

The 6th International Conference on Current and Future Trends of Information and
Communication Technologies in Healthcare (ICTH 2016)

Smart Safety & Health Care in Cities

Jabbar Al-Dulaimi*, John Cosmas

Department of Electronic & Computer Engineering, Brunel University, London, UB8 3PH, UK

Abstract

The emerging technology of Internet of Things (IoT) has become essential in several applications, more specifically health and safety products, and used by many growing organizations. The IoT has already enabled these bodies to develop a new network of intercommunicating objects of consumers' everyday life. Companies staffing many (potentially thousands) of employees may require hundreds of health and safety systems in continuous use. Building Service Managers, however, do not know which devices needs maintenance or replenishment and require significant amount of time to continuously check that their health and safety systems are maintained according to legislation requirements. The consequences of companies not meeting their health and safety obligations are serious and expensive if any of their employees are seriously injured as a consequence of the health and safety products not being in their original, immaculate order for use. Furthermore, insurance companies will refuse to pay compensation for injury to employees if it has been shown that the health and safety products are not in their original, immaculate order for use. Therefore, design and use an IoT based monitoring system to record the state of health and safety products within companies is an urgent response to market. This paper presents consequences and associated procedures for efficient application of the IoT.

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Peer-review under responsibility of the Program Chairs

Keywords: Internet of Things; Health/Safety Products; Cloud System; Wireless Hub; Sensor.

1. Introduction

The world enters new era of interconnection. With the coming of Internet of Things (IoT), the person's imagination comes true. However, there is more to the IoT than lifestyle development. It also includes a trade side,

* Corresponding author. Tel.: +44-7448578491.

E-mail address: Jabbar.Al-Dulaimi@brunel.ac.uk.

And many organizations are enquiring how they can benefit from findings in IoT applications and tools. The IoT enables companies to develop a new network of intercommunicating objects of consumers' everyday life. Using the analytics application of IoT, companies are able to reduce maintenance costs, avoid equipment failures and improve business operations. Furthermore, it interconnects the Things in order to exchange information to fulfill tasks for the users.

2. The problem and its solution

There are many papers on Internet of Things related to Health Care systems but there are no papers related to the management of health and safety products, with the exception of one paper which mentions that companies are also under pressure from clients, insurance companies, and regulatory bodies to become more transparent and technologies are increasingly being introduced into industrial workplaces to promote health and safety, prevent liability risks, and improve auditing and verification⁶.

Health and safety products are required by legislation to be available to employees of companies with more than five people and to be maintained so that they are always in an original, immaculate order for use. The problem is that companies that have thousands of employees also have hundreds of health and safety systems in continuous use and Building Service Managers do not know which devices needs maintenance or replenishment and require significant amount of time to continuously check that their health and safety systems are maintained according to legislation requirements. The consequences of companies not meeting their health and safety obligations are serious and expensive if any of their employees are seriously injured as a consequence of the health and safety products not being in their original, immaculate order for use. Furthermore, insurance companies will refuse to pay compensation for injury to employees if it has been shown that the health and safety products are not in their original, immaculate order for use. Therefore, it makes economic sense to design and use an Internet of Things based monitoring system to record the state of health and safety products within companies.

In this paper a monitoring system has been proposed to record the state of health and safety products within companies so that building services manager can more efficiently maintain them in an immaculate order for use. Nevertheless, this solution is not satisfied because it simply records the state of the systems and nothing else. There must be a central record of the usage and the state of all health and safety products in the company premises. As a solution to this problem, we use a cloud central record system, a central hub, analysis data system as well as sensor systems for the devices. As there are many employees involved in the maintenance of health and safety products in companies, a cloud solution is a good approach to solve this problem. Using analysis software in the cloud, it can manage the huge amount of data that is being produced. This enables the service manager to understand what are the problem health and safety product that need maintaining, what are his priorities in maintaining them and how he should schedule his maintenance workforce to keep them replenished and in good working order. This is an appropriate solution as it can automate the process of maintaining health and safety systems in companies. Consequently, they are maintained efficiently and comply with legislation.

3. Overall system operation

The role of Sales Manager is receiving and sending data between building service manager and building service store using a cloud. Healthcare Centre may have many health and safety products within its premises, as shown in the Fig.1. If any product needs maintenance, its sensor will send a signal message to the Cloud which records its usage through a wireless hub. The role of the Cloud in general works as a central storage and processor of data that can be accessed at any time and in any place with a less cost.

As shown in Fig.1. The cloud's role is to facilitate the sending and receiving of data between health care center, company organization and building service manager. The health care center informs the cloud of product installation and usage by communicating signals. If any product has been installed or used, it is routinely recorded on the Cloud. This information can be accessed by the sales office manager and building store manager to initiate actions to replenish the product with consumables. This information as well as the company database information of warehouse is then combined to establish a delivery schedule to replenish the consumable product.

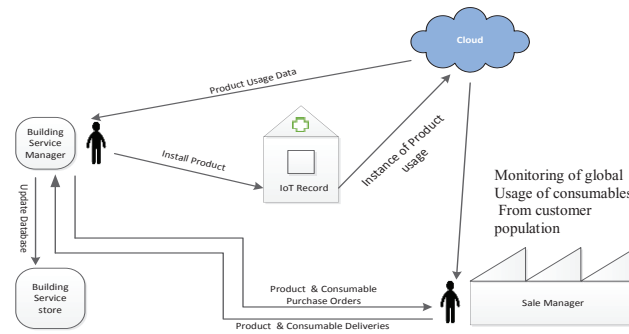


Fig.1. System operation diagram.

4. Layered system Design

There are many different functions in the deployment and management of internet of things systems and recent research has organized these into a six layered system, which is called Reference IoT Layered Architecture (RILA)^{1,2} and which consists of Application and Integration, Context Management, Thing Integration, Data Management, Device Management and Device Integration layers. In our research we adopt this approach and relate the functions required for a Health and Safety management system to this layered design.

The application integration layer links the user to the thing and can affect the system either on purpose or without its knowledge. Smart products often communicate with an external system via an application, which depend on a form of operating system. It can be seen as a service layer. The concrete architecture strongly depends on the use case for the thing under development, especially the rule engine & artificial intelligence (AI), which describe and achieve all of the rules essential for context assessment. This includes the objective and rules for creating the context situation and actions. The AI component might not have to be very developed for less intelligent things (e.g. a fire extinguisher). For things that collect context information from other systems these components will however have to be very well developed.

The context management layer defines the central business logic within RILA and is responsible for six tasks which are: Define the aims of the thing, consume the context situation of other things, produce the context situation of the thing, evaluate the context situation towards the aim, activate actions that support to accomplish the aim according to the evaluated rules, and announce context situations for other things.

The thing integration layer is responsible for finding other things and communicating with them. Once two things have found each other they have to start a registration system. This layer can evaluate the communication with the thing if it is possible to be joined with it. For this purpose, the context situation and action have to be compared. If the context situation and action is evaluated positively, the thing can inform the other thing. The context situations and actions are provided by the context management layer which must be communicated to other things. Thus the central component or the thing itself (e.g. auto-discovery network scan) can make the thing registration. These are supplied by the context management layer.

The data management layer can do only one possible operation, which is used as a central database that holds all data of a "thing". The data management might be a data warehouse within the system. The implementation of the data management layer thus strongly depends on the use-case for the specific thing.

The device management layer is seen as a control of the devices in the way that it knows which devices are connected to the system. It is responsible of taking device registrations and sensor-measurements from the device integration layer and links status changes for actuators down to the device integration layer. The information can be updated and stored when each change to a device's registration and incoming measurement data links from the device integration layer to the device management layer.

The device integration layer is responsible for three main jobs: connects all the different device types, consumes device measurements and communicates actions (on device level). The input of the actuators and the output of the sensors are defined by the protocol they implement. The device integration layer consists of three main components. First is a driver component which contains driver instances for every type of low level device known to the system

and also communicates different sensors. Second is the device discovery component which can be generated by two actions, one from the device management layer, which notifies this component to add a new device and the other by the driver component, which notifies this component in case a new device is added. Third, it is the device communication component which works as a bridge between the device management layer and the driver component. This component decides which driver is called when the device management layer addresses a device (see Fig.2).

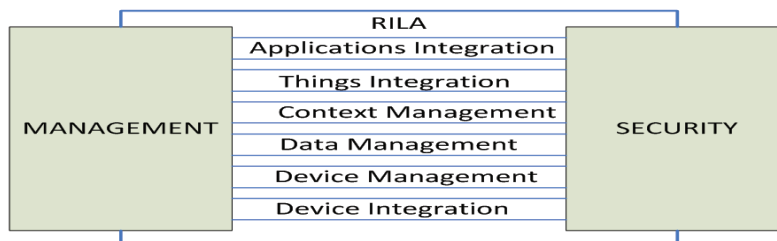


Fig.2. RILA Layers³

5. Device Integration

The different type of health and safety devices consists of first aid box Fig.3., fire extinguisher Fig.4, and earplug dispenser Fig. 5.

The first aid box is the most commonly used safety box in the workplace. The aim is to initiate notifications whenever the box has been used using a magnetic reed switch sensor. When the box is opened, it triggers off the sensor Fig.7, which indicates some of its contents have been used and may need to be refilled. The sensor attached to this product is able to be retrofitted to other products ensuring they can fit the majority of the health and safety products on the market today. The sensor electronics is powered by a rechargeable lithium-ion button battery, whose charge state is monitored by additional electronics. This battery has special requirement of not being affected by the number of the times it requires to be recharged with a low weight and little leaking when it is not used.



a



b



Fig.4. Fire extinguisher

Fig.3. First Aid Box; (a) outside shape,

(b) inside the box.



Fig.5. Ear plug Dispenser



Fig.6. First-Aid box end point

The fire extinguisher can be retrofitted with the first aid box sensor so that whenever it is lifted off its plinth it triggers off the sensor. However, the ear plug dispenser cannot be retrofitted with the first aid box sensor. It requires an imaging sensor to record when the number of ear plugs fall below a certain level (see Fig.5). The system diagram is shown in Fig.7.

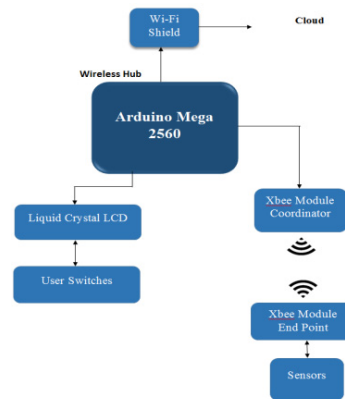


Fig.7. System flowchart

The Xbee module, which is based on the IEEE 802.15.4 communication standard for low power, low maintenance wireless networks, is used to communicate between the sensor and a central hub and was configured for the ‘Star topology’. This consists of having one main coordinator for the central hub unit with multiple end devices for the relevant sensors of the project. Different Destination Addresses were configured for the xbee end devices to allow multiple devices. On power up, the hub samples each of the xbee end devices of detection every 1 second.

6. Device Management

Device management requires that each Health and Safety product is uniquely identified, so that packets arriving from the Wireless Network can be associated with the product that had transmitted it. Each device end point is configured so that it is uniquely identified by a Source Address defined in the Received Data Frame, as shown in Fig.8.

Table 1. Example of data assumption stored on cloud from fire extinguisher

Customer Number	Fire Extinguisher number	Used Date and Time	Closed Date and Time
005	03	13.11.15 09.00am	13.11.15 03.15pm
		14.11.15 10:30am	14.11.15 16:00pm
006	05	14.11.15 2.00pm	14.11.15 17.30pm
		15.11.15 10:00am	15.11.15 11:40am
007	07	16.11.15 16.11.15	16.11.15 16.11.15
		14.00pm	16.30pm
070	19		
086	24		

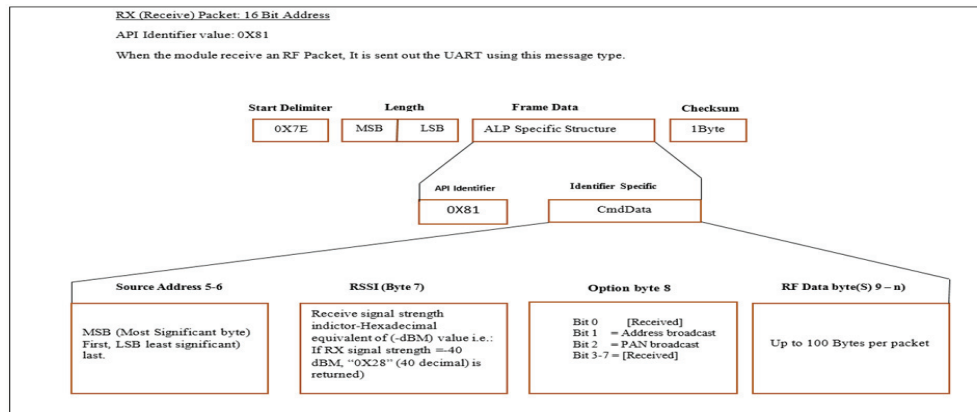


Fig.8. Received data frames structure

7. Data Management

The data format from any sensor consists of: organization id, hub id, end-device id, on/off state, lithium-ion button battery charge state, time, date.

Data recording on the Cloud is stored on a unique file for each device, which can be inspected by monitoring tools, namely: a location tool that identifies the location of the organization and a sensor reading tool that monitors the state of the sensor over a period of time.

Data Sorting: data is collected in a random order and random times and needs to be sorted by organization, hub and end-device before it can be analyzed. Data sorting function performs this sorting of data into files in folders.

8. Context Management

This defines how frequently we should collate data, how the data should be analyzed e.g. how many times does the first aid box need to be opened before someone checks it, how many times does the fire extinguisher move before someone checks it, etc. A magnetic sensor records how many times the box has been opened and this occurrence indicates that its contents need to be checked with different levels of urgency depending on the number of times that it been opened and closed to check that the contents are complete or whether they need to be refilled.

This also defines the possible sequence of actions required as a result of this analysis. The fire extinguisher's weight can either be measured or a simple Reed switch attached to it and triggered whenever it is lifted off its plinth so that its usage can be determined.

The ear plug dispenser can either incorporate a cheap laser beam and photo sensor to determine if number of earplugs has dropped below a certain level or it can use cheap camera to achieve the same result.

Typical data usage results for the fire extinguisher are shown in Table.1. Similar data can be obtained for first aid box and ear plug dispenser.

In our system we divide the context management into consumables data management and battery management.

Consumables Data Management: This analyzes the recorded data to determine which Health and Safety devices require inspection for possible replenishment.

Each company contains identify address, hubs and health and safety devices such as first aid box, fire extinguisher, ear plug dispenser. Each one of these devices contains identify address as well as a sensor. The sensor electronics is powered by a rechargeable lithium-ion battery, whose battery charge state is monitored.

The hub holds a record of usage data and battery charge state collected and a clock. When the health and safety devices send data to the hub it is accompanied by an identification number (i.e. device1, device2 or device3). The clock is used to obtain the time the data has been sent (i.e. hours, days, weeks or months. The hub keeps a record of

the frequency of use in a time-period of a device. The hub keeps a record of the maintenance threshold. i.e., this defines how frequently it is used before we act to replenish it and the battery data is important thing charge state is motive by electronic Then, all this usage data that have been collected by the hub and battery charge state will be regularly replicated in the cloud to know which device needs to be replenished. The cloud will be monitored by the building service manager to identify which health and safety products needs to be replenished.

Measuring the total weight of the consumables in a first aid box will allow the building services manager to avoid going to a box that has been opened but no consumables have been used i.e. the box door sensor has recorded that it has been opened but the total weights of the weight sensors on the shelves have shown that there has been no weight change. The total weight of the first aid box cannot be measured directly because the box is fixed onto the wall using screws. However the total weight of the box can be found from the total weights of consumables on each of the shelves.

The first aid box can enclose five internal shelves on supports which can measure the weight on each shelf using piezoelectric weight sensors in each side of the shelf supports. A first aid box can contain all sorts of consumables health care items such as plasters in a variety of different sizes and shapes, small, medium and large sterile gauze dressings, at least two sterile eye dressings, safety pins, disposable sterile gloves, tweezers, scissors, alcohol-free cleansing wipes, sticky tape, digital thermometer, skin rash cream, antiseptic cream, painkillers such as paracetamol, aspirin and distilled water for cleaning wounds eye wash and eye bath for which the total weight can be measured. Any changes in total weight of consumables in the first aid box can be measured by the piezoelectric sensors of the shelves, which can be measured using analog to digital converters on the hub, which records all its details (first aid box id, equipment id and sensor id, weight and battery charge) on the cloud⁵. Analysis software periodically compares the current weight and the original weight recorded on the cloud and if there is any change of the equipment's weight, it will send a notification to the manager who can make the decision on what action is required.

The fire extinguisher is another device which is required to ensure the achievement of the general safety requirements within companies. Embedding piezoelectric sensors in the fixed base of the fire extinguisher allows us to measure the weight of how much fire quenching agent is contained in it. When the extinguisher is returned back to its fixed base, the hub records the weight of the fire extinguisher using an analog to digital converter and this data is sent a signal to the cloud which keeps a record all the data related the device, i.e. (current weight, device id, device place, device weight etc.) Analysis software periodically compares between current weight and original weight and if there is any change due to its usage, leaking and miss placed a notification is sent to the building services manager who can make the decision of what action is required.

Using an image sensor in a micro digital camera beside a laser light that is affixed at a certain level of the other side of an ear plug dispenser is considered to be a suitable way to measure the number of the ear plugs in it in light and dark environments. The procedure of its working is by sensing the laser light with the image sensors of the micro digital camera when the storage of the device reaches to the sensor level. When the laser light is transmitted through the empty level to the camera, the camera records an image of the storage. This image is recorded, analyzed and the state of the ear plug dispenser is recorded on the cloud by the hub whose record registers all the data of the equipment with a new time and date of the recording. Analysis software periodically checks the state of ear plug dispensers and sends a notification either by an SMS message, an email or a website informing the building services manager about the remaining amount of earplugs in the dispenser so that he can make the decision of what action is required.

Battery Management: There are many methods to read and record data battery status by using sensors. One of these methods is to make a reading after switching OFF the device (end of usage). The sensors generate a signal and send it to the hub. This signal represents the energy of the battery (its current reading). The current reading declares the threshold. The sensor sends this reading status to the hub that has a data record and a clock to print the date and time. If the threshold is low, the alarm will be set to ON. The hub connects a copy of this reading to the cloud that begins to compare the results between the current reading and threshold. Analyzing the result, the cloud sends an alarm or a target to the manager through three ways. It either sends a SMS message, an email or records it on a website. The SMS has a short alarm to notify that details need to be inspected, while the email has more details about the situation. The website has more explanation of the details such as the device number, the place, the energy

situation, the company name and the floor level etc. The state of the energy level determines the situation. The system sends an alarm SMS message to the manager who has the authority to enter the management system by using a username and a password. The manager observes all the details regarding the situation by selecting the item. According to the importance of the details, the manager can decide how quickly the problem is required to be solved and which procedure can be used to remedy it i.e. recharge or replenish. This is recorded in a maintenance schedule. The manager sends the same alarm SMS message to the available maintenance engineer who is responsible to fulfill the recharge or replenish procedures according to the maintenance schedule. This message can be sent either by an SMS message, an email or a website to the maintenance engineer automatically or manually. It is sent manually to ensure the arrival of the commands and the alarms. After the procedure is completed, the sensor sends a new reading of the battery status to the cloud by the hub. The cloud sends a new data to the manager informing him that the alarm status is off.

9. Application Integration

Using various different sensors (some being magnetic and others using micro-digital camera and other methods) with a smart access to the remote cloud to monitor their sensors have become the most prototypical products in the health and safety sector today. Its task is to inform the building services manager of any usage of the health products and request attention to the specific products for replenishing through replenishment from stores or purchase of new consumables. Therefore, it makes sense for a health and safety products management system to be interfaced with individual organization's store management and purchasing systems.

However, it also makes sense for Seton-Brady Corporation to monitor the usage of all its client organizations' usage of health and safety consumables in the cloud so that it can ensure that it has sufficient stocks available to meet its clients purchase orders and if it does not contain sufficient stock to seek to replenish them by placing orders with its purchasing department. This data can also be accessed by the sales manager to determine global trends in usage of health and safety consumables over time.

10. Conclusions and future work

The Seton-Brady Corporation can adopt low-cost and retro-fittable sensors to each of its health and safety products in its product line with the aim is to create a system, which has the possibility to monitor the availability of various products at various levels to achieve a crucial role in meeting the regulatory requirements of always being compliant. This will be the first universal piece of monitoring equipment to reach the health and safety products' market. The future work is to collect the data from the workplace and store the data in the cloud such as, device quantity, devices types. As a result, each device has Device id, Shelf ID, and Battery power state. This data will be stored by various hubs in the cloud including the date and time when the device was used. Thus, a model of the system will be built which will include models of many health and safety devices in the field statistically generating user behavior. This large scale data will then be analyzed using an artificial intelligence system to help the facilities manager make decisions related to how to manage the health and safety products in the field that he is responsible for.

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