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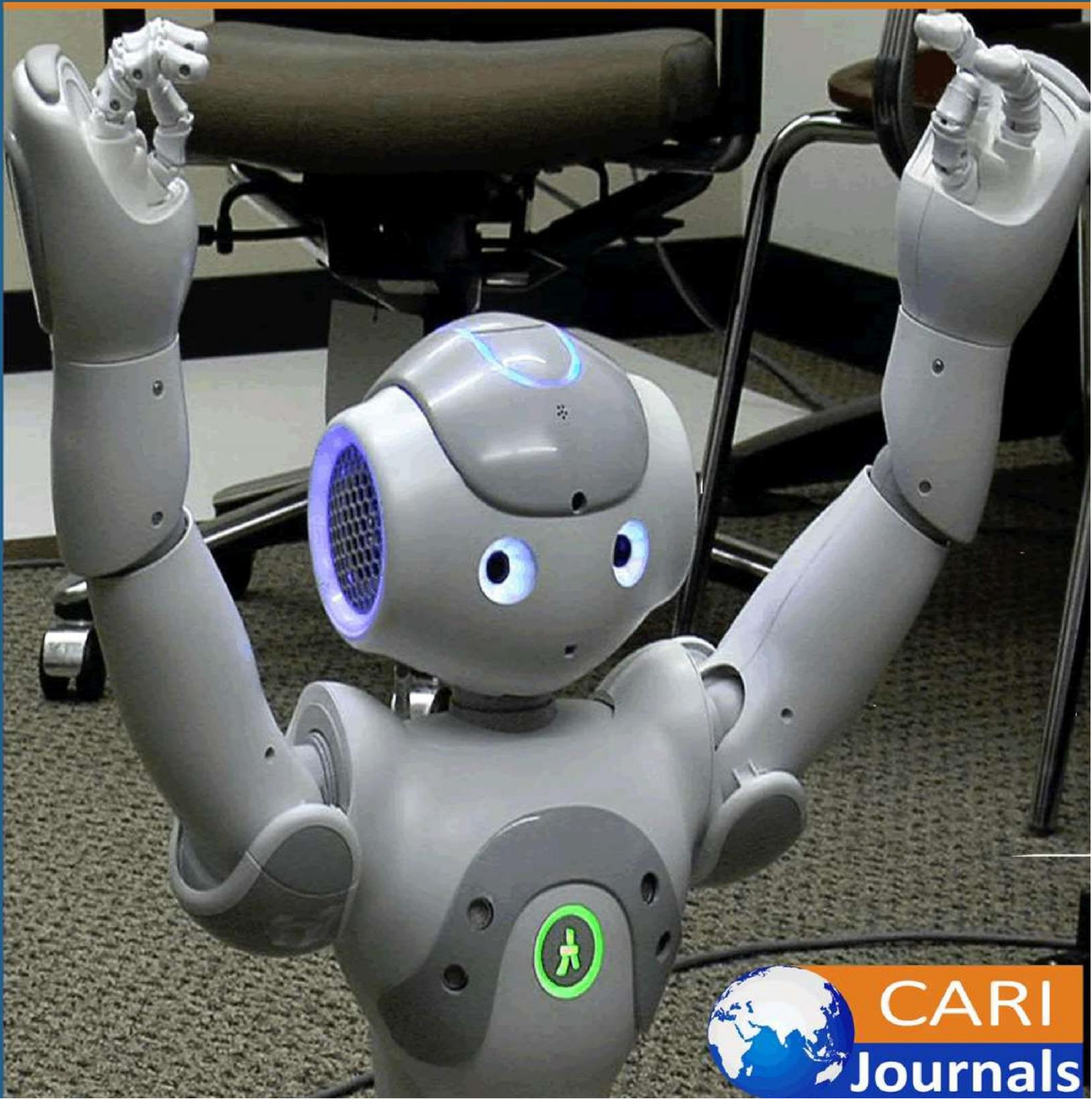

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Commercial Mobile Alert System LTE & 5g Network Optimization

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Abstract

Purpose: The evolution of telecommunication networks, spanning from LTE to 5G (NR) and WCDMA, has significantly transformed the landscape, extending the reach and capabilities of connectivity. While these networks have made substantial strides in enhancing the reliability of mobile communication, challenges persist in achieving optimal connectivity for the Commercial Mobile Alert System (CMAS).

Methodology: This research investigates the reliability and methodologies of the CMAS, delving into real-world challenges and proposing network optimization solutions aimed at fortifying the effectiveness of CMAS in both 5G and LTE networks.

Findings: The study endeavors to address these practical concerns, striving to elevate the LTE and 5G network infrastructure for CMAS

Unique contributor to theory, policy and practice: thereby contributing to the enhancement of public safety measures.

Keywords: *Commercial, Mobile, Alert, System, Network, Optimization*

Introduction

The Warning Alert and Response Network Act (WARN), approved by the US Congress in 2008, mandated the creation of a network to send out emergency alerts to wireless devices alongside additional mobile radio terminals on a local, regional, and national level. The Federal Emergency Management Agency initiated many synchronized public alert and warning system programs in response to the WARN Act. One such program is the Commercial Mobile Alert System (CMAS), which the Federal Communications Commission introduced. Government agencies can transmit emergency warnings to mobile devices in a specified geographic region via the CMAS, a public safety system available on LTE and 5G networks (Federal Communications Commission, 2023). The three kinds of communications that CMAS provides are presidential, imminent threat, and AMBER alerts. The Presidential alerts are of the highest priority warnings, as they notify people of local, regional, or national threats. Threats from recent years alert people to emergencies, like hurricanes or tornadoes; therefore, they can be solved immediately. AMBER alerts are connected to kidnapping or runaway incidents involving missing or endangered children (Kumar et al., 2022). Network optimization is essential to CMAS's ability to operate efficiently and notify the public of urgent notifications.

Wireless Emergency Alerts (WEA), rolled out nationwide by wireless carriers, have a system interface, CMAS. To improve public safety, FEMA, the Federal Communications Commission (FCC), and cellphone providers have partnered to create CMAS. With CMAS, public safety agencies may issue text-like, regionally targeted Wireless Emergency Alerts to the general population via FEMA's IPAWS Open Platform for Emergency Networks (IPAWS-OPEN) (Ballakur et al., 2015). Cell broadcast innovation, which CMAS employs, allows messages to be sent to wireless users in a matter of seconds, depending on their position. Unlike individual SMS technology, where cellular networks can be overwhelmed during peak activity, geographically-based messaging technological advances are suitable for emergency alerts because they can simultaneously connect with many individuals in a targeted region. Prioritizing CMAS alert messages over routine subscriber communications is mandated for cell swaps. The Emergency Alert System (EAS), which transmits alerts to radio and television over broadcast, broadband, satellite, and wireline communications channels, is supplemented by CMAS/WEA (Bean, 2019). Users will have the option to unsubscribe from AMBER or Imminent Threat notifications. This paper looks at the architecture of CMAS in 5G and LTE networks, decoding techniques, the problems with missing warnings that exist today, and possible fixes to improve CMAS performance.

Importance of CMAS Alerts

Broadcast-based notification methods cannot match the number of advantages that CMAS provides. Most notably, users can reject incoming messages apart from Presidential Alerts. Additionally, the system DELIVERS notifications straight to end users' phones instead of depending on their proximity to radio or TV (Campus Safety, 2012). The operating range of CMAS is another benefit; it may be restricted to a region as small as a single county, meaning warnings can be directed without providing "spillover" coverage to those in the unaffected areas. In contrast to blasting alarms across the country, for instance, notifications on a dangerous chemical leak will only be delivered to people in the affected zones (Campus Safety, 2012). By just delivering pertinent alerts, this focused strategy reduces alert fatigue. CMAS alerts play a vital role in public safety by informing affected communities of critical information. For people to take precautionary measures, CMAS can warn of impending hazards, including tornadoes, severe flooding, and chemical spills. To include the public in the recovery process, CMAS promptly disseminates information concerning kidnapped children through AMBER Alerts (Bean, 2019). Presidents can communicate with the whole country via CMAS at times of national emergency. The capability of CMAS to provide warning alerts depending on a user's geographic location adds value. With more Americans turning entirely to mobile devices rather than conventional media, CMAS offers law enforcement a vital means of immediately notifying residents via phone about imminent threats in their area.

Network Architecture

The LTE Public Warning System (PWS), which enables the concurrent broadcast of warning warnings to several users, is used by CMAS alerts. Operating within the framework of 5G NR (New Radio), the CMAS is a network architecture created for Cell Broadcast Services (CBS) (Schmidt et al., 2022). The architecture comprises several essential parts, each of which plays a distinct part in alert transmitting messages to mobile gadgets. Long Term Evolution (LTE) CMAS network structure includes Federal Alert Gateways, Commercial Mobile Service Providers (CMSPs), Cell Broadcast Centers (CBC), Mismanagement Entity (MME), and eNodeB (eNB). The following describes the architecture of the CMAS network: The service-based gateway for the Access and Mobility Management Function (AMF) is represented by Namf. Because it facilitates communication between different network elements, it is crucial to the CMAS architecture (Zhang et al., 2021). According to Third Generation Partnership Project (ETSI), N50 is another reference point between the Access and Mobility Management Function and the PWS or the Cell Broadcast Center Function (CBCF). This interface is necessary for the data transmission of alert messages. According to ETSI (2020), the CBC and PWS-IWF use the SBc framework as a reference point. This interface can be used to send warning messages to the CBC. Furthermore, N2 connects the AMF and the Next Generation Radio Access Network (NG-RAN). It is a communication channel between the RAN and the mobility monitoring function.

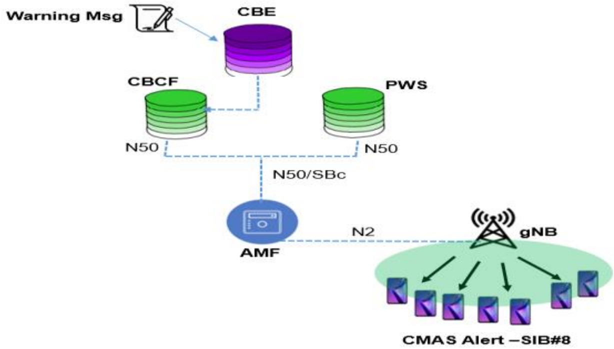

Figure 1:Network Architecture

The CBE formats and separates messages from the Cell Broadcast Service (CBS) into multiple pages (Lee et al., 2020). Although not covered by 3GPP specifications, the CBE is essential to the alert message delivery procedure. The CBCF is a 5G Core network component linked to several CBEs and AMFs (Bitsikas & Pöpper, 2022). Some important tasks that fall within the purview of the CBCF include assigning serial numbers to alert messages, choosing which cells a CMAS message should be sent to, and figuring out when a message should stop being sent out. Thus, to guarantee the effective and prompt broadcast of alerts to mobile gadgets in a 5G NR setting, the CMAS network design combines many reference locations and network components. The exact responsibilities that components such as Namf, N50, SBc, N2, CBE, and CBCF perform in this procedure add to the Cellular Mobile Alert System's general effectiveness.

CMAS Call Flow - Idle Mode

During the authentication procedure, a rogue eNodeB may send fictitious CMAS messages to idle mode UEs, interacting with the eNodeB with the most significant received power. To send critical alert messages to the user equipment in idle mode, the CMAS leverages the Cell Broadcast Service (CBS) architecture included in 3GPP specifications (Techplayon, 2023). The stages that make up the CMAS call flow are as follows:

1. The emergency alert information, which includes the message, warning, affected region, and time duration, is generated by the Cell Broadcast Entity (CBE).
2. CBCF sends the CMAS payload, target region, and broadcast characteristics to the Access and Mobility Management Function (AMF) as a Non-UE-N2 MessageTransfer (ETSI, 2018).
3. AMF uses the non-UE-N2-MessageTransfer to verify reception.
4. The target region's Next Generation Radio Access Network (NG-RAN) gNBs get a Write-Replace Warning Request from AMF.
5. The CMAS notification will be included in SIB8, which will schedule updated SIB1 broadcasts by gNB.

6. As part of the regularly scheduled system information, gNB broadcasts SIB8 with a CMAS payload.
7. Inactive mode UE maintains the control channel when there is paging, and it periodically updates SIB1 and SIB8 across the broadcast channel to receive the CMAS warning (Techplayon,2023).
8. To verify delivery, gNB provides AMF a Write-Replace Warning Response.
9. Notification of delivery status to CBCF by AMF is an optional step.

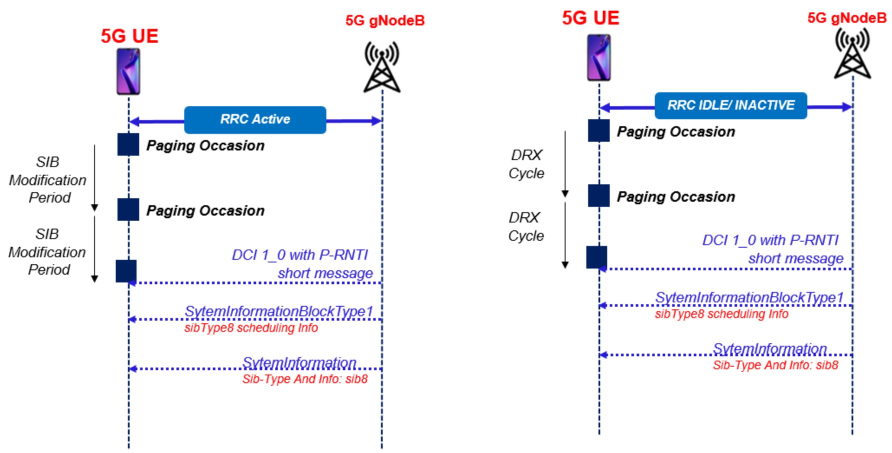

Figure 2:CMAS Call Flow

For idle mode UEs to obtain SIB12 scheduling information, the eNodeB pages them. After that, the UE examines SIB12 to get the authentic CMAS alert message that the eNodeB has broadcast. This procedure simultaneously alerts the coverage region's idle mode UEs (ETSI, 2021). Compared to other methods, such as SMS, which need creating RRC connections, the combination of paging and SIB12 for CMAS notifications offers an effective "push" technique for connecting with idle UEs (ETSI, 2018). Public warning systems use the broadcasting capabilities of LTE/5G networks. The CMAS architectural design and call flow incorporate paging, SIB12, and LTE/5G core network components for effective idle mode alert delivery, including the MME and eNodeB. Improvements such as location-based CMAS warnings can also be provided when 5G networks are deployed.

Current Issues

Even though the effectiveness of the CMAS architecture depends on conventional LTE operations, some particular issues might nevertheless result in overlooked CMAS alerts if network design is not optimal. Two primary problems have been noted: The authentic CMAS payload is included in SIB12; any mistakes made during decoding SIB12 would prevent the UE from receiving the emergency alert data. In contrast to a single-segment SIB, SIB12 is sent in numerous segments, SIB12 is susceptible to radio faults, potentially hindering decoding in scenario of weak coverage, leading to missing CMAS notifications (Kim et al., 2022). If a single segment includes essential information, even one failed decoding attempt might result in the missing of an alarm.

Conflicts may arise if the network allows SIB2 and SIB12 to happen at the same segment index and frequency, providing another problem. The Third Generation Partnership Project (3GPP) standards do not prohibit this alignment between SIB2 and SIB12 scheduling. But in this scenario, issues will surface as the UE is limited to decoding one of the two SIBs if there is overlapping. The UE prioritizes decoding SIB2 first since it provides crucial network access data, making SIB2 scheduling more critical and essential (Gunnarsson et al., 2022). However, this implies that the UE may overlook any co-scheduled SIB12 segments containing CMAS data. If SIB12 overlaps with SIB2, CMAS alerts are missed since the UE cannot decode both SIB2 and SIB12 concurrently on the same resources (McGrath et al., 2021). Even while there is still a chance of occasional SIB12 decoding achievements between SIB2 receptions, this is not a trustworthy way to send out public warning messages.

Solution

The main strategies for resolving SIB12 decoding errors and SIB2/SIB12 conflicts center on enhancing the dependability of SIB12 reception by optimizing network scheduling and resource allocation. As previously mentioned, overlap between SIB2 and SIB12 broadcasts is a significant cause of missing CMAS notifications. Conflicts can be prevented by ensuring that SIB2 and SIB12 utilize distinct periodicities and segment indexes (Gunnarsson et al., 2022). As a result, the UE may dependably receive both crucial SIBs. The effectiveness of this technique has been demonstrated by previous research showing that scheduling SIBs autonomously and separately reduces deficient CMAS significantly (Bergqvist et al., 2021). Consciously arranging the timing of SIB2 and SIB12 to prevent concurrent transmission can enable consistent CMAS delivery

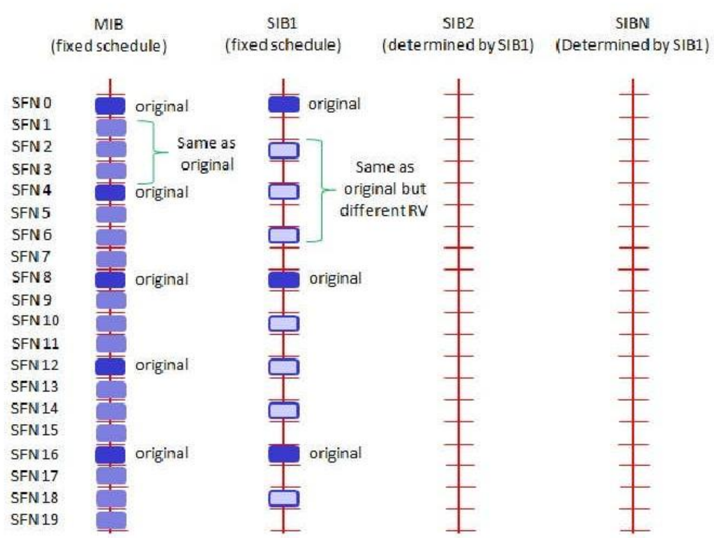

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Figure 3: Independent scheduling of SIB12 and SIB2

If their merged sizes permit, SIB2 and SIB12 can be transmitted in a single system notification message. Multiplexing prevents scheduling issues as well as concurrent transmission. However, multiplexing can sometimes be impossible if the total SIB size exceeds the transport block's bounds (Sangyeob et al., 2021). The Physical Downlink Shared Channel (PDSCH) limit bit count for system information is set by 3GPP at 21504 bits (ETSI, 2021). Therefore, if the combination of SIB2 and SIB12 is less than the set bit, multiplexing guarantees that both SIBs get delivered without requiring separate scheduling. Nevertheless, multiplexing is best used rarely, given the current SIB2 and SIB12 payload limits. By applying strategies like forward error correction (FEC), repetition, and linking, it is feasible to improve the effectiveness of SIB12 decoding and fortify CMAS reception against adverse radio settings (Shrestha et al., 2022). Furthermore, redundancy helps with error recovery. One example of this is the recurrent broadcasting of SIB12 footer segments. The transmission and segmentation overhead efficiency is reduced when many CMAS messages are combined into a single SIB12 payload (ETSI, 2021). Enhanced FEC coding capabilities on SIB12 protect against intermittent burst errors. These methods compensate for complicated deployments and cell effects on edges, resulting in efficient SIB12 decoding.

According to traffic characteristics, networks can adjust SIB12 periodicity and accessibility to balance overhead and delay. Dynamic scheduling fits SIB12 to demand, whereas frequent SIB12 wastes resources and long intervals impede alarms (Da Silva et al., 2019). SIB12 periods, for example, can be raised during regular operation to decrease signaling overhead and lowered during emergencies to offer timelier CMAS delivery. Additionally, periodicity can be synchronized with standard UE DRX cycles to avoid paging and SIB12 indicators being missed while idle. According to Park et al. (2022), DC enables SIB12 to be transmitted over the backup eNodeB, offering redundancy if overlooked. This protects against individual connection failures by using the advantages of multiple connectivity in terms of dependability. The secondary carrier steps in as a backup to cover any decoding gaps. This keeps CMAS loss from happening on a single link, even under poor reception conditions.

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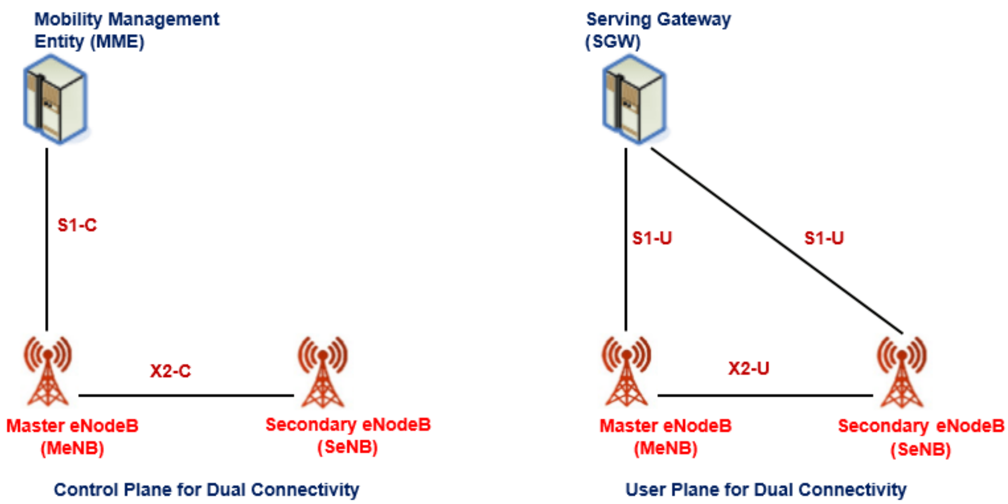

Figure 4:Dual Connectivity

SIB2 and SIB8 scheduling conflicts in 5G are subject to similar constraints. SIB decoding robustness is enhanced by the greater bandwidth and flexible 5G sequencing when combined with upgraded channel coding and more powerful transport blocks (ETSI, 2018). Coordination benefit is also obtained via distributed MIMO over many TRPs. If a conditional transition fails to occur on the source, delivery via the destination cell may be possible. Furthermore, with 5G, CMAS can only be directed to the designated geographic region by refining transmit beams depending on location (Techplayon, 2022). This improves the accuracy and efficiency of delivering these alerts.

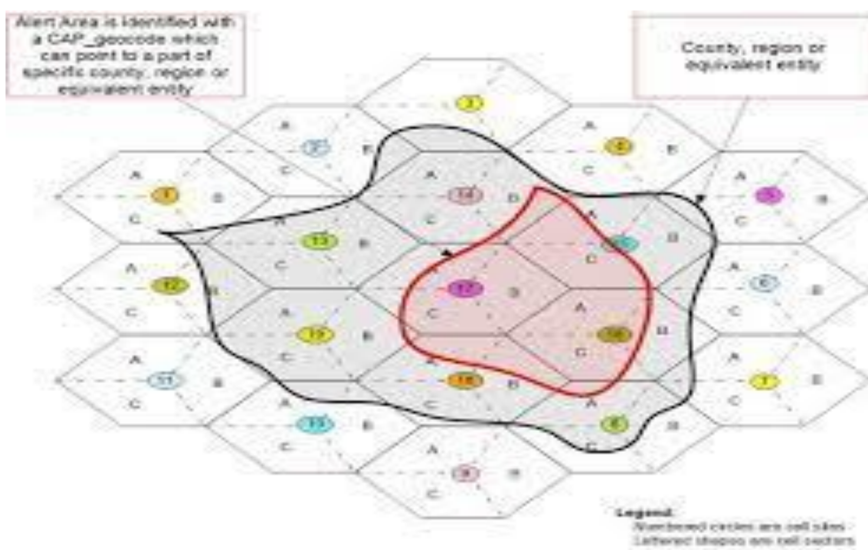

Figure 5:SIB12 Geolocation Targeting

A CMAS network slice that spans the core and RAN can be assigned guaranteed resources to guarantee operational isolation and dependability. In summary, networks may reduce the number of missed CMAS alerts and ensure dependable public warning delivery in LTE and 5G by implementing deliberate SIB scheduling, robust encoding methods, appropriate periodicity, advanced RAN capabilities such as DC and network slicing, and 5G-specific additions. To close the existing dependability gaps, a combination of these technologies offers levels of redundancy and optimization.

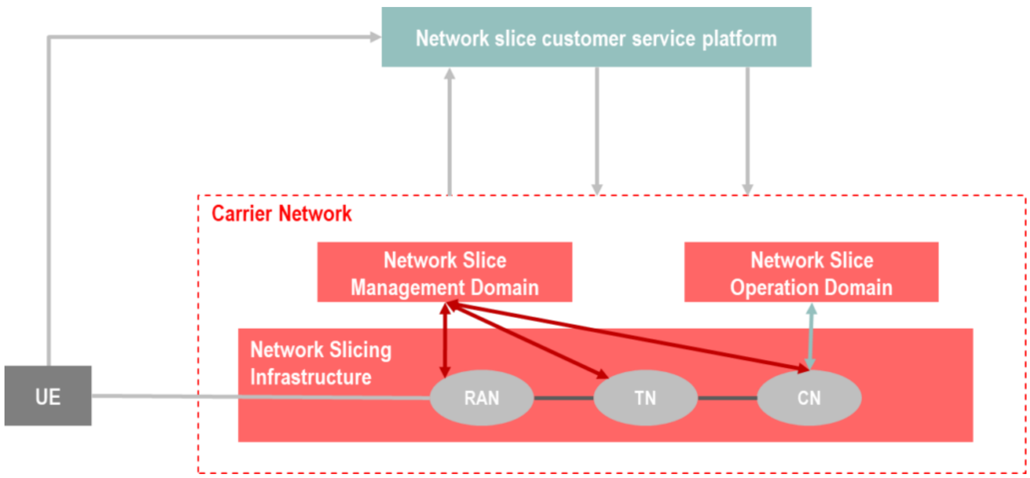

Figure 6: Network Slicing

Conclusion

During catastrophes and disasters, the Commercial Mobile Alert System gives authorities a vital tool: the capacity to deliver customized emergency notifications straight to mobile devices. Technical challenges include incorrect SIB decoding and network configurations that make regularly broadcast these critical public warning signals challenging. Using cutting-edge LTE/5G architectural features like dual connectivity and network slicing, avoiding scheduling conflicts between SIBs, continuously modifying SIB periodicity according to demand, and leveraging 5G-specific upgrades, a coordinated approach can maximize CMAS efficiency. With meticulous planning, warning delivery via LTE and 5G may become more reliable and effective. As wireless networks develop and gain popularity, CMAS plays an essential part in public safety by enabling life-saving alerts to be sent to the right people at the right moment. Mobile operators can maximize their CMAS structures by employing the strategies discussed in this article, which include SIB improvements, improved framework, proactive and intelligent scheduling, and future-oriented air interfaces. With proper planning and CMAS networking optimization, this potentially life-saving technology may be able to realize its full potential. In 5G networks, comparable conflicts between SIB2 and SIB8, which transport CMAS payloads, may occur. Preventing interference across transmissions by deliberately scheduling SIB2 and SIB8 at different periodicities and indices is possible. Moreover, 5G's shifting bandwidth and improved channel coding make it more resilient to decode both important SIBs. Optimal SIB scheduling, adaptive periodicity, resilient encoding techniques, and contemporary 5G air interfaces may all be used to increase CMAS warning delivery's reliability greatly.

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