Smartphone-Controlled Localisation and Management of Indoor Devices using the Internet of Things

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In the recent past, the growth of the Internet along with the widespread use of smart devices has resulted in an increased demand to connectdevices to the Internet a.k.a the Internet of Things (IoT). Using the concept of IoT, indoor smart devices including home appliances could be connected to better manage their use. Hence, IoT could be used to manage the use of indoor devices in an efficient way, if we had an algorithm to localise the devices and to control their use of energy using smartphones. A number of studies have already been conducted in the past targeting either localisation or monitoring of devices, but to the best of our knowledge, there isn't a single solution that treats both of these problems at one place. Thus, the objective of this work was to devise efficient algorithms that enables the localisation of home appliances without the use of GPS through smartphone sensors including the gyroscope and accelerometer. Moreover, we intended to use the concept of IoT to monitor and control the energy use of indoor devices. Measurements would be taken from the smart indoor devices related totheir consumption of energy, thus helping to identify which devices were consuming more energy than desired due to some problems. The indoor devices including the home appliances would be controlled and their usage would be better managed via a smartphone. This included, for example, switching on an air conditioner or a geyser via the Internet before getting into the home, or the ability to detect that a refrigerator might be consuming more energy than desired due to some malfunctions The smartphone application would also have information about which devices are currently running (and which are off), and how much total energy isconsumed at a particular instant, or in a period of time.

Key words: Internet of Things, IoT, device localization, home appliances

Mankind has seen a tremendous growth in Internet infrastructure and its use in the past two decades. To this end, the evolution of new applications, and the invention and widespread use of smart devices (e.g. smartphones, tablets, gadgets, e-book readers, PDA, etc.) has pushed the Internet growth even further by making it available and accessible to more people. Hence, there has been an increasing desire of users to connect anytime, anywhere while using their favorite applications that require Internet connectivity. On the other hand, the widespread use of smart devices has resulted in new communication paradigms, such as human-to-device and device-to-device communications, which has been a shift from traditional human-to-human communication as shown in Figure 1. These new communication paradigms along with the capability of supporting more routable devices using IPv6 ignited the concept of connecting devices to the Internet, a.k.a. the Internet of Things (IoT). (Al-Fuqaha *et al*., 2015)

The concept of IoT inherently suggests connecting everything to the Internet, such that devices are accessible and controllable via the Internet. These devices are usually equipped with sensors to sense the environment and have wireless interfaces. The data collected from the sensors are reachable from any place in the world. Moreover, these devices are expected to communicate and learn from each other.

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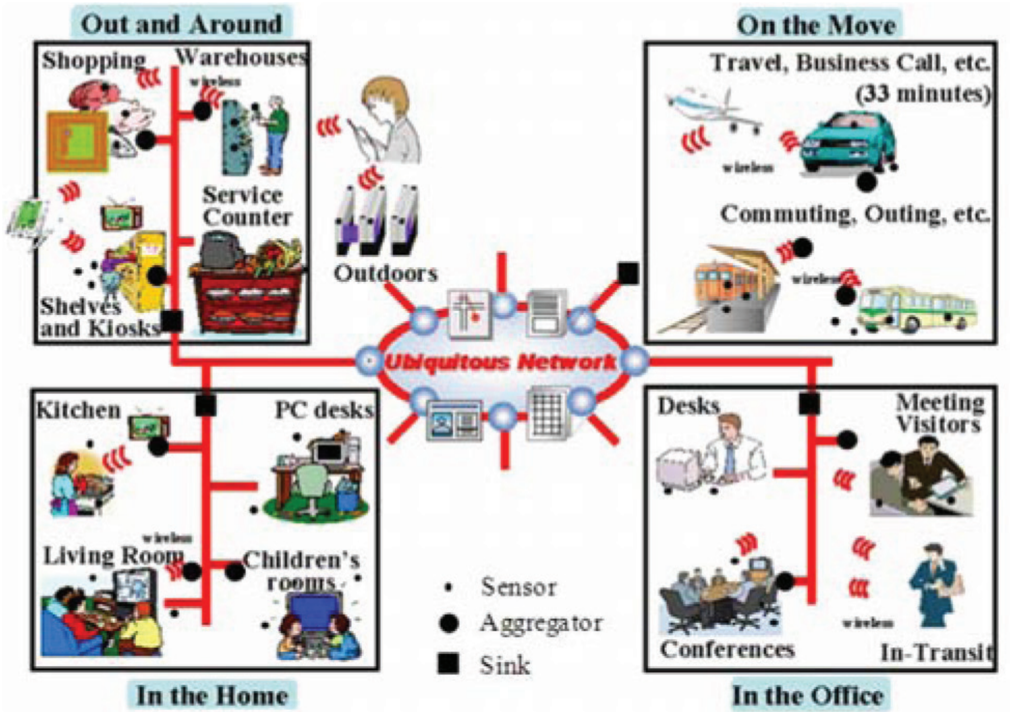

Figure 1. Desire to Connect Anytime, Anywhere

The principle of IoT can be applied to many real world scenarios, as shown in Figure 1. This includes indoor and outdoor networks such as shopping malls, offices, and homes. At shopping malls, the concept can be applied to get information about users' trends, preferences, and moving patterns. At offices, better planning of users' connectivity can be done, whereas domestic gadgets and home appliances can be better managed using IoT principles. For home devices, the overall objective is to make life more comfortable by managing the smart devices and appliances such as lightings, air condition and heating systems, and home security etc. The management of these smart objects requires attention in three aspects: localisation, control, and monitoring. All these three aspects are important in their own way and are generally considered independently in the literature.

A number of studies have been conducted in the past targeting indoor object localisation (Liu *et. al.* 2014, Azizyan *et. al*. 2009), home appliances control (Piyare, 2013) and indoor devices management through monitoring (Wang *et al*. 2013). However, to the best of our knowledge, there isn't a single study that attempts to target all these aspects in one solution, keeping in view the purpose of facilitating the user in a better way. This is the objective of this study. In this paper, we present a framework for control, monitoring and localisation of indoor devices including home appliances, where communication with (and between) devices is performed using the principles of IoT. A user will be able to locate indoor objects both relatively and in an absolute way. The framework allows a user to monitor and measure the energy consumption of home appliances and to control their use keeping in view the desired overall energy consumption within a period of time. The framework also utilises a gateway to connect and interact with the devices and allows access to these devices through the internet. An android-based smartphone application has also been developed to provide a user-friendly interface for thelocalisation, control and monitoring of indoor devices and home appliances. The overall contributions in this work are as follows:

1. A framework for control, monitoring and localisation of indoor devices, including home appliances.
2. Communication with (and between) devices has been performed using the principles of IoT while supporting both device-to-device and human-to-device communication modes.
3. Development of relative and absolute algorithms for the localisation of devices keeping in mind, the advantages of smartphone sensors such as the gyroscope, accelerometer and magnetometer.
4. An algorithm for the measurement of energy consumption of home appliances.
5. A smartphone application to provide a user-friendly interface to the end-user in order to implement the functionality of the framework.

DEVICE LOCALISATION

Indoor device localisation has been studied by many researchers in the recent past. Getting information about the absolute or relative location of a device helps in communicating with that device in an effective manner. Moreover, it can provide an idea of users' trends and preferences of visiting locations, especially in a convention centre-like scenario or in shopping malls. For home devices, localisation is important in many aspects. First, it helps the user to configure the device by providing a visual interface to the user. Second, mobile indoor devices such as a robot cleaner or a gadget can be located. Third, it facilitates device-to-device communication between indoor devices to help them communicate with the main server if they are unable to connect directly. Finally, the localisation of devices can be of great help for elderly or challenged people.

Most of the localisation works have been done in the context of mobile ad hoc and wireless networks (Niculescu & Nath, 2003), where GPS was generally assumed to be available. However, we cannot rely on GPS signals for the localisation of indoor devices. Some studies have proposed using the WiFi for indoor device localisation(Liu *et. al.* 2014), which relied on the received signal strength of beacon messages and responses to locate the devices. This required the systems to be trained using the WiFi fingerprinting mechanism (Azizyan *et. al*. 2009), and provided an accuracy of 2-5 m. An improvement was proposed using peer assistance. However, the localisation may still not be correct due to fading and interference issues.

For this purpose, our idea was to use the smartphone sensors including the gyroscope, magnetometer and accelerometer along with WiFi signals, which was expected to perform better in terms of the localisation of devices. A study will be conducted to check the feasibility of this idea.

SMARTPHONE-CONTROLLED LOCALISATION, CONTROL AND MONITORING

A framework will be designed that facilitates a user to localise and manage indoor devices including home appliances through a smartphone application. The communication with and between the devices are performed using the principles of IoT while supporting both human-to-device and device-to-device communication modes. The management of devices involves controlling them via a distance through a gateway, as well as monitoring their functional behavior by getting their measurements in the application. The application offers the user more control over the energy utilisation of indoor devices, and the ability to maintain their use as per their desire. An energy consumption measurement algorithm will be devised to register the energy use of devices and the data would be communicated to the user through the gateway. The gateway acts as an anchor node which enables communication between smart devices and the user. Thus, the user can connect to the home network even when away from home.

Device Localisation

As stated in the previous section, we will use the WiFi beacon and response messages to localise the devices, as proposed by [?]. In order to improve the location accuracy, we propose the use of smart sensors that are generally available in all modern smartphones: the accelerometer, gyroscope, and magnetometer. The accelerometer is used to get the information of the direction of the device while the other two provides information of the orientation of the smart device. This along with WiFi based approach promise to give better location accuracy than legacy solutions. The framework will support both relative and absolute localisations. By relative localisation, we mean that the location of devices with respect to each other or with respect to a moving smartphone will be computed. On the other hand, the framework is also capable of computing the absolute location of indoor devices with respect to a pre-defined indoor map (e.g. house map). The map will be displayed in the user application along with the location of indoor devices so that the user can control and monitor all the devices using an interactive visual map. The absolute localisation deals with four different types of locations in the home: location of devices/appliances in the corners, on the walls, on the roof, and in the middle of a place (e.g. centre or close to the centre of a room).

Device Control

Controlling capability is provided to allow the user to perform a number of operations via the smartphone application. These operations include making a device on or off, both manually and by setting a schedule. Moreover, the user is able to lock/unlock objects in the home including door locks, gadgets, and lockers etc. The user can also set the temperature at which home appliance may operate such as room air conditioners, heaters, and geysers.

Device Monitoring

The framework offers monitoring the functioning of home appliances and other smart devices using an efficient algorithm. Monitoring can be performed by observing or measuring the energy consumption of a particular device, or a set of devices. Moreover, with this algorithm, the user will be able to get information on devices that are utilised more than others. In this way, monitoring and control features of the framework go side-by-side.

Framework Features

The designed framework is expected to provide the following features:

1. The ability of self-organising and self-configuring the setup. The user will have to do only the minimum to use the features of the application once the initial setup is done.
2. Device control through a gateway. The gateway also oversees the route between the devices to realise the communication to the end-user, in case direct communication to the gateway is not possible.
3. Support of device-to-device and human-to-device communication modes. Routing mechanisms will have to be utilised to incorporate the communication between devices. An algorithm will be designed to monitor and react to the need of routing between devices.
4. The framework will allow the use of multiple interfaces in case some devices have more than one interface. This will provide interoperability between different radio interfaces, whenever possible.
5. The framework will offer vendor independence such that all devices do not need to belong to the same vendor to function in the system.

A Glimpse of the Smartphone Application

Figure 2 shows the main capabilities that the smartphone application will have in the framework. The user will have the option to configure the network as per the need, initiate the localisation algorithm, and control and monitor the home appliances.

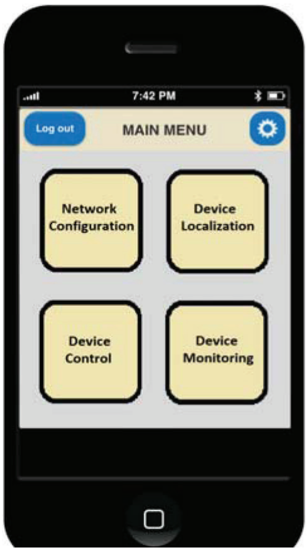

Figure 2. Glimpse of the Smartphone Application

Figure 3 illustrates a sample visual interface that the user will see when the user enters the device control or monitor functionality. Note that the map shows the location of devices that we are able to locate previously by running the localisation algorithm.

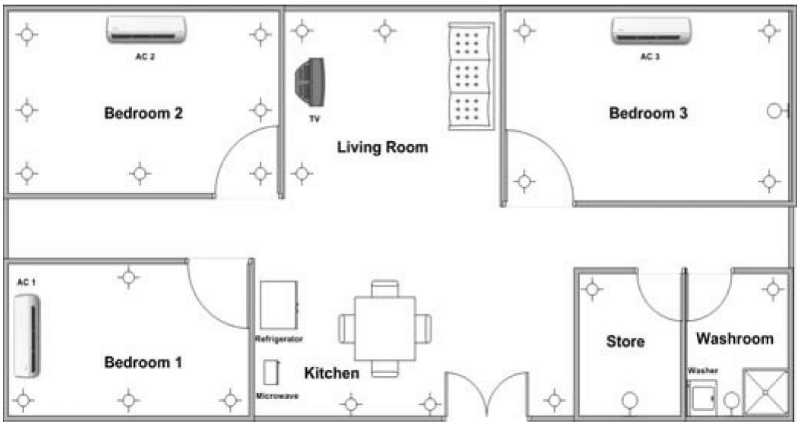

Figure 3. Sample House Map with the Localisation of Devices

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