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**Mykhailo Odarchenko,**  
State University "Kyiv Aviation Institute"  
orcid.org/0000-0002-7714-3558  
e-mail: odarchenko.m.s@gmail.com;

**Maksym Zaliskyi, Dr. Sc., Prof.**  
State University "Kyiv Aviation Institute"  
orcid.org/0000-0002-1535-4384  
e-mail: maximus2812@ukr.net

## FROM SMS TO RCS: INTELLIGENT FRAMEWORKS FOR RESILIENT MESSAGING IN EMERGENCY SCENARIOS

### Introduction

For over 30 years, Short Message Service (SMS) has served as a fundamental way of mobile communication. Despite its reliability and simplicity, SMS is increasingly seen as limited in an era dominated by rich media, IP-based messaging applications, and 5G infrastructure. To address these constraints, the GSM Association (GSMA) introduced Rich Communication Services (RCS) as a modern alternative to SMS and MMS. With the 2024 integration of RCS into Apple's iOS 18, the service has become cross-platform, significantly increasing its potential use cases [1].

In the context of emergency communications, however, both SMS and RCS hold a unique importance that goes beyond commercial or social messaging. SMS remains one of the most reliable ways to reach the public during crises, since it works on virtually every mobile device, requires no data connection, and is already embedded in regulatory frameworks for public safety alerts. Article 110 of the European Electronic Communications Code (EECC) requires that Member States establish public warning systems delivered over mobile networks (via Cell Broadcast or location-based SMS) [3]. In East Asia, for example, Japan's J-Alert system relies heavily on Cell Broadcast for area-based warnings, supplemented in some cases by SMS [4].

At the same time, RCS introduces new possibilities for emergency notifications by enabling richer, more interactive messages. Features such as embedded maps, actionable buttons, verified sender identities, and real-time updates can provide people with clearer instructions and reduce confusion during disasters [5].

Together, SMS and RCS represent a powerful combination: SMS ensures reach and reliability, while RCS enhances clarity and engagement. The challenge, however, lies in orchestrating these channels intelligently so that critical messages are

delivered quickly and effectively under unpredictable network conditions.

### Analysis of recent research and publications

When examining how messaging technologies like SMS and RCS can be used effectively during emergencies, two strands of research are particularly relevant: (1) technical performance and optimization of messaging platforms, and (2) studies assessing the practical applicability of these channels in real-world emergency contexts.

A recent contribution in the first category is Dusane's *Mastering Performance Optimization in Messaging Platforms: A Comprehensive Framework for Scalable Communication Systems (2025)* [7]. This work proposes a multi-layer framework that addresses the key bottlenecks of large-scale communication systems. Techniques such as asynchronous message processing, multi-tier caching, dynamic load balancing, predictive scaling, and real-time monitoring are described as ways to reduce latency, maximize throughput, and ensure stability during peak traffic. The paper also provides case studies showing how these methods improve responsiveness in enterprise and IoT messaging environments. The principles in Dusane's framework directly resonate with the assumptions behind the IGDP model, particularly its emphasis on penalizing latency, rewarding delivery robustness, and supporting adaptive routing logic.

A complementary perspective comes from Al-Shamaileh and Al-Dalahmeh (2018), who investigated how SMS and Cell Broadcast (CBS) perform in emergency management solutions, particularly in developing regions [8]. Their findings highlight both the strengths and weaknesses of SMS: it is widely available and affordable, but as a point-to-point service, it can suffer from congestion-related delays or failures during crises. CBS, by contrast, enables rapid area-based alerts without being affected by network

load, though it requires operator support and is not universally implemented.

An important insight from Al-Shamaileh and Al-Dalahmeh's study is that technological capabilities alone are insufficient for reliable emergency communication. Success also depends on policy frameworks, institutional readiness, and regulatory alignment. This aligns with the design of IGDP, which not only accounts for delivery probabilities and latency but also introduces a "freshness" factor to capture the accuracy and timeliness of channel availability data.

Taken together, Dusane's performance optimization framework and Al-Shamaileh & Al-Dalahmeh's real-world analysis provide a balanced foundation for the IGDP model. On one side, Dusane's work informs how scalable back-end architectures can support real-time routing and fallback; on the other, Al-Shamaileh and Al-Dalahmeh show why adaptability and situational awareness are essential when delivery reliability can determine safety outcomes.

### Problem statement

While RCS offers a rich, secure, and interactive messaging experience, its adoption in critical use cases, particularly emergency communications, remains limited. SMS continues to dominate public alert systems due to its offline capability and compliance with regulations such as Article 110 of the European Electronic Communications Code (European Commission, 2020) [3]. Countries such as Japan continue to rely heavily on Cell Broadcast for earthquake and tsunami alerts, with SMS sometimes used as a supplemental channel [4].

RCS, despite its capabilities for multimedia sharing, geolocation, chatbots, and suggested replies, does not have global standardization and guaranteed delivery mechanisms under low-connectivity or degraded network scenarios [5]. Its dependency on IP connectivity further restricts its applicability in critical situations where network infrastructure may be compromised.

This study aims to:

1. Assess the current landscape of SMS and RCS in the context of 5G networks and mobile messaging.
2. Explore the potential and limitations of RCS in emergency communication, particularly in comparison with SMS.
3. Introduce the Intelligent Emergency Messaging Optimization Framework (IEMOF), designed to enhance message deliverability through dynamic channel selection.

4. Propose and validate a quantitative model — the Guaranteed Delivery Index (IGDP) — that evaluates and optimizes emergency message delivery performance across RCS and SMS.

### Materials and methods

The introduction of 5G brings technical capabilities like ultra-low latency, high throughput, and edge computing, all of which enhance what RCS can offer [9]. For example, real-time interactions such as typing indicators or payment confirmations benefit especially from reduced latency. High bandwidth enables smoother multimedia in messages, while features like network slicing promise priority handling for emergency traffic [9]. Yet, these opportunities are tempered by challenges such as inconsistent device support, differences in how operators implement RCS, and the absence of fully standardized fallback mechanisms, which together affect reliability in emergency contexts [10].

The transition to 5G represents a fundamental enabler for large-scale RCS adoption. While previous LTE deployments provided a baseline for IP messaging, 5G's ultra-low latency and support for network slicing enable RCS traffic to receive prioritized treatment, reducing delivery time for mission-critical alerts. Moreover, 5G's native integration of IMS (IP Multimedia Subsystem) ensures better QoS enforcement, making RCS more reliable and scalable as a successor to SMS in both commercial and emergency domains.

RCS Business Messaging (RBM) already demonstrates promising commercial use cases, including verified branding, enhanced media, chatbots, and in-message payments [5]. However, emergency usage lags, partly due to the absence of formal regulatory standards and delivery guarantees [10].

To address these gaps, we propose the Intelligent Emergency Messaging Optimization Framework (IEMOF): a four-layer model designed to improve message deliverability dynamically across channels.

#### 1. Real-Time Capability Layer

This layer acts as the foundation of the IEMOF framework, responsible for collecting and interpreting data about device and network conditions. It continuously monitors whether a recipient's device supports RCS, has an active data session, or is limited to SMS-only communication. Data is sourced from systems such as the GSMA Device Map, which aggregates global information about device models, software versions, and operator capabilities [11].

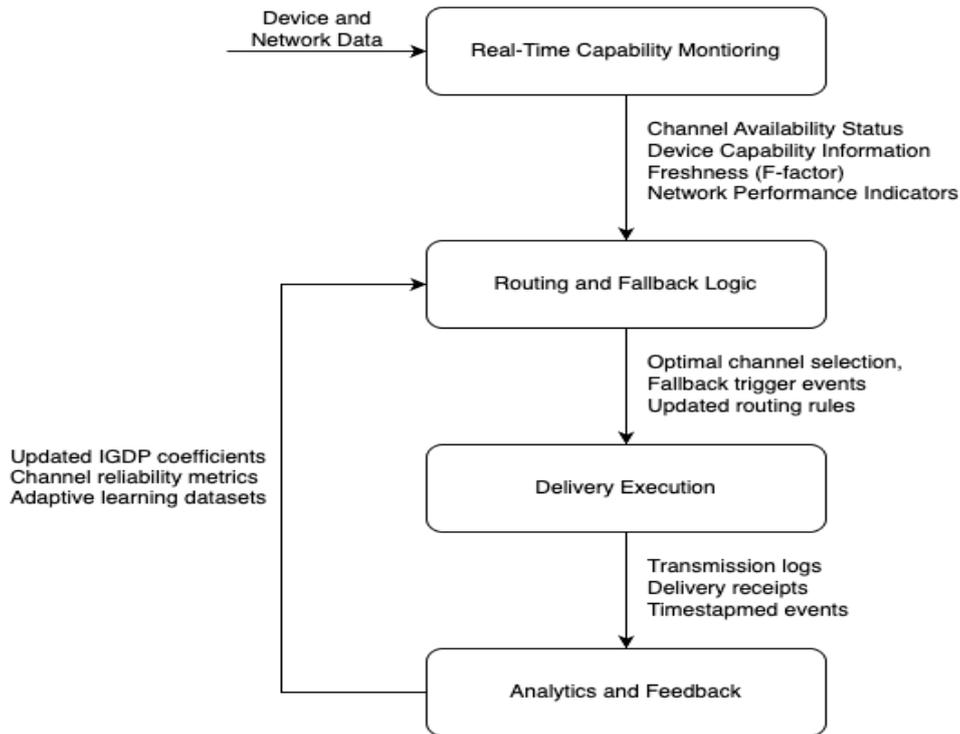


Fig. 1. Architecture of the Intelligent Emergency Messaging Optimization Framework (IEMOF)

The layer also integrates Delivery Status Reports (DLRs), network quality indicators, and CPaaS telemetry to evaluate the current readiness of each channel. When combined, these parameters form a dynamic capability matrix, which reflects the live communication environment. This matrix becomes the key input for routing decisions in the next layer.

Output: Channel availability status, device capability freshness (F-factor), network performance indicators.

2. Routing & Fallback Logic Layer

The Routing & Fallback Logic Layer performs intelligent channel selection using a multi-criteria decision model based on the Guaranteed Delivery Index (IGDP). It assigns a fitness score to each available channel according to delivery probability (P), latency (L), and freshness (F), applying tunable coefficients ( $\alpha, \beta, \gamma$ ) that reflect message urgency and context.

If a message sent via RCS does not receive a delivery acknowledgment within a threshold period (e.g., three seconds), the system automatically triggers fallback to SMS or another lower-latency channel. This process is guided by real-time performance data and historical outcomes to optimize future routing.

In addition, the layer supports context-aware prioritization – for example, emergency alerts may override promotional traffic or use pre-defined network slices for faster delivery. Machine learning can further enhance decision-making by recognizing recurring delivery patterns and adjusting scoring weights dynamically.

Output: Optimal channel selection, fallback trigger events, updated routing rules [10].

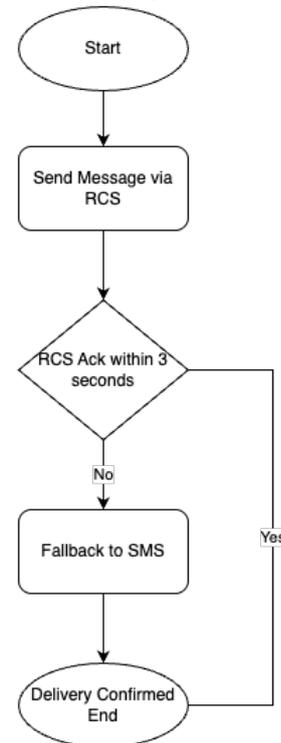


Fig. 2. Decision Flow for RCS-SMS Fallback in IEMOF Framework

3. Delivery Execution Layer

At this stage, the system carries out the actual message transmission using connections to CPaaS platforms (such as Sinch, Twilio, Infobip) and operator gateways via standardized interfaces (e.g., SMPP, HTTP, RCS Business Messaging APIs). The layer

manages message queues, confirms successful delivery, and retries failed attempts across redundant routes.

The Delivery Execution Layer is designed for resilience under stress: it includes mechanisms for traffic prioritization, load balancing, and message deduplication. During emergencies, the framework ensures that public safety messages receive highest priority, even under partial network degradation. Each transaction is logged with details such as channel used, latency, response code, and retry count, feeding critical information to the Analytics Layer.

Output: Transmission logs, delivery receipts, retry summaries, and timestamped events. [6].

#### 4. Analytics & Feedback Layer

This final layer forms the adaptive intelligence core of the IEMOF framework. It aggregates delivery reports, latency data, and error statistics from all channels to continuously update the IGDP metrics and refine routing efficiency. Using analytical dashboards and predictive modeling, it detects degradation trends (e.g., increased delay in a certain operator's network) and proactively adjusts channel priorities.

The Analytics Layer also retrains machine learning models using accumulated delivery data to enhance accuracy of channel fitness predictions. Over time, it becomes a self-learning feedback system capable of anticipating failures before they occur.

In addition to performance tuning, this layer supports visualization tools that display message distribution, delivery assurance rates, and geographic channel health. These insights guide both operational decisions and long-term policy improvements for emergency messaging systems.

Output: Updated IGDP coefficients, channel reliability metrics, and adaptive learning datasets.

The Guaranteed Delivery Index (IGDP) combines three factors – delivery probability, latency, and freshness of device/channel capability data – into a single performance measure [8].

**Delivery Probabilities.** For SMS, many devices and networks still show high reliability, though exact numbers vary by region [12]. For RCS, variability is greater depending on device compatibility and network support [2].

**Latency.** While precise figures depend on the network and region, 5G and modern LTE networks report reduced latencies relative to earlier generations; delays in heavy traffic can still degrade delivery speeds [9].

**Coefficients ( $\alpha$ ,  $\beta$ ,  $\gamma$ , etc.).** These are tunable based on context: urgency of message, allowed delay, and how fresh the channel/capability map is [10].

To ensure that the IGDP metric reflects real-world conditions, the model was validated using three complementary approaches:

1. Monte Carlo Simulations. Large-scale simulations were conducted to model message delivery across heterogeneous networks under varying load conditions. Monte Carlo methods are commonly applied in communication network analysis to account for uncertainty and variability [13].

2. Historical Delivery Data. Aggregated datasets from industry reports (e.g., GSMA [1], Mobile Ecosystem Forum [2]) and CPaaS providers (e.g., Twilio [6]) were used to establish baseline delivery probabilities and latency distributions. These datasets provided empirical grounding for the parameters  $P_{sms}$ ,  $P_{rcs}$ ,  $L_{sms}$ ,  $L_{rcs}$ .

3. Regression Fitting. Model coefficients were adjusted to minimize the difference between IGDP predictions and observed outcomes. Standard regression fitting techniques, widely applied in engineering contexts, were employed [14].

Together, these steps ensure that IGDP is not only theoretically consistent but also aligned with observed delivery performance across SMS and RCS.

The IGDP model is defined as:

$$IGDP = \alpha(1 - (1 - P_{rcs})(1 - P_{sms})) - \beta(w_{rcs} \cdot L_{rcs} + w_{sms} \cdot L_{sms}) + \gamma F$$

where:

- $P_{rcs}$  – probability of successful RCS delivery;
- $P_{sms}$  – probability of successful SMS delivery;
- $L_{rcs}$ ,  $L_{sms}$  – average latencies for RCS and SMS;
- $w_{rcs}$ ,  $w_{sms}$  – weight factors for latency penalty;
- $F$  – freshness of device/channel map (0 to 1);
- $\alpha$ ,  $\beta$ ,  $\gamma$  – tunable weights.

Example values:

$$P_{rcs} = 0,82, P_{sms} = 0,95;$$

$$L_{rcs} = 1,8s, L_{sms} = 1,2s$$

$$F = 0,85; \alpha = 0,6; \beta = 0,3; \gamma = 0,1; w_{rcs} = 0,7; w_{sms} = 0,3$$

$$IGDP \approx 0,6 \times 0,991 - 0,3 \times (0,7 \times 1,8 + 0,3 \times 1,2) + 0,1 \times 0,85 \approx 0,595 - 0,468 + 0,085 = 0,194$$

The following figure (Figure 3) illustrates the relationship between IGDP and the delivery probabilities of RCS ( $P_{rcs}$ ) and SMS ( $P_{sms}$ ). The surface plot confirms that IGDP increases most significantly when both probabilities are high, validating the advantage of a multi-channel delivery strategy with dynamic fallback:

Regression fitting between RCS and SMS delivery probabilities revealed a predominantly linear dependence within the operational range. This finding indicates that improvements in either channel contribute proportionally to overall IGDP growth when coefficients remain constant. Such linear behavior validates the assumption that, under steady network conditions, the combined delivery performance can be reliably approximated by a linear model. Nevertheless, in future work, non-linear models (e.g., polynomial or logistic regression) may be applied to capture saturation effects under extreme congestion.

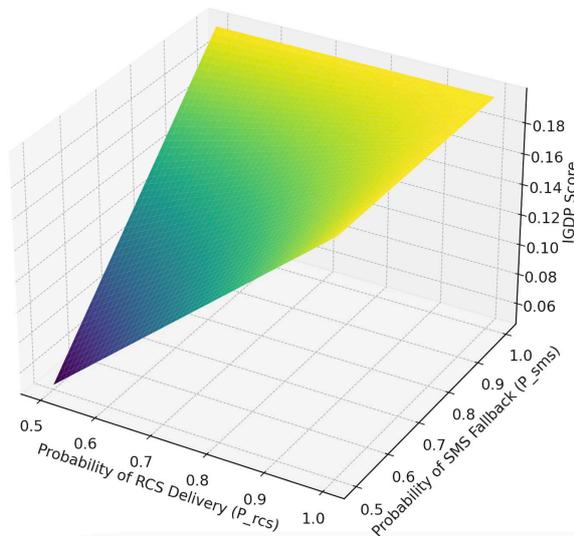


Fig. 3. Impact of RCS and SMS Delivery Probabilities

Simulation results demonstrate that multi-channel orchestration and dynamic fallback strategies significantly enhance message reliability. For instance, fallback from RCS to SMS within 3 seconds maintains high delivery assurance. Additionally, maintaining a fresh capability map ( $\leq 30$  min updates) substantially boosts IGDP.

The next figure demonstrates the effect of capability freshness on IGDP. As device and channel state data becomes more up-to-date, IGDP improves markedly, emphasizing the importance of frequent synchronization and capability checks:

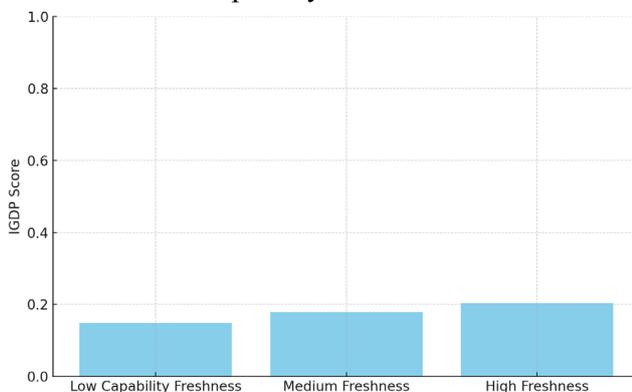


Fig. 4. Effect of Capability Freshness on IGDP

Global adoption trends show strong regional variation. In North America, carriers such as AT&T, Verizon, and T-Mobile, alongside Apple, support RCS fully. European operators like Orange and Vodafone are investing heavily in Google-powered deployments. In the Asia-Pacific region, Japan and Korea lead early adoption in fintech and commerce. Meanwhile, Latin America and Africa leverage RCS in mobile-first campaigns and government services.

Dynamic channel routing emerges as a practical solution to optimize delivery. Case studies, such as one from a European utility company using Infobip's

orchestration engine, report measurable improvements in deliverability and customer satisfaction.

### Future research

Further development of the Intelligent Emergency Messaging Optimization Framework (IEMOF) should move from theoretical validation toward full-scale implementation and empirical testing. One key direction is the deployment of pilot systems in disaster-prone regions to measure real-world performance across heterogeneous networks, varying traffic loads, and diverse device ecosystems. Such field studies would provide data for validating the Guaranteed Delivery Index (IGDP) and refining its weighting coefficients under operational constraints.

Another promising line of research is integration of machine learning models capable of self-optimizing routing decisions based on historical performance, user mobility patterns, and contextual risk assessment. Reinforcement learning approaches could dynamically adapt fallback thresholds or latency penalties, achieving near-real-time optimization of multi-channel delivery strategies.

Further investigation should explore cross-channel interoperability, extending IEMOF beyond SMS and RCS to include over-the-top (OTT) platforms such as WhatsApp, Viber, and Telegram. This would enable hybrid emergency communication systems resilient to both infrastructure degradation and network fragmentation.

From a policy standpoint, future studies should focus on standardizing RCS-based public alert protocols and establishing regulatory frameworks that ensure interoperability, authentication, and end-user trust. Integration with 5G network slicing and edge-computing infrastructures also represents a high-impact research path, allowing prioritized handling of emergency traffic with reduced latency.

Ultimately, future research should pursue the creation of an autonomous, self-learning emergency messaging ecosystem, where data analytics, AI, and network intelligence cooperate to maintain uninterrupted, reliable public alerting – even under extreme or degraded network conditions.

### Conclusion

In a 5G-enabled communication environment, the convergence of SMS and RCS technologies offers a resilient, intelligent, and flexible solution for public alerting and emergency communications. SMS remains indispensable for its universality and compliance with legal mandates. RCS, on the other hand, enhances user engagement and interaction with multimedia capabilities, security features, and branding tools.

The proposed IEMOF framework addresses delivery challenges by intelligently routing messages based on real-time device and network conditions. The IGDP model quantifies delivery performance, supporting fine-tuned optimizations. Together, these tools provide a blueprint for implementing robust emergency messaging strategies across hybrid messaging platforms.

Future research should focus on real-world testing of IEMOF in disaster-prone regions, development of regulatory standards for RCS alerting, and continued refinement of IGDP to include user behavior, message type, and contextual priority.

The evolution from SMS to RCS, supported by intelligent frameworks and underpinned by 5G, marks a new chapter in mobile communication – one where resilience, intelligence, and user-centric design can coexist in the service of public safety and engagement.

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**Одарченко М. С., Заліський М. Ю.**

## ВІД SMS ДО RCS: ІНТЕЛЕКТУАЛЬНІ СИСТЕМИ ДЛЯ СТІЙКОГО ОБМІНУ ПОВІДОМЛЕННЯМИ В НАДЗВИЧАЙНИХ СИТУАЦІЯХ

*У статті досліджено еволюцію технологій мобільного обміну повідомленнями — від традиційної служби коротких повідомлень (SMS) до сучасної розширеної служби обміну повідомленнями (RCS) у контексті 5G та систем екстреного оповіщення. Автори підкреслюють, що SMS залишається базовим засобом сповіщення населення завдяки універсальності та відповідності нормативним вимогам, однак має обмеження під час пікових навантажень мережі. RCS натомість забезпечує розширену інтерактивність і мультимедійність, але не гарантує доставку повідомлень у разі деградації мережесевих умов.*

*Для подолання цих недоліків запропоновано інтелектуальну систему оптимізації надсилання екстрених повідомлень (IEMOF) та індекс гарантованої доставки (IGDP). IEMOF є багаторівневою архітектурою, яка в режимі реального часу визначає оптимальний канал передавання з урахуванням стану мережі та пристрою, а IGDP є кількісним показником ефективності доставки, що враховує ймовірність, затримку та актуальність інформації про канали. Методологія дослідження включає моделювання методом Монте-Карло, аналіз емпіричних даних телеком-операторів і CPaaS-платформ, а також регресійне налаштування параметрів моделі.*

*Результати симуляцій доводять, що інтеграція SMS і RCS через механізми інтелектуального fallback істотно підвищує надійність і швидкодію доставки повідомлень в умовах надзвичайних ситуацій. Автори підкреслюють важливість підтримання актуальних карт пристроїв і каналів для точності маршрутизації. Зроблено висновок, що поєднання SMS та RCS на основі інтелектуальних фреймворків, таких як IEMOF, і використання IGDP як оціночного показника формує концептуальну основу для створення адаптивних, стійких і*

орієнтованих на користувача систем публічного оповіщення. Робота має як теоретичну, так і практичну цінність, сприяючи подальшій стандартизації гібридних протоколів зв'язку в інфраструктурі 5G.

**Ключові слова:** SMS, RCS, 5G, інтелектуальна маршрутизація, екстрені повідомлення, надійність доставки, IEMOF, IGDP.

**Odarchenko M., Zaliskyi M.**

## **FROM SMS TO RCS: INTELLIGENT FRAMEWORKS FOR RESILIENT MESSAGING IN EMERGENCY SCENARIOS**

*The article investigates the transformation of mobile messaging technologies from the traditional Short Message Service (SMS) to the modern Rich Communication Services (RCS) within the context of 5G networks and emergency communications. The authors emphasize that, despite SMS remaining the cornerstone of public alerting systems due to its universality and compliance with regulatory requirements, it demonstrates technical limitations during high-load situations. RCS, in contrast, introduces enhanced user interactivity and multimedia capabilities but lacks mechanisms for guaranteed delivery under degraded network conditions.*

*To overcome these challenges, the paper introduces two key concepts: the Intelligent Emergency Messaging Optimization Framework (IEMOF) and the Guaranteed Delivery Index (IGDP). IEMOF represents a multi-layer architecture that dynamically determines the optimal communication channel using real-time network and device data, while IGDP provides a quantitative metric for assessing delivery reliability based on probability, latency, and freshness of channel information. The methodology involves Monte Carlo simulations, analysis of empirical datasets from telecom operators and CPaaS platforms, and regression fitting to calibrate model parameters.*

*Simulation results demonstrate that integrating SMS and RCS through intelligent fallback mechanisms significantly enhances delivery performance and resilience during emergencies. The study also outlines the importance of maintaining updated device and network capability maps to ensure accuracy of routing decisions. The authors conclude that the convergence of SMS and RCS, guided by intelligent frameworks like IEMOF and validated by IGDP metrics, forms the foundation for next-generation, adaptive, and user-centric public alert systems. The research provides practical recommendations for the future standardization of hybrid emergency communication protocols and their implementation within 5G infrastructures.*

**Keywords:** SMS, RCS, 5G, emergency communication, intelligent routing, fallback, delivery assurance, IEMOF, IGDP.

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