Unified Services for Home Area Network

Yash Shah
Georgia Institute of Technology
Department of Electrical and Computer Engineering
shah_yash10@gatech.edu

Abstract

Today we are surrounded by dozens of network enabled devices from dozens of manufacturers that make up our home network. These devices can be remote operated/monitored, but each device is managed by a different application and use different network protocols, making the management of these devices difficult. The objective of this paper is to evaluate these existing network technology implementations of a Home Area Network and to propose a new system for the unification all devices within single networked system. We begin with the analysis of the existing system utilized for the implementation of various device and services in a Home Area Network, the need for a new system and propose a new system. We further discuss the method of implementation of the proposed system and the use of cloud services to enhance its usability and its emergent features. Concluding with the future scalability of the system with the introduction newer systems like IPTV.

1. Introduction

Broadband access networks and home networking are becoming household names as more and more residences are aquiring and utilizing numerous network enabled devices. Resulting in home networks becoming a point of convergence for the next generation of the digital infrastructure. As technology advances, eltronic devices like household appliances, television, stereos, home security systems, etc, are evolving with it and are being enabled with digital connectivity and contol over a network, forming a new breed of intelligent appliances communicating over a rapidly expanding digital network.

Previously, the limitation of broadband access networks formed a major obstacle towards the development and deployment of the home area networks. But with the introduction of high-speed broadband delivery systems, along with the advances in wireless access technologies, the demand for intelligent home and personal devices is increasing rapidly. This influx of various devices, is putting unnecessary burden on home networks because most of these devices operate on varied frequencies and protocols, throttling the efficient utilization of the available home network resources. Resulting in the need for the development of a unified home area network; for all the devices operating within it. The unified solution to this challenge should provide inter-connectivity between in-home devices, efficiently utilizing the high-speed broadband access and also implement security measures to protect the home network from intrusion forming a singular standard of home connectivity for the future devices.

2. Broadband Home Access Architecture

Broadband home access (BHA) architecture represents a technical solution that could bring pervasive computing to fruition at home [5]. It serves as an economic conduit that connects the next generation of internet based vendors with consumers located in the comfort of their home.
There are three distinct technological components in a BHA architecture that must be deployed as an integrated and interoperable system. They are 1) the residential gateway (RG) 2) the Home area network (HAN) and 3) the electro-domestic network device (END) [Figure-1].

2.1. Residential gateway

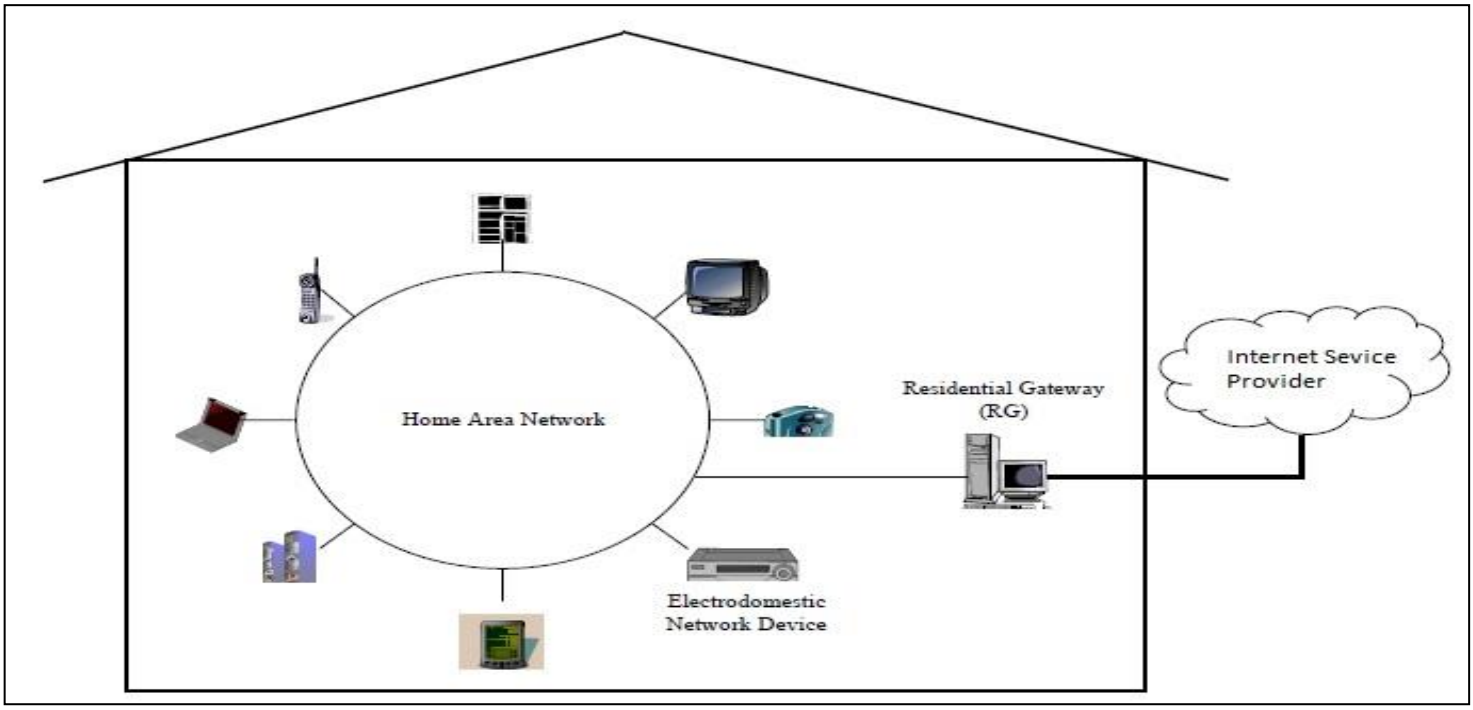

Figure 1: Broadband Home Access architecture

The residential gateway (RG) is the interface device that connects the in-home network to the outside world (Internet). It offers an effective bi-directional communication channel to every network device in the home. Since it serves as the centralized access point between the home and the world it serves as an important technological component in the BHA architecture [2]. Moreover the RG serves as the convergence point that bridges the different broadband and local area network (LAN) technologies.

2.2. Home area network

The home area network is a high speed in-home network that distributes the information to the devices. It provides interconnectivity for all devices within the home premise [3]. A wide variety of technology exist for interconnecting the devices within the home, but no single technology meets all the requirements for the diversity of applications that could be envisioned. In future sections we discuss the existing network technologies that represent a large fraction of this market [4].

2.3. Electro-domestic network devices

Intelligent devices or tools used in a home environment are referred to as electro-domestic network devices (ENDs). Such devices include computers, appliances, embedded electronics with network capabilities, devices which can communicate with each other [5]. These devices will not only be able to communicate with other in-home devices, but also have the capability to connect to the outside world (internet). The devices which are capable of communicating with the internet will enable the development of applications with remote administration and web-based home control and automation.

3. Home Networking Technology

Before we can propose a new solution a requirement analysis for the implementation of a home area network followed by an evaluation of the current system implementations is needed, so that we can draw upon their strengths and deficits for the creation of a new system.

3.1. Home area network application requirements

The factors driving the need for high performance Home area network applications are:

3.1.1. Multimedia Incorporation

The existing and emerging digital devices are creating a need to support multimedia content at home. The home network should possess the capability and the capacity to support all types of digital content including local content (e.g. DVD, MP3) and broadcast content (e.g. Video on demand, streaming media) [4,5]. Such multimedia traffic encompasses video, audio, voice and data. An ability to support all forms of media is expected to be a killer app that would enable a massive adoption of home networking systems. Therefore, a home network must support the coexistence of data and isochronous content (voice, video).

3.1.2. Adaptability to increasing nodes

With the boom in embedded smart electronics, the number of nodes connected to a home network is expected to continue rising. Since the wireless devices will share the same bandwidth, higher network throughput and speed is necessary to accommodate the additional devices. Therefore a wireless network with an access mechanism that supports multi-nodes inter-connectivity without performance degradation is essential to support the growing home wireless networks.

3.1.3. Access to High speed broadband network

The growing demand for online multimedia content and faster internet access is driving a massive deployment of high-speed broadband access network. Hence, it is imperative to avoid the formation of a choke-point between the home network and the broadband access. Thus the selection of a network protocols that can efficiently deliver the broadband access speeds to the home networked devices is imperative.

3.1.4. Security

Due to home appliances and devices gaining the ability for automation and remote access, especially the home automation systems, it is important to keep these devices secure against unwanted access or outside intrusion. Therefore security measures needs to be implemented alongside the home network to keep the networked devices from illegal intrusion.

3.2. Existing technologies

Currently there are many wireless systems in in several bands competing for the home network standard. Methods considered include point-to-point, point-to-multipoint and multipoint-to-multipoint for bringing broadband communication information and provide networking capabilities amongst the end users.

We will be evaluating four network communication protocols which form a prominent bulk of home network systems. These protocols are 1) ZigBee, 2) Z-Wave, 3) Bluetooth and 4) WLAN

3.2.1. ZigBee

ZigBee is a standards-based wireless technology designed to address the unique needs of low-cost, low-power wireless sensor and control networks a marketplace [6]. Since ZigBee can be used almost anywhere, is easy to implement and needs little power to operate, the opportunity for growth into new markets, as well as innovation in existing markets, is limitless. ZigBee's transmission distance is limited to 10–100 meters line-of-sight (Fig-2), depending on power output and environmental characteristics. This standard was brought into effect alongside Wi-Fi [7] as a low cost alternative for wireless connectivity. Since then it has gain popularity for WPAN implementations.

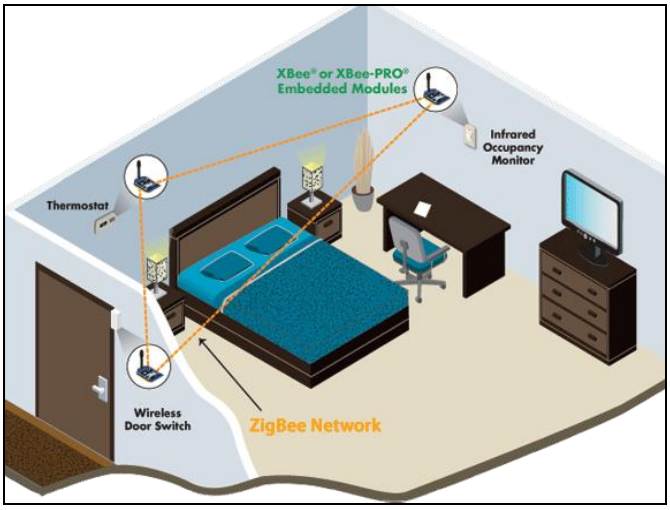

Figure 2 : ZigBee Network

3.2.2. Z-Wave

Z-Wave is a wireless communications protocol designed for home automation, specifically for remote control applications in residential and light commercial environments. The technology uses a low-power RF radio embedded or retrofitted into electronic devices and systems, such as lighting, access controls, entertainment systems and household appliances [fig-3]. Z-Wave operates in the sub-gigahertz frequency range, around 900 MHz. This band competes with some cordless telephones and other consumer electronics devices, but avoids interference with Wi-Fi, Bluetooth and other systems that operate on the crowded 2.4 GHz band. Z-Wave is designed to be easily embedded in consumer electronics products, including battery operated devices such as remote controls, smoke alarms and security sensors.

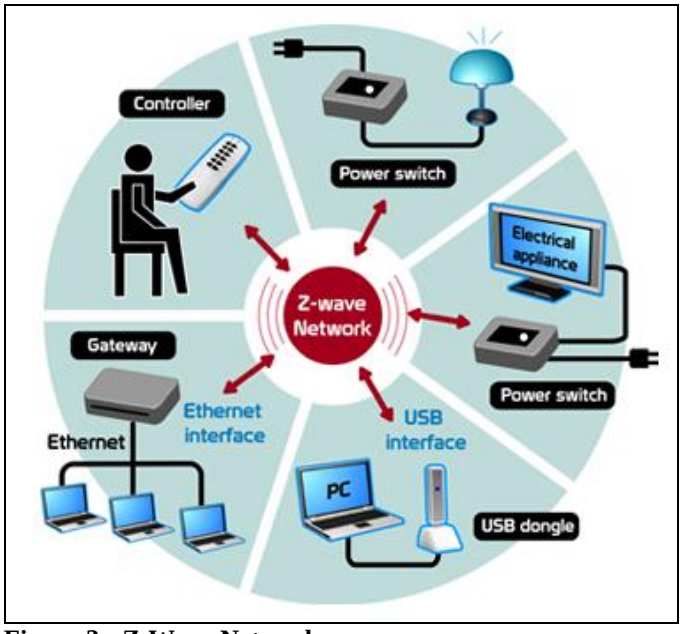

Figure 3 : Z-Wave Network

3.2.3. Bluetooth

Bluetooth is a very short range wireless network that can be used to exchange information between devices in the each of a person [fig-4]. Bluetooth wireless technology has become the de facto standard as well as specification for small-form factor, low-cost, short range radio links between mobile PCs, mobile phones and other portable devices. Bluetooth enables users to easily connect to a wide range of computing and telecommunication devices and therefore can be used for a variety of purposes.

One key issue in the feasibility of this technology is the inter-networking of wireless technologies to create a heterogeneous wireless network and its extremely short operation range.

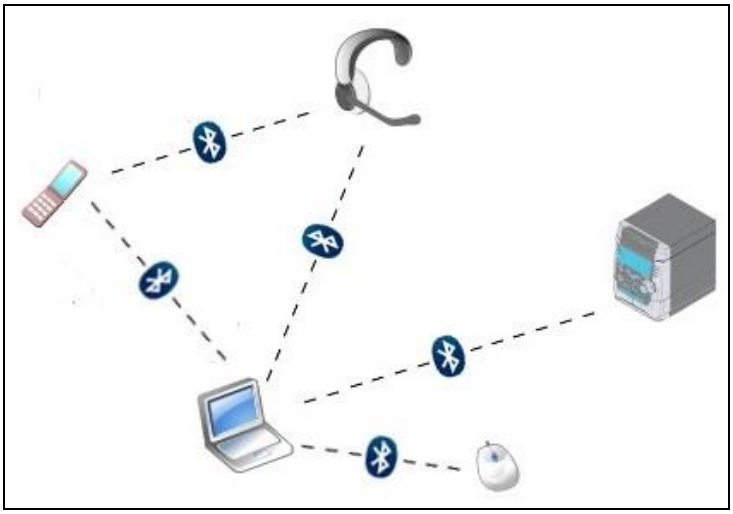

Figure 4 : Bluetooth Network

3.2.4. Wireless Local Area Network (WLAN)

A wireless local area network (WLAN) is a wireless computer network that links two or more devices using a wireless distribution within a limited area such as a home, school, computer laboratory, or office building [Fig-5]. This gives users the ability to move around within a local coverage area and still be connected to the network, and can provide a connection to the wider Internet. Today's home networking applications is driving the need for high-performance wireless network protocols with highly throughput and isochronous multimedia services. WLAN presents an ideal framework and the current popular solution for wireless networking as its operational characteristics can be compared to cellular networks with its frequency planning, mobility and its seamless channel handoff.

3.3. Technological comparisons and drawbacks

We're at the very beginning of seeing what connectivity truly means. It is a feat that seems so simple to implement, but in reality is out of reach

Figure 5 : WLAN Network

for all but the most dedicated homeowners right now. Today's connected home: a collection of appliances and home gadgets offer enhanced functionality but won't work together in concert unless are all from the same manufacturer — perhaps a x-company fridge, a x-company stove, a x-company washer, and a x-company dryer.
That is not very smart. What the smart home really needs is one single way for appliances to speak with each other — a standard that can do for appliances what Wi-Fi did for laptops, tablets, and the internet. The most prominent solutions today have their own drawbacks and associated limitations which prevent them from becoming the industry standard.

3.3.1. Z-Wave

The Z-Wave protocol is a great option for home networking - it allows every local Z-Wave device talk to each other; but it is limited by its manufacturers, these devices aren't interoperable worldwide, and it's not truly open to everyone. Z-Wave is a proprietary system made and licensed by one company, that means Z-Wave has been able to tightly control how its devices talk to each other — vetting each one to ensure that it can actually speak with the products it's supposed to but its deployment is limited due to Z-Wave's to high chip prices and product implementation controls as dictated by the Z-Wave Alliance.

3.3.2. ZigBee

ZigBee Alliance introduced a new standard to discounts Z-Wave proprietary standards. This new standard known as ZigBee is an open standard networking protocol. The ZigBee standard has been in the making for over a decade, and in that time it's both grown more capable, improving and adapting to achieve even greater interoperability. But ZigBee's been having some trouble doing that. Right now, not all ZigBee products can communicate with each other, and that's a major problem for what's intended to be a standard. It's a problem that the ZigBee Alliance has been working on but with no evident results.

3.3.3. Bluetooth

Bluetooth and its variant Bluetooth Low Energy (BLE) module system on a chip today can handle the networking on-boarding as well as offers much lower power consumption so devices can go a year without needing to replacement battery. Furthermore features of Bluetooth 4.0 also known as Bluetooth Smart include appealing features like advanced audio distribution profile (AADP) and development platforms for home-control applications, controlled directly from an app without the need for gateways or onerous network configurations allow for rapid development and deployment of Bluetooth enable devices. But the very short networking distance of the Bluetooth protocol limits its applicability in a home environment.

3.3.4. WLAN

The most well-known standard amongst all wireless network protocols is the Wi-Fi. As the Internet grew, industry standards like Ethernet came into being, which encouraged developers to adopt a similar standard for radio frequency communication as well and Wi-Fi soon rose to become the solution for short-range Wireless Internet. Technology as old as Wi-Fi evolves through many iterations. Wi-Fi is also unique in how it operates on both the common 2.4 GHz frequency and the lesser-used 5 GHz frequency in dual band versions. With a range between 100 and 300 feet on average and complex, hub-based network construction, Wi-Fi is the ideal solution for all wireless Internet network and wireless broadband access points.

But this protocol is mainly used as a wireless network access protocol for the internet. Recently applications have been developed to utilize this protocol multimedia streaming between devices, but the implementation is expensive as it requires additional interface devices.

3.4. Other emerging standards

Since no single standard has been defined to unify home network devices and other various devices, many new standards are being developed to solve this problem. Some of the more prominent efforts in this field are:

3.4.1. AllJoyn

AllJoyn is an open source project intended to enable compatible smart devices to recognize each other and share resources and information across brands, networks, and operating systems [10]. The project, initially developed by Qualcomm Innovation Center is now a collaborative open source project of the All-Seen Alliance. The AllJoyn protocol would enable manufacturers to create their own custom apps for onboarding devices onto a Wi-Fi network, complete with control and notification services.

3.4.2. Google's "The Physical Web"

The goal of The Physical Web is to provide "interaction on demand" so that people can walk up and use any smart devices without the need for intervening mobile apps [12]. This would make it possible for users to simply walk up to a bus stop and receive the time until the next arriving bus, without any additional software needed. The project is an ambitious bet on the future of smart devices.

3.4.3. Thread

Thread, a new IP-based wireless networking protocol, is a collaborative effort between Google's Nest, Samsung Electronics, Freescale Semiconductor and Silicon Labs [11]. The Thread protocol provides a common network language by which home devices like smart thermostats and smoke alarms can talk with each other forming an ecosystem for connected home devices and apps

4. Proposed system

Even though the mentioned technologies function efficiently within their own targeted application; each standard is used in different solutions:

- Wi-Fi primarily targets Internet hubs and connections.
- ZigBee is focused on home sensors and monitoring devices.
- Z-Wave plays nice with generation home automation and home security.
- Bluetooth primarily focuses on short range data transfer, widely used for audio streaming

But none of them covers all of the requirements for a Home Area Network. But Bluetooth and Wi-Fi, already an established standard, are slowly emerging as the protocol of choice for network implementation. These technologies with their new variations – Bluetooth Smart and IPv6 over low power personal area network (6LoWPAN), created to compete with ZigBee and such with its low power consumption.

Figure 6 : Current segregated standards

As we have discussed none of the technologies fulfill all the requirements for building a unified home area network, but each have their own strengths which makes them the technology of choice for home networking. Therefore, what is important is not the unification of all devices under a single standard, but the ability of the devices to

communicate with each other irrespective of the standard being used.

We can, to some degree, agree that device communication standards are irrelevant to end users. What is most important to them is ease of use and unrestricted access. Therefore my suggestion is to make standards irrelevant to developers too, allowing them the freedom to develop on standards of their choice and not be restricted by any single standard [13].

This can be achieved by consolidation of services, assembling a collection of appliances and get them all to communicate through letting devices speak to each other so long as they can sync with an internet-connected hub. The hub acts as a central point of contact to a cloud services to which all the ENDs are connected. By allowing every device to speak to a cloud system, inter-operability and inter-connectivity can be achieved virtually through the cloud. After all, it's easier to innovate in the cloud than force one monolithic standard for all communications.

The single point of connectivity for all the different protocols can be achieved through the use of already existing technologies like the AT&T's Digital Life controller built by Cisco or through Broadcom's Wireless group connectivity chipset or many other lesser known adapters that offer a single point of connectivity for all the various home network protocols. And the management of all these devices can be accomplished by using cloud computing's versatility of PaaS (Platform as a Service) and SaaS (Software as a Service)

4.1. Advantages

There are many advantages to this, some are evident other are emergent. It also addresses all the requirements for the establishment of a unified home area network.

4.1.1. Multimedia Incorporation

The implementation of this system which services all home network protocols, management of multimedia nodes becomes simple. As Wi-Fi and Bluetooth already have the capability to support not only data but also media streaming (music- Bluetooth, video- Wi-Fi, e.g. chromecast). The addition of a cloud interface can makes it possible to stream directly from the AP.

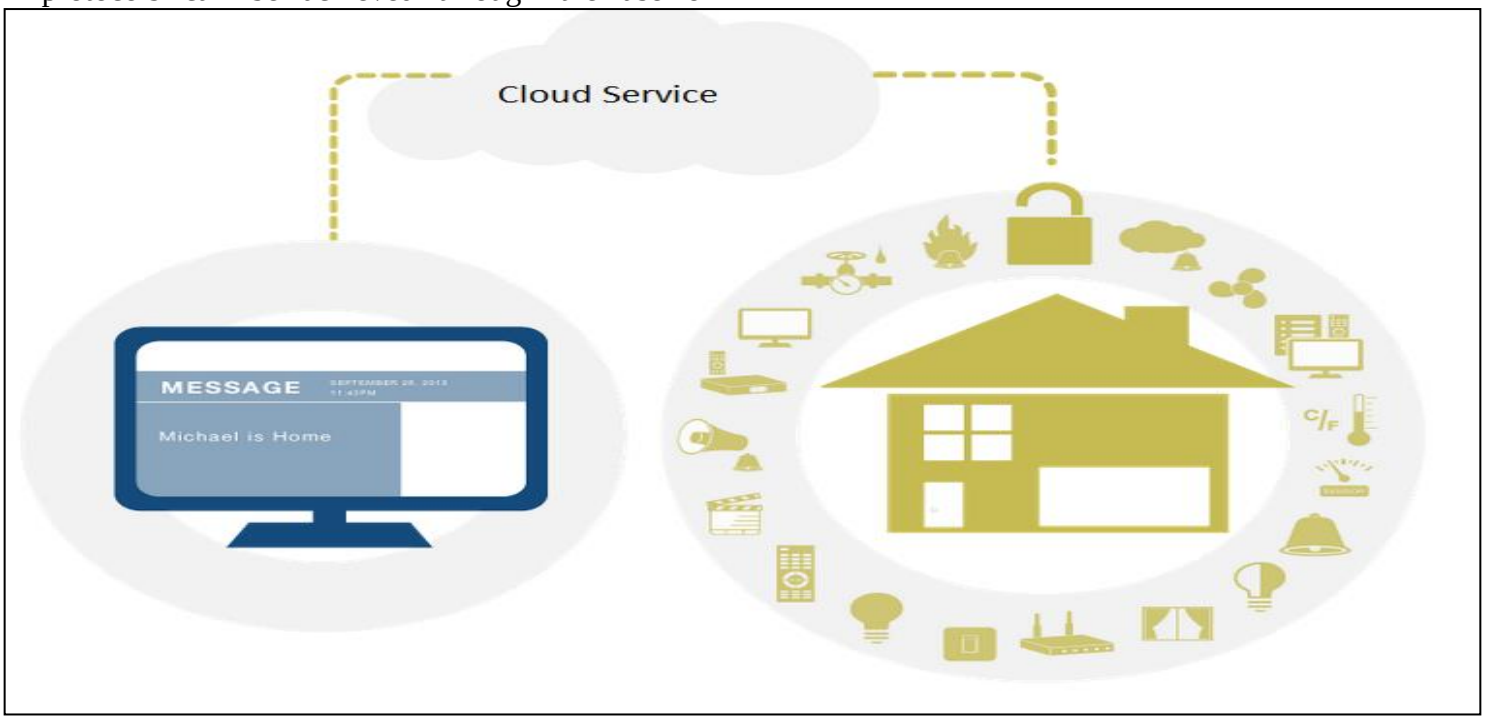

Figure 7 : Unified Home Area Network

4.1.2. Adaptability to increasing nodes

The rapid advancements taking place in WLAN technology overshadows the breakthrough in any other wireless technology. Using the current WLAN system, it is now possible to service the constantly increasingly number of END devices using a single AP, without severely affecting the liveliness of the other nodes.

4.1.3. Access to High speed broadband network

Since the RG already serves as data delivery device connecting the high speed WAN to LAN. Access to high-speed broadband access networks is assured. Furthermore it also acts an AP with Wi-Fi capabilities so it can be used as a unification point for our system.

4.1.4. Security

The different networking protocols used in the home environment leaves a wide margin of vulnerability that can be exploited. The proposed system creates a choke point for the home access technologies, making it easier to secure the network. Furthermore, due cloud services, it also becomes possible to use encrypted communications like SSH, VPN, etc., making the network more secure.

4.2. Emergent features

This system also demonstrated some emergent features in regards to content delivery system. To analyze the need of this feature I conducted a survey. The survey revolved around the Television viewing patterns of today's society and the changes in the content delivery system that needs to be made to tap into this market.

Based on this sample survey results (fig: 8-10) we can see that the demand for online media content is high and the users want access to their paid services not only at their home but on the go as well. The cloud platform makes it possible to implement this system. If the cable media broadcasters made their content online on a cloud platform, the content becomes accessible to the user through their cloud account anywhere, anytime as long as they have an internet access capable of managing the bandwidth requirements of this service

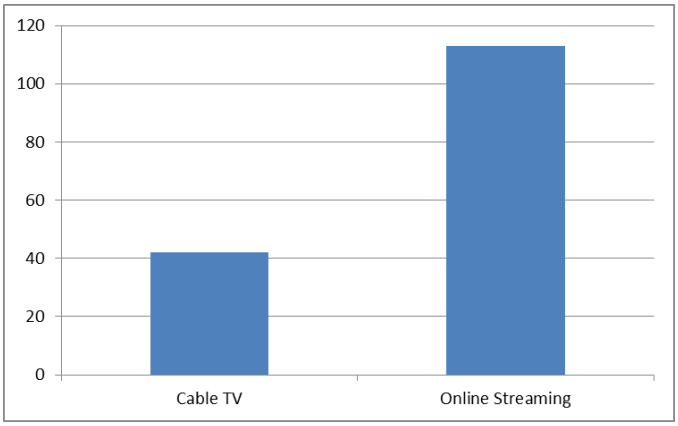

Figure 8 : TV viewing pattern

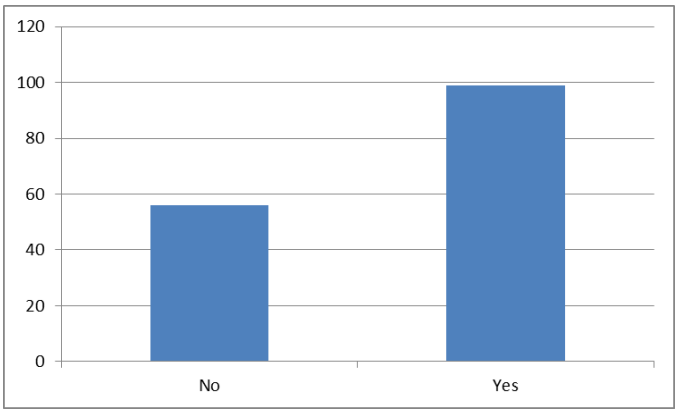

Figure 9 : Need for a single control platform for all HAN devices

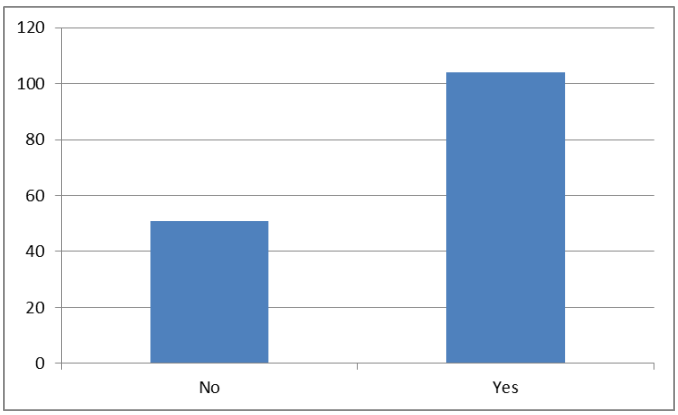

Figure 10 : Access to Subscribed media content online- on the go

5. Conclusion

As a conclusion we can say that, though a single standard for communication would be beneficial for the unification of HAN, no such standard has emerged or is expected to emerge in the foreseeable future. Furthermore the system proposed in this paper offers immediate resolution for this problem with emergent and scalable features that can not only unite all the existing standards under a single banner all also fulfill the vision of a truly unified Home area network.

6. REFERENCES

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