



# **Malmö University**

School of Technology  
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## **A proposal of a smart home platform for better home entertainment experience**

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### **Master Thesis Project**

By

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## **ABSTRACT**

Smart home is a topic that emerged in the 90s to improve the quality of human life. The evolutions of ambient intelligence, recent technology advancements, internet, and smart devices have had a large impact in smart home environment.

In the traditional smart home environment, devices are connected physically in the environment and there are interoperability issues between the devices, because the environment is heterogeneous and the devices do not allow to communicate with the outside world such as the internet.

In this master thesis we propose a conceptual design of a platform for better home entertainment experience. Smart phone, smart TV and a personal computer are the most important devices in this platform design. The platform provides a high degree of interaction and integration among devices within the environment.

The proposed platform model helps software architects and engineers to have an early involvement in the design process.

We proposed the platform to be implemented with the help of hybrid cloud computing model. Our suggested platform design is able to overcome the deficiencies of the previous models and approaches in this domain.

We conducted direct interviews with seven computer science teachers at Malmö University for the evaluation of our platform design. The results show that the platform design can be physically implemented with the specified devices, the clouds are better than the traditional approaches and hybrid cloud model is more acceptable in terms of security and economy. We encourage software architects, developers and project supervisors to adopt this proposed platform model in physical smart home environment.

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# TABLE OF CONTENTS

ABSTRACT.....	ii
ACKNOWLEDGMENTS .....	iii
TABLE OF CONTENTS.....	iv
LIST OF TABLES .....	vi
LIST OF FIGURES .....	vii
1 CHAPTER I: Introduction .....	1
1.1 Background .....	1
1.2 Motivations.....	2
1.3 Goal .....	2
1.4 Research questions .....	2
1.5 Results .....	3
1.6 Contribution to the area.....	3
1.7 Outline.....	4
2 CHAPTER II: Background and literature review.....	5
2.1 Ambient intelligence .....	5
2.2 Smart home .....	5
2.2.1 Smart home subsystems .....	6
2.2.2 Challenges.....	6
2.3 Digital entertainment.....	8
2.4 Smart phone technology.....	8
2.5 Smart TV technology .....	9
2.6 Cloud computing.....	10
2.6.1 Cloud Services .....	12
2.6.2 Cloud computing implementation models .....	12
2.6.3 Why use cloud computing?.....	14
2.6.4 Risks in cloud computing.....	15
2.7 Related work .....	15
2.7.1 Summary of the related work.....	18
3 CHAPTER III- Research methodology .....	19
3.1 Methods for platform design .....	19
3.2 Methods for the platform evaluation .....	20
4 CHAPTER IV: Results .....	21
4.1 Platform definition .....	21
4.2 Platform requirement.....	22
4.2.1 Quality requirements.....	22
4.2.2 Functional requirements.....	25
4.2.3 Design requirements .....	26
4.3 Platform conceptual design .....	28
4.3.1 Hardware components .....	31
4.3.2 Integration and interaction .....	32

4.3.3	Software components.....	33
4.3.4	Core server platform .....	36
4.4	Application of the platform for improving the entertainment.....	37
4.4.1	Functionalities and services .....	38
4.4.2	Movie wish list paradigm.....	39
4.4.3	Interoperability paradigm.....	40
4.5	Proposed platform VS existing ones .....	42
4.6	Limitations of the platform .....	46
4.7	Future vision of the platform.....	46
4.8	The potential: why to adopt this platform? .....	46
5	CHAPTER V- Evaluation.....	47
5.1	Interview Structure.....	47
5.1.1	Objective of study.....	47
5.1.2	Planning and preparation .....	47
5.1.3	Description of the instruments used.....	48
5.1.4	Participants.....	48
5.1.5	Threats to validity .....	48
5.1.6	Execution .....	49
5.1.7	Interview ethics.....	50
5.1.8	Data Analysis of the results .....	50
5.2	Interview results .....	51
5.3	Interview results discussion .....	53
5.3.1	Functionality evaluation.....	53
5.3.2	Design evaluation.....	54
5.3.3	Requirements Evaluation .....	54
5.3.4	Draft optimisation .....	56
6	CHAPTER VI- Conclusion and recommendations .....	57
6.1	Conclusion.....	57
6.2	Recommendations for future work.....	58
7	REFERENCES .....	59
8	APPENDIX A: Interview guide.....	62
9	APPENDIX B: Interview outcomes .....	64

## LIST OF TABLES

Table 1: Quality requirements .....	24
Table 2: Functional requirements .....	26
Table 3: Design requirements .....	27
Table 4: Alternative communication capability for devices without /with the platform ..	32
Table 5: Operating systems alternatives .....	34
Table 6: Fulfilment of the requirements with the proposed solutions .....	41
Table 7: Comparison between proposed and existing platforms .....	45
Table 9: Interview finding .....	55
Table 10: Summarised findings .....	56

## LIST OF FIGURES

Figure 1: Subsystems in a traditional smart home environment [9] .....	6
Figure 2: Traditional cloud. ....	10
Figure 3: The vision of connecting the hardware to the cloud .....	11
Figure 4: Public cloud model .....	13
Figure 5: Private cloud model.....	13
Figure 6: Hybrid cloud model.....	13
Figure 7: Platform sphere.....	21
Figure 8: solution 1- the platform conceptual design .....	30
Figure 9: Transmission media Alternatives [5] .....	31
Figure 10: solution 2- camera and smart phone communication using middleware .....	35
Figure 11: solution 3- implementation schema for the core server platform.....	36
Figure 12: solution 5- interoperability paradigm .....	40
Figure 13: Draft design .....	63

# 1 CHAPTER I: Introduction

## 1.1 Background

Our homes are becoming more and more dependent on hardware and software. The field of ambient intelligence has introduced a new concept of dream homes that are intelligent and designed to improve one's private life. Research in the field of ambient intelligence has evolved and a new subfield called cooperative ambient intelligence is currently emerging. Gross [1], [2] suggests that cooperative ambient intelligence aims to "improve users' work and private life by analyzing their current situation with a special focus on their social interaction and to adapt to the environment accordingly".

The topic of this master thesis is ambient intelligence with a narrow focus on the smart home environment. The topic of smart home environment has emerged during the last few years and there is not enough research in this area [3]. Ambient intelligence is particularly good for elderly and disabled people because as it improves the quality of life by generating user's communication with the environment. Currently the increase of elderly population in Europe has pushed forward research in this area. Therefore, Europe is the leading place in the field. [4].

Smart home enables one to convert an ordinary home environment into a more convenient one thus improving the quality of life and convenience for the users. The smart home allows automated domestic activities like heating control, domestic electrical activities.

Research in many aspects of smart home environment like security, heating, lighting, and control, etc. has been carried out in the past [1], [2], however, there are some areas that leave more scope for research. Smart home environment in entertainment was chosen as the authors of this thesis believe that this area needs to be improved. The main concern of this research is how we could improve entertainment within a smart home environment. Therefore the purpose of this thesis is to propose a conceptual design for a platform that integrates different entertainment devices with different technologies. This will enable accessibility within and outside the environment in order to enhance the home entertainment experience.

## **1.2 Motivations**

The application area of cooperative information systems (CIS) was chosen because we think that ambient technology in the future will change our home environment. It will change our general concept of home, office, conference halls etc... We also believe that much research is yet to be done in this field [5]. Although there are a number of digital equipments integrated in the home environment, these are still unable to provide the high impact in terms of technological solutions. Considering that smart home environment provides residents numerous benefits, the possibility of such convenience could in turn make humans completely dependent on the digital world [6].

This research will help in guiding the creation of an integrated smart environment.

## **1.3 Goal**

The goal of our research is to find how we can use the smart phone and smart TV in the smart home environment. At the time of writing, these devices are not a part of smart homes. We are keen to analyze their impact; what new functionality can these devices bring to users?

More specifically, we intend to use communication and entertainment features of smart TV and smart phone to see how they can be useful in smart home environment by designing a platform that will help researchers and developers identify the technical challenges involved in its implementation.

## **1.4 Research questions**

From the above mentioned goal we obtain the following research questions:

*1. How can we create an adaptive platform which binds smart technologies like smart phones and smart TV s, suitable for a smart home environment?*

*2. What are the functionalities that this platform can perform in a smart home environment?*

## **1.5 Results**

Our research will develop a critical understanding of the appropriate technologies required for the integration of digital entertainment devices in its adaptation to the smart home environment concept. Our research suggests new design concepts for the development of smart home entertainment depending on the data generated from exploring new technology in improving home entertainment experience (see chapter IV).

## **1.6 Contribution to the area**

Although research has already carried out in the area of smart home environment to tackle problems in control, implementation, integration and interaction, our contribution is to adapt and support latest technology in the context of smart devices and cloud computing to make the home environment connected to the outer world.

The proposed platform model design helps software architects and engineers to have an early involvement in the design process. Our main contributions to the research area are the following:

- A conceptual design model of a platform that provides a high level of integration and interaction amongst digital devices in home entertainment environment as well as enhanced communication with the outer world using cloud computing (see section 4.3.2).
- A proposal of functionalities and services that can be achieved by implementation (See section 4.5.1).

## 1.7 Outline

- **Chapter II:** This chapter provides the background information about important concepts, technologies, challenges and related work in the area.
- **Chapter III:** This chapter presents methodologies adopted to conduct the research.
- **Chapter IV:** This chapter covers the research results. It describes the proposed platform design, services and functionalities offered by it. It exemplifies hardware and software requirements for the proposed platform. Additionally, a comparison between the proposed and existing platforms, its limitations, future vision and potential.
- **Chapter V:** In this chapter it is presented an evaluation of the platform conceptual design, requirements, and functionalities through interviews and discussion.
- **Chapter VI:** The final chapter provides a summary of this work and recommendations for future work.

## **2 CHAPTER II: Background and literature review**

This chapter provides information about the main concepts of the research area, the technologies, definitions, and devices integrated in the environment. Information provided in this chapter helps the reader to develop a deeper understanding of the concept.

### **2.1 Ambient intelligence**

Aarts & Marzano [7] define ambient intelligence as “a digital environment that is sensitive, adaptive and responsive to the presence of people”. In this regard, the most important features of ambient intelligence are integration of technology in the environment, ability of technology to recognise user’s context, and the system’s ability to respond to user’s requests intelligently as described by Boldeanu [4].

Research in the field of ambient intelligence has been done and currently the field of cooperative ambient intelligence is emerging. Gross [1], [2] describes in his research that cooperative ambient intelligence aims to “improve users’ work and private life by analysing their current situation with a special focus on their social interaction and to adapt the environment accordingly”.

### **2.2 Smart home**

There are many terms used in the last decade for smart homes, intelligent homes and home networking to introduce the concept of having networked devices in the house or building. Other terms such as aware house, changeable home, and ambient intelligence are related to the home environment that should adapt and respond to the inhabitant’s changeable needs. Various definitions exist for smart home. According to the smart homes association given by Bierhoff et al. [5] a smart home is “The integration of technology and services through home networking for a better quality of living”.

Another definition of a smart home given by King [8] is “A dwelling incorporating a communications network that connects the key electrical appliances and services, and allows them to be remotely controlled, monitored or accessed”.

### 2.2.1 Smart home subsystems

A research done by Perumal et al. [9] asserts that a smart home consist of various systems such as heating, security, lighting, digital entertainment, phone, internet, etc. as a result smart home environment is divided into five subsystems that are illustrated in figure 1.

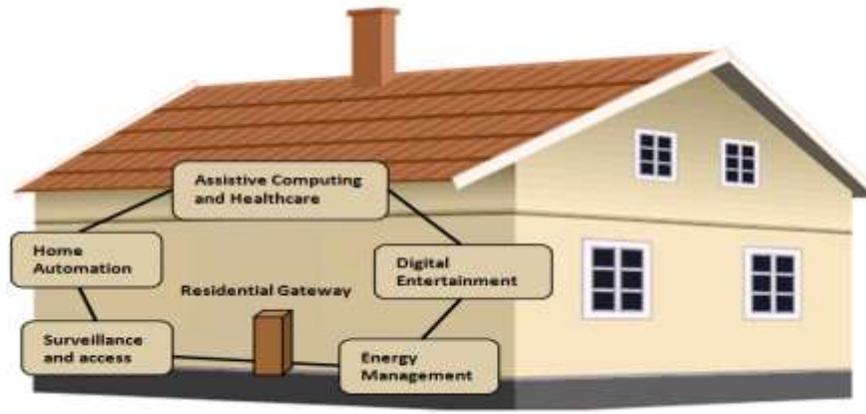


Figure 1: Subsystems in a traditional smart home environment [9]

- 1 Security system “Surveillance and access”
- 2 Digital entertainment
- 3 Home automation system
- 4 Assistive computing and health care
- 5 Energy management system.

The illustration in figure 1 shows the traditional smart home environment in which all the sub systems are connected to each other physically through a residential gateway server this gateway server joins two or more networks together in the local area network (LAN) and then connects the home to the internet. In this implementation there is a big challenge to obtain interaction and interoperability among the different devices and sub systems as the devices and sub systems run on heterogeneous platforms. Given that the devices come from different vendors with different operating systems and network interfaces.

### 2.2.2 Challenges

The challenges that need to be overcome in order to implement a smart home environment are based on the field study done by Edwards & Grinter [10] and are concerned with the technical issues, social and ethical directions in ubiquitous computing for smart home. The following are the most important challenges according to the study:

## 1. The accidentally smart home

- Accidentally smart home is an existing home that is unable to accommodate and integrate the new technologies. It is a phenomenon in which technological components are embedded gradually in the environment rather than the new smart homes that are purpose-built to support technologies. For example if a person brings Bluetooth-enabled speakers to home and set those to the nearest sound source may get different programmers that are originally set by a neighbour

## 2. Impromptu interoperability

- The ability to interconnect different components that were acquired at different times and are from different vendors without any advance planning or prediction that only such components will be able to interoperate.

## 3. No system administrator

## 4. Designing for domestic use

## 5. Social implications of aware home

- There can social consequences that can arise with the technologies are implemented into the smart home environment. The challenge of the designer is to deal with these social issues in efficient manner. The main social aspects to be considered are privacy, labour saving and good parenting.

## 6. Reliability

- Reliability is a big challenge to be considered in the smart home environment. In smart home environment different devices are integrated such as TV, microwave, washing machines, cameras, telephones etc that integrate with each other and with the environment. Developer must make sure that the devices never crash.

## 7. Inference in presence of ambiguity.

- In smart home user communicate and interact with the environment in order to perform daily routine functions with the help of sensors and cameras. To some degree the environment is aware of the user and its surroundings. The challenge for the designer is to create a system that ensure the user understands the realistic presence of sensors, other devices, interpretation and machine actions in their homes.

### **2.3 Digital entertainment**

Our main focus in this thesis is on digital entertainment within a smart home environment. King [8], points out two categories of digital entertainment, which are audio visual entertainment and internet.

The audio visual entertainment requires a smart TV in order to learn the family preferences, access control, record the desired program on given schedule from different channels. This entertainment category is to provide the music according to the user preferences in any location, time and space in the home.

The internet entertainment is concerned with the downloading of movies on demand, watching online movies, video game playing, and video call through your smart phone, smart TV or computer.

### **2.4 Smart phone technology**

Cassavoy [11] in his article defines a smart phone as “a device that lets you make telephone calls, but also adds features that you might find on a personal digital assistant or a computer”.

A smart phone can send and receive voice calls and text messages as traditional cellular phones, but in addition these phones include digital camera and large storage capacity, they are programmable and able to connect to the internet. Apart from this, there are many applications available to be used on these smart phones. Pitt et al. [12] discuss in their research five main characteristics that make a smart phone different from the traditional mobile phone. Those characteristics are:

1. Smart phones are multimedia devices that have cameras, large storage capacity, and internet connection. These features allow a smart phone to capture the media and to use the audio, video, or pictures as an input or an output source.
2. In order to detect and respond to the movement, most smart phones are equipped with accelerometers that detect the motion and change the display accordingly.
3. Smart phones are context aware and know the exact location of the owner with the help of GPS and Wi-Fi.
4. There are many applications developed for the smart phones for different purposes. These applications are available on the internet and can be downloaded for a particular smart phone. These applications can perform different tasks like playing games, weather updates, online transactions, and sports updates, etc.

5. Smart phones have similar advanced information processing capabilities to a laptop or a desktop with the exception of the smaller screen and the energy consumption that would have previously required a significant amount of power to be processed.

These features make the smart phone a suitable device to be implemented in a smart home environment in the context of digital entertainment.

## **2.5 Smart TV technology**

The term of smart TV used in this thesis describes the integration of internet into a television set or a set-top-box, in order to gain interactivity and to add advanced features to the traditional television [13]. According to the “interactive TV dictionary and business index” [14], the definition of the smart TV is “A set-top box with advanced hardware and features. It might be capable of video on demand, e-commerce, internet browsing, e-mail, chat, etc”.

Recently a large number of global companies like LG [15], Samsung [16], Sony [17], Panasonic [18], etc, are adding a layer of improved web features to the traditional television viewing experience using web connected applications that are specifically built for the TV in order to show the users favourite digital contents [19].

For example Google together with Sony and Logitech [20], have announced new services for the smart TV that can also be controlled from a mobile phone running on the Android operating system. This kind of TV solution offers new functionalities that were not present in the old TV, like Mail, social networks, TV channels, and web search, etc. [21].

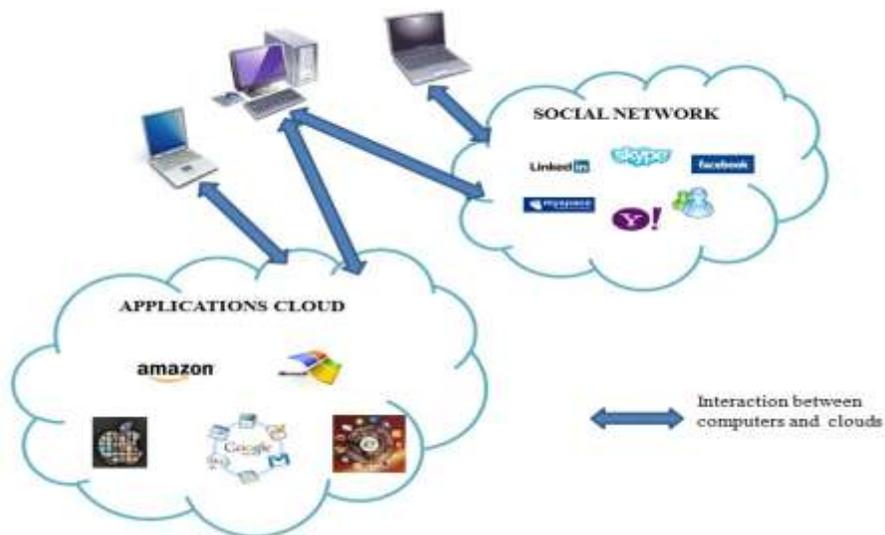
These features make the smart TV a suitable device to be implemented in a smart home environment in the context of digital entertainment.

## 2.6 Cloud computing

This section provides the information about cloud computing, its different implementation models and cloud services. It is very important to understand the basic cloud concepts as the proposed platform is required to be implemented with the help of cloud computing.

According to Badger et al. [22] from national institute of standard and technology “Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction”.

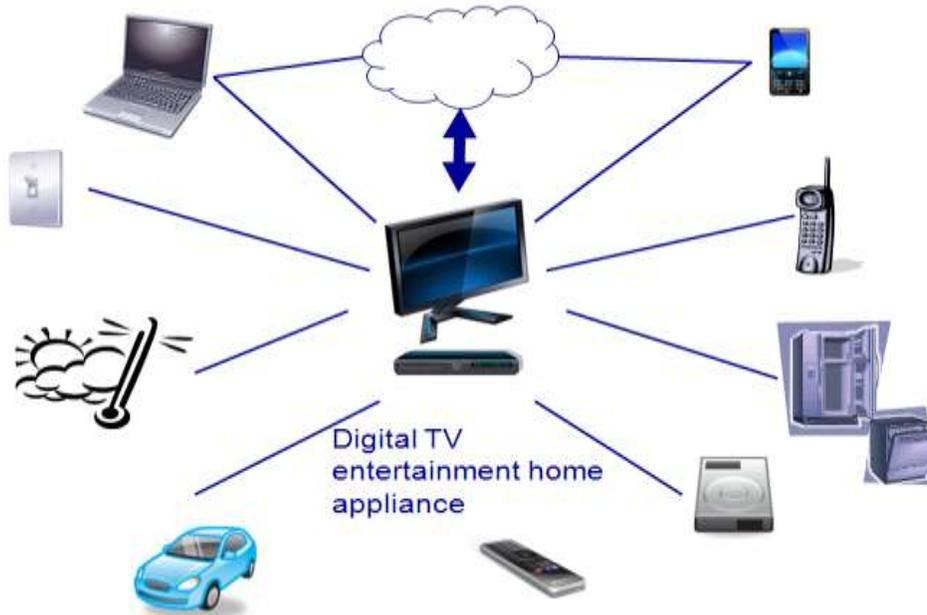
There are four implementation models and three service models for cloud computing that can be implemented depending on the user requirements. More information about these models is provided in the next sections.



**Figure 2:** Traditional cloud.

Figure 2 illustrates the initial form of a cloud that connects the computer to different online applications with the help of the internet. In this traditional use of cloud computers are only devices that were connected in a cloud. This was called the internet of computers. Following were the mobile telephones connected to the cloud. According to the concept of internet of things [23] more or less anything will be connected to the internet.

With the development of technology now, it is possible to connect different devices like the phone, TV, security alarms, and locks to a cloud.



**Figure 3:** The vision of connecting the hardware to the cloud

Figure 3 shows a vision described by Larus [24] of a smart home to be implemented with the help of cloud computing. Today we have TV, Digital Box, smart phones, security alarms, digital locks, computers, game consoles, and smart home appliances in our homes. Usually, these devices are not connected to each other since these are often from different vendors and run on separate platforms. These devices cannot provide cooperative functionalities in a smart home. The vision of using cloud computing [24] will make it easier and possible to integrate the devices in the environment, where the devices interact with the environment and with the other devices.

### 2.6.1 Cloud Services

Cloud computing provides services for all the needs ranging from hardware to end user applications. It allows for rental access to hardware resources such as servers, storages, routers, switches and also provides required application for end users on demand. Barga [25] proposed three categories of services SaaS, IaaS, and PaaS.

These categories are described as following.

**Software as a Service (SaaS):** is on demand service that provides a complete software application. The software is installed on a single computer in the organization and multiple users access it over the cloud within the organization.

**Infrastructure as a service (IaaS):** provides the all solution required to build an information technology (IT) infrastructure that usually consists of equipment, systems, software, and services. It provides storage and computing features as service on network. For hardware concerns it provides servers, switches, storage solutions, and routers, etc, and for computing purpose it provides all kind of applications from simple to high performance applications.

**Platform as a service (PaaS):** provides platform as a service to create high level services. The platform is equipped with all the resources required such as operating systems, application software, security, middleware, storage, programming language and development environment.

### 2.6.2 Cloud computing implementation models

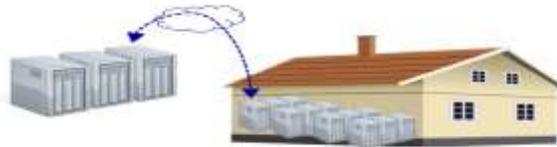
Cloud computing can be implemented in different ways and with different architectures. Mainly there are three models: public, private and hybrid [25]. These can be implemented according to the customer requirements. The three models are described below.

**Public clouds:** are open in the context of user can have access to large quantity of resources that are available over the internet. These clouds are hosted away from the customer's location and applications from different customers can be mixed on the cloud server, network and storage systems. Applications running on public clouds are transparent to both the providers and users. Public clouds are cheaper for implementation compared to other models. Figure 4 shows communication between a user and a public cloud provider.



**Figure 4:** Public cloud model

**Private clouds:** private clouds are built for a particular user and normally are located on his/her location. The customer owns the infrastructure and has a full control over the data, security and applications to be implemented. This requires higher cost for implementation. Figure 5 shows communication through servers deployed at the customer's location that are connected to the private cloud provider.



**Figure 5:** Private cloud model

**Hybrid clouds:** it combines the characteristics of both public and private clouds. These have ability to implement a private cloud with the use of public resources. Figure 6 shows the server deployed at the customer location but are communicating with the public cloud.



**Figure 6:** Hybrid cloud model

### **2.6.3 Why use cloud computing?**

Cloud computing architecture offers many benefits that distinguish it from the standard enterprise computing. Barga [25] in his work classify the three main benefits of cloud computing:

#### **1. Reduce runtime and response time**

Cloud computing allows applications to access large number of servers so it reduces the runtime as compared with the application running on a single server. A good example is New York Times that reduced runtime with the help of cloud computing [26].

#### **2. Minimize infrastructure risk**

Cloud computing minimizes the infrastructure risks in the context malfunction in e.g. equipment, systems, software or services; since in cloud computing a company or a user can access the cloud servers so it is not necessary to purchase the physical servers. This implies that when the work load in the context of processing capacity increases, a large number of servers needed, can be deployed quickly. Even if users are using a private cloud where they have their own servers installed, when their work load increases then this load can be shifted to the public cloud.

#### **3. Low cost of entry**

Cloud computing reduces the installation and entry cost in new markets; no need for advanced IT infrastructure. The main reason of the low cost is that the infrastructure installed in the cloud computing is rented, therefore no need to purchase servers, so the initial investment can be zero.

#### **2.6.4 Risks in cloud computing**

An important issue to be considered in the use of cloud computing is the migration of the data when the cloud provider close down. An article by Mearian [27] highlights that there is no such way for a cloud provider to migrate his/her personal data to another cloud. When a cloud goes down or the provider closes down, it returns the data directly to the customer who must then find another provider to store the data. Also there is no known satisfactory procedure for data erasure. The service provider marks the data to be deleted as a garbage collection and then it may take months to be deleted. In order to overcome such problems the technical group of SNIA (Storage Network Industry Association) is developing an application that will facilitate the migration of data directly from one cloud to another. There are also companies that now offer the secure erasure of data within the cloud so it may not be recovered. The better option to avoid such situation is the use of hybrid cloud in which the data is first stored at the customer location and then it is replicated to the cloud storage provider.

#### **2.7 Related work**

Providing better control and interaction among the devices is an active research area in the smart home environment. Our related work will be focused on smart home platform that enables higher integration and interaction among devices by combining different devices to perform a specific task within the environment.

A project in the field of smart home environment was carried out by Ciau et al. [28]. The basic purpose of their project was to provide the design and construction of a hardware prototype. The prototype was implemented with the help of a client server model for controlling different devices for illumination and security in the environment. The devices in the prototype communicated through a server and a client application. Ciau et al. define the device that requests information by the name of client and the device that responds to the request by the name of server. The outcome of this work ensures the correct functioning of the components used in the system's architecture and provides simple method of control achieved without needing the latest technology [28].

Research conducted by Perumal et al. [9] to achieve the interoperability in a smart home environment (see section 2.2.1). The authors define three sub-divided levels as a foundation for achieving a higher degree of interoperability: basic connectivity interoperability, network interoperability, and syntactic interoperability. The article describes the potential of web services technology using Simple Object Access Protocol (SOAP) in addressing the interoperability requirements for smart home environment. In the application gateway the developed software engine “component” was embedded to provide functionality required for managing services using SOAP. To provide operation mobility “multiple clients” in the context of operating different mobile devices such as laptop, mobile phone and pad. The “.NET” framework was used to manage and give access to the system by a single software.

Baker et al. [29] proposed a platform designed to deal with four issues, Zero configurations, Universality, Multi user, and Adoptability (ZUMA), in smart home environment. ZUMA is designed to deal with users, contents, and devices. This platform enables configuration and organization of content and network heterogeneous devices in smart home environment. It has different layers to complete a task initiated by a user. The user interacts with session which is responsible to deliver user’s task to an ambient operating system (OS) that continuously map these tasks into implementation. Sessions that run concurrently in ZUMA are home security, automation, entertainment, and health monitoring. A prototype was developed to validate the platform. The prototype includes the basic features and contains a routing hub, audio video clients, remote-control, sensors, and media storage devices. This routing hub is a hub server that deals with two types of threads, the client service threads and mapper threads. The client thread receives queries and requests from its clients, converts them to mapper events that are then added to a queue, while the mapper thread dequeues events and handles them according to the nature of task.

Merabti [30] has presented a framework for self adaptive network devices and he argues that the services should be described semantically. Research conducted by the author deals with configuration of devices, discovery and comprises of services in ad-hoc environment without human intervention. In this framework Merabti suggested that each device is required to have a service and a network interface that makes it open to network or internet. An intelligent middleware called Network Appliance Service Utilization Framework (NASUF) was developed by Merabti to address these issues. NASUF is service oriented middleware that allows ad-hoc services from the networked appliance within a peer-to-peer network.

In the concept of “internet of things” introduced by Raunio [23], almost anything will be connected and managed in a virtual private world. Computers and mobiles are already connected to internet and in the future, all kind of devices like home appliances, TV, and security equipments etc. will be connected to the internet.

The system architecture of a conventional smart home is usually server-centric, this causes problems such as the risk of a single point failure in the home gateway which causes the whole system to crash. To address the problems Wu et al. [31] claim that a smart home needs to conform: open standards, service integration, and mobility within the environment. To solve these problems the authors proposed a Service Oriented Architecture (SOA) based on Open Services Gateway Initiative (OSGi) and Mobile Agent (MA) technology for smart home environment. OSGi is an emerging open standard for deploying services to smart home environment. In OSGi platform deployed software components are called bundles that can be installed, updated or removed without disturbing the function of a device. SOA helps organization to share data among multiple applications. MA technology is used to avoid the risk caused by the client-server model. Multiple agents are used when the work load increases in smart home environment. The MA and OSGi combined with the SOA complete the proposed architecture by Wu. That is a peer-to-peer model consisting of several platforms that communicate with each other through service oriented architecture and MA technology to enhance interaction mechanism between the different devices.

### **2.7.1 Summary of the related work**

Summarising the related work we can observe that interoperability is a key factor to be considered in the smart home environment. It is very difficult to achieve a higher level of integration and interaction among the devices in a heterogeneous environment. To deal with these issues, different models and prototypes exist. Most of the solutions are based on server client models thus are unable to support new technology [28]. Another issue is that to integrate devices in the smart home environment requires a lot of effort such as special software, middleware, extra hardware as well as special equipment such as an application gateway is needed [9]. Furthermore these solutions provide very limited functionality within the smart home environment. Many models do not provide a better communication with the outer world [29]. Though some solutions offer better communication to the outer world, security measure for network level and user personal contents security is not considered [30]. Additionally in the smart home environment it is required to provide a controlled access to digital contents for all age groups. A better mechanism is required to distribute the work load from one server to the other [31].

In this chapter we have described functions, features and technology of smart TV and smart phone in the literature review because these are the most important devices to be adopted in our platform design. In addition there are some other devices required for the implementation of the platform such as computers, sensors, sound system, digital cameras, digital receiver, game console etc. These devices are not described in the related work because it would be too long to mention all these devices.

In section 4.6 we will consider information and concepts models gathered from the above mentioned related work and compare those concepts with our design. We discuss different angles why the proposed platform is more future-ready.

### **3 CHAPTER III- Research methodology**

It is very important to select the right research method in order to get the desired results in scientific research. There are different kinds of research methods such as qualitative methods, quantitative methods, and mix approaches that can be adopted according to the requirements and nature of a particular research. This section provides the information about research methodology that we adopted in order to conduct our research. It also explains the reason why a particular method is selected.

#### **3.1 Methods for platform design**

Our research field is smart home environment and our main concern is to design a platform that combines the functionalities of the smart TV and the smart phone in order to get a better entertainment experience.

According to the nature and field of research we adopted the design science approach described by March [32]. We believe that the design science is appropriate for our research because its purpose is to create or build artifacts “Constructs or concepts form the vocabulary of a domain. They constitute a conceptualization used to describe problems within the domain and to specify their solutions” [32]. It is technologically oriented and has roots in prescriptive research which aims to improve the performance of information technology “Information technology is technology used to acquire and process information in support of human purposes” [32]. The design science has two phases the first is the construction in which a researcher creates or design an artifact; the second is the evaluation in order to check the performance of the product in the environment in which it is implemented. The evaluation is similar to the discovery process in the natural science.

In section 1.3 we have listed two research questions that we need to answer in our thesis. In order to answer the first question a platform needs to be designed and this is done by applying the design science approach. The second question is dependent on the first one. After designing the platform we will suggest the main entertainment functionalities that the platform should be able to perform in the smart home environment. The functionalities will be based on different devices and technologies such as smart TV, smart phone, computer and internet.

Through literature review we identified the advanced features and functions of smart phone and smart TV that are the important devices for the proposed platform. The suggested functionalities would be the combination of smart TV and smart phone functions combined with computer and internet services.

### **3.2 Methods for the platform evaluation**

In the second phase of the research, we will conduct an evaluation of the platform by adopting a qualitative research method. The reason to select the qualitative research is that it helps to understand and increase the knowledge of a particular subject or area.

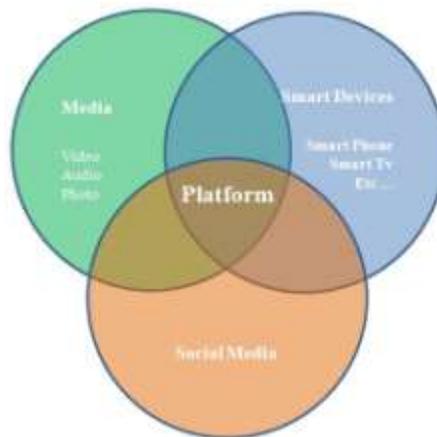
The reason not to adopt a quantitative research method in this phase is because quantitative data is not relevant in our case. There are different data collection methods that can be used to collect data in qualitative research. We choose the interviews as a data collection method.

The interviews were conducted with the computer science teachers in Malmö University because our project is a technical project and people that do not have knowledge of the area may not answer the questions. We conducted structured interviews, as we need to get the knowledge about a specific topic. For more details on the interview study please see section 5.1.

## 4 CHAPTER IV: Results

This chapter provides the results of our research: a proposal of a platform design model, its functionalities and limitations. A few elements of software and hardware implementation solutions have been discussed and exemplified in this chapter; however, the system implementation is outside the scope of this research.

We are designing a smart home platform for digital home entertainment. This platform is composed of new technologies and solutions for multimedia devices in the smart home environment. Figure 7 shows the topics covered by the platform.



**Figure 7:** Platform sphere

### 4.1 Platform definition

In computer science the definition of platform is described as “any standard that forms a basic environment under which compatible computer systems and application programs can be developed and run, as a specific computer processor or network connection” [33]. Our definition of platform is a conceptual design of embedding different devices that serve/make part of, the entertainment experience in a smart home. It is supposed to act as a bridge between users, devices, applications, services, and contents.

The proposed platform should provide the usability of different devices to serve different users with different usability preferences. In order to implement the platform, it is necessary to develop web application software. This software should be implemented on the server and will be responsible for registering users, services and devices. Registered devices can communicate with each other and to users/services, via TCP/IP protocols, with the help of software that exists virtually in the cloud [22].

## 4.2 Platform requirement

This section describes the requirements that the platform is desired to fulfil. These requirements were extracted from the literature review. We explored different technologies, services, devices, and existing platform models. This study helped us to specify key requirements for our platform design. We collected suggestion for the first draft of the platform design from all the interviewees (see chapter 5). Controlled access was adopted as one of the platform requirements. More detail about the requirements is provided in the following sections. The requirements are divided in categories as following.

### 4.2.1 Quality requirements

**Q1. Inter-operable:** The ability of the platform to create an environment that facilitates information exchange and usability between different smart home sub systems, applications, devices and components, in the present or in future.

*Motivation:* A key problem for smart home is to provide interoperability [9], since the devices come from different vendors with different operating systems and network interfaces. In this heterogeneous environment elements are required to perform joint execution of a task in a more efficient manner. In certain situations, it is required to have the devices running on the same technology. This phenomenon makes the environment closed and dependent, which is not desired [9], [31]. Furthermore a lot of efforts are required to integrate a device in the smart home environment such as software, extra hardware and special equipments [29]. The platform is required to work and integrate large number of different devices such as computers, sensors, speakers, smart phones, smart TV's, video cameras, game consoles, etc. It is very important for the platform to support a wide range of entertainment equipment types and the ability of interaction among those types [3], [8], [9] see table 1.

**Q2. Security and access control:** The platform should provide security and access control on user level within the smart home environment.

*Motivation:* An important aspect is to provide security on local and user base for the user's private information and data. It is desired that only the authorised users within the environment are privileged to interact with it. No outsider can access the environment and users have access only to

their own accounts. There are some personal contents such as pictures, videos, notes etc that need store locally within the environment rather than publicly in cloud [10], [22], [25] see table 1.

Likewise the platform should provide limited access to contents for all age groups from children to old age. It is vital to prohibit access to all those contents such as videos, websites, and programs that are not suitable for children (see table 8). In addition it is wanted to provide children with limited access to games and TV.

**Q3. Reliability:** The ability of systems, devices, and services to perform its required functionality as expected effectively with a low failure rate and can recover fast from an eventual failure.

**Motivation:** The platform should provide a certain level of reliability [10]. Combining services and devices from different vendors may result in a system failure or crash that may defect users life instead of improving it. Thus, reliability is a very important requirement to assure failure-free services to the end user [22].

**Q4. Entertainment experience:** The platform should be user friendly in order to provide users with an ambient entertainment experience.

**Motivation:** Users should be exposed to the entertainment in their natural environment “at home” where they can use different entertainment devices to enjoy diverse types of contents and resources. There are different preferences according to all age groups in the same environment. In this context the platform should provide a user enhanced entertainment experience by enabling the user interaction with the environment, “improve one’s private life” [1], [2], and “the ability to respond to user’s requests intelligently” [4]. Likewise it should be easy to configure and use for different age groups see table 1.

**Q5. Open standard “Optional”:** Comply with the Open Standards Requirement for which the source code is freely available.

**Motivation:** Enable the developer community to legally modify and improve the source code in order to create smart applications and services that contribute to the entertainment experience. If the user has closed system it becomes vendor dependent and the developments are strictly limited to the vendor’s, e.g. “research and development department”. This gives constrains to the variety of the available applications and services. Other reason is that advance users may miss the opportunity to develop their own applications and to improve services on the platform see table 1.

**Q6. Automatic update capability:** Programs updates are essential for devices, services, and other information that contribute to the improvement of the environment.

**Motivation:** The platform is required to deal with the heterogeneous environment that includes different devices with various software’s and technologies. In certain situations the software updates effects the particular programs and may cause a software or hardware crash [2], [9], [29], [40].

Table 1 provides the main quality requirements extracted from both literature review and suggestion of the interviewees obtained during the preliminary design of the platform.

**Table 1: Quality requirements**

<b>Requirement</b>	<b>Extracted From</b>	<b>Interview suggestion</b>	<b>Evaluated through interviews</b>
<b>Q1. Inter-operable</b>	sections: (2.2.1, 2.2.2, 2.2.7)	-	Yes
<b>Q2. Security and access control</b>	sections: (2.2.2, 2.6, 5.2 table 8)	Yes “control”	Yes “Security” / No “control”
<b>Q3. Reliability</b>	section (2.2.2)	-	No
<b>Q4. Entertainment experience</b>	sections (1.1, 2.1, 5.4)	-	Yes
<b>Q5. Open standard “Optional”</b>	sections (2.7, 5.4)	-	No
<b>Q6. Automatic update capability</b>	sections (2.6.1)	-	No

### 4.2.2 Functional requirements

The functional requirements are vital for the platform to provide different services and functionalities. These requirements are as following.

**F1. Authentication:** The platform should have the authentication capability for different devices and users in the environment.

*Motivation:* It is desired that only the authentic users and devices should be able to interact with the environment [22], [31] see table 2.

**F2. Accessible from any where:** The platform should provide the user with access to the devices integrated within the smart home environment regardless of geographical location.

*Motivation:* It is desired to access different devices and services from outside the smart home environment. A user should be able to control different devices from e.g. his/her office with the help of a smart phone or computer (see section 2.6, 2.7) [23], [24] see table2.

**F3. Level definition of services:** The platform should be able to register different entertainment services that enhance the entertainment experience in the environment.

*Motivation:* There might be certain cases where special services are required to enhance the entertainment experience. The platform should be able to register different services accordingly. The platform has to allow users to register services and functions within the smart home environment. [9], [21], [22], [25], [30], [31] see table 2.

**F4. Video conferencing:** The platform should facilitate video conferencing on different devices.

*Motivation:* it is desired to make video calls to different friends and family members on different devices such as computer, TV, and mobile [8] see table 2.

**F5. Access to social media:** The platform should provide access to social media.

*Motivation:* the platform should provide access to user's personal contents and different social media sources with the help of different devices and services such according to user mode [12], [21] see table2.

**F6. Audio and visual entertainment:** The platform should enable easy way of playing and storing music and videos content.

**Motivation:** it is desired to play music, videos, films etc. the platform should provide easy access to digital media contents and ability to store them on different devices. As well as it is desired to play the different home videos captured by the digital cameras or phone directly on the different devices such as computer and TV [8], [19], [21] see table 2.

**F7. Play games:** the platform should provide facility to play different game types.

**Motivation:** it is required to play and store different games either online or on a game console. The platform is required to provide easy access to different gaming sources [8], [12] see table2.

Table 2 provides the main functional requirements extracted from literature review and evaluated during the primary design.

**Table 2: Functional requirements**

Requirement	Extracted From	Interview suggestion	Evaluated through interviews
<b>F1. Authentication</b>	Badger [22], section 2.7 [31]	-	Yes
<b>F2. Accessible from any where</b>	section 2.6, 2.7 [23], [24]	-	Yes
<b>F3. Level definition of services</b>	Badger [22], Barga [25], section 2.7 [9], [30], [31]	-	Yes
<b>F4. Video conferencing</b>	section 2.3 [8]	-	Yes
<b>F5. Access to social media</b>	sections 2.4 [12], 2.5 [21]	-	Yes
<b>F6. Audio and visual entertainment</b>	sections 2.3 [8], 2.5 [19], [21]	-	Yes
<b>F7. Play games</b>	sections 2.3 [8], 2.4 [12]	-	Yes

### 4.2.3 Design requirements

There are hardware and software requirements that concern the platform design. The main requirements are as following.

**D1. Hardware:** The physical units, circuits, components, and mechanisms or the combination of them. The main hardware requirements for the platform are as following.

**D1.1. Smart input/output device:** Devices that can be connected to the internet and possess advanced processing, and visual presentation capabilities for managing information flowing through them.

**D1.2. Smart control device:** Devices that user is able to either carries it or place it at home, and control the smart system.

**D1.3. Access device:** The devices that provides access to the internet.

**D1.4. Backup-system “Optional”:** The system that provides multiple functionalities to users, devices, services, and programs via the internet.

**D2. Software:** A program that gives instruction to the hardware or software on what to do and what to perform. This program can be the combination of multiple programs e.g. operating systems, and applications.

Table 3 provides the main design requirements extracted from literature review and evaluated during the primary design.

**Table 3: Design requirements**

Requirement		Extracted From	Interview suggestion	Evaluated through interviews
<b>D1. Hardware</b>	<b>D1.1. Smart input/output device</b>	sections 2.2.1 [9], 2.3 [8], 2.4 [12], 2.5 [21], 2.7	-	Yes
	<b>D1.2. Smart control device</b>	sections 2.2.1 [9], 2.3 [8], 2.4 [12], 2.5 [21], 2.7	-	Yes
	<b>D1.3. Access device</b>	section 2.7	-	Yes
	<b>D1.4. Backup-system “Optional”</b>	sections 2.6 .1, 2.6.2, 2.7	-	Yes
<b>D2. Software</b>		sections 2.6.1, 2.7	-	Yes

### 4.3 Platform conceptual design

Based on the requirements mentioned in section 4.2, we decided to use the hybrid cloud model for the platform implementation design, because it is the best way to combine the advantages of public and private cloud computing (see section 2.6.2). Being implemented at the customer's location provides better security and control while using public resources. The hybrid clouds are cheaper as compared with the private clouds that have a tendency to be expensive and require a huge cost for implementation [22], [25].

In order to fulfil the requirements of the platform we believe that the use of the Platform as a Service (PaaS see section 2.6.1), the most convenient type of cloud services. This is because it provides all required services such as operating systems, security, version control, and interaction environment [22], [25].

The platform design provides a solution to the key problems of our research that are to achieve the interoperability among the devices and to enhance the entertainment within the environment. In order to deal such issues the platform combines different devices using cloud computing technology. The interoperability is achieved at the home devices cloud. Core platform server makes it easy to access different services in the cloud.

There are five different clouds presented in figure 8: social network, cloud services, media cloud, home device cloud, and core server platform. These are the conceptual design of the platform. These clouds are modules of the platform that work together to achieve the goal of better digital experience in smart home environment and this concept is called solution 1. Arrows between the clouds present the way of communication between the devices and clouds, as illustrated in figure 8. The thin arrow show the connection between devices in the cloud while thick blue arrows represent the interaction between clouds, and thick red arrows represent communication between clouds through an Application Programming Interface (API).

The *home devices cloud* is of much interest because it is responsible for integrating the devices locally or virtually replicated in the cloud.

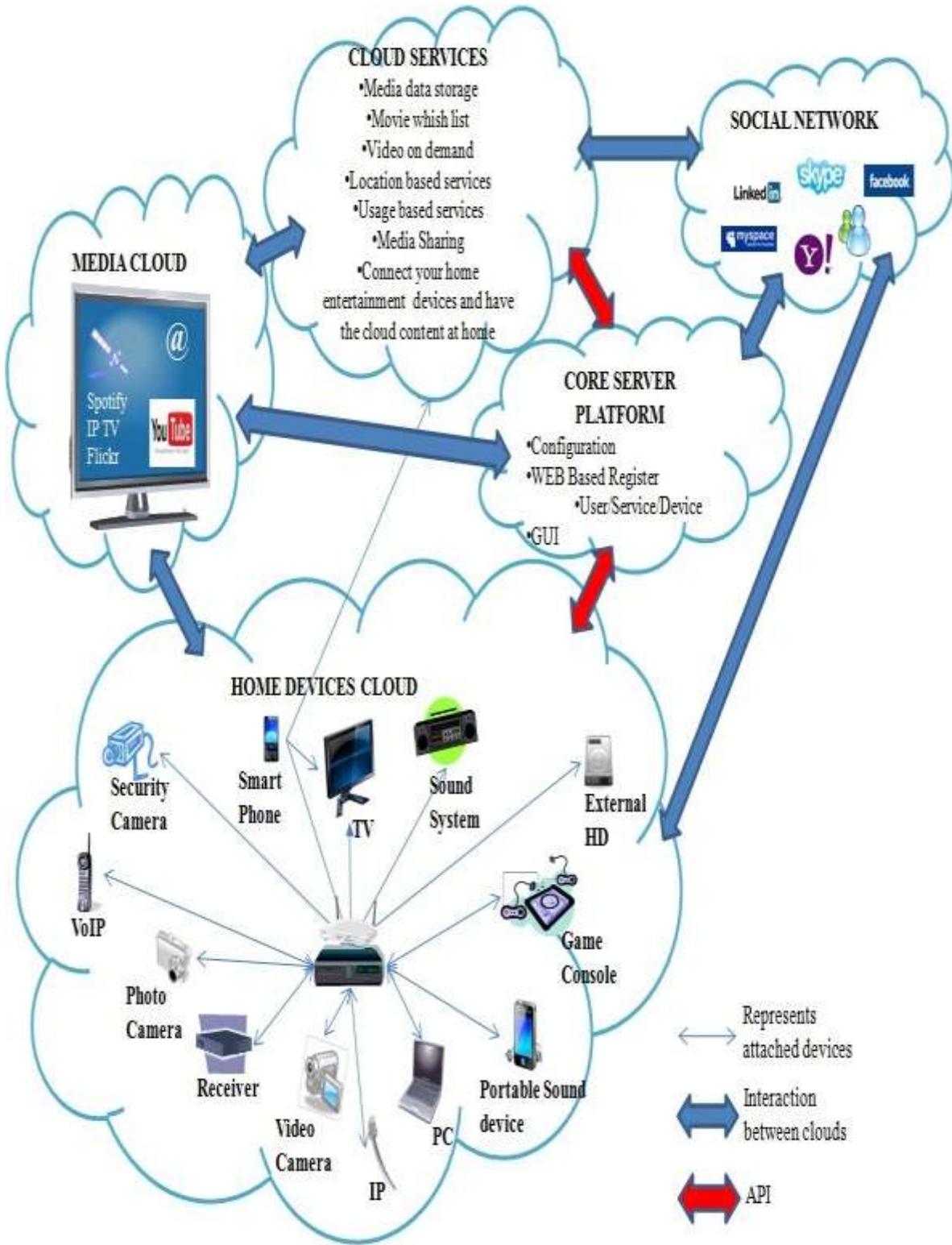
Each entertainment device within the home devices cloud is directly connected to a smart TV/set-top-box that itself is connected to the outer world. The devices within the cloud are connected through TCP/IP via access point. Thus, home devices cloud does not only provide interaction and integration locally, but also to the outer world. The *home devices cloud* is able to access certain web services directly or via the core server platform through API then provide interaction with different cloud services.

The *core server platform* is the core software/hardware engine of the platform, which can be installed locally or virtually. This cloud is responsible for registering the devices, the users, and the services. In this design, the core server platform acts as a bridge between the devices, the services and the clouds. This core server can also be used as a backup- system; there user's can store different data and information contents.

The *media cloud* is a public cloud that can be accessed directly by the home device cloud with the help of the smart TV, and the smart phone and by the help of the core server platform in certain situations. This cloud is responsible for providing contents such as TV programs, documentaries, music, movies, and sports etc.

Similarly, the *social network cloud* is accessible by the use of the smart TV and the smart phone. It provides access to different social media resources such as Twitter, Facebook etc.

The *cloud service* is responsible for providing several services to the user/device as per demand such as a movie wish list, video on demand, online media sharing etc.



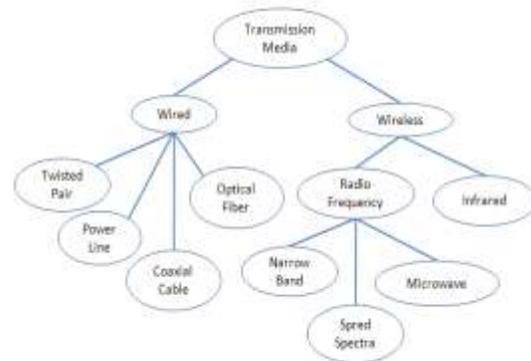
**Figure 8:** solution 1- the platform conceptual design

### 4.3.1 Hardware components

The main idea of the proposed platform is to be based on existing devices; this will consecutively make it feasible for implementation, widely available, and by default easier to be adopted in any home. We consider the platform as a smart solution providing more smart services to the entertainment experience at home.

According to design requirements, our suggested devices for the platform implementation are as following.

- **Smart phone.** Any alternatives that support any of the flowing operating systems (Android version 2.1 or higher, WM version 5 or higher, Apple IOS 3.0.1 or higher).
- **Smart TV / set-top-box.**
- **Personal computer (PC).** Any computer with an operating system that complies with the software requirements mentioned in section 4.3.2.
- **Access point.** Routers, network cables and Wi-Fi. The access point is responsible for providing internet connection to multiple devices like computers, mobile phones, TV's, etc., it is implemented by a device known as a bridge.
- **Server** (the part of a backup-system engine that provides specific role of controlled access and interaction functionalities to users, devices, services, programs and the internet).
- **Transmission media.** It could be wired such as (switches) or wireless devices such as (Wi-Fi devices and USB dongles). Figure 9 illustrates alternative transmission media [5].
- **Cables** (HDMI, Optical, Coaxial, etc...)
- **Digital cameras.**
- **Sound system.**
- **Sensors** (Motion, illumination)
- **Game console**



**Figure 9:** Transmission media Alternatives [5]

All of the above listed devices are available in the market and are sourced from different manufacturers so the devices can be connected regardless of manufacturers.

### 4.3.2 Integration and interaction

An important issue to be considered in the implementation design of the smart home environment is the ability to enable the integration and interaction among the different heterogeneous devices [2]. Usually the devices come from various vendors. Each device uses a different technology and as such, the devices fail to interact with each other. This brings into focus the main purpose of our proposed platform. Initially the interaction between devices is achieved by the functioning of an internal network. All the heterogeneous devices are connected to the internet. Most of the main devices in the smart environment are connected to this network by assigning an IP address. Other devices such as sensors are connected by non-IP communication that subsequently will communicate directly to services through its own communication protocols e.g. (long distance: SMS, Voice call etc. short distance: Bluetooth, IrDA, RFID etc) or indirectly through a Gateway e.g. (Middleware).

Table 4 shows, Input/output (I/O) communication alternative with and without the use of the platform. Please note that this table contains example of communication interfaces alternative that may vary from vendor to vendor.

**Table 4: Alternative communication capability for devices without /with the platform**

Devices	I/O Alternatives										Platform Alternative	
	WI-FI 802.11	Ethernet 10/100	COAX	HDMI	SCART	Component	RCA	Fire Wire	USB	Bluetooth		
TV	x	x	x	x	x	x	x		x	x	Via TCP/IP Protocols through services and applications	x
Smart Set-top box	x	x		x					x			x
Smart Phone	x			x					x	x		x
Sat Receiver	x	x	x	x	x	x	x		x			x
Network storage	x	x							x			x
PC/Mac	x	x		x			x	x	x	x		x
Server	x	x							x			x
Sensors	x	x										x
IP Telephone	x	x							x			x
Digital Camera	x		x	x	x	x	x	x	x			x
Game Consol	x	x	x	x	x	x	x		x			x
Access point	x	x							x			x

### 4.3.3 Software components

According to the design requirements this section presents the software and development tools needed when start constructing or building this platform while moving from “concept model” to “created model”. The exact software requirements of the platform have to be defined by software architects upon implementation which is outside the scope of this research. They will be based on existing software and development tools such as (APACHE, Linux, Linux Distribution, PHP, and SQL) that are explained as following.

**APACHE:** Apache software foundation supports different open source software projects. Apache HTTP server project provides a secure and extensible web server that compiles with modern operating systems and the current HTTP standards [34].

**Linux:** Open source Unix-like operating system (OS) that can be installed on different hardware devices such as computers, mobile phones, routers and Game consoles, etc. [35].

**Linux Distribution:** This is known as “Linux disto.” consists of a collection of free and open source software components [36].

**PHP:** Powerful open source tool for developing dynamic and interactive Web pages [37].

**SQL:** Structured Query Language, used for accessing and manipulating databases [38].

The usage of the above mentioned software tools are described as following:

- Database (SQL): Database will be used for storing all the relevant user data so a management can be done between services/devices/and other users.
- OS Linux disto. Preferably, due to its high portability and reliability, most of the available hosting companies and shared spaces in the cloud use a Linux system, which makes it easy to move all around.
- WEB server: For example, Apache and PHP (as programming language), are preferred due to the huge community available over the internet, similar to any open source solution, it is easy to move from place to place and to switch easily between developers’ communities.

The following section presents miscellaneous operating system (OS) for devices integrated within the environment.

**Operating systems**

There are different operating systems from different vendors that run on different devices table 5 gives an example of common alternative solutions available.

**Table 5: Operating systems alternatives**

Company	Apple	Open Handset Alliance(Google)/Vender’s using Android OS/open source operating systems	Microsoft
Mobil OS	iPhone iOS	Android 2.x	WM Windows CE 5.x
TV	4.2.2 based on iOS (Second Generation) or 3.0.2 based on (First Generation)	Android 2.x, WD Media Server, Samsung Smart TV, XBMC etc.	Window media center
Computer	Mac OS X	Ubuntu / Open SuSe /Google Chrome OS etc.	Window-XP SP2or later
Server	NA	Linux/UNIX	Windows Server 2003 or later

**Web browser**

Any web browsing application that is capable of retrieving, presenting, and traversing information sources on the World Wide Web.

**Applications**

Any application that enhances entertainment and is compatible with it’s specific device.

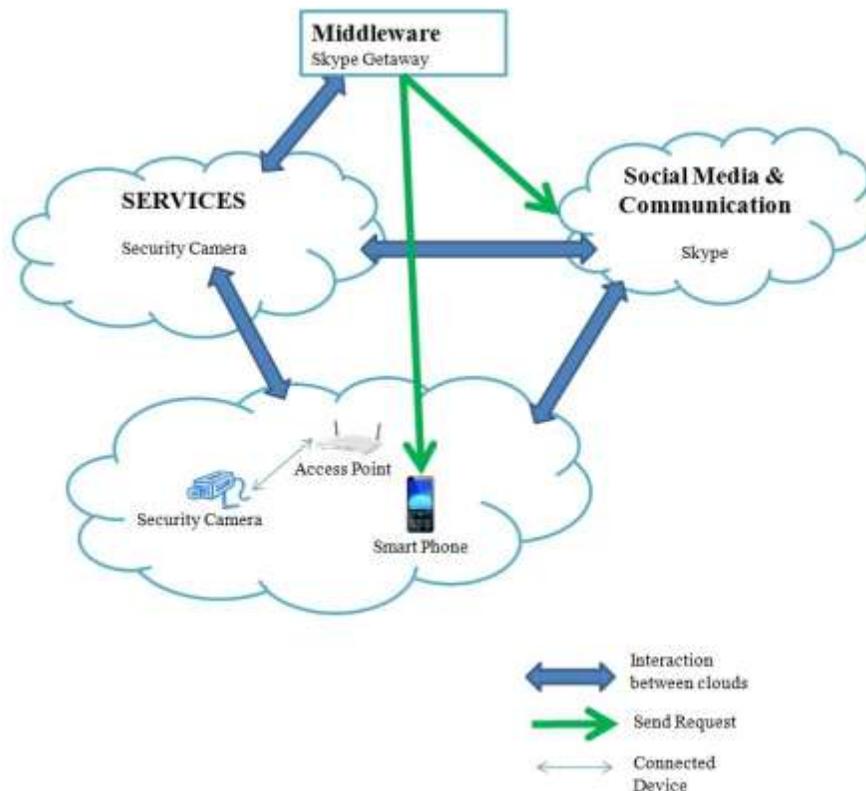
**Virtual servers**

Virtual servers as a part of a backup-systems are required in the cloud so that the customer/user may get access to the specified resources virtually rather than building and maintaining complex IT infrastructure [39].

## Cloud Middleware

There are heterogeneities between the clouds on different levels like scaling approaches, service interfaces etc. There is a need of middleware that can provide interoperation between different clouds. “Altocumulus” is a middleware that enables interoperation between the heterogeneous clouds. Furthermore it can backup and restore databases, creation and migration of cloud image [40].

Figure 10 below, illustrate an example of a middleware implementation solution called solution 2. A home IP Webcam that can be used for security reasons, this device is connected to a cloud (SERVICES) called “Security Camera”. If motion is detected, it automatically sends a request to the service server, more specifically exemplified in the illustration (Middleware “Skype Gateway”). The middleware makes calls to the registered person on the service either to the (Social Media & Communication) cloud or directly to the registered smart phone device, alerting them of motion activities detected in the house. This “service server” is a middleware that connects different layers of the clouds.

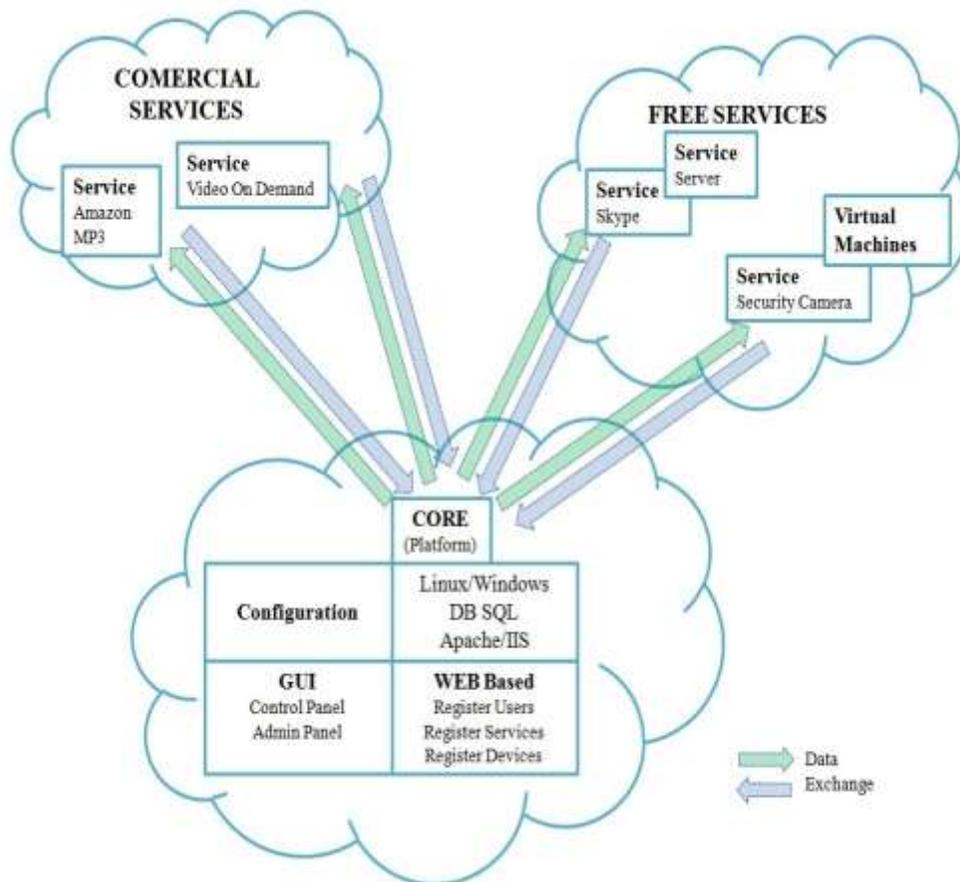


**Figure 10:** solution 2- camera and smart phone communication using middleware

### 4.3.4 Core server platform

An important part of the platform design is the core computer. The core computer is a server that is responsible for providing different tasks such as device registration, and user registration. The server has a database where the users and devices integrated within the environment are registered. The registration enables devices and users to perform the tasks with the environment. Likewise a web server is implemented on the core computer that serves the contents and devices in the cloud. The web server provides access to devices and contents from outside the smart home environment through a graphical user interface.

An example platform implementation schema would be a CORE computer (in the platform), with a Linux operating system, an SQL database and a Web server (see section 4.3.3) hosted at home or virtually anywhere in the cloud. Figure 11 illustrates the example schema for the proposed platform implementation and is called solution 3.



**Figure 11:** solution 3- implementation schema for the core server platform

Through this CORE computer:

- Users will be able to register themselves opting the desired services e.g. Social media (Facebook, Twitter, Security Cam etc.)
- Devices are registered in the database (DB) server. Precise definition of the devices is required according to its properties and functionalities. This can be classified into name, type, location, connection type, main functionality, other functionality, interaction, and services. The main devices such as computers, smart TV's and smart phones should be registered on CORE computer "the part of the backup-system engine" in order to provide better control and communication.
- Administrators can register/give rights to services (Facebook, Security Cam, Video on Demand, etc.), enable features e.g. (public / private), register users, and approve developers' applications and services.
- Developers can code services and applications, upload them for approval by administrators.

Each service can be hosted in the cloud and/or on a sever, making a hybrid cloud either on a virtual machine or in a shared space at a commercial/service company (for privacy).

Communication between Core and services will be done by requests from both sides through the platform engine API (see figure 8).

In this schema, the platform (CORE) by itself can be a cloud service, hosted entirely or partially in a remote location (see figure 8 "CORE SERVER PLATFORM" cloud).

#### **4.4 Application of the platform for improving the entertainment**

The proposed platform is designed to enhance the digital entertainment experience in the smart home environment by performing entertainment functionalities. These functionalities can be achieved after the physical implementation of the platform in the environment and depending on the devices integrated in the adopted solution according to the design requirements.

The platform inherits functionalities of the registered devices. For example if no device is registered there is no functionality; but in case of a registered device that has a web cam with an integrated microphone the platform by default, in this case inherits the audio video functionalities.

#### **4.4.1 Functionalities and services**

The solutions suggested by the platform emphasize the use of the smart TV and the smart phone and those two together with the core-server along in a cloudy infrastructure, make a smart way of living in a smart environment.

As mentioned previously, the main functionalities of the platform are to provide interoperability and interaction between devices. This platform is intended to adopt a cloud model service called Platform as a Service “PaaS” [22] that will serve other services and/or platforms in the context by offering easy to use interoperability and interaction between devices that are not available at this moment.

This platform will be ready for other future technologies, devices, and services, and by default will inherit all those functionalities that do not exist yet. For example, in the near future the smart phones will be able to communicate through NFC (Near Field Communication) which is a new technology that is not released yet in smart phones, by a new created service on the platform. This will enable the use of NFC as technology [41].

Another example is: when a smart phone and smart TV are integrated in the environment the platform inherits the functionalities of both devices and is able to perform multiple tasks that provide better entertainment within the environment.

By analyzing the functionalities and features of the most important devices listed in section 4.3.1 while connected to the internet. We propose some functions that the platform will be able to perform. The functions are based on our brain storming and can be achieved when computer, smart TV, smart phone, sound system, digital camera, and game console are connected to the environment. These functions are listed as below.

- Buy music or video online, play and store it on different devices such as phones, TV's, iPods, iPads, external hard-disks, and computers; and have access to it regardless of the geographical position.
- Make VoIP calls on TV or phone.
- Make Video calls on TV.
- The platform via smart TV/phone enables online search of public and personal contents, it provides the ability of connecting users to their social media preferences.
- Play or store the videos captured by the phone or digital camera directly on the smart devices or other media players that exist on the platform.
- Translate the captions of TV programs into any language with the help of the cloud translation services [42].
- Watch online movies on smart devices with the help of smart functionalities and services offered by the platform.
- Unlimited downloadable applications for smart TV's and phones.
- Use the phone as a remote control for the TV and the sound system or use it to access and control your home entertainment cloud.

In addition to functionalities there are certain services desired to enhance the entertainment experience within the smart home environment. The services need to be developed and implemented on the core server. The services combine the different devices and perform the functionalities as per user requirements.

#### **4.4.2 Movie wish list paradigm on the platform**

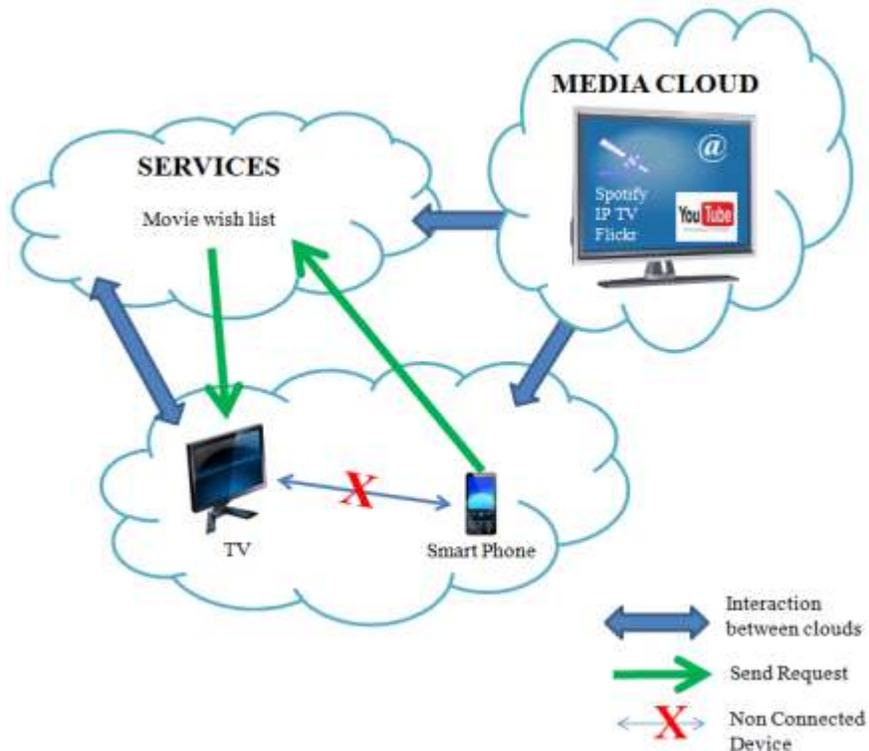
Users will be able to create a list of movies that they want to see on a registered service called "Movie wish list".

The platform will fetch all new TV programs from the local Cable TV caching them into the service database; then from time to time will try to match the movies from the wish list with the

TV programs; when a match is done, the platform will throw an alert to the user registered smart device (ex.: phone or TV) which will notify the user that soon the movie will be on channel 6 (for e.g.) giving the user the possibility to switch automatically to the channel. Mean while also suggesting him/her 20 minutes before to make some popcorn. Additionally, the user has the possibility to share via a service “what I am watching right now” will be available by posting on social media (Twitter, Facebook etc...) this paradigm is called solution 4.

### 4.4.3 Interoperability paradigm

User has a smart phone and a smart TV, that usually cannot communicate neither through Bluetooth, through IrDA, nor anything else due to “software proprietary protocols or closed system” (see figure 12).



**Figure 12:** solution 5- interoperability paradigm

The user receives an alert about his/her favourite show that will begin in 20 minutes on channel 6 on his/her smart phone. By accepting switching to channel 6 on the smart phone (green arrow illustrate *Accept Request*), the platform will automatically receive a request for the registered smart TV then will send the command to it directly through TCP/IP, there will be no direct communication between the smart phone and the smart TV, this way there will be no interoperability problems. This paradigm is called solution 5.

In table 6 can be seen the requirements that the platform is required to fulfill. There are three kinds of the requirements that are quality, functional and design requirements. The specified requirements could be achieved through different components of the platform after the physical implementation. These components are listed as below.

- Solution 1: the platform conceptual design see section 4.3
- Solution 2: service using middleware see section 4.3.3
- Solution 3: core platform server see section 4.3.4
- Solution 4: movie wish list paradigm see section 4.4.2
- Solution 5: interoperability paradigm see section 4.4.3

**Table 6: Fulfilment of the requirements with the proposed solutions**

		solution 1	solution 2	solution 3	solution 4	solution 5	
<b>Quality requirements</b>	Q1. Inter-operable	x	x	x	x	x	
	Q2. Security and access control	x	x	-	-	-	
	Q3. Reliability	-	-	-	-	-	
	Q4. Entertainment experience	x	-	-	x	x	
	Q5. Open standard "Optional"	-	-	x	-	-	
	Q6. Automatic update capability	-	-	-	-	-	
<b>Functional requirements</b>	F1. Authentication	x	x	x	x	x	
	F2. Accessible from any where	x	x	x	-	x	
	F3. Level definition of services	-	x	x	x	x	
	F4. Video conferencing	x	x	-	-	-	
	F5. Access to social media	x	x	-	-	-	
	F6. Audio and visual entertainment	x	-	-	x	-	
	F7. Play games	x	-	-	-	-	
<b>Design requirements</b>	D1. Hardware	D1.1. Smart input/output device	x	x	-	x	x
		D1.2. Smart control device	x	x	x	x	x
		D1.3. Access device	x	x	x	x	x
		D1.4. Backup-system "Optional"	x	x	x	x	-
	D2. Software	x	x	x	x	x	

## 4.5 Proposed platform VS existing ones

Actual existing platforms perform as a whole, strictly binding their services and devices to one another on the same platform using the same operating systems. In this section we discuss a comparison between our platform design and the design of other related work.

The model implemented by Ciau et al. [28] is very limited. It enhances the device state control (On/Off) with a limited connection to the outer world. This kind of solution make part of the basic connectivity interoperability described by Perumal et al. [9] and do solve partial issues in control, but we need more seamless interaction between the devices and services in the environment.

The work done by Perumal et al. [9] tackles the problem of distributed architecture used in smart home environment and the need of a certain degree of interoperability to manage sub-systems compared to different platforms. We found a similarity in this article where the above stated research also suggests the web services technology to be used in order to make the devices and subsystems connect with each other. In addition to the web services we have suggested, other services (direct services as well as third party services) were in the cloud computing for the same purpose proving an easy integration for many existing services available. Perumal *et al.* also suggested a single software engine to provide sub-systems functionality and management to be embedded in the application gateway while we suggested embedding the software engine that manages services, devices, users, system, and sub-systems in the cloud. Taking advantage of the cloud services for providing virtualized infrastructure, we left the possibility of third party services to take part of the proposed platform.

ZUMA platform designed by Baker et al.[29] provides a good interaction among the devices and controls all the tasks in the smart home environment, while our platform design not only provides interaction at a local level but also with the outer world, with the help of the clouds, by leaving the possibility of “virtually” creating several “routing hubs”, services will be able to easily define functionalities and communicate with devices. Another difference is that ZUMA has a set of abstractions for user and an ambient operating system (run time distributed system) to control the devices and to be implemented in the devices, while we suggest cloud computing for our concept

platform. Cloud computing makes it undemanding to implement (see section 2.6.3), when comparison with building complicated software or operating system [29].

Our proposed platform provides similar functionalities proposed by Merabti [30] of adding devices to the internet and to make interactions among them. But the NASUF framework is designed for ad-hoc environment; this can be limited in case of implementation on the proposed platform. We emphasize on the collaboration of different devices with different connectivity capabilities to be used and accessed in the cloud environment. We suggest the cloud and middleware to make devices open and enable interaction

Our platform design will be based on the vision of “internet of things” described by Raunio [23]. In the concept of “internet of things” almost anything will be connected and managed in a virtual private world. In our platform design we proposed the required devices and services to exist virtually on clouds, thus become parts of “internet of things”.

Proposed work by Wu et al. [31], underlines the platform necessity to “conform to open standards, service integration and mobility”. The solution proposed service oriented smart home architecture, giving a clear picture on best praxis implementation of MA and OSGi in peer-to-peer modelling. We propose different technologies for implementation such as cloud computing, middle ware, virtual servers in order to achieve interaction and communication between devices, services and users.

Tackling these issues with our proposed platform is done with more dynamicity:

- Devices are supposed to be content providers and will be able to serve as sensors too.
- Users will be able to interact with each other through their registered services and devices, e.g. like today’s social media services.
- Services as well will be able to interact, loan and share directly data between them bringing entertainment experience to a higher level.

Exemplifying scenario: User A’s registered smart TV will be able to communicate directly with User B’s registered smart phone, of course if User A and user B allows that. Another example can be a smart TV in the kids’ room, who’s not supposed to be on at 22:00 can alert one of the parent’s smart phone with a message leaving the possibility to switch off the TV or change the program to a more appropriate one.

Our concept platform differs by the way those technologies will interoperate and interact with one another. We emphasize on the possibility that registered devices will be able to communicate with other registered devices, regardless of the geographic position where the platform is placed, and regardless of the operating system or software that operates it.

The proposed platform is able to overcome lacks that we found in existing platforms in the research area. The most important issue to deal within the smart home environment is to achieve a higher degree of integration and interaction between the devices. For this purpose our platform suggests connecting devices through TCP/IP protocols within the environment that enables better communication. This platform design considers security issues such as network security and user's personal contents security. Other key issue that this platform deals within the smart home environment is to provide a control and limited access to digital contents for all age groups. It provides a seamless interaction among the devices, easy to configure and provides certain level of reliability. Another key feature of this platform is that it accepts and integrates a number of devices from different vendors, different operating systems and network interfaces. In addition then devices can be integrated without any extra efforts such as special equipments, extra hardware, and software, etc. (see section 4.2.2); the only requirement to integrate a device is to register the specific device on a server. This platform also enables the users to access different devices from outside the smart home environment with the help of the web server and web interface. For comprehensive comparison please see the table 7.

**Table 7: Comparison between proposed and existing platforms**

		Ciau Model	Perumal solution	ZUMA platform	Merabti framework	Wu solution	Proposed platform design	
<b>Quality requirements</b>	Q1. Inter-operable	X	X	X	X	X	X	
	Q2. Security and access control	X	X	X	-	-	X	
	Q3. Reliability	-	X	-	-	X	X	
	Q4. Entertainment experience	-	-	X	-	-	X	
	Q5. Open standard "Optional"	-	-	-	-	X	X	
	Q6. Automatic update capability	-	-	X	-	X	X	
<b>Functional requirements</b>	F1. Authentication	X	-	X	X	-	X	
	F2. Accessible from any where	-	X	-	X	X	X	
	F3. Level definition of services	-	X	-	X	X	X	
	F4. Video conferencing	-	-	-	-	-	X	
	F5. Access to social media	-	-	-	-	-	X	
	F6. Audio and visual entertainment	-	-	X	-	-	X	
	F7. Play games	-	-	-	-	-	X	
<b>Design requirements</b>	D1. Hardware	D1.1. Smart input/output device	-	X	-	-	X	
		D1.2. Smart control device	-	-	X	-	X	
		D1.3. Access device	X	X	X	X	X	X
		D1.4. Backup-system "Optional"	-	-	X	-	X	X
	D2. Software	X	X	X	X	X	X	

Table 7 shows a comparison between the existing solutions/platforms and our proposed platform design in smart home environment. It shows the main problems that we consider to overcome in this research and different existing models that also deal with these issues.

## **4.6 Limitations of the platform**

The main limitation of the design is its deficiency to support all generation of devices. Some of them are too old and have limited technologies to bind directly or through a bridge to the system. Only the registered devices can make the interface and can perform the functionalities.

Other limitations and privacy issues that can appear on the platform are strictly related to the available/published services. Those have to be restricted/controlled by the system (platform) administrators.

The full potential of the platform cannot be obtained without connection to the internet, e.g. if the platform implemented on a virtual server at home; in this case the platform is strictly operational internally with limited service functionality. Otherwise, if it is implemented virtually in the clouds access to the platform and its services will be impossible.

## **4.7 Future vision of the platform**

With the proposed platform model we envision that users of this platform will be able to share rights and access to their registered devices and services with groups and friends, exactly like in the existing social media platforms; this will allow a high level of security e.g. two users that have smart TV's and smart phones registered in the system, will be able by sharing /allowing access to each other, have the right to access a shared registered device by the other one.

Services should be easily accessible to any user as well as any software company interested, and should be presented as the extremely well known actual “application markets” like App Store from Apple or Android Market/Chrome Market from Google. A good developer’s community is essential to achieve a big number of creative innovative and high quality services.

## **4.8 The potential: why to adopt this platform?**

The main purpose of the platform is to provide a user with a better digital home entertainment experience as compared with the previous platforms within the smart home environment. Another important feature is that the platform will be user friendly for all age groups. Plug and play is also a key factor that makes it adaptable. Likewise it enables easy integration with already existing devices and services as well as it is future ready for upcoming devices, this will create a huge potential number of daily users.

## **5 CHAPTER V- Evaluation**

This section provides brief information of the evaluation of the platform. In this thesis we have designed a platform for a better home digital entertainment for the smart home environment. We adopted the design science method to design the platform. This platform is suggested to be implemented with the help of a hybrid cloud computing model. It is designed to provide some functions within the environment. This platform is a product that needs to be evaluated for its acceptability and intended performance.

In this phase we evaluated the draft of the platform. The draft was shown to all interviewees and is in the Appendix A, (see also figure 13).

We have adopted the qualitative research method for the evaluation process as per the nature of our project.

### **5.1 Interview Structure**

For the evaluation we conducted structured interviews with seven interviews. Participants were computer science teachers at Malmö University because only the person with IT background could answer our questions. The main reason to conduct direct interviews rather than surveys is that we needed to explain important concepts of area to the interviewee. Detailed information is provided in following subsections.

#### **5.1.1 Objective of study**

We conducted evaluation of our proposed platform's draft in order to check its validity and acceptability. Our main focus was to see whether this platform can be implemented physically with the devices and suggested technological solutions. Also we were keen to know any functional, technological, design lacks in platform.

#### **5.1.2 Planning and preparation**

Each interview was divided into two phases in first phase asked 13 questions in an interview. The questions were divided in two categories that are entertainment related and technical aspects of platform. Questions were selected on base of our research questions, goal and platform design. There were 6 questions related to entertainment that we asked in order to know entertainment preferences, audio visual contents accessed and digital devices being used by interviewees. The

basic purpose of these questions was to see the acceptability of devices and functionalities offered by the platform.

In the second phase we provided the interviewees information about the important technologies and concepts in the research area. The draft of the platform together with functionalities and services offered by the solution; was presented to the participants. After this we asked 7 technical questions to get support for our platform design.

### **5.1.3 Description of the instruments used**

We used interview forms that contained questions and also some basic information related to most important technical aspects of platform, further more a smart phone with an integrated record application was used in order to record and send the recorded data via cloud computing service directly to our mail.

### **5.1.4 Participants**

We conducted interviews only with computer sciences teachers in Malmo University. 8 people were contacted but 7 agreed to be interviewed. We contacted all subjects personally and engaged them for an interview.

### **5.1.5 Threats to validity**

It is very important to analyze threats to validity in order to meet the results criteria.

We found internal validity threats, as well as external validity threats. For internal validity the specific threat is the selection because some participants may predispose response in the context of disposing their thoughts very quickly. For external validity threats we have generalization. Other threats include construct validity and reliability. There are several procedures that can be adapted to deal with threats, information about the actions we perform in response to those threats are provided the following:

**Selection:** A key threat to internal validity is selection because the participants can answer the question very quickly without listening to it if they have sound knowledge about the area. To deal with this threat we selected teachers of different age groups and with different subject specializations that don't have special background to our research.

**Generalization:** A key threat to external validity in our research is generalization. In this research we required to validate the platform design, its requirements and functionalities for this purpose we conducted interviews with computer science teachers.

In this regards we only have internal validity it was better to include some professionals, researchers and developers in this research area. We believe that results are acceptable because all the interviewees were computer science teacher and were well aware about the research area.

**Threat to construct validity:** The main instrument that we need to validate in the construct validity is a questionnaire form where all the questions to be asked were listed. These questions were based on the literature review, the requirements extracted for the conceptual platform design, and the research questions. One member designed this questionnaire and other verified it for errors or missing parts. Therefore we believe that the questionnaire is complete and accurate.

Other key threat in this study was that the interviewees might misunderstand the topics involved and its implementation models. To avoid this situation there are several procedures that add validity to findings. We used rich description to convey findings by providing interviewee general description of area such as back ground, basic concept and technologies, and we had area related discussion during interviews.

**Reliability:** To avoid mistakes in results we made voice recording and hand written notes as well. Results were compared from both sources.

We extracted results individually and then cross checked for authenticity.

### **5.1.6 Execution**

We assumed the first interview as a pilot interview and it went very well, nothing weird or undesired happened. But during the second interview we skipped one question from the interview because it was redundant. We conducted seven interviews and in each interview we asked 13 questions. Interviews spanned between 25-30 minutes because we had to explain some concepts to subjects. It took almost one week to finish interviews. We met all the subjects personally and engaged them for interviews.

### 5.1.7 Interview ethics

There are some ethics to be considered in the interviews that are conducted with the humans and the interviews are expected to cause effect on them [44]. We have considered two key points in this informed consent and confidentiality.

**Informed consent:** Approval is required from the participants for the interview. At the same time it is required to provide them with information about the research area, the purpose of research and how their answers will be used.

In our case first we described the purpose of result and mentioned the way in which their answers will be used. All the interviews were recorded with the approval of participants.

**Confidentiality:** In interviews it is likely to reveal the personal details of interviewee such as profession, qualification, expertise etc. Thus it is required to inform them that their responses would be dealt with full confidentiality.

We decided to keep interviewees names anonymous according to their will.

### 5.1.8 Data Analysis of the results

There are different steps involved in the data analysis. Data collected through interviews is passed through different phases first of all the collected data is organized and arranged. This involves transcribing the interview data. In the second step the collected data is read in order to find the meanings of data. In the third step starts the detail analysis. In the fourth step description data findings is generated. Likewise, the fifth step represents the description. The final step consists of the interpretation of data [43]. These steps help to extract the meaning of the data that was collected through interviews.

According to the data analysis steps we first transcribed the collected data (see appendix B), and this transcribed data was further summarized according to the questions and opinions of the participants for each question (see section 5.2). Afterward the data was generalized in a more efficient fashion and presented it in the result discussion. From the result discussion the findings are provided in table 8 and table 9.

## **5.2 Interview results**

### **1. What are your preferences in entertainment?**

The most common entertainment activities that we found from participants were music, videos, movies, games, and TV shows (informative programs, society programs, history programs, sports, comedy shows and documentaries). Only one participant was also interested in listening to the radio.

### **2. What devices do you use for entertainment?**

The common devices being used were computers, TV, iPad , big screen /projector , DVD player and sound system.

### **3. What device is important for you in the entertainment?**

The devices that are most important for participants are the computer, TV and smart phone. While some of the participants also mentioned speakers, projector, and iPad.

### **4. What lack do you feel in your own entertainment system? What enhancements do you need in entertainment?**

Almost all the participants were not satisfied with their current entertainment system and they required some functionalities and enhancements in their systems except for only one subject that was completely satisfied with their current system. For this question, we got different opinions that there should be only one remote for all devices, easy and seam-less integration among the devices, wireless connection between the projector and computer and TV and easy availability and access to digital media.

### **5. Do you use the internet for entertainment? If so what do you seek over the internet?**

All the participants use the internet for entertainment but in different ways. Most of them seek audio/visual contents (music, movies, TV shows) and social media (Facebook, Twitter etc). Two participants said that they use the internet to get general information by reading online newspapers and articles, while only one participant was found seeking games.

### **6. Can you describe your vision of entertainment?**

Most of the participants think that there should be a system that makes it easy to control and access their favourite contents in terms of music, movies, videos, etc. One participant suggested a digital

library to keep track of music while another participant was completely satisfied with his current entertainment system.

**7. Is the platform design is acceptable for implementation? If no! Why?**

Most of the participants said yes it is acceptable. Two participants were not sure because they were not aware of the technical aspects of the platform and one participant said it sounds interesting to have such a platform implemented physically.

**8. Are these functionalities enough or would you like to see more? If not, what lacks do you see in the design?**

All the participants, except for two, were not satisfied with the listed functionalities; they suggested more functionalities according to their own requirements. Most of the suggested requirements are given under question 13, while some more are provided in the future work section.

**9. Is the use of cloud computing for the smart home environment better than the traditional approaches?**

All the participants said yes cloud computing is a better option.

**10. Whether the hybrid cloud is a better option than other cloud models?**

Almost all participants said yes, the hybrid model is better. One participant said the public cloud is better according to his requirements, while the other participant was not sure due to economical aspects.

**11. Does the platform support new entertainment trends?**

A major amount of participants said the platform seems to support the new trends. Two participants said they were not aware of new trends.

**12. Is the smart TV and smart phone enhance the entertainment experience?**

Four participants said yes two participants said they don't know because they don't use these devices for entertainment, while one subject was not sure.

### **13. Do you have any suggestion or comments with regard to the platform?**

We received comments and suggestions from all the participants for our platform and also for some other related areas. They suggested that there should be a software to combine all the devices in the environment; there should be a solution for connecting Wii (video game console) directly to the internet for playing and downloading games, user interface should be easy to understand and control; it should provide great security so the child may not access undesired contents, and seamless interoperability. There was also a suggestion that the software should also enable shared TV watching so people at different locations may enjoy the same program at the same time.

Our finding from the interviews discussions are summarized in Table 8 and table 9.

### **5.3 Interview results discussion**

Each interview was conducted in two phases in order to elicit the proposals validity and requirements, functionalities and design of the platform. The interviews not only helped us to evaluate our concepts but also to improvise on them by indicating through interpretation and data analysis the most common requirements of the individuals in using the proposal. The two phases are described below:

#### **5.3.1 Functionality evaluation**

In the first phase, we asked six questions to each of the seven participants in order to verify the requirements and functionalities proposed by the platform design. This phase helped us not only to verify the platform's existing requirements and functionalities but also provided some suggestions for improvement.

From the data gathered through the interviews we found that most of the interviewees were interested in watching TV shows, listening to music, watching movies and playing games. They used different devices like computers, smart phones, iPads, TV's, projectors, stereo systems and big screens, where the computer and TV were the most popular sources of entertainment. Almost all the participants used the internet to entertain themselves and mostly sought audio/visual contents, social media and general information in different areas of their interest. In spite of using modern digital devices and high speed internet connections, they were still dissatisfied with their entertainment systems. They pointed out some lacunae in their current systems. Some of the gaps mentioned by the interviewees were lack of integration, interaction, interoperability and easy

access to entertainment contents. These lacunae appear to be filled in by our proposed platform design and thus established validity. The summary of the requirements and functionality results is provided in tables 8 and 9.

### **5.3.2 Design evaluation**

The second phase involved the evaluation of the platform's primary design. An evaluation questionnaire (see appendix A) was prepared to verify the feasibility and the technical applicability of the proposed platform design. Through these questions (see appendix A) we found satisfactory results for our platform design. The majority of the participants believed that such a platform is acceptable for implementation. The questionnaire consisted of seven questions which were intended to cover the technical aspects of the design platform. Participants were convinced that cloud computing is a better approach for this kind of environment as compared to the traditional approaches. Meanwhile the majority said that according to their opinion, the hybrid cloud model is better than the other models in terms of personal content security and economy. Many said that this platform supports new entertainment trends and two smart devices (phone and TV) which provide better entertainment experience. The summary of conceptual design results is provided in tables 8 and 9.

### **5.3.3 Requirements Evaluation**

The requirements of the platform were also evaluated in this phase. There were three types of requirements for the platform; quality, functionality, and design requirements.

For quality requirements we had six requirements; Inter-operability, security and entertainment experience were evaluated in the second phase of the evaluation. Control was not evaluated because this requirement was integrated in the security requirement after the evaluation of the primary design. Reliability was not evaluated in the design because it was concerned with the physical implementation of the platform. Likewise open standards and automatic update capability, which are the optional quality requirements were not evaluated as these too are concerned with the physical implementation. Functional requirements such as authentication, accessibility from anywhere and level definition of services were evaluated during the second phase of the interview.

Design requirements, including hardware and software components required for the platform, were evaluated in both phases of the interviews.

**Table 8: Interview finding**

Questions	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee4	Interviewee5	Interviewee6	Interviewee7
<b>Entertainment preferences</b>	Music, Videos, Movies	Movies, TV programs, Documentaries	Movies, Games, Music	TV programs, Movies, Music	Music, Games, TV, Home Videos	Radio, Social medias, TV Programs, Podcast	Music, Videos, internet
<b>Devices used for entertainment</b>	DVD player/recorder, Big Screen, TV	DVD, Projector, Apple TV, iPad, iPhone, Computer	Computer, iPhone, Projector, Sound System	Computers	TV, DVD player, Computer, iPad	Computer, Projector, iPad, iPhone, Sound system	TV, Computer, iPad, Sound system
<b>Most important entertainment devices</b>	TV, Speakers	Projector, TV, iPhone, iPad	Computer	Computer with big screen, iPad	TV	iPhone for Podcast	TV, Computer, Smart phone
<b>Lacks in entertainment system</b>	1 remote for all devices	Integration between devices	Easy way to connect devices	Availability of digital contents	Satisfied with current system	Synchronization between the devices	Interoperability between the devices
<b>Vision of entertainment</b>	Easy to control devices	Online streaming on TV with Wi-Fi	Digital library for movies and music	Easy access to digital contents	Easy access to digital contents	Satisfied with current system	Seamless interoperability between the devices
<b>Use internet for entertainment</b>	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<b>What you seek on internet</b>	Videos, News paper, Generals, Articles	Videos, TV programs	Online gaming, social networks	Social networks, News, Online TV	Social networks, Movies, Music, Videos	TV shows, Games, Podcast	Audio visual contents
<b>Is design acceptable for implementation?</b>	Yes	Not sure	Yes	Yes	Yes	Not sure	Yes
<b>Are the functionalities enough?</b>	Not sure	Yes	Yes	Confused	Yes	Yes	Yes
<b>Use of cloud is better?</b>	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<b>Use of hybrid cloud is better?</b>	Yes	Yes	No	Yes	Yes	Yes	Not sure
<b>Does the platform support new entertainment trends?</b>	Yes	Yes	Confused	Yes	Yes	Confused	Yes
<b>Smart phone and TV enhance entertainment?</b>	Yes	Yes	Don't know	Yes	Not sure	Yes	Don't know
<b>Suggestions</b>	Low implementation costs, illumination integrated with entertainment	A software for the whole solution	Easy way to connect game console with	Platform is required to prove compatibility, Easy to use	Better control for devices and contents	Shared TV watching	Seamless interoperability

**Table 9: Summarised findings**

Interviewees		1	2	3	4	5	6	7
Entertainment preferences	Audio/ visual	x	x	x	x	x	x	x
	Games			x		x		
	Social networks			x	x	x	x	
	Radio						x	
Use of internet for entertainment		x	x	x	x	x	x	x
Entertainment devices	Computer		x	x	x	x	x	x
	TV	x	x			x		x
	Smart phone		x	x			x	x
	Big screen / projector	x	x	x			x	
	Sound system			x			x	x
	DVD player	x	x			x		
Acceptable for implementation		x		x	x	x		x
Cloud is better		x	x	x	x	x	x	x
Hybrid cloud is better		x	x		x	x	x	
Supports new trends		x	x		x	x		x

### 5.3.4 Draft optimisation

We evaluated the draft of the platform with its requirements, functionalities and services. The draft was acceptable as a solution. In addition we collected the suggestions for the improvement in design and functionalities. From these suggestions only the access control was added in the platform requirements by integrating it with the security. To deal with this issue and to provide a higher level of interoperability among the devices and heterogeneous clouds the draft was improved and a core server was added in the platform design (see figures 8, 11). The purpose of the core platform server is to improve the interoperability between the clouds and to make the platform more open to the outer world. The core server is a part of the “*optional*” backup system requirement, and is able to register services, devices and users on a data base. The access control can be achieved by registering a special service on the core server that registers user according to the age groups providing a limited access to the digital contents and devices. In the optimized platform design the core platform server is not evaluated; we recommend the core server to be evaluated by software architects and developers in this research area.

## 6 CHAPTER VI- Conclusion and recommendations

### 6.1 Conclusion

In this work we have proposed a platform for better entertainment experience in the smart home environment. This platform is a conceptual design that acts as a bridge between the devices, users, and services. The platform requires development of software for implementation. There are a number of digital devices suggested as part of this platform to enhance the entertainment; smart TV and smart phone are key devices in the environment. These smart devices with a core-server in a cloudy infrastructure make better user experience in environment. User can interact with environment by using the smart phone, smart TV, computer, etc.

In this thesis we had two research questions:

- RQ1. How can we create an adaptive platform which binds smart technologies like smart phones and smart TV s, suitable for a smart home environment?

In order to deal with this research question we reviewed different platforms and models in this research area. Based on the literature review we defined the platform and identified three types of requirements for the platform design (see section 4.2). Solution was proposed according to those requirements (see section 4.2). Further the draft was optimised according to the interviewee's suggestions and the initial design requirements (see section 4.2). This work provides the platform conceptual design (see section 4.3).

- RQ2. What are the functionalities that this platform can perform in a smart home environment?

In this thesis we described a set of functionalities that our platform can perform (see section 4.4).

The main limitation of the platform is its evaluation. The draft of platform was evaluated and improved. A slight addition was made in the draft and core server cloud was added in the design. The core server is responsible to register different entertainment services, and users in a centralized data base (see section 5.3.4). Other limitation of the design is its deficiency to support all old generation of devices; some of them are too old and have limited technologies for them to be able to bind directly or through a bridge to the system.

The platform needs different technologies, software, middleware, and devices in order to be implemented and to achieve its goal of enhancing the entertainment experience.

Based on our research, we found that cloud computing is a better technological solution than the previous traditional approaches used. It enables higher interaction at an internal base as well as better communication with the outer world. More specifically, we emphasized the use of hybrid cloud model for platform in terms of personal content security and economy.

The key features of our proposed platform that distinguishes it from other platforms are openness, easy user interface, and interoperability between devices enabling integration regardless of vendor and operating system. The device can be used effortlessly by simply registering it with a service. Another key feature is that it enables higher degree of integration and interaction among the devices. For the end user it provides seamless interoperability and easy user interface. It also supports the new entertainment trends, latest devices and technologies that enhance entertainment experience.

## **6.2 Recommendations for future work**

- The optimized platform design was not evaluated in this thesis. We recommend evaluating the platform design.
- Develop this platform in a simulated environment to evaluate its performance, then upon results developers can carry out a physical implementation.
- Create a smart identification system, a combination between MAC address ID, IP and username that allows each device to be entirely unique.
- Create the software to be completely transparent to NAT (routers) and Firewalls like the one from Teamviewer (see: [www.teamviewer.com](http://www.teamviewer.com)).
- Create a developer community to encourage and adopt more creative services and smart applications.
- Create the possibility for interoperability with other platforms in future such as SmartCity (see: [www.smartcity.com](http://www.smartcity.com)).
- Enhance user experience by making it user friendly in all age groups.
- Standardize procedures for the robustness and reliability of the system.

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## 8 APPENDIX A: Interview guide

Dated: -----

Interview No: -----

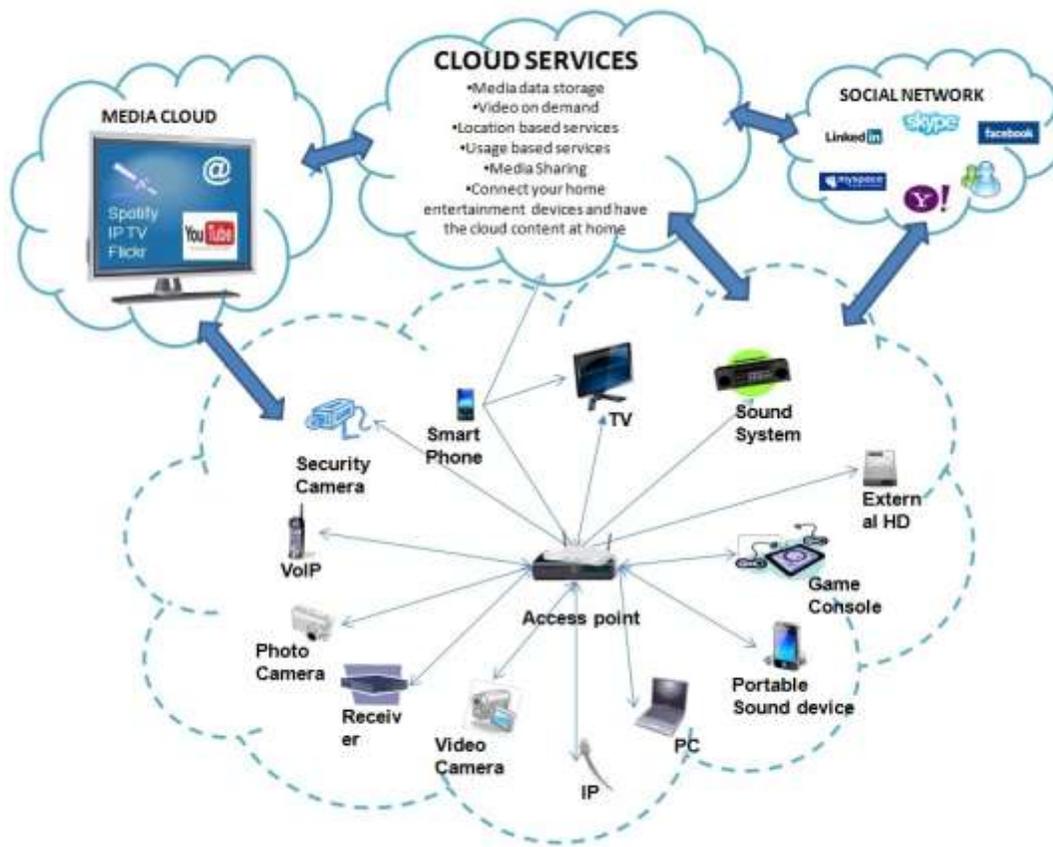
Interviewer: -----

### Purpose of interview

In this researched we have proposed a conceptual design of a platform that integrates smart TV, smart phone and other entertainment devices within the smart home environment to enhance the entertainment experience. Likewise we have proposed some functionalities and services that this platform offers in the smart home environment. The main purpose to conduct interviews was the evaluation of the platform primary design, its functionalities and requirements.

### Interview Questions:

1. What are your preferences in entertainment?
2. What devices do you use for entertainment?
3. What device is important for you in the entertainment?
4. What lack do you feel in your own entertainment system? è What enhancements do you need in entertainment?
5. Do you use the internet for entertainment? If so what do you seek over the internet?
6. Can you describe your vision of entertainment?



**Figure 13: Draft design**

7. Is the platform design is acceptable for implementation? If no! Why?
8. Does the platform provide the desired functionalities (Are this functionalities enough or would you like to see more)? If not, what lacks do you see in the design?
9. Is the use of cloud computing for the smart home environment better than the traditional approaches?
10. Whether the hybrid cloud is a better option than other cloud models?
11. Does the platform support new entertainment trends?
12. Is the smart TV and smart phone enhance the entertainment experience?
13. Do you have any suggestion or comments with regard to the platform?

## 9 APPENDIX B: Interview outcomes

### 1. What are your preferences in entertainment?

*1-Music, videos, movies,*

*2-Movies, different kind of informative programs, society programs, historical events & obviously music but not music video, documentaries*

*3-Play Computer Games, Watch movies, listen to music*

*4-three main media categories (TV series /show not from the television network “Buy or download them via the computer”), (different kind of casual Games on Tablet & PC, not game console), (Movies)&( I guess you can put music something you can have in the background Not super focus interest)*

*5-Watch TV(Films, Sports, some News programs, Comic shows), Listening to Music, Pictures, watching some home recorded Videos, Video games (2 Kids)”Necessity in home entertainment”, Maybe it would be cool to change Music, Pictures from your smart phone/ iPad*

*6-Listen to Radio (SW- P1), E mail, Social media (Facebook, Tweeter), Buy TV Programs (I tunes), Mostly Podcast (Swedish, American and British public Radio)*

*7- Music, Video, internet.*

### 2. What devices do you use for entertainment?

*1-DVD player/recorder, set-top box (to record TV programs while watching other channel), Big TV Screen*

*2-DVD/CD player, Projector, Apple TV, MAC, iPad, iPhone*

*3-Own PC (Mac), smart phone (iPhone), Big screen Projector (Not TV nor Satellite)*

*At the end the interviewed mentioned a sound system 7.1*

*4-different kinds of computer (Laptop / desktop / Tablet “on the couch”/ seldom the Mobile phone)*

*5-TV, DVD player, Computer & I Pad when he is not sitting in front of the computer*

*6-Projector, MacBook, iPhone, iPad, PC, Sound system*

*7-TV, PC, iPad, Sound system*

### 3. What device is important for you in the entertainment?

*1-TV, Speakers*

*2-Projector + Apple TV, MAC & I Pad combined solution*

*3-PC*

*4-Home desktop PC with the large monitor (Watch movies and play games)+ the I pad which is only good for entertainment as he see it for browsing the web play games and watch short movies and stuff.*

*5-TV*

*6-Podcast via iPhone!*

*7-TV, PC & sometimes the smart phone*

**4. What lack do you feel in your own entertainment system? è What enhancements do you need in entertainment?**

*1-Too many Remote Controls one is better*

*2-Integration between the devices like pc, TV and Satellite should be better*

*You can't use it for every think (example TV tuner connected to aerial outlet for streaming purposes)*

*3-Easy way to connect projector with all the computers (It is easy but the fact that we have several computers the need to connect them to the screen without plug and unplug the cables. Maybe via software we could visualise into the screen in an easy way)*

*4-One thing he needs the availability of digital media (Example if you live in US you can purchase basically every TV show But if you live in Sweden you can get them throw other Chanel's but that's a lack"), in terms of devices: more advanced thinking capability than there are available now (If you have an apple device ether the iPad or the iPhone you have to sync it via an actual cable to your computer for transferring the Media and since he have a dissent internet connection he prefers doing this on line ). One other thing (Since he lives alone in his apartment 27" Monitor is enough but if they are 4-5 Pearson's watching it would be better with a large screen)*

*5-Functioning TV, Pretty satisfied/More content that I can have access to*

*6-Syncing between the devices (Via cable) and keeping track of what she has listened to and what not! (Calendar sync not working also)*

*7-Interoperability between the devices*

**5. Do you use the internet for entertainment? If so what do you seek over the internet?**

*1-Yes*

*Watch YouTube, read newspaper and scientific generals, art and philosophy articles*

*2-Yes online historical programs ⇒ Video on demand & streaming video*

*3-Yes but I don't have any game's so I use On line games, Skype for communication with family & Linked in (only work related) / Face book (for event) ==> social network (I am not found with it "but you have to use it because people use it".)*

4-Yes social media like Facebook / Tweeter he describes himself as an Active Tweeter-er, off course special sites that I visit specialised in areas of his interest's (Hacker news), News & on line TV shop's

5-Yes / Seek Content (Mainly it's Music & films But he Realised that stuff like social network are coming (Tweeter, Facebook), SVT play , YouTube)

6-Yes, upon recommendation "You know you like something" Podcast(Story's and news mostly), TV shows, Games

7-Yes, General information, Audio (Music) and Video (You Tube) as well

## **6. Can you describe your vision of entertainment?**

1-Easy to control, user interface should be simple and easy to manipulate

2-a Tuner / or TV that is able to directly stream different Chanel's/ program from internet with Wi-Fi connection

3- Spottily problem (don't remember the music I like) Typical way of having a CD rack with a list of CD where you have a list of what you bought. ⇒ Our suggestion in this domain "User interface to manage music library or film database" she answered yes , yes

4-The notion of Ubiquitous access to all media regardless of place (Buss, on the couch Weather he is at home or out ) ⇒adaptable to his needs in accessing all his media or media he is interested in.

5-Gain Access to whatever hi is in the mode for, to enjoy whatever time he feels for it. He would like to have access to it throw whatever device he is holding ,. the setup will support him to realise what he feels for "release the full potential in whatever he fills like doing"(Example if I want to watch a film I just need to pickup my phone or my iPad and walk over to the TV or to the computer and just start it. if he wants to see a particular film it should be close to him ⇒ the access should not take too long to access or to stream // On demand)

6-Satisfied with the current system

7-To be Seamless, Interoperability between different devices

## **7. Is the platform design is acceptable for implementation? If no! Why?**

1-Yes

2-Not sure / Very nice if it's possible without any complication / User friendly

3-I don't have any technical concept view, Yes, Unknown technical aspects

4-Acceptable sure, But it include a lot of things that I want use (VOIP calling, Transferring Photo content from my phone to my Television "He does not have TV now", but he says that in the future he might use some foe this Functionality) the main think for him is how easy it is to

*get started with the system ether subset of it or installation process, how that will work. The feature set sound interesting*

*5-Yes (I don't see any reason not to say YES)*

*6-Sounds Interesting*

*7-Yes (Local server and the cloud services)*

**8. Does the platform provide the desired functionalities(Are this functionalities enough or would you like to see more )? If not, what lacks do you see in the design?**

*1-No / he was confused regarding the impact on people is unknown today.*

*Today's technology emphasizes the need of new trends even if you don't need them*

*2-Yes interesting fulfil the requirements*

*3-Many of this fun./ thinks can be done now if you buy special equipments!, example (You can see TV in your PC)==> only if you have you have a TV tuner installed in your pc!*

*4-At there is some kind of modularity in it like we said you can plug in services from new vendors// look how future prove is it(In the since that I am not locking myself into something which I can't' build on it in the future ) =>that was the most important aspect with the platform*

*5-Getting access to all the content is good but there are occasion where you want to restrict access to all content (Example children watching you Tube and searching for Pippi Long stocking) It would be cool that I am sure that when they are watching You tube that they accidental watch something inappropriate holding the same name. =>they get the real deal not some crappy shit some kid made up and submitted it. (Restriction is important).*

*“Translation cloud is cool he repeated “*

*6- Proposed service functionality for laundry booking (through an interface that give or alert the available attractive time). Ordering food and events (Have the plug and play but not too many things to the user in order not to be too much)*

*7-Yes Would like in case you buy music or film it should be available for all the devices, can access it from other places*

**9. Is the use of cloud computing for the smart home environment better than the traditional approaches?**

*1-Yes definitely*

*2-Yes and he emphasised hybrid is better*

*3-Yes*

*4-Yes naturally cloud “Because it has one huge benefit for me that it provides Ubiquitous access, basically having access to the content and information from places other than his home” =>cloud enabled*

*5-Its better approach*

*6-Yes quiet relevant*

*7-Yes*

**10. Whether the hybrid cloud is a better option than other cloud models?**

*1-Yes*

*2-Hybrid is better*

*3-Blue: -----*

*4-He imagine that / Yes, but the band limitation of transferring different types of media on line*

*5-yes prefer hybrid coz there is some stuff and application that is stored locally for security, and control*

*6-Yes, Privet content (Personal content not to be public) that will solve some problems*

*7-Yes from the Privacy/Integrity/Availability Perspective*

*Not Sure the economical perspective*

**11. Does the platform support new entertainment trends?**

*1-Yes*

*2-Yes*

*3-For me public is ok*

*4-He spouse that but he gives example of maybe new technology will come by apple that will enable the user to directly project the game from his phone directly.*

*5-It's the future for technical, economical and political reasons*

*6-Doesn't have knowledge of new trends in entertainment from own experience (talks about the limitation that closed system have. And added that although happy with the actual system but how it will work with the platform! Balancing the comfort ability aspect "Don't have to think much" and being closed system makes it work*

*7-Yes, seems that it support*

**12. Is the smart TV and smart phone enhance the entertainment experience?**

*1-Yes definitely*

*2-Yes absolutely*

*3-I don't know the new entertainment trends, technology is not ready yet, I just use my iPhone when not at home for internet applications but I would like to see the new trends, Wii should be directly connected to pc and internet*

*4-Sure "Smart TV will enable him to get smarter access to his content. Same for smart phone"*

*5-Not sure about*

*6-Yes off course*

*7-Don't know, yes (If the smart phone means getting access to content anywhere)*

### **13. Do you have any suggestion or comments with regard to the platform?**

*1-It should be free, may be you can pay a little amount for the services, plug able for the office and summer house, control of illumination during the entertainment.*

*2-It should be software to combine all the devices that are able to connect via Wi-Fi*

*3-wii should be directly connected to pc and internet so you can easily download and play games without purchasing game CD's==>"(most of the game console provide the online game playing or downloading into your console hard disk when you have done payments )"*

*4-for him to trust a platform the Platform must prove that it's credible, Compatibility, Open standards // or a large number of providers subscribes to it, Understand ability, User interface should be easy.*

*5-I am curies the structure you platform / triple play, control on content and information see this*

*6-Shared TV watching, streaming of different Chanel's, Shared entertainment experience.*

*Q: how do you differentiate between these services and others → by adding other service cloud.*

*Q: How do you interact with other social network → via application downloaded into the smart device → platform independent?*

*Q: How the platform will deal with multitude of different devices (Implement a platform independent standard based on it). → Recommendations for developing application that you can be download to your smart device in order to deal with the platform.*

*Proposed service functionality for laundry booking (through an interface that give or alert the available attractive time), Ordering food and events*

*7-Seamless, interoperability (Control heating from your phone/TV) & transparent*