ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, Vol 9(46), DOI: 10.17485/ijst/2016/v9i46/107848, December 2016 ISSN (Online) : 0974-5645

The Establishment of Disaster Communication System Through IoT Technology Convergence

Jung-Mo Yang and Jeong-Ho Kim*

Hanbat National University, Department of Computer Science, Daejun-city - 34158, Korea;
jmyang@auri.or.kr, jhkim@hanbat.ac.kr

Abstract

Objectives: To present a network-building measure for maintaining network through Internet of Things (IoT) technology convergence when the information and communication infrastructure collapses in a disaster situation. **Methods/Statistical Analysis:** Analyzing currently distributed and utilized IoT technology is necessary to remedy the disadvantages of the disaster and safety radio network based on PS-LTE technology through IoT technology convergence and to form the best network available in a disaster situation. The present study derived a new application of the existing technology by analyzing the sensing device technology for implementing IoT, the technology for coverage in shadow areas, and network expansion technology from the perspective of a disaster situation. **Findings:** IoT means that all things are connected to the Internet and interactively operated by utilizing the computing power and networking capabilities that are embedded in people, things, and the environment. From this point of view, the sensor nodes constituting a smart sensor network and the access point constituting a small cell are only one thing. The similarity of the architecture and required function between the sink nodes of the smart sensor and the access point of the small cell has verified the feasibility of technology convergence of the smart sensor and small cell. In other words, the smart sensor has computing power that the small cell does not have and its own power, which can be stably driven during a disaster. Furthermore, if coverage can be extended through the Wireless Mesh Network (WMN) technology convergence, the application to the field and party communication will be increased in a disaster situation. We designed a Disaster Response Smart Sensor Small-Cell (DR3S) network specialized in disaster situations by taking into account the characteristics of these technologies. **Improvements/Applications:** Through this study, we derived a network-building measure specialized in disaster situations, DR3S network, through IoT technology convergence. It is expected that the vulnerability of disaster network will be effectively supplemented.

Keywords: DR3S, Disaster Network, Internet of Things, Smart Sensor, Small Cell, Sink Node

1. Introduction

Disaster communication has been developed by applying the public safety LTE (PS-LTE) to address the problems of equipment dependency and shadow areas of TRS technology[1]. However, the LTE network has limitations; its network survivability is vulnerable when the information communication infrastructure, such as a base station and exchange, collapses, and its communication coverage is narrow in shadow areas, such as inside closed buildings and underground sections[2,3]. In this study, we demonstrate that compact computing power embedded in various objects and environments is an appropriate alternative for effectively overcoming this limitation. To achieve this, we analyze existing IoT-related technologies from the perspective of a disaster situation and present a network architecture that can efficiently build a disaster communication system by converging the technologies and its expansion measures.

*Author for correspondence

IoT-related technologies with the characteristics of maximizing the advantages of the existing technology and minimizing its disadvantages should be derived to apply IoT technology to the establishment of a disaster communication system. The smart sensor, a key component of the IoT, is equipped with data-processing capability and determining and communication functions that computers have. It is a compact, low-power sensor that performs the intelligent sensing function of measuring the physical, chemical, and biological information from a target and converting it into a transmittable signal[4]. The application of the smart sensor has been expanded into large-scale environmental monitoring systems and more. The smart sensor can configure the sensor network through a built-in communication function. In addition, since its low production cost, microminiaturization, low power consumption, and ability to be equipped with various devices are possible by utilizing the MEMS, semiconductor SoC, and embedded software technology, it is easy to link to the establishment of a disaster response system. Note the data-processing capabilities and communication function of the smart sensor itself[5] In general, the smart sensor serves to collect information on the situation according to its objective, processes it, and transfers it to the gateway.

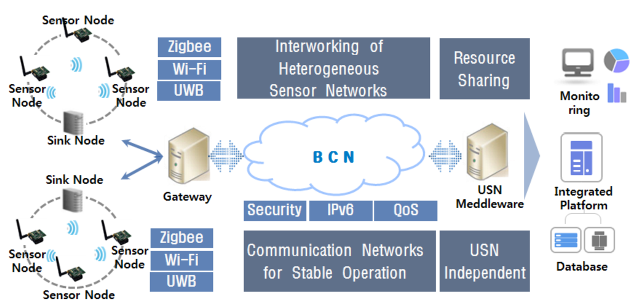

Figure 1. Configuration of Smart Sensor Network.

Although figure 1 shows a network configuration using a smart sensor, it is the same as the configuration of the ubiquitous sensor network (USN). The USN is a network that recognizes and transfers environmental information through sensor nodes installed in various locations, thereby supporting its utilization. It collects environmental information in real time through small-sized sensor nodes. In particular, the small-sized sensors constituting the USN are quickly being replaced by smart sensors due to the development of micromachining (MEMS) technology and VLSI. Therefore, it is difficult to classify the USN and smart sensor network as separate concepts. These small-sized sensors make up Ad-hoc, Multi-hop, and Mesh-Network by using various networking technologies, such as ZigBee, Wi-Fi, and UWB[6]. They interact and transfer information. The USN consists of the sensor nodes, sink nodes, and gateway. The sensor nodes collect sensing data and transfer them to the sink node. The small cell, another component of the IoT, is being utilized as a technology for improving indoor shadow areas (such as home, office, and underground sections) that radio waves do not reach well and receiving intensive data traffic in small areas. The advantages of the small cell are described in Table 1.

Table 1. Advantages of Utilizing Small Cells

Advantages	Description
Low power	Low power consumption by providing a service within low coverage
Provision of their own capacity	Providing their own capacity since they are connected to the mobile communication network using the Internet line as backhaul without going through the base stations
Easy infrastructure establishment	Can be installed regardless of location if there is an Internet connection
Serviceability	Simultaneously available voice and data services, can take advantage of the existing terminal

The convergence technology to be finally utilized is the WMN, which provides a high-speed wireless LAN service with wide coverage through the connection between the Aps in outdoor environments, such as a particular city, industrial field, or transportation facilities[7]. The WMN features self-configuration, which automatically configures networks in emergency situations when the communication infrastructure is poor, such as fires and disasters, because the communication reliability according to the multipath on a mesh topology is ensured through the self-configuration. It also provides automatic recovery of networks: physical network switching, searching for a new optimum route in traffic overload, and periodic searching for an optimum radio link. In addition, it has the following advantages: securing wide area coverage through multi-hop routing, reusing frequency through automatic frequency selection, consuming low power, and so on. Therefore, it is a suitable network technology for applications in disaster situations.

2. Proposed Work

Expanding networking technology is essential for configuring the sensor network by utilizing the smart sensor and linking the sensor network to the measure of establishing disaster communication. In other words, a smart sensor feature that can perform the role of the sink node and gateway, rather than only being equipped with a specific protocol stack for performing the intrinsic functions of the sensor node, such as simple information collection and transfer, is needed. Therefore, the first condition for applying the smart sensor to the disaster communication system is that the networking capability of the smart sensor should have the TCP/IP stack for external network interworking and the protocol stack of the sensor network itself at the same time. In addition, since the cell radius should be wide and the small cell should fully cover the number of users to utilize the small cell for disaster communication, it should provide a hand-over function between Femto-cells, Pico-cells, and Micro-cells[8,9]. Table 2 summarizes the features for the application of the smart sensor and small cell technology in disaster communication.

Table 2. Features of Smart Sensor and Small Cell Technology

Division	Smart sensor	Small cell
Applicability	Provides a base for prompt access due to being embedded in objects and environments	Installed and operating in homes, buildings, and underground sections based on existing mobile companies
Usability	Normal operation is possible under any circumstances due to having its own computing power	Possibility of not working in a disaster situation due toneeding to utilize external power
Communication	An integrated interface between heterogeneous USN networks by utilizing various communication protocols, such as ZigBee, Wi-Fi, and UWB, is needed	Handover function between Femto-cells, Pico-cells, and microcells, stable operation via implementation of frequency interference removal function
Computing power	Providing information processing and computing capabilities by having its own computing power	Centered on simple communication function without providing its own computing power
Wired or wireless	Operation is based on the wireless network, and only the sink node and gateway are wired	Wired network is essential to provide fixed-mobile convergence
Communication protocol	ZigBee, Wi-Fi, Bluetooth, UWB, etc.	Bluetooth, Wi-Fi, WiBro, etc.

While the smart sensor has superior applicability, usability, and computing power, it has a limitation: it requires an integrated interface of heterogeneous protocols and interworking with the wired infrastructure through the sink node, gateway, and so on. Due to being already commercially available and utilized, small cell technology provides fixed-mobile convergence and has superior communication. However, it lacks its own computing power and requires a connection to the wired network and external power supply. In terms of the coverage of shadow areas in disaster communication, the advantages and disadvantages of the smart sensor and small cell technology are complementary. In other words, the smart sensor has computing power (that the small cell does not have) and its own power that can be stably driven during a disaster, while the small cell has the necessary fixed-mobile convergence in smart sensor networks. Figure 2 conceptualizes the configuration of the operation of each smart sensor network and small cell.

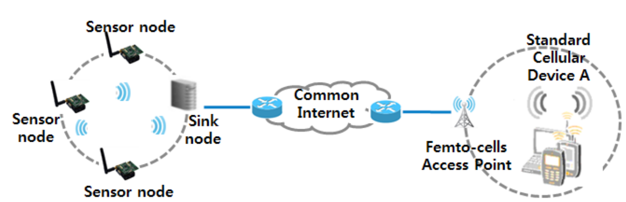

Figure 2. Conceptual Diagram of the Operation of Each Smart Sensor Network and Small Cell.

As shown in figure 2, the access point of the small cell and the sink node of the smart sensor network have a similarity: they are interworked with multipurpose internet networks. In the event of a disaster, the smart sensor network mainly transfers cognitive information on the disaster situation, while the small cell mainly maintains the communication system by eliminating call congestion and shadow areas. However, such a scenario can be realized under the condition that the sink node located at the end of the smart sensor network and access point (a key component of the small cell) have a reliable power supply and are connected to wired networks. However, the worst-case scenario—that the information and communication infrastructure may collapse in a disaster situation—cannot be ruled out. It is necessary to derive the common denominator of the smart sensor and the small cell technology to maintain a stable communication system even when the information and communication infrastructure collapses. As discussed so far, the smart sensor interworks the data collected in a heterogeneous sensor network with the wired network through the sink node and transfers it to the gateway. The access point of the small cell is installed in homes, buildings, and underground sections and interworked with the wireless cellular device and wired network, thereby providing voice and data communication services. In other words, the sink node of the smart sensor network and access point of the small cell both act as a gateway for interworking wired and wireless networks (the sink node of the conventional smart sensor network performs the role of a gateway at the same time). In addition, the smart sensor network is embedded in objects and environments in accordance with the advent of the IoT environment; therefore, it is easily accessible from various locations in our living environments. Figure 3 conceptualizes the possibility of interworking the smart sensor network and small cell by briefly outlining these similarities.

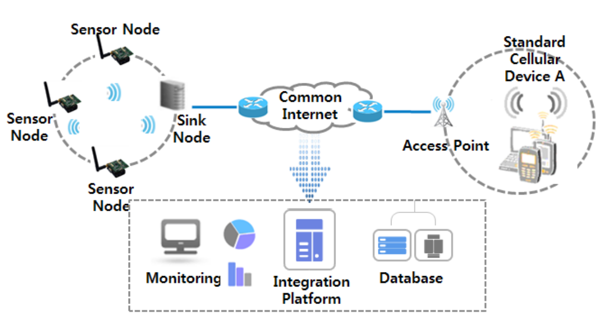

Figure 3. Possibility of Interworking the Smart Sensor Network and Small Cell.

The security, usability, communication, manageability, and so on of the analyzed small cell can be mostly covered by the sink node architecture. For example, if the certification module of the Wi-Fi Protected Access (WPA) and WPA2 is applied to the security module of the sink node architecture, the security of the small cell can be achieved[10,11]. In addition, the required function associated with the serial power that can replace the AC power of the small cell can be achieved through the rechargeable battery of the sink node. The similarity between this architecture and the required function demonstrates the feasibility of the technology convergence of the smart sensor and small cell and implies that it can be useful in the field and party communication in a disaster. Based on the results of this analysis, the architecture of the sink node constituting the DR3S that can be used in the field and party communication in disaster situations is designed as shown in figure 4. The architecture of the DR3S sink node is equipped with a rechargeable battery for properly operating the sink node in a disaster situation, AC power for the power supply in general conditions, and a basic security module[12,13]. It is also equipped with a network-capable application processor that can process various USN communication protocols, working memory, and flash memory, both of which temporarily store computing and calculated data and store the transit data. In addition, the architecture was planned for wired and wireless networking interworking so it was interworked with the high-speed internet network and base station by utilizing the modem chipset for the TCP/IP protocol stack and LTE connection and thereby providing a wire–wireless integrated network interface[14,15]. The DR3S sink node contains a protocol stack and modem chipset to perform the role of the access point of the small cell at the same time. In addition, it was configured so that the communication system with the cellular base station as well as the high-speed internet network through the wire–wireless integrated network interface was possible.

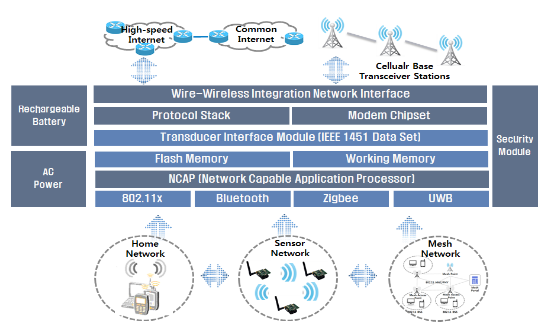

Figure 4. Planning of the Architecture of the Sink Node in DR3S Network.

The unit network at the bottom of the configuration covers the smart sensor network and small cell. From the perspective of viewing all the components of the unit network as one thing, the sink node performs the role of the access point at the same time. This configuration makes it possible to evenly accommodate the advantages of the smart sensor network and the small cell. The DR3S network is easily utilized for the field and party communication in a disaster.

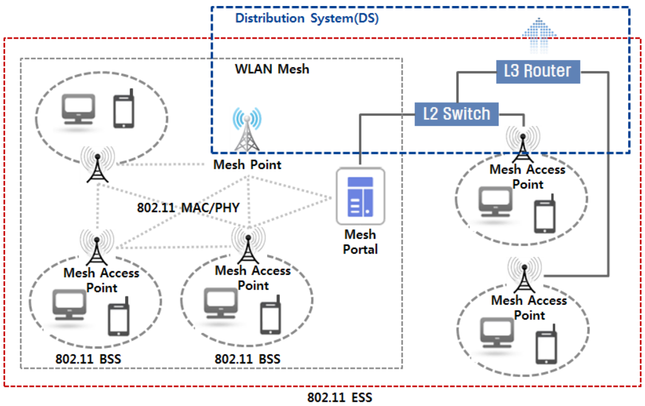

Figure 5. Planning of the Architecture of the Sink Node in DR3S Network.

As shown in figure 5, the mesh point (MP) serves to detect a neighboring MP and is responsible for the connection setup[16]. In addition, the mesh access point (MAP) performs the role of the AP, while the mesh portal (MPP) is responsible for the connection to the WLAN mesh and external network[17,18]. The AP of the basic service set(BSS) configuring the WLAN by default performs the role of the MP in the WMN. The MAP receives the information from the MPP to detect surrounding MP and MPP, and all the protocols are compliant with the 802.11 standard. The MPP is connected to the L2 switch via wired lines and to the external WMN. Thus, it extends the coverage by configuring the extended services set (ESS)[19,20].

3. Conclusion

In terms of the IoT, where all objects are connected to the Internet and interactively operated by utilizing the computing power and networking capabilities embedded in people, objects, and the environment, the sensor node and sink node configuring the smart sensor network and the access point and cellular device configuring the small cell are only one thing. Therefore, the perspective of viewing them as separate things and independently considering the networks is not desirable. A process of integrating the similar functions and improving the architecture, which are not compatible according to the aforementioned point of view, is required. The similarity of the architecture and required function between the sink nodes of the smart sensor and the access point of the small cell has verified the feasibility of technology convergence of the smart sensor and small cell. The DR3S network designed based on these characteristics can be utilized as the core network for establishing the full range of a disaster communication system, and its applicability can be further increased if the coverage is extended through WMN technology convergence.

4. References

1. Ministry of Government Administration and Home Affairs of Korea. Available from: http://www.mogaha.go.kr/eng/a01/engMain.do. Date Accessed: 2016.
2. National Information Society Agency. Disaster Response Best Practices Analysis for the Smart Age. IT & SOCIETY. 2011 Nov; (7):17–8.
3. Kim KY, Jung SH. Next-Generation Mobile Communications (3GPP LTE) Disaster Communications Technologies and Standards. Technology Transfer Accelerator Journal. 2010 Sep; 131:67–73.
4. National IT Industry Promotion Agency. Available from: https://www.nipa.kr/eng/main.it. Date Accessed: 2016.
5. Lee JI. Convergent Case Study of Research and Education: Internet of Things Based Wireless Device Forming Research. Journal of the Korea Convergence Society. 2015 Aug; 6(4):1–7.
6. Kang HS, Jo DH, Kim BJ. A Study on the Extension of Smart Sensor Network Coverage using Wireless Communication Switching Scheme. Proceedings of Symposium of the Korean Institute of communications and Information Sciences. 2014 Jun; 374–5.
7. Him BS, Yoo DH. Trends and Activation Plans for Next-generation Wireless Broadband Industry. Journal of the Korea Convergence Society. 2015 Dec; 13(12):13–21.
8. Pavan Kumar CHVMSN, Tamilselvan S. A Review on 3GPP Femtocell Networks and its Technical Challenges. Indian Journal of Science and Technology. 2016 Apr; 9(16):1–9.
9. Huang G, Li J. Interference Mitigation for Femtocell Networks via Adaptive Frequency Reuse. IEEE Transactions on Vehicular Technology. 2015 Apr; 65(4):2413–23.
10. Diane KR, Norbert E. The WPA Outcomes Statement, validation, and the pursuit of localism. Assessing Writing. 2014 Mar; 21:89–103.

11. Yancey KB. Standards, outcomes, and all that jazz. Debate and consensus after the WPA Outcomes Statement. 2005; 18–23.
12. Toghian M, Morogan MC. Suggesting a Method to Improve Encryption Key Management in Wireless Sensor Networks. Indian Journal of Science and Technology. 2015 Aug; 8(19):1–17.
13. Deng J, Han R, Mishra S. Enhancing Base Station Securityin Wireless Sensor Networks. 2003. Department ofComputer Science, University of Colorado. Tech Rep.CU-CS-951-03.
14. Jang J, Jung J, Cho YK, Choi SH, Shin SY. Design of a Lightweight TCP/IP Protocol Stack with an Event-Driven Scheduler. Journal of Information Science and Engineering. 2012 Nov; 28(6):1059–71.
15. Ji Z. Design of an Integrated Controller based on ZigBee Wireless Network. Indonesian Journal of Electrical Engineering. 2013 Mar; 11(8):4414–21.
16. Park HS, Kim JD. Design of Loss Resilient Diversity Mesh Point in Wireless Mesh Networks. The Korean Institute of Communications and Information Sciences. 2007 Jul; 1033–36.
17. Uemura K, Funabiki N, Nakanishi T. A Proposal of a Smart Access Point Allocation Algorithm for Scalable Wireless Mesh Networks. Lecture Notes in Engineering and Computer Science. 2010; 2181(1):848–53.
18. Li Y, Ji H, Li X, Victor CM. Leung, Dynamic channel selection with reinforcement learning for cognitive WLAN over fiber. International Journal of Communication Systems. 2012 Mar; 25(8):1077–90.
19. Hua YM, Tong LC, Premkumar B. A Power-Efficient Access Point Operation for Infrastructure Basic Service Set in IEEE 802.11 MAC Protocol. EURASIP Journal on Wireless Communications and Networking. 2006 Sep; 2006(1):1–14.
20. Al-Ahdal AA, Pawar VP, Shinde GN. Cross-Layer Protocol as a Better Option in Wireless Mesh Network with Respect to Layered-Protocol. International Journal of Electronics Communication and Computer Engineering. 2014; 5(1):238–40.