Design for Internet of Things
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Lecture – 29
Case Study on Sensing and Actuation

This module on sensors and actuators, it is a very good time for you to start looking at one good application, one good use case where sensing and actuation both are put together so, that you can build your own applications at the end of this module. So, that is the idea and it is a very common simple example that I would like to take and I will show you run through the whole process.

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And this is something that you may want to try also as a mini project when you go through this course. So, the area where I would like to focus essentially on the warehouse.

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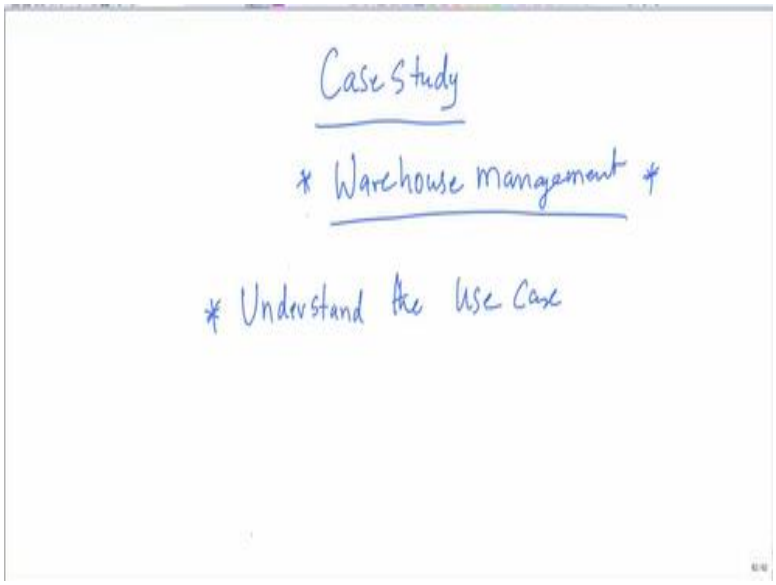

I want to take a case study of warehouse.

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Ware house management pdf it is a complete guide you can see that this is a nice document which will tell you about what is a warehouse management and statistics arranging your warehouse receiving and managing new stock and all of that. So, it tells you something very nice about the whole management of the warehouse itself. So, this is a very important document and you can spend some time it is a high level document.

It will tell you something nice about the warehouse management. There is a similar document which also talks to you about a modular warehouse management, receipt of goods warehouse management transportation, consignment, production management, goods issue and distribution performance and operating figures and so on.

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I would say top most priority is understand the use case. And I will show you what two students who took my course actually did that.

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I will now run through these slides. And these are the slides which I wanted to explain to you as far as warehouse automation technology is concerned.

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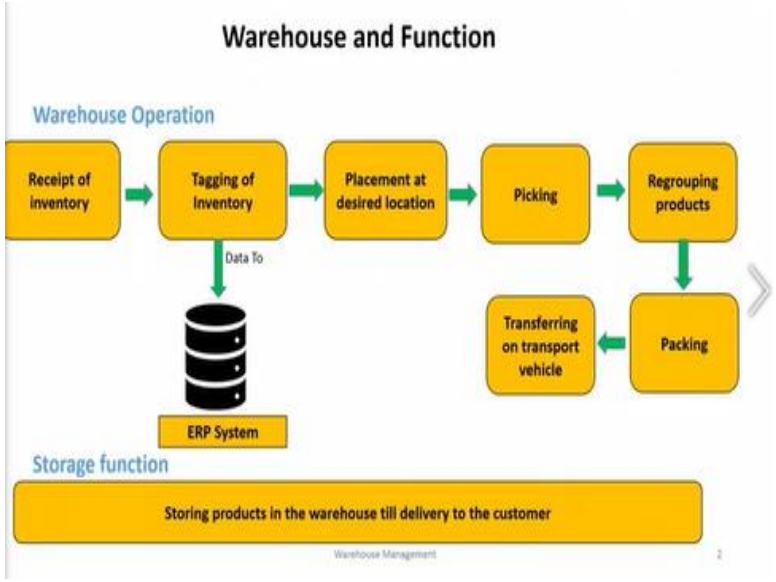

Look at what the students put together. They said receipt of inventory, tagging of inventory, once you tag the inventory it goes into the ERP system. The ERP system is a completely automated system, enterprise resource planning system and placement at a desired location. Picking see this picking very important, regrouping products, packing and transferring on transport vehicle. All what I showed you as top level bullets in the two documents are actually captured very nicely here.

The students have put this slide together. So, this is a very important thing background for each one of them you have to read those documents. For example, picking or for example transferring on transport vehicle or for regrouping, packing, all these are very important for the warehouse operation itself. And then the storage function, storing products in the warehouse till delivery to the customer.

Think about this folk, this is not easy because if it is meat, livestock and this kind of meat particularly or vegetables or fruits, it is one type of storage. If it is grains its a different type of storage. If it is shoes, clothes it is a different type of storage requirement. Each one of them have their own different storage requirements.

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Now the students also went and read quite like what I was mentioning. They read about the challenges in a warehouse and for them and look at what they have done. They have listed two challenges, challenge 1 and challenge 2 and they have done a proper literature work 1 2 3 4. There are four references you see here and these four references that you see here down below actually tell you that these four.

These references actually tell you that after reading these references they came to these conclusions. Warehouse containing itemized item, among all the warehouse operations order

picking process is the bottle neck operation. I mean this is where customer satisfaction comes into picture. It is actually a process and this order process is the bottle neck operation it accounts 50 to 55% of total operating expenses for anyone who is managing a warehouse.

It is also the most labour intensive and capital intensive operation. So, that is coming from this reference down below. The second challenge is warehouse for agriculture produce that means if you are talking about vegetable warehouse or agriculture products warehouse. When you say agriculture, it can also include production of grains, pulses and grains and all that. So, that is a proper warehousing of agriculture produce is inevitable for an efficient supply chain.

See your wheat and rice and other millets that are grown or even pulses that are grown there is a season over which they are grown. And after that you have to somehow store them very effectively. So, that you know they are free from worms and other type of pests and other related infestations that happen on the produce also rats, rat is a big problem in large warehouses. You have to ensure that it is free from rats, so that there is no loss.

So, it is a huge effort in trying to put up these large go downs and warehouses for agriculture produce. Proper utilization of the warehouse services is useful to mitigate marketing risk by postponing of sale till market becomes lucrative. Sometimes you do not want to sell it immediately, you want to sell the producer little for a better price. So, you will be looking for storing that for let us say a day or two days before you actually sell it.

So, you must use the warehouse service in a very effective way and ensure that it still protected and it is still fresh for customer to buy the produce. 30 to 40% fruits and vegetables and 10% of entire produce is wasted due to poor warehouse infrastructure. This is where IoT can come in a big way and you should look at this as a mini project. 30 to 40 % of fruits and vegetables 10 of entire produce is wasted, so it is a big number. So, that is the findings of the students who worked on this project.

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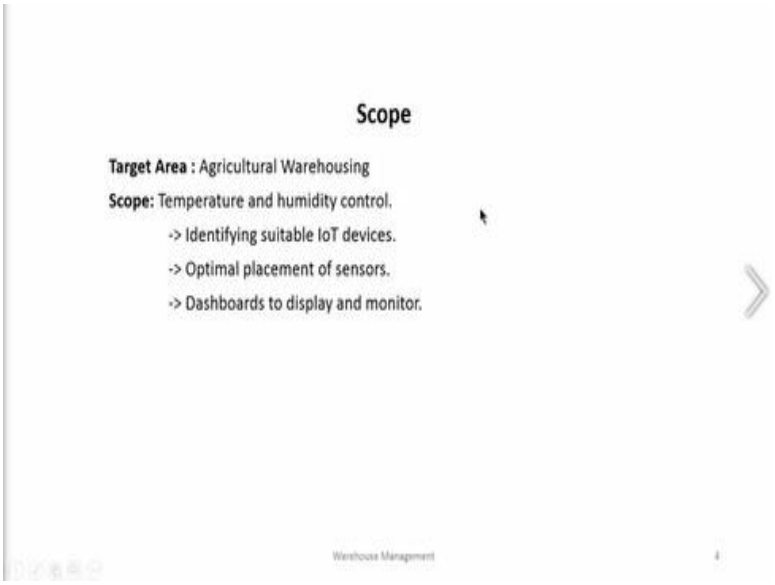

They said that let us put the scope to agriculture warehousing and temperature and humidity control are two important parameters for them. Identifying suitable IoT devices optimal placement of the sensors and dashboard to display and monitor including the personnel who is actually maintaining the warehouse should get super information about what is the current state of these two sensed parameters which is temperature and humidity control. And why are they important?

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They are important because of the following reason which I will explain. The implementation plan comprise of understanding temperature and humidity requirements. Implementation plan as well as the assumptions.

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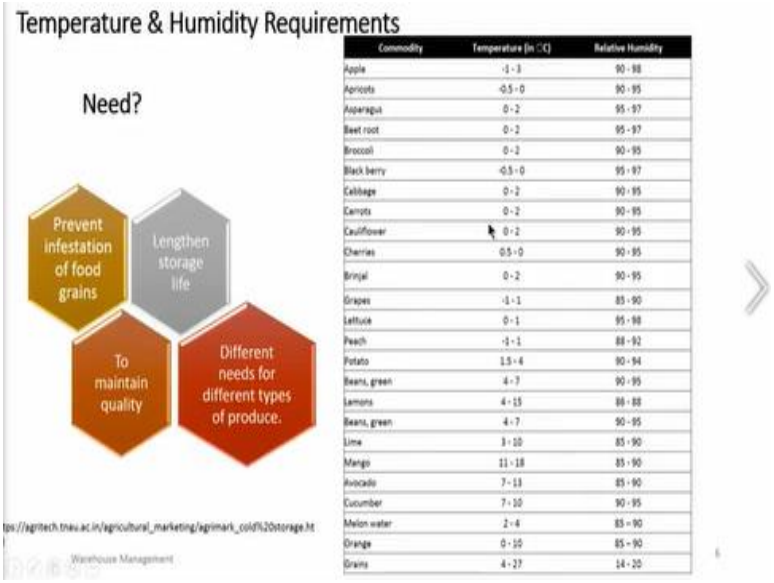

Commodity	Temperature (In □C)	Relative Humidity
Apple	-1 - 3	90 - 98
Apricots	-0.5 - 0	90 - 95
Asparagus	0 - 2	95 - 97
Beet root	0 - 2	95 - 97
Broccoli	0 - 2	90 - 95
Black berry	-0.5 - 0	95 - 97
Cabbage	0 - 2	90 - 95
Carrots	0 - 2	90 - 95
Cauliflower	0 - 2	90 - 95
Cherries	0.5 - 0	90 - 95
Brinjal	0 - 2	90 - 95
Grapes	-1 - 1	85 - 90
Lettuce	0 - 1	95 - 98
Peach	-1 - 1	88 - 92
Potato	1.5 - 4	90 - 94
Beans, green	4 - 7	90 - 95
Lemons	4 - 15	88 - 88
Beans, green	4 - 7	90 - 95
Lime	3 - 10	85 - 90
Mango	11 - 18	85 - 90
Avocado	7 - 13	85 - 90
Cucumber	7 - 10	90 - 95
Melon water	2 - 4	85 - 90
Orange	0 - 10	85 - 90
Grains	4 - 27	14 - 20

They are important because of the following reason. You want to prevent infestation of food grains. You want to lengthen the storage life, different needs for different types of produce and to maintain quality. Again, there is a website link which the students have pointed out. You must get to this and you must say what is the warehouse that I want to monitor and am I going to divide the warehouse into different zones.

And in each zone will I store different type of produce. For example, grain zone should be different from let us say apple and apricots as much as potato zone where you store different type of produce. So, you must divide the whole warehouse into different zones that is one way. If you have a single large warehouse divides them into different zones. So; that you can plan the temperature and relative humidity for different zones differently.

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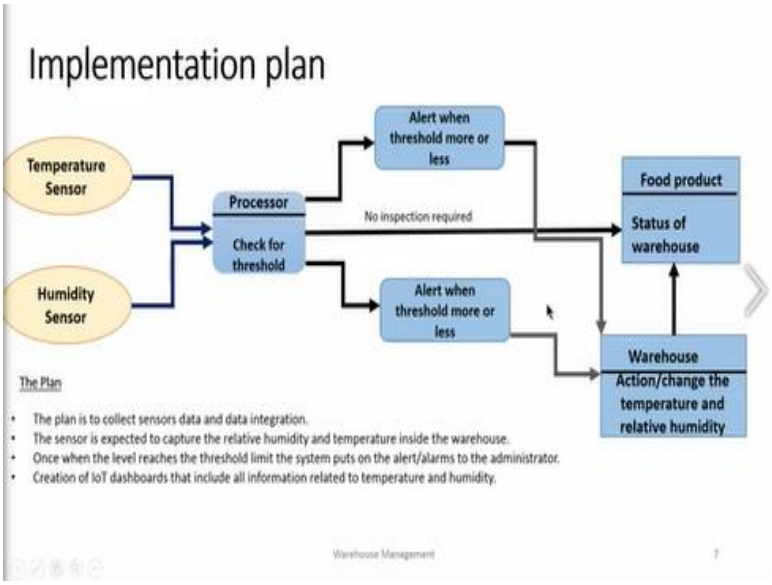

Here is the implementation plan as proposed by the students. Temperature sensor you have a system which will check for the thresholds and an alert will be issued and the status of the warehouse will be known to you. Similarly, if it is for humidity you will get at threshold. And then you may have to definitely do one thing no use in getting an alert. If temperature is going very high you must have a way to cool it down.

If humidity is going down you must have a way to increase the humidity. Those are the actuations that you want to do. Sensing as you know we are sensing temperature and humidity; actuation includes increase or decrease of the temperature or, increase or decrease of the humidity. So, that is where the sensing and actuation comes in in a big way and you must have a fantastic dashboard where operators can easily see them and everything should be automated.

And once you put these sensors, they should live for a very long time at least five years. You do not want to go and modify them. They must give you untethered operation.

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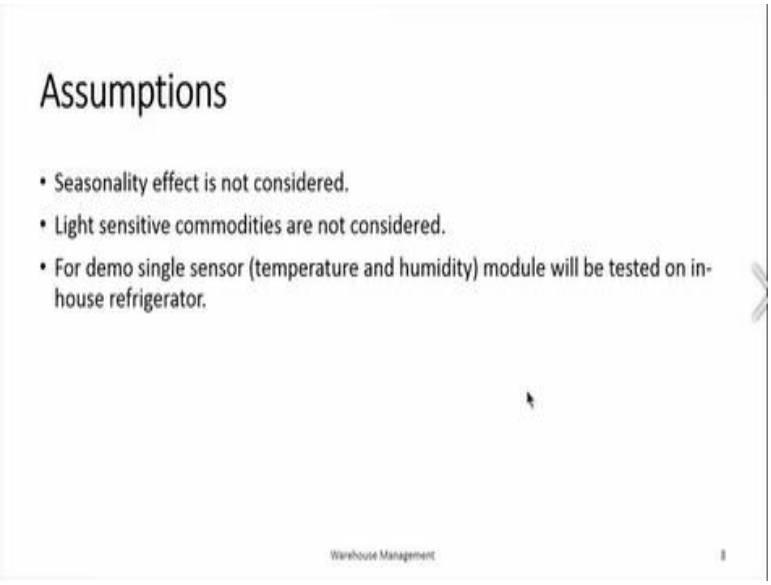

So, let us see what happens. But they have taken some assumptions before we they started you know instrumenting and thinking about a solution. They looked at the seasonality effect and they said that let us not look at that at the moment. Let us just put the IoT solution together. But they have recognized that this is an important requirement. In a real practical life, you have to be worried about it.

They also said light sensitive commodities are not considered that means exposure to sunlight is also an important thing for any degradation of stored items. So, they did not look at that at the moment and they said okay we will take a single sensor, we just divide it into many zones but will only instrument one zone with sensors and we will experiment with it. So, that is what they have put together.

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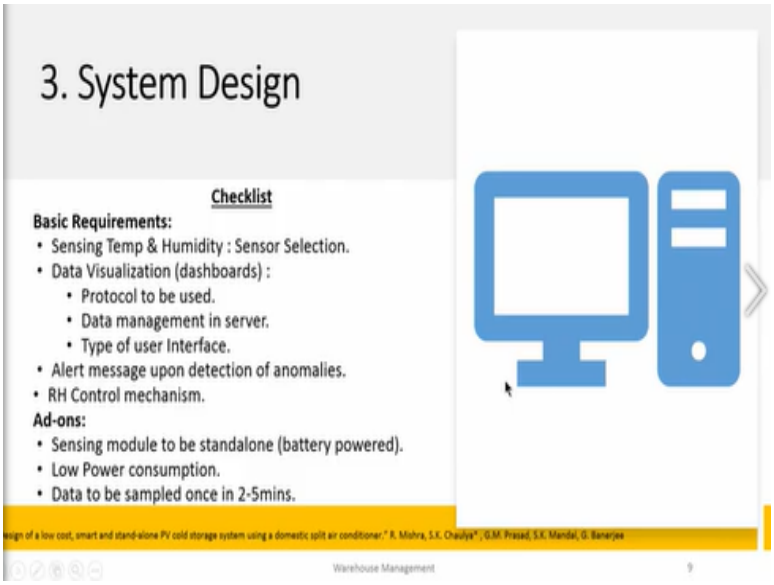

So, it is very important you also plan your stuff accordingly. Here is what they want to do that comes under system design sensing temperature and humidity. They want to visualize the data on a dashboard what IoT protocol should be used and so on. Data management in server, how do you manage once it is uploaded there? How do you manage the data are you going to put it into a database?

So, that it can be queried easily and how much of the data will have to be stored should you compress it and so on. All those actions that you will have to take on the server side will have to be looked up as well. And what is the type of user interface? Are you going to get everything on a laptop or a computer or on a mobile phone? Also, will have to be planned out in the beginning. Then of course you must be looking at sensing module should be in standalone.

It should be battery powered. Low power consumption is an important thing it should have extremely low power consumption. And what is should be the sampling frequency? Should you sample it every minute one sample per every two minutes one sample between zero and five minutes what is it that you should do? And these are decisions which they have considered based on a paper which they read down below.

You see again design of a low cost, smart and standalone PV cold storage system using a domestic splitter conditioner. So, that is an article and they started looking up this article before they did anything.

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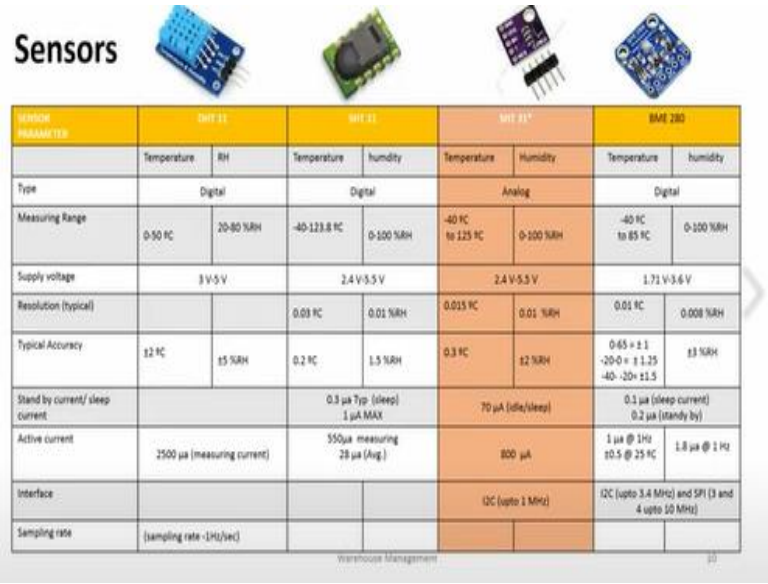

SENSOR PARAMETER	DHT 11		SHT 11		SHT 31*		BME 280	
	Temperature	RH	Temperature	humidity	Temperature	Humidity	Temperature	humidity
Type	Digital		Digital		Analog		Digital	
Measuring Range	0-50 ºC	20-80 %RH	-40-123.8 ºC	0-100 %RH	-40 ºC to 125 ºC	0-100 %RH	-40 ºC to 85 ºC	0-100 %RH
Supply voltage	3 V-5 V		2.4 V-5.5 V		2.4 V-5.5 V		1.71 V-3.6 V	
Resolution (typical)			0.03 ºC	0.01 %RH	0.015 ºC	0.01 %RH	0.01 ºC	0.008 %RH
Typical Accuracy	±2 ºC	±5 %RH	0.2 ºC	1.5 %RH	0.3 ºC	±2 %RH	0-65 = ± 1 -20-0 = ± 1.25 -40- -20= ±1.5	±3 %RH
Stand by current/ sleep current			0.3 µa Typ (sleep) 1 µA MAX		70 µA (idle/sleep)		0.1 µa (sleep current) 0.2 µa (standy by)	
Active current	2500 µa (measuring current)		550µa measuring 28 µa (Avg.)		800 µA		1 µa @ 1Hz ±0.5 @ 25 ºC	1.8 µa @ 1 Hz
Interface					I2C (upto 1 MHz)		I2C (upto 3.4 MHz) and SPI (3 and 4 upto 10 MHz)	
Sampling rate	(sampling rate -1Hz/sec)							

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Now here are a plethora of sensors which they can use of interest is DHT 11 and SHT 11, SHT 31 as well as BME 280, one is from Sensirion, one is from Bosch and there are other companies which are also making sensors. What are the parameters to look for? That is the question of interest. You can see that measuring range, supply voltage, resolution, typical accuracy, of course power consumption, very, very important.

Because you are looking at a 5 to 10 year lifetime. And what is the kind of interface? All of it is indicated here. You can see that SHT 31 gives you analogue out and SHT 11 gives you digital output that means all the analogue sensing and signal conditioning and giving you the digital out is already done by the SHT 11. Whereas SHT 31 you have to plan everything in terms of converting it into digital form, it is your choice.

And the measurement of humidity and temperature are clearly indicated here. You can see that it is indicated here, indicating here and so on here based on what you need you could pick your sensor of interest.

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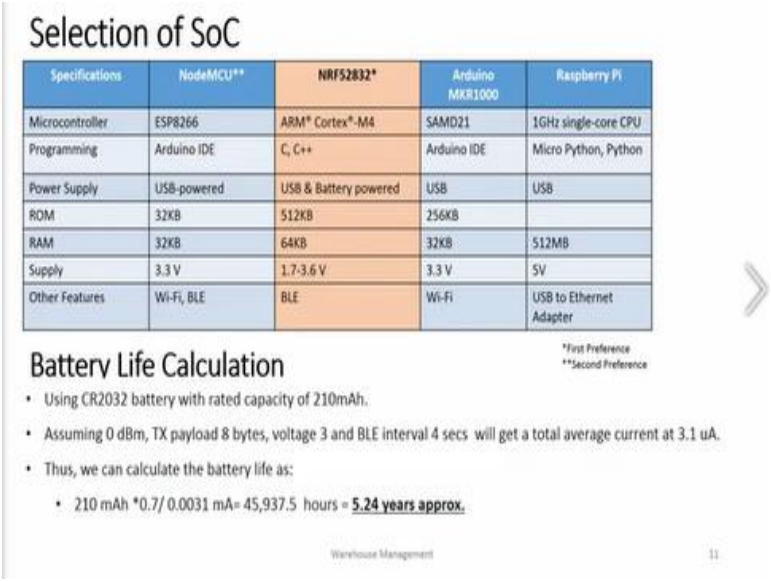

Then SOC, what is the SOC you should use? Well again they did a little bit of a small survey. Node MCU, NRF, Arduino, Raspberry Pi so, many were taken and they decided that at least they will narrow down on one of them and that appears to be the NRF52832. For the following reason that all they need look for is BLE interface, wide operating voltage range 1.7 to 3.6, 64 kilobytes good enough, ROM is 512 kilobytes.

It can program using C and C++. So, that was pretty straight forward. Now down below is an interesting thing. What they have done is they have calculated the battery life. They are assuming that the transmission is at 0 dBm, payload is just 8 bytes, voltage is 3 volts and BLE interval is every 4 seconds. We will get a total average current of about 3.1 micro amps and then they calculate the lifetime which is coming to a little over 5 years.

So, this is an important thing. So, please follow the process, it is not so much about the end result but about the process.

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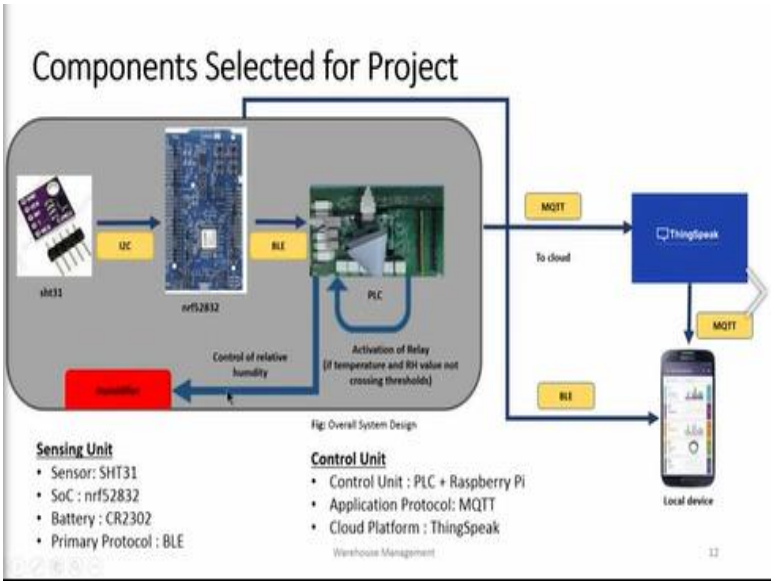

Fig: Overall System Design

Then they go into component selection. Look what they do. They choose NRF52832 as their first choice. They know that they have to interface it with SHT 31 and they know that SHT 31 indeed is out here is an analogue sensor. So, it will have to be connected to the analogue input of the microcontroller. So, SHT 31 over a digital bus, 2 wire I2C bus comes to this controller. And the controller has an integrated BLE.

And using that BLE it does a wireless transmission to another module which is BLE receiver here. And this is the openPLC which we have done a demonstration. And this contains a Raspberry Pi and it has the full PLC logic built into it. And activation of relay increase in humidity or decrease in temperature or increase in temperature everything is done through relays in this case. And users need not be there physically.

Why? Because there are IoT protocols such as MQTT and so on by which you can upload the data to a cloud. This thingspeak is actually integrated tightly with MATLAB and you could use thingspeak free if you are use if you have a licensed version of the MATLAB at least this is true for educational institutions. So, thingspeak you use and then send the data to the cloud. And then you have an application which is essentially uses the data that is uploaded by the system here which is typical of Raspberry Pi.

And then you design an application to get hold of the vital parameters of interest which includes temperature and humidity. And remember folks, once you do this you do not need to be in front of the system, you do not even need to be in the country. You can be checking your stuff automatically and that is where the IoT's strength actually comes from and all of that is written here.

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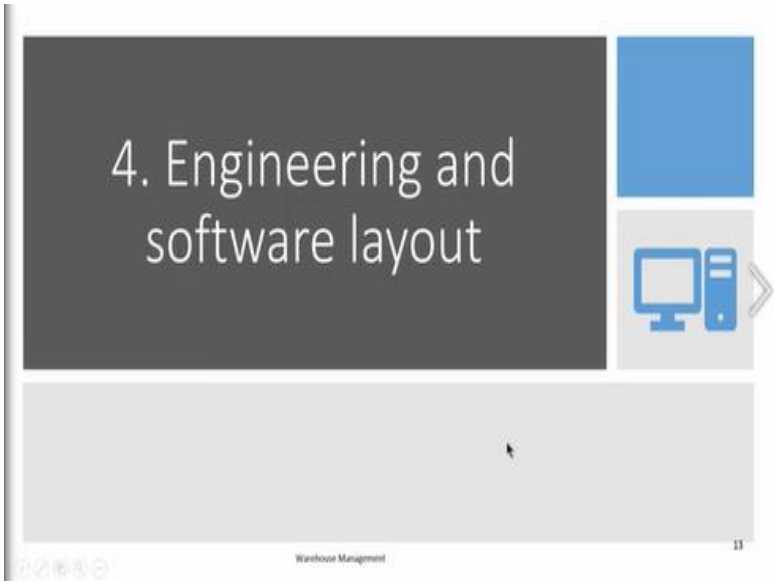

Then it comes to engineering and software layout.

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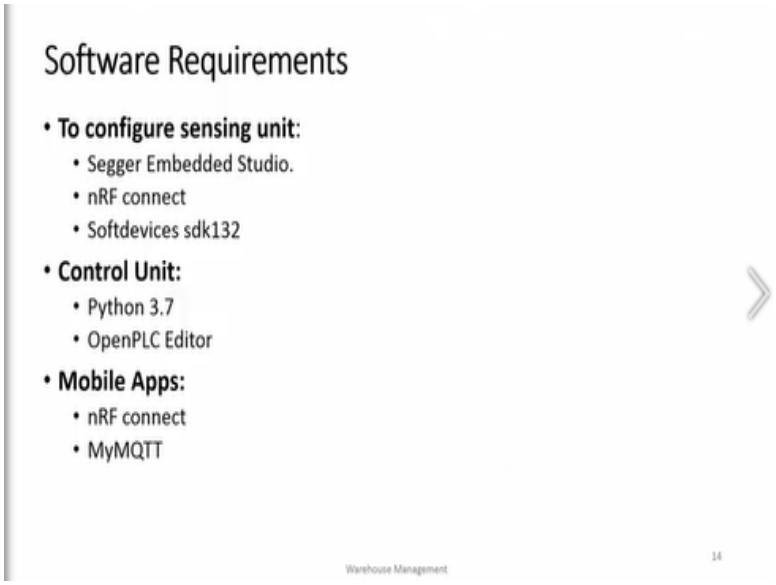

So, what did they use? They use Segger embedded studio, they use nRF connect, simple app. The soft device that they ran from nRF is SDK132. Control unit is essentially python 3.7 and also the open PLC editor which is coming from the open PLC system. So, there is a editor, you can use that. Then there are mobile apps you can either use nRF connect which comes along with the chips that you buy, the components that you buy.

You can download from either google play or one of them and use nRF connect. You can upload the data to cloud using MyMQTT. So, both are possible here.

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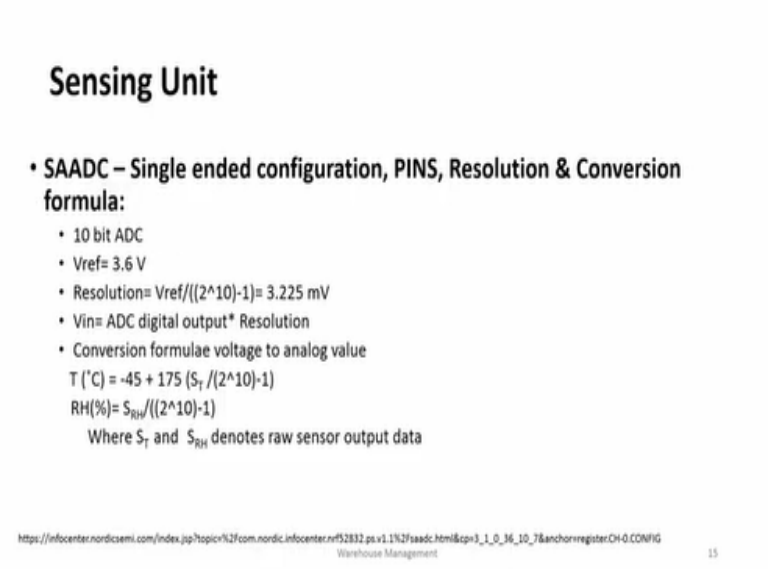

Now here is a nice thing. All that we studied in the previous class is also mentioned here. This is about the sensing unit, they chose a 10 bit ADC, V ref is 3.6 resolution they now know and quickly that it is V ref divided by 2 power n which will give you a minus one of course which will give you 3.225 millivolts. Now V in is ADC digital output into the resolution which is again very straight forward and there is a conversion for voltage to analogue value.

This is coming directly from the data sheet and this is important. Do not ever hesitate to look up the data sheet of the system. It will tell you what is it that it corresponds to as far as temperature is concerned. If you read a voltage, how do you substitute and how do you convert that is given here this expression. It is not our expression; it is from the manufacturer. Similarly relative

humidity there is an expression for it. You can choose this expression and then this is programmable peripheral interconnect.

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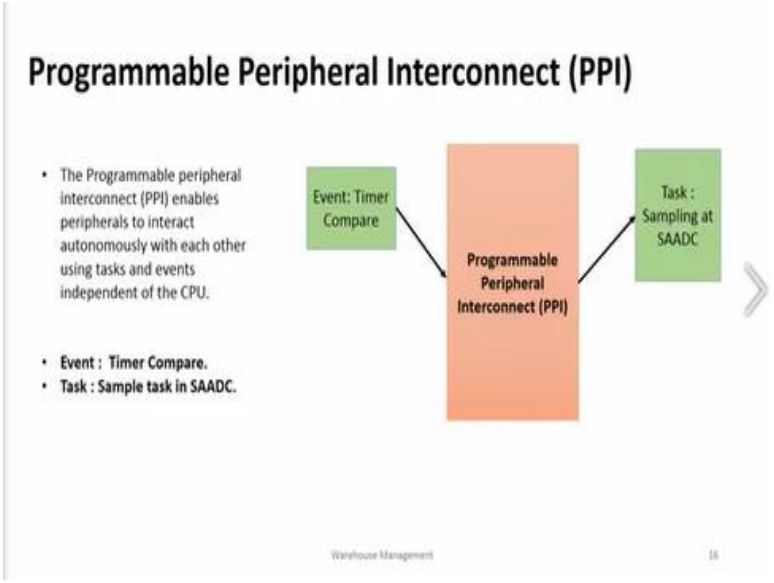

It is called PPI without disrupting the CPU, the CPU can continue to be sleeping. You can have even timers which will trigger periodically and go and acquire the data from the ADC and store the value and then go and interrupt the CPU. All of that you can do with programmable peripheral interconnect and that is shown here.

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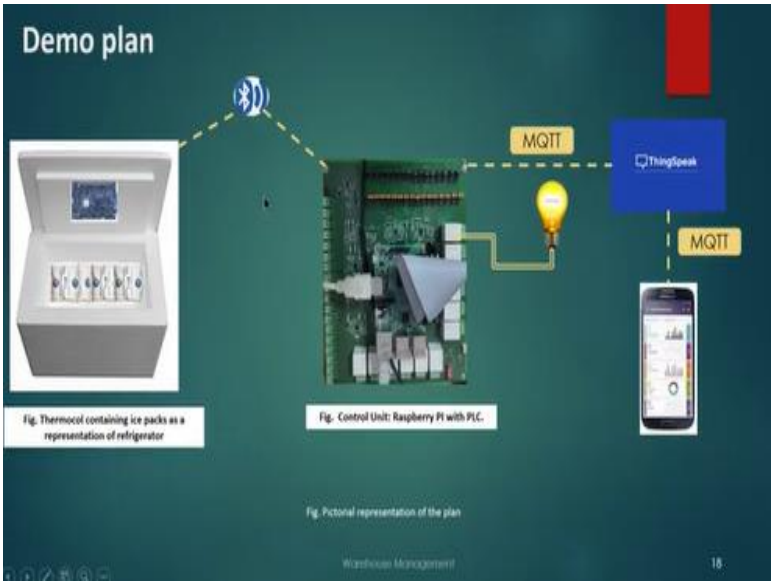

Now here is the demo plan. You can see that they have a thermocol enclosure for this is equivalent of their warehouse. They divide this thermocol enclosure into several zones and show a demonstration of a single zone. And the one in the middle is the Raspberry Pi with open PLC, then they communicate this data to the cloud using MQTT protocol, we will come to that as we cover that in the course.

And things speak is the service available on the cloud and from that you can use again MQTT to build your application of interest.

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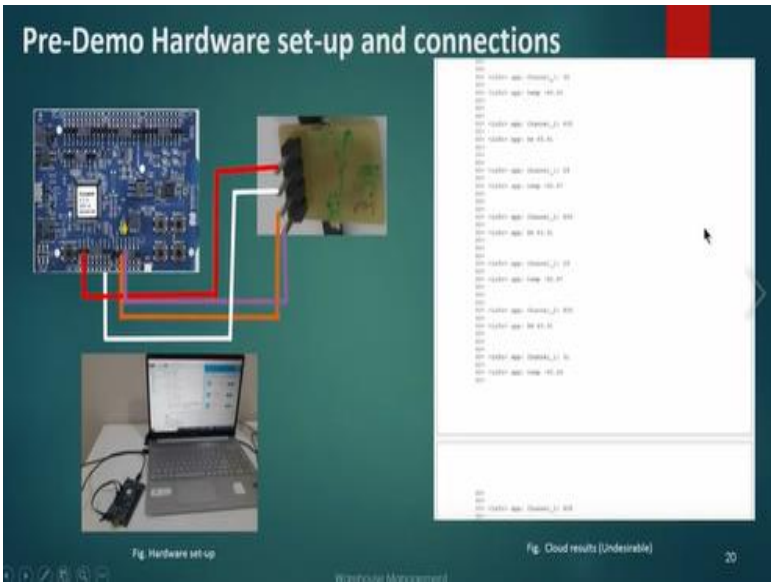

So, here is a final demo. Before we go on you can see that pre-demo hardware setup and connections are shown here. Extreme right is the serial port connection which you can use with PUTTY serial monitor which is you basically an SSH application and that is what is seen Nordic controller. Nordic controller SSH if you do with PUTTY, you will be able to get the data directly from the Nordic controller.

You can see that you have temperature, you have relative humidity, temperature, relative humidity and so on. It is all coming to you from different ADC channels which are being read. So, that is this part.

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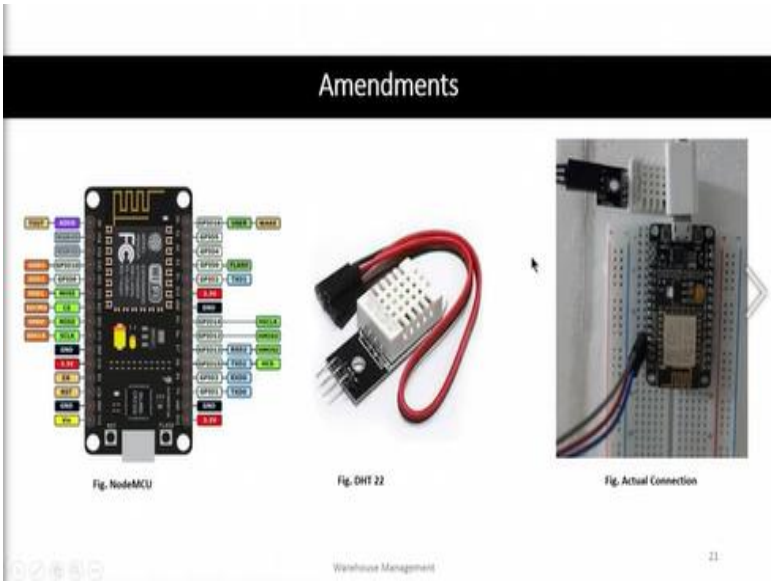

And you could also not necessary to use only those sensors and that microcontroller. You can also open up a little bit and see if you can try other type of sensors and controllers and that is what they the students actually tried. They used instead of Nordic 532 they used node MCU as their controller, they use DHT 22 as the sensor of interest and the actual connection is actually shown here.

So, before we do anything further what is also important is to look up the data sheets of these two sensors. So, let us look up the data sheet.

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You have SHT31 here. This is from a company called Sensirion, this is giving you humidity and temperature sensor. Students definitely tried this out as one option and then they shifted to the other option which we will come to very soon. So, it has a wide supply range, it will tell you that typical accuracy is plus minus 2% of relative humidity and temperature is 0.3 degree Celsius. Hopefully this is sufficient for your application as well.

So, this is important, so you have to note whether this is satisfies your requirement or not is very, very important.

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You can see that it gives you relative humidity and temperature as an output and the remaining parameters are out here. Humidity sensor specification is mentioned, temperature sensor specification is mentioned. So, characterization results are also shown here for SHT31. So, one can go and read up, look up these data sheets and understand them in extreme detail, this is very important. So, I am pointing you to the data sheet but I expect you to read them in detail.

Similarly, you have DHT11 humidity and temperature sensor, it looks like this. These are its specifications and these are the detailed specifications. Please do spend time understanding these data sheet parameters. How to interface a DHT11 is also mentioned here. Typical application and the timing related information is also mentioned. So, given these two data sheets now let us go back, look at what they did.

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They also tried as I mentioned DHT22 which is something which can be interfaced easily to node MCU.

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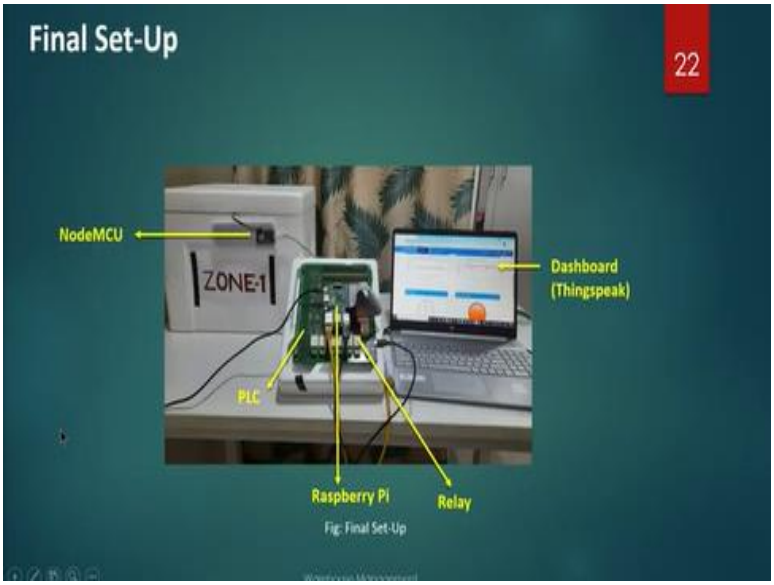

And here is the final setup that they show. You can see that they have tried this for zone 1 and this is something very interesting you see that they did not mount the node MCU inside. The reason is what you see is a bare PCB. And if the humidity is very high it is possible that the PCB may go bad. So, you have to protect with some way some porting or something you have to do. Before you actually place it inside which is a clear learning item; for you that given the time that is available in front of the student.

The student did not venture to put it inside, because it is of a bare PCB that you see there. So, that is one thing. What you see in the middle is the open PLC hardware? And what you see on the right side is a nice dashboard out there which goes to the cloud over a protocol, MQTT protocol which is a very popular IoT protocol. And you can see that both the temperature as well as humidity is displayed.

What also this picture shows is a relay? The relay ON is actually shown here with this little small light indicator saying that if there is a fall in temperature you have to switch on the heater, so that the temperature comes back. If there is a fall in humidity you may want to increase the humidity. So, all of that will have to be done by this PLC controller for a particular zone as required by the standard requirement of maintaining these two important parameters.

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You can see that this is the setup of the video. What you see on the right side top is the temperature and bottom is the relative humidity and the whole system is shown here which will allow you to see the demonstration. So, you can see that. So, there you go, it is displaying the data values. Humidity and also temperature both of them are shown and you see the operation of the open PLC for zone one. Students are checking everything if everything is in order.

And what you see on the right side is a live data. What you see right on the right side is the live data of this particular zone. The node MCU for which this demo is actually placed outside. Because it has not been protected against harsh environment inside, temperature is low then there is humidity and all that. What you see are ice boxes inside that will maintain a lower temperature, it is a thermocol box and the sensor itself is placed inside. So, that it can measure the temperature as well as the humidity.

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So, that is the demo for you, you can see that this is the open PLC editor script which essentially is a small script to control the humidity as well as the temperature. This script is for controlling the humidity and this uses the PLC, open PLC and it is just a simple language to code the PLC controller.

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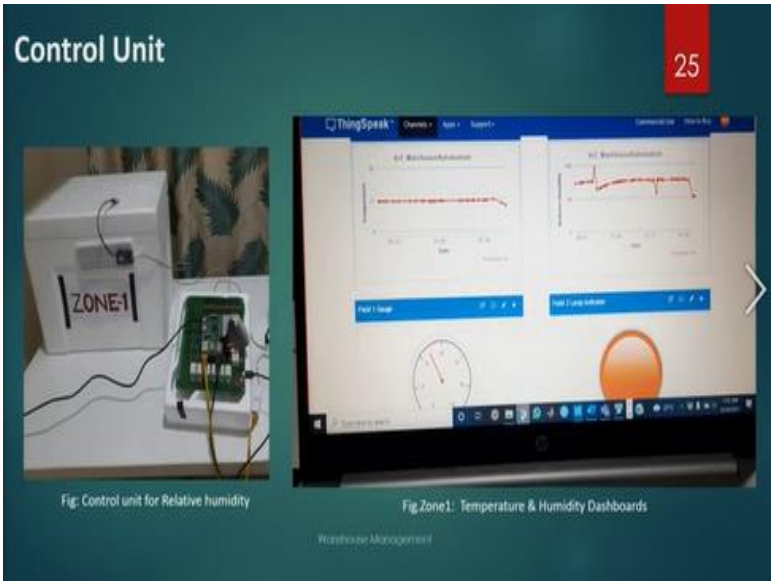

What you see is the control unit for zone 1 and you see, you get a beautiful dashboard which is cloud based and what you see on the left side is temperature and on the right side is relative humidity. You can have different types of dashboard items, you can have a dial, you can have lamp indicators and so on. So, this is an example that you can do all of this on things peak.

(Video Starts: 27:57)

So, you can see that is also a smaller video here. You can see that this is the open PLC, starting of the open PLC so that zone 1 can maintain its temperature. Now it is running, you see this is the simple code which has been written and temperature & humidity dashboards. T,his is the Modbus protocol which is monitoring the chamber inside and uploading the data.

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So, that is it we have demonstration of this simple sensor and actuator system. If you look at the broad picture you will see that the market size for IoT in agriculture was is this value which is pretty staggering, it is little over 16000 million dollars in 2017 and it is expected to grow like anything to 48 over 48000 million dollars by 2025. So, there is a potential for smart agriculture particularly warehouse monitoring for agriculture produce.

It is very nice use case of sensing and actuation. So, proper warehouse or warehousing of agriculture produce is inevitable for an efficient supply chain and you can apply IoT to precision farming, smart greenhouse, agriculture drones which can do inspection, you can do for climate conditions, you can do dot lot of things related to data analytics and so on. Here is what is a nice capsule folks; do your survey of warehouse before you actually start implementing anything as a mini project as part of this course.

So, again folks very important please note that power management, lifetime of this monitoring system is important. Therefore, power management technology or the controller of interest is important.

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You must look at the radio chips low power modes. You must look at the modem, you must see when the CPU is on, when you can use a DMA and when you should switch off wireless links and wireless radios. All of this will have to be borne in mind, the size of the complete IoT node is important. So, you cannot, you have to look at what kind of coin cell battery you want to choose and all the alternative arrangement for user receiving alarms over phone messages the whole range of software will have to be also chosen.

So, folks this is a full application of sensing an actuation which you can put together and build your own mini project after going through these modules. The steps are very important folks, the tables that you create, the comparisons that you do, the battery life calculations that you do, the application you write and testing your application thoroughly in labs before you put it out as a solution, the packaging that is required for these IoT nodes.

Given that you are going to put it in temperature and humidity controlled environments, all of this will have to be borne in your mind before you actually put a good IoT application in mind.

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In IoT there is absolute blurring of real and virtual systems.

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As you also recall the definition of IoT we said physical objects and virtual objects. Now here is a demonstration of what virtual actuation is all about. Here is a real cylinder what you see in front of you is a real cylinder. Now supposing you switch on your camera of your mobile phone and go close to the cylinder and there is an intelligent app running on that phone. Just imagine the kind of actuation signals that system is going to give you for safety operation of the cylinder.

(Video Starts: 32:18)

So, let us start the demo and I will show you a few things. Look at the first thing. Let me pause here look at the first thing, it is telling me, you go close to it is reading out the label and pulling out the most important aspect of it, asking you to check the specification of the cylinder in great detail. And it also has intelligence to read the specification itself to give you certain instructions that is also built into the app. Let us move on.

The next step is these are some safety features which it has already picked. It is advising you in other words the actuation done by the human is being prompted by this system here. Now let me pause here. If you look carefully there is a requirement of closing that knob there which is essentially a control gas pressure valve. You have to rotate it in which direction is also mentioned there it is in the clockwise direction and a spanner is thrown there.

If you see carefully there is a spanner thrown there. Well, that spanner is not a real spanner it is a virtual spanner given to the human the direction of rotation is actually supposed to be a half revolution of that spanner. The actual video demonstration is also done on the same mobile phone and you can see that is on top there. So, all this is the human is in front of a real system, he is holding on to a mobile phone. And what he is seeing on the mobile phone screen is all this.

On one end he sees a small video, on the other side he sees the steps in which he has to operate for safety of the cylinder and the kind of prompts the kind of actuation signals that he is getting is exactly what you see there. Let us move on. You see that the spanner is moving half and the rotation of the knob is also shown. As long as the human hand is close to that knob it continues to show that spanner as well as the rotation of the control gas pressure system.

So, then if you move on from here, you have to rotate the cylinder cover one revolution by hand. What you see on the extreme right small indented video is the actual video of a demonstration. And what you see in this synthetic knob that you see there are cylinder cover which you see on top is actually that is a synthetic one and the cylinder indeed is the real one. So, all of this is creating a sort of a maya situation for you, I am sure.

But that is essentially what actuation is all about helping, assisting you to do things in a safe manner and believe me operating hydrogen and other inflammable gases is a very tricky business. Even if you are unskilled, you will be able to operate these systems quite reliably. So, this is the next part of the video. Now going on there is this other part which is the plunger. You have to attach a plunger to this cylinder here.

And what you see on the extreme small picture and what it is actually showing you is on a real cylinder, where you are actually in front of it. It is attaching this virtual plunger system to you and showing you the direction in which you should attach that plunger. So, that is what you are seeing in terms of actuation, virtual actuation of the system. So, using these queues where on one side you have a video of what you should do.

And the other part actually trying to sort of juxtapose the requirement for you on to the real system. You should be able to apply these actuation signals which you are getting in a very effective manner. So, next step is the operation related to you know, applying some gauge sticks here and you have to check for leakage. So, you can see that this is telling you something very interesting. The real cylinder is out there, the arrows that you see are out there which are virtual again.

And then the video down below is a video being played also on your mobile phone and now it expects you to check for leakage. So, that is essentially the next step for the human use. You can see that the human is using some object to check for leakage and it expects that the human who is trying to check for leakage on this real cylinder is expected to do exactly the same thing. Moving on, we see that there are other requirements for from a safety perspective and the prompts and actuation signals that come to us.

You can see that this is another cylinder and the operation of the wrench is shown to you. There is a real cylinder, operation of the wrench is virtual, the nut out there which has to be open with the wrench is actually virtual but nicely positioned against the real one. So, that you know exactly in what direction to rotate and you also see a video of the same at the same time. So, you can see that, it says that attach gauge tightening wrench in a proper manner and so on.

So, this is a demo which will perhaps help you to understand what actuation actually means in today's world need not be real actuation that you know very well in terms of either a solenoid valve or let us say relays switching on and switching off or different types of physical systems that are actuated in everyday life for instance. Let us say a washroom door opens and closes by itself or your office door opens all by itself moment it sees that, it senses that there is a human and then closes the door soon after the human leaves.

All these are physical systems, physical actuations. You can also be talking about virtual actuations and this is a classic example of what you people can actually build right with simple open source tools. So, here is another demonstration of attaching an additional pipe to this system for perhaps filling from one cylinder to the another cylinder and that demonstration is also shown here.

So, in all I am sure you have enjoyed this demo and you get a feel of what actuation is all about which need not be restricted to physical actuation. There can be also this virtual actuation.

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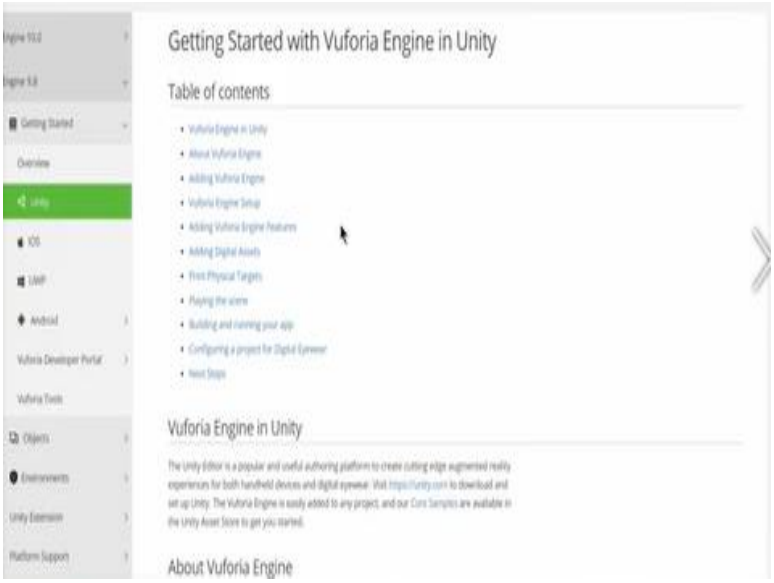

While you have seen the demonstration of this you may be also curious to know how to build one such application yourself. For that I would suggest that you look up this Vuforia engine in

unity. Look up Vuforia, look up Vuforia engine in unity and also look up unity which is essentially an unreal engine as they call. You can look up these engines and you can create the augmented reality applications. What we have shown you is actually augmented reality; it is not real.

It is augmented with what is real with all these virtual reality images and video that we have shown you. So, it is more augmented reality. And how can you build augmented reality applications? One is to use VR glasses as they call or you can also use mobile phone systems where there is a camera that itself can sort of juxtapose, the real world with the virtual world and it can show you whatever I have shown you in terms of demonstrations.

So, this is at best what we can tell you, because this is a topic which may not be in direct line with the course. But yet it is important to drive home the point that as far as actuation is concerned things can also be in the virtual world. Thank you very much.