

# Title Template for Degree project/Thesis (Arial 28/30 point size, bold)

SUBTITLE - Arial 16 / 19 pt

AUTHOR FIRST NAME AND SURNAME - Arial 16 / 19 pt



**KTH ROYAL INSTITUTE OF TECHNOLOGY  
*INFORMATION AND COMMUNICATION TECHNOLOGY***

Abstract

Write an abstract. Introduce the subject area for the project and describe the problems that are solved and described in the thesis. Present how the problems have been solved, methods used and present results for the project.

The presentation of the results should be the main part of the abstract. Use about ½ A4-page.

With the rapid development of the Internet of Things, Wireless Sensor Networks (WSNs) are deployed increasingly all over the world, providing, among other things, data that can help increase sustainable development. The characteristics of WSNs, however, demand that special care is taken in the design of communication models and communication protocols. WSN’s are resource restrained in respect to memory, processing power as well as

Keywords

Abstract

Svensk version av abstract – samma titel på svenska som på engelska.

Nyckelord

Table of Contents - Title (Arial 14/ 16 point size, bold, after effects (ae)=18 point size)

Two different styles:

KTH Rubrik 1 (Arial 12/14 pt, fet, af=12 pt, ae=12 pt)....................................... 1

KTH Rubrik 2 (Arial 10/13 pt, fet, af=12 pt, ae=4 pt) .................................... 1

KTH Rubrik 3 (Arial 10/13 pt, fet, af=12 pt, ae=3 pt) ................................ 1

1 KTH nRubrik 1 (samma som Rubrik 1, fast numrerad) ............................. 2

1.1 KTH nRubrik 2 (samma som Rubrik 2, fast numrerad) .................... 2

1.1.1 KTH nRubrik 3 (samma som Rubrik 3, fast numrerad) .............. 2

<Example>

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**Title 1 (Ariel 12/14 point size, Bold, af = 12 point size, ae = 12 point size)**

**1. Introduction**

Text (Georgia 10/13 point size, af = 0, ae = point size)

**Title 2 (Ariel 10/13 point size, Bold, af = 12 , ae = 4 point size), for example**

**1.2 Background / Bakgrund**

Text (Georgia 10/13 point size, af = 0, ae = point size)

**Title 3 (Ariel 10/13 point size, Bold, af = 12 , ae = 3 point size), for example:**

**1.2.1 The company X**

Text (Georgia 10/13 point size, af = 0, ae = point size)

*Title 4 (Ariel 10/13 point size, Italic, af = 12 , ae = 2 point size), for example*

*1.2.1.1 Company X’s requirements*

Text (Georgia 10/13 point size, af = 0, ae = point size)

###### To create a cover for your thesis

All degree project reports are to have uniform covers. The graphic elements of the covers vary however. Degree project reports have red elements.

Using this link, you can create your own cover to ex-job and print it in a regular printer [play-1.sys.kth.se:9001](http://play-1.sys.kth.se:9001/)

More information, see:

<https://intra.kth.se/en/administration/kommunikation/mallar/avhandlingarochexamensarbeten/skapa-omslag-till-ditt-exjobb-1.479838>

<AN EXAMPLE>

# Introduction

Provide a general introduction to the area for the degree project. Use references!

## Background

Present the background for the area. Give the context by explaining the parts that are needed to understand the degree project and thesis. (Still, keep in mind that this is an introductory part, which does not require too detailed description).

* Sensor-based networks can help improve sustainability
  + GreenIoT is one example
* To improve sustainability, the WSN need, among other things, efficient protocols, to decrease the number of packet transmissions.
* A protocol model we want to use is the ‘publish-subscribe’ method since it doesn’t require sensors to be always on
  + There are several protocols for constrained devices, the most poular being
    - MQTT
    - CoAP
  + However, not as many ‘publish-subscribe’ protocols.
  + CoAP is probably preferable to MQTT because it was originally designed for constrained devices
  + Our task is to continue the work of Jussi Haikara in implementing the IETF RFC draft that describes a CoAP ‘publish-subscribe’ extension to the CoAP protocol.

##### Use references

Detailed description of the area should be moved to Chapter 2, where detailed information about background is given together with related work.

## Problem

Present the problems found in the area. Preferable use and end this section with a question as a problem statement.

How can a CoAP pub/sub broker be implemented? What obstacles do we face along the way?

* Will a CoAP pubsub broker be more efficient than a MQTT pubsub broker?
* How shall it be implemented?
  + In C
  + C++
  + Java
  + Why or why not?
    - Resource constrained broker or not?
      * Kind of but not as much as the clients that use Contiki.

##### Use references

Preferable, state the problem, to be solved, as a question. Do not use a question that can be answered with yes and/or no.

## Purpose

The purpose of the degree project/thesis is the purpose of the written material, i.e., the thesis. The thesis presents the work / discusses / illustrates and so on.

It is not “The project is about” even though this can be included in the purpose. If so, state the purpose of the project *after* purpose of the thesis).

* The purpose of the written report
  + To provide a comparison between MQTT and CoAP pubsub protocols, discussing pros and cons of each.
  + To discuss pros and cons of how to implement a protocol extensions
    - Which libraries we used and why
    - Which programming language we used and why

## Goal

The goal means the goal of the degree project. Present following: the goal(s), deliverables and results of the project.

* To provide a more efficient broker in the GreenIoT network that could also be used in other WSNs.

### Benefits, Ethics and Sustainability

Describe who will benefit from the degree project, the ethical issues (what ethical problems can arise) and the sustainability aspects of the project.

Use references!

## Methodology / Methods

Introduce, theoretically, the methodologies and methods that can be used in a project and, then, select and introduce the methodologies and methods that are used in the degree project. Must be described on the level that is enough to understand the contents of the thesis.

##### Use references!

Preferably, the philosophical assumptions, research methods, and research approaches are presented here.

Detailed description of these methodologies and methods should be presented in Chapter 3. In chapter 3, the focus could be research strategies, data collection, data analysis, and quality assurance.

## Delimitations (Avgränsningar, swe)

Explain the delimitations. These are all the things that could affect the study if they were examined and included in the degree project.

Use references!

## Outline (Disposition)

In text, describe what is presented in Chapters 2 and forward. Exclude the first chapter and references as well as appendix.

# <Theoretic Background> Use a self-explaining title

In this chapter, a **detailed description about background** of the degree project is presented together with **related work.** Discuss what is found **usefu**l and what is **less usefu**l. Use valid arguments.

Explain what and how prior work / prior research will be applied on or used in the degree project /work (described in this thesis). Explain why and what is not used in the degree project and give valid reasons for rejecting the work/research.

Use references!

The Internet of Things (IoT) is a rapidly developing field within networking that poses its own challenges compared with more traditional networking. The primary difference between IoT and traditional networking are the devices that are connected. The idea with IoT is to not only connect computers, smartphones and so on, but to also connect all kinds of ‘things’ from houses and fridges down to lightbulbs. One field within the IoT is Wireless Sensor Networks (WSNs) where sensors are connected to the Internet to be able to provide data of interest for further analysis. These sensors may be used to collect weather data, air pollution data, water quality data and many other sorts of data. WSN’s may be used in a variety of ways, but one interesting way is in gathering pollution data in cities to help them to be able to become more sustainable by using the data to better plan infrastructure and transportation. This is exactly what is happening in the GreenIoT project which is being run in the city of Uppsala in Sweden. A system of WSN’s could be a part in making a city ‘smart’ and environmentally sustainable.

It is important that the sensors are placed in exactly those places where data is actually measured. This may result in sensors being placed in remote, rural and difficult-to-access places. Furthermore, the sensors used are oftentimes very resource-constrained. They are often low on memory, both RAM and ROM, they use 8-bit microcontrollers and they are low on power. The characteristics of the devices themselves also put special demands on the networks in which they are deployed. Because of the low-power, networks need to be very efficient with their energy use. Furthermore, it is also important, when using ICT to improve sustainability, to not induce unnecessary energy use by the hardware.

Therefore, in view of the built-in characteristics of WSNs as well as the wish not to use more energy than needed, all parts of a WSN need to be optimized as to not consume more resources than needed. One part of this optimization is of course to include hardware that use as little energy as possible, but it just as important to use the hardware in a resource efficient way.

The communication model within a WSN and the communication protocols used are essential in reducing energy use. In traditional networking, the client-server model is the most prevalent where a server is always on and ready to answer any inquiries from a client. When using WSNs in measuring air pollution data, for instance, one wants to be able to read the sensor data with frequent intervals. But the sensors are resource-constrained, maybe battery-powered, and should not be used more than necessary. Therefore, the traditional client-server model is not optimal and instead a publish-subscribe (pub/sub) model of communication is preferable.

In the pub/sub model of communication, there is an intermediary server added in the communication between two entities. That intermediary is called ‘broker’ and is a server that is always on. Instead of having clients directly inquiring data from a sensor, clients ‘subscribe’ to specific ‘topics’ provided by the broker, for example “temperature.” The intermediary broker removes the need for direct communication between client and broker. The sensor can wake up and send data whenever it is ready and sleep in between. It is the responsibility of the broker to forward data to subscribing clients. So far, the communication model.

However, not only is the communication model of importance when energy use needs to be minimized but also the protocols used in that communication. Depending on the application protocol, packet sizes will vary in length, retransmission procedures will vary, and the complexity of the protocol will also vary. The goal is to have as small packets as possible with as few retransmissions as possible while still providing an acceptable rate of packets reaching their final destination and also not having the protocol be more complex than necessary.

For resource constrained environments, there are not that many candidates of choice if one wants to use the pub/sub model of communication. So far, only the MQTT-SN protocol provides this functionality. However, the original MQTT is old and has been adapted and tweaked to be able to be used in a pub/sub environment. It is overly complex and also requires TCP as its transport protocol which, because of its realiable transmission services, will result in perhaps more retransmissions than might be acceptable when wanting to conserve energy.

The more recent Constrained Applications Protocol (CoAP) however, is a protocol developed specifically for resource constrained environments such as WSN’s. It has been standardized by the Internet Engineering Taskforce (IETF) and is in use extensively already. However, the standard does not yet provide pub/sub functionality, although a pub/sub extension to CoAP is currently under development. The CoAP protocol together with its pub/sub extension provides the benefits of being similar to the commonly used HTTP protocol, using methods such as GET and POST. It is explicitly stated that a goal is to provide familiarity for the user. Also, CoAP uses the UDP transport protocol by default and only implements some basic mechanisms of reliability on top of that protocol, thereby reducing network traffic.

As of yet, a complete implementation of a CoAP pub/sub broker has only been done in Erlang (??) which is of limited use in a more resource constrained setting. Therefore, an implementation of a CoAP pub/sub broker in C++ is here being presented along with a description of the problems and obstacles encountered when making the implementation. The work of this implementation builds on previous work by Jussi Haikara where the client side of the broker was implemented in the Contiki operating system, but because of time constraints, the broker was left to be implemented.

Why do we want to implement a CoAP pub/sub broker? What has been done before? What is the background needed to understand what we are talking about?

* Sensor-based networks can help improve sustainability
  + GreenIoT is one example
* To improve sustainability, the WSN need, among other things, efficient protocols, to decrease the number of packet transmissions.
* A protocol model we want to use is the ‘publish-subscribe’ method since it doesn’t require sensors to be always on
  + There are several protocols for constrained devices, the most poular being
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    - CoAP
  + However, not as many ‘publish-subscribe’ protocols.
  + CoAP is probably preferable to MQTT because it was originally designed for constrained devices
  + Our task is to continue the work of Jussi Haikara in implementing the IETF RFC draft that describes a CoAP ‘publish-subscribe’ extension to the CoAP protocol.

## Wireless sensor-based networks (WSNs) and their specific characteristics

Resource restrained, batteries, remote areas.

## GreenIoT – WSNs in the context of sustainable development

WSN’s used in the context of sustainable development. An example is the GreenIoT in which this specific implementation will be used.

## Resource-constrained environments need efficient protocols

## Previous work and why a CoAP pub/sub broker implementation is needed

## Use headings to break the text

Never use subtitles after each other without text in between the sections.

If figures are used, write Figure 1 in text to refer to the figure.

THE FIGURE / PICTURE

Figure 1. Text

If tables are used, refer to the table by Table 1.

Table 1. Text for the table

THE TABLE

Figures and Tables are numbered independently.

# <Engineering-related content, Methodologies and Methods> Use a self-explaining title

Describe the engineering-related contents (preferably with models) and the research methodology and methods that are used in the degree project.

When working on implementing the CoAP pub/sub broker, we followed the following steps in the order as listed below:

1. Litterature study:

First, relevant literature was studied. Jussi Haikara’s report on implementing a pub/sub client was read. Otherwise, primarily different RFC’s was used to provide relevant information for the project, such as RFC7252 (CoAP), RFC6690 (CoRE) and of course the CoAP pub/sub draft. But also literature about the GreenIoT project along with other literature providing background information was read.

2. Study of existing CoAP implementations:

After having a sufficient background and understanding of CoAP and CoAP pub/sub, different implementations of the CoAP protocol was studied and it was determined whether to build our own implementation of both CoAP and CoAP pub/sub or to use an existing implementation. Existing libraries were compared based on the following criteria:

* Programming language
* Ease of use
* Functionality
* Reliability.

Some libraries were selected and tried out with short examples.

3. Implementation:

After a suitable library had been chosen, implementation was started, building the CoAP pub/sub by adding one functionality at a time. The order of implementing the CoAP function set was chosen in such a way that it would be easy to add on functionality. The order chosen was: DISCOVERY, CREATE, PUBLISH, SUBSCRIBE, UNSUBSCRIBE, DELETE.

## Engineering-related and scientific content:

Applying engineering-related and scientific skills; modeling, analyzing, developing, and evaluating engineering-related and scientific content; correct choice of methods based on problem formulation; consciousness of aspects relating to society and ethics (if applicable).

As mentioned earlier, give a theoretical description of methodologies and methods and how these are applied in the degree project.

# (5 - 6) <The work> Use a self-explaining title

Describe the degree project.

Make bullets of what has been done so far and in what way

# (7) <Result> Use a self-explaining title

Describe the results of the degree project.

# (7 - 8) <Conclusions> Use a self-explaining title

Describe the conclusions (reflect on the whole introduction given in Chapter 1).

Discuss the positive effects and the drawbacks.

Describe the evaluation of the results of the degree project.

Describe valid future work.

References

IEEE Editorial Style Manual:

<http://www.ieee.org/documents/stylemanual.pdf>

KTH Templates for style:

[http://intra.kth.se/polopoly\_fs/1.391641!/Menu/general/column-content/attachment/KTH%20Formatmallar\_text.pdf](http://intra.kth.se/polopoly_fs/1.391641!/Menu/general/column-content/attachment/KTH Formatmallar_text.pdf)

Use one style (preferably Oxford) and be consistent. See IEEE Editorial Style Manual.

Appendix A

Appendix B

To create a cover for the thesis, use the link:

http://intra.kth.se/kth-cover/