M2M Protocols, Solutions and Platforms for Smart Home Environments

Integrating C.STATUS™ and the MediaSense

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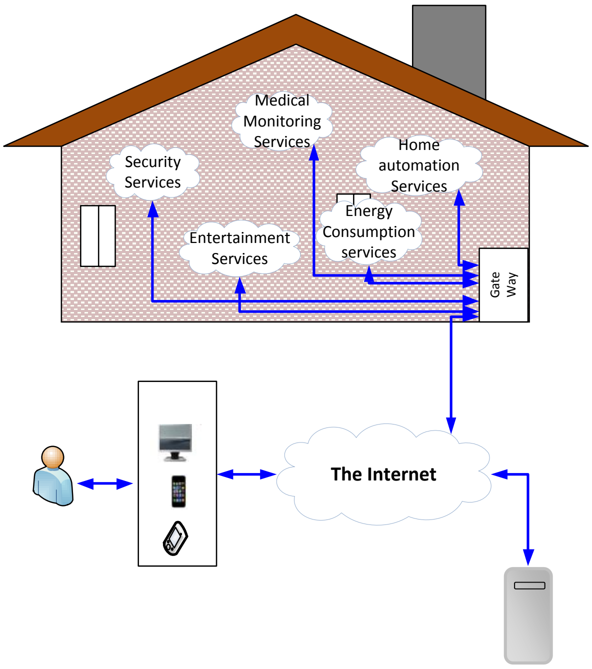

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Abstract

Digital technological breakthroughs have brought about a huge change in the way the society interacts, responds to the immediate environment and the way that people live. Furthermore, Ubiquitous Computing and dirt cheap sensors have created a new paradigm in digital technology where human beings could control their environment in a different approach. In a number of paradigms of digital technology, multiple proprietary solutions in industry results in a huge cost for the end users to use the technology and thus a very sluggish penetration of the technology into the society. Moreover, such unorganized and vendor oriented standards create additional burdens on a person concerned in design and implementation. This thesis presents existing and emerging technologies in relation to smart home environment having an aim to manifest available open standards and platforms. Smart Home Environment Infrastructures have been presented and discussed. Evaluation and integration of a proprietary elderly care sensor system dubbed C.STATUS™ and the MediaSense overlay network has also been presented. Performance measurement and comparison has been conducted in relation to the proprietary sensor system running on the top of the peer-to-peer MediaSense Platform with the existing C.STATUS™ centralized sensor system. C.STATUS™ User Interface has been designed and implemented for an Android mobile platform.

Acknowledgements

I would like to pass gratitude to all who participated in this thesis work by forwarding new ideas, comments, suggestions, advice and necessary resources on the technologies presented. Nevertheless, I would like to give special gratitude to my tutor Olle Johnsson who is a researcher at Acreo for providing me with devices to work on and other valuable information in addition to excellent supervision. I would also like to pass a warm gratitude to the other tutor, Stefan Forsström, a PhD Student at Mid Sweden University for providing me with both tools and guidance throughout the period of this thesis work.

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1 Introduction

Modern Smartphones come with bunch of cheap and powerful embedded sensors. In addition, each year the computing power of the smartphones keeps increasing. More importantly, these smart devices are programmable thus allowing developers from all corners of the earth to build different applications. This has meant that smartphones are becoming the central computing and communication devices for use in day-to-day human life; and due to the prevalence of dirt cheap sensors, a new paradigm of wireless sensory networks is immerging in one direction. In the other direction , different 'things ' such as ,house hold devices including refrigerators, stoves , microwave ovens, irons, doors , windows ;medical equipments, military tools and machineries , industrial monitoring equipments and environmental monitoring devices are being incorporated into today's wireless sensory networks with is thus moving towards what is going to be "Internet of things" in the future.

The combination of sensors embedded on smarthphones, Wireless sensory network, sensor systems, programmable devices and easy access to the corresponding programming tools opens a door for innovative research and the development of application that would turn the surrounding physical environment into a virtual object. Therefore, in this thesis analysis and categorization of open sensor network standards as has been applied to smart home environments will be conducted. In addition, the Integration of the C.STATUS™ sensor network and the MediaSense Platform is studied.

1.1 Background and problem motivation

Sensors are revolutionizing the life style of digital generation; Sensors are invading all aspects of life from the home, working place, streets, body... etc. Most Sensor network protocols and technologies interconnecting sensors with the corresponding backbone are proprietary. In this regard using a common platform for these sensor networks reduces the problems that might be encounterd by a programmer but may also ease intercommunication between different sensor networks. Thus, common platforms are crucial in the future. In this thesis different trends in the smart home environment will be thoroughly studied, focusing on the standards underlying the communication link between sensors and the control devices.

In this thesis a smart home environment scenario that is able to deal with doors and windows and which sends a message such as "I'm still open" or also stoves and irons which are able to send a message "I'm still on" to the display panel mounted next to the door when leaving a house , will be evaluated. In addition if a mechanism was available to enable to see these messages on mobile devices or if the person who cares for either children or the elderly would receive these messages remotely it would add a value for the system developed. Thus, application that display the information shown on the panels will be developed for an Android mobile platform.

Sensor networks span a wide range of scenarios, from simple sensor data displays to complex distributed sensor systems that can help to detect weapons of mass destruction. In response to this, both academia and industry are building sensor network solutions and ratifying protocols to address their own specific demands. However, interoperability between the different wireless sensor network solutions will be required, in order to gain advantages when combining different third party solutions through a common standard interface. Therefore, the problem in this thesis is to determine whether any protocol exists which is designed to serve as a common platform for smart home environment, as well as how interoperability with different types of smart home solutions is dealt with. Moreover, the performance of a sensor network built on the MediaSense platform will be measured and studied.

1.2 Overall aim

The project's overall aim is not only to study and examine different protocols and solutions related to smart home environment that exist today and those that will emerge in the near future but also to study the mechanism with regards to how to integrate the proprietary sensor system at Sensagon with the MediaSense platform. Moreover, an application which would retrieve data from Sensagon's server and display sensor data on an Android mobile platform is part of the overall aim of this project. In this case, a simple and very easy to understand user interface will be created.

1.3 Concrete and verifiable goals

The first goal of this thesis has been to analyze, evaluate and categorize the open standards for a smart home environment that currently exist and those that are emerging.

The second goal has been to study the mechanism regarding integrating the proprietary sensor network at Sensagon with the MediaSense Platform owned by Mittuniversitetet.

The third goal has been to develop an Android application for the project dubbed C.STATUS™, which updates users regarding the status of household appliances. This has been possible through a server acting as a central storage.

The fourth goal has been to analyze and evaluate the performance of the proprietary sensor network running on the top of the MediaSense platform.

1.4 Outline

The thesis has been organized into seven chapters including the first chapter which presents a brief introduction

Chapter 2 briefly describes existing wireless technologies (protocols, standards and platforms). This section has been presented in four subtopics: Wireless M2M Technologies, Wired M2M Technologies, Existing Wireless Sensor Network platforms and Middleware.

Chapter 3 briefly describes the methodology section. This chapter explains the strategy followed to attack the problem put forward in the first chapter.

Chapter 4 briefly describes the smart home environment from the protocols and platforms point of view. It then provides a comparison of protocols and platforms. Chapter 4 has been presented in three subtopics: Smart Home Environment Protocols Comparisons, Smart Home Environment Infrastructure and Possible Future Trends.

Chapter 5 presents the implementation section. Chapter 5 presents a three layer architecture in which the components of the smart home infrastructure have been categorized. This section has been organized into two sub-topics: C.STATUS™ Sensor System on Top of the MediaSense platform and Sensagon's Elderly Care Sensor system.

Chapter 6 presents the results section. Performance analysis and Comparison has been presented in this section.

Chapter 7 presents conclusion and future works.

1.5 Scope

The focus of the thesis has been analysis, evaluation and categorization of smart home environment standards. Specifically, the thesis work is concerned with the application protocols that have been employed to retrieve data from the sensor interface into the network. The evaluations of the protocols and platforms have been conducted by a means of data based on the standardization's specifications. In addition, studying the integration mechanisms of the proprietary sensor network at Sensagon and the MediaSense overlay network have been included. An Android application which provides user interface for the smartphones and tablets has been designed and implemented. Even though this application was intended to be used for commercial purpose, deploying the application has never been part of this project. This is obviously due to the fact that data security has never been taken into consideration

2 Theory

The digital technology and the further advancements within the field are revolutionizing all aspects of life for humans. Active research is going to further enhance the life style of the 21st century human being through digital technology in the area of residential, health monitoring systems, social, environmental, national security and energy consumption. This chapter presents the technologies targeted to build a smart home environment from the protocol and platforms point of view. Nevertheless, this chapter does not discuss all consumer electronics and related staffs in the area of residential environment rather it presents protocols, solutions and platforms that have been aimed at turning our homes into smart and intelligent environment.

A Smart home is defined as, "A dwelling incorporating a communications network that interconnects the key electrical appliances and services, and allows them to be remotely controlled, monitored and accessed."[1] The definition by the DTI smart homes project does not put forward a totally inclusive basis for smart home environment . However we believe that it provides basic knowledge regarding a smart home environment. Furthermore another high level definition explains smart home as "A smart home is a house or living environment that contains the technology to allow devices and systems to be controlled automatically and remotely" [2]. A paper by A. Sanchez and R. Tercero [3] argues that there is abuse of the term smart home. However, in this thesis the integration of artificial intelligence parlance into the smart home infrastructure is assumed to be analogous to installing an app that would do complex tasks on an Android platform. Therefore, the conclusion is that it all depends on how smart the environment has been made and it requires no additional hardware in the smart home environment infrastructure for the cause of the argument by A. Sanchez and R. Tercero.

Smart home environment infrastructure enhanced by cloud computing environment has been proposed by [5]. Nevertheless such an infrastructure for a smart home environment is rather a long way from becoming a reality in the day to day life of average world citizen. The most obvious reason is that cloud would have to be firstly introduced into private homes. It is agreed that cloud computing has been optimizing

different sectors of quite a number of industries and achieving very wide acceptance in this regard. However, it is also agreed that such a cloud enhanced smart home environment could provide a better solution in future but, based on the current penetration of the technology into private homes there is a significant amount still to be done.
A number of wireless network protocols have been ratified during the last couple of years and protocols such as WiMax, GSM, and other wireless technologies which are designed to serve different purposes and which could be used in conjunction with wireless sensor networks. However, in this thesis those technologies specifically designed for M2M communication and intelligent appliance control have been presented.

2.1 Wireless M2M Technologies

To the author, M2M (Machine-to-Machine communication) refers to the intercommunication between two or more devices without the intervention of human beings. Many proprietary M2M protocols exist today which only serve the specific needs of different groups.

2.1.1 Bluetooth Low Energy (BLE)

Bluetooth Low Energy formerly known as Wibree was a proprietary standard designed by Nokia, however, in 2008 Bluetooth SIG obtained ownership. Bluetooth technology first appeared in 1999 and was the result of SIG (Special Interest group) which includes large companies including Ericsson, Motorola ,Intel and Toshiba. Bluetooth Low Energy is an enhancement on the classic Bluetooth standard. Bluetooth low energy offers low power consumption, a higher range (150 meter maximum), low throughput and a low cost proprietary standard that operates on the 2.4 GHz (Industrial Scientific Medical) band [6].

2.1.2 IrDA (Infrared Data Association)

IrDA is a short range (1 meter) infrared wireless technology. The IrDA standard was set up by a group of companies including HP, IBM and Sharp in 1993 [7]. Infrared remote controllers are widely exploited for the remote control of consumer electronics in home. However, due to the high competition between companies which manufacture consumer electronics, each company owns its own non-interoperable device. The goal of the IrDA foundation has been to circumvent the interoperability problems between different consumer electronics manufacturers. IrDA provides a relatively low cost, simple and high-bandwidth solution.

2.1.3 Zigbee / IEEE 802.15.4

Zigbee (IEEE 802.15.4) provides a very low-cost and low-power-consumption RF wireless standard developed by the Zigbee Alliance (a consortium of technology giants Sony, Samsung, Panasonic and others) based on the 2.4GHz PHY/MAC IEEE 802.15.4 standard. Zigbee is the de facto standard for low data rate wireless control protocols. Currently the Zigbee alliance provides two standard specifications Zigbee 2007 and Zigbee RF4CE.

The Zigbee 2007 standard is capable of supporting a maximum of 64000 nodes in one network [33]. Zigbee 2007 comes in two feature sets Zigbee and Zigbee Pro. Zigbee is smaller and supports only hundreds of devices in a single network, whereas Zigbee Pro supports thousands of devices in a single network.

The Zigbee RF4CE standard defines the specification for remote control networks that would allow users to control consumer electronic devices remotely.
Zigbee is an open protocol, however, whoever wants to use Zigbee specifications for commercial purposes must firstly be a member of the Zigbee Alliance. Zigbee embedded solutions are far more widely popular than any other solution with a similar function. Zigbee technology can be embedded on a huge range of products across consumer, industrial, commercial, and governmental markets.

The Zigbee alliance has ratified a list of standards under the public profile included in RF4CE.The following are groups of Standards included in the public profile.

- Home automation
- Building automation:
- Smart energy:
- Remote control:
- Health Care:
- Input Device:.
- Light link:

- Retail services:
- Telecom services:
- Network Devices:

2.1.4 Z-Wave

Z-wave offers a low bandwidth half-duplex protocol designed for wireless communication in a low cost control network. The design goal of the protocol has been to transfer small amounts of time critical data. Z-wave is a preparatory protocol with very similar features as in Zigbee. Z-wave supports less data rate and a considerably less robust communication as compared to Zigbee [8]. Zigbee operates on different frequencies in different countries: 868MHz, 869MHz, 920MHz,908MHz, 919MHz,921MHz and 950MHz.

2.1.5 Dash7

Dash7 (Developers' Alliance for Standards Harmonization of ISO 18000-7) was added to the low power wireless solutions market in 2009. Dash7 is a protocol based on ISO-18000-7. The goal of the Dash7 standard was to expand the market for low power wireless technologies by leveraging ISO 18000-7. The protocol is intended for RFID and wireless sensor networks. Dash7 has been designed based on the "BLAST" Concept. BLAST is an acronym for Bursty, Light-Weight, Asynchronous and Transitive [9]. Dash7 operates in the 433 MHz frequency and achieves a data rate of 27.8Kbps. Dash7 is relatively long range, spanning 250m as compared to Zigbee's 75m.

2.1.6 INSTEON

INSTEON solution has been in the market since 1992. INSTEON is a dual- band mesh proprietary network solution which was developed by the Smart Labs Technology lead by a consortium of companies. INSTEON solutions use power line communication, RF or both. The solutions provided by INSTEON communicate in a peer-to-peer fashion. The goal of INSTEON has been to intercommunicate devices such as light switches, door locks, thermostats, clocks, smoke detectors, security sensors and remote controls, which were far from talking to each other due to the both complexity and expensive installation costs [10]. INSTEON RF operates on 915 MHz/ 869.85MHz/921.0MHZ frequencies in different countries and the power line uses 131.65.KHz.

INSTEON embedded devices can be used in a wide range of applications:

- Embedded Sensors, heating ventilation and air-conditioning systems, lighting, home appliances and security systems.
- Entertainment consumer electronics, energy management, Voice recognition and response, as well as other smart devices.

2.1.7 ONE-NET

ONE-NET provides an open design specification necessary to enable a low-cost, low-bandwidth wireless control network [11]. The design goals of the ONE-NET wireless control protocol was to achieve a wireless standard which is simple, multi-vendor , optimized low-power consumption , secure, low cost as well as open and free protocol specification. ONE-NET devices intercommunicate in a star topology. The master could interconnect with the client nodes in a peer-to-peer fashion. The master is in control of every message forwarded between the clients set up in a peer-to-peer topology. ONE-NET operates on 868MHZ/915MHz ISM frequency ranges. ONE-NET solution achieves a maximum data rate of 230.4 Kbps.

2.1.8 CEBus /EIA-600

CEBus (Consumer Electronics Bus) is an open protocol developed by EIA (Electronic Industries Association) for the intercommunication of consumer electronics. CEBus is a packet based peer-to-peer protocol and uses the application-to-application communication language known as CAL, short for Common Application Language CAL [12].The first version of the CEBus was released in 1992. The goals of the developers of the CEBus were to provide a universal low cost method for devices in the home to communicate regardless of the manufacturer, to connect new devices to an existing home network at minimum cost and in an easy manner for the consumers as well as addressing the main requirement of home control devices with a single multimedia standard and to minimize the redundancy of home control and operation methods among devices [13]. However the standard development group has never considered security issues.

CEBus Standard supports RF, infrared, Power line, twisted pair, coaxial cable and fiber optics.

2.1.9 RuBee

RuBee (IEEE P1902.1) provides a short range (3m to 15m) magnetic wave based protocol intended for very harsh and secure environments. RuBee is a bidirectional, on-demand packet based, peer-to-peer network protocol that uses a long wave-length transceiver mode under 450KHz [14]. RuBee offers unique features as compared to ZigBee, Z-wave and other protocols intended to serve similar goals, as RuBee tags can work from inside a water or steel environment in which the RF protocol fails to work. As a result, giant companies such as IBM, Motorola, Sony, Panasonic and others have backed RuBee technologies. RuBee protocols operates at 131.0072KHZ and a wave length of 2,289 meter, which lays inside a magnetic wave range.

2.2 Wired M2M Technologies

M2M communications (also known as Internet of things (IoT)) employs a multitude of technologies to turn the surrounding environment into an easily controlled object.

2.2.1 USB

USB (Universal Serial Bus) was developed in 1995 by a group of companies including Microsoft, Sun, Hewlet-Packard, Intel and NEC. The original design goals of USB have been to design an external expansion bus which could make extending computer peripherals very easy operation. In addition to ease of use, the group's goal was to design a low cost peripheral expansion bus. The first release, USB 1.0, had a data rate of 1.5Mbps/12Mbps. However, the second release, which is USB 2.0 had a maximum data rate of 480Mbps. USB is by far the most widely used standard for interconnecting computer peripherals with a PC. Currently USB is being used in industries for different purposes passing the limits of its initial intended goal. The developers of USB have designed a new protocol using UWB (Ultra WideBand) wireless technology. Using wireless USB peripherals it is possible to be connected within a range of maximum 3m and transfer at a maximum rate of 480Mbps[15].

The design goals of wireless USB was to meet the following key areas:

- Leveraging the existing USB infrastructure.
- Preserve the USB model of smart host and simple device.
- Provide effective power management mechanisms.

- Provide security
- Ease of use.
- Investment preservation.

2.2.2 FireWire

FireWire (IEEE 1394 or i.LINK) offers a standard for connecting computer peripherals and consumer electronics. FireWire was first developed by Apple Inc in 1986. The first version of the FireWire provides three data rates: 100Mbps, 200Mbps and 400Mbps. However, the latest version of FireWire, IEEE1394b provides a data rate of 800Mbps within a range of 100m yet some expect the future data rate support to be 6.4Gbps. Firewire offers flexible device-to-device connectivity in the home entertainment environment. FireWire could connect up to 64000 devices[16][17].

2.2.3 X10

The X10 power line communication protocol was developed by a company called Pico Electronics in 1978. X10 is the oldest protocol of its kind. X10 provides a very low bandwidth is only able to provide a maximum data rate of 100Kbps[18]. The first release of the X10 standard provides unacknowledged data transmission. Today, such kinds of devices are available in the market for cheaper prices. X10 has brought a new approach in which any device connected to an electrical wiring could be controlled remotely.

2.2.4 HomePNA / HPNA

HomePNA (Home Phone line Network Alliance) has been developed to ensure the development of user-friendly, low-cost, high data rate solution which operates on existing telephone and coaxial cables. The latest specification HomePNA 3.1, which was released in 2006, provides a maximum data rate of 320Mbps and aimed to perform best for IPTV [19]. The HomePNA 3.1 was designed to perform best for a house with an area of 10,000 square feet and a devices-to–devices communication range of 1000 feet. HomePNA supports a maximum of 63 devices in a network.

2.2.5 G.hn

G.hn was a result of an effort made by ITU-T in 2006 to develop a unified interoperable standard consisting of all types of existing cabling home phone line, power line, coaxial cable and Cat-5 targeted to work in a residential environment as well as in small and medium offices. G.hn has been developed with the goal of achieving a unified global standard which could provide a data rate of up to 1Gbps. G.hn can interconnect a maximum of 250 devices in one network [20]

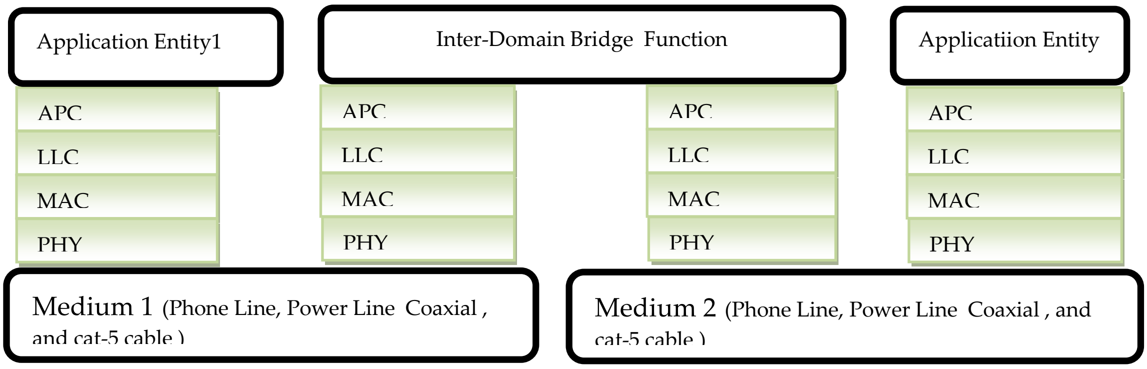


Figure 1 G.hn Inter- Domain bridge.

2.3 Existing Wireless Sensor Network Platforms

Wireless sensor network consists of multiple small computing devices known as nodes. WSN nodes have a capability of interacting with the surrounding environment, processing data as well as to forward and receive data. On the top of these basic requirements the industry has been working on optimizations on different crucial features including processing capacity, cost, node size and energy consumption.

2.3.1 MyriaNed

MyriaNed wireless sensor network nodes organize themselves in a fashion very similar to the natural organisms for example birds, ants, cells and so on. The behavior of the entire wireless sensor network is the result of the behavior of each node. MyriaNed wireless sensor network nodes exchange messages with each other in a gossiping manner where the node which receives a message from a sensor, sends message to a number of nodes but not to all so the nodes will resend the received message and finally the information will be known by each nodes[21]. MyriaNed platform offers very scalable (no limit on the number of nodes) and robust data communication.

Figure 2 MyriaNed Node

2.3.2 ANT/ANT+

ANT is a proprietary wireless sensor network protocol. ANT operates on a 2.4GHz frequency and provides a maximum data rate of 1Mbps. ANT nodes could be organized in a peer-to-peer, star and topologies. ANT is a very compact protocol stack when compared to protocols such as Zigbee [22]. ANT was designed to serve a specific and optimized goal. ANT+ is a managed network focused on the Personal Area Network this includes sports and fitness as well as wellness and home health monitoring. ANT+ has been introduced to interoperate the proprietary ANT protocol with other open protocols. This has been achieved through a predefined devices and data formats provided on the ANT+ platform.

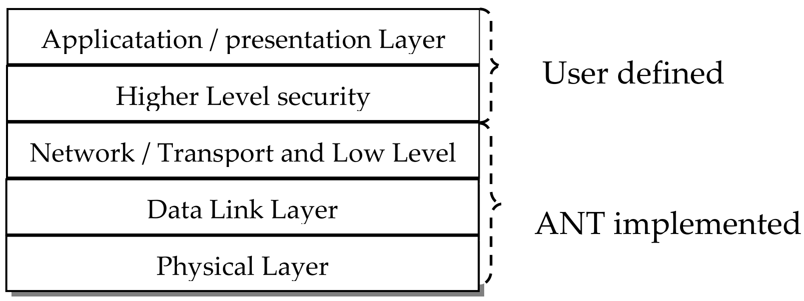


Figure 3 ANT OSI Layer Model

2.3.3 WirelessHART

WirelessHART is an open standard for measurement and control in the process industries. WirelessHART has arrived in market as an extension to the existing and widely used HART (Highway Addressable Remote Transducer) industrial automation protocol. WirelessHART has been designed specifically to address a wide range of process-industry use cases from simple monitoring to closed loop control [23]. WirelessHART relies on the IEEE 802.15.4 PHY layer standard for the 2.4GHz frequency.

2.3.4 TinyOS

TinyOS is a wireless sensor network open-source software platform designed for wireless embedded sensor networks[24]. TinyOS is a very small size (less than 400bytes), flexible operating system built from a set of reusable components that are assembled into an application-specific system. TinyOS was developed by NesC language and follows component-based programming model.

Interfaces Provided by TinyOS:

- ADC
- CLOCK
- EEPROM Read/Write
- HardwareId
- I2C
- LEDs
- MAC
- MIC
- POT
- Random
- ReceiveMsg /SendMSg
- StdControl
- Time
- TinySec
- WatchDog

2.3.5 Contiki

Contiki is an open-source operating system designed to be very small in size (42KB memory) so that it could be possible to install it on memory - constrained network embedded systems. Contiki is implemented in C language and has been ported to a number of microcontrollers architectures including the Texas Instruments MSP430 and the Atomel AVR[25][26]. A running Contiki operating system consists of Kernel, libraries, program loader and processes. Contiki uses two communication stacks : uIP and Rime. The uIP stack provides Contiki with TCP/IP networking support whereas Rime Stack provides primitives for lightweight communications designed for low-power radios.

2.4 Middleware Technologies

The multiple technologies adopted by service vendors and industries needs to interoperate for a number of reasons. A middleware abstracts the heterogeneity of the underlying technologies and provides a homogenous view for the end-user. This section presents the standards aimed to come up with a generic solution in regards to the interoperability issue.

2.4.1 OSGi

OSGi (a.k.a Open Service Gateway Initiative) is a an alliance of industries formed to specify , develop, and promote open service platform for the delivery and management of multiple applications and services to all types of network devices in home , vehicle , mobile computing and other environments [27]. The OSGi was set up by a group of industries and vendors including Ericsson, IBM, Sun Microsystems and Philips. The OSGi technology provides standardized approach that allows applications to be constructed from small, reusable and collaborative components[28]. Jave™ has been made the premier language in the componentization based on OSGi technology.

2.4.2 UPnP

UPnP, an acronym for Universal Plug and Play, is an open networking architecture intended to interconnect intelligent house hold appliances made by different manufacturers. The UPnP technology is a broad industry initiative that simplifies networking for small businesses and consumers [29]. UPnP is a technology that supports networking, and automatic discovery of different kinds of appliances including PCs, intelligent appliances and wireless devices [30]. UPnP uses Internet messaging protocols such as XML and SOAP where as TCP/IP is treated as a low layer. UPNP devices need no configuration (zero configuration devices) so these devices could discover each other right upon plugging.

2.4.3 KNX Technology

KNX is a merger of three companies (EIB, Batibus and EHS) engaged on building and home control .KNX technology provides manufacturer and application domain independent KNX bus that interconnect devices that can support twisted pair, power line, RF and IP communication in an integrated manner [34]. KNX offers platform independent global standard for its members.

2.4.4 The MediaSense Platform

The Mediasense platform is a distributed architecture overlay which enables IoT (Internet of things) applications based on sensor and actuator information [31] The MediaSense platform has been aimed to interconnect global sensors on a heterogamous network in peer-to-peer manner and with this platform scalability, real time data access and seamless integration are given emphasis. The MediaSense Platform could be used in a wide range of scenarios including health care, smart home environments, object tacking and social applications [32]

The MediaSense architecture consists of five layers:

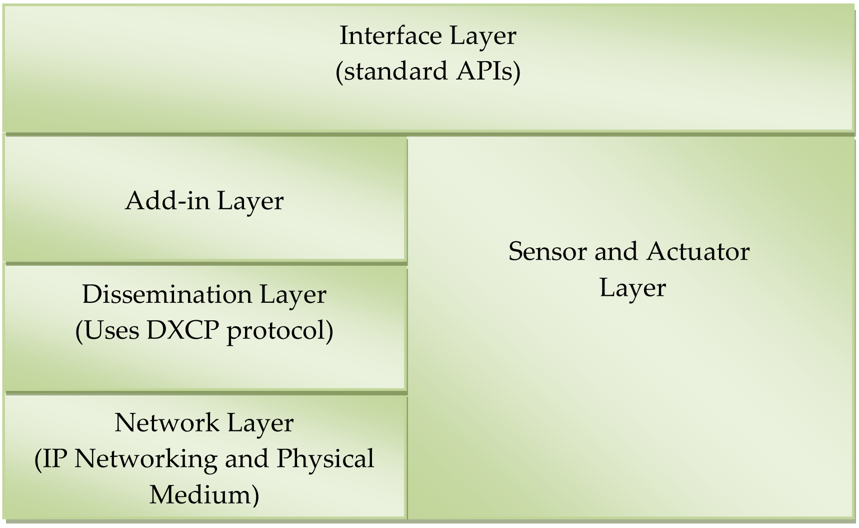


Figure 4 the MediaSense architecture Layers

3 Methodology

The thesis work follows “divide and conquer” principle to address the problem statement put forward in the first chapter. Accordingly, the first step has been to study and answer “what are the current trends in the implementation of smart home environment?” .The second step will be to examine open standards which could address interoperability issues. The third step has been to explain about standardizations for common platforms. Finally, the MediaSense platform and the proprietary sensor system called C.STATUS™ will be presented and briefly discussed.

In the area of smart home environment multiple standards exist and most of these hardware platforms are not compatible to one another. Therefore, in this thesis the most common trends used to deal with such a as problem in the smart home environments will be presented and studied. In the context of this thesis work smart home environment includes all the participants from the actual sensors till meaningful data gets displayed to homo informaticus. Theoretical evaluation and categorization of each of these standards will be done after studying available common standards. Presentation and discussion of integration mechanisms of the novel MediaSense platform and the proprietary Sensor network located at Sensagon will be done next. The last task will be to implement android application that could display smart home appliances’ status. In the project MySQL database running on Linux server bounces data coming from the smart home appliances’ and the information will then reach to a device on the hands of home owner through RESTful web services which is acting as a data abstraction layer.

3.1 Current Trends in the Smart Home Infrastructure

Technologies that have been applied towards the implementation of existing smart home environment will be thoroughly discussed keeping focus on the protocols and standards that have been used to turn the physical world to the virtual object. Besides, latest results in the smart home environment technology will be presented keeping focus on the protocols behind.

In chapter one it has been argued that common platforms are necessary not only for intercommunication of sensor systems but also creates a suitable environment for third parties engaged on Software development. In this case it helps software developers to focus on the optimization rather than wasting time on integration issues. For this, available standardizations and common platforms will be presented and discussed.

Part of the thesis work will be to evaluate existing and upcoming standards in the area of smart home environment. Comparison of the most common home automation protocols will be performed based on the following stringent factors: cost, scalability, security, access to global sensor, integrity, power effectiveness and Interoperability. These Standardizations will be categorized and explained.

3.2 The MediaSense Platform and Sensagon's Proprietary Sensor System

The MediaSense Internet of things platform will be discussed. Mechanism has been proposed to integrate the novel MediaSense platform with the existing Sensagon's elderly care sensor network. Moreover, we will implement the existing sensor network on the top of the MediaSense platform. Having done the implementation we will compare the performance of the existing sensor system against the one we implement.

3.3 Android App Design

Lastly this thesis work will be engaged on developing android app for the project called C.STATUS™. C.STATUS™ is the trade mark of the Sensagon's sensor network. Currently, Smart home appliances' statuses are displayed to the remote clients through a dedicated user interface .Android app that will allow customers to check status of appliances on their smart devices will be designed and implemented. To this end this part will be divided into two parts the first part will be to design and implement the interface. The second part will be to design and implement the database.

3.4 Analysis and Evaluation

Performance evaluation of wireless sensor network platforms could be done in simulation environment, on test-beds or on real environment depending on the time and money budget. This thesis will collect data from the actual environment. It presents the evaluation of the performance of the existing Sensagon's elderly care sensor network and the network we are going to build on the top the MediaSense IoT platform.

Performance evaluation of a sensor network could be studied using different metrics for example scalability, throughput, security, reliability and so on. The metrics such as energy consumption, scalability, throughput, security and reliability are all important to examine the performance of a network. Nevertheless, we pick one of these metrics due its convenience and volume of the thesis work. We study and evaluate the scalability of the existing C.STATUS™ sensor network and the sensor network that we will set up on the top of the MediaSense platform

4 Technologies for Smart Home Environment and Trends

In this section the protocols within the area of a Smart home environment are studied.A comparison is conducted in relation to wireless control protocols and wireless mesh network protocols by using the main features of these technologies including range, frequency, security, and latency. In the last sections of this chapter, the smart home environment infrastructure is presented. This section presents the smart home environments as seen from a new angle but is based on previous works by different researchers within the area of smart home. All the smart home environment components have been divided into five categories which run under each of the corresponding smart home environment services.

The smart home environment or “Home Automation”,which is in its widely known “name”, is not a brand new idea as it has been around since mid the 1970’s however the level of control and automation was in its infancy until recently. The smart home environments that are found today are the real versions of the imaginations that were read about in fiction books. In this regard, it could be stated that smart home is a new technology. The technological advancement and innovation within the area of wireless sensor networks have had a great influence on the smart home environment. A number of commercial organizations are setting up their own standards and platforms for the smart home environment while standardization bodies are striving hard to have common and open platforms. As a result, a number of consortiums have been established to address the interoperability issues and quite a large number of companies have arrived at their own preparatory solutions to circumvent the problem. In this chapter, smart home standardizations will be presented that are most widely used and they will be categorized based on the attributes that are believed to be very important within the area of smart home environment. In addition, technologies technologies will be discussed under each category, for example, power line communication, wireless technologies as well as smart home technologies built on telephone line and others.

A wide range of technologies have been brought onto the smart home environment platforms since the inception of the concept and yet more protocols are still being added to the existing list. In this regard, a number of factors could be cited for such a large number of standards and platforms. The main reasons being cost, energy consumption, flexibility, scalability, openness and interoperability issues. Many service vendors follow similar trends despite having different protocols. The most widely adopted architecture is that of client- server, however a small number of service vendors have implemented the peer-to-peer architecture. Different solutions and approaches have been followed despite the fact that all these technologies use one of the following communication technologies: IR, RF, Ethernet, PLC, Coaxial and/or telephone line and magnetic.

Recently, a number of researches have been conducted wireless sensor networks both in both academia and industries and more specifically, there is much focus on efficient energy consumption and energy harvesting wireless technologies. Companies who specialize in wireless sensor network solutions are in competition in order to provide better technology and thus acquire a greater market share. Widely used protocols such as zigbee/IEEE 802.15.4 provide all the basic and important features. However, other newer solutions have appeared with quite extensive features and an optimized performance. For example, protocols such as dash7, Rubee, Z-Wave, Ant/Ant+, and some others, outperform zigee in some features.

4.1 Smart Home Environment Affiliated Protocols Comparisons

Wireless technologies provide an ideal solution for smart home environments .Specifically, if the concern is in relation to the fiscal costs involved in installation and the extra related task of rewiring a house for the purpose of automation, wireless technologies offer better alternatives. As a result, a myriad wireless technologies for smart home environment with a wide range of choices are available at the present time. IR wireless communication works in a line of sight. Such wireless protocols are applicable for the control of TV, DVD players, garage door and so on. However, Radio Frequency has the ability to penetrate walls and would therefore span a larger area. Thus, for controlling home appliances from inside the home both the IR and RF protocols are equally competent, in fact, IR provides more security against eavesdropping. Therefore, in this sub section the existing wireless technologies will be presented and their features regarding protocols and platforms will be compared based on data collected from the respective protocol specifications.

Smart home environment running on existing home wiring are better solutions in those cases for which there is a where greater concern in minimization of installation costs. However, these environments are not sufficiently flexible enough .Moreover, there is a great deal of signal attenuation and interference coming from different signals passing through the medium. These technologies include infrastructure such as power lines, telephone lines, Ethernet and coaxial cables. Some of the technologies in these categories are extremely narrowband (for example X10, throughput 1/1000th of the bandwidth of dial up connection) and might not address today's voracious bandwidth applications inside the smart home. However, these have been covered in this thesis for comparison purpose. .

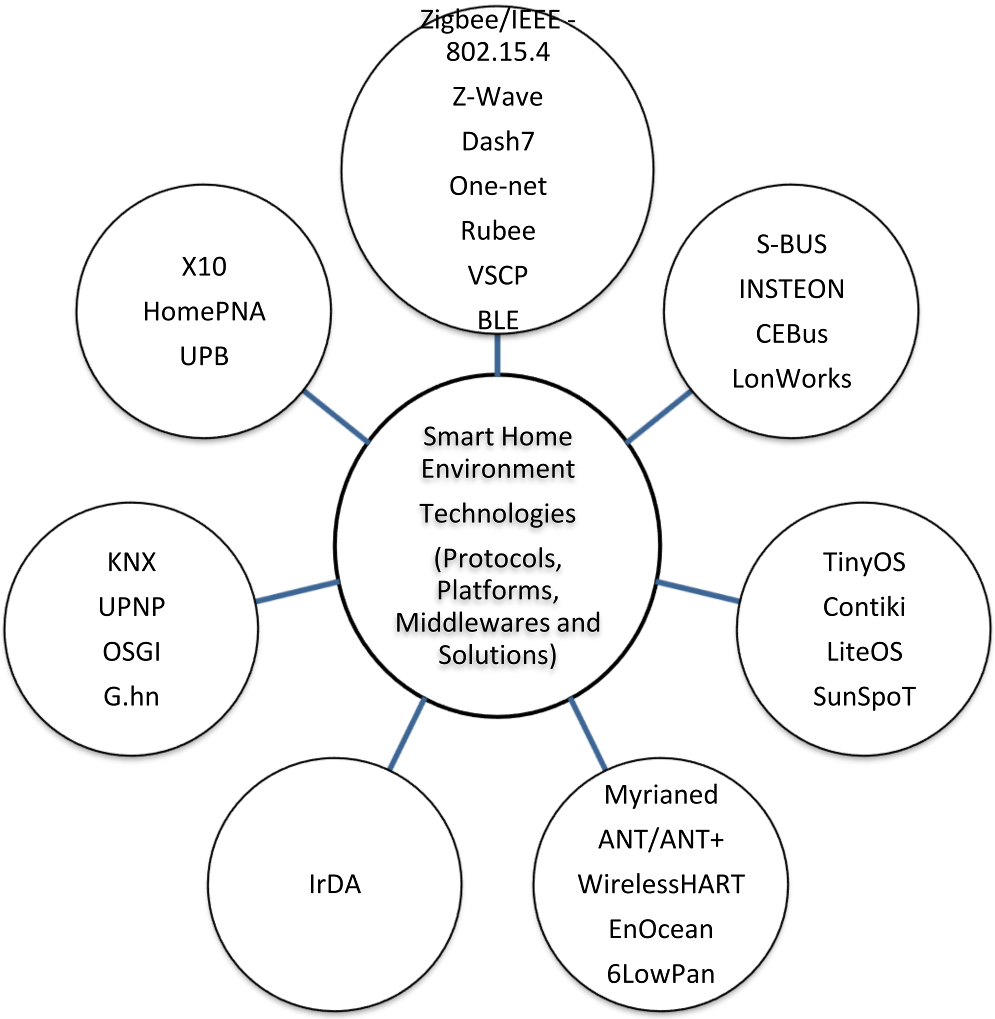


Figure 5 Protocols, Middleware's and Platforms

CATEGORY 1 Wireless protocols and platforms

A few companies have revealed their business plans by taking into consideration the fact that one protocol for example Zigee is unable to satisfy the requirements of all consumers in the market. Thus protocols ,for example, ANT/ ANT+ has been conceived from such a cause .Industries and standardization bodies have taken into consideration a in relation to this case. The most important factors being low energy consumption, low cost, security and reliability. Generally, it is not possible to arrive at the conclusion that one protocol is better than the other. However to reach such a conclusion, it is mandatory to be specific and have similar features to compare. Some of the protocols might perform better with regards to energy consumption, while the others might outperform in other parameters ,for example, throughput, security, reliability and cost.

Existing smart home environments are build in such a way that appliances are accessed remotely either through the Internet or by using some other technology, such as a telephone line or a power line. Moreover, with regard to IoT platforms, for example the MediaSense platform could address the same issue through quite a different approach and holistic solution. The fact that in the MediaSense every “thing” has an IP address assigned to it and these “things “could talk to each other in a peer-to-peer manner in real time from a remote network would convince that MediaSense IoT platform adopts a different approach. IoT is not limited to a small area but does interconnects with many more devices than today’s Internet.

Wireless protocols and platforms used in smart home environment are compared in table 1. The main features of wireless communication protocols (Range, Frequency, Security, Maximum number of nodes in a network, Data rate, and Latency) have been used to compare each of the technologies.

Table 1 Smart Home Environment Affiliated Protocols and Solutions

	Range	Frequency	Security	Scalability	Maximum Data Rate	Open Standard	Line of sight	Latency
Zigbee	75m	868MHz/915 MHz/2.4GHz	AES-128 hardware level	<65000 nodes	250 Kbps	No	No	50-100 ms
Z-Wave	30m indoor /100m outdoor	868MHz/869 MHz/920MHz /908MHz/919 MHz/921MHz /950MHz	Triple DES Software level	<232 nodes	20Kbp/s	No	No	1000 ms
Bluetooth Low Energy (BLE)	150m (Maximum)	2.4GHz	128 AES CCM	2 billion nodes	1Mbps	Yes	No	3ms
Dash7	10m-10km	433MHz	AES-128		200kbp/s	Yes	No	<2000ms
INSTEON[1]	45m	869MHz/921 MHz/915MHz	Encryption at SW and HW level		37 Kbps	No	No	1.823ms
ONE-NET	100m indoor/600m out door	865-868MHz/902-928MHz/	XTEA2 SW level	4096 nodes	38Kbps-230Kbps	Yes	No	
IrDA	1m / 3m	(850 nm - 900nm)			100Mbps / 5Gbps	Yes	Yes	
Rubee [2] / IEEE 1902.1	3m - 15m	131.0072KHz	Real time AES encryption		1200baud		No	
ANT/ANT+		2.4GHz	low level and user defined security.	65536 nodes	1Mbps	No	No	2seconds (Messaging period)

[1] Uses wired technologies also
[2] Rubee is magnetic protocol

CATEGORY 2 (Technologies built on existing home wiring)

Smart home environments which are built on power lines and existing telephone lines have been available in the market for a couple of decades. Standards such as HomeCNA that use existing Co-axial cables do exist today but they are hardly familiar. The advantage that -the consumers achieve from those technologies that reuse the existing home infrastructure is the minimal cost as compared to the standards that need rewiring and/or wireless solution. Some companies have come up with a standard that works on both power lines and telephone lines (e.g. G.hn,) and yet others have combined power lines, telephone lines and wireless solutions (e.g. INSTEON).

Table 2 Wired protocols and solutions

HomePNA/HPNA
USB
X.10
Firewire /IEEE1394
KNX
CEBus / EIA-600
G.hn
INSTEON*
LonWorks
HomePlug

4.2 Smart Home Environment Infrastructure

Smart home environment infrastructure components might vary depending on the level of control and the cost required to set up the environment. However, every smart home environment must have sensor nodes on every appliances which are supposed to be part of the system;

Control devices (Smartphones, PDAs , personal computers or other remote control device);and Data network media. See Figure 6.

Traditional smart home environments follow a centralized architecture. A single point of failure in the traditional architecture is an obvious disadvantage. The IoT platform, the MediaSense, could also serve the same goal by creating a fully distributed peer-to-peer environment. Integration of the MediaSense platform into a Smart home environment is discussed in the next chapter.

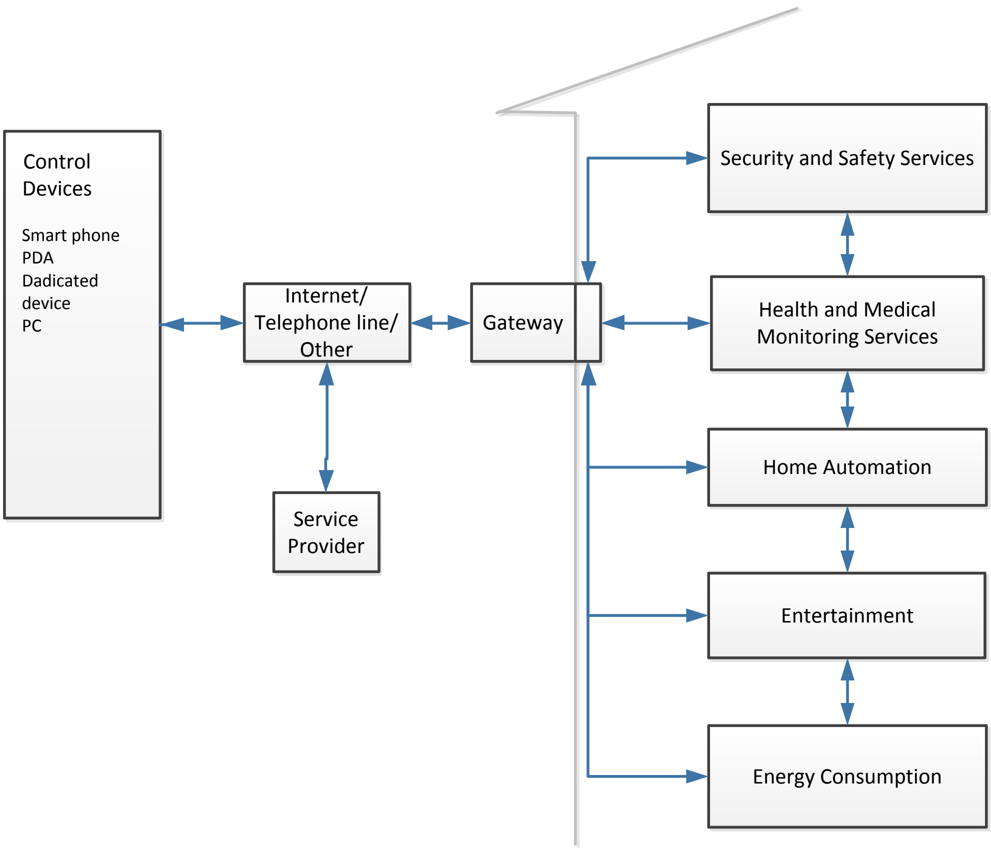


Figure 6 Smart home environment services and Infrastructure components

Security and Safety services allow users to control their home environment from a remote place on a smart phone or PC. Camera, motion sensors and other security devices embedded in doors, windows and other important places within the residential area send an alarm to the user and in that case the user could watch the situation remotely. In these safety services, a case as such as that for the care of the elderly and the disabled, has been included.

Medical monitoring services collect data for example; a heart rate sensor and blood pressure monitor send the patient's information to the concerned medical personnel. Basically, these services combine the data collected from BAN (Body Area Network) and sensors located in the patient's smart home environment. These services are usually treated separately from the rest of smart home environment however they have been included in the overall smart home environment infrastructure.

Entertainment services provide an environment where, for example, the TV would open the favorite channel depending on the time of the day whenever there is someone inside a house. The radio in the shower room tunes to a rock channel or some other channel whenever there is a person inside.

Home automation services could be as simple as a service that updates the status of kitchen appliances to a remote user or be very complex and trendy as in the situation where the refrigerator informs the user about the expiration of food kept inside and performs some sophisticated tasks such as ordering food from supermarkets.

Energy consumption services provide automated lighting control, heating system and an air conditioning system based on different factors such as the surrounding environment, time of the day, work environment and others.

4.3 Possible Future Trends

The fictitious "Future Home" project implements all the services that the current smart home environment can offer. The environment employs KNX smart home solutions. Therefore the smart home environment uses either a power line communication or a wireless communication whichever is the most suitable. Users control appliances from anywhere. A number of panels have been mounted on the walls and some others movable panels inside a house. These panels control appliances, display the status of the appliances and show context information such as weather. Generally, these panels provide full control for any device in the smart home environment. Moreover, "Future Homes" provides remote access through the Internet or on a smartphone, computers and a dedicated device. These remote control devices also provide control of the appliances inside a remote home with limited access.

Security Services collect data from cameras mounted on outside of the entrance and a couple of others inside the house, plus smoke detection sensors and security sensors embedded on the doors and windows. Therefore whenever the system finds out a threat it will send a message to the remote user.

Medical monitoring services provide the patient's current information to a medical doctor or nurse who takes care of these services remotely. These services obtain data from a body area network and sensors set up inside a medical monitoring room, which is set apart for remote medical monitoring purpose. Therefore these services provide the real time status of patient.

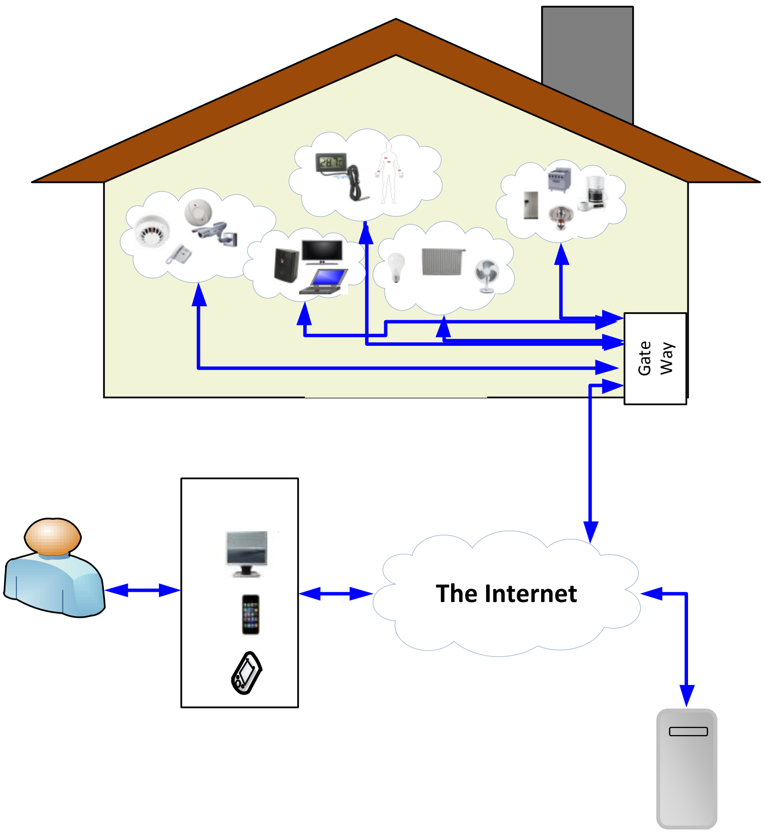


Figure 7 "Future Home" Smart Home environment

Entertainment services run on a server which provides a list of options for music, speakers are mounted on the ceiling of all rooms and sensors collect the contextual information. These services play different music depending on the context inside the room, time and user preferences. Furthermore, the entertainment service chooses a television channel depending on the surrounding context, time and user preferences. These services are intelligent such that if there is no activity inside the room they will turn off the television and music players.

Home Automation services run on the top of a smart refrigerator, stove, coffee machine, oven, blinders, iron, sprinklers and others. The refrigerator will order the delivery of food staff from a supermarket based on the expiry dates and consumption rate. The blinders in the bedroom react to the outside environment. The sprinklers will not sprinkle water unless they know that there will be no rain. So sprinkles read the weather data from the Internet. The other smart devices provide status information and can be controlled from anywhere.

Energy consumption services control lighting, heating ventilation and air conditioning systems (HVAC). Thus, services provide access to all the bulbs, radiators, AC's and fans. The radiator will not stay on forever but will adjust to the surrounding environment and can be controlled remotely, air-conditioning systems will not stay on indefinitely but will also adjusts to the immediate environment and the bulbs turn off depending on the context and user preferences.

5 Implementing the Smart Home

In this chapter a brief discussion with regards to the existing Sensagon's smart home environment in comparison with the smart home environment architecture is presented. Protocols pertaining to each layer in the smart home architecture are briefly discussed. Moreover, Sensagon's smart home environment is implemented on top of the MediaSense platform. Finally, the C.STATUS™ user interface is designed and implemented for an Android mobile platform.

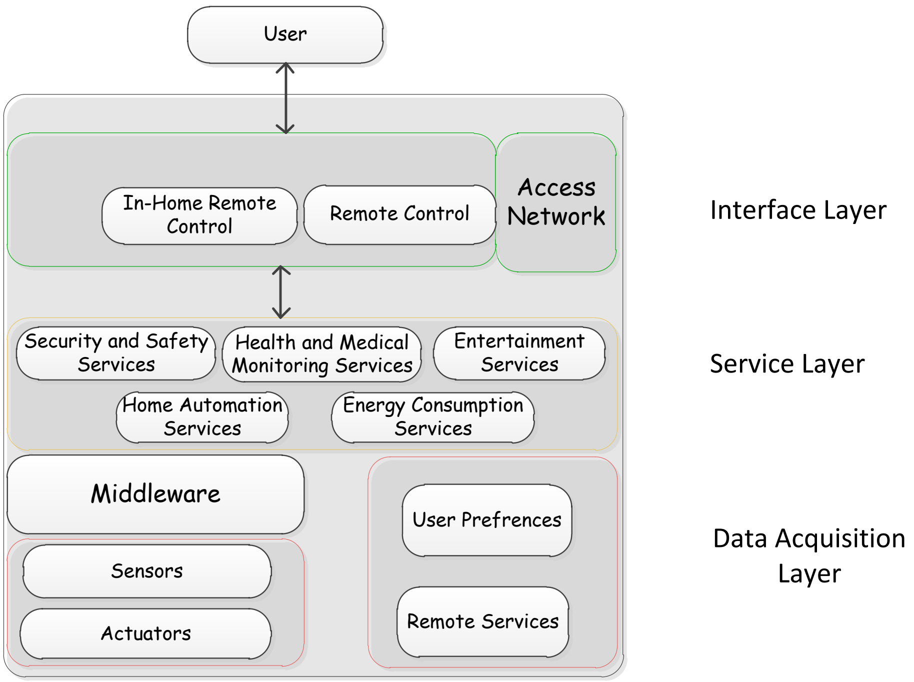


Figure 8 Smart Home Architecture

A three layered architecture illustrated in figure 8 shows all the sub-components which encompass the smart home environment infrastructure presented in the previous chapter. The layers have been segregated based on the tasks served smaller components.

The interface layer provides data to the user or to a computer application from inside a house or remote location. The Interface layer has the responsibility to access the underlying layers in a secure manner and prevent any malicious activity. The Interface layer might use different advanced technologies such as gestures and natural language user interfaces.

The next layer , underneath the interface layer, is the service layer and this layer provides at least one of these services: security and safety, health and medical monitoring services, entertainment services, home automation services, and energy consumption services. The service layer provisions data to the next layer using text formatting languages such as XML and JSON.

The data acquisition layer is the bottom layers upon which the entire system relies on for data input. The data acquisition layer is responsible for providing updated contextual information to the layers above it. Sensors, actuators and others such as user preferences, the Internet and WSN make up the data acquisition layer. In this layer sensors provide the raw data in different formats so that there should be middleware that has the ability to provide data to the next layer in a correct and compatible format ,therefore, the data acquisition layer provides data to the upper layer through a middleware as shown in figure 7 above. Moreover, this layer is responsible for storing and retrieving data from servers and other storage devices.

The access network refers to the network that is responsible for connecting the smart home environment to the public network. The access networks could be PSTN (Public Switched Telephone Network), WLL (Wireless Local Loop), Fiber Optics or ADSL

5.1 Sensagon's Elderly Care Sensor Network

The existing C.STATUS™ elderly care sensor network follows the traditional client-server architecture. See figure 9. The server collects data coming from the smart houses and then smart devices could obtain updates of the status of the smart home appliances located far from the person who wants to control the appliances.

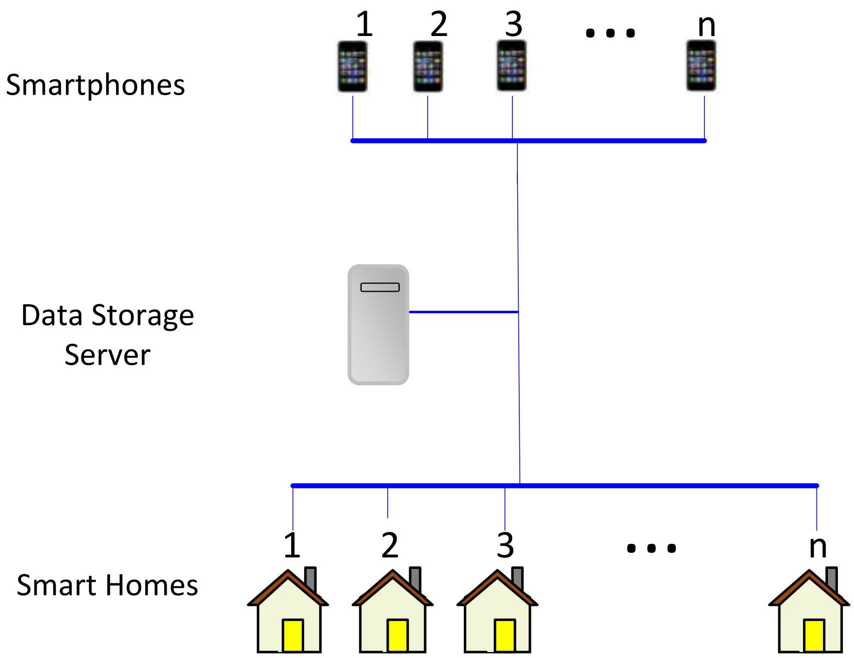


Figure 9 C.STATUS™ Centralized Sensor Network

The existing sensor network provides appliances status updates to the people living inside the house as well as to others remotely. The existing system uses a small panel that displays the status information to a person in charge of the house as shown in figure 10. A smart phone app has been developed in this thesis to provide a more flexible and comfortable user interface.

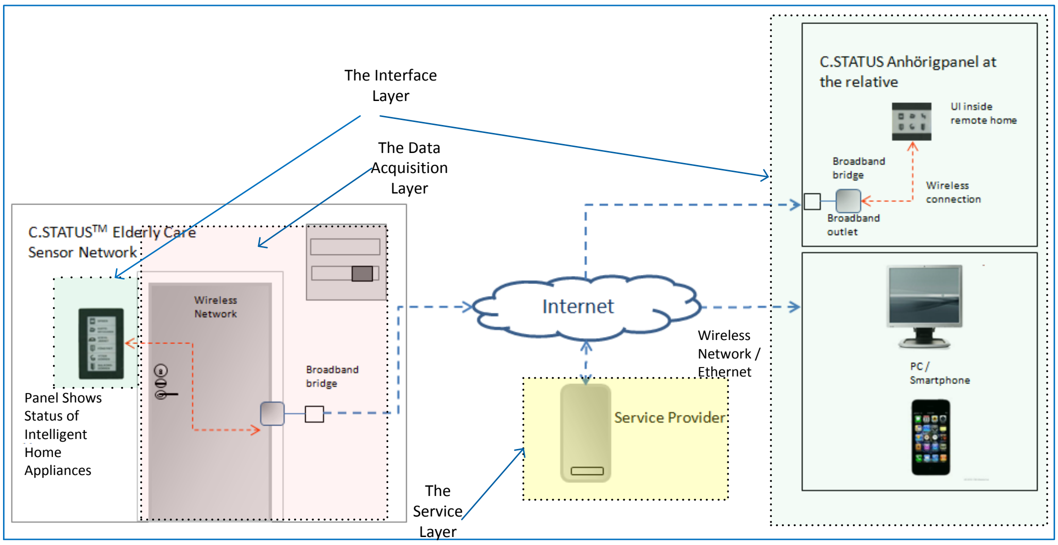
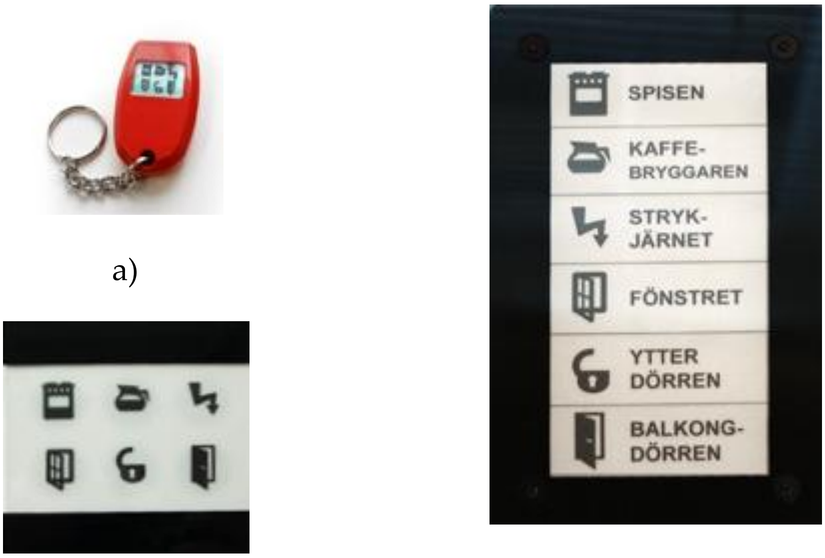


Figure 10 C.STATUS™ Sensor Network Layers

5.1.1 The Interface Layer

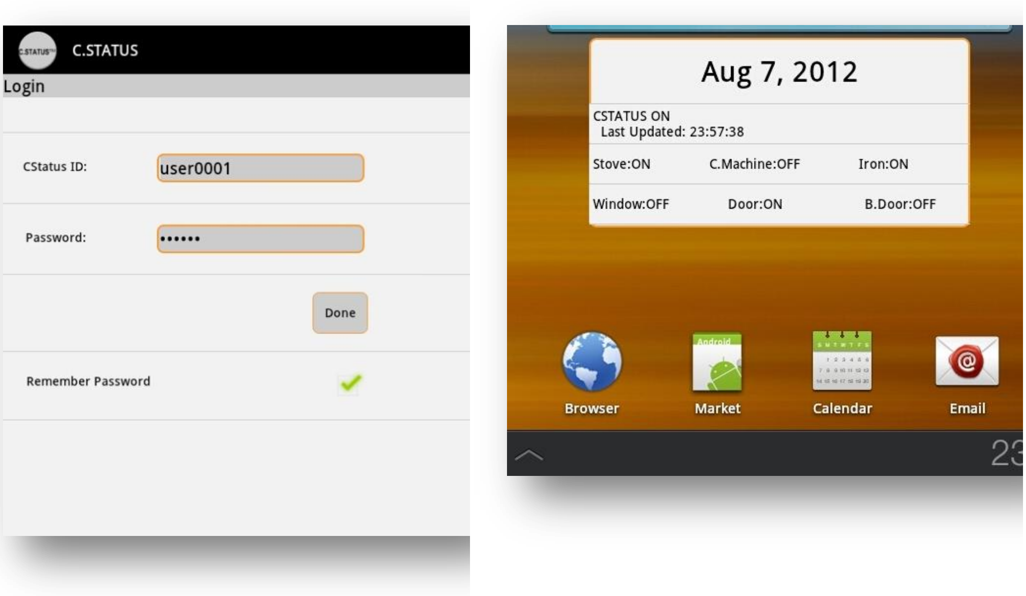
The interface layer provides very flexible and, in addition, multiple options. The interface layer deploys dedicated devices and smartphones as shown in figures 11 and 12 Users could choose from multiple UI options: a dedicated device attached on key chains, in-home control panels, remote control panels and apps on Smartphones. C.STATUS™ creates such a safe environment in which those house hold appliances that could harm children and senior citizens are controlled from a remote place.

C.STATUS™ retrieves status updates periodically from a server located remotely. Restful web services have been used to provide data from the Linux server. The RESTful web services ensure data abstraction.



a) c) b)

Figure 11 C.STATUS™ UI. a) C.STATUS™ Key Tag b)&c) Control Panel



a) b)

Figure 12 C.STATUS ™ on Android phone

5.1.2 The Service Layer

Sensagon's elderly care system consists of one service. The service retrieves data from the underlying sensors and passes the data through a central server from which the top layer could access. The central server running on Linux shares data to multiple users in a secured manner. The MySQL database running on the server is accessed through a Restfull web services. See figure 12.

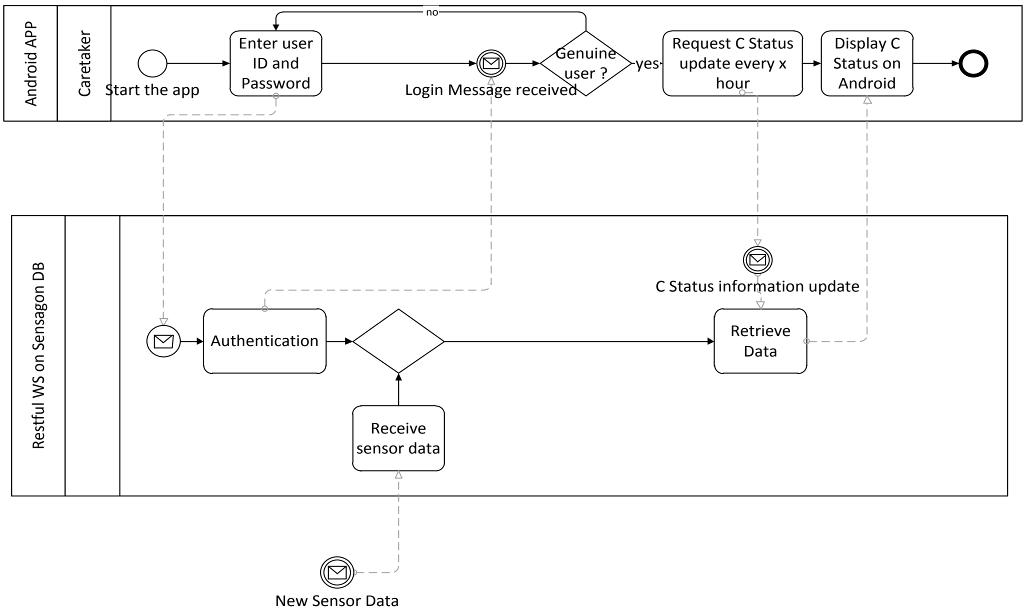
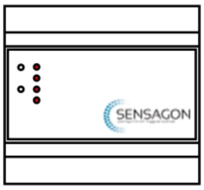


Figure 13 C.STATUS™ BPMN diagram.

5.1.3 The Data Acquisition Layer

Sensors are attached to ordinary kitchen appliances, doors and windows. Some sensors are mounted on electrical wires connected to the home appliances. See Figure 13



a)DIN-sensor

b) Door Sensor

c) Lock-Switch

d) LANTRONIX-XPort

Figure 14 a)DIN-sensor is installed on electrical wires connected to the appliances. b)Door-sensor is attached to the balcony door. c)The Lock-Switch is mounted on the doors and windows. d) A module to put sensor data on the web

5.2 C.STATUS™ Sensor System on Top of the MediaSense platform

The MediaSense is aimed for a peer-to-peer and real time data communication between multiple nodes. The first objective is to ensure that nodes are brought to the top of the MediaSense and that each nodes must have a capability to receive, process and forward data coming from the other nodes.

In a situation where every node of a network possesses a capability to process data and forward necessary information to the nearby nodes integration needs minimal effort and only minimal changes are required. However, in the existing Sensagon's Elderly Care System, it is necessary to find out a mechanism to change a client-server topology to a peer-to-peer as in figure 15.

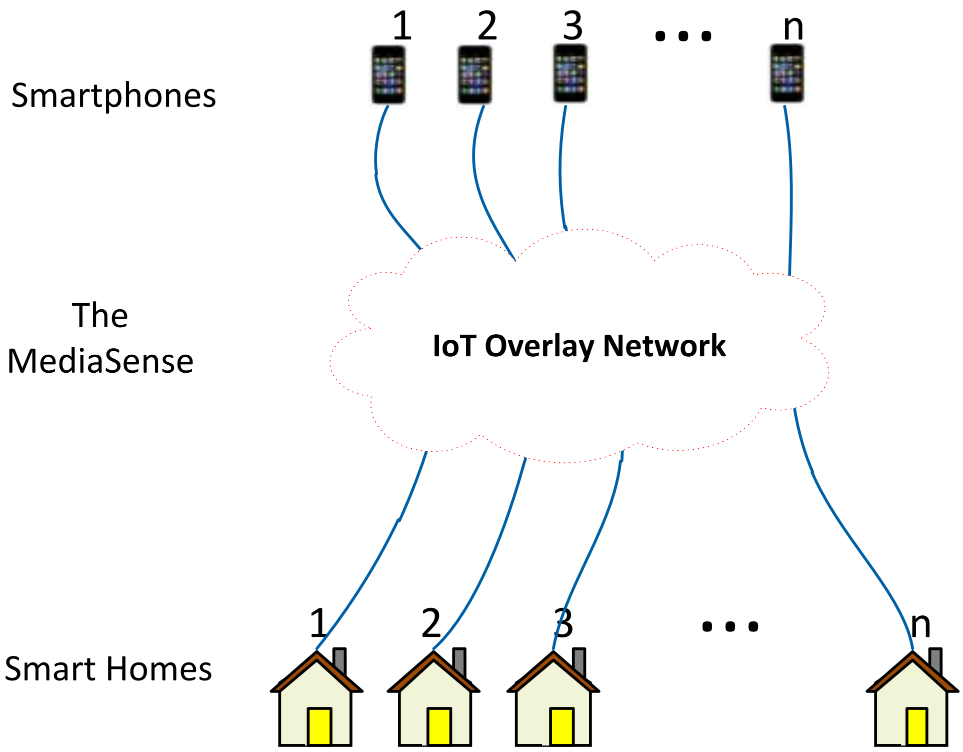


Figure 15 C.STATUS™ on the top of the MediaSense platform

5.2.1 Implementing the Interface Layer

The interface layer components are implemented with hardly any modification to the existing network. Messages are sent over the MediaSense overlay network. See Figures 16 and 17 .

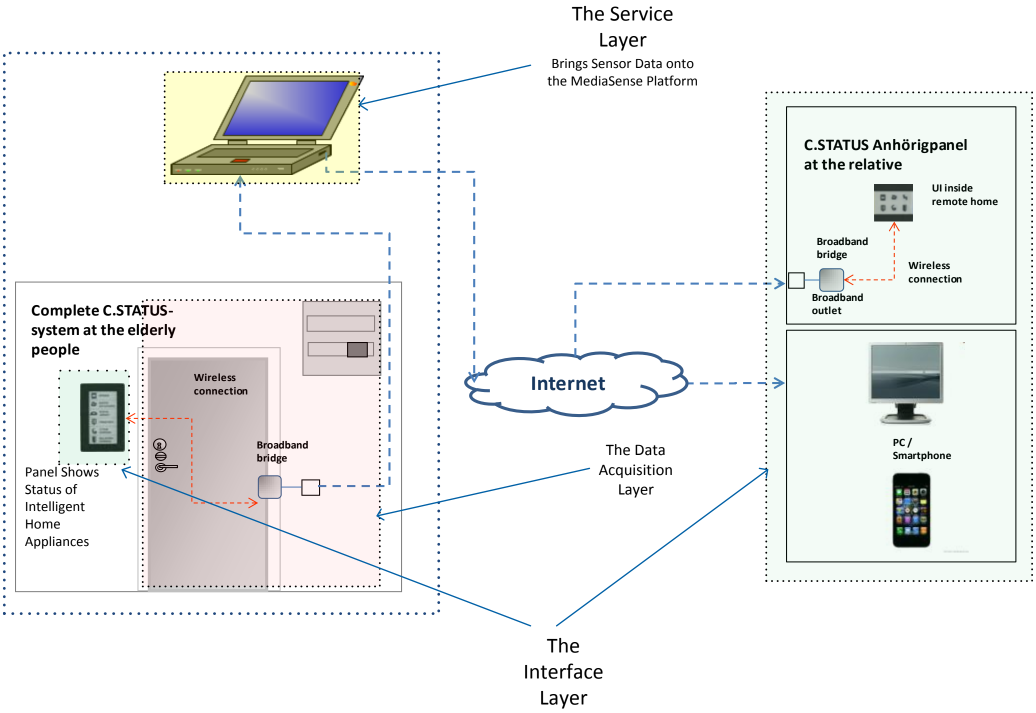


Figure 16 C.STATUS on the top of MediaSense Platform.

5.2.2 Implementing the Service Layer

The service layer communicates with the user in a peer-to-peer manner as shown in figure 17b thus the server, which has been acting as a data storage in the existing sensor network, has never been used to store and forward the data coming from the sensors embedded on intelligent appliances. In the same figure two categories of nodes are shown (node1... node6) and (node1'… node6'). The first group of nodes are control devices and the second group of nodes are intelligent appliances.

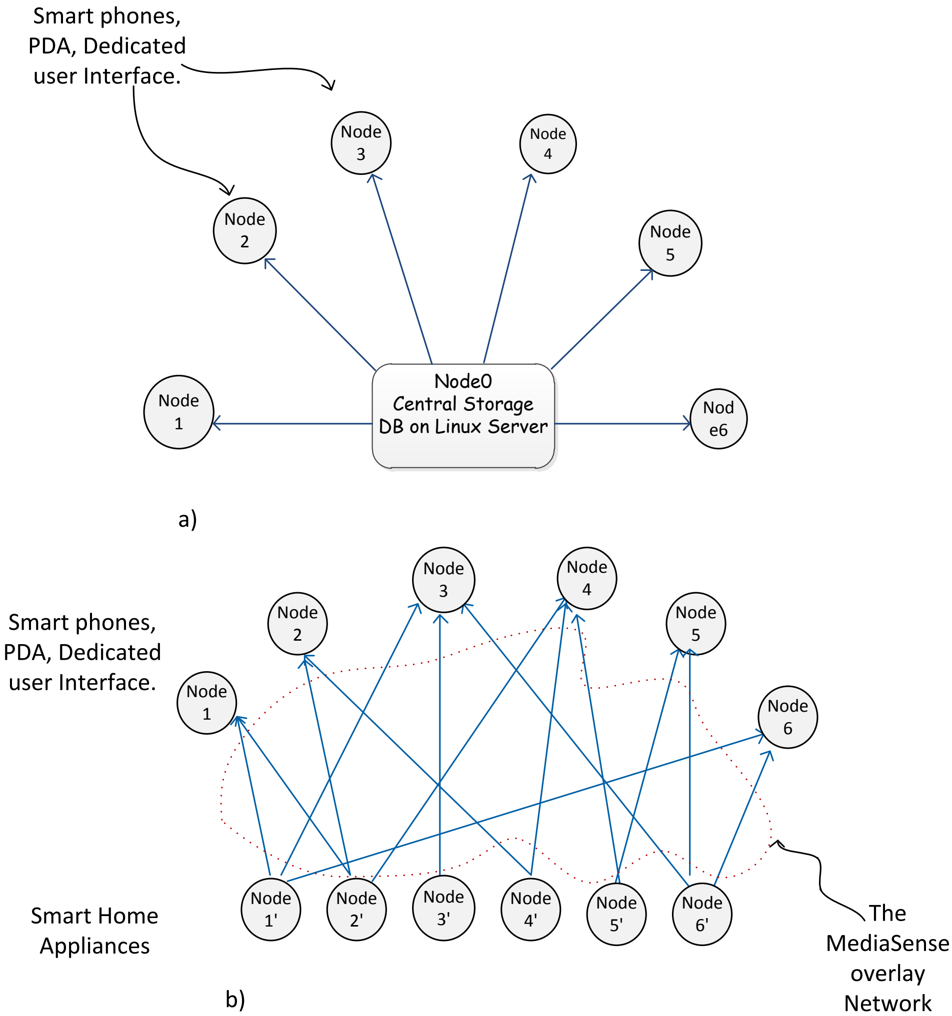


Figure 17 a) Existing Sensagon's Elderly Care Sensor network nodes b) Sensagon Sensor network nodes on top of the MediaSense platform.

The MediaSense platform has been intended for a situation in which two or more nodes could exchange data in a fully distributed manner. However, the existing Sensagon's elderly care system does not employ the usual wireless sensor nodes. Instead, sensors provide data to another computing device from which meaningful data can be collected. This will give us two options in order to achieve integration. The first , and the simplest , being to consider the existing sensors plus the accompanying computing device as one virtual node. However, this has no advantage in real terms over the existing system apart from simulating the peer-to-peer network. The second option has been to deploy wireless sensor nodes on each of those home appliances to be controlled remotely and implementing this way will make it possible to easily achieve a bi-directional communication easily. In the second case the (node1'… node6') in figure 17b are replaced with sensor nodes which have a capacity to gather data, process ,forward and receive data. The first option has been chosen in order to determine the scalability of the two networks as described in the next chapter.

6 Results

The end-to-end delay for the current system is measured sending and receiving data of different sizes to the central server. By doing this it is possible to capture the time it takes for packets to arrive using Wire-Shark. However, for the smart home environment running on the top of the MediaSense, the end-to-end delay in setting up an environment where two nodes (a Laptop and a tablet) are connected through public IP to send and receive data over the MediaSense overlay network are calculated. In both of these cases, the time the sensor node takes to update the server has been measured assuming that the sensor node updates at full potential. For example a Lantrox XPort AR Module would provide a maximum data rate of 230Kbps.

In general the time a packet takes to pass through a transmission medium could be summarized by the following formula.

Delay = [Queuing delay + Propagation delay + Transmission delay].

However, in a wireless sensor network, motes process data and forward it to the next node depending on the algorithm that rules the nodes interaction.

Therefore,

End-to-End Delay = [Queuing delay + Propagation delay + Transmission delay] + Processing Delay.

The fact that the existing sensor network is a centralized architecture means that every sensor node will send data periodically to the central storage and the nodes on the other side of the sensor network will retrieve data periodically. The existing system has never been intended to transfer data in real time. However the purpose has been to update intelligent appliances status periodically with high delays. Nevertheless, the possible minimum time data takes to transfer from one end to the other end has been calculated.

As has been explained in the previous chapter, the intelligent appliances do not understand each other so this will lead to the conclusion that two intelligent appliances, with the same data rate and hardware updating information at a time, equals twice that for the one updating its status at a given time .This assumption has been taken to achieve at the results shown in figure 18 and 20.

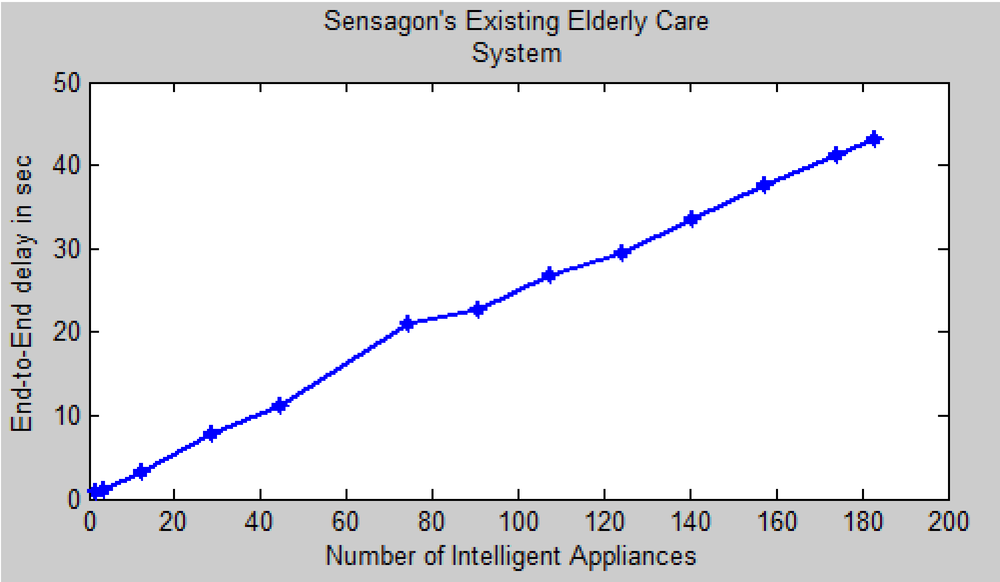


Figure 18 Sensagon's Existing Elderly Care System.

6.1 Sensagon on the top of the MediaSense Platform

The time a data packet requires to reach its intended target has been measured by using Wireshark. See figure 19. The delay has been measured for different data sizes.

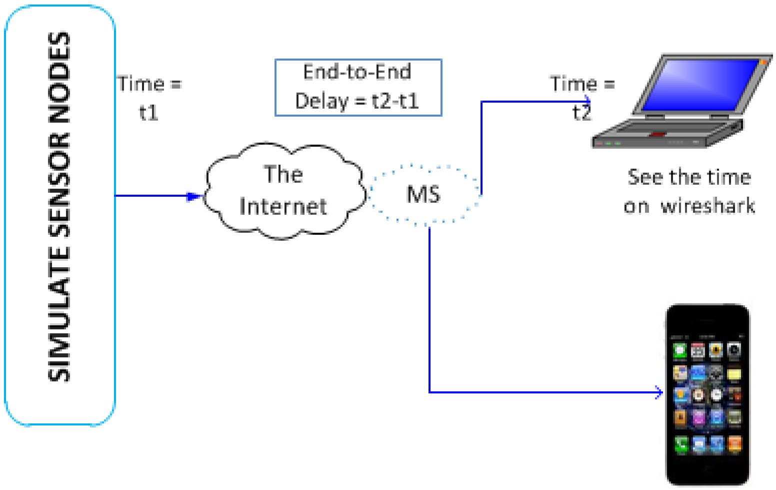


Figure 19 Environment we used to measure the end-to-end delay.

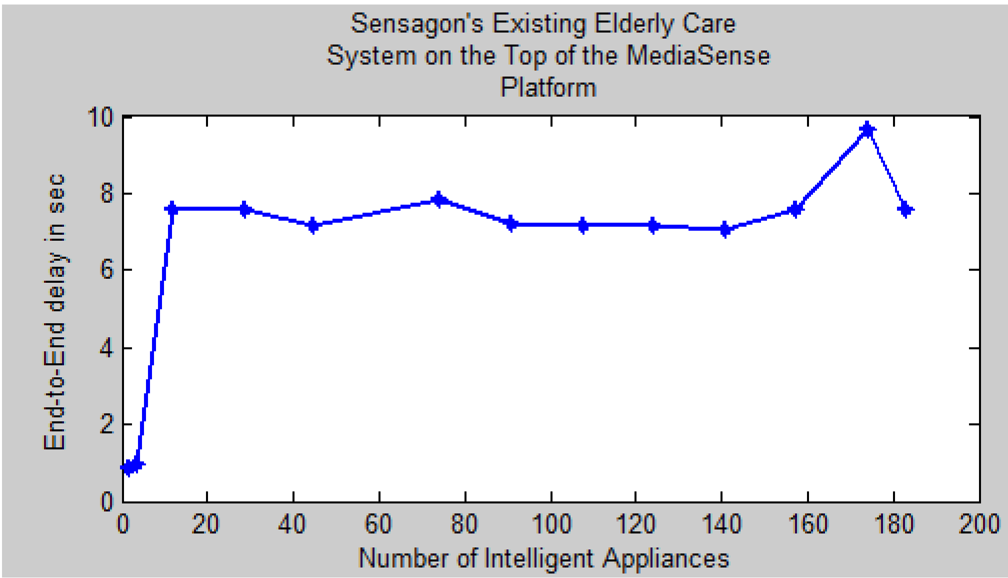


Figure 20 Sensagon's Existing Elderly Care System on the top of the MediaSense Platform.

6.2 Performance Comparison

The end-to-end delay measurement has only been conducted for a very minimal scenario in which only a maximum of two hundred appliances update the server at a time. Thus , the behavior of the sensor system when the number of nodes grows has never been determined. However, increasing the number of nodes has a significant impact on the sensor systems under comparison and , in particular, the centralized architecture will have a quite different performance. The expectation is that the existing system will reach a maximum number of appliances update per time, nevertheless, the MediaSense platform stretches out in unlimited fashion.

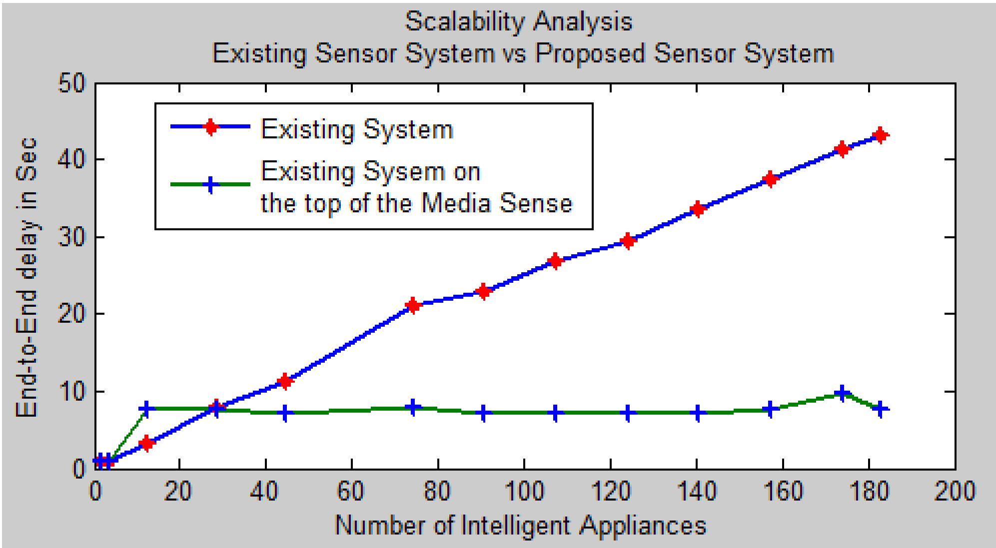
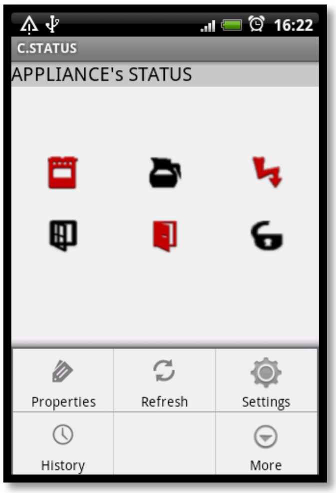


Figure 21 Scalability of Existing System versus proposed System.

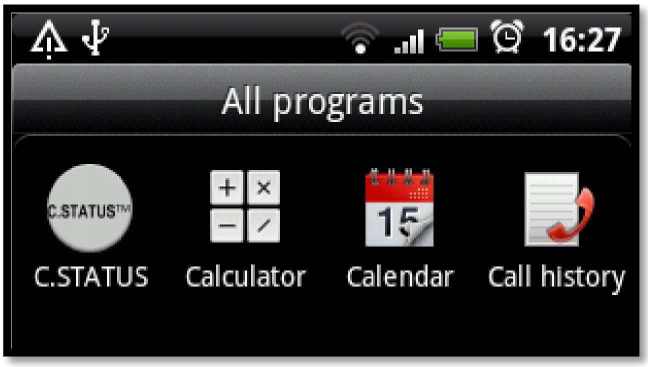
It should be noted that MediaSense provides a fully distributed scalable environment. However, this feature comes at the expense of privacy and data security problems. Therefore, in a situation, for which confidentiality and security are top priority, the belief is that the centralized architecture would provide a better solution at the expense of limited scalability.

6.3 C.STATUS™ and Web Services on Linux Server

The Android app developed allows the users to know the status of the home appliances remotely from anywhere. The app provides information about the status of the home appliances as shown in figure 22. The red symbols indicate those intelligent appliances are on or open .See figure 22a and 22d



a)



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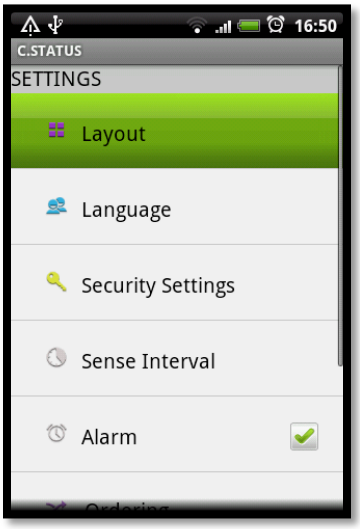

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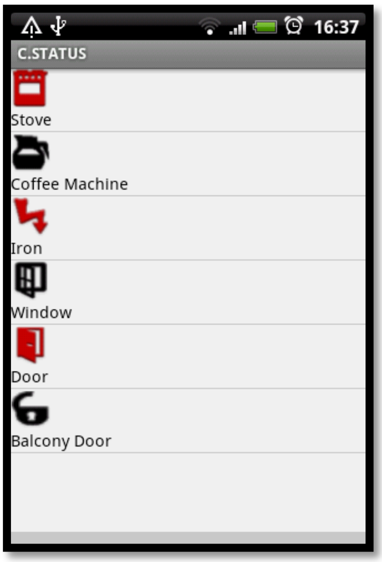
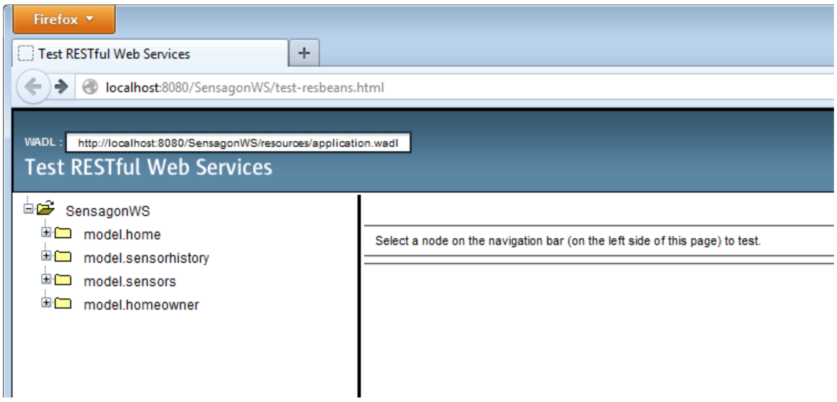


d)

Figure 22 C.STATUS™ Android App.

Web services were used to access the data residing on the Linux server. A service developed for the app receives periodical updates of current status. The period can be varied by the client. The app is designed to work in both in Swedish and English languages.



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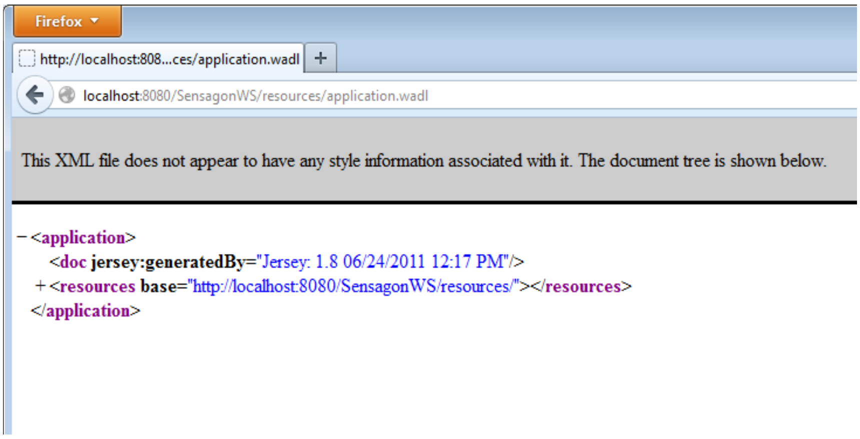


b)

Figure 23 Restful web services on MySQL Database

6.3.1 Android App Evaluation

The most crucial part necessary in order to make certain in relation to the developed app for the thesis is if all the requirements from Sensagon have been fulfilled. In this regard we believe we have considered all the requirements from Sensagon, in addition, important extra features have been added.

Requirements from Sensagon

1. Implement an app with a user interface that looks like our panel and shows status in the same manner. ”When you start the app it will show the status at home.

2. The App should show both the Panel´s and the Symbol panel's layout. It should be possible to alter both the text and the symbol (Within the app).

3. Figure out alternative ways of how to present the information if a) the system is installed in a) your home, b) your parents home or c) a home with children. Think about many perspectives / target groups/ scenarios.

4. Include functionality to administrate your own account. Examples can be Clear status, password, changing panel etc.

5. Design and Implement a database including functionality to administrate the DB.

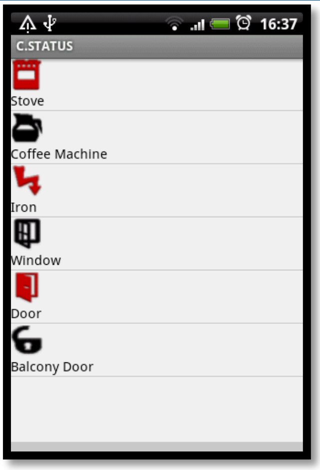
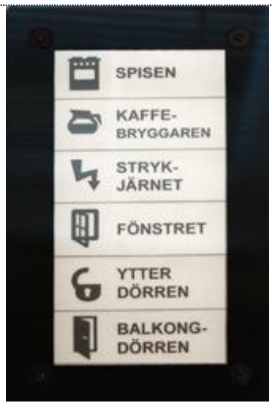
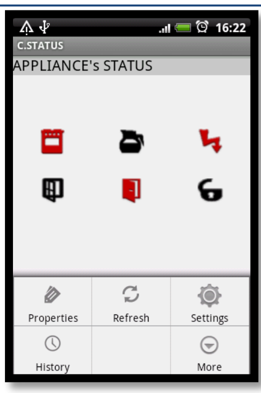
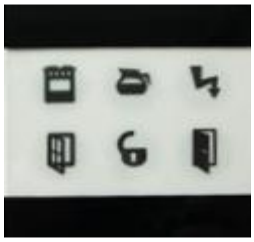
Extra Features

Alarm, Language (Swedish/English), Widget, History and Refresh

The app has been tested on the development environment using simulated data. The android app performs the intended tasks flawless manner.

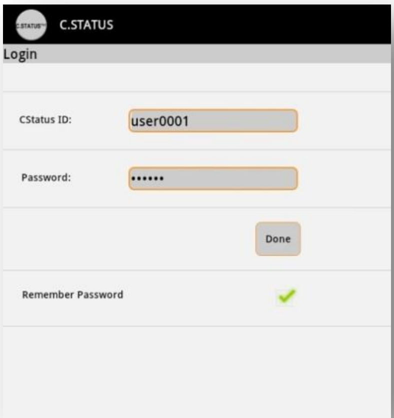
Intelligent home appliances' status on the android app and the dedicated Panels.

Table 3 the android app and the dedicated panel.

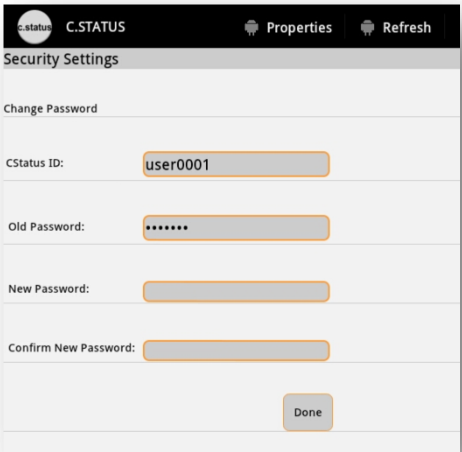
 Red Icons shows that the appliances are not turned off or closed whereas the black icons show that the appliances are turned off or close.	 In dedicated panels each item glows whenever there is an appliance that needs to be closed or turn off.
 Symbols panel layout offers a different layout to control appliances. The same purpose and features as in the fixed panel layout. You can change the languages, layouts, and so on using the action bar menu.	 Symbol panel layout is mounted on remote home where the person who takes care of the elders resides. Offers the same functionalities as in the fixed panel layout.

The widget shows the current status of each the home appliances. No need to open the android app to see the status the widget will show the information on the first page.

The Key tags inform the elders if they left the appliances turned on or open. These tags are connected to the panels inside the house through a radio signal.



Login window



Clients can change their Password on the android app.

C.STATUS™ Administrator can control clients, smart homes, intelligent appliances and view history using the Admin page

7 Conclusions

It is expected that smart home technology could see a revolution in coming in the coming few years due to two main factors. Firstly the Wireless sensor network is an active area of research both in academia and in industries. Secondly, the concept of Internet of things is sending its roots deeper and branching out very rapidly. In an infrastructure in which Smart Objects interact with one another as they do in IoT, Smart Home environment is only small part of the bigger IoT.

The first goal has been to analyze, evaluate and categorize standards for a smart home environment. In this regard this thesis has presented protocols and solutions designed to control appliances within the area of smart home technology. Some of the protocols covered are proprietary yet widely accepted. Wireless control protocols presented include Zigbee/IEEE 802.15.4, Z-wave, Dash7, ANT+, BLE and others. Moreover, wired alternatives have also been presented ,for example X10, HomePNA and G.hn. In this regard knowledge has been gained in relation to the standardization efforts aimed at arriving at one common standard by ITU-T and other consortiums. Besides the standards and protocols, wireless sensor network platforms such as MyriaNed , WirelessHART, TinayOS and Contiki have also been presented. The other aim of this paper has been to discover how interoperability is achieved between different solutions. To this end, different approaches have been covered: OSGi, UPnP and KNX. In addition, comparisons of the technologies have been made and categorization has also been conducted.

The second and the fourth goals have been to propose a mechanism for integrating and evaluating the MediaSense platform and C.STATUS™. The performance comparison for the existing sensor network dubbed C.STATUS™ has been conducted against a proposed sensor network running on the top of the MediaSense platform.

The third goal has been to develop an Android application for the existing system. Regarding the third goal a mobile application has been developed which allows users to check intelligent home appliances' status remotely. For this , Linux server and MySQL database has been used.

Sensagon's Elderly Care Sensor network is aimed to provide status update to a person responsible for determining the situation of smart home appliances. If the aim is merely to create a one-to-one communication link through a server, then the belief is that the existing system provides better data security and privacy. However, the existing system would face scalability problems as the number of clients as well as data updates and retrieval become huge larger. In this regard, the MediaSense overlay would provide a better choice. As a matter of purpose of the system, a somewhat different interaction between the nodes is seen in the Sensagon's Elderly Care Sensor network even though virtual nodes do exist that collect data and forward it. There is ,however, no communication among nodes inside a house (intelligent home appliances). Nonetheless, intelligent home appliances send status to the smart devices and these smart devices in return do not intercommunicate as is the case for nodes in a wireless sensor network. Such a node-to –node intercommunication could easily be extended on the MediaSense overlay.

7.1 Future work

This thesis has brought forward protocols, platforms and solutions on the emerging smart home technology. It has presented the smart home environment infrastructure and trends. In addition, the thesis has presented possible future trends in the smart home environment. In this area of research security should not be kept aside as it is mandatory. Therefore the extension work for this research paper could be how to deal with security and data privacy. The other extension work could be working on how to implement a two way data communication and updating the Android app that has been developed for the C.STATUS™.

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