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A Proposed Unified Standard IoT-Based Architecture Based on 7-Layers Framework (Case Applied: Car Accident System)

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ABSTRACT

Internet of Things (IoT) is one of the famous applications of internet commuting and of cloud computing, and it is a widely used applications by organizations or by individuals, i.e., smart city, smart home, etc. There are many different IoT platforms that have been developed and used by IoT cloud providers to provide services to their subscribers. These different platforms lead to difficulty understand of each platform by developers. So, the need of IoT standard system is highly required to mitigate the diversity of building IoT-based system using different software layers. In this paper, a unified IoT-based architecture has been proposed based on 7-layers framework to be as a de facto standard to the most of IoT-based applications. Moreover, the proposed architecture has been applied using the car accident system which is a known application of IoT based application using CubCarbon Wireless Senser Networks (WSN) simulator. The proposed architecture shows the consistency between its 7-layers and promising to be as a considered unified IoT architecture.

مقترح معمارية قياسية موحدة قائمة على انترنت الاشياء تعتمد على اطار عمل مكون من 7 طبقات (تطبيق حالة: نظام حوادث السيارات)

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الكلمات المفتاحية:
انترنت الأشياءIoT
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الملخص

إنترنت الأشياء (IoT) هو أحد التطبيقات الشهيرة للتنقل عبر الإنترنت والحوسبة السحابية ، وهو من التطبيقات المستخدمة على نطاق واسع من قبل المنظمات أو الأفراد ، أي المدينة الذكية والمنزل الذكي وما إلى ذلك. هناك العديد من منصات إنترنت الأشياء المختلفة التي تم تطويرها واستخدامها من قبل موفري إنترنت الأشياء السحابي لتقديم الخدمات لمشتركيهم. تؤدي هذه الأنظمة الأساسية المختلفة إلى صعوبة فهم المطورين لكل منصة. لذلك ، فإن الحاجة إلى نظام قياسي لإنترنت الأشياء مطلوبة بشدة للتخفيف من تنوع بناء نظام قائم على إنترنت الأشياء باستخدام طبقات برامج مختلفة. في هذا البحث ، تم اقتراح بنية موحدة قائمة على إنترنت الأشياء استنادًا إلى إطار عمل مكون من 7 طبقات ليكون معيارًا قياسا لمعظم التطبيقات القائمة على إنترنت الأشياء. علاوة على ذلك ، تم تطبيق البنية المقترحة باستخدام نظام حوادث السيارات وهو تطبيق معروف للتطبيق القائم على إنترنت الأشياء باستخدام محاكي CubCarbon Wireless Senser Networks (WSN). تُظهر الهندسة المعمارية المقترحة الاتساق بين طبقاتها السبعة وواعدة لتكون بمثابة بنية إنترنت الأشياء الموحدة.

1 Introduction

Internet of Things (IoT) is described as an energetic international network structure having self-configuring capabilities primarily based totally on preferred and interconnected communication protocols [1]. This term (IoT) become coined through Kevin Ashton, in the year 1999 and later become officially brought in 2005 with the aid of using the International Telecommunication Union (ITU) [2].

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Due to fast improvements in cell communication, Wireless Sensor Networks (WSN), Radio Frequency Identification (RFID), and cloud computing. IoT devices can co-running with one another. The 4 most important capabilities of IoT are sensing; data accessing; heterogeneous access, programs and services; and security privateness and trust [3]. The essential objectives of IoT are the configuration of smart surroundings and self-aware independent devices including smart dwelling, smart items, smart health, and smart towns amongst others [4]. Nowadays, the adoption price of IoT devices could be very high, an increasing number of devices are related through the net. In the future, the IoT will alternate our dwelling patterns and business models. It will allow human beings and devices to speak anytime, anyplace, with any tool under perfect situations using any network and any service [5]. The most important aim of IoT is to create a superior world for humans in the future.

In this paper, the work is organized into several sections to meet the aim of the paper which is to propose a Unified standard platform of IoT-based architecture and implementing it using a case applied to car accident system using the proposed 7-layers IoT-based architecture.

In section II and III: the problem statement and proposed solutions are raised to bounder the scope of this work. **In section IV:** the recent related work to this paper that consider to build a car accident system using IoT-based application are presented and discussed in term of benefits and limitations then the collected recently related work that present the lack of IoT-based standard platform and architecture are presented to discover the limitations and benefits of their works. **In section V:** the most common IoT-based platforms are presented in brief description for each layer. These different platforms prove that there is no a standard platform or architecture is established for IoT-based applications, each IoT service provider uses its own platform. **In section VI:** the proposed IoT-based architecture is presented and explained based on 7-layers framework. **In section VII:** the implementation of IoT-based car accident system is achieved using the proposed 7-layers framework architecture which is a main goal of this work. The implementation is achieved in simulated environment using CubCarbon hybrid IoT simulator version 5.0. **In section VIII:** the discussion of the used tool and experiment results are presented. **In the final section IX:** the conclusion of this work is discussed.

II- Problem statement

There is a growth in the unpredictable number of accidents that show up each minute on the road and there are situations where most of the accidents could not be reported properly to nearby police stations and the closest hospital help to provide the ambulance car on time, which will result in the loss of lives of the drivers and occupants. In order to build a system to implement all predicted scenarios related to a car accident system there is no a standard framework to follow or to be used to build a such system.

III- Proposed Solution

In order to implement the car accident system as in a modern application development, the need of building IoT-based application is highly requirement to collect information about the location of the car accident vicinity and the coordinates of the accident itself, the collected information by using the IoT-based smart system will help to determine and sending signals to the nearby police stations and the closest hospital for help. The proposed solution uses a location-awareness technique to determine the longitude and latitude of the accident car location and context-awareness technique to indicate the car accident vicinity. Furthermore, the IoT-based architecture is highly required to easily develop and improving a such system by developers. In this paper, a new IoT-based architecture is proposed to be a unified fashion framework for IoT-Based applications.

IV- Related work

Tulika Joshi, Palak, Mr. Prasad Kadam. [6]. Recommended the vehicle alert device primarily based totally on the geographical coordinates acquired via way of means of the usage of the GPS (Global Positioning System). The computerized system gives the alarm approximately the road accidents and their locations. The accelerometer is equipped in the car to provide the alarm, and even as unsafe use has been detected in conjunction with crashes or rolls. The signal from the accelerator is used for similarly monitoring. The region of the accident is tracked through using the geographic coordinates acquired from the microcontroller that upload the data through the ESP8266 on the web including the location of the accident. The most crucial difficulty of the proposed technique is the accuracy of the anticipated accident data primarily based totally on the Global System for Mobile (GSM) and GPS data.

Shivani et al [7]. Used the included system to send the accident alarm data to the registered address. It will warn the driver if the car is out of management based on the vibration sensor. The registered customer receives an alert message via their mobile number, following which the region can be shared with the GPS. Response time for changing the control system stays established upon the shared GPS region. After analyzing the associated works, there is a want to expand an automatic system for alerting the accident data to the control center. The proposed IoT has a primarily based totally system that gathers the vehicle data and, without delay, passes it to the closest assist centre.

Danish, K. and Jaspal, S [8]. Improvement of automated geofencing and unintended tracking system is based on GPS generation embedded in the car to discover street accident for instant medical assist and security reason in robbery prevention using single shock sensor. In case of accidental mode, the system informs routinely through a textual content message to the medical rescue crew indicating the location of the car vicinity. When the driver is out of the car, the system routinely is goes into security mode. At this mode, a robbery tries at the vehicle; this system sends an alert message to the owner. The mobile textual content messages containing the vicinity from GPS (Latitude, Longitude) could be despatched if the tool detects an accident. The fundamental shortcoming of this work consists of detecting the only cars that passed their most velocity limit; however incapable of detecting the accident prevalence and reporting equal with particular vicinity.

S. Chen, et al [9]. This paper provides an overview of China's IoT development, covering legislation, R&D initiatives, applications, and standardization. This study portrays such issues in technologies, applications, and standardization from China's perspective, as well as proposes an open and generic IoT architecture comprised of three platforms to address the architecture challenge. Many new issues have emerged as a result of the IoT development, including a lack of core theoretical support, confusing architecture, and immature standards. The proposed acting standard will, hopefully, strike a balance between competing interests, paving the way for future basic theory research, and stimulating/regulating IoT development.

Sobin, C. C [10]. This paper includes a thorough examination of most IoT concepts, including architecture, protocols, security and privacy, scalability and energy efficiency, and so forth. Connecting IoT systems to the software/application levels to extract insights from massive amounts of data is a difficult challenge because they are constructed with diverse hardware and networking technologies. In addition, for the benefit of future researchers, the paper briefly discusses the most recent research efforts linked with the notions addressed as well as open issues.

L. P. I. Ledwaba and G. P. Hancke [11]. The goal of this paper was to provide a comprehensive overview of the most important components of IoT, with a focus on IoT device architecture. As a result, the background and definition of IoT are presented first. Second, detailed explanations of the principles of IoT designs are provided. Following that, authors went over to take a look at a few major sectors where IoT-related research is now taking place.

B. B. Gupta and M. Quamara [12]. This paper discussed some of the field's statistics and predictions. Authors went over the IoT security architecture in-depth, which is made up of three layers: perception, transmission, and application. Each layer's key characteristics and technologies have been investigated. As well as the authors looked at the difficulties and existing solutions for Radio Frequency Identifier (RFID) and Wireless Senser Networks (WSNs), which are the domain's essential enabling technologies. A comparison between ZigBee and Wireless HART has been presented, as well as some of the important protocols developed by the Internet Engineering Task Force (IETF) community, their specifications, implementation advantages and obstacles, and existing solutions. Some open-source IoT development and research tools and datasets have also been discussed. The study concludes with a discussion of open research topics, present research activities, and future possibilities in order to provide insight into new work orientations in the field to address current and future challenges.

S. Krco, B. Pokric, and F. Carrez [13]. Reference architectures are an ideal technique for ensuring a shared understanding by offering a framework that caters to various applications and, in turn, allows the reuse of work across domains. This paper provides an overview of the initiatives undertaken throughout Europe to define the framework, as well as how it is being used and what the future holds for these efforts. The typical method to project organizations, including those operated under the EU-founded Seventh Framework Program (FP7), is to define scenarios and use cases, then identify technical needs, and finally design architecture.

I. Yaqoob et al [14]. Because trillions of devices are predicted to be connected to the Internet, this paper intends to investigate the architecture of the Internet of Things. Scalable, resilient, interoperable, energy-efficient and secure network architectures are thus required to accommodate this massive number of devices. Key needs for the architecture of the future internet of things are defined based on crucial parameters such as applications, enabling technologies, business objectives, architectural requirements, network topologies, and IoT platform architecture types.

S. A. Al-Qaseemi et al [15]. Because multilingualism, protocols, and standards are important issues, this paper discusses the lack of issues and challenges of standardization and reviews the current status of technical standards to highlight and overcome them by providing some technical solutions. Due to a lack of consensus on which one works best with the Internet of Things' different layers. It lacks a single platform for standardization; this issue can be addressed by proposing an integrated Azure IoT Suite platform within the IoT Azure Hub that can accommodate millions of existing objects while also adding new devices that support various programming languages, protocols, and operating systems. SmartThings is another option that has been offered. It's regarded as a smart home platform because it's easier to set up and use than Azure for developing simpler projects, as well as extensive IoT reviews of current industry standards.

H. Mrabet et al [16]. A novel condensed and optimized IoT architecture based on five layers is proposed in this survey article. Similarly, based on the new IoT architecture, authors proposed a new taxonomy of security threats and attacks. A physical perception layer, a network and protocol layer, a transport layer, an application layer, and a data and cloud services layer make up the IoT architecture.

V- Internet of Things platform

A platform allows developers to deploy and run their applications. Also, it could be a hardware plus software suite upon which other applications can operate. IoT-based Platforms could be made up of hardware or embedded devices that sits on top of an operating system. Various IoT platforms are now available that can be used for developing an IoT solution but in this paper, three popular platforms that are widely used for IoT solution building are listed in this section [17].

A- Amazon Web Services (AWS) platform and architecture

Amazon Web Services (AWS) [18]. It is an IoT system based on cloud technology from Amazon. The platform uses protocols such as Message Queuing Telemetry Transport (MQTT) and a web connection. The platform is also capable of many features such as artificial intelligence, machine learning, and edge technology. And they are divided in their structure into:

Layer 1- Device: AWS services and solutions to connect and manage billions of devices. For industrial, consumer, commercial, and automotive workloads, collect, store, and analyze IoT data.

Layer 2- Application: End-user software solutions are available.

Layer 3- Data Control: This function allows you to forward data from your device to cloud-based services this feature guarantees that the correct information reaches the appropriate people at the right time.

B- Google Cloud Platform and architecture

Google [19]. Because of its fast global network, Google's Big Data tool, pay-as-you-go philosophy, and support for a variety of devices, Google is one of the most popular IoT platforms. Available services of cloud like RiptideIO, Big Query, Firebase, Pub Sub, Telit Wireless Solutions, Connecting Arduino and Firebase and Cassandra on Google Cloud Platform and many more. And they are divided in their structure into:

Layer 1- Device: A fully managed service to easily and securely connect, manage, and ingest data from globally dispersed devices.

Layer 2- Application: For end-users, technology solutions.

Layer 3- Service: Cloud Functions, Cloud Dataflow, Cloud Big table, Big Query, Data Studio, and Cloud Data lab.

C- Azure IoT platform and architecture

Microsoft [20]. Azure manages to integrate enterprise systems, non-IP, and IP-capable devices with the help of its IoT hub and logic app tools. Additionally, Azure supports big data analysis, and augmented reality applications and provides a rich A collection of apps for the manufacturing sector, including one for a connected manufacturing strategy. And they are divided in their structure into:

Layer 1- Device: Azure IoT Hub provides a cloud-hosted solution back end to connect virtually any device.

Layer 2- Central: is a pre-built UX and API interface for connecting and controlling devices at scale, as well as delivering trustworthy data for business insights.

Layer 3- Business: Drive transformation and desired business outcomes by building intelligent environments that allow you to connect, monitor, automate and model devices.

VI- Proposed platform framework and architecture:

In this paper, A new IoT-based platform is proposed using 7th layers architecture. Fig. 1 shows the proposed framework.

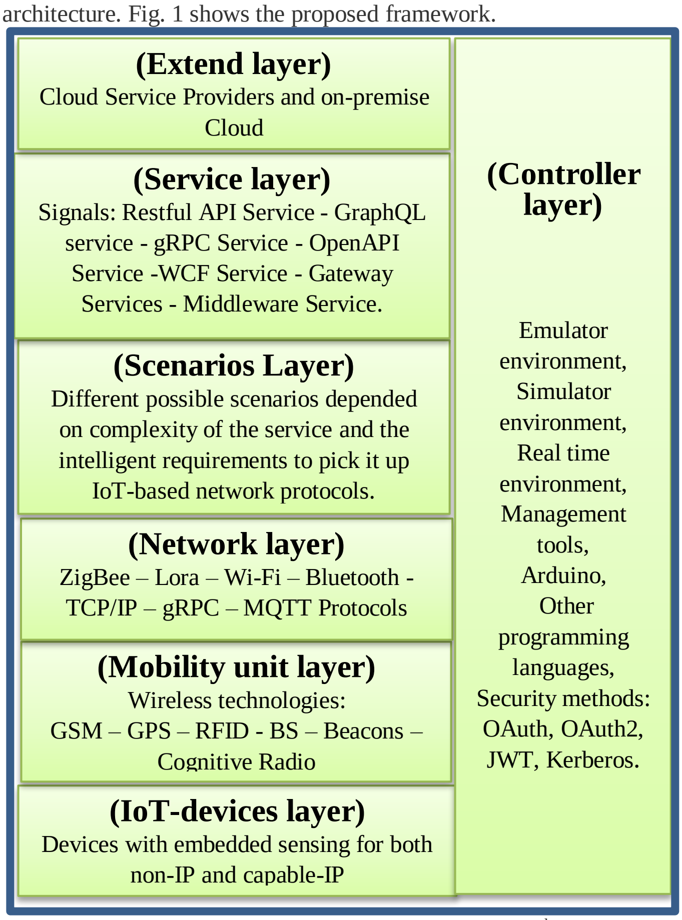

Fig. 1: Proposed IoT-based Architecture based on 7th layers.

In this section, the explanation of each layer of the proposed IoT-based architecture has been detailed as follows:

Layer 1: IoT Devices Layer

In this layer, the remote sensing devices are installed to connect the hardware environment. The environment could be static or dynamic environment. In static environment the IoT-based devices will connect to the infrastructure, some examples of this environment are smart home, smart healthcare hospital, traffic road monitor system, etc. In dynamic environment the IoT-devices will connect to the mobility unit layer directly using one of the wireless technologies, some examples of this environment are employee tracking system, the car accident system, etc. both types of IoT-devices, which are Non-IP and Capable-IP devices, can be connected either in the static environment or in the dynamic environment.

Layer 2- Mobility unit layer:

In this layer, wireless technologies could be connected to IoT-devices directly or they could be connected though the controller layer using one of the widely used software either open source or commercial software. Some of popular wireless technologies are as follows:

A- GSM (Global System for Mobile Communications): Provides terminal mobility, with personal mobility provided by inserting a Subscriber Identity Module (SIM) into a GSM (mobile station) network. The SIM card holds the personal number assigned to the mobile phone user.

B- GPS (Global Positioning System): It is a radio navigation system build upon satellite-based to provide users with position, navigation, and timing services. For the individuals who want to start their own GPS devices business, this is the best solution [21].

C- RFID (Radio Frequency Identification): It uses electromagnetic field to identify and track tags attached to objects. It refers to a wireless system consist of tow components which are tags and reader.

D- BS (Base Station): It is a transmission and reception station in a fixed location used to handle the cellular traffic and linking between the user 's mobile phones and the carrier's network.

E- Beacons: They are wireless transmitters that use low-energy Bluetooth technology to send signals to other nearby smart devices that could be any IoT-devices. Beacons are small devices connected to other smart devices using low-energy powers and they has long life time.

Layer 3- Network layer:

In this layer, the wireless technologies, IoT-devices, and internet protocols are interoperating with mobility unit layer and control layer. When interoperating with control layer the communication could be in the real time environment or in the simulated environment, this has been explained in more detail in the control layer in this proposed IoT-base architecture. Some of the technologies and protocols are listed as follows:

A- ZigBee: is a Wi-Fi technology that arose as an open worldwide standard in response to the needs of low-cost, low-energy Wi-Fi IoT networks.

B- Wi-Fi: may be ideal for IoT solutions that don't have to worry about energy consumption (e.g., devices that can be plugged into an outlet), that want to shiploads of information (e.g., video), and that do not want high-range. A specific example is probably a home protection system.

C-LoRa (Long Range Radio):

- **LoRa (short for long range)**: is a frequency-hopping spread spectrum (CSS)-based technique for diversity spectrum modulation. LoRa is an extended range, low-power wireless platform that has become the de-facto wireless platform of the Internet of Things (IoT) [22].
- **LoRaWAN:** As LoRa is capable to transmit over very long distances it was decided that LoRaWAN only needs to support a star topology. Nodes transmit directly to a gateway that is powered and connected to a backbone infrastructure. Gateways are powerful devices with powerful radios capable to receive and decode multiple concurrent transmissions [22].

D- gRPC (gRPC Remote Procedure Calls): It is an open-source high performance framework that can run in any environment. This protocol can be used in IoT-based environment to increase connectivity between IoT-devices in the real time environment though the internet.

E- MQTT (Message Queuing Telemetry Transport): It is a standard messaging protocol for the IoT. It is lightweight, publish-subscribe, machine-to-machine protocol.

Layer 4-scenarois layer:

In this layer, Different possible scenarios depended on complexity of the service requirements should be collected to build the IoT-based environment. Depending on the scenario, the suitable IoT-based protocol is selected. On another hands, the analysis of these scenarios would produce an intelligent IoT system that can be implemented using machine learning algorithms depending on the real time collected IoT-based data.

Layer 5- Service layer:

Internet of Things (IoT) services help aggregate data from physical objects, this would be collected from layer-1 that named IoT-devices layer though the layer-7 that named control layer on this proposed IoT architecture, and smartly use it for process automation and business intelligence. In this layer, different services are supported to accomplish the diversity of IoT-based services.

Nowadays, there are popular web services available that can be listed as follows:

- **Gateway Service Signal:** It is a service in which two different transport bearers can be bounded together. By using this service, the diversity of IoT-devices with different network protocols will be easily accomplishment.
- **Middleware Service Signal:** It is a software layered between the user's application using the origin server or databases and the operating system.
- **Other signals:** the other signals that need to be established in this layer it would be between the IoT-based environment and other cloud service providers or on-promises cloud which are provided by the layer-7 that named control layer in this proposed IoT architecture. Some examples of these services are RESTful Application Programming Interface (API), OpenAPI, GrappQL service, gRPC service, and Windows Communication Foundation (WCF) service.

Layer 6- Extended layer:

In this layer, the ability of extending the local IoT-based services environment, it might be on-premises cloud, would be easily when connecting one of the popular IoT services provider or to merge both services from cross-cloud service providers. The service cloud provider could be Google, Amazon, Azure, or any other service provider.

Layer 7- Controller layer:

In this layer, all layers in the proposed IoT-architecture would be communicating to each other through the layer-7 that named control layer. This layer could be used as simulation or emulator software, on-premises application, management tool, or as a security model. One of the IoT Simulator software is CupCarbon Wireless Senser Network (WSN). Security model is relay on this layer as well. The security model based on IOT-devices could be on-premises application or using one of the extended layer's services as cloud service, some examples of the security model are the Azure Active Directory (AAD) for authentication methods that produces JSON Web Token (JWT) to protect signals generated by IoT-based sensing devices. This JWT code uses Kerberos protocol to authenticate users or devices that can be managed using Active Directory Domain Services (ADDS). The JWT code could be generated using an embedded code by using one of the programming languages to build a IoT-based services using a web application as a controller management to the IoT-based environment. All of these security methods relay on the control layer of the proposed IoT-based architecture.

VII- Implementation of our framework

A- Description:

There is an increase in the number of cars on the road that contributes to serious daily accidents. One of the main causes of loss of life during an accident is the lack of immediate assistance that can save a person's life. Once the accident occurs, the lives of all the passengers in the vehicle are in danger, as well as the delay in the arrival of the police and ambulance to the scene of the accident. It all depends on the response time that can save their lives. In our model, we proposed Accident Management system depends on the different scenarios using CupCarbon simulator. Fig. 2 shows the IoT-based car accident system requirements which it explains the workflow of the system. In this scenario, the proposed IoT-based system will trigger action for both events when the car's airbag crashed or not crashed in order to send messages to corresponding actors.

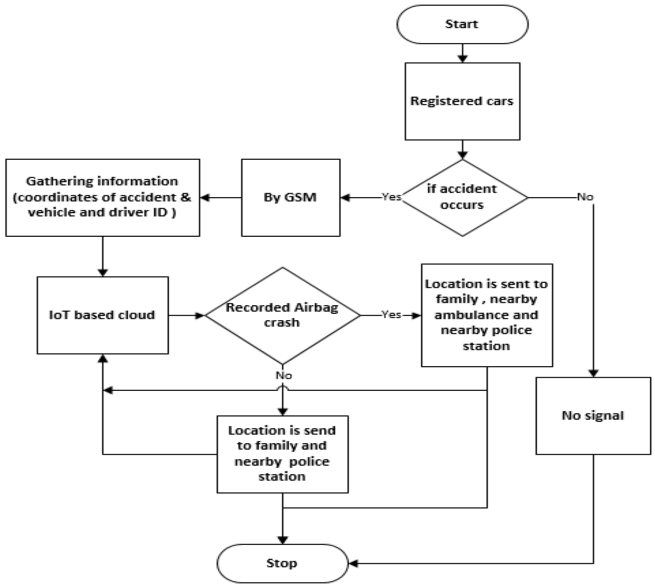

Fig. 2: the car accident IoT-based system requirements

B- IoT-based Environment Design:

The IoT-based environment design has been distributed in multi-layer which is the proposed IoT architecture that presented and has been explained using 7th layers architecture in section V.

The 7th layers IoT architecture is divided as follows:

Layer 1- IoT-devices layer: During an accident, the sensor that connected to the car sends a pulse to the GSM which uses the dynamic environment.

Layer 2- Mobility unit layer: After activating the GSM via the pulse sent by the sensor, it fetches the location and sends it to the server via GPS.

Layer 3- Network layer: In this layer, we used ZigBee technology in the CupCarbon simulator to transfer the location of the coordinates of the accident with the data of the vehicle and its owner.

Layer 4- Scenarios' layer:

This Business Scenario describes the business and technical environment for the platform and states a set of requirements that the platform should satisfy.

In this paper, only just one scenario has been presented in the simulation environment for applying the proposed IoT-based architecture. The system scenario is explained as text below:

Scenario: In the event of an accident, a message with the coordinate's location is sent through GSM to the Base Station (BS) and then to the telephone exchange, then to the server, and then to the police and ambulance if needed, to send help immediately to the location of the accident. The workflow has been described in the Figure 2 above. In this paper, one scenario was applied to the CupCarbon simulator as shown in the Fig. 3, and Fig. 4 below.

Layer 5- Service layer: In this layer, the CupCarbon simulator has been used as **GPS gateway** which offers tracking software to identify locations with regional. A map of the Libyan city Sabha Brak Al-Shati has been used to show the road on the map. The coordinates have been recorded and sent to corresponding actors which are the nearest police station and the closest healthcare hospital.

Layer 6- Control layer: A CupCarbon simulator based on Internet of Things has been used to show how to send and receive data in the car accident system based on IoT-devices.

Layer 7- Extended layer: A CuoCarbon's simulator version 5 which is a Wireless Sensor Network (WSN) simulator for smart city and the Internet of Things has been used to record the simulation messages generated by the system [23]. The car accident system would use on-premises cloud to store the schema, corresponding information about the cars and the owners.

VIII- Discussion of the experiment results

In this paper, CupCarbon version 5 has been used for the implementation of car accident system detection. The Libyan Sabha city map road has been used to simulate the car accident detection. In Fig. 3, the results of the experiment show the ability to send a message to the nearest base station contains the location of the accident using GSM network. In Fig. 4, the results of the experiment show the message when delivered to the police station and hospital via the server with the coordinates of the accident site. The tool has showed the capability of simulate the wireless environment easily using Zigbee wave.

IX- Conclusion

In this work, The IoT-based architecture based on seven layers has been proposed to be used as a de facto standard and promising architecture for all IoT systems. The proposed IoT architecture has showed the capability to design and implementing the car accident system easily as a popular IoT application using CubCarbon simulator. The main goal of this paper has been achieved through exploring the previous studies, and studying the most popular cloud providers of IoT platforms in order to innovate the new IoT based architecture that based on seven layers. The proposed model is bottom-up service approach layers, and each layer has an ability to communicate with the upper layer or through the controller layer that works as interoperability between all layers in the proposed IoT architecture. Moreover, two IoT-based systems classifications have been presented as a static IoT environment and a dynamic IoT environment which enables developers to build their IoT applications using a well-known environment and in standard framework.

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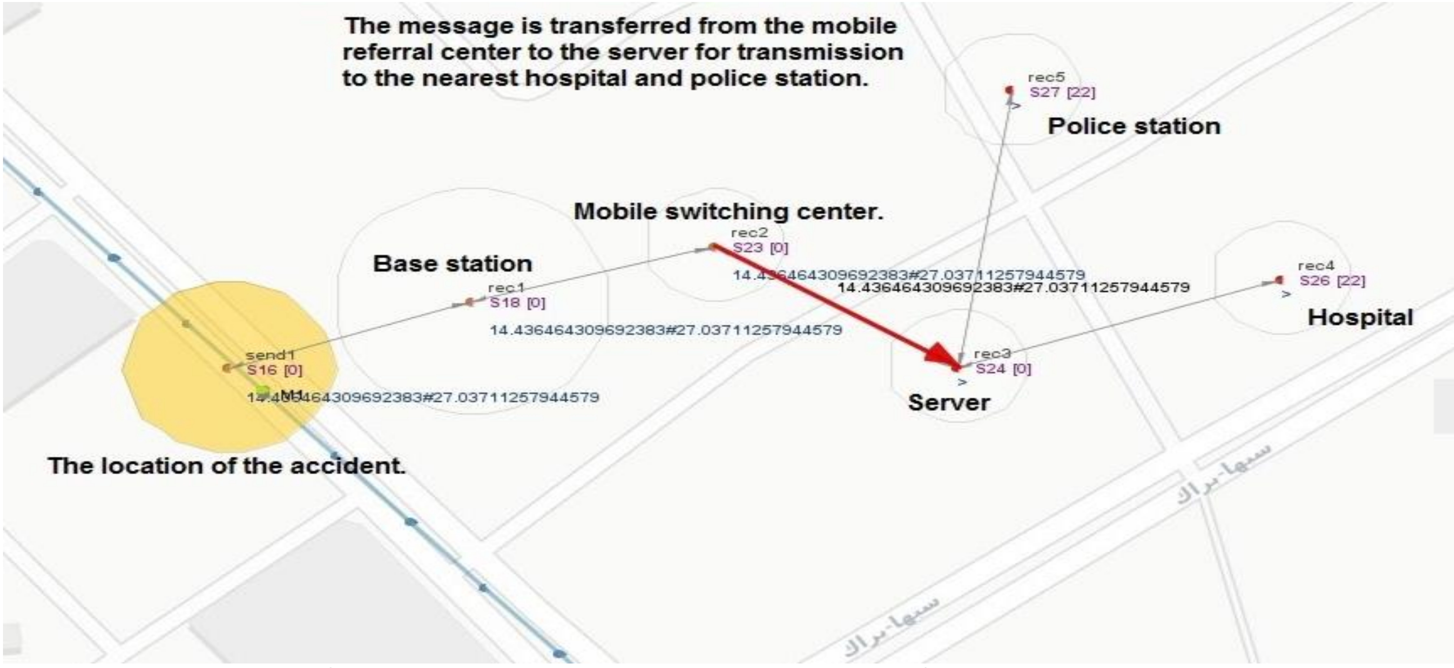

Fig. 3: At the moment of the accident and the sensor sends a message at the location of the accident to the nearest base station.

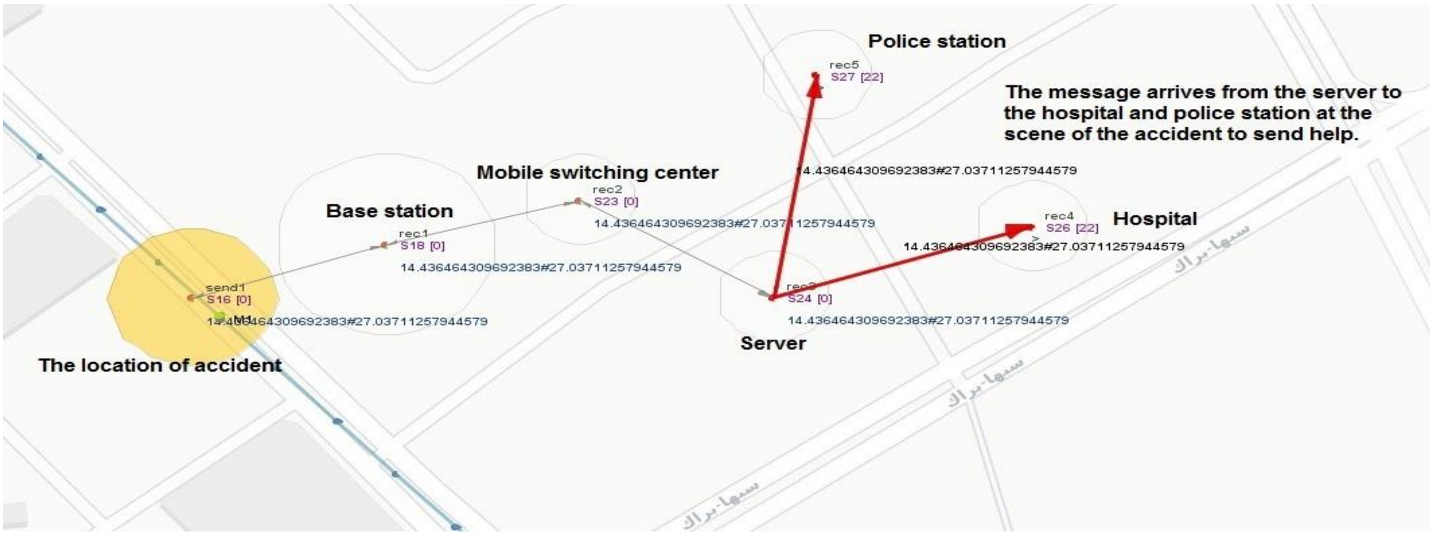

Fig. 4: At the moment, the message is delivered to the police station and hospital via the server with the