The Institution of Engineers (India)
Uttar Pradesh State Centre

Webinar

on

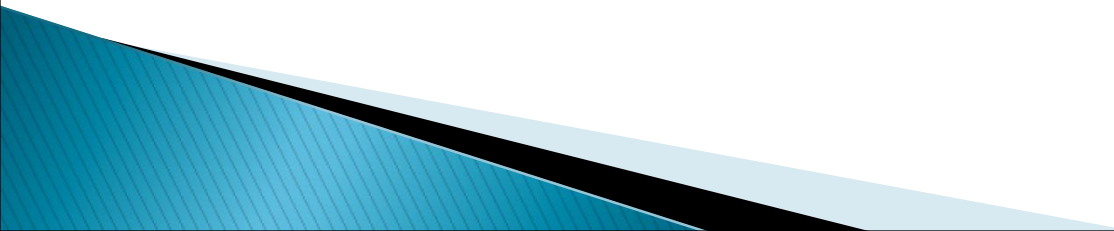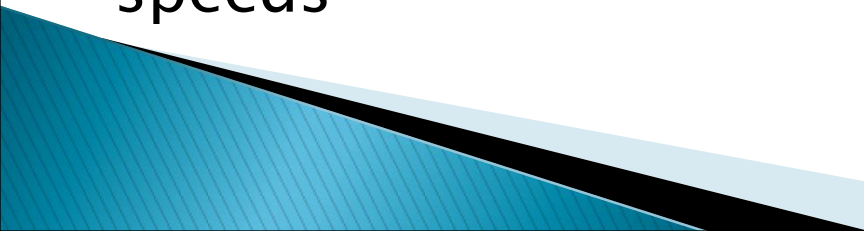# 5G and Future Technologies

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18 April 2025

Overview of PPT

- Introduction of 5G and Background
- Key Features of 5G and Evolution of 5G
- 5G Architecture and Technologies used in 5G
- Comparison 4G vs 5G vs 6G
- 5G Applications in Various Sectors
- 5G enabled IoT, AR, VR,
- Blockchain and Quantum Technologies
- Opportunities and Challenges
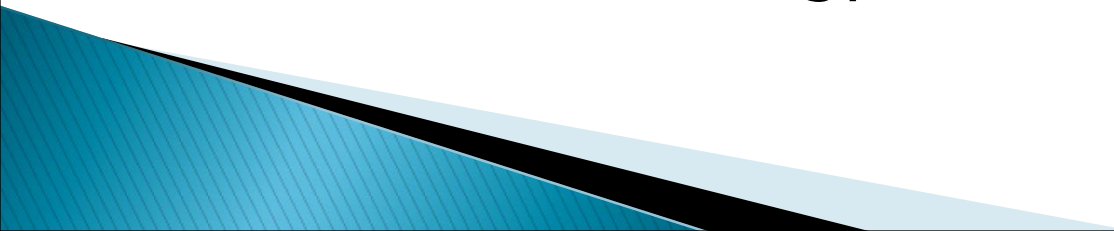- Security Concerns, Global Adoption
- Future Outlook and 6G
- Conclusion

What is 5G ?

▸ **A new standard** for cellular networks developed by the 3GPP in 2018 to replace the standards of 4G and 4G LTE. **Ultra-fast internet** speeds, **lower latency** and the ability to connect a **massive number of devices** simultaneously

➢ **5G network,** just an upgrade over 4G but a platform enabling new applications in fields like IoT, AI, and smart cities. **A whole set of new networks for different applications**

➢ **Operate in** the mmWave spectrum (30-300 GHz) advantage of sending large amounts of data at very high speeds

Why is 5G important?

- The demand for internet access (combined with the emergence of AI, IoT, and automation), is driving a massive increase in the amount of data created

- 4G mobile infrastructure is not designed to handle such a high information load (Data creation to the tune of several hundred zettabytes over the coming decade) thus 4G requires upgrading

- At the same time, with its high speed, massive capacity, and low latency, 5G could help to support several applications like cloud-connected traffic control, drone delivery, video chatting,etc.

Need for 5G

- Immense pressure on Network Operators to **upgrade their networks** continuously to handle mobile data traffic

- To reduce Operational Expenses and for generating new revenue opportunities for wireless service providers to support new applications

- Because of 5G limitless benefits and applications, say from global payments and emergency response to distance education and mobile workforce, there is need for 5G technology

5G Spectrum

Spectrum is critical for 5G success
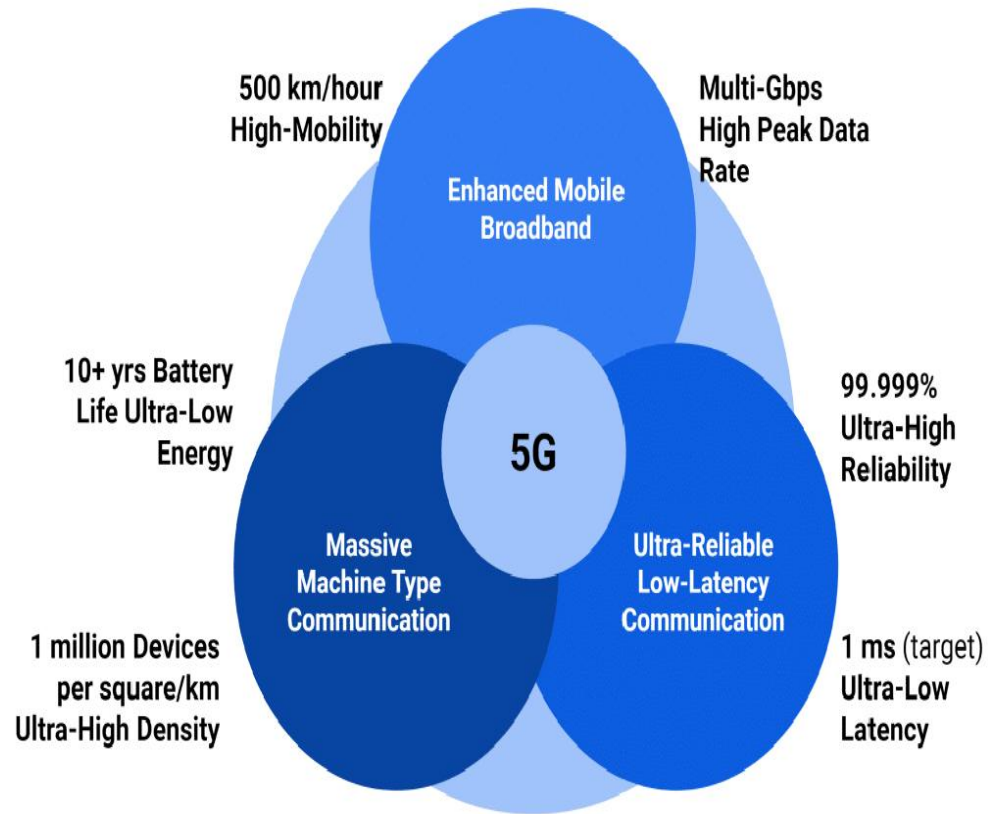### Using all spectrum types and bands

5G

Licensed spectrum
Exclusive use
Over 40 bands globally for LTE, remains the industry's top priority

Shared spectrum
New shared spectrum paradigms
e.g.: 2.3 GHz Europe/3.5 GHz USA

Unlicensed spectrum
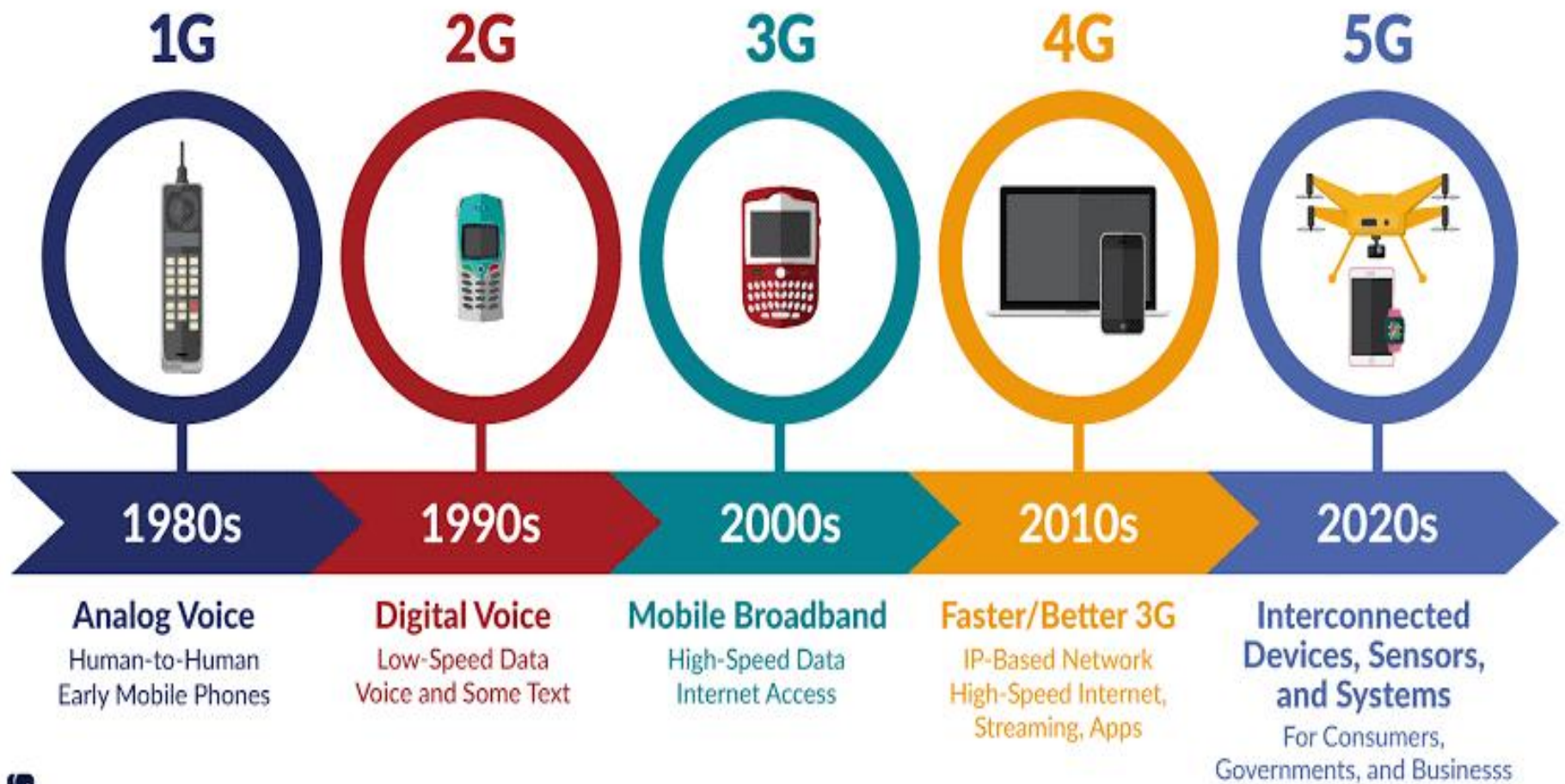Shared use
e.g.: 2.4 GHz/5.9-7.1 GHz/57-71 GHz global

High bands
above 24 GHz
(mmWave)

Mid bands
1 GHz to 6 GHz

Low bands
below 1 GHz
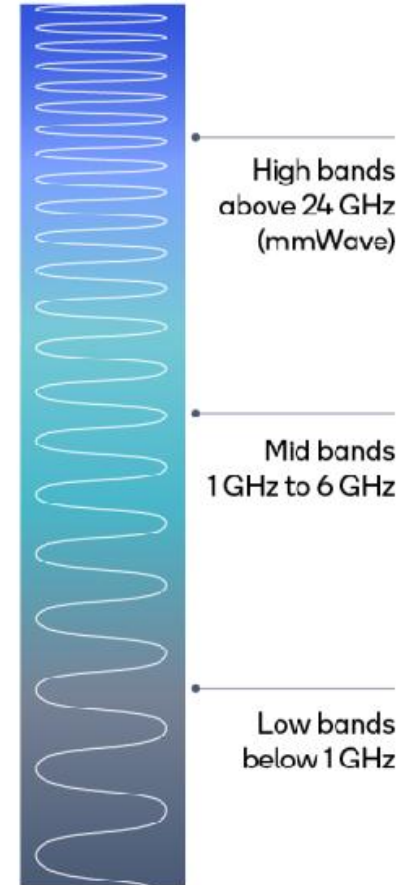
Key Features of 5G

- **High-Speed Connectivity**: Faster data transfer (up to 10 Gbps)
- **Ultra-Low Latency**: Real-time responsiveness (as low as 1ms)
- **Massive Device Connectivity**: Supports IoT, smart devices, and industrial applications
- **Enhanced Network Reliability**: Seamless and secure connectivity

500 km/hour High-Mobility

Multi-Gbps High Peak Data Rate

Enhanced Mobile Broadband

10+ yrs Battery Life Ultra-Low Energy

5G

99.999% Ultra-High Reliability

Massive Machine Type Communication

Ultra-Reliable Low-Latency Communication

1 million Devices per square/km Ultra-High Density

1 ms (target) Ultra-Low Latency

Evolution of 5G

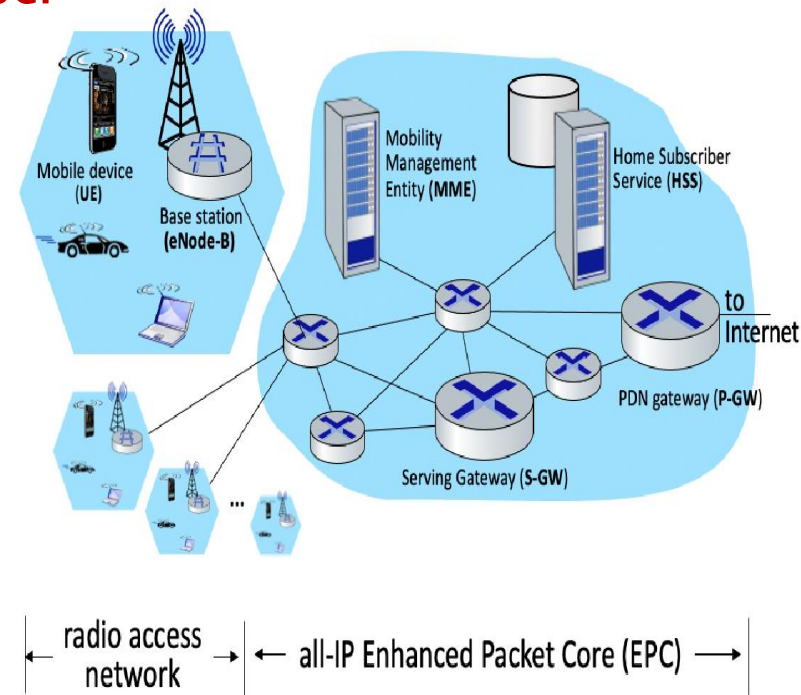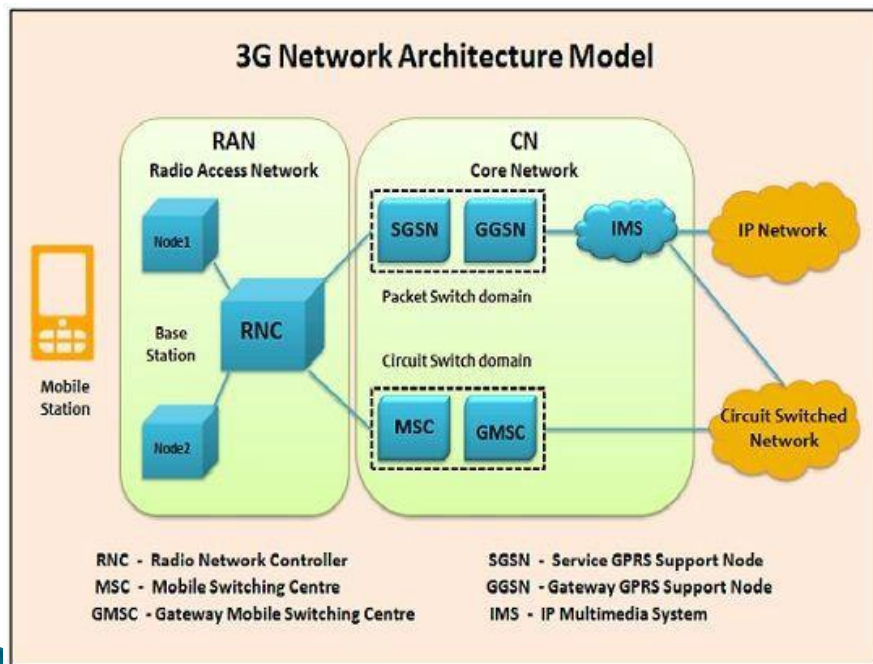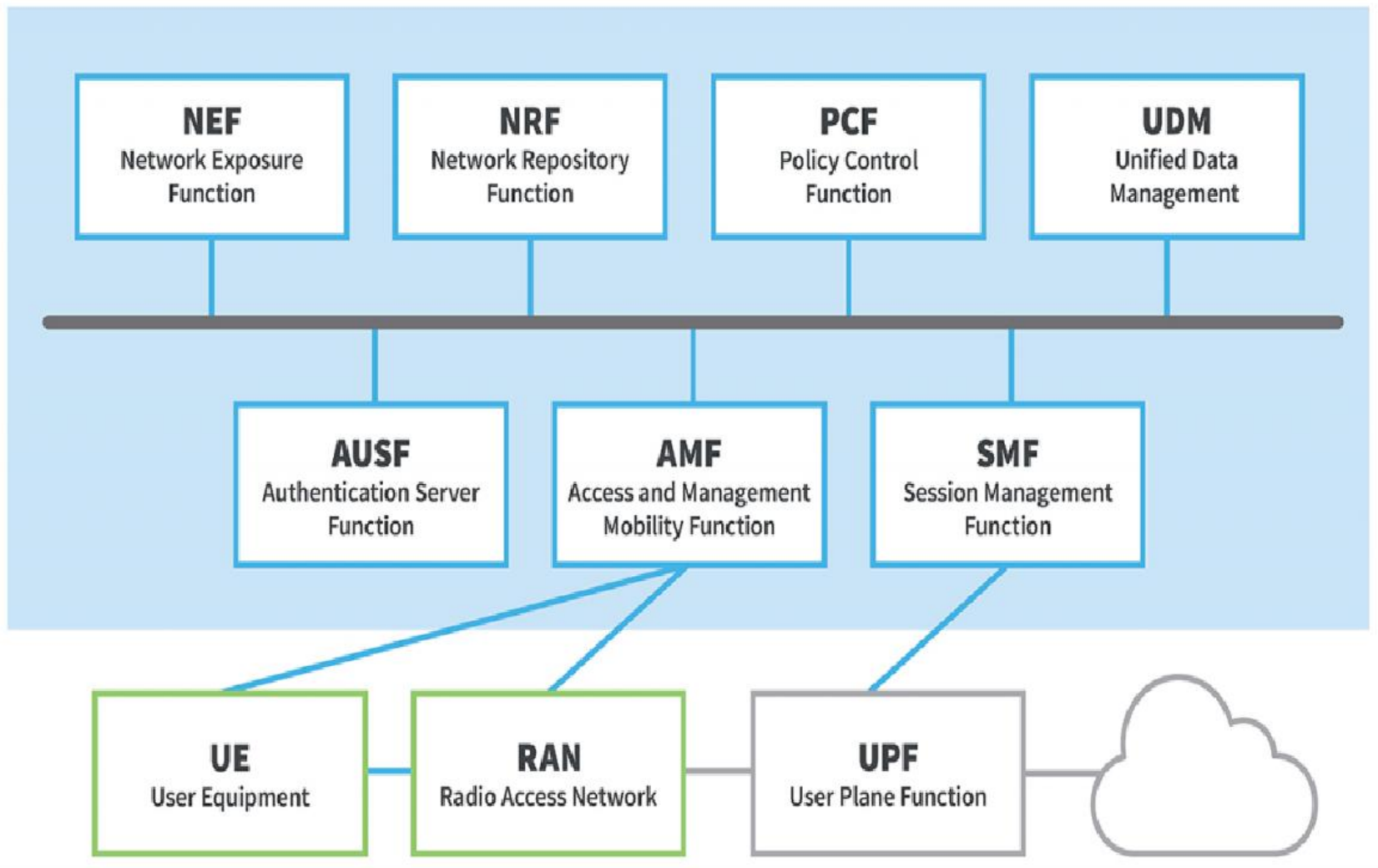| 1G	2G	3G	4G	5G
1980s	1990s	2000s	2010s	2020s
Analog Voice	**Digital Voice**	**Mobile Broadband**	**Faster/Better 3G**	**Interconnected Devices, Sensors, and Systems**
Human-to-Human Early Mobile Phones	Low-Speed Data Voice and Some Text	High-Speed Data Internet Access	IP-Based Network High-Speed Internet, Streaming, Apps	For Consumers, Governments, and Businesss

3G/4G Network Architecture

In 4G Network, the radio function is based on LTE- 3GPP standards, The core network is based on the Evolved Packet Core (EPC) –The significant change in 4G networks: in 3G the RAN function included in base station (NodeB) and in 4G LTE, the base station function is split into two key functions–Base Band Unit (BBU) and Remote Radio Head (RRH)
RRH is connected to BBU through optical fiber

3G Network Architecture Model

RAN
Radio Access Network

CN
Core Network

Node1

Base Station

RNC

Node2

Mobile Station

SGSN   GGSN

Packet Switch domain

Circuit Switch domain

MSC   GMSC

IMS

IP Network

Circuit Switched Network

RNC - Radio Network Controller
MSC - Mobile Switching Centre
GMSC - Gateway Mobile Switching Centre

SGSN - Service GPRS Support Node
GGSN - Gateway GPRS Support Node
IMS - IP Multimedia System

Mobile device (UE)

Base station (eNode-B)

Mobility Management Entity (MME)

Home Subscriber Service (HSS)

to Internet

PDN gateway (P-GW)

Serving Gateway (S-GW)

radio access network   ← all-IP Enhanced Packet Core (EPC) →

5G Network Architecture

User Equipment (UE) like 5G smartphones or 5G cellular devices connect over the 5G New Radio Access Network to the 5G core and further to Data Networks (DN), like the Internet

The Access and Mobility Management Function (AMF) acts as a single-entry point for the UE connection

Based on the service requested by the UE, the AMF selects the respective Session Management Function (SMF) for managing the user session

The User Plane Function (UPF) transports the IP data between the UE and the external networks

The Authentication Server Function (AUSF) allows the AMF to authenticate the UE and access services of the 5G core

Other functions: Session Management Function (SMF), the Policy Control Function (PCF), the Application Function (AF) and the Unified Data Management (UDM) provide the policy control framework, applying policy decisions and accessing subscription information, to govern the network behavior

mmWave (millimetre Wave): uses up to 100GHz which come in the range millimetre frequencies (30GHz to 300GHz).
In contrast, 4G technology operates in 1GHz to 6GHz band. The advantage of mmWave band--less used and carries much more data than lower frequency wave

5G New Radio (NR) is the global standard for a unified, more capable 5G wireless air interface. 5G NR uses two frequency ranges: sub-6 GHz frequency bands and frequency bands in the mmWave range (24-100GHz)

Major Technologies in 5G

Small Cell stations: **mmWave technology provides less coverage comparing to low frequency** counterparts. To overcome this, small cell stations are needed to connect the base stations and users. Small cells make use of **low-power**, short-range wireless transmission systems (or "base stations"), **cover small geographical areas**

Beamforming: visualized as a laser beam between transmitting entity and the user. It makes transmission of data more directional resulting in **reduced interference** and increased **energy efficiency** in txn- allows multiple signals to use the same frequency channel thus improving load capacity of every channel

- **Mobile Edge Computing** (MEC): MEC brings cloud computing closer to the user physically--has twin advantages- One, **reduced distance decreases the latency period** and second **it also reduces the amount of data that the server has to handle**, by keeping just the required data near the user, which also speeds things up

Massive multi-user MIMO: enables the network to have more antennas per signal towers, thus ensuring larger and faster transmission of data

Comparison: 4G vs 5G

Full-Form	Fouth-Generation Technology	Fifth-Generation Technology
Speed	Upto 100 Mbps	10 Gbps (20 – 30 times more than 4G)
Latency	50 milliseconds	1 millisecond
Range	Longer range due to lower frequencies	The shorter range on higher frequencies but compensated with more base stations
Bandwidth	600 MHz – 2.5GHz	28-39 GHz
Device Connectivity	Primarily Smartphones and tablets	Devices ranging from smartphones to IoT devices to industrial equipment

4G vs 5G

Network Architecture	Relies on large cell towers for coverage	Uses a combination of cell towers and small cell networks for consistent networks
Network Efficiency	Efficient but faces congestion in densely populated areas	Highly efficient with better traffic handling
Energy Consumption	Higher energy consumption	Designed to be more energy efficient
Backward Compatibility	Compatible with 2G and 3G	Compatible with 4G and earlier standards
Application	HD video streaming, high-speed browsing and mobile apps	Autonomous Vehicles, Telemedicine, AR/VR, Smart cities

Three Major Applications of 5G

Enhanced mobile broadband (eMBB) is mainly for high-bandwidth demand services such as **VR, AR**

Massive machine-type communications (mMTC) is mainly for services with high connection density requirements such as **smart cities** and **intelligent transportation**

Ultra-reliable low latency communication (uRLLC) is mainly for delay-sensitive services such as **internet-of-vehicles, unmanned driving, and UAV (unmanned aerial vehicle)**
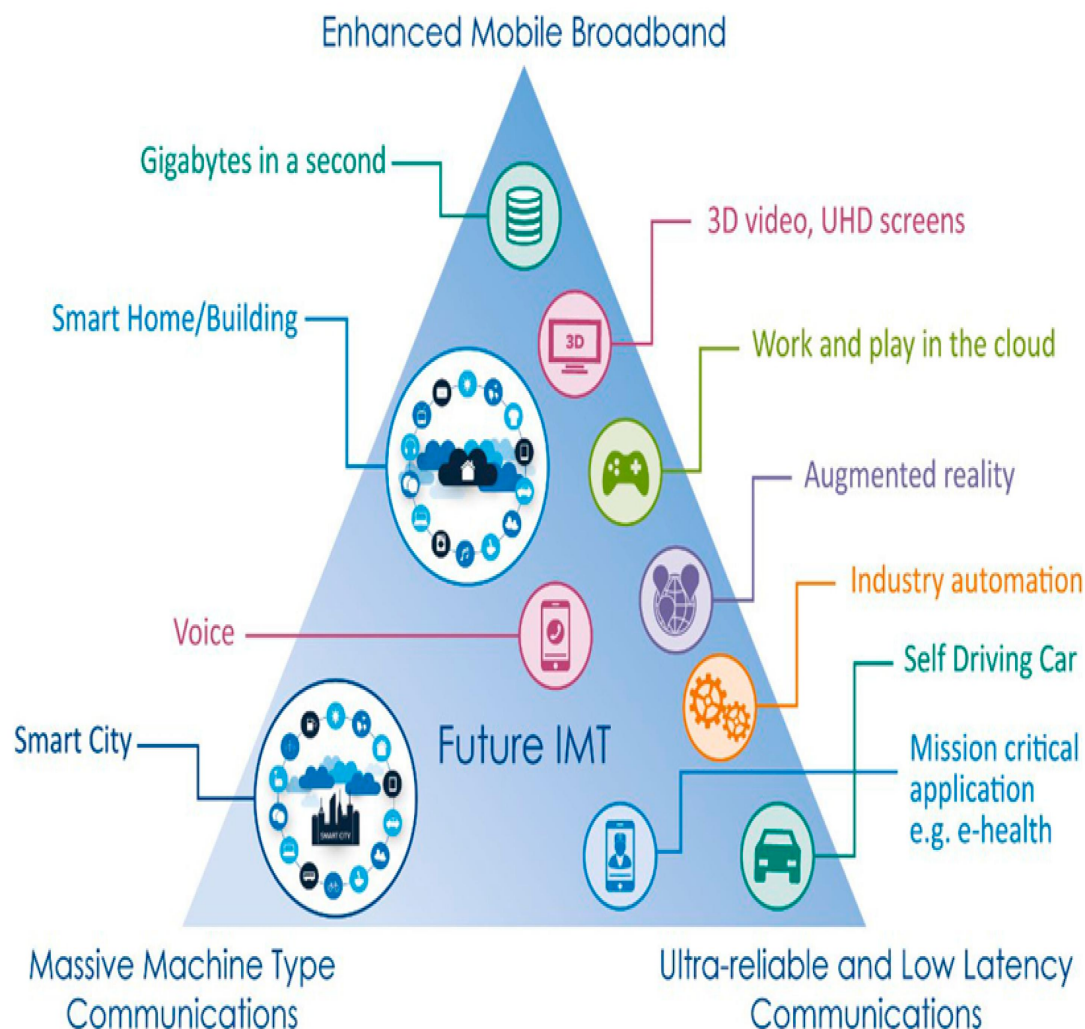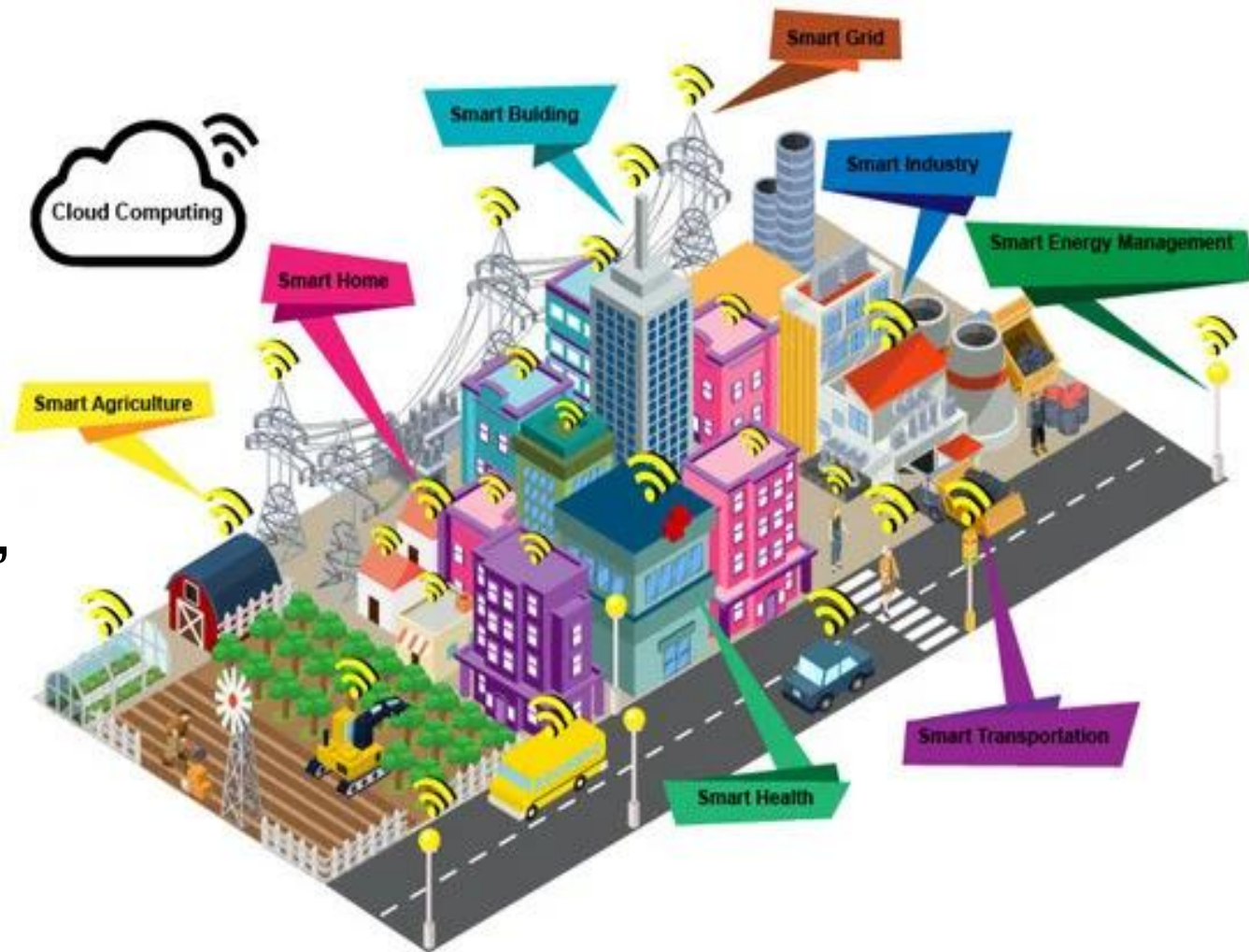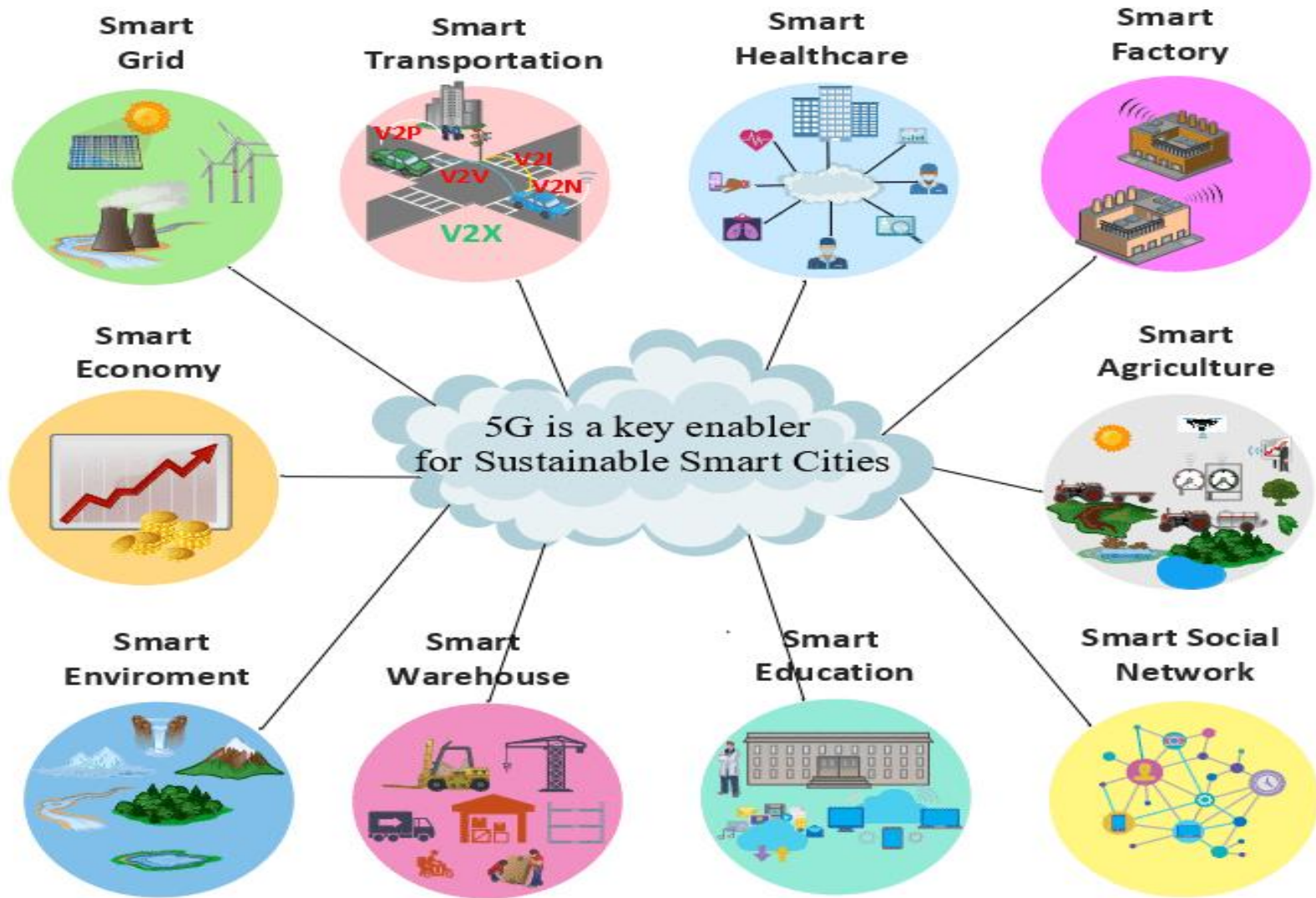
5G in Smart Cities and Infrastructure

- Smart Traffic Management: AI-driven traffic solutions
- Connected Public Services: IoT-enabled governance

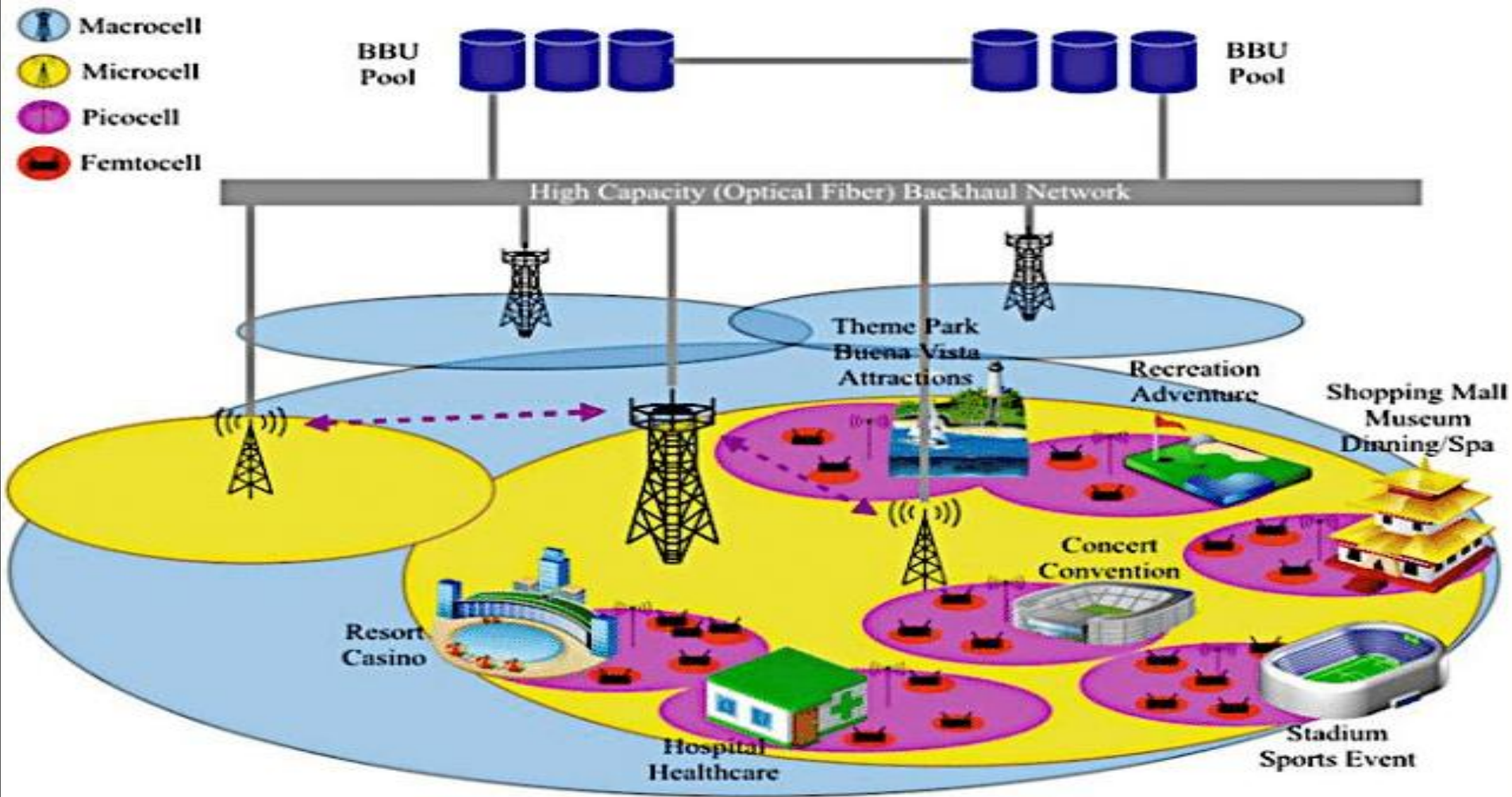**Efficient Energy Management**: Smart grids and real-time monitoring

Visual: an IoT-based Smart City, where services are connected into the grid

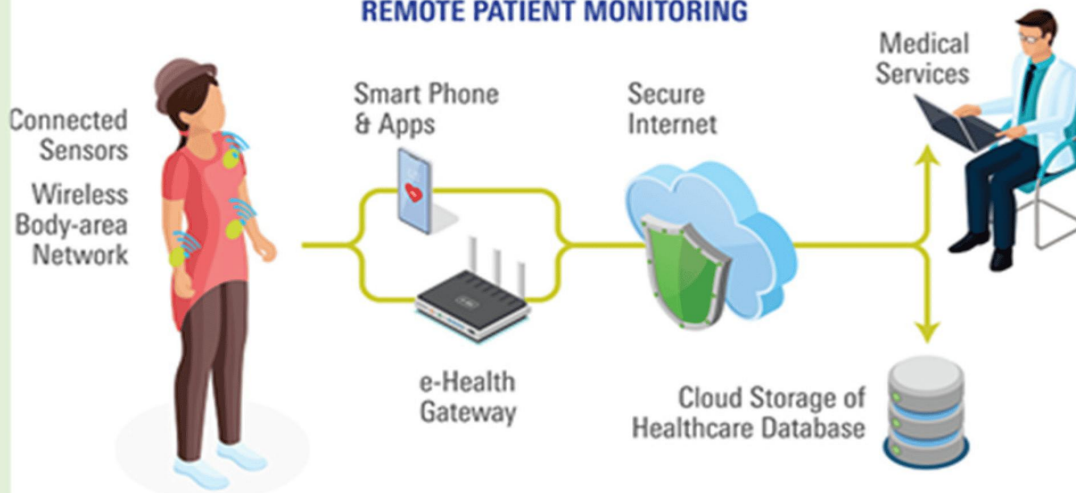# 5G to empower Smart Cities

Role of 5G in Smart Cities


Source:- Science Direct

5G's Role in Healthcare

‣ **Remote Patient Monitoring**: IoT-enabled wearables

‣ **Telemedicine & Surgery**: Real-time virtual consultations and robotic surgeries

‣ **Faster Medical Data Transfer**: Quick access to patient records

‣ Visual: 5G-enabled healthcare systems

5G and Industrial Revolution 4.0

- Automated Manufacturing: AI-powered production lines
- IoT in Supply Chain: Real-time tracking and smart logistic
- Predictive Maintenance: Reduced downtime through data analytics
- **Visual: Smart factories and connected logistics**
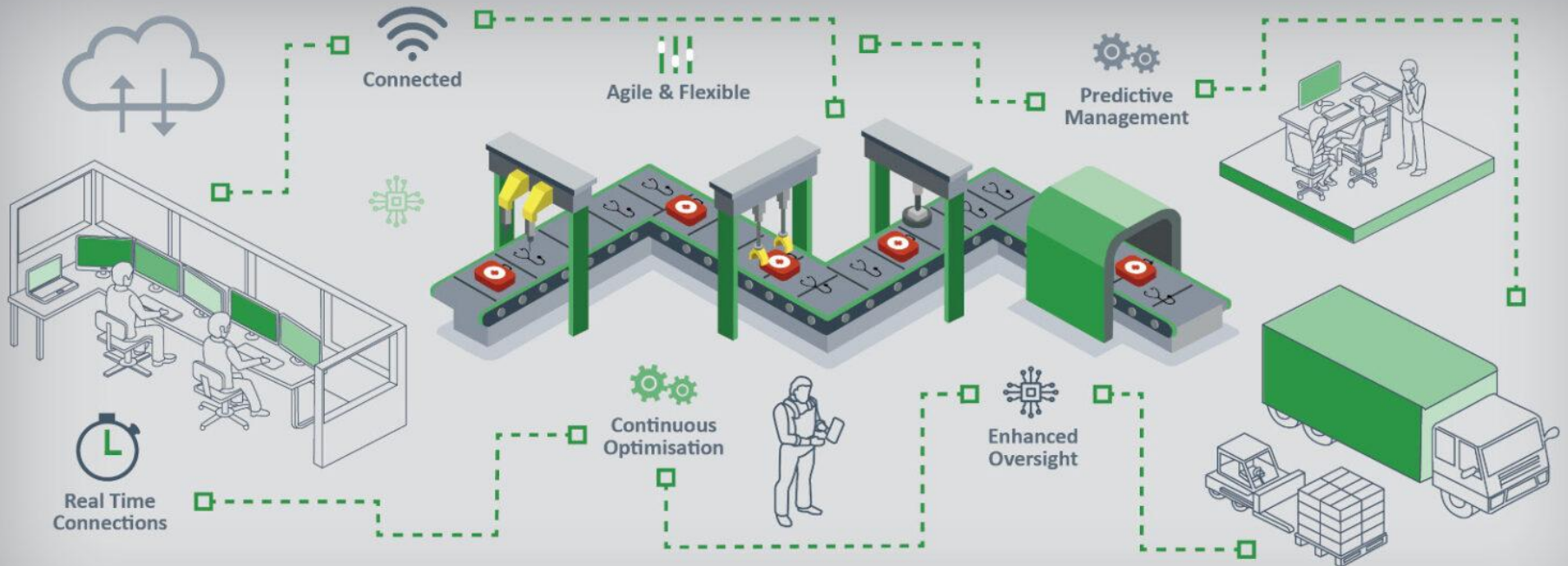
Future Trends of 5G Integration with AI, Blockchain & IoT

▸ 5G + AI (Artificial Intelligence)

Trend: Real-time data analytics, smart automation, intelligent network management

▸ **Examples**: 🚗 Autonomous Vehicles: Instant AI-driven decisions over 5G for safe navigation

📹 Smart Surveillance: Real-time facial recognition in public safety

🏥 Healthcare: Robotic surgeries with zero-latency precision using AI + 5G

5G + IoT (Internet of Things)
Trend: Massive machine-type communication (mMTC) enabling smart environments
Examples:
🏙️Smart Cities: Traffic, waste, pollution managed via 5G IoT sensors

🏭Industrial IoT: Automation using 5G-connected sensors and robots

🌾 Smart Farming: Drones & sensors monitor crops in real time

5G Integration with AI, Blockchain & IoT

▸ 5G + Blockchain

Trend: Decentralized, secure, transparent data exchange for connected systems

▸ **Examples:**

📦 Supply Chain: Real-time goods tracking and verification

Healthcare Data: Secure cross-hospital patient data sharing

🏠**IoT Device Security**: Identity & data integrity using blockchain

5G + AI + IoT + Blockchain

Trend: Intelligent, automated, and secure ecosystems

Examples:

⚡ Smart Energy Grids: AI predicts demand, IoT monitors usage, blockchain secures transactions

🚚 Connected Logistics: Real-time tracking, smart routing, and trusted data sharing

Next Gen Mobile Technology: 6G

▸ 6G technology- expected to become available in 2030- providing truly omnipresent wireless intelligence

▸ Speeds almost 100 times faster than 5G, it will enhance and drive new communication applications and will impact QoS, QoE and transform economies and lives everywhere

▸ Includes intelligent network management and control, integrated wireless sensing and communication

▸ 6G will make it possible to move freely in the cyber-physical continuum (Metaverse), between the connected physical world of senses, actions and experiences, and its programmable digital representation

5G vs 6G Comparison

Feature	5G	6G
Deployment Timeline	Commercial deployment began around 2020	Expected around 2030
Peak Data Rate	Up to 10 Gbps	Targeting 1 Tbps (Terabit per second)
Latency	~ 1 millisecond	Less than 0.1 millisecond
Frequency Band	Sub-6 GHz, mmWave (24-100 GHz)	THz bands (100 GHz to 1 THz)
Device Density	~ 1 million devices/km²	> 10 million devices/km²
Energy Efficiency	High	Ultra-efficient, green communication focus
Coverage	Urban & limited rural	Global: Satellite + rural + remote
Technology Integration	IoT, AI, Edge, Network Slicing	AI-native, Quantum, Tactile Internet, Holographic Comm.
Use Cases	Smart cities, AVs, Industry 4.0	XR, Brain-Computer Interface, Digital Twins, Smart Health
Network Architecture	Cloud-native, service-based	AI-driven, self-optimizing, ultra-flexible

5G Expansion Plans: Global & Indian perspectives

- Key Strategies for Global 5G Rollout
- **Spectrum Allocation**: Govts worldwide are auctioning spectrum in mid-band (3.5 GHz), mmWave (26-28 GHz), and low-band frequencies.
- **Infrastructure Investments**: Heavy investments in fiber optics and small cell deployment to ensure network densification
- **Public-Private Partnerships**: Collaborations between governments, telecom providers, and tech firms to drive 5G penetration
- **Security and Regulation**: Nations are implementing security policies to safeguard networks from cyber threats, particularly concerning Huawei's role in global 5G deployment

Indian 5G Expansion Plans

▸ India launched 5G services in October 2022, with Reliance Jio, Bharti Airtel, and Vodafone Idea leading the deployment

▸ By mid-2024, more than 3,00,000 5G base stations have been installed across major metropolitan cities and semi-urban areas

▸ **Current Status of 5G in India**: As on 28 Feb 2025, 4.69 lakhs 5G Base Transceiver Stations (BTSs) have been installed by the Telecom Service Providers (TSPs) across the country which is one of the fastest rollout of 5G network
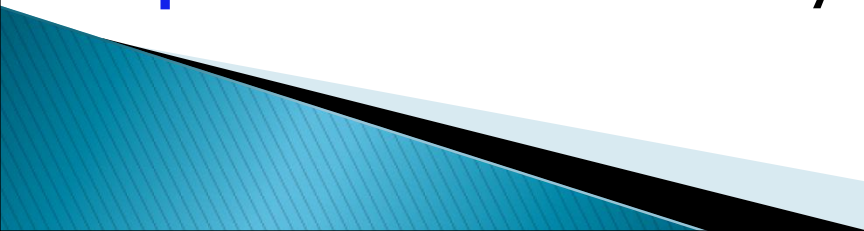
Government Policies & Spectrum Auctions

- The Department of Telecommunications (DoT) has allocated spectrum in 700 MHz, 3.3-3.67 GHz (mid-band), and 26 GHz (mmWave) bands

- The Telecom Regulatory Authority of India (TRAI) is ensuring competitive pricing and policy frameworks for efficient 5G rollout

- The Production Linked Incentive (PLI) Scheme encourages local manufacturing of 5G equipment

Key Players in India's 5G Expansion

- **Reliance Jio**: Developing an indigenous 5G stack, rolling out standalone 5G services

- **Bharti Airtel**: Partnering with Ericsson, Nokia, and Qualcomm for rapid network expansion

- **Vodafone Idea**: Struggling with financial challenges but seeking strategic investments for 5G

- **BSNL:** Expected to roll out 5G services by 2025 using indigenous technology.

Challenges in India's 5G Expansion

- **High Capital Costs**: Infrastructure development requires significant investments

- **Limited Fiberization**: <35% of telecom towers are fiber-connected, affecting backhaul capacity

- **Rural Connectivity Gaps**: Bridging the urban-rural digital divide remains a challenge

- **Regulatory and Spectrum Pricing Issues**: High spectrum costs may slow expansion efforts

Network Slicing

Network slicing is a technology primarily used in 5G networks that allows operators to create multiple virtual networks (or "slices") on a single physical infrastructure. Each network slice can be customized and optimized to serve specific use cases, offering different levels of performance, security, and functionality.
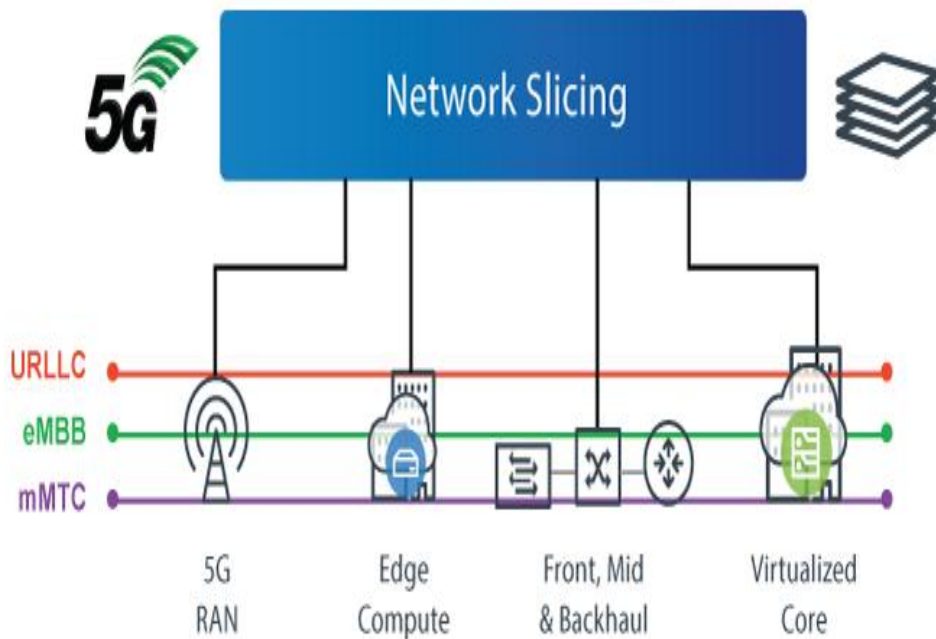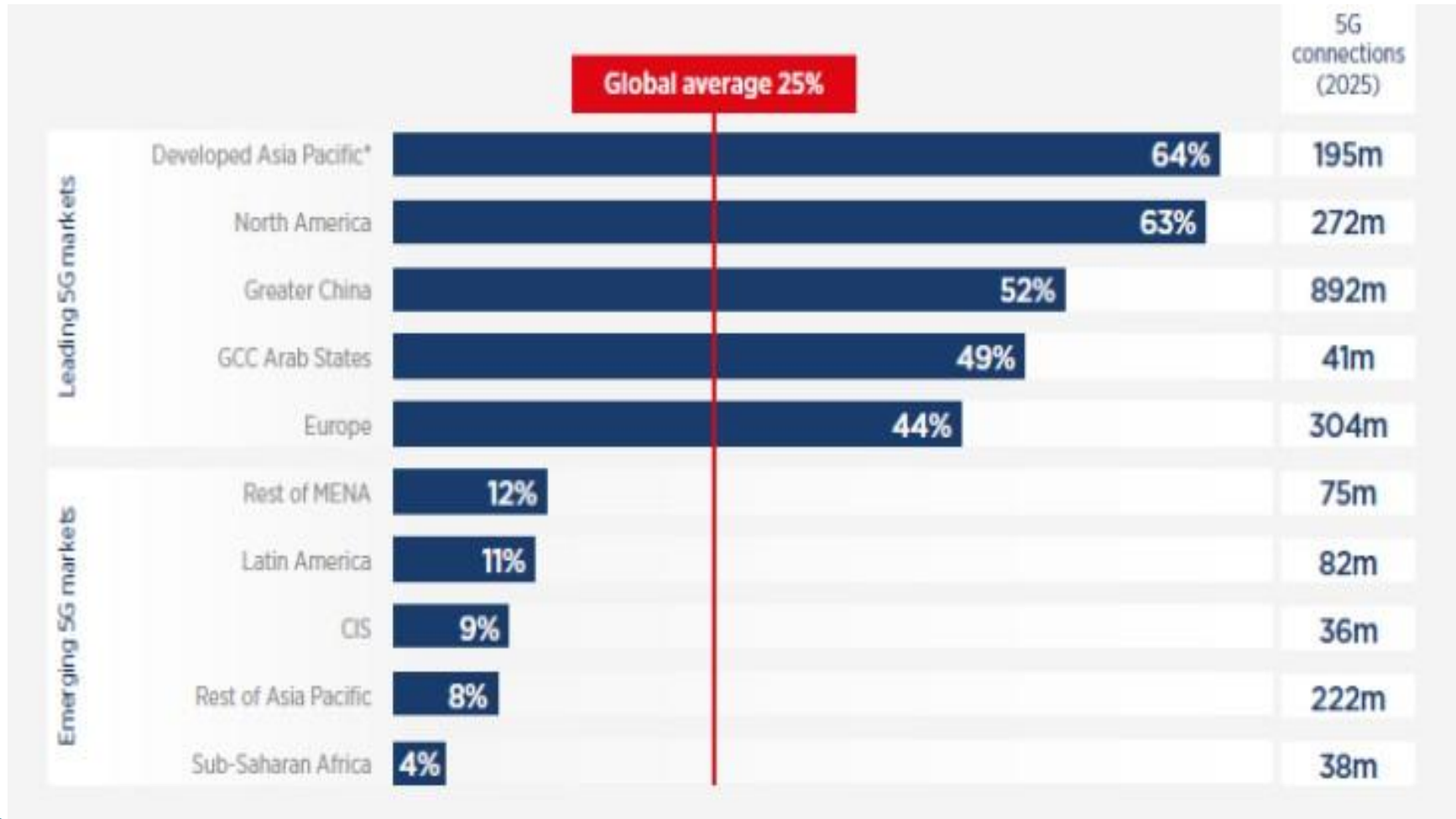
- **Enhanced Mobile Broadband (eMBB)** use cases which are high-bandwidth, video-centric, and generate the most traffic on a mobile network
- **Internet of Things (IoT)** use cases, supported by massive Machine Type Communication (**mMTC**), connecting billions of devices to the network
- **Ultra-reliable Low-Latency Communications (urLLC)** use cases that address activities like remote surgery or vehicle-to-X (v2x) communication, which require edge computing to reduce latency
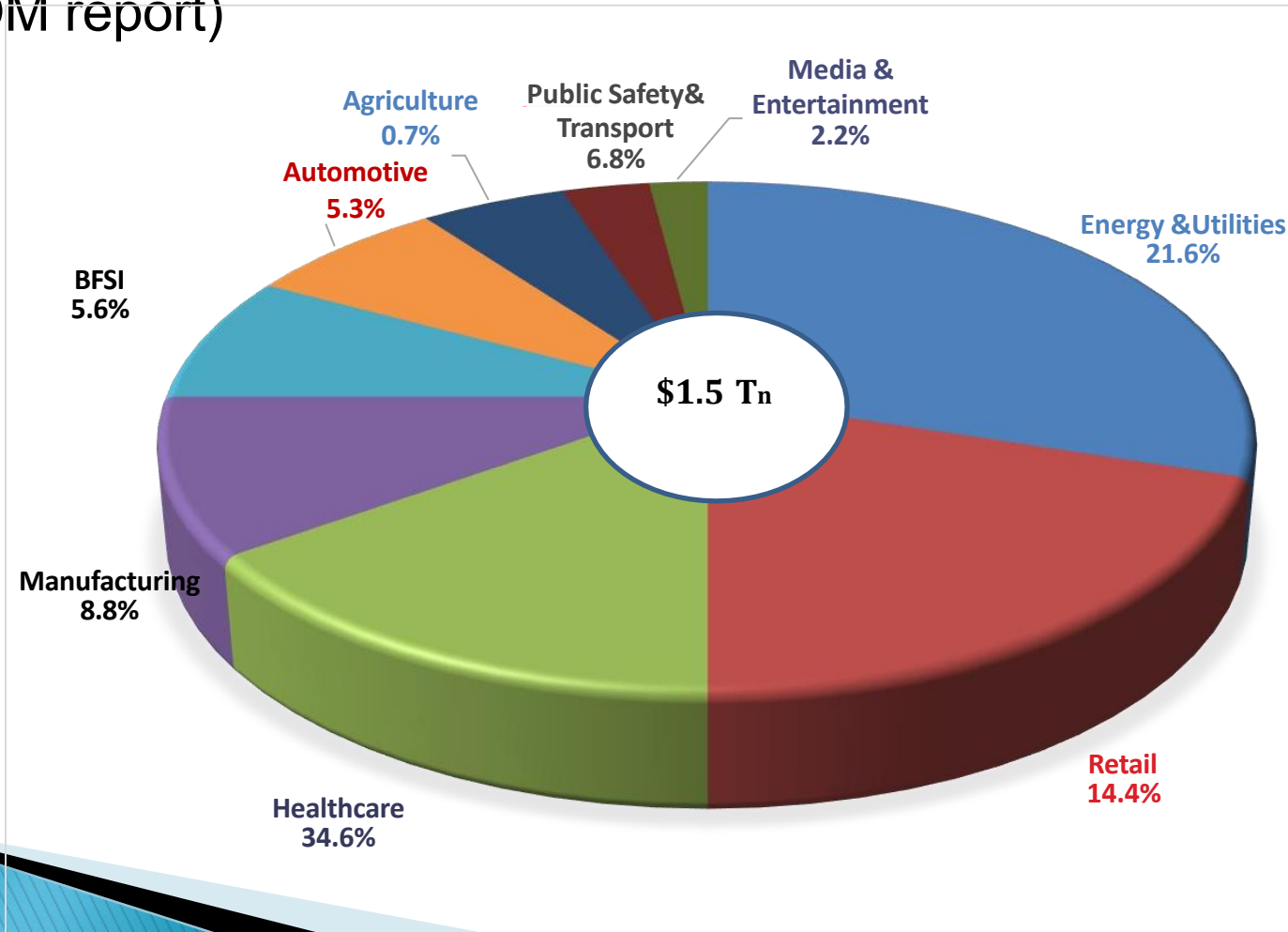
Global Connections (A GSMA intelligence report predicts that global 5G connections will cross 2 bn mark by the end of 2025)

	5G connections (2025)
Global average 25%	
Leading 5G markets	
Developed Asia Pacific* — 64%	195m
North America — 63%	272m
Greater China — 52%	892m
GCC Arab States — 49%	41m
Europe — 44%	304m
Emerging 5G markets	
Rest of MENA — 12%	75m
Latin America — 11%	82m
CIS — 9%	36m
Rest of Asia Pacific — 8%	222m
Sub-Saharan Africa — 4%	38m

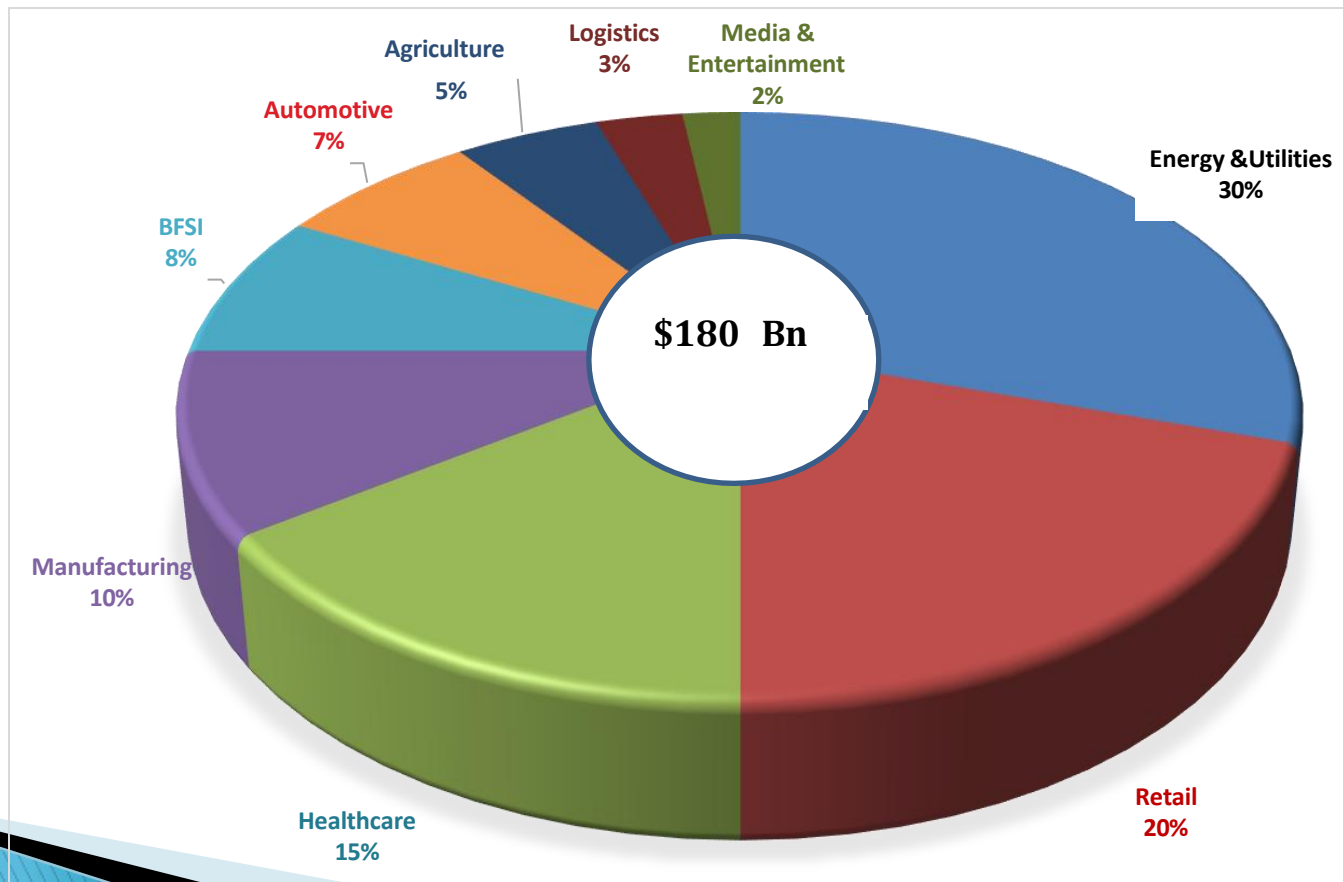# Impact of 5G & associated technologies on Global Economy

To benefit the global economy by more than $1.5 trillion in 2030--
Annual global 5G contribution by industry, 2030 (source: NASSCOM report)

Pie chart: Annual global 5G contribution by industry, 2030 — $1.5 Tn

- Media & Entertainment 2.2%
- Public Safety & Transport 6.8%
- Agriculture 0.7%
- Automotive 5.3%
- BFSI 5.6%
- Manufacturing 8.8%
- Healthcare 34.6%
- Retail 14.4%
- Energy & Utilities 21.6%

Impact of 5G & associated technologies on Indian Economy

5G is expected to power up to 2% of India's GDP, i.e., USD180 bn by 2030- increased market penetration, strengthening economy through Sectors: healthcare, energy & utilities, manufacturing, and retail to benefit the most from large-scale 5G adoption--   5G Contribution for select Industries in India 2030

Pie chart: 5G Contribution for select Industries in India 2030 — $180 Bn
- Energy & Utilities 30%
- Retail 20%
- Healthcare 15%
- Manufacturing 10%
- BFSI 8%
- Automotive 7%
- Agriculture 5%
- Logistics 3%
- Media & Entertainment 2%

5G deployment

▸ **The 5G standards describe a number of implementation models:** There are plans to deploy at least 5 additional options in future, the only option currently being deployed is Non Stand Alone (NSA) mode*

▸ **This is where** 5G base stations are integrated with an existing 4G network working in tandem with LTE base stations and connected to the LTE Core, relying on the measures and protections that the LTE core provides

▸ The Second phase of 5G deployment: Stand Alone (SA) mode*, more precisely SA-NR, consisting of 5G new radio network (NR) connected to a 5G core network (5GC)

5G Deployment in India

- 5G first launched 01-10-2022. At present, only Bharti Airtel and Reliance Jio, Vi are offering 5G services in the country

- Indian Telephone Operators have surpassed the **3 year 5G network rollout target** given to them **within 6 months.** Set up more than 3.25 lakh sites by end of 2023 covering majority of the towns

- Rising disposable income coupled with **affordable data tariffs** are kept encouraging the people to go digital

- **Growing smartphone penetration**, steep rise in OTT consumption, digital payments, E-commerce are some of the **major factors** driving this digitization

5G deployment in India (2/2)

- **India** has developed its **indigenous 4G/5G technology stack**: Poised to **emerge as a significant telecom technology exporter to the world** in the coming years

- **India held discussions with 18 countries that are planning to implement India's indigenously developed 4G/5G technology stack**

- 5G based Private Networks are also started being deployed in India

- **Bharti Airtel** deployed **Captive Private Network** at Mahindra's Chakan Auto manufacturing facility at PUNE in partnership with Tech-Mahindra

Metaverse

- The metaverse is the key to the next wave of digital transformation. Web3 and Metaverse will play an important role in building the **next version of the Internet** and leading the **next wave of digital adoption for Indian industries**

- Creates an **immersive space** for interactions that are enabled by a range of technologies—including, but not limited to augmented reality (AR), virtual reality (VR), extended reality (XR), artificial intelligence (AI), internet of things, and digital twins

- 5G Ecosystem– a necessity for Metaverse, Block Chain, AI & ML, Cloud/ edge Computing –has the potential of creating a simulated real- life environment where people can talk, work, and play using specialized glasses, headsets, controllers, etc.,

Associated Emerging Technologies shaping the Digital Economy

To realise economic benefits of the use cases NOT possible with 5G ALONE. With so much hype of 5G, to fully understand the strength of the 5G, we need to understand the associated technologies:

Edge computing

Cellular wireless connectivity

5G

Internet of Things

IoT

Artificial intelligence

Augmented/ Virtual reality
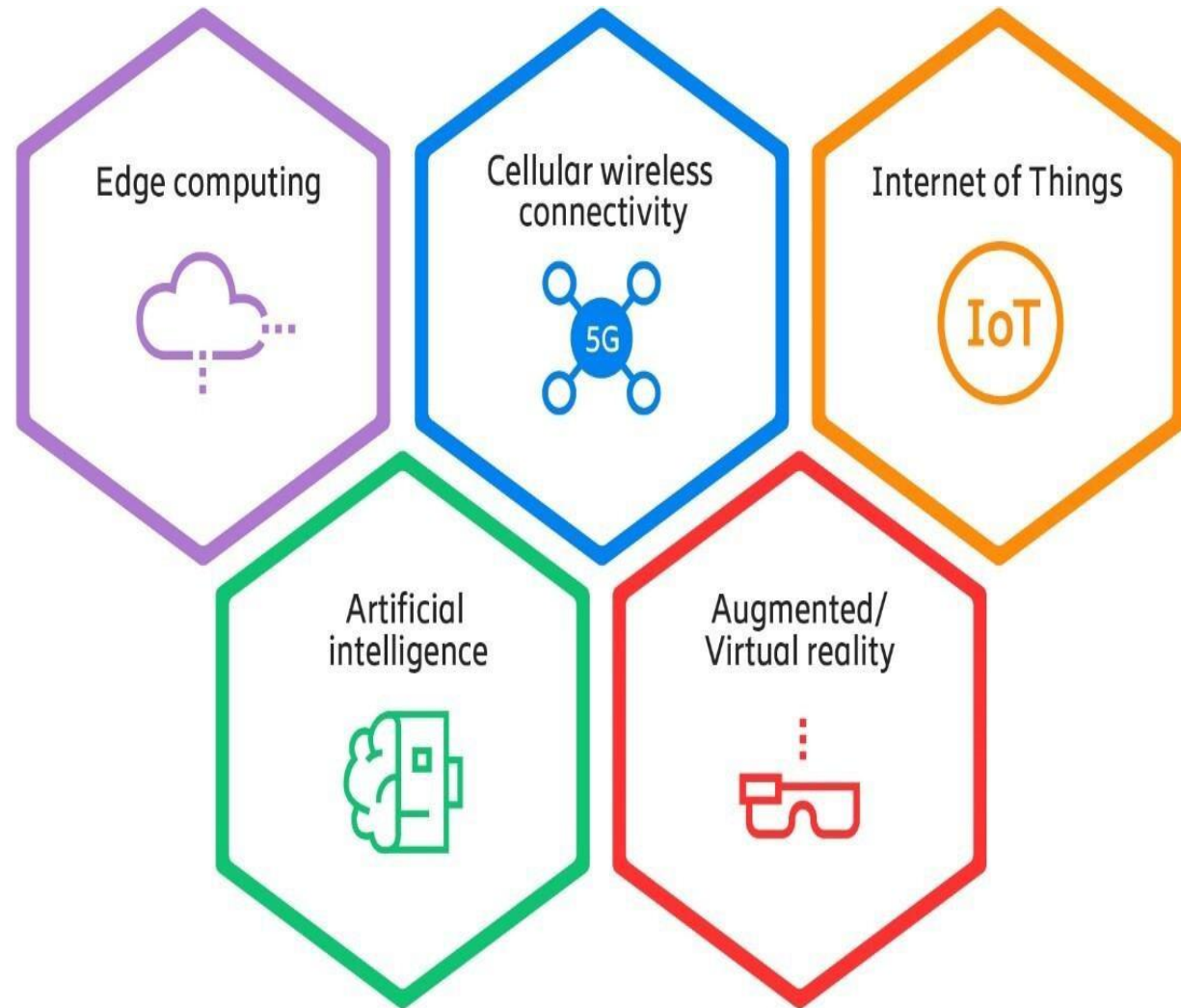
Metaverse

Mixed Reality (MR) is a blend of real world with virtual reality. The experiences that can transition between AR and VR form mixed reality, where the user may be personally and digitally present in the physical world, in the form of an avatar, to asynchronously collaborate with others at different points in time
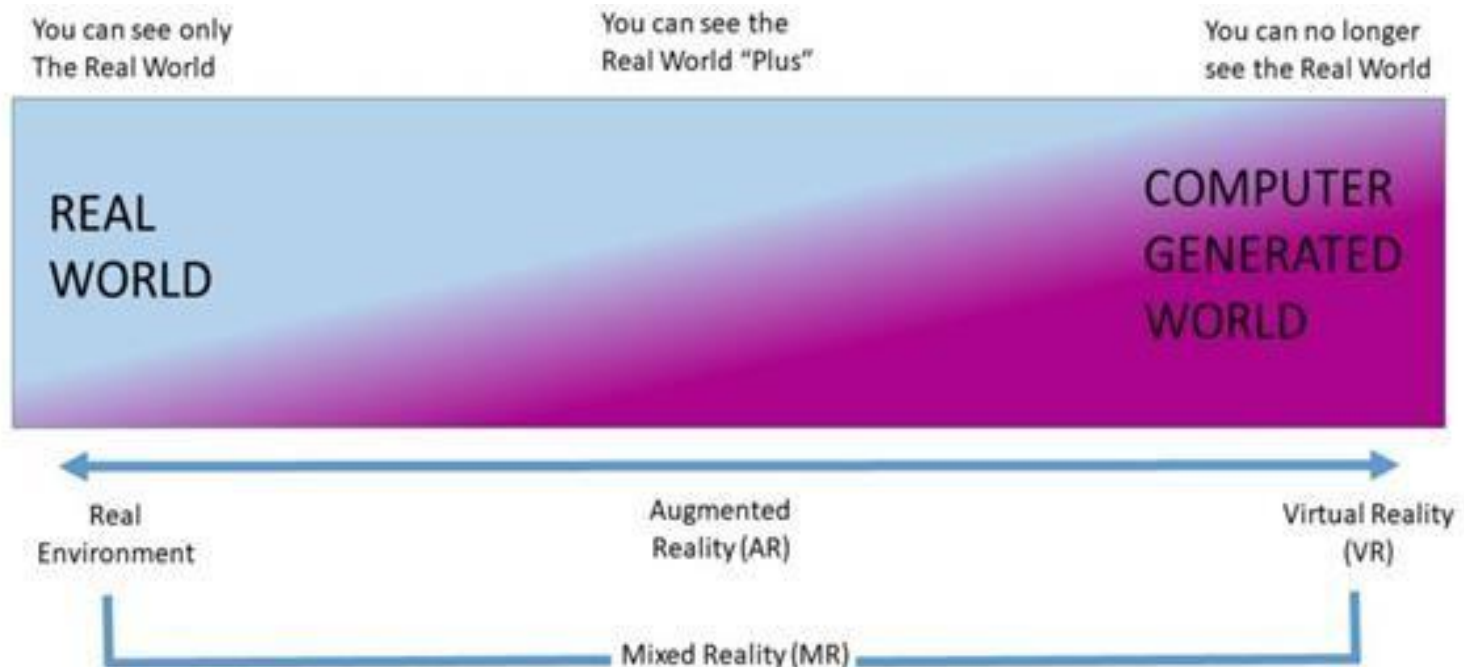
Digitization, Monetization & Sharing of Data

▸ India's ambitions of becoming a $5 trillion-dollar digital economy depends on its ability to harness the value of data. The process of extracting economic value out of data and information is referred to as Data Monetization

▸ **The Indian data monetization market is expected to grow at a CAGR of 7.02% over the forecast period of 2019-2024 (source: Polaris market research)**

Predictions for 2025-26

- **Metaverse** Will Shape the Future of Work
- **Quantum Computing** Will Transform Computing Power
- **Internet of Behavior** Will Connect Data and Human Behavior
- **AI and ML** Will Improve Automation and Personalization
- **Human-machine** interaction Will Redefine Our Relationship with Technology

‣ **Widespread 5G Rollout**:

By end of 2025, 5G is expected to be largely rolled out, with a significant portion of urban areas having access to ultra-fast mobile internet speeds, low latency, and the ability to connect billions of devices simultaneously

‣ **Growth in 5G Connections:**

Predictions indicate a substantial increase in 5G connections, potentially doubling over the next two years, reaching a figure of 2 billion by 2025

‣ **New 5G-Enabled Applications:**

2025 will see the emergence of transformative 5G-enabled use cases, including network slicing, 5G network APIs, and private 5G networks, which will enhance customer experiences and drive innovation

Private 5G Networks: Private 5G networks will continue to grow, particularly in manufacturing and logistics industries

E-SIM Adoption: is expected to increase, playing a crucial role in bolstering connectivity to high-speed networks, particularly as 5G expands worldwide
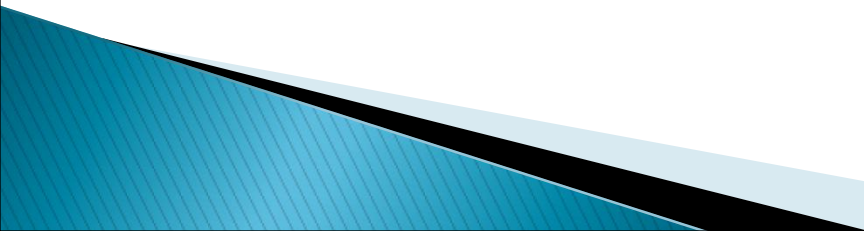
AI and 5G Convergence: will drive new use cases, such as real-time edge computing in autonomous vehicles and predictive IoT solutions for industries like agriculture and healthcare

Rural Connectivity: Significant investments in rural wireless infrastructure will expand connectivity to underserved areas, further enabling AI applications

Monetization Strategies:Telcos will focus on developing innovative business models and commercial propositions that link 5G with **digital services to effectively monetize 5G investments**

Conclusion

- 5G technology is a cornerstone for advancing sustainable production processes by enabling smarter, more connected, and resource-efficient operations

- By facilitating real-time decision-making, advanced automation, and efficient energy use, it drives industries toward achieving sustainability goals

- As businesses and governments prioritize environmental responsibility, the widespread adoption of 5G will play a critical role in creating a greener and more resilient industrial future

- When 5G is used along with AI, XR, and IoT, it will enable business and society to realise the full benefits of these other technological advances