Evolution of Air Interface Towards 5G
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Lecture – 06
Requirements and Scenarious of 5G

Welcome to the lectures on Evolution of wireless communication Towards 5 G. So, in this particular lecture we will see the Scenarios and Requirements of 5 G, but before we go into that let us briefly look at some of the things that we have seen in the previous lecture.

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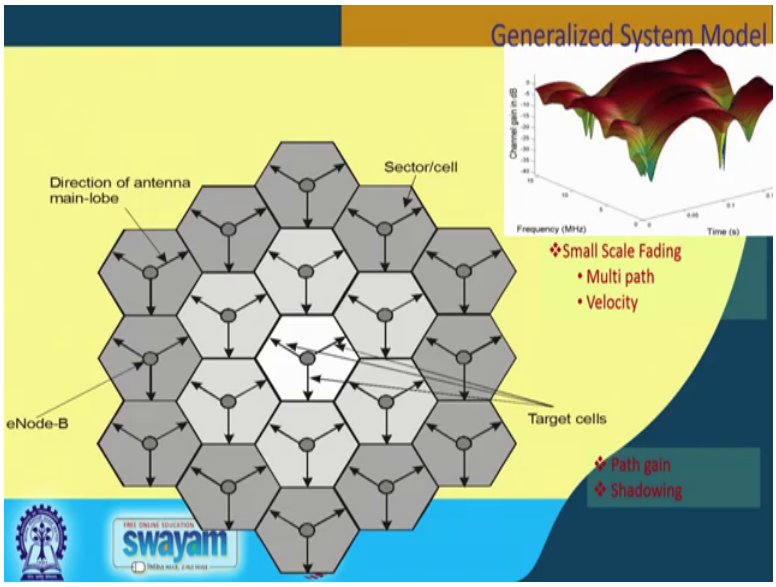

So, what we see is the generalized system model which we have briefly described I would like to revisit that before we proceed. So, what we described there was time frequency diagram where there was a time axis, frequency axis and on the z axis there was the channel gain, relative channel gain in decibels. So, the fluctuation as shown over there on your screen is basically the fluctuation of signal strength over time and frequency. And this is exactly what is exploited in the 3rd generation, 4th generation and rather expected to be exploited further in the 5th generation.

So, view of this is sometimes important and often one needs to recall in order to identify or understand the different mechanisms especially when we go towards MIMO and other techniques. So, as said that these particular things captured multipath it captures velocity

or Doppler and several things; so, that some of those things we will again see in details at a later part. And again when you do such simulations one has to take a cellular or a grid layout usually that is the model till now this particular picture shows around 57 sectors, 19 cells and each of them should be having such a thing as shown on the top corner.

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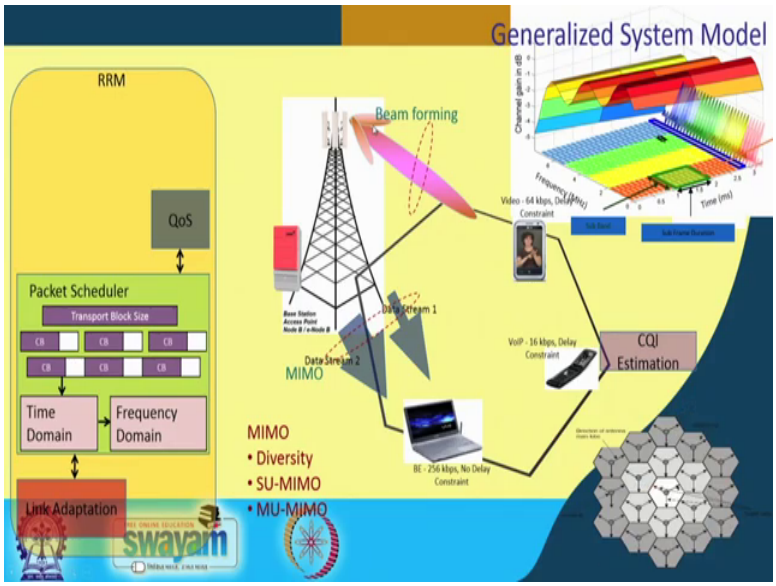

But usually we focus on the central cell and once we focus on the central cell the other cell acts as interference because, we have seen that we are moving into the full frequency reuse; that means, the situation where we have the entire area using the same center frequency. So, and just a quick iteration of what has what goes on is usually the reference signal is sent from the base station to the subscriber stations or the mobile stations. Then there is this CQI estimation that is channel quality estimation at the receiver followed by which it feeds back the CQI information. Then the base station does link adaptation; that means, selects the kind of a data rate that it is going to do over a particular link.

It also does like scheduling; that means, dividing the time amongst the different users so, that the link the entire area spectral efficiency can be maximized. So, you can inherently see that we are using the terms of definition that we have given before in terms of performance metrics of the system. So, when you do the packet scheduling there is a breaking down of the incoming bit stream into transport blocks of different sizes which are essentially sent into this time domain and frequency domain scheduler. So, they

essentially utilize these radio resources as per the fluctuation of the channel as well as taking into account, the various delays and traffic requirements of the different users.

So, there is a big scale optimization that goes on in the base station based on which these resource grids which we will describe further in later lectures are allocated to users. And this allocation is dependent on the QoS of the users as said because there is delay and data rate requirement and along with it we have also said that there are several MIMO schemes which goes on. So, again the base station has to identify the kind of MIMO it has to give to different users and accordingly a signaling of the different MIMO schemes have to come in. So, there is a whole lot of processing that goes on in order to ensure that the communication link is a pretty reliable.

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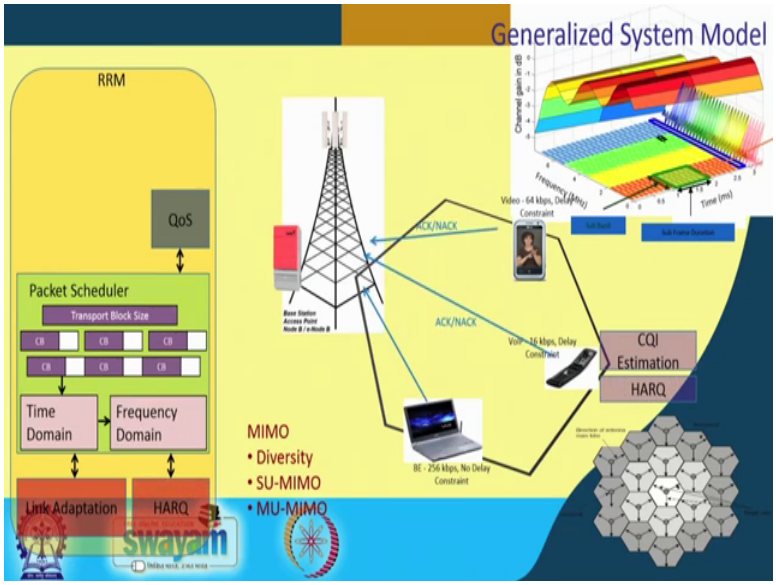

And so, I mean there is additional HARQ that is the Hybrid Automatic Repeat Request followed by all of these there are call admission and there are several process which goes on.

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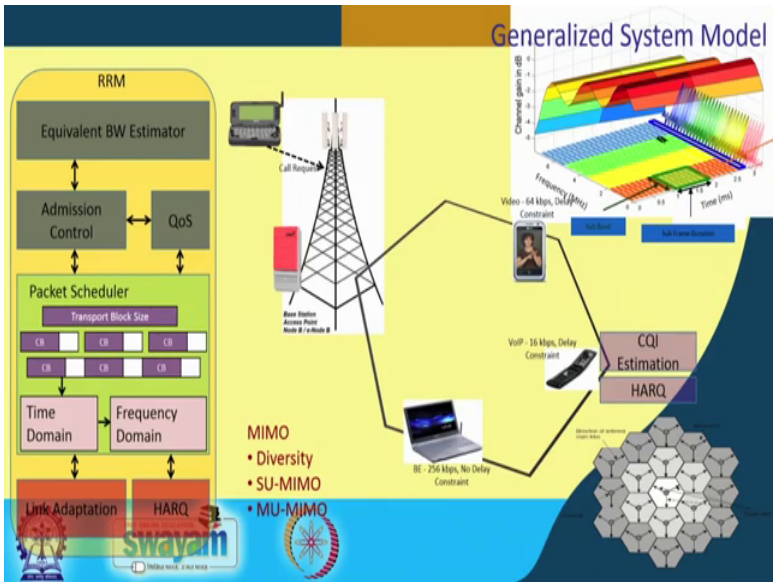

So, essentially what you see is that to get a reliable link there has to be several such process that already runs in the system. And, essentially providing some of the new requirements of 5 G where we will see one of which is to reduce the delay is not a straightforward enhancement of things as it seems to be. So, after discussing all of these we went on further and we will continue on this where we look into the requirements and scenarios. So, we had seen the definitions of some of the terms which are pretty common.

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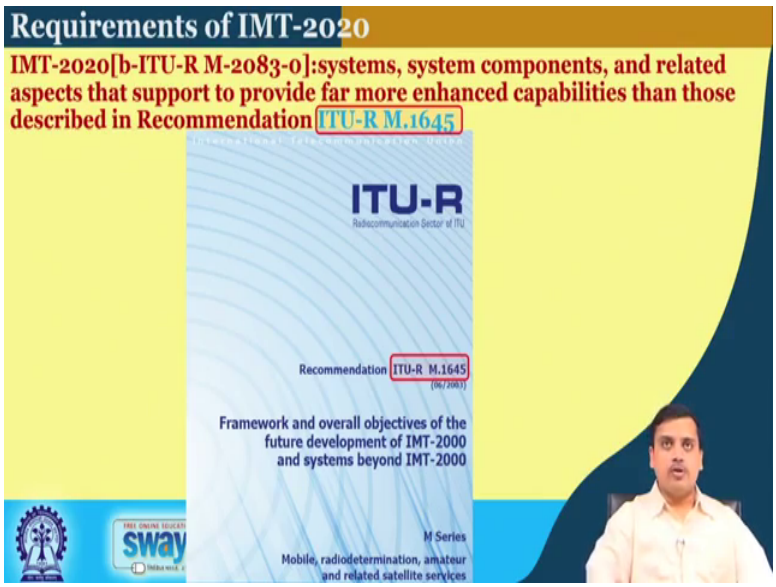

We have also talked about the documents which mention about the requirements of 5 G and how the evaluation has to be done. So, again as we have discussed the previous standards we will also start looking into these with respect to the ITU documents. So, especially as we have mentioned the IMT 2020 is referred to in the particular document 2083 which describes the requirements and the capabilities.

And, what it says is that should be far more enhanced capabilities than those described in recommendation M 1645. If you look at what is M 1645, its basically the framework and objectives of future development of IMT 2000 and systems beyond. So, this one is going towards IMT advanced.

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So, it says its much beyond that and here we have 2083 which is basically the similar kind of statements as you can see over here I am division framework. And, overall objectives of the future development of IMT; that means, this is the whole family of things for 2020; that means, the IMT advanced and beyond. So, that is why we are looking into these set of documents.

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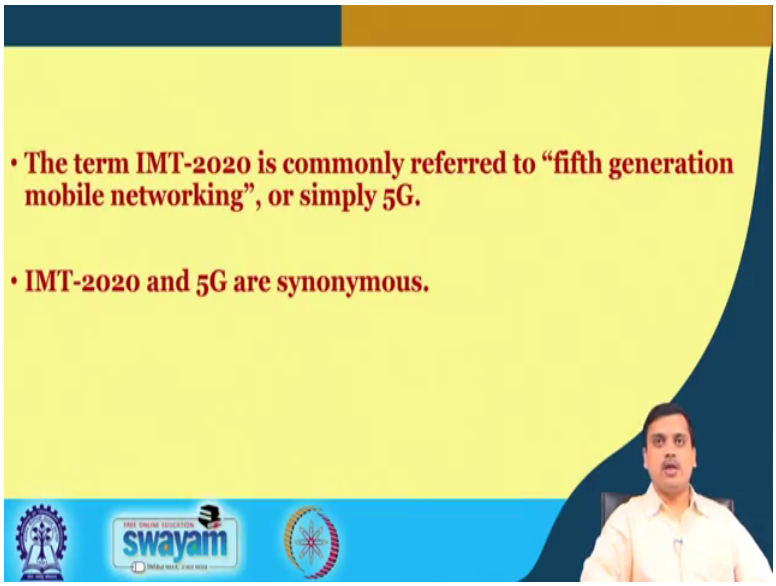

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These things we have already discussed that IMT 2020 essentially 5 G. So, we are going to use the term synonymously, we have seen some of the acronyms or the abbreviations.

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And we have also seen some of the basic statements that have been put forward like it is expected to be more traffic volume and diverse devices variety of quality of experience and better affordability. So, let us look at a deeper look because until and unless we understand the details of it, it is difficult to predict or think of or understand the solutions that have been proposed.

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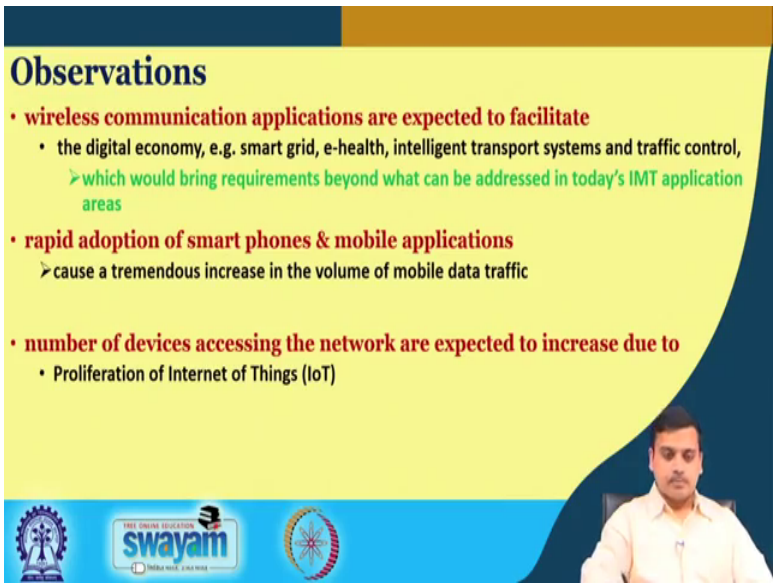

So, I mean the typical applications which have been pointed out we have discussed these things like wireless communication applications which are expected to be facilitated by

the new technologies are essentially digital economy which we are almost doing. But probably the scale of which things are going to happen would be far exceeding what we are doing today and probably one may expect things to go beyond human authentications.

So, could be self authenticated things where things could be much faster and it could go beyond just a simple economy, it could be more tools physical security things. For example, your smart home potentially which is a probably bigger than your economy in the sense that it there is precious life which is kind of guarded. So, you would like things to be done in a way that it is not shunting out the basic requirement in order to maintain security while, it does not allow mal or into it intuitive actions to be to be allowed and that to happen in a seamless manner. So, it looks a very big process, but we have to break down to the requirement into smaller requirements.

And come in to specific technical requirements, but that is: what is the objective of this particular lecture at least in the initial part. So, of course, there is rapid adoption of smart phones and mobile phones which are driving these things. And, the number of devices which are accessing the networks are expected to increase because of a internet of things. We will see numbers which are kind of predicted to tell you the difference in the numbers when people talk about internet of things and when they talk about smart phones. So, that will give us an indication that how this might be one of the major drivers for a 5 G.

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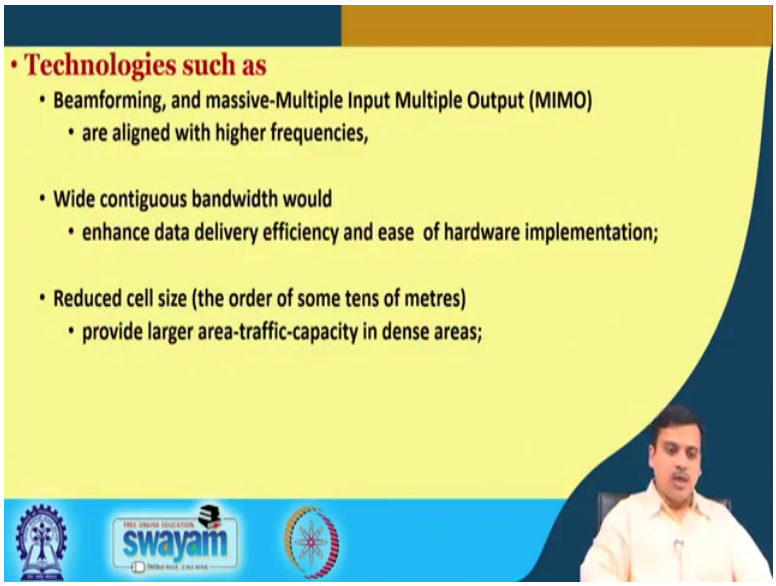

And some of the techniques which we have also mentioned last time was like beam forming, MIMO and white contiguous bandwidth reduced cell size or our objectives which we' will look at in details in a future slides. So, this basically captures in a broad scale some of the major things which are expected to be there and again these are not very new to 5 G, but there are enhancements which are going to come beyond the 4 G. So, we will look at the basis of the primary setup and we will see what exactly are expected in the 5th generation compared to previous generations.

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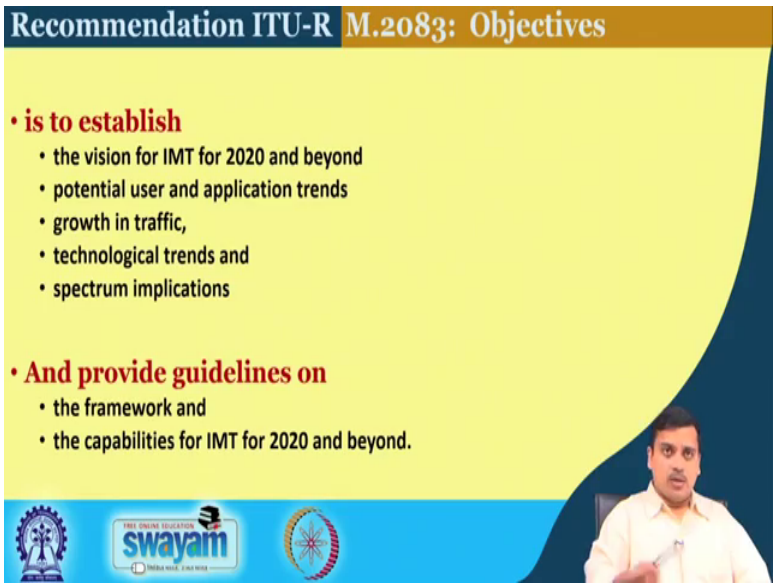

So, we have also read out this particular thing where we said that this particular document aims to establish the vision the potential user application trends growth in traffic technology trends as well as spectrum implications it also expected to provide guidelines on the framework and capabilities for 2020 and beyond. So, this is kind of naturally the document should provide us as per the title of the document and we are supposed to get into the details of it.

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And, the future IMT systems should support emerging new cases. So, so these are slowly we are getting into a slightly refined description of the requirements. So, one thing we can see is that very high data rate communications has been is still there I mean at some point we said that high data rate I mean as you go from 2 G to 3 G to 4 G to 5 G data rate is kind of growing that is pretty natural because, of certain things which we said in the past that the number of connected devices IOT and all kinds of things are simply growing. So, I mean the effective bandwidth and also the kind of the traffic; that means, let us say today we are more interested in video and other such multimedia traffic because more is given.

And people are getting more used to them and there is more demand more number of users hence hydrated requirement is an actual consequence, but we also said that this is not just the only one there will be large number of connected devices. And we will see certain more descriptions where you will see the massiveness of this ultra low latency

again for real time you can talk about cyber physical system relies I mean implementations. So, ultra low latency applications are very very necessary for example, control applications and high reliability applications are also essential I mean if you are talking of medical operations being done through such network connectivity in from a remote location.

Then of course, high reliability is absolutely essential as well as if you are doing certain mechanical large scale experiments or some work industrial work for all those things I mean both these things almost go hand in hand and their extreme requirements which are not so easy to bring out.

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So, I mean the users are expected to be connected instantaneously this also we have discussed and the flash behavior; that means, they do not want to wait and I mean this low latency high reliability as we just said these are the typical working situations which require such kind of protocol requirements. So, basically the communication system must provide these things and we would encounter activation of such use cases or protocols under these situations under these situations.

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So, furthermore what we see is that in the present day communication systems mostly it is designed with human user in mind I mean that is I do not need to explain it further because either it is the entertainment or there is a control. So, most of the time there is an end user who is having a control on the knobs and play button or let us say I mean fetching a new source of information or doing a search or maybe making the or pressing the submit button towards payment or kind of doing a maneuvering of the control through some joystick or even from the Smartphone

So, mostly it is the user and when it is the user is the human being there is more or less a limit in terms of response time because of the typical latency of human beings, but what is expected is that the next generation things there would be a lot of non-human communication. And beyond human probably you can say or subhuman up to up to you, but I mean the requirements are probably different than what human interface are required to be there.

So, there is a design is to consider machine to machine communication with real time constraints. So, this is very very important and if we take a look at driverless cars so, I mean it is pure machines talking to machines and machines controlling machines. So, human interface is almost not there I mean you can you can argue with this that no there would be some human around to take care of emergencies and other things true, but most of the immediate controls are through I mean machine to machine.

And beyond this even if we look at drones and UAV's the pilot would be at a far remote location whereas, this fleet of drones or this fleet of UAV's are supposed to interact with each other and they are supposed to sense the environment and make a decision and execute the decision on a local level. So, there will be lot of things that will be going on at the machine level with the intelligence which is not human which is kind of beyond human intelligence and control. So, there things have to be done in the corresponding perspective.

And furthermore it is also said that it would be like enhanced cloud services would are also expected to be facilitated by virtue of this because, probably a lot of cloud services can be accessed and they can be becoming more beneficial or more usable in these conditions. And of course, there is a list of operating scenarios and I think some of the important ones are traffic control, optimization I mean real flow of real traffic let us say cars and all other stuff and emergency and disaster response I think this is a very very critical e health is also adding one of the most critical applications. Efficient industrial communications are also very important because, if let us say and you cannot afford to have a failure in the systems because industrial application big levers moving and lot of I mean big machineries moving around.

So, you cannot happen to give a wrong command because you might have the system might have chosen the right command, but as it goes through the link if one of the bits flip the command becomes a different execution already. So, instead of probably transferring a huge sort of material from one point to another the whole bucket might be emptied over there immediately. So, it is very important to have a very reliable links in that cases and of course, we have discussed UAV situations.

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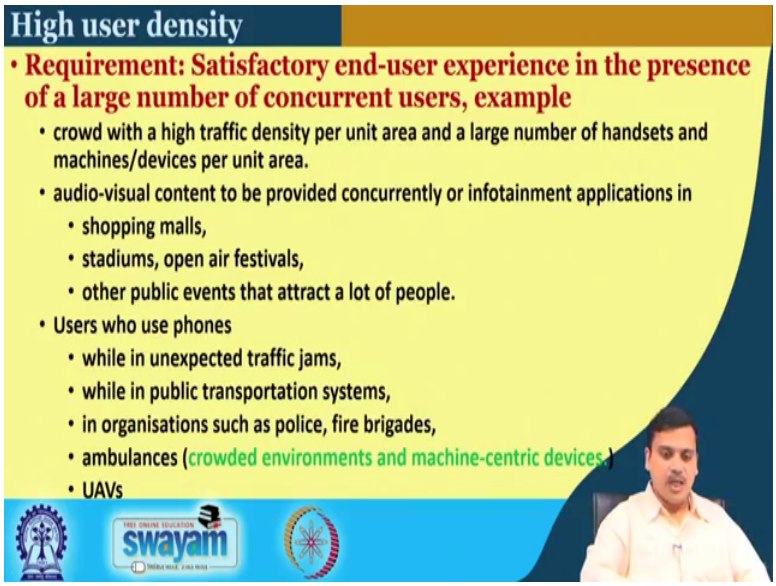

Yeah high user density is also another very very critical thing which we will see further like shopping malls stadiums open air festivals and there will be a lot of other users who will be using them in traffic jams probably or in public transit. So, these are a lot of a lot of scenarios which are expected. So, we will see a little bit more graphic descriptions of these where we will appreciate them.

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And of course, during mobility we would like to have higher quality while you are located inside moving platform let us say a car or a train and as its natural that the

mobility speeds are kind of increasing and we will see that the mobility definitions have changed from IMT advanced to IMT 2020. So, enhanced multimedia services further so, not only mobility, but along with that there are enhancement in the multimedia services for example, like ultra high definition displays multi view high definition displays mobile three projections augmented reality.

So, what we are seeing is that there is a much more enrichment of the media and content that are getting generated and hence being also consumed by the user. So, this particular content which was not so, rich earlier is now packing much more amount of data into it further the user conditions under which they are accessing such information is also changing from static indoor to high mobile.

So, we have lot of challenge to be addressed and we will see probably a better description of this and if we understand the details of it then only we can come up with a solutions which are appropriate in meeting such things. So, clearly I mean if you think of this in a very in a very short note there is a huge amount of information that is generated and there is a lot more users moving in a lot more random environment. So, I mean to meet to provide huge amount of information to a large number of highly mobile users is a big challenge which is being seen.

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Of course internet of things we have already said. So, the number of connected things are going to exceed the human user devices which we will see in numbers and further the

things that we are talking about can be Smartphone, sensors, actuators, cameras and vehicles. So, what it means is that there is a whole variety of different things which get connected it's not only one type of thing and hence the inner energy requirement.

And energy consumption will be different for the different kind of devices the transmission power the latency requirement because, depending upon the applications. For example, if its a camera if it will be just one way communication if there are like sensors and actuators there will be like two way communications in vehicles of course, it is two way communications.

So, the different kinds of things are going to come up different latency requirements cost and other indices are for suitable operations are also going to be different. So, all we are seeing is that one size fits all kind of a solution is not so, easy to come up with. So, we are just kind of a motivating in this particular part the complexity of the problem the variety of the problem and the kind of quote unquote flexible solution that is expected to be delivered in the future generation systems. So; that means, what we can see is that we cannot have multitude of solutions rather we should have solution which easily gels.

And be is flexible which can transform itself from one form to another and which can serve the different requirements in a in a seamless manner. So, of course, there are different application areas for this.

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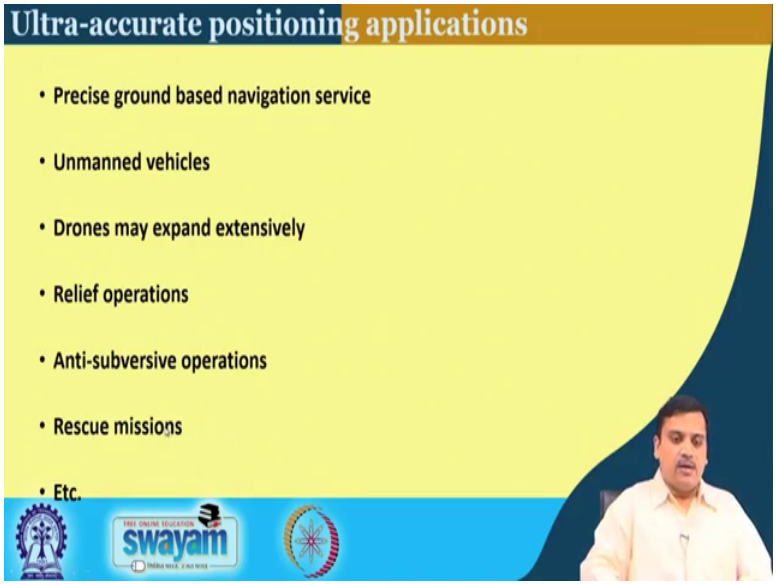

And ultra accurate positioning applications; so, I mean precise ground based navigation services are necessary I mean if you look at present day navigation services when it was initially available probably we were very excited that yes we have a lot of navigation aid these days. But beyond that what things have happened is the complexity of this problem has also increased our expectation have also increased if you go to cities I mean there are a lot of flyovers.

And multi tier road architectures there are tunnels, but we expect the service to be available in all situations whereas, we also require the accuracy. We would almost like our cars location in the lane to be provided as accurately as possible with today's technology I mean there is a huge amount of error we given the kind of expectations because at one point of time we were not having this service. So, when we got the service we were pretty happy that yes I know more or less I am in a particular lane in a particular street and I use additional information to maneuver to the left or to the right.

But now we expect that we to be told in which particular lane we are and when to take a right turn, when to take a left turn or if there is a change in the dynamic change in the traffic. So, I mean there is a huge amount of there is a huge amount of change that has happened further if we look at a drone based delivery of things automated delivery of things then of course, this is going to be a huge. So, with unmanned vehicles I mean its a huge thing.

So, in case of relief operations of course, you would like precise information you would be going around and probably picking up a living thing maybe a human being who is probably I mean somehow saved himself or herself and you would like to go to the exact location with the UAV's and probably help the person out of the situations. So, there you need even precise locations. So, what we are seeing is that then this new requirement has provided a lot more challenge and an opportunity to provide new solutions as well.

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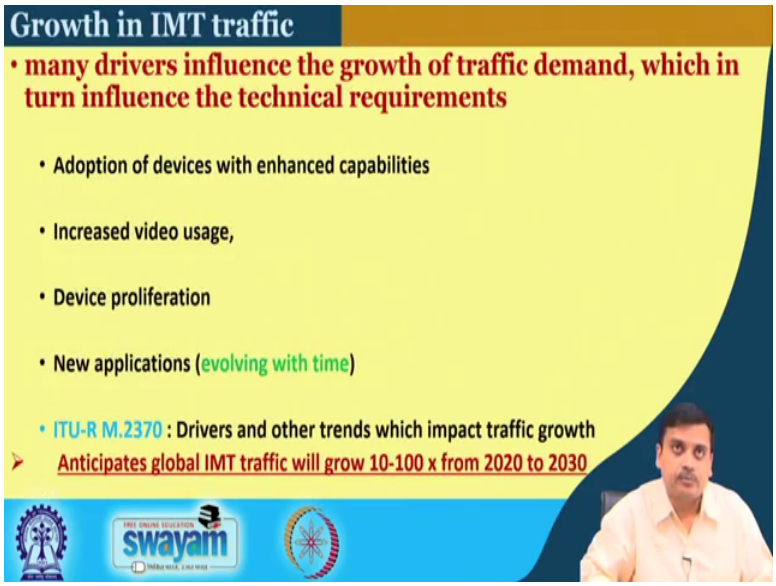

Amongst the many drivers which influence the traffic demand or adoption of devices with enhanced capabilities of course, I mean if you go back 10 years and see the kind of devices we had and see the kind of devices we have these days are kind of significantly different the kind of processing power, the displays and all are pretty different. So, that is one of the driving factors use of video device proliferation and also we should not forget the evolution of new applications with time. So, we should always anticipate that something new is going to come up.

And it is good if you can, if your solution can support certain new changes without much change in the architecture. So, this is another very very challenging area because you do not know what is going to come, but you would expect to be solving it in some manner at least and this particular document 2370 tells us that it anticipates that IMT traffic will grow 10 to 200 times from 2020 to 2020. So, while the traffic grows you cannot have a system a priori which is as per the finely predicted traffic, but you would like to invest slowly and you would like the system to be modular which can scale.

And so, that it could finally, take the new traffic requirements with added portions of newer portions of the traffic or the other system deployment. So, that it can grow with the traffic demand which appears to be very simple, but it's not so, straightforward when you go and implement things.

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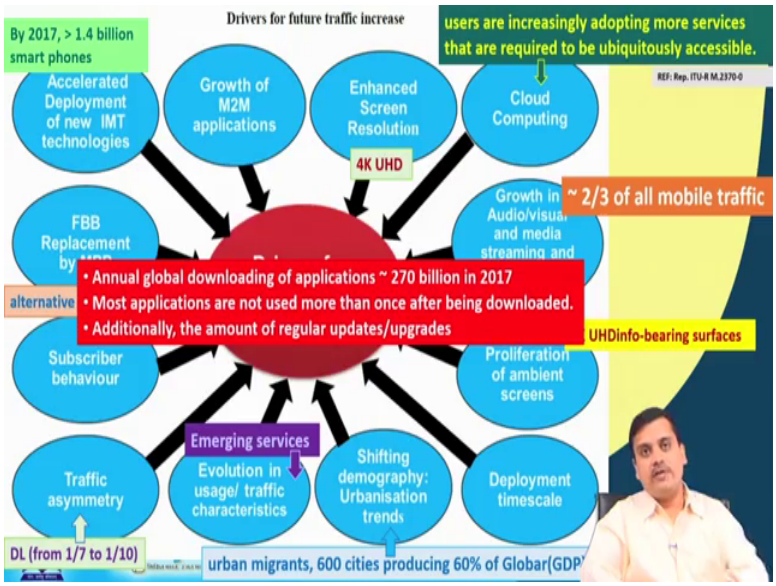

So, if we if we look at the different scenarios or the different drivers for traffic the increase beyond 2020 as described in the particular document as we have been referring to what we see is that there are a whole set of different requirements or different drivers which have been pointed out. So, one of them is the accelerated deployment of new IMT technologies.

So, kind of beyond two thousand seventeen is expected to be in more than one point four billion Smartphone's we will see some statistics of course, then enhance screen resolutions. So, kind of 4 K ultra high definition displays are some of the driving factors, cloud computing users are increasingly adopting more services that are required to be ubiquitously accessible.

Now, when we say ubiquitously accessible we will see the definition it does not mean that you access it over all places on the globe right it rather means that over sir over a service area there is a ubiquitous accessibility. But of course, I mean what it means is that cloud computing should be one of the facilities that to be provided growth in audio visual media streaming.

And what is expected that almost two third of the entire mobile traffic would be multimedia audio and visual or proliferation of ambient screens. So, there will be lot of lot of large screens and surfaces there are already displays which are like see through displays and depending upon situation you can wake up it can provide this place and then

can act as a window as well and it is kind of a 4 K ultra high definition info bearing surfaces. Then shifting demography is also another interesting figure or a fact that which we can look at is the urban migration. So, what it's expected is that around 600 cities produce around 60 pursuant of the GDP global GDP. So, it is kind of pretty skewed I mean if you look at the distribution of traffic.

So, over entire large area this is of course, over a large area, but if you concentrate on smaller areas I think similar features happen that you need to provide a network which can handle huge amount of traffic emanating from a small tiny place whereas, a large area is not having that much demand. So, it is not a uniform distribution traffic over a geographical area so, this makes the problem even more challenging. So, evolution in the usage or traffic characteristics so, which basically means the emerging services will be different pattern with traffic asymmetry. So, from one the downlink would be from 1 7th to 1 10th so; that means, uplink downlink ratio is going to be very very different. So, that is what it is saying.

So, if we are aware of these things the if the uplink and downlink ratio are different then we would redesign the system in a manner which can handle such changes right and like subscriber behavior or the place or the replacement of fixed broadband with mobile broadband. So, basically what we are seeing is that it is kind of expected in many regions of the world that you provide an alternative to the wired broadband through such wireless services. Now to provide a wireless broadband which is almost equivalent to wired broadband or a fixed broadband service is not an easy problem to handle given all kinds of variations. So, what we see is that there are various factors which drive the traffic increase.

So, not only it's just the volume, but also certain changes in behavior asymmetricity which are going to change the traffic characteristics beyond 2020. So, it is also predicted that the annual global downloading of applications or apps is kind of 270 billion in 2017 and interesting facts are that the most applications are not used more than once after being downloaded. So, probably if we can ask ourselves we will probably find that in our mobile phones we have downloaded many applications or some of them are pre loaded. So, that is sense that is better off, but if you are not using that application and if there is a huge number of such things happening then there is usage of bandwidth.

Now, you might question the usage pattern, but it is probably important also to accept the fact that it is a behavioral trait or it is happening and if you would deny that service probably it becomes a big question mark whether it is kind of the right approach or its kind of helping anyone because we are not sure about what is going to happen with the app once downloaded. So, additionally the amount of regular updates and upgrades I mean if you if you look at the number of apps that are in your phone and you would also be aware that these there is a regular up gradation of the apps like every week months is probably pretty good.

But sometimes everyday is that it waits for an update because without update it does not work any further now every device large number of such apps are happening in this manner. So, although we discount for it, but if we aggregate the total thing it's a huge number its number sometimes we carry multiple such phones and although we do not use them they are still I mean participating in the overall growth of traffic. So, these are some facts some factors which if we are aware we can probably design to provide service to such requirements in a manner which is going to help manage the entire thing in a nice manner.

For a very simple thing is that if it is not a very critical app we can probably delay the download of information or the up gradation of the app to a time. When the traffic demand is low overall we can distribute it for different users at different times and many other optimizations can be done of course, with the consent of the of the user.

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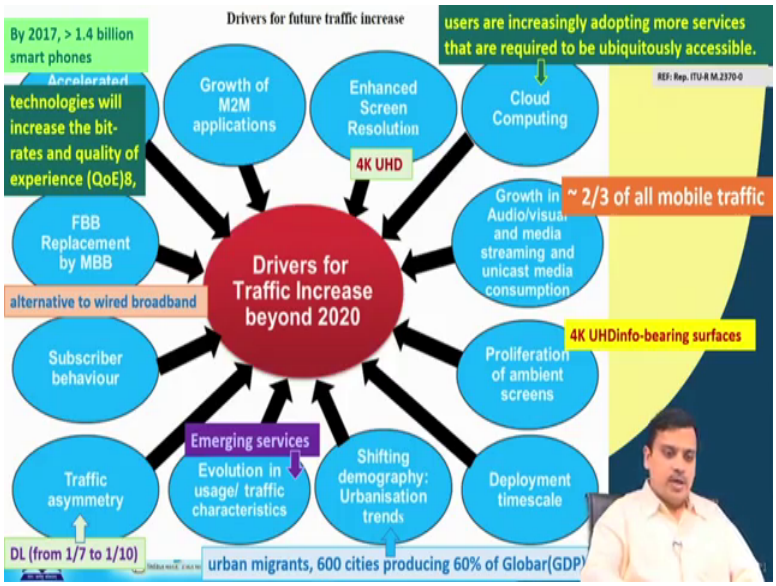

So I mean one more factor that is that is coming into play is that the technologies will increase the bit rates that is what is expected and the quality of experience. Of course, so, that is that is one additional factor which is going to come in furthermore the energy aspects are also very important.

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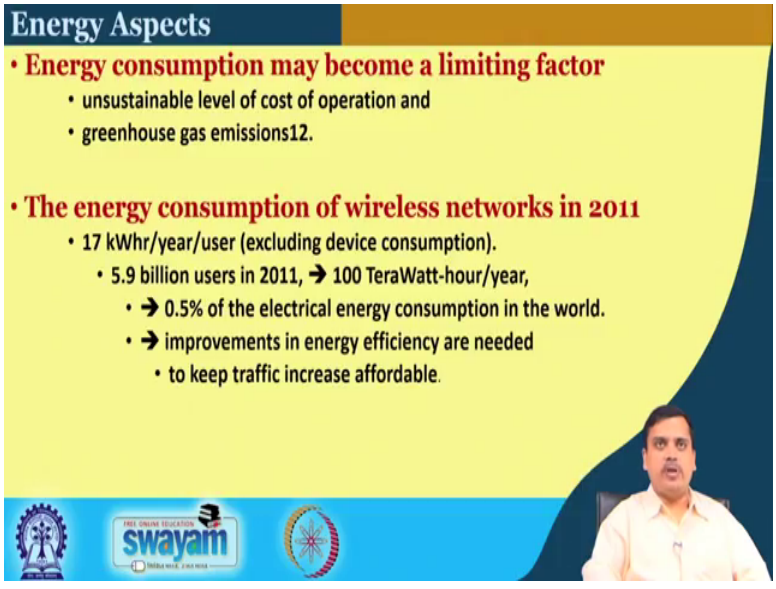

So, what we see is that the energy consumption may become one of the limiting factors. Because, if there is unsustainable level of cost of operation then things might take a different turn; so, we should be very very much careful about the energy consumption

also. And, this has been one of the important considerations for design of systems and according to how we layout we will see that we will actually try. And see one of the particular views in this particular direction and how things can be improved there of course, many ways, but at least we will see one of the reason.

So, energy consumption of wireless networks in 2011 was a 17 kilowatt hour per year per user. So, I mean if you add up all the users it was almost 100 terawatt hours for users. So, which is a big number which has already happened in 2011; now if you go to 2020 and down to 2030 when traffic is expected to grow ten to 100 times of the previous of the previous generation of systems. Then you can easily imagine the amount of energy consumption that is going to happen.

So, I mean this is a very important factor. So, what it essentially tells us is that most of the designs and solutions should consider the energy that is used overall in the system. So, that we can come up with a better design and ours our system is already pre-designed to reduce energy or energy comes as a constraint in the optimization problem which you are usually solving. So, that it is already taken into account at the design time and not at a later stage as a post connection.

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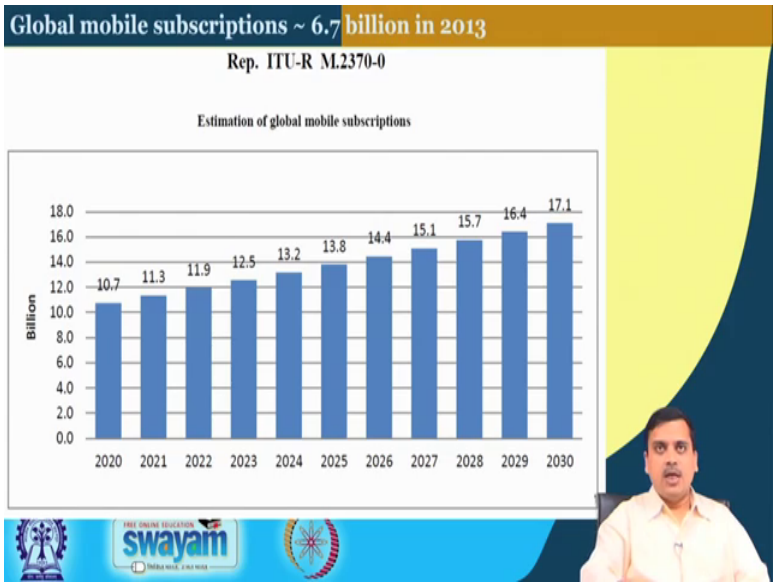

In this particular figure there is a kind of prediction of the global mobile subscription from 2020 to 2030. So, what we see is that there were its expected around 10 billion mobile subscriptions in the year 2020 and it was around 6.7 billion in 2013 and it is

expected to grow to seventeen billion in 2030. So, I mean that is the kind of a numbers in terms of mobile subscription that are expected over the next 10 years of the 5th generation of communication system.

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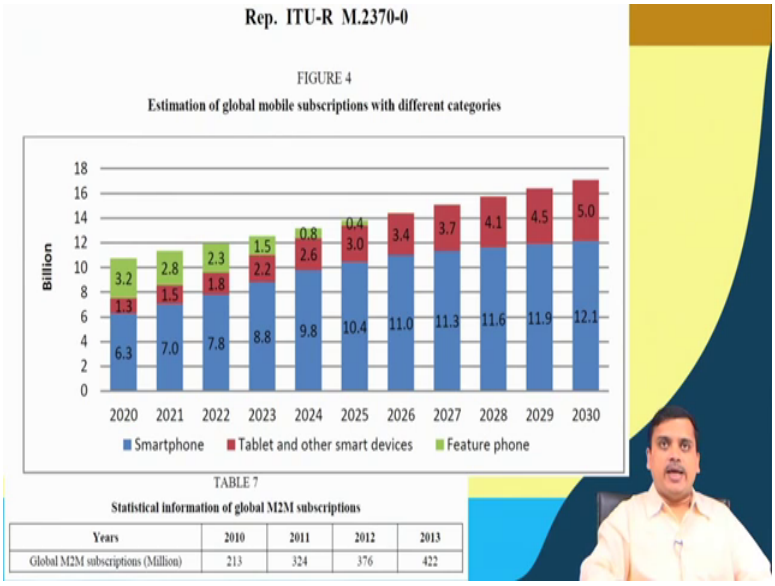

That we are trying to see and in this particular picture we are kind of seeing again this particular image is from M 2370 which is an ITUR document on the x axis it is the years from 2020 to 2030 and on the y axis it is the number of a different categories of devices. So, what we see in one particular column is that it is around 10 point something nearly around 11.

So, it is basically the number what we have here 10.7 billion devices that is broken down into different types of devices. So, there is a feature phone which is kind of 30 percent roughly speaking and around 13 percent of tablets or other smart devices and Smartphone's are around a big 63 percent or 60 percent plus kind of. So, so that is the change that has happened over years where actually earlier this was the major portion of devices and this was only a smaller portion of devices.

And it is expected by 2025 the feature phones would almost vanish in comparison to the entire network. Now if you have a very tiny fraction of such devices then what comes into play is that the traffic demand by these devices are significantly different compared to the traffic demand by these devices right. So, another hidden information which is

kind of coming out from this picture is probably the traffic that is generated by feature phones are going to vanish.

And it will be generated it will be dominated only mainly by smart-phones and tablets from this year onwards from around 2026. And, thereafter you are going to have devices which are much more multimedia capable and capable of and having multiple sensors. So, it will be every user will be generating a huge complicated set of traffic which we need to address. So, we stopped this particular lecture here and we will continue on this further in the upcoming lectures.

Thank you.