# A Personal Emergency Communication Service for Smartphones using FM transmitters

Yu-Jia Chen, Chia-Yu Lin, and Li-Chun Wang
National Chiao Tung University, Taiwan
Email :allan920693.cm99g@nctu.edu.tw, sallylin1987.cm01g@nctu.edu.tw and lichun@cc.nctu.edu.tw

***Abstract*— Communication networks such as cellular phone networks are quite likely to be severely damaged during a large-scale of disaster, making SOS message dissemination to rescue authorities extremely difficult. In this paper, we first propose a FM radio-based emergency communication service through the integration of FM transmitters into smartphones. FM radio provides a number of advantages such as longer propagation length and less susceptible to obstacles, making it suitable for broadcasting SOS messages. Besides, we design Morse code-based SOS message dissemination using FM transmitters (MCSOS-FM) and its corresponding communication procedure for the emergency communication service in order to improve communication range, victim localization and evacuation route planning. The combination of FM radio and Morse code is completely compatible with the current radio system equipped by rescue workers, and thus increases the possibilities of successful receiving and recognizing SOS messages. Our experiment result based on smartphone implementation shows that the proposed emergency communication service is cost effective and energy efficient with relatively large communication range.**

## I. Introduction

The world is stricken by catastrophic disasters (e.g., typhoon, mudslide and earthquake) every year. During a large-scale disaster, people who are trapped under collapsed buildings or landslides may have a large chance to survive if they are rescued in 72 hours. However, reaching those in trapped in 72 hours is challenging because communication networks, fixed or mobile, are usually down during disasters, making SOS message dissemination extremely difficult. For example,in Jiji earthquake, Chunghwa Telecom, the largest telecommunication operator in Taiwan, took 15 days to restore the whole mobile communication systems. Another example is all carriers halted communication service operations of up to 29,000 base stations in the great east Japan earthquake. As a result, people in the disastrous area was unable to call for help, making it difficult to locate them thereafter. Thus, it is crucial to establish a system of emergency communication in order to timely deliver SOS messages to rescue authorities.

Emergency communication has been studied extensively in recent literature and can be categorized into two approaches: (1) Rapidly deployable disaster communications and (2) Wireless ad-hoc and sensor networks (WASNs). Rapidly deployable disaster communications aim at deploying post-disaster networks in the disastrous area to provide sufficient connectivity between the field rescue worker, Master Operation Center (MOC), and the ordinary citizen affected by the disaster. This approach typically involves novel communication infrastructure (e.g. LTE mobile) and usually satellite communication. Although such approach provides strong communication support for the disastrous area, it requires extra and expensive equipment for supporting communication (e.g., a few trucks laden with communication antennas) [2]. Besides, power supplies and transportation for the communication equipment are challenging in the disastrous area. Another popular approach is to utilize the communication capabilities (e.g., Bluetooth or WiFi) of mobile devices to transmit SOS messages through wireless ad hoc network during a disaster. The limitation of this approach is its insufficient communication ranges and its susceptibility to obstacles or interference, making it unfavorable for some cases such as searching survivors under a collapsed building or landslide.

To overcome these limitations, we propose a personal emergency communication service by integrating FM radio transmitters into smartphones since the popularity of smartphones has been unprecedentedly increased. FM radio has various advantages such as longer propagation length and less susceptible to obstacles, making it suitable for broadcasting SOS messages. Note that broadcasting emergency messages to nearby people is considered to provide more instant help than distant rescue units [16]. Besides, in order to deliver digital data through a radio system and share in an easy way, we propose to use Morse code,a globally common language in rescue, to encode SOS information in the proposed system. The combination of FM radio and Morse code is completely compatible with the current radio system equipped by rescue workers, and thus increases the possibilities of successful receiving and recognizing SOS messages. Furthermore, we design and incorporate a FM radio localization mechanism for the case where global positioning system (GPS) information is not available. Contributions and novelties of this work are listed as follows:

- We propose a first FM radio-based emergency communication service by designing Morse code-based SOS message dissemination using FM transmitters



978-1-4577-1348-4/13/$31.00 ©2013 IEEE 

(MCSOS-FM) through the integration of FM transmitters and Morse code in smartphones.
- A corresponding communication procedure is proposed for the emergency communication service in order to improve communication range, victim localization and evacuation route planning.
- Experiment result based on smartphone implementation shows that the proposed emergency communication service is cost effective and energy efficient with relatively large communication range.

The rest of the paper is organized as follows. Section II describes background and related works for emergency communication services. Section III details the proposed personal emergency communication service. Section IV shows the experiment result of MCSOS-FM implementation on smartphones. Discussion and related research issues of MCSOS-FM are presented in Section V. We give our concluding remarks in Section VI.

## II. Background and Related work

### A. Emergency Communication

Emergency communication in recent literature can be categorized into two approaches: (1) Rapidly deployable disaster communications and (2) wireless ad-hoc and sensor networks (WASNs). First, rapidly deployable disaster communications aim at deploying post-disaster networks to support emergency communication including voice, text and video communication between the rescue worker and the operation center as well as the communication between the victim and the rescue worker. [1] described a quickly deployable package for post disaster communications called lifeline stations (LLS). LLS is a portable package with IP-based communication facility, which can be kept in small packages and mobilized to deploy network in a disaster site. [2] gave a preliminary report to design a disaster communication system using standards-based subsystems such as WiFi, satellite link, single-carrier GSM system and LTE pico base station. [4] proposed a distributed communication approach which is based on a layered network topology and presented a testing framework for the evaluation of a crisis response communication system. However, such approach requires extra and expensive equipment for supporting communication (e.g., a few trucks laden with communication antennas) [2]. Besides, maintaining power supplies and supporting transportation for the communication equipment are challenging in the affected area. Second, mobile devices or sensors with communication capabilities (e.g., ZigBee, Bluetooth and WiFi) can be used to gather emergency information and deliver response to rescue authorities. [13] and [14] constructed wireless sensor networks (WSN) to achieve efficient disaster response. [15] designed a data collection framework with sensor networks to collect and transmit damage data from various devices deployed in buildings. [8] and [9] proposed an ad-hoc group communication systems that uses notebook PCs to construct a mobile ad hoc network (MANET) based emergency communication and information system. [10] and [12] designed an application framework to propagate SOS messages from immobilized persons through a direct communication via Bluetooth. [6] proposed an emergency message dissemination system by taking advantage of epidemic routing algorithm, as well as Bluetooth and WiFi technologies in smartphones. The inherent limitation of this approach is its insufficient communication ranges and susceptibility to obstacles or interference, which cause it unfavorable for some emergency situations such as searching survivors under a collapsed building or landslide.

Instead of focusing on the above techniques, we design a personal emergency communication service by integrating FM radio transmitters into smartphones. Our experiment result based on smartphone implementation shows that the proposed scheme can provide a more convenient and effective personal emergency communication in large-scale of disasters.

### B. Morse Code

Morse code is a communication technique of transmitting text information as a series of on-off lights, tones, or clicks that can be easily understood by a listener without special equipment. The international Morse code encodes alphabets as standardized sequences of short and long signals called dits and dahs. Based on the definition of Morse code, the tone ratio of dit to dah has to be 1:3. Each dit or dah is followed by a short silence, equal to the dit duration. The dot duration is the basic unit of time measurement in code transmission [17]. Morse code is simple and less sensitive to poor signal conditions so it is still commonly used among radio communication, although it is no longer required for licensing in most countries, including the US. The most common distress signal SOS consists of a continuous sequence of three-dits/three-dahs/three-dits, which is internationally recognizable by rescue workers. Some smartphone applications have been developed to transmit SOS message by speakers or flashlight [18].

### C. FM Radio Broadcasting

FM broadcasting uses frequency modulation (FM) for high-fidelity broadcasts of music and speech. A narrow band form of FM radio is used for voice communications around the world. Broadcasting FM radio is popular and well-established in ubiquitous worldwide coverage. Police, fire and other rescue services also use FM radio on special frequencies. Most rescue workers carry a radio receiver/transmitter with them to receive a call to communicate with emergency relief operations. In recent years, FM receivers have been embedded in almost all smartphones. Short-range and license-free FM transmitters are also available at low cost on the market. FM radio has numerous advantages that makes it suitable for broadcasting SOS messages. First, FM is much more energy efficient than WiFi and Bluetooth. FM receiver consumes around 15 mW, while WiFi and Bluetooth typically consumes over 400mW and 150mW, respectively [19]. In addition, since low frequency radio waves are less sensitive to the weather/terrain conditions, FM signals are less affected by these minor influences. Finally, FM signals penetrate obstacles more easily than WiFi or GSM since the attenuation of radio waves by obstacles increases with frequency [20]. The aforementioned considerations suggest that FM radio broadcasting has a number of inherent advantages over the current high-frequency systems.

## III. Morse Code-Based SOS Message Dissemination Using FM Transmitters (MCSOS-FM)

This section explains in detail the proposed MCSOS-FM, a personal emergency communication service by integrating FM radio transmitters into smartphones for victims in a disastrous area. Section III-A describes how MCSOS-FM works. The design of MCSOS-FM is shown in Section III-B.

### A. Overview of MCSOS-FM

Communication networks, fixed or mobile, are usually down during disasters, which causes SOS message dissemination extremely difficult. Therefore, we propose a MCSOS-FM service which can help users to send SOS message in a disastrous area cut off from conventional services. That is, smartphones with the MCSOS-FM service can directly communicate with each other. Fig. 1 illustrates how MCSOS-FM works. We here assume that victim who is severely injured or is presumably trapped in a collapsed building would like to ask call for help. There are two communication circumstances. If base station signal is available, victim can use smartphones to call for help to police/medical cloud by GPRS or 3G . If there is no base station signal, the system will switch to rescue mode automatically. In this situation, victims can send FM radio signal to find viable propagators who are civilians passing nearby. When there is a propagator, victims can transmit an SOS messages including the international mobile equipment identity number (IMEI number) of his/her smartphone, the events they encounter and their location by Morse code to the propagator. The civilians passing by the area plays the role of propagators. The radio receiver on smartphones of propagators scans SOS messages periodically. If base station signal is available, they can relay the SOS messages which they receive from victims to police/medical cloud. If there is no base station signal, they broadcast SOS messages. The SOS messages broadcast serially until the messages are received by the smartphones which are able to relay the messages to police/medical cloud. In this system, the police/medical cloud can be regarded as MOC. Once receiving SOS messages, the police/medical cloud can go to rescue victims.

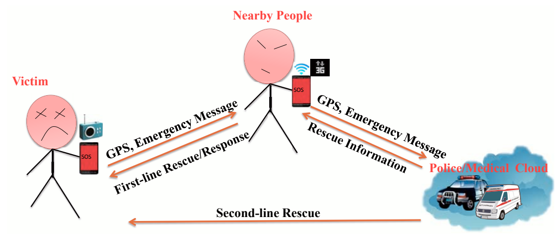
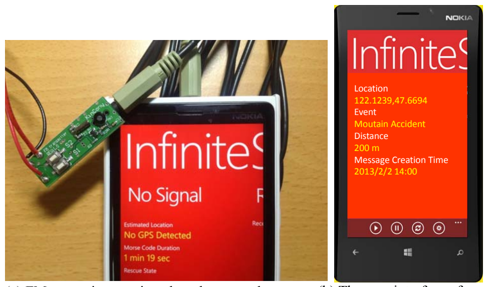



Fig. 1. Overview of MCSOS-FM.




(a) FM transmitter equipped on the smartphone. (b) The user interface of a propagator.

Fig. 2. The FM transmitter and user interface of MCSOS-FM.

### B. Design of MCSOS-FM

This section presents the design of MCSOS-FM. The hardware equipment is described first. After defining the message format of an SOS message, we describe the information decoding and radio broadcasting process. The mechanism of estimating the location of a victim is also described.

*1) Hardware Equipment:* The radio transmitter and receiver make victims can forward SOS message by FM radio without any base station signal. The FM radio transmitter and receiver should be equipped in smartphones. In recent years, FM receivers have been embedded in almost all smartphones. Short-range and license-free FM transmitters are also available at low cost on the market. The government can provide FM transmitters before forecasting disaster such as typhoon. During a disaster, rescue authorities can airdrop FM transmitters to disastrous area. People in emergency can equip FM transmitters and call for help by FM radio. Fig. 2(a) shows a FM transmitter equipped on the smartphone.

*2) Message Format:* Fig. 3 shows the format of a SOS message. SOS message consists of the IMEI number of the victim's smartphone, event information, estimated distance, estimated location, message creation time and sequence number. First, the IMEI number field contains the IMEI number of the victim's smartphone. This field can help rescuers find out the source of the SOS message. Second, the event information field describes the event that the victim encounters. The victim can select from the predefined messages or can purposely type a message. Third, the estimated distance field shows the estimated distance from the victim to the propagator. The victim do not need to fill this field. The propagator who

| IMEI number | Event information | Estimated distance | Estimated location | Message creation time | Sequence number |
|---|---|---|---|---|---|

Fig. 3. Message Format of MCSOS-FM.

helps to relay the SOS message to the next propagator or police/medical cloud use the received signal strength indication (RSSI) to estimate the distance from him/her to the victim and fills the distance in this field [21], [22]. Fourth, the estimated location field points out the victim's location. The victim can use GPS to get his/her location and fill in the field. However, as mentioned previously, victims may trap in the place without GPS signal. When MCSOS-FM cannot obtain GPS information, the field will be left empty. If a propagator finds out the field is empty, he/she can use location estimation mechanism to estimate the victim's location and fill in this field. Fifth, the message creation time field contains the generation time of SOS messages. The message creation time can be used to estimate the time when a victim starts to ask for help. Lastly, the victims may send many SOS messages to describe his/her situation. Thus, the sequence number field can help propagators find out the order of SOS message.

*3) Information Coding Process:* The SOS information that a victim fills in is digital data. In order to send digital data through radio system and share in an easy way, we integrate a Morse code encoder in MCSOS-FM to encode the SOS information into Morse code. The FM receiver of propagator receives the analog signal of Morse code and send the signal to Morse code decoder to translate to digital data. Fig. 2(b) shows the user interface of a propagator. The digital information that contains estimated location, event information, estimated distance and message creation time will show to propagator.

*4) Radio Broadcasting Process:* In order to improve communication range and evacuation route planning, we propose a radio broadcasting process to relay the SOS message. The radio broadcasting process checks whether the receiver has base station signal. If the receiver has no base station signal to relay the SOS message, the radio broadcasting process will broadcast the SOS message to other nearby users until the SOS message can be forwarded to police/medical cloud.

*5) Location Estimation Mechanism:* Following the above processes, SOS messages will be relayed via propagators until these messages reach the police/medical cloud. The police/medical cloud needs to know the victim's location to rescue victims. However, victims may trap in the place without GPS signal. We propose a location estimation mechanism includes three methods to estimate a victim's location. The first method to estimate location is based on the received signal strengths from FM radio stations [23]. The FM receiver can receive the signal from nearby radio stations which are commercial radio stations or deployed by rescue authorities. After a victim sends SOS messages, SOS messages may be received by many propagators. Thus, the second method to estimate a victim's location is based on the GPS location of nearby propagators. Once receiving the SOS message from the victim, the propagators find out that there is no location information in the SOS message. The propagator who has GPS location will send his/her GPS location back to the victim. The victim can use the GPS location from propagators to estimate his/her location. Finally, the third method uses victim's IMEI to find the latest base station which was communicated by the victim, which may indicate the nearly area of the victim. Combining the result of the three methods, MCSOS-FM can estimate victim's location more accurately.

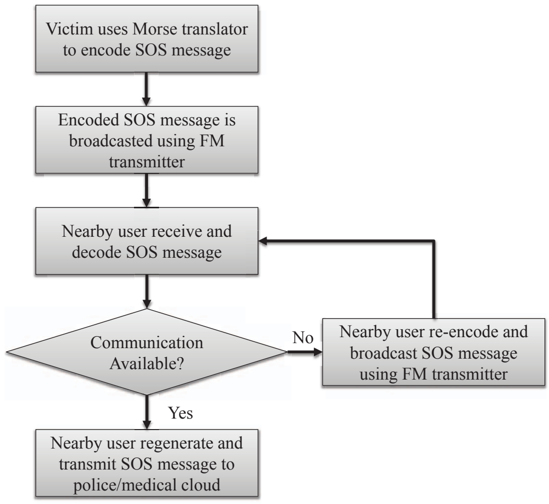



Fig. 4. System flow of MCSOS-FM.

*6) System Flow:* Fig. 4 summarizes the flow of MCSOS-FM. First, the victim uses Morse code translator to encode SOS message, and the SOS message is broadcasted by FM transmitter. Then, nearby propagators receive and decode SOS message. If propagators have available base station signal, they can regenerate and transmit the SOS message to police/medical cloud. If propagators do not have base station signal, they re-encode the SOS message and broadcast to other nearby propagators.

## IV. Experiment Result

This section presents the experiment results of the transmission range and the power consumption of MCSOS-FM. We implement MCSOS-FM on Nokia Lumia 920 which is a Windows Phone 8 system.

Fig. 5 shows the result of power consumption of rescue mode. The standby mode is executing on airplane mode without starting any rescue service. The battery can supply 350 hours power under standby mode. While starting rescue mode to transmit SOS message, the smartphone will be out of power after 250 hours. Besides, we also use

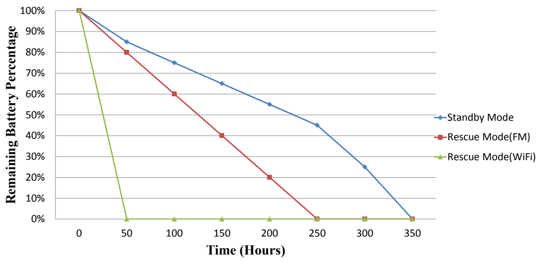



Fig. 5. Power consumption of MCSOS-FM.

TABLE I
THE TRANSMISSION DISTANCE OF FM AND WIFI

| Rescue Mode | Outdoor | Indoor |
|---|---|---|
| FM | 370 m | 240 m |
| WiFi | 75 m | 35 m |

WiFi to send SOS message and measure the power consumption. We can find out the power consuming of WiFi mode is larger than that of FM mode. The battery under WiFi mode can only supply power in 50 hours. Thus, we can conclude that FM radio is a practical approach to transmit SOS messages continuously .

Table I is the comparison of transmission distance between FM radio and WiFi. The transmission range of FM radio is up to 350 meters. However, the transmission range of WiFi is only 70 meters. All in all, no matter in indoor or outdoor, the transmission range of FM radio is much larger than that of WiFi. The actual transmission range of FM radio can be larger, which depends on the broadcasting power of FM transmitter.

## V. DISCUSSION AND ASSOCIATED RESEARCH ISSUES OF MCSOS-FM

### A. Coding for SOS Messages

In order to deliver digital data through a radio system and share in an easy way, we use Morse code to encode SOS information in the proposed system. Each dot is 60 ms long and each dash is 180 ms long. It takes about 90 seconds to transmit a complete SOS message. Such latency can be reduced by decreasing the dot duration in Morse code. However, a lower duration may increase the difficulty of recognition by rescue workers without computer-assisted decoders. Besides, SOS messages are transmitted as Morse-coded audio streaming which is generated by the smartphone with a stable rate. Since the recognition accuracy of Morse code depends heavily on a stable typing speed and a stable typing ratio from long to short intervals, the proposed system achieves 100% recognition accuracy in our test. Finally, since victims within a broadcast range in a large-scale disaster may share SOS information about certain common dependencies (e.g., location and evacuation route), it is worthwhile to redesign coding strategies for different emergency situations in order to improve the coding efficiency.

### B. FM Radio Broadcasting for SOS Messages

We employ FM radio to broadcast SOS messages in the proposed system by integrating FM transmitters into smartphones. Our experiment result shows that FM radio can provide relatively large communication range. Note that a rapidly deployable FM radio station can be constructed in the disastrous area to provide more considerable emergency communication support. In addition, we follow the basic communication process for international Morse code recommended by international telecommunication union (ITU) [17]. Note that the proposed scheme can also be extended to incorporate delay-tolerant network (DTN) and opportunistic network (oppnet) technologies which are popularly applied in emergency communication [7]. Other associated research issues for FM radio broadcasting are discussed as follows. First, robust communication with the ability of supporting heavy traffic during the emergency play a significant role in rescue services. Since SOS messages need to transport through the networks with minimum latency, autonomous radio channel switching is necessary, which allows each victim to always connect to the best channels with least interference and makes the system more robust to unanticipated workload increases in emergencies and large-scale of disasters. Besides, SOS message which contains data with different constraints in terms of delay, jitter, packet error/loss rate, and bandwidth should be transmitted with higher priority. In addition to reserved channels for emergency, a dynamic resource allocation scheme is essential to optimally transmit the SOS information subject to the required priority protection [24]. Finally, the proposed scheme can also be extended to employ FM radio data system (FM-RDS) which is a standard way of transferring digital data over FM radio channels [25]. FM-RDS is typically used in traffic information broadcasting and allows listeners to receive digital data without keeping tuned to a certain channel.

### C. FM Radio for Victim Localization

FM radio can be used to locate victims in the proposed system. The technique of localization using FM radio has been studied in several studies [21], [23]. The most prominent and widely used feature is RSSI, which yields the best localizing performance. RSSI measures the amplitude of the received radio signal. Theoretically, RSSI value is inversely proportional to the square of travel distance. Although most of the current FM chips employ RSSI to provide auto tuning functionality, only Windows phone provides application programming interface (API) for developers to access RSSI [26]. In the proposed scheme, we use RSSI to estimate the distance between victims, propagators, and rescue units (e.g., rescue workers and MOC). The broadcast range of FM radio is directly influence the capability of localization. Typically MOC has a radio system able to transmit/receive voice communication in a 30 km radius and rescue workers are equipped with portable radio devices which are able to broadcast radio in an area of 2-4 km around them. As a result, FM radio is favorable for victim localization even for large coverage of disastrous area. Moreover, the accuracy of the localization depends heavily on the amount of received signal. Since FM infrastructure is already widely deployed across the world and almost all smartphones include FM chips, the proposed scheme can provide satisfactory accuracy for victim localization. Finally, we note that an evacuation/rescue route can be found easily by the propagation route of SOS messages from a victim to a rescue unit.

## VI. Conclusion

In this paper, we proposed a first FM radio-based emergency communication service by designing Morse code-based SOS message dissemination using FM transmitters (MCSOS-FM) through the integration of FM transmitters and Morse code in smartphones. Besides, a corresponding communication procedure was proposed for the emergency communication service in order to improve communication range, victim localization and evacuation route planning. Some promising results have been demonstrated according to our experiment based on smartphone implementation. This paper can also be considered as a feasibility study of using FM radio to support emergency communication. We hope our work can help convince and motivate device makers to integrate FM transmitters into smartphones as well as open more related APIs. Thus, our solution can be easily migrated and become the intrinsic function of future smartphones.

## References


[1] D. Jalihal, R. Koilpillai, P. Khawas, S. Sampoornam, S. H. Nagarajan, K. Takeda, and K. Kataoka, "A rapidly deployable disaster communications system for developing countries," in *Communications (ICC), 2012 IEEE International Conference on*, 2012, pp. 6339–6343.

[2] Y. J. Chen, C. Y. Lin, and L. C. Wang, "Sensors-assisted rescue service architecture in mobile cloud computing," in *IEEE Wireless Communications Networking Conference*, 2013.

[3] K. Kataoka, K. Uehara, and J. Murai, "Lifeline station: A quickly deployable package for post disaster communications," in *Proc. Internet Conference*, 2009, pp. 41–47.

[4] D. Bradler, B. Schiller, E. Aitenbichler, and N. Liebau, "Towards a distributed crisis response communication system," *Proceedings of ISCRAM*, 2009.

[5] S. M. George, W. Zhou, H. Chenji, M. Won, Y. O. Lee, A. Pazarloglou, R. Stoleru, and P. Barooah, "Distressnet: a wireless ad hoc and sensor network architecture for situation management in disaster response," *IEEE Communications Magazine*, vol. 48, no. 3, pp. 128–136, 2010.

[6] K. Lorincz, D. J. Malan, T. R. Fulford-Jones, A. Nawoj, A. Clavel, V. Shnayder, G. Mainland, M. Welsh, and S. Moulton, "Sensor networks for emergency response: challenges and opportunities," *IEEE Pervasive Computing*, vol. 3, no. 4, pp. 16–23, 2004.

[7] T. Fujiwara, H. Makie, and T. Watanabe, "A framework for data collection system with sensor networks in disaster circumstances," in *IEEE Wireless Ad-Hoc Networks, 2004 International Workshop on*, 2004, pp. 94–98.

[8] Y. N. Lien, H. C. Jang, and T. C. Tsai, "A manet based emergency communication and information system for catastrophic natural disasters," in *Distributed Computing Systems Workshops, 2009. ICDCS Workshops' 09. 29th IEEE International Conference on*, 2009, pp. 412–417.

[9] H. C. Jang, Y. N. Lien, and T. C. Tsai, "Rescue information system for earthquake disasters based on manet emergency communication platform," in *ACM Proceedings of the 2009 International Conference on Wireless Communications and Mobile Computing: Connecting the World Wirelessly*, 2009, pp. 623–627.

[10] N. Suzuki, J. L. F. Zamora, S. Kashihara, and S. Yamaguchi, "Soscast: Location estimation of immobilized persons through sos message propagation," in *IEEE Intelligent Networking and Collaborative Systems (INCoS), 2012 4th International Conference on*, 2012, pp. 428–435.

[11] ——, "Using sos message propagation to estimate the location of immobilized persons," in *ACM Proceedings of the 18th annual international conference on Mobile computing and networking*, 2012, pp. 455–458.

[12] X. Wu, M. Mazurowski, Z. Chen, and N. Meratnia, "Emergency message dissemination system for smartphones during natural disasters," in *ITS Telecommunications (ITST), 2011 11th International Conference on.* IEEE, 2011, pp. 258–263.

[13] L. M. L. M. D. Morse, "International morse code."

[14] Simple Morse Flashlight: https://play.google.com/store/apps/details?id=com.ohmypixel.SimpleFlashlight&feature=also_installed&rdid=com.ohmypixel.SimpleFlashlight&rdot=1.

[15] A. Papliatseyeu, V. Osmani, and O. Mayora, "Indoor positioning using fm radio," *International Journal of Handheld Computing Research (IJHCR)*, vol. 1, no. 3, pp. 19–31, 2010.

[16] P. Vecchia, R. Matthes, G. Ziegelberger, J. Lin, R. Saunders, and A. Swerdlow, "Exposure to high frequency electromagnetic fields, biological effects and health consequences (100 khz-300 ghz)," *International Commission on Non-Ionizing Radiation Protection*, 2009.

[17] A. Popleteev, V. Osmani, O. Mayora, and A. Matic, "Indoor localization using audio features of fm radio signals," in *Modeling and Using Context.* Springer, 2011, pp. 246–249.

[18] Y. Chen, D. Lymberopoulos, J. Liu, and B. Priyantha, "Fm-based indoor localization," in *ACM Proceedings of the 10th international conference on Mobile systems, applications, and services*, 2012, pp. 169–182.

[19] J. Krumm, G. Cermak, and E. Horvitz, "Rightspot: A novel sense of location for a smart personal object," in *UbiComp 2003: Ubiquitous Computing.* Springer, 2003, pp. 36–43.

[20] Y. Teranishi and S. Shimojo, "Monac: Sns message dissemination over smartphone-based dtn and cloud," in *Peer-to-Peer Computing (P2P), 2011 IEEE International Conference on*, 2011, pp. 158–159.

[21] P. Pawelczak, R. Venkatesha Prasad, L. Xia, and I. G. Niemegeers, "Cognitive radio emergency networks-requirements and design," in *New Frontiers in Dynamic Spectrum Access Networks, 2005. DySPAN 2005. 2005 First IEEE International Symposium on.* Ieee, 2005, pp. 601–606.

[22] "Specification of the radio data system (rds) for vhf/fm sound broadcasting in the frequency range from 87.5 mhz to 108.0 mhz," 1998, p. ETSI Std. EN 50 067.

[23] Windows Phone FMRadio API: http://msdn.microsoft.com/en-US/library/windowsphone/develop/microsoft.devices.radio.fmradio(v=vs.105).aspx.

[24] K. T. Morrison, "Rapidly recovering from the catastrophic loss of a major telecommunications office," *IEEE Communications Magazine*, vol. 49, no. 1, pp. 28–35, 2011.

[25] K. Kanchanasut, A. Tunpan, M. A. Awal, D. K. Das, T. Wongsaardsakul, and Y. Tsuchimoto, "A multimedia communication system for collaborative emergency response operation in disaster-affected areas," *Asian Institute of Technology (AIT), Tech. Rep. TR*, vol. 1, p. 2007, 2007.

[26] P. Jiang, J. Bigham, E. Bodanese, and E. Claudel, "Publish/subscribe delay-tolerant message-oriented middleware for resilient communication," *Communications Magazine, IEEE*, vol. 49, no. 9, pp. 124–130, 2011.

[27] M. N. Bakde and A. Thakare, "Morse code decoder-using a pic microcontroller," *International Journal of Science, Engineering and Technology Research*, vol. 1, no. 5, pp. pp–200, 2012.