Use of Cloud Computing with Wireless Sensor Networks in an Internet of Things Environment for a Smart Hospital Network

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***Abstract*—In a hospital healthcare monitoring system, it is necessary to constantly monitor object movements. Wireless Sensor Networks (WSNs) represent a significant technology for collecting important and varied information from users and their environment. In addition, the use of emerging wireless sensor technology has become a significant element in providing next-generation healthcare services in real-time. The emerging technologies ZigBee and Radio Frequency Identification (RFID) are used to collect the data in real-time. Smart objects are universally becoming Internet Protocol (IP)-enabled, e.g., in personal health devices and home automation, industrial automation, smart metering and environmental monitoring systems. The recommendation of IoT6 to exploit the potential of IPv6 connection standards will help overcome the current disadvantages and fragmentation of the Internet of Things. In particular, these features provide interoperability with Cloud Computing, mobility, and supply of information between heterogeneous smart object components, services and applications. The paper indicates that using RFID and ZigBee sensors can provide real-time tracking of objects (patients, staff and equipment) and monitor their movement throughout the hospital.**

Keywords-Smart Patient tracking and monitoring; IoT; IoT6; IPv6 ;ZigBee; RFID; Cloud Computing.

I.INTRODUCTION

In recent years, information technology helped us changing our way of life and work through new methods of communication; this has contributing to Gross National Product (GNP) growth with reduced risk and improved users and customer satisfaction. The increase in competition between companies that provide and produce smart sensor technologies, which cover large areas to meet rapid changes and users' needs, has contributed to competitive advantage in location based services. The number and types of sensors used are contributing to numerous different applications, such as location based services, building environmental control and supply chain management, etc. Studies show that wireless sensor network industry is expected to increase up to 43% every year [1] and a predicted market share £2.3 billion by 2017 [2]. A smart sensor-based Cloud Computing system is composed of several sensors based on top of the physical wireless sensors and data collection layer, which have the ability to receive and transmit data automatically and wirelessly by users based on application demand [2]. The integration of Internet of Things (IoT), sensor technology and Cloud Computing is aimed at overcoming resource constraints as it enables different networks to cover large geographical areas so that they can be connected and used by several users at the same time when required [2]. In addition, the recent emergence of Cloud Computing and sensor awareness of infrastructure-architecture methods, service-oriented architecture, software delivery and development models [3] are also contributing factors to a smart environment. In order to provide real-time healthcare informatics, hospitals need some type of monitoring system to track objects and medical equipment in which security, efficiency and safety are ensured, with reduced occupational risks. The key feature of the smart monitoring system is to provide identification of users and objects, so that an adequate service customisation can be obtained. Accordingly, in this paper, a framework of integrating Cloud Computing technology and wireless sensor technology within the healthcare environment is proposed. The purpose of this framework is to apply the ever-expanding sensor data to our community-centric sensing applications that can be used as a real-time service in the Cloud. Several techniques can provide this framework with the ability to receive and transmit data automatically and wirelessly to multiple users. Since the entire network is dynamic, it can be used for exchanging information, smart identification, locating objects, and monitoring and tracking objects.

The paper is structured as follows: Section II describes the state of the art. Section III describes Cloud Computing. Section IV presents the wireless sensor networks. Section V describes the Internet of Things. Section VI deals with the use of Cloud Computing and IoT on healthcare. Section VII describes the proposed framework. Finally, Section VIII concludes the paper.

II.STATE OF THE ART

Currently, there is no automatic healthcare tracking and monitoring system for patients and asset tracking in Saudi Arabia, and many hospitals still rely on manual operation to collect the 'object' data. The healthcare systems in Saudi Arabia are not operating in real-time and this result in the hospital staff having difficulties in obtaining up to date information. For example, a relative cannot receive any help in real-time from the staff regarding patients status after an operation. Using emerging technologies such as RFID and ZigBee sensors which automatically scan and use non-contact and non-intervention for tracking objects. Users will be able to receive real-time information and visualization of objects such patients, staff and equipment location throughout the hospital which will improve the management information systems and provide more effective decision support systems [4] [5][6].

III.CLOUD COMPUTING

Cloud Computing technology was designed by the National Institute of Standards and Technology (NIST) [7] 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 [7] is the technology of sharing resources and data collection with users through the Internet, and it can also offer self-service network access [8]. The services which Cloud Computing provides to users are based on resources through virtual servers which the user can access regardless of their location or any detailed specifications [9]. The radical stage of Cloud Computing is the shift from mainframe computers to client/server deployment models, and it covers elements from grid computing, utility computing and autonomic computing [3]. Research shows that the Cloud Computing industry is currently worth £41 billion globally, and this is expected to grow by £10 billion per year, demonstrating a significance to the global economy which cannot be underestimated [10].

A. *Cloud Computing Service*

Cloud Computing technology services are used to support a variety of technical functions. The services provided by the Cloud are divided into three service models [7], Software as a Service (SaaS), Infrastructure as a Service (IaaS) and Platform as a Service (PaaS).

- *Infrastructure as a Service (IaaS):* This service uses the Cloud for management and continuous infrastructure usage. Users are able to access elements of the computing infrastructure through Internet technologies, and can use the processing power, storage mediums and required network components provided by the service provider, for instance IaaS Amazon, S3 and EC2 [11].
- *Platform as a service (PaaS):* This service allows users to create their own development environment or platform to run applications as a service on the Cloud, for instance PaaS Microsoft's Azure Platform, Google's Apps Engine and the Force.com [11].
- *Software as a service (SaaS):* This service is a model where an application is hosted on the Cloud, and the applications are provided by the service provider as a service through the Internet. Rather than buying the software and installing their own systems, users rent the software through a pay-per-use arrangement. Examples include SaaS, Salesforce and Google Docs [11].

In addition, there are different deployment models for providing Cloud services to enterprises, which include public, private and hybrid [7] [11].

B. Cloud Computing Benefits for Healthcare Applications

The use of Cloud Computing offers various possible benefits to users such as a reduction in waste of both information system resources and power, an increase in data centre efficiency and operation rates, and lower operating costs [12]. Healthcare applications based on Cloud Computing take advantage of the Cloud Computing environment which provides the following benefits to patients and care providers [13][14]:

- *Patient Privacy & Security:* The expertise afforded by the Cloud service provider offers enhanced security (Privet Cloud) to prevent leakage of sensitive healthcare data and processes.
- *Dynamic Sensor Data Rates:* The scalability of Cloud architecture allows for non-deterministic varied data flow collection.
- *Global Access and availability:* Cloud deployment models provide the system with globalised access.
- *Disaster Recovery, Reliability, and Redundancy:* Redundant Cloud architecture allows reliability of data security and processes.
- *Economical System Usage:* The Cloud's service model provides economical resource provisioning and usage.
- *Outsourcing Expertise:* A remotely managed Cloud service allows expertise of the system to be outsourced.
- *Scalability:* Resources for dynamic data flows are guaranteed, any time anywhere on real-time via the Cloud's elasticity.

The most important benefits of Cloud Computing are the large reduction in costs and time compared with conventional methods, for example, where large companies use server farms to keep user information secure become unnecessary as the Cloud offers the economy of scale and would also be the responsibility for the service provider. Cloud Computing systems can provide the accessibility to run a program on

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many connected computers, enabling a user to access an organisation'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.

IV.WIRELESS SENSOR NETWORKS

Wireless sensor networks are used as novel and smart solutions for information collection via the radio spectrum of different applications, such as transportation, business, healthcare, industrial automation, and environmental monitoring [15]. Collecting patient physiological indicators using multi-channel high-frequency wireless data transmission can enhance a hospital's modern information management system to create a real-time health monitoring system. Wireless sensor networks have a big advantage in term of deployment as sensor devices are small and low-cost and can be used anywhere [16]. In order to build a Knowledge Management System (KMS) for smart hospitals the emerging technologies ZigBee, Radio Frequency Identification (RFID) must be used to collect the data in real-time for use later in Decision Support Systems (DSS) applications. RFID is an automatic identification technology offering a solution to the identification of things by assigning a tag with a unique number, which is used to retrieve object information from the application database [17]. RFID technology can be used in a healthcare environment, which can enable the automating and streamlining of safe and correct information such as patient identification, tracking, and processing important medical equipment [18]. Components of a typical RFID system are one or more readers, antennas and tags, which can be active, semi-active or passive. RFID tags are assigned with a unique identification number (UIN), and, to ensure security, RFID tags can be programmed and protected by password [18]. The frequency bands used for RFID systems are: low frequency (LF) 125–134 KHz, high frequency (HF) 13.56 MHz, ultra-high frequency (UHF) 868–928 MHz, and finally microwave frequency 2.4 GHz [19].

The ZigBee protocol is based on the IEEE 802.15.4 standard and works on the 868/915MHz and 2.4GHz unlicensed bands [20]. ZigBee is a communication standard that can be used as automatic identification to provide short-range, low-cost and low-power consumption wireless solutions in several applications [20]. ZigBee is designed to allow up to 65,500 nodes to be connected in a star, tree or mesh topology network [20] and examples of ZigBee applications include home automation, personal healthcare, sensor networks, monitoring systems, remote control etc [21]. ZigBee technology is an ad-hoc network such that it provides the network with the ability to obtain infinite expendability [22]. Wireless Sensor Networks (WSN) [23] are used to collect the information needed by smart hospital systems. In addition, sensing devices make it possible to retrieve information about objects and their position, taking into account the environment of the sensor, when offering personalized on-line services.

V.INTERNET OF THINGS

Internet of Things (IoT) is a relatively new concept in connecting smart objects together. Smart technology is opening new development opportunities for service providers. Internet of Things was first introduced by Kevin Ashton in 1999 and can be used to identify, locate, track and monitor objects automatically in real-time. IoT is exponentially increasing to an ecosystem connecting billions of smart things [24], offering smart electric meter reading, telemedicine monitoring, greenhouse monitoring, and intelligent transportation using computer technology [25]. IoT enables physical devices to be connected to Smart networks. This concept of IoT along with the use of ubiquitous computing in different environments could improve people’s lifestyle and have specific applications in the field of healthcare.

Currently, Internet Protocol version 4 (IPv4) is reaching a very large number of global IP addresses [24]. Today, Internet users worldwide number approximately 2.4 billion, and this is projected to reach 3 billion by 2015. However, the number of objects connected over the internet has overtaken that of human users considerably, and is predicted to surpass the human population by 20 to 50 billion connected smart objects [24]. The Internet Protocol IPv4 was not designed to connect smart objects using Internet of Things (IoT), partly because of the limitation of 4 billion addresses. IPv6 has been accepted by the Internet Assigned Numbers Authority (IANA) and the Regional Internet Registries (RIRs), in order to go beyond the IPv4 limitations and address the growing demand to provide more address space to enable global reachability and scalability.

IoT6 [26] is a 3-year EU research project that is based on the Internet of Things. Its main recommendation for the future of the Internet of Things was to exploit the features of IPv6, in particular its interoperability with Cloud Computing, mobility, and intelligence supply among heterogeneous smart object components, services and applications [27]. Consequently, in this research project, an end-user perspective with the targeted realization of a green and smart IPv6 building will be integrated based on the Mandat International [26]. Both the Internet of Things and IPv6 may be needed to enable low-power wireless devices [28]. However, the use of IPv6 has the potential to improve the IoT’s progress because of the possible billions of new sensor devices that will require a unique IP address [29] in order to monitor the largest number of medical devices and the like over the Internet for service users. Smart objects, such as personal health devices and home automation, industrial automation, smart metering and environmental monitoring systems are universally becoming IP enabled [30]. In the network layer protocols for the sensor device, IPv6 will be installed to handle the framework of the IPv6 address that will be required to develop a Smart Hospital Management Information System (SHMIS) [31].

VI. CLOUD COMPUTING AND IOT EFFECTS ON HEALTHCARE

The integration of Cloud Computing with IoT is gaining popularity on ICT prototypes and has come to the attention of researchers over the past few years. Based on the type of resources that were delivered via the cloud, Cloud Computing is used to provide Software as a Service (SaaS) by connecting objects via the internet [32]. Knowing that Cloud Computing manages to store different data apart from its coverage area, the IoT in turn manages to provide systematic orders to be performed for any devices connectable to the internet. Hence, the capacity can be increased and rapidly enhanced by Cloud Computing and IoT without applying further infrastructure investments. Using Cloud Computing and IoT in healthcare impacts on both cost and time when undeveloped countries are provided with Cloud Computing facilities that can provide real-time services.

VII. PROPOSED FRAMEWORK

One of the most important and interesting applications in the smart environment is the Real-Time Locating System (RTLS). The increasing competition between healthcare providers needs to take into account the quality of performance, time management and complexity of the human. This system can be used as a safety mechanism, storing all recordable acts on a smart monitoring system, and thus allowing healthcare providers to track their staff and patients [23]. The proposed framework can be used as a novel and smart solutions for information collection via the spectrum of different applications, such as transportation, business, healthcare, industrial automation, and environmental monitoring [15]. The system is used to identify each object, locate its position automatically and provide users with the required services, without the need for human intervention [4]. A proposed design has been suggested for use in the field of healthcare management systems to track and provide automatic identification and real-time monitoring [25].

In this proposed system, the object is identified and cross-referenced to the RFID and ZigBee tags, thus the process can be recorded and tracked through a management information system. A healthcare service must be available in real-time, which is currently limited; therefore, the future of the Internet can include providing healthcare services through the local network or over the Internet. The proposed monitoring system has the capability to electronically store all patient records including documents, videos, and images enabling users to access patient data and use this information to provide a patient-focused service; for example, patient data could be exchanged between devices via Cloud Computing in real-time.

A. System Architecture

Figure 1 shows the proposed smart hospital network system architecture: a system for the purpose of detecting, locating and monitoring the object. This divided it into the following six layer system structure: a Data Processing layer, a Data Integration layer, a Cloud Computing layer, a Network structure, a Knowledge Reasoning layer and a Visualization layer. The first layer is the Data Processing using sensor-based technology and is 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 and would for example include data from location and movement of tagged 'objects' and digital imagery etc. The second layer is the Data Integration responsible for the organization, translation, rationalization, copying and storage of raw data from the Data Collection Layer into appropriate database for example data and/or digital imagery. The third layer is Cloud Computing. This layer is used to increase the capacity of shared resources provided by data collection in a rapid and secure way through the Internet for example collection and sharing patient data with hospital staff both at the hospital and high level data such as providing bed occupancy to the Ministry of Health in Saudi Arabia, and it can also be used to 'mirror' the database for backup purposes. The fourth layer is the Network Structure: this layer is used to provide the functional and procedural means of transferring multiple length data structures from different sources on one or multiple networks to a destination hub. The Network Structure 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, Wireless Local Area Network (WLAN), Cellular Mobile Network and PANs (Personal Area Networks). Cloud Computing can be used to provide remote access, and WLANs or mobile phone networks can also be used to connect data-collection devices to the data hub. The fifth layer is Knowledge Reasoning: this layer is responsible for processing the huge amount of data and information using knowledge to achieve the objectives of the organization for example, the data could be mined to determine how long a nurse or doctor on duty was within 0.6m of a patient in a ward 24/7. The last layer is Visualization, and this layer provides the visual representation and organization of data once it has been translated to make it accessible to the user community [4] so relatives of patents undergoing surgery could ascertain if the operation was completed to schedule or bed occupancy levels 24/7.

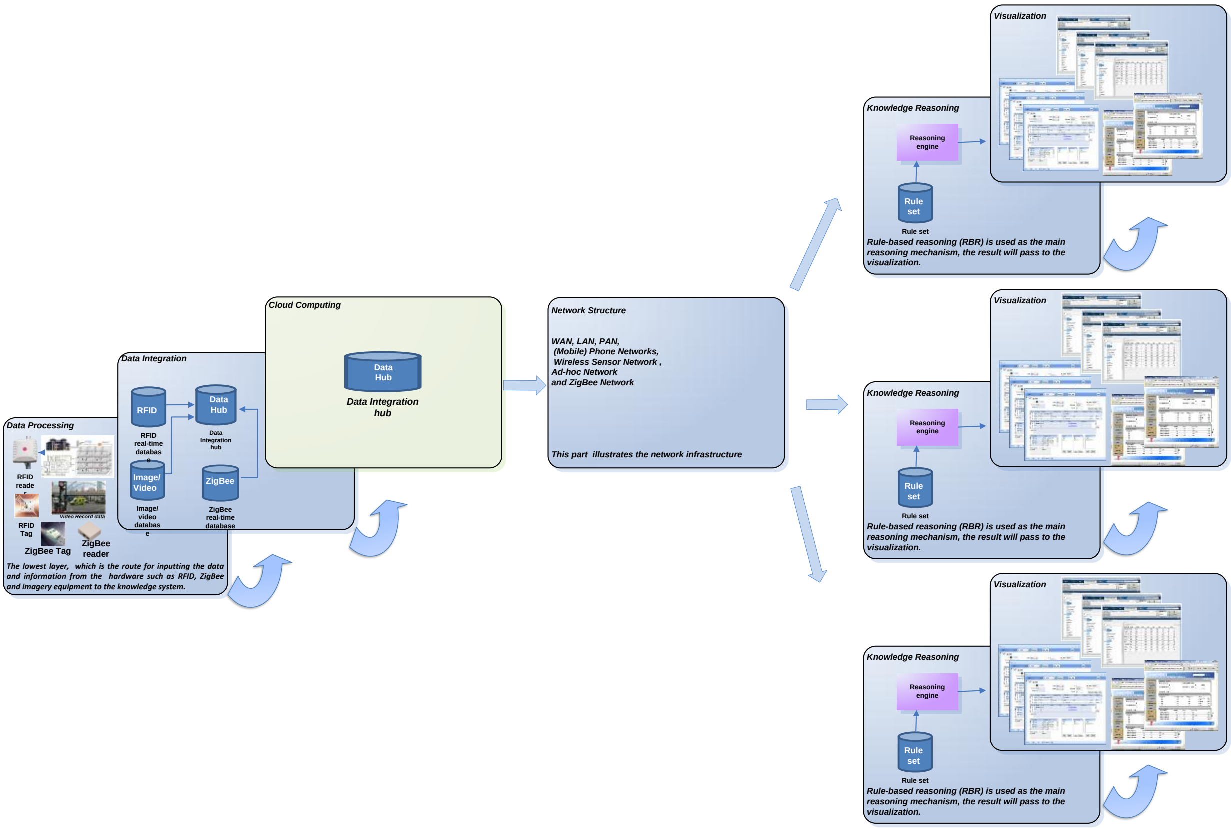

Figure 1: Six-Layers of Emerging Technologies for a Real-time Healthcare Management System

B. *Implementation*

The implementation of RFID system uses Alien Technology Company hardware [34] that includes the RFID equipment consisting of tags, readers, and antenna. RFID was used to provide specific location information through deployed 'gates' or 'check points'. RFID readers are similar to the application of optical bar codes. RFID tags contain information that can be used to identify the objects that carry them but requires no line of sight, automatic, non-intervention, low cost (<1p) no maintenance (tags) and can operate up to 11 meters. The RFID reader reads the tag and checks the database for location and movement with time. ZigBee is used to provide the real-time position of the object, with an average accuracy of less than 2 meters. The implementation of ZigBee system will be using Nebusens hardware [35] that includes the ZigBee equipment consisting of 4 tags, 20 readers, and 2 coordinators. This infrastructure was used to simulate the floor area of a maternity ward and deployed in the research centre of the university with an area of 280 m2. The ZigBee measurement equipment consists of the Coordinator (n-Core Sirius A) which, incorporates several communication ports such as GPIO, ADC, I2C and UART through USB to connect to different devices, the ZigBee Readers (n-Core Sirius D) which, are used as readers and the ZigBee (Core Sirius B) devices, which are used as tags [35]. SkyDrive was used as Cloud storage for framework files and is accessible everywhere. The movement of the object position was recorded through the smart system that generates and checks this object when the targeted object accesses the coverage area of RFID, ZigBee and RFID/ZigBee. The paper discusses the implementation of two important aspects of a Smart Hospital Management Information System: firstly, object identification and location position in real-time, and secondly, the use of low-power output devices using a combination of ZigBee technologies.

C. *Evaluation/Discussion*

The proposed system outlined in Section VII supports real-time functionally using real-time sensors which automatically scan and use non-contact and non-intervention Ultra High Frequency (UHF) RFID and ZigBee technologies. Laboratory experiments using UHF passive tags can provide up to 11 meters read range at the 'check points' ZigBee sensors can operate up to than 100 meters communications range from the antennas and provides real-time position of the objects, with an average accuracy of less than 2 meters. The operating communication range allows the system to check every object (patients, staff and equipment's) position in the system and monitor their movement in real time throughout the hospital.

D. The benefits of the proposed system

The demand for healthcare services is increasing in the UK, Europe and the Middle East North Africa (MENA) region with staff providing medical care 24 hours a day, 7 days a week, and the growing difficulties to respond to management information demands and financial constraints placed on healthcare services. For this reason, a smart system can help by linking smart devices to the network and monitoring medical staff 24 hours a day, collating information, storing, combining, and aggregating data. The proposed system can be used for security purposes and as smart solutions for information collection via the Internet including different application such as transportation, business, healthcare, industrial automation, and environmental monitoring. In healthcare cases, it can be used to provide better and smart patient care at a low cost, and can allow patients to access information about their personal treatment and support their ability to interact with medical staff [36]. In addition, the proposed system can be used to assist and support the increasing number of elderly people (>60) in many countries some may have dementia, and the possibility of them getting lost in the hospital environment. The number of elderly people globally is around 600 million, and will reach 2 billion by 2050 [37]. The traditional method of checking patients' conditions in hospitals by doctors using diagnostic non-movable medical equipment has a number of disadvantages, particularly in that it is inconvenient for patients and inflexible for the elderly or those with special needs [38]. The proposed system can be used to support medical staff in different ways, e.g., input-output devices and sensors which, provide improved patient care in different environments and with less human error, such as body sensors, patient activity monitoring and tracking at hospital and also, for elderly care patients, in a home environment [36]. A RFID/ZigBee tag (embedded in a wristband) can be issued to every patient on their arrival at the hospital, to enable the hospital monitoring system to identify and track patients during the period of their stay in hospital. The RFID/ZigBee tags can be used to store important information such as patient name, ID, drug allergies and blood group, etc., and also alert staff before a serious situation arises [18]. In some cases, this system can be helpful with patients who need more and/or regular health checks or who are unable to come to visit doctors or require medical support at home. Healthcare providers should consider smart health technologies because their use means that some medical monitoring, such as movement, weight and blood pressure, can be performed without a patient attending hospital. Using the IoT environment is a flexible way of connecting modern measuring devices and it can create smart networks at home at anytime and anywhere.

VIII.CONCLUSION

The aim of this paper was to evaluate the integration of Cloud Computing, wireless sensor technology and Internet of Things in a healthcare environment. The use of wireless sensor technology is emerging as a significant element of next-generation healthcare services in real-time. In this paper, we proposed a smart monitoring system, using RFID and ZigBee technology which is able to continuously detect, locate and monitor the movement of an object in a hospital. The system consists of a coordinator node to acquire the object information, on the data collection layer. ...

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