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IT Improvement Project in a Research Organization

Master's Thesis

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Aalto University School of Science and Technology Faculty of Information and Natural Sciences Degree programme of Computer Science and Engineering		ABSTRACT OF THE MASTER'S THESIS	
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<p>Abstract:</p> <p>An IT-environment of an organization is a critical element for the productivity of the employees, especially in research work which is very dependent on IT-infrastructure.</p> <p>This Master's Thesis presents an IT improvement project that was carried out at the Department of Biomedical Engineering and Computational Science (BECS) at Aalto University School of Science and Technology. The project was carried out using Action Research -methodology, that combines the goals of conducting scientific research and improving subjects in a practical situation.</p> <p>The improvement areas were investigated using a survey and user interviews. Several development areas were identified and improvement actions to solve the problems were prioritized according to the user needs.</p> <p>Major improvements implemented during the project include an IT service portfolio for managing the IT services, upgrading the Linux-workstations and renewing the structure of the network. Upgrading the Linux-workstations also included selecting a suitable Linux distribution and a tool for centralized configuration management. Other improvement actions include migrating the email service to a centralized system and improving printer and scanner reliability.</p> <p>The results of the actions were evaluated in a follow-up survey, which showed statistically significant increases in user satisfaction for Linux-workstations, email services and response times for IT-support. The validity of the research is analyzed according to both statistical and Action Research criteria. Also the transferability of the results to other similar situations is discussed.</p>			
Keywords: Action research, IT-support, IT services, service assessment, user support, SERVQUAL, ITIL			

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<p>Tiivistelmä:</p> <p>Organisaatioiden käyttämä informaatioteknologia (IT) on työntekijöiden tuottavuuden kannalta kriittinen tekijä erityisesti tutkimustyössä, joka on hyvin riippuvainen IT-infrastruktuurin toimivuudesta.</p> <p>Tämä diplomityö kuvaa IT-kehitysprojektin, joka toteutettiin Lääketieteellisen tekniikan ja laskennallisen tieteen laitoksella Aalto-yliopiston teknillisessä korkeakoulussa. Tutkimuksessa käytettiin toimintatutkimus-menetelmää, joka yhdistää tutkimuksen ja organisaation kehityksen käytännön ongelmatilanteessa.</p> <p>Tutkimuksen alussa IT-ympäristön ongelma-alueet kartoitettiin kyselyllä ja käyttäjähaastatteluilla. Organisaatiossa ilmeni useita kehitysalueita, ja toteutettavat parannustoimenpiteet priorisoitiin käyttäjien tarpeiden perusteella. Tutkimuksen laajuuden rajaamiseksi vain tärkeimmät parannustoimenpiteet valittiin toteutettavaksi tässä tutkimuksessa.</p> <p>Tärkeimmät toteutetut toimenpiteet tutkimuksen aikana olivat IT-palveluportfolion luominen, Linux-työasemien päivittäminen ja lähiverkon rakenteen uudistaminen. Linux-työasemien päivittämiseen kuului sopivan Linux-jakelun sekä konfiguraation-hallintatyökalun valitseminen. Muita toteutettuja toimenpiteitä olivat sähköpostipalvelun siirtäminen yliopiston keskitetylle IT-organisaatiolle sekä tulostimien ja skannereiden luotettavuuden parantaminen.</p> <p>Toimenpiteiden vaikutusta arvioitiin toisessa kyselyssä, joka osoitti käyttäjien tyytyväisyyden parantuneen tilastollisesti merkittävästi Linux-työasemien, sähköpostipalveluiden ja IT-tuen vasteaikojen osalta. Tutkimuksen luotettavuutta arvioitiin sekä tilastollisen päättelyn että toimintatutkimuksen kriteereiden perusteella. Työssä pohditaan myös tulosten siirrettävyyttä muihin samankaltaisiin lähtötilanteisiin.</p>			
Asiasanat: toimintatutkimus, IT-tuki, IT-palvelut, palvelun laadun arviointi, käyttäjätuki, SERVQUAL, ITIL			

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1 Introduction

The role of Information Technology (IT) in Universities and other research organizations is constantly getting more important. Especially in the area of computational science, the availability of adequate IT environment is an essential prerequisite for conducting the research organization's core tasks. IT also plays a significant role in the organization's administration.

This thesis describes an IT improvement project in Department of Biomedical Engineering and Computational Science (BECS) at Aalto University School of Science and Technology. The Department has traditionally maintained a very independent IT environment by having only minimal dependencies to systems not under the Department's control. The Department has provided both Windows and Linux workstations for the users. The Linux workstations have been implemented using Mandriva Linux-distribution and numerous servers provided file sharing and authentication services for the workstations. Many servers have previously been based on Compaq Alpha architecture, but servers acquired later are based on PC architecture and they are running Linux or a BSD-family operating system.

The goal of this work was to improve the satisfaction of the users by analyzing the users' opinions and challenges they are facing in the IT environment and to implement changes in the IT systems to improve the situation. The research was carried out using Action Research methodology, which combines the goals of solving practical problems and conducting scientific research. This methodology is well suited for information systems research, because it allows the researcher to act as an active agent in improving the situation and the subjective opinions users of the information systems can be used to measure the success of the improvements.

Before the research project was initiated, it was already known that there was some level of dissatisfaction among the users towards the Department's IT services. The Linux workstations had been criticized, but the exact problems and their root causes were unknown. To properly assess the users' satisfaction to current IT systems of the Department and to identify the problems, a survey was conducted among the Department's IT system users. The survey was supplemented with interviews with the users. Based on this assessment an improvement action was designed and carried out. The performed actions included initiating a service portfolio management process for controlling the array of IT services that are provided, renewing the network structure and upgrading the Linux distribution that is used on the Department's Linux workstations.

After the improvement actions were performed, a new survey was conducted to assess if the users' opinions about the IT services had changed.

The structure of the rest of this Thesis is the following: The background and the current state of information systems in the organization are presented in chapter 2. The research methodology is described in chapter 3. And in chapter 5, the design of the survey and the results of the assessment are presented.

Chapter 6 explains in detail the analysis of the problem areas and explains the design decisions that were made when implementing the improvements. Chapter 7 describes the result of the second survey that was used to measure the changes in the users' satisfaction. In chapter 8, the results are discussed in more depth. Chapter 9 presents the conclusions of the research and presents ideas for further research.

2 Background

The Department of Biomedical Engineering and Computational Science (BECS) is a part of Aalto University School of Science and Technology. The Department has been selected as a Centre of Excellence in Complex Systems Research by the Academy of Finland. The Department was created when the university's organization was restructured in 2008, combining the former Laboratory of Biomedical Engineering (BME) and the Laboratory of Computational Science (LCE). The Department currently employs approximately 100 people.

The former two laboratories were located in different buildings in the campus and they have also had separate IT systems and system administrators. The whole Department moved to new premises in the campus during October 2009. The plan is that at some point all employees of the Department will share the same IT systems. The two existing environments are not merged, but instead the staff will switch to using new services as they are upgraded.

This organizational change was one reason why the IT systems needed to be reviewed and improved. The IT systems used by the former BME were very minimalistic and they will be taken down when the system migration progresses. This study focuses on the IT systems of the former LCE unit, since most services of LCE will be utilized by the new Department. The LCE systems will be addressed simply as Department's systems in this work.

2.1 Current status of IT systems

The infrastructure consisted of an email server, a web-server, three DNS servers plus a dozen additional servers for miscellaneous purposes.

A general server, called Zeus, was acting as a main server. It shared storage capacity to the clients using NFS, acted as a NIS-server and an SSH-server for logging in from outside networks. The main server was under a transition. An old main server, which was a Compaq Alpha server, was being phased out, and a new main server was being phased in. The new server had two external storage arrays connected via SAS, providing total of 22.5 TB of raw disk capacity for the server. Also an automatic LTO-4 tape library with 48 slots was connected to the server for taking backups. Some of the services had already been migrated to the new server. Most of the data had been migrated to the new server and clients were accessing the data from there. A backup was automatically taken to the tape library every night. A NIS server was also running on the new server, but the workstations were still using the old NIS server. During the NIS server migration all changes had to be manually done to both servers. The old main server was also running a Common Unix Printing System (CUPS) server that shared printers for Linux workstations.

The email server was running Postfix mail server software and the web server was running Apache web server software. Both of these servers were running Red Hat Enterprise Linux on up-to-date server hardware with an active service contract.

The Windows server system was operated on four servers. Three of them were domain controllers and one was acting as a terminal server. The domain servers provided

authentication and group policy settings for the Windows workstations. The Windows servers also provided DHCP, DNS and file sharing services for the Windows workstations. The workstation group policies contained directives to install commonly used software packages on all workstations. The Windows server hardware was 3-8 years old, and there were no support contracts on them.

The network routing was based on three servers that were running BSD-family operating systems. The hardware of the main router (*lce-gw*) server was approximately 8 years old clone PC that had been fitted in to a rack-mountable chassis. The other two servers (*ras-gw* and *cls-gw*) were PC server hardware but they either did not have active support contracts. The router configuration is described in more detail in chapter 6.3.1.

The DNS system was distributed into several servers. The main zones in use were *lce.hut.fi* and *becs.hut.fi*. Most of the authoritative DNS zones were stored on a server *circe*. That server was a shadow master which meant that only the secondary servers could query data, the clients could not directly query it. Four other servers had been configured as secondary servers that the clients could send their queries to. The Windows zone *winlce.lce.hut.fi* was delegated to the Windows servers. The Windows server made dynamic updates to *circe* in order to upgrade the reverse DNS pointers of the Windows hosts. The zone *cls.lce.hut.fi* that was used by a cluster computing project was delegated to the server *cls-gw* that operated as a router to the cluster network.

The Department had numerous printers located around the premises. Some of the printers were located in corridors or designated printing areas and were available to all users. Some printers were located in office rooms and were in personal use. The printer hardware base was very heterogeneous. Some of the printers were over five years old and had problems with insufficient memory or an outdated PostScript interpreter. The Department had approximately 20 printers and almost all of them were different models.

The extent of documentation of the IT environment varied. The main method for documenting changes, receiving requests and communicating with users was an email list for the administrators. The messages posted to the list were archived. An internal website also contained information about the IT systems and instructions for users, but the information was mostly out of date. The email list archive proved to be a valuable resource for finding information about specific issues, but general level information such as a list of servers, network diagrams or a list of offered services did not exist.

2.2 System administrators

The IT infrastructure and services of the former Laboratory of Computational Engineering have been administrated by two full-time administrators. The two administrators had divided their work so that the other person provided support mainly for Linux systems and the other person mainly for Windows systems. The two administrators quit their jobs during spring 2009.

At that point, the author of this thesis became responsible for maintaining all the systems. To help with the tasks, an undergraduate student was hired to assist with the tasks during summer of 2009. A new full-time administrator was hired and he started his work in September 2009.

Through these events, the entire system administrator staff was rotated during the year 2009. This formed a challenge with transferring information, but also provided a possibility to renew the staff roles and IT-related processes. This point of change was well suited for performing an IT improvement project.

3 Methodology

This chapter defines the methodology that is used in conducting the study.

3.1 Action Research methodology

3.1.1 Description of Action Research

The traditional research method in natural sciences works by forming hypotheses and testing their validity in experiments to form results that are general, i.e., not dependent on time and place, and can be thus verified by other researchers (Checkland & Holwell, 2007). This method is based on three fundamental principles: reductionism, repeatability and refutation. This method, although very efficient, is not well suited for social-scientists, because the phenomena can rarely be reduced and the findings cannot be repeated as the phenomena are not independent of time and place. Action Research methodology emerged from these problems.

The origins of action research have been traced back to the social experiments of Kurt Lewin in the 1940s (Reason & Bradbury, 2006). The experiments began at Tavistock Institute and were applied to practices of social democracy and organizational change.

Toward the end of the 1990s Action Research began growing in popularity in information systems research. It produces highly relevant results because it is grounded in practical action, aimed at solving an immediate problem situation (Baskerville, 1999).

Baskerville (1999) defines the essence of action research as a two-stage process:

1. **Diagnostic stage** that involves a collaborative analysis of the social situation. Theories concerning the nature of the research domain are formulated.
2. **Therapeutic stage** that involves collaborative change experiments. Changes are introduced and the effects are studied.

Figure 1 depicts the process cycle of action research.

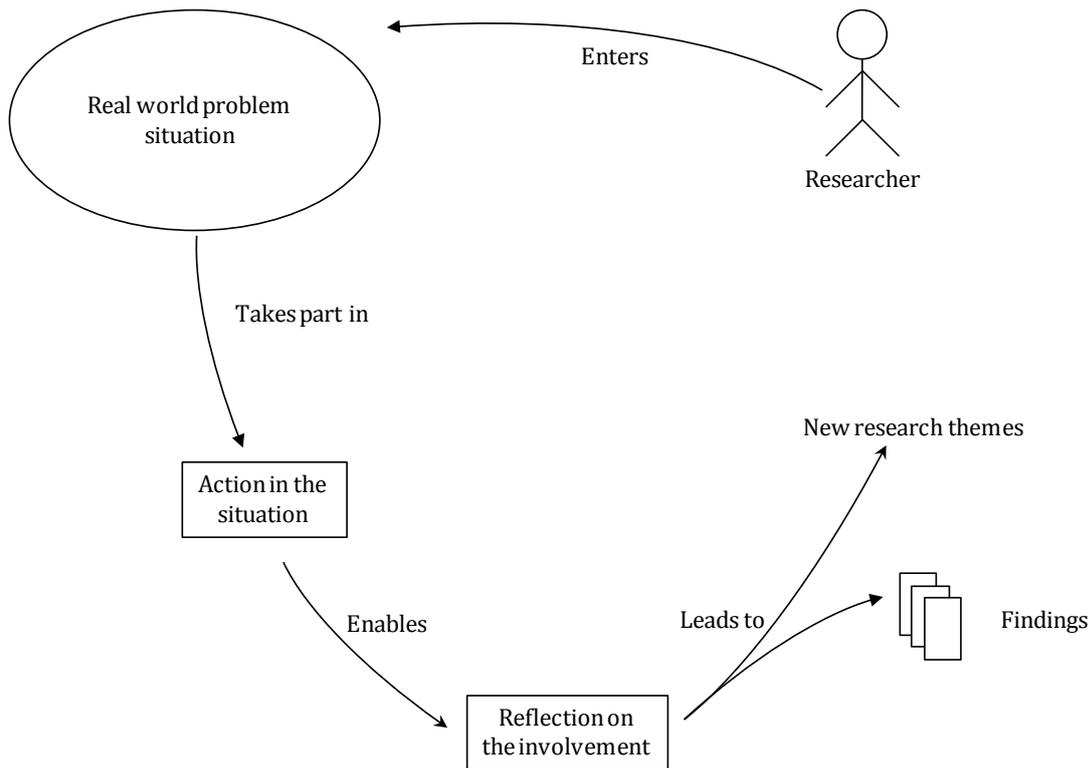


Figure 1. Action Research cycle, adapted from Checkland & Holwell (2007: 9)

In a traditional positivist research the researcher has a set of research hypotheses that can be refuted or confirmed during the research. In action research, the researcher does not form hypotheses prior to the research. The researcher only has a research theme within which the research activity happens.

The action researcher should first engage with the relevant literature and develop a clear picture of the state of the knowledge in this area (McKay & Marshall, 2007: 141). The researcher also has to define the methodology for how the knowledge will be applied to the problem area and for how new knowledge is created.

After declaring the existing knowledge and the methodology, the researcher enters a real-world situation in which the themes are relevant, and the researcher becomes involved both as a participant and a researcher (Checkland & Holwell, 2007). The action researcher implements changes aiming at improvement, which is judged by people in the situation. The action researcher must also commit to reflect the collaborative involvement and its outcomes.

McKay and Marshall (2007) argue that action research is best understood through as being comprised of two interconnected cycles of interest: a problem solving interest and a research interest. In the problem solving interest researches and participants collaborate, improve and change a situation of concern, and in doing so, hopefully learn about the problem and the problem solving process. In the research interest, the researches need to produce rigorous and relevant research to advance their understanding and knowledge of their discipline. Action research, if well planned and executed, leads to a win-win scenario for both organizational practitioners and researchers. Action research also leads to increased knowledge and skills for both practitioners and researchers.

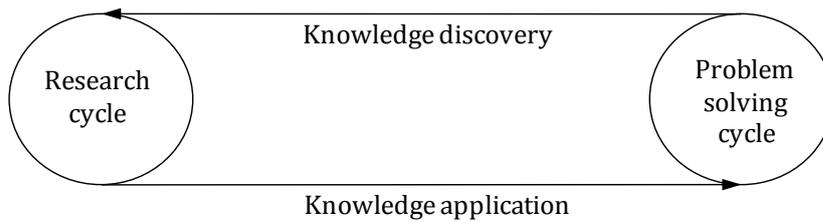


Figure 2. Problem-solving and research cycles in Active Research (Chiasson et al., 2008).

3.1.2 Validity

The action research process cannot produce law-like generalizations from involvement in a single situation (Checkland & Holwell, 2007). However, action research can lead to results that can be generalized and transferred to other situations as well.

Nielsen (2007) presents six criteria for designing, performing and evaluating action research. The criteria are:

1. Roles. Clarifying the roles in the research helps to establish the neutrality of the researcher.
2. Documentation. Explaining the data collection approach in detail distinguishes research from consulting. It is also an important prerequisite for establishing recoverability.
3. Control. The control over the research situation must be addressed. There are three control structures that the researcher should be aware of and report: control over the initiation of the research, determination of authority and degree of formalization in the contracts between the researcher and the organization.
4. Usefulness. Establishing useful findings in the problem situation creates a baseline for transferring the results to other similar situations. It is perhaps the most important criterion.
5. Frameworks. Relating results to an existing framework supports the impartiality of the research. It is a key discipline in all research that distinguishes it from consulting.
6. Transferability. The conditions for transferring the findings to other similar situations should be explicitly stated. It addresses the situation-dependency of action research and reveals the limitations that apply to generalizing the findings.

3.2 Data collection

This chapter describes the data collection methods used in the research.

3.2.1 Surveys

A survey is a systematic method for gathering information from a group of entities (Groves et al., 2009). The description “systematic” distinguishes surveys from other ways of gathering information. A survey can be instructed for a whole group of entities of interest, or just for a sample, in which case the aim is to generalize the results from the sample to the whole group.

Survey methodology is the study of sources error of error in surveys and how to make the data produced by surveys as accurate as possible. An important consideration of survey

methodology is to discuss under which conditions the results based on a sample can be generalized to the entire group.

Surveys can utilize a variety of methods of collecting information about the respondents. Perhaps the most common method is the use of a *questionnaire*, which is a standardized set of questions administered to the respondents, which are typically administered in a fixed order and often with fixed answer options (Groves et al., 2009). Interviewers can administer a questionnaire to the respondents or the respondents can complete the questionnaire themselves.

When designing questionnaires, special care must be taken to format the questions and the answers so that the questionnaire is not misleading, unclear and does not suggest the respondents to answer in a certain way. Methodological problems in a survey can cause *biases*, that mean that the results of the survey do not reflect the true state of the investigated phenomena.

Usually not all respondents that are included in a survey sample complete the survey. One special type of bias is *non-response bias*, which means that those who respond to the survey differ in some significant dimension from those who do not respond. Non-response bias can be mitigated with actions that lead to increased response rate. Groves et al. (2009) suggest several methods for increasing the response rate, e.g., offering incentives for the respondents, sending persuasion letters to persons who initially refused to answer and reducing the burden (survey length and the cognitive burden) for the participants.

3.2.2 Interviews

Myers (2008) presents three different types of interviews:

1. Structured interviews, where the questions and their order are pre-formulated.
2. Semi-structured interviews, that have some pre-formulated questions but they do not have to be adhered. The interview can take new directions based on the interviewees' responses.
3. Unstructured interviews, that have very few or none pre-formulated questions, and interviewees are free to say what they want.

Structured interviews provide consistency across interviews. The role of the interviewer is minimized because there is no need for improvisation. However, structured interviews take considerable time to prepare.

In unstructured interviews, the interviewee can talk freely about the topic of the interview. The advantage of unstructured interviews is that the interview is not limited to pre-defined questions, the interviewee is free to talk about issues that he or she considers important.

The semi-structured interviews have some pre-formulated questions, but the interviewer is allowed to improvise new questions based on the interviewee's responses.

3.2.3 Observation

Myers (2008: 138) defines *observation* as watching people from an outer perspective without taking part in the action, and *participant observation* as talking and interacting with the people, trying to gain understanding of their beliefs and activities.

3.3 Study design

The structure of the research process of this study is illustrated in Figure 3.

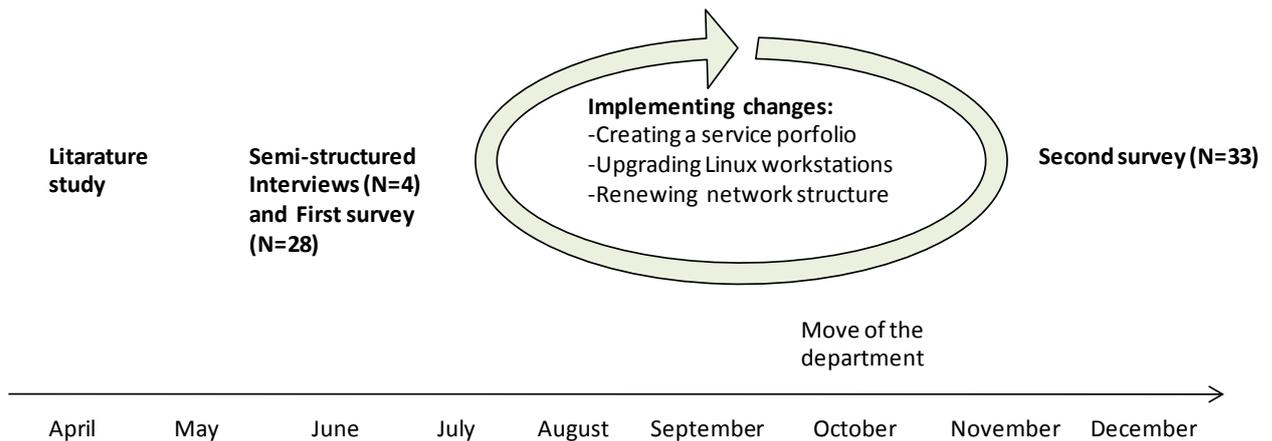


Figure 3. Structure of this study.

The study was initiated with a literature study of the relevant literature for the research theme. During this phase, the researcher also familiarized himself with the status of the IT systems and observed how user support functioned in the Department.

Observation was continuously performed as I provided IT related help for the Department's employees, solving practical problems that they faced in their work. This was a good opportunity to gain insight into the practical problems and challenges that people face in their daily work.

Semi-structured interviews were selected as the interviewing type for this study, because initially I might not be aware of all the existing issues in the problem domain of the target organization and thus it is important that interviewees can freely bring their own views to the discussion. On the other hand, completely unstructured interviews are not an appropriate method because there is a need for some direction to keep the interview relevant for the study.

Four people were interviewed in June 2009. Based on the interviews I was able to form a list of services to be studied, and identified certain problem areas related to those services. A questionnaire was designed to assess the quality of the services. The questionnaire was based on the IT SERVQUAL instrument (see chapter 4.1.5).

In June 2009 a first survey was performed to systematically assess the user opinion of the different areas of the IT services. The status of the IT services based on the interviews and the survey is presented in chapter 5.

After analyzing the current state of the systems and the identified problems, the actions to be taken were designed. Implementation of the changes begun in July and continued until the end of November. An important event that happened during this period was the move of the Department to the new premises in October. The move temporarily suspended the improvement actions and IT support resources had to be used to set up the IT infrastructure in the new premises. The implemented actions are described in detail in chapter 6 of this study.

The changes of user opinions were assessed in a second survey that was conducted in December 2009. After the second survey changes in opinions were analyzed. The results of the second survey are presented in chapter 7.

4 Literature review

4.1 IT Management frameworks

4.1.1 ITIL

Information Technology Infrastructure Library (ITIL) is developed by United Kingdom's Office of the Government Commerce (OGC). The latest released version of the ITIL collection is version 3 which was published in May 2007.

The core of ITIL is a collection of five books (OGC, 2007):

- Service Strategy
- Service Design
- Service Transition
- Service Operation
- Continual Service Improvement

The ITIL Service Management Model consists of elements. The description also emphasizes that all of the elements do not fit the typical characteristics of a process. ITIL gives guidance to various areas of IT management and operation, but in this thesis the particularly interesting area is ITIL guidance for managing the service strategy. The key concepts of service management and process for managing service portfolio are described in the rest of this chapter.

In ITIL-terminology, there are different types of IT service providers (OGC, 2008). The service provider can be embedded in an organizational unit (type 1), or it can be an internal service provider offering shared services to multiple organizational units (type 2) or it can be an external service provider (type 3). In ITIL-terminology, *customer* refers to the users of the IT services.

Service Portfolio represents all commitments and investments made by a service provider. It represents present commitments, new service development and ongoing service improvement programs.

Service Catalogue is the subset of the Service Portfolio that is visible to customers. It consists of services presently active in Service Operation phase. It is an expression of the service provider's operation capabilities. The Service Catalogue serves as a service order and demand channeling mechanism. It is an "acquisition portal" for customers, defining objective of each service as well as pricing and service level commitments.

Service Pipeline consists of services that are under development. After design, development and testing, the services are phased into operation with ITIL Service Transition processes.

Retired Services have been phased out of operation. They are not available to new customers unless special arrangements are made. The services that need to be withdrawn are phased out of use with Service Transition phase. This ensures that all commitments made to customers and duly fulfilled and service assets are released from contracts.

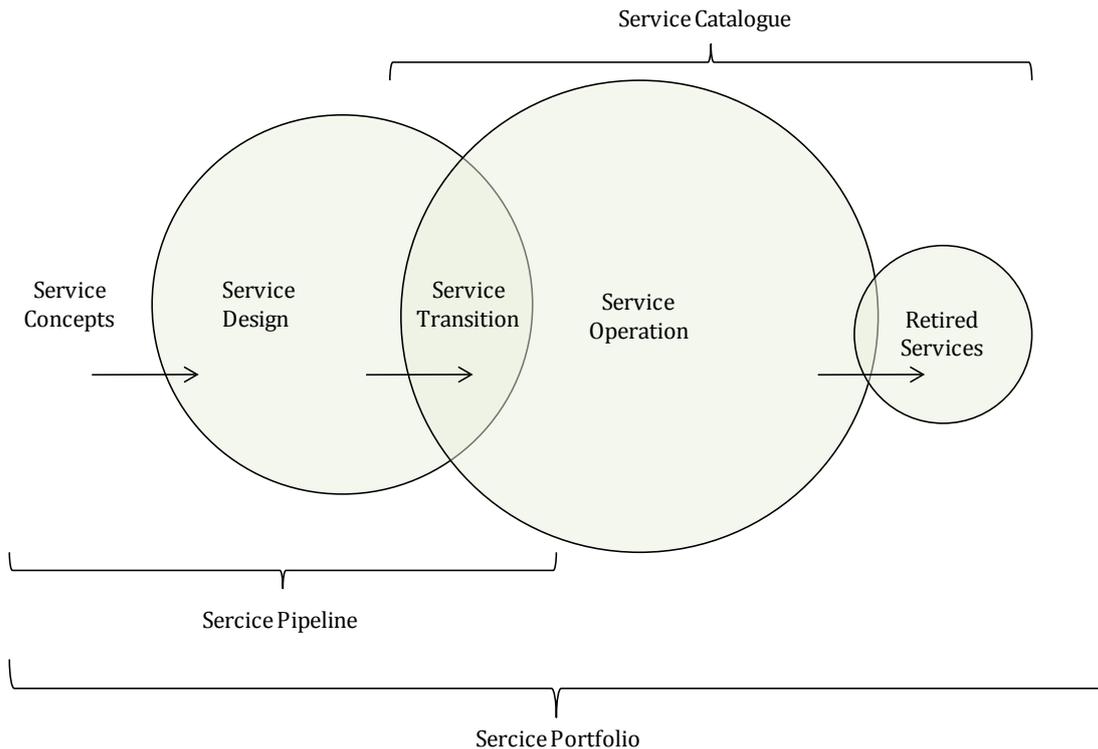


Figure 4. ITIL Service Pipeline, Service Catalogue and Service Portfolio. After OGC (2008).

Service Portfolio Management (SPM) is a process of maximizing the value of the services. It consists of the following steps (OGC, 2008: 34-39):

1. *Define*. In this step information is collected from existing and proposed services. The next step, *Analyze*, should be well defined before beginning this phase in order to understand what data should be collected for analysis.
2. *Analyze*. In this step the strategic position of the service provider is analyzed by considering what are the strategic goals of the service provider, what services support meeting those goals and what capabilities and resources are required to achieve those services.
3. *Approve*. The previous step establishes a target future state. In this step, deliberate approvals or disapprovals of services take place. The existing services fall into six categories:
 - a. *Retain*. The service is aligned with the organization's strategy. They are largely self-contained, with well-defined asset, process and system boundaries.
 - b. *Replace*. The service has unclear and overlapping functionality.
 - c. *Rationalize*. The service is composed of multiple releases of the operating system, same software or system platforms providing similar functions.
 - d. *Re-engineer*. The service has unclear process or system boundaries or it is performing redundant functions.
 - e. *Renew*. The service is functionally relevant but fails technical fitness.
 - f. *Retire*. The service does not meet the minimum levels of technical and functional fitness.
4. *Charter*. Creating a list of decisions and action items. The decisions should be aligned with budgetary decisions. Newly chartered services are promoted to

Service Design phase, existing services are refreshed in Service Catalogue, and retired services begin to phase out with Service Transition.

4.1.2 IT Service Capability Maturity Model

IT Service Capability Maturity Model was introduced by Niessink and van Vliet in their 1998 article. It is based on the Software CMM.

The ITSCMM has evolved and the latest version is 1.0RC1, published in 2005 (Niessink et al., 2005).

ITSCMM consists of five maturity levels, and each of them contains key process areas. The maturity levels are:

1. *Initial*. The Initial-level is characterized as ad-hoc, or occasionally even chaotic. Only few processes are defined, and success depends on individual effort and heroics (Niessink et al., 2005: 10).
2. *Repeatable*. Basic service management processes are established. There is discipline to repeat the earlier successes.
3. *Defined*. The processes are documented, standardized and integrated into standard service processes.
4. *Managed*. Detailed measurements are collected about the IT service delivery process and service quality. The processes and delivered services are quantitatively controlled.
5. *Optimizing*. Continuous process improvement is happening as well as piloting innovative ideas and technologies.

4.1.3 Control Objectives for Information and Related Technology (COBIT)

COBIT defines IT activities in a generic process model within four domains (ITGI, 2007: 21). COBIT claims to provide a common language for everyone in an enterprise to manage IT activities, and it also provides a reference process model.

COBIT 4.1 defines a total of 34 processes, and there are control objectives, management guidelines and a maturity model defined for each process (ITGI, 2007: 17-18). The management guidelines include the inputs, outputs, activities and goals of the process, as well as metrics to measure the achievement of the goals. The maturity model is based on the software development capability maturity model (CMM) by the Software Engineering Institute (SEI), but it has been tailored for the measurement of IT processes. Another difference to the SEI CMM is that there is no intention to measure levels precisely or try to certify that a level criteria has exactly been met, some conditions for a higher maturity level can be met even if all conditions for a lower level are not met.

The six levels for COBIT maturity model are (ITGI, 2007: 19):

0. *Non-existent*. Complete lack of any recognizable processes.
1. *Initial/Ad Hoc*. There are no standardized processes, instead, there are ad hoc approaches that tend to be applied on an individual or case-by-case basis.
2. *Repeat But Intuitive*. Similar procedures are followed by different people undertaking the same task, but there is no formal training or communication of standard procedures.

3. *Defined Process.* Procedures have been standardized and documented, and communicated through training.
4. *Managed and Measurable.* Management monitors and measures compliance with procedures and takes action where processes appear not to be working effectively.
5. *Optimized.* Processes have been refined to a level of good practice, based on the results of continuous improvement.

The COBIT 4.1 processes are divided into four domains (ITGI, 2007): Plan and Organize, Acquire and Implement, Deliver and Support, and Monitor and Evaluate.

4.1.4 Comparison of IT service management frameworks

The difference between ITIL and the IT Service CMM is in the architecture of the frameworks. IT Service CMM is an ordered set of key process areas that provide an improvement path for IT service providers (Niessink et al., 2005). ITIL on the other hand is a framework of best practices organized into processes.

The mapping of ITSCMM key process areas and ITIL processes is presented in Table 1. The mapping is not one-to-one because of the different nature of the frameworks, but it provides a mapping between the central concepts in both frameworks.

The ITSCMM level three key process areas Organization Service Definition, Organization Process Definition, Organization Process Focus and Integrated Service Management do not have a clear counterpart in ITIL, because ITSCMM assumes an organization will define its own processes, whereas ITIL provides those processes (Niessink et al., 2005: 207-208). The level three key process areas Training Program and Intergroup Coordination do not have clear counterpart in ITIL.

ITIL and COBIT have many similarities, although they have been organized differently. Both ITIL and COBIT define central service desk concepts such as Incident and Problem in identical way.

There is also a mapping for ITIL and COBIT processes that shows what the corresponding processes are in different frameworks (ITGI & OGC, 2008). This mapping shows that the overall scope of the frameworks is similar. The mapping has been jointly created by the authors of ITIL and COBIT.

4.1.5 Measuring IT Service Quality

One of the most influential models of service quality is the conceptual model presented by Parasuraman, Zeithaml and Berry (1985).

They also proposed a SERVQUAL-instrument for measuring the service quality (Parasuraman et al., 1988). The instrument was based on the service quality model. The original SERVQUAL instrument was a 22-item questionnaire that was designed for application to broad spectrum of service contexts.

It defines the following dimensions of service quality (Parasuraman et al., 1988):

- *Tangibles:* Physical facilities, equipment, and appearance of personnel.
- *Reliability:* Ability to perform the promised service dependably and accurately.
- *Responsiveness:* Willingness to help customers and provide prompt service.

- *Assurance*: Knowledge and courtesy of employees and their ability to inspire trust and confidence
- *Empathy*: Caring, individualized attention the firms provides its customers.

Kettinger and Lee (1994) introduced a modified version of SERVQUAL instrument for applying to information systems setting. However, critique was raised about the statistical validity of the SERVQUAL-instrument.

Kettinger and Lee (2005) published a refined form of the IS SERVQUAL. The article presents an extensive statistical analysis that aims to prove the statistical validity of the instrument. Based on a factor analysis, two original dimensions (empathy and assurance) were merged into a new concept that was named *rapport*. Also, four questions were removed (6, 10, 18 and 19) because of their statistical insignificance to the measured factors. The total number of questions is thus 18. The proposed questionnaire is based on a three-question format where three questions are asked for each aspect:

“When it comes to [question]:”

1. Minimum service level: The expected minimum level of service performance you consider adequate
2. Desired level of service: The level of service performance you desire.
3. My perception of the [Organization’s Computer Service Unit’s Name] performance.

The resulting questions and their related factors are presented in Table 2. The numbering of the questions has been changed to account for the removed questions.

Table 1. Elements of the IS ZOT SERVQUAL questions and their constructs (Kettinger & Lee, 2005).

1	Providing services as promised	Reliability
2	Dependability in handling customer’s requests	Reliability
3	Performing service right the first time	Reliability
4	Providing services at the promised time	Reliability
5	Maintaining the reliable technology and system	Reliability
6	Prompt service to customers	Reliability
7	Willingness to help customers	Responsiveness
8	Readiness to respond to customer’s requests	Responsiveness
9	Making customers feel safer in computer transactions	Rapport
10	IS employees who are consistently courteous	Rapport
11	IS employees who have the knowledge to answer customers’ questions	Rapport
12	Giving customers individual attention	Rapport
13	IS employees who deal with customers in a caring fashion	Rapport
14	Having the customer’s best interest at heart	Rapport
15	IS employees who understand the needs of customers	Rapport
16	Visually appealing facilities	Tangibles
17	IS employees who appear professional	Tangibles
18	Useful support materials (such as documentation, training, videos, etc).	Tangibles

The IS SERVQUAL-instrument has been criticized for the statistical problems in the use of so called “gap-scores” (Van Dyke et al., 1999). An expectation gap score is formed by

subtracting the expected quality score from the perceived quality score. The reliability of the gap score has been questioned, and utilizing only the perceptions score has led to higher statistical validity in some studies. The perceptions measure performed better as a predictor of the overall quality than the gap score. In this study the gap score is not utilized at all because of the possible problems in statistical validity. Instead the analysis of user satisfaction is based on the perception-component of the questionnaire.

4.2 Configuration management

In this chapter different methods for workstation and server configuration management are discussed. First, the evolution of configuration management tools is discussed and then the current trend, declarative configuration management, is presented in detail.

4.2.1 Evolution of configuration management systems

Sun (2006: 32-35) presents five levels of system configuration automation, from manual to most automated:

1. *Manual configuration.* In manual configuration, each system is configured entirely by hand. It is cost-effective for small-sized systems. It is often utilized even in large systems in which few changes over time are expected. The advantage of manual configuration is that system behavior is closely monitored during each step of configuration and errors can be easily corrected.
2. *Custom scripting.* In custom scripting, manual procedures are typed into script files using a high-level language. Custom scripting is a first attempt at configuration automation. Its main weakness is the difficulty of addressing and reacting to the pre-existing conditions of a host. Scripts also often require pre-conditions that are documented poorly or not at all, which makes them usable only on hosts that satisfy the pre-conditions.
3. *Structured scripting.* Structured scripting is an enhancement of custom scripting, containing mechanisms that make the script usable on a wider set of environments. Sun presents two approaches to structured scripting: execution management and variable instantiation. ISConf-software is an example of software that utilizes execution management. With ISConf, the management scripts are structured in stanzas. An administrator can specify which stanzas are executed for a host, and ISConf makes sure that the stanzas are executed in the pre-defined order so that dependencies are met. Variable instantiation means that certain variables take different values depending on the execution environment, and with these variables the script file can be engineered to work on different hosts.
4. *File distribution* means a strategy where an administrator maintains master copies of configuration files in a repository, and periodically distributes these copies to the managed hosts.
5. *Declarative syntax* is a configuration management strategy where an administrator creates a declarative configuration file that describes the “ideal state” of a host, and agent software then automatically takes actions that bring the host closer to the desired state.

The configuration management based on declarative syntax will be discussed in more depth in the next chapter.

4.2.2 Declarative configuration management

According to Sun (2006), declarative management represents a paradigm shift in configuration management, allowing system administrators to concentrate on making policies and rules for the system and let software to translate those policies and rules into implementation-level instructions and carry out the tasks.

Miller (2006) divides configuration management strategies in two categories: state-based (declarative) and action-based (imperative). In Miller's categorization, action-based means systems where an administrator specifies the actions to be performed and possibly also the conditions under which particular actions are performed.

In a declarative system, the administrator specifies the target final state of a system using a pre-defined notation and the management software then determines the actions that are required to bring the system into the desired state (Miller, 2006). The management software usually handles dependencies between configuration elements and automatically determines the correct order of the actions so that the dependencies are met.

In practice many configuration management solutions contain both declarative and imperative elements. For example, Miller (2006) classifies Cfengine as imperative and Sun (2006) classifies it as declarative. The classification depends on how the tool is used. It is possible to use Cfengine in a completely declarative way, describing only the desired states of configuration elements, as Lackey (2008) demonstrates. On the other hand, as Kemp (2006) shows, it is possible to call arbitrary system commands from Cfengine, making it possible to use it in a purely imperative manner.

It is reasonable that a configuration management tool offers the possibility to execute arbitrary commands, because the tool is not necessarily able to interpret and execute every type of configuration change. In the documentation of configuration tool Puppet it is stressed that the execute-commands must be specified in a way that they are *idempotent*, which means that they can be run multiple times with the same effect as being run only once, or they must have some other control mechanism of preventing the unwanted execution of the actions (Reductive labs, 2009).

4.3 Local area networks

This chapter introduces the common Local area network (LAN) technologies.

The most common method for understanding the different stacked network protocols is the OSI model, which separates the different layers in the protocol stack. The idea of the protocol stack is that the protocol in each layer interacts only with the layers directly above or beneath it (ISO, 1994). Each protocol offers some kind of service to the layer above it, using the layers below by itself. Each of the layers can have their own addressing mechanism. Both sides of the communication must have the matching protocol stack for the communication to succeed.

The OSI model assigns functions that each layer must implement. In practice, the functions of the different layer can be overlapping, e.g., error correction and flow control can happen at multiple levels of the protocol stack.

Figure 5 presents the seven layers of the OSI model and an example of a protocol stack that could be used in an office environment. In that example, the network is based on Ethernet technology and TCP/IP protocols and the application using them is SSH (Secure Shell). There are no protocols in layers 5 (Session) and 6 (Presentation), the application uses directly the Transport layer protocol. In Internet, this kind of protocol stack is very common, and the five layer protocol stack is commonly called “the Internet protocol stack” (Kurose & Ross, 2008).

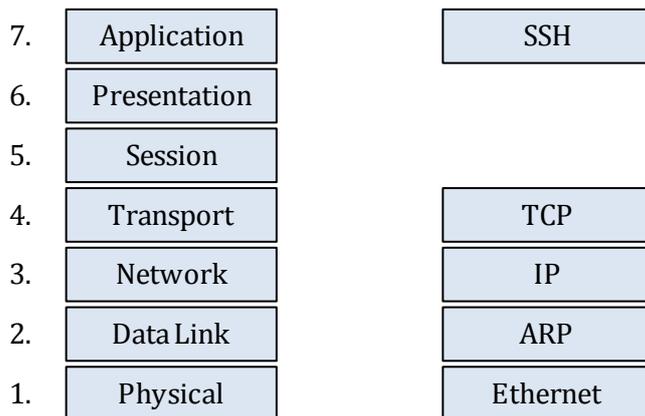


Figure 5. The OSI model on the left (ISO, 1994). On the right is an example of five-layer protocol stack, where the Session and Presentation layer protocols are not present, which is common in Internet environment.

4.3.1 Ethernet

Since its introduction in the 1970s, the Ethernet protocol has taken the dominant market share of LAN technology (Kurose & Ross, 2008).

The key to Ethernet’s success has been simple design that has ensured the low cost of the equipment. The standard has evolved during the years, and since 10BASE-T each new standard has multiplied the maximum speed by a factor of ten.

Table 2. Ethernet standards utilizing copper cable as their medium. (IEEE, 2008).

Standard Number	Standard Name	Standard Released	Maximum Speed	Cabling requirement
802.3i	10BASE-T	1990	10 Mbit/s	Category 3
802.3u	100BASE-TX	1995	100 Mbit/s	Category 5
802.3ab	1000BASE-T	1999	1 Gbit/s	Category 5e
802.3an	10GBASE-T	2006	10 Gbit/s	Category 6 (max. distance 55 m) Category 6a (max. distance 100 m)

Table 2 presents the Ethernet standards that utilize twisted pair copper cable as their medium. In addition to twisted pair copper cable, optical fiber connections are another possible medium for Ethernet (IEEE, 2008). The standards for optical fiber have the same

speed and other characteristics as the copper cable counterparts, except for the different transport medium.

Ethernet standards define the minimum requirement for the cabling, setting minimum requirements for the electrical characteristics such as propagation delay, capacitance and insulation. Higher cable classification can always be used instead of a lower one and it is often recommended to use higher than the minimum level of cabling for critical connections. When designing an Ethernet network, it is important to take to account the limits posed by the cabling infrastructure.

4.3.2 Addressing and routing

In the data link level (OSI layer 2), Ethernet uses MAC-addresses, that are also called network addresses or Ethernet addresses (Kurose & Ross, 2008). The address consists of six bytes, or 48 bits. One address is allocated to each network adapter operating in an Ethernet network. Two adapters in an Ethernet network should not have the same MAC address. In practice, this is achieved by allocating chunks of the address space to different equipment manufacturers, which in turn make sure that no devices have the same addresses.

Ethernet frames are forwarded by switches that keep track of which MAC addresses are located in which ports and forwards traffic accordingly. The switch learns the MAC addresses dynamically, saving addresses to the forwarding table when new MAC addresses are encountered. If the destination address is not found from the forwarding table, the switch forwards the frame to all ports. Forwarding tables usually contain an aging time, after which an address is removed from the forwarding table if no packets have been sent from it. Because of the self-learning procedure, Ethernet switches do not require any configuration. With some switches it is also possible to manually specify entries in the forwarding table.

A router in turn operates at the network layer, forwarding packages according to IP addresses. IP protocol version 4 addresses are 32-bit addresses that are global, meaning that there can only be one node in the Internet having the same IP-address. A router forwards IP-packets according to a routing table. In local area networks, the routing tables are usually configured manually, containing a list of networks that are connected to the router. One route is usually specified as the *default route*, which means that packets to an address that does not belong to any of the specified networks will be forwarded to the default router.

A router that filters traffic going through it is called a *firewall*. The filtering decision can be based on numerous factors, including source and destination addresses of the IP packet, the transport layer port number or the existence of a previously established transport layer connection between certain IP addresses and ports.

5 Assessment of present situation

5.1 Interviews

Initial interviews were performed on four users. Three of the interviewed users are researchers and one is a member of the administrative staff. All of the interviewed people had been in the LCE for over two years. Three were using Linux as their primary operating system, as almost all of the LCE's researchers did, and one user was using Windows as a primary operating system. The group of interviewees seemed to be a representative sample of the users of the IT systems and they had extensive experience from using the systems and working with the IT administrators.

The interviewees were asked for their general impressions about the IT environment and the provided services.

The terms that were most commonly used to describe the IT environment were "frustrating" and "outdated". The biggest source of the problems was the Linux workstation system. Two interviewees told that they felt it was challenging to request changes from the IT staff, because they were often answered that the request could not be carried out or that there was no time to do it. The users often felt that they had to go to the professors with their issues in order to get something to happen. One interviewee reported that some junior researchers were even afraid to contact the IT support because the response was often overly negative.

All interviewees however expressed that they are quite satisfied with at least some of the IT services. WWW-services and reliable network connection were the most satisfying services.

Below are listed the most important problems that the interviewees are facing in their daily work. They are sorted from most severe to less severe, in approximate order.

1. Linux workstations. Users felt that the software on the Linux workstations was too old. Some of the users had tried to compile newer software by themselves, but that had also become problematic because the operating system libraries were so old. Users would like to have a system where they could install new software by themselves or it could be quickly installed by the IT administrators when needed.
2. Workstation hardware. Most of the interviewees were not satisfied with the workstation hardware, saying it was too slow or had too little memory for their needs. The level of noise generated by the workstations was also mentioned as a disturbing factor. In some statements it was not certain whether the interviewee meant the software or the hardware of the workstations, the workstations were just described as "poor" or "unusable".
3. Network arrangements. Because of the software problems on the workstations, one research group had set up their own server for the research group's use. Users criticized isolating the server to a separate network segment, which made their work difficult. The network policy was characterized as being too strict and offering little flexibility.

4. Printing difficulties. Problems with printing were mentioned by two respondents. They told that printing often resulted in paper jams or error messages from the printers. The described difficulties were related to the problems with the printer hardware or the PostScript interpreter. The server infrastructure for sharing the network printers was not criticized.
5. Responding to requests. Most of the interviewees quoted difficulties with getting their issues resolved. The role of the IT administrators was unclear, and many interviewees reported that the IT staff was rather reluctant to take action into responding to users' improvement requests.

5.2 Questionnaire design

A survey was conducted in order to get statistical data about the Department's IT environment's status.

In addition to general questions about the response times and the reliability of the services, the following key areas were selected to be included in the questionnaire based on the interviews:

1. Email
2. Workstations (both Linux and Windows)
3. Administrative IT systems
4. Printers
5. Scanners

For all of the key areas, the triple-scale assessment proposed by Kettinger & Lee (2005) was used to measure the quality of the service. An open field was also provided so that users could input their feedback about the service. In addition, some specific questions were included in the survey to answer certain questions:

Email. The IT Services unit of the University provides an e-mail service for the students and faculty. In addition to this, the Department had provided its own email service for the Department's staff. It was known that some of the Department's staff was using the Department's own email system and some were using the email system provided by the University. I wanted to know which portion of the users were using the Department's own system and provided a space for users to justify their decision.

Workstations. In the interviews the lack of up-to-date software was identified as a common cause of dissatisfaction among both Linux and Windows workstation users. I decided to investigate this problem further by asking what software the users are using currently, and what software they would like to have on their workstation that was not currently available. The questionnaire was implemented as conditional so that the respondent was first asked whether the respondent used Linux or Windows workstation at all, and if the answer was negative, no further questions were asked regarding that workstation platform.

Administrative IT systems refer to the University's administrative systems such as reporting working hours and sending expense reports. These systems were characterized by the fact that every member of staff had to use them. The system is Windows-based, which caused problems for the users of Linux workstations. I wanted to know if users

could access these systems from their desktop workstation, and if not, where they used the system.

Printers. The printers were divided into two categories; personal printers located in user's room and shared printers located in hallways. The respondents were first asked if they had a personal printer. If they answered yes, the quality of service was asked for the personal printer. The quality of service of the shared printers was asked from every respondent.

Shared computers. There have been two computers available for general use in the Department's library. I wanted to find out if staff members were actually using the computers and what tasks were performed using them. The first question addressed whether the respondent had used the library's computers. If the answer was positive, the second question was presented that asked why the computers had been used. The identified options were scanning documents, using administrative IT systems and using commercial software that was not available at the users workstation. In addition to these options, there was an "Other" field that the respondent could fill with a reason that was not given as an option.

Scanners. There were several different methods for scanning documents. Some users had personal scanners in their rooms, shared scanners were available on the library's computer and the copying machine could be used for scanning documents as well. In addition to asking the quality of service for scanning, respondents were asked where they usually scanned their documents. The given options were "at the copying machine", "at the library" and "at a co-worker's scanner". There was also an "Other" field that the respondent could fill.

5.3 Results of the first survey

A total of 28 people responded to the first survey. The number of staff working in the Department at the time of the survey was approximately 50, which yields a response rate of 56%. The Department had numerous user accounts for people who were participating in research projects, but only the people working in the premises of the department were considered to be part of this study. Table 3 presents the division of the questionnaire responses among different personnel groups.

Table 3. Distribution of answers among personnel groups in the first survey.

Personnel group	Proportion of Reponses
Professors	7%
Senior researchers	21%
Researchers	43%
Research students	25%
Administrative staff	4%

The answers to the questions regarding quality of the provided services are summarized in Figure 6. The users' assessment of the perceived service level was a little above the minimum service level with email, Windows workstation and personal printer services. With Linux workstations and network printers, the perceived service level was below the minimum service level, meaning that users were particularly unsatisfied with these

services. With scanners, the perceived service level was little over the middle between the minimum and the desired service level, meaning that users were satisfied with the service to some extent.

The minimum service level of the scanners was the lowest (4.8), which means that users accept lower service level with scanners than with other services. The highest minimum service level was reported for network printers (6.3). Minimum service level for all other services was between 5.1 and 5.7.

The desired service level was between 7.6 and 8.0, except for personal printers (7.0) and scanners (6.5). This can be interpreted so that users do not need as good service with scanning.

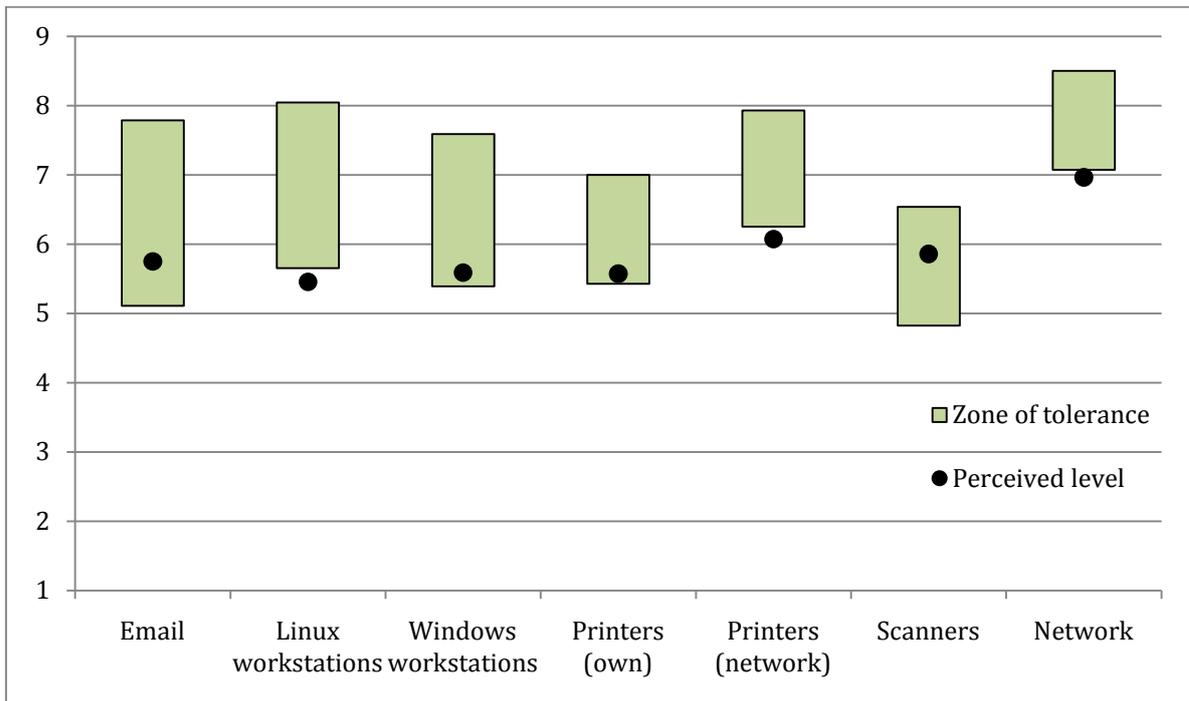


Figure 6. Users' perception of the general quality of IT services in the first survey.

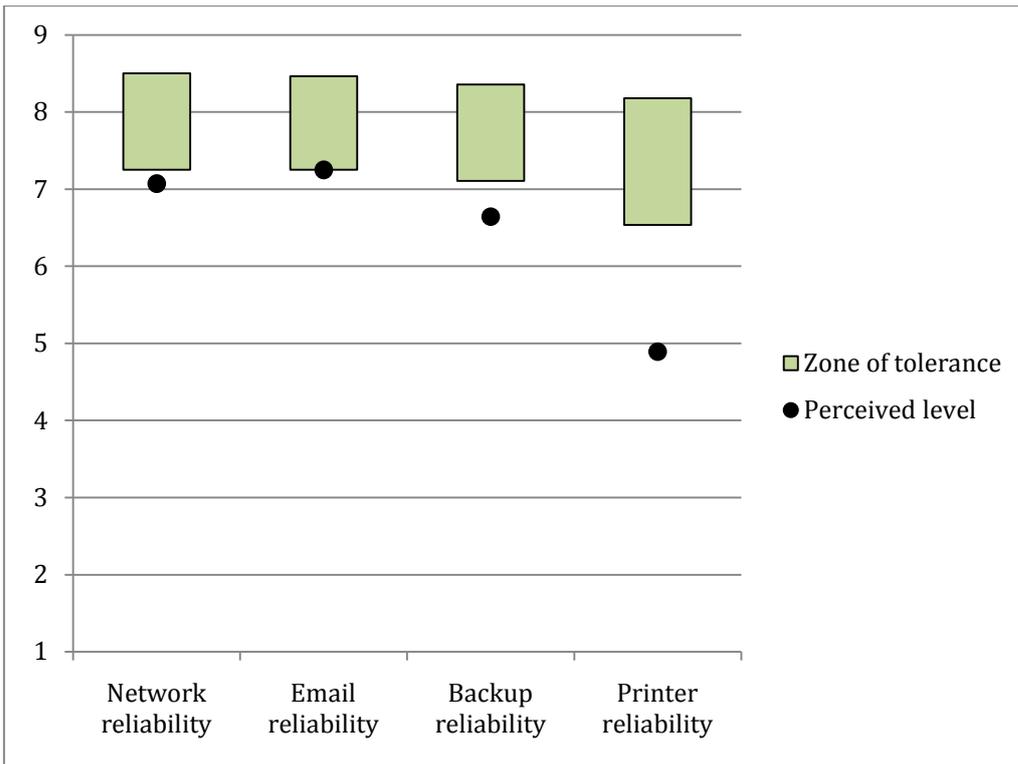


Figure 7. Reliability of services in the first survey.

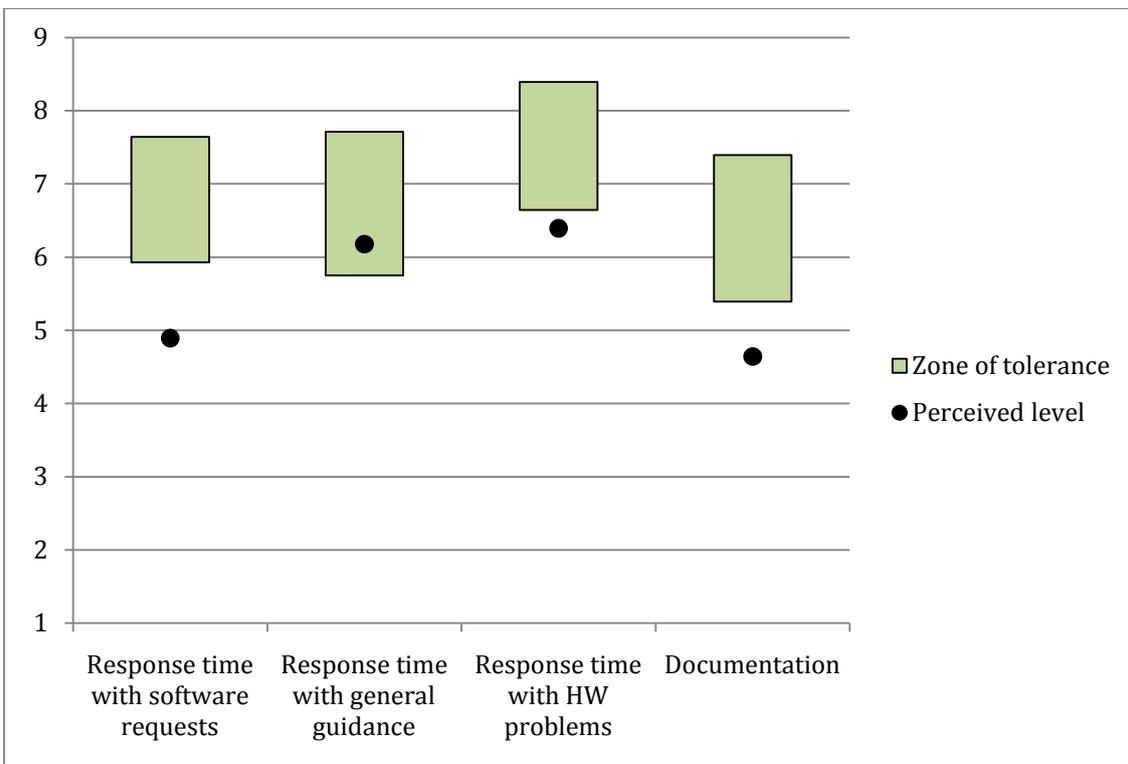


Figure 8. Users' assessment of response times and documentation in the first survey.

5.3.1 Email

The personnel of the Department use the Department's email service for handling 59% of their work related email, on average. 8 respondents (29%) reported that they used the Department's email system for all of their communication. The rest of the respondents use it only partially or not at all. In the open comments, 6 respondents (21%) reported that they used Gmail, a free email-service provided by Google, Inc. 7 respondents (25%) mentioned that they used the email service provided by the computing centre of the University. The reasons for not using the Department's email were various. Some reasons mentioned in the responses were lack of spam filtering, lack of web-access to the email, difficulty in handling attachments, clarity reasons for using the University's domain name in the address. One respondent specifically mentioned that the existing email domain (@lce.hut.fi) is confusing because the Department has been merged into a larger Department and the domain of the email address no longer reflects the organization's name.

5.3.2 Linux workstations

Most of the respondents (84%) said that they use Linux workstations at least sometimes. In the service quality questions the Linux workstations were an area where the perceived service quality was below the minimum acceptable level. In the open comments, eight respondents described the biggest problem to be outdated software and libraries. In other open comments respondents wished for a system that enabled users to install and maintain software on their own workstations, quieter workstation hardware and an easier system for burning CD/DVD discs.

The problem of outdated software was anticipated through the interviews and the questionnaire provided fields to specify what software is most used, and what additional software should be installed on the Linux workstations. The following tables present a list of software packages and how many respondents gave references to them.

Table 4. Most used software on the Linux workstations.

Software	References
Matlab	15
Emacs/Xemacs	11
Firefox	9
Latex	7
Acrobat reader	6
C/C++ compiler	4
Thunderbird	3
Openoffice	3
Python	2
gnuplot	1
NX	1
Xmms	1

Table 5. Additional software that should be available on the Linux workstations.

Software	References
Python	2
Inkscape	2
Scribus	2
Subversion	1
rdesktop	1

In addition to the software packages listed in Table 5, one respondent requested a solution for running the most common Windows software that is not available on Linux. Visualization software was also requested as well as an easy way to handle compressed files.

5.3.3 Windows workstations

17 respondents (61%) reported that they use Windows workstations at least sometimes. The respondents' perception of the service level was slightly over the minimum service level, which means that on average Windows users were more satisfied than Linux users. In open comments, two respondents stated that they prefer taking a remote connection to a Windows server from their Linux desktop to perform random Windows-tasks. Such a server is available, but the respondents complained that the server hardware and software installed on it are outdated. Another issue mentioned by two respondents was the poor availability of IT support for Windows users. Other mentioned issues were unclear license management, lack of backups and a too restrictive profile size limit.

The following tables present the most commonly used software, and additional software requested by the respondents.

Table 6. Most commonly used software on the Windows workstations.

Software	References
Microsoft Office	9
Matlab	6
Adobe Acrobat	2
Maple	1
Comsol	1
Adobe Illustrator	1
Adobe Photoshop	1
Latex	1
Lyx	1
Firefox	1
Zotero	1
Sharp Develop	1

Table 7. Additional software requested on the Windows workstations.

Software	References
Adobe Distiller	2
Adobe Illustrator	2
Adobe Photoshop	1
C-compiler	1

5.3.4 Administrative systems

19 respondents (68%) stated that they are able to access the University's administrative information systems from their workstation, 3 respondents (11%) were not able to access the systems from their workstations and 6 respondents (21%) said that they do not know the answer. From those who could not use the systems from their own workstation, 44% said that they use the workstations in the Department's library, and another 44% said that they use a secretary's workstation and one respondent reported that he has not used such systems.

5.3.5 Printers

Seven respondents (25%) reported to have a personal printer. When considering service quality, the not as good service was expected from the personal printers than from the network printers. The service quality of network printers was better, but users of personal printers were more satisfied when taking to account the minimum and expected service levels (see Figure 6). The top issues reported in answers to the open question regarding printers were often occurring postscript errors when printing (mentioned by 5 respondents, 18%) and paper jams in printers (mentioned by 4 respondents, 14%). Other mentioned issues were difficulties with printing from Linux and lack of instructions on handling printer problems.

On average the respondents agreed with the statement "Network printers are close enough to my room". On scale from 1 to 9, where 1 being "Completely disagree" and 9 being "Completely agree", the average of the responses was 7.3, so users can be considered generally to be satisfied with the proximity of the network printers.

5.3.6 Library's workstations

A majority of the respondents (89%) had used the computer available in the Department's library. It was also asked what the workstations were used for. In this question the respondents could select multiple answers. Out of those who had used the computers, 80% reported to have used them for scanning documents, 40% to access the University's administrative systems and 20% to use commercial software installed on the computers. In open comments several respondents stated that they use the computers for occasional Windows tasks that they cannot perform with their Linux workstations.

5.3.7 Scanners

Scanning was most commonly performed using the library's computers. The respondents were allowed to select multiple options, and 19 respondents (68%) said that they scan using the library's workstations, 8 respondents (29%) scan using the scanning function of the copying machine. 2 respondents (7%) reported using a co-worker's scanner. Only

three respondents (11%) said that they do not scan documents at all, meaning that scanning documents is quite common task. The users were generally satisfied to the scanning possibilities, as the perceived service quality was above the minimum level. In open comments respondents cited problems with the copying machine, problems with logging to the library's workstations and lack of software on the library's workstations.

5.3.8 Network

Network connectivity was considered as the most important service according to the highest minimum service level reported by the respondents. The perceived service quality was below the minimum level, meaning that in average users were not satisfied with the level of service. In the open comments several issues were mentioned. Most common comments were related to the remote use of the network resources. The possibilities for remote access were considered to be too limited or there were problems with them. Other mentioned issues were bad WLAN reception, lack of possibility to print through WLAN and network breaks.

5.3.9 Reliability of services

Figure 7 presents the users' perception of the reliability of services. Generally, the reliability was seen as bad. Reliability of the network was below the minimum accepted level. In open answers to question 29 regarding the network connectivity, Email reliability was seen as being in par with the minimum accepted level. The perceived reliability of backups (6.6) was below the minimum accepted level (7.1).

As for the printers, the minimum accepted level (6.5) was lower than for other services (7.1-7.3), but the perceived reliability was substantially worse (4.9), and the difference between the two was the largest. In the open responses to the question 21, the printer reliability was commonly criticized (see chapter 5.3.5). It clearly seems to be a significant issue for the users.

The desired levels of reliability of different services were in a relatively small range (8.2-8.5) meaning that the based on the desired reliability levels, no service can be considered more important than another.

5.3.10 Response times

The responses to questions about the response times are summarized in Figure 8. The perceived level of the response time for software installation requests was 4.9, which is below the minimum accepted level of 5.9. The desired level was 7.6. On average, users are not satisfied with the response time with software installation requests, which is in line with the responses given in questions regarding the workstations in chapters 5.3.2 and 5.3.3.

Perceived response time with general guidance (6.2) was above the minimum level (5.8), so users are generally satisfied with it.

As for the response time with hardware problems, both the minimum level of service (6.6) and the desired level of service (8.4) were higher compared with the response times to software requests and general guidance. Thus the users considered this service to be more important, which seems understandable. The perceived level of service was also higher

(6.4), but still below the minimum accepted level, so users cannot be considered satisfied with the response time to hardware problems.

5.3.11 Documentation

The perceived quality of documentation (4.6) was below the minimum accepted level (5.4). In open comments to questions, documentation was mentioned as an issue only regarding the printers (see chapter 5.3.5). This result was expected because very little documentation was available for the users. However, the survey did not provide insight on what areas should be particularly emphasized when creating documentation.

6 Actions performed

6.1 Creating a service portfolio

In the interviews multiple users stated that they did not know exactly what services were provided by the IT staff. On the other hand, the Department's management did not know exactly how the human resources allocated for IT were actually spent.

Creating a service portfolio, as defined by ITIL, seemed to be an appropriate solution to clarify the situation and to establish a framework for managing the services.

The process was carried out using the ITIL's four-step Service Portfolio Management (SPM) process described in chapter 4.1.1:

1. Define
2. Analyze
3. Approve
4. Charter

6.1.1 Collecting data

In the initial phase, the list of existing services was collected by reading the existing IT documentation, interviewing the users and observing what services were actually running on the servers. The results of the definition phase are in the Table 8.

Table 8. Existing and planned services.

Existing Services
Linux Printing
Windows Printing
Email
Email list server
Backup
Network connectivity
Guest Network
Public Computers
Linux Workstations
Windows Workstations
Computing servers
Scanning
WWW-services
Planned Services
Terminal Server
Wireless LAN
Intranet

6.1.2 Analysis

After collecting the data on running services, I proceeded to the analysis phase. In this chapter I will review the active services and plan actions that should be taken regarding them.

Printing services for Linux and Windows environments are key services provided for the users. In the interviews (chapter 5.3.5) users reported frequent error messages and paper jams, which are most probably caused by old printer hardware that needs to be brought up to date. The number of network printers seems to be good, because users generally considered that they are located near enough to their rooms. Also, the printers were shared on different Windows servers, making it difficult for Windows workstation users to find the network paths for the printers. A new centralized printing servers needs to be set up for Windows.

LCE had provided email service for the users. However, the email system was behind the current state of technology. The system did not provide spam filtering, web access and remote use was difficult. The only possibility to read email from outside of the Department's network was to open an SSH (Secure Shell) terminal connection and to read email through it, making it difficult to handle attachments. Many users complained about these shortcomings in the survey (see chapter 5.3.1), and only 21.1% of the respondents reported to use the Department's email system for all their work related communication. This means that majority of the users were already using some other email service to handle their email. The University's IT Services also offers an email service to all students and staff of the university, therefore providing our own email service was seen as redundant. The email service provided by the University's IT services unit was also much more advanced, including a web interface to remotely read email and remote access to emails through Internet Message Access Protocol (IMAP). Based on these arguments it was clear that users should be migrated to the email service of the University's IT services unit and the LCE's own email system should be phased out.

The email list server had provided email list services for the Department's use. The service was based on Mailman-software, which also provided a Web-interface for managing the email lists. It was found out that the University's IT Services provided a similar service based on the same Mailman-software. Thus, our own service was completely redundant and it was decided that the mailing lists should be migrated to the University's IT services' system and our own service should be phased out.

Taking backups is unarguably one of the most important tasks of system administrators. In the survey, users were generally not satisfied with the reliability of the backups (see chapter 5.3.9). In the interviews with users, many mentioned that they are not sure which storage areas are backed up, and there should be information available on which directories are backed up. There was also a technical limitation in the Amanda backup-software; it did not allow backing up partitions that were larger than a single tape. Some file servers contained larger partitions that the size of a single tape, so that they could not be included in the backups. The backup system was in need of renovation, the backup software needed to be changed and the system needs to be documented so that users are fully aware what level of data security is provided.

The network connectivity was considered the most important service in the survey (see chapter 5.3.8) but the level of service was below the minimum accepted level. The network structure needed to be re-engineered and that work is documented in more detail in chapter 6.3.

Linux Workstations were a source of a lot of user dissatisfaction. The operating system and software were old and there was no efficient mechanism for administering the workstations. The upgrading of the Linux workstations is documented in chapter 6.2.

Windows Workstations itself are in reasonable condition, but the server system that was running the Windows domain was in need of upgrading. Much of the software that was available to the workstations was outdated.

LCE had been providing computing servers that could be used for scientific computing. Users could log in to these servers and leave computation jobs running. Some of the server had Alpha hardware and were running Tru64 UNIX operating system. These servers were phased out, because the legacy operating system and libraries made it difficult to run software there, and according to the server logs they had not been actively used for years. Current computational research projects in the Department have a special characteristic that a large amount of memory, from 8 to 64 gigabytes, is required. This type of computation jobs cannot be run in normal workstations, and new computing server hardware is required. The computing server services should be updated to match the user needs, and the old hardware should be decommissioned.

Scientific computing was also performed on the Linux workstations. It was possible for the users to submit jobs that were distributed to be run on other users' workstations. This made it possible to efficiently use idle CPU time available on the workstations. This functionality, called grid computing, was enabled by software called Sun Grid Engine (SGE). A drawback of SGE was that it did not provide functionality to schedule jobs automatically only to those computers that were not actively used by a local user. Because of this, the jobs were ran on the workstations at the same time as users where using them, causing the workstation to slow down and thus annoyance to the users. The grid computing system should be renewed so that it can use the computers only when they are idle.

Additional resources for computation have been provided by a computation cluster that consisted of 64 nodes that all had the same hardware and software configuration. The cluster nodes had a similar configuration as the Linux workstations and they also had similar problems; old operating system libraries and software, and no efficient mechanism for upgrading. Because of these difficulties, only a few researchers were using it. The cluster hardware was also 5 years old and it was becoming obsolete. The cluster should be decommissioned after the researchers using it no longer have the need for it.

Scanning was also an important service, only 10.3% of survey respondents did not scan documents at all (see chapter 5.3.7). Many people reported that they had problems with logging to the library's workstations, because they used their Windows account rarely, or they did not have a Windows account at all. The copying machine would be an easier solution for scanning, but it has proven to be unreliable, because the scanned documents were sent to a network-attached hard-drive, that needed to be rebooted often. The

copying machine should be connected to reliable network storage to enable efficient scanning of documents. Users should also be educated about the possibility of using the copying machine for scanning, it is the easiest method for the users but only 27.6% were using it. However, users were generally satisfied with the scanning facilities, so improvement actions needed to be prioritized lower than with other services.

LCE had a WWW-server that hosted homepages for users, courses and research groups. The University's IT services offered also WWW-services, but it was too limited (small disk quota, no possibility for scripts) for the Department's use. The WWW-service should be retained.

6.1.3 Approving

Table 9 summarizes the actions that should be taken on the services:

Table 9. Decisions on the services.

Service	Action	Description of actions
Linux Printing	Retain	
Windows Printing	Renew	A new Windows printing server needs to be set up.
Email	Replace	The Department should migrate to using the Email system of the University's IT services.
Email list server	Replace	The Department should migrate to using the Email list service of the University's IT services.
Backup	Renew	Backup software needs to be changed. The scope of the backups must be well documented.
Network connectivity	Renew	Office network needs to be reorganized and the router has to be updated.
Guest Network	Retain	
Public Computers	Retain	
Linux Workstations	Renew	The operating system of the Linux workstations needs to be upgraded, and a method established for managing the workstation configuration.
Windows Workstations	Renew	The Windows servers need to be upgraded and updated software packages need to be provided for the workstations.
Computing servers	Rationalize	Retire the Alpha servers. Upgrade the hardware to match current research needs.
Computing cluster	Retire	Phase out the cluster after the current users do not need it.
Scanning	Re-engineer	Provide more stable storage for the copying machine and provide instructions for scanning.
WWW-services	Retain	

6.1.4 Chartering

The previous chapter lists the decisions that were taken on the Service Portfolio Items. The actions were prioritized, and the following actions were considered to be most important:

1. Upgrading the Linux workstations.
2. Renewing the network structure.

These two action items are described in detail in this thesis. Other actions are also performed during the research period but this thesis focuses on these two most important actions. The other minor actions to be implemented are:

3. Moving email service to the centralized email service provided by the IT Services unit
4. Moving mailing list service to the centralized server provided by the IT Services unit
5. Upgrading the printer hardware.
6. Improving scanner reliability.

6.2 Upgrading the Linux workstations

6.2.1 Analyzing the present situation

A common problem reported by the users was the currently used Linux distribution. The identified problems were:

1. The software and libraries available on the workstations are very old
2. Installation of new software is not possible
3. The hardware of the workstations is not satisfactory (too slow, too noisy)

The Linux distribution previously in use was Mandrake version 10.2. The administration of the workstations was done by maintaining a so called “master workstation” and then replicating the files from the master to the workstations using *rdist*-tool. For that purpose, the workstations were divided into netgroups. The netgroup-information was stored in the NIS-database and the netgroups could be utilized when copying the files.

The *rdist*-based file replication did not allow customization of individual workstations. Because of that the netgroup of Mandrake 10.2 workstations was further divided into two subgroups: one for workstations with Nvidia display adapters and one for workstations without one. The *rdist*-method also had a restriction that the files were copied only if the target workstation was online. If the target workstation was shut down, it would not receive the updates until the next time the *rdist* was successfully executed.

There was no supported way to upgrade the workstations to a newer version of Mandrake, and the only supported way was to reinstall the workstation.

6.2.2 Choosing a Linux distribution

A Linux installation contains the Linux kernel and software packages. This combination is called a *distribution*. A distribution provides a mechanism for installing the system. Usually distributions have a package management system that enables users to install software from already compiled binary packages.

The number of Linux distributions is substantial. Some distributions have been branched from existing major distributions, usually customizing it for a certain special use.

First, criteria for selecting the distribution is established:

1. Availability of up-to-date packaged software that can be easily installed
2. Ease of maintaining and upgrading the system
3. Easily installable hardware drivers
4. Large enough user- and developer base

Tracking the number of users and developers of each distribution is a difficult task. Comprehensive data on the subject does not exist; the available data is based mostly on surveys or web traffic analyses and are unrepresentative. For the comparison, a list of ten major distributions from DistroWatch-website (Distrowatch, 2009) was utilized. One of the listed distributions was based on BSD operating system, which was excluded from the comparison because the Department was specifically looking for a Linux distribution.

PCLinuxOS

PCLinuxOS was ruled out because it did not support 64-bit architecture (Distrowatch, 2009a). 64-bit architecture was essential for the research applications because the 4 GB limit of the 32-bit address space was becoming a serious limitation in the scientific computing.

Gentoo

A package management solution is an essential component of a Linux distribution. A key source of user dissatisfaction with the existing Linux desktops was the poor availability of software. Gentoo's packaging system, named Portage, is based on the idea of compiling the software on the workstation instead of providing ready-built binary packages (Gentoo Foundation, 2009). Gentoo also implements the idea of a "rolling update" which means that instead of bigger releases, the packages are updated continuously. The advantage of compiling the packages on the workstation is that the user can have very fine control of the compilation, i.e., the compiler can optimize the software for the host system architecture.

The experiments at the Department showed that a Gentoo system must be constantly upgraded to be able to install new software, otherwise the compilation can easily fail because the package dependencies are not met. The constant upgrading of the systems would require a lot of system administrators' time. For the Department's use, the advantages of the system were considered very marginal compared with the drawbacks of compiling all the software used instead of binary packages. For that reason Gentoo was not considered to fulfill the requirement 1 of availability of easily installable software.

Slackware

Slackware was ruled out because it does not support 64-bit architecture (Distrowatch, 2009).

Furthermore, Slackware's package management system is very rudimentary in a sense that it does not provide mechanism for tracking and solving dependencies between packages. Hicks et al. (2005) state that the dependency management is left up to the system administrator and say "that's the way we like it". A modern Linux workstation installation has hundreds of packages, and managing their dependencies manually would be very laborious. This shortcoming also ruled out the use of Slackware.

CentOS

CentOS-distribution is based on the commercial Red Hat Enterprise Linux (RHEL) distribution. The source code is taken from RHEL and the non-free parts are replaced with other solutions. CentOS uses the RPM package management system.

Upgrading between the major releases of the distribution e.g., from CentOS 4 to CentOS 5, is not supported. In CentOS documentation Schaffner (2009) provides advice for doing the upgrade but states that doing a fresh install is strongly preferred over upgrading.

The major shortcomings found in CentOS were the lack of packaged display drivers and the lack of possibility to upgrade the system. Reinstalling all the workstations of the Department to upgrade the distribution would be an unnecessary and time-consuming operation. Inability to upgrade the distribution had been one of the reasons why the workstations' software was old, which was a key element of user dissatisfaction. CentOS was considered to not satisfy the requirement 2.

Mandriva

Mandriva is developed by a company named Mandriva as well as by voluntary developers. It comes as three different versions: "Free" edition which does not have any proprietary software packages, "One" edition which contains also proprietary packages and "PowerPack" which is a commercial version that is not available free of charge (Distrowatch, 2009). A significant difference between these editions is that the One edition does not have a 64-bit installer available.

As stated earlier, the support for 64-bit architecture is an important requirement, which is only satisfied by the "Free" edition. The installation of the "Free" edition is not a good option either, because many important packages such as display drivers and other device drivers are not available on the "Free" edition as they are classified as non-free software. Thus Mandriva was ruled out for its lack of 64-bit support in the "One" edition and for its lack of available software in the "Free" edition.

Fedora

Fedora is a community-developed distribution that is sponsored by Red Hat, Inc. It supports both 32-bit and 64-bit architectures (Distrowatch, 2009). Display adapter drivers are not available as packages.

Also, Fedora does not have a supported method for upgrading to a newer release. The recommended method of upgrading is to boot from an installation media and to use the upgrade-option of the installer (Fedora Project, 2009). This fails the requirement 2.

OpenSUSE

SUSE was originally a commercial distribution, but after it was acquired by Novell, Inc. it was renamed to OpenSUSE and the distribution was made freely available. OpenSUSE is available for both 32-bit and 64-bit architectures (Distrowatch, 2009).

As with Fedora, the downsides of OpenSUSE are that it does not have packaged display adapter drivers and that the only supported method for upgrading the system is to boot from installation media (OpenSUSE, 2009). This fails the requirement 2.

Debian

Debian is an independent free distribution that was first announced in 1993. It is available on a wide range of architectures, including the 32-bit and 64-bit x86 processors (Distrowatch, 2009). It has a sophisticated packaging system (APT) and a large package base. Display drivers are available as ready-built packages. Upgrading to a newer release is handled automatically by the package manager.

Ubuntu

Ubuntu was announced in 2004, and it is based on Debian (Distrowatch, 2009). Compared to Debian, Ubuntu gives more emphasis on usability and availability of up-to-date software, and the delay of software releases propagating into the stable release is shorter than in Debian. The architecture support is not as wide as in Debian, but 32-bit and 64-bit x86 architectures are supported. It shares the same package management system (APT) and it supports automatic upgrading.

Analysis

After ruling out the distributions that did not satisfy the requirements, the following distributions remained: Ubuntu, Debian and LinuxMint. The relationship between these distributions is that Ubuntu is based on Debian, with added emphasis on usability and ease-of-installation. LinuxMint in turn is based on Ubuntu, containing a different user interface and a collection of applications called Mint Tools, designed to ease the administration of the system.

The Mint Tools were evaluated and they were not considered to be useful for the Department's environment, because in centrally managed system the system configuration and administration is done centrally and not by the end user with a graphical user interface.

Thus, LinutMint was missing the support upgrade mechanism compared to Ubuntu and it did not seem to contain any specific benefits, so Ubuntu was preferred over LinuxMint.

The final comparison was between Ubuntu and Debian. Ubuntu is based on Debian, so the architecture and technical solutions in these two distributions are very similar. However, the focus of the distributions is a bit different: Debian provides support for over a dozen architectures and has more emphasis on stability, hence the software release cycle is longer and software packages in releases are older. Ubuntu in turn has more emphasis on the desktop usability and newer software, at the cost of supported architectures. For the Department's purposes, Ubuntu is considered to be more suitable, because the availability of up-to-date software was a substantial criteria, even if it happened at minor loss of stability.

The selected distribution was Ubuntu Linux.

6.2.3 Choosing a tool for workstation configuration management

In order to efficiently manage the configuration of a set of workstations, a specialized software tool is needed.

The most common operations that are performed on the lab's workstations are installing packages and changing configuration files on the workstations. Thus, the configuration management tool should provide good support for at least the following key functionalities:

1. Installing new software packages.
2. Providing mechanism to automatically answer questions that the package might ask at the time of installation.
3. Making changes to the configuration files.

A problem with the present method for managing the workstations, described in chapter 6.2.1, was that it did not provide an easy way to make exceptions to the standard configuration. It was possible to create a new netgroup for a different configuration, but managing a large group of netgroups becomes impractical. The new configuration management tool should have an efficient mechanism for creating a different configuration for a group of workstations and creating exceptions to individual workstations.

Cfengine

Cfengine was originally developed at Department of Physics of University of Oslo and its first version was released in 1993 (Burgess, 1993). Since then it has grown into a one of the most well known free tools for configuration management of UNIX-type systems. The system is based on client-server architecture. It is a very comprehensive framework for managing even a large set of devices (Lackey, 2008).

Cfengine's configuration syntax has been criticized as being hard to learn (Walberg, 2008). Also, Cfengine does not provide built-in support for installing packages on Debian-type systems, and thus the installation packages must be handled through separate scripts (Kemp, 2006).

Puppet

Puppet is a newer configuration management tool than Cfengine. Puppet has ready-provided resource types for many types of configuration items. This means that the configuration can be performed on these abstract resource items rather than editing the configuration files and executing shell commands. This helps to keep the configuration files cleaner (Walberg, 2008).

Puppet has a built-in support for installing packages on various platforms including Debian and Ubuntu.

Bcfg2

Bcfg2 is a configuration management tool originally developed for internal use in the Mathematics and Computer Science Division of Argonne National Laboratory in the U.S.

and it is currently widely used also in other sites. The main difference between Bcfg2 and the other two tools is that it contains features to compare the state of the client workstation and the specification and to report the differences (Desai et al., 2009).

Bcfg2 also provides a Web user interface to monitor the state of the clients. It also has support for handling packages in operating systems that use APT-based package management, including Ubuntu. During testing it emerged that Bcfg2 does not have a feature to specify the install-time package configuration. Installation of packages that required install-time configuration failed. However, it is still possible to provide this functionality with custom scripts, similarly to Cfengine.

Analysis

All of the compared tools were able to distribute changes to configuration files.

Cfengine was the oldest of the compared tools, and performing high-level actions, such as installing packages, require the use of separate script files. Script files that can be used by Cfengine to perform different actions are freely available on the Internet, but I believe that this way the configuration of Cfengine can easily become complex and difficult to manage.

Puppet and Bcfg2 in turn provide built-in support for handling packages, but Bcfg2's functionality is incomplete in a sense that it does not have support for providing install-time configuration for the packages.

Because of the high-level configuration language used and support for package installation, Puppet seemed to be the most suitable tool for managing the configuration of the workstations.

6.2.4 Commissioning the new workstations

A test installation was made using Ubuntu 9.04 and a minimum configuration and a minimum set of packages was created that enabled the users to log in to the workstations using the centrally managed NIS accounts and home directories. The configuration was then written in Puppet server's configuration manifest and new workstations received the configuration automatically from the Puppet server.

First two workstations were commissioned for test users. Based on the feedback from the users, software packages were added to the workstations. Then, more workstations were slowly commissioned to use, responding to the users' requests at the same time. All the requested software packages and configuration changes were distributed to all workstations through the centralized configuration management.

The Puppet configuration after the commissioning is presented in Appendix 6. The configuration is fairly easy to understand, and doing basic configuration tasks such as adding software packages or changing configuration files is possible after a rather quick studying of the configuration language.

The only problem that could not be solved during the commissioning was that although it was possible to install Nvidia display driver packages with the configuration management system, enabling the drivers required a graphical user interface (an X display). The tool used for enabling the drivers was supposed to have a command-line interface, but running

it without an X display resulted in errors. A bug was filed about this flaw. Until the functionality is fixed, the drivers have to be enabled from the X display using the tool *jockey-gtk*.

6.2.5 Upgrading the workstations

Version 9.10 of Ubuntu was released on October 29th 2009. Immediately after the release, two test workstations were upgrade to the new version in order to discover possible problems with the new release as soon as possible.

No problems were found with the new distribution, and a workstation upgrade was scheduled to happen two weeks after the release of the new version. In the upgrade test runs there was a problem that the upgrade process initiated with command *apt-get upgrade* asked questions that required human intervention. Also, the dpkg packaging utility asked a question about a configuration file that was modified by the configuration management tool. The APT questions were suppressed by setting shell environment variable *DEBIAN_FRONTEND* to value “*noninteractive*” before running the upgrade-command which prevented the APT tool from asking anything during the process. The configuration options *force-confdef* and *force-confnew* were added to dpkg’s configuration file */etc/dpkg/dpkg.cfg* that caused dpkg to take the package’s default action in case of configuration file conflict, and if default action was not specified by the package maintainer, the old configuration was to be overwritten. These actions prevented the upgrade process from requiring any manual intervention, making it possible to run the upgrade process from a script.

Before the actual upgrade-command was included in the Puppet manifest, the APT package manager’s *sources.list* file was updated to point to the package archives of the new release. During the day of the upgrade, a few additional packages were added to the workstation configuration. Because the *sources.list* file was already upgraded, the dependencies of the new packages caused a large set of packages to be upgraded. The workstations were left to a state where it was usable, but it could not boot. The users of the workstations were presented a dialog that prompted to restart the computer after an upgrade. The users, who did select to restart their workstation, were left with a computer that could not start up. Luckily this happened in the evening and only four users restarted their computers and were left with non-bootable workstation. These workstations were fixed by booting from an Ubuntu installation CD-ROM and upgrading the rest of the packages to the 9.10 release. The rest of the workstations were automatically upgraded to 9.10.

6.3 Renewing the routers and network structure

This chapter describes the process of implementing changes to the Department’s network infrastructure.

6.3.1 Current network structure

The Local Area Network (LAN) of the Department is based on the Ethernet technology. The network sockets are connected to wiring closets that host the switch hardware. The network has been partitioned into several segments with Virtual Local Area Network (VLAN) technology. Each wall socket can be configured to belong to a certain network

segment by configuring the Ethernet switches. The segments connected to each other through routers.

The current network structure in the Department is presented in Figure 9. The network consists of three routers, which are PC servers running FreeBSD 4 operating system.

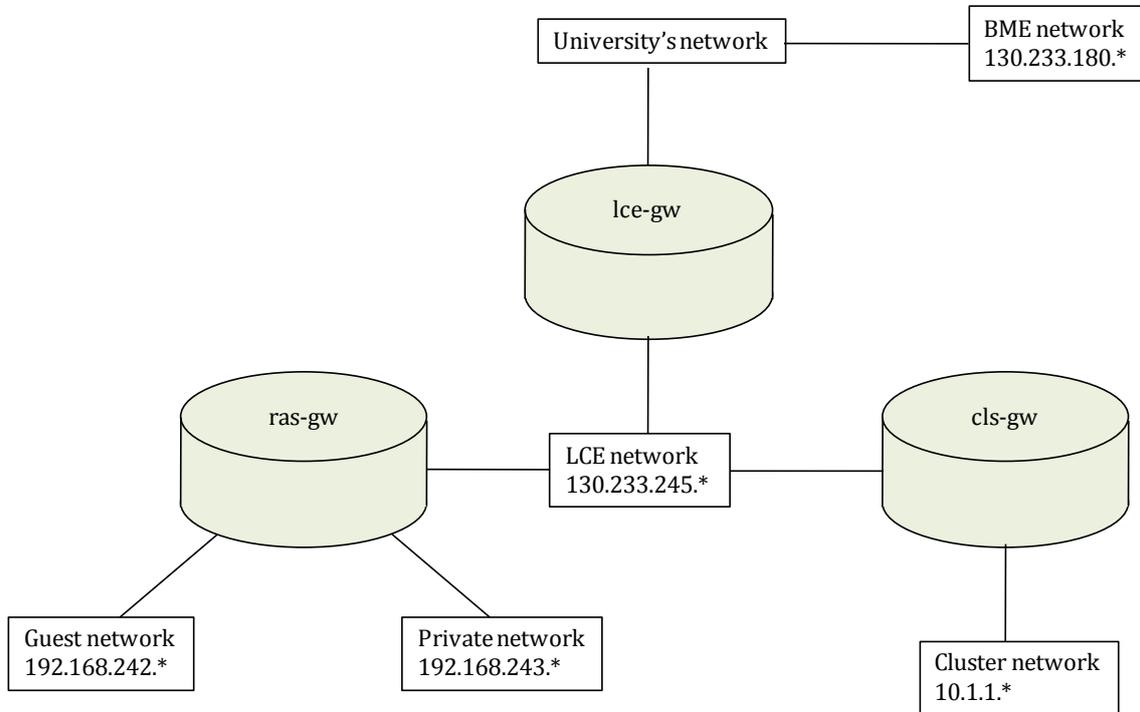


Figure 9. Network structure before the changes.

The *lce-gw* router connects the LCE laboratory's network to the University's network, which in turn is connected to the Internet. Most of the workstations and servers reside in the internal network, which has one C-class of IP addresses allocated for it. For security reasons, the internal network contains only workstations and servers that are administrated by the Department's IT staff.

The BME laboratory did not have an own router, their network traffic was routed by the University's IT services.

The guest network in the LCE was meant for employees or visitors who want to connect their own computers, including laptops, to the network. The guest network has access to the Internet but only a limited access to the Department's servers.

Also a private network has been built for special uses, for example a research group has their own server there that is managed by the group members. The original use for the private network was to host workstations and servers that contained classified data that had to be separated from the rest of the network. It is no longer used for this purpose.

The *cls-gw* router connects the internal network to a so called cluster network that hosts a scientific computation cluster consisting of 48 nodes and two front-end servers.

The workstation switches operate at the speed of 100Mbit/s. The trunk-connections between switches are 1Gbit/s and in LCE laboratory's network also most of the servers were connected to the internal network at 1Gbit/s.

In the LCE there had been some stability problems with the routers, as the *lce-gw* sometimes hanged and needed to be rebooted and also network interfaces at *ras-gw* sometimes froze and the server had to be rebooted.

The routers use FreeBSD *ipfilter* to forward and filter packets. Managing the configuration of the servers is time consuming, because of the complex rules and low-level format of the *ipfilter* configuration files. The *ipfilter* configuration file on *lce-gw* is more than 500 lines, and on *ras-gw* more than 1000 lines.

In LCE's network, the IP addresses for Windows workstations were assigned dynamically with Dynamic Host Configuration Protocol (DHCP) and the addresses for servers and Linux-workstations were statically configured. In BME's network, IP addresses for all network appliances were statically configured, and DHCP was not used at all.

In LCE's internal network there was a policy that all Ethernet switch ports were configured to allow only devices with a certain MAC address to connect to it. If a switch noticed traffic from a non-allowed MAC address, the switch port was automatically disabled, and an administrator had to manually re-enable it. This policy was in place to prevent connecting unauthorized devices to the network.

6.3.2 Analysis and designing actions

An obvious problem with the current network structure was the use of three separate routers that made the network structure unnecessarily complex and more difficult to manage. The functionality of the three routers could be combined into one router with more interfaces. This would create a single point of failure to the network, but in the current network structure *lce-gw* was at the similar position (see Figure 9), being a single point of failure on the connection to the Internet.

The LCE's network was split into multiple segments, which complicated the management of the network. It was also complicated for the users because one research group had to work with their server that was in a different network segment (the private network) than their workstations (the office network). According to the interviews, this seriously impeded their work, because the server could not access network resources located in the office network, making transferring files impractical. The reason for locating the server in another network was that the server was administrated by members of a research group and not by the Department's IT staff. The policy of the system administrators had been to exclude all computers from the office network that were not managed by them. After examining the situation, we agreed that the IT administrators will monitor the server, and the server can be allowed to reside in the internal network without risking the network security.

The guest network was meant for devices that could not connect to the office network, such as visitors' laptop computers. It was actively used, and with laptop computers becoming increasingly common, also many of the employees wanted to bring their personal laptop to the office and access the Internet. The guest network had to be kept

separate, because personal laptops and other untrusted devices could not be allowed to connect to the office network.

The policy of restricting the MAC addresses that could connect to switch port was causing additional workload for the administrators in the form of requests from users to change their workstations to different ports. The switch ports were sometimes locked because users connected a workstation to a port that its address was not authorized to connect. The locked interfaces caused disturbance and confusion for the users. The benefits of the address restriction policy were dubious. An attacker could simply disconnect an authorized workstation from the network, connect his device directly to the authorized workstations to obtain its MAC address, and then change his own device's MAC address to be the same. Changing MAC address is a simple operation that can be done for example with the standard *ifconfig* utility in Linux. This way an attacker can easily and quickly gain unauthorized access to the network despite the restriction. The restriction did not provide significant benefits from the asset management point of view either, because if the system administrations need to find a physical location of a device, the switch port of the device can be found in the management interface of the switches, and the room number can be looked up by the switch port number. The address restriction was consuming the system administration resources, causing inconvenience to the users and based on the mentioned arguments the restriction was not providing any significant benefits from security or manageability point of view. Thus it was decided that the MAC address restriction is removed from the switch configuration.

The new router device should support 1 Gbit/s speed on all interfaces, since the 100 Mbit/s speed was already becoming a bottleneck in certain research use and the size of research datasets and thus required bandwidth is increasing steadily.

The router could be implemented with PC hardware or with dedicated router hardware (a commercial product). A decision to stay with the present solution of using PC hardware was made because of the following reasons:

1. *Cost.* With quick market study, the price of dedicated router product with four 1 Gbit/s Ethernet interfaces is over three times higher than a PC server hardware suitable for the purpose (assuming the use of free software).
2. *Replaceability.* In a case of hardware failure, the hardware can be replaced with another PC server.
3. *Choice of operating system.* The operating system on a PC server can be changed if necessarily. With dedicated hardware there is no choice but to use the embedded software provided by the manufacturer.

There are many different distributions available that are specifically created to be used as a router or firewall server. A firewall distribution that offers an easy-to-use user interface for monitoring the status of the device and for modifying the firewall rules was required. The user interface is usually implemented through a Web-interface.

A firewall distribution called pfSense was chosen because it offers an extensive set of features for a router and firewall use, and a Web-based user interface for managing the server.

6.3.3 Implementing the changes

A good opportunity for implementing the new network architecture was the move of the Department to other premises in October 2009, which caused a break in the network connectivity in any case.

The networks and IP address spaces of both LCE and BME should be available in the new premises. This posed a challenge because people using different networks might need to connect to the network in different rooms. An obvious solution would have been to provide wall socket connections to both networks in every room, but this would have limited the number of usable wall sockets and been confusing for the users. Instead it was decided that the two IP networks will be run in the same Ethernet segment, sharing the same wall sockets. This was possible because BME's network did not utilize DHCP, otherwise a device connecting to a network with two DHCP servers would have received response from two DHCP servers, and arbitrarily be assigned to one of the networks, depending on which DHCP answer is received first. Both of the networks need to have a router in their IP address space that the appliances use as their default router. The two routers can reside in the same physical server.

The so called "private network" hosted only one server that was moved to the LCE's internal network. After this, the private network could be terminated, because no devices were connected to it. The cluster network was terminated as well, because the computing cluster connected to it was decommissioned at the time of the moving.

Because of the growing demand for the guest network connectivity, wall sockets for the guest network had to be provided in every room in the new premises. When employees arrived to the new premises, instructions were posted on the doors telling which network sockets are connected to the guest network and which are connected to the office network.

Figure 10 presents the new network structure that was set up in the new premises. After the changes the network had only two segments, the guest network and the office network that contained both IP address spaces. The new router (becs-gw) had an IP address in both IP address spaces.

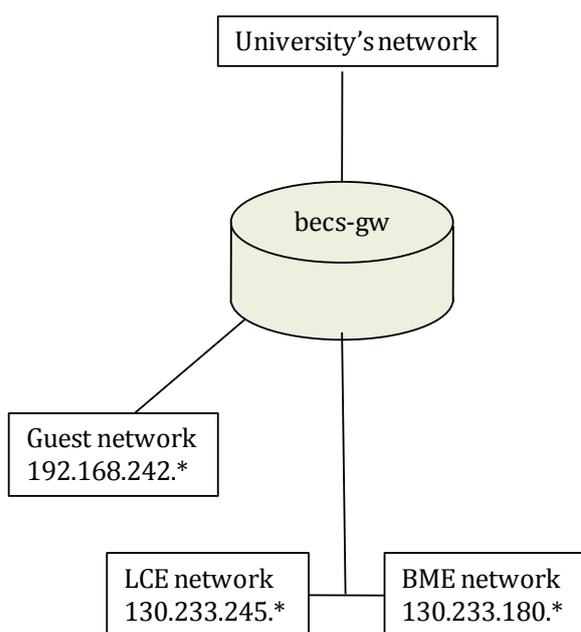


Figure 10. The new simplified network structure.

6.4 Other actions

This chapter describes minor actions that were done, and were not analyzed as intensively as the changes presented in the previous chapters.

Migrating the mailing lists

The email lists that had been available at the Department's own server at domain *lists.lce.hut.fi* were migrated to the IT Services unit's server. Chapter 6.1.2 provides further arguments about why this change was done. The IT Services unit was asked to setup mailing lists with similar names as the old lists to their system *list.hut.fi*. Then, the list configurations (the descriptions, list of administrators, administrative passwords and list of subscribers) were manually copied to the new lists. Because the number of lists was rather small (less than 20), it was more efficient to transfer the settings manually via the web interfaces than to set up a script that copied the settings. The list archives were not working on the old server, so they did not have to be copied. After the new lists were configured, aliases were created from domain *lists.lce.hut.fi* to the new list addresses at domain *list.hut.fi*. The changes were invisible to the list users, meaning that they could continue to send messages to the old address of a list, but the administrative actions such as adding or removing members had to be taken on the new web address at *list.hut.fi*.

Migrating the email system

The email service of the University's IT Services provided better features than the Department's own system, so it was reasonable to migrate to the centralized email service to provide better service for the users and to reduce the IT administrators' workload.

Most users already had an account at the University's IT Services, and thus they already had an email account there. The migration began by collecting the information about the

usernames of the Department's staff on the IT Services' systems. Most users had the same username at the Department's systems and at the IT Services' systems, but this was not certain and thus the usernames needed to be verified. An enquiry was sent to the users asking them to inform the IT staff of their username at the University's IT Services. Some users did not have an account at the IT Services, and they were given an option to have an account created or have email to their @lce.hut.fi address forwarded to another email service provider. After collecting all the information, the result was a list where each @lce.hut.fi email address should be forwarded, either to a mailbox at IT Services mailbox or to a mailbox at another email service provider. This list was sent to the IT Services along with instructions of changing the Domain Name System (DNS) records of domain *lce.hut.fi* so that mails are no longer sent to the Department's mail server, but are processed according to the forwarding list instead.

Renewing printers

The oldest black and white printers were causing a lot trouble for the users. They were causing most of the problems that users reported in the open comments (see chapter 5.3.5), the most severe problems being paper jams and frequent Postscript errors. The old printers were taken out of service, and two new black and white laser printers were ordered to replace them.

The new printers were ordered through the University's IT Services, because they had already selected recommended models with competitive prices that Departments could utilize. It was decided to proceed with this policy, because the process of selecting the printer was avoided and having a printer model that is similar with other units will be an advantage if the IT environments in different departments will be integrated in the future. The printer manufacturer provided a service that new toner cartridges or other supplies will be automatically sent to us when the printer reports that they are reaching the end of their life. This will simplify the maintenance of the printer, because ordering supplies for dozens of different printers also consumes system administrators' time.

Improving the reliability of the network scanner

A copying machine was available at the Department that also contained a scanning functionality. Documents could be fed to the machine and the machine would then save the scanned documents in a network location as PDF files. The documents were previously saved to a Network Attached Storage (NAS) device that had been connected to the internal Ethernet network. The users retrieved the documents from Common Internet File System (CIFS) protocol. The device was intended mainly for home use, and it needed to be rebooted almost weekly because it randomly became inaccessible. The situation was solved by setting up a shared directory from a file server that was shared via CIFS for Windows users and via NFS for Linux users. The file server was considerably more stable in comparison with the NAS device and Linux users could also access it directly from their file system instead of using a CIFS client.

7 Results

The user survey was repeated in November 2009 to assess the possible changes in the user satisfaction. Questions 3 and 4 regarding the use of Department's email services were removed from the survey, because the email services had already been transferred to the University's IT Services' system and thus the questions were no longer relevant. A free-form question was also added to the end of the survey that inquired if the respondent had any additional comments that were not covered by the previous questions.

7.1 Results of the second survey

There was total of 33 responses to the survey, which is 5 more than to the first survey. The response rate was 66%. Table 10 shows the distribution of the responses among the personnel groups.

Table 10. Distribution of answers among personnel groups in the second survey.

Personnel group	Proportion of Reponses
Professors	0%
Senior researchers	9.1%
Researchers	54.5%
Research students	30.3%
Administrative staff	6.1%

Compared with the response groups of the first survey, the most significant changes are that there are no professors represented in the second survey and the proportion of senior researchers has fallen from 21.4% to 9.1%. The proportion of researchers has increased from 42.9% to 54.5%, research students from 25.0% to 30.3% and administrative staff from 3.6% to 6.1%. All in all, it can be said that the participation in the survey has somewhat shifted from more senior members of the staff to more junior members.

The significance of the changes in the respondents' opinions between the two surveys was analyzed using the Student's t-test. The test requires that the two distributions that are compared are normally distributed and have the same variance. (Gopal, 2006). For this purpose I assume that the variances of the first and second answers to a question are the same.

The normality of the answers was tested using the Lilliefors goodness-of-fit test of composite normality, which confirmed that the answers to each of the questions pass the normality test with $p \leq 0.05$. This guarantees that the responses are close enough to normally distributed to use the Student's t-test.

The numerical results of the service quality in the second survey are presented in Appendix 4.

A possible bias caused by the changed respondent profile was tested by making the respondent group sizes equal in the first and the second survey by randomly eliminating responses from the survey with greater amount of responses. The statistical analysis performed on the size matched data showed the same statistically significant changes with

$p \leq 0.05$ as the original data. Thus the bias caused by the changed respondent profile is considered insignificant.

The following statistically significant ($p \leq 0.05$) changes were detected:

1. The perceived quality of email service increased from 5.8 to 6.8.
2. The perceived quality of Linux workstations 5.5 to 7.3.
3. The minimum level of service of Windows workstations increased from 5.4 to 6.8.
4. The perceived level of response time to software installation requests increased from 4.9 to 7.1.
5. The perceived level of response time with general guidance increased from 6.2 to 7.3.
6. The perceived level of response time with hardware problems increased from 6.4 to 7.7.

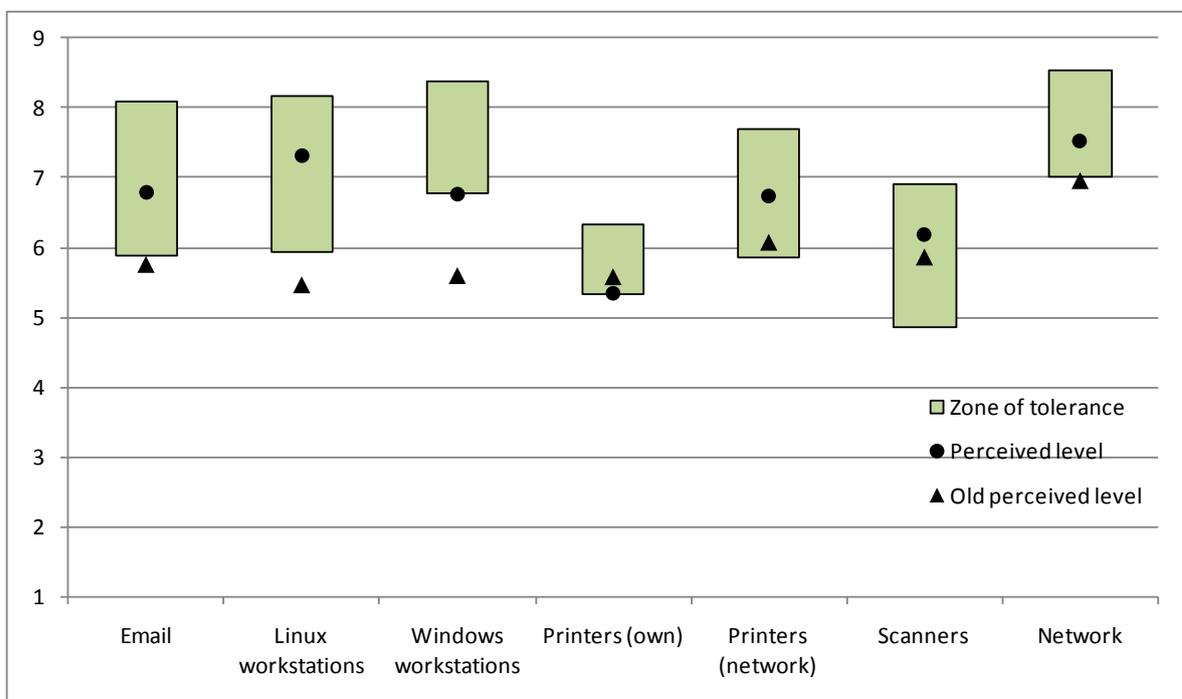


Figure 11. Users' perception of the general quality of IT services in the second survey.

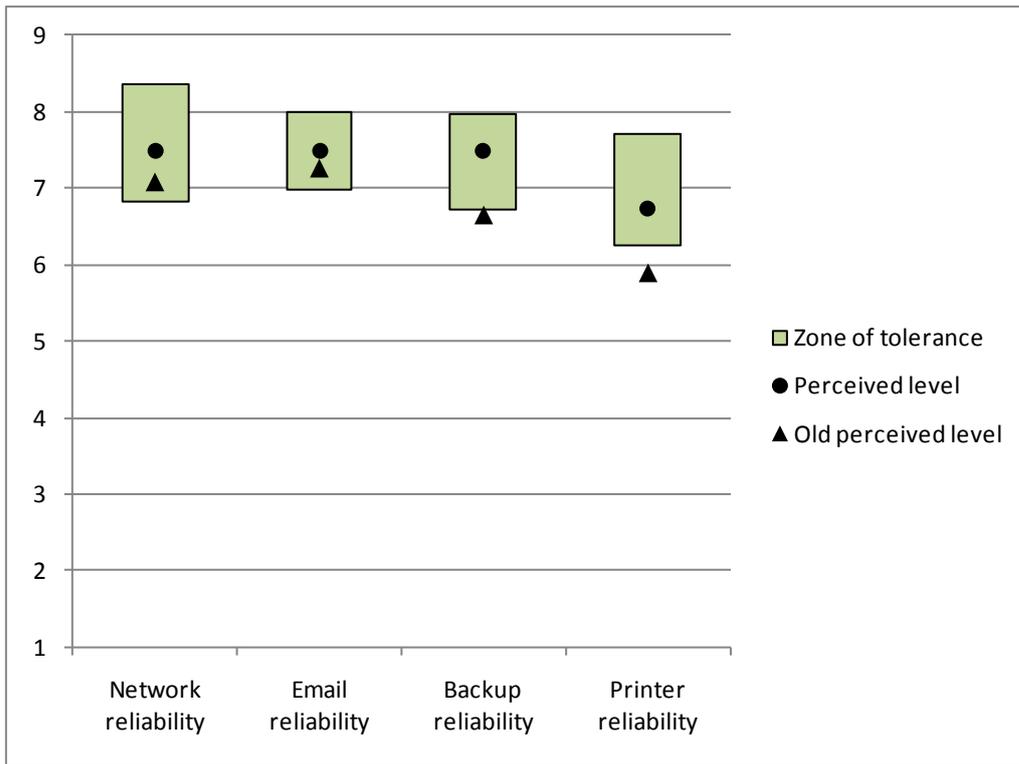


Figure 12. Reliability of services in the second survey.

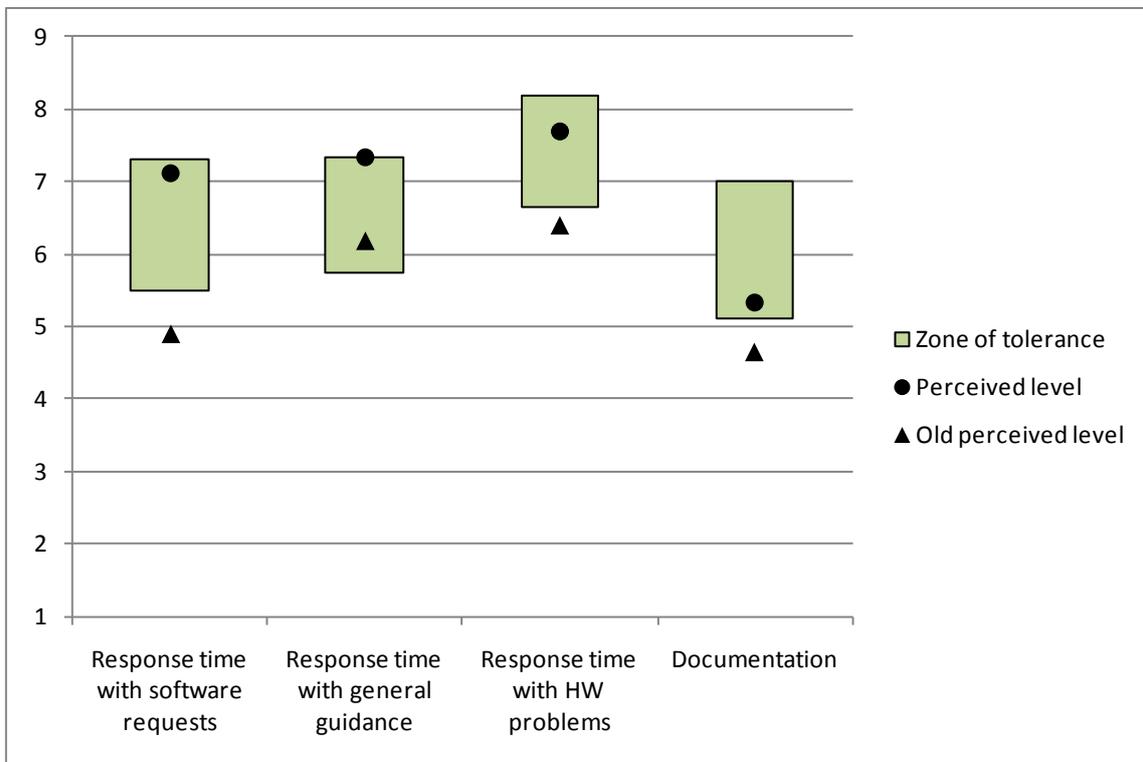


Figure 13. Users' assessment of response times and documentation in the second survey.

7.1.1 Email

The perceived quality of the email services increased from 5.8 to 6.8 and this change was statistically significant ($p = 0.020$). Also the minimum and the required level for the service increased, but those changes were not statistically significant.

In the open comments there were individual mentions of improvements: An SMTP server that would be accessible from outside, e-mail to the mobile phones and problems with configuring the account to Mozilla Thunderbird. As the service is now handled by the University's IT Services, the need for the SMTP server can be forwarded there. Access to mobile phones and access with Mozilla Thunderbird should already be possible; they are configuration problems that can most likely be solved by better documentation and user support.

7.1.2 Linux workstations

The percentage of users who responded to use Linux workstations at least sometimes was 88%, a figure that is slightly higher than in the first survey (84%).

The perceived quality of Linux workstation increased from 5.5 to 7.3 and the change was statistically very significant ($p = 0.000$). The perceived quality rose from below the minimum level into the zone of tolerance (see Figure 11). Although the minimum level and the required level rose as well, those changes were not statistically significant.

In the open comments, two respondents (6%) mentioned stability problems with using the Linux workstations, one respondent (3%) requested the possibility to also use the local storage of the workstations. Other things that were mentioned by individual respondents were possibility to use KDE-desktop, difficulties with attaching two displays and problems with opening certain websites that utilize Macromedia Flash.

Table 11 lists the software that the respondents reported as most used on the Linux workstations. The most used software is almost the same as in the first survey, but there is considerably more software packages listed that are used by only one respondent. Very common software that is used by every Linux user (such as command shells) were excluded from the list.

Table 11. Most used software on the Linux workstations in the second survey.

Software	References
Matlab	15
Firefox	14
emacs/Xemacs	12
Latex	6
Adobe Acrobat	5
Openoffice	3
Python	3
Pine	2
Xfig	2
Condor	2
Postscript tools	1

Thunderbird	1
Opera	1
Mendeley	1
Skype	1
Evolution	1
Google Desktop	1
Dropbox	1
fsl	1
GIMP	1
Pidgin	1
vim	1
mutt	1
octave	1
gnuplot	1
Inkscape	1
kdevelop	1

Table 12. Additional software that should be available on the Linux workstations in the second survey.

Software	References
XV	3
Virtualized Windows	2
wine	2
Unison	1
texmaker	1
maxima	1
dia	1
spice	1
latex2rtf	1
K3b	1
dict	1
Mercurial	1

The most requested software package was XV, which was mentioned by three respondents. Another common request was the ability to run Windows software in a virtualized environment on the Linux workstation. This and the wine-package were both mentioned by two respondents. Other requested software is listed in Table 12. The list did not contain any items that were mentioned in the first survey, as those packages had been installed on the workstations.

7.1.3 Windows workstations

13 respondents (39%) stated that they use Windows workstations at least sometimes. The usage rate was slightly lower than in the first survey (45%). The perceived level of Windows workstation service increased from 5.6 to 6.8 and the required service level from increased 7.6 to 8.4 but these changes were not statistically significant. However, the

minimum service level increased from 5.4 to 6.8 and this change was statistically significant ($p = 0.014$).

The list of most commonly used software packages reported by the respondents is listed in Table 13 and the requested new software in Table 14. The most commonly used software has remained mostly the same as in the first survey. There is an increase in the number of software packages that were mentioned only once. Adobe Photoshop and Adobe Illustrator were mentioned in both the first and the second survey in the list of additional software requested.

Table 13. Most commonly used software on the Windows workstations in the second survey.

Software	References
MS Office	9
Matlab	5
Firefox	3
Miktex	2
Maple	2
Adobe Acrobat	1
Lyx	1
Cmsol	1
Adobe Illustrator	1
Unison	1
Thunderbird	1
Winamp	1
PC Suite	1
Jarnal	1
Virtuawin	1
WinaXe	1
Chrome	1
SPSS	1
Statistica	1

Table 14. Additional software requested on the Windows workstations in the second survey.

Software	References
VLC	1
Inkscape	1
Gimp	1
Adobe Photoshop	1
Adobe Illustrator	1
Matlab	1
Mozilla Thunderbird	1
Winrar	1

7.1.4 Administrative systems

There were no significant changes in access to the University's administrative systems between the first and the second survey.

24 respondents (73%) answered that they were able to access the administrative systems from their personal workstations, one (3%) responded that he or she is not able to access them and 8 respondents (24%) stated that they do not know the answer.

One respondent was using the systems from a colleague's workstations, one on the library's workstation and five responded that they used a secretary's workstation.

7.1.5 Printers

Only two respondents (6%) stated that they have a personal printer in their room, compared with seven respondents in the previous survey. The perceived quality of the personal printers decreased from 5.6 to 5.3, but this result is statistically not significant, which is partly caused by the small number of respondents that have personal printers.

The reliability of the network printers rose from 6.1 to 6.7 but this change was not significant. In the open comments printing problems from Windows and lack of duplex printers were both mentioned two times. Problems with the printing to the copying machine were also mentioned two times. One respondent commented about the general low reliability of the network printers, and some users commented about problems or configuration issues with individual printer devices.

Respondents were asked how they agree with the statement "Network printers are close enough to my room". The average of responses to the question was 7.4 on the scale of 1 to 9 where 1 being "Completely disagree" and 9 being "Completely agree". There was very little change from the first survey, where the average of the responses was 7.3.

7.1.6 Library's workstations

15 respondents (45%) had used the computers available in the Department's library. This was a significant decrease from the first survey, where 86% of the respondents had used the computers. From those who had used the computers, 80% used them for scanning documents, 20% to use the administrative systems and 7% to use commercial software installed on the workstations. The usage of the computers had not significantly changed from the first survey.

7.1.7 Scanners

There were no significant changes to the user perception of the scanning possibilities. However, the scanning habits had changed somewhat. 17 respondents (52%) were scanning using the copying machine, 12 respondents (36%) using the library's computers and two respondents (6%) using a co-worker's scanner. The respondents were allowed to select multiple scanning methods. In the "Other" field three respondents (9%) answered that they scan documents at home. In the first survey the most common method used by 66% of the respondents was to scan using the library's workstations and only 28% were using the copying machine. The users have shifted from using the library's workstations to using the copying machine, however, this has not significantly raised their perceived quality of scanners.

7.1.8 Network

The perceived quality of the network services increased from 7.1 to 7.5 and the minimum service level decreased from 7.3 to 6.8, but these changes were not statistically significant. However, the perceived level is above the minimum level in the second survey.

Three respondents (9%) quoted breaks or slowdowns in the network service. Two respondents (6%) said that the network was working well, and there were individual comments about increasing the WLAN coverage area and allowing and allowing more ports from the guest network.

7.1.9 Reliability of services

The changes in the reliability of services can be seen in Figure 12. Some of the perceived reliability measures increased, but none of these improvements were statistically significant. The perceived reliability of the printers and the backup service were still below the minimum level, and the reliability of email and network services were above the minimum level.

7.1.10 Response times

The changes in the perceived levels of response times are presented in Figure 13. There was a statistically significant increase in all of the measured three response times: software installation ($p = 0.000$), general guidance ($p = 0.012$) and hardware problems ($p = 0.003$).

7.1.11 Open comments

The open comment field that was added to the end of the survey produced only few answers. Four respondents mentioned that the IT services have developed in a positive direction, and requests for more home directory quota and Mac-related services were mentioned once.

7.1.12 Documentation

As seen in Figure 13, the perceived quality of documentation improved from 4.9 to 7.1, and is now above the minimum level, but the change was not statistically significant.

7.2 Updated service portfolio

Table 15 presents the current service portfolio after the implemented changes. The network connectivity and Linux workstations were renewed in this study and the results suggest that no further actions are currently required. Windows printing and Windows workstations still need to be renewed, and pressure for this has increased since the user expectations for Windows workstation services have increased. There are no issues found with the guest network, public computers and WWW-services so no actions are needed on them. The scanning system still needs to be upgraded because users are still not satisfied with it. The computing servers currently seem to match the user demand, so no imminent changes are necessary, but the computing power demand from the users and the server load needs to be monitored.

Table 15. Service Portfolio after the implemented changes.

Existing Services	Comment
Linux Printing	No changes needed.
Windows Printing	Needs to renewed; new Windows printing server is needed.
Backup	Needs to be renewed.
Network connectivity	No changes needed.
Guest Network	No changes needed.
Public Computers	No changes needed.
Linux Workstations	Have been upgraded, no further changes needed.
Windows Workstations	Need to be renewed.
Computing servers	Current servers seem to satisfy the demand.
Scanning	Re-engineering needed to better satisfy users.
WWW-services	No changes needed.
Planned Services	
Terminal Server	
Wireless LAN	
Intranet	

8 Discussion

8.1 Action Research methodology

There are elements in Action Research that makes it well suited for information systems research. Firstly, the aim of the research is to improve a problematic situation which is often in line with the information system project objectives. Secondly, the results are practically very relevant and the findings can be hopefully easily transferred to other similar situations.

In this research Action Research methodology was used to combine a body of existing knowledge with a practical problem setting in an organization. In this case there had been no previous studies done on the IT infrastructure. Researchers who initiate Action Research in situations where no previous work is available have to be prepared to use considerable more time to analyze the present situation to properly understand the root causes of dissatisfaction. Initiating research in an environment where previous studies are available, or continuing an existing study with additional iteration is faster because the researchers can more quickly move to the implementation phase of the study.

Another thing that Action Researchers should carefully consider is the number of iterations in a study. In this study only one iteration was conducted, and that iteration contained quite many changes. Having multiple iterations can help to steer the research in a right direction, as the effects of the actions will be assessed in intermediate evaluations. In this study, some actions did not cause a significant increase in user perceptions and having multiple iterations might have provided further insights as to why there was no improvement in these certain areas. On the other hand, having multiple iterations consumes more time of the researchers, because data has to be collected and analyzed after each iteration. With certain type of research actions having multiple iterations can be difficult, for example if implementing an action takes a long time it might not be possible to split the research into multiple iterations.

8.2 Action Research validity

The validity of the research will be evaluated according to the criteria proposed by Nielsen (2007) which were presented in chapter 3.1.2. Each criterion is evaluated here.

Roles

The role of the author of this thesis was to act as an IT support person, at the same time developing new solutions, implementing them and to reflect the actions as a researcher. As Nielsen (2007) says, an action researcher “acts and simultaneously observes himself acting”. The main interaction with the users came from the support and guidance provided for the users. The users gave numerous improvement ideas and suggestions regarding the IT environment.

Documentation

Documentation is a prerequisite for establishing recoverability of the research (Nielsen, 2007).

The situation in which the research was initiated was documented in the chapter 2 of this thesis. Previously there was very little documentation available on the IT environment except the mailing list of the system administrators. At the same time as the author had to track down details of how the systems were configured, they were documented to a wiki-site was set up for the purpose. The implemented changes were described in depth in this thesis and certain technical details that were not considered beneficial to include in this thesis were documented in the wiki site. The surveys used to assess the users' opinions, their design and results are documented in chapters 5 and 7 of this thesis, and the raw data from the surveys is included in appendices 2-4.

Control

There levels of control presented by Nielsen (2007) are control over the initiation of the research, determination of authority and degree of formalization in the contract.

The research was initiated by the Department as they decided that a Master's thesis project should be initiated with the aim of improving the Linux workstations of the Department. Thus the control of initiation was held by the Department's management.

The author of this work had identical authority as the practitioners. The author was permitted to implemented changes in the organization but the senior staff of the Department was consulted before implementing any major changes.

The degree of formalization in the contract between the author and the client organization was low. All the agreements were made verbally and there was no formal statement of the objectives of the project. This gave the author a liberty to steer the improvement initiative in a direction suggested by the user surveys. The Department management did not try to direct the initiative, and the only step that was agreed was that the Linux workstations should be part of the improvement actions.

Usefulness

The usefulness of the findings has been established by surveys that show statistically significant increases in user perception of the service quality. The findings are likely to be useful for researchers and practitioners in other similar situations as well, because the research process and the technical procedures that yielded the results are well documented.

Frameworks

The survey method for measuring IT Service quality was based mainly on the model proposed by Parasuraman et al (1988). The SERVQUAL-model formed the basis for measuring the users' satisfaction.

The IT portfolio management practice was based on the ITIL process (see chapter 4.1.1).

Transferability

Nielsen (2007) prefers the term "transferability" rather than generalizability in describing the transfer of findings to other situations, because the results from action research tend to be concrete and not abstract. The research situation in this work has certain

characteristics that might limit the transferability. Firstly, the client organization is a university department, which might be different from a situation in a corporate environment. Secondly, the user requirements were relatively homogenous, the users shared a core set of software that most people used for the majority of their work and thus the need for special arrangements was relatively low.

8.3 Statistical validity

This chapter evaluates the validity of the statistical analysis and conclusions that were made during the study.

The IT SERVQUAL instrument has faced some criticism regarding its statistical validity. The ambiguity of the expectations gap -construct (see chapter 4.1.5) has been criticized (Van Dyke et al, 1999). The gap scores are not used at all in this study because of their problems with statistical validity and questionable usefulness. In this study I have tried to minimize the ambiguity by explaining as clearly as possible what is meant by the expectations-question and providing an informal scale for the answers. The exact wording of the questionnaire is shown in Appendix 1.

The SERVQUAL-instrument has also been criticized for collecting data in an ordinal scale and processing the data using methods only suitable for data in an interval-scale (Buttle, 1996). Buttle (1996) incorrectly presents that the SERVQUAL data collection is made on a Likert-scale and thus the resulting data is in ordinal scale. However, SERVQUAL does not utilize verbal Likert-scale (with options "Agree", "Strongly agree", etc.) but uses a numerical scale instead. In the medical sciences, for example, it is common to collect subjective data from patients. Under certain situations, the data collected can be considered to be in interval scale (McDowell, 2006). The issue depends on the presentation of the scale and the respondent's psychometric interpretation of the response scale. In this questionnaire, the scale is numerical (from 1 to 9), and the respondent is provided interpretations for the end points of the scale (see Appendix 1). It is believed that this design of the questionnaire leads the respondents to interpret the answer options as a fixed interval scale, and enables us to apply statistical concepts such as mean, variance and the Student's t-test meaningfully on the data. The fact that the data appears to be normally distributed, as tested with Lilliefors test in chapter 7.1, also supports the conclusion that the respondents interpreted the answers to be in an interval scale.

Shasidh et al. (2001) present a list of nine threats to the validity of statistical conclusions. The list of threats is presented here along with analysis how they might affect the conclusions of this study.

1. **Low statistical power.** The low statistical power of a test might lead a researcher to conclude a relationship as insignificant where in reality it is significant. The statistical power is conventionally defined as the probability that a test will reject the null hypothesis when it is in fact false (so called Type I error rate).

The statistical power of the t-test used in this study could have been improved with the pairing of the responses, meaning that the responses in the two surveys from the same respondents could be connected. The paired t-test has higher

statistical power, but in this study it was impractical because I wanted to implement the questionnaires anonymously. The statistical power could be also increased by increasing the number of respondents. The significance level of the tests was set $\alpha = 0.05$ which is a standard practice in social sciences.

- 2. Violated assumptions of statistical tests.** If the assumptions of the used statistical test are violated, the results of the test might be flawed. For example, if the test assumes that errors are independently distributed when in reality they are not, it can introduce severe bias to the standard error estimates can also to the test results.

The Student's t-test assumes that the population data is normally distributed and that the variance of the two distributions is equal. The normality of the sample has been verified using the Lilliefors normality test. Furthermore, the test is quite robust to violations of normality. The similar variance of the responses was checked by studying the histograms of the responses, which confirmed that the responses are approximately similarly distributed and thus have similar variance.

- 3. Fishing and the error rate problem.** The fishing-effect means that the data collection or analysis is performed multiple times, which increases the probability of type 1 error (incorrect rejection of the null hypothesis). This problem can also occur if multiple researchers reanalyze the same data.

In this study the first and the second survey were performed only once, and the complete data set was used for analysis and the analysis was done only once, so it is safe to conclude that this study does not suffer from the fishing-effect.

- 4. Unreliability of measures.** Drawing statistical conclusions from unreliable measures is naturally a risk for the validity of the conclusions. Unreliable measures can produce significant results when the true result is zero or produce zero results when the true results are significant.

The measures used in the statistical analysis of this study are subjective measures of the respondents' satisfaction. Even though references for the end points of the measures were given, the response is always subjective, and different respondents might interpret the answers differently. However, in this study no conclusions are derived from the absolute level of the answers, the user satisfaction is compared to the minimum level reported by the users, and the changes in opinions over time are analyzed. Because of the subjective nature of the study, there is little possibility for improving the measure, so this threat cannot be completely eliminated.

- 5. Restriction of range.** If the measured variables are forced to a narrow range, the variables might be restricted by floor or ceiling effects, which means that the values are clustered near the lowest or highest possible score. Restricting variance of the variable reduces the power of statistical tests.

The range of the responses in the numerical questions was restricted to a range of 1 to 9. This ranged seemed to be wide enough so that enough variance in the answers was reached. Floor or ceiling effects, which mean that the responses are clustered near the lowest or highest possible grade, were not present in the answers.

6. **Unreliability of treatment implementation.** This risk rises from the possibility that the actions of the researchers (treatment) might be implemented differently for different from site to site or from person to person.

In this study, the workstation installations were standardized and their configuration was controlled by a centralized configuration management system, and their implementation can be considered standardized. The main improvements that affected all users were based on solutions that affected all users similarly. However, the variety of solutions and help provided to the users make it possible that some users have received a different level of service than others, and the implementation unreliability cannot be completely eliminated.

7. **Extraneous variance in the experimental setting.** Conclusions about relations between the variables can be inaccurate if something in the experimental setting inflates error.

The setting in this study contained some extraneous elements that might have affected the results. The first factor is the change of IT support personnel. Because the whole IT staff was changed, part of the improved satisfaction might be caused by the change of staff and not by the improved procedures and technical solutions. The second factor is the move of the Department. The new facilities were better equipped and contained an up-to-date networking infrastructure, and this might have also affected the users' perception of the service level.

8. **Heterogeneity of units (respondents).** The heterogeneous properties of the respondents that can affect the causal relationship can increase error in the study if these properties are not taken into account. In other words, if the units are homogenous, it is easier to analyze the effect of the actions on the units.

In this study, I concluded that the users' needs are relatively homogenous and the properties of individual users do not have to be taken into account in the analysis. The users could have been divided into blocks based on e.g., the personnel group that they represent, but in that case the sample sizes would have likely been too small to reach statistically significant conclusions.

9. **Inaccurate effect size estimation.** Using improper methods for estimating the effect size can cause the effect size to be under- or overestimated.

This risk does not affect this study, because the statistical conclusions only aim to establish whether there has been a change in a certain area or not; the size of the effect is not estimated or discussed.

In the terminology used by Shasish et al. (2001), this study does not constitute an *experiment*, because the subjects of the study were not randomly selected to receive a treatment or an alternative treatment. Because this condition is not fulfilled, this study is classified as a *quasi-experiment*. Even though this might reduce the statistical credibility of the study, it is an essential part of action research that the researcher enters a real-life situation and tries to improve the subjects in the situation. Deciding randomly which users receive the benefits of the improvements would be unsuitable for the action research, because it would be likely to create dissatisfaction and even personal conflicts in the organization from the part of the users who do not receive the improvements and have to cope with their old systems just for the sake of statistical validity.

8.4 Changes in the user opinions

The results show that the general perception of the Linux workstation quality increased. Also, the users were more satisfied to the response time with software installation requests. These changes can be most likely attributed to the upgraded operating system and the configuration management tool. The Ubuntu operating system has a user friendly graphical interface and the distribution is frequently upgraded to contain up-to-date software. The new configuration management tool enabled the system administrators to install new software packages quickly and effortlessly, which made it possible to respond swiftly to software installation requests from the users.

Windows workstations were not a part of this improvement project and as expected, the perception of the general quality Windows workstations did not improve during the study. Surprisingly however, the users' minimum level of service for Windows workstations increased. This could possibly be explained by a hypothesis that the users of Windows workstations saw that broad actions were taken to improve the Linux workstations and the Windows users saw that no improvement was happening with Windows workstations and wished that similar action should be taken on Windows systems as well.

Perception of the email service quality increased, which can most likely be attributed to migrating the email system to the University's IT Services. Even if some users had problems during the transition phase, this perceived dissatisfaction was not visible in the survey. The answers to this question might also indicate increased satisfaction to the mailing lists which were also moved to the University's IT Services. Even though the survey question did not directly mention the mailing lists, the respondents might have conceptually combined these two into a same service.

The perceived levels of all three questions relating to the response times (software installation, general guidance and hardware problems) increased. The increased satisfaction to the software installation response times is most likely explained by the new operating system and configuration management tool as stated earlier.

A probable explanation for the change in the perceived response time with hardware problems is the decision of switching to use desktop workstations from a large manufacturer of workstations instead of clone PCs assembled by a local company from PC components. The new PCs proved to be more reliable and they were covered by an on-site repair service. This significantly reduced the time that the system administrators had to use to diagnose and repair workstation hardware problems.

The increase in satisfaction to response time with general guidance cannot be directly linked to any concrete technical changes. The open comments and verbal feedback from the users suggest that the users think that the IT support group has become more accessible and responsive. This is most likely caused by the change of the location of the personnel and the rotation of the IT staff. Previously the IT group was located in a separate wing as the other staff, so that users had to walk to a different wing of the building to reach their offices to communicate face-to-face with them. All of the IT personnel were changed during the project and the attitudes and motivation of the new staff might have effect on the user opinions.

There was no significant improvement in the perceived service quality of network printers. The updated printers completely eliminated the recurring postscript errors and they also had less paper jams. However, these improvements did not cause a significant increase in the user satisfaction. Two black and white printers were replaced, because those were causing most of the problems. This action might have been insufficient for solving the problems. Another possible explanation why the improvement did not cause significant increase in the user satisfaction might be that users have not had enough time to notice improvement in the situation before the second survey took place.

There was also no significant improvement with the perceived quality of scanners. The network scanner was fixed to use a more stable storage space that was easily accessible from both Windows and Linux workstations. One possible explanation for the failure to raise the perceived quality might be that the perceived quality was already quite good in the first place, as it was well over the minimum required level. Similarly to the network printers, another explanation is that the users did not have time to notice the improvement. This is especially possible with the scanners as most users do not seem to use scanners very often.

The user perception to network services showed no statistically significant increase, although the perceived level is now above the minimum required level. This is expected as changes in the network infrastructure have not yet produced noticeable enhancement for the users, because the new network system has only been in use for a few months. Actually, after the move to the new premises there have been more network breaks than usually because of installation work that was done and unexpected problems with new network equipment. In the long run the updated network structure and hardware is expected to bring positive effects to the users.

8.5 Configuration management

The configuration management of the workstations is greatly simplified if the hardware is homogenous. This eliminates the need for configuration exceptions that would be required by special hardware configurations. The greatest benefit is that the installation and re-installation of workstations becomes very easy. The workstations can be reinstalled by installing a disk image to the hard drive or initiating an unattended operating system installation from a removable media or via network boot.

The quick and effortless reinstallation becomes very useful when combined with a practice of keeping all the user data off the workstations hard drives. In the environment of this work, the users were only able to write to the home and project directories which

were located on a file server, and to the */tmp* directory which is automatically emptied on each reboot. Thus the workstations became completely stateless. This made it possible to solve the disrupted operating system state by reinstalling the workstation image to the hard drive, and hardware problems could be easily resolved by changing the workstation into a backup workstation. After the user logged in, all the settings and files were accessible from the user's home directory and the user could immediately continue working.

The experiences from the declarative configuration management method adapted in this work are in line with the literature that was discussed in chapter 4.2.2. The declarative paradigm makes the configuration management substantially easier when compared to the simple file distribution model that was used previously. The systems based on scripting or file distribution can be considered obsolete and based on the literature and experiences in this research the use of declarative configuration management is strongly recommended in workstation configuration management.

The Puppet tool that was selected for use in this study proved to be effective and easy-to-use. The most common actions such as installing software packages and distributing configuration files were easy to implement. However, there were some difficulties with implementing more complex actions. Initiating the distribution upgrade process that was described in chapter 6.2.5 had to be done using a very simplistic method of checking the file */etc/issue* for the current version and then initiating the upgrade through a series of commands. In optimal circumstances the process was completed successfully, but in case something went wrong or the process was interrupted, and this procedure did not provide functionality to recover from the situation. The distribution does not provide a high-level tool that could be used in scripting the upgrade-process, so there should be a functionality included in the configuration management tool or in an operating system script file that checks for different types of error situations and takes appropriate steps to recover the system from them.

Another problematic situation is when the distribution's package management system goes into a conflicted state that prevents installing new packages. In this case, the Puppet attempts to install the missing packages in each run, but all attempts fail and no automatic action is taken to resolve the conflict. The package management system can enter such a state as a result of interrupted installation that can be caused by a system crash or abrupt power down. The APT package management system provides measures from recovering from these types of situations, such as running the command *apt-get -f install* without any further arguments. This causes the APT to try to finish the installation of packages whose installation was interrupted. The problem is that the APT module of Puppet does not apply any measures automatically, and they have to be configured by an administrator. This type of functionality should be included in any Puppet configuration file, otherwise the package manager of the workstations can be stalled and installation of new packages will fail until manual intervention of an administrator.

8.6 Managing IT work

The research demonstrates the importance of managing the IT service portfolio. By restructuring and dropping obsolete services time consuming tasks that the system

administrators had to perform were eliminated. The additional time that was made available could be used to enhance the customer service.

Perhaps the most time frequent operation that was eliminated was the updating of the configuration of the Ethernet switches to contain an up-to-date mapping of the wall sockets for each of the workstations. As described in chapter 6.3.2, this policy was abandoned because it did not provide meaningful administrative or security benefits.

The upgrading of the Linux workstations was the second action that saved system administrators' time. After the new distribution and configuration management tool, solving workstation problems and installing new software became considerably easier. Because the distribution had more up-to-date software, it was easier to solve problems and users had fewer problems in the first place. It was also very quick to respond to software installation requests since nearly all of the requested software was available as ready-made binary packages.

The third action that saved system administrators' time was the transfer of the email service and email list service to be handled by the University's IT Services unit. After this change, the system administrators did not have to solve problems related to these services. The most common requests before the change were requests relating to changing the configuration of an email list and problems related to email routing and delivery.

In this study statistics about the time usage of the system administrators were not collected, the above time saving actions are based on the subjective opinion of the IT administrators. It would be interesting to perform a study where detailed information about system administrators' time usage is collected. Methodology for collecting the data can be challenging, as IT administrators' tasks are often unstructured, overlapping and fragmented as Gonzales et al. (2008) characterize their work.

The experiences of this study suggest that relatively few routine tasks can consume a significant proportion of the administrator's time, and focusing on optimizing these tasks or eliminating them altogether through a SPM process can free up considerable amount of system administrators' time. This is based on the subjective opinions of the IT staff. A new study with rigorous task and time accounting would be needed to get detailed information on how the system administrators' time is spent.

9 Conclusions

This thesis describes a study that was conducted to the IT systems of the BECS Department with the aim of improving the user satisfaction to the IT services. The study was conducted using Action Research methodology. The main result of the study was a significant increase in user satisfaction to Linux workstations.

First, the opinions of the Department staff were analyzed through interviews and a survey. The survey was targeted to users who were found to be dissatisfied with many aspects of the IT services. The services that needed most attention were Linux workstations, network services and the network printers.

The general IT service portfolio was analyzed using the ITIL Service Portfolio Management process. A conclusion was reached that many of the services should be renewed and some of the services were redundant or unnecessary altogether. The actions that were selected to be analyzed in more depth during this improvement initiative were upgrading the Linux workstations and renewing the network structure.

The upgrade of the Linux workstations was started with an analysis of the requirements for the Linux workstation system. Then a list of major Linux distributions was collected and they were compared to the requirements and Ubuntu was considered the most suitable distribution for the Department's needs. A configuration management tool was selected based on the theoretical foundation and the supported feature set of the tool. The selected tool was Puppet, which uses declarative syntax and provides a set of high level directives for expressing the configuration of workstations.

The structure of the Department's internal network was simplified and unnecessary network segments were terminated. The previously used three routers were replaced with one new router and a more modern operating system was selected for easier management of the firewall. The network policy was changed so that the MAC addresses are no longer locked to certain switch ports and users are allowed to connect their workstations to any network socket that is connected to the Department's network. The policy was changed because it caused additional administrative workload for the IT staff, additional nuisance for the users and the security benefits of the policy were marginal because the restriction was very easy to circumvent.

Numerous outdated computation servers were discarded and replaced by a new computation server. Old network printers were discarded and replaced with new ones.

The taken actions were evaluated in a second survey. The perceived level of Linux workstation services and response time to software installation requests showed statistically significant increase. The main cause for these improvements is most likely the upgraded Linux workstations and the new configuration management tool that enabled quick centralized installation of new software on the workstations.

The response time for hardware problems and response time with general guidance also showed a significant increase. This increase is believed to be caused partly by the practice of storing all user data to network drives which makes it possible to rapidly reinstall or

replace a problematic workstation with minimum harm to the user. The improved response times might also be explained by locating the IT staff along with the rest of the staff and the change of the IT personnel.

The perceived level of network printers, scanners and network services did not show statistically significant changes. The reason for this could be that the users have not noticed a change in the services or the improvement actions were noticed but they were not sufficient. After the move to new premises there were breaks in the network service that were caused by the installation and configuration of the new network hardware, which makes it likely that the users have not yet perceived change in the network reliability even if the new arrangement is expected to be technically more robust.

Windows workstations were not part of this improvement project, and as expected, the Windows workstation users did not report significant changes in their perceived level of service. However, the minimum required level of Windows workstation services increased.

The improvement project successfully increased user satisfaction to certain IT services. An IT Service Portfolio was established to manage the IT services offered by the Department. The electronic questionnaire form that was used to perform the user surveys is included as an appendix to this work, as it will be useful in organizing future user surveys. The configuration management file for the Puppet software is also included as an appendix, to serve as documentation and to help to create a baseline configuration in similar operating environments.

The practices that improved the user satisfaction in this study should be tested in different situations after which they could possibly be generalized. Action Research seems to be a well-suited method for information system research, which should be applied more widely in IT improvement research initiatives.

This study utilized the Service Portfolio Management practices of ITIL. However, there is little research or case descriptions available on applying the various IT management frameworks into practice. Further research should be done in this area to establish the usefulness and the generality of these frameworks. The IT frameworks are quite general in nature and case studies of their application would be highly valued by practitioners.

The nature of work and time usage of system administrators is also a potential area for new research. Due to the fragmented nature of system administration and user support work, it is difficult to measure how the time is actually used. This research suggests that time of the system administrators can be spent on maintaining services and systems that provide relatively little value for the end users, and user satisfaction can be increased by aligning the work priorities in line with the organization's objectives. Looking deeper into the IT staff time usage patterns could reveal further insight into managing the organization's IT function.

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Appendix 1: The Questionnaire

For all the questions that addressed the perceived service quality on scale from 1 to 9, the following help text was provided for the respondent:

When considering the level of service, think 1 as the level where the service can be barely said to exist and 9 as the level where all service requirements have been fulfilled.

- **Minimum level of service** is the minimum level that you are willing to accept.
- **Desired level of service** is the level of service that you would like to have.
- **Perception of the LCE's level of service** is your personal assessment of the current level of service.

General info

1. Which option best describes your role in the department?

Please choose **only one** of the following:

- Professor
- Senior researcher
- Administrative staff
- Researcher
- Research Student

Email

2. E-mail quality

When it comes to e-mail...

- My minimum level of service is: [0-9]
- My desired level of service is: [0-9]
- My perception of the LCE's level of service is: [0-9]

3. How much of your work-related emails do you handle with the laboratory's email service?

The laboratory's email addresses end with @lce.hut.fi. The emails for the addresses that end with @cc.hut.fi or @hut.fi are not provided by the laboratory.

[The respondents could answer to the question from 0% to 100% with 10% increments.]

4. Why you are not handling all of your work-related email with the laboratory's service?

[This question was only shown if the respondent answered less than 100% to the question 3.]

5. Do you have any other additional comments or suggestions for improvement regarding the laboratory's e-mail service?

Linux workstations

6. Do you use a Linux workstation?

Please choose **only one** of the following:

- I don't use Linux workstations at all.
- I use Linux workstations at least sometimes.

[Further questions regarding the Linux workstations were presented only if the respondent answered "I use Linux workstations at least sometimes" to question 4.]

7 Linux workstation quality

When it comes to providing Linux workstations...

- My minimum level of service is: [0-9]
- My desired level of service is: [0-9]
- My perception of the LCE's level of service is: [0-9]

8. What software do you use most at the moment on the Linux workstations? (Open question)

9. What additional software should be available on the Linux workstations? (Open question)

10. Do you have any other additional comments or suggestions for improvement regarding the Linux workstations? (Open question)

Windows workstations

11. Do you use a Microsoft Windows workstation?

Please choose **only one** of the following:

- I don't use Windows workstations at all.
- I use Windows workstations at least sometimes.

[Further questions regarding the Windows workstations were presented only if the respondent answered "I use Windows workstations at least sometimes" to question 9.]

12. Windows workstations

When it comes to providing Windows workstations...

- My minimum level of service is: [0-9]
- My desired level of service is: [0-9]
- My perception of the LCE's level of service is: [0-9]

13. What software do you use most at the moment on the Windows workstations? (Open question)

14. What additional software should be available on the Windows workstations? (Open question)

15. Do you have any other additional comments or suggestions for improvement regarding the Windows workstations? (Open question)

Administrative IT-systems

16. Can you access the administrative IT-systems (HALLI, etc) from your own desktop computer provided by the laboratory?

Please choose **only one** of the following:

- Yes
- No
- I don't know

17. Where are you using the administrative IT-systems (HALLI, etc)?

[This question was presented to the respondent only if question 14 was answered 'No' or 'I don't know'.]

Please choose **all** that apply:

- At my colleague's workstation
- At the laboratory's library
- At a secretary's workstation
- Other:

Printers

18. Do you have own printer in your room?

Please choose **only one** of the following:

- Yes
- No

19. Printers

[This question was presented only if the respondent answered 'Yes' to question 16.]

When it comes to providing **personal** printers...

- My minimum level of service is: [0-9]
- My desired level of service is: [0-9]
- My perception of the LCE's level of service is: [0-9]

20. Printers

When it comes to providing **network printers**...

- My minimum level of service is: [0-9]

- My desired level of service is: [0-9]
- My perception of the LCE's level of service is: [0-9]

21. Do you have any other additional comments or suggestions for improvement regarding the printers? (Open question)

22. What do you think about the location of the network printers?

"Network printers are close enough to my room.": [1-9]

1 = Completely disagree

9 = Completely agree

Library's computers

23. Have you used the computers available at the laboratory's library?

Please choose **only one** of the following:

- Yes
- No
- I don't know

24. Why have you used the computers in the laboratory's library?

[This question was presented only if the respondent answered 'Yes' to question 21.]

Please choose **all** that apply:

- To scan documents
- To use administrative IT-systems (HALLI, etc.)
- To use commercial software installed on the computers
- Other:

Scanners

25. Scanners

When it comes to providing scanners...

- My minimum level of service is: [0-9]
- My desired level of service is: [0-9]
- My perception of the LCE's level of service is: [0-9]

26. Where do you usually scan documents?

- At the copying machine
- At the library
- At a co-worker's scanner
- Other:

27. Please describe any problems you might have had when scanning documents (Open question)

28. Network connectivity

When it comes to providing network connectivity...

- My minimum level of service is: [0-9]
- My desired level of service is: [0-9]
- My perception of the LCE's level of service is: [0-9]

29. Do you have any other additional comments or suggestions for improvement regarding the network connectivity? (Open question)

Service Quality

30. The following questions assess the service quality perceived by the users.

The following three questions were presented for each of the service areas:

- My minimum level of service is: [0-9]
- My desired level of service is: [0-9]
- My perception of the LCE's level of service is: [0-9]

Service areas:

- Reliability of the network
- Reliability of the email service
- Reliability of the backup service
- Reliability of the printers
- Response time with installation of new software
- Response time with general guidance
- Response time with hardware problems (workstation breaks down, etc.)
- Documentation

Appendix 2: The results of the first survey

The answers to the questions related to the service levels are listed in Appendix 4. Answers to other quantitative questions of the first survey are listed in this Appendix.

Total number of responses for the first survey was 28.

1. Which option best describes your role in the department?

Professor	2
Senior researcher	6
Researcher	12
Research Student	7
Administrative staff	1

2. How much of your work-related emails do you handle with the laboratory's email service?

$$\bar{x} = 59.29, \sigma = 40.36$$

6. Do you use a Linux workstation?

I don't use Linux workstations at all.	5
I use Linux workstations at least sometimes.	23

11. Do you use a Microsoft Windows workstation?

I don't use Windows workstations at all.	11
I use Windows workstations at least sometimes.	17

16. Can you access the administrative IT-systems (HALLI, etc) from your own desktop computer provided by the laboratory?

Yes	19
No	3
I don't know	6

17. Where are you using the administrative IT-systems (HALLI, etc)?

At my colleague's workstation	0
At the laboratory's library	4
At a secretary's workstation	4
Other	2

22. What do you think about the location of the network printers?

$$\bar{x} = 7.32, \sigma = 2.04$$

23. Have you used the computers available at the laboratory's library?

Yes	25
No	2
I don't know	1

24. Why have you used the computers in the laboratory's library?

To scan documents	20
To use administrative IT-systems (HALLI, etc.)	10
To use commercial software installed on the computers	5
Other	8

26. Where do you usually scan documents?

At the copying machine	8
At the library	19
At a co-worker's scanner	2
Other	5

Appendix 3: The results of the second survey

The answers to the questions related to the service levels are listed in Appendix 4. Answers to other quantitative questions of the second survey are listed in this Appendix.

Total number of responses for the second survey was 33.

1. Which option best describes your role in the department?

Professor	0
Senior researcher	3
Researcher	18
Research Student	10
Administrative staff	2

6. Do you use a Linux workstation?

I don't use Linux workstations at all.	4
I use Linux workstations at least sometimes.	29

11. Do you use a Microsoft Windows workstation?

I don't use Windows workstations at all.	20
I use Windows workstations at least sometimes.	13

16. Can you access the administrative IT-systems (HALLI, etc) from your own desktop computer provided by the laboratory?

Yes	24
No	1
I don't know	8

17. Where are you using the administrative IT-systems (HALLI, etc)?

At my colleague's workstation	1
At the laboratory's library	1
At a secretary's workstation	4
Other	3

22. What do you think about the location of the network printers?

$\bar{x} = 7.39, \sigma = 2.03$

23. Have you used the computers available at the laboratory's library?

Yes	15
No	18

I don't know	0
--------------	---

24. Why have you used the computers in the laboratory's library?

To scan documents	12
To use administrative IT-systems (HALLI, etc.)	3
To use commercial software installed on the computers	1
Other	5

26. Where do you usually scan documents?

At the copying machine	17
At the library	12
At a co-worker's scanner	2
Other	8

Appendix 4: Changes in service quality descriptors between the surveys

The cells that have been changed with significance level of $p < 0.05$ are marked with green color.

	First survey			Second survey			P(T<=t) two-tail		
	Minimum	Required	Perceived	Minimum	Required	Perceived	Minimum	Required	Perceived
Quality of services									
Email	5.11	7.79	5.75	5.88	8.09	6.79	0.127	0.328	0.020
Linux workstations	5.65	8.04	5.45	5.93	8.17	7.31	0.555	0.708	0.000
Windows workstations	5.39	7.59	5.59	6.77	8.38	6.77	0.014	0.100	0.069
Personal printers	5.43	7.00	5.57	5.33	6.33	5.33	0.966	0.753	0.910
Network printers	6.25	7.93	6.07	5.85	7.70	6.73	0.382	0.489	0.150
Scanners	4.82	6.54	5.86	4.85	6.91	6.18	0.959	0.430	0.463
Network connections	7.07	8.50	6.96	7.00	8.55	7.52	0.868	0.850	0.097
Reliability									
Network	7.25	8.50	7.07	6.82	8.36	7.48	0.293	0.639	0.208
Email	7.25	8.46	7.25	6.97	8.00	7.48	0.494	0.133	0.466
Backup	7.11	8.36	6.64	6.73	7.97	7.48	0.482	0.289	0.093
Printers	6.54	8.18	5.89	6.24	7.70	6.73	0.492	0.128	0.059
Response times									
Software installation	5.93	7.64	4.89	5.48	7.30	7.12	0.327	0.356	0.000
General guidance	5.75	7.71	6.18	5.73	7.33	7.33	0.956	0.301	0.012
Hardware problems	6.64	8.39	6.39	6.64	8.18	7.70	0.986	0.425	0.003
Quality									
Documentation	5.39	7.39	4.64	5.12	7.00	5.33	0.586	0.361	0.219

Appendix 5: Comparison table of Linux distributions

Distribution name	Ubuntu	openSUSE	Fedora	Debian	Mandriva	Linux mint	PCLinuxOS	Slackware	Gentoo	CentOS
Stable release	9.04	11.1	11	5.0	2009.1	7	2009.1	12.2	2008.0	5.3
Previous major stable release	8.10	11.0	10	4.0	2009	6	2007	12.1	2007.0	4.7
Architectures										
i386	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
x86_64	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Package Management	DEB	RPM	RPM	DEB	RPM	DEB	RPM	TGZ	SRC	RPM
Supported upgrade mechanism from previous stable release	Automatic	Upgrade-install	Upgrade-install	Automatic	Automatic	Reinstall	Rolling upgrade	Automatic	Rolling upgrade	Reinstall
Driver package availability										
Nvidia	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	No
ATI	Yes	No	No	Yes	Yes	Yes	Yes	No	No	No

Appendix 6: The Puppet configuration file

```
# /etc/puppet/manifests/site.pp

import "classes/*"
import "resolver"
import "hostname"

Package {
  provider => $operatingsystem ? {
    debian => apt,
    ubuntu => apt,
    redhat => up2date
  }
}

# Line-function from Puppet Recipes
define line($file, $line, $ensure = 'present') {
  case $ensure {
    default : { err ( "unknown ensure value ${ensure}" ) }
    present: {
      exec { "/bin/echo '${line}' >> '${file}':":
        unless => "/bin/grep -qFx '${line}' '${file}'"
      }
    }
    absent: {
      exec { "/usr/bin/perl -ni -e 'print unless /\^\Q${line}\E\$/ ' '${file}':":
        onlyif => "/bin/grep -qFx '${line}' '${file}'"
      }
    }
  }
}

node base-linux {
  include aptkeys

  resolv_conf { "example":
    domainname => "becs.hut.fi",
    searchpath => ['becs.hut.fi', 'lce.hut.fi'],
    nameservers => ['130.233.224.1', '130.233.224.13'],
  }

  # Packages to install
  package { "exim4": ensure => installed }
  package { "emacs22": ensure => installed }
  package { "ssh": ensure => installed }
  package { "tcsh": ensure => installed }
  package { "portmap": ensure => installed }
  package { "autofs": ensure => installed }
  package { "cvs": ensure => installed }
  package { "python-numpy": ensure => installed }
  package { "python-scipy": ensure => installed }
  package { "ipython": ensure => installed }
  package { "python-matplotlib": ensure => installed }
  package { "python-sympy": ensure => installed }
  package { "python-tk": ensure => installed }
  package { "inkscape": ensure => installed }
  package { "swig": ensure => installed }
  package { "thunderbird": ensure => installed }
  package { "texlive-full": ensure => installed }
  package { "dstat": ensure => installed }
  package { "xemacs21": ensure => installed }
  package { "subversion": ensure => installed }
  package { "mailutils": ensure => installed }
  package { "flashplugin-installer": ensure => installed }
  package { "gv": ensure => installed }
  package { "xjed": ensure => installed }
  package { "gnuplot-x11": ensure => installed }
  package { "a2ps": ensure => installed }
  package { "lyx": ensure => installed }
  package { "zsh": ensure => installed }
  package { "ddd": ensure => installed }
```

```

package { "gststreamer0.10-ffmpeg": ensure => installed }
package { "gststreamer0.10-plugins-bad": ensure => installed }
package { "gststreamer0.10-plugins-bad-multiverse": ensure => installed }
package { "gststreamer0.10-plugins-ugly": ensure => installed }
package { "gststreamer0.10-plugins-ugly-multiverse": ensure => installed }
package { "ttf-mscorefonts-installer": ensure => installed }
package { "unrar": ensure => installed }
package { "valgrind": ensure => installed }
package { "vim-latexsuite": ensure => installed }
package { "xemacs21-supportel": ensure => installed }
package { "xemacs21-basesupport-el": ensure => installed }
package { "puppet": ensure => installed }
package { "pdftk": ensure => installed }
package { "xfig": ensure => installed }
package { "octave3.0": ensure => installed }
package { "pyxplot": ensure => installed }
package { "mutt": ensure => installed }
package { "mc": ensure => installed }
package { "r-base": ensure => installed }
package { "python-dev": ensure => installed }
package { "libboost-dev": ensure => installed }
package { "git-gui": ensure => installed }
package { "gnuit": ensure => installed }
package { "enscript": ensure => installed }
package { "octave-signal": ensure => installed }
package { "feh": ensure => installed }
package { "quota": ensure => installed }
package { "rubber": ensure => installed }
package { "pidgin": ensure => installed }
package { "referencer": ensure => installed }
package { "eclipse": ensure => installed }
package { "libgfortran2": ensure => installed }
package { "ispell": ensure => installed }
package { "gcc-4.1": ensure => installed }
package { "gcc-4.2": ensure => installed }
package { "gcc-4.3": ensure => installed }
package { "gcc-4.4": ensure => installed }
package { "gfortran-4.2": ensure => installed }
package { "gfortran-4.3": ensure => installed }
package { "gfortran-4.4": ensure => installed }
package { "tcl8.5-dev": ensure => installed }
package { "libnetcdf-dev": ensure => installed }
package { "mendeleydesktop": ensure => installed }
#package { "libvtk5.2": ensure => installed }
#package { "libqt3-mt": ensure => installed }
#package { "libqwt-dev": ensure => installed }
package { "paraview": ensure => installed }
package { "fsl": ensure => installed }

# Packages to remove
package { "apparmor": ensure => purged }
package { "network-manager": ensure => purged }

# Medibuntu packages
package { "acoread": ensure => installed, require => Exec[medibuntu-keyring] }
package { "skype": ensure => installed , require => Exec[medibuntu-keyring] }
package { "googleearth":
  ensure => installed,
  require => [
    Exec[medibuntu-keyring],
    File["/var/local/googleearth.debconf"]
  ],
  responsefile => "/var/local/googleearth.debconf"
}

file { "/var/local/googleearth.debconf":
  source => "puppet:///files/googleearth.debconf",
  mode => 600,
  backup => false,
}

# For MNE-suite
package { "liblapack-dev": ensure => installed }
package { "libplot2c2": ensure => installed }
package { "libtiff4": ensure => installed }
package { "libmotif3": ensure => installed }
file { "/usr/lib/libblas.so.3":

```

```

    ensure => symlink,
    replace => false,
    target => "/usr/lib/libblas.so.3gf"
}
file { "/usr/lib/liblapack.so.3":
    ensure => symlink,
    replace => false,
    target => "/usr/lib/liblapack.so.3gf"
}
file { "/usr/lib/libtiff.so.3":
    ensure => symlink,
    replace => false,
    target => "/usr/lib/libtiff.so.4"
}

file { "/var/local/nis.debconf":
    source => "puppet:///files/nis.debconf",
    mode => 600,
    backup => false,
}

package { "nis": ensure => installed,
    responsefile => "/var/local/nis.debconf",
    require => File["/var/local/nis.debconf"]
}

file { "/etc/nsswitch.conf":
    mode => 644,
    owner => root,
    group => root,
    source => "puppet:///files/nsswitch.conf"
}

# Printer configuration
file { "/etc/cups/client.conf":
    mode => 644,
    owner => root,
    group => root,
    source => "puppet:///files/client.conf"
}

# Matlab installation
file { "/usr/local/bin/matlab":
    ensure => symlink,
    replace => true,
    target => "/proj/matlab/matlab79/bin/matlab"
}

# Matlab installation
file { "/usr/local/bin/mcc":
    ensure => symlink,
    replace => true,
    target => "/proj/matlab/matlab78/bin/mcc"
}

# Matlab installation
file { "/usr/local/bin/mbuild":
    ensure => symlink,
    replace => true,
    target => "/proj/matlab/matlab78/bin/mbuild"
}

# Sudoers-file
file { "/etc/sudoers":
    ensure => present
}

line { sudoers_rootauth:
    file => "/etc/sudoers",
    line => "%rootauth ALL=(ALL) ALL"
}

# sux-command
file { "/usr/local/bin/sux":

```

```

mode => 755,
owner => root,
group => root,
source => "puppet:///files/sux"
}

# Mail configuration
file { "/etc/exim4/update-exim4.conf.conf":
  mode => 644,
  owner => root,
  group => root,
  source => "puppet:///files/update-exim4.conf.conf",
  require => [ Package["mailutils"], Package["exim4"] ]
}

exec { exim4-reload:
  command => "/etc/init.d/exim4 reload",
  logoutput => true,
  onlyif => "/bin/false",
  subscribe => file[ "/etc/exim4/update-exim4.conf.conf" ],
  require => Package["mailutils"]
}

# APT source list
file { "/etc/apt/sources.list":
  mode => 644,
  owner => root,
  group => root,
  source => "puppet:///files/sources.list.karmic"
}

exec{"/usr/bin/apt-get update":
  refreshonly => true,
  subscribe => File[ "/etc/apt/sources.list" ],
  require => File[ "/etc/apt/sources.list" ],
}

exec{"/usr/bin/apt-get --force-yes -y install medibuntu-keyring":
  require => File[ "/etc/apt/sources.list" ],
  creates => "/usr/share/keyrings/medibuntu-keyring.gpg",
  notify => Exec[ "/usr/bin/apt-get update" ],
  alias => medibuntu-keyring
}

exec{"/usr/bin/apt-get -y upgrade":
  require => File[ "/etc/apt/sources.list" ],
}

# Disable PC speaker
file { "/etc/modprobe.d/blacklist.conf":
  ensure => present
}

line { disable_pcsprk:
  file => "/etc/modprobe.d/blacklist.conf",
  line => "blacklist pcsprk"
}

# Java
file { "/var/local/java.debconf":
  source => "puppet:///files/java.debconf",
  mode => 600,
  backup => false,
}

package { "sun-java6-bin":
  ensure => installed,
  responsefile => "/var/local/java.debconf",
  require => File[ "/var/local/java.debconf" ]
}
package { "sun-java6-plugin":
  ensure => installed,
  require => Package[ "sun-java6-bin" ]
}
package { "sun-java6-jdk":
  ensure => installed,
  require => Package[ "sun-java6-bin" ]
}

```

```

}

file { ["/etc/dpkg/dpkg.cfg":
  source => "puppet:///files/dpkg.cfg",
  mode => 644,
  backup => false,
}

}

# Class for Fujitsu Celsius W370 machines
node nvidia-ubuntu inherits base-linux {
  exec { ubuntu-upgrade:
    command => ["/usr/bin/apt-get update; DEBIAN_FRONTEND=noninteractive
/usr/bin/apt-get --force-yes -fuy dist-upgrade; DEBIAN_FRONTEND=noninteractive
/usr/bin/dpkg --configure -a",
    logoutput => true,
    onlyif => ["/bin/grep 9.04 /etc/issue",
    timeout => 7200,
    require => [ File["/etc/dpkg/dpkg.cfg"], File["/etc/apt/sources.list" ]
  ]
}
}

```