Architecture of an IoT-based System for Football Supervision

(IoT Football)

Mohammed Abdulaziz Ikram
Computer Science Department in University of College Al-Jamoum, Umm Al-Qura University, Saudi Arabia
School of Software
Centre for Quantum Computation and Intelligent Systems, University of Technology Sydney, Sydney, New South Wales, Australia
Mohammed.a.Ikram@student.uts.edu.au

Mohammad Dahman Alshehri
Computers and Information Technology College, Taif University, Saudi Arabia
School of Software
Centre for Quantum Computation and Intelligent Systems, University of Technology Sydney, Sydney, New South Wales, Australia
Mohammad.d.Alshehri@student.uts.edu.au

Farookh Khadeer Hussain
School of Software
Centre for Quantum Computation and Intelligent Systems, University of Technology Sydney, Sydney, New South Wales, Australia
Farookh.Hussain@uts.edu.au

Abstract— Football, also called soccer, is one of the most popular sports in the world, if one considers the number of fans as well as the number of players. However, footballers face serious injuries during the match and even during training. Concussion, hypoglycemia, swallowing the tongue and shortness of breath are examples of the health problems footballers face, and in extreme cases, may lead to death. In addition, many sport clubs and sport academies spend millions of dollars contracting new professional footballers or even developing new professional footballers. The Internet of Things (IoT) is a new paradigm that combines various technologies to enhance our lives. Today's technology can protect footballers by diagnosing any health problems, which may occur during the match or training session, which, if detected early, may prevent any adverse effects on their long-term health. This paper proposes an IoT-based architecture for the sport of football, called IoT Football. Our proposal aims to embed sensing devices (e.g. sensors and RFID), telecommunication technologies (e.g. ZigBee) and cloud computing in the sport of football in order monitor the health of footballers and reduce the occurrence of adverse health conditions. The aim is to integrate the IoT environment, in particular the IoT application, into the field of sport in the form of a new application.

Keywords—IoT Architecure; IoT Football ; IoT application; RFID; WBANs.

I. INTRODUCTION

Football, with more than 270 million footballers around the globe, is one of the most popular sports in the world [1], if not the most popular. FIFA, the organization responsible for developing and improving the quality of football around the world, has recently introduced many innovations, which have improved the game. For example, Goal Line Technology (GLT) has been introduced which determines whether the whole of the ball has crossed the goal line which assists referees in their decision making. This technology has been implemented in approximately 37 stadiums around the world [2]. FIFA is also seeking to make football a healthy sport (e.g. anti-doping regulations [3], and nutrition for football [4]). In addition, FIFA has published technical recommendations and requirements for building new football stadiums [5] in order to create safe and comfortable environments. Recent research has reported on the frequency and nature of injuries, which occur during matches and training times [6-7]. Some of the injuries that players face include concussion, hypoglycemia, swallowing the tongue and shortness of breath [8]. These tend to occur when players are fatigued, and sometimes when they have face-to-face incidents with other players. The proposed IoT Football system will help the coach to make accurate decisions regarding the treatment of an injured or exhausted footballer by sending information from the player to the coach.

The Internet of Things (IoT) is a new generation of Internet services that enables physical devices to communicate with each other by using the World Wide Web. IoT can be explained as the framework used to collect information from the perception devices such as sensors, Radio-frequency identification (RFID) or mobile devices. It forwards this information to the network layer and then to the application layer. The IoT nodes have to be identified managed and controlled and must have the ability to interact with human or other objects within the Machine to Machine (M2M) environment [9]. IoT enhances an individual's or society's lifestyle, as it can be implemented in a wide range of applications such as health care [10], smart cities [11] agriculture [12] smart grid [13], saving energy [14] home automation [15], smart building [16], Intelligent Traffic system [17] and more.

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A number of studies have been published to develop the IoT architecture standard. These studies are dependent on the components, technologies and classifications that are required in a specific area. One of the most popular standards in IoT architecture is ETSI's M2M. This standard has many advantages in terms of components, classification and layers [20]. ESTSI's M2M is divided into two layers. The first layer is a default gateway, which consists of the components that gather information from the devices in the system. The second layer is the network layer and management, which includes accessing information securely, routing, storing information, analyzing and application information.

One of the key technologies that has been developed recently is Wireless Body Area Networks (WBANs). This kind of sensor can measure important physiological parameters such as blood pressure, heart rate, and body motion. Therefore, it is possible to build a monitoring health care system for a football player using this technology based on IoT technology, which has the potential to decrease the number of adverse health conditions faced by football players. In addition, this new generation of Internet services (IoT) enables the sensing devices to connect to the Internet by using interconnection technologies (e.g. ZigBee) [18]. Moreover, 6LoPWAN (IPv6) can place an IPv6 on small devices to transmit data with low power consumption and with reliable packet transmission.

In this paper, we propose IoT Football, which aims to carefully monitor players while they play, so that in the event of injuries, incidents and sport-related risks, these can be immediately analysed and accurately resolved. This technique is based on placing sensing devices on the footballers during the match or in training sessions to measure important functions (i.e. parameters) such as body temperature, sweat rate, heart rate, body motion and the respiration rate. Moreover, it collects information from the stadium such as the temperature and the intensity of illumination. Then, it transmits all this data to the cloud for storing and processing, and finally sends feedback to the coach or supervisor via the mobile application to inform them if anything happens to the footballer. This architecture proposal uses the ETSI's M2M standard to build and develop a reliable and robust system.

The remainder of this paper is organized as follows: Section 2 provides the literature review of the technologies needed in IoT Football, including the components required to build a reliable IoT-based application, while Section 3 details the architecture of IoT Football, including the case study that will be used in the development the IoT Football application, and then describes the elements and technologies in the IoT Football application. Section 4 illustrates some obstacles that could be faced during the implementation of this proposal in real life. Finally, Section 5 concludes the paper and gives directions for future work.

II. LITRATURE REVIEW

Nowadays, technology provides a huge amount of services which are increasingly convenient, safe and reliable. Wearable monitoring devices are capable of collecting important physiological parameters (e.g. pulse rate, blood pressure, blood oxygen level, daily activity and more) resulting in an improvement of the quality of life. This will lead to a change in the concept of the health care system in the future, which is mainly focused on providing proactive wellness management that can detect and prevent a disease early on. One of the most important and innvoative technologies that has been developed recently and has many implementations for health care is WBANs (Wireless Body Area Networks). Using WBANs in the health care system allows for the monitoring and recording of physiological characteristics (e.g. blood pressure, heartbeat and body temperature). Sensors gather this information and forward it to a gateway such as a mobile phone or even to an emergency center via the Internet communication system. The action that is taken is dependent on this information [19]. WBANs will be the main technology used in the future to diagnose disease early as well as register any abnormal events in the human body. It can also suggest a suitable treatment by analyzing the data gathered. WBANs can work with IEEE 802.15.6 to lower power transmission, short range and reliable wireless communication. This kind of sensor supports a data transmission range from 75.9 Kbps and up to 15. Mbps. In addition, WBANs have the ability to communicate over the Internet and other wireless network technologies such as ZigBee, WSNs, Wireless Personal Area Network (WPAN) and Wireless Local Area Networks (WLAN).

A number of recent research efforts have focused on developing health care monitoring systems based on WBANs. This research contributes to developing a new health care framework that aims to diagnose the health status of an individual before they suffer an adverse health event. However, there is a lack of research that concentrates on developing a framework for the field of sport, which is one reason for the motivation to propose an IoT Football architecture. Numerous other paradigms have been investigated and proposed in different articles. In Otto et al. [21], a health care system consisting of WBANs, and application software implemented on a personal digital assistant (PDA) or a personal computer is proposed. This system supports embedded sensor networks to monitor body activities and an ECG sensor type to monitor heart activity. In addition, Yu et al. [22] proposed a monitoring system used for daily life and for the purpose of sport. This system is based on Bodynets, which is mainly dependent on the Body networks. It measures multiple physiological parameters such as heart rate, blood pressure and the amount of oxygen (SpO2) that can be obtained by the photoplethysmography signal. After analyzing these parameters, the system can make a decision to help those engaged in daily physical exercise and professional sport. However, even though these two systems show effective results, they are very limited to a specific environment. Sports players require an uncomplicated device while playing and

training. Recent research expects that the future generation of health monitoring devices will be more lightweight, provide more accurate results, and will be easy to wear (i.e. T-shirt or bracelet) [23]. Lee et al. [24] proposed a wearable smart shirt for the monitoring of physiological ECG signals and physical activity in order to detect abnormal events in the patient's experience. The proposed system uses IEEE 802.15.4 for low power consumption. Sazonov et al. [25] introduced a wearable shoe-based device, which has the ability to measure different postures and activities (e.g. siting, standing, walking, ascending stairs, descending stairs and cycling). This system can help people who suffer from obesity. Moreover, [26] proposed a pH monitoring system using pH sensors based on collecting the amount of sweat from the patient.

Since the IoT paradigm has been created, there have been many scientific papers that focus on developing health care systems based on IoT architecture. In Chiuchisan et al. [27], an alternative system for patients was developed. Using IoT technology integrated into a health care system, the system allows patients to remain at home in what is known as a 'smart environment' for an Intensive Care Unit. In addition, it uses three components consisting of an intensive care unit monitoring device, Microsoft XBOX Kinect and finally, sensor devices. Moreover, the authors of [10] presented a case study of a health care system based on the IoT framework. The case study provides a comprehensive framework to build a reliable health care system based on the ESTSI's M2M standard.

However, there is a lack of literature on designing a health care system in the area of sport to provide monitoring services based on the IoT framework. *IoT Football* proposes an architecture framework aiming to protect players from injuries, incidents and sport-related risks. This system can monitor the footballer's activity based on measuring several parameters using sensing technology; also, it measures several parameters from the environment such as the temperature and the luminous intensity of the stadium. This goal can only be achieved through a network consisting of embedded sensor devices, which can be placed on the footballer's body, or can be implanted inside the body. These devices also have the same IoT characteristics, which can have its own IP address (i.e. 6LoWPAN), and Constrained Application Protocol (CoAP) technology to enable access by Web services. Furthermore, the Routing Protocol for Low Power (RPL) is a routing protocol which has been implemented in the IoT Football architecture. RFID is implemented also for player identification. This system is based on the proposed architecture and further research is encouraged in order to build a reliable, secure system to be implemented in a real scenario in a football stadium.

III. IOT FOOTBALL ARCHITECTURE

A. Case Study

It is well known that football (or soccer) is the most popular sport in the world with more than 3.6 billion fans, and more than two hundred million footballers around the world [28]. It is played on a rectangular field with a goal at each end, and of course, a ball. In this section, we provide a case study to illustrate how IoT Football can help football players in a case where the player experiences an accident, illness or condition while they are on the field. We present the issues and describe how our system can be used to address this problem while providing a solution. Figure 1 illustrates how the technologies will be implemented to facilitate effective, safe solutions, which lead to a quick recovery and higher levels of performance and success for the player, while ensuring they are as healthy and fit as possible.

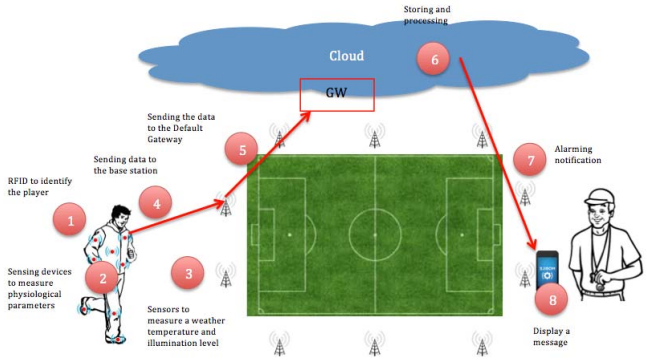

Figure 1: Case study scenario

Take the case study of Player A. Player A's name is John Smith. John has played football for ten years and is considered a professional in the field. Throughout his career, his medical history shows no major previous illnesses or conditions. One day, while playing a game, he becomes concussed. There is a possibility, as there is with all players, that something other than concussion could have happened to him on the field. For this reason, other illnesses or conditions are also monitored by this system. They include heart attack, swallowing of the tongue, fatigue, face-to-face incidents and more. Even though these are the main conditions targeted by the technology, it also has the ability to respond to other conditions such as a sprained ankle or knee, and other similar situations a player might regularly face. Our system will help the coach or supervisor to monitor these conditions during the match, and importantly, without delay, as the technology operates immediately. In the next section, we provide information about how we can use this technology to respond to and prevent these conditions when a player experiences a health problem.

Firstly, we use RFID to identify each player and provide information about him, including his name, ID, which team he belongs to, his prior medical history, etc. Then, the conditions of the stadium as well as the player's physical condition at the time of playing are analysed. These include: the temperature in the stadium, the level of illumination of the area, the player's blood pressure, respiration rate, body temperature, body motion, and sweat rate. We use the default gateway to transmit all these physiological signals to the cloud. In this instance, we

use ZigBee technology. This information is analysed by the cloud and sends an alarm notification as a warning message to the coach or supervisor by a mobile application, telling them that something has happened to John, and he needs to be taken off the field immediately and provided with medical support. If John experiences a heart attack next time he is on the field, be it years from this instance of concussion or weeks, it too can be picked up immediately by the same technology and reported to the coach or supervisor. Our proposed system means that the survival and health of the players is monitored very closely; the system has the ability to know even before the player himself, what their condition is and importantly, how to fix or prevent it. This means there is a reduced risk of injury or the occurrence of a serious health event for the player while he is concentrating on the game.

B. IoT Football Architecture

IoT is a new paradigm that enables a huge number of devices to communicate with each other using the World Wide Web. The IoT architecture to support the aforementioned case study is shown in Figure 2. There are a number of sensors that have low power consumption, are light weight, and have their own IPv6 capabilities (i.e. 6oLWPAN) as well as the ability to measure physiological parameters such as heart rate, body temperature, respiration rate, sweat rate and body motion and at the same time, these devices are able to transmit this information to the Default Gateway. Furthermore, there are other sensors around the stadium to measure other conditions, such as the temperature and illumination level. This layer is known as the perception devices. The Constrained Application Protocol (CoAP) is used in the sensor devices to communicate to the gateway. The CoAP is an application protocol used mainly to translate traffic between the devices and gateway to HTTP for integration with the web. Moreover, CoAP has many advantages in terms of low header overhead, multicast support, asynchronous message exchange and is based on User Datagram Protocol (UDP) transport with an application layer.

The second block is referred to as a Network layer, its main function being to gather all the information from the perception devices and transmit them to the cloud system. ZigBee technology is a default gateway that is used in the IoT Football system. The ZigBee base station transmits the data that is collected from the perception devices to the Internet using wired cables because it is highly secure, very reliable and has a high date rate rather than the wireless network technology (e.g. Cellular Network or WIMAX). The communication between the default gateways and the cloud service is by mld interface.

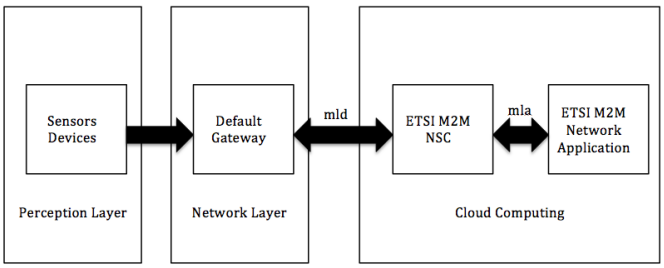

Figure 2: Football IoT Architecture

Cloud computing in the ETSI's M2M standard is classified into two parts. ETSI's M2M NSC (Network Service Capabilities) is used for registration, security, routing and NAT. The other part of the cloud is for the network application. The interface between NSC and the network application is mla interface, and is a bidirectional data flow.

In order to deploy IoT Football in reality, there are several functions and characteristics the system must possess. The next section details the functions that are required in each layer. The Football IoT consists of three main layers as follows:

1- Perception Layer
2- Network layer
3- Application in Cloud layer

First Layer: Perception Layer in IoT Football architecture

There are two networks of sensors in this layer. The body wireless area networks (WBANs) are the sensors that have the ability to measure the physiological parameters from the body of the footballer. These types of sensors must not weigh a lot as they are wearable, for example, a T-shirt. In terms of communication with the gateway, each sensor in the body must be able to have its own IPv6 (6LoWPAN), working with Routing Protocol for Low-Power (RPL). The sensors must operate with a gateway to send and receive packets in the CoAP protocol. In addition, the devices must be able to meet the security capabilities and the QoS requirement. Finally, in-the-body sensors must be able to be re-configured immediately to meet the requirements if there are any changes in the network topology. The devices around the stadium that measure the temperature and illumination levels do not necessarily have the same capabilities as the body sensors, but they need to be interoperable with the body sensors in terms of dealing with the same cloud service and should provide an accurate result.

Second Layer: Network Layer in IoT Football architecture

ZigBee technology is used for the base station in the system. The base station must be connected with a network domain via a wired connection. The base station also needs to work with 6oLWPAN, which means supporting the IEEE 802.15.4 based network. In addition, the gateway must implement the CoAP protocol to send and receive packets to and from sensor devices. Finally, it must have security capabilities and QoS requirements.

Third Layer: Application Layer in IoT Football architecture

Cloud services must analyse all the data traffic that comes from the devices to give accurate feedback to the coach or supervisor. Predictive analytics in data mining could be used for analysing and predicting possible injuries or conditions to the footballer. The cloud services must also activate the security capabilities and QoS. The data must be stored in a safe place. Finally, the cloud service must be compatible with different software platforms to provide all services to the coach or the supervision. For example, it should be able to provide the footballer's details including health status, previous illnesses, and fatigue level.

IV. DISCUSSION

Several obstacles could be faced while developing this framework for football stadiums as follows:

- The components and the technology needed will change the infrastructure of the football stadium, including the requirement to build an interconnecting system around the stadium, which could be expensive.
- The footballers may not agree to data on their health condition being collected by sensing devices, as they may feel that this is a breach of their privacy. For example, the system can measure some important functions of the player such as body motion and there could be adverse consequences if this information spreads to the public.
- The interoperability between different devices and technologies is crucial to the success of the entire system. They must operate at a high level of functionality and consistency in order to deliver results. IoT Football has many sensing devices and different layers to enable efficient communication between the sensors in the footballer's body and the coach.
- Any communication system will need to be regularly improved in terms of its performance levels. As time passes, technology will evolve in terms of the speed of connection, the quality of devices and other factors and remaining up-to-date will be necessary.
- Possible delays if there is a technological problem and the coach doesn't receive instant notifications from the cloud and the connection between the sensor devices and the gateway.
- There are many different IoT architecture standards that have been published recently and finding a suitable architecture to build the IoT Football architecture is pivotal to overall success.
- Developing a standard for other companies interested in making devices in this area can be easily implemented and followed.
- Maintaining the technology, equipment and systems to the highest level possible.

V. CONCLUSION AND FUTUREWORK

The Internet of Things (IoT) is a new generation of Internet services that enable physical devices to communicate with each other using the World Wide Web. It enhances the lifestyle of a society and individuals and there are many applications for it, including health care, smart cities, saving energy, home automation, smart building, intelligent traffic systems and more.

This paper, we proposed IoT Football architecture, which aims to monitor football players so that in the event of injuries, incidents and sport-related risks, these can be analysed and resolved. This technique is based on placing sensing devices on footballers during a match or training session and transmits all the data that is collected from the sensors to the cloud for storing and processing, and finally sends notifications to the coach or supervisor via the mobile application to tell them if anything happens to the footballer. This architecture proposal uses the ETSI's M2M standard. This architecture can be implemented in different sports such as volleyball, basketball and more.

The next steps will be implementing this system using TinyOS simulation and addressing any issues and challenges that could arise. This will be documented in detail in a new paper.

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