Design for Internet of Things
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Lecture - 48
LoRa – 01

Alright folks, I even showed you the LoRa board, the one that we have in our lab, which we were trying to experiment and trying to explain to you about the low power wide area network, okay. But you may be wondering why should we ever, anyone should ever study about LoRa, is it not? I want to point you to an article, which appeared in the IEEE spectrum. You see the connection to LoRa.

But before you see the connection, see what is actually the problem and how things are actually panning out in the direction of LoRa, okay.

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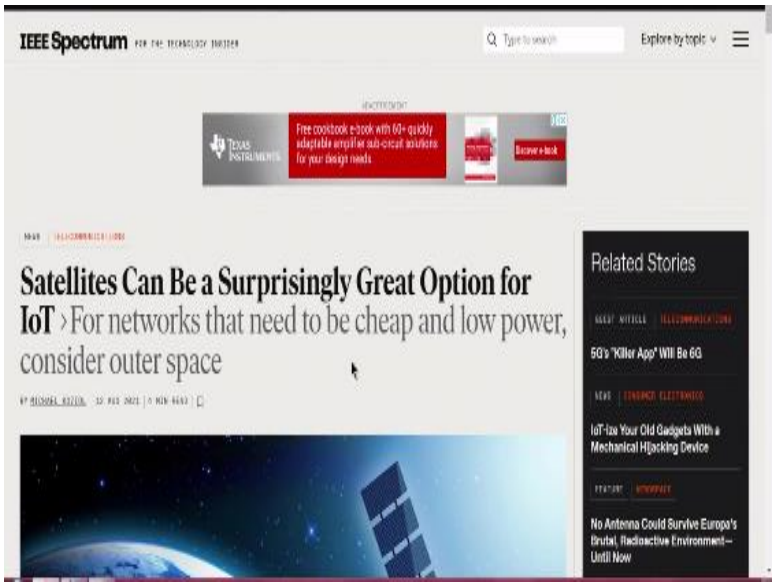

Here is an article in the IEEE spectrum. He says, satellites can be surprisingly great option for IoT. For IoT networks that need to be cheap and low power, consider outer space. So folks, where are we going? We are not looking at Bluetooth, Wi-Fi and you know ZigBee and this kind of networks anymore, we are looking at wide area. Even wide area connectivity, we are not even looking at terrestrial connections like cellular connectivity and so on.

We introduced LoRa which we said is also good because it is a terrestrial wide area up to 10 kilometer, we did that link budget calculation and so on. But this article is telling you do not do any of these, you can go out of space, out of this. Do not do it anywhere local to anything here. And here is the connection to the whole story that we need to understand.

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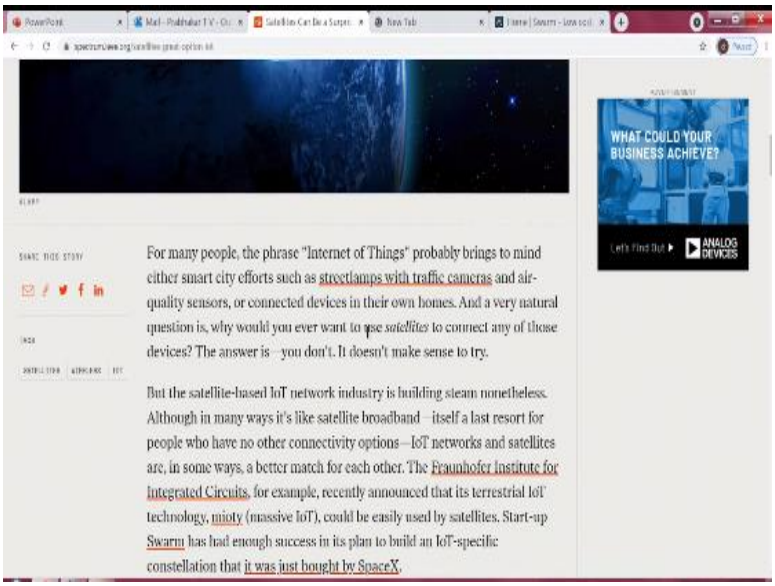

This article says many people think about IoT, just like connecting street lamps with, you know traffic cameras and air quality sensors and connected devices. All this is all fine. But what about satellites? Why should you ever use satellites to connect any of these devices, maybe really wondering right, you may be wondering.

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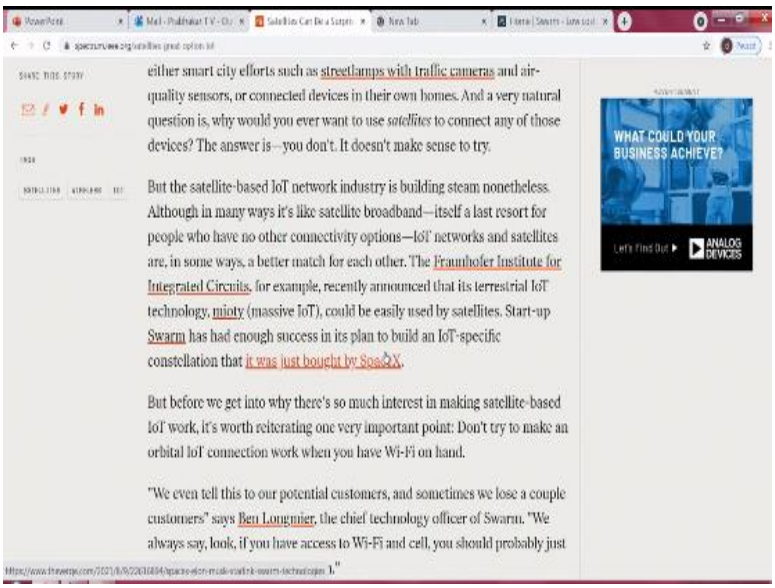

But the question really is that if you look at satellite based IoT network, you know it is gaining a lot of momentum. And the article clearly tells you that do not use satellite just because it is fancy. Do not use satellite, just because it is there. Do not use satellite, just because as an alternative to something else. Do not do that.

If you have very good terrestrial connectivity, if you have very good internet connectivity for your home, do not even think about satellite. That is what this article is saying. It is much better if you use whatever you have with you, okay. But there are several situations where satellite connectivity for IoT becomes an absolute requirement, okay. And that is where he tells you about, he brings into couple of important things.

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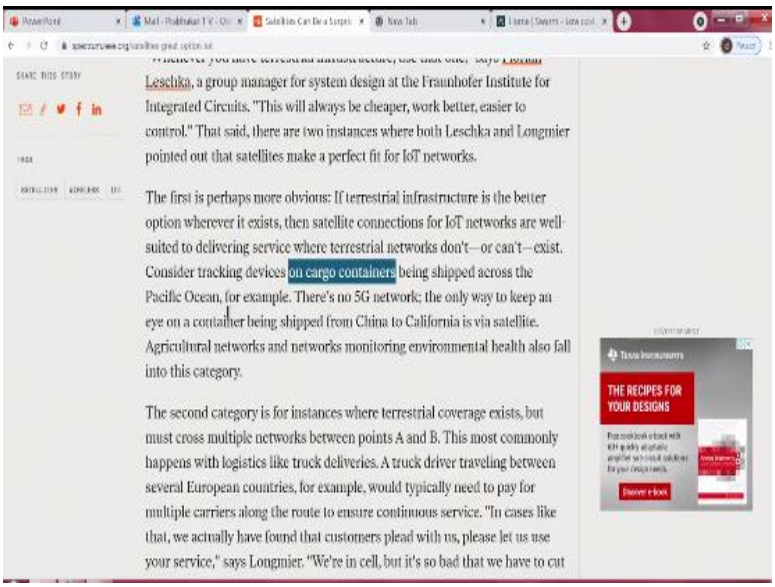

Think about one example here he is talking about is tracking devices on a cargo container being shipped across the Pacific Ocean. There is a huge cargo container on Pacific Ocean. There cannot be any terrestrial connection. There cannot be any Wi-Fi, Bluetooth, none of these things. No operator available in the middle of the deep ocean; that is not going to work.

You still want to know where your container is, when it is transiting across the Pacific Ocean. That is a good place, put a LoRa device there, put some device there, put something which will allow you to connect to the satellite okay directly, not LoRa, but he is talking about any satellite connection in general, okay. And of course, you cannot talk about 5G and so on.

The second reason why you may also want to go away from terrestrial although you are on land is because let us say a terrestrial connection in Europe from one end to the other, let us say if it is 1000 kilometers connection, where your source and destination are situated in a terrestrial network, it would not be from a single operator and it would not be from one country, it will be across countries.

And that is a pain if you want to have a service from one operator in one country to another operator in some other countries; that is going to be a difficult proposition. In India may not be so much because in India, it is 1000 kilometers you are not even you perhaps would not even have gone out of the state, right depending on where you are in a fairly large state like let us say UP or even Karnataka for that matter.

You may be just about going out of the state. That could be a problem. So you cannot go on having agreements from one country to another country across operators and it is a total mess. Therefore try to look for satellite connectivity. That is the second reason he says the article says that is a good thing for you to look up.

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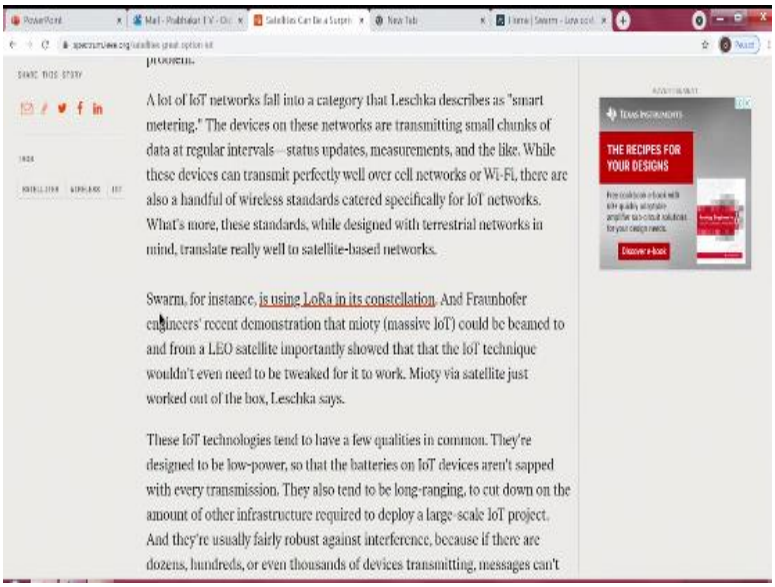

Then he points us to a beautiful website called Swarm where you can take services of LoRa constellation. Folks, LoRa has become so popular, fantastic connectivity that you can even reach out to low Earth orbiting satellites. Low earth orbiting satellites, which are a constellation of them can have LoRa receivers.

And you just need to buy your LoRa transmitter, LoRa system a transmitter which is able to reach out to this low earth orbiting satellites and then you will be able to do a satellite communication. So you do not need a satellite based modem and so on and so forth. You can use your standard IoT modem, IoT LoRa device and simply upload the content on to the satellite out there, which essentially has a LoRa receiver there.

So this is essentially what Swarm is doing, okay. Uses LoRa in its constellation. And Fraunhofer engineers' recent demonstration that could be beamed with a LEO, LEO means Low Earth Orbiting Satellite, importantly showed that the IoT technique would not need to be tweaked for it to work, okay. It is very simple, quite straightforward. You can buy it in the market, LoRa modem.

You do not need you know any special satellite transponders and so on. You just buy the LoRa modem, put up a sufficiently good antenna, beam it with sufficient amount of transmit power, you are done. You simply upload the data onto the, onto a low earth orbiting satellite. So essentially, for any large scale IoT project, which requires data upload, you can basically reach out quite easily.

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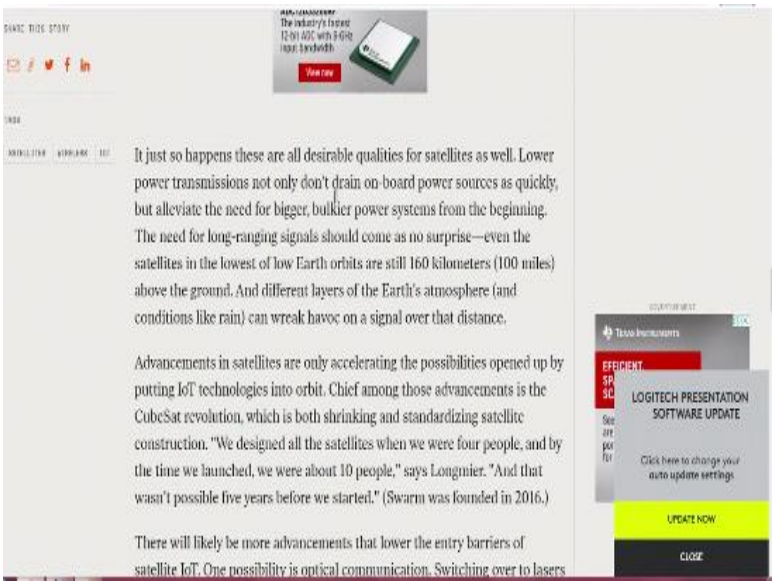

And now he goes on to tell us about a little bit about the low earth orbit satellites anywhere up to even as close as 160 kilometers you can have, and different layers of earth can wreak havoc on a signal over the distance. He is saying anywhere between 400 to 700 kilometers, anywhere even starting from even 150 kilometers upwards, low earth orbiting satellites are possible.

And there is the need for long ranging signals should come as no surprise. Even the satellites in the lowest of the low earth orbiting are still 160 kilometer. That means you can start with low earth orbiting satellites, how far are they? Minimum is 160 kilometers, it can go up to 700, if not even up to 1000 kilometers.

And that 150, above 150, 160 kilometers already, the link cannot be all that great. You can have conditions like rain and so on, which are which really create a lot of problem.

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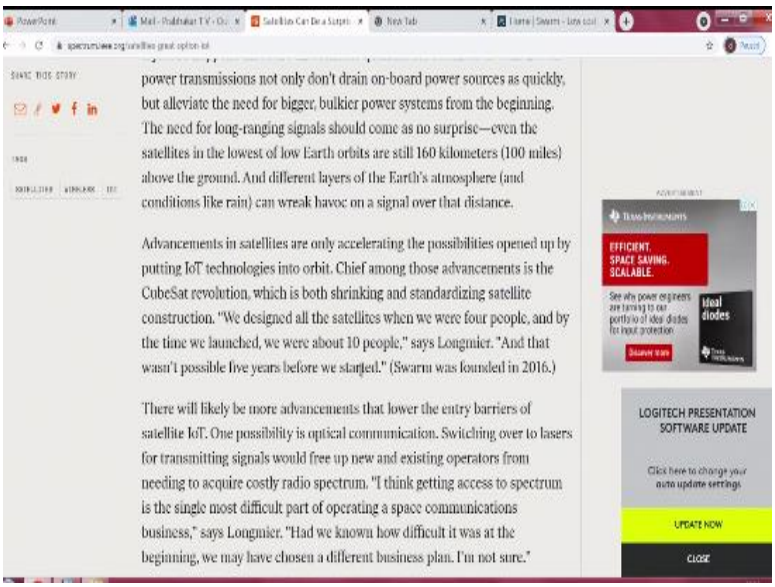

So advancements are happened in the satellite space, and they are accelerating the possibilities. Essentially, we are looking, they are looking at a constellation of satellites, which carry these LoRa receivers. And that will definitely be, it will lower the entry barrier for a satellite IoT a possibility with LoRa. So folks, you see LoRa definitely is the link between satellite communication and your IoT low power wide area network connection.

And essentially, I think you must seriously look up LoRa, understand LoRa technology in great detail, so that the communication in low power wide area network is possible in a successful manner. Before we move on to any further demonstration, let us go and look up this Swarm website.

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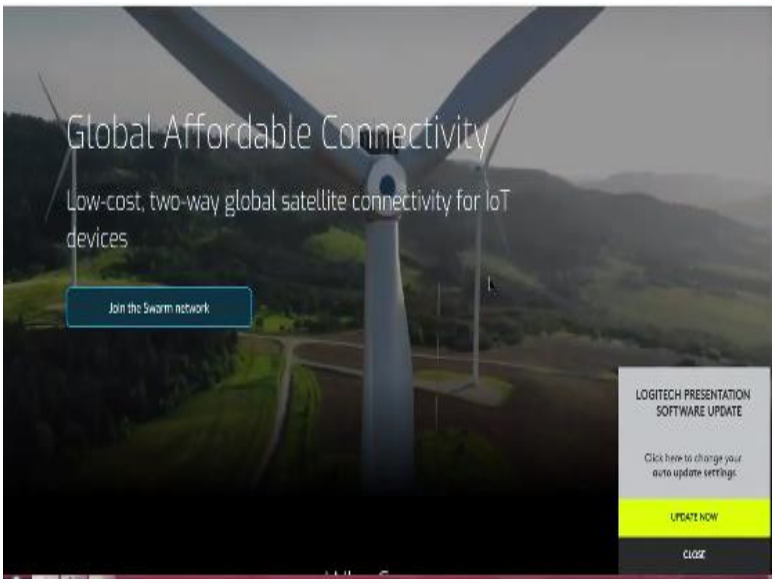

Look at this. This is what the website says, global affordable connectivity. Low cost two-way global satellite connectivity for IoT devices. You can join the Swarm network. And there are some nice pictures, it has global coverage and two-way communication.

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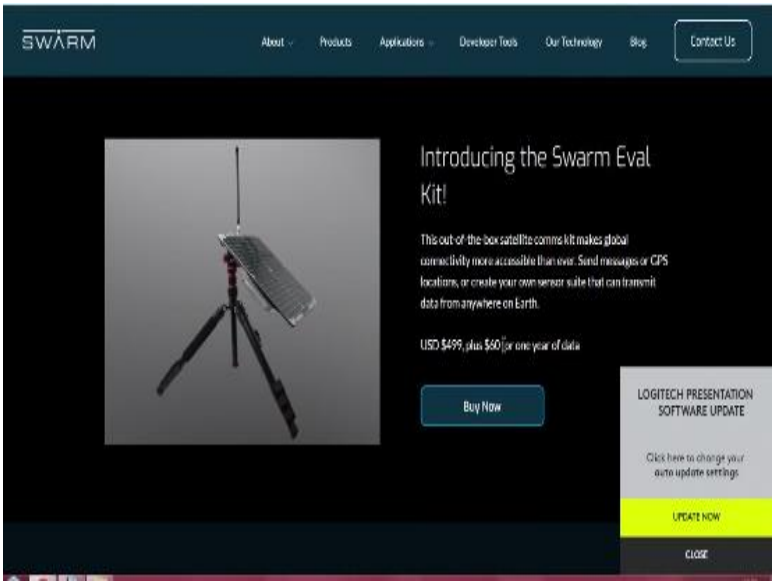

Look at this picture. This is introducing you to the $400 US dollar kit plus some $60 for one year data. You can go buy this kit. And essentially, it gives you global connectivity more accessible than ever. Send messages or GPS locations or create your own sensor suite that can transmit data from anywhere on the earth.

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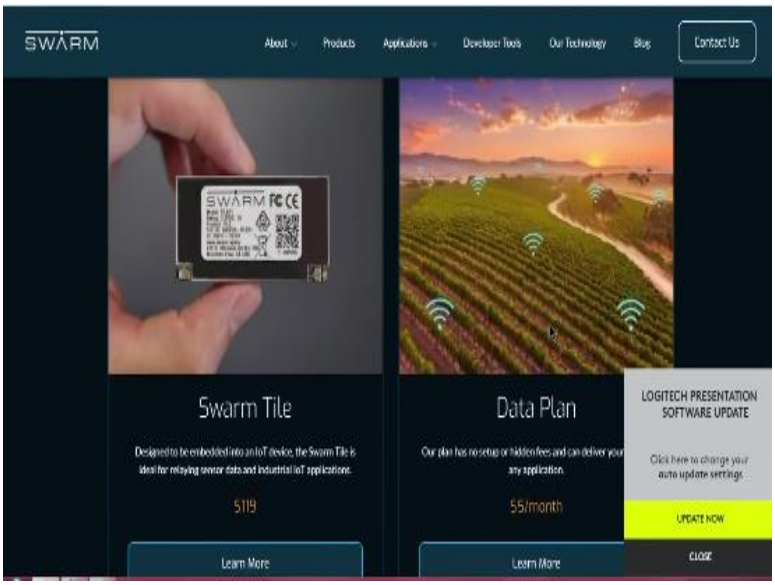

Here are some products. There is a Swarm tile. This is designed to be an embedded onto an IoT device. The Swamp tile is ideal for relaying sensor data and industrial IoT applications. And he shows you about the data plan and so on. So do look up this website. It will tell you some interesting things.

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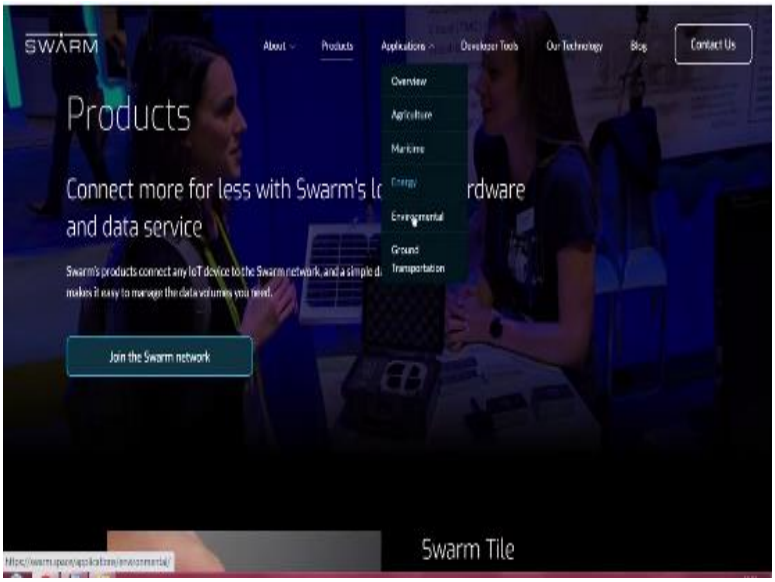

And there are lot of applications listed here. For example, agriculture, maritime, energy, environmental, ground transportation; big deal, right?

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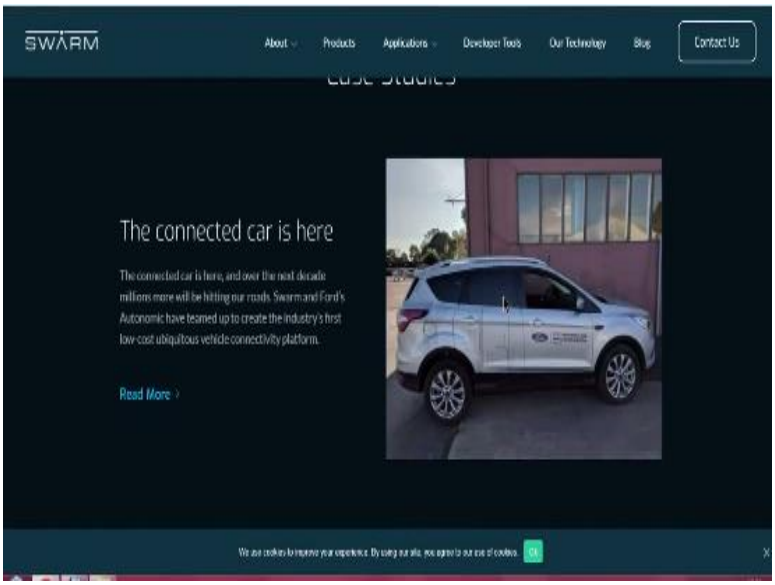

If you want to do ground transportation, you must be able to look at several new things, including connected car, and so on, right? So all these things. So please do spend time on reading up these articles.

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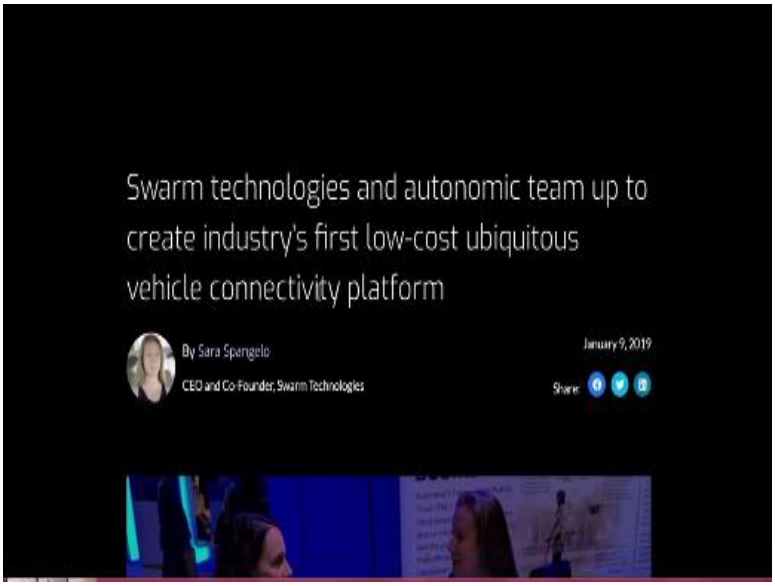

Swarm technologies and autonomic team to create industry's first low-cost ubiquitous vehicle connectivity platform. Look at the beautiful article that is out there. These are the new good things that are happening in the LoRa world. So before we read these articles and come up to speed, and understand the technology in great detail, there is also another company called Lacuna space, okay.

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Lacuna space is another website, like Swarm, which talks about connecting sensors, and providing data for smart agriculture solutions to improve proper yield, you can see proper yield. So you can see. They are also talking about LoRa, they are also talking about introducing these devices, lowering the entry barrier for application of satellite technologies to IoTs, okay.

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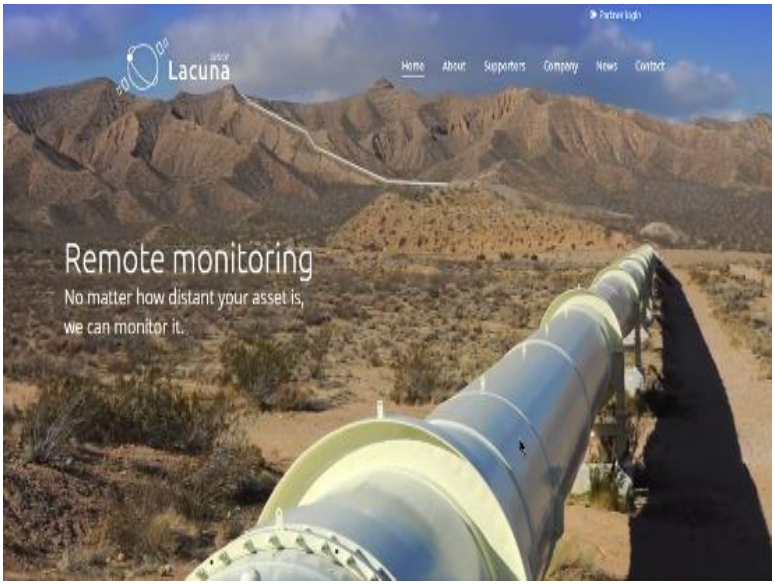

So you can even look at wildlife tracking, remote monitoring, and so many other fantastic applications that they are looking up, particularly when you do not have 5G or you do not have any terrestrial connectivity, this is the best that you can think of connecting it to satellites and tracking assets, or using satellite data because you do not need much data there. You just want to know one reading, right? And very intermittent reading. So please do understand this in great detail.

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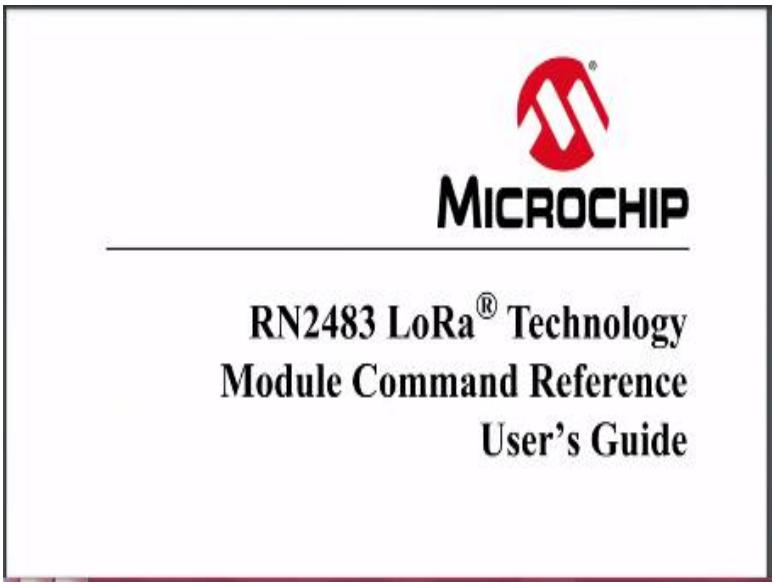

Let us see a little more into the data sheet of this particular one. So let me point you to this RN2483 LoRa Technology Module Command User's Reference Guide, okay. This is the Module Command Reference User's Guide. This guide if you read it gives you a wealth of information. But let me point you directly to some important parts in this which will help us to understand how this was configured. Basically, the LoRa this manual can be looked up in the following way. Alright.

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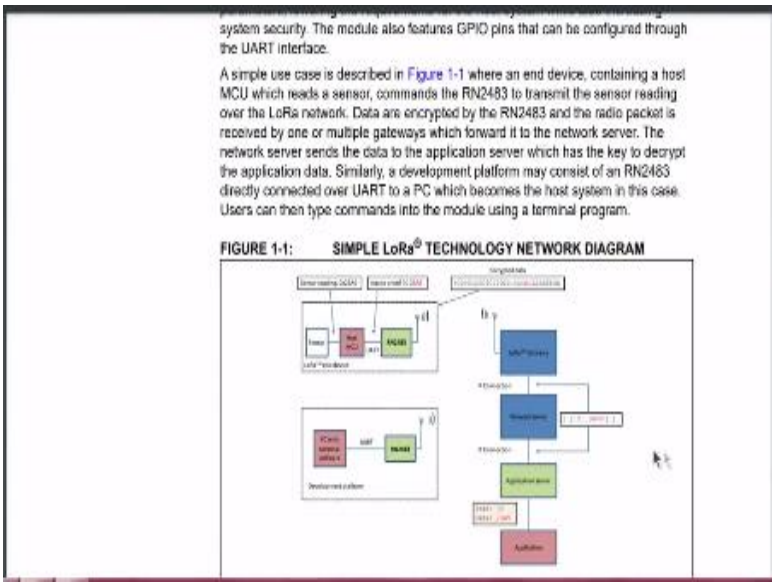
system security. The module also features GPIO pins that can be configured through the UART interface.

A simple use case is described in Figure 1-1 where an end device, containing a host MCU which reads a sensor, commands the RN2483 to transmit the sensor reading over the LoRa network. Data are encrypted by the RN2483 and the radio packet is received by one or multiple gateways which forward it to the network server. The network server sends the data to the application server which has the key to decrypt the application data. Similarly, a development platform may consist of an RN2483 directly connected over UART to a PC which becomes the host system in this case. Users can then type commands into the module using a terminal program.

FIGURE 1-1: SIMPLE LoRa® TECHNOLOGY NETWORK DIAGRAM

So this is giving you some pictures related to LoRa end device, how you can connect microcontroller, collect data from ADC port of the sensor, and give it to RN2483 which basically will be like a LoRa transmitter. You connect over UART and then you transmit that data. That is one way. Another way is if you want to configure

something in the RN2483, you can connect a PC directly over UART because these are ports which are freely available.

You can also do your development work using this configuration; that is connecting a laptop or a PC. Now the point here really is that data here is completely encrypted. So please note that the data is cannot be intercepted so easily. Then you have a LoRa gateway which might accept the data and then may decrypt it and then take things forward and give it to application.

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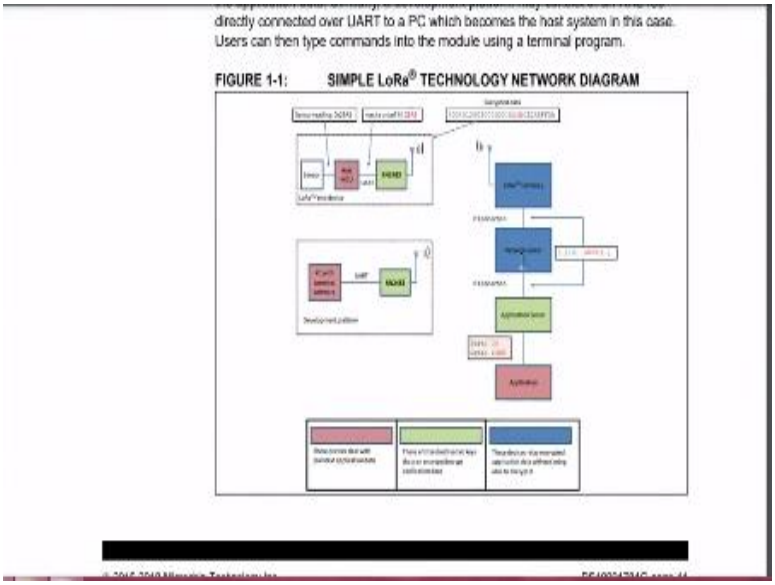

For example, there can be a IP connection, Internet Protocol connection, and then giving it to an application server and then ultimately to an application. This is definitely a possibility but that is not really the point.

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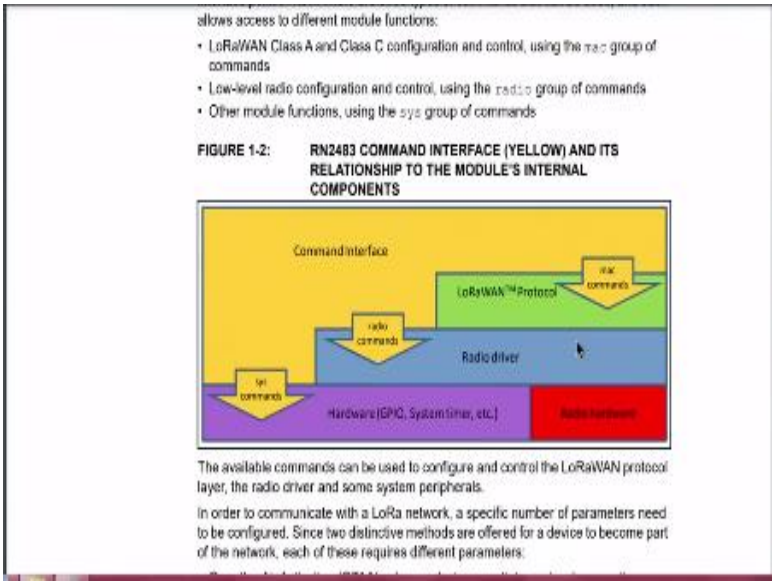
allows access to different module functions:

- LoRaWAN Class A and Class C configuration and control, using the mac group of commands
- Low-level radio configuration and control, using the radio group of commands
- Other module functions, using the sys group of commands

FIGURE 1-2: RN2483 COMMAND INTERFACE (YELLOW) AND ITS RELATIONSHIP TO THE MODULE'S INTERNAL COMPONENTS

The available commands can be used to configure and control the LoRaWAN protocol layer, the radio driver and some system peripherals.

In order to communicate with a LoRa network, a specific number of parameters need to be configured. Since two distinctive methods are offered for a device to become part of the network, each of these requires different parameters:

The point is if you want to work with this chip, there are three things you will have to configure properly. One is this picture is actually giving you a complete relationship of the internal components of this RN2483, okay. This is the command interface. What you see is its relationship to the module's internal components. Basically anything you want to do with the LoRaWAN protocol will essentially be configuring the using the mac commands.

Anything you want to play around with configuring the radio driver, you do it with radio commands. And anything you want to do with the system timer or GPIO or any of the hardware related things you use system commands. So this whole manual into three sections; mac commands, radio commands, and sys commands. So let us see what are the important mac commands that might be useful.

But if I have to show you that, you have to go back and see how we configured the LoRaWAN 2483 module.

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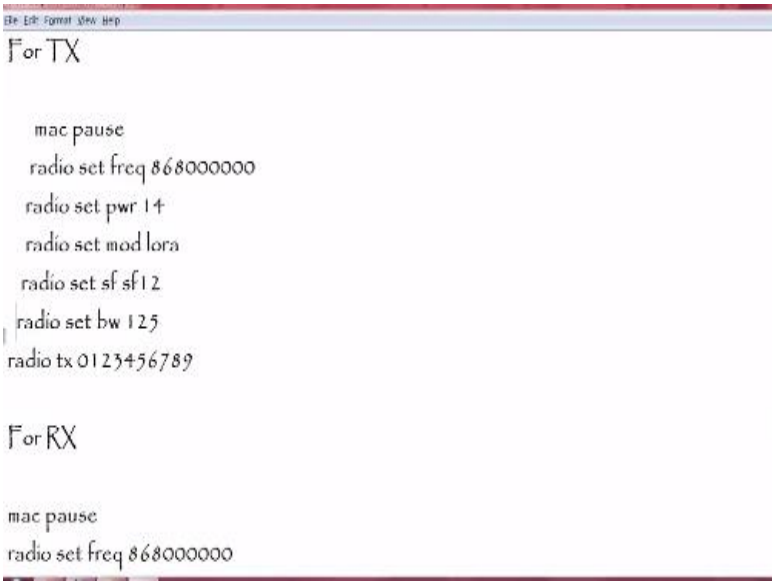

What I will do is I will show you what are the parameters that were set, okay. These were the parameters that were set. You can see obviously the one mac command that they seem to have used, which is very simple for you is the mac pause. So let us see what mac pause actually does, okay. So mac, so this is essentially the LoRaWAN protocol command.

And essentially these commands can be used to configure and control the LoRaWAN protocol. Not only that, the radio driver and some system peripherals as well, okay. So that is really the point. So let us see the mac pause command. I mentioned to you about the UART. UART baud rate can be set. And let us now look at the command syntax.

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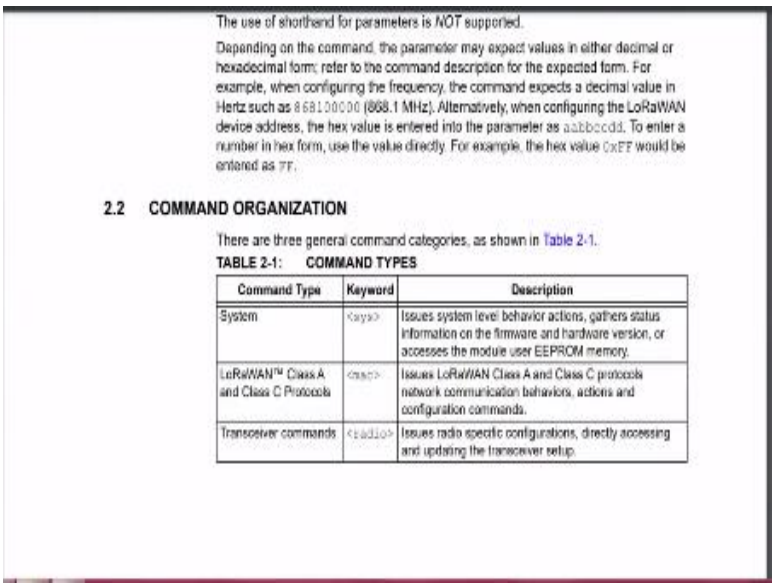

The use of shorthand for parameters is NOT supported.

Depending on the command, the parameter may expect values in either decimal or hexadecimal form; refer to the command description for the expected form. For example, when configuring the frequency, the command expects a decimal value in Hertz such as `868100000` (868.1 MHz). Alternatively, when configuring the LoRaWAN device address, the hex value is entered into the parameter as `aabbccdd`. To enter a number in hex form, use the value directly. For example, the hex value `0xFF` would be entered as `FF`.

2.2 COMMAND ORGANIZATION

There are three general command categories, as shown in Table 2-1.

TABLE 2-1: COMMAND TYPES

Command Type	Keyword	Description
System	<sys>	Issues system level behavior actions, gathers status information on the firmware and hardware version, or accesses the module user EEPROM memory.
LoRaWAN™ Class A and Class C Protocols	<mac>	Issues LoRaWAN Class A and Class C protocols network communication behaviors, actions and configuration commands.
Transceiver commands	<radio>	Issues radio specific configurations, directly accessing and updating the transceiver setup.

So you have essentially the mac which is confirming the LoRaWAN. Then you have the radio, basically all the transceiver related things and then of course the system related commands, which are also something very useful for configuring the device. All right, so let us move on. Here is the one of the mac commands, which is actually the mac save okay.

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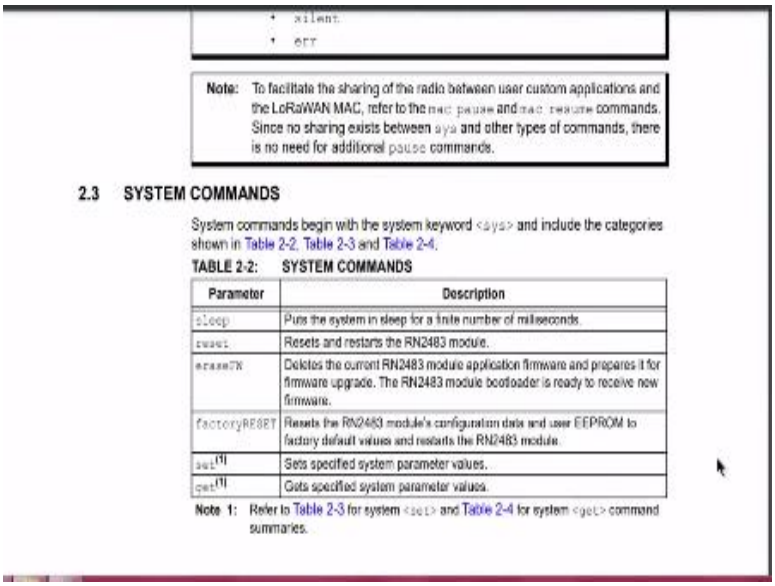

And then there are the system commands. The system commands are, you can see here sleep, reset, eraseFw, factoryRESET, set and get, okay these are the main commands. It puts the system to sleep for a finite number of milliseconds. That is that sleep. Then you have reset, you have so many of these commands, okay. Then, the detailed explanation of each one of these system commands are out there.

Then going down, you will also see some commands related to mac. And one of the mac commands that we saw is related to mac pause.

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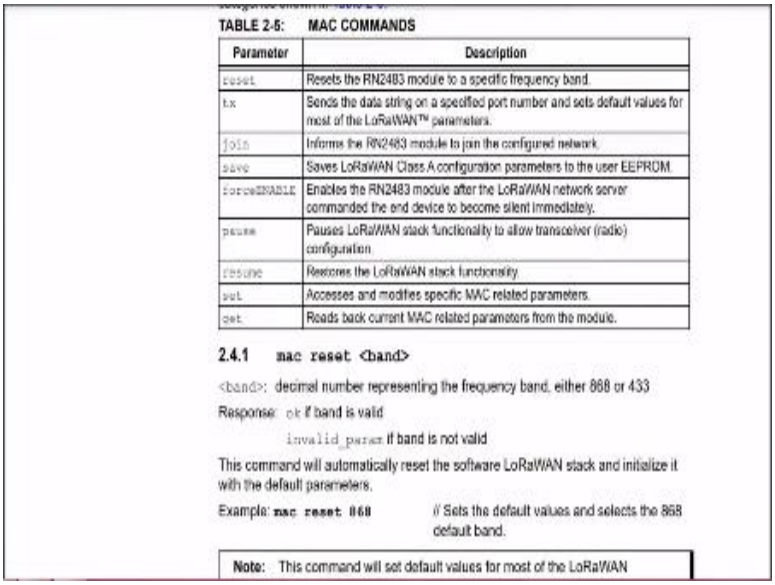

TABLE 2-5: MAC COMMANDS

Parameter	Description
reset	Resets the RN2483 module to a specific frequency band.
tx	Sends the data string on a specified port number and sets default values for most of the LoRaWAN™ parameters.
join	Informs the RN2483 module to join the configured network.
save	Saves LoRaWAN Class A configuration parameters to the user EEPROM.
forceENABLE	Enables the RN2483 module after the LoRaWAN network server commanded the end device to become silent immediately.
pause	Pauses LoRaWAN stack functionality to allow transceiver (radio) configuration.
resume	Restores the LoRaWAN stack functionality.
set	Accesses and modifies specific MAC related parameters.
get	Reads back current MAC related parameters from the module.

2.4.1 mac reset <band>

<band>: decimal number representing the frequency band, either 868 or 433

Response: ok if band is valid

invalid_param if band is not valid

This command will automatically reset the software LoRaWAN stack and initialize it with the default parameters.

Example: mac reset 868 // Sets the default values and selects the 868 default band.

Note: This command will set default values for most of the LoRaWAN

If you look at mac pause, pauses LoRaWAN stack functionality to allow transceiver configuration. If you want to configure the radio you have to do a pause. Essentially that is what it means. And there are other commands. There is reset, there is tx, join, save and so on. So what we have used is the mac pause. Alright. Then yeah, if you want to look up mac pause, you could definitely read it in detail.

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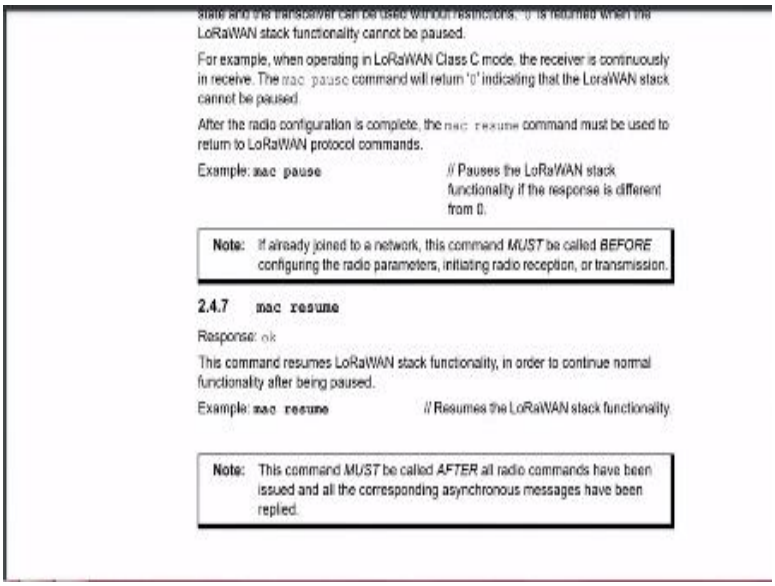

LoRaWAN stack functionality cannot be paused.

For example, when operating in LoRaWAN Class C mode, the receiver is continuously in receive. The mac pause command will return '0' indicating that the LoraWAN stack cannot be paused.

After the radio configuration is complete, the mac resume command must be used to return to LoRaWAN protocol commands.

Example: mac pause // Pauses the LoRaWAN stack functionality if the response is different from 0.

Note: If already joined to a network, this command *MUST* be called *BEFORE* configuring the radio parameters, initiating radio reception, or transmission.

2.4.7 mac resume

Response: ok

This command resumes LoRaWAN stack functionality, in order to continue normal functionality after being paused.

Example: mac resume // Resumes the LoRaWAN stack functionality

Note: This command *MUST* be called *AFTER* all radio commands have been issued and all the corresponding asynchronous messages have been replied.

It is here. So this command pauses the LoRaWAN stack functionality to allow transceiver configuration. Through the use of mac pause radio commands can be generated between a LoRaWAN class A protocol uplink application and the LoRaWAN class A protocol receive windows okay between the transmit and the receive windows.

This command will reply with the time interval in milliseconds that the transceiver can be used without affecting the LoRaWAN functionality. The maximum value is there, is returned whenever the LoRaWAN stack functionality is in idle state and the transceiver can be used without restrictions, okay. So 0 is returned when the LoRaWAN stack functionality can be paused.

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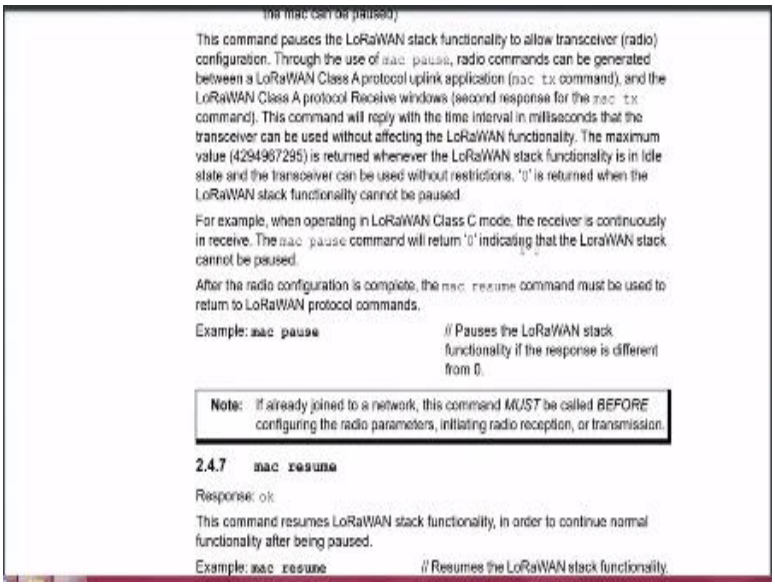

the mac can be paused)

This command pauses the LoRaWAN stack functionality to allow transceiver (radio) configuration. Through the use of mac pause, radio commands can be generated between a LoRaWAN Class A protocol uplink application (mac tx command), and the LoRaWAN Class A protocol Receive windows (second response for the mac tx command). This command will reply with the time interval in milliseconds that the transceiver can be used without affecting the LoRaWAN functionality. The maximum value (4294967295) is returned whenever the LoRaWAN stack functionality is in idle state and the transceiver can be used without restrictions. '0' is returned when the LoRaWAN stack functionality cannot be paused.

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2.4.7 mac resume

Response: ok

This command resumes LoRaWAN stack functionality, in order to continue normal functionality after being paused.

Example: mac resume // Resumes the LoRaWAN stack functionality.

So he gives you an example. I would urge you to read this example so that you can move on from there, okay. Then the other is also, the other part which is the radio part, okay. These are all mac commands. We will not spend much time here because you always have access to this by downloading this file. And it is anyway specific to the RN2483, right. So it is important you read every part of it.

Whichever chipset you buy you must look up the command in great detail, reference manual in great detail, okay. Then let us move on to radio. The radio perhaps comes towards the end. So I am just quickly yeah, here you are.

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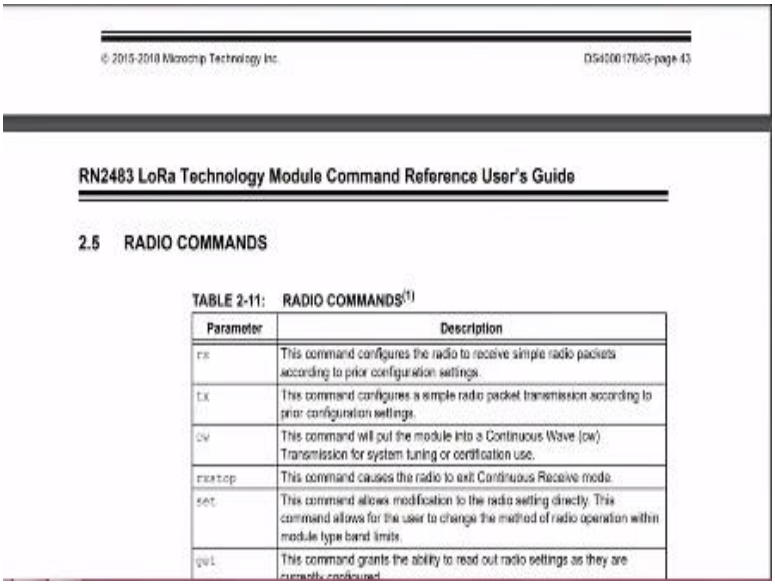

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RN2483 LoRa Technology Module Command Reference User's Guide

2.5 RADIO COMMANDS

TABLE 2-11: RADIO COMMANDS(1)

Parameter	Description
rx	This command configures the radio to receive simple radio packets according to prior configuration settings.
tx	This command configures a simple radio packet transmission according to prior configuration settings.
cw	This command will put the module into a Continuous Wave (cw) Transmission for system tuning or certification use.
rxstop	This command causes the radio to exit Continuous Receive mode.
set	This command allows modification to the radio setting directly. This command allows for the user to change the method of radio operation within module type band limits.
get	This command grants the ability to read out radio settings as they are currently configured.

Here is the radio. Radio what are the commands you can do? rx is this command configures the radio to receive simple radio packets according to prior configuration settings. The tx is this command configures a simple radio packet transmission according to prior configuration. cw this command will put the module into a continuous wave transmission for system tuning or certification.

There is rxstop. This command causes the radio to exit continuous receive mode. Then you have set. This command allows modification of the radio setting directly. This command allows for the user to change the method of radio operation within the module. And then there is get. This command grants the ability to read, read out radio settings as they are currently configured.

So folks essentially these are the different commands, their description in great detail. And now it will obviously be very useful for you to look up what all we have done here. The radio set frequency. That means you are setting the frequency of transmission. Then you are setting the radio set power of some value, which is 14. Radio set modem LoRa. Then we have done radio set spreading factor of 12. I will describe this separately. Then radio set bandwidth of 125 kilo hertz. And this is the payload that you want to transmit.

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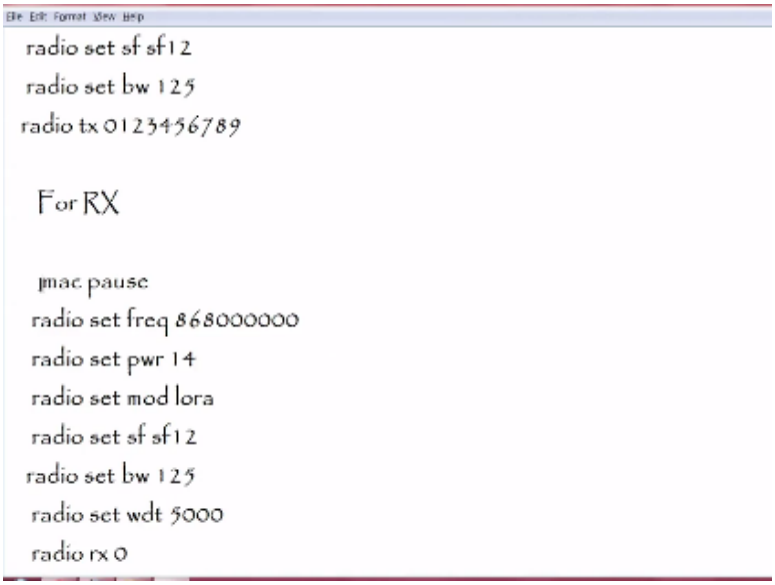

Alright, so you see there are a bunch of mac as well as radio commands that you see here. Radio set frequency, radio set power, which is set to 14, radio set modulation is LoRa and radio set spreading factor is 12. We will handle that separately. Radio set bandwidth is 125 kilo hertz, radio set watchdog timer is 5000 milliseconds. And radio is in reception state which is I think set to 0.

So essentially these are the commands and this is sufficient for completing a communication between the LoRa transmitter and a LoRa receiver. Alright, so now we will do something dramatic. We will try to see if we can do a good demonstration of LoRa. This is mostly the efforts of the teaching assistants who wanted to give you a feel for how good LoRa can communicate with whatever we have in the lab, okay.

So we are not attempting any satellite based things but we are just trying to see within the campus. What we have for demonstration is a very simple thing. Think about this as the IISc campus.

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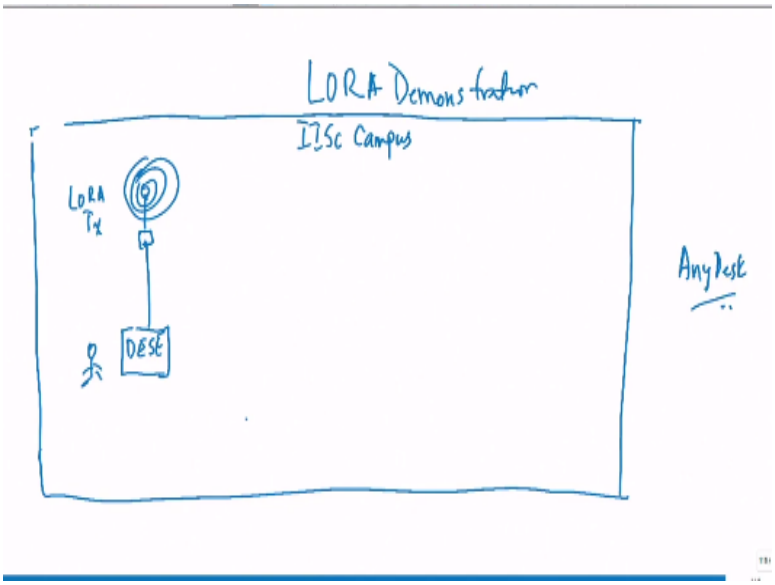

Think about this as the IISc campus and this is our building, okay. This is our building and we are all here. Now on top of the building we have put the LoRa transmitter. I will show you where exactly the LoRa transmitter is as the video starts.

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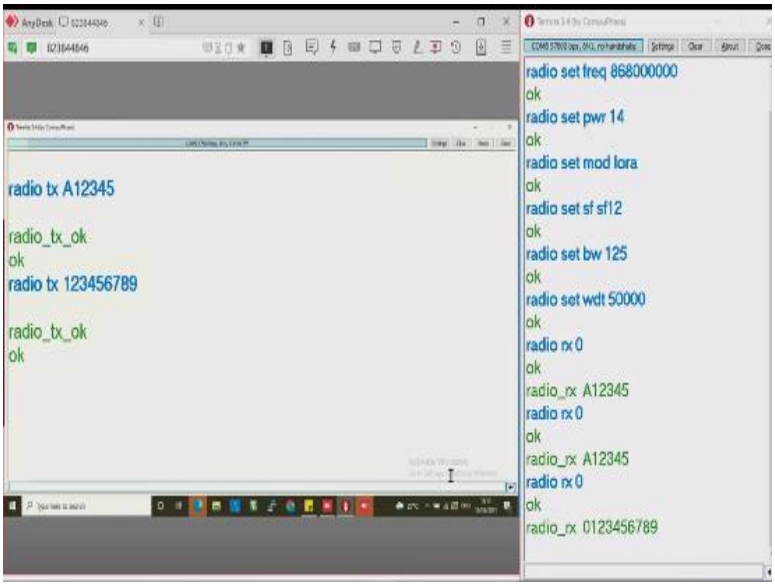

And then what you see here on this screen is essentially the screen related to the fact that the radio transmitter there is this number A 12345. Transmit seems to be okay and then you have 123456789 some numbers it is transmitting. That is basically the payload of what it is transmitting. Radio transmit okay. This is what is coming up from the modem, from the modem there, okay.

And so let us see how we go about with this demonstration. If you look at the screen, this screen essentially is the screen using LoRa transmitter which is mounted on top of

the building. And there is a simple laptop connected there and this screen essentially is shared from that system they are using a software called AnyDesk.

Please look up AnyDesk, is a open source software which can be used and you can share the laptop screen here. So you see that lot of commands the data payload you see in the main window and the right side you see all the settings which I mentioned to you, both the mac level then the radio level and the other commands. All these three commands are out here. So essentially those settings are there. So let us start the demonstration now.

(Video Starts: 23:40) (Video Ends: 28:18). So as you can see now our colleagues have climbed up the second floor plus also gone up a little distance and they have installed the LoRa transmitter out there. And I can share the GPS coordinates of that system soon.

You can see that the cable is going down and for protecting it against you know wind and I mean rain and other related things the modern electronics has been tied tightly so that it can be protected. Well this is not the right way to do. You need to put it inside an IP65 or an IP66 box which I can show you separately. But anyway this is for a quick demonstration, so we decided to mount it there.

Now what we will do is now that you know where the transmitter is at quite some height, slightly higher than the trees that you see down there. We will now see how far this signal can come. You can see in this screen here on the right side, the communication seems to be okay till now, okay because it says the radio transmit is okay. And it appears to be the transmitter and the receiver is seem to be okay.

So now let us see whether this transmitter that is mounted is working well and it is in good shape. This is the so we are trying to see whether the receiver is able to get the packet and also able to transmit back to the transmitter, okay. So essentially that is what is being attempted. So let us see this screen here should also get updated now with some data, there you are. You could see that radio rx is okay.

It just flashed that message and it is continuously telling that the radio rx is okay. Now let us see what our colleagues are doing is they are going into the transmit window and also onto the receive window, receiver side and making the receiver ready, okay. So first they will make the receiver to be ready. You can observe the command here. The receiver is ready and once it is ready, they will go to the transmit window and transmit a payload, okay.

Once the payload is transmitted, that should be received on the receiver side window, right? So that is the payload, that is 123456789. That is the payload and you can see that the transmit window which is on the left side you can see that on the right side the receiver has got that payload, okay. There is some discrepancy, it is 0123456789 what it has received, but what you have transmitted is 123456789.

There is some discrepancy which needs to be corrected, okay. Let us retransmit. Let us retransmit the data 123456789 and let us see whether we are able to receive that data, okay. First is to transmit the data. So rx is ready okay. And yeah, so now radio transmit is okay. So we have transmitted 1A23456789 and the receiver has received 1A23456789.

This clearly indicates that the communication is decent enough even after we moved away from the tower and we are not in line of sight and we are roughly 400 meters away from the transmitter and still without line of sight it appears to be working well. The please note that the transmitter is at quite a height, the receiver is at the ground level and not at sea level of course, because the city is really not at sea level.

Yet you can say comparatively there is a height difference between the transmit and the receiver. Now this should give you an highlight that the LoRa is very promising for extremely low data rate, but extremely, not only just extremely low data rate, but also highly reliable communication.

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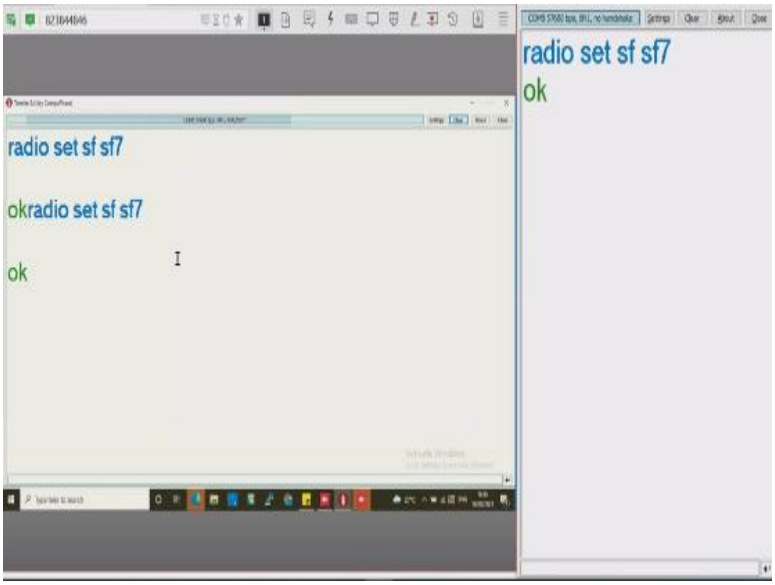

Now you can see that we have changed an important setting, radio set sf sf7 has been mentioned. And that is set okay, on the this is on the receiver side, okay. You should do the same thing on the transmitter side as well. You are changing the spreading factor to a number called sf7. And that sf7 is being changed on the transmitter side now. So let us do that change and see if the communication between the two radios transmit and receive radio is successful with sf7.

You can see that the transmit side is also set to sf7. Here it says radio set sf7, okay that is fine. So the transmit and receiver now are tuned to a spreading factor which has a number associated called the sf7. Thank you very much.