Master’s Thesis Template

Master’s Thesis

By

Author and Author

(Template by Peter Nilsson, updated 2015-11-26)

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|  |  | Another logo, e.g. company or other university. Check if they allow it! |

2015

Abstract

Here are my most important results described. The abstract is usually without abbreviations and references.

Acknowledgments

This Master’s thesis would not exist without the support and guidance of …

Name of the Authors

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Preface (if necessary)

This statement is a requirement if there are more than one thesis worker:

In this thesis work, author 1 has been working with X, author 2 has been working with Y, and part Z has been done together.

Here, scientific and popular papers contributing to this thesis can be listed, submitted papers as well.

List of figures (not necessary)

First time: Go to the *References* tab. Press *Insert Table of Figures*. Press *Options* and choose Style *New Figure Caption*. Press *NO* on *Do you want to replace* … if it appears.

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List of acronyms (not necessary)

CDMA Code Division Multiple Access

CMOS Complementary Metal Oxide Semiconductor

GSM Global System for Mobile Communications

PDA Personal Digital Assistant

UWB Ultra Wide Band Technology

Popular Science Summary

This thesis work is about …

Introduction

This chapter gives a brief description of the project …

Note that each new chapter should appear on an odd page (even if it is not so in this document)

Put pictures of Green Tech.

BS consumes a lot of energy 80% Fethwiser [1]

Refs from goal doc

Winner and traffic model

Poisson distribution user setup and

Ericsson also did it[2]

Quote Mills paper and cisco paper from Maria’s research paper. (teen paper yahin mil gaye refs ke liye)

Cite all the 10 top google paper on the Heterogenous networks Energy Efficiency a nad earth power model

Follow Intro background Motivation Theory Base Stations macro pico Energy/Power Model Earth Previous work (Fettweis, Henrik forssell, Gunther how much power, Laetitia ka paper, saare paper jo tu padhe unka result conclusion quote kar, feature saving Kihl ki quote kar, )

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Result and Conclusion

Future Work

1.1 Introduction [3]

The global mobile communication industry is growing rapidly. Today there are already more than 4 billion mobile phone subscribers worldwide [1], more than half the entire population of the planet. Obviously, this growth is accompanied by an increased energy consumption of mobile networks. Global warming and heightened concerns for the environment of the planet require a special focus on the energy efficiency of these systems [2]. The EARTH1 project [3] is a concerted effort to achieve this goal and as part of its objectives, a holistic framework is developed to evaluate and compare the energy efficiency of several design approaches of wireless cellular communication networks. For the quantification of energy savings in wireless networks, the power consumption of the entire system needs to be captured and an appropriate energy efficiency evaluation framework (E3F) is to be defined. The EARTH E3F presented in Section 1.2 provides the key levers to facilitate the assessment of the overall energy efficiency of cellular networks over a whole country. The E3F primarily builds on well-established methodology for radio network performance evaluation developed in 3GPP; the most important addendums, introduced in Sections 1.3 and 1.4, are to add a sophisticated power model of the base stations 1 EU funded research project EARTH (Energy Aware Radio and neTwork tecHnologies), FP7- ICT-2009-4-247733-EARTH, Jan. 2010 to June 2012. https://www.ict-earth.eu 1 2 Chapter 1. How Much Energy is Needed to Run a Wireless Network? Global Metric (long term, large scale) Large scale area & Long term traffic load Metric (short term scenario specific) S ll l (short term, scenario specific) system SmallͲscale, shortͲterm system level evaluations BS power P model Pin performance evaluations mobile channel P model out mobile Figure 1.1 EARTH Energy efficiency evaluation framework (E3F). (BSs) as well as a large-scale long-term traffic model extension to existing 3GPP traffic scenarios. Then, using the metrics defined in Section 1.5, in Section 1.6 the E 3F is applied in order to provide an assessment of the BS energy efficiency of a 3GPP LTE network deployed within an average European country. The energy efficiency of LTE is compared to that of already deployed networks is discussed in Section 1.7, and targets for the energy efficiency of future wireless networks are given.

*A. Power consumption model* [2]

To evaluate and compare the power consumption of the

reference network and the heterogeneous network, the power

model developed by the european project EARTH for year

2010 state-of-the-art base stations has been used [5]. Note that

a micro node in EARTH corresponds to a pico node here.

In the EARTH model, the power consumption consists of a

fixed part that is consumed in idle mode and a variable part

based on the traffic load served by the base station. The output

RF power *Pout* scales with the number of frequency resources

scheduled at the given time. If all frequency resources are

scheduled at a certain time, *Pout* reaches the maximum power

*Pmax*. This power model is an approximation of the measured

power consumption of a BS transceiver [5] as depicted in Fig.

1 for a macro BS that handles three sectors.

The modelled power consumption *Pin* of a node is expressed

as

*Pin* =

􀀀\_\_

*P*0 +Δ*p ・ Pout* if 0 *≤ Pout ≤ Pmax*

*Pμ* if *Pout* = 0 and micro DTX on

*Ps* if *Pout* = 0 and sleep mode on

The power model parameters are given in Table I. The values

for the micro DTX mode were obtained from [9]. For the pico

node sleep mode, a remaining power consumption of 10W is

assumed at the pico node. This is aligned with [10].

III. ENERGY EFFICIENCY SCHEMES [2]

A radio access node, i.e. a base station, is composed of

different components: power amplifier (PA), radio frequency

(RF) transceiver, the base band (BB) unit and finally the

power supply (DC) and cooling (CO). Basically in current

base stations, all components contribute to the overall power

consumption of the node even during the idle time when there

is no data nor signalling transmission to perform, as shown

in Fig. 1 [5]. The two energy efficiency features considered

here are based on the deactivation of certain base station

components during the idle time of a BS. Thus, a lower power

consumption in idle mode can be achieved. This puts however

new requirements on the hardware of a BS that may not be

met by current BSs but could be taken into account when

designing future base stations.

Macro and pico nodes have different roles in the network

and therefore shall meet different requirements concerning

their availability. Consequently different kinds of sleep mode

can be applied to them.

Macro nodes provide the basic coverage meaning they must

be always reachable by potential users. For that purpose,

even if there is no active user in a macro cell and no

data transmission is scheduled, the macro node still needs

to broadcast regularly cell-specific signalling information and

monitor the uplink to identify if a user wants to establish a

connection. A sleep mode based on the complete shut down of

a macro base station is thus hardly conceivable. Even if several

RATs are implemented at a macro node, the radio components

0 0*.*2 0*.*4 0*.*6 0*.*8 1

0

250

500

750

1*,*000

1*,*250

1*,*500

Resource utilization

Power consumption [W]

PA

CO

DC

BB

RF

Fig. 1. Power consumption breakdown of a 3-sector macro BS

related to at least one RAT should remain active so as to supply

mobile communication coverage.

Pico nodes are redundant nodes deployed to help the macro

node handle high traffic demand at certain points in time. A

larger variety of sleep mode mechanisms are hence applicable

to pico nodes.

*A. Micro DTX*

Micro Discontinuous Transmission (DTX) is a sleep mode

technique, introduced in [6] and [3], and which is suitable

for an Orthogonal frequency-division multiplexing (OFDM)

based system such as LTE. The idea is to deactivate the power

amplifier of a LTE base station (BS) during empty OFDM

symbols. In LTE an OFDM symbol with a normal cyclic prefix

length lasts 71.4*μ*s. So, the micro DTX assumes a quick

reactivation of the power amplifier in the order of less than

one OFDM symbol according to [6], [3].

The main advantage of this technique is to exploit very

short idle periods of the BS. These are expected to occur more

often in the future as there will be an increased amount of

traffic generated by means of regular small packets, e.g. social

networking type of traffic.

To enable a quick return to the normal operation mode, the

cell should remain visible to the legacy users. Therefore the

cell-specific signaling still need to be transmitted in certain

OFDM symbols even when there is no data transmission. In

particular the cell-specific reference symbols (CRS) which are

transmitted regularly limit the time where micro DTX can

be applied. Basically, a BS can go to the micro DTX mode

and reduces its power consumption only between two CRS

transmissions. For LTE, the highest possible micro DTX ratio

would be of 10/14, since from the 14 OFDM symbols that

compose each normal subframe, 4 OFDM symbols contain

CRS in case of a transmission with up to two antenna ports.

*B. Pico node sleep mode*

In addition to the micro DTX, the pico nodes introduced

in a heterogeneous network can be subject to a deeper sleep

mode technique, in which not only the PA but also the RF and

BB components of a pico node are deactivated. The inactive

state here is assumed to last in the order of a few hundred

milliseconds.

When applying this mode the control signaling can not be

transmitted by the pico node anymore, and therefore the pico

cell becomes invisible to the user. So all remaining users must

be handed over to another cell before entering the sleep mode.

This kind of deep sleep mode is possible for a pico node

in a heterogeneous network, as the overlaid macro cell that

provides the basic coverage can take care of remaining users.

Several implementations of the pico node sleep mode are

possible depending on the criteria used to trigger the reactivation,

and also on the level of integration of the pico nodes

into the macro network. For instance one could think of a

pico node sleep mode in which an uplink (UL) signal strength

sensor remains active and triggers the pico node reactivation

when the measured UL signal strength exceeds a threshold.

This indicates the presence of a user in the surroundings of

the pico node.

In this paper we consider a heterogeneous network in which

the pico nodes are able to tightly cooperate with the overlaid

macro node. A good connection between the macro and its

pico nodes is thus required. But such a setup offers a more

flexible pico node reactivation that can be based on more

elaborate criterion. In the following the macro node controls

the activation and deactivation of its underlaid pico nodes and

takes its decision based on the traffic load in the different

cell layers. This enables to react quickly to the traffic demand

variation and avoids the re-activation of pico nodes for users

that would not benefit from a higher available bitrate, e.g.

VoIP users. Moreover, compared to the pico node activation

based on uplink signal measurement, the present scheme does

not require long measurement filtering before triggering the

activation.

As shown in Fig. 2, the macro node regularly checks the

traffic load level in its cell. If the traffic load exceeds a certain

threshold, all pico nodes under its control are activated. An

activation delay of 100ms is assumed here. Note that a macro

node equipment is serving all sectors (or cells) of a site.

Here we assume that the macro node activates the pico nodes

located in the macro sector where the load is increasing. After

triggering the pico node activation, the macro node requests all

users to measure the signals from neighboring cells. This may

result in a handover of some users towards the pico nodes.

The activated pico nodes regularly monitor the served traffic.

If the traffic load remains low after a certain delay, *δactive*,

these pico nodes autonomously go back to sleep, see Fig. 3.

**The Framework:**

**WINNER**[**3]**

Energy Efficiency Evaluation Framework (E3F) The widely accepted state-of-the-art to evaluate the performance of a wireless network is to simulate the relevant aspects of the radio access network (RAN) at system level. The computed results are, e.g. the system throughput measured in bit/s, quality of service (QoS) metrics, and fairness in terms of cell-edge user throughput. In order to ensure that the results generated by different RAN system simulation tools are comparable, well defined reference systems and scenarios are specified. This is an outcome of extensive consensus work from standardization bodies, such as 3GPP [4], and international research projects, such as the EU project Wireless World Initiative New Radio (WINNER) [5], with partners from academia as well as from industry. The most recent example is the global effort in ITU to evaluate system proposals for compliance with IMT-Advanced requirements [6]. In that direction, the EARTH E3F builds on the 3GPP evaluation framework for LTE [4].

Power Model

Power Model [3]

1.3 Power Model This section provides a power model for various types of LTE Base Stations. The power model constitutes the interface between component and system level, which allows quantifying how energy savings on specific components enhance the energy efficiency at the node and network level. 1.3.1 Base Station Power Consumption Breakdown Fig. 1.2 shows a simplified block diagram of a complete BS that can be generalized to all BS types, including macro, micro, pico and femto BSs. A BS consists of multiple transceivers (TRXs), each of which is serving one transmit antenna element. A TRX comprises a Power Amplifier (PA), a Radio Frequency (RF) small-signal transceiver section, a baseband (BB) interface including a receiver (uplink) and transmitter (downlink) section, a DC-DC power supply, an active cooling system, and an AC-DC unit (mains supply) for connection to the electrical power grid. In the following the various TRX parts are analyzed. Antenna Interface: The influence of the antenna type on power efficiency is modeled by a certain amount of losses, including the feeder, antenna band-pass filters, duplexers, and matching components. Since macro BS sites are often situated at different physical locations as the antennas a feeder loss of about σfeed=3 dB needs to be added. The feeder loss of a macro BS may be mitigated by introducing a remote radio head (RRH), where the PA is mounted at the same

physical location as the transmit antenna. Likewise, feeder losses for smaller BS types are typically negligible. Power Amplifier (PA): Typically, the most efficient PA operating point is close to the maximum output power (near saturation). Unfortunately, non-linear effects and OFDM modulation with non-constant envelope signals force the power amplifier to operate in a more linear region, i.e., 6 to 12 dB below saturation [7]. This prevents Adjacent Channel Interference (ACI) due to non-linear distortions, and therefore avoids performance degradation at the receiver. However, this high operating back-off gives rise to poor power efficiency ηPA, which translates to a high power consumption PPA. Digital techniques such as clipping and digital pre-distortion [8, 9] in combination with Doherty PAs [7] improve the power efficiency and linearizes the PA, while keeping ACI under control, but require an extra feedback for pre-distortion and significant additional signal processing [9]. While these techniques are necessary in macro and micro BSs, they are not used in smaller BSs, as the PA power consumption accounts for a smaller percentage of the power breakdown, allowing for a higher operating back-off. The Small-Signal RF Transceiver (RF-TRX) comprises a receiver and a transmitter for uplink (UL) and downlink (DL) communication. The linearity and blocking requirements of the RF-TRX may differ significantly depending on the BS type, and so its architecture. Typically, low-IF (Intermediate-Frequency) or super-heterodyne architectures are the preferred choice for macro/micro BSs, whereas a simpler zero-IF architecture are sufficient for pico/femto BSs [10]. Parameters with highest impact on the RF-TRX energy consumption, PRF, are the required bandwidth, the allowable Signal-to-Noise And Distortion ratio (SiNAD), the resolution of the analogue-to-digital conversion, and the number of antenna elements for transmission and/or reception. Baseband (BB) Interface: The baseband engine (performing digital signal processing) carries out digital up/down-conversion, including filtering, FFT/IFFT for OFDM, modulation/demodulation, digital-pre-distortion (only in DL and for large BSs), signal detection (synchronization, channel estimation, equalization, compensation of RF non-idealities), and channel coding/decoding. For large BSs the digital baseband also includes the power consumed by the serial link to the backbone network. Finally, platform control and MAC operation add a further power consumer (control processor). The silicon technology significantly affects the power consumption PBB of the BB interface. This technology scaling is incorporated into the power model by extrapolating on the International Technology Roadmap for Semiconductors (ITRS). The ITRS anticipates that silicon technology is replaced by a new generation every 2 years, each time doubling the active power efficiency but multiplying by 3 the leakage [11]. The increasing leakage puts a limit on the power reduction that can be achieved through technology scaling. Apart from the technology, the main parameters that affect the BB power consumption are related to the signal bandwidth, number of antennas and the applied signal process-

ing algorithms. While the consumed power scales linearly with the bandwidth; MIMO signal detection scales more than linearly with the number of antennas. Power Supply and Cooling: Losses incurred by DC-DC power supply, mains supply and active cooling scale linearly with the power consumption of the other components, and may be approximated by the loss factors σDC, σMS, and σcool, respectively. Note that active cooling is only applicable to macro BSs, and is omitted in smaller BS types. Moreover, for RRHs active cooling is also obsolete, since the PA is cooled by natural air circulation, and the removal of feeder losses σfeed allow for a lower PA power consumption, PPA = Pout ηPA·(1−σfeed) , where ηPA denotes the PA power efficiency. Assuming that the BS power consumption grows proportionally with the number of transceiver chains NTRX, the breakdown of the BS power consumption at maximum load, Pout=Pmax, amounts to Pin = NTRX · Pmax ηPA·(1−σfeed) + PRF + PBB (1−σDC)(1−σMS)(1−σcool) (1.1) The efficiency is defined by η = Pout/Pin, whereas the loss factor is defined by σ = 1−η. Note that the maximum RF output power per transmit antenna, Pmax, is measured at the input of the antenna element, so that losses due to the antenna interface (other than feeder losses) are not included in the power breakdown. Table 1.1 summarizes the state of the art power consumption of various LTE BS types as of the year 2010. By introducing RRHs in macro BS sites, so that feeder losses σfeed and active cooling are avoided by mounting the PA close to the transmit antenna, the power savings exceed 40%.

The initial steps, based on new guidelines 2014, are basically as follows:

1. Students bring the form "Anmälan - examensarbete" to utbildningsservice. The program planners are
   1. Nora Ekdahl for C and D,
   2. Åsa Vestergren for E, BME,
   3. Helene von Wachenfelt for MSOC, and MWIR,
   4. Johan Hugosson for F and N.
2. The program planner checks that the student has the required prerequisites and signs a dedicated part of the form. Master students bring the form to the international office and have it signed there.
3. When the form has been signed, the work with constructing the goal document can begin.
4. When the goal document has been approved by both the examiner and the supervisor, the project can be registered. This is done by handing the form to Marianne Greiff Svensson.

The most important part above is that no actual work should start before utbildningsservice (international office) has checked the formal prerequisites.

Note that you cannot be registered to the thesis work before these initial steps are done and you will not get access to the thesis rooms before you are registered.

The goal document should include a project plan, as shown in Fig. 1. The figure is just to give a hint, i.e. it must be more detailed.

|  |
| --- |
| Project plan:  Task 1: 19th Jan – 16th Feb:   * Literature study * Theoretical investigation of … * …   Task 2: 17th Feb – 20th March:   * Simulation of important algorithms in e.g. Matlab and C++ … * Error analysis … * …   Task 3: 21st March – 20th April   * Implementation of selected algorithms * …   Task 4: 21st April – 20th May   * Validation of the simulation results from the implementation * …   Task 5, 21st May – 20th June   * Completion of the thesis report that of course have been written since the first day of the thesis project. |

1. The project plan for the thesis work.

A Gantt chart is a nice presentation form to give an overview over the project plan as suggested in Fig. 2.



1. A Gantt chart over the project plan.

To be continued …

Cross references

Figures, tables, and captions

Table 1 shows the objects in Fig. 3 and in Table 2, the objects in Fig. 4 are shown. Note that all figures and tables should be referred in the text, after appearance, like in this sentence.

1. The objects before eclipse.

|  |  |  |
| --- | --- | --- |
| A | B | C |

Using the IEEE standard, the table head font is in Small Caps using the font Times New Roman. Reformat the style to change.

1. The objects during eclipse.

|  |  |  |
| --- | --- | --- |
| 1 | 2 | 3 |

In Fig. 3, there are three objects before the eclipse. In Fig. 4, there are three objects after overshadow.

Fig 1.wmf

1. Three objects before the Eclipse.

The figure captions, in IEEE style, are written as “Fig. 1.” A figure is often referred in the text as “Fig. 1”, i.e. not as “Figure 1”. Whatever you choose, be consequent!



1. Three objects after the Eclipse.

Headings and Table of Contents

In the Microsoft Word Home tab you can press the small arrow to the right under styles to see all styles for this document. Some of the styles are new which can be useful in this document. The headings, i.e., “Heading 1 chapter”, “Heading 2”, and “Heading 3”, are only slightly modified, mainly formatting.

To be able to generate a Table of Contents, you need styles for the different levels for the chapter and sections, see the styles *New Heading 1*, *New Heading 2*, and *New Heading 3*, in the styles menu. For unnumbered headings, use the style *New Heading No Numbering*. The unnumbered headings can be used for the abstract, acknowledgements, references, etc. To update the Table of Contents, go to the Table of contents and right click on one of the lines and click “Update field”.

To make a cross reference to a heading, for instance section 3.2, click the *References* tab followed by *Cross-reference* in the *Captions* group. In the *Cross-reference* window, choose *Paragraph number* and mark *which numbered item* you want, see Fig. 5a. Press the *Insert* button.

Cross references to figures and tables

To make a figure or table caption that is useful for cross references, *New Figure Caption* or *New Table Caption* in the *Styles* menu can be used. A cross reference is done by clicking the *References* tab followed by *Cross-reference* in the *Captions* group. In the *Cross-reference* window, choose *Paragraph number* and mark *which numbered item* you want, as shown in Fig. 5b.

|  |  |
| --- | --- |
| (a) | (b) |

1. Reference to a heading in (a) and to a figure in (b).

Cross-references to references and equations

To make a reference list, place the cursor at the end of the document, type “References” or “Bibliography”, click on *New Heading No Numbering* in the *Styles* menu, press the return key, click on *New Reference List* in the *Styles* menu and add references after that. In the text, insert a reference, e.g. [5], by using *Cross-Reference* as shown in Fig. 6a.

References to equations are trickier. When adding an equation number, a 1-row 2-column table is to prefer since the equation number is right adjusted and the equation is not, see Table 3. Adding an equation number is done by clicking the *References* tab followed by *Insert Caption* in the *Captions* group and klick *OK*, see Fig. 6b.

1. Table for equation numbering

|  |  |
| --- | --- |
|  | (1) |

For some reason, the equation number will not stay in the table cell and there will not be any parentheses. Add parentheses and move the number to the table. In the following, copy and paste the table for new equations.

|  |  |
| --- | --- |
| (a) | (b) |

1. Reference to a Reference in (a) and to an Equation in (b).

Cross references to (2) and (3), will thus look like (2) and (3).

|  |  |
| --- | --- |
|  | (2) |
|  | (3) |

References and equations

Follow the reference style for books [1], conference papers [2], and journals [3], when referring to a bibliography item. Note that the style differs between [1], [2], and [3]. There should not be any bibliography items that do not appear the text. If possible, avoid references to web-pages since they often become out of date. References are preferably not placed in abstracts, captions, headings, etc., only in the body text. Note that the references should be numbered in the order they appear.

If you take a copy of an original picture from a book, internet, etc. or if you for some reason rewrite it but “keep the content,” you can refer to it in the text like – there are no evidence for the double eclipse theory [5]. Another option is to refer directly in the figure like, see Fig. 4. To my knowledge, you have no obligation to ask permission from the original source, as long as your publication is not commercial.

Equations

All equations should be referred in the text, usually on the IEEE form: “The function is shown in (1)”, not as “The function is shown in equation (1)”, or “The function is shown in equ. (1)”. The only exception is when the sentence starts with a reference, i.e. “Equation (1), shows the function” is correct but not “(1), shows the function” in the beginning of a sentence.

|  |  |
| --- | --- |
|  | (4) |

It can be feasible to use automatic numbering of references and equations as well. Note that the references and equations should be numbered in the order they appear.

Variables are in most cases written in italics, however not numbers and parentheses, which should be written with italics and roman (non-italics) for the numbers, like the variable *a*1(*k*), see (1). Matrices should be written in bold, but not in italics, like **A**, **H**, and **X**. Variables in digital design are large signal parameters. They are usually written with capitals, e.g. *VDD*, *VGS*, *ID* etc. A style with roman subscripts is also practiced, e.g. *V*DD, *V*GS, *I*D. Analog parameters are often small signal variables written as *vds*, *vgs*, *id* etc.

Unit values and units are written without space, in the IEEE style, like 3V, 4mW, and 2µA. However, this is in the contrary to the SI standard [6]. The SI standard seems to be the most common style. The recommendation is thus to be consequent! Note that the units are in non-italics. Values like 35cm x 48cm, 1MHz to 10MHz, and 123g ± 2g are preferred, but not 35 x 48cm, 35 x 48cm2, 1 to 10MHz, and 123 ± 2g.

Update Field

When changes are done in captions and cross references, the numbering might need an update. That can be done by right clicking in the text of the caption or cross reference. F9 updates the field as well and CTRL+a followed by F9 update all fields in the document.

To do a table of figures, click “Insert Table of Figures” in the “Captions” group, which will give the following result:

[Fig. 1. The project plan for the thesis work. 15](#_Toc436313882)

[Fig. 2. A Gantt chart over the project plan. 15](#_Toc436313883)

[Fig. 3. Three objects before the Eclipse. 16](#_Toc436313884)

[Fig. 4. Three objects after the Eclipse. 17](#_Toc436313885)

[Fig. 5. Reference to a heading in (a) and to a figure in (b). 18](#_Toc436313886)

[Fig. 6. Reference to a Reference in (a) and to an Equation in (b). 19](#_Toc436313887)

[Fig. 7. A figure with too small text 24](#_Toc436313888)

[Fig. 8. An example on a figure, which is not acceptable. 24](#_Toc436313889)

If anyone knows a better way to make cross references, I would be happy if you let me know!

About writing a Master’s Thesis

Format

The format of the thesis is 16.9 x 23.9 cm, like this template. The margins should be 2 cm on all sides. The text is preferably aligned to both right and left margins. The print will be two-sided, which affects the pagination, chapter pages, etc. That is, all page numbers cannot be to the right or to the left. They should be centered or alternating. Furthermore, if the first page of a chapter happens to be placed on a left page, a blank page should be inserted so that it will be placed on a right page. The front and back cover is designed by the printing office. Note that the thesis will be printed in black and white. A reasonable number of pages are around 50 to 100. The font is preferably 11pt Times New Roman, with single line spacing.

Hints about the writing

These hints are based on experiences that have been drawn from many first drafts of master’s theses. It is appreciated if you check them before you hand in your first draft.

In the area of Electrical Engineering, American English is commonly used.

The forms can’t, haven’t etc. are not used in technical writing. It should be cannot, have not etc.

Sentences should not begin with “So”, “And”, or “But”. “However,” can sometimes replace “But”. The word “so” should be excluded in the text as well since it is more like “spoken language”.

In American English, several listed possibilities should be written “a, b, and c”, note the comma after b, but not “a, b and c”, which is British English.

The words “I” and “we” can be used but not too often.

Avoid statements like “as described above”. It is better to write “as described in section x.y” or “as described on page z.”

Abbreviations should be defined first time they are used on the form “Device Under Test (DUT)” not “DUT (Device Under Test)”. It is also convenient for the reader have them redefined a few times later in the text.

The form for your work should be written as “… which **is** implemented …”, but when referring to another work the form should be as “… which **was** implemented by Smith”

A comma should separate in the case of “which” such as “A new method, which is good for …”, but not in the case of “that” like “A new method that is good for …”

Avoid expressions like “It is obvious that …”, “The rest is trivial”, “It is clear that …,” etc. especially if it is not like that.

Compared to or compared with? “Compared to” is the most commonly used when comparing statistical facts, results, etc. such as “Architecture A consumes 10mW, which is lower compared to architecture B that consumes 20mW.” “Compared with” is used for generalizations, such as “Compared with students in general; we are studying much more at home”.

To use “a” for consonants and “an” for vowels depends on how the word sounds, which in most cases are how it is written. However, a word like young is written “a young woman” and FFT is written “an FFT is used”.

Hyphens: When hyphenating a row, next row should start with a consonant followed by a vowel. Like syllabification can be hyphenated in many places, syl-la-bi-fi-ca-tion. The exception is when it is a compound word, like look-up table or astro-physics.

To be continued …

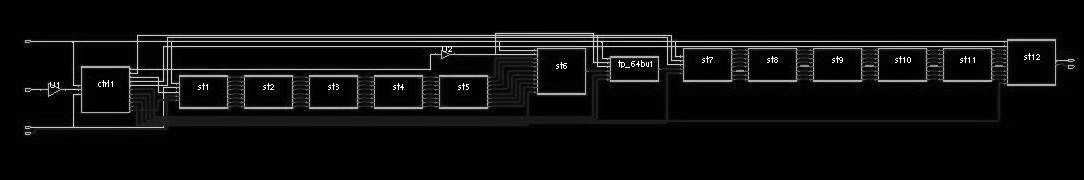
Figures

Fig. 5 shows a diagram, which is not acceptable. The text and the numbers on the axes are too small.



1. A figure with too small text

Fig. 6 show another figure taken direct from an Electronic design automation (EDA) tool. It is very hard to follow the block diagram. Often it is better to draw it by hand in black on white background.



1. An example on a figure, which is not acceptable.

Should it be one or two thesis students?

It is OK to be one or two master’s students in a thesis project. Two is to prefer since the project benefits from the interaction with each other. However, in the case of two students it is important to state how the work has been divided in the thesis, see the preface.

The presentation

Presentation

The presentation should **NOT** take more than 20 minutes. That means a maximum of 20 slides. Do a dry run in front of your friends before the presentation. Some hints:

* Start with a presentation of yourself.
* Content list can be used but it is not necessary. An alternative is to start by shortly answer the questions:
  + What?
  + Why?
  + How?
* Stand up and use the pointer.
* Switch the slides yourself.
* Talk in front of the audience.
* Do not read directly from a manuscript or the slides.

Opposition

You need to act as an opponent on another thesis work. It does not have to be in the same area as yours but it can be in the same area. To be approved on the opposition, you should ask about 5 relevant questions about the work. It should not be on the level “Here is a miss spelling.” Comments like that are appreciated and can be given to the presenter in person afterwards.

There can be opponents on your presentation but that is not a requirement.

The procedure

The usual procedure is like:

The supervisor or examiner takes a few minutes to present you.

The thesis worker(s) presents the work within 20 minutes.

The opponents, if any, ask their questions.

The rest of the audience can ask questions.

The examiner decides if you are approved on the presentation.

Hints about the slides

* All backgrounds are preferably white. Background color and patterns should be avoided.
* Colors can preferably be used to increase the clarity. Green color and light colors should be avoided.
* Animations can be used if it increases the clarity.
* Do not use too much text on the slides. It is better to split the slide into two.
* Figures are often better than text.
* Arial and Verdana are fonts that are recommended.
  + 36 to 44 pt for titles
  + 36 pt for sub-titles
  + 28 pt for major bullets
  + 24 pt for indented bullets
  + 24 pt (minimum) for text on graphs and figures.

Presenting results: Humans cannot understand more than two digits very easily [7]. Results in a table etc. should therefore be rounded. However, problems might arise when for instance percentages do not sum up to 100. This is often solved by adding or subtracting a value ε which is rounded again [7]. Table III shows an example. Note that in the thesis, the number of digits can be longer but only if they are significant.

1. Example of rounding percentages

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Value | Rounded | Add ε = 0.01 | Rounded |
| A | 40.43 | 40 | 40.44 | 40 |
| B | 32.47 | 32 | 32.48 | 32 |
| C | 16.99 | 17 | 17.00 | 17 |
| D | 9.49 | 9 | 9.50 | 10 |
| E | 0.62 | 1 | 0.63 | 1 |
| Total (%) | 100 | 99 | 100.05 | 100 |

Academic honesty

Note that this chapter should not be in the thesis! It is just for information about what is allowed and not.

Every year the Disciplinary Committee of Lund University convicts and suspends 30-40 students because of plagiarism or other kinds of cheating. A fairly large number of all students that are caught for plagiarism at Lund University are exchange or master students from foreign countries. Exchange or master students are not more willing to cheat, but we are certain that because of different traditions at some universities, students might be caught cheating because of the very strict rules at Lund University.

What is plagiarism?

Plagiarism is the adoption or reproduction of ideas, words or statements of another person without acknowledgment of the original author or creator.

Three quick examples of plagiarism:

A false claim that you have written a paper, when it is in fact another student who has done all work. It is considered as plagiarism even if the other student has given his/her permission.

If you rewrite a section from a book/article/website without mentioning that the information is from that source.

To copy a section of a book/article/website without mentioning that the information is copied from that source.

How does Lund University work with plagiarism?

Lund University has a long experience of working against plagiarism. All mentors and teachers are educated to look for signs of plagiarism in the students’ work. As a complement Lund University also uses complex computer software to scan all essays to find traces of plagiarism.

What does Lund University require from you?

First of all, Lund University recommends you to pay attention to all information regarding academic writing that can be found on the university homepage (www.lu.se) and at the webpage of your specific department. You must always state the source when using other people’s work in your own text, regardless if the source is a book, a magazine article, the Internet or even a verbal communication. Any departure from this rule will be reported to the vice-chancellor who then reports to the Disciplinary Committee (Disciplinnämnden) at Lund University.

As long as you take notice of the rules of academic writing and implement these methods in your work you will not only be free of plagiarism, but also be able to publish a better essay. It is in your very best interest to read about academic writing and work in that manner.

Source: Lund University

More information is given in [5].

Results

A summary of your results is presented here.

Conclusions

A short summary of your work is presented here.

Future work

Here are your thoughts about a future continuation of your work.

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Appendix A: Extended material

Some extra information for readers who would like more.