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ISCTE-IUL an Campus of Things-an IoT Approach Towards a Smart Campus

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Abstract— *In this research paper we describe our approach towards a smart campus based on a network of proper sensors, with data transmitted to a cloud server and then analyzed for knowledge extraction. Our approach uses academic work with external solutions to monitor energy and water consumption, control lights and temperature based on the number of persons. Also can be applied to control parking process and increase the number of vehicle at parking based on smart solution that monitor the usual time period that users stay at campus. Services and facilities are georeferenced and guidance or alarms is provided in mobile device. This approach is based on a modular service approach to time-based growth creating a Smart Campus of Things.*

I. INTRODUCTION

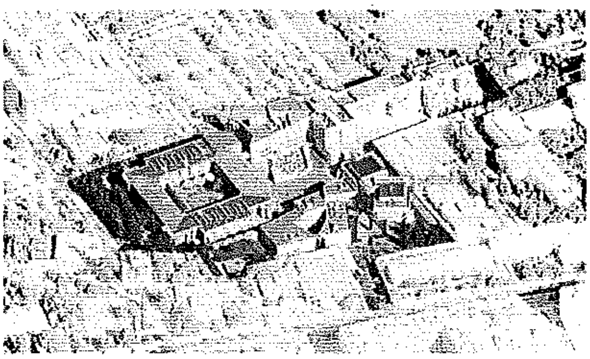
Internet of Things (IoT) is slowly becoming a new reality with a diversity of application and low prices. This is a network of sensors and applications enhancing our comfort, but they also give us more control to simplify routine work life and personal tasks. The potential of IoT reached USD 598.2 Billion in 2015 and the market is expected to reach USD 724.2 Billion by 2023 (estimation from https://www.forbes.com). The new Bluetooth Low-Energy (BLE) is a significant protocol for IoT applications because of significantly reduced power consumption considering that devices can be mounted using a battery and having no external power source. This is part of a new paradigm where it is possible to integrate every sensor in the Internet, allowing the Internet to be even more immersive and pervasive. These sensors can be applied for buildings monitoring processes like energy or water consumption, users' internal mobility, control temperature, alerts about services and help users to find the desirable service among others within the building. The output of these networks of sensing devices generate new data that can be used by owners, managers and operators for a new paradigm of facility management with greater awareness and insight to significantly reduce costs and improve performance. From these big data new challengers of knowledge extraction and data visualization emerge. This is a dramatic change in actions towards savings (energy, water) and services optimization.

In this complex scenario, the application of an IoT paradigm approach for Smart Campus is of particular interest: It will create great opportunities in improving the managing quality of complex and multi-dimensional institutions as universities; It responds to the several initiatives of smart cities with strong push from many national governments to adopt ICT solutions in the management of public buildings putting in place the so-called Smart City concept [1]; It will reduce the operational costs of the public administrations. The data collected reveals a completely different understanding of how buildings are working — or not working — with a new awareness into the origins of issues and problems, enabling new knowledge that leads to improved operational methods and design standards.

Managing a university campus has become a complex and challenging task due the number of persons involved, diversity of equipment and the need for cost reductions. There is also the need to support decision-making relating to campus infrastructure. University buildings are ageing which, together with the need to comply with ever evolving functional requirements, asks for improvements that will require structured information to be effectively designed.

Organizations like Universities usually have many inefficiencies and big bills of electricity and water. As an example, our ISCTE-IUL campus (www.iscte.pt), with a 53 thousand square meter gross built area, has an annual energy bill of 488 thousand euros, corresponding to 3,95 GWh/year final energy (81% electricity, 19% natural gas), 8,74 GWh/year primary energy and emissions of 1303 TonCO2/year. The campus is used by around 10 thousand persons.

There are considerable challenges embedded in existing University Campuses, where the big data can be manipulated for valuable knowledge extraction — seeing new information and new patterns in new periods for new outcomes. It is now possible to measure and sense, as well as visualize the information generated by a diversity of devices sensoring the exact conditions of practically everything in near real-time.



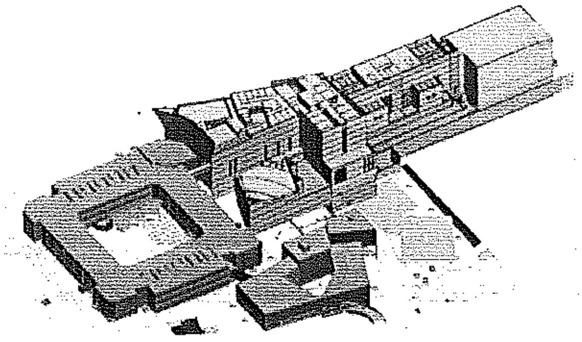


Figure 1. Image of ISCTE campus with a 3D representation

Now people, buildings, campuses and even entire cities are able to operate and interact in entirely new and different ways with better, more productive outcomes. The key point is that big data and analytics, when harnessed, become the new method for decision making and are the future of process improvement and savings. A university campus is a good candidate to apply IoT since its thousands of students are very active on social networks. In the case of ISCTE-IUL, there are around 10 thousand people on campus of which 9,200 are students. Our aim is to build IoT services that can be used to draw conclusions regarding the campus operations in relation to how the community interacts with the built infrastructure. The result will be expected major savings in resource usage (mainly energy and water), but also an opportunity to enhance sustainability-related communication creating new channels to reach users by using appropriate analytics. Progressively and continuously improving institutional sustainability requires a committed community willing to embrace behavioural changes. Therefore, accurate and fast communication is considered crucial for environmental and sustainability awareness, thus having a beneficial feedback in operations. An application that aggregates useful information from several sources is proposed in Figure 2, using a service approach. Such information includes daily academic data (such as schedules, various deadlines defined in the academic calendar, opening hours for administrative services, etc), and sustainability-related data (mainly related to climate, energy, water and building occupancy). Based on the provided data of the aggregator service, users can subscribe to events they are interested in. On the other hand, this service is a unique opportunity to collect information from users that is not available in any other way, such as how users get to campus (mobility issues) or how waste is generated and disposed of. Being able to collect and relate all of this information will certainly allow for a better understanding of how the campus is used but also to build a calibrated model that may be used as a preventive mid-term managing tool.

II. IOT SENSORS AND APPLICATIONS

Our approach is divided by several areas: 1) count users at the four main entrances, classrooms and other pre-defined locations and passive tracking; 2) parking places monitoring; 3) alerts about services and news on mobile devices; 4) guidance towards desirable places for foreigner persons and evacuation guidance related to security and safety issues; 5) guidance to books location in the library; 5) monitor external and internal environmental conditions (temperature, relative humidity, solar radiation, wind speed, noise pollution, and air quality); 6) check power and water consumption at main buildings, departments and floors – create data for future data analyses and improvements; 7) artificial lighting control.

Most of the implemented sensors are Bluetooth Low Energy (BLE), with internal battery to feed their energy consumption for one to three years with Bluetooth transmission capacity which makes installation easy because there is no need of cable. These sensors use a client/server model where the sensor has the data and it can transmit to a master Bluetooth device which, in turn, is able to transmit data to a central server through Wi-FI or 3G; alternatively a mobile phone can be used. Data is transmitted based on a 'polling' configured events.

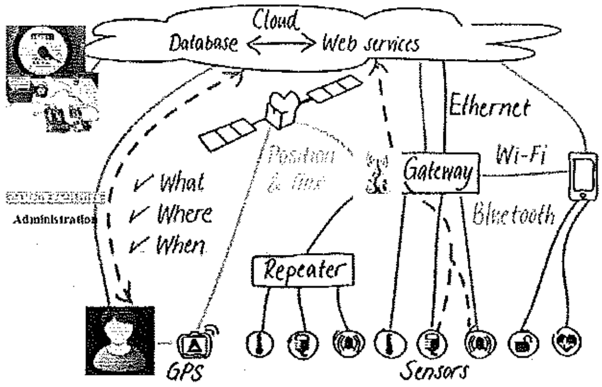


Figure 2. High level vision of proposed system

A. *Count Users and Passive Tracking*

The People Tracking approach allows to identify students' main movements, check number of students at lessons and guide external persons to correct locations. People Tracking refers to data output from wireless technologies, specifically Wi-Fi, which captures the users' journey — by tracking their mobile phone signals, using probe request on Wireless Access Points (AP). This probe requests are sent out by smartphones, laptops, and other devices that are not currently connected to a WiFi network. Most Android and iPhone devices send out this request every 40 to 60 seconds, which makes it especially useful using these requests to track users' movement.

For the WiFi sensor we installed an AP Cisco series 1250, but no AP with monitor capability could be used. Due to commercial reasons (because the project is connected to a company) we have used Cisco, but with other brands the process can be implemented. This is the case for obtaining the Received Signal Strength Indicator (RSSI) from every client's Probe Requests, which requires a Wireless LAN Controller (WLC).

The AP1250 series can be controlled from the WLC versions from 5 to 8. We used the 7.3.101.0 version, graciously borrowed from Cisco during 90 days, which matched the AP version 15.2(2), for details see [2].

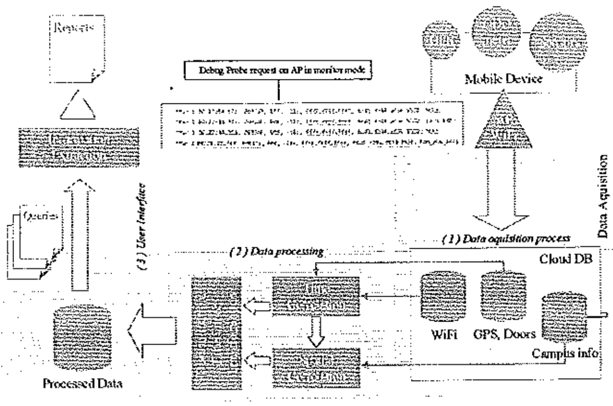


Figure 3. Implemented tracking

B. Parking Places

Parking space is limited and is not available for everyone. Therefore, our approach is to give parking time based on usual time that a person spends on campus and create a cheap IoT infrastructure to control this process. The main idea behind this is to use a beacon in each parking vehicle that identifies the vehicle and owner. This beacon is used to open the gate and to identify the place and time that the vehicle was parked inside the parking infrastructure. This process is based in a wall-mounting master Bluetooth receptor that is able to receive beacon signal and identify the power. Using a triangulation process it is possible to identify the place where the beacon is located. The main problem of this approach is the localization of the master Bluetooth receptors that needs to be carefully studied and calibrated to assure the triangulation process. Accuracy does vary depending on circumstances but can be as good as within +-0.5 meters. Based on the parking layout a network of BLE masters is created on each floor, in a grid pattern. These BLE have their own battery and no power is needed. Then one or more floor plans or maps are uploaded to the dashboard of the developed App. We georeferenced each BLE master installed and perform the calibration process based on power received versus distance.

An alternative to this approach is the beacon detection by each driver when parking transmitted with GPS position (if available) or mark in a map the position parked.

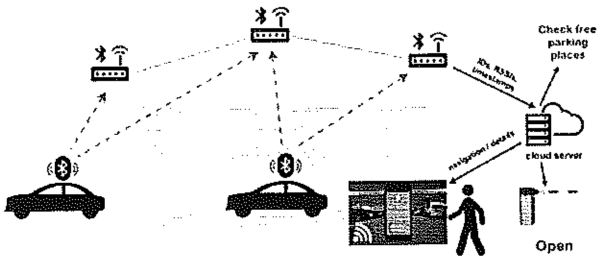


Figure 4. Beacon at veihicle used as electronic plate, used to identify and open access to parking facility, identification of placed parked and guidance

C. Georeferenced, guidance and alerts of available services, facilities

The greatest benefit for BLE Beacons is the ability to send "push" notifications to customers. This can be used in a campus environment to advertise events, administrative services. Due to low range communication, this information is only available when users are near the service or event. Therefore, beacons allow the academic services to directly contact the students, faculty or campus visitors in real-time.

It is possible to track mobile devices with BLE receivers. In this case, BLE receivers, are placed at known locations throughout a venue. This time, the mobile device Bluetooth signals are moving, attached to mobile assets or carried by people. The problem of this approach is that we need a list of power emitted from each mobile device model. When three or more BLE nodes detect the same Bluetooth signal, the system can triangulate the respective location.

Counting persons is based on low range communication and the ability of checking the number of Bluetooth communication at a Bluetooth receiver because each mobile device has a unique identification in the communication. If we correlate this identification with a person (previously defined) we can perform check-in operations, or identify what students attend a certain class.

Payment can be performed by NFC mobile device with encryption token (this subject is not described in this work).

A list of mobile device available services is illustrated in Figure 5.

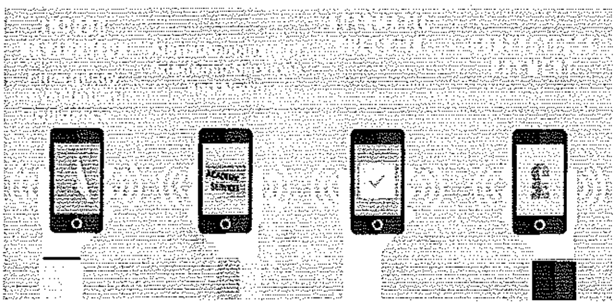


Figure 5. Campus Mobile Device Usage

D. Temperature and Air and Environmental Quality

A Smart Campus IoT can offer a noise monitoring service to measure the level of noise produced at any given hour in the places that adopt the service and this is important in our campus due to the proximity to the Lisbon international airport and the fact that the campus is located beneath the landing route. Together with building a space-time map of the noise pollution in the area, such a service can also be used to enforce public security, by means of sound detection algorithms that can recognize, for instance, the noise of glass crashes or brawls. Other environmental-related data is important to support a more detailed understanding of specific parameters conditioning building use and campus operation. Measuring temperature and relative humidity supplies information on micro-climate conditions affecting internal comfort. Figure 6, shows the proposal for the local development based on cheap sensors of temperature/humidity, O3, NO2, CO/CH4/VOC, noise and small particles sensor. A small LCD is attached and power autonomy is based on a Li-ion battery. Data can be stored on a flash storage or transmitted through Bluetooth to a 3G or 4G master device. A plastic water-proof box is planned to be developed in our Vitruvius FABLAB-IUL (http://vitruviusfablab.iscte-iul.pt/en). The cost is under 500€ and it can be placed at five locations in our campus (right side Figure 6)

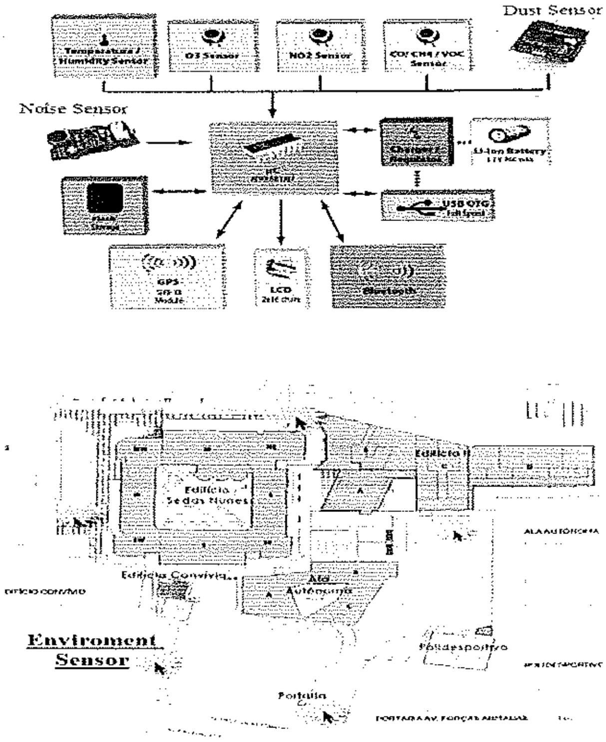


Figure 6. *Environment developed sensor and their planed location at our campus*

E. Monitor Energy Consumptions

IoT sensors can monitor energy and water consumption in several points of the campus buildings. This consumption can be correlated with weather events or occupancy rate among others and give useful information regarding resource management. Information from temperature and humidity sensors can give additional information for this process. By controlling these parameters, indeed, it is possible to enhance the level of comfort of the users living in these environments, which may also have a positive return in terms of productivity, while reducing the costs for heating/cooling and lighting. Equipment can also be turned on/off remotely to deal with intermittent behavior of renewable energy. This is possible with an OpenADR

Interface, where on/off commands can centrally be sent to equipment with the use of this interface. This is in a concept phase where we identify places for process monitoring and study the way of installation. An installation plan is being prepared.

Our intention is to create open data that can be used as a living lab, to study renewable integration, demand response approach and study savings with this monitoring process. Figure 7, presents our plan developed application that gives in real time consumption information based on energy, gas and water consumption sensors. This consumption can be detailed based on the installation of more consumption sensors. This is connected to renewable energy sources and correlated with weather conditions.

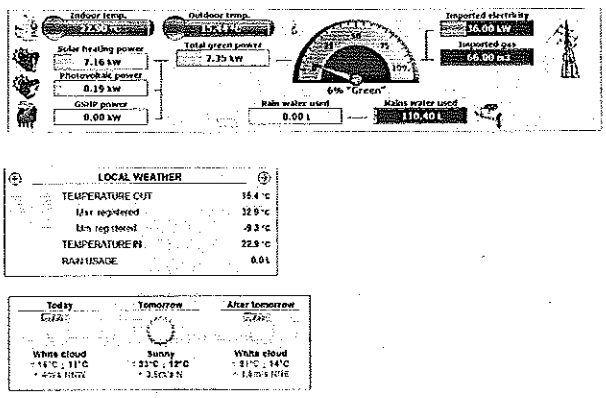


Figure 7. *Mockup of planned monitor energy consumption, correlated with weather condition and number of person in the campus*

This approach require sensors at each point of measurement. Most interesting are main distribution nodes at each building. We use Current transducers (CTs) in split-core or solid-core varieties. Split-core CTs make it easier to install in existing electrical installations, since you can open up the "donut," and then close it around the wire. Note that CTs are typically *not* interchangeable between different systems. The measurement is based on the magnetic field created as the current in the wire flows. When that magnetic field moves through the coil of the CT, it generates voltage proportional to the current flow. This voltage is measured by the electronics and converted into an amperage reading. At the same time, the voltage in the circuit is measured directly, and simple multiplication results in kW. Include the elapsed time, and kWh are computed. The sensors are hard-wired or communicate wirelessly through data loggers or transmitters that, in turn, send data to a local display.

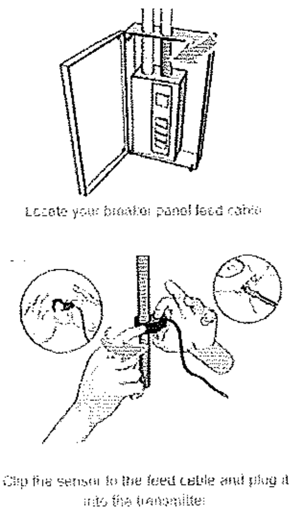


Figure 8. Energy sensor implementation

F. Lights and Temperature Monitor

Luminosity sensors can be used together with the information of users' presence and occupancy rate in a certain place to turn on/off the lights. This information can also be used to increase or decrease the room temperature. This heating and cooling system may be integrated with OpenADR interface [3] to coordinate consumption based on the availability of internal renewable production. When we have too much energy or too less we can turn on remotely this equipment and integrate this intermittent production behavior of renewable with a flexible demand at heating or cooling systems.

III. Data Transmission and Big Data Creation

Sensors are connected to master devices based on a Bluetooth connection with a range that goes until 70-80m in an open space. The master has network cards, most of them a 3G connection or a WI-FI card when wireless network is available, see Figure 8. This data is transmitted to a central cloud server where is stored in a pre-defined way. Value, data and position is stored. This real time transmission plays an important role in this smart campus process.

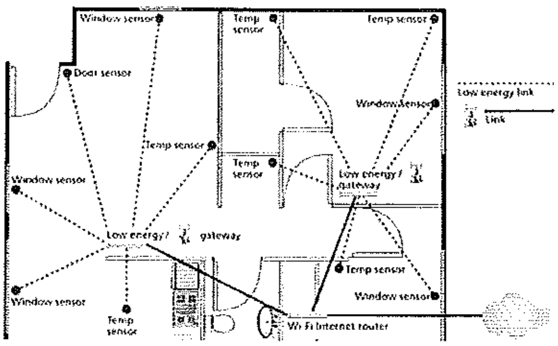


Figure 9. *Sensor data transmition process towards central data storage*

This Big data created from this IoT has the problem of security and privacy because these devices start collecting user information. To handle this problem we rely on network protocols to ensure IoT security and use encrypted communication to handle privacy protection. From the approach illustrated in [4] summarized all current security threats to the IoT network but these threat models are mostly derived from network Also [5] shows main attacks on privacy related with: (1) Eavesdropping and passive monitoring; (2) Traffic analysis; and (3) data mining. The data sharing and management, and data security matters remain open research issues to be fulfilled [6].

IV. SERVICE APPROACH ARCHITECTURE

Figure 9 shows our vision for the problem where a diversity of sensors were installed at campus. These sensors provide data to a central cloud server where data is manipulated toward the desirable goal. We are working in a service approach to get flexibility and reuse of several parts in terms of algorithms towards the desirable extracted knowledge.

We use four layers: 1) data layer captured from installed sensors; 2) information, where data is manipulated towards desirable information; 3) this information can be used for campus management, where specific functional roles act on infrastructure and systems to optimize operation conditions ; and 4) feed main applications in a service approach, where the information can be incorporated in related service; for example, the info about the number of empty spaces at the parking facilities can be used to increase the number of persons using parking facility.

Layer 2 – information extraction is based on Data mining algorithms. These algorithms are out of scope of this article. From the big data created, patterns can be extracted and analyzed. It is thus possible to make predictions about the physical or social phenomena being observed. The challenge in identifying patterns from big data is based on domain and oriented to a specific usage. In a university, the information to be collected and analyzed has the main objective of allowing an improved operations management that leads to savings and therefore to a more sustainable performance. Nonetheless, in this type of institution, the ability to have data and detect patterns should also be related to research and teaching goals. In fact, these big data sets are also a major opportunity in the search for models relating several levels of information: external environmental conditions (temperature, relative humidity, solar radiation, wind speed, noise pollution, and air quality); internal environmental conditions (air temperature, radiant temperature, relative humidity, air displacement, noise level and air quality); time, date and location-related occupancy patterns and rate; resource consumption and waste and emissions generation.

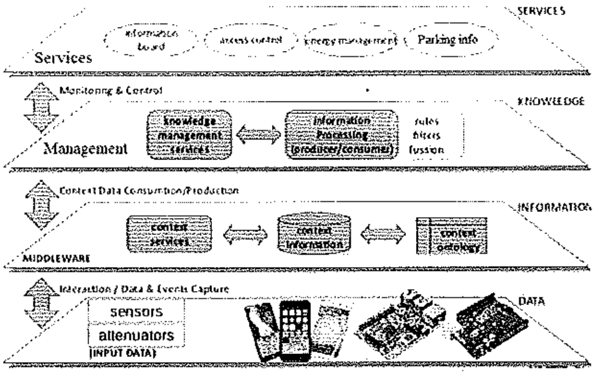


Figure 10. General overview of proposed architecture of our IoT smart campus system

V. CONCLUSIONS

Increasing market penetration of IoT sensors is a reality with application in different areas: energy, automotive, healthcare, consumer spaces and general facility management. Universities are facing new challengers with mobile and tablet devices transforming the traditional way of imparting education in the classroom. Academics management infrastructure face several challenges in controlling building infrastructures, consumptions and services needing digital processes to help on student information management. In a data-fueled academic era, IoT sensors assure data collection and data centralization. This is an important approach towards more efficient management, enabling educational institutions to capture and track data to connected devices such as smartphones. The IoT can also play an important role in campus planning, particularly space planning, addressing current problems of lack of available space due to the increase of the number of students and courses. This is an ideal opportunity

for an IoT application based on internal interest taking advantage of current state of technology (prices going down). In this paper we perform a high level vision about our proposed approach. This IoT approach are able to monitor persons and process and this data can be manipulated to extract knowledge. This knowledge have a profound impact on universities, streamlining campus operations, improving the student experience, and revitalizing engineering degree programs. This reality could also benefit, and contribute to collaborative interdisciplinary researching and teaching processes.

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