HELSINKI UNIVERSITY OF TECHNOLOGY
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Scenario-Based Techno-Economic Analysis of Digital Homes

Master's thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Technology

Espoo, January 29, 2008

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Households are slowly turning into digital homes as consumers are filling up their homes with a vast number of digital devices. As the number of devices grows, management of the devices and their interoperability is becoming increasingly complex so that only tech enthusiasts are able to handle the task. For many, the installation and maintenance of the devices is often too difficult to take care of by themselves and outside help is required.

By assessing an average Finnish household, this thesis aims to evaluate the digital home market of Finland and the possible roles of telecom operators in the market. The costs of purchasing and maintaining the devices were estimated to predict the possible growth of the market based on literature analysis and expert interviews. Four predefined scenarios were used for the analysis to depict the potential development paths of digital homes: the locally centralized, the globally centralized, the global specialists and local janitors, and the do-it-yourself-scenario.

The results of the study indicate that a sudden change in consumption habits and thus the overall growth of the digital home market is unlikely during the next five years. However, as the amount of money spent on digital homes is expected to increase due to the digitalization of more traditional services, the number of devices in an average household most likely keeps steadily growing and the entire market along with it. The digital home market will most likely be a combination of two or more of the scenarios and their attributes. During the analysis also some deficiencies were found in the scenarios used and had to be taken into consideration in this thesis.

Keywords: Broadband connection, digital device, digital home, scenarios, techno-economic analysis, telecom operator

TEKNILLINEN KORKEAUKOULU Diplomityön tiivistelmä

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Kotitalouksien laitemäärät kasvavat ja kodit muuttuvat vähitellen digitaalisiksi. Uusissa laitteissa on yhä useammin mahdollisuus verkkokäyttöön yhdessä muiden laitteiden kanssa. Laitteiden lukumäärän kasvaessa niiden hallinta ja yhteensovitus kuitenkin monimutkaistuu ja vain harvat suoriutuvat näistä vaativista tehtävistä. Monet joutuvat turvautumaan ulkopuoliseen apuun.

Tässä diplomityössä pyritään arvioimaan keskivertokodin kautta Suomen digitaalisten kotien markkinoita sekä tietoliikenneoperaattoreiden roolia näillä markkinoilla. Kirjallisuustutkimuksen ja asiantuntijahaastattelujen perusteella laadittiin arviot laitteiden hankinta- ja ylläpitokustannuksista digitaalisten kotien kasvun arvioimiseksi. Tutkimuksessa käytettiin neljää erilaista jo aiemmin määriteltyä skenaariota kuvaamaan markkinoiden mahdollisia kehityssuuntia; paikallisesti keskittynyt, globaalisti keskittynyt, globaalit spesialistit ja paikalliset huoltomiehet sekä tee-se-itse-skenaario.

Tutkimuksen tulokset viittaavat siihen, että mullistavaa yhtäkkistä muutosta kulutustavoissa ja sitä kautta digitaalisten kotien markkinoiden kasvussa ei ole odotettavissa seuraavan viiden vuoden aikana. Digitaalisiin laitteisiin ja palveluihin käytettävä raha puolestaan kuitenkin kasvaa, kun perinteiset hyödykkeet digitalisoituvat. Digitaalisten kotien markkinat jatkavat kasvuaan ja ne tulevat todennäköisesti olemaan kombinaatio kahdesta tai useammasta tässä työssä käytetystä skenaariosta. Tutkimuksen aikana löytyi myös puutteita käytetyistä skenaarioista, jotka piti ottaa huomioon tässä työssä.

Avainsanat: Digitaalinen koti, digitaalinen laite, laajakaistayhteys, skenaario, teknis-taloudellinen analyysi, tietoliikenneoperaattori

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Preface

This Master's thesis concludes my studies for the Master of Science degree. The work for the thesis was carried out at the TKK Networking Laboratory as a part of the national InHoNets research project.

I want to take this opportunity to thank Professor Heikki Hämmäinen for giving me the possibility of writing this thesis under his supervision and for his valuable comments and guidance during the process. In addition, I want to thank my instructor Mathias Tallberg for his assistance. I am also grateful to all the members of the networking business team for their advice and comments, and most of all for providing an enjoyable working environment

I would also like to thank the interviewees for their valuable time and comments, which greatly helped me in the analysis process of this thesis, and the InHoNets project partners and researchers for useful comments at the project meetings.

Finally, I want to thank my family and friends for supporting me throughout my studies. Special thanks go to my sister Ida for proofreading and commenting this thesis. Last, but certainly not least, I am very grateful to my dear Katri for her support and patience during my studies and especially during this final phase.

Espoo, January 31, 2008

Lauri Salminen

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Abbreviations

3G	*Third generation of mobile phone standards*
ACS	*Auto-Configuration Server*
ADSL	*Asymmetric Digital Subscriber Line*
ARPU	*Average Revenue Per User*
CAPEX	*Capital Expenditures*
CATV	*Cable Television*
CD	*Compact Disc*
CE	*Consumer Electronics*
CEA	*Consumer Electronics Association*
CELTIC	*Co-operation for a European sustained Leadership in Telecommunications*
CPE	C*ustomer Premises Equipment*
CWMP	*CPE Wide area network Management Protocol*
DLNA	*Digital Living Network Alliance*
DMT	*Discrete Multi-tone*
DOCSIS	*Data-Over-Cable Service Interface Specifications*
DSL	*Digital Subscriber Line*
DVB	*Digital Video Broadcasting*
DVC	*The Digital VCR Conference*
DVD	*Digital Versatile Disc*
ETSI	*European Telecommunications Standards Institute*
FTTH	*Fiber To The Home*
GPRS	*General Packet Radio Service*
HD	*High-Definition*

HD-DVD	*High Definition Digital Versatile Disc*
HDMI	*High-Definition Multimedia Interface*
HDTV	*High-Definition Television*
HiperMAN	*High Performance Radio Metropolitan Area Network*
HomePNA	*Home Phone line Networking Association*
HR	*Human Resources*
HSDPA	*High Speed Downlink Packet Access*
HSPA	*High Speed Packet Access*
HTTP	*Hypertext Transfer Protocol*
ID	*Identification*
IEEE	*Institute of Electrical and Electronics Engineers*
InHoNets	*Interconnected Broadband Home Networks*
IP	*Internet Protocol*
IPTV	*Internet Protocol Television*
IRR	*Internal Rate of Return*
IT	*Information Technology*
LAN	*Local Area Network*
MAN	*Metropolitan Area Networks*
Mbps	*Megabits per second*
MPEG	*Moving Picture Experts Group*
MP3	*MPEG-1 Audio Layer 3*
NAT	*Network Address Translation*
NPV	*Net Present Value*
OA&M	*Operation, Administration and Maintenance*
OFDM	*Orthogonal Frequency-Division Multiplexing*
OPEX	*Operational Expenditures*

OS	*Operating System*
PAN	*Personal Area Networks*
PC	*Personal Computer*
PDA	*Personal Digital Assistant*
PLC	*Power Line Communication*
PS3	*Sony PlayStation 3*
PSP	*PlayStation Portable*
PSTN	*Public Switched Telephone Network*
PV	*Present Value*
PVR	*Personal Video Recorder*
QoS	*Quality of Service*
ROI	*Return On Investment*
SP	*Service Provider*
TCO	*Total Cost of Ownership*
TCP	*Transmission Control Protocol*
UDP	*User Datagram Protocol*
UPnP	*Universal Plug and Play*
USB	*Universal Serial Bus*
UWB	*Ultra-WideBand*
UWB-RT	*Ultra-WideBand Radio Technology*
VCR	*Videocassette Recorder*
VDSL	*Very High Speed Digital Subscriber Line*
VHN	*Versatile Home Network*
VoIP	*Voice over IP*
WCDMA	*Wideband Code Division Multiple Access*
Wi-Fi	*Wireless Fidelity*

WiMAX	*Worldwide Interoperability for Microwave Access*
WLAN	*Wireless Local Area Network*
WAN	*Wide Area Network*
WWRF	*Wireless World Research Forum*

1 Introduction

1.1 Background

Most current homes already possess a great number of electronic equipment. The number of devices in a single home has been growing steadily during the past years and is expected to continue to grow at least at the same rate for the next five years. A mix of analog and digital devices and technologies still exist in the average home. However, analog devices are disappearing and the trend is strongly towards an all-digital home with computers, digital video cameras, HDTV (High-Definition Television), MP3 players, PDAs, etc.

Typical households have at least four independent networks carrying audio, data, telephony, and TV. Until recently, the telecom operators have mainly focused on providing their customers a connection to the public IP network. In other words, operators have primarily offered customers a bit pipe to the Internet. Lately however, operators have begun to broaden their service offerings by entering the equipment vendor market, traditionally dominated by consumer electronics (CE) retailers. In addition, telecom operators have introduced new digital services, such as IPTV, an alternative to the traditional cable and terrestrial broadcast services.

To the average user the management and configuration of the digital devices and the interoperability of the bundle of devices is getting more and more challenging. As users adapt to new technologies and homes fill up with different digital appliances, there seems to be an increasing demand for management and maintenance services. Whether this would be something for the telecom operators to include in their services or for a third party to take care of, remains to be seen.

This thesis focuses on the expenses of an average digital home and the role of telecom operators in the market. The techno-economic analysis assesses the potential growth of the digital home market through the costs and investments a typical Finnish household needs to make to become a digital home. Four different scenarios are used to study possible development paths of the market.

This thesis is part of a national research project called Interconnected Broadband Home Networks (InHoNets), in which the Networking Laboratory of Helsinki University of Technology (TKK) is participating along with a number of leading industry partners in Finland.

1.2 Research Problem

This thesis seeks to answer the following questions:

- How will the Finnish digital home market evolve during the study period from 2007 to 2012?
- How much capital and operational expenditures are required from consumers to set up and maintain a digital home?
- What are the most significant variables in capital and operational expenditure estimations in terms of uncertainty?
- Which of the four scenarios suggested by Nordlund et al. (2007) are the most realistic?

1.3 Scope

This thesis focuses on the techno-economics of an average digital home. Due to the variety of households, it was decided to restrict the study to an average household instead of breaking the households down to a number of smaller categories. The generalization of households using average figures was required due to the limited availability of statistics.

The thesis is restricted to the Finnish digital home market and to the entertainment and data services available for private users. This exclusion leaves home automation outside the scope. Thus, the calculations include digital equipment and services present in common households. Despite the attempt to answer the question of how the market will evolve during the next five years, only services and devices already in the market or predefined in the scenarios are taken into the calculations. Including possible new solutions and services would have redundantly expanded the thesis and added unnecessary uncertainty to the results of the analysis.

As mentioned, four operator centric scenarios describing the evolution of the digital home market during the study period, developed by Nordlund et al. (2007) earlier in the InHoNets project, are used for the techno-economic analysis of this thesis. These scenarios are the locally centralized-, the globally centralized-, the global specialists and local janitors-, and the do-it-yourself- scenario. Despite the operator point of view, the scenarios depict the market conditions valuably for the households. Quantitative results are presented as very exact sums of money, but they are to be treated more as estimates and indicative figures.

1.4 Research Methods

The research methods of this thesis consist of a literature study, expert interviews and a techno-economic analysis.

The literature study conducted as a background research for this thesis focused on the technical and economic aspects of the digital home. The main focus was to discover the current state of the digital home and how the near future looks. Not much literature exists yet on digital homes and their management, therefore theories of the different parts of digital homes is applied.

To improve the credibility of the information used as input for the techno-economic analysis and thus the results, experts from major Finnish companies involved in the digital home business were interviewed.

The techno-economic analysis carried out was based on the analysis methodology of the Microsoft Excel based ECOSYS-tool, which is a result of multiple EU research projects in the techno-economic field. The tool itself was not used, due to its lack of applicability to the techno-economics of digital homes from the homes' perspective, but applied as a guideline for constructing a spreadsheet model for the techno-economic analysis. The scenarios provide an overall look at the market and its development from the network operator's perspective. However, after careful thought and consideration, instead of a network operator, it was found most practical to use an average household for the techno-economic analysis. Available statistics were used as the figures required as inputs for the techno-economic analysis. In addition, a number of estimations based on supplementary market data had to be made.

1.5 Structure of the Thesis

First, this thesis gives an introduction and takes a look at the current situation of digital homes. Second, the methods are described and last, the techno-economic analysis and its results are presented. This thesis is divided into chapters so that the second chapter presents the general technical information and definitions of the digital home, including the current situation in terms of available technologies, standards, devices and services. An overview of how the digital home market is predicted to evolve is also presented in the second chapter.

The third chapter covers the theory of the techno-economic method. The model's inputs and outputs are explained here. Risk and sensitivity analysis is also discussed in brief in the chapter. The ECOSYS and Crystal Ball tools and their methodologies are presented at the end of the chapter.

The techno-economics of a digital home are discussed in the fourth chapter. The digital home model constructed for the techno-economic analysis is presented here along with the logic and structure of the model. The inputs used in the analysis and the results of both the economic analysis and the risk and sensitivity analysis are covered in the chapter.

The overall situation of the digital homes is discussed in chapter five. The final results of the study are concluded in the sixth chapter and their importance is assessed. In addition, further research ideas are given.

2 Digital Homes

This chapter describes the trends, technologies and players in the digital home market today and in the near future.

2.1 Definitions of Digital Home and Home Network

Digital home is defined in this thesis according to Nordlund et al. (2007). It is a term used to describe all the devices and wired and wireless connections connecting the devices in a private residence. A digital home has three fundamental components: devices, intra-home network connections, and a public access network connection.

The term *home network* can be interpreted in two different ways. From a networking point of view it can be understood to refer to the wired or wireless connections between the devices. On the other hand it can also refer to the whole network including the devices, i.e. the *digital home*. In this thesis, home network is considered to include not just the connections, but also the devices and to be equal with the term *digital home*.

2.2 Key Enabling Technologies

The merging of the PC Internet world, the mobile world, and the CE broadcast world will, according to a widely accepted assumption, be driven by the Internet and IP-based technologies. The intra-home networks in digital homes are rather small, in terms of the distance between different devices. Therefore Personal Area Networks (PAN), using Bluetooth (IEEE 802.15) and Firewire (IEEE 1394), and Local Area Networks (LAN), using Wireless LAN (WLAN) and Ethernet, are the most suitable types of networks and technologies for the connections of digital homes. Access network technologies, which are used to connect the homes to the outside world, are either Wide Area Networks (WAN), or Metropolitan Area Networks (MAN), depending on the area covered by the network. This categorization of different networks by size is depicted in *Figure 2.1*. The following section describes the key technologies vital to the digital home environment and for providing services into digital homes.

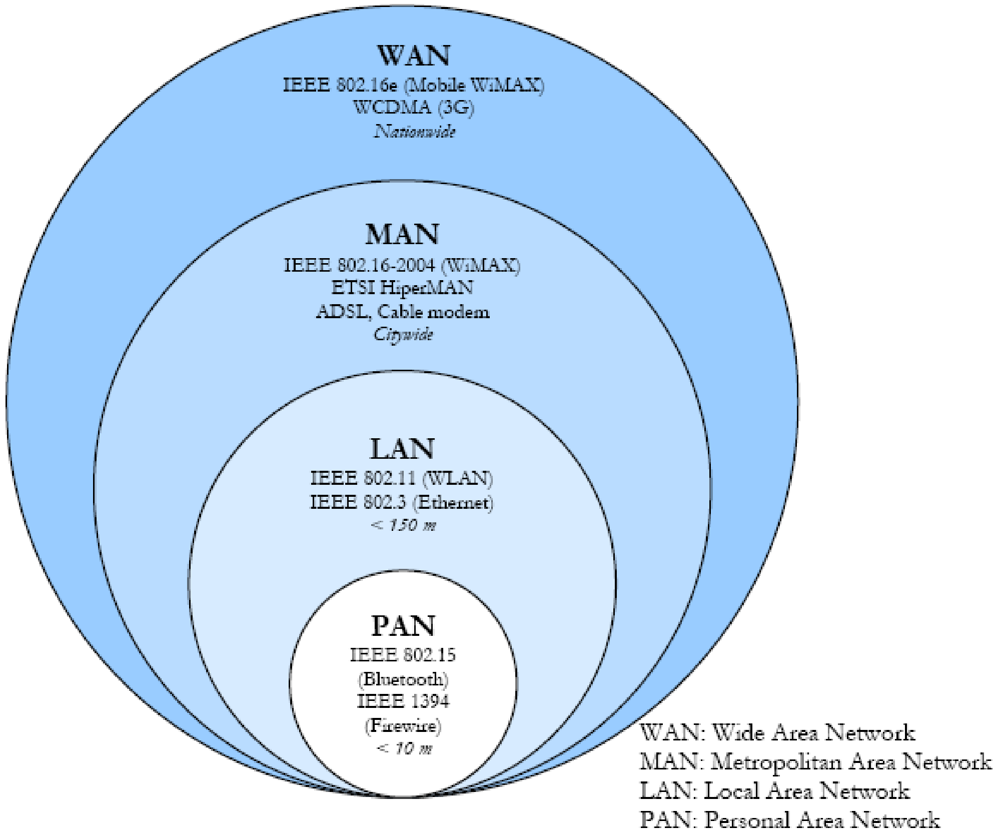

Figure 2.1: Networks categorized by size (Based on OECD (2006), modified by Nordlund (2007))

2.2.1 Access Network Technologies

The part of the network that connects the home to the core network is called the access network. DSL and cable modem networks are the most widespread commercial fixed network technologies today, comprising 97% of all broadband subscriptions in Finland (Ficora 2007). The benefit of these fixed access network technologies is the utilization of the existing telephone and cable networks. Wireless access network technologies are emerging and will in the future enable broadband networks to spread to areas where the infrastructure does not allow the current, let alone the future technologies. Some access network technologies in use today are compared in *Table 2.1* below.

Table 2.1: Available access network technologies (Elisa (2007), Digita (2007), Maxisat (2007), Saunalahti (2007), TeliaSonera (2007))

Wireless

Technology	Data rate (downlink / uplink)	Advantage	Disadvantage	Use case
WCDMA	384 / 128 kbps	Wide coverage, lots of users	Limited speed	Mobile handsets, laptops
HSDPA	2 Mbps / 384 kbps	Upgrades 3G networks, low latency		
@450 / Flash-OFDM	1 Mbps / 512 kbps	Large cell size, cheap to build	Limited speed, no QoS	Portable devices in urban areas, last mile access in rural areas
IEEE 802.16d Fixed WiMAX	10 / 5 Mbps	Often cheaper to build than DSL in rural areas	Expensive terminals, capacity shared within a cell	Last mile access in rural areas

Fixed

Technology	Data rate (downlink / uplink)	Advantage	Disadvantage	Use case
Cable modem (EuroDOCSIS)	10 / 1 Mbps	Utilizes CATV network capacity	Availability of cable networks	Last mile access in CATV homes
ADSL / ADSL 2+	24 / 1 Mbps (1.5 km)	Utilizes telephone networks	Speed depends on distance from closest exchange	Last mile access

Fixed technologies are suitable for urban areas, where the population is dense and distances are short. Wireless networks are not cost-effective, because densely populated areas require small cell size, due to the large number of users sharing the bandwidth and buildings restricting the coverage of the cell. The existing infrastructure already enables several technologies to be deployed and new ones, such as FTTH (Fiber To The Home), are cost-effective to build.

In rural areas, where distances are great and the population density low, wireless solutions are more suitable than the fixed. The existing infrastructure often does not allow true broadband access without serious improvements to the cabling and other network elements. The expenditures of building or improving fixed networks grow along with the distances and therefore it is not always reasonable to invest in the fixed network in the rural areas. Wireless access network technologies on the other hand are more suitable for the rural areas. The number of users per sq. km is lower and buildings are not an issue, which allows larger cell size and therefore the distances between base stations stay long enough for cost-effectively building the networks. *Table 2.2* presents some future access network technologies.

Table 2.2: Future access network technologies (CableLabs (2006), Gray (2006), OECD (2006), Qualcomm (2004))

Wireless

Technology	Data rate (downlink / uplink)	Advantage	Disadvantage	Use case
IEEE 802.16e Mobile WiMAX	10 / 5 Mbps	Coverage	Mobile WiMAX license required	Portable devices in urban area, last mile access in rural areas
HSPA	10 / 5 Mbps	Coverage, low latebcy	3G license required	Mobile handsets, laptops

Fixed

Technology	Data rate (downlink / uplink)	Advantage	Disadvantage	Use case
Cable modem (DOCSIS 3.0)	160 / 120 Mbps	Utilizes excess CATV network capacity	Availability of cable networks	Last mile access in CATV homes
VDSL	100 / 100 Mbps (0.5km)	Utilizes telephone networks	Speed depends on distance from closest exchange	Last mile access
Fiber (FTTH)	> 1 / 1 Gbps	High capacity	High initial investments	Last mile access in urban areas, backbone networks

2.2.2 Intra-Home Network Technologies

Previously the access network has been the major bottleneck to the growth of digital homes and despite the development of the access network technologies and the increase in average speed, it still remains a bottleneck. In addition, the intra-home network connections, which connect the devices in the home together, are problematic. The number of devices in homes steadily grows, but still most of the devices are not equipped to support interoperability with other devices. A vast number of standards, both fixed and wireless exist, but no single technology has yet become dominant. Common intra-home network technologies are presented in *Table 2.3* below.

Table 2.3: Wireless and fixed intra-home technologies (Kilpinen (2006), Porcino & Hirt (2003), Zaharidis et. al (2002))

Wireless

Technology	Max. data rate	Max. distance	Advantage	Disadvantage	Use case
IEEE 802.11g/n (WLAN)	54 Mbps / 540 Mbps	30-100 / 50 m	Fast, popular	Microwave interference	Data and A/V connections
Bluetooth v.1 / v.2	723 kbps / 3 Mbps	10 / 100 m	Low power and cost	Microwave interference, limited speed	Connecting personal devices
IEEE 802.15.3 (UWB)	> 100 Mbps	10 m	Low power	Coverage	A/V connections
IEEE 802.15.4 (Zigbee)	250 kbps	30 m	Low power and cost	Limited speed	Sensors and control devices

Fixed

Technology	Max. data rate		Advantage	Disadvantage	Use case
IEEE 802.3 (Ethernet)	10 / 100 Mbps, 1 / 10 Gbps		Reliable	QoS not inherited	Fixed core connections
IEEE 1394 (Firewire)	3.2 Gbps		QoS	Multi-device performance	A/V connections
USB v.1 / v.2	12 Mbps (v.1), 480 Mbps (v.2)		Plug 'n' Play	Limited distance	PC peripherals
PLC HomePlug etc.	100 Mbps		Uses existing electrical wiring	Interference with electrical devices	Home automation, A/V devices

The trend in the intra-home network is towards wireless; however fixed technologies still continue to play an important role, due to their reliability and transmission data rate. Some of the fixed network technologies reuse the existing wirings present in most typical homes, e.g. power-line technologies reuse the power distribution network and HomePNA the phone lines. Other technologies such as Ethernet, Firewire, and USB require new wirings, which many users find impractical.

Universal Serial Bus (USB)

USB was developed to solve the problem of complicated and difficult installation of different peripheral devices to the PC. It aims to replace all the various serial and parallel port connectors with one standardized plug‘n’play interface. As most PCs today have at least two USB ports on-board that are accessible from outside the case, and as most operating system providers include device drivers for USB in their standard distributions, connecting new USB devices is more or less an automatic process. Moreover, USB enables the power requirements of a device to be sensed automatically and then delivered, eliminating in many cases the need for additional power supplies.

USB provides both asynchronous data transfer and isochronous audio/video streaming channels. USB 2.0 promises transfer rates up to 460-480 Mbps, covering the requirements of bandwidth demanding devices such as digital cameras, hard-disk drives, and DVD drives. (Zaharidis et al. 2002.)

Next generation Hi-Speed USB will be wireless and will have a targeted bandwidth of 480 Mbps at distances under 10m. The Wireless USB specification maintains the same usage and architecture as wired USB with a high-speed host-to-device connection. Wireless USB could become a dominant wireless interconnect capable of supporting usage models across all three environments—PC, CE, and mobile market segments. (USB 2007.)

Firewire

The IEEE 1394 standard, commonly known as Firewire, was initially proposed for entertainment appliances, but today provides a low-cost digital interface that integrates entertainment, communication, and computing products into a single consumer multimedia network. The standard originated by Apple Computer as Firewire for desktop LANs and was further developed by the IEEE 1394 working group. Because the standard was originally designed for consumer purposes, it has been accepted as the standard digital interface by a number of standardization bodies including DVB (Digital Video Broadcasting), DVC (the Digital VCR Conference) and the Consumer Electronic Association's (CEA's) K4.1 and R7.4 Versatile Home Network (VHN) subcommittees.

Firewire operates over copper or fiber cables, and some companies even offer solutions that use coaxial cable. The latest version of the standard, IEEE 1394b, enables transmission speeds up to 3.2 Gbps over distances of 100 meters with plastic and glass fiber optics.

The value received by the consumer when using Firewire is the replacement of several wires with a single Firewire cable. Like USB, Firewire supports hot plugging, i.e. users can add or remove Firewire devices while the bus is active and no additional terminators or device IDs are needed. Home networks require both asynchronous data transfer, used in traditional computer file transfer, and isochronous data transfer, used when guaranteed transfer rates are needed. Both types of transfer mode are supported by the standard. IEEE 1394 supports peer-to-peer networking so that it is possible not only to connect to devices together without a computer in the middle, but to also share a device by several computers. (Rose 2001, Zaharidis et al. 2002.)

Ethernet

Ethernet is the default local-area network (LAN) technology for PCs and perhaps the most widespread and well-known LAN technology used in corporate and enterprise networks. Ethernet is also widely used in homes due to the availability of low-cost devices and wiring. The term Ethernet refers to the family of local-area network (LAN) products covered by the IEEE 802.3 standard. Four data rates are currently defined for operation over optical fiber and twisted-pair cables:

- 10 Mbps 10Base-T Ethernet
- 100 Mbps Fast Ethernet
- 1 Gbps Gigabit Ethernet
- 10 Gbps Gigabit Ethernet

The strengths of the standard include fast and reliable transmission, easy implementation, management, and maintenance, low-cost network implementations, extensive topological flexibility for network installation, and interconnection and operation between devices regardless of manufacturer. (Cisco 2006)

The standard has several drawbacks that have slowed down its mass deployment as an intra-home technology besides connecting the computer to DSL modems. First, it requires new wirings that are not already present. In new buildings this problem can be easily dealt with by wiring the new buildings with Category 5 or better cables, but as one of the interviewees stated, it is still not always the case. Second, the technology is PC-centric requiring some knowledge of networking to set up. Third, Ethernet does not support quality-of-service (QoS) and is therefore not entertainment-friendly. Lastly, because of the broadcast nature of Ethernet copyrights of content becomes an issue and content providers have therefore developed encryption methods, to make sure the consumer has rights to the content. (Rose 2001, Zaharidis et al. 2002.)

Power Line Communication (PLC)

Power Line Communication has the major attraction of reusing the power lines of the home. The existing power lines can be used as both a last mile technology, or as an intra-home network technology.

Despite the advantage of reusing existing home wiring the technology has some major downsides to it. The power line carrier was not specifically designed for data transmission and provides a harsh environment for it. Varying impedance, considerable noise that is not white in nature and high levels of frequency-dependent attenuation are the main issues. Noise in power lines is a significant problem for data transmission. This is because it rarely has properties similar to the easily analyzed white Gaussian noise of the receiver front ends. Home devices plugged into the network are sources of noise. To protect against the severe noisy conditions and fading in the power line channel, very high levels of error control coding need to be provided. Hence, products based on the Discrete Multi-tone (DMT) standard only have achieved data rates up to 14 Mbps, instead of the theoretical data rate of 100 Mbps. Another major issue is the radiation emission of power lines and its effect on other frequency bands for communication. In addition security and privacy of PLC are still problems, because the power lines of neighboring homes are not necessarily fully separate from one another, the networking signals generated in one home may show up on the power line in another home.

Wireless Local Area Network (WLAN)

Wireless local area networks are designed to provide coverage in a small area, such as a building, hallway, park, or office complex by extending or replacing wired LANs (such as Ethernet). The main attraction is the flexibility and mobility supported by a wireless LAN; bandwidth considerations are secondary. (Varshney & Vetter 2000.)

IEEE 802.11 is the most mature wireless standard for wireless local area network communications. The standard, commonly known as WLAN or Wi-Fi (Wireless Fidelity), was originally developed in 1990 primarily for indoor use in offices. Lately due to reduced costs the technology has become popular in private homes as well. The IEEE 802.11 is a wireless version of the Ethernet standard. Several sub standards, such as the 802.11b, 802.11g and the latest 802.11n, have been released by the IEEE, the main improvements being in transmission rates and security. The standard supports several wireless LAN technologies in the unlicensed bands of 2.4 and 5 GHz support theoretical transmission rates of 54 Mbps in the 802.11g and 248 Mbps in the 802.11n standards. Besides the radio interface, an infrared technology is supported as well by the standard, but has not been adopted by manufacturers.

Bluetooth

The Bluetooth wireless technology is an attempt to replace the cables between different devices, mainly small portable ones such as laptops, cell phones, digital cameras etc. The technology focuses on providing flexible and reconfigurable interconnection between several personal devices from different manufacturers. (Bisdikian 2001.)

The Bluetooth technology is used in a wide range of applications such as mobile phones, automobiles, medical devices for use by consumers, industrial markets, enterprises, etc. The benefits of the Bluetooth technology include low cost and power consumption, good interoperability between different types of devices, and the ability to simultaneously handle both data and voice transmissions, enabling such solutions as hands-free headset for voice calls, printing and fax capabilities, etc.

The downsides of the technology include the rather short range and the interference with other devices such as microwaves using the same 2.4 GHz band. Also the low bandwidth capability of 3 Mbps permits only limited and dedicated usage, and prevents Bluetooth being used for in-house multimedia networking. (Bluetooth.com 2007, Zaharidis et al. 2002.)

UWB

Ultra-Wideband (UWB) technology is loosely defined as any wireless transmission scheme that occupies a bandwidth of more than 25% of a center frequency, or more than 1.5 GHz. The technology is aimed to and is based on optimally sharing the existing radio spectrum resources instead of searching for new, but possibly unsuitable bands. The potential classes of UWB devices are many, ranging from imaging systems (ground penetrating radar, wall-imaging systems, medical systems, and surveillance systems) to vehicular radar systems, and communications and measurement systems. In terms of digital homes UWB can be used to implement intelligent networks and to control sensor and security systems in the home. It is widely anticipated that UWB-RT (UWB Radio Technology) will have a sizable impact on the multimedia- driven home networking and entertainment market, and will allow implementation of intelligent networks and devices enabling a truly pervasive and user-centric wireless world. (Porcino & Hirt 2003.)

Zigbee

Zigbee is a wireless standard operating in the 2.4 GHz spectrum along with Bluetooth and Wi-Fi. Bluetooth was not suitable for automation, because it was too expensive and power consuming for the applications requiring automation. Zigbee has not yet become a commercial success, but the developers of the technology hope for Zigbee chips to open up the market for remote wireless control of light fittings, heating, ventilation, and security systems in commercial and residential buildings. Zigbee is much like Bluetooth, but it has a lower data rate and is more energy efficient due to the snoozing of the devices while inactive. (Evans-Pughe 2003.)

2.3 Digital Home Standards

A typical household has up to ten or even more digital devices, which are usually manufactured by several different equipment producers. Rarely have consumers concentrated on a single manufacturer and the more devices one possesses the more difficult it becomes. Interoperability of different devices is a key driver of the digital home business. Difficulties often occur when trying to connect two different devices together.

2.3.1 DLNA

Digital Living Network Alliance (DLNA) is a cross-industry alliance of leading companies in consumer electronic, computing and mobile device industries. DLNA has well over 200 member companies including such leaders in their own fields as Sony, Nokia, Microsoft, Dolby, IBM, HP, and the list goes on. (DLNA 2007.)

The alliance develops and tests interoperability between media servers such as advanced set-top boxes and personal video recorders (PVR), and media players such as TV monitors, home theaters, and mobile devices including MP3 players and digital cameras. DLNA aims to provide manufacturers guidelines for developing interoperable electronic devices with their own and other companies' products. The guidelines are based on recognized industry standards. The development process is based on usage scenarios and technical requirements of the scenarios. Besides writing guidelines, DLNA grants certificates to products meeting its requirements for interoperability.

The DLNA guidelines focus on connectivity and networking, device discovery, remote control, media management, media format profiles, and media transport. The first version 1.0 of the DLNA guidelines depicts pulling media from a media server (e.g. personal computer (PC)), to play on a media player (e.g. digital TV). Pushing content to media players as well as interoperable remote control are both to be included in the later versions of the guidelines. The latest version 1.5 of the guidelines was published in 2005 and the certifications started in 2007. At the moment DLNA still only focuses on the interoperability of imaging, audio, and video devices. Other aspects, including home automation, are to be added in the future. (DLNA 2004, Schilit & Sengupta 2004.)

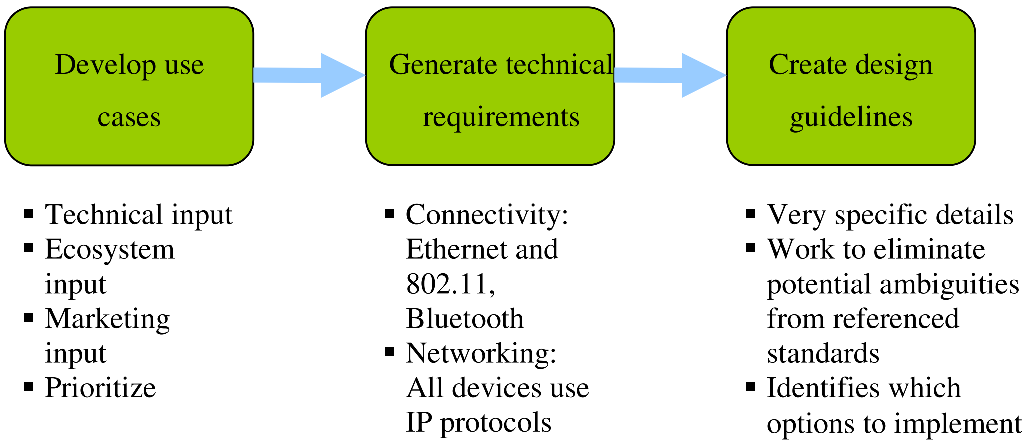

Figure 2.2: DLNA development process

2.3.2 UPnP

The Universal Plug and Play (UPnP) is a framework designed to enable developers to create products that free their customers from configurations, setup, and maintenance of the home network. Besides having some of the largest companies in the industry developing the framework (Microsoft, Intel, etc.), UPnP has the advantage of being included in Windows XP and Vista and in addition incorporated into standards by the DLNA.

The UPnP architecture supports zero-configuration and automatic discovery whereby a device can learn about the presence and capabilities of other devices and leave a network smoothly and automatically without leaving any unwanted state information behind. UPnP automatically assigns IP addresses and DNS names to devices. The framework defines interoperability standards around existing lower-layer network protocols, such as IP, UDP, TCP, and HTTP, rather than at the application layer

UPnP technology enables digital content to be accessible from various devices in the home regardless of where the media is stored. It enables data communication between any two devices under the command of any control device on the network. UPnP technology is independent of any particular operating system, programming language, or network technology. (Intel 2007, Schilit & Sengupta 2004, UPnP 2007.)

2.4 Current Digital Homes

This subsection discusses some of the key players and current solutions of the digital home market. Communication companies are mainly interested in the network functions of the home server. Game companies are trying to develop a home entertainment server based on their game consoles. Consumer electronics companies also propose their own architecture of the home server adding PC functions to the consumer electronics products such as refrigerators. (Bae et al. 2003.)

2.4.1 Digital Home Devices

This section gives definitions to the different components of digital homes and lists the devices included in the average digital home of this study.

Media Center

The term media center refers to a central device in a digital home with enhanced media capabilities. A traditional PC or a specially designed PC for media use may be used as a media center. The media center has a large storage space for all the content and information needed in the home environment. As the media center is not used in front of a desk as a PC is, a remote control operable user interface for entertainment functions is required. The user interface distinguishes the media center from a media server, which has only storage capabilities. Besides a PC, a gaming console may also be used as a media center, but to act as the central media device in the household a TV tuner needs to be integrated or hooked up to the console. This applies also to the PC. The definition of a media center given here does not restrict it to a specific single device, but as digital homes differ from one another, so can the media center. As said, different devices can act as a media center, as long as they meet the following criteria: server-like storage capabilities, remote control operable user interface and a TV tuner.

Home Gateway

The home gateway, sometimes also referred to as residential gateway, is the central device connecting the digital home devices together. It provides all the IP connected devices in the home with IP addresses and if necessary, allows the devices to operate behind a single IP address using network address translation (NAT). The home gateway, typically just a single small box, integrates often if not all, a number of the following functions: an Ethernet switch, firewall, IP router, a WLAN access point and an xDSL or cable modem. If a modem is integrated into the home gateway, it is the interface between the home network and the operator's network, providing access to the public IP network.

The home gateway was at first just for bringing IP connectivity to the home. Currently, operators are integrating value added services, such as multicast TV and voice over IP (VoIP) with data transport. This integration is referred to as triple play. In the near future operators plan to open the service delivery chain. The roles currently assumed by the Internet access provider will be split between connectivity provisioning and service provisioning. Instead of being tied to a single service provider for television and phone over IP, the end user will have a variety of choices and will gain from competition in both price and diversity. This business model is referred to as multiplay. (Royon & Frénot 2007.)

Mobile Handset

Mobile handsets have the capabilities of connecting to the home network both in and outside the home. WLAN or Bluetooth can be used inside and GPRS or 3G technologies outside the home. This allows users to export and import content to and from the home.

Other Devices

A variety of different digital devices, IP connected or not, can be connected to the home network to provide additional value to the user. As this thesis is restricted to the data and entertainment devices, home automation devices are not taken into account here. The devices listed below in *Table 2.4* are the ones taken into the calculations of the techno-economic analysis discussed later in the thesis.

Table 2.4: Digital home equipment

Mobile	Consumer Electronics
Cell phone	Television
MP3 player	Digital TV receiver
	IPTV Set-top-box
	Personal Video Recorder
	DVD player
PC Internet	DVD recorder
Computer	Home theater system
Laptop	Video camera
Printer	Digital camera
WLAN base station	Game console
VoIP equipment	HD-DVD/Blu-ray player

2.4.2 Key Players in the Digital Home Market

This subsection defines the different categories of players operating in the Finnish digital home market. Only the most relevant players present in the scenarios of the techno-economic analysis of this thesis are discussed here. Besides the definitions, a brief look is taken at the key players of the categories.

Local Telecom Operators

In this thesis the focus is on network operators offering their products and services to private households, i.e. digital homes. Companies focusing solely on corporate customers are excluded. The term network operator or telecom operator for the purposes of this thesis refers to service providers offering an IP connection to private users, i.e. an access to the Internet.

A few large companies dominate the telecom operator business in Finland. Elisa and TeliaSonera are the two major broadband access operators in Finland; both also operate mobile access networks. Saunalahti operates both broadband and mobile access networks as well, but it is owned by Elisa. In addition to the two dominant players, DNA is a smaller company focusing on the mobile access network business and Finnet, a group of small local telephone companies, on the fixed network business. Welho operates in the cable network of the largest cities and offers broadband services and TV broadcasts. Besides these large companies a number of less significant companies operating in smaller areas also exist in the market.

Global players

In this thesis, the term global players refers to large companies operating worldwide, that have developed a wide selection of digital home products and services to the market. This subsection briefly describes some of the key global players in the market, also referred to as software platform companies.

Apple

Apple is the leading company in the portable music player and digital content sales, with over 100 million sold Apple iPods and over two billion downloaded songs from the iTunes music and video service. Apple offers a wide range of digital home devices and services with the Mac computers in addition to the music players and online music and video store.

Apple TV is a small set-top box that plugs into a flat-panel TV and wirelessly connects to a Mac or PC over an 802.11n network, allowing digital content from iTunes to be synchronized to the hard drive of the Apple TV or directly streamed from the Internet (Kratzit 2007). The converging of the TV and the computer itself is a huge business opportunity, but Apple’s intentions and goals with the Apple TV can be expected to be in boosting the newly introduced possibility to purchase movies and TV series from iTunes. Apple has distribution deals with two major studios and is looking to sign more to begin offering video rentals through iTunes at some point in the future, possibly sometime in 2008 (Apple 2007).

Microsoft

Microsoft has been the dominant player in the PC software business for a long time and its position does not seem to be considerably threatened even by the emergence of open source software. During the past years Microsoft has aimed to grab a larger share of the digital home market by introducing new products such as the Media Center platform, XBox 360 game consoles, and mobile handsets based on the Windows Mobile platform. Microsoft tries to stay in control of the intelligence in its digital home equipment, by including the Windows OS in all of its platforms.

Following Apple's success in the digital content and player market, Microsoft has included television shows and movie downloads to its XBox Live service, which was previously only for downloading games and multiplayer gaming services. With this transition Microsoft aims to turn the XBox 360 game console into a central device for entertainment in the digital home. (Microsoft 2006.) In addition to offering videos, Microsoft also sells music and other content online on its Zune marketplace to be played on its portable music player Zune (Zune 2007).

Nokia

Nokia's main focus is on its mobile handsets and their development. In terms of the digital home Nokia's devices enable users to connect to the home network and move content in and out of the home. Nokia is working towards interoperability with its own devices and other digital home devices, further supporting the playback and storage function of the mobile handsets. Mobile handsets and especially the multimedia handsets developed by Nokia are not only mobile phones, but also include functionalities of other digital home devices, such as digital music player, radio, camera, web browser, and e-mail. The convergence of such functionalities to a single mobile handset enables the expansion of the digital home services outside the consumer premises. (Nokia 2005.)

Nokia is expanding from a focus on mobile devices to offering a range of Internet services with the introduction of the Ovi service. Ovi is the gateway to Nokia's Internet services, including the Nokia Music Store, Nokia Maps, N-Gage games and web communities, enabling people to access their content, communities and contacts from a single place. (Nokia 2007.)

Sony

Sony has been a dominant player in the consumer electronics market for a long time with a wide variety of products such as televisions, sound systems, DVD players and so forth. Sony is also one of the largest game companies in the world with their Sony PlayStation and PlayStation Portable (PSP) gaming devices.

Today Sony is trying to acquire a large share of the converging digital home market with the Sony PlayStation 3 (PS3), a single central device aimed to handle much of the digital entertainment media in the home and even to be used for data as well. In addition to DVDs and CDs, the PS3 supports the Blu-ray technology. The PS3 resembles more and more a traditional PC with WLAN connectivity, flash memory card readers, USB, HDMI and Ethernet interfaces, and a 20-80 GB replaceable hard drive. The game console supports installation of other operating systems onto the device, such as Linux.

Like the other global players mentioned earlier in this section, Sony is attempting to enter the digital content market by introducing a unified online service for the PlayStation 3 console, much like Microsoft's Xbox Live network. The service is not only for online multiplayer gaming with peers but customers are also able to purchase games and additional features along with some of PlayStation 1 and PlayStation 2 titles online from the PlayStation Network. (Sony PlayStation 2007.)

Other Local Service Providers

Local service providers are considered in this thesis to be different types of businesses offering digital home related services. These services include selling or leasing digital equipment, different types of connections or any kinds of management services. Small independent retailers, large retail chains, small local network owners, independent entertainment or data service providers, and local IT janitors are the types of businesses which fall under the category of other local service providers.

2.5 The Development of the Digital Home Market

This chapter describes the outlook of the Finnish digital home market based on the current situation and past development. The market was estimated by using the existing data to predict the development of the penetration of certain electronic devices and different types of connections in the Finnish households. The results of the literature study and analysis was a start for the thesis and a basis for the techno-economic analysis explained in detail later on. Besides studying existing data and literature, the results were shown to experts for comments and validation.

2.5.1 Digital Homes 2007-2012

The digital home today is a scattered collection of computers, televisions, telephones and additional devices related and possibly connected to the above mentioned. The home today is divided into three separate groups: the computing world with the computers and the connected devices, such as printers, MP3 players and digital cameras, the broadcast world including TV and radio with the additional set-top-boxes, DVD players, etc., and last the telephone world with the traditional PSTN and the mobile phones operating in GSM and 3G networks. The three worlds are almost completely separate and there is very little data transfer and interoperability between the three worlds.

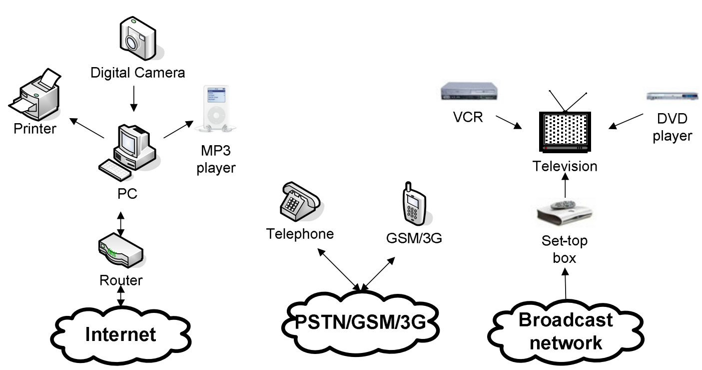

Figure 2.3: Digital home 2007

By the end of the study period, in 2012, these three separate worlds will converge more or less towards a single digital home. The electronic devices in a home will be more interoperable with one another and be connected to a central server or a home gateway, through which all the traffic from the separate devices is carried to and from the outside world and the Internet. The devices on the left hand side of *Figure 2.4* are IP connected devices and act as mediators to the right hand side. These devices are techno-economically more interesting and important, than the ones on the right hand side, due to their role as traffic creators via the home gateway to the outside world. The non-IP connected devices mainly act as input or output devices to the IP-connected devices.

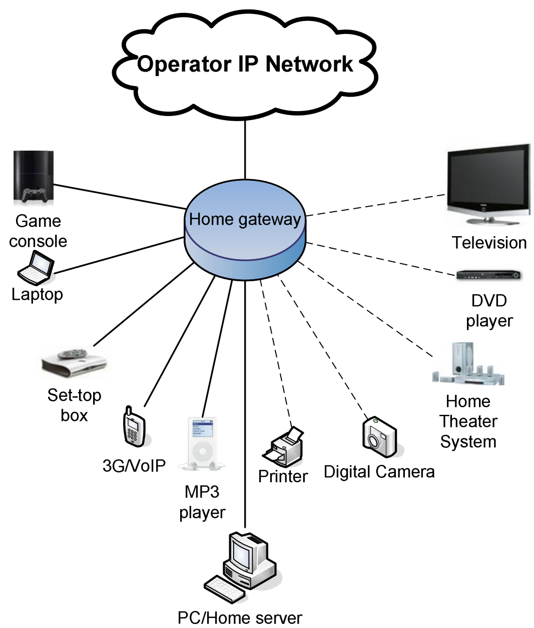

Figure 2.4: Digital home 2012

Some of the devices in *Figure 2.4* are likely to not just communicate with one another, but to converge together into one device. Set-top-boxes used to receive digital television broadcasts are already strongly converging with televisions, in fact most televisions sold today are already equipped with a digital tuner. Regular digital cameras and MP3 players are converging into features on a cell phone, along with the trend of cell phones turning into multidevices.

2.5.2 Connections

How the home is connected to the outside world is vital for the development of the digital homes. The penetration of cell phones is constantly drawing closer to full and with the new and developing mobile data transfer technologies the mobile phones are likely, as is already happening, to develop towards small portable computers instead of just telephones. Faster data transfer rates and features such as cameras and music players, enable mobile phones to become a way of transporting and accessing content in and out of the home.

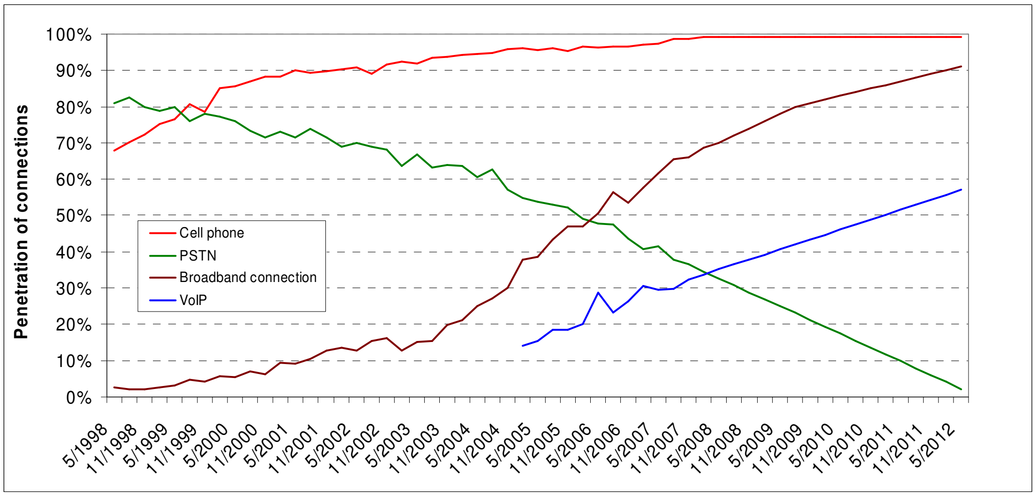

Figure 2.5: Connections in Finnish households 2007-2012 (Statistics Finland 2007)

The average speed of the broadband connection in the home will be a critical factor in the development of the digital home market. The estimation of the broadband connections' price development over the next five years was divided into four classes: 1 Mbps, 2 Mbps, 8 Mbps, and 24 Mbps and over, which at the moment of the study means connections up to 100 Mbps.

The consumers are willing to pay a fixed amount of money around 30€-50€, for their broadband connection. This sum does not vary significantly over the years, but the received service does. As can be seen in *Figure 2.6*, the price of the 8 Mbps connections is predicted to decrease to the current price level of the 2 Mbps connections by the year 2010 and respectively the connections of 24 Mbps and faster by the year 2011.

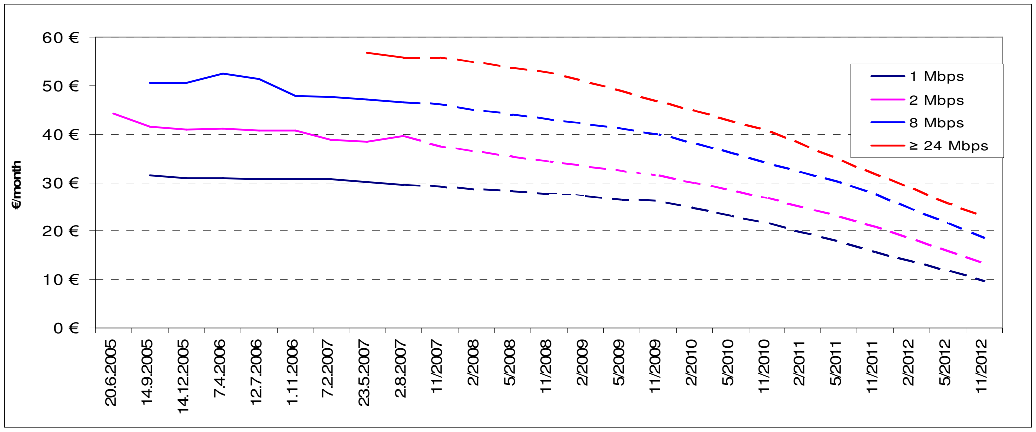

Figure 2.6: Price development of broadband connections (Ficora 2007)

The prices of broadband connections are valued in 2007 Euros throughout the study period, i.e. the prices are not affected by inflation. The same applies to all costs and prices used in this thesis.

2.5.3 Digital Devices

The penetration of different electronic digital home devices, including computers, game consoles, cell phones, etc., in an average household is projected to grow steadily over the next five years. The linear estimates depicted in *Figure 2.7*, are rather rough, but instead of being exact, they valuably indicate the direction and the rate of the change.

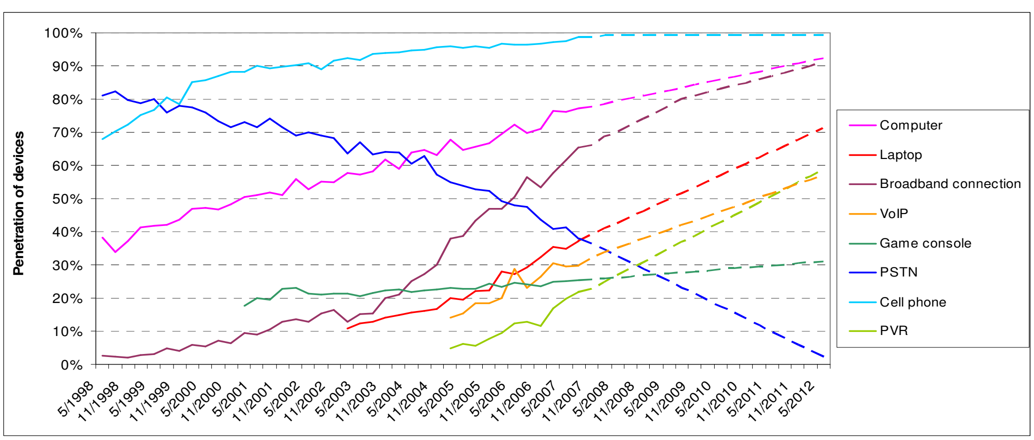

Figure 2.7: Penetration of connected devices in Finnish households (Statistics Finland 2007)

The number of connected devices in an average Finnish household and the number of devices in at least 85% of the households are very important numbers, because if the estimate of 85% of households having eight or more electronic devices by the year 2012 holds out to be true, there can be expected to be a real market for the digital homes and especially for digital home management. The estimate for the number of devices is based on previous data, as was the case for individual devices. However, the estimate emphasizes the last two years when the growth has been faster, and the pace can only be expected to speed up along with the improvement of usability and reliability of equipment.

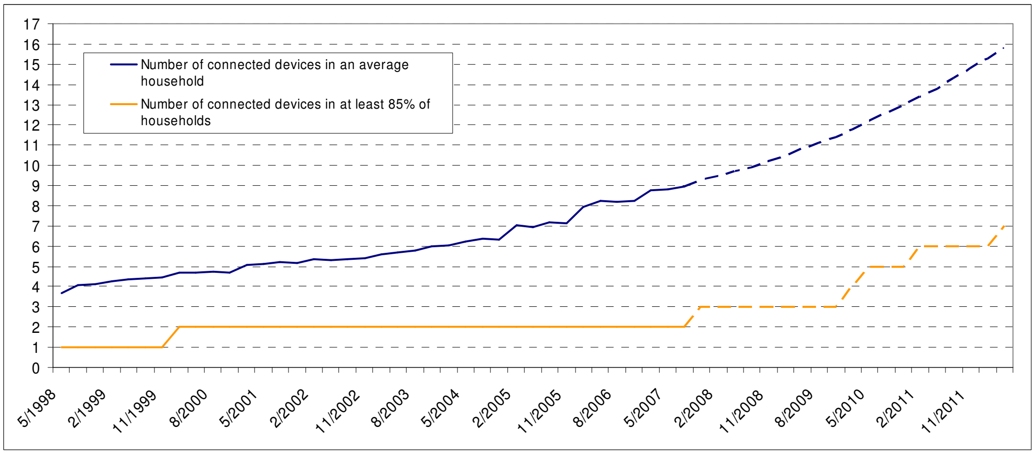

Figure 2.8: Number of connected devices in Finnish households (Statistics Finland 2007)

2.5.4 Consumption habits of Finnish consumers

The Euros spent on communication by an average Finnish household have in fact almost tripled from 1990 to 2002 (Statistics Finland 2003). This rise in the standard of living and the growth of disposable income of Finnish consumers has been greatly affected by the overall growth of the economy and low interest rates. Lately, interest rates and inflation have risen, causing the living costs to also rise and force households to slightly cut back on their disposable income, of which communication makes up a large portion. If the interests and inflation keep on rising or even stay at the current level, basic living costs will rise along. This could put a stop to the growth of the disposable income and communication and other expenditures related to digital homes. However, the amount of money spent on communication is still expected to grow during the study period.

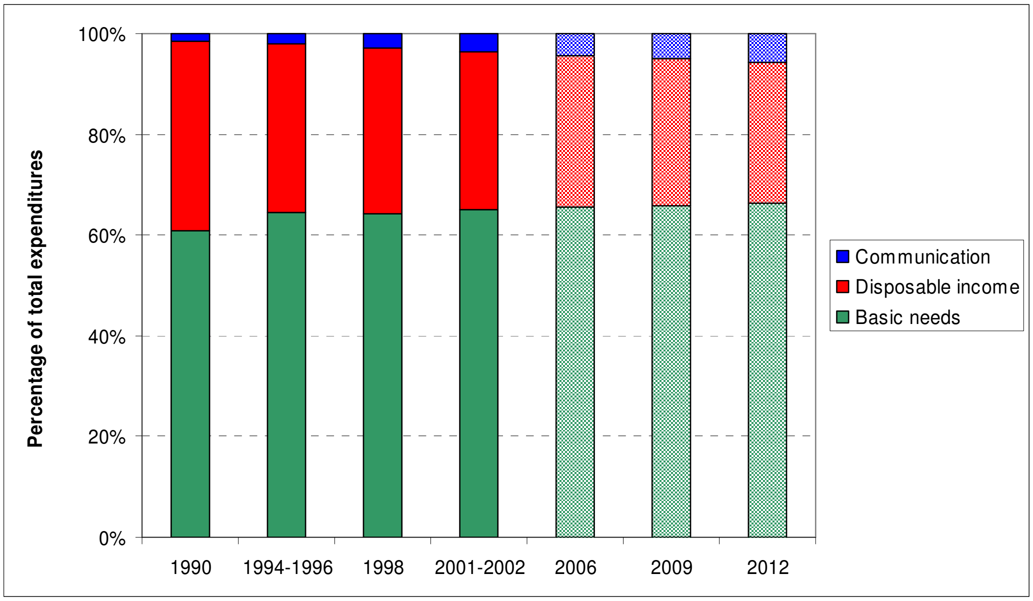

Figure 2.9: Consumption distribution (Statistics Finland 2003)

The Finnish customers are used to owning most, often all, of the electronic devices and equipment in their homes. With the increasing number of devices in a single home and the complexity of having these devices communicate with one another, it can be assumed that there will be a demand for rental of the digital home devices with management and service included in the bundle. This should open up whole new possibilities for operators in terms of becoming equipment retailers instead of just providing the connections. By bundling the equipment and the services, operators can become strong players in the market of digital home devices and competitors to the traditional equipment retailers.

2.5.5 Usage of the Internet

According to studies conducted by Statistics Finland in 2004, 2006 and 2007 there is a significant change in Internet usage locations in Finland (Statistics Finland 2007b). From 2006 to 2007 the numbers have stayed fairly the same, but the growth in users using the Internet either at home or at a friend's home from 2004 to the current level, play an important role in the digital home market. The percentage of 15-74 year olds using the Internet at home has grown from slightly under 50% in 2004 to 70% in 2007 and at a friend's home from under 20% close to 30% respectively. This is naturally the result of broadband connections becoming more common in private homes. In terms of the Digital home, this growth is needed for the customers to purchase and use more devices that can be connected together and thus allows the operators to introduce new services.

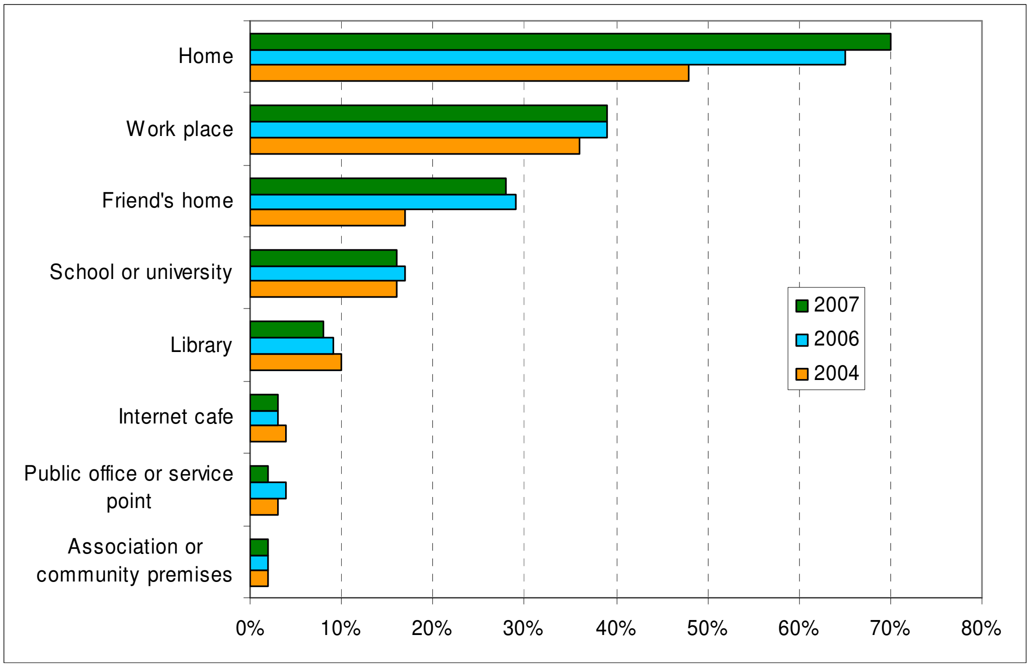

Figure 2.10: Internet usage locations (Statistics Finland 2007b)

2.5.6 Intra-home network technologies

The possible solutions for the intra-home network have been described above in *section 2.2.2.* An estimate of the market shares of different intra-home technologies is shown in *Figure 2.11*. The figure depicts the development of the number of particular network interfaces in the Finnish market. The predictions are based on the forecasts made for separate electronic devices, in which these interfaces are physically located. The figure present the number of interfaces integrated into the devices at home, not necessarily which interfaces and technologies are in use. The graphs are complete estimates and the actual numbers may be off the real values even quite radically. However, the figure valuably points the direction of the change and evolution happening in the market. The overall number of intra-home network interfaces can arguably be expected to grow significantly during the study period, as the number of electronic devices, and the number of different interfaces integrated into a single device, are expected to keep increasing at the same time.

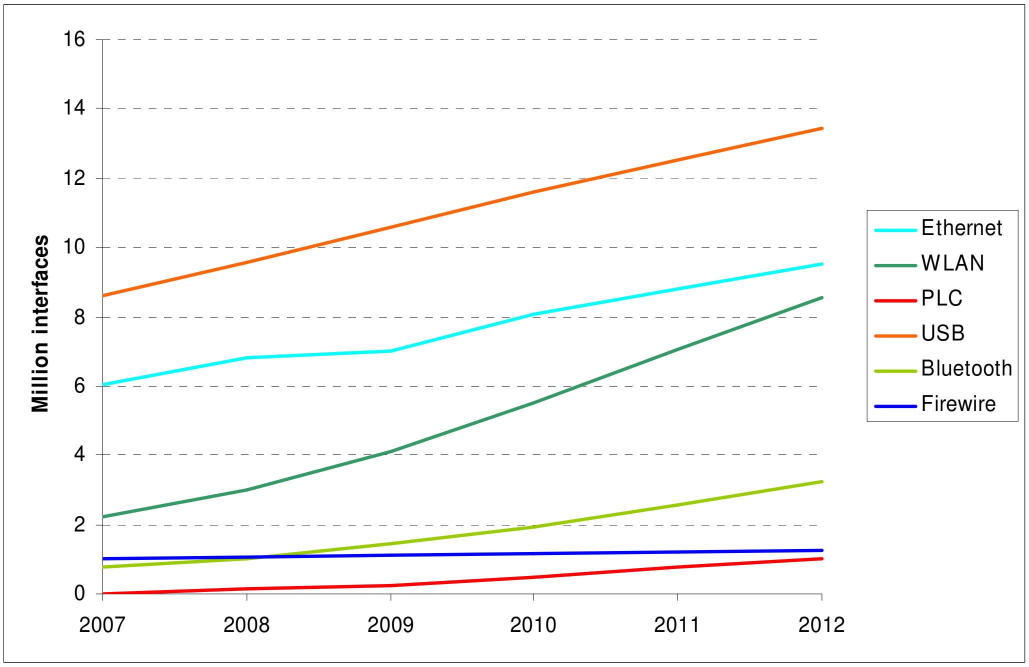

Figure 2.11: Different intra-home network interfaces in Finland

The fastest growing technology in the estimate is the Wireless LAN, which indicates the transition to more wireless home networks. However, wired solutions such as Ethernet and USB are also growing rapidly suggesting that the consumers will have more options for connectivity in their devices. Besides more interfaces being integrated into a single device, the graphs follow the overall growth of the digital devices.

Wireless

Wireless technologies are very appealing to consumers, as more and more devices need to be connected together increasing the popularity of WLAN and Bluetooth. The wireless technologies are considered to have issues with transmission rates, power consumption, reliability, and security, but the technologies are constantly improving and already today e.g. WLAN and Bluetooth are adequate for a variety of tasks in the digital home. With further improvement the possibility of replacing wires becomes reality in a growing number of usage cases. The IEEE 802.11 standard will be used in continuous data transmission, which requires considerable bandwidth, and between devices not necessarily in the same room. Bluetooth on the other hand will be in use where the data transmission is lower and more infrequent, e.g. control devices.

Fixed

Despite the development of wireless technologies, Ethernet still remains superior in terms of reliability and transmission rates. As transmission technologies have developed, content has also become heavier in terms of number of transmitted bits. With the emergence of IPTV and High-definition (HD) quality content, the required bandwidth only grows. Therefore Ethernet along with other wired technologies is still very much required.

Power-Line Communications cannot be expected to become a real contestant for the existing technologies during the study period. Despite the reuse of existing wires, the limitations of the technology and the lack of a single standardization body do not allow PLC to become a common interface in the home. Devices are currently not integrated with PLC-interfaces, which strongly limits the spreading of the technology. For consumers to start adopting a new technology it cannot create additional costs, which exceed the consumer surplus. Therefore the interfaces need to be integrated to the devices, to avoid unnecessary costs for the consumer. Home automation and control is a possible area of utilization for the technology, due to the low and infrequent nature of data transmission. The rather positive estimate of the growth of the number of PLC interfaces is based on an assumption of the interfaces being integrated into home automation and control devices. This does not necessarily mean the technology will actually be used, but that the number of PLC interfaces in electronic devices will grow.

2.6 Digital Home Management

Each new device in the service path adds complexity to the process of initial installation, coordination, reconfiguration, fault diagnosis, and restoration. Consumers have expectations and demands for the reliability of products and quality of service in case of failure. If the performance, capabilities and simplicity requirements are not met, consumers are unlikely to adopt and pay for digital home products.

Today the remote management of digital homes is restricted to help desks advising users on the phone or via e-mail. The help desk of the broadband service provider is often the first to be contacted in case of need for assistance in a problematic situation. The majority of calls are initiated during the installation process and at times of service failure. The cost of a single help desk call is comparable to the revenue for a whole month of broadband access service. (Nikolaidis et al. 2007.) The more management information that can be given to the consumer in a meaningful manner about the health of their home network devices, the less likely they are to require support. Should a consumer require support for a device, they should know who to call and not be faced with the situation where they are passed on to another company without satisfactory resolution of their problem. (DLNA 2004.)

As the consumers contact the help desk, operators often have to base their first diagnosis solely on how the consumer describes the problem. In some cases operators are able to configure, diagnose and partially fix their networks remotely but are still blind beyond the home gateway. The CWMP (CPE wide area network (WAN) Management Protocol) of the DSL forum addresses management not only in DSL, but also in any IP-based multi-service environment. CWMP is a bidirectional remote management protocol for CPE, intended for communication between CPE and the management entity known as the auto-configuration server (ACS). It supports functionality to manage the CPE, including auto-configuration, dynamic service provisioning, software/firmware image management, status/performance monitoring, and diagnostics. (Nikolaidis et al. 2007.)

Broadband operators and their help desks are not the only possible direction users can turn to in case of an unsolvable problem. The following have been identified as potential players to take care of management tasks by Nordlund et al. (2007):

- Broadband access operators (e.g. Finnish firms Elisa, TeliaSonera, Welho)
- Software platform companies (e.g. Microsoft, Apple)

- Security software providers (e.g. F-Secure, Norton)
- Other application software providers (e.g. Adobe)
- IT Janitors (e.g. house managing firms, one-man companies)
- Media companies (e.g. Sony BMG)
- Friends or relatives
- End-users

3 Techno-Economic Methodology

Techno-economic analysis is focused on seeking the economic feasibility of a technology. The methodology is used to analyze the economic aspects of new technologies and innovations and associated business models.

Since 1990 several framework programmes funded by the European Union have been carried out related to emerging broadband networks. Because of the digital homes' close relation and dependency on broadband networks, the techno-economic terminology, methodology and tools developed in these programs, are also applicable to the purposes of this thesis with the proper changes.

The original methodology was introduced under the first framework program for communications research, RACE I. The work has continued under successive programs, and has most recently been taking place under the ECOSYS (techno-ECOnomics of integrated communication SYStems and services) research project of the European R&D program CELTIC (Co-operation for a European sustained Leadership in Telecommunications). The first methodology and accompanying analysis tool was SYNTHESYS, a simple geometric model for quantifying duct and cable lengths. The techno-economic assessment methodology implemented into the final version of the ECOSYS tool is based on the work carried out within ECOSYS and its predecessor's RACE 2087 TITAN, AC226 OPTIMU, AC364 TERA projects as well as IST-25172 TONIC project. (Olsen 1999, Lähteenoja et al. 2006.)

The overall objective of the ECOSYS project has been to develop a strategic techno-economic analysis framework, apply it on case studies and draw conclusions and recommendations from that. As the technology solutions develop, the entrepreneurial players are needed to take managed risks to make the change happen. ECOSYS is aimed to provide them with strategic information to back up their decision-making. (CELTIC 2007, ECOSYS 2007.)

The basic procedure for conducting a business case study using the ECOSYS methodology is the following (Bouillon et al. 2002):

1. Make a survey of necessary applications and future needs.
2. Translate the future needs into relevant services and/or architectures.
3. Evaluate the services and/or architectures with the tool.
4. Interpret the tool's economic output and draw conclusions.

Several telecommunication operators in Europe, including Deutsche Telekom, France Telecom, Telenor, and KPN, have used the methodology and approach in practice (Lähteenoja et al. 2006).

The following sections will introduce the most important concepts of techno-economic analysis. The required inputs and outputs will be discussed, as well as risk and sensitivity analysis used to assess the reliability of the results. Finally, the ECOSYS tool used to conduct techno-economic analyses, and the Decisioneering Crystal Ball tool used for sensitivity and risk analysis will be introduced. The structure of this chapter is partially based on Smura (2004) and Heikkinen (2007).

3.1 Inputs to the Techno-Economic Analysis

The market under study in a techno-economic analysis first needs to be modeled in terms of e.g. geographical areas and customer segments to be served, the services to be provided, and the technology to be used to provide the services. In addition a number of assumptions and predictions need to be made e.g. on the level of competition in the market, the penetration rates of different devices and connections, and the price evolution of service tariffs, equipment prices and network components.

3.1.1 Expert Interviews

Expert interviews were conducted mainly to verify the assumptions and predictions made about the development of the digital home market. Instead of structured questionnaire type of interviews, a number of graphs and figures presenting the future of the digital homes were shown to the experts for comments. Based on the comments, the required changes were then made.

3.1.2 Scenarios as Inputs

Scenarios are a valuable tool for evaluating the possible future outcomes of any industry to help decision makers try to make the correct strategic choices. The tool can be applied to any market, but it is particularly valuable when a market is at an early stage such as the digital home market, and high uncertainty is present. Scenarios are not an attempt to forecast what the market will look like after a period of time, but a way to describe the possible future when certain decisions are made.

The ultimate idea of scenario thinking is to give decision makers a space of possible outcomes, so that they can prepare for any of them (Schwartz 1998). The ideology behind the scenario approach is not to attempt to predict the most likely scenario, but to be aware of the possible directions and be able to change the organization accordingly when necessary. To gain value from the scenario planning process for the decision makers, at least two scenarios need to result from the process. A single scenario could come either true or not and would not give decision makers significant help.

The following guidelines have been identified by van der Heijden (1996) for the scenario development and planning process.

- There has to be at least two scenarios to reflect uncertainty. More than four is often too complex to deal with.
- Each scenario must be plausible. The scenarios must show logical evolution from the past to the present.
- The scenarios must be internally consistent: the events within a scenario must have cause/effect relations.
- They must be relevant to the issues that are being researched.
- The scenarios must provide new ideas and insights that can be useful in strategic planning.
- They must produce a new and original perspective on the problem.

These guidelines allow the scenario planner to flexibly choose the construction method for the scenarios, as long as the above guidelines are met. The planner is able to decide what to include in the descriptions, and decide how to cut up the territory into individual scenarios.

It is not enough to describe the market situation after a number of years. The path to the situation must also be explained thoroughly. As van der Heijden (1996) explains it, a scenario is a story, a narrative that links historical and present events with hypothetical events taking place in the future.

Instead of constructing new scenarios, it was found reasonable to conduct the techno-economic analysis of this thesis according to the digital home scenarios developed by Nordlund et al. (2007). The scenarios will be explained in detail later in the thesis.

3.1.3 Total Cost of Ownership

For the classification of the digital home costs, total cost of ownership (TCO) was at first considered as a possible framework. TCO is a purchasing tool and philosophy aimed at understanding the true cost of buying a particular good or service from a particular supplier. TCO includes such elements as the price paid for the item, order placement, research and qualification of suppliers, transportation, receiving, inspection, rejection, replacement, downtime caused by failure, disposal costs and so on. (Ellram 1995.) After careful consideration, classifying the costs to capital and operational expenditures was found to be more suitable for the purposes of this thesis. The framework will be explained in detail in the next subsection.

3.1.4 Capital and Operational Expenditures

The costs of the studied instance in a techno-economic analysis can be divided into capital (CAPEX) and operational expenditures (OPEX). CAPEX consists of the investments to the fixed infrastructure of the company, including network infrastructure and devices, in addition to the hardware required e.g. network management systems and billing and charging systems. These investments are depreciated annually over time. OPEX on the other hand includes all the cost of keeping the company and the network operational. This includes such costs as labor, operating and managing the networks, marketing, sales, customer care etc.

Verbrugge et al. (2005) have categorized the common operational expenditures of a telecom operator into three broad categories: expenditures *to operate an existing network*, *OPEX for setting up a network*, and *non telco specific OPEX*. Since this thesis focuses on digital homes and telecom operators in the digital home business, with the appropriate changes the proposed classification is applicable for the techno-economic analysis of digital homes. The categories are explained below and summarized in *Table 3.1*.

Expenditures to operate an existing network consist of costs specific to the telecom operator business. The category is divided down to seven subcategories, combining all expenditures to operate an existing network. The first subcategory is a telco specific continuous cost of infrastructure, which includes the cost to keep the network operational in a failure free situation. Second subcategory, maintenance, covers the cost to maintain the network or to operate the network in case of a failure. Third, reparation means actually repairing the failure in the network, if this cannot happen in routine operation. The fourth important part of OPEX is the process of provisioning and service management, which provides the predefined service to the customer. Pricing and billing makes up the fifth category. The ongoing network planning activity to continuously improve the network is considered the sixth category; operational network planning. The last category of the expenditures to operate an existing network is marketing, the cost for acquiring new customers to specific services.

OPEX for setting up a network is the second category of operational expenditures. This includes first of all the cost for up-front planning, which denotes all planning done before the decision “let’s go for this approach” is taken. Planning studies to evaluate the building of a network, changing the network topology, introducing a new technology or a new service platform etc. are tasks to be performed here. The second part consists of all the costs related to installing the equipment. This includes the actual connecting and installation of the new component to the network, as well as the necessary testing of the component and installation.

Non telco specific OPEX contains some OPEX subparts that are present in every company; they are not specific for a telecom operator. Non telco specific continuous cost of infrastructure includes buildings to house the personnel, energy for PCs, heating etc. Non telco specific administration includes the administration every company has, like the payment administration for employees, the secretaries, the HR department etc. Pricing and billing on the other hand can be seen as telco specific expenditures and are therefore included in the first category. (Verbrugge et al. 2005.)

Table 3.1: Operational expenditures for telecom operators (Verbrugge et al. 2005)

Category	Subcategories
Expenditures to operate an existing network	Telco specific continuous cost of infrastructure Maintenance Reparation Service provisioning Pricing and billing Operational network planning Marketing
OPEX for setting up a network	First time installation Up-front planning
Non telco specific OPEX	Non telco specific cost of infrastructure Non telco specific cost of administration

3.2 Outputs from a Techno-Economic Analysis

Techno-economic analysis seeks to answer the question, is the investment project in question profitable or not and when it will turn profitable. The measures most commonly used to evaluate the profitability include the project's net present value, internal rate of return, and payback period. In addition a cash balance curve is a useful output of the techno-economic analyses.

Net Present Value (NPV) is generally considered the most consistent of the measures used to evaluate the profitability of an investment project. The NPV rule states that if NPV is positive, the company should invest in the project. NPV is calculated by subtracting the required investment from Present Value (PV). To calculate PV, expected payoffs are discounted by the rate of return offered by equivalent investment alternatives in the capital market, often referred to as opportunity cost of capital, because it is the return foregone by investing in the project rather than investing in securities.

The Internal Rate of Return (IRR) is defined as the rate of discount which makes NPV = 0. The IRR rule is to accept an investment project if the opportunity cost of capital is less than the IRR. The project's internal rate of return, if used correctly, should always identify projects that increase shareholder wealth. The internal rate of return is often preferred over NPV by companies as a criterion for investment decisions. Even though the two measures are formally equivalent when properly stated, IRR has its deficiencies and should be used with careful consideration.

The payback period of a project is found by counting the number of years it takes before the cumulative forecasted cash flow equals the initial investment. When using the payback rule a company defines a number of years as the cutoff date, by which the project needs to pay itself back, if it is to be accepted. The payback rule has two major deficiencies; it ignores all cash flows after the cutoff date and gives equal weight to all cash flows before the cutoff date. Since the payback rule ignores all cash flows after the cutoff date, a firm has to decide on an appropriate cutoff date, in order to use the rule. If it uses the same cutoff regardless of project life, it will tend to accept many poor short-lived projects with negative NPV and reject many good long-lived ones with positive NPV. The discounted-payback rule asks how many periods does the project have to last in order to make sense in terms of net present value? This modification to the payback rule surmounts the objection that equal weight is given to all flows before the cutoff date. However, the discounted-payback rule still takes no account of any cash flows after the cutoff date. (Brealey & Myer 2000.)

3.3 Risk and Sensitivity Analysis

According to Olsen (1999), the predicted service demands, the competition between operators, the costs of network components, and the costs of operating the new network architectures are the main sources of uncertainty for investments in access network upgrades. The same uncertainties can be expected to appear in digital home investments from the operators' perspective. These uncertainties and their effects on the viability of the investment projects are assessed by the means of risk and sensitivity analyses

Pike & Neale (2003) have identified two broad approaches to evaluate these uncertainties and risks on the viability of the investment decision process by the means of risk and sensitivity analysis. Probability analyses or simpler methods such as *sensitivity, scenario, and simulation analyses* aim to describe the rate of risk in a given investment project.

Sensitivity analysis aims to identify the impact of changes to key assumptions on the profitability (e.g. the NPV) of the project. *Figure 3.1* presents an example of how the results of a sensitivity analysis can be plotted in a sensitivity graph to depict the sensitivity of each variable. The steeper the line in the graph, the greater the impact of changes is on the NPV. Sensitivity analysis is widely used to identify the critical factors with the greatest impact on a project's profitability. Despite of the methods simplicity and ability to focus on particular estimates, decision makers should still pay careful attention to the probabilities of the critical factors' deviations from the expected values, as they are not assessed. Therefore the method cannot be used to actually evaluate the risks related to the factors.

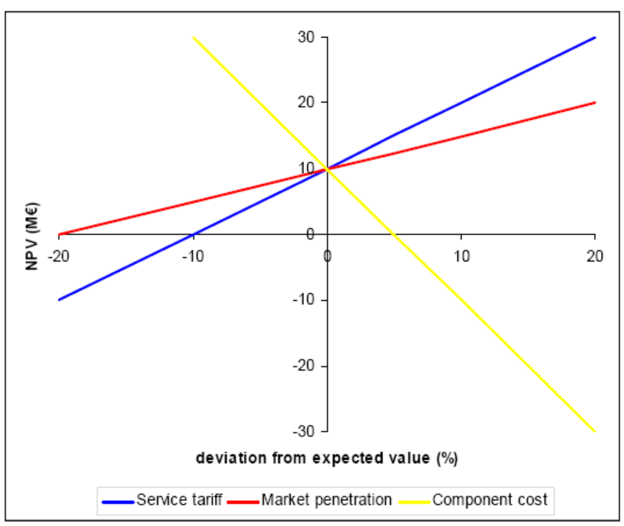

Figure 3.1: Example of a sensitivity graph (Pike & Neale 2003)

Scenario analysis is a method used to find the best and the worst possible scenarios of a project. Instead of changing only one of the key assumptions like in sensitivity analysis, several if not all variables can be changed simultaneously in scenario analysis.

Simulation analysis is an extension to scenario analysis where hundreds of possible combinations of variables are generated according to a pre-defined probability distribution, e.g. Monte Carlo simulation. Each of the hundreds of scenarios produces an NPV, and the NPVs from all the scenarios all together form a probability distribution as the outcome of the simulation. The down side of Monte Carlo simulation is the difficulty of forming the necessary probability distributions for all of the variables. (Pike & Neale 2003.)

3.4 Analysis Tools

Several tools exist for techno-economic analysis. The ECOSYS tool, for building the model of the case and the Crystal Ball tool for analyzing the model are presented in the following subsections.

3.4.1 ECOSYS Tool

For the results of a techno-economic analysis to be of value and useful, identifying and quantifying the cash flows, revenues and costs, accurately is of great importance and difficult in any type of market.

The ECOSYS tool is a Microsoft Excel based techno-economic analysis tool developed in the ECOSYS project already presented previously. ECOSYS aims to evaluate various business cases emerging in the fixed and mobile communications industry. Estimating the return on investments (ROI) and other performance indicators for a successful business requires a firm understanding of the changes in value networks in the industry and identification of business models suitable for the future. (Kaleelazhicathu et al. 2004.)

The ECOSYS framework presented in *Figure 3.2* depicts the main principles of the ECOSYS methodology and the vital inputs and outputs of the framework. The framework converts the generalized concepts discussed earlier in this chapter to a functional framework. The components database makes up the heart of each model and holds the cost figures for the network components, such as cost evolution, operation, administration and maintenance (OA&M) costs, and manufacturing volume. This information is gathered from operators, suppliers, and standardization bodies.

The next step of a network evaluation is to specify the services provided to the customers, define the network architectures for the selected services and a geometrical model needs to be identified for the calculation of cable lengths and civil works for their installation.

The last step is to model the market evolution by predicting and estimating the future market penetration and the tariffs associated with them, according to the operators' policies. This information can be gathered by conducting expert interviews and surveys.

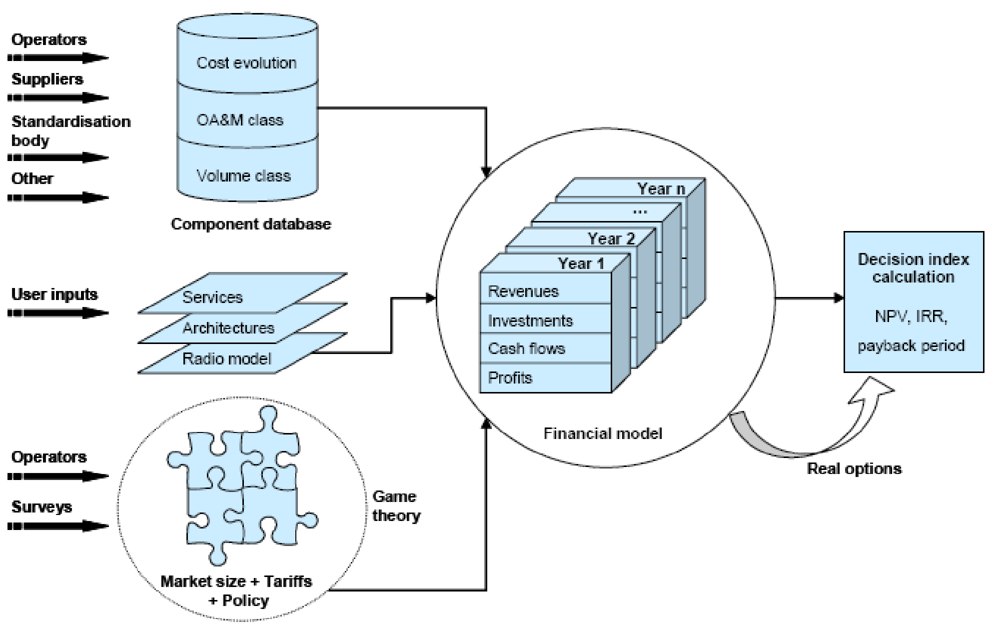

Figure 3.2: Calculation elements in the ECOSYS tool (Lähteenoja et al. 2006)

Using the input data discussed earlier and the financial model, the ECOSYS tool calculates the revenues, investments, cash flows and profits of the study network architectures for each year of the predefined study period. In addition to the financial figures the tool calculates critical indexes (NPV, IRR, payback period) for the evaluation of the investment project's profitability. (Lähteenoja et al. 2006.)

The ECOSYS tool itself is not used in this thesis, due to its lack of applicability to the techno-economics of digital homes from the homes' perspective. However the methodology and guidelines of ECOSYS were used to build a model depicting the techno-economics of digital homes using Microsoft Excel.

3.4.2 Crystal Ball Tool

Crystal Ball is a Microsoft Excel based graphically oriented analytical tool designed to help make decisions by performing simulations on spreadsheet models. Instead of a stand-alone spreadsheet calculation model providing a single result at a time, the Crystal Ball tool can be used to randomly generate thousands of values for each uncertain variable. Crystal Ball uses the Monte Carlo or the Latin Hypercube Sampling method, to forecast the range of results possible for a given situation and confidence levels for the results.

The basic process for using Crystal Ball is to:

1. Build a spreadsheet model that describes an uncertain situation.
2. Run a simulation on it.
3. Analyze the results.

As outputs the Crystal Ball tool produces simulation forecasts based on the assumptions made as inputs to the simulation. The tool runs a user specified number of simulations based on pre-defined probability distributions, assumptions, for each of the variables. As a result the tool produces a probability distribution from the hundreds of single scenario results for a given value, forecasts. (Decisioneering 2006.)

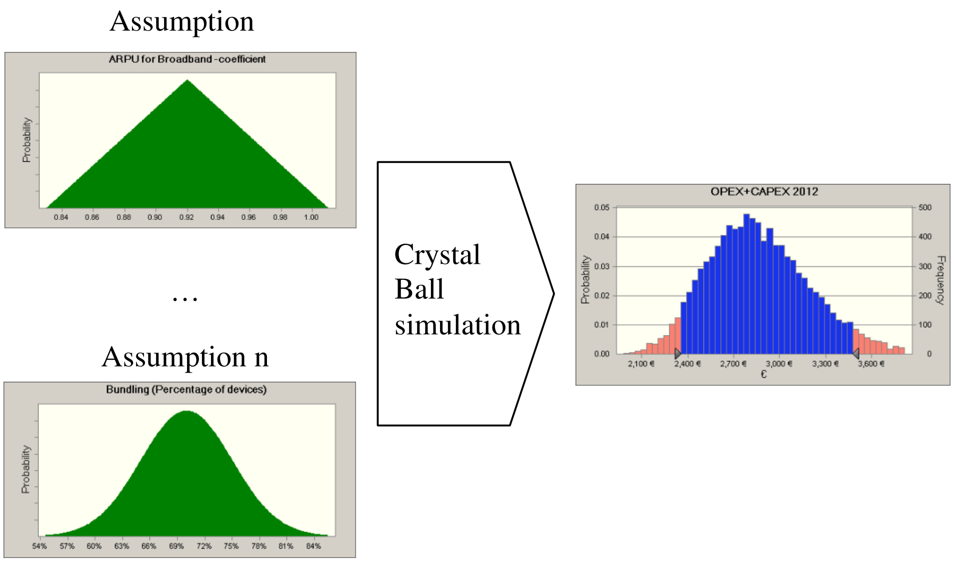

Figure 3.3: The principle of the Crystal Ball simulation method

Crystal Ball also provides several additional tools. The Tornado Chart tool measures the input of each model variable one at a time, independently, on a target forecast. The inputs are the target forecast and the assumptions, decision variables, and precedent cells to test against. The output is a tornado chart, which shows the sensitivity of the variables using range bars, or a spider chart, which shows the sensitivity of the variables using sloping lines. The Tornado Chart is used to find the variables which affect the simulation results the most. (Decisioneering 2006)

A more detailed description of using Crystal Ball for sensitivity and risk analysis can be found in Elnegaard & Stordahl (2004).

4 Techno-Economic Analysis of Digital Homes

This chapter covers the process of the techno-economic analysis, including the construction of the spreadsheet model, the simulation and the parameters needed for it, and the analysis of the results. The spreadsheet model built for the purposes of this thesis represents the possible development of the digital home market in four different scenarios. As the scope of this thesis is restricted to the Finnish digital home market and the entertainment and data services, the spreadsheet model concentrates on the expenditures of an average Finnish household, resulting from the most typical and popular digital equipment and services.

4.1 Digital Home Model

The principles and the logic behind the digital home model are presented in this section. As mentioned, the household that the model represents is very much an averaged one. Finnish households differ greatly in the number of occupants, size of the home, income, and consumption habits, to mention a few factors. Therefore it was necessary to make assumptions and define an average household. In addition, the equipment and services present in the actual digital home market vary from cheap low-end products to more expensive high-end products. Here also a compromise had to be made and an average price needed to be determined for the different devices and services present in the model. This type of averaging sets some restrictions to the usage of the results and unavoidably results in more or less serious deficiencies. The Crystal Ball tool proved to be very useful in reducing the effect the averaging had on the results by enabling distributions to be set for prices and other figures in the model. The distributions will be explained more thoroughly later in the analysis part of this thesis.

The variables in the model, e.g. percentage of devices leased, cannot be expected to rise to the scenario specific saturation level directly at the beginning of the study period. Therefore a simple logistic growth model was used to model the development of different variables depicting the consumption habits of consumers. The simple logistic growth model is defined as follows:

$$X_t = \frac{a}{1 + c\exp(-bt)},$$

where *a* denotes the saturation level and *b* and *c* are growth related parameters (Meade & Islam 2003).

In addition, the constant growth model was used to predict the growth of equipment penetrations and for coefficients depicting e.g. renewal rate of devices and price erosion.

The digital devices included in the digital home model are those already present in the market at the beginning of the study period and included in the statistics collected by Statistics Finland (Statistics Finland 2007). In addition to the devices included in the statistics, IPTV set-top-box and Blu-ray were also taken into calculations as technologies that have just entered the market. WLAN base stations were also added to the list collected by Statistics Finland.

The list of possible services present in a digital home is rather long and hard to predict even a few years ahead. To simplify the model, services were classified under a few general ones: installation, maintenance and storage services, and pay TV as a form of content service.

4.2 Cost Classification

The development of the digital home market is very much dependent on how expensive the purchase, usage and upkeep of the digital equipment is to the consumers. The costs can be divided into two categories, as previously defined: capital expenditures (CAPEX) and operational expenditures (OPEX). Since the techno-economic model is an evaluation of an average household, the expenditures resulting from services and equipment purchases have been somewhat averaged out as well. *Figure 4.1* presents the logic behind the cost classification in this thesis.

Purchasing devices create a onetime or a predetermined number of payments, but is not continuous. Households are not accountable and therefore do not need to depreciate their equipment annually as companies are required to. However, despite not completely fulfilling the definition of CAPEX, in this case of the digital homes, all equipment purchased to the home is treated as capital expenditures.

OPEX for the digital home includes all expenditures billed in regular intervals. These expenses can be divided in three categories: management services, data and voice transmission, and additional services. Management services consist of installation and maintenance. Installation could also be classified under CAPEX, since it is a onetime expenditure and related to purchase, but has been treated here as an OPEX element for clarification. Data and voice transmission include the expenditures resulting from broadband and cell phone usage. Additional services include such services as pay TV, TV license and data storage. The costs resulting from purchased equipment are generally classified under CAPEX, but since leased devices create costs continuously and in predetermined intervals, they are here treated as operational costs.

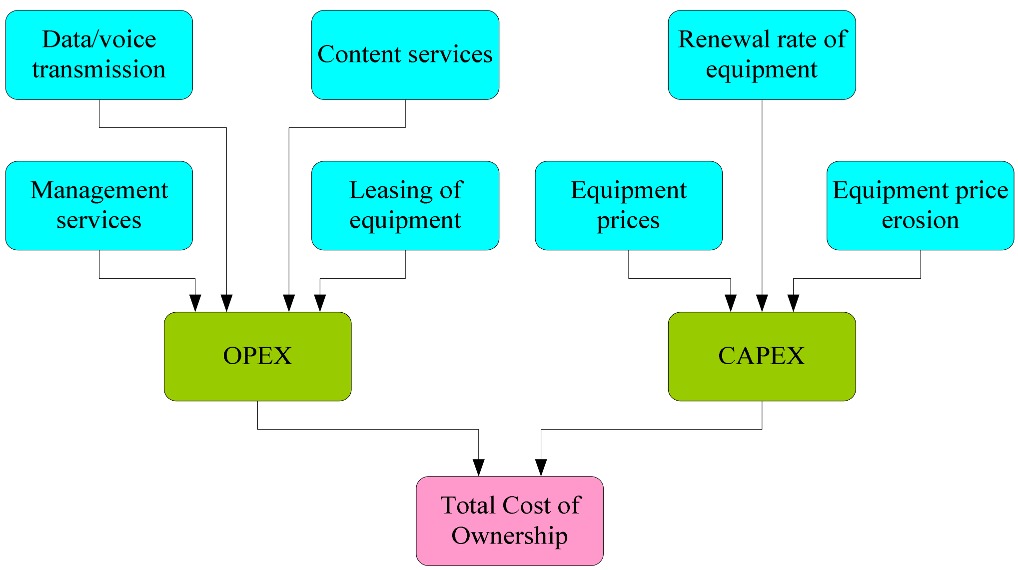

Figure 4.1: Cost classification

4.3 Techno-Economic Model for Digital Homes

The model used in this thesis and the relations in the model are based on the techno-economic model presented in *Figure 4.2*. The techno-economic model was constructed as a result of the literature study and the analysis of the current situation of digital homes. The model has been validated in the expert interviews.

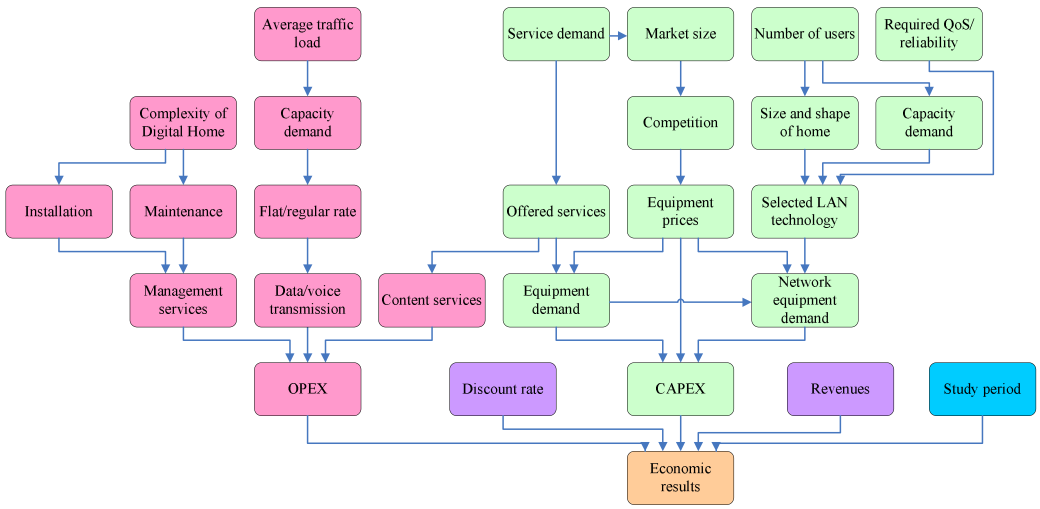

Figure 4.2: Techno-economic model of digital homes

The model follows the cost classification to CAPEX and OPEX. Revenues are also presented in the model, but since the model depicts the situation from the perspective of the household and not the service provider, no directly related revenues exist. As it became evident in the expert interviews, some revenues could emerge, but not necessarily in the form of cash. Instead, for a service performed or time used, consumers could e.g. be given credits to be used for an additional service or vouchers to an online store. However, because these types of revenues are still more or less predictions of the future, they were not taken into account in the model.

The study period is the previously mentioned time between 2007 and 2012. Discount rate is not used in this thesis as all the prices and costs are considered to be of the same value as at the start of the study in 2007.

Capital and operational expenditures, and what they both include have already been defined in previous sections. The techno-economic model further defines what affects the quantity of the expenditures. Since CAPEX includes all the equipment purchases, it mostly depends on the equipment demand, which is further dependent on offered services, service demand and equipment prices. Competition in the market and the size of it are factors to the equipment prices. Operational expenditures greatly depend on the adaptation of different services, which further reflects the number of devices in a household and thus the complexity of networking between the equipment.

The digital home model is constructed in such a way that not necessarily all factors present in the techno-economic model are as numbers in the model, but several different factors can be squeezed into a single factor or have been taken into consideration when deciding assumptions for the Crystal Ball tool.

4.4 Input Scenarios

This chapter describes the different digital home scenarios and their development over the study period as suggested by Nordlund et al. (2007). The techno-economic analysis of this thesis is based on these scenarios. The scenarios describe four possible future environments for management of digital homes.

The scenario construction process conducted by Nordlund et al. (2007) follows the approach of Karlson et al. (2003). The approach is based on identifying dominant trends in the environment and classifying those to predetermined trends common to all scenarios and uncertainties that vary from one scenario to another. The predetermined trends and uncertainties identified by Nordlund et al. (2007) are listed shortly below.

Predetermined trends

- Technology Drivers
    - Complexity of home networks will increase.
    - Amount of digital content will increase.
    - Broadband penetration and capacity will increase.
    - Capacity of wireless WANs will increase but will not reach the capacity of fixed WANs.
    - Access networks will remain slower than intra-home networks.

  - Digitalization will increase.
  - Internet development will be dominating.
  - Battery capacity will increase slowly.
  - Processing power will increase exponentially.
  - Memory capacity will increase exponentially.
  - Optical network capacity will increase exponentially.
- Socioeconomic and Political Drivers
  - The problem with e-mail spam, viruses, intrusions, and malware will not disappear.
  - Globalization will continue.
  - Fighting against terrorism and crime, particularly cybercrime will continue.
  - Shift towards knowledge economy and services.
  - Population will continue to age in developed countries.
- Business and Industry Drivers
  - Companies will become more service-oriented.
  - Market uncertainty around home networks will decrease.
  - Value networks will increase in complexity.
  - Companies strive towards market dominance.
  - Economies of scope will attract companies to aggregate their offerings.
  - Economies of scale will increase the efficiency of large service providers.
  - There will be new entrants to the digital home service market.
- Users, Values, and Attitude Drivers
  - Increased technology adoption in everyday life.
  - Values change at the pace of generations.
  - Importance of family and friends will stay high.
  - Need for mobility and communication will increase.
  - Environmentalism and health concerns will increase.

Uncertainties

- Commonness of outsourcing digital home management.
- Distribution of digital home management.
- Position of different players.
- Users' trust over digital home firms.
- Number of actors.
- Leasing of devices.
- Amount of bundles.

To convert the scenario explanations to suitable numbers for the spreadsheet model, a number of modifications were required. As the analysis focuses on operators in the digital home market, some of the uncertainties concerning the position and number of other players could be left out of the model. The uncertainties used in the calculations and their weightings in different scenarios are presented below in *Figure 4.3* and *Figure 4.4*. The operators have been positioned in the different scenarios in terms of strength, users' trust towards the operators and how much the regulation favors the operators. The three factors have been valued for the Excel-model based on the original scenario descriptions on a scale from 1 to 5; 5 depicting the strongest emphasis. In addition to positioning the operators, the model includes uncertainties such as outsourcing digital home management, management distribution, leasing of devices, amount of bundling and operators market share of the digital home market, valued as percentages. Detailed explanations of all the predetermined trends and uncertainties can be found in Nordlund et al. (2007).

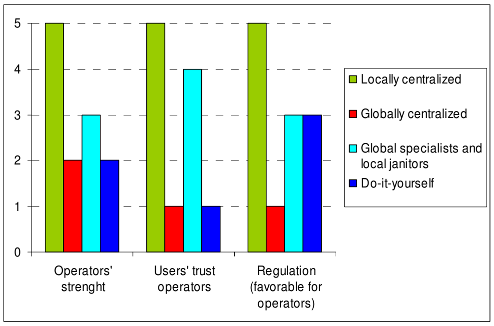

Figure 4.3: Operators' position in the scenarios

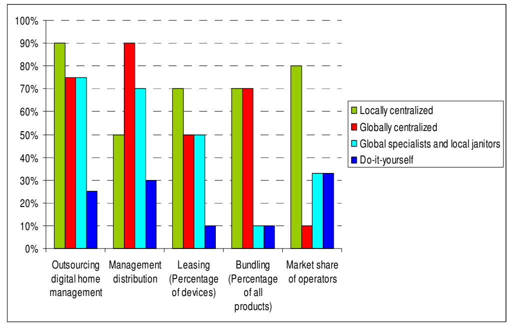

Figure 4.4: Differentiating variables of the scenarios

The scenarios are described in the following subsections. First, a general look at the market situation in the scenario is taken. Second, the development of the scenario during the study period is presented. More thorough explanations of the scenarios and their construction process are available in (Nordlund 2007) and (Nordlund et al. 2007).

4.4.1 Scenario 1: Locally Centralized

In the first scenario operators are the key players in the management business. By offering a whole product to the customers, including Internet access, leased hardware devices, and a full management service, the operators are able to acquire a majority of the customers. In addition, the operators offer the possibility of storing backups on the operators' side of the network. This and the possibility of storing configuration data on the operators' servers and remotely configuring the digital homes makes this scenario locally centralized.

Ever growing complexity of digital homes and increased network security threats forced consumers to change their behavior in this scenario. The average home users realized that they could no longer take care of their digital home systems by themselves, so they began to trust in service firms to handle management. The obvious choice for many consumers was the local broadband operators, with whom they already had business relationships. At the same time, operators went more and more into hardware business with leasing of digital home devices becoming increasingly popular. (Nordlund et al. 2007).

4.4.2 Scenario 2: Globally Centralized

The digital home service business is dominated by global companies in the second scenario. PC-based home networks are expected to become the norm in the digital home in this scenario. Therefore software platform companies providing the operating system (OS) are in a strong position. These companies might, in addition to the OS, provide other software applications and hardware devices as well. The management of the digital homes is taken care of by the software firms, including security, software application updates, and configuration, which are automated and integrated to the OS.

While in the first scenario the updates and backups are stored on the operators' local servers, in the second scenario the same is done on a much larger scale on the software platform companies' servers globally. The global structure is more efficient, but does not enable individualistic management the same way as the locally centralized does. Therefore the local operators have the possibility of offering their services in more individual and difficult problems that may even require on-site management. (Nordlund et al. 2007).

Because the fragmentariness of digital home systems was hindering in the scenario, the penetration of home networks and thus the development of services, regulatory authorities decided not to restrict global players that had started to expand into digital home management. Software platform firms acquired security companies and other management specialists or developed their own solutions. As global companies concentrated more on security issues, users' trust in them began to increase.

4.4.3 Scenario 3: Global Specialists and Local Janitors

The third scenario is not dominated by a single player, unlike the first two scenarios. Instead numerous players are involved in management provision and different players have specialized in certain management tasks. Besides the dominant players from the previous two scenarios, the operators and software platform companies, IT janitor companies offering on-site management take a role in this scenario. This resembles the present situation with the exceptions that in the scenario, management services are more developed and more widely available, and users are ready to pay for management.

The most explicit differences between scenario 3 and the situation of today are that home networks have been widely adopted in the scenario and their management is outsourced to companies rather than done by consumers themselves. With the help of favorable actions from the regulator in the scenario, the bottleneck caused by the difficulty of the initial installation of hardware, software and networks, and especially the initial configuration that made everything work was passed, and the digital homes could really grow. Because these tasks were expensive to handle by sending a person to the customers' premises, the changed regulation allowed specialized IT janitor firms to emerge, and operators enter the business. Operators that provided rental equipment commonly aggregated on-site installation and configuration to the connectivity contract. (Nordlund et al. 2007).

4.4.4 Scenario 4: Do-It-Yourself

The last scenario resembles the present situation the most out of the four scenarios, and therefore it is perhaps the most probable one to occur in the near future. At the moment, management services are not widely available and users are not willing to pay for management, with the exception of some critical services such as security services. Therefore management is mostly handled by the users themselves, excluding automatic software updates for the OS, security programs, and some other applications. This forms a bottleneck for the spread of home networking, because only a limited proportion of consumers are able and willing to handle these tasks. The structure is flexible in the sense that users can build exactly the kinds of systems they like, but on the negative side is the need for manual control.

The market does not change much during the study period and the growth is rather slow. (Nordlund et al. 2007).

4.4.5 Scenario Inputs

The inputs used in modeling the scenarios in the spreadsheet are presented in the following subsection.

Study period

A study period of five years was used in this thesis, covering the years from 2007 to 2012. This time period was chosen as the qualitative study conducted by Nordlund et al. (2007), on which this study is based on, covers the same time period.

Financial Assumptions

Inflation was not taken into consideration and cash flows were not discounted in this study. Instead all the prices and costs were considered to be of same value as those for the year 2007. This thesis covers the techno-economics of a digital home; therefore taxes, deductibles and interest rate are not factors to the study.

Market Assumptions

This thesis focuses on the Finnish digital home market and as the study specifically focuses on digital homes, instead of the entire population of 5.28 million inhabitants, the 2.44 million households in 2007 are the target market of this thesis. The number of households is expected to grow at an approximate rate of 0.6 % annually. (Väestörekisterikeskus 2007, Statistics Finland 2007)

As the available data is not specified to different types of households by any means, it was decided to focus on the average Finnish household in this thesis.

The four scenarios used in this thesis, locally centralized, globally centralized, global specialists and local janitors, and do-it-yourself, have been defined by Nordlund et al. (2007) to differ from one another by the consumers' consumption habits and how and by whom the management of the digital homes is taken care of. The different scenarios have already been explained previously in this chapter. *Table 4.1*, *Table 4.2* and *Table 4.3* present the differentiating market factors and how they evolve during the study period.

Table 4.1: Percentage of bundled devices

	2007	2008	2009	2010	2011	2012
1: Locally centralized	3%	19%	35%	51%	62%	67%
2: Globally centralized	3%	19%	35%	51%	62%	67%
3: Global specialists & local janitors	3%	3%	5%	7%	9%	10%
4: Do-it-yourself	3%	3%	5%	7%	9%	10%

Table 4.2: Outsourcing of management

	2007	2008	2009	2010	2011	2012
1: Locally centralized	3%	11%	19%	32%	47%	62%
2: Globally centralized	3%	9%	16%	27%	39%	52%
3: Global specialists & local janitors	3%	9%	16%	27%	39%	52%
4: Do-it-yourself	3%	3%	5%	9%	13%	17%

Table 4.3: Operators' market share of management

	2007	2008	2009	2010	2011	2012
1: Locally centralized	28%	60%	75%	79%	80%	80%
2: Globally centralized	4%	7%	9%	10%	10%	10%
3: Global specialists & local janitors	12%	25%	31%	33%	33%	33%
4: Do-it-yourself	12%	25%	31%	33%	33%	33%

CAPEX Assumptions

The assumptions made for typical digital home equipment are presented in *Table 4.4*. The assumptions are average prices for the digital equipment at the beginning of the study period, and are based on an analysis of available price data. Due to the users' willingness to pay for services and generally faster market growth, price erosion is the strongest in the locally centralized –scenario and the global specialists and local janitors –scenario. The exact price erosion factors can be found in A*ppendix A.1*: *Table A. 2* and *Table A. 3*.

Table 4.4: Equipment prices

	2007
Television	1,000 €
Digital receiver	100 €
IPTV Set-top-box	100 €
PVR	500 €
MP3 player	200 €
DVD player	150 €
DVD recorder	200 €
Home theater system	350 €
Video camera	200 €
Digital camera	200 €
Computer	1,000 €
Laptop	1,000 €
Printer	150 €
WLAN base station	80 €
VoIP	50 €
Game console	350 €
Cell phone	250 €
HD-DVD/Blu-ray player	700 €
Weighted average price	593 €

OPEX Assumptions

This subsection presents the assumptions made for operational expenditures in the digital home model and the logic behind them.

Instead of determining price rates for different speed classes, broadband connection prices are included in the model in the form of average revenue per user (ARPU), presented in *Table 4.5*. However, broadband price erosion has been separately determined for each speed class in the different scenarios, which collectively affect the erosion of ARPU.

Table 4.5: Broadband ARPU

	2007	2008	2009	2010	2011	2012
1: Locally centralized	37 €	36 €	35 €	34 €	31 €	29 €
2: Globally centralized	37 €	36 €	35 €	34 €	31 €	29 €
3: Global specialists & local janitors	37 €	37 €	36 €	34 €	33 €	31 €
4: Do-it-yourself	37 €	37 €	37 €	36 €	36 €	35 €

The sum of money spent on additional services, such as Pay TV, TV license, data storage, and mobile phone usage have been assumed to remain the same during the study period and not erode or rise. The prices are presented in *Table 4.6*.

Table 4.6: Monthly additional service prices

	2007	2008	2009	2010	2011	2012
Pay TV price	30 €	30 €	30 €	30 €	30 €	30 €
TV License price	17 €	17 €	17 €	17 €	17 €	17 €
Data storage price	2 €	2 €	2 €	2 €	2 €	2 €
Mobile phone bill	30 €	30 €	30 €	30 €	30 €	30 €

The penetrations of Pay TV and storage services in different scenarios are presented below in *Table 4.7* and *Table 4.8*. The growth rate and saturation level of the Pay TV penetration depends on the general growth of the market in the particular scenario. The growth of the storage service penetration on the other hand, depends on the consumers' trust in the operators in the scenarios. The growth in both cases follows the simple logistic growth model presented in *section 4.1*.

Table 4.7: Pay TV penetration

	2007	2008	2009	2010	2011	2012
1: Locally centralized	20%	31%	43%	54%	61%	65%
2: Globally centralized	17%	27%	37%	46%	52%	56%
3: Global specialists & local janitors	16%	25%	35%	43%	49%	52%
4: Do-it-yourself	14%	22%	31%	38%	43%	47%

Table 4.8: Storage service penetration

	2007	2008	2009	2010	2011	2012
1: Locally centralized	15%	21%	28%	36%	43%	48%
2: Globally centralized	25%	35%	47%	60%	71%	80%
3: Global specialists & local janitors	20%	28%	38%	48%	57%	64%
4: Do-it-yourself	5%	7%	9%	12%	14%	16%

The prices of management and installation services are presented in *Table 4.9*. In the locally centralized –scenario management services seem cheaper to the consumers due to the wider acceptance of leasing and more common bundling of services. As a result of the weak position of operators in the globally centralized –scenario, less management and installation services are sold and they are rather expensive. Since consumers are most willing to pay for more developed services in the global specialists and local janitors –scenario, the prices need to be lower. In the do-it-yourself –scenario management services are rare and therefore expensive.

Table 4.9: Management and installation service prices

Management	1: Locally centralized	2: Globally centralized	3: Global specialists & local janitors	4: Do-it-yourself
Maintenance price (monthly)	6 €	13 €	3 €	13 €
Installation price (per device)	100 €	150 €	70 €	150 €

Table 4.10 depicts the percentage of the households purchasing installation services for newly purchased equipment and *Table 4.11* the percentage of consumers paying for maintenance services. Both assumptions depend on how much the consumers are outsourcing the management of their digital homes, defined separately for each scenario.

Table 4.10: Installation service penetration

	2007	2008	2009	2010	2011	2012
1: Locally centralized	26%	40%	56%	69%	78%	84%
2: Globally centralized	22%	34%	47%	58%	65%	70%
3: Global specialists & local janitors	22%	34%	47%	58%	65%	70%
4: Do-it-yourself	7%	11%	16%	19%	22%	23%

Table 4.11: Maintenance service penetration

	2007	2008	2009	2010	2011	2012
1: Locally centralized	22%	32%	43%	54%	64%	72%
2: Globally centralized	19%	26%	35%	45%	53%	60%
3: Global specialists & local janitors	19%	26%	35%	45%	53%	60%
4: Do-it-yourself	6%	9%	12%	15%	18%	20%

Table 4.12 presents the percentage of the digital home equipment leased by the households in each scenario. The saturation levels are set in the original scenario definitions for each of the four scenarios. The growth rate follows the simple logistic growth model presented in *section 4.1*.

Table 4.12: Percentage of devices leased by consumers

	2007	2008	2009	2010	2011	2012
1: Locally centralized	3%	13%	23%	37%	50%	59%
2: Globally centralized	3%	8%	15%	24%	32%	38%
3: Global specialists & local janitors	3%	10%	18%	29%	39%	47%
4: Do-it-yourself	3%	2%	3%	5%	7%	8%

Equipment Assumptions

Data regarding the penetration of different equipment in the Finnish households has been collected over the years by Statistics Finland and is used in this thesis as a basis to determine the penetration levels for the study period. The penetrations of the devices included in this study are presented below in

Table 4.13. The linear growth rates for different devices have been derived from the available data (Statistics Finland 2007).

Table 4.13: Penetration of devices in Finnish households

	2006	2007	2008	2009	2010	2011	2012
Television	95%	95%	95%	95%	95%	95%	95%
Digital receiver	95%	95%	95%	95%	95%	95%	95%
IPTV Set-top-box	0%	0%	3%	4%	5%	6%	7%
PVR	13%	22%	38%	41%	45%	50%	54%
MP3 player	33%	44%	52%	61%	69%	78%	86%
DVD player	50%	57%	61%	65%	69%	72%	76%
DVD recorder	13%	17%	20%	24%	27%	30%	33%
Home theater system	20%	22%	23%	25%	26%	28%	29%
Video camera	22%	21%	22%	23%	23%	24%	25%
Digital camera	52%	60%	66%	72%	78%	84%	90%
Computer	70%	74%	79%	83%	88%	92%	97%
Laptop	29%	37%	44%	51%	58%	64%	71%
Printer	52%	58%	61%	64%	66%	69%	72%
WLAN base station	10%	15%	26%	37%	48%	59%	70%
VoIP equipment	23%	30%	35%	41%	46%	52%	57%
Game console	24%	25%	27%	28%	29%	30%	31%
Cell phone	97%	99%	99%	99%	99%	99%	99%
HD-DVD/Blue Ray player	0%	2%	20%	26%	32%	37%	42%

Since extensive data exists on the penetration level of digital equipment in the households, they were considered to be stable enough to hold the same in each of the scenarios. On the other hand, the renewal rate of devices, which includes the percentage of households replacing their old equipment, varies from one scenario to another. Together with the percentage of households purchasing devices for the first time, the renewal rate of devices determines the number of devices bought on average by each household. *Table 4.14* presents these numbers for the do-it-yourself – scenario. The figures for the other three scenarios can be found in *Appendix A.1*: *Table A. 13*, *Table A. 14*, and *Table A.* 15.

Table 4.14: Percentage of households purchasing devices (Do-it-yourself -scenario)

	2007	2008	2009	2010	2011	2012
Television	6%	7%	8%	9%	10%	11%
Digital receiver	10%	9%	8%	7%	6%	5%
IPTV Set-top-box	1%	4%	2%	3%	3%	3%
PVR	17%	24%	12%	12%	12%	12%
MP3 player	26%	23%	24%	24%	25%	25%
DVD player	23%	19%	19%	18%	16%	15%
DVD recorder	11%	9%	9%	9%	9%	9%
Home theater system	5%	4%	4%	4%	4%	4%
Video camera	2%	4%	4%	4%	4%	4%
Digital camera	18%	16%	17%	17%	18%	18%
Computer	15%	15%	18%	18%	20%	20%
Laptop	18%	17%	20%	20%	22%	22%
Printer	12%	9%	9%	9%	9%	9%
WLAN base station	15%	21%	22%	22%	23%	23%
VoIP	17%	15%	16%	16%	17%	17%
Game console	6%	6%	8%	8%	10%	10%
Cell phone	37%	35%	37%	37%	39%	39%
HD-DVD/Blu-ray player	5%	21%	9%	11%	14%	15%
Number of devices purchased on average	2.44	2.57	2.46	2.48	2.61	2.61

The renewal rate for the calculations is based on the estimate made for the year 2007, which is then multiplied by a coefficient determined separately for each scenario. The renewal rate evolves linearly during the study period towards the predetermined coefficient. In the locally centralized and globally distributed –scenarios, the renewal rate is slightly faster compared to the scenario that most resembles the current situation, the do-it-yourself –scenario, because of the more common leasing and bundling in the former two scenarios. In the global specialists and local janitors –scenario, where consumers are the most open towards new services and prices erode quickly, the renewal of devices is the most frequent. The renewal rate coefficients are presented in *Table A. 12* of *Appendix A.1*.

4.4.6 Sensitivity Inputs

The first step of the sensitivity analysis was to determine probability distributions for the different assumptions in the model and to analyze which of them influence the forecasts bundling discounted OPEX+CAPEX –forecast the most. The Tornado Chart tool of the Crystal Ball software was used for this purpose. The test was run using a testing range of -20 % to +20 % and 100 testing points. The full results of the analysis are presented in *Appendix A.2*. As it is not reasonable to have too many variables in the analysis, only the most sensitive ones were chosen as assumptions. The chosen assumptions and their probability distributions are described in the subsections below.

Normal Distribution

The normal distribution is the most important distribution in probability theory because it describes many natural phenomena, such as people's IQs or heights. Decision-makers can use the normal distribution to describe uncertain variables such as the inflation rate or the future price of gasoline. (Decisioneering 2006b.) In this thesis the normal distribution is mainly used for price and penetration assumptions where the mean is the average price or the expected penetration at the end of the study period. The parameters for the variables with normally distributed assumptions are presented in *Table 4.15*. For the penetrations of the devices the normal distribution was found to be the most suitable one, because the values are forecasts and could only be determined a likely value based on existing data. For the equipment prices, the normal distribution represents the normal variation in prices.

Table 4.15: Sensitivity assumptions with normal distribution

Normal distribution						
	Mean					
Assumption	1: Locally centralized	2: Globally centralized	3: Global specialists & local janitors	4: Do-it-yourself	Std. Dev.	
Bundling (Percentage of devices)	70%	70%	70%	70%	5%	
Computer (Leasing price)	25 €	25 €	25 €	25 €	4 €	
Computer (penetration)	92%	92%	92%	92%	9%	Max. 95%
Computer (price)	1,000 €	1,000 €	1,000 €	1,000 €	300 €	
Digital camera (penetration)	90%	90%	90%	90%	9%	Max. 95%
DVD player (penetration)	76%	76%	76%	76%	8%	
Game console (Leasing price)	20 €	20 €	20 €	20 €	2 €	
Installation price (per device)	100 €	100 €	100 €	100 €	10 €	
Laptop (Leasing price)	25 €	25 €	25 €	25 €	5 €	
Laptop (price)	1,000 €	1,000 €	1,000 €	1,000 €	200 €	
Leasing (Percentage of devices)	70%	45%	55%	10%	5%	
Maintenance price (monthly)	6 €	13 €	3 €	13 €	3 €	
MP3 player (penetration)	86%	86%	86%	86%	8%	
Operators' market share	80%	10%	33%	33%	8%	
Television (price)	1,000 €	1,000 €	1,000 €	1,000 €	200 €	

Lognormal Distribution

The lognormal distribution is widely used in situations where values are positively skewed, for example in financial analysis for security valuation or in real estate for property valuation. Stock prices are usually positively skewed, rather than normally (symmetrically) distributed. Stock prices exhibit this trend because they cannot fall below the lower limit of zero, but might increase to any price without limit. Similarly, real estate prices illustrate positive skewness since property values cannot become negative. (Decisioneering 2006b.)

Some of the price assumptions follow the lognormal distribution as the mean value is not far from zero, but still a great number of consumers spend significantly more than the mean value. Cell phone price is one such assumption. The majority of consumers purchase a low-end or mid-range phone, whereas a small proportion chooses a significantly more expensive high-end model. Even though this proportion is relatively small, they still make up a significant part of the mobile vendors revenues. The variables with lognormal distributions are in *Table 4.16*.

Table 4.16: Sensitivity assumptions with lognormal distribution

Lognormal distribution		
Assumption	Mean	Std. Dev.
Cell phone (price)	250 €	150 €
Mobile phone bill	30 €	10 €
PayTV price	30 €	10 €
TV License price	17 €	2 €

Triangular Distribution

The triangular distribution describes a situation where the minimum, maximum, and most likely values to occur are known. The distribution can be used to describe, e.g. the number of cars sold per week when past sales show the minimum, maximum, and usual number of cars sold. (Decisioneering 2006b.)

In this thesis the triangular distribution is used for different coefficients determining the development of several factors in the model, such as price erosion and renewal rate of devices. The particular distribution was found to be the most suitable for these variables, because they can be defined more accurately. The parameters are in *Table 4.17*.

Table 4.17: Sensitivity assumptions with triangular distribution

Triangular distribution						
	1: Locally centralized			2: Globally centralized		
Assumption	Min	Likeliest	Max	Min	Likeliest	Max
ARPU for Broadband -coefficient	0.83	0.92	1.01	0.89	0.98	1.07
Bundling discount	2	3	4	2	3	4
Installation service penetration	80%	90%	90%	65%	75%	75%
Leasing price -coefficient	0.81	0.90	0.99	0.95	1.04	1.13
Monthly maintenance service penetration	80%	90%	90%	65%	75%	75%
Number of leased devices	1.00	2.00	3.00	1.00	2.00	3.00
PayTV penetration	50%	60%	60%	60%	70%	70%
Price erosion -coefficient	1.01	1.12	1.22	0.99	1.10	1.21
Renewal rate -coefficient	1.13	1.22	1.31	1.07	1.16	1.25
	3: Global specialists & local janitors			4: Do-it-yourself		
Assumption	Min	Likeliest	Max	Min	Likeliest	Max
ARPU for Broadband -coefficient	0.85	0.94	1.03	0.89	0.98	1.07
Bundling discount	2	3	4	2	3	4
Installation service penetration	65%	75%	75%	15%	25%	25%
Leasing price -coefficient	0.95	1.04	1.13	0.91	1.00	1.09
Monthly maintenance service penetration	65%	75%	75%	15%	25%	25%
Number of leased devices	1.00	2.00	3.00	1.00	2.00	3.00
PayTV penetration	46%	56%	56%	40%	50%	50%
Price erosion -coefficient	0.99	1.10	1.21	0.93	1.04	1.15
Renewal rate -coefficient	1.25	1.34	1.43	0.91	1.00	1.09

4.5 Economic Analysis

This section describes the base case results for the four scenarios. As can be seen in *Figure 4.5*, the base case of the total OPEX+CAPEX does not vary significantly in the first three scenarios, the locally centralized, the globally centralized and the global specialists and local janitors –scenarios, but there is a difference in how the sum adds up from the total OPEX and the total CAPEX. This difference is explained by the difference in the amount of leasing of devices in the scenarios.

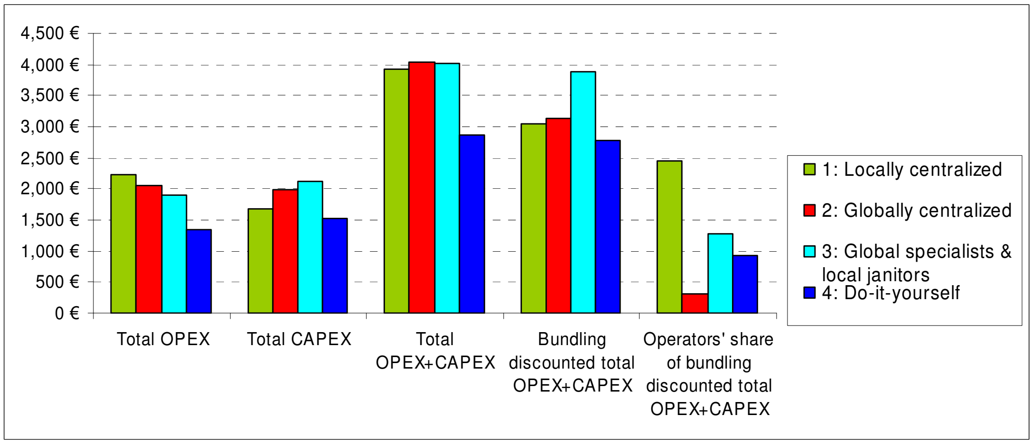

Figure 4.5: Base case OPEX and CAPEX for the scenarios at the end of the study period

The total OPEX, total CAPEX, and total OPEX+CAPEX are remarkably lower in the do-it-yourself –scenario than in the other three scenarios. In the first three scenarios the digital home market is expected to grow more rapidly and consumers are assumed to be more willing to invest and spend their income on digital home equipment and services.

The bundling discounted total OPEX+CAPEX reveals the effect bundling has on the total expenditures. Depending on the commonness of bundling in the scenario, the total OPEX+CAPEX is deducted by an estimated sum resulting from service and equipment bundles. The total OPEX+CAPEX is close to 4000 € in the first three scenarios, but as bundling is more common in the first two, the actual expenditures experienced by the households drop down closer to 3000 €. The operators' share of the total expenditures depends directly on the strength of the operators in the particular scenario. As *Figure 4.5* suggests, the local operators are strong players in the locally centralized –scenario and weaker in the globally centralized –scenario, which is dominated by large global software platform companies.

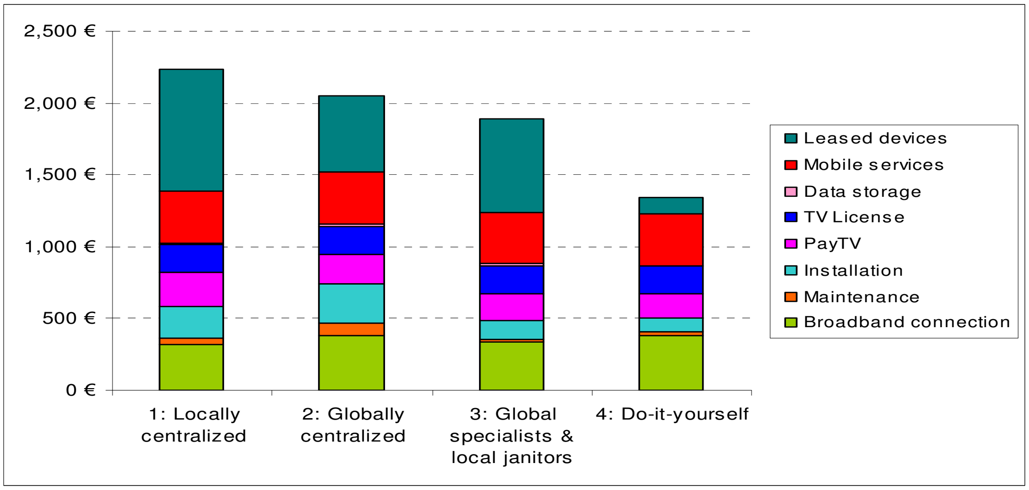

Figure 4.6: OPEX distribution at the end of the study period in base case scenarios

Figure 4.6 shows how the total OPEX builds up from the different types of operational expenditures, the largest contributors being *leased devices*, *mobile services* and *broadband connection*. As already mentioned above, the total operational expenditures are very much influenced by the commonness of leasing. In scenarios where consumers are more used to leasing the digital home equipment rather than owning it, operational expenditures are higher. In scenarios, such as the do-it-yourself –scenario where leasing is rare, the expenditures resulting from equipment acquisition are classified under CAPEX.

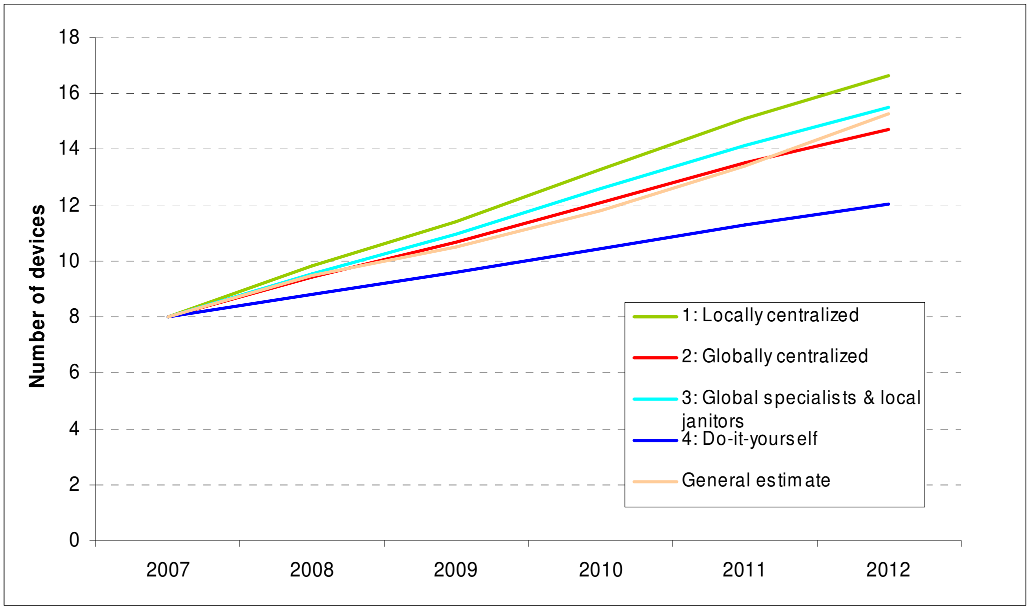

Figure 4.7: Average number of devices in a household (base case scenarios)

As the average number of devices in a household grows, so does the entire digital home market. *Figure 4.7* shows how this number evolves in the four scenarios compared to the general estimate made earlier. The 1.9 additional devices in the locally centralized –scenario compared to the globally centralized –scenario and respectively the 4.6 devices to the do-it-yourself –scenario, in a time period of only five years can be explained by the consumers' general willingness to invest in the digital home and by the popularity of leasing equipment instead of purchasing it.

Households do not expect their investments to their digital home to be profitable ones. No revenues are projected from the digital home, since it is not a business of any sort and therefore it does not make sense to try and calculate NPV or IRR for it. However, households, and more specifically the occupants of the household, receive income from other sources in the form of salary. Of this income, households spend a certain percentage on telecommunications, entertainment, digital equipment and other digital home related goods and services.

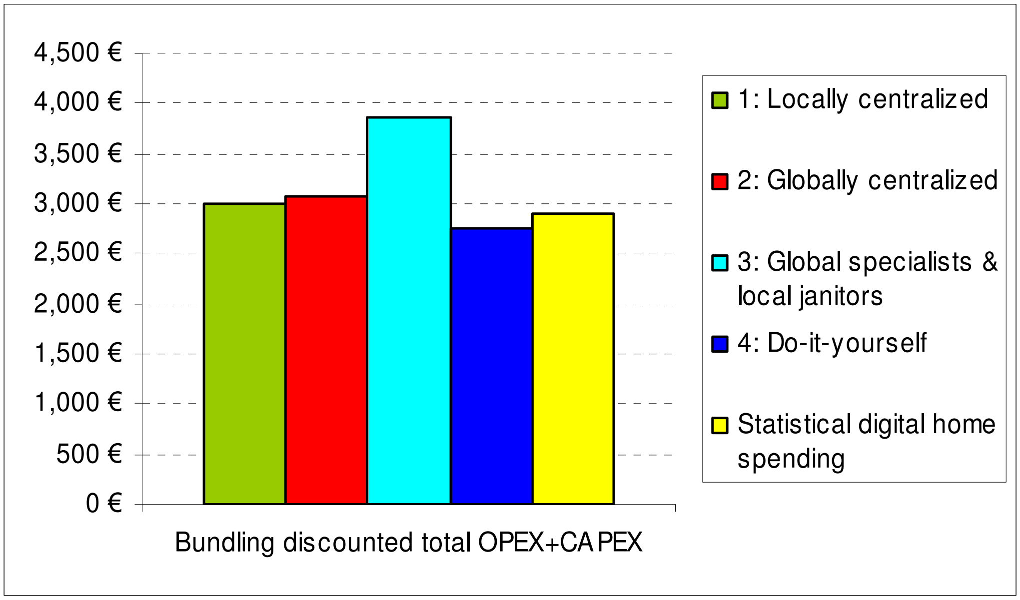

Figure 4.8: Bundling discounted OPEX+CAPEX compared to the statistical estimate of digital home spending in 2012

Stordahl et al. (2005) have gathered statistics of household spending distribution. This data was used to calculate an estimate for the portion of the income spent on the digital home at the end of the study period in 2012. The annual amount spent by an average household on digital home equipment and services in 2012 was determined to be 2900 €. Besides the linear growth of disposable income, other expenditure categories of disposable income are expected to shift towards the digital home category during the study period. This, a result of new digital services becoming available, e.g. video rentals can be done directly over the broadband connection, causes the portion spent on digital homes to grow faster than just the linear growth speed. As can be seen from *Figure 4.8*, the total expenditures are very close to the estimate in three of the four scenarios. The significantly higher expenses in the third scenario can be explained by the low bundling in the scenario. As it is not justified to assume for total income and the percentage of it spent on the digital home to radically change in either direction, the assumption received from the statistics can be considered the most probable estimate.

4.6 Risk and Sensitivity Analysis

This section presents the results of the risk and sensitivity analysis conducted for the model of the digital home with the Crystal Ball tool. As stated in the previous section, the digital home is not a business for consumers from which they could expect revenues. Therefore it was not reasonable or even possible to use the Crystal Ball tool for analyzing the risk levels of the investments. Because of the variety of types and sizes of households in Finland, the averaging of the households results in very sweeping numbers and figures.

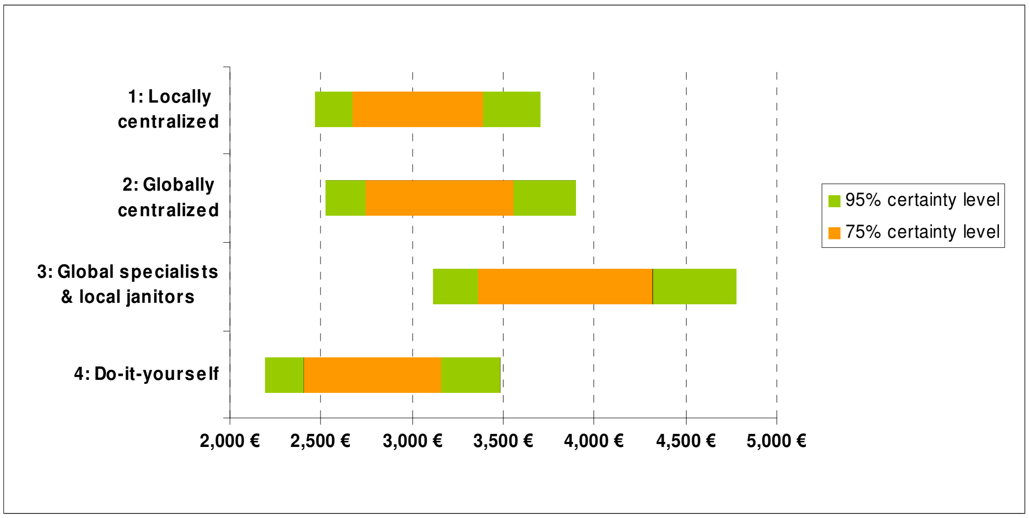

Figure 4.9: Bundling discounted OPEX+CAPEX at different certainty levels

Instead, Crystal Ball proved to be very useful in assessing the expenditures of an average household. Since it is possible to define different distributions for assumptions, such as equipment penetration and prices, the market can be modeled more realistically. Instead of just the base case results representing the mean value, Crystal Ball allows to examine how much the expenditures spread around the mean at a certain certainty level. *Figure 4.9* shows how the bundling discounted OPEX+CAPEX representing the total expenditures, spreads out in each of the scenarios. As both 95% and 75% certainty levels are presented in the figure, it can be seen that the results do not spread out evenly, but that the mean is closer to the minimum value and the tail is somewhat long, especially in the third scenario.

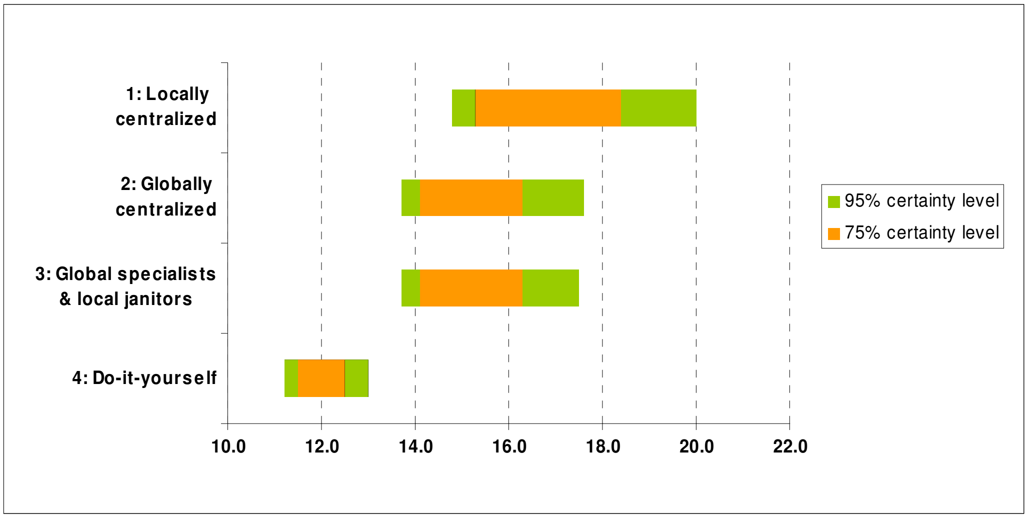

Figure 4.10: The average number of devices per household at different certainty levels

As for the total expenditures, it was valuable to see how much the number of devices varies from one scenario to another. As *Figure 4.10* illustrates, the higher the projected number of devices, the more it varies. In the locally centralized –scenario, where the base case result is 16.6 devices per household; the number of devices varies 5.2 devices between 14.8 and 20.0 in 95% of the cases. At the other end, in the do-it-yourself –scenario the numbers are 1.8, 11.2 and 13.0 respectively. This depicts a greater uncertainty and more diverse consumption habits, which makes the result more realistic than the corresponding figures for the more conservative do-it-yourself –scenario. The variance of only 1.8 devices in as high as 95% of the cases, seems very unrealistic. As was the case with the spreading of the expenditures, the same phenomenon can be seen with the average number of devices even more clearly, the mean number of devices is closer to the minimum number and the tail is here even longer. This indicates that the number of devices in the households investing more in the digital home varies more than in the households spending less.

5 Discussion

During the last decade or so, various digital technologies have emerged and become mainstream products. Cellular phones, the digitalization of the television broadcasts, digital music players along with the Internet with its vast number of services have really boomed and become a major part of everyday life. The next step would be the convergence of the different parts of the digital world, which would enable the devices in the home to interoperate seamlessly. If equipment manufacturers are not able to simplify the maintenance and installation of the devices and services, expensive outside help may be needed by the majority of the common users. This equation is not an easy one to solve and some major work is still to be done in the area of digital home management.

The number of connected devices in a home is the key figure for the growth of the digital home market. An estimate has been made earlier in this thesis that there will be 16 connected devices in an average home by the end of the study period in 2012. This estimate does not take into consideration possible new entrants to the market. As the number of devices grows, connecting them becomes an issue. The cables in the home are already an unbearable problem to many, which wireless technologies could be a solution to. The Wireless World Research Forum (WWRF) has a vision stating: "7 trillion wireless devices serving 7 billion people by 2017" (WWRF 2007). This would mean 1000 wireless devices per person nine years from now. The number includes all wireless devices, not just intelligent ones in the home that are the key focus of this thesis. However, a great number of these devices would be in the home and form true wireless home networks.

Digital homes are a rather fresh and constantly evolving concept. Instead of being a single product available from operators or equipment vendors, normal households are slowly developing into digital homes. As this evolution continues and the range of devices becomes more diverse, consumers are required to handle complicated installation and management tasks, if they want to get the most of their home networks. Not all possess the skills to perform these tasks by themselves. At the moment of the study, management services are expensive and not widely available.

Therefore only technology enthusiasts are able and willing to take care of the management themselves, and the growth of digital homes remains limited. Two possible solutions can be seen to this problem. For one, affordable management services need to be available to consumers. However, as it came up in the interviews, consumers like to be in control of their own homes and devices and not have to be dependent on outside help. Paying for management services is also easily seen as an unnecessary cost and it would require the service providers to somehow bundle the management with the services to hide the costs. The second solution to the management problem is in the hands of the equipment manufacturers and developers. The devices need to be easy enough to use for an average consumer to install and operate. Devices from different manufacturers also need to interoperate together. This requires intensive work from the standardization bodies.

The most likely direction of the digital home management is not one or the other of the two solutions, but a combination of them both. Sending an actual repairman to the premises of a customer is always very expensive; therefore consumers will have to bring nonfunctional devices to a shop for often simple reparation. Remote management is a very cost effective and time saving alternative to actually visiting the location. Automatic updates and special remote management programs allowing service providers to access the customers' equipment remotely are very useful tools for management of digital homes. Since remote management is much cheaper than on-site management, the costs of it are easier to conceal from the consumers in the costs of the actual service or product. Designing the equipment to be easy to use and remotely updating and servicing the system can be seen as an applicable solution to the management problem of digital homes.

The thorough analysis of the predefined scenarios used for the techno-economic analysis resulted in finding some deficiencies in the scenarios. As mentioned in this chapter earlier, usability is a major issue for the future development of digital homes and its development should be clearly included in the scenario definitions. Usability can be thought to be already included in the definitions, as it affects the consumers' willingness to purchase devices and content, but it is something that should be a clearly defined uncertainty for each scenario. Another deficiency is the lack of leasing in the do-it-yourself –scenario. It is in fact very likely that the consumers will handle the management of their homes themselves and that there will be a significant amount of device leasing present. Bundling of devices and services reduces the costs significantly in the scenarios where it is strongly present. In the third scenario bundling is low and the expenditures therefore higher than in the other scenarios. Most likely this difference in prices would be taken care of in some other manner, so that the total expenditures would drop down to the same level with the other scenarios. For example stronger price erosion in both devices and services could be a possible solution.

The network operators are in a very strong position in the emerging digital home market. The worlds of consumer electronics, PC Internet, and mobile devices are converging and the traffic is moving towards all-IP, where the operators have the benefit of offering the access to the public IP network needed by all users. As the operators have already tied the consumers with the broadband connection, it is easier for them to introduce new digital services and bundle devices to the existing connection. Additionally, remote management is more effortless for the operators as they own the access network.

6 Conclusions

The results of this thesis are summarized and assessed in this chapter. Exploitation of the results in practice is also discussed and finally ideas for future digital home research are given.

6.1 Results

In this thesis, four predefined scenarios have been the target of a techno-economic analysis. Now after the analysis, it can be said that none of the four scenarios are likely to be the future of digital homes as they are defined. The market will certainly be a combination of two or more of the scenarios and their attributes.

The total expenditures in the four scenarios are slightly above or below the estimate derived from existing statistics, which indicates that the scenarios are possible and that it cannot be said if one is more likely than the others. In the global specialists and local janitors –scenario the total expenditures are however somewhat higher than the general expenditure estimate. This difference in expenditures can be explained by the lack of bundling in the scenario. As already discussed in the previous chapter, it is assumable that the lower costs can be achieved by other means in this scenario.

Disposable income is expected to grow at a steady pace during the study period, but the portion of it that is spent on digital homes grows faster. The reason for this is the change in consumption habits, which results in money being shifted from the more traditional categories to the category of digital homes. What the consumers are purchasing with their money does not necessarily change much, but with new technologies and services it is possible to receive and experience the services using the digital equipment at home.

Besides the estimate for total expenditures, perhaps an even more important and valuable figure received from the analysis is the average number of devices per household. The number of different connected devices at home has been growing steadily in the past years and the pace has picked up during the last two years. As technologies mature and usability and reliability of devices improves, the rate of growth can be expected to increase even more. The general estimate made for the average number of devices falls in between the scenario estimates. The locally centralized, and the global specialists and local janitors –scenarios, where leasing is more common, the number of devices is slightly above the general estimate. In the do-it-yourself –scenario, where practically no leasing exists, the number of devices is significantly lower than in the others. As mentioned in the discussion part of this thesis, the lack of leasing in the scenario is a deficiency.

The process of quantifying the scenarios for the techno-economic analysis required very thorough examination of the trends and uncertainties defined for the scenarios. During this process some deficiencies, already covered in the discussion chapter, were found in the scenarios. These deficiencies have been taken into consideration when reviewing the results and their affect has been minimized.

6.2 Assessment of Results

Constructing a techno-economic model for a technology at such an early stage as the digital home is, proved to be somewhat difficult. Due to the rapidly evolving technologies and lack of a leading solution, it is difficult to predict what the digital home will look like in 2012. Giving figures to the uncertain development was even more difficult as data was not directly available for all relevant factors. The results clearly point to the right direction, but because of the uncertainties involved in the construction phase, the results should be viewed critically and with careful consideration. If we look back five years in time, the equipment and connections related to digital homes have evolved in huge steps and new ones have emerged. With the continuation of similar development it is difficult to say which of the devices and services of today will still be present in five years. Even though some of the equipment taken into calculations here may be replaced by more advanced ones and despite all the uncertainty present, the results as a whole are a valuable addition to the analyzed scenarios.

As this thesis is restricted to the Finnish market and data on the consumption habits of an average household have been used a basis for the calculations, the results are specific for Finnish households. The general ideas could however be used for other

Western European countries as well, especially with the appropriate changes to the data.

6.3 Exploitation of Results

The conclusion that the total expenditures exceed the linear growth estimate in all of the scenarios could be interesting to new entrants to the market or service providers planning on investing in their digital home business. Network operators might find the fact that the broadband connection and leased devices are very large contributors to the operational costs very valuable. As the broadband connection is already in a key role, it gives the operators an advantage to bundle other services and products to the package.

6.4 Further Research

The results acquired from this thesis are based on calculations made for an average household. Using a single type and generalized household sets limitations to the applicability of the results and needs to be kept in mind when reviewing the results. For further research the market could be further split down to smaller segments of households with different types of consumption habits.

The focus here has mainly been on a PC centric digital home, connected to the public IP network through the network operators fixed broadband access network. The role of mobility has been left with little attention in this study. However, it is a constantly increasing phenomenon and mobile devices along with mobile operators are likely to play an important role in the digital home business in the future. The time spent at home and the usage of mobile services at home, are both very significant. According to a mobile service study conducted by Verkasalo (2007), 51.8% of active smart phone usage takes place during the 49.9% of the day that smart phone users spend at home. The mobile services discussed and involved in the calculations have been treated as a single package. Even though WLAN-enabled mobile handsets are a part of the study, more thorough analysis of different mobile services and mobility in general is something that deserves to be kept in mind in the future.

Revenues are not considered part of the techno-economics of a digital home in this thesis. In the interviews it came up several times, that households could have some sorts of revenues from their digital home. Not necessarily in the traditional form of money, but as goods or rights to a service free of charge. This is something that could be worth a deeper look.

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A Appendices

A.1 Scenario Inputs

Table A. 1: Bundling discount

Scenario	2007	2008	2009	2010	2011	2012
1: Locally centralized	1%	6%	12%	17%	21%	22%
2: Globally centralized	1%	6%	12%	17%	21%	22%
3: Global specialists & local janitors	1%	1%	2%	2%	3%	3%
4: Do-it-yourself	1%	1%	2%	2%	3%	3%

Table A. 2: Price erosion of equipment prices

	2007
Television	3%
Digital receiver	12%
IPTV Set-top-box	2%
PVR	6%
MP3 player	6%
DVD player	6%
DVD recorder	6%
Home theater system	4%
Video camera	4%
Digital camera	4%
Computer	1%
Laptop	4%
Printer	2%
WLAN base station	8%
VoIP	2%
Game console	6%
Cell phone	3%
HD-DVD/Blu-ray player	15%

Table A. 3: Price erosion of equipment prices –coefficients

Scenario	2007	2008	2009	2010	2011	2012
1: Locally centralized	1.00	1.02	1.05	1.07	1.10	1.12
2: Globally centralized	1.00	1.01	1.02	1.02	1.03	1.04
3: Global specialists & local janitors	1.00	1.02	1.04	1.06	1.08	1.10
4: Do-it-yourself	1.00	1.01	1.02	1.02	1.03	1.04

Table A. 4: Average broadband prices

	2007
1 Mbps	29 €
2 Mbps	37 €
8 Mbps	46 €
> 20 Mbps	56 €
ARPU	37 €

Table A. 5: Broadband price erosion

Scenario	2007	2008	2009	2010	2011	2012
1: Locally centralized	4%	5%	7%	9%	11%	12%
2: Globally centralized	2%	2%	3%	4%	5%	6%
3: Global specialists & local janitors	3%	4%	5%	7%	8%	9%
4: Do-it-yourself	1%	2%	2%	3%	4%	4%

Table A. 6: ARPU for broadband –coefficients

Scenario	2007	2008	2009	2010	2011	2012
1: Locally centralized	1.00	0.98	0.97	0.95	0.94	0.92
2: Globally centralized	1.00	1.00	0.99	0.99	0.98	0.98
3: Global specialists & local janitors	1.00	0.99	0.98	0.96	0.95	0.94
4: Do-it-yourself	1.00	1.00	0.99	0.99	0.98	0.98

Table A. 7: Number of leased devices per household

Scenario	2007	2008	2009	2010	2011	2012
1: Locally centralized	0.27	1.16	2.10	3.32	4.49	5.33
2: Globally centralized	0.27	0.74	1.35	2.14	2.89	3.43
3: Global specialists & local janitors	0.27	0.91	1.65	2.61	3.53	4.19
4: Do-it-yourself	0.27	0.17	0.30	0.47	0.64	0.76

Table A. 8: Leasing prices (monthly)

	2007
Television	33 €
Digital receiver	3 €
IPTV Set-top-box	5 €
PVR	10 €
MP3 player	5 €
DVD player	3 €
DVD recorder	7 €
Home theater system	7 €
Video camera	7 €
Digital camera	7 €
Computer	25 €
Laptop	25 €
Printer	5 €
WLAN base station	5 €
VoIP	2 €
Game console	20 €
Cell phone	9 €
HD-DVD/Blu-ray player	21 €
Total	166 €

Table A. 9: Leasing price erosion

	2007
Television	6%
Digital reveiver	12%
IPTV Set-top-box	2%
PVR	12%
MP3 player	6%
DVD player	6%
DVD recorder	6%
Home theater system	6%
Video camera	4%
Digital camera	4%
Computer	1%
Laptop	6%
Printer	2%
WLAN base station	12%
VoIP	2%
Game console	6%
Cell phone	6%
HD-DVD/Blu-ray player	30%

Table A. 10: Leasing price –coefficient

Scenario	2007	2008	2009	2010	2011	2012
1: Locally centralized	1.00	0.98	0.96	0.94	0.92	0.90
2: Globally centralized	1.00	1.01	1.02	1.02	1.03	1.04
3: Global specialists & local janitors	1.00	1.01	1.02	1.02	1.03	1.04
4: Do-it-yourself	1.00	1.00	1.00	1.00	1.00	1.00

Table A. 11: Renewal rate of devices

	2007
Television	6.0%
Digital receiver	10.0%
IPTV Set-top-box	1.0%
PVR	8.0%
MP3 player	15.0%
DVD player	15.0%
DVD recorder	6.0%
Home theater system	3.0%
Video camera	3.0%
Digital camera	10.0%
Computer	10.0%
Laptop	10.0%
Printer	6.0%
WLAN base station	10.0%
VoIP	10.0%
Game console	5.0%
Cell phone	35.0%
HD-DVD/Blu-ray player	3.0%

Table A. 12: Renewal rate of devices –coefficient

Scenario	2007	2008	2009	2010	2011	2012
1: Locally centralized	1.00	1.04	1.09	1.13	1.18	1.22
2: Globally centralized	1.00	1.03	1.06	1.10	1.13	1.16
3: Global specialists & local janitors	1.00	1.07	1.14	1.20	1.27	1.34
4: Do-it-yourself	1.00	1.00	1.00	1.00	1.00	1.00

Table A. 13: Percentage of households purchasing devices (Locally centralized -scenario)

	2007	2008	2009	2010	2011	2012
Television	6%	7%	9%	10%	12%	13%
Digital receiver	10%	9%	9%	8%	7%	6%
IPTV Set-top-box	1%	4%	2%	3%	3%	3%
PVR	17%	24%	12%	13%	14%	14%
MP3 player	26%	24%	26%	27%	28%	29%
DVD player	23%	19%	20%	20%	18%	17%
DVD recorder	11%	9%	10%	10%	10%	10%
Home theater system	5%	5%	5%	5%	5%	5%
Video camera	2%	4%	4%	4%	4%	4%
Digital camera	18%	16%	18%	18%	20%	21%
Computer	15%	15%	19%	19%	22%	23%
Laptop	18%	17%	21%	21%	24%	25%
Printer	12%	9%	9%	10%	10%	10%
WLAN base station	15%	21%	23%	23%	25%	26%
VoIP	17%	16%	17%	18%	20%	20%
Game console	6%	6%	9%	9%	12%	12%
Cell phone	37%	37%	40%	42%	46%	48%
HD-DVD/Blu-ray player	5%	21%	9%	12%	15%	17%
Number of devices purchased on average	2.44	2.65	2.62	2.72	2.95	3.04

Table A. 14: Percentage of households purchasing devices (Globally centralized -scenario)

	2007	2008	2009	2010	2011	2012
Television	6%	7%	9%	10%	11%	13%
Digital receiver	10%	9%	9%	8%	7%	6%
IPTV Set-top-box	1%	4%	2%	3%	3%	3%
PVR	17%	24%	12%	13%	13%	14%
MP3 player	26%	24%	26%	26%	28%	28%
DVD player	23%	19%	20%	19%	17%	16%
DVD recorder	11%	9%	9%	10%	10%	10%
Home theater system	5%	5%	5%	5%	5%	5%
Video camera	2%	4%	4%	4%	4%	4%
Digital camera	18%	16%	18%	18%	20%	20%
Computer	15%	15%	18%	19%	21%	22%
Laptop	18%	17%	21%	21%	24%	24%
Printer	12%	9%	9%	9%	10%	10%
WLAN base station	15%	21%	23%	23%	25%	25%
VoIP	17%	16%	17%	17%	19%	19%
Game console	6%	6%	9%	9%	11%	12%
Cell phone	37%	36%	39%	41%	44%	45%
HD-DVD/Blu-ray player	5%	21%	9%	12%	15%	16%
Number of devices purchased on average	2.44	2.63	2.57	2.66	2.86	2.92

Table A. 15: Percentage of households purchasing devices (Global specialists and local janitors - scenario)

	2007	2008	2009	2010	2011	2012
Television	6%	7%	9%	11%	13%	15%
Digital receiver	10%	10%	9%	8%	8%	7%
IPTV Set-top-box	1%	4%	2%	3%	3%	3%
PVR	17%	24%	13%	14%	15%	15%
MP3 player	26%	25%	27%	28%	30%	31%
DVD player	23%	20%	21%	21%	19%	18%
DVD recorder	11%	10%	10%	10%	11%	11%
Home theater system	5%	5%	5%	5%	5%	5%
Video camera	2%	4%	4%	4%	5%	5%
Digital camera	18%	17%	19%	19%	21%	22%
Computer	15%	15%	19%	20%	24%	25%
Laptop	18%	17%	22%	22%	26%	27%
Printer	12%	9%	10%	10%	10%	11%
WLAN base station	15%	22%	23%	24%	26%	27%
VoIP	17%	16%	18%	19%	21%	22%
Game console	6%	6%	9%	10%	13%	13%
Cell phone	37%	37%	42%	45%	50%	52%
HD-DVD/Blu-ray player	5%	21%	9%	12%	16%	18%
Number of devices purchased on average	2.44	2.69	2.70	2.85	3.14	3.27

A.2 Tornado Chart Analysis

Table A. 16: Tornado Chart analysis results for input

Bundling discounted OPEX+CAPEX 2012	Input		
Variable	*Downside*	*Upside*	*Base Case*
Price erosion -coefficient	0.83	1.25	1.04
Renewal rate -coefficient	0.80	1.20	1.00
ARPU for Broadband -coefficient	0.78	1.18	0.98
Mobile phone bill	24 €	36 €	30 €
Computer (price)	800 €	1,200 €	1,000 €
TV License price	14 €	20 €	17 €
Laptop (price)	800 €	1,200 €	1,000 €
PayTV penetration	40%	60%	50%
PayTV price	24 €	36 €	30 €
Leasing (Percentage of devices)	8%	12%	10%
Cell phone (price)	200 €	300 €	250 €
Bundling discount	2	4	3
Television (price)	800 €	1,200 €	1,000 €
Bundling (Percentage of devices)	8%	12%	10%
Computer (penetration)	74%	111%	92%
Installation service penetration	20%	30%	25%
Installation price (per device)	120 €	180 €	150 €
Digital camera (penetration)	72%	108%	90%
MP3 player (penetration)	69%	104%	86%
DVD player (penetration)	61%	91%	76%
Printer (penetration)	58%	86%	72%
Laptop (penetration)	57%	85%	71%
WLAN base station (penetration)	56%	84%	70%
VoIP (penetration)	46%	68%	57%
MP3 player (price)	160 €	240 €	200 €
PVR (price)	400 €	600 €	500 €
Monthly maintenance service penetration	20%	30%	25%
Maintenance price (monthly)	10 €	15 €	13 €
Digital camera (price)	160 €	240 €	200 €
Computer (LP)	20 €	30 €	25 €
Leasing price -coefficient	0.80	1.20	1.00
DVD recorder (penetration)	26%	39%	33%
Game console (penetration)	25%	37%	31%
Game console (price)	280 €	420 €	350 €
Home theater system (penetration)	23%	35%	29%
DVD player (price)	120 €	180 €	150 €
Laptop (LP)	20 €	30 €	25 €
HD-DVD/Blue Ray player (price)	560 €	840 €	700 €
Video camera (penetration)	20%	30%	25%
Game console (LP)	16 €	24 €	20 €
PVR (penetration)	47%	70%	59%
DVD recorder (price)	160 €	240 €	200 €
Printer (price)	120 €	180 €	150 €
Home theater system (price)	280 €	420 €	350 €

HD-DVD/Blue Ray player (penetration)	23%	35%	29%
Video camera (price)	160 €	240 €	200 €
HD-DVD/Blue Ray player (LP)	17 €	25 €	21 €
VoIP (price)	40 €	60 €	50 €
WLAN base station (price)	64 €	96 €	80 €
Cell phone (LP)	7 €	10 €	9 €
Digital camera (LP)	6 €	8 €	7 €
Video camera (LP)	6 €	8 €	7 €
PVR (LP)	8 €	12 €	10 €
DVD recorder (LP)	6 €	8 €	7 €
Home theater system (LP)	6 €	8 €	7 €
Printer (LP)	4 €	6 €	5 €
IPTV Set-top-box (LP)	4 €	6 €	5 €
Digital receiver (price)	80 €	120 €	100 €
Storage service penetration	16%	24%	20%
Data storage price	2 €	2 €	2 €
MP3 player (LP)	4 €	6 €	5 €
IPTV Set-top-box (price)	80 €	120 €	100 €
DVD player (LP)	3 €	4 €	3 €
IPTV Set-top-box (penetration)	6%	10%	8%
WLAN base station (LP)	4 €	6 €	5 €
VoIP (LP)	1 €	2 €	2 €
Digital receiver (LP)	278%	417%	347%

Table A. 17: Tornado Chart analysis results for output

Bundling discounted OPEX+CAPEX 2012			
Variable	*Downside*	*Upside*	*Range*
Price erosion -coefficient	1,666 €	2,877 €	1,212 €
Renewal rate -coefficient	1,796 €	2,332 €	537 €
ARPU for Broadband -coefficient	1,866 €	2,316 €	450 €
Mobile phone bill	1,972 €	2,110 €	138 €
Computer (price)	1,997 €	2,086 €	89 €
TV License price	2,004 €	2,079 €	75 €
Laptop (price)	2,007 €	2,075 €	68 €
PayTV penetration	2,009 €	2,074 €	65 €
PayTV price	2,009 €	2,074 €	65 €
Leasing (Percentage of devices)	2,018 €	2,064 €	46 €
Cell phone (price)	2,022 €	2,061 €	39 €
Bundling discount	2,025 €	2,052 €	28 €
Television (price)	2,028 €	2,055 €	27 €
Bundling (Percentage of devices)	2,055 €	2,028 €	27 €
Computer (penetration)	2,029 €	2,053 €	24 €
Installation service penetration	2,029 €	2,053 €	24 €
Installation price (per device)	2,029 €	2,053 €	24 €
Digital camera (penetration)	2,029 €	2,053 €	24 €
MP3 player (penetration)	2,030 €	2,053 €	23 €
DVD player (penetration)	2,031 €	2,051 €	20 €
Printer (penetration)	2,032 €	2,051 €	19 €
Laptop (penetration)	2,032 €	2,051 €	19 €
WLAN base station (penetration)	2,032 €	2,050 €	18 €
VoIP (penetration)	2,034 €	2,049 €	15 €
MP3 player (price)	2,034 €	2,048 €	14 €
PVR (price)	2,035 €	2,048 €	13 €
Monthly maintenance service penetration	2,035 €	2,047 €	12 €
Maintenance price (monthly)	2,035 €	2,047 €	12 €
Digital camera (price)	2,036 €	2,046 €	10 €
Computer (LP)	2,037 €	2,046 €	9 €
Leasing price -coefficient	2,046 €	2,037 €	9 €
DVD recorder (penetration)	2,037 €	2,046 €	9 €
Game console (penetration)	2,037 €	2,045 €	8 €
Game console (price)	2,037 €	2,045 €	8 €
Home theater system (penetration)	2,037 €	2,045 €	8 €
DVD player (price)	2,038 €	2,045 €	7 €
Laptop (LP)	2,038 €	2,045 €	7 €
HD-DVD/Blue Ray player (price)	2,038 €	2,045 €	6 €
Video camera (penetration)	2,038 €	2,044 €	6 €
Game console (LP)	2,038 €	2,044 €	6 €
PVR (penetration)	2,038 €	2,044 €	6 €
DVD recorder (price)	2,039 €	2,044 €	5 €
Printer (price)	2,039 €	2,044 €	5 €
Home theater system (price)	2,039 €	2,044 €	5 €
HD-DVD/Blue Ray player (penetration)	2,040 €	2,043 €	3 €
Video camera (price)	2,040 €	2,043 €	3 €
HD-DVD/Blue Ray player (LP)	2,040 €	2,043 €	3 €

VoIP (price)	2,040 €	2,043 €	3 €
WLAN base station (price)	2,040 €	2,043 €	3 €
Cell phone (LP)	2,040 €	2,043 €	3 €
Digital camera (LP)	2,040 €	2,042 €	2 €
Video camera (LP)	2,040 €	2,042 €	2 €
PVR (LP)	2,040 €	2,042 €	2 €
DVD recorder (LP)	2,040 €	2,042 €	2 €
Home theater system (LP)	2,040 €	2,042 €	2 €
Printer (LP)	2,040 €	2,042 €	2 €
IPTV Set-top-box (LP)	2,040 €	2,042 €	2 €
Digital receiver (price)	2,040 €	2,042 €	2 €
Storage service penetration	2,041 €	2,042 €	1 €
Data storage price	2,041 €	2,042 €	1 €
MP3 player (LP)	2,041 €	2,042 €	1 €
IPTV Set-top-box (price)	2,041 €	2,042 €	1 €
DVD player (LP)	2,041 €	2,042 €	1 €
IPTV Set-top-box (penetration)	2,041 €	2,042 €	1 €
WLAN base station (LP)	2,041 €	2,042 €	1 €
VoIP (LP)	2,041 €	2,042 €	1 €
Digital receiver (LP)	2,041 €	2,041 €	0 €