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Appraisal of the Fifth-Generation (5G) Wireless Communication Technology

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ABSTRACT
Wireless communication in mobile technology is driven by man's desire to interact with each other over long distances either through voice, messages, images, or even video. Wireless communication technology is a cost-effective process as it eliminates the use of costly and tiresome physical connections between various equipment such as connecting cables in buildings and industries. There has been a formidable growth in the wireless communication industry, from improved mobile technology to the variety of services now offered and a staggering subscriber base. From one generation to another up till the present (5G), the technology has been all-encompassing. There have been tremendous changes at the architectural level *i.e.* Core Network (CN) and Radio Access Network (RAN). Changes at the CN affect all network layers from the physical, application, transport session to security layers within their complex architecture. At an end-user level, the mobile equipment (MEs), mobile units (MUs), a mobile station (MSs), or user equipment (UEs) have changed progressively in line with the technological evolutions attained on the road from 1G to 5G. This paper focuses on the appraisal of entire 5G wireless Technology with particular respect to its architecture, objectives, Specifications, prospects and challenges.

Key words: Core Network (CN), Radio Access Network (RAN), User Equipment's (UEs), Mobile Units (MUs)

INTRODUCTION

Fifth-Generations (5G) is also referred to as beyond 2020 mobile communications technologies. Chinese providers began deploying 5G cell sites at a rapid pace and announced plans to launch 5G in 2019, ahead of the 2020 timeline. Industry observers called this the "China Surge. In June 2018, South Korea auctioned both mid-band and high-band spectrum for 5G use. Telecommunication providers in South Korea committed to the plan of launching 5G on the same day: a day the government called "Korea 5G Day" and later launched fixed 5G to business users on December 1, 2018, while announcing plans to launch mobile 5G for consumers in March 2019 when 5G phones became available. Verizon launched fixed 5G services in 4 cities on October 1, 2018, while AT&T launched in 12 cities on December 21, 2018.

There are two views of 5G systems: evolutionary and revolutionary. In the evolutionary view, 5G (or beyond 4G) systems are capable of supporting WWWW (World Wide Wireless Web) allowing a highly flexible network such as a Dynamic Ad-hoc Wireless Network (DAWN). Technologies including intelligent antenna and flexible modulation are used to optimize the ad-hoc wireless networks in the evolutionary view. In revolutionary view, 5G systems is an intelligent technology capable of interconnecting the entire world without limits as shown in Figure 1. An example is a robot with built-in wireless communication and artificial intelligence (AI). 5G is considered to be 'ultra-fast, ultra-reliable, ultra-high capacity transmitting at super low latency' by the National Infrastructure Commission in the report [1].

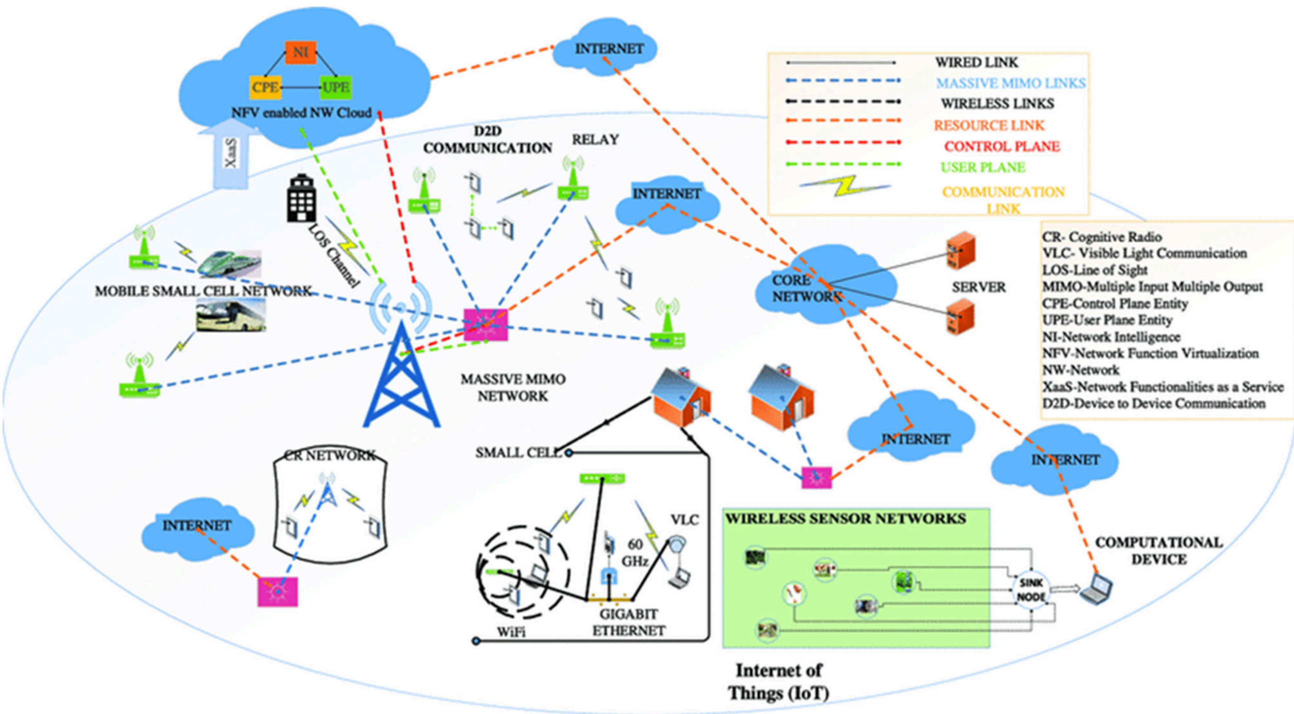


Fig. 1 5G cellular network architecture

The following are the requirements that must be met to qualify a network as 5G as shown in figure 2

- 1-10Gbps connections to endpoints in the field
- 1 millisecond end-to-end round trip delay (latency)
- 1000x bandwidth per unit area
- 10-100x number of connected devices
- (Perception of) 99.999% availability • (Perception of) 100% coverage
- 90% reduction in network energy usage
- Up to ten-year battery life for low power, machine-type devices.

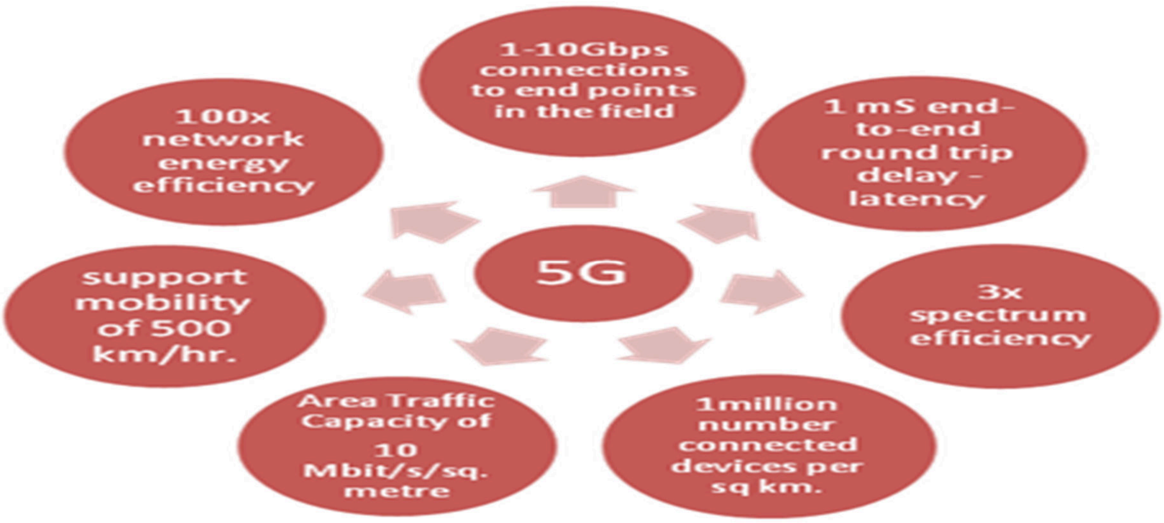


Fig. 2 Visions of 5G Mobile Technology [3]

The innovations of the fifth generation (5G) are based on the following objectives as shown in figure 3

- ✓ Implementation of large scale capacity and large connectivity
- ✓ Supporting all kinds of services, applications, and users.
- ✓ Flexible and efficient use of all non-contiguous spectrum for wildly different network deployment scenarios.

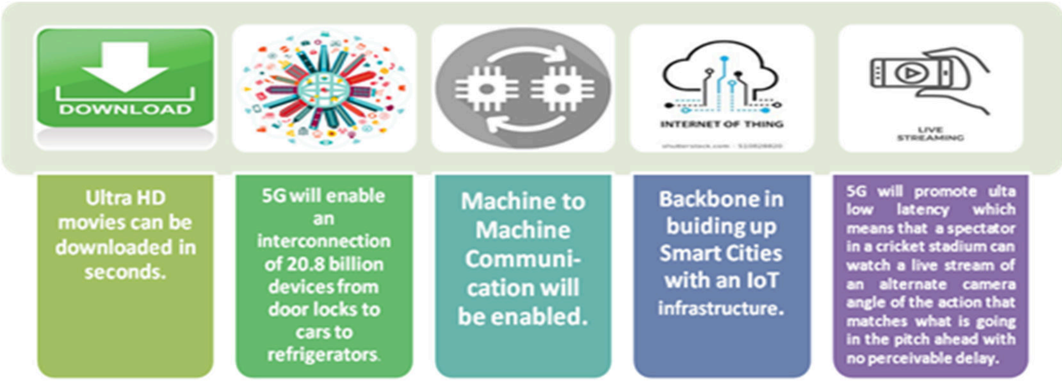


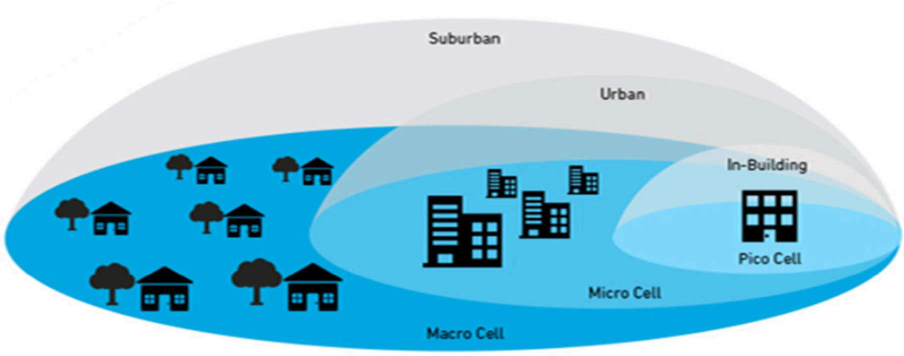
Fig. 3 Why we need 5G [3]

5G Technology

1G cellular network emerged in the 1980s but made use of analog transmission for speech services. It was first launched commercially in Tokyo, Japan by NTT (Nippon Telegraph and Telephone) in 1979 but unlike 0G, these systems offered handover and roaming capabilities but could not be used to make wireless connections between different countries. Then came 2G in the 1990s that used digital multiple-access technology, such as TDMA (time division multiple access) and CDMA (code division multiple access). 2G ushered in 3G which was launched by NTT DoCoMo in Tokyo, Japan in May 2001 and went commercial on October 1, 2001, using the WCDMA technology. In 2002 the first 3G networks on the CDMA2000 EV-DO technology were launched by SK Telecom and KTF in South Korea and Monet in the USA. By the end of 2002, the second WCDMA network was launched in Japan by Vodafone KK (now Softbank). In March the Three/Hutchison group launched Europe's WCDMA 3G in Italy. 3G cellular networks had about 295 Million subscribers by 2007, which reflected 9% of the total worldwide subscriber base with $^2/_3$ of these on the WCDMA standard and $^1/_3$ on the EV-DO standard. Sprint made history in September 2008 when it became the first major US carrier to launch a 4G network in Baltimore. And just when the world thought it was over, the phenomenal 5G surfaced [4]. The under listed technologies are used for 5G operations

- **Millimeter (mm) Waves:**

Telecom Service Providers (TSPs) make use of radio frequency spectrum to send and receive data. More data is being consumed with an increasing consumer base but this data is crammedonthesamefrequencybands, thereby allocatinglessbandwidthforeveryone and making the service sloweror dropping more connections. The mm-wave band uses a higher frequency than the radio waves that have long been used for mobile phones. This mm-Wave band from 20~50 GHz alone accounts for 10 times more available bandwidth than the entire 4G cellular band. A disadvantageis that such high frequencies of mm waves are not able to travel through buildings or obstacles as they are absorbed by foliage andrain [1].



Cell Type	Output Power (W)	Cell Radius (km)	Users	Locations
Femtocell	0.001 to 0.25	0.010 to 0.1	1 to 30	Indoor
Pico Cell	0.25 to 1	0.1 to 0.2	30 to 100	Indoor/Outdoor
Micro Cell	1 to 10	0.2 to 2.0	100 to 2000	Indoor/Outdoor
Macro Cell	10 to >50	8 to 30	>2000	Outdoor

Fig. 4 The output power, cell radius sizes, and other features of different base station types, from small cells to macro cells [3]

- **Small Cells:**

Small cells are portable base stations that work with minimal power and are deployed every 250 meters throughout the coverage area due to the short range of mm-Wave signals as shown in figure 4. It forms a dense network called the Het.

Net (Heterogeneous Network) that receives signals from other base stations and sends them to the users at different locations, like a relay, thereby preventing signals from being dropped. The term 'small cell' encompasses picocells, microcells, femtocells and can comprise indoor/outdoor systems [3].

- **Massive MIMO:**

MIMO (Multiple Input Multiple Output) is a wireless system that employs two or more transmitters and receivers to send and receive more data at once. 5G base stations support over a hundred ports, with each array accommodating much more antennas and capable of sending and receiving signals from as many users at a time, thus increasing the capacity of mobile [2]. Below is a list of major technological characteristics of massive MIMO.

1. Fully digital processing: Antenna signal at each base station are processed coherently together. Full digital processing measures complete channel response on the uplink and immediately respond to changes in the channel.
2. Computationally inexpensive pre-coding/decoding**:** Every transmitter in MIMO is made up of a LOS path to every receiver (Figure 5a). Signals could interfere due to reflection or diffraction from the surrounding atmosphere that may cause low SNR (Signal to Noise Ratio) at the receiver preventing the data streams from being decoded effectively. Thus pre-coding is used on the transmission to equalize the signal reception across multiple receiver antennas.
3. Channel hardening: Channel fading causes channel gain to fluctuate randomly due to microscopic changes in the environment. Channel hardening is when the fluctuations in the gain do not impact the transmitted data, thus removing the effects of channel fading.
4. The reliance on *the reciprocity of propagation and TDD (Time Division Duplex) operation*reciprocates the need for prior or structural knowledge of the downlink propagation channel since the downlink channels can be estimated from uplink pilots.
5. The array gain offers the link budget improvement and the spatial resolution of the array results in interference suppression which facilitates the provision of good quality of service to all terminals in a cell.

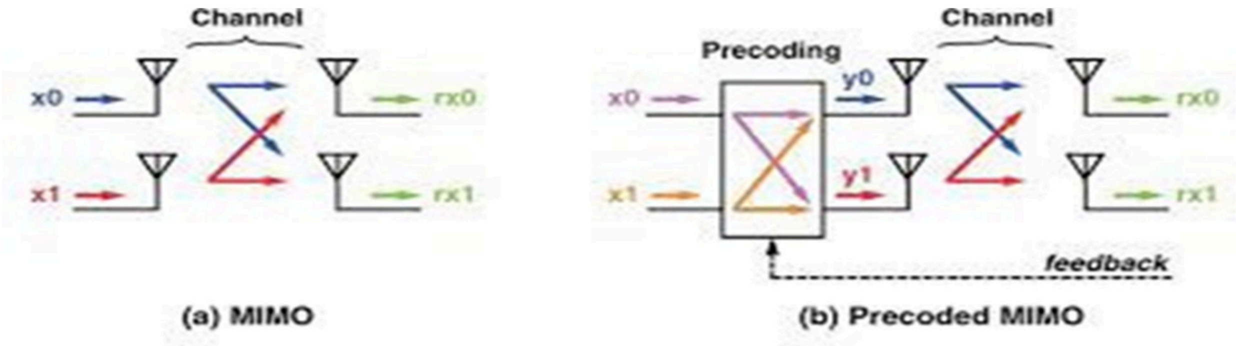


Fig. 5 Difference between MIMO and Pre-coded MIMO [3]

- **Beam-forming:**

Beam-forming reduces the interference from nearby users by recognizing the most efficient data delivery route from a cellular base station to a particular user. At massive MIMO base stations, the best transmission route is determined with the help of signal-processing algorithms and the individual data packets are transmitted in different directions in an orderly pattern, avoiding obstacles as shown in figure 6. Exchanging a large amount of information between users and antennas on massive MIMO arrays (by choreographing the packets' movements and arrival time) is made possible by Beam-forming [2].

Increased bandwidth, constant connectivity, and low latency services that improve consumers' and businesses' experience of mobile telephony are provided by 5G. With 5G, full-length, high-definition movies can be downloaded within seconds; uninterrupted video streaming; as well as online gaming with mobile devices from anywhere. They support interconnected devices (e.g., smart homes, medical devices), and advance IoT (Internet of things) such as autonomous vehicles, precision agriculture systems, industrial machinery, and advanced robotics.

Fig. 6 Visual representation of Beam-forming technology [2]

Advantages of 5G Systems

1. 5G provides large amounts of data with speeds in Gbps (Giga Bytes per Second) that can serve even IoT and the Cloud technologies.
2. 5G brings all networks under a single platform thus incorporating previous networks like 3G and 4G networks to ensure availability to voice and data.

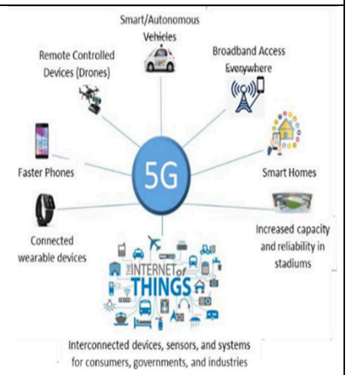
Disadvantages of 5G Systems:

1. It's an emerging technology and a lot of research still needs to take place for the technology to be functional.
2. The speed achieved by using 5G looks impractical as technological support to implement it is absent in most parts of the world
3. It is costly to implement because new infrastructure is still being developed
4. Old devices are obsolete, so 5G users need to get new devices which can be costly

Comparison between the different generations of wireless communication technology

Table -1 Comparison between the different Generations of Wireless Communication Technology [5-6]

Technology	1G	2G	3G	4G	5G
Requirements	Not official Analog Technology	Not official Digital Technology	ITU"s IMT-2000 required 144 kbps Mobile 384kbps pedestrian 2Mbps indoors	ITU"s IMT Advanced requirements include the ability to operate in up to 40 MHz radio channels and with very high spectral Efficiency	At least 1 GB/s or more data rates to support ultra-high-definition video and virtual reality Applications10 GB/s data rates to support mobile cloud service
Data	1.9 kbps	14..4 kbps to 384 kbps	2 Mbps	2 Mbps to 1 Gbps	1Gbps & Higher (as demand)
Core network	PSTN	PSTN Packet Network	Packet network	All IP Network	Flatter IP Network 5G Network Interfacing (5G-NI)
Bandwidth	150-900MHz	900MHz	100MHz	100Mhz	1000 * Bandwidth per unit area
Service	Analog voice	Digital voice Higher capacity Packetized data	Integrated high quality audio Video Data	Dynamic information access Wearable devices HD streaming global roaming	Dynamic information access Wearable devices HD streaming Any demand of users Upcoming all technologies Global roaming smoothly;
Standards	NMT AMPS, Hicap CDPD TACS ETACS	GSM GPRS EDGE	WCDMA CDMA 2000.	All-access convergence including: OFMDA MC-CDMA Network-LMPS	CDMA BDMA
Multiple	FDMA	TDMA,	CDMA	CDMA	CDMA, BDMA

access		CDMA			
Switching	Circuit	Circuit Packet	Circuit Packet	Packet	All Packet
Frequency	800-900 Reference MHz	850-1900MHZ	1.6-2.5GHZ	2-8GHZ	3-300GHz
Deployed	1980-1990	1990-2000	2000-2010	2010-2018	2018 to date
Speed	0.002 Mbps	0.064 Mbps	2-10 Mbps	10-100 Mbps	1000- 1400 Mbps
Time to download 2-hr movie	N/A	N/A	10-26 hours	6 minutes	2-15 seconds
Device & Functions	 First mobile phone Basic voice services Limited coverage Expensive	 Voice and some text Digital standards offered higher qualityvoice More coverage More affordable	 Voice, data, and access to the internet (email, audio, andvideo) First mobile broadband iPhone was introduced People begin using their phones as computers	 Voice, data, high-speed access to the internet on phones, tablets, laptops True mobile broadband; unlimited plans; devices used as hotspots Streaming, new applications, onlinegaming	

Prospects and Challenges

I. **Standards**: Integrating the various standards of engineering practice requires a systematic and exhaustive approach.

II. **Platform:** A common architecture for interconnecting all engineering practices to regularize the interconnectivity issues and knowledge sharing is required.

III. **The super core concept**: Flat IP architecture will lessen the burden on aggregation point (BSC/RNC) and traffic will directly move from Base station to Media gateways. However, with the transition from legacy (TDM, ATM) platforms to IP, a common ALL IP platform has emerged where all network operators (GSM, CDMA, WiMAX, Wire line) can be connected to one Super core with massive capacity, thereby achieving a single network infrastructure, reducing the number of network entities in the end to end connection and reducing latency considerably.

IV. **High redundancy:** For all network operators moving to single-core infrastructure in the Super core concept, high redundancy and security among core network entities will be required as a failure of one node can hugely affect a large number of subscribers across different network operators.

V. **Flatter IP concept**: Semiconductor manufacturers advancing to a new generation with smaller feature sizes will allow them to incorporate more functions into a given area of silicon and new capabilities in electronic devices like cell phones. An increase in processing capacity will allow Mobile devices to perform more tasks (on per seconds basis) than before, thereby leading to a Flatter IP network. Flatter IP will shift some of the RR (Radio Resource) functions to Mobile devices from the Base station and cell phones will also perform some functions of Radio Resource Management.

VI. **Managed Services**: Super Core will complement managed services as all network operators will have a single massive super core, which will be managed by different vendors under managed service contracts and regulated by SLA (Service level agreements). Under 5G, mobile network operators may become service retailers and due to single infrastructure, MNO (Mobile network operators) will become MVNOs (Mobile Virtual network operators).

CONCLUSION

The latest generation of wireless technologies aims at bringing all the technologies under a single platform which requires data speeds in Gbps. Network operators desire to use lower frequency bands which were used for earlier generations to save the cost of acquiring frequency spectrum and reach greater distances with minimal or no interference. 3rd, 4th and 5th generations of wireless mobile communication combined can provide uninterrupted services for voice and data in any location. The Fifth-Generation areas of research are as follows: Real wireless world or IoT with limitless access and location, wearable devices having Artificial Intelligent (AI) capabilities and Internet protocol version 6 (IPv6), where mobile IP addresses are assigned based on location and connected network.

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