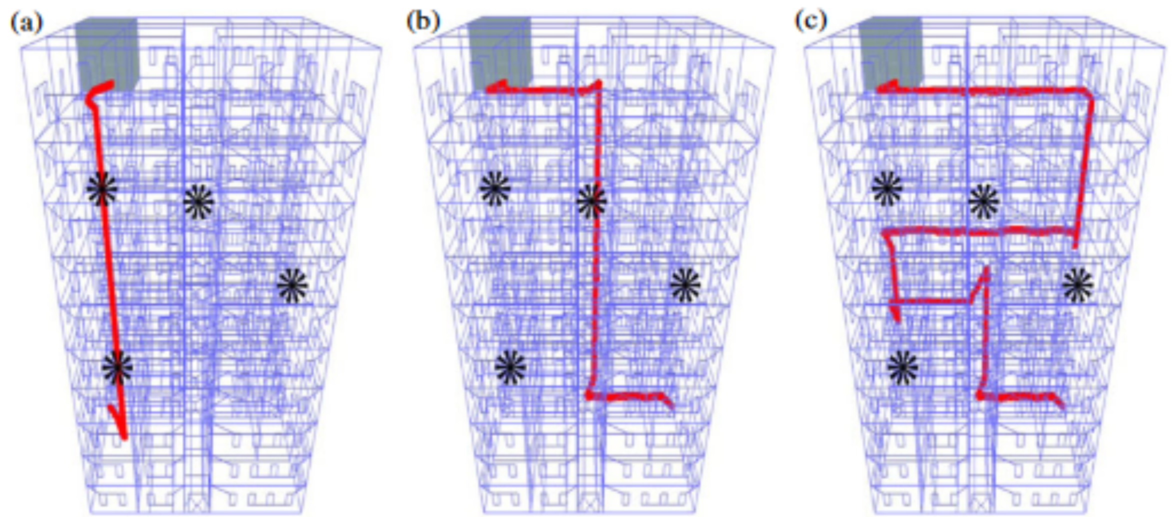


Fig. 14. (a) The shortest route P_0; (b) the balanced route P_{11}; (c) the safest route P_{165}.

Technology Description

- Algorithm for optimizing indoor navigation routes
- For use during search & rescue operations in extreme conditions when BIM information is available
- Based on several foundational theories with considerations for propagation of hazards from multiple sources, Analytical Hierarchy Process and binary search
- Route based on tradeoffs of hazard proximity, route complexity and travel time
- Validated in the Doha World Trade Center using BIM information as a map basis

Comparative Value Proposition

- Incorporates the parameters of an extreme event with multiple hazard epicenters
- Requires BIM data but can also produce travel routes that require breaking through a wall taking into account wall thickness & material for ease of drilling/cutting

Univ. of Arkansas at Little Rock

Little Rock, AR, USA.
Founded in 1927.
http://ualr.edu/cxye/

Technology Description

- Smart Cane Robotic Navigation Aid
- Comprised of off-the-shelf time-of-flight camera
    - Illuminates environment with modulated infrared light
    - Detection range of up to 5m with a ±5cm accuracy.
- Server uses 2-Step Graph SLAM to extract the floor plane as a landmark
- Uses global path planning module to find the shortest by applying the A* algorithm to a POI-graph

Comparative Value Proposition

- Speech interface works both to give navigational commands (e.g. go to room #555) & to receive directions from the system (e.g. go forward 1m).
- Compared to planar SLAM and RGBD-SLAM, the endpoint position error of the proposed method is much smaller, it is closer to ground truth pass, and the runtime reduction of the algorithm is 33.6%.

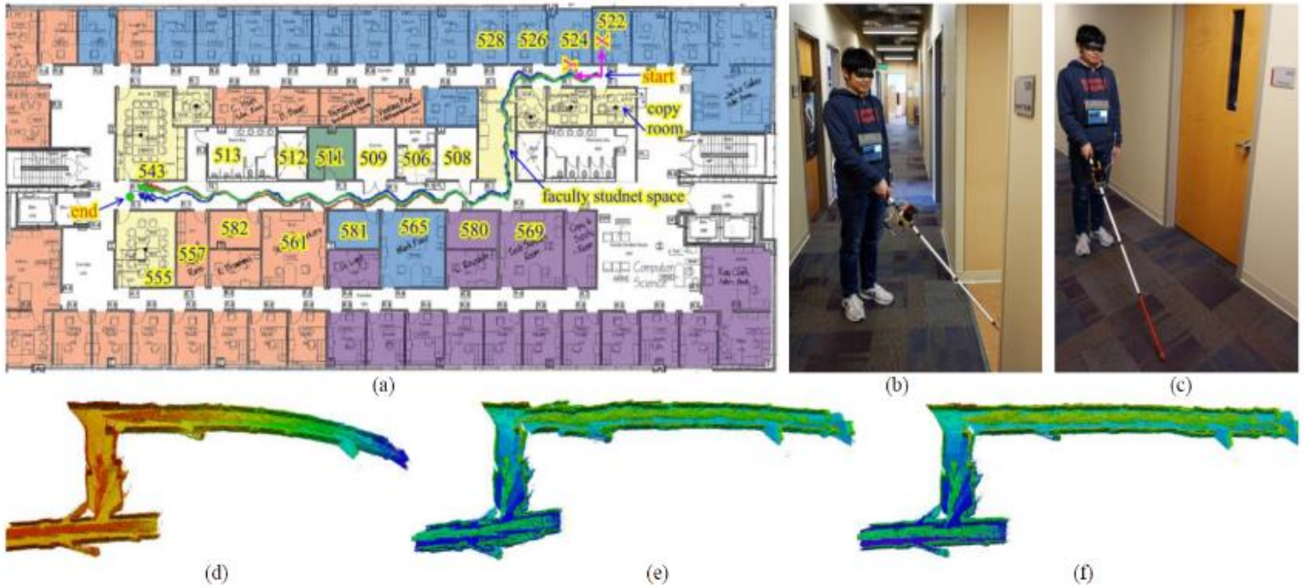


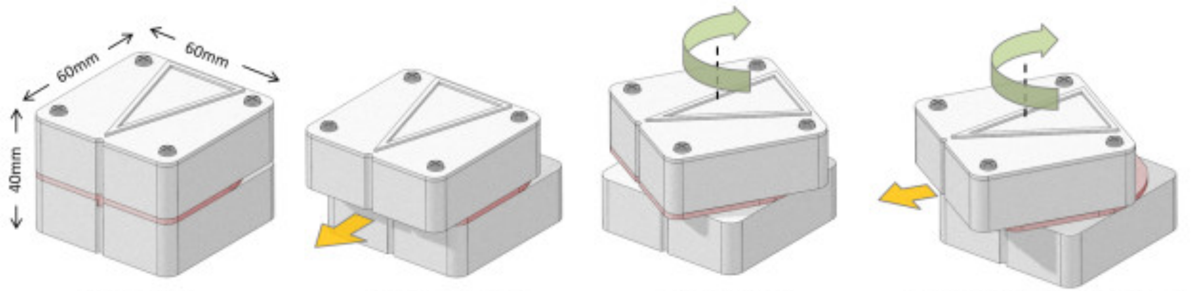
Fig. 11. Experiment 1 (5th floor. EIT building). (a)Trajectories produced by the three SLAM methods: RGBD-SLAM (red), planar SLAM (green), the proposed method (blue); (b) Human subject was turning left (at the 1st T-junction) to the faculty student space; (c) Human subject was walking nearby RM 582; (d) Octomap of RGBD-SLAM; (e) Octomap of the planar SLAM; (f) Octomap of the proposed method.

yet2

Yale University

Technology Description

- Handheld device for navigation for the visually-impaired
- Bilayer cube twists to indicate direction a user should move
  - Extends/retracts to provide haptic clues for remaining distance/arrival
- Used as part of an interactive theater experience
- Tracks movement with RF-based localization system and wearable magnetometers
  - Wirelessly relays position information to a computer



(a) Home (b) Extension (c) Rotation (d) Rotation & Extension

Ducere Technologies

Technology Description

- Lechal shoe insoles provide vibratory input for navigation
- Insoles receive route data from Lechal app either using internet signal or pre-loaded maps
- Insoles provide left/right vibration for turns and alter vibration frequency to alert the wearer to their approaching destination
- Insoles include an IMU, magnetometer and an RF device
- Retail for around $150

CONCLUSIONS

Conclusions

INDOOR MAPPING

- Advanced tech. available for SLAM. A trend toward decreasing cost/size
- Many consumer-facing displays and smartphone mapping apps that could be leveraged for first responders
- Great need for standardization and central storage of maps

INDOOR LOCALIZATION & TRACKING

- A lot of research work from Universities worldwide without a real pathway to commercialization
- A trend toward consortium building

INDOOR NAVIGATION

- Opportunity to leverage mapless SLAM navigation algorithms
- Opportunities in navigation for autonomous vehicles/ disabled persons/haptics
- Opportunity to leverage consumer-facing apps

Conclusions

- Technologies are being developed for other applications but there is a huge opportunity here for the first responder community to share insights, needs and visions.

- We're here to spark conversations throughout the conference. Come find us to learn more!
  - Alicia Evangelista, Ph.D. - AEvangelista@yet2.com
  - Brienne Engel, Ph.D. - BEngel@yet2.com

Advancing Public Safety Analytics Through PSCR's Innovation Accelerator Grant Program

PSCR

2017

PUBLIC SAFETY BROADBAND
STAKEHOLDER MEETING

#PSCR2017

Analytics are Pervasive

Analytic technologies will be part of every stage of the public safety communications workflow

Capture → Encoding → Compression → Transmission/ Communications → Broadcasting/ Distribution → Alerting → Triage → Forensics → Data Storage and Management

The needs are diverse

PSCR

PSIAP Funding Opportunity – Analytics

Novel Analytics and Analytic Applications

Tools and Frameworks to support

Agile R&D, Measurement, and Future Standards

Datasets to Enable and Foster Research

PSCR

Partnering with public safety organizations was required to both engage the end users and foster transfer

Analytics Grant Awardees

all presenting in poster sessions

- **CMU** with CMU PD (PA)
- **New Jersey State Police** and NJ Office of Homeland Security Preparedness (NJ)
- **Prominent Edge** with Hanover Fire EMS (VA)
- **Southern Methodist University** with Dallas Fire-Rescue (TX)
- **University of Cincinnati** with U o C Public Safety (OH)
- **University of Houston** with City of Houston (TX)
- **University of Michigan** with Oakland PD (CA)
- **University of VA** with VA DoH EMS Div., TJ EMS Council, North Garden VFC (VA)
- **Voxel 51** with Oakland PD (CA) and Baltimore Citiwatch (MD)
- **Western Fire** with 35 FDs (several western states)

PSCR

Future Outreach Areas Under Consideration

- Video quality metrics for analytics and compression challenge competitions
- Textual data de-identification challenge competition
- Public Safety analytics interoperability needs and knowledge exchange forum
- Education for public safety in the development and use of analytics

PSCR

Presentations

a snapshot of the diversity of the portfolio

Carnegie Mellon University

Real-Time Video Analytics for Situation Awareness

Western Fire

Creation of a Unified Analysis Framework and Data Comparison Center

University of Virginia

Towards Cognitive Assistant Systems for Emergency Response

Prominent Edge

StatEngine: A Real-time Open Source Data Analytics and Visualization Platform for Public Safety Organizations

PSCR

Event Reconstruction

Alex Hauptmann
Carnegie Mellon University

Urban Event Reconstruction

Interactive tools ‘reconstruct’ an event

- Situation awareness
  - What is happening now (real-time)
- Forensic assistance
  - What happened here (retrospective)

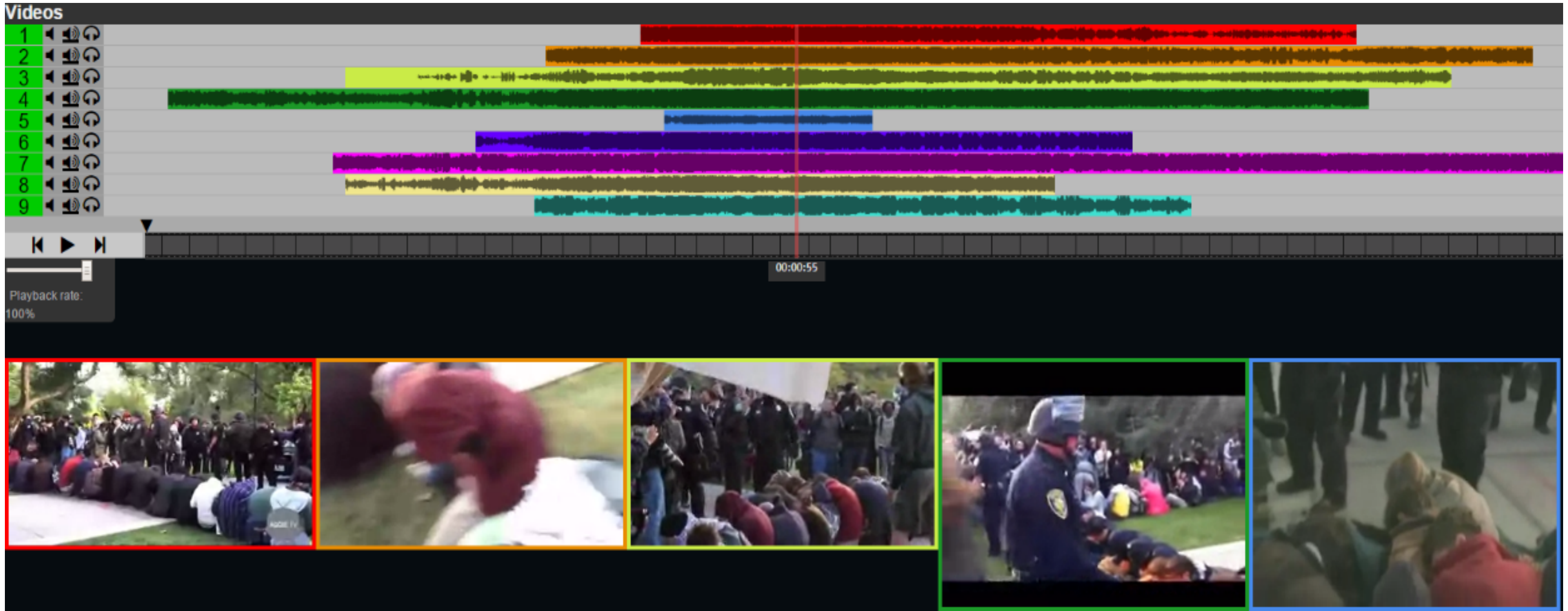
There are too many videos

- Need to find ones that are relevant
  - Recorded at the right time
  - Recorded at the right place (where the event happened)
- **Synchronization over time**
- **Geo-localization**
- **Tracking of groups/individuals**
- **Specific situation/activity/event detection**

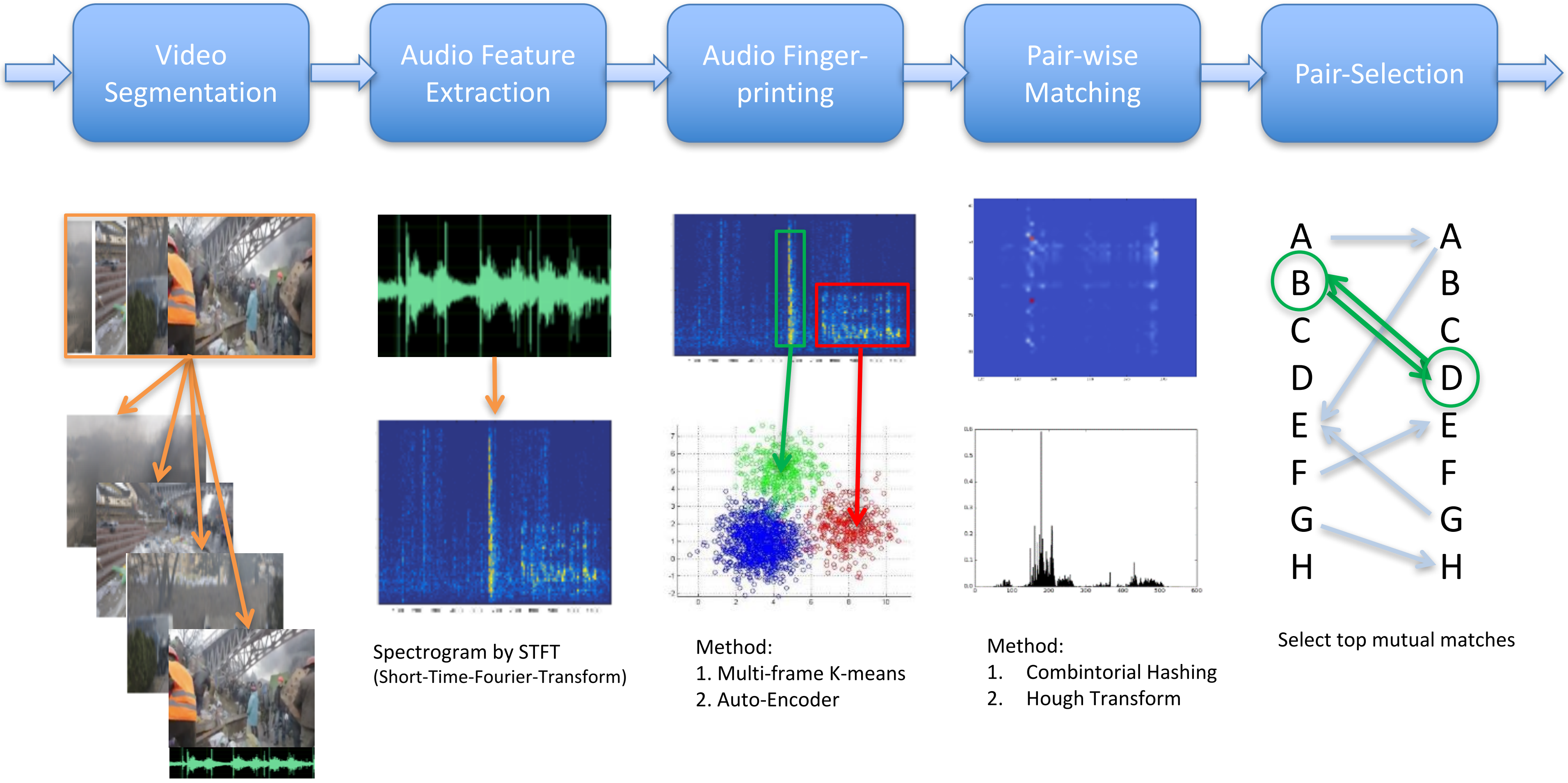
Synchronization

– Synchronizing event videos in time
– Spatial-temporal alignment and retrieval of important/interesting events
– Minimizing human efforts

Example



Pipeline Overview



Content-based Scene Detection

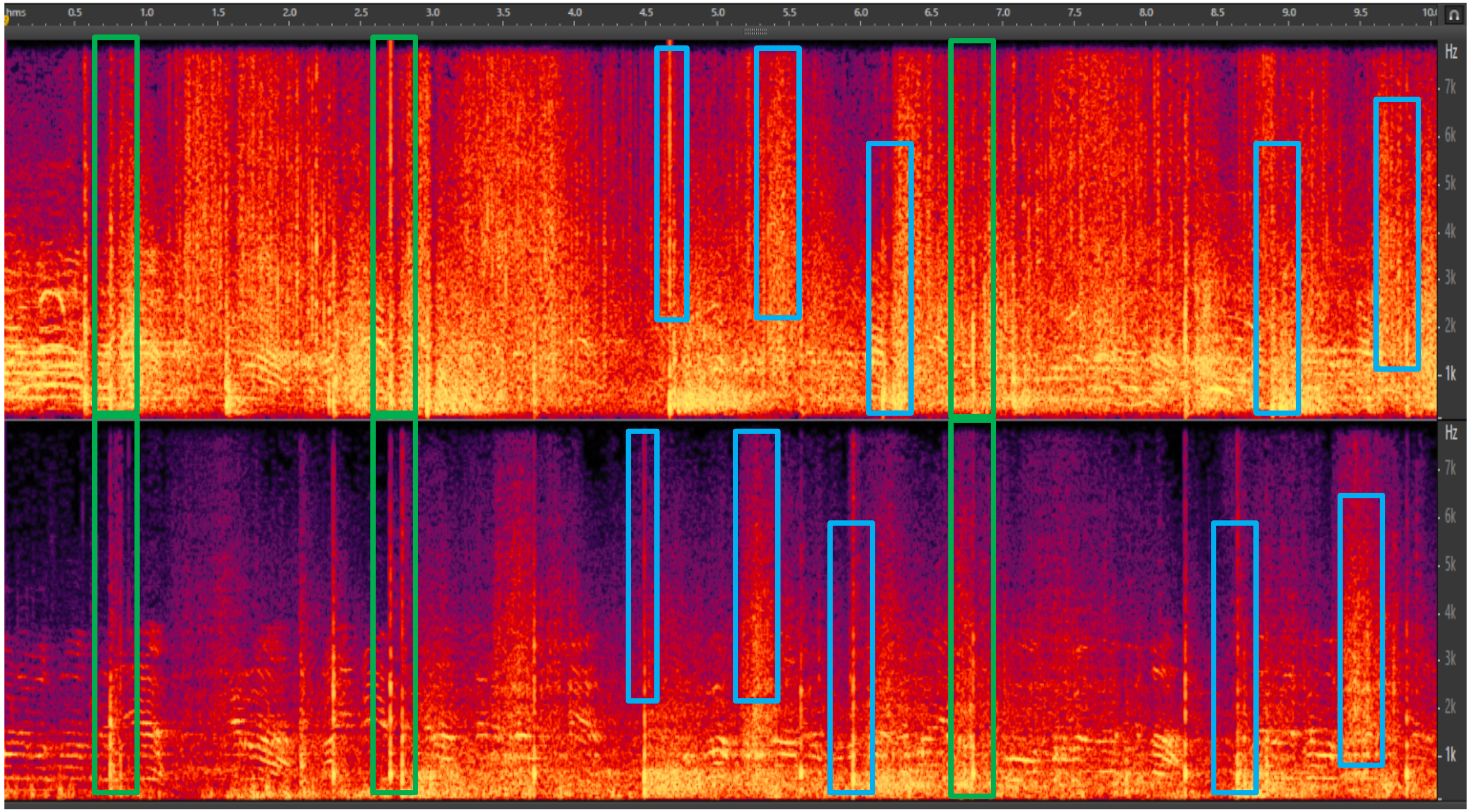
Spectrogram by STFT
(Short-Time-Fourier-Transform)

Method:
1. Multi-frame K-means
2. Auto-Encoder

Method:
1. Combintorial Hashing
2. Hough Transform

Select top mutual matches

Fingerprint example2

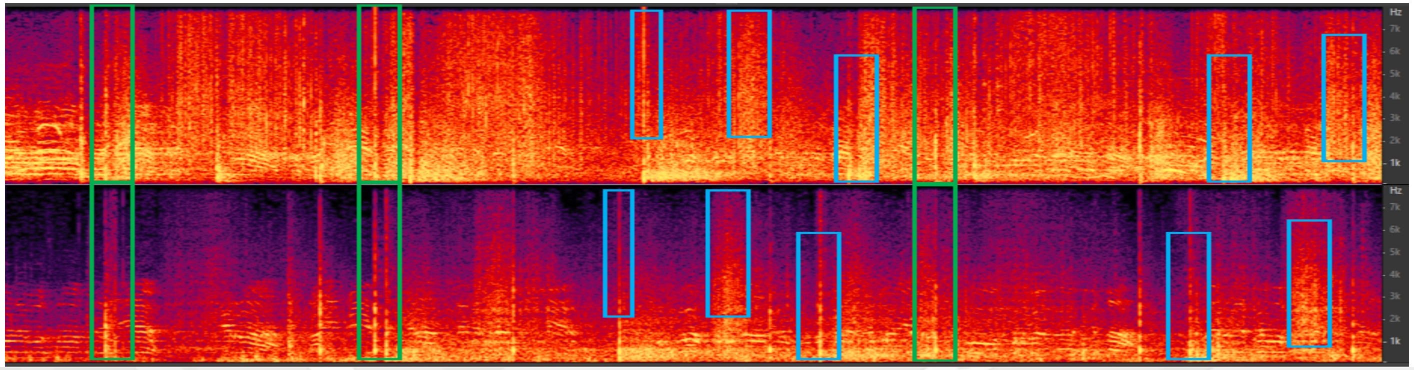


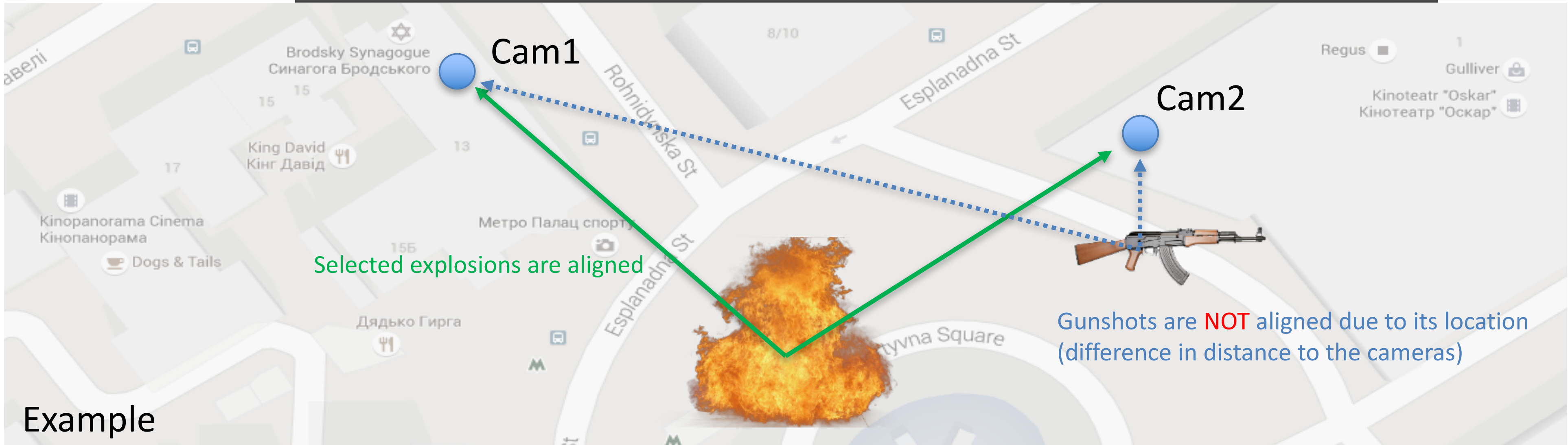
Alignment Approach

- Content-based automatic audio alignment
  - Match video pairs based on broadcast, sirens,explosions, gunshots
- Challenges (and opportunities): Multiple sound sources in the wild

Cam1/Video1

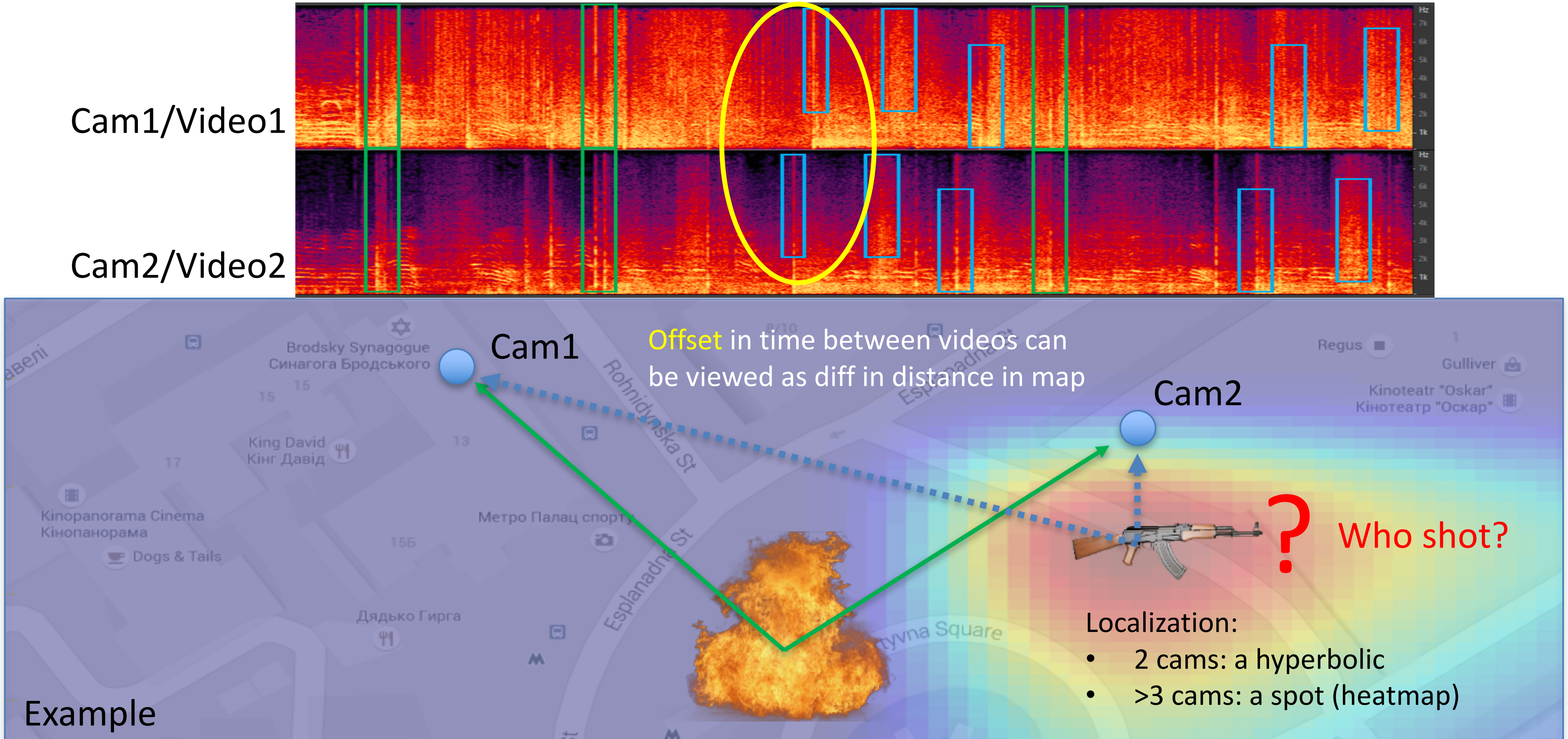
Cam2/Video2



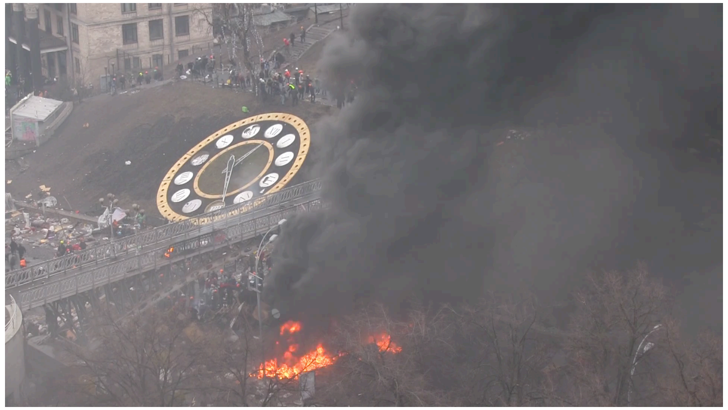


Future Work

- Automated multi-video matching
- Locate the hidden shooter: audio localization
  - Triangulation from multiple (>3) videos with geo-tags

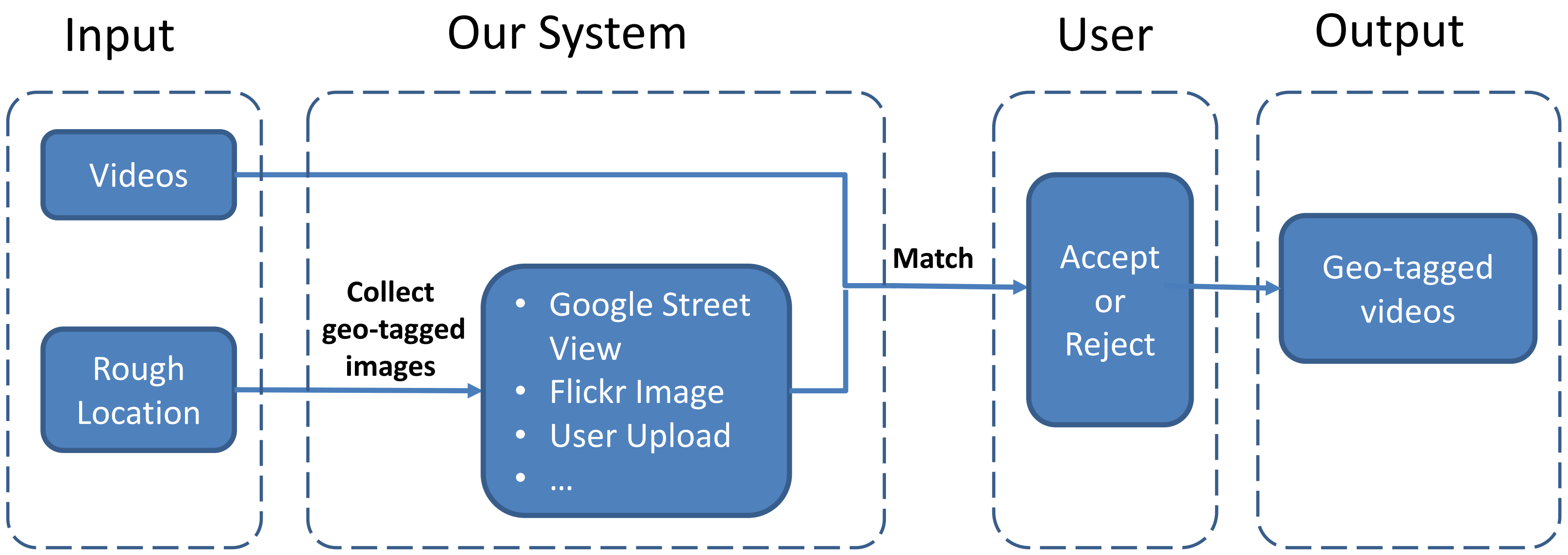


Where is this happening?



Video Localization System

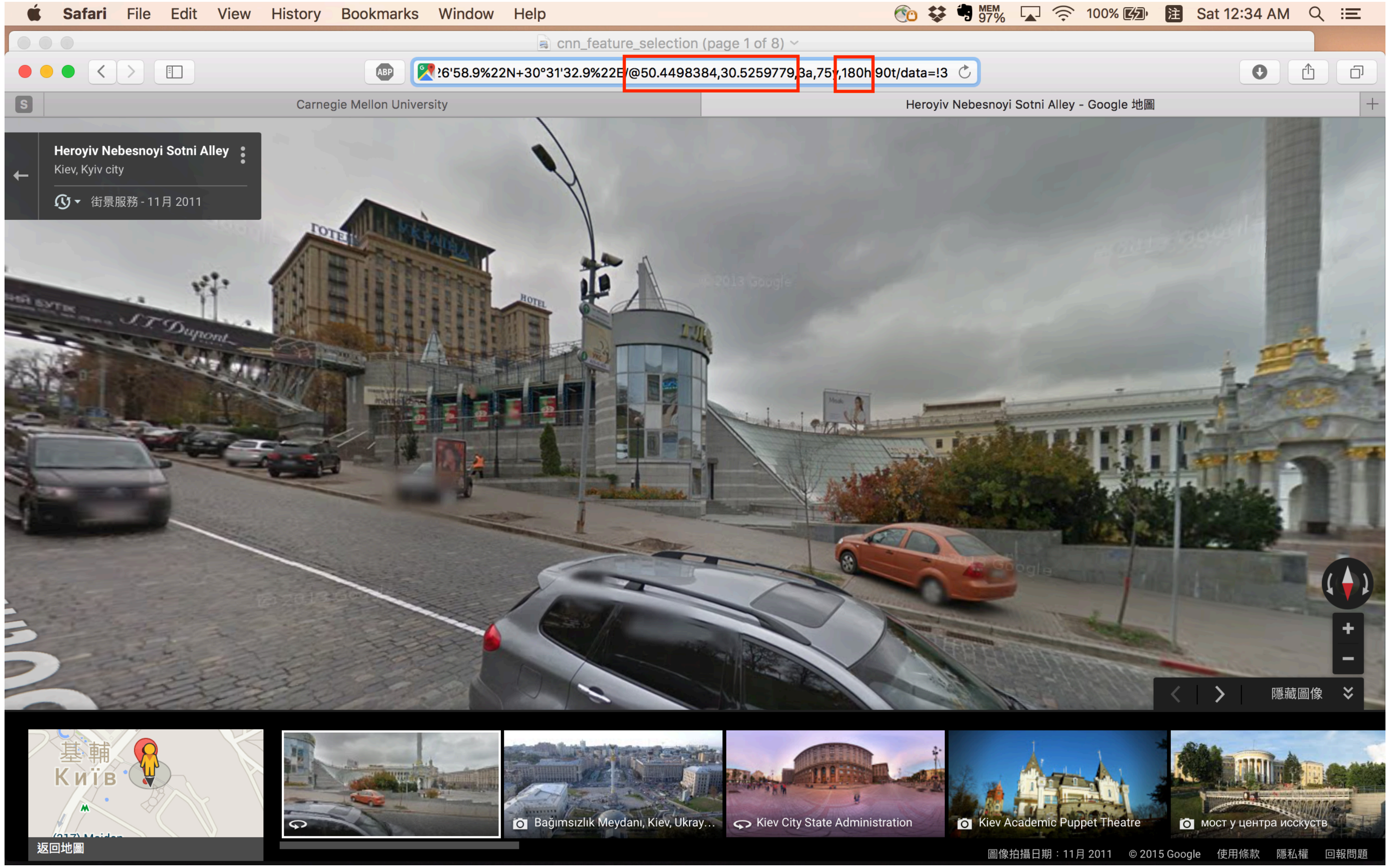
- Input is a set of available videos
  - Also need a rough location where the event took place (e.g. Maidan Square, Kiev)
- System automatically downloads other geotagged images from the area together with Street View images if available
- Matching event videos to known location images/videos resolves the geo-location problem
- User accepts/rejects system matches



Sources like StreetView and Flickr

StreetView provides location of camera, direction of view and elevation

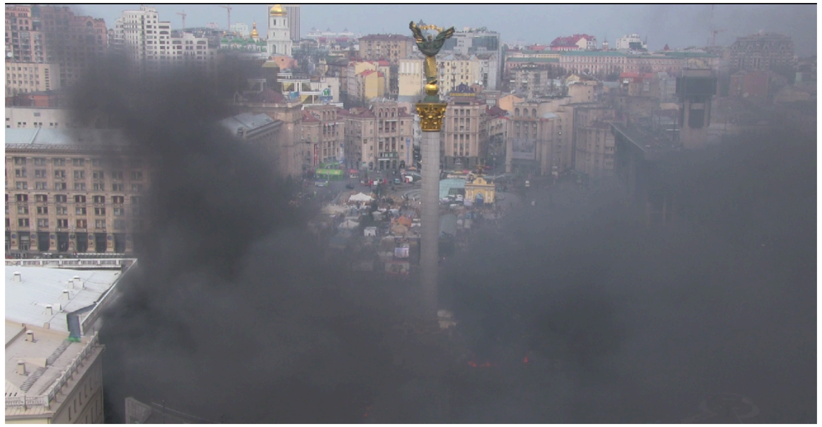
Flickr provides camera location and time (in file header)



Geo-tagged Image Samples

Example Geolocation Results

- Query Image
- Frame 2976 from video 00580.MTS



- Response Image
- Lat:50.4500   Lon:30.5241

Example Geolocation Results

- Query Image
- Frame 30600 from video 40_min_skyhundred.mp4

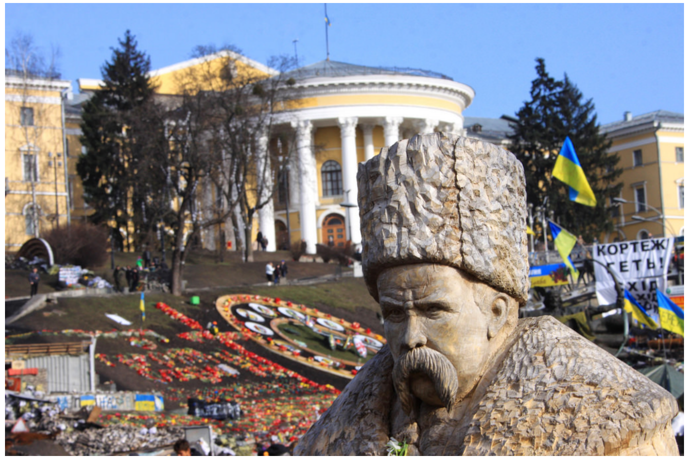
- Response Image
  Lat: 50.4479   Lon: 30.5294

Example Geolocation Results

- Query Image
- Frame 2580 from video

  250. ЄвроМайдан – EuroMaydan Facebook.mp4

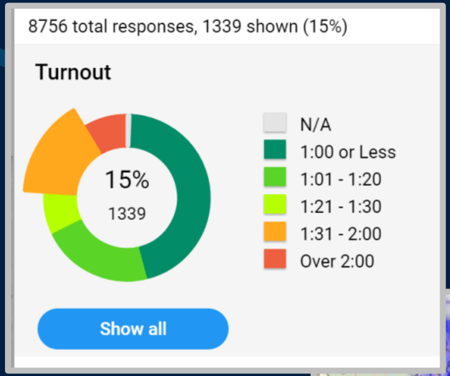
- Response Image (2NN)
- Lat: 50.4479 Lon: 30.5294

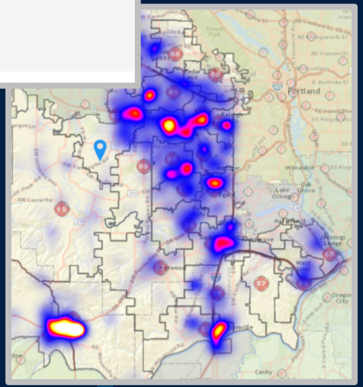


DATA COMPARISON CENTER

Unified Analysis Framework for Public Safety Data

WESTERN FIRE CHIEFS ASSOCIATION





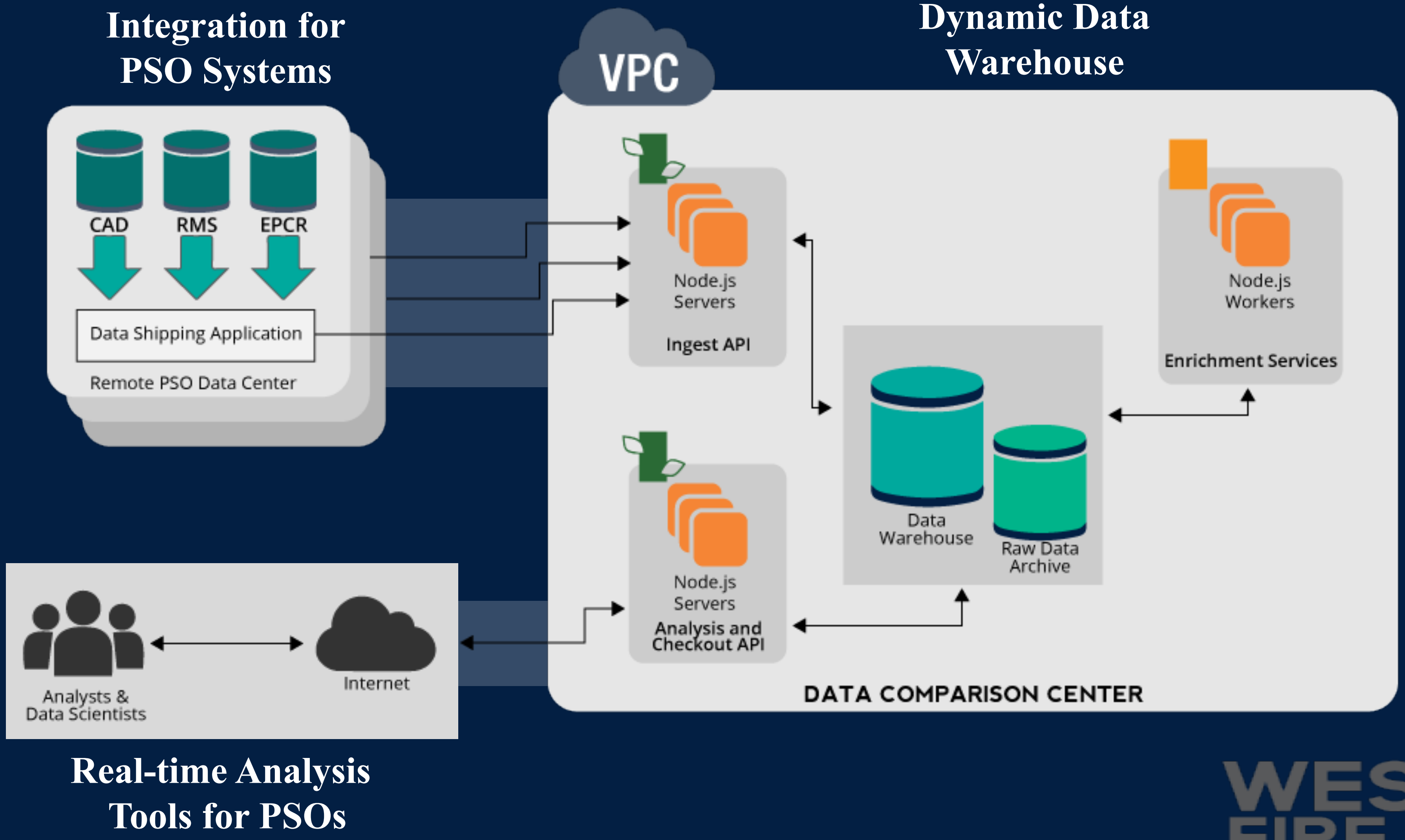
DATA DRIVEN DECISION MAKING

PROBLEM STATEMENT

The Fire Service has been slow to adopt data driven decision making

- PSOs collect large amounts of data but are limited in control and application of data
- Data and systems are single function/single jurisdiction
- Over-reliance on consultant-based, manual analysis
- Lack of a master data set of real-world data
- Limited and slow adoption of analytical tools such as big data and predictive analytics

WHAT WE ARE GOING TO DO



UNIQUE

- WFCA is a PSO-driven organization with a mission to lead the fire service as a community
- PSOs get data analysis capability on day 1 as they assist the greater fire service

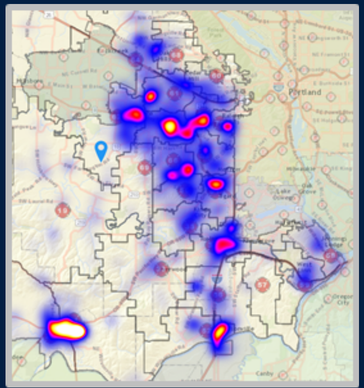
PROJECT OBJECTIVES

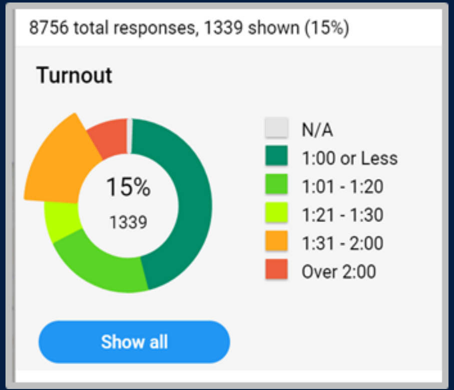
- Accelerate data driven decision making in the fire service

  - Provide near real-time analytics tools to PSOs
  - Create a ‘live’ dynamic master data set
  - Deploy framework and data tools
  - Create a community of mentor departments

Development Activities

- Provide near real-time analytics tools to PSOs
    - Internal Department Performance (reliability, outcomes, success rates)
    - Incident Metrics (types and locations, predictive analytics, target hazards and risk vs performance)
    - Comparative Analytics (predictive, comparison of approaches vs outcomes – staffing, resources)





Development Activities

- Create a ‘live’ dynamic master data set

Data schema (incoming raw, normalized performance data, incident metrics)

Data check-out API

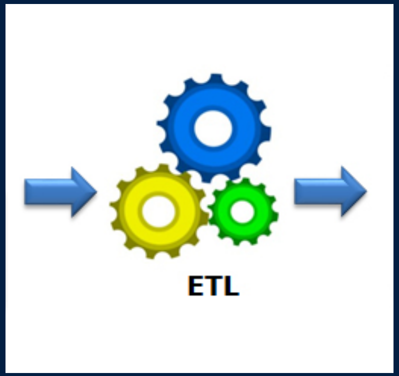
Development Activities

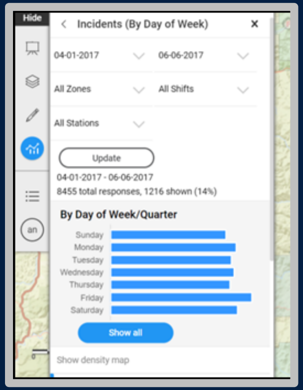
- Deploy framework and data tools

Simplified ETL and integration processes

Metrics visualization toolkit

Comparative web portal for normalized data reporting, comparison, and query





Development Activities

- Create a community of mentor departments

Working group led by lead departments in each state

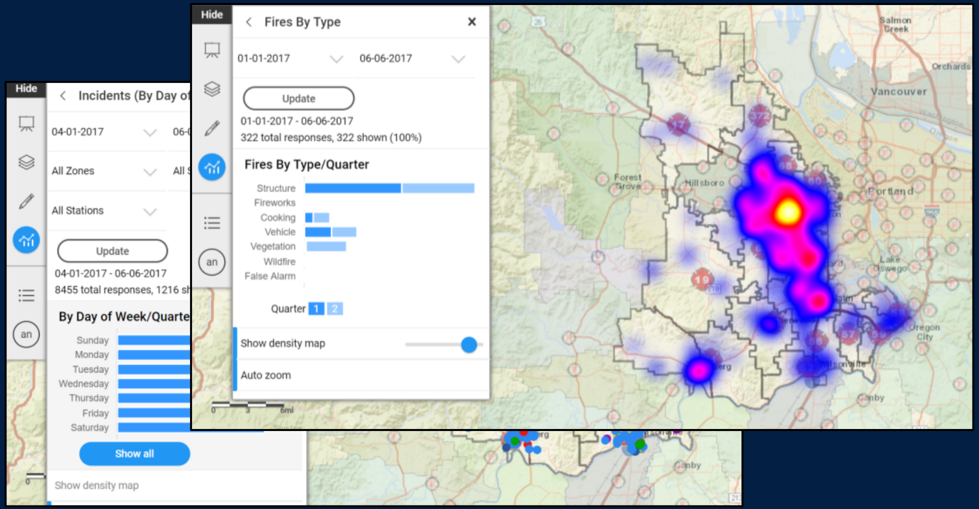
Education forums on applications of data driven decision making at each WFCA event

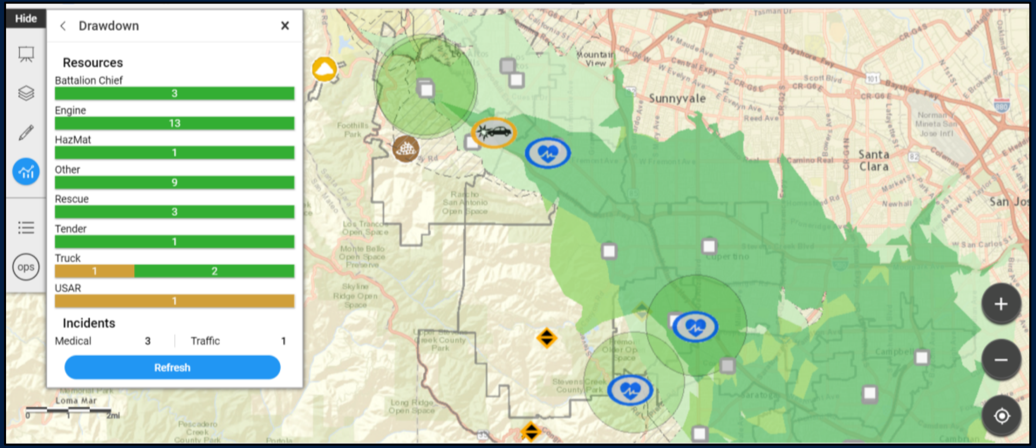
Vision Summits to identify ‘hard issues’ facing Fire Service and link to analytical efforts



IMPACTS

- PSOs get capability on day 1
  - Situational Awareness
  - Performance Assessment
  - Response Planning and Execution
- Improved joint operations across PSOs
- Community-wide data driven decisions
  - Expanding cadre PSOs
  - Wider access for research and analysis





MILESTONES

- Year 1
  - Onboard New PSOs
  - Ingest data into DCC
  - DCC ‘Data Checkout’ API
  - Year 1 Comparative Metrics Deployment
  - Year 1 Visioning Summit
- Year 2
  - Onboard Additional PSOs
  - Year 2 Comparative Metrics Deployment
  - Year 2 Visioning Summit

Towards Cognitive Assistant Systems for Emergency Response

Homa Alemzadeh, Jack Stankovic, Ronald Williams, Sarah Masud Preum

University of Virginia
ENGINEERING

Big EMS Data

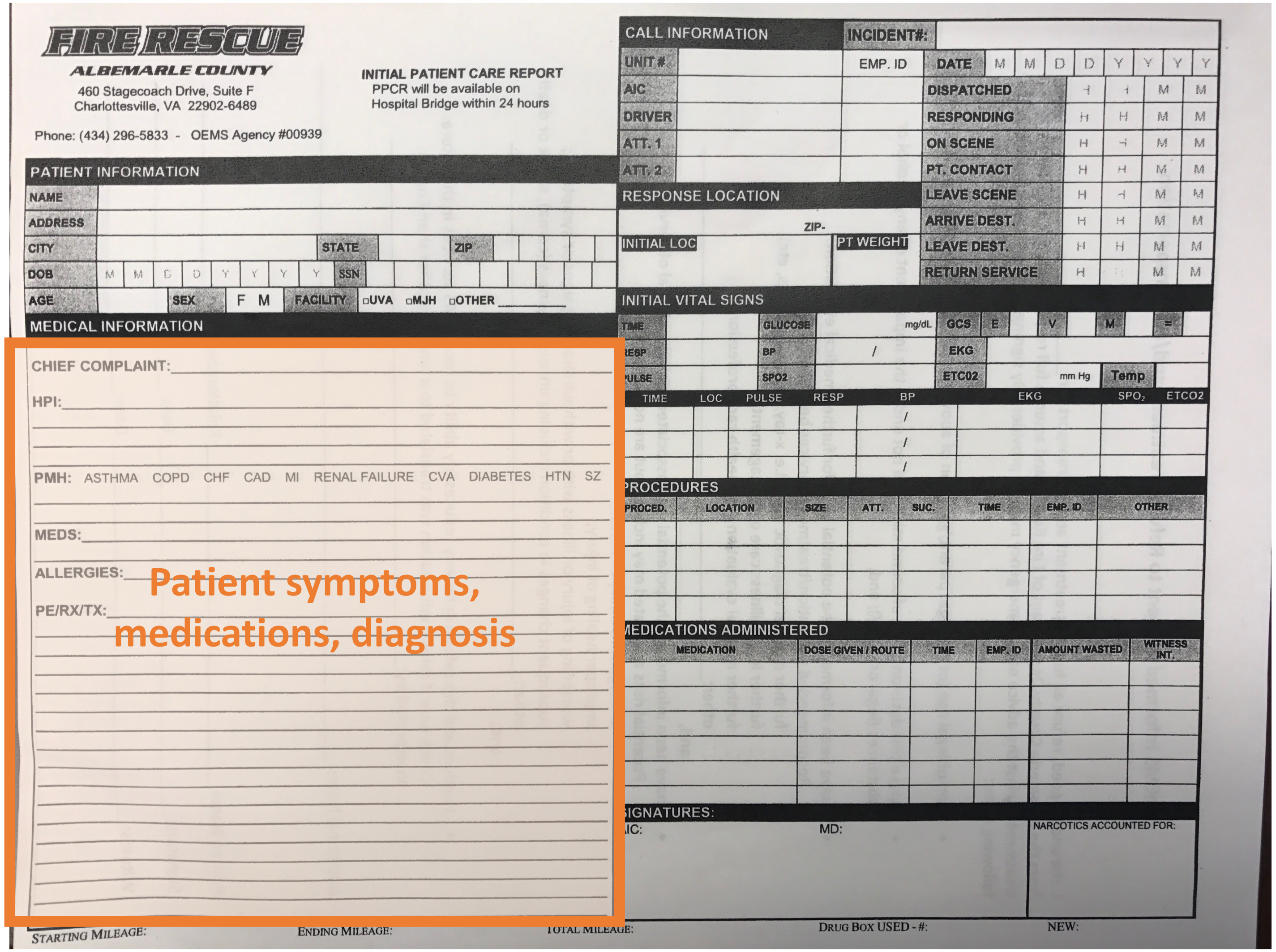
- Over 19,400 credentialed EMS agencies
- 826,000 credentialed EMS professionals
- Over 36,698,000 EMS events were responded to in 2009*

- **Variety of data sources at incident scene:**
    - Observations and communications with center/other responders
    - Sensor data from wearables, mobile, IoT devices
    - Physiological data from patient monitors/medical devices
    - Public data (e.g., protocol guidelines, audio, video, social media)

** G. Mears, et al., "2011 National EMS Assessment (Report No. DOT HS 811 723)," Washington, DC: National Highway Traffic Safety Administration.*

Challenges in Data Analytics

- **Manually reported**
  - Incomplete
  - Inaccurate
- **Unstructured format**
  - Textual reports
  - Voice communications
  - Voice calls
- **Cognitive overload**
- **Resiliency**


FIRE RESCUE
ALBEMARLE COUNTY
460 Stagecoach Drive, Suite F
Charlottesville, VA 22902-6489
Phone: (434) 296-5833 - OEMS Agency #00939

INITIAL PATIENT CARE REPORT
PPCR will be available on
Hospital Bridge within 24 hours

CALL INFORMATION | INCIDENT#:
UNIT # | EMP. ID | DATE M M D D Y Y Y Y
AIC | DISPATCHED
DRIVER | RESPONDING
ATT. 1 | ON SCENE
ATT. 2 | PT. CONTACT
LEAVE SCENE
ARRIVE DEST.
LEAVE DEST.
RETURN SERVICE

PATIENT INFORMATION
NAME
ADDRESS
CITY | STATE | ZIP
DOB M M D D Y Y Y Y | SSN
AGE | SEX F M | FACILITY □UVA □MJH □OTHER

RESPONSE LOCATION
ZIP-
INITIAL LOC | PT WEIGHT

INITIAL VITAL SIGNS
TIME | GLUCOSE mg/dL | GCS E V M =
RESP | BP / | EKG
PULSE | SPO2 | ETC02 mm Hg | Temp
TIME | LOC | PULSE | RESP | BP | EKG | SPO_2 | ETCO2

MEDICAL INFORMATION
CHIEF COMPLAINT:
HPI:
PMH: ASTHMA COPD CHF CAD MI RENAL FAILURE CVA DIABETES HTN SZ
MEDS:
ALLERGIES:
PE/RX/TX:

PROCEDURES
PROCED. | LOCATION | SIZE | ATT. | SUC. | TIME | EMP. ID | OTHER

MEDICATIONS ADMINISTERED
MEDICATION | DOSE GIVEN / ROUTE | TIME | EMP. ID | AMOUNT WASTED | WITNESS INT.

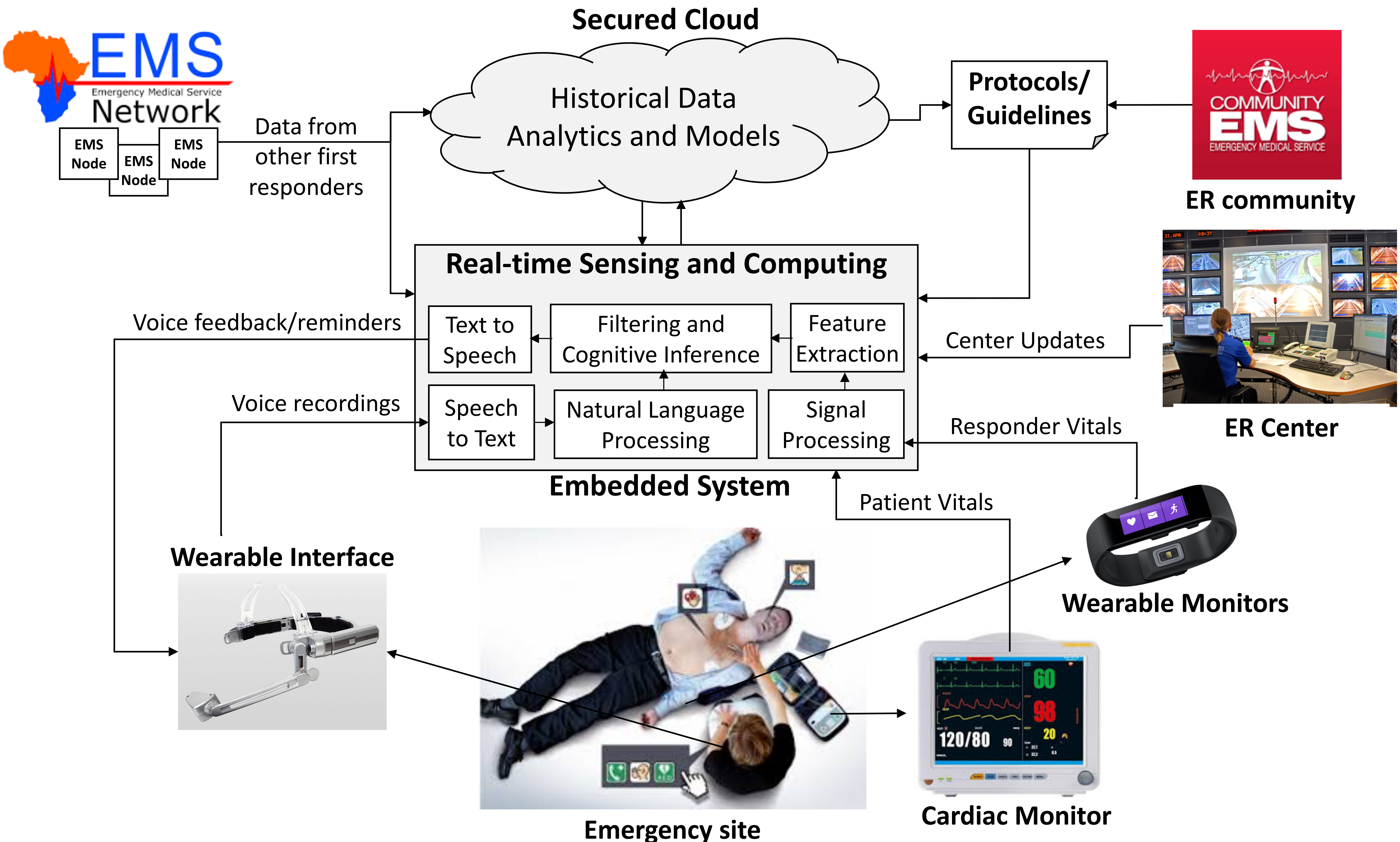
SIGNATURES:
AIC:
MD:
NARCOTICS ACCOUNTED FOR:

STARTING MILEAGE: | ENDING MILEAGE: | TOTAL MILEAGE: | DRUG BOX USED - #: | NEW:

Cognitive Assistant Systems for EMS

- **Resilient data analytics**
- Automated *collection* and *analysis* of data from incident scene
- Filtering and aggregation of in-situ/public data
- Providing dynamic data-driven feedback on effective response actions

- **Anytime real-time sensing and computing**
- Embedded system architecture for real-time data analytics
- Dynamic reconfiguration for resiliency



Secured Cloud
Historical Data Analytics and Models
EMS
Emergency Medical Service
Network
EMS Node
EMS Node
EMS Node
Data from other first responders
Protocols/ Guidelines
COMMUNITY EMS
EMERGENCY MEDICAL SERVICE
ER community
Real-time Sensing and Computing
Text to Speech
Filtering and Cognitive Inference
Feature Extraction
Speech to Text
Natural Language Processing
Signal Processing
Embedded System
Voice feedback/reminders
Voice recordings
Center Updates
Responder Vitals
ER Center
Patient Vitals
Wearable Interface
Wearable Monitors
120/80
60
98
20
Cardiac Monitor
Emergency site

Public Safety Partners

VIRGINIA DEPARTMENT OF HEALTH

Protecting You and Your Environment

www.vdh.virginia.gov

Office of Emergency Medical Services

Thomas Jefferson EMS Council (TJEMS)

North Garden Fire Department

Stat Engine

A real-time open source data analytics and visualization tool for Public Safety Organizations

Tyler Garner

Software Architect / Co-Founder @ Prominent Edge

The Problem

- PSOs **struggle to quickly and effectively** analyze data to answer even the most basic questions about the service they provide

  - Why?
    - Lack the tools
    - Lack the technical expertise to keep up with the fast paced technology horizon
    - Limited budget for personnel and software

- PSOs operate independently of one another yet have similar challenges

The Goal

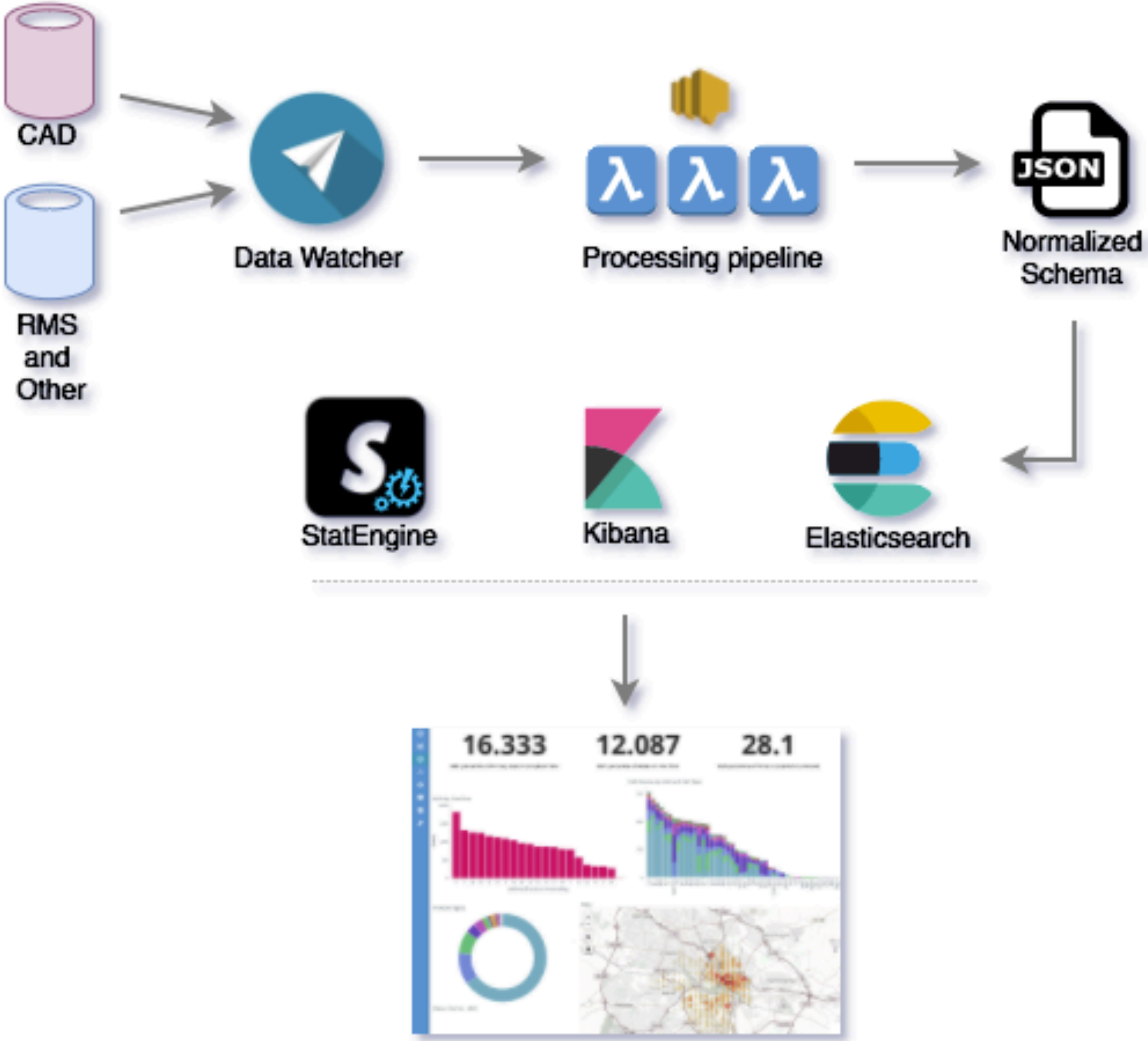
- Reduce the barrier of entry for PSOs to leverage proven, production-ready open source analytics platforms.

Our Approach

- Stand on the shoulders of giants to provide best of breed open source solutions
  - Used by: Facebook, Uber, Netflix, Walmart, Microsoft
  - **Allows us to focus on reducing implementation complexity and tailoring the platform to needs of PSOs**

Our Approach

- Open source technology:
  - Reduces development costs
  - Maximizes transparency
  - Maximizes flexibility
  - Maximizes return on investment
  - Reduces risk
  - Can still be commercially supported
  - Allows cost sharing for PSOs
  - Eliminates vendor lock in


CAD
RMS and Other
Data Watcher
Processing pipeline
JSON
Normalized Schema
StatEngine
Kibana
Elasticsearch
16.333
12.087
28.1

Objectives

- Low/no-cost, scalable, browser-based analytics platform
- Automate installation and configuration of the infrastructure
- Reduce complexity involved in extracting, transforming and loading data
- Deploy and maintain a highly scalable, secure cloud instance of the platform
- Develop re-usable schemas
- Author training material
- Expand the open source community

Milestones

- Continuous delivery making StatEngine available to PSO partners ASAP and improve the offerings throughout the life of the project
- 4 major releases: December 2017, May 2018, November 2018, May 2019

Partner Engagement

- Identify analytical needs for PSOs
- Testing and user feedback
- Validation of schemas
- Validate automated installations
- Validate documentation

Expected Impact

- Significantly accelerate wide scale PSO adoption of data analytics by simplifying the installation, integration, and exploitation of these powerful tools, and offering PSOs a cost-effective solution to the data analytics challenge

PSCR

2017

PUBLIC SAFETY BROADBAND
STAKEHOLDER MEETING

Public Safety Communications Security

Update on current projects from the PSCR Security team

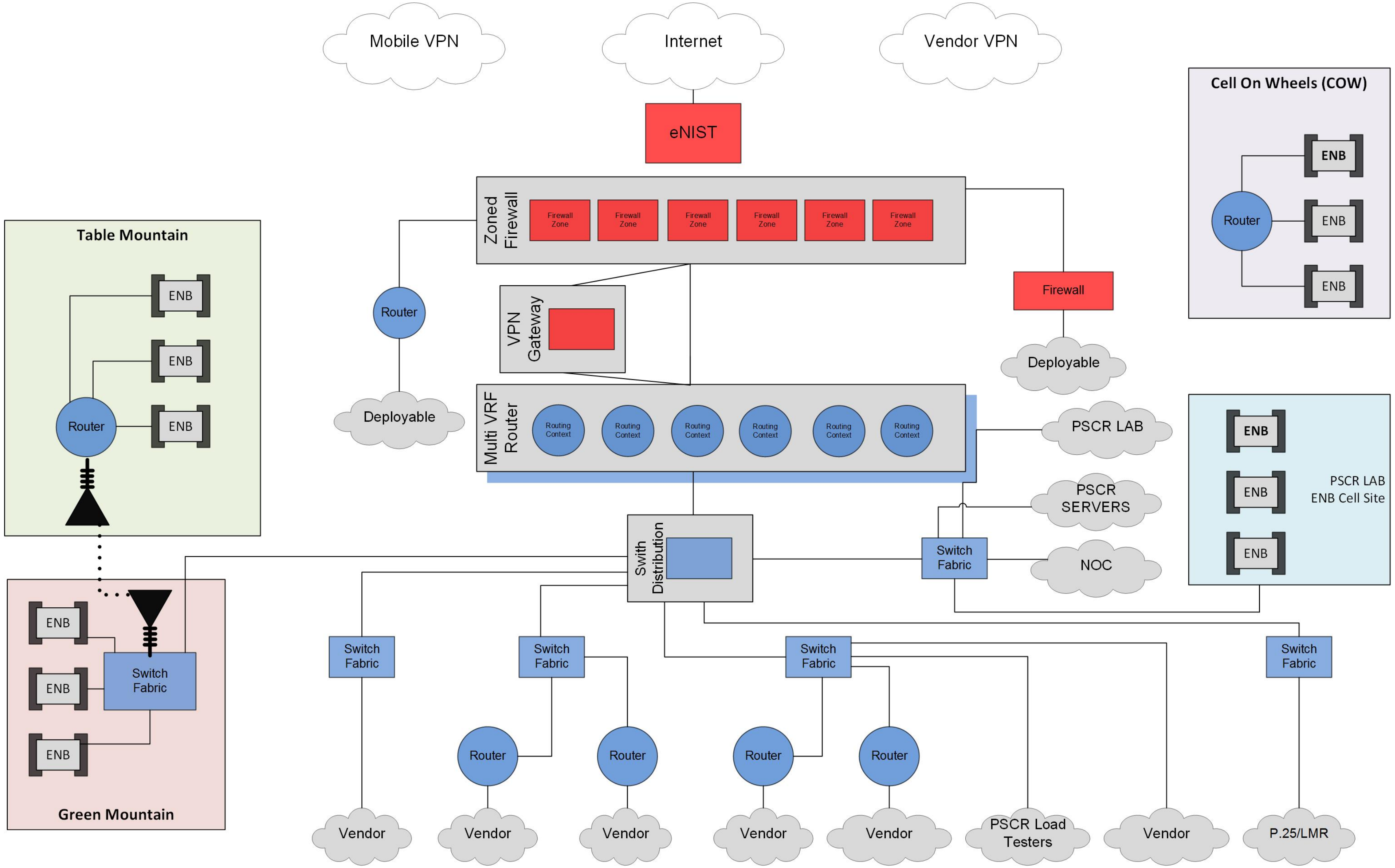
#PSCR2017

Speakers

- **John Beltz,** PSCR Security
- **Jeff Cichonski,** NIST Information Technology Laboratory (ITL)/PSCR
- **Michael Ogata,** NIST Information Technology Laboratory (ITL)/PSCR
- **Gema Howell,** NIST Information Technology Laboratory (ITL)/PSCR

PSCR

PSCR Demonstration Network



PSCR Demonstration Network – Security Services

- Splunk SIEM
- Tenable Network Scanning
- Secure SSL VPN Remote Access (Multi-Factor Authentication)
- Intrusion Detection Service
- Baseline Secure Configurations
- Central Patch Management
- Central Antivirus
- Active Directory Group Policy
- Web Content Filtering
- Automated Account Management
- RADIUS Authentication
- Asset Inventory
- Secure Deployment Process
- User Rules of Behavior Policy
- Equipment Removal Policy
- Data Management Policy

PSCR

PSCR Security Services

1. Maintain Security of our Demonstration Network
2. Provide Security overlay for all PSCR research
3. Security specific research projects

PSCR

PSCR Security Sessions

- **Tuesday 4-5 pm**: A tutorial on PSCR's research into Identity Credential and Access Management (ICAM) and Mobile Single Sign-on (SSO)
- **Tuesday 5-6 pm:** Join the PSCR Security Community: Q&A session on topics of your choosing within PSCR security research
  - Don't forget to take the Poll!
- **PSCR Security Demo Table**
  - Day 1 & 3: Public Safety Security; Conversation with the PSCR Security Team & Demo of Malicious Malware and Prevention for Public Safety Devices
  - Day 2: Public Safety Identity Management; Demo of Mobile Single Sign-On (SSO) and Meet the Research Team & Vendors

PSCR

PSCR

2017

PUBLIC SAFETY BROADBAND STAKEHOLDER MEETING

NCCoE Mobile Single Sign-on

Achieving a secure, reliable, usable SSO solution for Public Safety and First Responders

#PSCR2017

Mobile SSO for Public Safety and First Responders

- ICAM: Identity Credential & Access Management – set of security tools that will allow public safety to enable the right individual to access the right information for the right reason

- SSO: Single Sign-on - a session and user authentication service that permits a user to use one set of login credentials (e.g., name and password) to access multiple applications

PSCR

Mobile SSO for Public Safety and First Responders

Project Goal

- Demonstrate strong and reliable multi-factor authentication and SSO using standards-based, commercially available technology to enable rapid and secure data access in the Public Safety operational environment

- This project will result in a publicly available NIST Cybersecurity Practice Guide that will enable Public Safety organizations to implement multifactor authentication and mobile application SSO in their own environments

PSCR

Partnership with the NCCoE

- National Cybersecurity Center of Excellence (NCCoE)
- part of the National Institute of Standards and Technology (NIST)
- a collaborative hub where industry organizations, government agencies, and academic institutions work together to address businesses’ most pressing cybersecurity challenges
- Paul Grassi of NIST Applied Research Division and Bill Fisher of NCCoE as Researcher Leads

NCCoE Project Community of Interest

NCCoE brings in Industry experts to design and build the Reference Design:

Mobile SSO Technology Vendor Build Team:

Value to Public Safety Personnel

Efficiency

Save time and efficiency by reducing the need to authenticate to multiple mobile applications individually

Simplicity

Allowing a user to manage less username/password credentials

Flexibility

Multiple options for multifactor authentication

Value to Public Safety Organizations

Modern

Solution takes advantage of the latest commercially available mobile technology and best practices

Interoperable

Technology uses standard protocols and flows to improve interoperability

Security

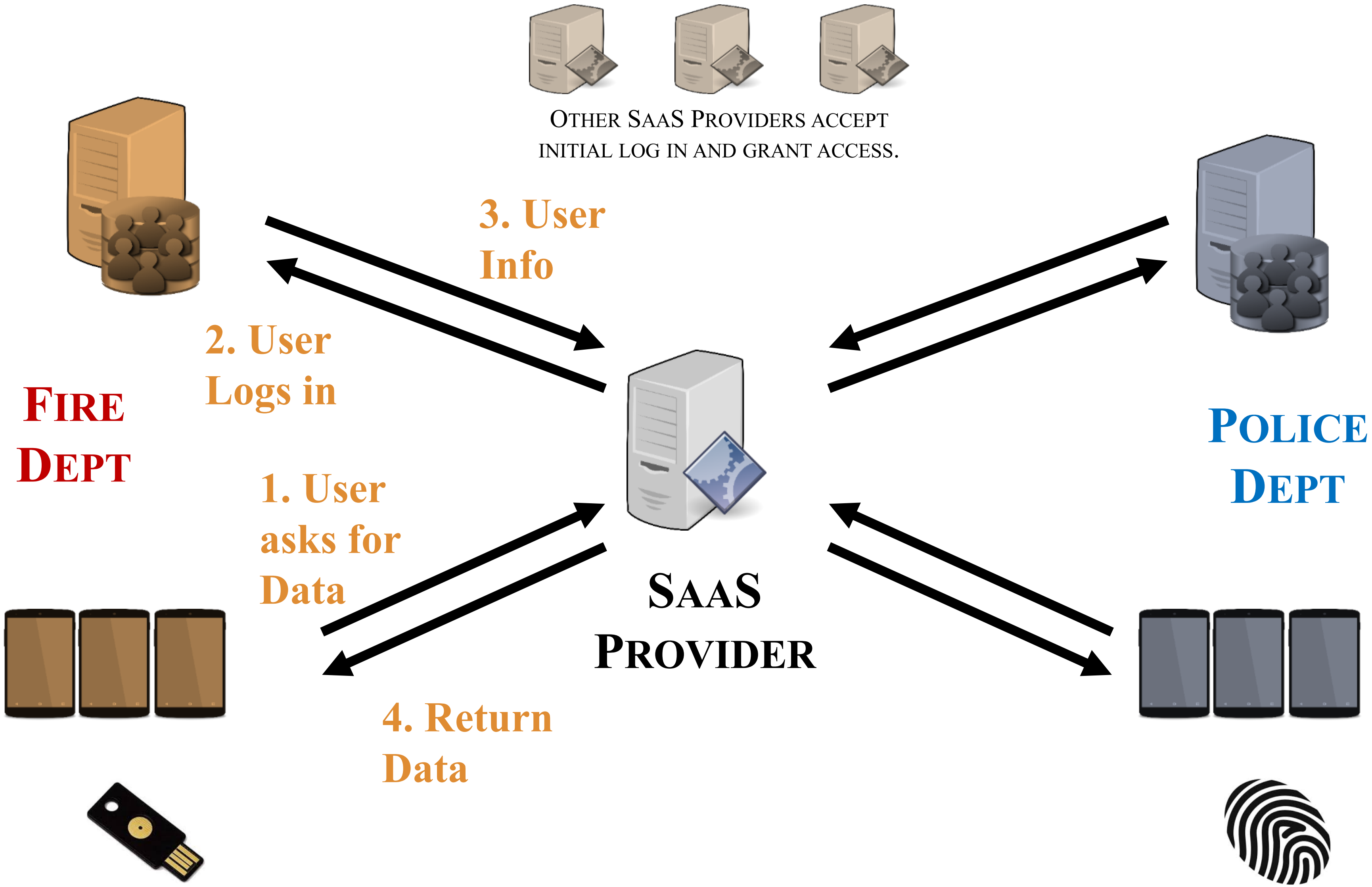
Architecture designed with security characteristics as core requirement

Cost Savings

Reduction in costs - NCCoE delivers requirements, architecture and a reference implementation

PSCR

Simple SSO Scenario



PSCR

Over the Air Updates for UICC

Jeff Cichonski

NIST, Applied Cybersecurity Division

IT Security Engineer

PSCR

2017

PUBLIC SAFETY BROADBAND STAKEHOLDER MEETING

#PSCR2017

SIM Cards and Over the Air Updates

- UICC known as a 'SIM Card' is the security anchor for the LTE Network.
- Store sensitive cryptographic keys used for authentication and to protect communication
- Public Safety specific features in LTE may increase the use of Over the Air (OTA) updates to enable features such as Group and Device to Device Communications (e.g., Proximity Services).
- Updates to the SIM card can occur over the air

PSCR

Background

- The 3GPP TS 33.303 Technical Specification Group Services and System Aspects; Proximity-based Services (ProSe); Security Aspects provides several areas of interest for further applied research.
- This project aims to explore section 5.3.3.1 that states;
  - Configuration information relating to the ProSe enabled device is stored in the UICC and this information may need to be updated using LTE's existing OTA mechanism.
- The LTE OTA mechanism is an implemented and used method of updating UICC information remotely.
- This focus allows for applied security research and testing on a critical function that 'might' be used to enable Public safety specific features.

PSCR

Benefit to Public Safety

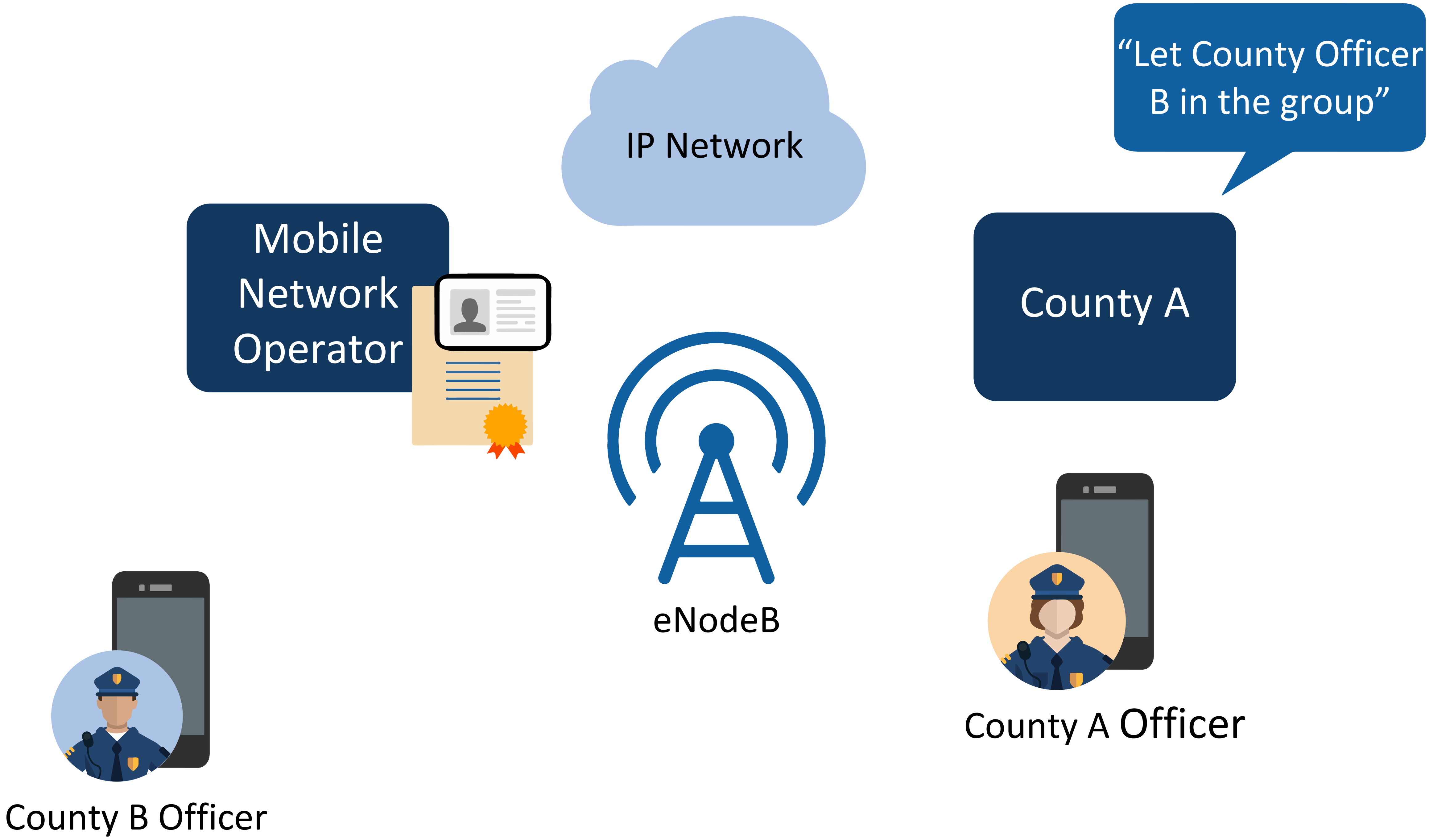
- Gain organizational expertise about critical UICC OTA update function
- Prevent malicious UICC updates to help protect public safety devices.
- Educate Public Safety Community about how UICC OTA updates are used to support their missions.
- Present threats relevant in public safety scenarios.
- Provide guidance for updating the UICC over the air securely.

PSCR

Public Safety Example Use Case

- An Officer from neighboring County B arrives on-scene to assist County A .
- The officer from County B needs to communicate in a talk group with Public Safety Personnel from County A seamlessly.

PSCR



"Let County Officer B in the group"
IP Network
Mobile Network Operator
County A
eNodeB
County A Officer
County B Officer

Potential Threat Examples

- If security is flawed on UICC OTA update function, these are some potential negative outcomes being explored in this research
- Potential security implications if UICC OTA update function not implemented correctly
  - Loss or theft of device
  - Cross-contamination of assets within SIM
  - Disclosure of sensitive information on SIM
  - Unauthorized modification of data
  - Unauthorized user granted access to talk groups
  - Malicious updates to SIM
  - Corruption of SIM

PSCR

Project Objectives

Standards, Specifications, and Vendor Documentation → Use Cases for OTA Updates for Public Safety Scenarios → Threat Model for OTA Updates and UICC → Security Guidance & Best Practices

PSCR

Challenges to Research Objectives

- Lack of ProSe enabled devices for UICC OTA updates with Device to Device specific entries.
- Many of the components needed for this work are not available.
  - UICC OTA for ProSe specific updates not available for evaluation.
  - Lack of Mission Critical deployments exists for evaluation of when the UICC needs to be updated over the air.

PSCR

Benefits

- Gain organizational expertise about critical UICC OTA function process and it's dependency and/or interconnection with MCV
- Inform Public Safety Community of potential threats and implications to their mission
- Validation that ProSe can leverage current implementations of UICC OTA updates in a secure manner
- Security Guidance that can influence industry implementation and use of the UICC OTA update process
- PSCR may find areas of weakness or improvements that can be made through Grants and Prize Challenges based on outcomes of this research

PSCR

THE UICC Security TEAM

Jeffrey Cichonski

NIST – Gaithersburg, MD

Jeffrey.Cichonski@nist.gov

Scott Ledgerwood

NIST/PSCR – Boulder, CO

Scott.Ledgerwood@nist.gov

Michael Bartock

NIST – Gaithersburg, MD

Michael.Bartock@nist.gov

PSCR

Mobile Application Security

Michael Ogata

NIST, Applied Cybersecurity Division

IT Security Engineer

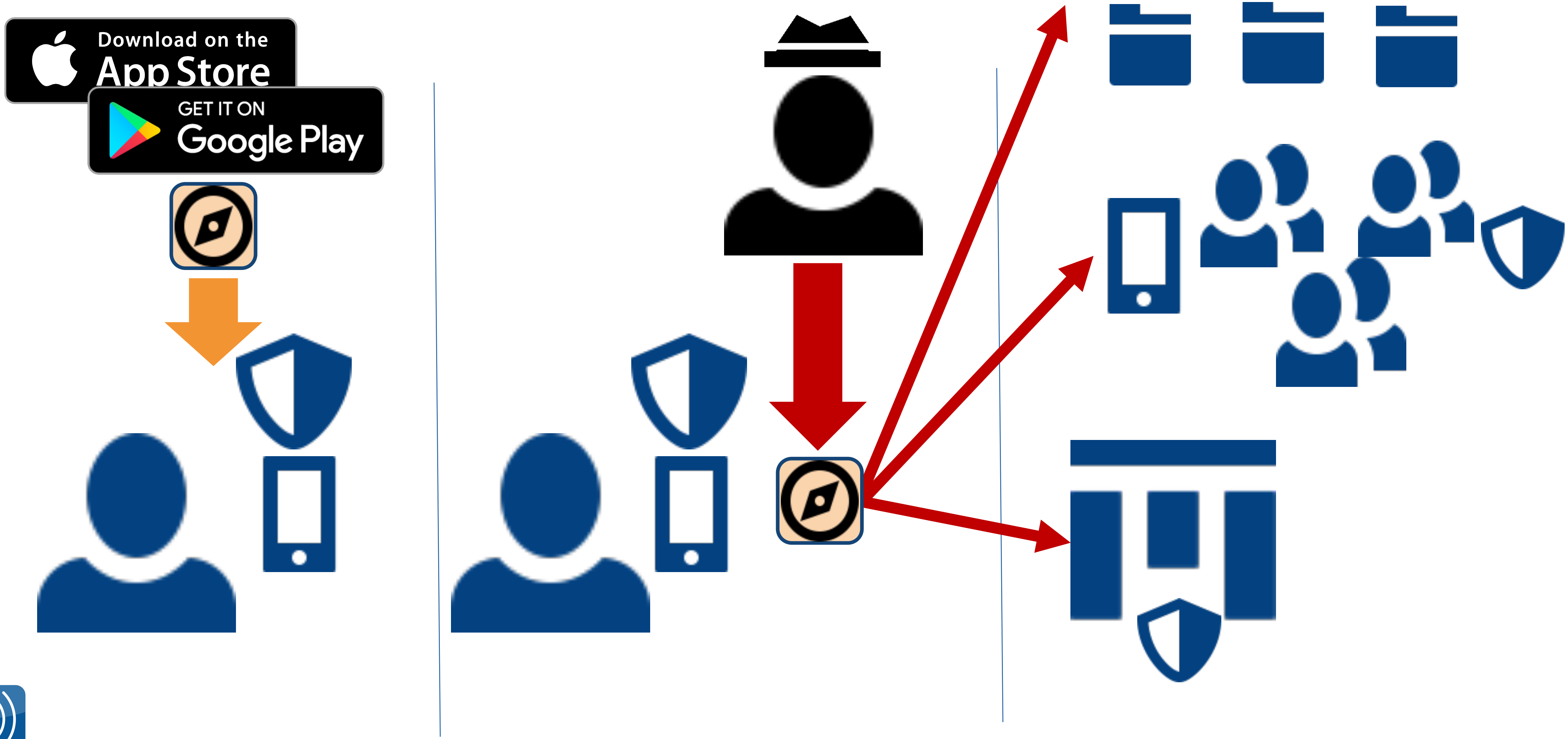
PSCR

2017

PUBLIC SAFETY BROADBAND
STAKEHOLDER MEETING

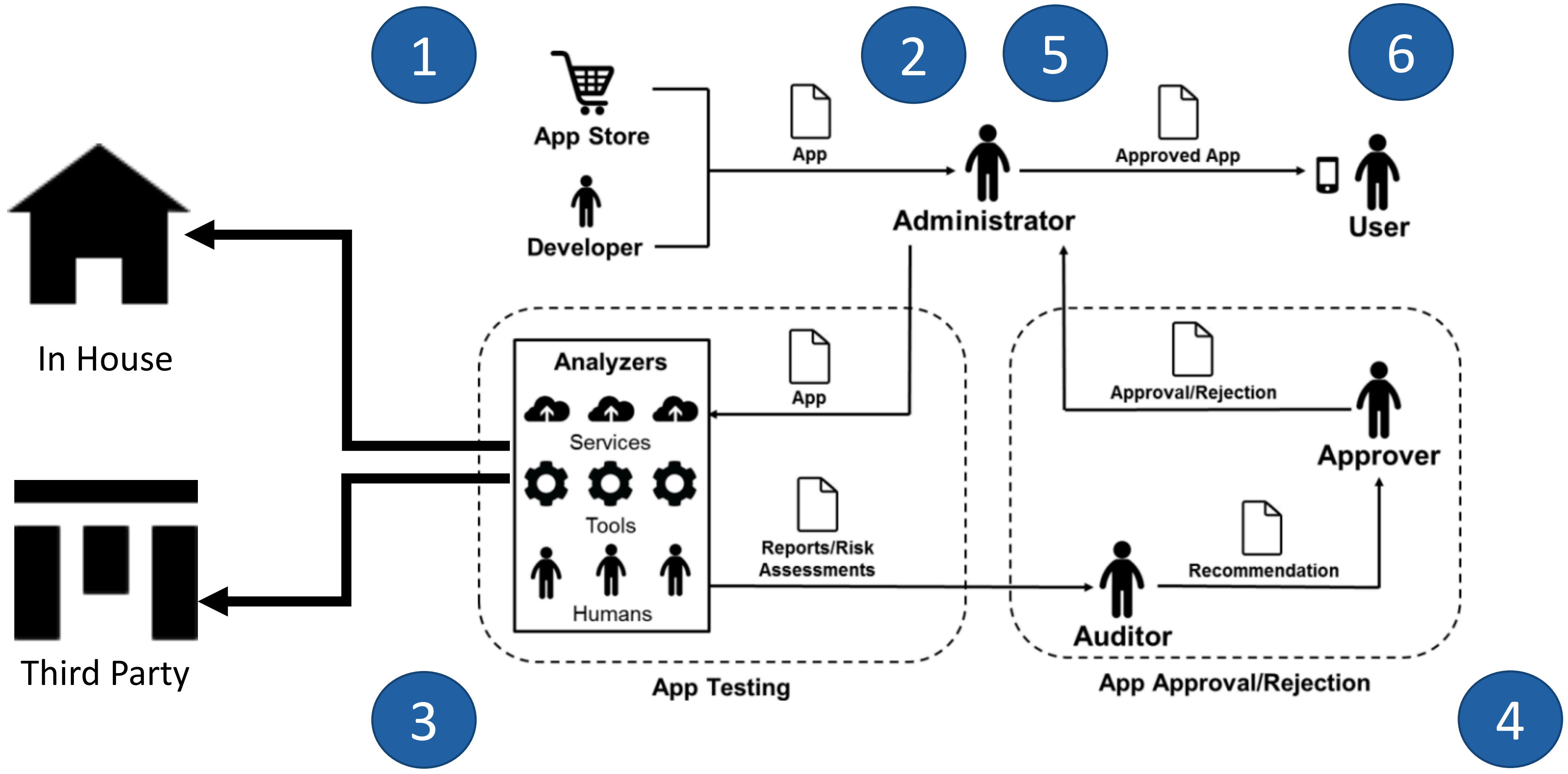
#PSCR2017

A Vulnerable App Can Endanger the Entire Enterprise



Officer Smith wants to use a mobile application on his PSBN enabled device. The application looks reputable, and he sees that it is available in default public app store. The app store dutifully displays the proper information label description. After downloading and using it for a few weeks, it is determined that this application had been sending personal information from the device to an unknown server in a different country. The Police department must now commit a full investigation to determine what, if any, information was exposed to unknown 3rd parties.

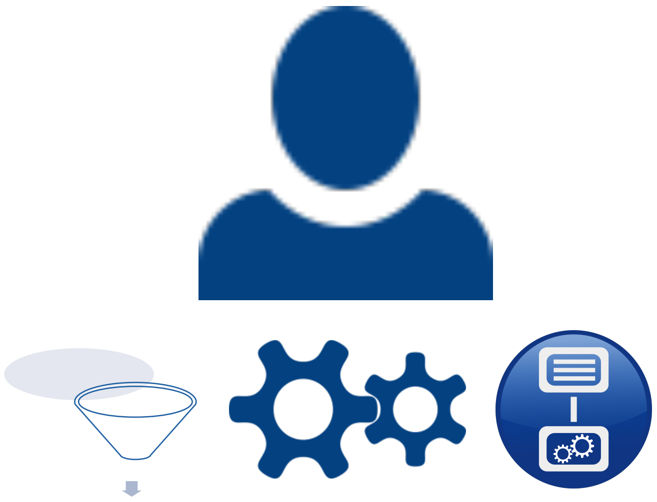
Application Vetting as Process

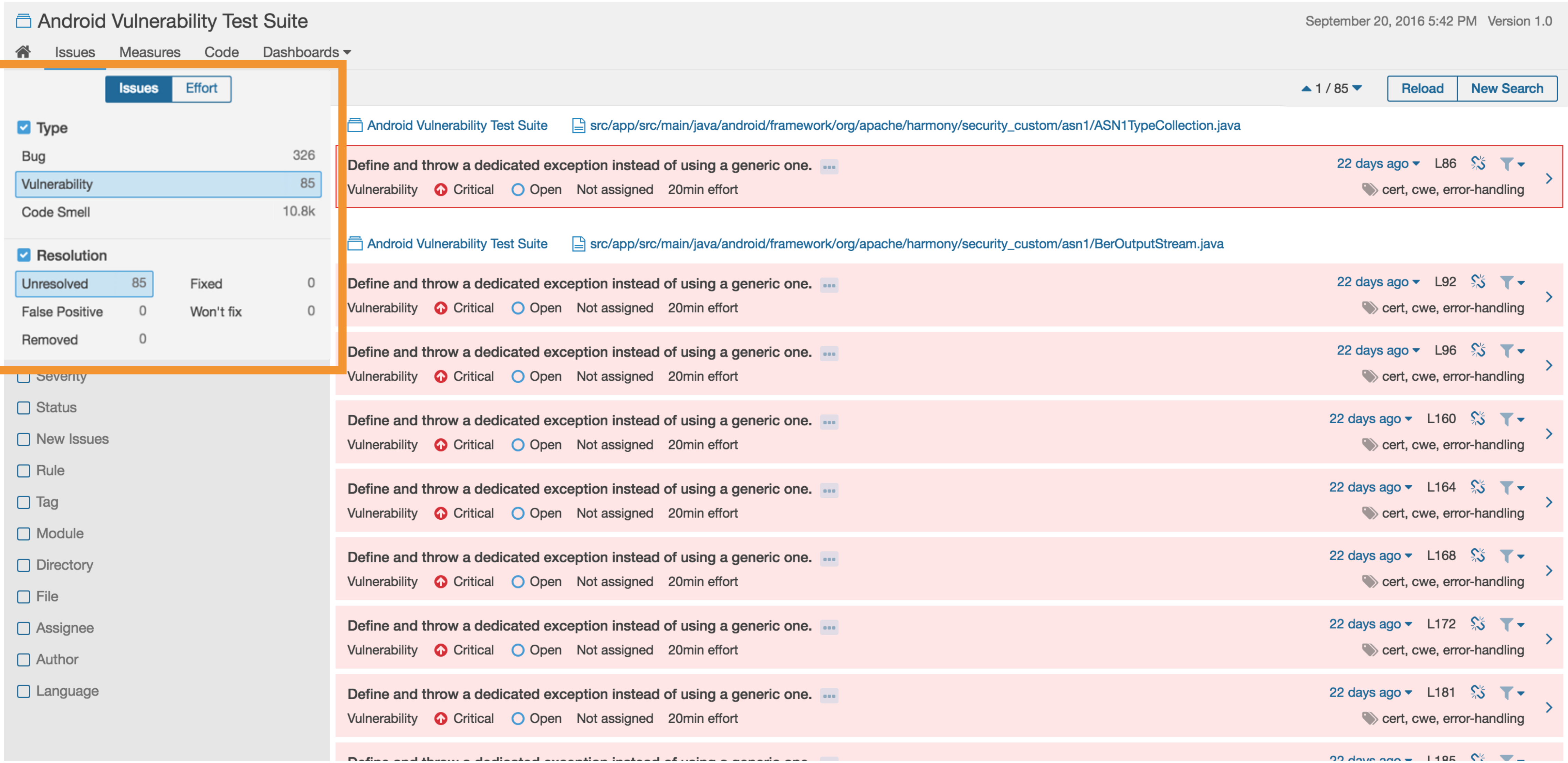


PSCR

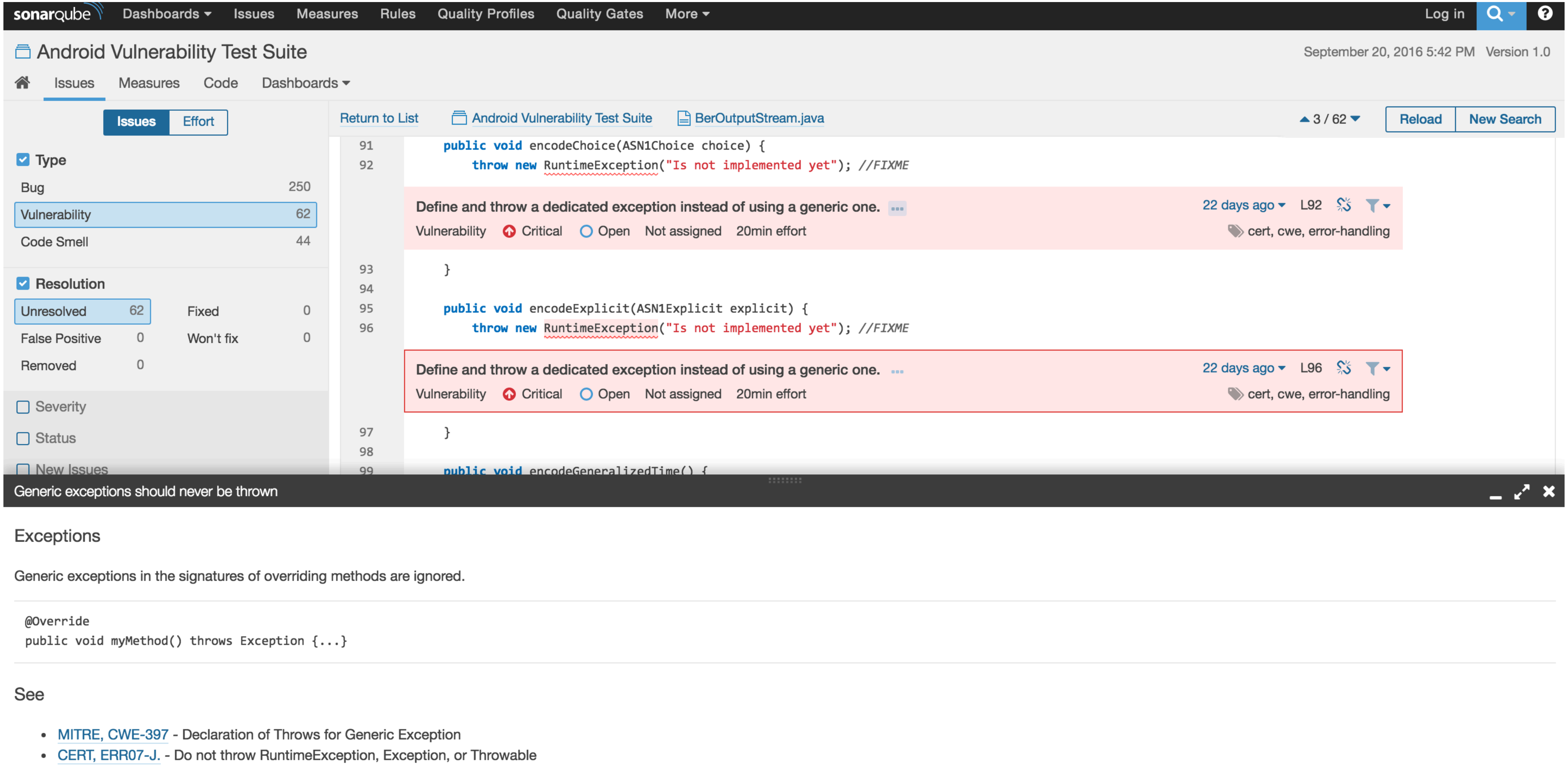
What is the Benefit to Public Safety?

- Increased trust in mobility as a platform
- Increased protection from threats
- Access to modern mobility functionality




Android Vulnerability Test Suite
September 20, 2016 5:42 PM Version 1.0
Issues
Measures
Code
Dashboards
Issues
Effort
1 / 85
Reload
New Search
Type
Bug 326
Vulnerability 85
Code Smell 10.8k
Resolution
Unresolved 85
Fixed 0
False Positive 0
Won't fix 0
Removed 0
Severity
Status
New Issues
Rule
Tag
Module
Directory
File
Assignee
Author
Language
Android Vulnerability Test Suite
src/app/src/main/java/android/framework/org/apache/harmony/security_custom/asn1/ASN1TypeCollection.java
Define and throw a dedicated exception instead of using a generic one.
Vulnerability Critical Open Not assigned 20min effort
22 days ago L86
cert, cwe, error-handling
Android Vulnerability Test Suite
src/app/src/main/java/android/framework/org/apache/harmony/security_custom/asn1/BerOutputStream.java
Define and throw a dedicated exception instead of using a generic one.
Vulnerability Critical Open Not assigned 20min effort
22 days ago L92
cert, cwe, error-handling
Define and throw a dedicated exception instead of using a generic one.
Vulnerability Critical Open Not assigned 20min effort
22 days ago L96
cert, cwe, error-handling
Define and throw a dedicated exception instead of using a generic one.
Vulnerability Critical Open Not assigned 20min effort
22 days ago L160
cert, cwe, error-handling
Define and throw a dedicated exception instead of using a generic one.
Vulnerability Critical Open Not assigned 20min effort
22 days ago L164
cert, cwe, error-handling
Define and throw a dedicated exception instead of using a generic one.
Vulnerability Critical Open Not assigned 20min effort
22 days ago L168
cert, cwe, error-handling
Define and throw a dedicated exception instead of using a generic one.
Vulnerability Critical Open Not assigned 20min effort
22 days ago L172
cert, cwe, error-handling
Define and throw a dedicated exception instead of using a generic one.
Vulnerability Critical Open Not assigned 20min effort
22 days ago L181
cert, cwe, error-handling

PSCR


sonarqube
Dashboards
Issues
Measures
Rules
Quality Profiles
Quality Gates
More
Log in
Android Vulnerability Test Suite
September 20, 2016 5:42 PM Version 1.0
Issues
Measures
Code
Dashboards
Issues
Effort
Type
Bug 250
Vulnerability 62
Code Smell 44
Resolution
Unresolved 62
Fixed 0
False Positive 0
Won't fix 0
Removed 0
Severity
Status
New Issues
Return to List
Android Vulnerability Test Suite
BerOutputStream.java
3 / 62
Reload
New Search
public void encodeChoice(ASN1Choice choice) {
throw new RuntimeException("Is not implemented yet"); //FIXME
Define and throw a dedicated exception instead of using a generic one.
22 days ago
L92
Vulnerability
Critical
Open
Not assigned
20min effort
cert, cwe, error-handling
}
public void encodeExplicit(ASN1Explicit explicit) {
throw new RuntimeException("Is not implemented yet"); //FIXME
Define and throw a dedicated exception instead of using a generic one.
22 days ago
L96
Vulnerability
Critical
Open
Not assigned
20min effort
cert, cwe, error-handling
}
public void encodeGeneralizedTime() {
Generic exceptions should never be thrown
Exceptions
Generic exceptions in the signatures of overriding methods are ignored.
@Override
public void myMethod() throws Exception {...}
See
MITRE, CWE-397 - Declaration of Throws for Generic Exception
CERT, ERR07-J. - Do not throw RuntimeException, Exception, or Throwable

PSCR

Mobile Application Vetting As a Service

Service Descriptors

- Analysis Type
  - Static
  - Dynamic
- Target Operating system
  - Android
  - iOS
  - Windows

Analysis Capabilities

- Malware detection
- Use of system resources
  - SMS, GPS, etc.
- Network and Storage encryption
- Network Traffic
- Hard coded information
  - Password, URLs, email addresses, IP addresses
- Use of third party libraries

PSCR

Application Vetting Reports Vary in Content

Example iOS App

	Number of pages in report
Tool A	12
Tool B	19
Tool C	69
Tool D	140

Example Android App

	Number of pages in report
Tool E	8
Tool F	31
Tool G	181
Tool H	180

PSCR Research Goals

- Identify the capabilities of vetting technology and how they can be used for public safety
- Identify strengths and weaknesses in mobile app vetting technology
- Aid in improving the state of the art in vulnerability detection

PSCR

PSCR Research Activities

- NISTIR 8136: An Overview of Mobile Application Vetting Services for Public Safety (January 2017)
  - https://doi.org/10.6028/NIST.IR.8136
- Mobile Application Security Exercise(July 2017)
- Expanding the Static Analysis Tool Exposition (December 2017)

PSCR

Handset and Wearable Security

Gema Howell

NIST, Applied Cybersecurity Division

IT Security Engineer

PSCR

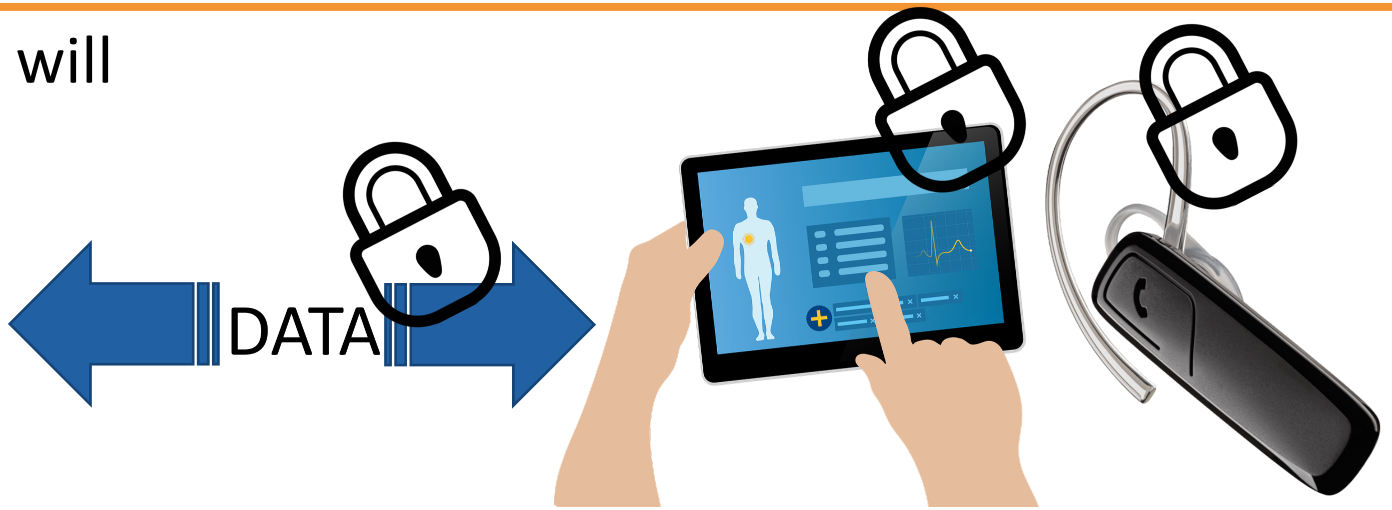
2017

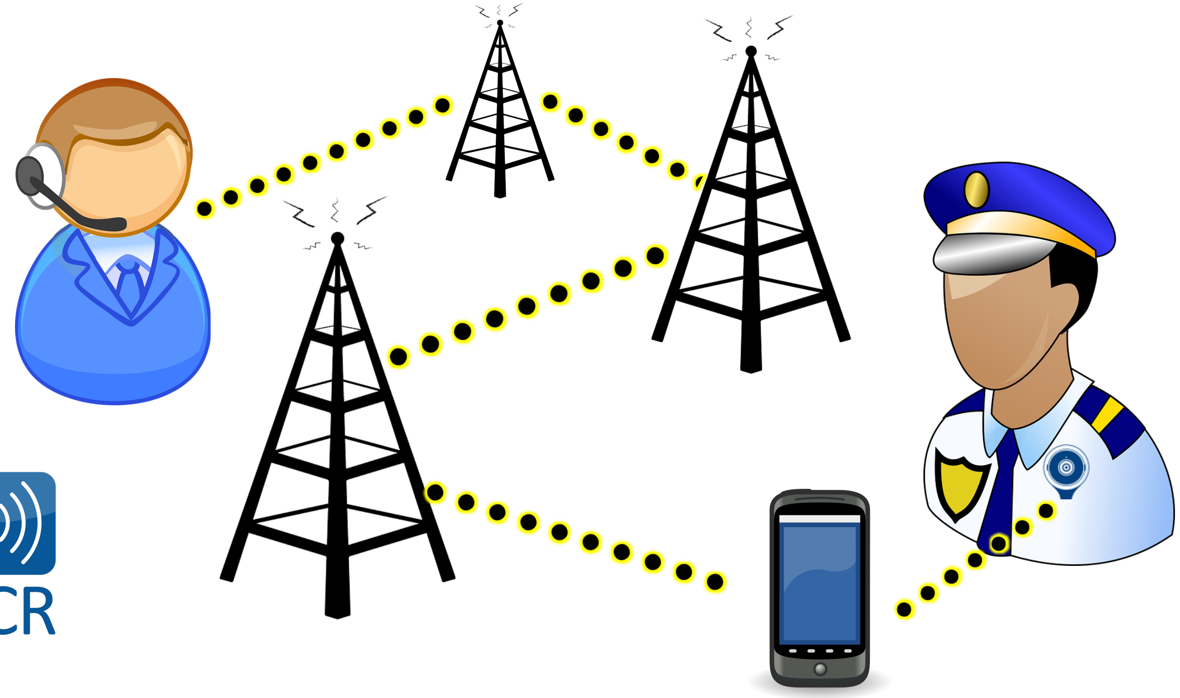
PUBLIC SAFETY BROADBAND STAKEHOLDER MEETING

#PSCR2017

Importance to Public Safety and the NPSBN

- Mobile devices and wearables will be used on the NPSBN
- Securing mobile devices and wearables ensures life saving activities can continue





- What are the security needs for public safety devices?
- How can we provide guidance to architect secure public safety systems?

PSCR

Security Objectives

Identify Mobile Security Objectives → Analyze Public Safety Devices → Gap Analysis and Recommendations

PSCR

Project Status

Identifying Mobile Security Objectives

Working Documents:

- Identify public safety use cases
- Analyze attacks on public safety system
- Identify list of public safety devices

In Progress:

- Discussions with public safety entities

PSCR

Mobile Device Examples

Bittium Tough Mobile

Sonim XP7

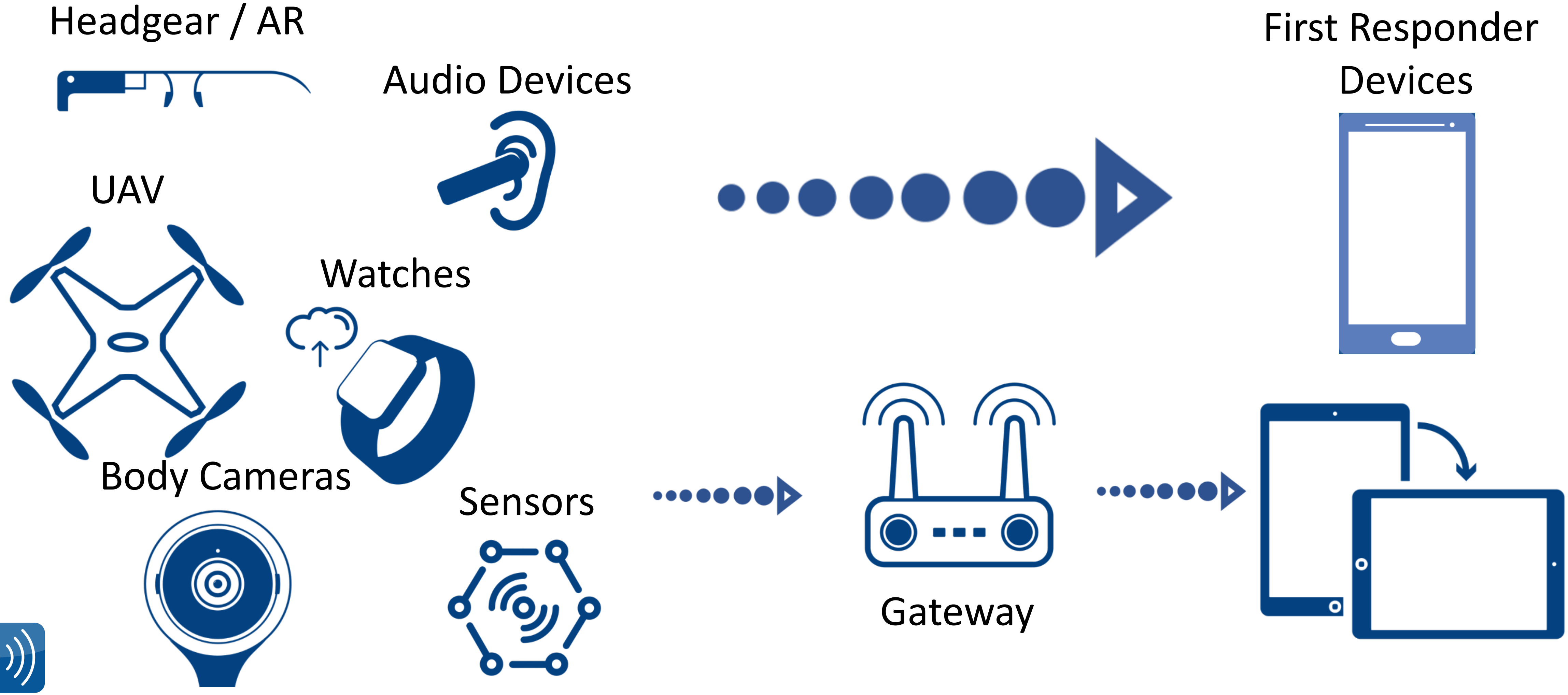
Motorola LEX L10

Blackphone 2

PSCR

Wearable Examples

IoT Architecture



Join Us!!!

PSCR Security Q&A Panel and the PSCR Security Community

Topics:

- Handset and Wearable Security
- Mobile Application Vetting
- Security for OTA Updates to UICC

PSCR

THE HWS TEAM

Joshua Franklin

NIST – Gaithersburg, MD

Joshua.Franklin@nist.gov

Scott Ledgerwood

NIST/PSCR – Boulder, CO

Scott.Ledgerwood@nist.gov

Gema Howell

NIST – Gaithersburg, MD

Gema.Howell@nist.gov