Design for Internet of Things
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Lecture - 28
LPWAN technologies

So, let us now focus on what is known as a new technology required for the completion of uploading data to the cloud ok.

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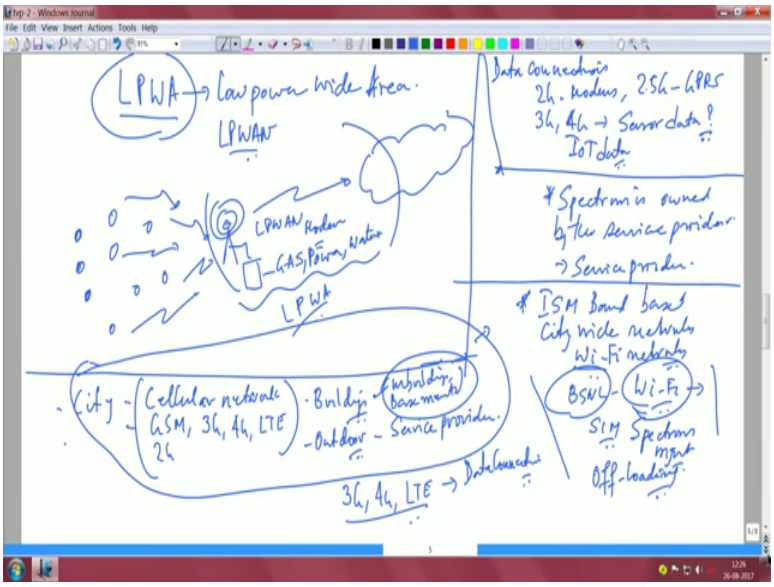

You gather data from several censors, give it to a gateway device and somehow from that device it should be uploaded to the cloud. So, in order to do that you must look at Low Power Wide Area. This is low power low power wide area network essentially. So, people talk about LPWAN, LPWAN low power wide area network systems.

So, let us quickly put down several censors here which are gathering data and an equivalent of a base station which or is nothing but a gateway kind of device which ultimately receives data. It can also transmit data 2 way communication is possible. And somewhere in onto the internet you want to upload the data right. You want to upload the data to some cloud based system. And we are talking about a technology of this nature here; this is low power wide area coverage. So, you can imagine to get a feel of what we are looking at we can take a city wide network or a town based network ok.

When you say a city wide network what occurs to us first is the cellular network right. Cellular network nothing but the cell phone network, which is nothing but the telecom service provider network, wireless networks; you can talk about GSM technology then people talk about 3G 4G and LTE and so on and so forth. So, lot of this is nothing but the 2G technology and so on. This is what occurs to us. And it is a beautiful network the city wide network, because we will see that it works well inside buildings, it is not bad if it is I mean there are pockets where coverage is very poor. But by and large you know that there are ways by which you know, if you come closer to a point you get a good signal.

So, people are managing and there are limitations on wireless technologies, but the fact that it works inside buildings outdoor is good. If at all there is a coverage problem outdoor it is, because the service provider, the service provider perhaps has not put up his power and adjusted the adjusted the antenna. That is the only reason. Otherwise the by and large outdoor coverage is very good. When we say buildings you talk about in buildings, you talk about in buildings; you talk about basements, correct? You also talk about basements and so many other places where the coverage more or less is good. So, it is a well time tested network, people have had problems, but people have also found that you know sort of it is a mature system, the mobile phones are very reliable and they are cheap and their availability is good.

And it is a well tested technology. That is one thing and of course, if you talk about 3G 4G LTE and so on, all of these technologies give you data connections as well data connections right. One idea might occur to you that if such data connections are actually possible with you know, 2G modems 2G modems 3G or GPRS 2.5G, GPRS modems 4G 3G, 4G and so on, why can not we use this technology directly for uploading our censor data that might occur to you, right?

Well your thought that has occurred is perfectly valid. In fact, there are very exciting technologies which take care of how to tune these existing technologies cellular network technologies in order in a manner that they can actually carry IoT data. We will have to put down a few requirements for the cell networks telecom service networks to carry IoT. Data this is one part of the story. The other part is in the existing part of the story itself when you talk about GSM, 3G, 4G, LTE, and so on and so forth, mind that you are actually talking about licensed spectrum. Spectrum is, spectrum is owned, owned by the

service provider right. The service provider owns the spectrum and therefore, if you are talking about an LTE or a 3G or 4G LTE kind of network modem for carrying IoT data.

That means that service has to be offered by the service provider that is one thing. So, service provider has to offer you a service of carrying IoT data. This is one part of the story. The other part of the story is you can have ISM band you can have ISM band based city wide networks, city wide networks what occurs to you is Wi-Fi networks, Wi-Fi networks and service providers now also are trying to offer Wi-Fi networks for example, BSNL is serious of offering Wi-Fi connections to home users ok.

So, essentially you know you subscribe you have a BSNL sim card with you, and using this BSNL sim and you have a smart phone which not only gives you BSNL you know 3G 4G and other cellular data connections, but BSNL also collocates let us say an Wi-Fi access point. Then what actually happens is in order to do proper spectrum management what BSNL can actually do is, if it senses that this user is closer to a BSNL tower and is also closer to a Wi-Fi access point or a hotspot set up by BSNL, then that connection it could be data connection or it could also be voice over packet voice can actually now start going over Wi-Fi. So, such models are slowly emerging and this place is actually called offloading, this is purely from the purposes of spectrum management of a of a service provider.

He could be doing that. What occurs to you is Wi-Fi, but you know that Wi-Fi while it works in the 2.4 gigahertz range it is penetration in inside buildings in basements and so on penetration, penetration of the signal, of the signal and is poor basically right.

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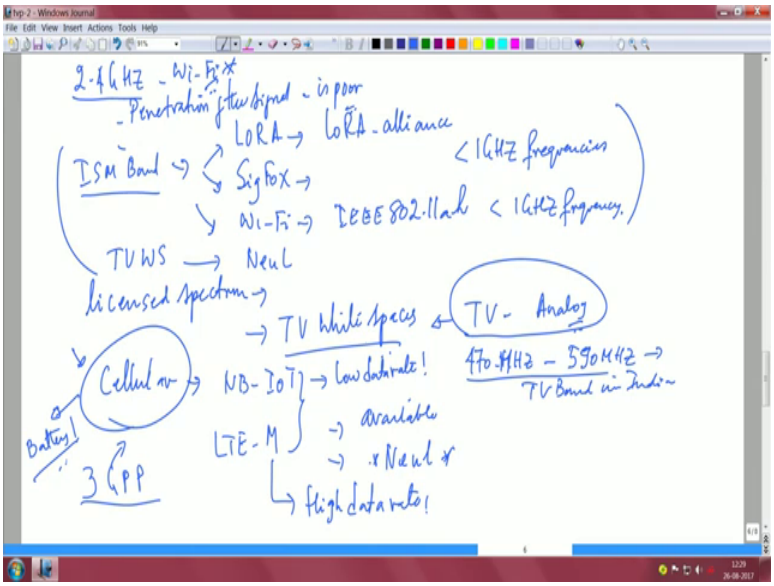

So, you can not be talking about a IoT technology where data for carrying IoT data with Wi-Fi it does not seem to make a any mode sense, it works in certain pockets, but you can not expect it to be ubiquitous. Therefore, a Wi-Fi is not really a choice.

And as a result of that many efforts have come about in trying to use ISM band, ISM band, but not necessarily Wi-Fi. 2 competing technologies seem to come up which used the ISM band. And one is called LORA, this is from the LORA alliance LORA alliance and one more is called SigFox. This is called SigFox. This is also from the ISM band. And both of them are the sub 1 gigahertz frequencies. Do not forget Wi-Fi is not going to keep quiet. Wi-Fi also is available now in the sub 1 gigahertz range, it is called the 802 I triple, I should put IEEE 802.11 which is the also the sub 1 gigahertz frequency band right.

So, this is what you should be worried about now. So, in other words you could be talking about license spectrum, you could be talking about unlicensed spectrum. License spectrum is again even more interesting things are happening, licensed spectrum licensed, licensed spectrum. We mentioned to you about we mentioned to you about the cellular spectrum, cellular network spectrum. You can also be talking about TV wide spaces, TV wide spaces. See if you look back let us say 2 decades back, TV transmission was analog, used to be analog and it the TV bands are country specific, but the 470

megahertz to I think 560, I do not recall correctly no 590, I think here 470 to 590 megahertz use this use the is nothing but the TV band in India ok.

Now, you could be talking about why should if, if TV bands TV band has been allotted this frequency and TV transmission is actually not happening terrestrial transmission is not happening in this frequency. So, this frequency is actually available, but it is licensed it is available, but licensed therefore, it becomes tougher you know accompany which wants to exploit which wishes which desires, to exploit TV white spaces to sort of carry IoT data. Nevertheless there have been efforts by communities to exploit TV white spaces and such a technology is called neul, neul, neul, neul technology.

And this so, if you now go and you know sort of look back at what all is possible. In the ISM band you can have these 3 TV white spaces, TV band you can use neul, neul, neul and in the cellular space you can exploit 2 very interesting technologies, one is called narrow band IoT the other one essentially is also these are basically from 3GPP. One is called narrow band IoT and the other is called LTE-M LTE LTE-M what is the difference between the 2? Well, this is low data rate and this is for high data rate, that is all.

Both of them use the cellular frequencies itself, and the standards are mostly from 3GPP, let me write 3 properly so that you can look up the standards. So, this is called 3GPP alright.

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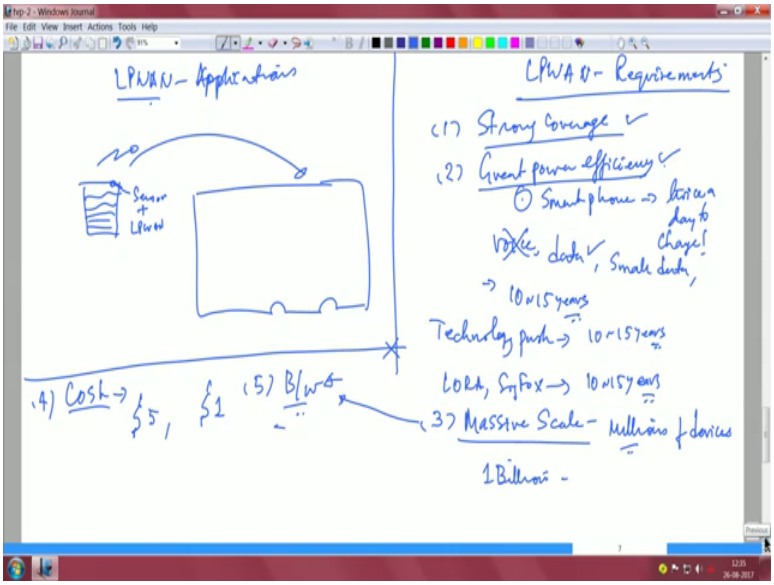

Now having given you this overview, I will put down the requirements, requirements very, very important, requirements for LPWAN. Before you put down the requirements for LPWAN you must also understand; what are the applications for LPWAN, applications for LPWAN, many, many applications. Smart cities when you say smart cities, you can say for smart meters, you can be talking about utility meters, such as gas city wide gas supply for cooking purposes, could be metered and such meters, can be equipped with LPWAN kind of systems, which not just gather data from you know this kind of large censors, but indeed ok.

So, let me go back and just put down. Yes, not necessarily gathering data from many, many such the sensors, but each one of these gas meters can actually be gas censor can directly be connected to this LPWAN modem, this LPWAN modem. It could be even for other utility like power. It could be for water, it could be for garbage collection, so many applications people talk about for LPWAN. It could be for smart garbage cans, smart garbage cans. All the litter that is here and once the litter is full there is a sensor, sensor which says which detects the amount of garbage inside the garbage can and perhaps send out a data packet, to a garbage collection unit which essentially might deploy a truck to come and collect the garbage.

One of the first things you need is a strong coverage over large areas right. So, that is one of the requirements, then you need great power efficiency let me give you a quick contrast on power efficiency. Very, very quick contrast, just imagine you have a smart phone with you. You have a smart phone with you, and let us put back this picture, this understanding. You are talking about cellular NB, IoT low data rate right which means well known experience of each one of us over a billion as Indians who seem to own phones is with respect to cellular technology right. And you also all of us may have perhaps seen a smart phone used a smart phone, clearly one issue of a smart phone is with respect to the battery, battery. You buy a 50 thousand rupee phone and you end up charging the battery twice a day, twice a day, twice a day to charge. Well, this is not going to work.

Because you are talking of here we are not even talking about voice, but we are actually talking about data. We are not talking of large data we are talking of small amount of data of prime importance is not about the amount of data that you are carrying, but of prime importance is the fact that, if you fix to your garbage can a device which is

supporting LPWAN then you are talking about 10 to 15 years lifetime with a battery. So, that is a very key important requirement. Almost impossible for you to imagine that on a cell phone network you can get this kind of lifetimes. So, you can quickly say; how is it that a well known cellular technology is. So, well is working. So, well for the purposes of carrying IoT data, you may be wondering.

Well, that is the beauty. And that is the reason why there is a strong technology initiative technology push invention of new technologies which ride on existing cell phone technologies to give you this kind of support for 10 to 15 years. What are these mechanisms? We will come to that as we go along; it isn't that all of that is just limited to the cell phone network technologies. But also the open ISM band technologies like (Refer Time: 20:44) and LORA are also expected to give you LORA and SigFox are also expected to give you 10 to 15 years lifetime. What you mean by this? Simply means if you put a battery and you leave it with a LORA modem or a SigFox modem. It should be it should work unattended for 15 years anywhere between 10 to 15 years that is the key requirement.

So, power efficiency becomes important. The third thing you are talking about is massive scale, massive scale, what are you talking about? Potentially millions of devices, not necessarily concentrated at one point, but overall number of devices that it should work it should scale is to millions. Again let me point you to a very strong issue here, 1 billion population of Indians are more or less expected are statistic show actually own phones, which is a clear indicator that the cell phone technology appears to scale to this kind of numbers. And therefore, it is perhaps useful to look at a technology which is around the cell phone telecom service provider based technology which will allow us to scale to the kind of numbers that we are referring to. So, massive scale is a third requirement ok.

Strong coverage greater power efficiency massive scale, what about cost? You can not be talking of very expensive technologies either. So, cost is an important requirement. And it should be the usual it can perhaps be to begin with the bit expensive like 5 dollars or so, but then it should quickly fall down to about one dollar one US dollar and therefore, cost becomes a very important thing. And there so 1 2 3 4 4th one is cost.

Fifth one indeed is bandwidth, but this is no big deal we already said this right. We are not talking of large amount of data rates. If you are talking about a garbage can

application you just send out a few bytes of data from each individual garbage cans just carrying the data that it is the garbage can is full. That is about it you do not need to carry many bytes.

Therefore, bandwidth is not really very important, but if you are talking about massive scale, and support for massive scale devices massive number of devices, particularly if you are talking about concentration of many such devices in a given area, particularly sensor networks the large sensor networks, then you are to be worried about you are too worried about the bandwidth.

And therefore, higher the bandwidth is always a very nice thing right. So, that is a very useful thing alright. So, this is one thing, another thing is, what are the limitation of these technologies? That becomes important. Now we will put broadly we will sort of reason out what is a good technology to try again design of internet of things means choice of technology right.

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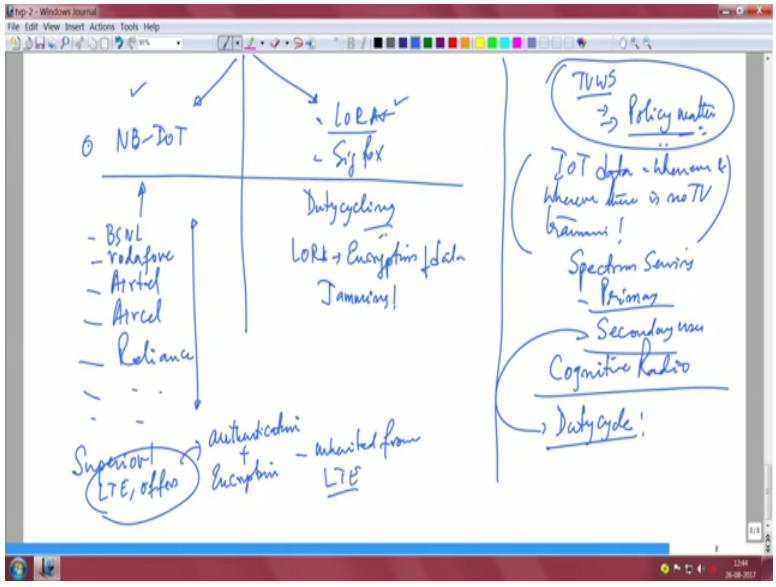

You have you have choices to choose from. Let us put NB-IoT on one side and LORA SigFox on the other side. And let us go on comparing between the 2, and let us say when I say NB-IoT, I mean the licensed spectrum part. I have not put no l for instance here because it is not really picking up. The issue why TV wide space is TV white I just have a word about this before we move on.

See, many things for a success or failure of a technology also can come from a policy related matter, from a policy matter. What it means is, the TV white space is owned by TV broadcasters, TV channels right. They own the spectrum. Technology for carrying IoT data is in place, but spectrum is owned by others. Technology is demonstrated it is there on the table for people to use. The only way by which such white spaces which are available on TV can be used is government takes a decision to permit carrying of IoT data whenever there is or wherever there is no TV transmission.

Whenever and wherever, there is no TV transmission when I say whenever, I mean there is TV coverage, but at that instant there is no TV transmission, then you can also use TV white space. There could be other regions in the country where there is no TV coverage at all that is wherever there is no TV coverage. It should be able to do it. Which brings us to a very important technology push which is seen enormous amount of literature work happening in the last 5 years, and this is with respect to spectrum sensing spectrum sensing, primary users secondary users, secondary users. All of it leading to a large bubble in research called the cognitive radio, cognitive radio right. Cognitive radio essentially is that just take the example of this TV white space. If I have a cognitive radio based modem IoT modem he will transmit only when there is no TV signal. He will just push that data is not very huge.

So, he can quickly complete transmission of the data and keep quiet right. So, you can duty cycle, you can duty cycle send data exactly at the time when there is no TV transmission which clearly indicates that he becomes a secondary user. The primary user continues to be the TV broadcaster who owns the spectrum, whoever owns the spectrum is the primary user whoever is riding on top of the primary users you know let us say benevolence that he can use the spectrum comes from the secondary user. All of this means government policy should be there for the purposes of providing permitting cognitive radio based you know secondary users. So, that is a very important.

So, I am not even talking about TV white space systems because that is well it could appear here on the left side of the chart, but let us keep that out of discussion. So, we will just concentrate on NB-IoT LORA and SigFox. And we will try and see if we can show you a demonstration of LORA and Madhuri and Anuja are here and they can actually show a few things with respect to that. So, we will come to that in a moment, but let us complete this discussion quickly alright.

So, here the trouble with LORA SigFox and NB-IoT is this is licensed on the left side right. Shows you are actually using cell phone technology primary user is himself offering you services to carry data right. So, who are your primary spectrum owners? BSNL, Vodafone you can have airtel, you can have aircel, you can have reliance, and so on and so forth right. All these people are basically service providers. They themselves will provide you a modem and they will say no problem you can use our license spectrum.

So, in a way you get access to the license spectrum for all these applications LORA and SigFox have a problem. They not only use the ISM band they also have restrictions of duty cycling, duty cycling. They have a problem of duty cycling they cannot essentially be on all the time and use the circuit transmitting all the time that is not possible, whereas there is no problem of duty cycling here. And this indeed takes a little bit of a issue if you talk about duty cycling, but we can look at that as we go along now another thing which will worry us is about security right.

As I mentioned to you security has to go with all these technologies. If you look at NB-IoT because they use the cell phone technology cellular infrastructure technology, the security is quite superior. Whatever LTE offers, whatever LTE and 3G offers you get all those features because it is based on the cell phone technology. Whereas, LORA, LORA does encrypt data there is no problem. It does encrypt data there is encryption. Encryption of data is possible, but data can be jammed. Jamming is still an issue. SigFox I do not think actually even encrypts data, it just transmit is data and there is an issue there.

So, the authentication and the authentication and encryption is superior because it is offered by the cell phone network. So, that is a very attractive thing. So, I will say authentication and encryption authentication plus encryption is inherited by, inherited from sorry, inherited from LTE. That is the key point alright. So, we covered that.

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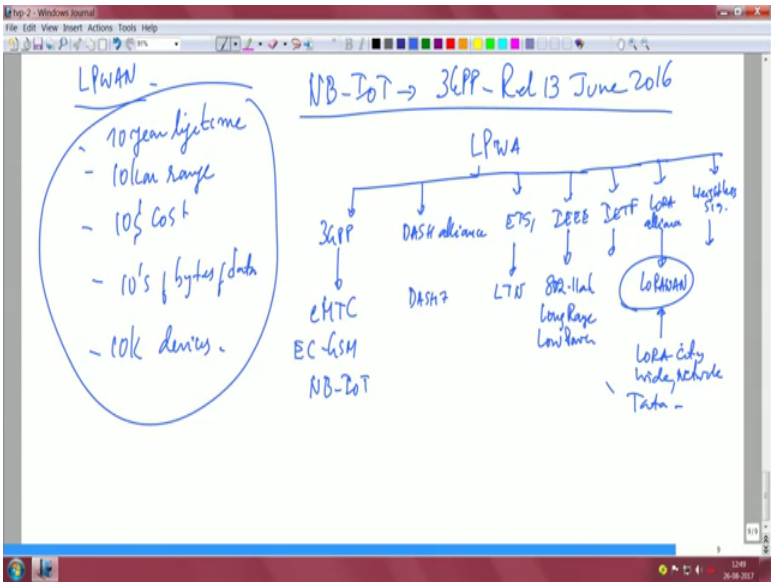

Normally when people talk about the LPWAN requirements people talk about 5 things that LPWAN is supposed to provide you, it is supposed to provide you 10 year, 10 year lifetime, 10 year lifetime, 10 kilometer range, 10 kilometer range, 10 dollar cost, 10 dollar cost, tens of bytes of data and 10 thousand devices. So, it sort of covers everything here 10 year lifetime and so on. So, really it is an interesting thing there are as I mentioned to you there are other competing technologies. So, we already mentioned that. So, if you want to understand anything more about NB-IoT.

NB-IoT you will have to look at 3GPP, 3GPP, 3GPP release 13 June 2016, this is very, very critical. Read up everything about NB-IoT by reading up this particular it is a open source you can easily get the standard; not at all really an issued for you to figure out. So, in a broad perspective if you talk about LPWAN standards, you will be talking about 3GPP efforts, you can be talking about dash alliance you can be talking about ETSI, ETSI, you can be talking about IEEE, you can be talking about IETF, you can be talking about LORA alliance, you can be talking about what is known as the weightless, weightless Sig so many of them out there. In the low power wide area standards, here we can talk about enhanced machine type communication extended coverage GSM.

You can be talking about NB-IoT, dash alliance is dash 7 there is a standard ETSI, ETSI there is something called a low throughput network. Then IEEE standard is there 15.k, 15.k4G and so on. Long range low power this is what I was telling about the standard

low 802 that is standard; which is the low long range low power and so on. Here LPWAN 6 low pan wide area network and all that you can be talking about some technologies here, not important and LORA, LORA alliance, LORA wan weightless is the another part.

Here LORA So, it is exciting to also know a lot about LORA, because service providers can also offer you not only cell phone coverage, but they can also deploy ora city wide network. LORA city wide network for example, Tata indicom, Tata s have proposed set up of a LORA city wide network. Like imagine, city which has cell phone coverage, beside that cell phone coverage you can actually be talking about a LORA city wide coverage systems, because LORA is also expected to give you a long range and quite a popular technology for carrying IoT data ok.

I will now contrast you to some very important points. Contrasting NB-IoT with SigFox and LORA you must know this ok.

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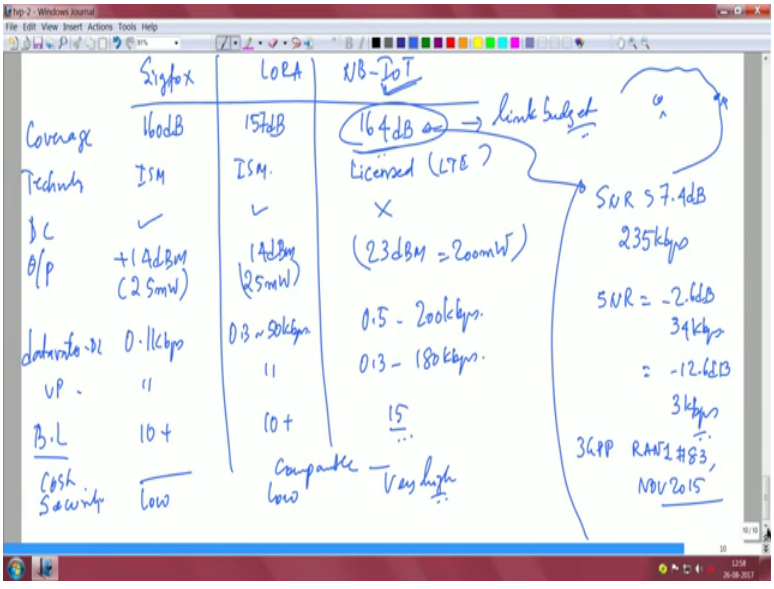

So, let us put down SigFox LORA and NB-IoT sorry, NB-IoT. Why am I harping on only these 3 and not did not talk So much about the others? The reason is one of them will succeed and it appears to me more and more that NB-IoT will succeed, replacing LORA insulations. SigFox insulations are already there mostly in France. But LORA is already proposed by many Indian companies service providers who want to establish a LORA network beside the cell phone network. But if cell phone is already giving you in license

spectrum many good features why should I look at LORA that is the reason that comes, but you should know it. I am going to put a very important point, and the point I am going to say is about the technology itself. And before we go to that the important point is about the coverage, this is 160 dB. This is a 157 dB and this is a 164 dB coverage.

Straightaway hands down basements, indoor, outdoor, all coverages are possible because of NB-IoT that is the reason. Now SigFox technology this is unlicensed right. ISM also ISM unlicensed this is licensed, this is licensed, licensed. It could be LTE it could be very one of them what about duty cycling DC simply I will call it DC. This is duty cycled this is duty cycled, no duty cycling, no duty cycling is possible. What about output power because it is duty cycling you can emit at higher power? But you are offsetting by the fact that 99 percent of the time you are sleeping that is the problem. So, if you look at output power this is plus 14 dBm this is about 25 milliwatt of power. And this is also 14 dBm LORA which is also 25 milliwatt. But this guy is 23 dBm, 23 dBm this is equivalent to 200 milliwatts of power. You get licensed? You get higher power, what about data rates?

Data rate this is 0.1 kilo bits per second SigFox, very low dribbling data rates. You get maximum in LORA about 50 kilobits per second kilo bits per second. But in NB-IoT you can get from 0.5 kilo bits to about 200 kilo bits per second, what about uplink this is downlink what about uplink. If you take the uplink it is a same here it is the same here and here it is 0.3 to about 180 kilobits per second. What about battery life? B.L here I will give 10 plus here I will also give 10 plus here. I am not going to give 10 plus here, but here I mean it is going to be more I will tell you, why it can even be up to about 15 years again this can be 15 years.

The reason is very simple if you have a cell phone coverage. Let us say this is the tower and this is closer to the tower these are all far off from the tower. If you are closer to the tower you get many, many more years of lifetime, but if you are talking about at the edge of this you will be down to about 15 years. So, that is the beauty. So, really coverage depends on where is the modem how far is the modem from the actual cell phone tower. Cost well cost more or less I would say they are all comparable cost is comparable. So, I will say comparable I will say simply say comparable, I do not think you will get any lower cost systems.

Security I mentioned to you many, many times success of IoT means that the security should be extremely you know versatile and robust I would give these 2 low and this is very, very high. Mere encryption of data by LORA is insufficient it is an issue. So, this 164 dB comes from the link budget. This is the link budget calculation. And the link budget here is a 164 dB which is very, very good now less to spend a little more time on this aspect in the case of NB-IoT. If the SNR, if the SNR is greater than 7.4 dB you will get downlink data rate of 235 kilobits per second. And if the SNR is down to let us say minus SNR is down to minus 2.6 dB you will get 34 kilobits per second. And if your SNR is down to minus 12.6 dB you will get 3 kilobits per second.

Extreme coverage; that means, cell phone tower is here and this is the edge here we are talking about here this is where you will get a very, very low data rates, but as you have closer your SNR as seen by the receiver modem NB-IoT modem is high and you will get very high data rates. This is not numbers which you have which I have by hearted. You should simply look up the summary of NB-IoT evaluations, that were done by 3GPP and that document is available you can just download I will point, you to the document 3GPP RAN radio access network. RAN 1 hash 83 of November 2015. So, that is a important document for you to look up. This duty cycle is indeed an issue, duty cycle is indeed an issue, why is this an issue?

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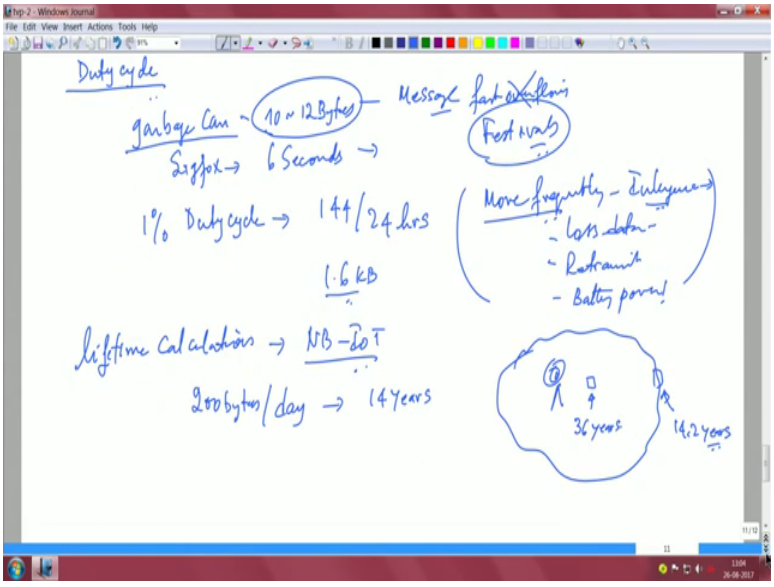

If you take let us say, a garbage can, garbage can monitoring the garbage and sends out a piece of data. How many bytes will it be? You can take anywhere between 10 and 12 bytes, let us say 10 or 12 bytes let us say, 10 to 12 bytes ok.

And if you take the SigFox technology, if you take SigFox technology; it takes about 6 seconds, to transmit this message. At one percent duty cycle, if you consider a one percent duty cycle, SigFox device can actually send a 100 and each is a message here this is each is a message, this is a message. It can send about 144 messages per 24 hours. And if you now recalculate what is the daily data maximum rate maximum data that you can send it is about 1.6 kilobytes. So, 144 messages per 24 hour period, for a daily data maximum of about 1.6 kilobytes that is the idea ok.

This may not be a problem at all, if your garbage can is not overflowing fast, overflowing is not a problem. Fast overflowing no problem, but if these cans keep getting over or overflowing at a very fast rate, particularly during festivals right. Lot of garbage is generated, it could be garbage from flowers which we holy garbage let us say. Lot of that garbage is out there then your, these messages will start this data has to go out at a much higher pace. That is an issue right. This may not be a problem for normal purpose, but yes indeed that s an issue. And therefore, the modems will switch on more frequently, more frequent.

When they switch on more frequently there is bound to be interference. When there is interference you are likely to lose data loss of data. Because you lost data what you do you? Retransmit, if you retransmit your battery goes down. So, you see one leads to the other and therefore, you this is this is something that does not really scale well. So, this duty cycle issue has to be borne in mind that is an important thing.

So, lifetime, lifetime calculations, lifetime calculations actually depend on the amount of data that is sent out by each modem; if you are talking about 200 bytes. So, essentially you will be talking about I am just talking of NB-IoT. So, I am really not talking about the other technologies, if you are talking about if you are saying 200 bytes per day, and you are at the edge of the network; that means, your SNR is really low, you would have 14 years of lifetime, and if you are very close to the cell phone tower.

If the garbage can is close to the cell phone tower as compared to being at the edge, this will give you 14 years sorry, this will give you at least theoretically they say for 20 to

200 bytes per day you will get 36 years. And here you will get 14.2 years. These are estimations go back and look up the estimated battery life from the 3GPP RAN 1 hash 83 November 2015 datasheet which will allow you same one 3GPP RAN 1 hash 83 this will also tell you about the battery life. Now if you want NB-IoT gives you some downlink performance, right?

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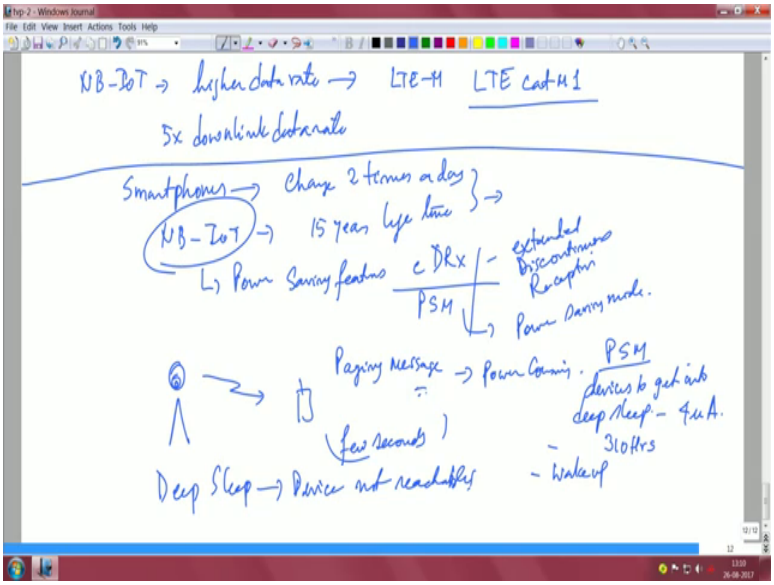

We mentioned it gives you 200 kilobits per second and we did show some things from the standards, suppose you want to go even to higher data rates, higher data rate. Then you could consider LTE-M this is for higher data rates. Here this LTE-M is also called LTE called LTE cat LTE cat M 1 also called cat M 1.

LTE-M is less flexible in it is deployment models and it is coverage is not as strong, but it will give you 5X, 5X down link data rate, 5X the downlink data rate and So, that is useful. So, I will just leave it at that stage to tell you about the LTE-M. Now you may ask that key question. Smart phones smart phones you need to charge twice a day, 2 times a day right. But NB-IoT using the same cell phone systems gives you this magical 15 years lifetime, how is that possible? 15 years it brings us to a very important point. That there are 2 fantastic changes that have happened to support NB-IoT in the cell phone in the cell phone structure, and these 2 features power saving features power saving features are called eDRX and PSM ok.

Let us spend a little time, understanding eDRX and PSM. EDRX actually stands for extended, discontinuous, discontinuous reception. And PSM simply stands for power saving mode, it stands for power saving mode. So, when a device is connected to the network what it does the network periodically sends, the network periodically sends what is known as a paging message right. Paging messages are sent down by the network. Now these messages happen very every few seconds, otherwise how will the network keep track of where the user is right. Even at high speed you are able to people are able to contact you when you are inside a car, clearly paging message will keep telling the network where a particular user with a smart phone is actually sitting.

Now, this paging message is a power consuming operation, it is power consuming and therefore, it takes a beating on the battery life. Now what you do? In PSM power saving mode this enables devices to get into deep sleep. And when you say deep sleep for a device what is the deep sleep current? 4 micro amperes, 4 micro amperes; and typically in deep sleep you are talking about sleeping for 310 hours that is what the standard says, 310 hours you can sleep continuously. Then you wake up; that means, you are not receiving this paging message anymore, you are just sleeping continuously for this as long as 310 hours, you wake up to update the network and sleep again listen to pages for a brief period before sleeping again, that is how you keep doing.

During deep sleep device is not reachable: device not reachable. Suppose you want to reach to the device you want to be in sleep, but you want the device to be reachable.

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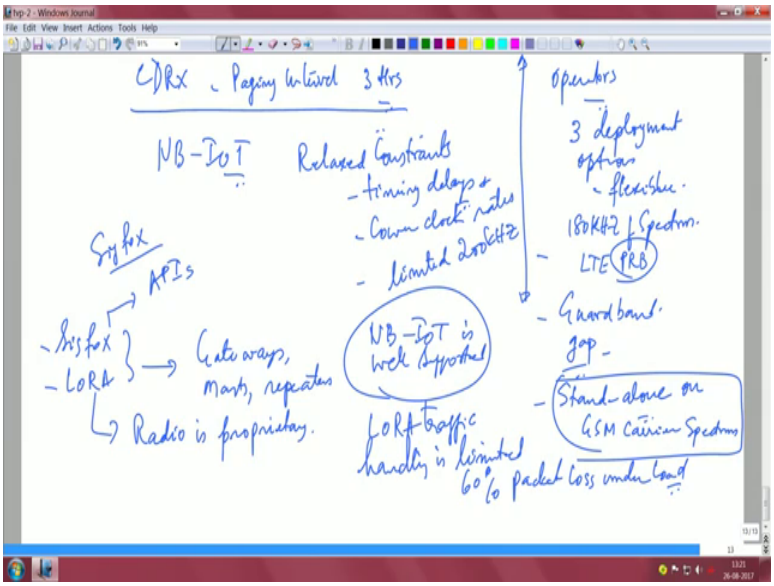

Then you could set it to eDRX extended discontinuous reception mode. This paging then you can actually extend this paging interval. So, you are extending the paging interval, interval up to nearly 3 hours. From seconds you make it move to hours; so up to 3 hours. So, in a way you can do a combination of PSM and eDRX and adjust the devices in a manner that lifetime are satisfied. So, that is the very, very important requirement thing that you can do. What are the other features that seem to contrast the NB-IoT from cell phone infrastructure? The constraints are much more relaxed, relaxed constraints unlike a smart phone. Constraints relaxed constraints and this could include timing delays chip design itself can be relaxed making chip design.

So, when you say timing delays can be relaxed. So, they are not very there is no stringent requirement this chip design itself can be can account for this right. Because of this the chip itself becomes cheap and the design itself will be influenced largely by that. Lower clock rate also, lower clock rates, clock rates are low and good use of the well known limited 200 kilohertz that we know very well. Cost comes down becomes (Refer Time: 60:01) though.

Now, as far as the operators are concerned, that is network cell phone operators are concerned there are many there are 3 deployment options, 3 deployment options for them. And So, the thing is it is much So, 3 deployment options to basically to suit the network environments. And therefore, it makes an NB-IoT perhaps the most flexible one

gives you makes it very flexible system. Is basically fits into that fit into that 180 kilohertz of spectrum, basically talk about the LTE physical resource block ok.

It is designed to fit into 180 kilohertz spectrum. So, it is nearly fits nearly within one or more standard LTE PRS physical resource blocks. So, NB-IoT can also be deployed in the guard band. So, you can put it either in the 180 kilohertz PRB LTE PRB or you can also put it in the guard band guard band. At the edge of an LTE allocation basically you can be talking about the gap between this is nothing but the gap between the frequency bands that is designed to prevent interference right. You can put it in the guard band between the frequency bands that is designed to prevent interference NB-IoT that is another thing.

NB-IoT can also be deployed as standalone, can also be deployed as standalone can also deployed as standalone on a single GSM a single GSM carrier spectrum right. So, this gives you the advantage that in locations where carries full 4G roll out plans RNT are defined or standalone alongside an LTE spectrum band, you can put NB-IoT there, you can deploy NB-IoT there. So, that is an advantage of NB-IoT. If you look at again we have to understand with respect to SigFox and LORA, if you look at contrasted because we have been making this nice comparison, in the world of these 2 technologies you require gateways, you require masks, repeaters, and so on, if you want to use this SigFox and LORA technology all that is actually avoided right.

SigFox as I mentioned to you is entirely a proprietary technology. So, when you talk about SigFox client device hardware the network operators deploying SigFox networks. All data moves through SigFox cloud only everything goes to the SigFox cloud. And you access it through APIs it is proprietary. So, you have to use their own APIs that are given out by them in order to access the data. LORA is back by the LORA alliance LORA is given by the LORA alliance, it is actually co developed by IBM it is open source, but the underlying radio technology is proprietary again, radio is proprietary that is the trouble right. LORA is radio is proprietary. So whereas, NB-IoT is well supported NB-IoT is well supported and it appears that it might succeed more.

It might be the one that will be a solution for the low power wide area coverage. It is also easy to integrate into cellular technology ecosystems, because it is gone. So, it just (Refer Time 68:21) into the existing cell technology. NB-IoT appears to be a maybe will

perhaps be a bigger success. LORA. For example, traffic handling is extremely limited. LORA traffic handling is limited. For example, you can have under traffic high traffic load you can have up to about 60 percent packet loss. Under load, load is the problem you do not know when such networks will get loaded with lot of data right. So, that is the time when you really wanted to get assured packet delivery becomes an issue and that in turn has barying on the battery life.

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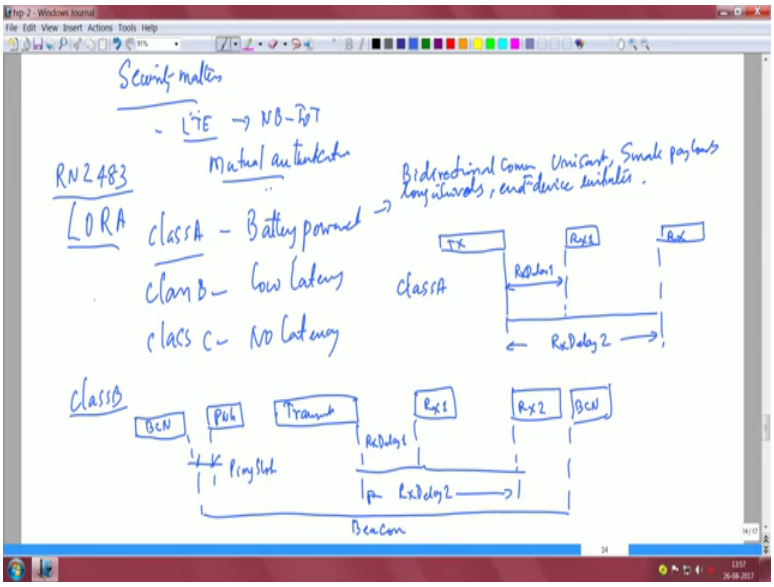

Now finally, about security matters, security matters. If you I mentioned to you that NB-IoT inherit is everything from LTE authentication and whatever is done by LTE NB-IoT simply gets it from there. IoT simply gets it from there, mutual authentication for instance.

Mutual authentication is well supported. So, that is in brief what you need to know about NB-IoT. Let us spend a little more time on LORA alright. So, let us do a demonstration of LORA technology, but before we get into LORA let me show you an let me give you an overview of LORA itself so that you will appreciate the technology and the matureness of the technology, ready to use actually. Let me point you to what I wrote here LORA gives you know provides you 3 types of devices, there is a class A kind of a device which is battery powered for battery powered applications, the communication is bidirectional.

You can also do uni caste communication, small payloads typically, long intervals and essentially all communication is initiated by the n device. This picture will help you understand how class A works. So, you see this block is the TX block. You have RX 1 and RX 2 in class A what happens is there is a transmission by the device, initiated by the device. And for a 2 very short intervals one shorter interval, one short and one slightly longer interval you have 2 reception modes. It is called RX 1 and RX 2 after which the device simply goes back to sleep right. So, that is class A purely for battery powered applications and very, very energy efficient power efficient. Because it is not up for long intervals of time you can see this part is only twice.

Now, you have class B. Class B LORA modem is for low latency applications, and essentially I put down the class B here where you can see from in contrasting to this picture. This one says transmit there is a RX 1 then there is a RX 2 again. And there is also what is known as a beacon interval, and there is a (Refer Time: 72:12). So, there is a beacon to beacon interval and then this repeats again. So, here you do not have a beacon based system in class A, but in class B you have a beacon to beacon in between is this transmit receive 1 receive 2 and then of course, there is a ping slot also for testing the health of the modem whether it is on off and all that. And then soon after the beacon after the beacon you showed this transmission RX 1 RX 2 happens. And again you get a beacon and then you essentially again have a ping transmit RX 1 and RX 2 essentially repeating.

This is for low latency applications anything which requires sort of close to real timeness. Then you can also have class C. I have not shown a picture here, but essentially soon after transmission the RX 1 simply comes up here straightaway. So, which is a clear indicator that there is no requirement for any delay this delay RX 1 delay and RX 2 delay are actually close to 0, which will allow you to transmit and immediately listen back. So, that is the different types of modems LORA modems that are available.

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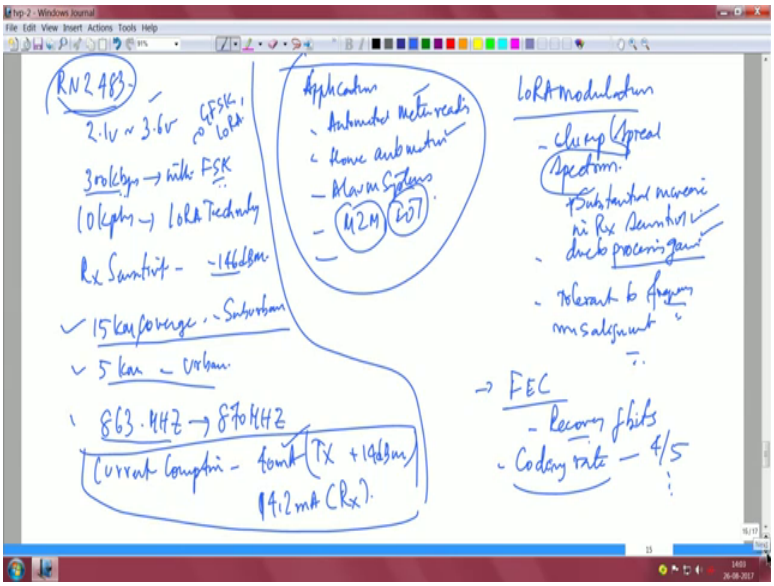

Now, LORA applications have been many we discussed them broadly you can use it for automated meter reading home automation, building automation, alarm systems, broadly machine to machine and other IoT applications. LORA uses what is known as a (Refer Time: 74:21) spectrum modulation. And because of this spread spectrum modulation there is a substantial increase in receiver sensitivity due to high processing gain. And also because of this spectrum technique it is tolerant to any sort of frequency misalignments.

LORA also has forward error correction, for recovery of bits, you can set the coding rate 4 by 5 and many other coding rates are actually possible. Now let us look up one specific modem that we want to you can actually look up the datasheet. It is called RN2483 this is from microchip it operates from 2.1 volt to 3.6 volts it supports different data rates depending on the modulation. For 300 kilobits it supports for FFK modulation it supports 300 kilobits per second. And LORA modulation technology is also available, which I described to you earlier. Receiver sensitivity is as good as minus 46 dBm. The manufacturers claim that if it is suburban you get a 15 kilometer coverage. If it is an urban environment you will get 5 kilometer coverage, and the frequency can be set anywhere from 863 megahertz to 870 megahertz. Look at the current consumption and look at how attractive the system indeed is.

It gives you a plus 14 dBm maximum transmission power forty mili amperes of power is of current is consumed which means if you are operating at 2.1 volt you are talking about

a little over 80 mili watts of power, transmission power. And it consumes 14.2 mili amperes in reception mode ok.

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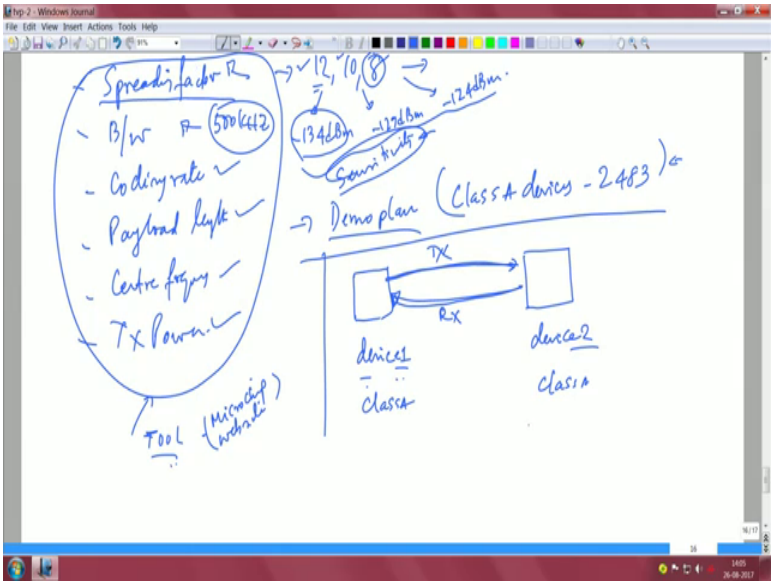

So, that is what this chip actually does. Now what are the options which you can use with this particular modem? Well, you can change the spreading factor. You can change it to 12, you can change it to 10, 8 and so on.

For each change in the spreading factor, the sensitivity goes on improving for example, for spreading factor of 12 you get sensitivity of minus 134 and for a spreading factor of 8 you get minus 124 dBm. So, this is excellent already because the LORA technology allows you to do spread spectrum LORA modem technology particularly the LORA the LORA, as we call the LORA let me quickly. LORA modulation technique allows you this you know to do spread spectrum, does improve the processing gain of the system, and offers you very good sensitivity. Bandwidth is also settable you can set it to even 500 kilohertz, coding rate can be set, payload length can be set, centre frequency can be set and transmit power can also be set. So, all these can be set you can actually download a nice tool and play with this tool.

Which you can actually download from the microchip website, microchip website or from LORA alliance website you can actually download and try around install this tool and actually try a few changes in parameters. Just to get you familiar with what the technology does. Now as far as demo plan is concerned Madhuri and Anuja are here,

what we will show you is device 1 class A device 2 is also class A, we will do a transmission and we will show you a reception, and just to give you an idea of how big or how the card looks how the actual hardware looks it is a very simple demo let us see and of course, all these parameters can be modified also in that process.

Let me shift topics now a little bit and go back to the low power wide area network protocols we discussed LORA NB-IoT and so on. I will just point you to 2 you know datasheets which are of interest to us. One is from a company called u blocks ok.

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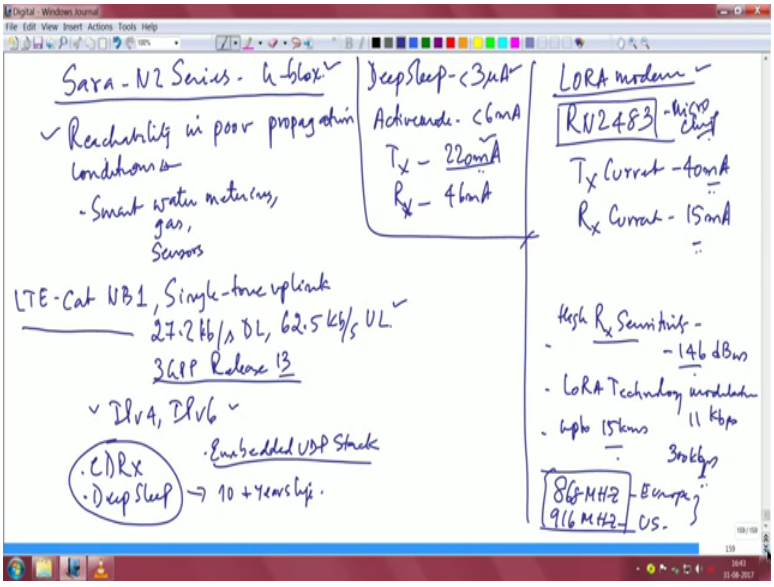

This is you can look up sahara: sahara n 2 series of modules which are slowly started appearing in the market. And they expect that these are NB-IoT modules essentially, wherever you want reachability in poor propagation conditions, it seem to offer you very good alternative. And it claims that there are applications worth smart bottom monitoring, metering, smart gas metering, then smart sensor applications and so on. Essentially it follows the LTE cat n B one single tone uplink gives you 27.2 kilobits per second in downlink, and 62.5 kilobits per second in the uplink.

It adheres to the 3GPP release 13, supports IPV4 and IPV6, and it supports these 2 important interventions in the cellular world for 3G 4G applications particularly 4G LTE applications. Where you talk about discontinuous reception and deep sleep requirements right. This is what will lead you to the 10 plus years, 10 plus years of lifetime. And they also claim to have an embedded UDP stack well within the module. Let me point you to

some numbers which they seem to claim sort of very interesting, deep sleep current I mentioned to you if you want to get you know lifetimes of 10 plus years, you need to be under the less than the 4 microampere kind of currents.

This module claims it is to be about 3 microamperes active mode is 6 miliamperes, but when the radio comes on well it pumps at 200 and 20 miliamperes, but the data rate is. So, high that the amount of time it remains in transmission mode is unmatched to any other technology and therefore, this is not a scary number at all; given the fact that the transmission time is highly reduced due to the high data rate. And reception is reception takes 46 miliamperes, which is also reasonable. Overall very promising technology for a low power wide area; LORA is also very importantly what we should remember about LORA is that LORA in Europe operates in the 868 megahertz and it operates.

In 916 megahertz in US and North America this is Europe. So, please look out for LORA modems depending on where you want to apply them use select the modems of your interest in your specific country and region.

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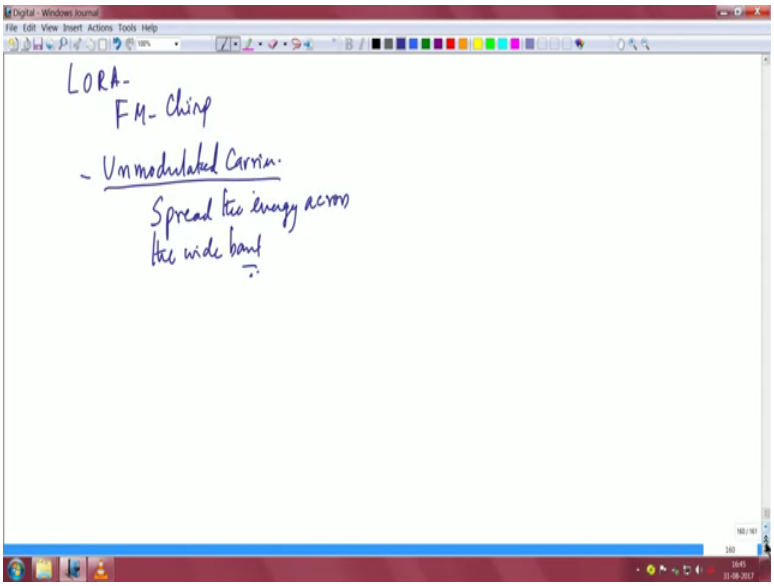

And look at the regulations that are required for use of LPWAN using LORA. What is important about LORA is that it uses what is known as a FM chirp modulation. So, and it is indeed spread spectrum, but not direct spread spectrum. In other words what it uses is a un modulated career, it uses and un modulated career unlike direct spectrum which modulates the career if this uses n modulated career FM chirping. So, that it can spread

the energy, So that it can spread the energy across the wide band across the white band. This part is the same even for direct spread spectrum except that the difference is this is done using un modulated career white band. So, that is another important feature.

So, let us what we will do is we will run through a very small demo using these microchip modules, microchip RN2483 modules, and just to give you a flavor of what are the possible settings that one can do with these modems ok.

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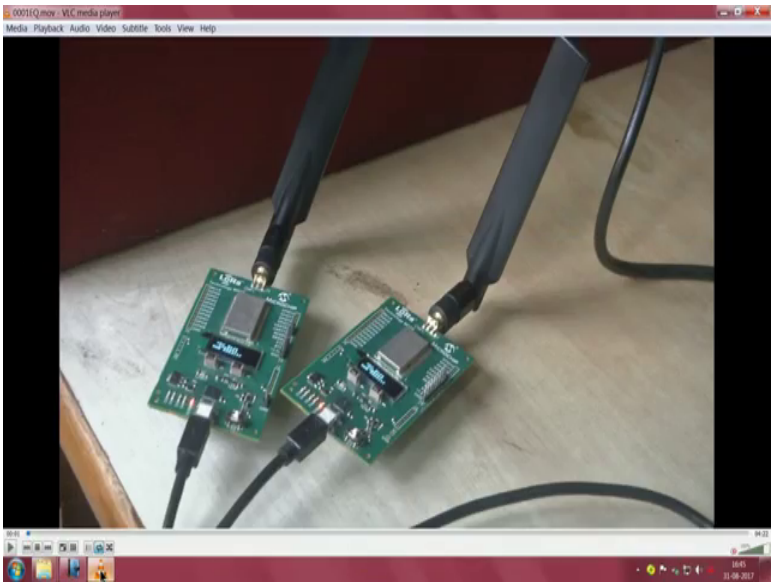

So, let us run through that video and move on from there. So, what you see on the left side here is actually the transmitter. And on the right side what you see is the receiver. Now the right side screen that you see here is the transmit screen and on the left side what you see is the receiver screen.

So, let us see; what are the different settings that Miss Madhuri is trying. She is setting the radio frequency as you can see that frequency is being set. And you see that actually she is using the parameter to get. So, essentially she is reading what has already been set. So, she gets this value back, now she is changing the parameter related to spread factor. And so, you can see she said get off a spread factor, and it displayed that the spread factor chosen was 12. She said get radio power then it said it was at plus 1 dBm. So, she decided to change it to 14 dBm and so, she used this word set. And then she reads it back and then it echoes that it has indeed read 14 dBm plus 14 dB m.

Now, she is setting the career sorry, the circular redundancy check. Whether it is on or off and then that sees on. The preamble length is also she is trying to get, which is 8. And then she is then changing the coding rate right. Here it uses 4 by 5 coding rate. This is the watchdog timer, which is set to a number, she requires a lot of time to move between the screen on the right and the screen on the left. So, she increases this time to ninety thousand milliseconds. So, that milliseconds time is set, and she reads it back to see whether ninety thousand milliseconds alright.

Now, she is all set left side is a receiver, but again you could set the watchdog timer value to something reasonable. So, that it is demonstrable to us. So, she said set to some numbers some 80 thousand milliseconds. And she has to put this into essentially the reception mode, but can you also configure the transmit mode on this I think so, it is possible you can. So, she will try also trying to she will try and configure the transmit on that on the receiver side. So, watchdog timer is done radio get watchdog timer he reads it back soon after she will set the power to plus 14 dBm.

Well, it is not really required because she is just in the reception mode, but if she is striping out something from the current trans receiver to a transmitter then she may have to set the transmission power. Now, she has set the receiver to she has set the modem to the reception mode and she is all set to so, to transmit something. And you can see that she has transmitted 5 6 4 6 7 8 9 which comes on to the receiver side. So, she can also try sending a very long string to see whether that appears back on the receiver side and yes indeed it comes.