IST-Africa 2016 Conference Proceedings
Paul Cunningham and Miriam Cunningham (Eds)
IIMC International Information Management Corporation, 2016
ISBN: 978-1-905824-54-0

Internet of Things Technologies in Smart Cities

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Abstract: A smart city is a developed urban area that excels in the area of economy, governance, people and life through strong human capital, social capital and ICT infrastructure. It is a new approach to managing the complexity of city life, increase efficiency, reduce expenses and improve the quality of life of the citizens. This paper is on potential smart cities applications as applied to the domains of smart transport, smart tourism and recreation, smart health, ambient-assisted living, crime prevention and community safety, governance, monitoring and infrastructure, disaster management, environment management, refuse collection and sewer management, smart homes and smart energy. These smart cities applications support the future vision of cities, which aim at exploiting ICTs, namely internet of things technologies (IoT), for value-added service delivery. Furthermore, the paper presents a technical solution for energy control and comfort in a home for proof of concept of a smart city infrastructure application. The demonstrator described here is on how smart applications can manage energy control and comfort in a room that has a varied number of people and electrical appliances, with each being a source of heat.

Keywords: smart cities, internet of things

1. Introduction

The concept of the 'smart city' highlights the importance of ICT for enhancing the profile of a city. A city may be called 'smart' when investments in human and social capital and traditional and modern communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources through participatory governance (Caragliu, 2011). A smart city is also defined as a city connecting the physical infrastructure, the ICT infrastructure, the social infrastructure and the business infrastructure to leverage the collective intelligence of the city (Harrison, 2010).

The Internet of Things (IoT) is considered a major research and innovation stream leading to plenty opportunities for new services by interconnecting physical and virtual worlds with huge amounts of electronic devices distributed in houses, vehicles, streets, buildings and many other public environments (Moreau, 2012). Urban IoTs are designed to support the smart city vision, which aims at exploiting the most advanced technologies to support value-added services for the administration of the city and its citizens (Zanella, 2014). Smart cities worldwide live under a 'data deluge" in which big data generated by people and sensors are processed for decision-making (Molinari, 2014).

The objective of this paper is to showcase the role that IoT can play in a smart city. The paper starts by reviewing services and applications that support a smart city. These services fall into the domains of smart transport, smart tourism and recreation, smart health, ambient-assisted living, crime prevention and community safety, governance, monitoring and infrastructure, disaster management, environment management, refuse collection and sewer management, smart homes and smart energy. Finally this is substantiated through an example of a demonstrator as proof of concept on energy conservation and comfort in a room.

The rest of the paper is organised as follows. Section 2 is the problem statement. Section 3 covers smart city applications for the various domains. Section 4 is on the architecture of the demonstrator developed as proof of concept. Section 5 is the conclusion.

2. Problem statement

Rural-urban migration tends to impact on the delivery of services in the cities due to constrained resources. As a result, the concept of a smart city has been adopted to improve delivery of services in urban areas. This research is on how cities can be smartened through the adoption of IoTs. A literature survey was conducted on what constitutes smart cities and what domains of any city can be made smart through the adoption of IoTs. The domains of transport, tourism, health, ambient-assisted living, crime prevention, governance, infrastructure management, disaster management, environmental management and energy management were identified. Through sampling of literature, IoT applications for these various domains were identified. In addition, in a laboratory environment, a prototype technical solution for energy control and comfort in a home for proof of concept of a smart city infrastructure application was developed. The demonstrator described here is on how smart applications can manage energy control and comfort in a room that has a varied number of people and electrical appliances, with each being a source of heat.

3. Smart city applications

This section offers examples of smart city applications for smart transport, smart energy, smart health, ambient-assisted living, crime prevention and community safety, governance, condition monitoring and maintenance of infrastructure, disaster management and emergency, smart homes, tourism and recreation and environmental management.

3.1 Smart transport

An integrated transport system would need a single ticket in the form of a smart card which can be loaded with money and is swiped at any point of entry into a transport system using Near Field Communication (NFC) technology to transmit information from the card to the reading machine and back. Payment is deducted accordingly from the card for the trips made. At each parking bay is a meter that detects the presence a car parked through a tag on the number plates as soon as the car enters the bay and starts calculating the charges for the parking as they accumulate. Motorists register etoll accounts with the roads agency and are issued with radio-frequency identifier (RFID)-enabled etoll cards which are attached to the cars. As the car drives under an etoll gate the driver’s details and the details of the distance they have travelled are read by the card reader on the etoll gate, and relayed to a server at the roads agency.

3.2 Smart tourism

A museum has augmented reality systems with QR codes placed at strategic points in the museum. Visitors use smart phones to takes a picture of QR codes. Each QR code connects the phone to a URL which gives details on the section of the museum they are in.

3.3 Smart health

Mobile applications, body area network sensors and personal health management ecosystems have been recognised as essential components of the technological platforms of the next generation of healthcare for their potential to allow citizens to play an active role in the management of their health (Nollo, 2014). Mobile health applications (smartphone and tablet) can connect to medical devices or sensors (e.g. bracelets, smartwatches, patches, etc.) and provide personal assistance and reminders. Through the use of sensors directly connected to mobile devices, it is now possible to gather a considerable amount of data.

3.4 Ambient-assisted living

To encourage the elderly to stay in their homes for longer and not in nursing homes, they wear body sensors to detect body parameters. These sensors connect to their caregivers wirelessly. Should any of the parameters go out of range, an alarm to the caregiver is triggered.

3.5 Crime prevention and community safety

Identification of criminals has been made easier through mobile biometric detection machines. Fingerprints of a suspect are captured to a police mobile biometric machine. This data is sent via a network to a fingerprint database located at the Department of Home Affairs for comparison and it returns the identity of the suspect (Dlodlo, 2013).

3.6 Governance

The number of available online services, their effectiveness and usage level and their level of interaction are important indicators of the 'smartness levels" of e-government (Fioroni, 2014). Water, sewage, electricity and rates bills each have an ID tag which is read by the tag reader at the counter and automatically matched against user details in the database and update with payment is made.

3.7 Condition monitoring and maintenance of infrastructure

Heavy load trucks carrying cargo across a bridge which is their regular route tend to strain the bridge due to their weight. Sensors that detect structural integrity of the bridges report to the roads agency via a private network on the structural soundness of the bridges when trucks pass over them.

3.8 Disaster management and emergency

Satellites detect heat signatures of a fire that has just started in an area. The satellites relay the information to a control centre that registers the fire in their systems and dispatches fire trucks. The same control centre triggers fire sirens that are placed at strategic points in the area to alert the inhabitants.

3.9 Environmental management

The city engineers install sensors across the city which measure temperature, relative humidity, carbon monoxide, nitrogen dioxide, noise and particles. If any of the parameters go above a set threshold, the GPS-enabled sensors send an alarm to a central node. The node in turn sends the information to the cell phones of the habitants.

3.10 Refuse collection and sewer management

The municipality has sensors placed in the septic tanks so as to raise an alarm when the septic tank reaches a preset level. Trucks are then dispatched to remove the waste from the septic tanks. The municipality places bins at strategic positions in the city. The bins have sensors which raise alarms when the bin is full and a refuse collection truck is dispatched to collect the waste (Dlodlo, 2012).

3.11 Smart home

The houses we live in can be configured to identify individuals, whether they are the usual family members, guests, or unauthorised people. Individuals are identified by means of what they have on person, for example, a smart phone that is identified through radio waves. If an individual inside the house has no such ID then they are identified as unauthorised and an alarm signal is routed to the relevant external body or to the house owners.

3.12 Smart energy

An application running on a mobile phone enables individuals to remotely control their home electrical devices. Users select an appliance from the application and switch it off. The request to switch off traverses the GSM network to the IP address of the home appliance (Sensormind, 2015).

4. Architecture

4.1 An overview of using IR to control appliances

Research was conducted to automatically control an appliance that is usually controlled by means of a hand-held remote controller. This controller relies on infrared (IR) radiation for communication with the appliance. Here, an IR light-emitting diode (LED) in the remote controller sends information which is picked up by an IR receiver in the appliance. Initially, the IR module in the appliance receives an infrared signal from the remote controller, demodulates it and outputs the received codes to the microcontroller embedded in the appliance. These received codes trigger the logic circuits in the appliance every time a remote controller button is pressed.

In order to automatically control the appliance using IR signals, we incorporated a circuit containing a microcontroller. This microcontroller executes an IR library which both receives and sends IR remote codes in multiple protocols. To control an appliance with an IR LED connected to the microcontroller, the protocol used by the appliance must be known to the microcontroller. This is accomplished as follows: Using the remote control of the appliance, the IR receiver interprets data that results from the remote key press, copies it onto the microcontroller and then sends it to the IR LED for transmission when needed. Since the protocols differ from manufacturer to manufacturer, the manufacturer of the appliance needs to be set to properly use the library executing on the microcontroller.

Therefore the steps that are required are:

1. Obtain the IR codes from the existing remote control,
2. Embed these IR codes onto the microcontroller e.g. an Arduino,
3. When required, the microcontroller transmits the code via the IR LED to actuate an appliance,
4. The IR receiver on the appliance receives the code, and
5. The appliance performs the necessary action

4.2 Controlling an air conditioner in a room

One of the features of a smart city is optimum control of energy consumption in the home while still providing comfort at the ideal temperature. A method to maintain comfort in the home is by adjusting temperatures through air conditioning. This system’s architecture is an experiment in providing the right temperature for optimum comfort in a simulated room environment. It incorporates various sensors to detect whether people are in a room, whether the windows or doors are open or shut, and whether the air conditioning should be switched on or off to maintain an ideal temperature. The body of a human generates heat, leading to increases in temperature in a room, thereby creating uncomfortable conditions. In addition, the room usually also houses electrical appliances such as computers which also generate heat.

4.2.1 Components of the systems

The control system employed in this research project consists of a microcontroller circuit called an Arduino, a microcontroller circuit called a Raspberry Pi, an ultrasonic distance sensor, a passive infrared sensor, a current sensor, window and door status sensors, middleware, an infrared transmitter, an air conditioner, a data analytics component, and an application to control the system.

4.2.1.1 Arduino

The Arduino is an open-source prototyping platform based on flexible and easy-to-use hardware and software. It is a single-board microcontroller, designed to make the process of using electronics in multidisciplinary projects easier. The exposed connectors in the Arduino enable the processor to be connected to add-on modules. The Arduino is able to communicate with software executing on a connected computer. The Arduino system easily interfaces with a computer via USB when programming is required. The Arduino on the other hand has no significant permanent storage abilities, but mostly incorporates volatile RAM. The Arduino cannot just directly connect to either a monitor or keyboard and usually does not host an operating system.

In the laboratory environment, and the envisioned real-world application, the Arduino in the smart home obtains the IR codes from the sensors in the home. The codes are temperature up, temperature down, turn the appliance up, and turn the appliance down. The obtained codes are then embedded into the Arduino to be transmitted when the need arises.

4.2.1.2 The Raspberry Pi

The Raspberry Pi is a single-board computer developed by the Raspberry Pi foundation. It uses a Linux kernel-based operating system. Compared to a desktop computer, the Raspberry Pi is limited in RAM and CPU power. It can be connected to a monitor, keyboard and mouse. It also connects to the internet directly and has storage facilities and an operating system.

4.2.1.3 Middleware

The middleware is a system that allows easy communication between things and humans via a number of protocols (or communication channels) such as email, Extensible Messaging and Presence Protocol (XMPP), Hyper Text Transfer Protocol (HTTP), Facebook, Jabber (Instant messaging), MXit, Radio Frequency Identification (RFID) tags, Quick response (QR) codes, Short Messaging Service (SMS), Multimedia Messaging Service (MMS) and Twitter . The main component of the middleware is the controller. The middleware is the interface between business services and the channels. These business services can range from a calculator, to a tweet back on dam levels or the temperature of an object, to the determination of a plant's moisture levels, etc. Requests for services in middleware come from the user via any of the above-mentioned channels. They are routed via the controller to the business services.

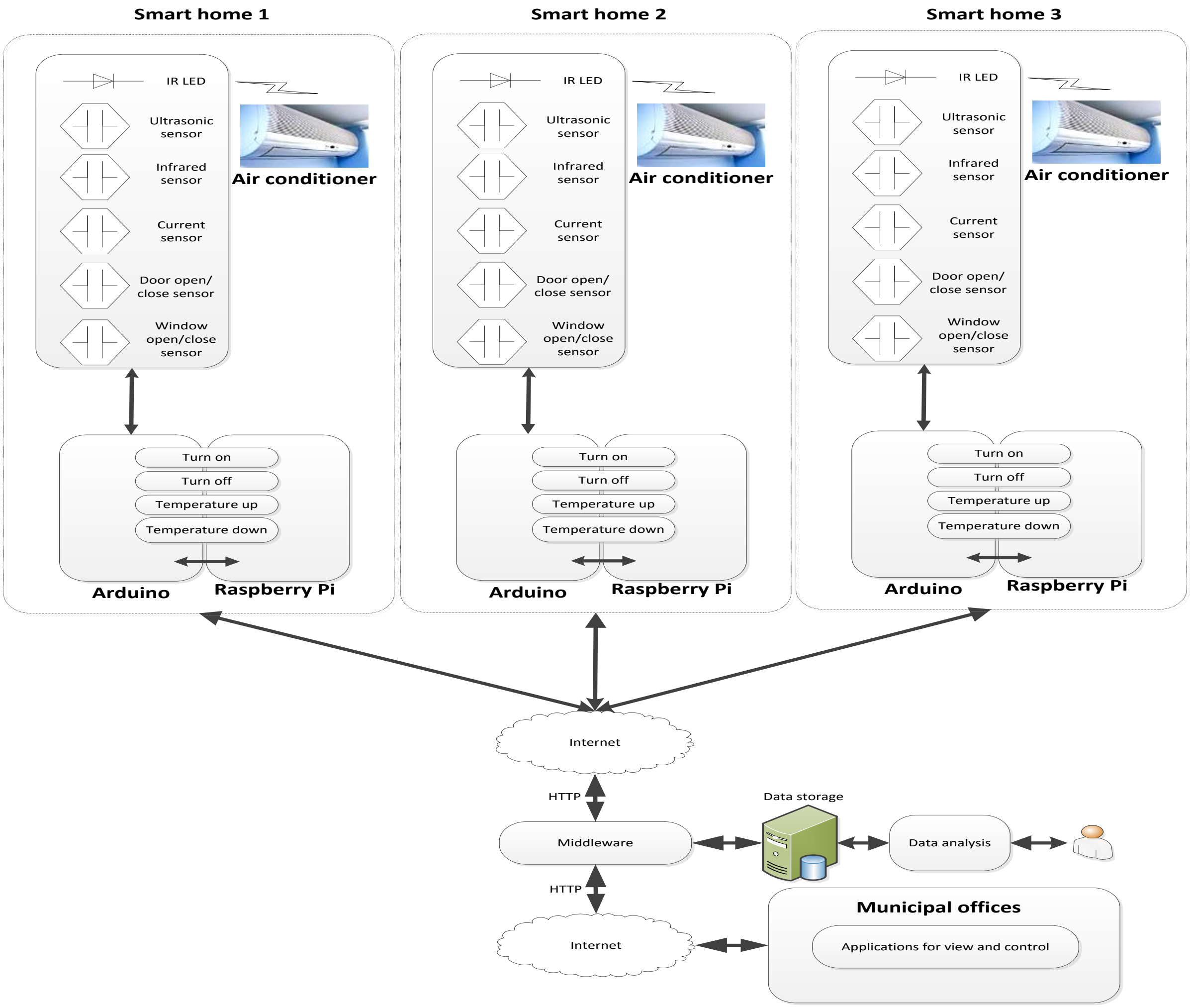
4.2.1.4 Data analytics component

Analysis of data is the process of inspecting, cleaning, transforming, and modelling data with the goal of discovering useful information, suggesting conclusions and supporting decision-making. In this case the system continuously monitors the temperature of the room according to the presence of people in the room and according to certain rules, controls the air conditioning. The temperature in the room is kept constant even when the numbers of people in the room varies. The information generated is transmitted to a rules engine which then decides where to turn the air conditioning on or off.

4.2.1.5 *Application*

The application component contains rules which govern the decisions taken on the control of the smart homes. It is envisaged that the application will also receive information from the power utility regarding electricity provision, and information from the weather bureau. The application then makes a decision on rules such as “If the door is closed and the window is closed and the temperature is below a certain degree, then adjust the air conditioning accordingly”. The ideal is to ultimately be in a position to control a whole neighbourhood of smart homes in this fashion.

4.2.2 *The architecture of the system that controls air conditioning in the room*



The experimental room consists of the following sensors, as well as an actuator.

- A passive infrared sensor to detect a warm body once it is within range
- A current sensor to measure the energy consumption of the air conditioner
- Sensors to detect if the doors/windows are open or closed
- An air conditioner that can be turned on/off, or its temperature can be increased or decreased

The goal is that the sensors in the home connect to an Arduino. The Arduino in turn connects to a Raspberry Pi via a USB cable. At first glance the Arduino and the Raspberry Pi perform the same functionalities. Both connect to the physical world. The difference is that the Raspberry Pi takes more effort in terms of putting together an electronic circuit to connect to the physical world as compared to the Arduino. The Arduino functionality may be increased by the addition of “shields”. The Raspberry Pi, however, has considerable processing power compared to the Arduino.

The Raspberry Pi connects to the internet via an Ethernet cable, and then to the middleware. The middleware is the software that translates between different protocols. On the other side of the middleware is an application that consumes data and sends instructions to the actuator that controls the air conditioner. Intelligence lies in the application for decision-making and control of the air conditioner.

5. Conclusions

The paper discusses the application of IoT in smart cities. The adoption of ICT in city services and infrastructure has transformed the way cities operate and deliver services. The application domains for ICTs in smart cities range from transport, tourism, health, ambient-assisted living, crime prevention, governance, infrastructure, disaster management, environment management, smart homes to smart energy.

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