Evolution of Air Interface Towards 5G
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Lecture – 05
Evolution of Wireless Communication Standards from 2G to 5G (Part – 4)

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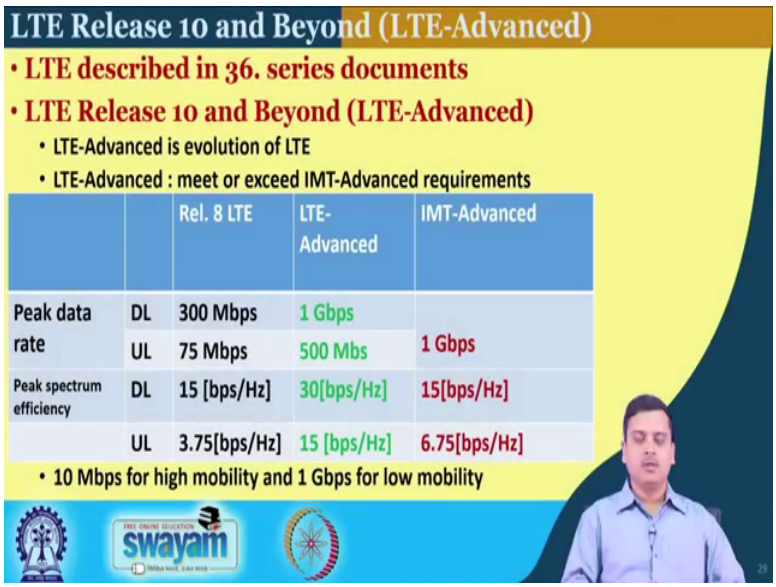

Welcome to the next lecture on evolution of air interface towards 5G. In the previous lecture we have seen the different requirements for 4 G and have also seen some of the capabilities by which it could achieve the target. And what we have summarized in this particular slide is the requirement from ITU which is given under the heading of IMT advanced and on the left the LTE advanced which is the 4G radio interface technology. And it is as can be seen and was discussed in the previous lecture that it meets the requirements of IMT advanced and hence it is a 4G technology.

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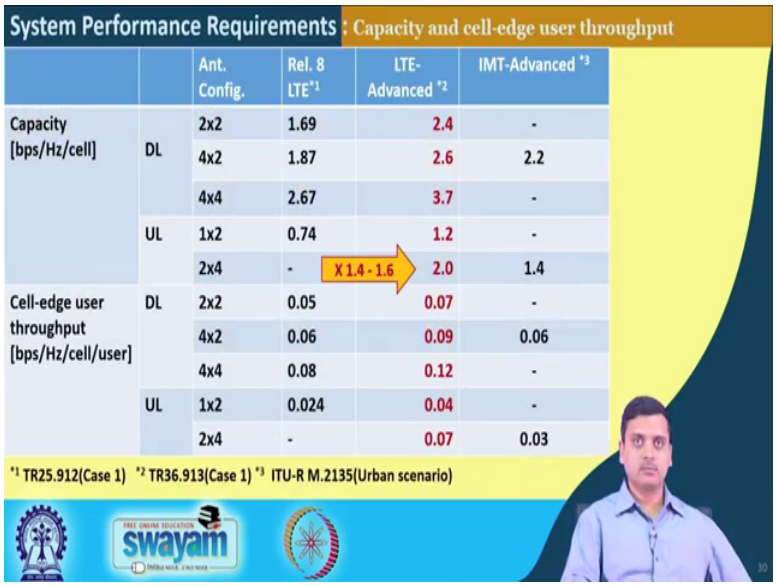

So, in this particular slide now what we have is the cell capacity that is bits per second per hertz per cell which we have described earlier and I have compared them for IMT advanced and LTE advanced.

So, what we clearly see is that the requirements are quite nicely met and are actually exceeded in this case and how these have been evaluated are actually described in these series of documents where we have said earlier that M-2135 describes the scenario. And in this the urban scenario has been taken for these set of results and the 36 series of documents have been used to describe the LTE advanced systems and the case 1 for 25 series document has been used in this particular one. What we see over here is that factor of 1.4 to 1.6 is the increase in the bits per second per hertz per cell as we go from LT to LTE advanced and they are able to meet the IMT advanced requirements.

The cell edge throughput which again we have described in the previous lecture which presents or which describes the bits per second per hertz per cell per user or which could also be taken as the 5 percentile point of the area spectral efficiency. So, there we see again the numbers which are exceeding the requirement, hence this particular technology is an IMT advanced compliant technology.

So, there are many such results which are available through which it can be seen that LTE advanced meets the IMT advanced requirements.

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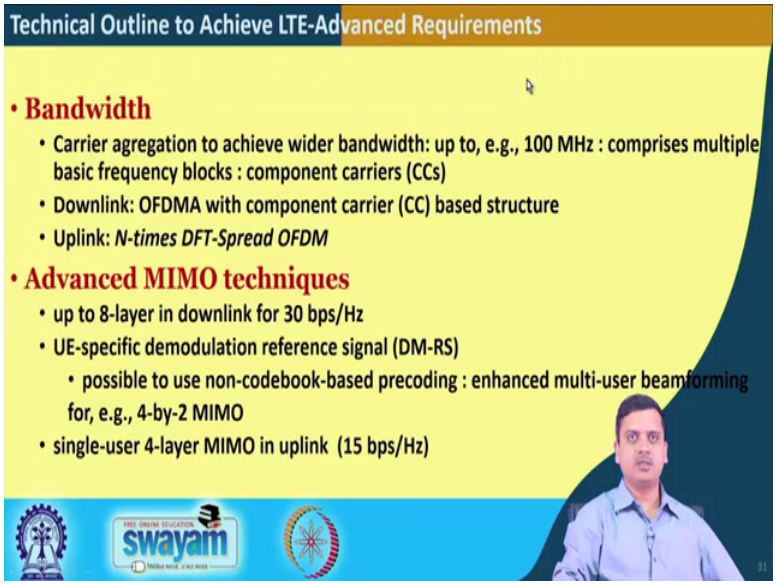

So, now we look forward to the technical outline to achieve the LTE advanced requirements. So, for that what we see is that in terms of bandwidth up to 100 megahertz which comprises of multiple basic frequency blocks or component carriers can be used.

So, this is an enhancement. So, as you increase the bandwidth you can clearly enhance the data rate. So, this directly contributes to the data rate enhancement in downlink OFDM a with component carrier based structure is used and in uplink the DFT spread OFDM which is used. So, these are again well described in the IMT advanced technology, will also oversee through them when we are discussing the details of the waveforms as things move towards 5G.

In MIMO up to 8 layers in downlink for 30 bits per second per hertz is doable. So, 8 layer means 8 spatial streams so; that means, simultaneously 8 data streams which operate on the same time and frequency are accessible in downlink. So, they multiply the (Refer Time: 04:13) data rate by a factor of N or here it is 8, further there a UE specific demodulation reference signal. So, when you have such reference signal then it is possible to use non codebook base precoding.

Now, code book based precoding are the ones where you have predefined code books and you choose the best match of the codebook with respect to the channel conditions whereas, if you use non codebook based; that means, you can derive the code book or the

antenna weight vectors which are complex in nature. So, as to match the output signal from the transmit antenna to the channel in the best possible manner and you can use them in a multiple ways like whether you go for beam forming or you can go for special multiplexing. So, it is there is provision to do such things.

In a single user 4 layer MIMO in the uplink is feasible. So, in the downlink it is 8 layer in the uplink it is 4 layer allowing it to achieve 15 bits per second per hertz. So, as increase of factor of two happens over here from 4 to 8 you can see that the same increase is applicable in the from the uplink to the downlink. So, these are some of the specifications or technical parameters by which LTE advanced is able to meet the IMT requirements.

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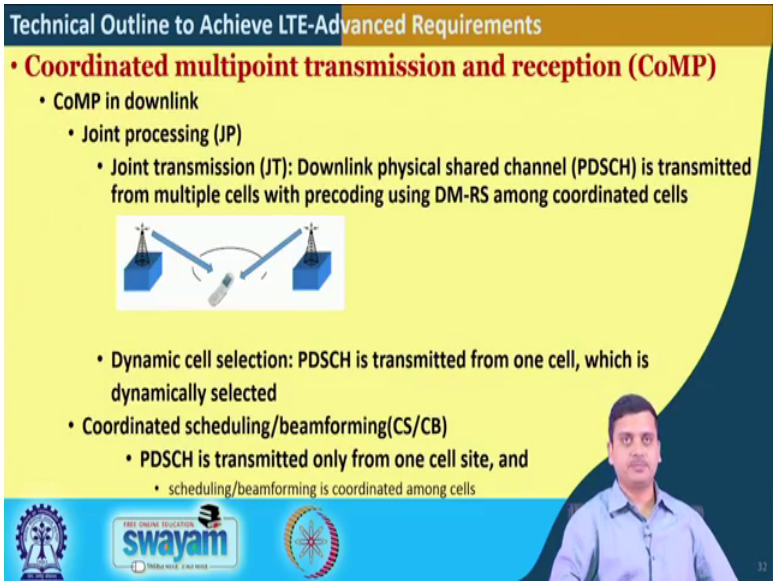

Another important technical solution which is supported known as the coordinated multi point transmission and reception. So, in this there is joint processing mode which is allowed so; that means, joint transmission that is the downlink physical shared channel which carries the data is transmitted from multiple cells with precoding using the demodulation reference signal among the coordinated cells.

So, here there are different base stations which coordinate amongst themselves and they can send signals so as to provide the best spectral efficiency to the user. Then there is dynamic cell selection, also there is coordinated scheduling and beam forming. So, here

the PDSCH which has been described here is transmitted only from one cell side and scheduling or beam forming is coordinated from the other cell side.

So, basically from one cell you transmit the data and from the other cells they manage the interference by knowing or having information about the scheduling information from the other cell.

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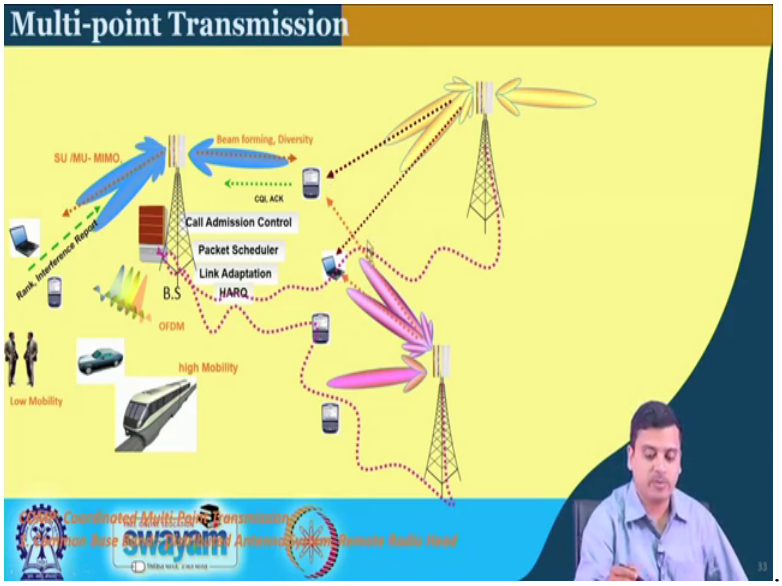

So, pictorially what we can see is that one base station with multiple antennas enabled and beams formed in different directions. So, they will communicate with the different users via several such prior procedures which enable the communication and along with it there could be other base stations nearby and they would be connected. So, there is this central processing unit.

So, that they can send signals to the user equipment especially those who are towards the edge region which are supposed to get interference from nearing base stations. So, instead of getting interfered they rather send signals in such a manner that they exploit the channel properties as well as the architecture of the network and instead of having a worse condition they rather enhance the users capability and the experienced quality of service by this mechanism.

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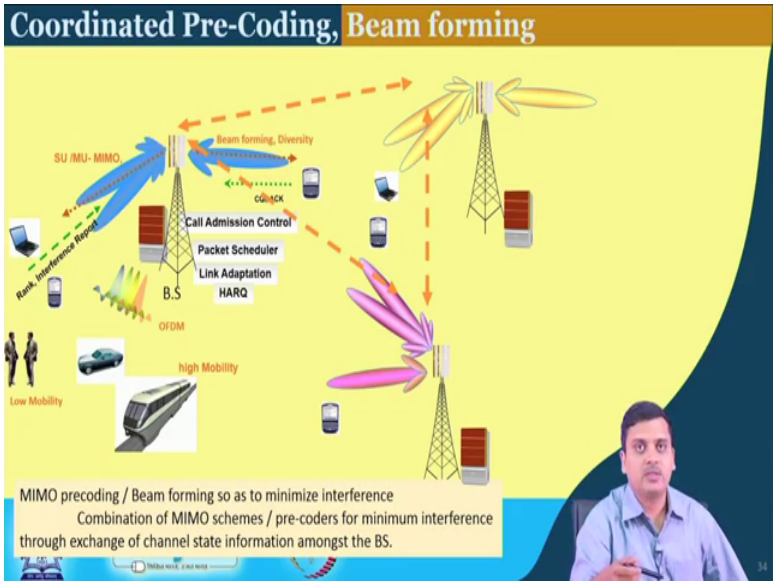

In the coordinated precoding or beam forming one of the base stations communicates with the user and the other base stations the coordinate amongst themselves so that they can choose the precoding weight matrix in such a manner. So, that the users experience minimum interference from co channel transmitting base stations and the weight matrixes are chosen in such a manner that after post processing at the receiver there is maximization of snr or as well as the capacity.

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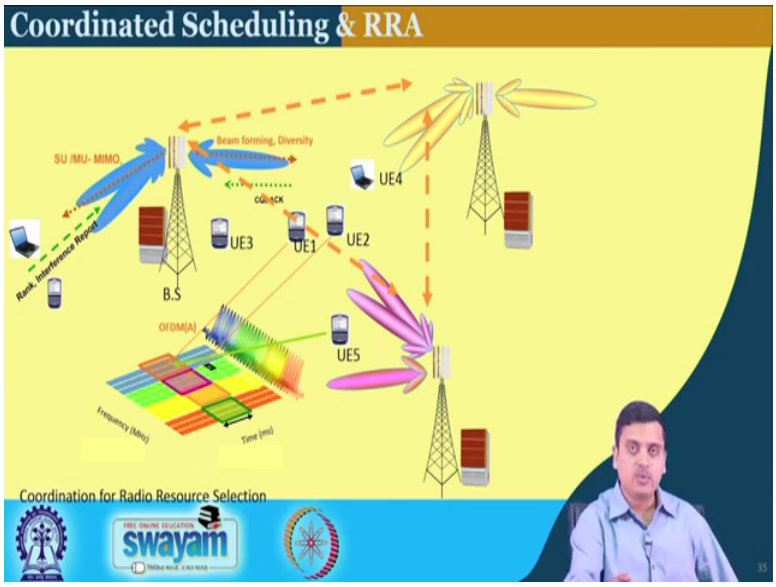

So, in coordinated scheduling these are the time frequency resource grids. So, when they communicate with each other the base stations they also dynamically choose the resource block along with the weight vectors that are to be used so that the optimized or maximized spectral efficiency can be achieved in this manner. So, there is heavy amount of signaling that undergoes between the base stations, but usually one of them communicates with one of the units, there are many such details which are there in the in the IMT advance system rather the LTE advanced system and as we progress we will see the different mechanisms.

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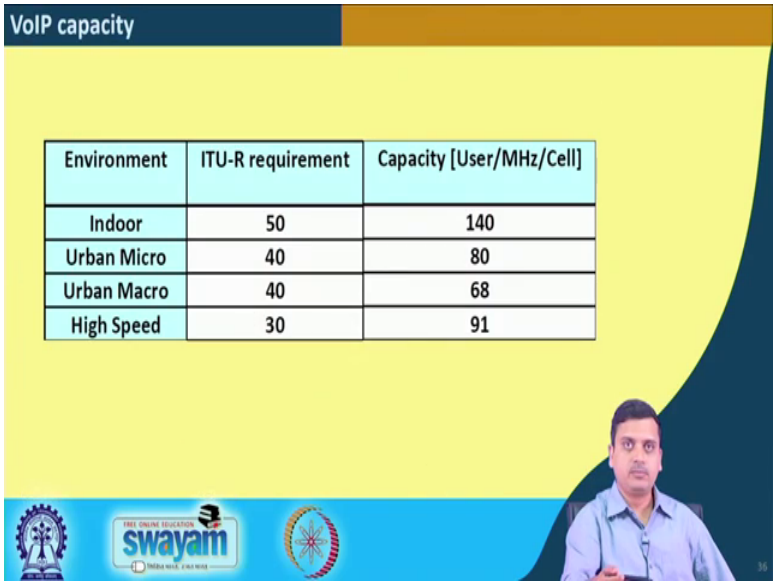

So, now let us take a look at the VoIP results we had at an earlier point discussed about the ITU requirements. So, if you evaluate the performance in one specific case these are the VoIP capacity of number of users per megahertz per cell that are supported by LTE advanced. So, what we see there is a clear cut exceeding of the requirements of ITU-R so; that means, ITU-R as it was said was the minimum set of requirements and these numbers clearly show that in different environments in all cases this technology is able to meet the ITU requirement.

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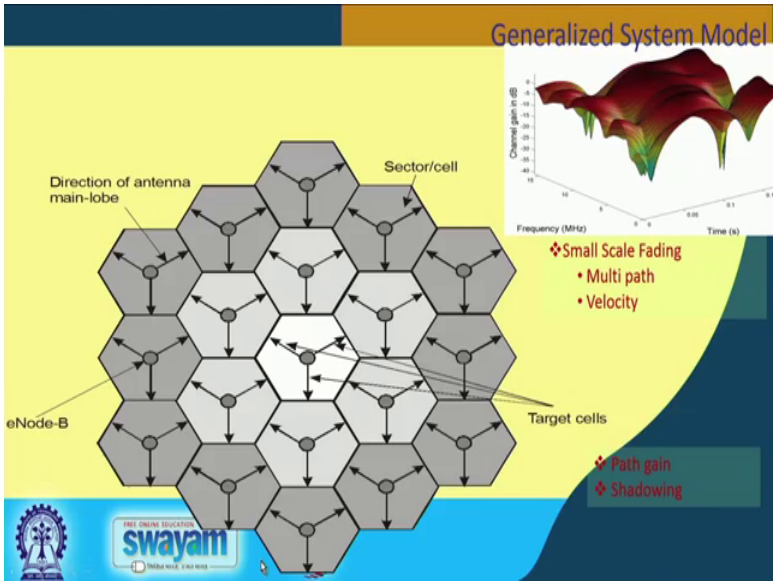

So, in this particular picture we try to depict the overall process of how things happen. So, in this particular image on the top corner what we have is the frequency and time grid along this axis and this axis represents the channel gain. So, typically in a wireless channel you have the channel strength fluctuating across the time frequency grid as can be seen over here. So, this is the channel strength in decibels it is an indicator figure and this keeps on changing with time.

So, its it is a snapshot of the random realization of the channel and you have the hexagonal cell layout, now this is for evaluation purpose and you have nineteen cell layout with 57 sectors. So, and you take your desired cell as the one in the center while you have interference from all other neighboring.

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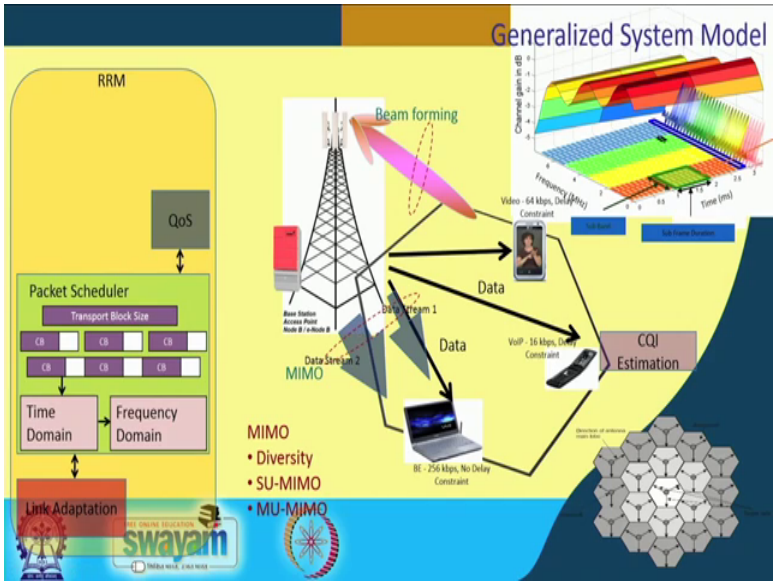

And then you have the resource block while each of the resource block sees different channel conditions.

Now, each user will see such different channel conditions in the desired cell and there will be heavy interference from all the neighboring cells, the base station communicates with the user equipments with reference signal. They demand different services simultaneously and they send back the channel quality indicator which is a representation of the kind of links that the users experience based on the input that the base station receives one of the primary activities which is does is link adaptation and packet scheduler, we have briefly talked about these things earlier.

So, when this packet scheduling happens transport block size or dividing the packets into smaller segments code block segment CRC all these things are done at the base station then followed by time demand scheduling, then frequency domain scheduling. By time domain scheduling what is meant is the packets are differentiated in time domain so, that different requirements can be met for different users and by frequency domain it takes advantage of the fluctuations along the frequency axis so as to allocate the appropriate resource block to the appropriate user.

Along with that there is a selection of MIMO mode whether it is beam forming whether it is special multiplexing and that to codebook based or all kinds of decisions are being

made based on the feedback of channel conditions and accordingly communication begins.

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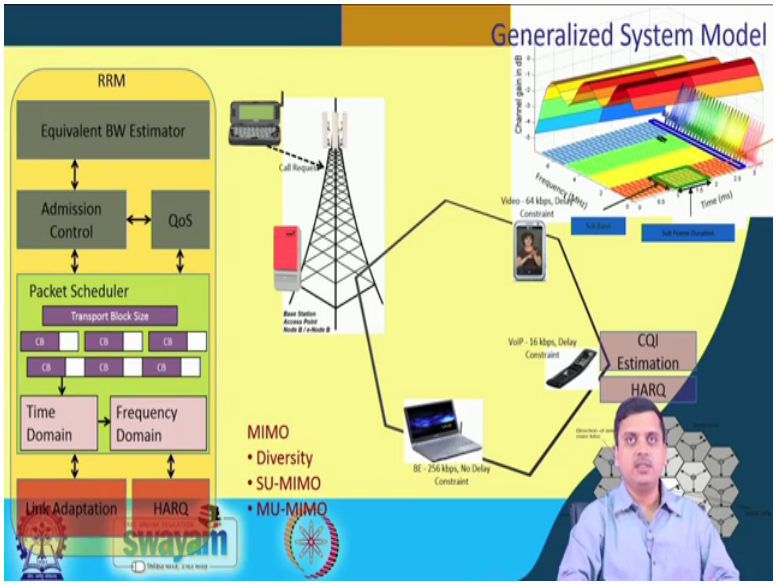

So, all this is to ensure that the users QoS is satisfied then there is HARQ mechanism we have earlier talked about it that is hybrid automatic repeat request and all these features are used along with the admission control and QoS management.

So, what it means is that the high level mechanisms of admission control and QoS management do consider all these events that are happening at the lower layer. So, huge java not exercise goes on in order to provide the huge data rate or the capabilities that are provided by LTE advanced. So, what we can also see is that when things move beyond 4G to 5G such situations are not only going to remain, but going to escalate and things are going to become more and more complicated in order to meet the newer and more challenging requirements.

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So, in this discussion we start our requirements and operating scenario analysis of IMT-2020 or 5G. So, far we have discussed about the previous generations that is the second generation the third generation the fourth generation that is IMT advanced and now we are at the doorsteps of talking about the fifth generation given our basic understanding of what prevails and so that we can compare and see what new things are going to come up.

So, in this discussion we will look at the requirements of IMT-2020 also traffic prediction and the operating scenarios. Now this is a very crucial because when we talk about the traffic prediction because this is one of the early activities that usually happens. So, when we have a traffic requirement being projected that will give us an indication of what is the change that is required to be done for example, if there is a huge growth in traffic and we know that there is a certain limited bandwidth that is available. So, given all the new technologies that get developed, we can more or less predict given the bandwidth what is the maximum spectral efficiency that can be achieved. Now given the bandwidth and the spectral efficiency you can naturally compute the maximum data rate that can be achieved.

Now, if this data rate that can be achieved or which is technically feasible is less than the traffic predicted, the next important thing that you need to look at is higher spectrum or more bandwidth in order to meet the requirements otherwise the requirements cannot be met. So, the first step is requirement analysis which talks about the requirement then also

traffic prediction as well as operating scenario. So, when we discuss operating scenarios things will be clear. So, together we will find that they describe or put in the problem or the question that needs to be solved.

So, when this kind of question is well described then we can look at the different technological solutions which can help us meet the different objectives that have been set up.

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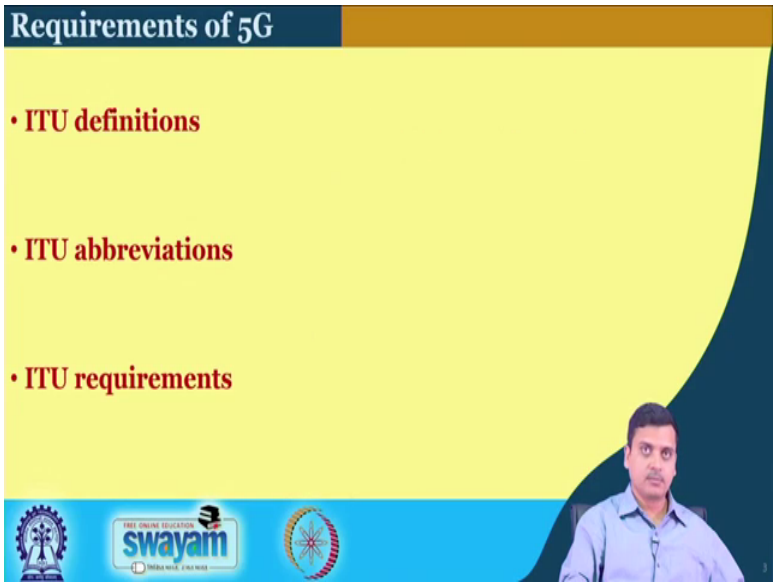

So, in this we will cover ITU definitions, because as we have done earlier we will also have a few definitions and abbreviations and requirements. So, mainly it will be the abbreviations which we will be looking at in this particular discussion.

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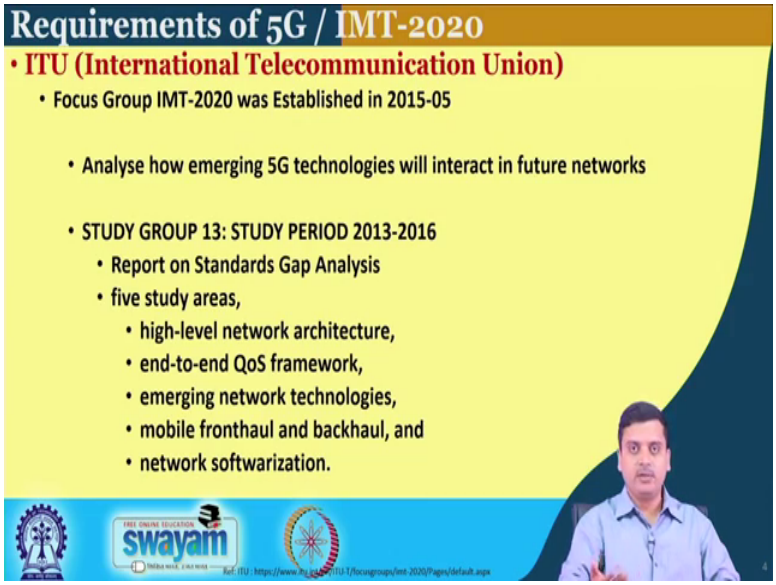

And let us begin with the requirements of 5 G as has been the topic. So, ITU started off with a focus group on IMT-2020 in around 2015 and the task was to analyze how emerging 5G technologies will interact with future network. The study group 13 was there in the period 2013 to 2016 which prepared a report on the standards gap analysis; that means, there is a certain amount of requirement there is a certain thing that the standard provides. So, how much extra that needs to be done and it provided results in the 5 areas of the study that is high level networking architecture, what should be their end to end QoS framework emerging network technologies mobile fronthaul and backhaul as well as network softwarization.

So, these this particular document is available in ITU website and just as a side note for all these parts that we have been discussing I would urge that you look up the ITU documents which we have mentioned earlier and they give you pretty precise description and. In fact, we have taken things exactly from those documents because they are uniform set of documents which we can refer to and which is referred globally.

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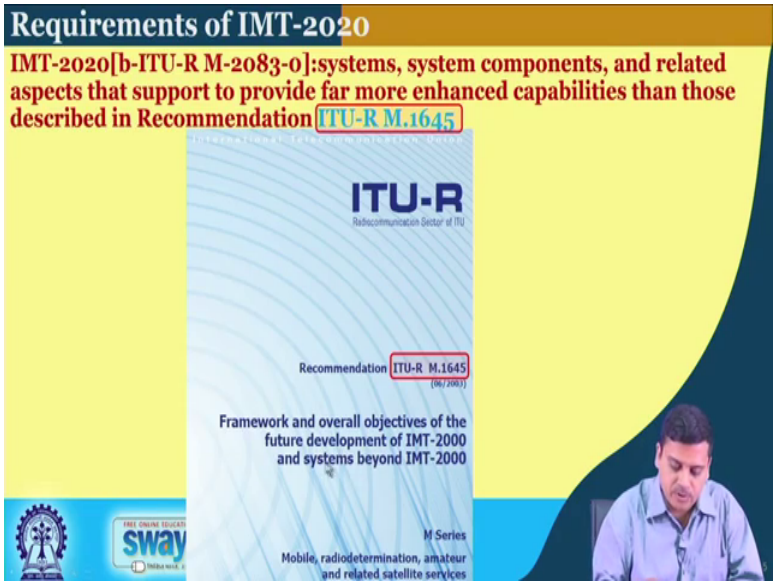

So, the IMT-2020 which is described in the document M-2083 it is the systems and system components and related aspects that support to provide far more enhanced capabilities than those described in IMT recommendation M-1645. Now what we see is that M-162545 is framework and overall objectives of future development of IMT 2000 and systems beyond IMT 2000 right. So, beyond IMT 2000 is basically IMT advanced.

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So, here we have the ITU M-2083 which is the IMT vision the framework and overall objectives of the future developments of IMT-2020 and beyond systems ok.

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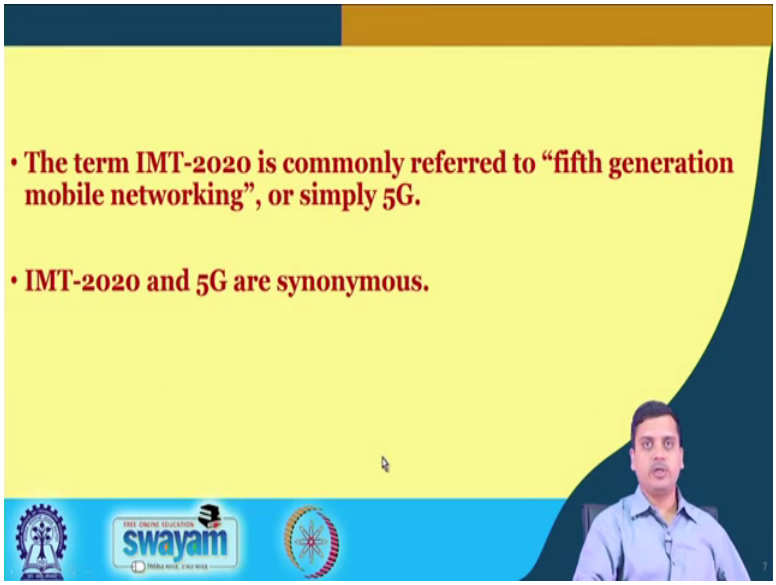

So, we are going to follow primarily this particular document and here as we have been using the term there is a very clear cut statement that the term IMT-2020 is commonly referred to as the fifth generation mobile networking or simply 5G. So, this is a very clear cut statement. So, whenever we use the term 5G we are inherently referring to IMT-2020 and vice versa. So, basically they are all synonymous terms.

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A brief list of abbreviations. So, more or less because we might encounter them so it is better to have them very clear ICT is pretty well described over here, IMT we have been

referring to. IoT is again a very common term so it is internet of things M2M indicates Machine to Machine. So, whenever we encounter M2M what we will mean is that it is machine to machine communication.

MIMO which we have referred already is well known Multiple Input Multiple Output QoE is essentially Quality of Experience, QoS is the well known Quality of Service, RAT is Radio Access Technology and RLAN is the Radio Local Area Network there are many more, but I found them to be pertinent so I have just put them over here.

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So, the document begins with a command and which we would all agree, is that mobile communications is now intricately tied to the socio economic fabric of the modern generation human beings.

So in fact, it is not uncommon to find a lot of emergence of notes. In fact, videos which describe about the menace this particular system has created, but we are here to discuss about the technologies which can provide them and we would always desire that this technology is used in the right sense. But what is true that our everyday life is now enabled through such communication systems only a piece of working warning that we should not get addicted to such system beyond our needs.

So, the tight coupling between mobile communication systems and socio economic trends are expected to continue beyond 2020, 2020 is going to come in near short terms,

but probably we are going to get matured and things might work differently, but at least this trend which has started is going to be present. In fact, it is one of the technologies on which our modern day life is almost dependent on and it is also foreseen, it also states that it is also foreseen that there will be more traffic volume. This is one of the interesting things which we will explore and more devices diverse requirements we will see all of these things better quality of user experience.

So, that is to be supported better affordability because with more affordability there is more proliferation and if there is more proliferation then there is more enabling of different kind of services as well as administration and many more things and will require an increasing number of innovative solutions. So, this is a very important for technologists and researchers especially an students that as your requirements come up and as they evolve with time you have a lot of opportunity to be creative and produce many new solutions.

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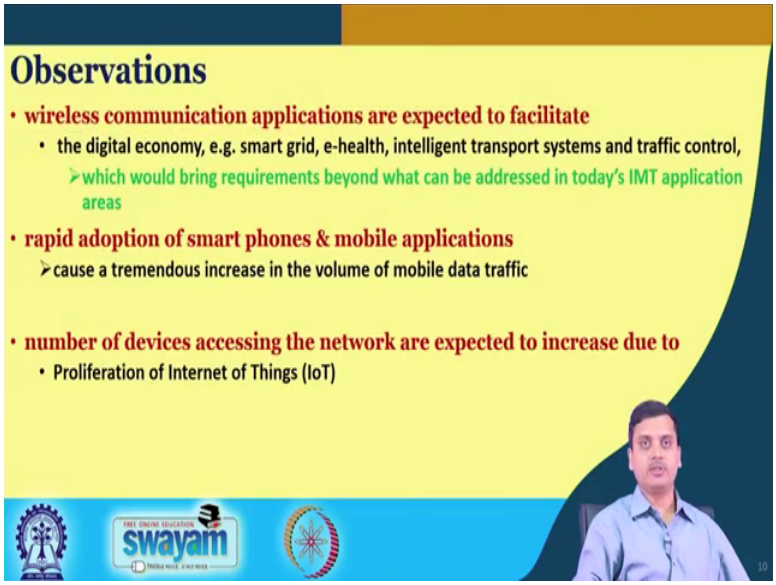

Further observations are that the wireless communication applications are expected to facilitate digital economy which we are already seeing further smart grid, e-health, intelligent transport systems and traffic control. So, we will see more of the descriptions and some of them we have already started to see where is in 5G we expect a huge enhancement of these services delivered through 5g networks so which says that which would bring requirement beyond what can be addressed in today's IMT application area.

So, that will be clear as we further go into the details that it will be almost obvious that today's IMT systems are not capable of providing the new requirements, that is pretty natural because the design of IMT advanced was based upon certain requirements which were at an earlier time whereas, after using IMT advanced we are coming up with new requirements. So, it is pretty natural that we need a newer solution and earlier solutions would be limited in meeting these new requirements.

Further there is a rapid adoption of smart phone and mobile applications. So, it is very well known with the huge number of mobile phones that are getting sold every day and things are becoming cheaper and cheaper and advanced features are coming even in low cost devices. And the number of devices accessing the network are expected to increase amongst many other things due to the proliferation of internet of things.

So, we will see certain numbers which are really mind boggling when you see the number of connections and devices that IoT is going to bring in.

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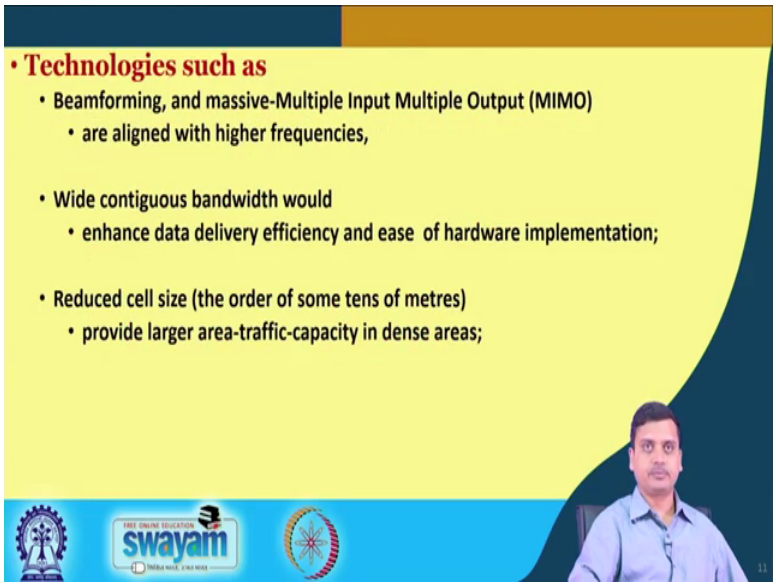

And it also predicts technologies such as beam forming massive MIMO are aligned with higher frequencies. So, we will see these things in due course of the course as we go down wide contiguous bandwidth as have been discussed is going to enhance delivery of data. Because if the user can access a huge band then that band can be supported by various forms which again we will come and see.

Reduce cell size; so we will again see at a certain point that amongst the various methods which have been able to increase or provide an increase in capacity the reduction of cell size is one of the very important such factors although it is very classical its one of the very important factors which can enhance the capacity by a significant factor.

So, from the classical few kilometers of cell radius today we have situations where cell radius are down to few meters and people are talking about cell less coverage ubiquitous. So, I mean you really do not form a cell, but you form almost a gel like or a superfluous kind of a network where they are operating autonomously almost.

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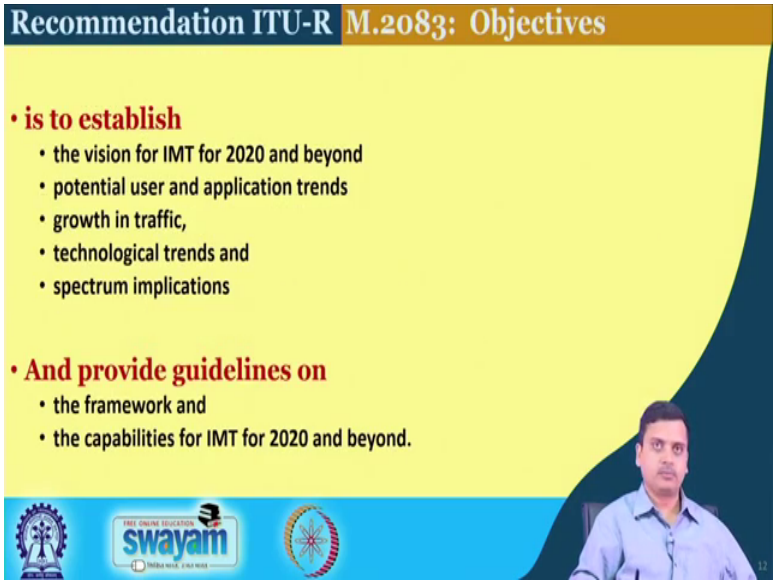

And the objectives of this particular document 2083 is to establish the vision for IMT 2020 and beyond. So, this is very much pertinent for what we are going to discuss and the potential user and application trends because these will be the drivers. It will also discuss the growth in traffic technology strains and spectrum implications and it is expected to provide guidelines on the framework and capabilities for IMT-2020 and beyond systems.

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Future IMT systems should support emerging new use cases the requiring very high data rate. So, we were talking about the scenarios. So, will later on see the details of this and it is also required to support a large number of connected devices. Now as we have gone through in the previous few lectures we are seeing how the requirements are evolving. If we just take a few seconds and get back when things were in the second generation the primary requirement was to provide digital voice across entire Europe with roaming.

Now, see the changes that have come in the voice is not featuring at all in the set of requirements this is assumed that it will be amongst the multimedia services things have gone much beyond voice and very high data rate numbers are not specified over here, numbers are going to come up at the end of it. Large number of connected devices this was never a requirement earlier. Ultra low latency such things were not much feasible at an early stage. But; however, when 3G and 4G came into play the requirements such as lower latency came into picture because we had seen definitions of control plane latency user plane data latency. So, latency definitions who are coming into play and now we are talking about ultra low not simply low latency we will see the numbers.

High reliability applications will be present for example, remote surgery where you require a very high reliability autonomous vehicles and things like that.

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So, for example, in the very low latency and high reliability human centric communications, users are users expect instantaneous connectivity so; that means, flash behavior within a split second you are connected right.

Further if this is feasible then cloud services would be possible because when services are in the cloud and you have to access them there is a natural delay because there is a huge mechanism through which you have to go and get your service. So, if it is possible to provide very low latency network then cloud services would be feasible which will enable a huge number of applications, low cost applications and would further help enhance the kind of experiences that people get as well as support a huge number of applications which would benefit the society at large.

Further virtual reality applications augmented reality applications are of course, going to going to be supported by low latency and high reliability scenarios. Further now for low latency and high reliability communication the enablers are E-health of course, we talk about remote surgery and many other things. Safety naturally comes into play, office environment entertainment and other sectors for example, games and controls and many other things for example, control of drones or any other vehicles is naturally going to be supported by this particular scenario.

So, given the time constraint of this particular lecture module we stopped at this particular section. In the next lecture we will continue into the details of the requirement specification of fifth generation communication system thereafter we will slowly get into the different solutions which are expected to provide the methods by which these different requirements can be met.

Thank you.