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SHAPING THE FUTURE e& UAE'S 6G VISION

WHITE PAPER
2025

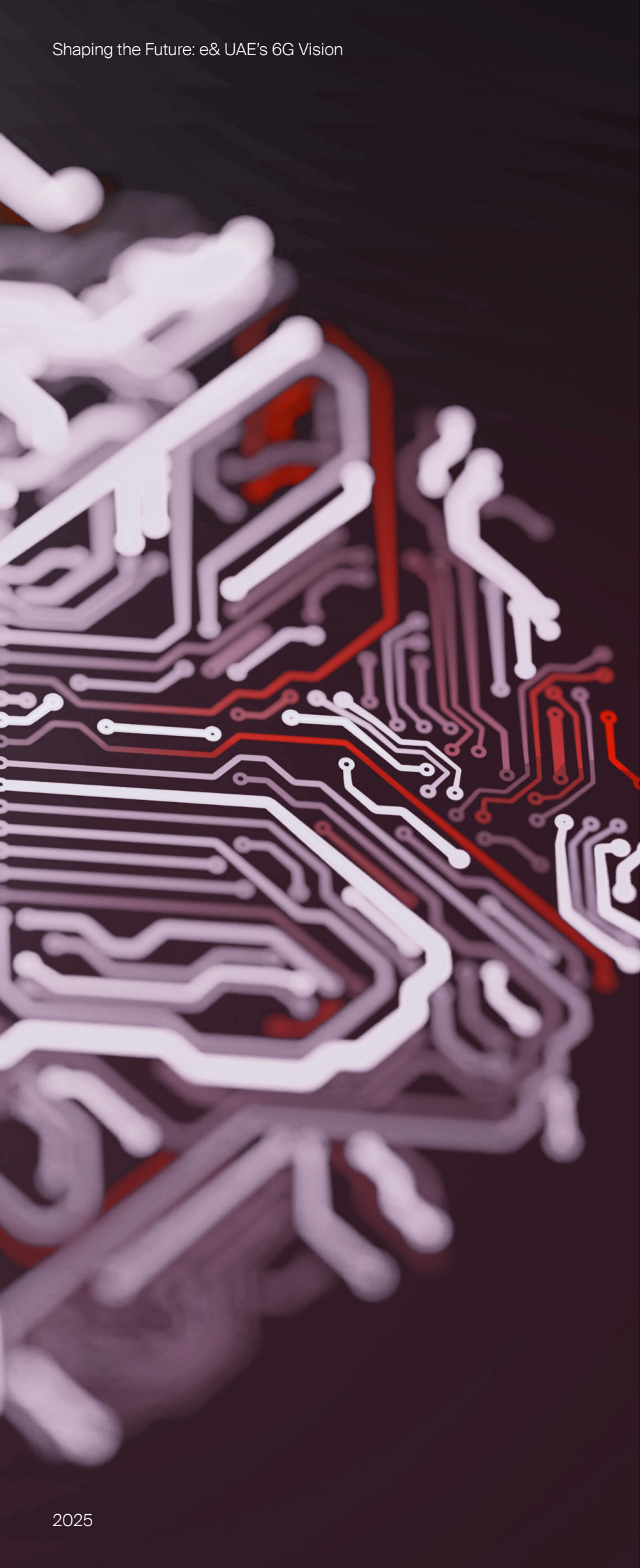
6G Represents the next evolutionary leap beyond 5G and 5G-Advanced,

01. Executive Summary

Promising to transform connectivity with unprecedented capabilities. It is envisioned to build on the 5G foundation by integrating advanced technologies such as **AI-driven networking up to sub-terahertz (THz) spectrum, integrated sensing, and quantum-grade security.**

Collectively, these will enable **extreme performance** – peak data rates on the order of terabits per second, air-interface latencies below a millisecond, and reliability approaching "six nines" (99.9999%) or better. More than just higher speeds, 6G aims to usher in intelligent, ambient connectivity that seamlessly links the physical, digital, and biological worlds.

For telecom operators like e& UAE, 6G is both a natural progression and a strategic opportunity. Having established a leadership position in 5G (including record-setting 5G-Advanced speed of 62 Gb/s at GITEX 2024), e& UAE is poised to drive 6G innovation.



The company envisions 6G as a catalyst for an **"advanced, intelligent, and inclusive"** digital ecosystem. Key enabling technologies – from **AI-native networks to non-terrestrial satellite integration** – are being explored to support **ultra-immersive user experiences, autonomous systems, massive IoT expansion, and new industry vertical solutions.** In parallel, e& UAE's 6G vision emphasises **sustainability, security, and inclusivity** as core design principles, aligning with global 6G objectives to bridge the digital divide and minimise environmental impact.

In summary, 6G will not simply be "5G but faster." It is a paradigm shift toward networks that are **cognitive, ubiquitous, and capable of services beyond communications** (such as high-precision sensing and integrated computing). This whitepaper outlines the global 6G landscape with an emphasis on e& UAE's perspective – covering the technology drivers, use cases, business models, and roadmap for 6G. It highlights how e& UAE intends to shape the 6G era through early R&D investments, ecosystem partnerships, and leadership in standards – ensuring that the UAE remains at the forefront of connectivity innovation heading into 2030 and beyond.

02. Introduction

The journey from 5G to 6G is driven by a clear rationale: future societal and industry needs will soon surpass what 5G and even 5G-Advanced can offer ([2]). By 2030, after a decade of 5G deployment, new applications and lessons learned will reveal gaps – for example, demands for even greater bandwidth (e.g. ultra-HD holographic communication) and capabilities beyond communication (like environmental sensing). While 5G-Advanced (3GPP Releases 18 and 19) extends 5G with improvements in throughput, latency, XR support, and network efficiency, it remains an evolutionary step. 6G, in contrast, is conceived as a revolutionary leap to enable "critical services, immersive communication, and omnipresent IoT" on a new level. The drivers for 6G include:

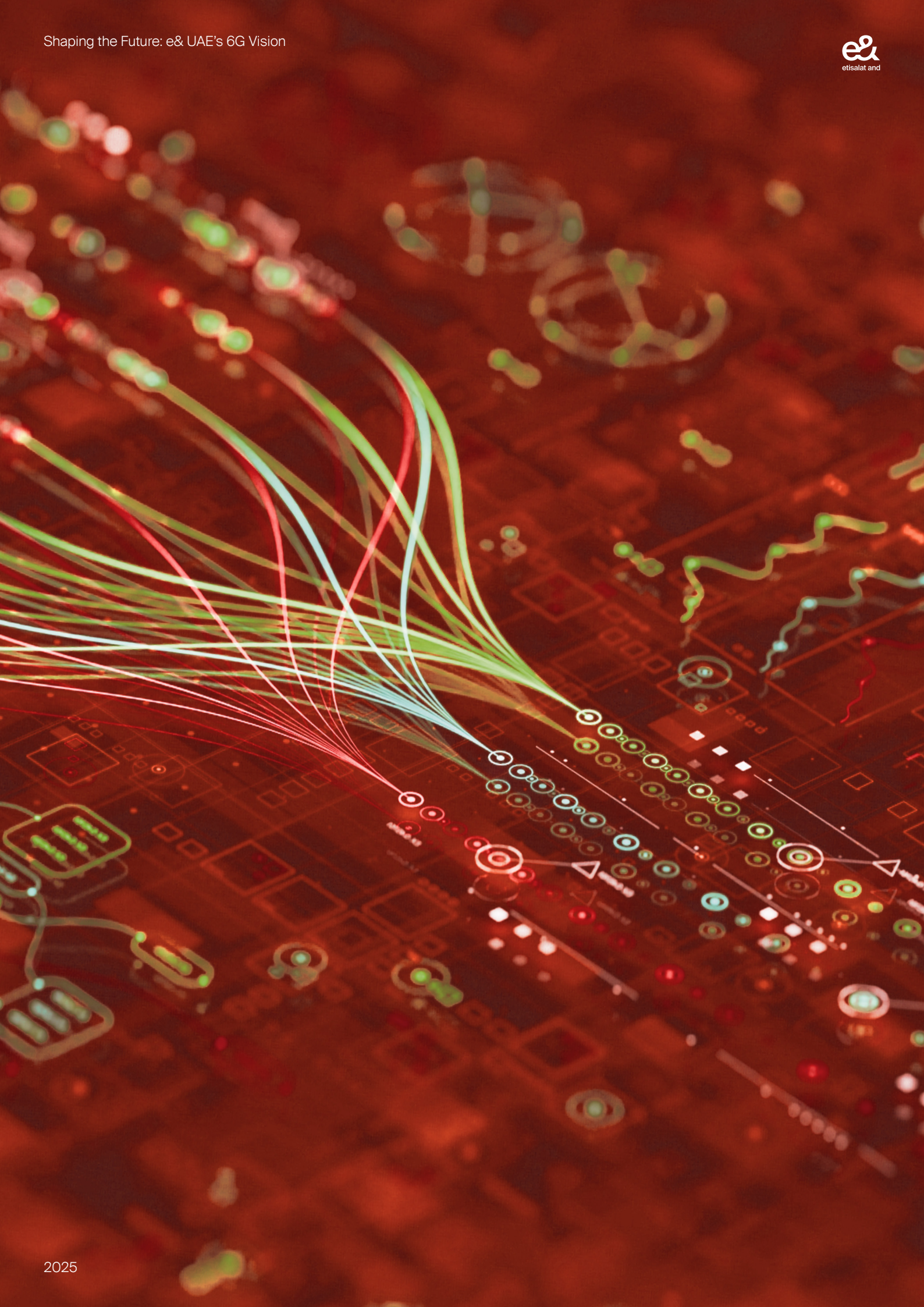
- **New applications & business models** (such as holo presence, tactile internet, and industrial automation at scale) that demand capabilities beyond 5G's scope.
- **Proliferation of intelligence** (AI/ML everywhere) requiring networks that not only carry data but collaborate in real-time computing and decision-making.
- **Sustainability & social goals**, pushing for networks that are far more energy-efficient and inclusive (connecting remote or underserved areas) than today.

For telecom operators, the transition to 6G is a strategic imperative. Operators like e& UAE will play a pivotal role in shaping 6G development and deployment, leveraging their operational expertise and market position. e& UAE's early adoption of 5G – being the first in MENA to launch 5G and achieving the world's fastest 5G speeds – illustrates how operator leadership can accelerate a new generation of technology.

With 6G, e& UAE is actively collaborating with global forums (e.g. ITU's IMT-2030 groups, 3GPP, GSMA, and research alliances) to contribute to the vision and requirements of 6G. The operator's role spans from R&D and standardisation (influencing technical specs based on real-world insights) to eventually infrastructure deployment and service innovation. In shaping 6G, e& UAE is focused on aligning the technology with national priorities – such as smart city initiatives, digital economy growth, and the UAE's intelligent nation aspirations. By investing early in trials and nurturing an ecosystem of startups and industry partnerships, e& UAE aims to ensure that by the time 6G standards solidify (around 2027–2028) and commercial equipment arrives (~2030), the UAE will be ready to lead in 6G adoption just as it did with 5G.

Ultimately, 6G's anticipated impact is broad and profound.

It is expected to empower intelligent hyper-connectivity for everything, everywhere – from autonomous vehicles and drones to AR glasses and industrial robots – with a fabric of intelligence and sensing built into the network. This introduction has outlined why 6G is needed and the operator's role in making it a reality. The sections that follow delve deeper into the enabling technologies, comparative performance, use cases, business implications, and the roadmap for realising the 6G vision of e& UAE.



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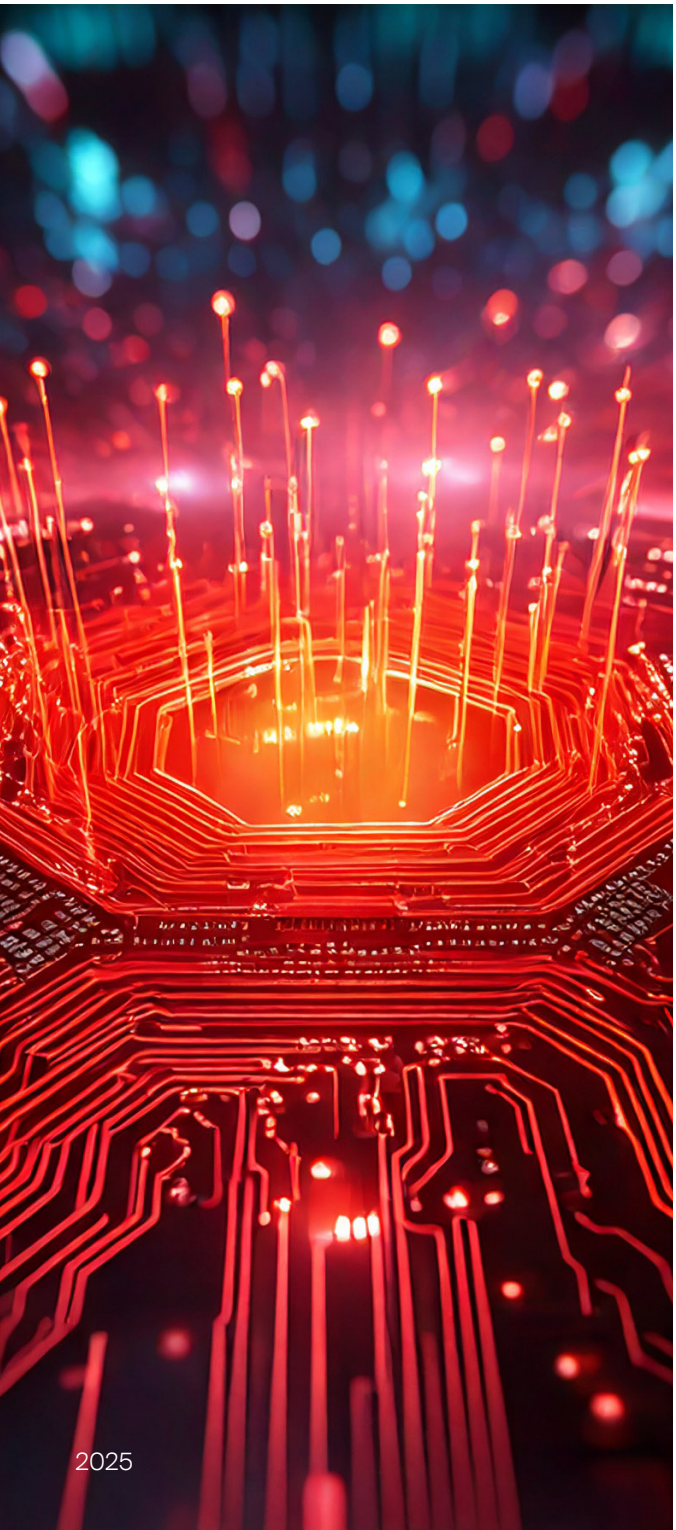
03. Key Technologies Driving 6G

Achieving the ambitious vision of 6G will require breakthroughs and convergence in multiple technology domains. The following are the key technology pillars driving 6G development:



AI-Native Networks

6G networks are envisioned to be **AI-native**, meaning AI/ML is deeply embedded into the design and operation of the network from the outset. Instead of today's bolt-on AI tools, 6G will have **inherent intelligence** across all layers – enabling automation, self-optimisation, and real-time adaptation at an unprecedented scale. This involves two aspects:

- **AI for Networks:** Using AI to control and optimise the network. 6G will leverage advanced machine learning for predictive resource allocation, anomaly detection, and autonomous management. For example, AI-driven predictive analytics in 6G can foresee and mitigate congestion or faults before they impact users. Ultimately, this could yield a fully self-organising network that dynamically tunes itself for optimal performance and efficiency.

- **Networks for AI:** Designing network architecture to best support AI applications and services. 6G will provide distributed computing capabilities to run AI models at the edge with minimal latency. High-throughput data flows feeding AI systems will be the norm, effectively making the network a distributed "AI computer." In 6G, **running AI at the edge** (near the data source) will achieve ultra-low latency and privacy benefits. The network will also facilitate **AI training via big data** collected from myriad devices, thus turning connectivity infrastructure into an engine for AI development.

An AI-native 6G network will learn and improve continuously.

It can offer on-demand network slices optimised by AI for specific needs (e.g. an AR/VR slice with guaranteed low jitter, or an industrial slice with extra security). Such intelligence will also enable hyper-personalised services – networks that anticipate user needs in real time. e& UAE sees the convergence of 6G and AI as transformational: 6G's ultra-low latency and massive data will supercharge AI, while AI will drive 6G to be autonomously managed. This symbiosis is expected to unlock new levels of customer experience and efficiency in the UAE's future networks.

Spectrum Advancements (Sub-THz and New Mid-Band)

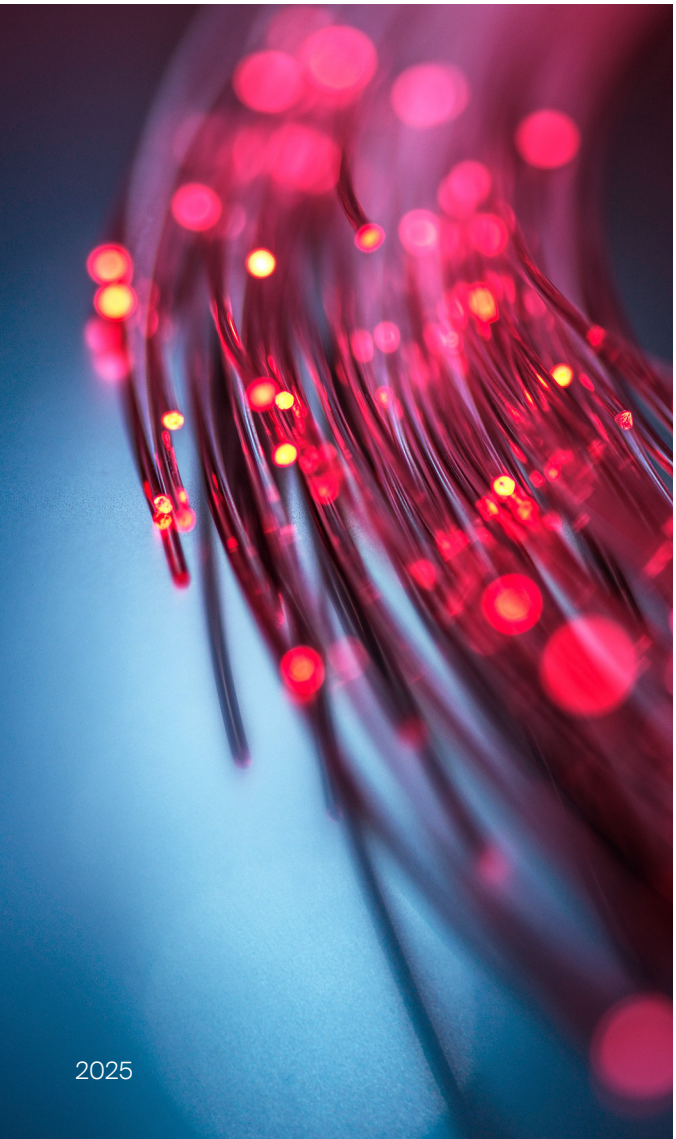
To deliver 100× higher data rates and support new services, 6G will exploit new frontiers of wireless spectrum. Two major expansions are foreseen:

- **New Mid-Band Frequencies (7–15 GHz range):** While 5G primarily uses mid-band up to ~6 GHz, 6G is exploring slightly higher mid-bands (for example, 7–15 GHz) that offer a favourable trade-off between coverage and capacity.

  Frequencies around 6–15 GHz (sometimes called "centimetric" bands) provide more bandwidth than today's sub-6 GHz while still propagating significantly farther than millimetre waves. These bands could become pivotal for wide-area 6G coverage with multi-gigabit performance. Early discussions include the potential 6GHz band, 10 GHz, and others in this range, subject to international spectrum harmonisation efforts.

- **Sub-Terahertz (100+ GHz) Bands:** 6G is pushing into **sub-THz frequencies** roughly from 90 GHz up to 300 GHz. In particular, bands around 92–114 GHz and 130–175 GHz are under investigation for 6G. These extremely high frequencies offer huge contiguous bandwidths (tens of GHz) to enable data rates in the order of tens or even hundreds of gigabits per second for a single user.

  For example, laboratory trials and proposals suggest 6G could support peak rates ~1 Tb/s by using such THz bands ([1]). However, THz signals face very short range and require line-of-sight conditions. Thus, early 6G use of sub-THz will likely focus on specific scenarios (indoor wireless, hotspot kiosks, device-to-device links, etc.) rather than wide coverage. There is also a **cautious approach** in the industry – emphasising that adoption of THz should be driven by genuine use-case needs (like holographic video or ultra-high-speed backhaul) and accompanied by advances in semiconductor and antenna technology, rather than chasing theoretical top speeds.



In practice, 6G will utilise a multi-band spectrum strategy: continuing to rely on low bands (<1 GHz) for broad coverage (critical for IoT and rural coverage), existing mid/high bands for capacity, and adding new mid-band and sub-THz bands for extreme capacity where needed. This spectrum expansion must be guided by global harmonisation to ensure economies of scale. Global bodies like the ITU have noted that 6G will require multiple frequency ranges to meet capacity and coverage needs, and they envision IMT-2030 using everything from sub-1 GHz up to bands above 100 GHz.

Spectrum harmonisation for 6G – aligning key bands internationally – will be crucial for affordable devices and roaming [4]. Regulators (including in the UAE) will play a key role in opening these bands (e.g., at future World Radiocommunication Conferences, decisions on e.g. 7–15 GHz and >94 GHz for IMT might be taken). By proactively engaging in these discussions, e& UAE aims to secure the spectrum resources needed for nationwide 6G deployment.

Integrated Sensing and Communication (ISAC)

One of the defining features of 6G will be the **convergence of wireless communication and sensing** – essentially giving 6G networks the ability to **"see" and "perceive"** the environment even as they carry data. Today's cellular systems are nearly blind beyond their communication functions; 6G intends to change that by designing signals and protocols that jointly serve connectivity and sensing purposes. This concept is known as ISAC (Integrated Sensing and Communication).

In practice, ISAC means 6G base stations and devices will use their radio waves as a form of radar. For example, a 6G cell site could transmit signals and analyse their reflections to detect objects, monitor movement, or map the surroundings with high precision.Already, research shows that variations in a radio signal's propagation can reveal useful information – e.g. mmWave links attenuated by rain can act as rain sensors, or reflections of a wideband signal can detect human presence and gestures. By reusing communication signals for sensing, 6G can achieve situational awareness without dedicated sensor infrastructure [2]. This radio vision unlocks many applications:

- **High-Definition Positioning:** 6G networks could locate devices or objects to within a few centimetres by analysing signal echoes. This is a leap from current GPS or 5G localisation (which is on the order of metres). Such precision can enable autonomous drones and vehicles to navigate safely, or allow virtual objects to be overlaid accurately in AR.

- **Environmental Monitoring:** A network of 6G nodes could collectively monitor traffic flow, crowd movement, or even heartbeats in a room, all via wireless sensing. It can detect anomalies (e.g. a fall by an elderly person at home) and trigger alerts.

- **Gesture and Presence Detection:** On the consumer side, phones or wearables with 6G sensing might interpret hand gestures as input commands or detect when a user enters a room (enabling context-aware smart home behaviours).

Crucially, integrating sensing doesn't just add features; it also can **enhance communication performance.** Shared sensing data allows the network to better predict channel conditions and mobility patterns. Furthermore, combining sensing and communication in one system can be more cost-effective and power-efficient than separate systems [2]. For instance, instead of deploying expensive radar systems for autonomous cars, 6G V2X communication itself could provide cooperative sensing (vehicles and roadside units sharing what they "see").

e& UAE is particularly interested in ISAC for smart city and public safety applications.

Integrated sensing will enable hyper-aware networks in urban environments – envision UAE's cities where traffic lights adapt in real-time based on network-sensed traffic conditions, or security systems use 6G networks to detect incidents with high reliability. By planning 6G infrastructure with ISAC capabilities, e& UAE could offer Sensing-as-a-Service to governments and enterprises, opening new revenue streams beyond connectivity. Overall, ISAC transforms the 6G network into a distributed sensor system alongside being a communications platform, marking a key differentiator from previous generations.

Quantum-Secure Networks

Security is a foundational aspect of 6G, especially as networks become even more critical to economies and daily life. A major emerging threat is the potential of quantum computers to break current cryptographic schemes. 6G is being designed with quantum-resistant security from the zstart, often termed quantum-safe or quantum-secure networking. This involves:

- **Post-Quantum Cryptography (PQC):** These are new cryptographic algorithms (for encryption and digital signatures) that are believed to be resistant to attacks by quantum computers. Standards bodies (like NIST) are already vetting such algorithms. 6G networks will likely employ PQC to secure communications – ensuring that even if data intercepted today is later subjected to quantum decryption attempts, it remains safe.

- **Quantum Key Distribution (QKD):** For certain high-security applications, 6G may incorporate QKD systems, which use quantum physics (transmitting photons) to share encryption keys with provable security. Any eavesdropping on quantum keys can be detected due to the properties of quantum states. While QKD has limitations (range, cost), it can provide an **extra layer of security for sensitive links** (e.g., between core network sites or for government communications). Notably, operators and vendors (e.g., Toshiba and NTT) are already trialing QKD over telecom fibre to complement classical encryption.

Beyond encryption, 6G's **native trustworthiness** will be enhanced by several technologies. **Distributed ledger/blockchain** could be used in 6G for secure identity management or to ensure integrity of network configurations. **Physical layer security** techniques, such as intelligent jamming of eavesdroppers or exploitations of unique radio hardware fingerprints, may also play a role. Additionally, federated learning and differential privacy will be employed so that AI in the network learns from data (e.g., user equipment stats) without compromising user privacy

The goal is that 6G networks be "secure by design", not as an afterthought. This is recognised in global 6G objectives – the ITU's framework includes security and resilience as core aspects. For e& UAE, which serves critical national infrastructure and enterprises, quantum-secure 6G means network communications remain confidential and resilient even in the face of next-gen cyber threats. By investing in quantum-safe technologies early, e& UAE can assure governments, businesses, and consumers that the 6G era will be trustworthy, protecting data sovereignty and privacy. In summary, as quantum computing advances, 6G will stay ahead with cryptographic agility (ability to swap in new algorithms) and potentially quantum-based security tools, ensuring end-to-end security and integrity for all 6G services.

Cloud and Edge Computing

6G's performance targets (like <1 milliseconds (ms) latency and massive IoT data processing) demand a radical shift in network architecture toward a **distributed cloud-edge paradigm.** Building on trends from 5G (MEC – Multi-access Edge Computing), 6G will integrate **cloud computing capabilities natively into the network fabric,** blurring the line between communication and computation:

- **Ubiquitous Edge Computing:** 6G networks will feature compute resources deployed at the network edge (base stations, local data centres, even on-site at enterprises) to enable ultra-low latency services. By processing data and running applications closer to end-users, edge computing can reduce round-trip latency dramatically (critical for real-time interactivity in AR/VR, industrial control, etc.).

  For example, a complex machine-vision algorithm for an autonomous car could run on an edge server in the 6G cell serving the car, rather than in a far-away cloud, allowing instantaneous decisions. Telco operators are evolving into "techcos" by leveraging their central offices and cell sites as distributed data centres.

  As SK Telecom describes in its 6G vision, the future telco infrastructure will "provide both connectivity and AI computing" at the edge, combining the strengths of cloud and on-device processing. This concept, which SKT calls Telco Edge AI, is one model for 6G where operators host AI and compute workloads at edge nodes, delivering new services with minimal latency

- **Integrated Network-Cloud Architecture:** Rather than treating network and cloud separately, 6G likely will have a unified architecture. Network functions (RAN, core) themselves will be highly cloud-native (containerised, microservices), enabling rapid scaling and deployment of new features.

  Beyond that, the network will expose computing as a resource – meaning applications can seamlessly request network slices with computing power attached. For instance, an AR gaming application could request a 6G slice that guarantees not only bandwidth and latency, but also an allocation of GPU processing in the nearest edge cloud for rendering.

  This tight integration of communication and computing is sometimes referred to as 6G = Communication + Computing + Caching + Control (the 4Cs). It envisions base stations that might cache popular content and even run user-app code. Indeed, the ITU's 6G usage scenarios explicitly include "Integrated AI and Communication", indicating the network will support AI workflows inherently.

From e& UAE's perspective, this cloud-edge convergence opens new business avenues.

Network-as-a-Service (NaaS) offerings can bundle connectivity with edge cloud services. e& UAE could, for example, offer platforms for smart city developers to deploy their applications on e&'s 6G edge cloud with guaranteed QoS.

Moreover, by offloading heavy processing to the edge, devices can be lighter and more power-efficient, enabling sleek AR glasses or longer-lived IoT sensors (since the network does the heavy compute).

Architecturally, achieving this requires investment in distributed data centres, high-speed fronthaul/backhaul (possibly fibre to connect edge sites), and intelligent orchestration software to place workloads optimally. AI orchestration will be crucial – deciding when to execute tasks at the device vs edge vs central cloud to meet performance at the lowest cost ([6]). e& UAE's cloudification journey of its core and adoption of network function virtualisation are stepping stones.

By 6G, we anticipate fully software-defined networks, where spinning up a network slice with certain compute at a given location is as simple as a cloud service request. This will enable ultra-responsive 6G services like immersive virtual meetings, real-time industrial robot control, and city-wide AR overlays that are impossible to achieve with a centralised cloud alone. Also, the UAE has been recognised as the global leader in Fibre to the Home (FTTH) penetration where e& UAE continues to support the nation's standing as a global frontrunner in high-speed fibre connectivity. This fibre infrastructure will support e& UAE's 6G vision for edge cloud.

Non-Terrestrial Networks (NTN)

6G aspires to provide **connectivity anytime, anywhere** – including in skies and seas where traditional cell towers don't reach. Thus, 6G networks will deeply integrate **Non-Terrestrial Networks** (satellites, high-altitude platforms, aerial drones) into the overall service architecture. Unlike 5G, where satellite connectivity is an afterthought or niche add-on, 6G treats NTN as a **first-class component:**

- **Satellite Integration:** Constellations of low-Earth orbit (LEO) satellites, potentially supplemented by medium or geosynchronous satellites, will work in tandem with terrestrial 6G networks. These satellites will provide coverage in remote or rural areas, oceans, and for moving platforms (aircraft, ships) – ensuring truly global 6G service coverage.

  The 6G-NTN research project in Europe, for example, is developing a fully integrated 6G NTN component that can deliver broadband and ultra-reliable low-latency service to users in outdoor and light indoor conditions. The target is for satellites to support eMBB and URLLC use cases, not just basic phone calls. Key technology enablers include multi-beam antennas, inter-satellite laser links, and compatibility with 6G waveforms.

  By 2030, we envision a user device seamlessly connecting to a satellite if terrestrial coverage is unavailable, using the same handset. The integration will be such that a user might not even realise whether their 6G link is via satellite or a tower – it will hand off intelligently.

This vision is already taking shape. Vodafone recently completed the world's first space-based video call using a standard mobile phone connected to commercial satellites, from an area with no terrestrial coverage. This milestone demonstrates the potential of non-terrestrial networks (NTN) to offer a full mobile broadband experience, reinforcing our belief that satellite integration will be a cornerstone of the 6G era [12].

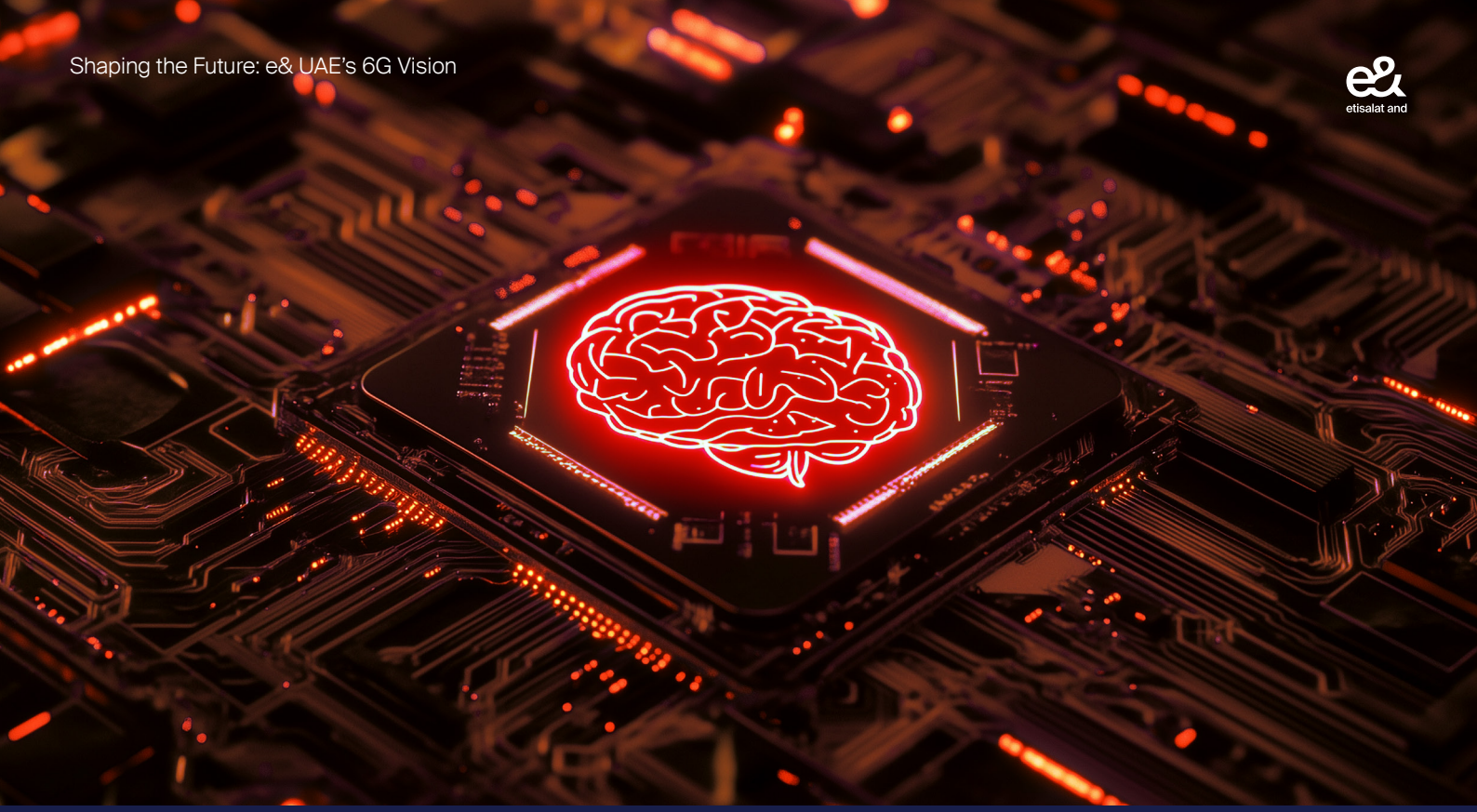
While this technology is still in its early stages, with challenges such as latency and bandwidth to address, the progress made thus far underscores the feasibility of our envisioned seamless integration between terrestrial and satellite networks by 2030.

e& UAE has taken a significant step towards enhancing global connectivity by signing a MoU with Yahsat (Space 42), the UAE's leading satellite solutions provider. This collaboration positions e& UAE as the first telecom operator to partner with Space 42 under its Direct-to-Device (D2D) strategy, known as Project SKY [13]. The partnership aims to explore various initiatives and projects within Yahsat's planned D2D ecosystem, enabling voice, text, and data satellite connectivity directly to standard smartphones. This technology is designed to provide seamless connectivity, ensuring users remain connected even in areas lacking traditional terrestrial coverage.

- **HAPS and UAVs:** High Altitude Platform Stations (HAPS) – essentially solar-powered communication drones or balloons in the stratosphere (~20 km up) – can fill the gap between terrestrial towers and satellites. HAPS can hover over a region to provide supplemental capacity or coverage (for instance, during a large event or after a disaster knocking out ground towers). Similarly, fleets of communication drones (UAVs) can act as rapidly deployable cell sites. 6G networks will natively support such aerial nodes and manage them as part of the network topology. These nodes might carry 6G small cells to deliver high capacity from the sky.

NTNs in 6G will provide not just coverage but also **additional resilience** and capabilities. For example, satellites can offer alternative positioning and timing sources (important if GNSS like GPS is unavailable – 6G could use "GNSS-free" positioning via satellite signals. They can also assist in sensing – e.g., a satellite could bounce signals off the Earth's surface for wide-area remote sensing.

The integration will require overcoming challenges: signal delays (LEO has ~20–50 ms latency) and handling Doppler shifts for fast-moving satellites, designing antennas for devices that can work with both cell frequencies and satellite frequencies, and regulatory hurdles in spectrum sharing between terrestrial and space. Ongoing work in 3GPP for 5G-NR over NTN is a foundation that 6G will extend, likely with more flexible waveforms and protocols to accommodate dynamic satellite links ([7]).



For e& UAE, NTN integration in 6G aligns with the goal of ubiquitous connectivity (a key IMT-2030 objective).

The UAE's geography and regional influence make satellite coverage strategically important (serving desert, maritime, and aeronautical communications). By leveraging 6G NTNs, e& could ensure continuous service to airline passengers, remote oil fields, and even support IoT in agriculture or environmental monitoring across vast areas. In short, 6G will erase the boundaries between terrestrial and non-terrestrial networks, creating one unified network of networks that users and devices can roam seamlessly for truly global coverage.

Energy-Efficient & Sustainable Networks

Sustainability is a cornerstone of the 6G vision – a recognition that future networks must drastically reduce their environmental footprint while supporting exponential traffic growth. Key innovations for energy-efficient and sustainable 6G networks include:

- **Green Air Interface and Hardware:** 6G will explore new materials (for example, graphene-based antennas or advanced semiconductors) and hardware designs that reduce power consumption per bit. Techniques like ultra-massive MIMO and reconfigurable intelligent surfaces (RIS) can focus energy where needed, avoiding wasteful omni-directional transmission.

  Additionally, new modulation and coding schemes will aim for higher energy efficiency. For instance, **backscattering communication and passive IoT** devices (which reflect signals instead of generating new ones) could enable sensors that consume near-zero energy.

- **Network Optimisation for Low Power:** AI will play a role in intelligently powering down or sleeping parts of the network during low usage, and dynamically adapting transmission power. Cloud-native architecture also allows for consolidating workloads to minimise idle hardware.

  The concept of a **"circular economy" model for networks** is being embraced – designing 6G equipment for longevity, recyclability, and upgradability to reduce waste. IMT-2030 explicitly calls for energy efficiency and low power design for both devices and network, including methods like energy harvesting (devices pulling energy from ambient sources to recharge).

- **End-to-End Sustainability Metrics:** 6G will introduce metrics and KPIs to measure energy per bit and carbon emissions of network operations. These will drive technology choices. For example, if an algorithm routes traffic in a way that uses 5% more energy, the network orchestrator might choose a greener alternative even if it's slightly less optimal for latency.

  The **design target** is often quoted as 10× to 100× improvement in energy efficiency over 5G, meaning much more data delivered for the same energy cost. This is crucial as 6G could connect orders of magnitude more devices – without efficiency gains, power consumption would be unsustainable.

At e& UAE, sustainable networking aligns with corporate responsibility and cost efficiency.

Reducing power consumption not only lowers carbon footprint but also OPEX. e& UAE has already prioritised energy efficiency in 5G (for instance, using AI to turn off unused 5G carriers during off-peak hours). In 6G, power-saving will be ingrained at every layer. Renewable energy powering of cell sites (solar panels on towers in the sunny UAE climate) combined with 6G's smarter energy use can approach net-zero operations. The UAE's national strategies for sustainability (e.g., Net Zero 2050) provide additional impetus for 6G to be green.

In summary, 6G's technological advances are not solely about higher performance – they equally emphasise higher efficiency. Innovations from battery-less IoT devices, to AI-orchestrated sleep modes, to climate-conscious manufacturing of network gear will make 6G networks far more sustainable than predecessors. This ensures that growth in connectivity does not come at the cost of the planet, supporting both economic and environmental goals.

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4. 5G vs 6G: Evolutionary Comparison

6G will build upon the capabilities of 5G and 5G-Advanced, delivering improvements across all performance metrics and introducing new functionalities that address current limitations. The Figures and Table below provide a high-level comparison of network capabilities for baseline 5G (i.e., IMT-2020), and anticipated 6G (i.e., IMT-2030) targets.

Figure 1: The ITU's "wheel diagram": the six Usage Scenarios of IMT-2030 (6G)

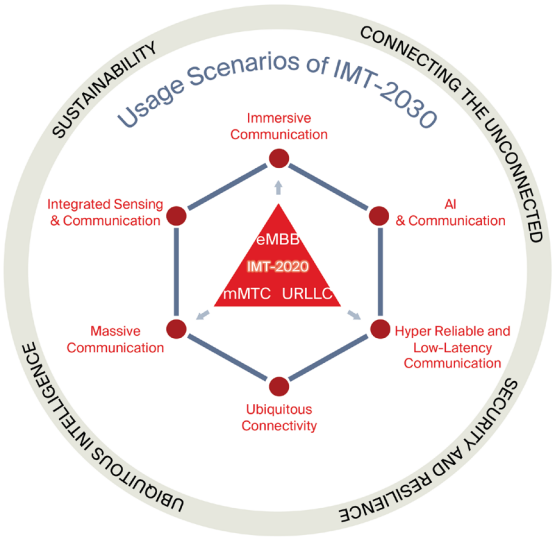


Figure 1

The ITU's "wheel diagram" illustrates the six usage scenarios for IMT-2030 (6G). Building upon IMT-2020 (5G), three scenarios are extended: Immersive Communication (evolving from eMBB), Massive Communication (evolving from mMTC), and Hyper-Reliable & Low-Latency Communication (evolving from URLLC). The framework introduces three novel scenarios: Ubiquitous Connectivity, AI & Communication, and Integrated Sensing & Communication (ISAC). Moreover, four "overarching aspects" serve as fundamental design principles applicable across all usage scenarios: Sustainability, Connecting the Unconnected, Ubiquitous Intelligence, and Security/Resilience.

Figure 2: The "palette diagram": the 15 Capabilities of the IMT-2030

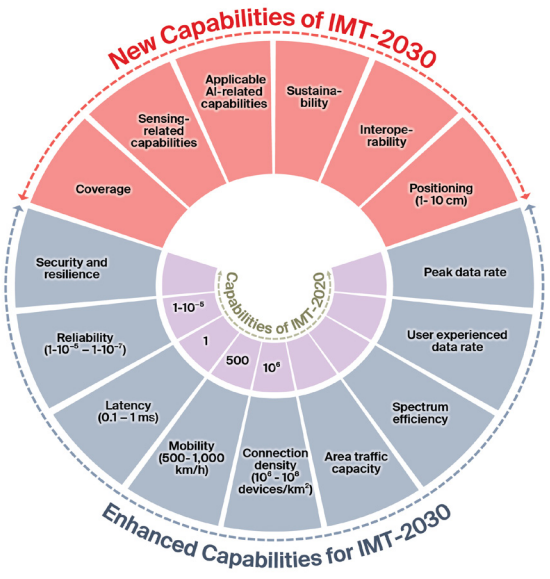


Figure 2

Table1 : Capabilities of 6G versus 5G

ITEM	5G	6G
Peak Data Rate	20 Gbit/s	50, 100, 200 Gbit/s (e& UAE demonstrated 62 Gbps)
User Experienced Data Rate	100 Mbit/s	300 Mbit/s, 500 Mbit/s
Spectrum Efficiency	30/0.3 b/s/Hz (Peak/Experienced)	1.5 to 3 times IMT-2020
Area Traffic Capacity	10Mb/s/m^2	30 Mbit/s/m2, 50 Mbit/s/m^2
Connection Density	10^6 devices/km^2	10^6 – 10^8 devices/km^2
Mobility	500km/h	500 – 1,000 km/h
Latency	1ms	0.1 – 1 ms
Reliability	1-10^{-5}	1-10^{-5} to 1-10^{-7}
Maximum BW	1GHz	100GHz
Jitter	Not Specificed	1 micro second
Positioning	50-200 m	1 – 10 cm
Sensing-related Capabilities	Not specificed	Range/velocity/angle estimation, object detection, localization, imaging, mapping, etc.
Applicable AI-related Capabilities	Limited	Support AI enabled applications including distributed data processing, distributed learning, AI computing, AI model execution and AI model inference, etc.
Security and Resilience	Not speifcied	Security: Confidentiality, integrity, availability; Resilience: Operational during disturbances
Sustainability/ Energy efficiency	Not speifcied	Energy efficiency is expected to be improved appropriately with the capacity increase in order to minimize overall power consumption. (1Tb/J) ~ 10 Years for sensor
Interoperability	Limited	Interoperability in the radio interface so as to enable functionality(ies) between different entities of the system including Terrestrial and non-Terrestrial.

The above "palette diagram" for IMT-2030 defines 15 essential capabilities, expanding on nine foundational capabilities from IMT-2020. These capabilities are accompanied by estimated target ranges, intended to guide research and investigation. For each distinct usage scenario, specific performance values within these ranges will be standardised in forthcoming ITU-R recommendations and Reports. Importantly, IMT-2030 is designed to contribute significantly to environmental, social, and economic sustainability, aligning with and supporting the objectives of the Paris Agreement under the United Nations Framework Convention on Climate Change.

As seen above, 6G is expected to significantly outperform 5G and 5G-Advanced in raw performance – offering **10–100× improvements in data rates**, an order of magnitude lower latency, and far greater device connectivity. For example, while 5G-A might enable a few Gb/s to an AR/VR device, 6G aims for multi-Gb/s or even 1 Gb/s uplink to support holographic uploads. Reliability and availability will also step up, catering to critical applications like remote surgery that require near-zero error rates.

However, the **evolution is not only quantitative but also qualitative.** 6G introduces new capabilities that address limitations of 5G-A:

- **Integrated Services (Communication + X):** 5G and 5G-A were primarily about communication services (with some positioning). 6G natively integrates other services like high-precision positioning and sensing alongside communication. For instance, where 5G- A might offer an add-on positioning feature (~<1 m accuracy in ideal conditions), 6G could make localisation and imaging a built-in service with cm-level precision – enabling things like indoor navigation and environment mapping that 5G-A cannot do. This convergence of communication and sensing is a key differentiator.

- **AI-Driven Networking:** 5G networks are starting to use AI for optimisation (e.g., 5G-A introduces AI in the RAN for link adaptation), but it's largely supplemental. In 6G, AI will be ubiquitous and deeply integrated, from the core to the radio, enabling self-healing and adaptive networks in real time. This means 6G networks can manage complexity far better than 5G-A. For example, handling thousands of network slices or highly dynamic spectrum sharing will be feasible with AI, whereas 5G-A has practical limits.

- **Extremely Low Latency and Jitter:** While 5G URLLC set ~1 ms latency goals, achieving that end-to-end is challenging, and some applications (like high-speed industrial control or haptic feedback) are still limited by jitter and slightly higher latencies. 6G plans to push latency down to a few hundred microseconds on the radio link ([1]), and perhaps 1 ms end-to-end with edge computing.

This essentially closes the gap to real-time perception,enabling truly interactive remote experiences (e.g. a surgeon operating a robotic scalpel remotely with immediate haptic feedback – not viable if even a few milliseconds of jitter exist in 5G).

- **Network of Networks:** 5G-Advanced is making initial moves to incorporate non-terrestrial networks (NTN support in Release 17) and unlicensed spectrum integration, but 6G is designed as a network of networks from the start. It will fluidly interconnect cellular, satellite, Wi-Fi, optical fibre, and even direct device-to-device links. The user will experience one 6G network that intelligently uses the best path. 5G-A cannot, for instance, seamlessly handover a session from a terrestrial base station to a low-earth orbit satellite, but 6G likely will, addressing the coverage gaps of 5G.

- **Addressing Current 5G Limitations:** 6G also aims to fix pain points observed in 5G deployments. For example, mmWave 5G coverage is very limited; 6G's use of new bands (like sub-THz and advanced beamforming) might offer more robust high-band coverage, or alternatively provide mechanisms (like smart repeater networks or RIS) to extend coverage. Another limitation: device battery drain in 5G when handling massive data – 6G's edge offloading and low-power air interfaces (like wake-up radios or passive comm) will allow devices to last longer despite higher performance demands ([4]). In essence, 6G is being crafted to be more user-friendly and efficient in real-world conditions, not just hitting peak lab metrics.

In summary, 5G-Advanced (around 2024–2028) can be seen as the bridge that enhances 5G to support new use cases (like better XR and IoT) and to experiment with early versions of technologies (AI, NTN, etc.) that will be fully realised in 6G.

6G (~2030 onward) will then take the torch to dramatically extend capabilities (100× performance in some dimensions) and introduce new paradigms (network sensing, integrated AI, etc.) that fundamentally expand what networks can do.

By addressing the current limitations – whether it's coverage holes, energy usage, or the inability to natively support certain applications – 6G will fulfill the promise of a truly ubiquitous, versatile network that 5G began.


Carla Coe
ROUND WIN
Marta Baker
Wallet

05. 6G Use Cases & Industry Applications

The capabilities of 6G are being designed with transformative use cases in mind. Below we explore several high-impact use cases and industry applications that 6G will enable or significantly enhance, highlighting how they differ from or extend beyond what is possible with 5G/5G-A:

Immersive Communication & the Metaverse

One of the hallmark visions for 6G is to enable truly immersive experiences that blur the line between physical and virtual reality.This includes holographic telepresence, extended reality (XR combining AR/VR/MR), and even multi-sensory communications (transporting touch, taste, smell data). With 5G, we see early Metaverse applications (VR gaming, AR overlays) but they are constrained by bandwidth, latency, and device form factors. 6G will amplify immersive communication in several ways:

- **Holographic Telepresence:** 6G networks could carry hologram video streams in real-time, allowing life-size, 3D representations of people to be rendered remotely. This requires extremely high data rates (a hologram can be on the order of many Gbps) and low latency synchronisation. 6G's target of 1 Tb/s peak and ~<5 ms latency would make interactive holographic calls feasible – e.g., having a meeting where colleagues appear as realistic 3D projections.

  Massive device uplink capacity will allow even consumer devices to capture and send holographic data (for example, using an array of cameras/sensors on a future smartphone) – something 5G cannot support. Already, researchers note that holographic communication and **five-sense media** (audio, video, haptics, etc.) are key applications expected to ride on 6G.

- **Extended Reality (XR) Everywhere:** 6G will drive XR from niche to mainstream. Lightweight AR glasses could become as ubiquitous as smartphones, constantly connected to edge compute via 6G. Users might experience a persistent metaverse overlay on the real world (for work, education, entertainment). For this to work, 6G provides the necessary **100× throughput and reliability** – future multi-user, massive XR might demand up to 1 Gbps downlink **per user** with strict 5 ms latency for truly convincing AR.

  5G-Advanced XR can do perhaps 20 ms latency and tens of Mbps, which is fine for today's applications, but falls short for fully immersive holographic or tactile experiences.3D projections. Massive device uplink capacity will allow even consumer devices to capture and send holographic data (for example, using an array of cameras/sensors on a future smartphone) – something 5G cannot support. Already, researchers note that holographic communication and five-sense media (audio, video, haptics, etc.) are key applications expected to ride on 6G.

- **Multi-sensory & Tactile Internet:** Beyond sight and sound, 6G's high bandwidth and low latency will enable transmission of touch (haptic feedback), and possibly smell/taste (via digital scent technology) to enrich remote interactions.

  We talk about the **Tactile Internet**, where users can physically interact over networks (e.g., a doctor feeling tissues via remote robotic surgery, or a shopper feeling textures of a product online). Achieving this requires end-to-end latencies below the human touch perception threshold (~<10 ms) and extremely high reliability. 6G's URLLC enhancements (HRLLC – Hyper Reliable Low Latency Comm) aim exactly at that, far exceeding what current 5G URLLC can maintain over wide areas.

These capabilities will unlock countless applications: virtual collaboration with full immersion, training and education in VR with realistic teacher/student presence, immersive sports or concert experiences where fans feel virtually on-field, and new media forms we can hardly imagine (interactive 360° holographic movies, etc.). The metaverse vision becomes much more convincing when 6G solves the technical barriers of today's XR (such as bulky headsets and limited mobility). With 6G, most heavy rendering could happen in the edge cloud, so XR glasses become lightweight and comfortable, only streaming video and sensor data back and forth to the network Unlike previous generations, uplink performance in 6G will be equally critical. e& UAE sees innovation in uplink spectrum allocation and hardware design as vital for enabling user-generated XR content, real-time holography, and metaverse applications.

e& UAE anticipates immersive communications to be a major driver of 6G adoption in consumer and enterprise domains. For example, in healthcare and education – two focus industries in UAE's innovation agenda – 6G holographic and AR applications could enable remote medical consultations with 3D visuals and virtual classrooms where students and teachers interact as if in person. Entertainment and tourism in the UAE (imagine virtual tourism experiences at cultural sites or a metaverse extension of EXPO events) will also benefit.

e& has already taken bold steps into the metaverse space.

e& enterprise and Miral have partnered to launch the Yas Island Metaverse Project, which aims to create immersive virtual experiences for business venues on Yas Island – reinforcing the potential of spatial computing in enterprise and tourism applications [14]. Furthermore, e& launched 'e& universe', a pioneering virtual world that allows users to experience immersive environments across culture, entertainment, and business, laying the foundation for broader adoption of 6G-powered XR experiences [15].

During the ITU's 6G usage scenario discussions (the "wheel diagram"), Immersive Communication was identified as a direct evolution of 5G's eMBB, and e& UAE plans to leverage this by enhancing services like UHD streaming, VR gaming, and digital entertainment parks with 6G capabilities as they emerge. In short, 6G will make the metaverse truly mobile and persuasive, enabling an "internet of senses" that revolutionises how we communicate and experience media.

Autonomous Mobility

6G will be a key enabler of the next generation of autonomous transportation systems – from self- driving cars and trucks to autonomous drones and rail – by providing the ultra-reliable, low- latency V2X communication and advanced sensing needed for safe and coordinated mobility:

- **Advanced V2X (Vehicle-to-Everything):** While 5G introduced C-V2X for connected car applications, 6G will enhance it with higher reliability (close to zero packet loss) and the capacity to share massive sensor data in real time. Autonomous vehicles in a 6G network could exchange high-definition Light Detection and Ranging (LiDAR) or video feeds with each other and with roadside units, essentially giving each vehicle a collective perception of the environment beyond line-of-sight.

  This is sometimes called cooperative sensing – e.g., a car rounding a blind corner can warn another car by sharing what its sensors detect. The extreme link reliability (6G HRLLC) ensures that safety messages (brake alerts, etc.) get through with 99.9999%+ success, reducing accidents. Latencies of under 1 ms mean vehicles can effectively operate in sync (a swarm of drones or a platoon of trucks reacting to a lead vehicle's behaviour instantaneously).

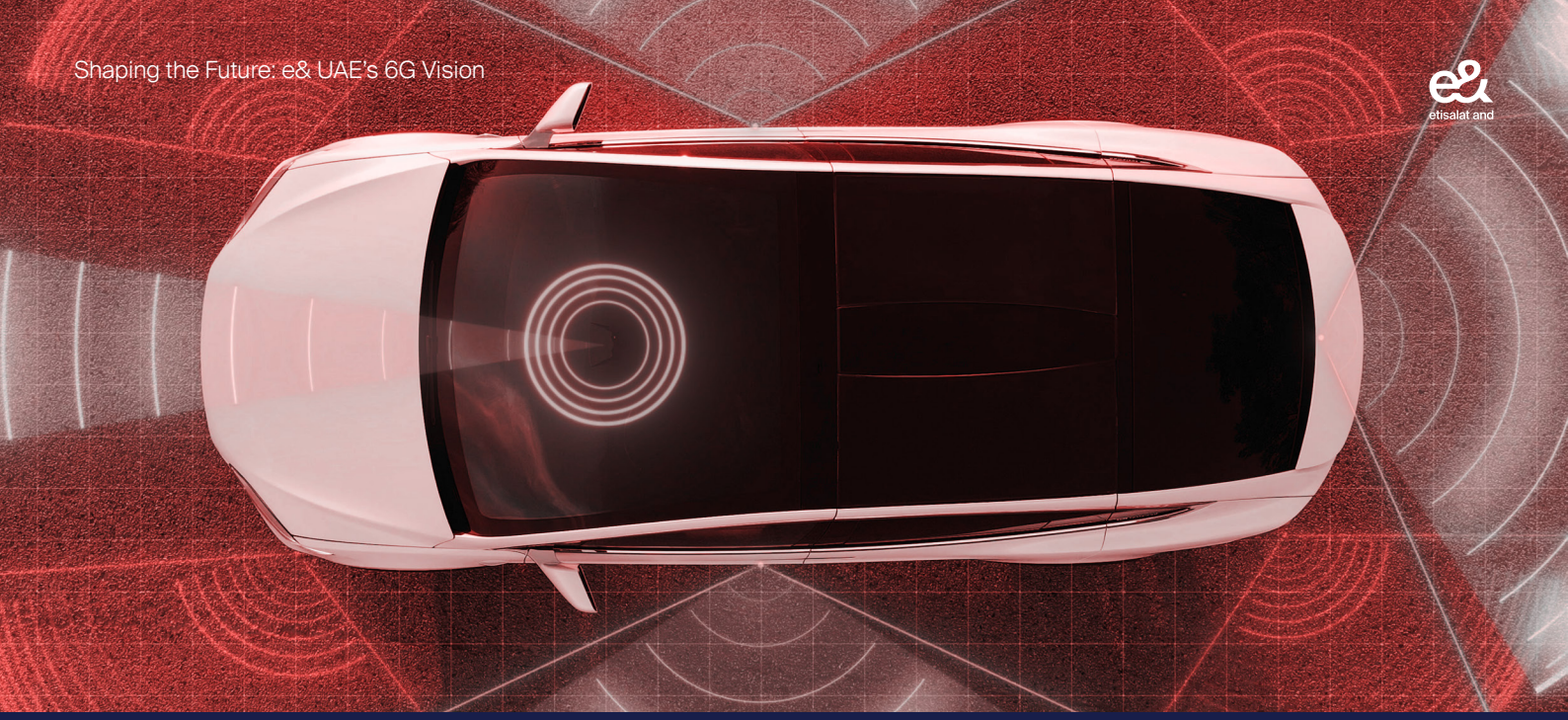
- **Autonomous Driving Ecosystems:** 6G will support not just individual vehicle autonomy but an entire infrastructure-backed autonomous ecosystem. For example, smart traffic lights connected via 6G could communicate with approaching autonomous cars to optimise traffic flow. City traffic management systems could receive real-time data from all vehicles and, using edge AI, adjust routes or speeds to prevent congestion and incidents.

  This requires a network that can handle massive machine-type communications (millions of vehicles and sensors) with low latency – well-suited to 6G's mMTC+ and ubiquitous connectivity advancements. Additionally, precise positioning from 6G (centimetre-level) would allow vehicles to localise themselves much more accurately than GPS, crucial in urban canyon environments or tunnels where satellite signals are poor.

- **Drones and Urban Air Mobility:** 6G's support for high-mobility and 3D coverage via NTNs will be vital for unmanned aerial vehicles (UAVs) and future air taxi services. We expect 6G to manage fleets of delivery drones in cities, connecting them to control centres and to each other for collision avoidance. The network's ability to provide coverage at altitude via aerial base stations or satellites ensures continuous links.

  Autonomous drones will use 6G to receive control commands, stream HD video to operators or AI systems for monitoring, and even do cooperative tasks (e.g., multiple drones carrying pieces of a large object together – needing tight synchronisation). Current 4G/5G networks have very limited support for aerial vehicles (cells often don't cover above building-height well), but 6G is being designed to cover airspace as a service area.

For the consumer, these capabilities mean safer and more efficient transport. Imagine commuting in a self-driving vehicle that rarely encounters traffic jams or accidents because every vehicle and traffic light shares data and adapts in real time – a choreography made possible by 6G. Logistics and delivery will also transform: packages might move through a chain of autonomous robots and drones seamlessly connected by 6G, improving speed and cost.



The UAE has been actively exploring autonomous transport

(e.g., Dubai's trials of autonomous taxis and Abu Dhabi's drone delivery pilots). Dubai Autonomous Transportation Strategy aims to transform 25 per cent of the total transportation in Dubai to autonomous mode by 2030. It aims to reduce traffic accidents and losses by 12 per cent, and increase the productivity of individuals by 13 per cent. It will save 396 million hours on transportation trips yearly. It will also reduce the spaces allocated for parking.

With 6G, e& UAE can provide the communication backbone for these initiatives – enabling, for instance, an entire section of a highway to operate in 6G-connected autonomous mode or supporting the "sky corridors" for flying taxis planned in UAE. In such scenarios, network slicing in 6G could dedicate an ultra-reliable low-latency slice to transportation, with guaranteed isolation and priority. This addresses a limitation of current networks where vehicular communications contend with general traffic; 6G will ensure mission-critical mobility data isn't delayed by, say, someone's video stream. In summary, 6G's blend of high reliability, low latency, sensing, and global coverage is foundational to realise the vision of self-driving cars, smart roads, and autonomous aerial systems becoming part of daily life.

Smart Cities & IoT Expansion

The Internet of Things (IoT) will reach massive scales with 6G, powering truly smart cities that leverage ubiquitous connectivity and real-time data analytics. While 5G started the IoT expansion (with mMTC and improvements like NB-IoT, LTE-M, and in 5G-A the RedCap devices for simpler sensors), 6G will amplify both the quantity of devices and the quality of their connectivity and intelligence:

- **Massive-Scale IoT:** 6G networks are designed to connect an order of magnitude more devices per square kilometre than 5G ([1]). This means cities can deploy swarms of sensors – for air quality, water leakage, structural health of bridges, smart parking, waste management – without network congestion. Each lamp post, traffic camera, and utility metre becomes a 6G node, collectively generating a constant stream of data. Importantly, 6G's efficiency improvements (energy harvesting, low-power wake-up radios) will enable IoT devices that can last for years or decades on battery or ambient power ([4]), addressing a 5G IoT limitation where battery life can be a bottleneck.

- **Real-time City Analytics:** The blend of massive connectivity, edge computing, and AI in 6G means cities can implement real-time digital twins – virtual models of the city that update live with sensor data. For example, a city's 6G control centre could monitor transportation flows, energy usage, weather events, and public safety incidents all in real time, and then use AI to optimise city operations.

  Integrated Sensing (as discussed, 6G base stations sensing environment) augments this with data like foot traffic counts or road surface conditions that are detected via the communication network itself. For instance, 6G signals reflecting off roads could detect flooding or accidents and alert authorities instantly. Such capabilities go beyond what current isolated smart city solutions (often on WiFi or 4G) can do. 5G is a stepping stone with pilots in smart lighting and connected CCTV; 6G would allow every streetlight to also be an environmental sensor and communication relay, all feeding into a city AI.

- **Urban Automation:** Smart cities will extensively use automation via 6G – from autonomous public service robots (for cleaning or security patrol) to drone-based infrastructure inspection. These require robust connectivity. A security drone fleet, for example, would rely on 6G for high-quality video feed and control commands as they navigate city blocks at night. Likewise, vehicle-to-infrastructure (V2I) communication in 6G (cars talking to smart traffic lights, as mentioned earlier) makes traffic management automated and adaptive. Emergency response can also be enhanced: 6G-connected sensors in buildings (fire alarms, etc.) and wearables on citizens could give first responders instantaneous situational awareness during an incident and even deploy 6G networked robots into hazardous areas for search and rescue.

In the UAE context, smart city development is a national focus (e.g., Dubai's Smart City initiative and Smart Dubai 2021 Strategy). e& UAE can leverage 6G to provide a unified platform for smart city services. Currently, many smart city deployments suffer from fragmentation (different networks for different services). 6G's combination of massive IoT, network slicing and sensing will allow e& to offer city authorities an integrated service: a slice for utility IoT (water, electricity meters), a slice for public safety (cameras, drones, emergency comms) along with integrated sensing etc., all on one network. The connect the unconnected principle of IMT-2030 also means reaching areas like less-developed city outskirts or rural villages – 6G's cost efficiencies and NTN help extend smart services there, bridging urban-rural digital divides.

In summary, 6G will supercharge the vision of smart cities by providing the scalability, latency, and intelligence needed for city-wide automation and real-time responsiveness. Imagine a future city in the UAE where traffic congestion is predicted and prevented, resources (like electricity) are dynamically allocated based on usage patterns, and city services from trash collection to policing are optimised through 6G connectivity and AI – that is the promise of 6G-powered IoT expansion.

Healthcare & Telemedicine

The healthcare sector stands to be revolutionised by 6G through advances in telemedicine, remote surgery, and personalised medicine facilitated by high-speed, ultra-reliable connectivity and sensing. Some key 6G-enabled healthcare applications include:

- **Remote Surgery and Haptic Telemedicine:** 5G has begun to trial remote surgery (a surgeon controlling robotic instruments from afar), but scaling this is challenging due to the extreme network demands – even minor lag or a dropped packet can have life-or-death consequences. 6G's ultra-reliable low latency links (URLLC+) will make telesurgery viable on a routine basis. With end-to-end latency potentially around 1 ms and jitter so low as to be negligible, a surgeon's precise movements can be mirrored by surgical robots in a distant operating room in real time. Additionally, 6G's high bandwidth enables high- definition 3D video and tactile feedback to be transmitted. The surgeon could feel the tissue resistance via haptic devices as if present in person. Research indicates 6G's high QoS/QoE will enable new applications like telesurgery and holographic communications, truly allowing doctors to "be present" remotely. In rural or underserved regions (or even on a battlefield or space station), expert surgeons could operate via 6G links – vastly expanding access to specialised care.

- **Bio-Digital Twins and Wearables:** 6G can support continuous streaming of data from a myriad of health monitors on/in the body – from smart wearables (watches, AR glasses) to ingestible or implantable sensors. This data deluge (heart rate, blood pressure, blood sugar, even real-time medical imaging) can be processed by AI to create a digital twin of a patient – a real-time digital replica of their health state.

  Doctors (or AI systems) can use these to predict issues or test treatments in simulation. The heavy data and computing requirements (imagine each patient generating gigabytes of data per day) would be enabled by 6G's massive machine-type communication and edge computing for on-the-fly analysis. 5G is only starting to connect wearables; 6G could handle orders of magnitude more biosensors with guaranteed QoS, perhaps dedicating a personalised slice for each patient's data.

- **Augmented Reality for Diagnosis and Training:** With 6G, a paramedic in an ambulance could wear AR glasses that live-stream patient vitals and high-res video to specialists at a hospital, receiving AR overlays with instructions on performing emergency procedures en route. Likewise, specialist doctors can use AR/VR to guide local practitioners through complex procedures remotely (e.g., seeing the local surgeon's field of view and overlaying outlines where to cut or what to do next).

  This requires the kind of low-latency uplink and downlink that 6G will provide (e.g., sharing a live 8K video feed of a surgery to a remote consultant). Medical training can also benefit: students can practice in VR with realistic haptic feedback and even multi-sensory simulation of surgery, connected to instructors and AI tutors via 6G.

During the pandemic, the world saw the importance of telehealth. 5G improved video consultations, but 6G can take it much further – to fully immersive telepresence doctor visits. Imagine a holographic doctor in your living room for a consultation, able to "virtually examine" you with the help of high-fidelity sensors on or around you, and AI analysis – this could make specialist care accessible anywhere.

For the UAE, which has a goal to be a healthcare hub and also to provide advanced care to remote areas, 6G's telemedicine potential is crucial. e& UAE could partner with healthcare providers to deliver 6G-enabled telehealth services – for instance, equipping hospitals with 6G infrastructure and offering managed services for remote surgery. Data security (with 6G's quantum-safe encryption) will ensure patient data confidentiality even as more of it traverses networks. Additionally, the multi-sensory communication aspect of 6G could be employed in therapy and wellness – e.g., mental health treatments using VR worlds that engage all senses for relaxation or phobia treatment.

In summary, 6G will help overcome physical distance in healthcare, making high-quality medical expertise and monitoring available ubiquitously. It addresses current 5G limitations by providing the level of performance and reliability needed for truly real-time, life-critical medical applications, thus promising better health outcomes and more equitable access to care.

Industry 4.0 & Digital Twins

6G will be a linchpin for Industry 4.0 – the next wave of industrial automation and smart manufacturing – by enabling wireless connectivity that is as reliable and deterministic as wired connections, coupled with AI, sensing and digital twin technology. Key applications include:

- **Factory Automation and Robotics:** In many current factories, robots and machines are still wired or on proprietary wireless links due to reliability needs. 6G's HRLLC will provide **wire-like reliability and ultra-low latency wirelessly**, allowing flexible deployment of robots, sensors, and automated guided vehicles without cables. This means factories can be reconfigured quickly (machines can be moved without re-running cables) – supporting agile production lines. For instance, robotic arms on an assembly line could be coordinated via 6G, moving in synchrony with <1 ms timing precision.

  The high capacity of 6G also allows streaming of machine vision data (e.g., dozens of high- resolution video feeds inspecting products for quality) to an edge AI that controls the line in real time. Predictive maintenance is enhanced as machines can continuously send high- volume telemetry to AI models that predict failures before they happen, minimising downtime.

- **Digital Twins of Industrial Processes:** A digital twin is a virtual replica of a physical system that mirrors its state. 6G will enable real-time digital twins of entire plants or supply chains. Every device and sensor on the factory floor streams data into the twin. With 6G's massive connectivity, even individual components (motors, valves) have sensors relaying status. The digital twin uses this to simulate and optimise operations. For example, an operator with AR glasses might visualise the running state of a production line's twin overlaid on the real equipment, seeing bottlenecks or predicting wear on parts.

  They can test adjustments in the twin (e.g., changing a production parameter) and if beneficial, apply to the real line with confidence. The sheer amount of data needed for high-fidelity twins (vibration profiles, temperatures, speeds from thousands of points) requires 6G-level connectivity. 5G begins this with private networks, but 6G can scale it factory-wide and even connect multiple facilities' twins together for integrated supply chain management.

- **Extreme Environment and Remote Industrial Operations:** Industries like oil & gas, mining, or construction will benefit from 6G's combination of robust wireless and sensing. Imagine a mining site where equipment is operated remotely by drivers sitting in a safe control room wearing VR (teleoperation).

  5G might allow line-of-sight remote control; 6G would enable haptic feedback and full situational awareness for the operator as if they were on the vehicle, due to higher reliability and sensor integration (dust, obstacle detection etc., via network sensing). Also, 6G NTN connectivity means even offshore platforms or remote solar farms can be integrated into the same industrial network for monitoring and control, something currently done via patchy satellite links.

e& UAE has a unique interest in Industry 4.0 because the UAE's economy includes advanced manufacturing, logistics hubs, and a strong oil & gas sector where digital transformation is ongoing (e.g., ADNOC's smart oilfield initiatives).

e& UAE has already deployed the world's largest private 5G network for ADNOC's oilfields. With 6G, such private networks will become even more powerful – potentially enabling fully autonomous operations in hazardous industrial environments by connecting AI, robots, and drones. e& UAE can provide 6G campus networks with guaranteed SLAs for factories – for example, guaranteeing <0.5 ms latency for motion control or 99.9999% uptime for safety systems. Furthermore, 6G's native support for time-sensitive networking (TSN) and high-precision clock sync will allow it to meet industrial control timing requirements that 5G struggles with.

Digital twins powered by 6G will also allow businesses in the UAE to innovate with new services. Consider the logistics sector: ports and warehouses could have digital twins to optimise the flow of goods; 6G connecting every pallet (via cheap IoT tags) and every vehicle means the twin has real-time inventory and location data. This can drastically improve efficiency and throughput, making UAE's ports and free zones even more competitive.

n summary, 6G will take Industry 4.0 to the next level by providing untethered, ultra-reliable connectivity for machines, enabling comprehensive digital twins and AI-driven control. This addresses current limitations of 5G in ultra-critical industrial control (where any uncertainty is unacceptable) and opens the door to factories and industrial sites that are fully wireless, continuously monitored, and intelligently automated. The outcome is increased productivity, safety, and flexibility in industrial operations.

06. Business Opportunities & Investment Models

The advent of 6G not only brings technical enhancements but also unlocks new business opportunities and necessitates innovative investment models for operators and ecosystem players. Here we discuss how 6G might be monetised, its economic potential, and areas for investment:

Monetisation Strategies for 6G

Traditional mobile revenue streams (voice, data plans) will evolve by 2030, and operators must leverage 6G's unique capabilities to create new value propositions:

- **Network-as-a-Service (NaaS):** With 6G's extensive network slicing and virtualisation, operators can offer slices on-demand to enterprises, essentially selling network capability in a cloud-like model. For example, a manufacturing company could subscribe to an ultra- reliable low-latency slice for its factory robots, or a media company might rent a high-bandwidth slice during a live event for holographic streaming. This goes beyond APN or VPN of today – it's a guaranteed portion of the 6G network with specified performance.

  Operators can charge premium fees based on SLA (latency, throughput, coverage area, security level) rather than just volume of data. e& UAE with its 6G network could become a connectivity cloud provider, allowing customers to spin up slices via an API.

  This NaaS model extends to Edge Computing-as-a-Service too – combining connectivity with edge processing. For instance, an AR gaming company might pay for a slice that includes edge GPU resources on e&'s 6G network, enabling it to serve customers with minimal infrastructure of its own.

- **AI-Driven Telecom Services:** An AI-native 6G network means operators will have powerful AI infrastructure that can be monetised. One approach is offering AI analytics services derived from network data. With appropriate privacy safeguards, the operator can provide insights: e.g., footfall analytics in retail (based on network sensing of movement), or predictive maintenance for connected machinery (analysing IoT data). Another aspect is delivering Quality of Experience (QoE) as a service.

  For instance, an OTT content provider might pay the operator to ensure a certain QoE (like zero buffering 8K video or glitch-free XR) for its customers by using AI to optimise that traffic flow. Essentially, the operator's AI optimisations become a selling point – "we guarantee your application runs better on our 6G network." Moreover, telecom operators can package some network AI capabilities for enterprise use, such as security (AI-based threat detection in network traffic) or customer engagement (telco AI providing analytics for a smart venue, etc.).

- **Immersive Content and Experiences:** 6G will enable new products in media and entertainment – hologram calls, AR cloud experiences, VR sports events, etc. Telcos can diversify into becoming experience providers. For example, e& UAE might offer subscription-based immersive meeting services (where instead of Zoom, you have 3D holo-conferencing over 6G) or partner with content creators for AR tourism (remote visitors paying to virtually explore UAE landmarks in AR with 6G-provided high fidelity).

  These services could be monetised via one-time charges or subscriptions and would rely on 6G connectivity quality. Telcos may also enter revenue-sharing models with content companies: e.g., a metaverse gaming company gets guaranteed performance from the telco, and revenue is shared for in-game purchases or tickets to virtual events. The key is that connectivity becomes intertwined with the content – unlike 4G/5G where operators often only sell data, with 6G they can co-create and directly sell advanced digital services that only work with 6G.

Another angle is enterprise digitalisation solutions: 6G can enable comprehensive solutions like remote factory operations, telehealth systems, or smart city platforms. Operators can move up the value chain to offer end-to-end solutions (device connectivity + platform + analytics). For instance, e& could sell a smart agriculture service to farm operators that includes 6G-connected drones for crop monitoring, plus an AI platform analysing the data – rather than just selling SIMs for the drones. This solution selling is facilitated by 6G's capabilities (massive IoT and reliable links allow the solution to actually function at scale).

6G's Economic Potential

The economic impact of 6G is expected to be substantial, potentially surpassing previous generations given its pervasiveness across industries. By enabling new markets (like autonomous systems, integrated sensing, AI native, metaverse economies, etc.), 6G will generate new revenue streams for many stakeholders:

- **Emerging Business Models:** As outlined, NaaS and slice-based offerings create more **B2B opportunities** for operators. We may see models like **marketplaces for network slices or edge compute** – where third parties can buy/sell capacity dynamically. Additionally, **data marketplaces** might flourish: anonymised sensor data collected via 6G could be traded (with user consent) for purposes like traffic optimisation, retail planning, etc. 6G's trustworthy framework might make participants more willing to exchange data. There's also talk of the **"experience economy"** – monetising not the data, but the experience delivered (e.g., charging per minute of a holographic concert experience).

- **Estimated Market Value:** While projections vary, industry research pegs the global 6G market to be tens of billions of dollars within a few years of launch. For instance, some forecasts estimate the 6G market to grow from roughly **USD 4–7 billion** in 2030 (initial deployments) to **around USD 60–160 billion by 2035**.

  This implies a very rapid CAGR (over 70% by some accounts) in the early 2030s, reflecting how quickly 6G could be adopted and scaled. For comparison, 5G's global market (including infrastructure and services) is expected to reach a similar magnitude by the mid-2020s, so 6G might reach that level even faster due to broader use cases. In the UAE, given the high-tech appetite and government support, we can expect local 6G-related market value to be significant – fueling telecom, device manufacturing, app development, and new startups. Entire new sub-industries may be born (for example, companies specialising in holographic content creation or sensor analytics powered by 6G).

- **Productivity and GDP Impact:** 6G's influence spans verticals – manufacturing, transportation, healthcare, energy, entertainment, and more. By some analyses, the productivity gains and new services enabled by 6G could add several percentage points to global GDP over time. For instance, smarter logistics and reduced downtime in industry saves billions; improved healthcare outcomes reduce costs and increase societal productivity. For the UAE, integrating 6G into industries supports the diversification and digital transformation goals, potentially adding high-value tech jobs and tech exports (if solutions developed here are sold abroad). One could envision the UAE becoming a testbed economy for 6G – attracting global companies to trial and invest in 6G apps (which brings in investment).

Overall, the economic potential of 6G is not just in direct telecom revenues, but in the enablement effect – the way 6G serves as a platform for innovation across all sectors. It's analogous to how 4G brought us the app economy and multi-billion dollar companies built on mobile internet; 6G could enable a new wave of companies and services built on ubiquitous AI-infused connectivity.

For e& UAE, capitalising on this potential means being agile and open to partnerships

e.g., with cloud providers, device makers, and vertical industry specialists – to co-create services and share revenue. It's notable that e& itself has rebranded from Etisalat to e&, signalling an expansion beyond traditional telco into areas like fintech, media, and digital services. 6G will accelerate this convergence of telecom with other digital industries.

Investment Opportunities

Realising 6G will require significant investment across different domains, but it also offers opportunities for returns in those areas:

- **Infrastructure Investment:** Deploying 6G will involve new infrastructure – from upgrading mobile sites with 6G radios (especially new higher-frequency equipment requiring dense deployments in urban areas) to installing edge data centres, satellite systems, and fibre backhaul. There is an opportunity for **infrastructure investors and partners** to co-fund these.

  For example, cloud, content and CDN providers might invest with operators in edge computing nodes (seeing the benefit of extending their cloud to the far edge). Governments might provide incentives or public-private partnership (PPP) models for rural 6G coverage using satellite or HAPS, seeing it as critical infrastructure akin to roads or power.

- **Spectrum Investment:** 6G will necessitate access to new spectrum bands. Operators will need to invest capital to acquire licenses for mid-band (e.g., 7–15 GHz) and possibly sub- THz bands if those are licensed. There's an opportunity for **collaborative R&D in spectrum** – for instance, jointly developing techniques to use difficult bands (above 100 GHz) effectively could save costs and might attract government research grants. Also, if the UAE leads in some spectrum experimentation (like allowing early 6G trials in certain bands), it could attract international players to test here, effectively investing intellectual and financial resources in the local ecosystem.

- **Collaborative R&D and Innovation Ecosystem:** Developing 6G technology and standards is already underway globally (in initiatives like Hexa-X in EU, Next G Alliance in US, etc.). e& UAE can invest in partnerships with universities (for fundamental research in areas like new waveforms, AI algorithms, etc.) and with vendors in joint innovation centres. These R&D investments, while not immediate revenue generators, are crucial for **IP creation and strategic advantage.**

  By contributing to patents or standards, e& could both influence the 6G features to suit its market and possibly gain licensing revenue or cost benefits. The UAE will establish a **6G innovation hub** – offering funding or facilities to startups focusing on 6G use cases (like AR, robotics, sensing, or satellite tech). This not only fosters local talent and solutions but ensures the country reaps economic benefits from the global 6G value chain.

- **Human Capital and Training:** Another area of "investment" is in the workforce – training engineers and specialists in 6G technologies (AI, advanced RF, big data analytics, quantum security). Programmes to develop these skills will be important so that by the time 6G rolls out, there's a knowledgeable talent pool to deploy and operate it. These investments often involve partnerships with academic institutions (scholarships, research chairs) and can be aided by government initiatives. The payoff is having local expertise and possibly exporting that expertise.

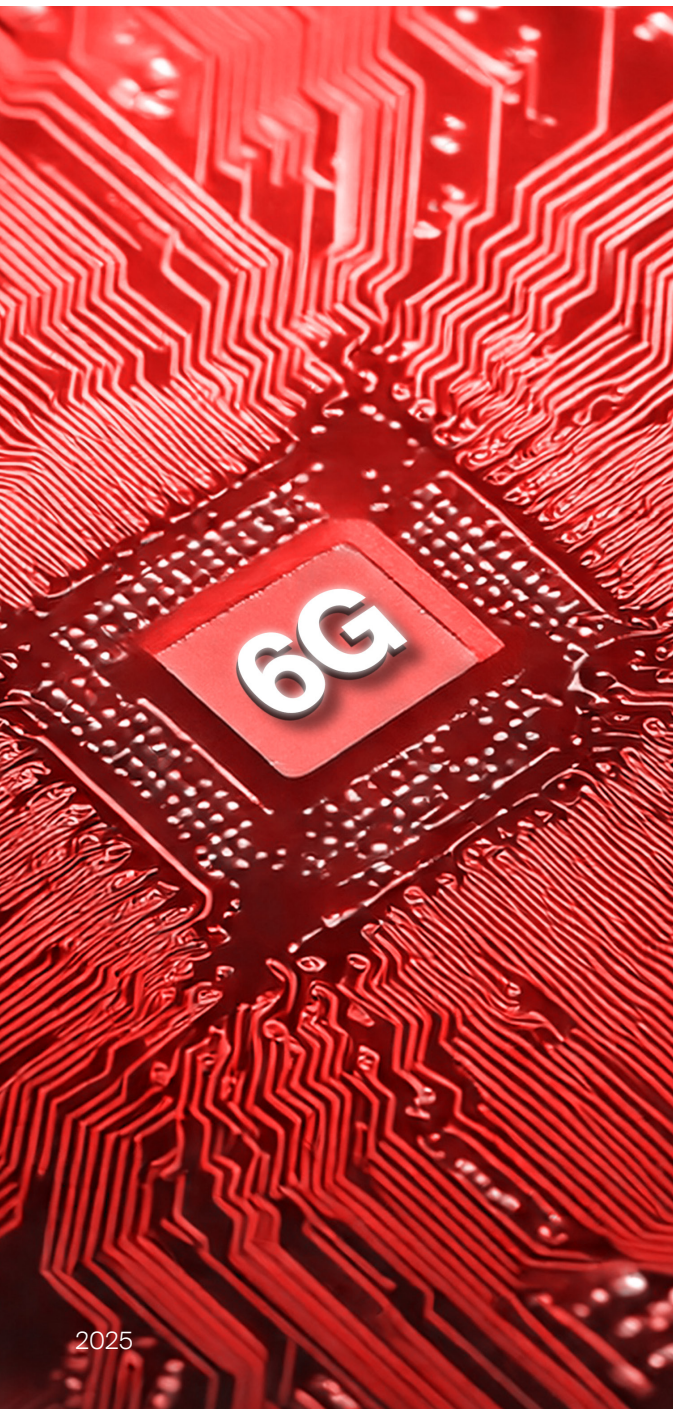
From a business perspective, the players who invest early and wisely in these areas stand to gain a first-mover advantage.

For e& UAE, early infrastructure trials (maybe around 2027–2028, according to the roadmap) would iron out technical kinks and allow development of services aheadof competitors. Engaging in standardisation (through ITU, 3GPP contributions) and aligning with global tech partners can also reduce risk by sharing the development load.

In conclusion, 6G opens a rich tapestry of business models – many still to be invented. The networks will be more flexible and powerful, allowing operators and other stakeholders to think beyond connectivity to platform and experience-based monetisation. The economic stakes are high: those who adapt could tap into significant new revenue streams, whereas sticking to traditional models might mean missing the 6G wave. Thus, strategic investment – in infrastructure, spectrum, R&D, and partnerships – is imperative now (in the mid-2020s) to capture the opportunities of the coming 6G era.

07. Policy & Regulatory Considerations

The success of 6G will depend not only on technology development but also on supportive policy and regulatory frameworks. Key considerations include standardisation timelines, spectrum management, and ensuring security/ privacy in this hyper-connected future.



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6G Standardisation Timeline and ITU/3GPP Roles

The journey to 6G is charted by international standards bodies. The ITU (International Telecommunication Union) has officially named 6G as IMT-2030, indicating the target timeframe. The ITU's Working Party 5D has outlined a multi-step process

- **2021–2023:** Vision and Framework – The ITU finalised the **Framework and Overall Objectives for IMT-2030** in late 2023. This includes usage scenarios (the "wheel diagram") and initial key capabilities. This high-level vision (Rec. ITU-R M.2160) now guides what 6G should achieve.

- **2024–2026:** Technical performance requirements (TPRs) – The ITU will define the detailed performance requirements and evaluation criteria for 6G (e.g., what data rate, latency, reliability metrics it must meet, in which scenarios). This involves contributions from industry and is crucial because it sets the bar that any proposed 6G technology must meet.

- **2025–2027:** Technology development in parallel – Forums like **3GPP** will be conducting research and starting preliminary standardisation for 6G around this time. In fact, in March 2024, 3GPP approved a tentative timeline for 6G work, aiming for initial specs by 2028. It's expected that 3GPP Release 20 (around 2025) and Release 21+ will gradually introduce 6G functionalities, with a full 6G specification possibly in Release 22 or 23 by 2028–2029.

- **2027–2028:** Submission & Evaluation – Various organisations (3GPP, maybe others like IEEE) will submit their candidate 6G Radio Interface Technologies (RITs) to the ITU for consideration as IMT-2030. The period from late 2027 through 2028 will see **evaluation by independent groups** of these candidates against the ITU requirements.

- **2029–2030:** Finalisation – The ITU will review evaluation results and finalise the IMT-2030 specification by 2030, deciding which technologies (likely 3GPP's 6G and possibly others) are officially 6G. This aligns with the goal of initial commercial 6G deployments around 2030.

During this, 3GPP plays the central role in fleshing out the technical standards (the detailed protocols for 6G). We expect 3GPP to start a Study Item on 6G around 2025 and a Work Item by 2026. By ensuring alignment (3GPP aims to finish specs in time for IMT-2030 submission), commercial networks can launch by ~2030. **Ericsson, Nokia, Huawei, Samsung**, etc., are already contributing to pre-standard research, and e& UAE (through its partners or directly via forums like GSMA, NGMN) will feed its requirements into that process.

Spectrum Management for 6G

Regulators will face critical decisions on spectrum for 6G. As noted, 6G will utilise frequency bands from low (sub-1 GHz) to high (sub-THz) as indicated in the below Figure. Key considerations:

Spectrum in 2022

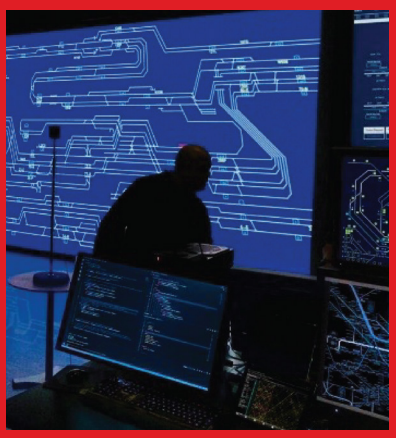
5G

- Legacy 2G/3G/4G spectrum
- Low bands (e.g. 600 MHz, 700 MHz)
- Mid bands (e.g. 3.5 GHz, 4.4-4.9 GHz)
- High bands (e.g. 26 GHz, 28 GHz)

Spectrum in 2025-2030

5G-Advanced

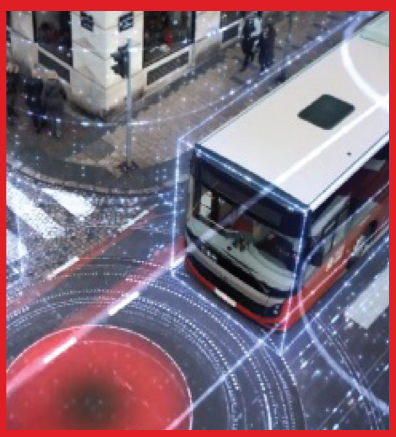
- Legacy 2G/3G/4G/5G spectrum
- Low bands (e.g., 600 MHz)
- Mid bands (e.g., 6 GHz)
- High bands (e.g., 40 GHz)



Spectrum beyond 2030

6G

- Legacy 2G/3G/4G/5G/5G-A spectrum
- From the essential centimetric range:focus on 7-15 GHz
- From the complementary sub-THz range:
- focus on 92-114 GHz and 130-175 GHz



- **Identification of New Bands:** World Radiocommunication Conferences (WRC-27 in 2027, and possibly WRC-31) will consider spectrum for 6G. Bands in discussion include parts of 7–24 GHz (upper mid-bands) and above 95 GHz ([1]). Regulators must balance incumbent uses (e.g., satellite or military use of some bands) with the benefits of allocating them to IMT. For example, the 6 GHz band (5925–7125 MHz) is a hot topic – some regions eye it for 5G/6G licensed use, others for Wi-Fi.

  Similarly, frequencies around 140 GHz or 230 GHz may be considered for IMT-2030. The UAE will need to formulate its position and coordinate with regional groups (e.g., Arab Spectrum Management Group) to advocate for bands that serve national interests. Early spectrum planning can ensure availability so that by late 2020s, trials can legally use those bands. Unlike previous generations, uplink performance in 6G will be equally critical. e& UAE sees innovation in uplink spectrum allocation and hardware design as vital for enabling user-generated XR content, real-time holography, and metaverse applications.

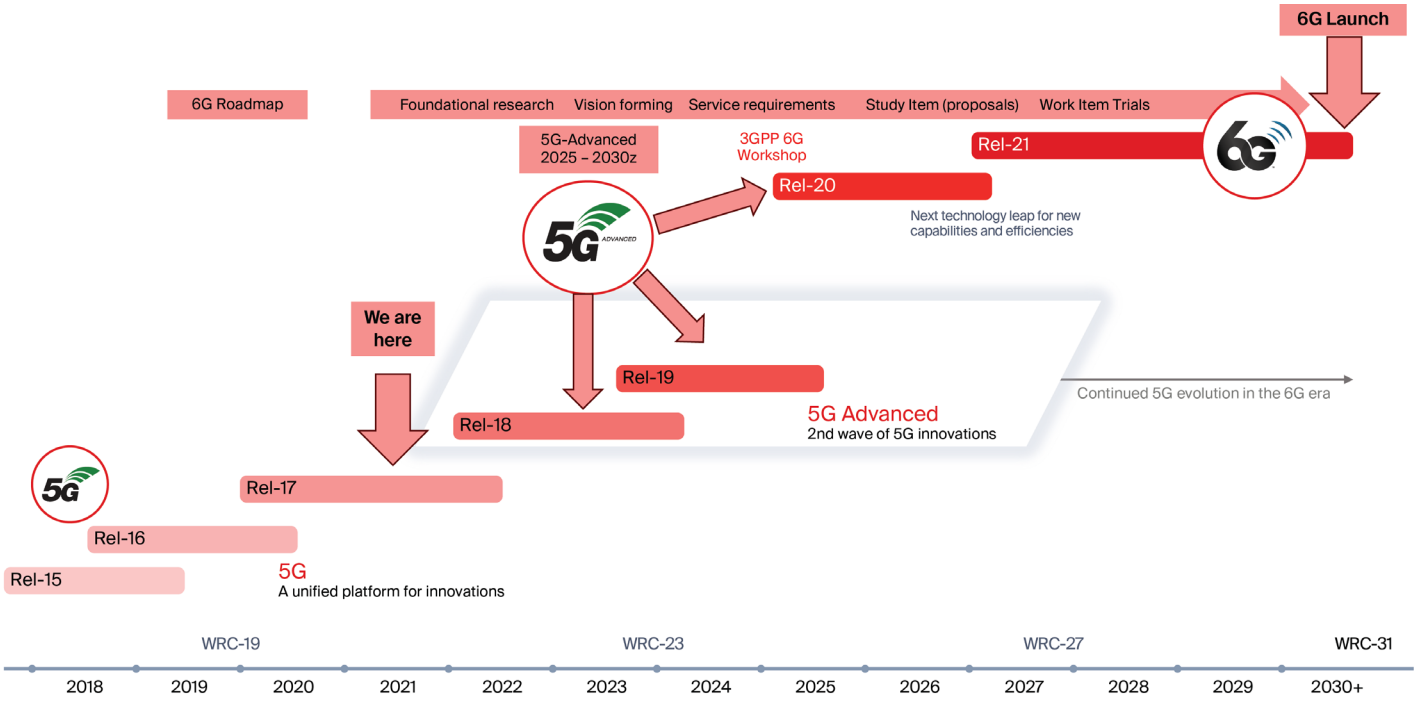
- **Harmonisation:** To maximise global roaming and economies of scale, regulators will strive to harmonise key 6G bands. As mentioned earlier, spectrum harmonisation yields lower device cost and complexity ([4]). The policy challenge is achieving consensus globally. The ITU process helps, but national agendas differ. The UAE, given its early adoption stance, will likely harmonise with international bands for 6G (like it did for 3.5 GHz in 5G). It may also act regionally to align GCC or Arab states on common band plans for 6G, which will be beneficial for cross-border services and device availability.

The Telecommunications and Digital Government Regulatory Authority (TDRA) announced the allocation of 600 MHz and the upper 6 GHz bands for mobile service identified for IMT. The UAE will thus be one of the first in the world to offer 6 GHz mobile broadband and one of the earliest movers on 600 MHz in EMEA. This forward-thinking decision positions the UAE at the forefront of superfast connectivity and lays the foundation for groundbreaking innovations in 5G-Advanced and 6G technologies. By unlocking the potential of the 600 MHz and 6 GHz bands, the UAE is set to deliver enhanced connectivity — transforming the digital landscape for businesses and consumers alike.

e& UAE has successfully completed a groundbreaking 5G-Advanced trial, achieving a world- first 10Gbps throughput on the 6GHz band – the highest ever recorded on this frequency. Conducted in collaboration with the TDRA, this milestone reinforces the UAE's leadership in next-generation connectivity and sets a strong foundation for the transition to 6G.

08. Roadmap to 6G & e& UAE's Role

The path to 6G will be a decade-long journey involving research, trials, standard development, and gradual deployment. Below is a projected timeline of milestones on the road to 6G and how e& UAE is positioning itself at each stage:



- **2024–2025 | Foundational Research & Vision Alignment :** These years are focused on exploratory R&D and shaping the 6G vision. Globally, research communities (universities, vendor labs, alliances) are investigating key technologies (as discussed earlier) and crystallising use case requirements. The ITU's IMT-2030 Vision has been set, and now detailed study items in 3GPP and other Standards Development Organisations (SDOs) will begin. **e& UAE** is actively engaging in this phase by **collaborating with academia and industry partners**. For instance, e& might sponsor research programmes at UAE universities on AI in networks or THz propagation in desert climates, contribute to early whitepapers, and align internally on its 6G strategy (what use cases to prioritise for the UAE market).

  By 2025, e& aims to have defined its own **6G vision and roadmap**, ensuring it is ready when standardisation picks up. This period is also about **global collaboration** – e& UAE will ensure representation in global 6G forums to voice operator needs and learn from others. Also, e& has signed a strategic Memorandum of Understanding (MoU) with New York University Abu Dhabi (NYUAD) to advance research and development (R&D) of 6G technology in UAE.

Additionally, e& contributed to a collaborative whitepaper with the Telecommunications and Digital Government Regulatory Authority (TDRA) and Khalifa University, titled '6G: Next Generation Connectivity in the UAE'.

- **2026–2027 | Standardisation and Early Prototyping:** Around 2026, formal standardisation of 6G will intensify (e.g., 3GPP Release 20+ discussions focusing on new services). The first experimental systems and prototypes of 6G technologies will start to appear in labs. It's expected that initial 6G prototype trials – testing things like new waveforms, ISAC, terahertz links, AI-driven network controls – will occur in controlled environments. e& UAE's role here is to begin internal trials and testbeds in partnership with vendors.

  For example, e& will set up a 6G innovation lab to evaluate ISAC use cases, assess sub-THz radio link between two buildings, or test an AI-powered network management system on a slice of its existing network (as an emulation of 6G autonomy). At this stage, e& would also work closely with device and chip makers to understand device readiness (since 6G phones or sensors will need new chipsets).

- **2028–2029 | Technical Trials and Pre-Commercial Testing:** As 6G specifications near completion and candidate technologies are submitted to ITU, real-world field trials will take place. These are larger-scale tests, possibly in outdoor environments, city testbeds, or specific industry sites. We anticipate 6G trial networks in select locations globally by 2028. e& UAE intends to be among the first operators to host 6G trials in the world. This could involve deploying a pilot 6G cell to test coverage, throughput, and new use cases.

  Trials with enterprise customers might also happen – for instance, ISAC use cases in manufacturing and logistics. Around 2028, device ecosystem will still be limited (test devices, not consumer handsets), but e& will work with manufacturers to test form-factors like 6G CPEs or modems. This stage is critical for identifying challenges early – e.g., unforeseen propagation issues or interoperability bugs – so they can be addressed before commercial launch.

- **2030 | Early Commercial Launch:** If standardisation stays on track, the first commercial 6G networks are expected around 2030. These will likely be limited in scale – select cities or specific use-case deployments – as device availability ramps up. e& UAE's goal is to be a leader in launching 6G in the region and among the first in the world.

  The initial launch might focus on high-profile, high-demand areas or applications: for instance, a 6G coverage in downtown Dubai or around key industry zones to showcase enhanced mobile broadband (like truly seamless AR experiences for tourists or citizens), and industry 4.0 deployments for major UAE industrial players (oil fields, ports with 6G private networks). e& UAE's selection of those will align with UAE's strategic sectors (e.g., smart cities, advanced healthcare, transport, etc., as discussed).

- **2031 and Beyond | Widespread Adoption:** After the initial launch, the 6G rollout will expand to nationwide coverage through the early-to-mid 2030s. By 2032–2035, 6G networks could be as ubiquitous as 4G/5G are today. During this phase, consumer adoption picks up as more affordable 6G devices hit the market. e& UAE will aim for a full 6G network deployment covering urban and rural areas, integrating satellite components for 100% geographic coverage.

In summary, the road to 6G is mapped out in stages: research (now), standardisation (mid-decade), trials (late-decade), initial deployments (~2030), and then scaling. e& UAE is proactively engaging at each stage to ensure it remains at the forefront. The company's early achievements in 5G give it credibility and experience to influence 6G. The vision is that by the early-2030s, when 6G is widespread, e& UAE will have been a pioneer, leveraging 6G to deliver on national digital transformation goals and to secure its position as a global technology leader.

e& UAE recognises the lessons learned from 5G—particularly the fragmentation introduced by NSA deployments innovation. The 6G journey will embrace a more unified architecture and holistic experience design from Day One, ensuring simplicity, scalability, and real-world readiness.

09. Conclusion & Future Outlook

As we stand on the cusp of a new decade, the outline of 6G is coming into focus: a **network of networks that is immensely fast, intelligent, and all-pervasive**, yet also human-centric, secure, and sustainable. 6G represents more than just an evolutionary step in mobile communications – it is a platform for innovation that could fundamentally transform how we live, work, and interact.

It promises to realise experiences that today seem futuristic: holographic telepresence in our daily communications, cities that autonomously respond to real-time data, vehicles that never crash, and an internet that connects not just our devices but our senses and intelligence.

For e& UAE, the 6G vision is both an opportunity and a responsibility.

The opportunity is to leverage 6G to drive the UAE's digital economy to new heights – fostering industries around immersive media, AI, and IoT, and significantly enhancing quality of life through technology. The responsibility comes from the role of being a national enabler: ensuring that the benefits of 6G (ultra broadband access, smart services) are broadly accessible, bridging any digital divides and doing so securely and sustainably.

e& UAE's proactive approach – from achieving world-leading 5G performance to investing in AI and 6G research – positions it to fulfil this role. By shaping standards, experimenting early with new technologies, and building partnerships, e& aims to make the UAE not just an adopter of 6G, but an innovator and leader in the 6G era.

Looking beyond the horizon, the journey to 6G will require unprecedented collaboration across the global ICT ecosystem. No single company or country can realise 6G alone. It calls for a coalition of telecom operators, network vendors, semiconductor companies, cloud providers, academia, and government bodies. Industry collaboration is a clear call to action – to share knowledge in research forums, to establish interoperability through common standards, and to jointly address challenges (like spectrum availability and global coverage solutions). Likewise, investment is needed at multiple levels:

R&D funding for breakthrough technologies (antennas, chipsets, algorithms), capital expenditure for new infrastructure, and workforce development to equip engineers with the skills for this multidisciplinary network (spanning AI, quantum security, etc.). This whitepaper highlighted how returns can be significant – enabling new revenue streams and efficiencies – but upfront commitment is essential.

In conclusion, the transition to 6G heralds a future where the boundaries between the physical and digital worlds blur, and where connectivity is as omnipresent and effortless as air and water. This future holds immense promise: safer transportation, enriched entertainment, smarter cities, healthier lives, and more sustainable use of resources.

Achieving this will require vision, perseverance, and cooperation. e& UAE's 6G vision – as detailed in this paper – is aligned with this global perspective, yet tailored to the aspirations of the UAE. It is an ambitious vision of a connected, intelligent nation empowered by 6G, in which the UAE's citizens, businesses, and government all thrive on the next generation of connectivity. The next steps are clear.

We must continue to experiment, innovate, and break new ground in technologies over the coming years. We must engage in the international dialogue to ensure 6G develops in an open, inclusive way. And when 6G technology matures later this decade, we must be ready to deploy it swiftly and broadly to realise its benefits.

The future outlook is that by 2030, we will witness the dawn of 6G networks starting to transform the world – and with the groundwork laid now, e& UAE and the nation will be ready to embrace and lead in that future. The call to action is for all stakeholders to join in this journey: to contribute ideas, to pilot applications, to build the ecosystem. 6G is coming, and if we prepare diligently, it will indeed enable a hyper-connected, intelligent world that delivers on the promise of technology for human advancement.

2025

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