A State of the Art Review on RFID Technology for IoT-Based Personal Healthcare

Sandeep Jain, Assistant Professor

Department of Electronics & Communication Engineering, Vivekananda Global University, Jaipur

Email Id- sandeep_jain@vgu.ac.in

ABSTRACT: The Internet of Things (IoT) paradigm involving sensors (environmental, wearable, and implanted) spread throughout domestic environments with the goal of monitoring the user's health and activating remote assistance can help to accelerate the current evolution of the traditional medical model toward participatory medicine. Through low-cost, energy-autonomous, and disposable sensors, RF identification (RFID) technology is now developed enough to offer part of the IoT physical layer for personal healthcare in smart settings. A review of the state-of-the-art of RFID for usage in body centric systems and for collecting data (temperature, humidity, and other gases) about the user's living environment is given here. Many alternatives are detailed up to the application level, including RFID systems that can gather and analyze multichannel data about human activity while adhering to power exposure and sanitary standards. Finally, open problems and potential new research trends are addressed.

KEYWORDS: Healthcare, Internet of Things, RF Identification, Sensors, Wearable Sensors.

1. INTRODUCTION

The increase in life expectancy and the resulting progressive aging of the population, combined with an increase in the prevalence of chronic diseases, necessitates careful consideration of the role and modes of providing care to people in order to ensure a decent quality of life while avoiding traumatic changes in habits and the home environment [1]. Remote monitoring and assistance therefore become key instruments for implementing long-term social programs. In this view, the capacity to measure health states and human interactions with the environment in a ubiquitous, discrete, and usually uncooperative manner is the first step toward providing all of the knowledge needed to adjust existing healthcare procedures to new requirements. Personal Smart-Health systems with new interconnections between the person's natural habitat, his body, and the Internet, as well as a wide variety of increasingly cheap sensors (wearable, implanted, and environmental) have the potential to put in place new interconnections between the person's natural habitat, his body, and the Internet in order to produce and manage "participatory" medical knowledge [2].

By placing wireless sensors on clothing and personal items inside the home, it becomes possible to monitor the macroscopic behavior of the person while maintaining privacy, compile statistics, identify precursors of dangerous behavioral anomalies, and finally activate alarms or prompt for remote actions by appropriate assistance procedures. Because of the energy autonomy of battery-free tags, RF identification (RFID) devices may constitute a key enabling component among the many technologies that may converge to this situation. Furthermore, their cheap price makes them suitable for broad distribution and throwaway applications. A passive RFID system consists of a tag, which has an antenna and an IC chip with a unique identification code (ID), and a reader, which is a radio scanning device. Despite the fact that RFID technology is currently primarily used in the logistics of goods, new research is pursuing other avenues with the goal of extracting physical information about tagged objects and the surrounding environment using low-level processing of electromagnetic signals received and backscattered by the tags. As a result, RFID systems may make it possible to implement the final few meters of the Internet of Things in terms of ubiquitous quantification of a person's contact with the environment in a simple and efficient manner [3].

This article aims to sketch a picture of current RFID sensing research from the standpoint of IoT for personal healthcare. The study will look for passive (non-battery-operated) devices in the UHF band (860–960 MHz) that can offer services and have adequate read ranges to create a network of sensors for tracking human health and monitoring local environmental quality. The talk will cover both physical and signal processing problems, all the way up to the application level [4]. A Smart-House equipped with a distributed network of readers, enforcing uniform and robust coverage in the most relevant spaces, and a heterogeneous set of battery-less tags with sensing capability, could be an RFID-powered environment supporting new pervasive healthcare services [5]. Readers may communicate with a concentrator node through WiFi or Bluetooth, for example, allowing for connectivity with external services that handle data processing and assistance procedure activation.

Ambient sensors (Section II), which can detect physical environmental factors like temperature, humidity, and the presence of hazardous substances, may be used to measure the environment's healthiness and evaluate its relationship with a person's health [6]. Wearable and implanted tags (Section III) may alternatively offer indirect information about a person's presence in a space, his mobility, social contact, and, in more future body-centric applications, data about the health status of prosthetic or artificial organs. Data collected from the RFID environment, such as that generated by ambient tags or by the user's interaction with the house, could be processed using data-mining algorithms to analyze the user's movements and trajectories, classify its gestures in daily and sleep conditions, recognize critical events, and issue alarms. Finally, the whole technological infrastructure must meet the electromagnetic safety requirement for power absorption in the human body and radiated field strength in living situations [7].

1.1 ENVIRONMENTAL PASSIVE SENSORS:

Continuous and reliable monitoring of key factors such as temperature, presence/level of humidity, and certain other gases may improve people's wellness and healthcare evaluation in living and medical settings[8]. Detecting volatile chemicals in a noninvasive and direct manner may also aid clinical diagnosis by allowing doctors to use breath analysis to identify marker gases that can be used to distinguish between healthy and ill individuals. Air monitoring is also helpful in common areas to prevent workers from inhaling anesthetic gases or from contaminating the patient undergoing surgery. In many medical settings, temperature is used to evaluate the quality of medicines as well as to pinpoint the location of an epidemic source causing a fever surge. When a passive RFID tag is functionalized with specific chemical compounds or linked to microchips with sensing characteristics, it becomes capable of detecting changes in the chemical/physical parameters of the surroundings[9].

- Sensors for Volatile Compounds: Volatile chemicals may be detected by using a correctly designed tag antenna with specific chemically interactive materials (CIMs) that can alter their electromagnetic characteristics and, as a result, the tag response during gas exposure. The reader may therefore monitor and decode changes in turn-on power1 or backscattered power, providing information about the presence and concentration of particular gases. Several CIM species have been tested for use in RFID sensors, with the majority of them focused at sensing humidity and ammonia utilizing carbon nanostructures (CNTs), conducting or insulating polymers, and even blotting paper. The loading of a foldable patch tag with "PEDOT:PSS" [poly (3, 4-ethylenedioxythiophene):poly (styrenesulfonic acid)], a chemical compound capable of absorbing water molecules and increasing its permittivity and conductivity, yielded remarkable results. A single drop of this CIM was found to be sufficient to produce a 0.5 dB/RH2 humidity sensitivity. Because of the existence of a ground plane, the tag may be applied to both walls and meals or medicines. Several types of CIMs, such as a matrix of doped tags capable of responding selectively to the presence of distinct gases, may also be integrated into a wireless nose. Layers of doped PSS, Pedot:PSS, single-walled Carbon Nanotubes, agarose, doped agarose, and dimethyldiallylammonium chloride polymer (PDAC) exposed to saturated vapors of water, ethanol, ammonia, and hexane are shown in Fig. 2(b). The response bars indicate that the collection of CIMs has a high selectivity, implying that chemical categorization is possible.
- Temperature Tags : In the past several years, three types of passive UHF RFID temperature sensors have been tested and, in some instances, marketed, ranging from threshold sensors to continuous sensors to higher performing digital data-loggers [10].

1) Temperature Sensors with a Threshold: An RFID "thermal switch" or fuse is based on a physical phenomena in which the material changes state when the external temperature exceeds a certain threshold, and the event is permanently recorded in a physical memory. The melting of an ice area (low-temperature threshold) loading the tag's antenna , the melting of a paraffin substrate (high-temperature threshold) of a planar antenna , or the geometric alterations of shape memory alloys such as Nitinol are examples of thermal-controlled events (both low and high temperature). In these instances, the temperature shift causes a sudden change in the antenna response, causing the microchip to be activated or deactivated depending on whether the temperature exceeds a pre-defined threshold. For example, a two-chip threshold sensor with a temperature-controlled Nitinol switch . The normal state corresponds to the transmission of just ID1 (product label), while an overheating incident is indicated by an extra ID2 code (thermal event). These devices may be used to evaluate the safety of food and medicines, as well as to detect fires and overheating in household appliances.
2) Continuous Temperature Sensors: Instead of an immediate RFID temperature sensor, a CIM capable of constantly reacting to temperature changes is used. assumes a (distilled) water area enclosed around the

tag, whose conductivity and permittivity vary with temperature and, as a result, alter the tag's resonant frequency observable by the reader.

3) Digital Data Loggers: A new generation of RFID microchips with an embedded temperature sensor and a local Analog to Digital Converter is likely to kickstart a genuine revolution in autonomous RFID temperature sensing. As a result, the temperature data is read from the tag in a digital format right immediately. These chips can be utilized in both passive and battery-assisted modes, with the tag triggering a temperature measurement and storing the data in the microchip's user memory in the latter instance. The price to pay for this unique feature is a higher chip cost (1–3 $ vs a few cents for regular RFID chips) and a relatively low power sensitivity when utilized in completely passive mode (10 dB less than normal chips), limiting the read distance to a few meters at the moment.

1.2 BODY-CENTRIC RFID TAGS:

Autonomous RFID tags that may be placed on or near the body are the essential enabling devices for developing body-centric healthcare systems that are completely invisible to the user. Because of the massive power attenuation produced by human tissues, wearable and even implanted passive UHF tags have been a technological no-no for a long time. The majority of body-centric networks studied so far are based on active devices. Instead, the emergence of COTS low-power RFID microchips has totally altered the game, and numerous prototypes of passive body-centric tags have been successfully created and tested with read distances suitable with real remote monitoring in the past five years.

- Wearable RFID Tags; Because the human body has significant electromagnetic losses, the energy scavenging efficiency of a wearable antenna is very low , as are the anticipated read distances in the case of passive systems. The electromagnetic contact between the antenna and the body may be reduced by employing multilayer tags, such as dipoles with dielectric insulators, or more efficiently folded patches, which are also suitable for embedding in plasters. RFID tags have also been effectively integrated into clothing using embroidery methods. According to current microchip sensitivity, the maximum read distance achievable today with an RFID transmitter that complies with regional power emission constraints is 5–6 m, and it will continue to improve over time thanks to advancements in microchip transponder technology (3 dB reduction in chip sensitivity every 1–2 years). Current link performance, on the other hand, is sufficient to monitor a person equipped with two tags placed over the front and back torsos, or over the arms, within a normal room.
- RFID Tags That Can Be Implanted: By identifying body prostheses, sutures, stents, or orthopedic fixings, RFID technology has been shown to be potentially helpful in taking care of the human health-state from the inside. For the ambitious aim of monitoring biophysical processes in evolution, such as tissue regeneration and prosthesis displacement, each item may be tracked in real time or on demand by the IoT infrastructure. Tags will be placed in prosthetics in this instance, transforming them into multi-functional devices capable of generating data in addition to delivering the original medical usefulness. The main difficulty in the development of implantable tags is to provide a comfortable communication connection while staying under local emission regulations. The minimum power (estimated by numerical simulations 3) that is requested to the UHF RFID reader to activate (turn-on) a small dipole tag implanted, in various positions, into a homogeneous (muscle-like) phantom resembling the human body and interrogated by a 5-dB gain PIFA antenna is shown in Fig. 5. The diagrams take into account a well-reviewed RFID IC (power sensitivity,) as well as a better-performing chip family (power sensitivity) that might be available in a few years. The 30-dBm straight line in the graphs represents the maximum possible power for most commercial readers.
- The figures demonstrate that establishing an RFID connection with subcutaneous implants up to 0.1–0.5 m from the reader (up to 1 m in the near future) is now a realistic goal with potential applications for monitoring specific body regions and vascular prostheses. A link range of approximately half a meter may be sufficient for a reader-equipped door to scan the health-state of a user's prosthesis without the user's participation. Deeper implants, such as those in the stomach (, will continue to be difficult for passive RFID systems to operate under existing power restrictions, even in the long run. A vascular stent placed into an artery to restore normal blood flow following angioplastic. Surgery is an example of near subcutaneous prosthesis ideal for RFID integration. The RFID tag functionalities have been strongly integrated within the stent geometry itself to work as a self-sensor in, by exploiting the dependence of the tag's input impedance and back-radiation on the dielectric properties of the tissues in the close vicinity of the so obtained Stenting. This allows for the detection of potential in-stent-restenosis

processes (ISR), such as diffuse neointima growth early after the implant or a new atherosclerotic plaque over time, both of which may result in new arterial blockage. The measurements taken across a phantom neck show that the grad.

2. DISCUSSION

The studied RFID technology for IoT Healthcare and the personal experience of the writers reveal a tale of mixed possibilities and fragmentation. Worldwide university laboratories are currently studying and producing prototypes of RFID sensors, both passive and semi-active that can be probed from a distance suitable with the interaction with a network infrastructure. On the other hand, very few items are commercially available for large-scale applications. A highly concentrated effort is, therefore, required to manage the transfer from experiments to the actual usage and large manufacturing inside a such potentially ast expanding industry. The overcoming of the slowing factors demands a concerted effort of the IoT community to stimulate interest in prospective final consumers and, in parallel, to accelerate the evolution of readers, software, and devices toward a more interconnected viewpoint

3. CONCLUSION

The future of healthcare seems to be difficult, since the population, particularly in Western nations, is aging while individuals are receiving better and more comprehensive health services. This will inevitably raise the cost of medical treatment, necessitating the development of innovative ways to both reduce costs and improve the efficiency of the job. Healthcare procedures must become more efficient and less burdensome for healthcare workers in order to provide the service that consumers expect. IT and its use in healthcare have been widely researched in attempt to develop more efficient healthcare procedures. RFID technology is a promising technology that may be used to simplify operations while also making them more secure. Patient identity, material identification, equipment identification, device identification, medicine identification, access control, location, and information transfer are only a few of the applications (figure 4). Finally, the technology improves patient safety and enhances the efficiency of healthcare workers' job. The majority of the systems seem to be focused on patient identification. There are many other automated identifying technologies that healthcare may use, such as bar code technology and NFC (Near Field Communication) technology. For example, NFC, a relatively new technology in healthcare, may be used to identify patients and medications during drug delivery. NFC technology is also available in mobile phones that have a reader built into the phone's casing. This offers NFC a significant advantage over RFID since the "reader" may now be utilized for communication as well. [21] Finally, RFID technology provides a method for automating identification procedures. Many research and initiatives in healthcare demonstrate that it may both enhance patient safety and simplify healthcare costs, lowering expenditures and reducing the burden of healthcare workers. In this article, we presented the findings of a study that looked at how RFID is utilized in healthcare and what sort of outcomes have been discovered.

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