Design for Internet of Things

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Lecture - 31
Case Study 2 - Cloud Based Systems

So now what we will do today is we will look at another example of what we did previously in one of the previous weeks. This is related to the pulse sensor. Recall that example, where we showed the hardware features of the hardware that system which had an NFC for, and it was a battery less system if you recall.

So, you had an NFC system NFC built into the pulse finger pulse system, and there was a mobile phone which came close by then charged the capacitor so that it holds charge for a certain amount of time. And during that interval of time you are able to do a record. You are able to sense the pulse of the human, acquire the data, process the data and display the data right. All of this happened on the mobile phone. What is a next step, if you are really looking at completing the loop and looking at analytics and you are looking at trying to understand data collection in a big way, you obviously, need a cloud based system right.

So, let us see if we can show you something related to the cloud based system. How such a data from a pulse sensor, can essentially start like this we can start of by talking about an end to end IoT system.

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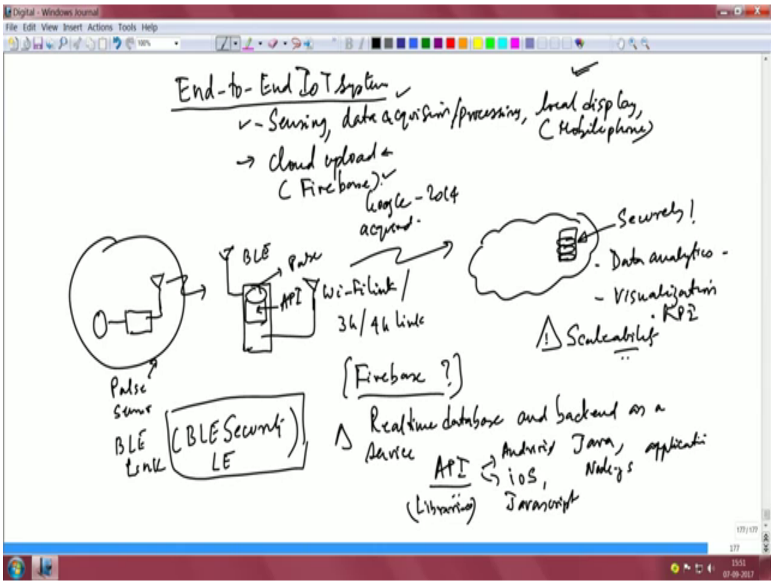

We talk about sensing, you talk about data acquisition and processing, local display I will simply say mobile phone, mobile phone right. And then cloud upload.

For cloud upload we have set up, something called fire base. And we will get into the detail of this fire base shortly, but essentially this is a mobile and web application development platform, and it was developed by fire base and now currently it is with Google acquired in sometime in 2014Google acquired. So, let us put down a nice picture. So, I will remove this picture, and we will put some nice block level understanding, this is the pulse sensor, this is the pulse sensor.

And it is transmitting data, over a over a BLE link right. It is transmitting data over a BLE link to a mobile phone. So, this is part of this hardware. So, I will actually show this like this, actually maybe I should show it properly, sensor some microcontroller and some system here, all of it put together is the pulse sensor. So, I just have to put this arrow pointing here. This is BLE link, it goes to a mobile phone which also supports BLE all right. So, then once it is here, you develop a beautiful app just to see this local display part.

I already showed you that in the previous videos you can go back and look at that video. So, you will actually see the pulse. As we mentioned it is insufficient for you to see it here, but indeed you need to go to the cloud. So, you extend this app nicely, such that it has all the necessary APIs it has all the necessary API s to network either using a Wi-Fi link or directly over a 3G, 4G link, 3G, 4G link. And once it happens that way. So, if it is going through Wi-Fi it is going through a Wi-Fi router and from the Wi-Fi router it goes to the cloud. So, ultimately somewhere on the cloud your data lies right. And this cloud basically will provide you a cloud server, and it will offer you feature where your data can be stored securely right.

And then once data is available, you can do data analytics on this, you can perform run analytics on the data that you gathered. And then ultimately perform visualization; this could be in terms of key performance indicators and so on right. Basically it is about ultimately this architecture should essentially scale, scale ability. Now put back the whole story you are talking about a hospital. The hospital there are number of beds, number of patients and a paramedic like a nurse is going round from bed to bed.

Collecting pulse information, temperature information, blood pressure information call it whatever in this case we are talking about just the pulse information pulse data from each and every patient on the bed. And all that the nurse paramedic actually has is a mobile phone in his or her hand. The pulse sensor is already sitting on the finger and the paramedic goes with the phone puts the phone there charges the capacitor that is there powers the module essentially and then measures the embedded module measures the pulse and then displays it back on to the mobile phone over a BLE link. You could have actually used an NFC link as well, but then you have to hold the phone close to the NFC coil such that data is actually acquired.

So, in order to avoid that you can also transmit over a BLE link only thing is you have to take care of BLE security which we discussed in one of the previous modules. So, if you are talking about BLE think about the BLE security the LE module; so LE security module right. Which is a very involved process and you have to really worry about the security of such data when it is coming from each and every patient. Simple thing could include the encryption of the data itself you could have an a ES key sitting on either side and only if the key matches you are able to decrypt using the city as a s key. And then the pulse is actually displayed on the phone all right. So, this should be a scalable scalability is important. So, scalable architecture is a very important requirement. So, this is overall view of the end to end IoT system that we want to see if we can demonstrate.

Now let us spend a little time understanding what is this fire base. What is this cloud API h development platform and what are it is main features this system. So, for that we can share several you can look up Google I mean, you can Google and look up such quite a bit, but I will just quickly briefly on briefly brief you on the main features. Basically this is a real time database, this is a real time database and back end remember it has to be back end otherwise scalability of data from several hundreds of patients is not a possibility at all. So, it is a real time data base and back end has a service is available basically it offers you an API which you can integrate into your application sitting on the mobile phone.

It could mean that it has any AIP for android it has a API for iOS operating systems and there is a so, these are all libraries essentially right. Libraries are available libraries are available for android iOS JavaScript, JavaScript library then java then, so many other related thing including node.js right so many other related applications which you can build right. So that API is available. So, how do you start? Well you start by creating a basically start with creating a, if you have a Google account you should be able to create an account on the cloud server you can use the Google account straightaway.

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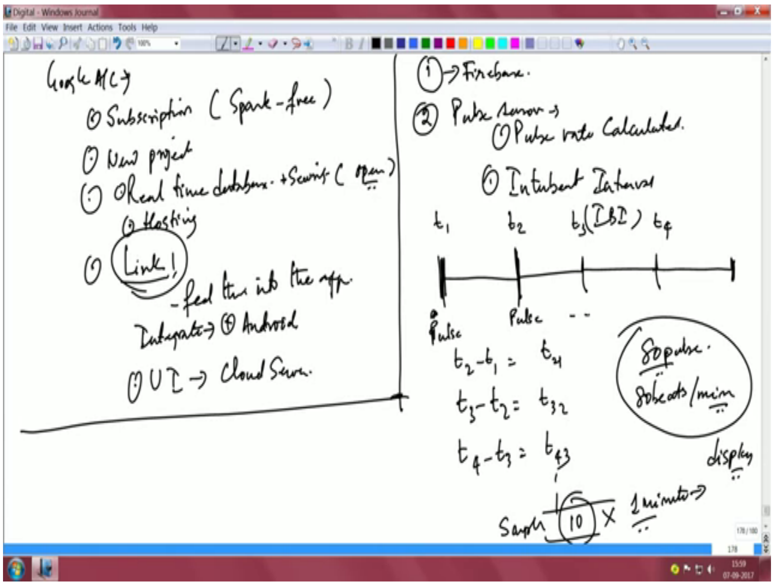

And you can choose what is known as a subscription, you can choose a subscription there is something called in our case for the demo purpose we will say. This is a something called spark free this is free then, you start a new project pretty straight forward if you go to the website you can get familiar with all this. And then choose real time data base real time database. Well you could have chosen hosting as another possibility right. And so many other related hosting, hosting and so on right. Of course, you can say real time database with security enable, but in our case what we have done for the purposes of demo we have made it open.

So, we do not go into much detail, but you could do real time database plus security is a very important thing. And then ultimately after you do all that what you will get is a link ultimate output as a link. Now this link is the one that you have to feed this into the app. Suppose, you are developing an android app use this particular link which it is created from that step into this arc. We will show you a few things physically in terms of screens so that you actually appreciate the whole integration into an android app and we will start that very soon, but let me give you a overall view first. So then So, feed this into the app integrate in other words.

Integrate into the android app, then you add you do a few other things like dependencies and so on let us we will talk about that when we have to. And then finally, you had package information of this particular fire base API and then you basically have the user interface ready UI ready which will allow you to upload everything to the cloud server. So, this is overall view of the system. I do not prefer to go into when I show you the demo I do not want to go into the hardware, because the hardware the power requirements for the sensor size of the capacitor NFC related issues all that was discussed previously.

So, we will not get into that detail. So, first part of the demo we will see a little bit on the basic integration of this cloud based API development platform called fire base. API for a programmer it is called an API because he is that is the actual set of libraries that the programmer will be using, but fire base broadly is a development platform. So, you have to they both mean the same, but development platform means for a programmer you have a development platform, but how do I use it you use it through an API basically that is the difference. So, we can use this words interchangeably in that manner. So, this is first part. The second part is to do with the pulse sensor itself pulse sensor itself, which means you have to talk about how is the pulse rate how is the pulse rate.

Calculate it what is critical there and how do you use this IR reflective type of sensor for estimating what is known as the inter beat inter beat interval. It is also called IBI. Essentially there is one beat another beat another beat another beat all of them hopefully I have not shown it uniform, but it should be shown with uniform thing and this is the inter interval right. Inter interval beat is essentially you start a timer here you stop the timer here. This is t 2 this is t 1, you say t 2 minus t 1 you store it somewhere again you have t 3 and then you do t 3 minus t 2, you have t 3 minus t 2 store it somewhere. And then you have t 4 storage somewhere call it sometime.

So, I will say t 2 one just like that this is t 3 2 right. And t 4 minus t 3 is t 4 3 and so on right. You take about let us say something like 10 samples and then multiply it into essentially you do it for 10 seconds, basically you do it for 10 seconds and you find out how many how you how you got the what was the IBI inter beat interval for which in this 10 pulses that you got. And that essentially actually do not wait for 10 seconds you do it for 10 pulses. And then from there you find out what is the inter beat interval multiply that into for 1 minute then you multiply it into 1 minute equivalent of 1 minute.

How many pulses you would get for a minute? And then use that to display right. So, if you have let us say as an example normal let us say pulse is 80. Then if you get how do you get 80. You could get 80 with somehow you get a number 80. This is 80 beats per minute essentially and it is 80 beats per minute. You find out for time for 10 beats what is the time you took for 10 beats and then what would be the time for 60 seconds you find out multiply it get it into time for actually you multiply, whatever number you got into now you scale it in a manner that it is that is for 10 for 1 minute. And then that number you simply show it here. So that is the basic idea. And it is never going to be easy to do this measurement because noise is going to be a problem for you ok.

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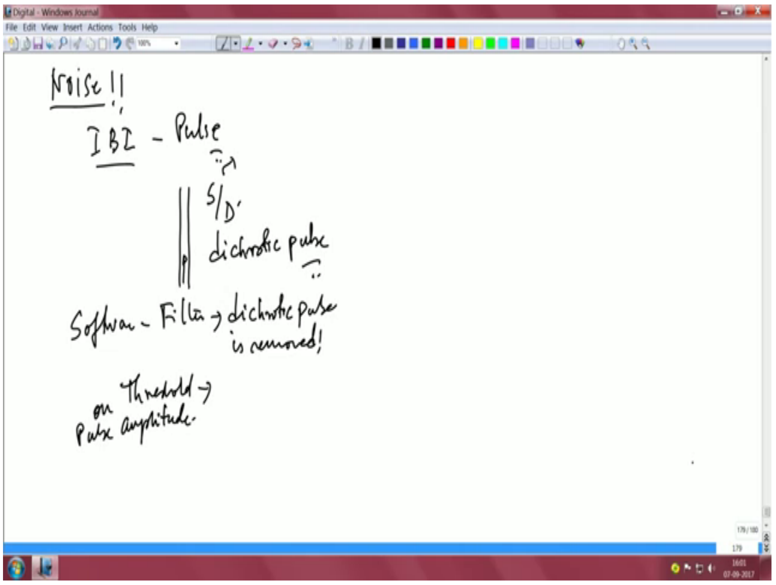

I will give you an idea. See the heartbeat the pulse essentially is the heartbeat is one part of the story and you are trying to find out the inter beat interval by looking at the pulses right. Every time you get a pulse you are making a note of the first pulse, the second pulse and so on like what we said here each one is a pulse here this picture, this is a pulse right.

This is a pulse. This is another pulse and so on. Now how are you sure you are actually latching on to the right? Pulse indeed this is a pulse due to the heartbeat, how do you say? The reason is if you take a blood vessel and you have basically the systolic and the diastolic blood pressure, the gushing of the blood into the blood vessel itself is a measure of the blood pressure right. The systolic and the diastolic pressure which is the up and the lower pressures, this itself will create what is known as a dichrotic dichrotic pulse. Now the trouble is the pressure blood pressure which creates a dichrotic pulse can be easily confused for the actual pulse which means you need somewhere in the software a filter which removes the dichrotic pulse is removed, this is important.

Then of course, once you remove the dichrotic pulse then it is simple you put a threshold for the amplitude and then you say amplitude, amplitude of what amplitude? Of the pulse amplitude you put a threshold, threshold on amplitude on pulse amplitude and then you declare it as a right. Pulse for the measurement of inter beat interval.

So that is the second part. So, let us go back and put this populate it here one and 2 is done. Then of course, with this you will actually demonstrations one and 2 are completed you will actually see that you would have ended up getting data in a manner that you can build end to end IoT systems. So, Miss Madhuri is with me here and what we will do is we will show you a demonstration of the embedded code which is running on the nordic SOC. Essentially we will turn our attention to the screen which is essentially displaying all the source code.

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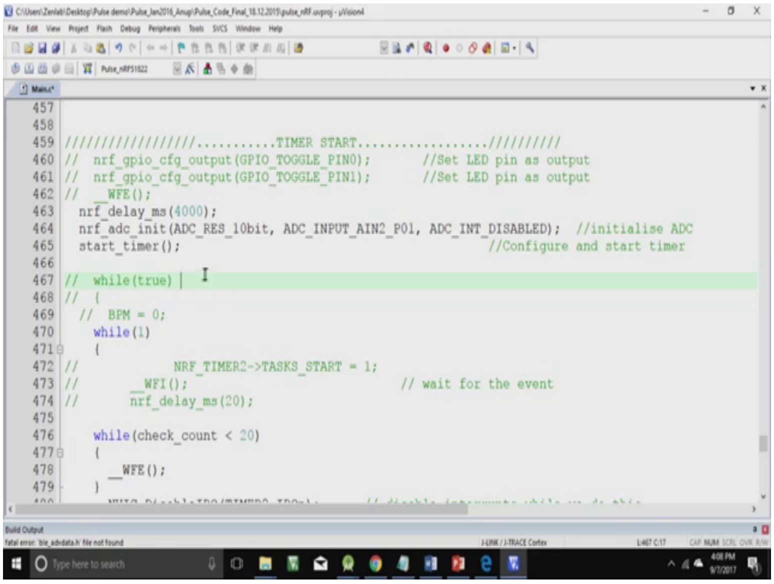

The very first step as you know I have not been getting into details of powering the system and all that, is to basically initialize the ADC. So, you can see nrf ADC in it is already there it is a 10 bit ADC it is initializing the ADC and then it will start the timer. And why do you need the timer? Go back to the screen here, go back to the screen here you notice that the timer is required because you have to start looking at the pulses right. So, you need to get the pulses. So, you need to start the timer. So, the code that you saw their initializing ADC and start timer means it is going to start from the point where it is going to start counting the pulses.

So, let us go back to the code and let us see essentially what happens in the code; the need to keep track of the time in milliseconds right. With essentially can we go right. Keep track of the time in milliseconds with this variable monitor the time since the last beat to avoid noise I mentioned to you about the dichrotic noise you can see.

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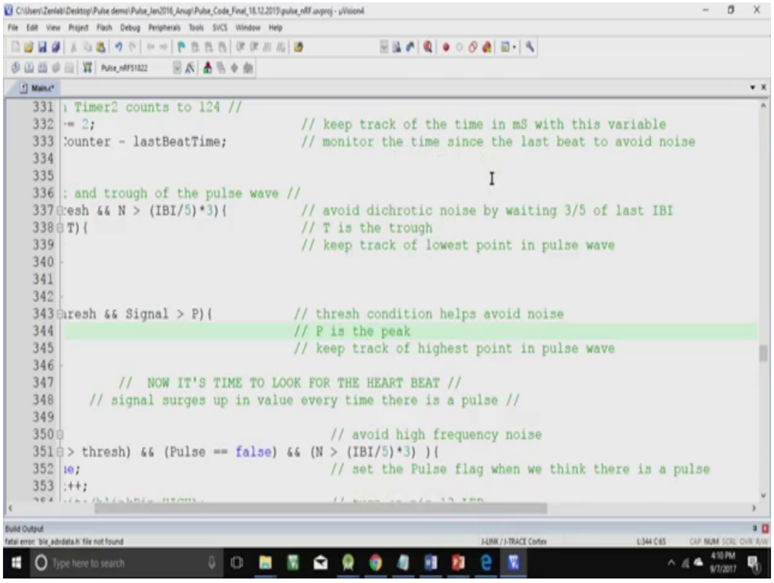

That essentially when you talk about the wave to count the pulses you essentially has a peak and trough right, of the pulse. So, you should not you should under any circumstance not end up you know looking at the dichrotic noise which is also emanating at the same time. So, for that this little routine here which you can see avoid dichrotic noise by waiting 3 by 5 of last IBI t is the trough track of the lowest point in the pulse wave is already there.

And then you essentially start counting the IBIs. That essentially means let us go to that part of the code where the IBI is so, you have a the running total of the total 10 IBI values.

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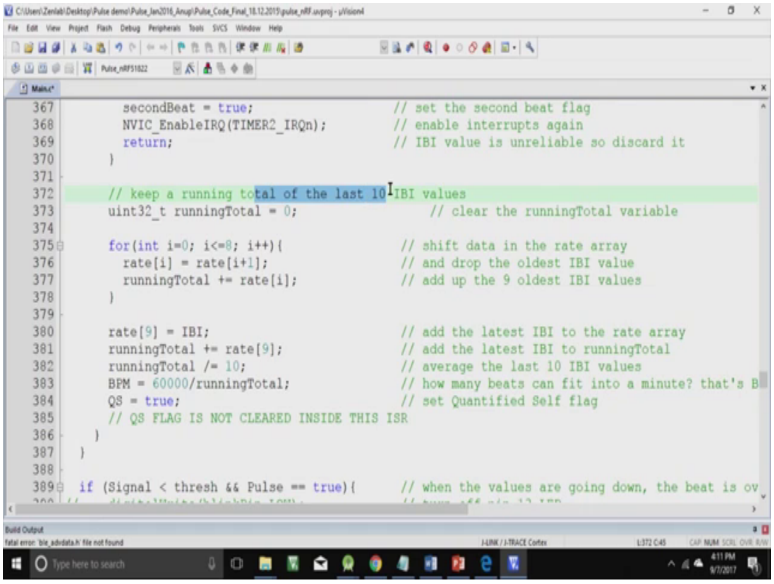

Then you say shift data into the rate array, drop the oldest idea value add up to 9 oldest IBI values. So, you get 10 basically you get all the 10 of them running total of 10 IBI average the last 10 IBI values and after you get the 10 IBI values, you then ask the question how many beats can fit into a minute right. And that gives you the beats per minute this is the ultimate thing you want to get to BPM. So, the BPM calculation is done.

Here you can see that it is a very simple expression you take 60 seconds and then you divide it by the running total you will get the beats per minute all right. Now what you should do? You have already acquired the beats per minute. You need to transmit this value. So, go back to what I showed you we mentioned about acquiring data processing data and then communicating the data right. So, you have to send it out as a Bluetooth low energy packet into the into the BLE transmission.

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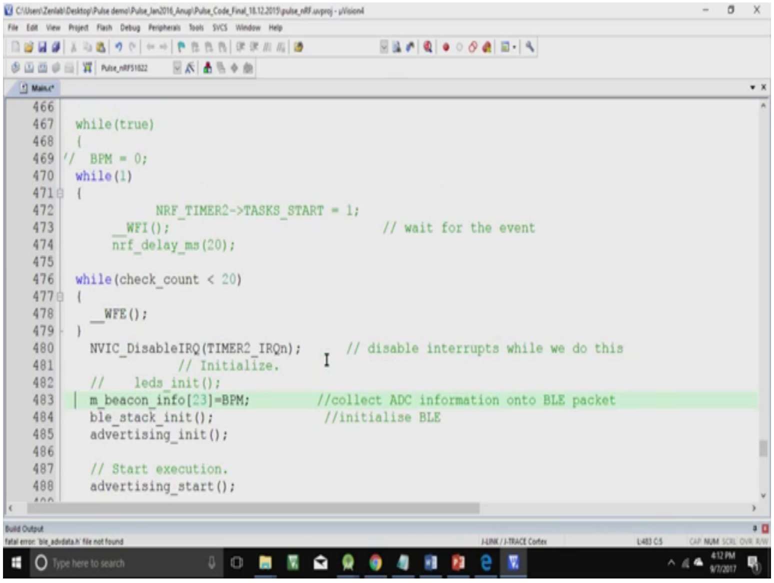

So, you can see m underscore beacon underscore info is whatever that thing in that that line indicates is to collect ADC information into the BLE packet. Now this is ready to be transmitted. So, you then invoke BLE communication BLE stack in it you start advertising and you push the data either you could send it through a connection oriented system or an advertising system. In this demonstration we have shown that this pulse information is actually being advertised. Nevertheless encryption is an important thing.

Please note that even advertising packets can be encrypted. So, there is really no problem. What is interesting here is till the time the BLE BPM is actually you know, collected and made it into a BLE packet, you are actually not switching on the radio BLE radio; that means, the initialization of the BLE stack happens much later. This way energy harvesting applications can actually save a lot of power, and only when required you switch on the radio and do a communication in this case it is simply advertised.

So, this is essentially what happens in the embedded code as far as the pulse sensor is concerned. Now let us shift our topic to the fire base and I have with me Zuhaib who will demonstrate the features of fire base. Now let us go through a set of steps which will give some clarity on the way by which you can upload data. So, you can see on the left side of, can you expand this a little bit? That should be fine.

You see on the left side you can basically store data onto the database either through an authentication process or so authentication is an important requirement right. So, database authentication database storage, hosting, functions, and so on and so forth. Crash reporting so many issues performance all of this is part of what the basic web application development platform offers you.

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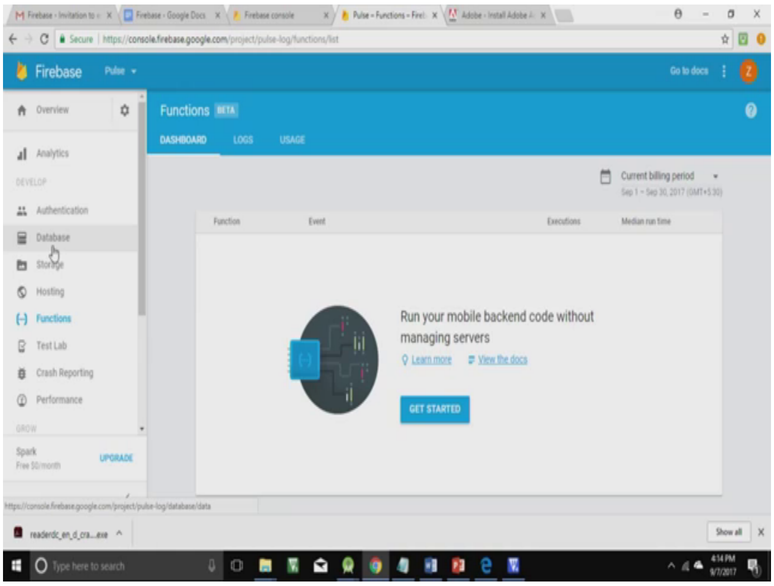

You start by basically logging in with your Google account. And then going through you can see that we have used Zenlab Dese as the Google account we are logged in with that and then created a nice project here. And name of the project that we have the database essentially is, this is the fire base as I mentioned to you; the screen that you see here.

Essentially the kind of the data that is being uploaded the let us say the number of data samples which are being uploaded can be recorded, can be seen you can analyze a lot of that using this analytics button. Authentication is a very important thing so that is you can set the authentication authenticate and mange users from a variety of providers, without server side codes so that is interesting already, so that is possible then storage, right.

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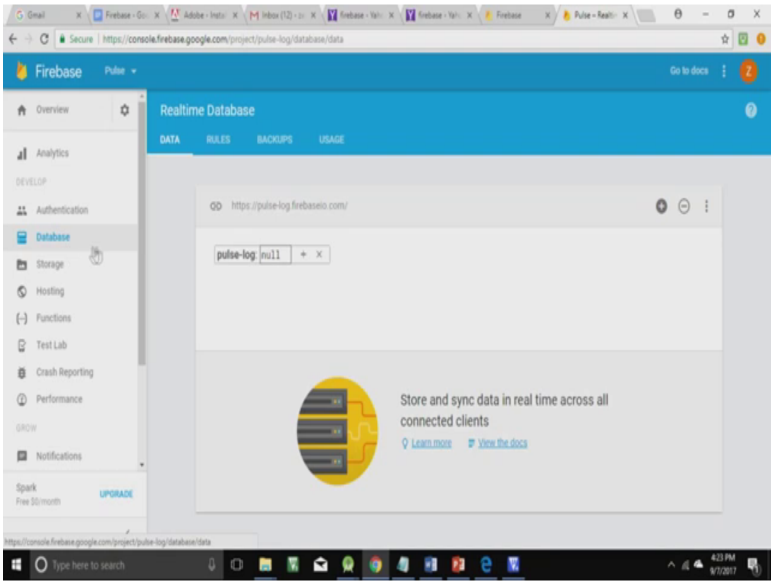

What you see here is this pulse data that we want to actually measure from a patient in a hospital let us say, and automatically it should appear on this cloud system. Of course, there should be a local display on the mobile phone which is a point of care device, but the same value should also appear on the on the database cloud based server right. So that is what we should be able to see then we need to go into the rules.

On essentially which talk about what is it that you can do with this data.

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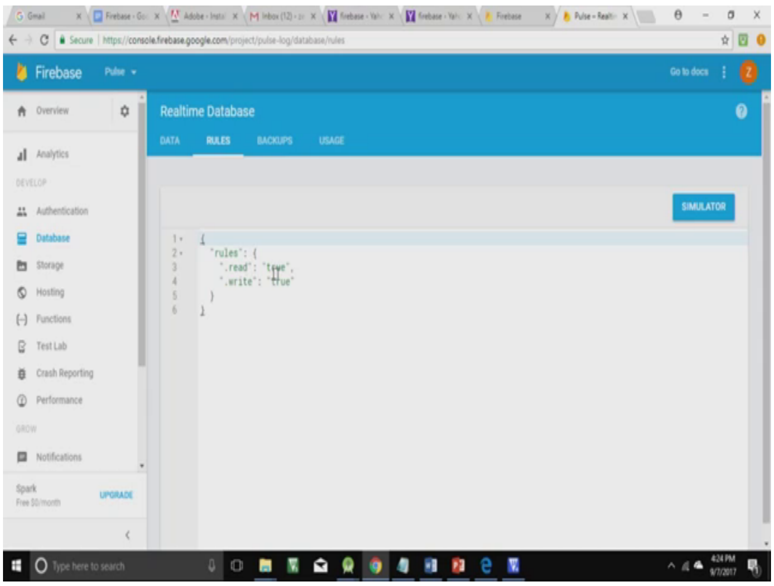

You can read you can write and essentially these rules are have to be programmed on the on the server side right. So that is another thing, then as far as hosting you are not using you are only using storage, and as I mentioned to you already the name of the file which contains information can be stored there. And you can archive files here and all files operation can actually happen from there you can you can do you can upload the file somewhere and you know all file manipulations are possible.

So, that is it their other features like crash reporting and so on. Performance is an important thing and of course, notifications. So, you can just let us click on notifications once.

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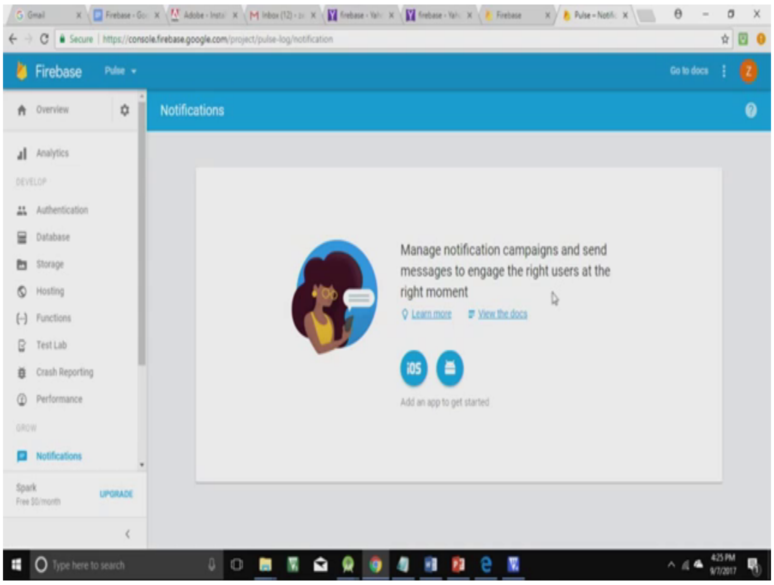

So, what exactly shows up there? Manage notification campaigns and send messages to engage the right users at the right moment very, very important interesting things can happen once data is acquired you can either do it for apple hand phones or for android based development systems. And use this server site for notifications. Please note at the left corner you see I think you should go a little to the left because I do not see it coming there yes. So, you see their spark it says free 0 dollars per month this is for all your testing and trials and all that you can go with the free spark model. But then soon you may want to upgrade and that for which you have to perhaps you have to it is a paid subscription.

Good so, in overall that is what it is let see how we can measure patients pulse. See a local display of that pulse and then see if we can upload that value onto the cloud. Since we are doing this in a lab environment, you do not expect the pulse to be in reasonable values because there can be a lot of artifacts which are created because of movement right. So, motion artifact is the major issue. So, do not worry about the actual value that appears here, but indeed the process in which the whole thing happens in a seamless manner by uploading data.

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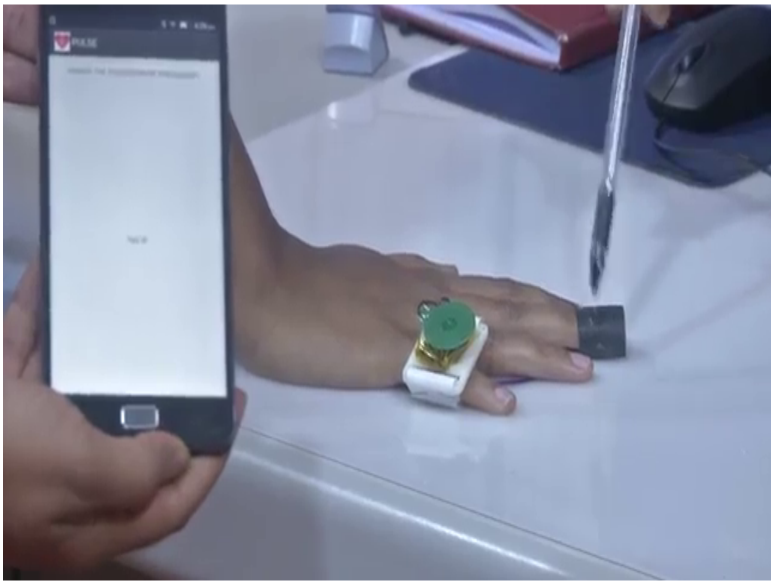

This is the finger pulse that patient is worn here. And this is the piece of electronics which essentially has the controller Bluetooth low energy module and of course, the NFC coil. This phone is going to be placed close to the system here. And it is supposed to not only display the value of the pulse locally, but also supposed to upload the data automatically to the cloud. So, let us go closer so that you will be able to I hope you remember this demo the NFC this is a battery less system.

So, NFC energy from the phone energy from the phone is being transferred to the embedded module using the NFC coil. And the system charges the capacitor in turn switches on the microcontroller. The microcontroller then energizes the pulse sensor. The pulse sensor, the pulse sensor ADC port initialized and then the pulse sensor does all the pulse sensor acquires the data the controller computes the IBI and then packages it into BLE frame.

And then does a does an encryption of the BLE data, and then broadcast that data to the to a gateway. In this event here the phone actually has a connection to the internet. So, what we have seen is that the pulse the heart rate is 80 bit is per minute as displayed on the mobile phone. The same number appears also on the fire base on the cloud based system.

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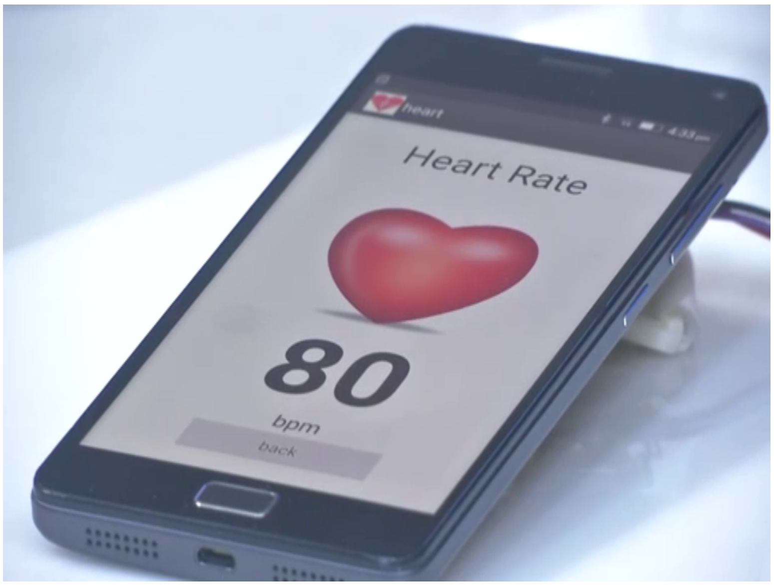

So, in other words quite seamlessly you can see the data is now available on the cloud. So, you could basically take data from several patients and simultaneously analyze The data from each one of them.

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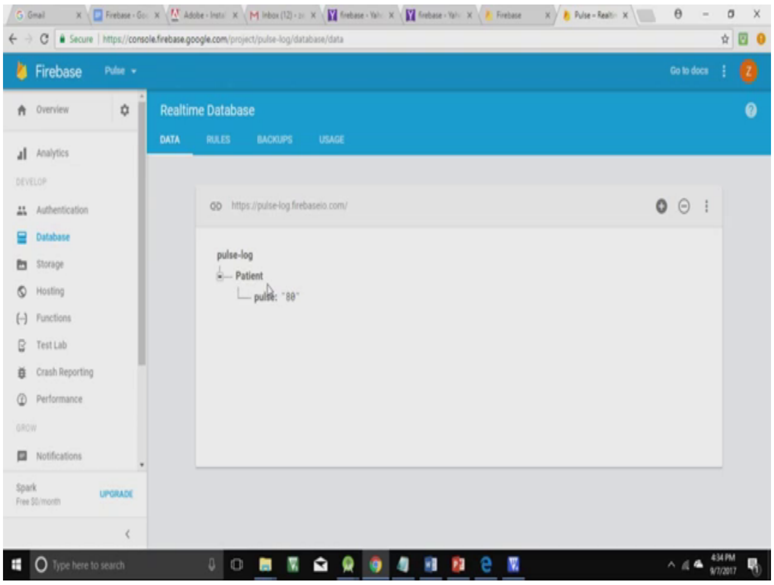

You can give a patient name and along with the patient name the pulse information can be fed and at the end of let us say a certain amount of time, you can actually plot what was the pulse over the let us say period of one week 10 days or whatever time, or which the patient is in the hospital. So, in a sense this is what will allow you to build a end to end IoT system.

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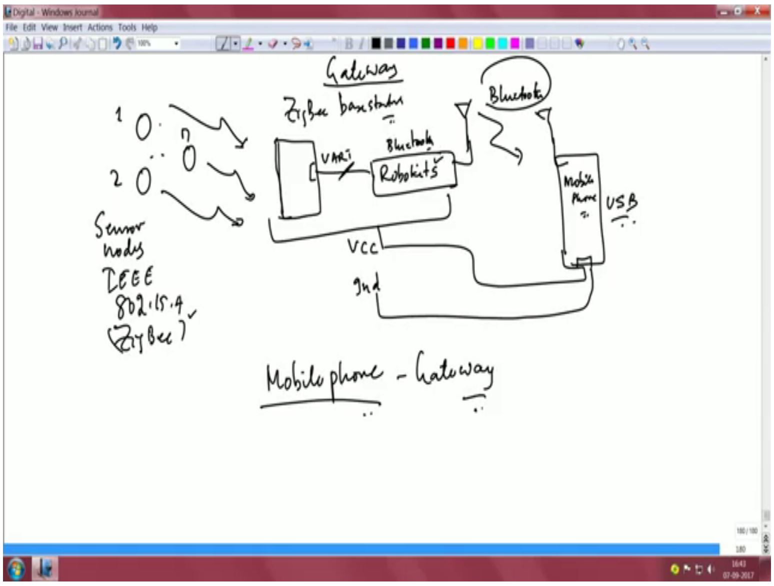

So, imagine a situation where you still want to use the mobile phone. You still want to use the mobile phone as a gateway all right. And you want to upload this data which you are acquiring from several sensors, to let us say the kind of cloud server that we demonstrated a few a little while ago. Assume however, the nodes are all ZigBy enabled 15 dot 4 nodes; that means, let me show you a picture here.

You have a sensor node 1, you have sensor node 2 and you have sensor node n. All these n sensor node are all IEEE 15, 802.15.4 nodes. And for some reason you want to you want to upload this data right. So, here is a nice way to do it. One thing is you need a ZigBy gateway you need a ZigBy base station, you need a ZigBy base station which essentially aggregates data from several sensor nodes. And then locate a base station system which actually has a serial port.

Now that serial port data now you have acquired data on this serial port, data or the wireless link on 15 dot 4 communicate it over a serial port to, let us say a Bluetooth module, Bluetooth module typically. You can buy a model for 2 hundred rupees from robokids. Now over a serial port you configure the serial link specify the (Refer Time: 35:14) rates specify parity stop beats start beats and so on, because it is AUR code you configure those parameters.

And then simply communicate this data over a Bluetooth link as you can see this is a Bluetooth link over which it is communicated. Now this Bluetooth data is caught by the mobile phone. And now it becomes quite simple for you to use this fire base back end to simply communicate this data acquired from the ZigBy nodes. Interestingly you can make everything look for compact you do not need any power supply for instance to power all these unit, because if you take a mobile phone UART USB port.

Power is available on USB right. So now, what I will do is, I will use the USB power itself to power this complete electronics, what will you end up with this? What will you end up? What you will end up with; will be a system like this, look here.

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This has the ZigBy base station; it has this UART to a Bluetooth module. And it is communicating over wireless over a wireless link and to power this box am using this cable. Purely for the purposes of powering and communication from here to this phone actually is over Bluetooth and as I said this is purely for the purposes of powering this module. So, let us see a basic demo of this system, what I will show you is a. So, this is the system which essentially so you can see colour changing here.

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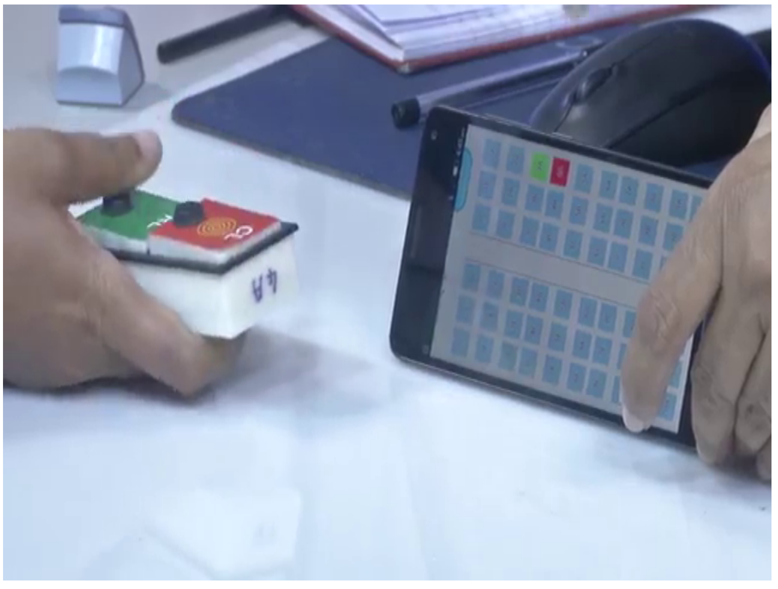

Clearly this data is coming over 15 dot 4 coming to this system here, which is here coming to this transmitting this data onto a UART port to a to a Bluetooth module. And Bluetooth wirelessly is communicating to this phone and therefore, the system is actually accepting data and this data once it is on the phone it is easy to give it to a fire base kind of a cloud server.

So, let us now look at one more application which will which is quite an exciting thing. See as you know the mobile phone has become very powerful it can be used as a gateway it can be used as an edge device for several applications. It also is a very, very sensor rich in other words, you have different types of sensors sitting on the mobile phone itself. For instance it has the inertial measurement unit is like accelerometer, gyroscope, then magnetometer, barometer for pressure measurement proximity sensor right. So, so many sensors are there which are there on the phone. Now supposing you want to use see the accelerometer for instance, the IMU sensor sensors for instance. For let us say indoor localization. So, you want to localize humans using whoever has a smart phone in their hand, what does it mean? Let me turn your attention to the screen that I wrote here. Here you want to do indoor localization.

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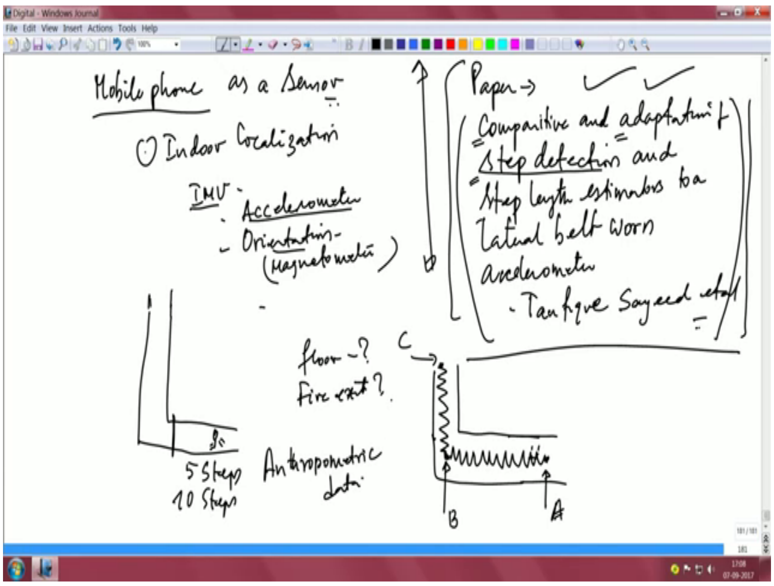

So, essentially you want to use IMU it could include accelerometer or an orientation sensor. Take a very simple case of trying to find out where a human is inside the inside the inside a building indoor, where there is a long corridor and then there is a turning which is quite typical right. This is identical on different floors. So, you want to know in which floor you are, and where in that floor you are actually available. Actually where are you standing or wherever you are located, but why is this important?

You can take cases of such that, if there is let us say you want to find out where is the nearest fire exit. You want to know where your nearest fire exit. First of all you should know where did the fire occur, and where is the in which direction are you moving are you moving towards the direction of where the fire is, or you have to move away if So, where is the nearest fire exit such that, you can safely exit the building. Let us say that is one use case and there are lot of sensors which are trying to sense fire and so on and so forth we will not worry about the use case. In fact, it is a very large project even to think of where you know we have associated ourselves with C dag Bangalore with being a government of India project we actually tried to build these things, but that is besides the point.

Here you are just interested in let us say localizing somebody, how will you use it? What is the sensor? What is the basic data you will get from such sensors? And how can you build applications on top of such basic data that you get? On the right side I have shown you a classic paper. This paper you can try download and understand this paper in detail. It is called comparative and adaptation of step detection, and step length estimators to a lateral belt worn accelerometer. Taufique Sayeed Etal, so this is the name of the paper. What this is saying is coming back to this picture. If I hold a mobile phone in my hand and I hold this phone, let us say I would call this the texting mode; I call this the texting mode. Then I can be in the walking mode, I will be walking with this when I am walking.

I can be walking with a phone like this or I could be walking with a phone like this in my hand some people can also hold phone like this right. And if you are a natural left hander you will be holding the phone in this hand right. And you can have a combination like this as well. Then if there is panic you could be running right. See look at how this phone is oriented it is going in a particular it is going in a quite a random manner. And if you are a natural left hander it would be going in this manner. Clearly the accelerometer which is sitting here if it is 3 axis, gives you data in these 3 axis.

Now you can know what are the 3 axis and what is the phone x axis, y axis, z axis is something that you may want to know as a first step. One of the things is this is if you if the phone moves like this the x axis moves, you will get data on the x axis, you will see a peak a nice wave wavy nature going this way this way is giving you a sort of a sinusoidal action right. You will get a nice wave in this direction, but if the phone moves like this the y axis will become a dominant thing. And if you move forward with it that is you are texting and you are moving forward with it z axis will move.

Now imagine that you are holding the phone in this in your hand and you are walking. So, what would happen just go back and imagine a little bit, the y axis goes up down, up down; sorry, this is the z axis. The z axis actually this is y axis. I am sorry this is the y axis and this is the z axis, this is the x axis. So, y there would not be much of a movement, but z indeed will keep moving up and down. So, just imagine your hip movement happens your movement from the leg will happen.

And every time the leg movement happens the z axis goes up down, up down, and up down and so on. So, you can actually see a nice waveform and you can actually make sense out of that waveform and say. So, I have maximum minimum, maximum minimum, maximum minimum. Some value going around maximum minimum, maximum minimum right. And if can find out the distance between the maximum and the minimum. So, essentially if you have a let us say time series of this maximum and minimum.

You can nicely plot that graph. And from that graph you can make out how many steps were you know you know how many steps were actually put by the owner of the phone right. You can do that, but the trouble is not about the steps is quite straight forward. What about stride length? How much distance was did he cover he or she cover, that will be the question. Because come back here right. You may have covered up to here in either 5 steps here or you could have taken even 10 steps. This is lot of anthropometric data anthropo sorry, anthropo anthropometric data, which says if this is the height of the individual the stride length is sort of you can more or less guess; what is the stride length of the individual that data is available. But that is one part right, but how do you do it in software how do you do it with phones how do you do it with the sensors that you have? So, this paper is actually saying something nice of you read this paper.

You will know how to do step detection, which is appears to be quite straight forward. You can also do step length estimation stride estimation. These are the 2 important things. Let me now direct you to a sort of small right up which our lab Praveen Ramaswamy prepared. And we will run through that and sort of it connects several of these things that we discussed. We will see that and then I will wrap up with challenges for this application. And that will sort of give you food for thought, how you can build, using the IMUs how will you build a full fledged a full blown indoor localization application.

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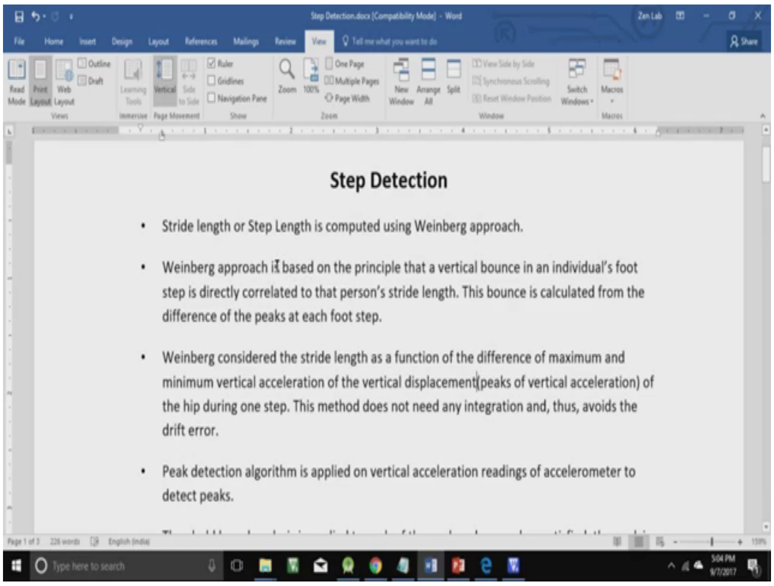

So now, let us go through this little document which praveen has prepared, and let us run through it. This paper this document is actually you know extract of the paper I described to you previously from this picture I showed you here, this one here, can I have the camera on this please; this picture. This picture here, this one this document that I am referring to comes from this paper. So, let us go back to this screen here and focus on the step detection good. Essentially the stride length or step length is the one that actually tells you; what is the distance that was covered by an individual. The paper says it uses what is known as a Weinberg approach.

Essentially the Weinberg approach is based on a principle that a vertical bounce in an individuals foot step is directly correlated to that person s stride length. It is a beautiful paper you should read it. This bounce is calculated from the difference of the peaks at each footstep ok.

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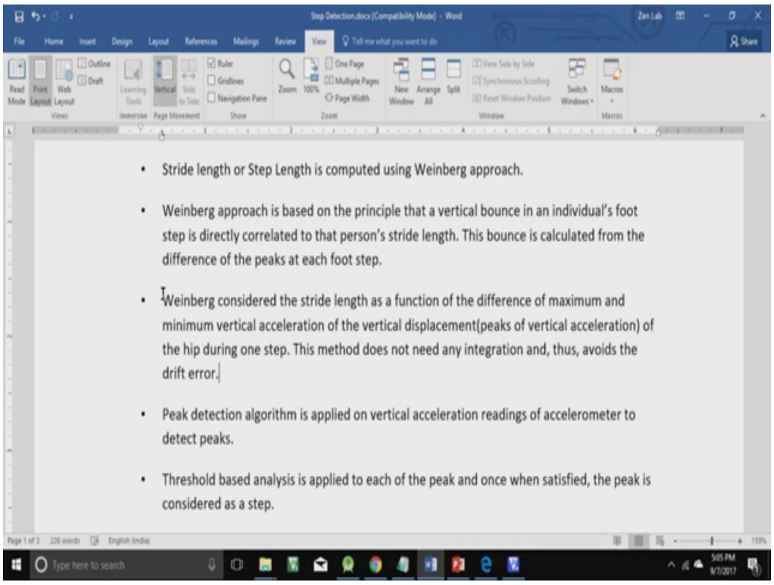

Weinberg considered the stride length as a function of the difference of maximum and minimum, vertical acceleration of the vertical displacement peaks of essentially nothing but, the peaks of vertical acceleration of the hip during one step. This method does not need any integration and thus avoids the drift error, so that is already very good. Now peak detection algorithms are quite straight forward many, many applications actually use them including ECG right. Medical ECG also uses some form of peak detection and that appears to be straight forward. Peak detection algorithm is applied on vertical acceleration readings of accelerometer to detect these peaks.

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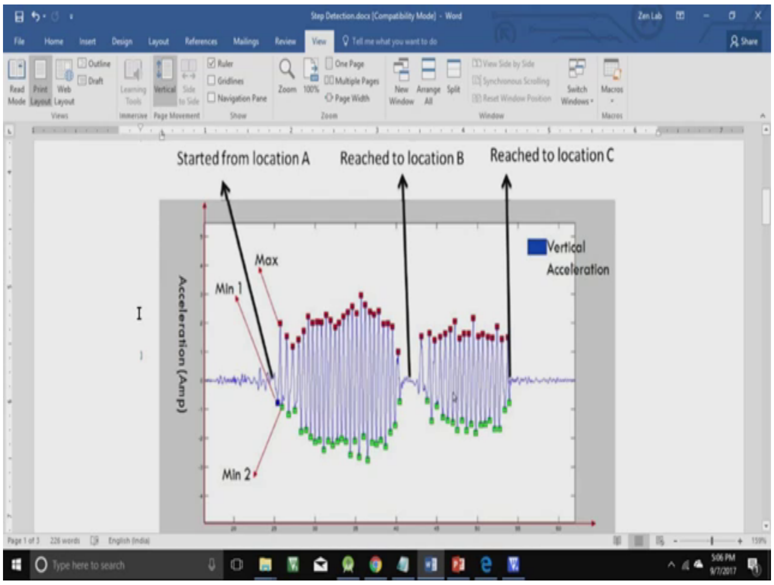

Now, you see this is a snapshot which praveen has actually experimented with the nexus Google nexus 5 phone, and this is what he got on the for the zed axis. What you see on the x axis is time, the y axis you see is the acceleration, and you see that each time an individual takes a step forward there is a maximum there is a minimum 1 and a minimum 2, and that indeed is nothing but a step. And you can see max min, max min, max min and all that essentially are steps right. It starts from a location A then goes to location B and then reaches location C. Let me put back again, let me go back and redraw this picture so that will help you to understand. This is A.

And this is B and this is C. This is A. I have thrown shown 3 bullet us B and this is C. You can see the individual has walked here, so just to make it a little more colorful. I will show it like this right, and then right. This is what you could essentially, each one is a step. And this is the stride length which you have to measure. And here there is a small dead zone collet or a little bit of place where he turns and that is the time when you have almost no acceleration because he has just turned and there is no step there. And after that again he starts walking he or she starts walking towards the destination C. So, let us go back to this screen. Here and you can see it exactly reflects the data that praveen has captured. Now using this data you have to use the paper that we mentioned and actually calculate the stride length and the step count.

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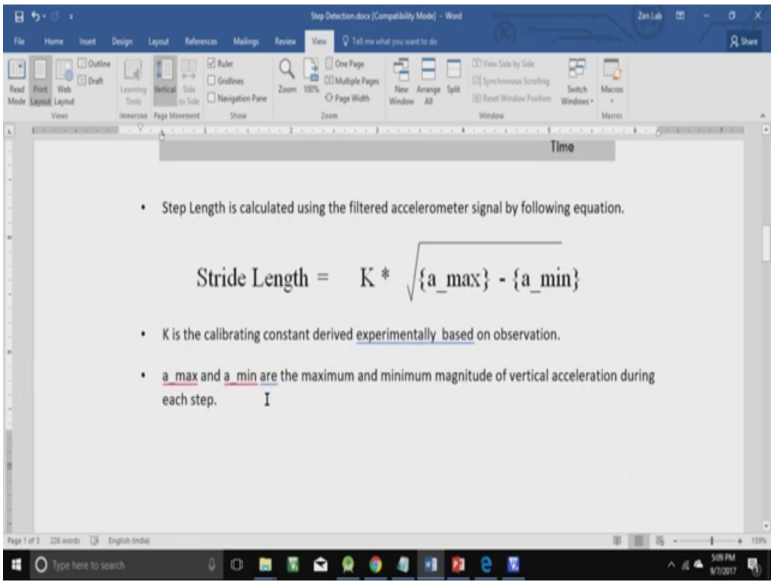

The stride length here is given by this little expression, k here is essentially the calibrating constant which you have to derive experimentally based on several observations, tens and hundreds perhaps even thousands of observations. You know that you get the max and the min from the you have curve there, use that straightaway there are 2 minima minimum 1 and minimum 2 use minima 1 minimum 1.

And then you have the maximum there use that and essentially calculate the stride length, it seems to give quite accurate results there. So, can you come down now all right. So that is one thing. The second thing is let me now show you another picture, which is here.

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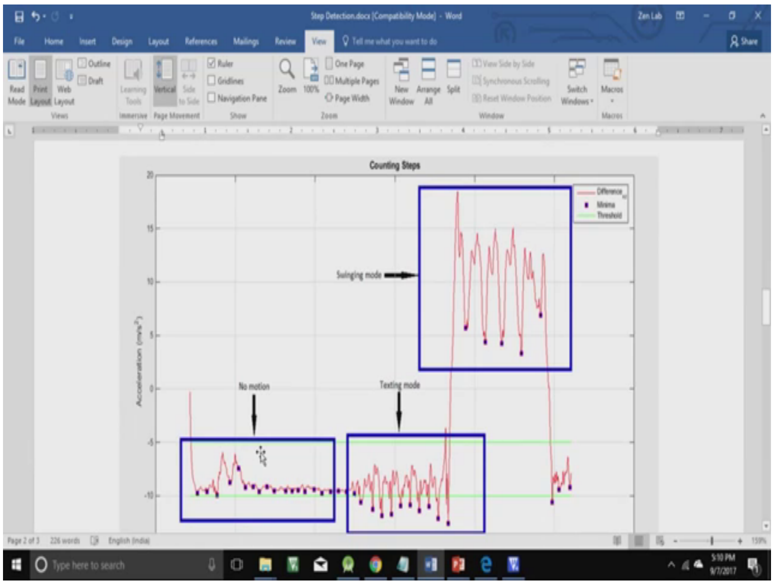

What we have taken into consideration is, that the phone is purely in the texting mode; that means, z axis alone is captured and everything is happy and nice. But never expect the individual to always be in texting mode right. He can actually take the phone he or she Now, that result that you saw till now is limited to the texting mode. What happens if from texting mode he suddenly he or she suddenly realizes to go into starts walking? So, dynamically you should be able to switch to another signature which is coming from the accelerometer and that signature analysis you should do.

In a manner that you will be able to do again step count and stride length estimation right. And from swinging he may actually start running right. So, again random motion of the phone axis gets completely disturbed. You have to pull out the signature again of running mode you should detect that it is in running mode. And noise and nothing else and then from there you should be able to do again step length and stride length estimation. And only then you should be able to you will be able to say you will be able to localize the human inside the building, so that is another thing. So now, we did a little bit few things as well there.

And let us go back to the screen which focuses on the fact that you have no motion on the left side. You have texting on the right side and then automatic detection from texting to swinging mode. So, you can see that the signature has slightly changed and of course, I let you decide figure out how you will capture the different axis as well. Again this picture has x axis as time and the y axis as acceleration which is meter by meter per second square. Come down on this document then you can do an app building and so on and then you can actually find out the distances.

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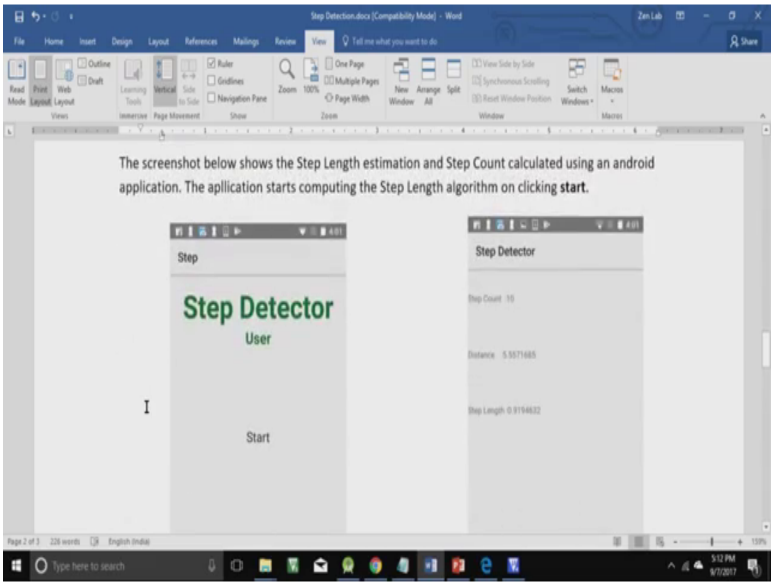

So that is in brief what we have with respect to the basic cell phone cell phone as a sensor and cell phone as cell phones I knew which can be used for the purposes of the indoor localization. I said that I will summarize everything with some of the challenges.

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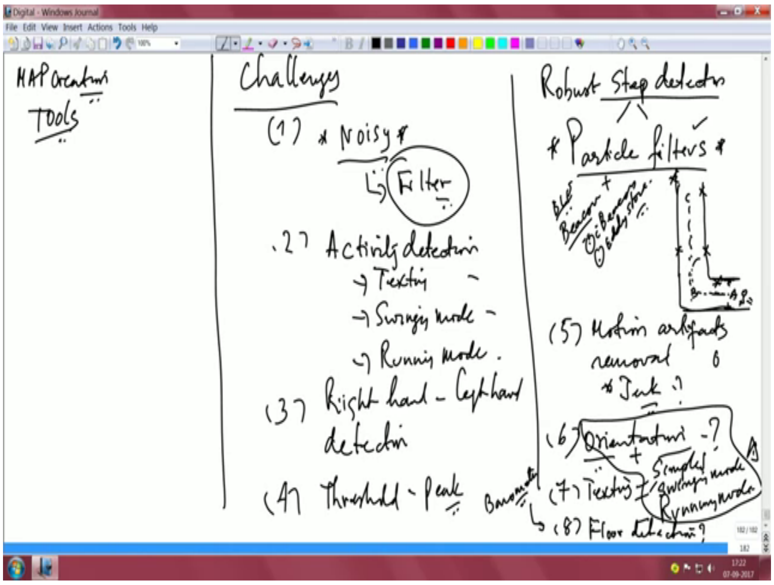

Which are open thoughts for you to in order to solve them and actually prepare you know go ahead and actually build an application right. So, what are the challenges? First thing is be hundred percent sure that the best of the IMUs also that you get integrated into very high end phones very high end phones continue to be noisy. Look at this. Noise thing comes to you at every stage. So, noise reduction in embedded systems is an important thing. Please pay attention to the fact that accelerometers are very noisy IMUs are very noisy therefore, you must pass it through a nice filter.

You may have to consider different types of filters; I would suggest that you gather you get raw data first. Take it find a mechanism to get the data, take it inside a good package like matlab. Try different filters there and see which one of them accurately give you the step length and stride length estimation. So, you must try number of filters whichever is suitable you may want to try them.

So that is one thing. One challenge, the second thing is, on the fly you should be able to do activity detection right. You should be able to do; that means, texting mode to shrinking mode to running mode. One is detection of these modes the other is much more complicated right. You have to do step length and step count step detection and stride length estimation for each one of them, only then you can do localization.

Therefore, second challenge is to do activity detection. Third thing very simple, are you a natural left hander or a right hander? Texting mode in left hand or texting mode in right hand? And so on and so forth all these things. So, you may have to do right hand right hand left hand detection right. This is another important thing. So, your ultimately your goal is to come up with robust step detection which will include step length estimation step count and step length estimation. You cannot avoid use of particle filters; you may have to consider the use of particle filters. I would quant you urge you to look up particle filters, because when you walk you must know here your right side of the boundary is, where is your left side of the boundary where exactly are you walking therefore, it can be easily you can it can be easily localized.

If your corridor has openings doors and so on, where it goes into different offices, then you may if you do not have a proper map creation tool you may end up entering some of the office buildings. The application thinks that you have entered somewhere actually you would be walking straight. So, unless you consider use of particle filters a little out of scope in this course you may end up with an improper implementation. So, step detection particle filters are definitely things that you would require in order to remain in the corridor mainly, if you are looking at localization in the corridor space of office buildings. Then what is a threshold? How do you perform the peak detection? So, in other words peak how do you detect these peaks. So, peak detection becomes an important thing, that is one thing finally, you also have problems of the following nature right.

Let me show you one classic problem. You are holding the phone and suddenly tells someone tells you that there is fire in the building, what happens you start shivering? When you shiver you are not moved, but step length step detection has actually happened. So, phone shivering. So, I will say motion artifacts, motion artifacts removal is one important requirement, unless you do that you will not be able to detect them, you can not be able to do step the localization accurately.

So, this would include you know you may have to do jerk detection right. You may have to do some sort of jerk detection in order to detect in order to remove this motion. 6 I would say is go back to this picture here A to B, B to C. What happened to the orientation? What happened to the orientation? You change the orientation. Step length and step count will not show you anything there, orientation has changed. So, how will you find out? So, you have to use the orientation sensor as effectively as possible. And I would say that is important. Then just try texting is simple. I am sure you will be able to build it soon, but you will find a lot of difficulty when you go into swinging mode.

Swinging mode is not going to be easy at all. And perhaps the toughest is the running mode. So, combine simple texting mode swinging mode running mode with a orientation is indeed very, very hard problem. It is a hard problem I mean it is doable it is it is a lot of fun to do, but then it is not easy it is going to take you quite a bit. What we did not describe here is you can localize, but what about map creation, I did not want to put it as part of this because this can be a separate activity.

So, map creation tools are require here. So, you may have to look at map creation separately. Here coming back finally, every floor will look identical right. Every floor will look identical if you are talking from a multistory building. You may have to do floor detection is also a challenge. Which floor are you in? Are you in the fifth floor?

Sixth floor? How will you know? Particularly if there is fire you often lose track of where you are right.

However, you do not want your app to do any of that. So, you must be able to detect the system should be able to detect the floor. So, you can you could have reached that floor either using staircase in which case accelerometer can actually give you nice signature. Or you may have used a lift right: an elevator, in which case you perhaps will find it difficult with an accelerometer, but barometer maybe able to catch.

So, use of barometer maybe required right. Finally, I would say none of these things will give you very good accuracy you may want to actually look at beacon based systems. In other words come back to this picture you could be installing at regular intervals at regular points in the corridors beacons. Now we will talk about the beacon technology in detail particularly BLE beacons.

I will not get into the detail, but quickly ibeacons and eddystone standards, eddystone beacons can be used and you could use beacons plus particle filter and whole range of IMU sensors and solve this large problem of with all the challenges I mentioned to you in a manner, that you create a beautiful good working app which essentially ends up saving lives of humans in a fire situation inside a building. So, when we put these curtains down on this course if you recall we covered many things right. We look at the architecture we defined what IoT definition is from ITU beautiful definition there then we took an example of bearing went into bearing as a good sensor for you know battery less applications and condition monitoring which is a very important things for industrial applications, then we went slowly into the fact that you can have battery less systems. We looked at power was a very important section in this course. We looked at energy harvesting and power.

Both and when we went to power we looked at devices we looked at datasheets. We looked at LDOs versus switching regulators, and showed the advantage of each one over the other and slowly moved on to talk about RFID systems. For instance we said we will be having passive tags your passive tags you have active tags localization is a very important aspect there and so on right. Then that is all about I would say battery less related thing, I am not telling you is sequence, but I am just telling you broadly what we covered.

Then we went into a MCU, MCU was a very important choice right. When we say design for internet of things choice becomes important. Choice in the MCU will you choose a risk processor will you choose a SISC processor what about memory as an important parameter there. How do you calculate whether you should go based on low power consumption or how do you calculate that, how do you evaluate that right. So, those issues related to choice of MCU were a very important thing. Even getting into architecture details of an MCU for example, single instruction multiple data was a very important thing right

So that is a even choice between an MCU a microcontroller and a DSP where the operations related to multiply and accumulate Mac operation as they called very, very critical. Then we went and did lot of things on protocols choice of protocols we looked at COAP rest based core constrained rest architecture based slow a we looked at NQTT public subscribe. We looked at AMQP right. Which was a again choice of protocol that we had.

Then we also looked at, I would say local low power communication systems like, BLE then ZigBy and to some extent NFC these were 3 covered. Then we looked at LPWAN right. Low powered wide area networks, we looked at LORA SigFox as another alternative. Then we also looked at n BIoT, LTEM cat LTEM, these standards which are coming up, and how systems can actually communicate over a metropolitan area networks wide area networks and so on.

Finally, we looked at some end to end systems; we took examples of an energy meter particularly we looked at joule jotter. By the way joule jotter is a joint effort of the Indian Institute of Science and the Delft University of Technology. So, we developed this thing with a grant, and from ACM, ACM sigcom he was a grant and we built this energy meter with that grand. Then we had I showed you an example of how joule jotter can be built, including source code the requirements for the most popular IoT Wi-Fi module which is that ESP module right. And then we also looked at the pulse application which we showed in the previous demo, but we said how do you build such a system right. And then cloud how do you upload data to the cloud and actually reflect everything back to the cloud.

We summarized finally, with mobile phone as a feature with sensor gateway edge device and everything all in one kind of a device and we took one case of mobile phones sensors, particularly the inertial measurement unit. And then elaborated a little bit on the step the indoor localization issue, which can be nicely solved with a mobile phone any user holding a phone you can have you can do localization provided. There are a set of challenges which you can which you have to go over in a manner that you will be able to accurately localize the human.

So, this is in summary we covered in this complete course. Hope you enjoyed this course, and I must tell you that a number of people were involved in making this course the way it looks at the moment. We had Nagakrishna Maikoly, and then we had Madhuri, Madhav Madhuri Madhav, Abhirami a big support there. Then we had Zuhaib Ahmed, then we had Praveen, then we had Anuja right. And all the team members who did all the recording work for us of course, I can not forget some of the very senior project staff, like Madhuri Iyer who also helped me here to understand to setup the systems. And show demonstrations of several things right. Overall it is being fun and I hope you enjoyed the course.

Thank you very much.