RESILICOMM: A Framework for Resilient Communication System

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ABSTRACT

Disasters, when they strike hard, may cause the disruption of many vital services. ‘Telecommunications’ is being considered one of the vital lifeline services as many disaster relief operations rely on it. Effective communication is dependent on a telecommunication network infrastructure that is working properly. Unfortunately, the infrastructure may be damaged during a disaster causing no-coverage and/or congested network traffic in the disaster-affected areas. In this paper we propose a conceptual framework for building a resilient communication system that not only considers the communications infrastructure but also other driving factors which are necessary for its success. The proposed framework is based on five key pillars, namely: robustness, redundancy, adaptability, agility, and readiness to build capability for developing a resilient communication system. The findings reported in this paper provide some insights into resilient communications that may help network researchers/engineers to contribute further towards developing a robust and resilient communication system capable of coping with disasters.

Keywords

Resilient communications, Telecommunications, Reconstruction, Resourcing, Resilience maturity

INTRODUCTION

Emergency situations caused by natural and/or man-made disasters cannot be predicted 100%, and those which may be predicted cannot be avoided fully. During the last few decades, natural disaster events are becoming very common; just in 2017 a total 318 natural disasters affecting 122 countries have been recorded (CRED, 2018). These statistics raise a great concern that the efforts we are doing to deal with these events should be escalated in the right directions i.e., identify ways to develop more resilient communication systems.

Information and Communication Technology (ICT) can play a vital role in addressing many of the areas of emergency response and recovery. Many research institutes and organizations have developed a number of protocols and ICT-based systems addressing varying disaster management needs (Suh and Won, 2018; Ray and Turuk, 2017; Wu, 2014). Almost all of these systems require a network infrastructure to work on. This is one of the reasons that the communication network is considered a very critical infrastructure worldwide for not only aiding in the proper management of disaster events but also for the day-to-day activities.

The effect of a disaster event on the telecommunications infrastructure varies depending on the severity of the disaster and/or emergency event. The effect can be as minimal as no harm to infrastructure but significant network traffic, including messages and/or calls to and from the disaster-affected area, may be produced after an emergency event. On the other hand, the effect can be so severe that the network infrastructure is damaged with system failure across the disaster affected areas. This research is focused on building a resilient communication system with the capability to deal with disaster events and their aftermath in a more effective way. In this paper we propose a conceptual framework for communication infrastructure which has the ability to absorb the effects of a disaster event and maintains its functionality. The details of the proposed framework are discussed next.

RESILICOMM: A Conceptual Framework for Resilient Communication

Communications services have proven to be significant for emergency and disaster response and recovery (Marchetti, 2011; Ran, 2011; Kongsiriwattana, 2017). To this end, we focus on the provision of telecommunications services that can be used in post-disaster situations. The idea is to accelerate the response and recovery services and to minimize the adverse effects of the disaster by providing adequate communication means for organizations/agencies involved in disaster response and recovery.

Figure 1 illustrates the proposed conceptual framework that can be used to build a resilient communication system in the country. The framework identifies the key factors affecting the adaptive reconstruction of communications infrastructure when disrupted by disasters; and then resource these factors to build capability towards a resilient communication system.

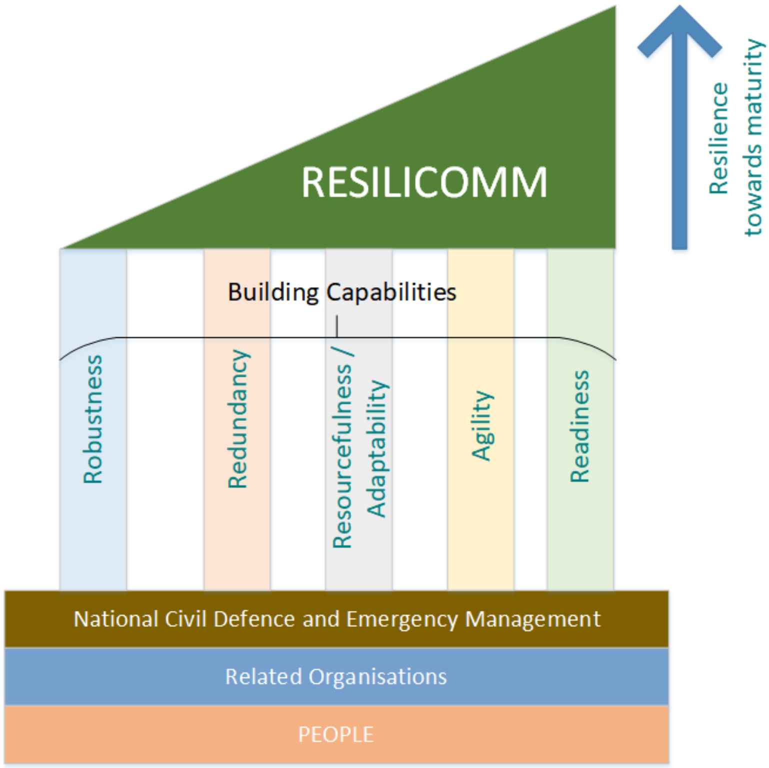


Figure 1. The Proposed Conceptual Framework for Resilient Communications

Factors driving the resilient communications

In this research we identified four key factors driving resilient communications. These factors are people, organizations/entities involved in disaster response and recovery activities, national civil defense/emergency management, and communications infrastructure. The following sub-sections highlight the role of each of these driving factors.

People

People are the foremost important factor towards the success of any resilient system. It is very crucial to make people aware of the emergency plans and/or the choices they have in such situations. Many surveys (Tsou et al., 2017; Koçak et al., 2015; Sonneborn et al. 2018; Kim and Hastak, 2018) show that most of the time people are not even aware of any emergency plan and/or services available. Unawareness might sometimes leads to resistance which may cause difficulties and/or delays in response and recovery operations. Another important fact worth-mentioning is that often people are aware of the emergency plans and/or services but they have no idea how to access those services.

Considering people as foundation for our proposed conceptual framework, we suggest to identify means to reach out people, to make them aware of the emergency plans/services and to train them on how to use or access these services when needed.

Related Organisations

We identify the organizations and/or entities involved in emergency response and recovery operations as the second driving factor. These are the organizations which will have direct interaction with the people and/or disaster's victims, guiding them and helping them through that event. These organizations are important as these will be working as the interface between any emergency plans and the disaster victims.

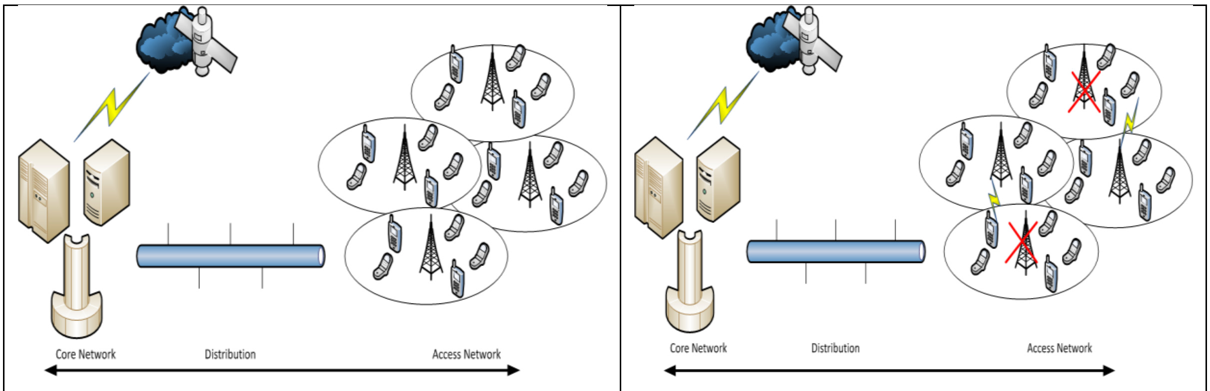
Nation-wide Emergency Management

The third driving factor is the national emergency management/civil defence plan. This plan may help the country to define rules/legislations for Government agencies to combat such unforeseen events/disasters. The idea is to make disaster plans/procedures available to the relevant organizations/institutions for the creation and updating of action plans and the organization of periodic information sessions.

Communication Infrastructure

Communication infrastructure is one of the main factors in building a resilient communication system while the other three factors described earlier play their role to make the communication infrastructure more resistant to disaster events. However, we aim to build resilience towards maturity which is a novel concept included in the conceptual framework (Figure 1). One can observe that the communication infrastructure is based on the five pillars, including robustness, redundancy, adaptability, agility, and readiness to build capabilities of a resilient communications infrastructure. The maturity measure of the communication system will reflect the competency of the network infrastructure for handling any unforeseen interruptions such as disasters. A number of studies have been conducted for calculating a maturity score (Chaudhary and Chopra, 2017; Persse, 2006). We are aiming to use the Capability Maturity Model Integration (CMMI) (Team, 2014) approach as a basis for measuring maturity in our proposed framework. As our work is still in the early stages, the details of this process along with the related measurements are not included in this paper.

To make the communication infrastructure resilient we propose to use the concept of never-die-networks along with cognitive radio capabilities. The core idea is to get the best out of what has survived the disaster event. Figure 2 illustrates the difference between a communication infrastructure in operation, and a post-disaster communication scenario by focusing on the key concept of our proposed resilient communication. Figure 2(a) shows a high-level view of a working communication infrastructure scenario. Figure 2(b) shows a post-disaster network scenario where some of the communication links are collapsed as a result of disasters. However, victims in the affected areas would be able to communicate with their loved ones using a device-to-device communication approach and to extend the communication range by reaching the surviving base stations.



(a) A communication network scenario (normal operation)

(b) A post-disaster communication network scenario

Figure 2. A Typical Operating and a Post-disaster Communication Infrastructure

The proposed communication infrastructure logically divides the communications system into three components: access, distribution, and core. These components are discussed next.

Access Network: The access network provides an interface to end-users with the overall communication network. This component is dependent on the working of the cell-phone towers and/or base station towers located in various places. These towers get the data from the cell phones and other mobile devices and communicate it further. When a disaster strikes such as earthquake, tsunami, floods etc. there is a high probability for these base station towers to get damaged hence, they will be unable to provide wireless coverage in that area (as shown in Figure 2(b)). However, the mobile phones (of disaster victims) will be functioning but because of lack of infrastructure (i.e., no functioning cell tower), they will not be able to communicate.

We propose that these mobile phones will be using a cognitive radio approach to identify an emergency situation automatically. Once a disaster situation is identified the mobile handsets will shift to an emergency mode and try to locate any surviving base station nearby using multi-hop communications. This link will then be used for relying emergency messages and other related information.

Distribution Network: The distribution network is another important component of our proposed framework. The main idea is to provide a mechanism, path or way to communicate data/information from the disaster affected area to the core network. Due to the disaster, some components of the distribution network may also be affected. Therefore, a multi-hop approach will be used to identify nearby working hotspots, access points, and other communication network links to establish a path for emergency communications.

Core Network: It is the job of the core network to link the disaster area with the rest of the world. The core network will be accessing the Internet via satellite or other available communication channels such as fiber. Once the communication link is completed then the data/information from the disaster-affected area can be accessed by organizations involved in disaster relief operations.

In using our proposed framework one can maintain a communication link to connect disaster affected areas to the rest of the world. The idea is to automatically establish new communication paths when existing links are destroyed during a disaster event. This new communication link will provide uninterrupted communication so that we can share disaster related vital information (e.g. disaster locations, number of victims) with the rest of the world. This information dissemination may help to accelerate disaster response operations through directed search of victims quickly, and consequently significant human lives can be saved.

DESIGN CHALLENGES AND IMPLEMENTATION ASPECTS OF RESILICOMM

Although many network researchers have worked in the field of resilient communications, the practical system implementation has not been fully solved yet. In fact, there are many research challenges that need to be overcome before the actual implementation of the system.

However, for the implementation of the proposed RESILICOMM framework, the following research questions need to be solved/answered.

What can be done to detect the disaster incidents instantly and automatically? How smart phones and other internet-enabled handheld devices can be used for disaster response and recovery? How victim’s mobile phones can form ad-hoc networks for emergency communications in the absence of network infrastructures?

In addition to technical challenges, we need to ensure that the driving factors such as people, organizations and national civil defence/emergency management can work together within the scope of our proposed framework to make it available to people.

By integrating key functionalities of cognitive radio, network coding, and Internet of Things, one can build a RESILICOMM framework (software).

CONCLUSION

In this paper a conceptual framework for a resilient communication system is proposed. This framework is based on five pillars (robustness, redundancy, resourcefulness/adaptability, agility and readiness) and four driving factors (people, organizations, national civil defence/emergency management, and telecommunications infrastructure) which are essential elements to build a robust resilient communication system moving it to maturity.

Moreover, we have also highlighted the technologies, such as cognitive radio and never die networks, to be used in building capability for a resilient communication infrastructure. This infrastructure helps to establish a communication link between disaster-affected areas and the rest of the world automatically. This can be used to communicate vital information about disaster victims and their locations. This information may then be utilized by organizations involved in disaster response activities to have more directed and effective rescue operations. As a result timely help can be provided to victims which will help in saving precious lives.

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REFERENCES

Chaudhary, M., & Chopra, A. (2017), CMMI Overview, In *CMMI for Development Apress, Berkeley, CA,* 1-7.

CRED (2018) CRED Crunch 50 - Natural disasters in 2017 – Lower mortality, higher cost, *Center for Research on Epidemiology of Disasters (CRED).* http://cred.be/sites/default/files/CredCrunch50.pdf.

Kim, J., & Hastak, M. (2018), Social network analysis, *International Journal of Information Management: The Journal for Information Professionals, 38(1),* 86-96.

Koçak, H., Çaliskan, C., Kaya, E., Yavuz, Ö., & Altintas, K. H. (2015), Determination of individual preparation behaviors of emergency health services personnel towards disasters, *Journal of Acute Disease, 4(3),* 180-185.

Kongsiriwattana, W., Gardner-Stephen, P., & Lloyd, M. (2017), Historical distribution of duration of unplanned power outages in queensland: Insights for sustaining telecommunications during disasters, In *IEEE Global Humanitarian Technology Conference (GHTC),* 1-8.

Marchetti, N. (Ed.) (2011), Telecommunications in disaster areas (Vol. 12), *River Publishers*.

Persse, J. R. (2006), Process improvement essentials: CMMI, Six Sigma, and ISO 9001, *O'Reilly Media, Inc*

Ran, Y. (2011), Considerations and suggestions on improvement of communication network disaster countermeasures after the Wenchuan earthquake, *IEEE Communications Magazine*, 49(1).

Ray, N. K., & Turuk, A. K. (2017). A framework for post-disaster communication using wireless ad hoc Networks, *Integration, the VLSI Journal*, 58, 274-285.

Sonneborn, O., Miller, C., Head, L., & Cross, R. (2018), Disaster education and preparedness in the acute care setting: A cross sectional survey of operating theatre nurse's disaster knowledge and education, *Nurse education today, 65,* 23-29.

Suh, K. J., Jeong, S. S., & Won, S. H. (2018) U.S. Patent No. 9,961,524. *Washington, DC: U.S. Patent and Trademark Office*.

Team, C. P. (2014), CMMI® for Development (CMMI-DEV), V1. 3, *Software Engineering Institute, 2010*.

Tsou, M. H., Jung, C. T., Allen, C., Yang, J. A., Han, S. Y., Spitzberg, B. H., & Dozier, J. (2017, July), Building a Real-Time Geo-Targeted Event Observation (Geo) Viewer for Disaster Management and Situation Awareness, *In International Cartographic Conference (pp. 85-98). Springer, Cham*.

Wu, C. H. (2014), U.S. Patent No. 8,731,511. *Washington, DC: U.S. Patent and Trademark Office*.