Towards the Next Generation of IoT-enhanced Smart Communities

By Georgios Bouloukakis

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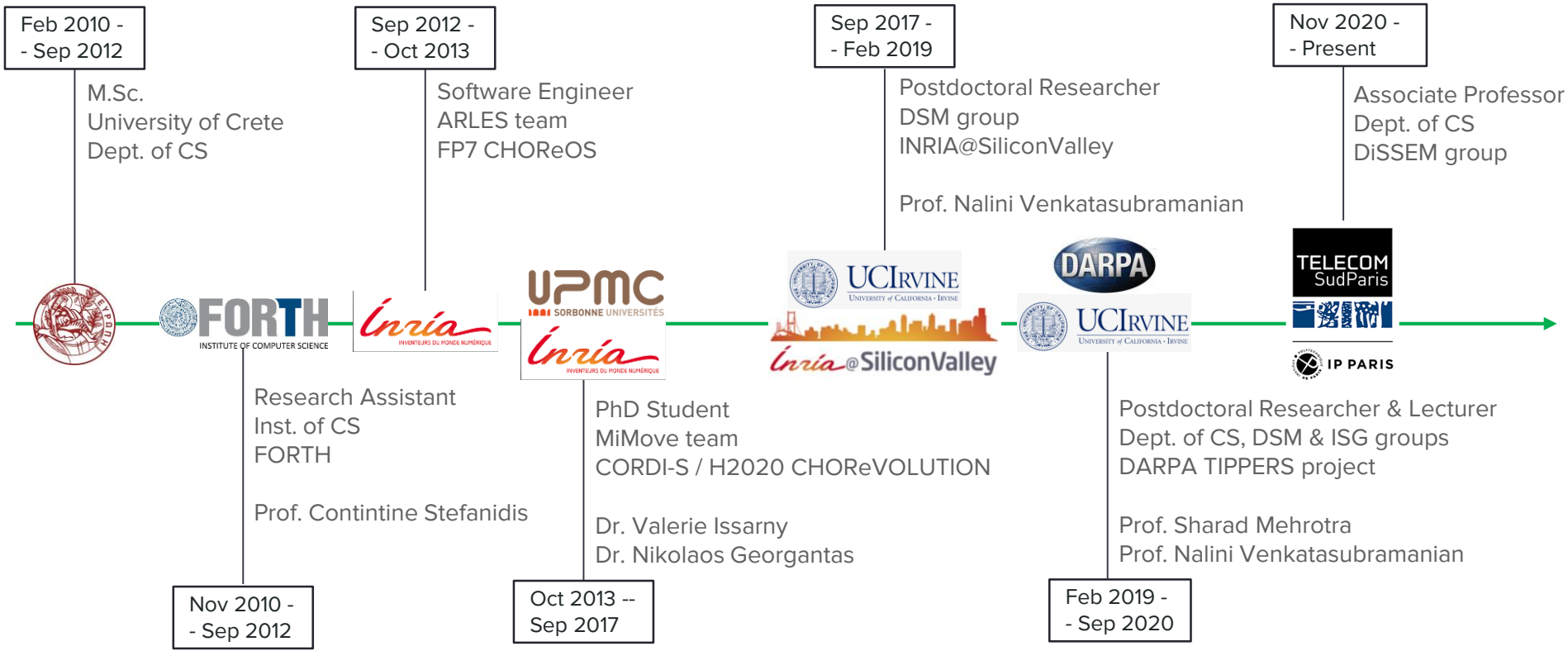
Nov 26, 2020 - ACMES Seminar

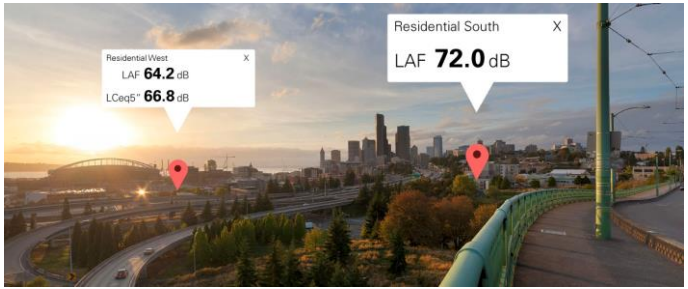
About me


Feb 2010 -
- Sep 2012
M.Sc.
University of Crete
Dept. of CS
Nov 2010 -
- Sep 2012
Research Assistant
Inst. of CS
FORTH
Prof. Contintine Stefanidis
Sep 2012 -
- Oct 2013
Software Engineer
ARLES team
FP7 CHOReOS
Oct 2013 --
Sep 2017
PhD Student
MiMove team
CORDI-S / H2020 CHOReVOLUTION
Dr. Valerie Issarny
Dr. Nikolaos Georgantas
Sep 2017 -
- Feb 2019
Postdoctoral Researcher
DSM group
INRIA@SiliconValley
Prof. Nalini Venkatasubramanian
Feb 2019 -
- Sep 2020
Postdoctoral Researcher & Lecturer
Dept. of CS, DSM & ISG groups
DARPA TIPPERS project
Prof. Sharad Mehrotra
Prof. Nalini Venkatasubramanian
Nov 2020 -
- Present
Associate Professor
Dept. of CS
DiSSEM group

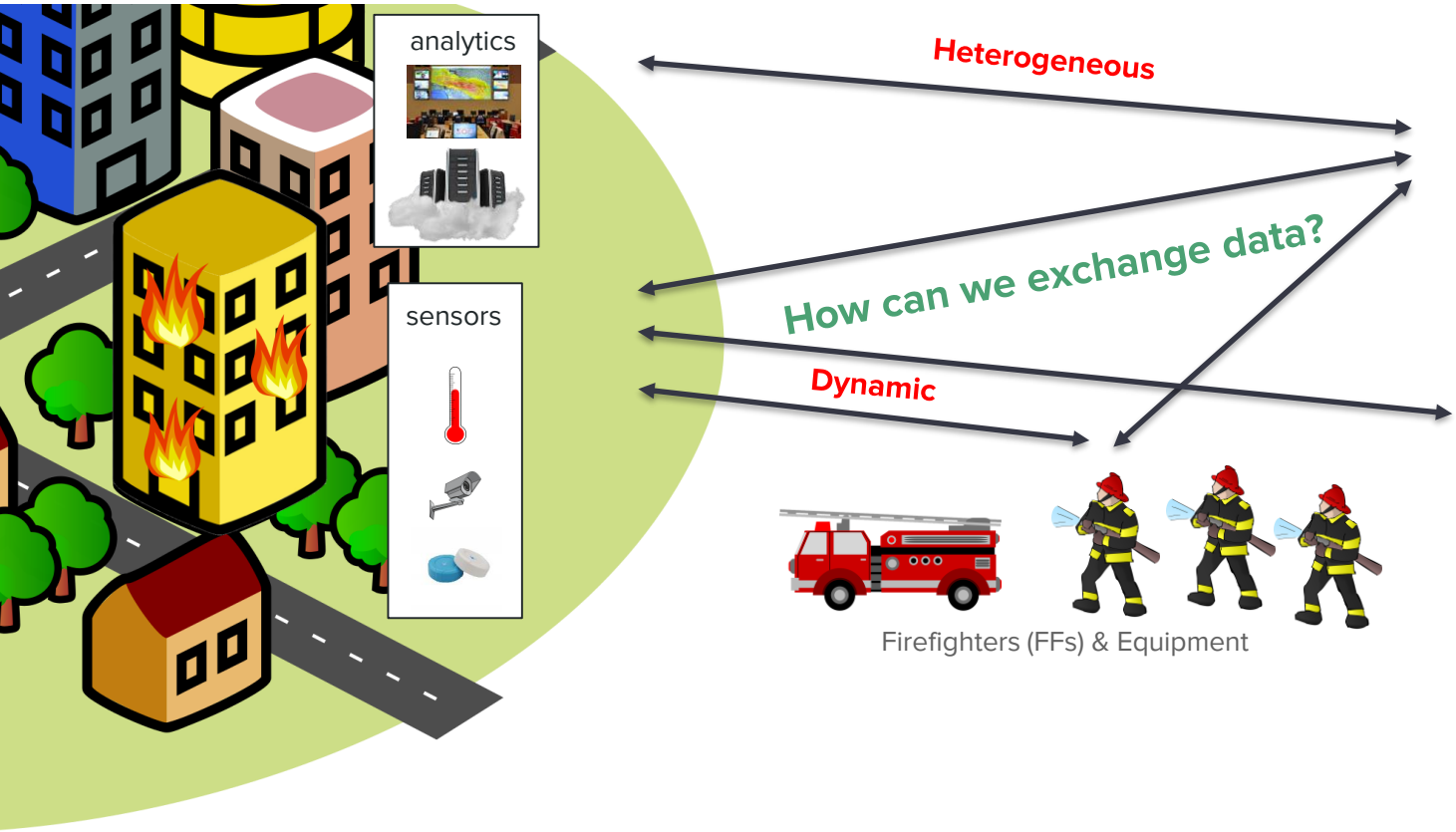
My research focus

- Research interests relate to ***Middleware***, ***Edge Computing***, ***Internet of Things*** and ***Distributed Systems***
- Current research focuses on the **design of extensible** and **efficient IoT systems** by leveraging **fundamental mathematical models** and **state-of-the-art technologies**
- Design IoT systems starting from the **formal analysis/modeling** to **prototype implementations** and **real deployments**

Sensorized IoT ecosystems



IoT-enhanced structural fire response



Abstracting IoT spaces for extensible and efficient systems

Past research

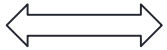
Major Publications:
ICSOC 2015 & 2016, ICC 2017, ICPE 2017, MobiQuitous 2018
Middleware 2018, ICIOT 2018, ICC 2019, ICDCS 2019, Buildsys 2019,
FGCS 2019, TIOT 2020, VLDB 2021,

Meeting QoS Requirements in IoT spaces

Different groups of stakeholders

Information requirements:

Utility functions	< “presence”, 200 >
	< “smoke”, 100 >
Latency requirements	< “presence”, 500 ms >
	< “smoke”, 5 sec >



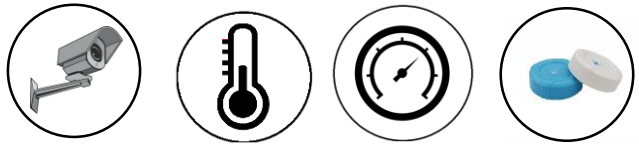
Constrained network

failed components

lossy channels

Heterogeneous IoT sources

data size | relevance | urgency



- How can we enable the exchange of **heterogeneous data** while considering stakeholders‘ **information requirements** and **network conditions**?

Meeting QoS Requirements in IoT spaces

Different groups of stakeholders

Information requirements:

Utility functions	< “presence”, 200 >
	< “smoke”, 100 >
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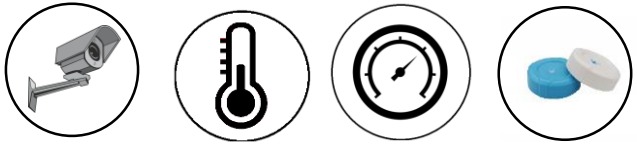
PrioDeX

Constrained network

- failed components
- lossy channels

Heterogeneous IoT sources

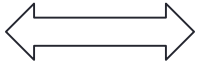
- data size
- relevance
- urgency



Abstracting IoT spaces

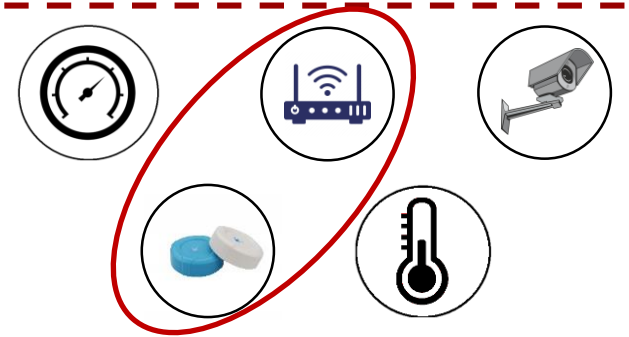
App request:

- *"**Occupancy** of rooms with **Temperature** above x"*



People's world

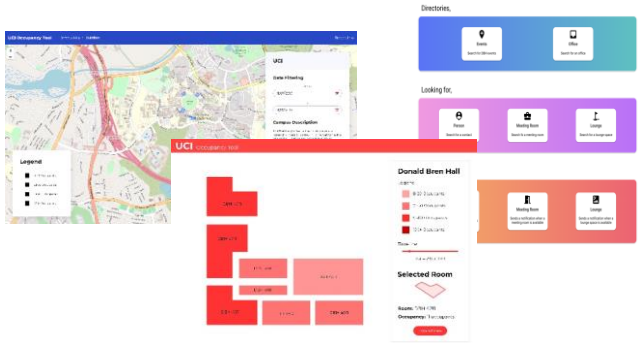
SEMANTIC GAP



Device's world

- variety of devices to reply to a request
- Apps constrained to specific devices/protocols
- Difficult to port apps to other IoT spaces

SemIoTic: End-to-End IoT Framework



App request:

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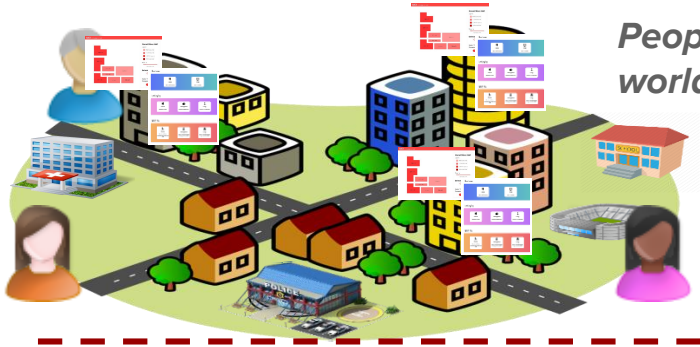
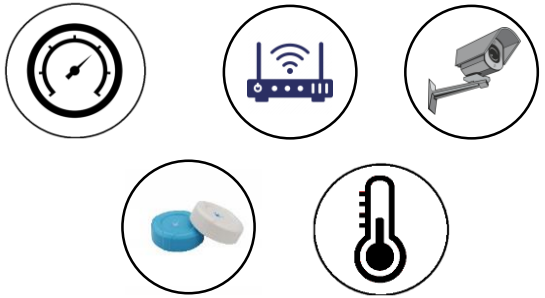
SemIoTic



People's world

SEMANTIC GAP

Device's world

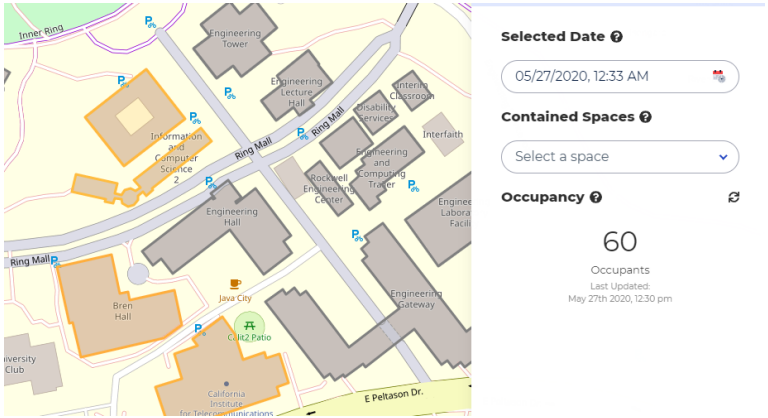


Real deployment at UC Irvine

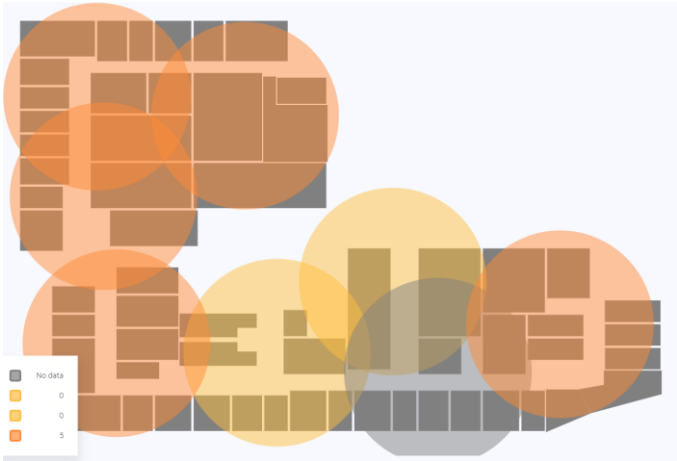
- SemloTic is being developed as part of the DARPA TIPPERS project
- TIPPERS has been deployed in UC Irvine using WiFi data of 24 buildings provided in real time

https://hub-tippers.ics.uci.edu

UC Irvine Occupancy tool



Donald Bren Hall -- Floor 2



UCI deployment - COVID-19 monitoring application

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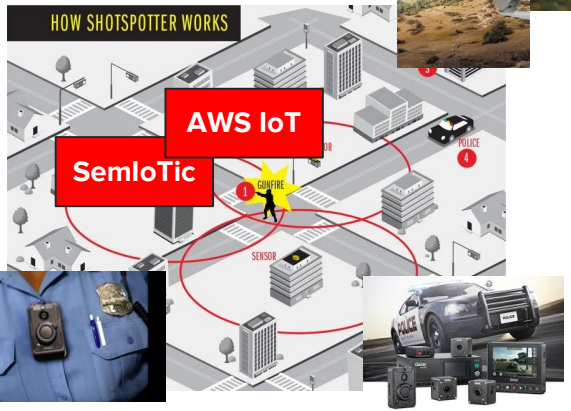
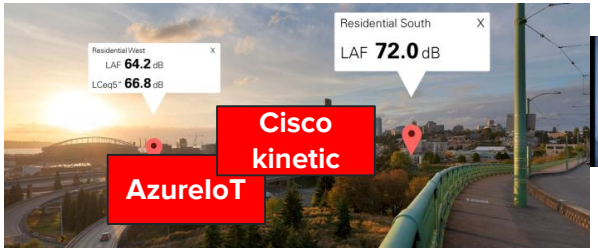
Future research

Platforms deployed in IoT ecosystems

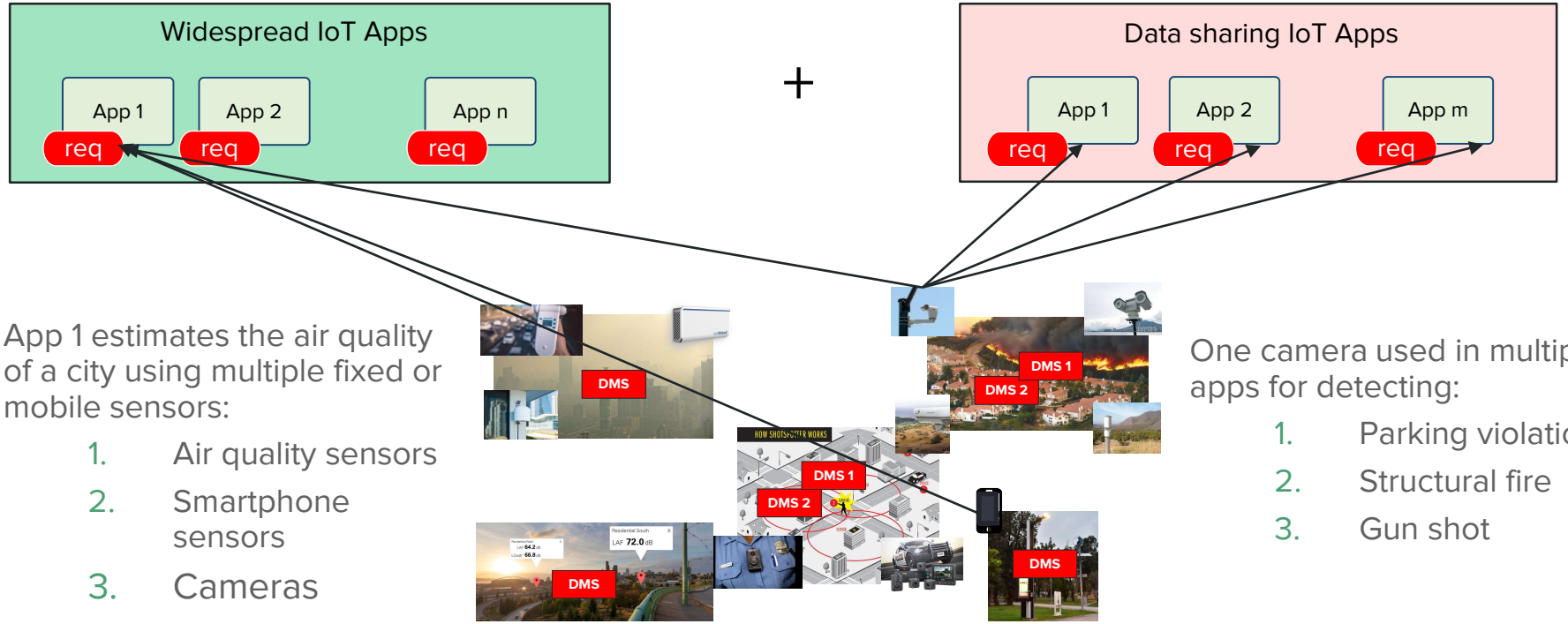




New generation of IoT Apps

Managers wish to leverage IoT sources to develop intelligent, multi-purpose applications:

- Apps using data from multiple IoT sources are deployed in spaces, owned by different people / organizations



App 1 estimates the air quality of a city using multiple fixed or mobile sensors:

1. Air quality sensors
2. Smartphone sensors
3. Cameras

One camera used in multiple apps for detecting:

1. Parking violation
2. Structural fire
3. Gun shot

Designing the next generation IoT systems

1. Designing IoT systems for widespread, data sharing Apps
2. Planning for IoT infrastructure placement
3. Enabling extensible and dependable IoT systems

Designing systems for widespread, data sharing Apps

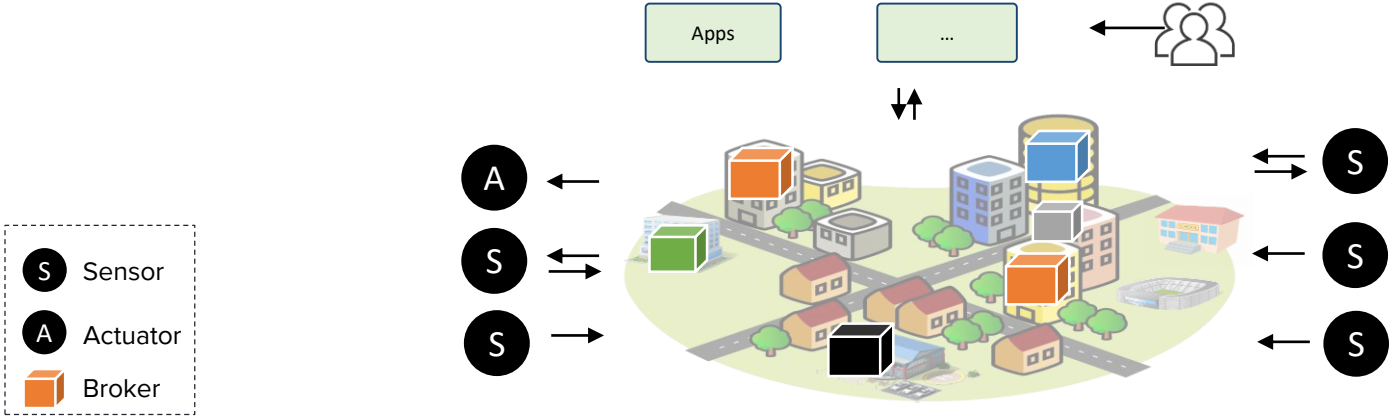
IoT systems must be designed to:

- Handle same data flows for multiple apps based on the app requirements (e.g., QoS, accuracy, etc.) and networking constraints (e.g., access network, bandwidth)
- In different circumstances, sensor data must be dynamically separated in different data flows -- e.g., emergency evacuation plans and surveil city occupants
- Preserve privacy based on device, data & space permissions

We must design advanced system architectures supporting widespread, data sharing IoT apps

Distributed data management systems

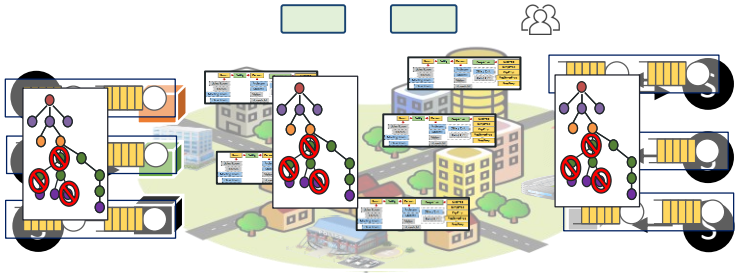
- Leverage distributed pub/sub brokers as the data exchange infrastructure across a large area (e.g., city of Paris)
- Design complex workflows driven by raw and semantically-enriched data
  - exchanged between sensors, actuators, message brokers and processing nodes
- Enable management of privacy polices for personal IoT data captured from fixed or mobile IoT devices in smart spaces



Real-time execution of actions in IoT-enabled spaces

Actions are requests, actuation commands and privacy policies

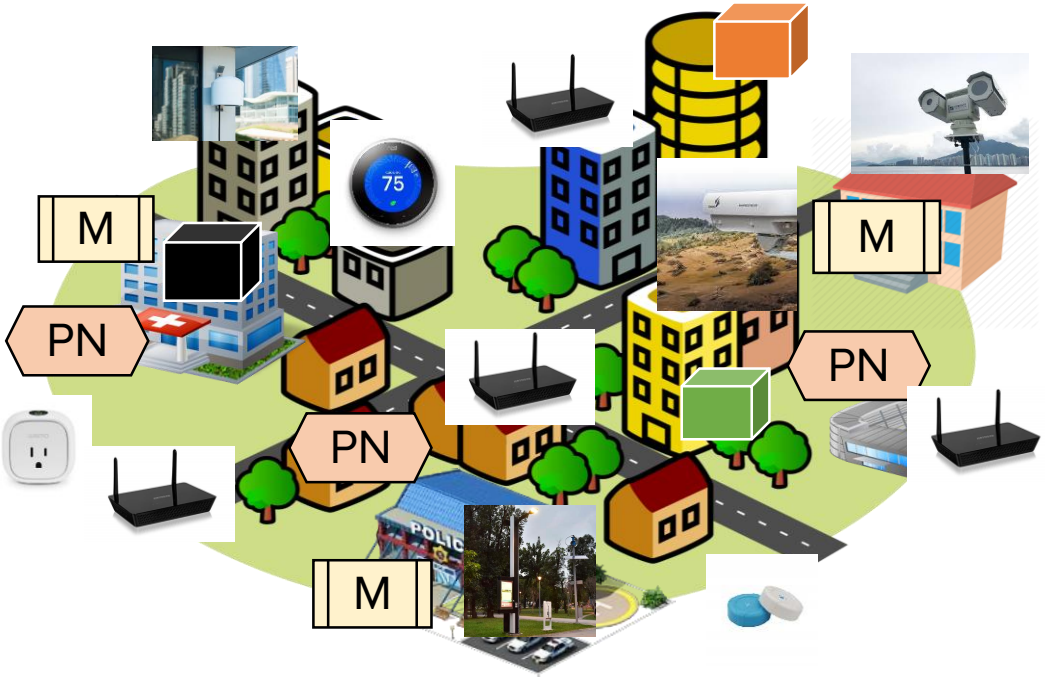
- Domain models to represent spaces, people (with static or dynamic properties) and devices
  - New sources of data to can be analyzed, processed and utilized to identify further research challenges
- Generic APIs and languages that support action execution/scheduling over distributed applications (e.g., health care, **smart energy**, **occupant comfort**, etc) deployed in IoT-enabled spaces
- QoS modeling of different data flows (e.g., **critical**) based on:
  app-requirements, devices characteristics and Edge network constraints
- Novel algorithms for action execution/scheduling by considering:
  sensor permissions and app/space-requirements



Designing the next generation IoT systems

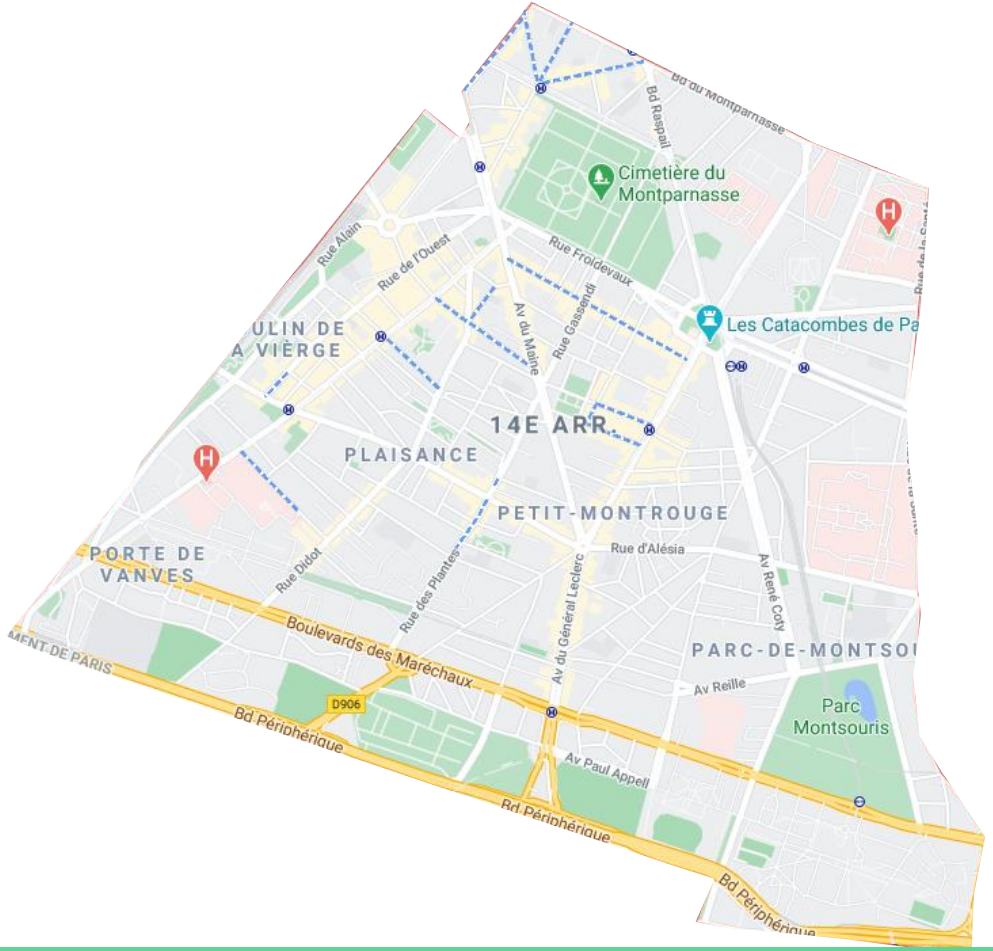
1. Designing IoT systems for widespread, data sharing Apps
2. **Planning for IoT infrastructure placement**
3. Enabling extensible and dependable IoT systems

IoT deployments for smart spaces

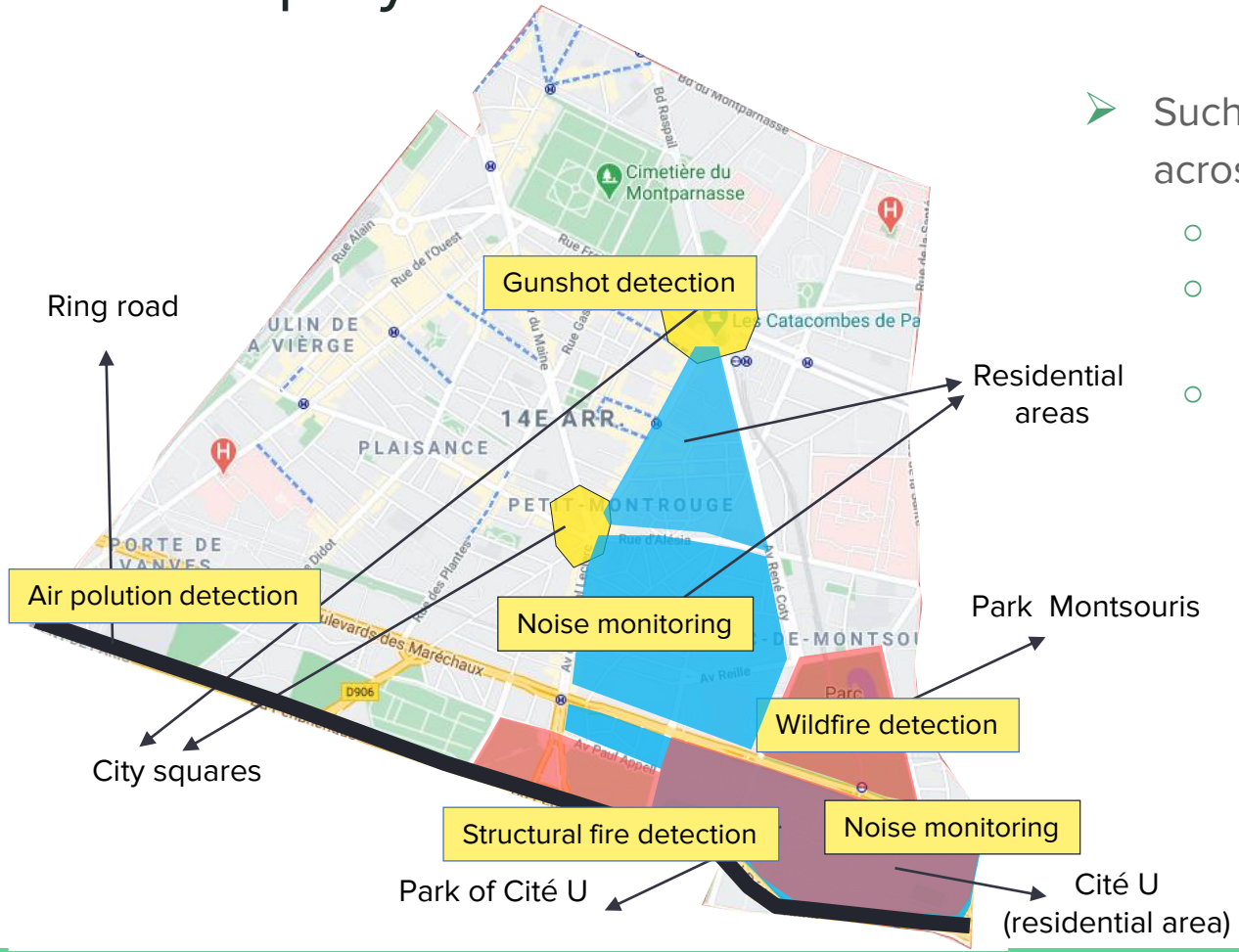


- A manual, “by-experience” process that is error-prone and time-consuming
- Investigate automated approaches for infrastructure placement

IoT deployments in 14th arr. of Paris

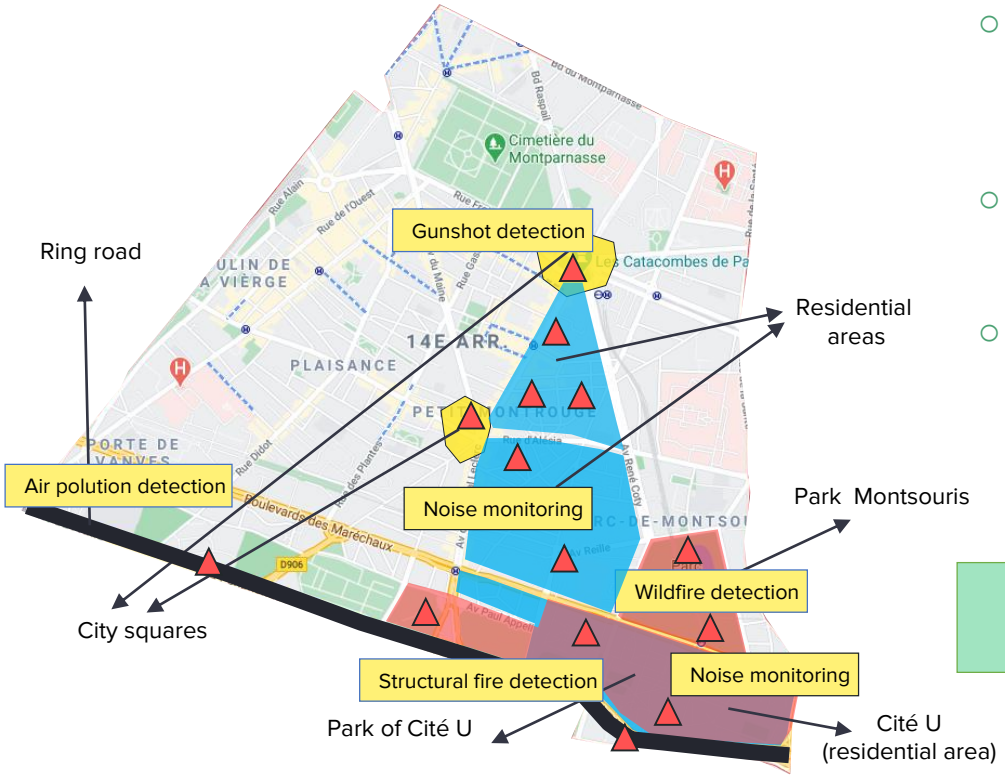


IoT deployments in 14th arr. of Paris



- Such applications include devices across multiple layers:
  - **device-layer**: sensors and actuators
  - **middleware-layer**: processing nodes, mediators, message brokers
  - **network layer**: access networks & access points (APs)

IoT deployments in 14th arr. of Paris



- Study a two-fold coverage problem:
  - the operation coverage problem using:
    - sensor capabilities (e.g., the ability to cover multiple applications), sensor location and communication/computation capabilities
  - the network coverage problem using:
    - location of APs and the characteristics of access networks (e.g., range, bandwidth)
  - Constraints:
    - Budget constraints (deployment and operation)
    - Resource constraints (network and computing)
    - QoS requirements (bandwidth)

Objective: **maximize** the **service coverage** of required applications of communities

Designing the next generation IoT systems

1. Designing IoT systems for widespread, data sharing Apps
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3. **Enabling extensible and dependable IoT systems**

Dependable and Extensible IoT systems

- Extensible IoT systems:
  - have the ability to function in dynamically changing environments consisting of evolving heterogeneous devices, networks, platforms, protocols, and applications
- Dependable IoT systems:
  - guarantee QoS under different types of failures or changing needs of end-applications while ensuring timely capture, delivery, and processing of information
- Extensible vs. Dependable IoT systems
  - Extensibility at the cost of additional overhead
  - Dependability at the cost of interoperable systems

Cross-layer modeling and analysis

- Design QoS models that include application, middleware and networking components by considering:
  - Different resource types, including computation, networking, and storage
  - Heterogeneous communication channels, including networks and protocols
  - Different action execution topologies (e.g., centralized, distributed)
- Leverage models for resilience techniques that manage QoS requirements for reliably executing the sensing, communication and computation processes

Concluding remarks

- Collaboration with the industry and local authorities for real deployments:
  - Télécom Paris, Télécom SudParis, EDF R&D, more
  - City of Paris, Safety and protection organizations
- National, EU and International collaborations:
  - INRIA, ICS FORTH, USC, UC Irvine
  - Keeping in touch with industrial and academic top groups related to the school's research

Thank you

Questions?

https://gbouloukakis.com