ISSN (ONLINE):2456-5717
International Journal of Advanced Research in Basic Engineering Sciences and Technology (IJARBEST)
Vol.4, Issue.6, June 2018

Millimeter Waves - An Enabler for 5th Generation Internet of Things

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Abstract – **The future analysis of data connectivity shows that there will be a very great demand for internet connection. Already, with 4G on a go, there is unexpected level of data trafficking as many users are connected to 4G network leading to a spectrum crunch. There is also a great demand for IoT and the network capable of guaranteeing us with this facility. In order to meet this demand, we move to a new generation of networking- 5G. This paper illustrates, with few predictions, the strategy to be handled to establish the 5G network. The medium with which 5G communication can be made possible is explained. There are, of course, many issues to be handled before setting up the network. Most of the issues are provided with the solutions possible to be executed. These solutions, in this work, mainly deal with usage of millimeter waves.**

Keywords: **Data trafficking, 5G, IoT, Mobile communication, Millimeter waves, Spectrum crunch.**

I. INTRODUCTION

International networking (Internet) is presently controlling our lives. There is a great deal of things that we can do through internet. Conventional examples are listening to music, getting good education, watching movies and sports, establishing communication with friends and relatives and the likes. The list is now beginning to elongate rather uncontrollably. We are in an era where anything and everything can be done if we are connected to global networking, through mobile phones in hand and data connectivity in our mobile phones and this is making people use data more and more. Ultimately, there is a hike in data users. Here comes the necessity for the data providers to provide users with high data-usage speed and efficiency. This is assured to us by 5th Generation of data connectivity provider. Besides, internet is extending its capability to network with different electronic gadgets, leading to the concept called Internet of Things (IoT). For this to work, we depend on 5G. 5G IoT is going to benefit the world with many of its features and characteristics.

II. INTERNET OF THINGS

The Internet of Things is the international networking of things. It is a sort of connection amongst any physical electronic gadget we encounter. By "thing", we mean smart devices. They include mobile phones, tablets, personal computers, televisions, refrigerators, ovens, electricity supply system, biochips, vehicles and even traffic signals. Thus, IoT offers great connectivity to any possible device that is capable of being identified and integrated into a communication network.

This inter-communication can be brought into practice with the help of sensors and actuators. These sensors and actuators are installed in the electronic gadgets to be networked. These sensors provide very useful information which is uploaded to the internet. The internet uses this information to modify even our environmental situations. For example, if a biochip is installed, and it senses high blood pressure in a user, then its networking will allow this data to be passed, ultimately turning on a melody rhythm in the car or home audio system based on the user's location. This is possible also because of the sophisticated algorithms applied in software that the user uses, permitting the devices to operate independently. There will be no restriction to the place and the time of data abstraction. Consequently, any remote area can also be accessed, making this world a techno-hub. It is expected that 212 billion sensors would be connected to a network worldwide by 2020.

Simply, Internet of Things (IoT) can be defined as a network which allows independent communication amongst things (smart devices) capable of networking in order to improve productivity and efficiency effectively and thus, transforming our lives.

III. 5G AND ITS VISION

In simplest terms, 5G is the fifth generation of networking. It is the next generation of data connectivity provider, which is expected to support any device capable of networking. It is expected to make all the current data networks irrelevant. 5G is expected to satisfy the users with much luxury. Its vision is to provide the following:

- Extremely low latency of the order of 1 millisecond.
- Up to 90% reduction in power consumption of devices utilizing 5G.
- 100% coverage worldwide(consequently, remote areas can be networked as well)
- Comparatively high spectrum efficiency.
- A vast IoT, connecting billions of devices, efficiently at that.

Researches have been fruitfully carried out to establish 5G technology all around the globe in all countries and unions. Many developed and developing MNCs and companies are planning to construct devices to support 5G data as early as in 2020, since this technology can never be an analogy of the previous ones. This also requires new structural design of antennas,

on which research is also carried out, fruitfully. A result of these researches is that, 5G can work on millimeter waves of radio wave spectrum as is explained in short.

IV. HOW IS 5G DISTINCT AND UNIQUE

There are four parameters with which 5G can be shown unique and distinct in comparison with other generation networks. They are discussed, with each parameter showcasing the need for 5G and the greater efficiency and reliability with which 5G would operate when brought into use.

Speed and Latency:

Latency is defined as the time lag between the input of a command and the accomplishment of the command. The speed at which the command is processed is essential in determining the efficiency of a network. Present day mobile networks operate with a latency of 50 to 80 milliseconds. 5G aims at providing a latency of 1 millisecond. In layman terms, today's network is capable of downloading 5-12 megabytes (MB) in one second. However, 5G aims at downloading 1 gigabytes (GB) in one second.

By achieving this high speed, applications like virtual reality, multiplayer game and the likes will be productively developed in our own mobile phones. This speed is very essential in developing these applications. It is also essential in keeping pace with near future where internet of things (IOT) will cost our lives. For instance, if traffic control system is an element of an IOT, it will demand a great speed for execution of command. Under this scenario, if 5G does not guarantee a minimum of 1GBps, then the nightmare resulting will be beyond explanation or imagination, with our life in line.

Emergence:

Until date, there has been four generation of data connectivity, with each generation having its own positives and feedbacks. The first generation of was unidirectional. For instance, radios' beginning stage permitted only one way communication. Whatever said in the transmitting end was received in the receiving end. The second generation became advanced where connectivity was bidirectional. 2G was developed mainly to communicate over phones and cells. Later, 2G also adapted to providing data connectivity which was not very efficient leading to a pathway for development of 3rd generation. 3G provided very high speed compared to 2nd generation data connectivity. An even advanced generation, 4th generation-4G (actually 3.9G), is now operating with unimaginable speed and efficiency. Thus, any generation of connectivity until now has been an advancement of the prior generation. So, 4G is an advanced 1G (advanced radio system).

Unlike 4G, 5th generation has not evolved from the previous generation network. It is not an extension of 4G. But it is actually a vast network, which integrates 4G, Wi-Fi, cloud services, millimeter waves, EHF waves (extremely high frequency waves) and other accessible networks. So, 5G IoT will be a very vast internet, connecting devices like even mere fan or an induction stove. In short, 5G can be defined as a system that senses and collects data from billions of devices and transmits the computed information to the right device at right time after processing using right platform.

Connected Devices:

3G network initially supported only 15 to 20 devices within its access. Later it was developed and a comparatively large number of devices were supported. Then 4G gave way to support devices other than conventional tele-devices like smart-watch. With increasing number of users and devices, there is a need for one base station to connect to as many devices as possible. This gives rise to 5G wireless technology.

5G is expected to support nearly 50 billion connected devices and 212 billion connected sensors worldwide. These devices include any electronic gadget that we encounter in our routine, which may include cars, remote controlled devices, refrigerators, oven and even machinery. This way even the tiniest of devices would become a sensor controlled minicomputer, positively lowering the cost of devices and sensors. So, connection will be bound and unobtrusive. This connection ensures towing of these systems to the internet. This leads to the execution of any predetermined task without human interference (as in case of artificial intelligence).

For instance, if a refrigerator is networked to 5G and is initially asked to report on the vegetables in short storage, it will keep the user notified of the shortage if any.

Intelligence of Network:

The future of 5G is mainly characterized by its intelligence. The emerging field of technology, Artificial Intelligence (AI), is at a complete disposal of 5G. This AI will be used in 5G network in efficient navigation and decision-making. 5G network will have digital hubs which will act similar to a base station. The hubs are erected to handle the traffic flow of data packets. With too many devices tethered to a 5G network, there will be data packets which may face traffic leading to attenuation or superimposition leading to loss of critical information. This can be controlled by hubs employing AI at 5G's command. 5G's intelligence will decide which data packet should be transmitted first based on the user's priority. So, intelligent decision-making is guaranteed. By reducing the data packets to be transmitted at a time based on priority, traffic flow will be smooth ensuring efficient navigation as well.

This intelligence can be used to enable applications like driverless cars, robotics, interactive television and other applications. Thus, a 5G will stream information and requests and also manipulate them online based on the predetermined interests and preferences of the users.

For instance, traffic control system can be considered. At peak hours, if one wants to avoid traffic and choose a jam free path, then, map will be fed with that path's direction with the user's destination set and the user would be notified of the change in the route.

V. TRANSMISSION OF RADIO WAVES

Firstly, let us deal with digital data transmission. Any digital data is divided into a number of "packets". A "packet" is a frame which contains several memory bits of data based on the memory allocation of packets. Generally, data is divided into three groups of packets namely header, body and the footer. Header contains information such as the IP/TCP address of the sending and receiving devices and the number of packets involved in transmission. Body contains the original data. Here, any number of packets can be present. The footer contains end of data intimidation and the error-checking protocol. The data packets are then transmitted with the help of certain media of transmission like cable, waves or current. Then the header packet checks the address of the receiving device and chooses a base station based on the address.

But analog waves are transmitted by superimposing them on carrier waves of very high frequencies. The data is transmitted to the receptor through the base station.

A base station plays an intermediary role between the transmitter and the receptor. It is nothing but an antenna or any similar device. It takes data from the transmitting end and delivers it to the receiving end. This will take place only if the base station is fore-handedly connected to the receptor, and apparently the transmitter, so that there is no issue for a receptor to access data from the base station. This forehand connection is called channel access method and there are the following methods: Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA), Code Division Multiple Access (CDMA), Space Division Multiple Access (SDMA) and Power Division Multiple Access (PDMA). Any of these methods can be used, based on the efficiency of usage in different cases, so that the base station keeps track of the predetermined receptors connected to it.

So, now the header packet reaches the base station with its body and footer and is given to the corresponding receptor. The receptor, whose user gives permission to access the data and turns on the connection to the base station, searches for the data packets. The packets are randomly occurring so the receptor sheds much power in the data-seeking process and manages to intercept the data.

However, 5G is expected to support nearly 50 billion devices and 212 billion sensors worldwide. With these many devices connected to a network, there emerges a complication. This issue is called "spectrum crunch", which should be dealt with for efficient transmission of data.

Spectrum Crunch:

In order to understand spectrum crunch, we must know two terms "frequency" and "bandwidth". Frequency, as we all know, is number of cycles of a wave per second, measured in hertz. Bandwidth however is a range of frequencies with a lower (frequency) limit and a higher (frequency) limit. Any application provider, such as television, radio broadcasting companies, etc., has a unique channel assignment. 'Channel assignment' is a process which allocates a fixed bandwidth in corresponding channel to the transmitter and a receiver through a base station. As a result of channel allocation, the data in the form of radio waves can be transmitted to the correct receptor through the correct base station only if it has a frequency within the assigned bandwidth. Thus, the superimposition of carrier waves and data is a crucial process because only the frequency of the carrier waves, decides if the modulated wave, ready for transmission, can be passed to the receiver through the base station, keeping an account of the bandwidth assigned to the data to be transmitted through the modulated wave. This allocation is done in order to improve the spectral efficiency, (i.e.), to improve the amount of data that can be transmitted per second in a given bandwidth. This also prevents co-channel interference, (i.e.), the data cannot be intercepted by other bandwidth users.

Now, since several application providers market themselves, nearly all the frequencies used for electronic gadgets have been already assigned to different users. Consequently, we are running short of spectrum (range of frequencies available for broadcasting data). The shortage of spectrum is technically called "spectrum crunch".

Millimeter waves:

As already stated, 5G is expected to connect several billion devices and sensors. Already with 4G on a go, it will result in spectrum crunch. So with these many devices connected to 5G, there will definitely be no room for data connection in few devices due to spectrum lag. Researches have been carried out regarding this issue and many have come up with quite a few solutions. But none matches the efficiency and reliability with which millimeter frequencies of radio waves would guarantee us with.

For 4G we have been using radio waves whose frequency ranges from 2GHz to 8GHz. Extending further, we are about to use radio waves of frequency band ranging from 30GHz to 300GHz for mobile communication. With this high frequency range, these waves have very small wavelength of the order of millimeter. So, radio waves within this range are called millimeter waves. Since they have very small wavelength, they guarantee high frequency utilization. So these waves are also called Extremely High Frequency (EHF) waves. These waves

are presently being used in indoor video transmission with high quality and satellite communication because of short wavelength.

The disadvantages of using these waves are that they have short transmission lengths and they are vulnerable to the environment. This leads to loss of data in the midway of transmission and also, absorption of data spectrum by the rain drops or dust or air in the environment. The researches carried out by great companies conclude with some solution for these issues. The mm waves have not been used till date also because of the fact that only few electronic devices can receive and respond to these waves. But, now, as a result of technological establishments, devices which are capable of responding to mm waves without any deterioration in the construct and data are about to take up space in markets in near future, as is told by the researchers.

VI. CHALLENGES POSED BY 5G

Battery Performance:

As explained in the working, the frequencies of the radio signals are not directional but are scattered in all directions. They tend to direct themselves to the receptors based on the channel access methods. Thus, the receptors connected with the base station should emit signals such that the frequencies can be intercepted. This process is battery consuming. 4G radio waves are sparse and thus, the receptors accessing this network is more battery draining. For this reason, the receptor is provided with 4G along with 3G and 2G sensors so that the interception of different frequencies provides the user an uninterrupted network service.

However, with billions of devices connected to 5G network, things will become worse. The receptors will be lagging in the battery performance. To avoid this, the following challenging features should be developed:

- More spectral efficiency should be guaranteed, so that data service can be reliably utilized.
- Coordination between the base station and the receptors can minimize this issue, as there will be a good directionality of data developed by doing so.
- Features such as node sleep (switching off data connectivity if not needed), minimization of signaling of receptors when not in use can help the needy receptors in network detection and synchronization, thus lowering the battery shedding.

Behaviour with Environment:

Atmospheric conditions don't really support the progress of millimeter waves which is the basis of 5G. These waves are easily absorbed by fog, dust and smoke dwelling in the atmosphere. The resonant frequencies of certain molecular gases are comparable to the frequencies of mm waves. So, they are easily absorbed by gases. For example, at 60GHz, oxygen

is capable of interfering with mm waves and thus, absorbs it. (However, the satellite communication is well beyond the ozone. So, mm waves are successfully employed there). This poses a real problem to use the mm waves in long distance transmission, which is very much required for 5G IoT. Reliability can be re-established only by caution. For example, the channel allocation to the transmitter and the receptors can be banned for a frequency of 60MHz, due to interference from the oxygen gas. But this requires serious attention for better efficiency.

Dense Deployment Issue:

As we all already know, mm waves have very high frequency range. It turns out that their wavelength is low of the order of 1-10mm. Thus, these frequencies cannot travel long distances without data losses. The intensity cannot be maintained as well and fades away. Thus long distance communication becomes impossible. Besides, 5G is expected to support billions of devices and it also assures implementation of IoT. Thus, it is assured that there will definitely be numerous sub-networks and intra-networks. With the lack of distance coverage and dense deployment in areas, there is a need for numerous base stations and sub base stations. This results in need of mass erection of base stations and antennas. This may lead to an economic crisis.

Model Requirement:

One of the major issues regarding mm waves is that these waves cannot penetrate thick bodied things. They have issues of even penetrating a wall. Besides, these waves are randomly occurring in nature. But it is found that mm waves can be made directional. So, new models of gadgets need to be built. This model should act as a mini base station, to which few devices within close vicinity could be connected forming a mini IoT. The directional property of the frequencies can be exploited and the new models can be used to direct the frequencies to the devices in urgent need. These devices thus help to improve the battery performance and to utilize the spectral efficiency of the waves thoroughly. The design of such models is considered a big challenge.

VII. CONCLUSION

Everyone is now armed with a mobile phone with data connection. This results in an increase in demand for data-delivery-efficiency. 5G is sure to provide us with a solution to meet up with the demand. With 5G on a go, the LTE and other networks are about to become as irrelevant and outdated as 3G seems now. 5G promises "zero" latency, which is incomparable to the currently existing 4G network. 5G is also expected to come up with a solution to spectrum-efficiency management. The solutions to this can be brought by millimeter waves. Millimeter waves' uses are yet to be exploited. As far as until now, these waves have been used for different applications other than mobile and electronic devices' communication due to lack of

technological establishments then. But now, it is time for these waves to set up standards in the field of communication as well, which can never be matched by other electromagnetic waves for years to come. Basically, this standard includes setting up of IoT s, which is a dream for many great techno-startups now. Ultimately, establishment of IoT is sure to contribute in globalization towards which we have started our journey.

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Roopni Devanathan is currently a second year student, in the department of ECE in PSG Institute of Technology and Applied Research, Coimbatore. She is currently working in 5G communication and various ways of bringing 5G into effect. After millimeter waves, she concentrates in Orthogonal Frequency Division Multiplexing (OFDM), for Visible Light communication, which is currently used in indoor communication. The work is to establish outdoor and long-distance communication through MIMO OFDM for visible light communication. Her works are constantly accelerating into implementation. She also takes an active part in Researchgate community, following updates on any means of improving the efficiency of communications.