

A comprehensive overview of key performance, key values and enterprise architecture indicators in 6G development

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Abstract.

The next generation of mobile wireless communication (6G) is still in the development phase, expected to be deployed in 2030, but the academia and industry have started the investment into research and development from the early stages of the capabilities, applications, technologies and use cases of 6G. Due to the introduction of new capabilities, technologies and applications, the set of key performance indicators must be increased by introducing new metrics that will cover all the areas. This paper aims to provide the reader with a systematic literature review on key performance indicators, a comparison between 5G and 6G being structured into four main categories: data rate & delay, capacity & coverage, service efficiency and diversified service evaluation, the impact of security and privacy, where a set of security key performance indicators has been analyzed, the role of Artificial Intelligence in 6G network and a set of possible KPIs that can evaluate the capabilities of AI, key value indicators with the applicability in 5G and 6G and enterprise architecture indicators. The paper will complete the literature by highlighting the relationship between these three types of indicators, their impact on mobile wireless communication and will facilitate the analysis from two perspective a: technical metrics of the services and from the business perspective, focusing on the capabilities of the companies from telecommunication industry.

Keywords: 6G, mobile wireless communication, key performance indicators, 6G KPI, key value indicators, enterprise architecture indicators.

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Introduction

Telecommunication industry is evolving rapidly, where the current generation of mobile wireless communication (5G) is revolutionizing industries and societies, there is a demand for new technologies, capabilities and applications that will lead the society to the next generation (6G).

This paper aims to provide the reader with a systematic literature review on key performance indicators, a comparison between the actual generation and 6G being structured into four main categories: data rate & delay, capacity & coverage, service efficiency and diversified service evaluation, it was the impact of security and privacy, where a set of security key performance indicators has been analyzed, the role of Artificial Intelligence in 6G network and a set of possible KPI that can evaluate the capabilities of AI, key value indicators with the applicability in 5G and 6G and enterprise architecture indicators. The paper will complete the literature by highlighting the relationship between these three types of indicators, their impact on mobile wireless communication and will facilitate the analysis from two perspective as technical metrics of the services and from the business perspective and the capabilities of the companies from telecommunication industry.

While the method of conducting a systematic literature review can be perceived to be a foundational activity as part of the academic research process, this paper's novelty brings to the attention of researchers in the fields of key performance indicators, key value indicators and enterprise architecture indicators in mobile communication. Through a systematic literature review, this paper will synthesize and analyze relevant academic research to explore key performance indicators, key value indicators and enterprise architecture indicators in the next generation of mobile wireless communication (6G).

Literature review

In comparison with the recent 4G, the actual generation (5G) of mobile wireless communication offers improvements compared to the fourth generation, there are limitations that cannot meet the performance demand of the future applications for the next generation as 6G. Researchers concluded that some of the actual applications and services require better communication performance that exceed the capabilities of 5G [1].

In the future, 6G is expected to fix the issue with true global coverage, with the integration of maritime and satellite communication. The speed of actual technology is considered insufficient, while 6G is expected to be a speed level that can support services such as telemedicine and ultra-high-definition video. [1,2,3,4,5].

Latency must be lower in 6G and is critical for real-time applications, while connection density needs an improvement as 5G cannot support the expected number of devices [6,14,15,16]. Position accuracy must be improved as 5G is not as precise enough, reliability must be improved because actual generation cannot support critical applications, while 6G is expected to increase network energy efficiency and the level of intelligence [17,18,19].

The scope of the 6G will be defined by key performance indicators (KPI), which measure technical performance and by key value indicators (KVI), which measures the impact of technology, especially in domains or areas like sustainability, security, inclusiveness and trustworthiness, that must be aligned with the United Nation's sustainable development goals [3,13,15,20].

Artificial Intelligence will play a significant role, expected to be deeply integrated and will allow security automation. Creating new forms of security threats will be inevitable and the security risks will increase and include more intelligent and powerful adversaries. In this case, it will require the evolution of 6G security by incorporating intelligent and flexible security mechanisms that can intelligently predict, detect, mitigate and prevent security attacks [3]. Beside security, privacy and trust are considered significant goals because it's crucial to ensure privacy and trust in the respective domains and among the stakeholder, while the correlation between security and privacy is "closely coupled topics". Between security and privacy is a one-way relationship, as only security is exclusive from privacy, but privacy without security is not valid because to assure privacy, there are required security mechanisms to protect the data [3].

Enterprise Architecture is defined as "a comprehensive and integrated approach in line with the organization's strategic planning and macro business policies, which analyzes the various components, aspects and elements of the organization (including organization resources, systems, etc.)" [19].

Methodology

To achieve the aims of this paper, it was carried out a systematic literature review which contains four steps as:

- I. Define research objective
- II. Literature review criteria
- III. Literature review refinement
- IV. Literature review findings

In the first phase, based on the combination of the following key words: 6G, key performance indicators, KPI, network KPI, mobile communications, KVI, key value indicators, enterprise architecture, with the year range between 2020-2025, there were listed 136.718 articles in IEEE/IET Electronic Library (IEL).

In the second phase, based on the combination of the keywords from the Table 1, with the year range between 2020-2025, there were selected thirteen papers, and the results were captured in Table 1.

In the third phase, after the analysis of the papers from the academia, an additional search was performed to extract the findings from industry reports which resulted in seven selected whitepapers and reports that the companies have on 6G development. Several combinations have been attempted, out of which the following have been selected as considered the most relevant:

Table 1. Paper selection in IEEE/IET Electronic Library (IEL),

Keywords	Results	Selected
6G and KPI or 6G key performance indicators (KPIs)	167	3
6G and architecture and network	3761	4
6G, 5G, wireless communication, artificial intelligence, 6G network	296	5

architecture		
6G and KVI	17	1

Source: Authors' own contribution

Results and further discussions

Key differences, main areas of improvement between actual generation of mobile communications and the next one as “6G” have been addressed in [1,2,3,4,5,8], while the Table 2 summarized a comparison between 5G and 6G from key performance indicators perspective.

As can be noticed in Table 2, the key performance indicators were organized into four main categories. Three indicators were proposed to evaluate the performance of 6G communication for the first category, where higher rate and lower delay are critical for the next services that are expected. Peak data rate can reach a higher value with the help of the new technologies, also user experienced data rate defined as “the speed guaranteed to a user 95% of the time”, latency and delay jitter are expected to be improved significantly in order to support the critical applications like intelligent driving and remote surgery [2,6,7,8,9,11,12].

For the second category, higher air traffic capacity and connection density are considered essential conditions to support the expected new scenarios like smart factories and smart cities. Beside those ones, global coverage is considered one of the major goals of 6G, as it's expected to include terrestrial, aerial and maritime coverage [2,7,11].

The third category includes increased target values for spectrum efficiency based on the development of advanced spectrum management technologies, network energy efficiency (EE) refers “to the number of bits transmitted over 1 Joule” where the goal is delivering more efficient services with lower or the same energy consumption, while the last one is cost efficiency, being designed to balance profitability with service quality [2,8,11,12].

Based on the above findings, 6G is expected to exceed the capabilities of actual generation by introducing new applications, it's also required to design other indicators that can evaluate the diversified service quality for 6G communication systems, as it goes beyond the actual metrics designed for the capabilities of 5G. Mobility is one of the indicators, as 6G is expected to support extreme high-speed scenarios, like aircraft and ultra-high-speed trains. Battery life and reliability are considered important because the effect can be seen on IoT communication development, being a limited obstacle from the battery perspective, while the requirements of reliability are application-specific, considered critical for IoT as well [2].

Positioning and sensing are considered the foundation for smart and interconnected systems. To evaluate the service capability of the 6G system, there were proposed two indicators as: security capacity and intelligence level, as 6G is expected to have endogenous or built-in security, using technologies quantum communication and blockchain, which means a higher security capacity of the system. As Artificial Intelligence is expected to have a higher implication in 6G development, it is expected a higher enhancement of the intelligence level in the 6G communication system, but these two indicators were not quantitatively studied [2,7,8,9,11,12].

The next generation is expected to integrate features like integrated sensing, artificial intelligence, local computing, which the advancements will require a new set of metrics beyond what have been used for the actual generation. Based on the new technical aspects, artificial intelligence is expected to have a significant impact on how security key performance indicators will be designed and measured, while some examples of key performance indicators are: sensing accuracy, computational round-trip-time, artificial intelligence convergence model [3, 15, 16].

Table 2. Comparison of 5G and 6G KPIs

Category & KPI name		Definition	5G	6G	Enhancement
Data rate & Delay	Peak data rate	Maximum achievable data rate under ideal conditions per user/device	20 Gbps	1 Tbps	50×
	User experienced data rate	The data rate that is available ubiquitously across the coverage area to a mobile user/device	100 Mbps	10 Gbps	100×
	Latency	The time from when the source sends a packet to when the destination receives it	1 ms	0.1 ms	10×
	Delay jitter	The latency variations in the system	1 ms	1 μs	1000×
Capacity &	Area traffic capacity	Total traffic throughput served per geographic area	10 Mbps/m ²	10 Gbps/m ²	1000×

Coverage	Connection density	Total number of connected and/or accessible devices per unit area	10 ⁶ devices/km ²	10 ⁸ devices/km ²	100×
	Coverage	The coverage percentage of network service	10%	99%	10×
Service efficiency	Spectrum efficiency	Average data throughput per unit of spectrum resource and per cell	30 bps/Hz	≥90 bps/Hz	≥3×
	Network energy efficiency	The quantity of information bits transmitted to/from users per unit of energy consumption	10 ⁷ bit/J	10 ⁹ bit/J	100×
	Cost efficiency	The ratio of user's data consumption benefit and its data traffic cost	10 Gb/\$	500 Gb/\$	50×
Diversified service evaluation	Mobility	Maximum speed at which defined QoS and seamless transfer between radio nodes can be achieved	500 km/h	1000 km/h	2×
	Battery life	The lifespan of IoT equipment batteries	10 years	20 years	2×
	Reliability	Percentage of packets successfully received under a given delay limit	99.999%	≥99.99999%	≥100×
	Positioning	Accuracy of positioning for indoor and outdoor	1 m & 10 m	10 cm & 1 m	10×
	Sensing/Imaging resolution	Resolution of sensing and imaging	1 m	1 mm	1000×
	Security capacity	Trustworthy information rate from transmitter to receiver under eavesdropper threat	Low	High	-
	Intelligence level	Intelligent level of communication system	Low	High	-

Source: Wang et al. (2023). On the road to 6G: Visions, requirements, key technologies, and testbeds. *IEEE Communications Surveys & Tutorials*, 25(2), 905-974

Creating new forms of security threats will be inevitable and the security risks will increase and include more intelligent and powerful adversaries in 6G [3], the Tabel 3 contains a set of KPI focused on security and aligned with 6G vision.

Table 3. Security KPIs and 6G Vision

KPI	Description	6G Impact
Protection level	The guaranteed level of protection against certain threats and attacks	More stringent due to the pervasive utility of 6G and burgeoning risk level
Time to Respond (mean, max)	Time for security functions to counteract in case of malicious activity	Much smaller due to compressed timescale of 6G networks, e.g., an attack can cause havoc at an order or faster
Coverage	The coverage of security functions over the 6G service elements and functions	More challenging due to diverse 6G technologies and ultra-distributed functions
Autonomic level	A measure of how autonomic security controls can act	Expected to be easier to implement with pervasive AI, but also may be counter-beneficial due to AI security issues
AI robustness	The robustness of AI algorithms in the network hardened for security	More difficult to maintain consistently system-wide but more critical due to AI's role in 6G

Security AI model convergence time	Time for learning models working for security to converge	Although more advanced AI/ML models are emerging and hardware capabilities are improving, the data availability and complexity are challenging factors for this KPI.
Security Function Chain round- trip-time	Time for chained security functions to process for ingest, analyze, decide and act (related to "Time to respond" KPI)	Security architecture in 6G is supposed to be more distributed, leading to challenges. But at the same time, device-centric and edge-centric solutions will help.
Cost to deploy security functions (mean, max)	Various cost metrics for measuring the cost of deployment	Substantially increases due to complexity, thus harder to meet target KPI values

Source: Porambage, P., Gür, G., Osorio, D. P. M., Liyanage, M., Gurtov, A., & Ylianttila, M. (2021). The roadmap to 6G security and privacy. *IEEE Open Journal of the Communications Society*, 2, 1094-1122)

Being identified as a key enabler in the development of 6G network, while authors mentioned the need of KPI related to AI and there is not set clearly defined, [17] introduced a possible of KPIs for Artificial Intelligence and related capabilities. Artificial Intelligence (AI) and Machine Learning (ML) have a fundamental role in 6G mobile communications and will be used in different areas like network operation, where it will improve the core network functions as network optimization, mobility enhancement, security and privacy and radio interface, while AI or ML will be applied in performance and services, where the scope is to enhance the key performance indicators like, latency, energy efficiency, reliability, throughput, and scalability and also to enable and improve new services and applications [17].

Applicable AI-related capabilities refer "to the ability to provide certain functionalities throughout IMT-2030 to support AI enabled applications" [18], where these functionalities include distributed data processing, distributed learning [18], while Table 4 summarized proposed KPIs for AI/ML.

Table 4. Proposed KPIs for AI/ML

KPI	Definition	Target value	Evaluation method
Training complexity	Number of real-valued of operations needed for training an AI model until convergence (assuming fixed input data distribution)		-
AI/ML Precision (Type-I errors)	A measure of the accuracy of a classification model, specifically the ratio of true positives to the sum of true positives and false positives. Type-I errors refer to incorrectly identifying a negative instance as positive.	Not a number	-
AI/ML training effectiveness	A measure of how well a machine learning model performs on unseen data after training, often assessed through validation metrics such as accuracy, precision, recall, or F1 score.	-	-
AI/ML processing times	The time taken to process input data and generate predictions or outputs from a trained machine learning model.	<0.15ms	-
Level of Automation achieved	Degree of Automation achieved	>80%	Evaluation of tasks performed automatically versus manual ones
ML accuracy	Accuracy of ML classification model	>0.9	Measure obtained using formula on labeled data and predictions.

Source: 6G SNS IA (White Paper) "6G KPIS –DEFINITIONS AND TARGET VALUES" (2025) DOI: 10.5281/zenodo.14621168.

The scope of the 6G will be defined by key performance indicators (KPI), which measure technical performance and by key value indicators (KVI), which measures the impact of technology, especially in domains or areas like sustainability, security, inclusiveness and trustworthiness, that must be aligned with the UN's sustainable development goals [3,13,15,20]. Figure 1 contains a set of KVI proposed by [14], being structured in two areas: growth and sustainability & efficiency.

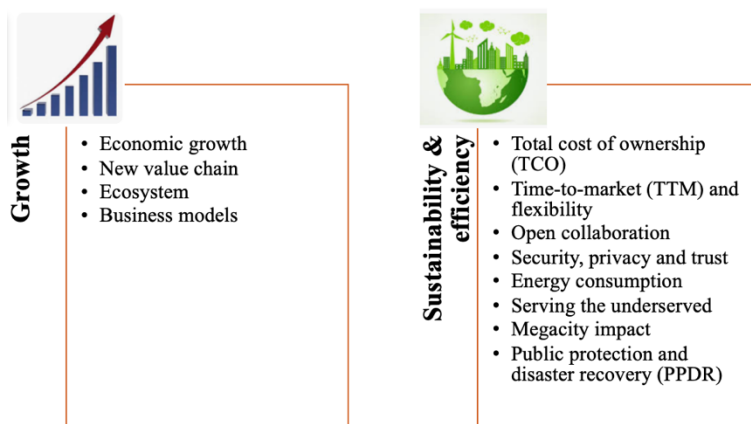


Figure 1. Key values indicators proposed by [14]
Source: Authors' own contribution

Figure 2 contains the enterprise architecture indicators proposed in [19], where scalability refers to “the ability of an architecture to handle increased demands in terms of users, devices, applications, and data volumes without degrading performance”[14], while flexibility refers to “the architecture's ability to adapt and respond to changing requirements, emerging technologies, and evolving industry standards”.

The IT landscape, infrastructure, applications, data, and IT components of the organisation are analysed to assess their compatibility, interoperability, and alignment with business needs [19].



Alignment with the business strategy, this assessment determines to what extent the enterprise architecture supports the strategic goals and business objectives of the organization [19].

Scalability and flexibility assesses the architecture's capacity to scale and adapt to evolving business requirements, market changes, and technology advances [19].



Governance and control, this indicator examines the presence of governance structures, processes and controls to ensure appropriate decision-making, alignment with standards and adherence to architectural principles [19].

Integration and interoperability shows the architecture's ability to integrate different systems, **applications** and data sources within the organization with external partners or suppliers [19].



Security and risk management, the ability of the architecture to deal with security threats, protect **sensitive** information and ensure compliance with legal requirements is evaluated using this criteria [19].

Figure 2. Enterprise architecture indicators proposed by [19]
Source: Authors' own contribution

The impact on scalability and flexibility will be visible in the ability to support expansion and allowing businesses to manage diverse applications and adapt quickly to customers or changing needs. Integration and interoperability will be visible in the advanced integration, including real-time data exchange, faster decision-making, and increased operational efficiency. The advanced capabilities will create new security challenges and organizations must implement strong cyber security measures to protect the sensitive information [19].

The impact on governance and control will lead to improve the decision-making process by implementing real-time data monitoring and analysis, integration of emerging technologies, enhanced efficiency and risk management, automated performance monitoring, resource optimization. In the alignment between business strategy and enterprise architecture, edge computing is a key and plays an important role, as it will enable data processing and analysis at the edge of the network, while edge computing will increase operational efficiency, reduce latency, and will enable real-time decision-making capabilities. In this way, organizations can successfully align their business strategies with

technological advancements, and it will create a competitive advantage that can ensure adaptability, flexibility and scalability [19].

Conclusions

Concluded by the academia, the actual set of key performance indicators must be extended due to the new capabilities that will be available, mentioning research areas as: integration featured of integrated sensing, artificial intelligence, local computing, which the advancements will require a new set of metrics upon 6G development.

The value and the performance of 6G is defined by the potential of this generation to transform the society and the industry from the strategic point of view by merging three words like: physical one (hardware and system-on-chip advances), digital one (next-generation software and digital twins) and the biological one (human-machine interaction) which will lead in creating new user experiences and intent-based automation [18].

From enterprise architecture point of view, the transformative capabilities of 5G and the anticipated one of 6G will have a huge effect on the “evaluation criteria of organizational architecture”, which means the change in the way of designing and assessing the business [19].

Key performance indicators or “key technical enablers” represents the technical metrics that can evaluate the performance of the network itself, being used by enterprises [1,2,3,4,5,6,14,15,6,17,18,19], while enterprise indicators represent the internal metrics to measure its own technology, systems and processes [19] and in the end the key value indicators that measure network’s broader societal and business value [18,20]. These are the three perspective that must be taken into consideration in the development of 6G, while these indicators measure the impact on the service or on the network, the impact within the company and the value added in the society.

The study investigated the overall landscape concerning 6G KPIs. Future studies can consider more focused research from both theoretical and practical perceptions from specific geographical locations, to identify regional flavors of 6G KPI influences. Additionally, future studies can consider interviewing SMEs (Subject-Matter Experts) who are working with early versions of 6G technologies to identify what are the expectations pre-launch and thus set the scene for a comparison post-6G technology adoption by the general population. This study considered IEEE resources only, as this is only experimental technology and IEEE was identified as the most relevant source for such a study.

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