

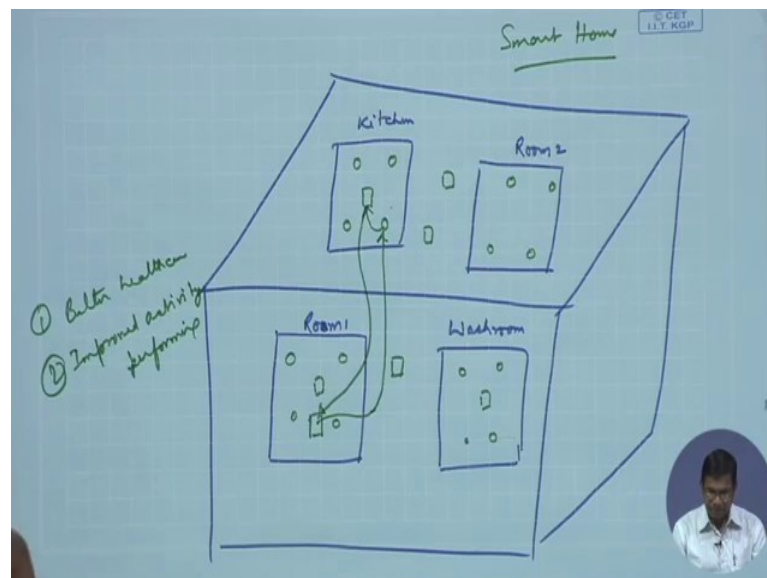
**Introduction to Internet of Things**  
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**Department of Computer Science & Engineering**  
**Indian Institute of Technology, Kharagpur**

**Lecture - 48**  
**Smart Cities and Smart Homes – III**

So, we now come to the part 3, the third part of smart cities and smart phones and unlike in the previous 2 lectures where we focused mostly on smart cities. Here in this particular lecture, we are going to focus on smart homes. So, when we talk about smart homes we are talking about the integration of ICT technologies like the once that I mentioned as part of the previous 2 lectures or even the once that we spoke about throughout in this course taking help of these different technologies, how we can make our home smart.

So, let us consider a scenario like this. So, we have, we have, let us say a smart home in a home.

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We have different rooms, we have you know, let us say let me let me just for simplicity. Let me just denote these different rooms here and so on. I am not as you can see I am not very good in this art particularly when it comes to 3 D pictures. So, let us say that this is a room 1, this is room 2, then you have a kitchen, then you have the wash room.

So, in a smart home you have different, you have different sensors that are basically deployed in different places. Then the same time you also have some actuators as well let us say that these are the different actuators which can be could be even some could be in the room itself. So, you have different sensors actuators and different types of other like NFC devices or you know, different other IoT devices and they talk to each other.

So, let us consider that you know we have in a smart home. We have to do something better. So, do what let us say that we have to you know cook something in a better manner. So, what can be done is you know from a particular room where we are sitting. So, from that point on there could be some kind of a device which can go and which can which can go to the kitchen you know, and from the refrigerator of the kitchen it can take out something. And then you know in kitchen there is a microwave device it is going to put that in the microwave device then it is going to boil it or you know it is going to you know warm up in the micro wave oven and then it is going to serve me right.

So, this is one example, like this you know there are different other things at home different activities that we do at home these could also be made smarter. So, this is an example of smart home, in smart home you need better health care, better health care you know improved activity ah, you know improved activity, I would say that; you know performing and so on like this you know. So, whatever regular activities that you do those can also be improved. So, that the activities can be done you know efficiently.


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**Introduction**

- ✓ Smart home infrastructure consists of:
  - Intelligent networking device infrastructure
  - Seamless integration of various devices using wired/wireless technologies
- ✓ Allows ease of use for household systems.
- ✓ Creates a highly personalized and safe home space
- ✓ Corporations seriously indulging in smart home systems include GE, Cisco, Google, Microsoft, and others.

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

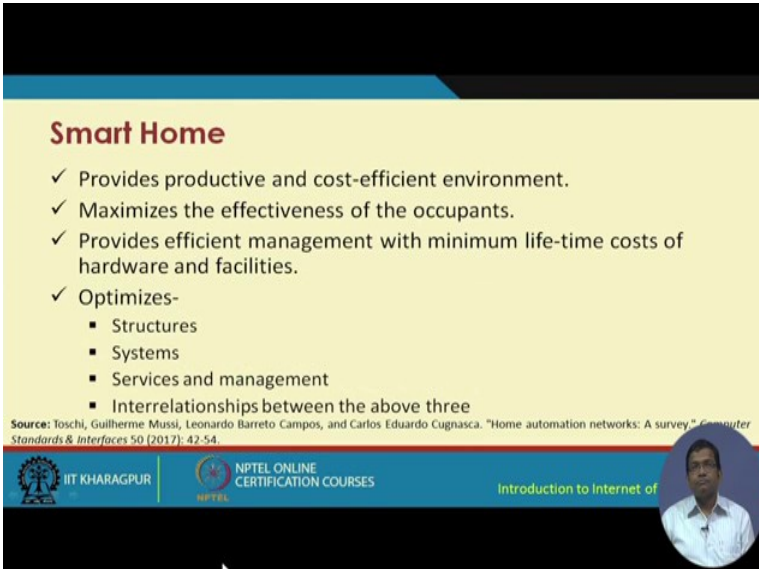
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So, going back let us look at the smart home infrastructure. So, you need these different infrastructure, these infrastructure as I telling you so far, that you have these different sensors actuators different robotic devices that are there at your home. And also you need the networking infrastructure. So, you have intelligent networking device infrastructure, there is seem less integration of this various devices the sensor actuators etcetera, using wireless typically wireless technologies are used, but wire technology could also be used in addition.

So, this basically allows the ease of use of house hold systems. So, improving the efficiency of performing different activities in a smart home or the use of these different house hold systems can be improved. It creates a highly personalized and safe home space so, you know whatever I need you know I can do things efficiently you know, and why it is efficient? Because let us say that you know if I have run out of the groceries the grocer is going to be informed. So, that will make it more efficient. So, corporations like you know; Cisco, Google, Microsoft and many others they are seriously thinking about building smart home systems, they are seriously thinking about they are inversing on building smart home systems. So, smart home systems have become very popular in the recent years.

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**Smart Home**

- ✓ Provides productive and cost-efficient environment.
- ✓ Maximizes the effectiveness of the occupants.
- ✓ Provides efficient management with minimum life-time costs of hardware and facilities.
- ✓ Optimizes-
  - Structures
  - Systems
  - Services and management
  - Interrelationships between the above three

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

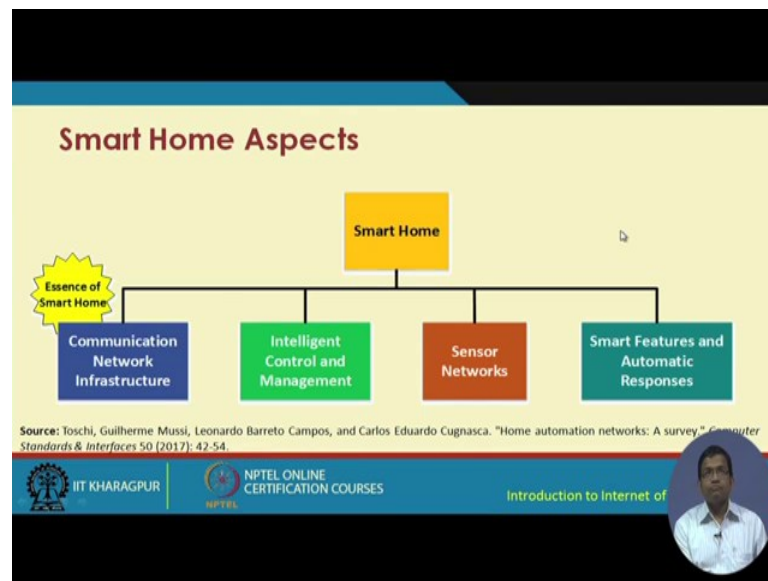
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So, smart home basically provides productive and cost effective environment, because you know if you are doing things efficiently the cost is going to improve you know is

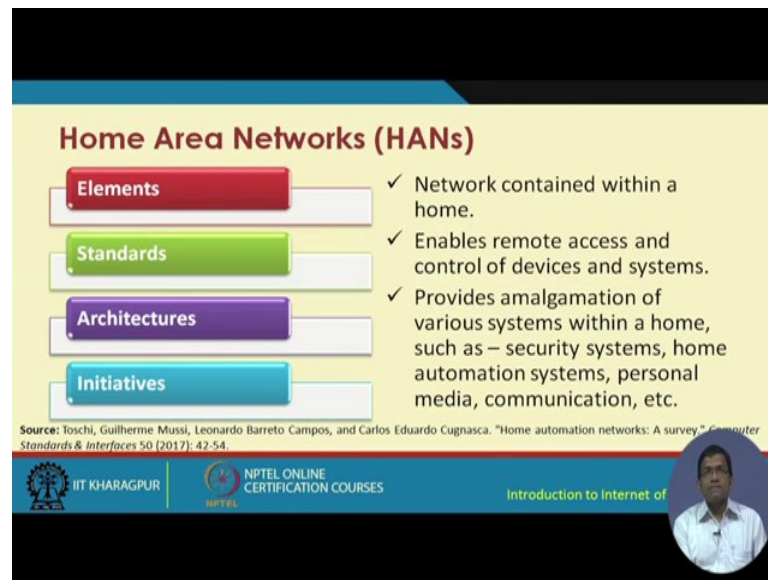
going to reduce. So, it is going to be cost efficient maximizes the effectiveness of the occupants provides efficient management with minimum life time costs of hardware and facilities and optimizes things such as structures systems services and management interrelationships between the above three. So, all these are going to be optimized in a smart home environment.

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So, in a smart home basically the different components are sensor networks, sensor networks, intelligent control, intelligent management, communication network infrastructure and smart features and automatic responses.

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So, in a smart home we are typically talking about something known as home area network, which is analogous to something like a local area network in a building or couple of buildings together when you know typically we have these local area networks. So, smart sorry, and then we have this personal area network. So, personal area network is very much like you know small in terms of the range typically you know human bodies have the personal area networks, or then we can have this personal area networks out of this different peripheral devices in a computing system.

So, personal area networks is too small. Then the local area networks are much bigger. Then we need something in between for use in smart homes and this is known as the home area network. So, in a home area network we have different components we have these home area network elements which we are going to talk about in more details shortly. So, the network is basically content within a particular home in a home area network. Then we have there is different standards, the architectures then we have the different initiatives.

So, basically you know. So, we are going to talk about each of these in further detail with respect to the home area network home area network elements home area network standards home area network architectures and the different other initiatives we are going to talk about shortly. So, the network is contained within a home it enables the remote access and control of devices and systems, and provides amalgamation of various

systems within a home such as security system home automation system personal media communication and so on.

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**HAN Elements**

- ✓ Internet Protocol (IP)
  - Multi-protocol gateway bridges non-IP network to IP network.
  - Bridging between new technologies is limited.
  - For new technologies or networks, a new mapping is required for bridging to perform satisfactorily.

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

Diagram illustrating HAN Elements:

- Internet Protocol (IP)
- Wired HAN
- Wireless HAN

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So, let us start with the home area network element the first one is IP protocol. So, we have multi protocol gateway bridges the non IP network to IP network. In other words you know, so you have in a home area network, support for both IP based networks the traditional internet based networks as well as there are some non IP based networks as well. And there are gateways that would bridge multiprotocol gateway; that means, support you know those gateways basically support they understand the language of different protocols both IP based protocols they understand as well as the non IP based protocols both they understand. Bridging between new technologies is limited with the help of you know, IP based a thing; IP based protocol and for new technologies or networks a new mapping is required for bridging to perform satisfactorily.

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### HAN Elements

- ✓ Wired HAN
  - Easy integration with pre-existing house infrastructure.
  - Low cost.
  - Can use power lines, coaxial cables, telephone lines, optical fibers, and other such technologies for communication.

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

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The next one is the wired home area network. So, these basically enables easy integration with pre existing house infrastructure like existing telephone systems existing cables you know cable television cables and so on. So, easy integration is possible with the help of this it is low cost because you know, you do not need additional wiring additional infrastructure you know with the help of these existing systems it can be done. And you know this is cheaper, but at the same time you know it is it has you know different limitations it has different limitations because mobility is one issue.


So, if it is all wired you know you cannot move around and mobility is very important you know, where easy ease in mobility is very important in a in a in a smart environment in any smart environment and in a smart home as well. So, you know all though wired technologies in a home area network are less expensive compared to the wireless counterpart but at the same time it also restricts the mobility of the users at home.



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### HAN Elements

- ✓ Wireless HAN
  - Can use popular home Wi-Fi, ZigBee, and even new standards, such as 6LoWPAN.
  - Wireless makes implementation easy.



Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

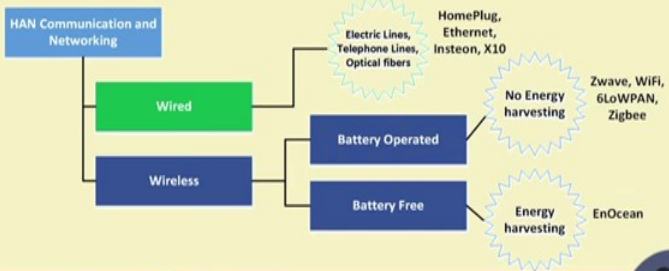
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Wireless home area network uses different technologies like Wi-Fi, ZigBee and the different others that is spoke about in this course by earlier part of this course. For example, the ones that we covered in module one the different technologies those can be used for wireless home area network. So, wireless makes implementation easy it improves the mobility of the users there by improve the satisfaction and the utility of home networks you know over all this utility is going to improve.


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### HAN Medium Classification



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graph LR; A[HAN Communication and Networking] --> B[Wired]; A --> C[Wireless]; B --> D["Electric Lines, Telephone Lines, Optical fibers"]; B --> E["HomePlug, Ethernet, Insteon, X10"]; C --> F[Battery Operated]; C --> G[Battery Free]; F --> H["No Energy harvesting<br/>Zwave, WiFi, 6LoWPAN, Zigbee"]; F --> I["Energy harvesting<br/>EnOcean"]
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So, the classification of home area networks. So, we have the home area network communication and networking technologies which are wired or wireless. Wired would take help of electronic sorry electric lines, telephone lines, optical fibers that are already existing at home, even the cable television cables cable TV cables and so on. Wireless basically are typically battery operated or they can even be better if free, and the battery operated there is no energy harvesting in battery free there is energy harvesting. And some of this protocols that basically help in this battery operated energy harvested communication in a home area network are given over here. So, we have Zwave, Wi-Fi, 6LoWPAN, ZigBee and so on. In enocean basically harvests energy and it is battery free wireless technology.

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**HAN Standards**

- ✓ Universal Plug and Play (UPnP).
- ✓ Application layer technology, mainly web-based.
- ✓ TCP/IP protocol stack provides support for the lower layers, and enables seamless integration of various technologies.
- ✓ Provides transparent networking with support for zero-configuration networking and automatic discovery of devices.

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

UPnP  
DLNA  
Konnex  
LonWorks  
Zigbee  
X-10

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The slide features a yellow background with a blue header and footer. On the right side, there is a vertical list of HAN standards, each represented by a colored bar: UPnP (red), DLNA (grey), Konnex (grey), LonWorks (grey), Zigbee (grey), and X-10 (grey). A small circular inset image of a man is located in the bottom right corner of the slide.

Now, the different standards that are supported. We have the most important one the most popular one the UPnP, universal plug and play. Universal plug and play is a protocol standard that is used typically in most of the smart environments and particularly for building smart homes. See universal plug and play is an application layer technology particularly for web based applications it is used.

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**HAN Standards**

- ✓ Digital Living Network Alliance (DLNA)
- ✓ Trade organization created by Sony, Intel, and Microsoft.
- ✓ Connects cable-based networks with wireless networks for increased sharing of media, control and access.
- ✓ Domestically shares network media resources.

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

UPnP

**DLNA**

Konnex

LonWorks

Zigbee

X-10

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So, the TCP/IP protocols stack provides support for the lower layers and enables seamless integration of the various technologies and provides the transparent networking with support for zero configuration networking and automatic discovery services.

Then we have the DLNA the full form of which is digital living network alliance DLNA. It is a trade organization that is created by companies like Sony, Intel and Microsoft. It connects cable based networks with wireless networks for increased sharing of media control and access. So, cable networks come up with lot of media content, sharing those with the help of other wireless networks with the users. So, the DLNA digital living network alliance basically this helps in this kind of content being made available the media reach content being made available in domestic front for use by the domestic users at home.

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**HAN Standards**

- ✓ Konnex (KNX): an open important standard for home and building networks.
- ✓ Utilizes the full range of home communication infrastructure – Power lines, coaxial cables, twisted pair, RF, etc.
- ✓ Must be setup and configured via a software before its proper usage.

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

UPnP  
DLNA  
**Konnex**  
LonWorks  
Zigbee  
X-10

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Then we have this Konnex standard in short it is also known as the KNX standard, which is an important standard for home and building networks. Which utilizes the full range of home communication infrastructure including power lines, coaxial cables, twisted pair, RF etcetera. When whatever is existing those existing infrastructure the communication infrastructure at utilized in Konnex. And this must be set up and configured via a software before it is proper usage.

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**HAN Standards**

- ✓ Local Operation Networks (LonWorks).
- ✓ Every device includes a Neuron Chip, a transceiver and the application electronics.
- ✓ Neuron chip is a SOC with multiple microprocessors, RAM, ROM and IO interface ports.
- ✓ Splits device groups into intelligent elements, which can communicate through a physical communication medium.

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

UPnP  
DLNA  
Konnex  
**LonWorks**  
Zigbee  
X-10

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Then we have the LonWorks, local operation networks LonWorks, where every device includes a neuron chip. You know, LonWorks has different devices which include something known as the neuron chip which has a transceiver and the application electronics.

So, then neuron chip is a system on chip with multiple microprocessors RAM, ROM, I/O interface ports and so on it is split is the device groups into intelligent elements which can communicate through a physical communication medium. Then we have the ZigBee and ZigBee. We have actually discussed in a lot detail in module one.

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**HAN Standards**

- ✓ Zigbee consists of four layers – Physical, Medium Access Control, Network, and Application.
- ✓ Physical and MAC layers are defined by IEEE802.15.4, whereas Network and Application are defined by Zigbee.
- ✓ Aims at low-cost, low-energy devices.
- ✓ ZigBee Alliance is composed of Mitsubishi, Honeywell, Invensys, Motorola and Philips

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

UPnP  
DLNA  
Konnex  
LonWorks  
**Zigbee**  
X-10

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So, I am not going to talk about in too much detail here. But from a home area network perspective ZigBee is very commonly used. It has the different layers the physical layer, the mac layer, the network, layer and the application layer as you already know. By virtue of your existing knowledge of ZigBee in the module one of this course.

Physical and mac layers in ZigBee are defined with the help of the 802.15.4IEEE standard whereas, the network and application layers are defined by ZigBee, ZigBee itself. It aims at low cost low energy devices and there is a ZigBee alliance comprising of the companies such as Mitsubishi, Honeywell, Invensys, Motorola and Philips.

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**HAN Standards**

- ✓ X-10 enables remote control of compliant transmitters and receivers over power lines and electrical wirings present in the house.
- ✓ Adopted by GE and Philips.
- ✓ Standard defines procedures for transmission of bits over AC carrier signals.
- ✓ Low-speed and low data rate.
- ✓ Mainly used for control of lighting, appliance networks and security sensors.

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

UPnP  
DLNA  
Konnex  
LonWorks  
Zigbee  
**X-10**

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The slide features a horizontal bar chart on the right side, where each bar represents a HAN standard. The standards listed from top to bottom are UPnP, DLNA, Konnex, LonWorks, Zigbee, and X-10. The X-10 bar is highlighted in red and is the longest, indicating its prevalence. The other bars are in shades of gray and decrease in length in descending order.

So, this basically guides the development of the ZigBee standard forward. X-10 is another standard that enables remote control of compliant sorry, of compliant transmitters and receivers over power lines and electrical wirings that are already present at home. It was adapted by GE and Philips, and this standard defines the procedures for transmission of bit is over carrier alternating carrier current carrier signals. And it has low speed and low data rate and is mainly used for control of lighting appliance networks and security sensors.

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**HAN Architectures**

- ✓ Uses XML for description and web-services for control.
- ✓ Follows a Service oriented Architecture (SOA).
- ✓ Not tied to any software, language or architecture.
- ✓ A central gateway connects different technologies.
- ✓ A tech Manager for each technology provides web services for control and access.

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

**DomoNet**  
Jini

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The slide features a horizontal bar chart on the right side, where each bar represents a HAN architecture. The architectures listed from top to bottom are DomoNet and Jini. The DomoNet bar is highlighted in red and is the longest, indicating its prevalence. The Jini bar is in gray and is shorter. The other bars are in shades of gray and decrease in length in descending order.

Now, let us talk about in brief about the different home area network architectures. The home area network architectures two of them are quite popular, the first one is the DomoNet which uses xml for description and wave services for control follows, follows a service oriented based architecture. And it is not tied to any specific type of software language or architecture. Here in DomoNet a central gateway is there which connects different technologies. And there is also a tech manager for each technology that provides a web services for control and access.

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The slide is titled "HAN Architectures" in red. It lists five bullet points with checkmarks: connects various devices with auto-configuration and auto-installation; based on JAVA environment and pursued by Sun Microsystems (Now, Oracle); constructs an organized distribution system without a central node (federation); Jini apps use bytecode to run JVM, and are portable; and follows Object Oriented Paradigm. To the right, there are two boxes: a grey one labeled "DomoNet" and a green one labeled "Jini". At the bottom left, there is a source citation. At the bottom right, there is a small circular video feed of a man speaking. The footer includes logos for IIT KHARAGPUR and NPTEL ONLINE CERTIFICATION COURSES, along with the text "Introduction to Internet of".

**HAN Architectures**

- ✓ Connects various devices sharing their resources with auto-configuration and auto-installation.
- ✓ Based on JAVA environment and pursued by Sun Microsystems (Now, Oracle).
- ✓ Constructs an organized distribution system without a central node (federation).
- ✓ Jini apps use bytecode to run JVM, and are portable.
- ✓ Follows Object Oriented Paradigm.

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

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Then we have this Jini architecture that helps in connecting various devices sharing their resources with auto configuration and auto installation. It is based on the java environment and is perused by the company sun microsystems which later one became oracle.

It constructs an organized distribution system without a central node Jini applications use the byte code and the JVM. So, this is basically java environment compliant that is the reason actually it is using the JVM and the byte code and are portable. Because you know it is it is based on the use of JVM and byte code byte code based technologies. So, where ever this JVM is installed So, you know byte code is basically portable technology in java and that is the reason Jini is also very much portable it follows the object oriented paradigm.



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### HAN Initiatives

- ✓ Middleware for embedded intelligent systems.
- ✓ Connects a Service Oriented Architecture Network.
- ✓ Connected devices may have limited resources, low processing power, memory or energy consumption.
- ✓ Each device has an embedded HYDRA client which acts as a proxy between the device and the middleware.

**Project HYDRA**

**Amigo**

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

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In terms of the initiatives there is that HYDRA project which is about some middle ware for embedded intelligent systems. So, that middle ware was you know was proposed a for a use in IoT kind of environments, where there are embedded intelligent systems or intelligent devices. It connects a service oriented architecture network, the connected devices may have limited resources low processing power memory or energy consumption. Here in HYDRA each device has an embedded HYDRA client which acts as a proxy between the device and the middle ware.

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### HYDRA Protocol Stack

**Applications**

**HYDRA Middleware**

OS: TinyOS, Windows, etc.

Physical layers: Bluetooth, Zigbee, WLAN, etc.

**HYDRA Middleware**

Application Elements | Device Elements

Semantic Layer

Service Layer

Network Layer

Security Layer

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

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So, in the HYDRA protocol stack there are these different there are different layers. We have at the very bottom, we have the physical layer you know. Having Bluetooth ZigBee wireless local area networks and so on top we have the operating system comprising of TinyOS windows etcetera. So, TinyOS is an operating system of window as of sensors. So, it is commonly used along with the sensors. So, TinyOS operating system then we have the HYDRA middleware and then we have this applications. In the HYDRA middle ware we have this application elements and the device elements and they basically handset with respect to this different three layers, the network layer the service layer and the semantic layer and there is a vertically cutting across security layer in HYDRA.

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**HAN Initiatives**

- ✓ Aimed at:-
  - Ambient intelligent systems
  - For networked home systems
- ✓ Features user-friendly interfaces, interoperability, and automatic discovery of devices and services.

**Project HYDRA**

**Amigo**

Source: Toschi, Guilherme Mussi, Leonardo Barreto Campos, and Carlos Eduardo Cugnasca. "Home automation networks: A survey." *Computer Standards & Interfaces* 50 (2017): 42-54.

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So, this is how the overall HYDRA protocol stack looks like. And then comes the other you know architecture which is the Amigo architecture sorry, Amigo initiative not architecture the Amigo initiative which is aimed at ambient intelligence systems for networked home environments. Amigo basically features user friendly interfaces it takes care of interoperability and also the issues of automatic discovery of devices and services, which are very important in IoT environments particularly when we are talking about home area networks, home users and home you know smart homes.

So, with this we come to an end of this lecture. Specifically focusing on smart homes, we have seen the different protocols that are used in smart homes, the different architectures

of smart homes and also the different initiatives the HYDRA, and the Amigo initiatives that use that that are that have that these initiatives are therefore building smart homes.

Thank you.