Novateur Publications
International Journal of Innovations in Engineering Research and Technology [IJIERT]
ISSN: 2394-3696 Website: ijiert.org
Volume 13, Issue 4, April – 2026

NEW METHODS FOR RAPID PUBLIC NOTIFICATION VIA SMS IN EMERGENCIES: AN APPLIED STUDY

Sultaniyazov Berdax Baxitbay ugli
Independent Researcher, Tashkent State Technical University

Abstract
This article presents an applied comparison of three SMS-based methods for rapidly notifying the public during emergencies: conventional sequential SMS distribution, geotargeted parallel SMS distribution, and Cell Broadcast Service (CBS) technology. Queueing theory (the M/M/c model and Erlang C formula) and an additive model of delivery time are employed, and simulation-based calculations are performed for a district with a population of 250,000. The results indicate that geotargeted parallel distribution reduces the time required to notify 90% of the population by approximately 13.3 times compared with the conventional method (from 39.9 to 3.0 minutes), while CBS reduces this time to 30 seconds. The proposed hybrid scheme combines CBS with priority-queued parallel SMS delivery, thereby increasing coverage and reducing network load.

Keywords: Emergency, SMS notification, Cell Broadcast, early warning system, queueing theory, Erlang C, coverage probability, public alerting.

Introduction

During emergencies, human lives depend on decisions made in the first few minutes. Research on public warnings indicates that message effectiveness is determined by its content, source, and, most importantly, the speed at which it reaches the population [1; 2]. During earthquakes, floods, industrial accidents, or fires, every minute of warning delay increases the risk of casualties.

Under present-day conditions, mobile communication is the only mass communication medium that people routinely carry with them. In Uzbekistan, the number of mobile subscriptions exceeds the population, making SMS notification one of the most affordable and widespread public-alerting channels. However, conventional SMS distribution has several limitations: messages are sent sequentially through a Short Message Service Center (SMSC); queues form under heavy traffic; precise geographic targeting is limited; and messages are delayed when the network becomes congested.

These challenges necessitate the exploration of new warning approaches, including geotargeted delivery through parallel channels, priority queues, and cell-based broadcasting (Cell Broadcast, ETSI TS 123 041 [3]). Existing studies have generally examined these approaches separately, while their quantitative comparison within a unified mathematical model remains insufficiently developed.

Methodology

The study employed a systems approach, queueing theory, and simulation modeling. The system architecture is presented in Figure 1: the emergency service sends an alert to a central gateway, which delivers the message to subscribers through two paths: the SMSC (parallel channels) and the Cell Broadcast Center (CBC).

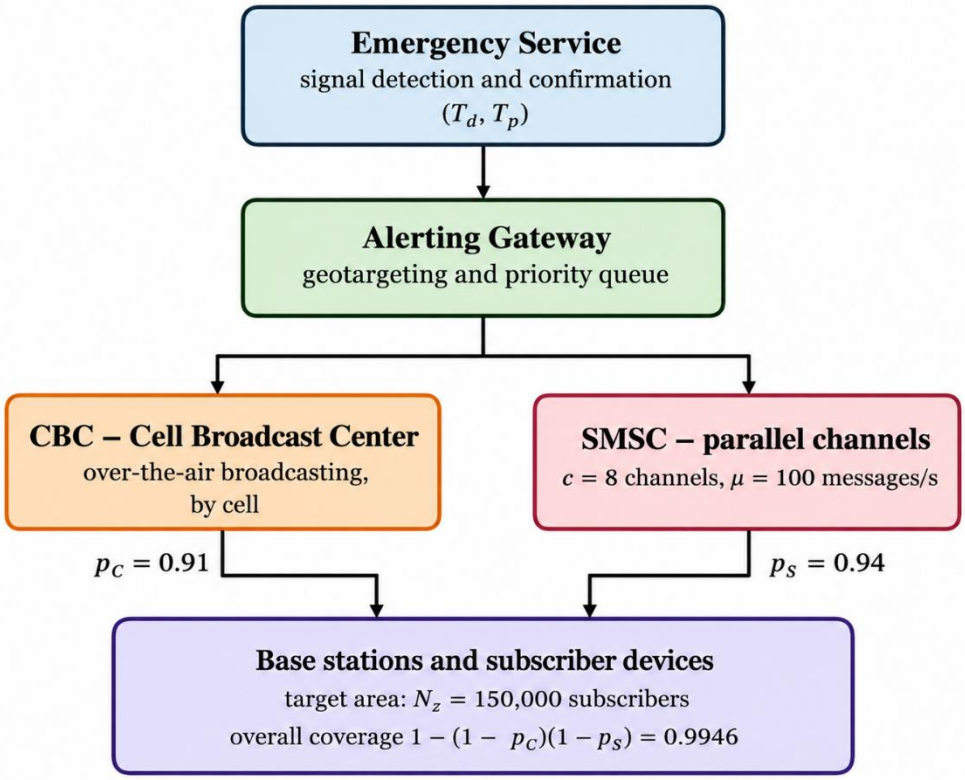

Figure 1. Architecture of the hybrid public warning system

2.1. Additive model of warning delay

The total elapsed time between the detection of an emergency and receipt of the message by a subscriber can be expressed as the sum of the following components:

$$T = T_d + T_p + T_q + T_t + T_r \qquad (1)$$

where T_d is the time required to detect and verify the incident; T_p is the time required to prepare and authorize the message; T_q is the queueing delay; T_t is the network transmission time; and T_r is the time required for the subscriber to notice and read the message.

2.2. Parallel distribution and coverage model

Let N denote the number of subscribers in the target area, μ the throughput of a single SMSC channel (messages/second), c the number of parallel channels, and p_s the probability of successful delivery of an individual message. The proportion of subscribers notified by time t (the coverage function) is then:

$$F(t) = \min\left\{p_s, \frac{p_s c \mu t}{N}\right\} \qquad (2)$$

The time required to reach a target coverage level β (for example, β = 0.9) is:

$$t_\beta = \frac{\beta N}{p_s c \mu}, \quad \beta \le p_s \tag{3}$$

Geotargeting reduces the number of subscribers to be notified from N to N_z (N_z < N). Introducing the area-density coefficient k = N_z/N reduces the distribution time by a factor of k:

$$t_\beta^{geo} = k \cdot t_\beta, \quad k = \frac{N_z}{N} \tag{4}$$

2.3. Queueing system: the M/M/c model

Assume that messages arrive at the SMSC at rate λ (a Poisson arrival process) and are served by c identical channels (an M/M/c system). The system utilization is:

$$\rho = \frac{\lambda}{c\mu} < 1 \tag{5}$$

The probability that a message must wait in the queue is determined by the Erlang C formula [4; 5], where a = λ/μ:

$$P_w = \frac{\frac{a^c}{c!} \cdot \frac{c}{c-a}}{\sum_{k=0}^{c-1} \frac{a^k}{k!} + \frac{a^c}{c!} \cdot \frac{c}{c-a}} \tag{6}$$

The mean queueing time is:

$$W_q = \frac{P_w}{c\mu - \lambda} \tag{7}$$

The mean number of messages in the system is related to the mean time in the system by Little's law [6]: L = λW.

2.4. Integrated effectiveness indicator

To assess the methods comprehensively, an integrated indicator was introduced that accounts for the exponential decline in the value of a warning over time:

$$E = \int_0^{T_{max}} f(t)\, e^{-t/\tau}\, dt, \quad f(t) = \frac{dF(t)}{dt} \tag{8}$$

where τ is the time constant governing the loss of warning value (depending on the type of incident; τ = 5 minutes in our calculations), and T_max = 10 minutes.

2.5. Simulation parameters

The following hypothetical parameters were adopted for the simulation: population N = 250,000; affected-area population N_z = 150,000 (k = 0.6); single-channel throughput μ = 100 messages/s; message delivery

probability p_s = 0.94; c = 8 channels for parallel distribution; and a proportion of CBS-compatible devices of 0.91. For queueing analysis, the peak arrival rate was set at λ = 600 messages/s.

3. Results

3.1. Queueing analysis. At a peak arrival rate of λ = 600 messages/s and μ = 100 messages/s, a = λ/μ = 6. With one channel (c = 1) or six channels (c = 6), the system is unstable (ρ ≥ 1), meaning that the queue grows without bound. With c = 7 channels, ρ = 0.857, P_w = 0.614, and W_q = 6.1 ms; with c = 8, ρ = 0.75, P_w = 0.357, and W_q = 1.8 ms. Thus, adding one channel reduces waiting time by approximately 3.4 times, and eight channels virtually eliminate queueing delay (T_q ≪ T_t).

3.2. Delivery time and coverage. Table 1 presents the performance of four schemes calculated using Equations (3) and (8). In the hybrid scheme, CBS first broadcasts an alert across the entire area, after which parallel SMS reaches the remaining subscribers. Accordingly, total coverage equals 1 − (1 − 0.91)(1 − 0.94) = 0.9946.

Table 1. Comparative performance of warning methods (simulation: N = 250,000; N_z = 150,000)

Method	Channels / technology	Time to 90% coverage, $t_{0.9}$	Coverage at 5 min, F(5)	Integrated effectiveness, E
A. Conventional sequential SMS	c = 1; entire population	39.9 min	11.3%	0.098
B. Geotargeted parallel SMS	c = 8; target area only (k = 0.6)	3.0 min	94.0%	0.699
C. Cell Broadcast (CBS)	Cell broadcast; device share 0.91	0.5 min (30 s)	91.0%	0.866
D. Hybrid (CBS + parallel SMS)	CBS first; SMS second	0.5 min (30 s)	99.5%	0.930

Method B reaches 90% coverage approximately t_A/t_B = 39.9/3.0 ≈ 13.3 times faster than Method A. This result is fully consistent with the theoretical expression: the speedup factor is determined by the number of channels c and the geotargeting coefficient k:

$$\frac{t_A}{t_B} = \frac{c}{1} \cdot \frac{1}{k} = 8 \cdot \frac{1}{0{,}6} \approx 13{,}3 \qquad (9)$$

3.3. Coverage dynamics over time. Figure 2 shows the coverage function F(t) for the four methods over a five-minute interval. Within the first minute, CBS and the hybrid scheme reach more than 90% of subscribers, while parallel SMS reaches its upper limit of p_s = 0.94 after three minutes; the conventional method reaches only 11.3% after five minutes.

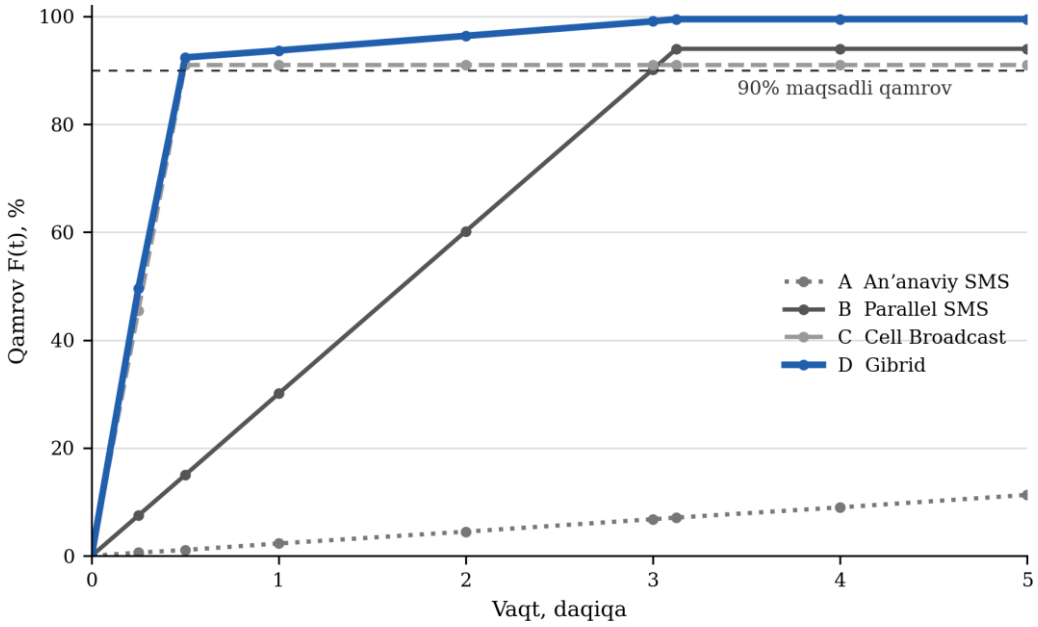

Figure 2. Proportion of subscribers in the target area who received an alert, F(t)

Discussion

The results confirm that the primary factor determining warning effectiveness is not simply message content but, above all, the speed with which the warning reaches the public. Conventional sequential SMS distribution requires almost 40 minutes for 250,000 subscribers; during events such as an earthquake or dam failure, such a delay may render the warning ineffective. Parallel channels and geotargeting jointly increase delivery speed, and the relationship c/k demonstrates that their effects are multiplicative: doubling the number of channels while halving the target area increases delivery speed fourfold.

Cell Broadcast offers the best delivery speed because the message is broadcast simultaneously within a cell rather than transmitted individually to each subscriber, and it does not depend on the SMSC queue. However, its coverage is limited by device compatibility and user settings (0.91 in the model). Therefore, CBS should be used alongside parallel SMS rather than as the sole channel. In the hybrid scheme, assuming independence between the two channels, coverage reaches 99.5% according to $1 - (1 - p_C)(1 - p_B)$.

Studies of warning systems also emphasize the "milling" phase between receiving an alert and taking action [1; 2]. Therefore, warning messages should be concise, unambiguous, and action-oriented, specifying the type of incident, location, time, and required protective actions. This helps reduce the T_r component of the model.

Study limitations. First, the calculations are simulation-based and rely on hypothetical parameters (μ, p_s, c, N_z); the model therefore requires calibration against actual mobile operator data. Second, the model does not account for human behavior after message delivery (T_r). Third, it does not consider the possibility of base-station failures during network disruptions or power outages. Future work will incorporate these factors into a stochastic model and validate the results using data obtained from practical exercises conducted with a mobile operator.

Conclusion

1. Emergency public warning time can be described using the additive model T; its principal controllable components are queueing time T_q and network transmission time T_t.
2. According to the M/M/c model, at peak load (λ = 600 messages/s), at least c = 8 parallel channels are required; the resulting mean queueing time is 1.8 ms.
3. Geotargeted parallel SMS distribution reduces the time required to reach 90% coverage from 39.9 minutes with the conventional method to 3.0 minutes, a 13.3-fold reduction.
4. Cell Broadcast achieves 91% coverage within 30 seconds, although its reach is limited by device compatibility.
5. The most effective solution is a hybrid scheme combining CBS and parallel SMS, providing 99.5% coverage and the highest integrated effectiveness (E = 0.930).

As a practical recommendation, a unified national warning gateway incorporating geotargeting, priority queueing, and CBS should be implemented in cooperation with mobile operators and regularly tested through emergency exercises.

References

1. Mileti D.S., Sorensen J.H. Communication of Emergency Public Warnings: A Social Science Perspective and State-of-the-Art Assessment. Oak Ridge National Laboratory, ORNL-6609, 1990.
2. Sorensen J.H. Hazard Warning Systems: Review of 20 Years of Progress // Natural Hazards Review, 2000, Vol. 1, No. 2, pp. 119–125.
3. ETSI TS 123 041. Digital cellular telecommunications system (Phase 2+); Technical realization of Cell Broadcast Service (CBS). ETSI.
4. Erlang A.K. The theory of probabilities and telephone conversations // Nyt Tidsskrift for Matematik B, 1909, Vol. 20, pp. 33–39.
5. Kleinrock L. Queueing Systems, Volume 1: Theory. New York: Wiley-Interscience, 1975.
6. Little J.D.C. A Proof for the Queuing Formula: L = λW // Operations Research, 1961, Vol. 9, No. 3, pp. 383–387.
7. Mileti D.S. Disasters by Design: A Reassessment of Natural Hazards in the United States. Washington, D.C.: Joseph Henry Press, 1999.
8. Law A.M. Simulation Modeling and Analysis. New York: McGraw-Hill.
9. Law of the Republic of Uzbekistan “On the Protection of the Population and Territories from Natural and Technogenic Emergencies,” August 20, 1999.
10. ITU-T Recommendation E.107. Emergency Telecommunications Service (ETS) and Interconnection Framework for National Implementations of ETS. ITU, Geneva.