PSCR

2017
PUBLIC SAFETY BROADBAND STAKEHOLDER MEETING

Day 3

Wednesday, June 14

#PSCR2017

2017

PUBLIC SAFETY BROADBAND
STAKEHOLDER MEETING

Jeff Johnson

FirstNet Board Vice Chairman & Retired Fire Chief

Keynote Address

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.

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Acronym Glossary

- API = Application Program Interface
- ARW =
- BLE = Bluetooth Low Energy
- BOLO = Be on the Lookout (alert)
- CAD = Computer Aided Dispatch
- CCTV = Closed Circuit Television
- CEP = Circular Error Probable
- CMUT = Capacitive Micromachined Ultrasonic Transducer
- CPU = Central processing Unit
- CS = Compressive Sampling
- D2D = Device-to-Device Communications
- DSLR = Digital Single Lens Reflex
- DTN = Delay Tolerant Networking
- eNB = E-Ultran Node B
- EPC = Evolved Packet Core
- GHz = Gigahertz
- GIS = Geographic Information System
- GPS = Global Positioning System
- HetNet = Heterogeneous Network
- HIPAA = Health Insurance Portability and Accountability Act
- HRP = Human Resources Protection
- ICAM = Identity, Credential, and Access Management
- IDMS = Intelligent Data Movement Service
- IBR-DTN = Framework for DTN (Delay Tolerant Networking) applications
- IMU = Inertial Measurement Unit
- INS = Inertial Navigation Systems
- IoT = Internet of Things Communication
- IPIN = Indoor Positioning and Indoor Navigation
- LBS = Location-Based Systems
- LoDN = Logistical Distribution Network
- LoRa = Long Range Wide-Area Network
- LoRS = Logistical Runtime System
- MEMS = Microelectromechanical Systems
- NGFR = Next Generation First Response
- NIOSH = National Institute of Safety and Health
- NIROPS = Naval Industrial Reserve Ordnance Plant
- NOFO = Notice of Funding Opportunity
- P-GW = Packet Data Network Gateway
- ProSe = Proximity Services
- PS = Public Safety
- PSC = Public Safety Communication
- PSCR = Public Safety Communication Research
- R&D = Research and Development
- RAN = Radio Access Network

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Acronym Glossary

- RF = Radio Frequency
- RS = Resilient Systems
- SDA = Software Defined (Spectrum) Access
- S-GW = Satellite Gateway
- SiFi = the name of Spectronn's cloud-managed HetNet wireless technology
- SIP = Session Initiation Protocol
- SOP = Standard Operation Procedure
- SLAM = Simultaneous Localization and Mapping
- UAS = Unmanned Aircraft Systems
- UWB = Ultra-Wideband
- WB = Wideband
- WLAN = Wireless Local-Area Network
- ZUPTing = Zero Velocity Updating

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Advancing Location-Based Services & Resilient System Technologies Through PSCR's Innovation Accelerator Grant Program

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Location-Based Systems

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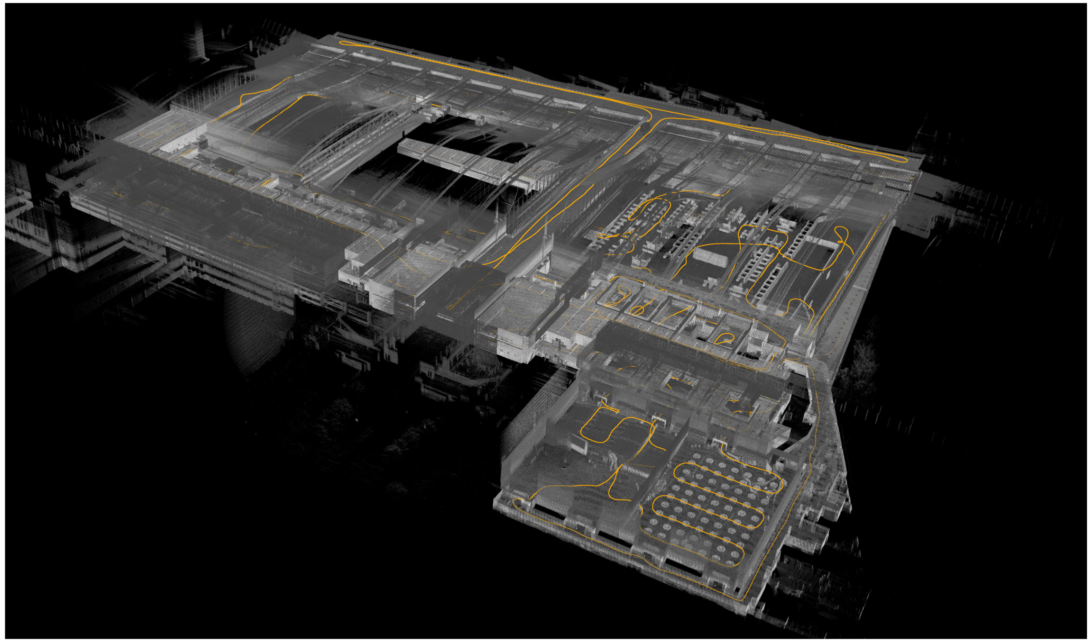
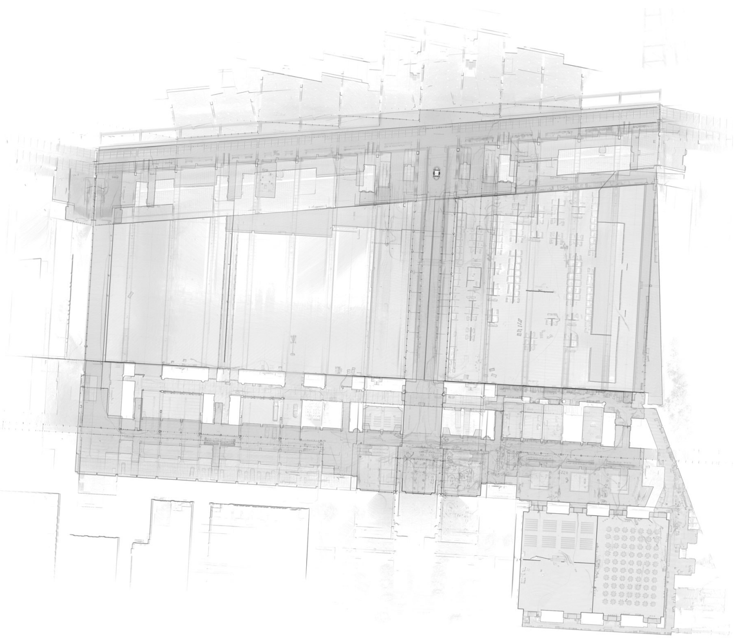
LBS Goals FY17-22

- Mapping
  - Accelerate indoor mapping and 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



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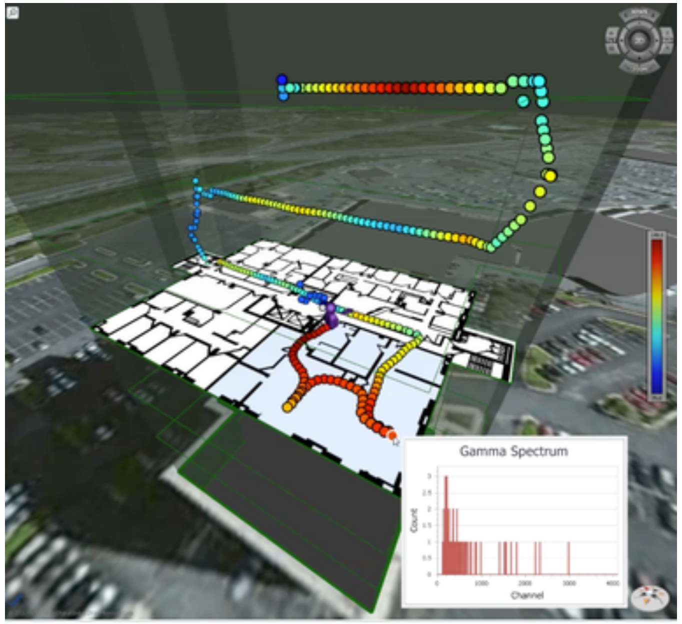
LBS Goals FY17-22

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



TRX Systems

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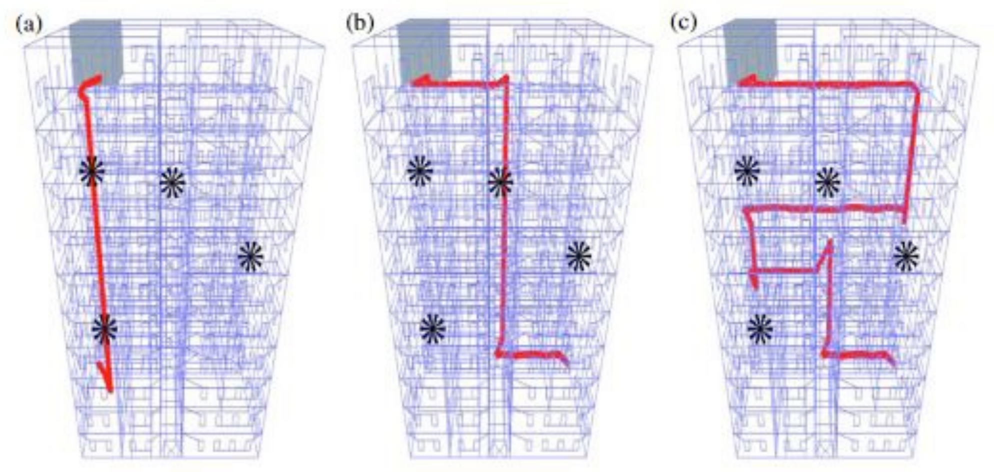
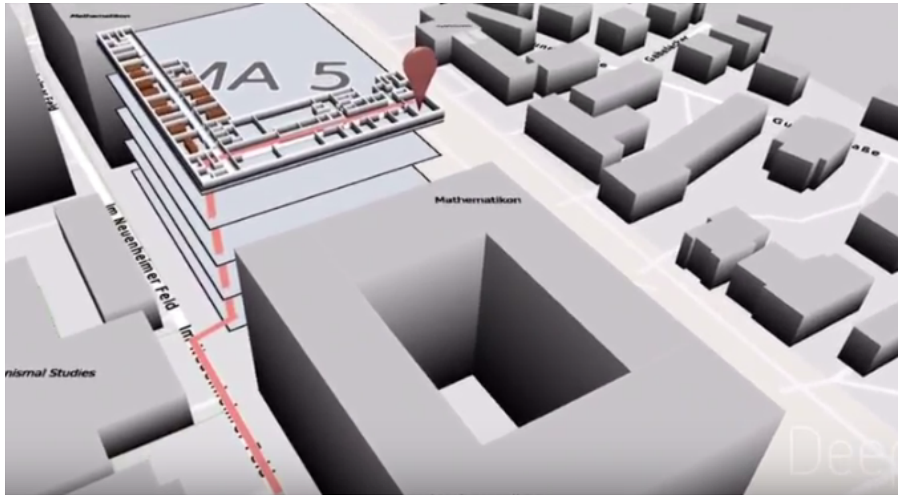
LBS Goals FY17-22

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



Univ. of the West of England

Accenture



DeepMap

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Sample of NIOSH Fire Fighter Fatality Reports Where Lack of Location Tracking Was a Factor

Career Fire Fighter Dies From an Out-of-Air Emergency in an Apartment Building Fire—Connecticut
https://www.cdc.gov/niosh/fire/reports/face201419.html

Career Female Fire Fighter Dies After Becoming Lost and Running Out-of-Air in a Residential Structure Fire - Pennsylvania
https://www.cdc.gov/niosh/fire/reports/face201425.html

Career Fire Fighter Dies during Fire-Fighting Operations at a Multi-family Residential Structure Fire - Massachusetts
https://www.cdc.gov/niosh/fire/reports/face201131.html

Career Fire Fighter Dies While Conducting a Search in a Residential House Fire – Kansas
https://www.cdc.gov/niosh/fire/reports/face201013.html

Volunteer Captain Runs Low on Air, Becomes Disoriented, and Dies While Attempting to Exit a Large Commercial Structure – Texas
https://www.cdc.gov/niosh/fire/reports/face201016.html

Volunteer Lieutenant and a Fire Fighter Die While Combating a Mobile Home Fire - West Virginia
https://www.cdc.gov/niosh/fire/reports/face200907.html

Career Probationary Fire Fighter and Captain Die as a Result of Rapid Fire Progression in a Wind-Driven Residential Structure Fire – Texas
https://www.cdc.gov/niosh/fire/reports/face200911.html

Career Lieutenant Dies Following Floor Collapse into Basement Fire and a Career Fire Fighter Dies Attempting to Rescue the Career Lieutenant – New York
https://www.cdc.gov/niosh/fire/reports/face200923.html

A Career Captain and a Part-time Fire Fighter Die in a Residential Floor Collapse—Ohio
https://www.cdc.gov/niosh/fire/reports/face200809.html

Volunteer Fire Fighter Dies While Lost in Residential Structure Fire- Alabama
https://www.cdc.gov/niosh/fire/reports/face200834.html

Career Fire Fighter Dies in Wind Driven Residential Structure Fire - Virginia
https://www.cdc.gov/niosh/fire/reports/face200712.html

Nine Career Fire Fighters Die in Rapid Fire Progression at Commercial Furniture Showroom – South Carolina
https://www.cdc.gov/niosh/fire/reports/face200718.html

Two Career Fire Fighters Die Following a Seven-Alarm Fire in a High-Rise Building Undergoing Simultaneous Deconstruction and Asbestos Abatement—New York
https://www.cdc.gov/niosh/fire/pdfs/face200737.pdf

One Probationary Career Fire Fighter Dies and Four Career Fire Fighters are Injured at a Two-Alarm Residential Structure Fire - Texas
https://www.cdc.gov/niosh/fire/reports/face200502.html

Career Fire Fighter Dies While Exiting Residential Basement Fire - New York
https://www.cdc.gov/niosh/fire/reports/face200504.html

Career Fire Fighter Dies of Carbon Monoxide Poisoning after Becoming Lost While Searching for the Seat of a Fire in Warehouse - New York
https://www.cdc.gov/niosh/fire/reports/face200404.html

Career Fire Fighter Dies Searching For Fire in a Restaurant/Lounge - Missouri
https://www.cdc.gov/niosh/fire/reports/face200410.html

Volunteer Fire Fighter Dies Following Nitrous Oxide Cylinder Explosion While Fighting a Commercial Structure Fire - Texas
https://www.cdc.gov/niosh/fire/reports/face200303.html

Career Fire Fighter Dies and Two Career Fire Fighters Injured in a Flashover During a House Fire - Ohio
https://www.cdc.gov/niosh/fire/reports/face200312.html

Volunteer Fire Fighter Killed and Career Chief Injured During Residential House Fire - Tennessee
https://www.cdc.gov/niosh/fire/pdfs/face200212.pdf

Two Career Fire Fighters Die in Four-Alarm Fire at Two-Story Brick Structure - Missouri
https://www.cdc.gov/niosh/fire/pdfs/face200220.pdf

Structural Collapse at an Auto Parts Store Fire Claims the Lives of One Career Lieutenant and Two Volunteer Fire Fighters - Oregon
https://www.cdc.gov/niosh/fire/reports/face200250.html

Volunteer Fire Fighter (Lieutenant) Killed and One Fire Fighter Injured During Mobile Home Fire-Pennsylvania
https://www.cdc.gov/niosh/fire/reports/face200104.html

Supermarket Fire Claims the Life of One Career Fire Fighter and Critically Injures Another Career Fire Fighter - Arizona
https://www.cdc.gov/niosh/fire/pdfs/face200113.pdf

High-Rise Apartment Fire Claims the Life of One Career Fire Fighter (Captain) and Injures Another Career Fire Fighter (Captain) - Texas
https://www.cdc.gov/niosh/fire/pdfs/face200133.pdf

Structure Fire Claims the Lives of Three Career Fire Fighters and Three Children-Iowa
https://www.cdc.gov/niosh/fire/reports/face200004.html

Residential House Fire Claims the Life of One Career Fire Fighter-Florida
https://www.cdc.gov/niosh/fire/reports/face200044.html

Six Career Fire Fighters Killed in Cold-Storage and Warehouse Building Fire - Massachusetts
https://www.cdc.gov/niosh/fire/reports/face9947.html

Warehouse Fire Claims the Life of a Battalion Chief - Missouri
https://www.cdc.gov/niosh/fire/reports/face9948.html

Single-Family Dwelling Fire Claims the Lives of Two Volunteer Fire Fighters--Ohio
https://www.cdc.gov/niosh/fire/reports/face9806.html

Commercial Structure Fire Claims the Life of One Fire Fighter-California
https://www.cdc.gov/niosh/fire/reports/face9807.html

Eight-Alarm Fire in a 27-Story High-Rise Apartment Building for the Elderly Nearly Claims the Life of One Fire Fighter—Missouri
https://www.cdc.gov/niosh/fire/pdfs/face9826.pdf

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PerfLoc

- Performance Evaluation of Smartphone Indoor Localization Apps
- Goal: advance indoor localization and tracking technologies leveraging commodity smartphone sensors and widely available RF signals
- Data:
  - Four different smartphones
  - Four large buildings (over 30 000 m^2)
  - 900+ precision surveyed test points
  - WiFi and cellular RF signal strength
  - Sensors: accelerometer, gyroscope, magnetometer, barometer, step counter, light, temperature, humidity, etc.
- Evaluation: web-based, top three – live demo
- Prizes: $20,000 / $10,000 / $5,000 + trip to IPIN Conference
- More information at: https://perfloc.nist.gov/

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LBS Grant Awardees

Carnegie Mellon University (2)

Massachusetts Institute of Technology

TRX Systems

University of California, Irvine

University of Cincinnati

University of Michigan

University of Oxford

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LBS Presentations

TRX Systems

- TRX First Responder Location and Mapping Services

Carnegie Mellon University

- An Infrastructure-Free Localization System for Fire Fighters

University of Oxford

- Pervasive, Accurate and Reliable Location Based Services for Emergency Responders

University of California, Irvine

- Ultimate Navigation Chip (uNavChip): Chip-Scale Personal Navigation System
- Integrating Deterministic Localization and Probabilistic Signals of Opportunity

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TRX First Responder Location and Mapping Services

Public Safety Innovation Accelerator Program, FY2017

7500 Greenway Center Drive
Suite 420
Greenbelt, MD 20770
(+1) 301-313-0053
info@trxsystems.com

TRX systems

LOCATE. MAP. TRACK. INDOORS.

Objective: Accelerate Availability, Robustness of Key Location and Mapping Tools

- Deliver robust, higher accuracy 3D location for first responders
  - Use wider array of location inputs and constraints
- Make available comprehensive map data sources and tools
  - Expand use of known and inferred building information
- Deliver easy to use 3D visualization
  - Enhance map databases to make them easy to modify, validate, synchronize

Team Members

TRX systems
LOCATE. MAP. TRACK. INDOORS.

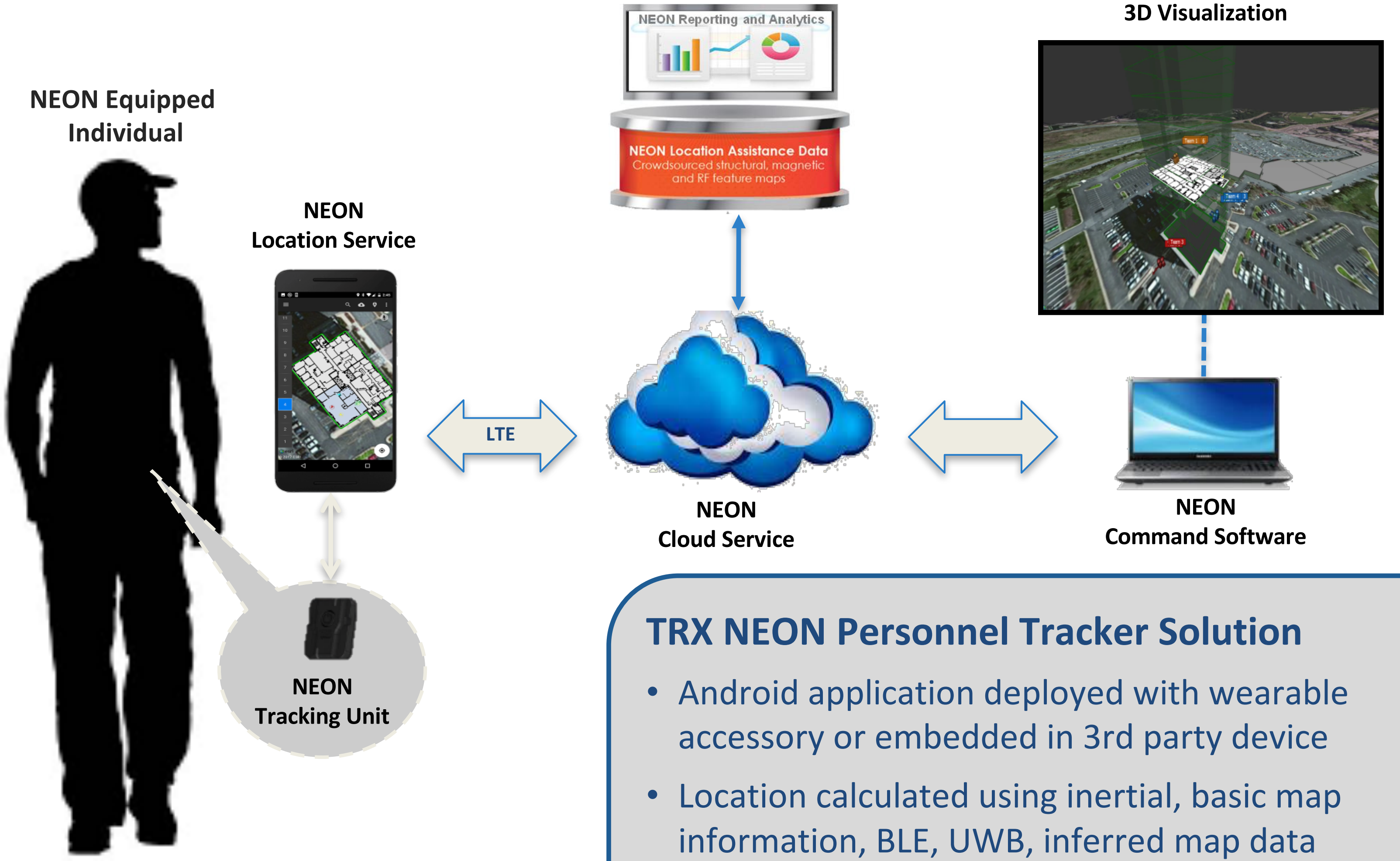
NEXTNAV

ARLINGTON COUNTY FIRE DEPARTMENT

Harris County Public Safety Technology Services

Starting Point: NEON 3D Location Solution

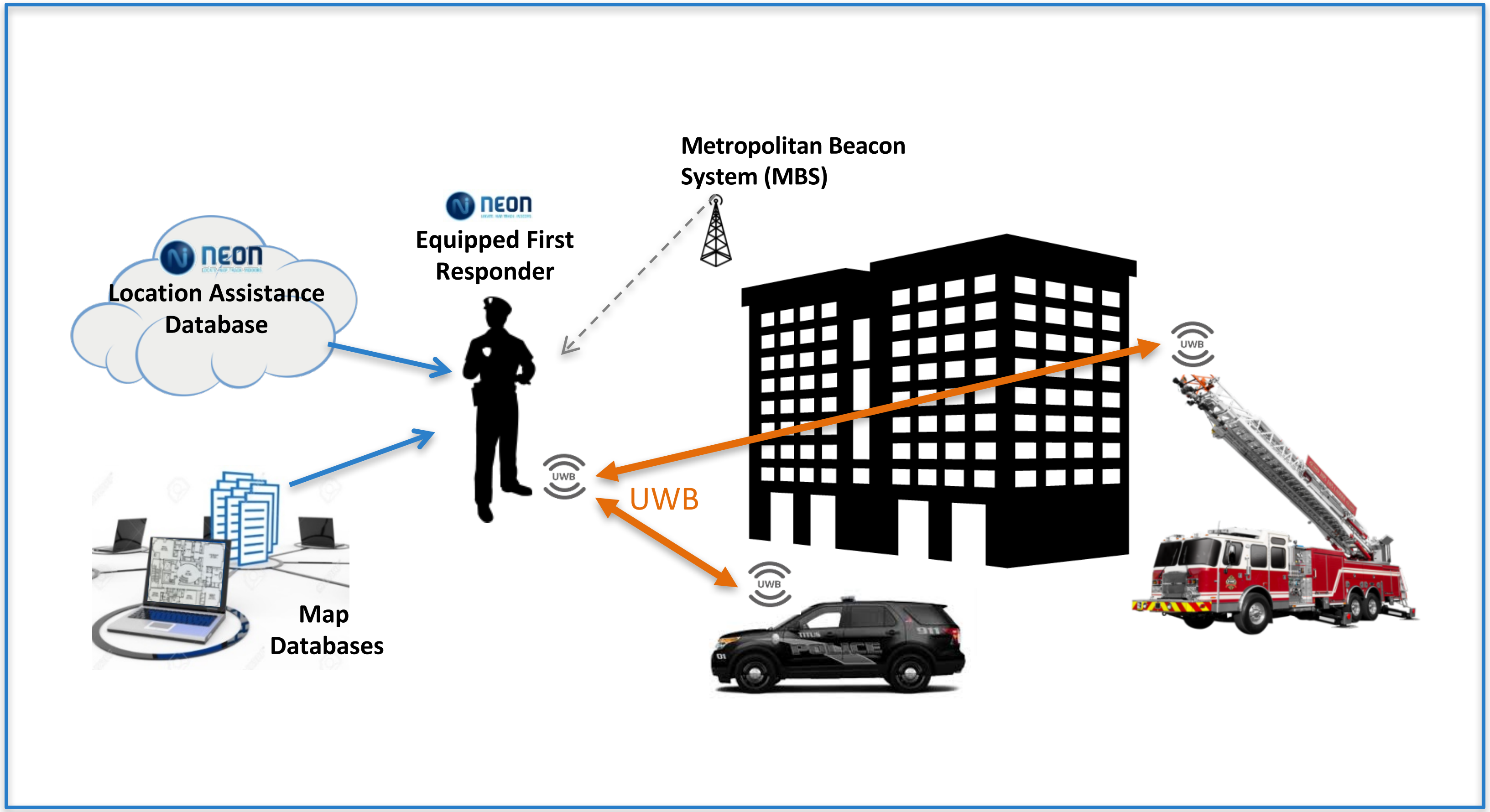
NEON Personnel Tracker



TRX NEON Personnel Tracker Solution

- Android application deployed with wearable accessory or embedded in 3rd party device
- Location calculated using inertial, basic map information, BLE, UWB, inferred map data
- Easily integrated with third party position/ location sources

Proposed Solution Architecture

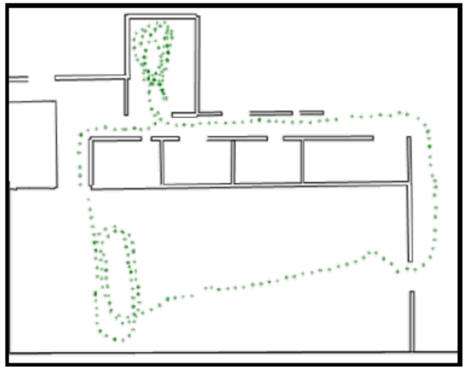


Targeted Use Cases: Tactical Law Enforcement & Fire Personnel

Enhance 3D Location Robustness and Accuracy

1. Leverage known high accuracy indoor maps (map feature matching) when available
2. Support initialization with mobile incident ground UWB (fire truck, law enforcement vehicle mounted)
3. Utilize signals from NextNav Metropolitan Beacon System as constraint

Indoor Maps



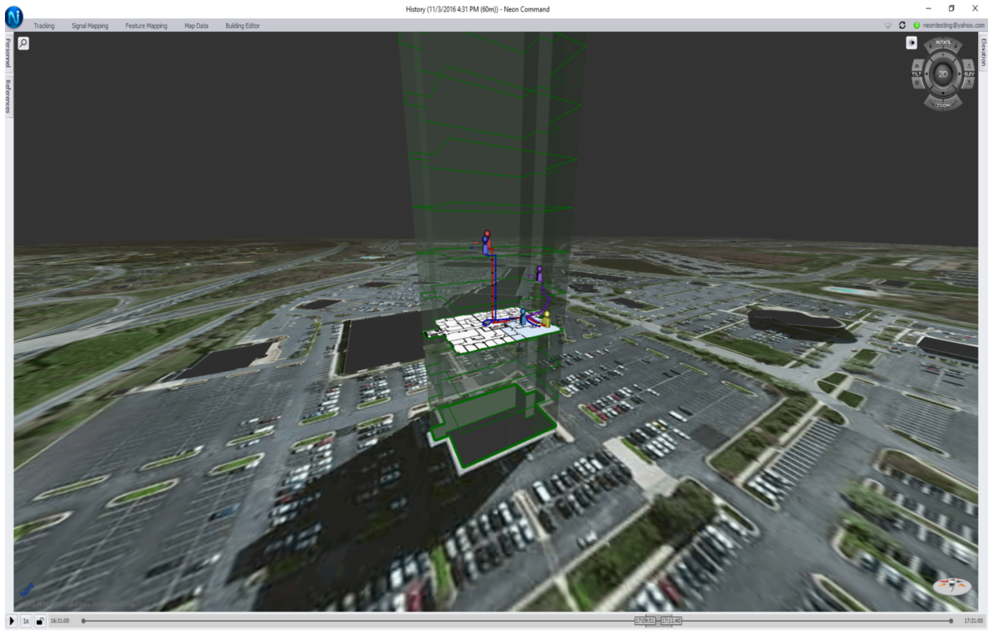
NextNav MBS

Support Expanded Preplanning and Dynamic Map Data Collection

1. Expand mobile "mapper" allowing first responders to add preplan data directly from mobile device
2. Support dynamic data synchronization with third party map databases
3. Integrate real-time SLAM mapping, validation and localization corrections
4. Support map information sharing across departments
5. Develop and make available open mapping data API

Visualization of Building and Associated Sensor/IoT/Points of Interest Data

1. Simplify the Command Software mapping interface (usability enhancement)
2. Implement hierarchical user policy function for map changes
3. Expand data types (operational data, assets, IoT devices, points of interest)



User Use Case Definition and Functionality Validation

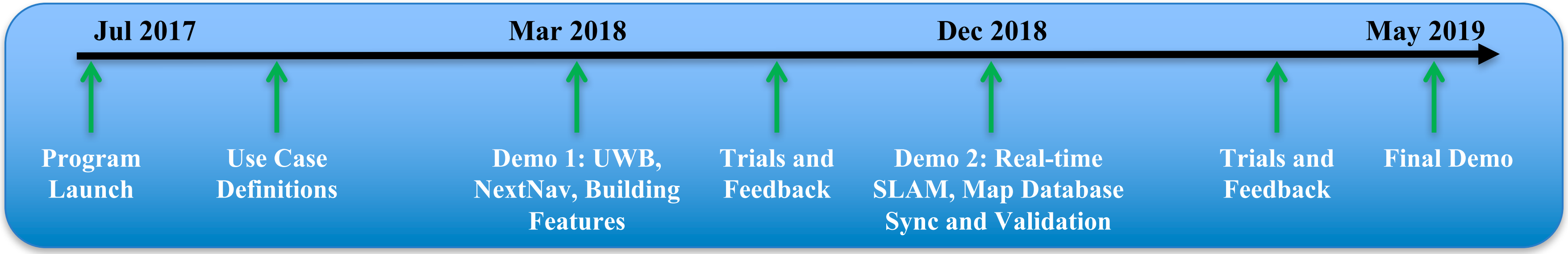
1) Requirements and use case definition
2) Training on the solution and new features
3) New development end user trials
4) Usability assessments, gap analysis, end user feedback

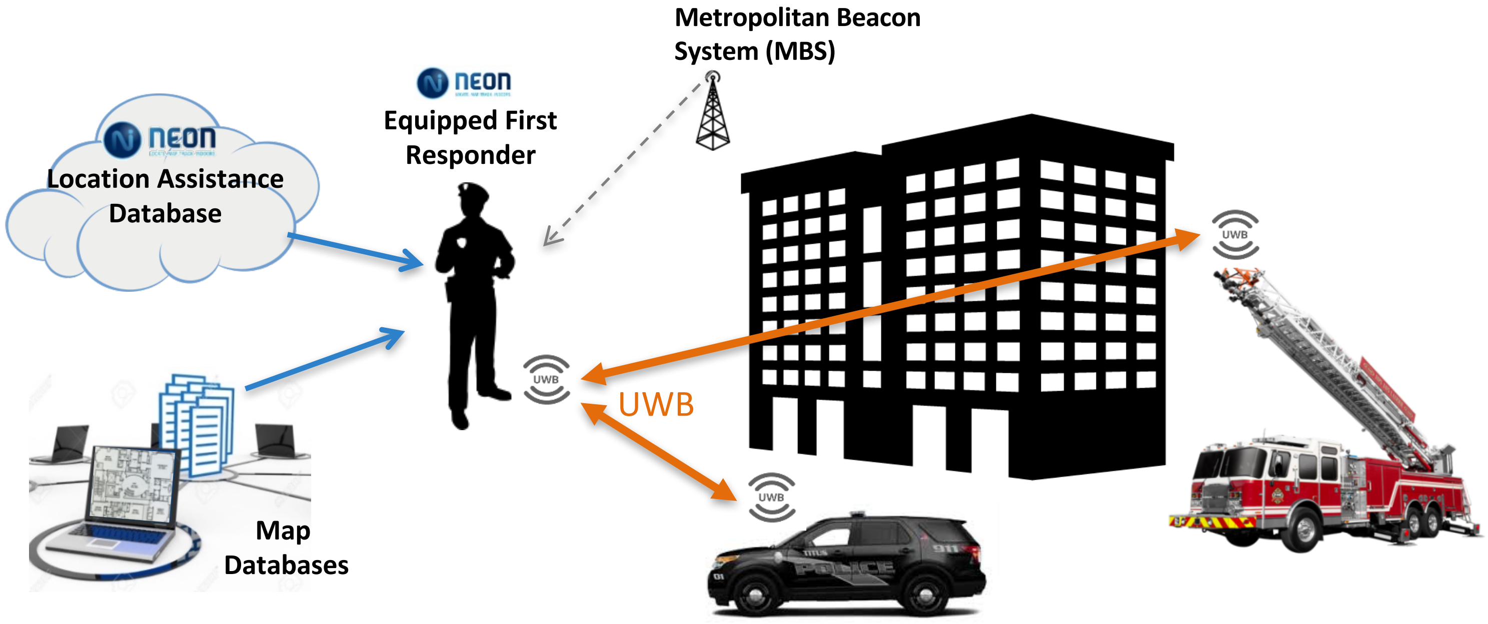
Arlington County Fire Department

Harris County Public Safety Technology Services

Law Enforcement, Fire, EMS including new Active Violence Procedure Protocols

Schedule


Jul 2017
Mar 2018
Dec 2018
May 2019
Program Launch
Use Case Definitions
Demo 1: UWB, NextNav, Building Features
Trials and Feedback
Demo 2: Real-time SLAM, Map Database Sync and Validation
Trials and Feedback
Final Demo


Metropolitan Beacon System (MBS)
neon
Equipped First Responder
neon
Location Assistance Database
Map Databases
UWB
UWB
UWB
UWB

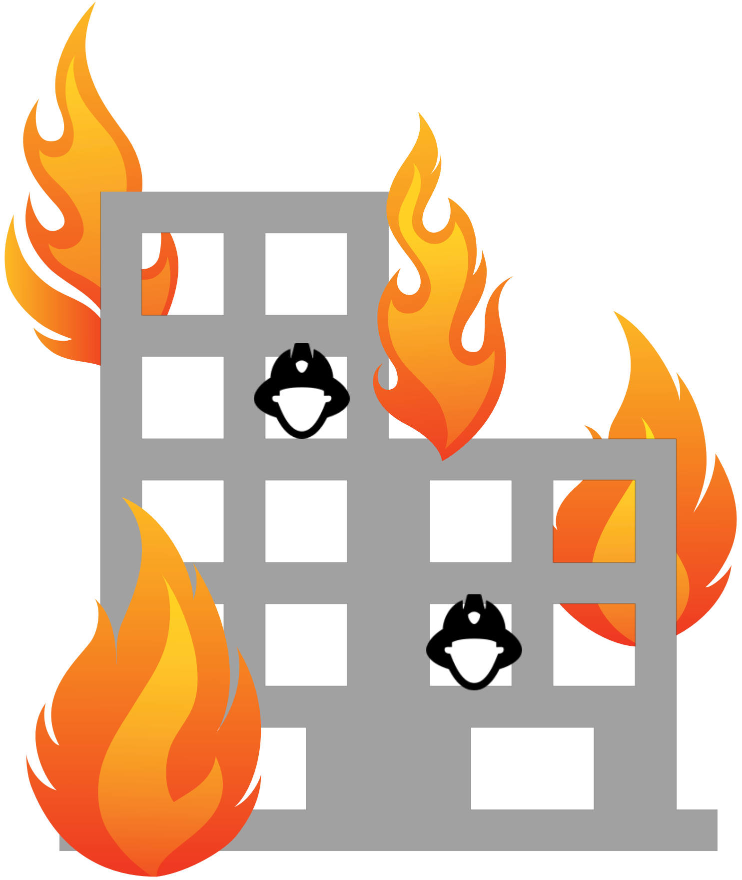
TRX First Responder Location and Mapping Services

7500 Greenway Center Drive
Suite 420
Greenbelt, MD 20770
(+1) 301–313–0053
info@trxsystems.com

TRX systems

LOCATE. MAP. TRACK. INDOORS.

I wish I had: "**An Infrastructure-Free Localization System for Fire Fighters**"



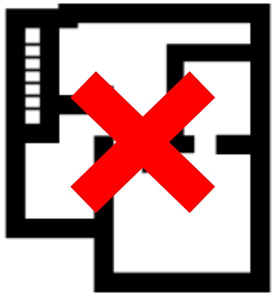
Anthony Rowe
Associate Professor
Electrical and Computer Engineering Department
Carnegie Mellon University

Carnegie Mellon University

Electrical & Computer ENGINEERING

Indoor Localization Platform Goals

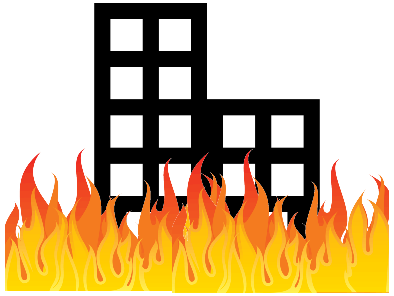
No prior information or infrastructure



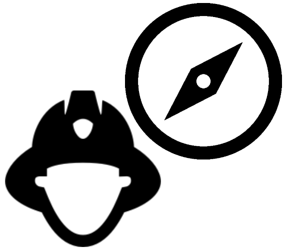
Poor visibility

Rapid deployment

Restricted perimeter



Orientation critical

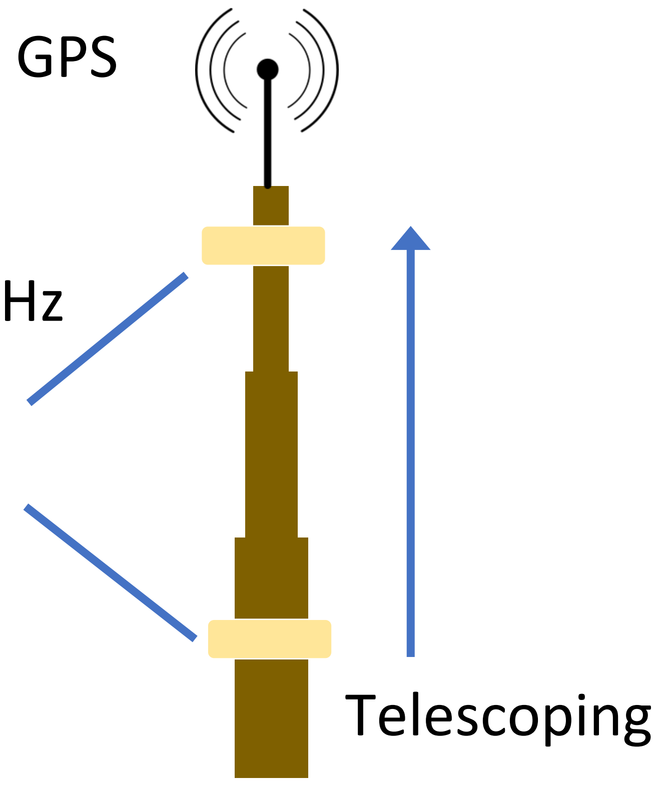


Power, accuracy

Our Approach

- LoRa (Long Range <1 GHz Communication)
- UWB (Ranging Radio)
- Air Pressure Sensors
- Inertial Measurement

- LoRa (Long Range <1 GHz Communication)
- UWB (Ranging Radio)
- Air Pressure Sensors

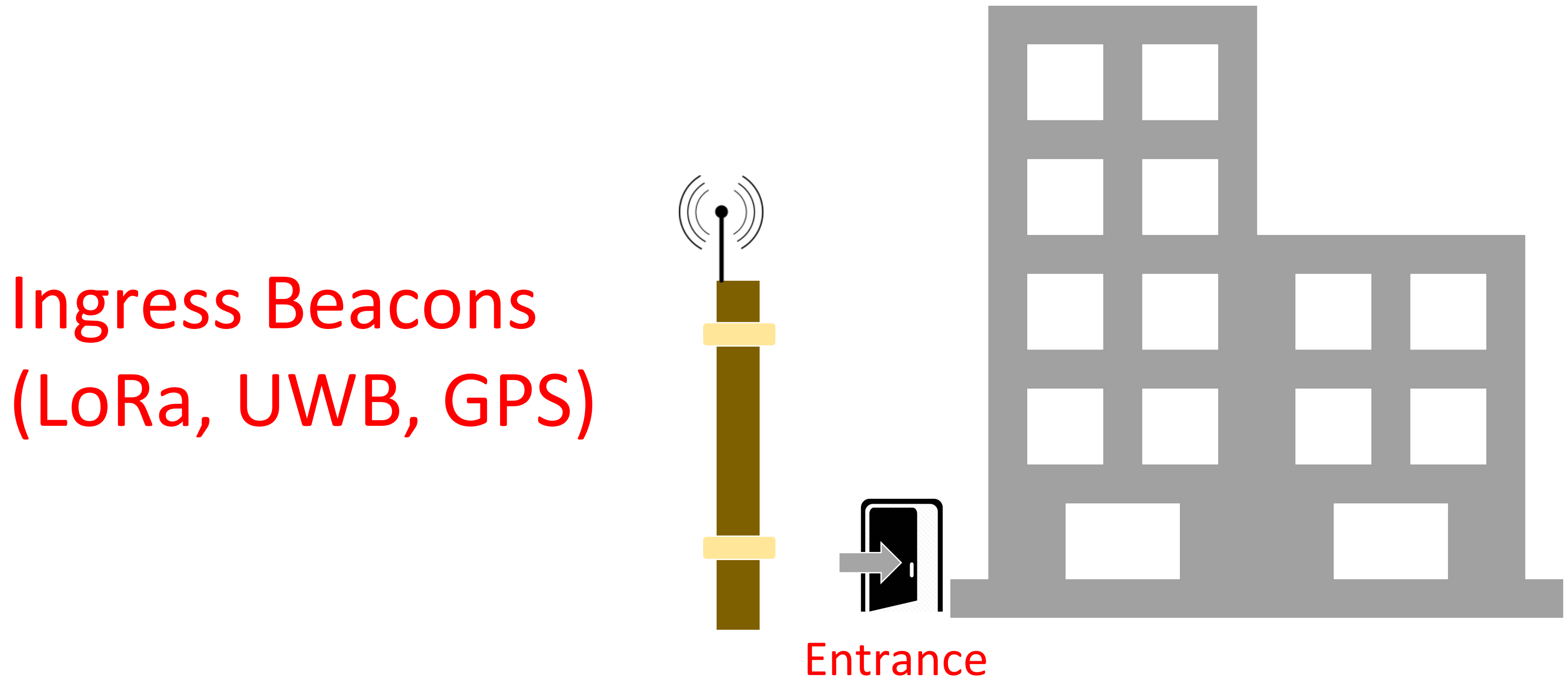


(1) Ingress Beacons

(2) Airpack Transponder

Our Approach

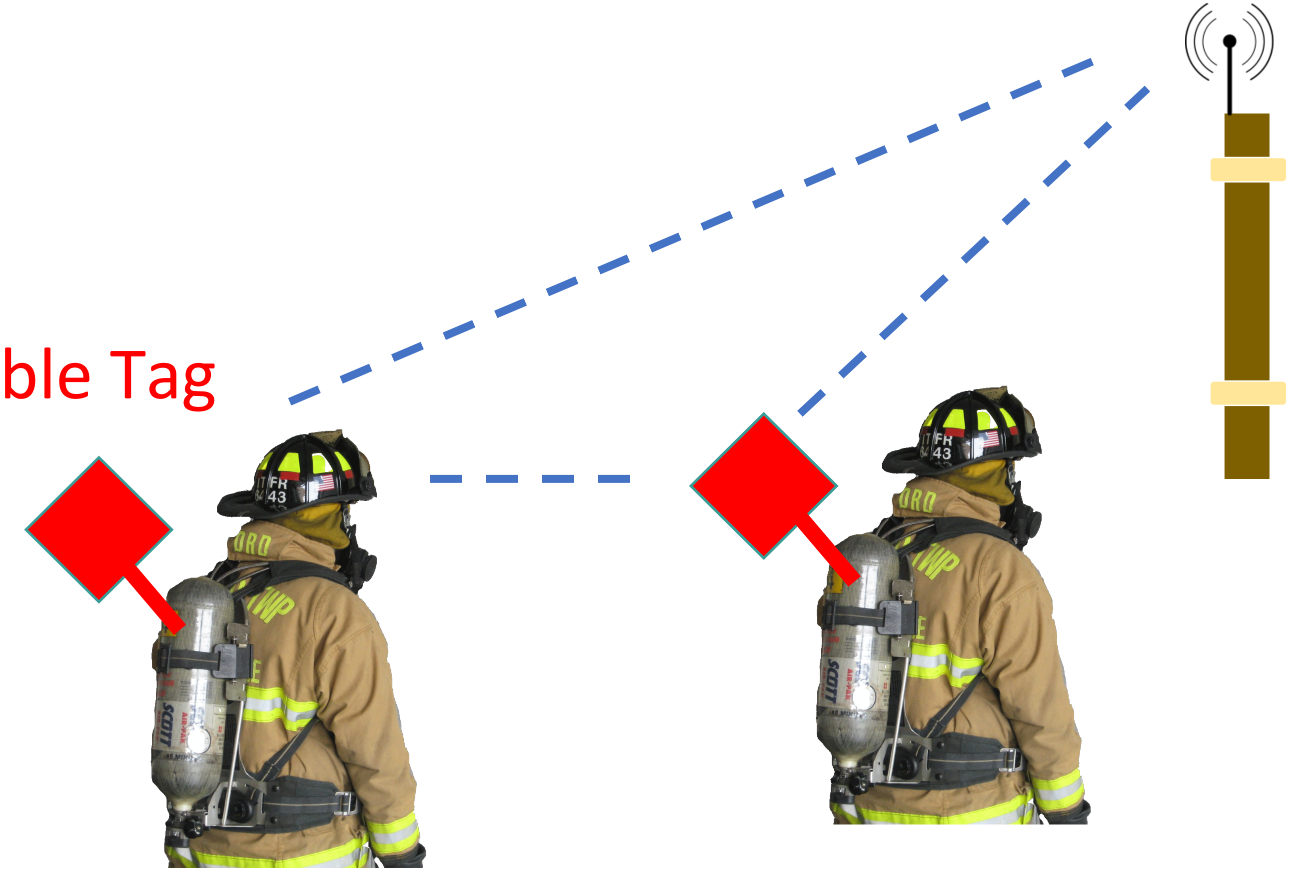
Step 1: Deploy beacon near entrances on site



Our Approach

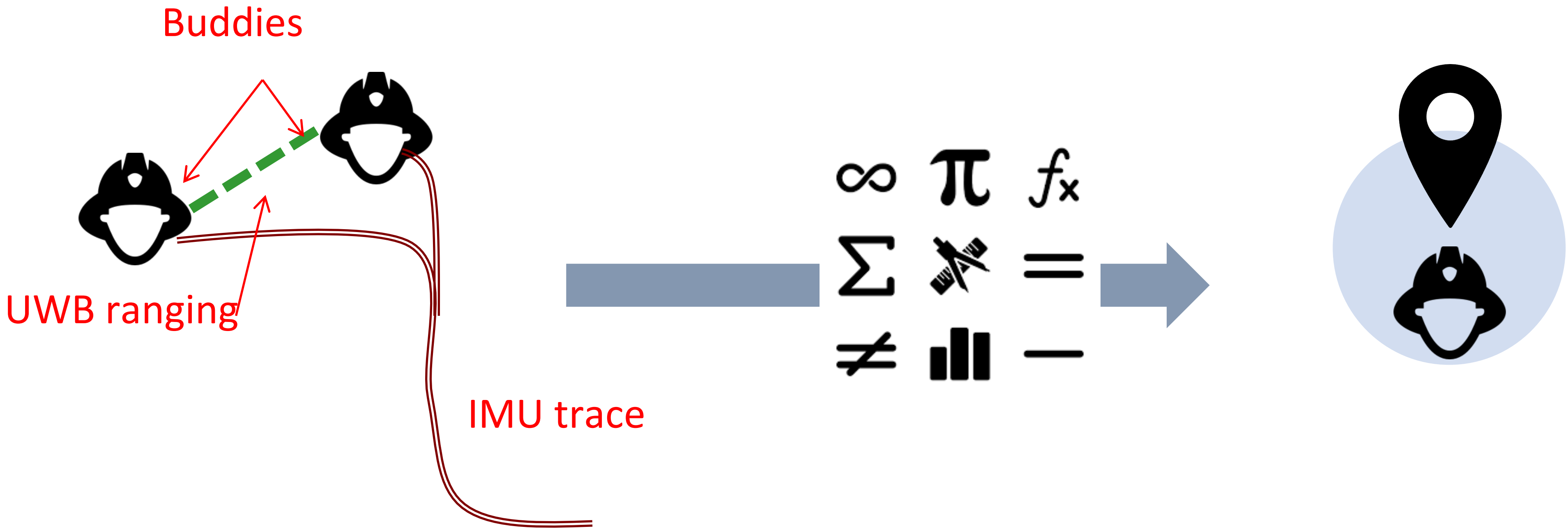
Step 2: Attach smart RF tag to fire fighter airpack

Fire Fighter with Wearable Tag
(LoRa, UWB, IMU)

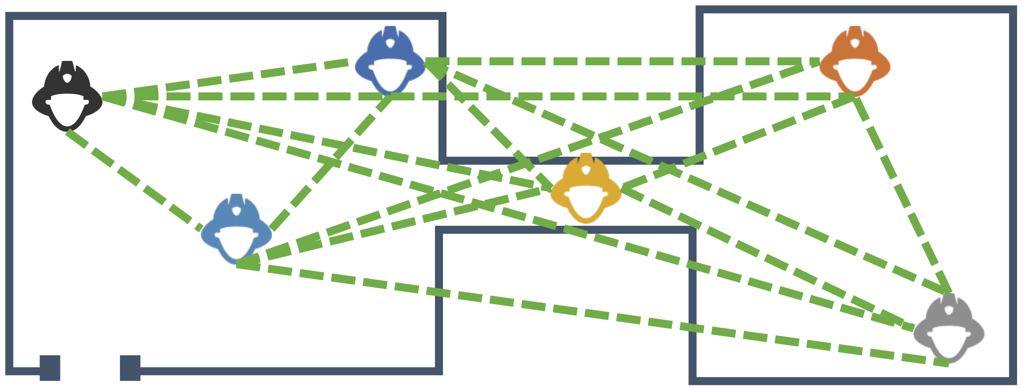


Our Approach

Step 3: Utilize ranges between fire fighters and beacons, fused with inertial measurement data to track location

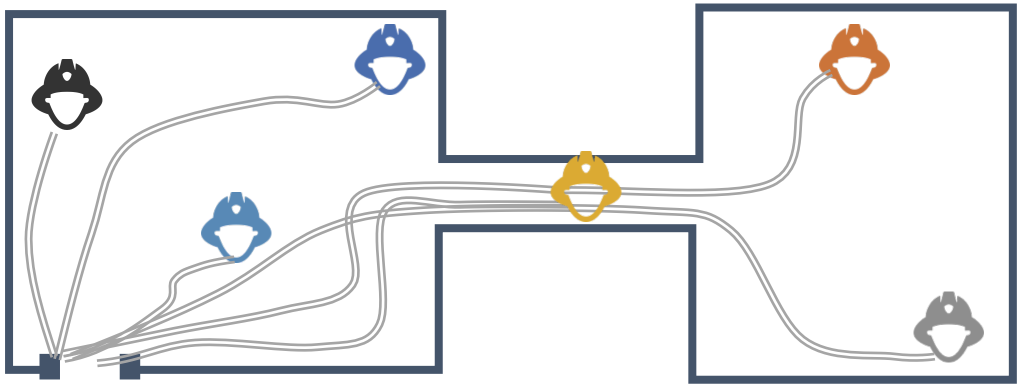


Why We Think This Can Work?



Perfect ranging → Solvable

UWB Time-of-flight shows promise

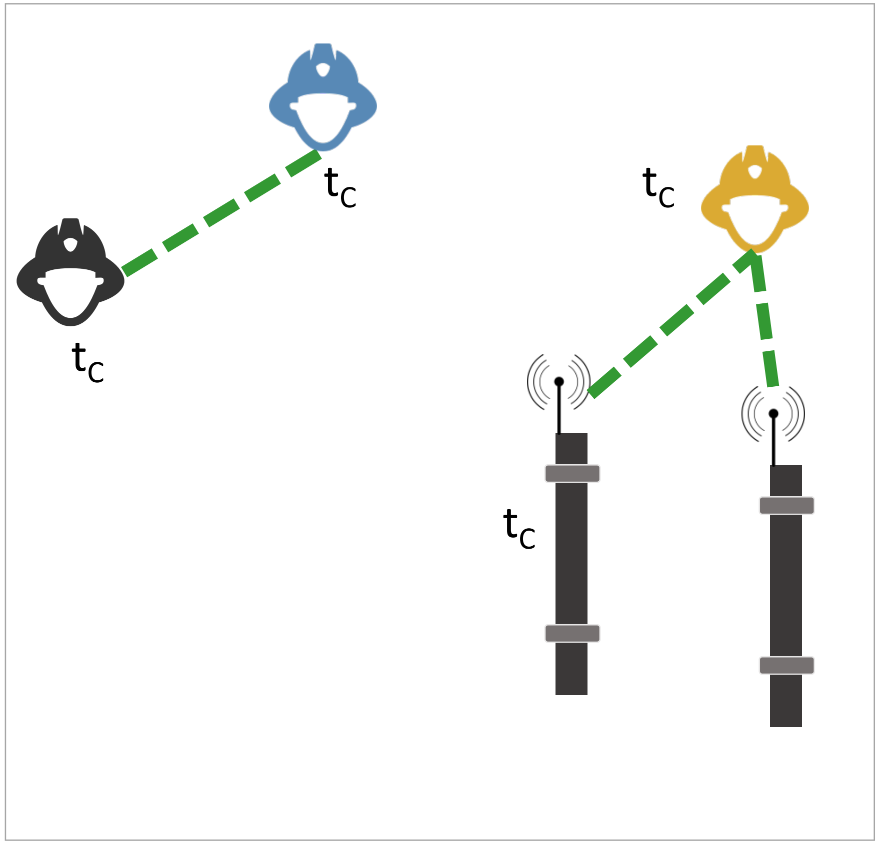


Perfect IMUs → Solvable

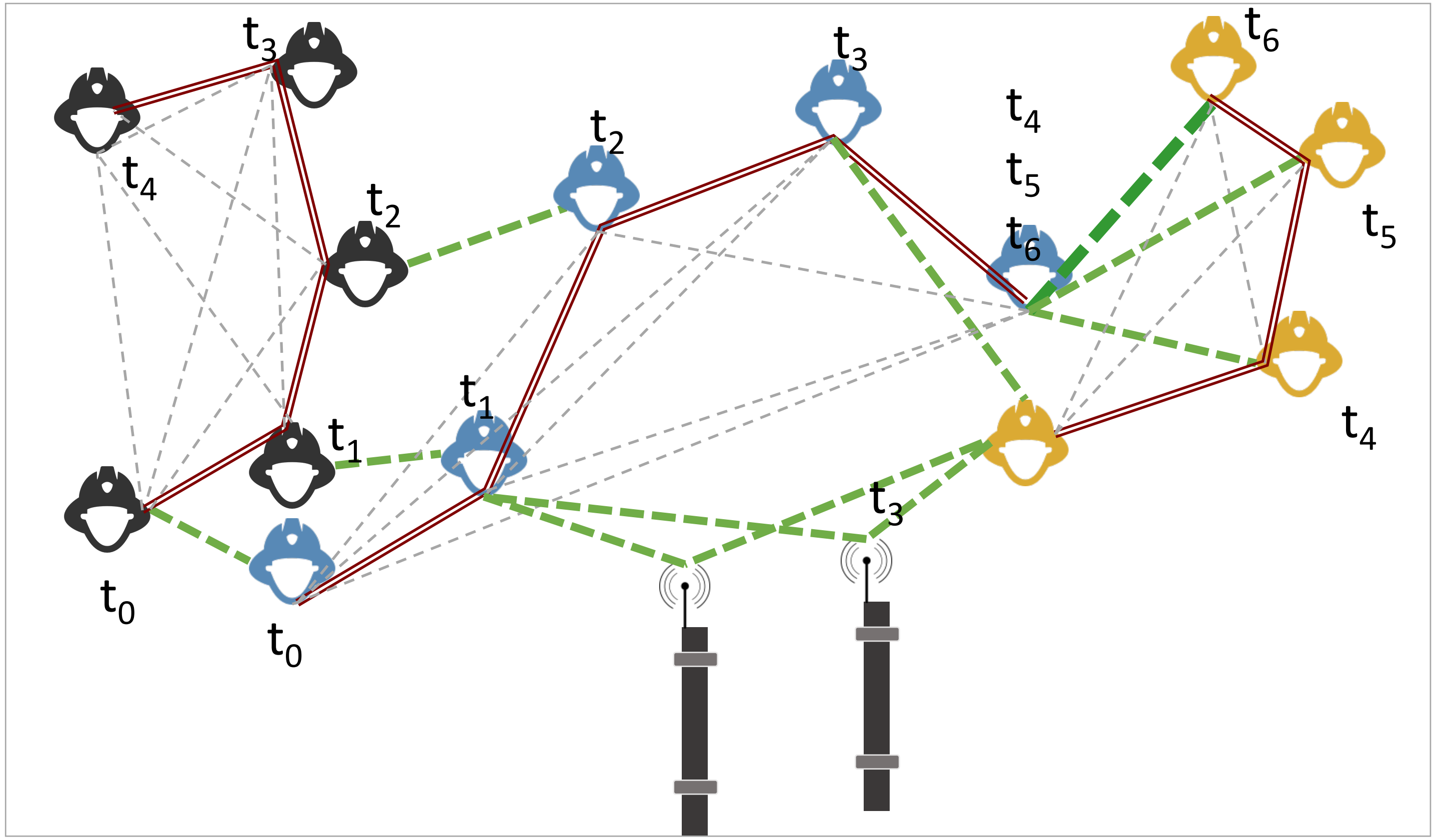
IMUs are decreasing in cost and increasing in performance

Key Insight: Inter-node ranging of mobile devices can correct IMU drift and vice versa.

Why We Think This Can Work?

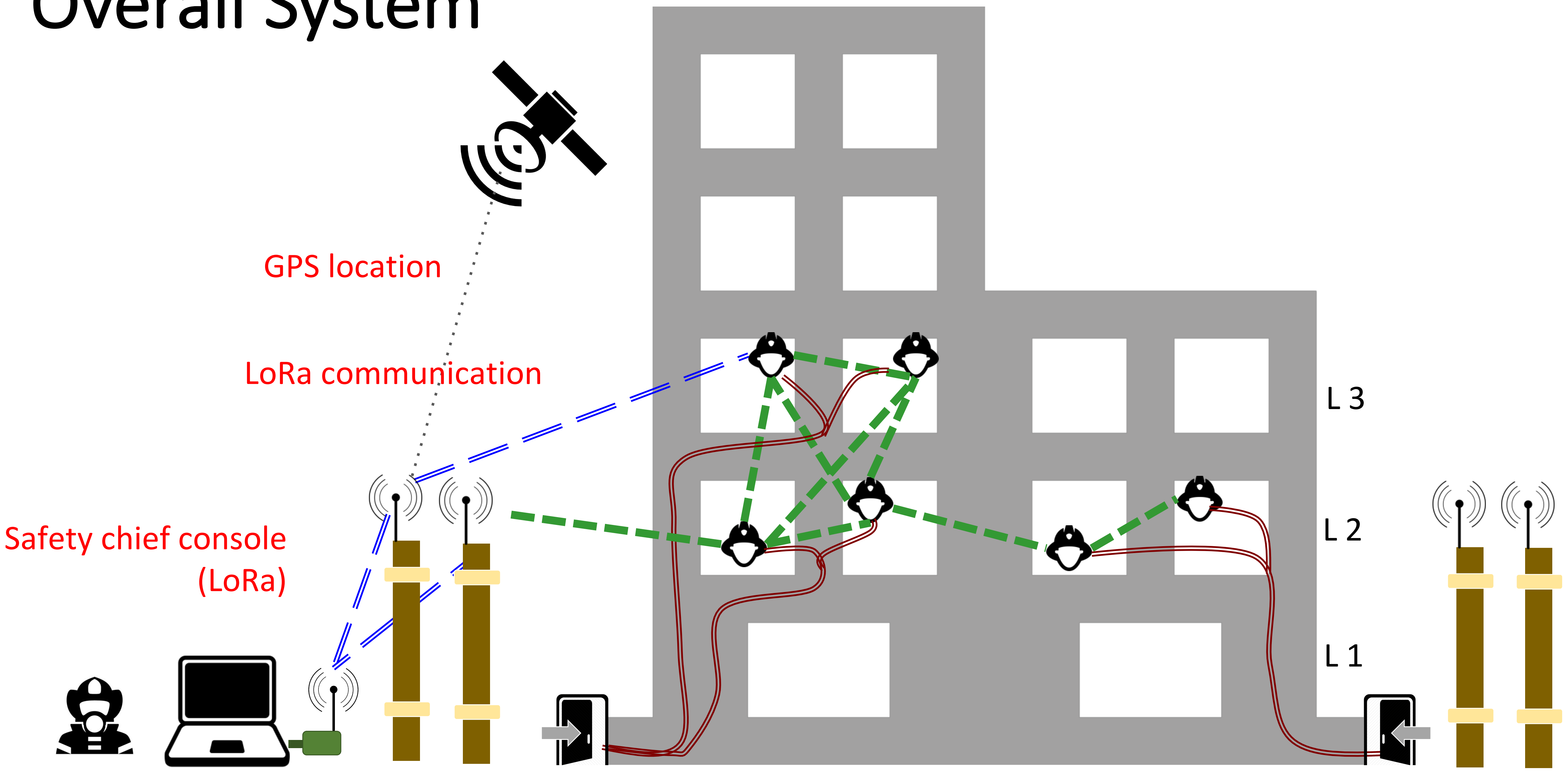


A Snapshot: Not Solvable

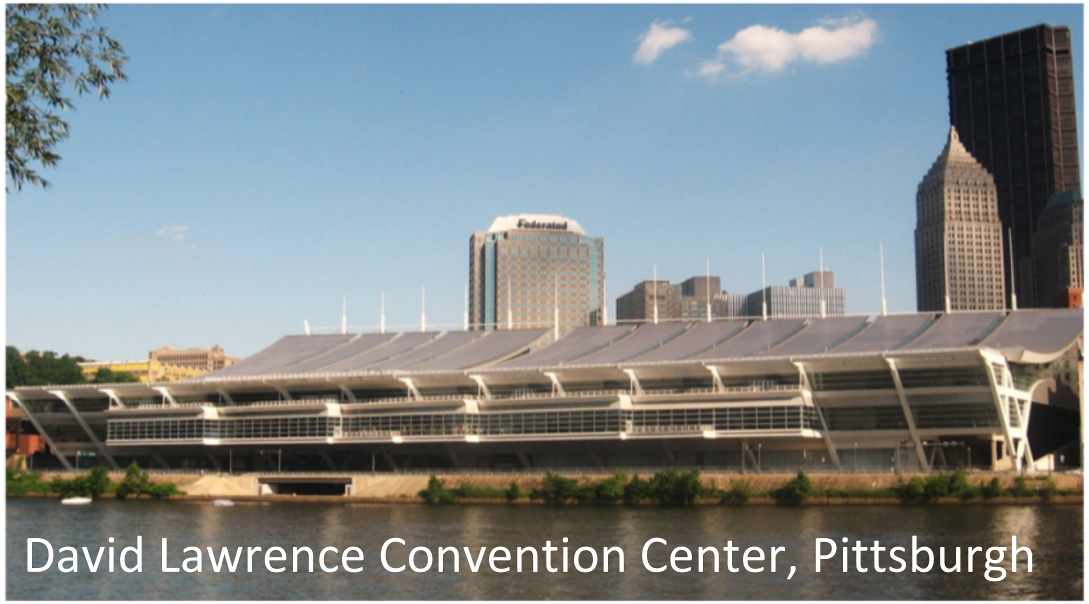


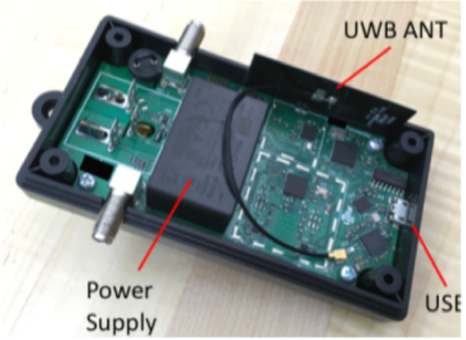
Snapshot Over Time: Solvable!

Overall System



Our Team





Niranjini Rajagopal (PhD) – Signal Processing / Estimation / Tracking / SLAM

Patrick Lazik (PhD) – Communications / Hardware

Anh Luong (Post-Doc) – Hardware / Localization / RF Design / Communications

Bruno Sinopoli (Prof ECE) – Controls and Estimation

Anthony Rowe (Prof ECE) – Embedded Systems and Wireless Communications

Thank you!

Pervasive, Accurate and Reliable Location Based Services for Emergency Responders

Niki Trigoni and Andrew Markham
Sensor Networks Group
Computer Science Department, University of Oxford
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Gregory Dean, John Donnelly
District of Columbia Fire and Emergency Services

Dave Curry, Andy Bowers
Hampshire Fire and Rescue Services

Public Safety Broadband Stakeholder Meeting
June 12-14, 2017
San Antonio, Texas

Our vision

To make location based services a key safety tool, enabling better coordination and faster incident resolution

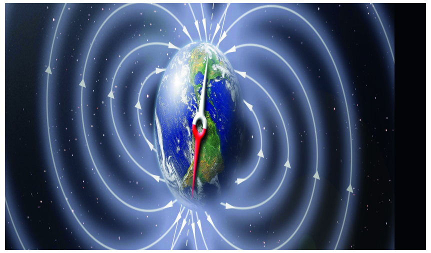
To develop location based services that are

- easy to deploy
- accurate and
- reliable

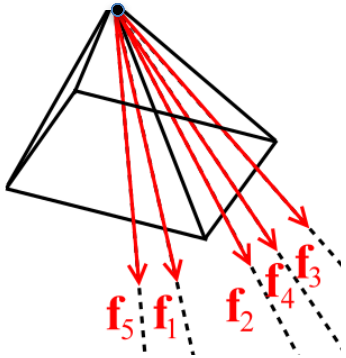
Positioning in GPS-denied environments

Inertial [+ WiFi]

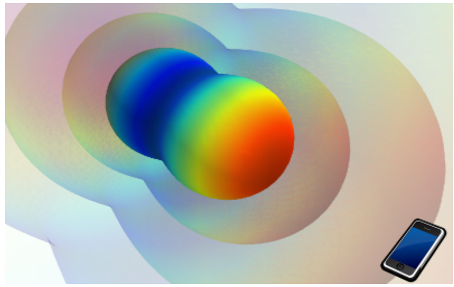
Geomagnetic field



Vision



Low-frequency magnetic fields



Inertial tracking

- Inertial sensors (**accelerometer, gyroscope**) are
  - inexpensive
  - ubiquitous
  - easy to embed in wearable devices

- We have developed
  - inertial tracking algorithms that are robust to device attachment
  - map matching techniques that fuse inertial trajectories with maps

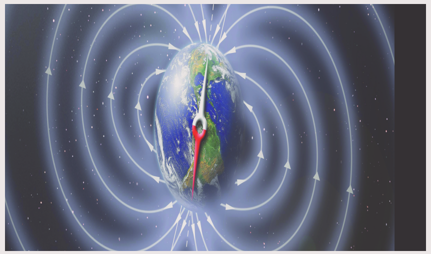
Unique challenges

- Issues with inaccurate / missing floor plans
- No time for survey to build WiFi maps
- Unique way of walking in breathing apparatus
- Unique way of searching a building

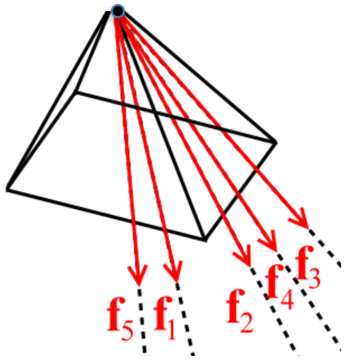
Positioning in GPS-denied environments

Inertial [+ WiFi]

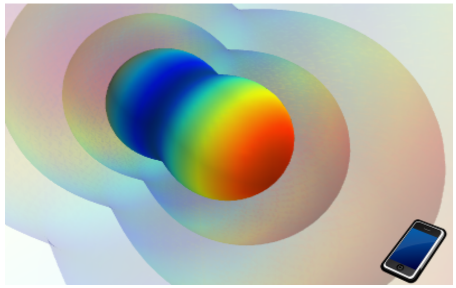
Geomagnetic field



Vision

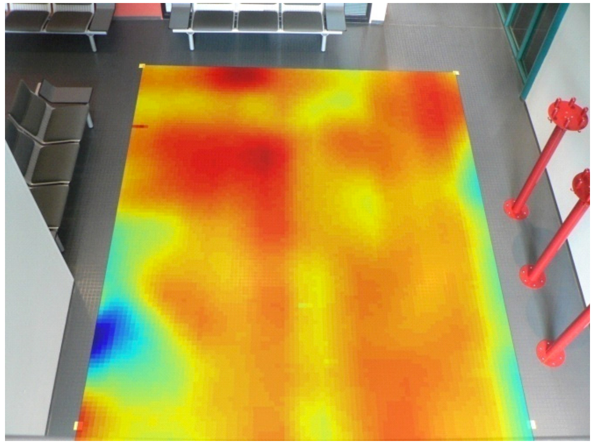


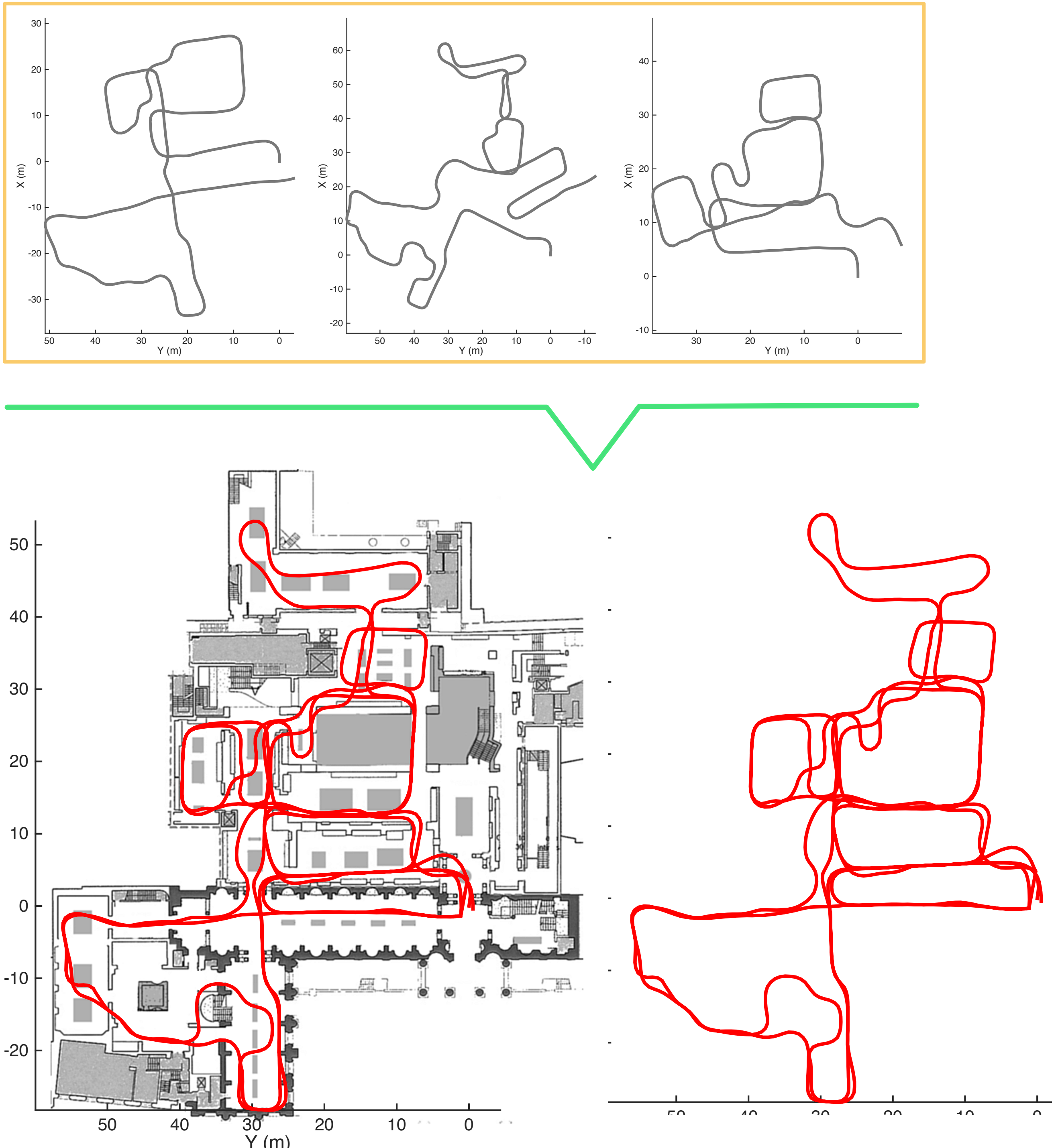
Low-frequency magnetic fields



Geomagnetic positioning

- The earth’s magnetic field is distorted indoors
- Distortions are informative; often unique to a location
- They can help detect a place that has been visited before





X (m)
Y (m)

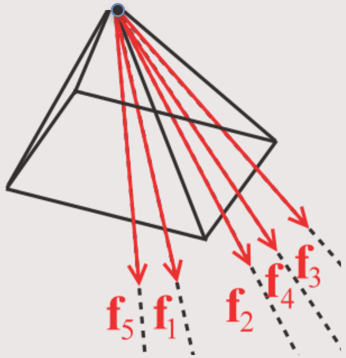
Unique challenges

- Geomagnetic positioning works best if people move at a normal pace along corridors
- We cannot assume significant overlap between trajectories
- We cannot expect many trajectories on any single floor
- Need for new sensor modalities and algorithms to align trajectories

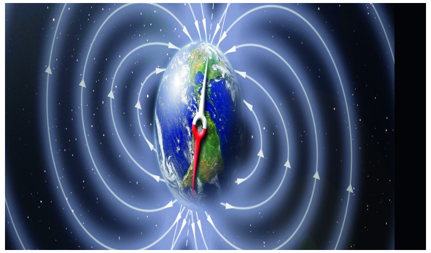
Positioning in GPS-denied environments

Inertial [+ WiFi]

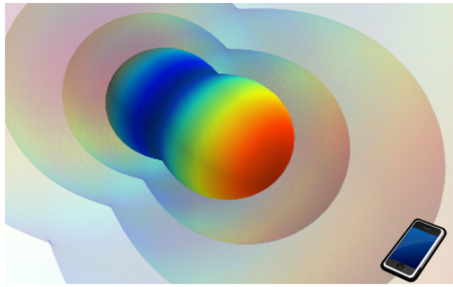
Vision



Geomagnetic field

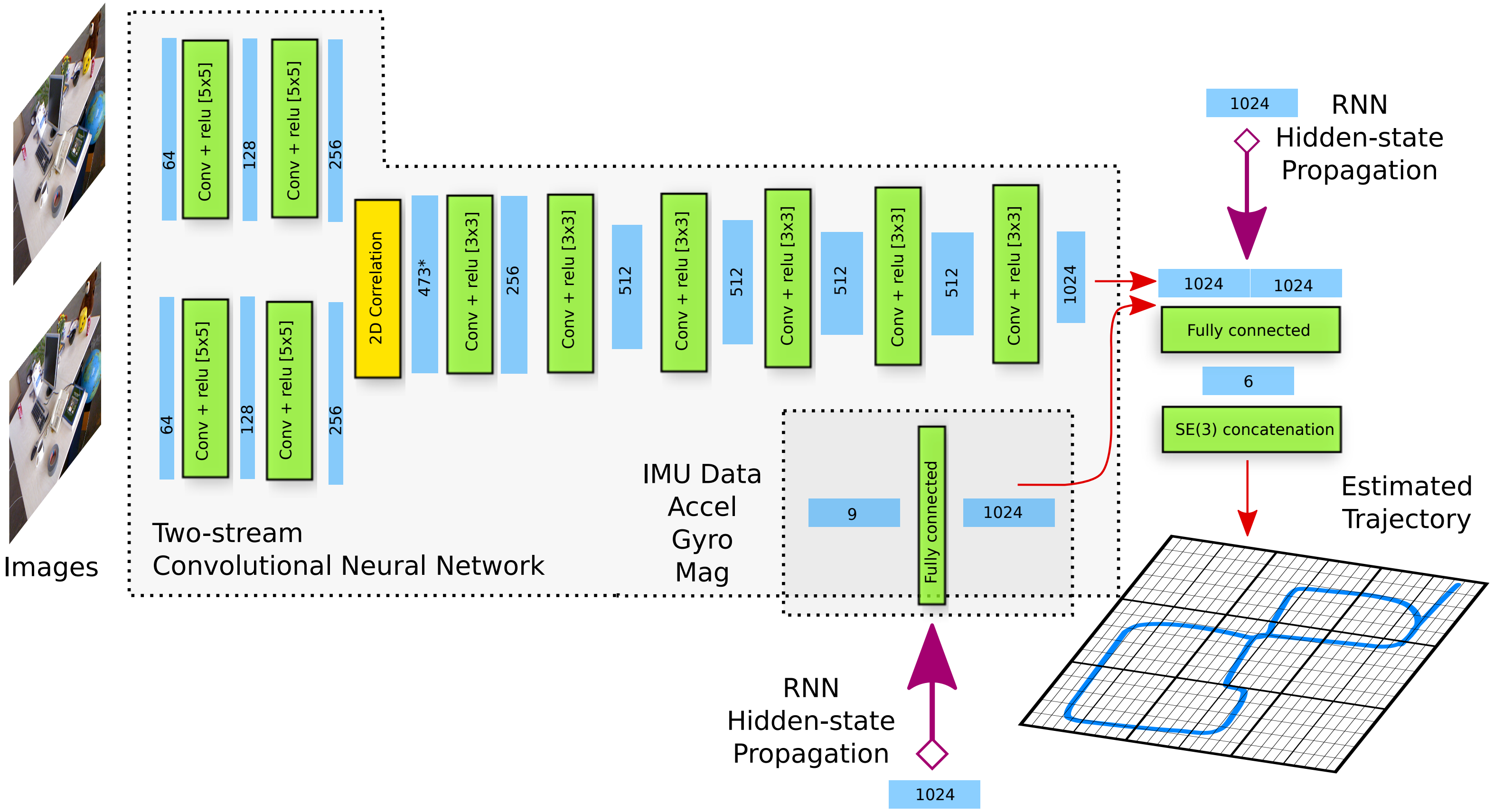


Low-frequency magnetic fields



Visual odometry

- Visual odometry system based on deep neural networks

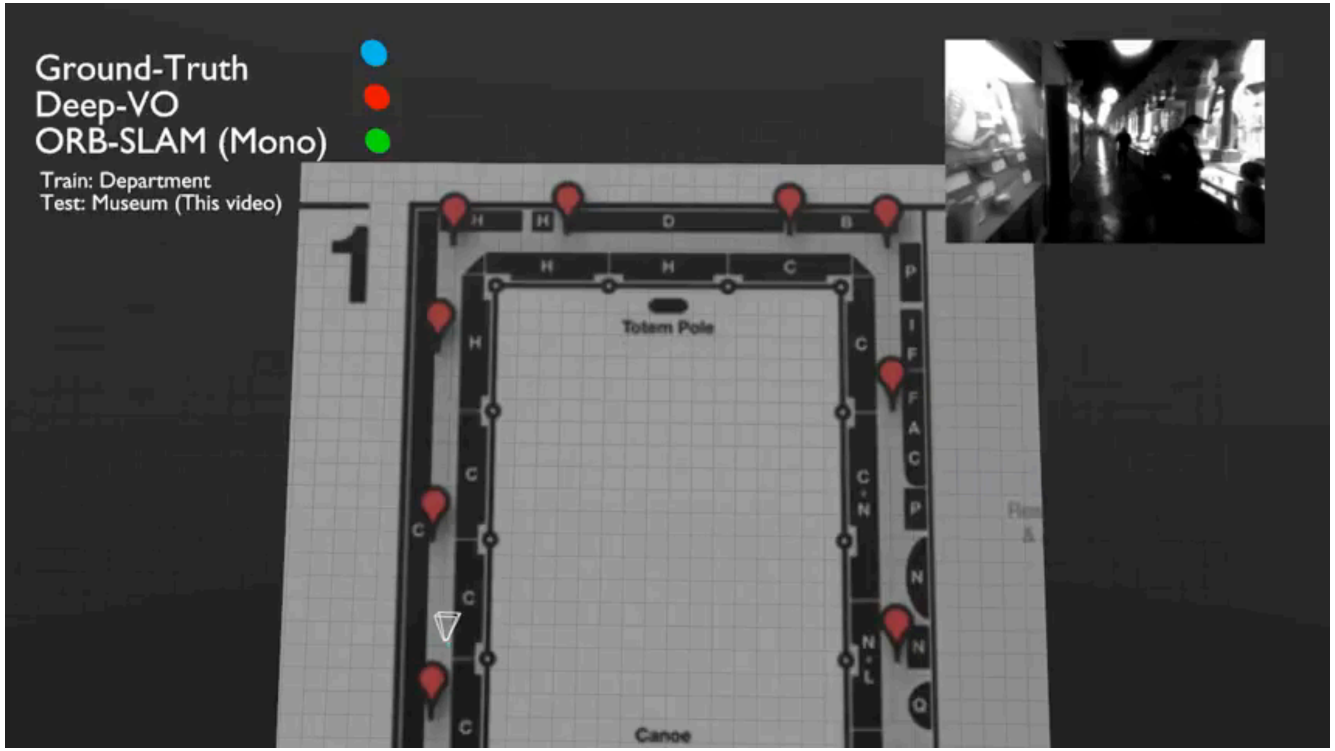


"VINet: Visual-inertial odometry as a sequence-to-sequence learning problem". R. Clark, S. Wang, H. Wen, A. Markham and N. Trigoni. --- **AAAI 2017.**

Visual odometry – in action

Test in Natural History Museum

- Video taken by a smartphone camera in a busy cafe



Unique challenges

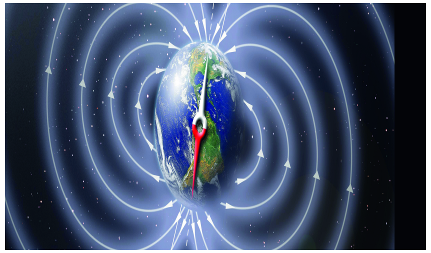
Issues with visual positioning in fire fighting scenarios

- Poor lighting conditions or smoke
- Erratic movement of camera => blurry images
- Obstructions in field of view
- Computationally expensive, currently runs offline

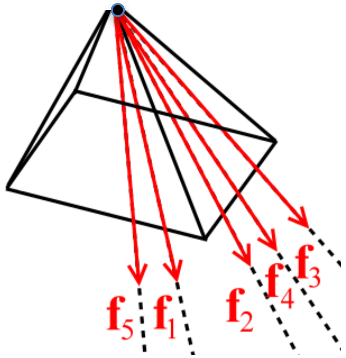
Positioning in GPS-denied environments

Inertial [+ WiFi]

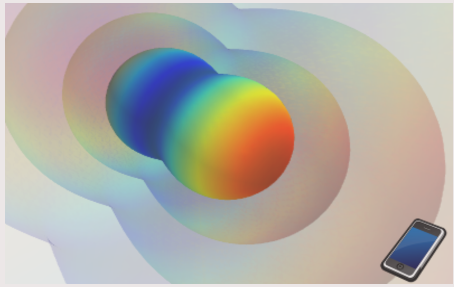
Geomagnetic field



Vision

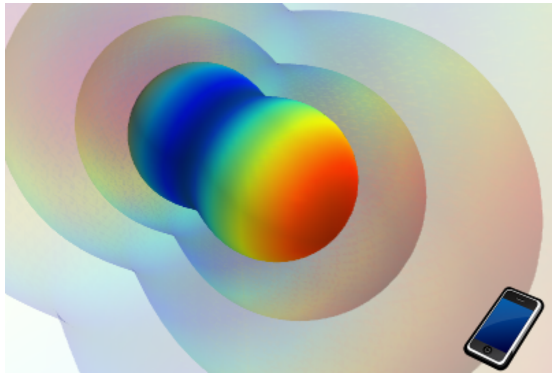


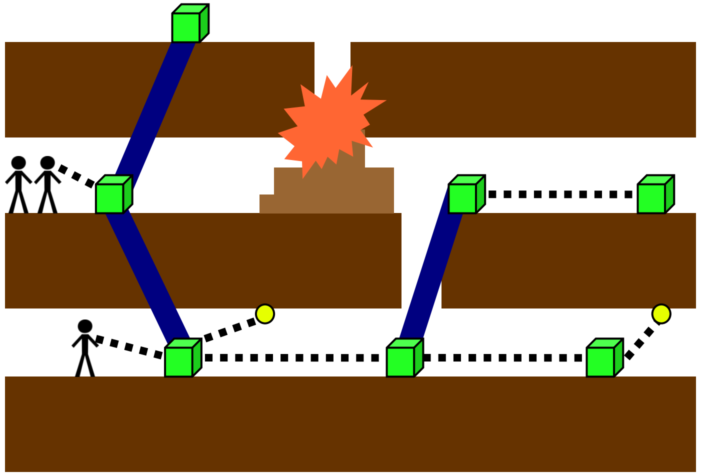
Low-frequency magnetic fields

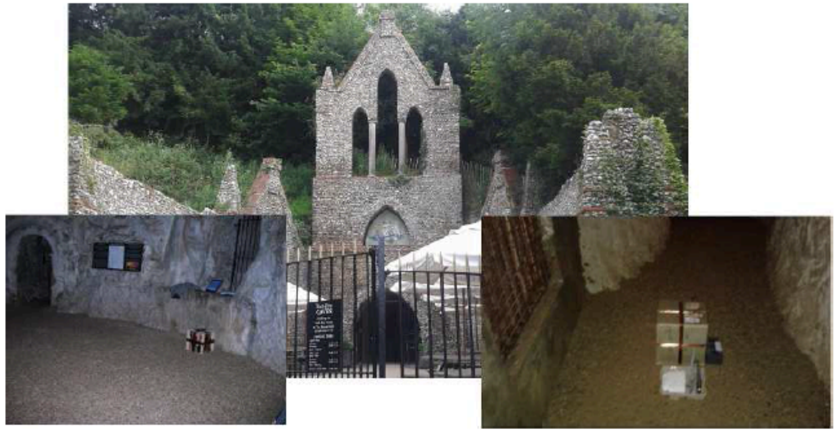


Why low-frequency magnetic fields?

- Low-frequency magnetic fields unaffected by multipath and shadow fading
- Penetrate walls, furniture, air, water with minimal attenuation







Safety in radio-denied underground environments

Range ~ 30 m

Reliable sub-meter ranging accuracy

Reliable communication channel

“Distortion Rejecting Magneto-Inductive 3-D Localization (MagLoc).” T. Abrudan, A. Markham, Z. Xiao and Niki Trigoni --- JSAC 2015.

“A Case for Magneto-Inductive Indoor Localization.” Traian Abrudan, Andrew Markham and and Niki Trigoni --- EWSN 2014 (best poster paper).

Unique challenges

Issues of low frequency magnetic fields in fire fighting scenarios

- Limited size of transceiver carried by fire fighters
- Low bandwidth links used for both positioning and communication
- Low signal-to-noise ratio

Conclusion

- Many technologies at different levels of maturity
- Different sensor modalities have different pros and cons
- This project is aimed at testing them at their limits, in very challenging environments
- Our goal is to find optimal ways of fusing them taking into account the uniqueness of fire fighting scenarios

uNavChip:

Ultimate Navigation Chip

Chip-Scale Personal Navigation System Integrating Deterministic Localization and Probabilistic Signals of Opportunity

Andrei M. Shkel – Principal Investigator (ashkel@uci.edu)
University of California, Irvine

Zak Kassas – Co-Investigator (zkassas@ece.ucr.edu)
University of California, Riverside

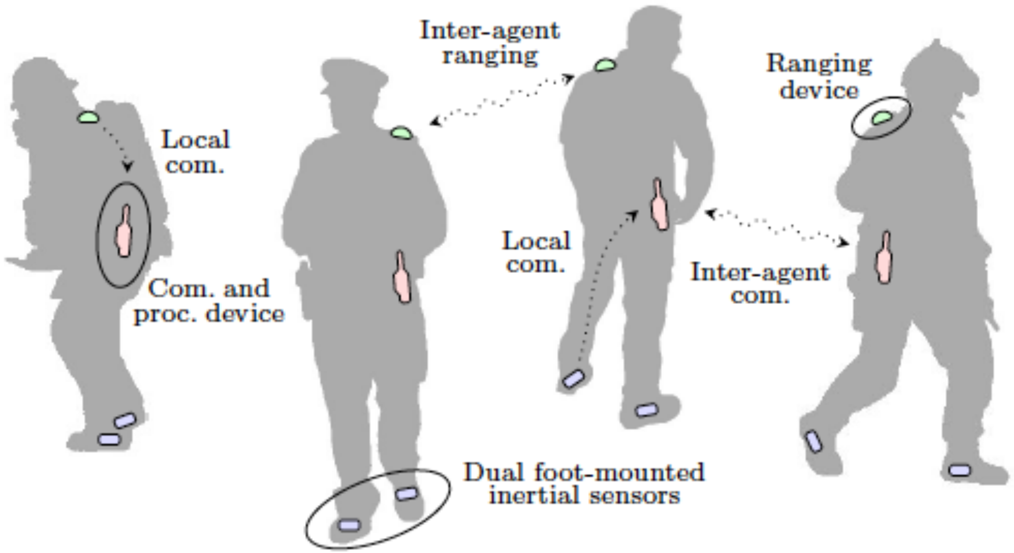
Solmaz Kia – Co-Investigator (solmaz@uci.edu)
University of California, Irvine

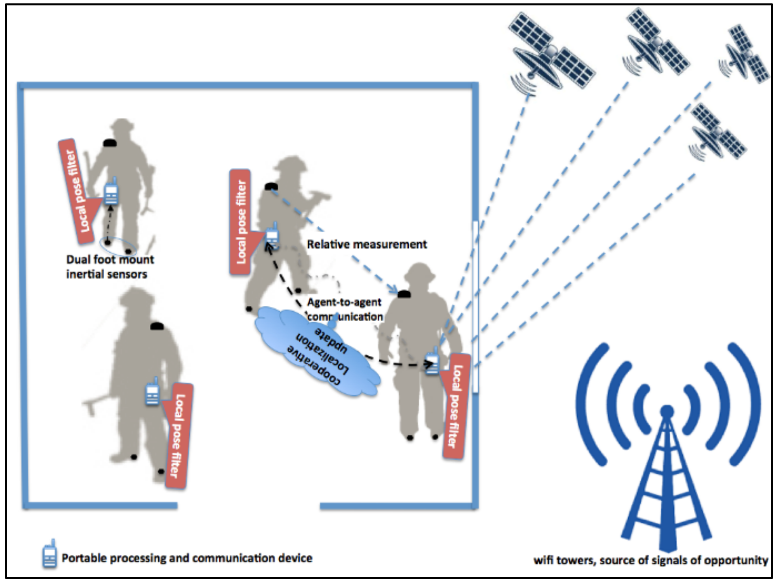
PSCR
2017
Public Safety Broadband Stakeholder Meeting
June 12-14, 2017
Marriott Rivercenter
San Antonio, TX
www.pscr.gov

Team Members

Institutions:	
UC Irvine, University of California	UC Riverside, University of California
Principal Investigator:	
Dr. Andrei M. Shkel UC Irvine	Microtechnology for Positioning, Navigation, Timing (microPNT)
Team:	
Dr. Zak Kassas UC Riverside	SoP-aided INS and Synthetic Aperture Navigation
Dr. Solmaz Kia UC Irvine	Cooperative Localization, Multi-agent Systems

The Problem Statement



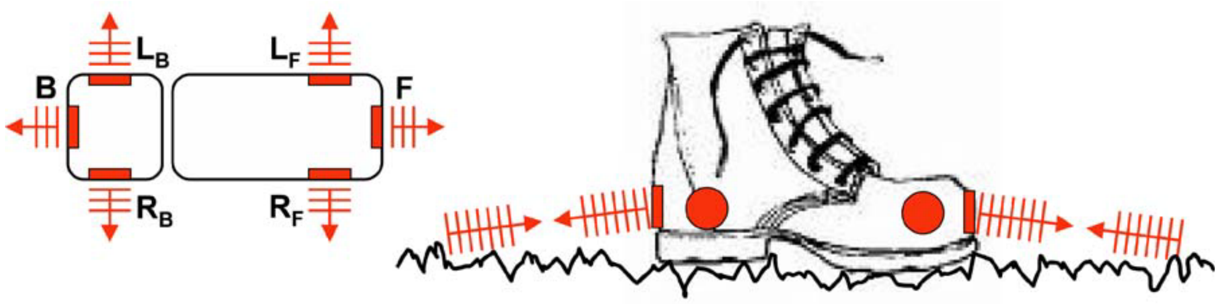


- Localization + Communication
- Situation awareness, coordination, support
- Localization w/o any infrastructure

Our Approach

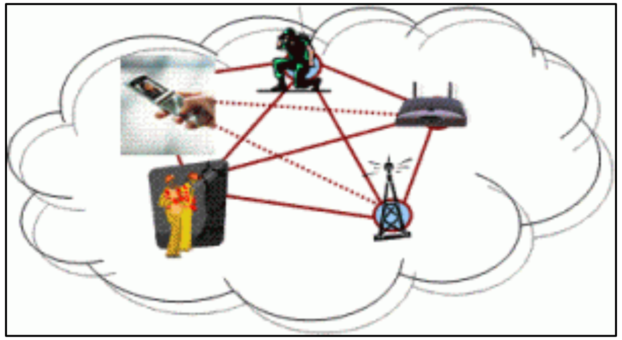
- **Deterministic + Probabilistic + Cooperative**

Deterministic

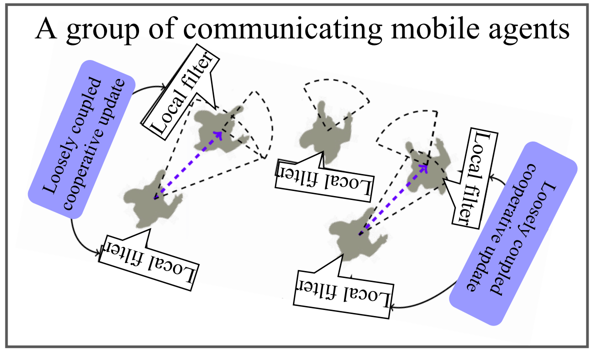


Inertial navigation, foot-to-foot ranging, and ZUPTing

Probabilistic

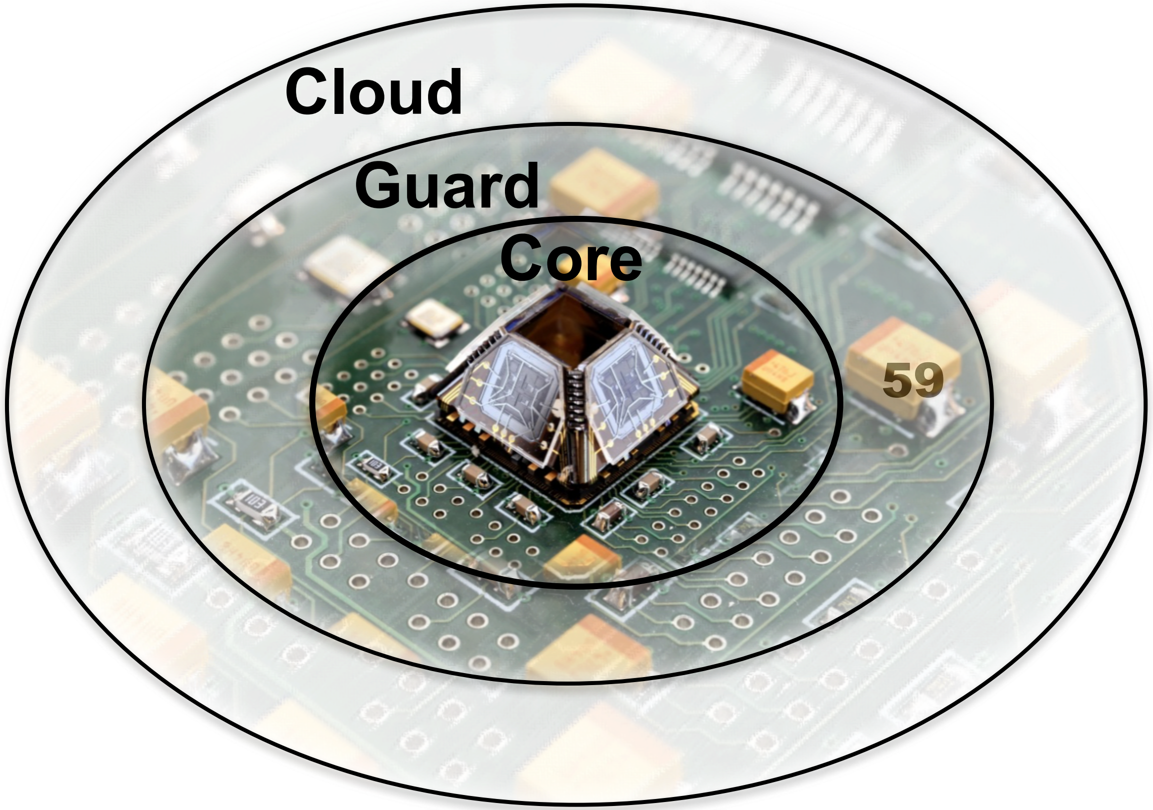


Cloud of signals of opportunity



Cooperative localization

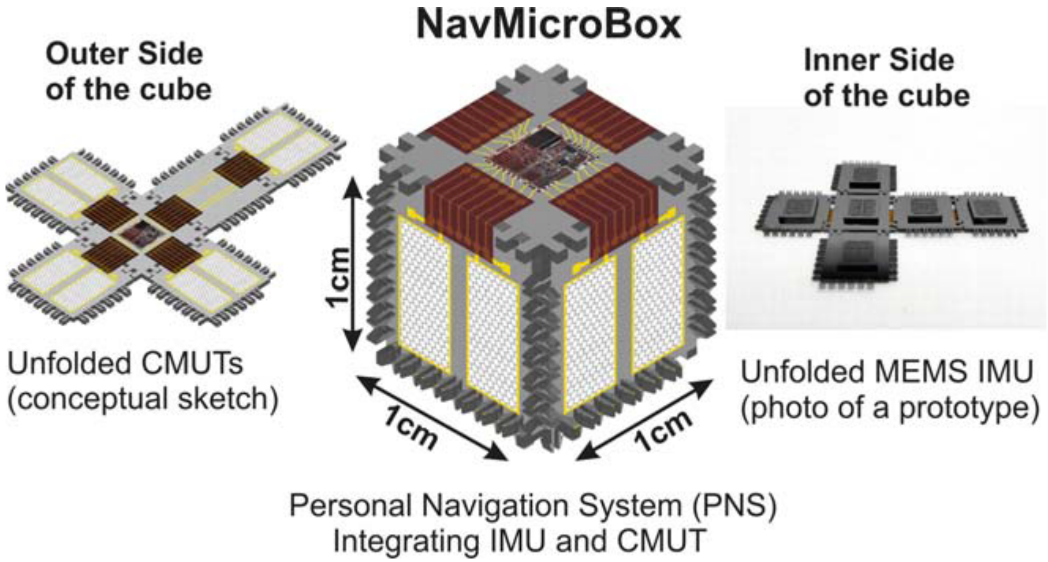
The Concept of *uNavChip*

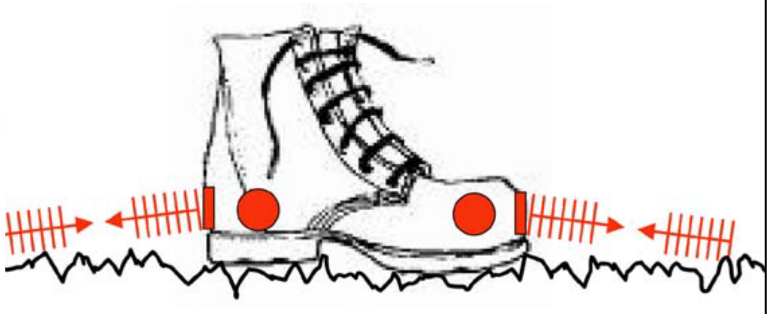


- **Core**
  Inertial measurement unit, clock, altimeter, proximity sensor
- **Guard**
  Authenticate external signals of opportunity
- **Cloud**
  Detect external signals of opportunity

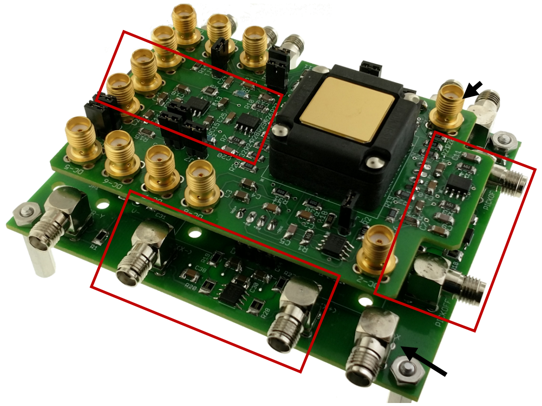
- **Provide maximum autonomy, security, precision**

Implementation





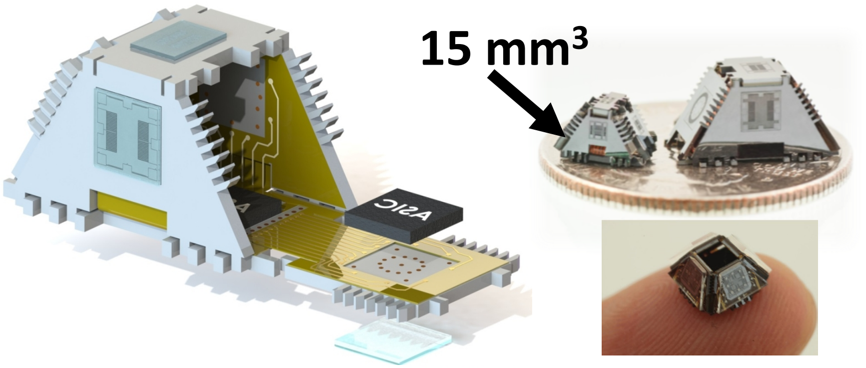
On-Board Detection and Processing of Signals of Opportunity

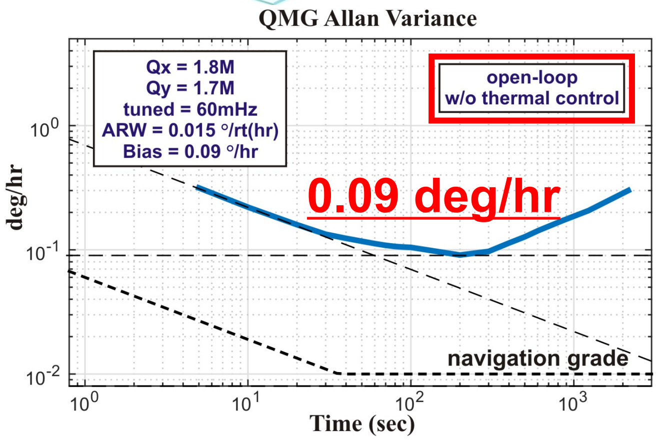


- Radio SLAM with signals of opportunity (SOPs)
- Indoor and covered outdoor cellular SOP reception stochastic modeling and analysis
- SOP-aided INS and synthetic aperture navigation
- Processing of ranging for cooperative localization

Enabling Technology

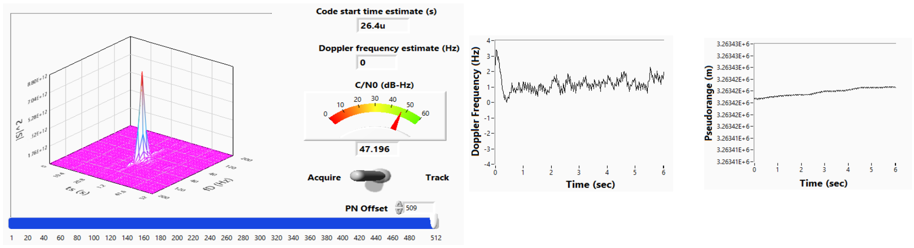
- **Micro-Electro-Mechanical Systems (gyros, accel, CMUT)**





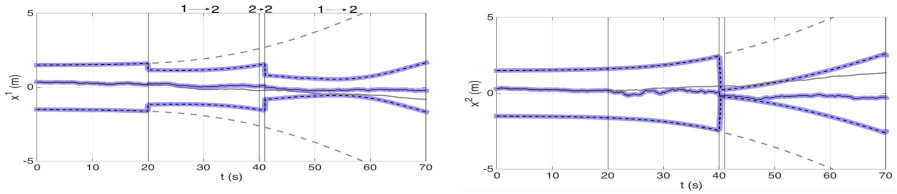
Demonstrated near-Nav grade on-run ARW and bias floor

- **Advanced Signal Processing (RF SLAM/SoP)**



Demonstrated SOP-aided INS with 5.1 m CEP after 30 sec (~27.5 m with GPS)

- **Optimal Estimation Theory (Aiding & Coop. Localization)**



Predicted over 70% improvements due to cooperative localization

Expected Impact

- uNavChip Technology: maximum autonomy, security, precision
- Miniaturized Personal Navigation Technology for GPS-challenged environment
- Achieve the localization accuracy on the level of 1 meter
- Hours of operation with the level of accuracy

Resilient Systems

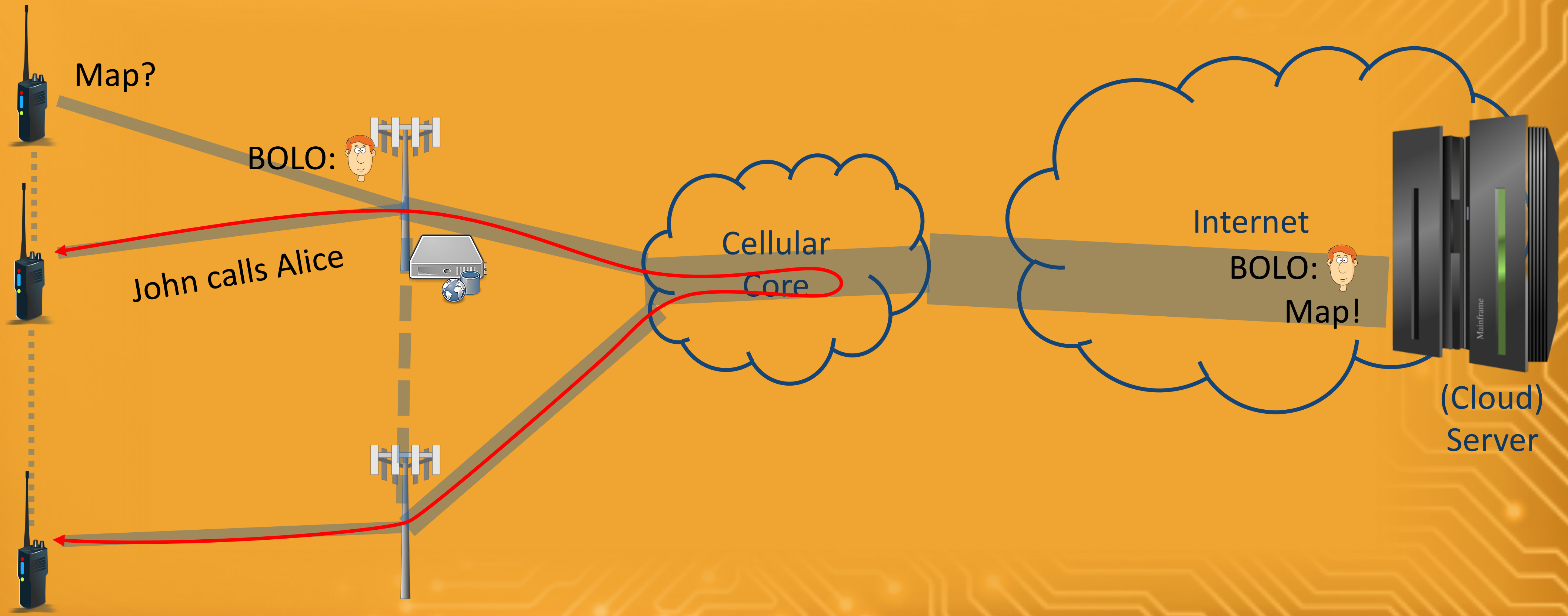
PSCR

2017

PUBLIC SAFETY BROADBAND
STAKEHOLDER MEETING

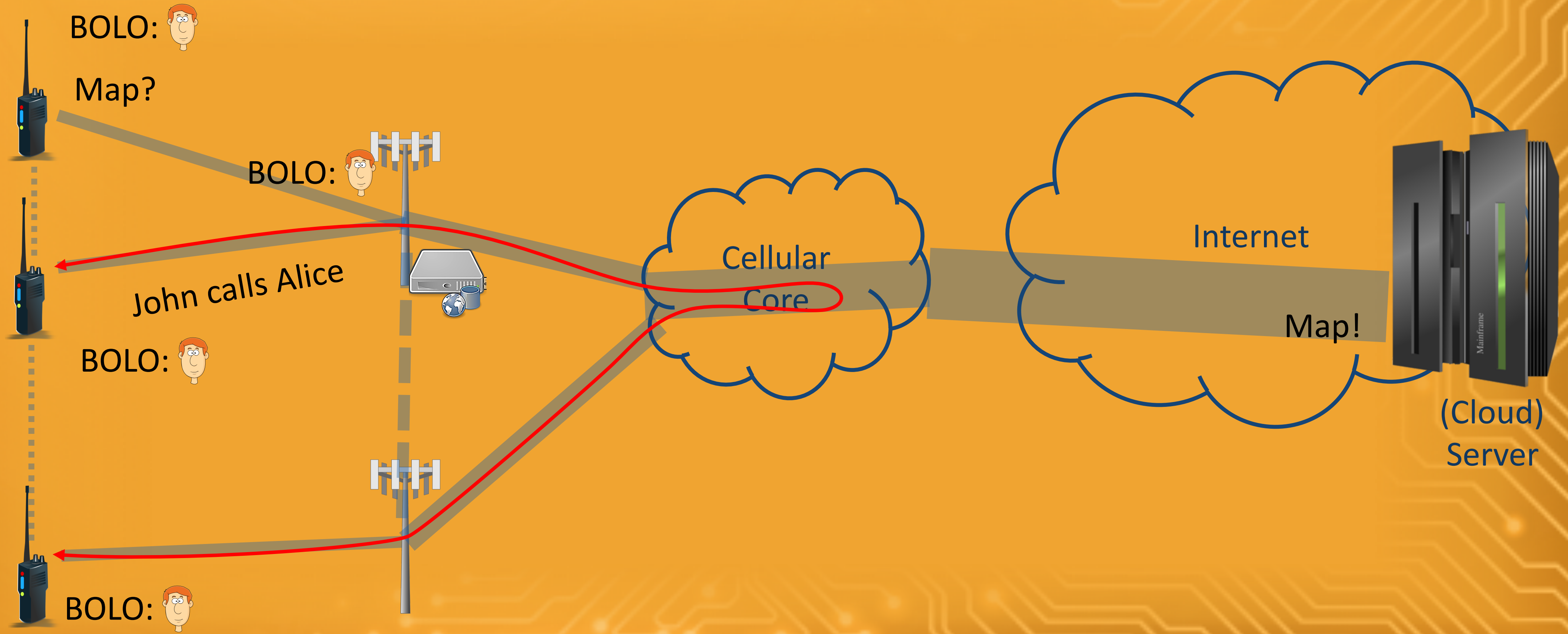
#PSCR2017

Normal Cellular/Internet Operation



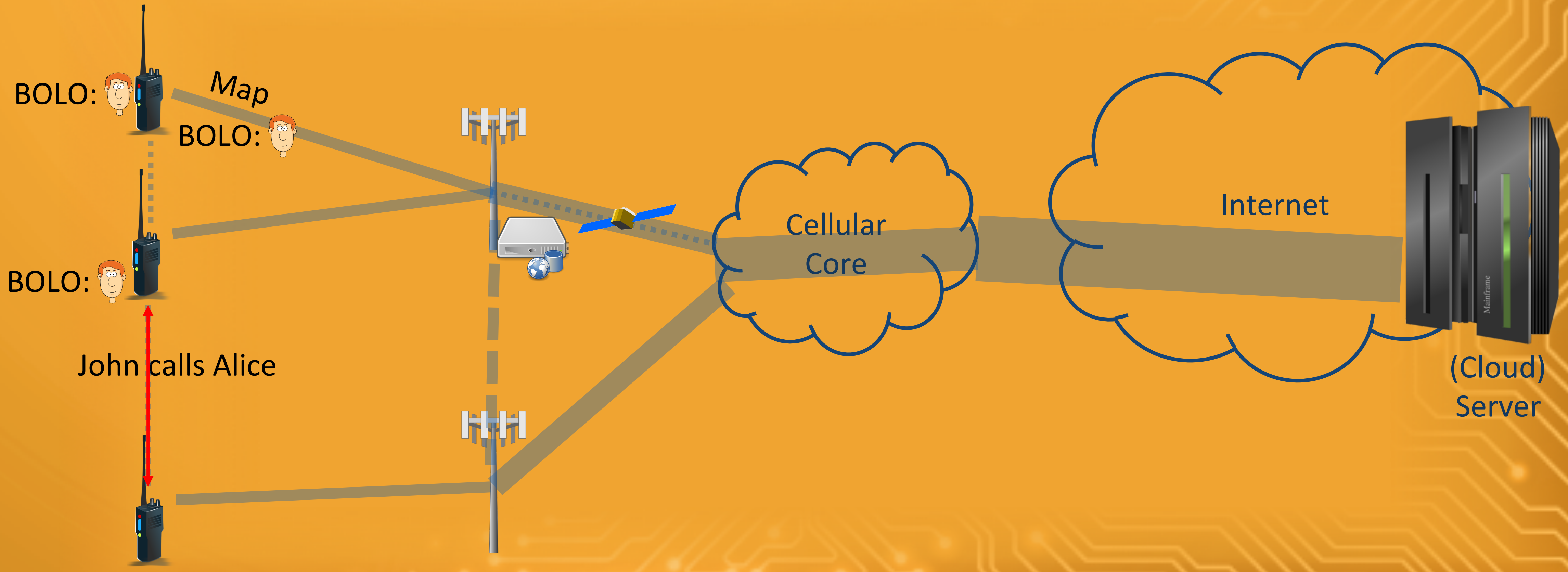
PSCR

Normal Cellular/Internet Operation

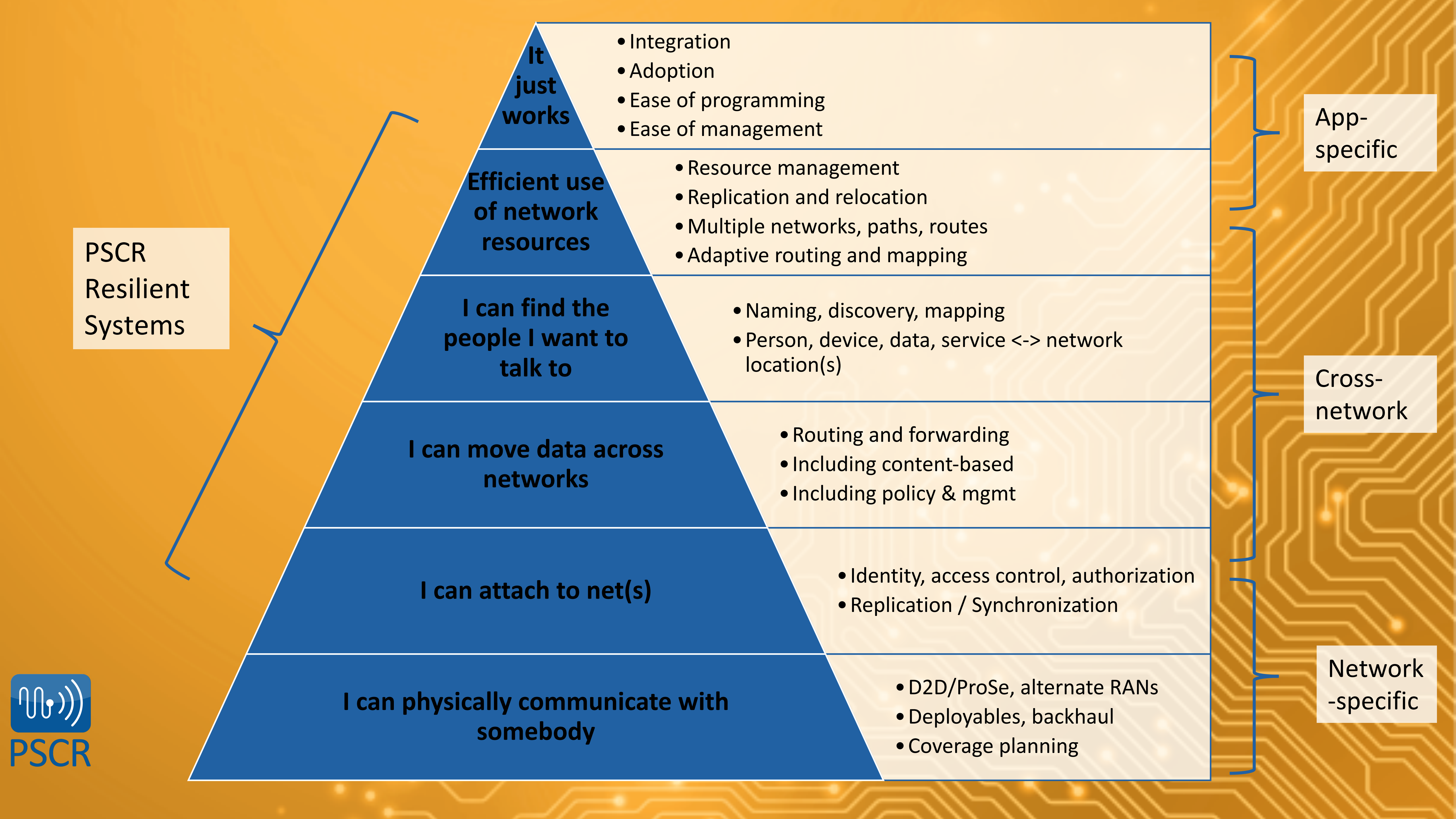


PSCR

Goal: Impaired Network Operation



PSCR


It just works
Integration
Adoption
Ease of programming
Ease of management
Efficient use of network resources
Resource management
Replication and relocation
Multiple networks, paths, routes
Adaptive routing and mapping
I can find the people I want to talk to
Naming, discovery, mapping
Person, device, data, service <-> network location(s)
I can move data across networks
Routing and forwarding
Including content-based
Including policy & mgmt
I can attach to net(s)
Identity, access control, authorization
Replication / Synchronization
I can physically communicate with somebody
D2D/ProSe, alternate RANs
Deployables, backhaul
Coverage planning
PSCR Resilient Systems
App-specific
Cross-network
Network-specific
PSCR

Resilient Systems Grant Awardees

Cornell University

Michigan Technological University

Spectronn

Texas A&M University

University of California, Riverside

University of Colorado

PSCR

RS Presentations

Texas A&M University

DistressNet-NG: Resilient Mobile Broadband Communication and Edge Computing for FirstNet

Spectronn

Heterogeneous Fog Communications and Computing for Resilience

Michigan Technological University

Resilient System Solutions for Data Sharing for Wildland Fire Incident Operations

University of California, Riverside

Modeling and Development of Resilient Communication for First Responders in Disaster Management

PSCR

DistressNet-NG: Resilient Mobile Broadband Communication and Edge Computing for FirstNet

Radu Stoleru (PI), Walt Magnussen, Harsha Chenji

NIST PSCR Annual Public Safety Broadband Stakeholder Meeting 2017

Team

Radu Stoleru
Associate Professor
Texas A&M University

Walt Magnussen
Director Internet 2 Evaluation Center,
Director Telecommunications
Texas A&M University

Harsha Chenji
Assistant Professor
Ohio University

Partners/Collaborators

1. Texas A&M Engineering Extension Service (TEEX)
   - ❑ Training emergency responders
   - ❑ Disaster City

2. Texas Military Department / Texas National Guard
3. Texas Department of Public Safety

Project Overview

Proposal responding to topics:

F (Resilient Systems) and E (Research and Prototype)

Objective:

"To enhance the resilience of both public safety mission critical systems and services in the face of connectivity challenges by developing fault tolerant, energy efficient and load balanced solutions for mobile broadband communication and mobile edge computing."

Team Experience

Fog/Edge Computing

6.6.1 Functional Budget and Committed Industrial/Practitioner Support

Functional Budget Table (Year 1)	
Function	%
Thrust 1 Remote Condition Assessment	11.8%
Thrust 2 Fog/Cloud Computing	**8.0%**
Thrust 3 Polycentric Decision Support	10.3%
Thrust 4 Data Federation Processing	7.7%
Thrust 5 Social Computing Systems	3.8%
Research Total	41.6%
General & Shared Equipment	0.8%
New Facilities/ New Construction	0.0%
General Operating Expenses	1.5%
University Education Program (Excluding REU)	5.8%
Research Experience for Undergraduates Program	1.1%
Pre-College Education Programs (excluding RET)	1.6%
Research Experiences for Teachers Program	1.1%
Industrial Collaboration/Innovation Program	3.7%
Leadership/ Administration/ Management	10.5%
Center Related Travel	1.3%
Other (Indicate Expense in a Footnote)	5.0%
Indirect Cost	26.0%
Total	100.0%

Committed Ind Support (Year 1	
Source	(
Committed Member Firms (Total not by Name)	$
State Government	
Local Government	
Federal Government	
Total	

2008 Texas A&M University ($20M Proposal):

NSF Engineering Center on Emergency Informatics (ERC)

INTERNET 2 TECHNOLOGY EVALUATION CENTER
TEXAS A&M UNIVERSITY

CSEC

NENA THE 9-1-1 ASSOCIATION

ICE - Industry Collaboration Events

NG9-1-1

Walt Magnussen
@WMagnussen
Follow

Working on FirstNet testing for CAUSE IV. This will be a DHS border crossing interop test held in April in Canada

DistressNet (2011 – 2015)

DistressNet

Search

HOME ABOUT PUBLICATIONS MEMBERS SOURCE CODE OUR LAB CONTACT

Welcome

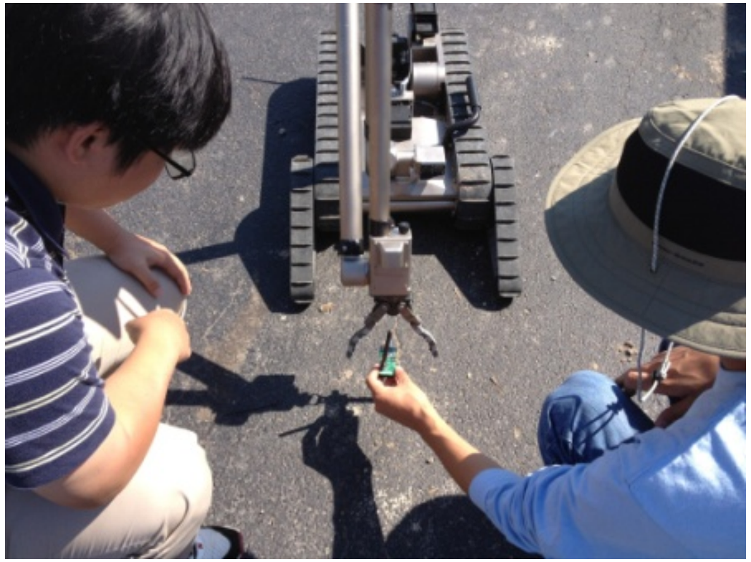
Situational awareness in a disaster is critical to effective response. Resources are scattered across large areas and communications are impaired. Disaster responders require timely delivery of high volumes of accurate data to make effective decisions. DistressNet is an adhoc wireless architecture that supports disaster response with distributed collaborative sensing, topology-aware routing using a multi-channel protocol, and accurate resource localization. Sensing suites use collaborative and distributed mechanisms to optimize data collection and minimize total energy use. Message delivery is aided by novel topology management while congestion is minimized through the use of mediated, multi-channel radio protocols. Novel estimation techniques improve localization accuracy in difficult environments.

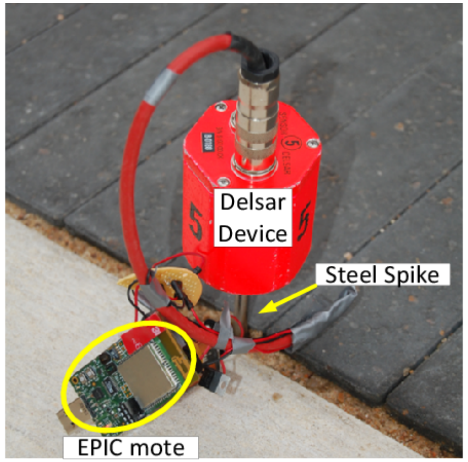
We gratefully acknowledge the partial funding of this research by NSF via the following awards:

1. **Award number 1127449: SDCI Net: A Wireless AdHoc and Sensor Network Cyberinfrastructure for Emergency Response**

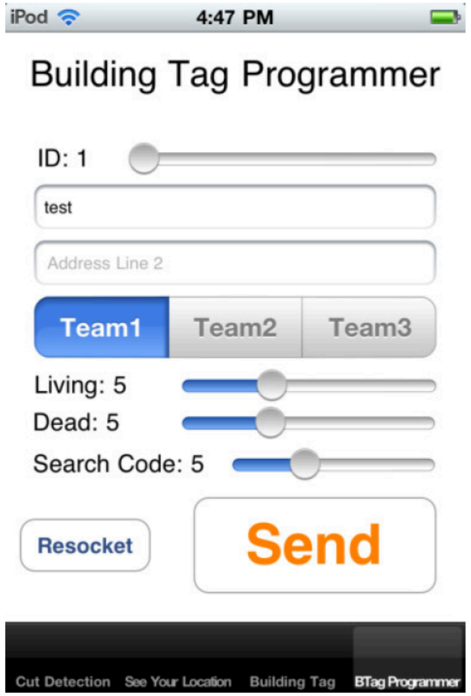
Intellectual merit: This project develops a cyberinfrastructure consisting of a set of new protocols, software components

DistressNet: Disaster City, College Station, TX





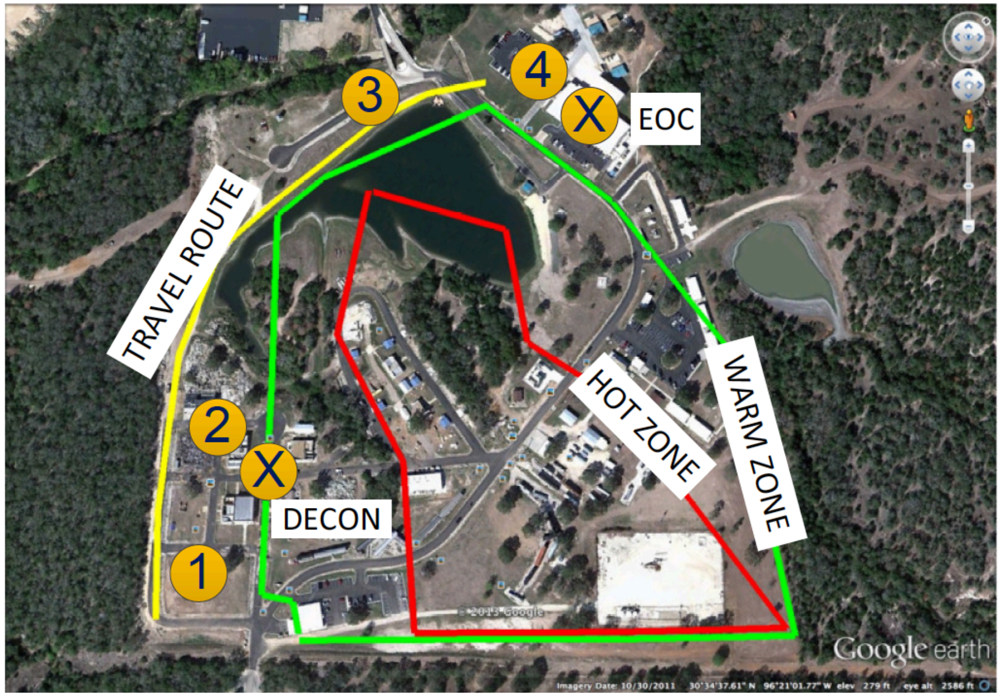
DistressNet: Hazmat Disaster Response (Disaster City, TX)



(a) BTag Programmer

(b) Router

(c) Disaster City



(d) Map of DistressNet deployment at Disaster City

www.distressnet.org

Key Idea

Enabling mobile edge computing paradigms

Data and computation are pushed to the user equipment, not just in the EPC
Fully wireless and resilient LTE EPC and backhaul
First-class support for heterogeneous mobility
Fault-tolerant and reliable distributed computing, data storage and retrieval

In challenged environments

Like a disaster response environment

Can improve situational awareness

Data at ultra high temporal and spatial resolutions
Ability to share data among teams

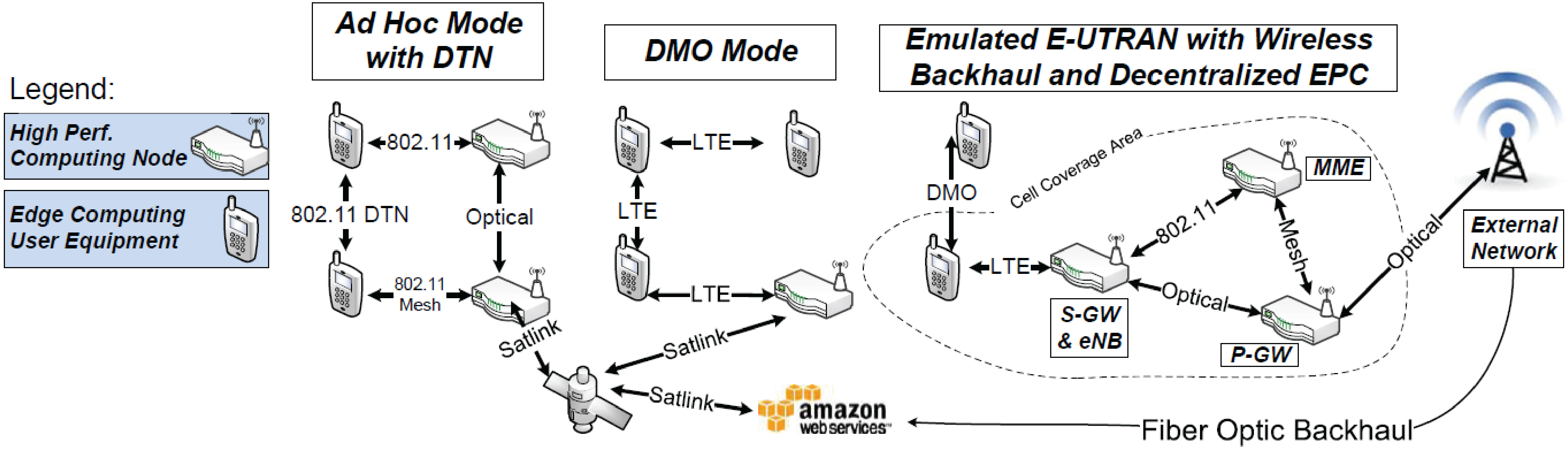
DistressNet-NG: the Next Generation

Mobile Edge Computing

- ❑ Resilient network architecture
- ❑ Energy efficient algorithms
- ❑ Load balanced performance

Decentralized LTE

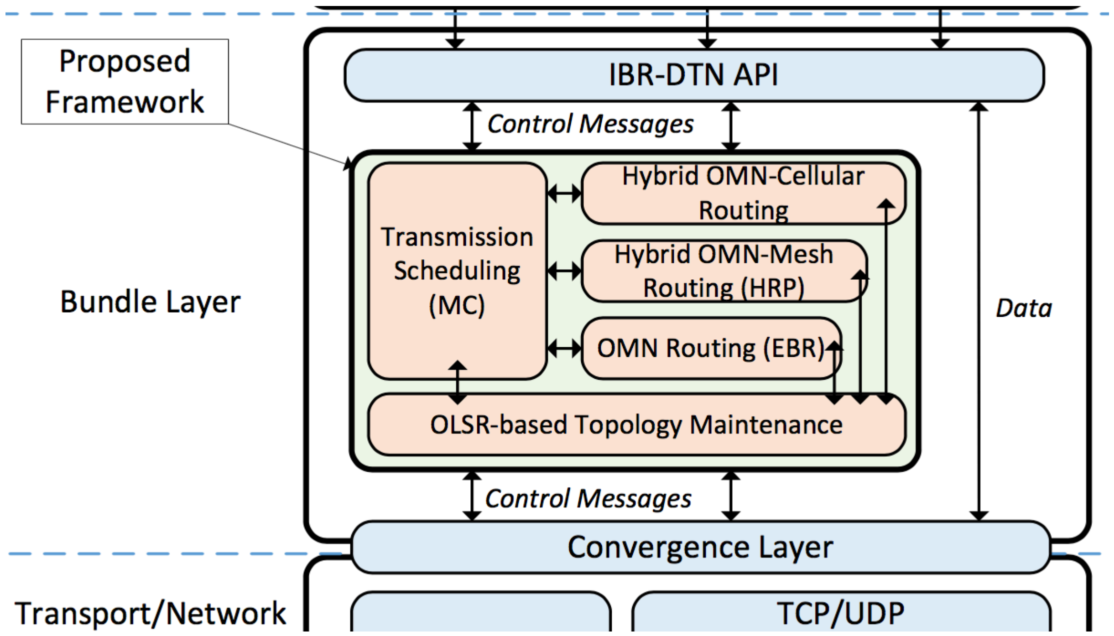
- ❑ LTE-as-a-Service
- ❑ Heterogeneous routing and mobility
- ❑ Fully wireless backhaul



Mobile Edge Computing

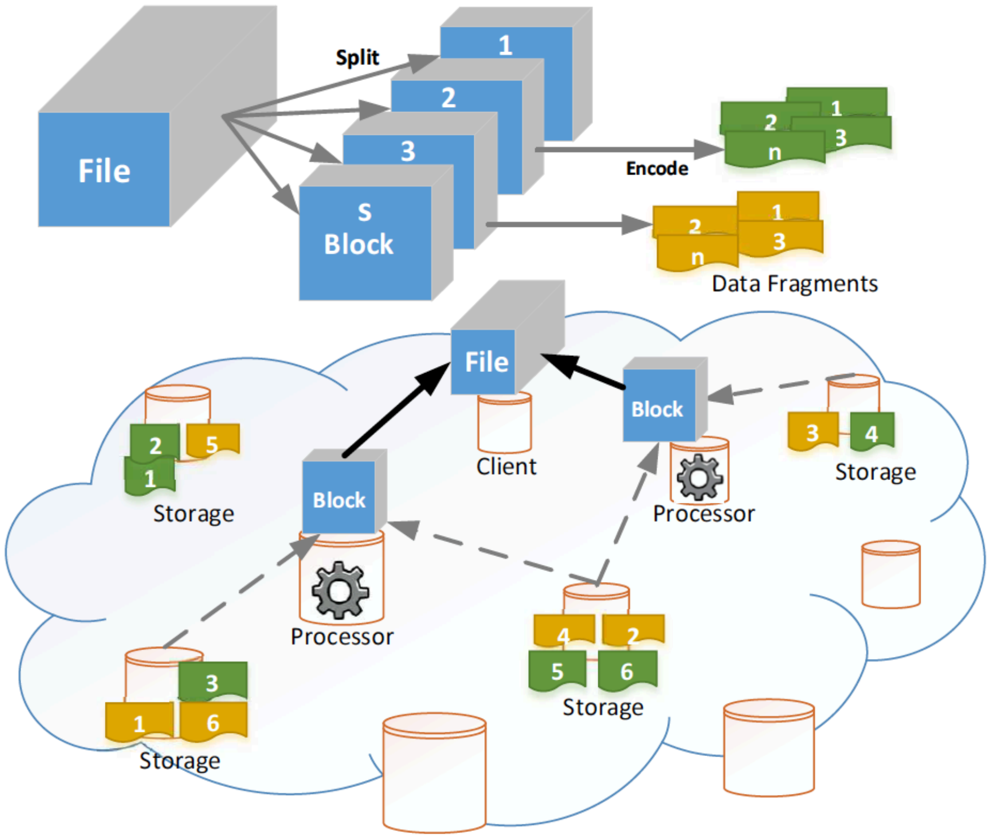
1. Research Thrusts:
   - ❑ Routing Across Heterogeneous and Opportunistic Networks:

“Design a multi-domain routing framework for wireless networks with diverse connectivity, based on theoretical analysis for the benefit of packet replication and delayed transmissions.”



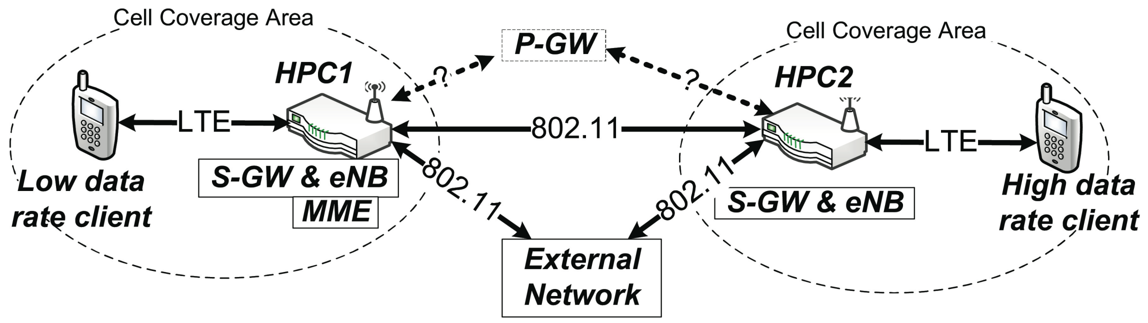
Mobile Edge Computing

1. Research Thrusts:
   - Resilient, Energy Efficient and Load Balanced Edge Computing:
     "Design algorithms for data storage and processing based on the k-out-of-n framework for reliability."

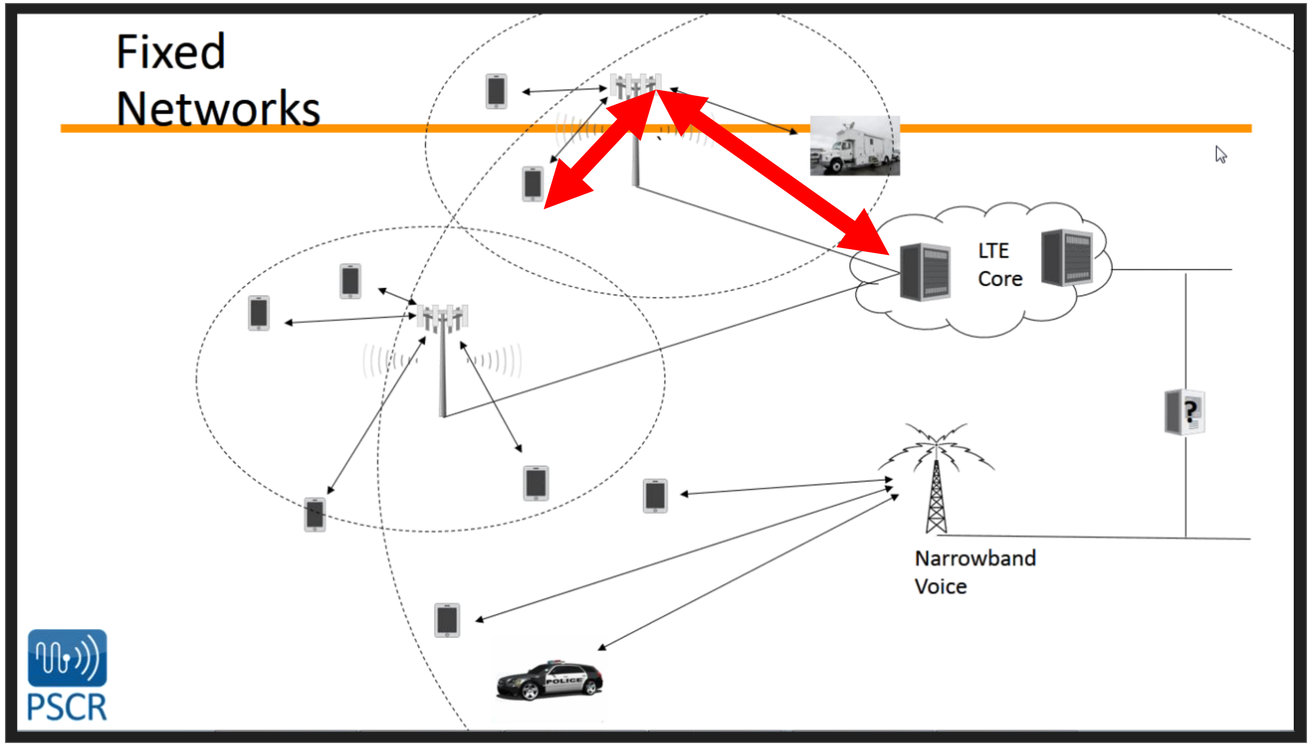


Decentralizing LTE

1. Key idea: **<u>LTE-as-a-Service:</u>** Dynamically (de)spawn LTE elements
   - ❑ Create "islands of connectivity" quickly
2. Store the "state" such as HSS database in the mobile edge/cloud!
   - ❑ Lowers the call setup delay, QoS/QoE, traffic locality



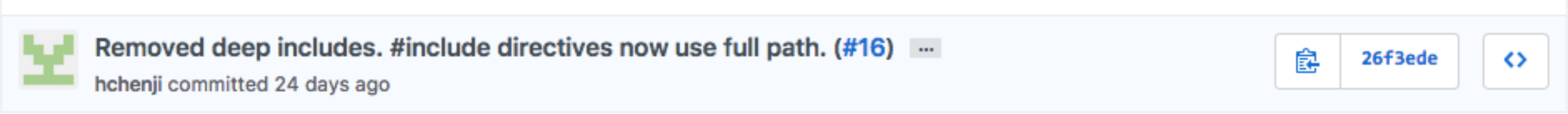
From the NOFO webinar



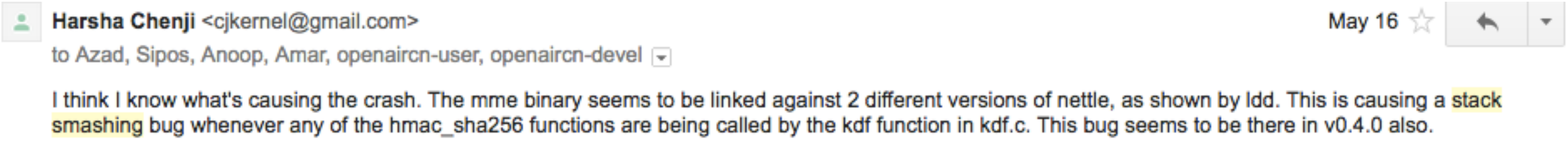
Current Work and Commitment to Open Source

1. Working OpenAirInterface EPC has been built at Ohio Univ.
   - Uses OAISIM to simulate UEs

2. Omnet++ - SimuLTE plugin: minor code contributions



3. Minor contributions to OpenAirInterface-corenetwork



Harsha Chenji <cjkernel@gmail.com>
May 16
to Azad, Sipos, Anoop, Amar, openaircn-user, openaircn-devel

I think I know what's causing the crash. The mme binary seems to be linked against 2 different versions of nettle, as shown by ldd. This is causing a stack smashing bug whenever any of the hmac_sha256 functions are being called by the kdf function in kdf.c. This bug seems to be there in v0.4.0 also.

Collaboration with Other NIST PSIAP Teams

1. Public Safety Analytics
2. Modeling and Simulation
3. Public Safety Communication Security
4. Mission Critical Voice

Questions/Comments/Collaboration

DistressNet-NG: Resilient Mobile Broadband Communication and Edge Computing for FirstNet

stoleru@cse.tamu.edu
w-magnussen@tamu.edu
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Heterogeneous Fog Communications and Computing for Resilience

R. Chandramouli (Mouli), CEO

End-to-end Resilient Public Safety Communications Problem

Disruption in spectrum access

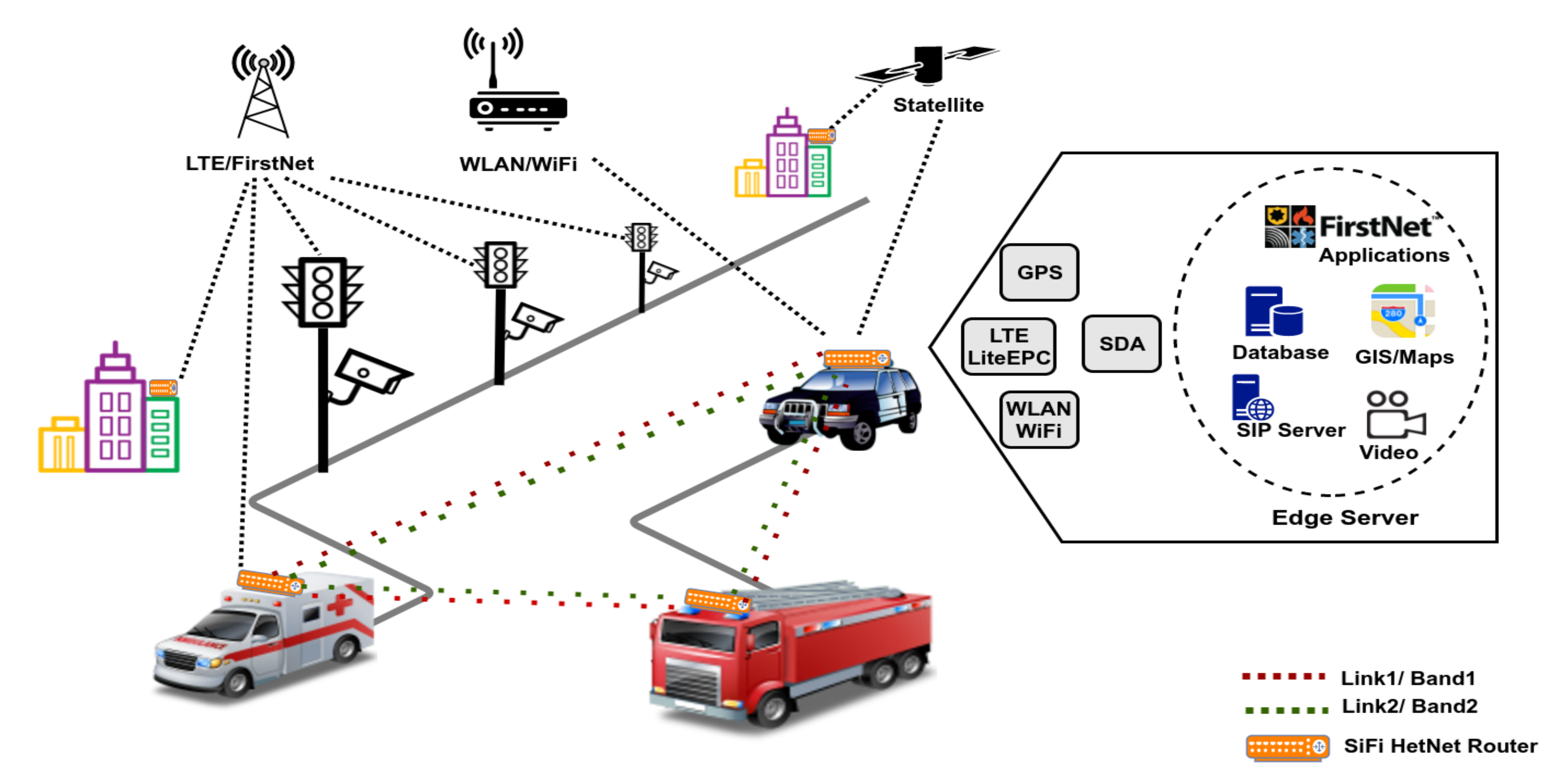
Hurricane Sandy also disrupts cellular networks and wired Internet

AT&T, Verizon, T-Mobile, and Sprint are all hit by outages.

Congestion in backbone network

Cellphone networks overwhelmed after blasts in Boston

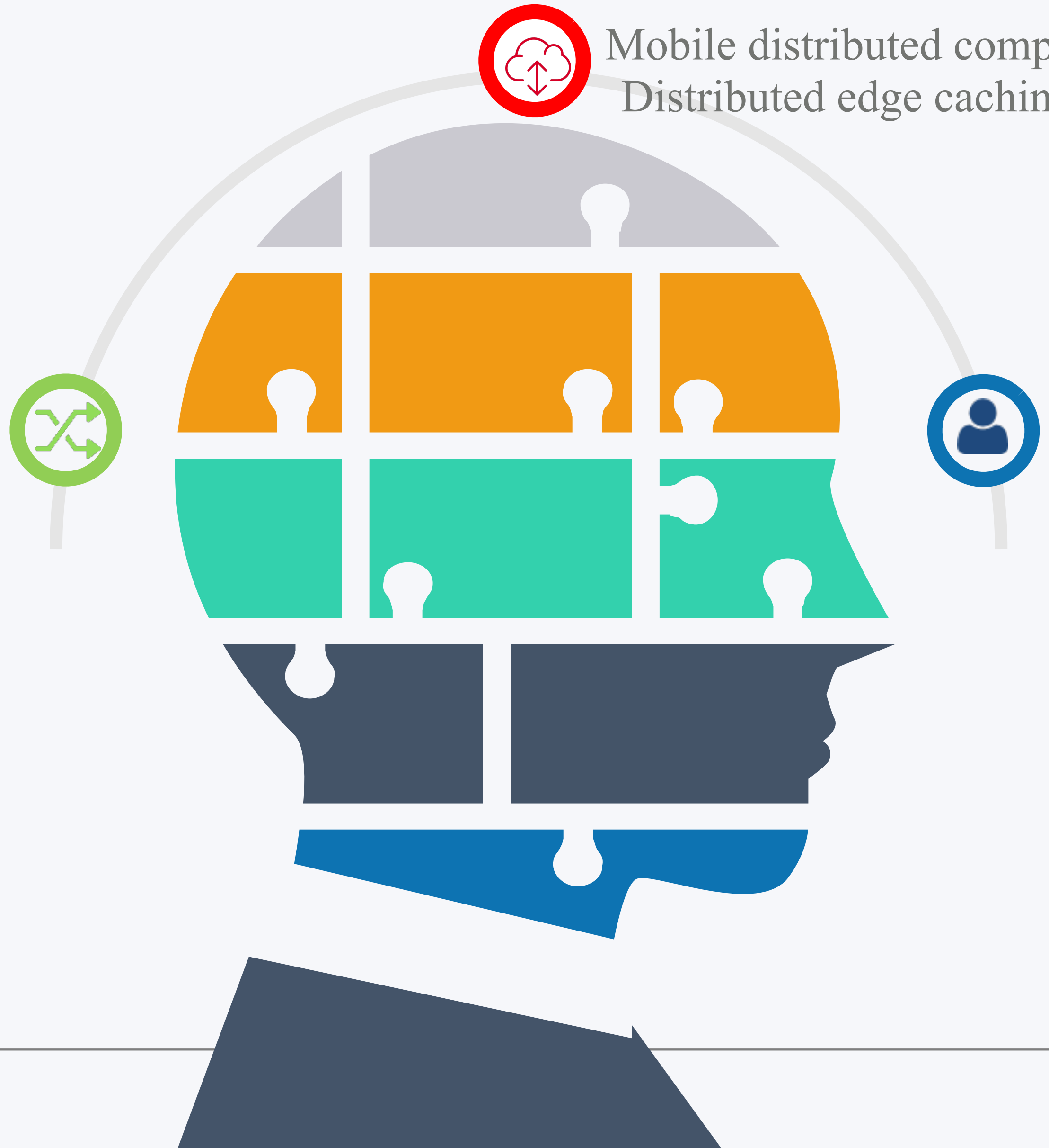
Our HetNet Fog Communications+Computing Architecture



R&D Goal: Cognitive "Take Your Network and Cloud" Infrastructure

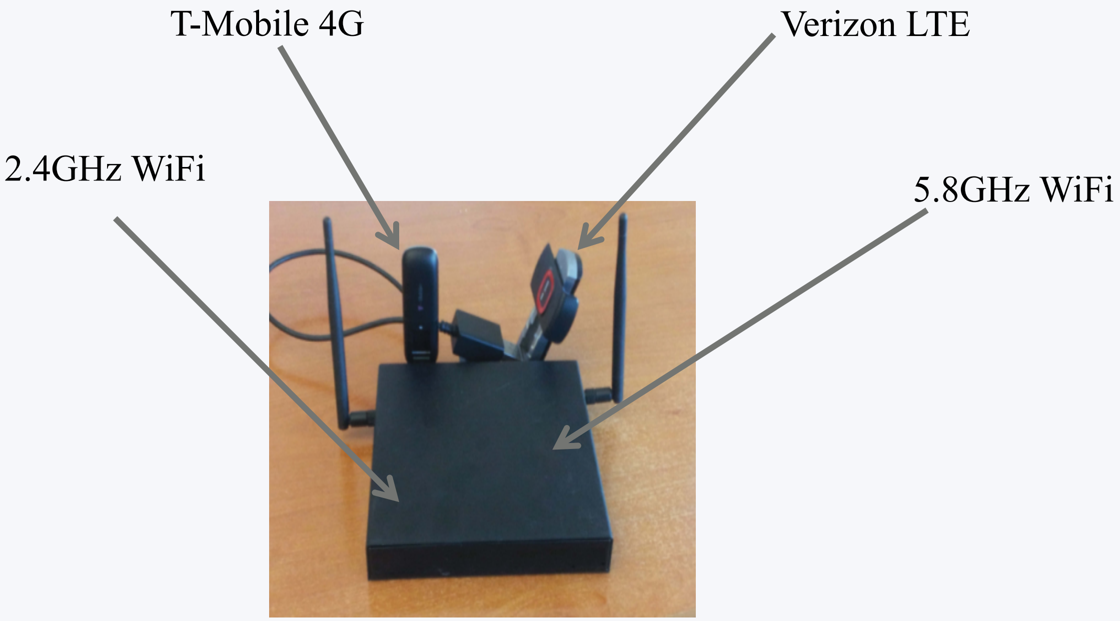
Mobile distributed computing
Distributed edge caching; data access

Dynamic spectrum management
Edge HetNet wireless networking; mobile mesh

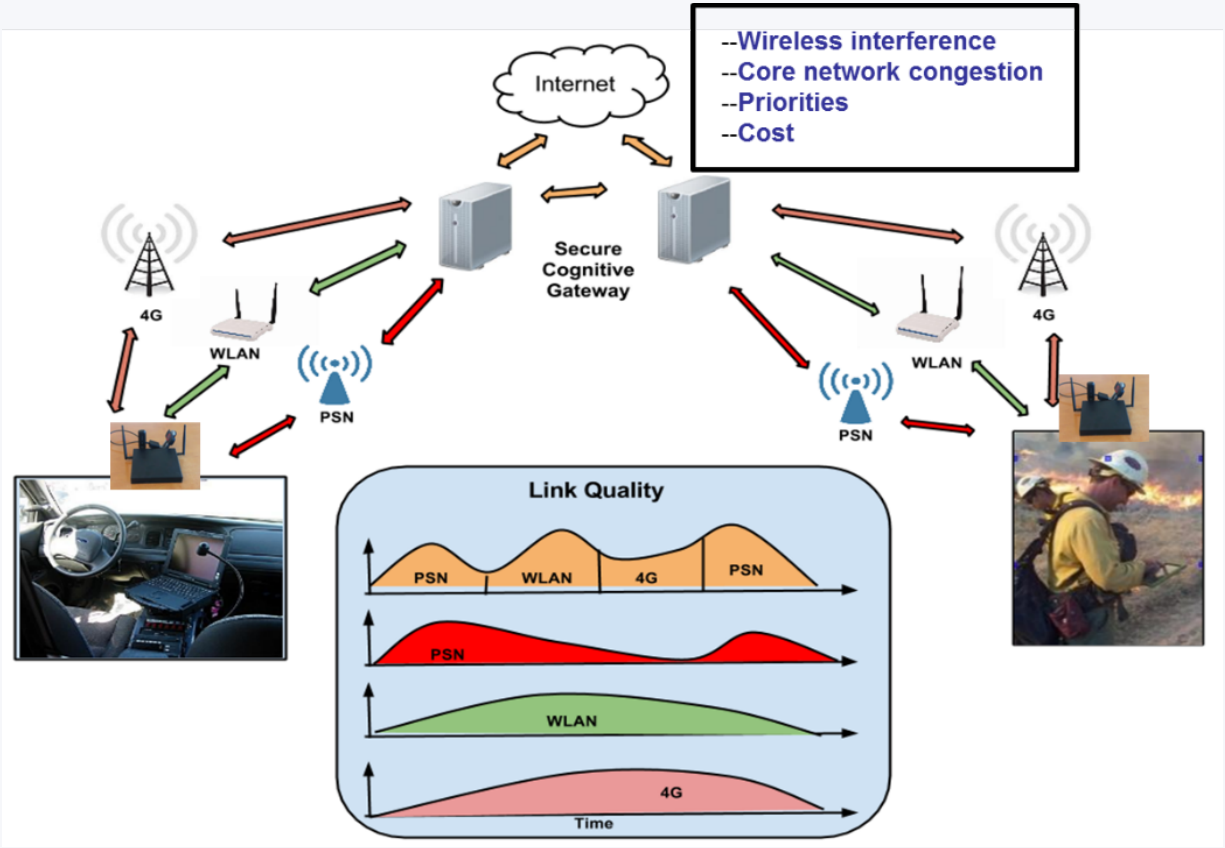


Field demonstration
With Brookline PD

Cognitive Mobile Networking



SiFi HetNet Gateway



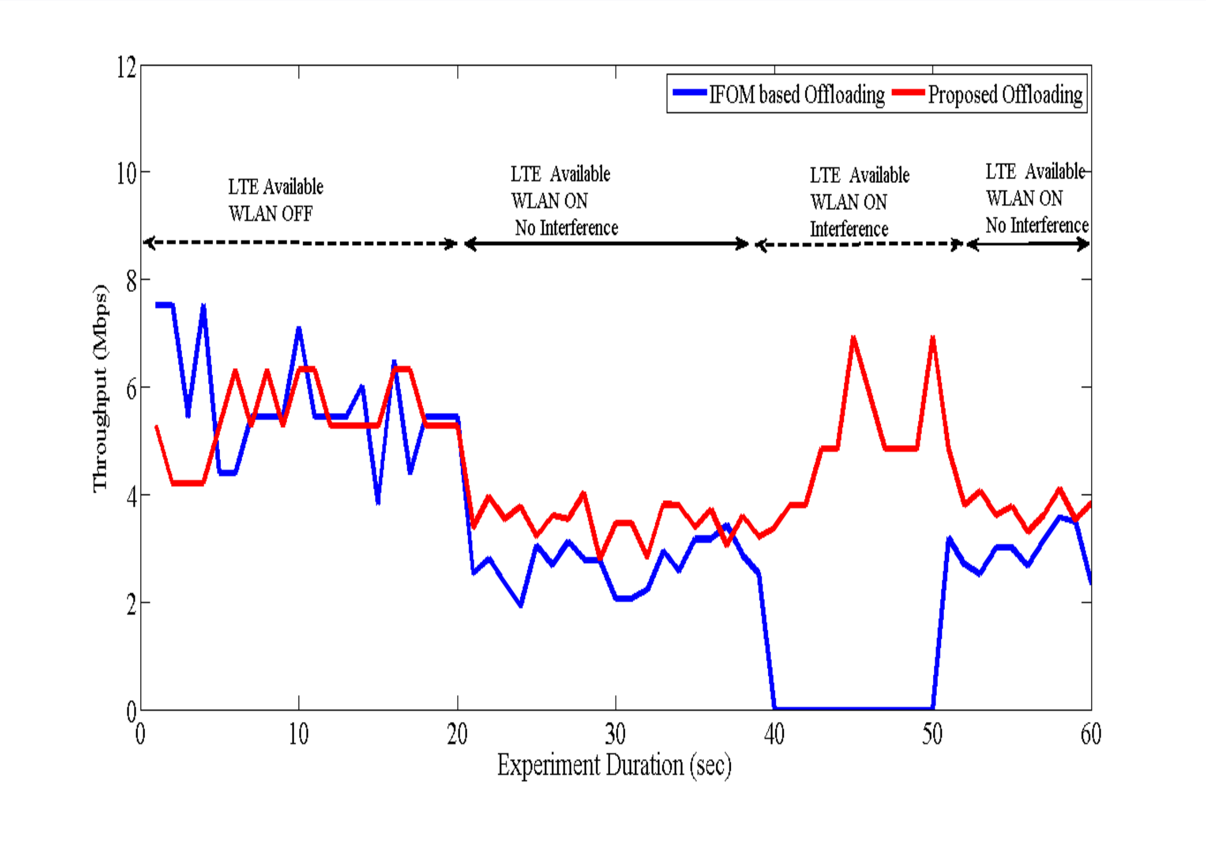
Received Video Quality

WiFi under interference

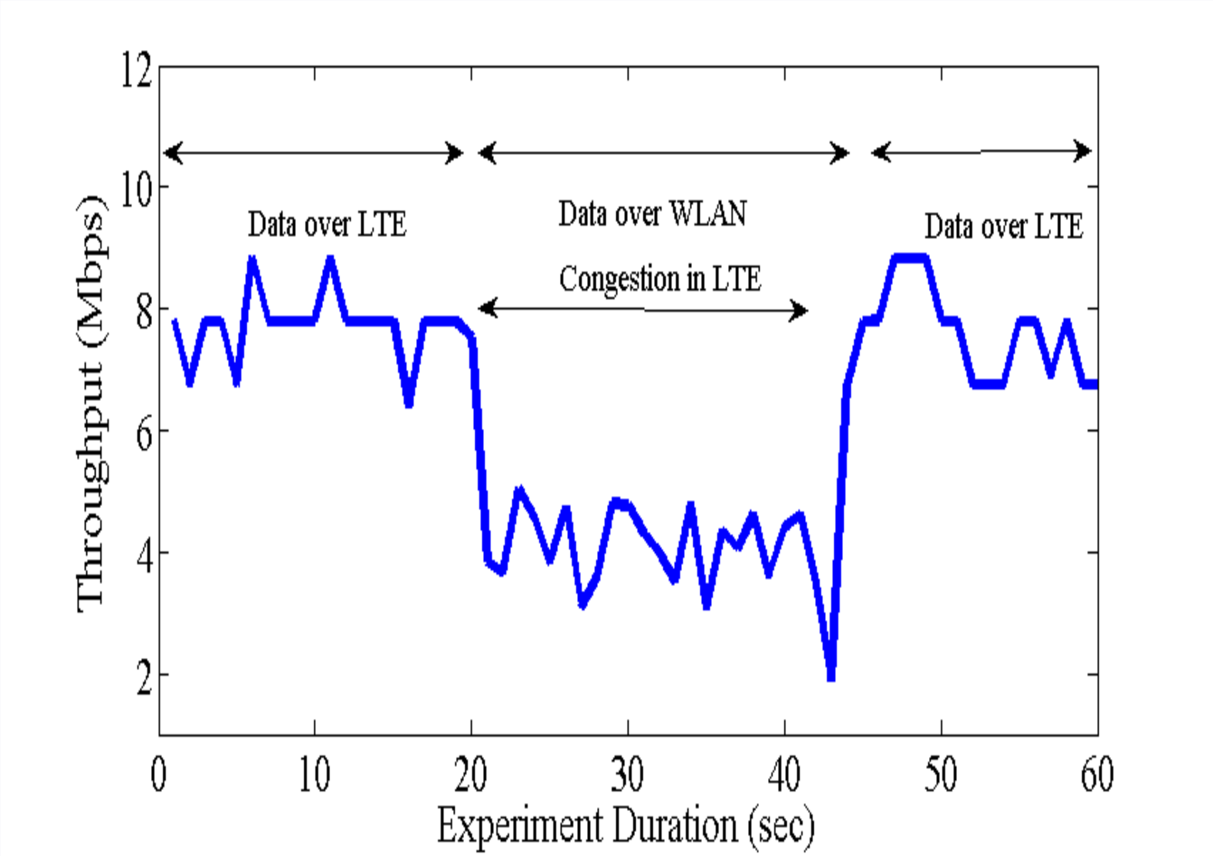
SDA WiFi under interference*

*SDA : Software Defined (Spectrum) Access

Real-time End-to-End Network Sensing



Loss of spectrum access mitigation



Backhaul congestion mitigation

Real-time Data to Decisions

"This technology is an insurance policy that the first responders will always have what they need, regardless of the connectivity."

— Scott Wilder, Brookline PD

Testbed Environment at Brookline PD

Contact

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http://www.spectronn.com

Michigan Tech Research Institute

Resilient System Solutions for Data in Wildland Fire Incident Operations

Development of the Wildland-fire Data Logistics Network (WildfireDLN)

Nancy HF French, PI

Michigan Tech Research Institute

D Martin Swany

Indiana University

Micah Beck

University of Tennessee, Knoxville

Michigan Tech Research Institute

INDIANA UNIVERSITY

THE UNIVERSITY OF TENNESSEE KNOXVILLE

NIST National Institute of Standards and Technology U.S. Department of Commerce

PSCR

Problem Statement

Wildland firefighting operations are regularly obstructed by the construction and maintenance of ad hoc communication networks due to:

- Network coverage
- Data portability

As a result, incident command decisions and wildfire containment are delayed.

- Property damages
- Human illness & injury, including deaths
- Environmental impacts

Above: Incident Command morning briefing (National Park Service Photo)

Left: Excessive post-fire erosion from the Hayman Fire (Photo by Mary Ellen Miller)

Team & Capabilities

Michigan Tech

Michigan Tech Research Institute
A part of Michigan Technological University

Bill Buller, Co-I
– senior engineer
Ben Hart, Co-I
– hardware design
Reid Sawtell
– software support
Sam Aden
– project support

Dr. Nancy French, PI

National Interagency Fire Center

Equipment, supply, crew, and aircraft;
Intelligence and predictive services.

– US Department of Interior
– US Forest Service
– Tribal, State, Local Fire agencies

INDIANA UNIVERSITY

Center for Research in Extreme Scale Technologies (CREST)

- Dr. Ezra Kissel
  – software development
- Graduate student

Dr. Martin Swany, Co-I

THE UNIVERSITY OF TENNESSEE KNOXVILLE

Department of Electrical Engineering & Computer Science

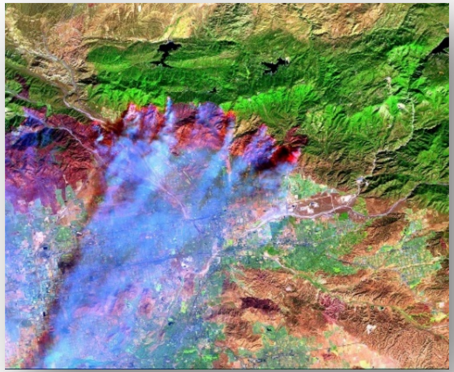
- Dr. Elaine Wenderholm
  – senior research associate
- Graduate student

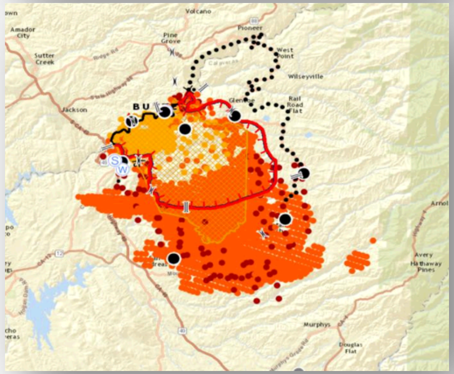
Dr. Micah Beck, Co-I

Project Motivation

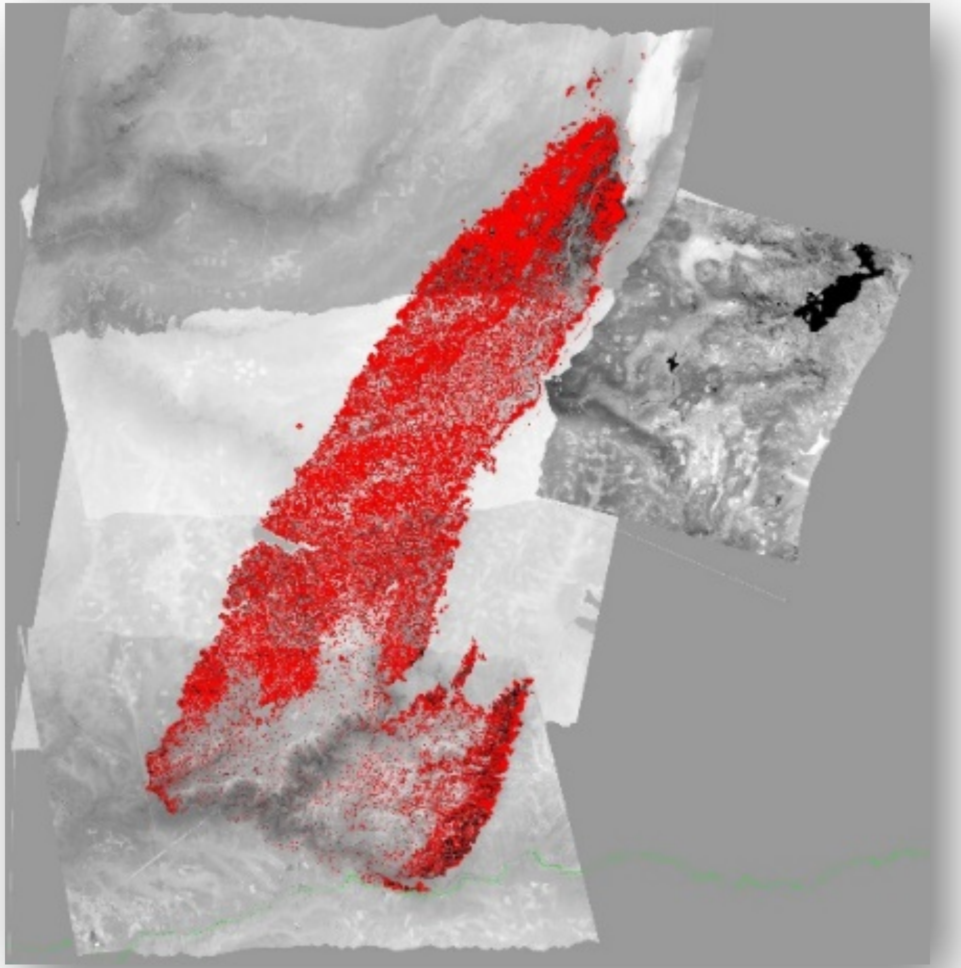
Remote sensing technologies provide valuable data for wildland firefighting tactical operations.

Spaceborne & airborne systems routinely provide large data for decision support





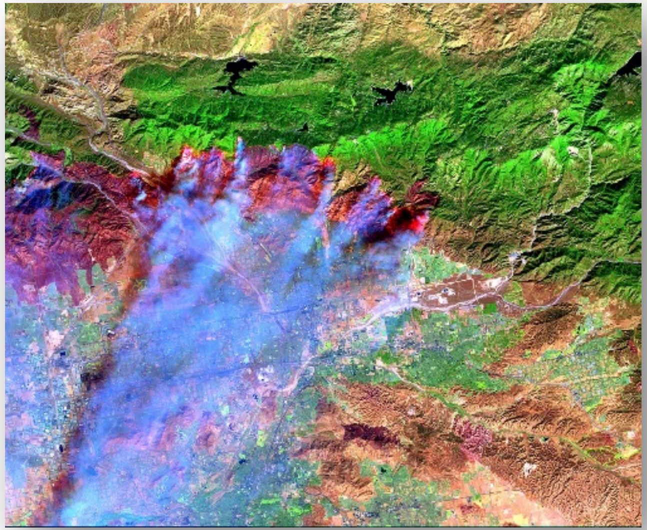
These datasets rely on significant manual processing to reduce data size in order to be integrated into incident command decision making.

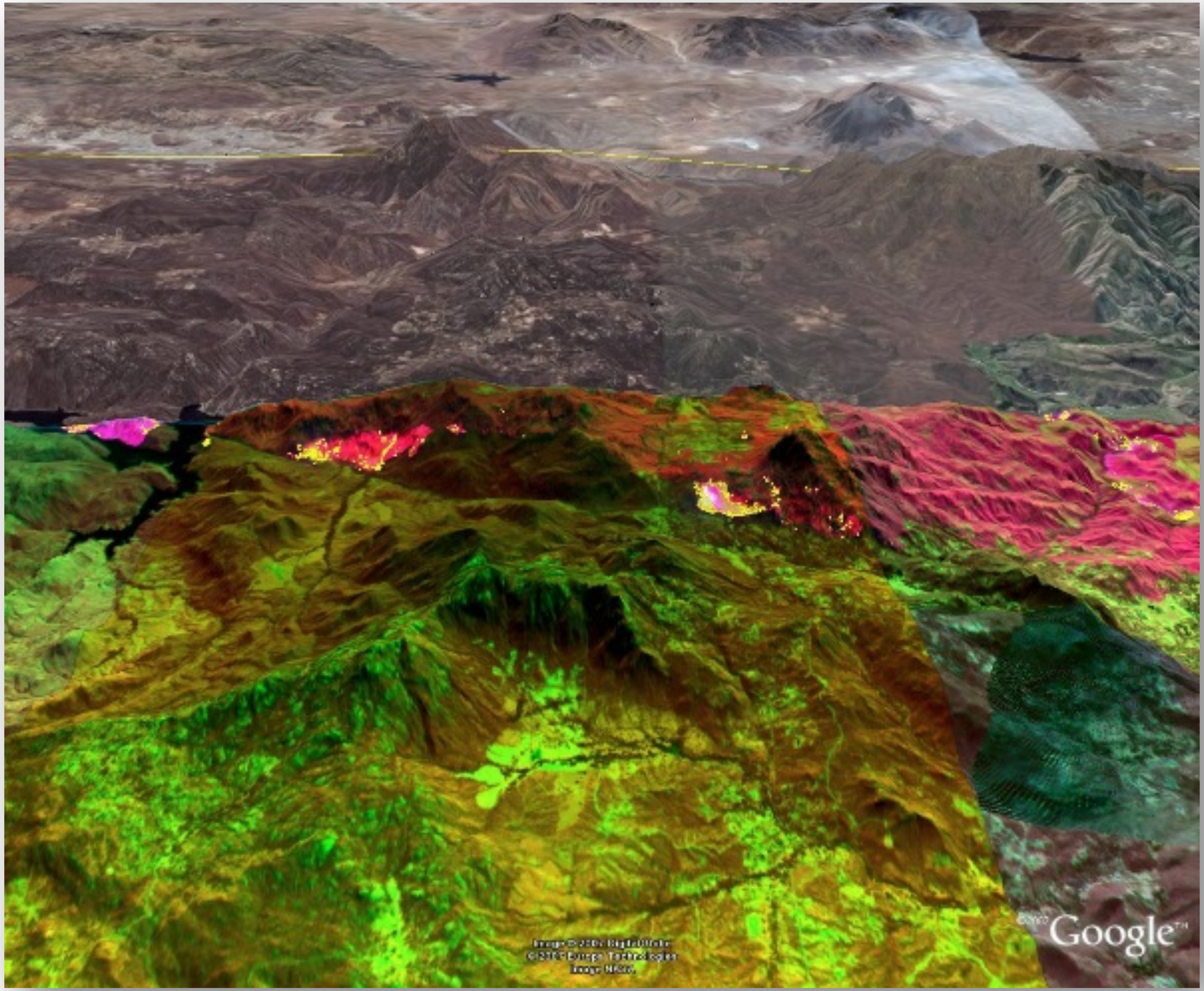


Above: NIROPS image of night-time fire hot-spots

Project Motivation

Aim: To deliver rich and informative data with a robust system that supports file transfer and access across disconnected, heterogeneous networks.





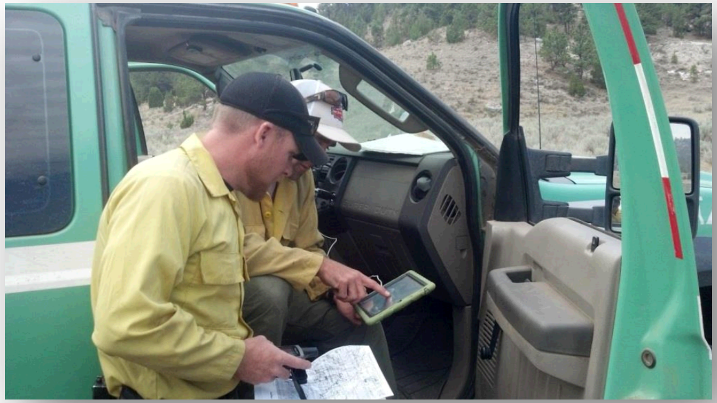
Landsat Images showing an active fire.
Right: 3-D rendering to visualize fires across the landscape can improve decisions.

Project Objectives

- Work with the wildland fire management community to define specific requirements of an enhanced, resilient data sharing system.

- Co-develop software systems for data logistics based on existing tools, including future proofing and generation of ideas to advance capabilities with further R&D.

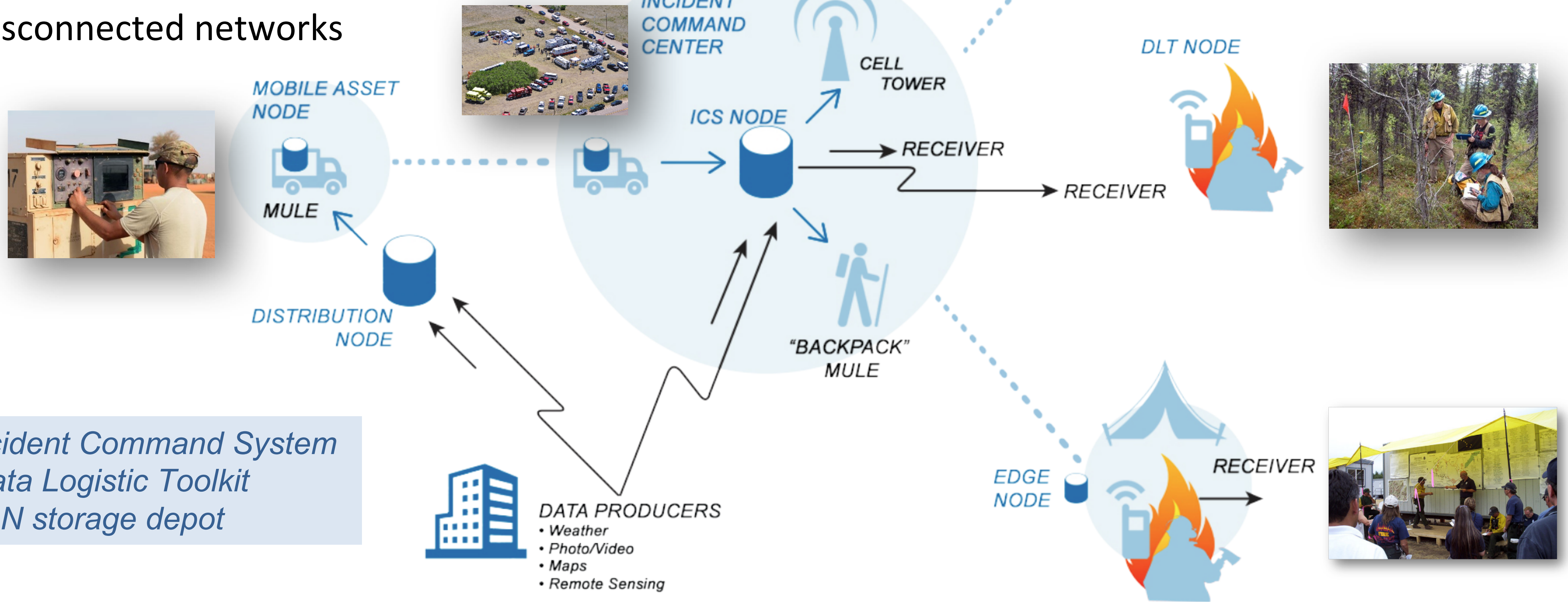
- Deploy and test prototype hardware-software system with fire operations personnel that integrates the new data sharing system with existing capabilities and relevant data.



System Overview
The Wildland-fire Data Logistics Network

WildfireDLN key features:

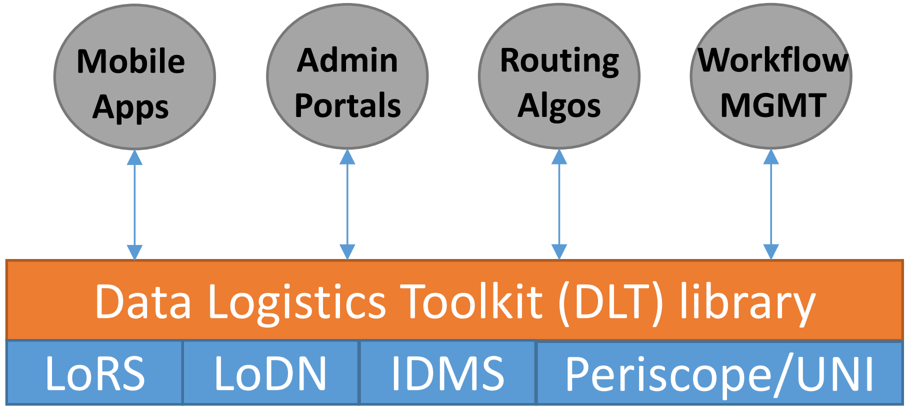
1. Reduced data access barriers
2. Multiple distribution modes in dynamic, mobile environments
3. Resilient in the face of frequently disconnected networks



ICS = Incident Command System
DLT = Data Logistic Toolkit
= DLN storage depot

System Architecture – Software

- Local operation – decentralized federation of available nodes and connected devices
  - Dynamic architecture that operates over intermittently connected and heterogeneous networks
- Logistical data distribution – managed workflows for prioritizing and filtering data of importance over geographic and/or temporal criteria



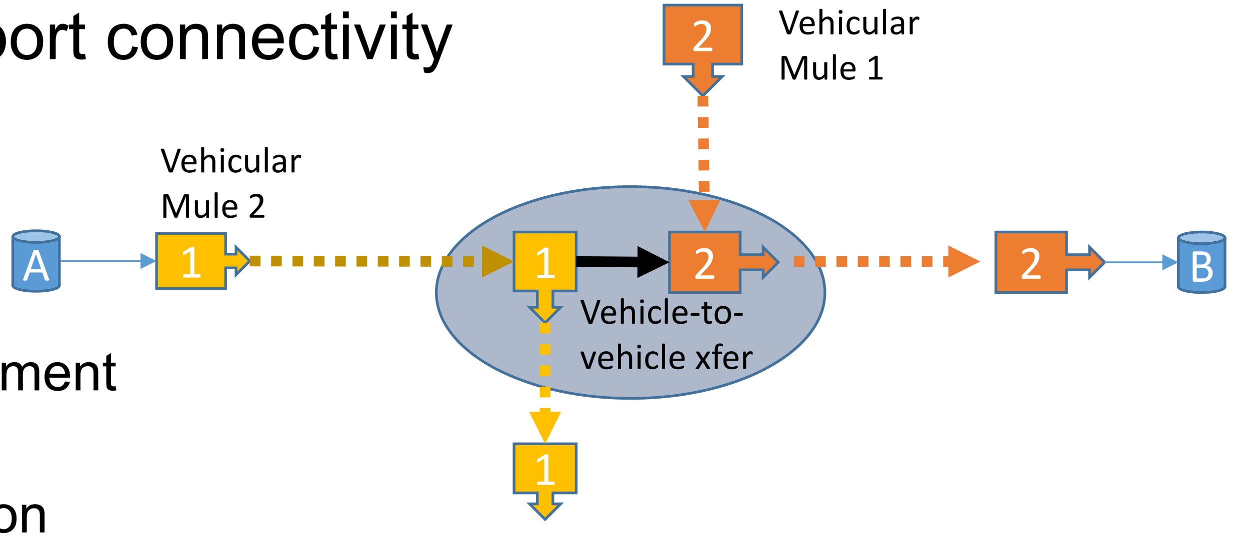
- LoRS – Logistical Runtime System
- LoDN – Logistical Distribution Network
- IDMS – Intelligent Data Movement Service
- Periscope– Network topology and measurements via UNIS (database)

http://data-logistics.org

Disconnected Routing

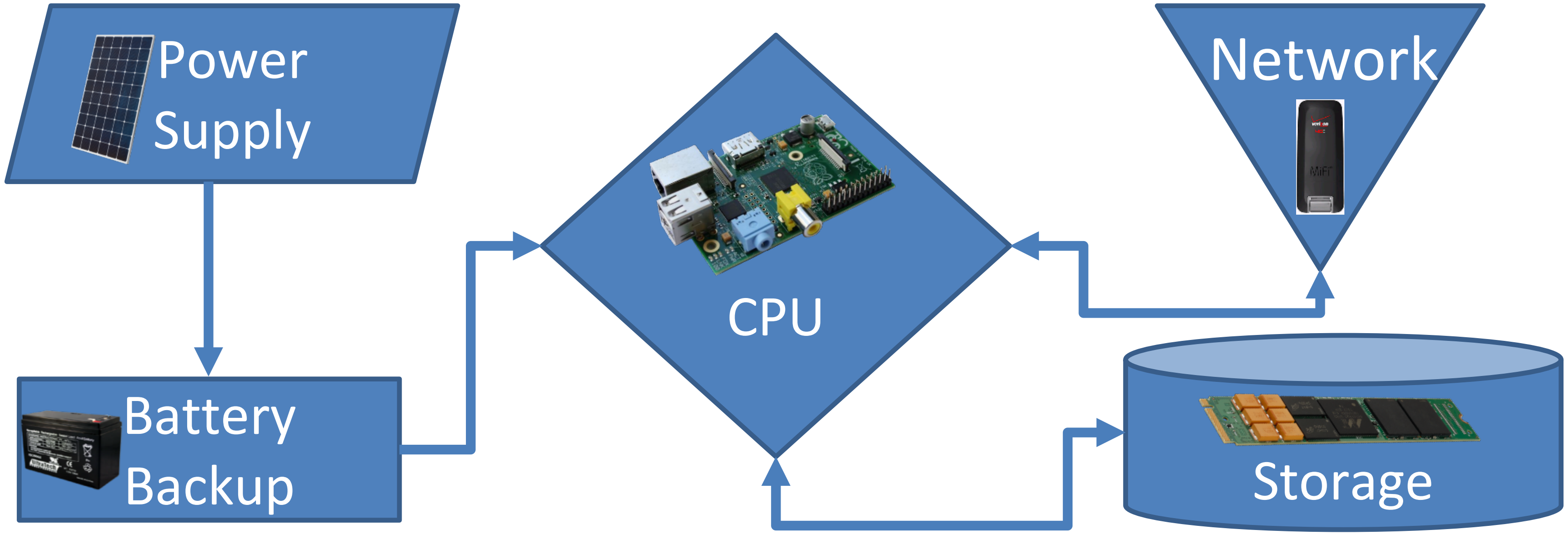
- Drones and Data Mules are not always connected

- Connectivity paths may be intermittent
- Some vehicle patterns can support connectivity



- Work Plan
  1. Literature survey
  2. Algorithm selection and/or development
  3. Simulation and/or Emulation
  4. Implementation and Experimentation

System Architecture – Hardware



Hardware Options (mix and match)

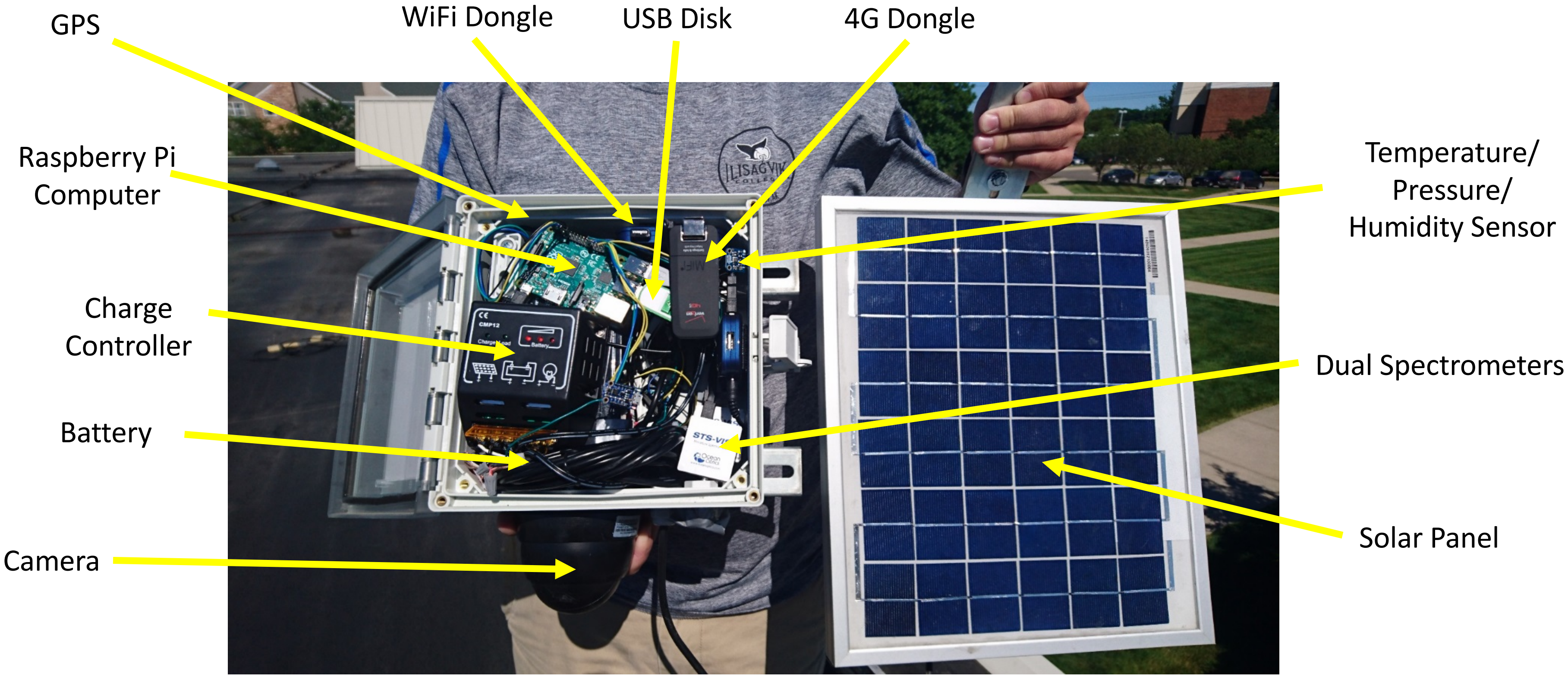
- **Power**

  Requires batteries (various sizes)
  - Utility
  - Generator
  - Solar
  - Wind
- **CPU**

  Anything Linux
  - Raspberry Pi
  - Beaglebone
  - BRCK
  - PC
  - Rack Server
- **Network**
  - WiFi
  - 4G
  - Bluetooth
  - Ethernet
- **Storage**
  - USB drive
  - Hard Drive
  - SD Card
  - Server Rack

System Architecture – Hardware

Example of existing compact system – similar to a potential "backpack" (portable) version of a depot node



Application Readiness Level

- The WildfireDNL system will be built by adapting pre-existing software and hardware systems.
  - Software is backed by academic peer review and is in use with data storage depots analogous to what is required by WildfireDNL
  - Commercial off the shelf parts will be used to construct the physical WildfireDNL Nodes
  - These pre-existing components act as a proof-of-concept for the WildfireDNL, what remains is assembling them into a combined system that meets the needs of wildland fire agencies

Component	Start TRL	End TRL	Notes & References
Contributing Software	3-7+	--	Data Logistics Toolkit (DLT), Logistical Runtime System (LoRS), and Logistical Distribution Network (LoDN)
Contributing Hardware	9	--	Prototype nodes built using commercial off the shelf parts
WildfireDNL System	3	5/6	Demo system will be deployed in pseudo-operational environment

Project Milestones

- Objective 1: Define specific requirements of an enhanced, resilient data sharing system
  - Develop system architecture with end user input (summer 2017)
  - WildfireDLN end user scoping workshops (fall 2017; spring 2018)
  - WildfireDLN system design & documentation (prelim Y1; final Y2)
- Objective 2: Software customizations for WildfireDLN
  - Create and maintain testbed environment to support prototype (ongoing)
  - Integrate WildfireDLN with mobile devices (develop Y1 & deploy Y2)
  - Develop IDMS (service) data distribution policies and control (year 1)
  - Implement architecture for ad-hoc deployments and self-management (year 2)
- Objective 3: Deploy and test prototype system
  - Hardware-software system packaging and testing (year 1)
  - System demonstration and user feedback (prelim Y1; final Y2)

Project Impact

Goal: Enhance and extend current operational data sharing capabilities for:

- Improved fire fighter and public safety
- Better wildland fire predictions
- More informed fire operations (wildfire and prescribed fires)

PSCR Vision: Through the use of advanced communication technologies, the public safety community can more effectively carry out their vital mission to protect lives and property – from day-to-day operations to large events and emergencies.

Above: The Yarnell Fire began on Jun. 28, 2013, 1.5 miles from Yarnell, AZ from a lightning strike.

Left: The funeral procession passes through Yarnell, honoring 19 fire fighters killed.

U.S. Forest Service photos

Modeling and Development of Resilient Communication for First Responders in Disaster Management

Project Members

Prof. **K. K. Ramakrishnan** – University of California, Riverside

Assoc. Prof. **Murat Yuksel** – University of Central Florida

Assist. Prof. **Hulya Seferoglu** – University of Illinois at Chicago

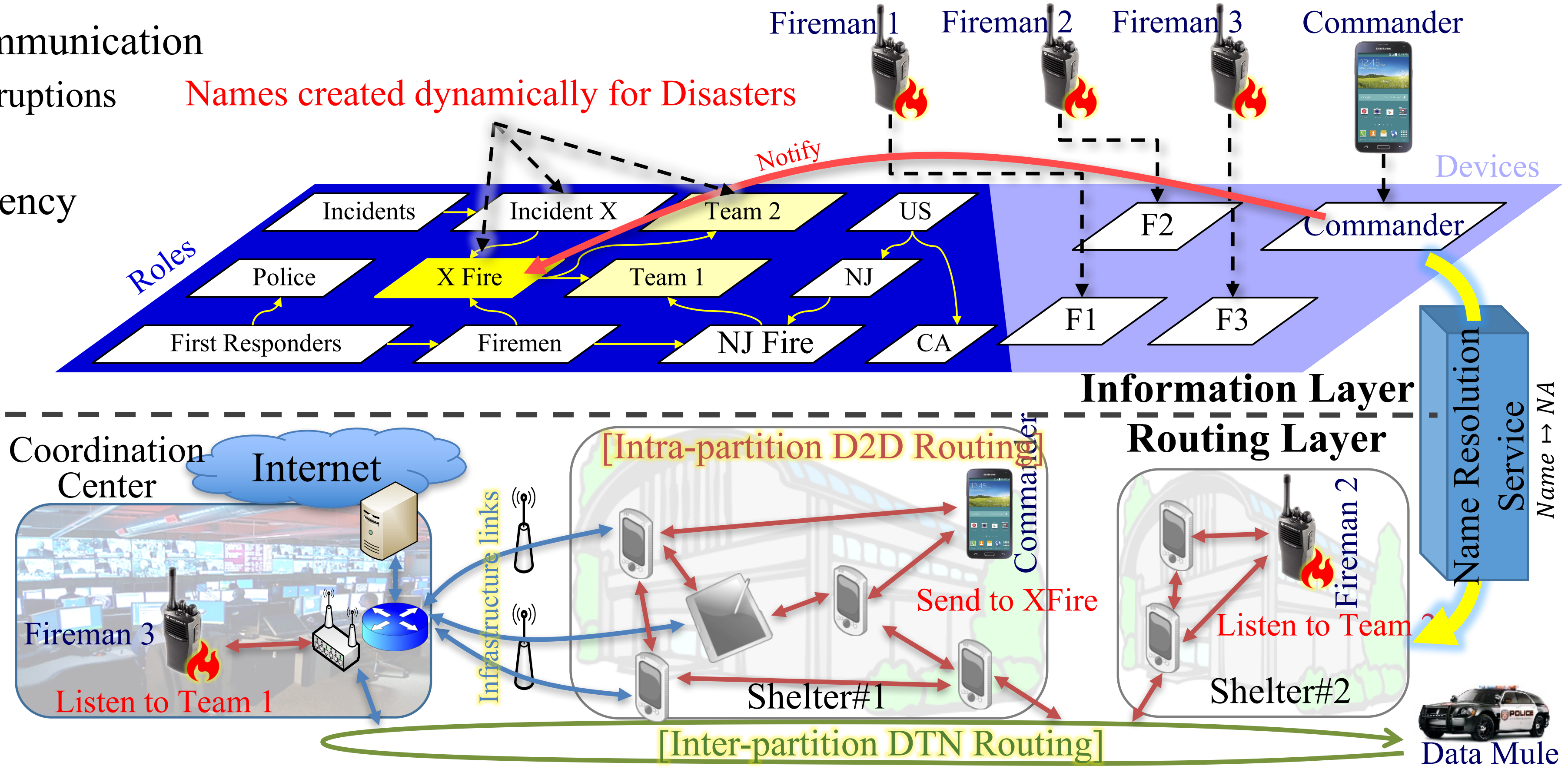
Dr. **Jiachen Chen** – WINLAB, Rutgers University

Importance of Communication for Disaster Management

- Communication is key to improving outcomes in the aftermath of a disaster
- However, it is in the aftermath of a disaster that we are likely to face communication challenges
  - Infrastructure may be impacted
  - Communication channels may be congested
- Key to an effective response to a catastrophic incident
  - Effective communication within and among dynamically formed first responder teams
  - Public safety teams comprising law enforcement, health, emergency, transport and other services, depending on the nature and scale of the emergency
  - Communication with stranded individuals and the public at large

Proposed Project Objectives and Architecture

- **Information Layer**
  - Facilitate communication among dynamically formed first-responder teams
  - Information-Centric Communication
  - Communication based on dynamically created roles, rather than locations
- **Routing Layer**
  - Intra- & inter-partition D2D communication
    - Resilient to the infrastructure disruptions
    - Smart mode switching
  - Coding for robustness and resiliency
  - Content-based security

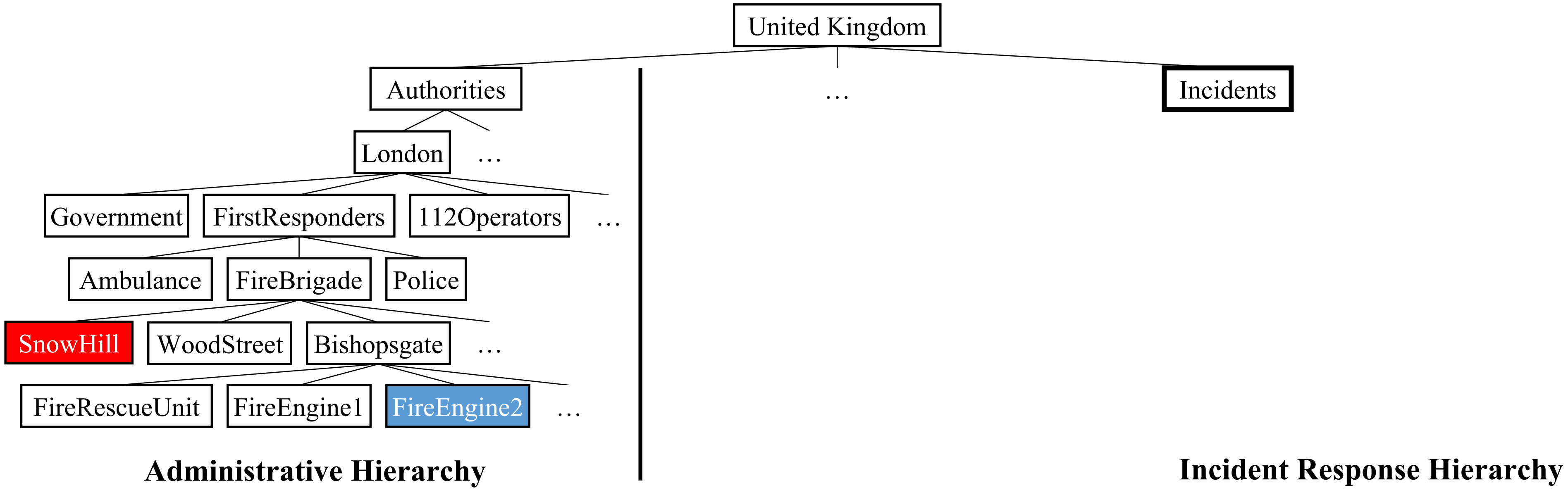


Situational Understanding

- Preliminary examination of several recent disasters
  - Adversarial: *London Bombing (2007)*, San Bernardino shooting (2015)
  - Accidental: Kaohsiung gas explosion (2014)
  - Natural: Haiti (2010) and Fukushima (2011) earthquakes
- Our observations
  - Multiple incidents occur at the same time
  - Messages were not disseminated to the right people initially
  - Lack of proper communication among different services hampered coordination
  - Other departments play an important role, requiring coordination
  - Possible loss of infrastructure
  - Security
- Summarize requirements and develop models for public safety communication traffic demand that can be used for studying and planning future incidents

Naming Schema & Protocol

- Naming schema that can be used for normal communication & disaster management
  - Using hierarchical structure helps to match the real-world command chain
  - Administrative hierarchy – for normal communication among first responders
  - *Incident Response Hierarchy* – place holder for disasters
  - First responders listen to (propagate FIB & subscribe) names to instantiate a role



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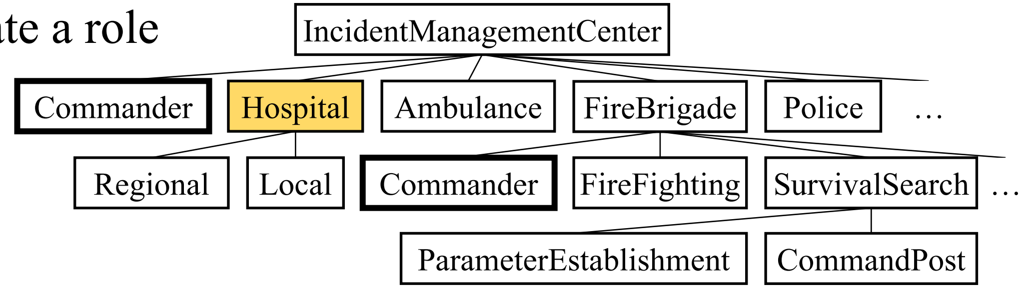
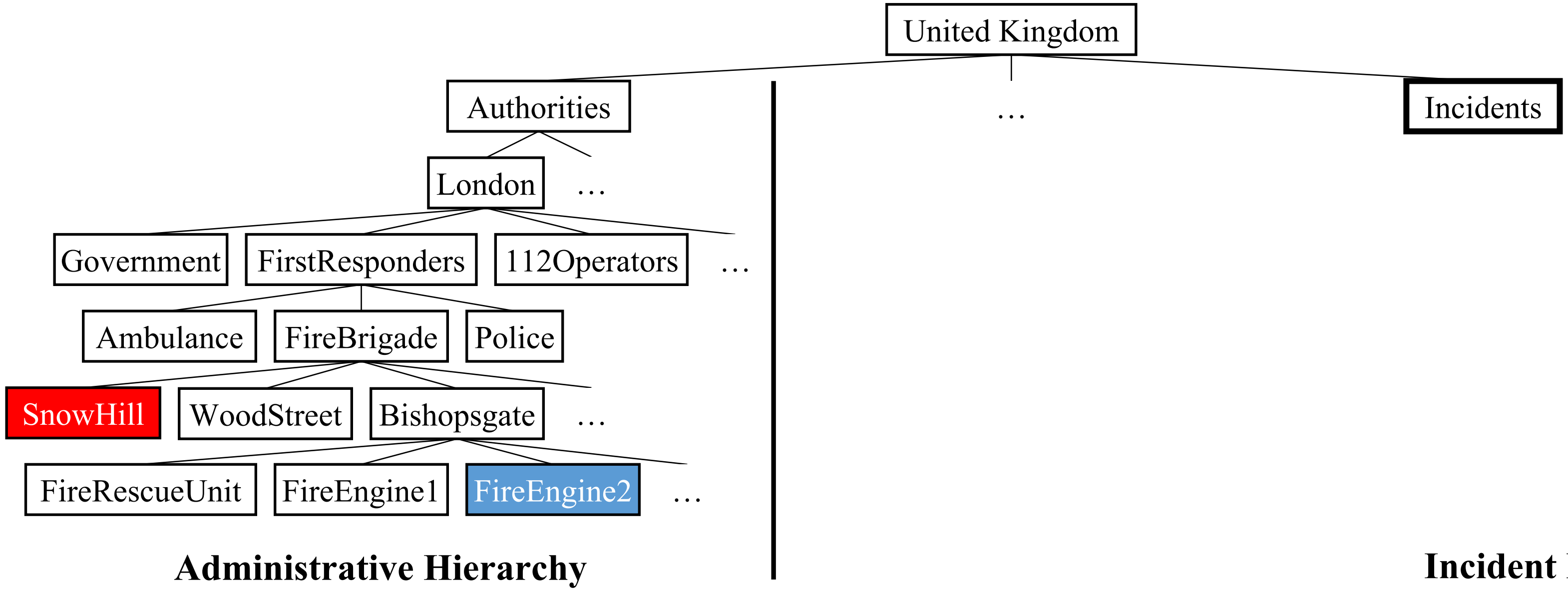
- Disaster templates
  - Preplanned namespaces for disasters





Administrative Hierarchy

Incident Response Hierarchy

Naming Schema & Protocol

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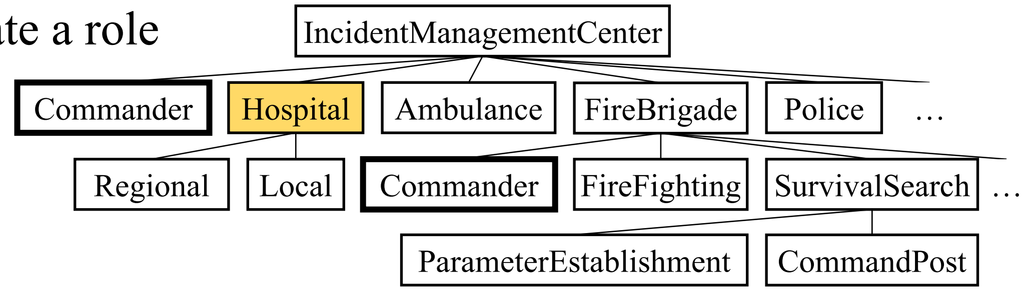
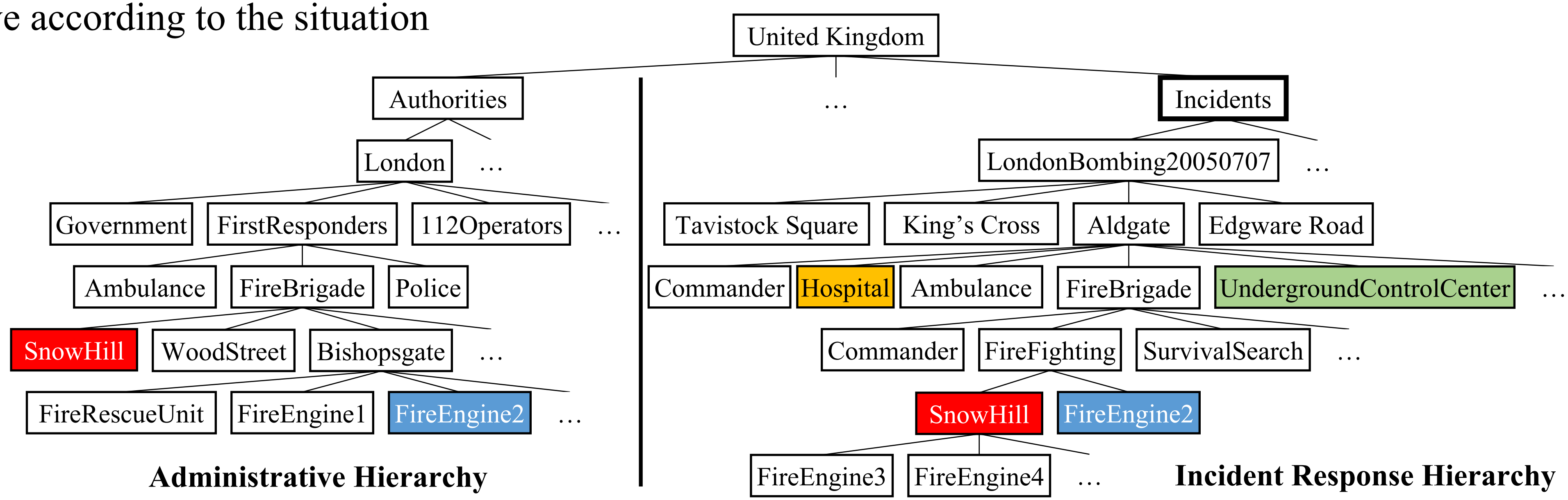
- Disaster templates
  - Preplanned namespaces for disasters
- Dynamic installation of disaster namespaces
  - The namespace can evolve according to the situation





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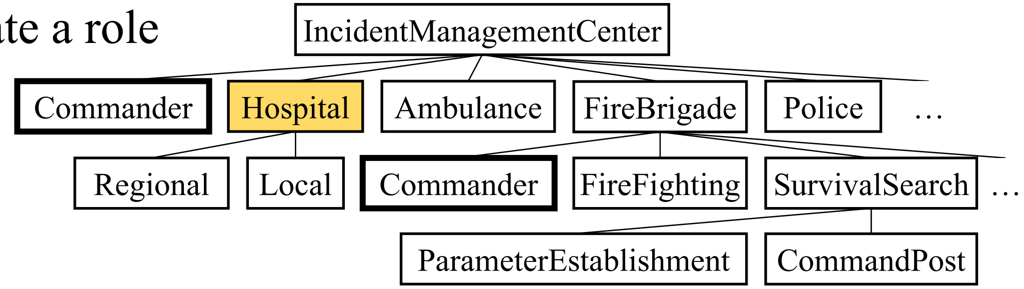
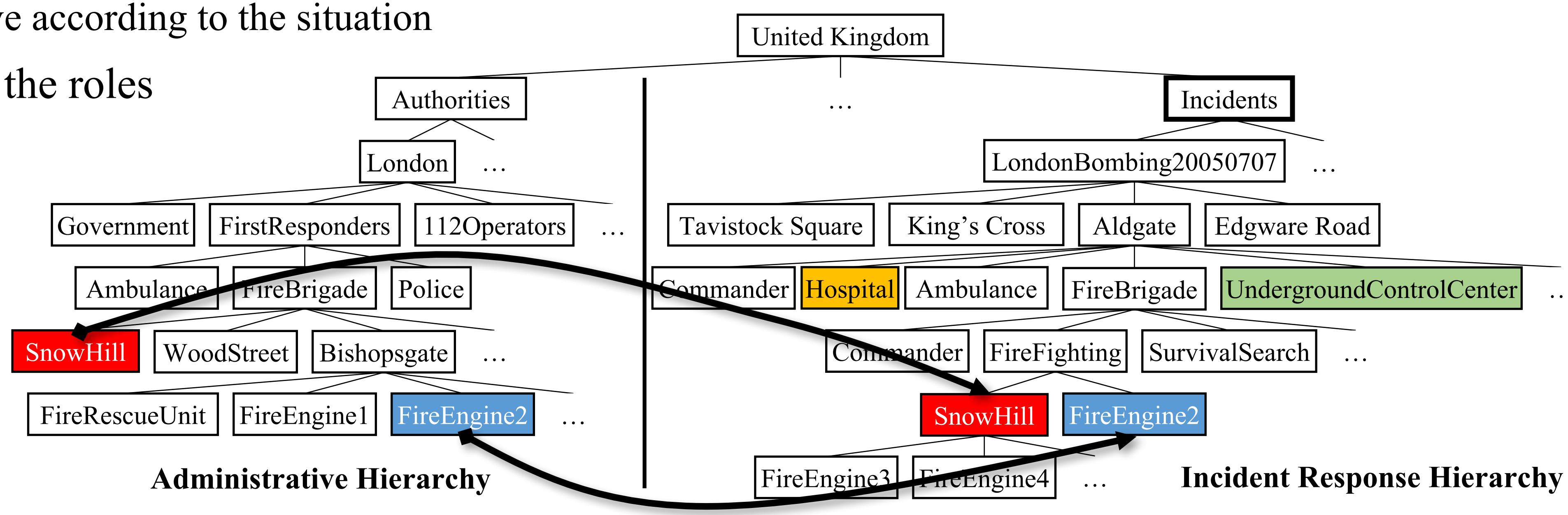
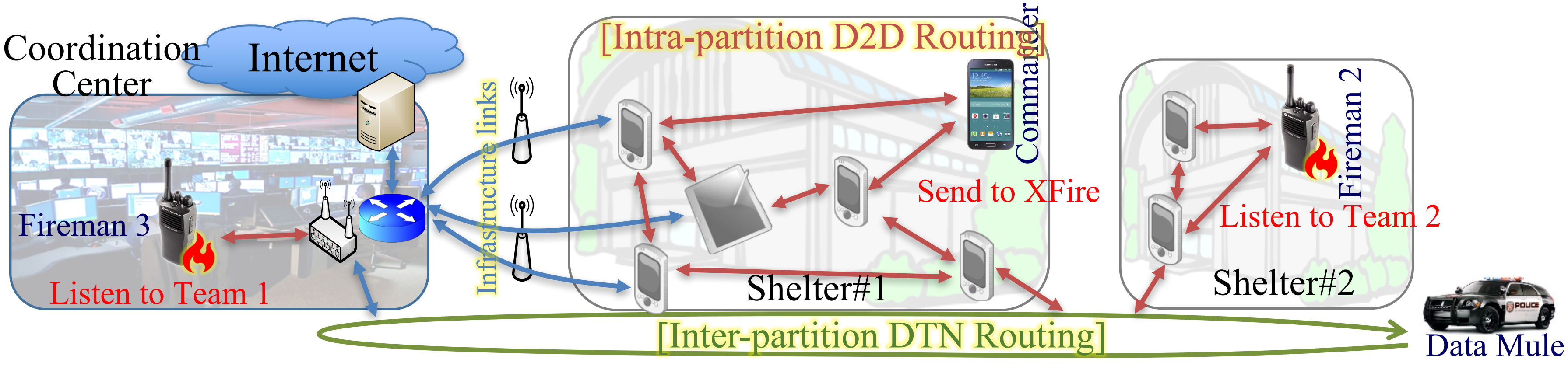
  - The namespace can evolve according to the situation
- Dynamic instantiation of the roles





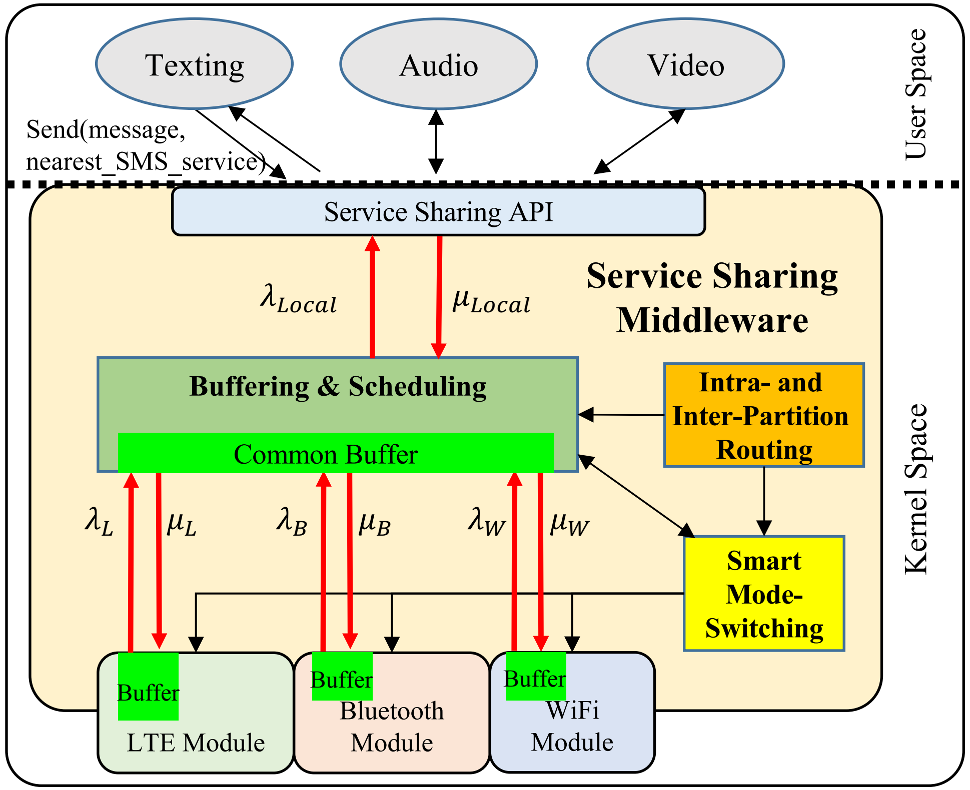
D2D Communication & Routing

- Routing in a disaster
  - Partitions created during the disaster due to the infrastructure failures, e.g., each shelter is a partition
  - First responders need to communicate within partitions and sometimes among partitions
  - Flooding is not efficient in terms of energy (battery-life) and storage
- D2D routing
  - Name-based, gossip-like protocol for resource/device discovery
  - Intra-Partition Routing
    - Control: Probabilistic, evenly distributed, weak state
    - Data follows the most probable path
  - Inter-Partition Routing
    - Control: Partition-summarizing floods: name-hash + MAC-hash
    - First responder vehicles as data mules
    - DTN-style opportunistic forwarding



Middleware APIs & Interfaces

- Mobiles have multiple wireless interfaces: LTE, WiFi, Bluetooth
- With LTE gone due to infrastructure failures, need to
  - Utilize all the available interfaces
  - Cope with their heterogeneity and multi-hop D2D traffic dynamics
- Will develop a middleware that:
  - Abstracts each connectivity resource as a service
  - Offers a common API to public safety apps e.g., **`Send(message, nearest_SMS_service)`**
- Buffering & scheduling over heterogeneous interfaces
  - OS-level implementation
  - Per-interface and common buffering
  - Reuse well-known queuing disciplines
- Smart mode-switching
  - How to decide?: infrastructure vs. ad-hoc modes
  - Intercept the frames to set the mode
  - Use help from routing and neighboring nodes' features



Coding & Security

Coding

- Reliability and throughput improvement via network coding
  - Coded D2D groups mitigate data transmission bottlenecks by having each device perform coding.
  - Coding enhances reliability in D2D networks, where there is limited or no infrastructure support and may have more packet loss than infrastructure-based systems.
- Reliability for distributed storage and computing with the help of coding
  - Each node in our architecture caches name-to-network address mappings
  - Distributed coding can be crucial in first responder and PSC systems; *e.g.*, creating a map showing disaster.

Security

- D2D networks
  - Should be open; easy interaction among devices.
  - More vulnerable to adversarial attacks.
  - *E.g.*, some first responder devices acting as end points may be compromised, or some civilian devices are used as relays
- Goal: Secure communication, storage, and computation.
- Features:
  - Data integrity, authentication & provenance – self-certifying contents
  - Confidentiality – coding naturally provides security thanks to randomization of data.
    - Alternative against sniffer attacks where compromised first responder devices or civilian devices may try to access crucial data.

Milestones and Impacts

- Analytical models for traffic demand and mobility patterns based on publicly available disaster reports
- A prototype that demonstrates the feasibility and efficiency of the proposed architecture
  - Naming schema that reflects the command chain for both normal and disaster communications
  - Android-based GUI for efficient target role selection
  - Middleware for smooth transition between infrastructure and D2D
  - Network coding for security and reliability
- Evaluate the performance in ORBIT Lab and GENI Testbed

Tasks and milestones

Task	Year-1		Year-2		Year-3	
T1: Network Architecture for Resilient Communication	■	■	■	■		
T2: Analysis and Modeling of Disaster Communications	■	■	■	■		
T3: Design of End-System Protocol Stack, D2D Forwarding	■	■	■	■		
T4: Coding for Resilient D2D Communication	■	■	■	■		
T5: Naming Schema for First Responder Communication		■	■	■	■	
T6: Security for Resilient D2D Communication		■	■	■	■	
T7: D2D Communication and Routing in Fragmented Networks		■	■	■	■	
T8: System & Application Design, Prototyping, and Experimentation			■	■	■	■

Anticipated Impacts

- Enable rapid response with efficient, precise communication among first responder teams
- Enable first responders to communicate
  - Even when network infrastructure is damaged in disaster situations (fragmentation; congestion)
  - Communicate among dynamically formed teams
  - Communicate using multiple modalities

Taking The Network Wherever You Go

Deployable System Research for Public Safety

Ben Posthuma

Principal Investigator – Deployable Systems

PSCR

2017

PUBLIC SAFETY BROADBAND STAKEHOLDER MEETING

#PSCR2017

This work is sponsored by:

Department of Homeland Security
Science & Technology Directorate
Office for Interoperability and Compatibility
(DHS S&T OIC)

Introduction

- Today we will discuss next-generation deployable networks
    - What is a deployable network, and why do we need it?
    - Previous PSCR focus and research in deployable networks
    - What is a next-generation deployable network?
    - Forward looking research areas
    - The Next-Generation Deployable Networks Test Bed
    - Follow up and next steps

Deployable Systems Overview

- Deployable systems are mobile and portable networks intended to augment the National Public Safety Broadband Network
- These systems often have the following attributes:
  - Single or Multi-Sector Cells
  - Self-Contained Power
  - Portable (trailer, truck, etc.)
- There are two primary classifications of deployable systems:
  - Core-Enabled Deployable Systems (System on Wheels - SOW)
    - Includes the LTE radio access network (RAN) and Evolved Packet Core (EPC)
    - Self-contained network
  - Core-Ready Deployable Systems (Cell on Wheels - COW)
    - LTE radio access network only
    - Requires backhaul to a core for any network functionality

Public Safety's Need for Deployable systems

Public safety agencies have a need for a rapidly deployable solution to provide broadband communications between first responders in diverse scenarios when existing infrastructure may not be available or may be overloaded

- Scenarios for deployables include:
  - Natural disaster areas where existing networks are unusable
  - Congested areas where the existing network is saturated
  - Remote and geographically isolated areas without network access
- The deployed solution must also be fully interoperable
  - Seamless interoperability with the fixed NPSBN and with other deployed systems

PSCR Research Into Deployable Systems

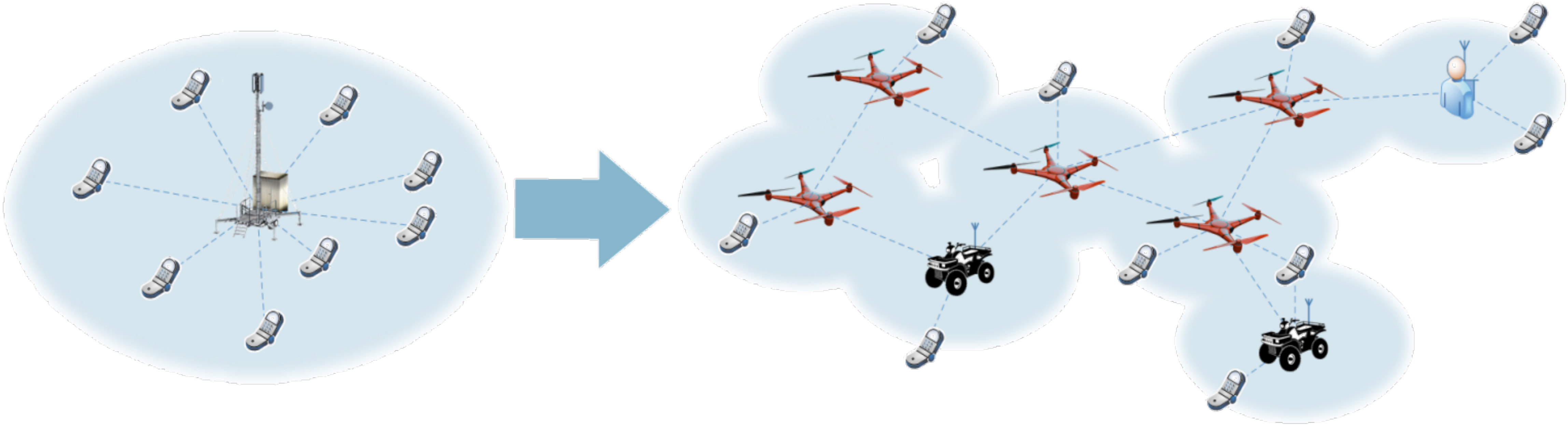
- Previous research conducted by PSCR has focused on the analysis of standalone deployable systems
- Our ongoing research is intended to investigate the operations of deployable systems as they coexist in a common dynamic ecosystem
  - This research will enable deployable systems to continue supporting the network as technology evolves
  - Smaller form factor systems, software defined networking, advances in unmanned platforms, and evolving security practices contribute to rapidly deployable and highly optimized public safety networks

Completed Research Topics

- Power consumption
  Published DHS report publicly available
- Time to deploy
- Effects of backhaul-induced latency
  Provided report internally to DHS
- Real-world deployments
  - USCG Maritime Deployment, Boston, MA – Oct 2016
  - Grant Co. Sheriff's Department, Grant Co. WA – May 2017
- In-band interference study
  Provided report internally to DHS

Next-Generation Deployable Networks

- Technology evolution provides natural transitions to key features:
  - Small cells – many more small LTE networks in the environment
  - Rapidly deployable – brought in at a moment's notice
  - Multi-platform – airborne (UAS), vehicles, backpacks, etc.
  - Adaptive networking – decentralized, content-centric networks



Research Goals

- What we are focused on:
  - Areas for future innovation
  - Operations of deployable systems as they coexist in a common dynamic ecosystem
  - Definition of user expectations and stakeholder requirements
  - Metrology standards for deployable systems
  - Lessons learned and best practices for implementing future technologies
  - Advocating collaboration and partnerships among industry, academia, and government

- What we are **NOT** focused on:
  - System certification or device testing
  - Identification of specific LTE deployable systems or vendors
  - Overall LTE network architecture
  - Policies and regulations for deployable networks

Our intent is to ***understand the needs*** *of public safety,* ***identify areas*** *for technology advancements,* ***provide tools for measuring*** *the effectiveness of the systems, and* ***collaborate with stakeholders*** *to improve public safety communications*

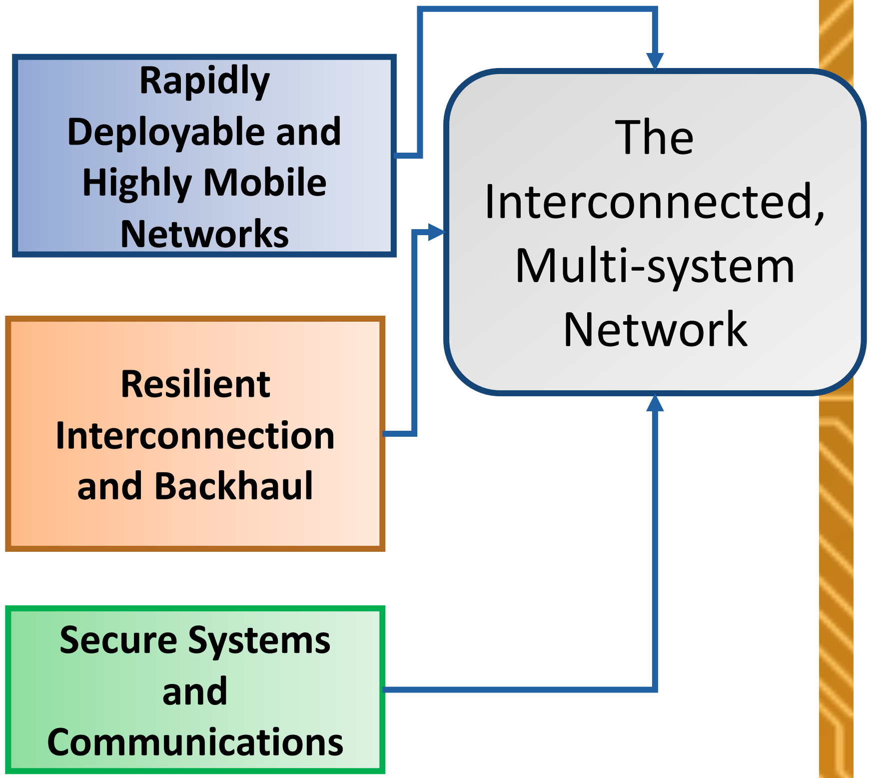
PSCR Research Areas for Deployable Systems

- Research for deployable systems has been divided into three categories:
  - Rapidly deployable and highly mobile networks

    The platforms, physical connections, and interfaces used to connect network elements and users
  - Resilient interconnection and backhaul

    The software and networking protocols and techniques utilized to provide the most optimized connectivity
  - Secure systems and communications

    The implementation of security tools to allow for authorized authentication on appropriate networks, security when sharing data across databases, vulnerability mitigation for data on the network, and offline provisioning for devices and users on the network



Rapidly Deployable Network Research Areas

Ad-Hoc, Reliable, Self-Forming, Self-Healing Mesh Networking

With mesh network systems, multiple networks deployed in the same ecosystem can detect and connect with one another. The benefit of using a mesh network topology is that individual networks connect with any other networks as they move about the environment, enabling full mobility of the network and its subscribers.

Converged Systems and Shared Resources

With multiple complete networks (e.g., a cell, full core, etc.) operating in the same environment, resources can become common. With a network between two or more systems, one system will operate as the common core which allows for inter-network mobility, data sharing, decentralized backhaul, load balancing, and other key benefits.

Dynamic Interference Mitigation

With multiple networks operating in the same space, networks can automatically and dynamically control transmitter power levels, which can reduce inter-cell interference, advocate for handovers to other cells, and direct power to key operational areas.

Small Form Factor Systems

As technology advances, systems require less size, weight, and power. Research in this area focuses on the management, control, and operations of small cells.

Multi-Platform Deployment

With the advances in small cells, locations to deploy the network become more flexible. This research area focuses on deployment of LTE cells on UAS, vehicles, backpacks, and other highly portable options.

Rapidly Deployable and Highly Mobile Networks

The Interconnected, Multi-system Network

Resilient Backhaul Research Areas

Data Collection and Processing at the Edge
Data is consumed in the field (at the edge), and the newest and most important data is often produced there. Reliance on backhaul is greatly reduced, and the overall network is optimized when data is processed close to the users.

Data Replication and Synchronization
Data collected by a device on one network should be available on other networks. As much as connectivity allows, shared data should be consistent, available, accurate, and timely.

Optimized Data Use
As data is synchronized and shared across networks within the incident area and from backhaul connections, the data usage and throughput must be managed so that operations may continue without interruption. This area focuses on need-aware prioritized use of communication (and other) resources.

Dynamic and Content Based Networking
The individual LTE networks within the multi-system network are highly mobile and, with the mesh network interconnecting all LTE networks, direct connection points and network routing must be dynamic to be fully optimized. This research area focuses on enabling content based networking techniques to develop a fully decentralized network while allowing for full system connectivity as the specific connection points move.

Resilient Interconnection and Backhaul

The Interconnected, Multi-system Network

Security Research Areas

Secure Information Sharing

As the convergence of multiple different LTE networks with multiple different groups of users enables the sharing of data from one network to another, secure information sharing is critical. Different agencies will have access to different databases and will collect different types of information. This information will be processed and archived at the edge and will be made available to all users in the incident for total situational awareness. However, there are privacy and other security considerations to be made. Research in this area will focus on enabling controlled access to data from users outside of the home network which will ensure all responders have access to the right information without jeopardizing the security of the data.

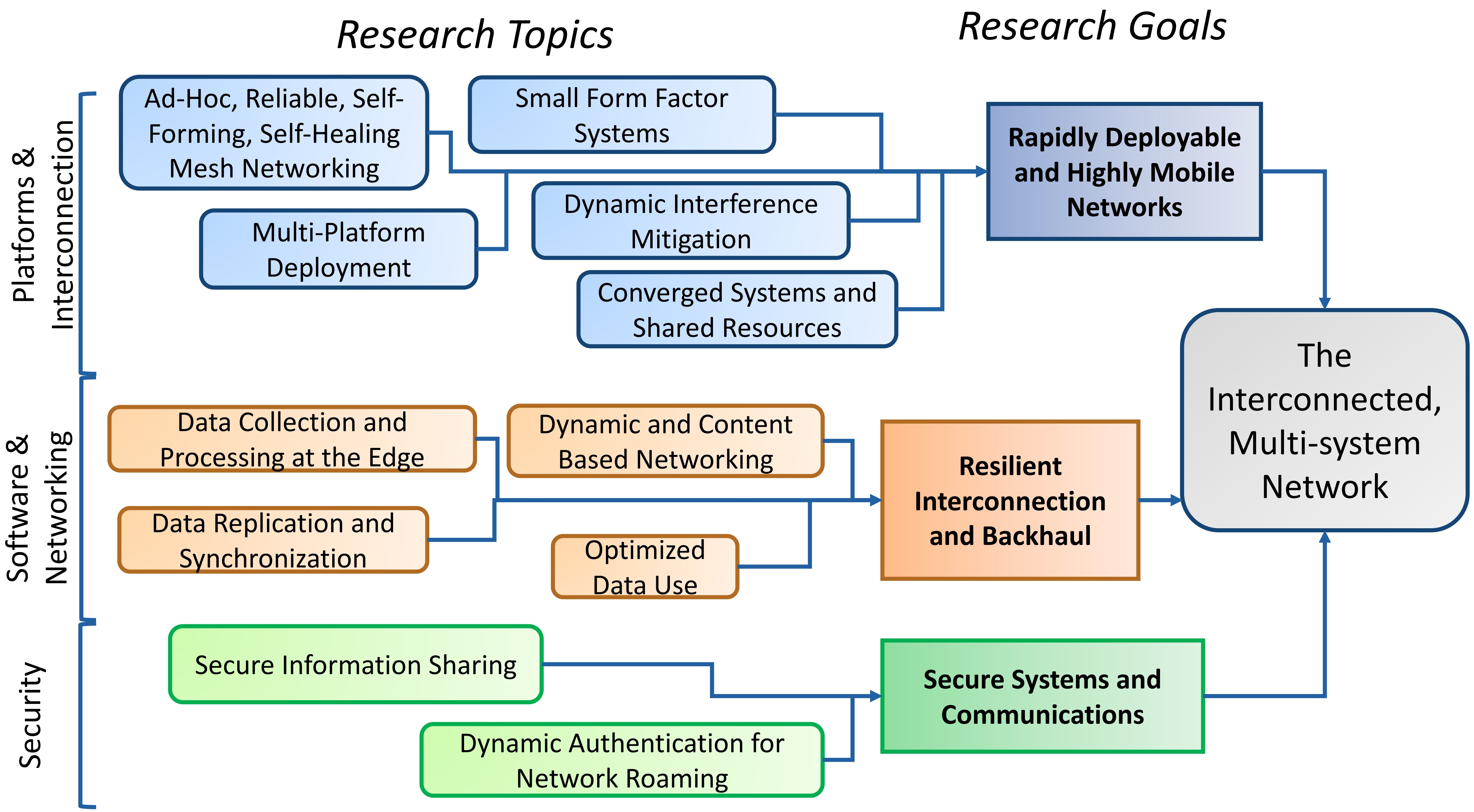
Dynamic Authentication for Network Roaming

FirstNet is working on a global ICAM solution where agencies can integrate and share credentials with one another, and PSCR's current research is focused on ad hoc provisioning through assisted enrollment. Ensuring authentication remains even when the network is not connected to a centralized ICAM or other authentication service is a critical research area for the highly mobile deployable network. This goes beyond simply attaching to the network, but extending to the access and authorization level granted to a user.

Secure Systems and Communications

The Interconnected, Multi-system Network

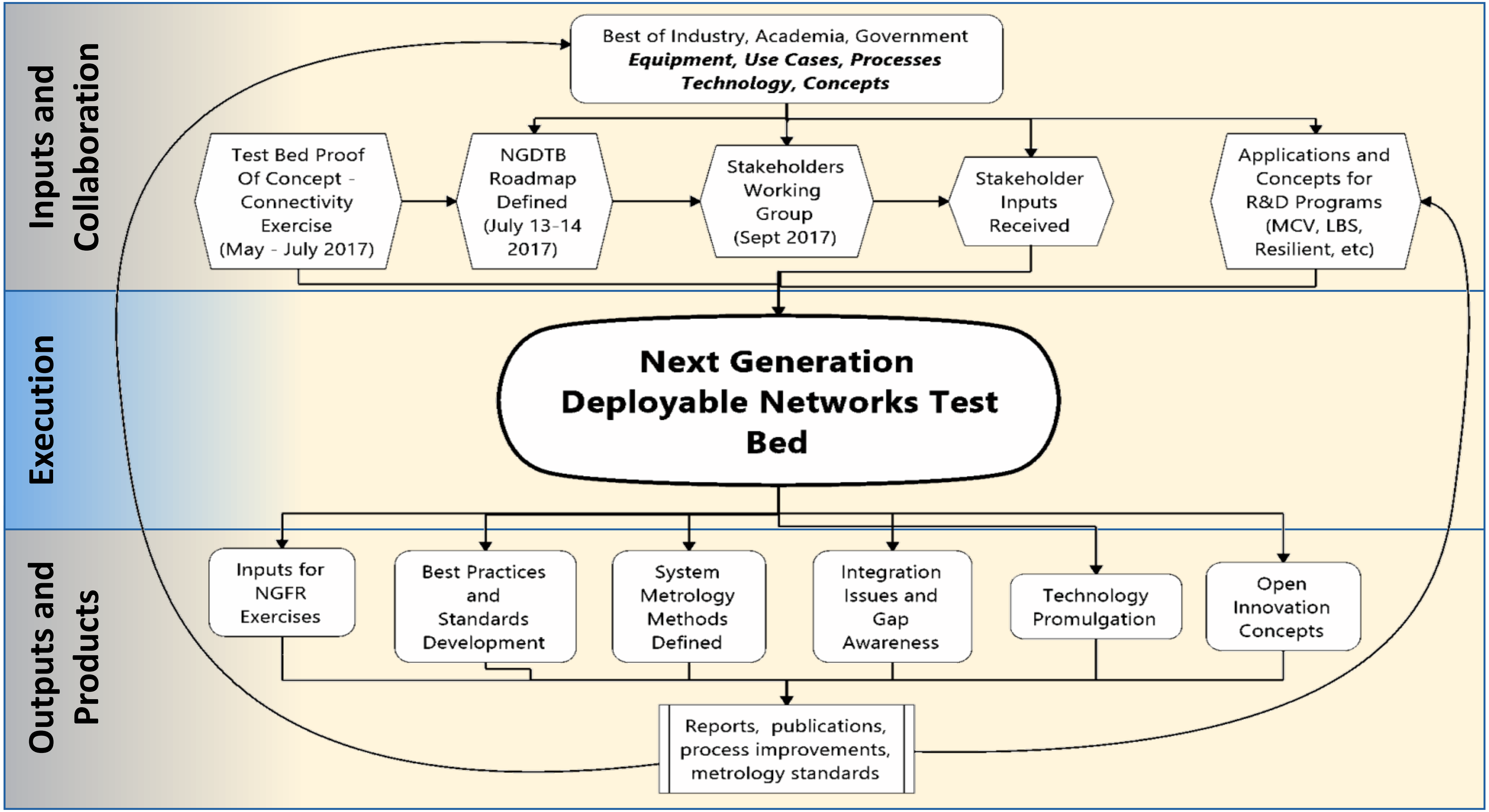
Overall Research Areas for Deployed Systems



The Next Generation Deployables Test Bed

- PSCR is creating an environment which is representative of a multi-system deployed network
- A roundtable process will be conducted to determine the priority of experimentation for the testbed
  - The process will include a roadmap development session (July 13-14) as well as a working group (September TBD) to establish specific experimentation plans
  - Focus areas include:
    - Network delivery platforms (UAS platforms, small form factor cells, etc.)
    - Convergence of multiple independent networks
    - Security across all aspects
    - Resilient interconnection and backhaul
    - Edge-based services
- The goal is to provide an environment where industry, academia, and government can bring key technologies together to advance deployable systems

NGDTB Process



Key Outputs of the Test Bed

Next Generation Deployable Networks Test Bed

Outputs and Products

Inputs to NGFR Exercises	Defined System Metrology Methods	Integration Issue/Gap Awareness	Technology Promulgation	Best Practices and Standards Development
As public safety exercises evolve and are planned, the concepts and outputs from experiments conducted in the test bed can feed into the exercises	*As best practices and general operations begin to materialize, we can rely on our metrology expertise to define industry standard measurement techniques*	*By bringing multiple systems and concepts together, we can identify what works and what doesn't work from an integration perspective and communicate issues/gaps to stakeholders*	*By working with the best of industry, academia, and government, we can provide awareness of the state of the industry so that first responders can take full advantage of the technologies*	*By conducting interoperability and coexistence experiments, we can derive the best methods for multi-agency and multi-network operations*

A Few Final Thoughts

- Deployable systems exist and are critical for a nationwide public safety network, and they must be able to communicate with other networks
- The deployable public safety network needs to evolve along with the technology to continue being as effective as possible
  - As technology emerges, deployable systems can benefit significantly as long as the research is forward looking
- We have established research goals to continue to advance deployable public safety networks and have established a test bed to experiment with concepts, processes, equipment, and ideas to further this research

Involvement of stakeholders such as the public safety user community, industry, academia, and other government organizations ***is key to the advancement of public safety communications***

Making the Most of Image and Video Quality

Margaret H. Pinson

mpinson@ntia.doc.gov

100+ Interviews

- Law enforcement, fire, and emergency medicine
  - Federal, state, and local
  - Rural and urban
  - Small to very large
- Related professionals
  - District attorneys' offices
  - Manufacturers
  - Instructors and researchers
  - Public safety organizations
- First responder publications

Bridge the Gap

Image and Video Quality Problems

R&D Opportunities

Quality of Experience
First Responder Feedback

Better

- CAD drawings
- Google Earth® building photos
- GoPro® camera for training
- InTouch® Telestroke robot
- License plate reader
- Point-and-shoot camera
- Thermal imaging camera
- Vehicle backup camera
- Wildlife camera

Worse

- Body cameras
- CCTV
- DSLR
- In-car cameras
- Remote learning
- Video conferencing
- Video streaming to 911 call center
- Video surveillance

“Video is not an accurate media”

Grant Fredericks
Law Enforcement Video Association (LEVA)
LEVA Level 3 Photographic/Video Comparison

Emergency Medical Response

Roadblocks to Adoption

Camera

- Interoperability
- User Interface

Not The Camera

- Cost of the system
- Department does not understand HIPAA obligations
- Liability concerns
- Medical care does not improve
- Physicians are too busy

NPSTC
National Public Safety Telecommunications Council

"EMS Telemedicine Report: Prehospital Use of Video Technologies"
By NPSTC, February 24, 2016

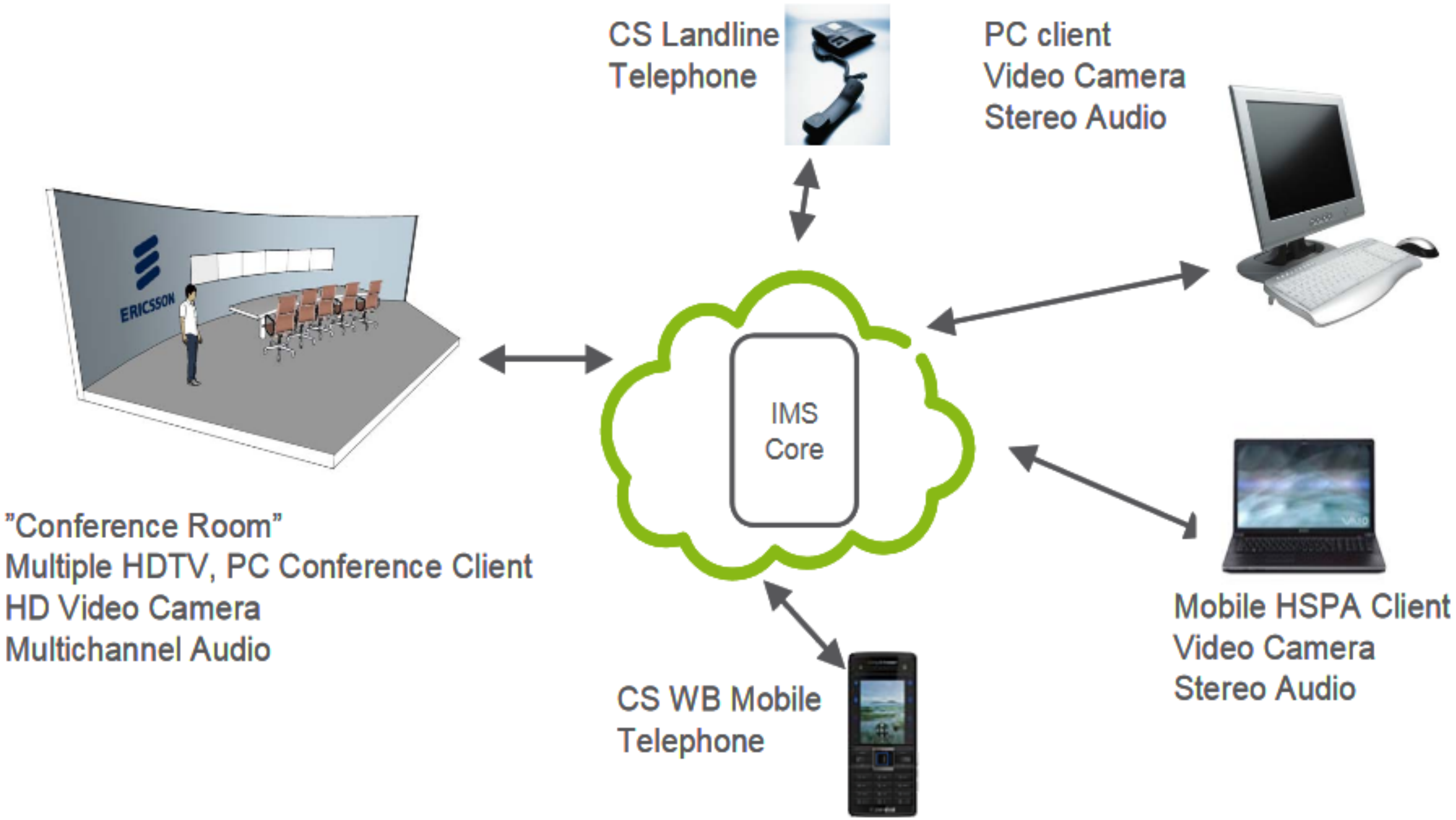
Telemedicine

"…observe or monitor a patient's status…"

"…interactive video systems coupled with the appropriate instrumentation and a simple-to-use interface."

President's Information Technology Advisory Committee

R&D Opportunity—Telepresence

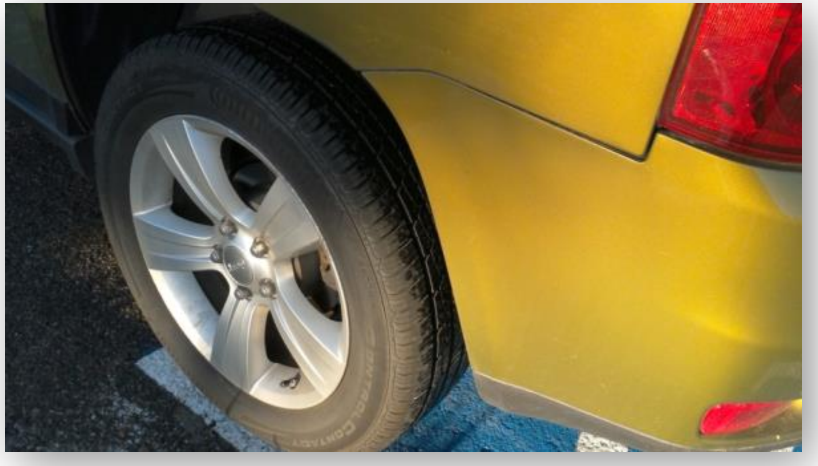
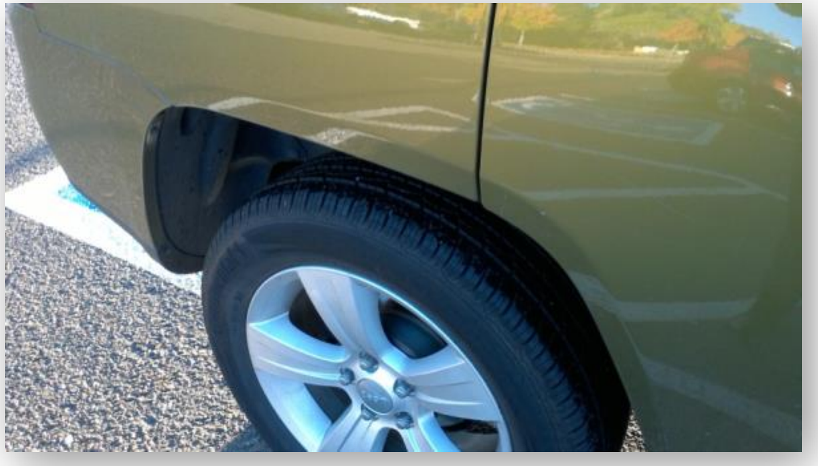


Color Constancy

Color Consistency Between Cameras

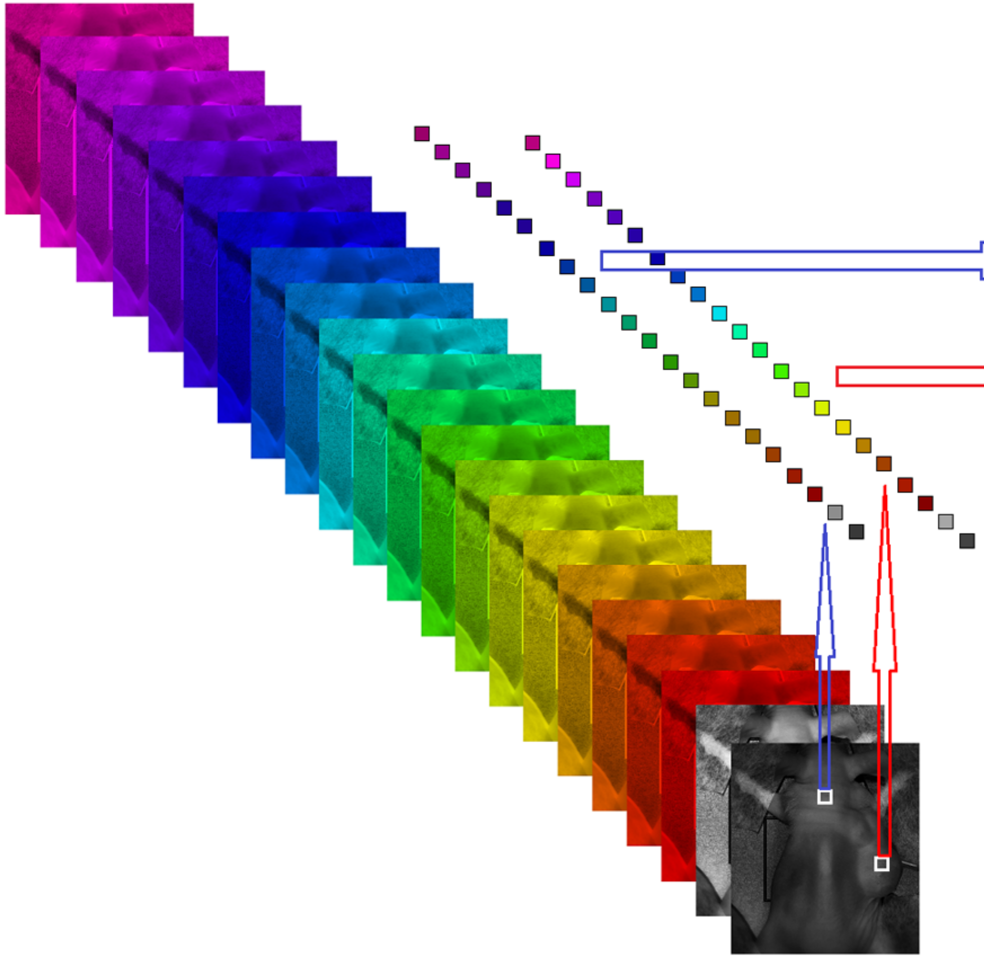
  

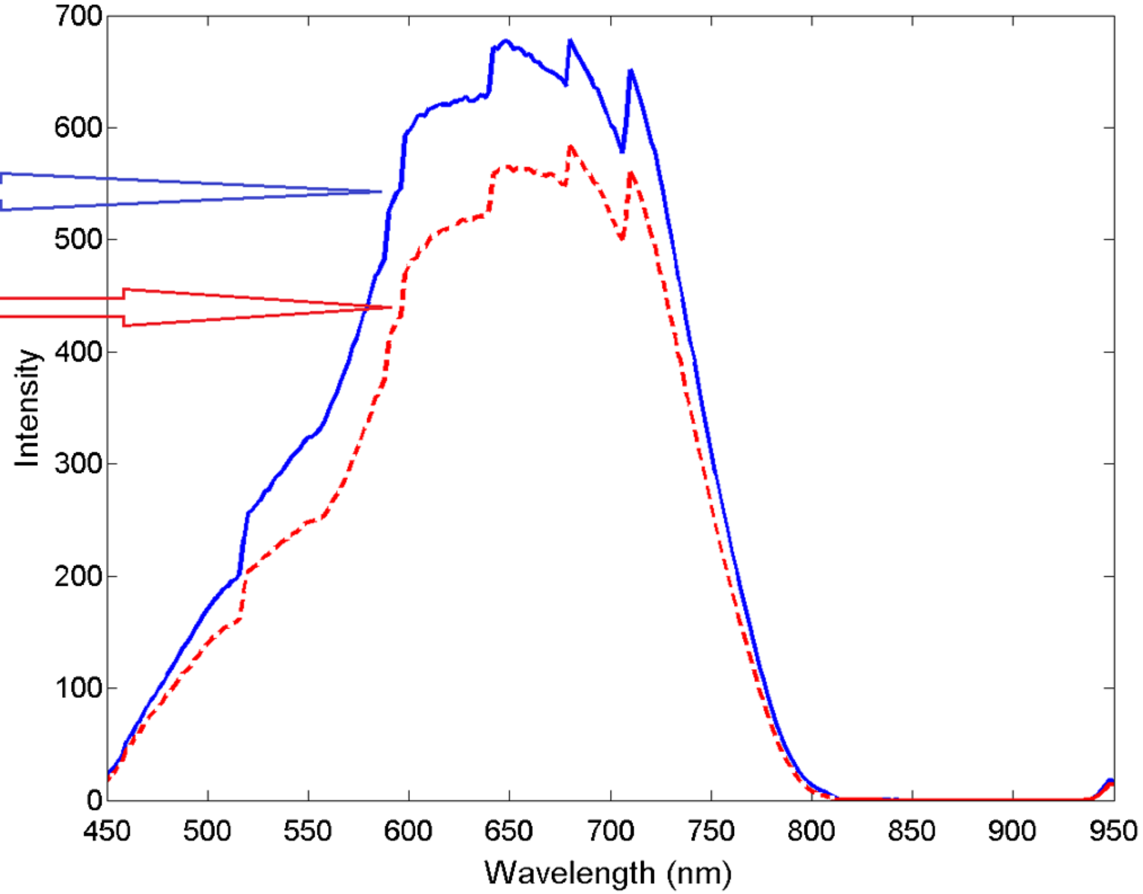
Color Consistency Across Time

Color Consistency Across an Image

R&D Opportunity — Color Constancy

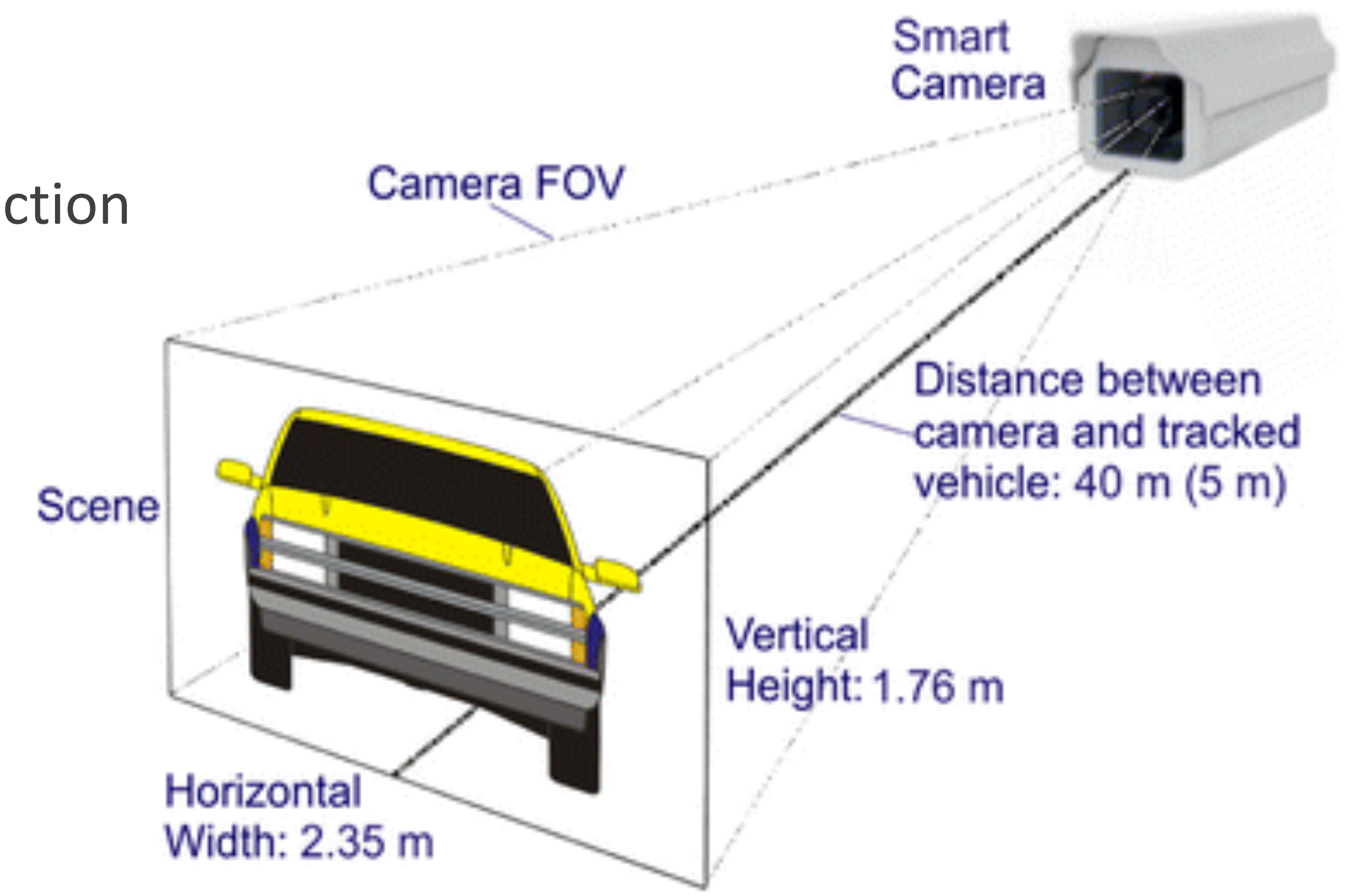




"Hyperspectral imaging and quantitative analysis for prostate cancer detection"

R&D Opportunities—Target Specific Applications

- Color benchmark for cameras
- Vehicle color identification
- Person tracking color features
- Remote sensing image color correction



Fire Fighters

Cameras Often Not Helpful

R&D Opportunity—Improved Smoke Detector

Smoke conditions prior to flashover

Light and medium smoke

R&D Opportunity—Discriminating Fine Shades

Law Enforcement

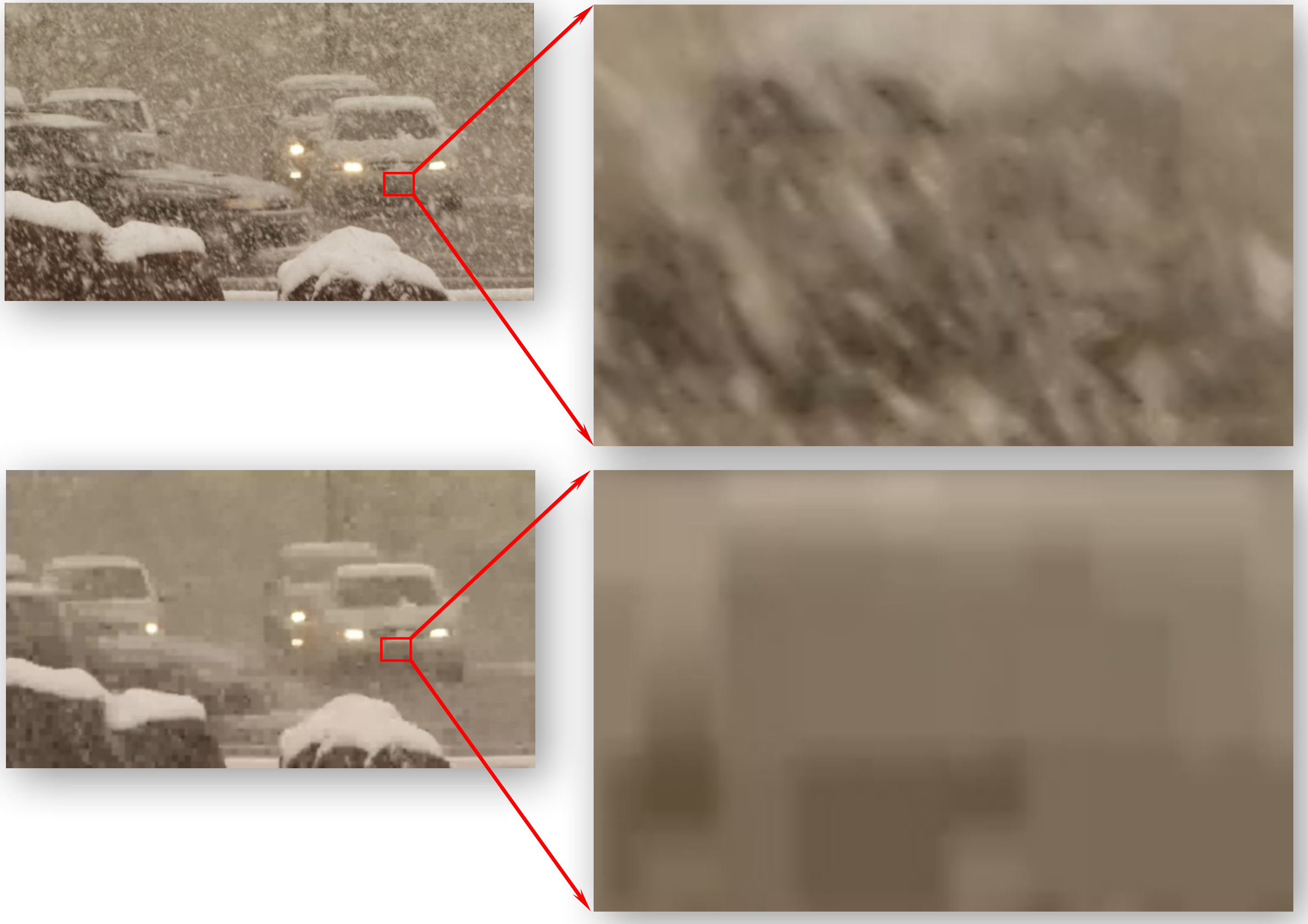
Promising Future for Video and Images

- Detect and dissuade criminal activity
- Real-time reconnaissance
- Crime scene imaging
- Automatic suspect identification
- Video game training

Obscurants Preserved = Evidence Lost

Obscurants Preserved = Evidence Lost

Remove Obscurants Before First Encoding



100 Mbps

1 Mbps

R&D Opportunities—Remove Rain, Snow, Dust, Haze, …

Raindrops on glass

Haze

Snow

R&D Opportunity—Shadow Removal

Simulation

Research

R&D Opportunity—Reflections

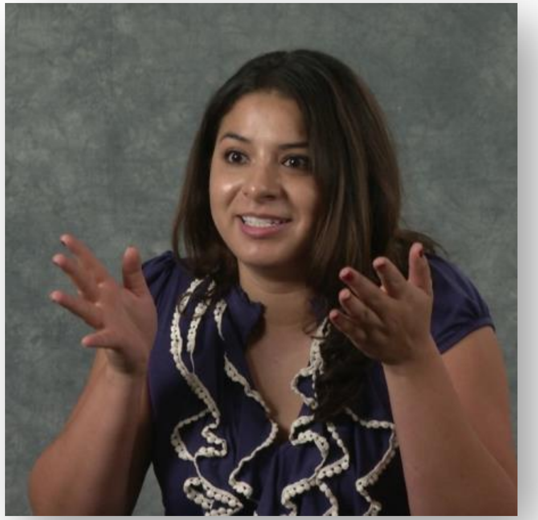
Research

Video Surveillance Recordings

Video Surveillance Recordings

Law Enforcement Priority

1. Identify
2. Track
3. Observe the crime



Video Surveillance Recordings

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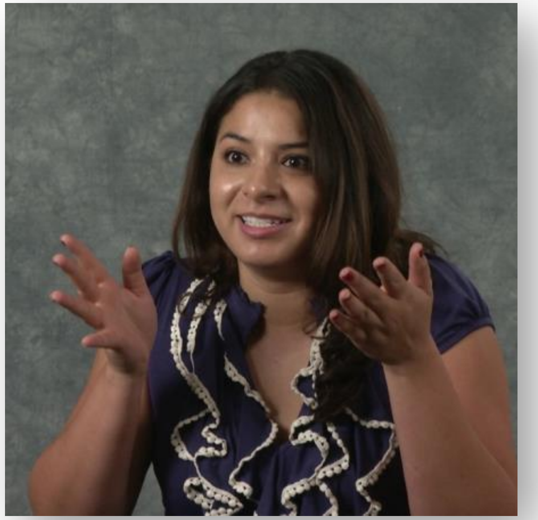

System Design

1. Observe the crime
2. Track
3. Identify

R&D Opportunity—Evidence System

R&D Opportunity—Basic Surveillance System for Law Enforcement

- Intelligently craft photos for identification purposes
  - Each person who enters the store
  - Each vehicle that enters the lot
- High resolution JPEG files (10 mega-pixels)
- Timestamp with universal time

Next Steps

- “Technology Gaps in First Responder Cameras” by Margaret H. Pinson
  - 46 R&D opportunities
- PSCR federal funding opportunities (FFO)