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ALS-ORAN 5G: Adapting to Lowpower-WAN & Satellite - Open Radio Access Network in 5G

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Abstract

In this paper we explain 3 different wireless communication technologies available to connect handheld mobile devices and machines under the Internet Of Things (IoT). Next, our focus is on 5G technology which claims to be the fastest wireless communication technology, and the first suited to provide the connectivity between machines. 5G is compared with two other major wireless technologies: Satellite Internet and Low Power Wide Area Network, which also provide connectivity between machines with arguably wider coverage in area terms and suitability over many use cases. In contrast, 5G requires newer user equipment, modified and denser base station infrastructure, possible business model changes on account of this denser infrastructure, besides ultra-competitive spectrum license fees. Thus, IoT networks, satellite Internet or modified versions of 4G are better-suited for many use cases that 5G is being articulated for. In view of these risks, the phenomenon of 'unbundling' is natural in Tech, and hence we also highlight the business case that ORAN represents for software companies, esp. IT system integrators in India, that would not normally be associated with activity in core telecoms domain.

1. Introduction

There are many wireless connectivity methods available now to connect the electronic devices to exchange data. Bluetooth and WiFi are examples of wireless technologies which can enable communication channels between the devices in a close and restricted area. Whereas, cellular network and satellite internet are examples for the technologies which are not restricted to a close area i.e building. We can choose these communication mediums according to many factors such as the cost, network speed, coverage area, availability of peripherals etc. The following figure is an approximate representation of the data rate and coverage of different wireless technology[1][2].

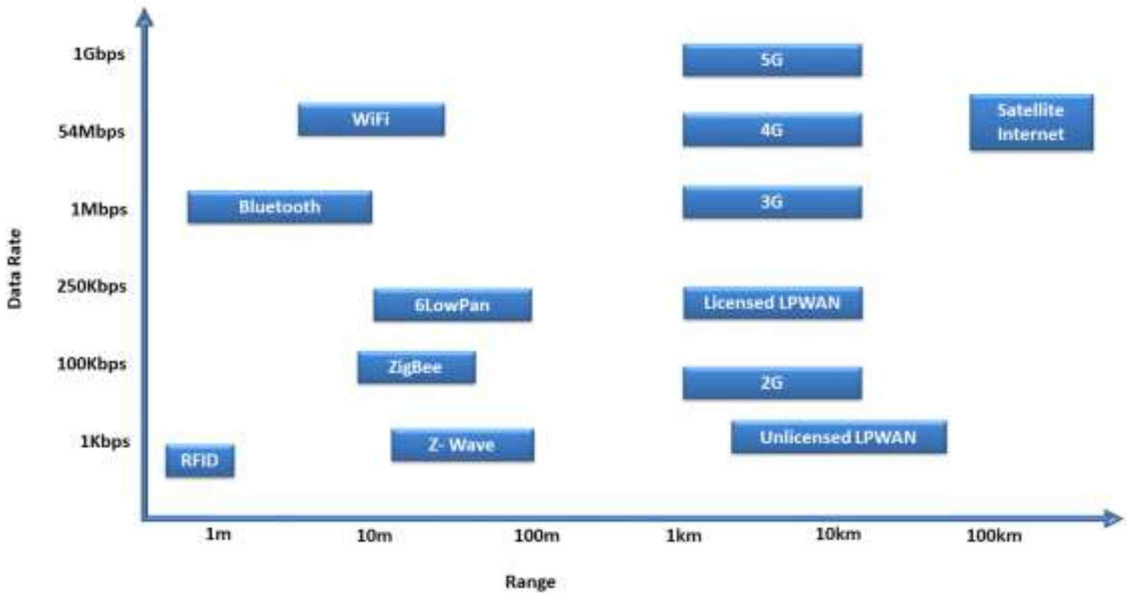

Figure: 1

Advancements in wireless technology and machine learning have also paved the path to technologies like Internet Of Things (IoT). These are devices connected and exchange data using the internet. IoT has several applications like smart home, healthcare, environmental monitoring, agriculture and many more[3]. Some devices in IoT need a very low data rate to communicate with each other while some devices like self-driving cars, remote medical assistance, low latency gaming and drones might need higher bandwidth connections[4] in certain use-cases. The bandwidth usage of different indoor IoT devices estimated by a Home Telecom internet provider is as follows[5]:

Device	Bandwidth	Device	Bandwidth
Smart Watches	1 Mbps	Media Sharing	10 Mbps
Home Assistants (Eg. Alexa)	1 Mbps	Streaming HD Video	10 Mbps
Smart Doorbell	2 Mbps	Video Chat	10 Mbps
Basic Web Use	2 Mbps	Wi-Fi Enabled Washer and Dryer	12 Mbps
Streaming Music	2 Mbps	Online Gaming	25 Mbps
Smart Thermostat	6 Mbps	Large File Downloading	50 Mbps
Outdoor Home Security System	6 Mbps	Cloud Storage	50 Mbps
Smart Refrigerator	8 Mbps		

Table: 1

Another notable implementation of wireless communication technology is the in-flight WiFi facility provided by the airlines. This facility allows the passengers to stay connected to the internet while they are traveling in the flight. The connectivity in the flight can enabled with the use of following methods[6]:

➔ *Air To Ground (ATG)* - This is implemented in the similar fashion as the ground based cellular data network, but here the signal from the tower is projected upward and the antennas fitted on the bottom of the aircraft receive the signal and send it to the server inside the aircraft.

➔ *Satellite* - The antenna is placed on the top of the aircraft to receive the signal from the satellite. The signal is sent to the onboard server, and a separate controller is required to adjust the position of the antenna to receive the signal from the satellite. This method is faster and more reliable than ATG. Even as of Nov 2017, the Australian airline Qantas had a supplier willing to guarantee 12Mbps per passenger while in flight, though the airline thought 20Mbps per passenger as fully feasible using the Australian satellite network over that country's landmass [48].

2. Wide area wireless connectivity methods

There are technologies like Bluetooth which is used to connect *Things*, but it can only cover devices within a restricted area. Let's look into the connectivity methods/technologies which provide a relatively wider area of coverage and are used for connecting IoT devices.

2.1. 5G

As the name denotes, it is the 5th generation of the cellular communication network for humans and also the 1st generation of cellular network for the machines. This new wireless communication standard claims to have very high data rate, low latency and better quality of service than its predecessors[7]. The high speed is achieved because 5G networks operate in the high-frequency spectrum (Sub-6 GHz and millimeter Wave)[8] and also by implementing the new technologies of massive Multiple-In, Multiple-Out (MIMO) and beamforming[9]. As an example, 5G or 5G-like networks operate in 3.5GHz or the 28-39GHz zones (called the millimetre-wave band) in contrast to 4G at 700MHz-2500MHz. The difficulty here is that high frequency waves cannot travel very far and cannot penetrate walls or other obstacles[10]. So the 5G network providers have to deploy small cell sites[11] to increase the coverage. Also, in contrast to 4G, beamforming and MIMO antennas direct the beam of radio signals at the user's instrument, even if the user - or group of users, e.g. a train - is moving within the base station's frame of reference. The comparison of 5G with its predecessors is listed in the below table[12].

Features	**3G**	**4G**	**5G**
Launched In	2002	2010	2015
Standards	WCDMA, CDMA 2000	OFDMA, MC-CDMA	CDMA, BDMA
Data Rate	2 Mbps	2 Mbps to 1 Gbps	1 Gbps and higher
Frequency	800 MHz, 850 MHz, 900 MHz, 1.7 GHz, 1.9 GHz and 2.1 GHz	600 MHz, 700 MHz, 1.7/2.1 GHz, 2.3 GHz, and 2.5 GHz.	Low Band : < 1 GHz Mid Band : 1 - 6 GHz High Band : 24 - 40 GHz

Table: 2

Initial generations of mobile networks used low frequency spectrum as the goal was to cover maximum area with less number of base stations. The high frequency radio signals in 5G, like satellite TV broadcasts, cannot penetrate walls and thus require the equivalent of a courtyard dish or equivalent HW to be set up[13]. A useful description of 5G's inability to penetrate walls is in [49], suggesting that added boosting or repeating hardware will need to be acquired by office or apartment complexes, or given to them by Telcos.

This is in addition to our personal devices and base station requiring to be updated inorder to attain the data rate claimed by 5G, the cost involved thus being high. To migrate to 5G tech incrementally and smoothly, the Global Mobile Communication Standards Organization 3GPP has released the following two specifications that the communication service providers can choose while transitioning to 5G[14]:

➔ *Non- Standalone (NSA)* - This anchors the control signalling of 5G to the existing 4G base stations. 5G supported devices and handsets will continue using the 4G infrastructure to make voice communications and for increased data rate Sub-6 GHz and mmWave frequency bands (High Band) will be used. This solution is perceived to be low cost and transition-sensitive compared to Standalone.

➔ *Standalone (SA)* - The control signalling does not depend on the existing 4G base stations, 5G base stations are connected directly to the 5G core network. Both Sub-6 GHz and mmWave frequency bands will be used.

As per a recent 5G user experience report[15] published by a mobile analytics firm, the following are the average download speed and 5G availability (the proportion of the time users with 5G device have a 5G connection) experienced by the 5G users from different service providers in the US:

Provider	Average 5G speeds	5G Availability	Price
Verizon	47.4 Mbps	9.50%	$70 - $90/month
T-Mobile	58.1 Mbps	30.10%	$60 - $85/month
AT&T	53.8 Mbps	18.80%	$65 - $85/month

Table: 3

2.2. Satellite Internet Access

A key contender is the internet access provided through the Geostationary (GEO), Low Earth Orbit (LEO) or Medium Earth Orbit (MEO) communication satellite - popularly called Satellite internet. Comparatively high speed and low latency internet access can be provided by Satellite internet. The coverage area radius of satellite internet ranges from 100 km to 6000 km. Apart from the communication satellites, ground stations aka gateways that relay the radio waves to and from satellite, for each subscriber an antenna dish and modem are the important components for accessing Satellite internet[16]. However, newer service providers like Elon Musk's Starlink expect only a WiFi antenna at user's device (e.g. a conventional mobile phone), and also do not require ground stations in any geographies as the constellation of satellites will route packets between themselves using laser. The Ground Station which has a large antenna is connected to the internet using fiber. Signal from the ground station is sent to the satellite via radio waves. The signal from the satellite is captured by the dish antenna placed outside the home which is aligned with the satellite. A modem is connected to the dish antenna with cable[17].

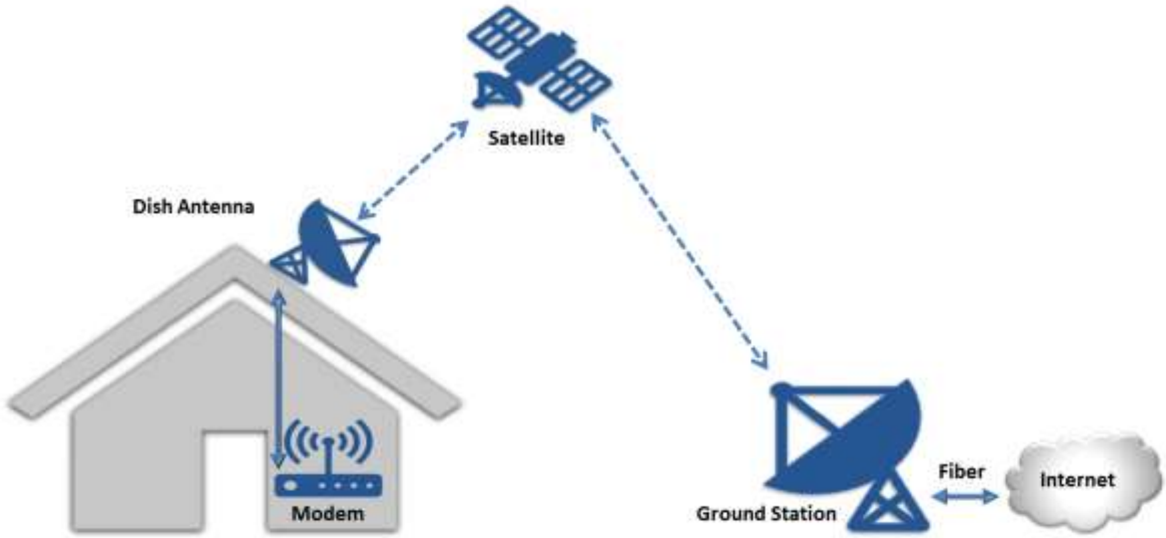

Figure: 2

As of August 2021, there are three Satellite internet access providers in the United States of America including the Beta testing program from Starlink. Following table has the data offerings by these providers[18]:

Provider	**Download Speed**	**Data Cap**	**Price**
Starlink (Beta)	50 - 150 Mbps	Unlimited	$99.00/month
Viasat	12 - 100 Mbps	12 - 300 GB	$30.00 - $150.00/month
HughesNet	Upto 25 Mbps	10 -50 GB	$59.99 - $149.99/month

Table: 4

A survey conducted in the US indicates that 55% of people are ready to switch to satellite internet if it results in faster internet even if it may be expensive. The result from another survey about upgrading the home internet - i.e. upgrading fixed home broadband or Fibre to the Home (FTTH) in India to 5G - shows that 35.77% of the people are not sure about switching to 5G and 46.46% are not willing to switch to 5G[19]. In addition, achieving the mark of 40Mbps via 4G itself was within the realm of projections very early on (ref. Cisco's Visual Network Index, 2012). In India, as of now the satellite internet will be provided by four service providers which includes Bharti Airtel - Oneweb, Kuiper by Amazon, Starlink from SpaceX and Tata group's Nelco[20]. Indicating cost-efficiency, Bharti Airtel invested around $10 Billion for setting up the 5G infrastructure in India[21], whereas only $500 Million was the investment for a stake in Oneweb with an aim to set up countrywide satellite internet in India[22].

As per a satellite based IoT service provider “only about 25% of the world’s landmass is covered by cell towers and to enable machine to machine connectivity in remote and rural areas coverage will need to be available beyond cell towers”[23], indicating the limited role 5G will have in many use cases. A report[24] from India’s DOT indicates that there are 37,439 villages in India without even 3G/4G mobile internet coverage, most likely owing to lack of base stations in their vicinity.

A large number of common-area connectivity problems can be solved by the WiFi-6E standard inside stadiums, arenas, malls and even moving trains such as subways using Track Side Networks [50]. In such locations where social distancing is minimal, both data and voice can be made available on the WiFi systems owned by the public premises’ operators - even without the mobile-phone service provider offering any 5G. An analogy is in Telco offerings in India such as ‘Airtel Xstream Fiber’, where one of the features is a WiFi-hosted call on the mobile phone whilst the user is inside their home, the call being automatically shifted to service provider’s open-area base-station wireless network once user leaves home. The Wi-Fi 6E standard offers less interference between neighbouring WiFi networks and approaches the theoretical limit of 9.6 Gbps per user. Note that for a public space operator, investment in WiFi-6E access points would be more universal than investing in ‘femtocells’ of different mobile service providers on their premises. These concerns would affect such operators’ ROI calculations.

2.3. LPWAN

Low Power Wide Area Network (LPWAN) is designed to connect the Internet of Things’ devices, also called ‘motes’, by carrying very low bit rate data to conserve the power of the devices. These devices will only have low power ability due to a battery cell replaced once in several months, or harvesting of solar power by the device with limited surface area. The motes mentioned above are sensor beds for temperature, moisture, humidity, or a sensor for the infrared-spectrum. Motes with image sensing or *actuators* - i.e. moving arms or wings to perform useful work - will require more reliable power sources e.g. an existing power supply infrastructure. Currently, there are two types of LPWAN based on the frequency spectrum:

- ➔ *Cellular LPWAN* - operates inside the licensed spectrum and is offered by mobile network operators. They use synchronous protocols and thus the connected devices use comparatively more power than the below variant.

➔ *Non-cellular LPWAN* - operated outside the licensed spectrum. As these are using asynchronous communication protocols the energy used by the devices is very low.

Following table summarizes the LPWAN provided by three protocols[25].

	Sigfox	**LoRaWAN**	**NB-IoT**
Maximum data rate	100 bps	50 kbps	200 kbps
Range	10 km (urban), 40 km (rural)	5 km (urban), 20 km (rural)	1 km (urban), 10 km(rural)
Frequency band	Unlicensed ISM bands	Unlicensed ISM bands	Licensed LTE frequency band

Table: 5

As seen in the above table, the data rate supported by the LPWAN providers is very low. Irrespective of 5G availability LPWAN might be a good choice if the data to be sent by the IoT devices or sensors is structured and is in small amount (e.g. smart electricity meters), but when it comes to some of the devices used in smart farming like agricultural drones, automated tractors, seeding-weeding robots or where there is a need to access live video feeds LPWAN might not be a good solution[26][27]. Besides, even in LPWAN a far-apart network of base stations is required to be set up by providers to send the data from IoT motes to a centralized data-processing server as motes are unlikely to have the computing power to engage in *edge processing*.

3. Radio Access Network

Radio access network (RAN) is the part of the cellular network which connects the User Equipment (UE) such as a mobile phone or computer to the Core Network (CN)[28]. Radio access network and core network kept evolving over the time and different types of RAN and CN reflected the advancement in telecommunication technology. A key component of 5G is the RAN, and a component-based structure to RAN where protocols of intercommunication are clear amounts to the Open-RAN (ORAN). Figure 1 gives a description of the connection between UE, RAN and CN.

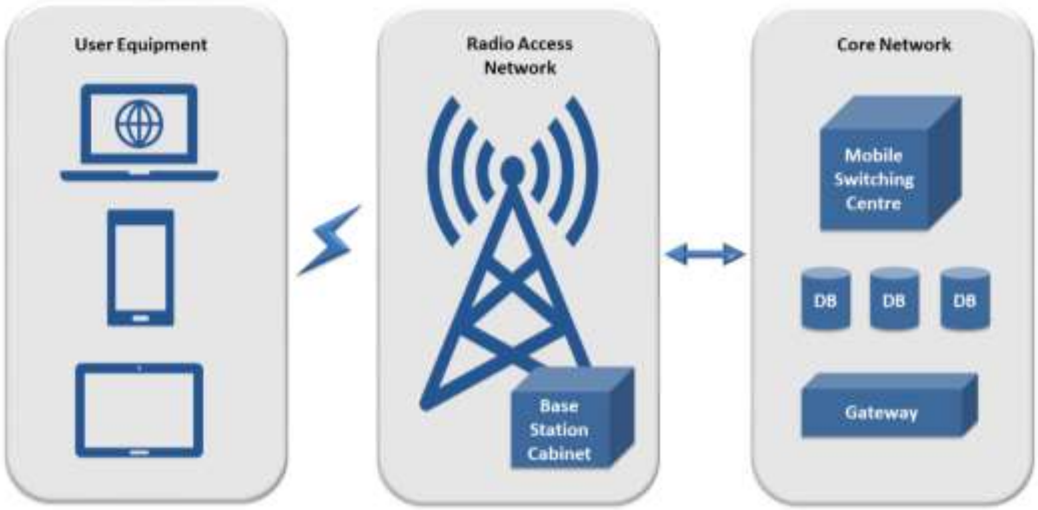

Figure: 3

As and when a new generation of cellular communication network has been introduced, the RAN went through functional splits or architectural changes to improve the quality of service. Following are the major components in the traditional RAN:

➔ *Remote Radio Head (RRH)* aka *Remote Radio Unit (RRU)* or simply *Radio Unit (RU)* - This unit is installed next to the service provider's antenna at the base station. It receives, amplifies and digitizes the radio frequency signals from the antenna and sends it to the Baseband Unit (BBU), the reverse operation being done while transmitting the signal onwards to User Equipment. Radio unit typically has one or two common public radio interface (CPRI) optical cable ports to connect to BBU. It must be mentioned that CPRI amounts to an early ORAN-like industry-wide specification that is now a decade old[29][30].

➔ *Baseband Unit (BBU)* - In the traditional base station, BBU is installed in the equipment room at the base of the tower. Multiple RRUs can be connected to a single BBU. This unit translates information bits into digital baseband waveforms and vice-versa (digital modulation and demodulation)[31]. The term baseband refers to frequency ranges near 0, since after reaching the service provider's antenna the signal is no longer obliged to be in the frequency ranges specified by the regulator.

➔ *Controller Unit* - There are controller units in 2G and 3G called Base Station Controller (BSC) and Radio Network Controller (RNC) respectively, which are connected to multiple Base Stations or Base Transceiver Stations (BTS). Controller units are connected to the Core Network. It controls handover from BTS to BTS, and BTS to Mobile Switching Center (MSC) only in the case of inter-BSC handover and thus reduces the load on the MSC[32][33].

3.1. Integrated RAN and Distributed RAN

The RAN in 2G is called GERAN (GSM EDGE Radio Access Network) and it has an integrated RAN architecture. The communication between the analog radio processing unit and the digital baseband processing unit requires a high-bandwidth bus. This requirement of high-bandwidth data exchange resulted in an integrated base station in a single piece of hardware[31] in 2G. This integrated unit was installed in a big cabinet near to the base of the cell tower. Many such base stations were connected to a Base Station Controller (BSC).

The advancements in fibre optics technology aided in the implementation of a distributed RAN architecture in 3G. The analog and digital signal processing units were separated; the Radio Unit (RU/RRU/RRH) was placed closer to the antenna and it was connected to the digital signal processing unit called BBU (Base Band Unit) which was installed in the cabin near the base of the cell tower. Further, these base stations were connected to a Radio Network Controller (RNC). The 3rd generation RAN was named UTRAN (UMTS Terrestrial Radio Access Network). In 4G, the RAN is called Evolved UTRAN (eUTRAN) and it retained the distributed RAN architecture from 3G, but the BBU was directly connected to the core network.

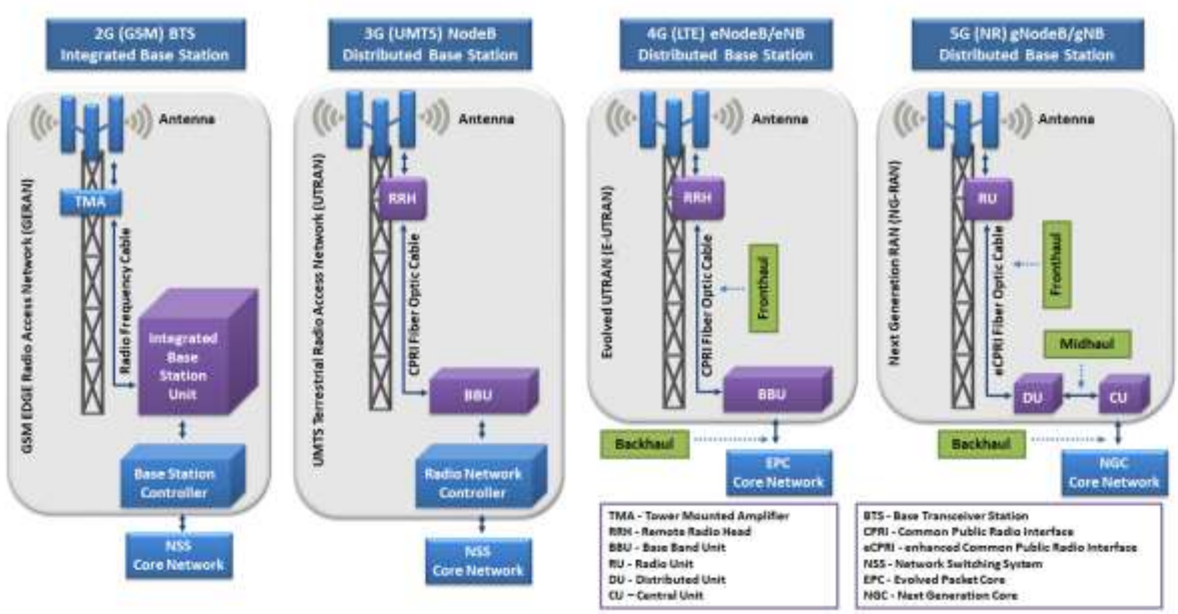

Figure: 4

In 5G RAN (Next Generation RAN) architecture, the RRH is called a Radio Unit (RU) and the BBU is split into two functional units called DU (Distributed Unit) and CU (Central Unit). The splits are made according to the functionalities in the lower layers of the OSI network model (Physical Layer, Data Link Layer and Network Layer)[34].The interface between RU and DU is called *Fronthaul*, DU and CU is called *Midhaul*, DU and the core network is called *Backhaul*. Note how from 4G to 5G, the abilities of a conventional Tech system integrator become valuable, in cloudifying or virtualizing DU or CU. This specific arrangement has been pursued in BSNL 4G Chandigarh demonstrator: with Tejas Networks being vendor for RRH + BBU, Evolved Packet Core (EPC) network by the indigenous Centre for Development of Telematics (CDOT), and internal services such as billing being handled by prime vendor TCS. This latter job will be evolved into virtualizing + cloudifying or edge-computing of DU and CU components.

3.2. Centralized RAN

In the traditional distributed RAN architecture, each RRH/RRU is connected to a specific BBU. In centralized RAN, the RRH will be placed in the cell site close to the antenna, but the BBU will be placed remotely in a building called the BBU Hotel[35]. BBU Hotels could be many kilometres away from the cell site. RRH and BBU will be connected using CPRI protocol via fiber cable. Multiple BBU nodes are placed in a single BBU Hotel and it enables dynamic computing resource allocation to the RRH units connected.

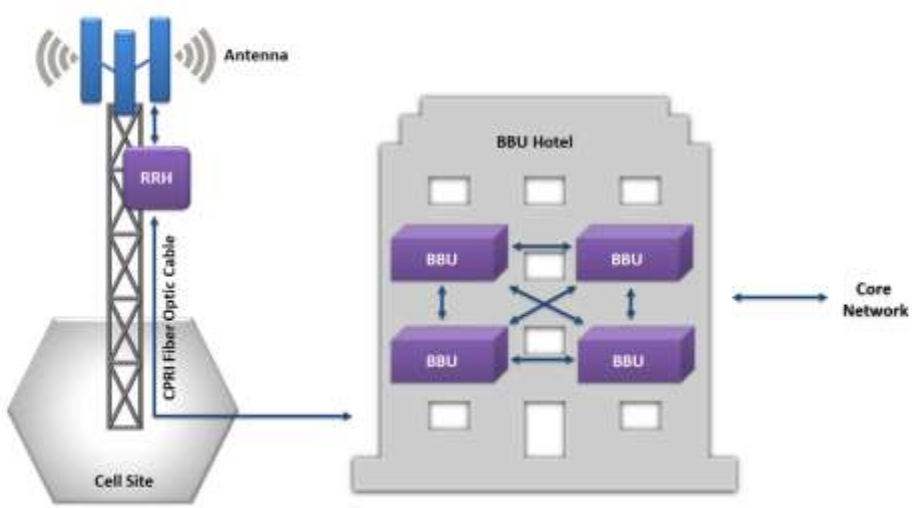

Figure: 5

3.3. Virtualized RAN

In traditional Base Station setup, each RRH/RRU belongs to a physical BBU which is built on proprietary purpose-built (closed) hardware and software from a single vendor - often the turnkey provider of mobile services as opposed to the mobile services brand or holding company. In Virtualized RAN (vRAN) aka Cloud RAN, the RRH is connected to a BBU pool deployed in the cloud. BBU pool has multiple BBU nodes which run baseband software on a general purpose (open) hardware (x86/ARM CPU based servers). The high-performance processing capacity is dynamically allocated by the cloud infrastructure based on the demand. This achievement is via virtualization, a common method of dynamically allocating computing resources to, say, enterprise application servers[36][37].

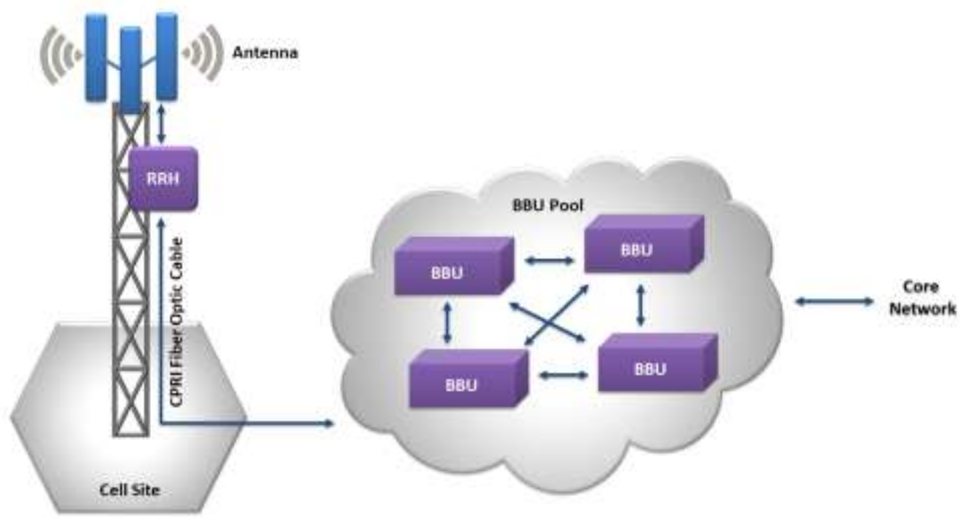

Figure: 6

In the cell site, only antenna and radio units will now exist and all baseband activity will be carried out from a centralized cloud infrastructure. Many RRHs can be connected to this centralized BBU pool thus reducing the cost involved in setting up individual BBUs, power and cooling units[38]. This also makes Antenna + RRH boxes available in compact kits to be placed in smaller cells called femtocells or picocells, often on favoured commercial premises - alongside other network-effect electronics platforms such as card-swipe machines.

3.4. Open RAN

Open RAN (ORAN) is the concept of introducing unified open standards in the RAN interfaces (fronthaul, midhaul and backhaul) to enable interoperability between the RAN elements from multiple vendors[39]. A system-integrator -led model for 5G networks will likely rely on ORAN in order to combine equipment or technology stacks from different vendors. Often, a diversity of vendors is chosen on account of geopolitical considerations (e.g. to avoid Chinese vendor equipment), or to ensure a combination of technologies that local system integrator expertise can put together (e.g. BSNL 4G pilot network executed by TCS).

Many key equipment vendors for mobile networks who earlier had turnkey contracts for mobile service providers, e.g. Nokia, Ericsson, and Samsung, have also come around to the possibility that future mobile networks will operate in ORAN mode. A preliminary project under ORAN, that of the BSNL 4G pilot network by TCS, has however demanded that 128 deviations be made permissible - likely a consequence of the ORAN unbundling and limited system integrator expertise to match pre-ORAN systems [51].

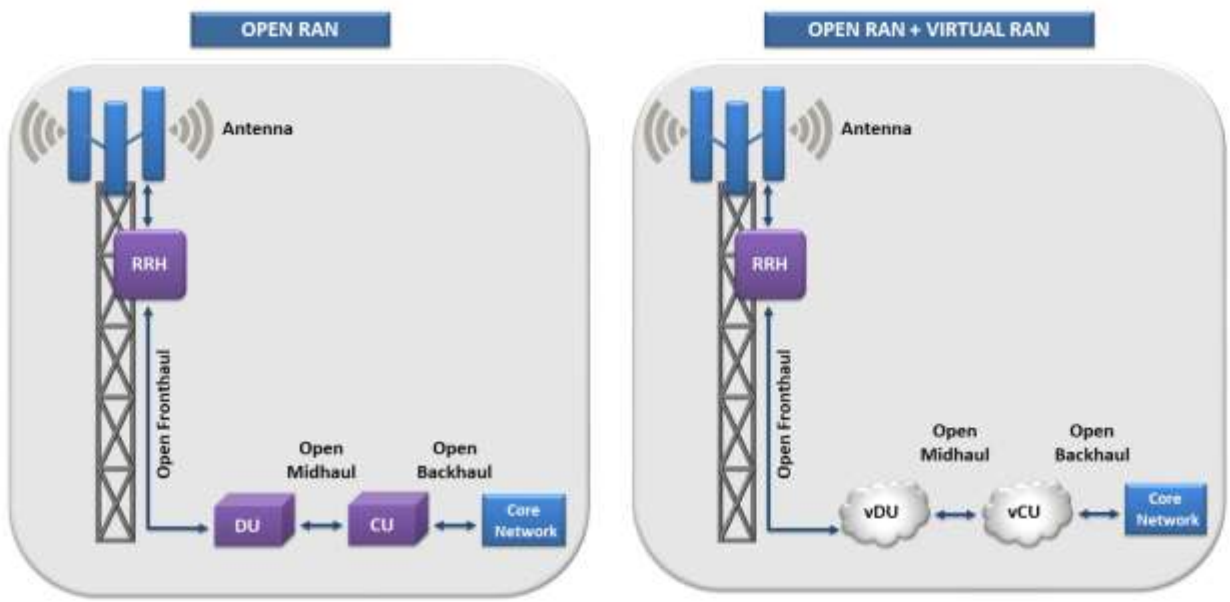

Figure: 7

ORAN in conjunction with vRAN can form a vendor neutral RAN, where the signals are processed by the RAN units (DU and CU) which are run on an open hardware with open source software and these units interconnected by open interfaces (fronthaul, midhaul and backhaul). Implementing ORAN and vRAN can reduce the capital and operational expenditure for the telecommunication operators. New entrants can come with their solutions and there will be more competition among the suppliers. India's 5G network implementation is expected to have the software and hardware solutions developed by local Indian companies under the aegis of 'Aatmanirbhar Bharat'[40]. RAN can be made more intelligent by adding a new network element called RAN Intelligent Controller (RIC) which brings in artificial intelligence and machine learning[41][42].

4. 5Gi Standard

India's own version of the 5G standard is developed by IIT Hyderabad, IIT Madras and Centre of Excellence in Wireless Technology (CEWiT). This Radio Interface Technology named 5Gi is developed inorder to expand the mobile connectivity in the rural area and to provide better coverage in high density areas. Media impressions in Jun 2021 indicated that Airtel (a large mobile services provider in India) and IT services firm TCS had tied up for a 'Made in India' 5G, though the same two companies are ranged across the divide as regards the recommendation for India-specific 5Gi (Aug 2021). The latter recommendation was made by TCS to India's Department of Telecommunications which also involved unprecedented open letters of support by faculty members of IITs[43]. It appears possible that the deviations requested by TCS in the BSNL 4G tender form part of the 5Gi proposal, although a clearer indication is about the following:

As mentioned in the earlier sections of this paper, the signal coverage of the original 5G standard is very low due to high frequency. The 5Gi standard is built on the concept called Low Mobility Large Cell (LMLC) which uses a new transmit waveform that can enhance the signal transmission range of a base station significantly by transmitting signals on the lower bands on the spectrum. This can benefit the service providers especially in the rural areas where it is difficult to build many base stations because of the challenges of geographical terrain. as the number of base stations needed is less and also the subscribers of the service especially in the rural areas because of the increased coverage area[44][45].

Existing 5G tests carried out by operators are on the mid band frequencies and the mobile devices available in the market which supports 5G also supports only these mid band frequencies, however currently these devices don't support the frequency at which 5Gi operates. The support for the 5Gi frequency band would need a change in the hardware level and the necessary software updates[46]. The 5Gi standard has obtained approval from the International Telecommunications Union (ITU), but is still awaiting approval of 3GPP - the international mobile services and vendors' body.

Even within earlier 4G tech, the system-integrator -led model is now in vogue for proof-of-concept in certain circles of the Govt-run Co. Bharat Sanchar Nigam Limited. Within this, the core network component appears to be awarded to C-DOT, with radio equipment from Tejas Networks, and overall system integration and services (e.g. billing) likely to be the responsibility of Tata Consultancy Services. Such an outcome was unlikely until indigenous Cos. were necessarily retained in the tender owing to terms of 'Aatmanirbhar Bharat' local manufacturing program, with turnkey vendors Nokia, Ericsson, Samsung and Huawei having to quit the tender - the latter for geopolitical reasons. Further, 4 SIs (L&T, Tech Mahindra, HFCL) also lost out due to inability to demonstrate Proof-of-Concept with Bengaluru-based PertSol's core network. This is in addition to reports on controversy surrounding 10s of deviations in network parameters requested by the pilot demonstration of TCS [51].

5. Conclusion

The world is moving towards the next generation of mobile communication called 5G, which claims to have higher bandwidth. India has also recently contributed to the global communication standard by introducing 5Gi which can cover a wider and rural area compared to 5G. Our description of satellite internet, LPWAN, 4G modifications suggests 5G adoption remains questionable for many use cases in IOT, as well in the face of copious adoption of 4G for human handheld devices that has occurred already. In addition, 5G's 'mobile-broadband convergence' advantage also applies to existing combinations such as 4G + WiFi-6E. It appears that network effects in base-station placements, esp. femtocells and picocells on urban establishments' premises, and resultant ancillary lines of businesses, are presently driving 5G operator enthusiasm - in addition to the 'penguin effect' that is colloquially captured as 'all dive or none does'.

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