Are Cellular Phones a Useful Tool for Supporting Medical Treatment in the Aftermath of Disasters?

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Abstract

The number of cellular phones has sharply increased over the past few years in Japan. However, it has the problem of it becoming impossible to use it at the time of a disaster. One of the major reasons for the high degree of failure of cell phone calls made during a disaster is the number of people calling to inquire after the safety of their friends and family. This paper estimates the call loss probability of cell phone calls during disasters based on a simulation study using data from the Sanriku Minami Earthquake. It predicts that under the current cell phone system, even priority terminals for emergency calls will be disabled, due to serious traffic congestion. Because emergency calls have (1) low teledensity and (2) long duration, the cell phone is not useful for medical control during disasters. For proper medical control during disasters, an isolated, nationwide network is necessary.

Keywords

Disaster medical communication

1. Objectives

Cellular phones are considered an effective communication tool in the aftermath of natural disasters or terrorism. In reality, however, cellular phones relying on the public phone network are reported to fare poorly during disasters. This is due to the tremendous number of calls made by people trying to contact friends and relatives in the affected area, the volume of which overloads the network.

Emergency medical calls (to organize transport for the injured and for medical equipment, to report the condition of injuries, to communicate with paramedics, etc.) during a disaster last much longer than safety-inquiry calls, although their overall allotted volume is much smaller. It is essential that medical calls be given the highest priority during disasters to enable crisis management. The question remains, however, as to the wisdom of using the existing public phone network for medical communications during disasters. This paper examines the usefulness of cellular phones relying on the public network for medical communications during disasters, based on a simulation using data for communications made in earthquakes, specifically the one that occurred in Sanriku Minami, Tohoku, Japan, in May, 2003.

2. Survey

2-1. Overview

The number of cellular phones has sharply increased over the past few years in Japan. There are now over 82 million contracts for cellular phones or PHS (as of the end of June, 2003; Source: Telecommunications Carriers Association—TCA). There are now more contracts for cellular phones than that for conventional fixed-line telephones, with over half the population using cellular phones. As more people use cellular phones, the ratio of emergency calls from cellular phones has increased year on year. According to the Fire and Disaster Management Agency, about 17% of all 119 calls (emergency calls in Japan) came from cellular phones in FY2001. In terms of medical services for emergency or disaster, the cell phone is an important tool which serve as the end terminal of the public phone network. However, the number of calls made in a widespread major disaster like a major earthquake exceeds network capacity (traffic congestion), rendering cellular phones inoperable.

As a solution to such traffic congestion, some priority terminals are prepared for emergency calls in the case of a disaster. These priority phones, however, do not work successfully because too many people need to use them over a limited period of time during a disaster.

2-2.The use of cellular phones in recent natural disasters

In the Hanshin-Awaji Earthquake of January 17, 1995, cellular phones worked effectively as an emergency communication tool regardless of traffic congestion compared to fixed-line telephones. However, now that the number of cellular phones has increased, both cellular phones and fixed phones create communication overloads due to increased calls during earthquakes or heavy rain (Fig. 1, 2).

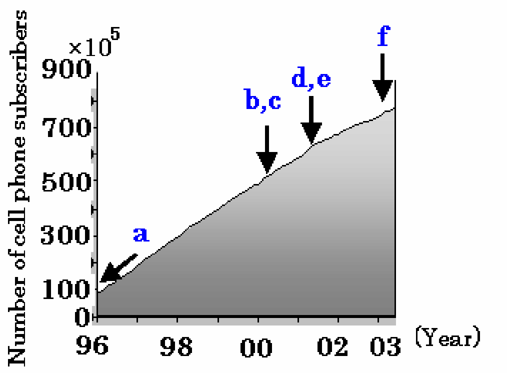

Figure 1. Growth figures for the number of cell phone subscribers and major natural disasters

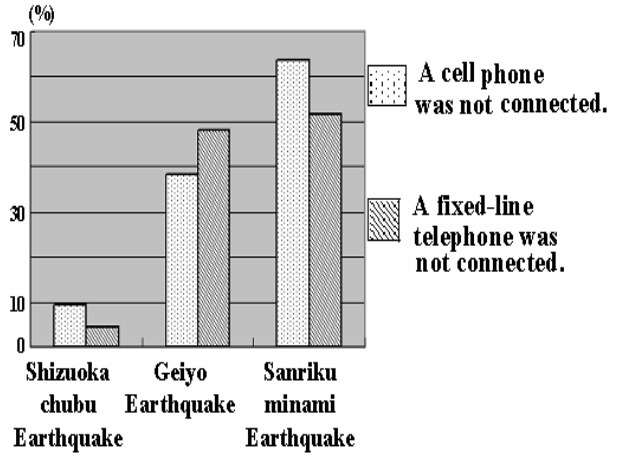

Figure 2. The ratio of people experiencing connection problems in the immediate aftermath of an earthquake

Source: This data is the result of incorporated company Survey research center (Japan) performing a residents questionnaire.

3. Simulation

3-1. Methodology

In the simulation, we used the communication records and statistical sheets for the Sanriku Minami Earthquake of May 26, 2003. During that earthquake, the leader of the rescue center in Akita Prefecture did not come to the city hall where the rescue center was set up at the right time, because his cell phone was unreachable due to traffic congestion. When calculating call loss probability, we used the Erlang B equation.

$$\text{Call loss probability} = \frac{a^c e^{a}}{1-P(c+1,a)} \quad \text{[Erlang B equation]}$$

$$P(c+1,a) = \sum_{x=c+1}^{\infty} \frac{a^x e^{a}}{x!} \quad \text{[Poisson distribution]}$$

c: Number of channels
N: Number of calls (per hour)
d: Duration of call
a: N x d / 3600

3-2. Preconditions of simulation

* Assumption 1: The rescue leader of Akita Prefecture was carrying his cell phone from Company N in a densely populated area of Akita City.
* Assumption 2: Each cell phone in Company N is contracted and owned by a different individual.
* Assumption 3: Under normal conditions, the maximum number of calls from Company N's cellular phones in this area is 14780 calls/hour (calculated from statistical data published by the Telecommunication Bureau, Ministry of Public Management, Home Affairs, Posts and Telecommunications). The transit station of Company N in this area is designed to handle up to that volume of calls.
* Assumption 4: The channels for cell phone calls are designed to reduce call loss probability to 5% or less (standard call loss probability for cellular phones in Japan). Because the number of cell phone calls lasting 30 seconds or less account for 40% of total cell phone calls for the national average (according to statistical information from the Ministry of Public Management, Home Affairs, Posts and Telecommunications), the Erlang B equation based on this statistical data, indicates that 12 channels per station is sufficient.
* Assumption 5: A member of the rescue team calls 16 times over 16 minutes (once a minute). His phone is a priority fixed phone prepared for emergency calls, which does not suffer from congestion.
* Assumption 6: The cell phone transit station installed in the area of the rescue leader's location covers an area of $3.14km^2$ (circle of a radius of 1km).
* Assumption 7: The average duration of cell phone calls made immediately after the earthquake is the same as that under normal conditions, i.e., 30 seconds.

3-3. Facts

The Sanriku Minami Earthquake occurred in Tohoku at 6:24 p.m. on May 26 (Monday), 2003. It had a seismic intensity of 4 in Akita City. A member of the rescue team made an unsuccessful attempt to contact the Deputy Governor on his cell phone. It was only at 6:40 p.m., sixteen minutes later, that he was able to contact him.

If this situation is simulated with the Erlang B equation, the call loss probability is 93.8% (probability of successful calls is 1/16) and traffic intensity is 192.450 (Erl.). These figures imply that the call traffic was 23186 times/hour in the immediate aftermath of the earthquake. (Fig. 3)

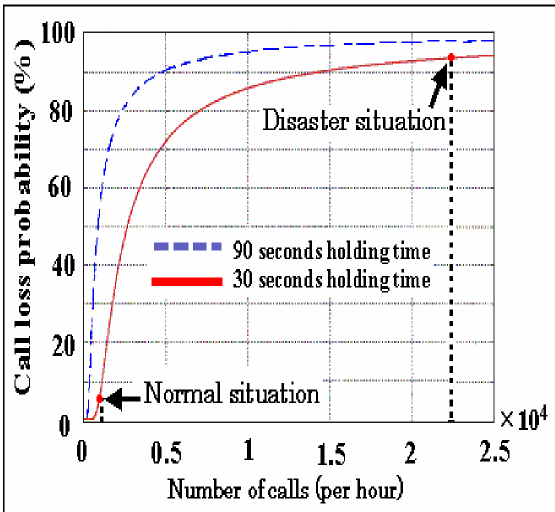

Figure 3. Call loss probability calculated using the Erlang B equation (when using 12 channels)

・Normal situation: The usual prediction value (Number of calls869/hour, Call loss probability 5% or less.)
・Disaster situation: The simulation of the Sanriku minami earthquake. (Number of calls23186/hour, Call loss probability 93.8%.)
・90 seconds holding time: The simulation was performed supposing the case where 1 time of telephone call time becomes long.

4. Simulation results

The simulation results (Fig. 3) indicate that the number of cell phone calls reached about 27 times their normal level in the densely populated area of Akita City. It was thus extremely difficult to make a successful cell phone call. According to the Tohoku Bureau of Telecommunications, Ministry of Public Management, Home Affairs, Posts and Telecommunications, the number of calls attempted during the earthquake was 30 times greater than usual in Tohoku. This is consistent with our simulation results.

5. Discussion

One of the major reasons for the high degree of failure of cell phone calls made during a disaster is the number of people calling to inquire after the safety of their friends and family. Those calls are of a private nature, and such calls constitute an application of communications networks to private communications during a disaster. Safety-inquiry calls are short and concentrated, but the wireless communication units, switches and channels in the cell phone local station are saturated and shut down due to excessive calls at one time. In the Sanriku Minami and Tottori Seibu earthquake, even the cell phone dial tone could not be heard after the earthquake, whereas PHS was reportedly more successful. This may imply that the phone network and switches downstream of the local stations were still active, but that their wireless units had shut down due to traffic congestion. Under such conditions, the cell phone mechanism is currently unable to prioritize priority terminals prepared for emergency calls.

The teledensity in Japan today (cell phone channels per 100 people) is over 60%. If people make safety-inquiry calls all at once immediately after a disaster, the call loss probability will sharply increase in proportion to the increase in calls made, as demonstrated by the simulation shown in Fig. 3. For example, if the frequency of calls triples, 50% of all calls are lost due to traffic congestion, and cellular phones are instantaneously disabled.

Currently, there are about twenty thousand priority terminals for emergency calls in Japan, with a teledensity of 0.015%. For these priority terminals to be useful during a disaster, it is necessary to completely deactivate the other general phone terminals. At present, however, the Telecommunication Business Law does not permit complete suspension of calls. This means that the priority terminal will not work during a disaster.

The number of medical calls is much smaller during a disaster than that of safety-inquiry calls, while the duration (channel occupation time) of each call is longer than safety-inquiry calls, due to the amount of medical information on the victims exchanged. Specifically, although the typical call duration for real-time teleconsulting using image data is about 30 minutes (Ref. 7), it may take much longer, even a few hours, for medical control during a disaster, since patient transport alone may take 30 minutes or longer. It is impossible to maintain such a long call when the cell phone network is suffering from traffic congestion.

As a consequence, cellular phones are not a useful tool for medical control during a disaster because (1) the teledensity of emergency calls is very low and, (2) the call duration is too long. The organization of medical control in the aftermath of disasters will require an isolated, nationwide network.

6. Conclusions

This paper estimates the call loss probability of cell phone calls during disasters based on a simulation study using data from the Sanriku Minami Earthquake. It predicts that under the current cell phone system, even priority terminals for emergency calls will be disabled, due to serious traffic congestion. Because emergency calls have (1) low teledensity and (2) long duration, the cell phone is not useful for medical control during disasters. For proper medical control during disasters, an isolated, nationwide network is necessary.

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