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Reacting to Fire Incidents in Infrastructure-less Zones: A WBAN-Cloud based Approach

Sarra Berrahal, Noureddine Boudriga and Atoine Bagula

***Abstract*— Forest fires are among the most hazardous incidents that may cause untold suffering to mankind and irreparable damages in properties. Wireless Body Area Networks (WBANs) can be utilized in fire surveillance applications as ad-hoc mobile sensor infrastructures to enable advanced sensing and monitoring purposes. Unfortunately, implemented as stand-alone systems in hazardous areas, the WBANs are likely to face many challenges in terms of users' mobility, communication range, and processing of the huge amount of collected data. Cloud computing is a paradigm that provides a configurable platform to enable collaborative services and to offer countless benefits including, but not limited to, the provision of omnipresent and fast service access, the support of mobility, and the freedom of deployment. This paper proposes a fire monitoring system that relies on the integration of WBANs and cloud platform and provides two-axis based contribution. First, a global architecture that tackles the important issue of structuring networks of WWANs and storage cloud platform as distributed databases in an infrastructure-less environment is proposed. Second, an active real-time querying approach is designed to efficiently analyze either the stored real-time data collections or to evaluate instantaneously the WBANs' continuous data streams.**

***Keywords*—WBAN, Infrastructure-less, Cloud Databases, continuous querying.**

I. Introduction

The world has witnessed many natural and human-induced disasters, such as forest fires, which threat the public safety and cause innumerable suffering to mankind and irreparable damages in properties [15]. For instance, more than 1.2 million fires were reported in the United States (US) in 2014. These fires caused 3,275 civilian deaths, 15,775 civilian injuries and $11.6 billion in property damage [19]. In such scenarios, collaboration among several firefighting organizations and safety providers including healthcare professionals and police forces are needed to implement effective protective tactics and to save many lives. Such a collaboration cannot be successfully attained without designing a system for collecting, storing, and sharing of the disaster-related information among the safety providers.

Sarra Berrahal
University of Carthage, Communication Networks and Security Research Lab.
Tunisia

Noureddine Boudriga
University of Carthage, Communication Networks and Security Research Lab.
Tunisia

Atoine Bagula
University of the Western Cape, Department of Computer Science,
South Africa

Unfortunately, communication infrastructure in the area affected by the disaster may be destroyed, non-existent as is the case in many rural areas, or it may be even overloaded.

Wearable communication and sensing technologies such as Wireless Body Area Networks (WBANs) have the potential to significantly improve safety provisions through a wide range of applications including the rescue and emergency management in disaster areas, the assistance of workers in hazardous environments [4] and the monitoring of patients' health in medical environment [3, 12]. However, when they are implemented as stand-alone systems in hazardous areas, WBANs are likely to face many issues in terms of communication, reliability, security and privacy, storage of the huge amount of processed data, and users' mobility.

Cloud computing is a paradigm to provide configurable platform to support collaborative services and presents a huge revolution in the information and communication technology [6, 10]. Accordingly, the management of WBANs, with their aforementioned limitations, can be tackled by exploiting cloud computing to provide an integrated platform, namely Cloud-WBANs infrastructure that offers easy and global access to the processing and storage infrastructure at effective costs, and eases the collaboration among several public safety providers and users with the cloud framework [10]. In addition, advanced services such as video streaming and on-demand real-time data extraction may be easily added to this system. Since data from WWANs can be stored on multiple servers in the WBAN-clouds, even if some data is lost there are still backup copies in the cloud, which fortify data reliability and guarantee that the application can still continue running in the cloud without interruption [17].

Several solutions that integrate wearable technologies with cloud computing have recently been reported in the literature [1, 16, 7, 13, 8]. However, all these works were basically built to provide services to applications dealing with health monitoring applications. The solution in [1] only focuses on connectivity-related issues between the patients and the global cloud (using networked routers and computers) without referring to any cloud or NIST characteristics. In addition, the mobility of WBANs in these works is considered stable and restricted to the hospital environment or to the area within the communication ranges of the WBAN. The absence of communication infrastructure is a challenging issue that has been ignored. The querying approach proposed in [7] only considers the real-time processing of data already stored in the cloud server.

Motivated by these issues, we propose in this paper a system that integrates WBAN-clouds (i.e., for data collection and communication) and cloud-database platform (i.e., for data storage and processing) to provide a distributed storage system running in infrastructure-less environments, where real-time parameters are continuously collected, stored, and processed using active querying mechanisms. The major contributions are the following.

- We design a global architecture that tackles the important issue of structuring WBANs and storage cloud platform as distributed active storage systems in an infrastructure-less environment for fire surveillance.
- We propose an active storage system that manages the public safety databases by means of querying approach that takes into consideration the requirements of data collections. The querying approach allows tracking the evolution of a fire threat based on the collected information and implements an active querying allowing cooperative answers from the aggregated cloud elements.

The rest of this paper is organized as follows. The second section presents the proposed distributed storage system. Section 3 describes the querying approach of Cloud-WBANs databases. Section 4 proposes an evaluation of the proposed approach through simulations. And the last section concludes the work.

II. A Cloud-WBANs for Outdoor Fires Management

In this section, we investigate the possibilities of supporting outdoor fires incidents management with the design of a system that integrates WBANs and cloud computing.

A. *WBANs for fires management*

Wireless Body Area Network (WBAN) is composed of communicating wearable sensor devices that are in charge of sensing and transmitting collected measurements (e.g., vital signs, motion parameters, environmental parameters) to the corresponding main node. The latter is a powerful device that is able to process the received data packets in a real-time manner and to transmit it wirelessly to a remote base station. Therefore, by enabling effective and real-time tracking of environmental risks, a WBAN system can be viewed as a part of the firefighting system. The WBAN will be in charge of gathering information regarding the fire. The collected data will be then sent to the fire department in order to manage the fire, to predict its geographical expansion, and to take decision to moderate any future aggravation. However, in real life, coping with large-scale threats requires cooperation among several public safety organizations, including fire department, police, and healthcare institutions.

The WBAN system encompasses heterogeneous sensor devices that differ in functionality, semantics and processing capacities. In addition, the use of a local data server to store voluminous data is a costly choice that needs the use of back-up and recovery systems, and requires personnel to manage it [5]. As many safety departments can be implicated in fighting large-scale fires and rescuing individuals in risk, the data formats, access interfaces, and management tactics may vary from one organization to another, consequently cooperation between heterogeneous systems will not be feasible, especially, when WBANs are implemented as standalone systems. This rises additional challenges including the storage and the querying of the huge amount of real-time data and the network connectivity instability in the affected environment. In addition, communication infrastructures at the site of the disaster may be destroyed, overloaded and even unavailable.

B. *Building Distributed Storage Area Network in Infrastructure-less areas*

Cloud Computing offers the ideal environment for integrating heterogeneous sensor nodes and large amounts of data storage spaces and services. Indeed, virtualization provides the possibility of outsourcing the processing from sensors in the WBANs to the cloud server that has almost unlimited resources compared to sensors [1]. Therefore, the data collected and transmitted by the WBANs can be stored on the cloud for real-time processing and effective storing. Mobile cloudlet is an architectural element that represents a fully cloud system capabilities but in small scale in order to bring the cloud capabilities closer to the users [11]. It offers several benefits including the provision of omnipresent and fast service access, the support of mobility and locality, the freedom of deployment and use of new services as well as the reduced hardware maintenance costs [8, 14].

In this context, we consider in Fig. 1 a three-level architecture. The first level consists of a network of cloudlets, essentially formed by a group of nearby mobile users; each one is equipped with its own WBAN system and is in charge of collecting valuable information. These mobile users are defining the cloudlet nodes and are able to communicate with each other using wireless technologies (e.g., Bluetooth or WiFi) and can send data to or receive data from their associated cloudlets, from other nodes in the network, or from the private cloud. All the collected information are then transmitted to the associated private cloud system of a given public safety division (e.g., firefighters, police department, and medical units). These private cloud systems represent the second level of the proposed architecture and define the centralized management and storage layer, which can be accessed by the different users affiliated to the relative mobile cloudlets. This level is composed of a set of private databases where data collected by the mobile cloudlets are stored in private databases and in the cloudlet nodes themselves, enabling one to query both in real-time manner. Here, the WBAN systems act as part of the database and may receive messages that are transmitted either by the corresponding cloudlet system or by the private cloud. Since the WBAN nodes are deployed in dynamic environments, real-time measurements must be sent to the destination within a specified deadline; otherwise, the collected information expires and is no longer useful. Consequently, the responses to a specific task have to ensure that the returned data is conforming to logic and temporal constraints. The third level is the centralized public cloud that defines the public database(s) where abnormalities' detection and irregular measurements sent by the private databases are logged to be available for other organizations (e.g., medical professionals, police, and fire department) that are interested in a certain type of data and for further analysis.

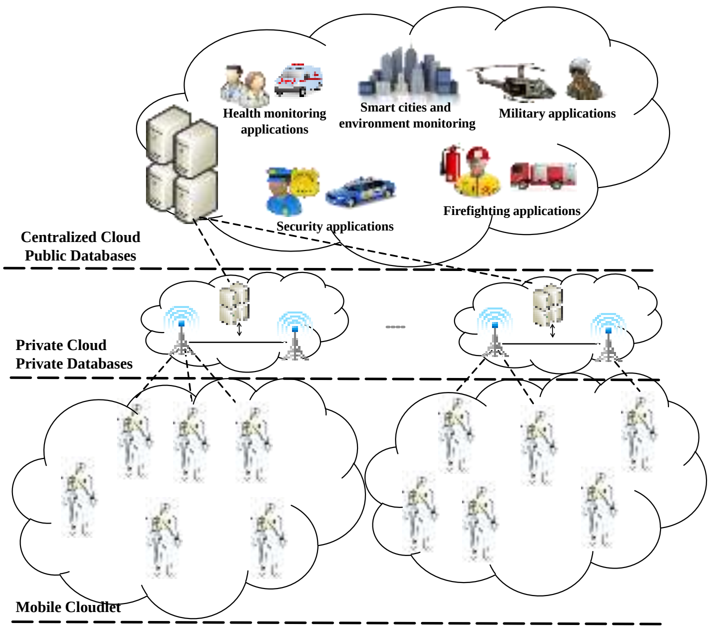

Figure 1- Global Architecture of a Distributed Storage Area Network

C. *Providing a communication platform*

The proposed platform can be considered as an alert system for monitoring the diffusion of forest fires, determining the sources and the spreading patterns, tracking its geographical expansion, and predicting risk aggravation. This systems provide a mobile platform for data collection and processing in infrastructure-less environments.

At any given instant, a mobile WBAN node can be in one of following scenarios: (i) it is in the communication coverage of a private cloud, then the user can transmit data packets directly to the associated private databases; (ii) it is only in the communication range of another WBAN node, which is directly connected to a private cloud. Then a cloudlet domain may be formed and the WBAN user can transmit data packets using multi-hop communication; (iii) it is out-of-coverage where no communication infrastructure is available. Then, if the WBAN tries to transmit a high priority traffic the WBANs in its vicinity are solicited to form a mobile cloudlet domain to relay the generated traffic; otherwise, the collected data should be buffered until one of the previous scenarios becomes available.

III. QUERYING THE STORAGE AREA NETWORK

Data collections in dynamic and frequently changing environments are time dependent and have a temporal validity within which the information is no longer useful. In addition, data freshness is another issue that should be provided since collections become, as time advances, less accurate until they do not reproduce the current state of the captured phenomenon. Unlike traditional storage systems, a real-time database should emphasize also on the temporal constraints of the received queries [13]. Indeed, missing queries deadlines or using useless information may cause disastrous consequences in real-time public safety applications. In the other hand, previous work on behavioral tracking applications in very large databases has focused on techniques that scale well for offline data using map-reduce technique such as SCOPE [18]. However, map-reduce approach has some limitations to deal with application having stringent temporal requirements [5]. Consequently, rather than collecting large amounts of data, storing it on the distributed databases, and then analyzing it, we propose in this section an active querying approach that tries to analyze continuous data streams and temporal data collected by the WBAN nodes in a real-time manner to enable fire departments to perform either preventive or proactive actions just-in-time before the fire aggravation.

To define the structure of the stored data we use definitions from [11] that denote a data item in a real-time database by: (value, timestamp, max_{valid}). Where value denotes the current state of the data, timestamp indicates the time instant of data-related observation and max_{valid} denotes the maximum time interval within which the data is valid. In monitoring applications, the identification of the different WBANs id as well as their geographic location loc_{id} is vital to refine data analysis and to secure data collection. The execution of a query is coordinated by a broker, who is in charge of constructing the execution graph and distributing work across available WBANs in the cloud-WBANs. The broker tracks the state of the query execution on each runnable WBAN.

A. *Real-time query*

Each received query describes a logical set of data that the user wants to have and express them based on definitions in [11] and the following variables: (i) id_{query}, which denotes the identification of the query; (ii) $time_{query}$, which defines the query's execution time (generally it is the time within which all the resources for the query processing are available); (iii) tar_{loc}, denotes the location identifications targeted by the transaction; and (iv) $resp_{delay}$, which represents the time interval within which the response should be available; otherwise it's no longer useful. Upon receiving one real-time query, the broker analyses it by checking its temporal and logical validity and then generates a query execution plan that consists of the best possible execution of the query inside the storage area networks as follows:

- If the required data is available in the public database and is recent enough to reply the query within its response delay $resp_{delay}$, $Timestamp + max_{valid} \leq timequery$, then the query may be implemented locally in the public databases and the requested information is sent back to the user.
- If the temporal requirement of the stored data is not verified, then the broker should decompose the global query into several sub-queries, which are executed individually in the private databases as local queries. The latter may be implemented either to retrieve the stored data (fresher than those stored in the public databases) or to update. To this end, we consider that the WBANs of a given cloudlet act as part of the database and contribute in event identification through the collection of additional data. Thus, each cloudlet targeted by the user query solicits its affiliated WBANs to store temporary their data gathered in a given region to collect additional information for more detailed views of the monitored event. Data from WBANs may be retrieved by applying a simple select. For example, in the TinyDB system that is a distributed query processor for smart sensor devices [14], a select query may expressed by:

```
SELECT CW. value
FROM Cloudlet-WBANs AS CW
WHERE condition
SAMPLE PERIOD [time]
```

The clause WHERE < x > specifies that the received query should be executed once the filtering condition is satisfied. In our approach, this condition may be temporal, geographical or application. Application filtering condition specifies that the selected parameters should report on a given phenomenon to confirm its occurrence. Tuples required by the query are produced at well-defined sample intervals using the clause SAMPLEPERIOD. After the accomplishment of its works, the WWAN node should send the results to its corresponding private cloud, which is in charge of updating its database to provide a valid query's response while complying with the required temporal constraint ($resp_{delay}$).

B. *Alert-based real-time queries: Writing in cloud-WBANs*

In mission-critical applications WBANs, typically, deliver data in streams continuously. The streamed data may be in the form of real-time readings, images or even short videos captured by specific sensors on the WBAN. Queries over those streams keep getting continuously executed and have to be processed in real-time manner, as data arrives, because they may represent critical issues such as fires detection. Consequently, it is crucial to react in real-time for every abnormality detection and alert generation.

Alert-based real-time queries can be used, in case of suspicious events, for retrieving meaningful information from the distributed WBANs based on the description referenced by the query. We propose to describe our alert-based real-time querying approach based on the Continuous Query Language (CQL)[2]. The latter is an SQL-based declarative language used for continuously querying streaming and dynamic data [11]. Considering CQL semantics, the following query may be expressed:

SELECT **Istream**(*)
FROM Cloudlet-WBANs [*Range Unbounded*] AS CW
WHERE condition

This query encompasses a window time-based operator [*Range Unbounded*] that allows to output a relation containing all the Cloud-WWANs measurements up-to current time, a clause WHERE to restrict the relations that not satisfy the filtering condition, and **Istream** operator that insert new streams in the relation. TinyDB supports events as a mechanism for initiating real-time data collection using ON EVENT clause. Every time an event occurs, the query is issued from the detecting node and the required parameters are collected from nearby WBAN nodes [14]. By combining both TinyDB and CQL languages an alert-based real-time query may expressed by:

ON EVENT **event-detection** ():
SELECT **Istream** (*) FROM Cloudlet-WBANs [*Now*]
WHERE condition

We consider that multimedia data such as short videos can be returned as an answer to an alert-based real-time query when requested because events may have sub-events related with scenes contained in the filmed video. After receiving an alert-based real-time query the broker (i.e., of a private cloud) checks its temporal and logical validity requirements and then disseminates it to the concerned group of cloudlet nodes for execution. Due to nodes mobility, we consider that temporary channels should be established between the broker and the targeted cloudlet until the accomplishment of data streaming. During communication establishment, each cloudlet runs a selection query to acquire collections from its affiliated WBANs corresponding to the attributes and fields referenced in the received query. Data are then streamed to the broker directly or using multi-hop communication for real-time delivery to the end user. Depending on the received data, the safety providers can take immediate actions. In the case of threat confirmation, the broker can configure the system to change the sampling period in the WBANs and the threshold limits so that the system can provide improved disaster management results.

IV. Simulation

We consider a simulation area of 5x30 sub-squares and divided into two main areas: (i) A covered area that covers an area of 5x5 sub-squares and has a unique access point placed in its center; and (ii) An infrastructure-less area where no communication infrastructure is available. We assume that a set of WBAN nodes is deployed. These WBANs are in charge of detecting fire events and forwarding them to the cloud server through the access point. The transmission rate in every WBAN node is set to 1Mbps and the packet length to 128 byte. A set of fire events are generated. A fire event is characterized by its coordinates (x, y) and is progressing along the monitored area randomly. During the first time slot, the WBANs are injected in the area. The value of a time slot is set to a unit of time, and the duration of the simulation is set to 900 time slots. In each time slot, the WBAN may either remain at his place or moves randomly to an adjacent sub-square.

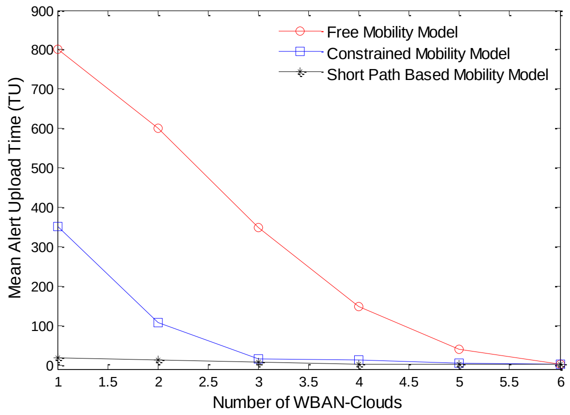

Figure 2- The mean upload time of a detected fire event as a function of the number of deployed WBAN-Clouds

In the first simulation, we evaluated the mean upload time of a detected fire event as a function of the number of deployed WBAN-Clouds. For this we considered that once a fire is detected, the WBAN moves according to three mobility models. The Free mobility model, the Restricted mobility model, and the Shortest path based mobility model. Accordingly, we obtained in Figure 2, decreasing curves in function of the number of WBAN-Clouds. In fact, as the number of WBAN-Clouds decreases, the time required for the WBAN node to upload the detected event increases. This is more noticeable for the free-mobility and restricted mobility models where users are randomly moving in the infrastructure-less area without being obliged to move to the covered area. The difference between the obtained mean upload times for the three mobility models is important for a limited number of clouds. As the number of clouds increases, this difference decreases. For the short path based mobility model the difference between the mean upload times for different number of clouds is negligible compared to the results obtained for the two others models.

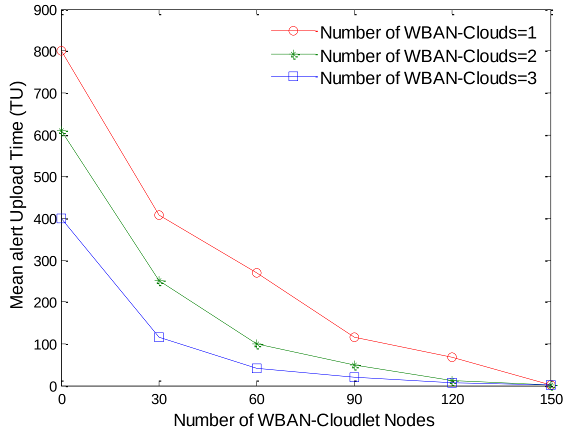

Figure 3- The impact of the number of WBAN-Cloudlets on the alert upload time

In the second simulation, we considered that a set of WBAN nodes with enhanced communication capabilities may form a cloudlet-WBANs and act as a gateway node to relay the event to its destination. The results illustrated in Figure 3 show that the mean alert upload time is inversely proportional to the number of WBAN-Cloudlets. The upload time decreases with the increase of the number WBAN-Cloudlets. Therefore, rather than keeping moving in the until being under the coverage of the cloud-WBANs, the WBAN node may minimize the time required to reach the covered area by forwarding the alert through a cloudlet-WBANs in its close vicinity. In addition, by increasing the number of WBAN-Clouds, the upload time is decreased. This is due to the minimization of the number of hops required by the WBAN-cloudlet nodes to relay the alert to its destination and the minimization of the time required by the WBAN nodes to reach the covered areas.

V. Conclusion

In this paper, we investigated the benefits of integrating WBANs and Cloud Computing to build a Cloud-sensor platform to support fire detection and management in infrastructure-less areas. The proposed solution tries to track the evolution of the fire through the management of alerts generated by WBANs carried by mobile individuals and belonging to public and private clouds. To support communication, cloudlets of WBANs may be formed to bring the cloud's capabilities closer to the user.

References

[1] Almashaqbeh, G., Hayajneh, T., Vasilakos, A. V., and Mohd, B. J., "Qos-aware health monitoring system using cloud-based WBANs", Journal of Medical Systems, 38, 121 (August 2014).

[2] Arasu, A., Babu, S., and Widom, J, "The CQL continuous query language: semantic foundations and query execution", The International Journal on Very Large Data Bases (VLDB) 15, 2, (2006), pp. 121-142.

[3] Berrahal, S., and Boudriga, N., "A smart QoS-based traffic management for WBANs". In Proceedings of the 14th International Symposium on Communications and Information Technologies (ISCIT) (Incheon, Korea, September 2014), pp. 161-165.

[4] Chammem, M., Berrahal, S., and Boudriga, N., "Smart navigation for firefighters in hazardous environments: A ban-based approach", vol. 7719 of Lecture Notes in Computer Science. Springer Berlin Heidelberg, Istanbul-Turkey, 28 - 30 November 2013, ch. In Proccedings of the 7th International Conference on Pervasive Computing and Application (ICPCA) and the 4th International Symposium of Web Society (SWS), 2012, pp. 82-96.

[5] Chandramouli, B., Goldstein, J., and Duan, S., "Temporal analytics on big data for web advertising", In Proceedings of the 28th International Conference on Data Engineering (ICDE '12) (Washington DC, USA, April 2012).

[6] Dash, S. K., Sahoo, J. P., Mohapatra, S., and Pati, S. P., "Sensorcloud: assimilation of wireless sensor network and the cloud", vol. 84 of Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering. Springer Berlin Heidelberg, Berlin, Germany, 2012, ch. In Proceedings of the Second International Conference, CCSIT 2012, pp. 455-464.

[7] Diallo, O., Rodrigues, J. J., Sene, M., and Niu, J., "Real-time query processing optimization for cloud-based wireless body area networks", Information Sciences 284 (2014), 84-94.

[8] Diallo, O., Rodrigues, J. J. P. C., Sene, M., and Lloret, J., "Simulation framework for real-time database on WSNs", Journal of Network and Computer Applications, Elsevier 39 (March 2014), 191-201.

[9] Diaz-Ramireza, A., Tafoyaa, L. A., Atempaa, J. A., and Mejia-Alvarezb, P., "Wireless sensor networks and fusion information methods for forest fire detection. In Proceedings of 2012 Iberoamerican Conference on Electronics Engineering and Computer Science (Mexico, 2012), pp. 69-79.

[10] Fortino, G., Fatta, G. D., and Pathan, M., "Cloud-assisted body area networks: state-of-the-art and future challenges", Wireless Networks 20, 7 (2014), 1925-1938.

[11] Gupta, R., Gupta, H., and Mohania, M., "Cloud Computing and Big Data Analytics: What Is New from Databases Perspective?", vol. 7678 of Lecture Notes in Computer Science. Springer Berlin Heidelberg, 2012, ch. Big Data Analytics, pp. 42-61.

[12] Ivanov, S., Foley, C., Balasubramaniam, S., and Botvich, D., "Virtual groups for patient WBAN monitoring in medical environments". IEEE Transactions on Biomedical Engineering 59, 11 (November 2012), 3238-3246.

[13] Li, Y., and Wang, W., "Can mobile cloudlets support mobile applications?", In Proceedings of IEEE INFOCOM (2014).

[14] Madden, S. R., Franklin, M. J., Hellerstein, J. M., and Hong, W., "Tinydb: an acquisitional query processing system for sensor networks". ACM Transactions on Database Systems (TODS) 30, 1 (March 2005), 122-173.

[15] Misra, S., and Chatterjee, S., "Social choice considerations in cloud-assisted wban architecture for post-disaster healthcar:e data aggregation and channelization", Information Sciences 284 (2014), 95-117.

[16] Quwaider, M., and Jararweh, Y., "Cloudlet-based efficient data collection in wireless body area networks", Simulation Modelling Practice and Theory 50 (January 2015), 57-71.

[17] Wan, J., Zou, C., Ullah, S., Lai, C., Zhou, M., and Wang, X, "Cloud-enabled wireless body area networks for pervasive healthcare. IEEE Network 27, 5 (2013), 56-61.

[18] Zhou, J., Bruno, N., Wu, M.-C., Larson, P.-A., Chaiken, R., and Shakib, D. Scope: Parallel databases meet mapreduce. The International Journal on Very Large Data Bases (VLDB) 21, 5 (October 2012), 611-636.

[19] Hylton J.G. Haynes. Fire Loss in the United States During 2014. Quincy, MA. National Fire Protection Association. September 2015. Print