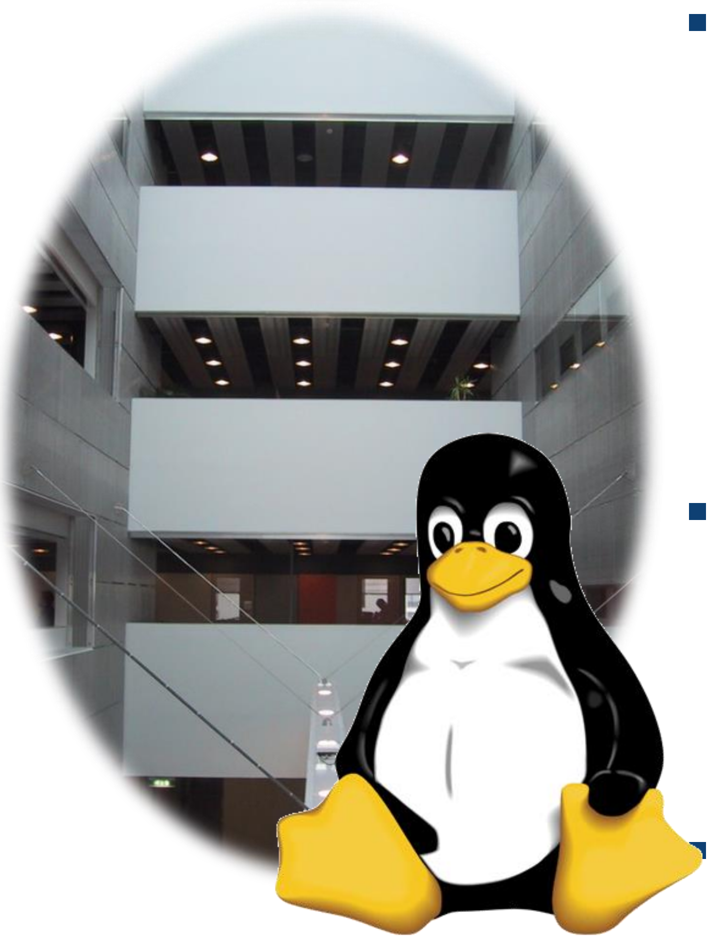
LOW-COST SUPPORT FOR SEARCH AND RESCUE OPERATIONS USING OFF-THE-SHELF SENSOR TECHNOLOGIES.

Petteri Nurmi, Sasu Tarkoma

50 YEARS OF EXCELLENCE



- **Department of Computer Science**
- Leading institution in Computer Science in Finland
  - #1 in Finland in QS Ranking 2017
  - #1 in Nordic Countries in Times Higher Education 2017
- **Core Computer Science and Data Science**
  - 17 professors and over 200 employees
- **Industry Research Centers:**
  - Nokia Center for Advanced Research (NCAR)
  - Intel CRI-SC

INTRODUCTION

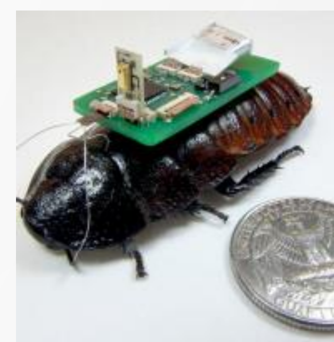
- Incidents that cause people getting trapped or missing infrequent but unpredictable and potentially highly damaging
  - Building collapses
  - Earthquakes
  - Mine/cave collapses
  - Bombings
- Finding victims of incidents as fast as possible key to survival
  - Likelihood of survival low after 72h
- Incidents unpredictable ➔ first response often slow or lacking

RESEARCH VISION

- First response often responsibility of people located within close vicinity of incidents
  - Unlikely to have formal training for the tasks ➔ reduced effectiveness and risk of additional casualties
- Our vision is to facilitate these operations by ***augmenting human capabilities*** with ***low-cost off-the-shelf technologies***
  - Improve effectiveness of search-and-rescue operations
  - Safeguard the people carrying out the operations to mitigate risk of additional casualties
- In this work we look at technological support for ***key tasks*** within search-and-rescue operations

RELATED RESEARCH

- Human-Robot systems
  - “Extreme” terrain robots, go over rubble, water, and other obstacles (e.g, KOHGA3)
    - Search for survivors before rescue teams sent
  - Swarms
    - Multiple small robots that can move through and around obstacles, E.g., cyber-roaches
- Requires ***remote operator*** for coordinating the search efforts
  - Limited depth vision and field-of-view ➔ difficult to maintain situational-awareness
- Wearable systems
  - Mainly focused on individual tasks
  - Most focus on firefighters
    - Communication, navigation, or building mapping



RESEARCH OVERVIEW

- Our research explores “augmenting” human capabilities with sensor technologies
  - Wearable sensing units combined with wearable interaction devices
- Focus on using *off-the-shelf technologies*
  - Affordable for dense deployment, e.g., one unit per building or even one per home
- Our paper explores the required *technological and algorithmic foundations*
  - Further research required to integrate everything into practical units

KEY TASKS

- The focus of our work is on supporting key tasks in search-and-rescue missions carried out in urban environments.

- Tasks:
  - Finding Survivors
  - Avoiding Danger
  - Maintaining Location-Awareness
  - Team Communication

FINDING SURVIVORS

- Finding people who are trapped or otherwise in need of help the most important task for rescue operations
- We combine visual and audios sensing to support this task
- Visual sensing:
  - Depth or thermal imaging to enhance vision in low-light conditions
  - Automatic identification of humans (skeletal tracking for depth images, visual shape recognition for thermal images)
  - Can also be used for detecting sharp/dangerous objects
- Audio sensing:
  - Identify loud human voices (e.g., calls for help) and provide a coarse-grained location for them (directionality estimated using microphone arrays or dual microphones)

AVOIDING DANGER

- Ensuring safety of rescue personnel crucial ➔ we support automatic detection of dangerous situations
  - Main focus on *audio* based detection and feedback combining tactition and visual cues
- Audio sensing
  - Peaks in the energy of audio frames used to identify potential dangers
  - When available, microphone-arrays (or dual microphones) used to provide a direction estimate for the audio
- Feedback
  - Hip-mounted actuators (belt with integrated actuators or two mobile phones placed at hip) provide tactile feedback
  - Additional notifications shown on visual interface

MAINTAINING LOCATION-AWARENESS

- Rescuing survivors that are found often requires additional help.
- It is crucial to track the location and path of the rescue personnel.
- Off-the-shelf smartphones, as well as wearable trackers, contain motion sensors which can be used for pedestrian dead reckoning
- Alternatively, the combination of depth and motion sensors can be used to construct floor plans on-the-fly, enabling more fine-grained localization.

TEAM COMMUNICATION AND COORDINATION

- Coordination between the rescue personnel is paramount to the effectiveness of the mission.
- In many cases, such as building collapses, earthquakes, and other related incidents, national communication infrastructure can suffer damage and be rendered ineffective.
- Off-the-shelf consumer electronics are increasingly equipped with technologies for wireless local area connectivity (such as WiFi direct and Bluetooth Low Energy) which can be used to form ad hoc connections between rescue personnel.
- We are investigating a Network-in-a-Box concept for 4G and 5G networks for on-demand network creation

PROTOTYPES I

- Earliest prototype was constructed as part of a student project
  - Consisted of a Kinect sensor, head-mounted display (HMD), two mobile phones, and portable power source
- Kinect used to support finding survivors
  - Depth camera feed shown on the HMD, human shapes detected with skeletal tracking and highlighted on the feed
  - Microphone array on Kinect used for speech identification and localization
- Hip mounted mobile phones used to warn about dangers
  - Monitor level of audio activity
  - Vibrate when intense sounds observed




PROTOTYPES II

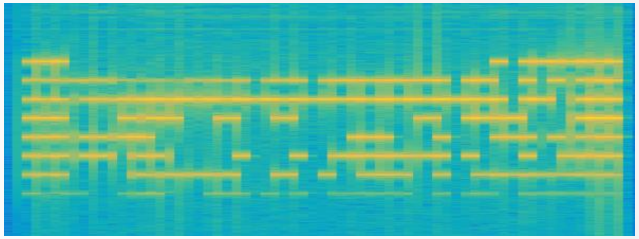
- Two other prototypes based on a similar setup, but use high-end smartphones instead of Kinect
- Prototype II: Lenovo Phab2 smartphone
  - Integrated depth camera + Google Tango for processing the depth sensor images.
- Prototype III: Caterpillar CAT S60 smartphone
  - Integrates a consumer grade forward looking infrared (FLIR)
  - Additionally dust and waterproof

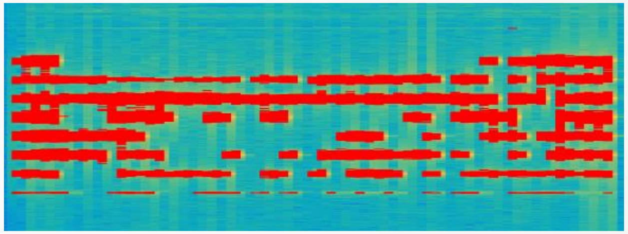
- Currently both prototypes rely on external laptop for image processing due to better availability of image processing libraries
  - Both smartphones have high-end processing capabilities so processing can also be implemented on device

DISCUSSION

- The cost of each of our prototypes is around $600 and is likely to decrease in the near future as the corresponding sensor technologies increase in popularity.
- In particular, depth and heat cameras are currently only available on top-end smartphones, but are likely to be available on more and more devices in the near future.
- The required processing power and support for local connectivity, on the other hand, is readily available even on low-end smartphones.
- Further reductions in cost can be achieved by using dedicated components instead of off-the-shelf consumer devices.

EXTENSIONS: MULTI-CHANNEL COMMUNICATION

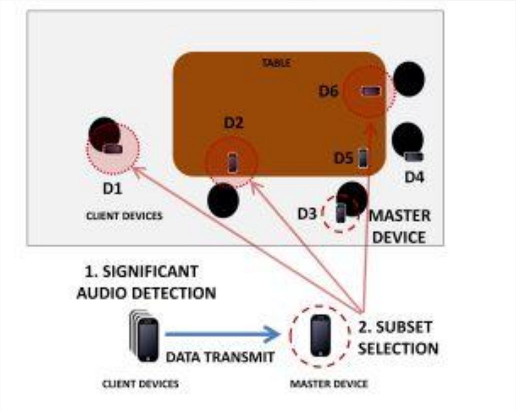


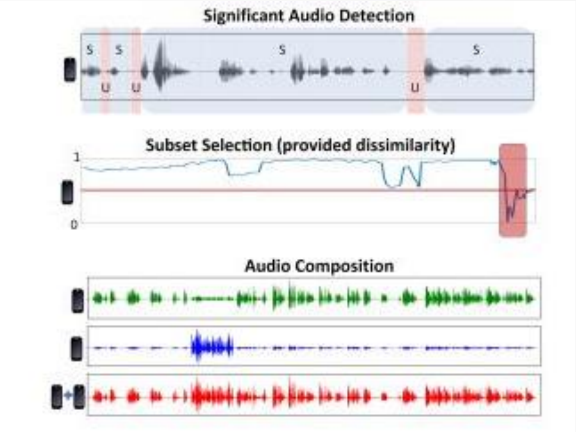


- Currently exploring ways to enable communication with multiple modalities
  - Wireless (WiFi, BLE)
  - Audio
- Different characteristics ➔ can overcome weaknesses of each other
  - Different sensitivities to obstacles and interference ➔ best effort delivery on multiple channels
- Multi-channel audio communication
  - Information encoded as audio, each bit on a separate frequency
  - Mostly operate near-ultrasound (18kHz and above)

EXTENSIONS: DISTRIBUTED SENSING

- Another topic we are exploring is the use of collaborative and cooperative sensing
- Combine sensor measurements from multiple devices with the aim of augmenting their sensing capabilities
- Our existing work has focused on multidevice sensing of the audio environment in an open space
  - Devices form a cluster where they share audio information with other devices
  - Informativeness of audio content used to optimize when to sense and share
    - – Minimize resource consumption
    - – Reduce effects of noise on audio

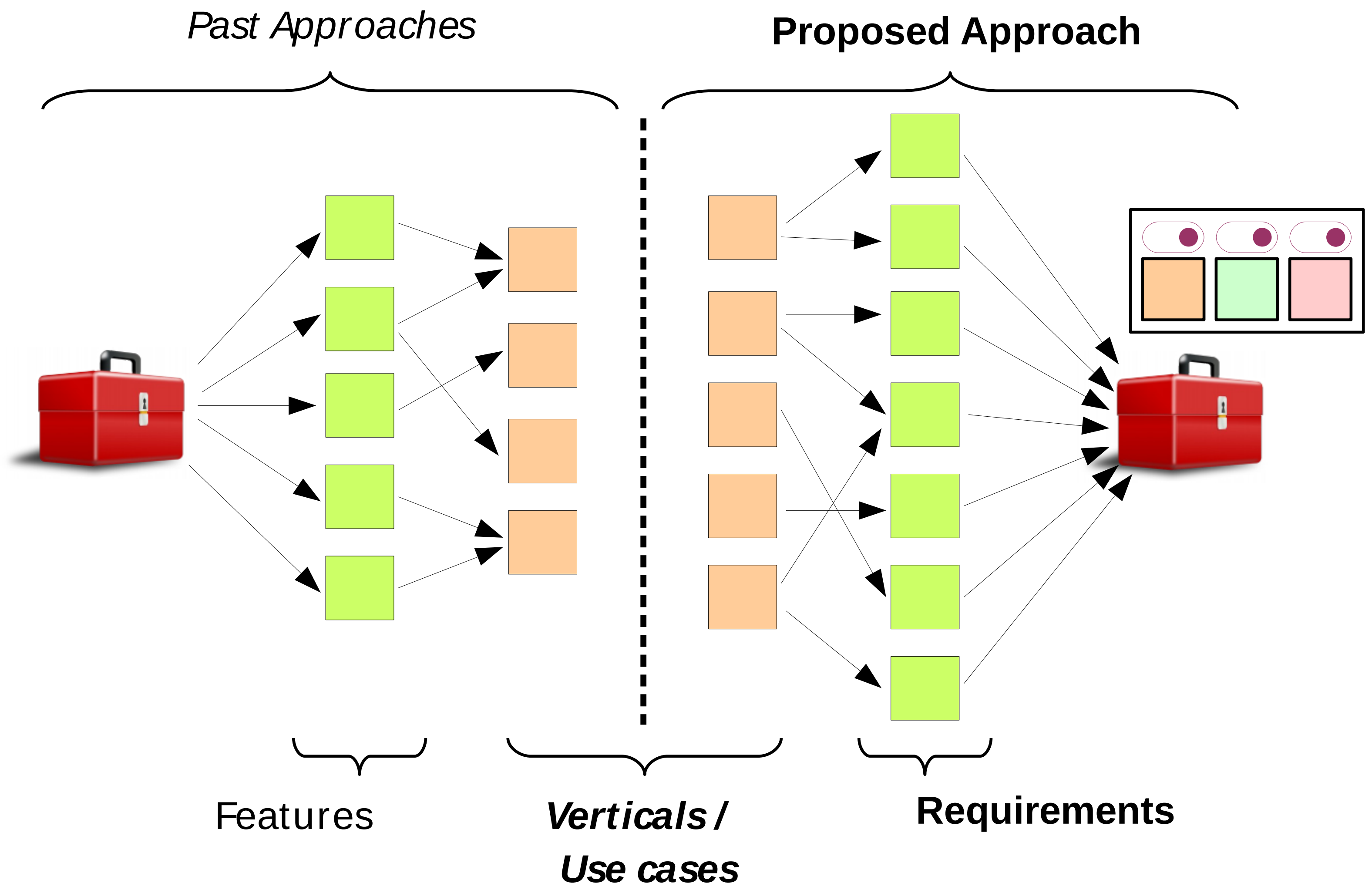




NETWORK-IN-A-BOX

- What is a Network-In-a-Box?
- Single device that provides connectivity services to a group of disconnected devices
- Easy to deploy + minimum setup effort
- Use-cases:
  - after-disaster scenario
  - connectivity provisioning in poor/remote areas - enterprise networks
  - tactical networks

NETWORK IN A BOX
CREATE, SCALE, UPGRADE NETWORKS



NETWORK REFACTORING

Three steps:

1. Identifying the **roles** of the network functions

2. Splitting each network function into **modules**, creating one module for each role of the network function. For each module, we identify the requirements of a physical device instantiating that module.

3. Changing the **mapping** between physical devices and modules depending on the requirements (cost, latency, security, ...) from the network.

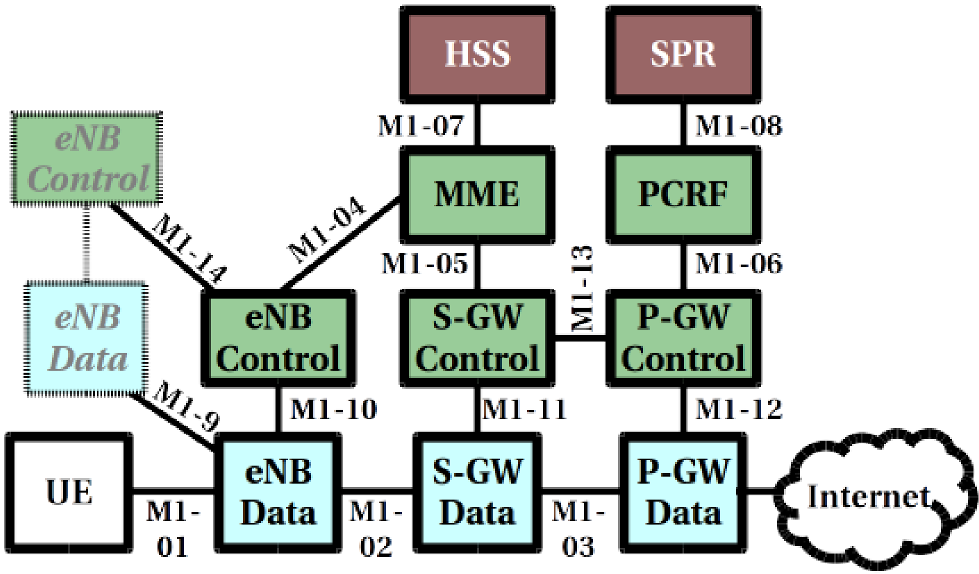
LTE control plane example:

Modularize architecture

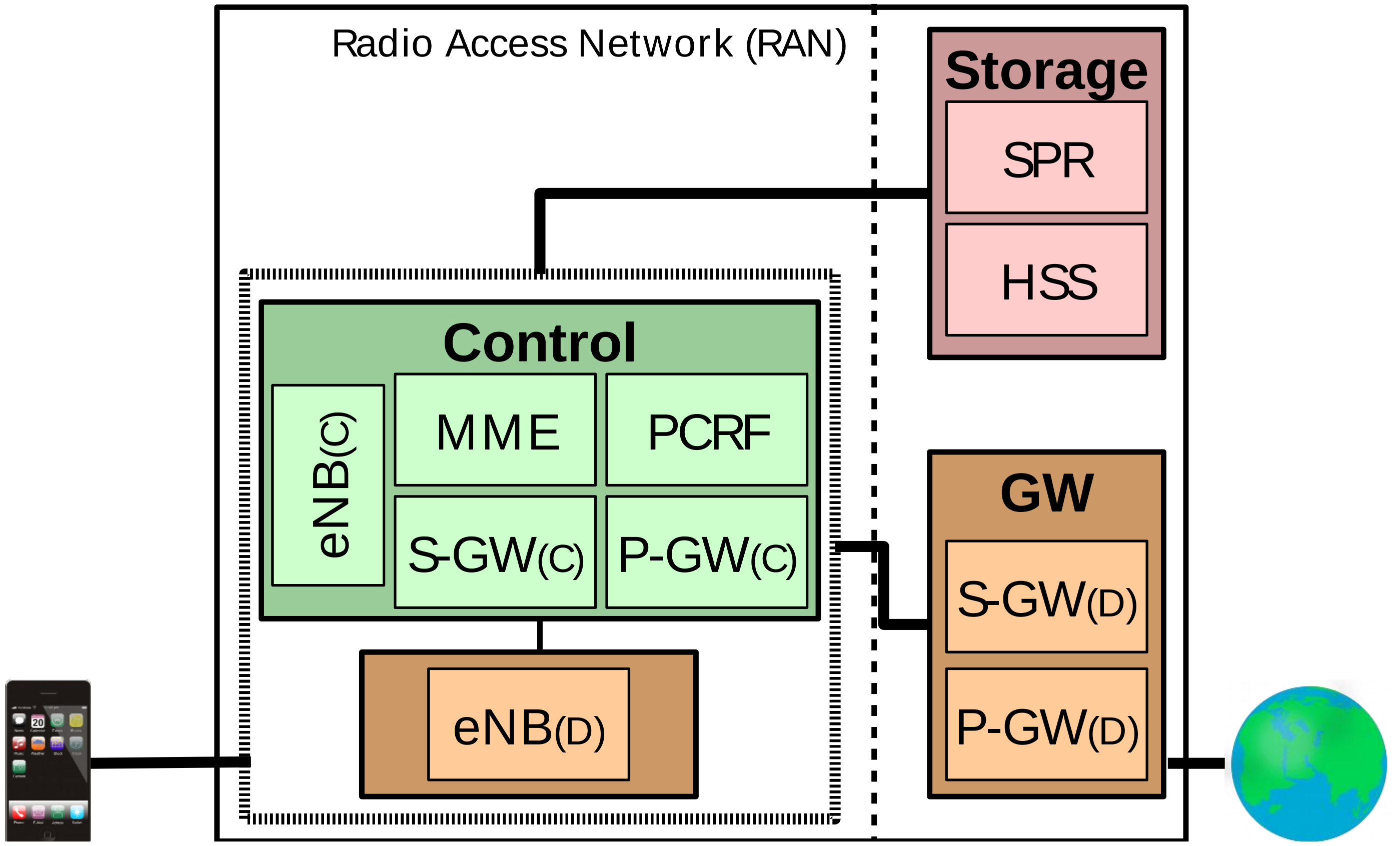
Identify **state variables**

Study **signals** between functions

Combine modules

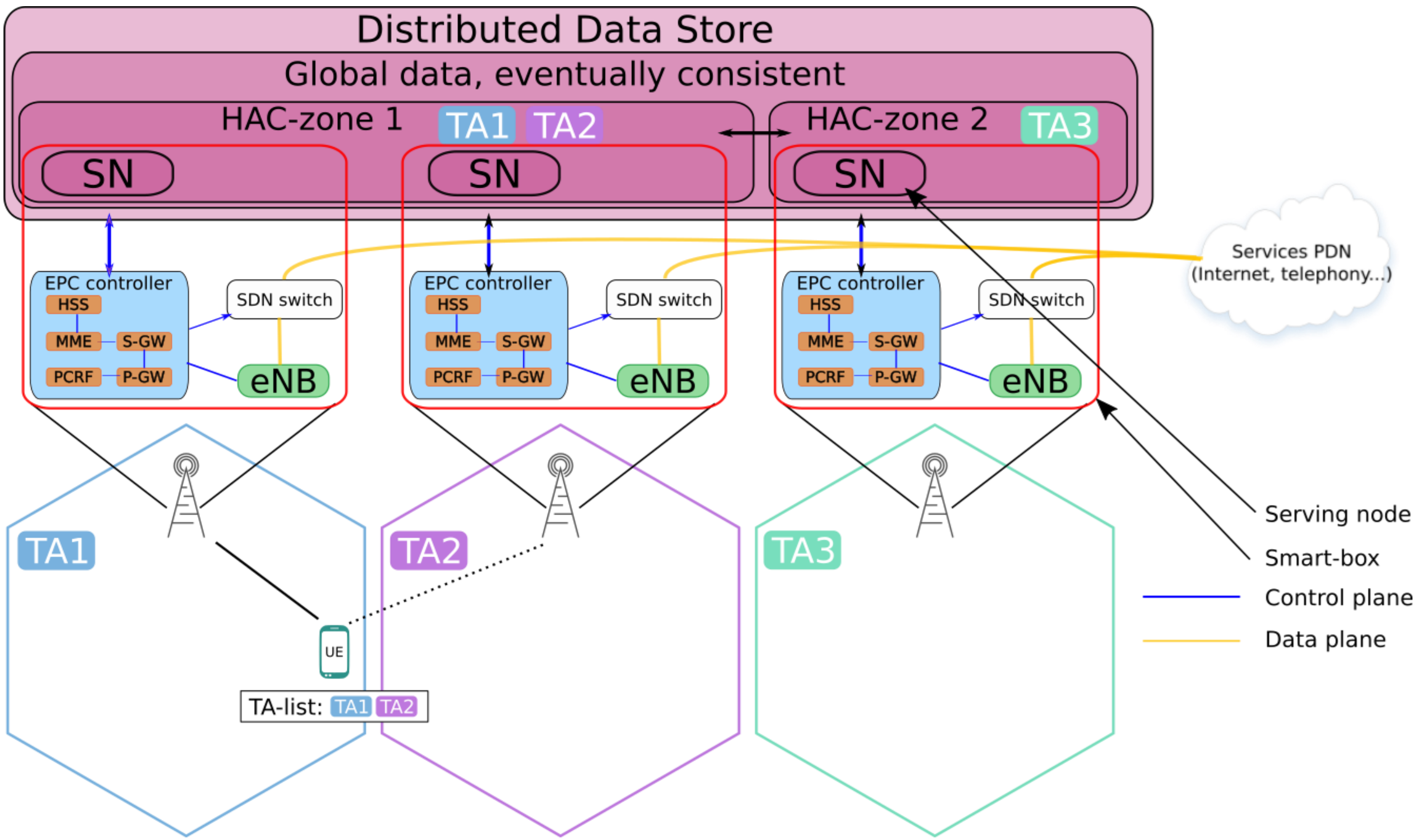


REFACTORING: INTELLIGENT EDGE



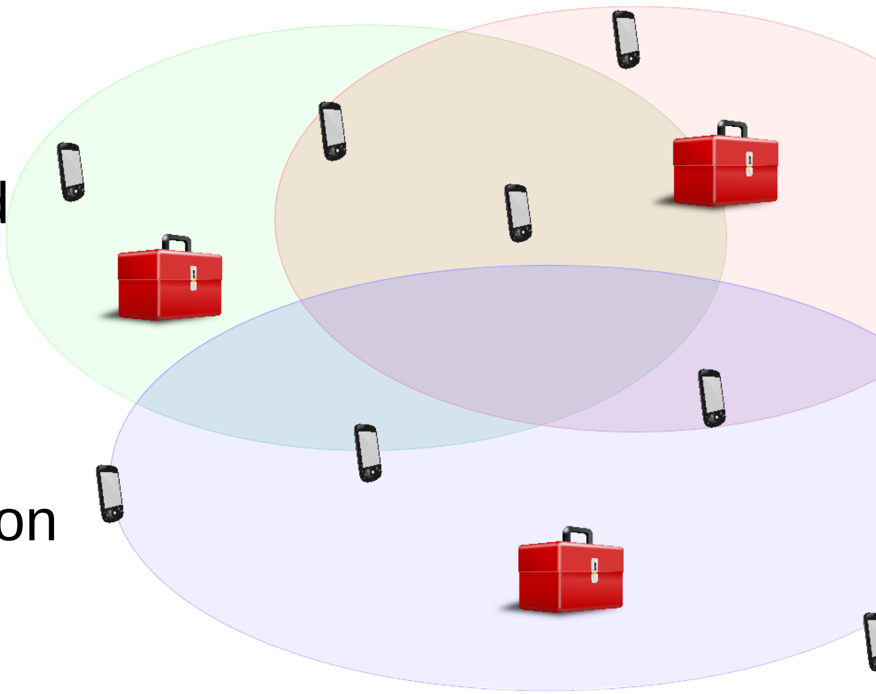
A Refactoring Approach for Optimizing Mobile Networks. Matteo Pozza, Ashwin Rao, Armir Abujari, Claudio Pallazi, Hannu Flinck, and Sasu Tarkoma*. In the Proceedings of IEEE ICC 2017*

CORELESS MOBILE NETWORKS
A STATE MANAGEMENT PERSPECTIVE



Frans Ojala, 2016

LOCALIZATION OPPORTUNITIES



How to leverage a base stations-based localization service?

Disaster scenario

Deploy some NIBs on the disaster area. Install the localization service on them

Immediate localization of all phone-holders in the area

No need of interaction from (potentially injured) survivors

SUMMARY

- We have contributed by discussing the suitability of low- cost, off-the-shelf sensor technologies for supporting search-and-rescue missions, and presenting three low-cost prototypes that provide support for tasks involved in search-and-rescue missions.
- By assisting key tasks within search-and-rescue operations, our research attempts to improve the success rate of early response to incidents triggering such operations. In particular, we have shown the potential of low-cost technological support for these tasks.
- Network-in-a-Box for versatile on-demand 5G cellular networks.

THANK YOU!

SASU.TARKOMA@CS.HELSINKI.FI
PETTERI.NURMI@CS.HELSINKI.FI