

# Intelligent Connectivity - The fusion of 5G, AI and IoT

*Prof C.Murali<sup>2</sup>, Academic Expert,  
Distinguished Fellow,  
IETE, India*

**Abstract:** Networking of objects / things with human beings need intelligent connectivity. Developments in IoT, AI and 5G technologies play a big role in providing such connectivity. Fusion of these technologies improve decision making and delivery of personalized experiences. In IoT, Objects / Things make themselves recognizable and they get intelligence as they can communicate. To enable a sustainable smart world, IoT should be characterized by energy efficiency. Green IoT focuses on reducing the energy consumption to fulfill the requirement of smart world with sustainability. 5G wireless networks envision increase in wireless data rates, bandwidth, coverage, and connectivity with a massive reduction in round trip latency and energy consumption. Essence of 5G wireless networks lies in exploring the unused, high frequency mm wave band (3 ~ 300 GHz). Human beings and animals display natural intelligence. AI analyses its environment and takes actions to maximize its chance of success. Intelligent connectivity is expected to play a dominant role in five key areas: Public safety & security, Industrial & Manufacturing operations, Healthcare, Transportation & Logistics, and many other sectors.

**Keywords:** IoT, Green IoT, 5G, mm Wave, AI, ML, NLP.

Human beings by nature are smart and intelligent. They can sense, process, and act with remarkable speed. Networking of objects / things with human beings need intelligent connectivity. Developments in IoT, AI and 5G technologies play a big role in providing such connectivity.

In the intelligent connectivity vision, the digital information collected by the machines, devices and sensors making up the IoT is analyzed and

contextualized by AI technologies and presented to the users in a more meaningful and useful way. Fusion of these technologies improve decision making and delivery of personalized experiences to the users. There are many uncertainties and challenges to be addressed. Fusion is possible as artificial intelligence is becoming increasingly sophisticated. Machine learning tools are available for creating advanced algorithms. IoT is getting closer to become a mainstream phenomenon. 5G can represent the missing element to bring these technologies to new levels and enable the intelligent connectivity vision.

Let us have a peep into these three technologies.

## I. INTERNET OF THINGS

IoT is a new revolution of Internet (Future Internet) evolving from the Internet and short-range communication network. Move is from Internet of people to Internet of Things. There will be a paradigm change from passive send / receive to active query / react. IoT is a cyber-physical system facilitating the integration of the physical world and the digital world. In IoT, Objects / Things make themselves recognizable and they get intelligence as they can communicate information about themselves, and they can access information that has been aggregated by other things. It is in short, connecting anything, anyone, anytime, anyplace to realize a smarter world (Figure 1).

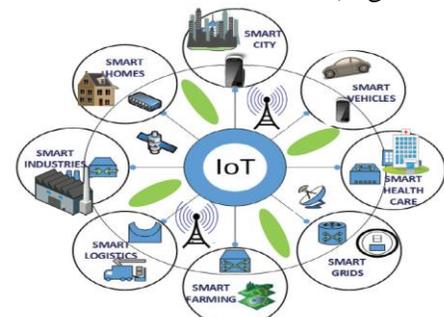
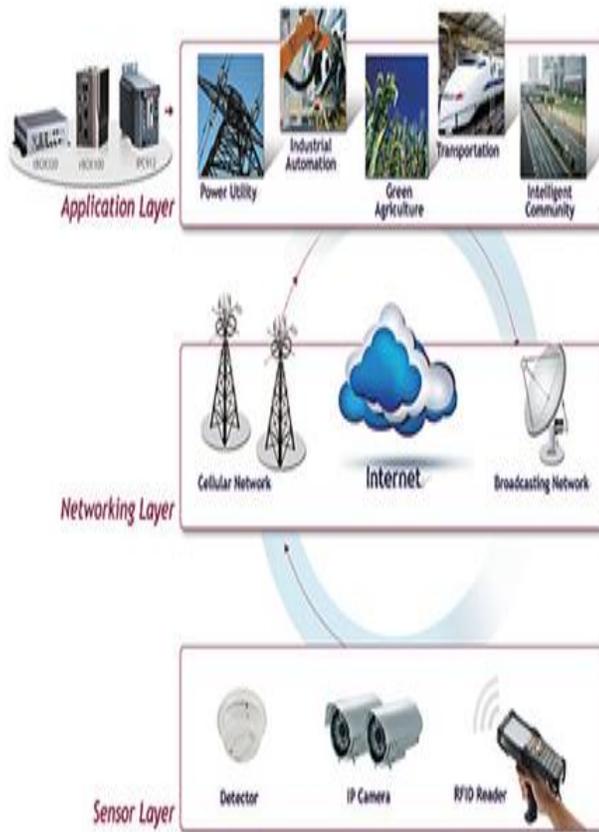


Fig 1



**Fig 2**

IoT architecture can be broadly divided into 3 layers - Perception layer (consisting of two-dimension code tag and code reader, RFID tag and reader, camera, GPS, all kinds of sensors, sensor network, M2M terminal, and sensor gateway, ...), network layer consisting of converged network formed by all kinds of communication networks and Internet, management and information center, and application layer to achieve a broad set of intelligent application solutions (Figure 2).

IoT has many challenges to be considered like, technological standardization, data security and privacy, a trillion points of vulnerability, trust, and data integrity. Everyday household items could potentially be exploited by cybercriminals to gain access.

Green IoT: IoT connects everything in the smart world. To enable a sustainable smart world, the IoT should be characterized by energy efficiency. Green IoT focuses on reducing the energy consumption to fulfill the requirement of smart world with sustainability. Entire life cycle of green IoT should focus on green design, green production, green utilization, and finally green disposal / recycling to have no or very small impact on the environment.

## II. 5G NETWORKS

5G wireless communications envision increase in wireless data rates, bandwidth, coverage, and connectivity with a massive reduction in round trip latency and energy consumption.

Major requirements of next generation 5G systems are: 1 to 10 Gbps data rates in real networks, 1 ms round trip latency, High bandwidth in unit area, enormous number of connected devices, almost 100% coverage for 'anytime anywhere' connectivity, reduction in energy usage by almost 90%, development of green technology, high battery life, reduction in power consumption by devices, perceived availability of 99.999%. 5G network should practically be always available. Wireless industries, academia and research organizations are collaborating in different aspects of 5G wireless systems.

Presently, most of the wireless communications use spectrum in 300 MHz to 3 GHz band. Essence of 5G wireless networks lies in exploring the unused, high frequency mm wave band (3 ~ 300 GHz) (Figure 3). With the requirements of sub millisec latency and bandwidth limitation in traditional wireless spectrum, cellular networks need to shift from BS centric to user centric architecture where the user is expected to participate in storage, relaying, content delivery and computation within the network (Figure 4). You need to have backhaul, which is high capacity, but when it comes to covering the last mile, 5G and beyond is a fantastic solution.

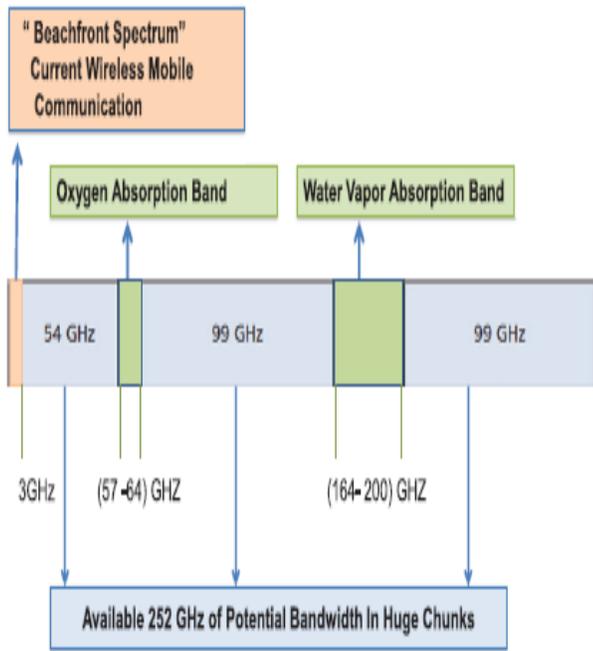


Fig 3

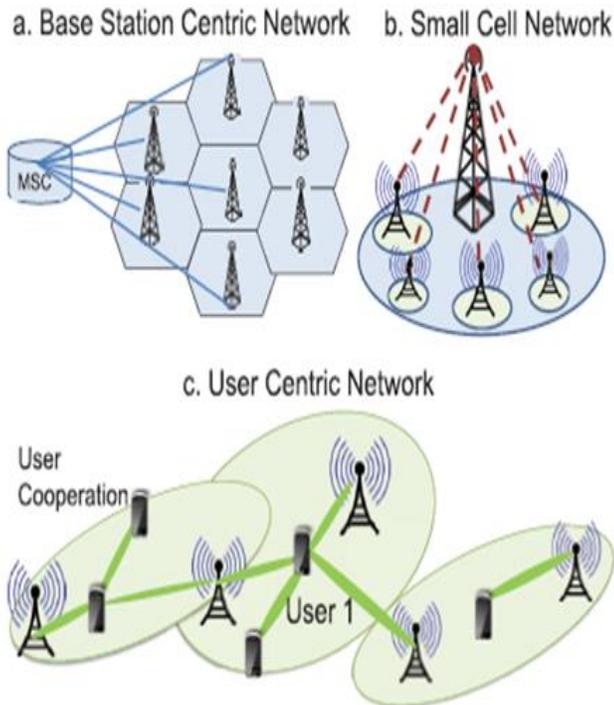


Fig 4

Key performance indicators of 5G are more comprehensive than previous generations. They are average spectral efficiency (bps/Hz/cell), and energy efficiency (bits/J).

Mobile Internet and IoT are the two major services envisioned for 5G systems. Different services require different data rates and latency. For IoT, information-collection type of services includes low speed applications (meter reading), and high speed applications (video monitoring). There are two families of control type machine to machine communications - delay sensitive (vehicle to vehicle Communication) and delay non sensitive (various applications of our daily life).

Figure 5 depicts various aspects of 5G networks.

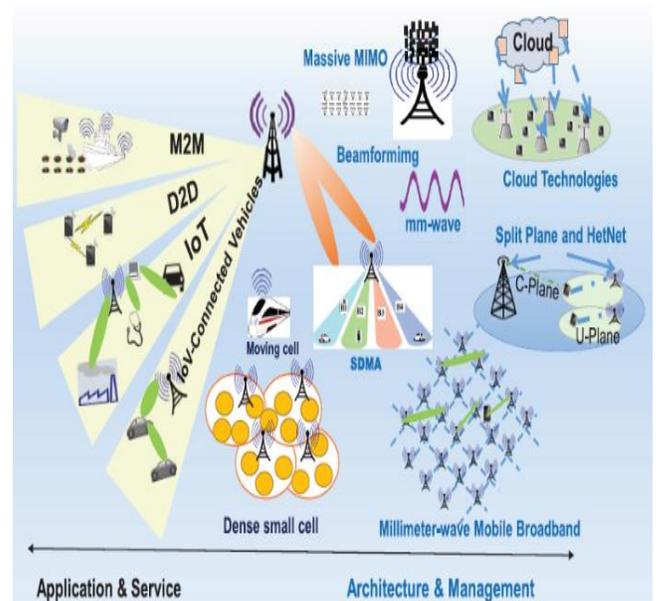


Fig 5

### III. ARTIFICIAL INTELLIGENCE

Human beings and animals display natural intelligence. AI called machine intelligence, is intelligence demonstrated by machine. AI can also be defined as the system's ability to correctly interpret external data, to learn from such data, and to use those learning's to achieve specific goals and tasks through

flexible adaptation. AI is heavily used in robotics. AI analyses its environment and takes actions to maximize its chance of success. AI revolves around the use of algorithms which are capable of learning from data or can themselves write other algorithms. Machine learning, a fundamental concept of AI research is the study of computer algorithms that improve automatically through experience. Existing AI lacks several features of human common-sense reasoning as space, time, and physical interactions.

Natural language processing (NLP) gives machines the ability to read and understand human language. Machine perception is the ability to use input from sensors such as cameras (visible spectrum or infrared), microphones, wireless signals, and active lidar, sonar, radar and tactile (related to the sense of touch) sensors to deduce aspects of the world. Applications include speech recognition, facial recognition and object recognition, computer vision (ability to analyze visual input).

#### IV. INTELLIGENT CONNECTIVITY

Intelligent connectivity is the combination of high-speed, low latency 5G networks, cutting-edge artificial intelligence (AI), and the linking of billions of devices through the Internet of Things (IoT). When these three technologies combine, they will enable transformational new capabilities in transport, entertainment, industry, public services, and much more... It is estimated that, by 2025 there will be 25 billion connected devices and 5G networks are likely to cover one-third of the world's population. This hyperconnectivity will be enabled by undisturbed mobile broadband, which will be the prime enabler of intelligent connectivity.

Intelligent connectivity will have a significant and positive impact on individuals, industry, and society, marking the beginning of a new era defined by highly contextualized and personalized experiences. Augmented and virtual reality will change the way we watch live sports and music concerts, drones will deliver packages to our homes, and virtual personal

assistants will manage our lives for us to a better future.

It is expected to play a dominant role in five key areas: Public safety & security, Industrial & Manufacturing operations, Healthcare, Transportation & Logistics, and many other sectors (Figure 6).

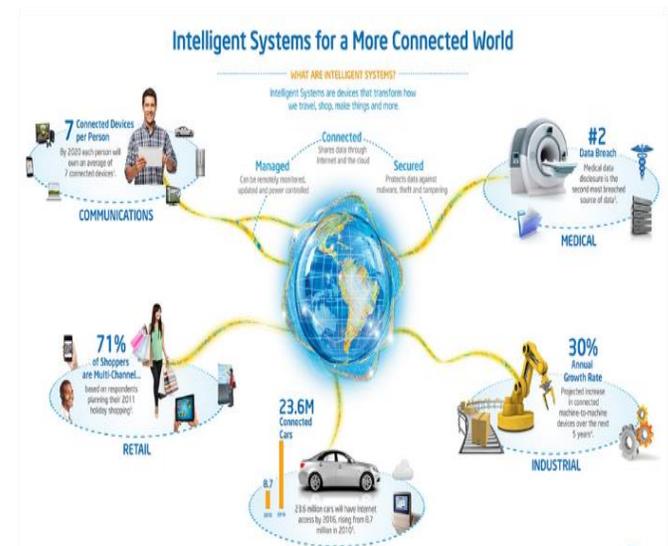


Fig 6

**1 Public safety & Security:** Intelligent Connectivity can make cities safer and help the governing bodies to fight crime by improving the efficiency of video surveillance, security systems and emergency services while reducing their costs. 5G networks facilitate deployment of massive numbers of security alarms, sensors and cameras and enable the transmission of real-time, high-quality videos to enhanced remote surveillance and better assessment of crime scenes. AI based systems automatically analyze activities, body language and facial expressions of suspects, detect crimes and spot offenders in real time for tracking suspicious characters as they move among the fields of view of different cameras. By analyzing data on past crimes, AI based platforms can predict future offences and help to optimize the use of crime prevention resources (Figure 7).



Fig 7

## 2. Industrial & Manufacturing operations:

Intelligent connectivity leads to improved productivity, reduced human errors, lower costs, and increased worker safety. It enables remote operations to industrial facilities, lowers the need for onsite employees, and increases the flexibility in choosing where to locate production facilities, as the latter would become independent on the geographical availability of skilled labor.

## 3. Healthcare:

Intelligent connectivity help to provide effective preventive care at an affordable cost while allowing healthcare managers to optimize the use of their resources. It can facilitate remote diagnosis and enable remote surgery, can revolutionize access to medical care that today is limited to the geographical location of medical experts. The tactile (real time) nature of intelligent connectivity Internet applications enabled by the high speed, low-latency, and ultra-high reliability delivered by 5G networks enable doctors to provide a full medical examination from remote locations with full audio visual and haptic (touch) feedback, making it possible to provide a diagnosis

anywhere at any time, to perform remote surgery by operating specialized robots using 5G and IoT technologies.

**4. Transportation and Logistics:** Intelligent connectivity can lead to better level of road safety and efficiency with smooth traffic flow. It has the potential to improve efficiency and flexibility in the delivery of goods, making logistics faster and cheaper. Combination of 5G and AI allow driver assistance and traffic monitoring systems to reach their full potential. Low latency of 5G networks help road users and the roadside infrastructure to collect and share real time information. Ex: Data about the location and speed of vehicles, bikes and pedestrians on the road, weather, road surface conditions, traffic jams and other obstacles on the road. Intelligent traffic monitoring systems and AI based on board computers can use this information to provide help drivers to avoid accidents and collisions with other vehicles and dynamically plan best route to the destination (Figure 8).



Fig 8

Self-driving vehicles will be provided with an AI based on board computer that, based on data collected by on board sensors and provided by roadside units and other

vehicles via the 5G network will be aware of the vehicle's surrounding environment and able to adjust to any situation. This can support high volumes of both terrestrial and aerial unmanned vehicles, such as unmanned delivery robots and drones, allow operators to precisely coordinate their movements, avoiding collisions, buildings, or other static obstacles along their path.

**5. Other sectors:** Virtual personal assistants - combination of 5G and AI make it much faster and easier to retrieve information, make reservations or buy goods. Cloud based gaming servers could allow players to enjoy videogames without the need for bulky and expensive equipment, while making their experiences more immersive using AR/VR visors and devices with haptic feedback. 3D hologram (image) displays could provide users with a realistic feeling of a live sporting or music event in a location far away, while comfortably sitting at home or in a nearby location. The combination of AI with 5G networks further enhance the real time collection and analysis of data from sensor networks, increasing the efficiency of how we use energy, irrigate fields, or distribute goods while reducing waste and pollution.

## V. CONCLUSION

There are many uncertainties and challenges to be addressed. It is early to declare the era of intelligent connectivity. Elements required to enable this vision are yet to reach maturity. Applications involving aspects such as VR/AR, the tactile Internet or self-driven vehicles are still at a very early stage of development. Technical and regulatory issues need to be solved. 5G is still at an early stage of deployment. Industry must mature in determining the actual needs of the technology users. It is believed that it will take at least another five to ten years for the application scenarios described earlier become viable.

## REFERENCES

- [1] .*Research Directions for the Internet of Things*, John A. Stankovic, Life Fellow, IEEE, *IEEE Internet of Things Journal*, vol. 1, no. 1, February 2014
- [2] .*Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications*, Ala Al-Fuqaha, Senior Member, IEEE, Mohsen Guizani, Fellow,

IEEE, Mehdi Mohammadi, Student Member, IEEE, Mohammed Aledhari, Student Member, IEEE, and Moussa Ayyash, Senior Member, IEEE, *IEEE communication surveys & tutorials*, vol. 17, no. 4, fourth quarter 2015

[3] *Green Internet of Things for Smart World*, CHUNSHENG ZHU1, (Student Member, IEEE), VICTOR C. M. LEUNG1, (Fellow, IEEE), LEI SHU2, (Member, IEEE), AND EDITH C.-H. NGAI3, (Senior Member, IEEE), November 2015, Digital Object Identifier 10.1109/ACCESS.2015.2497312

[4] .*Next Generation 5G Wireless Networks: A Comprehensive Survey*, Mamta Agiwal, Abhishek Roy, and Navrati Saxena. *IEEE communications surveys & tutorials*, vol. 18, no. 3, third quarter 2016

[5] *5G Technology of Mobile Communication: A Survey*, 2013 *International Conference on Intelligent Systems and Signal Processing (ISSP)*

[6] .*IoT Analytics*

[7] .[www.huawei.com](http://www.huawei.com), [www.gsma.com](http://www.gsma.com)

[8] *Seminars, Webinars*

<sup>2</sup>**Prof Murali**, is an academician and educationist having B.E. degree in electronics from UVCE, Bangalore University and M.E. Degree in electronics from BITS, Pilani.

He has more than four decades of academic experience as a lecturer, Asst. Professor, Professor and HoD and served various Institutions / Universities as a BoS member, BoE chairman, Advisory committee member for UG and PG. He has served M S Ramaiah Institute of Technology, Bangalore for 34 years and Ramaiah University of Applied Sciences, Bangalore as Associate Academic Registrar in Faculty of Engineering & Technology.

Apart from this, he has worked as an expert for UPSC, NBA-AICTE and Proficiency at IISc and his areas of interest are Microwave Engineering, Computer Networks and Wireless Mobile Networks. He has authored books on Computer Communication Networks and Data Communications & Computer Networks.

Prof. Murali is a distinguished fellow of IETE, life member of ISTE and IMAPS (India), served at IETE Bangalore centre as EC Member, Joint Secretary, Vice-Chairman and Chairman, at IETE, New Delhi as Governing Council member for Three terms, Academic Committee Chairman and Vice President. Under his guidance various activities like syllabus revision, Introduction of CGPA System, publication of Lab manuals, learning materials, dual programs and ISF activities were initiated and successfully executed.

Prof. Murali has delivered invited talks, Presented technical papers, keynote addresses, reviewed papers, conducted workshops and seminars at IETE, University, state and National levels.

Prof Murali has received **Awards of** Dewang Mehta National Educational Award as best professor in Electronics & Communication Engineering in Aug 2017, IETE B.R.Batra memorial award 2018. He is also listed in the directory of Indo-American who is who publication and Biographical international, South Asia publication.

He has provided consultancy in the development of microwave trainer kits, fabrication of teaching and training aids and his hobbies are reading, photography, philately. He is a trustee of traffic engineers and safety trainers, Bengaluru.