An Overview of IoT-Aware Architecture for Smart Healthcare Systems

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ABSTRACT: The compelling advancements in the development of Internet-of-Things (IoT) enabling technologies have sparked the emergence of new and interesting applications in recent years. This adaptive tendency is being led by Radio Frequency Identification (RFID), Wireless Sensor Network (WSN), and smart mobile technologies, among others. In response to this trend, this article presents a new IoT-aware smart architecture for automated monitoring and tracking of patients, staff, and biomedical devices in hospitals and nursing institutions. We propose a Smart Hospital System (SHS) that depends on various, but complimentary, technologies, such as RFID, WSN, and smart mobile, interoperating with each other via a CoAP/6LoWPAN/REST network architecture, in keeping with the IoT vision. The SHS uses an ultra-low-power Hybrid Sensing Network (HSN) made up of 6 LoWPAN nodes with UHF RFID functionality to gather both ambient and patient physiological data in real time. The sensed data is sent to a control center, where a sophisticated monitoring program makes them available through a REST web service to both local and distant users. The basic proof of concept used to verify the proposed SHS has shown a number of important capabilities and unique features that constitute a substantial advancement above the current state of the art.

KEYWORDS: CoAP, Healthcare, 6LoWPAN, RFID, WSN

1.INTRODUCTION

Improving the efficiency of hospital infrastructures and biomedical systems is one of contemporary society's most difficult objectives[1]. In reality, one of the most pressing issues is how to provide high-quality care to patients while lowering healthcare expenses and addressing the nursing workforce deficit. In reality, as stated in existing processes for patient monitoring, care, administration, and supervision are often conducted manually by nursing personnel. This is, in effect, an inefficiency bottleneck that may lead to catastrophic mistakes in reality[2]. Smart systems to develop and enhance healthcare and biomedicine processes are being developed as a result of recent advances in the design of Internet of Things (IoT) technologies. Only a few potential applications include automatic identification and tracking of individuals and medical equipment in hospitals, accurate drug-patient relationships, and real-time monitoring of patients' physiological data for early diagnosis of clinical deterioration. Ultra-High-Frequency (UHF) Radio Frequency Identification (RFID), Wireless Sensor Network (WSN), and smart mobile are three of the most promising technologies for implementing smart healthcare systems, among many others[3]. RFID is a low-cost, low-power technology that consists of passive and/or battery-assisted passive (BAP) devices, known as tags, that may transmit data when powered by an interrogator, also known as a reader. Because passive RFID tags do not need an external source of energy to function, their lifespan may be measured in years, making RFID technology suitable for a wide range of applications, notably healthcare[4].

The current availability of UHF RFID tags with enhanced capabilities, such as sensing and computing, adds to the value. RFID-based detection in healthcare, in fact, allows for low-cost, low-power monitoring and transmission of patients' physiological data. The major disadvantage of RFID tags, however, is that they can only function inside the reader coverage area, which is up to 15 m and 25 m for fully-passive and BAP tags, respectively[5]. Obviously, this constrains the use of UHF RFID technology to object/patient identification and monitoring in very limited regions[6]. WSNs, on the other hand, are self-organizing ad hoc networks of tiny, low-cost devices (motes) that communicate/cooperate in a multi-hop manner to offer monitoring and control functionality in key applications such as industrial, military, residential, automotive, and healthcare[7]. Most WSN motes are now battery-powered computing platforms with analog/digital sensors and an IEEE 802.15.4 radio with a range of up to 100 meters in the open air (single hop). Compared to UHF RFID tags integrating sensing and computing capabilities, WSN motes consume significantly more power, thus making the overall network lifetime the major limitations of such technology. In such a context, RFID and WSN represent two complementary technologies whose physical integration might provide augmented functionalities and extend the range of application, e.g. in the healthcare domain to the best of authors' knowledge, only few attempts have been done to leverage the combined use of UHF RFID and WSN technologies in healthcare application scenarios. Furthermore, none of the available solutions realizes a seamless integration of different technologies, according to the so-called Internet of Things (IoT) vision. Basing on this concept, IoT devices will be remotely accessible through the Internet, thus allowing the development of innovative applications able to exploit pervasive collected data and leverage on the new control possibility offered by the IoT enabling solutions. In this work, a novel IoT-aware Smart Hospital System (SHS) is presented and discussed [7].

It is able to guarantee innovative services for the automatic monitoring and tracking of patients, personnel, and biomedical devices within hospitals and nursing institutes, by exploiting the potentialities offered by the jointly use of different, yet complementary, technologies and standards, including such RFID, WSN, smart mobile, 6LoWPAN, and CoAP. Specifically, the designed SHS uses an ultralow-power Hybrid Sensing Network (HSN) made up of 6 LoWPAN nodes that integrate UHF RFID Class-1 Generation2 (Gen2 hereafter) functionalities to collect both environmental and patient physiological parameters in real time. Two new types of WSN nodes are proposed in particular. In order to store sensor data and patient information, the former includes an RFID Gen2 reader, while the latter includes an augmented RFID Gen2 tag. In this way, RFID Gen2 readers dispersed throughout the hospital can easily retrieve physical indicators of patients and deliver them to a control center, where a sophisticated surveillance application makes them available to both local and remote users via a Representational State Transfer (REST) web service[8]. As a result, no WSN-based transmission is performed during normal operations, reducing node energy usage and limiting network capacity impact. The designed system is also able to timely and reliably manage emergency cases. In this instance, the WSN-based transmission is enabled so that the nursing staff is notified as soon as possible through Push Notifications on a tailored mobile application[9].

Doctors may also use the same mobile application to communicate with patients' nodes during daily medical checks by connecting their smartphone to a portable UHF RFID reader. Micro-electromechanical systems (MEMS) have recently advanced to the point that they may now be used to create smart surroundings. Several sensors for evaluating various kinds of vital signs (e.g., heartbeat, body temperature and pressure, ECG, motion, etc.) have been created, allowing the creation of new services that may significantly enhance citizens' healthcare[10]. Among the many research efforts previously reported in the literature in this area, those involving the use of UHF RFID technology are mostly focused on patient monitoring in hospitals and nursing homes. The authors of combine wearable tags with ambient tags to create NIGHT-Care, a completely passive RFID system for monitoring the health of handicapped and elderly persons at night. NIGHT-Care, in particular, is based on an ambient intelligence platform that can assess sleep characteristics, categorize human behavior, and detect aberrant occurrences that need urgent intervention. RFID locator, a web-based tool created in cooperation with Sun Microsystems at the University of Fribourg (CH), has been suggested to enhance the quality of medical services in.

Passive RFID technology has also been successfully utilized in hospitals to locate equipment. The application of UHF RFID technology is restricted to patient/device monitoring and tracking in very small settings, as shown by the referenced literature, since RFID tags can only function inside the reader coverage area. Another set of related research suggests using WSN technology to develop solutions that can satisfy the unique needs of ubiquitous healthcare applications. In a WSN is described that provides patient localization, tracking, and monitoring services inside nursing institutions. The received signal strength indicator (RSSI) and particle filters are utilized in the localization and tracking engine, while bi-axial accelerometers are used to categorize patient movements describes a wireless localization network that can track patients' whereabouts in interior settings while simultaneously monitoring their physical condition. proposes a location-aware WSN for tracking patients that uses a range algorithm based on the surroundings and mobility adaptive filter (REMA).

1.1 SYSTEM ARCHITECTURE OVERVIEW:

The goal of this project is to develop and build an IoT aware Smart Hospital System (SHS) with the capacity to easily integrate various, but complimentary, technologies to enable new features. Essentially, the technology we envisage should be able to gather both environmental and physiological data from patients in real time and send them to a control center. An sophisticated monitoring program should now evaluate the data and deliver alarm messages in the event of an emergency. The proposed SHS has been implemented in accordance with the architecture. It is made up of three major components, as shown: (1) an RFID-enhanced wireless sensor network, dubbed Hybrid Sensing Network (HSN) hereafter, (2) an IoT Smart Gateway, and (3) data visualization and management user interfaces. The HSN is made up of four different types of RFID-WSN 6LoWPAN routers: (1) 6LowPAN Border Routers (6LBR), (2) 6LowPAN Routers (6LR), (3) 6LowPAN Router Readers (6LRR), and (4) 6LowPAN Host Tags (HT). The 6LBR is responsible for connecting the network to the Internet by converting 6LowPAN packets into IPv6 packets and vice versa, according to the 6LoWPAN standard, while the 6LR is responsible for forwarding and routing. The 6LRR indicates a typical 6LowPAN Host (i.e. a node without routing and forwarding capabilities) interfaced with an RFID Gen2 tag in the proposed RFID-WSN integrated system, whereas HT identifies a typical 6LR node interfaced with an RFID Gen2 tag in the proposed RFID-WSN integrated system. Section IV contains further information about HSN nodes with RFID Gen2 capability. The suggested SHS implies that multiple 6LR are placed throughout the hospital to gather data from the environment, such as temperature, pressure, and ambient light conditions, at a finer degree of detail.

The primary purpose of 6LRR nodes, in addition to sensing capabilities, is to monitor patients, nursing personnel, and biomedical equipment using RFID Gen2 tags. We envisage patients wearing an HT node capable of detecting key physiological characteristics such as heartbeat and movement/motion. The RFID Gen2 tag's user memory is regularly recorded with sensed data, enabling 6LRR nodes in the environment to retrieve and send them to the IoT Smart Gateway. This one, on the one hand, is directly linked to the HSN and, on the other, to the Internet through a Local Area Network (LAN). As a result, the gateway in the proposed design serves as a 6LBR, allowing communication between WSN nodes and distant users. The data is analyzed and stored in the database (Control DB in Fig. 1) by a Monitoring Application (MA) operating on the gateway. The REST Web-based paradigm was used to make the gathered data available to both local and distant users. A Web-based software tool, for example, enables network operators to control sensor and actuator node environmental parameters. Doctors with appropriate credentials may view both real-time and historical patient data via the same interface.

Medical personnel may also handle such data remotely using a specialized mobile software application. Doctors may also be outfitted with a smartphone that is linked to a portable RFID Gen2 scanner and runs a bespoke application called Medical App. During daily medical checks in the hospital, doctors can use this App to communicate directly with the patient's HT base station and check his or her physiological parameters by reading the most recent information stored in the RFID Gen2 tag's memory or historical information stored in the Control DB. The Medical App also enables physicians to refresh the memory material with essential reminders (such as the most recent visit, changes in patient treatment, health exams, and so on). As shown in the next section, RFID Gen2 technology not only allows quasi-zero-power read/write memory operations but also providing standardized EPC global identification and tracking of both patients and nursing personnel wearing the HT node.

The designed SHS architecture can also handle emergency circumstances in a timely manner thanks to the RFID-WSN connection. Indeed, the HT node only uses its long-range, high-power, and dependable IEEE 802.15.4 radio transceiver to transmit a notification to the MA in the event of a critical event, such as a patient fall or heartbeat abnormalities. This approach enables the HT nodes to constantly utilize the RFID Gen2 radio interface for regular activities, such as medical inspections, data recording, and identification/tracking, while keeping the IEEE 802.15.4 radio turned off for the majority of the time, extending battery life. The MA uses Push Notifications (PN) at the IoT Smart Gateway to notify nursing staff about patient location (i.e. the last place where the RFID Gen2 tag was read) and health condition. The doctor may then use the Web application or his or her smartphone to check the patient's vital signs. Because the system gathers sensitive and private data, the platform must guarantee that data access and management are secure.

As a result, users must first authenticate in order to use the site. Local and distant communications, too, must be properly safeguarded. In the first scenario, the mobile application might use a local Access Point (AP) to connect to the LAN and communicate with the SHS. To provide the required degree of security, the mobile app must, of course, be correctly set. Because the interaction between the remote application and the SHS takes place over the public Internet, a stronger communication channel is required in this instance. The suggested method does this by using a Virtual Private Network (VPN) channel that connects the mobile device to the IoT Smart Gateway. The user may operate on the system once this access is given, whether local or remote.

1.2 HYBRID SENSING NETWORK:

An integrated RFID-WSN 6LoWPAN network makes up the HSN. The REST Request/Response model, which is based on CoAP communications, was used in the HSN design to enable smooth interoperability with the Internet. CoAP is one of the most widely used communication protocols in the IoT, with the main goal of providing lightweight access to physical resources in order to accommodate embedded devices' restricted capabilities. Because it offers a request/response model interaction between two endpoints and contains important Web concepts like URI and media types, CoAP's architecture is comparable to that of HTTP. Furthermore, CoAP has a resource monitoring mechanism that enables a client to be notified if the status of resources it has already subscribed to changes. An addition to the CoAP protocol based on the notion of conditional views has been suggested since in many situations an observer is only concerned in state changes that meet a particular condition (i.e. the state of a resource exceeds a specific value).

2. DISCUSSION

Due to the massive growth in population, traditional healthcare is unable to meet everyone's requirements. Medical services are not accessible or cheap to everyone, despite having great infrastructure and cutting-edge technology. One of the objectives of smart healthcare is to assist consumers by informing them about their medical conditions and keeping them informed about their health. Users with smart healthcare may self-manage certain emergency circumstances. It focuses on enhancing the user's quality of life and experience. Smart healthcare enables the most efficient use of available resources. It allows for remote patient monitoring and lowers the cost of therapy for the user. It also enables medical professionals to expand their services beyond geographical boundaries. With the growing trend toward smart cities, an efficient smart healthcare system ensures that its people live a healthy lifestyle. In general, connected health refers to any digital healthcare solution that can operate remotely, and it is a catch-all term for subsets like telemedicine and mobile-health, but with the addition of continuous health monitoring, emergency detection, and automatically alerting appropriate individuals. The goal of connected health is to enhance the quality and efficiency of healthcare by allowing self-care and supplementing it with remote care. Its roots may be traced back to the telemedicine period, when consumers were taught about their health and provided feedback as needed. Smart healthcare refers to solutions that can run entirely on their own, while connected healthcare refers to systems that allow consumers to get feedback from doctors.

The end user market is the most significant categorization that defines the smart healthcare economy. The cost, power, and architecture of extending the applications for which the healthcare system is intended vary greatly depending on whether the healthcare network is to be deployed for people or hospitals. Remote health monitoring through the Internet of Things (IoT) may be made easier with the efficient integration of tiny devices via wireless technologies. A Bluetooth module, 6LowPAN, or RFID may be utilized with a customized monitoring device such as a wrist band. To connect the gadget to the internet, you'll need to utilize this. However, in a hospital setting where a healthcare network is maintained, Wi-Fi is necessary. To ensure continuous internet connection and handle high data flow, both ethernet and ground cables are needed. The medical field On-body sensors and stationary medical equipment are two types of devices used to achieve smart healthcare. Biosensors that are attached to the human body for physiological monitoring are known as on-body sensors. These In-vitro and in-vivo sensors are the two types of sensors. In-vitro sensors are connected to the human body from the outside. entity that aids in the reduction of the use of lab or hospital facilities in healthcare Implantable in-vivo sensors devices that are implanted into the body after meeting sterilizing requirements and standards.

3. CONCLUSION

A new, Internet-of-Things-aware Smart Hospital System (SHS) architecture for automated monitoring and tracking of patients, staff, and biomedical equipment inside hospitals and nursing institutions is presented in this paper. In order to enable interoperability between UHF RFID Gen2, WSN, and smart mobile technologies, a sophisticated network architecture based on CoAP, 6LoWPAN, and REST paradigms was developed with the IoT vision in mind. An ultra-lowpower Hybrid Sensing Network (HSN) has been developed, taking use of the zero-power RFID-based data transfer. It may record real-time changes in any important patient's physiological parameter as well as the surrounding environment. The detected parameters are sent to a control center, where they are made available through a customized REST web service to both local and distant users. To verify the suggested SHS, two distinct use cases were implemented. The former is concerned with patient monitoring, whereas the latter is concerned with the treatment of an emergency situation resulting from patient falls that are identified quickly using 3-axis acceleration measurements. The obtained findings show that the suggested system is capable of not only identifying and tracking patients, nursing staff, and biomedical equipment inside hospitals and nursing institutions, but also of providing energy-efficient remote patient monitoring and emergency response.

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