Introduction to Internet of Things

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Lecture – 58
Case Study: Healthcare

Now, we are going to cover some case studies particularly focusing on healthcare, so the use of IoT for healthcare. So, we have seen in the previous lectures in the different modules that we have covered so far in this course that different types of sensors are possible and these sensors can help in sensing whatever they are supposed to sense. So, in the context of healthcare there are different sensors that have been fabricated that has that have been developed to monitor the physiological condition of human beings. So, for example, there can be body temperature sensor which can measure exactly what a normal temperature normal thermometer does, there can be blood pressure sensor which can measure the blood pressure of human being. There can be likewise different other types of sensors for example, pulse oximeter sensor, ECG sensor, EMG sensor and many other different types of sensors.

So, in the IoT sphere these different sensors which have been developed individually by different companies different research labs and so on they can be used to build the sensor nodes and we have in a previous lecture we have already gone through what are the different components of a sensor node. So, sensor is one of the one of those components likewise there are different other components there is a processing unit that is required there is a communication unit there is a power unit and so on.

So, all these different units put together is basically a sensor node and the sensor node can sends the physiological parameter based on the sensor that is fixed with that particular node. And likewise in the human body there could be different sensors which can be basically you know sense sensing the different physical physiological phenomena and sending to the sensor node either singly or different sensor nodes together they can be sending different data to one particular one particular such node and from that node the data can be sent elsewhere for further processing and so on.

So, what we have? We have number one the sensing number two is the communication of the sense data to somewhere and then from that place the data either has to be you

know it has to be processed locally or it has to be sent somewhere else for better processing for faster processing and dissemination of the results of the processing. So, this is exactly what is typically done in most of the IoT healthcare solutions. So, in this particular lecture I am going to cover what are the different IoT healthcare sensors that are there and how these can be used to build different systems that can help in continuous real-time with remote monitoring of patients which is taken up as a specific case study and this is the system which is known as the AmbuSens system that we have developed in our lab in the (Refer Time: 03:53) lab of IIT Kharagpur and so in the little part we are going to talk about what this particular system does and some of the important salient features of this particular system, AmbuSens system.

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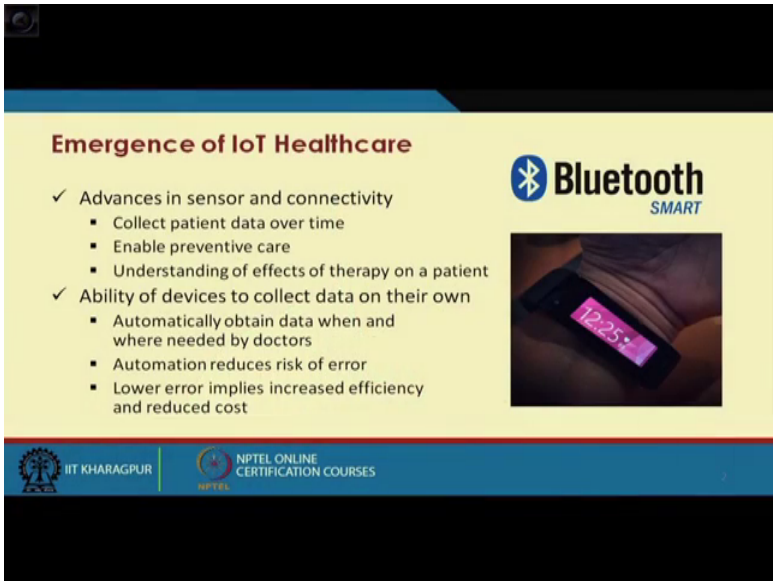

So, you know when we talk about the sensors the sensors in the context of health care the sensors they can collect the patient data over time and I have already mentioned what kind of data. So, these data could measure blood pressure or body temperature or you know oxygen saturation in the blood and so on and so forth. So, this data is collected and this data can be analyzed further either locally or remotely for you know for different purposes for example, to enable preventive care. So, you know preventive care means like you know you collect a data over time and based on that you try to understand that whether there is a critical element that is going to come in the future for that particular patient so this is number one.

Number two is that if a particular patient is in the hospital for instance then that patient you know is typically you know it is the patient is under different types of medications and the patient is fitted with different types of devices and so on. So, understanding the effects of the therapy, therapy that is being you know subjected to that particular patient, the effects of the cell therapy on the patient. So, this is another advantage of using the sensors. And connectivity basically what it does is the connectivity will allow these sense data to be sent remotely for remote processing decision making and so on.

Now, that the devices they have different types of ability to collect data they can you know they can either automatically obtain the data and the data can be sent to doctors you know then and there itself or it can be the data can be stored in some server or something like that where then will be some kind of analytics that will be run that will be executed. And based on the analytics if somebody in if a patient is likely to get some serious condition then the corresponding doctor is going to be notified. So, as you can understand that by automating these things with the help of sensors and connectivity what we are trying to do is number one we are trying to reduce the manual intervention; that means, the attention of the doctors continuously.

Second thing is the chances of error the risks of errors occurring also get reduced because automation inherently basically reduces the chances of error and that overall you know these things would overall increase the efficiency while reducing the cost of operation cost of you know maintenance and operation of a of healthcare system.

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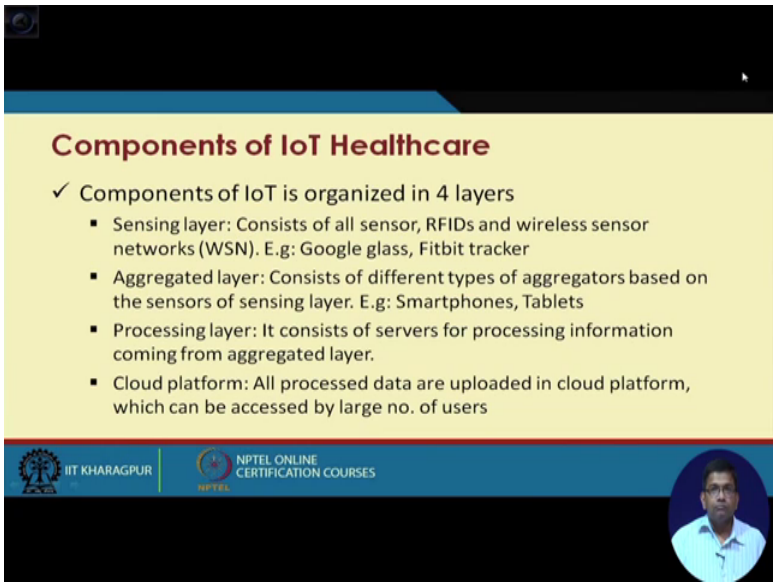

So, there are different components of IoT healthcare. So, I already mentioned that you know there has to be sensors the physiological sensors. So, these sensors are part of the sensing layer and the sensors you know they could consists of all these different types of sensors that I mentioned the RFIDs you know sensor networks and so on and Google glass and fitbit tracker these are some of these different devices that execute in the sensing layer.

Then you have the aggregated layer which basically you know aggregates the data that are received from the sensors of the sensing layer and this data aggregators could be things like you know smart phones or tablets and so on. So, what these data aggregated does is from the different parts of the human body the different sensed data that are obtained these are basically connected and these are you know these are put together and you know and instead of sending the individual data together you know reduced number of data are sent forward from that particular aggregator node. So, then you have the sensing layer the aggregator layer and then we have the processing layer where basically the processing layer and the cloud platform these are responsible for the storing of the data and the processing of the data that have been collected and analyzing further that you know what action should be taken based on the received data.

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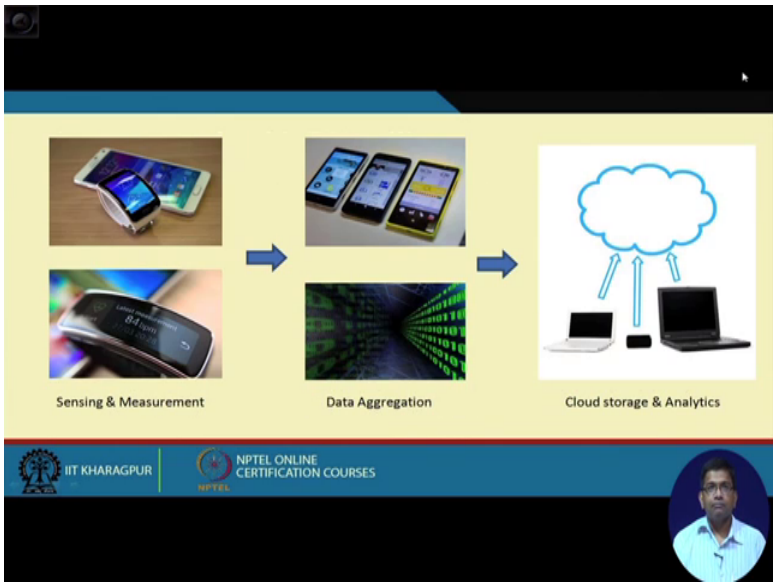

So, we have these different types of sensors as part of the sensing and measurement. So, you have these different sensors the smart watch and blood pressure sensor and so on which would sense and measure the physiological conditions data are sent to these different aggregator nodes you know which could be like these different PDS or you know mobile phones, smartphones and so on. And from the data aggregator the data are sent further from the aggregator by the way this segregator is also known as the LPU sometimes the; that means, the local processing unit. So, typically if you are talking about a human body the body area network. So, typically in a body area network you have a single LPU which receives the sensor data from the different parts of the body.

So, every human being has that LPU which is a smartphone or a tab or something of that sort and that particular device connects receives all these data and this data is further processed in the cloud and in the different servers. And based on that you know different decision making can be made and based on the decisions the corresponding stakeholders could be informed about what is happening with the patient if it is required.

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So, there are different directions of research in IoT healthcare number one is remote health care and this is where we have done a little bit of work in our lab and so what happened says you have the all these different sensors the blood pressure monitor sensor the temperature sensor and so on which typically are developed by different vendors different companies. So, what happens is you know at the same time remotely with the help of the sensors the doctors and the paramedics you know they can the healthcare professionals in general they can monitor the condition of different patients in a large scale you know in numbers they can monitor the different patients even remotely. So, that is the remote health care.

So, this wireless IoT different solutions being health care to patients rather than bring the patients to the health care. So, typically you know earlier what is used to happen or the in the traditional healthcare the patient should have to go through the healthcare facilities like hospitals or the nursing homes and so on. And in the IoT based health care what happens is all these different medical devices they are portable they are wearable and so on. So, they can be the human beings the patients they can wear and only thing that has to be done is that somehow this data from this wearable sensors have to be sent to the corresponding medical professionals for example, your personal doctor you know the family doctor and so on who you know if it is required you know the doctor would intervene further maybe because of some serious condition going on in the patient and so on.

So, securely in this sort of systems would capture a variety of medical data through IoT based sensors analyze the data with different smart algorithms and this wirelessly this data that is obtained from this different sensors are sent wirelessly to different medical professionals for the recommendation.

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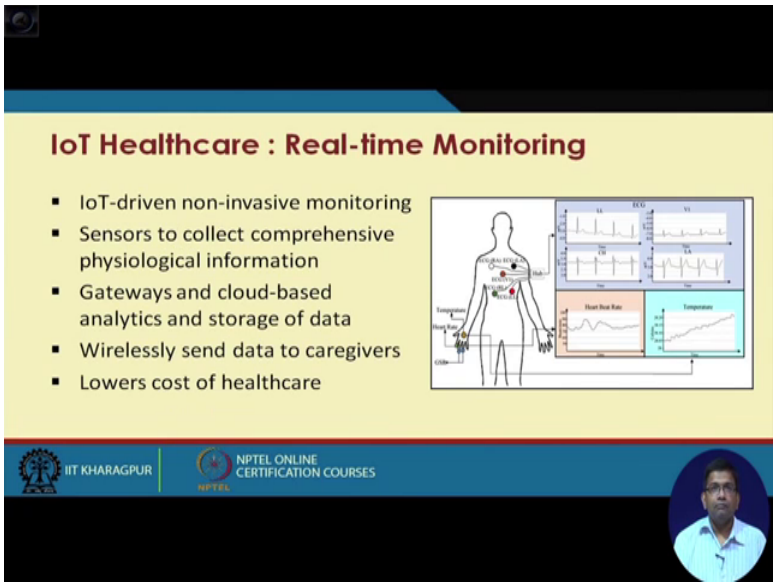

Real-time monitoring is possible as a result of the use of the different sensors this biomedical this you know physiological sensors real-time monitoring is possible. So, earlier what is to happening is that if you need to monitor you know if you need to know how much is your blood pressure you would have to go to the hospital and get your blood pressure measured or even if you have a blood pressure measurement device at home you know typically what happens is you do not measure it all the time right.

So, in the case of this kind of system where there are different sensors the blood pressure sensor you know the blood pressure sensor would be you know with the help of the sensors it will be possible to monitor the condition of the patients in real-time round the clock it is possible. But then you know it depends on the implementation policies and so on that how often this measurement is going to be done based on the requirements of the stakeholders. The sensors are used to collect comprehensing physiological data then that this data are sent to the cloud through the gateways for further analysis and storage rather storage analysis.

So, wirelessly this systems would send the data to the caregivers and thereby overall the system as a whole would reduce or would lower the cost of healthcare. So, this is the schematic of you know how such a system would work you have these different sensors these different heterogeneous sensors you know denoted by different colours. So, these sensors would sends and send the data and that those data would be made available to the remote doctors and the doctors can monitor in real-time how much how with the heart rate is varying for a particular patient or how the body temperature is varying and so on.

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And the next advantage is of preventive care. So, in preventive care what you need to do is you know you have some of this target group of patients treated with different physiological sensors and for instance in the case of seniors senior citizens who do not have any caregiver at home they could be fitted with different sensors and one of the common problems with this senior people is that you know they often fall down right.

So, fall detection is an important problem and this fall detection is part of this preventive health care and so what happens is if there is an emergency situation that occurs and the detection of this emergency situation and alerting the family members under those situations. For example, the senior citizen has fallen down at home. So, if there is a proper system IoT healthcare system in place then the corresponding people in the person's family or the different relatives they could be they could be informed about this particular event; that means, the falling of the person.

Then there are different interesting tools from machine learning that that could be used to track the trend and to predict what is going to happen in the future for example, if there is any anomaly detection of the anomaly and how this anomaly is varying with time and what can be done in the future to prevent. So, all these things are possible with the layer with the help of different machine learning tools. So, now, we come to the AmbuSens system and as I already told you initially this AmbuSens system has been developed by us and it was actually funded by a joint project supported by IIT Kharagpur and majority through funds from majority government of India.

And, so this in this project we have developed a system which can help in remote monitoring remote continuous monitoring of patients in ambulances when they are transferred from remote health care centers to city hospitals you know which is a very typical kind of scenario that happens in the case are in a for health care in our country and we have developed a system for that and Neeloy Saha he is going to explain to you about the different functionalities of the system how it works how it has been built what are the different challenges and so on.

And thereafter we are going to go through simulation which will an animation sorry an animation which will which will show you how IoT healthcare solutions can be deployed in order to give better healthcare to the different citizens of a country.

Hi, I am Neeloy Saha a research scholar under doctor Sudip Misra and I will discuss about the different facets of the AmbuSens system. The AmbuSens project mainly aims at addressing the shortcomings of the existing healthcare infrastructure in our country with a particular focus on ambulatory healthcare using the communication and the sensing technologies of the internet of things.

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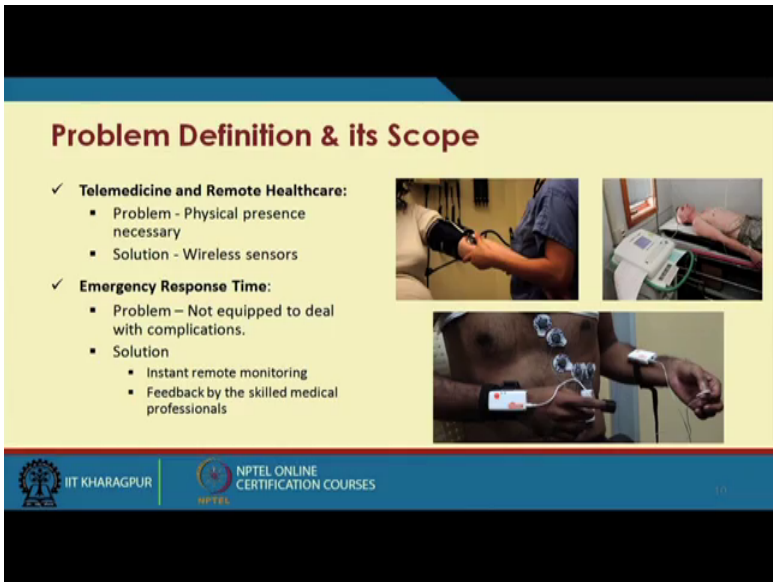

One of the main problems of the existing healthcare system is that it is more of a manual operating system that is it requires the physical presence of the patient at the health care centers. So, using the variable sensing technologies and the wireless sensors which are often small in size and variable, using the AmbuSens project we attempt to bring the healthcare closer to the patients.

Another problem that is existing in the traditional healthcare is and that is especially pronounce in the case of ambulatory healthcare is that of emergency response type. Often times the medical personnel or the technicians who accompany the patients in the ambulance are not well equipped to deal with any complications that may arise that is because they do not have the technical expertise to deal with such complications. Using the AmbuSens projects and its instant real-time monitoring capabilities we have the provision for remote feedback and monitoring by the skilled personnels at some remote place and this significantly can help in dealing with such complicated complication and such problems that may arise during transit in an ambulance.

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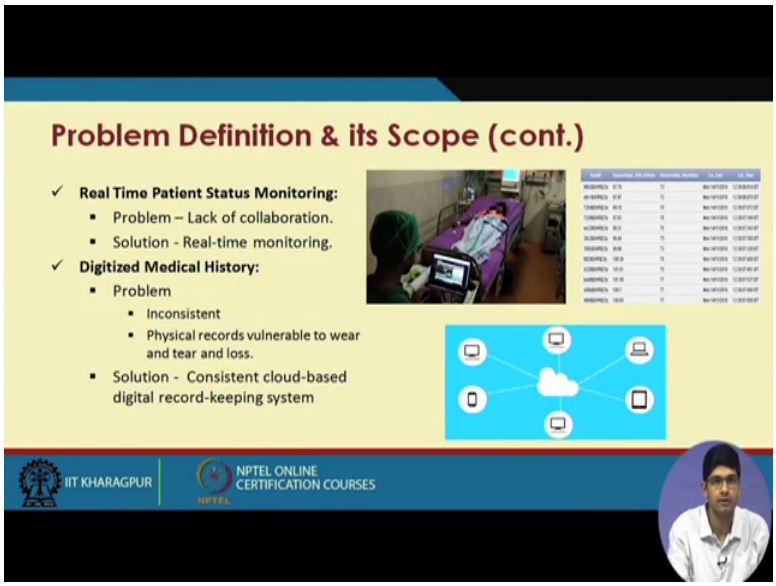

Another problem that often arises is that of real-time monitoring; for example, let us consider a case in which a patient is transferred using an ambulance from a primary or secondary care hospitals in some town or rural area to a specialized clinic in the city. So, while the patient is actually going from the town to the city in the ambulance the condition of the patient is not monitored at all. This may lead to some problems such as the patient condition may degrade over time and when the patient actually reaches the destination hospital the doctors they are may not be equipped to deal with that condition.

So, using the real-time monitoring we can or the AmbuSens system we can track the dynamic changes of the patient's condition over time and this can significantly reduce the latency of the medical care. The existing system traditional healthcare also requires each patient to carry his or her own medical records with him whenever he visits the healthcare facilities, but these physical records are vulnerable to physical laws wear and tear. So, the AmbuSens project also incorporates a cloud based digital record keeping system to deal with these kind of challenges.

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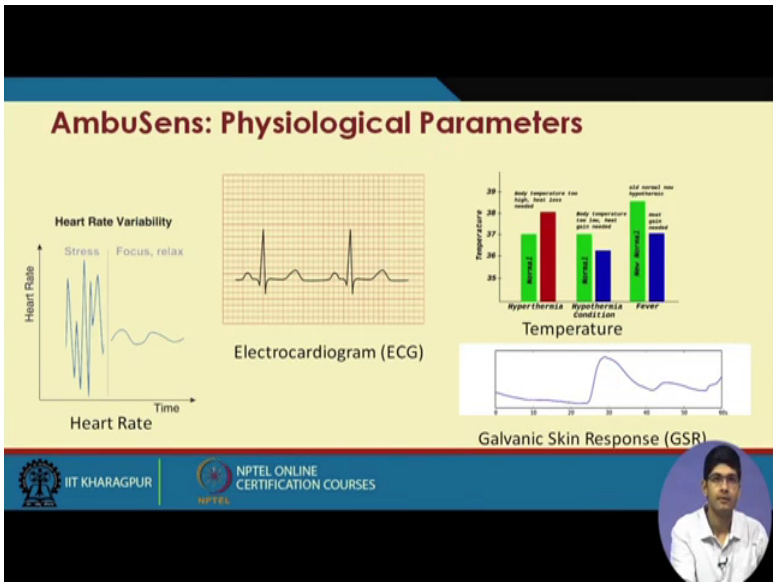

The AmbuSens project incorporates different IoT based sensing technologies and is capable of monitoring different health parameters some of the parameters monitored are heart rate electrocardiogram, temperature, galvanic, skin response etcetera. The exact parameters which are monitored depend are often dependent upon the particular application scenario for example, if we consider the case of a patient having some cardiac disease the electrocardiogram or ECG will be of primary importance. Also in a pediatric case the temperature of an plays a vital role.

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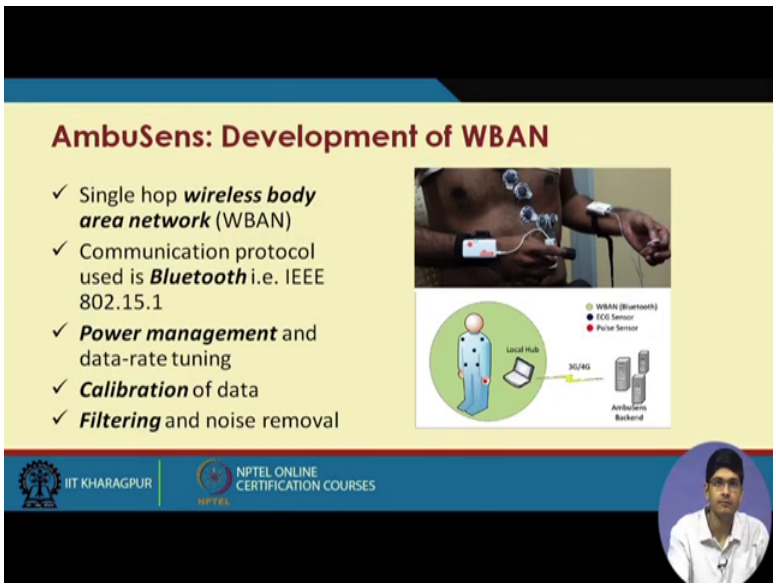

The sensing layer of the AmbuSens project consists of different wireless sensors which sample the physiological data coming from the patient and using internet of things communication technologies such as Bluetooth, Zigbee among others the data is sent to a local herb or a local data processing unit where the data is aggregated and sent further for processing.

Now, the challenges that we faced in the aggregation layer include power management data rate tuning and noise data rate tuning is a challenge because it is often times related to power management for example, and also data fidelity for example, when dealing with electrocardiogram or ECG data we found that minimum sampling rate of 1024 herds what was needed to preserve the fidelity of the ECG data. Noise is a important parameter that must be taken into account at the sensing layer especially never scenario where we are dealing with the mobility of a patient often times due to the movement and the jerking of the ambulance the thinners that we are receiving corrupted in the presence of noise.

So, we implemented different kinds of filtering algorithms in the local data processing unit to obtain a clean noise free signal.

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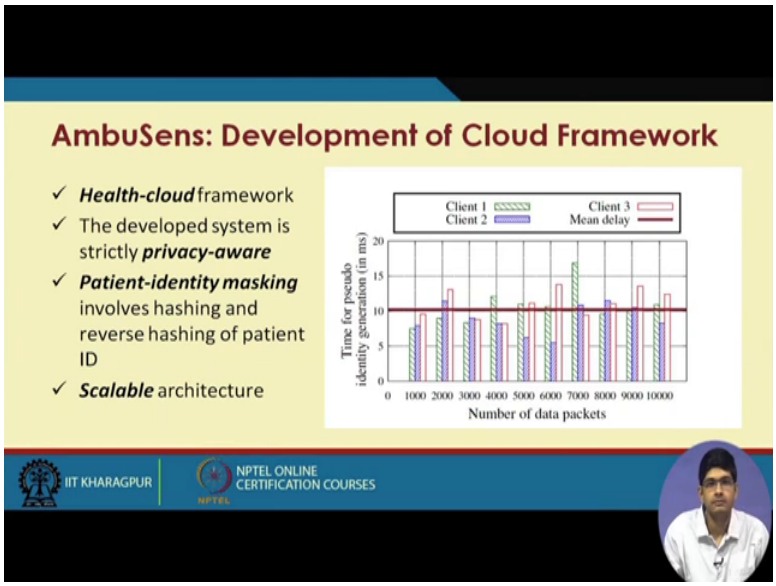

The AmbuSens project also leverages the power of cloud computing for storage and analytics, but here the challenge is that we are dealing with medical data which is often of a sensitive nature for a privacy stand point. The cloud computing and storage is often

vulnerable to compromise of a patients identity. So, here we have developed a health card framework which is totally privacy aware.

The AmbuSens system incorporates a novel identity masking module which suppresses the part of a patient's identity before sending it to the cloud so that cloud computation and analytics can be carried out on a incomplete data set clear by preserving the patients identity.

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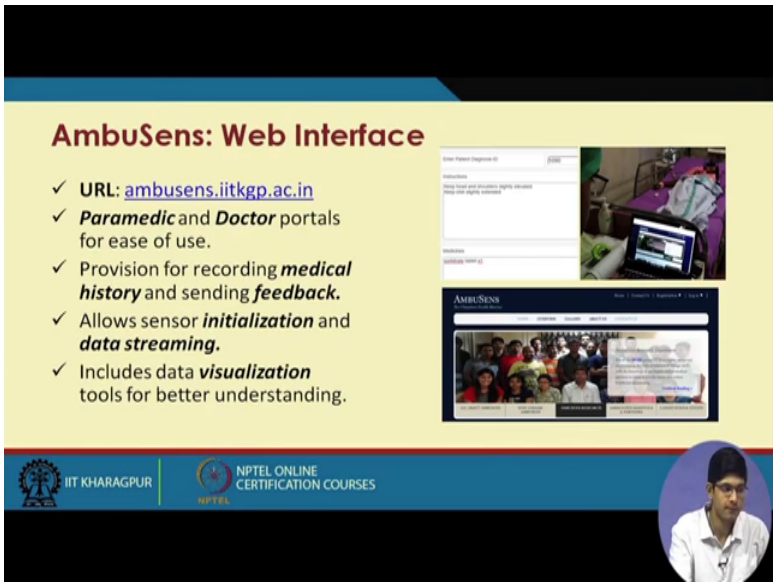

As is evident from this figure as we increase the number of clients the mean delay remains constant thus leading credence to the scalability of the system. The AmbuSens project also incorporates a web based interface for doctors and paramedics for using the different functionalities of the system. Functionalities may include features such as we have developed provisions for recording the medical data we have developed a feedback system so that doctors can give their feedback and their skills skilled expertise to the paramedics who were travelling in the ambulance, also it includes advanced data visualization graphing tools for better understanding of the data it also helps in sporting patterns and trends in the real life data streams that are coming.

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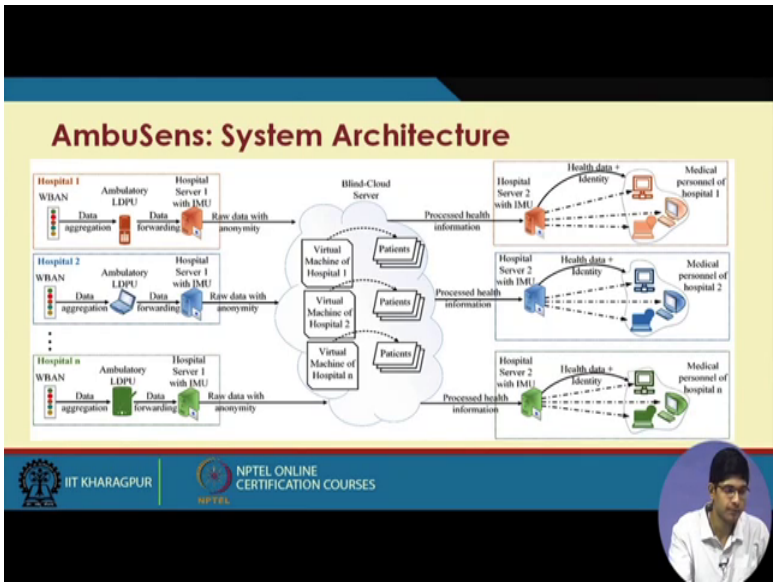

Now, as I have already explained the different modules of the AmbuSens system work together to achieve real-time monitoring. Here first we have the wireless body area networks which are formed by parallel sensing devices which capture the medical data the health parameters which indicate the condition of the patient and using communication technologies such as Bluetooth and Zigbee.

The data is sent to a local data processing unit where it is aggregated and filtering algorithms and (Refer Time: 25:56) techniques may be used and further using communication technology cellular technology such as LT or wireless land technologies such as IEEE 802.11. We forward the data to a server hospital server which contains a identity masking unit which suppresses the part of the patients identity as discussed. And the raw data is now anonymous and before it is sent to the cloud the data in the cloud apart from being anonymous with respect to a patient's identity also is stored in different virtual machines which are unique for each hospital thus extending the isolation between the data and preserving the privacy further.

The data is stored in the cloud and analytics may also be carried out and on demand that process held data is sent to a second server at the hospital where we have the reverse identity masking unit identity management unit which helps in getting back the original data set complete data set and from there the paramedics the doctors and all the

caregivers who are authorized to access the data can view the data through the web interface in graphical format for analysis and prognosis.

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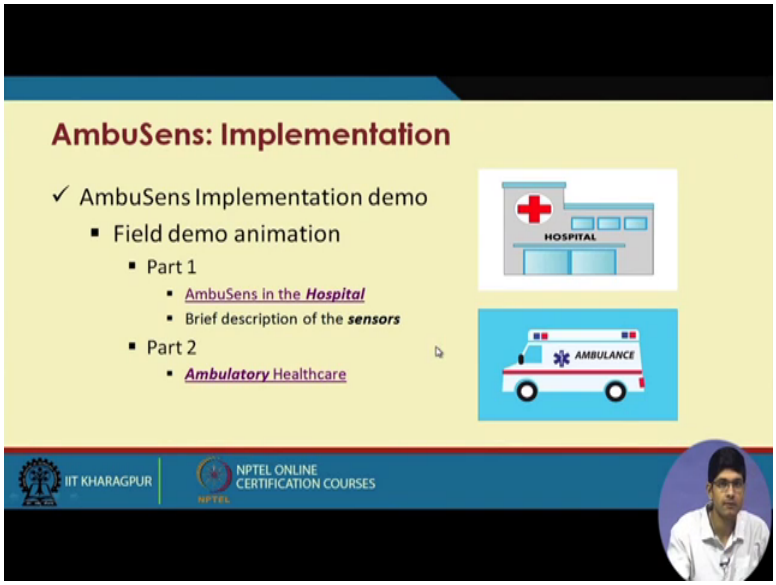

Now we come to an implementation and demonstration of the AmbuSens system. Unfortunately due to privacy concerns we cannot actually show you the use of the AmbuSens system on a real patient instead we will prevent an animation which shows the use of at the AmbuSens system into different scenarios. Part one details the use of the system in a static hospital scenario and it also includes a brief description of the sensors. Part two includes the use of the AmbuSens system in a typical ambulatory care scenario.

So, here we consider a typical scenario in which the developed IoT based healthcare system namely AmbuSens may be used. Here we consider a patient lying on the hospital bed with a nurse or paramedic attending him or her. Let us consider a situation when the patient needs to be monitored in real-time by doctor who is at some remote place. Now this situation may arise due to a couple of reasons a, this situation may be a rural hospital, but there is a lack of specialized doctors capable upliftment. Particular affliction which is aiming the patient it may also be the case that with a doctor who is regularly attending to the patient maybe on leave and some emergency regarding the status of the patient may require remote monitoring.

To enable remote (Refer Time: 29:35) monitoring you may use the AmbuSens system as follows. The nurse or paramedic who is attending to the patient is required to place the

wireless sensor divisors to the patient body as shown. The wireless sensors used can be of many heterogeneous types and are application specific depending on the types of physiological parameters that we may want to monitor. For example, here in the AmbuSens system we have the provision for measuring the pulse rate the electrocardiogram or ECG and also the temperature of the patient.

For the sake of probity here we display only two types of sensors the heart rate and a ECG sensors. The heart rate sensor he may use is spaced on the (Refer Time: 30:28) of (Refer Time: 30:29) gram or EPG this principle hinges light emitting diodes to illuminate the skin each cardiac cycle there is a difference in the pressure of blood flow so the arteries in the (Refer Time: 30:42) tissue or skin which leads to a difference in light absorption. These in turn is encoded and can be used to calculate the heart rate of the patient.

Here we also measure electrocardiogram or ECG of the patient. Now electrocardiogram records that electrical activity generated by heart muscle depolarization which propagately pulse rating electrical waves versus (Refer Time: 31:08). Although the amount of electricity is in fact very small it is in micromoles it can be picked up quite reliably with ECG electrodes attached to the skin as shown in the diagram these heterogeneous sensors together make up a sensing layer or the IoT architecture.

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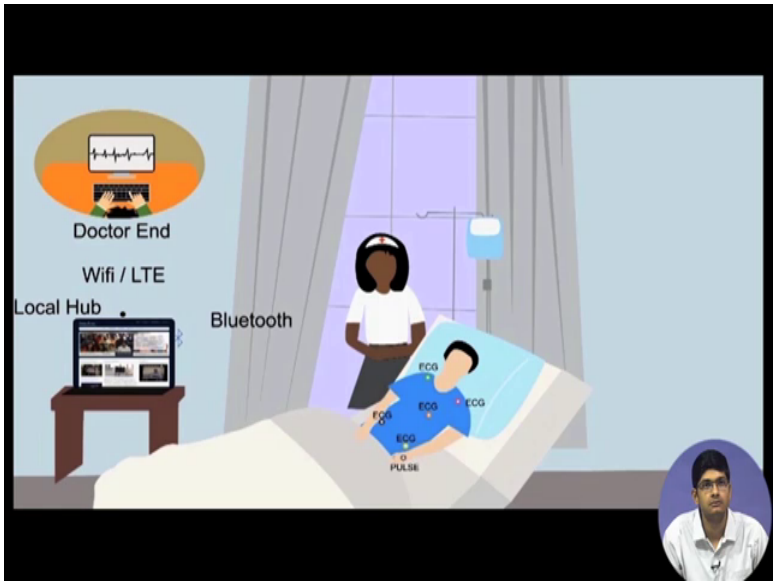

The sensor nodes treated on the patient's body at equipped to the Bluetooth transceiver unit which is used to send the sends data to a local hub for data acquisition and preliminary process here we have used a laptop or a local hub. So, preliminary processing includes calibration of the data in proper format for further processing and filtering to remove access noise generated calibration includes algorithms to convert EPG reading obtained from the heart rate sensor intellectual heart rate readings etcetera. The local hub that is the laptop is capable of receiving the data through Bluetooth and then it transmits the data using either wireless LAN, Wi-Fi or cellular technologies such as 3G or LTE to the AmbuSens servers.

All of this is done while the sensors are active and data sensing is going on to achieve real-time data aggregation and processing local hub performs part of the activities of the aggregation and processing layer of the IoT architecture. At that remote end the doctor is capable of accessing the real-time data by logging in to the AmbuSens servers and the wave interface at AmbuSens dot (Refer Time: 32:54) dot ac dot in using authorized credentials and using the data visualization tools which are available on the website, he or she is able to get a graphical representation of the real-time data captured from the patient.

Here we consider another scenario which is particularly well suited for the application of the AmbuSens system that of mobile ambulatory health monitoring. Let us consider the case of a patient we transported by an ambulance to another far away healthcare facility. This situation is quite common especially in the case of a rural or some urban hospitals where the patient which quite often referred to a specialized (Refer Time: 33:47). Inside the ambulance we see the patient lying on his stretcher we can paramedic accompany him or her typically in this scenarios the patients health condition while in transit is not monitored by doctors at either end.

The doctors (Refer Time: 34:03) and inform about the status of the patient when we first commences his journey, but while in transit the patient condition may have change the significantly thus doctors are be prepared to give the best possible care to the patient this is where the ambulance system comes into the picture. As we had seen in the hospital scenario the paramedic attaches the wireless sensor devises to the patient body. The wireless (Refer Time: 34:31) of the sensor devises make them easily variable and makes his easy for the patient to be moved to and from the ambulance.

The sensor communicate with the local hub using Bluetooth technology. A local hub in his cares has been replaced (Refer Time: 34:46) and enabled android device, the rationally behind is to provide mobility support about a ubiquitous connectivity. The mobile nature of the environment introduces more noise into the system whose require robust noise filtering mechanisms to make the stringent reliability constraint in post by medical data. This part is also handled by the local hub thus the local hub provides functionalities common to both are aggregation then the processing layer of the IoT architecture. While the ambulance is in transit real-time sensor data is tooled using the lte connection to the AmbuSen server the doctors in the both hence that if at the referee, end the refer can login to the AmbuSens website that is AmbuSens dot IoT k g p dot ac dot in and access there is data in real-time to monitor the status of the patient into probable real-time feedback to the paramedic.

Thus we present the AmbuSen system as use case of IoT in healthcare where we use the different aspects of a internet of things such as wireless sensors heterogeneous communication technologies to solve some of the challenges present in modern healthcare. To conclude we encourage the viewers to think about what particular challenges the mobility can introduce into this system and how we may go invoke solving them.

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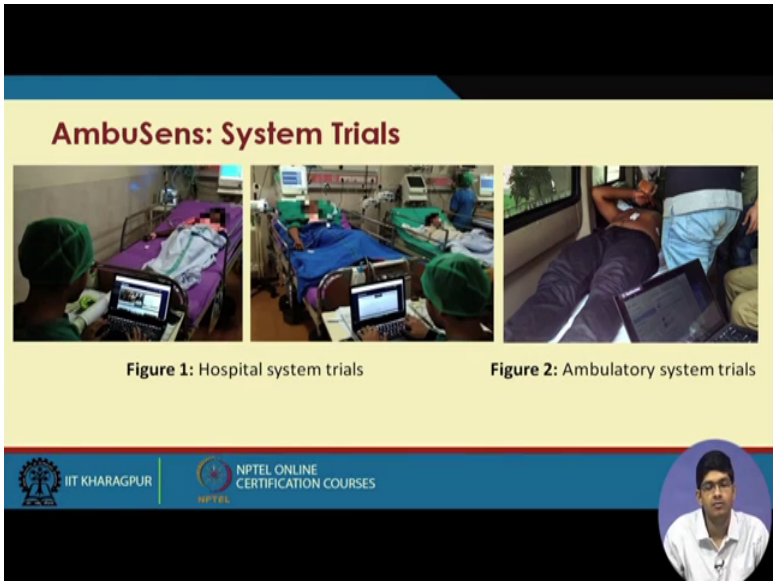

The two scenarios of deployment shown in the animation that systems were tried out in those two scenarios - figure one shows the trials in the hospital scenario, and figure two shows the trials in the ambulatory scenario. Both trails were carried out successfully and through a number of iterations we have successfully calibrated and tested out the system the results are shown in the next slide.

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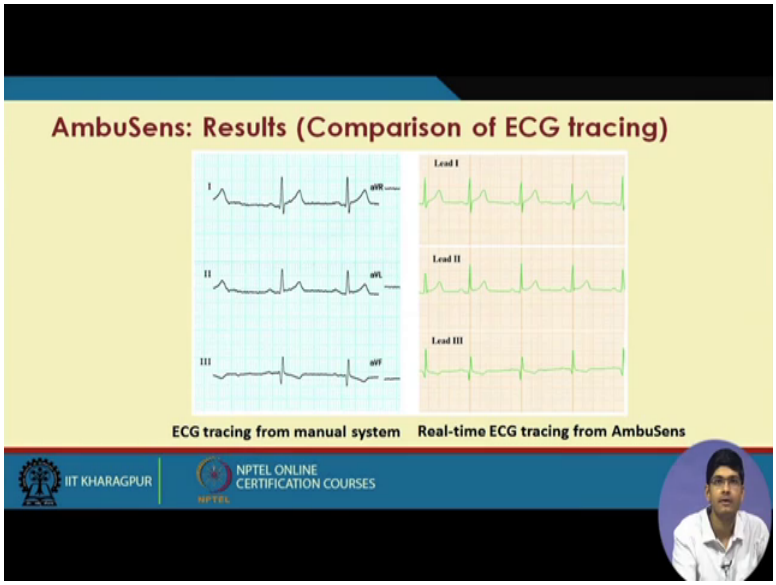

The figure on the left is that of a ECG tracing from a traditional wired ECG system and on the right you can see the real-time trace generated from the AmbuSens system comparison within the two traces shows the validity of the system.

Thus in conclusion IoT based technologies the sensing and the communication technologies of the internet of things may be used to enhance the existing healthcare system in our country and I hope that this example inspires you to develop IoT based healthcare systems on your own.

Thank you for listening.