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AN INTEGRATED TECHNO-ECONOMIC FRAMEWORK FOR SMS DELIVERY OPTIMIZATION IN 4G/5G NETWORKS

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Abstract**—***Short Message Service (SMS) remains a critical signaling-layer communication mechanism in 4G and 5G mobile networks, particularly within Application-to-Person (A2P) ecosystems supporting authentication, financial notifications, public services, and IoT fallback signaling. The transition to LTE packet-switched delivery and further to 5G Service-Based Architecture (SBA) introduces dynamic routing, SLA differentiation, multi-channel fallback, and cost variability. Traditional Quality of Service (QoS) indicators are insufficient to assess operational efficiency in such environments. Furthermore, Artificially Inflated Traffic (AIT) distorts economic performance without necessarily degrading technical KPIs. This paper proposes an integrated techno-economic framework for SMS delivery optimization in next-generation networks. The framework introduces the Price Delivery Gap (PDG) as an economic deviation metric and develops the Integrated Gap-Delivery-Performance (IGDP) model combining QoS, Quality of Experience (QoE), and PDG into a unified optimization function. An intelligent architecture incorporating message categorization, AIT detection, adaptive routing, and closed-loop monitoring is presented. Scenario-based evaluation under mixed A2P traffic conditions demonstrates reduced economic deviation and improved integrated efficiency compared to static and partially adaptive approaches.*

Keywords—SMS; 4G/5G; A2P; PDG; IGDP; QoS; QoE; AIT; intelligent routing; economic effectiveness.

I. INTRODUCTION

Short Message Service (SMS) remains one of the most resilient and universally interoperable communication mechanisms in mobile networks. Despite the dominance of over-the-top (OTT) messaging platforms, SMS continues to serve as a critical signaling-layer service, particularly in Application-to-Person (A2P) communication scenarios. Unlike IP-based messaging applications, SMS operates over standardized control-plane infrastructure and guarantees device-level reachability independent of IP session availability [1].

In modern digital ecosystems, SMS plays a strategic role in:

- one-Time Password (OTP) authentication;
- financial transaction verification;
- banking and e-government notifications;
- emergency warning systems;
- IoT device control and fallback signaling.

According to the GSMA Mobile Economy Report [2], A2P traffic accounts for more than 60% of global SMS volume, and this proportion continues to grow due to increasing reliance on API-driven authentication services and automated digital workflows.

The operational characteristics of SMS delivery have evolved significantly across mobile network generations.

In GSM and UMTS networks, SMS delivery was based on SS7/MAP signaling and centralized SMSC store-and-forward mechanisms. Routing paths were relatively static, and cost structures were predictable.

With LTE deployment, SMS delivery migrated to the packet-switched domain via IP-SM-GW integration [3]. This transition enabled:

- improved scalability;
- IMS-based integration;
- packet-domain routing.

In 5G Standalone (SA) networks, SMS is implemented through the SMS Function (SMSF) within the Service-Based Architecture (SBA) [4]. SBA introduces:

- network function virtualization (NFV);
- service-based interfaces (HTTP/2);
- dynamic routing and orchestration,
- network slicing with differentiated SLAs.

While architectural flexibility increases service programmability and scalability, it also introduces new complexity dimensions:

- routing variability;

- retry cascades;
- fallback mechanisms (e.g., Rich Communication Services (RCS)).

Consequently, SMS delivery in 5G environments becomes a dynamic, multi-variable process rather than a deterministic signaling procedure.

In next-generation networks, high delivery ratio does not necessarily imply economic efficiency. For example:

- retry mechanisms may maintain delivery success while increasing effective cost;
- SLA differentiation may shift traffic to higher-cost routes;
- fallback switching may reduce latency but increase operational expenses;
- artificial traffic may inflate volume without degrading QoS indicators.

Therefore, purely QoS-based evaluation frameworks are insufficient in modern A2P ecosystems.

Artificially inflated traffic (AIT) represents a structural challenge in A2P SMS markets [6]. AIT typically manifests in OTP segments, where automated systems generate excessive verification requests without genuine user interaction.

Artificially inflated traffic causes abnormal traffic concentration at prefix level, increased retry propagation, inflated interconnect costs, distortion of economic metrics.

Importantly, AIT may not significantly degrade delivery ratio or latency, making it difficult to detect under traditional QoS monitoring frameworks. As a result, economic inefficiency accumulates while technical KPIs remain within acceptable ranges.

This phenomenon reveals a fundamental disconnect between technical performance metrics and economic sustainability.

The transformation of SMS delivery from static SS7 signaling to dynamic SBA orchestration requires a rethinking of evaluation methodologies.

Specifically, there is a need to quantify economic deviation in delivery operations, integrate technical reliability and user perception with cost efficiency, incorporate AIT mitigation into optimization logic, enable closed-loop adaptive routing in programmable 5G environments.

Therefore, the objective of this article is to develop a unified techno-economic optimization framework capable of integrating technical reliability, user experience, and economic sustainability.

II. Literature Analysis

Early SMS performance research focused on SS7/MAP signaling and SMSC queue management in GSM and UMTS networks. With LTE introduction, IP-SM-GW enabled packet-switched delivery, increasing dependency on EPC congestion conditions [3]. In 5G SBA, SMSF is implemented as a native network function interacting with AMF, UDM, and NEF over HTTP/2 interfaces [3]. Research in this domain mainly addresses architectural flexibility and network slicing, but not economic evaluation.

QoS frameworks defined in ITU-T Y.1541 [4] and ETSI TS 102 250-2 [7] establish objectives for:

- end-to-end delay;
- packet loss;
- availability.

However, these frameworks focus on technical performance and omit cost deviation modeling.

Historically, both academic studies and industry mitigation strategies have primarily addressed vulnerabilities at the signaling and transport layers of SMS networks. Widely recognized threats have included SS7 and Diameter protocol exploitation, SMS spoofing, large-scale spam distribution, and grey-route bypass schemes. To counter these risks, network-oriented security standards and frameworks – such as GSMA FS.11 and FS.19 – were introduced to enhance protection against inter-operator signaling abuse and routing manipulation [5]. Although these measures have substantially improved the resilience of core network infrastructure, they provide limited safeguards against fraud scenarios that exploit legitimate enterprise messaging processes and application-level workflows.

Artificially inflated traffic detection approaches rely on traffic anomaly detection and prefix-based aggregation. While effective for identifying abnormal traffic spikes, such methods do not integrate cost modeling into optimization.

Based on the literature review, the following research gaps are identified.

1) Absence of a formal economic deviation metric. Current SMS performance evaluation frameworks focus on QoS metrics (delivery ratio, latency, retry rate). There is no formalized metric quantifying the deviation between nominal tariff-based expectations and effective operational cost in dynamic 4G/5G environments.

2) Lack of integrated techno-economic modeling. Existing studies treat technical performance and economic modeling separately. No unified framework integrates:

- QoS reliability;
- user-perceived quality (QoE);
- economic sustainability.

3) Insufficient integration of AIT into optimization models. AIT research focuses on anomaly detection and fraud mitigation. However, its systemic impact on economic performance and retry-induced cost amplification is not incorporated into multi-objective optimization models.

This study addresses the identified gaps by introducing the Price Delivery Gap (PDG) as a formal economic deviation metric, developing the Integrated Gap-Delivery-Performance (IGDP) model combining QoS, QoE, and PDG, incorporating AIT detection into techno-economic optimization, designing a closed-loop intelligent routing framework aligned with 5G SBA principles.

III. PROBLEM STATEMENT

The architectural evolution of mobile networks from circuit-switched GSM systems to packet-based LTE and service-based 5G Standalone (SA) environments has fundamentally transformed the operational logic of Short Message Service (SMS) delivery.

In GSM networks, SMS operated within a relatively deterministic signaling framework based on SS7/MAP protocols and centralized SMSC entities. Delivery delay, retry mechanisms, and operational cost were largely stable and predictable.

In LTE and especially in 5G SA networks, SMS delivery is executed through:

- IP-SM-GW in LTE;
- SMSF (Short Message Service Function) within 5G Service-Based Architecture (SBA);
- HTTP/2 and JSON-based service interfaces;
- SLA-based prioritization;
- multi-hop inter-operator routing;
- OTT and RCS fallback mechanisms.

As a result, SMS delivery becomes a distributed service transaction rather than a static signaling procedure. This introduces variability in latency, routing cost, retry propagation, and traffic classification, significantly affecting delivery efficiency.

In modern A2P (Application-to-Person) messaging ecosystems, SMS is tightly integrated with CPaaS platforms and API-driven authentication systems. The performance of SMS delivery is typically assessed using technical Quality of Service (QoS) metrics:

- delivery delay L;
- delivery ratio DR;
- retry rate r;
- throughput T.

However, in commercial A2P environments, technical performance does not fully reflect economic efficiency.

The effective delivery cost is influenced not only by nominal tariff rates but also by: retry amplification, routing asymmetry, fallback channel activation, fraud-induced traffic distortion.

The effective cost of delivery can be expressed as:

$$C_{eff} = C_{nom} + C_{retry} + C_{delay} + C_{fallback},$$

where C_{nom} is nominal cost; C_{retry} is retry cost; C_{delay} is SLA-related cost adjustment; $C_{fallback}$ is additional channel-switching cost.

Under certain conditions, delivery ratio may remain within SLA thresholds, while retry rate and routing complexity increase, causing effective cost escalation.

This reveals a systemic inconsistency: compliance with technical KPIs does not guarantee techno-economic efficiency.

To quantify this inconsistency, we introduce the Price Delivery Gap (PDG) indicator.

Price Delivery Gap represents the deviation between expected (contractual) and effective delivery cost:

$$\mathrm{PDG} = C_{nom} - C_{eff}.$$

Interpretation is following:

- $\mathrm{PDG} > 0$: economically efficient delivery;
- $\mathrm{PDG} = 0$: neutral efficiency;
- $\mathrm{PDG} < 0$: economic degradation.

The effective cost is modeled as a function of QoS and QoE parameters:

$$C_{eff} = C_{nom}\left(1 + \alpha\frac{L}{L_{ref}} + \beta r + \gamma\left(1 - \mathrm{DR}\right)\right),$$

where L_{ref} is reference delay threshold; α, β, γ are empirically derived sensitivity coefficients.

Thus, PDG serves as a quantitative bridge between technical quality indicators and economic impact.

However, PDG alone does not account for user-perceived quality or multi-scenario prioritization.

To address the multi-dimensional nature of delivery efficiency, we define the Integrated Gap-Delivery-Performance (IGDP) model:

$$\mathrm{IGDP} = w_1\mathrm{QoS} + w_2\mathrm{QoE} + w_3\mathrm{PDG},$$

where QoS captures objective network performance; QoE reflects user-perceived service quality; PDG represents economic deviation; w_1, w_2, w_3 are scenario-dependent weights.

For example: A2P authentication prioritizes QoS and PDG, IoT scenarios prioritize QoS stability, Public Warning Systems prioritize latency and coverage, Marketing campaigns may emphasize QoE.

IGDP enables a unified efficiency index adaptable to traffic category and SLA policy. Yet, even this integrated model remains vulnerable to traffic anomalies.

Artificially Inflated Traffic (AIT) introduces abnormal traffic growth and retry cascades that distort both technical and economic indicators.

Artificially Inflated Traffic manifests as:

- prefix-level burst anomalies,
- repetitive OTP request patterns,
- synthetic traffic amplification,
- disproportionate retry propagation.

QoS metrics may remain within SLA bounds while PDG deteriorates due to hidden economic distortion.

Therefore, classical QoS-based monitoring frameworks fail to detect AIT-induced inefficiency.

Based on the above analysis, the core research problem can be formulated as follows:

To develop an intelligent techno-economic framework for SMS delivery in 4G/5G networks that integrates QoS, QoE, and economic deviation (PDG), while ensuring robustness against AIT-induced distortions.

The problem includes the following challenges:

1) Formalization of a unified techno-economic efficiency metric.

2) Integration of quality and cost parameters into a single adaptive model.

3) Incorporation of AIT detection into routing decision logic.

Scenario-based optimization under mixed traffic conditions.

IV. Method and Materials

Universal mathematical models of SMS delivery based on aggregated quality of service indicators cannot fully consider the context of service use and semantic differences between different types of messages. In modern A2P scenarios, SMS delivery covers a wide range of service tasks, from critical transactional messages to mass informational and marketing mailings. Ignoring this heterogeneity leads to a distortion of integral delivery performance indicators, in particular PDG, and reduces the practical value of the estimates obtained [8], [9].

According to the recommendations of international standards and industry organizations, the requirements for the quality of message delivery depend significantly on their purpose. For transactional messages, in particular one-time passwords, banking and security notifications, the key parameters are minimum delivery delay and high probability of successful receipt. At the same time, for marketing or informational messages, wider delivery time windows are acceptable without significantly affecting the perceived value of the service [10]. This necessitates the division of A2P traffic into categories with different delivery efficiency requirements.

Within the proposed methodology for integrated assessment of delivery efficiency, the categorization of messages allows the PDG indicator to be interpreted not as a universal metric, but as a context-dependent value, the meaning of which is formed considering the type of message and its service role. Thus, identical values of delivery or delay probability can have different effects on the PDG value for different message categories, which is fundamentally important from the point of view of the economic efficiency of the service [11].

The practical implementation of message categorization can be based on the analysis of metadata, historical delivery characteristics, and traffic behavior patterns.

Combining message categorization with mathematical delivery models allows us to move from static performance evaluation to adaptive delivery process management. For each category, specific performance targets, acceptable delivery time windows, and risk thresholds can be defined, which are directly considered when calculating PDG. This approach is consistent with the recommendations for context-oriented assessment of telecommunications service quality set out in ITU-T and ETSI standards [4], [10].

An additional advantage of categorization is the ability to localize the negative impact of abnormal delivery scenarios. Separating atypical or artificially generated traffic into a separate category avoids skewing the overall performance metrics for legitimate messages and ensures more stable PDG estimates, which is critical for practical delivery management.

Thus, message categorization is a key element of intelligent SMS delivery performance management.

It provides a link between statistical delivery models and real service requirements and creates a basis for adaptive decision-making in CPaaS systems of 4G/5G networks.

Within the proposed methodology for integrated assessment of effectiveness, AIT is considered not only as fraudulent activity, but also as a risk factor that directly affects the economic efficiency of message delivery. An increase in the share of AIT in total traffic leads to an increase in delivery costs without a corresponding increase in useful results, which is reflected in the negative dynamics of PDG even with stable technical delivery indicators [12].

Integrating AIT detection and controlled restriction mechanisms into the overall delivery performance evaluation process allows us to move from passive recording of fraudulent activity to proactive management of service performance. In this case, the reduction of the negative impact of AIT is directly reflected in the stabilization of PDG values and an increase in the reliability of management decisions regarding message routing and billing [13].

Thus, the detection of artificially generated traffic is an integral part of intelligent management of SMS delivery efficiency. The combination of AIT detection methods with message categorization and mathematical delivery models creates the prerequisites for the formation of an integrated framework for efficiency management.

The framework for intelligent SMS delivery performance management proposed in this paper (Fig. 1) is based on PDG as an integral metric that reflects the economic feasibility of message delivery, taking into account actual performance, risks, and service context. Unlike traditional approaches, PDG within the framework is considered not only as a measurement result, but as a controllable parameter, the value of which can be purposefully changed by adapting the delivery process.

RCS and OTT platforms (in particular WhatsApp) that support A2P interaction in accordance with GSMA and platform manufacturer specifications can be used as alternative delivery channels [14] – [16].

Structurally, the framework consists of several interconnected levels. At the basic level, delivery parameters are collected and aggregated, including time characteristics, delivery success and stability indicators.

The next level implements message categorization, which allows interpreting the obtained efficiency estimates considering the type of traffic and service requirements. For each message category, specific performance targets, acceptable delivery time windows, and risk thresholds are defined, which are directly considered when calculating PDG. Thus, the framework provides a transition from universal assessments to context-dependent delivery management [15].

A separate functional component of the framework is the module for detecting and controlling artificially generated traffic (AIT). The results of AIT detection are used to adapt the delivery process, by adjusting priorities, changing routes, or reducing the weight of the corresponding traffic when calculating integral performance indicators. This approach allows localizing the negative impact of AIT and preventing distortion of PDG values for legitimate traffic.

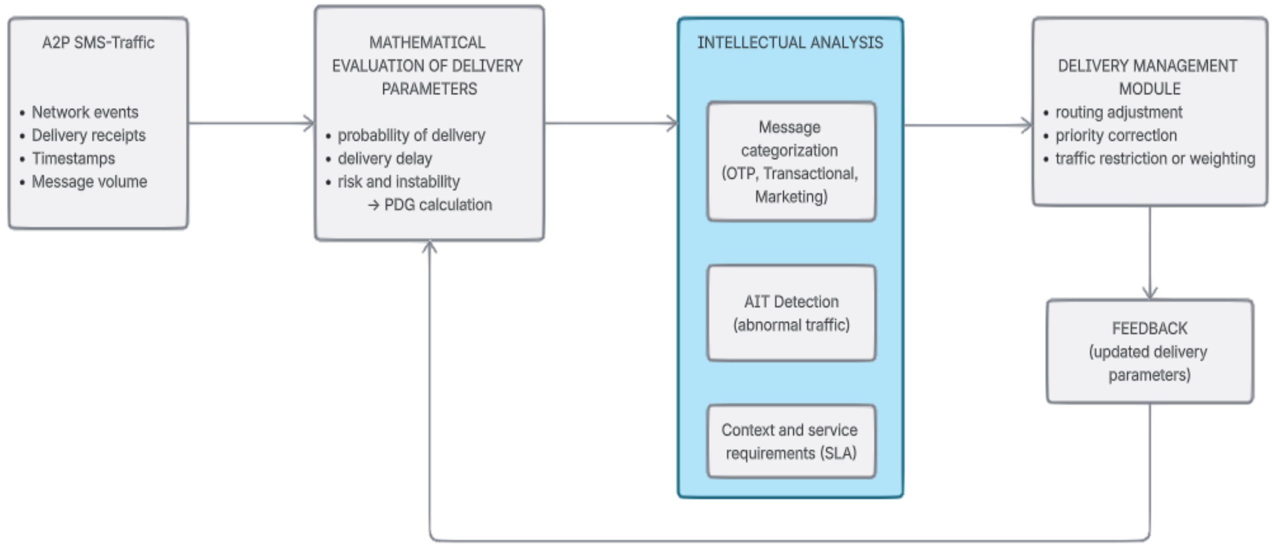

Fig. 1. Integrated framework for intelligent management of SMS delivery efficiency

The integration of these components ensures the implementation of a closed-loop delivery performance management system. Based on current PDG values and the results of intelligent analysis, the system generates management actions aimed at optimizing the delivery process, after which the updated delivery parameters are used again to evaluate performance. This iterative approach is consistent with the recommendations of international standards for telecommunications service quality management and allows the delivery system to adapt to dynamic changes in load and traffic structure.

The proposed integrated framework is not tied to a specific network infrastructure implementation or service provider and can be applied in both operator networks and CPaaS platforms. Its modular structure allows for expansion by adding alternative delivery channels, such as OTT or RCS, as well as adaptation to new types of services and usage scenarios. This creates the basis for the practical implementation of intelligent management of SMS delivery efficiency in 4G/5G networks.

V. Results and Discussion

Below is a scenario-based assessment of the effectiveness of the proposed integrated framework for managing message delivery in mixed A2P traffic, which includes legitimate OTP and marketing traffic with an admixture of artificially generated traffic (AIT). The purpose of the assessment is to quantitatively demonstrate the impact of message categorization, AIT detection, and adaptive use of alternative delivery channels on the PDG performance index in realistic operator scenarios.

The assessment is carried out for two operators (hereinafter referred to as Operator A and Operator B), which differ in terms of tariff policy, delivery quality characteristics, and coverage of alternative channels. This allows us to verify the universality of the proposed approach and avoid tying the results to one specific network profile.

Mixed A2P traffic with a fixed structure is considered:

- share of OTP messages – 30%;
- share of marketing messages – 70%.

Artificially generated traffic is present only in the OTP segment, which corresponds to practical scenarios of fraudulent OTP request generation. AIT is not considered for marketing traffic.

The following scenarios are considered to assess effectiveness:

1) Scenario 1. SMS only, without a framework. All traffic is delivered via SMS without message categorization, without AIT detection, and without adaptive management.

2) Scenario 2. Multichannel delivery without intelligent management. SMS and alternative channels (RCS, WhatsApp) are used according to static fallback rules without considering the type of messages and the risk of AIT.

3) Scenario 3. Categorization and AIT detection (SMS only). OTP and marketing traffic are separated, AIT in OTP is localized, but alternative delivery channels are not used.

4) Scenario 4. Integrated framework. Message categorization, AIT detection, and adaptive use of SMS and alternative delivery channels are applied, taking into account cost, delay, coverage, and delivery risk.

For scenario analysis, a normalized form of the PDG indicator was used, which allows comparing the relative effectiveness of different delivery strategies at fixed weight coefficients.

Delivery efficiency for message type $k \in \{\text{OTP}, \text{MKT}\}$ over channel $c \in \{\text{SMS, RCS, WA}\}$ defined as:

$$E_{k,c} = \left(P_c C_c\right)\left(1 - AIT_{k,c}\right) - \alpha Cost_{k,c} - \beta L_c,$$

where P_c is probability of successful delivery; C_c is share of the subscriber base covered by the channel; $AIT_{k,c}$ is share of artificially generated traffic; $Cost_{k,c}$ is cost of delivering one message; L_c is average delivery delay; α, β are normalization coefficients, identical for all scenarios.

If the message type is delivered through multiple channels, the effectiveness is aggregated as follows:

$$E_k = \sum_c \omega_{k,c} E_{k,c},$$

where $\omega_{k,c}$ is portion of traffic type *k*; routed over channel *c*.

Overall campaign effectiveness:

$$E_{total} = \lambda_{\text{OTR}} E_{\text{OTR}} + \lambda_{\text{MKT}} E_{\text{MKT}},$$

A normalized indicator was used to compare scenarios:

$$\text{PDG}_s = \frac{E_{total,S}}{E_{total,S1}},$$

where scenario 1 (S1) is taken as the baseline.

Based on the described methodology, the normalized PDG indicator was calculated for scenarios S1–S4 for two operators (Tables I – IV). Scenario S1 (SMS only, without framework) was taken as the baseline, and its PDG value was normalized to 1.00 for each operator separately.

TABLE I. DELIVERY PARAMETERS (OPERATOR A)

Parameter	SMS	RCS	WhatsApp
Message cost (OTP)	0.035	0.030	0.030
Message cost (MKT)	0.035	0.040	0.060
Coverat, %	99	70	50
Average latency, s	23	15	19
Delivery Rate, %	90	95	92
AIT % in OTP	15	0	0

TABLE II. OPERATOR A SCENARIOS

Scenario	Description	Etotal	Normalised PDG
S1	SMS only, no framework	0.586	1.00
S2	Multi-channel no message categorization	0.557	0.95
S3	Categorization + AIT (SMS)	0.732	1.25
S4	Integrated framework	0.593	1.12

TABLE III. DELIVERY PARAMETERS (OPERATOR B)

Parameter	SMS	RCS	WhatsApp
Message cost (OTP)	0.025	0.025	0.03
Message cost (MKT)	0.025	0.02	0.015
Coverat, %	99	80	60
Average latency, s	19	20	15
Delivery Rate, %	88	93	94
AIT % in OTP	10	0	0

TABLE IV. OPERATOR B SCENARIOS

Scenario	Description	Etotal	Normalised PDG
S1	SMS only, no framework	0.630	1.00
S4	Integrated framework	0.623	0.99

The results of comparison of normalized PDG are shown in Figs 2 and 3 for operators A and B, respectively. As can be seen in Fig. 2, the use of only multi-channel delivery without intelligent control (S2) does not provide an increase in economic efficiency compared to the baseline scenario. The maximum PDG value is achieved in scenario S3, which corresponds to local optimization of SMS delivery, taking into account categorization and AIT detection. In scenario S4, global delivery optimization using alternative channels is applied, which leads to a slightly lower PDG value, but provides an increase in reliability and delivery coverage in general.

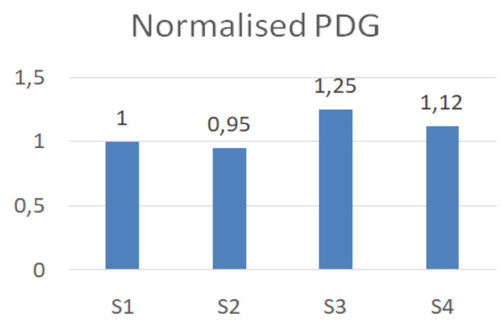

Fig. 2. Comparison of delivery scenarios based on the normalized PDG indicator for operator A

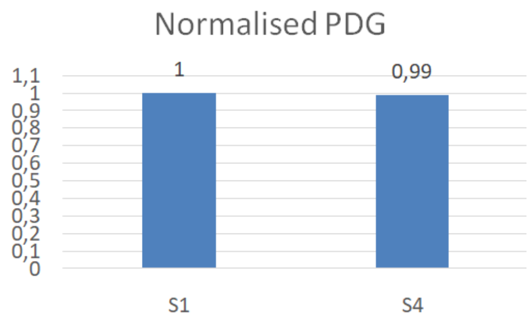

Fig. 3. Comparison of delivery scenarios based on the normalized PDG indicator for operator B

For Operator B (Fig. 3), scenarios S2 and S3 are not presented separately, since due to the lower cost of SMS delivery and the smaller share of AIT, the baseline scenario S1 already provides near-optimal efficiency. Under these conditions, the intermediate scenarios do not lead to significant changes in the PDG indicator and do not provide additional information on the impact of the integrated framework. Therefore, for this operator, a direct comparison of the baseline scenario S1 and the integrated scenario S4 was carried out to verify the universality of the proposed approach.

For Operator B, the baseline level of SMS delivery efficiency is higher due to lower costs and better delay characteristics, resulting in a smaller absolute gain from using the integrated framework. At the same time, the results show that using the framework does not worsen PDG, providing additional stability of estimates and control of AIT risks.

VI. CONCLUSIONS

The numerical results of the scenario assessment confirm that the use of an integrated delivery management framework can increase the efficiency of legitimate A2P traffic in the presence of artificially generated OTP traffic. For Operator A, scenario S4 provides a 12% increase in PDG compared to the baseline scenario, with the main contribution to the improvement coming not from improved network QoS parameters, but from the localization of AIT impact and the contextual use of alternative delivery channels.

The comparison of scenarios S2 and S4 is fundamentally important: it shows that simply adding alternative channels without message categorization and risk assessment not only does not guarantee an increase in efficiency but can lead to a decrease in efficiency. Instead, the integration of categorization, AIT detection, and adaptive routing allows multichannel delivery to be transformed into a tool for improving PDG.

For Operator B, the results confirm the universality of the approach: even in cases where the baseline delivery efficiency is high, the integrated framework does not reduce PDG and provides additional controllability of the delivery process. This demonstrates the applicability of the proposed framework in networks with different economic and technical characteristics without the risk of efficiency degradation.

VII. Future Work

Although the proposed integrated techno-economic framework demonstrates measurable improvements in delivery efficiency under mixed A2P traffic conditions, several research directions remain open for further investigation.

The current study evaluates the framework using scenario-based modeling and normalized PDG comparison. Future work should focus on implementing the framework in real-time 5G Service-Based Architecture (SBA) environments.

This would allow PDG to function not only as a post-analysis metric but as an active control variable embedded in the 5G control plane.

In the present work, PDG is computed based on explicit parameter relationships between delay, retry rate, cost, and delivery ratio. However, large-scale operator datasets may exhibit nonlinear dependencies and latent factors.

Future research may explore supervised regression models for PDG forecasting, anomaly-aware PDG prediction using time-series modeling, hybrid statistical and ML approaches for AIT-aware cost minimization.

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М. С. Одарченко, М. Ю. Заліський. Інтегрований техно-економічний фреймворк для оптимізації доставки SMS у мережах 4G/5G

Сервіс коротких повідомлень залишається критично важливим механізмом сигналізаційного рівня в мережах 4G та 5G, особливо в екосистемах Application-to-Person, що забезпечують автентифікацію, фінансові сповіщення, державні сервіси та резервну сигналізацію для IoT. Перехід до пакетно-орієнтованої архітектури LTE та сервісно-орієнтованої архітектури 5G зумовив зростання складності маршрутизації, диференціацію SLA, використання альтернативних каналів доставки та варіативність витрат. Традиційні показники якості обслуговування (QoS) не дозволяють повною мірою оцінити операційну та економічну ефективність доставки повідомлень у таких умовах. Додаткову проблему становить штучно згенерований трафік, який спотворює економічні показники без істотного погіршення технічних KPI. У роботі запропоновано інтегровану техніко-економічну модель оптимізації доставки SMS у мережах наступного покоління. Введено показник Price Delivery Gap як формалізовану метрику економічного відхилення між номінальною та ефективною вартістю доставки. Розроблено інтегровану модель Integrated Gap-Delivery-Performance, що поєднує показники QoS, якості користувацького досвіду (QoE) та PDG в єдину функцію оптимізації. Запропоновано інтелектуальний фреймворк, який включає категоризацію повідомлень, виявлення AIT, адаптивну маршрутизацію та механізм замкненого циклу управління ефективністю. Сценарна оцінка в умовах змішаного A2P-трафіку для різних операторських профілів демонструє зниження економічних відхилень і підвищення інтегрованого показника ефективності порівняно зі статичними та частково адаптивними підходами. Отримані результати підтверджують доцільність застосування інтегрованого техніко-економічного підходу для управління доставкою SMS у 4G/5G мережах.
Ключові слова: SMS; 4G/5G; A2P; PDG; IGDP; QoS; QoE; AIT; інтелектуальна маршрутизація; економічна ефективність.

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