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GSM Based Disaster Communication System

A Case for the Expected Istanbul Earthquake

Levent Aksoy[1],Yiğit Kayda[2]
[1]*Department of Economics, Konya Food and Agriculture University*
[2]*RF Planning Department, Turkcell GSM Operator*

Abstract—Continuing communications is imperative in disaster zones. There are various wireless systems which will provide some levels of communication. However, during a large scale disaster, like the one expected in Istanbul, an equally powerful systems need to be established. The paper investigates the need for and possibility of GSM based communication system.
Keywords—GSM; communication; disaster; management; logistics;

I. INTRODUCTION

Istanbul, home to more than 15 million people, is expecting a major earthquake in the coming years. The type of the damage ranges from collapsing buildings and other structures to damages to utilities infrastructure. There might be long running traffic jams, hunger, communicable diseases and social disorder. Among the many other damages, the communication system is expected to receive a major damage [1].

Normal operations of existing communication systems rely on multiple factors: physical infrastructure such as wired and wireless communication devices, buildings and towers; electric power either from the city network or from a generator; human resources such as maintenance personnel and network operators; and, reasonable usage-capacity ratio – usage less than the designed capacity. During and after an emergency all of these factors will be negatively affected. Data centers, communication towers and lines will get damaged; there will be long term power outages; many of the operations and maintenance personnel will not be available; and, the usage will be many times the normal, possibly exceeding the capacity.

During a disaster of the size that is expected to affect Istanbul, tens of thousands of workers would be taking part in search and rescue, and, relief operations. For efficient and effective operations, uninterrupted digital communications will be needed; old style verbal communications might still be used in on-site search and rescue missions and other emergencies, however, larger scale planning and control of relief operations require widespread data collection and processing. The sheer amount on data need to be collected, transferred and processed necessitates a working wide area data network.

The following sections discusses various wireless options and proposes a GSM based disaster area communication network for relief teams.

II. NETWORK TYPES AND COMPARISONS

The communications needs in a disaster zone by the emergency and relief teams are obvious, however, the type of the communication network to be established depends on the requirements. The area to be covered, the density of the operations, security issues, ease of deployment are all important in deciding the type of the network. In designing the network,a framework similar to one proposed by Huang and Lien [2] is used.

A. Network Types

In choosing a communication network type in addition to the practicability, popularity, usability and capacity dimensions, set-up time will also be considered. Practicability is the primary consideration for the operator and has cost, equipment and deployment ease as factors. Popularity is an end-user dimension and is determined by user friendliness of the system and amount of available terminals. Usability is another end-user dimension which includes factors such as task orientation, quality of service and mobility. Deployment time is the set-up time for service readiness. The network types considered are two-way radios such as walkie-talkies, trunked radios usually used by emergency services, satellite communications such as Iridium, Wi-Max systems, Wi-Fi and long range Wi-Fi systems, Ad-Hoc systems such as MANET, and, a dedicated emergency GSM system as in proposed in this paper.

B. Needs and Requirements

We consider the scenario of a major earthquake with a magnitude larger than 7.5 hitting the city of Istanbul. A detailed study of expected damages [3] is summarized by Erdik and Durukal [4]. Approximately 5% of the total building stock is expected to get completely damaged and a quarter will receive moderate damage; there will be damages to utilities infrastructure. Based on the scenarios proposed by another study [5] roads will be blocked by debris and there will be serious gridlocks which will prevent rescue and relief teams reaching the inner parts of the city. Each disaster being unique, the comparison of the network types are based on the conditions in the aftermath of the earthquake in the city. The communication requirements are also analyzed in terms of level of disaster management (strategic, tactical and operational) as well as its stages (planning, managing and control).

For strategic planning and control of the disaster relief efforts in a city of 15 million, a disaster management information system is necessary. Such a system cannot be run without extensive data collection, processing and reporting ability. Two way radios are useful for small teams to control on-the-scene operations. They are on the other hand is of very little use to at the tactical level. Similarly trunked radio is a voice-only system; it is useful to run operations of larger emergency teams (police, medical, fire, civil defense, military) however, the verbal data need to be digitized by a dedicated team. Satellite communications are quite useful in remote areas where a communication network is hard to set up, but the equipment is prohibitively expensive.

Wireless networks are useful if the area to be covered is small; setting up wireless data networks which will span the whole metropolitan area requires an army of technicians installing a totally new communication system. The Emergency GSM (E-GSM) network considered is an earthquake resistant system that will be installed before the disaster strikes. It will be deployed almost instantaneously after the earthquake, available to all pre-assigned search and rescue and relief teams, it will use off-the-shelf smartphones, requires minimal learning and experience, adaptable (through apps) to individual needs.

Type	Practicability	Popularity	Usability	Deployment Time
Two-Way Radio	HIGH	MEDIUM	LOW	SHORT
Trunked Radio	MEDIUM	MEDIUM	LOW	SHORT
Satellite	HIGH	MEDIUM	MEDIUM	SHORT
Wi-Max	MEDIUM	LOW	MEDIUM	LONG
Wi-Fi	MEDIUM	HIGH	HIGH	LONG
Ad-Hoc	MEDIUM	LOW	HIGH	MEDIUM
EmergencyGSM	HIGH	HIGH	HIGH	SHORT

Table 1. ECN comparisons

We see obvious benefits of building an E-GSM network before the disaster. The system will provide voice and data access to all registered teams. Although it will allow voice calls most of the bandwidth will be used for messaging and data exchanges by specialized apps to and from servers. These apps might include status reports by and work orders to utility maintenance crews, reports by victim identification teams, planning reports and requests by relief workers and other non-governmental organizations.

The apps will mostly communicate text and numerical information however multimedia files may be included in status reports and disaster victim identification (DVI). Apps provide standardized communication between planners and field workers as well as minimize the data transfers and bandwidth.

III. PLANNING AN EMERGENCY GSM NETWORK

The E-GSM is analyzed in terms of network operations, physical infrastructure, human resources, disaster operations and financials. The effect of a semi-open network on the development of new emergency applications is discussed in the last section.

A. Network Design

The network is to be designed to cover most of the Istanbul metropolitan area with enough channels to support majority of the relief teams. Therefore based on the topography and population density of the city locations for 45 base stations are selected. The following map shows the locations of those base stations and the simulated signal strength.

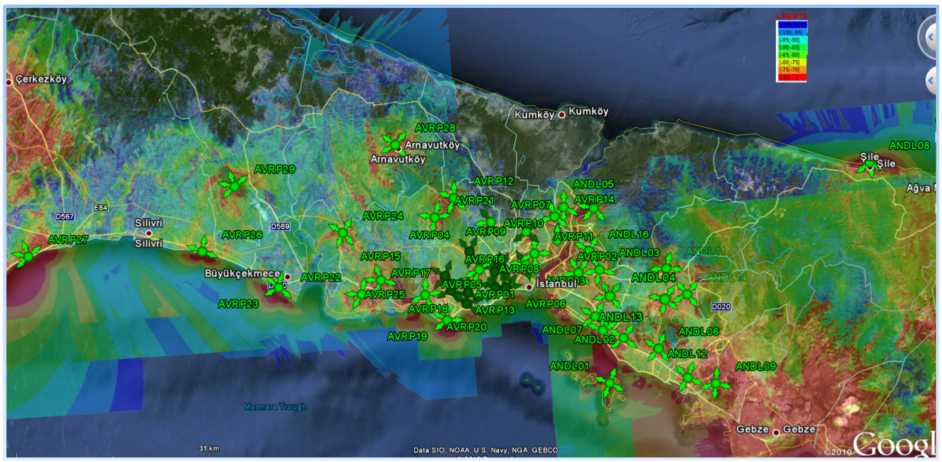

Figure 1. Base stations and signal strength

The system provides a good coverage especially to the more risky southern coast and towards the city center. The signal strength is above -90 dBm for an area of 5,000 km^2. The following figure show the distribution.

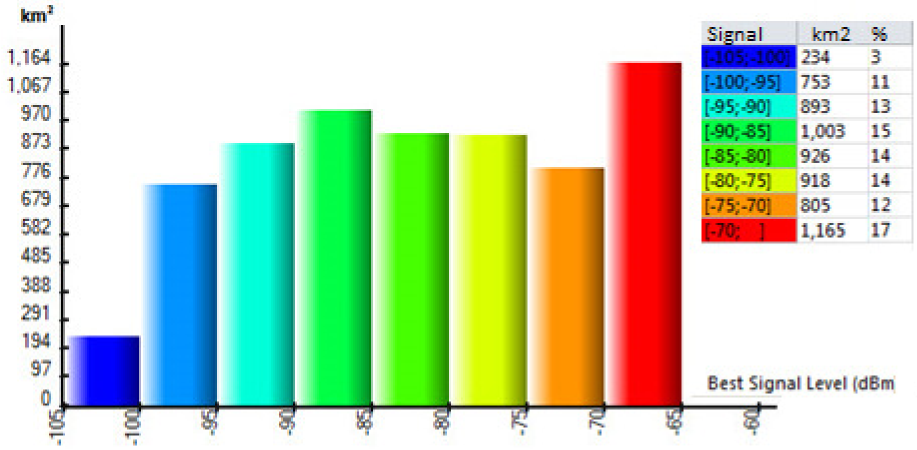

Figure 2. Signal strength distribution

Each base station have 3 sectors (a total of 135 sectors) and each sector can serve approximately 1,000 subscribers. Assuming responsible usage by mostparties, the system can therefore handle the needs of almost all the emergency workers. The backhaul connectivity needs to be robust as well; a dedicated fiber network backed up by microwave (LMDS) transmission will connect all base stations to two disaster operations centers located in both European and Asian sides of the city. A satellite link might also be considered to increase the reliability of the system. These operation centers will either host or have robust connections to command centers of all responding emergency and relief organizations.

B. Physical Infrastructure

The earthquake could be more powerful than expected. Severe weather conditions might coincide with the earthquake. Therefore the network is to be designed and built to withstand multiple and strong disasters. The towers must be strongly built; they need to have enough clearing from risky structures including other buildings and power lines. All the equipment, including BSCs, batteries, generators and fuel, needs to be secured from theft and vandalism. After the earthquake personnel will be assigned to guard and maintain the station 7/24; therefore a small cabin will be installed with minimal amenities. The power will be supplied by a 20 KVA generator; the fuel requirements for the generator will be around 150 lt/day or 1 ton/week. The fuel and other supplies stored at the station should need to be sufficient for at least 2 weeks.

C. Human Resources

After the earthquake each station will be maintained and guarded by on-site personnel. Since the time of the earthquake is random throughout the day, the exact whereabouts of the assigned personnel at the time of the earthquake will not be known. In the most unwanted case the personnel might be helping others needing immediate assistance, might be quite far away from the station, might get injured, even lose his/her life. The chances that he/she will arrive to his/her assigned post will be low. To increase the probability that someone will attend the station immediately several technicians and operators residing in the neighborhood need to be assigned. During disasters, loved-ones take priority; to avoid the personnel having other priorities and leaving his/her post, young, unattached people should be selected. The disaster conditions will put a pressure on human health; the personnel need to be in good health, therefore must be screened before assigning the task. The disaster environment affects everybody emotionally and psychologically. To minimize the adverse effects and to increase efficiency of the personnel, they should be prepared for the situation. Psychological counselling as well as live simulations will prepare these people for the important task they are undertaking.

D. Construction and Operations

There are two stages of the E-GSM system. The first is the construction stage which consists of project planning, budgeting, technical planning, procurement, assembly and activation stages. Most of the stages are straightforward except for additional technical planning considerations put forth by disaster management requirements such as ease of access to location, structure strength, personnel cabin and extra fuel tank.

In addition to get the systems up and running, the activation stage also includes registering the initial set of users to the databases.

The stand-by (pre-disaster) operations meanwhile consists of continuous monitoring of the health of the system and maintaining it. During stand-by operations, stations do not need to be manned except for monitoring, testing, maintenance and training purposes. Remote controlled operations (including security) will be sufficient to keep the system in good health.

Drills are an essential part of increasing any disaster system's readiness; simulated earthquakes and other disasters.

E. Financial Feasibility

The cost of E-GSM base stations will be more than typical towers. The typical cost of a base station is around 100,000 USD. When the robustness of a base station is increased the budget can reach twice the standard amount to around 200,000 USD. The cost of 50 of such base stations will be in the vicinity of 10 million dollars. This does not cover the cost of emergency two data centers yet. Each costing around 10 million USD, the total cost of data centers will be 20 million USD. The personnel cost to build the system will be less than 1 million USD, so it can beignored. The total cost will be around 30 million USD. Since such a system can be built on public land, all land costs are excluded.

The average cost of the system is going to be calculated in two ways: The first will calculate the cost per citizen of the city. The total cost (30 million) divided by the number of people residing in the city (15 million) is about 2 USD/person. The second method is cost per saved souls. Although it would be impossible to estimate the exact contribution of the E-GSM to the lives saved, we can calculate the value for certain scenarios. If the number were 1,000 people (which is very plausible), the cost of the system would 30,000 USD/person; for 3,000 people the average would be 10,000 USD/person.

F. Leading Role

The system wouldn't be complete without its users. To promote the usage of the system, sample emergency applications might be developed by the operations teams. Developing applications have many benefits. Operators actually seeing applications running will help improve the systems capabilities. It will also increase the popularity of the system among relief teams; teams themselves will have further motivation to develop their own apps as well. Even independent developers might start using and testing their disaster related applications; creating an ecosystem of development. The teams may participate in the drills as well.

IV. CONCLUSION

We proposed a GSM based emergency network based on the need for a much diversified emergency response community. GSM provides a common platform to tens of thousands of people in terms of hardware, applications and usage. Installation of the system is rather straightforward and there's enough supply of technical skills. The costs are reasonable considering the area and population of the city. Once installed, the system is also expected to provide a platform for developing emergency applications.

REFERENCES

1. H. Eyidoğan, "A Compilation on the Earthquake Risk of Marmara Region and the City of Istanbul(Marmara Bölgesinin ve İstanbul Kentinin Deprem Tehlikesi Üzerine Bir Derleme)," Proceedings of Symposium on Disaster by the Turkish Chamber of Engineersand Architects (TMMOB Afet Sempozyumu Bldiriler Kitabı), 2006, p.15.
2. J. Huang and Y. Lien, "Challenges of Emergency Communication Network for Disaster Response," Proc. IEEE ICCS, 2012, p.528.
3. M. Erdik, M, N. Aydınoğlu, A. Barka, Ö. Yüzügüllü, B. Siyahi, E. Durukal, Y. Fahjan, H. Akman, G. Birgören, Y. Biro, M. Demircioğlu, C. Özbey and K. Şeşetyan, "Earthquake Risk Assessment for Istanbul Metropolitan Area,"Bogazici University Publication, 2002.
4. M. Erdik, E. Durukal, "Earthquake risk and its mitigation in Istanbul," Natural Hazards, 2008, p.181.
5. M. Tanyaş, Y. Günalay, L. Aksoy and B. Küçük, "Disaster Logistics Guidelines for the City of Istanbul (İstanbul İli Afet Lojistik Planı Kılavuzu)," İstanbul Development Agency (İSTKA) Project Report, 2013.

