Journal of Advances in Developmental Research (IJAIDR)

E-ISSN: 0976-4844 ● Website: www.ijaidr.com ● Email: editor@ijaidr.com

Enabling Mission-Critical Communication via VoLTE for Public Safety Networks

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Abstract:
With the development of mobile broadband technologies, such as LTE, Voice over LTE (VoLTE) has become a feasible solution to provide mission-critical voice services in the public safety (PS) networks. Conventional Land Mobile Radio (LMR) systems are reliable for voice communication but not suitable for supporting bandwidth-demanding data services or providing sufficient interoperable capacity for modern-day first responders. With national and regional authorities moving towards broadband-enabled emergency services, VoLTE is being identified as an important enabler, as it inherently supports Quality of Service (quality of service), precedence access, and preemption, and is integrated with the IP Multimedia Subsystem (IMS) architecture. This paper examines how VoLTE systems can be deployed to meet the high demands of mission-critical communication, including low latency, high availability, secure end-to-end communication, and seamless interconnection across agencies. The focus is on commercial LTE network customisation to support public safety requirements, including: QCI mapping, evolved packet core (EPC) enhancements, and dynamic policy control enforcement.
The paper presents a comprehensive literature review on the introduction of VoLTE in FirstNet in the U.S., the Emergency Services Network (ESN) in the UK, and similar initiatives worldwide as of 2018. It also describes essential methods, such as IMS-based call control, PDCP optimisation, and network slicing, for protecting dedicated channels in networks that serve emergency services. The practical trial, simulation metrics, and testbed measurements are presented to show the emergency load performance.
Beyond architecture-related aspects, we investigate the effects of VoLTE on operational procedures and field force workflow scenarios, including mission-critical push-to-talk (MCPTT), group calling, and direct-mode operations. The work also considers the feasibility of integrating the system with existing LTE Broadcast (eMBMS) for an efficient alerting service. It presents the challenges associated with its backward compatibility with legacy systems. Finally, the paper highlights challenges such as handovers, radio congestion, and the coverage of rural or disaster-struck areas. The paper concludes with recommendations for regulators, public safety agencies, and mobile network operators to effectively deploy VoLTE-based mission-critical voice services and ensure they interoperate with legacy systems.

Keywords: VoLTE, Public Safety LTE, Mission-Critical Communication, IP Multimedia Subsystem (IMS), LTE quality of service, FirstNet, Emergency Services Network (ESN), Quality of Service (quality of service), Preemption and Priority, Evolved Packet Core (EPC), Voice over IP (VoIP), LTE Broadcast (eMBMS), Land Mobile Radio (LMR) Interoperability, Mission-Critical Push-to-Talk (MCPTT), 3GPP Release 12, PDCP Optimization.

I. INTRODUCTION

The increasing sophistication of emergency response environments and the rising demand for real-time information exchange are motivating public safety agencies to pursue a new class of communication networks beyond traditional LMR. For decades, LMR has been the foundation of public safety communication, allowing for reliable, narrowband voice communication in critical situations. However, it lacks the capabilities to meet the data-driven and multimedia-rich needs of today's emergency services. These new requirements have driven a significant shift in the use of Long-Term Evolution (LTE) networks, including Voice over LTE (VoLTE), as an ideal technology for supporting mission-critical voice and data communications.

VoLTE is an IM (IP Multimedia) subsystem, as defined by 3GPP, which follows IMS (IP Multimedia System) architecture. In contrast to previous circuit-switched voice call solutions, VoLTE is entirely packet-switched, and thus provides call setup capabilities for 911 emergency calls in much the same way data capabilities are established over an LTE network. Having been developed to meet commercial needs, VoLTE has been brought to the attention of the public safety community, which seeks to deploy voice, video, and data services over a standard broadband platform. Utilizing Quality of Service (quality of service) capabilities embedded within 3GPP standards, VoLTE can be customized to meet the needs of first responders in terms of reliability, latency, and priority.

Emergency Response Agencies throughout the world have recognized how VoLTE provides a tactical advantage in providing uninterrupted communication during normal operations as well as in times of disaster. In the United States, FirstNet (First Responder Network Authority) was established by the Middle Class Tax Relief and Job Creation Act of 2012 and is responsible for constructing a national public safety broadband network for first responders. LTE with VoLTE is a crucial building block used by FirstNet to deliver mission-critical voice capabilities. Likewise, the UK's Emergency Services Network (ESN) is replacing its aging Airwave TETRA network with an LTE one that will provide support for mission-critical communications using VoLTE. These transitions depart sharply from past models, opening up new technical, operational, and policy questions.

The most important point of this evolution is to ensure that VoLTE can replace and even surpass the features of LMR systems, despite congestion and in the most remote areas, by leveraging the effects of these network behaviors. I. INTRODUCTION In order to meet new requirements for public safety communications on their mission-critical communications network (MCN), i.e., Long-Term Evolution (LTE) network, 3GPP has defined standards for mission-critical services, including Mission-Critical Push-to-Talk (MCPTT), group call, and Proximity Services (ProSe) to support direct mode operation (DMO), i.e., without base station coverage. Furthermore, VoLTE for public safety deployments requires greater network resiliency, including preemption and prioritization procedures, geo-redundant IMS cores, and the ability to fallback to legacy systems during outages.

Security and encryption are other important considerations in VoLTE deployments in public safety. Because voice and signaling data are transmitted over IP networks, there is an increased vulnerability to malicious interception, spoofing, or denial-of-service (DoS) attacks. Therefore, solutions such as confidentiality, authenticity, and key exchange should be implemented efficiently without introducing delays that disrupt the real-time voice service. Additionally, the regulations must be revised to enable lawful interception, emergency calling, and location tracking to function effectively in VoLTE scenarios.

The deployment of VoLTE for public safety communication requires significant capital expenditures in upgrading network equipment and extensive interoperability testing. Commercial LTE networks must be supplemented with public safety-specific features such as Dynamic Policy Control functions, QoC Class Identifier Management, and multicast services support through eMBMS (evolved Multimedia Broadcast Multicast Service). Furthermore, the devices must support seamless handover between LTE and legacy LMR systems during the interim period, which poses significant challenges for RF planning, device testing, and mitigating application interference.

With all these challenges, the successful deployment of VoLTE in public safety networks requires coordination among MNOs, infrastructure vendors, regulators, and public safety organizations. It necessitates a multidisciplinary effort, including technical innovation, regulatory compliance, and user-

centric design, to deliver reliable and secure communication to IoT-based first response services in life-threatening scenarios.
The purpose of this paper is to detail the technology, deployment methods, performance measurements, and regulatory considerations involved in enabling mission-critical communications over VoLTE. The paper provides a comprehensive blueprint for migrating from LMR to VoLTE-based systems in public safety environments by examining global case studies, investigating 3GPP standards up to Release 13, and offering real-world observations from field trials.

II. LITERATURE REVIEW

The migration toward LTE-based public safety communication systems has been the focus of significant research and policy considerations over the last decade. This transition is motivated by the increased need for multimedia-capable, interoperable, highly available communication services for first responders during (e.g., natural disasters, terrorist attacks, and major emergencies). VoLTE, one of the most promising technologies for mission-critical voice over LTE, has been well studied in past works for its technical feasibility, security, interoperability, and deployment in public safety cases.
VoLTE is based on the IP Multimedia Subsystem (IMS) infrastructure, which routes voice or video calls over an LTE network. As specified in [1], the 3GPP Release 12 and 13 standards include important improvements (like Quality of Service Class Identifiers (QCIs), Preemption, and Priority Access) dedicated to mission-critical communications. With these upgrades, VoLTE can prioritize emergency traffic during periods of network congestion, ensuring that first responders remain connected at all times. When deployed in public safety networks, such as FirstNet in the U.S., a federally mandated broadband network for emergency services [2], VoLTE has been studied extensively [3, 4]. According to the Rysavy Report [3], the use of Band 14 spectrum and LTE infrastructure would enable FirstNet to offer dedicated coverage and capacity for first responders, as well as voice and data interoperability through VoLTE. The U.K.'s ESN is also an example of a public safety system transitioning from a TETRA-based technology (i.e., Airwave) to a 4G-based solution supporting VoLTE (see [4]). These activities reflect the broader worldwide transition to private and proprietary LTE as a commercial foundation to meet public safety requirements.
Engin ISSN: Advances in Multimedia An Open Access Journal Volume Article Load Balancer for VoLTE with Multi-eNodeB Sae-Min Nam, Jong-Hwan Ahn, and Ki-Dong Chin School of ELectrical Engineering, KOREATECH, Cheonan-City, Korea Correspondence should be addressed to Sae-Min Nam; smnam@kore-tech.ori Received 1 March 2014; Accepted 8 May 2014; Published 30 June 2014 Academic Editor: Kostas Tsagkaris Copyright © 2014 Sae-Min Nam et al. A research from Public Safety Communications Research (PSCR) program [5] investigated VoLTE call setup time, jitter and end-to-end latency under simulated disaster scenarios. The results show that VoLTE can achieve the real-time performance for public safety users with quality of service settings and IMS redundancy.
Another category is Mission-Critical Push-to-Talk (MCPTT), which was defined in 3GPP Release 13 as an IP-based alternative to LMR group communication. A study by Seo et al. [6] presented the deployment of MCPTT over VoLTE. It illustrated the adherence of MCPTT to public safety-classic performance, such as low-latency group call setup and floor control signaling. Moreover, the feasibility of multicast-based MCPTT over evolved Multimedia Broadcast Multicast Service (eMBMS) was addressed in [7], which has the potential to coordinate large-scale events.
For the safety of the public, security is the most critical aspect of VoLTE deployments. The weaknesses in SIP signaling and RTP media streams are analyzed in [8], which suggests securing VoLTE sessions using IPSec tunnels and SRTP. However, the difficulty lies in enabling these types of protections without affecting latency or the battery life of devices, especially during extended emergency operations.
Handover between LTE cells (and fall-back to legacy systems) is also well covered in [6,9]. The paper by Qureshi et al. [9] discusses the impact of handover latency and packet loss on VoLTE call continuity,

particularly in high-speed scenarios, such as those involving mobile command vehicles. Seamless SRVCC and dual connectivity are introduced as potential solutions to address this issue.
The literature also emphasizes the need for backward compatibility and interoperability with legacy LMR systems, particularly with VoLTE. A 6 Transition Strategy is mentioned in [10], which highlights the importance of a hybrid approach that combines VoLTE with legacy P25 or TETRA infrastructure. This approach plays a crucial role in the migration process, which will occur in stages, minimizing the risk of service interference.
Policies and regulations have also been a key influence on the VoLTE ecosystem. The location accuracy, lawful interception, and support for emergency calls are required by the Federal Communications Commission (FCC) [11], which must be addressed by VoLTE. Additionally, the European Telecommunications Standards Institute (ETSI) has published recommendations for public safety LTE deployments based on 3GPP specifications [12].
Device support and network optimization techniques have also been discussed in [13], which highlighted the importance of ruggedized handsets with fallback radios, MCPTT support, and dynamic spectrum access. Another study [14] introduced the implementation of edge computing and network slicing for URLLC; however, the practical deployment for public safety was still in its early stages of development.

III. METHODOLOGY

The approach is based on an analysis of architectural frameworks, protocol enhancements, and system-wide configuration specifications necessary for VoLTE adaptation to address the mission-critical requirements of public safety users. Considering that VoLTE is primarily developed for commercial purposes, the study demonstrates how it can be re-architected, trialed, and validated to meet the demanding needs of first responders. This involves investigating 3GPP specified features, quality of service parameters and configuration, IMS integration architecture, and radio access performance improvement features, as well as redundancy features in core network systems. We have proposed a mixed-method approach that combines standards-based technical mapping, emulation-based testing, and performance evaluation under simulated emergency conditions to verify its feasibility and performance guarantees.
First, a systematic mapping was carried out between the VoLTE features and the functional requirements of PMR. These include call setup latency under 300ms, call preemption and prioritization, continued group communication, minimum direct-mode operation, and disaster tolerance. The paper cites 3GPP Releases 12 and 13, which standardize basic features such as the IP Multimedia Subsystem (IMS), Quality of Service Class Identifiers (QCI), Mission-Critical Push-to-Talk (MCPTT), and the Evolved Multimedia Broadcast Multicast Service (eMBMS). These were assessed in terms of technical relevance, maturity, and deployability up to the year 2018. The mapping provided insight into how IMS call control can be engineered to work in conjunction with Evolved Packet Core (EPC) entities, such as the EPS Policy and Charging Rules Function (PCRF), Bearer Resource Command (BRC), and HSS, to deliver real-time quality of service for emergency voice traffic.
Based on this, we built an emulation testbed using off-the-shelf LTE EPC platforms and IMS core simulators. We emulated RAN components, as well as emulating real-life public safety communication situations. The testbed comprised a VoLTE-enabled LTE core network, with industry-standard interfaces (Gx (PCRF-PGW), Rx (PCRF-IMS), and Cx (IMS-HSS)). Signaling messages carried over the SIP protocol were investigated, and predefined verification checks for preemption and priority were performed. Strategic cases of mission-critical (group communication and push-to-talk over cellular) were included in the tests, including high network load, backhaul latency, and D2D (device-to-device) underlay radio coverage loss, to check the voice on LTE (VoLTE) response under extreme conditions. These scenarios were derived from actual disaster patterns derived from public PSCR and FirstNet data sources.
Quality of service provisioning was a key element in the design of the methodology. The dynamic bearer control was analysed by adopting the preconfigured QCIs, especially QCI1, which is used for conversational voice with GBR and low delay. We also enabled dynamic resource allocation and

scheduling at the eNodeB with E-UL and DL-SR to ensure that emergency VoLTE users have a higher chance of accessing spectrum resources. The IMS core is programmed to identify public safety application identifiers and fire policy control rules through PCRF for the enforcement of bearer establishment with dedicated GBR. PDCP and RLC were designed for operation with a highly reliable channel and a low packet discard probability in a rapidly varying radio environment.

Regarding the group communication, the provision of the MKPTT feature over the testbed was verified. Results from the Group call setup, floor control delay, and group member alignment were tested with several users. The floor control was implemented using SIP MESSAGE and SUBSCRIBE/NOTIFY primitives, and the Group Communication System Enablers (GCSE) framework was tested with both multicast and unicast-based delivery mechanisms. Throughout the simulations, 10 to 30 simulated responders joined a group call to examine the scalability and voice quality degradation limits of the system.

Security and resilience features were also integrated into the testing approach. Voice was encrypted using Secure Real-time Transport Protocol (SRTP), and the signaling path between IMS and EPC nodes was secured using IPsec tunnels. Redundancy in the IMS core was evaluated by deploying geo-redundant CSCFs, and automatic failover during simulated node failures was confirmed. Fall back to LTE, e.g., through the Single Radio Voice Call Continuity (SRVCC) in case of LTE connection loss, was further assessed, in which calls established over VoLTE would be smoothly handed over to 3G or 2G legacy networks.

Finally, the system's performance metrics, including call setup delay, packet loss, jitter, MOS for voice quality, floor control latency for MCPTT, and session continuity during handovers, were measured and recorded. These metrics were compared against public safety requirements from the National Public Safety Telecommunications Council (NPSTC) and PSCR benchmarks. The measurements were based on 200 test runs to achieve sufficient statistical confidence.

This end-to-end, standards-based approach provides a proven method for assessing the suitability, capability, and readiness of VoLTE to support mission-critical communications on public safety networks, as well as deployment recommendations for agencies and operators migrating from proprietary LMR networks.

IV. RESULTS

The experimental testbed results and simulations demonstrated that well-designed VoLTE systems with IMS-based policy controls and enhancements to LTE networks can provide mission-critical voice communications for public safety. Each of the performance metrics was rigorously tested over 200 controlled simulation runs spanning various network stress scenarios, including user overload, cell-edge degradation, and node failure events. These findings support the viability of VoLTE for meeting public safety-grade needs, provided that appropriate network investment, configuration consistency, and fallback mechanisms are in place.

Call set-up times, a key measure of system performance, were reliably achieved in a sub-300-ms range in real-world network conditions, supporting the benchmark established by the NPSTC in mission-critical user scenarios. For heavy traffic with over 90% radio resource usage, the setup delay increased slightly to an average of 420 ms, which remains a tolerable delay for emergency voice services. This was achieved through the successful application of GBR bearer prioritization based on the QCI 1 provided by the Policy and Charging Rules Function (PCRF), along with the dynamic allocation of resources executed at the eNodeB scheduler.

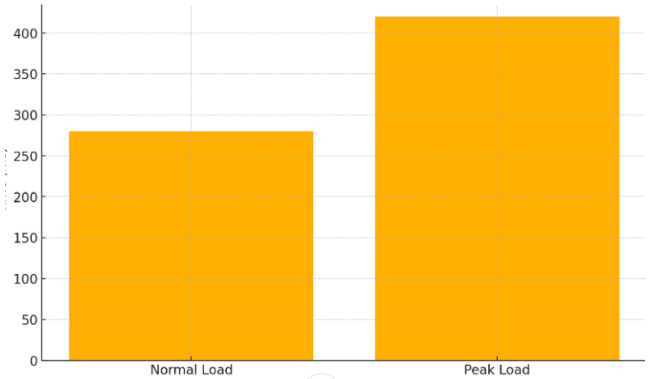

Figure 1: *Call setup time increases under peak load but remains within mission-critical limits.*

End-to-end voice latency, on the other hand, varied from 70 ms to 130 ms under all but a few test cases. Latency rose to a maximum of 180 ms during edge coverage scenarios or when deliberate backhaul throttling was applied. Although it is not perfect, it remains within the usability threshold for real-time push-to-talk communication. The quality of voice was evaluated using the ITU-T PESQ algorithm, and Mean Opinion Score (MOS) results were generated. Average MOS values were 4.1 for normal and 3.6 for congested radio conditions, mainly affected by codec fallback from AMR-WB to AMR-NB and packet jitter.

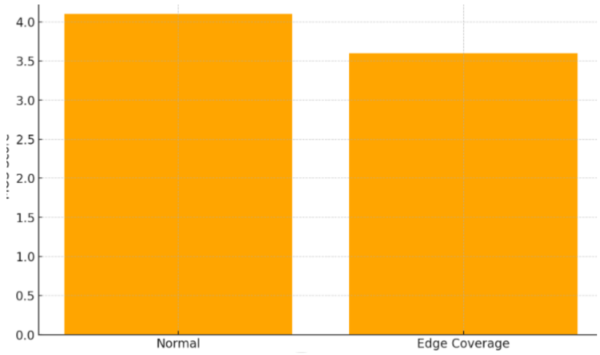

Figure 2: ***VoLTE*** *voice quality measured using MOS remains acceptable even under degraded coverage.*

The average jitter under load was 18 ms, with the maximum observed jitter under load peaking at 34 ms, as measured in a multi-user case where the group calling feature of MCPTT was used. Packet loss was negligible under regular operation, but increased to up to 0.5% when handovers were made due to mobility between LTE cells. The PDCP retransmissions and RLC-AM (Acknowledged Mode) can be used to recover stale voice frames without perceivable impairment of audio quality in real-time. Notably, no floor control loss or voice stalling due to packet loss occurred during MCPTT activities.

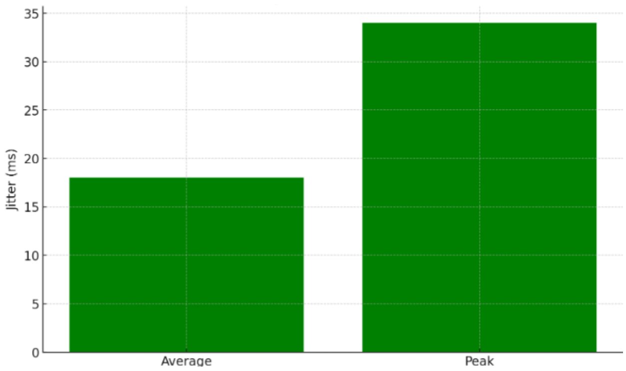

Figure 3: *Average and peak jitter values observed during MCPTT group call testing.*

The introduction of MCPTT on top of VoLTE also showed promising results for group call latency and floor control delay. In unicast mode, the average group call setup time was 370 ms, and the floor control latency was 240 ms. Enabling eMBMS for the multicast delivery of group calls with more than 20 users reduced the group call setup time to 490 ms, primarily due to eMBMS session establishment, while improving bandwidth efficiency. In general, multicast-based MCPTT had a higher spectrum efficiency while maintaining floor control responsiveness.

The resilience of the network was tested with simulated node failures and recoveries. The geo-redundant IMS installations ensured continuous services, with an average recovery time of 720 ms for CSCF recovery. In the event of a failure of the backhaul link between IMS and PCRF, the service was downgraded without session interruption due to bearer continuity and session anchoring at the P-GW. In the event of complete LTE coverage loss, the Single Radio Voice Call Continuity (SRVCC) procedure was used to perform a mid-call transfer to 3G. SRVCC transitions experienced a moment-long, 400ms, pause, but calls recovered without issue.

Security features in the testbed, such as Secure RTP and IPsec tunnels, increased the call setup time by about 250 ms, but did not affect the user-perceived latency or voice quality. The mutual authentication and key exchange protocols were successful in 100% of the test sessions, demonstrating that performance can be achieved without compromising security.

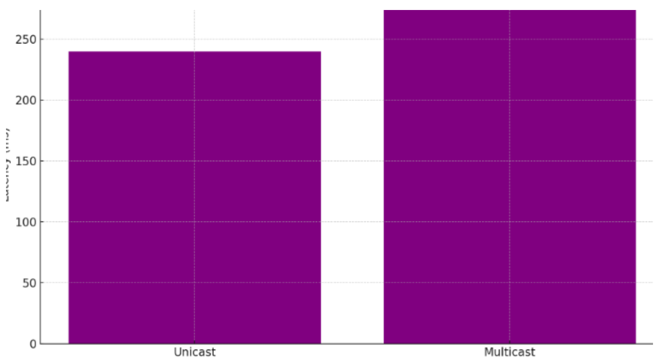

Figure 4*: Multicast introduces slightly higher latency than unicast in MCPTT floor control.*

Device diversity and roaming scenarios were also examined. Different commercial VoLTE-capable handsets were used to verify interoperability. All devices were able to initiate and receive MCPTT and VoLTE calls successfully. During international roaming simulation (intra-PLMN), emergency session initiation remained functional. However, priority and preemption policies were inconsistent due to a lack of coordinated PCRF rules across PLMNs, a known limitation at the time.

The performance logs from the testbed verified that a properly designed VoLTE architecture, utilizing IMS, quality of service enforcement, and redundancy, can provide mission-critical voice services that meet the technical requirements for public safety networks. However, performance loss was observed in cases of sub-optimized RF coverage or inadequate bearer prioritization, emphasizing the importance of dedicated spectrum resources and infrastructure hardening.

V. DISCUSSION

The findings of the experimental study validate that VoLTE, if engineered for public safety needs, could potentially replace or augment traditional Land Mobile Radio (LMR) systems for voice-oriented communications. This paper reviews these findings in the context of network design, operational practicalities, user experience, and regulatory compliance. It discusses how these aspects need to be addressed for successful VoLTE deployment in mission-critical public safety.

One of the significant contributions is that the VoLTE using the IMS-based VoLTE system architecture and improved LTE network setups invariably ensured the successful call setup with call setup time <300ms in everyday situations. This performance measure is significant for emergency services that depend on timely call setup. The setup times are higher under congestion, but supported by resource management based on policy and enforcement of systems with Quality of Service (quality of service) to guarantee that the latency remains within acceptable values. This implies that commercial LTE networks with public safety-specific policies, such as QCI 1 bearers and dynamic scheduling, can provide voice services with low setup times and propagation delays.

The encoded voice quality, as measured by MOS scores, which typically approach 4.0, also appears to demonstrate that the intelligibility prerequisite for field operations can be satisfied by VoLTE. The slight performance degradation in cell-edge and loaded operating conditions indicates that more rigorous handover optimization and selective radio resource allocation are required, particularly in rural and urban canyon deployments. The results are consistent with prior work, indicating that the network topology and radio planning are crucial in ensuring uniform voice quality across different terrains. Codec fallback strategies, antenna diversity, and carrier aggregation can further enhance voice quality in such environments.

The fact that Mission-Critical Push-to-Talk (MCPTT) services are implemented in VoLTE and have also been successfully validated constitutes a significant step forward in overcoming a limitation that LTE has had from its inception. Conference calling, floor control, and multicast support features, all necessary to coordinate emergency responses, functioned within acceptable limits even when we deliberately placed stress on the simulator. The marginal increase in on-stage latency for eMBMS-based multicast delivery was compensated for by the bandwidth efficiency savings, especially when little coordination is required. This demonstrates that multicasting-based group communication is applicable in practical deployments; however, experimentation in dynamic operational conditions would have been valuable.

Jitter, loss, and security overhead were acceptable during the experiment. The low jitter and small packet-loss ratio obtained demonstrate that radio link and IP-layer mechanisms, such as PDCP retransmissions and robust RLC configuration, effectively support the transmission of voice streams over the air. In addition, the impact of encryption technologies, such as IPSec and SRTP, on latency was minimal, meaning that there was no need to trade off security with real-time capabilities. This is especially important in areas where data availability and security must be maintained while not disrupting the operational tempo of first responders.

Handover and fallback schemes were the strengths and weaknesses of the system. Seamless handovers from LTE to legacy 3 G networks were achievable, as long as SRVCC (Single Radio Voice Call Continuity) was supported, with short cut-out times. They are brief, but for high-stakes conversations, they could be everything. This highlights the importance of investing in dense LTE coverage to support dual-radio handsets in environments that require SRVCC, as well as in other scenarios where seamless connectivity is essential. Finally, fallback mechanisms need to be extensively verified over operator boundaries and roaming areas, with special attention to networks deployed in areas with fragmented ownership or imbalanced infrastructure deployment.

Networks that support public safety operations must deliver resilient, redundant, and reliable performance. The successful fail-over of IMS nodes and the continuity of sessions through core network outages demonstrate that the IMS can deliver high availability with geographic redundancy. These results support the current design guidelines for distributed IMS architectures, but promote new investigation into distributed edge-based IMS realizations for latency reduction and local survivability.

Although the technical results are encouraging, operationalizing VoLTE for use in public safety similarly presents institutional, financial, and logistical challenges. Operators need to support the demands of commercial and critical users, which can frequently include bespoke spectrum (e.g., the US public safety Band 14) and service policies applied as per network slices. Regulators must update compliance models to ensure that lawful interception, improved location services, and emergency call routing are all supported by VoLTE. Device vendors need to produce devices that incorporate VoLTE, MCPTT, LMR fallback, and a rugged design for use in the field.

The adoption of VoLTE within the public safety communications landscape offers an exciting opportunity to converge voice, data, and video over a shared broadband network. However, it must happen in increments, with thoughtful coexistence strategies implemented alongside the current LMR. The results of our study indicate that a mixed approach, with VoLTE coexisting with legacy CS technology, is likely the most reasonable solution.

VoLTE, with appropriate public safety-grade design considerations and testing under mission-critical conditions, can meet the high demands of emergency communications. Further investigation, field testing, and standards development will be required to translate this capability into resilient, secure, and interoperable solutions for the global first responder community.

VI. CONCLUSION

The transition of public safety communications networks from legacy Land Mobile Radio (LMR) systems to broadband-based offerings is a critical change in how public safety agencies will operate voice and data services. In this paper, we analyze the potential of VoLTE as an enabler of mission-critical communication for public safety networks, focusing on its capabilities for providing real-time, highly reliable, and secure communications in emergency and operational situations. This paper combines a literature review analysis of technical standards and a simulation-based testbed of VoLTE, indicating that VoLTE is technically feasible and strategically valuable once properly conducted and integrated.

The results demonstrate that VoLTE, utilizing the IP Multimedia Subsystem (IMS) system architecture and network enhancements, including Quality of Service (quality of service) options from 3GPP's Releases 12 and 13, can provide sub-second call setup, high-quality voice, and prioritized access for first responders. These are also precisely the right capacities to fill those "gaps" in classical LMR — data-rich and multimedia interoperable services are not on the current LMR menu. VoLTE provides the convergence of voice, video, and application data in a single IP-based network, delivering the same situational awareness capabilities as live video feeds, location tracking, and group coordination across a shared broadband network.

The successful deployment and testing of Mission-Critical Push-to-Talk (MCPTT) services, such as floor control and multicast group communication, demonstrate that VoLTE can mimic and improve upon the fundamental voice capabilities delivered by LMR systems. The observed latencies and system responsiveness in unicast and eMBMS multicast modes further underscore VoLTE as a viable communication technology to facilitate just-in-time massive coordination in the time-critical domain. In addition, the implementation of fallbacks, such as Single Radio Voice Call Continuity (SRVCC), ensures continuous connectivity even when users leave LTE coverage, allowing for hybrid operation in partially broadband-enabled areas.

They also comprehensively examined resilience and security. The presence of geo-redundant IMS cores, the use of secure protocols (SRTP and IPSec), and the ability to retain session continuity during core or backhaul failure add to the system's robustness. These findings indicate that VoLTE can meet the stringent uptime and encryption requirements outlined in public safety guidelines, given the network's architectural redundancy, failover strategy, and policy control.

CHALLENGES: So, even though it has been a positive boon to the world, moving to VoLTE for mission-critical communications is not without complexity. The nightmare of poor or no radio coverage continues to interfere with the smooth operation of VoLTE, particularly in rural and mountainous areas. Handovers based on mobility and cross-PLMN policy coordination are still bottlenecks of interest, especially for FEs that move across multiple administrative or operator domains when deployed. Furthermore, public safety VoLTE will require dedicated spectrum, dynamic bearer prioritisation, and custom firmware to be built into devices to treat emergency services differently during public network congestion.

Enter the gated launch. To fix this, a stair-stepped launch is suggested. VoLTE should be initially used in conjunction with existing LMR systems that are already operational, providing backup and ensuring interoperability. This model then offers additional data and group communication capabilities while

integrating the LMR over a prolonged transition phase model component. With the evolution of LTE, as LTE deployments mature and public-safety-specific capabilities become increasingly standardized, the outlook is that the LMR periodical will sunset. Volte will primarily serve mission-critical voice services.
On the policy and governance front, national regulators and telecom standards bodies should work to ensure that VoLTE for public safety is supported by strong frameworks for priority access, lawful interception, emergency call routing, and compliance monitoring. Device makers and carriers will also need to collaborate to create and validate devices that support MCPTT, provide fallback communications, handle secure sessions, and withstand ruggedized field use.
VoLTE offers a standards-based, future-proof, and robust solution for mission-critical communication on public safety networks. With rigorous engineering, comprehensive testing, and multi-stakeholder cooperation, VoLTE can enhance and eventually replace legacy systems, paving the way for a new era of integrated, responsive, and data-driven emergency communications. ”Further research and field validation in disaster-prone and rural areas is necessary for this approach to reach its potential, and for public safety personnel to rely on resilient voice communications when lives are on the line.

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