

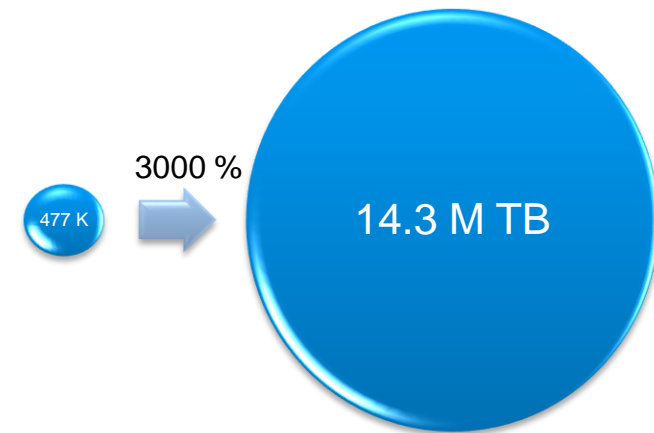
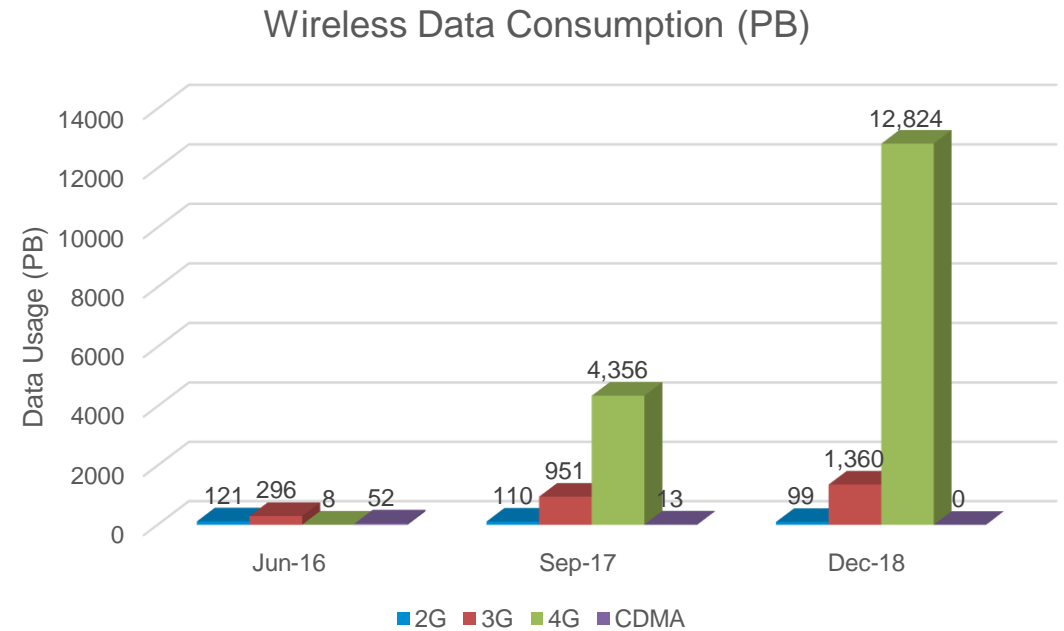
5G – A Key Business enabler

Not just a new Radio Access Technology

PK Bhatnagar | 27-06-2019



- India was ranked 155th in the world for Mobile Broadband in 2016 with the total data consumption at 477 K Terabytes in the Quarter ending June 2016.
- By Sep 2017, India climbed to first rank in the world with Indians consuming more mobile broadband data than users in US and China – with the total data consumption rising to 5,430 K Terabytes.
- **By Dec 2018, India is consuming 14.3 Million Terabytes**
- High Definition voice on cellular network was never experienced at such an unprecedented scale. India led the world in HD quality voice with VoLTE adoption at a scale never seen before anywhere in the world.



- In 2035 5G will enable **\$12.3 trillion of global economic output**. That is nearly equal to US consumer spending in 2016 and more than the combined spending by consumers in China, Japan, Germany, the United Kingdom, and France in 2016.
- The Global 5G value chain will generate **\$3.5 trillion in output** and support **22 million jobs** in 2035. This figure is larger than the value of today's entire mobile value chain. It is approximately the combined revenue of the top 13 companies on the 2016 Fortune Global 1000 - a list that includes Walmart, State grid, China National petroleum, Royal Dutch Shell, Exxonmobil, Volkswagen, Toyota, Apple, Berkshire Hathaway and Samsung.
- The 5G value chain will invest an average of **\$200 billion annually** to continually expand and strengthen the 5G technology base within network and business application infrastructure; This figure represents nearly half of total US federal, state, and local government spending on the transportation infrastructure in 2014.
- Moreover 5G deployment will fuel sustainable long term growth to global real GDP. From 2022 to 2035, **the total contribution of 5G to real global GDP will be equivalent to an economy the size of India** - currently the seventh largest economy in the world.

*IHS-Markit report on 'How 5G Technology will contribute to the global economy'

- **Global mobile data traffic will increase seven-fold between 2017 and 2022.** Mobile data traffic will grow at a Compound Annual Growth Rate (CAGR) of 46 percent from 2017 to 2022, reaching 77.5 Exabytes per month by 2022. How much is a Exabyte – A Million Terrabyte (10^{18} bytes).
- **By 2022 there will be 1.5 mobile devices per capita.** There will be 12.3 billion mobile-connected devices by 2022, including M2M modules - exceeding the world's projected population at that time (8 billion) by one and a half times.
- **Mobile network connection speeds will increase more than three-fold by 2022.** The average mobile network connection speed (8.7 Mbps in 2017) will reach 28.5 Megabits per second (Mbps) by 2022.
- **Nearly four-fifths of the world's mobile data traffic will be video by 2022.** Mobile video will increase 9-fold between 2017 and 2022, accounting for 79 percent of total mobile data traffic by the end of the forecast period.
- **By 2022, mobile-connected tablets and PCs will generate 6.8 GB of traffic per month on average, a doubling over the 2017 average of 3.3 GB per month.** Aggregate traffic associated with PCs and tablets will be three and a half times greater than it is today, with a CAGR of 28 percent.
- **The average smartphone will generate 11 GB of traffic per month by 2022, more than a four and a half-fold increase over the 2017 average of 2 GB per month.** By 2022, aggregate smartphone traffic will be seven times greater than it is today, with a CAGR of 48 percent.

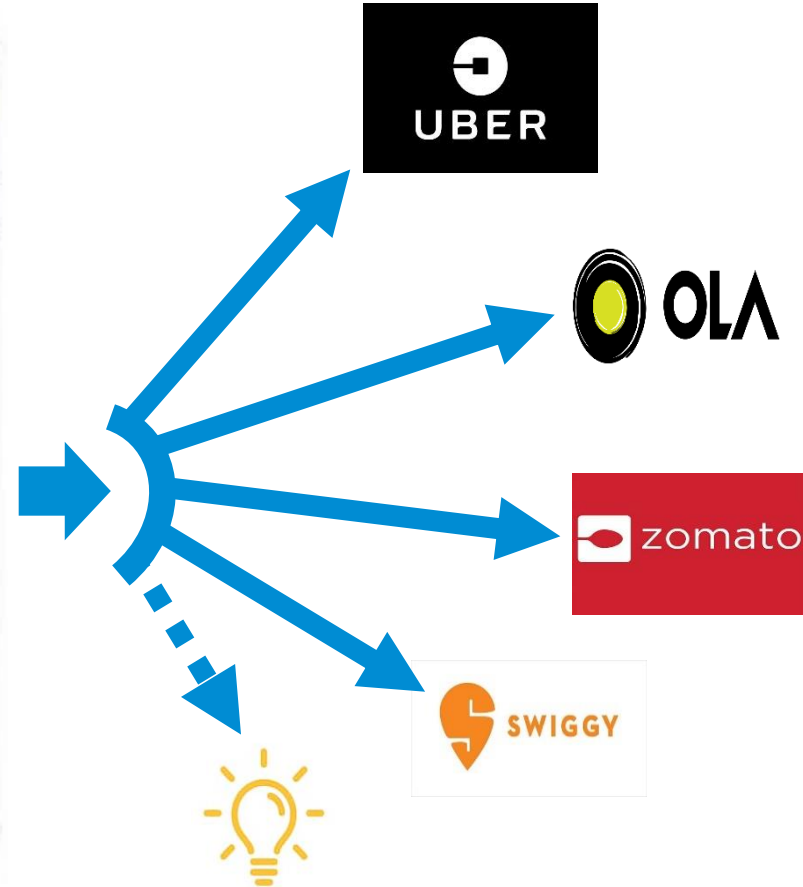
*Snippets from Cisco Visual Networking Index (VNI) Report

5G enhanced Mobile Broadband (eMBB) is a must to create sufficient capacities that can deliver video streaming bit rates to large number of mobile phones and other wireless devices

Transformative impact potential of technologies

Wireless Mobile technology has transformed the way we live and work, providing unprecedented access and opening-up a world of conveniences to customers and unlimited opportunities for entrepreneurs.

Location determination – one sub-technology on Smartphones has catalyzed disruptive innovation in multiple fields – from travel to food industry to hyperlocal content delivery and many more resulting in creation of new Services and Business opportunities.



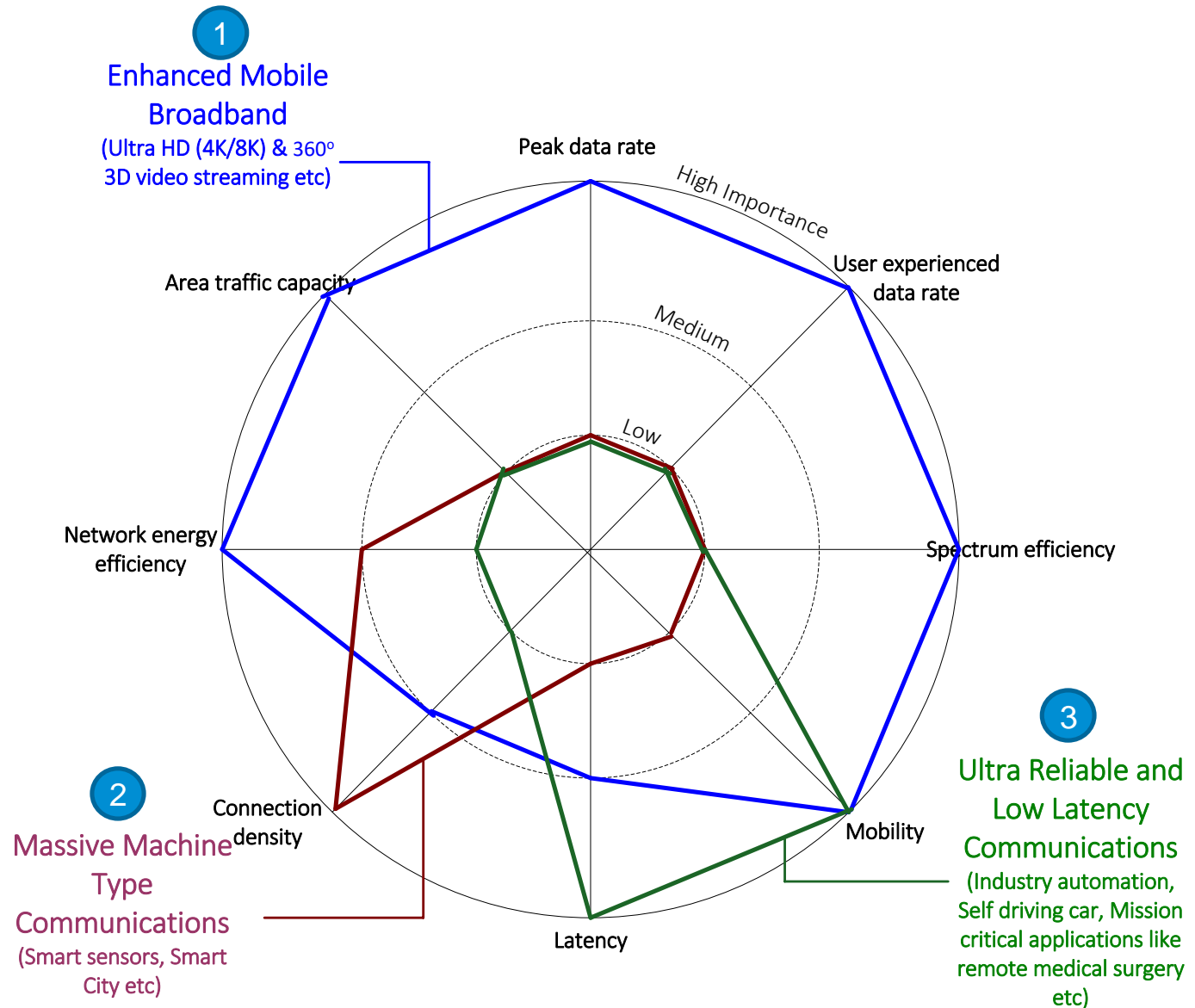
5G will be the enabler of many such new services and not only a new Radio Access Technology. While unrivalled data speeds and low latency are at the core of 5G, the transformative impact on consumers and Businesses will be way beyond these two USPs.

With connectivity at the heart of India's Digital transformation, 5G will be an innovation engine bringing disruptive changes spanning across businesses and society as a whole. The introduction of 5G will create enhanced services with new use cases, new revenue streams and new business models for operators and consumers.

Therefore the primary design objective of 5G is to create high capacity networks that can scale to the extreme requirements of data rate, mobility, latency, reliability and connection density which cannot be fulfilled with the 4G networks.

Prospective use cases - based on the requirements they put on the key performance attributes like data rate, connection density, latency, mobility and energy efficiency etc. can be broadly classified as:

- Enhanced Mobile Broadband (eMBB)
- Ultra-reliable and Low-latency Communications (uRLLC)
- Massive Machine Type Communications (mMTC)





Societal innovations

- 5G will enable enhancements in existing social applications such as real-time multi-player gaming, multi-person video conferencing, connected cars etc.
- Drive industries of the future such as autonomous cars, innovative e-health care services particularly in remote areas and the next generation of industrial automation. Flexible integration of between cellular and Wi-Fi will enable seamless mobility



Hyper Connectivity

- Designed for connecting everything – humans to machines and machines to machines
- Will empower citizens to have better control of their productivity (agriculture, industries), health (wearables), safety and security (wearables and Home IoT), convenience and comfort (Home IoT), travel (Vehicular IoT) and many more.



Higher Demand

- 5G will enable new services like Augmented Reality and Virtual Reality not only for entertainment but also for education, medicine, product design and industrial applications.
- It will enable higher throughputs and more connections with higher bandwidths

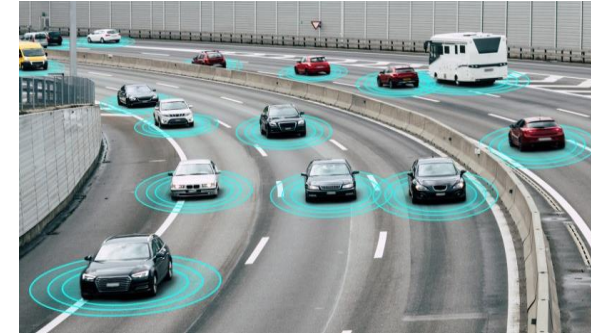
5G – Will Revolutionize many industries



Media & Entertainment



Healthcare



Transportation



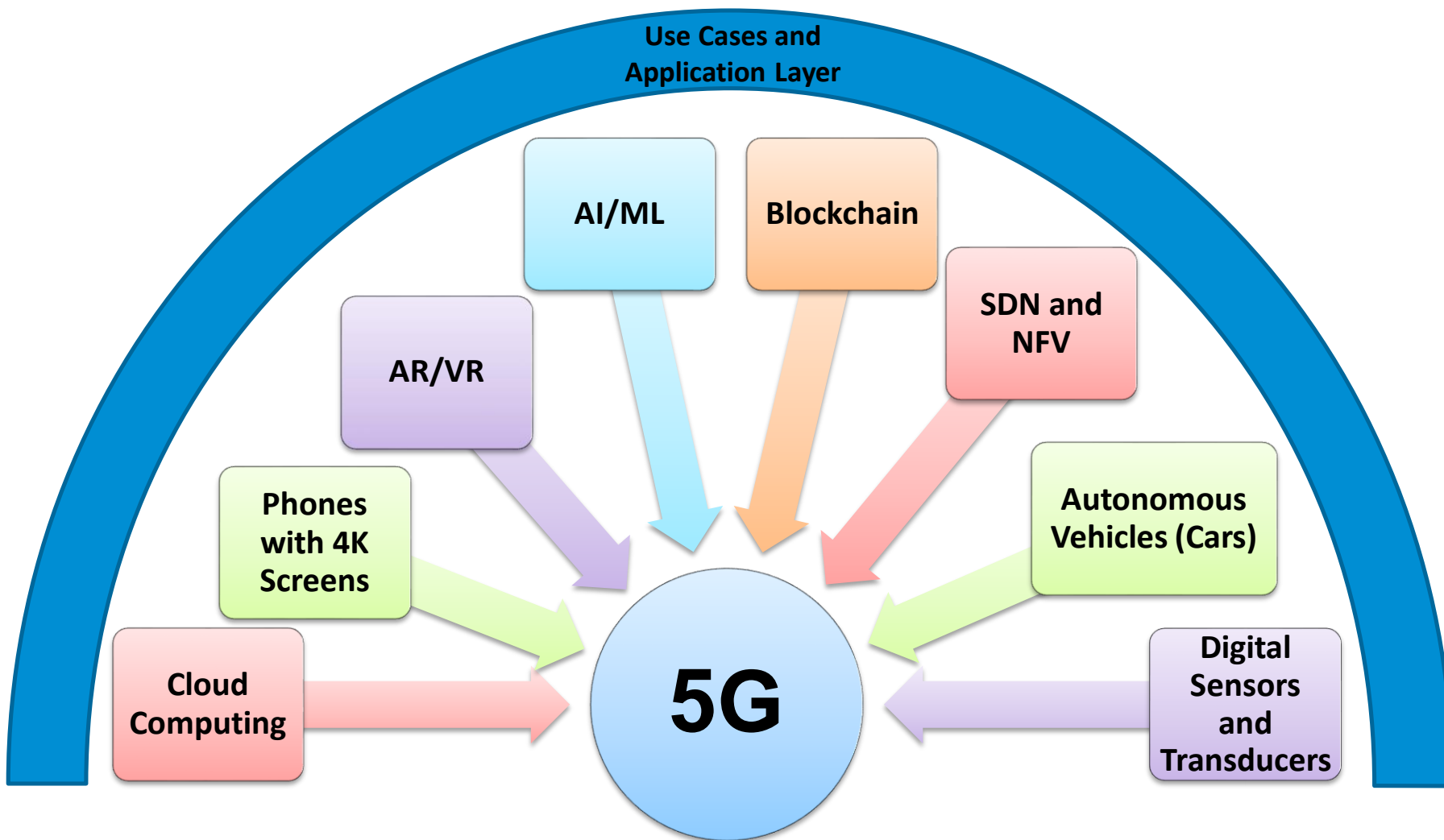
Public Safety



Agriculture



Manufacturing



Example 1

5G Massive IoT enables Digital Sensors to communicate with each other and also send data to cloud.

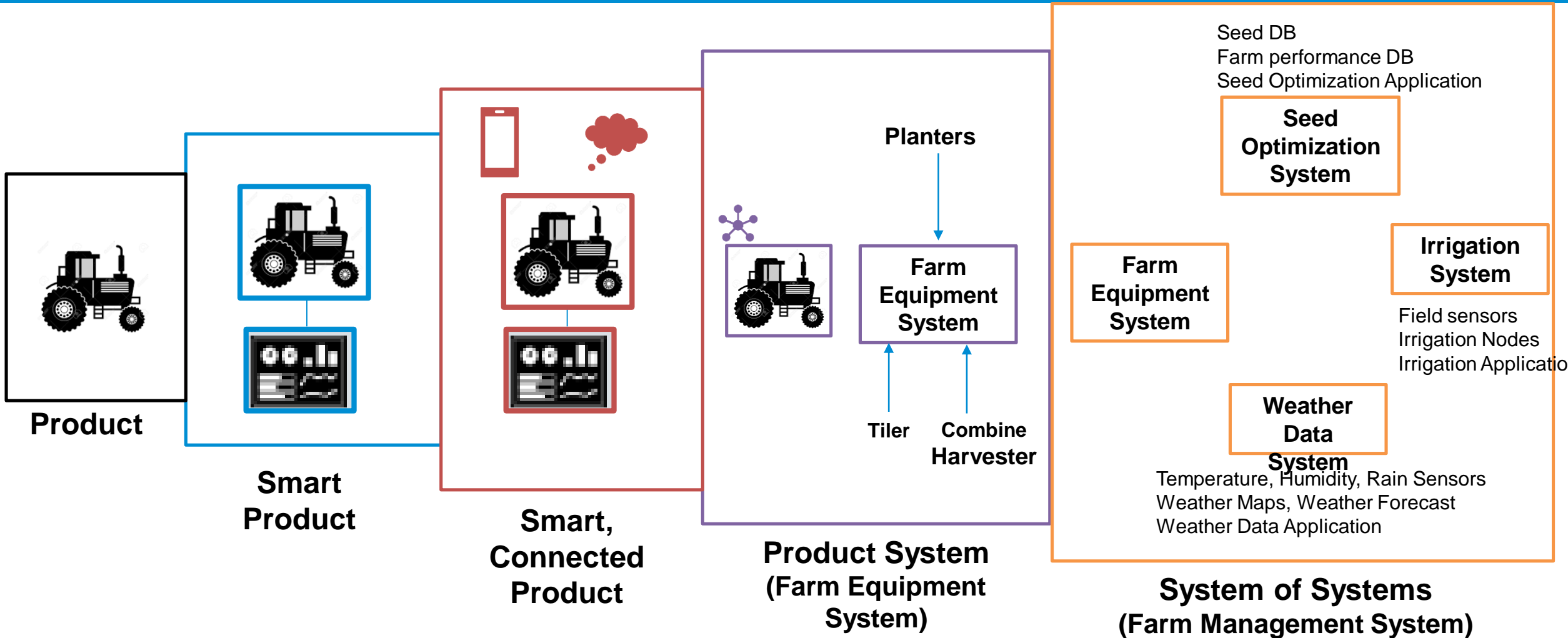
AI / ML is used to derive insights from Sensor Data

Industrial and Smart City use cases can be created using this gamut of 5G Massive IoT, Sensors, Cloud and AI/ML technologies

Example 2:

Using **5G mmWave FWA and Mobile Broadbands** makes **AR/VR** content stored on **Cloud** can be accessed at home for Entertainment and Learning

5G can be imagined as a “**Binding Agent**” which brings together various contemporary technologies to make a variety of next generation use cases and applications possible



5G while enabling connectivity, will drive the digital transformation journey of products for integration and enablement of complete ecosystem – System of systems

A model by M. Porter and J Heppelmann, "How Small, Connected Products are Transforming Competition," Harvard Business Review, November 2014, p. 5

- With introduction of newer generation of cellular technology, there has been a tendency to “Hunt” for a “Killer Application” that will drive its market adoption.
- This “hunt” happened during early days of 3G and 4G and the same is happening now for 5G also.
- However, if we look back at the success of 4G in India, we find that adoption happened at such rapid pace without any specific “Killer Application”.
- Prior to 4G: The Internet existed but was not accessible to masses due to lack of broadband speed and lack of “Affordable Smart phones”
- Jio 4G brought along with it Broadband Speeds at Affordable Data Rates.
 - This in turn fueled the demand for Affordable Smart Phones
 - With more Affordable Smart Phones, the consumption of 4G data increased
 - This resulted into a Domino Effect – both Smart Phones and 4G Data grew at rapid pace
 - » Together Smart Phones and 4G provided a “boost” to the “On-line Market Place” and creation of “Innovative Services” that are only possible when

- Search for a Killer Application is not necessary on the road to 5G.
- Availability of 5G along with its Allied Technologies will fuel growth of new services and applications through enablers like “smart phone”.
- IoT Sensors and Applications can be a potential Enabler for adoption and growth of 5G

Enabling Always Connected World with Internet of Everything (mMTC)

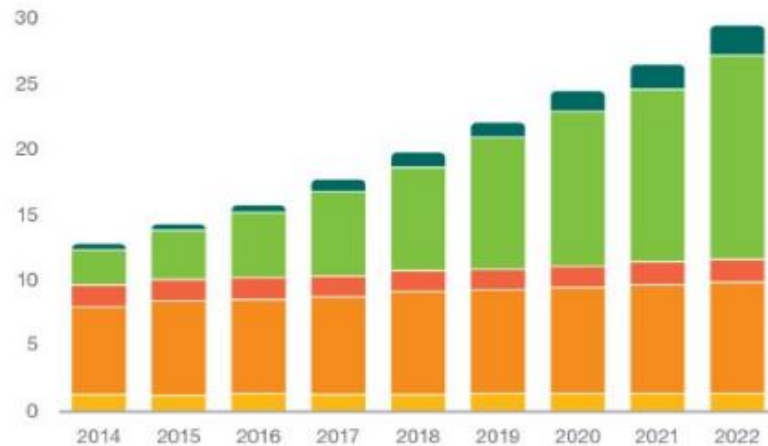


Rapid growth of IoT and the number of connected devices is driven by emerging applications and business models. Standardization has catalyzed falling device costs, further accelerating new use-cases characterized by high connection volumes and small data traffic volumes, low cost devices and low energy consumption. These use-cases will span across Smart Homes, Cities and Farming among others.

The number of internet connected devices is expected to reach more than **27.1 billion** on **service provider networks** by **2021-22**. This is **3x the global population** by 2020. [Cisco VNI Report]

Cellular IoT connections benefit from ease of installation and provisioning, device management, service enablement and security. **1.5 billion IoT devices** will be based on **cellular connections** by **2022**, out of the 2.1 Billion devices on Wide-Area IoT networks. [Ericsson Research]

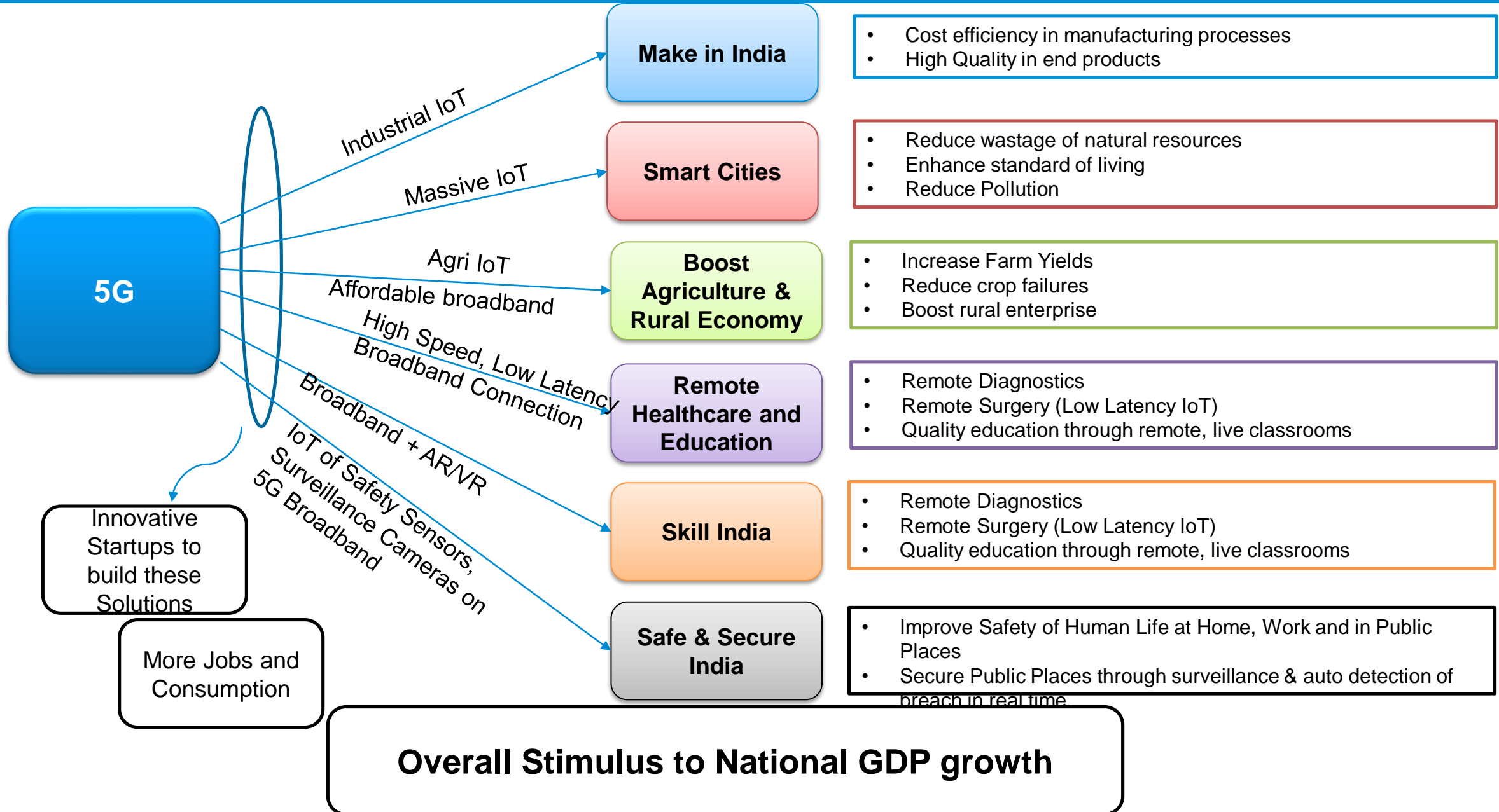
Connected devices (billions)



	2016	2022	CAGR
Wide-area IoT	0.4	2.1	30%
Short-range IoT	5.2	16	20%
PC/laptop/tablet	1.6	1.7	0%
Mobile phones	7.3	8.6	3%
Fixed phones	1.4	1.3	0%
	16 billion	29 billion	10%

*Ericsson Report

5G Massive Machine Type Communication – mMTC is a must to cater to the growing demand of Sensor based IoT Applications for Smart Homes, Smart Cities and Villages and Smart Farms



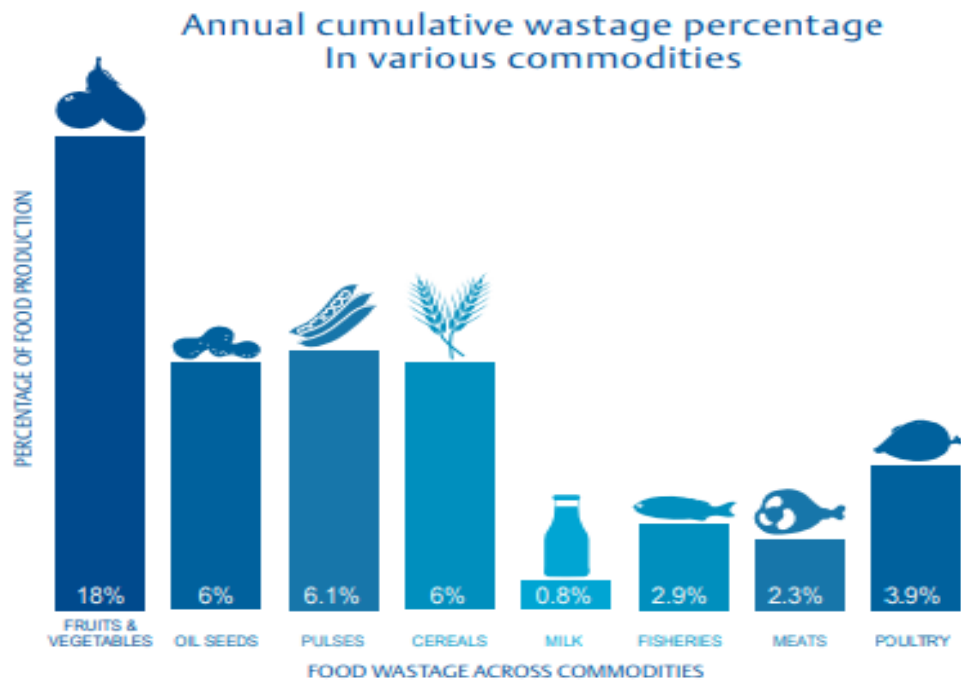
- Agriculture provides livelihood to half of India's workforce yet its contribution to nation GDP stands at only 16%. [Indian Economic Survey 2017-18]
- Indian agricultural industry is mired by use of primitive agricultural practices thereby generating meagre per hectare revenue.
- Farmer suicide incidents are on a rise due to increasing debts and deteriorating yield.
- Massive IoT based **Smart Agriculture** can be the **next Green Revolution** for Indian agricultural sector.
- Field sensor network can provide soil health report card based soil moisture content, soil pH value, soil temperature, etc., which will increase yield.
- Local weather forecasts along with field health information can be pushed using SMS based notification to farmers from the integrated Massive IoT platform.



mMTC use cases for India (2/4) – Smart Food Storage Management



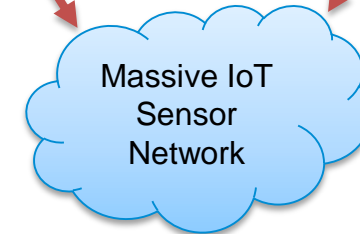
- As per “Vision 2050 Report by Central Institute of Post-Harvest Engineering & Technology (CIPHET), 2013”, India wastes food worth Rs. 44 billion every year with lack of proper storage infrastructure being one of the main reasons.



Source : Central Institute of Post Harvest Engineering and Technology (CIPHET), Ludhiana



Vegetable Cold Storage









Food Grains Storage



Cold Storage for fruits

- Massive IoT sensor network can be used to detect rotting of the food produce at an early stage to raise alarms and prevent wastage. It can also help keeping track of available storage capacity to accommodate further produce.

Massive IoT can transform the education sector as we know it today - by using technology to give customized and interactive learning experience to the students.

-  Enhanced Student Engagement
-  Interactive Learning
-  Mobile Assisted Learning
-  Personalized Education
-  Learning Anywhere
-  Safer Learning Environment

Massive IoT Powered Smart Education

- Interactive Whiteboards
- Personalized Coursework
- Attendance Tracker
- Automatic Light and Air Control
- Automatic Door Locks

- Massive IoT can have major applications in Public Safety domain.
- Smart wearable integrated with sensors in form of lockets, wristbands etc., can report victim's location for prompt action.
- Open manhole detection is another example where Massive IoT can be used to avert any mishaps risking lives.
- Many manhole covers remain in opened condition either by maintenance staff or miscreants. This creates potential life-threatening situation for people walking/driving through the lanes.
- Situation becomes more grim during monsoon when visibility of manholes gets blocked due to water logging.
- Massive IoT based public safety solution can be the best and economical solution for the government to provide safety to the public.
- Field sensor network can monitor, detect and report any abnormal incidents including dislocation, cover theft and missing manhole covers for timely action.



Smart Wearable with Threat Detection Sensors



Manhole Sensor

- The third important category - URLLC also referred to as “mission-critical” communications has stringent requirements for capabilities such as throughput, latency and availability.
- Some examples include **vehicle-to-vehicle communication, autonomous vehicles, remote medical surgery, smart grid**, transportation safety, wireless control of industrial manufacturing or production processes.
- The two key requirements for this are low latency (< **1ms**) and high reliability (**no packet drops, no packet delays, no erroneous decoded packets**).
- Low-Latency is made possible through:
 - Creation of a new radio interface with **very small TTIs/mini-slots** compared to 1 ms TTIs available currently
 - **Faster processing** for instance in **1-2 OFDM symbols** and **Grant-free UL** transmission
 - Deploying the Core Network User Plane Function and the Application Servers as close to the Radio as possible. This is also referred to as Mobile Edge Computing or **Multi-Access Edge Computing (MEC)**
- High Reliability is achievable through:
 - One-shot transmission: Through **very low code rate** increasing reliability of decoding
 - Multi-shot transmission: **Repeat transmission** of code blocks
 - Retransmissions (through HARQ): **Repeat only when needed**

Illustrative URLLC use case for India - Safer Roads with V2X



- In 2017, India recorded loss of nearly 1.5 lakh lives in road accidents.
- More than 90% of the road accidents are caused due to human errors such as rash driving, breaking traffic rules, falling asleep while driving, drunk driving, etc.
- Vehicle-to X (V2X) communication can transform the road safety paradigm in India.
- V2X communication requires ultra-fast response to take real-time decisions making it a key 5G URLLC service use case.
- As shown in adjoining figure, V2X enables comprehensive connectivity of vehicles with the surroundings – which could be another vehicle, a pedestrian or road infrastructure such as traffic lights with or without having to communicate with the network.
- 5G can truly bring the concept of autonomous driving to reality.
- Customers can also be provided a more enriched experience by clubbing eMBB services such as AR to show road ahead of a vehicle in front.

