A Network Structure for Medical Assistance in Rural and Urban Areas Using IoT Technology

E. Serafim, and S. Motoyama
Faculty of Campo Limpo Paulista - FACCAMP
Master Program in Computer Science
Campo Limpo Paulista, S. Paulo, Brazil

Abstract - *A network structure using IoT technology for application in healthcare is proposed in this paper. The main idea is to combine the body sensor network (WBAN) that monitors the vital signs of a patient with RFIDs. RFID readers placed strategically close to the patients, collect data from the WBAN, and through a clustered configuration of these readers reach the medical centers where they are processed and presented to physicians for monitoring purposes. In this paper, the configuration of proposed network structure is presented and main issues for good operation of network are discussed. The link capacity necessary for good operation of network is estimated using queuing theory and the number of RFIDs that can be accommodated in a given link capacity is also estimated.*

Keywords: internet of things, RFID, sensor networks, IoT cluster.

1 Introduction

The Internet of Things (IoT) consists of many smart objects interacting with people and other objects to achieve common goals. The IoT will allow simple objects such as air conditioners, refrigerators, cars, houses, etc. become intelligent and can be identified and accessed through the Internet. Such achievement will be possible due to technologies like RFID and sensor networks, which will provide these objects with intelligence, and thus can communicate [1].

One of the areas that can be benefited by IoT technology is healthcare. The applications of IoT in healthcare can be in areas such as tracking objects and people (staff and patients), identification and authentication of persons; automated data collection and patients monitoring [2].

The IoT technology can be beneficial to the medical care in country like Brazil, due to poor hospital infrastructure existing. The patients may stay in their homes without occupying hospital beds, but being monitored remotely and having prompt medical attention in case of emergencies. In this paper, we propose a network structure that is convenient for patient monitoring in areas of high human concentration, as well as in rural areas. This structure aims to integrate body sensor networks (WBANs) with the Internet, through the interconnection of RFID readers configured in a cluster. These readers should communicate with each other, transferring the data obtained from the sensor network through RFID tags, until they reach a sink node and through the Internet a medical center where they are processed.

The paper is structured as follows. In section 2 the concept of IoT is presented. The related works are described in section 3 and in section 4 the proposed network structure for medical care in urban and rural areas is presented. In section 5 the link capacity and number of RFIDs necessaries for good operation of proposed network are estimated. Finally, in section 6, the main conclusions and future work are presented.

2 Internet of Things

In a broad sense, IoT is the interconnection of the everyday objects of the real life environment with the Internet which is a virtual environment, becoming the objects smarts. This is possible thanks to the use of sensors and addressable RFID tags, attached to the objects, which communicate through a network, and then to the Internet [1] [2] [3] [4] [5] [6] [7]. This concept can be seen in Figure 1.

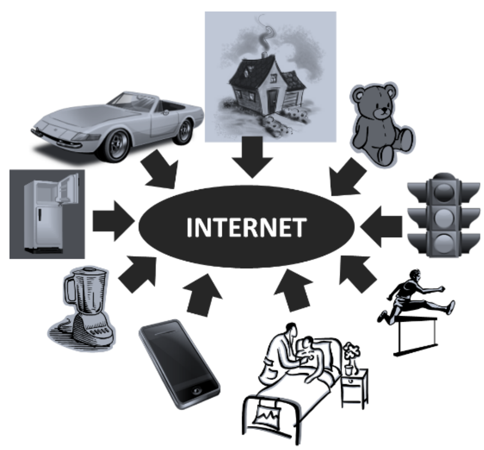

Figure 1. An overview of IoT concept.

Besides the use of RFID, the IoT should include technologies such as artificial intelligence, nanotechnology and embedded systems, which enable an interconnection machine-to-machine [1] [2] [6]. This will lead to a new form of ubiquitous communication, in which objects can communicate with people and other objects independently.

Although the IoT paradigm is very attractive, many questions remain open, which deserves special attention from researchers [1] [2]. The impact on security requires more attention and standards, especially for applications in health.

Because the Internet is an unsafe environment currently, patient privacy may be violated. Despite being the subject of efforts of various organizations such as the Auto-ID Center, EPCGlobal and Unique / Universal / Ubi-quitous architecture IDentifier (UID) in Japan, the lack of standardization is also a big issue today [1] [2] [3] [4] [8] [9] [10].

3 Related work

A platform for Remote Monitoring and Management of Health Information (Remote Monitoring and Management of Healthcare Information Platform - RMMP-HI) was proposed in [11] to monitor the health and preventing disease, improving quality of life, thus relieving the public health system. The project is to deploy sensors in patient body, through a WBAN network, and connect this network to the Internet through a cell phone or a router. Such information reaches the doctor who can track the health of patients.

In [13] a cooperative approach to IoT to monitor and control the parameters of health in rural area was proposed. In this approach, the vital signs such as blood pressure (BP), hemoglobin (HB) blood sugar, abnormal cell growth in any part of the body, etc. are monitored. The proposal is a mechanism for cooperative communication, which is more appropriate for Ad Hoc wireless sensor networks than cellular networks. Each node acts as a user (source), as well as transmitter, transmitting to multiple nodes forming an Opportunistic Large Array (OLA), being significantly flexible and scalable.

The use of RFID for identifying patients to improve health management in rural areas in India is proposed in [14]. The idea is to use an electronic medical record in consortium with RFID tags. The main objective is to enable easy and reliable identification of patients.

4 Proposed network structure

To improve the quality of patients lives, in this article a network structure for patients monitoring through the integration of RFID and WBANS is proposed. The proposed structure uses the monitoring concept presented in [11] associated with the cooperative Internet of Things presented in [13].

The proposed structure is presented in Fig. 2. The patients with WBAN receive an active RFID tag with high range. Active RFID tags should have its range from 5 to 200 meters, so that a near RFID reader can read the data. The tags carry information about the patient, and also serve as the interface between the WBAN and IoT cluster.

RFID readers should be close to the patient, such as in your home or near neighborhood. However, these readers may also be placed in other locations, seeking the wider possible coverage of IoT cluster. In urban centers, squares, parks, rural communities, among others, may be local to placing these RFID readers.

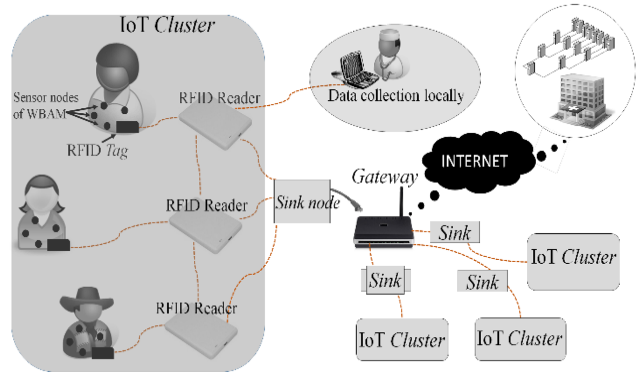

Figure 2. Proposed network model for patient monitoring in rural and urban communities using IoT cluster.

At the edge of the cluster, a sink node is used to collect and send the data to a gateway, which must be connected to the Internet through a conventional link. Through the Internet, the data are sent to a medical center or a larger hospital, which will collect the data, process them and store them.

The health professionals can also collect data locally directly from RFID readers. This procedure will allow the access to the patient data when the doctor is visiting the community. In this case the medical staff shall have a mobile computer that has a USB RFID reader attached, as well as a version of the system software installed.

At the medical center, a software interprets the information in real time, generating reports and alerts to the medical staff. In case where there is patient life-threatening, the alerts should be issued so that the rescue can be provided in a timely manner. Thus, to complement the proposed structure, the network should provide feedback to the doctor, any person responsible for the patient or the user himself. This feedback strategy is detailed in Fig. 3.

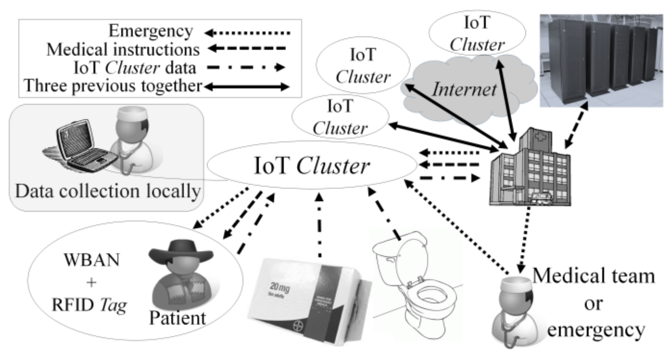

Figure 3. Feedback structure of the proposed network.

Furthermore, other "smart things" can be inserted, which justifies the use of IoT as the proposed center. With other everyday objects comprising this network, it is possible a better analysis of the patient's daily life and routine activities. Examples of this analysis may include measurements of bathroom use in people with kidney problems, control of medicine administration, moving between the rooms of the environment in which the patient lives, among many other possibilities. In Fig. 3, for example, there are a drug and a toilet with RFID tags. The use of one and the other can be measured, and its data can serve as a basis for further analysis in the medical center.

4.1 Components of the network structure

The network structure proposed in this section consists of many elements, which are detailed below.

At the health center, the end of the proposed structure should have a technological apparatus capable of receiving data generated by smart objects, process them and store them. Thus, in this center one or more servers must be provided and software that enables the real-time monitoring of the patients is required. As the data are received, the system must analyze them to determine whether data are classified as normal or need medical emergency.

These servers can be located in the medical center, a clinic, or even in some rented datacenter. Regardless of location, the system should always be running and available for access by health staff.

Since much information about the patients is stored in the server, often confidential, special care must be taken, ensuring the privacy and integrity of the system user. Thus, encryption and security mechanisms must ensure that data are protected and are only accessed by authorized personnel. This security protection should be applied to system software, sensors, readers, tags, etc.

The medical center system must be interconnected with the IoT cluster, preferably full-time. Such interconnection could be through the Internet using a conventional link. If a cluster grows large in size, the link may become overloaded at certain times of heavy use. If there are a lot of smart objects at the network, the throughput can also be a critical factor affecting the stability of the system. Thus, a careful link dimensioning must be made for interconnection between the IoT cluster and the health center. In section 5 a study is presented for this link estimation.

In rural communities, where the Internet is not available, an alternative would be to use the 3G network to connect the system to the IoT cluster. This alternative is attractive because usually the cell phone coverage is more present in these regions. Even in the absence of the cell phone structure, the radio can be installed to provide Internet access. In extreme situation, where even the use of radio is not possible, one option is the use of satellite which can greatly raise the cost of the system, but since has global cover, is an alternative solution.

The sink node should be a device capable of receiving traffic generated by IoT cluster, and convert it to protocols commonly used in the Internet. If possible, this functionality can be embedded directly into the gateway. The IoT cluster comprises the entire RFID infrastructure and the sensor network. Indeed, the sensor network only delivers the data to the cluster IoT, which serves as a bridge between WBAN and the health center.

In rural areas, each village may have only one cluster interconnected with the IoT gateway. In urban areas, several clusters can be provided, reaching many houses in a certain neighborhood. If the patient moves through the city, in public places may exist RFID readers to ensure greater coverage, such as plazas, subway stations and airports.

RFID readers have the function to capture the information of RFID tags placed in patients. Information from other RFID tags attached on smart objects should also be captured by readers covering the environment. If the patient is on the bed and cannot move, the reader can be positioned next to the bed.

Another function of RFID reader is the ability to communicate with others in order to expand the scope of coverage. This allows a data packet to be routed among the readers to reach the sink node. Thus, the readers can be configured as an ad hoc multi-hop network.

Readers should be coordinated by a routing algorithm that allows the choice of a leader or master reader node. The function of master node is the coordination of others nodes indicating the best way to reach the sink node.

The readers will form a set of transceivers operating as an asynchronous distributed joint communication system, constituting an array where work collaboratively, and are configured on an OLA (Opportunistic Large Arrays) of cluster of readers [13]. This arrangement of readers is shown in Fig. 4.

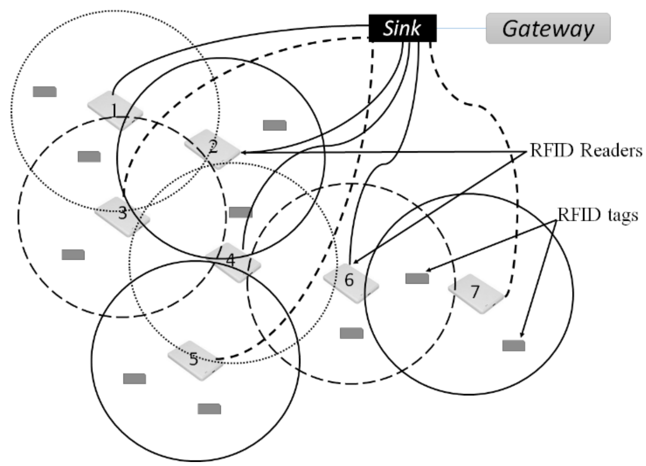

Figure 4. Configuration of cooperative communication among RFID readers.

As can be seen in Fig. 4, all RFID readers have potentially direct access to the sink node. Some readers do not have enough coverage to reach the sink node, because they are far from sink node, as shown in dotted lines. However, the readers can be moved from one place to another for better RFIDs readings and in this new rearrangement may have direct access to the sink node. This rearrangement ensures flexibility to the network configuration, even with frequent repositioning of readers.

Each RFID reader should check, initially, if there is a direct communication with the sink node. If it exists, forward the packet directly to the sink node, but must inform the closest reader that has direct communication.

The patient must have a long-range RFID tag. If the patient move out of range of the reader for some time, for example, to go to work in the field in rural areas, or move to some urban place without coverage of IoT cluster, the data from the sensor network must be stored in the tag, and when the patient reaches within range of the RFID reader, the data are transmitted to the medical center. Another possibility could be the use of Smartphones equipped with RFID readers that could store information while the patient is off-line.

5 Link dimensioning

The estimation of link capacity of the sink node is important factor for the good operation of the proposed network structure. In this section the link capacity estimation is carried out using simple queuing model. To model the proposed network, the WBAN can be considered as the packet generator and RFIDs readers constitute a network to deliver the packets to the sink node, as shown in Fig. 5.

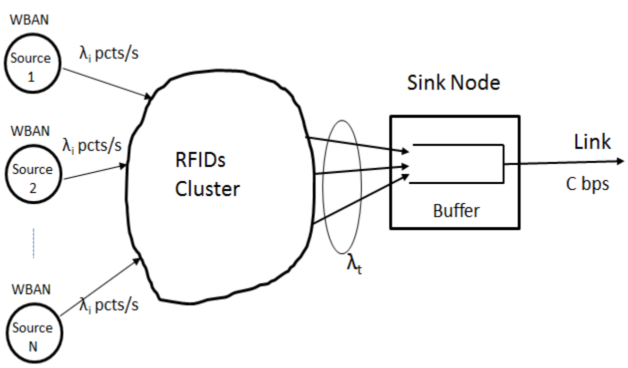

Figure 5. Network structure model for the estimation of link capacity of sink node.

For the estimation of link capacity of sink node, RFIDs cluster is just a delay network to deliver all the packets generated by WBANs. Thus, for the link capacity estimation, the analytical model can be just a buffer with a link and with a total packet rate $\lambda_t = \sum_i^N \lambda_i$ arriving to the sink node. Assuming that packets arrive to the sink node obeying Poisson distribution, as used in [15] and the packet length has negative exponential distribution, a simple M/M/1 queuing can be used to model the sink node.

5.1 Channel capacity estimation

For an M/M/1 queuing model, the waiting time in the system, that is, the queuing time in the buffer plus the packet transmission time, is given by

$$E\{T_S\} = \frac{1}{\mu - \lambda_t} \quad (1)$$

where $E\{T_s\}$is the waiting time in the system, λ_t is the packet arrival rate and μ is the packet rate at the output of buffer.

The output rate μ can be written in function of the link capacity C as

$$\mu = \frac{C}{E\{X\}}, \quad (2)$$

where E{x} is the average packet length in bits.
Rewriting $E\{T_s\}$in function of C and E{x}and separating C, the following expression can be written

$$C = \frac{(1 + E\{T_S\}\lambda_t)E\{X\}}{E\{T_S\}}. \quad (3)$$

5.1.1 Numerical examples

For the illustration of above equation, some numerical examples will be given. As the design criterion it is assumed that the waiting time in the system, $E\{T_{s,}\}$, is small, so that, a packet spends short time at sink node. So, three values are considered, $E\{T_{s,}\}$= .1 sec, .5 sec and 1 sec. Assuming E {X} = 1000 bits, and varying the input packet rate λ_t the link capacity, C, can be estimated.

Figure 6 shows the estimation of capacity for three values of $E\{T_s\}$ in function of input packet rate. As can be seen in the figure, for smaller waiting time in the system, a greater link capacity is required. For example, for λ_t = 10 the necessary link capacities are 20 kb/s, 12 kb/sec, and 11 kb/sec, for waiting time of .1 sec, .5 sec and 1 sec, respectively.

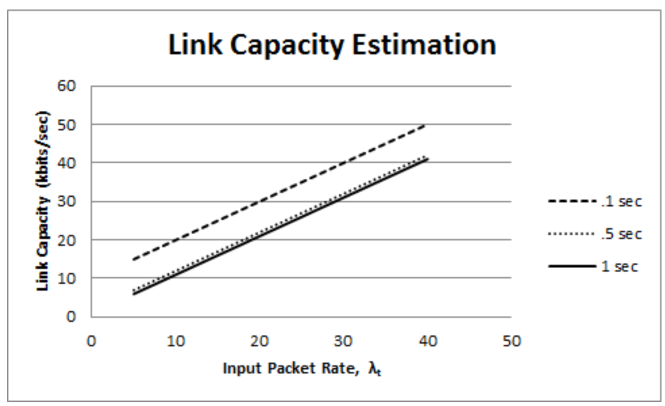

Figure 6. Link Capacity in function of input packet rate for various values of waiting time in the system.

5.2 Number of RFID tags estimation

The number of RFID tags can also be estimated, considering that the capacity is given. Using the Eqs. 1and 2, λ_t can be written as

$$\lambda_t = \frac{E\{T_S\}\frac{C}{E\{X\}} - 1}{E\{T_S\}} \quad (4)$$

5.2.1 Numerical examples

Considering the waiting time in the system, $E\{T_s\}$= .1 sec, and the channel capacities of 50 kb/s, 100 kb/s and 200 kb/s, the total input packet rate, λ_t, using Eq. 4, will be 40 pkt/s, 90 pkt/s and 190 pkt/s, respectively. Considering an estimation of 1 pkt/s for each RFID tag, the numbers of RFIDs that can be accommodated are 40, 90 and 190. Table 1 shows the number of RFID tags that can be accommodated for other values of $E\{T_s\}$.

Table 1. Numbers of RFIDs tags in function of link capacity considering 1 pkt/s rate per RFID

$E\{T_s\}$ (sec)	**Capacity**		
	50 kb/s	**100 kb/s**	**200 kbp/s**
.1	40	90	190
.5	48	98	198
1	49	99	199

6 Conclusions

In this paper, a network configuration using IoT technology for application in healthcare is proposed. The proposed configuration is appropriate for medical care of patients in their own homes. The main concept was to combine the WBAN network that monitors the vital signs of a patient with RFIDs. RFID readers placed strategically close to the patients, collect data from the WBAN, and through a clustered configuration of these readers, the data is transferred to a sink node, and then transmitted to a gateway. The gateway has an Internet connection, and thus the data of patients can reach medical facilities where they can be processed and presented to physicians for monitoring purposes.

In this article, the main points of the network are detailed, and some design considerations for good operation of network are pointed out.

The link capacity of sink node and number of RFID tags are estimated using simple queuing model for good operation of the network.

In future work, the best kind of routing in the cluster of RFID readers to deliver the packets to the sink node will be studied.

7 References

[1] Yang, D., Liu, F., Liang, Y. (2010). "A Survey of the Internet of Things". International Conference on E-Business Intelligence (ICEBI-2010): *Advances in Intelligent Systems Research*, pages 358 – 366. Atlantis Press.

[2] Atzori, L., Iera, A. and Morabito, G. (2010). "The Internet of Things: A Survey". *Computer Networks*, pages 2787-2805 Vol. 54, No. 15.

[3] ITU International Telecommunication Union (2005): "The Internet of Things. Executive Summary", http://www.itu.int/osg/spu/publications/internetofthings/, July.

[4] Fleisch, E. (2010). "What is the Internet of Things? An Economic Perspective". *Auto-ID Labs White Paper WP-BIZAPP-053*.

[5] Wu, M., Lu, T., Ling, F., Sun, J., Du, H. (2010). "Research on the architecture of Internet of things". *Advanced Computer Theory and Engineering (ICACTE).* 3rd International Conference, pages V5-484 - V5-487.

[6] Mazhelis, O., Luoma, E., Warma, H. (2011). "Defining an Internet-of-Things Ecosystem" *Springer-Verlag*, Heidelberg, Berlin.

[7] Auto-Id Labs. (2013) Available: http://www.autoidlabs.org/.

[8] Xue, X., Li, G., Liu, L., Liu, M. (2012). "Perspectives on Internet of Things and Its Applications". *2nd International Conference on Computer Application and System Modeling*. Atlantis Press, Paris, France.

[9] Vermesan, O., et al. (2011). "Internet of Things Strategic Research Roadmap". *European Research Cluster*. http://www.internet-of-things-research.eu/

[10] Bauer, M., et al. 2011. Introduction to the Architectural Reference Model for the Internet of things. First Reference Model White Paper. *IOT-i The Internet of Things Initiative.* [Online] Available: http://ww.iot-a.eu/ [Accessed 14 July 2013].

[11] Zhao, W., Wang, C., Yorie, N. (2011). "Medical application on internet of things". *Communication Technology and Application* (ICCTA 2011), IET International Conference, pages 660 – 665.

[12] Briseno, M., Cota, C., Garcia, E., Lopez, J. (2012). "A proposal for using the internet of things concept to increase children's health awareness". *Electrical Communications and Computers (CONIELECOMP*). 22nd International Conference, pages 168 – 172.

[13] Rohokale, V.M, Prasad, N.R, Prasad, R "A Coopera tive Internet of Things (IoT) for Rural Healthcare Moni toring and Control", Wireless Communication, Ve hicular Technology, Information Theory and Aerospace & Electronic Systems Technology (Wireless VITAE), 2011 2nd International Conference, pages 1-6.

[14] Chia, S., Zalzala, A., Zalzala, L., Karimi, A. 2011. RFID and Mobile Communications for Rural e-Health. A community healthcare system infrastructure using RFID for individual identity. IEEE Global Humanitarian Technology Conference. Computer Society, pp 371 – 376.

[15] S. Motoyama, "Hierarchical Polling-based MAC scheme for Wireless Body Sensor Network" in International Conference on Wireless Networks - ICWN-13, 2013, Las Vegas. pp. 103-109.