A View of 6G from the Perspectives of Standardization, Research, Network Operators, and Vendors

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Abstract—**The sixth generation of mobile communication systems (6G), formally referred to as International Mobile Telecommunications-2030 (IMT-2030) by the International Telecommunication Union–Radiocommunication Sector (ITU-R), represents a significant architectural evolution in wireless communication systems. Each generation of mobile communication has carried a defining promise, 3G enabled mobile Internet access, 4G facilitated the app-centric digital economy, and 5G extended connectivity to industrial verticals and the Internet of Things. In contrast to 5G, which primarily focuses on connectivity, 6G introduces integration of communication, sensing, computing, and artificial intelligence (AI), thereby transforming the network into an intelligent and ubiquitous platform capable of supporting future societal and industrial demands. This paper presents a comprehensive synthesis of perspectives from key stakeholders, including the ITU-R standardization framework, the Third Generation Partnership Project (3GPP) technical evolution, operator-driven requirements from the Next Generation Mobile Networks (NGMN) Alliance, vendor-driven architectural strategies from Nokia and Huawei, and research initiatives such as the Hexa-X-II project. The analysis reveals that while there is broad agreement on the target vision of an AI-native, cloud-native, sensing-integrated, sustainable and secure unified 6G system, significant divergence exists in the proposed architectural realization approaches. Based on this comparative analysis, the paper proposes two complementary 6G architectural models, an evolutionary architecture grounded in 5G structural continuity and operator feasibility, and a revolutionary architecture driven by native intelligence, sensing and a clean-slate architectural redefinition, which are expected to shape the realization of 6G systems by 2030.**

Keywords—IMT-2030, ITU-R, 3GPP, NGMN, Hexa-X-II, Nokia and Huawei, AI-native networks, Cloud-native architecture, ISAC, TN/NTN.

I. INTRODUCTION

Emerging applications such as extended reality (XR), digital twins (DTs), autonomous systems, and multi-sensory IoT require not only higher data rates but also integrated sensing, distributed intelligence, and ultra-reliable operation. The ITU-R IMT-2030 framework defines this evolution by introducing new capability dimensions beyond those of IMT-2020. 5G systems were designed to address diverse service requirements through three primary usage scenarios enhanced Mobile Broadband (eMBB) for high data rates, Ultra-Reliable Low-Latency Communications (URLLC) for mission-critical and real-time applications, and massive Machine-Type Communications (mMTC) for large-scale device connectivity whereas 6G systems extend this paradigm by introducing six broader capability domains, namely Immersive Communication, Artificial Intelligence and Communication, Massive Communication, Hyper-Reliable Low-Latency Communication, Ubiquitous Connectivity, and Integrated Sensing and Communication (ISAC). These capabilities extend the role of mobile networks from data transport infrastructures to intelligent platforms capable of perception, reasoning, and adaptive control. [1]

ITU-R projects mobile data per subscription per month will increase from only about 5.3 GB in 2020 to approximately 257 GB by 2030, which is roughly 50-fold increase over a single decade, motivating seamless integration of the physical, digital, and human worlds beyond 5G's design scope. [2] Multiple stakeholders contribute to this evolution, each with distinct objectives and constraints. Standardization bodies define global requirements and technical specifications, research initiatives explore disruptive technologies, operators emphasize deployment feasibility and cost efficiency, while vendors translate these concepts into implementable architectures. [3]

In continuation of prior analysis conducted in [4], this paper provides a systematic comparative analysis of how these stakeholder groups perceive and approach 6G system design. By examining publicly available technical specifications, white papers, project deliverables, and operator position statements, we identify areas of strong architectural convergence as well as persistent divergences rooted in institutional mandates. The analysis addresses three questions:

1. What are the preferences of each stakeholder group, and what technical reasoning underlines these preferences?
2. Where do these perspectives converge, and where do they diverge?
3. What does these stakeholder landscape imply for the probable architecture of future 6G systems?

II. STAKEHOLDER PERSPECTIVE

A. Standardization Perspective

Global standardization of mobile communication systems 6G is led by the ITU-R, which defines the IMT-2030 vision, use cases and capability requirements. The below comparative Table 1 shows that 6G is envisioned to dramatically outperform 5G across most metrics while also introducing new functional dimensions which has no parallel in 5G including AI native integration, sensing capabilities, sustainability, and enhanced resilience. [1]

3GPP translates the high-level requirements from ITU-R into implementable technical specifications. Current developments in 5G-Advanced, including service-based architecture (SBA), network slicing, sensing and non-terrestrial network (NTN) integration, form the baseline for 6G evolution. Release 20 initiates formal 6G study items, while Release 21 is expected to define normative specifications. So far, the proposed 3GPP Release 20 study items focus on early technical directions for 6G system development. These include AI integration across Radio Access Network (RAN) and Core for automated network operation, ISAC for combined communication and sensing capabilities, and exploration of sub-THz/THz spectrum for ultra-high data rates. Additional topics address distributed and network-native computing, high-accuracy positioning, energy-efficient network operation, and the expansion of NTN to support wide-area and global coverage. [5]

Table 1: Capabilities Comparison 5G vs 6G [1]

Metric	IMT-2020 (5G)	IMT-2030 (6G)
Peak data rate	Up to 20 Gbps	Up to 200 Gbps
User-experienced rate	~100 Mbps	300–500 Mbps
Spectrum efficiency	~30 bps/Hz (1x)	45–90 bps/Hz (1.5-3x)
Area traffic capacity	10 Mbps/m²	30–50 Mbps/m²
Connection density	~10^6 devices/km²	~10^8 devices/km²
Latency	~1 ms	0.1–1 ms
Reliability	10^{-5}	10^{-5} to 10^{-7}
Positioning accuracy	~10 m	1–10 cm
Additional capabilities	AI-assisted network optimization, Terrestrial (TN) focused & NTN integration	AI-native, sensing, sustainability focused, Terahertz (THz) spectrum usage, TN & NTN seamless unified interoperability

B. *Research Perspective*

Research initiatives play a critical role in exploring pre-standardization technologies and validating architectural concepts. European 6G flagship Projects such as Hexa-X-II propose holistic end-to-end system architectures incorporating AI-native design, integrated sensing, and distributed intelligence across cloud–edge environments. These architectures introduce enabling frameworks such as machine learning operations, federated learning, and data-centric system design. The network is envisioned as a data-native platform where intelligence is embedded across all layers, enabling autonomous operation and adaptive optimization. [6-7]

In parallel, 6G-NTN research provides a detailed analysis of the architecture, design, and functionality of a three-dimensional network that integrates terrestrial and non-terrestrial components, such as High-Altitude Platforms (HAPs) or drones, Low Earth Orbit (LEO), Geostationary(GEO) satellites to provide seamless coverage, especially in underserved areas. It is expected to improve resilience, global connectivity, and positioning, and in many 6G visions it is treated as a native part of the 6G architecture rather than an add-on. Also, Sustainability-driven initiatives such as SUSTAIN-6G emphasize energy efficiency as a fundamental system constraint rather than a secondary optimization goal. [8, 9]

Organizations such as the National Institute of Standards and Technology (NIST) contribute to frameworks, including the Cybersecurity Framework and Zero Trust Architecture, provide essential guidelines for designing secure and trustworthy AI-native 6G systems, while ongoing work in post-quantum cryptography (PQC) ensures long-term resilience against emerging threats. [10]

C. *Operator Perspective*

The NGMN Alliance, representing ~70 operators, emphasize deployment feasibility, cost efficiency, and backward compatibility. Their guiding backward compatible principle for 6G evolution is “evolution rather than revolution,” ensuring that new capabilities are introduced only when they provide clear operational value.

Key requirements include modular architecture, energy efficiency, interoperability, and smooth migration from existing 5G infrastructure. Operators prioritize total cost of ownership (TCO), scalability, and reliability, making evolutionary approaches more favourable for practical deployment and global harmonization. [11-12]

D. *Vendor Perspective*

Industry vendors play a dual role in 6G development by contributing to both research initiatives and standardization processes by providing diverse architectural visions for 6G. Nokia advocates an evolutionary approach based on modular, cloud-native architectures and infrastructure reuse, enabling gradual integration of new capabilities. Within this framework Network Functions (NFs), protocol layers, and even physical components can be dynamically reconfigured according to service requirements, device constraints, and environmental conditions. By focusing on infrastructure continuity and cost efficiency, Nokia’s strategy aligns closely with operator requirements. [13-18]

Huawei proposes a more disruptive paradigm centred on AI-native communication systems, where intelligence becomes the primary system function. The dual approach AI for Network (AI4NET) and the Network for AI (NET4AI) creates a system that can learn, predict, and self-adjust continuously. This approach introduces concepts such as semantic communication and intent-driven networking laying the architectural foundation for intelligent, context-aware, and adaptive services. [19-22]

Table 2: Comparative Analysis of 6G Stakeholder Perspectives [1-22]

Stakeholder	Primary Objective	Preference	Constraints
ITU-R (IMT-2030)	Define global vision and requirements	Neutral (requirement-driven)	Does not prescribe Implementation details
3GPP	Specify the technical realization of IMT systems	Based on 5G-Advance and a gradual path towards 6G	Must preserve interoperability
NGMN (Operators)	Practical, sustainable, trustworthy & affordable	Strongly evolutionary	Backward compatible, Global Harmonization & cost efficient
Nokia (Vendor)	Innovative, modular and scalable deployment	Evolutionary	Infrastructure reuse, redesign, & reinforce-ment of existing technologies
Huawei (Vendor)	Transformational intelligence-driven networks	Revolutionary	Requires new paradigm
Hexa-X-II (Research)	Pre-standard innovation and validation	Hybrid	Pre-commercial validation

E. *Comparative Analysis of 6G Stakeholder Perspectives*

The comparison reveals that all stakeholders agree on fundamental principles, including AI-native operation, cloud-native deployment, integrated sensing, and sustainability inline with IMT-2030. However, divergence arises in implementation strategies, particularly between evolutionary and revolutionary approaches as illustrated in below Table 2.

Operators, and Nokia advocate an evolutionary user-centric approach to preserve existing investments and ensure deployment feasibility. In contrast, Huawei and research-oriented perspectives explore more disruptive paradigms, particularly in AI-native communication and semantic information exchange. This tension between evolutionary and revolutionary approaches constitutes the central architectural debate in 6G system design. [1-22]

III. EVALUATION OF STAKEHOLDER PERSPECTIVES

The comparison presented in Table 3 provides a structured evaluation of how different stakeholders influence the design space of 6G systems. This section synthesizes these dimensions into a set of technical findings, highlighting convergence, divergence, and their architectural consequences.

A. *Architectural Convergence and Divergence*

The evaluation demonstrates strong convergence across stakeholders at the level of fundamental system principles, including AI integration, sensing, sustainability, and security. ITU-R defines these as capability classes within the IMT-2030 framework, while 3GPP investigates their realization through ongoing study items and future specifications. [1, 5]

NGMN and Nokia emphasize an evolutionary approach that ensures backward compatibility and supports gradual migration. In contrast, Huawei promotes a clean-slate architecture where intelligence becomes the central system function with AI Core (A-Core) and AI RAN (A-RAN). This divergence directly explains the coexistence of evolutionary and revolutionary architectures. [12, 13, 21]

B. *Artificial Intelligence as a System Dimension*

AI represents a key differentiating dimension across stakeholders. ITU-R introduces AI as a capability class, whereas 3GPP investigates AI-native integration across RAN and core NFs. Operators utilize AI for automation, optimization, and DT-based network management. [1,5, 12]

Nokia embeds AI within closed control loops and Joint Communication and Sensing (JCAS) enabled architectures, enabling adaptive optimization. Huawei extends this concept further by treating AI as the primary system entity, where the network supports AI workloads and future AGI systems. This progression reflects a transition from AI-assisted networks to AI-native systems, forming a critical distinction between evolutionary and revolutionary architectural paradigms. [13, 21]

C. *Radio Access Strategy*

A key divergence arises in radio access design for uniform ground, air and space integration. Huawei adopts cell-free Multiple-Input Multiple-Output (MIMO) architectures combined with Reconfigurable Intelligent Surfaces (RIS) and THz communication, enabling high spectral efficiency and uniform coverage. Cell-free MIMO has emerged as a promising user-centric architecture that eliminates traditional cell boundaries and provides uniform service quality, outperforming conventional cellular massive MIMO (mMIMO) deployments in terms of spectral efficiency and edge-user performance. In contrast, Nokia provides an evolutionary alternative based on Multi-Radio Spectrum Sharing (MRSS), mMIMO, and coordinated RAN techniques. MRSS enables dynamic spectrum sharing between 5G and 6G systems, while mMIMO and coordinated transmission approximate the benefits of cell-free MIMO without requiring dense distributed infrastructure. From an evaluation perspective, cell-free MIMO offers higher theoretical performance but introduces significant challenges in synchronization, fronthaul requirements, and deployment cost. Nokia’s approach provides a balanced trade-off between performance, scalability, and feasibility, making it more suitable for early 6G deployment. [13, 20, 23]

D. *Spectrum and Sensing*

Spectrum strategies further reflect this divergence. ITU-R defines a wide spectrum range from sub-1 GHz to THz bands, while 3GPP explores multi-band operation and NTN integration to support coverage, capacity, and extreme use cases, including studies on frequency bands up to 71 GHz and beyond. Operators prioritize spectrum reuse and mid-band expansion, aligning with Nokia’s MRSS approach. In contrast, Huawei advocates a more aggressive spectrum strategy, emphasizing the utilization of higher frequency bands, including sub-THz and THz ranges that supports all 6G use cases from the beginning. This approach targets ultra-high data rates and capacity enhancements but introduces significant challenges related to propagation characteristics, hardware complexity, deployment cost, and global interoperability. World Radiocommunication Conference 2027 (WRC-27) is expected to play a pivotal role in shaping 6G spectrum strategy by identifying and harmonizing candidate frequency bands.

ISAC is defined by ITU-R as a primary usage scenario, with ongoing standardization studies in 3GPP. Operators position sensing as a network-exposed service enabling high-precision localization and environmental mapping. Nokia extend this through JCAS and Sensing Management Function (SeMF), while Huawei conceptualizes the network as a continuous environmental sensing fabric, where sensing is integrated with DT and intent-driven communications. [1, 5, 13, 21, 24]

E. *Sustainability and Security*

Sustainability is a fundamental 6G design constraint driven by regulatory alignment with Sustainable Development Goals and operational demands for energy-efficient, low-impact networks. Operators emphasize cost and energy-aware optimization, Nokia supports this through energy-aware artificial intelligence and infrastructure reuse, while Huawei proposes AI-native power management and green hardware solutions.

Security and trust are universally prioritized through security-by-design, zero-trust architectures, and post-quantum cryptography. Operators require built-in

Table 3: Evaluation of stakeholder perspectives across 6G design dimensions. The comparison highlights the separation between requirement definition (ITU-R), technical realization (3GPP), deployment constraints (NGMN), and contrasting vendor strategies (Nokia and Huawei). [1-22]

Dimension	ITU-R	3GPP	NGMN (Operators)	Nokia	Huawei
Primary Objective	IMT-2030 framework and capability definition	Technical realization and specification development	Practically deployable, cost efficient, and sustainable	Simple, Modular, Standalone, Implementable system	AI-driven system transformation
Architecture Philosophy	Requirement-driven, user-centric, no fixed architecture	Continuation from 5G to 6G, early 6G studies	Evolution, backward compatible, reusable, simplicity, single architecture	Modular SBA evolution with NF reuse, user and operator centric	Clean-slate AI-native: A-Core and A-RAN, data-centric
AI Integration	AI as capability class in IMT-2030	AI-native networking is being studied in Release 20	AI for automation and digital twin services	AI in closed control loops and JCAS integration	AI is central, with AGI-driven communications and network-side intelligence.
Spectrum and RAN Strategy	Sub-1 GHz to above 100 GHz including sub-THz	Multi-band operation up to 71 GHz & beyond and NTN under study	Spectrum reuse <8GHz and expansion 6–15 GHz; use sub-THz only where justified.	MRSS, mMIMO, coordinated RAN	THz, RIS, cell-free MIMO, A-RAN
Sensing Capability	Sensing defined as IMT-2030 capability	ISAC under study	Sensing as service enabler	JCAS with sensing NFs	Network as continuous sensing platform using DT
Security and Trust	Security-by-design, resilience, Post-Quantum Cryptography	Zero-trust and AI-aware security, early 6G studies	Built-in trust and quantum-safe security	Modular Non-Access Stratum security and forward secrecy	Federated learning and privacy-preserving security
Sustainability	Energy efficiency and sustainability targets	Energy-aware system, under study	Cost-efficient and optimized operation	Energy-aware AI and infrastructure reuse	AI-driven power optimization and green hardware
Migration Strategy	Coexistence for 5G and 6G	Release 20 study phase to Release 21 normative work	Smooth migration with minimal hardware changes	Network Function reuse and gradual upgrade	Clean-slate approach with service-level compatibility

trustworthiness and quantum-safe mechanisms, whereas vendors adopt differentiated approaches, Nokia adopts a modular security approach, applying protection mechanisms at the level of individual network functions and Huawei introduces federated learning and multi-party computation for privacy-preserving distributed intelligence. [1, 5, 9, 10, 12, 18, 22]

F. *Migration and Deployment Feasibility*

Migration is the most critical factor for practical deployment. ITU-R and 3GPP define coexistence for 5G and 6G, while NGMN mandates smooth migration with minimal hardware changes. Nokia aligns with this requirement through NF reuse and incremental upgrades. Huawei's clean-slate approach, although technologically advanced, introduces higher complexity and deployment challenges. This reinforces the conclusion that evolutionary architectures are more feasible for initial deployment, while revolutionary architectures define long-term system evolution. [1, 5, 16, 19]

IV. PROPOSED ARCHITECTURES

The architectural synthesis is derived from prior analysis conducted in [4], Section II and III. Specifically, an evolutionary trajectory emphasizing backward compatibility, cost efficiency, and incremental enhancement is contrasted with a clean-slate paradigm advocating native intelligence, deep integration of sensing and communication, and architectural redefinition.

A. *Evolutionary Architecture*

The evolutionary architecture extends the 5G SBA by incorporating AI-driven orchestration, edge computing, and sensing capabilities. It enables gradual migration and aligns with operator requirements for deployment feasibility. The developed probable evolutionary architecture as shown in Figure 1, preserves the structural logic of the 5G Core while introducing 6G-specific capabilities as modular, native extensions. Multiple stakeholders Network Operators (NOPs) manage infrastructure, Communication Service Providers (CSPs) deliver connectivity services, Digital Service Providers (DSPs) offer value-added services through exposed capabilities, and Capability Operators (COPs) specialize in managing specific network functions are supported across verticals Healthcare, Manufacturing, Transportation, Collaborative Robots (CoBots), XR, Digital Twin Network (DTN). [7]

A unified Service Exposure and Programmability layer exposes capabilities as composable services Compute as a Service (CaaS), AI as a Service (AIaaS), and Network as a Service (NaaS) via standardized APIs generalizing Common API Framework (CAPIF). Embedded within are edge-cloud orchestration, Compute & Storage, AI ML (Artificial Intelligence and Machine Learning) Model Catalogue, Training & Validation, Security/Resilience/Privacy, and AI Operations, Administration, and Maintenance (OAM).

The 6G RAN coexists with the 5G RAN under RAN Sharing, built on an O-RAN lower-layer split with an Radio Unit (RU) handling Extreme-MIMO (E-MIMO) and sub-THz waveforms. Cell-based architecture with enhanced coordination and spectrum sharing. Three additional capabilities sensing, computing, and AI are integrated directly within the RAN and can be dynamically activated or scaled according to service requirements, device constraints, and operational conditions. The 6G Core

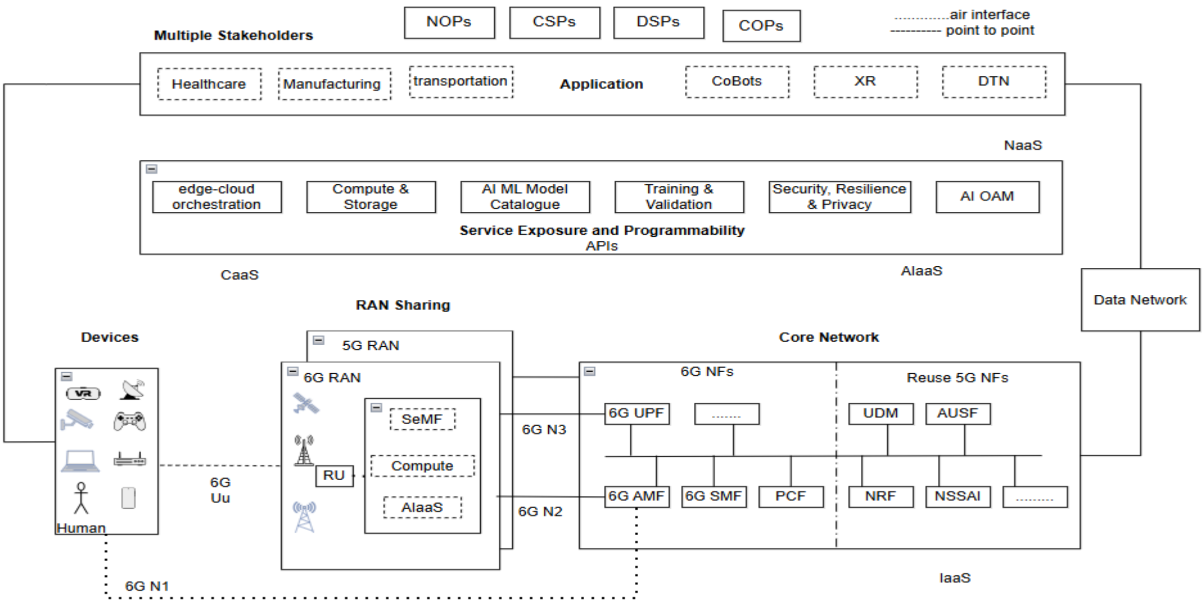

Figure 1: Developed Evolutionary Architecture

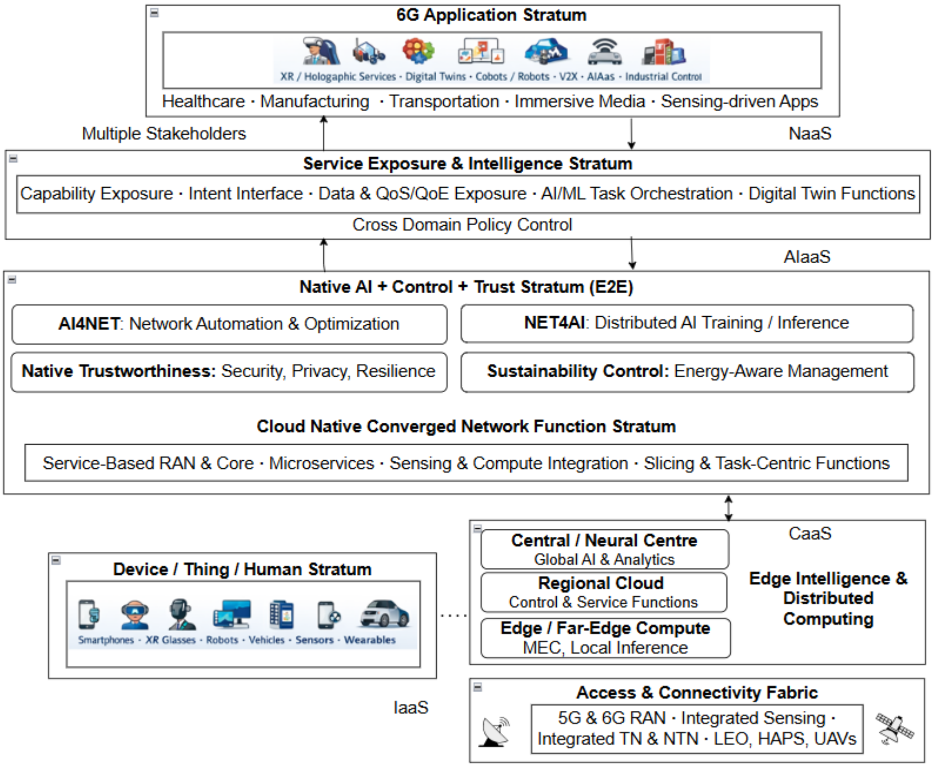

Figure 2: Developed Revolutionary Architecture

introduces only required 6G NFs and reuses 5G NFs directly protecting operator investment. [13]

The 6G User Equipment (UE) connects to the shared RAN via the 6G Uu air interface, which remains a wireless interface similar to 5G but enhanced with sensing and AI capabilities. In addition, UE maintains a control-plane interface with the shared core network through 6G N1 for Non-Access Stratum (NAS) signalling. The RAN interfaces with the core network through point-to-point interfaces for control and user plane, 6G N2 and 6G N3 respectively. Integrated terrestrial and non-terrestrial access enables seamless connectivity, while the cloud-native core operates over Infrastructure as a Service (IaaS). Single Registration (SR) combined with shared IP anchoring enables seamless mobility and session continuity by maintaining a unified device context and persistent IP session across heterogeneous access networks. This preserves the modular interface structure of 5G while enabling evolutionary 6G enhancements. This developed evolutionary probable architecture are user-centric contribution from Nokia and Hexa-X-II whitepapers and is globally aligned directly traceable to 3GPP Release 20 study items and the NGMN operator mandate, making it the most viable IMT-2030 deployment. [7][13]

B. Revolutionary Architecture

The revolutionary architecture represents a clean-slate design integrating communication, computation, and sensing into a unified AI-native system. It introduces semantic communication and distributed intelligence across cloud, edge, and devices. The developed probable revolutionary architecture as depicted in Figure 2, is a clean-slate, intelligence-first design structured into five strata.The 6G Application Stratum spans XR/Holographic Services, Digital Twins, CoBots/Robots, Vehicle-to-Everything (V2X), AIaaS, and Industrial Control all demanding AI-native infrastructure, not an afterthought. Secondly, the Service Exposure and Intelligence Stratum provide Capability Exposure, Intent Interface, Data & Quality of Service (QoS)/Quality of Experience (QoE) Exposure, AI Task Orchestration, and Digital Twin Functions under Cross Domain Policy Control.

The Native AI + Control + Trust Stratum end-to-end is the "Brain" of the 6G network and is AI4NET, which applies AI for network automation and optimization, and NET4AI, which enables the network to support distributed AI training and inference. Native Trustworthiness (Security, Privacy, Resilience), and Sustainability Control - Energy-Aware Management all operating as a unified end-to-end plane, not layer-by-layer additions. Below it, the Cloud Native Converged Network Function Stratum hosts service-based RAN and Core microservices, Sensing & Compute Integration, Slicing, and Task-Centric Functions.

The Edge Intelligence and Distributed Computing continuum spans three tiers: Central/Neural Centre (Global AI & Analytics), Regional Cloud (Control & Service Functions), and Edge/Far-Edge Compute (Multi-Access Edge Computing (MEC), Local Inference). The Access and Connectivity Fabric unify 5G & 6G RAN, Integrated Sensing, and Integrated TN & NTN such as LEO Satellite, HAPs, and Unmanned Aerial Vehicles (UAVs). Large number of distributed access points jointly serve users without cell boundaries.

The Device/Thing/Human Stratum encompasses Smartphones, XR Glasses, Robots, Vehicles, Sensors, and Wearables. The developed revolutionary architecture aligns with Huawei and Hexa-X-II by adopting an AI-native, data-centric, deep integration of communication, sensing, and computation, and distributed intelligence across the device–edge–cloud continuum as a fully integrated system design. While challenging from a deployment and standardization perspective, it represents the long-term evolution of 6G beyond incremental 5G-based architectures that seeds the infrastructure required for this artificial general intelligence (AGI)-era networks. [7,19-22]

V. CONCLUSION

Although a coherent vision of 6G architecture is emerging, standardization remains in an early and evolving phase, and significant work is required to achieve globally harmonized, interoperable, and implementable systems. This paper comparatively evaluated stakeholder perspectives and identified two architectural directions, evolutionary and revolutionary, both conceptually viable, but only one realistically deployable by 2030.

The evolutionary architecture aligns with operator-critical requirements by preserving 5G NFs investments, enabling gradual spectrum migration via MRSS, and introducing advanced capabilities such as AI-native, cloud-native, and sensing-integrated functionalities as modular extensions rather than requiring complete infrastructure replacement. In contrast, the revolutionary architecture offers significantly higher innovation potential, its Native AI + Trust Stratum, NET4AI distributed intelligence plane, and task-centric converged NF design defines what 6G must ultimately become to support AGI-era services. However, it introduces substantial challenges in standardization maturity, interoperability, and deployment complexity.

Overall, 6G development demonstrates convergence in system capabilities but divergence in architectural realization, with near-term deployment following an evolutionary path and long-term evolution progressively incorporating revolutionary concepts.

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