Emerging Trends in IoT Testbeds

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IoT Lab
Crowdsource The Future

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IoT Testbeds: Novel aspects and challenges

IoT Lab
Crowdsource The Future

a. Federation of constrained IoT devices

b. Crowdsourced resources (smartphone sensors)

c. User incentivization

d. Mobile and portable testbeds

e. Virtual and modelled testbeds

f. Experiment composition (generic yet specific)

g. Wireless power transfer algorithms

a. Federation of constrained IoT devices

Testbed as a Service – TBaaS

- Making diverse testbeds **accessible in a uniform and transparent way** by using **cloud** technologies
- Testbeds integrated into a **“meta-testbed facility”**
- **Ad-hoc nature and big expected volume** of collected data

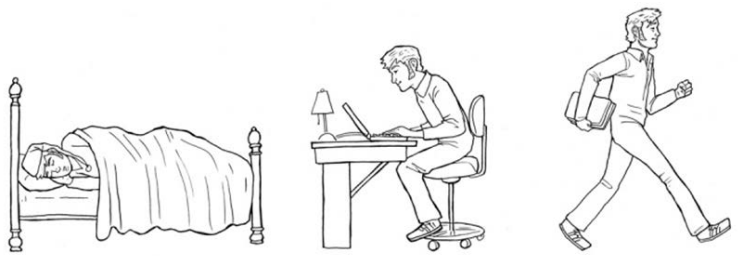
Different to other approaches**, the main focus lies on federating heterogeneous, constrained IoT devices**

- Virtualization of a wide and **heterogeneous set of resources** (IoT, smartphones, virtual, vehicles, etc.)
- **Extended representation scheme**, to support more resources with more attributes

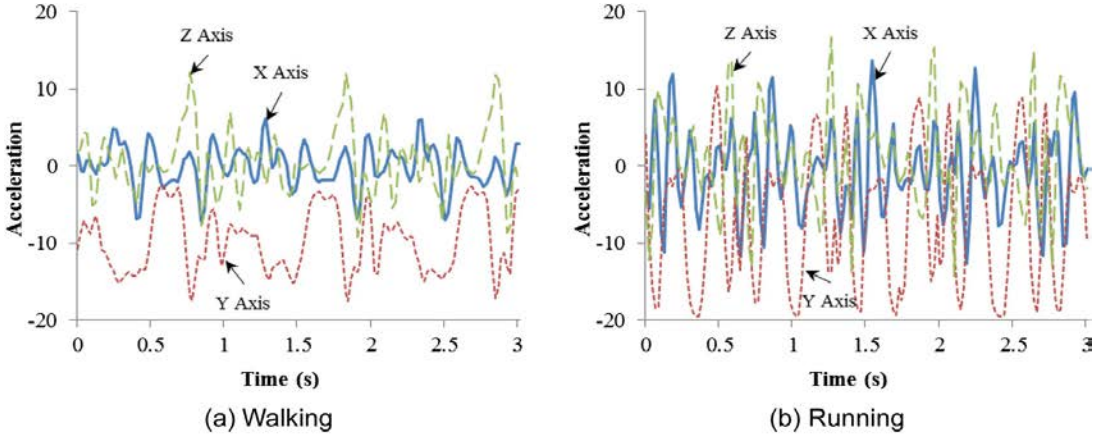
b. Crowdsourced resources

- **Ubiquitous presence of smart devices** - capability of being always connected from everywhere
- **Ephemeral nature** of crowdsourced resources

- **Personalization** – device correlated to corresponding user
- **Privacy** oriented design
- Focus on **crowdsensing**/exploiting device sensory capabilities
- **Mobile sensing and feature extraction** of the user's state using **machine learning**



User state / Temperature



Accelerometer readings (walking / running)

b. Crowdsourced resources

How Many Sensors are in a Smartphone?

- Light
- Proximity
- 2 cameras
- 3 microphones (ultrasound)
- Touch
- Position
  - GPS
  - WiFi (fingerprint)
  - Cellular (tri-lateration)
  - NFC, Bluetooth (beacons)
- Accelerometer
- Magnetometer
- Gyroscope
- Pressure
- Temperature
- Humidity

c. Incentive mechanism design

- Necessary for **effective user engagement** in the experiments
- **Persuade users** to complete task segments
- Particularly useful in large scale applications (e.g. **airport scenario**)

- Each user is an autonomous agent with **different join patterns**
- **Different incentives** for different applications (utility functions)
- **Direct** (monetary, prizes) / **indirect** (bandwidth allocation, road traffic info, donations to charities) awards
- **Game-theoretic** approaches apply

d. Mobile/portable resources

- **Portable** resources/testbeds
  - **Easily deployable** in any environment at different geographical locations - **Flexible** configuration
  - All devices and interfaces are set through **“one step” procedures** - **“Plug&Play”** character with minimum user effort
  - **Automatic device discovery** and **resource advertising** in databases, which can be seen and accessed globally
  - Resources can be **manipulated** and **reserved remotely**, gaining access to previously **non reachable locations or services**
  - That gives a great advantage to a user, with no previous experience, who can receive the resources and **set up a testbed** in their own settlement
  - A testbed provider can **spatially augment** an existing facility

- **Mobile** resources
  - **Smartphones**
  - **Mobile** sensor motes
  - **Vehicles** (e.g. ekoNET buses in Novi Sad, Serbia)

e. Virtual and modelled testbeds

Regular extension of testbed facilities infers costs in budget/effort

- New, customized testbeds including **both physical and virtual resources**
- Such facilities are **not simulators**

Two methods for extending IoT testbed facilities

- ***Virtual Testbeds:*** increasing the number and types of available resources seamlessly
  - Virtual resources are **interlaced with physical** resources
- ***Modelled Testbeds:*** using 3D models to visualize facilities and enable custom testbeds and testbed libraries definition.
  - **Visual model** of the actual facility

f. Experiment composition (simple but expressive)

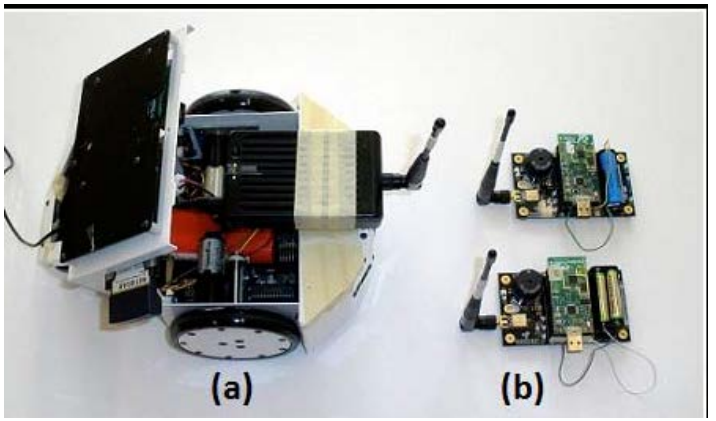
Efficient description of diverse experiments in a generic yet specific way:

- **Automated procedure** for the execution of experiments
- **Specific mechanism, yet generic** – wide experiments variety supported
- Enables reservation/provisioning/construction of '**If-This-Then-That**' experiments.
- **Complexity/Specialization** via **compositions** of simple conditional/logical expressions.

g. Wireless power transfer algorithms

A new paradigm: Chargers **wirelessly transferring energy** to nodes

Algorithmic issues
- Optimal charger **movement trajectories**
- Good **energy exchange strategies**
- Electromagnetic **radiation** control
- Inter-charger **coordination**
- **Peer-to-peer** energy exchange



New Book:
Wireless Power Transfer Algorithms and Applications in Ad hoc Communication Networks
Springer, July 2016

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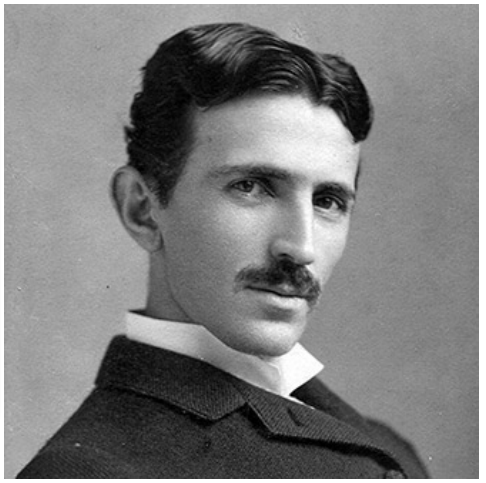


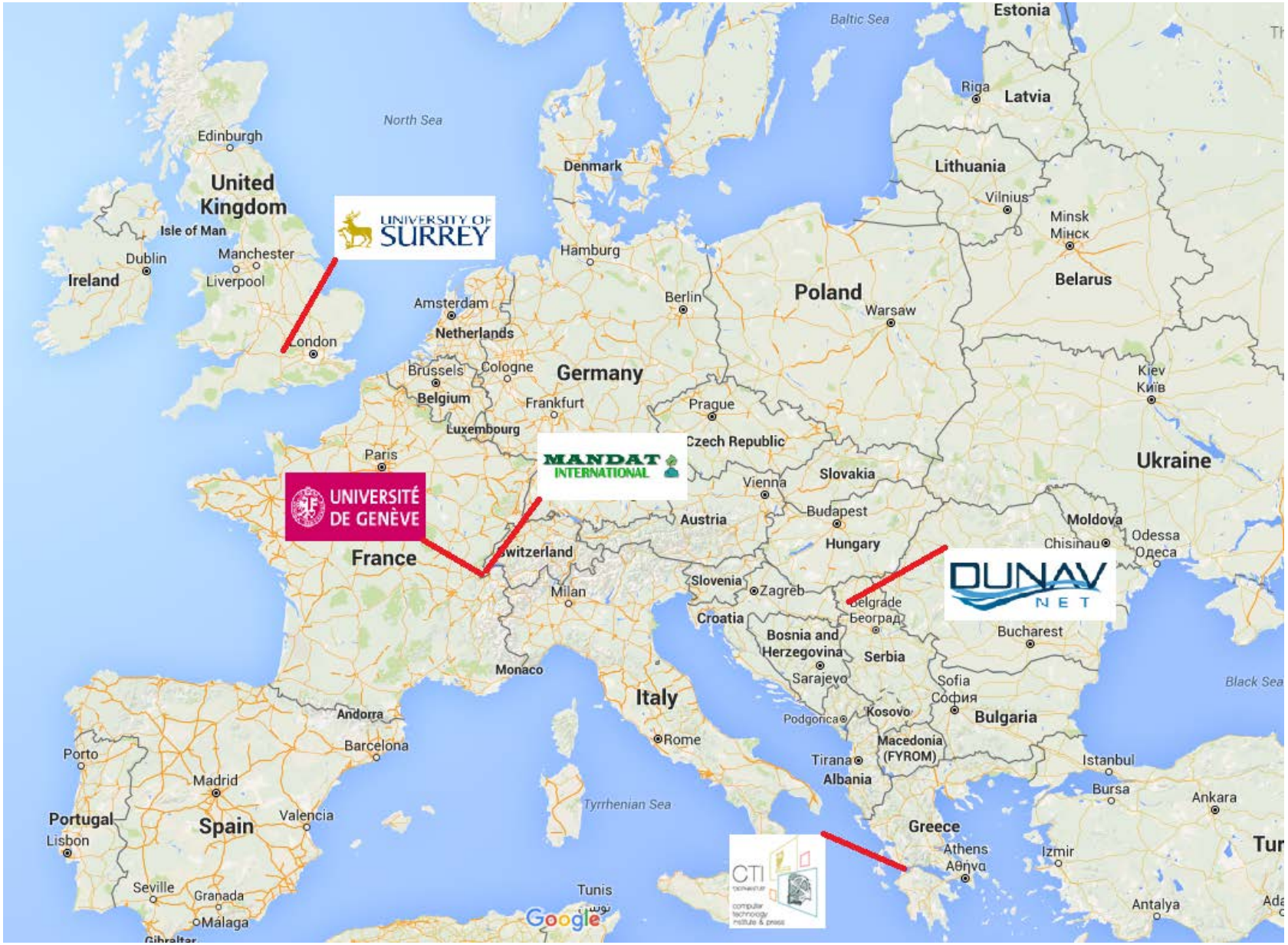
The IoT Lab project

- IoT Lab is a European Research project which aims at researching the potential of **crowdsourcing** to **extend IoT testbed infrastructure** for **multidisciplinary experiments** with more **end-user interactions**.

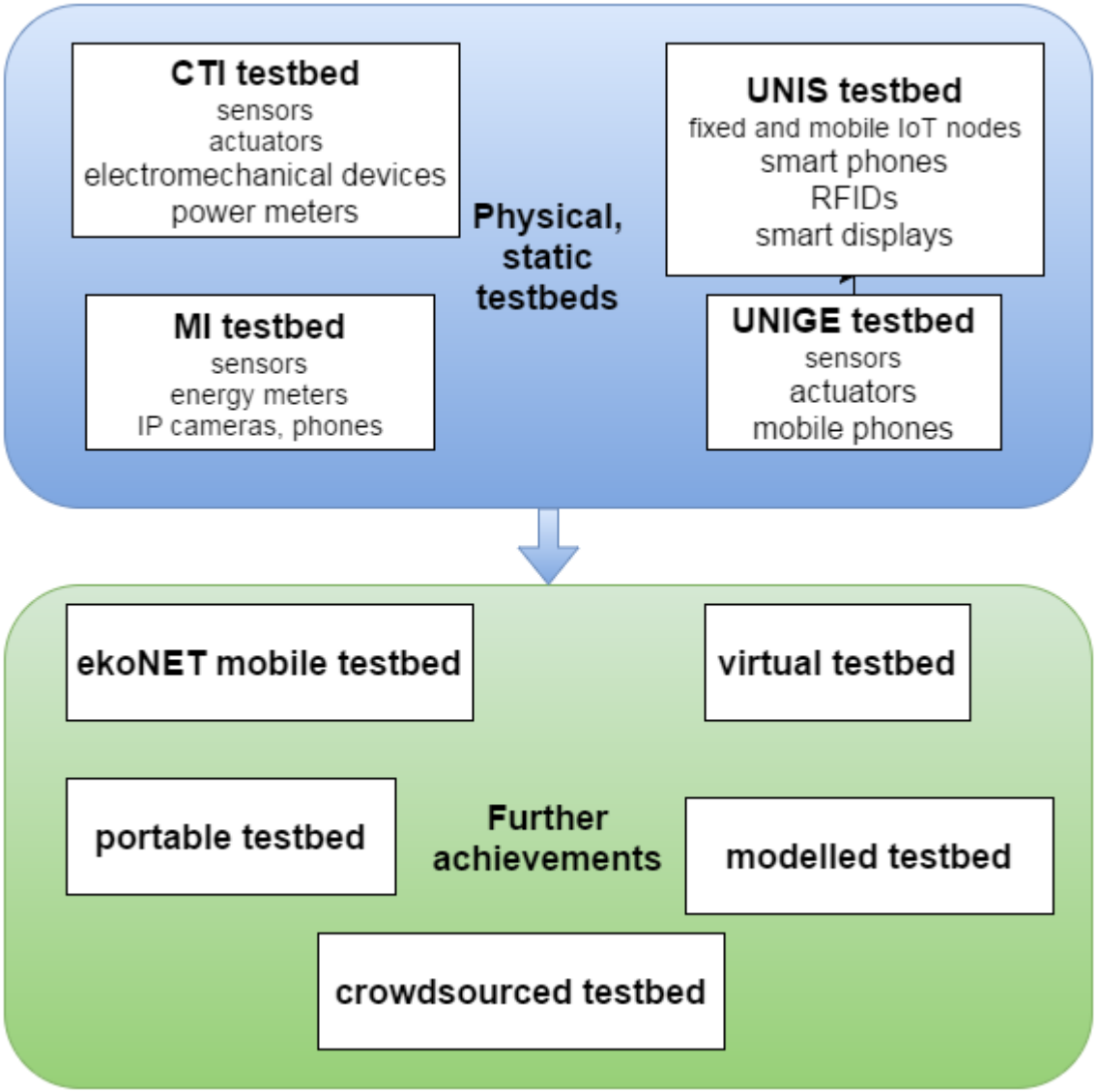
It addresses topics such as:

- **Crowdsourcing** mechanisms and tools
- Crowdsourcing-driven research
- **Virtualization** of crowdsourcing and testbeds
- Ubiquitous Interconnection - **Cloudification** of testbeds
- **Testbed as a Service** platform
- **Multidisciplinary** experiments
- **End-user and societal** value creation

Federation of testbed facilities



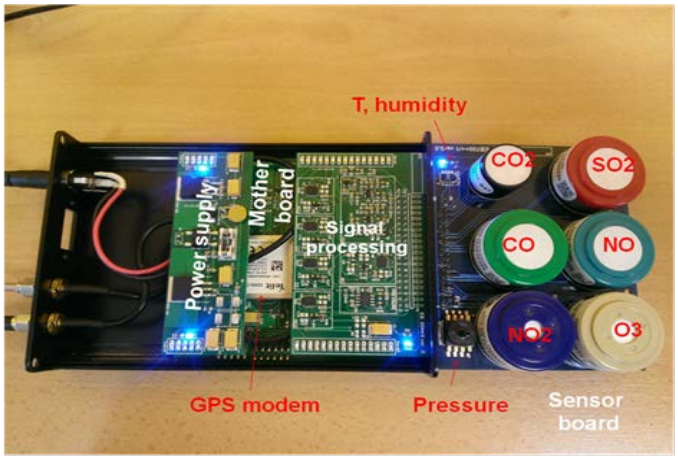
IoT Lab testbeds evolution

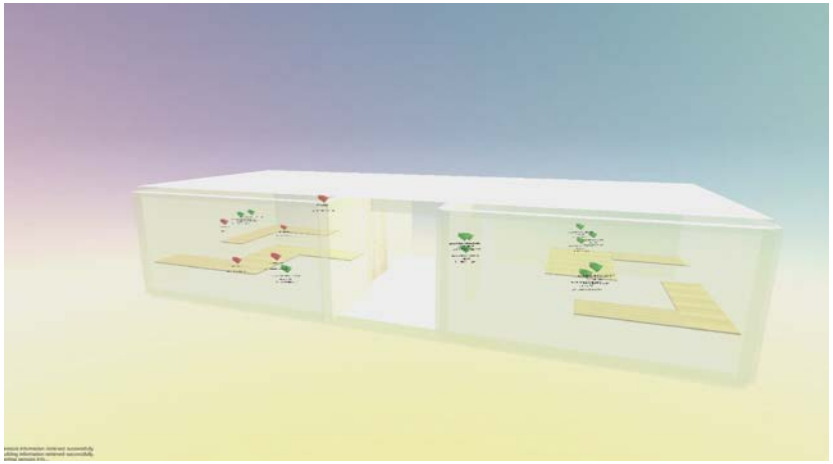


Mobile and virtual resources

Mobile Resources - ekoNET

- Mobile **environment monitoring** solution
- ekoNET devices are placed on **public buses** in the city of Novi Sad, Serbia
- Network of **moving resources** with multiple sensors.
- **Easily deployable** in any environment at different geographical locations.

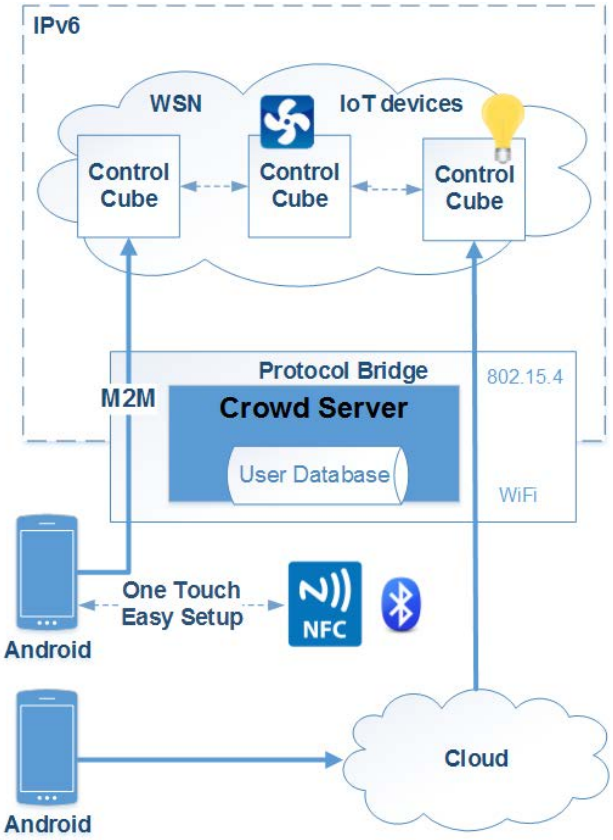




Virtual testbeds and resources

- **Extend the number of available resources** seamlessly to the end-user of the facility
- Virtual resources belong to the same testbed provider and are **interlaced with physical resources** and **extrapolate ambient readings** by them
- Virtual resources run on software and are virtualized via the same IoT Lab **virtualization interfaces**
- An experimenter can **discover, provision and use** in experiments **both virtual and physical resources** via the same IoT Lab tools and systems

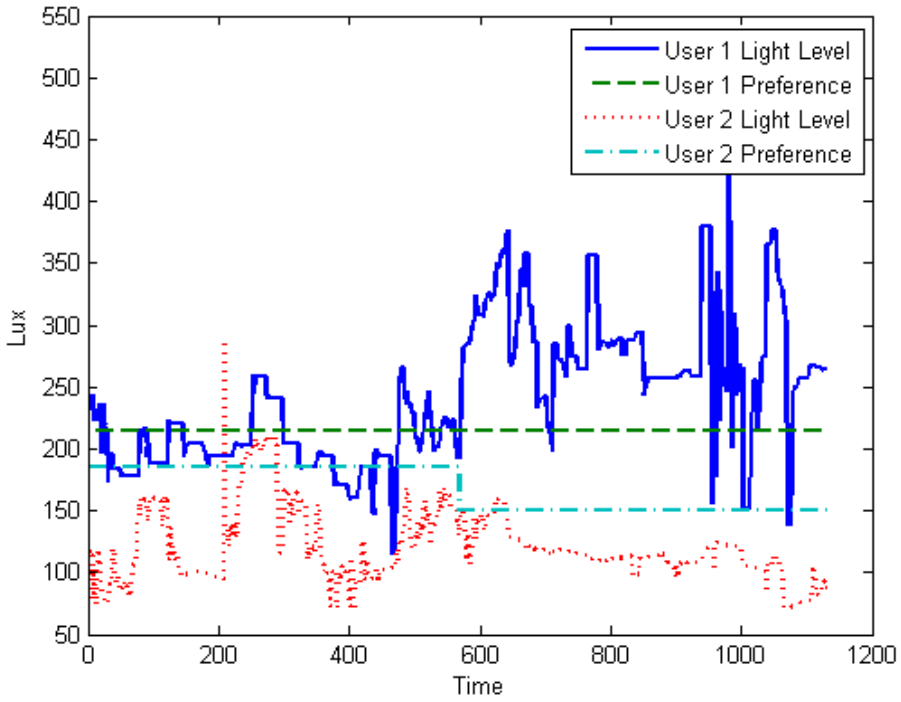
Crowdsensing support: a UoP campus use case



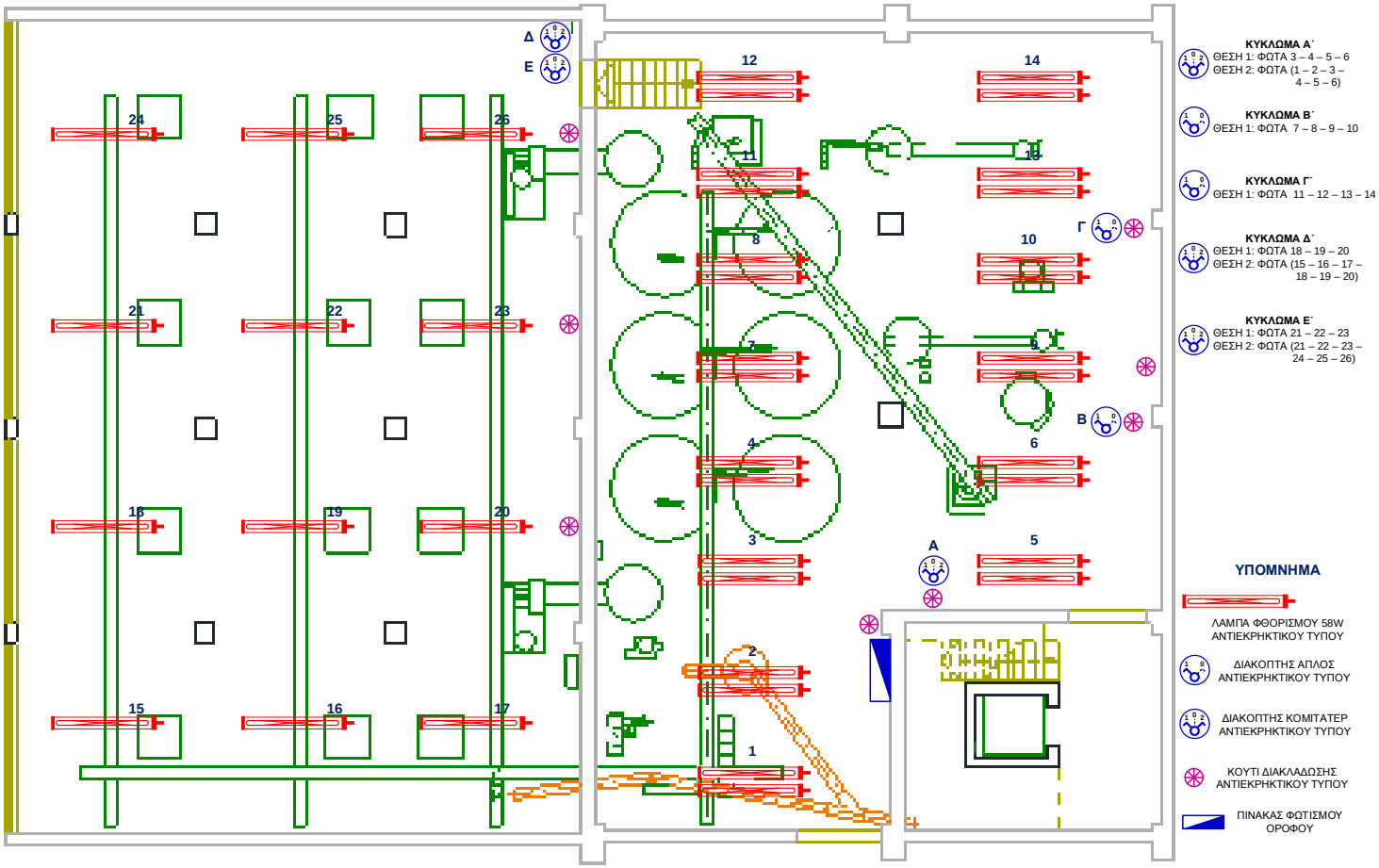
- **User-enabled Architecture** with Mobile Crowdsensing Support for Smart Buildings
- Seamless and scalable **interaction with crowd-enabled resources**
- **Agile experimenting platform**

- **Smart luminance scenario** - users are incentivized to provide access to their hand-held devices from which data on the ambient environmental conditions are collected and aggregated into live luminance maps

- Indoor lighting units are adjusted based on
  - **luminance maps**
  - **feedback provided by the users** to the system on their **personal preferences** and **comfort**



An IoT Lab use case in Heineken brewery



- **Smart energy management –** lights control via sensors, actuators, powermeters
- **CO2 monitoring** – sensors, alerts, notifications
- **Mobility/portability** support
- Federation with the **IoT Lab platform**
- Virtual sensors for **extrapolation of physical readings**

Thank you!