# Final Task

Simulation and Modelling
of Communication Networks

Institute of Communication Networks, TUHH

Summer Term 2018
July 3rd

## 1 Introduction

You are hired as experts on communication networks by a team of researchers working on autonomous vehicles. They have recently built a test laboratory with a test range, but they are still unsure about the communication part of their technology.

In Section 2 you can find a detailed description of the scenario at hand. Section 3 follows with the task you are hired to do. The description and task are a general formulation of the problem; it is up to you to retrieve those pieces of information out of it that are essential to the solution, as well as deciding which specific aspects you will look into in your modelling and simulation, how you will analyse, and how you can deduce a meaningful conclusion from your results.

## 2 Problem Description

A laboratory on autonomous vehicle technology wants to evaluate autonomous truck clustering. A truck cluster consists of a single cluster head and several cluster member trucks.

A special truck in front acts as cluster head. You can assume cluster member trucks to be randomly positioned behind the cluster head in an area of $30\,\mathrm{m} \times 100\,\mathrm{m}$. The cluster head controls the platoon behaviour and gives control instructions through wireless communication. For this it has an access point mounted on its roof. To prevent packet loss the access point packet queue is rather generously sized and can hold up to 50 packets.

The access point is connected through a 100 Mbit/s Ethernet connection to the cluster head router, which in turn is connected via a Long Term Evolution (LTE) radio link to the test lab router at the test laboratory. We can simplify this link as a point-to-point radio link with no loss, 10 ms packet delay and a data rate of 8 Mbit/s.

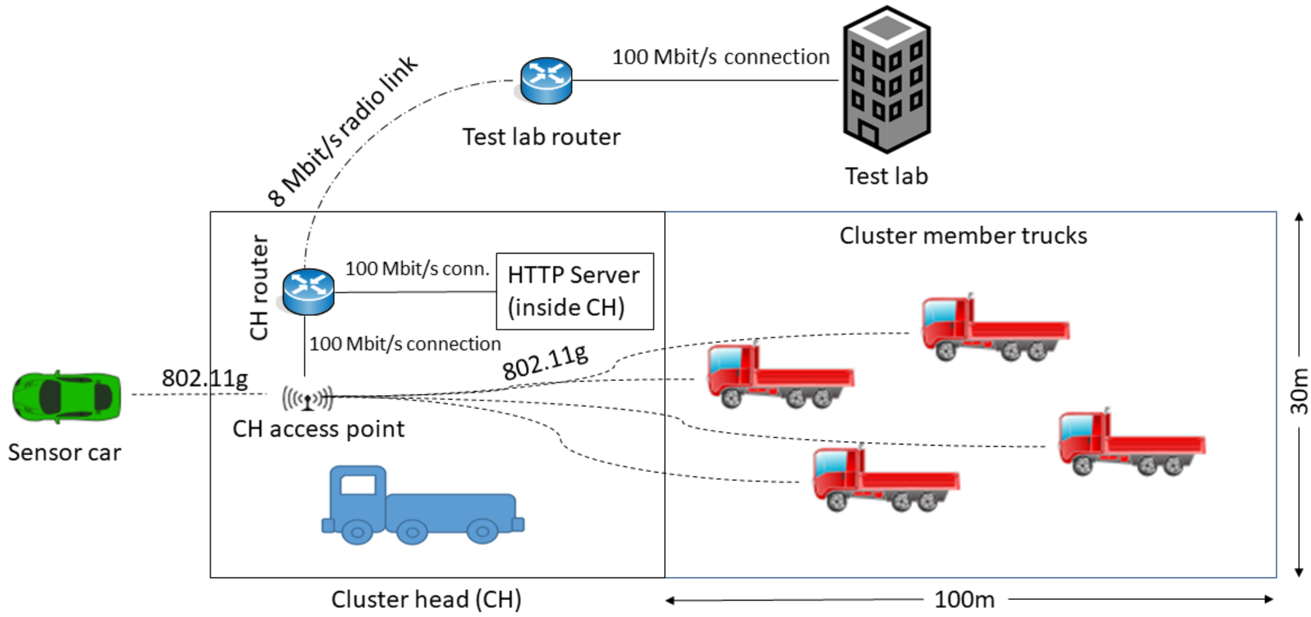
Cluster members request control information from the cluster head through Hypertext Transfer Protocol (HTTP) requests via 802.11g Wireless Local Area Networking (WLAN). The HTTP requests have a fixed size of 200 Byte and are sent periodically every 100 ms. The requested control information consist of Global Positioning System (GPS) position, speed, acceleration and planned movement actions (steering). The cluster head sends corresponding HTTP replies with a fixed size of 400 kB, containing the requested control information. The HTTP server is connected to the cluster head router through a 100 Mbit/s Ethernet connection with the delay modelled as exponentially distributed with a mean of 30 ms.

A special *sensor car* is driving in front of the cluster head, which is equipped with sensors to capture a 3D model of the environment. The raw 3D model data is continuously sent via the access point and the point-to-point radio link to the test lab using User Datagram Protocol (UDP). The data is processed at the test lab.
The UDP connection is bidirectional because cached environment data is also sent from the test lab to the sensor car so that the cluster can be made aware of upcoming road conditions. This UDP stream comes with two strict requirements for both directions: first, packets should take no longer than 150 ms; second, a packet loss of no more than 10 % can be accepted. Note that packets discarded due to a delay larger than 150 ms also contribute to the total packet loss.
The 3D sensor data packet sizes depend on the environment and are not constant. A trace file is provided to you that contains real-world measurements of these data packet sizes. You will be provided with more network parameters including the interarrival time of these packets. The UDP stream server at the test lab is connected to the test lab router through a 100 Mbit/s Ethernet connection with the delay modelled as exponentially distributed with the mean of 30 ms.

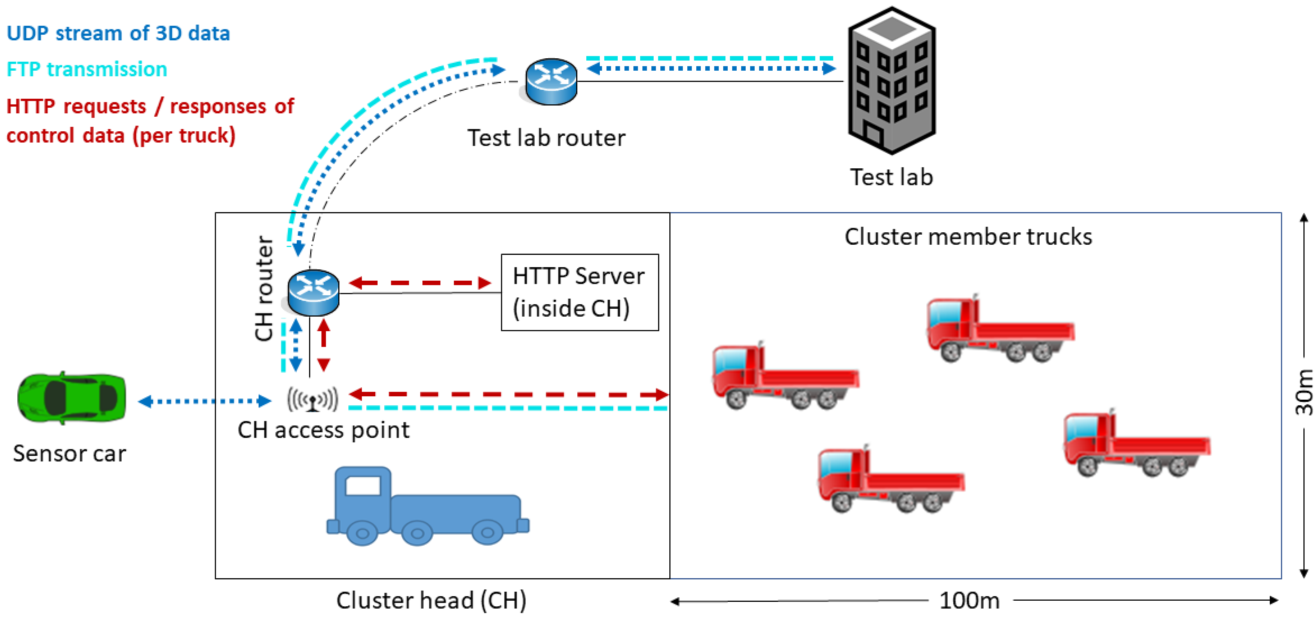
Additionally, one car inside the platoon continuously transmits a large file using File Transfer Protocol (FTP) from the cluster to the test lab. The FTP server is connected to the test lab router through an Ethernet connection with 100 Mbit/s and constant delay of 5 ms.

Figure 1 visualises the scenario, where Figure 1a describes the infrastructure and Figure 1b shows the data flow.

On the test range the truck cluster drives on a circular path around the test lab, and the cluster member trucks succeed in keeping a constant distance from the cluster head. Consequently, mobility can be neglected in this scenario, as radio transmission distances are constant.
As the test range is located in a desert area we can safely ignore interference from other radio transmissions as well as multipath propagation.




(a) Infrastructure view of the scenario.




(b) Color-coded data flow view of the scenario.

Figure 1: Graphical representation of the scenario. Icons from [1].

# 3 Task

You, as communication network engineers, are tasked with evaluating the wireless communication taking place in the scenario described in Section 2, and judging whether the infrastructure in place is sufficient. To do so, please abstract the described scenario into a simulation model, and gather data through simulation. Then analyse this data for the relevant aspects. Make justified statements as to whether the infrastructure supports the current needs or why it does not if this is not the case. Should you find an aspect that could be improved, then please describe in detail how it would benefit the system, make clear your expectations about the change, and if feasible it would be best if the change is implemented and evaluated through simulation. If you are not sure on how to continue, please consult your tutor.

An interview with the researcher team has identified a number of key issues that should give a focus for your efforts:

- How can the 3D sensor data packet sizes be modeled, based on the trace file?
- How many cluster members can be supported with the infrastructure so that the transmission of 3D sensor data is within the allowed range?
- How does the FTP transmission affect the behaviour?
- Is the LTE radio link dimensioned appropppriately?

The researchers emphasize that they are still in the early stages of their communication network design. This manifests in these few, general questions. The researchers are thankful for any help you can provide, especially regarding improvements upon their envisioned system that go beyond the general questions.

*The two team members in your team should divide the task as follows:*

1. One member should evaluate the scenario for the *uplink* case where the FTP connection *uploads* data from a truck to the test lab.
2. The other member should evaluate the scenario for a *downlink* FTP connection from the test lab to the truck.

# 4 Formalities

## 4.1 Time Schedule and Submission

- The report needs to be submitted by **Sunday, August 19th 23:59**.
- Submit the report **via e-mail** to your tutors *and* to `comnets@tuhh.de` **and also as a printout** on **August 20th until 14:00** to Ms. Stolz in `E1.058` or by postal mail.
- The e-mail should contain the report as a **PDF file**. The simulation model (all `.ned`, `.ini`, `.cc`, `.h`, ... files) as well as result scalar files (not vector files) can be uploaded to your repository on GitLab or emailed to use in a `.zip` archive, or uploaded as a `.zip` archive to the TUHH upload service at `http://upload.tuhh.de` and the link to the archive emailed to your tutor.
- We generally expect a discussion of the results, and a presentation of your approach in the form of a **coherent report**. Please do not simply answer the questions one by one.

- The report should be submitted in the form of a **document**. We provide a LaTeX template to you, but using Word or another text editor and layout is up to you.
- We expect between 10 to 20 pages, but **this is not a hard limit**!
- Please indicate how you divided the tasks between the team members, so that it becomes clear to the reader who did what. The general parts **should be written cooperatively**.

## 4.2 Presentation

- Presentations will be held on **Monday, August 27th** and **Tuesday, August 28th**. The specific time slot for your team will be announced separately.
- Your presentation needs to be **emailed** to your tutors and to `comnets@tuhh.de` by **August 26th 23:59**.
- The presentation should show and discuss the problem that you investigated, how you investigated it and your results. Details of your implementation, and the configuration of your simulation model **should not** be part of the presentation.
- It should be held by all members of your team. Each member should present some part, and individual tasks done by specific members need to be presented by the respective author.
- The presentation **must not exceed** 30 min; 20 to 25 min are recommended.
- You can expect a discussion and possibly follow-up questions on the presented results, about implementation details and about all the theoretical background learned in the lecture and exercises. Please prepare accordingly.

## 4.3 Comments

- Read the task description carefully! Ask us if anything is not clear.
- You are the consultant. The customer has no interest in implementation details and code, and so your report and representation should contain as little of it as required. Of course you must still be able to answer questions on it.
- The task is designed for 1 to 2 weeks of full-time effort – if you seem to require more time than this, then please contact us to get advice.
- Please make use of our offer of consulting with us if anything is not clear. A reasonable amount of discussion will give us a positive impression!
- General consultation hours are, starting from July 24th: **every Tuesday 10:00 to 11:00** in the institute seminar room `E1.022`, till the 14th of August.
- Please use our **Mattermost channel** to discuss with us and others about problems that you are having.
- You can use the TUHH pool computers to run your simulations. You can login via SSH from home as well.

### 4.4 Hints

- Unspecified connection parameters can be assumed as being ideal or default.
- Give indications for the confidence of your simulation results.
- The operating systems' TCP/IP implementations are based on TCP New Reno and the receiver side advertises a receive window of 1000 times the maximum segment size (MSS).
- For Ethernet, the maximum transmission unit (MTU) is 1500 Byte and this limits the size for the protocol data units (PDU) of the upper layers. However, the PDUs of upper layers (e.g., TCP) should be as large as possible to reduce protocol overhead.

# References


[1] Open Clip Art. URL: `https://openclipart.org/` (visited on May 22, 2018).