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An IoT Application for Locating Victims Aftermath of an Earthquake

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***Abstract* — This paper presents an Internet of Things (IoT) framework which is specially designed for assisting the research and rescue operations targeted to collapsed buildings aftermath of an earthquake. In general, an IoT network is used to collect and process data from different sources called *things*. According to the collected data, an IoT system can actuate different mechanisms to react the environment. In the problem at hand, we exploit the IoT capabilities to collect the data about the victims before the building collapses and when it falls down the collected data is processed to generate useful reports which will direct the search and rescue efforts. The proposed framework is tested by a pilot implementation with some simplifications. The initial results and experiences are promising. During the pilot implementation, we observed some issues which are addressed in the proposed IoT framework properly.**

Keywords — IoT; Internet of Things; search and rescue; framework

I. Introduction

Recently, internet-connected gadgets are present in many application domains; from smart environments and healthcare to transportation and logistics. The empowering technology is named *Internet of Things* (IoT). The term IoT was first coined in the context of RFID infrastructure in 1999 [1]. After then, its definition has been extended and evolved. Below, we provide some current IoT definitions:

- A radical evolution of the current Internet into a Network of interconnected objects that not only harvests information from the environment (sensing) and interacts with the physical world (actuation/command/control), but also uses existing Internet standards to provide services for information transfer, analytics, applications, and communications [2].
- IoT refers to a state where Things (e.g. objects, environments, vehicles and clothing) will have more and more information associated with them and may have the ability to sense, communicate, network and produce new information, becoming an integral part of the Internet [3].
- IoT is a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual 'things' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network [4].

The common keywords in these definitions are *network, sensing, information exchange and processing, interaction, intelligence*. Thus, we believe that actually the IoT term is an umbrella concept for holding all these related technologies and concepts together for creating smart and intelligent systems.

In accordance with these definitions, in this work, we propose an IoT framework which is developed for assisting research and rescue operations aftermath of a disaster. The details of the problem and the IoT based solution are provided in the following sections.

II. Problem Definition

Due to natural disasters, thousands of buildings collapse every year. In Table 1, we presented some of the damage figures of the earthquakes. As seen in the table, the number of collapsed buildings can be very large.

TABLE I. The damages of Some earthquakes

Location	*Year*	*Damaged Buildings*	*Died*
Northern Sumatra, Indonesia [6]	6/12/2016	10,534	103
Pacific Coast of Tohoku, Japan [5]	3/11/2011	128,530	15,891
Bam, Iran [7]	26/12/2003	25,000	41,000
Izmit, Turkey [8]	17/08/1999	133,683	17,480

After such disasters, search and rescue teams arrive at the scene to locate and rescue the people captured in the collapsed buildings. The first thing to decide is which building should be first selected to investigate. As the number of the search and rescue teams is limited and the time is vital, the selection of the collapsed buildings is utmost important. The key criteria of selecting might be the number of people captured in the building and their locations. A building trapping many people should have priority over the one with less number of people. Other criteria would be the victims' location. If the victims are mostly located on the upper floors of the collapsed building they can be reached sooner with relatively less effort. Rescue teams needs this kind of information about the victims to efficiently plan search and rescue (SaR) operation.

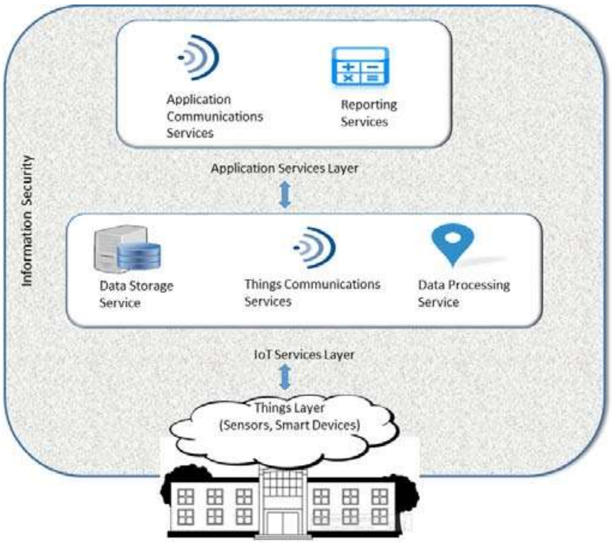

Fig. 1. The proposed IoT Framework.

In the current situation, the SaR teams first attempt to collect the related information using local data, if available. The limited-capacity technology helps to gather such data from the affected area by spending considerable time. After collecting as much as data, SaR teams make an assessment of the buildings in their responsible area, and then, they begin to rescue operations.

In this IoT framework, we aim to develop a smart system including various sensors, communication channels, and storage environments such that when SaR teams arrive at the damaged area they can easily collect data, make assessment of the buildings, accordingly team-up. Thus, SaR teams can save valuable time and immediately start their operations.

In the following section, we provide the Earthquake SaR Support System (ESSS).

III. Proposed Framework

The proposed IoT framework is summarized in Fig. 1. The proposed framework is layered into three tiers. The bottom layer is called Things Layer (TL). TL manages the sensors and smart devices located in a building. The IoT Service Layer (ISL) communicates with TL to gather information about the habitants. ISL also provides necessary storage, communications, and data mining algorithms for processing the collected information. At the top of the proposed IoT framework is Application Services Layer (ASL). ASL behaves as the interface to the applications that will use the proposed IoT framework. Therefore, ASL provides services which can be used by Search and Rescue (SaR) applications in an emergency situation. The details of the layer are provided in the following sections.

A. Things Layer

Things layer (TL) consists of things that are able to collect data which can be used to create information about the number and location of people in the building at given time. These things can be various types of sensors, smart devices:

- *Sensors*: In a building, there are several sensors already installed. For example, there can be motion or light sensors deployed on the ceilings and door or temperature sensors installed on cabinets and doors [9]. The machines used in daily life at any home such as refrigerator, washing machine, dish washer, television, oven, computers can also be furnished with various sensors such as temperature, mode, status, electric consumption for gathering data [10]. These sensors can constantly and discreetly observe the daily activities of the residents and communicate with IoT Service Layer.
- *Smart Devices*: Nowadays, there are various kinds of wearable smart devices such as smart watches, phones, sport shoes, pedometers, etc. These devices collect, process, and share data about their users. Related to the question at hand, these devices can help to locate a person in different levels of accuracy: some can work with GPS signals and report the location with high accuracy whereas some can just guess the distance from a nearby fixed device [11]. Either case, one can collect valuable data about the whereabouts of the user [12].

B. IoT Services Layer

IoT Services Layer (ISL) serves two main objectives: collecting data from Things Layer (TL) and serving information to Application Services Layer (ASL). Thus, ISL should process, store, and convert the collected data from TL such that ASL can handle the requirements of the application. In other words, ISL hides the complexity and heterogeneity of the underlying TL from ASL. For this reason, ISL is composed of several services:

- *Things Communication Services:* The communication between the things and the IoT Services Layer (ISL) could be event-based, demand-based, or periodic. In the event-based model, when sensors sense pre-determined events or state changes (i.e., from “door closed” to “door open” or from “no motion” to “motion”) they can initiate the communication. In the demand-based mode, TSL initiates the communication by querying things. In the periodic mode, things broadcast their states or the collected data. In these three modes, the communication between things and ISL can be direct or indirect. In direct communication, ISL can address the thing and between them there will be nothing else. However, in the indirect communication ISL either cannot address the individual things or communication requires some other devices to route the traffic. In these cases, some well-known routing solutions such as clustering, multi-hopping, etc. in wireless sensor networks (WSN) can be exploited [13].
- *Data Storage Services:* The locations of the fixed sensors or smart devices should be recorded in data storage. Moreover, the collected data from these resources should be stored and updated for further processing. Thus, Things Communication Services is one of the users of this service. Another user of the service is the Location Estimation Services as explained below.

C. *Application Services Layer*

Application Services Layer (ASL) is designed to aid SaR to contact with the underlying Things Layer. The important services are as follows:

- *Data Processing Service*: The aim of the IoT framework is to find out the number and location of the trapped people after a demolition. This service is the crucial part of the proposed framework. Using the stored data and necessary data mining algorithms, this service estimates the number and location of the inhabitants in the building. This task is complex since the semi-structured or unstructured data produced by heterogeneous sensors with different levels of accuracy and for different purposes. Moreover, the binding of individuals to the sensed data is also hard as one individual's presence in a location would be reported by many sensors in different methods and sensitivity. The output of the services is stored in the database.
- *Reporting Service*: This service will provide different reports to the SaR teams. The basic report consists of the location and number of victims after the demolition. A detailed report can provide if these people have any sign of living provided that the things in the building are still able to sense and communicate with the ALS.
- *Application Communication Services*: Reporting Service needs to communicate with SaR teams. The communication means is basically wireless. As, most of the time, aftermaths of an earthquake, the communication and power infrastructures are damaged and cannot serve for a long time, ad hoc wireless communication is a good option. Thus, Application Communication Services (ACS) should manage the possible communication methods. First of all, ACS should be able to contact Internet if the communications infrastructure is up and working. Otherwise, ACS should create an Ad Hoc network by setting up a hot spot. In either case, SaR teams should easily locate and connect to each building's ACS quickly. Therefore, ACS should provide simple but effective admission control mechanisms.

D. *Information Security Service:*

In addition to above three layers, the proposed framework should be secured from possible unauthorized accesses. Since valuable information about the people living in the building is gathered by the proposed framework, information security becomes utmost importance. The information security is utmost important in any IoT application [18]. There have been some proposed methods such as limiting access to collected data, anonymizing the collected data, etc.

In the proposed application, we assume that Information security should cover each layer in the framework and ensure the security of the communications among these components. Besides, it should allow the SaR teams to access the collected and processed data easily and efficiently while blocking unauthorized access. Therefore, directly implementing Authentication and Authorization methods into the service is not trivial [18]. One simple mechanism would be that Reporting Service will only be functioning after an earthquake is sensed. Another mechanism can be to anonymize the user data such that profiling cannot be done [19].

IV. A SIMPLIFIED IMPLEMENTATION OF THE PROPOSED FRAMEWORK

In order to test the validity of the proposed framework and improve the proposed mechanisms, we implement a simplified version of it. In this implementation, we only use the smart devices such as phones and tablets and Wi-Fi Access Points (AP) as "*things*" as seen in Fig. 2. Moreover, we combine two layers, namely Application and IoT layers, into a single layer in order to accelerate the implementation.

The use case scenarios are as follows. Users install a mobile application on their smart devices such as smart phones and tablet PCs. The application periodically discovers the surrounding Wi-Fi *Access Points* (APs). The AP with the strongest signal power is selected as the nearest one. The *Basic Service Set Identifier* (BSSID) of the selected AP and the suitable *Device Identifier* (MAC address/ IMEI number, etc.) is uploaded to a web service. The web service logs these records along with the time stamp into a *database*. Thus, the smart devices can register their whereabouts in a simple way.

The web server is installed on a *mini PC* connected to the Internet. The mini PC is furnished with a *mobility sensor* which signals the mini PC during an earthquake or fall-down, and a *long-life battery* as a back-up power if the electricity goes off. After then, the mini PC initiates a hot spot. When Search and Rescue (SaR) teams arrive the field, they can easily get connected to the mini PC to download the *occupation report*.

Data Storage Service is a relational database management system (RDBMS). There are two important relations in the database. The first one is *Configuration Table* and the second is the *Log Table* as seen in Fig. 3. The configuration table should be filled in when the proposed system is installed. The location and the direction of APs are stored in this table. The log table stores the records sent by the application installed on smart devices.

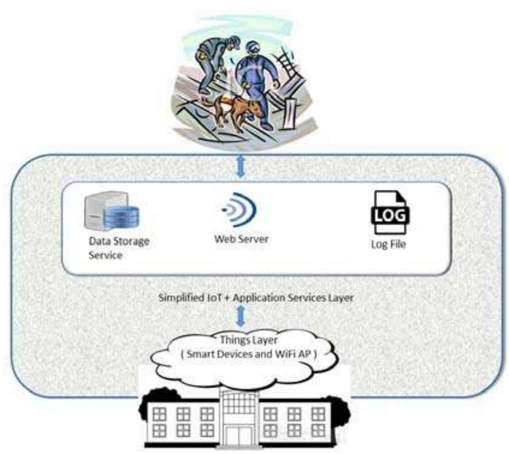

Fig. 2. The simplified version of the proposed IoT Framework.

Several reports can be prepared by joining these two tables. An example reports are given in Fig 4. Report file type can be html or XML to ease the processing of SaR Teams.

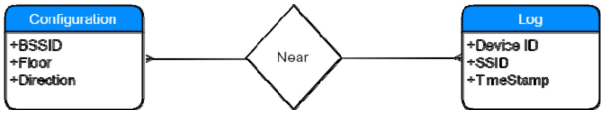

Fig. 3. The ER diagram of the database.

During the implementation of this simplified version of the framework, we have experienced the following points:

- Using Android Studio [14], we developed a mobile application for periodically scanning surrounding Wi-Fi APs. We also realized the web service by using Apache HTTP Server [15]. The RDBMS is selected as MySQL [16]. We observe that all these components are well-matured and stable. MySQL is argued to be able to support the requirement of IoT applications efficiently [17]. In essence, we believe that the proposed framework can be realized by using existing technologies.
- The number of smart devices belongs to single person can be larger than one. When user activates more than one device the exact location of the user cannot be easily determined. One solution is to prefer one of the devices as considering it as "the major". For example, smart phones are expected to be close to its user most of the time. Related with this problem, the reported number of victims can be exaggerated by the device number. These issues can be solved by applying suitable data mining techniques in the Data Processing Service of the proposed IoT framework.
- The number of Wi-Fi APs at a home can be very limited; usually a single AP is located. However, in public buildings such as university campuses, there could be more APs which help to locate victims more accurately. As a more realistic environment of IoT, there will be more things to collect data about the people and their location.
- The developed application should refresh its AP scanning which consumes battery. Therefore, the scanning period should be set properly. If the periods are too frequently, users can be affected negatively and even uninstall the application. On the other hand, if the scanning period is too long, the generated report can be misleading. The trade-off is important.
- One major problem we faced in the implementation is the users' concern about their privacy. Most of the time, users would like not to be tracked or monitored. Moreover, they are sensitive about the security of the collected information. If someone can hack the storage unit, he will be aware of if the house is occupied or not. So the thieves can break into houses which seem to be unoccupied. In the simplified implementation, unfortunately, we have not developed any information security mechanisms. Therefore, as we suggested in the framework, Information Security is a fundamental service for the proposed IoT framework.

Occupation Report Building Adress and Map

BSSID	Floor	Direction	# Estimated People	Last Activity Recording Time
94:b4:0f:16:02:f1	1	North-East	1	10:25 @ 23/12/2016
44:4c:6f:a6:12:e3	1	East	2	10:45 @ 23/12/2017
	1	TOTAL	3	
c4:54:bc:e6:22:2a	3	West	1	10:28 @ 23/12/2018
	2	TOTAL	1	
d1:33:a2:64:5a:89	4	East	1	10:37 @ 23/12/2019
33:b4:0f:16:02:f5	4	South-West	5	10:23 @ 23/12/2020
	4	TOTAL	6	
9a:44:cf:16:12:f6	6	North-East	2	10:33 @ 23/12/2021
	6	TOTAL	2	
bc:b4:0f:16:02:ff	7	West	7	10:25 @ 23/12/2022
74:c4:0f:16:02:c1	7	East	2	10:25 @ 23/12/2023
	6	TOTAL	9	
		GROSS TOTAL	21	

Fig. 4. A sample report format.

V. Conclusions and Future Work

In this paper, we propose an IoT framework which will help to Search and Rescue (SaR) teams to determine the number and locations of the victims in a collapsed building. SaR teams need this piece of information to execute their functions effectively and efficiently.

The proposed framework has three layers: Things, IoT, and Application. Each layer has some services for gathering data, storing and processing it, and finally sharing the information with upper layers and SaR teams. We design these layers and services by considering a search and rescue operation's requirements. Furthermore, we test the concept by applying it in a simpler use scenario. While the first results and experiences are promising, there are some issues which require sophisticated solutions. Indeed, these issues are planned to be covered in the proposed framework as the services at different layers.

As a future work, we plan to integrate more *things* available in a building such as light sensors, light switches, electricity and water meters, etc. to locate people. In addition, we will develop a fusion method to combine the data from all different things to more accurately estimate the location and number of people. Enhancing the implementation with proper information security measures will be another important service to be integrated to the implementation. Because of the insufficient security measures, there is a considerable risk of unauthorized use of the framework to observe the movement of individuals. Our final aim is to develop the proposed framework as a complete system and evaluate its effectiveness and efficiency thoroughly.

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REFERENCES

[1] F. Mattern and C. Floerkemeier. "From the Internet of Computers to the Internet of Things." In *From active data management to event-based systems and more*. pp. 242-259, Springer Berlin Heidelberg, 2010.

[2] J. Gubbi, R. Buyya, S. Marusic, and M. Palaniswami, “Internet of Things (IoT): A vision, architectural elements, and future directions” Future Generation Computer Systems, *29*(7), pp. 1645-1660, 2013.

[3] IoT Special Interest Group, Internet of Things (IoT) and Machine to Machine Communications (M2M) Challenges and opportunities: Final, paper, tiny.cc/iotchallengesfinal, May 2013

[4] O. Vermesan, et al. "Internet of things strategic research roadmap." Internet of Things: Global Technological and Societal Trends 1, pp. 9-52. 2011.

[5] M. Kazama, and N. Toshihiro "Damage statistics (Summary of the 2011 off the Pacific Coast of Tohoku Earthquake damage)." *Soils and Foundations* 52.5 (2012): 780-792.

[6] Earthquake Report Web site, http://earthquake-report.com/2016/12/06/ very-strong-earthquake-northern-sumatra-indonesia-on-december-6-2016/.

[7] A. Beverley, “The Bam (Iran) Earthquake of December 26, 2003: Preliminary Reconnaissance Using Remotely Sensed Data and the VIEWS (Visualizing the Impacts of Earthquakes with Satellite Images) System”, Multidisciplinary Center for Earthquake Engineering Research, https://mceer.buffalo.edu/research/Reconnaissance/Bam12-26-03/bamprint.asp

[8] The Grand National Assembly of Turkey, “Deprem Riskinin Araştirilarak Deprem Yönetiminde Alinmasi Gereken Önlemlerin Belirlenmesi Amaciyla Kurulan Meclis Araştirmasi Komisyonu Raporu” https://www.tbmm.gov.tr/sirasayi/donem23/yil01/ss549.pdf/

[9] G. Sprint, D. Cook, R. Fritz and M. Schmitter-Edgecombe, "Detecting Health and Behavior Change by Analyzing Smart Home Sensor Data," 2016 IEEE International Conference on Smart Computing (SMARTCOMP), St. Louis, MO, 2016, pp. 1-3.

[10] O. Berat Sezer, S. Z. Can and E. Dogdu, "Development of a smart home ontology and the implementation of a semantic sensor network simulator: An Internet of Things approach," 2015 International Conference on Collaboration Technologies and Systems (CTS), Atlanta, GA, 2015, pp. 12-18.

[11] T. Moriyama, A. Polo, F. Viani, E. Giarola and A. Massa, "Improved wireless localization of mobile devices in smart indoor scenarios," 2015 IEEE 15th Mediterranean Microwave Symposium (MMS), Lecce, 2015, pp. 1-4.

[12] Y. Gu, L. Quan, F. Ren and J. Li, "Fast Indoor Localization of Smart Hand-Held Devices Using Bluetooth," 2014 10th International Conference on Mobile Ad-hoc and Sensor Networks, Maui, HI, 2014, pp. 186-194.

[13] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, Wireless sensor networks: a survey, Computer Networks, Volume 38, Issue 4, 15 March 2002, Pages 393-422, ISSN 1389-1286.

[14] Android Studio, The Official IDE for Android, https://developer.android.com/studio/index.html.

[15] The Apache HTTP Server Project, https://httpd.apache.org/.

[16] MySql RDBMS, https://www.mysql.com/.

[17] MySQL for the Internet of Things, White Paper, https://www.mysql.com/ why-mysql/white-papers/mysql-for-internet-of-things/.

[18] Z. K Zhang M. C. Y. Cho, , C. W. Wang, C. W. Hsu, C. K. Chen and S. Shieh, “IoT security: ongoing challenges and research opportunities. In Service-Oriented Computing and Applications (SOCA)”, 2014 IEEE 7th International Conference on (pp. 230-234). 2014.

[19] J.H. Ziegeldorf, O.G.Morchon, and K.Wehrle, “Privacy in the Internet of Things: threats and challenges”. Security and Communication Networks, 7(12), pp.2728-2742, 2014.