MEDINFO 2019: Health and Wellbeing e-Networks for All
L. Ohno-Machado and B. Séroussi (Eds.)

doi:10.3233/SHTI190374

IoT, Cloud Computing and Big Data: Integrated Framework for Healthcare in Disasters

Samaneh Madanian[a], Dave Parry[a]

[a] *Department of Computer Science, AUT University, Auckland, New Zealand*

Abstract

Currently, healthcare in disaster management context faces a number of challenges mostly due to the lack of availability of reliable data from diverse sources required to be accessible by appropriate authorities. Therefore, the main objective of this study is the introduction of a framework based on the integration of three technologies, Internet of Things (IoT), cloud computing and big data to solve this issue in all disaster phases and provide precise and effective healthcare. This framework supports healthcare managers by enabling data sharing among them and assists them in performing analytical calculations to discover meaningful, logical and accurate trend(s) required for strategic planning and better preparedness in the face of disasters. Also, the outcome of the framework may help decision makers to identify and predict the health consequences of the disasters for any specific geographical location in any country based on its geographical properties and disaster background.

Keywords:

Medical Informatics, Disasters, Disaster Planning

Introduction

Disasters (natural, manmade, or epidemic) have detrimental effects and annually force huge expenses on governments nationwide in terms of economical, social, environmental, and human conditions and life. According to the statistics from Centre for Research on the Epidemiology of Disasters, the number of disasters and their complexity and severity (damage to life and property) shows an upward trend over recent decades. Only in 2017, 536 disasters occurred causing 16,458 deaths, affecting 95,979,187 people and costing USD 337,542,768,000 globally [1].

Regardless of disaster types and sources, their consequences mostly threaten people's health and wellbeing to varying degrees. This includes injuries or deaths of the affected people or even disrupting the healthcare systems that affects both disaster injuries and people with chronic healthcare conditions who still require care. Therefore, the greatest challenge to healthcare systems is probably when it is to deal with disasters; they should change swiftly from their everyday activities to adjust to the conditions of great uncertainty that, at the same time, may exceed their available resources and their ability to attend to a large number of casualties in a short time [2].

Although most disasters are not preventable, having a proper healthcare preparedness plan in advance can significantly lessen the harmful effects of disasters and diminish their adverse consequences. For such a plan and addressing citizens' healthcare requirements more effectively, reliable data from diverse sources are needed to be shared among different authorities and parties in disaster management. In this regard, effective data gathering and sharing is the building block leading to more accurate data analysis and information extraction required for a disaster healthcare plan. This issue is a challenging task and has not been effectively addressed yet.

The attempt in this paper is to introduce an integrated framework of three technologies. This framework aims to address challenges in data collection and sharing that are faced by different authorities, including healthcare, within Disaster Management Cycle (DMC). The framework enables automatic data collection and sharing that can be categorized for each region and the whole country before, during and after disasters. Also, it can further be used for real-time decision making, discovering trends, and possibly forecasting healthcare consequences of disasters on communities, or predicting epidemics outbreak. Moreover, it is expected that authorities will be able to prepare customized healthcare disaster management plans based on the geographical location properties, disaster history and the healthcare background of their inhabitants.

The rest of this article is organized as follows. First, the research methods and motivations are explained. Then, a brief background of the utilized technologies is provided. After that, the proposed model is presented followed by detailed explanations of its layers and its implications.

Research Methods and Motivation

As a part of Disaster e-Health (DEH) project (see [3] and [4]), a comprehensive scoping study in three fields of disaster management, disaster medicine, and healthcare was conducted. The scoping study was carried out in two different phases of controlled and uncontrolled search in 13 different databases including Scopus, CINAHL, ProQuest, IEEEXplore, Science Direct, and PubMed. In these databases, keywords or combination of keywords such as disaster, healthcare, technology, e-health and challenges, were used to extract relevant studies. Among 3956 captured articles in uncontrolled search and 925 articles in controlled, after considering the exclusion factors, 264 and 328 articles in each method, respectively, were selected for review.

Citizens' health requirements and demands following disasters are varied and highly depend on the disaster types, location, and intensity. Therefore, efficiency and effectiveness of healthcare disaster response activities are of prime importance due to finite resources compared to the number of affected population. In most disasters, preventing further life loss has a direct relation to the level of preparedness and readiness of different organizations in a community. Thus, pre-disaster phases, that is, preparedness and mitigation, are key elements of effective response; however, their importance may be hidden or underestimated unless a major disaster occurs [5]. By managing pre-disaster phases wisely and properly in their planning, there will be no, or less need to run response and recovery phases as the disaster risks are prevented or reduced and appropriate systems, procedures, and resources are in place to assist affected population [6]. Consequently, rather than a reactive system, governments can shift to a proactive system.

However, most healthcare centers are still struggling to prepare an appropriate disaster management plan. According to the results of the scoping review, some of the identified root cause challenges are:

- Data gathering (considering data quality and reliability)
- Data sharing (which data, how to share and with whom)
- Data analysis (healthcare risk analysis to prepare for disaster threats, respond to and recover from them)

Data gathering and availability can be the greatest challenge for preparing an effective disaster management plan for healthcare centers most of which suffer from a lack of reliable and relevant data. This deficiency forces most countries, especially developing ones, to have a general, or national, disaster management plan mostly prepared and designed based on the assumptions for the whole country with no or a very few customizations for different regions [7]. However, based on regions' backgrounds, having some customization is a must. It is expected that disaster healthcare plans would be more effective if created for each geographical region by considering the number of its inhabitants and its disaster background information, including type, frequency, severity, and consequences. This information helps healthcare authorities to prepare region based and customized disaster healthcare plans, which are possibly more effective and efficient, and they may result in a better and effective healthcare response.

For a precise and effective disaster healthcare plan, it is necessary to have information regarding past disasters, and the effectiveness, success or failure rates of healthcare response activities. However, many countries have little information regarding the real effectiveness and efficiency of their healthcare response activities or their challenges and deficiencies [8, 9]. Therefore, healthcare response shortcomings have not been identified properly, and consequently, learned lessons from past disasters are poorly considered for future healthcare planning. This issue results in having mitigation and preparedness plans mostly based on the assumptions and not on the real data or information. This not only wastes a lot of valuable resources, but it also results in not being able to meet some of the demands of disaster casualties, specifically the healthcare related demands [10].

Technology Background

Information Technology (IT) utilization could be a viable solution for the identified challenges. It has the potential to improve overall disaster management, better prepare against disasters, facilitate response when disasters occur, enhance support after disasters, and keep records for better future preparedness.

In the proposed framework, three different technologies are utilized. These technologies have already revolutionized other fields/industries such as supply chain, healthcare and military. Therefore, it is believed that they may offer a huge potential for healthcare within disaster DMC. Although these technologies by themselves are powerful, it is expected that they may exploit further potential if they integrate with each other.

Internet of Things (IoT)

IoT is a technological phenomenon that stems from new advances and ideas in ICT, and it is related to ubiquitous communication/connectivity, ambient intelligence, and pervasive computing [12]. It comprises sensing devices and technologies such as sensors, Radio Frequency Identification (RFID), and Global Positioning System (GPS) [12] and network and communication components such as Wireless Sensor Network (WSN), 4/5G communication, and Wide Area Network (WAN). IoT integrates humans, physical objects and digital devices by making use of distributed sensors in environments [13]. IoT enables people to automatically gather all sorts of data and information such as location, movement, sound, and heat. Since IoT encompasses different types of technologies and components, its scope covers a broad range of applications in different fields such as healthcare, military, supply chain, and agriculture. IoT Devices are already starting to appear in the consumer space in the form of wearable devices and smart appliances so that it may be possible to both use data from these devices and the infrastructure being built to support them.

Cloud Computing

Cloud computing is a framework of "abstracted, virtualized, dynamically scalable, managing, computing, power storage platforms and services for on-demand delivery over the Internet." [14]. It consists of both hardware and software that offer various services in different levels of infrastructure, platform and software [15]; it has revolutionized IT resources utilization in different industries. Cloud services are available anywhere at anytime and bring flexibility and scalability of IT services and resources while enhancing their employment in different levels and organizations. Cloud computing provides a series of advantages for the organizations as mentioned by [16] including scalability, reliability, efficiency, and data storage.

Big Data

The "Big data" concept has emerged as a result of a massive increase in data with regard to its quantity, type and speed of generation. Big data can be defined as "high volume, high velocity, and/or high variety information assets that require new forms of processing to enable enhanced decision making, insight discovery and process optimization" [17]. Big data is used in different organizations for analytical purposes. Its data are from diverse sources, and sometimes in real-time manner, fueled by the latest development in technologies such as mobile devices adoption, social media, IoT, and RFID [18].

Related Studies And Research Objectives

Although the applications of the discussed technologies in other fields are increasing, only in recent times have the researchers started exploring the role of these technologies for disaster management purposes. However, there are some gaps in these studies. A significant number of solutions concentrate on utilizing only one technology: ([19, 20] on IoT, [21, 22] on big data, and [23] on cloud computing). Some others have utilized these technologies for a specific disaster phase: ([24] on disaster recovery, [22, 25-27] on disaster response, [28] on disaster response and preventive monitoring). Still, some other studies look into a specific activity in a specific disaster phase ([21] on big data for disaster relief activities and supply chain management). Only a few research studies proposed their solutions based on technology integration for addressing the disaster management challenges ([29] integrated big data and cloud computing, [30] proposed big data and IoT integration, and [25] integrated cloud and IoT). Among the identified studies, only, [31] integrated all the mentioned technologies for the purpose of event detection and sending alerts, and coordinating rescue and medical operations. Therefore, it can be said that among all the recent research, little attention has been paid to technology integration and healthcare operations, specifically for pre-disaster phases.

In this context, in this research, the proposed framework has the potential to be used in supporting and assisting healthcare and governmental authorities in their decision making and disaster healthcare planning for any disaster type, in different phases and for different regions. The objectives of the framework are:

- automatic gathering precise and real-time or near real-time data at all disaster phases
- aggregating the captured data to facilitate data sharing among different parties
- identifying and revealing any meaningful trends in the captured data that can be utilized for forecasting future disasters and the required healthcare actions resulting in accurate disaster healthcare planning and precise response
- enabling authorities to customize and localize disaster healthcare planning based on regions' precise data.

Technology Integration and Proposed Model

One of the greatest challenges for preparing an effective disaster management plan for healthcare is the lack of reliable and relevant data. It is believed that a great number of issues can be prevented in healthcare by having better and quality data. These data can be a great source for healthcare disaster planning and management as we cannot manage something when we cannot measure it.

Therefore, the proposed framework in this research integrates and utilizes three advanced technologies in three layers (Figure 1) to facilitate data gathering, sharing and analysis which are necessary for an effective disaster healthcare plan and management, as these areas have been identified by several researchers as barriers [10, 32-34].

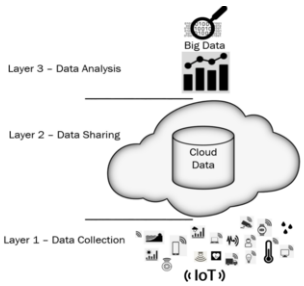

Figure 1 – Proposed Technology Integration Model

Layer One: IoT

The aim of this layer is to solve the problem of data availability and reliability by utilizing different IoT devices. The IoT devices are able to precisely capture different types of data for a particular case (object or human) with no or minimum human intervention in a periodic or continuous form in a specific location. These data can be people's vital signs or location, environment temperature, humidity, location of the objects, etc. The variety in the data types makes IoT suitable for monitoring purposes and transmitting or receiving real-time data regarding different conditions in the implemented environment. Furthermore, as most of the IoT devices have embedded memory and are battery powered, if network and power are disrupted by disasters, they can save data in their memory and upload them whenever their connection reestablishes. Therefore, the effects of disruptions in network communication after disaster could be mitigated.

Based on IoT functionalities and by giving digital identity to the objects, IoT sensors are able to be context-aware, sense the monitoring environmental conditions, communicate with neighboring nodes and even sometimes perform some basic computations on the collected data [35, 36]. These unique features of IoT can integrate the objects in the real world with the digital environment which, eventually, brings an integration, and relevant and quality data/information for healthcare planning at all phases of disasters. IoT also provides a cooperative monitoring environment either for environmental conditions or physical objects. Moreover, as IoT sensors require no or little human intervention, they can be used in harsh or infectious environments where conditions are not suitable for human work [35]. In such situations, the sensors can be set to execute processes to activate specific actions or create services [36].

Layer Two: Cloud Computing

Although in disaster healthcare planning, data availability and quality are crucial, sharing these data with right authorities is vital. Otherwise, even having quality datasets, may lead us to thousands of silos of fragmented data. While data sharing is the other common problem in healthcare planning. Therefore, the second layer of the framework attempts to address this problem by utilizing cloud computing technology. Furthermore, to apply the full potential of IoT, it seems that utilizing cloud computing in parallel with IoT is vital [37].

Cloud computing can provide the required virtual infrastructure for integrating the monitoring devices [37]. As it is required to store a wide range of data types, cloud facilitates deployment of a system for data sharing across different platforms and through a unified framework for a fast and easy access with unlimited data storage [16, 37]. This technology is an efficient and reliable solution for data sharing among different parties and authorities and supports collaborative work and access anywhere. Moreover, it is potentially more resilient and scalable in terms of physical locations.

In this layer, the captured IoT data available in a single cloud repository ultimately facilitate sharing of data and enhance collaboration and cooperation of people, programs, processes and services [36]. This issue is particularly important in healthcare as all the parties will be able to work on a common and aggregated data and establish a network to coordinate and exchange data more effectively and efficiently that, in turn, also supports strategic planning and research. Moreover, different authorities and governmental agencies, including healthcare, monitor different types of objects, locations and environmental conditions in a way that if any significant issues happen, they can respond swiftly.

Layer Three: Big Data

The outcome of the lower two layers is an integrated repository of data of differing quality, provenance and or reliability which disaster management and planning can use for evidence-based plans and responses. For this purpose, the analysis and validation of all the captured data from monitoring devices are required. In this context, big data algorithms and analytics can be considered since they have the potential to make use of those data and extract the available trends and evidences. As in the previous layer cloud computing has been used, big data sharing and exchange becomes possible without further investing in big computing assets [38]. Big data algorithms and analytics can be used to visualize the connected IoT objects, make sense of them and help IoT for acceptance, usage and influence [18]. For this purpose, big data analytics tools and applications can be used to exploit the full potential of the proposed framework by converting the data into information and knowledge. In other words, big data "takes the amount of intelligence within the network to another level where devices reason and take action in ways that aren't necessarily preprogrammed or even initially understood by humans" [18].

This layer's outcome could facilitate supplying information and knowledge required for disaster healthcare planning as well as enhancing the quality of the plans and decisions in both normal and disaster situations. The generated information can be real-time for immediate decision making in any alarming situations [2], such as epidemics outbreak, or about the past disasters to support healthcare resilience and prevention research.

Discussion

Appropriate and precious healthcare planning, for normal or disaster situations, relies on past together with real-time data from various sources. If these data are available and reliable, their aggregation in a single repository with further processing and analysis may result in extracting important information and trends that have the potential to enhance the quality of disaster healthcare planning and preparedness. Hereof, it is believed that integrating the discussed technologies can support governments and authorities to provide a more accurate, robust and customized disaster preparedness and response plans based on the geographical locations by considering their geographical conditions, healthcare and disaster backgrounds. The proposed framework can be seen as a possible solution to the identified challenges in the disaster healthcare. The following paragraphs discuss the contribution of each technology.

IoT connects the physical objects with the digital world and makes objects identifiable and traceable. It also can collect and disseminate data from the monitoring areas to the control centers. Besides this offered convenience, these connected and intelligent devices could have the life-saving applications during disasters and be considered critical applications [39] as they can capture and then disseminate accurate data with minimal human interventions.

However, for a complete realization of the IoT potential, an efficient, secure and scalable storage is required. Consequently, in the proposed framework, cloud computing is suggested that can also provide a reliable and ubiquitous access to the dynamic IoT objects [37]. Therefore, the large amount of the collected data from IoT devices are aggregated and shared among different centers through cloud computing. In this way, collaboration among parties is improved, and critical data are swiftly distributed to the top decision makers [36].

This integrated repository can be considered as an easily accessible platform for using data mining models to discover new facts and trends. For this purpose, big data approaches such as large-scale visualizations, stream processing, machine learning, etc. can be used to generate knowledge and discover trends. This information can be employed by decision makers and other authorities for a quality strategic planning and predicting future requirements and demands in the face of disasters.

As a result of adopting this framework of interconnected sensing devices, sharing data across different platforms through a unified framework becomes possible. Therefore, healthcare decision-makers will be able to use the real-time and precise data for real-time decision making [36, 37] and for better understanding the impact of disasters and reacting more appropriately [40] with respect to the healthcare consequences. Additionally, every healthcare center is able to be integrated into the disaster plans, along with its critical components of the response efforts [41], and its situations can be assessed by using big data and cloud computing. This framework can also make data and information available for the wider and authorized access that may enhance data processing and sharing.

This approach may also enhance and facilitate decision making in the healthcare response missions as different objects in the monitoring environment are inter-connected via their properties [13]. Therefore, IoT for the disaster management application not only can be seen as a data acquisition technology, but it can also facilitate establishing a more effective, intelligent and goal-oriented communication [11]. Moreover, information regarding medical resources availability and location can be tracked and shared among related organizations automatically and without any human intervention that, in turn, results in enhancing tasks efficiency and accuracy. Consequently, matching the available medical resources and staff with the region population can be performed in disaster preparedness, and the chance of overwhelming different systems and organizations can be decreased in the disaster response.

Conclusions

IoT, cloud computing and big data are powerful on their own but together can potentially improve disaster healthcare. The combination of these technologies will require work to assure privacy and safety. However, research in these areas may produce synergistic benefits. Frameworks for integration of these approaches are vital for effective implementation.

References

[1] Centre for Research on the Epidemiology of Disasters, The International Disaster Database in, CRED, 2018. https://www.emdat.be/emdat_db/ (accessed October 12, 2018)

[2] Y. Bar-El, S. Tzafrir, I. Tzipori, L. Utitz, M. Halberthal, R. Beyar, and S. Reisner, Decision-support information system to manage mass casualty incidents at a level 1 trauma center, *Disaster Medicine and Public Health Preparedness* **7** (2013), 549-554.

[3] A.C. Norris, S. Martinez, L. Labaka, S. Madanian, J.J. Gonzalez, and D. Parry, Disaster e-Health: A new paradigm for collaborative healthcare in disasters, in: *The 12th ISCRAM International Conference*, Agder University, Kristiansand, Norway, 2015.

[4] D. Parry, S. Madanian, and A.C. Norris, Disaster e-health: Sustainability in the extreme, in: *2nd Intl Conf on Big Data Intelligence and Computing and Cyber Science and Technology*, Auckland, New Zealand, 2016, pp. 943-946.

[5] PAHO, Natural disasters: Protecting the public's health, in, Pan American Health Organization, Washington, D.C, 2000. https://www.mona.uwi.edu/cardin/virtual_library/docs/1226/1226.pdf (accessed October 9, 2018)

[6] A. Ahmed and L.F. Sugianto, A 3-tier architecture for the adoption of RFID in emergency management, in: *Proceedings*

of the International Conference on Business and Information, Tokyo, Japan, 2007, pp. 1-14.

[7] A. Unlu, N. Kapucu, and B. Sahin, Disaster and crisis management in Turkey: a need for a unified crisis management system, *Disaster Prevention and Management: An International Journal* **19** (2010), 155-174.

[8] M.L. Birnbaum, E.K. Daily, A.P. O'Rourke, and J. Kushner, Research and evaluations of the health aspects of disasters, part VI: Interventional research and the disaster logic model, *Prehosp Disaster Med* **31** (2016), 181-194.

[9] T.D. Kirsch and E.B. Hsu, Disaster medicine: What's the reality?, *Disaster Medicine & Public Health Preparedness* **2** (2008), 11-12.

[10] A. Boyd, N. Chambers, S. French, D. Shaw, R. King, and A. Whitehead, Emergency planning and management in health care: priority research topics, *Health Systems* **3** (2014), 83-92.

[11] A. Dohr, R. Modre-Opsrian, M. Drobics, D. Hayn, and G. Schreier, The internet of things for ambient assisted living in: *Information Technology: 7th International Conference on New Generations,* IEEE, Las Vegas, NV, 2010, pp. 804-809.

[12] K. Zhao and L. Ge, A Survey on the Internet of Things security, in: 9*th International Conference on Computational Intelligence and Security*, 2013, pp. 663-667.

[13] A. Zelenkauskaite, N. Bessis, S. Sotiriadis, and E. Asimakopoulou, Interconnectedness of complex systems of Internet of Things through social network analysis for disaster management, in: *4th International Conference on Intelligent Networking and Collaborative Systems*, IEEE, Bucharest, Romania, 2012, pp. 503-508.

[14] E. AbuKhousa, N. Mohamed, and J. Al-Jaroodi, e-Health cloud: opportunities and challenges, *Future Internet* **4** (2012), 621-645.

[15] B. Ludwig and S. Coetzee, A comparison of platform as a service (PaaS) clouds with a detailed reference to security and geoprocessing services, in: *Proceedings of the First International Workshop on Pervasive Web Mapping, Geoprocessing and Services,* Como, Italy, Citeseer, 2010.

[16] L. Jun and Z. Song, *E-health web application framework and platform based on the cloud technology*, Master, Kristianstad University, 2013.

[17] Gartner, The importance of 'Big Data': A definition, in, 2012. https://www.gartner.com/doc/2057415/importance-big-data-definition (accessed October 9, 2018)

[18] F.J. Riggins and S.F. Wamba, research directions on the adoption, usage, and impact of the Internet of Things through the use of big data analytics, in: *48th Hawaii International Conference on System Sciences*, 2015, pp. 1531-1540.

[19] C. Yang, Q. Huang, Z. Li, K. Liu, and F. Hu, Big Data and cloud computing: Innovation opportunities and challenges, *International Journal of Digital Earth* **10** (2017), 13-53.

[20] M. Kamruzzaman, N.I. Sarkar, J. Gutierrez, and S.K. Ray, A study of IoT-based post-disaster management, in: *2017 International Conference on Information Networking*, 2017, pp. 406-410.

[21] T. Papadopoulos, A. Gunasekaran, R. Dubey, N. Altay, S.J. Childe, and S.F. Wamba, The role of Big Data in explaining disaster resilience in supply chains for sustainability, *Journal of Cleaner Production* **142** (2017), 1108-1118.

[22] S. Choi and B. Bae, The real-time monitoring system of social big data for disaster management, in: *Computer Science and its Applications,* J.J. Park, I. Stojmenovic, H.Y. Jeong, and G. Yi, eds., Springer Berlin Heidelberg, Berlin, Heidelberg, 2015, pp. 809-815.

[23] N. Jangid and B. Sharma, Cloud computing and robotics for disaster management, in: *7th International Conference on Intelligent Systems, Modelling and Simulation*, 2016, pp. 20-24.

[24] V. Chang, Towards a Big Data system disaster recovery in a Private Cloud, *Ad Hoc Networks* **35** (2015), 65-82.

[25] K. Chung and R.C. Park, P2P cloud network services for IoT based disaster situations information, *Peer-to-Peer Networking and Applications* **9** (2016), 566-577.

[26] L. Yang, S.H. Yang, and L. Plotnick, How the internet of things technology enhances emergency response operations, *Technological Forecasting and Social Change* **80** (2013), 1854-1867.

[27] A. Rauniyar, P. Engelstad, B. Feng, and D.V. Thanh, Crowdsourcing-based disaster management using fog computing in Internet of Things paradigm, in: *2016 IEEE 2nd International Conference on Collaboration and Internet Computing*, 2016, pp. 490-494.

[28] J.P. de Albuquerque, B. Herfort, A. Brenning, and A. Zipf, A geographic approach for combining social media and authoritative data towards identifying useful information for disaster management, *International Journal of Geographical Information Science* **29** (2015), 667-689.

[29] R. Ranjan, Streaming big data processing in datacenter clouds, *IEEE Cloud Computing* **1** (2014), 78-83.

[30] Y. Sun, H. Song, A.J. Jara, and R. Bie, Internet of Things and Big Data analytics for smart and connected communities, *IEEE Access* **4** (2016), 766-773.

[31] D. Puthal, S. Nepal, R. Ranjan, and J. Chen, A secure big data stream analytics framework for disaster management on the cloud, in: *2016 IEEE 18th International Conference on High Performance Computing and Communications*, 2016, pp. 1218-1225.

[32] S. Underwood, Improving disaster management, *Communications of the ACM* **53** (2010), 18-20.

[33] A. Ahmed and L.F. Sugianto, RFID in emergency management, in: *Auto-identification and ubiquitous computing applications,* J. Symonds, J. Ayoade, and D. Parry, eds., IGI Global, Hershey, PA, 2009, pp. 137-155.

[34] D.W. Callaway, C.R. Peabody, A. Hoffman, E. Cote, S. Moulton, A.A. Baez, and L. Nathanson, Disaster mobile health technology: Lessons from Haiti, *Prehospital and Disaster Medicine* **27** (2012), 148-152.

[35] M.S. Aliyu, H. Chizari, and A.H. Abdullah, Integrated sensor and RFID network node placement in disaster monitoring applications, in: *RFID-Technologies and Applications (RFID-TA), 2013 IEEE International Conference on*, IEEE, 2013, pp. 1-5.

[36] S. Agrawal and M.L. Das, Internet of Things-A paradigm shift of future Internet applications, in: *Nirma University International Conference on Engineering*, IEEE, Ahmedabad, Gujarat, India, 2011, pp. 1-7.

[37] 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** (2013), 1645-1660.

[38] J. Moock, Cloud Computing creates climate change in teleradiology, in, *Modern Medicine Network*, 2011.

[39] P. Johnson How the Internet of Things could become a critical part of disaster response, 2014.

[40] H. Petersen, E. Baccelli, M. Wählisch, T.C. Schmidt, and J. Schiller, The role of the Internet of Things in network resilience, *arXiv preprint arXiv:1406.6614* (2014).

[41] A.H. Kaji and J.F. Waeckerle, Disaster medicine and the emergency medicine resident, *Annals of Emergency Medicine* **41** (2003), 865-870.

Address for correspondence

Samaneh Madanian, Department of Computer Science, Auckland University of Technology, Auckland, New Zealand, email: Sam.madanian@aut.ac.nz.