Design for Internet of Things

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Lecture - 50
NBIoT, LTEM1

Alright folks, now let us look at another space in the low power wide area networks, you know technologies. We discussed the LoRa protocol quite well. And we also spoke about the class of devices classes A, Class B, Class C and so on. Fundamentally, the difference between the three classes we know now very well. Who initiates the connection in class A, it was the device that initiated the connection, latency was very high.

But lifetime was also fantastic because I decide as a node, when to wake up and when to transmit and I that is my prerogative, right? But if I transmit the gateway, the network server has the ability via the gateway to reach me. This paradigm of Class A, Class B, and Class C cannot be shaken up at all folks. Whether you apply it in LoRa paradigm or whether you apply it in the any other technology, it is the same story.

Just replace, and think about your mobile phones that you have in your pockets, okay. Think about a fantastic way of doing the following. I am sure you would have done these simple experiments all by yourself. Supposing you have a smartphone, which is capable of giving you let us say 4G and 5G connections and 5G phones are also released now. You have all that. You might say I do not want any of that.

I just want to make phone calls. I just want 2G, I do not want anything else. Then automatically you find that you are not browsing, so your internet connection, IP address acquisition from the service provider; all that is gone. You cannot make, you cannot even browse, okay. You will get only messages, SMS, and you can only make a phone call and be done.

Just examine that lifetime as compared to that of browsing, putting up your Wi-Fi, doing so many things, tethering, so many things that you do. Everything is power consuming. One of the biggest power guzzlers indeed is the display. Suppose you can shift the display to let us say, a completely blank it out and then just use it like old Nokia 3310 or Nokia 1110 phones, then your lifetime is already, it used to be the in those days, it used to be Nokia 1110.

Lifetime used to be 5 days, 6 days on a full charge, right? Now you have to do a charge every 5 hours, perhaps, right? So this is the situation. Everything is revolving around battery life and so on and so forth. The imagination you must have is think about a nice thing that, can you ever get 10 years lifetime by contacting a mobile tower from your device? The answer is yes.

With IoT devices contacting a mobile tower, you can get up to 10 year. The devices can have up to 10 years of lifetime, using a normal battery that can be applied there. How is that possible? And what is that magic? Do not change any new, do not think about any new logic. Think about Class A, Class B and Class C devices. More or less everything falls under that paradigm only, okay.

That is indeed the nice thing about the LoRa technology that we discussed there. So question is this. You already said that if you look at LoRaWAN, you are not worried about data rates, you are only worried about longevity, long range, longevity of the device, because you are talking about 10 plus years. And we know all that is now possible with that. Same thing in the mobile space.

If you are using Telecom, terrestrial networks, telecom service providers, standards for IoT devices to connect using mobile phones, mobile towers, not mobile phones mobile towers, has also propelled quite a bit. All of that effort by the mobile in the mobile space, telecom provider space is standardized by a body called 3GPP, third generation partnership project 3GPP.

So if you type in 3GPP.org, you will get a whole bunch of information out there, okay. Let us see if I can browse for you and take you to 3GPP.org.

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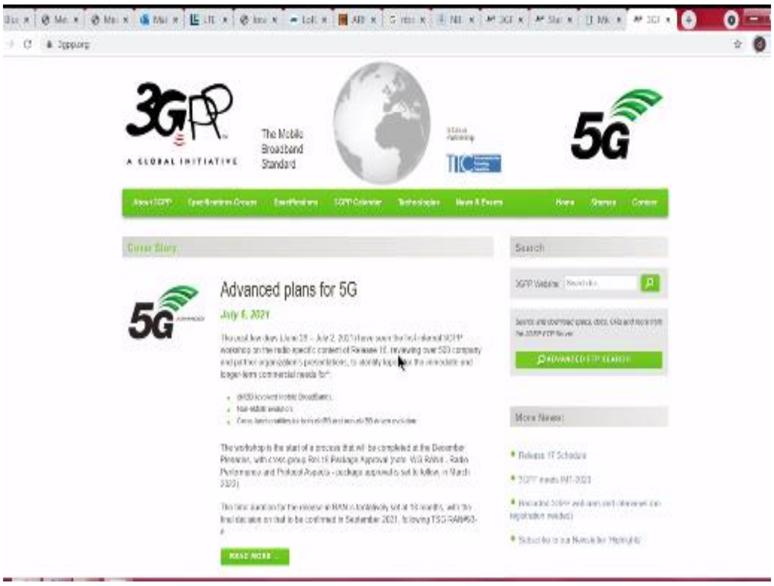

This is 3GPP.org. Anything that you want to know about technologies for IoT using mobile telecom service, everything should start from this one particular page. And therefore, we will study not in detail, but from a lifetime perspective two important technologies which was standardized by 3GPP.

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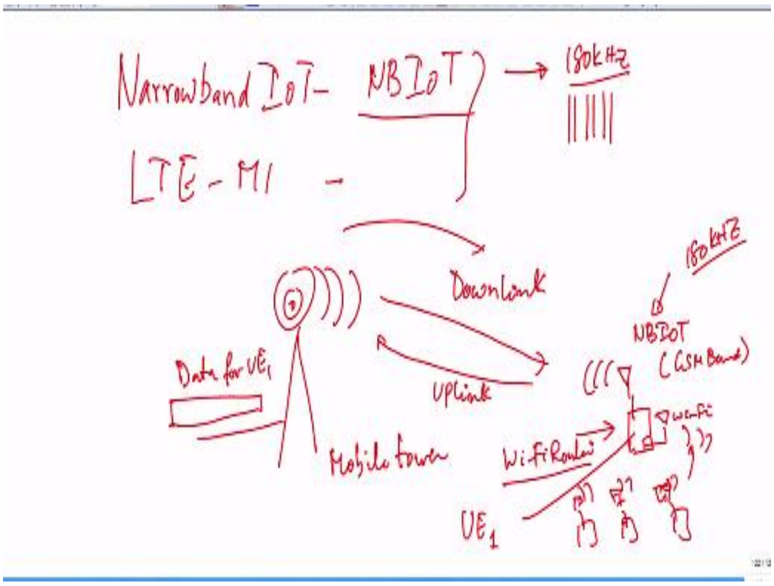

One such standard that was finalized by 3GPP organization is called the narrowband IoT. When you say narrowband IoT, this is interesting because it is really narrowband. It is using a 180 kilohertz of bandwidth; that is all. Remember what your bandwidth was in LoRa, it was 125 kilohertz. Here it is 180 kilohertz. Again, there are multiple channels here. Again, there are multiple channels.

Extremely low narrowband channels, but everything aggregating only to a 180 kilohertz. And where do they push these channels folks? That is interesting, right? How do they get this 180 kilohertz bandwidth at all?

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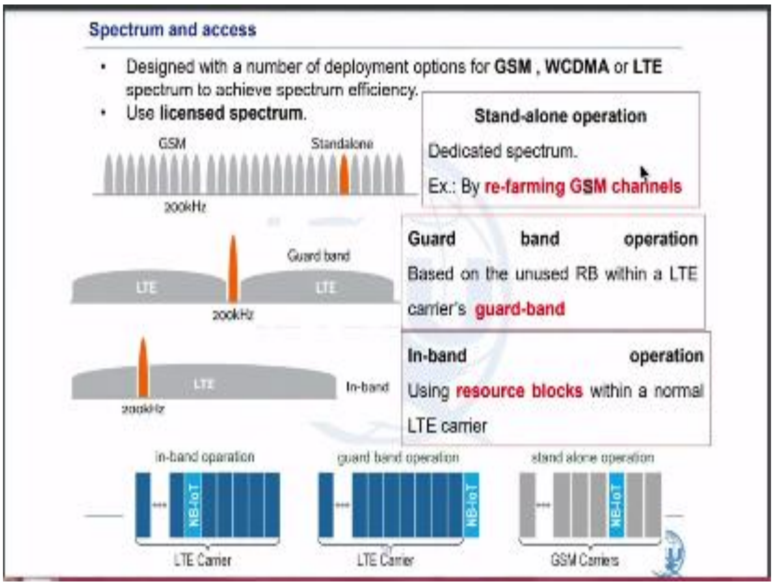

This is really an eye opening picture. What actually happens is you look at this. This is the GSM network, okay. Here you re-farm the GSM channel. Old GSM that we used to work on your systems were all 200 kilohertz folks. Each GSM channel was 200 kilohertz. Now what are you talking about NBIoT, 180 kilohertz. That means it should fit well within the 200 kilohertz bandwidth that GSM was offering, okay.

So you re-farm GSM channels and if you have a GSM tower, you should be able to use narrowband IoT for low data rate, uploading of data to the cloud using narrowband IoT modems. That is indeed the story here. And how can one sketch that picture? The picture can be sketched quite easily. I drew it here. Let us say this is your user equipment, end user equipment which is nothing but a narrowband IoT modem, okay.

Now this one also has let us say Wi-Fi as an example. So let me write it neatly okay, so that you will be able to connect back. This is typically of a tower, a mobile phone tower which you can see somewhere in the outdoor, okay. You have your UE equipment here. It is called user equipment and this is talking a narrowband IoT, okay. And this may be also in the GSM band no problem, GSM band.

However, it has another radio which is Wi-Fi or any other radio. Here this Wi-Fi radio will connect to other sensing devices, okay. These are all other devices. Now those devices like you know your home Wi-Fi router, right. So this is like equivalent of your Wi-Fi router, okay. It accepts on Wi-Fi and then transmits over the using your mobile phones folks and tethering to give tether to some of the devices, exactly like that.

So this is something that you can do, okay. But NBIoT is a standard which was so beautifully designed, it said that I will put everything into this 180 kilohertz, the standard is for 180 kilohertz, so that I can push it wherever I like. Even if it is not GSM and if it is LTE, I can I should be able to push it there. And how is that coming about? Here is the beauty. Look at the first one. It says GSM 200 kilohertz standalone.

You can look at this color here. So many of them are all GSM bands except one they have pulled out and made it into a narrowband IoT for data communication. So this is channel being used. This particular one will be used for purposes of transmission of data at low data rates. So essentially you can do standalone operation using GSM.

Even more interesting is supposing your network infrastructure, mobile phone service providers like Airtel or BSNL, Vodafone, whoever they are, have all switched to LTE okay, they are all giving you 4G network. Even there you can push NBIoT and how do you push it? You can push it inside the guard band. See here. LTE one channel, LTE another channel. In between you have a guard band.

That guard band gives you 200 kilohertz guard band. Inside the 200 kilohertz you are only using 180 kilohertz. So happily, you can also deploy a narrowband IoT on LTE bands, okay. Now you may ask that can I not push it into the LTE space itself? Oh yes, you can. You can see this. He has pushed it into the LTE space.

Here there are what are known as when you do in-band, you assign what are known as resource blocks within the normal LTE carrier. And those resource blocks essentially carry NBIoT technology related data. So you can see the picture here. Here is in-band, this is NBIoT one of them, this is guard band operation. That means all these channels here are LTE carrier bands.

But NBIoT is getting pushed here, because of this particular thing. It comes here as another color outside the LTE carrier in the guard band. And then you can also do in terms of GSM carriers in the top picture here. One of them can be denoted for carrying the IoT data, right? So if you ask someone a question, so is this a very attractive proposal for people who want to have something equivalent of what LoRa can do?

The answer is yes, folks. This is something like what LoRa can do. But in the mobile space, okay. There you needed LoRa devices, you had a gateway, then you had a network server, and then you needed to connect it to the application gateway, and so on and so forth. Here directly on your next available, openly available, freely available tower, you can send your IoT data to the cloud using the LTE or GSM space and deploy using narrowband IoT.

So this is an important aspect of narrowband IoT. So this is about narrowband IoT. That was just one way of, you know uploading IoT data using the technologies that we describe taking it and putting it into the channel into either GSM based technologies or into LTE based technologies. While that is one part, the 3GPP also finalized native to LTE, how to transmit IoT data.

They did not want to compete with narrowband IoT, they wanted broadband IoT. That means you want higher data rates. You want multi, let us say, much higher bandwidths, and many more scalable solutions are to be built. If that is your requirement, then you may want to shift to LTEM1 also for carrying IoT data. Both of them have to be contrasted in a manner that you understand it better. To do that I am showing you a chart here.

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Comparison with LTE-M

Attribute	CAT-1	LTE-M		NB-IOT	
		Rel 13	Rel 14	Rel 13	Rel 14
Spectrum	LTE bands	LTE bands Stand Alone (1.4MHz)		LTE Bands Stand Alone (200KHz)	
Typical MNO	LTE Coverage	Good LTE Coverage		Mix LTE and 2G	
Bandwidth	20 MHz	1.08MHz (CAT-M1)	5 MHz (CAT-M2)	180kHz	
Number of DL Antennas	2	1		1	
Duplex Modes	FD-FDD/TDD	HD-FDD, FD-FDD,TDD		HD-FDD	
UL Modulation	QPSK, 16QAM	QPSK, 16QAM		Pi/2 BPSK, Pi/4 QPSK	
DL Modulation	QPSK, 16QAM	QPSK, 16QAM		QPSK	
Spectral Efficiency	V.Good	Good		OK	
Power Class	Class 3 (23dBm)	Class 3 (23 dBm) Class 5 (20 dBm)		Class 3 and 5	*14 dBm
UL Multple Access	LTE SC-FDMA	LTE SC-FDMA		LTE SC-FDMA + Single tone transmission with 3.75kHz and 15kHz bandwidths	

The chart says look at the extreme right, says about NBIoT, okay. There is a LTE-M and then there is a CAT-1 okay? There are minute differences between them. You actually have two competing standards when you talk about supporting IoT data in the broadband using native LTE. That time you will have LTE CAT-1 as well as LTE-M. So anyway, there is very minute differences which you can see here.

First let us resolve what we have with respect to narrowband IoT. Everything was done in release 13 of the 3GPP documents and 13 and 14. The good thing is the mobile network operator can either be 2G or it can be mixed with LTE. Both are possible, that is why typical MNO is mix of LTE and 2G. Bandwidth we discussed, it is only 180 kilohertz. Number of downlink antennas is 1.

Duplex mode is HD-FDD, frequency division duplex. The uplink modulation and downlink modulation. Spectral efficiency is okay, not all that great, but it is still good. And you have transmit power of +14 dBm that is allowed in narrowband IoT. And there is a power class which is called 3 and 5 supporting +14 dBm. So you can see that power is not all that great.

And spectral efficiency is not all that great, but works very well because MNO can be a mix of LTE plus 2G. So that is a good thing about it. And it is more of an evolution of what you can do to carry IoT data in old traditional legacy GSM systems without modifying anything in the base station or anything, you can just carry data.

So this is LTE single carrier FDMA, single tone transmission with 3.75 kilohertz and 15 kilohertz bandwidth, both are still possible. You can still go lower than 15 kilohertz as well it appears. All of that is what NBIoT does. Shifting to LTE-M the release came up in 13 and 14 as well. You can see the LTE coverage is good.

Gives you higher data rate and supports higher modulation schemes and therefore you get higher data rates. The transmission power is 23 dBm, you get a much higher coverage. So this chart tells you that the development in the mobile network operator space has also propelled into extremely interesting options for IoT devices to connect.

Now you see you have NBIoT, CAT LTE, then you have CAT LTE-M1 okay. And other competing technologies. There is come something called GC GSM and so on. Several, you know what shall I say standards have evolved from 3GPP to support IoT data. Low intensity data, use narrowband IoT. You want high data rates, high capacity systems, use CAT LTE-M1 and so on.

Modems will start coming. Do not have to do anything much with the existing mobile phone infrastructure, you can start using them directly, depending on what your application is. But folks, I did not answer an important question. And that was related to the fact that I said you should get 10 years of lifetime for any one of these technologies that you use with mobile phone.

It is almost impossible for you to imagine that your mobile phone can give you on full charge 10 years, it is impossible. You cannot even think about it. But that is what is possible with using the same mobile infrastructure with IoT devices. And how is that possible?

Well, there are some very exciting changes that 3GPP have brought about and if you know those three changes that have evolved, you will understand what a fantastic thing that has come about in the space related to power saving of devices. And that brings us to a very important document which I found on the internet and you can download and read it as well.

This just gives you an overview of what exactly are the interventions that allow you to bring in the 10 plus years of lifetime.

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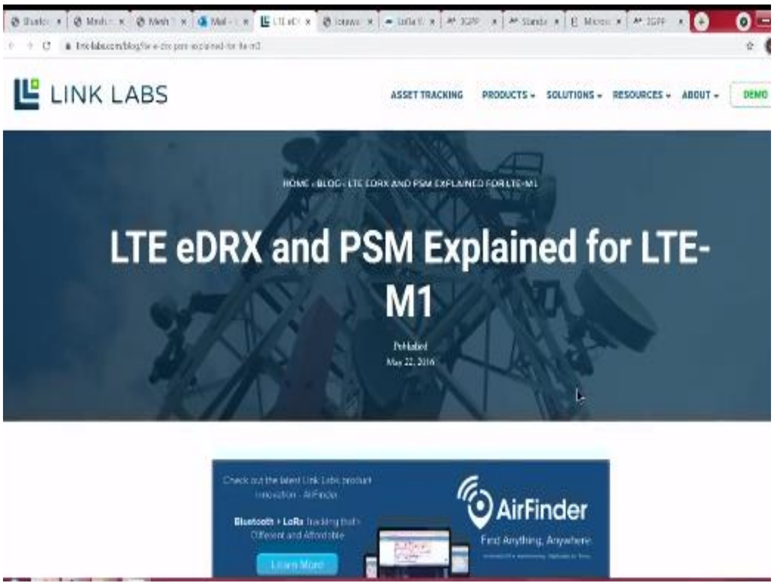

There are three interventions, okay. First intervention is called DRX, okay. Let me explain this to you three interventions that are there. First one is called the DRX. The second intervention is called eDRX. And the third intervention is called the PSM, okay.

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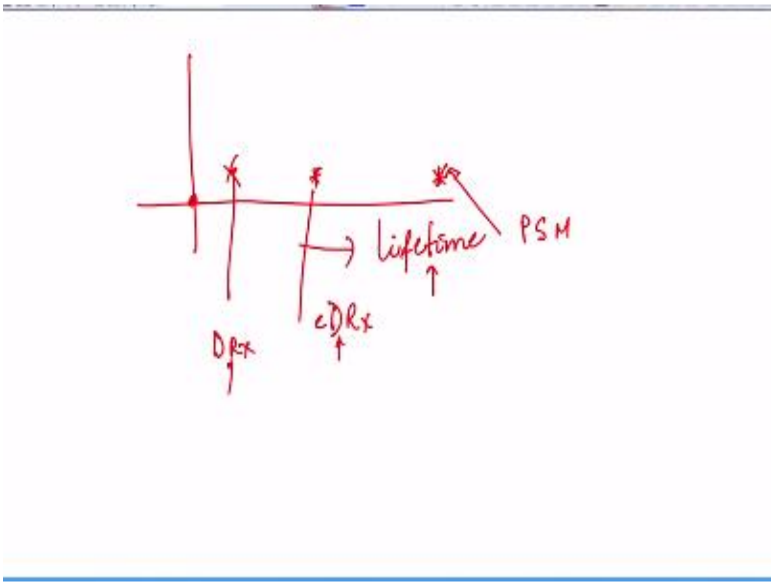

Now if you have to plot a picture okay, if you have to put this as lifetime, this as the lifetime, then you would get maximum lifetime with PSM, you will get with eDRX. But if you do DRX you may be here. And if you do nothing you will be right here consuming power all the time, okay. So you can see that I have plotted lifetime on the right on the x axis and you see that this is amazing, right?

And therefore, you must understand what these things are. And we will spend a little time trying to understand the three definitions that we have in front of us, okay.

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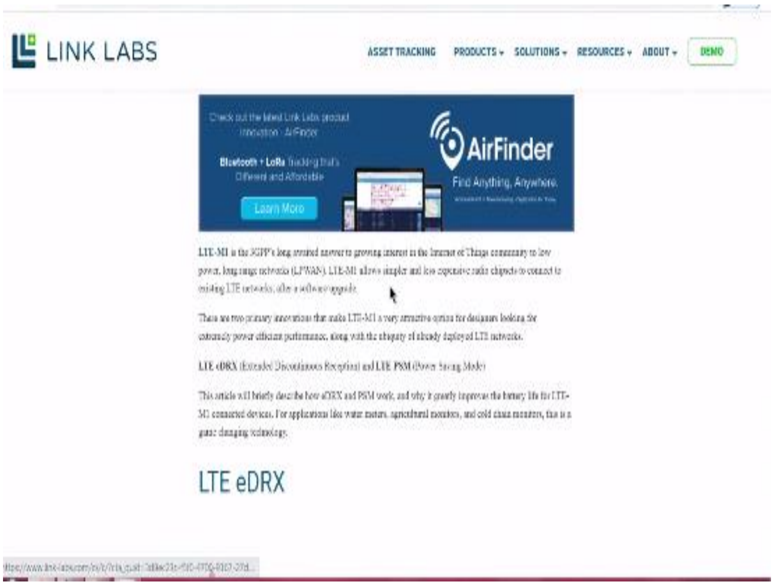

First thing is CAT LTE, the LTE-M1 is standard which I mentioned to you is something that is an evolution, clean slate development of supporting IoT data on LTE technologies. The fit into the LTE is essentially the narrowband IoT. You are trying to fit because you made it narrowband, you made it 180 kilohertz, you are trying to fit it, okay. But whereas LTE-M1 clean slate development of IoT technology.

So M1 will allow you simpler and less expensive chipsets to connect to LTE networks and so on. This discussion is irrespective of whether it is narrowband IoT or LTE-M1. I am talking about battery life purely from battery life perspective, irrespective of the technology that you have in mind. So this is important, okay. There are two primary innovations he says in M1, which make it very attractive for designers.

One is called LTE eDRX and the other is called LTE PSM. I said three, he has written two here. I said three because 'e' is extended discontinuous reception. But before extended discontinuous came, there was already a discontinuous reception. So that was already there, which was called DRX, okay. Please note, you can replace this word LTE with NBIoT. It will still make a lot of sense, okay. That is all I want to say. Alright. So now let us see what actually happens and why does it actually give you the 10 plus years kind of lifetime. All right, look at this picture.

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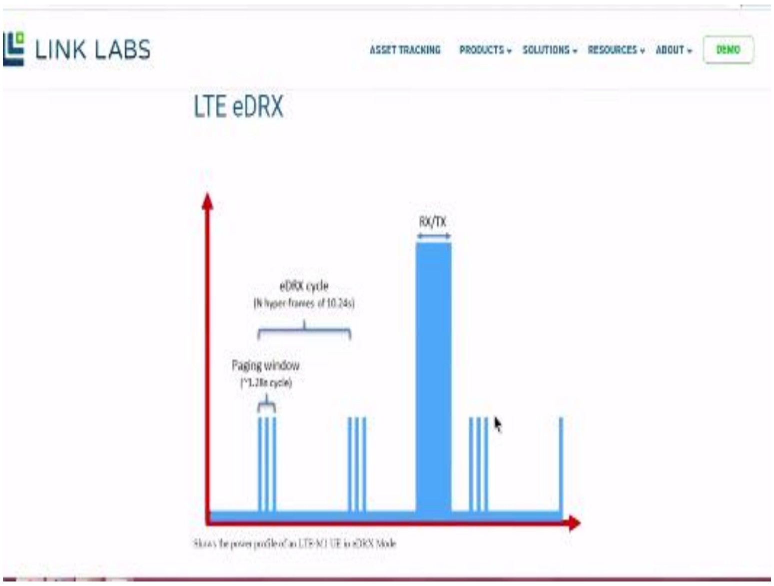

So the picture shows something interesting. Shows the power profile of LTE-M1 UE that means end device, the IoT device, which has aggregated data from several sensors, and it is we are talking about the lifetime of that device, okay. This is a picture directly showing you the eDRX mode. Now the DRX mode is go back and look folks at what you have done here folks.

You are saying that I will sleep for a certain period of time, this is that period here. And then I will make available a window over which I can be disturbed. That is the paging window. That is of 1.28 seconds cycle, okay. So you are disturbed here. You can be disturbed here, you can be disturbed here, and you can be disturbed here. Again, you will go back and sleep.

And again you will go back and can be disturbed. Who will set all this? The network and the end device will have to negotiate. And then they will be able to set this thing. By and large it is the network which decides this. Now folks ask yourself the following question. How different is this from class B of LoRa. It is not any different folks. It is the same paradigm that is coming repeatedly in a different avatar.

That is all you need to imagine. So let us now read this. It says, this article will briefly describe eDRX and PSM and why it greatly improves battery lifetime for LTE-M1 connected devices. For applications like water meters, agriculture monitors, cold chain monitors and all that it is a game changing technology. This is LTE eDRX.

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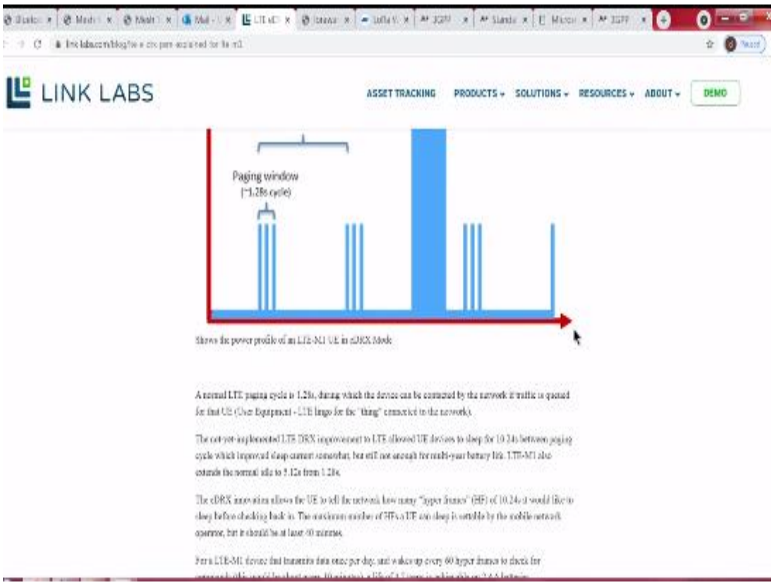

Now see normal paging cycle is 1.28 seconds, you cannot do anything with this. This is what the 3GPP standard is for LTE technologies. If you are looking at a 4G mobile phone in your hand, your mobile phone will implement this perfectly as per the standard. So you will be having a paging cycle of 1.28 seconds during which the device can be contacted by the network if traffic is queued for the UE.

That means if you have data here, data for UE 1 let us say and I will call this the UE 1. It should go in this direction downlink, there is data, you have to deliver it, right? Now what should happen? It cannot deliver the data at all odd times but it can deliver the data at the paging times. It can be contacted by the network traffic if there is data queued for that device.

The not yet implemented LTE DRX improvement to LTE allows UE devices to sleep for 10.24, you can see this number here. This is amazing. The eDRX cycle is in hyper frames of 10.24 seconds, okay. LTE allows UE devices to sleep for 10.24 seconds between paging cycle which improved sleep current somewhat, but still not enough for multi-year battery life.

You cannot do much by just looking up that. The LTE-M1 also extends the normal idle to 5.12 seconds from one 1.28 seconds. You can see this normal idle is actually now available from 1.28 seconds. Alright, so the cycle is extended.

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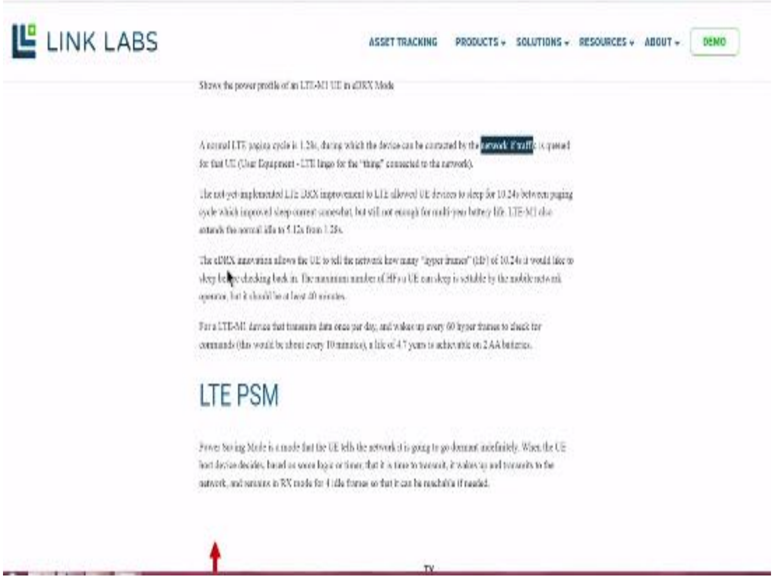

Now the eDRX innovation allows the UE to tell the network how many hyper frames, HF as it is called, of 10.24. One hyper frame is of 10.24, how many into ‘n’, how many hyper frames you do not want to wake up can also be specified and that is the beauty. It would like to sleep before checking back. So you are requesting the base station. Think about Class B device, okay.

Think about Class B in which one, LoRa. You are requesting the network saying that you can page me after so much of time. That is HF, each HF is 10.24 seconds. You multiply it into n times. Supposing ‘n’ is 4, you have (10.24×4) right? That is the overall time after which the base station can contact the UE so that if there is data, the data can be pushed to the UE. And if UE has any data it can push it up.

That means it can do uplink or it can receive data, UE can receive data over the downlink; both are possible, okay. Now there is also a nice thing about, it should be at least 40 minutes. So that is the good thing. You can see the maximum number of HFs a UE can sleep is settable by the mobile network operator, but it should be at least 40 minutes. So that is fantastic right?

If unlike your mobile phones which keep getting interrupted every time, here in the IoT world, you are not going to contact the cell phone tower for 40 minutes which is a huge amount of savings in battery life. For LTE-M1 device that transmits data once per day and wakes up 60 hyper frames, this will be about every 10 minutes, a lifetime of 4.7 years is achievable with two double A batteries.

So already folks our 10 plus has become 4.7, that is almost half of that, right? Now what is the further intervention that you can do in order to improve?

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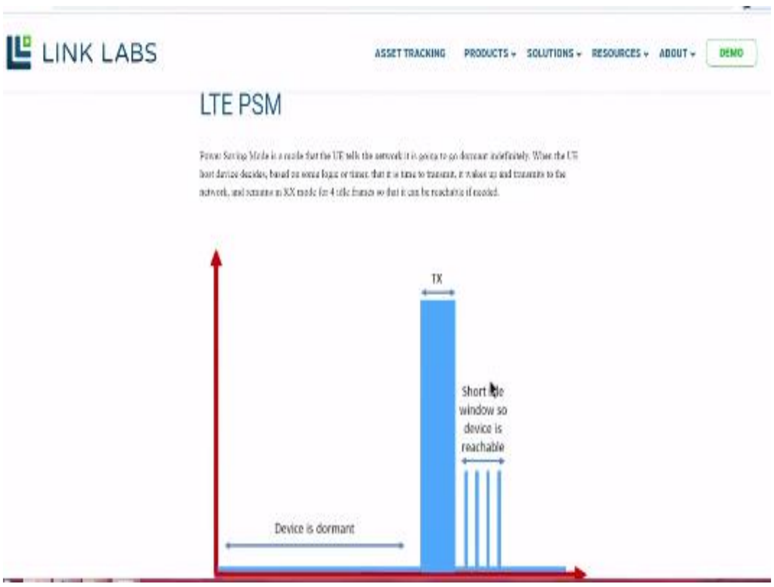

That comes out by the LTE PSM which is true also for narrowband PSM. This is even more fantastic. What does it do? Here the idea is the UE tells the network, that means the end device tells the network it is going to go dormant indefinitely. Do you not think that this is very similar to the what type of device, the Class A device of LoRaWAN, right? Nothing but Class A. It is equivalent of Class A.

So everything is the same paradigm folks, nothing much to worry about. When the UE host device decides based on some logic or timer that it is time to transmit, it wakes up and transmits to the network and remains in Rx mode for 4 idle frames so that it can be reachable if needed. Same like Class A device, nothing wrong if you want to replace interchangeably.

So you see device is dormant and here is transmission. Here is a short window so device is reachable. See folks, there is a difference from the previous picture. In the previous picture, you had reachable paging points here, right? You had paging points here. Here there is no paging. Which means the device has even disconnected from the tower. It is in full disconnection mode.

Whereas here it is not about disconnection, it is just about sleeping because you can still reach it over the paging window and therefore it is actually not disconnected. It is just sleeping. Here it is completely sleeping and disconnected from the tower, the end device. So it is giving you huge, humongous amount of power savings.

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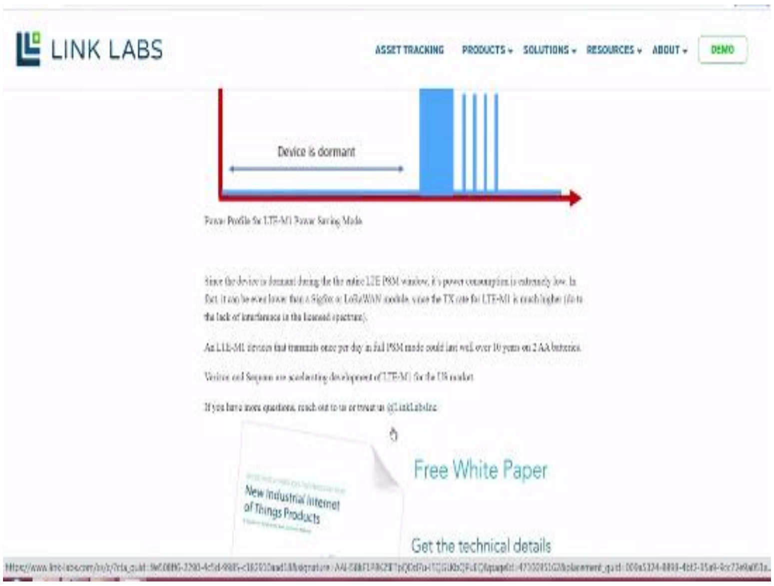

Alright, so since the device is dormant during the entire LTE PSM window, its power consumption is extremely low. In fact, it can be even lower than Sigfox or LoRaWAN module since the Tx rate of LTE-M1 is much higher due to the lack of interference in the license spectrum. Look folks, he has just turned around the table and saying that I can do even better.

If you choose PSM, I can do even better than LoRaWAN’s power consumption, okay. An LTE-M1 device that transmits once per day, in full PSM mode can last well over 10 years on two double A batteries. So that is indeed the way by which the technologies are competing one against the other so that the low power wide area network systems definitely has a bright future. You will be looking at something close to 10 plus years of existence of these devices once they are deployed. Thank you very much.