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Technical Seminar Report

on

"An IoT-Aware Architecture to improve safety in Sports environments "

Submitted in Partial Fulfilment for the Award of Degree of

Bachelor of Engineering in Electronics and Communication Engineering

Submitted by

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
(Accredited by NBA for the Academic Years 2018 - 19, 2019 - 20 and 2020 - 21)

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This is to certify that the Technical Seminar work entitled ***"An IoT-Aware Architecture to improve safety in sports environments "*** has been successfully carried out by **CHIRAG ADIGA,** bearing **1RN15EC038** bonafide student of RNS Institute of Technology in partial fulfilment of the requirements for the award of degree of **Bachelor of Engineering in Electronics &Communication Engineering of Visvesvaraya Technological University, Belagavi** during academic year 2018-2019 It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the report. The Technical Seminar report has been approved as it satisfies the academic requirements.

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DECLARATION

I, CHIRAG ADIGA bearing **1RN15EC038,** student of Bachelor of Engineering, Electronics and Communication Engineering, RNS Institute of Technology, Bangalore, hereby declare that the technical seminar entitled, "**An IoT-Aware Architecture to improve safety in sports environments"** has been independently carried out by me under the supervision and guidance of **Dr. Vipula Singh**, Professor and HoD, Dept of E&C Engg., RNSIT, submitted by me as a partial fulfilment for the award of **Bachelor of Engineering** degree in Electronics and Communication Engineering from **Visvesvaraya Technological University, Belagavi** during the academic year **2018-19**. I also declare that the technical seminar has not been submitted previously for the award of any degree or diploma, by me, to any institution.

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ACKNOWLEDGEMENT

The joy and satisfaction that accompany the successful completion of any task would be incomplete without the mention of those who made it possible.

I consider myself proud to be a part of RNS Institute of Technology, the institution which stood by me in all my endeavours.

I express my gratitude to our beloved Chairman **Dr. R N Shetty**, for providing state of art facilities in the Institute.

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I would like to express my gratitude to **Dr M K Venkatesha**, Principal, RNS Institute of Technology for providing me excellent facilities and academic ambience which has helped me in satisfactory completion of this Bachelor's Degree.

I extend my sincere thanks and heartfelt gratitude to my guide **Dr Vipula Singh,** Professor and Head of Department, for providing me an invaluable support throughout the period of my Internship.

Finally, I take this opportunity to extend my earnest gratitude and respect to my parents ,teaching and non-teaching staff of the department, the library staff and all my friends who have directly or indirectly supported me during the period of my seminar.

CHIRAG ADIGA

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ABSTRACT

The introduction of Internet of Things enabling technologies into the sport and recreational activities domain provide an interesting research challenge.Their adoption could significantly improve the sport experience and also the safety level of team sports.Despite this, only few attempts have been done to demonstrate the benefits provided by use of IoT technologies in sport environments. To fill this gap, this paper propose an IoTaware Sport System based on the jointly use of different innovative technologies and standards. By exploiting the potentialities offered by an ultra-low-power Hybrid Sensing Network (HSN), composed of 6LoWPAN nodes integrating UHF RFID functionalities, the system is able to collect, in real time, both environmental parameters and players' physiological data. Sensed data are then delivered to a Cloud platform where a monitoring application makes them easily accessible via REST Web Services.

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CHAPTER 1

INTRODUCTION

Smart environments are expected to become the main actors of the Future Internet, which will be no longer seen as a mean to connect people to services but to access the resources made available by small smart objects. This vision of the Internet fits into the broader concept of the Internet of Things (IoT), according to which everyday objects, such as domestic appliances, actuators, and embedded systems of any kind, will become proactive actors of the global Internet, with the capability of generating and consuming information. By exploiting the new possibilities offered by the IoT enabling technologies, innovative smart applications could be developed in many heterogeneous scenarios, such as home and industrial automation, healthcare and wellness, smart grids, automotive, and many others[1],[2] . Among these, sports and recreational activities provide interesting research areas that include several of the critical challenges for next generation of services in a variety of scenarios. Football is one of the most popular sports in the world and, therefore, it could represent an interesting starting point for the introduction of IoT technologies into sport environments. FIFA, the organization responsible for developing and improving the quality of football, periodically introduces innovations in the football field, such as Goal Line Technology (GLT), in order to improve the game experience [3],[4] . FIFA also aims to make football a safe sport. Concussion, hypoglycemia, heartbeat irregularities and shortness of breath are some of the injuries to hich players are subjected during a football match [5] . The adoption of emerging IoT technologies in the football field could help coaches and doctors to identify possible emergency situations and promptly help a player in trouble.

The designed solution has been customized and prototyped for the game of football, due to its great popularity, however, its design is generic enough to be easily applied to other team sports (i.e., volleyball, basketball, rugby, tennis). More in depth, the system is able to collect both environmental conditions and players' physiological parameters via an ultra-low-power Hybrid Sensing Network (HSN). This last one describes a typical 6LoWPAN network embedding also two new kinds of WSN nodes integrating UHF RFID Class-1 Generation-2 (Gen2 hereafter) functionalities. The former integrates an RFID Gen2 reader while the latter integrates an augmented RFID Gen2 tag. In such way, physiological parameters of player can be easily retrieved by RFID Gen2 readers deployed near the benches located in the football field. The retrieved data is then delivered to a Cloud platform, where a customized monitoring application makes them easily accessible via REST Web services [6],[7]. During the normal situation, therefore, no WSN-based transmission is performed, thus reducing the node power consumption and limiting the impact on the network capacity. The designed system is also able to timely and reliably manage emergency situations. In this case, indeed, the WSN-based transmission is activated so as to promptly inform coaches and doctors in the field. Doctors, equipped with a smartphone connected to a portable UHF RFID reader, can use a customized mobile application to interact with players' sensor nodes during their interventions. Finally, the system allows also to retrieve and store important data about the environmental conditions, which could be used to provide alternative services to citizens or researchers, within the realization of a Smart City infrastructure.

CHAPTER 2

TECHNOLOGICAL BACKGROUND

2.1 RFID and WSN

RFID is a low-cost and low-power technology mainly consisting of passive devices, called tags, which are able to transmit data when powered by the electromagnetic field generated by an interrogator, called reader. Such devices are usually classified according to the frequency band used (e.g., LF, HF, UHF) and the type of coupling (i.e., magnetic and electromagnetic) between tag and reader antennas. Since passive RFID tags do not need a source of energy to operate, their lifetime can be measured in decades, thus making the RFID technology well suited in a variety of application scenarios. The recent availability of UHF RFID tags with increased capabilities, e.g. sensing and computation, represents a further added value. Nevertheless, the main drawback of RFID tags stems from the fact that they can operate solely under the reader coverage region. Such an aspect limits the use of UHF RFID technology to object identification and monitoring within small areas. WSNs consist of a large number of low-cost, low-power embedded devices, called sensor nodes, which are able to self- configure and self-organize. These characteristics make them suitable to be deployed even in harsh environments in order to detect important parameters (e.g. temperature, light, humidity, etc.) without human intervention. The collected data are then delivered, in a multi-hop fashion, to a central point (sink) for proper utilization. This simple, yet fundamental functionality, has enabled the widespread adoption of WSN technology in many heterogeneous scenarios, such as building automation, surveillance, military operations, healthcare, logistics, etc. However, one of the main issues to be addressed in the development of complex applications is the power consumption. WSN motes, indeed, are usually battery-powered computing platforms integrating analog/digital sensors and an IEEE 802.15.4 radio enabling up to 100-m outdoor communication range (single hop).
They are typically deployed in large areas where changing or replacing batteries could be impractical or completely unfeasible. For this reason, the use of effective solutions to increase the network lifetime is fundamental in real applications.

2.2 Constrained Application Protocol (CoAP)

Well-known and widely used Internet protocols are often unsuited for IoT devices, which are usually constrained, especially in terms of computational power, memory, and ransmission bandwidth. For this reason, in the last years, many researchers focused their activities on designing protocols for the IoT. One of the main outcomes of this research effort is

Constrained Application Protocol (CoAP)[12], a specialized Web transfer protocol defined by the IETF Constrained RESTful Environments working group to allow the implementation of REST mechanisms on constrained devices. The main idea of this protocol is to provide a lightweight access to physical resources in order to meet the limited capabilities of embedded devices, such as WSN nodes. CoAP provides a request/response model interaction between two end-points and it includes key concepts of the Web as URI and media types. CoAP, like HTTP provides the following four methods for resources' manipulation: (i) GET, to retrieve a representation of the resource identified by the request URI; (ii) POST, to request that the representation enclosed in the request is processed; (iii) PUT, to request that the resource identified by the URI is updated or created with the transmitted representation; (iv) DELETE, to request that the resource identified by the specified URI is deleted. In addition to the HTTP features, it offers a built-in mechanism for the resources discovery, it supports the IP multicast, and it natively provides a server-push model and an asynchronous exchange of messages. It also has a small-size header in order to be used on low-power networks like

6LoWPAN over IEEE 802.15.4. It can also run on top of proprietary networks that are connected to IPv6 Internet. Moreover, it bases the communication on the UDP for reducing

the communication costs. CoAP also provides a resource observation mechanism, which allows a client to receive notifications upon every change in the state of resources it has

previously subscribed to.

CHAPTER 3

SYSTEM ARCHITECTURE DESIGN

The designed system has been put into effect according to the architecture illustrated in Fig. 1. As shown, it is composed of four main parts: the Hybrid Sensing Network (HSN), the IoT Smart Gateway, the cloud platform, and the user interfaces. The HSN consists of an integrated RFID-WSN 6LoWPAN network composed of four types of nodes: (i) LowPAN Border Router (6LBR), (ii) 6LowPAN Router (6LR), (iii) 6LowPAN Router Reader (6LRR), and (iv) 6LowPAN Host Tag (HT). According to the 6LoWPAN standard, the 6LBR is in charge of connecting the network to the Internet by translating 6LowPAN packets into IPv6 packets and vice-versa, a 6LR describes a node able to provide forwarding and routing capabilities, while the 6LRR is defined as a 6LR interfaced with an RFID reader. Finally, an HT node identifies a typical 6LowPAN Host (i.e. a node without routing and forwarding capabilities) interfaced with an RFID Gen2 tag. The designed system assumes that 6LR, equipped with light, humidity and temperature sensors, are deployed along the perimeter of playing field in order to detect environmental conditions, while 6LRR nodes are placed on poles located near benches reserved for players. Indeed, the main function of 6LRR nodes is to identify and monitor players labeled with RFID Gen2 tags. More in detail, players wear a HT node capable to detect important physiological parameters, such as body temperature and heartbeat. During the match, sensed data are periodically logged on the memory of the RFID Gen2 tag. In this way, 6LRR nodes can retrieve such information when players approach the benches and delivered to the IoT Smart Gateway. In the envisioned architecture, IoT Smart Gateway is a more powerful device placed near the exit from the playing field. It is connected, on the one hand, directly with the HSN and, on the other hand, with the Internet through a 3G-communication interface. The gateway, therefore, plays the role of 6LBR, enabling the communication between HSN nodes and remote users. Moreover, the gateway enables the RESTful communication with the cloud platform.

This last one is equipped with three different modules: (i) Data Storage Module, in charge of storing the received data; (ii) a Data Management Module, responsible to remotely control and manage sensors deployed in the field; and (iii) a Management Application (MA), able to execute the business logic. In particular, the MA module plays a key role within the developed architecture. It is responsible to timely manage emergency situations. As previously introduced, in case of critical events, such as player's heartbeat irregularities, the HT node activates its long-range IEEE 802.15.4 radio transceiver to send a notification to the MA. This last module is able to analyze heterogeneous information (i.e., the environmental conditions as well as the player's physical condition) in order to detect potentially dangerous situations. In such a case, the MA exploits Push Notifications (PN) to inform the coach and the doctor in the field that the player needs to be immediately taken off the field and provided with medical support. This strategy allows the HT nodes to always use the RFID Gen2 radio interface for routine operations, e.g. data logging and identification, while keeping the IEEE 802.15.4 radio off for most of the time, thus maximizing battery lifetime.

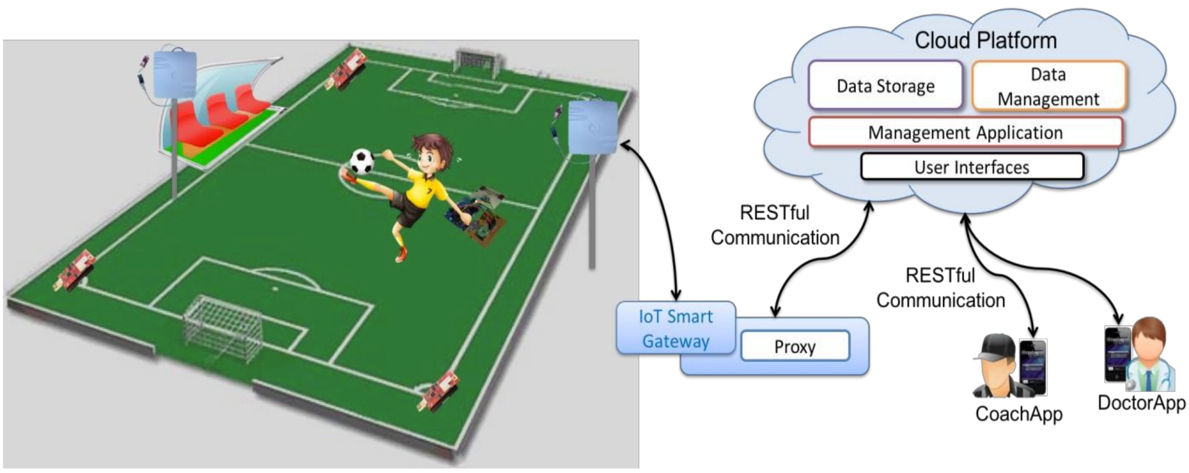

Fig. 1. Overall system architecture

CHAPTER 4

RFID AND WSN INTEGRATION

In Fig. 2 the proposed RFID-WSN integration approach is sketched: a conventional UHF RFID tag featuring the I 2 C interface is physically connected to the microcontroller unit (MCU) of a WSN node. In this way, information exchanged between the tag and the RFID reader via the EPCglobal Class- 1 Generation-2 (Gen2) air interface are directly available also on the I 2 C interface and, therefore, accessible by the MCU. Potentially, the proposed RFID-WSN integration enables EPCglobal standardized data to be spread, in a multi-hop fashion, throughout an IEEE 802.15.4 network. In particular, the RFID Section of Fig. 2 has been realized through the prototype shown in Fig. 3.

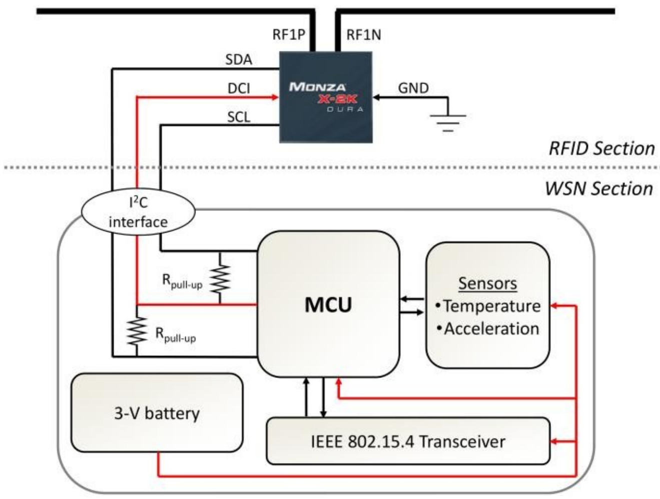

Fig. 2. Proposed integration approach between RFID and WSN. Red connections show how the on-board power is routed to the functional blocks

The main elements are an antenna, a chip, and a battery Holder. The battery older could be used to enable a stand-alone mode of operation as a battery-assisted passive (BAP) RFID tag, even though it is not exploited in the proposed RFID-WSN integration since the required power is fed directly from the 3- V battery of the WSN node.

The used chip is an Impinj Monza X-2K RFID chip, which is a new-generation UHF RFID Gen2 integrated circuit (IC) with 2176 bits of non-volatile memory (NVM) and an I 2 C interface. As an I 2 C device, Monza X-2K operates as a standard EEPROM whose contents can also be accessed via the Gen2 air interface. In the fabricated prototype, the small female header, which exposes the I 2 C bus, is used to interface the RFID chip with the WSN Section thus physically realizing the RFID-WSN integration sketched in Fig. 2. As the input impedance of the chip at 866.5 MHz, i.e. the center frequency of the European UHF RFID band, is Z chip =R chip +jX chip =20.83-j181.39 Ω, the designed antenna has been optimized to guarantee the conjugate matching with such impedance. More in detail, the designed dipole-like UHF RFID antenna takes cue from the commercial ALN-9660 RFID tag inlay which uses meander lines to achieve a very compact form factor (i.e., 7.5x1.7 cm 2). Detailed simulations taking into account the effect of the DC metal traces have been carried out in order to maximize the performance and optimize the design of the final prototype. Three main elements define the antenna structure: (i) the central loop, which primarily impacts on the tuning of the real part of the input impedance and prevents potential high-voltage discharge, (ii) the meander lines to reduce the antenna size, and, finally, (iii) the capacitive loads at the antenna tips, which facilitate the impedance matching. Simulations were performed by the CST MW Studio setting the input impedance of the antenna port equal to R chip and adding a capacitive lumped element with reactance X chip . In this way, the problem is led back to the design of classic antennas with real impedance.Finally, the antenna design has been optimized by setting the inimization of the reflection coefficient at the desired frequency as the fitness function and by adopting a gradient- based interpolated quasi-newton optimizer. A detailed comparison between simulation and measurement results for the proposed RFID tag antenna is reported in.

CHAPTER 5

SYSTEM DETAILS

5.1 HYBRID SESNSING NETWORK

As already introduced, key elements of the designed HSN are the HT nodes and 6LRR devices. The former has been described in the previous section, while the latter consists of a commercial off-the-shelf (COTS) RFID Gen2 Reader interfaced with the XM1000 mote from Advanticsys via the universal asynchronous receiver/transmitter (UART) communication bus. Specifically, the Sensor ID Discovery Gate UHF reader has been used.

As summarized in Table 1, three different kinds of resourcesm can be identified in the proposed architecture: (i) health sensors,,ii) ambient sensors, and (iii) RFID-related resources. 6LR nodes scattered in the football field can monitor only environmental parameters and, therefore, expose just CoAP ambient sensor resources

(e.g. coap://[aaaa::1]/ambient/light And coap://[aaaa::1]/ambient/temperature). In addition to such kind of resources, 6LRR nodes can expose an RFID Resource

(coap://[aaaa::3]/RFID/reader) which represents an aggregated information of tags read within the 6LRR RFID range. Finally, HT nodes also expose an RFID resource

(coap://[aaaa::3]/RFID/tag , which identifies the memory content of the integrated Gen2 tag) in addition to both ambient and health (e.g. coap://[aaaa::3]/health/heartbeat , which provides sensor readings from the integrated 3-axis accelerometer) sensor resources. In this way, each resource can be individually accessed from anywhere in the Internet by using CoAP methods.

TABLE 1.

Node	Resource	Examples of resource path
6LR	Env. Sensor	`coap://[aaaa::1]/ambient/light` `coap://[aaaa::1]/ambient/temp`

6LRR	Env. Sensor
	
	RFID Reader
		`coap://[aaaa::2]/ambient/light`
		`coap://[aaaa::2]/ambient/temp`
		`coap://[aaaa::2]/RFID/reader`

HT	Env. Sensor
	Health Sensor
	RFID Tag
		`coap://[aaaa::3]/ambient/light`
		`coap://[aaaa::3]/health/heartbeat`
		`coap://[aaaa::3]/RFID/tag`

For the sake of simplifying the development of the proposed solution, we drawn on the implementation presented in where Erbium (Er), a low-power REST engine for Contiki, has been extended to support conditional observations through a Conditional Observation Module. Such implementation has been adapted to our hardware. Specifically, in the proposed solution, the HT node embeds sensors able to monitor not only environmental conditions, but also vital signs, e.g. heartbeat, which should maintain predefined values in players with good health conditions. However, if their values fit outside a specified range, it might indicate the player needs attention. The use of conditional observation methods allows client applications to be notified only when critical thresholds are violated.

5.2 SMART GATEWAY

The Smart Gateway is another important element of the designed architecture. It works as a bridge between the HSN and the Cloud platform. It has been realized by connecting a Rasperry Pi 2 Model B board [22], equipped with the Raspian operating system, to the 6LowPAN Border Router. The gateway has been also equipped with a 3G module, to guarantee data communication. Raspberry Pi is a credit card-sized computer powered by the Broadcom BCM2836 system-on-a- chip (SoC). This SoC includes a quad-core ARM Cortex-A7 CPU, clocked at 900 MHz. It is equipped with 1 GB of RAM and powered by a 5 V micro USB AC charger. In our implementation, the Smart Gateway embeds a proxy subsystem, which enables transparent communication with oAP devices. It has the burden of translating HTTP requests oming from the Cloud platform into CoAP messages and vice-versa. It has been developed by using the Spring Framework and deployed on the Jetty application server installed on the Smart Gateway. The proxy logic has been extended by implementing a caching service, thus supporting multiple requests to the same resource and limiting the amount of traffic injected into the IoT peripheral network. This feature is particularly important for constrained nodes, which are not able to simultaneously manage requests from multiple clients.

5.3 CLOUD SERVICES

Storing, organizing, and retrieving information related to the players' performance during a match and environmental conditions are expensive processes from both the computational and memory point of view. For this reason, the cloud seems to represent the solution that best suits this kind of needs, as its storing and computing capabilities allow to process data more Efficiently. In the proposed system, a cloud platform has been used to store and manage the information retrieved by the HSN and all the data related to players' health conditions.

We deployed the proposed solution on Amazon Elastic Compute Cloud (EC2). pecifically, as previously introduced, the cloud platform has been equipped with the following modules: (i) Data Storage Module, (ii) Data Management Module, and (iii) Management Application (MA). In particular, the last one represents the functional core of the proposed architecture. More in depth, the MA registers itself as an observer to the CoAP resources exposed by HT nodes and to the RFID reader related resources exposed by 6LRR nodes deployed near the benches. In such a way, when a football player enters within the coverage region of a 6LRR node, all the information stored into the memory of the RFID Gen2 chip can be read and delivered to the MA for a further analysis. At the same time, the use of conditional observation methods allows the MA to be notified only when he value of player's physiological parameters fit outside a specified range, thus substantially reducing the number of notification messages in the network. The MA is also able to send Push Notifications to the mobile devices of coaches and doctors. To this purpose, we resorted to the Amazon Simple Notification Service (SNS), since it can seamlessly scale and add an abstraction level allowing programmers to use the same APIs for sending notifications on different platforms (e.g. iOS and Android).

5.4 MOBILE APPLICATIONS

Users can interact with the system through user interfaces, accessible via Web browser by both desktop clients and mobile devices. Such interfaces implement RESTful services, thus enabling the communication with the Cloud platform. They offer two main functionalities depending on two possible client profiles.

Coach Interface: This interface allows coaches to visualize current and historical information from environmental sensors, and data about players' performance as well. Coaches can interact remotely with the system by using the CoachApp, a customized Android application. As previously described, the App also allows coaches to receive notifications in case of emergency situations.

Doctor Interface: This interface allows doctors to visualize information about players' health status and to access to the health sensor data of each patient wearing an HT node. Doctors can interact remotely with the system by using the DoctorApp, a customized Android application. As previously described, the DoctorApp also allows doctors equipped with an RFID-enabled smartphone to directly retrieve and manage player's healthy

data stored into the tag's memory during the football match breaks. Finally, the DoctorApp is able to receive PNs in case of Emergency.

CHAPTER 6

PROOF-OF-CONCEPT

In this section, a prototype implementation of the proposed system is described and validated by means of a simple proof of concept. Specifically, the ADXL345 digital 3-axis accelerometer connected to the multi-sensor board of the HT node has been exploited to detect possible heart problems and generate an alert. According to the algorithm proposed in [23], the signal is initially passed through a band-pass filter. Next, the algorithm computes the first and second derivative of the signal using two approximate 5-tap filters with integer coefficients. The results are added together and considered in absolute value. A 6-tap moving average is then applied, and the result compared against a threshold to detect any peaks that may indicate physiological issues. It is worth to notice that the aim of this paper is to demonstrate the feasibility of the proposed system. Therefore, the definition of specific, optimum algorithms to detect heartbeat irregularities is outside the scope of this work The considered validation scenario is depicted in Fig. 4. The two main actors are: (i) the HT node, in charge of monitoring the player's health status, and (ii) the 6LRR node, in charge of reading and delivering to the IoT Smart Gateway data retrieved from the memory of the RFID chip equipping the HT node. The RFID tag embedded into the HT node contains, in addition to player’s physiological information, the Electronic Product Code (EPC), used to univocally identify the football player. A Nexus 4 mobile phone running Android 4.4.3 “KitKat” connected to the BlueBerry RFID Gen2 reader from TERTIUM Technology [24] is used as handled reader. The DoctorApp is installed on the Nexus 4 and uses the Wi-Fi or 3G Internet access. When an irregular-heartbeat event is detected the application receives the PN sent by the MA and notifies the doctor with a sound. The DoctorApp also allows the doctor to retrieve from the cloud further details on the occurred event and historical data about the player’s health status.

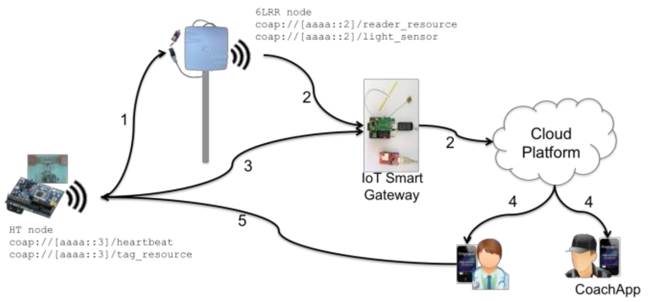

Fig. 4. Use case scenario

Fig. 5. Screenshots of the DoctorApp: (a) PN on the mobile phone; (b) visualization of details about the emergency situation.

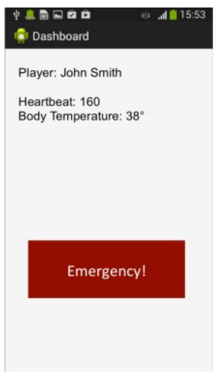

Fig. 6. Screenshot of the CoachApp .

CHAPTER 7

CONCLUSIONS

In this paper, a novel Sport System architecture for automatic monitoring of players has been proposed. Let us observe that this work represents an extended version of a previously presented paper. Respect to this last one, more details about the designed architecture have been presented. Furthermore, the Sport System has been extensively validated on a real football field. More in depth, according to the IoT vision, a complete network infrastructure relying on a CoAP, 6LoWPAN, and REST paradigms has been implemented so as to allow the interoperation among UHF RFID Gen2, WSN, and smart mobile technologies. The designed solution has been prototyped for the game of football, due to its great popularity.

In particular, an ultra-low-power Hybrid Sensing Network (HSN), able to collect the real-time variation of any critical players' physiological parameter as well as of the environmental conditions, has been implemented. The sensed parameters are delivered to a Cloud platform and made easily accessible via customized REST Web Services. To validate the proposed system, two different use cases have been implemented. The former deals with players' monitoring, the latter with the management of an emergency situation. The achieved results demonstrate the appropriateness of the proposed system.

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