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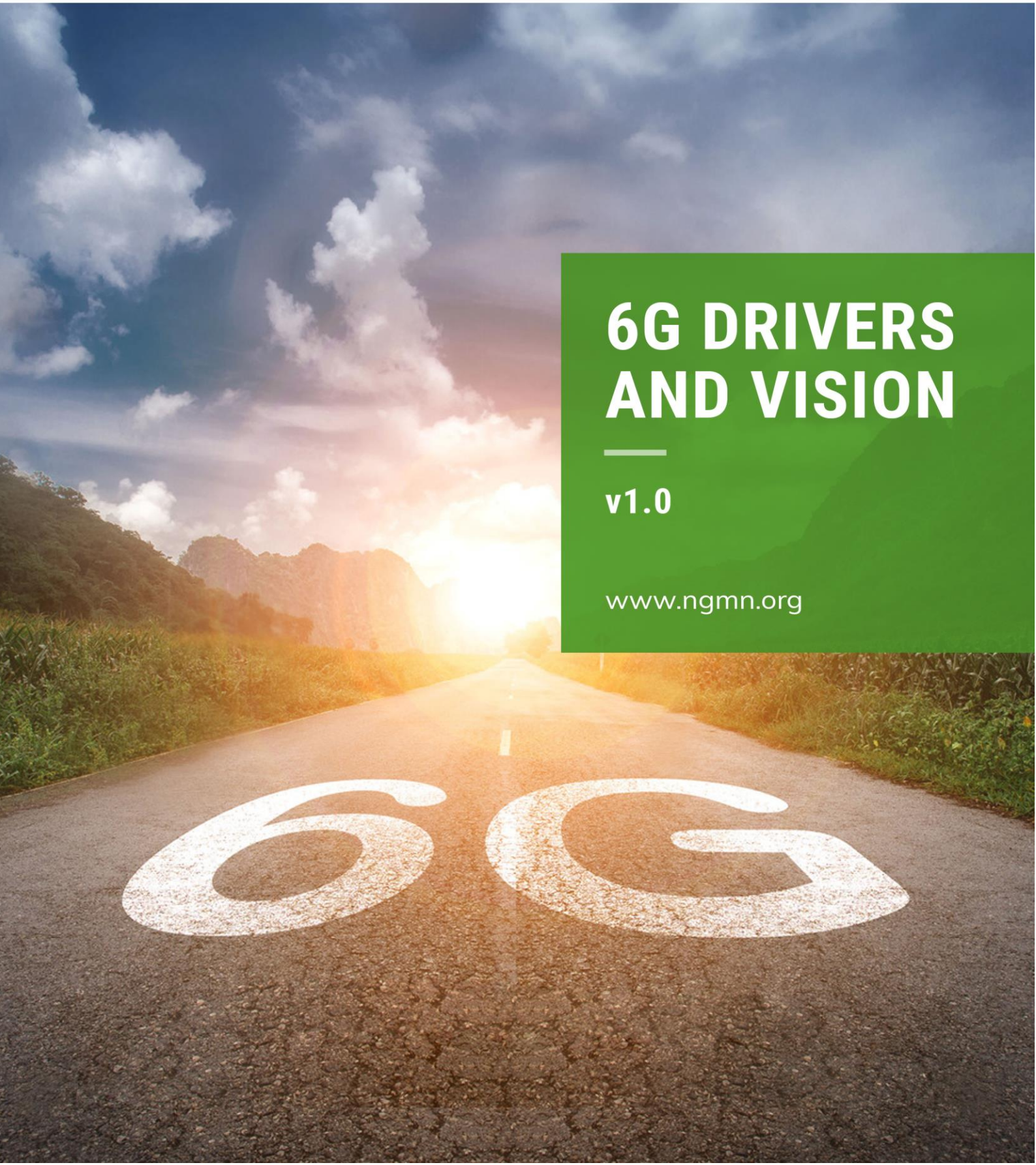

6G DRIVERS AND VISION

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6G Drivers and Vision

by NGMN Alliance

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1 Background and Introduction

The 5G vision, outlined in successive NGMN White Papers [1,2] sets out a framework for enabling digital transformation for society and across industry, with a wide range of use cases and associated requirements.

Commercial deployments of 5G are now progressing around the globe, delivering new capabilities and improved performance for customers. For Mobile Network Operators (MNOs), a set of features that underpin 5G, including disaggregation, softwarization, cloud-native design and operation, autonomous and distributed computing and intelligence, and a multi-access composable core, are enabling new technologies and business models.

This digital transformation of industry is just beginning and its realisation will continue well beyond this decade, supported by continuous evolution of 5G to meet the requirements of diversified industries.

In this paper, the NGMN MNOs, with input from NGMN Partners (vendors, research institutions), outline their vision for 6G representing a future evolution of networks enabling differentiated services with expanded market opportunities and novel experience. It first describes the drivers for 6G, and the key necessities to guide the future technologies to respond to the needs of the end users, societies, and MNOs. This is followed with NGMN's vision of 6G, its novelty and capabilities to meet the drivers identified.

We discuss a number of fundamental aspects, including new scope and approach, that need to be considered in design and development of the next generation of standards and technologies. Furthermore, we recommend that research and the development of future ecosystems prioritize the key gaps and challenges discussed in this paper.

2 Motivation and Drivers for 6G

We believe that the continuing evolution of the mobile industry, and the underlying technologies, must be guided by the imperative to satisfy three fundamental needs facing the society at large, and the telecoms industry in specific, namely:

1. **Societal Goals:** The need to address societal objectives at large, as also expressed in the United Nations (UN) Sustainable Development Goals (SDG).

2. **Market Expectations:** The need to satisfy customer requirements by offering new services and capabilities, supported by evolving technologies in a cost-effective manner.

3. **Operational Necessities:** The need to make the planning, deployment, operations, management, and performance of the mobile operator's networks increasingly more efficient.

Any future technology development should be contextualized in terms of how it can help the society, the end users, and the MNOs' value creation and delivery.

This section captures the main attributes which are required to address the expectation of the society, the marketplace, and the MNOs. With these drivers, the MNOs shall be able to deliver differentiated new services to their customers, while managing and operating the networks much more efficiently.

Motivations and Drivers for 6G

2.1 Societal Goals

Advances in communications technologies are expected to play an important role in addressing and mitigating global societal challenges.

The UN Member States have adopted the SDGs [3]; we believe that future technologies can help contribute further to the success of a number of SDG goals such as: Environmental sustainability (including smart city technologies), efficient delivery of health care, reduction in poverty and inequality, improvements in public safety and privacy, support for ageing populations, and managing expanding urbanization.

Network infrastructure is essential to societal needs, and it is expected to become more critical as the role of communication networks expands in every aspects of the society. Therefore, factors such as the following will be central in considering future technologies: cyber security, resilience (to climatic events, cyberattacks, equipment failures, software bugs, human errors, etc.), end-to-end environment impact of our ICT industry, energy efficiency and digital inclusion.

These are only some examples where advancements in communications technologies can help address societal needs. The actual impact of future communications technologies would be far broader in scope and larger in scale, limited only by our imagination and creativity in applying these technologies for the benefit of all.

2.2 Market Expectations

In our continued journey towards digital transformation and automated industries, the existing and emerging 5G technologies promise to offer new types of services based on very high capacity, throughput, reliability and very low latency, thus significantly expanding the scope of mobile applications broadening human and machine communications. We expect that tens of billions of devices will be connected using existing wireless technologies over the next decade.

As an industry, we need to identify a quantifiable and differentiated role for any new technology that is justified by market and commercial needs. To achieve this, new technologies should enable significant and novel capabilities, supporting radically new and differentiated services, opening up greater market opportunities than the currently existing technologies:

- **Novel and Differentiated Services:** New applications and services based on future technologies should be sufficiently differentiated from existing services to minimize overlap of functionalities. These new services should be customer focused, and driven by specific new use-cases, not supported by existing technologies.
- **Expanded Market Opportunity:** New applications and services based on future technologies should be driven by their scope and scale for applications, and market opportunity. Development of new technology should consider the law-of-diminishing-returns, among others, quantifying demand for it in terms of market value and comparing it against the cost and environmental impact of implementation. From a business model perspective, new paradigms need to emerge to ensure value to the society and sustainable return on investment for MNOs and the various partners and players of the value chain.
- **Fulfilment of Service Expectations:** Any future technology should make practical, significant, and cost-effective gains in delivering fundamental service expectations such as ease of accessibility, service experience, security, and privacy.

In addition, any new communication technology needs to have sufficient flexibility in its design to be able to adapt to needs that were not anticipated at the time it was designed, and sufficient potential to enable innovation beyond the imagination of today.

2.3 Operational Necessities

Historically, wireless standards and technology development efforts have rightfully focused on radio, transport and core technology innovations. Since the first generation of wireless networks, there have been significant advancements in these technologies, leading to a fundamental change in the way people communicate with each other and a significant impact on societies.

However, with the implementation of multiple generations of technology, deployment of greater amounts of spectrum bandwidth, and demand for greater service reliability (whilst catering to an increasing velocity of change), the task of deploying, operating, monitoring, and managing the networks and services has become increasingly complex and difficult. In short, the need to manage complexity, drive efficiency, and reduce costs is now paramount, in the 5G roadmap and the path towards 6G.

To ensure that these technologically intricate networks and services do not outstrip our ability to deploy, operate, monitor, and manage them efficiently, the industry will need to focus on operational aspects such as:

- **End-to-end System Automation**: To manage growing network complexity, reduce operational overheads, and increase ecosystem resilience, seamless hyper-automation is essential. A complete automation framework would allow fully automated life-cycle management by operators, across services, networks, and business/policy domains. This would require end-to-end system visibility and would rely on fully integrated Artificial Intelligence (AI) functionality.

- **End-to-end System Visibility**: To enable 360^{O} system visibility, it is essential to develop a comprehensive end-to-end system monitoring and data collection capability. A complete framework would encompass full visibility across services, networks, and business/policy domains with appropriate data resolution and granularity, ensuring sufficiently rapid data collection and response capabilities. Data security, privacy and anonymity functions would be natively built in.

- **System Efficiency and Management**: As the infrastructure grows, it is vital to ensure that all aspects of system efficiency (beyond automation) are considered and addressed fully. For example, a non-exhaustive list of topics where the industry faces system efficiency and management challenges are as follows (more details on these topics will be provided in future publications):

    - Advanced spectrum utilisation efficiency and management functions
    - End-to-end energy efficiency, monitoring, and management capabilities
    - Significant reductions in network node form-factors and energy consumption
    - Fully automated inventory and network topology detection and management functions
    - Advanced device management capabilities
    - Fully integrated security management functions
    - Integrated Electromagnetic Field (EMF) measurement and management functions

It should be noted that these topics are independent of any particular phase and generation of radio and core network technology.

We recommend that these topics be given the same attention as has been historically given to the radio, transport and core development, and ensure that these critical functions are fully and systematically standardized, natively and horizontally integrated, and operate seamlessly within the holistic ecosystem.

3 A Journey Towards 6G

By addressing the expectations of the society, the marketplace, and the industry at large, we will make great progress towards a healthier society, superior customer experience, and more autonomous and efficient networks, operations and services. Our vision is to help make this a reality.

To be successful, not only will we have to establish what the details of the next generation of standards and technologies should be, but it will also be essential to re-evaluate how the standards and technologies are developed.

3.1 Developmental Considerations

The way future wireless standards and technologies are developed will be crucial. There is a need to broaden, align, and rationalize the scope of standards and technology development process to support a healthier and more vibrant ecosystem. To date, the development of generations of mobile technology has been piecemeal based on proposals that cover specific aspects of the system. For the next generation, the industry needs to ensure that technologies are developed holistically across different standards organisations. NGMN will continue to take an active role to provide guidance in this regard.

This section identifies some fundamental aspects which need to be considered before starting the development of the next generation of standards and technologies:

- **Need for Increased Scope for the Standards Developing Organisations (SDOs)**: In order to drive full ecosystem automation, enhance visibility, and improve efficiency, the SDOs need to expand (or make whole) the scope of their activities to include new aspects which are not yet (or fully) part of the current standards development requirements. The hope is that the SDOs and the industry in general take a holistic end-to-end view of the entire ecosystem, and not only its parts.

- **Need for New Standards Evolution Paradigm**: It is important to reconsider the traditional notion of a “generational” change driven solely by advancement in radio and core technologies. The focus of standards and technology development should become broader in scope, but also more incremental and agile in detail, building on the existing 5G system.

- **Need for Unity and Integrity of Global Standards**: Over the years, the standards development landscape has changed significantly. Rightfully, many new (and sometimes competing) SDOs have arisen to address shortcomings in the existing standards, but in addition new geo-political realities are under development and these pose a potential challenge to the overall unity of the standards driven paradigm. Therefore, it is vitally important to prevent standards duplication which causes market delays and confusion, as well as standards divergence which threatens fragmentation.

- **Need for Differentiated Technology Evolution**: Any new technological development should be assessed with respect to its differentiation from 5G, and any improvements should be benchmarked, including pragmatic deployment scenarios, with the law of diminishing return in mind.

- **Need for Supply Chain Diversity and Security**: The industry must foster and encourage a healthy and competitive development of the new and existing solution providers to ensure a stable global supply chain without any major disruptions. Such a development should be based on open trade, and unhindered global competition, in order to materialize significant improvements in technologies and lower costs.

3.2 Vision of 6G

We expect the fundamental goal of enabling socio-economic transformation and automated industries will naturally continue to be realized beyond this decade and beyond the 5G design goals. We expect 6G in its novelty and capabilities to meet the drivers we have outlined, to involve new advancements in pushing the envelope of performance, provide significant change in enablers, and in addition, break new frontiers (e.g. with respect to environmental impact, societal benefits, users, scenarios, players, value creation, spectrum, etc.), new business models, and potential new paradigms unknown today. We also require features of 6G to be introduced in a way that enhances trustworthiness, security and resilience.

Given the forward-looking vision and design of 5G, the trends towards cognitive, autonomous, multi-access convergence, and disaggregated software-based networks, and its embedded capabilities, 6G is expected to break from the historical approach of technology generations. The approach for 6G should be based on agile and fully flexible systems, with distributed intelligence including at the edge. 6G will thus be built upon the features and capabilities to be introduced with 5G, alongside novel capabilities, in order to deliver new services and value. As indicated earlier, any new technology, nonetheless, should enable superior functionalities and capabilities, supporting radically new and differentiated services, advancing digital transformation and opening up greater market opportunities compared to those enabled by current technologies.

In its role to meet the expected goals, 6G will involve enabling a seamless and ubiquitous experience, and service continuity, considering efficiency and affordability. Sustainability that includes energy efficiency and adoption of green technologies and green energy, towards carbon neutrality is a key focus of NGMN, for this decade and beyond, and should be a fundamental design consideration for 6G. This can only succeed with a holistic approach by the entire ecosystem, including global standards, ecosystem design, service footprint, metering and monitoring, and deployment strategies, among other factors. Beyond network infrastructure, this holistic approach must involve user terminal design, to foster upgrades, reusability, repairability and recycling with the goal to extend their life, as well as service / applications design to optimize the amount of data to be exchanged over the networks.

A healthy and vibrant ecosystem, including the essential role of interdisciplinary research and innovations, and global standardization and ecosystem, will be vital to deliver such a profound change, addressing the drivers of 6G, including those unimagined and unknown today.

Therefore, we recommend that research, and the development of future ecosystems, should prioritise the following key challenges:

- Address societal and environmental needs, including well-being, prosperity, sustainability, trust, safety, affordability, resilience and inclusion. Advance enablement of digital transformation and automated industries to address future market needs, with expanded and differentiated opportunities, operational efficiency, productivity, sustainable business and return on investment. Some examples of attributes and design considerations are indicated below more specifically;

  - Introduce new human machine interfaces that extend the user experience across multiple physical and virtual platforms, sensing, and immersive mixed realities for a variety of use cases, including the use of large bandwidths in existing and new spectrum bands;

  - Advance enablement of seamless multi-access service continuity, using terrestrial and non-terrestrial networks, and provide coverage across land, sea, and sky, efficiently addressing any traffic and connection density;

  - Ensure cost and energy efficient delivery of heterogeneous services that have extremely diverse requirements, under the stringent constraints of energy consumption and carbon emission limits and towards achieving the goals of sustainability and carbon neutrality;

  - Advance and build from design the forward-looking capabilities introduced with 5G such as disaggregation and software-based agile, cognitive and autonomous networks, to ensure the introduction of new technology plug-ins in both the network and the user terminal / interaction mechanisms, that are market driven, support innovation, and create new value opportunities;

  - In support of AI by design, develop an energy and cost-efficient structure that is highly scalable, flexible, and portable, allowing abstraction and distribution of complexities, development of digital twin representation, and embedded intelligence. Identify appropriate AI-based frameworks, with the objective of supporting value creation and delivery, resource allocation optimization, and sustainable deployment and operation, among others;

  - Address the future demands through the support of regulatory systems and harmonized and coordinated global standards and ecosystem, in accordance with developmental considerations outlined above, that ensures interoperability, sustainability, and massive economies of scale supporting value creation and delivery by MNOs and their partners, in a broad ecosystem.

NGMN, with its unique perspective and collaborative approach, plans to provide relevant and timely guidance to the ecosystem throughout the 6G developmental cycle. This White Paper is the first of several papers that NGMN is planning to publish over the next several years; alongside its support of full 5G realization outlined in NGMN 5G White Paper 2. We plan to build upon the high-level guidance provided in this White Paper and orient towards greater details and specifics.

NGMN will establish and maintain a dialogue with representatives of future users (citizens, industries, cities, communities) at all stages of the technology design, to ensure support of society needs, market relevance and efficient technology development and later deployments. As a first step, NGMN has launched a questionnaire that aims at collecting inputs from a broad

variety of organizations and geographies regarding their digital service expectations at the 2030-2035 horizon. These inputs will be used in addition to the NGMN Members and Partners inputs to refine the 6G NGMN vision.

LIST OF ABBREVIATIONS

AI	Artificial Intelligence
EMF	Electromagnetic Field
ICT	Information and Communications Technology
MNO	Mobile Network Operator used here to represent a provider of connectivity and services
SDG	Sustainable Development Goals
SDO	Standards Developing Organisations
UN	United Nations

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