



Home Automation – Analysis of Current

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Abstract: Home automation systems have been in existence since decades. The implementation of home automation systems have led to the visions of smart homes. However these systems have not been widely adopted due to various barriers. These barriers are high cost of ownership, inflexibility, poor manageability, and difficulty achieving security. The existence of these barriers is a result of the inflexible protocols used by proprietary systems which provide little or no customization. We realize that home automation systems can be made more efficient by eliminating the need for structural changes for installing home automation, providing users with simple security primitives that they can confidently configure, and enabling composition of home devices.

Key words: Home Automation, Gesture recognition

INTRODUCTION

Home automation is the use of one or more computers to control basic home functions and features automatically and sometimes remotely. An automated home is sometimes called a smart home.

Home automation can include the scheduling and automatic operation of water sprinkling, heating and air conditioning, window coverings, security systems, lighting, and food preparation appliances. Home automation may also allow vital home functions to be controlled remotely from anywhere in the world using a computer connected to the Internet. Besides the functions already mentioned, remote control can be extended to telephones and answering machines, fax machines, amateur radios and other communications equipment, and home robot s such as automatic vacuum cleaners.

The fundamental components of a well-designed home automation system include a computer (or computers) with the appropriate programming, the various devices and systems to be controlled, interconnecting cables or wireless links, a high-speed Internet connection, and an emergency backup power source for the computer, its peripherals, and the essential home systems.

The existing home automation system relies on proprietary connection mechanisms for automating home appliances.

The problem with this approach is that the same automation system cannot be extended to accommodate a growing variety of home appliances. Integration of another device becomes difficult as the device might be using a different protocol for automation. The usual reason for manufacturers to use proprietary standards for interfacing their devices to home automation systems is that their standard can handle custom requests from the device to the automation controller. The drawback for this mechanism is that automation controlling devices that don't implement the custom protocol cannot interface with the appliance.

Working of Home Automation Systems

Home automation systems are composed of hardware, communication and electronic interfaces that work to integrate electrical devices with one another. Domestic activities can then be regulated with the touch of a button. From any remote location, users can adjust the controls on home entertainment systems, limit the amount of sunlight given to houseplants, or change the temperatures in certain rooms. Home automation software is often connected through computer networks[3] so that users can adjust settings on their personal devices.

Features of Home Automation Systems

Different home automation systems offer a variety of services and functions. Some of the common features available through these platforms may include

- fire and carbon monoxide monitoring
- remote lighting control
- thermostat control
- appliance control
- live video surveillance
- security cameras,

- alarm systems and
- Real - time text and email alerts.

Customers can save on energy bills by reducing the length of time that lights stay on or lowering temperatures when they have left a room.

Functionality of Home Automation Systems

- Ease of use
- Energy efficient
- Remote Access
- Programmable
- Randomized programs
- Wired/ Wireless system
- Voice control
- Security monitoring service

VARIOUS HOME AUTOMATION SYSTEMS

X10

This granddaddy of home automation protocols dates back to the 1970s and has gone from power line-based to wireless. X10 is not known for robust speed or great communication between units on the home automation network. It started out as a powerline-based system, but eventually went wireless.

X10 advantages:

- Inexpensive
- No new wiring is required .
- Simple to install
- 100's of compatible products
- Control up to 256 lights and appliances
- Time proven -- it has been around for over 30 years

Because X10 products talk over your home's electrical wires they may have difficulties in two situations. The first is when there is an appliance running that generates noise onto the power line. Appliances that may cause problems are motors and advanced electronics.

The second issue with X10 is when your X10 transmitter is on one phase of your home's electrical wiring and the receiver is on the other side. Many times the signal either bridges the two phases at the transformer at the street or via some 220V appliance in the home.

ZigBee

It is based on wireless 802 standard from the IEEE. The ZigBee Alliance is made up of vendors who made products to work with it. It uses one of the key elements in IEEE 802.15.4 which makes a mesh network so that most of the devices communicate equally. It also consumes very low power and uses a mesh network structure to offer excellent range and speedy communication between devices. However, some users have noted that Zigbee devices frequently have difficulty communicating with those made by different manufacturers, so it might not be the best option if you're looking for seamless interoperability.

Advantages:

- Zigbee has always had a focus on ultra low power consumption which made it ideal for battery operated devices or locations where wiring would be difficult.
- This multi-hop mesh networking approach can use redundant pathways to make sure the message gets through even if one of the devices is out of order[5].
- ZigBee devices can be strung together in networks of up to 65,000 nodes[5].
- It enables quality-control engineers to scatter ZigBee units throughout a factory to monitor vibrations that might indicate an imminent equipment failure.
- It allows building managers to control campus-wide electrical and security systems from a single computer

Disadvantages:

- Zigbee is integrated only at the radio level.
- Device makers develop propriety software only.
- Less quantity and availability of other competing devices in comparison with other systems.
- Interoperability among brands is short of guaranteed.

Z-Wave

Z-Wave is a wireless home automation protocol that runs on the 908.42MHz frequency band. It's relatively new in terms of home automation protocols, but has grown quite rapidly in the past few years. The group behind it, the Z-Wave Alliance, now boasts over 1,000 different compatible devices, giving you a wide range of

options when it comes to automating your home. One of the key features of Z-Wave is that it utilizes a type of network called a “mesh network,” which essentially means that one Z-Wave product will pass the signal along to another until it reaches its intended destination. This relay system greatly extends its range. It’s also extremely low power, which is ideal for devices that rely on battery power. Z-Wave-enabled devices create a mesh network between them, and it gets more strong-like-bull the more devices you add.

All Z-Wave modules are produced by a single manufacturer, Sigma Designs. In order for a manufacturer to sell a device, it should be able to “talk” to every other Z-Wave product on the market. This is an example of a deep integration, at both the radio and application levels.

Insteon

Insteon may be the best of all protocols because it combines wired power line-based protocol with wireless. Both perhaps work as a mesh; all nodes on an Insteon home automation network are peers that can communicate when in proximity. If one fails, the other mesh can take over. You can buy Insteon devices at Smarthome.com, which is run by Smart Labs, the developers of Insteon. It’s compatible with X10.

Insteon is a home automation protocol designed to bridge the gap between powerline-based[2] and wireless protocols, so it uses both. It’s also compatible with x10 devices, so it’s not a half bad choice if you’ve got a house filled with X10 stuff already and are looking to transition to wireless. A wide range of Insteon devices are available right now.

Advantage:

- The Insteon Starter Kit is cheaper than the Insteon Hub on its own.
- It will set the foundation for a system that can include a variety of sensors and devices.
- Unlike some other options, Insteon doesn’t charge a monthly fee for the use of its system.

Disadvantage

- The clunky Insteon app is a bit limited and more frustrating to use than it ought to be, making it one of the weaker home automation systems that we’ve tested.

- The user certainly need to expand upon this kit in order for your system to be particularly useful.

Wi-Fi Based.

This is the networking protocol we’re all used to for sharing an Internet connection among laptops, game consoles, and so much more. It’s **super-fast and ubiquitous**. So, of course, it’s inevitable that some vendors would make home automation products to take advantage of that. The other protocols use less power and bandwidth but Wi-Fi’s reach can’t be understated, even if it is overkill to use it to turn a lamp on and off.

Of course, Wi-Fi[4] is already fairly ubiquitous, so it’s not surprising that a broad range of manufacturers have begun making smart home devices that work with it. If you already have a wireless router, you won’t need to pick up a hub/access point in order for your compatible devices to connect to it.

This does, however, come with one key drawback: **interference and bandwidth issues**. If your house is already full of Wi-Fi-connected gadgets then your smart devices will have to compete for bandwidth and will potentially be slower to respond.

Wi-Fi also consumes a lot of power, so it’s **not ideal** for battery-based smart devices like doorbells and locks.

CHALLENGES IN HOME AUTOMATION SYSTEMS

Cost

Although the home automation systems are in existence since decades, it is still limited to wealthy customers only. Today this kind of system is mainly used by technology freaks and wealthy people who can afford to pay a technician to install the system. The challenge really is to enable the people with few financial resources to purchase desirable sensors and actuators for a home automation system from different suppliers and potentially using different communication technologies and different protocols and then establish the interoperability and configure it to meet the desires of the residents.

These systems also usually cost thousands of dollars — or for elaborate systems, tens of thousands or even hundreds of thousands of dollars. While you can add components to the package, you can’t substitute for what’s already in it or you cannot remove what you

don't want. The hardware itself is very costly. The amount of work required for installation of a whole home automation system is very high. Also, the services, maintenance and extended warranty costs can shoot up the total monetary cost of system. The number of applications preinstalled in the system is less. To get access to other applications, the purchase cost becomes higher.

Systems can start from a \$100 for single product items, up to \$3,000 for a small multi-room system. While for a full luxury home automation system you need to spend approximately \$70,000 - \$130,000 and beyond. The other costs like electricity, maintenance and service may add up more.

One of the key ways to save costs on any multi-room system, is to look at how the system is controlled. Replacing touch screen panels with iPhone, tablet or any smartphone would not only make the system way cheaper but it will also increase the efficiency and ease of use for users. The Do-it-yourself (DIY)[1] facility to users would also drop the cost of service and installation to zero making it more affordable.

Interoperability/ Fragmentation/ Inflexibility

The established home automation system is developing at an incredible pace but this system still lacks a single, simplified and widely used protocol which can be integrated into all systems.

There are dozens of manufacturers who show off their complete Home Automation Systems. Each manufacturer had the same general selection of keypads, touch-screens, remote-controlled light switches, and plug-in modules.

However, each offering was based on one of several incompatible standards. And therein lies the problem: With no single technology standing out as being the best in flexibility, performance, reliability and cost, we have a mishmash of incompatible products.

They lack system Scalability, which is the ability of a system, network, or process, to handle growing amount of work in a capable manner or its ability to be enlarged to accommodate that growth.

For example, system upgrade/downgrade by adding/removing hardware interface module should be easy and systematic task

Choosing to use multiple brands meant dealing with the challenge of integrating separate systems. These

difficulties made some of the devices disconnected from the network. Different systems and brands use their own different proprietary protocols[1]. This leads to the fragmentation of compatible devices. This problem may not be noticeable much but this leads to lot of compromises. A better product of one type may be compromised for another product just due to incompatibility issues. This problem may lead to poor manageability and lack of freedom for user.

Proper interoperability by using well established network protocol. For allowing several third party developers to make additions to the framework in the future, it is essential that the framework core is stable. This will ensure that the entire system will not crash due to a faulty addition of new components.

Complex Operation:

Home automation systems are built for automation, trying to figure out things and ways to perform multiple tasks by reducing user input as far as possible. This is usually done using sensors and/or rule based systems. The difficulty here is that rules cannot cover all possible cases and sensors are practically inaccurate.

Majority of the home automation implementations require some kind of technical expertise to use. User interfaces are kept for users to interact with the system. This is an implication of the fact that the systems are not fully autonomous. To achieve this autonomy systems use sensors to try and understand the environmental factors. Based on these sensors, a decision in conjunction with the automation rules is taken. But the sensors may not be accurate or sometimes be so accurate that the wrong decision is taken by the system. Because of this, the systems have some kind of overrides in place to avoid false triggering of automation tasks. These overrides again require user intervention and further adds to the complications in the system operation.

Inflexibility[1] adds to the complexity of the system. Many households constantly change their home appliances and this requires changes in the system that are difficult to carry out without user actions. Addition of new devices usually requires the user to setup some parameters of the appliance in the system with addition of rules and triggers that will automate the device. Granted this is only one time activity, but again due to human intervention, complexity goes up. Every time a new appliance is added, setting up rules is a tedious task. Also human errors in setting up the rules and

triggers may also cause distress to the user. This leads to debugging problems.

Complexity contradicts the basic goal of a home automation system-to automate tasks. Reduction in complexity will greatly increase use of automation systems in homes. Management tasks required on the system should be minimal. Autonomy is greatly required in setting up of new devices to be added to the system.

Security:

Security has sometimes meant trade off with features. Managing passwords is a tedious task for users and biometric or facial recognition solutions are expensive to implement. Users are also sometimes leak passwords and sometimes the security mechanism themselves are flawed.

Many home automation systems implement a password based security mechanism. This is secure as long as the user does not forget the password or leaks it. Passwords can also be guessed making them insecure. Also, such mechanisms get in the ways of features, additional interactions required with the system hinders the goal of automation.

Different approaches to security have been tried out to minimize user interaction. One of them being use of facial recognition for security. But this also is not as fool proof as many times false positives are made by the facial recognition software. A physical card or RFID system can also be put in place however managing the RFID chip or card is also cumbersome.

Remote access has also been a topic of debate to be included in the automation system. It makes the system more vulnerable to outside intruders. However people installing home automation systems are more inclined to using remote access. Securing remote access is crucial for the success of automation in the home market.

Security can also be a problem for guests in the house. Every time requiring a family member to authenticate actions is not feasible. Therefore temporary access should also be implemented to provide minimal obtrusive security.

A passive security system requiring little or no interactions with the system where credentials can be obtained from natural actions of the user is a necessity.

Difficulty understanding user context:

There are many variables and parameters that lead to a decision from the rules in a home automation system. However a slight drift or change or incorrect measurement of any of these variables can cause a significant change in the final decisive outcome of the automation action. Sophisticated AI[5] methods that are learning and are adaptive to the user can be employed to understand the user context better, however these methods rely on probabilistic outcomes and since they are learning in nature, the past outcomes effect the current situation. This can cause a problem in places where sudden environmental changes occur.

A good measure of the user context requires increasing the number of parameters that affect the outcome. A way of doing this would be to increase the number of devices that capture user interactions with the environment. For example increasing the number of sensors. However there is a limit to this too. We could interface with the already existing devices with the user like smartphones and other appliances to increase the number of variables that affect the final outcome.

Reliability

No system can be successful unless and until it is reliable. The lack of reliability is a major factor for the snail pace growth of present home automation systems.

Home automation technology use is limited to technology enthusiasts, largely because of the inherent growing pains the industry experienced. As reliability increases, so will the number of users. Home automation technology can be expanded from being an expensive play toy to becoming a useful tool that could be used by anyone and everyone. Each technology has evolved to the point that reliability seems to be pretty solid but when it comes to the end-user experience the scenario is different.

Out of the existing technologies, X-10 power line technology is probably the most unreliable, largely due to distance and phase limitations. The hard-wired home automation systems is more reliable as the complete wiring and device installation is done as a part of the system only. Making the home automation system modular and using simple technology or user-friendly trigger actions can make user understand the system and also make the home automation system more efficient and reliable.

RESULTS/OBSERVATIONS

Many of the existing automation systems compromise on flexibility for a low power or low cost home automation solution. For example, to reduce cost and to setup a wired system without adding additional cabling, the X10 standard uses existing powerlines and transmits automation messages as analog signal to devices. Wireless solutions like Zigbee and Z-wave use protocols and devices adhering to a particular standard, thus requiring additional devices to be installed both at the home and to the devices that are to be automated.

The X10 standard uses power lines as a medium for transmission of automation messages because of its high availability in households. The above table shows the growth of internet users in the last decade. We can observe that internet penetration rate within the population is increasing at a rapid rate. By the end of this decade, we can safely assume that internet will penetrate 60% of population. Thus a protocol that runs over the WLAN or Ethernet standard can be considered as a viable option for transmission of messages given their popularity and the number of connected devices. As more and more devices become connected via internet, it makes more sense to use existing protocols instead of using a separate hardware component dedicated for home automation. This also solves the problem of flexibility

Zigbee and Z-Wave protocols were designed to be power efficient and dedicated towards home automation. The requirement for low power consumption came as these standards were operating over separate devices dedicated to home automation. However a Wifi based system will operate over the existing WLAN devices thus eliminating the need of dedicated separate hardware for connectivity.

The general scheme for automation devices is to take input via sensors and immediately take relevant action or inform the central controller. Such a scheme is good where input is simple, however this leads to a problem of user context detection. For detecting user context, usually a collective decision must be taken by multiple sensors sensing the user environment. This is possible if the sensors can connect with each other and sufficient bandwidth is available to them for sending complex messages in time. Many standards do not support high bandwidth transmissions to reduce power consumption

or they are not flexible enough to transmit dynamically generated messages. A wifi network will be better suited for this operation. Table I below shows the comparison of technologies in Home Automation.

Table I: Comparison Of Technologies In Home

	X10	Zigbee	Z-Wave	Insteon	Wifi Based
Cost	Very Low	Initial Cost Low	High Cost	High Cost	High Initial Cost
Flexibility	None	Mid	Low	Low	High
Complexity	High	High	High	Low	Low(based on implementation)
Security	None	Available	Available	Available	Available
User Context Detectability	None	Available	Available	Available	Available

Automation

An alternative to using multiple sensors is to use gesture based automation. Gestures are natural language of the body and can be successfully be used to generate multiple parameters for input. Gesture control requires less learning curve, less number of input devices and provides more flexibility over the input parameters as the input is not governed by the type of sensor but on the user generating the gesture.

We require a solution that takes best of all the technologies and with little or no compromise achieves flexibility, low cost and security.

CONCLUSION

Considering various factors that affect mass adoption of home automation, we have identified that wifi based automation system that uses gesture recognition provides a feasible home automation solution.

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