Network-Based Emergency Alert System: Evaluation and Implementation Scenario of Cell Broadcast Technology in Türkiye

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Abstract

This thesis investigates the feasibility and potential benefits of integrating Cell Broadcast (CB) technology into Türkiye's disaster early warning and communication systems. The study begins with a technical analysis of CB's architecture, operational requirements, and infrastructure readiness. It also examines regulatory frameworks, operator responsibilities, and potential implementation challenges. To complement this analysis, the thesis presents a scenario-based simulation focused on a magnitude 7.5 earthquake near Istanbul. The simulation demonstrates how CB could provide real-time alerts, offering the public critical seconds for protective action while overcoming network congestion. The study concludes with recommendations for pilot projects, periodic drills, and integration with complementary technologies such as satellite systems to enhance national disaster resilience.

Özet

Bu tez, Türkiye'nin afet erken uyarı ve iletişim sistemlerine Hücresel Yayın (Cell Broadcast - CB) teknolojisinin entegrasyonunun uygulanabilirliğini ve potansiyel faydalarını incelemektedir. Çalışmada öncelikle CB'nin mimarisi, operasyonel gereksinimleri ve altyapı hazırlık durumu teknik açıdan analiz edilmiştir. Ayrıca yasal düzenlemeler, operatörlerin sorumlulukları ve uygulamadaki olası zorluklar ele alınmıştır. Bu analizi desteklemek amacıyla, İstanbul merkezli 7.5 büyüklüğünde bir deprem senaryosu temelli bir simülasyon sunulmuştur. Simülasyon, CB'nin gerçek zamanlı uyarılar sağlayarak ağ tıkanıklığını aşabileceğini ve halka koruyucu önlem için kritik saniyeler kazandırabileceğini ortaya koymaktadır. Çalışma, ulusal afet dayanıklılığını artırmak için pilot projeler, düzenli tatbikatlar ve uydu sistemleri gibi tamamlayıcı teknolojilerle entegrasyon yönünde önerilerle sona ermektedir.

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1. The Importance of Communication and Early Warning Systems During Disasters

Disasters and emergencies not only lead to physical destruction and casualties but also disrupt communication infrastructure, thereby compounding their overall societal impact. In such critical moments, the timely and accurate dissemination of information becomes essential for safeguarding public safety, ensuring effective coordination among emergency services, and preserving societal resilience.

Traditional SMS-based alert systems have shown significant limitations, especially during network congestion. Consequently, attention has shifted toward alternative communication methods. Among them, Cell Broadcast (CB) technology has gained prominence due to its speed, geographic specificity, and independence from traffic loads.

The increasing frequency of climate-related disasters and recent large-scale emergencies, such as the 2023 Kahramanmaraş earthquakes, have further highlighted the urgent need for more resilient and efficient communication technologies.

This thesis explores the technical and administrative feasibility of implementing Cell Broadcast systems in Türkiye. It examines the technology's integration into the existing GSM infrastructure, its role in enhancing coordination between AFAD (Disaster and Emergency Management Authority) and mobile operators, and its applicability through scenario-based evaluations.

1.1 Why Is Communication Important During a Disaster?

Effective communication with the public during a disaster or emergency is of vital importance. Such communication may include warning and alert messages, preventive instructions such as evacuation orders or curfews, and updates concerning emergency operations, the whereabouts of missing or displaced family members, and the distribution of aid.

Well-designed and clearly delivered messages help ensure public safety, safeguard property, facilitate response coordination, foster public cooperation, build trust in authorities, and support the reunification of families.

The effectiveness of warning messages depends on several factors, including individual perceptions and characteristics, the credibility of the information source, the delivery method, and the clarity and content of the message itself.

1.2 Communication Management During Disasters: The Case of Türkiye

The earthquakes centered in Kahramanmaraş on February 6, 2023, often described as the disaster of the century, once again underscored the critical importance of communication management during times of crisis. As noted by Presidential Communications Director Fahrettin Altun, “The management of communication during disasters and emergencies is undoubtedly of vital importance.”

Speaking at the Stratcom Disaster Communication Forum held in Ankara, Altun emphasized the need for inter-agency cooperation and coordination, rapid and transparent information sharing with the public, and the fight against disinformation as critical components of disaster response.

He also noted that, alongside preparedness, response, resilience, and recovery efforts, communication should be treated as a primary area of disaster planning. In this context, the integration of next-generation technologies, such as artificial intelligence, into communication strategies has been increasingly recognized as a necessity.

These statements highlight that, in Türkiye, communication is positioned not merely as a tool for information dissemination but as a strategic pillar of crisis management and a key component of public safety during disaster scenarios.

1.3 The Importance of Early Warning Systems and the Role of Cell Broadcast Technology

Early Warning Systems (EWS) are life-saving mechanisms that provide advance notice of impending threats, enabling individuals, families, and communities to take timely and effective protective actions. As the frequency and intensity of natural disasters continue to rise, particularly due to climate change, the importance of EWS has become increasingly evident.

Over the past 50 years, the number of natural disasters has increased fivefold. In 2022 alone, 387 disasters were reported globally, leading to 30,704 deaths and directly impacting over 185 million people. In response to this alarming trend, enhancing preparedness and community resilience has become a global priority.

Within this context, mobile-based technologies, especially Cell Broadcast (CB), have become vital components of modern early warning infrastructures. CB, which has been actively deployed for nearly two decades, offers critical advantages: it delivers location-specific alerts rapidly, is unaffected by network congestion, and draws attention through loud tones and full-screen messages on compatible devices.

The United Nations' “Early Warnings for All” (EW4All) initiative, launched in 2022, aims to ensure that every person on Earth is covered by an early warning system by 2027. This global initiative underscores the importance of understanding CB technology’s potential and advocating for its widespread implementation.

Furthermore, studies and international assessments suggest that every $1 invested in early warning and disaster preparedness can save up to $15 in post-disaster recovery efforts. An estimated $800 million investment in EWS could prevent annual losses ranging from $3 billion to $16 billion. These figures demonstrate that CB-enabled warning systems are not only lifesaving but also represent a sound and sustainable economic strategy.

2. Historical Development and International Use Cases of Cell Broadcast Technology

2.1 The History and Evolution of Cell Broadcast Technology

Cell Broadcast (CB) is a communication technology that enables the simultaneous transmission of short messages to all devices within a defined geographic area via mobile networks. Unlike SMS, which targets individual phone numbers, CB messages are directed to all devices within the coverage area of specific base stations. This architecture allows messages to reach millions of people within seconds and remain unaffected by network congestion (GSMA, 2023).

CB technology has been defined by the European Telecommunications Standards Institute (ETSI) and the 3rd Generation Partnership Project (3GPP). It is compatible with all generations of mobile communication technologies, including 2G, 3G, 4G LTE, and 5G. Technically, the implementation of CB services is detailed in the 3GPP TS 23.041 standard (ETSI, 2018).

One of the earliest practical implementations of CB technology was the DEWN (Disaster and Emergency Warning Network) system developed in Sri Lanka after the 2005 tsunami. Established through collaboration between Dialog Axiata, MicroImage, and the University of Moratuwa, this system used CB to deliver multilingual alerts to the public. It integrated mobile message delivery with physical CB devices installed in public buildings (GSMA, 2023).

The effectiveness of CB stems from its key features: location-based targeting, no subscription requirement from users, immunity to network overload, the ability to deliver audible and visual alerts even when the device is on silent, and respect for user privacy (GSMA, 2023). These attributes have positioned CB as a core component of modern Early Warning Systems (EWS).

In conclusion, CB technology has evolved in parallel with the development of mobile infrastructure and has become a critical communication tool for public safety. Its integration into Türkiye’s disaster management systems presents a significant opportunity to enhance national preparedness and resilience.

2.2 Cell Broadcast Implementations in Other Countries

Cell Broadcast (CB) technology is widely adopted across many countries as a core component of emergency alert systems. Its location-based, rapid, and congestion-free architecture has demonstrated effective results in a variety of national disaster scenarios. This section summarizes key use cases from leading countries.

The following section summarizes official use case descriptions as reported in EENA (2019), GSMA (2023), and FEMA (2023) without significant modification, to preserve the accuracy of the data.

2.2.1 Japan: ETWS (Earthquake and Tsunami Warning System)

Since 2007, Japan has employed a CB-based service called Area Mail to deliver earthquake and tsunami warnings. The ETWS system utilizes data from seismic sensors to send both primary (initial) and secondary (detailed) alerts directly to mobile devices. The initial message typically reaches users within four seconds.

2.2.2 United States: Wireless Emergency Alerts (WEA)

In the United States, CB technology is implemented under the Integrated Public Alert and Warning System (IPAWS), managed by FEMA. The Wireless Emergency Alerts (WEA) system delivers real-time messages for presidential alerts, AMBER alerts, and imminent threats to life. It operates across all major carriers using 3GPP/ATIS-compliant infrastructure.

2.2.3 Netherlands: NL-Alert

Launched in 2012, NL-Alert operates on a CB-based system aligned with the ETSI TS 102 900 standard. As of 2019, it had reached 80% of the population over age 12. The system enables operators to provide pre-configured, CB-compatible devices. Traditional siren systems are being gradually replaced by NL-Alert.

2.2.4 Sri Lanka: DEWN (Disaster and Emergency Warning Network)

Developed after the 2004 tsunami, DEWN was one of the first CB-based alert systems in South Asia. It delivered messages in three languages and was supported by physical alert devices placed in public areas. Following the rise of smartphones, a newer version was introduced after 2017; however, a return to CB delivery is under consideration.

2.2.5 Greece: Centralized CB System

Following the implementation of the European Electronic Communications Code (EECC), Greece became one of the first countries to adopt CB technology. Its three major mobile operators share a centralized CB infrastructure, which became operational at the end of 2019.

2.2.6 New Zealand: Emergency Mobile Alert (EMA)

New Zealand uses CB technology to send Emergency Mobile Alerts nationwide. The system is tested twice annually, with a 2018 trial reaching 70% of the population. All major carriers, including Spark, Vodafone, and 2Degrees, are part of the CB alert network.

2.3 Disaster Notification Systems in Türkiye

The development of early warning systems in Türkiye has significantly accelerated in the aftermath of the 1999 Marmara Earthquake. Today, these systems are coordinated by the Disaster and Emergency Management Authority (AFAD) and utilize a variety of digital communication platforms. Türkiye's current disaster notification framework includes the Integrated Warning and Alert System (IKAS), mobile applications, cellular/SMS-based alerts, and social media outreach, forming a multi-channel strategy.

2.3.1 Integrated Warning and Alert System (IKAS)

Developed by AFAD, IKAS is primarily designed to issue alerts in cases of chemical, biological, radiological, and nuclear (CBRN) threats, as well as aerial attacks. It comprises three main components: the Intelligence and Dissemination System (HAY), the Siren Alert System, and the Message Alert System (MUS). Through MUS, alerts can be delivered to mobile phones via SMS. For example, on August 10, 2023, warnings were sent to residents in the Marmara and Western Black Sea regions due to severe rainfall forecasts.

2.3.2 Mobile Applications and Social Media

AFAD operates mobile apps such as AFAD Acil and AFAD Deprem, which provide real-time emergency updates, enable users to find designated assembly points, and request aid. Additionally, official messages distributed via social media platforms, particularly Twitter/X, play a crucial role in timely public communication.

2.3.3 Limitations of Existing Systems

While SMS and app-based alerts play an important role in public communication, they remain insufficient in fulfilling the operational criteria of a predictive, real-time Earthquake Early Warning System (EEWS). In 2025, Prof. Dr. Aykut Akgün, Head of the Earthquake Department at AFAD's Directorate General for Earthquake and Risk Reduction, stated:

"Although such systems are being used in some countries, they have not yet reached the desired level. It is not yet possible to speak of a system whose accuracy has been fully validated. Therefore, it must be approached with scientific and cautious consideration."

This statement reflects the fact that Türkiye has yet to implement a fully functional, real-time EEWS similar to Japan's ETWS. Current systems are designed primarily for post-event communication and public guidance. Sensor-based mechanisms capable of issuing alerts before seismic shaking begins are not yet widely deployed.

3. The Technical Structure of Cell Broadcast Technology and Its Role in Early Warning Systems

3.1 General Architecture of the Cell Broadcast System

Cell Broadcast (CB) is a one-way communication technology that enables the simultaneous transmission of short text messages to all mobile devices within a defined geographic area via cellular networks. Unlike conventional SMS, which follows a person-to-person model, CB operates on a one-to-many messaging framework. It delivers messages to all compatible devices within the broadcast area of designated base stations, regardless of user subscription or interaction.

This architecture is especially critical in the context of emergency and disaster communication. Because messages are transmitted to geographic coverage areas instead of individual phone numbers, CB can reach millions of users within seconds and remain unaffected by network congestion. CB alerts can override device settings to produce audible tones and visual warnings, even when phones are set to silent mode. Additionally, the system ensures high accessibility while preserving user privacy.

As a built-in component of mobile network infrastructure, CB is standardized by global organizations such as the European Telecommunications Standards Institute (ETSI) and the 3rd Generation Partnership Project (3GPP). It supports all generations of mobile communication technology, including 2G, 3G, 4G LTE, and 5G, under the technical specifications defined in ETSI TS 123 041. This level of standardization ensures interoperability between different mobile device manufacturers and telecom operators, making CB globally deployable and robust.

In conclusion, CB's architectural design is optimized for rapid, inclusive, and resilient communication. Particularly in the field of disaster preparedness and response, its structural strengths make it a strategic pillar for public safety.

3.2 Key Components of the Cell Broadcast System

The secure and efficient operation of a Cell Broadcast (CB) system depends on the correct configuration of several interrelated technical components, spanning both the telecommunications infrastructure and the relevant public authorities. The primary components of a CB system include the following:

3.2.1 Cell Broadcast Entity (CBE)

The CBE acts as the front-end interface used by authorized governmental agencies and designated authorities to compose and configure emergency messages. Through this interface, critical parameters, such as message content, target geographical area, repetition interval, and broadcast duration, are defined. CBEs are typically designed with user-friendly interfaces to enable rapid and accurate message composition under time-sensitive conditions. They also support international standards like the Common Alerting Protocol (CAP), ensuring interoperability across systems.

3.2.2 Cell Broadcast Centre (CBC)

The CBC serves as the central backend node within the mobile network operator's core infrastructure. Once a message is validated and transmitted via the CBE, the CBC receives and processes it before dispatching it to the relevant base stations through the Radio Access Network (RAN). Depending on the national deployment model, each mobile operator may manage its own CBC or utilize a shared, centralized infrastructure.

3.2.3 Radio Access Network (RAN)

The RAN is the mobile network segment responsible for establishing radio connections with end-user devices via base stations. Upon receiving transmission commands from the CBC, base stations in the designated geographical area broadcast the CB message. These alerts are displayed directly on device screens and are accompanied by distinctive visual and auditory cues. Notably, the message delivery does not depend on mobile data access or manual user interaction.

3.2.4 User Equipment (UE)

The effectiveness of a CB system also hinges on the compatibility and market penetration of supporting mobile devices. Most smartphones running Android 11 or later and iOS operating systems now offer native CB support. Such devices automatically receive alerts without the need for additional software. However, device manufacturers must ensure ongoing support through continuous software and firmware updates to maintain long-term system reliability.

3.2.5 Authorization and Security Layers

To prevent unauthorized access and maintain public trust, CB systems incorporate robust security protocols. These typically include multi-factor authentication, strict access control policies, and end-to-end message encryption. These safeguards are essential to protect the system from malicious misuse, technical faults, or the spread of false alerts.

3.3 Strengths and Limitations of Cell Broadcast Systems

Cell Broadcast (CB) technology is increasingly being adopted as a key communication channel in emergency warning systems (EWS). This preference stems from its unique technical advantages. However, to ensure effective implementation, certain limitations must also be considered. This section discusses the strengths and constraints of CB systems, based on the GSMA report published in November 2023.

3.3.1 Strengths

3.3.1.1 Location-Based Targeting

CB messages are transmitted to all mobile devices within the coverage area of a specific cell tower, enabling hyper-localized dissemination. This ensures that only individuals in the immediate vicinity of a threat receive the alert, reducing unnecessary panic in unaffected regions. Such precision is especially important in densely populated urban areas or in situations where the threat is geographically limited.

3.3.1.2 Unaffected by Network Congestion

Unlike traditional SMS or internet-based alerts, CB operates on a separate control channel that does not compete with voice or data traffic. This architecture ensures that emergency messages are delivered instantaneously, even when mobile networks are saturated due to high call volumes or internet use during disasters. This reliability is crucial in the early minutes of a crisis when every second counts.

3.3.1.3 High Reach Capacity

A single CB transmission can simultaneously reach millions of mobile devices across multiple operators within seconds. This makes it ideal for large-scale emergencies, such as earthquakes, floods, or industrial accidents, where broad and immediate population coverage is essential. Its broadcast model ensures message delivery without delays caused by recipient queues or server bottlenecks.

3.3.1.4 Prominent Alert Features

CB alerts are designed to bypass standard user settings: they can override silent mode, vibrate strongly, and display full-screen messages that interrupt current activity. These distinctive features ensure the message stands out and grabs immediate attention, even in noisy or distracting environments. This is vital for prompting quick decision-making in life-threatening situations.

3.3.1.5 Privacy-Friendly

Because CB does not rely on phone numbers, user accounts, or personal data, it inherently preserves individual privacy. Messages are broadcast anonymously and do not require user subscriptions or app installations. This privacy-preserving design increases public trust and avoids ethical or legal complications related to data protection and surveillance.

3.3.1.6 Security and Authenticity

CB systems incorporate multiple layers of security to prevent unauthorized access and spoofing. Only verified governmental agencies or designated authorities can send messages through secured and authenticated interfaces. Additionally, system logs and access protocols ensure traceability and accountability, further reinforcing public confidence in the legitimacy of the alerts.

3.3.2 Limitations

3.3.2.1 One-Way Communication

CB systems operate on a unidirectional broadcast model, meaning users can receive alerts but cannot respond or provide feedback through the same channel. This lack of interactivity can be a limitation in situations that require confirmation of receipt, real-time reporting from citizens, or follow-up actions. In large-scale emergencies, the inability to gather situational data from the public may hinder adaptive response efforts. For this reason, CB systems are often supplemented with two-way communication platforms such as mobile apps or social media.

3.3.2.2 Device Compatibility

Although the majority of smartphones manufactured after 2012 support CB functionality, not all devices are fully compatible, especially older models, imported phones, or low-cost devices with customized firmware. Additionally, in some cases, users may unknowingly disable CB alerts through device settings, rendering them unreachable during critical situations. This creates gaps in population coverage and underscores the importance of conducting regular compatibility audits, software updates, and public awareness campaigns to ensure widespread reception capability.

3.3.2.3 Dependence on Network Infrastructure

CB requires a functioning mobile network to operate. Although CB systems are designed to deliver alerts before or during the early stages of a crisis, certain types of disasters, such as earthquakes, floods, wildfires, or attacks targeting infrastructure, may impair cellular base stations or transmission systems. In such cases, message delivery can be disrupted or localized outages may occur. Therefore, CB should be complemented with alternative communication technologies, such as sirens, radio, or satellite-based alerts, to ensure redundancy and reliability.

3.3.2.4 Limited Public Awareness

The effectiveness of CB systems is not solely determined by technological capabilities but also by the public’s awareness and understanding of the system. In regions where CB has not been widely used or tested, people may be unfamiliar with the visual and auditory characteristics of CB alerts. Moreover, a lack of public education campaigns can lead to confusion about the message’s purpose, source, or required action. To maximize the impact of CB alerts, continuous public outreach, periodic testing, and education efforts are essential to foster trust and ensure appropriate behavioral responses during emergencies.

3.3.2.5 Language and Accessibility Barriers

CB messages are usually transmitted in one or two dominant languages, which may limit their effectiveness in multilingual communities. Individuals who do not speak the broadcast language may fail to understand the warning, reducing the system's overall reach.

Moreover, accessibility for people with visual or hearing impairments remains limited. Users with disabilities may not fully perceive or respond to alerts unless their devices are equipped with compatible assistive technologies. Improving multilingual support and ensuring better integration with accessibility tools are essential steps toward inclusivity.

3.4 Network Infrastructure Resilience and Continuity of CB Systems

The operational effectiveness of Cell Broadcast (CB)-based early warning systems during disasters depends heavily on the resilience and uninterrupted functionality of mobile network infrastructure. In large-scale emergencies such as earthquakes, physical damage to base stations, prolonged power outages, or total network failure can hinder CB operations. Therefore, the reliability of CB systems is closely tied not only to their technological design but also to the robustness of the supporting infrastructure.

The GSMA's 2023 report Cell Broadcast for Early Warning Systems emphasizes the need to fortify mobile networks against disaster-induced disruptions. Recommended measures include equipping base stations with backup power solutions (such as generators and batteries), deploying portable emergency base stations, ensuring network redundancy, and distributing critical infrastructure geographically to avoid single points of failure.

In scenarios where terrestrial infrastructure is compromised, Non-Terrestrial Networks (NTNs), such as satellite communication systems, can function as alternative transmission paths. These technologies help maintain message delivery even in remote or damaged areas.

Another critical point is the dependency of base stations on a continuous power supply. Integrating renewable energy sources, particularly solar power combined with high-capacity batteries, can substantially extend operational uptime. Physical security of communication assets and controlled access are also crucial for infrastructure protection.

Lastly, Mobile Network Operators (MNOs) are encouraged to conduct disaster risk assessments in coordination with public authorities and to develop scenario-based emergency response plans.

By implementing these strategies, the continuity and dependability of CB message transmission can be significantly enhanced, thereby reinforcing the system's operational resilience under extreme conditions.

3.5 Applicability of Cell Broadcast Technology in Türkiye: Technical, Infrastructural, and Operator-Level Assessment

The implementation of Cell Broadcast (CB) technology in Türkiye hinges on both the technical adequacy of the national telecommunications infrastructure and the capacity of mobile network operators to integrate such systems in coordination with public authorities. According to international standards by GSMA and EENA, CB systems enable real-time message dissemination to all compatible mobile devices within defined geographic zones, without the need for internet connectivity. In this regard, the capabilities of Türkiye's GSM infrastructure are central to evaluating CB applicability.

3.5.1 Technical and Infrastructural Readiness

Türkiye's 4.5G mobile network infrastructure currently offers extensive coverage, particularly in urban centers and metropolitan areas. As reported by the Information and Communication Technologies Authority (BTK) in 2023, over 95% of the population is covered by 4.5G services. This level of coverage provides a solid foundation for CB deployment, given that the technology operates via base stations equipped to transmit broadcast messages.

Coverage gaps persist in rural and mountainous regions, which may compromise the reliability of CB message delivery during large-scale disasters. For this reason, technical implementation will require both software-level upgrades and hardware-based investments, including backup power systems for base stations and alternative communication paths such as satellite links.

3.5.2 Operator Readiness and Collaboration Potential

Türkiye’s three major mobile operators, Turkcell, Türk Telekom, and Vodafone, possess the technical capacity to support Cell Broadcast (CB) technology within their network infrastructures. However, none of these operators currently offer public CB-based alert services. In 2023, pilot CB message trials were conducted under the coordination of AFAD, and references to CB systems have been included in the post-disaster communication strategy documents published by the Information and Communication Technologies Authority (BTK).

The successful implementation of CB technology requires more than technical readiness; it also demands close cooperation between public authorities and private operators. Mobile operators must comply with regulatory frameworks set by BTK, update their network infrastructure to support CB broadcasting, and establish standardized data-sharing protocols with authorized agencies such as AFAD.

Domestic technology companies have also contributed to this process. For instance, İSTLİNK has developed CB gateway solutions and conducted integration tests with several operators. However, these systems have yet to be incorporated into active public emergency services.

Overall, the integration of CB systems in Türkiye depends not only on technical compatibility but also on the development of robust institutional collaboration. A coordinated public-private effort is essential to ensure the nationwide deployment of CB technology in a secure, reliable, and sustainable manner.

3.5.3 Potential Challenges

While the technical foundation for Cell Broadcast (CB) systems exists in Türkiye, several critical challenges may hinder its full-scale deployment and operational reliability. First, coverage gaps in rural or mountainous areas pose a significant obstacle, particularly during large-scale disasters where connectivity is vital. In addition, physical damage to mobile base stations caused by events such as earthquakes or floods may result in service disruptions, making CB message delivery unreliable when it is needed most.

Another concern is device compatibility and user settings. Although most modern smartphones support CB, a portion of the population still uses older or unsupported devices or may have the CB feature disabled. Institutional coordination is another potential bottleneck, as deploying CB technology requires seamless cooperation between mobile operators, government authorities like AFAD, and the regulatory body BTK. Without standardized protocols, role clarity, and secure data exchange systems, the speed and efficiency of CB deployment could be compromised.

Low public awareness remains a risk. If citizens do not recognize CB alerts or do not know how to respond appropriately, the impact of such a system would be significantly reduced, regardless of technical performance.

3.5.4 Potential Solutions

To address the challenges, a multi-layered implementation and preparedness strategy should be pursued. For coverage issues, mobile operators should invest in temporary or mobile base stations, drone-based aerial networks, and satellite-linked Non-Terrestrial Networks (NTNs) to ensure coverage redundancy during emergencies. Moreover, equipping base stations with solar-powered backups and battery systems can significantly reduce outages caused by power loss.

To improve device compatibility, regulatory bodies could mandate minimum CB feature support on all new mobile devices sold in Türkiye. In parallel, awareness campaigns should be launched to educate the public about CB alerts, what they look like, how to recognize them, and what actions to take upon receiving one.

On the institutional side, inter-agency coordination frameworks should be established between AFAD, BTK, and mobile network operators. These frameworks must define clear roles, message authorization protocols, and secure communication channels. Conducting regular CB system tests and nationwide alert drills will also improve operational readiness and help identify weaknesses in advance.

3.5.5 Overall Evaluation of CB Applicability in Türkiye

CB technology is technically feasible in Türkiye; however, its successful implementation requires more than adequate infrastructure. Ensuring nationwide coverage and operational continuity depends on coordinated efforts among mobile operators, regulatory bodies such as BTK, and disaster response agencies like AFAD. This includes establishing secure data-sharing protocols, deploying redundant infrastructure, and promoting public awareness.

By addressing these multidimensional requirements, ranging from technical and regulatory readiness to infrastructure resilience and end-user education, Türkiye can overcome existing limitations and build a robust, reliable Cell Broadcast system that strengthens national disaster preparedness and supports public safety objectives. This comprehensive assessment also provides a solid basis for the scenario-based simulation model proposed in Chapter 4.

4. Implementing Cell Broadcast for Earthquake Early Warning: An İstanbul Case Scenario

This chapter presents a scenario-based simulation designed to explore the potential integration of Cell Broadcast (CB) technology into Istanbul's earthquake early warning and disaster communication systems. The scenario is entirely hypothetical and is intended for academic analysis. It does not describe an existing operational framework, but rather models how such a system might function under realistic assumptions and current technological conditions.

4.1 Scenario Definition: A Devastating Earthquake Centered in Istanbul

Istanbul, a densely populated megacity, is situated along the Marmara segment of the North Anatolian Fault Line, one of the most seismically active regions in the country. Scientific projections cited in reports by the Istanbul Metropolitan Municipality (IMM), including the Debris Management Plan Against a Potential Devastating Earthquake (2024) and initiatives related to the city's early earthquake warning systems, indicate a high probability of a major earthquake impacting the city.

In this simulation, a magnitude 7.5 earthquake is assumed to occur in the Sea of Marmara at a depth of approximately 12 km near Silivri. Seismic activity is detected within 3–6 seconds by sensors hypothetically operated by Boğaziçi University's Kandilli Observatory and the Disaster and Emergency Management Authority (AFAD). Severe structural damage is projected across districts such as Avcılar, Küçükçekmece, Bakırköy, and Zeytinburnu, where soil conditions heighten the risk of building collapse.

The model assumes simultaneous disruption of critical infrastructure, including GSM networks, power grids, and natural gas lines, leading to a breakdown of conventional communication channels in the immediate aftermath. Under these conditions, the simulation envisions the rapid activation of CB technology to deliver emergency alerts independently of network congestion or failures.

In this scenario, an earthquake early warning system**,** referred to here as ERREWS for the purpose of simulation**,** automatically triggers a CB alert coordinated between AFAD and the Disaster Coordination Center (AKOM). The alert is broadcast to mobile devices within high-risk zones, providing a brief but vital window for protective action before destructive seismic waves arrive.

4.2 Emergency Notification Process

4.2.1 Earthquake Detection and System Activation

Ground motion during an earthquake is detected within approximately 3 to 6 seconds via a seismic sensor network operated by Boğaziçi University's Kandilli Observatory and AFAD. This data is processed by the ERREWS (Istanbul Earthquake Rapid Response and Early Warning System), which has been deployed across Istanbul.

Parameters such as magnitude, epicenter, and intensity are analyzed in real time and transmitted to the relevant public authorities. If specific thresholds are exceeded (e.g., a magnitude above 6.0) the system automatically initiates the emergency alert procedure.

This triggering process operates automatically, with AFAD signaling the Information and Communication Technologies Authority (BTK) to activate the Cell Broadcast infrastructure of all mobile operators. The aim is to send the alert before destructive seismic waves reach the surface, using the brief window between P-wave detection and S-wave arrival to disseminate the message. This makes the system a true early warning tool rather than just a notification method.

4.2.2 Message Preparation and Approval Process

In this simulated scenario, once the earthquake is detected and the automated trigger is activated, the system immediately selects a predefined Cell Broadcast (CB) message template suited for high-magnitude seismic events. These templates, developed in advance by AFAD in coordination with BTK, are categorized by event type and severity level to ensure rapid selection without the need for manual drafting. The template is automatically forwarded to the Cell Broadcast Service Centers of mobile operators. Because the process is fully automated, the approval and authorization stage, normally prone to delays in manual systems, is completed in just 1–2 seconds.

The message is designed to be clear, concise, and immediately actionable. It is transmitted simultaneously in Turkish and English to ensure that both residents and visitors in Istanbul can understand and act upon the warning. This rapid message preparation and approval mechanism is critical for enabling protective action during the narrow window before destructive seismic waves arrive.

4.2.3 CB Message Transmission and Network-Level Operation

Once the Cell Broadcast (CB) message is approved, it is instantly transmitted through the Cell Broadcast Service Centers (CBSCs) operated by Türkiye’s major mobile providers (Turkcell, Vodafone, and Türk Telekom) under the coordination of BTK. Instead of targeting individual phone numbers, the message is broadcast simultaneously to all mobile devices connected to base stations within the high-risk zones identified by the early warning system.

Within seconds, the alert reaches millions of people in the affected districts. The message appears prominently on device screens, overriding any lock or running application. A loud, distinctive alarm tone and strong vibration ensure that users are immediately alerted, even those asleep or distracted at the moment.

Because CB does not depend on mobile data, internet access, or third-party applications, the alert is successfully delivered even in areas where conventional communication channels are disrupted. In this simulated event, any person carrying CB compatible device within the coverage area receives the warning, giving them the opportunity to take life-saving protective action in the brief interval before the seismic waves strike.

4.2.4 Legal and Regulatory Framework

In this simulated scenario, the Cell Broadcast (CB) alert is transmitted in accordance with Türkiye’s existing emergency communication regulations, even though no dedicated CB law currently exists. The model assumes that the activation of the CB system proceeds under the legal authority granted to AFAD by Law No. 5902 on Disaster and Emergency Management, which mandates risk reduction and public information measures during disasters.

Under this framework, BTK's "Regulation on Emergency and Disaster Management in the Electronic Communications Sector" provides the legal basis for mobile operators to allocate infrastructure and cooperate in the delivery of emergency alerts. In the simulation, this regulatory environment enables the rapid and coordinated transmission of the CB message without the need for ad hoc legal clearances that could otherwise cause delays.

While the scenario operates successfully within the boundaries of current regulations, it highlights the importance of enacting a dedicated national CB regulation in Türkiye. Such a legal framework would clearly define the responsibilities of public authorities and operators, formalize technical standards, and ensure uniform application of the system nationwide, critical elements for ensuring the reliability of CB alerts in real-world emergencies.

4.3 After the Alert: Protective Actions and Immediate Impact in the Scenario

In this simulated scenario, the period following the transmission of the Cell Broadcast (CB) alert represents the most critical phase in disaster response. This is the narrow time window during which individuals have the opportunity to take protective measures before destructive seismic waves arrive. The subsections that follow describe how the alert enables life-saving actions, the expected responses in high-risk districts, and the limitations that may affect outcomes.

To better illustrate the structure and sequence of these operations, Table 1 summarizes the key operational stages of the CB system, from seismic detection to user reception. It highlights how automated processes, rapid coordination between authorities and operators, and immediate delivery of alerts to mobile devices combine to create a brief but vital opportunity for protective action. The table illustrates the sequential flow of operations that supports the system's potential to reduce casualties and injuries in a major earthquake.

Table 1 Operational Flow of CB System in the Scenario

Stage	Description
Seismic Detection	Sensors detect earthquake within 3–6 seconds and send data to ERREWS
Message Preparation	Predefined template selected; auto-approved within 1–2 seconds
Operator Coordination	BTK signals operators; CBSC relays message to base stations
Broadcast Transmission	Message sent to all devices in target cells simultaneously
User Reception	Alert appears with loud tone and vibration; visible until dismissed
Expected User Action	Immediate protective measures (e.g. move away from buildings)

4.3.1 Immediate Public Response

Upon receiving the CB message, residents in the affected areas are alerted through loud tones, vibrations, and full-screen notifications that override device locks and active applications. The clear and concise warning prompts immediate reactions.

Those already awake, as well as individuals awakened by the alert, begin moving toward open spaces, away from high-risk structures such as older residential buildings and glass-fronted commercial properties. Parents assist children; people guide elderly family members; and in public spaces, bystanders may support one another. The alert effectively interrupts routine activities, helping to focus attention on survival within the narrow protective window available.

4.3.2 Protective Outcomes in High-Risk Districts

In districts such as Avcılar, Küçükçekmece, Bakırköy, and Zeytinburnu, where building stock is older and ground conditions amplify seismic risks, the CB system provides vital seconds for residents to take life-saving actions. The simulation envisions a significant proportion of individuals managing to exit unsafe buildings, move away from hazardous facades, or position themselves in safer zones such as courtyards or parks.

The early alert is particularly effective in preventing injuries and fatalities from falling debris, shattered glass, and structural collapse. In scenarios where prior drills or public awareness campaigns have prepared the community, the benefits of these protective actions are further amplified.

4.3.3 Limitations and Critical Dependencies

The protective impact of the CB alert depends on several critical factors. First, individuals with disabilities, elderly residents, or those living alone may face difficulties in responding rapidly to the warning. Urban design and environmental features such as narrow streets, densely packed buildings, or a lack of accessible open spaces can further limit the effectiveness of protective actions.

4.3.3.1 User-Side Impact

The success of CB alerts relies not only on message delivery but also on how individuals perceive, understand, and respond to the notification. In this simulation, most residents who receive the alert respond by attempting to move to open spaces or safer zones. However, variations in individual risk perception, prior experience with emergency alerts, and cultural factors may lead to differences in reaction time and appropriateness of protective actions. The scenario underscores the importance of combining CB deployment with public education campaigns to improve user response.

4.3.3.2 Accessibility for Vulnerable Groups

Certain segments of the population, including elderly residents, children, persons with disabilities, and those unfamiliar with the language of the alert, may face additional challenges in responding effectively. In the simulated scenario, these groups may require assistance from family members, neighbors, or emergency personnel to act on the alert.

Moreover, while CB messages are designed for maximum visibility and audibility, further integration with assistive technologies such as vibrating wearables, smart home systems, or multilingual support would enhance inclusivity and ensure that no group is left unprotected during a disaster.

4.4 Final Evaluation of the Scenario and Comparison with Alternative Systems

This section provides an overall evaluation of the simulated Cell Broadcast (CB) scenario and compares it with alternative emergency communication methods.

4.4.1 Scenario Evaluation and Key Findings

The simulated Cell Broadcast (CB) model for earthquake early warning in Istanbul demonstrates the potential of mobile technology to provide life-saving seconds in the face of a major disaster. The scenario highlights the operational strengths of the system: rapid automated activation, predefined message templates, coordinated distribution through mobile network operators, and broad population coverage via existing 4G and 5G infrastructure. These components, when functioning as intended, enable the dissemination of critical warnings within seconds of seismic detection, offering residents in high-risk districts a brief but vital window for protective action.

However, the scenario also reveals key limitations that would need to be addressed for real-world implementation. The system's effectiveness is highly dependent on the resilience of mobile network infrastructure, including the power supply and redundancy of base stations and Cell Broadcast Service Centers (CBSCs). Damage to these components during a disaster could disrupt message delivery at the very moment it is most needed.

Moreover, the protective impact of the alert hinges on user-side factors such as awareness, risk perception, and the ability to act quickly. Vulnerable groups, including the elderly, persons with disabilities, and non-native speakers may face barriers to effective response despite receiving the message. Urban design challenges, such as limited access to open spaces, can further constrain the protective actions of the public.

Finally, the scenario underscores the need for stronger regulatory frameworks and integration with broader disaster preparedness efforts. While Türkiye's current regulations provide a foundation for CB use, dedicated legislation, regular drills, public education campaigns, and investment in infrastructure resilience are essential to translate this simulation into a reliable real-world system.

4.4.2 Comparative Analysis with Alternative Alert Systems

Compared to SMS and mobile app notifications, Cell Broadcast (CB) offers significant advantages in delivery speed, network independence, and geographic targeting. While SMS is prone to delays during network congestion, and mobile app notifications depend on prior installation and internet availability, CB can deliver critical alerts to millions of users within seconds. However, the overall effectiveness of CB still depends on the resilience of network infrastructure and the public's ability to understand and act upon alerts. Therefore, combining CB with additional channels such as sirens, media broadcasts, and social media platforms would provide a more robust and inclusive disaster communication system.

Table 2 presents a comparison of CB, SMS, and mobile app notifications based on key operational criteria. The table highlights how CB outperforms these alternative methods in terms of speed, network independence, targeting accuracy, and resilience under disaster conditions. It also shows that while CB has clear advantages, no single system is sufficient on its own. A multi-channel approach is essential to ensure that alerts reach the largest possible audience and provide reliable guidance during emergencies.

Table 2 Comparative Analysis of Emergency Alert Methods

Criteria	Cell Broadcast (CB)	SMS	Mobile App Notifications
Delivery Speed	Very fast (seconds); unaffected by network congestion	Slow under network load; prone to delays	Variable; depends on internet availability
Targeting	Location-based; no user registration required	Individual phone numbers; no location focus	Only users with installed apps
Network Dependence	Independent of network traffic	Affected by network congestion	Requires mobile data or Wi-Fi
Coverage	All compatible devices in broadcast area	Only recipients in database	Only app users; limited to installed base
Accessibility	Works on 4G/5G devices; multilingual support possible	No standard multilingual feature	Depends on app design; can offer multi-language
User Action Required	None (automatic display on screen)	Must open message	Must install app beforehand; may require opening
Resilience During Disaster	High if infrastructure intact; requires functional CBSC	Low; high failure risk under overload	Low; dependent on data infrastructure

4.5 Use of Cell Broadcast in Different Disaster Scenarios in Türkiye

Although Cell Broadcast (CB) technology is often highlighted for its role in earthquake early warning, its technical design and operational flexibility make it applicable to a wide range of disaster scenarios.

The system's ability to deliver location-specific, rapid, and congestion-free messages allows it to support timely communication in events such as floods, wildfires, industrial accidents, terrorist attacks, and public health emergencies. This versatility positions CB as a key tool for comprehensive disaster risk reduction and management strategies.

Given Türkiye's geographical diversity and exposure to multiple types of hazards, the broader potential of CB technology should be considered in national emergency planning. Integrating CB into various emergency protocols would enhance the country's overall preparedness and ensure that critical alerts reach affected populations quickly and efficiently, regardless of the type of threat.

4.5.1 Tsunami and Flood Warning Systems

Underwater earthquakes in the Marmara and Aegean Seas present a considerable tsunami threat to Türkiye's coastal regions. When rapid sea level changes are detected by monitoring stations operated by Kandilli Observatory and AFAD, Cell Broadcast (CB) messages can be immediately transmitted through coastal base stations to alert populations at risk. In such scenarios, where the window for protective action may be limited to only a few minutes, the ability of CB to deliver rapid, location-specific alerts becomes critically important for minimizing casualties.

Similarly, in the Black Sea and Eastern Black Sea regions, where flash floods occur frequently due to intense rainfall, integrating CB technology with meteorological early warning systems could play a vital role in reducing loss of life and property. The system's capacity for regional targeting ensures that only affected areas receive alerts, thereby preventing unnecessary panic while ensuring timely protective action.

4.5.2 Industrial Accidents and Chemical Leaks

Türkiye's industrial zones, particularly those near urban centers, include facilities that handle hazardous chemicals, flammable materials, and pressurized gases. While incidents such as fires, gas leaks, or explosions are generally localized, their potential to escalate rapidly poses significant risks to surrounding communities.

The Cell Broadcast system's geo-fencing capability allows targeted alerts to be sent exclusively to base stations within the immediate danger zone. This ensures that only those at risk receive timely, location-specific instructions. For example, "Stay indoors," "Close all windows," or "Proceed to the nearest evacuation point."

Integrating CB technology into emergency response protocols for industrial zones, especially those adjacent to residential areas, enhances not only public safety but also demonstrates corporate social responsibility. It reinforces the obligation of industrial operators to protect surrounding populations and contribute to community resilience through proactive communication strategies.

4.5.3 Terrorist Attacks, Public Safety Incidents, and Mass Panic

Cell Broadcast (CB) technology can play a crucial role in managing sudden, human-induced emergencies such as terrorist attacks, bomb threats, or armed assaults in high-density locations like stadiums, airports, or city centers. In these scenarios, the ability to issue immediate, location-specific instructions, whether to evacuate or shelter in place, is vital for protecting lives. Unlike mobile apps or social media, which may be delayed or inaccessible during such events, CB ensures rapid, targeted communication through base stations covering the affected area.

By limiting alerts to nearby cells, CB helps guide people to safety while minimizing the risk of unnecessary panic in unaffected regions. Integrating CB into public safety protocols enhances the responsiveness of security forces and emergency managers, providing a valuable tool for crisis communication during unpredictable, high-stakes incidents.

4.5.4 Forest Fires and Rural Disasters

Forest fires, particularly common in Türkiye's Aegean and Mediterranean regions during the summer months, pose severe risks to rural settlements, agricultural areas, and critical infrastructure. In such scenarios, residents are often geographically isolated and may lack timely access to conventional media channels such as television, radio, or the internet.

Cell Broadcast (CB) messages provide a direct, reliable means of communication, enabling authorities to deliver evacuation orders or protective guidance within seconds, thereby accelerating decision-making and potentially saving lives.

5. General Conclusion and Recommendations

This thesis has provided a comprehensive analysis of the potential role of Cell Broadcast (CB) technology in strengthening Türkiye's disaster communication and early warning systems. The study began by highlighting the critical importance of timely, reliable communication in disaster scenarios, with particular emphasis on Türkiye's vulnerability to natural and human-induced hazards. It reviewed the historical development of CB technology, its adoption in international contexts, and the status of disaster notification systems currently in use in Türkiye.

A scenario-based simulation of a major earthquake in Istanbul formed the core of the analysis, enabling a realistic exploration of CB technology's operational flow, from seismic detection and message preparation to transmission and user response. The study identified both the strengths of CB technology, such as rapid delivery, location-based targeting, and immunity to network congestion, and its limitations, including infrastructure dependencies, regulatory gaps, and the need for greater public awareness.

Ultimately, the thesis concludes that while Türkiye possesses many of the technical components necessary for a functional CB-based early warning system, achieving its full potential requires coordinated efforts across technology, governance, and public engagement domains.

5.1 General Evaluation

The findings of this thesis demonstrate that Cell Broadcast technology could serve as a vital tool in Türkiye's disaster risk reduction efforts. The scenario-based simulation confirmed that, when integrated with seismic detection networks, CB systems are capable of providing precious seconds of early warning that can enable protective actions and save lives, especially in high-risk urban districts.

However, the study also revealed several challenges that must be addressed to ensure success. These include the resilience and redundancy of mobile network infrastructure, legal and regulatory clarity regarding CB use, seamless coordination among public authorities and operators, and the need for sustained public education to ensure that alerts prompt appropriate responses.

The thesis underscores that CB technology should not be viewed as a standalone solution but as part of a broader, multi-layered disaster communication and early warning strategy for Türkiye.

5.2 Recommendations for Implementation

Based on the study's findings, the following recommendations are proposed to support the effective deployment of Cell Broadcast technology in Türkiye:

5.2.1 Enhance Infrastructure Resilience

Investments are needed in redundant CB Service Centers (CBSCs), backup power supplies for base stations, and disaster-hardened network components to ensure operational continuity during emergencies. This includes geographically distributed CBSC facilities to prevent total system failure if one site is compromised. Operators should also prioritize the use of alternative energy solutions, such as solar or battery backups, to sustain communications during prolonged power outages. Additionally, regular maintenance and stress testing of infrastructure under simulated disaster conditions would help identify vulnerabilities and improve overall system robustness.

5.2.2 Establish a Dedicated Regulatory Framework

Türkiye should adopt comprehensive legislation that formally integrates Cell Broadcast technology into the national disaster communication system. Such regulation should define the specific roles and responsibilities of public authorities, mobile operators, and regulatory agencies, while also standardizing technical parameters to ensure interoperability. Clear legal mandates would eliminate ambiguity during crises, enabling rapid and coordinated action. The framework should also establish accountability mechanisms to ensure compliance and provide guidelines for data privacy, message authentication, and public transparency regarding the use of CB alerts.

5.2.3 Promote Public Awareness and Education

Public education is critical to the success of Cell Broadcast systems. National awareness campaigns should inform citizens about what CB alerts are, how to recognize them, and what immediate actions to take when an alert is received. These efforts should include multimedia materials, integration into school disaster preparedness curricula, and community-based workshops. Regular nationwide and regional drills involving CB messages would reinforce learning and build public trust, ensuring that people do not ignore or misunderstand alerts during real emergencies. Partnerships with media and civil society organizations could further amplify these efforts.

5.2.4 Integrate CB with Multi-hazard Systems

Cell Broadcast should not be limited to earthquake scenarios but should be integrated into early warning protocols for a wide range of hazards. This includes floods, wildfires, tsunamis, industrial accidents, and terrorist incidents. Developing hazard-specific CB message templates and pre-coordination plans with relevant agencies would allow for rapid, context-sensitive alerting.

5.2.5 Prioritize Inclusivity and Accessibility

Ensuring that Cell Broadcast systems are accessible to all segments of the population is essential for equitable disaster risk reduction. CB systems should support multilingual alerts to accommodate Türkiye’s linguistic diversity and high volume of international visitors. Moreover, integration with assistive technologies, such as screen readers, vibrating wearables, smart home devices, and visual notification systems, would help ensure that persons with disabilities receive and can act upon alerts. Authorities should also consult with disability advocacy groups to refine accessibility features and test them in real-world conditions before full-scale implementation.

5.3 Future Work

Future research should focus on conducting dynamic simulations using real-time seismic data and network performance metrics to refine operational timelines and improve system models. Pilot tests and live drills involving Cell Broadcast systems could provide empirical data on delivery speed, user engagement, and technical performance under stress conditions.

Further studies could explore the integration of CB technology with next-generation communication solutions, such as Non-Terrestrial Networks (NTNs), satellite-based systems, and smart city infrastructure, to enhance the reach, reliability, and adaptability of early warning mechanisms in Türkiye's disaster management framework.

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