

The IoT and Cyber-Physical integration in making of Campus Connect

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Abstract:

The Internet of Things (IoT) has the potential to significantly change the lives of many people in addition to improving business operations. The Internet of Things may be a useful tool for tracking human behavior over time and understanding behavioral trends that may yield more data for the development of Internet of Things technology. Nowadays the majority of Internet of Things technology experiments are carried out on testbeds located in labs also known as simulators. In general, a more realistic environment for the testing process is becoming much more necessary. The participation of real end users in the experimental lifecycle is a prerequisite for this desire. This study introduces *CampusConnect*, a user-centric experimental research facility built for Internet of Things technologies. The current testbed deployment is mostly focused on smart buildings, which are an essential part of future cities. CampusConnect is distinctive in that it serves as a programmable experimentation substrate by fully integrating heterogeneous Internet of Things (IoT) devices in an actual office scenario. In contrast to current laboratory-based testbeds, this enables flexible experimentation with real end users.

INTRODUCTION

From the Last few years the cities around the world have been trying to become smart or intelligent by integrating various IoT devices and a big reason behind this shift is the rise of Internet of Things (IoT) technologies. Many difficulties are solved by IoT, making cities smarter. IoT bridges the physical and digital worlds by providing computers and other instruments greater information and control over real-world processes. This will let individuals comprehend complex urban surroundings and make choices on their own, which improves urban service management. Living and working buildings offer areas for people to accomplish activities in smart cities. IoT technology optimizes water, gas, and electricity usage in buildings, improving quality of life and greening communities. Flexible IoT products and services must be tested and developed properly before being marketed. A recent assessment discovered issues with IoT testbed facilities and desired functionality [1]. The SmartCampus testbed creates lab IoT testbeds using reality, devices, and user engagement. Simulating the ultimate solution enables more accurate testing and early design problem detection, reducing roll-out costs and development time. The numerous forms of IoT allow trying new ideas and early use simpler. Use end-user testing to evaluate IoT goods. IoT solutions offer advantages, but their intrusiveness may deter users. Cheap IoT solutions that rely on human behavior and can't make choices will fail. Looking at popular IoT devices may help us understand human behavior. Now testbeds may be residences

with many devices, not only laboratories. Communication is examined on testbeds. Specialized energy-tracking applications limit flexibility and user engagement. This research displays SmartCampus, a European user-focused IoT testbed at SmartSantander. SmartCampus in a full-fledged workplace avoids lab-based testbed issues while maintaining control and configuration choices. The tiny lets researchers study smart building utilization and IoT system performance. More complex testing tools demonstrate improvement. Previous assessments of the testbed indicate its potential for IoT research in several sectors. The Process of creating IoT systems that actually work in the real world is harder than it sounds. Before these solutions can be used widely, we need proper spaces to test them out. Most simulation models feel like real-life environments, and that causes problems later when the technology meets actual users. Earlier studies have pointed out that many testing setups lack realism, have limited types of devices, or do not involve everyday users at all—which is strange because people’s behavior heavily affects how these systems work. A few simulation models have expanded into whole buildings, which is a good start, but most of them still focus on narrow goals like communication testing or energy monitoring. This makes them difficult to adapt or reuse for broader IoT research. To address these gaps, we developed CampusConnect, a user-focused IoT testbed inside a functioning office building. It is part of the European project. The idea is to offer a realistic place where researchers can try out new IoT ideas, study how people interact with them, and find out the issues that can only appear in real-life settings.

THE CAMPUSCONNECT FACILITY

Design Considerations

This section is about how we built our device using the ideas that we discussed. Our goal was to create an experimental facility where user centric IoT studies could be carried out in a real environment and not only in a controlled lab. We wanted a place where different types of IoT devices could be tested together and where real users could give natural feedback during their daily routine. The long-term aim is to cover indoor and outdoor areas across the whole university campus but we first started with a smart building setup called *CampusConnect*. This initial deployment helped us learn what works and what needs improvement. Work on outdoor extensions is still ongoing [13] and more deployments are planned after learning from the European Project outdoor trials. Another important requirement for any IoT project is flexibility. IoT experiments can vary a lot so the testbed had to support quick changes. Hence, we created a kind of “living lab” inside our research centre where staff members automatically become part of the experiments during everyday work. Each room was equipped with a variety of heterogeneous IoT devices sensors to support various studies, communication modules, and so on several other devices like mobile nodes were added that users can carry around, along with interactive displays to support user interaction when needed.

ARCHITECTURE OVERVIEW

1. **Server tier:** hosts all back–end systems and provides access for experimenters.
2. **Gateway (GW) tier:** the backbone layer inside the building.
3. **IoT tier:** includes all sensor nodes, smartphones, and smart displays.

IoT nodes can connect through wireless methods (IEEE 802.15.4, WiFi, Bluetooth) or through

wired USB links to the gateways for configuration and debugging. Smartphones and smart displays only use wireless connectivity, either through gateways or directly to the main network.

The architecture works across two planes:

- **Data plane** (cyan): carries real IoT data such as sensor readings, user interactions, and communication between devices.
- **Control & management plane** (red): handles experiment configuration, firmware updates, debugging information, and log collection.

Since these planes are separate, experiments can run without being disturbed by management operations, which helps a lot during development.

HARDWARE COMPONENTS

1.1 IoT Nodes

It shows a combined architecture with an energy meter to monitor appliance usage. A custom sensor board adds measurements for light, noise, temperature, motion (PIR), vibration, and an LED indicator. Around 200 such nodes were installed across the CampusConnect building.

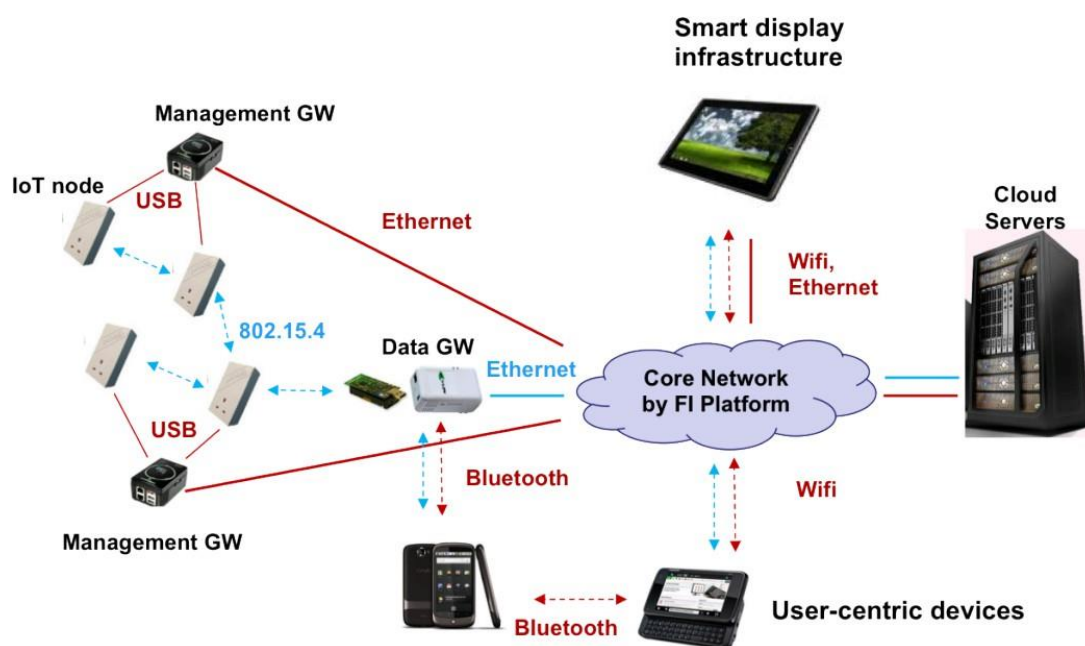


Figure 1: The network architecture of the testbed. The design consists of three main tiers

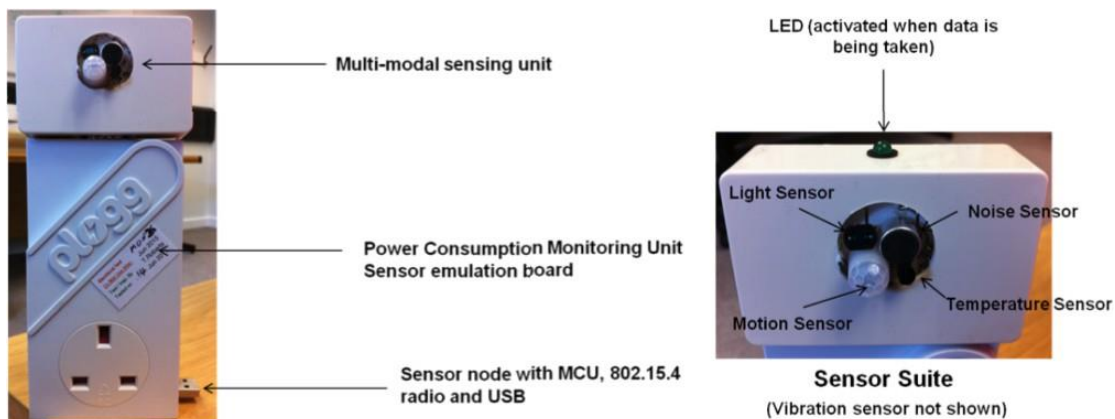


Figure 2: the IoT node design. Each node uses a TelosB mote

1.2 Embedded Gateways

To connect IoT nodes to the system, we deployed 100 embedded Linux gateways (Guru Plug units) with a 1.2 GHz processor, 512 MB RAM, Ethernet, WiFi, Bluetooth, and USB. Depending on the room, the IoT node to gateway ratio varies between 1:1 and 1:4.

For outdoor testing, we later developed a cheaper and energy-efficient observer device named *Smart-Eye*, used for monitoring outdoor IoT deployments.

1.3 Smartphones

Smartphones serve both as user-centric sensing devices and as interaction tools. The testbed includes 30 Android phones (Sony Xperia S and HTC One S) that connect via WiFi, Bluetooth, or 3G. These are distributed to staff and students during experiments.

1.4 Smart Displays

Ten Android-based smart displays (Samsung Galaxy 10.1 tablets) are installed at key building locations—corridors, entrances, meeting rooms. They support experiments such as indoor guidance, emergency evacuation, and other user-centric scenarios.

1.5 Servers

The server layer consists of 10 high-end servers (12-core Xeon processors, 24 GB RAM each) with 8 TB storage running a VMware cloud platform, used for data management and testbed control.

SOFTWARE COMPONENTS

The software architecture (shown in Figure 3) builds on top of the SmartSantander framework [10] and WISEBED APIs [11]. These enable node reservation, reprogramming, and out-of-band data collection. Additional features were added to simplify the entire experiment workflow.

Experimenters interact with the system using a Java-based interface named *TMON*, which helps in configuring resources, selecting devices, executing experiments, and analysing results. Since the testbed includes many heterogeneous devices, selecting the right ones can be challenging. To support this, two major tools are provided:

- **Resource Explorer:** browses available devices and their capabilities.
- **Topology Explorer:** visualizes connectivity relationships and interference levels.

Static capabilities are stored in a semantic RDF database, while dynamic conditions such as interference and link quality are stored in a separate frequently updated database.

Experiments are executed using a reservation system and scheduler. During execution, results are collected in a MySQL database and provided through REST APIs for analysis. TMON allows both live monitoring and post-experiment inspection.

DEPLOYMENT

Across the three floors of the building at the University, we installed 200 IoT nodes and 100 gateways. While IoT nodes primarily use wireless communication, they also maintain USB connections to gateways for management. Smart displays (not shown in the figure) are placed at corridor intersections, entrances, staircases, and meeting room doors.

CONCLUSION

This paper introduced *CampusConnect*, a testbed created mainly for user-centric IoT experimentation. The idea behind CampusConnect is to move experimentation closer to real life instead of keeping everything inside a controlled laboratory space. Since the system is deployed inside an actual office environment, researchers are able to observe how people and devices interact in a natural and everyday setting.

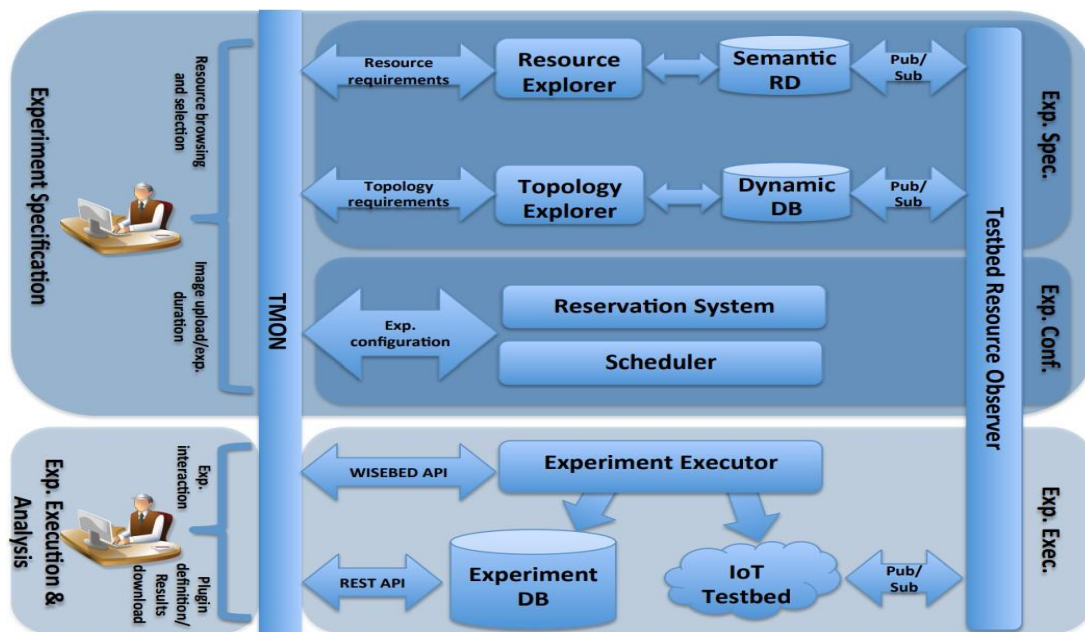


Figure 3: Different components of Software used in project

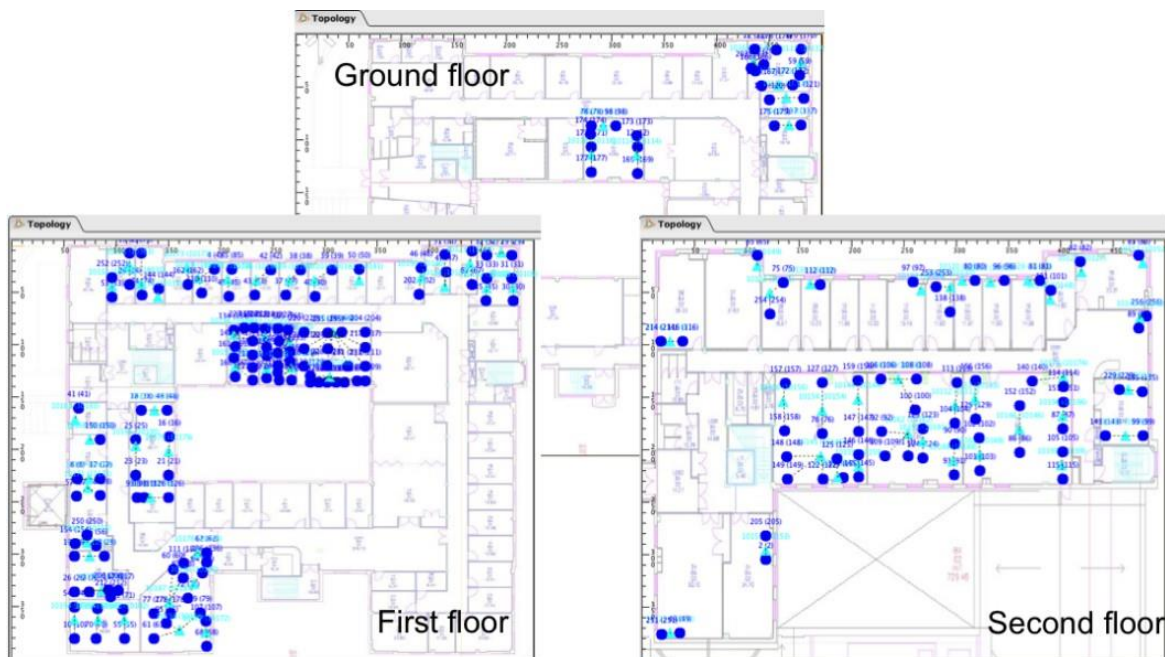


Figure 4: CampusConnect Nodes and Deployment

At the same time, CampusConnect still provides the convenience and flexibility normally associated with lab-based testbeds. Experimenters can easily reconfigure devices, run different types of tests, and collect data without too much difficulty. This combination of realistic conditions and controlled experimentation makes CampusConnect a practical and meaningful platform for studying various IoT solutions.

REFERENCES:

1. A. Gluhak, S. Krco, M. Nati, D. Pfisterer, N. Mitton, and T. Razafindralambo, "A survey on facilities for experimental Internet of Things research," *IEEE Communications Magazine*, vol. 49, no. 11, November 2011.
2. G. Werner-Allen, P. Swieskowski, and M. Welsh, "Motelab: A wireless sensor network testbed," in *Proceedings of the 4th International Symposium on Information Processing in Sensor Networks (IPSN'05)*, 2005.
3. V. Handziski, A. Kopke, A. Willig, and A. Wolisz, "Twist: A scalable and reconfigurable testbed for wireless indoor experiments with sensor networks," in *Proceedings of the 2nd International Workshop on Multi-hop Ad Hoc Networks: from Theory to Reality (REALMAN'06)*, pp. 63–70, 2006.
4. I. Chatzigiannakis, S. Fischer, C. Koninis, G. Mylonas, and D. Pfisterer, "WISEBED: An open large-scale wireless sensor network testbed," *Sensor Applications, Experimentation, and Logistics, LNCS*, Springer, vol. 29, pp. 68–87, 2010.
5. S. Dawson-Haggerty, J. Ortiz, X. Jiang, J. Hsu, S. Shankar, and D. Culler, "Enabling Green Building Applications," in *Proceedings of the 6th Workshop on Hot Topics in Embedded Networked Sensors (HotEmNets'10)*, 2010.
6. K. Marios, C. Konstantinos, N. Sotiris, and R. Jose, "Passive target tracking: Application with mobile devices using an indoors WSN Future Internet testbed," in *Proceedings of the*

- International Conference on Distributed Computing in Sensor Systems (DCOSS'11), vol. 6, pp. 27–29, 2011.
7. R. Pozza, A. Gluhak, and M. Nati, “SmartEye: An energy-efficient observer platform for Internet of Things testbeds,” in Proceedings of the 7th ACM International Workshop on Wireless Network Testbeds, Experimental Evaluation and Characterization (WiNTECH'12), pp. 59–66, 2012.
 8. Memsic Inc., “Wireless Sensor Networks: TPR2420,” Available: <http://www.memsic.com/wireless-sensor-networks/TPR2420>.
 9. M. Nati, A. Gluhak, H. Abangar, S. Meissner, and R. Tafazolli, “A Framework for Resource Selection in Internet of Things Testbeds,” in Proceedings of the 8th International Conference on Testbeds and Research Infrastructures for the Development of Networks & Communities (TRIDENTCOM'12), vol. 44, pp. 224–239, 2012.
 10. SmartSantander Project, Available: <http://www.smartsantander.eu/>.
 11. EU FP7 ICT WISEBED Project, Available: <http://www.wisebed.eu/>.
 12. TMON Live Monitor, Available: <https://www.dropbox.com/s/2a371fhgiqqwg50/ALBAR-exp.mov>.
 13. R. Pozza, A. Gluhak, and M. Nati, “SmartEye: An energy-efficient observer platform for Internet of Things testbeds,” in Proceedings of the 7th ACM International Workshop on Wireless Network Testbeds, Experimental Evaluation and Characterization (WiNTECH'12), pp. 59–66, 2012.
 14. A. Zoha, A. Gluhak, M. Nati, and M. A. Imran, “Low-Power Appliance Monitoring Using Factorial Hidden Markov Model,” in Proceedings of the IEEE International Conference on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP'13), 2013.