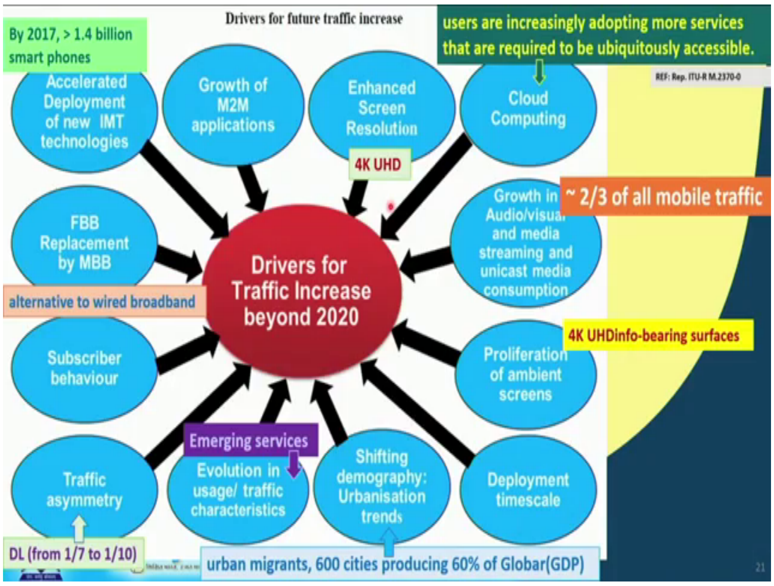
Evolution of Air Interface Towards 5G
Prof. Suvra Sekhar Das
G. S. Sanyal School of Telecommunications
Indian Institute of Technology, Kharagpur

Lecture – 07
Requirements and Scenarious of 5G (contd.)

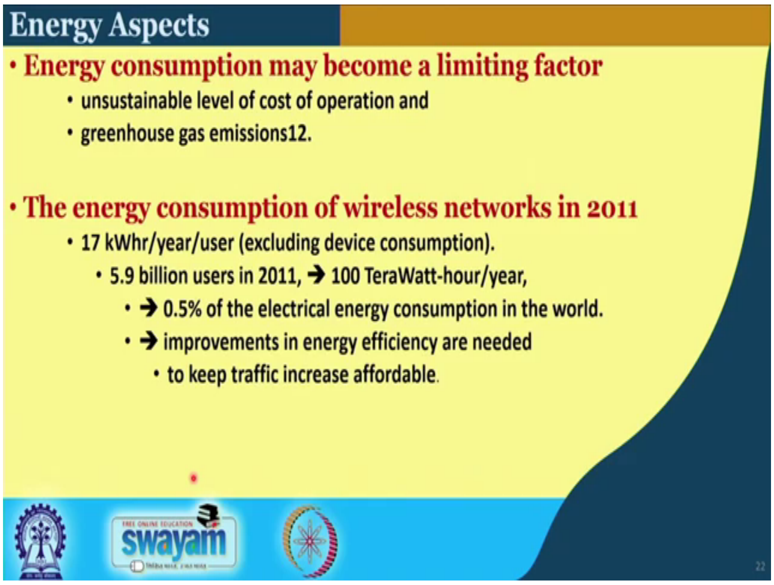
Welcome to the lectures on Evolution of Air Interface Towards 5G.

(Refer Slide Time: 00:23)



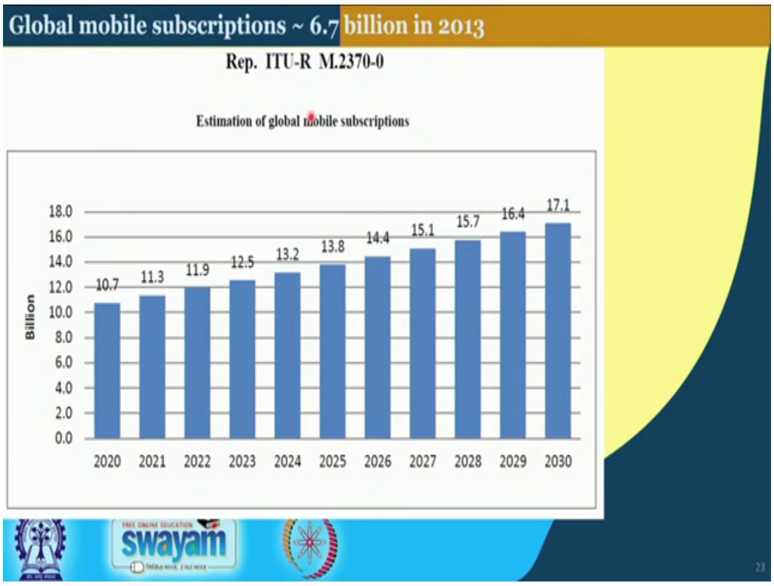
So, we have been seeing the drivers for traffic growth and we will just summarily look at that. So, this is the particular slide that we were looking at and various factors, which are driving the increase of traffic 2020 and beyond are basically captured in this particular slide. And, we have more or less discussed some of the aspects and reasons why and we have also said that it is important to look at these kind of parameters. Because, when you get trained in designing new systems, you must start looking at it from this perspective.

(Refer Slide Time: 01:01)



So, the other thing that we also mentioned is energy is also a very crucial parameter in the whole thing and it must be taken into account in the design. And we will obviously, see at certain point that how energy saving mechanisms have been built and at least one energy saving mechanism.

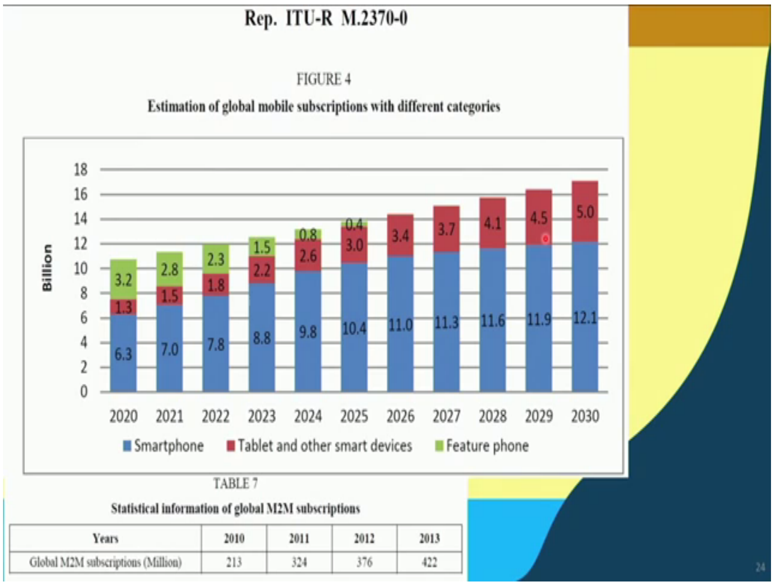
(Refer Slide Time: 01:17)



And in this particular slide, we have also discussed this, where it projects the growth of traffic up to 2030 on y axis is a billions of global mobile subscription.

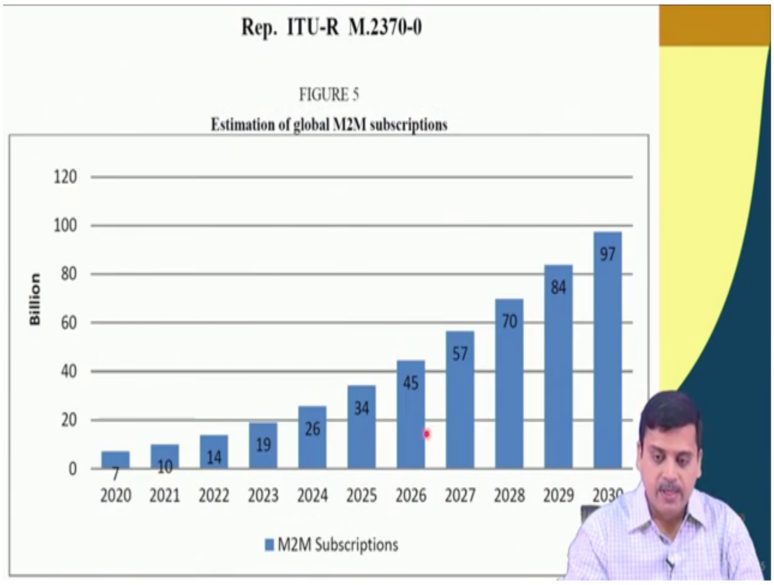
So, what we have is around 2020 it is expected that around 10.7 billion connections would be there and it will grow to 17.1 billion, this is what we discussed in the previous lecture.

(Refer Slide Time: 01:42)



And also this particular one image, which is again from M2370 discusses the breakup of the kind of devices which accesses the connectivity. And so what we see is around 2020, there would be quite a few feature phones, while the larger numbers would be smart phones. And mid way up to 2030 the feature phones are almost going to be negligible and finally, they are going to go out that is what is predicted and mostly it will be tablets and smart phones in part of global mobile subscription.

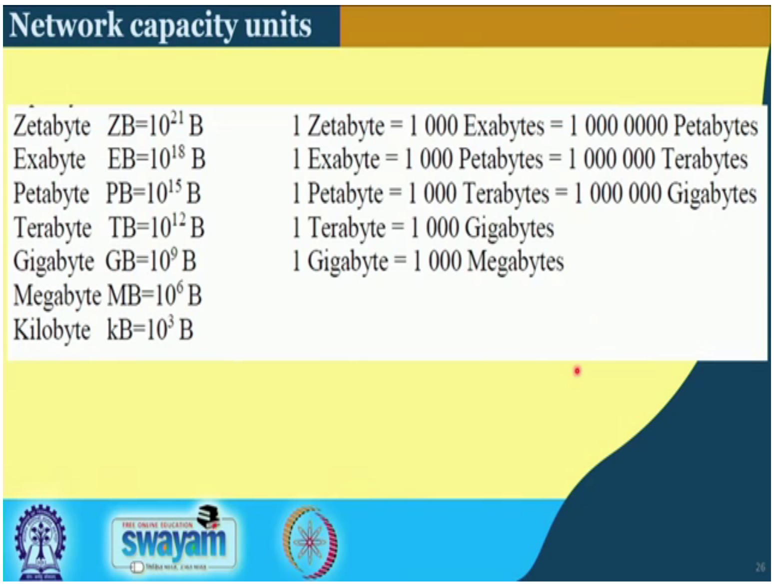
(Refer Slide Time: 02:24)



What we have also seen is that the M2M that is machine to machine, it is expected that around 2020 2030, there will be 97 billion devices, which will be connected and this is as per M2370 which is an ITU-R report.

So, what we see is the massive growth in devices is one of the huge things that are going to come up and accordingly we will see a scenario, which talks about large number of connectivity as well. So, these predictions help us set targets for the next generation systems and also design solutions, which would meet such large volume of connectivity.

(Refer Slide Time: 03:13)



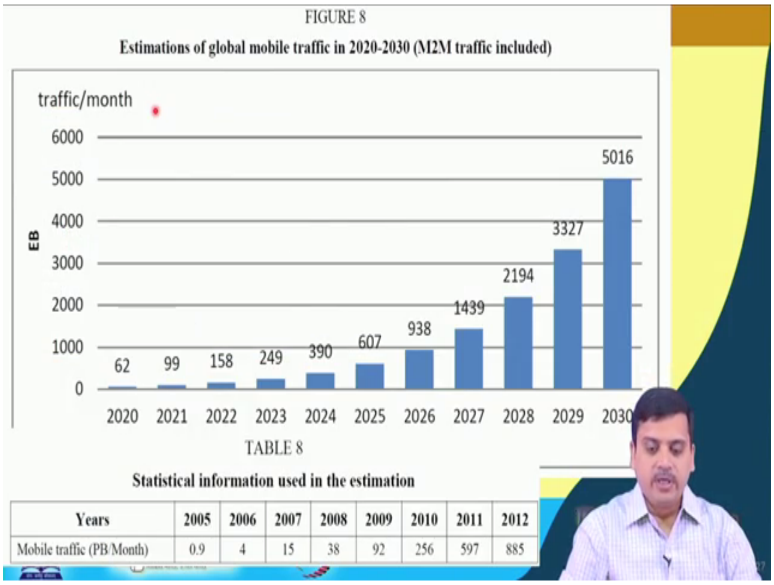
So moving beyond what we have here is a summary of definitions in terms of network capacity units. Because, when you have a huge number of things connected and data is flowing through the network, we have to measure in bytes and bytes is a basic unit rather bits is a basic unit. But, the number of 0s that get added when you have so many devices and such large number of such large connectivity it is not easy to use the simple bits per second.

So, I mean as you know that at some point of time kilo bits or kilo bytes was a good number to capture, the data rate and whereas, now we have moved through megabyte and through gigabyte in terms of connectivity and then terabytes, we are used to in terms of personal data storage. So whereas, at some point personal data storage of few kilobyte was a huge number whereas now, we are used to a few terabytes TB in short form like we buy hard drives 1 TB 2 TB. At certain point 1 GB was a big number; so now, it is like our phones come with gigabytes of memory storage.

So, as you look at the network traffic capacity, these numbers are not enough to take care of the description of the traffic which flows. So, there are other units which have been; which have been developed like the petabytes, which is 10 to the power of 15 bytes, exabytes 10 to the power of 18 and zeta bytes it is 10 to the power of 21. So, it is growing in the same rate like 1000 terabytes make 1 petabyte, 1000 petabyte makes 1 exabyte, 1000 exabyte makes 1 zetabyte.

So, these are the units which are usually used in terms of describing the traffic flow. So, we are kind of getting ourselves accustomed to these numbers and this would also serve handy, whenever you want to refer to a particular specification, I mean these this table would always help you. So, just a quick reminder terabyte is what we are in, the next level is petabyte that exabyte then zetabyte and each grows by a factor of 10 to the power of 3.

(Refer Slide Time: 05:35)

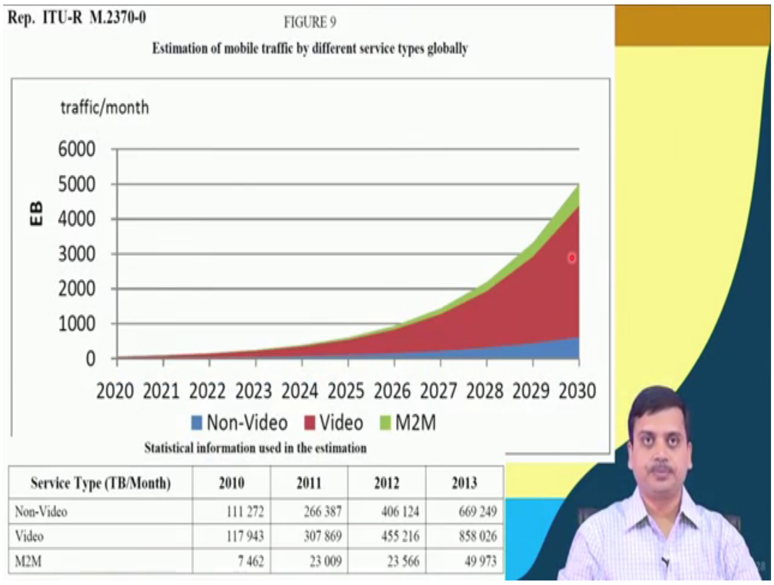


So, in this particular figure, now again we have estimation of global mobile traffic in the period 2020 to 2030 and this is M2M traffic is included in this particular picture. So, it is expected from 2020 to 2030, the traffic would grow from 62 exabytes. So, what you see is exabyte is 10 to the power of 18 bytes that is kind of 1000 petabytes, that is kind of 1 million terabytes right. So, that you can clearly see and 1 billion gigabytes; so, that is what is the number over here and it would grow significantly.

So, by in 2 years it is expected to double and a rather more than double in 2 more years is it is more than double and it is growing in more or less the same phase, it is kind of more than double of this and again in 2 years it is more than double of that and then again it is significantly grow. So, there is kind of exponential growth that is expected. So, around here it is around 5000 exabytes. So, that is kind of 5 zeta bytes of data that is are expected around 2030. So, which are huge numbers.

So, the network has also to be designed in a manner that it can handle this amount of traffic, which is like significant growth, I mean huge growth from where it is and in this period it is expected that the network is capable of absorbing this traffic. And as said earlier it is not, it is required that you do not lay out the entire network. Because, you would like to invest slowly as and when the demand comes in, but we are just getting ourselves aware that such kind of requirement have to be supported by the same network in future.

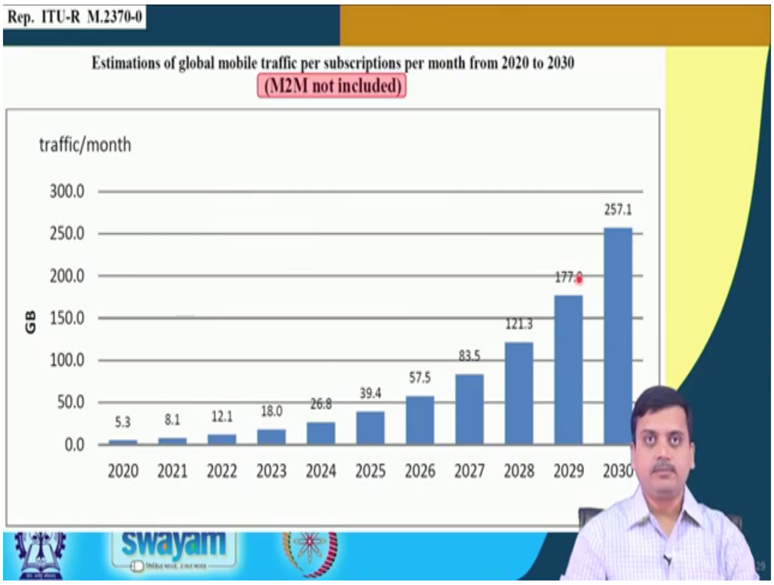
(Refer Slide Time: 07:26)



In this particular slide it is shown the estimation of mobile traffic by different service types globally. So, again these are exabytes of data again, this is the year as we have been showing. So, what we see is that video is going to be a major portion of the traffic a major chunk is expected to be video. So, this again there gives us some information about the kind of traffic and hence the kind of resource allocation the kind of mechanisms, which are feasible, which are non-feasible, the way you should divide the bandwidth, the way you should divide your resources and things like that.

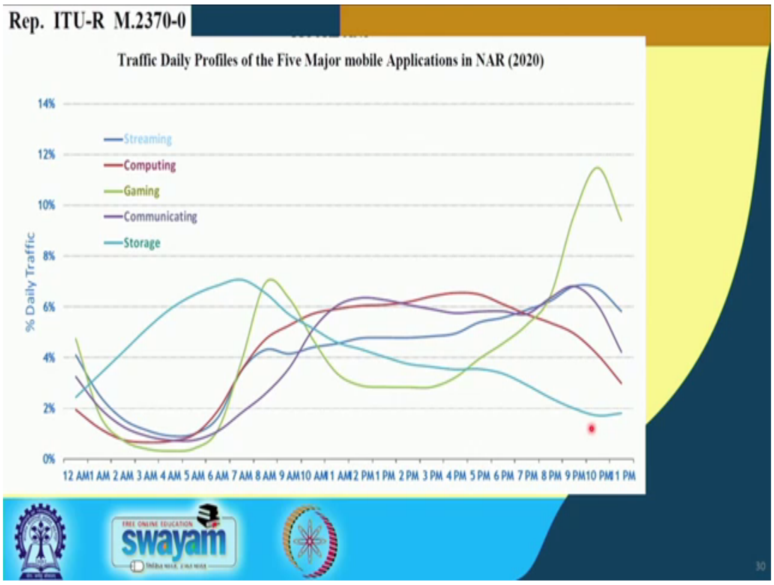
So, this prediction helps us in taking lot of technological decisions towards deployment and accepting solutions as accepted part of the technology solution M2M is going to be a major part as well as non video will be there. So, these are the broad classifications of which video is expected to be the major chunk of traffic.

(Refer Slide Time: 08:29)



In this one again, it is the estimation of global mobile traffic subscription per month from 2020 to 2030 in terms of gigabytes. So, what we see again 5.3 to 257. So, that is again a factor of would like 20 plus I mean it is a huge number, it is around kind of 50; it is kind of a huge number. So, more than 20, it is more than 40 50 nearly a factor of 50 growth from 2020 to 2030. So, that is that is again like exponentially everything is growing between 2020 and 2030.

(Refer Slide Time: 09:09)



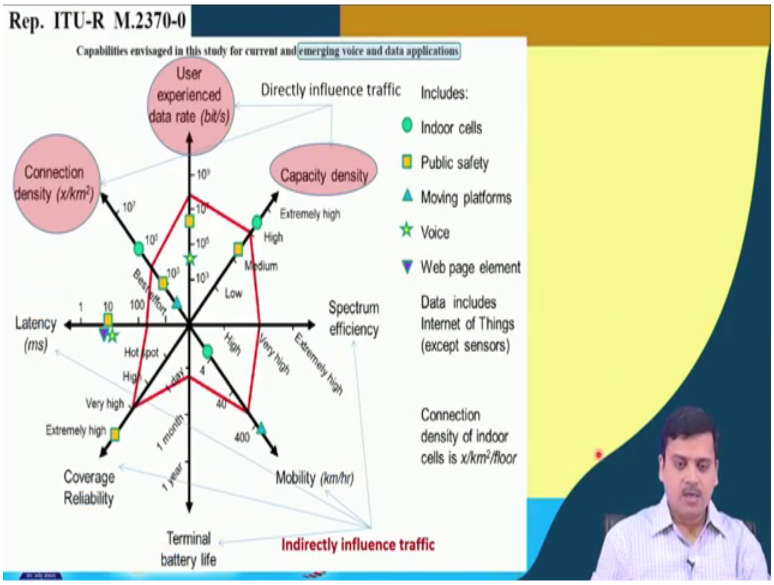
So, in this is an interesting a figure, which is slightly different compared to the traffic growths that were shown in the previous slides. So, these were all traffic growths in different forms, what we see over here is the daily traffic profile of I mean this is for North America region again as given in 2370 of major applications as they are predicting in 2020.

So, there is a streaming application, there is storage, there is communication, there is gaming and there is computing and this is the hours of the day on the x axis midnight starts over here 12 midnight. These are the hours, when people are travelling towards their office and this is the usual office hours and these are the hours, when people start returning back home and this is where they are at their home. So, what we see is that one particular profile, which is for the gaming is kind of given over here this there is not much nothing much to say, except that this is more or less something to be expected.

So whereas, what we can make an observation over here is that the streaming traffic is kind of here, this is the curve for the streaming traffic as you can see and communication is here. Computing is following the mark that I am trying to follow through over here and storage is kind of this. So, these are the hours, which it is expects the daily traffic profile to be and what you can see is that there are some traffics, which are similar in certain part of the day, when they are actually low, which is in percentage and in some portions it is pretty contrast with other traffic.

So, these differences are and these similarities are actually the ones, which can help us make designs, which are more meaningful, we will see especially one particular application, which is related to energy savings, where we will show that how this traffic profile fluctuation has been used to provide mechanisms to save energy. And many others solutions could also be taken care of by being aware of the distribution of traffic in a 24 hour period.

(Refer Slide Time: 11:38)



So in this particular figure, what has been captured again in the same report M2370 is that there are different dimensions of the performance metric, which are important and of which we have identified like connection density as one of the important measures, user experience data rate as well as capacity density. So, these 3, which have been encircled in this particular figure are the ones which directly influence traffic and this is basically the capabilities envisaged in there in the particular study that is 2370 for the current and emerging voice and data applications.

So, these are mostly the when it is voice and data, it is kind of human connected situations, where they will be using and this red particular curve is kind of indicating the core capabilities. While, these individual markers as has been shown over here are the individual situations which make them different. So, as we can see as given in this particular figure that, these 3 primarily, they are the ones which directly influence the traffic right. So, for example, the connection density the higher the connection density, the higher is the traffic, higher the user data rate higher is the traffic higher is the capacity density higher is the traffic.

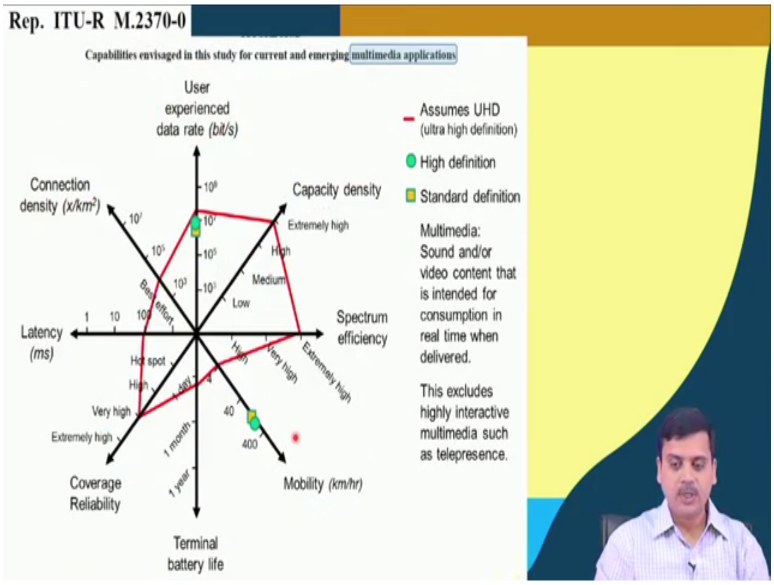
So, I mean that is the kind of direct influence whereas, there are some other parameters also which also influence the traffic, but not directly indirectly rather like latency as we have over here in milliseconds. So, latency is kind of a QoS metric that you would require to traffic to be delivered within certain duration that is not pushing the traffic much higher, but it is more of a demand on the radio resource utilization algorithms, which would have to deliver the service. So, although the traffic is not huge, but you might have to reserve a lot of resources in order to guarantee the delivery of service within a certain deadline or a certain latency. A spectrum efficiency yeah I mean of course, if you have higher spectrum efficiency then you can provide high quality services. Mobility is also an influencing factor because, higher your mobility generally your spectral efficiency goes down and the capability to push more data within a narrow bandwidth becomes less.

So, you have to provide more and more bandwidth and if you have to provide the same data rate at high mobility then; obviously, you require more bandwidth and so basically there is a complicated relationship with all other factors. Terminal battery life is also one which influences traffic in a way that, if you would like longer terminal battery life then you would have to schedule the traffic in a manner that, it utilizes the most of the awake time to transmit the data and has a has a periodic sleep hours so that, it could conserve most of the energies and the terminal devices could last for a long duration.

Similarly, coverage probability is also very very important and as these markers are indicating like let us say this public safety; obviously, I mean for public safety applications. You would like to have a coverage reliability, which is very high and when if we take the indoor situations, there again the connection density is expected to be very high. And similarly, I mean all other different things like when you are in moving platforms for example, in vehicles or in trains. So, there the mobility factor is one of the critical factors. So and let us say this particular marker, which is the web page element.

So, when you are loading some web page and it has certain objects which, need to be updated or uploaded or which needs to be rendered. So there again, the latency factors come in to play and similarly, this star with the yellowing inside, which you see his voice is also another critical application, where latency is very very crucial. So, I mean this in through this particular picture, you can capture the different the different capabilities, which are required of the services that are expected of 5G and as well as which kind of situations demand, which kind of capabilities in more importance compared to others.

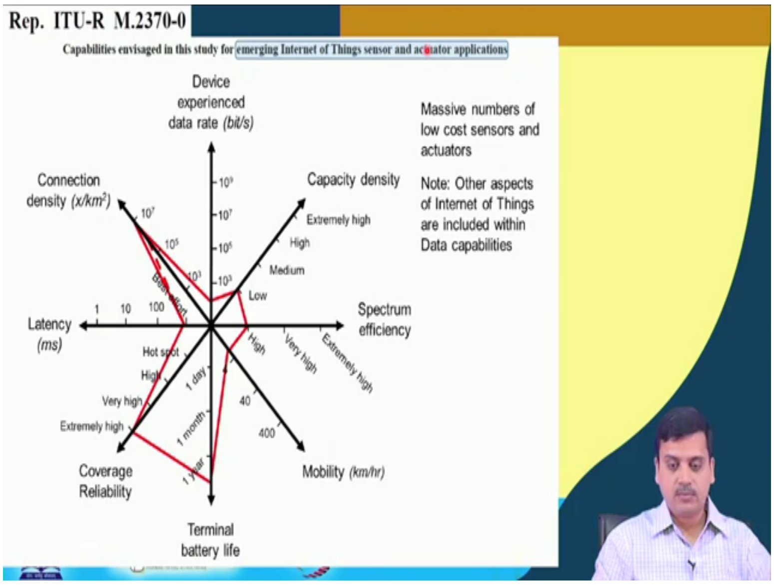
(Refer Slide Time: 16:25)



In this particular picture again, the from the same report it talks about the capabilities envisaged for current and emerging multimedia applications right. So, I mean this particular one is for assuming with ultra high definition and again what we see is that, there are different metrics as has been highlighted for the different situations; that means, let us say spectrum efficiency is expected to be very high.

So, if spectrum efficiency is very high then you can provide very high bit rate. On the other hand, if the mobility is pretty high then providing very high quality is kind of pretty weak. So, basically at relatively lower mobility you are expected to provide this kind of services. So, more or less this again captures for another set of situation.

(Refer Slide Time: 17:21)

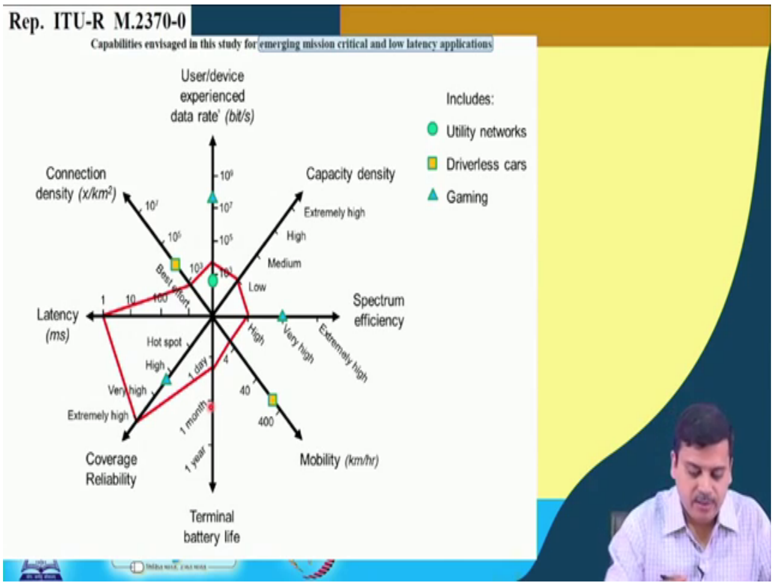


In this particular one again, the capabilities for emerging internet of things sensors and actuator applications are kind of demonstrated. So, what we see over here is connection density will be high because, internet of things. So, there will be large number of such devices, which will be deployed and coverage reliability has to be high because, if these are sensors and actuators. So, if you have an automated system then you would like that the system gets input from all the sensors and it serves the purpose.

So, in that manner your coverage reliability has to be high and again since, these are sensor networks it is typically required that the terminal battery life is also high because, you would not like to go and replace the battery very often. Whereas, mobility requirement is not that high spectrum efficiency need not be high, because generally speaking for such things, it is usually the case that there is intermittent data, which is usually small amount of data which is sent and the devices need to last long.

So basically, you need to save the battery life, it needs to be lasting longer spectral efficiency requirement is not extremely high, but high is; obviously, good but relatively lower compared to the higher end demands the capacity density can be low. And the device experience data rate can be low relatively low compared to the other values. So on and off they would be sending data large number of devices need not have a stringent latency requirement, but should have high coverage reliability and high terminal battery life that is how this emerging internet of thing and actuated applications are the scenario is described through the different requirements of the different parameters in this particular figure.

(Refer Slide Time: 19:25)



And then we look into some more applications like mission critical and low latency applications and as the name suggests a low latency. So, your latency requirements would be very very stringent, what you see the latency requirement here the number is decreasing as we go away from the center. So here, we have around 1 millisecond as the latency requirement and of course, reliability factor is high.

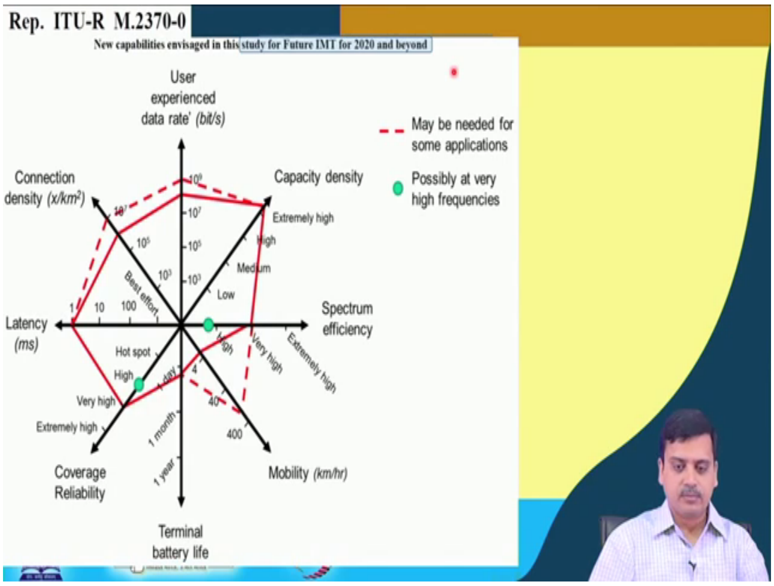
So, if we go back along with it the terminal battery life was required to be high, but here the terminal battery life may not be required to be high, it is much lower. So here, what you see is in order of years. So, generally it is kind of 10 years that is required for internet of things that is kind of expected a few years at least whereas here, that is not a stringent requirement because, it is mission critical requirement. So, probably there is some availability of power in this particular case.

Well, in this situation mobility has not been kept very high. However, it might be like as you are seeing driverless cars situation, there could be high mobility where it could be 100s of kilometers per hour. So, I mean there are aberrations which have been captured by these extra markers and spectrum efficiency a on the lower side compared to this, overall the spectrum is a requirement is high, but this particular application, because it is mission critical it is more important that, these two are satisfied heavily maybe at the cost of this, because that is we can see when we will go into deeper discussions will kind of find out why this may be kept low right.

Whereas, if you are talking of gaming applications then the spectrum efficiency requirement needs to be high for a large amount of multimedia service multimedia or rich content to be delivered. And here again, as you are seeing for mission critical applications generally speaking the user data rate is not very high, you would send critical information. For example, location or some update or help needed and maybe the health status and things like that whereas, if it is a gaming application you can clearly see that the user data rate requirement is high.

So, these pictures basically captured the different scenarios in terms of description of parameters of the future generation system that we are discussing.

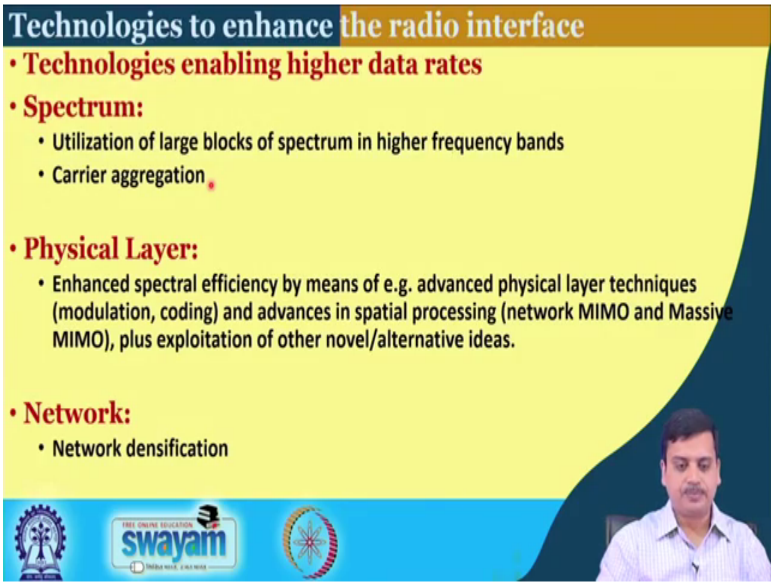
(Refer Slide Time: 21:53).



So, this particular figure captures the capabilities that are expected to be required for future IMT 2020 and beyond applications; so, for the new capabilities that that would be expected. So again, there is variety of different parameters, you can read them quite easily from the points that have been marked over here and as have been given over here that different markers possible at very high frequencies. So, high spectrum efficiency and high reliability and may be needed for some application.

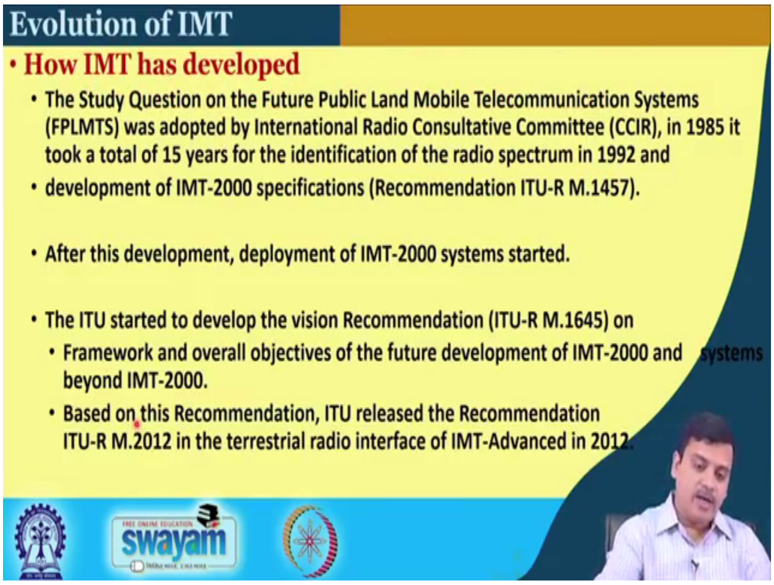
So basically, they have described the different scenarios and different marks, different lines and different numbers, which have been clearly indicated over here which are expected.

(Refer Slide Time: 22:44)



So, some of the technologies, which are required to enhance the radio interface are basically this spectrum, which is required that large blocks like carrier aggregation things, which have been going on. In the physical layer again, it is expected that lot of these MIMO and massive MIMO and lot of other things would come in which is, which we are going to discuss network densification. As we have said is again another important technical aspect which is, there is a hope that it would provide us a lot of this capacity demand that is being placed will be satisfied when it is network densification and yeah.

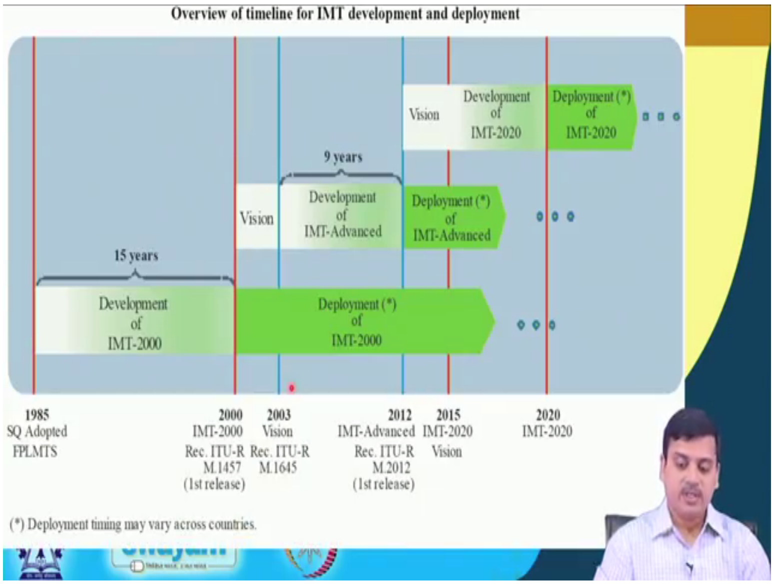
(Refer Slide Time: 23:28)



So, I mean if you look at how all these things have been have been developed, we have already given a picture earlier that it has been through years of such development, we are coming to a close of this particular discussion.

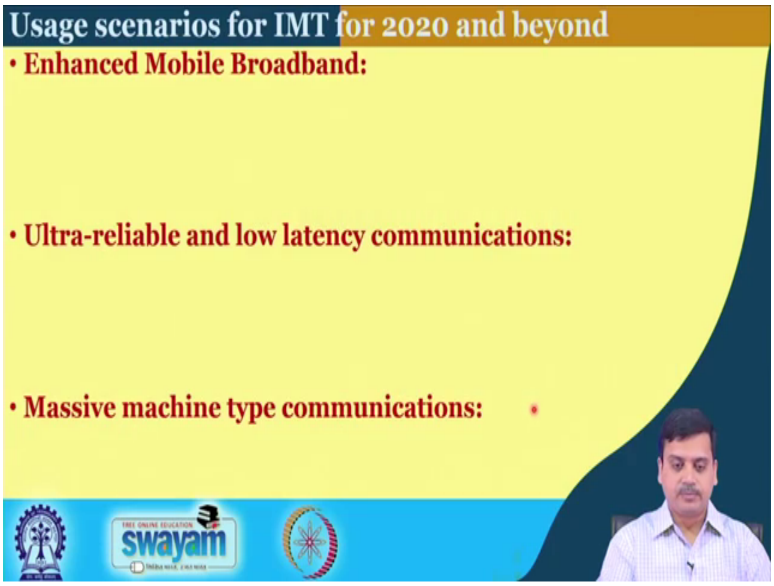
(Refer Slide Time: 23:37)

(Refer Slide Time: 23:39)



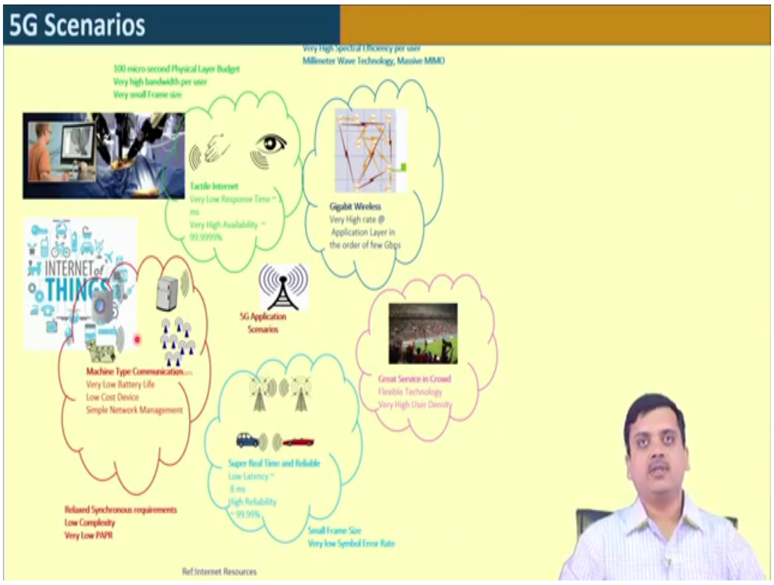
So again, it is available from IM III ITU that which describes the development of different I IMT standards. So, initially it was a 15 year cycle then it was a 9 year cycle when it was IMT 2002 IMT advanced and then again from IMT advanced to IMT 2020, it is kind of decreasing time period. But, I mean only time will tell us that, whether this changeover is going to be becoming smaller and smaller it is going to remain roughly at an average of 10 years from deployment of one technology to another technology.

(Refer Slide Time: 24:16)



So, the usage scenarios as we have been describing are broadly categorized into the enhanced mobile broadband, ultra reliable and low latency communications massive machine type communications. So, these are significantly different situations, which are expected to be present in 5G or it is kind of broadly categorized in those ways.

(Refer Slide Time: 24:42)



So, amongst the different scenarios, there is this tactile internet is also one of the important things, where the response time is expected to be pretty fast. I mean much faster than human response time, I mean which is typically applicable for remote surgery and where 100 microsecond physical layer budget kind of things are expected. And, then there would be gigabyte wireless application scenarios, where a very high spectral efficiency per user is kind of required and some of the technology, like massive MIMO and millimeter wave are expected to deliver the solution.

Then massive machine type is another scenario, which is expected to be there and which is primarily going to be driven by internet of things. And there would be requirement of relaxed synchronization, there would be requirement of low complexity and low peak to average power ratio at the device end. Then there could be super real time scenarios requirement like automated driving and there could be great crowd great service in crowd.

So, these are broadly some of the scenarios, which are expected to appear in 5G. And we will see we have already seen some of the characteristics will see a little bit more of them in the upcoming lectures. And, then we will proceed towards meeting the solutions, which are expected to provide methods to address these different scenarios.

Thank you.