Design for Internet of Things
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Lecture - 03
Challenges Part-01

Today what we will do is we will try to understand, see if we got the introduction for IoT quite well right, and we also give the definition for IoT, we took some examples and explained what IoT can do as an impactful thing. Now IoT when you say it, what does it comprise off? It must comprise of some devices, some ultra low power devices, which have the capability of sensing which has the capability of computing something.

And communicating it and then also actuating it. So, all these functionalities will have to be built into the system.

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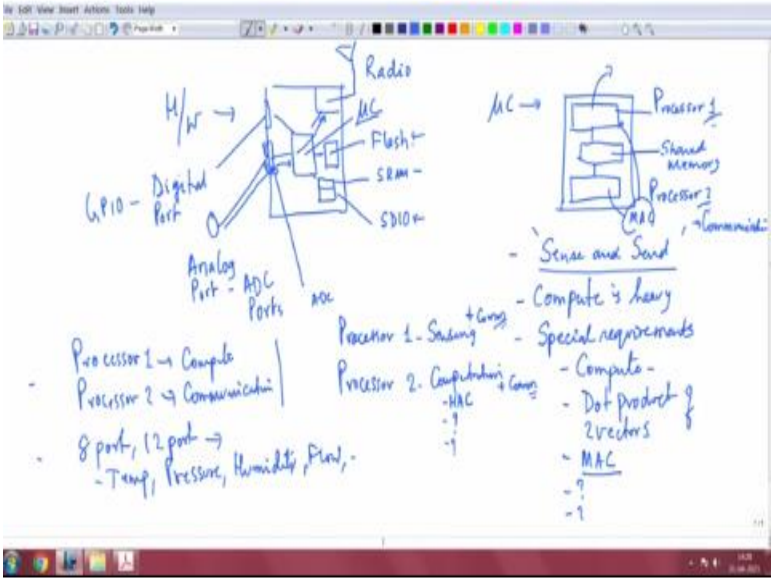

So, what all will it have? It will have a hardware it and it is so; it will look like a system like this, which perhaps has an ability to compute which means that will come from a Microcontroller, it will have the ability to communicate which means it will have a low power Radio. It will have the ability to sense which means it will have analog ports or it will also have digital ports, port I call it.

This is port these are typically also they are called GPIO (General Purpose Input Output) these are also called ADC ports, Analog to Digital Converter Ports. And of course, you cannot forget the ability to have Memory, and this can be both SRAM and it can also have a SD card. SD memory which is like a flash on the outside put it on a piece of memory stick, which essentially it can also be storing data archiving data.

And apart from that you can also have OS memory are the system memory are from where the system boots which will be the flash, flash memory. So, all of this will definitely be possible will be there. So let me just connect all of them. I did not connect this. So, it is very important. Actually, the controller when you switch it on it boots from this flash memory it boots from here, and it gives you either a prompt or it execute some program and so on.

We all have it, which is there, your sense data, which you want to archive you usually use an SD card which is connected external to the system. So, we can divide this into let us say I will put a line here, this is this could be, let me be a little more precise. So that we can understand it better. So, I will put a block like this. And I will divide it like this. This I will put as SRAM and this I will put as is the SDIO or SD card memory.

Obviously, SD card will have a higher memory space as compared to SRAM and this can be in it can be 10 kilobytes it can be 128 kilobytes and all that in the case of SRAM. But this will be in megabytes and Flash also will be sometimes it will be in 128 megabyte, 256 megabytes and so on. So that will also be considerably in megabytes, basically will depend on controller to controller.

See when I say controller Microcontroller, you have to note that this is a very generic name. I gave you can actually be talking of 2 processors. This is processor 1 and this can be processor 2, and they can be communicating over what is known as a shared memory. So, I just simplified the picture and just showed you that as a single block. Now, you may ask why do you want to do this?

Why do you want to complicate the whole process of having what are the applications which will require 2 processors, so that much amount of compute is required? Surely, I think, see, it depends on the application of interest if you are doing a simple Sense and send, if you are doing simple sense and send, that means you have a sensor connected to this port here, analog sensor, let us say it is connected through this ADC port, we said this is the ADC.

That is what I wrote here, there are multiple of them. Multiple ports, and to one of the ports is the sensor connected. And if you are just sensing so controller simply accesses the data that is coming from Analog sensor and then communicates it, then you do not need this kind of sophistication, you do not need this 2-processor system. But if the compute is heavy or you have special requirements, what it means is look at this example.

In this example, you are taking the sensor what is the path, processor takes the data from the sensor, and then does some simple filtering I suppose, and simply gives it to this Radio that is why it is called Sense and Send, it is not doing anything on this as far as a compute is concerned. But if you take special requirement, it could mean that you are doing a compute. Let us say you want to calculate the dot product of 2 vectors, if you want to do that, you obviously need to multiply and accumulate instruction, right you need a MAC instruction.

So, simple sensing and all that can come from this processor and the MAC instruction can come from this Processor. So, this could be a MAC instruction alone, so I have just given an example of if it is just one function, then even this one function can be integrated here and you can still manage with a single processor. But supposing you have many more such functions, not just MAC but other related functions.

Then you need let us say you want to do FFT, for some reason on the controller itself for some reason and you are looking for some signature, then such instructions may have to be performed with a special processor and you need that special processor to ensure that it works in conjunction with the other processor that special processor could be processor 2, it has to work with processor 1.

This is one way. Another way that processor 1 could be for all the applications related to sensing, computation including FFT and so on and processor 2 could be purely for communication. That is also possible. So, you can say processor 1 can be for compute and processor 2 can be for communication. This is one way of organizing. Another way we said is processor 1 is purely for sensing and processor 2 for all the computation, which we said some very simple stuff from MAC to even more complicated functions.

Somewhere you need to also bring in communication is in it. So, let us say sensing plus communication can come from processor 1 or we can have processor 2, which will do computation and then followed by communication. So, the communication function can either be attached to processor 1 or it can be attached to processor 2. So, any one of them is possible this is as far as process concerned, we just abstracted that.

Now ADC if you take ADC, you can have 8 ports ADC, you can have 12 port ADC, what this means is you can connect 8 sensors or 12 sensors and let us take some examples of some sensors which give you a analog output one could be temperature, the other could be pressure, you can have humidity, you can have flow, you can go on like this. So, several sensors you can I have taken some typical examples.

So, it could be depending on the number of sensors you want to connect, you could be connecting it to different ADC ports of the system. And you have to write a program to acquire this data from the sensors which are connected. So, let us take that picture. So, I will perhaps go to another sheet which will allow you to expand.

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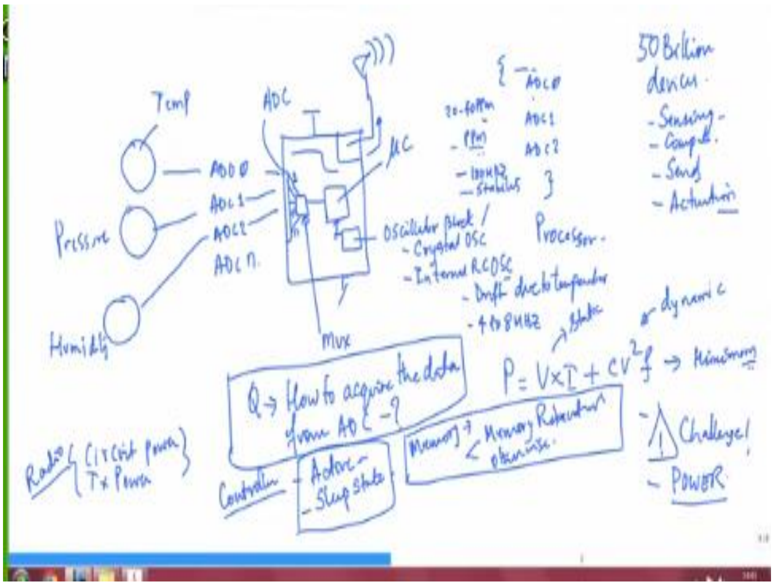

This is the microcontroller block, and this is the just the ADC is in it, and it is connected here. Before I show you that, I had to show you something interesting, see the ADC how many ever lines that are there, this is the microcontroller. This is a multiplexer and these multiplexer give you the different ADC 0 to ADC N it can be anything 8, 12, 16 so on. So, all these as 1and then this can be N with a multiplexer there and please note, again, I have abstracted this as a microcontroller this should be can also be a 2 processor system.

Can be processed 1, 2, all that I would not go into the detail. So let us say you have ADC 0 which is connected to temperature and ADC 1 this can be pressure, ADC 3 can be humidity. So, it is ADC 0. This is ADC 1, and this is ADC 2, and this is Radio. Other blocks are their memory the things question is how do we acquire their data from ADC? We have to answer this question.

So, we will see this question and we will understand few things. Why this question is actually important. We will have to even ponder about that. After all what is there you connect sensors, you can acquire the sensors one by one, but that is not to be dismissed in that way because of the following reason. Look at the simplest option that you can think of what you can say is, I will write my code such that I acquire from ADC 0 then I will acquire from ADC 1, ADC 2 and then come out of the loop.

Now look at it from the process perspective look at it from the processor’s perspective. processor is on and the clock is supplied to the processor. So, Processor requires a clock. So, we have to show another block which is the Oscillator Block, here we can be talking about Crystal oscillator, or we can be talking about Internal RC oscillator. The advantage of internal RC Oscillator is you do not need external components.

You can directly switch on the controller, and it will provide the clock directly to the Processor. But the trouble with the RC Oscillator it is R is resistor, C is capacitor. So, it is an RC oscillator means uses components like resistances and capacitances, which are put right on the silicon chip to give you the oscillators, these suffers from problems related to drift due to temperature, they can have a problem that the frequency can shift due to temperature.

And you can also not have very high frequencies that can be generated from RC oscillators. There are limited to anywhere between, I think, give you a ballpark it may be limited by 4 or even up to maximum 8-megahertz clock frequencies, you cannot even go so high, but I have just given you a ballpark whereas if you put crystal oscillator, the frequency can be quite high. It can even go up 100 megahertz and even higher.

In fact, again, I am talking only from the IoT nodes perspective, I am not talking about bigger processors, like Intel, you know processors like i5 and all they will be running clock multiplication and the clocks will be in gigahertz. You are not looking at that, we are just looking at small embedded systems. That is one thing. And so, if you are so you can be talking about oscillator which can go run into much higher frequencies, stability is super, very good stability due to temperature, so you would not have drifts, and so on.

The stability is so good, it is quite accurate, it is usually measured in terms of parts per million, ppm. So, another ballpark is to say anywhere between 20 to 40 ppm is already good for embedded system applications. So, 20 to 40 ppm, you can use crystal, so, you have to buy a crystal which has a certain value associated ppm value associated with not only the frequency of the crystal is mentioned, but also the ppm value for the crystal is also mentioned.

And that you should pick and then put it onto your system here. Now, why am I giving such a big story is the question? The reason is, if you look at the power consumption of such an embedded system, it comprises of the voltage which is applied to the controller into the current which is flowing all through these blocks. There is a current required for driving the Radio, transmit power for driving the Radio circuitry requires power.

So, you have circuitry, circuit power and transmit power are just for the Radio block this is just for the Radio. What about controllers? So, if it is Radio, if you look at controller can either be in active state in which case it requires significant amount of power or it can be in sleep state, in which case the power consumed will be quite low similarly, memory. So, memory is typically divided into banks, how many banks of memory should be kept alive?

Whether you want to keep the memory data stored in the memory to be available, or you want it to be lost that means that you are shutting off the memory. So, these two settings are possible you can do memory retention or memory completely lost or other or otherwise I will simply say, you can do that and as I said SD memory is also used. So, whether you want to energize the SD controller block or not is another story that also you can decide accordingly.

So overall, there are quite a few power guzzling components which might bring down the battery, which might drain the battery at a very high speed, and you put the battery today tomorrow it can be completely discharged. So, you must find a way by which you are able to improve the lifetime of these embedded devices. Because there are so many things associated here for example, we never answered this question, how to acquire this data?

Next question is how to set the controller to active and sleep state? How to ensure whether memory should be in the memory retention mode or whether it can be erased? These questions can be answered. So, just before we answer any one of them, let us just look at this basic expression. Power consumed by this embedded node can be given by V cross I plus C V square f.

This is called dynamic power, and this is called if this is dynamic this has to be static. So, this is static power and dynamic power which means, it is a combination of both. And unless you ensure that the algorithms the way you write your code and the algorithms that are associated with data acquisition and transmission know that acquisition computation and then communication all of them will have to ensure that this simple expression is at the minimum level should be kept at the minimum level.

You only then you can talk about large lifetimes and therefore, what is important is to look at mechanisms which will allow you to improve lifetime of these embedded nodes. So this, itself is a challenge. So, one of the challenges in IoT is related to power, because you have to do so many things, yet you have to improve the lifetime of the system. It is in not that there are no standard examples folks.

Even if you have to arrive at what is a good lifetime to even ponder about, if you want to do if you want to say that, let me give throw a number. It can be 10 years. You put build your embedded system, put a battery to it and place it somewhere. Maybe it is doing pollution monitoring. Maybe it is checking when to send out the information related to high pollution in a particular area.

So that the air, water, mixture equipment can arrive in quick time and bring down the pollution by, you know throwing water by spraying water in the area where there is very high particulate matter content. So, you want it to work for 10 years, and it will be small embedded system mandatory for 10 years. And that is a challenge you do not want and because you are talking about billions of devices, you are talking about something close to 50 billion devices.

In the next, maybe, one two years, you are talking about so many billion devices, all of them, what are they doing they are sensing, they made compute, they might compute, they will definitely send, and they will definitely be actively participating in actuation. So, all of this may be being done, some of them will be just sensing. Some of them may or may be doing all functions.

So, you see now, the first challenge indeed is related to power. I will throw in the second challenge for you. But the second challenge is actually quite obvious from this picture. What you see here in this picture, is this Radio. See, I was very clever in not even defining what this Radio is.

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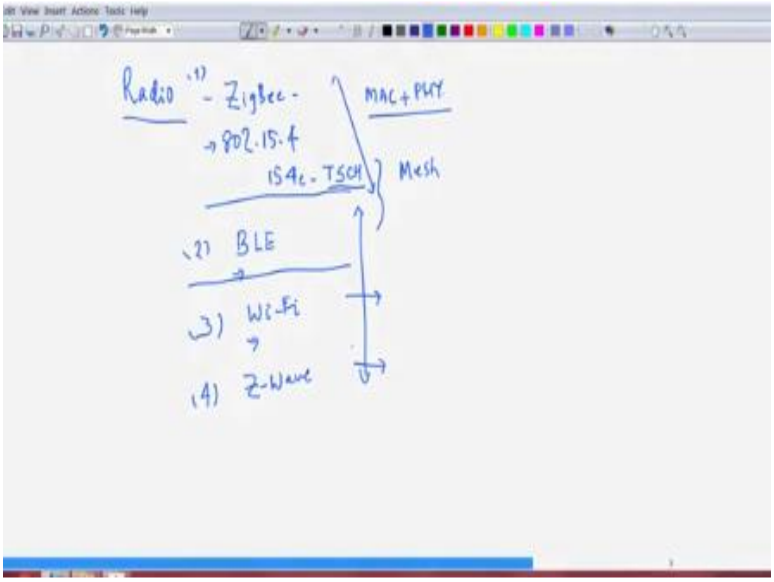

Went on saying Radio, but we never said anything about what the Radio is, people talk about low power Radio, and people talk about ZigBee Radio, ZigBee standard, this is a consortium standard. IEEE also calls it 802.15.4 standard and there is a variant for this which is 15.4e which is called time synchronized channel hopping. This is one type of Radio you can be talking about.

So actually, this is Radio come, MAC layer, medium access layer comprised of both the medium access layer and the Radio, for the physical Radio, people with communication background will appreciate that this is also the PHY layer as they call. So, this is one type of Radio. The second one which you may have heard is the Bluetooth Low Energy. There is an equal and IEEE standard also for this.

Then there is Wi-Fi, wireless fidelity, there is an excellent IoT. I mean IEEE standard for this there is a fourth protocol called Z-wave and there it is again a consortium protocol, and therefore you can be talking about any one of them, no one really has any clarity which one to use, and what are the advantages of using one over the other. Let me contrast this ZigBee is supposed to it was the one that actually started off, which could be applied to ultra low power nodes.

And ultra low power and IoT kind of nodes. And these, this technology was quite popular, and it also went through several revisions. The latest one, which appears to be quite promising is the TiSH protocol. It is also called TiSH, time synchronized channel hopping. And we will try and spend some time in understanding that if time permits. There is also Bluetooth Low Energy.

If you contrast the two of them, both of them can do what is known as mesh. Many too many nodes network is a possibility. Wi-Fi also has evolved for IoT. And there is a Wi-Fi standard specific for IoT requirements. That is also an interesting thing. Z-wave is a industry Consortium. It has a limit on the number of IoT devices. I think it is 250 or so. But which is a sizable number already.

But it’s another standard. Then other protocols are their other technologies are there we will come to them as we go along. Thank you very much.