LAPPEENRANTA
UNIVERSITY OF TECHNOLOGY

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TOWARDS OPEN ACCESS NETWORKS - PROTOTYPING WITH THE LAPPEENRANTA MODEL

Thesis for the degree of Doctor of Science (Technology) to be presented with due permission for public examination and criticism in the Auditorium 1382 at Lappeenranta University of Technology, Lappeenranta, Finland on the 2nd of October, 2009, at noon.

Acta Universitatis
Lappeenrantaensis
349

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ISBN 978-952-214-802-5
ISBN 978-952-214-803-2 (PDF)
ISSN 1456-4491

Lappeenranta University of Technology
Digipaino 2009

Preface

The work presented in this thesis was carried out between 2001 and 2008 in the Laboratory of Communications Engineering in the Department of Information Technology at Lappeenranta University of Technology. The practical work was done mainly during a WLAN research project from 2001 to 2004.

First I wish to thank everyone who participated in the WLAN project: Jari Porras, Jouni Ikonen, Janne Oksanen, Tomi Lapinlampi, Harri Hämäläinen Vladislav Kurz, Radek Spáčil, Sami Seppänen, Antti Seppänen, Dmitri Petchatnikov, Riikka Aholainen Antti Sutela and Jenni Hyvärinen. They did a great deal of work and turned the Lappeenranta Model from a sketch on a piece of paper into a working environment.

Two people in particular have had a great influence on the contents of this thesis: Dr. Jouni Ikonen, who I would like to thank for his inspiring and encouraging way of thinking, and Professor Jari Porras, who supervised this work.

This thesis was financially supported by The Emil Aaltonen Foundation, Lappeenranta University of Technology, The Research Foundation of Lappeenranta University of Technology, The Ulla Tuominen Foundation and The Finnish Foundation for Economic and Technology Sciences – KAUTE. Their support is gratefully acknowledged.

As well as a fulfilling working life, I am lucky to have a loving family. My wife Elisa with our daughters, Anniina and Eveliina have brought added meaning to my life. I also wish to thank my parents, Marjatta and Martti, for their continuous support throughout my educational.

Matti Juutilainen

Mikkeli, 11th of August 2009

Abstract

Matti Juutilainen
**TOWARDS OPEN ACCESS NETWORKS –
PROTOTYPING WITH THE LAPPEENRANTA MODEL**
Lappeenranta, 2009
88 p.

Acta Universitatis Lappeenrantaensis 349
Diss. Lappeenranta University of Technology

ISBN 978-952-214-802-5
ISBN 978-952-214-803-2 (PDF)
ISSN 1456-4491

The provision of Internet access to large numbers has traditionally been under the control of operators, who have built closed access networks for connecting customers. As the access network (i.e. the last mile to the customer) is generally the most expensive part of the network because of the vast amount of cable required, many operators have been reluctant to build access networks in rural areas. There are problems also in urban areas, as incumbent operators may use various tactics to make it difficult for competitors to enter the market.

Open access networking, where the goal is to connect multiple operators and other types of service providers to a shared network, changes the way in which networks are used. This change in network structure dismantles vertical integration in service provision and enables true competition as no service provider can prevent others from competing in the open access network.

This thesis describes the development from traditional closed access networks towards open access networking and analyses different types of open access solution. The thesis introduces a new open access network approach (The Lappeenranta Model) in greater detail. The Lappeenranta Model is compared to other types of open access networks. The thesis shows that end users and service providers see local open access and services as beneficial. In addition, the thesis discusses open access networking in a multidisciplinary fashion, focusing on the real-world challenges of open access networks.

Keywords: **open access, open access network, operator neutral network, Lappeenranta Model, Sainet**

UDC 004.7 : 338.46

Summary of Publications

This thesis consists of six publications related to open access networking.

Publication 1

M. Juutilainen, J. Ikonen, and J. Porras, *Connecting Multiple Operators to a Regional Network*, The 2nd IASTED Conference on Wireless and Optical Communications (WOC 2002), July 17-19, 2002, Banff, Alberta, Canada, pp. 545-550, ISBN 0-88986-344-X.

This publication describes the concept of connecting multiple ISPs to a regional access network. The publication discusses issues concerned with having multiple ISPs in one shared access network and introduces the basic structure of the new network model as well as the central components developed in the Wireless Lappeenranta project at Lappeenranta University of Technology during the years 2001-2003. The publication analyses the benefits and drawbacks of using an Operator Interface but does not go into details.

The main ideas of Publication 1 are from Jouni Ikonen and Jari Porras, who for several years had been considering connecting several Internet-operators and service providers to a shared access network. The author of the thesis participated in developing the ideas and wrote most of the paper.

Publication 2

M. Juutilainen, J. Ikonen, and J. Porras, *Evaluation of a Next Generation Public Wireless Multi-ISP Network*, The 27th Annual IEEE Conference on Local Computer Networks (LCN 2002), November 6-8, 2002, Tampa, Florida, USA, ISBN 0-7695-1591-6.

This publication gives an overview of the development history of wireless multi-ISP networks and introduces a next generation network model and its basic operating principles. The presented Lappeenranta Model allows the building of centrally managed public multi-ISP networks. Opening the regional network to the public affects all connected participants. ISPs, end users, as well as service providers and local authorities benefit from the changed infrastructure. The centralized management eases the network manager's workload and reduces maintenance costs.

Publication 2 continues the discussion of open access networks and was mainly written by the author of the thesis with the support and ideas of the co-authors.

Publication 3

M. Juutilainen, J. Ikonen, and J. Porras, *Comparison of Different WLAN Network Models*, 3rd IEEE International Conference on Networking (ICN'04), February 29-March 4, 2004, Gosier, Guadeloupe, French Caribbean, pp. 374-381, ISBN 0-86341-326-9.

This publication introduces different WLAN network models that can be found worldwide and illustrates their effect on developments towards open network provisioning. The models are compared in terms of network architecture, technology, and the opportunities that the network is capable of providing.

Publication 3 was mostly written by the author of the thesis with the support of the co-authors.

Publication 4

M. Juutilainen, T. Lapinlampi, J. Ikonen, and J. Porras, *Structure and Performance of Open Access Networks - Case Lappeenranta Model*, The 6th International Network Conference (INC 2006), July 11-14, 2006, Plymouth, UK, pp. 71-80, ISBN 1-84102-157-1.

Publication 4 describes a concrete example of the structure of an open access network. The paper briefly defines the Lappeenranta Model and its functionality, new features (like positioning and advertising), technical implementation options and performance compared to traditional proxy systems.

Practical implementation of WLPR.NET was done by the WLPR project staff. The performance tests were carried out by Tomi Lapinlampi and he wrote the basis for the performance part of the paper. The author of the thesis wrote the other parts of the paper.

Publication 5

M. Juutilainen, J. Ikonen, and J. Porras, *Towards Information Society - eEurope and Evolving Networks*, The 13th IEEE International Conference on Software, Telecommunications and Computer Networks (SoftCOM 2005), September 15-17, 2005, Split, Marina Frapa, Croatia, 5 pages, ISBN 953-6114-78-X.

This paper evaluates the European Union's roadmap towards an information society, the eEurope program. The program sets the requirements for networking for the near future. The paper discusses the evolution of networks, concentrating on open access, and evaluates the ability of different networking options to provide the necessary features to meet the eEurope program's goals. The publication further discusses whether services should be provided to access networks globally as nowadays or locally as new open access networks may allow.

Publication 5 was produced by the author of the thesis with the support of the co-authors.

Publication 6

M. Juutilainen, J. Ikonen, L.-M. Sainio and J. Porras, *Open Access Networks: Operating Options and Challenges of Business Logic*, The 14th IEEE International Conference on Software, Telecommunications and Computer Networks (SoftCOM 2006), September 29 - October 1, 2006, Split, Dubrovnik, Croatia, 5 pages, ISBN 953-6114-87-9.

Publication 6 evaluates options for operating different types of open access networks. The evaluation is based mainly on the network operator's role. The publication also considers different aspects of generating business in open access networks and individualizes sources of income and expenses for each player in network.

Publication 6 was mostly written by the author of the thesis with the support of the co-authors. Sainio wrote the sections on the business aspects and disruptiveness of WLAN.

In this thesis, these publications are referred to as *Publication 1*, *Publication 2*, *Publication 3*, *Publication 4*, *Publication 5* and *Publication 6*.

List of Abbreviations and Terms

Abbreviation/Term	Meaning
Access Controller	A component that resides between an access network and external networks controlling traffic inbetween.
Access Network	The part of a computer network that end users connect to. Delivers data from end users' computers to the? access network operator. Can also be called edge network.
Access Network Operator	An organization that is responsible for managing and keeping the access network functional.
ADSL	Asymmetric Digital Subscriber Line (standardized in ANSI T1.413-1998 Issue 2). A DSL technology that reserves most of the capacity to transmit downstream to the user from the network. Provides a maximum downstream speed of 8 Mbps and 1 Mbps upstream.
ADSL2	Asymmetric Digital Subscriber Line 2 (standardized in ITU G.992.3). Improves the speed of ADSL to a maximum of 12 Mbps (downstream) and 3,5 Mbps (upstream).
ADSL2+	Asymmetric Digital Subscriber Line 2+ (standardized in ITU G.992.5). Improves the speed of ADSL to a maximum of 24 Mbps (downstream) and 3,5 Mbps (upstream).
Advertisement System	A service defined in the Lappeenranta Model that allows the showing of predefined advertisements or announcements to end users.
Bandwidth	Bandwidth is the throughput of the communication channel, i.e. bandwidth determines the network speed. Typically measured in bps. Bandwidth also has an alternative definition; the difference between the lower and upper cutoff frequencies in transmission. Typically measured in hertz, Hz. This thesis uses the former of the two definitions.
Broadband	Broadband (sometimes referred to as high bandwidth) indicates a connection speed that allows using the content in information networks to transfer fluently. The definition of the speed varies but generally the minimum broadband speed is considered to be between 256-1024 kbps. Broadband also has an alternative definition, indicating that certain network technology utilizes a broad spectrum of frequencies. This thesis uses the former of the two definitions.
Cache	A special high-speed storage mechanism (either memory or disk) that stores the most recently accessed data for fast retrieval. When data is found in the cache, it is called a c*ache hit*, and the effectiveness of a cache is judged by its *hit rate*.
CGI	Common Gateway Interface. A standard that defines an interface for connecting external applications with information servers, typically web servers.
Closed Access	A network owner limits other customers' and/or service providers' access to the network.
Closed Access Network	A network where the participation of service providers other than the network owner is limited or prohibited.
Commercial OAN	A network built by a neutral and reliable commercial organization. The network is leased to all under equal terms.

Community Network	A network usually built by individuals that exists for connecting users to each other and optionally to the Internet. Anyone must be allowed to connect and transfer any data in the access network. In this sense community networks are usually free networks.
Core Network	A backbone network that provides any-to-any connections among devices in the network.
DHCP Relay	A DHCP server that listens to DHCP traffic from DHCP clients and relays this traffic to DHCP servers that are located in different subnets.
DHCP	Dynamic Host Configuration Protocol. A protocol that allows network administrators to assign network settings to devices automatically.
Digital Divide	The gap between users that have effective access to digital information and those without access.
Disruptive Technology	A new technology that unexpectedly displaces an established technology.
DNS	Domain Name Service. A service that translates host names into IP addresses.
DSL	Digital Subscriber Line. A technology for transmitting digital information at high bandwidth on existing phone lines to homes and businesses.
DVB	Digital Video Broadcasting. A suite of internationally accepted open standards for digital television. Consists of several standards suitable for different uses, for example, DVB-T (terrestial), DVB-C (cable), DVB-S (satellite) and DVB-H (handheld).
Edge Network	*See Access Network.*
Fiber	*See Optical Fiber.*
Free Access Network	An open access network that is free to join and use. This does not necessarily include free Internet connection or free services, just free access and a possibility to transfer information in the local network.
Free Network	A network that anyone can join and use for transferring information with no charge.
FTTH	Fiber-to-the-Home.
Gbps	Gigabits per second, billions of bits per second.
Global Service	A service that is located in the Internet. Reaching the service requires Internet access.
Housing Cooperative Network	The housing cooperative has its own access network connecting the apartments together. The access network is then connected to the Internet through a shared (both bandwidth and price) connection.
HTTP	Hypertext Transfer Protocol. A communications protocol used for transferring hypertext documents (typically web pages).
Information Society	A state of society where the importance of information has grown substantial. Everyone must have equal access to information.
Internet Service Provider	A company that provides consumers with access to the Internet.
Internet	A decentralized global network connecting millions of computers. Transmits packet data with the Internet Protocol (IP).
IP Address	A unique address that is used to identify device interfaces in any IP-based network, like the Internet.

ISDN	Integrated Services Digital Network. A circuit-switched telephone network system that allows digital transmission of voice or data over ordinary telephone cables.
ISP	*See Internet Service Provider.*
kbps	Kilobits per second, thousands of bits per second.
LAN	*See local area network.*
Lappeenranta Model	An open access network approach that strongly emphasizes locality and local interaction of services and people.
Last Mile Network	*See Access network.*
LIS	*See Location Information System.*
Local Area Network	A computer network covering a small geographic area, such as a home, office, or group of buildings (for example, a school).
Local Service	A service that can be used directly inside an access network without the need for an Internet connection.
Location Information System	A service in the Lappeenranta model that can be used to get location information about a certain user (i.e. a device) to the accuracy of one WLAN access point.
MAC Address	A unique address given to every network adapter. Used for communication inside subnets.
MälarEnergi Stadsnät	A commercial open access network in the Västerås district in Sweden.
Mbps	Megabits per second, millions of bits per second.
MPLS	Multi-Protocol Label Switching. A technology for speeding up network traffic flow and making it easier to manage.
Multi-Play	Bundling of several different telecommunication services (like broadband Internet access, television, telephony, voice-over-IP etc.) in one package.
NAT	Network Address Translation. Enables the use of one set of IP addresses for internal network traffic and a second set of addresses for external traffic.
Neutral Network Operator	Supervises access network management and allows all service providers an equal opportunity to offer services to the access network users.
Neutral Network	In a neutral network everyone is able to provide any services in the access network under equal terms, which ensures fair competition.
OAN	*See Open access network.*
Open Access	Any service provider may join a communication network under equal terms and solicit its own customers, and any end user may freely choose any service provider(s) in the network. Open access can also be defined technically as the unbundling of different networking layers. This thesis uses the former of the two definitions.
Open Access Network	An access network that is not closed, i.e. network access or usage is not limited by the network owner. An open access network owner must make the network available to everyone under equal terms and must not interfere with data transmission in the OAN.
Open Network Access	Anyone can connect to the access network and use the access network infrastructure for communicating with each other or for reaching external networks.

Open Network	Anyone should be free to use and provide any services in the OAN and extend the OAN.
Open Service Access	Anyone can get access to all services in the OAN, i.e. the access network owner does not limit service usage or provision.
OpenSpark	A community for wireless network users in SparkNet. Consists of WLAN access points owned by community members. Each access point is separately connected to the Internet by the owner.
Operator Interface	The core of the Lappeenranta Model. Includes all the functionality needed to keep the solution operational.
Operator Neutral	*See neutral network.*
Operator	Operators provide the medium for service providers to reach the end users.
Optical Fiber	A glass or plastic fiber that guides light along its length. Allows high-speed communication (typically 1-10 Gbps) over long distances (tens of kilometers).
panOULU	Public access network OULU. A wireless network in the Oulu region in Finland that provides broadband Internet access to everyone.
Perl	Practical Extraction and Report Language. A popular, dynamic programming language.
Polygraph	*See Web Polygraph.*
PolyMix-4 workload	A workload for the Web Polygraph proxy bechmark. Consists of 10 phases that each represent different load on the system.
POTS	Plain Old Telephone Service. The voice-grade telephone service that remains the basic form of residential and small business service connection to the telephone network in most parts of the world.
Proxy Server	A server that is located between a client application, such as a web browser, and a real server. Intercepts all requests to the real server to see if it can fulfill the requests itself. If not, it forwards the request to the real server.
QoS	Quality of Service. Specifies a guaranteed throughput level in a packet-switched network. Can be used to provide different speed classes to different applications, users or data flows.
Quadruple Play	Bundling of triple play service of broadband Internet access, television and telephone with wireless service provisioning.
RADIUS	Remote Authentication Dial In User Service. An AAA (Authentication, Authorization, and Accounting) protocol for controlling access to network resources.
Regional network	People build their own access network themselves. Usually built in rural areas, where ISPs find it unprofitable to provide broadband access.
Sainet	A wireless open access network that operates in the Lappeenranta-Imatra region of South Karelia in Finland. Based on the Lappeenranta Model.
SDSL	Symmetric Digital Subscriber Line. A DSL technology that uses the same data rate in both directions.
Service Provider	Offers services to end users.
Service Selection Gateway	Offers service providers a means for menu-based service selection. For example, network users may be given a login page where they can select the service provider.

SparkNet	A commercial open access network in Turku, Finland. Based on the StockholmOpen.net.
Squid	An open source proxy server and web cache.
SSL	Secure Sockets Layer. A protocol that provides secure communications via the Internet.
StockholmOpen.net	A framework for building open access networks. Based on using a DHCP relay.
Telco	A telecommunications company.
Triple Play	Bundling of broadband Internet access, television and telephony together in one package that is sold to end users.
UMTS	Universal Mobile Telecommunications System. One of the third generation (3G) mobile telephone technologies.
Vertical Integration	The same company owns and controls the whole service stack from network infrastructure to content and service delivery.
VLAN	Virtual Local Area Network. A group of hosts that communicate as if they were attached to the same wire, regardless of their physical location.
WDSL	Web Service Description Language. An XML-based language for describing Web services.
Web Cache	Caching of web documents (such as HTML pages, images etc.) in order to reduce bandwidth usage, server load and network delays.
Web Polygraph	A high-performance proxy benchmark that models a diverse set of characteristics of normal web traffic.
Web Proxy	A proxy server that concentrates www traffic.
Open Wireless City Network	A wireless (usually WLAN) network in a city. Opens access to everyone, disseminates information and provides affordable connectivity
WISP	Wireless Internet Service Provider. An ISP that provides wireless connections.
WLAN	Wireless Local Area Network. A local area network that uses high-frequency radio waves rather than wires to communicate between devices.
WLPR.NET	A research network based on Lappeenranta Model. Currently known as Sainet.

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1 Introduction

An extensive WLAN project was started at the Department of Information Technology, Lappeenranta University of Technology in January 2001. The original project plan, dated October 10, 2000 describes the aim and goals of the project.

"The goal of WLAN project is to act as a pioneer and ***promote wireless networks and services for cities and communities****, and to build up information society where everyone has an* ***equal opportunity of using electronic services****. Flow of information can be accelerated and canalized so that people get new ways of obtaining information, developing their skills, and studying and working in network. The project will create a base that allows building* ***new kinds of services*** *on top of it, for example new workplaces, business opportunities, e-mail and home page services for everyone.* ***A research network will allow testing*** *new network technologies and services before possible commercialization."*

The project was the commencement of the author's research work that concludes this thesis.

1.1 Motivation

The WLAN-project started at a time when the first wireless local area networks (WLANs) were emerging. The first standard IEEE 802.11 had been ratified two years earlier and the update 802.11b was just coming to the markets. The commercial use of WLANs for providing networks to end users was still unclear. Internet Service Providers, ISPs, were starting to provide the last mile with WLAN networks to end users. For example, in Finland Jippii Group started to provide customers with WLAN networks in 2000. If multiple ISPs wanted to provide WLAN connections to end users each of them needed to build their own network to compete with other operators. Building multiple networks in the same area causes interference between networks [Yee02] and requires unnecessary investment in several networks. At the time there were no known solutions to the problem of how to share a network between multiple ISPs efficiently and fairly.

The vision of the WLAN project was to create an environment that would allow sharing a local access network, i.e. connecting multiple ISPs to the same access network, and would promote local services. This vision was soon to be realized not only in local research but also in overall networking development around the world. The StockholmOpen.net project started to research the issue at approximately the same time and introduced their solution in March 2001 [Sto07]. Their motivation was also to create a shared multi-ISP network but they did not focus on providing local services.

Since that time several options for building the environment have been seen but usually the main goal has been to share the network rather than provide local services.

Modern societies are currently undergoing a change towards broader exploitation of information. As Castells [Cas00] describes, in the recent past, industrialism has generated most of the gross national product in the developed world but now the rise of informationalism is changing the focus towards the creation, distribution and manipulation of information. Many existing technologies, like RFID, are technically ready to be utilized and the development issues currently concentrate on the use of information itself. As the importance of information is growing, it is becoming the most significant activity both in economics and culture. This development is driving humanity towards an information society. These issues were discussed for example at the recent IST 2006 conference [IST06].

One of the key issues in the information society is that everyone must have equal access to information. Existing computer networks usually impose limits to users' ability to get access to information as network bandwidth, price or availability may be insufficient. This causes a *digital divide* between users that have effective access to digital information and those without such access [Com01]. Since open access networks (OANs) aim to ease end users' access to networks (and to information) they can be used to boost the development towards an information society and to reduce the digital divide.

1.2 Problem Statement

The research work presented in this thesis started at a time when WLANs were first being developed and this development allowed new approaches to building access networks that connect end users to the Internet. WLAN was used as a last mile technology and there were many problems, especially regarding competition between operators as interference between overlapping WLANs makes it difficult to provide many competing networks in the same area. In such a context the problem was how to technically build a shared network for all operators and how to ensure fair competition between all operators and service providers. The WLAN-project also wanted to develop a structure that would enable local services as at the time location based services were gaining in popularity.

This thesis promotes knowledge about the different options of open networking. The thesis discusses the current development in networking from closed access towards a more open direction with a multidisciplinary discussion of open access networking, focusing on the real-world challenges for delivering OAN services. One option for building an OAN, the Lappeenranta Model, is examined in detail.

1.3 Contributions

The core contribution of this thesis is the Lappeenranta Model, which is one option for building an open access network. A research network called Sainet, which is built according to the Lappeenranta Model, is used to show that *it is technically possible to build a viable open access network with the Lappeenranta Model*. Performance tests demonstrate that *running the Lappeenranta Model requires similar equipment to running any standard web proxy installation*, i.e. the model does not drastically decrease the overall system performance. Surveys and interviews are used to show that *end users and service providers see this kind of local open access and local services as beneficial*.

The contributions of this thesis are verified by several different methods. First, the work shows by using a *prototype* (Sainet) that the Lappeenranta Model can be used to build a viable OAN. The Lappeenranta Model was prototyped with different implementation options to find out the best option for functionality and performance. *Business analysis* was done to verify the network's potential uses and sources of income. In addition, *surveys* of end users and potential service providers were conducted to ascertain their opinions and ideas about the network.

This thesis does not try to present ready-made and all-inclusive solution for providing open access to everyone but to evaluate different options and the overall development towards open access on a general level. There are different environments and cultures for which different solutions work best. The Lappeenranta Model represents a working example of implementation of an open access network and will be described in greater detail in this thesis. However, the author appreciates that every networking option has its own benefits and drawbacks and the Lappeenranta Model is not to be favored over other options. The work does not include a full performance analysis of the whole Lappeenranta Model – the goal of the thesis is to measure overall performance and compare it to standard proxy systems to see the performance difference to traditional closed access systems.

This thesis discusses different aspects of societal and business phenomena that are closely related to open access networks. These issues are, however, only used to put open access networks into the correct context – the issues are not dealt with comprehensively.

The field of open access networking has changed quite considerably since the research work started in the beginning of 2001. At that time there were fewer options for open access networking and the terms were not as fixed as today. This thesis and the publications it consists of follow the historical development phases of open access networks. Therefore it should be borne in mind that each of the publications represents the situation at that time.

2 Development towards Open Access

This chapter describes the development of access networks from a closed towards an open approach. The *access network* (or edge network or last mile network) is the part of a computer network that end users connect to. The access network delivers data from the computers of end users to the access network operator. The operator has connections onwards, for example, to other operators via core networks. [Hua00] provides more information on these network types and protocols. This chapter mostly deals with last mile access as it is generally the most expensive part of the whole access network and the only part of the network that customers can directly influence [Che03].

Several different network technologies can be used to build access networks. ISPs use different technologies in different parts of the access networks. Fast core networks that connect local area networks together are usually built with optical fiber, which provides substantial capacity. For the last mile to end users further possibilities exist that can be used in parallel.

Today most people (about 62 per cent worldwide) are connected to information networks with DSL technologies that provide speeds up to 24 Mbps in urban areas [OECD07]. These speeds, however are available only in bigger cities and in the immediate vicinity of an ISP's telephone center. In practice, the maximum speeds that most end users can currently achieve are in the magnitude of 2-8 Mbps. See, for example, [Gre97] or [Sta98] for more information on ADSL and [Woo05] for updated information and comparisons with its newer versions ADSL2 and ADSL2+.

Governments are driving the development towards universally-available faster connections. For instance, the European Fibre-to-the-Home Council [EFT07] is promoting the deployment of optical fiber in order to ensure quality-of-life enhancements. Many emerging services like high-quality video or TV streams require fast networks and optical fiber allows the transmission of data remarkably fast, currently the speed used in a fiber network is usually about 1-10 Gbps but the maximum limit is far greater. Although fiber networks are becoming more popular, the actual state of access networks is still far from having optical fiber installed to every home. Some information on the current state of Fiber-to-the-Home networks throughout the world can be found in the literature, for example, in [Gre04], [Lii05a], [Koo06] and [Wou07].

Figure 1 classifies different network types according to their openness and how they are related to each other. The figure also gives examples of each network type, labeled in italics.

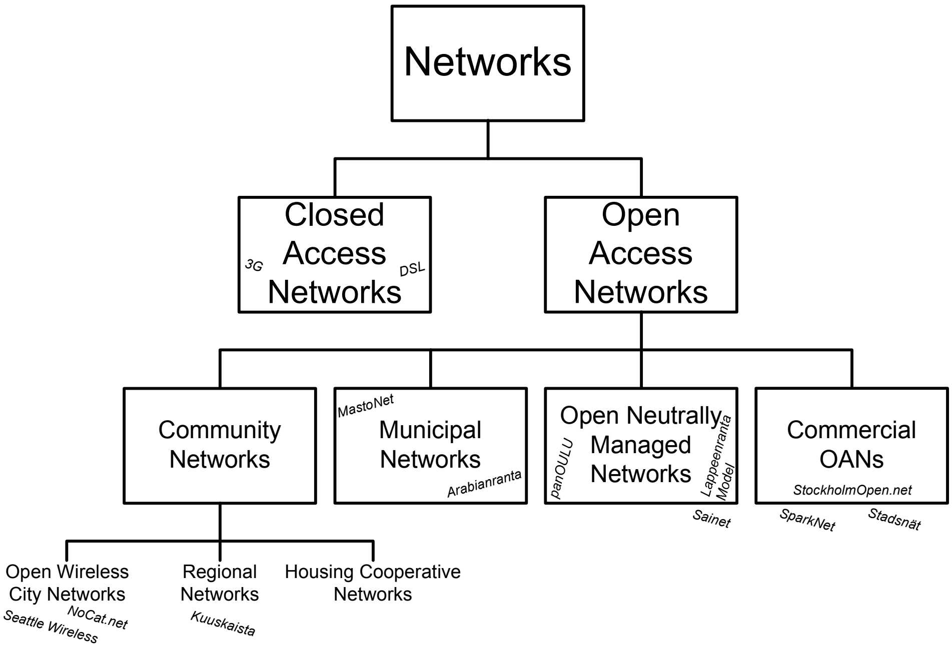


Figure 1. Classification of networks.

Development phases from traditional closed access towards open access are discussed in *Publication 2*. The publication describes the development of wireless local area networks but as WLAN is only one of many access technologies the following evaluation considers the issue at a more general level.

2.1 Closed Access Networks

Operators have been building access networks for decades in order to provide connectivity to potential customers. These networks include telephone networks (Plain Old Telephone Service, POTS), TV networks, etc. A common factor with these networks is that their usage is restricted by the network owner and based on subscription.

Traditionally, a local telephone operator has built a telephone cable network to a new residential area at the same time as the area itself is being built. Being the only operator that provides telephone connectivity in the area, the residents have consequently bought telephone services from the operator. This has lead to a situation where local operators have gained monopolies in certain areas and have been able to prevent their competitors from entering the market. As there is no real competition, the operator has considerable control over services prices, resulting in high service fees, poor service level and slow development. Battiti et al. describe this kind of situation in [Bat03] and [Bat05].

One of the greatest problems with closed access networks is *vertical integration*: the same company owns and controls the whole service stack from network infrastructure to content and service delivery. A more detailed description of vertical integration can be found, for example, in [Bat03], [Bat05] and [Leh98a]. As Figure 2 illustrates, vertical integration makes it difficult to compete with large ISPs that already have access network coverage in certain areas. In order to provide services to the area a new ISP would either have to pay rental fees for using the existing ISPs connections or build a new overlapping network. In many cases, the interconnection fees have been high, especially for smaller ISPs, generating considerable revenues for the access network owner and acting as a barrier-to-entry.

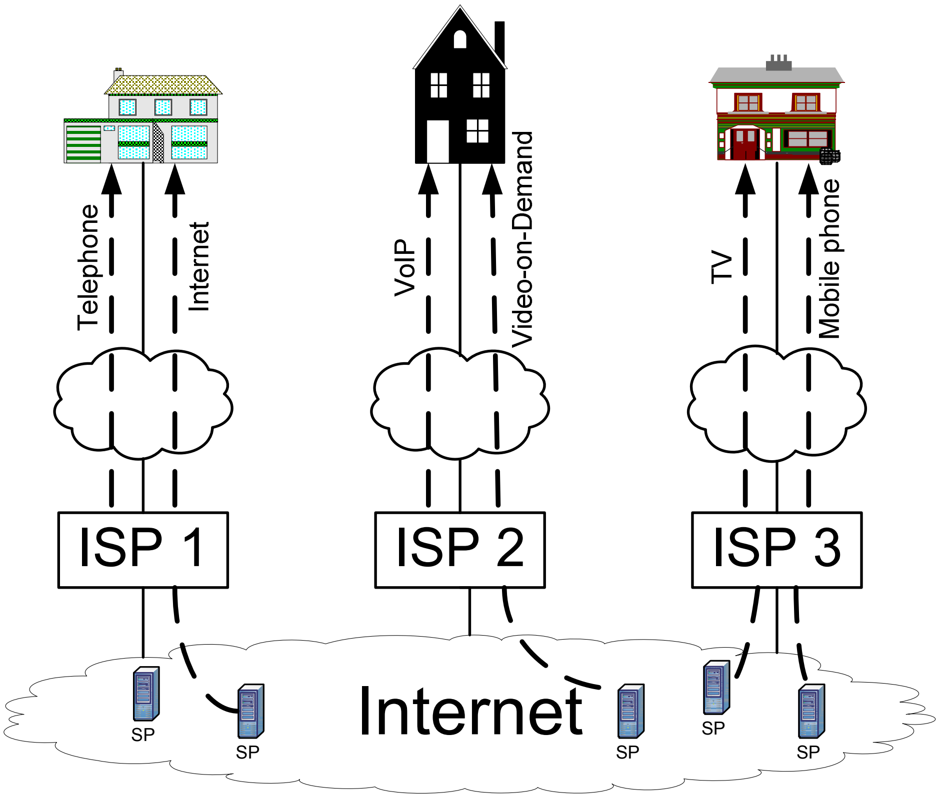


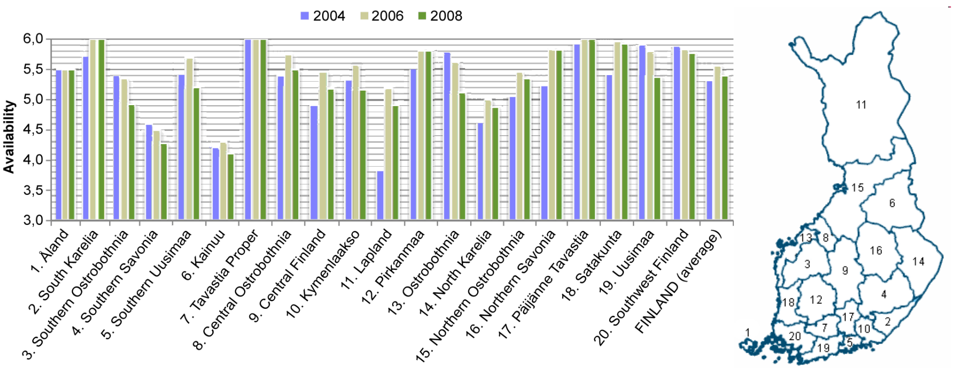
Figure 2. Vertical integration of services (Internet connection and other examples).

The technical implementation and management of a closed single-ISP network is rather straightforward, using access controllers that authenticate customers against a customer database [Ala01]. Closed access networks provide connections to the access controllers of the ISP that controls the connections onwards to the Internet. The local last mile network includes usually no services except some login and info pages in the access controller. Additional value services (like web pages, e-mail, messaging etc.) are located behind the access controller, in the Internet. In order to reach these services the customer needs to get through the access controllers. In other words, the user has to make a contract with the ISP and pay the connection fee in order to pass the access controllers and reach the services in the Internet.

2.1.1 Limitations of DSL Coverage in Finland

Building an access network, especially the "last mile" to reach the end users, is expensive due to large amount of cables and labor needed to reach every residence. This is not a problem in urban areas as there are lots of potential customers in a small geographical area. Building access networks to rural areas, however, where distances are great and population is sparse may not be of interest to ISPs, who give the least profitable areas lowest priority in their expansion plans.

DSL is the leading technology on broadband connections in Finland. About 77 per cent out of 1 760 000 broadband connections are made with DSL technology [Lii08a]. However, as Figure 3 illustrates the availability of DSL connections varies greatly in different parts of Finland. The DSL coverage is near 100 per cent in some municipalities but most municipalities have some shadow regions. The coverage is also reduced in some areas because other broadband technologies (3G, Digita's @450, and cable modems etc) have become more common.



0 = service not available, 1 = <20,0 %, 2 = 20,0–39,9 %, 3 = 40,0–59,9 %, 4 = 60,0–79,9 %, 5 = 80,0–94,9 %, 6 = 95,0–100,0 %

Figure 3. Availability of DSL connections in Finland (reproduced from [Lii05b] and [Lii08a]).

Table 1 provides more details on the regional differences in the availability of DSL connections in Finland. The bigger, more urbanized and denser the population in the municipality, the better is the availability of DSL connections and the greater the number of service providers. In other words, ISPs have invested in places with the largest number of potential customers in the smallest possible area. For example, the degree of urbanization in 18 of Finland's 20 municipalities is less than 25 per cent and in these areas there is exactly one available ISP to choose from. In more urbanized regions there are options, which bring more competition to the area. The availability of DSL connections is also lower in rural areas than in highly urbanized areas. The same problem relates to municipalities that have a low population numbers or scarce population density. The table further reveals that most municipalities in Finland are small in terms of number of citizens. Only 15 municipalities out of 415 have over 50 000 citizens and about half of the municipalities (209) have fewer than 5 000 citizens.

		Availability of DSL connections *	Number of ISPs
Population	**Below 5 000 (209)**	5,4	1,7
	5 000 – 19 999 (153)	5,7	2,8
	20 000 – 49 999 (38)	5,9	3,8
	50 000 – 99 999 (9)	6,1	4,0
	More than 100 000 (6)	6,2	7,5
Degree of urbanization	**0,0–24,9 % (18)**	5,3	1,0
	25,0–49,9 % (124)	5,3	1,7
	50,0–74,9 % (162)	5,5	2,3
	75,0–100,0 % (111)	6,0	3,6
Population density	**Below 10 citizens / km^2 (182)**	5,1	1,8
	10,0 – 19,9 citizens / km^2 (111)	5,8	2,3
	20,0 – 99,9 citizens / km^2 (82)	6,0	2,9
	More than 100 citizens / km^2 (40)	6,2	4,5
	Average (415)	5,6	2,3

* 0 = Service unavailable in the municipality (available to 0 % of the households)
1 = Service available only to a small amount of the households (< 20 %)
2 = Service available to remarkably less than half of the households (20,0-39,9 %)
3 = Service available to about half of the households (40,0-59,9 %)
4 = Service available to remarkably more than half of the households (60,0-79,9 %)
5 = Service available to most of the households (80,0-94,9 %)
6 = Service available to almost every household (95,0-99,9 %)
7 = Service available to every household in the municipality (about 100 %)

Table 1. Influence of municipality population, urbanization and population density on the availability of DSL connections in Finland (reproduced from [Lii08a]).

2.1.2 Competition in Broadband Internet Services

As [Fin02] describes, there are both wholesale and retail markets for broadband Internet services. A *service operator* forms the retail market for broadband services and sells Internet access to consumers and private firms. To access the Internet, the service operator obtains network capacity from a *network operator*. This forms the wholesale market of broadband services.

In 1998 Lehr claimed in [Leh98b] that there is a need for a centralized authority to regulate the competition in broadband markets both in US and Europe. As explained in *Publication 5*, governments have since become involved with the problems associated with competition by enacting legislation and obliging operators to rent their access networks to outside service providers at a price relative to the real maintenance costs. In the United States, the Federal Communications Commission (FCC) made telephone companies (telcos) open their access networks also to the competitors. The FCC has, not, however, required the same from cable companies, giving them an opportunity to maintain their monopolies [Med07]. Other publications also describe the current situation in the U.S., see for example [Hau01] and [Wu05] for more information.

Just as in the United States, in Europe governments have obliged telcos to share their access network with competitors at a reasonable price [Bar97]. In Finland, for example, the Communications Market Act 393/2003 [Fin03b] contains obligations for telcos with significant market power. Telcos have been obliged to divide their operations into network operator and service operator parts. The network operator sells Internet access to any service operator that offers connectivity to consumers and private companies. The network operator must rent Internet access to outside service providers on equal terms.

The Finnish Competition Authority has examined potential competition restraints in broadband service markets in Finland. Their Annual Report on Competition Policy Developments in Finland from April 2002 to February 2003 [Fin03a] states that despite the legal obligations, in some geographical areas there are problems with broadband provision. According to the report, competition functions well in the cities but problems arise in sparsely populated areas and are related to the dominant position of the local telcos that own the local network and control competitors' access to the network. These local telcos provide network access while at the same time competing with outside service providers for customers. Restraints identified by the Finnish Competition Authority mainly relate to bundling of products (i.e. selling the Internet services, access to the Internet via local network and the necessary equipment together). Separate prices for individual products may not have been specified or may be high.

Although there is a legal obligation to rent the access network to every service provider, calculating a reasonable price for rental is far from simple as it must include the "real" costs of both maintaining the network and amortizing the building costs. [Met01] and [Wei04] address the issues and potential solutions for interconnecting ISP networks.

The above examples of governmental intervention show that there have been and still are problems with closed access competition. As *Publication 5* points out, most problems are related to unfair competition and the difficulty of getting broadband access to sparsely populated areas. There are other additional pitfalls in the development process towards an information society that makes services and information available to everyone. If ISPs have full control over the whole network and its customers, it will be difficult to promote unrestricted service provisioning in the access network. Free connectivity to the access network may be useless – an Internet access is needed anyway to reach any useful services. Internet access will most probably never be free, as there is always someone (usually the ISP) paying for the connection to the Internet backbone. A contract is, therefore, required to pass the access controllers of the ISP and reach the Internet, which limits the services and information for those that have the contract.

2.1.3 Towards Wireless Access Networks

The rapid development in the late 1990's of new wireless access technologies, especially WLAN (Wireless Local Area Network) caused ISPs to extend their access network provisioning also to the wireless area. These wireless ISPs, WISPs, used wireless technologies as a last mile solution to reach customers and were on many occasion challengers to incumbent wired operators. As it is expensive and sometimes impossible to build several overlapping networks, WISPs started to connect their networks together to allow their customers to roam between the networks. Every WISP still owns its network, but allows customers of other WISPs to connect. This requires a contract between the WISPs and a strict policy on billing mechanisms. [Ver02] and [Shu03] present business practices in WISP networks.

2.2 Open Access Networks

In addition to reviewing closed access networks there have been efforts to dismantle the vertical integration of Internet access services by open access networks. In general, *open access* means that

a) any service provider may join a communication network under equal terms and strive for its own customers, and
b) any end user may freely choose any service provider(s) in the network.

An *open access network* (henceforth OAN) generally means that the access network is not closed, i.e. network access or usage is not limited by the network owner. In short, an OAN owner must make the network available to everyone under equal terms (not necessarily for free) and must not interfere with data transmission in the OAN. [Bat05] describes the term OAN in greater detail.

Battiti et al. define [Bat03] a set of rules for open access. They divide open access networks into two categories: open networks and neutral networks.

- In an *open network* any user must be free to select any service provider, any service provider must be free to deliver services over the OAN, and anyone should be allowed to extend the OAN. Networks that meet these rules are supposed to be able to grow with needs.
- *Neutral network* defines an environment that enables viable business activities in OANs: every service provider must be offered transport services at different architecture levels at the same terms and, in order to prevent unfair competition, the network owner must not offer services to end users. In a neutral network, the circumstances under which competition occurs are the same for all actors, i.e. every service provider should have equal access to the OAN under equal terms.

A third term is also widely used: *free network* [Fre07]. In a free network anyone can join the local access network and transfer information freely with no charge (free local transit). A free network does not necessarily include free Internet access or any other free services.

Free usage and service provision do not mean that there cannot be service differentiation in use. In many cases there is a need to define different traffic classes and give the highest-value traffic precedence over lower-value traffic. In other words, open access does not exclude the usage of Quality of Service to differentiate various types of traffic. User classes can be differentiated such that different resources are allocated (guaranteed higher speeds, lower delays etc.) in the network.

Figure 4 shows how OANs change vertical integration of Internet access to an open horizontal market that allows fair competition between service providers. Service providers now share the same access network. As none of the service providers can prevent customers from choosing the provider freely, the service provider that offers the best value for the money will probably attract the most customers.

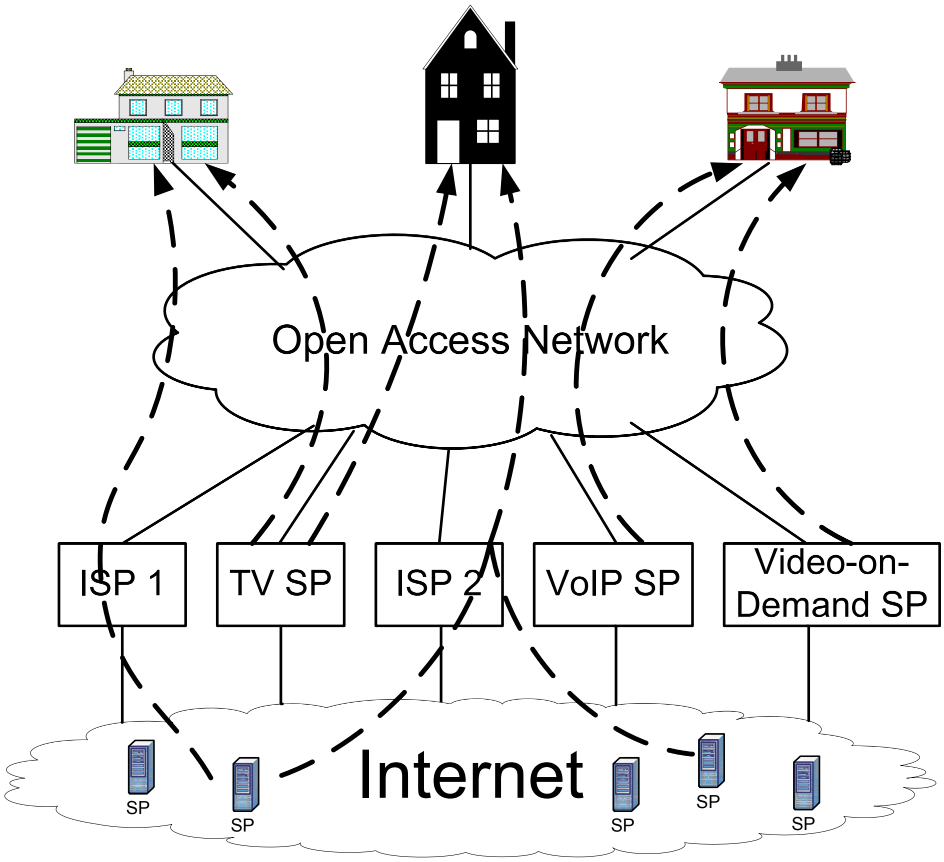


Figure 4. How OAN dismantles vertical integration.

One common factor to OANs is that the traditional ISP which has previously provided both the access network and Internet services is now separated from control of the access network. The ISP is equally one service provider among many, i.e. the Internet connection is now one service among others.

Technically, open access can be considered in different layers. Just as networks can be divided into different layers like in TCP/IP [Cer74] and ISO/OSI models (see [Zim80] and [ISO7498]), the open access network functionality is also divisible into network access and service access in order to separate providing network access and network services into different operations. The network access layer consists of the actual access network with its active/passive devices that connect network users to the service providers. The service access layer means the active part of the networking, like packet routing and service provision. The layers may also simplify contractual issues between the participants in the network.

Open network access means that anyone can use the access network infrastructure to communicate with each other or to reach external networks, like the Internet. Joining the network may not necessarily be free of charge but anyone is allowed to join under equal terms. If joining the network is free, the network is a *free access network*. However, free access does not necessarily include a free Internet connection or free services, just free access and a possibility to transfer information in the local network.

There may be differentiation between the participants in terms of Quality of Service (QoS) but the key idea is that everyone can participate under equal terms.

Open service access means that anyone can get access to any service in the OAN, i.e. the access network owner does not limit service usage or provision. This gives end users freedom to contract with any service providers and change service providers without the need to change the access network. However, open service access does not mean that the services are free of charge. Open service access offers an interesting viewpoint as it does not necessarily require an open network access, i.e. network access of end users can be limited while any service provider is free to provide services under equal terms. As [Mat06] describes, most European OANs currently utilize open service access and the network is controlled independently of the service provisioning.

There are many different types of networks that can at least by some properties be counted as open access networks. The range is from community networks built by private people to commercial networks from commercial organizations. The division of network types is far from simple and different networks that seem to belong to the same category may differ greatly from each other. Furthermore, the role of OAN manager is dependent on the network type, local players, goals of the network etc.

Publication 3 divides open access networks into three categories: community networks, open operator-neutral networks, and commercial open access networks. This thesis categorizes the networks in a more detailed way into community networks, open wireless city networks, regional networks, housing cooperative networks, municipal networks, and open neutrally managed networks. These categories will be examined more closely and examples will be presented in a chronological order.

2.2.1 Community Networks

For as long as there have been commercial ISPs, private people have wanted to bypass them, especially in local communications, and get affordable access to the Internet and different services. The technology used in the traditional access networks of ISPs was too expensive for individuals but when the first WLAN standard was published and the devices began to become affordable in late 90's different types of community networks started to emerge. This development was accelerated by the 2.4 GHz frequency license exemption in most places.

One common attribute of most community networks is their main rule: anyone must be allowed to connect and transmit any data inside the access network without any charge. In this sense, community networks are usually free networks, according to the rules described in section 2.2. It has to be remembered, however, that the openness does not apply to the Internet connection but just to the local access network.

Virtually all community networks are built by individuals and exist to connect users to each other and optionally to the Internet. It is also possible to build commercial community networks. Business income can be generated, for example, from selling access to some services in the community network or providing an Internet connection (provided that the ISP allows its connections to be shared with a third party).

There are two different ways to build the connections: either wireless or wired, which both have different technical options. Community networks are divided further into three categories: open wireless city networks, regional networks and housing cooperative networks.

Open Wireless City Networks

The main motivation for building open wireless city networks has been the desire to bypass ISPs in local communications and open the access network to everyone. An additional goal has been to disseminate information, educate individuals on networking, and provide easy and affordable connectivity for everyone.

Building an open wireless city network typically starts with a couple of interested network enthusiasts that are ready to dedicate a great deal of effort into connecting people in the local area. They buy suitable equipment (usually WLAN access points) and configure them in a way that allows also other people to connect to the network. The open wireless city network starts expanding as more people get interested in the idea and join the effort. After a while, the open wireless city network consists of individual hot spots that are connected to each other. Anyone is welcome to contribute to the network building and the new hot spots are connected to the rest of the network. Flickenger describes in his book [Fli03] the typical procedure for building these wireless community networks.

Open wireless city networks are an attempt to connect people and test wireless hardware. But when considering economic use, there are typically two major problems: a lack of centralized management and the uncertainty of the Internet connection. The lack of centralized management means that there may be no one keeping the network structure coherent and guaranteeing its functionality. There might be a non-profit organization guiding and motivating people, but the network infrastructure maintenance depends usually on voluntary work.

The second problem is the uncertainty of the Internet connection. Local connections are nice but most of the real services are located in the Internet. It is technically easy to share one's Internet connection to the open wireless city network but connecting people from the wireless network raises trust issues and has legal implications. The idea of providing everyone free access to the Internet is nice, but unfortunately no one can provide a totally free Internet connection: there is always someone paying for it. In most cases, a hot spot provider has a commercial Internet connection to an ISP and shares the connection to the hot spot users. Many ISPs refuse to allow their connections to be shared but there are some ISPs allowing users to share their connection to a third party. A list of these wireless-friendly ISPs in the United States can be found in [EFF06].

In Finland most ISPs currently forbid their users to share connections with other people. For example, one of the biggest ISPs in Finland states in a service description for ADSL subscriber connections that "the capacity of the connection is not allowed to be shared with a third party" [Son08a]. This makes it difficult to build open wireless city networks in most places. However, there are some exceptions when some ISPs allow the connection to be shared, as described later in sections 2.2.3 and 2.2.4.

There are several well-known open wireless city networks, like Seattle Wireless [Sea07] and NoCat.net [Noc06] in the United States and Freifunk [Fre08] in Europe. More examples can be found in [Fre07]. See also *Publication 3* for the differences between open wireless city networks (the more general term *community network* is used in the publication) in different countries.

Regional Networks

In addition to open wireless city networks, regional networking is becoming more common. As in open wireless city networks, regional networking means that people build their own access network by themselves. The main difference to open wireless city networks is that regional networks are usually built in rural areas where ISPs find the provision of broadband access unprofitable. This applies especially to wired technologies like DSL as laying cable underground for only a few customers is seldom profitable. When the traditional closed access models fail to build the network in the last mile to the customers, local organizations and communities can take the initiative and build that part themselves to connect to a point of presence of an ISP.

Unlike the technological enthusiasm found in open wireless city networks, the main focus in regional networking is usually on providing *services* to end users. Users that have a need to access services (usually in the Internet) will figure out a way to reach the services. In rural areas where ISPs are not interested in providing services, for example, to remotely located farm houses, the only way to get an Internet connection is to build the local access network (i.e. the last mile) oneself. The chosen technology is usually optical fiber as it is rather inexpensive and provides high reliability and speed over long distances. In many cases, people living in the countryside have also needed machinery to bury the optical fiber in the ground. In many cases ISPs become interested in providing connections to a larger group of already connected potential customers and now, having built an access network, the network users can buy one shared (both costs and bandwidth) Internet connection for everyone instead of paying a separate Internet connection for every single user.

As regional networks are typically built using optical fiber the capacity of the access network is very high compared to, for example, open wireless city networks. Having a fiber-to-the-home (FTTH) network gives additional service opportunities in the local network, as emerging services like Video-on-Demand and HDTV can be provided, services that require higher bandwidth than modern open wireless city networks or DSL network can provide.

One important characteristic typical to regional networks is *operator neutrality*. Based on the concept definition of Battiti et al. [Bat03], regional networks typically meet the rule set describing *neutral networks* since in regional networks, the local people own the local access network and can therefore let anyone provide any kind of services to the network users under equal terms.

In many cases regional networks are also *open networks* in the sense of joining the network. Anyone is usually welcome to connect to the access network provided that the person joining the network bears the building costs of the new access medium needed. When building a new network the costs are typically divided equally among all of the participants.

Regional networking is becoming very popular in Finland. There are several examples of successful regional networks, for example, in the area of Pohjanmaa in north-western Finland. Finnish magazines have actively reported that people in rural areas have “built a modern information society for themselves" [IT04a] and "made call charges obsolete" [IT04b]. These regional networks are technologically advanced, providing very fast FTTH connections to all participants and allowing operator neutrality in the local network. The Finnish Regional Networks Association [Seu07] has actively promoted the building of FTTH networks and has spread information on regional networking in Finland since 2001. [Kar06] describes Finnish regional networks and compares them to the rules of Battiti et al. [Bat03].

A good example of a regional network in Finland is the Network Co-operative Kuuskaista [Kuu08] located in the Kuusiokunnat region in central Finland which has been building a high speed FTTH network in a region of about 3 400 km^2 with about 10 000 households (30 000 people). Currently, about 1 100 households are connected to the fiber network and there are additionally about 300 "cold connections", meaning that the cables are in place but there are not yet in use [Kau08]. The price for connecting a household to the network starts from 1 100 euros. In addition to Internet access, there are some local services in the network, like VoIP and IPTV. Each of the services is priced lower than the services offered by local ISPs.

In addition to providing fast local and Internet connections, regional networking also boosts local development. Fast local network allows the provision of new types of services, like video rental and telemedicine services that can provide local SMEs with new business opportunities.

As in any networking regional networking also needs continuous network management. The network owners have to make the decision to operate the network themselves or hand over management to an external party. In many cases network management services are bought from local ISPs or telcos as it is their core know-how. Thus without having to build and own the access network the telcos have additional business opportunities operating open networks.

New emerging wireless technologies like Wimax and flash-ofdm may in the future compete with or even supplement wired networks, especially in rural areas. The frequencies for these technologies are licensed, which limits network provision to license holders only. In this sense these networks are not open, nevertheless in the future they are still likely to bring down wireless coverage building costs (and usage costs). Both Wimax and flash-ofdm networks are currently being deployed in Finland.

Housing Cooperative Networks

A third type of community network exists: housing cooperative networks. Housing cooperative networks are in many ways similar to regional networks. The main difference is that housing cooperative networks are more common in city environments.

To understand the background of housing cooperative networking it is necessary to explain that most people in urban areas in Nordic countries live in apartment blocks and most apartments are privately owned. Usually the apartments are legally organized as housing cooperatives, which helps in sharing the costs of necessary services (like janitor services, waste disposal, electricity, TV subscriptions, water subscription etc.) and equipment (like a lawnmower, snow blower etc.).

As many services and equipment are already bought together and shared, sharing an Internet connection is also becoming more common. This brings savings as the connection fee is divided among all participants. As described earlier, not all ISPs allow their connections to be shared in this way. Particularly the biggest ISPs that have the strongest position in the area are usually reluctant to allow their connections to be shared. Some of the smaller, competing ISPs countenance the idea more willingly.

In addition to benefits for the participants, this kind of development adds to the number of open access networks and promotes faster local networks. In this sense, the housing sector can be seen as an agent for change towards open access.

2.2.2 Municipal Networks

As well as private people many local governments and municipalities are also interested in providing networks in their area. Municipal networks are open access networks and provided (or funded) by public authorities. In Finland there are several examples of networks that local municipalities have supported, for example MastoNet in Lahti and the Arabianranta network in Toukola, Helsinki. They represent different types of municipal networks as MastoNet is a wireless network and the Arabianranta network is based on optical fiber.

MastoNet

MastoNet in Lahti [Mas07] is a wireless network available to residents and visitors of the city of Lahti. MastoNet's purpose is to enable the use of the internet and its services, irrespective of time and place. A further aim is to facilitate the development of services based on local information, for the use of both business and society. The network enables the transaction of business through different electronic services.

MastoNet is administered by the city of Lahti and provided on an "as is" basis to the users, i.e. the city does not provide any technical support for network users. The local energy company, Lahti Energia has added its access points to the network. MastoNet currently has (August 2008) 85 access points and about 400-500 daily users.

The Arabianranta network

The Arabianranta access network is a network being built in Helsinki, Finland, in a growing residential area. The city of Helsinki has obliged all builders to build an optical fiber connection to each apartment block and enable a LonWorks based automation network (see [Lon07] for more information on the automation system). As the builders distribute fiber already at the building stage the additional costs are minimal and have no overall effect on the cost of the residence. This kind of network, however, attracts residents and adds value to the whole area. The residential area is still under construction and there are currently (August 2008) about 2000 households and 3000 end users. The area is planned to be completed by 2012, having about 8 000 inhabitants.

The Arabianranta network allows a fast (10/10 Mbps) Internet connection to every household in the area. The backbone network for each building is 1 Gbps or faster [Saa08]. The Internet connection is free for residents and the high speed allows new types of bandwidth-thirsty services such as video and IPTV. In addition, there are several additional value services available, such as e-mail (at 20 euros per year) and IP-telephony (no monthly costs, free local calls and affordable calling costs to telephone subscribers outside the local area). The services can be differentiated by using virtual LANs. More information on the Arabianranta network can be found in the Helsinki Virtual Village, see [Ara07].

2.2.3 Open Neutrally Managed Networks

Open neutrally managed networks aim to open the access network to everyone while at the same time making the provision of different services (Internet among others) easy and attractive. The key difference to community networks is that instead of just opening the access network for free traffic, open neutrally managed networks allow a controlled environment for generating business.

Neutral management means that there is a neutral network operator that administers the access network management and allows all service providers an equal opportunity to offer services to the access network users.

Open neutrally managed networks are discussed in section 3 of *Publication 3*. The publication uses the term "centrally managed public multi-ISP networks" to describe these networks. *Publication 6* studies neutral management of different types of open networks.

panOULU

panOULU (public access network OULU) [pan07] is located in Oulu, Finland. panOULU is a combination of networks provided by the city of Oulu, the University of Oulu, Oulu Polytechnic, Pulmonary Association Heli, VTT Technical Research Centre of Finland, Elisa Plc., Netplaza Ltd. and Oulun Puhelin Plc. It is important to note that the latter three are telcos that also provide commercial connections to end users. Despite this fact they are still participating in the panOULU effort. Public organizations provide their campus networks to the users and telcos sell panOULU subscriptions.

Currently (August 2008) panOULU consists of about 1050 access points located both indoors and outdoors. As Figure 5 shows the number of users has been growing since the network was established in 2004 and the maximum number of unique users per month has been about 13 400.

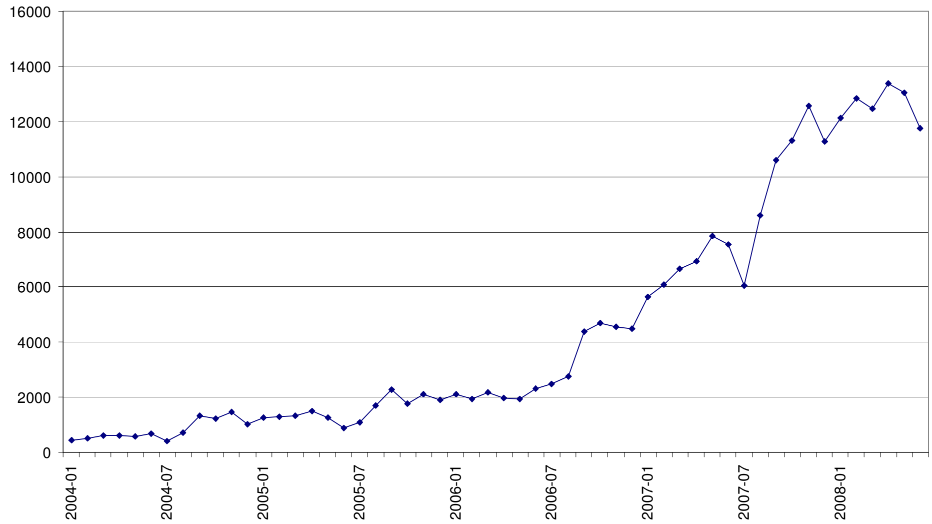


Figure 5. Unique MAC addresses per month in panOULU.

Currently panOULU is open to the general public as there is no registration, payment or login to the network. All users with suitable equipment get an Internet connection without the need for visitor passwords. This is possible as the network founders sponsor the connection. In addition to free Internet, panOULU includes free local services such as a location service (called Luotsi) and an E-mail service for network users.

Lappeenranta Model

The Lappeenranta Model is a technical approach for building an open access network. It allows end users to connect to a shared local access network where local interaction and services are strongly encouraged. ISPs are separated from the access network operation, which means centralized distribution of network settings by a neutral access network operator. This allows network users to communicate directly in the access network. The Lappeenranta Model is described in detail in chapter 3 of this thesis.

2.2.4 Commercial Open Access Networks

A commercial OAN means that an established commercial organization builds an access network (usually with optical fiber) and leases it to everyone *under equal terms*. The organization owns the access network and takes care of management of the physical network infrastructure. Basically this means that the organization's role is as a neutral network operator.

A commercial OAN is usually built by a naturally neutral player, e.g. an energy company that already has a widespread network of cables on the ground. Creating the access network core by laying optic fiber at the same time as renovating existing network cables is cost-effective. The network owner can then generate extra income from renting the access network to the service providers and charging connection fees from end users. There is one clear advantage from the viewpoint of end users, namely, they can get major utility services (energy, Internet, TV, telephone etc.) charged to one bill from the energy company. Collecting the services together can be considered as vertical bundling of services but clearly differs from the vertical integration of the whole service stack typical of closed access networks. Commercial OAN networking is further described in [Leh03]. Some services that have been seen to be popular and that closed access network operators are also starting to implement are, for example, video rental services or a "virtual VCR" that allows subscribers to watch past TV programs [Son08b].

The main difference to other types of OANs is that commercial OANs have a strong player that builds and manages the local access network. Of course other types of OANs may also have a strong network manager but the situation is most typical of commercial OANs. In this sense commercial OANs can even be compared to closed access networks although the difference to closed access networks is that now the access network owner does not compete with the other service providers. A similar approach can be found for example in the @450 network [Dig07] currently being built in Finland by Digita, where Digita is the neutral network operator and sells network capacity to service providers under equal terms.

As in OANs there are multiple service providers in one access network routing service traffic to correct end users and preventing traffic from reaching end users that have not subscribed the service requires special abilities from the network equipment. There are several options for routing service traffic correctly. Usually the routing is based on Virtual Local Area Networks (VLANs) [Raj97] or Multi-Protocol Label Switching (MPLS) [RFC3031]. See [Li02] for examples of these techniques in networking.

The line between open neutrally managed networks and commercial open access is thin and many neutrally managed networks could as well be considered commercial networks. The main difference from the viewpoint of end users is that in a commercial OAN the business perspective is clearer: users can buy a connection from a commercial organization. In many other types of OAN the end user must actively participate in getting the connection to the access network. Secondly, in commercial OANs end users are typically separated from each other preventing local interaction.

StockholmOpen.net Framework

StockholmOpen.net is defined as an open access system. This means the main goal is to share one access network to multiple ISPs and eliminate the problems of unfair competition. The implementation and structure of StockholmOpen.net is described more closely in [Pel02]. Different aspects of StockholmOpen.net are also analyzed in *Publication 3*, *Publication 5* and *Publication 6*.

The core component of StockholmOpen.net is a DHCP relay that welcomes new users with login pages where they can choose the ISP to be used. After selecting an ISP the DHCP relay directs the traffic to the correct ISP. ISPs then allocate network settings directly to their customers that are located in the StockholmOpen.net access network. Besides login pages and network maintenance services, there are no local services in the access network.

Currently there are about 100 WLAN access points in StockholmOpen.net research network [Sto07]. The number of concurrent users is of the magnitude of 250. More importantly, the StockholmOpen.net framework is in use in other OANs, which are next discussed in closer detail.

SparkNet & OpenSpark

Currently (August 2008) SparkNet [Spa07] in Turku is the largest WLAN network in Finland. SparkNet was founded in 2003 and consists of over 2400 WLAN access points. SparkNet is based on the StockholmOpen.net framework as SparkNet uses their public software in the service selection gateway. The gateway offers network users a page on which they can select the service provider. The DHCP relay then redirects the device to the chosen service provider to get a new IP address and other network settings.

In addition to SparkNet there is another version of the network: *OpenSpark*, which was founded in March 2005. Users can join the OpenSpark community by purchasing an OpenSpark enabled WLAN access point and letting other community members use their Internet connection. This means that every user needs an Internet connection from some ISP. By joining the community the user gets an account that can be used to access the Internet through all OpenSpark and SparkNet access points. All SparkNet accounts are also valid in the OpenSpark community.

SparkNet or OpenSpark cannot be used freely. This applies both to the local network and the Internet connection. As [Spa07] describes, using the network requires belonging to some of the funding organizations, purchasing vouchers or joining the OpenSpark community (there is no monthly fee but an Internet connection is required).

As described earlier in section 2.2.1 there have been some problems especially in open wireless city networks related to the fact that many ISPs do not allow sharing of their connections to non-paying customers. The development of commercial OANs has also raised the issue of whether ISPs want to allow their connections to be shared. For example, in the case of OpenSpark the network members are required share their Internet connection to other OpenSpark users. Many ISPs deny permission for such sharing but some ISPs do allow connection sharing. In particular smaller ISPs that do not have a strong position in the markets of that area want access to a share of customers that they have not been able to reach before. In fact, allowing connection sharing has become a clear competitive advantage for these ISPs as all OpenSpark users will buy their Internet connections as opposed to those of ISPs refusing to allow connection sharing. Currently, the following ISPs allow their connections to be used in OpenSpark:

- Elisa Oyj
- Song Networks Oy
- MP-MasterPlanet Oy
- Lännen Puhelin / DNA (must be informed if the account is used in OpenSpark)

It is important to notice that Sonera, one of the biggest ISPs/telcos in Finland, is missing from the list. On the other hand Elisa Oyj is of similar size and allows connection sharing in SparkNet. Both Sonera and Elisa currently have about 33 % market share of Finnish broadband connections (see [Eli07] and [Son05]).

SparkNet has spread the solution to other cities and currently has some coverage in Espoo, Helsinki, Kaarina, Kevo, Lahti, Lieto, Loimaa, Merimasku, Naantali, Parainen, Raisio, Rauma, Salo, Tuorla, Turku, Turunmaan saaristo (Turku archipelago), Uusikaupunki, Rovaniemi and Vantaa.

MälarEnergi Stadsnät

MälarEnergi's Stadsnät (Citynet) [Mal07a] in the Västerås district in Sweden is a good example of a commercial OAN. Building of the network started in 2000 with PacketFront's [Pac07] equipment capable of doing MultiProtocol Label Switching (MPLS). Stadsnät is operator neutral, meaning that the local energy company, MälarEnergi, provides a portal that any service provider can join under equal terms. There are currently some 60 service providers offering end users a wide variety of services like IP-telephony, TV over IP, Video-on-Demand, Internet connections, security and property related services. A comprehensive list of available services can be found in [Mal07b]. There is a rule that no service provider is allowed to technically tie in users to itself alone, i.e. the users must be allowed to use also other the services of service providers.

Currently (August 2007) Stadsnät consists of about 20 000 kilometers of optical fiber, which provides over 33 000 customers (both private households and companies) a backbone network that has a capacity of 1 Gbps. Building this backbone has required an investment of 320 million Swedish kronas (about 34 million euros at the exchange rate of August 2008).

Property owners need to build the property network themselves. The cost of joining a property network to Stadsnät starts from about 20 000 Swedish kronas (about 2 100 euros). Once the property network is joined to Stadsnät all services offered are available. The lowest priced 1 Mbps Internet connection is 95 kronas (about 10 euros) per month and the fastest 100 Mbps Internet connections are priced at 245-394 kronas (about 26-42 euros per month). In addition to the Internet connection other services include, for example, TV and telephone services, online games, a music portal, videochat and alarm services.

There are other commercial OANs that can be compared to MälarEnergi's Stadsnät. For example, Northport [Nor07] sells an open access environment (Modulution) for multiple services that is based on set-top-boxes. Other examples are Perspektiv Bredband [Per07] and Kristianstad's Stadsnät [Kri07].

2.3 Discussion

The development of access networks has led to a new type of networking. Open access networks are becoming more common and there are several options for building OANs. Many incumbent ISPs are currently strongly resisting the development but changes in global legislation and pressure from new service providers and users may eventually shift the balance of networking towards open access, as open networking has many advantages over closed access networks:

- Dismantling of monopolies benefits end users and competing service providers
- Shared access network building costs
- A technologically neutral approach allowing cost savings
- Better coverage area with the same relative investment
- True competition on all networking layers
- Dynamic business models (small service providers may find new niches that larger inflexible organizations cannot fill)

- Transparency of conditions between networking layers (everyone can use and trade between the layers under equal terms)
- Local dynamic control over the network and solutions (encouraging new types of local services)
- Encouragement of local innovation
- A large mass of end users
- A local high-bandwidth access network

There are, however, also potential problems related to open access, for example:

- Dismantling of monopolies causes strong opposition for change
- Increasing complexity due to the dynamic structure and diversity of services
- Responsibility issues regarding network functionality
- Responsibility issues regarding CRM (Customer Relationship Management)
- Routing service traffic reliably and preventing misuse
- Difficulties preserving company brands

Responsibility and trust are among the major difficulties in OANs. The open access business model (as described in *Publication 6*) requires trust in other organizations. For example, a service provider is dependent on the access network manager that supplies the infrastructure for reaching customers. There must be no conflicts of interests between service providers that are dependent on each other. Otherwise one of the service providers might promote its own services over other service providers, which would result in unfair competition.

Overall it can be said that current last mile networks (cable modem, ADSL, WLAN, etc.) can be considered as a bottleneck for developing a new generation of services. It can be surmised that especially video services will become popular in the near future but transferring high-definition video to households is not possible in today's access networks. Optical fiber may be the solution: either Fiber-to-the-Home or fiber-to-the-telephone centers as typically in ADSL networks today. From the local telephone centers the households can be connected through any technology, maybe by putting Ethernet-to-the-Home to existing copper wires. This would enable new high-bandwidth services.

There are currently problems in providing computer networks to citizens in a way that everyone could afford to use the network. As [EU07a] states, competition is the major driver of broadband take-up. Lack of competition in broadband provision kept the prices of broadband connections high for a long time. In 2002 the prices in Finland started dropping from a starting price of 50 euros/month and currently (August 2008) broadband prices start from around 25 euros/month.

Municipal networks and other types of sponsored networks may raise issues related to fair competition. Commercial operators may not be able to compete with subsidized municipal networks. In addition to defining obligations for access network renting as described earlier, the Finnish Communications Market Act 393/2003 [Fin03b] also advocates public communications networks that are available to a set of users that is not subject to any prior restriction.

This will, however, change as in May 2006 FICORA announced a note on how to apply the Communications Market Act to current open wireless networks in Finland [Fic06a].

Current network providers were requested to send response statements back to FICORA who then concluded the note (see [Fic06b]) in June 2006. In August 2007 FICORA published a memorandum that summed up the procedure. The memorandum states that any network community (including open access networks) is responsible for delivering identification information on network users to a regulating authority whenever necessary. This ruling, however, still allows the provision of free networks as the interpretation does not require identification of every network user. [Fic07]

As [Spi05] describes ISPs are nowadays unwilling to promote open networks as they want to make the most out of the existing technologies. Large companies usually cannot or are unwilling to adapt quickly to changes in the market preferring to maximize revenues from already deployed technologies.

A key problem is that in Finland all big telcos currently have a “home region” in which they have a monopoly or quasi-monopoly position. This situation discourages the telcos from truly competing in foreign regions, although they generate good business in their home regions. Telcos do not want fully open competition as they would loose their advantage in their home regions. Consequently, their opposition to high-bandwidth last mile and open access is more a political than a technological decision.

Telcos also see that open access will make them vulnerable and endangers their position as a network provider. However, in the current networking situation one should consider how secure the position of the telcos in the markets is anyway. As the Communications Market Act obliges the telcos to lease their network to competitors, it could at least in theory be possible that a big international telco might enter the market and displace local telcos in their own home regions with a better range of services and more competitive pricing.

Telcos’ are correct that open access would probably drastically change the market situation but is there really an option? Open access would let any service provider, national or international, offer their services under equal terms (just as today in closed access networks) but changing the service provider would become easier for end users. On the other hand, open access would prevent international competitors from invading and dominating any local networks, as they would only get to be one service provider among others.

As private sector enterprises aim to generate short-term profits for shareholders, they are not very interested in investing in long-term development of open access networks. The main problem when building a new OAN is that initially there is an insufficient number of customers in the network. Many service providers are not interested in providing services to a small number of customers, i.e. if there is no profitable market, there are no services and vice versa. This is why, in many cases, public support is needed to create a stable environment where all the actors can operate and provide new services (that attract new customers) to the network as quickly as possible. When the access network reaches a critical mass of users and services it is able to operate independently of public support.

3 Lappeenranta Model

The Lappeenranta Model is a technical approach for an open access network. It allows end users to connect to a shared local access network where local interaction and services are encouraged. This chapter describes the working principle, components and performance of the Lappeenranta Model and introduces a research network, Sainet [Sai07] (formerly WLPR.NET [Wir07]), built according to the Lappeenranta Model specifications. This chapter also describes the provision of services locally in the access network and shows from survey results that end users and potential service providers see local services and open access as beneficial.

3.1 Objectives

The Lappeenranta Model has three objectives:

1. Open network access
2. Open service access
3. Local interaction (between end users and between end users and local services)

As described earlier, *open network access* means that everyone must have an equal right to connect to and use the access network.

Open service access means that everyone must have an equal right to provide and use the services in the access network. The services may be whatever IP-based services are available, IP-telephony, Internet access, IPTV (provided that the access network's capacity allows such services) etc. No service provider may by any means prevent users from using the services of other service providers.

Local interaction means that the access network can be freely used for communication and service provision. End users can communicate with each other in the local access network without the need for Internet access as the users are located in the same network segment and the traffic is routed via the shortest route. This brings new opportunities for network users and local service providers. Direct communication makes local data transferr more effective as the traffic can be routed directly instead of circulating through access controllers or the Internet.

3.2 Operating Principle

The operating principle of the Lappeenranta Model is described in section 2.1 of *Publication 4*. Figure 6 shows a flow chart describing messages between the device of an end user and components of the Lappeenranta Model. These components include services that are necessary for the network operation: DHCP server, web server and web proxy in the local access network and authentication server in ISP's network.

Let us assume that a new user (i.e. a user that has not connected to the network before) enters the coverage area of the open access network. The user has a device with a network card (for example a WLAN card) connected and operating correctly. The user wants to access some web page in the Internet and starts a web browser to retrieve the page. Figure 2 illustrates what happens in the network.

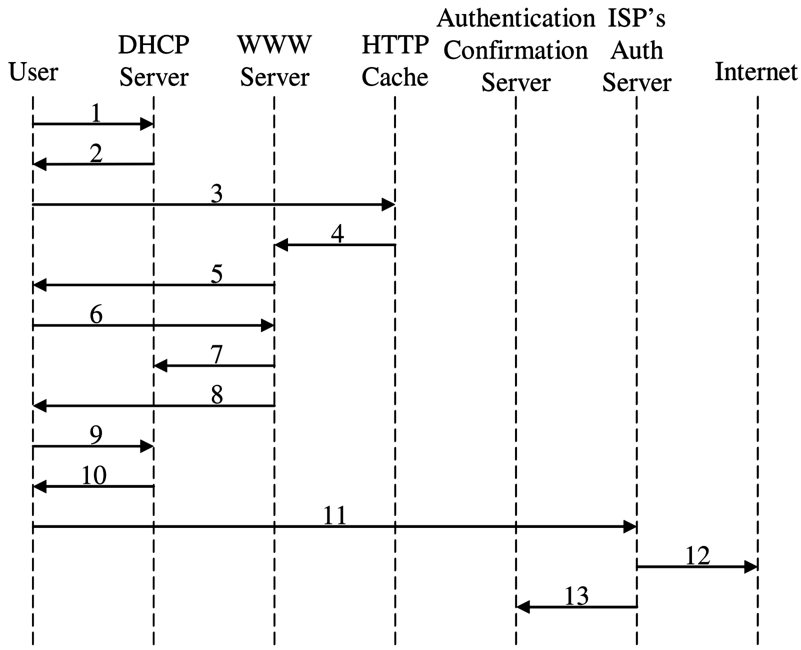


Figure 6. Flow chart describing messages between Operator Interface components (*Publication 4*).

1. In order to work properly in the access network the user's device needs an IP address. It sends a request for a new IP address.
2. The DHCP server hears the request and checks from the user database if the device is already known. If the user has already registered to the network the procedure continues directly at item 10 of this list. Otherwise if the user is new and the MAC address of the device cannot be found from the database, the DHCP server gives the device an IP address belonging to an address block of unregistered users. These temporary IP addresses have a short lease time (for example one minute) in order to enable a registration process without long delays. The access network's IP addresses can be either private or public, but private addresses seem more suitable as every device in the access network needs an IP address.
3. Having the new temporary IP address, the device sends a request for the web page requested by its user.
4. Let us assume that the user wants to browse in the Internet. Because the user has not yet been registered in the network (i.e. the device has a temporary IP address), HTTP cache catches the request for the web page and forwards it to the Operator Interface's WWW server. Devices having these temporary IP addresses can only get to a login page and some other predefined pages (for example information on the local network, user instructions etc.). Every user has to

register in order to get access to the actual content of the network or to the ISPs providing connections to the Internet.

5. The WWW server sends a login page to the user (see Figure 7). The login page includes a selection of the ISPs that can be used. There is also an option not to choose an ISP at all. Without an ISP, the user can freely browse the access network content and any whitelisted addresses from the Internet. However, an ISP is required for an unrestricted Internet connection.

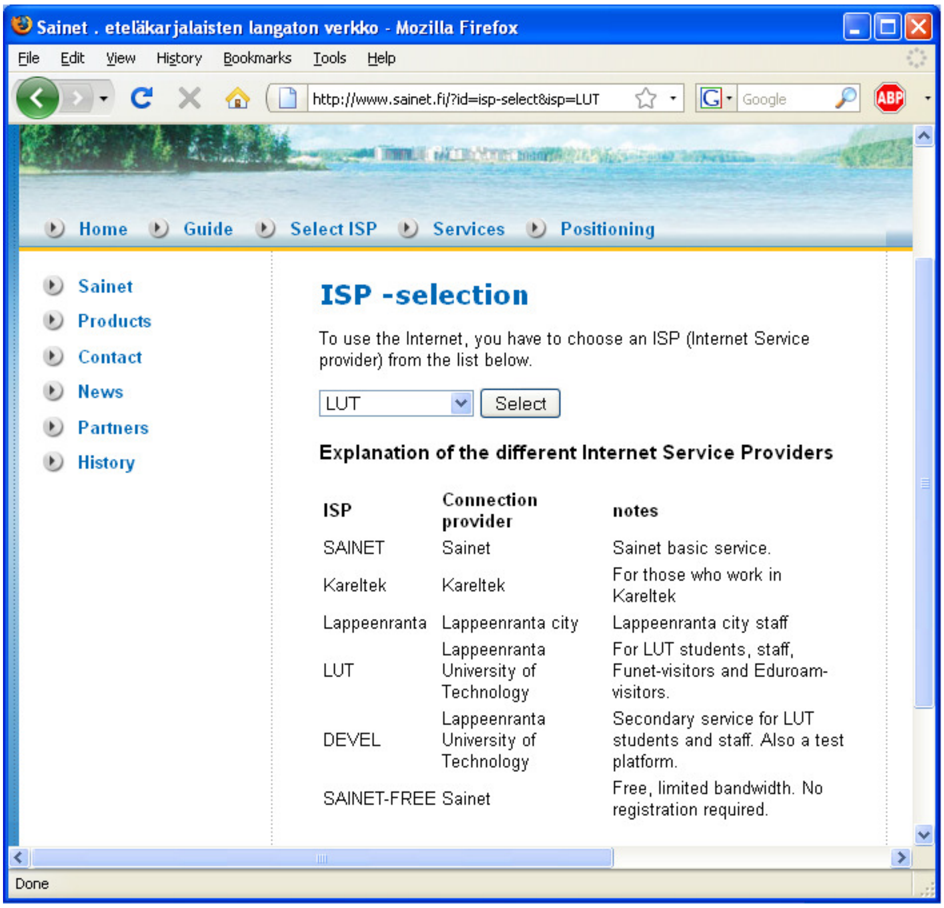


Figure 7. Sainet login page.

6. After the user has selected the ISP, the device sends the information from the web page form to the WWW server.
7. A script in the WWW server processes the ISP choice and informs the DHCP server to change the device's IP address. The user database is updated and the device must wait for the lease time of the temporary IP address to expire in order to refresh the new IP configuration.
8. The WWW server also sends a web page to the device informing the user to wait until the IP address update is complete.
9. When the lease time of the temporary IP address expires, the device requests a new IP address from the DHCP server.

10. The DHCP server now finds the device's MAC address from the user database and gives a new IP address according to the chosen ISP. This will happen automatically in subsequent connections. Each of the ISPs has its own predefined IP address space.
11. Now the device has an IP address that will be routed outside the access network if requested. The user has requested a WWW page from the Internet, so the request is routed to the ISP chosen by the user. The ISP is responsible for authenticating users trying to connect to the Internet through the ISP's connections.
12. The ISP's authentication server authenticates the user before allowing a connection to the Internet. Authentication can be done by any means and the ISP can use its existing authentication mechanism (login name & password, RADIUS, electronic certificate, etc.). After successful authentication, the authentication server will allow the user to access the Internet. The subsequent connections will automatically be routed through the ISP's connections (until the lease expires).
13. If required, the ISP's authentication server may also send a confirmation message to an optional Authentication Confirmation Server located in the Operator Interface. The confirmation message consists of information whether the authentication procedure was successful or not. The message may also include additional information such as the expiration date of the authentication or the user's credential information. The message can also be used to block suspicious users from connecting to the ISP, if needed.

It was mentioned in previous list under item 2 that one reason for using private IP addresses is the lack of free addresses. Another reason is that when using private addresses a large number of devices in the access network can easily be addressed in the same network so that they can hear each other. This allows direct local communications and prevents the need to circulate local traffic through the ISPs and the Internet. When connecting to the Internet through some of the ISPs, the private address can be translated into public addresses using Network Address Translation (NAT), if needed.

If needed, there is an optional component in the Lappeenranta Model that may be used in service provision: the *Authentication Confirmation Service* (ACS). The ACS may be used to collect authentication information of users authenticated by the ISPs. The information can then be made available to services in the access network and it can be used, for example, to differentiate local services for different user groups. The ACS can tell the services directly whether a specific user is authenticated by any of the ISPs. ISPs could also use ACS to block unwanted users from the access network. The ACS is currently not in use as there are legal limitations on storing this kind of login information. According to Finnish law for information security in electronic communication [Fin04] identification information may only be delivered to a third party that would anyway have the right to access the information in the relevant situation.

3.3 Operator Interface

The Operator Interface is the engine of the Lappeenranta Model. It includes all the functionality needed to keep the solution operational. Figure 8 shows the logical structure of the Lappeenranta Model including the components of the Operator Interface. The operator neutral access network is located at the bottom of the figure and the Internet is at the top. The Operator Interface is a cluster of servers located between the open access network and the service providers that are connected to the access network through access controllers.

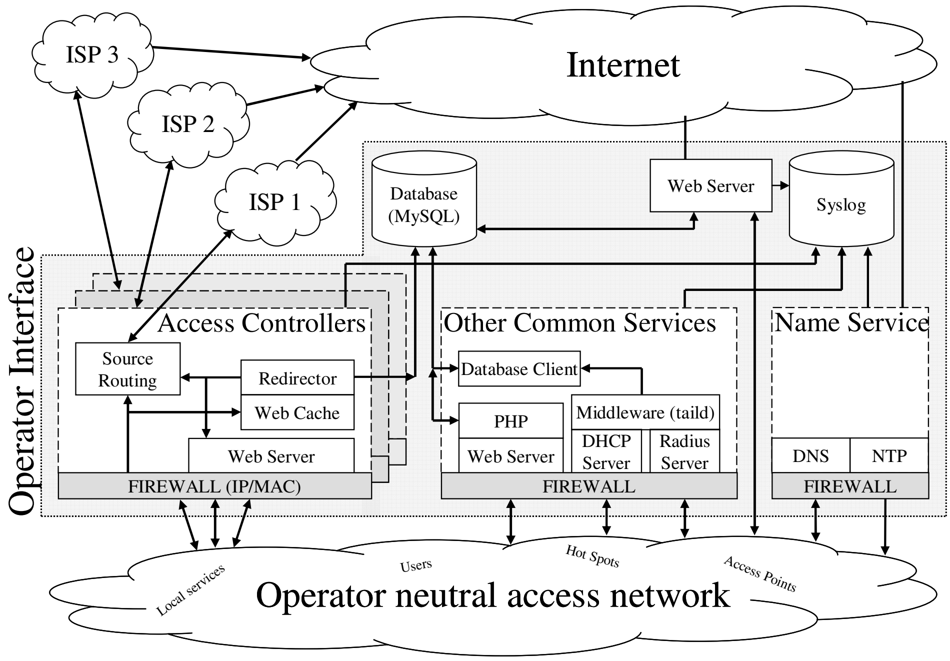


Figure 8. Lappeenranta Model – the logical structure and key components (*Publication 4*).

The Operator Interface consists of components that are used to manage the access network. The most important components are the access controllers, other common services and the name service. These components allow multiple ISPs to be connected to the same shared access network and traffic to be routed to the correct ISP. The Lappeenranta Model's components are described in *Publication 1*, *Publication 2* and *Publication 4*.

3.3.1 Access Controllers

Access controllers are used to connect service providers that offer external connections. These service providers are ISPs in most cases but also companies or organizations may provide their employees with connections to their own networks. The Access Controller operates as a default gateway for OAN users of a certain service provider and all network traffic from the OAN to service providers travels through the Access Controller. There can be one or multiple Access Controllers in the network. One Access Controller can serve either one or multiple service providers.

The Access Controller routes IP packets according to source address (assuming that the Access Controller is serving multiple service providers). Routing based on source address can be implemented, for example, with Linux iproute2 tools, which allow a separate routing table for each service provider.

The Access Controllers can also act as a transparent web proxy that is capable of providing network users with announcements and advertisements based, for example, on their physical location in the network. As [Bar00] describes, transparent proxy means that it is capable of intercepting network traffic to the end user's browser transparently and can redirect the browser to a page other than that which was requested.

An Example Implementation

In order to demonstrate that the Access Controller can be implemented as defined in the Lappeenranta Model, an example implementation was built to be used in the Sainet research network [Sai07]. This Access Controller is capable of

- authenticating OAN users against a RADIUS server,
- filtering IP and MAC addresses,
- providing OAN users with advertisements and announcements with a transparent web proxy,
- providing OAN users with a name service, and
- logging OAN users automatically out from the access network.

Components of the example implementation are illustrated in Figure 9.

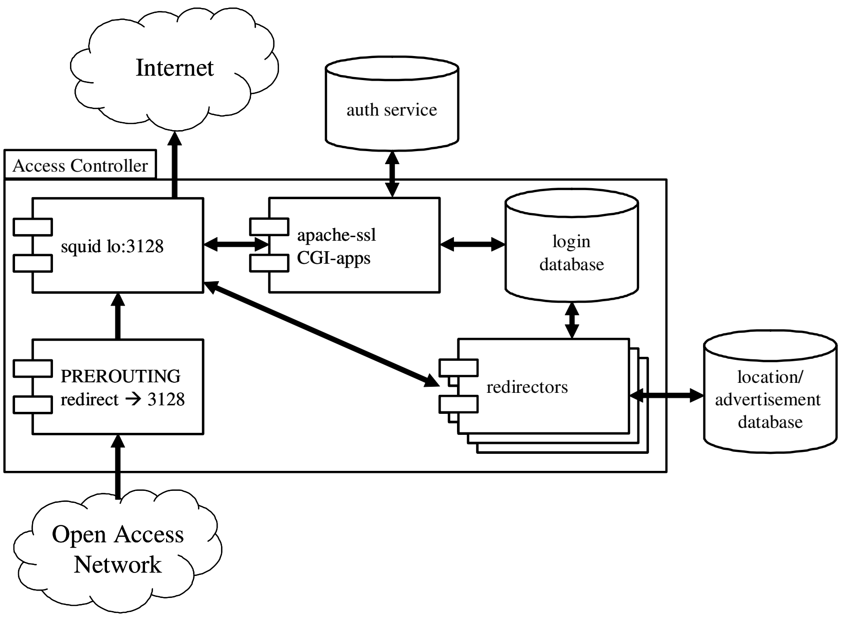


Figure 9. Example of the Operator Interface's Access Controller structure.

The transparent web proxy is implemented with the Linux iptables tools REDIRECT option which redirects all incoming HTTP traffic (TCP traffic to port 80) to local port 3128 that is listened to by squid. Squid is an open source proxy server and web cache daemon [Squ07]. The Access Controller's squid starts up redirector processes that check whether to provide the user's web browser with a web page other than requested. Such pages can, for example, be advertisements, announcements, the login page or a suggestion to use DHCP. The login page is created with a local CGI script working with an apache-ssl server. The CGI script is written with Perl and has connections to an external RADIUS database and local login database.

After a successful login the Access Controller creates rules for routing the user's traffic. Additionally, login time, MAC and IP addresses, and the user name are added to a login database. In order to prevent users from posing as other users, the Access Controller has a firewall that checks whether the user's MAC address corresponds with the IP address given by the DHCP server. Forcing usage rules like this is discussed in [Spá02a] and [Spá02b].

The Access Controller can automatically log users out from the network. This is done with a Perl script that operates as a watchdog process monitoring the state of users logged in by sending "ICMP Echo Request" packets. If a device does not respond to ping the time is saved to the login database. If the device does not respond within a certain time the user is logged out from the network.

3.3.2 Other Common Services

Other Common Services (OCS) include the services necessary to keep the access network operational: the DHCP server, RADIUS server and web server. These servers are connected to a database that is used for storing user IP addresses, choice of ISP and the physical location in the network.

- *DHCP server* shares the network settings to end users. Each ISP has its own IP address space in the access network. After selecting the ISP, the device's MAC address is stored in the database in order to provide an IP address of the correct ISP automatically next time by using RADIUS accounting.
- *Web server* is used to provide end users with a welcome page that can be used for selecting an ISP. Web server can also store any other web pages meant for the access network users.
- *RADIUS server* receives messages from the access points. These messages are used to locate network users to the accuracy of one access point. This solution requires RADIUS support from the access points.

3.3.3 Name Service

Name service provides Domain Name Service (DNS) for the access network users. The DNS server is configured to operate as the primary DNS server for the network users. The server can also do recursive queries to DNS servers in the access controllers. This allows network users to query both local and Internet names.

3.3.4 Additional Built-In Components

In addition to the core components, the Lappeenranta Model has other built-in features that can be used to enrich the local service provision: Location Information System and Advertisement System.

Location Information System (LIS) [Kos05] can be used to get the location information of a certain user (i.e. a device) to the accuracy of one WLAN access point. Naturally, the location information is confidential, which has to be taken into account when implementing services that use location information. LIS has a WSDL (Web Service Description Language, see [W3C07]) definition, which can be used to create new positioning services by using the functions described in the interface. LIS has an administration interface that can be used to manage the locations of access points. The interface allows uploading map files in which access points, areas and spots can be inserted each with different parameters and keywords that can be used for searching. Figure 10 shows the Lappeenranta harbor area in the administration interface.

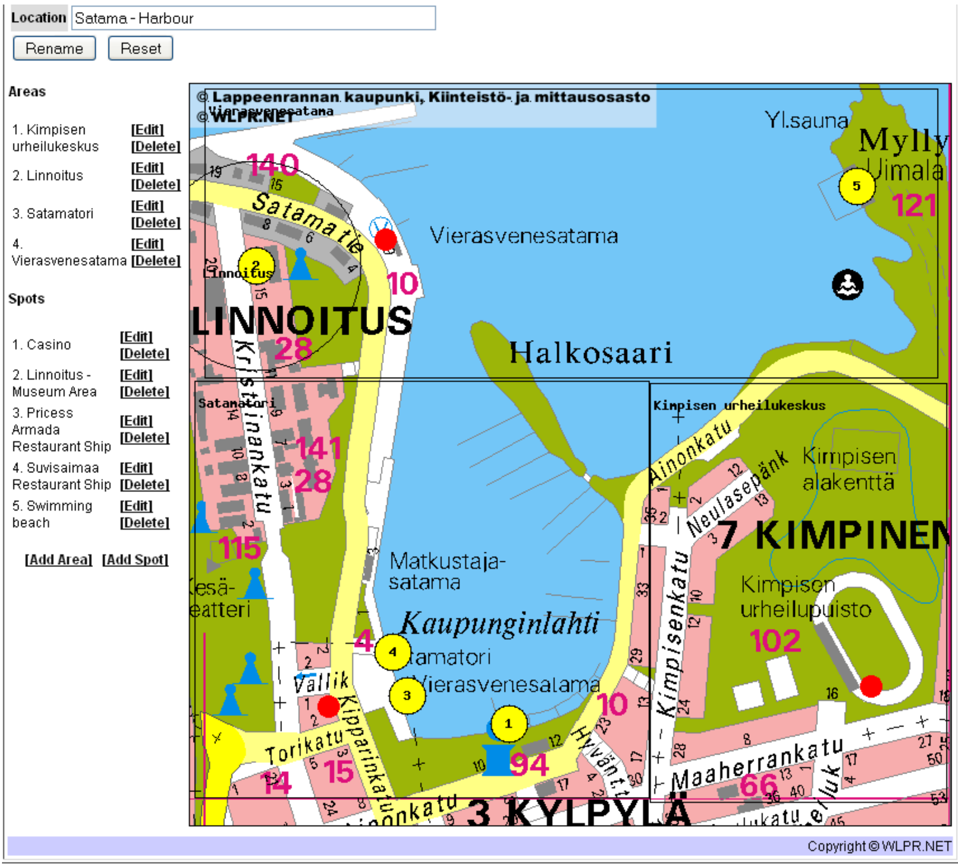
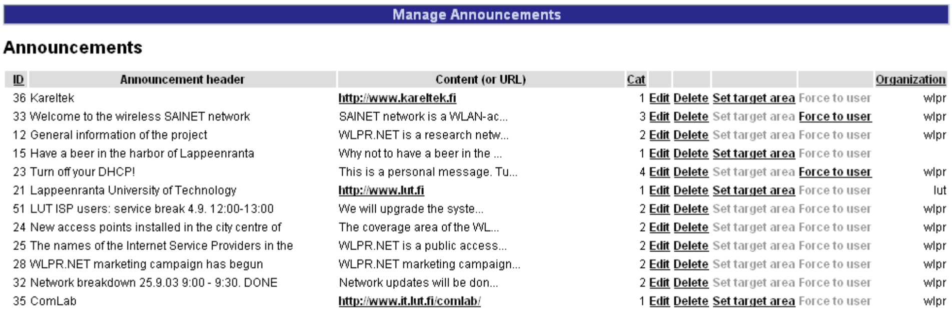


Figure 10. Lappeenranta harbor area in the positioning administration interface.

As described in section 3.3.1, the transparent web cache (see also *Publication 4* for more information) of the Lappeenranta Model allows an easy implementation of the *Advertisement System* [Kur02a]. The Advertisement System can be used to push information to access network users, who get the information as soon as they send a request for the next web page. The information can be allocated to all or certain WLAN access points and to a certain group of users. The information can be news, notices, advertisements etc.

Figure 11 shows a view of the administration interface of the Advertisement System. The interface can be used to insert advertisements with certain starting and ending times, content in different languages, and priority and a category varying from a general advertisement to a personal alert to a certain user. An administrator can also choose the target area (desired access points in the network) for the advertisement. Advertisements can be immediately forced to certain users (i.e. MAC addresses) if needed. Permissions can be individually set to different administrators to allow advertisements to be added to certain areas. This allows, for example, a restaurant that has sponsored an access point to the network to add advertisements only to a certain area.



Manage Announcements

Announcements

ID	Announcement header	Content (or URL)	Cat					Organization
36	Kareltek	http://www.kareltek.fi	1	Edit	Delete	Set target area	Force to user	wlpr
33	Welcome to the wireless SAINET network	SAINET network is a WLAN-ac...	3	Edit	Delete	Set target area	Force to user	wlpr
12	General information of the project	WLPR.NET is a research netw...	2	Edit	Delete	Set target area	Force to user	wlpr
15	Have a beer in the harbor of Lappeenranta	Why not to have a beer in the ...	1	Edit	Delete	Set target area	Force to user	
23	Turn off your DHCP!	This is a personal message. Tu...	4	Edit	Delete	Set target area	Force to user	wlpr
21	Lappeenranta University of Technology	http://www.lut.fi	1	Edit	Delete	Set target area	Force to user	lut
51	LUT ISP users: service break 4.9. 12:00-13:00	We will upgrade the syste...	2	Edit	Delete	Set target area	Force to user	wlpr
24	New access points installed in the city centre of	The coverage area of the WL...	2	Edit	Delete	Set target area	Force to user	wlpr
25	The names of the Internet Service Providers in the	WLPR.NET is a public access...	2	Edit	Delete	Set target area	Force to user	wlpr
28	WLPR.NET marketing campaign has begun	WLPR.NET marketing campaign...	2	Edit	Delete	Set target area	Force to user	wlpr
32	Network breakdown 25.9.03 9:00 - 9:30. DONE	Network updates will be don...	2	Edit	Delete	Set target area	Force to user	wlpr
35	ComLab	http://www.it.lut.fi/comlab/	1	Edit	Delete	Set target area	Force to user	wlpr

Figure 11. Administration interface of the Advertisement System.

Section 3.6 describes additional real-life examples of the features described above.

3.3.5 Implementation options

As *Publication 4* describes, the Operator Interface can be implemented in numerous different forms, i.e. distribution of the components into one ore more server computers is rather free. However, it is important to notice that there are three components that cause most of the load to the system: creating and using redirectors, utilizing the web cache (squid) and updating the login database.

The redirector and web cache bond tightly to each other and both use the same database. For most cases, therefore, it is logical to distribute the database to a different server computer. Distributing the database to an external computer will additionally increase the security of the system as no connections from the access network can be made directly to the database computer. Distribution of other components into these servers is optional.

3.4 Lappeenranta Model vs. StockholmOpen.net framework

The Lappeenranta Model and the StockholmOpen.net framework have been compared to each other in *Publication 3*. Figure 12 sets the Lappeenranta Model and StockholmOpen.net framework side by side. The Lappeenranta Model separates ISPs from the local OAN whereas in StockholmOpen.net the ISPs connect directly to the OAN. The Lappeenranta Model, however, allows ISPs to be directly connected to the OAN, if wanted. Compared to the StockholmOpen.net framework the Lappeenranta Model is more complex as it needs network management software and also includes some local services, like the location service.

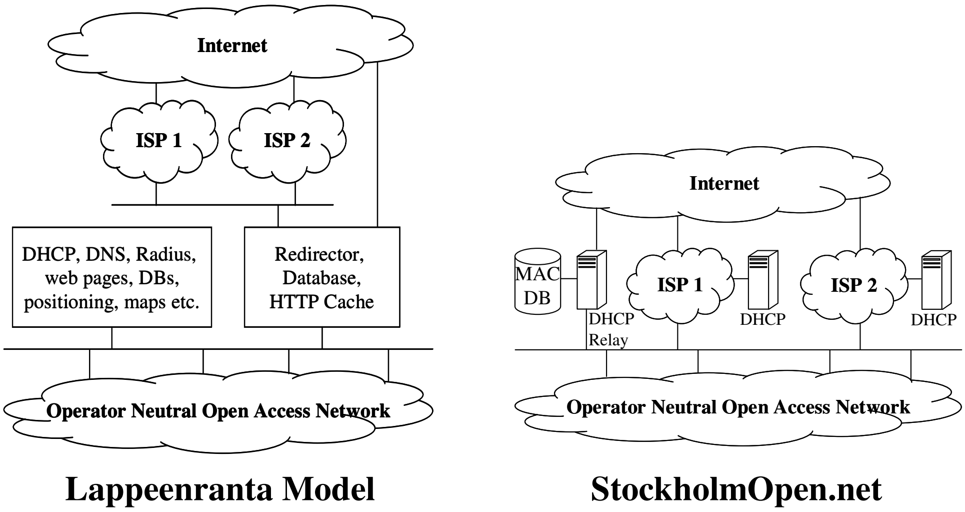


Figure 12. Lappeenranta Model vs. StockholmOpen.net framework.

The most evident difference between the Lappeenranta Model and StockholmOpen.net is that normally the Lappeenranta Model separates the ISPs from the local OAN. In practice this means that the Lappeenranta Model manages the OAN up to layer 3 whereas the StockholmOpen.net framework leaves layer 3 to the ISPs. StockholmOpen.net is based on a DHCP relay that directs the traffic to a chosen ISP, which provides end users with network settings. The OAN operates just as an access network and provides only a minimum number of shared services whereas in the Lappeenranta Model there are also additional resources to local end users and service providers.

As described in section 3.3.4 the Lappeenranta Model has two components related to local service provision: the Location Information System and the Advertisement System. These components are unique and cannot be found in StockholmOpen.net or other known OANs.

3.5 Performance Measurements

The Lappeenranta Model's performance was tested in order to measure its behavior in a high load situation. *Publication 4* describes the testing procedure, equipment used and some key findings. The results of the performance test will be described more closely here.

As described earlier, the Lappeenranta Model adds components to a standard web proxy (squid). The main goal was to find out how these additional components affect the overall performance of the system. It was expected that the performance will decrease as using redirectors and web cache and making database queries always takes some time. The Operator Interface was implemented by combining the redirector and web cache to one server and distributing the login database to a different server.

3.5.1 Testing Procedure

The performance of the Lappeenranta Model was tested in a closed network environment shown in Figure 13.

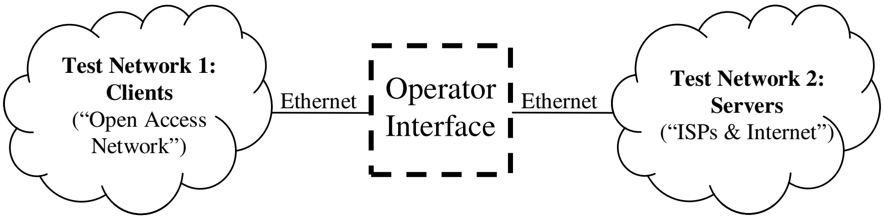


Figure 13. Operator Interface testing environment.

The Operator Interface was located between two testing networks that simulated the access network and the Internet. In test network 1 (Open Access Network) clients were acting as normal network users generating requests for web pages, IP addresses, transferring different sized files both in the access network and between the test networks etc. In test network 2 (ISPs & Internet), servers were emulating the content that real ISPs provide for their clients. Figure 14 shows the testing environment. *Publication 4* describes the essential hardware that was used in each computer.

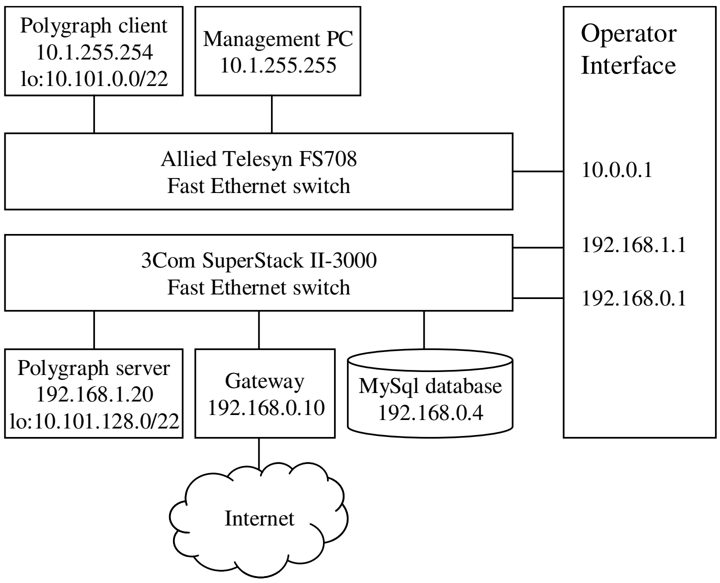


Figure 14. Operator Interface testing environment hardware (*Publication 4*).

The performance and functionality of the Operator Interface was evaluated by generating heavy network traffic and measuring its ability to handle different situations. 100-megabit Ethernet network interfaces were used in the testing environment as that speed was more than the equipment could handle. Because the measurements were made simultaneously in multiple computers, it was important to keep all the computers synchronized. An Ntpd time server daemon was used in all the computers.

The Polygraph server and client had a FreeBSD 4.3 operating system optimized by Measurement Factory [Mea07]. The overall network performance between the Polygraph server and client was measured with netperf. The TCP stream throughput from server to client averaged 81,40 Mbps and from client to server 87,36 Mbps.

Web Polygraph [Web07a] was used for the testing. Web Polygraph is a high-performance proxy benchmark (see [Rou04]) that models a diverse set of normal Web traffic characteristics. Web Polygraph utilizes so called robots in the client server that simulate the behavior of a normal user. The tests were run with version 2.7.4 of Web Polygraph and the PolyMix-4 workload consisting of 10 phases, each representing a different load on the system [Web07b].

Phases *framp*, *fill* and *fexit* initialize the working set that is later used in the testing. In our test the overall duration of these three phases was about 200 minutes. Phase *inc1* (20 min) increases the robot population size and overall system load to the peak level and *top1* (4 hours) keeps the load at the peak level. Phase *dec1* (20 min) decreases the robot population to 10 % and reduces the system load. Phase *idle* (20 min) keeps the robot population at 10 %. Phase *inc2* (20 min) again increases the robot population to 100 % and phase *top2* (4 hours) keeps the population and system load at the peak level. The last phase *dec2* (20 min) decreases the robot population to 0 % and ends the test. Total test duration was about 13 hours.

3.5.2 Test Results

The test results and the main components of the Operator Interface are explained in *Publication 4*. As described, the redirector is the component responsible for the core functionality of Operator Interface, i.e. the redirector routes traffic to the correct service providers. The redirector can also be used to check from a database whether a certain user should be shown a web page different from the one the user is requesting. This functionality allows, for example, users to be redirected to login pages or to be shown announcements and advertisements. In cooperation with the database and web cache, the redirector generates practically all the CPU and I/O load in the Operator Interface.

The performance of the Squid (as well as that of other web proxies) is mostly dependent on the server hard disk performance since most other delays (for example in the network) cannot be controlled in the caching system itself [Rou99]. The importance of hard disk I/O performance applies also to the tests of the Lappeenranta Model and the difference between IDE and SCSI hard disks can clearly be seen in Table 2 and the following figures. Using IDE hard disks raises the average Squid response time by about 600-800 milliseconds compared to SCSI disks.

The clients were configured to generate 150 queries per second, as it was a suitable rate to take the equipment used in the test to its performance limit and still maintain response time and network speed at a reasonable level. As seen in Table 2 the maximum response time with this query rate was 3,6 seconds and the generated network traffic was about 8 Mbps. According to [Kob03] 146 end users generate 2 requests per second in normal web use. Therefore the 150 queries per second that was used in the performance tests is equivalent to about 11000 network users actively browsing the Internet.

To find out the effect of redirector processes on the delays, tests were done with and without the redirector. Using the redirector raises the system response time by about 250 ms with IDE hard disks and about 70 ms with SCSI hard disks.

	IDE		SCSI	
	With redirector	**Without redirector**	**With redirector**	**Without redirector**
Throughput	150.36 rep/s	150.44 rep/s	150.43 rep/s	150.43 rep/s
Bandwidth	8.27 Mbps	8.25 Mbps	8.35 Mbps	7.87 Mbps
Mean response time	2883.30 ms	2619.51 ms	2018.57 ms	1959.32 ms
- misses	3638.50 ms	3320.52 ms	2632.92 ms	2592.92 ms
- hits	797.83 ms	570.82 ms	157.08 ms	123.63 ms
Hit ratio	29.57 %	28.24 %	26.51 %	27.36 %
Errors	0.00 %	0.00 %	0.00 %	0.00 %

Table 2. Summary of Polymix-4 test results in phase *top2*.

The three figures 14-16 show the variation of response time during the Operator Interface test phases. As described earlier, the tests were run with the PolyMix-4 workload. There are two phases in the test that generate heavy load on the system and those phases (*top1* and *top2*) can be clearly seen in the figures. The Operator Interface is tested with both IDE and SCSI hard disks, and in both cases with and without the redirector.

Figure 15 shows the mean response time of the Operator Interface (both web cache misses and hits) during the test. It can be clearly seen that the SCSI system outperforms the IDE system. In a low load situation IDE and SCSI disks perform similarly but in high load situations (phases *top1* and *top2*) the SCSI system is about 600-800 milliseconds faster than the IDE system. Using the redirector causes some delays (about 260 milliseconds on average) with IDE disks but when using SCSI disks the difference is marginal (about 60 ms on average).

Figure 16 shows the response time of the Operator Interface during the test in the case of a web cache miss. With a cache miss the information requested by the user needs to be fetched from its original source causing response times from 2500 to 3500 milliseconds. Again, the difference between IDE and SCSI disks in high load situations is clear, as the SCSI system is about 1000 milliseconds faster than the IDE system. When using IDE disks the response time with the redirector increases by about 200-300 milliseconds compared to standard web proxy functionality. With SCSI disks the performance difference with or without the redirector is marginal.

Figure 17 shows the response time of the Operator Interface during the test in the case of a web cache hit. Now the response times are lower than in Figure 16 as the requested information can be found in the local cache. As before, in low load situations the IDE and SCSI perform similarly. At high load the difference is about 500 milliseconds in favor of SCSI. Again, switching redirector on causes some increase in response times: about 30 milliseconds with SCSI and about 230 milliseconds with IDE.

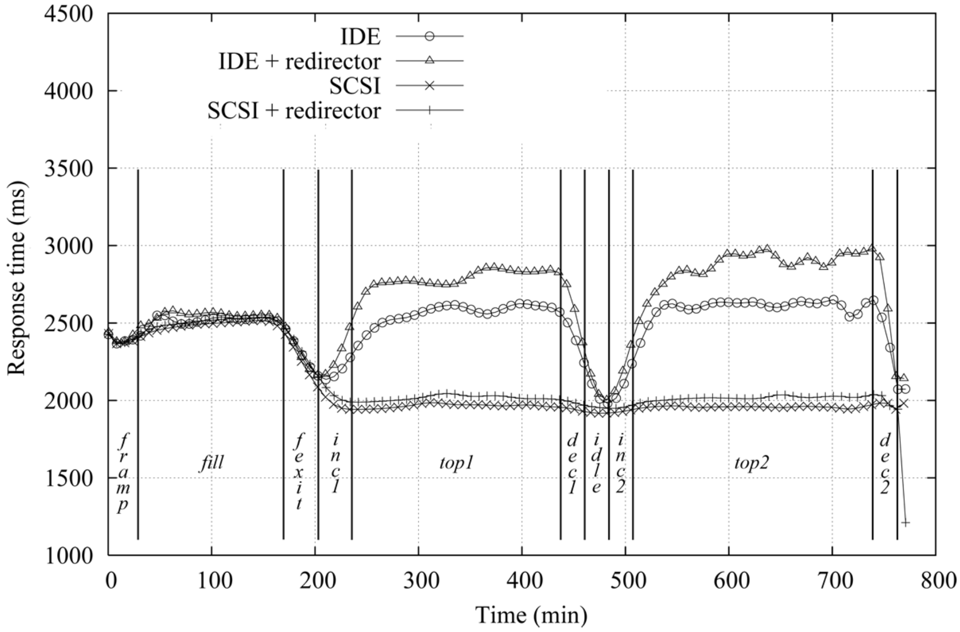


Figure 15. Operator Interface response time (mean).

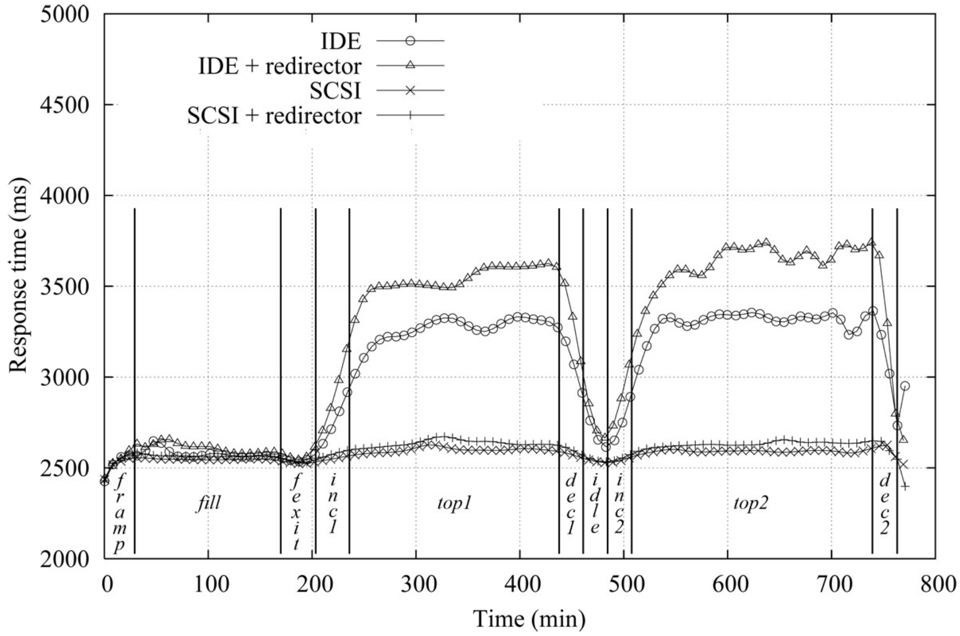


Figure 16. Operator Interface response time (cache miss).

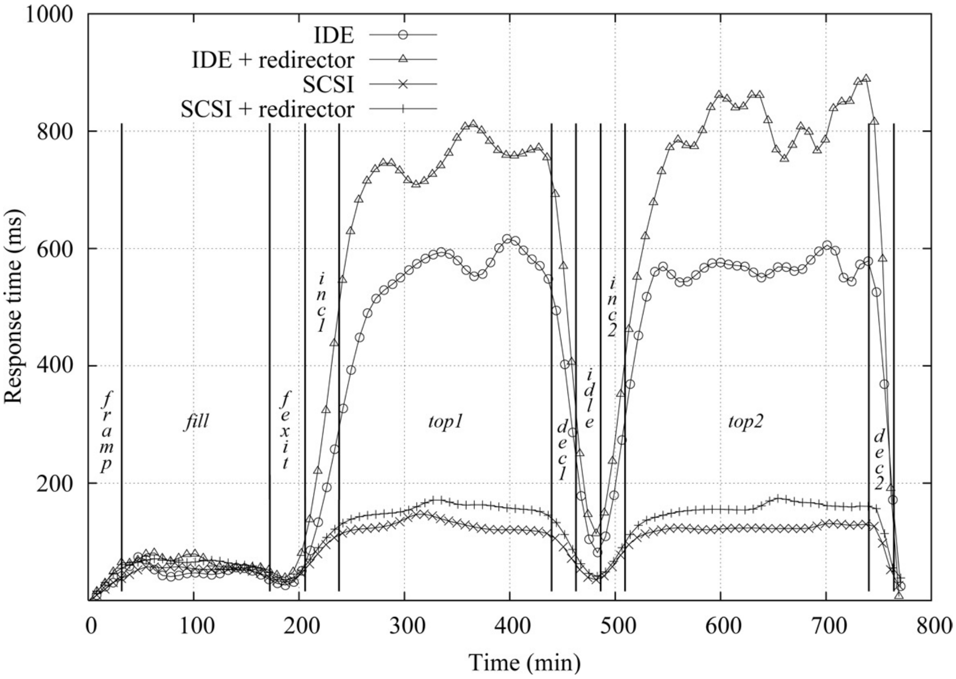


Figure 17. Operator Interface response time (cache hit).

To summarize the scalability tests, it can be said that the Operator Interface acts like a standard web proxy. There is a slight increase in delay times but the difference to a standard web proxy is marginal, especially with SCSI disks. The conclusion can thus be drawn that running the Operator Interface requires similar equipment to running any Squid web proxy installation. The tests also show that the most important factor is good I/O performance of the hard disks, i.e. SCSI disks are to be favored in any large scale installations. The above results match those of [Kur02a] and [Kur02b].

In addition to enhancing I/O performance there are also other means to increase the overall performance of the Operator Interface. The response times could be reduced by optimizing database queries and indexing. The redirector process is currently written in Perl, so rewriting the process with C would enhance the performance.

Although not tested, it can be estimated that a centralized Operator Interface would be suitable for small environments, like airports, hotels and apartment buildings where single computer could handle the load. If necessary, some of the services and functions could still be distributed to different computers to increase performance. It may also be possible to implement the centralized Operator Interface using several identical servers balancing the load. This option has, however, not yet been tested in practice.

It is evaluated that the distributed implementation option a) will be most suitable for general use. It is likely to offer the best balance between manageability and performance. The equipment used in the tests was capable of processing about 150 requests per second with a reasonable response time but the performance could be improved with more modern disk techniques (like Native Command Queuing in SATA systems and Serial Attached SCSI).

3.6 Sainet

Currently (August 2008), there is one OAN that has been built according to the Lappeenranta Model: Sainet [Sai07]. Sainet is named after Lake Saimaa (the biggest lake in Finland) is at the heart of the South Karelian reqion. Sainet was formerly known as the Wireless Lappeenranta Network (WLPR.NET) [Wir07]. The network was originally built for research purposes for the WLAN-project of Lappeenranta University of Technology. Today Sainet is operated by a local company.

At present Sainet consists of about 120 WLAN access points (~90 indoor, ~30 outdoor). Most of the access points are located in the vicinity of Lappeenranta University of Technology but also surrounding districts and the city center are covered. Figure 18 shows the current network coverage area. Lappeenranta University of Technology is located in the top left corner of the picture and the city center is on the right side.

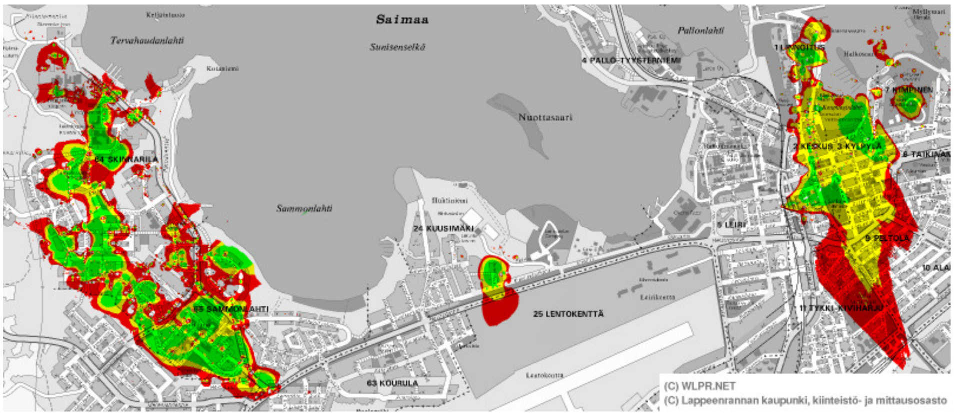


Figure 18. Sainet coverage area in the city of Lappeenranta.

There are currently six registered ISPs in the network. Sainet has about 1100 active users (used the network within a month) and about 85 concurrent users. See Figure 19 and Figure 20 for an example of user numbers and traffic through one ISP of Sainet to the Internet.

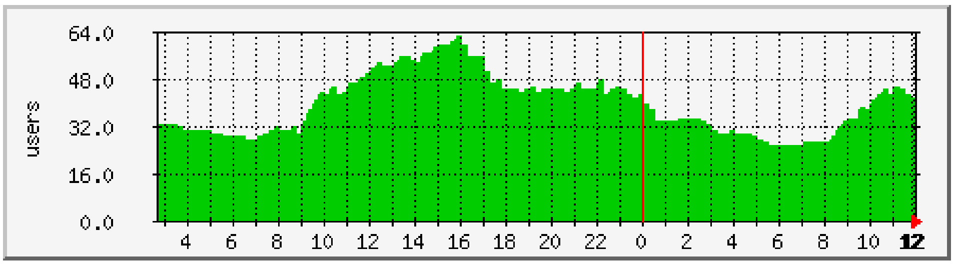


Figure 19. Daily graph of on-line user numbers of one ISP in Sainet (5 min average)

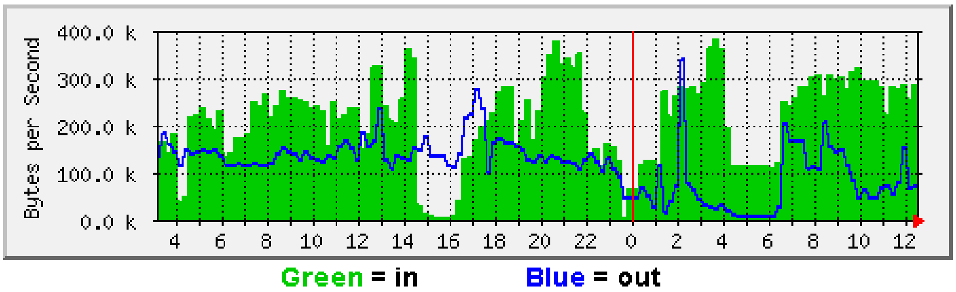


Figure 20. Daily graph of traffic of one ISP in Sainet (5 min average).

Figure 21 illustrates the total number of logins per month as a function of time (WLPR.NET before August 2006). As the Figure shows, the number of users has been growing and the maximum number of logins per month has been about 11 000. The periodic fluctuation of user amounts can be explained by the fact that most of the network users are students at Lappeenranta University of Technology. They have vacations from May to August and in December, which reduces the number of users during those months. Due to hardware failure there is no data for the period from January to June 2006. Due to a problem in a component collecting the statistics there is no data after July 2007.

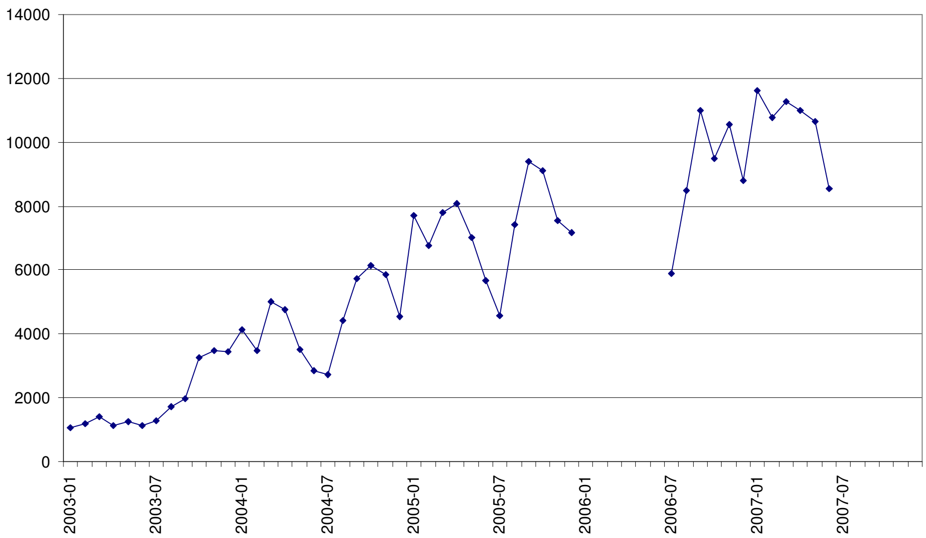


Figure 21. Logins per month in Sainet (WLPR.NET).

Sainet has some experimental local services since the Lappeenranta Model encourages free and easy local service provision in the access network. One example is the My Location service that uses the services of LIS [Kos05]. As shown in Figure 22 a network user can locate him/herself in the network and get a map showing the current location and surrounding places. On the left side links are given to local places found nearby.

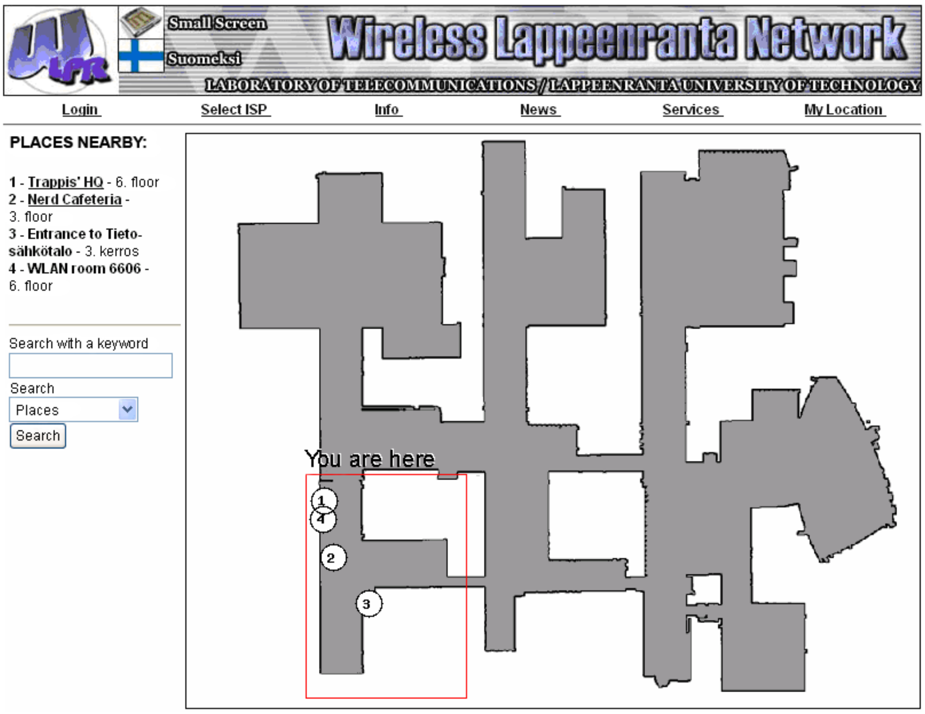


Figure 22. WLPR.NET's My Location service.

Another experimental local service that also utilizes LIS is Skyline [Mul04]. Skyline allows users to leave "Floating notes" on any location in the network and browse notes others have left. See Figure 23.

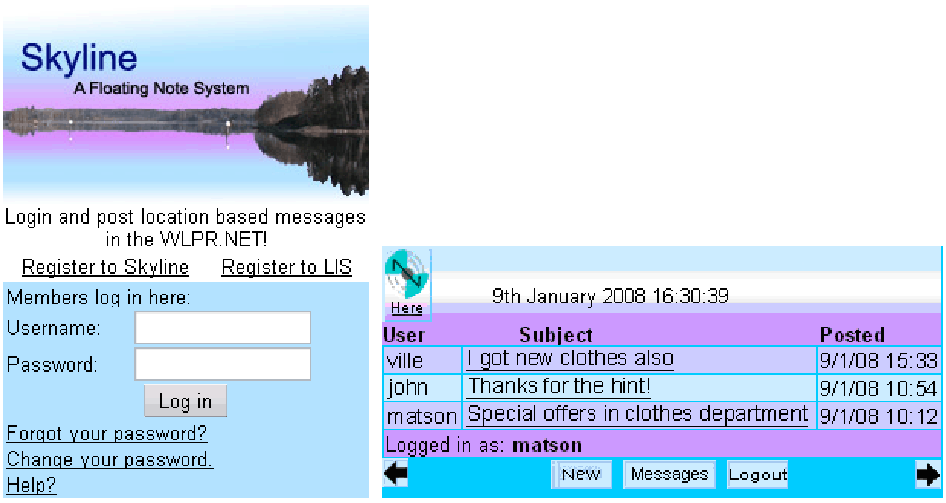


Figure 23. Skyline login page and a floating note screen.

Sainet has a built-in advertisement system that can be used to send news, advertisements or announcements to network users. This system is described in *Publication 1*, *Publication 2*, *Publication 3*, *Publication 4*, and *Publication 6*. The technical structure and operating principle of the advertisement system is described in [Kur02a] and [Kur02b]. The service is run by HTTP proxies and works by replacing a web page which a user is trying to access with another web page. Network management applies this function to inform the users about network problems and maintenance. Operation of this system requires that the user is trying to access the Internet and the page requested is replaced by the information page from management. The weakness of the system is that it requires the user to access the Internet. An advantage is that it does not require users to have specialized software installed on their devices. Figure 24 shows an example of the advertisement system in operation.

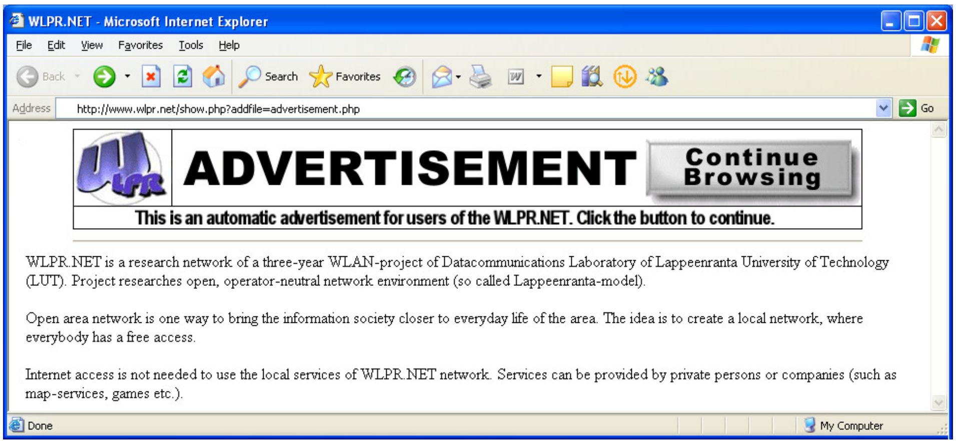


Figure 24. Advertisement system showing a forced announcement to a network user.

Sainet is participating in the eduroam (Education Roaming) agreement. Eduroam [edu07] is a RADIUS-based infrastructure that uses 802.1X security technology to allow inter-institutional roaming. Eduroam enables visiting users to login to Sainet with their native user accounts (the same credentials the user would use at their home institution).

3.7 Challenges in Implementation

Building an open access network requires co-operation with many different parties. As there are different types of OANs the building process may vary a lot. The following analysis is done based on the phases that were encountered while implementing the Lappeenranta Model into WLPR.NET (and later Sainet).

The launching of WLPR.NET required co-operation with local organizations. WLPR.NET was mainly built by utilizing existing access networks in the city of Lappeenranta and the most important partners that allowed WLPR.NET traffic in their networks were

- The city of Lappeenranta,
- Lappeenranta Student Housing Foundation (LOAS),
- Lappeenranta University of Technology, and
- Technology Centre Kareltek.

Estimating building costs is difficult as WLPR.NET was built alongside the WLAN project. Network administration was first run with project staff and when the project ended with voluntary work. It is estimated that running WLPR.NET (or Sainet) requires one full-time manager who would be responsible for keeping the network operational (rebooting access points and replacing their antennas or transformers if necessary), expanding the coverage area by planning new access point locations in co-operation with local participants, and installing access points. A further cost is the Internet connection, for example an ADSL line, needed to connect the Operator Interface to the Internet.

When WLPR.NET was implemented in 2001-2003 open access networking was a new phenomenon and major ISPs opposed the development. It, therefore, proved difficult to get commercial ISPs to provide Internet connections to the network. Some of the co-operation partners, however, acted as ISPs and provided Internet connections to their personnel. For example, Lappeenranta University of Technology provided authentication for its staff and students. WLPR.NET manager has also provided free Internet connectivity to everyone in the network. The speed of the free connection is, however, limited.

Another difficult issue was making formal contracts with network users, service providers and ISPs. Contracts with network users were easy to realize as the users are required to accept network usage rules when registering to the network (i.e. choosing the ISP). Contracts with service providers (especially with Internet service providers) proved to be problematic because WLPR.NET was formed by connecting several networks operated by partners in co-operation. The network was also administrated alongside the WLAN project and there was no separate company or organization responsible for managing the network. Thus it was difficult to guarantee that possible network problems could be solved quickly enough and the reliability of the network would meet the requirements of the service providers, especially the ISPs.

Currently the access network (Sainet) is run by a commercial organization, Wispnet Oy, which keeps the network operational and extends the coverage area of Sainet to the surrounding areas. Although the organization can make contracts with other commercial organizations the access network still consists of several inter-connected networks and is difficult to control as a whole.

3.8 Providing Services in the Access Network

The Lappeenranta Model encourages local interaction and the provision of different services to access network users is made as easy as possible. Service provision is free and services provided may vary from private gaming servers to public real-time video rental services. Although service provision is free there is an additional component dedicated to helping service provision: *Service Interface*. *Publication 2* describes the operating principle of the Service Interface.

To end users, the Service Interface looks like a service portal that is used to gather the services in the access network to a single location where they can be easily found and accessed. To service providers, the Service Interface offers useful extra resources (such as location information) that can be used to improve the services. The general level usage of location information in WLAN networks is studied in [Sep02].

Service provision directly in the access network raises some fundamental issues about the characteristics and business logic of the services. *Publication 5* deals with the question of providing services either globally or locally. Nowadays most services are global, meaning that they are located in the Internet. Reaching the services requires Internet access and bandwidth is nowadays typically limited to 2-8 Mbps with ADSL technology. Local services can be offered directly inside the access network, which may allow (depending on the technology used in the access network) remarkably faster connections.

3.8.1 Opinions of End Users about Local Services

Three surveys were conducted in 2005-2007 to establish the opinions of end users and potential service providers whether they see open access and local service provisioning as beneficial. All three surveys show that both end users and potential service providers see open access and local services as beneficial.

Survey in WLPR.NET (2005)

In 2005 a web based survey of WPLR.NET users [Alm05] was done in order to ascertain their interest in using the local access network and its local services. The questions concentrated on finding out how people were using the network, their opinion of network functionality, and how they saw the idea of locality and did it have any influence on their network usage.

The survey was open for two weeks and during that time there were a total of 2062 logins to the local network. This gives information on the total number of network users but does not tell how many of them actually noticed the announcements for this survey. The total number of respondents was 98. As Figure 25 shows, most of the respondents were students at Lappeenranta University of Technology, while one fifth was employed by some local company. The third option consists of eight respondents of which seven were both studying and working, and one was a housewife.

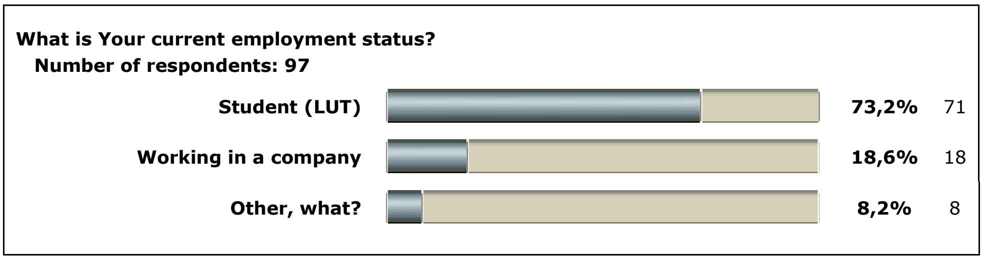


Figure 25. Employment status of the respondents [Alm05].

Half of the participants used the network occasionally and one third were daily users. Taking the relatively short survey time (two weeks) into account, it may be assumed that the questionnaire might not have reached all potential occasional users. The remaining 15 % of the participants were only experimenting with the network.

Figure 26 shows that most of the end users (55 %) had not used any of the local services. Nevertheless, respondents' comments imply that they are interested in local services; there just are not enough interesting services currently available. The most popular local service was the My Location service and the second most popular was a local map service. The large number of people that had not tried local services implies that either they saw the local services as unnecessary or there were no interesting local services available. As the available local services were just experimental and, except for My Location and the mapping service, provided little value for the end user, the latter option seems the most likely interpretation.

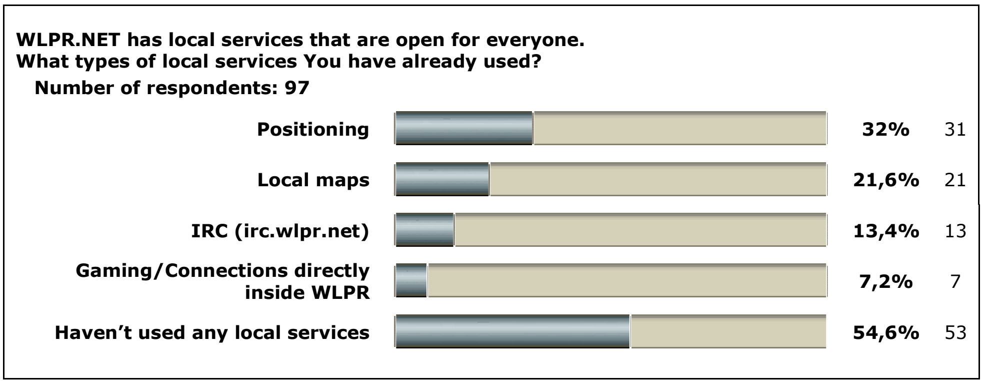


Figure 26. Usage of WLPR.NET's local services [Alm05].

Keeping in mind that few local services were available, one of the most interesting questions in the survey was what types of local services people would like to have in the network. As seen in Figure 27, 72 % of respondents would be interested in services related to their housing, such as reservation of laundry facilities, car parking slots, and the housing corporation sauna. 55 % would like to have a service for locating friends in the network. 40 % would like to have local gaming services that would allow them to play local network games. 25 % would like to easily chat with friends directly in the local network. There were also some other suggestions for local services, like ordering pizza or getting a taxi and easy portal access to public transportation timetables. One interesting detail was that 25 % of the participants did not answer this question. This implies that it is difficult to come up with ideas of services that should be local.

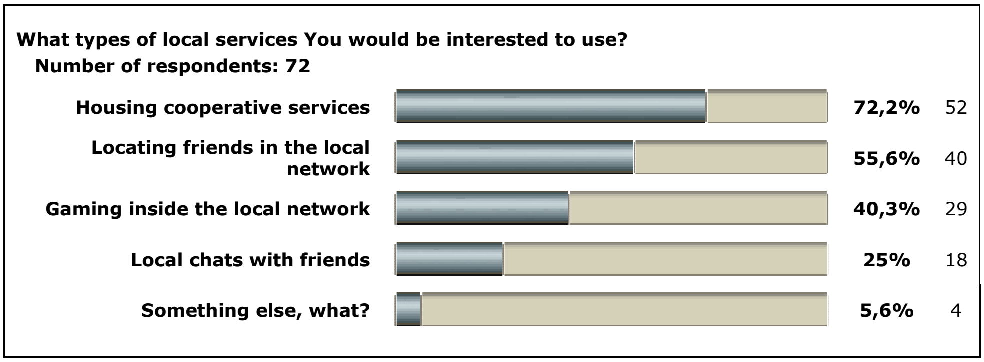


Figure 27. Types of local services that respondents would be interested in using. [Alm05].

A cross tabulation of previous local service types with the age of respondents shows in Figure 28 that users between the ages of 20-35 seem to be more interested in gaming and locating friends in the local access network than older users. On the other hand, the number of answers for older users is too small to draw firm conclusions.

What types of local services You would be interested to use?
Number of respondents: 72

Age	Local chats with friends	Gaming inside the local network	Housing cooperative services	Locating friends in the local network	Something else, what?
<20	**0%** 0	**0%** 0	**0%** 0	**0%** 0	**0%** 0
20-24	**10.2%** 6	**20.3%** 12	**39.0%** 23	**28.8%** 17	**1.7%** 1
25-35	**14.5%** 11	**21.1%** 16	**34.2%** 26	**27.6%** 21	**2.6%** 2
36-50	**14.3%** 1	**14.3%** 1	**42.9%** 3	**14.3%** 1	**14.3%** 1
>50	**0%** 0	**0%** 0	**0%** 0	**100%** 1	**0%** 0

Figure 28. Cross tabulation of the ages of respondents and interest in different local services [Alm05].

It is interesting to note that as Figure 29 shows, about 40 % of respondents would not want to pay anything for local services. Many of them mentioned, however, that a reasonable price for example for Video-on-Demand service or a dedicated high speed connection (100 Mbps or greater) would be acceptable.

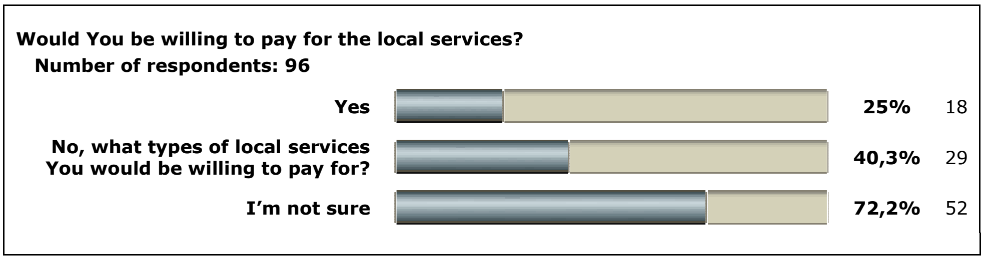


Figure 29. Respondents' willingness to pay for the local services [Alm05].

Although most of the respondents had not used any local services and would not be willing to pay for the local services, they still consider that locality and local services bring additional value to WLPR.NET. The survey showed that although most of the respondents (about 44 %, see Figure 30) felt the local nature of WLPR.NET was beneficial there are also difficulties associated with locality. The main reasons for positive answers were:

- Locality allows end users to access some local content/services directly
- The ease of transferring information inside the local network without the need for an Internet connection
- Positive effect on local employment
- Coherent student community benefits from the locality
- Ability to easily get into contact with other people in the same area
- Good channel for local announcements
- Good area for testing different things
- The wireless connection itself was seen beneficial

Negative answers were mostly related to the current state of local services: respondents were not interested in the current services and would like to see new types of services (like video renting or virtual VCR). As the reason for a negative answer some respondents mentioned that the types of local services they need could be provided directly in the Internet without the need for locality. Another reason was that the connection was used mainly just for surfing the Internet and reading e-mails, which does not require any locality.

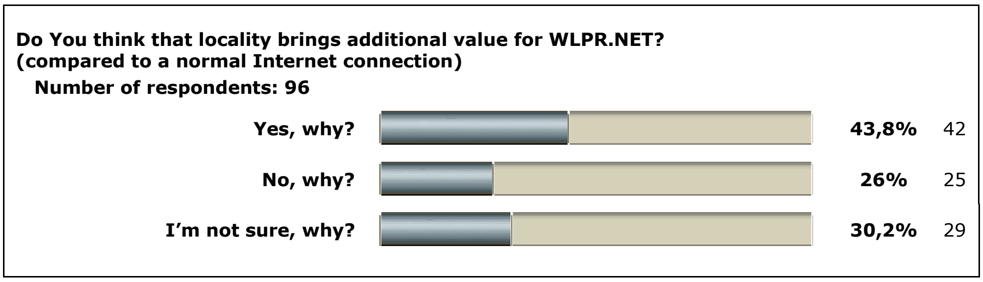


Figure 30. Opinion of respondents on the additional value of locality [Alm05].

Survey in WLPR.NET (2006)

In 2006 another survey [Van06] was conducted in WLPR.NET in order to find out what types of local services end users are specifically interested in. There were a total of 59 respondents in the survey. As seen in Figure 31, this time the proportion of students is smaller than in the previous survey (see Figure 25).

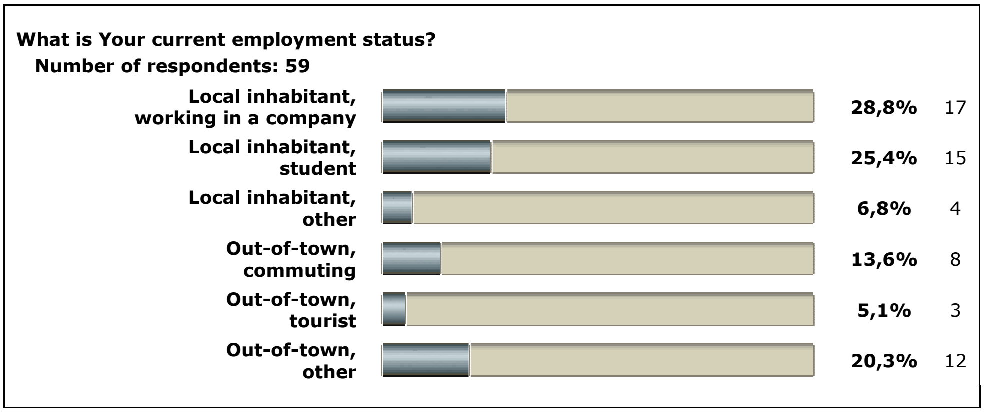


Figure 31. Employment status of the respondents [Van06].

75% of interviewees were interested in the opportunities that a public WLAN could offer. About one third of the users were also interested in local services, while two thirds would be satisfied with a normal Internet connection. Figure 32 shows the services most demanded by end users. The most popular services are e-mail, news, weather and city services (restaurants, cafés and hotels). Dictionaries and search services, timetables, banking and maps also get many votes. It is important to notice that many of these services are local-oriented and could be provided locally without the need for an Internet connection. This implies that many of the respondents may not have realized the potential of local services.

The respondents also listed additional ideas for local services. The ideas were mostly related to getting connections to company intranets and providing services that could enhance distance-working opportunities. A local news service was also suggested.

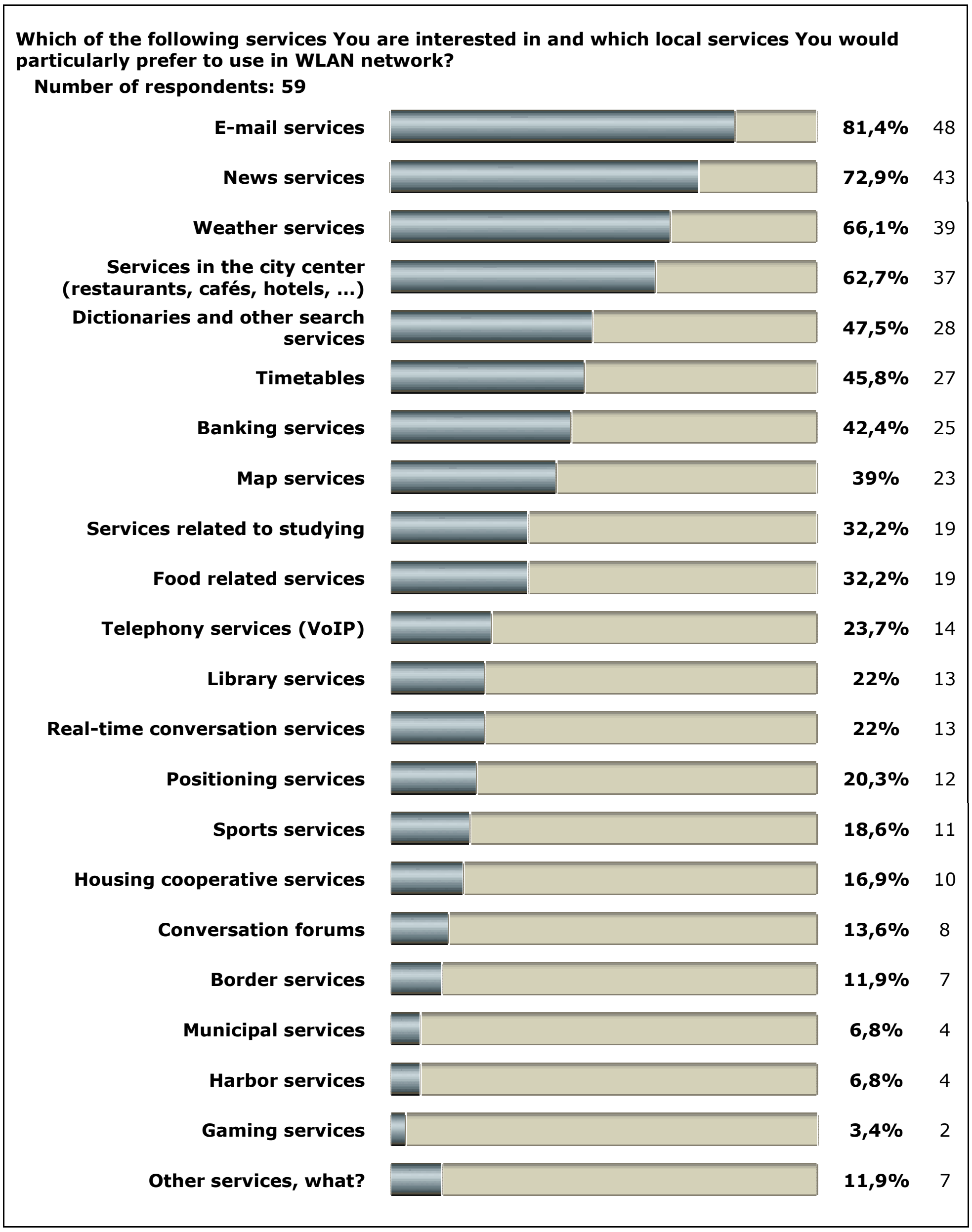


Figure 32. The most popular services among end users [Van06].

An interesting point is that respondents' interest towards housing cooperative, location and gaming services is now much lower than in the previous survey (see Figure 27). The differences can be explained by the different structure of the respondents' employment status, as students and younger people more typically live in housing cooperatives. The larger number of choices may also have directed the respondents' attention towards other types of services.

Although 30 % of the respondents feel that they do not need local services, three-quarters of them consider that local services bring additional value to the network. Compared to the previous survey (see Figure 30), respondents' opinions towards local services seem to be more positive.

Survey in Sainet (2007)

About two years after the first survey ([Alm05]) a similar usage survey [Kar07] was conducted in Sainet (rebranded from WLPR.NET). The survey had similar questions to the first survey although many of them were more specific and attempted to analyze if there had been changes in network usage habits. This survey was concluded in March 2007 and there were 78 answers.

Two thirds of the participants were students at Lappeenranta University of Technology. The second largest group (37 %) was employees of the university. Only a small number identified themselves as employees of local companies. There was not much change in the audience of the survey from 2005 to 2007.

Sainet supports multiple Internet service providers. Access to the Internet requires users to select an Internet connection provider via a web form. When users access the Internet they are authenticated by their service provider, if the policy of the service provider requires authentication. Most respondents (69) indicated that they used the Internet service of the local university. This was expected as a large number of users are from the university. The next largest user groups are connections via unauthenticated Internet connection (17), which requires only the acceptance of the usage rules, and connection through the local technology center (19). An interesting detail is that three (3) users indicated that they use the network only for local services, i.e. not for services located in the Internet. Many of the answers indicated that many users used more than one service provider. Some of the reasons for using multiple Internet connections were: "no need to use own passwords on temporary devices", "normal ISP was not working" and "my ADSL service had problems". An important factor was the wish to avoid additional login procedures.

The network covers large areas in Lappeenranta city and the study wanted to analyze how users use the network. The network can analyze where each device is connected to the network, but it was wanted that users themselves identify where they need the network most. The local university was a popular answer (58 users), but almost all respondents indicated that they also actively use the outdoor access points (74).

One way to determine the importance of the network can be by studying how often the users need the network in their tasks. Twenty (20) of the users stated that they use the network daily, 29 on a weekly basis, and 28 identified their usage to be occasional. Users who identified their usage as occasional stated that they normally use wired access, but might need a wireless connection when they are working away from their usual working places, for example in a task which requires students to use their own laptops in the university. In comparison to the 2005 survey there was a strong shift to a continuous need for network access.

The Sainet network covers large outdoor areas, so it was studied whether users are able take advantage of that facility. The climate in Finland limits or at least places special requirements for network usage as it is hard to imagine users typing their laptops outdoors for a long periods when the temperature is below 0 Celsius. Most users answered that they had not used the network outdoors (48). However 12 users identified that they had tried and more importantly 17 users identified that they had used and needed the outdoor network coverage. There was a clear increase in the number of users who used the network in outdoor spaces compared to the survey of 2005. One factor that explains the development is that WLAN capable mobile phones were rare in 2005 but are becoming more common.

One of the ideas in Sainet is that users can use the network in many places in the town. Users were asked if they used the network in a mobile fashion. Most users (35) indicated that they had used the network in many places but the usage is actually nomadic, i.e. users move around and try to get a network connection when they need one. None of the users indicated that they had used the network in a mobile fashion and roamed between access points while moving. This is however something that might be expected to become more common as WLAN capable mobile phones get popular VoIP (Voice over Internet Protocol) and instant message clients. There are clearly more nomadic users than two years earlier and users were asked what kind of devices they use to access the network. The largest group of access devices was laptops (73). Seventeen (17) users stated they use also a cellular phone, which was considered a significant fact as there were not many WLAN capable phones on the market. Some of the users also used their home PCs (Personal Computer) with a WLAN adapter (10) or personal digital assistants (9).

The network was planned so that the users can offer local services to each other and use services provided by local access network. It was clear that the Internet (with its services) is the main service which users want, but the study wanted to identify if there are local service in the access network which users use directly. 27 users said that they had used or tried a local service. As shown in Figure 33 the most popular service was the local positioning service which had been tried out by 14 users. The Internet relay chat (IRC) service was used by 8 users. Both services had a link in the internal web page of the network, which made them easy to find. Seven users had moved files inside the access network and one said that he had used peer-to-peer in the access network.

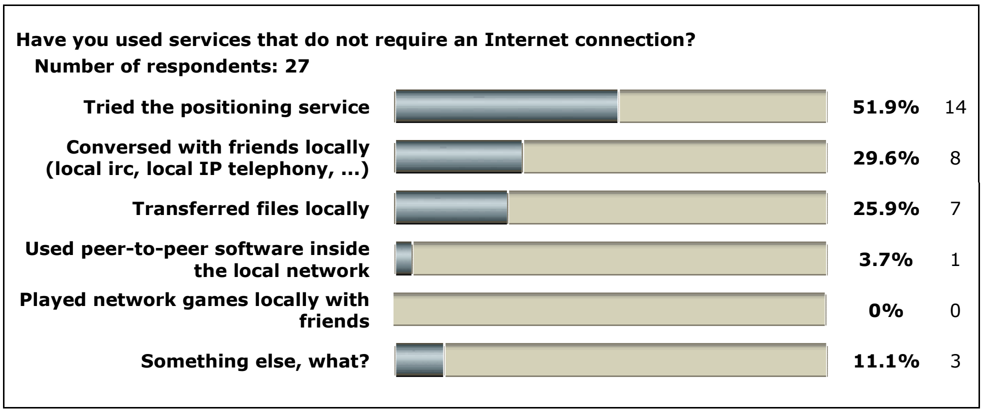


Figure 33. Usage of current local services [Kar07].

The respondents were also given a list of services and asked if they would use them if they were available in the network. About 62 % of the respondents indicated that they would be interested in using local services. Figure 34 illustrates the respondents' interests. Again, services based on location information are popular, as well as local newsletters.

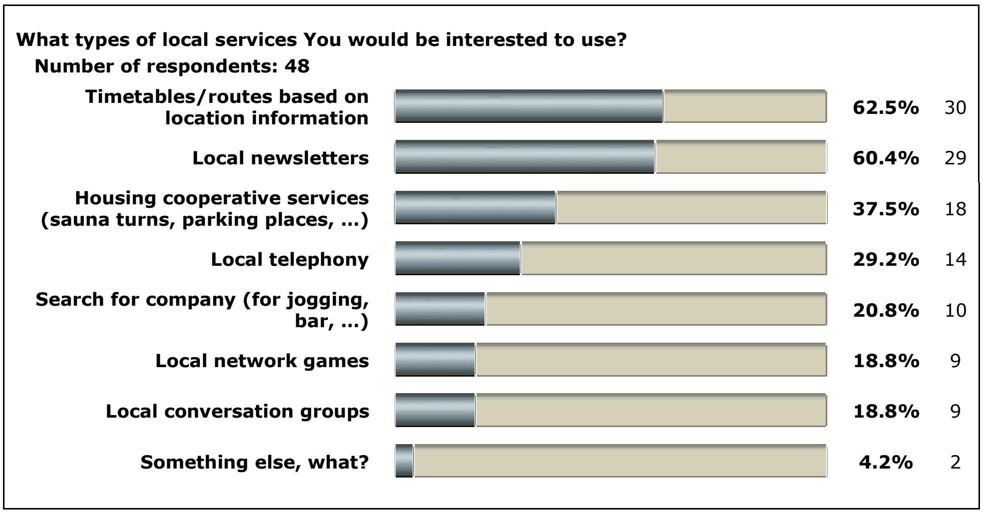


Figure 34. Respondents' interest in different types of local services [Kar07].

Users were more interested in services which would provide local added value and were currently not available in the Internet. However most of the services can be realized as an Internet service and utilized by granting access to the Internet. Users were clearly more interested in the idea of local services in the survey of 2005.

Many community networks are built and managed by community members and hobbyists. One aim was to find out if Sainet users would be interested in actively participating in a communal network. Sixteen (16) users answered that they would be interested. Further questions asked for specific areas where they would be interested to help and answers included user help desk work (9), management of services (8), network management (7), service production and development (7), and content production (3). The indication that some of the users are interested in developing local services and providing content is remarkable as local content and services are desired. More research is needed to determine if sufficient support and help can be provided to make such services a reality. An interesting research topic may be the study of whether the network could be run by a group of active users like in many community networks.

3.8.2 Interview of Service Provider Candidates

The network structure of Sainet allows end users to offer services to each other in the local access network. It was assumed that local services could create new economic growth and support existing business operations. One of the initial ideas of the Lappeenranta Model was to operate as a platform for service innovation. Services have, however, not started to appear and an interview-based survey [Van06] was conducted to find possible service providers and ideas for services. The survey concentrated on the business and public sector. The main goal was to find services which a potential provider could offer and what kind of services users would adopt.

The questionnaire for the interview consisted of three parts:

- Background, which was used to classify the interviewees.
- Interviewees' experiences of various services and whether they see potential in them.
- Future needs for services. This section gathers information about the kind of services interviewees may need in the future.

It is easy to list a large number of services, but it is important that both the services provided and the network are financially viable. The Sainet access network requires resources to remain operational and an initial business model was designed for Sainet (or more accurately for WLPR.NET, which preceded Sainet) by Kiviniemi [Kiv02a].

Interviews were conducted mainly face-to-face, but a small number of the interviews were done by Internet questionnaire. In the case of the Internet questionnaire, a phone or email introduction to the interview was given prior to answering the questionnaire. The questionnaire was answered by 24 persons. Although the sample size is small, the answers have been considered and justified more carefully than in a normal web based survey.

The potential service providers were classified to public sector service providers 42% (10 interviews) and commercial service providers 58% (14 interviews). All but one of the interviewees (i.e. 23) expressed interest in WLAN and the possibilities it could provide. Interviewees were asked if they believed they could receive substantial gain by offering services in a city-wide WLAN network and 63% of them responded positively. The commercial service providers, however, were more cautious and more gain was envisaged by respondents from the public sector. Those who did not see substantial gain raised questions about WLAN security, the small initial number of users and difficulties in estimation of the gain. Many of the commercial service providers believed that gains could be achieved only in the long run, when there would be a large enough user base and the network would be fully deployed.

All the potential service providers believed that a public WLAN provides a positive image for the city and companies associated with it. Besides image, 71% of interviewees had personal interest in the network. The main reasons were the possibility to work in a more flexible way (multiple places) and to use the network also during free time. Access bandwidth and sufficient coverage was seen to be very important to the acceptance of the network. A very important result from the interviews was that 75% of interviewed parties were willing to support the network and possibly participate in future development. As cross tabulation in Figure 35 illustrates, 70 % of public service providers believe that they get significant benefit from providing services in the local network. Commercial service providers are more cautious than public service providers as many of them thought the benefits would come only later if the number of users in the network would be higher when the network is fully deployed. Those who did not see substantial benefits raised questions about WLAN security, the small initial number of users and difficulties in the estimation of the benefits.

Do You think that your company would benefit from providing services in the local access network? Number of respondents: 24	Yes	No
Public service provider (10)	**70.0%** 7	**30.0%** 3
Commercial service provider (14)	**57.1%** 8	**42.9%** 6

Figure 35. Cross tabulation of public and commercial service providers' views on benefits of providing services in local access network [Van06].

18 out of 24 respondents were willing to participate in providing services to the local access network. They saw the developmental potential of this kind of a network as very high, although the problem at this point was the small selection of available small-sized WLAN capable devices, which currently limits the number of end users.

Commercial service providers were more optimistic about the success of their possible local services than public service providers. Funding is the main problem with public services as it may not be clear who is willing to pay for the services. Nevertheless, travel services, for example, were seen useful.

Potential service providers listed the following services as potentially interesting (in the context of services in a public WLAN):

- Providing Internet connections
- Advertising
- Use as information delivering channel
- "Ad-hoc" network for events
- Logistic services
- Security services
- Reservation services
- Ordering services
- Profile service
- Calendar services
- Feedback channel

Answers indicate that a public WLAN was seen as a way to generate new business and to support current operations. Many answers stated, however, that probably many important future services have not been invented yet. Interviewees expressed the view that development of the network must be continued systemically and legal agreements must be defined. They stated that the network has a good starting point with co-operation with the local city and student housing company, and access to fiber optic networks of multiple organizations as a backbone. As participation criteria, many respondents stated that the network should have a sufficiently broad user base, there should be evidence of the usefulness of the network, and the network should have a well established position in the community. Areas in which service providers wanted improvement were: communications (public relations), marketing, customer service, and general information on technology, usability, error situation and security.

3.9 Discussion

The Lappeenranta Model is an OAN approach that strongly emphasizes locality and local interaction of services and people. With its special features, like the Location Information System, Authentication Confirmation Service and Advertisement System, it allows new kinds of local services to be generated.

There are some issues to be improved in the operation of the Lappeenranta Model. One of them relates to the functionality of the DHCP server. When choosing or changing the Internet operator used, the end user must wait for the device's IP address lease time to expire before the device gets updated with new network settings. This causes a delay (about half a minute) to the network user before the new IP address is allocated. The delay could be prevented by using a DHCP server that can force the devices to change their IP address immediately. RFC 3203 [RFC3203] describes the DHCP reconfigure extension, which has a "FORCERENEW" message that allows instant updating of a client's network addresses. However, this functionality is not yet widely supported and at the time when the Lappeenranta Model was realized, there were no known DHCP servers capable of solving the problem.

Another issue, which also concerns the DHCP, is that users may set the network settings by hand and possibly mislead the system to route their traffic to an incorrect ISP. This issue is described in more detail in [Spá02a] and [Spá02b], who also suggest some solutions to the problem.

As described, the Lappeenranta Model has some special characteristics like free local use and true locality with local services (advertisement system, location informationn system etc.) In section 3.8 surveys and interviews show that both end users and potential service providers see a local access network and local services as beneficial. Despite all the opportunities offered by the new viewpoint it has proven difficult to find a commercial basis that allows all the opportunities to be taken advantage of. [Kiv02a] and [Kiv02b] describe commercial aspects on utilizing the Lappeenranta Model in greater detail.

The surveys of end users and potential service providers show that an open access network and its local services is seen as beneficial. However, few users have been using the local services offered, which can be explained by the small number of useful services locally available and the rarity of portable WLAN capable devices.

4 Comparison and Effects of Open Access Networks

The open access networks described in chapters 2 and 3 each have different architectures and goals. While a direct comparison may not be reasonable, some similarities and differences can still be found.

In closed access networks users do not get a network connection without making a contract with the network operator. Additionally, users typically get only an Internet connection; there is no locality (i.e. direct communication between users inside the access network). On the other hand, in many OANs the user can get a free connection to the access network and use the local network quite freely. Local connection and services, however, are seldom enough for end users: they usually require a connection to the Internet. Local services only supplement the vast service selection of the Internet. Yet, many bandwidth-thirsty services (like IPTV) that require fast network medium cannot always be delivered directly from the Internet over current technologies such as ADSL.

4.1 Comparison of Open Access Networks

Publication 3 compares different network models in terms of structure and the new opportunities they can provide. *Publication 6* takes a business approach and compares different models in terms of enabling sustainable business. Also [Ron03] and [Kar06] study different types of community and regional networks. Table 3 is adapted from *Publication 3* and is extended to cover all network types introduced in this chapter. Please note that as mentioned before, the distinctions between the different network types are small and therefore the table addresses *typical* values of each network type by using the mentioned networks as examples of the type. At the top of the table there are criteria for comparison of these network types.

		Openness	Goals	Typical costs to end users: joining € / monthly €	Number of users / access points	Starting year	Free local services	Network manager	Closed / open / neutral / free network
Closed access networks		Closed	Get revenues, provide Internet	0-50 / 20-50	Varies	Varies	No	ISP	Closed
Community networks	**Open Wireless City Networks**	Open hot spots (WLAN), Internet?	Provide Internet & local links, bypass the ISPs	0-5 / 0	Varies	Varies	Possible	Private people	Open, neutral, free
Community networks	**Regional Networks**	Open access network (FTTH), Internet?	Get networks and services to rural areas	2000 / 0-10	Varies	Varies	Possible	Private people	Open, neutral
Community networks	**Housing Cooperative Networks**	Open access network (FTTH / Ethernet), Internet?	Get fast local network & cheaper Internet connections	200-500 / 5-15	Varies	Varies	Possible	Private people	Neutral?
Municipal Networks	**MastoNet**	Open access network (WLAN), open Internet	Provide an open wireless Internet connection freely for everyone	0 /0	500 / 85	2005	Yes	City	Free
Municipal Networks	**Arabianranta**	Open access and Internet for residents	Provide home automation services and fast access network for residents	0 / 0 (included in apartment price)	3 000 / Fiber, Ethernet	2001	Yes	ISP	Open?, neutral
Open Neutrally Managed Networks	**panOULU**	Open access network, open Internet	Provide an open wireless Internet connection and local services freely for everyone	0 / 0	12 500 / 900	2003	Yes	Neutral operator	Open, neutral?, free
Open Neutrally Managed Networks	**Sainet (Lappeenranta Model)**	Open access network, closed Internet	Provide a open access network with local services and interaction	0 / 0	1 000 / 120	2001	Yes	Neutral operator (& private people)	Open, neutral?, free
Commercial Open Access Networks	**Sparknet & OpenSpark (Stockholm Open.net)**	Open only for members (low joining costs)	Wide wireless access network for people already having an Internet connection	Like closed access networks but broader coverage	N/A / 2 100	2003	Possible	Neutral operator	Neutral
Commercial Open Access Networks	**MälarEnergi Stadsnät**	Open only for members (high joining costs)	Operator neutral high-speed access network with several services	500-2000 / 10-30	32 000 / Fiber	2000	Possible	Neutral operator (network owner)	Neutral

Table 3. Comparison of different network types.

4.1.1 Openness

Openness means whether the network allows occasional visitors in the access network and whether there is an open Internet connection. Closed access networks generally do not let unauthorized users to the access network. Open access networks usually allow occasional visitors to connect to the access network and use it for transferring information.

The Internet connection is a further issue. In closed networks there is one service provider that usually offers just the Internet connection. In open access networks there may be several service providers of which some may provide Internet connectivity. It depends largely on the network type whether there is Internet availability or not. In open wireless city networks, for example, where the access network coverage may be scattered, reaching the Internet is uncertain. If the connection is available, it is rarely free as there is always someone paying at least for the core network used to connect access networks to the Internet. However, as in panOulu, the Internet connection may be sponsored for network users. This raises some potential problems regarding fair competition as it is hard to sell Internet connections if someone else is offering free connectivity (financed by some other means, like public funding or taxes).

In conclusion it could be said that except in closed access networks, a connection to the access network is usually allowed. In open access networks, the access network may be used for local information transferring or reaching local services. The price and availability of an Internet connection depends greatly on the network type.

4.1.2 Goals

In a closed access network the goals are self-evident: to provide a service for as many paying customers as possible. In closed networking competition is market based and some companies may attain a monopolistic position. Although different types of OANs may have some differences in their goals, in general OANs try to provide a better service level by removing monopolies and unfair competition.

Another motivation might be faster local connections (especially in fiber networks). In regional networks a motivation is also the fact that this type of networking may be the only way to get broadband Internet connections to the region.

4.1.3 Typical Costs to End Users

Costs to end users include both joining and running costs. Joining costs mean how expensive it is for an end user to get connected to the network. Running costs mean the monthly charges for the connection. The numbers in the table are estimations of normal costs to a single end user, which are in many cases highly dependent on the case (distance to the closest point of presence of the operator, number of customers in an apartment, level of self-help etc.) The numbers in the table should, therefore, be considered suggestive rather than exact.

In closed access networks, joining costs are low (usually free) and monthly costs start from about 20 euros per month. In OANs, joining the access network is usually free (excluding commercial OANs). In many cases, however, the user has to connect to the access network and that may prove to be expensive, especially in regional networks in rural areas where making the connection may require laying kilometers of fiber underground (and additionally buying active network appliances like media converters and network switches).

The monthly costs in OANs depend on the services to which the user subscribes. The point here is that compared to closed access networks, competition between service providers is tougher and therefore the prices of services are lower. However, some service providers (usually telcos) currently resist the development towards OANs by pricing their services more expensively in an OAN thereby trying to get customers to choose their closed access network.

4.1.4 Free Local Services

Free local services means whether there are free local services in the access network. Local means that these services must be usable without requiring an Internet connection. Of course, it is possible to provide local services in any type of network and there usually are at least some types of local services in any network. However, these local services are usually login pages, connection statistics etc. that are required for network operation but offer limited value to the end user. In Table 3 local services are considered to be services that provide additional value to users. These services may be direct local communications, positioning, IPTV, virtual VCR etc. In an OAN this usually means open service provision, i.e. anyone (or service providers chosen by the access network operator) can provide services in the access network.

4.1.5 Network Manager

In closed access networks, the network operator is usually the network builder who also owns the network and is usually the only service provider in the network. As there are several options for building open access networks, there are also several options for managing them. *Publication 6* describes operational issues in different real-life network environments. Common to all open access networks is that the network operator must be neutral in order to ensure fair competition. In community networks it is typical that private people take care of the network functionality. This leads to exceptionally low operating costs but also reduces the overall network reliability.

In other types of OANs there is usually a neutral network operator. It may be the network builder or owner but it may also be a company or an organization that is hired to keep the network operational. In order to keep the access network running costs as low as possible, the neutral network operator is in many cases a non-profit organization. The neutral network operator can get income to cover managing expenses, for example, from service providers, end users, advertising etc. A neutral network manager has several important tasks, such as

- ensuring that everyone gets equal opportunities in the network,
- organizing a help desk for access network users,
- being a partner and adviser for service providers and companies that participate in the network operation,
- extending the network coverage area and/or being a supportive player to promote network extension,
- marketing and spreading information on the network,
- developing and improving network functionality and regulating the workings of the network (both technologically and economically),
- making agreements with participants (at least with service providers and network extenders),
- investing in the network, and
- bringing continuity and reliability to the open access network.

In order to ensure fair competition, the access network operator should be a neutral actor that has no interest in competing with other service providers in the network. In many cases an energy company has taken the role of neutral network operator. There are also other examples, like the @450 network [Dig07] currently being built in Finland by Digita, where Digita is the neutral network operator and sells network capacity to service providers under equal terms. There are some interesting viewpoints in [Bat05] and [Kor02], describing how, for example, house owners could own the network. As suggested in *Publication 6*,some parts of the network management could be given to active network users.

4.1.6 Closed, Open, Neutral, and Free Network Approaches

Closed network means that joining the network is limited. Open and neutral networks have been defined by Battiti et al. in [Bat03]. *Open network* means that the end user must be free to select any service provider, any service provider must be free to offer services, and any interested party should be free to extend the network. *Neutral network* means a fair playing field for competition: all service providers get transport services under equal terms (not necessarily freely) and the network owner does not compete with other service providers. *Free network* means that joining the network, transferring information and providing services locally is free.

There is some variation in openness, neutrality and freedom in community networks. Open wireless city networks are open, neutral and free since they provide a free connection to everyone and do not limit use of the local access network. None of the other open access networks studied in this thesis fulfill all four requirements. Regional networks, for example, are open and neutral but they are seldom free as joining requires that the user lives in the area and connects physically to the network (causing costs). Additionally, regional networks usually have some fixed monthly fee to cover expenses arising from network upkeep Housing cooperative networks are usually not open in the sense that the service provider(s) are usually chosen by housing corporation decision, so individual users cannot choose the service provider freely. Whether these networks are neutral or not depends on the approach adopted by the cooperative.

There are also differences between municipal networks. Some of them (like MastoNet) are free but not open or neutral, as there are only certain pre-defined services for end users. Others, like the Arabianranta network, are not free as only residents in the area can join. The network is open in the sense that the residents can choose any service but not open in the sense that the offered services are chosen by a service company (Arabian Service Ltd.) representing the residents. The service company allows neutrality as it can offer equal terms to all service providers chosen.

Open neutrally managed networks, like panOULU and Sainet (The Lappeenranta Model) are open as end users can choose any service provider and all service providers can provide services under equal terms in local network. These networks do not fulfill the requirements of neutrality in the sense that the network provider acts also as a service provider. Both panOULU and Sainet are free; anyone can join and use the access network with no charge.

Commercial OANs are not open or free as they require users to be a member of the community (which is not free). They are neutral as they provide equal terms for service providers and the network owner does not provide services for end users.

4.2 Effects of Open Access Networking

Changing a network from closed to open access requires changes to the network structure, administration, authentication, billing, responsibilities and security. These issues will be discussed in this section and further discussion can be found, for example, in [Kor02], [Kur02a], [Kur02b], [Pet02] and [Sep03].

4.2.1 Effects on the Players

In a closed access approach the access network is operated by the network owner. Usually, the only service offered is an Internet connection. On the other hand, it must be remembered that an Internet connection allows all the services in the Internet to be accessed, which is usually exactly what end users want.

Publication 2 and *Publication 6* have analyzed the communications market from the point of view of three actors: service providers, network users and network operators. End users are the consumers to whom service providers and operators want to offer new and tempting services. In many cases, open access gives end users opportunities in the form of a better service level and lower usage fees. This is because dismantling the vertical integration in service provisioning allows fair competition between different service providers. Especially small (and perhaps local) service providers get improved opportunities to compete with their large rivals, who in traditional networking have in many cases achieved a monopoly position.

The difference between service providers and operators is that operators can be seen as enablers for the service providers, i.e. operators provide the medium through which service providers reach the end users. There are also regulators and policy makers that define the rules for the markets.

The openness of networking also has an influence in local city areas and surrounding districts. Openness and the local nature of the network brings people together as they share the same access network and can use it to help each other.

4.2.2 New Service Concepts

Provisioning of services in open access networks is discussed in all publications attached to this thesis. As described in chapter 3.4 and in *Publication 5*, today's services are mostly global. Providing services directly in the access network allows new kinds of opportunities that are linked especially to bandwidth-thirsty services like TV or video services.

As [Ala03] describes, locality allows the provision of new service concepts. The most interesting ones, technically and economically, are services that are difficult (or too expensive) to provide from the Internet through modern broadband connections. These services (like IPTV, Video-on-Demand, virtual VCR, etc.) usually require high-capacity network connections. It may also be advantageous to transfer some local information (security services, measurement data etc.) directly in the local network without the need for Internet connections. The network operator could perhaps generate income from providing the service providers with additional value services (like advertisements to the network users, location information etc).

4.2.3 Business Logic

As Christensen describes in [Chr97], it is typical that larger companies work with existing and already-proven technologies and try to make their use more effective. Disruptive is a term that describes a new technology that unexpectedly displaces an established technology. Disruptive technologies may experience various problems (for example, performance, reliability and interoperability) as a result of their new and novel nature. These technologies may require changes in organization structure or way of operating. Consequently, smaller companies that can adapt quickly can use disruptive technologies to compete effectively against large companies that seek to get revenues from already deployed technology. Today, OANs test the ability of incumbent operators to adapt to new access methods and threaten established business models.. Therefore, it is not surprising that many large operators currently oppose OAN development while smaller operators try to use open access to find new ways of generating business.

Publication 6 deals also with other aspects of challenges to the business logic of OANs. In order for OANs to generate sustainable business, it is important that the networking model provides new business opportunities for the players. End users get better and more affordable services, service providers get a broader customer base, and the need for a neutral network operator creates a new niche for operator organizations or a new source of income for existing companies. If there is no distinct, neutral operator in the OAN, generating business may be complicated. This is mostly because the owner and manager status is more unclear, i.e. the network is being run either by voluntary work or there are several network operators each taking care of a small part of the access network.

4.2.4 Information Society Development

As Castells describes in [Cas00] and [Cas02], the world is shifting from old national industrial economics to new global informational and networked economics. The development has been spearheaded by information technology companies. The development of an information society is very strong in Finland and takes into account the current societal starting point: the need to provide the same services for both rich and poor. This is ensured with Finnish Government Information Society Program [Inf07] which aims is "to improve competitiveness and productivity, to promote social and regional equality and to improve citizens' well-being and quality of life through effective use of information and communications technologies."

Publication 5 describes the broader development of information society in the European Union and evaluates the suitability of different networking architectures within the context of this development. The EU has introduced an ambitious program called eEurope [EU07b], which has the aim of making the EU the most competitive knowledge-based society in the world by 2010. A follow up program also exists, called i2010 [EU07c], which focuses on bringing together ISPs and content industry.

Every networking option has its benefits and drawbacks but open access may have an important role in the context of information society development. This is because open access allows unbiased distribution of information society services to everyone. In other words, open access dismantles vertical integration in network and content provisioning, i.e., it allows true competition in these areas.

Regardless of the techniques used, service provisioning is becoming ubiquitous in nature, i.e., users expect the services to be present anywhere and anytime. [Taf06] presents some interesting visions for the future of communications, including, for example, a concentration on personal information and new innovative services that help users to find relevant information in always available networks.

4.3 Discussion

As described earlier, community networks are typically used for connecting private citizens together and to some external networks. Community networks offer an interesting and affordable way for people to try and study especially wireless networking technologies and share thoughts with others. Community networks may also be used to share costs when connecting the community to external networks, usually the Internet.

Municipal networks that are provided by some public authority can promote networking in certain areas and even provide citizens with a free Internet connection. Using public funding for providing services that are also sold by ISPs raises some problems related to fair competition. However it is good to remember that the coverage area of municipal networks is usually limited to public places, like libraries, town hall etc.

Open neutrally managed networks and commercial OANs differ from other types of OANs. The biggest difference is in the management, which is more carefully coordinated than in other types of OANS. Open neutrally managed networks and commercial OANs are, however, not suitable for all environments as they need a (usually larger) organization to build, promote and manage the access network.

In general, every open network solution described in this thesis has its benefits and drawbacks and each solution is best suited to different environments. Thus, the purpose of use decides which of networking model (or a combination of them) should be chosen.

The role of traditional ISPs is currently at a turning point. Different open access solutions are slowly changing the markets in access network provisioning and breaking the ISPs control over the market. The development will be beneficial especially to end users who will get better service at lower access fees. The development will additionally generate new business activities and boost overall development towards a true information society.

Although different kinds of city networks and regional networks are popular, it seems that neutrally managed open access networks and commercial OANs will get the biggest slice of business. From the viewpoint of service providers this type of open access has the advantage of allowing them to make business contracts directly with other companies. This simplifies contractual issues compared with, for example, regional networks and guarantees a clearer division of responsibilities.

From the point of view of end users the development is welcome. Open access networks will ensure improvements in network bandwidth, service level and price. Open access networks that offer pure open access, connectivity and local services would offer the most benefits to end users but several issues remain to be studied and improved. The freedom that these solutions give to the end users results in more complicated network management and contract issues which makes generating sustainable business a great challenge.

As described in section 4.2.4 there is currently a powerful trend towards an information society. The reluctance of big telcos to change towards open access and their considerable lobbying power has influenced EU level goals, resulting in slow development in terms of opening up competition in access networks.

In Finland the parliament is driving the country towards an information society. The propagation of broadband connections to end customers has been actively promoted and as a result the number of Finnish broadband users has already reached over 1,7 million subscribers in a population of five million [Lii08b]. This has been supported mainly by subsidizing building of ADSL networks to sparsely populated areas. As [Ete07] describes, for example in the Etelä-Karjala region all 96 telephone centers were upgraded during 2004 to allow for the provision of ADSL connections. Public funding of over 1 million euros was given to TeliaSonera Finland so that the company could upgrade 84 telephone centers which would otherwise been unprofitable to upgrade due to low population density and long distances. The problem was that the public funding went to a big telco to extend its closed network and competition on the access network remained restricted. Public funding has not reached private open access networking projects.

Broadband technologies used for connecting end users to operators are constantly developing towards faster and better coverage. Prices are coming down and services are developing. These factors may in future reduce interest in open access networking. However this is only one part of the truth as developments are leading towards more open networking - whether the final solution will be OAN or not.

The trend towards open networking is already present in modern communications and shows, for example, in the change from centered provision of information towards decentralized ways of communication. The huge popularity of the Internet and peer-to-peer (P2P) networking represent this change and this type of networking will most probably increase in the future since it makes the dissemination of information more effective. Peer-to-peer networks also help to concentrate information to those that are really interested in it.

5 Conclusion

Current developments are leading towards open access since open access networks enable a cost effective way of sharing network access and promoting Information Society services. Governments all over the world are driving citizens towards an Information Society but the technological means are not specified. The means vary in different countries and on different continents but the Information Society goal in the long run is the same: unlimited access to information and an ability to use it for every citizen. The biggest question is how this can be achieved?

The goal of this thesis is to investigate the current development towards more open networking and to propose a new approach for building open access networks, the Lappeenranta Model. The approach emphasizes locality and local interaction between people and allows the building of open access networks with local services. Using surveys of end users and service providers this thesis shows that local interaction and local services are seen as beneficial.

In addition to the Lappeenranta Model, there are several other options for building an open access network, each with its own benefits and drawbacks. These options are discussed in this thesis and the differences are evaluated. The effect of open access networking is estimated.

The author believes that in the future network provision will, in many cases, be based on open access. This means that

- the access network will be usable by any service provider under equal terms resulting in true and fair competition,
- end users can join any access network and choose any service from any service provider, and
- several overlapping networks will no longer be required for different needs – home automation, distant control of equipment (heating, electricity, lights, traffic lights etc.), entertainment, business etc.

The world has changed quite a lot since the first wireless community networks were built in the late 1990’s and a great deal has been learned from the community viewpoint. As open access networking is gradually developing towards a sustainable business good use can be made of the enthusiasm common in community networks and communal development can be promoted that ties people together in local areas.

As a conclusion, it can be seen that open access networking is increasing in the developed world. People will get new options for connecting themselves to different types of local networks and through them to the Internet. The role of information is increasing and in the future it will be important to know how to find and use relevant information. This kind of development may further increase inequality between people worldwide as many less developed parts of the world have no networking infrastructure – millions of people still have never made an ordinary telephone call.

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