Sensor Technologies using ZigBee and RFID within the Cloud of Internet of Things in Healthcare Applications

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Abstract— The paper discusses the emergence of Smart technologies of ZigBee, Radio Frequency Identification (RFID), Wireless Sensor Networks (NSN), Internet of Things (IoT), Cloud Computing and Cloud of Internet of Things (ClOT) in terms of providing competitive advantage and improved service quality for Knowledge Management Systems (KMS) in Smart hospitals. A 5-stage integrated model is proposed which indicates the potential to provide real time healthcare informatics in terms of patient monitoring, tracking, and asset management. The visualisation layer linked to knowledge layer of the model can be used to provide Decision Support Systems (DSS) in real time. The system can also be linked to digital imagery and used to provide additional security such as ‘lock downs’ and automatic video streaming across the hospital complex in terms of monitoring and tracking facilities particularly in dealing with vulnerable patients and/or maternity wards applications etc.

Keywords— Smart technologies, ZigBee, RFID, IoT, ClOT, Decision Support Systems

I. INTRODUCTION

This paper outlines an approach to using sensor technology as a service, the integration of sensor technology and internet services, and methods of communication between them. Smart technologies have become increasingly popular in the field of object tracking and location due to their promising capability in different environments. At present, coal mine real-time Management Information Systems (MIS) based on radio frequency identification (RFID) technology, ZigBee technology and Internet of Things (IoT), are being used to track and locate objects in real time. The term ‘real-time system’ refers to systems that provide an automatic identification and collection of location information. A sensor device is attached to objects that are interconnected to exchange services, which in turn are integrated the organization’s computing network[1]. IoT is a new concept that is closely related to and motivated by sensor technologies; it is founded on environments which produce real-time data and support the monitoring and control system in different locations. RFID systems can be used to record and receive data through electronic devices using radio frequencies to provide several automatic services such as data management, control and device management. ZigBee is used as a wireless protocol to provide communication between various sensor devices and applications that require reliable and low data rate transmission, low power consumption within a comparatively short distance and a longer battery life [2]. The collected information is can be made available on Cloud Computing to provide remote access.

There are many reasons to study the use of sensor technologies in a healthcare environment such as time factors and the potential for this technology to be used in different ways within operations management. The information that derives from these devices will challenge the traditional approaches to data management and assist with the emerging prototype of large data in providing a more effective management system. The information received from the sensors will be used to build a framework and design for a Management Information System (MIS) for healthcare. The technologies are classified by their functionality in this framework. The network framework focuses on the system structure and data flow in the system, and the relationship between each component. A structured interview process with two senior hospital administrators, the Director of the Hospital and the IT Director, was conducted in one of the main hospitals in Medina in Saudi Arabia. The process included providing an overview of the proposed concept and outputs to seek advice and solicit opinions on the value and practicality of the work. In this section an explanation of the motivation and concept has been outlined. The rest of the paper is structured as follows: inSection2 Sensor and Wireless Sensor Networks (WSN) are discussed, the Internet of Things is explained in Section 3; Section 4 considers the Cloud Computing, while Section 5 discusses the Cloud Internet of Things and presents the proposed system, and Section 6 concludes the paper.

II. SENSOR AND WIRELESS SENSOR NETWORKS

The wireless sensor network (WSN) concept is based on connecting the sensor node with the ability to communicate wirelessly and automatically transmit and receive data between users and the system[3]. Smart environments have become a challenging issue because many people want to use cheap technology to benefit their everyday lives. WSN’s have become an indispensable component of our daily lives in term of monitoring and controlling environments. WSN’s consists of fairly low-power nodes which are connected wirelessly. WSN’s are
used to enable novel and smart solutions, or as a new method for information gathering across a variety of enterprises, and can be widely used for military purposes, transportation, business, health-care, industrial automation, and environmental monitoring[4]. WSN’s have become essential in providing a solution to customer demands and offer a cost-efficient managerial system which can reduce human error. In hospitals Smart environments are often required in different applications such as tracking patients and staff, management and status checking of medical equipment, supply chain management and the tracking of product lifecycles. Real-time monitoring and control systems are based on sensing techniques, and often require communication technologies that are used to identify objects automatically without any manual involvement or use of a computer. WSN’s are networks that include sensor devices to sense a physical world [5].

Radio Frequency identification (RFID) refers to an automatic identification technology which is used to achieve the automatic identification of stationary or moving objects without any manual intervention and can work in a variety of environments [3]. RFID systems with wireless sensor networks offer a smart environment to enable the system to detect and record contextual changes in different locations. To ensure data integrity, RFID technology will be combined with WSN sensors to monitor the information from all directions[3].RFID can be used for monitoring object movement and asset tracking. Using a combination of RFID and WSN, an intelligent wireless sensor monitoring system can be built through which the object will be located and be detected; information gathered from sensors such as temperature and humidity will also be uploaded automatically to the system. RFID has the ability via ‘gates’ or ‘choke points’ to make readings from near field communications (NFC <0.5m), close conditions (11m), or far conditions (>100m), which allows RFID to work with WSN in different environments depending on the application from NFC, and whether passive or active RFID tags are used [6].

ZigBee is a wireless communications standard, used between a large numbers of consumer devices in commercial applications. ZigBee is designed for wireless personal area networking (WPAN)[7] or WSN, to enable computers and other devices to connect over a single network using radio communication (RF). Connecting ZigBee products such as thermostats, alarms, lights, and utility meters to the network or Internet enables these devices to collect and control specific information and upload it to the system.

Cloud Computing refers to data storage, data-processing needs applications, platforms and infrastructure, and access to shared computing resources over the Internet[8]. The integration of WSN and Cloud Computing can be used to provide WSN applications on Cloud Computing. The main reason for using Cloud Computing with WSN is to increase and improve the capacity quickly without the need for additional investment in infrastructure, while also making it possible to control the capacity quickly and efficiently[4].

III. INTERNET OF THINGS

Internet of Things (IoT) is a new concept referring to connecting smart objects together over the Internet. IoT means everyday objects are identifiable, readable, recognizable, addressable, and controllable via the Internet[9]. IoT thereby enables communication between people and things, things and things and people and people in a secure manner[10]. IoT is widely used in many environments such as military applications, transportation, business, healthcare, industrial automation, and environmental monitoring real time. The significant development of IoT is opening new opportunities for service providers to connect the billions of sensor devices that can communicate, compute and potentially activate devices. Service providers can use IoT to link sensor devices to the internet for different purposes such as monitoring medical staff, collating information, storing, combining, and aggregating data, environment lighting control, water systems, fire sensors and to contribute to smart buildings such as using green technology in building control[11]. For healthcare environment cases, IoT can be used with patients who need regular health checks such as monitoring of temperature, blood pressure, weight and heartbeat, or for those who are unable to visit doctors or require medical support at home. Several IoT applications can be used in the healthcare environment for medical monitoring services in different locations. IoT technology is beneficial in creating smart networks for connecting modern measuring devices at anytime and anywhere to assist and support the increasing number of elderly patients[12]. The demand for healthcare services is increasing in the UK, Europe and the Middle East North Africa (MENA) region with medical staff working 24hours a day, 7days a week, and it is becoming increasingly difficult to respond to all the demands and financial constraints on healthcare services.

IV. CLOUD COMPUTING

Cloud computing technology designed by the National Institute of Standards and Technology (NIST) to increase the capacity of shared computing resources in a rapid and secure way in various locations around the world. Cloud computing is useful because it adds new capabilities to the existing system without the need to invest in new infrastructure, train new personnel, or license new software; it needs only minimal management input or service provider interaction. Cloud computing is characterized by three main entities, according to the National Institute of Standards and Technology (NIST): Software-as-a-Service (SaaS); where software is provided as a service to customers according to their requirements, and this enables them to use the services offered by Cloud hosting provider; Platform as a Service (PaaS); where customers are provided platform access, to enable them to upload their own applications or software to the cloud; and Infrastructure as a Service (IaaS); where customers receive rent processing, storage, network capacity, and the
ability to manage their own operating systems, applications, storage, and network connectivity[13,13]. The most important benefits of Cloud computing are the large reduction in costs and time compared with conventional methods, for example, where large servers to keep user information secure become unnecessary. Cloud computing systems can provide the accessibility to run a program on many connected computers, enabling a user to access an organization’s data from anywhere, at any time, through various devices such as computers or mobile phones. Cloud computing is responsible for ensuring the continuity of service which is important to the management within organisations. The main disadvantage of cloud computing is the possible loss of information due to connection failure or power outages during its use, making it crucial for users to have their own backup servers to secure their data.

V. CLOUD OF INTERNET THINGS (CIOT)

With the increasing population and the growth in IT products, which provide services all over the world via the Internet, monitoring different objects in real time is becoming ever more difficult. Cloud of Internet of Things is a concept combining technologies connected via the Internet to provide services in different places and environments in real-time. Cloud of Internet of Things enables sensor technology as a service in real-time over the Internet. This system is concentrated by Cloud Computing, modern data communication and industry process data sensor technologies[14]. The services provided include monitoring systems used in the field of healthcare, transportation, agriculture, public places, border control and drug control etc. The system depends on the data being collected from the sensor and transmitted to a MIS for action to be taken. ZigBee and Wi-Fi technology is used to communicate between sensor devices, data collection, transmitting equipment, and the MIS system which is responsible for the deep data analysis[14]. Cloud of Internet of Things can be used in database design, integrating the Cloud and the Smart Hospital Information System, which will use real-time sensor technologies to collect information from many sensor devices connected to the hospital system in different locations and business process areas via Internet services to provide a healthcare service available in real-time[15]. Using a Cloud of Internet of Things system, hospitals could electronically store all patients’ records including documents, videos, and images enabling authorized users to access patient data and provide a patient focused service. Also, service providers could use Cloud of Internet of Things to exchange data between hospitals and themselves in real time quickly, and at low cost.

A. Proposed System

The proposed system is a real-time data collection service which aims to provide the best real-time decisions. The components of the proposed system area Data Processing layer, a Data Integration layer, a Cloud Computing layer, a Network structure, a Knowledge Reasoning layer and a Visualization layer, as shown in Figure 1.

B. Data Processing layer

The first layer, the Data Collection Layer, is sensor-based technology responsible for collecting real-time data from different sources. The data will be captured from physical world devices which have the ability to receive and transmit data wirelessly. In this layer there are three feature blocks: the Identification, Location, Video records and Other Data Acquisition. The technologies used for the purpose of identification and locating technologies in this layer are listed as RFID, ZigBee, NFC, barcode technologies and digital cameras and most of these are used in proven commercial/ security industry applications. These technologies are used in object/item identification and location: the objects required to have ‘tag(s)’ and a ‘receiver’ as the two main components to track and identify the location of objects. The real-time system requires an inexpensive node or tag attached to the embedded object that enables it to be tracked or monitored by the system. The receiver which reads these tags is deployed at a designated location, where it can easily receive the wireless signals from these tags and the system [16].

C. Data Integration Layer

The second layer is the Data Integration layer, which is responsible for the organization, translation, rationalization, copying and storage of raw data from the Data Collection Layer. Data from multiple sources will be processed and integrated into the Data Integration hub. The process of integration includes three types of technologies: RFID databases, ZigBee databases and Digital Images/videos. The Data Integration Hub is the main storage in this layer, where all applications and software from web pages to smart mobile phone applications are stored. However, the Cloud Computing function used increases the difficulty and security risk at the same time. Cloud Computing is used for distributed data and data warehousing to increase the capacity of
shared computing resources and enable data collection from multiple database systems through the Internet as the basis of the Online Analytical Processing (OLAP) function[17]. Cloud Computing holds data for longer periods to enable access from different locations around the world.

D. Cloud Computing Layer

The third layer is based on Cloud Computing technology which is used to increase the capacity of shared resources provided by data collection in a rapid and secure way through the Internet. This layer greatly reduces the cost and time of storing data compared with conventional methods, as there is no need for a large server to keep user information secure. This layer can provide the accessibility to run a program on many connected computers enabling the user to access the organization’s data from anywhere, at any time, through various devices such as computers or mobile phones. The network access can be self-service [18], the service available in real-time to support different e-application infrastructures. This layer is only a Platform as a Service (PaaS); customers are provided platform access to enable them to put their own applications or software on the Clouds.

E. Network Structure Layer

The fourth layer is the Network Layer which provides the functional and procedural means of transferring multi-length data structures from different sources on one or multiple networks to a destination hub. The Network layer contains several technologies which provide the functionality of a structured data exchange using a computer network.

These technologies can work independently or be integrated with each other, and include Cloud Computing, ZigBee, WLAN, Cellular Mobile Network and PANs (Personal Area Networks).

Cloud computing provides remote access, and WLANs (Wireless Local Area Network) or mobile phone networks will be used to connect data-collection devices and the data hub. Internet services and Cellular Mobile Networks provide mobile access features that can be accessed anywhere, used over large-scale areas, and can link sites over a large geographic distance of national size. ZigBee is a wireless communications standard, used between large numbers of consumer devices in commercial applications, and has a low power output with larger coverage.

Ad-hoc Network and ZigBee technology needs to be connected and for nodes to be installed consequently, the cost is relatively higher and it is unsuitable for national-scale applications, being more appropriate for a manufacturing plant. Because of their limited coverage, PANs and WLAN are typically for personal use, and they are usually affected or interfered by metal objects. WSN (Wireless Sensor Network) is a communication standard using radio frequency (RF) to communicate between computers and other devices[16].

F. Knowledge Management Layer

The fifth layer is the ‘Knowledge Management’ layer, which is responsible for processing the huge amount of data and information using knowledge to achieve the objectives of companies. This layer provides logistical support, guidance for operational staff support and collection arrangements, and incident solutions. It is based on information and data gathered from the lower layer, and adopts a knowledge-based technology with rule-based reasoning. The collected information is processed and the reasoned result sent to the higher layer. The rule-based Knowledge System is the most important part in this layer, assisting in, for example, a real-time monitoring and management system for patient and staff movement, pharmaceutical drug administration to patients, patient check-ups and the location of specific equipment or assets in the hospital. In this layer two components are used: a knowledge base which stores the domain knowledge used in making a rule, and the fact base, which stores the current situation and equates to the main database in the lower layer. A reasoning engine is responsible for providing the best results by applying the domain knowledge to the current situation.

G. Visualization Layer

The visualization layer provides the visual representation and organization of data once it has been translated to make it accessible to the user community, for example through creation of text, tables, pictures and diagrams to provide a Management Information System for healthcare. This layer presents automatic identification and collection of healthcare information systems and user best-solutions for real-time remote sensor data access, processing, visualization, or for a different application for the same purpose. This explanation is one of the features of this layer, and uses the explanation mechanism of the Knowledge-Based System (KBS) to explain the results and the reasoning procedure used in a user-friendly and easily understandable format. The result will be translated and displayed on a terminal device, which enables communication with a computer. Depending on the user device, for example computer screen, phone or smart device, a short message or web pages may be displayed. Additionally, this layer uses a Human-Machine interface function to communicate between users and the system. This function receives a command from the user community, sends it to the system, and presents the feedback to users.

The Visualization layer and Knowledge Management Layer are the main features for achieving system functionality, and make a system usable in many different cases, which is the core characteristic of this system. The Cloud Computing layer provides storage and opportunities for sharing resources between users. The Network layer provides the functionality of a structured data exchange using a Computer Network. The Data Collection Layer and Data Integration Layer are used for data collection, storage and management[16].
H. Possible Applications of Cloud of Internet of Things

In this system, the upper two layers can be changed or modified for use with different application and domain areas, but the lower two layers have to be redesigned based on the application requirements, as shown in the following examples[19]:

1. **Hospital:** ZigBee/RFID tags are attached to identify, detect, and locate patients, staff, and equipment to provide continuous monitoring inside and outside of the hospital.

2. **Air shipping companies:** ZigBee/RFID tags are attached to identify, detect, and locate customer consignments and to provide continuous monitoring in real-time.

3. **Hotels:** ZigBee/RFID ZigBee tags are attached to identify, detect, and locate equipment and staff to provide continuous monitoring inside and outside of hotels.

4. **Shops:** ZigBee/RFID ZigBee tags are attached to identify, detect, and locate a product, locate shopping carts, and provide continuous monitoring within shops.

5. **Police:** ZigBee/RFID ZigBee tag are attached to detainees and visitors to provide continuous monitoring in police stations.

VI. CONCLUSION

This paper proposed a Cloud of Internet of Things (CIoT) system, which is not currently present in the Smart environment, so that objects can be identified and located in real-time. The ZigBee/RFID ZigBee tags must be attached to the object. The proposed system was designed and developed to create a versatile Smart environment for healthcare purposes. The Cloud of Internet of Things will collect, manage, process, store, and provide visualization using a user-community driven approach.

This system can be used to provide a feasible and flexible visual interface to provide different strategic and operational decision support views for different end-users and also provide ‘what-if’ analysis in real time. Structured feedback from two senior Hospital Directors (Administration and IT) in one of the main hospitals in Medina in Saudi Arabia was used to provide advice and solicit opinions on the value and practicality of the work, and this provided encouraging feedback for the design of the system.

VII. ACKNOWLEDGEMENT

The authors would like to thank the assistance of Lynette Atkins in the production of the paper.

REFERENCES


[16] L. Zhang, A S Atkins H Yu and N Alharbe, “Patient/Infant Tracking and Management Application System using a Combination of ZigBee and RFID Technologies,” SIRT - Journal of Engineering,
