Radio Capacity Planning in the Case of Major Incidents for Public Safety Agencies

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Abstract. Public Safety Agencies deal with emergency events on a regular basis. They require reliable, highly available and secure network to provide services to the public. Furthermore, the demand for new features, such as video and audio streaming, transmission of still pictures, short messages and access to database applications, is on the rise. It is up to the design engineers to plan and support all current and future requirements. This paper will simulate emergency scenario where Public Safety agencies are called upon and analyze the network impact from the capacity point of view.

Keywords: Erlang · Interoperability · Public safety agencies · Radio capacity · Land mobile radio · Traffic requirements

1 Introduction

The idea to have one uniform and fully integrated and interoperable communication system between the public safety agencies is as old as the agencies themselves. But more than often, this is not the case. Because of budget restrictions, multi-layer government structures, even social and cultural differences, the result is multiple communications systems operating on different frequency bands and different technologies.

In cases of the emergency events and in day-to-day operations, public safety agencies rely heavily on the ability to communicate via their established private land mobile radio (LMR) systems, such as P25 and TETRA. There is a requirement to secure radio spectrum to plan for the unknown and to accommodate communication requirements. To accomplish such a task, we have to start taking actions such as making priority spectrum available and developing associated spectrum policies, processes and technical standards. These can be accomplished by defining the regional radio spectrum plan [1].

The issue of radio interoperability is a broad and complex matter [2, 3]. The issue is even more challenging based on the variety of vendor proprietary technologies, different levels of security [4], spectrums used, functionalities, standard operating procedures, etc. Developing associated spectrum policies, processes and technical

V. Atanasovski, L.-G. Alberto (Eds.): Fabulous 2015, LNICST 159, pp. 212–218, 2015.
DOI: 10.1007/978-3-319-27072-2_27

standards greatly improves the communication compatibility. Optimizing the network design, based upon the user and environmental requirements, provides the final step in highly accessible and reliable networks.

In this paper we implement simulation framework using OPNET Modeler and quantify the effect of increased traffic. Results will show the need of proper channel and capacity design in order to accommodate Public Safety agencies requirements.

The paper is organized as follows. Section 2 discusses the background and scenario which is used for the analysis. Section 3 summarizes the scenario and our simulation results related to the effects of the increased traffic load during the major incidents. Finally, we conclude our work in Sect. 4.

2 Background and Scenario

Technology is developing rapidly. This is more accurate for the commercial users but the public safety agencies are demanding some of those services, too. This is a high pace environment which demands changing the communication requirements. The need of sending and receiving short messages (SMS), videos, alerts, status updates, GPS coordinates, etc. is already embedded into the public safety agencies strategic plans to provide services to the public. For the time being, public safety agencies will use whatever mean of communications to provide services to the public, even if that means using commercial networks.

The technologies used as communication infrastructure in Public Service networks include security mechanisms needed to meet the requirements for secure communications among users. Typical algorithms are deployed for data encryption, data integrity, authentication, etc. Radio interfaces (wireless links) are more vulnerable and specially designed mechanisms provide the necessary security level (e.g. over the air re-keying). Besides the protection of data over the radio interfaces, additional cryptographic mechanisms are used to provide end-to-end security for various applications at application level. However, as any other communication network, these networks are still vulnerable and open to various types of security threats and attacks which may corrupt, compromise or even disable the normal network operation. Therefore, special care should be taken in order to provide the necessary security level for the critical information infrastructure used by Public Safety Agencies.

Public Safety users have higher demand of availability and reliability as compared to the commercial users. This is known as QoS (Quality of Service) or GoS (Grade of Service) term mostly used for the private networks. GoS mechanism controls the performance, reliability and usability of a telecommunications service. The grade of service standard is the acceptable level of traffic that the network can lose. GoS is calculated from the Erlang-B formula, as a function of the number of channels required for the offered traffic intensity.

GoS for the public safety agencies is defined by the clients and it is usually 1 %, 97 % of the time and 97 % terrain coverage availability and DAQ (Delivered Audio Quality) of 3.4.

In comparison with the Public Safety requirements, commercial (cellular) circuit groups usually demand GoS of 2 %, 50 % time and 50 % coverage availability and DAQ of 3. These facts will have direct impact on the network design.

Technologies for the Land Mobile Radio Networks [5–8], such as TETRA and P25 are trying to integrate some of these clients' requirements for additional data traffic in their product lines. IV&D (Integrated Voice and Data) infrastructure has been introduced. The capacity and throughput are not comparable to the new commercially available technologies such as LTE and LTE-A [9], but it is a good step forward. In addition, integrating LTE into LMR design is on the roadmap too and it will provide even more capabilities for the public safety agencies.

In order to plan the radio capacity, first we have to define some of the scenarios. As we previously said, there will be unknown scenarios, but based on experience, we can predict the worst-case scenarios and plan accordingly. The definition of the worst case scenarios is the situation were the affected area is geographically bigger, number of involved people is greater and maximum number of public safety agencies are put in service. Some of the scenarios defined in the crisis management center of the Republic of Macedonia [10, 11] are:

- Fire
- Flood
- Earthquakes
- Ecologic catastrophes
- Others (explosion in the major oil refinery, major incident on the main traffic arteries and celebrations or protests).

The common element for all of these scenarios is the involvement of all public safety agencies (police, fire and ambulance) and broader public safety agencies (crisis management center, tow track services, clean-up crews, etc.).

The first step is to define the number of radio channels (in this simulation TETRA technology has been used) that will always be available for the public safety agencies for inter and intra operability during the crisis. It is imperative to understand that any of the subjects coming to the scene have multi-layered structures. This further complicates the interoperability capacity requirements during the Major Incidents (MI).

To calculate the maximum number of communication paths and the number of interoperability radio channels to accommodate the communication requirements, the following formula can be used [12]:

$$Q = \frac{A * x\left(t_{(s)} + t_d\right)}{3600} * \frac{c(c-1)}{2} \tag{1}$$

Where:

Q is the number of interoperability channels
A is the number of users
x is the number of calls per user
$t_{(s)}$ time duration in seconds
t_d system time delay in seconds (network access and hang time)
C is the number of Agencies at the scene.

The formula calculates the traffic capacity and the maximum communications paths based on the number of agencies on the scene. The formula calculated for the worst case scenario expected in the predicted emergency/major incident, as described in section B. Using the Erlang's table [13], Q can be converted into the number of radio channels including the control channels.

In order to maximize the use of the dedicated radio spectrum, Public Safety Agencies and the Crisis Management Centre have to define and implement standard operating procedures. This will include the hierarchy (priority users), and when and how the capacity will be used. In some cases, these challenges can be great, where additional training will have to be provided, cultural and linguistic barriers have to be overcome, etc.

The scenario analyzed in this paper is the explosion in the oil refinery. It is assumed that a large explosion occurs at a 50,000 m^2 oil production plant in the industrial area of a suburb of the capitol of Macedonia, Skopje. The blast shatters windows of buildings in the immediate vicinity. There are a significant number of casualties both from within the oil plant and outside. Multiple sensors detect and report the incident to the Police, Fire and Emergency Medical Services dispatch center. Within minutes, the dispatch centers are also flooded with calls from motorists, pedestrians, and residents. Soon, commercial cellular networks become overloaded. Air quality sensors around the area detect hazardous substances emanating from the site of the accident. The wind speed and direction reported from environmental monitoring stations indicate that the fumes will drift over a residential area with an elementary school, a high school, a library, a hospital, and numerous retail businesses. As it drifts over the major highway Skopje - Kumanovo, car accidents ensue and some motorists abandon their cars to escape the scene on foot. Debris expelled by the explosion damages a nearby electrical sub-station, causing a localized power failure.

Expected effects of the scenario are: since the accident is between two major cities, emergency calls will be directed to both dispatch centers; dispatchers will assign immediately neighboring Fire Department, Police and Emergency Medical Services; Fire department will be deployed to extinguish the fire; Police will be there to secure the site and the first responders; initially, no one would have the accurate information what caused the explosion, multiple teams from the Police and Crisis Management will be responding.

3 Analysis and Results

The topology for the analyzed scenario is presented in Fig. 1. There are two Dispatch Centers presented (Skopje and Kumanovo), day to day users, extension 1, add on users from SK (Skopje), KU (Kumanovo) and VE (Veles). For the backhaul we have used MW links and fiber over the PSTN network. In the center of the screen is Okta, the place where the Major Incident (MI) takes place, based on the scenario. For the simulation, Core Server has only the users included into the MI to analyze only the traffic occurred during the normal day to day operation and the MI.

The suburb of the capitol of Republic of Macedonia, Skopje, has been used as location where the predicted MI scenario could take place. The results will present normal day to day operation and when the major incident occurs.

Parameters used into the analysis are:

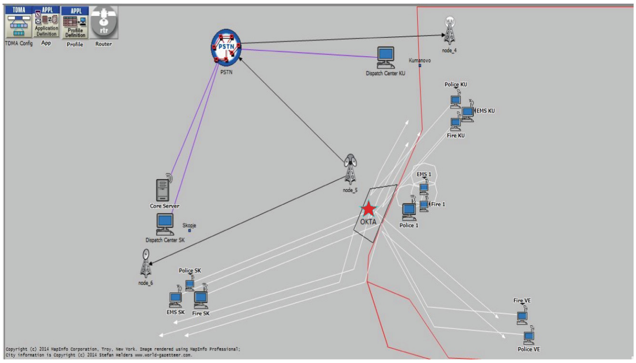

Fig. 1. MI simulation topology

For TDMA Analysis
Utility TDMA Configuration
Users TDMA mobile nodes

Increased based on the scene arrival
All users have created trajectories for roaming and access to and from the MI.
Traffic generation

Start - Normal day to day use	Erlang 0.1 is used
During - during the MI	Erlang 2 is used
After the MI – back to regular operation	Erlang 0.1 is used

Work conducted regarding presentation of the traffic analysis is based on OPNET Modeler 14.5. The simulation has been run over 2 days but the focus was and extract taken for the period of 6 h from the beginning of the MI. Traffic after the MI will be back to the regular day to day levels and it is not part of this analysis.

For TETRA/TDMA analysis, parameters that have been used into the calculations are:

- All the nodes are mobile;
- All mobiles have predefined trajectories for in/out of the scene;
- Capacity is defined for the start/during/after the MI as presented above;
- TETRA and P25 TDMA (formerly Phase II) have been used to generate the simulation.

The results are shown as follows: Light blue line presents the normal day to day traffic use at the scene. The results show average traffic load of 42Kbps with load of 0.1 erlangs. This traffic would include regular police highway patrols and EMS units on standby in the region, as per their plan of coverage during and off rush hours (Fig.2).

Green line presents the beginning of the MI, the immediate arrival of the units from Skopje and added traffic to the network. First at the scene would be Police units for

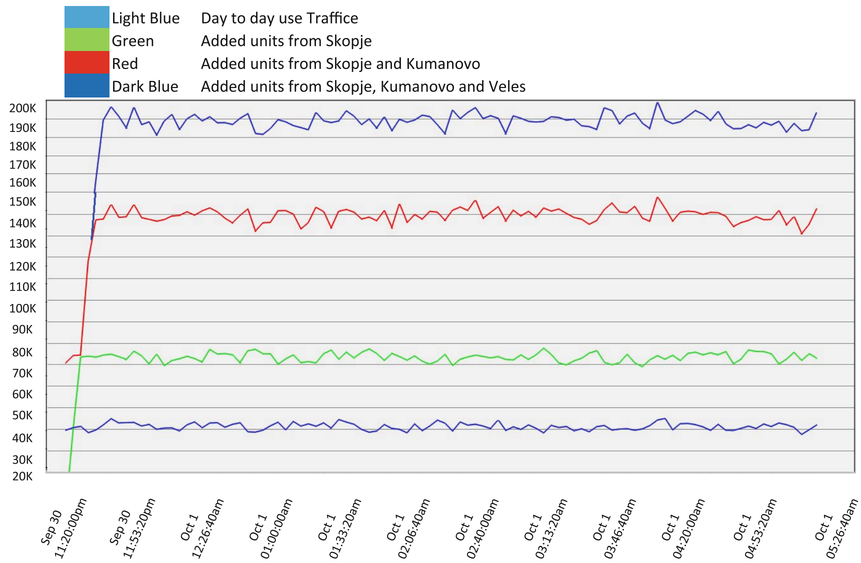

Fig. 2. MI simulation traffic results

securing the area, plus additional EMS and Fire units deployed for rapid response. The results show average traffic load of 75Kbps with load of 0.1 erlangs.

Because the MI is on the major highway and the area is covered by 2 dispatcher centers, units from the neighboring Kumanovo have been dispatch. Red line presents the arrival of the additional EMS, Fire and Special Police units at the MI scene. The traffic load rises to average of 140 Kbps with load of 2 erlangs.

Dark blue line presents the final number of units deployed to the MI. These numbers include Police (HWY patrols, special investigation units and local police), Fire and Emergency Medical Services (including the rapid deployment units). Traffic load for the simulated scenario averages 195 Kbps with load of 2 erlangs.

The results based on the predicted and simulated scenario shows the exponential increase of the traffic load by introducing more users at the scene of the MI.

Based on the number of users, which can be added into the analysis and their pre-requirements for accessing applications and voice communication, historical records of capacity utilization, radio and data channel capacity can be design to accommodate Public Safety user requirements. As previously mentioned, dedicated voice only, voice and data and data only channels will be assigned to accommodate the traffic.

After collecting the results from the simulation, formula (1) can be utilized to calculate the maximum number of communication paths and the number of interoperability radio channels. The results should be used for network design and optimization.

The analysis were conducted for this one scenario but can be used for multiple planned and/or unplanned events, where first responders are called upon. Historical reports of traffic accidents, natural disasters can be utilized to properly plan for these events.

4 Conclusion

Network for Public Safety Agencies have to be designed for the worst case scenario. This simulation is one of the possible future events where maximum number of users can be called at the scene and point reference to design the network. Ideally, the network will be designed to be scalable, where the capacity will be reserved and ready to be deployed as the demand arises and use only the day to day capacity on regular bases.

This paper presented the possible outcome of the simulated scenario and the way to calculate the radio channel capacity to accommodate the demand.

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