Evolution of Air Interface Towards 5G
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Lecture – 08
Requirements and Scenarios of 5G (Contd.)

Welcome to the lectures on Evolution of Air Interface Towards 5G, we are discussing the Requirements and Scenarios of IMT 20 20 that is 5G.

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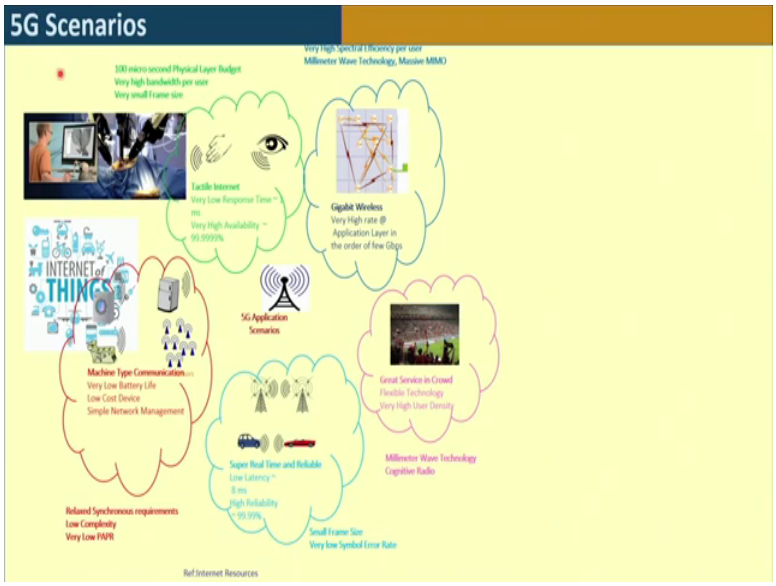

And in the previous lecture the last thing we were discussing is basically the scenarios, where we have summarized that tactical internet could be one potential situation, which needs to be addressed where remote surgery is one of the strong potential applications, which is the need of the day. And, then there could be machine type communications, there could be super real time and reliable requirements as well as, there would be a gigabit wireless scenarios and great service in crowd situations. So, let us take a look at some of these cases.

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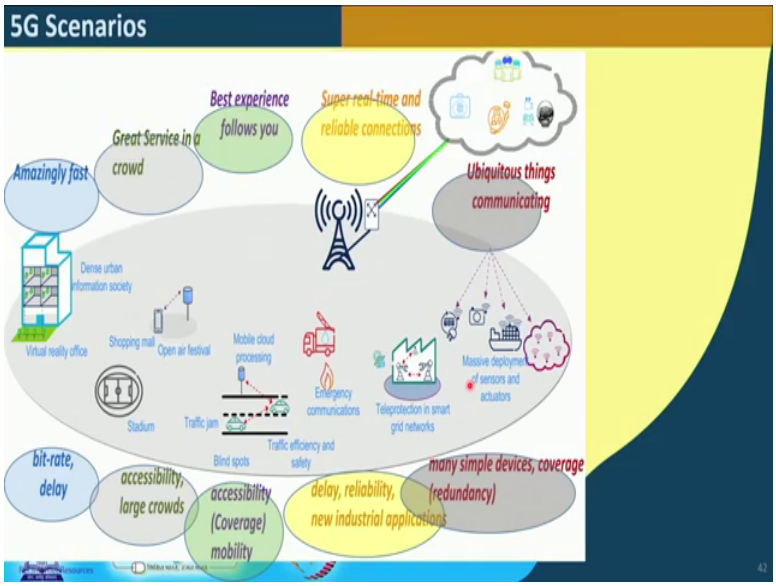

So, overall if we have a huge picture, which captures more or less all the scenarios that come into play and we categorize the different situations, we have on one end amazingly fast as the description of the scenario and which we could map down to a requirement on bit rate and delay. For example, if we have a situation which requires amazingly fast connectivity, the data rate would be very high as well as the delay requirement would be pretty stringent; that means, that very small delay with very high data rate, you have to provide connectivity.

A great service in crowd situation would effectively mean accessibility; that means, all devices are connected in large crowds. Then there was also at some point of time description about the best service follows you which is again a key word or acronym or a particular description from the industry, which would translate to accessibility, coverage and mobility. That means, while you are moving around and you have access from all situations in different mobility conditions.

Then there is like super real time and reliable connections, which would translate to delay reliability and which would apply to industrial applications, where there is control of production, machinery and all the kinds of things. There would be a requirement of ubiquitous things communicating; that means different kinds of things communicating, which would translate to many simple devices connected as well as this coverage is an important issue and redundancy in connectivity is also important.

So, there could be same kind of data going through while on one hand while on the other hand, you need to provide communication while not flooding the entire network. So, then there are different scenarios and which each scenario would translate to different requirements, we have seen a different pictorial representation earlier and this is another way of looking at a similar thing.

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So, like the gigabit wireless situation could be addressing work and infotainment, where there would be like a great user experience provided by data rate one could imagine virtual office scenario and many other situations. If we look at this particular picture as shown here it is kind of picture representing a dense urban information society.

So essentially, if we look at the density of connections in this particular environment and try to imagine the amount of data rate that could be required to be provided to the large number of users, it is a huge-huge challenge that needs to be addressed. So, situations like this are coming up it is a reality and everybody in this particular situation in this environment would like to have a same kind of service and a huge great experience at the same time. So, finding solutions to meet them is one of the focus of the fifth generation communication system.

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Great service in crowd; so, again these pictures highlight the situation of a shopping mall as over here and a stadium and an open air festival and an event. So, what we see is the crowd is huge that is very large number of people and almost everyone over here would like to be connected, while they are participating in a particular activity. So, here there could be infotainment as well as shopping and advertisement and many things going on. So, the user devices would have to be connected offers of different products and different launches would have to be given to users based on their location and their interest.

So this is one scenario, where you have a huge crowd while at the same time you have a heavy quality of service requirement. In stadium situations again, you see in a small area as well as in this there is a huge density of people around. And, although they are participating in a live event many of them would like to convey the information of the field off the field, while some of them would like to see a replay or a closer view of what is happening in the field. There could be more immersive experience like there could be multiple cameras around and taking different views and one would be switching from one view to another, could be seeing a particular operation or a particular event happening in one location of the field and so on and so forth.

So, if you look at this situation probably, this is more challenging than the other two and while these situations have advantage that there is some kind of an infrastructure available through, which you can provide service. But, on the other hand these

environments as you can clearly see are not going to be crowded throughout the day over here there are certain cycles over which the crowd appears then over a period of 7 days the crowd changes, while over a period of months the crowd changes. For example, before big festivals like in India, we have this Durga Puja and other of occasions before that there is a heavy presence of crowd in the shopping malls in sporting events, this happens intermittently this situation would happen once in a year and then once in a few years the crowd would be unimaginable.

So, providing great service in this kind of situations is not a easy task, whereas on the other hand the demand of users are increasing with time; that means, they are getting a better service in the previous year and they expect that at least that quality is maintained, while every year the crowd is becoming more and more and more. While for example, this situation you do not get to have this situation throughout the year, it is once in a year and probably one day and maybe only a few hours in a day. But, you require to provide the same service as if there were maybe 100 the 1000 or maybe 1 10000 of the population around over here in other times of the year.

So, designing a network which is flexible, which is scalable, which is able to handle these kind of situations, which is dynamic, which is reconfigurable and which is readily deployable to address these situations is a challenge, which is required to be addressed by 5G.

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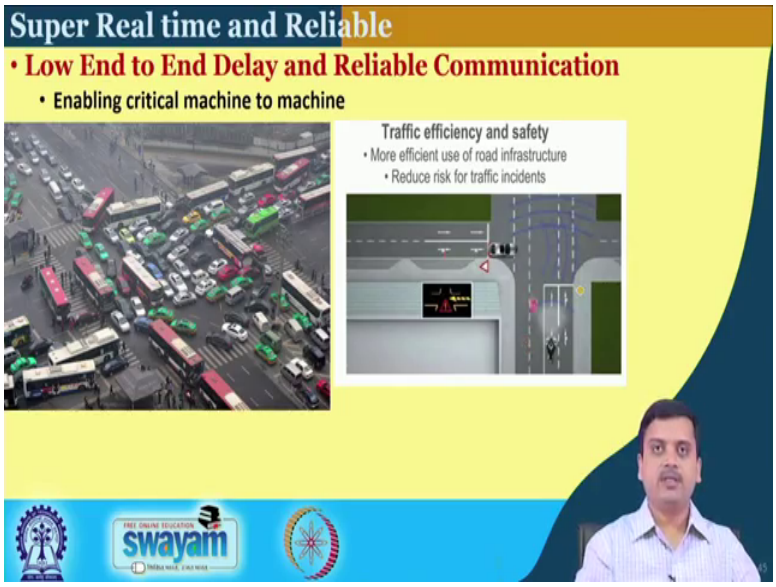

Other situation are like super real time and reliable communications like typical situation of traffic getting stuck or bottleneck in crossings although this is a much better situation, I mean typically things are much worse. So, had there been communication between the vehicles and the nodes around these crossings.

This entire traffic could be managed in a much more efficient manner and; obviously, among several things which get saved is fuel. And of course, we all know the heavy demand and price of fuel, which is affecting the entire economy all over the world, further the time that the users spend while traveling would be significantly reduced, if a real time communication between the moving platforms and the infrastructure is enabled which is finally, able to drive the traffic in the path by which the entire system is optimized like there are certainly certain stretches, which people like to use whereas, there could be another option at that point of time which is more beneficial for a particular user.

So, if there is a communication with the infrastructure and the traffic is controlled through a global connected network then such efficient or such advanced or better quality of a experience or quality of life can be delivered to the users and such situations could be easily avoided and you would end up in a situation, which is much simpler and more efficient.

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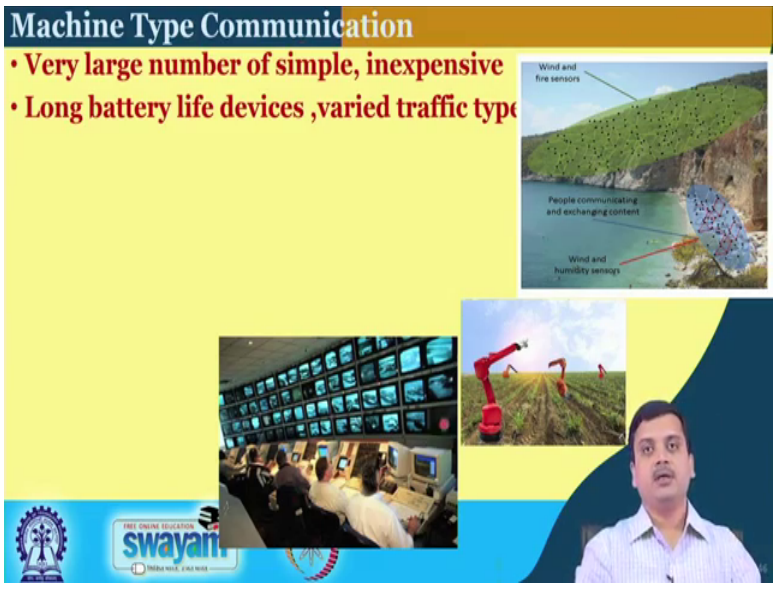

And in a massive machine type communication example situations; we have representative images taken from the internet, which shows that there are different kinds of requirements on one hand, which could be collecting information related to the weather, to the environment, to the biodiversity, which are not. So, often which is one way flow of information, there could be other situations would which would require actuators and control may be the farming operations as represented over here, sensors while these are being controlled from a remote locations.

Whereas, these situations which are capturing CCTV images of a huge event that is going on maybe there is a huge amount of data flow from one direction and on the same time, you may require to process this information and take control action on the other side. So, in these 3 situations, what we see is that there is a significant difference in the kind of traffic that is flowing while here there is intermittent low data signal going in here it is bidirectional, whether it is control information has to come in here it is kind of single direction.

But huge amount of information which may require to flow, but the common thing is there could be a large number of devices, which are connected. Here, it could be situation, where there is redundant data and you would not like to replace, I mean take care of these devices very often, you would like to deploy and let them run. Here the energy may not be an issue and here you would you can probably provide energy on a daily basis. So, there is again different requirements or scenarios in terms of energy, in terms of data rate, in terms of traffic flow, which need to be addressed under the category of machine type communication again 5G is expected to be flexible enough to provide support for these devices.

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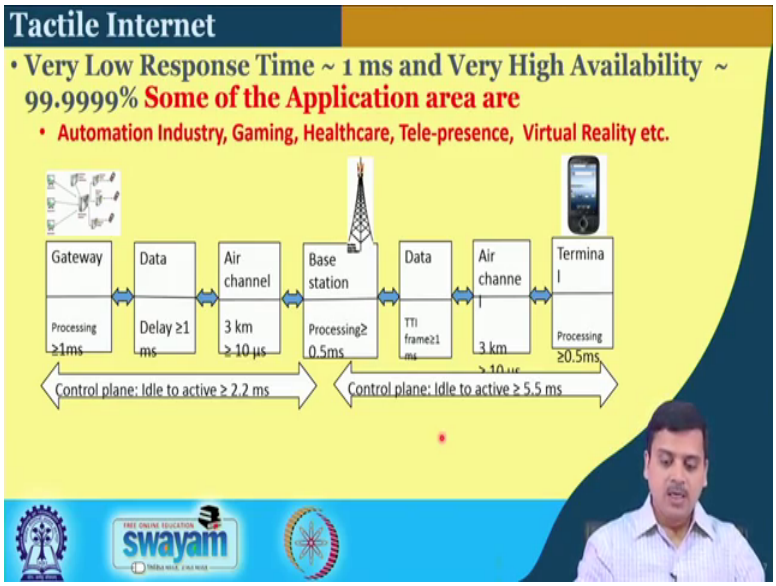

When we look at the tactile internet situation So, here a response time of less than 1 millisecond is required, while very high availability is required, if we look at the typical flow of information from the core network to the user terminal, we will find that the overall delay is significantly large it turns out to be in orders of a few milliseconds up to 10 milliseconds in present day network. So, I mean there could be a processing delay in just propagation processing delay at the base station then there is a basic frame structure and there is again processing at the user terminal and then the entire process has to repeat in the reverse direction then only some activation can happen.

So, if we want fast control this entire loop, if it is required to be processed within 1 millisecond, you need to change the different parts altogether, you need to reduce the propagation time, you need to reduce the processing time. And, hence in turn you need to reduce the ttis or in terms in other words, the frame duration which would rather result in changing of the symbol duration and if the symbol duration changes that could result in a significant growth of the bandwidth so; that means, if you have to make symbol duration smaller the bandwidth would become larger, if the bandwidth occupied by the signal becomes larger then the effects of the multipath fading would come in that would mean that which was previously experiencing flat fading condition and the receivers were designed to operate in a very simple manner would now have to be completely changed.

So, what we are trying to point out is that such requirements although, appears very simple is not so easy and straightforward, if we look into the breakdown of the details and if we try to crunch the entire time, there is significant impact on the overall physical layer signals, which needs to be completely changed and thereby affecting the entire technology in a significant manner.

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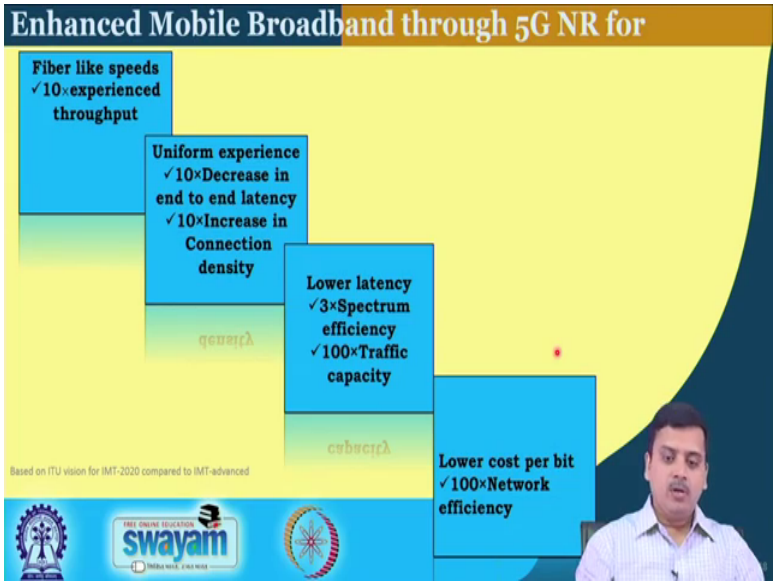

So overall, what we see is a that in the next category that is a enhanced mobile broadband, which is again another scenario as has been has been described earlier, it is expected to provide fiber like speed; that means, almost like wire line speed, which is 10 at least 10 times of what is experienced today uniform experience.

So; that means, when we are connected to wire line usually there is less fluctuation in the quality of service compared to wireless scenario, we will see of course, and many of you already are aware that in wireless scenario the signal strength fluctuates with time and space. So, we would like to have a same quality of service at different situations, unlike wire line in wireless as we have seen the connection density can also be different and the different new applications that are coming up. So, you would like to have uniform experience under all these conditions in the category of enhanced mobile broadband, the latency is a lower latency is expected higher spectral efficiency is required to be supported and huge enhancement in the traffic capacity is supposed to be supported

again, because of the multimedia services that are going to come in are expected to be more reach in content.

So, overall there is a huge scaling up of all the demands or the all these parameters that are existing today under this category. While at the same time whereas, your bits per service are increasing one would not like to increase the cost. So, in other words, if you have to maintain even the same pricing then the cost per bit has to be lowered significantly and that can be done, if the efficiency of the system is increased by a huge factor.

So again, under this category there are lot of demands that are to be met and hence lot of challenges that have to be catered by the fifth generation system.

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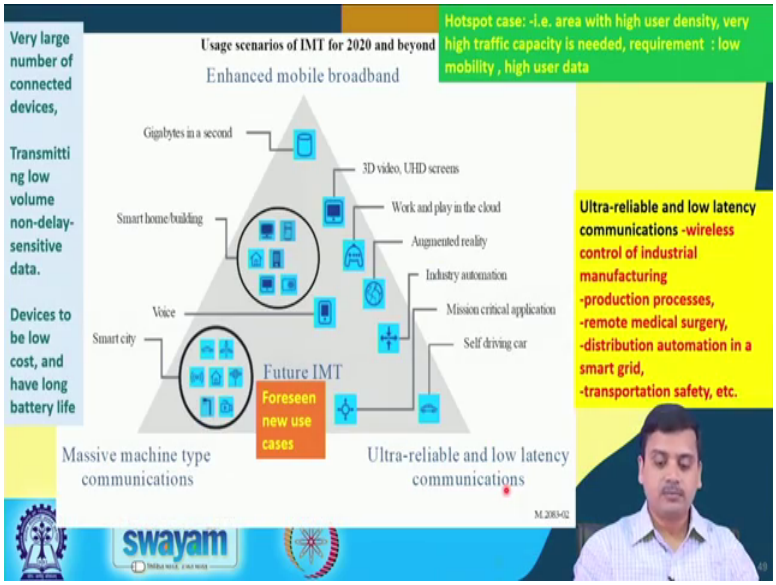

Again as we take a look at this picture, which is in 2083 M 2083 itu document, which captures the 3 environment, which you have been talking about, there is massive machine type communication on one end of the spectrum, there is ultra reliable and low latency communication on the other end of the spectrum and enhanced mobile broadband on the other end of the spectrum.

So, these 3 are the prime are scenarios, where you have variety of applications coming up as has been given in the particular description. So, what we see in the enhanced mobile broadband in the hotspots case that is the area with high user density very high

traffic capacity is required and low mobility with high user data rate. So, I mean that is a classification or description of one of the scenarios whereas, if you look at ultra reliable low latency situation applications would be control industrial control in terms in case of manufacturing let us say, an automated factory production process, remote medical surgery, distribution of automation in a grid and transportation, safety, etcetera.

So, there is a significant difference in the kind of requirements and services in these different operating scenarios. In case of machine type, we have been saying there would be large number of users connected and they would be transmitting low volume, non delay sensitive data and devices are required to be low cost and having a long battery life. So, this is the overall picture, which captures the different scenarios that required to be supported by 5G.

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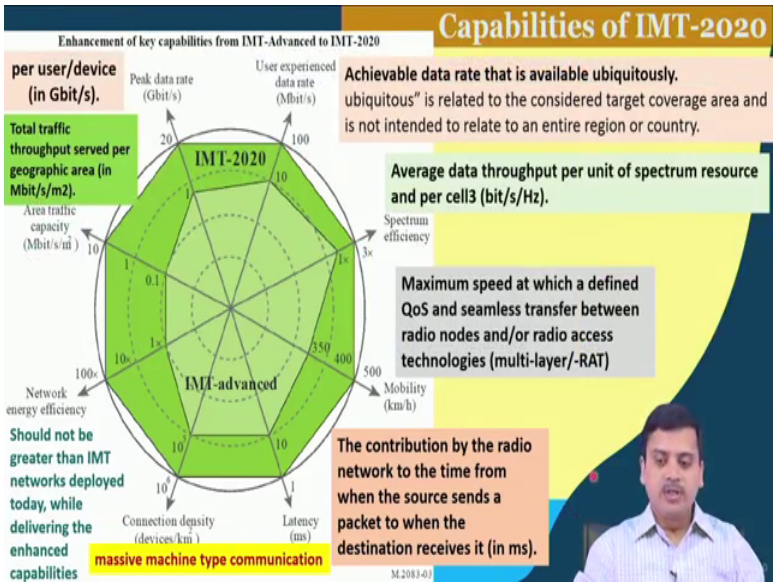

So, in this picture we have summarized all the things that have been that we have been discussing and again this particular picture is present in M 2083. So here, what you see is that the outer radius and the different points describe the IMT 20 20 requirements will again go through them further and this inner one is the IMT advanced requirements.

So, as we have said the spectrum efficiency requires to be 3 times that of the previous generation system, we can clearly see that indicated in this figure and the network efficiency is required to be 100 times that of the previous generation system, the area traffic capacity has to be 10 compared to 0.1 that is a factor of 100 again over here, peak

data rate has to be significantly large and so on and so forth. So, what we see is that there are different requirements and these parameters, which have been existing before required to be simply bloated up that is what this particular diagram brings out.

So, for example, if we look at over here the achievable data rate that is available ubiquitous is what is the user experience data rate and throughout our discussion whenever this ubiquitous term comes in it is actually meant and to describe that the target coverage area and not intend to relate an entire region or a country.

So, whenever we think of ubiquitous, it is wherever there is coverage the entire coverage area has to have ubiquitous coverage. Now simply in wireless just because of path loss the user, who is closer to the transmitting station gets a better signal to noise ratio and hence can access a higher data rate whereas, users who are far away from the transmitting point experience a lower data rate. Now it is desired that this discrepancy is as low as possible and enhanced by virtue of different mechanisms, which can be introduced.

So, I mean here again when we talk about mobility it defines about it talks about the maximum speed at which a defined quality of service and seamless transfer between radial nodes or radio access and multi layer radio access technology that can be supported ok. So similarly, different things are described and can be referred to you as these slides would be given back as coarse material.

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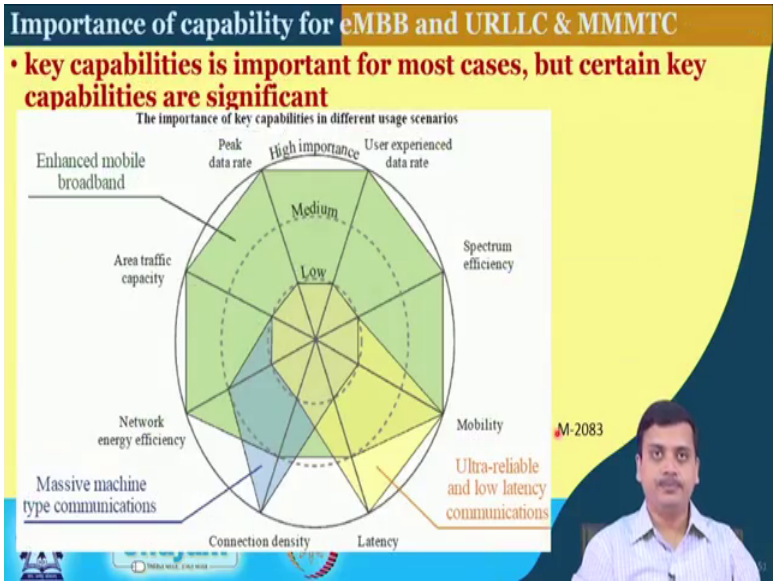

So, in this particular figure again from M 2083 the importance of capabilities of eMBB and URLLC and MMMTC are described. So, what you see is this particular sector, which describes the ultra reliable low latency communication situations. So, here what is required that latency demands are very stringent, in the massive machine type communication what we see is that the connection density is required to be stringent. Whereas, when we look at the enhanced mobile broadband service, we see that network efficiency, traffic capacity, all these parameters are required to be important.

So, broadly speaking the enhanced mobile broadband act uses a few set of parameters which are more important for it whereas, massive machine type has a different parameter or capability which is important for it and URLLC is another has another important parameter, which is very very critical for it. So, that is how these different scenarios have come up and when you talk about a particular scenario with this picture, you can clearly identify what are the important metrics that are relevant for the particular connection then a particular scenario.

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So, the other capabilities are of course, flexibility, reliability, resilience, security and privacy and operational lifetime.

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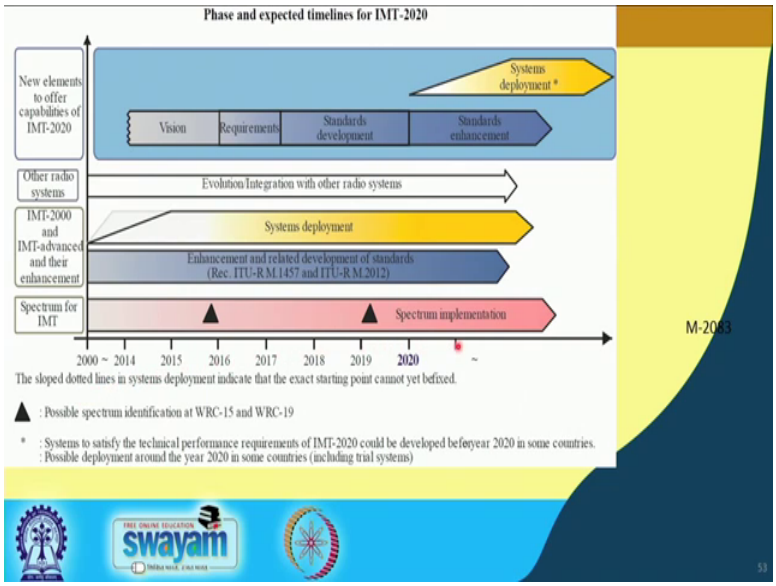

So, these are also added requirements as described in it and in this particular figure it basically, shows the timeline of how the IMT 20 20 has been developing over the years.

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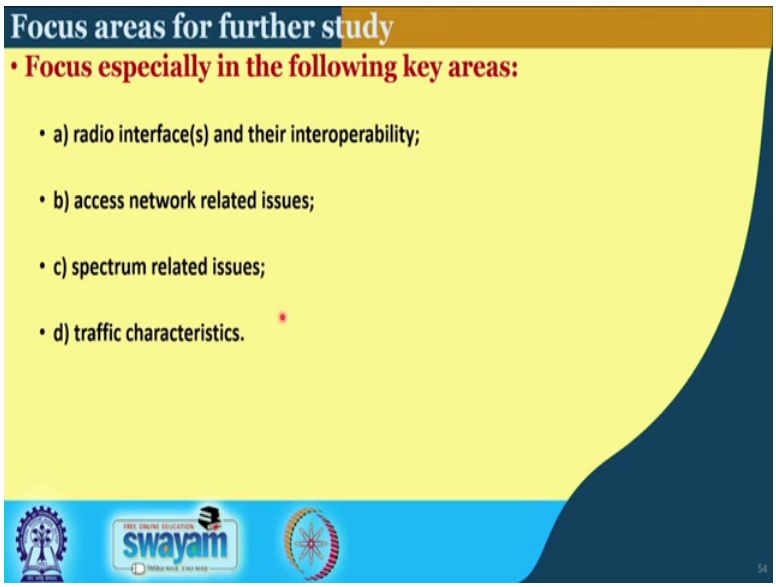

So, this also suggests that the focus area for providing the solutions are in the radio interfaces and the interoperability access network related issues spectrum related issues and traffic characteristics. So, what we can see is that the solutions that are supposed to be looked at are primarily driven by the traffic, while most of the solutions lie in the air interface or the radio access technology, which is the main focus of this particular course.

And, this is this statements as have been put down over here are essentially statements put down by ITU suggesting the different areas, which one has to investigate in order to find solution towards IMT 20 20.

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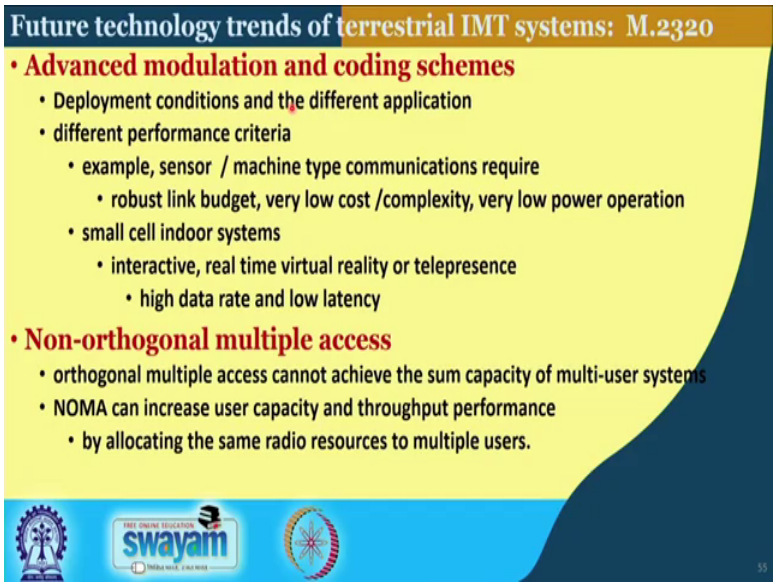

So, the technology trends as has been identified by 2320 are advanced modulation and coding schemes, which we intend to also discuss and they will be influenced by the different deployment conditions like machine type communications, small cell in the systems, etcetera. It also talks about non orthogonal multiple access, which we again aim to discuss in this particular course, because non orthogonal multiple access has the potential to achieve becomes some capacity, which the orthogonal multiple access cannot achieve.

So, all the orthogonal multiple access is a much easier to implement and can be easily deployed the NOMA system has a potential to improve the capacity requirements over non orthogonal multiple axis and we have seen through over the previous few lectures that the connection density is very becoming a critical requirement, the data rate is becoming critical requirement. So, we have to find mechanisms by which these can be enhanced and at least two methods have been identified and we aim to discuss this in the upcoming lectures.

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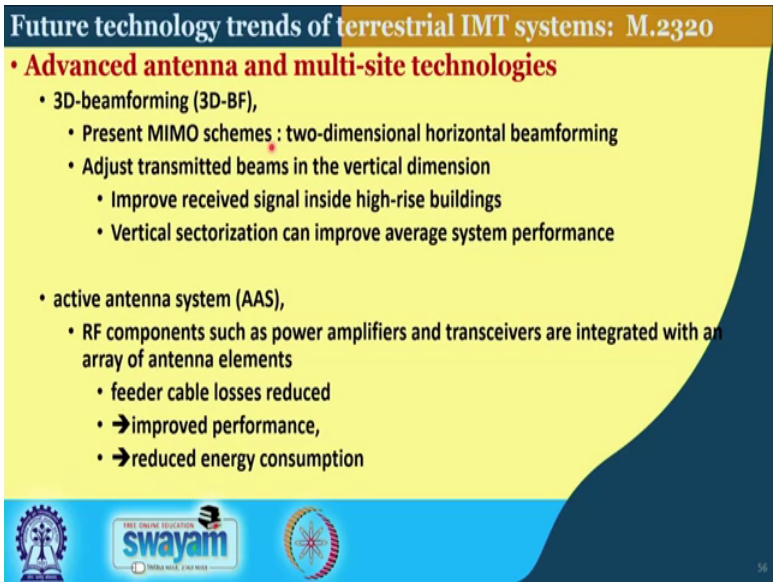

Advanced antenna systems and multi site technologies are also expected like 3D beam forming. So, this was as described in M 2320 and we also aim to discuss them active antenna systems. So overall, this comes under the category of multi antenna, while on one side there is a specific enhancements of MIMO schemes, while on the other side it talks about the RF components such as power amplifier transceivers are integrated with an array of antenna elements. So, thereby providing improved performance and reduce energy consumption. So, this is more of a realization of a particular mechanism whereas, here what we see is, there is a lot of signal processing advancements that have to come in order to provide these.

Now, with the 3D beam-forming what it says is that as there will be high rays buildings then if one can provide a 3 dimensional sectors then there is even more aggressive reuse of the other spatial reviews of the frequency, which earlier had been restricted to the two dimensional plane. Whereas, now it will be in the 3D and with more precise beam-forming one could provide better coverage to indoor situations in a dense urban situation in a scenario.

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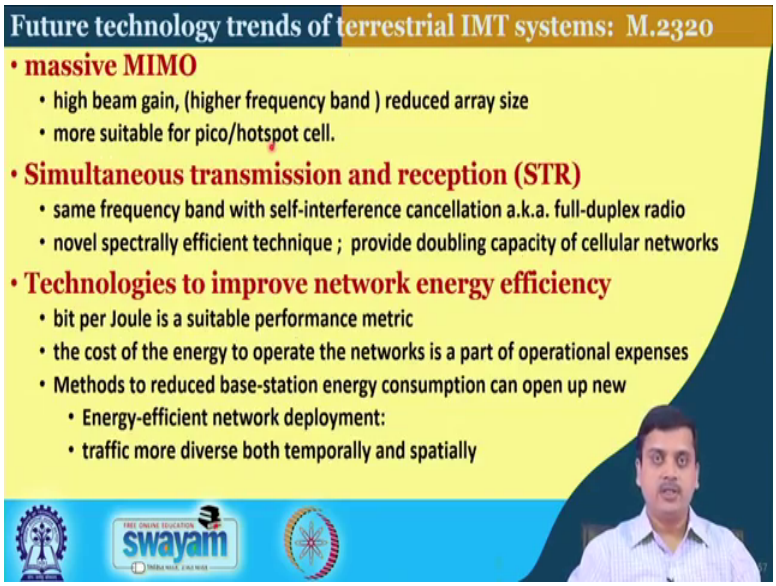

Massive MIMO is again one of the technologies, which are expected to provide support towards meeting the different requirements. Because, with massive MIMO one can get high beam game maximum essentially talks about providing very large number of antennas and interestingly the newer spectral bands, which are expected to be used are the ones where the wavelength will be much much smaller, thereby the spacing between the antenna elements are expected to go down even further.

So, if that is going to happen then within a small area, one can plug in a large number of antenna elements. So, if we go to the millimeter band; that means, 30 gigahertz, 60 gigahertz then a large number of antennas can be packed into a small space and if that can be done then we have very large number of antennas, which at one point was called large MIMO systems. And, now the common terminology is massive MIMO systems, which can provide very high gains in terms of beam forming as well as spectral efficiency, which we also plan to investigate in this particular course.

So, technology is to improve network energy efficiency at some earlier stage, we said that energy is a very important point it should be taken into account. So, bit per joule is a suitable performance metric and the cost of energy to operate network is part of the operational expenses and methods to reduce base station energy consumption can open up new energy efficient network deployment and the traffic this is primarily, because the traffic will be both diverse in temporal and spatial domain. So, if that can be exploited

then probably a huge amount of energy can be saved, which will again see towards the end of the course.

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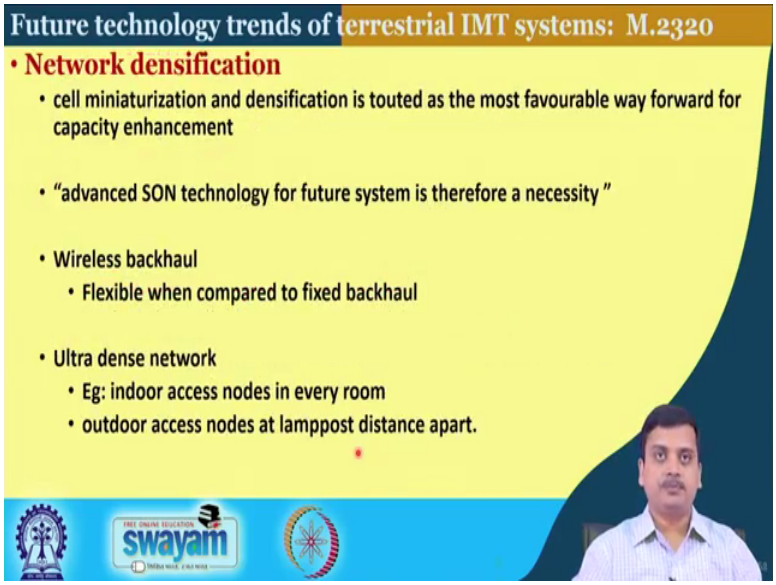

Network densification is of course, we have mentioned that it is one of the ways to increase the spectral efficiency. So, a cell miniaturization is a one way and that is what is happening. So, you have more and more closely packed based stations and when you have them then managing the manually is almost not a feasible task. So, the self optimizing network methods are expected to be operating. So, that these can coordinate amongst themselves and choose operating parameters and maybe handover act as relays and probably coordinate and do many many things, while at the at the same time the ultra dense network are also expected to come in.

So, they all are expected to operate in a hand in hand manner and they also go hand in hand if it is a dense ultra dense network making SON that is self optimizing network is a natural way of doing things. So, they are expected to operate together and provide a better spectral efficiency support more connection density and a larger traffic.

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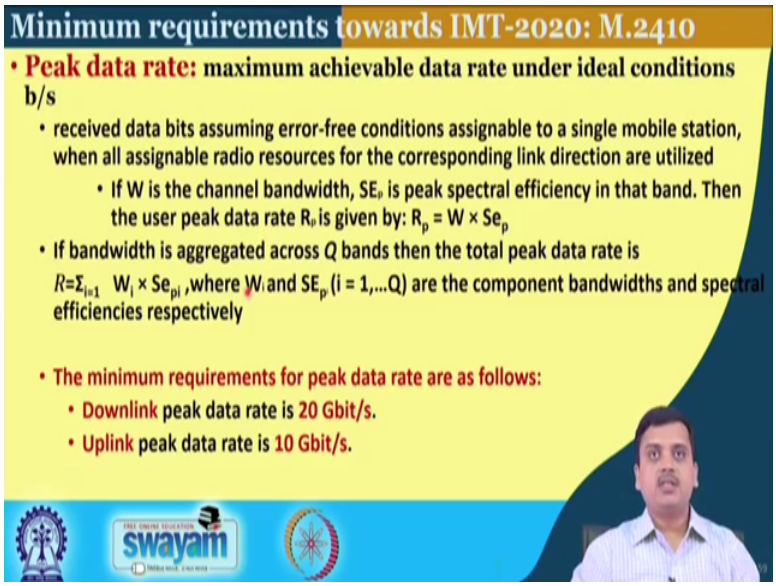

So, with this we stopped this particular lecture over here, in the upcoming lectures we will specify the minimum requirements of IMT 20 20 and thereby setting the ground for looking into the technological solutions, which we expect to meet those basic minimum performance requirements.

Thank you.