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From Set Top Box to Home Media Center

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Master's Thesis

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Abstract

Although Set-top-Boxes(STBs) are widely deployed today to connect a media source to a display (traditionally a television set), the market is changing due to the introduction of Internet Protocol Television, Over-the-Top streaming devices, gaming console, home theater Personal Computer, smart TV, etc. There is an evolving concept of a Home Media Center (HMC). This HMC provides consumers with an integrated home media environment and experience.

This thesis explores the transition from STBs to HMCs. The specific questions that this thesis project answers are: What will a future HMC look like? What will its functions be? What interfaces and protocols will it use? Who will make these HMCs? How can STB vendors evolve to be HMC vendors or will they simply cease to exist? This thesis project designed and evaluated a hypothetical HMC prototype based upon current technology trends and user expectations. This prototype was used with 68 volunteers to identify and prioritize the most important features that a HMC should provide. Based upon the most important of these features a conceptual HMC prototype is designed to define a HMC product roadmap for 1, 3, and 5 years. This roadmap is used to project the economic impact of HMCs on the current STB industry. This economic analysis considers Sweden as the target market.

This thesis could be used by current STB vendors to define their own company specific roadmaps to support their transition to the future HMC market.

Sammanfattning

Även digitalboxar är spridda i dag för att ansluta en mediakälla till en bildskärm (traditionellt en TV) är marknaden förändras på grund av införandet av Internet Protocol Television, Over-the-Top streaming anordningar, spelkonsol, hem teater Personal Computer, smarta TV osv. Det finns en framväxande begreppet Home Media Center (HMC). Detta HMC ger konsumenterna ett integrerat hem mediemiljö och erfarenhet.

Denna avhandling utforskar övergången från digitalboxar till HMC. De specifika frågor som detta examensarbete skall besvara är: Vad kommer en framtida HMC se ut? Hur kommer dess funktioner att bli? Vilka gränssnitt och protokoll kommer den att använda? Vem kommer att göra dessa HMC? Hur kan digitalboxar leverantörer utvecklas vara HMC säljare eller kommer de helt enkelt att upphöra att existera? Detta
examensarbete designar och utvärderar en hypotetisk HMC prototyp baserad på nuvarande tekniktrender som användarnas förväntningar studie. Denna prototyp användes med 68 frivilliga att identifiera och prioritera de viktigaste funktionerna som en HMC bör ge. Baserat på de viktigaste av dessa funktioner en konceptuell HMC prototyp kommer att utformas för att definiera en HMC produkt färdplan för en, 3 och 5 år. Färdplanen kommer att användas för att projicera de ekonomiska konsekvenserna av HMC på den aktuella digitalboxar industrin. Denna ekonomiska analysen kommer att överväga Sverige som målgrupp.

Denna avhandling kan användas av nuvarande digitalboxar leverantörer för att definiera sina egna företagsspecifika färdplaner för att stödja övergången till den framtida HMC marknaden.

Acknowledgements

We are very grateful to our academic supervisor, Professor Gerald Q. Maguire Jr, who offers his great patience, enthusiasm and genius talent during our thesis project. We receive many valuable guidelines and suggestions from him throughout the whole project. He always point out the right direction for us when we struggle to make progress. We could not imagine that we could have finished this thesis project without his supervision.

We would like also show our appreciation to our industrial supervisor, Product manager Andreas Eriksson from Zenterio AB, he provided a lot of domain knowledge regarding the IPTV industry from both technology and business points of view, which helped us to gain deeper understanding of STB. Further more, his opinions about the need for a product roadmap inspired us to formulate a decision matrix and finalize out HMC product roadmap.

Special thanks to all our experience lab interviewees. your curiosity and encouragement help us to devise the future HMC conceptual prototype. We could not have had a successful survey without your participation.

Stockholm, Sweden October 6, 2014

Ruimin Li and Yi Fu

Table of Contents

List of Figures

List of Tables

Acronyms

ABR	Adaptive bit rate streaming
API	Application Programming Interface
APP	Application
A/V	Audio/Video
BD	Blu-ray Disc
CA	Conditional Access
CODEC	Coder-Decoder
CPU	Central Processing Unit
DLNA	Digital Living Network Alliance
DMC	Digital Media Controller
DMP	Digital Media Player
DMR	Digital Media Renderer
DMS	Digital Media Server
DRAM	Dynamic Random Access Memory
DRM	Digital Right Management
DVB	Digital Video Broadcasting
EPG	Electronic Program Guide
eSATA	External Serial Advanced Technology Attachment
FLAC	Free Lossless Audio Codec
GPU	Graphics Processing Unit
HD	High Definition
HDD	Hard Disk Drive
HDMI	High-Definition Multimedia Interface
HDS	HTTP Dynamic Streaming

HEVC	High Efficiency Video Coding
HLS	HTTP Live Streaming
HMC	Home Media Center
HSS	HTTP Smooth Streaming
HSTB	Hybrid Set-top Box
HTTP	Hypertext Transfer Protocol
IC	Integrated Circuit
IGMP	Internet Group Management Protocol
IP	Internet Protocol
IPS	Internet Protocol Suite
IPTV	Internet Protocol Television
IR	Infrared Receiver
ISP	Internet Service Provider
LAN	Local Area Network
LPG	Live Program Guide
MCDA	Multi-criteria Decision Analysis
MMS	Meidamätning I Skandinavien
MPEG-DASH	Dynamic Adaptive Streaming over HTTP
MPO	Multi Picture Object
OS	Operation System
OTT	Over-the-Top
P2P	Peer-to-Peer
PC	Personal Computer
PVR	Personal Video Recorder
QoS	Quality of Service
RCA	Radio Corporation of America
RF	Radio Frequency
RTCP	RTP Control Protocol
RTMP	Real Time Messaging Protocol

RTP	Real-time Transport Protocol
SIP	Session Initiation Protocol
SMS	Short Message Service
SNS	Social Networking Service
SoC	System on Chip
S/PDIF	Sony/Philips Digital Interface Format
SPDM	Stuart Pugh Decision Matrix
STB	Set-top Box
TCP	Transmission Control Protocol
TIFF	Tagged Image File Format
TRP	Tivo Roamio Pro
TV	television
UDP	User Datagram Protocol
UHD	Ultra High Definition
UI	User Interface
USA	United States of American
USB	Universal Serial Bus
USF	Universal Subtitle Format
UTAUT	Unified theory of acceptance and use of technology
VoD	Video on Demand
XML	Extensible Markup Language
2D	Two Dimensional
3D	Three Dimensional

Chapter 1. Introduction

This chapter describes the general area of this thesis, the problem definition, the goals, an overall plan for the thesis project, and the structure of the planned thesis.

1.1. General introduction to the area

Although STBs are widely deployed today to connect a media source to a display (traditionally a television set), the market is changing due to the introduction of Internet Protocol Television (IPTV), OTT streaming devices, gaming console, home theater PC, smart TV, etc. There is an evolving concept of a Home Media Center (HMC). This HMC provides consumers with an integrated home media environment and experience.

This HMC provides integrated multimedia entertainment experience. A HMC is one-stop solution for the consumer, as it is the only device they need to fulfill all of their home media viewing/listening/... requirements. All media capable consumer device vendors are looking for a roadmap to evolve their products to HMC. Of these STB vendors are currently the largest players in providing media playout in the home, hence STB vendors are the foucs of this thesis project.

1.2. Problem definition

The problem that this thesis explores is the evolution or revolution in the transition from STBs to HMCs. The problem context is illustrated in Figure 1.1. In this figure the CPU is the central processing unit associated with the STB or HMC. PCi is one or more personal computer in the home. The disk(s) connected to the PC are assumed to be accessible via the network. The router marks the limits of the home network. S1 to S8 are speakers (some of which may not exist in a given configuration). The “Display” can be one or more displays or projectors. Note that

none of the connections between the CPU, speakers, and display are explicitly shown. The connections could be via wires, fibers, radio, etc. Also not shown are other devices that might be connected to the CPU, such as Bluray Disk player or other media players, tuners, decoders, amplifiers, etc. These other devices will be addressed in Section 3.2. Also not included in this figure are any media sources outside of the home, such as a media streaming service, cloud storage, cloud computing, etc. The specific questions that this thesis project should answer are:

- What will a future HMC look like?
- What will its functions be?
- What interfaces and protocols will it use?
- Who will make these HMCs?
- How can STB vendors evolve to be HMC vendors or will they simply cease to exist?

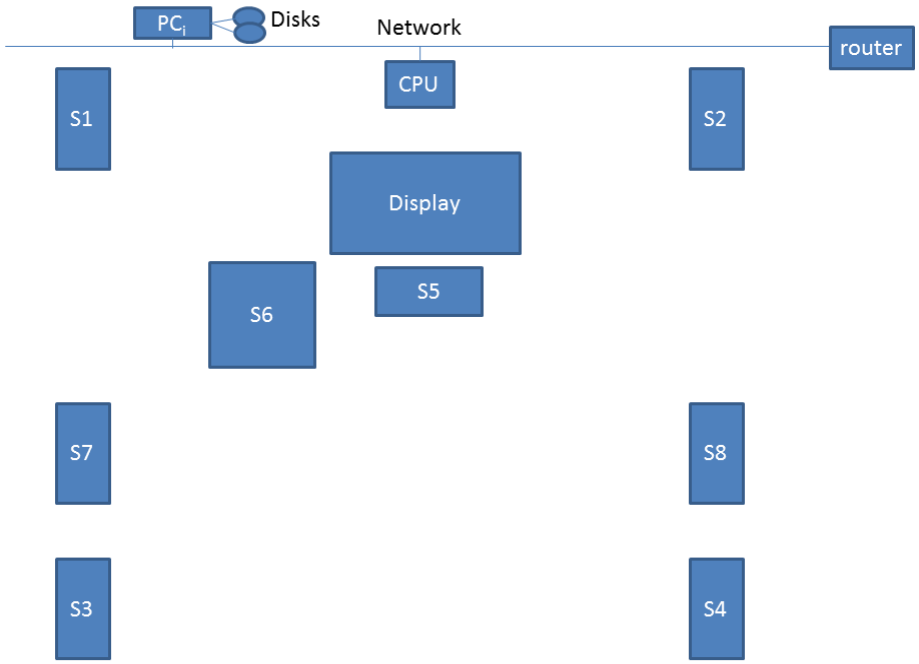

Figure 1.1. A typical setting with a display, speakers, CPU, PCs, and home network

1.3. Goals

In this thesis project we will design and evaluate a HMC prototype based upon current technology trends and user expectations. Part of the evaluation will be an analysis of the economic impact which such an HMC will have upon the current STB industry. The ultimate deliverable from this thesis project is a final thesis, that includes the following:

1. Prioritized HMC feature list, Section 4.1.2
2. HMC conceptual prototype: hardware and software specification, Section 4.2
3. Evaluation of the proposed HMCs projected economic impact on the current STB industry, Section 4.3
4. HMC product roadmap for 1, 3, and 5 years. Section 4.4

1.4. Steps in this thesis project

The basic plan for carrying out this thesis project is shown in Figure 1.2 and described below:

Literature study We proposed an initial hypothetical HMC feature list. This feature list is based on features of existing HMC-like products (for example,Tivo Roamio Pro (TRP), Microsoft Xbox One, Roku's RokuL3, and Apple TV), as well as features discussed in research papers.

Feature evaluation With the hypothetic feature list in hand, we designed and build a HMC prototype which implements these features for the purpose of testing user acceptance. As actually implementing all of the features envisioned for this prototype would have been very time consuming and out of the scope of this thesis project, hence most of these features were be mockups, in order to provide interviewees with a similar experience to what could be offered by the envisioned HMC. An experience lab was set up to evaluate this prototype. A questionnaire was devised to test user acceptance of this HMC prototype. The Unified theory of acceptance and use of technology (UTAUT) framework were applied for the questionnaire that the interviewees filled in before and after their session in the experience lab (where they experience the envisioned HMC features). The feedback from this survey was analyzed to evaluate each of the hypothetical features. The survey results were used to revise the HMC feature list and to prioritize each of the evaluated features.

Prototype design Based upon the highest priority features we design a conceptual prototype which implements these features. This prototype design includes:

the hardware specifications, hardware interfaces, and high level software architecture (hardware abstraction layer, operation system, protocols, middleware components, and application layer).

Economic analysis The economic impact of this HMC prototype was analyzed. The envisioned HMC value network was devised and compared to the current STB based value network. All stakeholders involved in the value network are presented and the impact on each of them of a transition process from their current status to the envisioned HMC market was analyzed. Sweden was considered as the target market for this economic analysis.

Product roadmap Based on the prioritized feature list, a requirements analysis was conducted and a technical requirement list devised as the outcome. This requirements list maps all of the elements of the prioritized feature list to detailed technical features, which were used as input for product road map decision making. The Stuart Pugh Decision Matrix (SPDM) was chosen as the method to make decisions among several options and to schedule the activities in the HMC product roadmap accordingly.

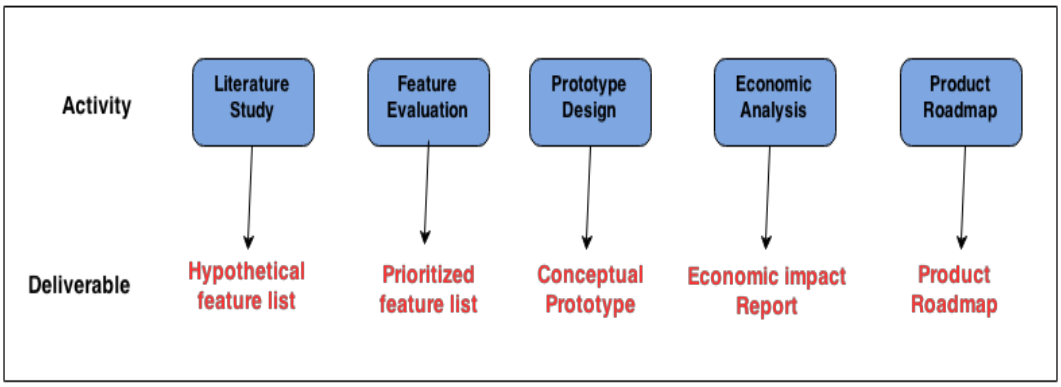

Figure 1.2. Steps in this thesis project

1.5. Structure of the thesis

Chapter 2 presents current status of STB and HMC-like products, explain the concept of UTAUT, and introduce the SPDM method. Following this background, *Chapter 3* presents the research methodology utilized in this thesis project.

Chapter 4 we analyze data collected from experience lab survey; detail explanation are also given, we propose a HMC conceptual prototype; high level hardware and software design are illustrated and elaborated; we make a economic impact analysis which cover both current STB industry value chain and devised future HMC value chain;

all the stakeholders and competitors to STB; finally we propose a general product roadmap as a guideline for STB venders to evolve to HMC.

Chapter 5 conclude this thesis with a summary of all the goals we have achieved, answered the questions we proposed at the beginning of this project, suggests interesting topics that could extend our work.

Chapter 2. Background

In this chapter, we present features, functionalities, and interfaces current STBs have. Some HMC-like products in the market will be mentioned and their characteristics will be discussed. We also explain the Unified theory of acceptance and use of technology (UTAUT) framework and the Stuart Pugh Decision Matrix (SPDM) method. UTAUT is used as a guideline for our survey question design while the product roadmaps are decided by SPMDM method.

2.1. Set-top Box (STB)

A STB is an information appliance that generally contains a TV-tuner for input whose output is connected to a television set. The STB turns the source signal into content in a form that can then be displayed on a television screen or other display/projection device. STBs are used in cable television, satellite television, and over-the-air television systems.

Some STBs are also IP enabled, these are called a Hybrid Set-top Box (HSTB). HSTB, such as those used for Smart TV programming, enable viewers to access multiple TV delivery methods (including terrestrial, cable, internet, and satellite). IPTV boxes can provide video on demand, time-shifting TV, Internet applications[3], video telephony[4], surveillance, gaming, shopping, TV-centric electronic program guides, and e-government. By integrating various delivery streams, HSTBs enable pay-TV operators more flexible application deployment, which decreases the cost of launching new services, increases speed to market, and limits disruption for consumers.

In the following subsections we use Tivo's latest product, Tivo Roamio Pro (TRP)[5], to show the main characteristics of a typical HSTB. In these subsection we list and explained TRP features and functionalities.

2.1.1. TRP's Personal Video Recorder (PVR) features

TRP can record up to 450 hours of High Definition (HD) video and audio content. See Table 2.1 for the pixel layout of several HD video modes. As the TRP has 6 TV tuners, it can simultaneously show and record up to 6 TV channels from the cable TV interface[6].

TRP supports record, pause, and fast forward functionality[7]. These functions can be invoked by the user using either an Infrared Receiver (IR) or Radio Frequency (RF) remote controller.

Table 2.1. HD and UHD Video Modes

	Video Mode	Pixels(Width x Height)	Scanning type
HD	720p	1280 x 720	progressive
	1080i	1920 x 1080	interleaved
	1080p	1920 x 1080	progressive
UHD	4000p (also called 4k)	4096 x 3072	progressive

2.1.2. A TRP supports the following entertainment options

Search across live TV and web Applications (APPs): When a user searches for content, not only live TV, but also the content of installed APPs, such as Netflix and Youtube. This idea is to provide a unified search experience to the user.

Recommendation/suggestions: Tivo Guru Guide[8] recommendations are lists of television programs hand-selected by experts for users. the benefit of these recommendations are that the user is always guided to freshest, hottest, most interesting programs. TiVo Suggestions are personalized shows selected to match users' preferences. These shows are suggested according to users' viewing history and rating[9].

Cable operator video on demand: If the cable operator offers a Video on Demand (VoD) service, TRP can integrate this service with other VoD services.

Pay-per-view access: The user can choose to watch a specific episode and only pay for this view, rather than needing to pay for whole show or TV channel.

VoD APP: TRP has an application store, which user can install VoD applications, such as Netflix, Hulu Plus, Amazon.

Music APPs: TRP has application store, which user can install music streaming applications, such as Pandora, Spotify.

Sports APPs: TRP has an application store, from which a user can install sports applications such as MLB.

User home movies: TRP can play a user's home movies. supported formats are:

Windows Media Video (.wmv)

QuickTime Movie (.mov)

MPEG-4/H.264 (.mp4, .m4v, .mp4v)

MPEG-2 (.mpg, .mpeg, .mpe, .mp2, .mp2v, .mpv2)

DivX and Xvid (.avi, .divx)

User home photos: TRP can display a user's home photos. supported formats are: BMP, TIFF, DIB, GIF, JPG, and PNG

User music library: TRP can play user personal music library from PC. The supported formats is MP3.

Record and playback Three Dimensional (3D) content: TRP can also record and playback 3D content.

2.1.3. TRP's Connectivity

TRP provides extensive connectivity, so the user can access content from anywhere , at any time.

Out of home streaming: The user can stream live TV or recorded programs from any geographic location where they have Wi-Fi connectivity.

Transfer/download recorded shows to mobile device: The TRP can show, record and watch recordings within home network on mobile devices

2.1.4. TRP's Hardware Interfaces

The TRP supports a number of standard interfaces. Figure 2.1 shows the back of the TRP. These interfaces are:

1. Connection to power
2. Ethernet port used to connect the device to a Local Area Network (LAN)
3. Coaxial cable jack used to receive a cable television signal
4. Optical audio jack used to provide audio signal output
5. Composite jack used to provide video and audio output
6. Component jack used to provide video output

7. High-Definition Multimedia Interface (HDMI) provides combined video and audio output
8. Universal Serial Bus (USB) can be used to connect to an external hard drive
9. External Serial Advanced Technology Attachment (eSATA) can be used to connect to external hard drive
10. CableCARD is a PCMCIA card that allows the device to view and record digital cable television channels on digital video recorders. This card is provided by the cable TV provider.

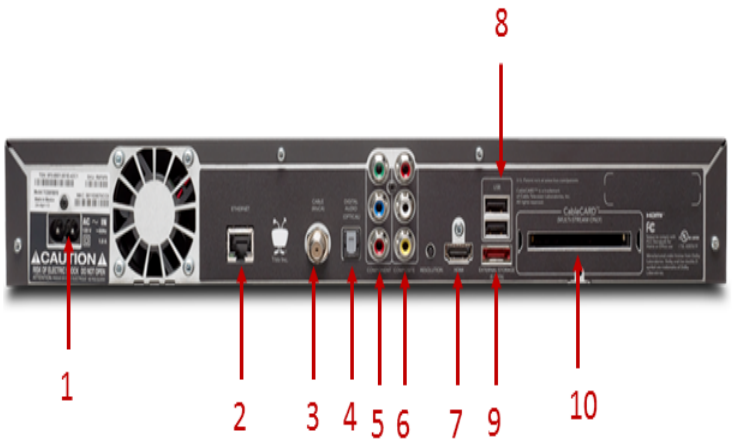

Figure 2.1. Tivo Roamio Pro hardware interface

We note that these interfaces vary from traditional computer interfaces (such as the Ethernet interface, USB, eSATA) to mixed computer interfaces (HDMI and optical audio jack) to traditional component connections for audio and video (using Radio Corporation of America (RCA) phone jacks) and broadband cable (via an F type connector).

2.2. Home Media Center

Today, there are some HMC-like products already in the market, i.e., products that have some of the features and functionalities that we expect that a HMC will require. These products are steps along the evolutionary path from STB to HMC. Clearly these products are potential competitors to existing STBs. In the following paragraphs we present three examples of such products from different product categories: gaming consoles (Microsoft Xbox One), streaming media players (Roku 3), and digital media players (Apple TV).

2.2.1. Microsoft Xbox One

Microsoft Xbox One was launched on Sep, 2013 as a successor of Xbox 360. Xbox One is next generation game console. However, as it integrates far more features than just gaming, it is quite similar to a HMC[10]. As Xbox One is mainly for gamers, it enhances the user's gaming experience. Several interesting features includes:

PlayTo: The PlayTo feature enables Xbox One to play streaming content from other devices, such as a Microsof Windows-based PC. This is a partial Digital Living Network Alliance (DLNA) implementation of a Digital Media Renderer (DMR), which allows a DLNA Digital Media Server (DMS) to render content to Xbox One.

Social Integration: Xbox One has strict strategy regarding social media integration. For example, they dropped Twitter integration from year 2013, but integrated Twitter microbloging service directly into Xbox One's TV experience in United States of American (USA) market in June, 2014 [11]. At the sametime, Xbox One continuously added new third party APPs to enhance their users entertainment experience.

Ultra High Definition (UHD) support: According to Xbox One hardware specification[12], Xbox One's HDMI input/output has 4k support, However, no statement has been made about 4k video and gaming support

Voice command: Xbox One is equipped with Kinect. It is a webcam-style peripheral, it is also a voice and motion sensor, so it can capture voice and gesture input from user to interact with game console without the need for a game controller. The interaction between user and console is more natural.

Motion detection: Kinect can also recognize users' gestures[13], many game titles have utilized this extraordinary feature to engage players more in games.

Video call: Powered by Kinnect and the preinstalled software Skype, users can make audio/video and conference calls directly on Xbox One.

2.2.2. Roku 3

Roku 3 is a streaming media player that allows users to access OTT streamed video or audio services through televisions, subscription-based services, and services that are available through the receiver free of charge. It can provide similar services to traditional cable TV, with even more functionalities, it is considered as a replacement for traditional cable and satellite TV. [14]

Some of its interesting features are:

Signal sourcel: Roku 3 is IP network based OTT streaming player, thus all content are delivered via an IP network, hence it does not rely on traditional cable TV provider.

Plenty of channels: In Roku, services are delivered through channels. There are over 1000 channels available on Roku, most of them are free channels, others require a subscription to access VoD, live TV, live sports and games.

Wi-Fi Direct support: Roku utilize Wi-Fi Direct technology to communicate between a remote control and the Roku device, instead of using Bluetooth or other 2.4 GHz RF technologies. the advantage of Wi-fi Direct over Bluetooth is transmission distance and speed[15], the disadvantage is its higher power consumption.

External hard drive: Roku 3 allows a user to connect external hardware to play home movies and user stored music, photos, etc.

2.2.3. Apple TV

Apple TV is a digital media player developed and sold by Apple Inc. It is a small network appliance designed to play digital content from the iTunes Store and other OTT services like Netflix, Hulu Plus, YouTube, Flickr, etc. Similar to Roku, it only supports connectivity via an IP network.

Apple TV has some unique features:

Multiple user profiles: Each Apple TV user has their own profile, which connects to the user's Apple ID, thus users can get personalized recommendation and suggestion.

Plenty of APPs: Backed up by the Apple ecosystem, many existing APPs in the Apple Store can be used on an Apple TV. There is a huge developer community, which can deliver large number of APPs tailored for Apple TV.

Airplay: Airplay is a proprietary protocol stack developed by Apple Inc to stream multimedia content(audio, video and photos) among iDevices in LAN network environment. Airplay is basically a counterpart to the DLNA protocol suite. Unlike the openness of DLNA, Airplay is a proprietary protocol suite, so the connection and streaming capability is limited to a small number of different types of devices.

2.2.4. smart TV

Pierre Labiausse developed a media box prototype based on smart TV system[16]. This media box centralize functions and controls as much as possible, it can be controlled by both touchscreen mobile devices and traditional remote controller, the software platform is open to third-party applications. Although this prototype has only limited functions implemented, it showed how smart TV can evolve to HMC.

2.3. Unified theory of acceptance and use of technology (UTAUT)

UTAUT is a technology acceptance model formulated by Venkatesh and others in "User acceptance of information technology: Toward a unified view"[17]. UTAUT tries to explain user intentions to adapt to an new information system and subsequent usage behavior. The theory is based upon 4 key constructs:

1. performance expectancy,
2. effort expectancy,
3. social influence,
4. facilitating conditions.

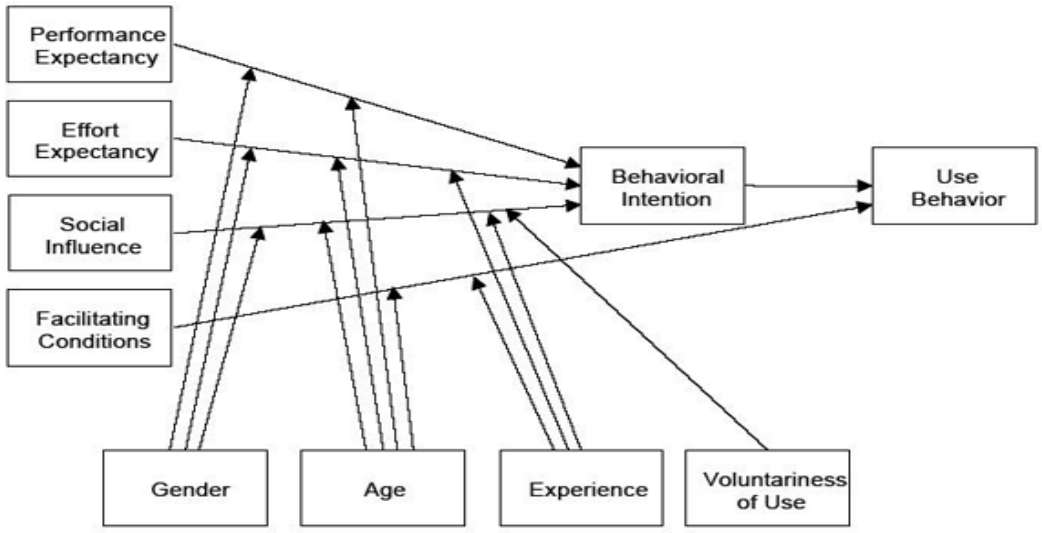

Figure 2.2. Unified theory of acceptance and use of technology (UTAUT)

Being the first three direct determinants of usage intention and behavior, and the fourth a direct determinant of use behavior. Additionally, gender, age, experience, and voluntariness of use are posited to moderate the impact of the four key constructs on usage intention and behavior. The theory was developed through a review and consolidation of the constructs of eight models that earlier research had employed to explain information systems usage behavior. The models are theory of reasoned action, technology acceptance model, motivational model, theory of planned behavior, a combined theory of planned behavior/technology acceptance model, model of personal computer use, diffusion of innovations theory, and social cognitive theory. Many user acceptance test are based on this unified model [18].

In this thesis, this framework is utilized as a guideline to design a questionnaire and to evaluate user acceptance of HMC features.

2.4. Stuart Pugh Decision Matrix (SPDM) method

SPDM is a criteria-based decision matrix which uses criteria scoring to determine which of several potential solutions or alternatives should be selected. The technique gets its name from Stuart Pugh and has become a standard part of the Six Sigma methodology.

SPDM allows the analyst to organize various criteria (or features) of a solution in a structured way for easy comparison;SPDM facilitates a team-based process for disciplined concept generation and selection. Additionally, it allows the analyst to develop a optimal solution which is a hybrid of other strong solutions.[19]

Daniel Ignat proposed a Weighted SPDM method to evaluate implementation roadmap in his thesis “Utilization of DLNA in a IPTV Solution” [1]. In his Wighted SPDM method, each criteria is given a weight, criteria with higher weight has higher influence for decision making. In this thesis project, we apply a Weighted SPDM method to decide product roadmap for HMC.

Chapter 3. Method

In this chapter, we explain the methodologies applied in this thesis project.

In order to come up with future HMC product prototype, we need to understand user expectations towards such a product. We start by studying current market environment for HMC, features of HMC-like products, features in research papers, then design a hypothetical feature list.

To verify these hypothetical features, we apply quantitative research methodology by composing a questionnaire. We planned to conduct a survey via the Internet, however, as our supervisor pointed out, it is hard to conduct such a survey because we do not have a tangible product, thus the feedback from our survey takers will not be accurate. Instead, we set up a laboratory environment and designed a series of user cases, so that users can experience the HMC's features. In this way, we receive the users' first impression which should accurately reflect their experience.

During the survey result collection phase, we conducted reliability and validity test, revise our questionnaires accordingly. the first 3 interviewees used our first version of questionnaires (shown in Appendix A.1). All others used the final version shown in Table **??**.

We collected and analyzed user expectation data from the users' interactions with the prototype in the experience lab. Next we constructed a decision matrix using the weighted SPDM method (proposed by Daniel Ignat) and proposed general HMC product roadmaps according to the calculated final score.

3.1. HMC hypothetical feature list

We devised a hypothetical feature list for a HMC and designed a initial HMC prototype based on our literature study. In order to evaluate the actual user acceptance of this initial prototype, we build up an experience lab. In this lab environment, volunteers use the HMC prototype under the guide of well devised use cases, then give their

feedback through a survey questionnaire. The hypothetical features are listed and explained in Table A.1

Table 3.1. Hypothetical Feature List

Category	FEAID	feature description
Video	FEA1	user can watch streaming movie/video clips with Ultra HD quality
	FEA2	user can watch streaming movie/video clips without buffering
	FEA3	user can watch broadcasting TV channel
	FEA4	user can watch sports, concert and other live events with lowest latency possible
	FEA5	user can choose on which channel to watch live events (live event guide)
	FEA6	user can watch home movie stored in LAN
	FEA7	user can easily find and play music from music library in LAN
	FEA8	user can easily access family photos in LAN
	FEA9	user's media resources on HMC are discoverable by other device in the home network
	FEA10	user can display content on whatever screen he/she wants
	FEA11	user can easily watch home movie stored in cloud
	FEA12	user can record a live TV show for later watch
	FEA13	user can pause a live show to watch later
	FEA14	user can discover what events/programs are currently live broadcasting
	FEA15	user have a personalized channel, in which user picked video programs are scheduled
	FEA16	user can get notified by email or sms or popup when a scheduled program is about to start
	FEA17	user can play blueray disk
	FEA18	user can plugin external hard disk to watch local video
Game	FEA19	user can play game with Ultra HD quality without any lagging
	FEA20	user can share their game archivement to Social Networking Service (SNS), (like facebook, game communities etc)
	FEA21	user can play online game together with other people remotely
Music	FEA22	use can stream looseless music from music streaming service providers, like Spotify
	FEA23	user can access their favorite music streaming service,like spotify, deezer
Picture	FEA24	user can access photo storage service like flickr, picassa
Interaction	FEA25	user can use remote control to interact with HMC
	FEA26	user can use smart phone and tablet to control HMC
	FEA27	user can speak to HMC
	FEA28	user can use body motion to interact with HMC
	FEA29	user can play video game while listening to music
	FEA30	user can play video game and broadcasting live screen
	FEA31	user can watch video while surfing on internet on second screen
Other	FEA32	user can watch TV while making video chat with friends/family
	FEA33	each user has a profile, so they can login with different preference
	FEA34	user get recommendation by activity history
	FEA35	user get content recommendation from friends
	FEA36	user can search all available content in one place
	FEA37	user can surf on internet
	FEA38	user can make video call
	FEA39	user can install third-party application and use them on HMC

3.2. Design of experience lab

In order to test users' acceptance to proposed hypothetical HMC features as accurate as possible, we setup an experience lab, in which users can experience each of the features. After this experience each participant answer questions. With this approach, we decease the possibility that survey responders misunderstand questions and give inaccurate feedback, thus we increase our data reliability. For further detail, see Section 3.4.3.

The experience lab was set up based on a typical living room setting,(such as that shown in Figure 1.1). The CPU in this context refers to a HMC. As the HMC is a concept prototype, all of the features are emulated by using other devices, specially

Table 3.2. Use Case Scenario

Scenario ID	Experiment scenario
SCE1	user watch 4 sample videos, same content, different quality: sample1: 4k sample2: 1080p sample3: 1080i sample4: 720p
SCE2	user watch 1 sample videos in the following 3 cases: 1) video plays smoothly, without any lagging 2) video pause for buffering for 2 second in a interval of 20 seconds 3) video pause for buffering,5 second in a interverval of 10 seconds
SCE3	user watch video from 2 devices, one has only VoD content; the other has both VoD and broadcasting TV channels;
SCE4	user watch video from 3 devices, one can stream live events with less than 10 seconds latency; one can stream live events with 10 minutes delay; another one can only replay the event when it finish
SCE5	user found out a interesting football match to watch through Live Program Guide (LPG), this match is available live on several channels, user can choose on which channel to watch based on channel quality, price
SCE6	user want to access home multimedia content, they are stored on home PC, and also backed up in cloud 1) HMC automatically discover home video files stored in home network and play without waiting time. 2) use external Hard Disk Drive(HDD) to copy video from other PC and plugin to HMC to play
SCE7	user want to watch home video stored in cloud 1) connect to cloud service, download video file to HMC and play 2) connect to cloud service, locate the video file and play directly
SCE8	user have a,favorite football team playing a very important match this afternoon, but user need to work at that time, what do you want to do? 1) ask HMC to record this match, then you can watch it when,you come home 2) you know this match will be available on a sport site for free, as you can't watch it live anyway, you will turn to that site to watch it when you have time
SCE9	You are in the situation like that:You are watching a very important football match, then it is time to pick up your kids from kindergarden„what do you want to do? 1) pause the game, continue watch the game when you come back 2) I know this match will be available on a sport site for free, as I can't watch it live anyway, I will turn to that site to watch it.
SCE10	user use smartphone or tablet to browse what is currently live broadcasting, if user click on his/her interesting program, a window pop up with a list of all available screen, user choose on which screen to watch this program
SCE11	user browser video library and add interesting video to personalized channel and scheduel when to play, if the video is a live program, it is scheduled by its broadcasting time, user can optionaly set notification for scheduled live program
SCE12	user play game at different resolution: 1) 4k 2) 1080p
SCE13	user play a game on HMC, live broadcasting to Twitch, when the game is finished, share the archivement to Facebook
SCE14	user paly a online game with friends in another city
SCE15	user can listen to music with different quality: sample1: loosless sample2: mp3 stereo sample3: mp3
SCE16	user add spotify to HMC
SCE17	user add flickr to HMC
SCE18	user play a game, use voice/smartphone/remote control to find and launch the game„use body motion to control the player in the game
SCE19	use login to HMC, the system present all personalized information. history, recommendation, connect to SNS, etc.
SCE20	user navigate to recommendation page, show recommended content based on user activity on HMC
SCE21	user navigate to recommendation page, show recommended content based on friends activity
SCE22	user needs to find a desired movie, 1) one search box, find out all movie locations from multiple service provider 2) go to differnt video service provider and search
SCE23	user browse internet on HMC
SCE24	user make video call from HMC on TV screen
SCE25	user name several app, they can be installed from app store

a PC, Xbox One, Roku 3 and TPR. The designed use cases are listed in Table 3.2.

We briefly describe how we mocked up each scenario below. The scenarios are numbered in the form: SCE#, where # is an integer.

SCE1: Using a UHD screen, we present same content video clip at 4 different resolution, UHD, 1080p, 1080i, 720p. we play these 4 clips in a PC randomly.

SCE2: A 5 minutes video, play it on PC in 3 different cases: 1) play without pause, 2) pause 2 seconds every 20 seconds, 3) pause 5 seconds every 10 seconds

SCE3: Use Roku to watch Netflix movies, then use TRP to watch both TV broadcasting and VoD.

SCE4: Using a football match clip, play one copy on a PC as "live" broadcasting, play another copy 10 minutes after the first one.

SCE5: Create a Live Program Guide User Interface (UI), which shows multiple channels from which the football event is available, when a user click on a channel, the user is connected to that channel and starts to watch the event.

SCE6: After Installing Plex media server[20] on the PC, we stored several home video, several home photos on Plex media server; install Plex Roku channel. Using this combination of client and server participants could easily discover the home video and then view photos through a Roku channel.

SCE7: Using the same setting as SCE6, but instead we assume that same multimedia resources are stored in the cloud instead of on a device attached to LAN.

SCE8: Use TRP PVR feature to record match.

SCE9: Use TRP PVR feature to live pause the football match and watch it later.

SCE10: Use a mobile phone to browse the Electronic Program Guide (EPG) to find an interesting live program, click on the desired choice to play then choose which screen should be used to display the selected content.

SCE11: Append one personalized channel to the EPG and add the participant's favorite programs to this channel.

SCE12: User watches video games at UHD and 1080p resolution.

SCE13: User play video game on PC and live broadcast to Twitch(a real time game broadcasting platform), then share this video clip to Facebook.

SCE14: A user from Stockholm plays online video game with friend in another country using Xbox One.

SCE15: The same song is played with 3 different quality: loosless, MP3 stereo, MP3.

SCE16: I install and use Spotify on PC

SCE17: I install and use Flickr on PC

SCE18: Play a Kinect game on the Xbox One, using voice command to navigate, and using body motion to control the on-screen player.

SCE19: Set up a profile on Xbox One. All activity history and achievements are associated with this profile.

SCE20: using TRP's "What to Watch Now"[21] content recommendation mechanism to recommend content according to the user's viewing history.

SCE21: Use the Xbox One to show what games friends have played recently.

SCE22: On the TRP install Netflix, then using search box search for live TV and Netflix.

SCE23: Use PC as HMC to browse web pages.

SCE24: Use Skype on Xbox One to make a video call

SCE25: Select several channels from the channel store on Roku to install third party channels.

3.3. Design of Survey questionnaire

To test user acceptance of hypothetical features, a survey questionnaire is devised to elicit the user's experience with each feature. To align with UTAUT framework, we devised questions to ask for some demographic information. A complete list of survey questions is given in Table 3.3

From Table 3.3, we can see that each question corresponds to a hypothetical feature. Each question have 5 answers using a Likert scale from strongly disagree to strongly agree, recorded as a numeric value ranging from 1 to 5. The numeric value is used to calculate a final score for the user's expectation during the data analysis.

3.4. Survey methodology

In this section, we use statistical methods to determine survey sample size, sample method and conduct data validity and reliability tests.

3.4.1. Sample size determination

To determine our sample size, we set the following parameters:

Confidence level: 90%

Confidence interval: 10%

Target population: 9,644,864 (the whole population of Sweden 2013) [22]

For this target population, our criteria is to include anyone who enjoys video, music, games, and other entertainment at home. We assume that almost everyone in our target market (Sweden) fits this criteria, so we take the whole population of Sweden as our target population. Note that this is an over estimate of the size of the target population as there will be children who are to young to do any of these activities (by themselves) and there will be others who choose not to do any of these activities.

$S = (Z - score)^2 - StdDev * (1 - StdDev)/(marginoferror)^2$

S: Sample size

Z-score: with 90% confidence level, the value is 1.645

StdDev: Standard deviation, use regular value 0.5[23]

margin of error: same to confidence interval, 10%

According to formula above, we determine that we need **68** interviewees to participate in our survey.

3.4.2. Sampling method

Convenience sampling is used to select experience lab interviewees. The sampling method was chosen due to that fact that the survey target HMCs and we assumed that a HMC is universally applicable to almost all people living in Sweden. Another reason we chose this sampling method was that we had a limited amount of time for this thesis project.

3.4.3. Data Validity and Reliability test

Reliability refers to the consistency and/or stability of a particular result from procedures done in the different circumstances, assuming the variable factor/s has/have not changed[24]. The reliability of the quantitative study was ensured using internal consistency, by testing the hypotheses in a single survey. In this thesis we assessed our survey results by using two prominent types of Correlation tests, which are Cronbach alpha and Pearson product-moment correlation (Pearson correlation).

Cronbach alpha presents consistency of several variables. The assessment for the Cronbach alpha's values is mentioned in [25] and shown in Table 3.4.

Pearson correlation (r) shows whether the variables correlate each other and the strength of their correlation. It also represents the reliability. However, it only can be used to measure two variables. Pearson correlation may show negative or positive value, which the negative value means the negative correlation between two variable

(one increase, the other decrease), and vice versa. The assessment values are shown in Table 3.5.

For our validity test, we apply both face validity and content validity methods.

For face validity: we asked our first few interviewees to give their general opinion as to whether the experience scenarios covers HMC features they expect or not. Several hypothetic features are added (specifically FEA15, FEA31). Some features were not easy to understand, hence we updated the question to avoid technical terms, in order that every interviewee would understand the feature clearly.

For content validity: we invited 4 reviewers, Andreas Eriksson, Fredrik Paulsson,Marco Frattolin,Joakim and Larsson Edström from Zenterio AB to review survey items and updated them accordingly.

3.5. Define HMC product roadmap criterion and weights

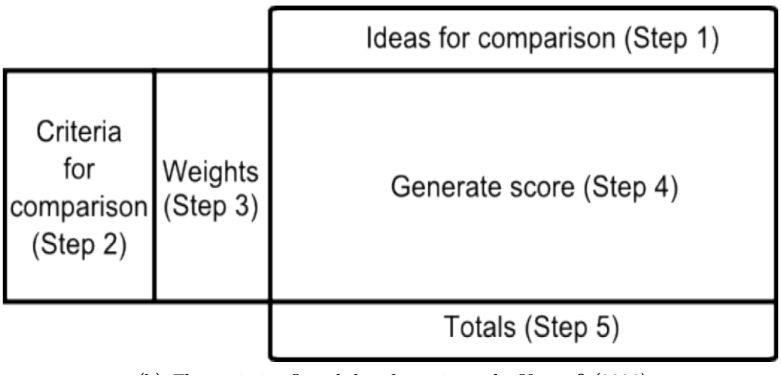

Figure 3.1. Stuart Pugh Decision Matrix (SPDM) steps[1]

Daniel Ignat proposed a process for deciding upon a product roadmap [1]. We follow his steps to propose our HMC roadmap. These steps are shown in Figure 3.1.

For step 1, each feature in the prioritized feature list is an idea for comparison. We need to identify criterion for comparison (step 2) and a weight for each criteria (step 3).

To decide upon the criterion and weights, we consult experts from STB industry (Andreas Eriksson, Fredrik Paulsson,Marco Frattolin,Joakim and Larsson Edström from Zenterio AB). they helped us to identify most important criterion and weights. The resulting weights are shown in Table 3.6.

Table 3.3. survey questionnaire

QID	Question
Q1	What's your age? under 20, 20 to 35, 36 to 50, over 50
Q2	What's your gender? male, female
Q3	Do you think 4k video quality is better than others? Strongly disagree, Disagree, Neutral, Agree, Strongly agree
Q4	How important to you that the video should play smoothly without stop for buffering? Not at all, Not really, Undecided, Somewhat, Very much
Q5	How much do you need to watch broadcasting TV channel? Not at all, Seldom, Sometimes, Much, Very Much
Q6	How important do you want to watch events "live"? Not at all, Not important, Neutral, Important, Very Important
Q7	How important you can decide on which channel to watch video? which language actors speak and which language to show on the screen Not at all, Not important, Neutral, Important, Very important
Q8	Do you like to easily access your content stored in other place in LAN? Not at all, Not much, Neutral, Somewhat, Very much home videos; music library; family photos
Q9	Do you want media resources stored on HMC is discoverable by other devices in same network? like your phone, tablet...etc? Not at all, Not much, Neutral, Somewhat, Very much
Q10	Would you like to watch video on any screen available? Not at all, Not much, Neutral, Somewhat, Very much
Q11	How much do you like to easily access your home movie from anywhere, at anytime Not at all, Not much, Neutral, Somewhat, Very much
Q12	Do you want HMC to record a match for you? Not at all, Not much, Neutral, Somewhat, Very much
Q13	How much do you want HMC to pause the match when you want to watch it later? Not at all, Not much, Neutral, Somewhat, Very much
Q14	How much do you like to be able to discover live program/events? Not at all, Not much, Neutral, Somewhat, Very much
Q15	How much do you want your personalized channel on HMC? Not at all, Not much, Neutral, Somewhat, Very much
Q16	How much do you want to get a email or/and sms notification 15 minutes before your scheduled program start? Not at all, Not much, Neutral, Somewhat, Very much
Q17	Do you think it is necessary to play Bluray on HMC? Not at all, Not much, Neutral, Somewhat, Very much
Q18	Do you think it is necessary to plug in external hard drive to HMC? Not at all, Not much, Neutral, Somewhat, Very much
Q19	Do you think 4k game resolution is better than others? Strongly disagree, Disagree, Neutral, Agree, Strongly agree
Q20	Would you like to share your game experience to friends through Facebook or Twitch? Not at all, Not really, Neutral, Somewhat, Very much
Q21	How much do you like to play online game with other people? Not at all, Not really, Neutral, Somewhat, Very much
Q22	How much do you like high quality music? Not at all, Not really, Neutral, Somewhat, Very much
Q23	How much do you like to get your music service provider on HMC? Not at all, Not really, Neutral, Somewhat, Very much
Q24	How much do you like to access your photo storage service from HMC? Not at all, Not really, Neutral, Somewhat, Very much
Q25	Do you like to control HMC in the following ways: Not at all, Not really, Neutral, Somewhat, Very much traditional remote,smartphone/tablet,voice,body motion
Q26	Which of the following activities do you want to do at the same time? Not at all, Not really, Neutral, Somewhat, Very much Play video game while listing to music,Play video game and broadcasting live,Watching video while surfing on Internet Watching TV while having a video chat with friends/family
Q27	Do you want to have your own profile? Not at all, Not really, Neutral, Somewhat, Very much
Q28	Do you like to get recommendation from? Not at all , Not really , Neutral , Somewhat , Very much by activity history/profile,by friends
Q29	Do you like to find all the contents you want in one place? Not at all , Not really , Neutral , Somewhat , Very much
Q30	Would you like to have the following Features on HMC? Not at all,Not really,Maybe,Somewhat,Very much surf internet,make video call,install app from app stor

Table 3.4. Interpretation of Internal consistency from Cronbach alpha

Reliability Coefficient	Internal Consistency
$\alpha \geq 0.9$	Excellent
$0.8 \leq \alpha \geq 0.9$	Good
$0.7 \leq \alpha \geq 0.8$	Acceptable
$0.6 \leq \alpha \geq 0.7$	Questionable
$0.5 \leq a \geq 0.6$	Poor
$\alpha \leq 0.5$	Unacceptable

Table 3.5. Interpretation of Correlation coefficient from Pearson Correlation

Pearson Correlation	Correlation coefficient
-0.09 to 0, or 0 to 0.09	None
-0.3 to -0.1, or 0.1 to 0.3	Small
-0.5 to -0.3, or 0.3 to 0.5	Medium
-1.0 to -0.5, or 0.5 to 1.0	Strong

Table 3.6. Decision matrix criteria and weights

Criteria	Weights(1 to 5)
User expectation	5
Implementation Cost	4
Ease of Use	3
Hardware Capabilities	2
Software Capabilities	1

Chapter 4.
4 Analysis

In this chapter, we analyze data collected via the survey, then we propose a HMC conceptual prototype, HMC high level hardware and software design is elaborated. Following this we make a economic impact analysis,discuss the current STB industry value chain and then a devised future HMC value chain and evaluate the impact upon the STB industry. Finally, we propose a general product roadmap for the period of 1 to 5 years for STB vendors to evolve to HMC vendors.

4.1. Survey Analysis

In this section, we analyze data collected via the survey. At first, we presents sample characteristics. Then we analyze survey result by calculating average value of each question, we also calculate confidence interval of each question, which leads to lower and upper boundary of each average value. We propose prioritized feature list based upon each feature's score. Finally, to get deeper understanding of the data and their correlation, we conducted cross tabulation analysis and cross question analysis.

4.1.1. Sample characteristics

According to UTAUT model, we asked for interviewees' demographic information, age and gender. The result is shown in Table 4.1. 57.35% of interviewees are male and 42.65% of them are female. None of them are from age group "under 20", the majority of them are from age group "20 to 35"(82.35%), while 13.24% are from age group "over 50" and only 4.41% are from age group "36 to 50".

Table 4.1. Sample characteristics

Age/Gender	Male	Female	Sum
under 20	0	0	0
20 to 35	32	24	56
36 to 50	3	0	3
over 50	4	5	9
Sum	39	29	**68**

4.1.2. Prioritized HMC feature list

In order to decide priority of each feature in hypothetical feature list, we calculated mean value confidence interval with preset 90% confidence level. The result is shown in Table 4.2 and Figure 4.1. Note: all value are rounded to 2 decimal places.

Table 4.2. Survey responses - mean value with upper and lower boundary (confidence level 90%)

	Q3	Q4	Q5	Q6	Q7	Q8.1	Q8.2	Q8.3	Q9	Q10
Average	3.68	4.49	3.47	2.81	3.59	3.06	3.22	3.65	3.22	3.62
Lower	3.5	4.31	3.27	2.54	3.36	2.79	2.93	3.39	2.95	3.38
Upper	3.86	4.66	3.68	3.08	3.82	3.32	3.51	3.9	3.49	3.86
	Q11	**Q12**	**Q13**	**Q14**	**Q15**	**Q16**	**Q17**	**Q18**	**Q19**	**Q20**
Average	3.25	3.13	3.56	4.03	3.5	3.54	3.24	3.4	3.44	2.9
Lower	2.99	2.83	3.27	3.83	3.26	3.29	2.97	3.14	3.25	2.65
Upper	3.51	3.43	3.85	4.23	3.74	3.79	3.5	3.66	3.63	3.15
	Q21	**Q22**	**Q23**	**Q24**	**Q25.1**	**Q25.2**	**Q25.3**	**Q25.4**	**Q26.1**	**Q26.2**
Average	3.13	4.16	3.53	3.32	3.54	3.79	3.16	2.85	2.76	2.21
Lower	2.85	3.98	3.25	3.08	3.29	3.55	2.89	2.57	2.49	1.97
Upper	3.41	4.35	3.81	3.57	3.79	4.04	3.43	3.14	3.04	2.44
	Q26.3	**Q26.4**	**Q27**	**Q28.1**	**Q28.2**	**Q29**	**Q30.1**	**Q30.2**	**Q30.3**	
Average	2.85	2.85	3.54	3.53	4.12	4	2.93	3.47	2.74	
Lower	2.58	2.59	3.3	3.31	3.93	3.77	2.67	3.24	2.49	
Upper	3.12	3.11	3.79	3.75	4.3	4.23	3.19	3.71	2.98	

To further analyze priority and how significant the difference is, we sorted the survey data by mean value. The result is shown in Figure 4.2. We can see from this Figure that Q4 has highest mean value and its range has no overlapping with other questions; Q26.2 has lowest mean value and it is range does not overlap with other questions; all others overlap with their neighbors. Thus we can conclude Q4 and Q26.2 have significant difference to other questions, Q4 tested feature FEA2 has highest priority while Q26.2 tested feature FEA30 has lowest priority. The complete prioritized HMC feature list is shown in Table 4.3.

In general, consumers have more interest in video and music, than photo and games. We believe that the reason behind this is that only a small portion of people are

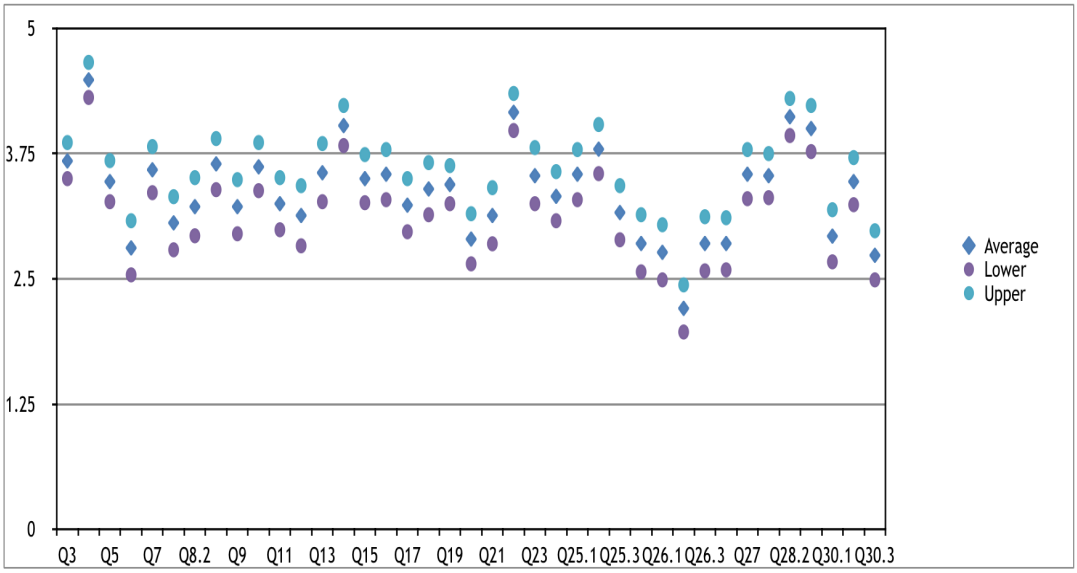

Figure 4.1. Survey responses- unsorted

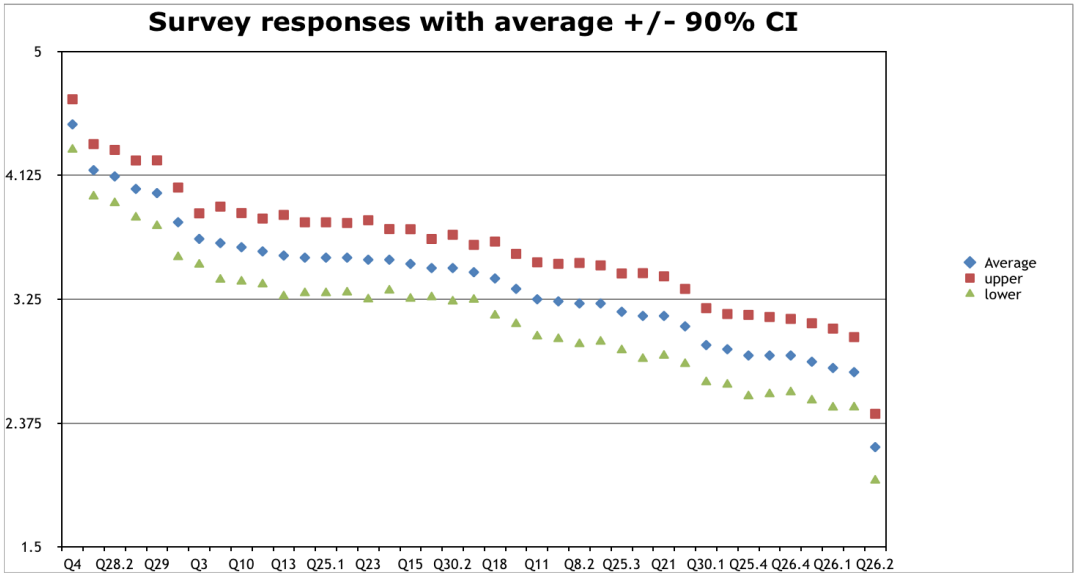

Figure 4.2. Survey responses with average +/- 90% CI

active gamers, but watching videos and listening to music are common activities for most people.

Consumers expect more content and more options to choose where and how they want to view content. Regarding connectivity, they expect easy access to both online services and their own data stored at local network. In terms of interactivity, consumers tend to retain their existing habit of using remote control, however more

Table 4.3. Prioritized feature list

Low	High	Ave.	QID	FEA ID	Feature description
4.31	***4.66***	***4.49***	***Q4***	***FEA2***	***user can watch streaming movie/video clips without buffering***
3.98	4.35	4.16	Q22	FEA22	use can stream looseless music from music streaming service providers like Spotify
3.93	4.3	4.12	Q28.2	FEA35	user get content recommendation from friends
3.83	4.23	4.03	Q14	FEA14	user can discover what events/programs are currently live broadcasting
3.77	4.23	4.00	Q29	FEA36	user can search all available content in one place
3.55	4.04	3.79	Q25.2	FEA26	user can use smart phone and tablet to control HMC
3.5	3.86	3.68	Q3	FEA1	user can watch streaming movie/video clips with Ultra HD quality
3.39	3.9	3.65	Q8.3	FEA8	user can easily access family photos in LAN
3.38	3.86	3.62	Q10	FEA10	user can display content on whatever screen he/she wants
3.36	3.82	3.59	Q7	FEA5	user can choose on which channel to watch live events (live event guide)
3.27	3.85	3.56	Q13	FEA13	user can pause a live show to watch later
3.29	3.79	3.54	Q16	FEA16	user can get notified by email or sms or popup when a scheduled program is about to start
3.29	3.79	3.54	Q25.1	FEA25	user can use remote control to interact with HMC
3.3	3.79	3.54	Q27	FEA33	each user has a profile so they can login with different preference
3.25	3.81	3.53	Q23	FEA23	user can access their favorite music streaming service like Spotify Deezer
3.31	3.75	3.53	Q28.1	FEA34	user get recommendation by activity history
3.26	3.74	3.50	Q15	FEA15	user have a personalized channel in which user picked video programs are scheduled
3.27	3.68	3.47	Q5	FEA3	user can watch broadcasting TV channel
3.24	3.71	3.47	Q30.2	FEA38	user can make video call
3.25	3.63	3.44	Q19	FEA19	user can play game with Ultra HD quality without any lagging
3.14	3.66	3.40	Q18	FEA18	user can plugin external hard disk to watch local video
3.08	3.57	3.32	Q24	FEA24	user can access photo storage service like flickr picassa
2.99	3.51	3.25	Q11	FEA11	user can easily watch home movie stored in cloud
2.97	3.5	3.24	Q17	FEA17	user can play blueray disk
2.93	3.51	3.22	Q8.2	FEA7	user can easily find and play music from music library in LAN
2.95	3.49	3.22	Q9	FEA9	user's media resources on HMC are discoverable by other device in the home network
2.89	3.43	3.16	Q25.3	FEA27	user can speak to HMC
2.83	3.43	3.13	Q12	FEA12	user can record a live TV show for later watch
2.85	3.41	3.13	Q21	FEA21	user can play online game together with other people remotely
2.79	3.32	3.06	Q8.1	FEA6	user can watch home movie stored in LAN
2.67	3.19	2.93	Q30.1	FEA37	user can surf on internet
2.65	3.15	2.90	Q20	FEA20	user can share their game archivement to SNS (like facebook game communities etc)
2.57	3.14	2.85	Q25.4	FEA28	user can use body motion to interact with HMC
2.58	3.12	2.85	Q26.3	FEA31	user can watch video while surfing on internet on second screen
2.59	3.11	2.85	Q26.4	FEA32	user can watch TV while making video chat with friends/family
2.54	3.08	2.81	Q6	FEA4	user can watch sports concert and other live events with lowest latency possible
2.49	3.04	2.76	Q26.1	FEA29	user can play video game while listening to music
2.49	2.98	2.74	Q30.3	FEA39	user can install third-party application and use them on HMC
1.97	***2.44***	***2.21***	***Q26.2***	***FEA30***	***user can play video game and broadcasting live screen***

people are expected to adapt to new ways of interactivity, such as using their smart phone or tablet computer to control HMC. Participants also showed an interest in controlling their HMC with voice commands, while motion detection is not widely accepted yet. These overall finding aligns with the study by Markku Turunen, et al. in "User Expectations and User Experience with Different Modalities in a Mobile Phone Controlled Home Entertainment System"[26].

Each survey question's result is shown in Appendix A and a summary of these results are given below (The questions are on page 23).

Q3: Most interviewees perceive that 4k video quality is the a bit better than 1080p video, but do not think it is significant improvement.

Q4: Almost all interviewees have high expectation for smooth video playing. a little lag is acceptable but a large lag reduced their satisfaction.

Q5: Most interviewees indicated that they watch live broadcast TV channels sometimes, as a result of shifting to VoD services. Overall there were more people watching

TV than the number of those who do not watch TV at all.

Q6: The distribution of answers to this question was quite flat which means people have a high tolerance to live broadcast delay. For example a few seconds delay of live events was totally acceptable.

Q7: Most interviewees had high expectations of having multiple options, so they have the freedom to choose best suited.

Q8.1: Half of interviewees need to play home videos stored in their local network, the other half do not have this requirement.

Q8.2: More interviewees need to play music library stored in their local network than those who don't need to.

Q8.3: Most interviewees need to access family photos stored in their local network.

Q9: The ability to discover content stored in HMC is required by most interviewees.

Q10: Most interviewees expect to choose on which screen to watch their selected video.

Q11: There is high demand to play media content from anywhere and any time.

Q12: More interviewees want video recording features than those who do not want.

Q13: Most interviewees like the idea of "live pause", which records video for later play even though they know this video will be available to watch somewhere else.

Q14: The need to view, discover, search Electronic Program Guide (EPG) is prevalent.

Q15: Most of the interviewees like the idea of personalization and customization.

Q16: Notification is a must have feature, and interviewees expect multiple way of notification, pop up, email, Short Message Service (SMS).

Q17: The need to playback Blu-ray Disc (BD) is moderate.

Q18: Majority of interviewees want to playback media files stored in external hard drive.

Q19: Similar to Ultra High Definition (UHD) video, most of the interviewees think Ultra High Definition (UHD) game experience is close to or a little bit better than 1080p game from visual effect point of view.

Q20: Few interviewees want to share their game experience to Social Networking Service (SNS) or live streaming service.

Q21: The distribution of answers is quite even, while more people like online multi player game experience.

Q22: The majority of interviewees preferred high quality music, especially lossless compression music.

Q23: The majority of interviewees like to be connected to their online music streaming services from HMC, Spotify, Deezer

Q24: There is less interest of photo storage service on HMC than video and music, but still over half of interviewees want this feature.

Q25: For the ways to control or interact with HMC, using traditional remote control is widely accepted. Additionally, there was high interest in using a smart phone or a tablet as control device. Additionally, voice control was acceptable to half of the respondents, while the experience of controlling a HMC with body motion was less interesting.

Q26: Most interviewees do not want to play video games and live broadcasts at the same time. Also more than 19 % people do not like to play video game while listening to music. However, quite a few people like to watch videos while surfing on Internet, or want to watch TV while having a video chat, but the number of people who prefer these combinations of activities is less than half of total interviewees.

Q27: The majority of interviewees showed a high interest in having their own profile on a HMC in order that they can be provided personalized services, such as recommendation.

Q28: Recommendation is highly acceptable.

Q29: One stop search is favored by most interviewees.

Q30.1: Not many interviewees liked the experience of surfing the Internet on HMC with big screen, they prefer to do it on a PC or their smart phone.

Q30.2: Making a video call to family and friends was rated as a excellent experience on a HMC, especially seeing them on big screen.

Q30.3: Installing third party application is very popular, as this enable users to choose their own desired services, hence offering a freedom of choice experience.

4.1.3. User characteristic analysis

To understand how users with different characteristics (age, gender) impact their expectations on different features, we applied cross tabulation method[27] to conduct user characteristic analysis. As majority of our survey respondents are from age group "20 to 35" (56 out of 68), we mainly focus on this age group for our analysis.

In Table 4.4, we created cross tabulation matrix for Q3 split by interviewees' age and gender. the first column is age groups and second column is gender group. For age group "20 to 35", The outstanding difference is half of the female interviewees chose option neutral while majority of the male interviewees (over 65%) deem 4k videos are better than other resolutions.

Table 4.4. user characteristics analysis - Q3

Q3	**%**	**Do you think 4k video quality is better than others?**				
Age	**Gender**	**Str. disagree**	**Disagree**	**Neutral**	**Agree**	**Str. agree**
20 to 35	**male**	3.12	3.12	28.12	43.75	21.88
	female	0	0	50	33.33	16.67
36 to 50	**male**	33.33	0	0	66.67	0
	female	-	-	-	-	-
over 50	**male**	0	0	50	25	25
	female	0	0	80	0	20

Cross tabulation matrix for Q22 is shown in Table 4.5. By comparing result from different age group, we can see that young people like high quality music more than elder people. the difference between male and female group is not much.

Table 4.5. user characteristics analysis - Q22

Q22	**%**	**How much do you like high quality music?**				
Age	**Gender**	**Not all all**	**Not really**	**Neutral**	**Somewhat**	**Very much**
20 to 35	**male**	0	0	15.62	34.38	50
	female	0	0	8.33	41.67	50
36 to 50	**male**	0	0	0	66.67	33.33
	female	-	-	-	-	-
over 50	**male**	0	50	0	50	0
	female	20	20	40	20	0

Table 4.6 shows cross tabulation matrix for Q19, which is the survey result about 4k game resolution quality. More people in young age group agree that 4k game quality is better than other resolutions, than people on "over 50" group. Most of the females chose option neutral while males have various opinions.

Table 4.6. user characteristics analysis - Q19

Q19	%	Do you think 4k game resolution is better than others?				
Age	**Gender**	**Str. disagree**	**Disagree**	**Neutral**	**Agree**	**Str. agree**
20 to 35	**male**	6.25	12.50	18.75	46.88	15.62
	female	0	4.17	45.83	41.67	8.33
36 to 50	**male**	0	0	33.33	33.33	33.33
	female	-	-	-	-	-
over 50	**male**	25	25	50	0	0
	female	0	0	100	0	0

Regarding Q24, how much people like to access photo storage service from HMC, the result distribution between males and females are quite even among young people, while people in age group "over 50", especially females, do not really need this feature.

Table 4.7. user characteristics analysis - Q24

Q24	%	How much do you like to access your photo storage service from HMC?				
Age	**Gender**	**Not at all**	**Not really**	**Neutral**	**Somewhat**	**Very much**
20 to 35	**male**	6.25	15.62	25	31.25	21.88
	female	8.33	16.67	16.67	33.33	25
36 to 50	**male**	0	66.67	0	33.33	0
	female	-	-	-	-	-
over 50	**male**	0	50	0	25	25
	female	0	100	0	0	0

4.1.4. Cross question analysis

Besides the feature priority analysis, we are also interested in correlation between survey questions. In this section, we conduct cross question analysis, study internal consistence among these questions through Cronbach Alpha and Pearson correlation coefficient introduced in Section 3.4.3. In this thesis, we use open source statistic software R to calculate Cronbach Alpha and Pearson correlation values.

To study correlations between questions, we formulated several hypotheses based on the survey result

Hypothesis 1: Users expect to access all their multi media resources within local network.

Hypothesis 2: Users expect to listen to high quality music also expect to access music service from HMC.

Hypothesis 3: Users expect to use all 4 ways to interact with HMC.

4.1.4.1. H1: Users expect to access all their multi media resources within local network

There are 3 questions that gather information whether those interviewees expect to access all their multi media resources within local network. Do they want to easily access home videos stored in local network (Q8.1), do they want to easily access their own music library stored in local network (Q8.2), do they want to easily access their home photos stored in local network (Q8.3). The interviewees' answers are shown in Appendix A.2. The mean values are shown in Table 4.2.

Table 4.8. Internal consistency of questions 8.1, 8.2, 8.3

Cronbach Alpha	Pearson correlation		
Q8.1,Q8.2,Q8.3	Q8.1,Q8.2	Q8.1,Q8.3	Q8.2,Q8.3
0.7339923	0.6056101	0.4573266	0.4573266

The average values for Q8.1, Q8.2 and Q8.3 show that users have media expectation to access all resources stored in their local network as the value are slightly above 3.

We tested the reliability of these data, as shown in Table 4.8. It reveals that Cronbach Alpha value is in the range of acceptable. The value of correlation coefficients from Pearson correlation between Q8.1 and Q8.2 are in the range of strong, which means interviewees' expectations to access home videos have tight correlation with their expectations to access music library. The correlation coefficients between Q8.1 and Q8.3, Q8.2 and Q8.3 are in the range of medium, this means there is correlation between interviewees' expectations to access home videos and expectations to access home photos, there also is correlation between interviewees' expectations to access music library and expectations to access home photos, but these correlations are not as strong as correlation between Q8.1 and Q8.2. However, all those data supports the hypothesis that users expect to access all their multi media resources within local network. Thus we accept the first hypothesis.

4.1.4.2. H2: Users expect to listen to high quality music also expect to access music service from HMC

There are 2 questions that gather information whether those interviewees expect to listen to high quality music and expect to access music services such as Spotify, Deezer on HMC. Do they want to enjoy high quality music (Q22), Do they like to get their music service providers on HMC (Q23).

The average values shown in Table 4.2 reveal that high quality music has high expactation among interviewees while expectations on accessing music services are slightly lower.

We tested the reliability of these data, as shown in Table 4.9. It shows that Cronbach Alpha value is in the range of acceptable, Pearson correlation value is in the range of strong, which means interviewees' expectations for high quality music have tight correlation with their expectations to access online music services. Thus we accept the second hypothesis.

Table 4.9. Internal consistency of questions 22, 23

Cronbach Alpha	Pearson correlation
Q22, Q23	Q22, Q23
0.722225	0.614335

4.1.4.3. H3: Users expect to use all 4 ways to interact with HMC

There are 4 questions to measure 4 means users can interact with HMC. Do they like to control HMC with traditional remote controller (Q25.1), or using smart phone/tablet computer (Q25.2), or using voice command (Q25.3), or even using body motion to command HMC (Q25.4).

We did reliability test on these data. the result is shown in Table 4.10. It reals that the Cronbach Alpha value is in the range of poor. The Pearson correlation value for Q25.2 and Q25.4 is in the range of strong, which means interviewees want to use voice command to control HMC also want to use body motion to control HMC and vice versa. All the other correlation values are in the range of small, which means user like to use one mean to interact with HMC, do not necessarily like to use another mean to interact with HMC. Thus we reject this hypothesis.

Table 4.10. Internal consistency of questions 25.1,25.2,25.3,25.4

Cronbach Alpha	Pearson correlation					
Q25.1, Q25.2, Q25.3, Q25.4	Q25.1, Q25.2	Q25.1, Q25.3	Q25.1, Q25.4	Q25.2, Q25.3	Q25.2, Q25.4	Q25.3, Q25.4
0.5760476	0.1128194	0.1232882	0.1447052	0.280091	0.2022838	**0.6093919**

In summary, the hypotheses test result is shown in Table 4.11.

Table 4.11. Hypotheses result

Hypothesis	Result
Users expect to access all their multi media resources within local network.	**Accepted**
Users expect to listen to high quality music also expect to access music service from HMC.	**Accepted**
Users expect to use all 4 ways to interact with HMC.	**Rejected**

4.2. Specification of a HMC conceptual prototype

In this section, we propose our HMC conceptual prototype base on features listed in our prioritized feature list Table 4.3. Both hardware and software components are discussed in this section.

4.2.1. Hardware specifications

The proposed HMC hardware block diagram is illustrated in Figure 4.3. Each component is described in Table 4.12.

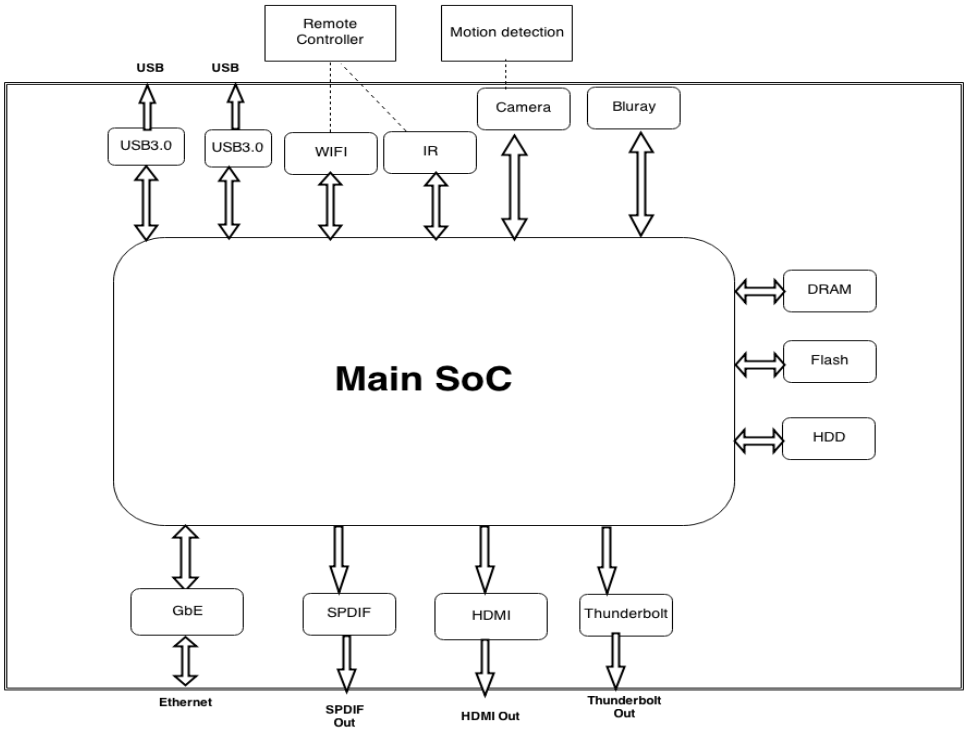

Figure 4.3. HMC conceptual prototype hardware block diagram

You may notice that we do not include a tuner in the hardware design. In contrast a tuner is considered an essential component of a traditional STB. The reason for excluding a tuner is that we believe HMC data transportation will occur purely via IP network for the following reasons:

1. bidirectional data communication

   Bidirectional data transmission unlike one way data transmission (typical of older cable networks, satellite and terrestrial transmission) can support more

Table 4.12. Hardware components

Component	Description
SoC	An IC that integrates all components of a computer or other electronic system into a single chip. it is the main component of HMC hardware, general requirement for sub modules are: CPU: 8 cores, Frequency 2.75 GHz GPU: need to support UHD hardware codec, including H.265 and VP9
DRAM	Main memory for HMC, basic configuration: 1GB GDDR5,frequency more than 5500 MHz; to support large 3D game, up to 8GB is required
NAND Flash	NAND memory contains file system and store operation system
NOR Flash	Contains bootloader and various configuration options and settings required by the system
Sound card	Support hardware accelerated sound codec
Motion sensor/Camera	To capture body motion for motion recognition; record video for video call feature.
Wireless Network Card	Support 802.11 b/n/g,WPA2,WiFi Direct
IR	sends information from an remote control by receiving and decoding signals. HMC use IR to receive signals from remote controller and interpret command channel zapping, VoD navigation etc.

services, as exemplified by VoD: where video is delivered based on a user's request.

2. support for all multimedia services

   All multimedia services can be carried on IP network. In addition to video streaming, other multimedia services, such as online music streaming, online multi player gaming and interactive video/audio communication all rely on an IP network to deliver data.

3. improved QoS

   Cable TV's assurance of Quality of Service (QoS) is vanishing. Cable TV operators argue that they provide ensured QoS, which was the biggest advantage they claim over IP based TV solutions. However, this advantage is vanishing due to the development of the IP network infrastructure and the introduction of IP based QoS solutions[28]. For IPTV, as noted by Qiu, "IPTV is a closed network, in which the service provider not only controls the IPTV system, but also controls the Internet access of the users. In the current Internet, the bottleneck for most connections is normally at the user's Internet access link, which is sometimes called the last mile. In the core of Internet, optical fibers have been deployed to provide tens of Gbps bandwidths and hence are unlikely to be the bottleneck."[29]. Today IPTV provides ensured QoS through a controlled network, while OTT services is running on top of public networks, operates on a best effort basis, hence OTT offers no quality guarantee. Even for uncontrolled OTT video streaming service, several effective QoS solutions have been adopted to narrow the gap between controlled network and uncontrolled network. Some of the solutions are Adaptive bit rate streaming (ABR) and an OTT head end monitoring P2P architecture[30]. OTT service providers can also cooperate with operators to improve QoS[31].

4.2.2. Hardware interfaces

In addition to the earlier IR and wireless interfaces, we expect that an HMC should have the following hardware interfaces:

Universal Serial Bus (USB): USB 3.0 supports up to 5 Gbps, this is sufficient to support UHD at 30 fps[32]. USB 3.0 can be used to connect to an external Hard Disk Drive (HDD).

HDMI: HDMI 2.0 supports up ot 18Gbps, this is sufficient to support for UHD at 50/60 fps. Today the HDMI interface is supported by most display devices.

Thunderbolt[33]: supports up to 10Gbps for a single channel. Thunderbolt 2 incorporates DisplayPort 1.2 support, which allows for video streaming to a single UHD video monitor or dual HD monitors. Thunderbolt 2 is backwards compatible, which means that all Thunderbolt cables and connectors are compatible with Thunderbolt 1.

Gigabit Ethernet: support up to 1 Gbps.

Sony/Philips Digital Interface Format (S/PDIF): S/PDIF is a digital audio interconnect used in consumer audio equipment to transfer digital audio over reasonably short distances. Its drawback is it can not support a high dynamic range lossless audio format as this requires greater bandwidth than is available via this interconnection.

4.2.3. High level software architecture

Figure 4.4 is the high level software architecture of HMC. it generals divide the software stack into 4 layers: Operation System, Hardware abtraction layer, Middleware platform and Application layer.

Operation System (OS): This is software that manages the computer's hardware and software resources and provides common services for computer programs. Linux OS is open sourced, so it is easy to do deep customization. Linux has been ported to more computer hardware platforms than any other operating system, so it has wide hardware support, especially for embeded system. Additionally, Linux has build in support for the TCP/IP stack. All these characteristics fulfill the requirements of a HMC, i.e, that the OS be high customizable, wide range hardware support, native TCP/IP support. This is the obvious choice for a HMC OS.

Boot loader: The boot loader is small low level program embeded in NOR flash. This software is used to boot load operation system.

Hardware abstraction layer: The purpose of the hardware abstraction layer is to allow desktop applications to discover and use the hardware of the host system through a simple, portable, and abstract Application Programming Interface (API), regardless

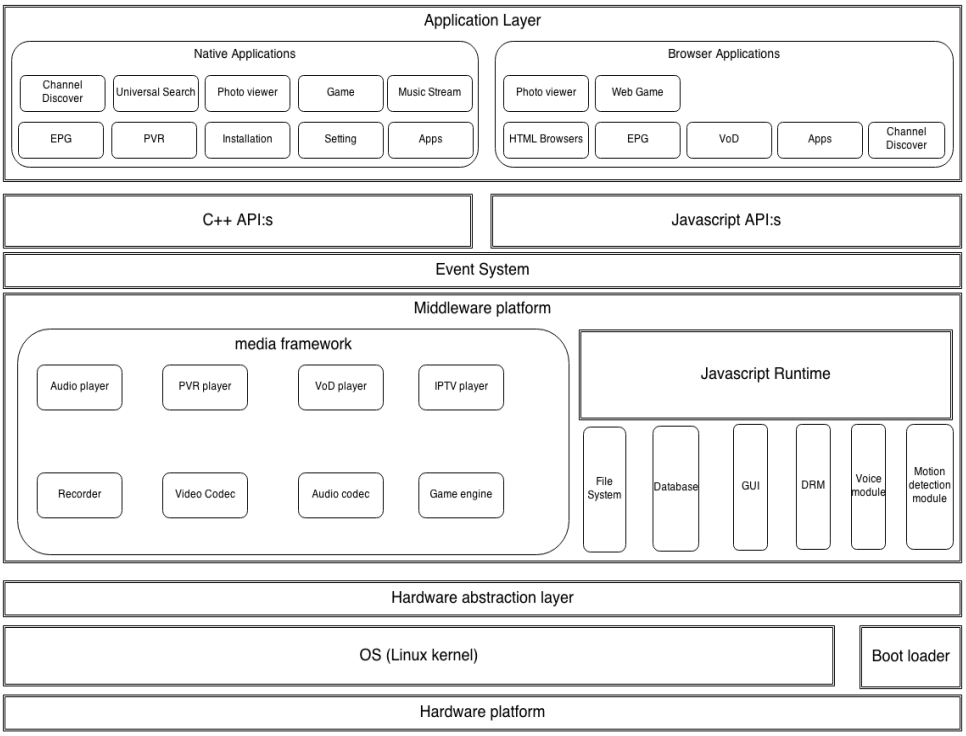

Figure 4.4. High level software architecture

of the type of the underlying hardware. This layer is on top of the Linux kernel. It provides hardware agnostic API to the middleware platform.

Middleware platform: The middleware platform provides core function of HMC features and exposes both C++ and Javascript APIs for application layer. C++ API is invoked by native applications, while Javascript API is embed in a web browser and invoked by web applications.

The media framework is responsible for media related functionalities, including:

Audio/Video (A/V) Coder-Decoder (CODEC): audio/video encoding and decoding.

PVR recording: recording live channels to hard drive

PVR player: playback recorded video

IPTV player: playback IPTV channels

VoD player: playback VoD videos

Audio player: playback audios

Game engine: expose API for game development. support both Two Dimensional (2D) and 3D game development

Application layer: This layer utilizes the functionalities exposed by the media framework and provides both native and web applications used by end users. As the proposed HMC is an open platform in order to integrate other services, applications can also be categorized as:

1. HMC core APPs which deliver core media features to the end user or

2. Third party APPs developed by other developers to provide rich media experience beyond the HMC's core features. These APPs could include a music streaming service from Spotify or Deezer, a photo storage services from Flickr or Picasa, and much more.

4.2.4. Protocols

The proposed HMC must supported protocols shown in Figure 4.5. In this figure we use the Internet Protocol Suite (IPS) model to separate these protocols into 4 layers. Examples of protocols in each layer are described below.

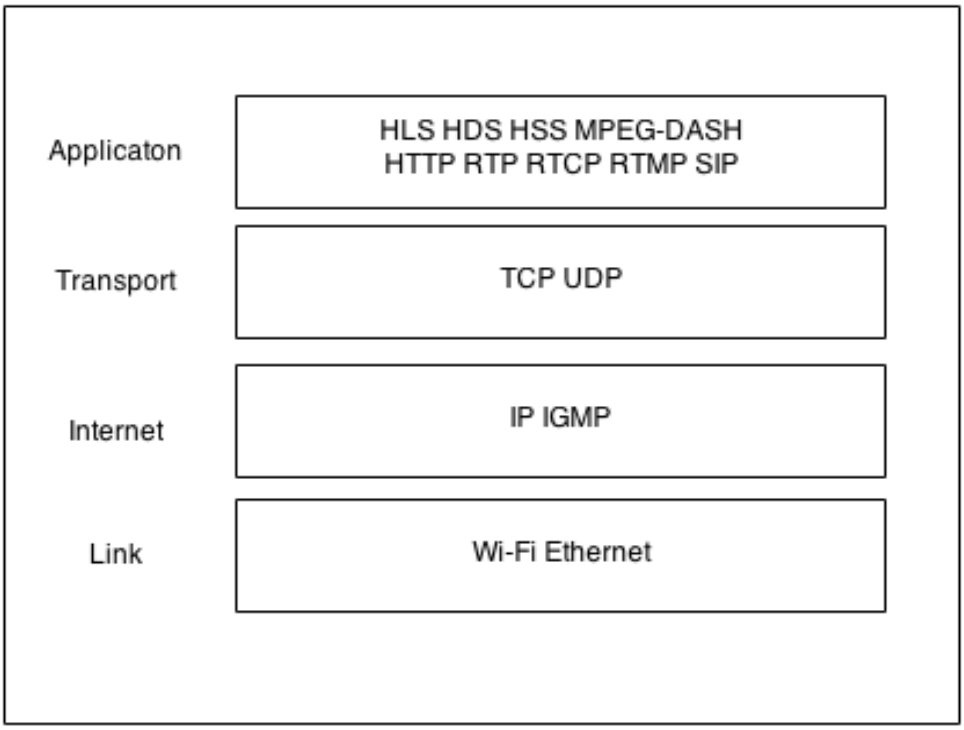

Figure 4.5. HMC protocol stack

4.2.4.1. Link layer

In computer networking, the link layer is the lowest layer in the IPS. The link layer protocols only operate on a link that the host is physically connected to. The most common link protocols that we expect HMCs to support are Ethernet and Wi-Fi.

4.2.4.2. Internet layer

Protocols in the Internet layer transport datagrams from the originating host across network boundaries to the destination host specified by a network address. The most important Internet layer protocol is Internet Protocol (IP).

IP: All Internet transport protocols use IP to carry data from a source host to destination hosts. IP is a connectionless (datagram) internetwork service. IP provides no end-to-end delivery guarantees. Thus, IP datagrams may arrive at the destination host damaged, duplicated, out of order, or not at all.

Internet Group Management Protocol (IGMP): IGMP is a communications protocol used by hosts and adjacent routers on IP networks to establish multicast group memberships. IGMP is an integral part of IP multicast. HMCs utilize IGMP to subscribe to a live multicast stream and to change from one multicast stream to another.

4.2.4.3. Transport layer

The transport layer provides end-to-end communication services for applications.

Transmission Control Protocol (TCP): is a reliable connection-oriented transport service that provides end-to-end reliability, resequencing, and flow control.

User Datagram Protocol (UDP): is a connectionless datagram transport service.

4.2.4.4. Application layer

The application layer is the top layer of IPS. It contains the communications protocols and interface methods used in process-to-process communications across IPS. HMC utilize many application layer protocols to implement different applications.

Hypertext Transfer Protocol (HTTP): Hypertext is structured text that uses logical links (hyperlinks) between nodes containing text. HTTP is a protocol to exchange or transfer hypertext.

Real-time Transport Protocol (RTP): RTP defines a standardized packet format for delivering audio and video over IP networks. RTP is used extensively in communication and entertainment systems that involve streaming media, such as telephony, video teleconference applications, television services, and web-based push-to-talk features. Labrosse Alexandre compared performance between TCP and RTP in the context of live video streaming and found out that RTP has better performance than TCP[16]. HMC uses RTP together with RTCP and IGMP to provide live streaming services.

RTP Control Protocol (RTCP): RTCP is used in conjunction with RTP. RTP carries the media streams, while RTCP is used to monitor transmission statistics, QoS, and aids in synchronization of multiple streams.

Session Initiation Protocol (SIP): SIP is a signaling protocol, widely used for controlling multimedia communication sessions such as voice and video calls over IP networks.

Real Time Messaging Protocol (RTMP): RTMP is a protocol for streaming audio, video and data over the Internet, between a Flash player and a server.

HTTP Live Streaming (HLS): is an HTTP-based media streaming communications protocol. It works by breaking the overall stream into a sequence of small HTTP-based file downloads, each download transfer one short chunk of an overall potentially unbounded transport stream. As the stream is played, the client may select from a number of different alternate streams containing the same material encoded at a variety of data rates, allowing the streaming session to adapt to the available data rate.

HTTP Dynamic Streaming (HDS): HDS was developed by Adobe as an alternative to their RTMP protocol. HDS allows for adaptive streaming over HTTP to any device that is compatible with Adobe Flash or Adobe. A benefit of streaming with HDS instead of RTMP is not having to rely on a Flash Media Server, which significantly decreases the cost of operating the stream. Adobe has released a module for Apache, the most popular Open Source HTTP server, that allows Apache to act as a streaming origin server[34].

HTTP Smooth Streaming (HSS): HSS is Microsoft's foray into adaptive HTTP streaming that runs on their Internet Information Services web server and Silverlight player. The Silverlight player detects local bandwidth and CPU conditions and dynamically switches bitrates to offer uninterrupted streaming. HSS supports multiple audio and video CODEC, and is highly customizable. HSS is often used for very large-scale streams.

Dynamic Adaptive Streaming over HTTP (MPEG-DASH): MPEG-DASH is an adaptive bitrate streaming technique that enables high quality streaming of media content over the Internet delivered from conventional HTTP web servers. It works by breaking the content into a sequence of small HTTP-based file

segments, where each segment containing a short interval of playback time of a content. The content is made available at a variety of different bit rates, client automatically selects from the alternatives the next segment to download and play back based on current network conditions. It is the first adaptive bit-rate HTTP-based streaming solution that is an international standard[35].

4.3. Projected HMC economic impact on the current STB industry

There are several candidates that could serve as the starting point for the evolution to a future HMC, for example, home theater PCs, game console, smart TVs, and STBs. Each candidate has advantage and disadvantage to become the future HMC from both market and technical points of view. In this section, we focus on analyzing the current STB market, the STB based TV market value chain, the stakeholders and a potential future HMC market value chain and its stakeholders. Based on this analysis, we will be able to understand the economic impact of HMC evolution on the current STB industry. In the meanwhile, we briefly summarize the advantages and disadvantages of other candidates that could evolve towards a future HMC.

4.3.1. Potential competitors to STB on the way to HMC

In this section, we list potential competitors to STB, then discuss their advantages and disadvantages.

4.3.1.1. PC

The PC has very high penetration rate in households already. PC provides all kinds of services in our daily life, including computing, A/V processing, text editing, communications, data storage, Internet access, etc. Using this same hardware, a different OS could be installed to satisfy different purposes. To provide general support for all services, a PC normally has high computing capability and good compatibility. Unlike STBs and game consoles, which have high A/V processing capability, most PC do not have dedicated A/V components in the form of a specialized Graphics Processing Unit (GPU) . At the same time, the price for a PC is relative high compared to a STBs, as the later is specially designed for A/V related services.

4.3.1.2. Game console

A game console is designed for playing video games. Such a device has very high performance on video processing as compared to a normal PC, the disadvantage that a game console faces in evolving to HMC is that gaming console audience size is much smaller than that for STBs. hence these devices do not have a large volume and they are not optimized to have a low price. According to our survey, watching TV and listening to music are the most popular entertainment activities in the living room, hence a gaming console would be overkill.

4.3.1.3. OTT streaming devices

OTT streaming devices have a pure IP network connection and can be used as a client to online streaming services, such as Netflix or Spotify. Devices such as Roku make it very easy to access content from hundreds of channels. The problem with OTT device is that all services are running in a uncontrolled public network, hence there is no guarantee of QoS, so user satisfaction quickly deteriorate with traffic congestion.

4.3.1.4. Smart TV

A smart TV is also called a connected TV or hybrid TV. Such a device provides not only display functions, but also Internet surfing and STB functions. The number of consumers who purchase smart TV is increasing, but most consumer do not use the smart features of it. According to a YouGov poll, 76% of consumer bought a smart TV because of its thinner, larger screen, and better picture quality, rather than for its online connectivity[36]. Another factor is that the life cycle of a TV in the living room is much longer than a STB, game console, or PC. This is because the most important function of TV is to display a picture of a specific format, hence it does not need to upgrade frequently.

4.3.2. STB market

Digital television is the outcome of innovative evolution in the TV industry started in the mid-90s. Digital television provides the consumer with more channels to choose from and deliver higher quality content than the earlier analogue TV. To display compressed digital content on a TV display, a STB converts the source signal from format used by different distribution platforms to a format that can be displayed. TV distribution platforms today include cable TV networks, satellite, terrestrial broadcast, and IP networks. TV signals from these platforms have different physical layer and data link layer definitions, which mainly differ each other in the modulation schemes and error correcting coding. So a different tuner is required on the STB in

order to receive TV signals from different distribution platforms. Besides displaying digital content from a TV distribution platform, a STB can also provide a consumer with other services. These services include

Hybrid zapping: A HSTB supports receiving a TV signal from both an IP network and Digital Video Broadcasting (DVB) network, thus a consumer can smoothly zap (switch between) channels from different platform.

EPG: A electronic programming guide gives consumers the program schedule information for all available channels.

Parental control: The STB detects the age rating of a program (based uppon information encoded in the digital stream) and allows parents to set passwords for certain channels/programs.

VoD: VoD allows users to select and watch/listen to video or audio content when they choose to, rather than having to watch at a specific broadcast time.

PVR: PVR supports recording of consumer favorite program.

Digital Right Management (DRM): DRM protects the right of content provider.

Internet surfing: A STB browser can be used by the user to surf Internet.

According to Mediavision, the Swedish TV market reached 21 billion in year 2013, of which Internet TV like Netflix and Viaplay is the sole driver of industry for this growth. Traditional broadcast TV has been zero growing, including revenue from both advertising and pay TV. Instead, Internet TV was accelerated, contributing to a 2% increasing for the whole Swedish TV market turnover in 2013[37].

The technical development and breakthrough of connectable STB provides more alternatives for consumers to choose from which platform to watch TV. Internet TV challenges traditional TV distribution and shorten the value chain between content aggregator and consumers, while attempting to attract more consumers to watch TV. This value chain will be described in the next subsection.

4.3.3. TV market value chain

The TV market value chain is under pressure to change because of the emergence of new technologies. The most obvious change is the introduction of Internet TV, also called an Over-the-Top (OTT) service. Internet TV connects content aggregator and consumer. The traditional distributor is not involved in the value exchange in the new means of content delivering. The TV market value chain is shown in Figure 4.6.

There are basically two different forms of transmitting OTT: one form is the direct delivery of TV program played according to timetable (in the manner of traditional

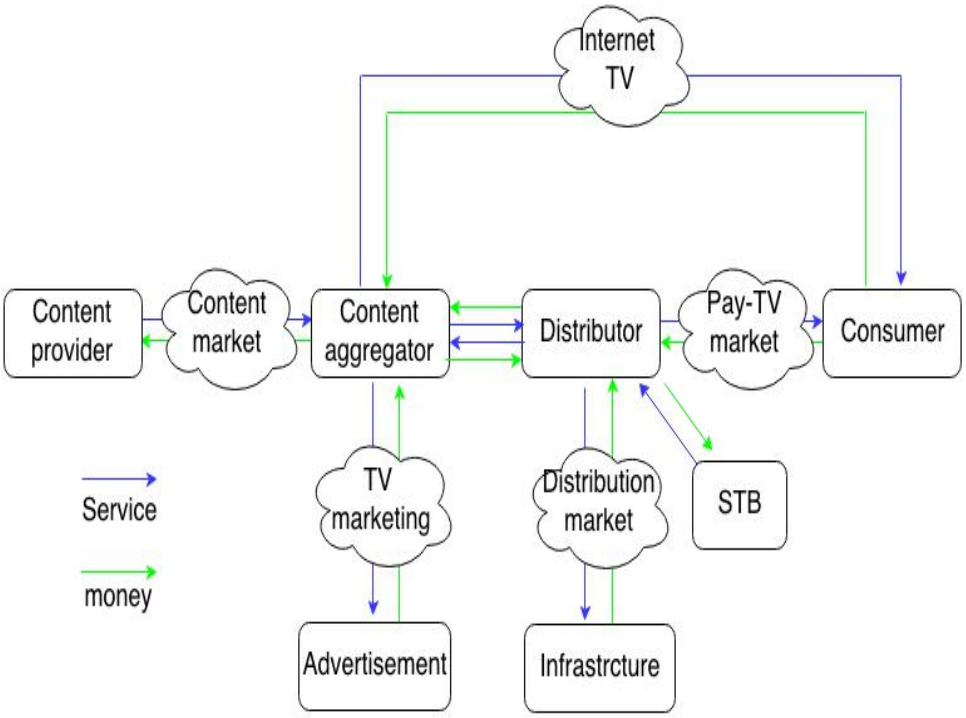

Figure 4.6. Current TV market value chain

TV). For example, SVT in Sweden allows consumers to watch SVT programs directly from its homepage. Another form is VoD, such as Netflix, in this case programs are placed into different catalogs and each consumer can decide when and what to watch.

4.3.4. Stakeholders of current TV market value chain

In this section, we use statistical data from Sweden's Post-och telestyreslsen (communication authority in Sweden) and Meidamätning I Skandinavien (MMS) to analyze TV market value chain in Sweden. By comparing data from different years, we can see how the TV market has changed in Sweden.

4.3.4.1. Consumer

The total number of subscription in 2013 in Sweden was 5.2 million. This number is more than the total number of Swedish households. The reason for this is that many household have more than one subscription within one or more distribution platforms. The traditional way of watching broadcast TV has decreased 3% compared with that

of 2012[2]. Information about the different fractions of the subscriptions is shown in Figure 4.7.

The emerging OTT subscription volume has increased dramatically, from 500,000 households in March 2013[38] to 825,000 households in March 2014[39] , i.e, a growth rate of 60% in one year.

4.3.4.2. Distributor

The distributor is responsible for providing consumers with a TV service. Most of the time, the distributor operates a specific physical infrastructure for delivering the service(s).

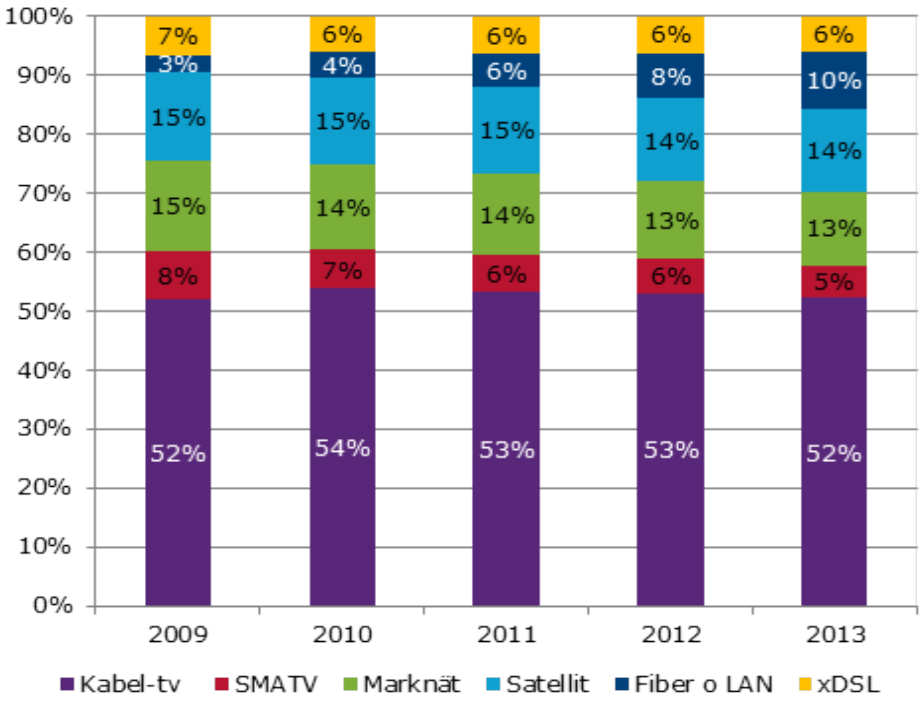

Figure 4.7. Traditional TV-subscription per distribution platform in Sweden from 2009 to 2013 [2]

In Sweden more than half (54%) of TV subscriptions are distributed over digital technologies (terrestrial, digital cable, satellite, and IPTV). The remaining (46%) is distributed over analog cable TV networks. The most obvious change is the rapid growth of Fiber to LAN subscription number from 2009 to 2013. Figure 4.8 shows the increasing of IPTV subscribers. At the end of 2013, total number of IPTV subscription was 722,000, with a growth of 13% compared to a year earlier. The increase in IPTV subscription is due to the increasing number of subscriptions over

fiber or fiber to LAN. The total number of IPTV over fiber subscription was 444,000 with a growth rate of 26% compared to a year earlier. In the meanwhile, the total number of IPTV over xDSL subscription has decreased 3% [40].

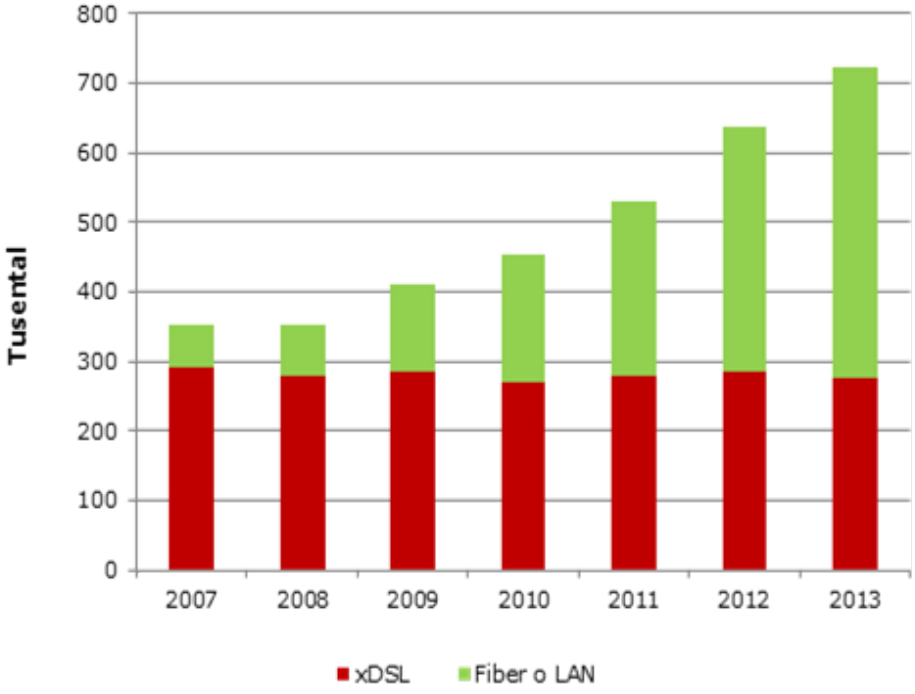

Figure 4.8. Total subscription number of IPTV [2]

4.3.4.3. STB suppliers

Most STBs are proprietary, which means a given STB device can only receive a TV signal from a certain distributor. For example a DVB-S STB can be used to receive satellite TV signal, while an IP STB can be used to receive IPTV signal. This means if a consumer wants to change their subscription to another distributor, a new STB is required. Electronic suppliers design and deliver STBs according to the specifications from TV distributors. Additionally there are televisions in the market with build-in STB functions.

4.3.4.4. Content aggregator

Content aggregators buy content from content providers, package and aggregate this content into one or more channels which they later sell to distributors in the traditional TV market. They finance themselves either by selling transmission

timeslots to advertisers or by receiving subscription fee through one of their distributors.

Today, with the emergence of new technologies, a content aggregator can distribute their content directly from their home page to the end consumer by using OTT. This direct subscription includes a subscription to both a tradition TV channel and to a VoD service.

4.3.4.5. Content provider

The content provider provides content to content aggregator. They constitute of a very heterogeneous group which includes global famous film studios (such as Warner Bros, Fox and Disney) to local film producers, artists and musicians.

4.3.4.6. Advertiser

The content aggregator sells time slots during or between programs to advertisers. The cost of an advertisement time slot depends on the total number of TV program watchers expected for this time slot.

In Sweden, MMS continuously measures TV-watching behaviors and this data provide basis for advertisement price of different time slots.

4.3.5. HMC value chain

The evolution to HMC dramatically changes the traditional TV market. The most important change is that the consumer becomes the center of values changes and controls what content to watch, at what time, at which place, and by what device(s). Consumer is creating personal channels/schedules, and uses a HMC as a unified platform to enjoy other entertainments, such as listening to music, playing video games, and accessing other online services in their living room. The HMC value chain is shown in Figure 4.9.

Compared with the traditional TV market value chain, the consumer connects directly to the content aggregator and traditional distributor disappears. With an Internet connection from an Internet Service Provider(ISP), consumer is able to access video content directly from content provider such as Netflix or SVT.

In an advertisement funded HMC value chain, the consumer does not pay a service fee for watching video or listening to music, as an advertiser pays to service provider while the consumer watches/listens to advertisements. This advertisement funded HMC value chain is shown in Figure 4.10

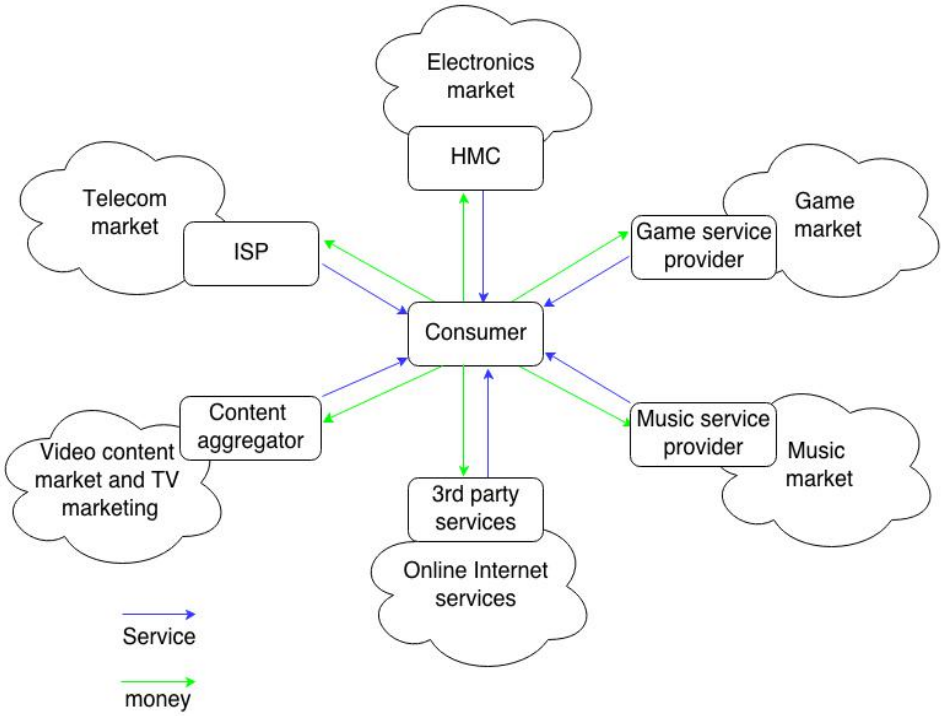

Figure 4.9. HMC market value chain

4.3.6. Stakeholders of HMC market value chain

In this section, we list all stakeholders in the HMC market value chain, then discuss their roles and the value exchanges among them.

4.3.6.1. HMC

The HMC is a compact and integrated home media center designed to satisfy consumer's diverse entertainment requirements: it connects to a TV to display content, connects to Internet to offer different online services, such as SNS and Skype, connects to amplifier for listening music, and also supports gaming. The proposed HMC is an IP based open platform, which provides QoS ensured multimedia (video, audio, gaming) experience to consumers. The HMC has a central position in the HMC value chain.

4.3.6.2. ISP

The ISP provides consumer Internet access and QoS to time sensitive services, Such as video and gaming. The consumer subscribes to an ISP's service in order to have

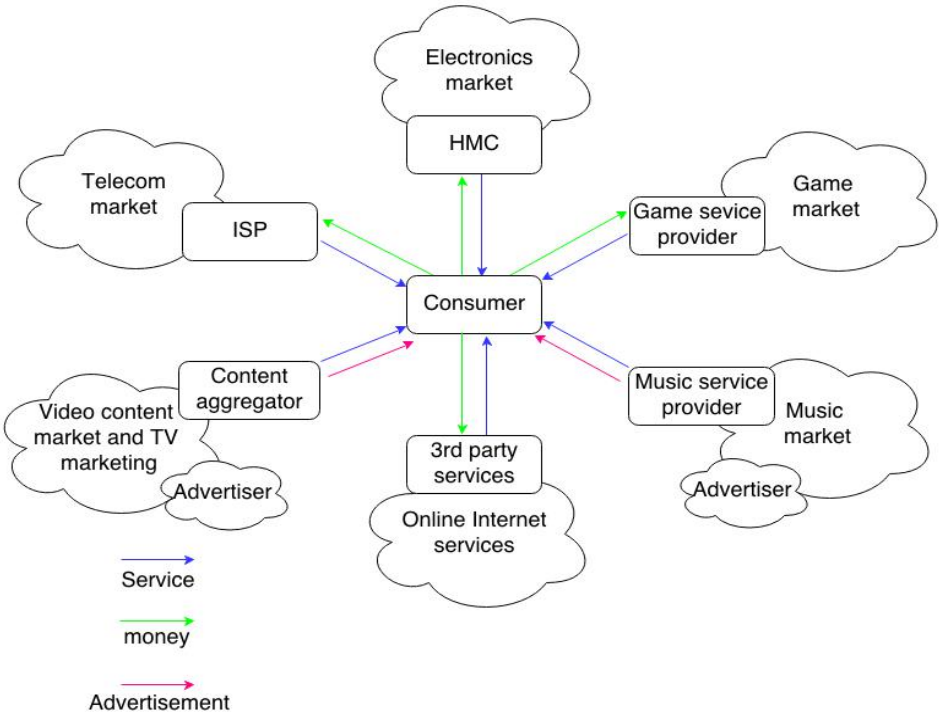

Figure 4.10. The Advertisement funded HMC market value chain

access to other services.

4.3.6.3. Content aggregator

The content aggregator aggregates content and provides services to the consumer. The content services supported are both live content (the tradition TV channels and Video on Demand).

4.3.6.4. Music provider and game provider

Similar to other content aggregators, music providers and game providers provide music and game services to consumer

4.3.6.5. Third party online service

The HMC provides access to online services provided by third parties. These services enriches the experience and convenience provided to the consumers in the living rooms.

4.3.7. Impact to STB industry

STBs were initially designed to convert the source signal from a distribution platform to the format which TV could display, so natively a STB has strong hardware and software support for A/V content. According to our survey, the quality of video is the most important feature to the consumer. The strong support for providing this function is an advantage STB has in the evolution toward a future HMC. However, we mentioned earlier, most of STBs are proprietary, and the STB suppliers design and deliver STBs according to the specifications from TV distributors. That is to say, the market for most of todays STB vendors is distributors, rather than consumers. From a distributor point of view, protecting their existing investment, making a profit from subscriptions, and maintaining access control are the key functions that a STB should have besides the basic A/V and other related functions. The disadvantage of STBs in the evolution to HMC is also obvious: most of todays STBs in the market are proprietary to a certain distributor and do not have a consumer-oriented design. Additionally, there is limited support for other third party online services and STBs lack compatibility with different content providers/aggregators.

To become dominant as a HMC in living room in future, the evolution of STB industry should be:

- Consumer-oriented and consumer market driven. How to build brand from scratch? what strategies to take to compete with other device vendors who are already in consumer market? All these questions bring big challenges to current STB vendors.
- STB vendors should consider first satisfying the diverse requirements of consumers, increases the capability to support other popular activities in the living room (such as music and gaming).
- An open platform to allow access to different content aggregators
- To benefit consumer, an open platform is required to enable the access to all available content aggregators, for both live content and streaming content.
- More compatible to third party services.

4.4. HMC product roadmap for 1, 3, and 5 years

To determine an HMC product roadmap, we first identified all of the technical features required to implement the most desired user experiences. We compared these technical features with Zenterio AB's OS specification to elimilate already implemented features, the remaining list of features are input for the decision matrix. Some user cases require multiple technical features be implemented. The resulting set of options as to what features should be implemented are compared, then only the

best option is chosen or multiple options are chosen but these may be implemented in different phases.

Devising a product roadmap based on SPDM method introduced in Chapter 3. The resulting decision matrix is shown in Table 4.13. The score for the criteria "User Expectation" is derived from prioritized feature list (shown in Table 4.3). This table is ordered by final score from highest to lowest, so we can plan the road map accordingly to focus on the highest priority functions first.

For the year 1 roadmap, the focus is on supporting additional video and audio formats(VP6, VP8, FLAC), adding functionality for viewing images, BMP format suport, and support for adaptive bit rate streaming (HLS) and multimedia calls (SIP). There is no gaming support. This is aligned with our survey results: user expects smooth video playing experience and high quality music service more than other services.

VP6: is a proprietary lossy video compression format and video CODEC

VP8: is a proprietary lossy video compression format and video CODEC, Google has irrevocably released all of the VP8 patents it owns under a royalty-free public license.

browser EPG: TV EPG in a browser, user can channel zap from browser EPG. As web browser forces "same origin policy"[41], browser was not allowed to access system native functions, in this case, zapping between channels on HMC. Thomas Joelsson in his master thesis proposed a proxy server solution to overcome this problem[42]. However, this is no longer a issue as the development of new standard and browser developers now can expose javascript APIs, which can invoke device functionalities directly. For example, by using a Javascript API any web developer has the tools to use telecommunication functionalities in web APPs[43].

Universal Subtitle Format (USF): USF is a subtitle file format. It is a Extensible Markup Language (XML) based format feature in unicode support, hierarchical system, flexibility, and ease of administration.

Multiple subtitles: Our proposed HMC support multiple subtitles, so a user can choose which subtitle to show when playing a given video.

File playback: HMC can play A/V files stored in HMC or a network attached HDD

Free Lossless Audio Codec (FLAC): an audio format similar to MP3, but lossless, meaning that audio is compressed without any loss in quality.

music streaming : The proposed HMC integrates with music streaming service , such as Spotify or Deezer.

photo viewer: The proposed HMC should include an application to show images stored on HMC or a network attached HDD.

Table 4.13. Decision Matrix Result

Weight	5	2	1	4	3	
Technical Feature	User Expectation	Hardware Capabilities	Software Capabilities	Implementation Cost	Ease of Use	Final score
VP6	4.49	1	1	1	1	32.45
FLAC	4.16	1	1	1	1	30.8
Music streaming	4.16	1	1	1	1	30.8
VP8	4.49	1	1	1	0	29.45
Photo viewer	3.65	1	1	1	1	28.25
BMP	3.65	1	1	1	1	28.25
view picture API(C++ SDK)	3.65	1	1	1	1	28.25
browser EPG	4.03	1	-1	1	1	28.15
Universal subtitle format (.USF)	3.59	1	1	1	1	27.95
Multiple subtitle	3.59	1	1	1	1	27.95
live pause	3.56	1	1	1	1	27.8
popup notification	3.54	1	1	1	1	27.7
HLS(Apple)	4.49	1	0	0	1	27.45
SIP	3.47	1	1	1	1	27.35
EPG search	4.03	1	1	1	0	27.15
File playback	3.4	1	1	1	1	27
WebM	4.49	1	1	0	0	25.45
Theora(Ogg)	4.49	1	1	0	0	25.45
VobSub(.IDX)	3.59	1	1	1	0	24.95
Closed Caption	3.59	1	1	1	0	24.95
APE	4.16	1	1	1	-1	24.8
cloud multiple profiles	3.54	1	1	1	0	24.7
SNS sharing	2.9	1	1	1	1	24.5
HDS(Adobe)	4.49	1	0	0	0	24.45
HSS(MS)	4.49	1	0	0	0	24.45
photo storage service	3.65	1	1	0	1	24.25
DLNA DMR	3.62	1	1	0	1	24.1
DLNA DMS	3.62	1	0	1	0	24.1
Wifi Direct	3.79	1	0	0	1	23.95
recommendation by history/habit	3.53	1	1	0	1	23.65
recommendation by friends	4.12	1	1	0	0	23.6
browser support	3.5	1	1	0	1	23.5
cloud PVR	3.56	1	-1	1	0	22.8
RTMP(Adobe)	4.49	1	1	0	-1	22.45
virtual channel	3.5	1	1	1	-1	21.5
universal EPG	4.03	1	0	-1	1	21.15
DLNA DMP	3.62	1	1	0	0	21.1
DLNA DMC	3.62	1	1	0	0	21.1
unified search	4	1	0	-1	1	21
Subrip(.srt)	3.59	1	1	0	0	20.95
Client multiple profiles	3.54	1	1	0	0	20.7
P2P	4.49	1	0	-1	0	20.45
Bluetooth 4.0	4.1	1	-1	0	0	21.5
MPEG-DASH	4.49	1	-1	0	-1	20.45
Unified UI	4.03	1	-1	-1	1	20.15
App store	3.59	1	1	-1	1	19.95
Second screen	3.62	1	-1	0	0	19.1
TIFF	3.65	1	1	0	-1	18.25
email notification	3.54	1	1	0	-1	17.7
sms notification	3.54	1	1	0	-1	17.7
WebRTC	3.47	1	1	-1	0	16.35
Multiple audio track	3.59	1	0	-1	0	15.95
Airplay	3.62	1	-1	-1	0	15.1
Blu-ray playback	3.24	-1	1	-1	1	14.2
companion devise	3.62	0	0	-1	0	14.1
SubstationAlpha(.SSA)	3.59	1	1	-1	-1	13.95
H.265	3.68	0	-1	-1	0	13.4
multi tasking	3.1	1	1	-1	0	14.5
MPO	3.6	1	0	-1	-1	13
UltraHD video	3.68	-1	0	-1	0	12.4
video call	3.47	-1	1	-1	0	12.35
VP9	3.68	-1	-1	-1	0	11.4
game store	3.44	1	-1	-1	-1	11.2
game engine	3.44	-1	-1	-1	0	10.2
voice navigation	3.16	0	0	-1	-1	8.8
voice search	3.16	0	0	-1	-1	8.8
voice channel zapping	3.16	0	0	-1	-1	8.8
UltraHD game	3.68	-1	-1	-1	-1	8.4
Game live streaming	2.21	0	-1	0	-1	7.05
motion navigation	2.85	-1	-1	-1	-1	4.25
motion game control	2.85	-1	-1	-1	-1	4.25
motion channel zapping	2.85	-1	-1	-1	-1	4.25

BMP: BMP is a raster graphics image file format used to store digital images, independent of the display resolution.

view picture API: The HMC should provide a native C++ API to enable third parties to display images on the HMC.

popup notification: The proposed HMC should include a build-in notification system, so that pop up message can be displayed on screen according to preset notification rules.

For the roadmap in year 3, video is still the priority, with yet more formats supported, especially web based formats (WebM, Ogg); advanced features will be implemented, such as cloud PVR, universal EPG, and unified search. The focus shifts from music to connectivity. More streaming protocols should be supported, DLNA should be supported. Internet service will be integrated in the HMC (by providing browser support) and the user experience will be more personalized.

WebM: WebM is a video file format intended primarily for royalty-free use in the HTML5 video tag.

Theora(Ogg): Theora(Ogg) is a free and open video compression format. It can be used to distribute film and video online or on physical media without licensing and royalty fees or the vendor lock-in associated with other formats.

VobSub: VobSub extracts the DVD subtitles from a DVD and dumps them to a .sub file. It also creates a .idx Index file with the times and byteoffsets for each and every subtitle.

Closed Caption: Closed Captioning is the process of displaying text on a visual display to provide additional or interpretive information. The term "closed" indicates that the captions are not visible until activated by the viewer.

virtual channel: The user can create a virtual channel, then schedule programs from other broadcast channels or VoD channels to this virtual channel.

cloud PVR: Instead of storing media content in the HMC, content can be stored in a provider's remote server. This content can be played when requested by the user.

universal EPG: A universal EPG will gather all EPG information from all channels and display it via a unified UI.

SubRip: SubRip (SubRip Text) files (named with the extension .srt) contain formatted lines of plain text in groups separated by a blank line. SubRip is a broadly compatible subtitle text file format.

photo storage service : The proposed HMC should support one or more photo storage services, such as Flickr or Picasa.

Wi-Fi Direct: Wi-Fi Direct is a Wi-Fi standard that enables devices to directly communicate with each other(avoiding the need for an access point). The remote control use Wi-Fi Direct to communicate with HMC.

DLNA DMR: The HMC should render or play content received from a DMS.

DLNA DMS: The multimedia resources stored on a HMC can be discovered by DMP (see below) and available for DMR.

DLNA Digital Media Controller (DMC): The HMC can establish connections between the DMS and DMR.

DLNA Digital Media Player (DMP): The HMC can discover multimedia content offered by a DMS.

recommendation by history/habit: The HMC can recommend multimedia content based on viewer history and user habits.

recommendation by friends: The HMC can recommend multimedia content based on friends' recommendation.

browser support: The HMC has build-in web browser support.

cloud multiple profiles: Each HMC user has a profile, personal information (such as viewing history, preferences)is stored in cloud.

SNS sharing: Information about the user's activities and selection of multimedia contents can be shared with others via a SNS.

unified search: All multimedia contents can be searched using a single user interface.

client multiple profiles: Each HMC user has a profile. The resulting personal information is stored in the HMC. All private information is encrypted.

unified UI: All multimedia contents are displayed using a single user interface.

WebRTC: WebRTC, Web Real-Time Communications, is revolutionizing the way web users communicate with multi media contents. WebRTC adds standard APIs and built-in real-time audio and video capabilities and CODECs to browsers without a plug-in. With just a few lines of JavaScript, web developers can add high quality peer-to-peer voice, video, and data channel communications to their collaboration, conferencing, telephony, or even gaming site or application[44]. WebRTC will be used in HMC for web based real time communication and local network streaming.

In the 5th year roadmap, the user's gaming experience and interactivity are the focus. UHD will be fully supported for both videos and games, the voice recognition and motion recognition technologies will be more mature and will be implemented in the HMC to enhance human-machine interactivity. The HMC will be a open platform and become the central hub in the user's living room. The HMC will be used to provide a high quality media entertainment experience to consumers.

Multiple audio track: If a video supports multiple audio tracks, user can choose which audio track to play while watching the video.

SubstationAlpha: SubstationAlpha is a subtitle file format that allows for more advanced subtitles than the conventional SubRip and similar formats.

H.265: H.265 also called High Efficiency Video Coding (HEVC), doubles the data compression ratio compared with H.264/MPEG-4 AVC while preserving the same level of video quality. H.265 can also be used to provide substantially improved video quality at the same bit rate. H.265 supports 8K UHD and resolutions up to 8192x4320[**?**].

UHD video The HMC should support UHD video playout.

VP9 VP9 is an open and royalty free video compression standard being developed by Google. It reduces the bit rate by 50% compared to VP8. VP9 is another CODEC to support UHD video.

APE: APE is another audio format which provides lossless compression.

game store: A user should be able to download games from a game store.

game engine: The HMC should support a game engine so that third party developers can develop HMC games.

game live streaming: HMC users should be able to view live streaming while playing a game.

UHD game : The HMC should support UHD games.

Tagged Image File Format (TIFF): TIFF is a computer file format for storing raster graphics images.

Multi Picture Object (MPO): MPO is a image file format which consists of multiple JPEG images.

Peer-to-Peer (P2P): P2P computing or networking is a distributed application architecture that partitions tasks between peers. HMC support a P2P architecture for VoD, thus a user can share their storage of content with other users.

Airplay: Apple's Airplay is a proprietary protocol stack/suite. That allows wireless streaming of audio, video, and photos, together with related metadata between devices. The HMC should support both DLNA and Airplay for interoperability.

voice navigation: The user can use voice commands to navigate in the menu.

voice search: The user can use voice commands to search for content via the HMC's unified search interface.

voice channel zapping The user can use voice commands to change channels.

motion navigation: The user can use body movements to navigate via HMC's UI.

motion game control: The user can use body movements to control a player in a game.

motion channel zapping The user can use body movements to change channels.

APP store: The user can install third party APPs from an APP store.

second screen: The HMC should support a second screen to interact with the HMC's UI.

email notification: The notification system is to be extended to email.

SMS notification: The notification system is to be extended to SMS.

video call: The user should be able to make video call on HMC.

companion device: The HMC has a companion device to pair to, thus the paired HMCs can support multiple activities at same time.

We believe the above provides a reasonable roadmap for STB venders strategy to evolve to HMC. The focus builds their strength by first enhancing video and music services, then expands the set of functions to fulfill consumer's highest expectations. This can be used to establish a leading market position among competitors. Having established the path toward an HMC by providing high quality A/V experience, the next step is to expand to other areas in order to provide consumers with a full multimedia entertainment experience in their living rooms. These three roadmaps are summarized in Table 4.14.

Table 4.14. HMC product roadmap for 1,3,5 years

Category/Timeline	1 year	3 year	5 year
Video	VP6	WebM	Multiple audio track
	VP8	Theora(Ogg)	SubstationAlpha(.SSA)
	browser EPG	VobSub(.IDX)	H.265
	Universal subtitle format (.USF)	Closed Caption	UltraHD video
	Multiple subtitle	virtual channel	VP9
	File playback	cloud PVR	
	EPG search	universal EPG	
		Subrip(.srt)	
Music	FLAC	-	APE
	Music streaming		
	File playback		
Game	-	-	game store
			game engine
			Game live streaming
			UltraHD game
Photo	Photo viewer	photo storage service	TIFF
	BMP		MPO
	view picture API(C++ SDK)		
Connectivity	SIP	Wifi Direct	Airplay
	HLS(Apple)	HDS(Adobe)	
		HSS(MS)	
		DLNA DMR	
		RTMP(Adobe)	
		DLNA DMS	
		DLNA DMC	
		DLNA DMP	
		P2P	
		MPEG-DASH	
		WebRTC	
Interactivity	-	-	voice navigation
			voice search
			voice channel zapping
			motion navigation
			motion game control
			motion channel zapping
Others	popup notification	recommendation by history/habit	App store
		recommendation by friends	Second screen
		browser support	email notification
		cloud multiple profiles	sms notification
		SNS sharing	video call
		unified search	companion devise
		Client multiple profiles	
		Unified UI	

Chapter 5.
5 Conclusions and Future work

Section 5.1 summarizes the knowledge that we have gained during this thesis project and answers the questions we raised at the beginning of this project. It also gives our vision of a potential HMC industry. Section 5.2 discusses potential extensions of this thesis. Finally Section 5.3 offers some reflections.

5.1. Conclusions

Our proposed HMC is a conceptual product designed to fulfill consumers' multimedia entertainment expectations in their living rooms. In addition to STBs, currently the main device used in a TV watching experience, there are many other devices which are evolving toward the envisioned HMC. These devices include home theater PCs, game consoles, OTT streaming devices, and smart TV. The other devices are all competitors to STBs and they each have their own advantages and disadvantages. All of them partially fulfill consumers' current expectations but want to evolve to become a HMC. The HMC is expected to become the central device and only device in consumers' living rooms.

In this thesis, we studied user expectations for living room multimedia entertainment, user acceptance of potential HMC features, and propose a prioritized list of expected features of a future HMC. To test the actual user expectation on those proposed features, we designed an experience lab, in which our interviewees could experience these features and immediately give their feedback. Based on data collected, we proposed a HMC conceptual prototype and gave a high level hardware and software design. We also analyzed the economic impact on current STB industry to gain a deeper understanding of a potential future HMC industry. Finally, we proposed a product roadmap to guide STB vendors to evolve their STBs to a HMC.

The questions we raised at the beginning of this project are answered as follows:

- What will a future HMC look like?

  How a potential HMC look like is illustrated in Figure 4.3. the dimension of the hardware could vary based upon different industrial designs, the dimension could be around 200x200x50(mm). (Without support for a Bluray Disc player, the dimension could be reduced to much smaller size 100x100x25(mm)).

- What will its functions be?

  As a multimedia box, the HMC should support the whole range of multimedia entertainment functions, including video services, such as IPTV, VoD, Live streaming; music services, such as high quality music play, online music streaming; photo viewing; and gaming services. The HMC should support integration with Web 2.0 services, such as Facebook and Twitter, as well as communication services, such as Skype audio and video calls. The HMC should support UHD videos and games. A HMC should have enhanced local network interoperability, so that it can discover multimedia resources stored in other devices and vice versa. The HMC should be able to play any multimedia resource on any screen. Ideally, the HMC can be controlled in multiple ways, including by a traditional remote control, smartphone/tablet, voice commands and even body motion.

- What interfaces and protocols will it use?

  An HMC will have a Gigabyte Ethernet port and Wi-Fi interface to connect to an ISP for high speed Internet access. It will use IR and Wi-Fi Direct to communicate with various remote controllers. It will be equipped with a camera to support motion detection, which provides support for motion based interactivity between the user and the HMC. The camera also provides support for video call functionality. There should be at least 2 USB3.0 ports connect to external hard drives. S/PDIF can be used to output audio to amplifier while HDMI port is used to ouput A/V stream to a display screen/projector. Similarly, a Thunderbolt port is used connect to a Thunderbolt compatible display. Unlike traditional STB or HSTB, no tunner is required in an HMC. All data transmission is via IP networks due to the advantages of: bidirectional data communication, support for all multimedia services, and continuously improving QoS.

  As a open platform, HMC should be able to support various multimedia services (as discussed in Section 4.2.3). In addition to the basic TCP/IP network stack, the HMC should support many other protocols, including: HTTP, RTP, RTCP, RTMP, HLS, HDS, HSS, SIP, and some specific P2P architecture protocol stack. To interoperate with other LAN devices, such as smart phones and tablets, the HMC complies with DLNA protocol stack and Airplay protocol stack.

- Who will make these HMCs?

  According to our economic analysis, PCs, game consoles, online streaming devices will be the major competition for STB in the future HMC market. We believe that smart TV has little chance, primarily due to 2 reasons:

  1. Most smart TV users do not use its Internet connection feature
  2. The life cycle of a display is much longer than for a STB, PC, etc

  For PCs, game consoles, online streaming devices, their functionalities will evolve to support functionalities of a HMC to provide full living room multimedia entertainment services. However, as each of them has its own strength and weakness, we believe that they will coexist and serve different consumer market segment. For example, STB based HMC can provide guaranteed high quality video services (through cooperation with operators) for movie lovers while game console based HMC will provide the ultimate gaming experience to gamers.

- How can STB vendors evolve to be HMC vendors or will they simply cease to exist?

  According to our survey results, most of the potential HMC users like high quality video and music services, while only a small portion of users expect good game experiences. Our economic analysis further supports this: more than half of all households in Sweden has cable TV or IPTV subscription. From a technical point of view, STB vendors currently are known for providing guaranteed high quality video services. From a market point of view, current STB users are largest user base of the potential HMC users. However, In current TV value chain, STB vendors are operator oriented, not consumer oriented. This bring big challenge to STB vendors. They need to build up brand in consumer market from scratch throughout their transition to HMC. To evolve to HMC, STB venders need to focus on their strengths by providing more innovative audio and video related features, then expand to high quality musics, games, photo viewing in order to provide full multimedia entertainment experience to their users. Removing cable/satellite/terrestrial...tuner support to only support IP networks and the industry can remove their close ties to the cable TV industry. Additionally, by making STB based HMC an open platform, it should support additional open standard, allow third party services, improving the interoperability with other devices in the household, and enhance interactivity so users have more options to interact with the HMC. From business perspective, as STB vendors do not have brand awareness in consumer market, they could consider to cooperate with other well established brands to quickly gain HMC market share.

In summary, we believe traditional cable TV networks will eventually disappear and that STBs will evolve to HMCs.

5.2. Future work

Although we discussed quite a number of topics regarding HMC in this thesis, including priority feature list, hardware and software design, economic impact upon current STB vendors, and a proposed product roadmap, there are many interesting topics we have not covered due to the limited duration of this thesis project. We list them here for future work.

- Detail hardware software design of HMC

  In this thesis, we only give a very high level hardware and software design, hence more work is required to develop detail hardware and software design that could be implemented by a vendor.

- Make a real HMC prototype

  We proposed a conceptual HMC prototype in this thesis project. It would be very interesting to realize a concrete HMC prototype based on this conceptual design.

- Propose more features for evaluation

  Due to our limited time and knowledge, the features we proposed for a potential HMC were limited. As new innovative products come to the market, additional innovative features could be proposed and added to the HMC.

- Apply the same method to analyze other markets

  In this thesis, our target market for economic impact analysis was Sweden. Sweden has a very solid IT infrastructure, well educated people, and a free market for players to compete. Other markets could have totally different situations, for example China. Hence it would be interesting to apply the same method used in this thesis to analyze another market and compare the differences in the decision matrix.

- Consider regulation when analyzing economic impact

  We only discussed technology and market aspects for the HMC industry, we have explicitely not considered regulation aspects. Regulation impact upon features and the value chain could be an extension to our work.

- Discuss from IPTV operator's point of view

  As the central shareholder of current IPTV industry, IPTV operators have a great impact on STB venders. These operator's position and strategy towards HMC will greatly influence the evolution path for STB. As this thesis focuses on the evolution of the STB itself, the analysis of the impact of the greatest influencer on this market will be good extension.

- Discuss sustainability aspects of the evolution toward a HMC?

  There will be millions of existing STBs that need to be recycled and millions of new HMCs that need to be manufactured during this evolution. How will it impact the environment is an interesting topic to discuss.

5.3. Required reflecitons

This thesis project studies user expectation on HMC, proposes general roadmap for STB to evolve to HMC, this general roadmap could be used by current STB vendors as guideline to define their own specific product roadmap to support their transition to future HMC market. We gain deeper knowledge about STB from both technology and economy point of view.The method used to study user expectation and make technical decision could easily apply to other new consumer devices. Due to the limitation of this project, the proposed future work points out possible extension for continuous study in this area. the sustainability aspects of evolving from STB to HMC is mentioned in Section 5.2 as one of the future works.

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A Appendix A.
Quantitative Survey

A.1. First version of Questionnaire

Table A.1. Hypothetical Feature List

Category	FEAID	feature description
Video	FEA1	user can watch streaming movie/video clips with Ultra HD quality
	FEA2	user can watch streaming movie/video clips without buffering
	FEA3	user can watch broadcasting TV channel
	FEA4	user can watch sports, concert and other live events with lowest latency possible
	FEA5	user can choose on which channel to watch live events (live event guide)
	FEA6	user can watch home movie stored in LAN
	FEA7	user can easily find and play music from music library in LAN
	FEA8	user can easily access family photos in LAN
	FEA9	user's media resources on HMC are discoverable by other device in the home network
	FEA10	user can display content on whatever screen he/she wants
	FEA11	user can easily watch home movie stored in cloud
	FEA12	user can record a live TV show for later watch
	FEA13	user can pause a live show to watch later
	FEA14	user can discover what events/programs are currently live broadcasting
	FEA15	user can get notified by email or sms or popup when a scheduled program is about to start
	FEA16	user can play blueray disk
	FEA17	user can plugin external hard disk to watch local video
Game	FEA18	user can play game with Ultra HD quality without any lagging
	FEA19	user can share their game archivement to SNS, (like facebook, game communities etc)
	FEA20	user can play online game together with other people remotely
Music	FEA21	use can stream looseless music from music streaming service providers, like Spotify
	FEA22	user can access their favorite music streaming service,like spotify, deezer
Picture	FEA23	user can access photo storage service like flickr, picassa
Interaction	FEA24	user can use remote control to interact with HMC
	FEA25	user can use smart phone and tablet to control HMC
	FEA26	user can speak to HMC
	FEA27	user can use body motion to interact with HMC
	FEA28	user can play video game while listening to music
	FEA29	user can play video game while watching TV on second screen
Other	FEA30	user can watch TV while making video chat with friends/family
	FEA31	each user has a profile, so they can login with different preference
	FEA32	user get recommendation by activity history
	FEA33	user can search all available content in one place
	FEA34	user can surf on internet
	FEA35	user can make video call
	FEA36	user can install third-party application and use them on HMC

A.2. Survey result distribution

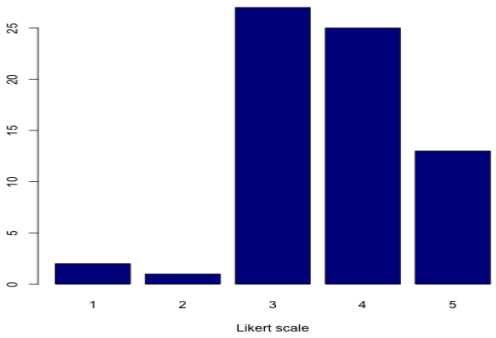

Figure A.1. Q3: Do you think 4k video quality is better than others?

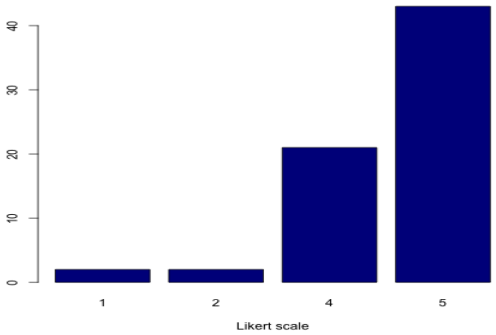

Figure A.2. Q4: How important to you that the video should play smoothly without stop for buffering?

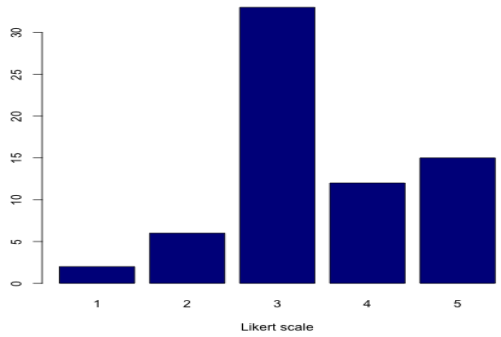

Figure A.3. Q5: How much do you need to watch broadcasting TV channel?

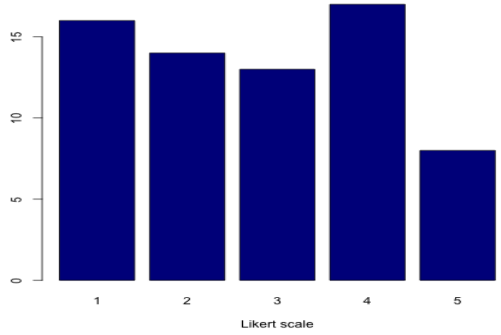

Figure A.4. Q6: How important do you want to watch events ”live”?

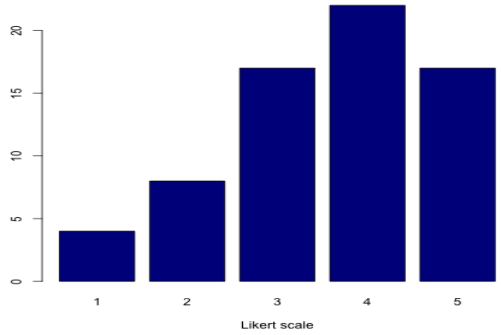

Figure A.5. Q7: How important you can decide on which channel to watch video? which language actors speak and which language to show on the screen?

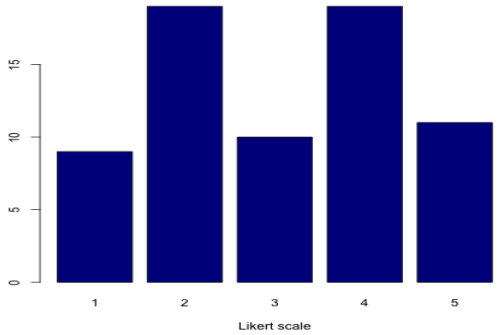

Figure A.6. Q8.1: Do you like to easily access your content stored in other place in LAN? - home video

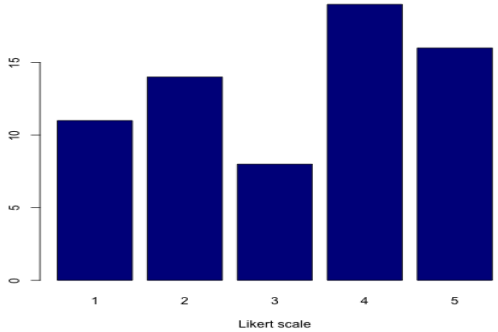

Figure A.7. Q8.2: Do you like to easily access your content stored in other place in LAN? - music library

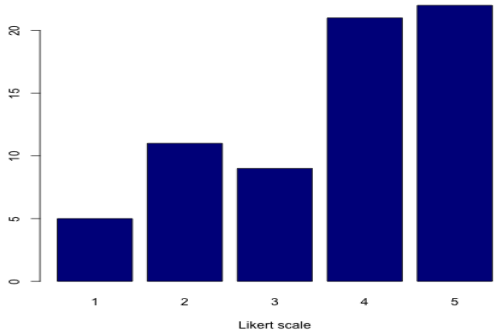

Figure A.8. Q8.3: Do you like to easily access your content stored in other place in LAN? - family photos

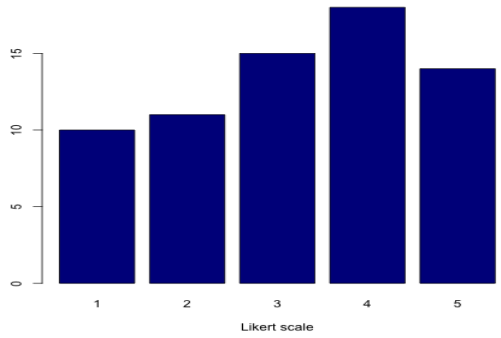

Figure A.9. Q9: Do you want media resources stored on HMC is discoverable by other devices in same network? like your phone, tablet...etc?

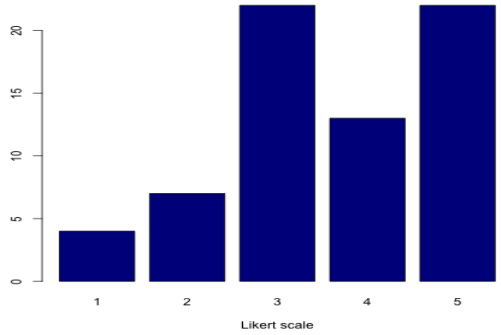

Figure A.10. Q10: Would you like to watch video on any screen available?

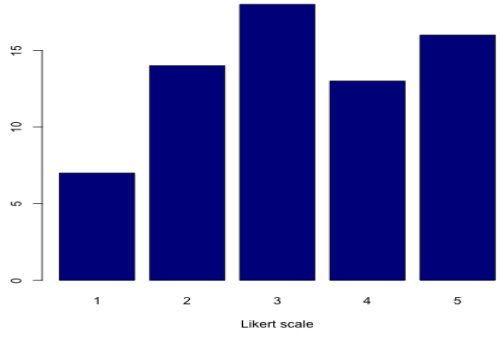

Figure A.11. Q11: How much do you like to easily play your home movie from anywhere, at anytime?

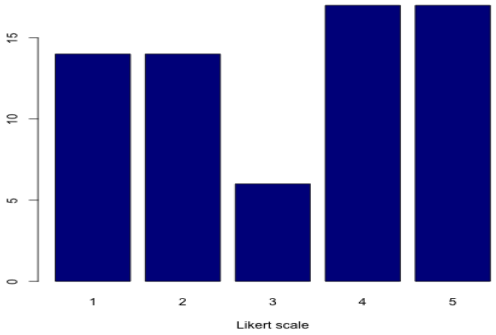

Figure A.12. Q12: Do you want HMC to record a match for you?

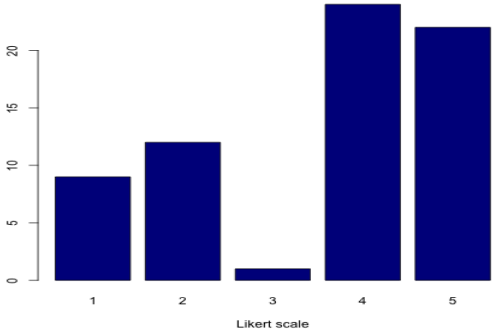

Figure A.13. Q13: How much do you want HMC to pause the match when you want to watch it later?

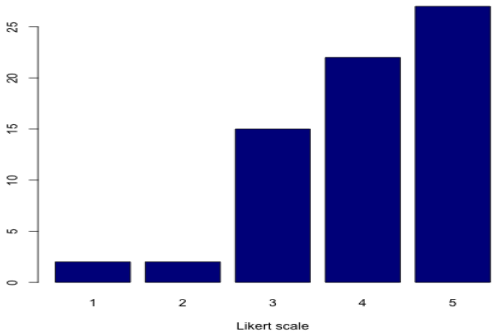

Figure A.14. Q14: How much do you like to be able to discover live program/events?

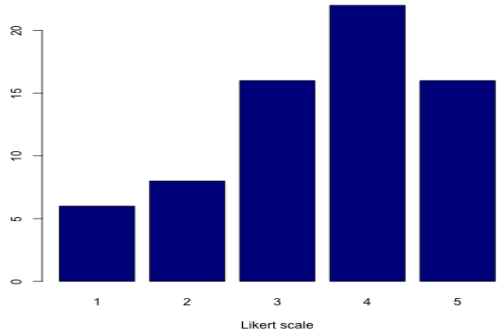

Figure A.15. Q15: How much do you want your personalized channel on HMC?

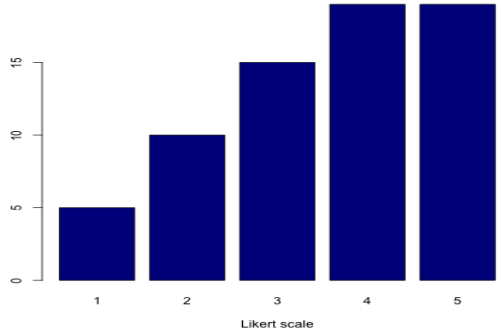

Figure A.16. Q16: How much do you want to get a email or/and sms notification 15 minutes before your scheduled program start?

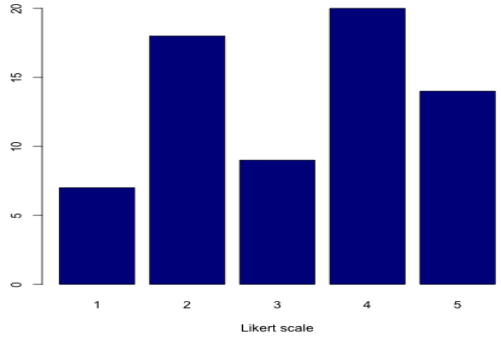

Figure A.17. Q17: Do you think it is necessary to play Bluray on HMC?

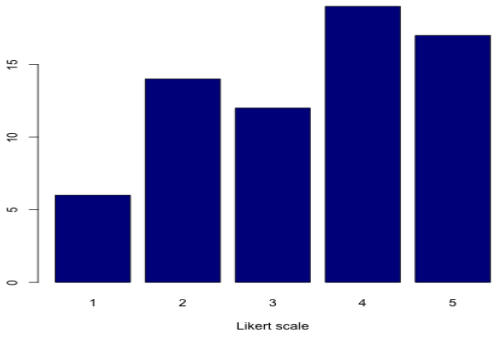

Figure A.18. Q18: Do you think it is necessary to plug in external hard drive to HMC?

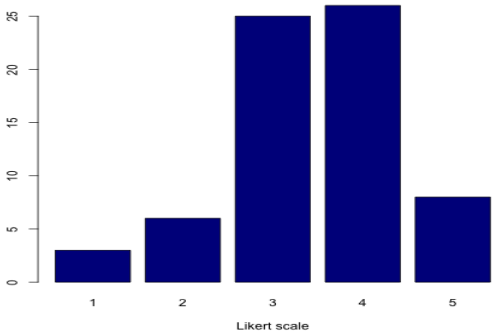

Figure A.19. Q19: Do you think 4k game resolution is better than others?

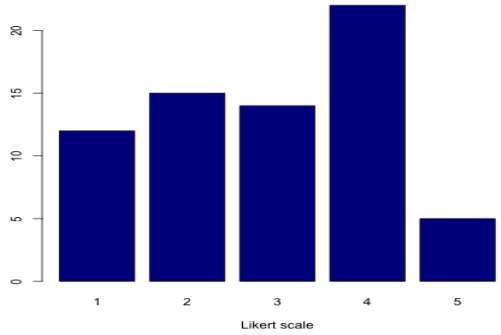

Figure A.20. Q20: Would you like to share your game experience to friends through Facebook or Twitch?

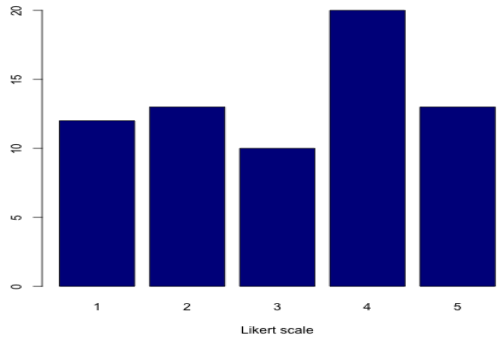

Figure A.21. Q21: How much do you like to play online game with other people?

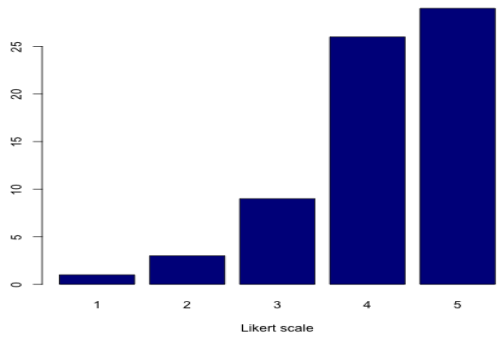

Figure A.22. Q22: How much do you like high quality music?

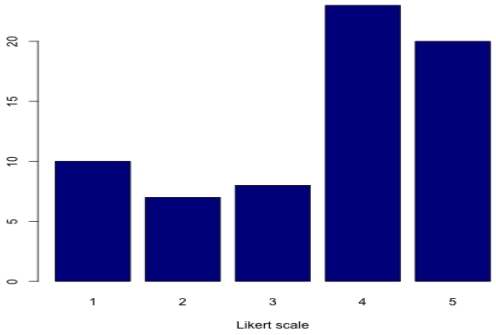

Figure A.23. Q23: How much do you like to get your music service provider on HMC?

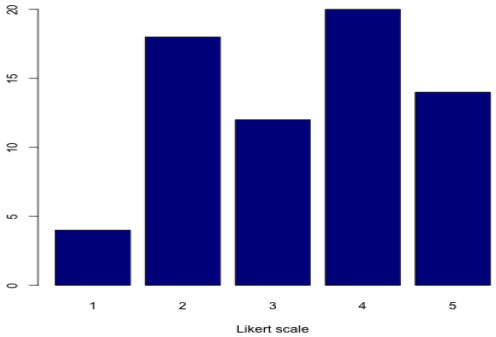

Figure A.24. Q24: How much do you like to access your photo storage service from HMC?

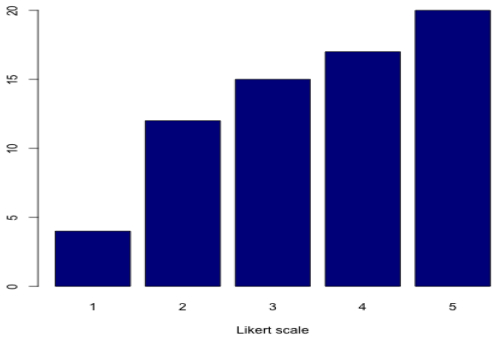

Figure A.25. Q25.1: Do you like to control HMC in the following ways? - traditional remote control

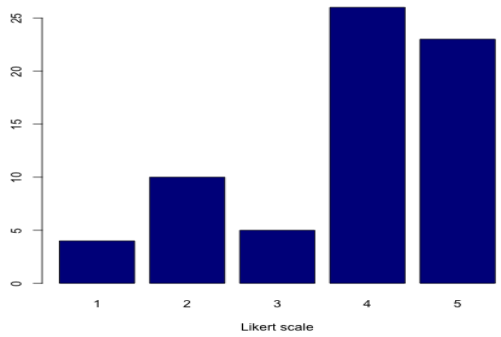

Figure A.26. Q25.2: Do you like to control HMC in the following ways? - smartphone/tablet

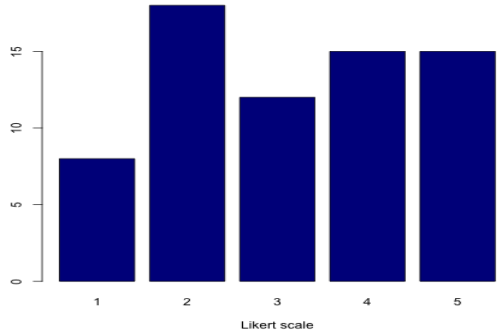

Figure A.27. Q25.3: Do you like to control HMC in the following ways? - by voice

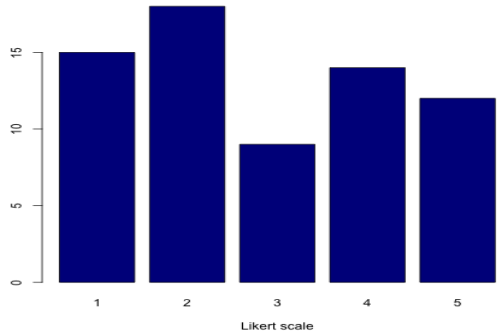

Figure A.28. Q25.4: Do you like to control HMC in the following ways? - by body motion

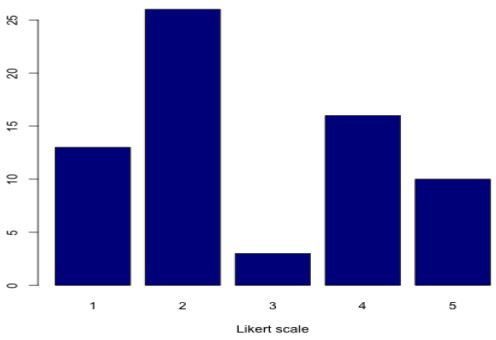

Figure A.29. Q26.1: Which of the following activities do you want to do at the same time? - Play video game while listening to music

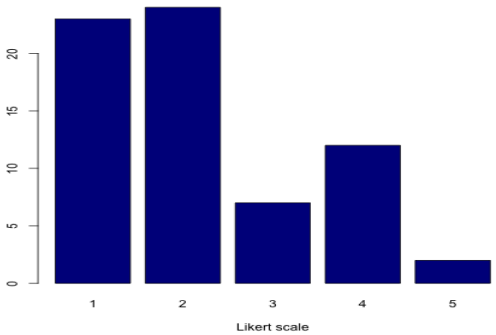

Figure A.30. Q26.2: Which of the following activities do you want to do at the same time? - Play video game and broadcasting live

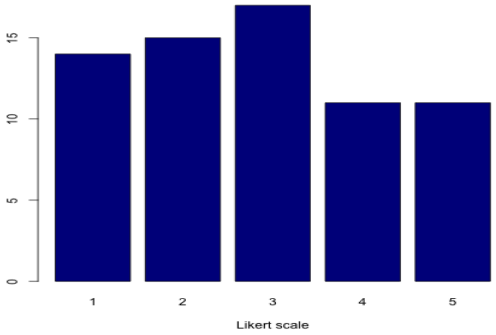

Figure A.31. Q26.3: Which of the following activities do you want to do at the same time? - Watching video while surfing on Internet

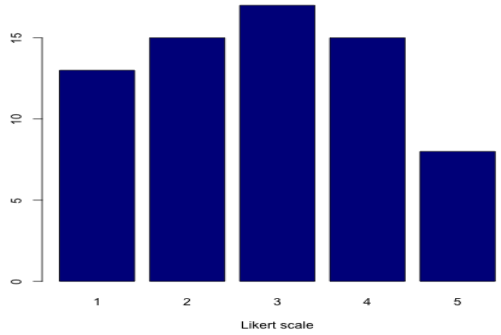

Figure A.32. Q26.4: Which of the following activities do you want to do at the same time? - Watching TV while having a video chat with friends/family

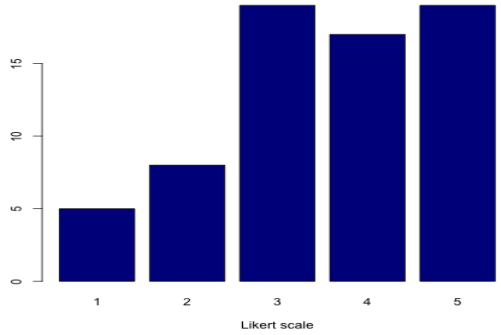

Figure A.33. Q27: Do you want to have your own profile?

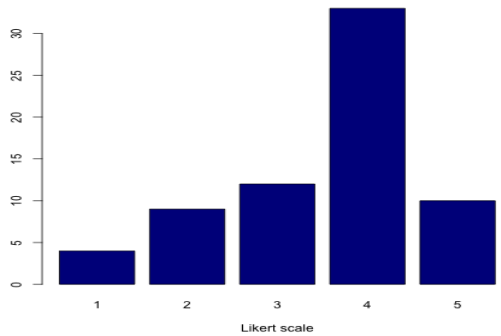

Figure A.34. Q28.1: Do you like to get recommendation from? - activity history/profile

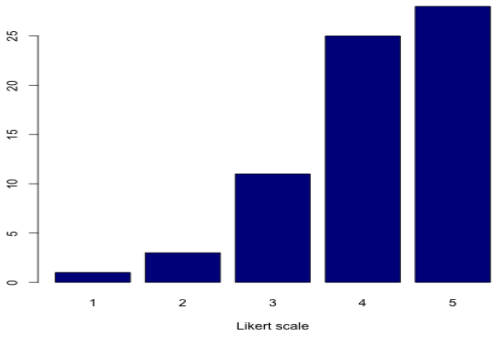

Figure A.35. Q28.2: Do you like to get recommendation from? - friends

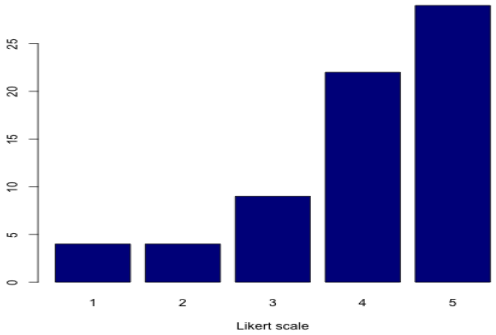

Figure A.36. Q29: Do you like to find all the contents you want in one place?

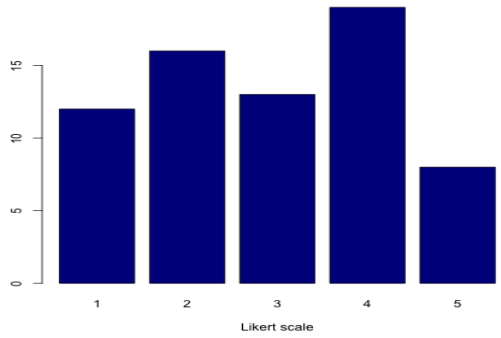

Figure A.37. Q30.1: Would you like to have the following Features on HMC? - surf internet

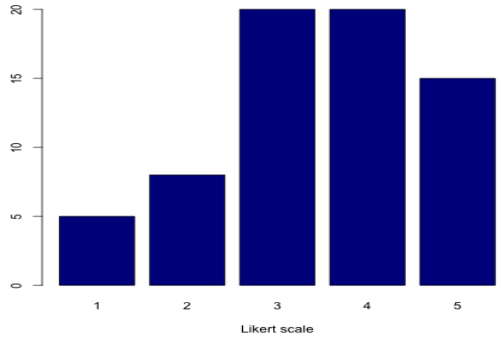

Figure A.38. Q30.2: Would you like to have the following Features on HMC? - make video call

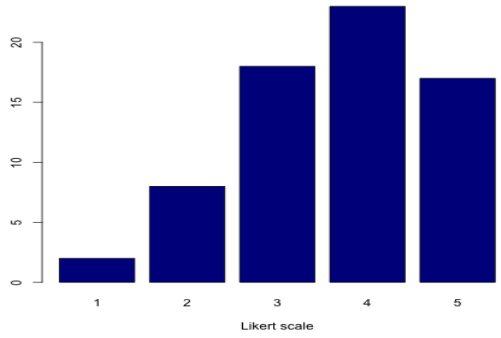

Figure A.39. Q30.3: Would you like to have the following Features on HMC? - install app from app store

TRITA-ICT-EX-2014:144