Embedded Systems
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Lecture -37
Pervasive and Ubiquitous Computing

Today, we shall look into a area, which has emerged because of the success of embedded systems. In fact, this is the last lecture in the series of talks on embedded systems. So, what I decided; I decided to look into area which is emerging, which is based upon the various principles; an architectural aspects that we had studied about embedded systems. In this lecture, we shall not possibly answer many questions because; the fail itself would require study in depth. We shall possibly encounter the question and can understand where we can go with embedded system technology. So, today we shall talk about briefly, pervasive and ubiquitous computing.

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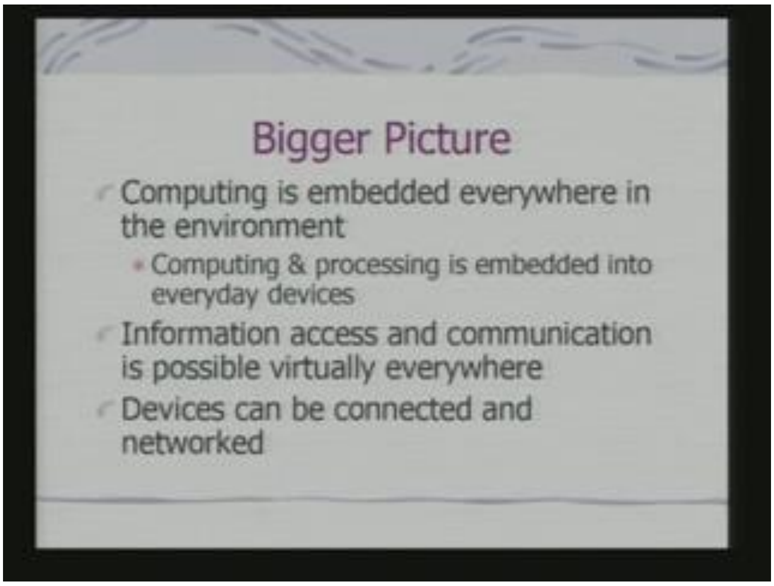

The basic idea is the computing is embedded everywhere in environment. So, when you are talking about computer being embedded into appliances therefore, in a way computer now can be embedded everywhere. It can be embedded onto your chair; it can be embedded on to your table, it can be embedded onto the worlds of your house. So, computing is embedded everywhere in the environment. And that is possible given the current state of the art of the embedded technology.

So, information access and communication is possible virtually everywhere. And devices can be connected and networked. We are not talking about connecting or networking just computers, we are talking about connecting devices, connecting appliances, given standard house world devices themselves can be connected over a network. And that is the bigger picture of embedded systems. And that leads us to what is, what I am referring to here as ubiquitous and pervasive computing.

What is ubiquitous mean?

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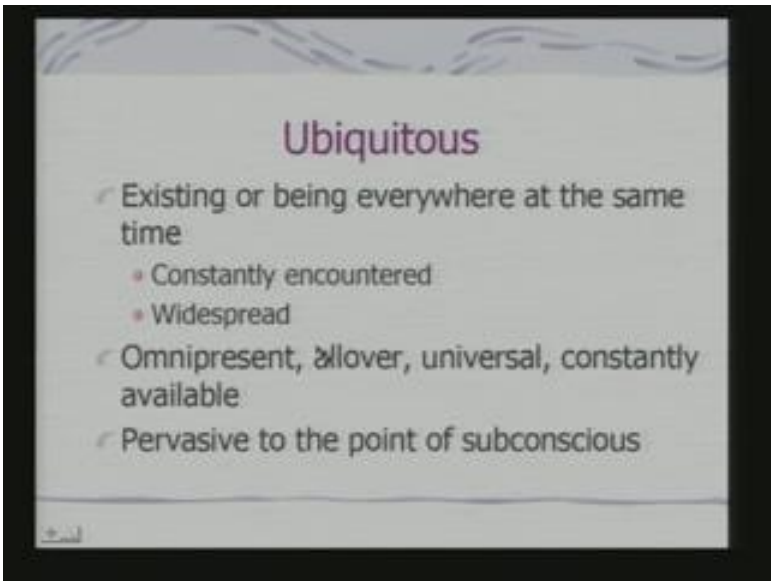

Existing or being everywhere at the same time; constantly encountered, widespread. Another way; omnipresent, allover, universal and constantly available. So, that means, whenever I am in a room in this room, itself if I want to have I look at my email; it may be possible the computer senses that I am here, it figures out where is my email server and presents my email on my screen.

So, the only presence of yourself along with the computer, along with the communication is what is ubiquitous. Even the computers can be part of your dress itself, you may ware a shirt, which has got the senses as well as a processing element as well as a communication element, which being monitor your body temperature and accordingly automatically adjust the temperature in an environment. So, it is present being present everywhere.

So, the whole idea is that, embedded systems should be pervasive to the point of subconscious. In fact, there is the straight when we said that, technology is really successful when the technology can make itself disappear. So, if you are varying a short and you are not conscious that, it is actually having a set of senses, computers and communication elements, the technology itself has disappeared and it has pervaded you are being or existing and that is the basic philosophy or the picture that is being looked at.

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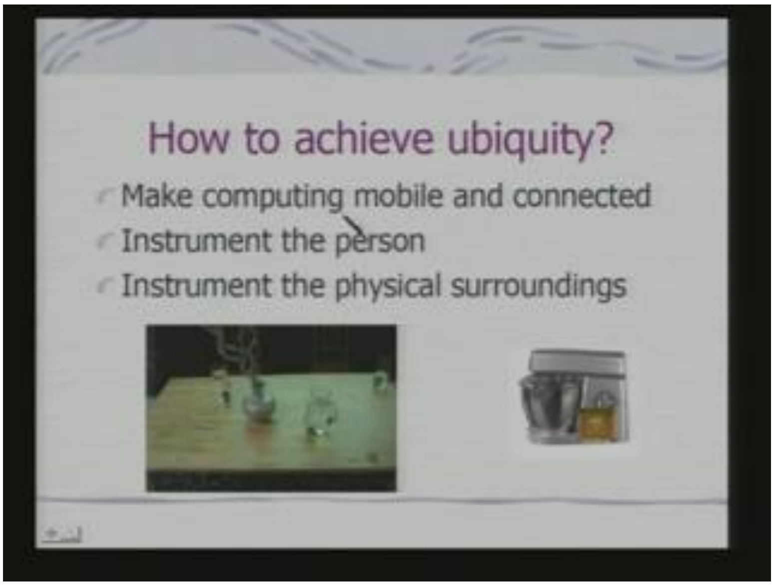

How do you achieve ubiquity? So, basic technology wise, make computing mobile and connected. In fact, all the devices that you have talked about; maturity of them or mobile devices in Samsungs or other and if they have the networking capability, they can be connected. Say for example, these can be a coffee making machine or a tea making machine, which can have a computer setting inside, which can be connected, which can even have a camera or may not have a camera, you come in and typing your code; it can prepare coffee that the correct mix, correct amount of sugar that you would like to put in it. At the same time can read out your image.

So, in the morning, when you come to your office and want to have the first cup of coffee, you go to the coffee making machine and it provides everything that you would like to start your day. That is the philosophy and the picture that you are looking at. So, what do you say that, making computing mobile and connected and at the same time, instrument the person and instrument the physical surroundings.

So, if I instrument myself, then I am connected my various parameters are connected and I get information over that. At the same time I can instrument the whole surroundings. In fact, this is an example, where standard house world item like say glass of water; you're a vas, everything has been associated with the sensor and it is also associated with the communication link. And in fact, your environment itself in that case provides an interface to work with the world.

So, in a sense you can think that, if there are two persons talking to each other in this sense environment, you can create a complete image of the environment on the screen, communicated to a third person who is remotely located. And what you can do is you can actually have the feeling that the third person is also there in the meeting with you, you can have something like a virtual remote presence of the person. In fact, your environment completely has been instrumented and since the environment itself is instrumented, interacting with the pervasive computing system, voice down to interacting with the environment.

How can instrument the person? You can put various gadgets onto him, it is not, so what do you get is in many cases known as wearable computing; you are not seeking for computer computers is with you that is the basic idea. So, ubiquity can be achieved by making computing mobile and connected. In fact today, in a way we have reached that level, in the sense that, all of us almost carry a mobile phone or fpda or a communicator which is actually has got connectivity as well as computing. And then if you can make interesting appliances built with similar kind of a capability, then your entire environment becomes sensitive to your needs and sensitive to your needs of the world around it. And that is the basic concept and the motivation for going ubiquity.

In fact, there is very interesting effect of this. In fact, philosophically it says that, is everything is interconnected, if your environment is interconnected, when culturally people across the globe can become interconnected and you can actually become conscious about cultures and diverse cultures across the world. And you want philosophy it says that, ubiquity computing or pervasive computing can be a road to peace because, people would know each other much more closely.

So, technology is not area which is void of society or society demands and requirements. So, in that way, pervasive and ubiquity computing is related to human needs and aspirations.

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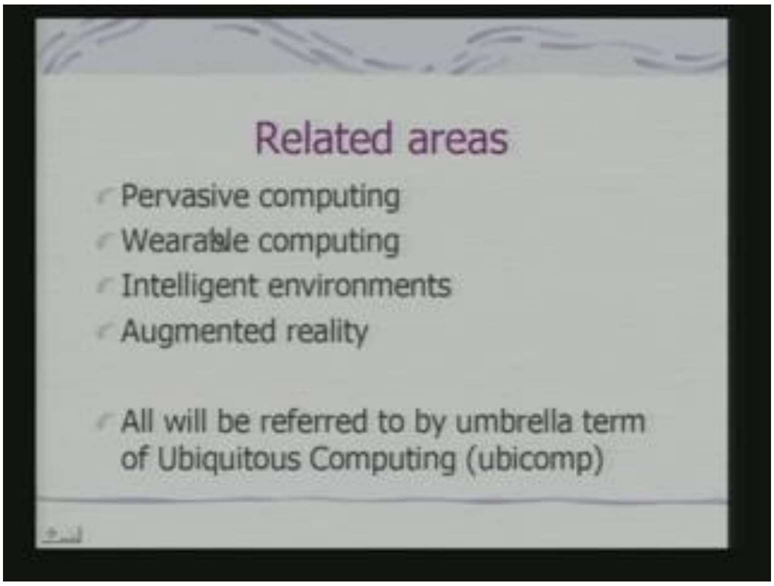

The related areas are pervasive computing, wearable computing, intelligent environments, and augmented reality. Obviously you can see that, wearable computing when you are instrumenting a person; actually you are making computing wearable, the example of a short; that I have already talked about. And if your environment has to the sensitive to your needs, sensitive to the person with whom it is interacting with and sensitive to needs of the people around you, when that environment has to be implicit, devices have to be inplident.

So, intelligence in a way obviously means, dealing with complex algorithms, complex logic. And if your embedded system is really have capability to run complex algorithms, then your intelligent algorithms or AI techniques, can be built into this embedded systems, making your entire environment intelligence. Related to this is that of a augmented reality. The point I was telling that, if I can make my entire environment instrumented; say with the glass of water and the glass of water effectively have got a sensor and the communication capability and that entire table with being instrumented, can be actually projected on to the screen, as the shadow what is happening in this room. And there can be a third participant, who may not be physically present there, but he can be integrated into this environment through similar instrumentation at a remote site. And effectively what we are creating, you are creating a kind of an augmented reality environment with there are three or more participant, with respect to an identical environment, although they are not physically code located.

So, what you get is augmented reality scenario. There is a reality and you are augmenting or you nothing to your reality. In fact, this requires not only this kind of an intelligent analysis, you also require amount of graphical processing power in terms of your displace; in terms of your environment. In fact, you can really feel that, I am in a meeting room which is located many 1000s of mile away provided; I have created a kind of computer based sensitive environment which may be identical or two different places. And iIn fact, it helps in various ways.

If we want to have a kind of collaborative work between people was situated distances apart, the basic means today we talk about is many communication over telephone, communication over emails all may be physically traveling from one place to other. But we would like to extend this whole concept into a more tangible interaction. How can be tangible interactions for example, if I am drawing a graph on a piece of paper, is it that of participant situated miles apart, can directly point onto that graph and tell me something.

So, actually what I am doing; I am working with a kind of instrumented artifacts, through which I can share ideas. It just not the computers screen, it just not the text over email adjust the voice, by which I am sharing the ideas. It is through the artifacts the way in actually we shall do say for example, in a meeting if I am explaining something in a piece of paper, the other participants can look at the paper, make pointers on the paper, write notes on the paper and that way I can have an interaction. Design can emerge through that kind of an interaction.

The question is; you can create artifacts through which this kind of an interaction possible, you can have a collaborative work done through these artifacts, which are nothing, but computers embedded into them with communication facilities and with a kind of a graphical support to create the virtual reality of that environment, at distinct places. So, all these actually, can be refer to and be group together umbrella term of ubiquitous computing.

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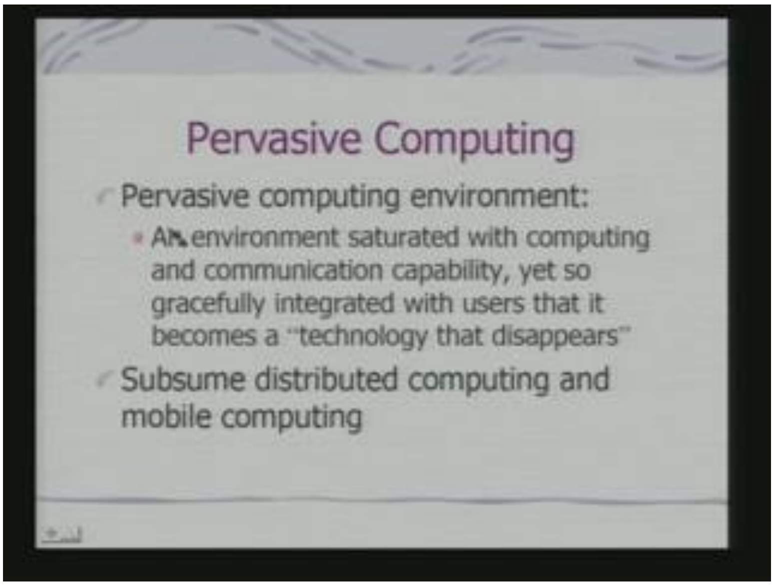

And for pervasive computing formally, can be defined as an environment saturated with computing and communication capability, yet so gracefully integrated with users that it becomes a technology that disappears. And it subsumes distributed computing and mobile computing. And the basic technology enabling all these things is your embedded systems.

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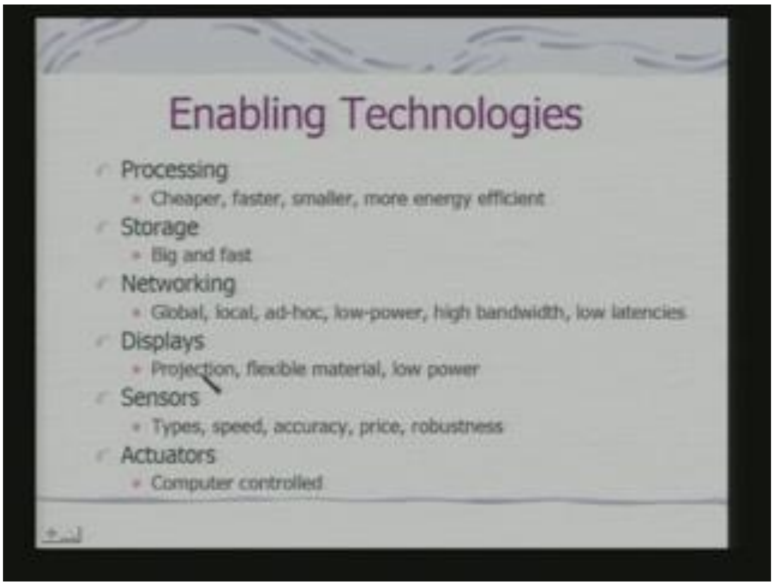

So, enabling technologies, we today look at. In fact, all of these we have studied as part of this course, processing it is becoming cheaper, faster, smaller, more energy efficient.

The storage is big and fast because, you need to store lots of information because; if you want to have an intelligent environment, you know need to know lots of things about the environment. Networking; there are varieties of networking schemes available; local ad hoc low power high bandwidth low latencies. In fact, ad hoc networking with enable you a person moving in which is device in any environment being networked and connected Displays; displays are important to create the elution of a distance world or a different world, in a pervasive environment.

So, the displays can be projection displays, there are flexible materials being used for display and low power displays. In fact, interestingly there are there has been work which has developed like; paper like displays, like electronic paper, where you can have the displays, you can also write on the paper and that writing can be transmitted, as well as it may be disappear. So, it just not a screen kind of an interface being talked about. And there are varieties of sensors. In fact, sensors are required to understand, basically the situation to understand yourself in the environment. And if anything has to be done, then there you will need actuators, which will today computers control.

In fact, all these things form part of an embedded system technology. And since there has been enhancement in this embedded system technology, you are taking one step further, making this embedded systems intelligent, making this embedded system networked and making the whole system of the environment intelligent and sensitive to the needs of human beings. So, the whole idea is that, it is not just a desktop or a keyboard based environment, in which you are interacting with computers.

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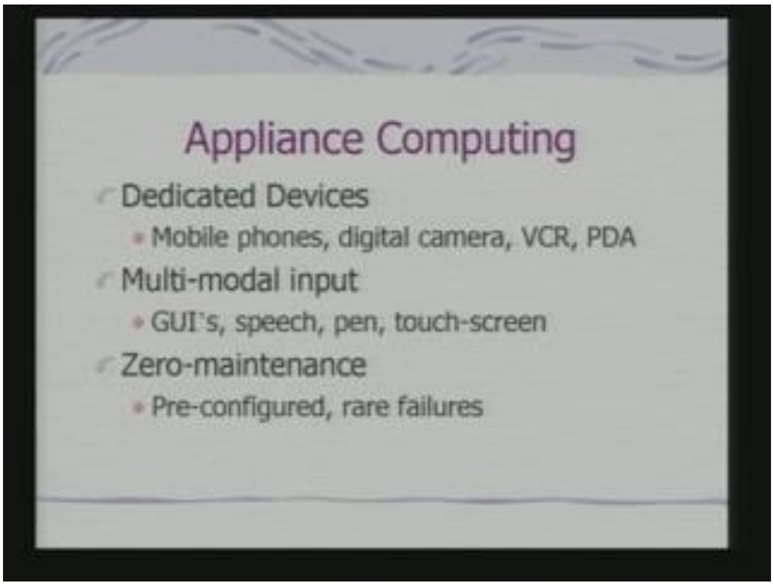

Your devices or everywhere and you were interacting with them. So, what we say where we are moving into is beyond desktop a kind of an appliance computing. We have dedicated devices; mobile phones, digital camera, VCR PDAs. And with this you combine multi modal inputs. Today, you have got speech interfaces, pen touch screen and these technologies have matured enough to give reliable results and to be able to be, to be implemented onto processes with energy cost, energy budget much less.

So, they can be put into your handled devices. So, hand writing in fact, was almost disappearing because, of your manners of keyboard, because if you become a keyboard savvy, you tend not to write. But handwriting has got its own flavor, handwriting got its naturalist. Now, the whole thing is that, if you look at the handwriting or a pen or a device that has coming, because of it is embedded system technology because, pen is the device is nothing, but an embedded system. An electronic pen today you get on which you can write just like you write on a paper, the whole data goes into via USB port to some device.

In fact, on you PDAs, you have got completely pen based interface. Your hand writing recognition technology has matured enough to recognize your handwriting. So, your interface would PDA is no longer really keyboard based, but handwriting based. Now, handwriting recognition has gone into PDA simply because, you have got more powerful processors, which can be put into your PDA, which can have these algorithms, complex algorithms for handwriting recognition being implemented over there. At the same time speech recognition, the speech recognition algorithm can be over there and you can actually have a speech interface to PDA.

The other objective which is coming up in a big way is zero-maintenance. The system should be preconfigured and should a rare failure; that means the reliability. In the last class you have talked about dependability of the system, which also include reliability and availability. So, effective design objective is; if you can make systems more available, then they really become zero-appliance and zero-maintenance. Once you become a zero-maintenance, then what happens? The whole technology goes to general human being. It is no longer a technology for technology savvy people.

So, mobile phone is you do not need any specialized degree or anything to operate your mobile phone. Now, what you would like you would like that, entire computing environment to become all pervasive and ubiquitous unnatural so that, you need not be technology savvy to user and also it has to be reliable.

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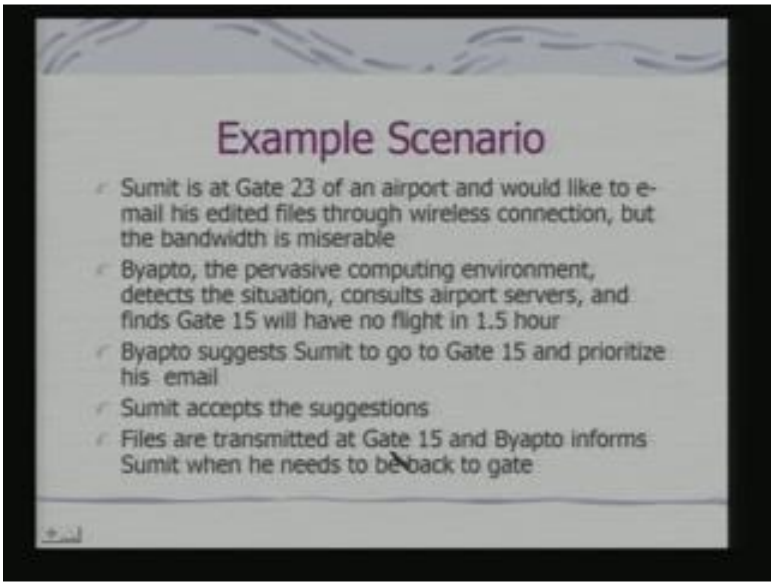

So, let us look at some example scenario; what we can achieve with these kind of perspective and philosophy. So, this is the story; let us say a character called Sumit is at gate 23 of an airport and would like to email his edited files through wireless connection, but the bandwidth is measurable. In fact, first part of the story is very real today. Various airports today have electronic points, basically wireless communication points, to which you can connect your PDAs or your laptops are get connected onto the internet. So, these hot spots are very common in various airports and even hotels.

So, here we are looking at a scenario, which is going beyond that of just using a hot spot for doing wireless communication. So, what it has I am referring to some kind of pervasive computing environment called say byapto. The pervasive computing environment detects the situation, consults airport servers and finds gate 15 will have no flight in 1 and half hour. What does that mean? That means, wireless link at gate 15 can give a better bandwidth, likely to give a better bandwidth.

So, it suggests Sumit to go to gate 15 and prioritize his email. Sumit accepts the suggestions. And then files are transmitted at gate 15 and the pervasive environment informs Sumit when he needs to be back to gate. Now, this is just not that of using a hot spot in an airport. You see that, when you are talking about a pervasive computing environment and talking of a completely network environment including the intelligent software, which can judge which node will have less load, which link will have less load, it can a device or user accordingly. It is also getting track of the fact that, the user has to catch a flight, so he should be allotted to go back to its reporting gate to catch the flight.

So, what the point I was telling is; it just not that of putting computing devices, connecting the things together, it is also that of intelligently monitoring and analyzing the environment. So, what you are bringing it you are bringing it into a network embedded computing environment, substantial amount of intelligence to guide and help the users. So in fact, what we have talked about so, far is that of building infrastructure. What we are talking or referring to write now is with this infrastructure, how you can deliver services to a human being?

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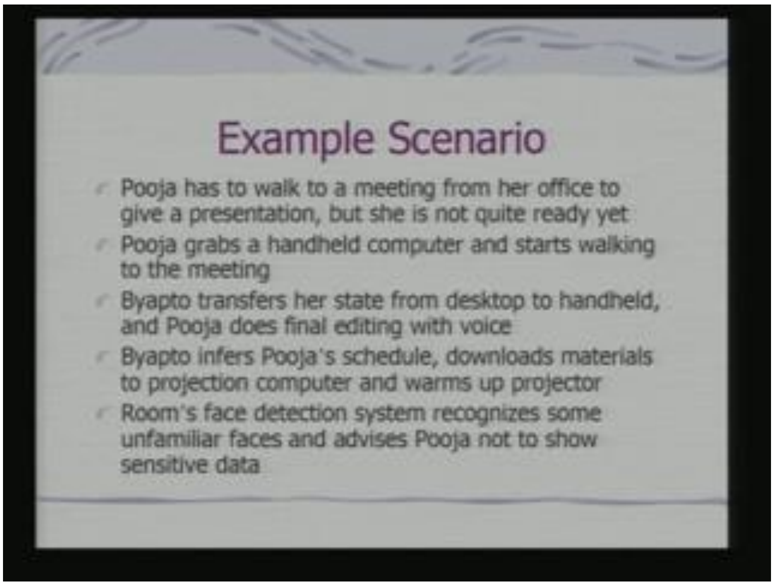

Let us take another scenario. This is the character called Pooja has to walk to meeting from her office to five a presentation, but she is not quite ready yet. She grabs a handheld computer and starts walking to the meeting. She was working so far on a desktop system. So, the pervasive computing environment should realize that, now the work is getting transfer onto a handheld, so the data the environment should get automatically loaded onto the handheld. She transfers here state from desktop to handheld and Pooja does final editing with voice because, if you have a voice interface to your handheld computers, it becomes much faster.

While traveling, you can actually do anything to voice. It infers that environment byapto, inverse infers Pooja’s schedule, downloads materials to projection computer because, if you are wirelessly connected everywhere, then prompt that handheld computer itself, it can be downloaded onto your projection computer. Your projector itself becomes the computer because, it is no longer up stand alone projector, which is to be connected to a PC, it itself is the device embedded with computing power, downloads materials to projection computer and warms up projector. Rooms when she enters the room meeting room, the rooms face detection system recognizes some unfamiliar faces and advises Pooja not to show sensitive data.

So, what we have used here if you see, various kinds of perceptual techniques in the context of embedded systems. Speech recognition face recognition and in fact, if you see these are the technologies which are it is not that, they are not usable and feasible they are available, it is the question of setting of the environment setting of the prototypes, using these technologies and taking the thing further. In fact, face detection recognition system is reasonably mature, speech recognition is also gets matured today. And if you have this kind of a network environment with intelligence built into, you can deliver similar services.

So, this is what is your pervasive computing, that is, taking embedded systems network embedded systems 1 step further with intelligence and context sensitivity.

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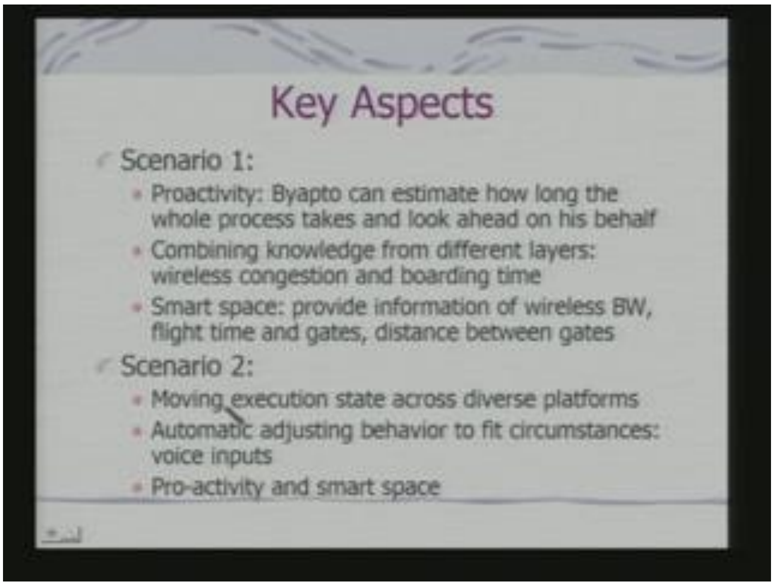

So, what are the key aspects from this example we can look at. Proactivity; the environment can estimate how long the whole process takes and look ahead on his behalf. And this proactivity can come provided, you a built in intelligence into that system. Then combining knowledge from different layers, wireless congestion and boarding time, this is the two different kinds of information and this has to be combined together and this information can transform two different stores using two different kinds of processing. And what do you create this effectively what we called smart space. It provides information of wireless bandwidth, flight time and gates, distance between gates.

The entire space is actually mapped. And the movement you have got a smart space, you can do lots of things. This is the smart space providing the user is navigational aide and airport so that, you can send an email. At the same time, this kind of smart space and al well used to help the blind navigate a airport.

Let us look at scenario two; moving execution straight across diverse forms. Now this is a more of a software technological problem, but you need a mechanism to do that. Then automatic adjusting behavior to fit circumstances because, your handheld computers now can work with voice inputs because, the person is on move. Proactivity and smart space b, the meeting room has got a face recognition system and it recognizes it faces and if it finds that the face is unknown or unfamiliar, it can accordingly advise the user.

So, with the face recognition system, this is highly feasible and possible. In fact, you can build system which can open a doors by looking at an one face; obviously, there is the failure rate associated with it, but it can open of a door if there is an known face, if it is an unknown face, it can simply allot the user. This is the very simple application these applications can be built any time anywhere today. This is one step beyond then what I have talked about.

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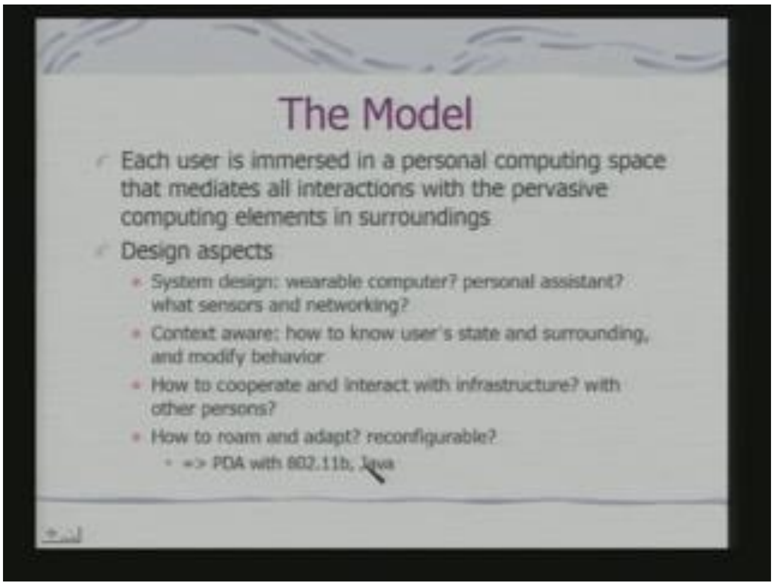

So, what is the basic model? The basic model is the user is immersed in a personal computing space that mediates all interactions with the pervasive computing elements in surroundings. And this immersive environment in the environment, whatever computing we are talking about its not computing just from computers, its computing from variety of devices and house hold items can be. So, what are the design aspects? System design, that is, be a wearable computer a personal assistant a PDA like kind of a thing, what sensors what kind of networking to be provided. So, these are technology issues which part of in fact embedded domain.

Next is context awareness, how to know users state and surrounding and modify behavior. This is part of a kind of intelligent processing which is to be built in to the embedded system. Associated with this is how to cooperate and interact with infrastructure with other person. Now, here we are talking about a protocol. A protocol for communication, but these protocol at a much higher level, then that of a standard communication, text purely at an application an usability level protocol.

Next thing which comes which is obvious and we have looked at how to roam and adopt. So, how do you move about, is it a PDA with 82.11 b, is it which Java because, Java can have compile code which can be downloaded and executed on any platform. So, what would be the technology issues related to this? So, these are all design aspects, which are important if we want to create this model of pervasive computing. So, what we have smart object or environment and this provides services.

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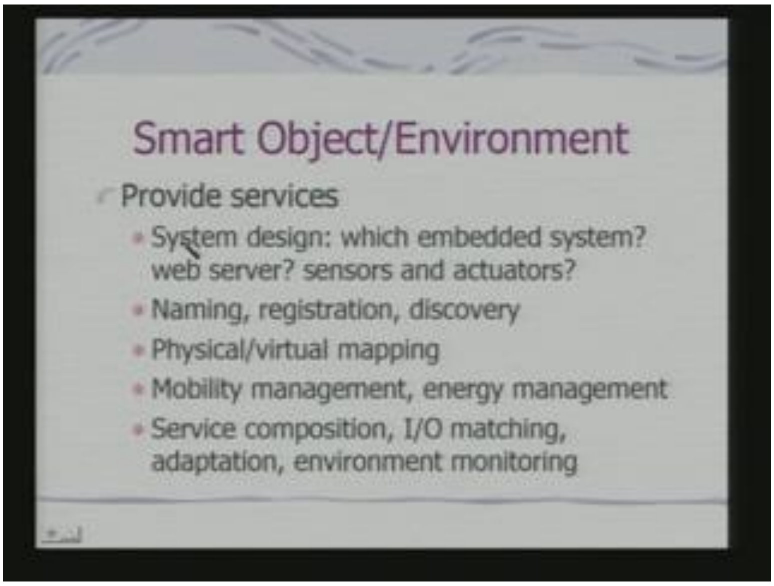

As we have referred to the system design, the question comes is which embedded system to be used, what will be the feature of that embedded system because, if I am creating a smart environment, let us try to understand. The smart environment is consisting of smart objects. Smart objects means; entities which can compute, which can take decision on its own, which can interact with the user, which can interact with other sets smart object in the environment. So, effectively a smart environment is consisting of smart object, smart object are nothing, but embedded systems. So, the question comes up which kind of embedded systems, we lead have an embedded server built into it, what kind of sensors and actuators to be provided with this smart objects. Associated with this is that of naming registration discovery, is it that whenever I put in a smart object in an environment, how can it be refer to, what should be the naming convention because I cannot have a static address associated with it. So, how can it be discovered, how can it registered itself with the environment manager.

Then physical and virtual mapping, what is physical and virtual mapping means; say for example, if I am referring to say a glass of water, with the sensor and I am physically moving it around so that physical movement of that glass have to be mapped onto may be its virtual existence at a remote location, to be existent at a remote location. In fact, Microsoft develop a very interesting demonstration of this kind of a scenario, it is for clipping parents in touch, with their children's. The basic scenario something like this; the children's are staying and the parents are away staying alone.

So, the question is they would like to keep in touch with their son or the daughter. So, they created a kind of a an artifact, where it says that, if you come back from the office, you drop your key chain your purse may be coins onto that artifact. And as you drop that the parents who are located at remote place gets at filling that, that key has been dropped over that sound that vibration a kind of a virtual feel that, the son has come back home. In fact, they created that environment, then the demonstrated that environment.

So, it is a kind of a physical to virtual mapping. So, physical you have got in an artifact on which you are actually putting this stuff. And there is the virtual environment and created for a part and it just not screen, its again an artifact which is producing similar sound vibrations and thinks of that is what and actually when feel that, your loved once your son or daughter is has come back home.

So, just see that how emotions and this kind of technology gets mingle together and that is what they say the feature of a kind of pervasive computing, feature of computing being dissolved into your everyday world. Obviously related to this is more technology issues that of modality management, energy management. And how do you combine different services, what IO modality to be used can it be can the whole system be adaptive and can you really have environment monitoring? So, these are the different kinds of issues which are related to that of creating a smart object or smart environment.

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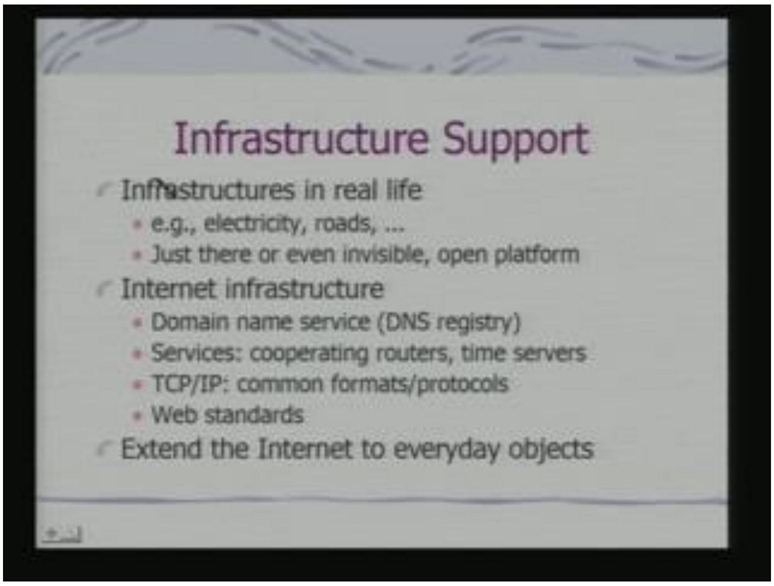

The infrastructure support; infrastructure is basically we talk about electricity roads, which are today almost invisible. We really do not realize the various electricity and there is road under unless electricity goes off or road is started beyond navigation. So, the basic infrastructure in internet infrastructure and this can happen if you extern internet to everyday objects. And it is not only just internet, but I am referring to internet in a more generic sense. It is just not in terms of this protocol, but in a generic sense that, were any kind of networking finally, gives you visibility across the world and that is the key infrastructure. That is key communication infrastructure.

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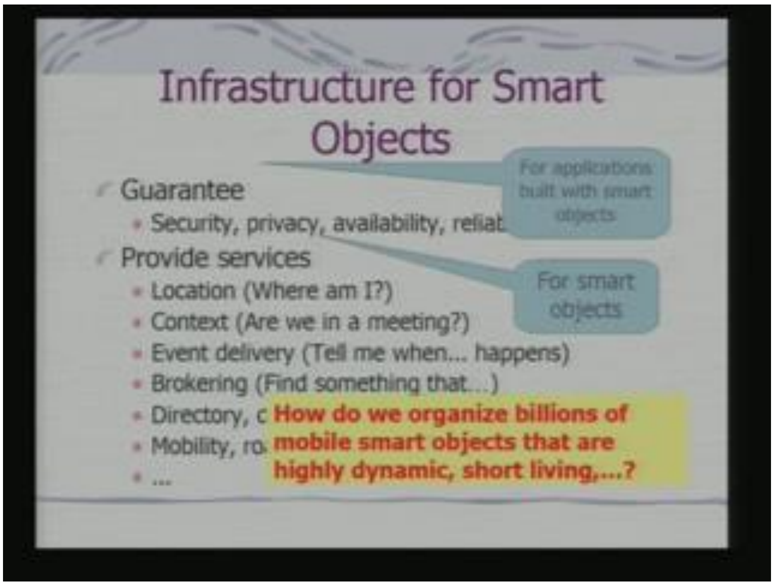

And other infrastructure issues that the smart objects should guarantee some amount of security, privacy, availability and reliability. In fact, these are all this points, which ahead this in the last class, in a context of designing dependable embedded systems. So, dependable embedded systems can only be a smart object in an environment, should provide services, location; where am I?. Context; are we in a meeting?. Event delivery; tell me when something happens?. Brokering is it can do thinks for me that is, find something which I am looking for, so I can delicate my task to a broker. There should be directory service so that, I know what are the smart objects are available, discovery of smart objects and the registry should be maintained. They should have the ability to move around, the mobility and the roaming capability should be there.

Now, you can realize that, all this things can be provided there is an amount of intelligence built into it. And other thing is that a kind of a cooperation protocol, cooperation protocol across objects which you really do not know. If brokering is to be provided for, brokering can be actually mean that, the smart object les to interact other object a different locations looking for some information. So, what should be the protocol for such a kind of a thing? And here it is just not it may not be just information, it may be actually requirement for providing a service. And service with the complete understanding of the semantics of the service. Service not in a sense of a syntactic features, but understanding the semantics of the service.

Now, what is that mean? It means that, say for example consider an extreme case, you need a service to be provided to a patient immediately, now, the brokering interface should have the intelligence to figure out what is the best medical service, which can be brought in to play in minimum, time given the current circumstances. So, that can not be done, if you are looking for a service to the key word medical service. That can be done only if you have a complete understanding of the semantics of the medical service, what are the constraints related to the medical service and how it can be delivered.

So, brokering also needs a kind of a framework for that. So, what you say in this case that, the guarantee with the smart objects are related for applications build with smart objects. And these are primarily for smart objects go to you are looking at. And another question which is how do we organize billions of mobile smart objects that are highly dynamic and short living. So, it just not the question of networking a communication. What we are looking at is you are talking about managing; so many smart objects together so that, they actually give a unified picture something as whole and not individually.

So, if you look at a set of swarms are flies, now you look at them as swarm and really individual roll of a fly not really important. So, you are looking at multiple smart objects. So, smart object as a whole what they can really deliver. That is a big question; how do smart object can self organize themselves, can the self organize themselves to deliver a service, can the self themselves to deliver the service. In fact, in many cases when we discussed to the sensor network, we talked about this protocol. But here now the protocols can come in at more from the application perspective, rather than from the communication perspective. And that makes this problem more interesting.

Next thing is user intent.

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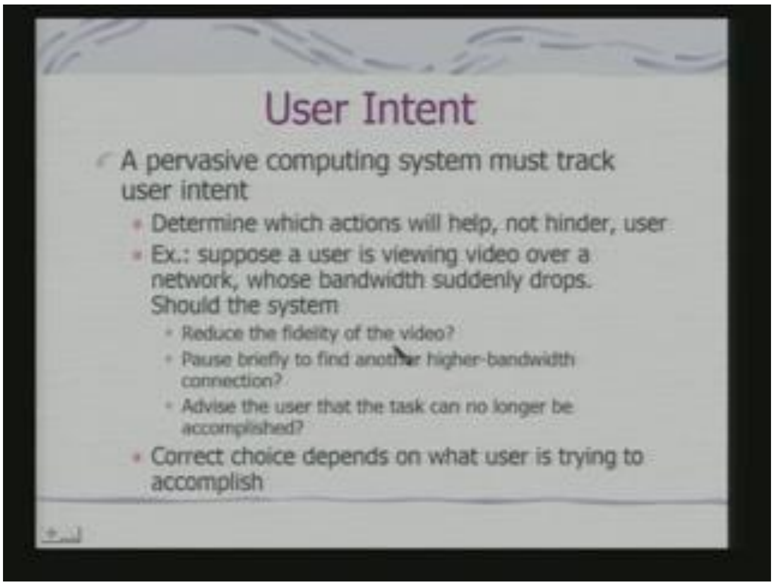

A pervasive computing system must track user intent, determine which actions will help and not hinder user. Suppose a user is viewing video, over a network whose bandwidth suddenly drops. Should the system reduce the fidelity of the video? Pause briefly to find another higher bandwidth connection? Advise the user that the task can no longer be accomplished? So, what we are getting an intelligent video player.

So, video player is sensing what is happening and trying taking decision, depending on may be the user's intent. And if it has to take a decision of the basis of the user intent, it possibly any two have users profile. You need to track of the user has behaved in a pause built up its profile and then it is delivering service. So, what we are getting is kind of a personalized service from the variety of devices. So, correct choice depends on what user is trying to accomplish.

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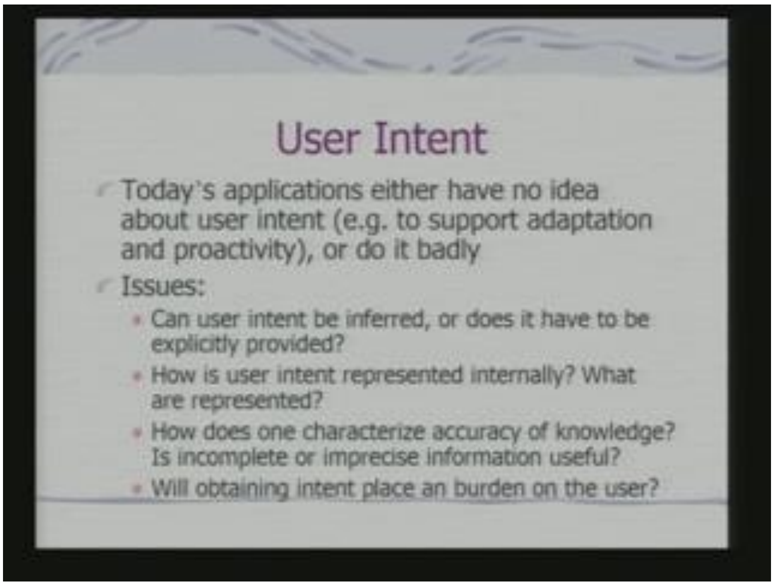

So, user intent, if you see today applications either have no idea about users intent, examples to support adaptation and proactivity or do it badly. So, the issues are; can user intent be inferred or does it have to be explicitly provided? How user intent represented internally and what is are represented? How does 1 characterize accuracy of knowledge is incomplete or imprecise information useful? Will obtaining intent place an burden on the user? All these are usability issues.

In fact, with the embedded system, the usability is the big issue. I can design an embedded system with lots of features, but if I have not taken care of how the user will interact with the system, then the system is bound to fail. It is not just making a design which will go into a box; it is that of engineering design so that, user would be attracted to use it and that is is fundamental point. And if you now bring in users intent to it, if you now bringing the capability to asses user intent and make the system behave according to users intent, so what you get; you get a personalized device which is a kind of a dream for everybody. I would like to know that, on my mobile phone the calls that are coming whether there is important or not. And then only the calls should be admitted, otherwise it may be rejected.

In fact, I can put the mobile phone off, but in many cases, I may not like to put them mobile phone off, I shall only, would like to accept those calls which are critical when I am busy. So, can I have a personalize mobile phone? That is the basic question. And today, if you have more processing power and if you can build in these capabilities, this is this can be a reality.

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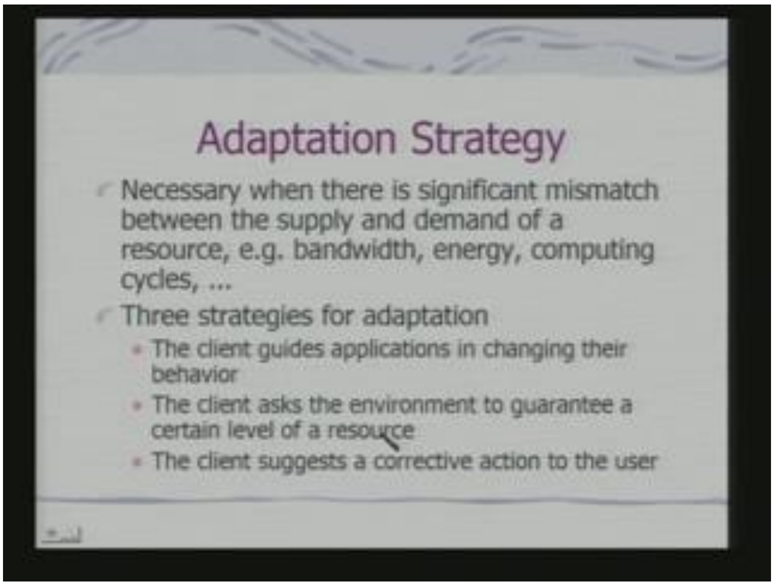

So, next question is adaptation strategy necessary when there is significant mismatch between supply and demand of a resource, which is true everywhere today; bandwidth, energy, computing cycles. There can be various strategies for adaptation. The client guides applications in changing their behavior. The client asks the environment to guarantee a certain level of a resource. The client suggests a corrective action to the user.

So, this is just not a key words negotiation, this is more from the perspective of the application and the users need an intelligent management of the resource.

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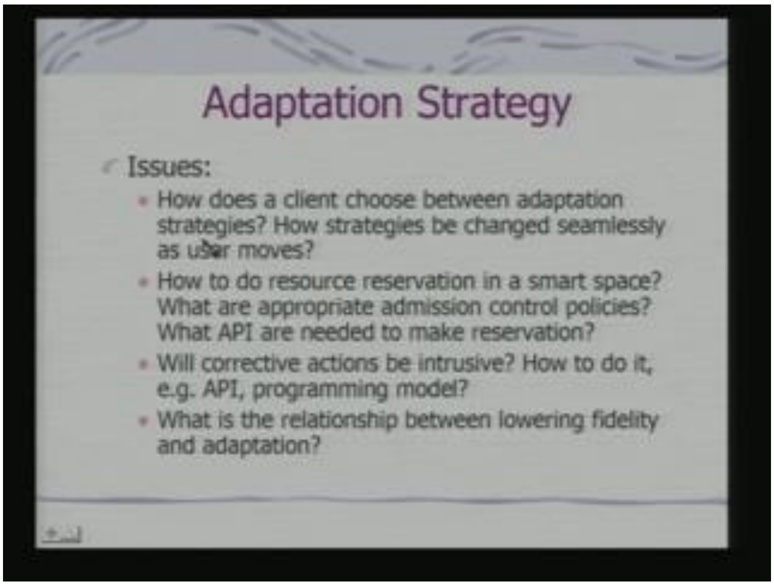

So, it says how does a client choose between adaptation strategies, how strategies can be changed seamlessly the user moves? Because, as the user moves the bandwidth can also; available bandwidth can dynamically change. How to do resource reservation in a smart space? What are appropriate admission control policies? What API are needed to make reservations? Will corrective actions be intrusive? How to do it? What could be API of the programming model? What is the relationship between lowering fidelity and adaptation? These are just questions.

These are the issues, which needs to be addressed. Now the question is what kind of programming models be used so that, you can actually model and adaptive corrective behavior. So, the behavior is not completely preprogram, the difference where it is coming up. We are talking of an adaptation process that the program of the software or system as a whole, adapts to the scenario and accordingly takes autonomous decision. And if it is taking autonomous decisions, the question is; how do you built in the autonomy into the system?

Let us look at high energy management.

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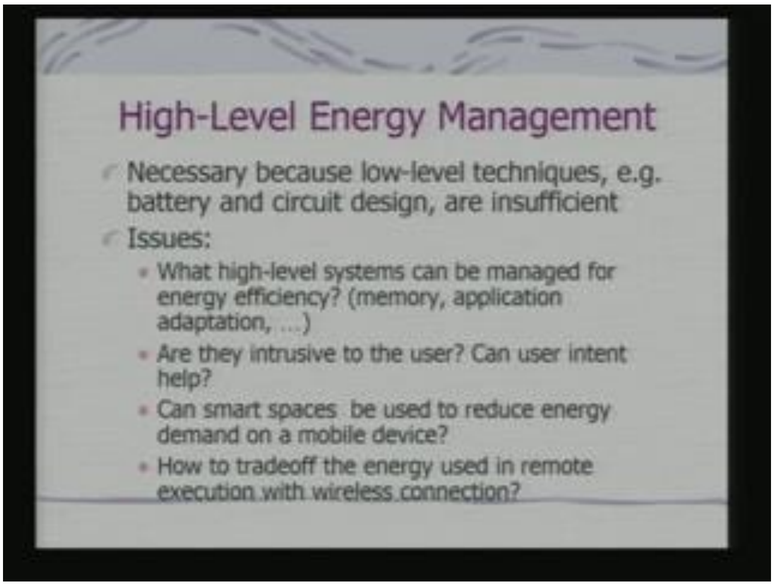

We are talked about and discussed about energy management because; energy management was the key problem in embedded system because, maturities of the devices are battery power. And we have talked about so far low level techniques; battery, circuit design then intelligent scheduling, we have looked at intelligent scheduling also. But can it be done form a high level perspective from an application level perspective. Issues are what high level systems can be managed for energy efficiency, memory application adaptation all this things. Are they intrusive to the user can user intent help?

If user currently is not really interested in watching the TV, then what can happen? I can simply shut off the TV and keep the link open or any incoming messages. By that process I can actually say energy. So, this energy saving strategy is more from the user intent on the perspective. And if I can really judge or assessed users mood by may be recognizing his facial expressions, then it becomes system of a different kind all together. Then energy management is depends upon the users mood and taking actions.

Now, this is where the technology is being dreamt of, this is where the technology is intent to go. And that is are the interest in excitement is all above. And the question is how to tradeoff the energy used in remote execution with wireless connection? So, remote execution when we are doing wireless connection, then you need not use the complete energy over there. How we are using clients and at every level there will be clients which have been used.

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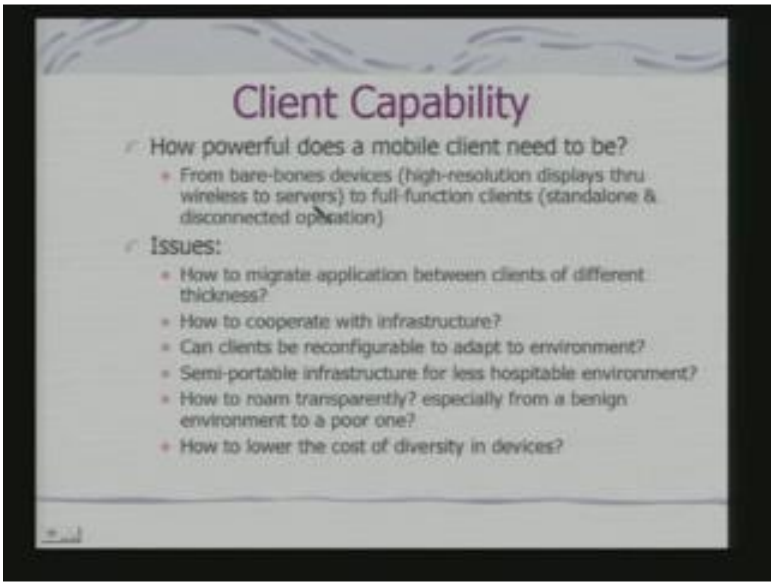

How powerful does a mobile client need to be. From bare bones devices high resolution displays thru wireless to servers, there can be variety of these kind of client capabilities depending on the room because, the environment in the room can be really a client as well. So, the question is how to migrate application become clients of different capabilities? How to cooperate with infrastructure? Can clients be reconfigurable to adapt to environment? Semi portable infrastructure for less hospitable environment because, environment need not be similar under all kind of circumstances.

How to roam transparently, especially from a benign environment to a poor 1? How to lower the cost of diversity in devices? It should not be that, in this room I need to 1 device, when I go out in the external environment I need to be use another device, the diversity have to be minimized. So, these lectures what is; this is all related to what is context aware computing.

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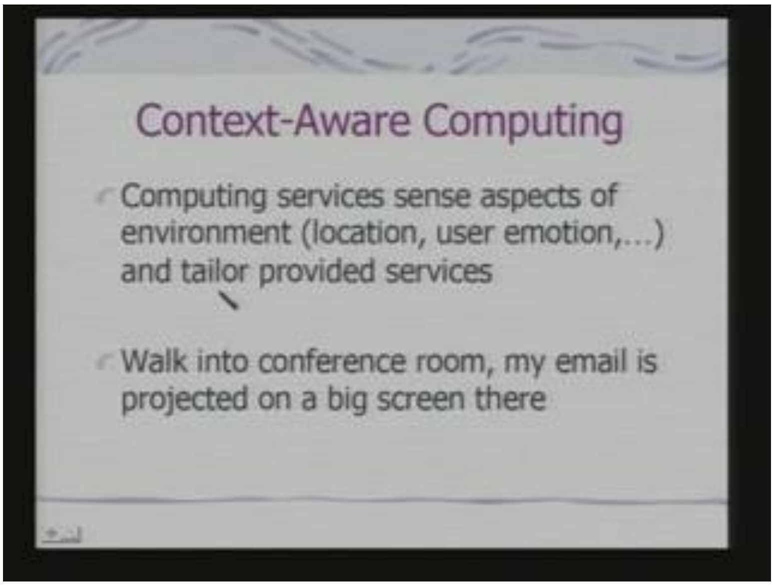

Computing services sense aspects of environment, location, user emotion and tailor provided services. So, the example is walk into conference room, my email is projected on a big screen there. So, everybody can see the email because, I might have sent that email to the people participating in that meeting.

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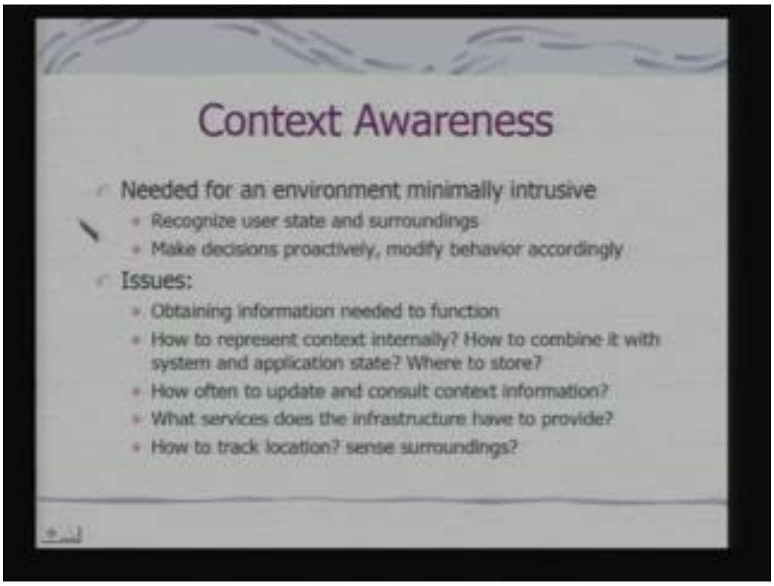

So, context awareness is needed for an environment minimally intrusive. It should recognize user state and surroundings, make decisions proactively and modify behavior accordingly. Issues; obtaining information needed to function, how to represent context internally? How often to update and consult context information? What services does the infrastructure have to provide? How to track location and sense surroundings? You have since very simple context sensitivity, when we move around with your mobile phone and you say you see that message that with the place you are that location awareness. And that one aspect of your is context awareness of the system.

Context awareness; obviously, means you need to have lots of information. The storage also to become an important issue and what is the rate at which it is updated? Because, that update will make the system correctly context sensitive. So, let us take an example.

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In fact, this is an example device, which was spell long back called active badge. It is nothing, but again an embedded system. It contains a microprocessor and an infrared transmitter. And if you talk about, this is basically something like your active. The badge broadcast identity of its owner. So, it can have the owner information, it carry that badge. And it can open automatic door, it can permit you to login to a system. So, it makes you makes the environment sensitive to you. In that sense is the context awareness.

Now, there are also intelligent spaces systems for recognizing user moods from the facial expressions. So, in a room you can be recognition accordingly, once you walk into a room the music channel music can actually change to suit your mood.

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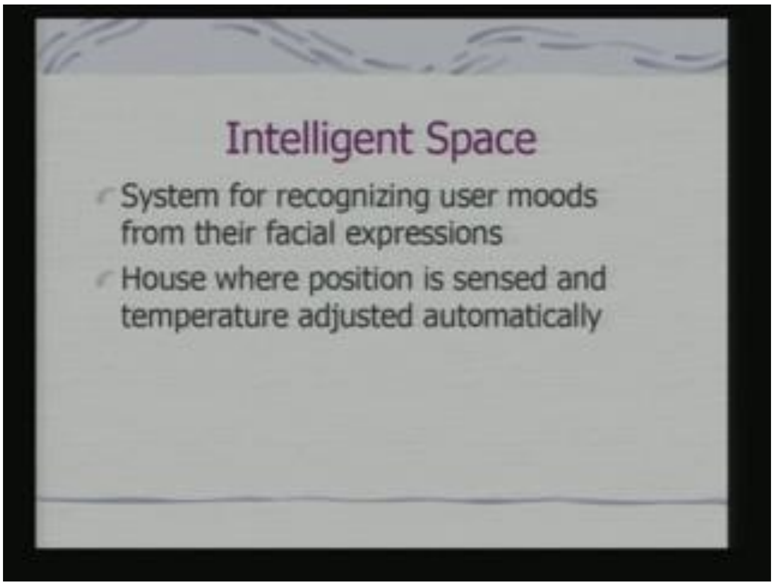

Next thing is house, where position is sensed and temperature adjusted automatically. In fact, your sensor network can provide the basic framework to provide this kind of a feature intelligent. Intelligent buildings are critic common today. Then, proactivity.

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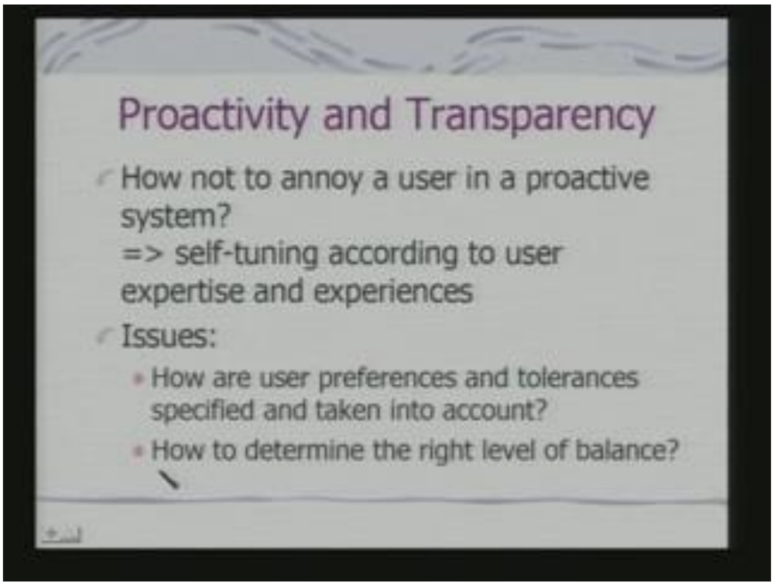

How not to annoy a user in a proactive system? So self tuning, according to user expertise and experience, this is become a social computing issue. They should not be disturbed beyond a certain level and take an annoyed such that, they might not like to use the pervasive computing system. You should not be like that, every time I write I, I becomes capital and I have to come back and correct that. So, next question is privacy and trust.

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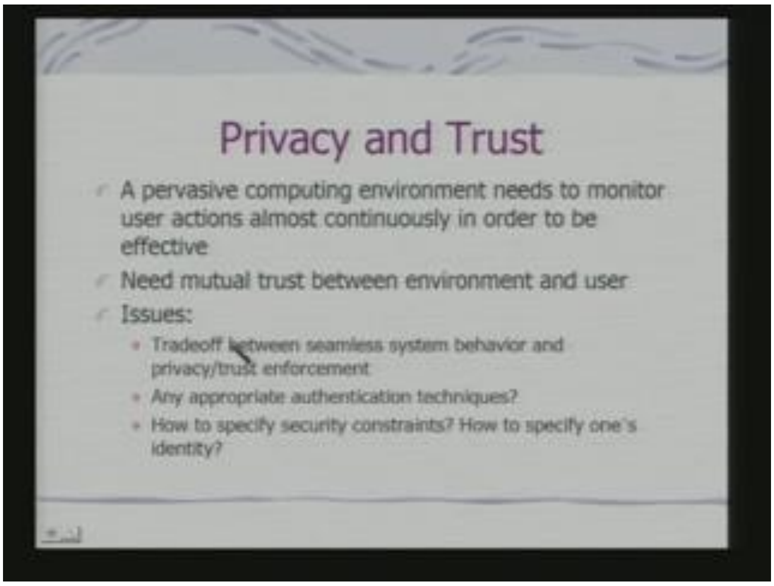

So, if I have to use them that, I should be sure about privacy of my environment, privacy should not barked into that, details of that should not be transmitted to an unauthorized user. It should need a mutual trust between environment and user. And you are seeing various kinds of cyber crimes are coming in, which are actually breach of this privacy consideration and this cyber crimes are imagine again because, of your embedded systems, then things being able to put in a variety of places. And when you are talking about pervasive computing, where exactly referring to that kind of a scenario with the additional condition that, privacy and trust. That is the key component; otherwise you really cannot have this kind of a pervasive setting.

The layering; the layering is relationship because; pervasive computing has to be taken information across multiple layer.

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So, let us take an example, this is the live board example, a pervasive computing system. So, this is the board, where the pictures can be projected. The teachers can explain can write on the entire thing, at the same time goes into the screen in front of the participant, which may be located anywhere. And these participants can also interact to the screen on their own and that is gets reflected over here. So, in this kind of a class room setting, every one of you will have this test and you can actually point out to, to a point over here and asking a question.

So, this is an example of a pervasive computing system, the live board where actually this itself is the device an embedded system, each one of the terminals are embedded systems and they are all connected via communication link. The other interesting example is a pin and play network.

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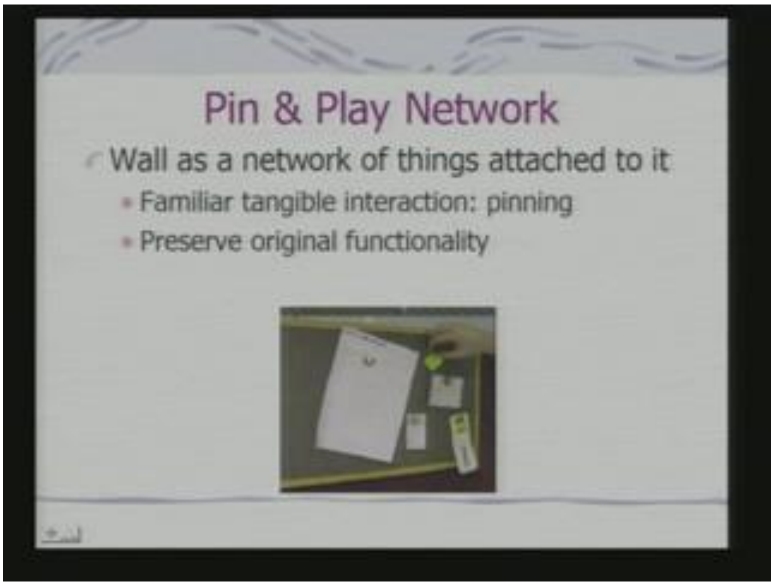

So, wall as a network of things attached to it; familiar tangible interaction pinning because, if you have a board, you would like to pin things over there. And preserve original functionality. So, this is the board, where you pin various things, as you pin this each 1 of them gets actually connected to the network fine. So, you can actually know that, this is the piece of paper that is available there. So, what the architecture says.

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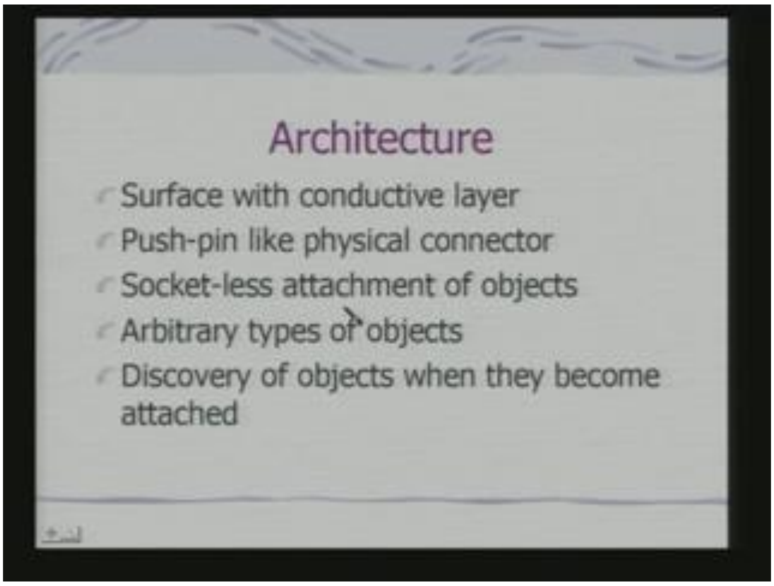

Surface to the conductive layer, push pin like physical connector, socket less attachment of objects. It can be arbitrary types of objects. In fact, sockets can be provided with that information. Sockets can even sense that information. And discovery of objects, when they become attached.

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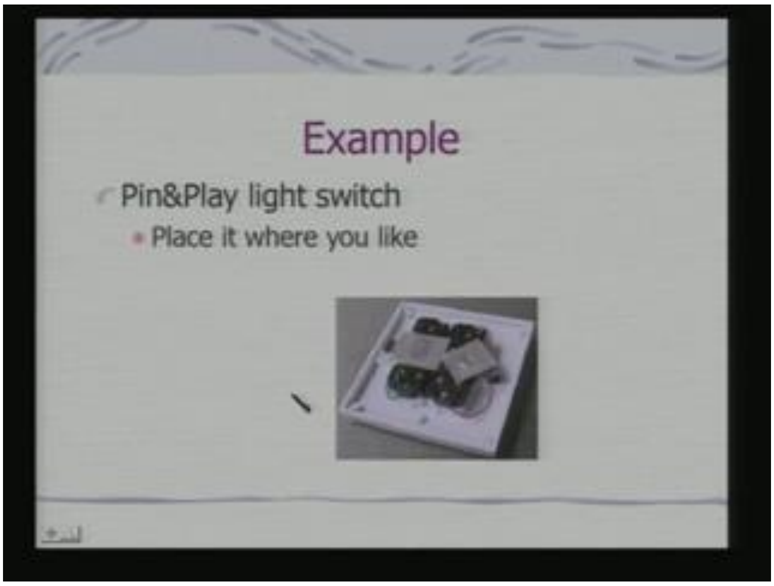

So, example is pin and play light switch place it where you like. In fact, that is already available you can put in anywhere and have the light switch. So, it is what you have got the switching over a network. You are putting light switches over a network, it can be connected anywhere.

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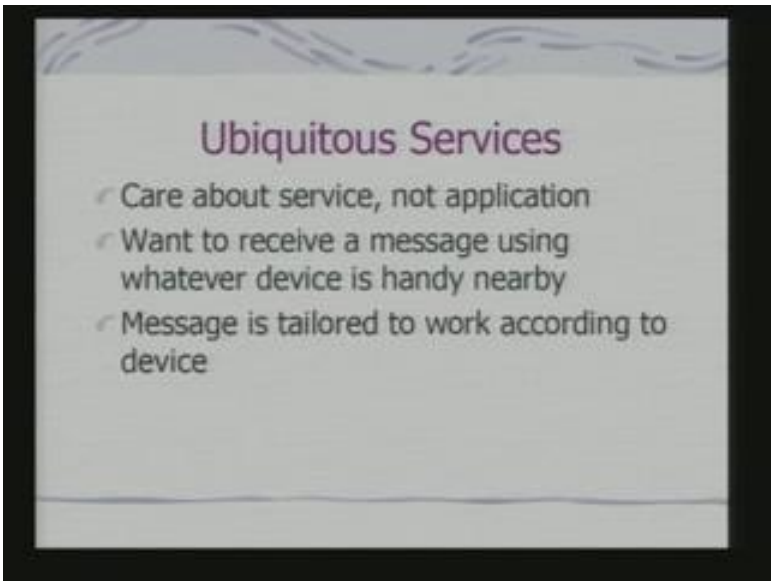

Ubiquitous service is; want to receive a message using whatever device is handy nearby. And message is tailored to work according to the device, it just not that you have to have the messaging program running on your system or on your mobile, it can be on anything. It should sense which device is currently accessible. That is the kind of a ubiquitous services.

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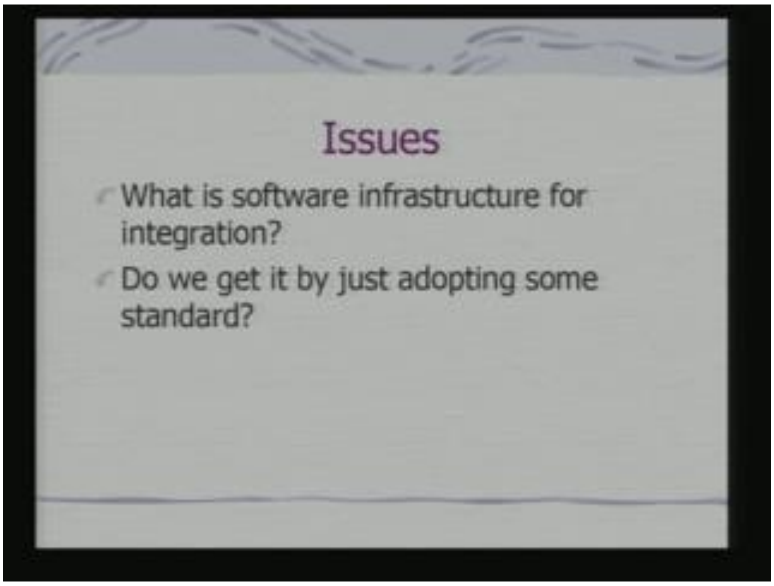

And; obviously, you have the issues are infrastructure and how the standards have to be adaptive and we cannot adapt 1 standard. So, there has to be flexibility with regard to that. The other thing which has emerged is interfaces.

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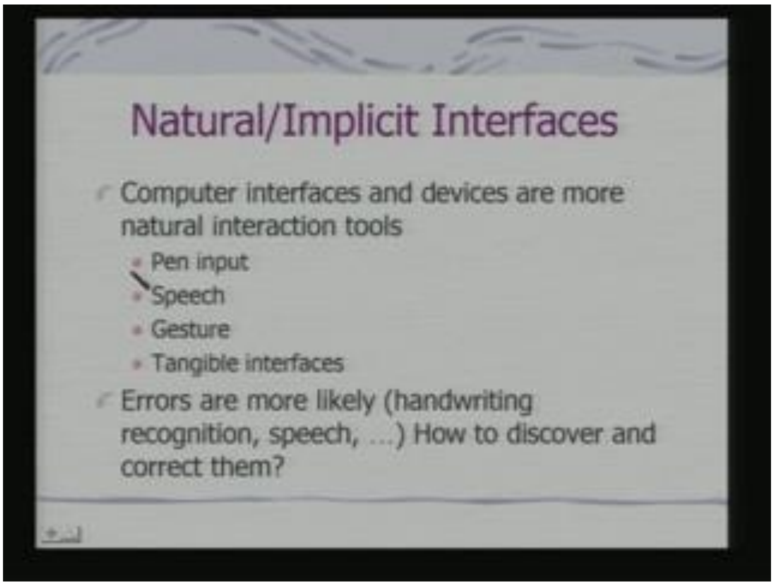

Pen input, speech input, gesture, as well as tangible interfaces. Like; I have talked about interface like a pen things in. So, this is possible simply because, you can provide this kind of an ability through your computing. So, if you are interacting with an environment, has to be multi mobile, it has to be multi modality as well as the mobile. And here again because, of the capability as the point I had already talked about. Errors are more likely and you can correct them, discover them, your software can become more powerful because, you have a more powerful processor.

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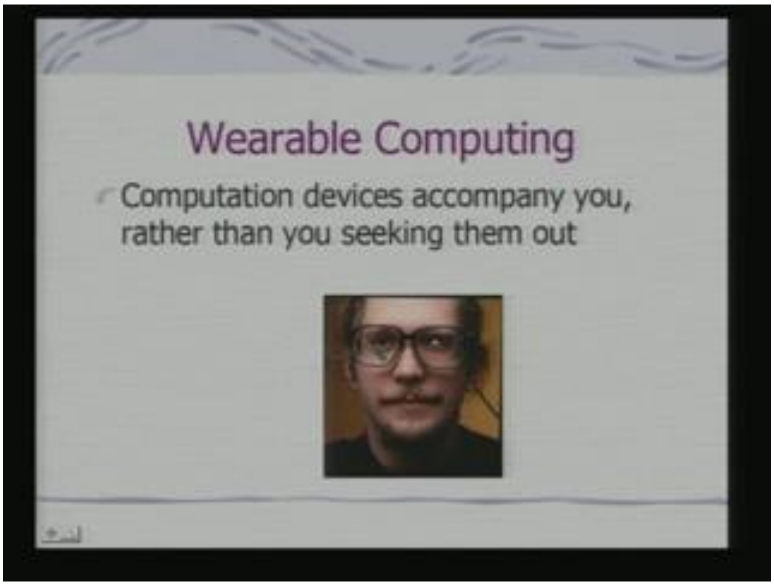

Next comes a wearable computing, you can wear them your basically specs itself can have a computed eyes display, which gives you a much better display mediate 3D display for remote site or a kind of a much better display of the world. You can have a rist pan which senses your hot rhythm and take care of your hot conditions or short the example which I had already given.

So, wearable computing is another very interesting aspects of your pervasive computing and they are also what do you have putting in nothing, but embedded system.

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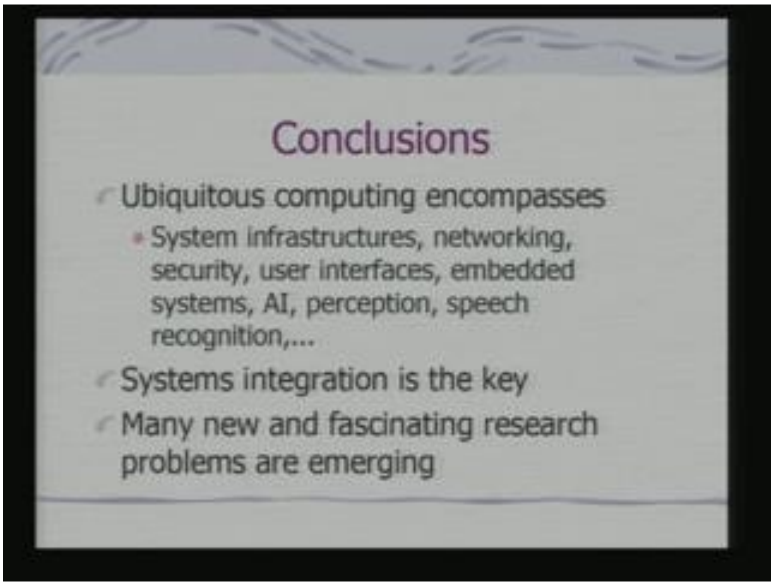

So, we come to the conclusion of this lecture as well as that of the course. What do you find that, embedded systems has let to if you see ubiquitous computing that, ubiquitous computing encompasses system infrastructures, networking, security, user interfaces, embedded systems, AI, perception, speech recognition and everything put together. And the key the base behind them has been the advancement in the embedded systems and here the system integration is the key. And what this is leading to, leading to many new interesting and fascinating research problems.

So in future, with the basic background of this course; if you are going to designing embedded systems and explore this research problem; that would be very interesting.

Thank you.