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Cell Broadcast for Early Warning Systems:
A review of the technology and how to implement it

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A note on terminology

In this report, early warning systems (EWS), public warning systems (PWS) and multi-hazard warning systems (MHWS) are referred to collectively as EWS.

Although EWS come in many sizes and forms, in this report, EWS should be generally understood as a national-level, multi-hazard early warning system.

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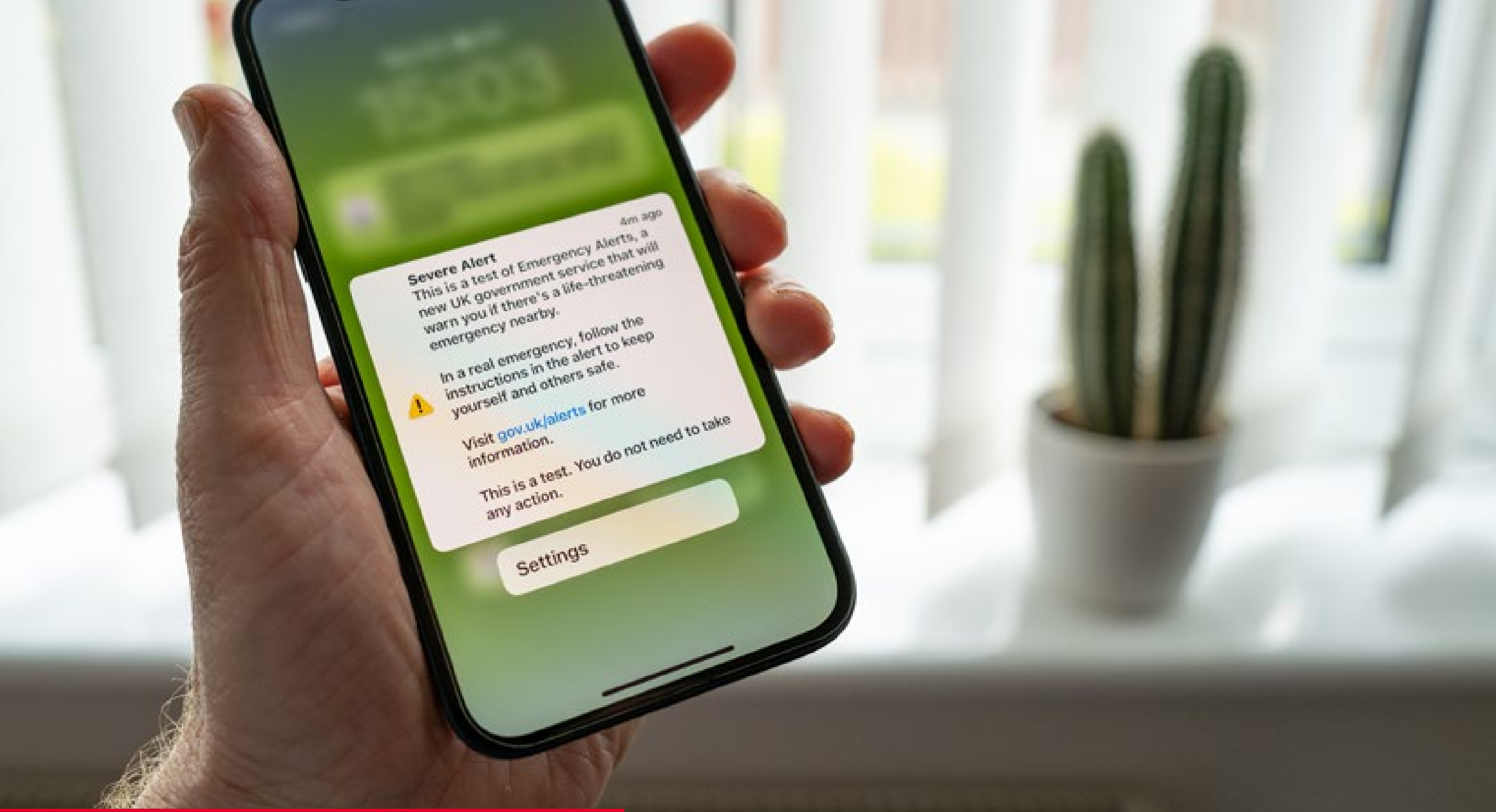
Contents

	Executive summary	2
	Introduction	5
1.	What is cell broadcast and how does it work?	8
	Overview of cell broadcast technology and cell broadcast-enabled early warning systems	9
2.	Innovation in cell broadcast	15
3.	Key considerations and recommendations	19
	Operational considerations	21
	Technical considerations	23
	Financial considerations	28
	User-facing considerations	33
	Conclusion	36



Executive summary

Early warning systems (EWS) save lives when disaster strikes. They provide critical advance notice of impending hazards and crises, enabling people to take swift and appropriate action to protect themselves, their families and their communities. Mobile technology, particularly cell broadcast (CB),[1] has played a pivotal role in EWS for more than two decades.

As the United Nations (UN) Secretary General leads a global commitment to expand EWS coverage and humanitarian response efforts shift increasingly towards anticipatory action, assessing how CB technology has evolved is key. It will provide a greater understanding of new and emerging opportunities, as well as prevailing challenges, in leveraging CB technology as part of an effective EWS.

CB has gained recognition for its ability to deliver targeted warnings based on location, avoid network congestion and ensure that users are alerted to critical information with audible alerts and on-screen messages. It is a key channel to disseminate information. However, to successfully reach everyone at risk, multi-channel systems are essential. CB can and should be used in conjunction with other channels, such as location-based SMS (LB-SMS), radio, television and sirens. CB complements these channels, and the Common Alerting Protocol (CAP)[2] should be implemented across channels to ensure harmonisation.

At its core, CB is a technology that allows mobile network infrastructure to communicate with mobile handsets in one direction. As part of day-to-day network functionality, cell towers communicate with mobile handsets within their reach, providing information such as the network they are currently connected to. Usually, this information is invisible to the handset user and exists only to enable the network to function on connected handsets.

1 Also referred to as a cell broadcast service (CBS)

2 The Common Alerting Protocol (CAP) is the international (ITU) standardised format for emergency alerts and public warnings, developed by OASIS, to allow messages to be sent over multiple channels.

However, CB has several characteristics that make it well suited to EWS:

Strengths of CB

One-to-many	Cell broadcast messages (CBMs) are disseminated from a mobile network's radio cells rather than to a specific mobile device. CB works on a one-to-many basis.
Rapid distribution	A CBM can be distributed to millions of compatible handsets in just a few seconds. It does not cause network congestion and cannot be affected by it.
Geographically targeted distribution	The specified target area for a CBM can be anywhere from a single radio cell (and even smaller when using geofencing technology, as discussed in chapter 2) to an entire mobile network. Because it uses a network's radio cells, CB is a location-based technology. Messages can be set to broadcast repeatedly over a defined period, so handsets entering the target/at-risk area will receive the message even if they arrive after the initial alert is sent.[3] Handsets in the target area will not receive the alert twice.
Audible and visual alert	CBMs for national alerting systems can be configured to sound an audible and unique alert tone, overriding silencing/mute settings. CBMs appear automatically on the screen of a mobile handset without needing to be opened, providing a visual alert.
Privacy conscious	A CBM is anonymous by nature and will be received by any compatible phone in the target area. Because the message is broadcast to the user equipment and not the mobile number, no pre-registration is required and no mobile subscriber information is used or stored in the broadcast of the message.[4] **"A broadcast is blind, so we don't know where you are. Data privacy is a huge advantage of cell broadcast."** – Cross-cutting expert
Secure/difficult to infiltrate or replicate	Unlike an SMS, it is very difficult to fake a CBM. Physical protection of CB facilities and authorisation stages can reduce the risk of impersonation.
Reach	Since CB can be automatically enabled on user handsets and does not usually require users to opt in, it has the power to reach many users, especially compared to services that require users to download or subscribe to a service.

3 Intersec. (12 August 2018). "Cell broadcast".
4 One2Many. (n.d.). Why Cell Broadcast is More Important than Ever for Emergency Alerting!

To leverage CB for EWS effectively, there are several important considerations. These can be grouped into four main categories – operational, technical, financial and user-facing – and are summarised in Table 1 below and explored in greater depth in this report.

Table 1
Considerations for leveraging CB in EWS

Operational	How should partners collaborate? What role do standards and regulations play?
Technical	Is CB an appropriate channel? What are the limitations in terms of message dissemination? What are the handset requirements, and are handsets compatible with CB systems? How does CB interact with existing network infrastructure? How resilient is network infrastructure? Is there adequate network coverage?
Financial	What are the costs of implementing a CB-enabled EWS? Who pays for the system? Is there a choice between third-party vendors and a DIY approach? Do cost-saving measures exist?
User-facing	How can communities be made aware of EWS? How can stakeholders create a culture of risk? How can stakeholders ensure CB-enabled EWS are accessible? How can stakeholders build and maintain trust in CB-enabled EWS and messages?

While there are technical weaknesses to CB, many of the drawbacks highlighted in this research have either already been addressed through industry standards and will therefore decrease naturally over time as handsets and networks modernise, or they are being addressed through innovation. Technical limitations are not the main challenges of leveraging CB effectively for EWS, however. Rather, financing CB-enabled EWS, coordinating stakeholders effectively and ensuring the public is educated about the system and aware of the risks, are perhaps the biggest stumbling blocks. Strong government leadership, clear roles and responsibilities of partners, effective awareness-raising campaigns and sustainable financing for both initial set-up and ongoing maintenance, are all critical.

Introduction

Early warning systems (EWS) save lives. They provide critical advance notice of impending hazards, enabling people to take swift and appropriate action to protect themselves, their families and their communities from disasters. Mobile technology, particularly cell broadcast (CB), has played a pivotal role in EWS for nearly two decades.

CB has gained recognition as a critical EWS channel for its ability to rapidly deliver targeted location-based warnings, avoid network congestion and ensure that recipients are alerted to critical information with audible and unique alerts and on-screen messages. As the importance of anticipatory action becomes clearer, and the United Nations (UN) spearheads a global commitment to ensure everyone on Earth is protected by an EWS by 2027, understanding the potential of CB for EWS is crucial. This report will present the opportunities, challenges and considerations associated with CB-enabled EWS.

Natural hazards, preparedness and early warning

Disasters and natural hazards cause loss of life and life-changing injury, as well as destruction of property, infrastructure and livelihoods. As the number of people exposed to climate-related hazards continues to rise, the risks are greater than ever before. Natural hazards have increased by a factor of five over a 50-year period, driven by climate change, more extreme weather and improved reporting.[5] In 2022, there were 387 recorded natural hazards and disasters[6] worldwide, resulting in the loss of 30,704 lives and affecting 185 million individuals.[7] The total death toll in 2022 was three times higher than in 2021, and below the 2002–2021 average of 60,955 deaths. This average is already set to be exceeded in 2023.[8]

Against this backdrop is a concerted focus on enhancing preparedness and building resilience. EWS are one of the most immediate and substantial tools to save lives in the face of climate change. The United Nations Office for Disaster Risk Reduction (UNDRR) calculates that every dollar invested in risk reduction and prevention can save up to $15 in post-disaster recovery.[9] While every disaster situation is different, in certain contexts, just 24 hours' notice of a hazardous event can cut damages by 30%, and it is suggested that spending just $800 million on EWS in low-income countries would avoid losses of $3 billion to $16 billion a year.[10]

Recognising the life-saving potential of EWS, in March 2022, the UN launched the Early Warnings for All (EW4A) initiative.[11] The aim of EW4A, led by the World Meteorological Organization (WMO) and UNDRR, is that every person in the world should be protected by an EWS by 2027.

The fundamental purpose of an EWS is to ensure people receive warnings in advance of hazardous events, so that they can take necessary actions to save their lives and livelihoods and support longer-term resilience.[12] Multi-channel systems with multiple dissemination techniques are essential to reach as many people in at-risk areas as possible. While the number of disasters has increased in the past 50 years, the number of deaths has decreased by almost three times thanks to improved early warnings and disaster management.[13]

Advances in telecommunications and connectivity have been a major contributing factor.[14] Today, 95% of the world's population is covered by a mobile network, there are 5.4 billion unique mobile subscribers and almost three out of four people own a mobile phone.[15] As a critical communication channel, mobile plays a key role throughout the entire cycle of disasters and emergencies, from preparedness and resilience-building to response and recovery, enabling access to critical information and the ability to maintain contact with loved ones and emergency services.[16] Mobile technology has been recognised as playing a particularly important role in the dissemination and communication of early warnings.

5 WMO. (2021). WMO Atlas of Mortality and Economic Losses from Weather, Climate, and Water Extremes 1970–2019.
6 CRED defines a disaster as "a situation or event that overwhelms local capacity, necessitating a request at the national or international level for external assistance; it is an unforeseen and often sudden event that causes great damage, destruction and human suffering."
7 CRED. (2023). 2022 Disasters in Numbers.
8 OCHA. (February 2023). "Türkiye/Syria: Earthquakes - Feb 2023"
9 UNDRR. (n.d.). "Our impact".
10 It is worth noting that there has been some caution around the use of these statistics: Stephens, L. (2023). "Are we stating the facts? Tracing the origins of early warning statistics".
11 WMO. (2022). Early Warnings for All: Executive Action Plan 2023–2027.
12 WMO. (2021). WMO Atlas of Mortality and Economic Losses from Weather, Climate, and Water Extremes 1970–2019.
13 Ibid.
14 H.E. Prof. Petteri Taalas, Secretary-General, World Meteorological Organization, comments on the launch of EW4All.
15 GSMA. (2023). The Mobile Economy 2023.
16 GSMA. (2023). Mobile for Humanitarian Innovation: Annual Report 2023.

Box 1

Definition of an early warning system

"An integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of hazardous events."

– As defined 1 December 2016 by Resolution 69/284, United Nations General Assembly[17]

This report focuses specifically on the dissemination and communication of early warnings. The monitoring and forecasting of hazards, as well as disaster response, are core elements of EWS but beyond the scope of this research.

Two mobile-based technologies are best suited to disseminating and communicating warning messages: cell broadcast (CB) and location-based SMS (LB-SMS). While these mobile channels are critical, it is important to recognise that mobile alone will not be sufficient. Multi-channel EWS are essential to ensure the maximum number of people are reached. Channels like radio, television, billboards, satellites, social media and sirens, all serve an important purpose, and each have strengths that can be leveraged for certain contexts and use cases. Only by leveraging multiple channels can everyone at risk be reached.

Cell broadcast

This report focuses on the potential of CB technology as a channel for facilitating and disseminating EWS. Developed in 1988 and first used for the distribution of early warning messages in 2005, the technology has been celebrated for attributes that lend it so well to this purpose. While it has limitations, as discussed later, continued development and innovation have expanded its potential. This report outlines the current state of play for CB-enabled EWS, providing a follow-up to a GSMA report on CB published in 2013.[18]

Methodology

This report is based on the findings of a desk-based literature review and key informant interviews (KIIs). A total of 18 individuals were interviewed as part of this research, representing organisations from the mobile industry, disaster risk reduction (DRR) sector, as well as other experts and practitioners. More than 50 research reports and other relevant publications, including guides, blogs and informational materials, were reviewed.

Overview of report

This report is divided into three chapters. Chapter 1, ***What is cell broadcast and how does it work?*** provides an overview of cell broadcast technology, its key components and how it works in the context of EWS.

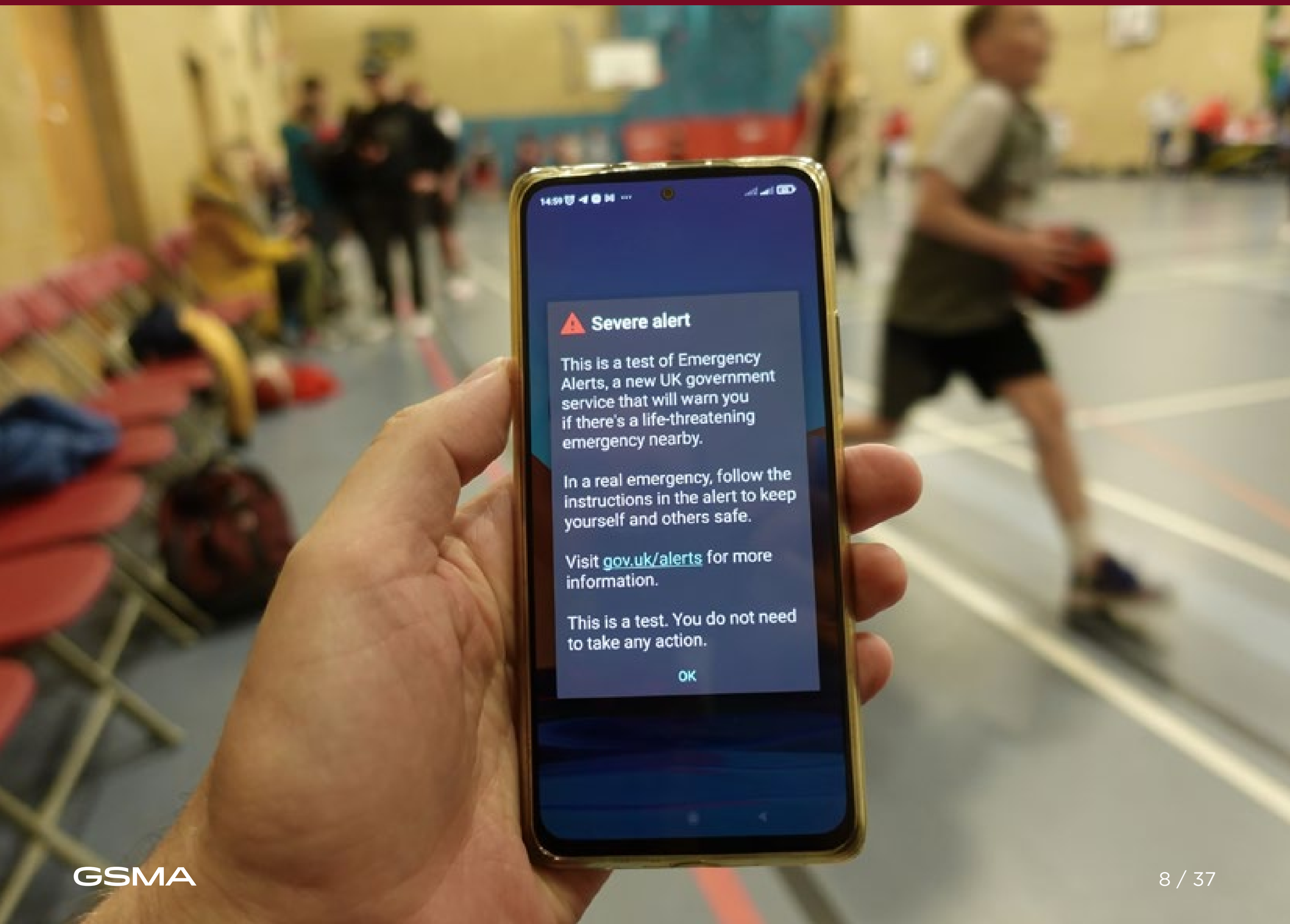
Chapter 2, ***Innovation in cell broadcast***, profiles emerging innovations that are increasing the utility, impact and resilience of CB-enabled EWS, and improving how it can be implemented.

Chapter 3, ***Key considerations and recommendations***, lays out key considerations related to the planning, development, implementation and management of CB-enabled EWS. These considerations are divided into four categories: operational, technical, financial and user-facing. The report concludes with a summary of the primary findings.

17 UNISDR. (2009). 2009 UNISDR Terminology on Disaster Risk Reduction.
18 GSMA. (2013). Mobile Network Public Warning Systems and the Rise of Cell Broadcast.

01

What is cell broadcast and how does it work?



According to the Cell Broadcast standards of the European Telecommunications Standards Institute (ETSI), early warning systems should have the following characteristics:[19]

- Reach the maximum proportion of a population
- No download/sign-up necessary, including for visitors (national and international)
- Location-specific information to be received during a crisis in specific areas
- Fast delivery
- Should always work, even if the mobile network is congested or network access is barred
- Should not compromise privacy
- Only government agencies should be able to issue alerts
- Attract the public's attention and initiate a call to action
- Adhere to international standards
- Be free to receive (i.e. no cost should be associated with the service)

Since CB has many of these characteristics, it has been recognised as particularly well suited to EWS. This chapter will provide an overview of CB technology, its key components and how it functions in the dissemination of early warning alerts.

Overview of cell broadcast technology and cell broadcast-enabled early warning systems

At its core, CB is a technology that allows mobile network infrastructure to communicate with mobile handsets in one direction. As part of day-to-day network functionality, cell towers, hereafter referred to simply as cells, communicate with mobile handsets within their reach, providing information such as the network it is currently connected to. Usually, this information is invisible to the handset user and exists only to enable the network to function as it should.

The communication of information from cells to handsets, and the technology that enables it, are known broadly as "cell broadcast". CB standards are defined by ETSI and the 3rd Generation Partnership Project (3GPP), and are part of 2G, 3G, 4G LTE and 5G mobile standards.[20] CB is defined by a technical standard, 3GPP TS 23.041, "Technical realization of Cell Broadcast Service (CBS)".[21] This standard outlines the norms and requirements for how the technology functions and how it can be used.

With the addition of interfacing network infrastructure, CB technology can be leveraged by mobile network operators (MNOs) to send short messages across their networks. Unlike SMS, which is a one-to-one channel, CB is a one-to-many technology. This means that one message can be sent to millions of devices within a few seconds. CB works by distributing content via specific cell sites based on a subscriber's location. Unlike SMS, CB does not require a phone number to send a message. It therefore enables location-specific emergency alerts to be sent without the need to register or track devices. As well as being more private than SMS, visitors to the target area, including from abroad, will also receive alerts, and even in their own language if the system is multi-language enabled.[22] Messages of up to 1,395 characters can be shared.

The advantages of using CB for this purpose are detailed in Table 2. Combined, these factors make CB an ideal channel for sharing early warning messages. Naturally, there are challenges and weaknesses associated with CB as a channel for EWS. These will be discussed in greater detail in chapter 3, which provides considerations and recommendations for implementing a CB-enabled EWS. It is important to note that multi-channel EWS are key to reaching the maximum number of people in an at-risk area. While CB is a key channel, it is most powerful when used in conjunction with others.

19 ETSI. (2018). ETSI TS 123 041 V15.2.0 (2018-06). Technical Specification.
20 The ETSI EMTEL committee (Committee on Emergency Telecommunications) has also produced the standard ETSI TS 102 900.
21 ETSI. (2018). ETSI TS 123 041 V15.2.0 (2018-06). Technical Specification.
22 One2Many. (n.d.). Why Cell Broadcast is More Important than Ever for Emergency Alerting!

Table 2
Strengths of CB

	One-to-many	Cell broadcast messages (CBMs) are disseminated from a mobile network's radio cells rather than to a specific mobile device. CB works on a one-to-many basis.
	Rapid distribution	A CBM can be distributed to millions of compatible handsets in just a few seconds. It does not cause network congestion and cannot be affected by it.
	Geographically targeted distribution	The specified target area for a CBM can be anywhere from a single radio cell (and even smaller when using geofencing technology, as discussed in chapter 2) to an entire mobile network. Because it uses a network's radio cells, CB is a location-based technology. Messages can be set to broadcast repeatedly over a defined period, so handsets entering the target/at-risk area will receive the message even if they arrive after the initial alert is sent.[23] Handsets in the target area will not receive the alert twice.
	Audible and visual alert	CBMs for national alerting systems can be configured to sound an audible and unique alert tone, overriding silencing/mute settings. CBMs appear automatically on the screen of a mobile handset without needing to be opened, providing a visual alert.
	Privacy conscious	A CBM is anonymous by nature and will be received by any compatible phone in the target area. Because the message is broadcast to the user equipment and not the mobile number, no pre-registration is required and no mobile subscriber information is used or stored in the broadcast of the message.[24] **"A broadcast is blind, so we don't know where you are. Data privacy is a huge advantage of cell broadcast."** – Cross-cutting expert
	Secure/difficult to infiltrate or replicate	Unlike an SMS, it is very difficult to fake a CBM. Physical protection of CB facilities and authorisation stages can reduce the risk of impersonation.
	Reach	Since CB can be automatically enabled on user handsets and does not usually require users to opt in, it has the power to reach many users, especially compared to services that require users to download or subscribe to a service.

23 Intersec. (12 August 2018). "Cell broadcast".
24 One2Many. (n.d.). Why Cell Broadcast is More Important than Ever for Emergency Alerting!

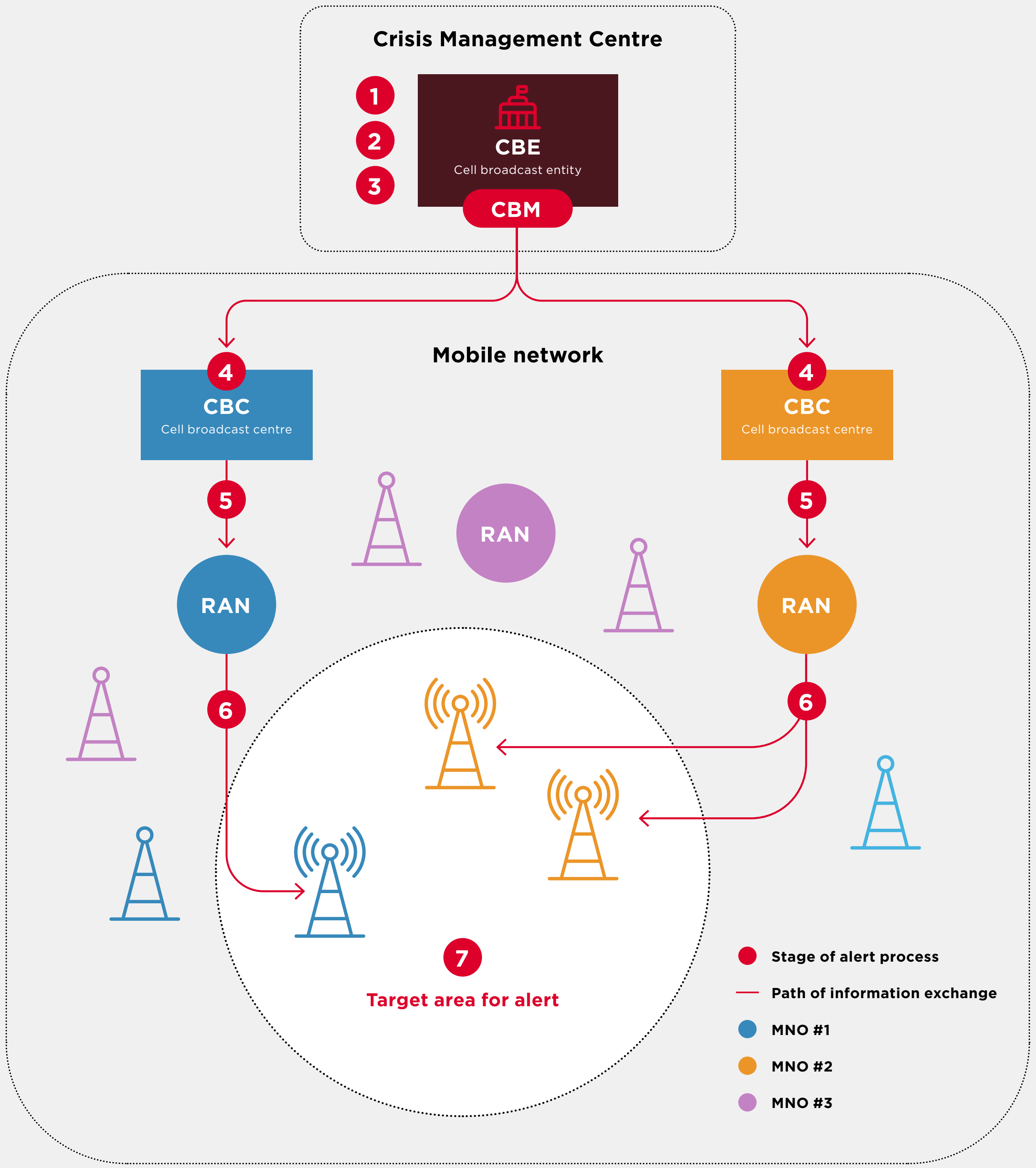
It is important to note that although the CBS standards are supported within mobile networks, they require specific equipment to be installed and integrated before a CB service can be provided to end users.[25] Therefore, to leverage CB effectively as a channel to send messages, investment in additional infrastructure is needed to enable a message to be created, prepared and delivered to the appropriate cell towers and end users. When an EWS is mono-channel, two main infrastructure components are required: cell broadcast entities (CBEs) and cell broadcast centres (CBCs). This infrastructure needs to be secured with both physical and authorisation access protection to prevent misuse or the broadcasting of unauthorised messages. When an EWS leverages multiple channels rather than a CBE, a command centre allows multiple communication channels to interface.

Figure 1 shows the information exchange of a CBM, from creation in the CBE to delivery to the target cell.

25 Everbridge. (n.d.). What does it cost to build an in-house Public Warning System front end? The true cost of "Do It Yourself" (DIY).

Figure 1

Path of information exchange of a CBM



* RAN = Radio Access Network

Note: Figure 1 shows a decentralised system. As discussed below, a centralised, CB-enabled EWS is possible. In that case, the CBC would sit within the Crisis Management Centre (CMC).

1. Alerting authorities, typically a government or public safety body, decide to issue an alert, usually based on the analysis of data related to a potential threat.

   Note: Messages should follow the CAP format (see Box 2) so that they can be disseminated in a harmonised way across multiple channels.

2. Usually operating in a CMC or similar, a CBM will be created.

   Note: It is best practice that the templates for these messages are created in advance, with input from relevant subject matter and communication and behavioural experts, and pre-approved for use if certain criteria are met.

3. The CBM is created on a CBE. This is a front-end application that allows a CBM to be created and defined. This includes the content of the message and the definition of the target delivery area.

4. Once the CBM and target area are defined, the message is sent and the CBE communicates this information via an authenticator, who verifies the sender and authenticates the message for the CBC. The CBC is made up of both hardware and software and connects to the MNO's core network.[26]

   Note: Each MNO requires a CBC within their network (known as a decentralised system) unless they opt to share a CBC (known as a centralised system). In practice, most MNOs opt for a decentralised system due to the privacy and security concerns associated with sharing one point of access to multiple mobile networks.

5. Each CBC determines for the network which cell towers within the target area are needed to broadcast the CBM and communicates with the corresponding Radio Access Network (RAN) controllers, determining which network technologies are required to successfully broadcast the CBM to those locations. The RAN controller is the entity in the MNO's radio network that manages a group of cells and distributes the CBM to the target cells.

6. The message is broadcast via cell towers in the target area, transmitting the CBM to every handset within this area.

7. The message is received on every handset in the target area at the same time.

Box 2

Common Alerting Protocol

The Common Alerting Protocol (CAP) is the international (ITU) standardised format for emergency alerts and public warnings, developed by OASIS, to allow messages to be sent over multiple channels.[27] It was designed to enable interoperability between emergency information and warning systems, and the efficient exchange of key facts across multiple networks and different warning channels. It provides a template to ensure that the information transmitted over multiple delivery systems is consistent.[28]

To publish a CAP emergency warning, an alerting authority enters key facts into a form that is designed to cover all types of emergencies, and then posts that warning to an internet newsfeed.[29] CAP reduces costs and operational complexity by eliminating the need for multiple custom software interfaces to the many warning sources and dissemination systems involved in all-hazard warnings.

"CAP is a protocol, but it enables an ecosystem that's extremely important."

– Cross-cutting expert[30]

Given the important role that CAP plays in facilitating interoperability between warning systems, it is essential that it is implemented when developing and implementing CB-enabled EWS.

26 Celltick. (n.d.). "CBC – Cell Broadcast Center".
27 OASIS. (1 July 2010). Common Alerting Protocol Version 1.2, OASIS Standard.
28 Ibid.
29 UNDRR. "The Common Alerting Protocol (CAP)".
30 Stakeholder interview, technical cross-cutting expert

Case study

Dialog Sri Lanka: an early CB adopter

In December 2004, an enormous earthquake off the coast of Sumatra, Indonesia, caused a tsunami that devastated the region. It remains one of the deadliest disasters ever recorded, killing almost 250,000 people. Sri Lanka was the second most-affected country, after Indonesia; 35,000 people were killed. While there was a 90-minute window between the earthquake and the arrival of the first waves in Sri Lanka, there was no warning mechanism in place. By some estimates, up to 85% of the lives lost could have been saved if an EWS had been in place in 2004.[31]

Recognising this gap, in 2005, Dialog Axiata, Sri Lanka's largest MNO, joined forces with MicroImage and the University of Moratuwa to look into creating the first-ever EWS using GSM networks. Together, they created the Disaster and Emergency Warning Network, or DEWN. The first version had two main components. First, a CB alerting system for the general population that could share warning messages in Tamil, Sinhala and English. Since most of the population had feature phones at the time, CB was the obvious technology to reach the largest number of people quickly and avoid network congestion. The second component was physical devices placed in divisional secretariats or community centres. The devices included small screens that could display 60-character messages sent via CB, along with radio capabilities, an SOS function to send a user's location, an alarm and a light. The device stored various templates based on disaster type, which could be customised to relevant circumstances.

By 2014, Sri Lanka's mobile landscape had shifted as many in the country transitioned to smartphones and the country upgraded to 4G. This created new challenges for CB as network infrastructure had to be upgraded to maintain CB capability and CB was not automatically enabled on most first-generation smartphone handsets.[32] By 2017, DEWN officially retired the use of CB and, instead, leveraged the increased capabilities of smartphones to develop a new version of the EWS: DEWN 2.0.[33]

DEWN 2.0 included three main components: tower-mounted loudspeakers along the coastline, the DEWN app and an SMS-based government alert network. Dialog has encountered multiple challenges with the new system, including sustaining and maintaining it. The number of app downloads have been very low (3,600 in a population of 22 million), and efforts to promote the app have had minimal impact. This has resulted in alerts being sent via the app and few in the risk area receiving it.[34]

As Dialog reflects on the successes and challenges of the DEWN system, it is clear there may still be a role for CB. "We're at a crossroads of how to give the next life to DEWN. It's timely to have this review, bring the parties together to look at how we make it more tech ready and replicate the UK type model otherwise it will have natural death and it won't be relevant," said Supun Weerasinghe, CEO of Dialog Axiata.

Given recent advancements and the increasingly standard use of CB technology in EWS, Dialog Axiata is considering reintroducing CB as a channel to share DEWN warnings.[35]

31 GSMA. (2015). DEWN: Dialog's Disaster and Emergency Warning Network.
32 Stakeholder interview, technical expert
33 Stakeholder interview, MNO
34 Stakeholder interview, MNO
35 Stakeholder interview, MNO

02

Innovation in cell broadcast

While the core technology behind CB and its functionality has remained much the same,[36] innovative research and new developments are now underway. This chapter provides a snapshot of some of these innovations.

Device-based geofencing

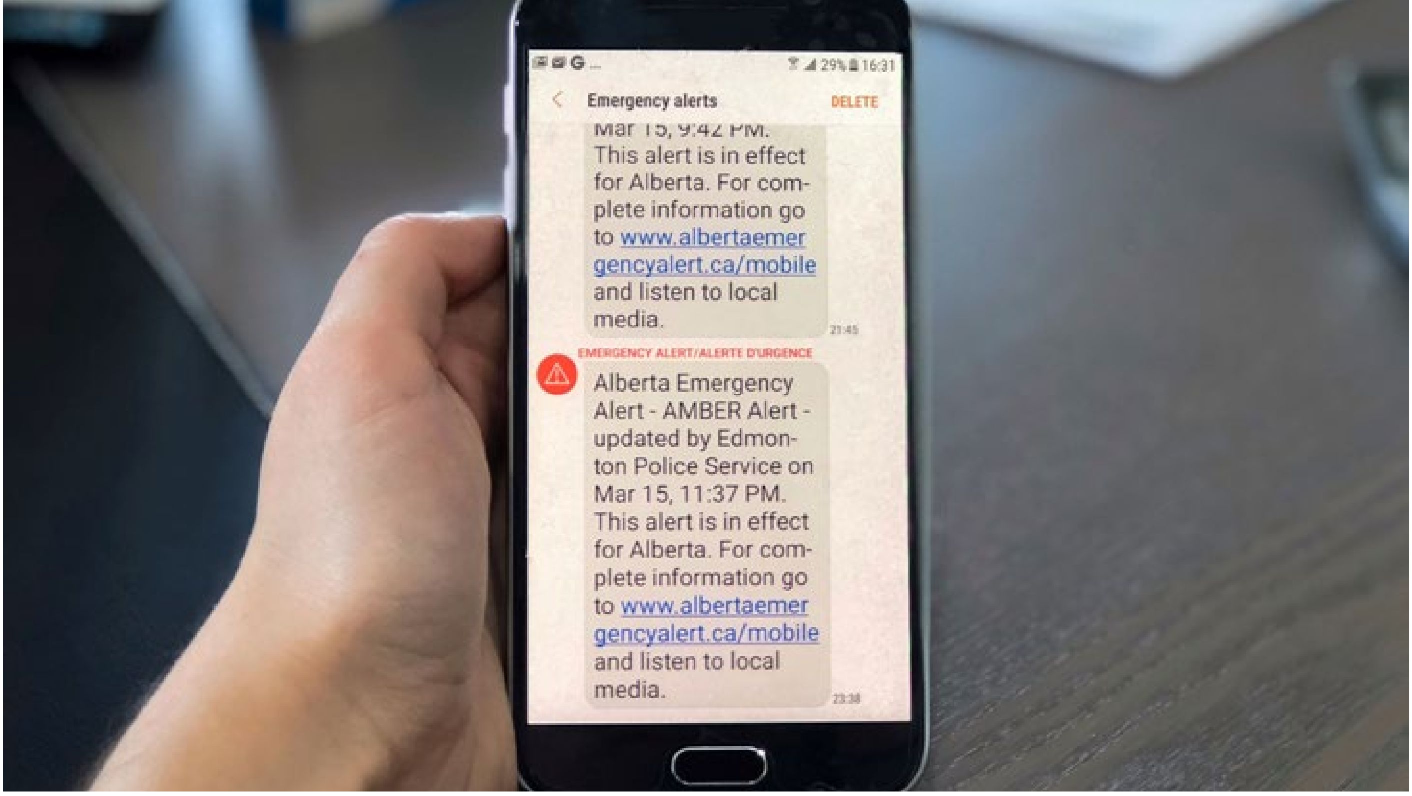
A geofence is a virtual perimeter created to demarcate a real-world geographic area. Geofencing technologies are improving the accuracy and specificity of CB alerts and are being implemented around the world. While CB has been based on drawing polygons and circles within a network that broadcast CBMs, geofencing can create a more granular target area with more narrowly drawn polygons.[37]

Improvements in location accuracy and geofencing extend the opportunity for CB-enabled EWS to reach those in need with highly targeted information. Enhanced targeting also reduces panic and alert fatigue, both of which can threaten the efficacy of, and trust in, public warnings.[38] For example, sending a warning message to a large area may trigger evacuations even for those not in danger, leading to blocked roads and impeding response efforts.[39] In addition, community members who frequently receive warnings that do not apply to them may grow frustrated and opt out of receiving emergency alerts via the settings on their handset. Research on this issue has found that individuals are more likely to take protective action when warnings are more targeted.[40]

Geofencing is an area that is benefiting from the application of artificial intelligence (AI). For example, a generative model based on deep learning can automatically create coordinates of emergency broadcasts to avoid over- or undershooting.[41] In future, AI may also support advanced processes that determine how appropriate a warning message is for an individual based on their likely surroundings and context.[42]

However, advancements in geolocation raise important privacy questions. To maintain public trust, careful attention should be paid to data anonymisation, transparency and other ethical principles to ensure user protection.[43] Best practice would be to restrict AI applications to emergency warning use only.

36 Multiple stakeholder interviews with digital humanitarian, MNO, regulatory, technical and satellite experts
37 One2Many. (n.d.). How Device-Based Geo-Fencing Works to Improve Emergency Alert Accuracy.
38 Stakeholder interviewees noted the importance of narrowing the alert area to prevent people from becoming annoyed by unnecessary alerts.
39 Raths, D. (January/February 2019). "Next-Generation Emergency Alerts – What's Working Where?" Government Technology.
40 Nagele, D.E. and Trainor, J.E. (2021). "Geographic specificity, tornadoes, and protective action".
41 Lee, S. and Donghyeok A. (2021). "Applying a deep learning enhanced public warning system to deal with COVID-19".
42 The National Academies of Sciences, Engineering, and Medicine. (2018). "Chapter 2: Building an Integrated Alert and Warning Ecosystem". Emergency Alert and Warning Systems: Current Knowledge and Future Research Directions. The National Academies Press.
43 GSMA. (2022). The AI Ethics Playbook.



Footprinting, or situational awareness

In a CB-enabled EWS, "footprinting" is the act of taking a regular snapshot (or footprint) of the handsets in a CB polygon at a certain time. This makes it possible to send a CBM to those handsets later even if they are no longer in the CB target area. Unlike a regular CB, this creates a store of handset-related data, which has privacy implications. However, this information is only stored in the network temporarily and does not leave the system. The phone number associated with the handset is not collected or stored.

One use of this technology overcomes a limitation of CB: its inability to provide follow-up communication to individuals who receive an initial message. While it is possible with LB-SMS to send a subsequent message to all the numbers that received an initial message regardless of their current location, this is not usually possible with CB. For example, if an evacuation order is broadcast to an area, a subsequent alert could be sent to tell evacuees that it is safe to return. Footprinting also enables a count of compatible handsets in a target area at a specific time, which can support response efforts.

Smart switching

Several public warning systems (PWS) providers use algorithms that automatically switch between CB and SMS to deliver warnings based on several contextual factors. The solution addresses a major challenge of EWS: knowing which communities are best reached by which channels. The Everbridge Public Warning Platform, for example, automates the selection of SMS, CB or both, to reach certain cell towers and the greatest number of people in the target population. The algorithm estimates the time it will take to disseminate messages on different channels (depending on the channel technology, generation of mobile network, congestion and demographic characteristics).[44]

This allows messages that are less urgent to be sent via LB-SMS (if it meets all the other parameters). However, if there is so much network congestion that the message will not be received by all handsets within the parameters, then the system will switch to CB to ensure the alert is received across the entire target area in a timely manner. Depending on the scenario and if it can be sent quickly, this system can help prevent the overuse of CB in situations where an LB-SMS would suffice. However, for this system to work, both CB and LB-SMS must be implemented. This may require separate technical implementations in the network infrastructure, which are not in place in many countries. The patent has been approved and implemented in Norway.[45]

44 Everbridge. (5 March 2021). "Everbridge Awarded Revolutionary New Public Warning Patent for Technology that Automates the Selection of the Optimal Communications Channels to Reach the Broadest Hyper-targeted Populations – as Fast as Possible – During a Crisis".

45 Ibid.

Non-terrestrial networks

Developments in the non-terrestrial network (NTN) sector, including satellites and high-altitude platform systems (HAPS), are creating a range of opportunities for EWS.[46] For example, satellites carrying infrastructure, including network equipment, have made it possible to transmit messages from space. While this type of solution may still require partnerships with MNOs, it has several advantages, including the ability to provide coverage in areas without adequate terrestrial mobile infrastructure. It can also remove the risk posed by damage to networks or loss of power and add redundancy options for terrestrial networks. There are also NTN-based solutions that do not require a partnership with MNOs, such as the Galileo Global Navigation Satellite System (GNSS) and other low Earth orbit (LEO) satellites. The potential of satellite technology to extend the reach of early warnings and target them to within 2 to 3 metres makes this is an EWS innovation to watch.[47]

Symbols and images

While CB technical standards initially only allowed the dissemination of text-based messages, the 3GPP has looked into expanding these capabilities, which is now possible with 5G. The enhancement of public warning systems (ePWS) focuses largely on this,[48] and the Federal Communications Commission (FCC) in the US is exploring how images and maps might be incorporated into broadcast messaging.

"We believe handsets today have the capabilities to do what we want them to do. For example, one of the things that we're asking for is for wireless emergency alerts to be able to display a map showing the recipients location, against a backdrop of the alert area."[49]

– CB technical expert

Language and text-to-speech capabilities

One accessibility feature of CB-enabled EWS on the horizon is greater language flexibility. Text-to-speech systems have become common and are already being used to disseminate forecast or warning information through screen-reading functionality. The FCC is looking into adding text-to-speech capabilities to heir CB-based Wireless Emergency Alert system to better reach individuals with visual impairments.[50] As part of this process, the FCC is gathering information on challenges with accuracy, reliability and pronunciation, and accommodating multiple languages in text-to-speech.

Access needs

Engineers at PWS providers also foresee providing more targeted messaging to individuals with specific access needs. For example, it might be possible for a user to identify themselves as a wheelchair user on their handset. In the event of an early warning alert, that user could receive a context-specific alert with wheelchair-accessible advice on an evacuation route.[51] Likewise, among European PWS providers there are discussions of how to better include people with hearing impairments, for whom the unique tone of CB does not add value. Discreet notifications (discussed in the next section) could be more appropriate, informative and inclusive.[52]

Discreet notifications

Another area being explored is how to best send discreet CB alerts that do not sound an alarm or create attention. Use cases include terrorist incidents or active shooter situations where an alert directing an evacuation must not inadvertently reveal the location of individuals taking cover in the immediate vicinity.[53]

46 Costella, G. et al. (August 2022). Beyond Borders: Satellite Applications for Humanitarian Emergencies. Caribou Space.
47 Stakeholder interview, MNO
48 See: 3GPP TR 23.735; TS22.268[17] and TS23.041[16]
49 Stakeholder interview, government expert
50 FCC. (21 June 2023). "Emergency Alert System; Wireless Emergency Alerts: A Proposed Rule by the Federal Communications Commission". Federal Register: The Daily Journal of the United States Government.
51 Stakeholder interview, PWS provider
52 Documented in ETSI TS 102 900.
53 Stakeholder interview, government expert

03

Key considerations and recommendations

This chapter outlines critical challenges and considerations related to the planning, development, implementation and management of CB-enabled EWS. Several key considerations emerged from the research that can either be key enablers of, or barriers to, the successful implementation of CB-enabled EWS. These considerations are categorised as Operational, Financial, Technical and User-facing.

It is important to note that this is not a guide to designing and implementing a CB-enabled EWS. Rather, it provides a starting point for stakeholders to identify issues that should be carefully examined when they are working to implement a successful CB-enabled EWS.

Table 3
Considerations for leveraging CB in EWS

Operational	How should partners collaborate? What role do standards and regulations play?
Technical	Is CB an appropriate channel? What are the limitations in terms of message dissemination? What are the handset requirements, and are handsets compatible with CB systems? How does CB interact with existing network infrastructure? How resilient is network infrastructure? Is there adequate network coverage?
Financial	What are the costs of implementing a CB-enabled EWS? Who pays for the system? Is there a choice between third-party vendors and a DIY approach? Do cost-saving measures exist?
User-facing	How can communities be made aware of EWS? How can stakeholders create a culture of risk? How can stakeholders ensure CB-enabled EWS are accessible? How can stakeholders build and maintain trust in CB-enabled EWS and messages?

Operational considerations

Managing an EWS can be a complex process involving many stakeholders. To standardise and clarify processes, there are several issues that need to be considered. While this is not an exhaustive list, the following considerations highlight important aspects of operationalising a CB-enabled EWS.

How should partners collaborate?

"There are only a few technical challenges for cell broadcast, whereas the main challenges are linked to operationalising them, and related political issues."
– Regulatory expert

By their very nature, most EWS are the result of a coalition of organisations working in partnership. There is strength to be found in partnerships that bring together the public and private sector, and their respective resources, expertise and abilities, for humanitarian outcomes. However, forging cross-sector partnerships can be challenging. Organisations often have objectives, ways of working and language that are not aligned, making it difficult to find common ground.[54] Previous GSMA research has found that, to be successful, partnerships in the digital humanitarian sector need to identify shared value, align expectations, use a shared language and allow sufficient time for implementation.[55] An effective CB-enabled EWS requires the collaboration of multiple stakeholders, as this ensures that potential challenges and opportunities are well understood, different capabilities and needs can be planned for and expectations met.

It is also critical to have strong and decisive leadership and ownership of the planning and implementation process. From an operational perspective, it is critical to identify a designated alerting authority(ies) and that there are clear processes in place for how an alert will be triggered and authorised.

For optimal results, it is advisable that either a government entity, such as a Disaster Management Authority, Civil Protection Agency or another dedicated, EWS-focused, government-mandated organisation, take the lead. A frequent challenge is a clash of competencies or lack of effective coordination between government agencies or local agencies.[56] These challenges often translate into lengthy delays in implementation.[57] Clear leadership helps to ensure that the competing interests of various stakeholders are managed effectively and sustain the momentum needed for success.

Considerations

Working in partnership, stakeholders from government, the public and private sectors, as well as humanitarian and technical experts, can combine their resources, expertise and abilities to create effective EWS. Working in collaboration, key stakeholders can ensure that potential challenges and opportunities are well understood, different capabilities and needs can be planned for and expectations met. Clear leadership provides accountability and direction and can smooth the process.

- Critical stakeholders should be mapped early in the process and invited to collaborate
- All stakeholders should adopt principles for effective collaboration and work to add value to the process
- Leadership, whether a government stakeholder or other, should be clearly identified

54 GSMA. (2023). "The GSMA Humanitarian Partnership Framework".
55 Baah, B. and Downer, M. (2020). Partnering During Crisis: The Shared Value of Partnerships between Mobile Network Operators and Humanitarian Organisations. GSMA.
56 Stakeholder interview, regulatory expert
57 Dugan, E. (6 April 2023). "'Sound that could save your life': UK disaster alert to buzz phones on 23 April". The Guardian.

What role do standards and regulations play?

CB is defined in a range of standards,[58] namely 3GPP TS 23.041 version 18.2.0, published in September 2023,[59] and ETSI TS 102 900, the main European standard for CB (EU-Alert). The former includes specifications for integrating CB in the standards for 2G, 3G, 4G and 5G. The European Emergency Number Association (EENA) also documents available solutions and reviews certain use cases for the European Union (EU).[60]

Standardised protocols have been developed to manage the effective implementation of EWS, including CAP and the CBS. Developed in response to lessons from the past two decades, these standards allow CB and CB-enabled EWS to be implemented smoothly and effectively. Incorporating them, even when they may not be a regulatory requirement, will ensure that new EWS incorporate best practices and technical standards, and that, where necessary, are interoperable.

In addition to standards, careful attention should be paid to existing national regulation. In many countries where there is not specific, EWS-focused regulation, regulators are moving towards implementing certain positions. Anticipating and designing systems that intend to align with potential regulation can "future proof" investment. For MNOs, working hand-in-hand with the regulator as these systems are designed can also be a positive way to approach implementation. Since MNOs may be mandated to do this, they should be proactive in the conversation.

For example, a recent EU Directive[61] requires all EU and European Economic Area (EEA) countries to implement EWS using mobile network communication channels by June 2022. While many EU governments and MNOs were already exploring EWS, the directive provides renewed emphasis and a set of essential criteria. Best practice suggests a legal framework should be in place to cover interactions between agencies and the authorisation of alerts. For example, regulation in many countries provides MNOs with indemnity against liability if false alerts are sent over their networks by alerting authorities.[62]

Considerations

Regulation has been credited with ushering in EWS in countries that did not previously have systems in place, therefore increasing EWS coverage. However, in some cases, it has also left room for interpretation, leading to long negotiations between key stakeholders. The inclusion of various technical specifications within standards is ensuring consistency and helping to overcome technical challenges once associated with CB.

- Where regulation on EWS is in place, all stakeholders should actively engage to implement systems that fulfil these requirements and deliver effective EWS
- Where regulation is not in place, MNOs should work proactively with government to design suitable systems for the context
- In countries where technical challenges or compatibility issues remain a barrier to CB being a widely available channel for EWS, regulation should be put in place to ensure handset manufacturers prioritise CB for EWS

58 One2Many. (2021). "Standards".
59 3GPP. (1999). "Technical realization of Cell Broadcast Service (CBS)".
60 European Emergency Number Association (EENA). (2019). Public Warning Systems: Update.
61 Directive 2018/1972 establishing the European Electronic Communications Code.
62 World Bank Group. (2023). A Strategic Roadmap for Advancing Multi-hazard Impact-based Early Warning Systems and Services in the Caribbean.

Technical considerations

There are several factors that can influence whether an CB-enabled EWS is technically feasible and how it should be designed. While CB still has technical limitations or weaknesses as a channel, many of these have been addressed as new standards have been incorporated. For example, the standardisation of handset compatibility since 2012, as discussed in the next section.

Is CB an appropriate channel?

In any country, there should always be an early assessment of the right approach to EWS. This assessment is important because CB is not the most appropriate channel for all contexts. This could be due to several reasons, including mobile penetration, handset compatibility or upcoming upgrades to network infrastructure. The most appropriate channel will be the one that reaches the largest proportion of the population most effectively. Ultimately, the best system will be a multi-channel system capable of reaching the entire population.[63]

CB may also not be the right channel for all types of alerts. Since the unique sound makes it impossible for users to ignore and invites immediate action, CB may not be suitable for less urgent alerts, such as heatwaves, pandemics or pollution.

Considerations

While CB-enabled EWS can be highly effective, there are several contextual factors that will determine its reach and feasibility in a given country.

- Stakeholders should conduct an assessment to understand how appropriate a CB-enabled EWS would be in their country context, how it could be designed and implemented to maximise reach and impact and how this would affect the cost of the system
- Wherever possible, implement multi-channel EWS that can supplement CB alerts and ensure maximum reach

What are the limitations in terms of message dissemination?

While CB has many advantages that make it well suited to EWS, there are several technical limitations that should be considered. First, CB does not provide a read receipt, nor does it allow for two-way communication. It is also not possible to send a follow-up CBM to devices that received the first message, and users cannot respond to a CBM.[64] It is possible to include a call centre number or a weblink within a CBM to allow user engagement and two-way communication, but it is worth considering how many people may simultaneously try to engage with that information and overwhelm the network.[65]

Considerations

Consider ways to enable two-way communication, including increased investment in response capability. Innovations in footprinting may begin to address some of the challenges associated with follow-up messages.

63 Stakeholder interviews, regulatory expert and cross-cutting technical expert
64 This topic is discussed in chapter 2.
65 Stakeholder interview, regulatory expert

What are the handset requirements, and are handsets compatible with CB systems?

Handset capability is often identified as a potential challenge to implementing CB-enabled EWS,[66] as some handsets may not be compatible to receive alerts. However, this was standardised in mainstream devices in 2012,[67] and both Apple iOS and Android (Android 11 onwards) now include CB functionality by default.[68]

In some markets with high numbers of older handsets, there may be greater compatibility issues. This may also be the case in markets where a larger percentage of older phones remain in circulation. However, in most markets, this should become less of an issue as mobile handsets are gradually replaced with modern, compatible devices.

Several of the experts interviewed for the research noted that CB is not automatically enabled on every handset and that some users must first activate the function in their handset's settings before they can receive alerts. Since this could require a substantial marketing campaign to raise awareness and prompt users to switch on alerts, it is easier to work directly with handset manufacturers to ensure CB functionality is enabled by default. This is now the case for most mobile phones and, again, should become less of an issue as newer phones enter circulation.

It is also important to note that individuals can choose to switch off (opt out of receiving) CBMs by navigating through their handset settings.[69] Given the potential for subscribers to opt out if they feel overwhelmed or simply irritated by the volume of messages they receive, commercial use of CB is not advised.

Considerations

Handset compatibility and default device settings can mean that early warning CBMs will not be received by every mobile phone user. While this challenge has been addressed, in part, with the inclusion of CB technology in handset standards, this is not universally applied. In markets where it is, compatibility challenges should be relatively low and decrease over time.

- Efforts should be made to foster a clear understanding of the mobile handset landscape in each country prior to implementation
- Handset manufacturers that do not yet include CB functionality should do so, and it should be activated by default
- Stakeholders can advocate for these changes when necessary, and governments can regulate them
- In parallel and where required, all stakeholders can support public awareness campaigns aimed at encouraging populations to opt in to CB alerts

66 Stakeholder interviews, MNO
67 Stakeholder interview, PWS provider
68 One2Many. (n.d.). Why Cell Broadcast is More Important than Ever for Emergency Alerting!
69 There are, however, some types of alerts, called "Presidential Alerts", that end users cannot opt out of receiving.

How does CB interact with existing network infrastructure?

Although CB is built into all network generations[70] (2G, 3G, 4G, 5G), the infrastructure required to run it on these networks is not uniform, and MNOs will not be able to leverage CB-enabled EWS on their networks without investment. Typically, EWS run on either 2G/3G or 4G/5G networks. If a system is installed and operating on 2G/3G, it will require additional investment before it can operate across 4G/5G. As MNOs around the world make network upgrades to introduce 5G,[71] decisions will need to be made about whether to implement a CB-enabled EWS on 2G/3G or wait until 4G/5G is prevalent enough. Otherwise, the system may have a short lifespan before requiring major upgrades[72] as MNOs will eventually phase out 2G and 3G networks.[73]

Systems also need to be interoperable. While standards such as CAP help to maintain consistency across systems, governments will still likely have requirements for how the system will operate and its capabilities. This necessitates technical collaboration between all entities involved to ensure the necessary interoperability is in place, particularly if MNOs are using different vendors or pursuing in-house solutions.

Considerations

CB systems, whether for EWS or any other purpose, will require different infrastructure to operate on 2G/3G networks than 4G/5G networks. As mobile networks around the world upgrade to 4G/5G, a choice may need to be made to implement CB-enabled EWS on 2G/3G networks, 4G/5G networks or both. Implementing CB-enabled EWS across all networks would maximise reach, but may not be cost-efficient.

- MNOs and governments should discuss the most appropriate networks on which to implement a CB-enabled EWS, taking into consideration reach, handset compatibility and planned network upgrades
- Ensure systems are interoperable between entities

70 ETSI. (2018). ETSI TS 123 041 V15.2.0 (2018-06). Technical Specification.
71 Future Networks. "5G". GSMA.
72 Stakeholder interview, regulatory expert
73 Ofcom. (3 August 2022). "Switching off the UK's 3G mobile networks: what you need to know".

How resilient is network infrastructure?

A CB-enabled EWS ultimately depends on mobile network infrastructure, which can be vulnerable to certain types of disasters or service interruptions. In the event of extreme weather like cyclones or wildfires, cell towers can be damaged or destroyed and the functionality of the network badly affected or wiped out completely. In these cases, NTNs can play a vital role.

Geography can also affect network resilience. For example, if a single fibre connects two islands, the lack of redundancy creates increased vulnerabilities, leaving residents more at risk. For Small Island Developing States (SIDS), these challenges are compounded by a higher risk of disasters, as discussed in Box 3.

Box 3

Small Island Developing States

Small Island Developing States (SIDS) make up less than 1% of the global population but bear the disproportionate impacts of natural hazards and disasters, like cyclones and hurricanes, making them key actors in the implementation of CB-enabled EWS. Some island nations, such as the Solomon Islands, are made up of hundreds of small islands. Volcanic islands may be mountainous, whereas coral atolls may have a maximum elevation of only a few metres.[74] While these features vary across islands and countries, some may pose challenges to implementing and maintaining the network infrastructure on which CB depends. For example, greater distances between base stations and challenging terrain can increase the implementation and maintenance costs for MNOs,[75] and equipment on remote or less populated islands may be more difficult to maintain properly.[76] While individual cell towers are capable of covering multiple islands if they are close enough together, it may be challenging to sustainably fund the implementation and maintenance of CB-enabled EWS.[77] In these instances, a regional system might be a more appropriate solution, and can provide crucial points of redundancy for EWS[78] while also creating a single, standardised and secure source of alerts.

Considerations

It is important to build redundancy into networks, to leverage multi-channel systems and to have contingency plans in place for network disruption. This could include, for example, temporarily increasing power to the cell towers' neighbouring damaged or destroyed cells or leveraging NTNs as back-up.

CB-enabled EWS is only as reliable as the network on which it operates, and geographically challenging environments can limit network coverage or increase vulnerability to disasters. Where the core costs of CB infrastructure (including CBCs and CBEs) remain standardised, the cost of implementing a system in a small country can be similar to a larger implementation, making CB-enabled EWS comparatively more expensive.

- MNOs and governments should assess vulnerabilities in network infrastructure and, therefore, vulnerabilities in CB-enabled EWS coverage, and build in resiliency measures and redundancies
- Governments may wish to consider whether a regional CB-enabled EWS could overcome geographical challenges

74 Stakeholder interview, humanitarian connectivity expert
75 GSMA. (2023). The Mobile Economy Pacific Islands 2023.
76 GSMA. (2018). The 2017 Atlantic Hurricane Season: Mobile industry impact and response in the Caribbean.
77 Stakeholder interview, humanitarian connectivity expert
78 This is crucial because, in the event of a disaster, remote countries can be cut off from crucial communications, resources, services and support.

Is there adequate network coverage?

In areas with no network coverage, it is not possible to distribute a CB-enabled alert. In most contexts, local roaming agreements are in place to support locations where only one MNO provides coverage.

Where roaming is in place, a handset roaming on the network will receive the CB as if they were on their own network. This is also the case for international roaming.

Considerations

CB-enabled EWS will only provide early warning coverage to areas with network coverage unless satellite-enabled redundancy is in place.

- MNOs and governments should discuss whether gaps in network coverage place any limitations on an EWS, particularly in risk-prone areas where an early warning alert might be required
- Stakeholders should explore how a multi-channel EWS could help bridge coverage gaps in mobile-enabled systems

Financial considerations

What are the costs of implementing a CB-enabled system?

It is difficult to calculate the precise cost of implementing a CB-enabled EWS, given the range of factors that can affect price, including the number of networks (2G/3G, 4G/5G), type of system (centralised CBC or decentralised), size of the network (number of cell towers in the network), type of infrastructure in place and type of system being installed. The infrastructure required for each MNO will depend on these factors, and country-wide costs would need to take them all into account. It is also important to consider that there are both upfront costs and ongoing costs. Alongside the major, more visible costs, such as the infrastructure itself, there are also hidden costs, such as staff training, sensitisation campaigns and system maintenance.

A recent study in the Caribbean estimates that the cost per MNO might be, on average, £390,000 ($478,184) for a single CBC, although some experts expect it would be closer to £200,000 ($245,274).[79] There would then be additional integration costs per MNO and country-wide system, so upfront investment might be $1.2 million to $2.5 million for a country with three MNOs, although costs may vary depending on the maturity of the networks. Maintenance, rent and essential upgrades can be expected to require approximately £200,000 ($245,274) per year. However, these numbers can vary widely. A public overview of New Zealand's CB-enabled EWS by the vendor, Everbridge, put the total cost for the country's three MNO system, including CBCs, CBEs and software costs, at €6.8 million ($7.2 million), with an estimated annual budget of €1.9 million[80] ($2 million). Comparatively, the estimated cost for Samoa's CB-enabled EWS, albeit in 2012, including five-year maintenance and support, was $330,000.[81]

It is important to note that these costs could be quite different for larger countries, for countries with more or fewer MNOS and for MNOs with varying levels of maturity or the need for more complex systems. However, due to the essential requirements of the system (including the CBC and CBE), a very small country should not necessarily expect to have a smaller bill.

Considerations

A number of factors influence the anticipated cost of implementing a CB-enabled warning system. These can range from the number of MNOs that need to be integrated in the system, to the nature of the terms agreed with a third-party vendor to effectively manage the system.

While there are ways to control or reduce certain costs, other costs may be fixed or essential to implement a CB-enabled system. Although challenging to measure, estimates put the return on investment of EWS at 10 times their initial cost.[82] Considering the impact, the amounts listed above may seem modest.

- All involved stakeholders should participate in a detailed assessment of the most appropriate EWS for the country context and, as part of this process, gain a clear understanding of the costs involved
- Ideally, the effectiveness of the system and potential impact will always be more important than cost, although appropriate sources of funding will need to be identified
- Cost-saving measures such as shared infrastructure can be considered, as well as centralised versus decentralised systems, where possible

79 Stakeholder interviews, digital humanitarian and regulatory experts; World Bank Group. (2023). A Strategic Roadmap for Advancing Multi-hazard Impact-based Early Warning Systems and Services in the Caribbean.
80 One2Many. (n.d.). New Zealand's Nationwide Emergency Mobile Alert Project, Using Cell Broadcasting Technology.
81 HEAL, Apia, Samoa. (2012). Collaborative Tools for Emergency Response in a National Disaster.
82 Global Commission on Adaptation. (2019). Adapt Now: A Global Call for Leadership on Climate Resilience.

Who pays for the system?

This is one of the biggest questions to answer when planning a CB-enabled EWS.[83] Unresolved, this issue becomes a major stumbling block and can slow down planning and implementation. Many interviewees pointed out that if funding were not an issue, many of the other challenges associated with implementation would be more easily overcome.

A CB-enabled EWS implemented at the national level may be paid for by public funding or a mix of public and private funding. It may also be financed by international funders or development finance institutions (DFIs) that can support countries vulnerable to natural hazards with smaller national budgets. This can include both upfront investment costs as well as ongoing maintenance. In some cases, the national government will pay for the entire system, including operating costs. Where some costs are carried by MNOs, tax incentives could be put in place to offset this expenditure.

Considerations

Determining who is responsible for financing a CB-enabled EWS is not always straightforward. While different actors may have strong opinions, what is ultimately important is that these systems are implemented. There are multiple ways in which costs can be distributed, from one entity paying 100% of costs, to a cost-sharing model.

- All stakeholders should explore economically viable options for financing CB-enabled EWS. For low- and middle-income countries (LMICs), this includes exploring funding options from international donors and DFIs
- Creative financing options including Universal Service Funds, reducing licencing fees and in-kind contributions like the use of MNOs' core infrastructure, should all be taken into account
- Ongoing costs should be considered to ensure the system is sustainable in the long term

Is there a choice between third-party vendors and a do-it-yourself approach?

Mobile technology vendors will be able to supply MNOs with most of the network infrastructure needed to enable and support CB services. There are also several third-party vendors offering end-to-end service delivery for CB-enabled EWS, many of which combine CB and LB-SMS systems. It is possible for MNOs to build in-house systems, however, previous experience with CB and EWS and in-house capability should guide this decision, as it can be a costly and lengthy process. Vendors can also have the benefit of expertise from other implementations and lessons learned.

Considerations

Consider in-house and third-party vendor experience when making this decision.

- Stakeholders should consider whether they are able to develop a system themselves or if there is a vendor that could provide the desired capabilities and required level of ongoing support and management (and if they have the freedom to select their own CB vendor)
- If MNOs choose to pursue an in-house solution, they should ensure that:
  - It meets all government standards, particularly in relation to interoperability
  - It will perform as required and expected
  - They are aware of the potential hidden and ongoing costs, which may make a DIY system more costly over time and less effective than one provided via a vendor

83 Commonly referred to as the biggest challenge in stakeholder interviews.

Do cost-saving measures exist?

There are several approaches that may make CB-enabled EWS less costly to implement:

- **Cloud-based systems:** Rather than investing in physical infrastructure, CBC and CBE systems can be cloud based (CBEs often are). This would reduce costs associated with hardware, maintenance and server space, as well as enable greater redundancy. However, it still requires investment in cloud hosting. While cloud-based CBCs are possible in theory, not many appear to have been implemented as they are sensitive equipment connected to the core network (see the next point). However, a regional cloud-based system is being explored in the Caribbean.
- **Centralised systems:** In a centralised system, a single CBC feeds into multiple MNO networks as opposed to a decentralised system in which each MNO has a separate CBC in their own network. Given the costs associated with each CBC, only needing one CBC instead of three or four could be a significant upfront saving. However, centralised systems may cause concern for MNOs because they open their networks at a common access point. Since they consider this a risk, there are very few examples of MNOs opting for centralised systems.
- **Regional/multi-country systems:** An EWS that is shared by various countries in a region, as opposed to separate national systems, might mitigate some of the costs associated with infrastructure and leverage the potential for a cloud-based system. A regional system also opens the possibility of discounted rates with vendors and suppliers.[84] A regional approach is being explored by the Climate Risk and Early Warning Systems (CREWS) initiative,[85] with a focus on SIDS in the Caribbean. It should be noted that a regional system does not imply that governance issues are regional; all decisions to send an alert remain within the authority of a country.

Considerations

Cost-saving measures may make it faster and more feasible to implement a CB-enabled EWS. However, in certain cases, they may create undesirable operating conditions for key stakeholders, or even reduce the potential effectiveness of the EWS.

- Any trade-offs between cost-saving measures and impact should be weighed carefully

84 World Bank Group. (2023). A Strategic Roadmap for Advancing Multi-hazard Impact-based Early Warning Systems and Services in the Caribbean.
85 WMO. (2023). Climate Risk and Early Warning Systems (CREWS).

Case study

Telefonica Chile and Telefonica Germany: a market comparison

Telefonica is actively engaged in EWS in eight[86] of their 12 global markets. In six of these markets, CB technology is the channel. While Brazil and Ecuador currently rely only on LB-SMS for their EWS, the national regulator (ANATEL) and MNOs in Brazil have reached an agreement to implement CB by the end of 2023. Meanwhile, a December 2022 resolution by Ecuador's national regulator (ARCOTEL) establishes a period of 12 months for MNOs to implement the CB service (CBC) once they have been notified by the government's Integrated Security Service (ECU911) that the CBE has been installed Examples of CB-enabled EWS from two of Telefonica's markets – Chile and Germany – are shared below. These show the different regulatory, funding and governance arrangements tailored to these countries.

86 Chile, Brazil, Ecuador, Germany, Mexico, Peru, Spain and the UK

Country	Chile	Germany
MNO	Movistar (Telefonica)	O2 (Telefonica)
CB-EWS launch date	2011	2023
CB-EWS service	SAE (Emergency Alert System)	CB or DE-Alert
Alert-issuing authority	National Service for Disaster Prevention and Response (SENAPRED)	Federal Office of Civil Protection and Disaster Assistance (BBK)
Funding model	Mixed (public-private). The civil protection authority finances the CBE while MNOs cover the implementation and maintenance costs of adapting their network to receive the alerts and send them to subscribers. This includes funding the CBC and all ongoing maintenance.	The government reimburses the MNO for all expenses related to the implementation of the CB service in their networks, including the staff resources required. Ongoing maintenance costs are not reimbursed and must be covered by the MNO.
Regulation	• 2011 Telecom Law: MNOs are obliged to transmit emergency messages for free • 2017 Chile national regulator (SUBTEL) resolution: every phone sold in Chile must incorporate a multiband seal in their packaging identifying the network bands on which the MNO operates the EWS service. To approve the devices, a physical space/room is set up for vendors to test the compatibility of the devices with the CB service.	• 2018 European Electronic Communications Code (EECC): from 21 June 2022, MNOs must transmit public warnings about emergencies and disasters to citizens, if such systems are already in place • 2021 Transposition of EU Directive (art. 110 EECC): EU countries are required to implement by amending national Telecommunication Actd to require MNOs to implement and cooperate on PWS • An order issued by the German government regulates additional requirements for MNOs, such as security and redundancy requirements for the system, as well as specifications for the availability and response time of MNO service staff • A technical guideline issued by the national regulatory authority (BNetzA) defines the technical requirements of the system
Sensitisation	Telefonica provides information via the Movistar customer-facing website: Sistema de Alerta de Emergencias | Movistar To test the functioning, operability and scope of the Emergency Alert System for mobile phones, in 2021 SENAPRED established a calendar for community testing (every Thursday of the year at 11 a.m.).	Detailed information provided via the O2 customer facing website. A campaign was also conducted: Phase 1a (service testing) in November 2022: SMS sent prior to nationwide alarm trial with a link to the website Phase 1b (service testing) on 8 December 2022: nationwide test of CB with a test alert from the BBK Phase 2 (service launch) in February 2023: SMS alerting customers of service launch Phase 3 (annual awareness campaign): telecom operators must inform customers once a year of the existence of the service Annual test on the second Thursday of September.[87]

87 Warnung der Bevölkerung. (2023). "ISF Bund-Länder-Projekt Warnung der Bevölkerung".

User-facing considerations

Before a CB-enabled EWS is designed and ready for implementation, there are several key considerations about how the system will be managed, especially how it is communicated to the target population.

How can communities be made aware of EWS?

Sensitisation is a critical element of the design and launch of a CB-enabled EWS.[88] A balance must be struck between an alert attracting attention and prompting a response that causes panic. Individuals should immediately recognise an alert, not become indifferent to them or, worse, seek out the setting on their mobile phone to switch off alerts.

Given that CB can be an unfamiliar way to receive communications, it is important that the system is introduced with care. In many countries, CB-enabled EWS are trialled publicly as part of the implementation process and many also run annual awareness-raising events, including EWS tests.

Good sensitisation provides populations with information about the system in advance, explaining why it is important, how it will work in practice and what trials or tests will look like. Many MNOs choose to support the sensitisation process.

As mentioned earlier, it is important that users do not grow accustomed to CB messages. Overuse, or use for commercial purposes, risks reducing the impact of CBM or, worse, users opting out of CB capabilities through their handset. Limiting CB to severe emergency alerts can reduce these risks.

How can stakeholders create a culture of risk?

The experts we interviewed emphasised that EWS is not just about setting up an alerts system and then sharing an alert. A "culture of risk"[89] is also needed for people to respond to warning messages appropriately, to have a certain level of preparedness and to ensure that these systems provide the correct information in a timely manner to equip individuals to manage their safety during emergencies. Working with the media, for example, can be one way to raise public awareness.

Considerations

Public sensitisation is a critical element of implementing a CB-enabled EWS.

- MNOs, governments/Disaster Management Authorities (DMAs), the media and other key stakeholders should work together to design effective communication and awareness campaigns that introduce the EWS and CB, taking into account public familiarity with CB and EWS and using trustworthy sources of information
- Trials or tests should be conducted to demonstrate what an alert will look like if it is issued. These tests should be widely publicised, in cooperation with the media, to avoid causing alarm and may continue on an ongoing basis
- MNOs may choose to highlight and explain the role they play in the EWS with regards to providing the infrastructure, and the role of other stakeholders in creating the content and authorising alerts to be sent
- CBMs should be reserved for emergency purposes to reduce risks of message fatigue or users opting out of receiving messages

88 Smith, K.R., Grant, S. and Thomas, R.E. (2022). "Testing the public's response to receiving severe food warnings using simulated cell broadcast". Natural Hazards, 112, pp. 1611–1631.

89 Stakeholder interview, cross-cutting technical expert

How can trust in EWS be maintained?

Research has identified two primary types of scenarios that can erode trust in EWS: false alarms and near misses. A "false alarm" is an event that does not occur when a warning is issued. A "near miss" is an event without a warning that could have caused harm but did not.[90] The effect of false alarms and near misses on public trust has long been thought to be that when people become sceptical of warnings, they may become desensitised to the risk. Importantly, it has been found that public response to a single false alarm is different than repeated false alarms. If the public understands why a false alarm has happened, response to another warning will usually not decrease. Transparency can help mitigate scepticism and enhance trust in both the message and message source.[91]

With any human-led process, there is potential for error. While this risk can never be mitigated completely, additional levels of authorisation and approval can reduce the chance that messages are sent in error or that the content of alerts is not approved.

Ensuring that CB-enabled EWS are secure against security threats also reduces the opportunity for bad actors to abuse the system. Both physical and technology security measures are required, particularly where the CBE is hosted, as well as throughout the broader network. Human processes, such as requiring multiple levels of message approval, can prevent security breaches as well as human error.

Considerations

Trust is key to an effective CB-enabled EWS. Trust can be built and maintained in several ways, supported by the nature of CB, but it can also be easily damaged or lost.

- MNOs, governments/DMAs and other key stakeholders should work together to ensure that trust in the system is built and maintained
- Pre-approval processes can reduce the chances of messages being sent in error
- Training of alert issuers can also help to reduce errors
- Mistakes or errors should be addressed transparently to maintain or rebuild confidence and trust in the system. This responsibility lies with the messaging authority, but it is in the interest of all stakeholders to support.

90 Mackie, B. (n.d.). Briefing Note: False Alarms and Near Misses. UCL Warning Research Centre.
91 Ibid.

How can stakeholders ensure CB-enabled EWS are accessible?

Accessibility can be affected in many ways. People with disabilities, minority language speakers and those with lower literacy rates, for example, can all be excluded from accessing or acting on CB alerts. If systems are not designed to take these individuals into account, they risk excluding them.

As with any programme, designing for accessibility is key. Broadly speaking, inclusion in this context has two primary components: ensuring individuals can access mobile devices that receive CBMs, and ensuring CB alerts are comprehensible and relevant to all recipients.

Increasing accessibility can include removing barriers to handset access, increasing ownership and coverage, as well as access to power and digital literacy skills.[92] It can also mean removing technical barriers to a handset being CB-enabled, including working with manufacturers and operating systems to ensure capability is included and automatically set to opt in. Finally, the content of the CBM itself must be accessible and understood by recipients. In a multi-channel system, additional channels can complement CB to address some of these challenges, such as interactive voice response (IVR) to overcome literacy barriers.[93]

Language also plays a role in accessibility. If implemented within the CB infrastructure, there are currently two channel ranges – primary and secondary – that allow alerts to be disseminated in two languages. Work is underway to expand the language capability of CB.[94] When implemented, this would mean that, rather than receiving an alert in one of two languages, the language of the alert would be determined by the language settings on the individual's handset. Ensuring CB-enabled alerts can be sent in multiple languages increases the accessibility and reach of the entire EWS.

Considerations

Designing for inclusion is key to ensuring equitable access to CB-enabled EWS.

- Technical experts, MNOs and humanitarian/community organisations should come together to design systems that are appropriate and accessible for their context, and all stakeholders should consider accessibility in the design phase of the CB-enabled EWS
- Technological features that improve accessibility should be trialled and implemented if effective
- Community-based organisations can and should be involved in the design process to ensure the needs of the groups they represent are being considered
- Standards that increase the accessibility of CBM content, such as the inclusion of images or integration with screen readers, should continue to be explored
- Governments/DMAs should determine which language(s) a CB-enabled EWS should use and, if deemed necessary, multi-language systems should be explored, recognising that alerts are likely to be most impactful if they are received in the primary language of the recipient
- Solutions that allow CB-enabled alerts to be received in the language of the handset settings should continue to be developed

92 Casswell, J. (2019). The Digital Lives of Refugees. GSMA.; GSMA and UNHCR. (2023). The Digital Worlds of Displacement-Affected Communities; Bryant, J. (2022). Digital technologies and inclusion in humanitarian response. Overseas Development Institute (ODI).

93 Stakeholder interview, MNO

94 FCC. (21 June 2023). "Emergency Alert System; Wireless Emergency Alerts: A Proposed Rule by the Federal Communications Commission". Federal Register: The Daily Journal of the United States Government.

Conclusion

Leveraging MNO infrastructure, CB-enabled EWS have the ability to reach millions of people within seconds, delivering an attention-grabbing alert directly to their mobile phones. While the core components of CB have remained constant, advances have made it standardised, interoperable and accessible as a tool for disseminating early warnings. Many of the technical barriers identified by stakeholders, including handset incompatibility and opt-in requirements, will continue to decrease over time as the mobile ecosystem modernises and new handsets enter circulation. Meanwhile, innovation in CB continues to increase the accessibility, targeting capacities, resilience and overall utility of the channel for EWS.

Several overarching considerations emerged from this research:

1. Multi-channel EWS are essential to ensure everyone everywhere can be reached with emergency warnings. CB is one potential channel to leverage for EWS, but far from sufficient on its own. CB is most effective when used in conjunction with other digital and analogue dissemination channels.

2. EWS are most successful when a diverse set of stakeholders collaborate and bring together their unique competencies including, for example, DMAs, meteorological agencies, MNOs, satellite companies, third-party vendors, civil society organisations and humanitarian organisations. Government agencies should lead the process to initiate the implementation of CB and ensure smooth management.

3. Stakeholders, especially international donors and private-sector partners, should continue to invest in innovation and ensure that industry standards continue to support CB capabilities so that CB-enabled EWS can reach the maximum number of people possible. MNOs have a key role to play in supporting this work.

4. Financing initial set-up and ongoing costs may be the greatest barrier to implementing a CB-enabled EWS. Creative solutions that are viable in the long term should be explored with governments, donors and partners.

5. End users must be considered and involved from the start, from sensitisation campaigns, to creating a culture of risk in which the public is aware of hazards and emergency protocols, to accessible messaging.

CB creates significant opportunities to save lives as risks from climate change increase year on year. To fully realise the vision of the Early Warnings for All Initiative, addressing these considerations will be critical to move forward and maximise these opportunities.

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