



UNIVERSITY OF STAVANGER

BACHELOR THESIS

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**Make the Internet Faster!**  
**Improving Alternative Backoff with ECN in Linux**

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*Students*

Dan Erik RAMSNES

Erlend Moen AL-KASIM

*Supervisor*

Naeem KHADEMI

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# Abstract

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# Contents

|   |          |  |           |
|---|----------|--|-----------|
| <b>Abstract</b>                         | <b>i</b> |  |           |
| <b>1 Introduction</b>                   | <b>1</b> |  |           |
| 1.1 Motivation . . . . .                | 1        |  |           |
| 1.2 Goals and Research Questions . . .  | 1        |  |           |
| 1.3 Research Methodology . . . . .      | 1        |  |           |
| 1.4 Contributions . . . . .             | 1        |  |           |
| 1.5 Thesis Structure . . . . .          | 1        |  |           |
| <b>2 Literature Review</b>              | <b>2</b> |  |           |
| 2.1 Network Delay and Latency . . . .   | 2        |  |           |
| 2.2 Bufferbloat . . . . .               | 2        |  |           |
| 2.3 Network Congestion . . . . .        | 3        |  |           |
| 2.4 Transmission Control Protocol . . . | 3        |  |           |
| 2.4.1 Congestion Control . . . . .      | 3        |  |           |
| 2.5 Active Queue Management . . . .     | 3        |  |           |
| 2.6 Explicit Congestion Notification .  | 3        |  |           |
| 2.6.1 Legacy ECN . . . . .              | 3        |  |           |
| 2.7 Alternative Backoff with ECN . . .  | 3        |  |           |
| <b>3 Methodology</b>                    | <b>4</b> |  |           |
| 3.1 Network Topology . . . . .          | 4        |  |           |
|   |          | 3.1.1 Raspberry Pi 4 Cluster . . . .                                 | 4         |
|   |          | 3.2 TCP Experimentation with TEACUP                                  | 4         |
|   |          | 3.2.1 Exposing TCP State with web10g . . . . .                       | 4         |
|   |          | 3.3 Achieving Low Latency with ABE                                   | 4         |
|   |          | 3.4 Improving ABE by Adapting Its Reduction Factor $\beta$ . . . . . | 4         |
|   |          | <b>4 Results</b>   | <b>5</b>  |
|   |          | <b>5 Conclusion</b>  | <b>6</b>  |
|   |          | <b>A The PI4-Cluster Testbed</b>                                     | <b>7</b>  |
|   |          | A.1 Setting Up Dual Boot . . . . .                                   | 7         |
|   |          | A.2 Compiling Mainline Kernel 5.5 for Raspberry Pi 4 . . . . .       | 8         |
|   |          | A.3 Patching web10g on Mainline Kernel 5.5 . . . . .                 | 8         |
|   |          | <b>Terms</b>   | <b>9</b>  |
|   |          | <b>References</b>  | <b>10</b> |

# Introduction

This chapter aims at giving an introduction and overview of the thesis. It starts with a brief explanation of why Internet today still feels slow despite major advances in technology, followed up by establishing the goals and research questions for the entire thesis. To address the research questions, a small look into the research methodology is presented. In the final section, an outline of the thesis structure is discussed.

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## 1.1 Motivation

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## 1.2 Goals and Research Questions

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## 1.3 Research Methodology

## 1.4 Contributions

## 1.5 Thesis Structure

# Literature Review

This chapter presents the background theory for which this thesis is based upon.

## 2.1 Network Delay and Latency

The time it takes for a bit of data to travel across the network from one communication endpoint to another is known as *delay*. The process for such a transmission involves many components. Let us demonstrate with a typical example where the data traverses an intermediate device before reaching destination. First, the data to be sent is usually created by an application. The data will then be handed over to the **Operating System (OS)** which passes it to a network card. From there, the data will be encoded and transmitted over a physical medium and eventually received by an intermediate device, such as a router. The router will then analyze the data and retransmit it over another medium that points to the destination. Finally, the data reaches the receiver. The whole process can happen in either multiples or fractions of seconds.

Network delay is therefore divided into the following four parts:

- Processing delay – time it takes router to process the packet header
- Queuing delay – time the packet spends in routing queues
- Transmission delay – time it takes to push the packet's bits onto the link
- Propagation delay – time for a signal to reach its destination

It is common to notify the sender that the receiver actually got the data. This is done by sending a signal from the receiver to the sender, known as an **Acknowledgement (ACK)**. The total time it takes for a sender to send data *and* receive back an **ACK** is known as *latency* or *rtt*.

In this thesis, we are mainly concerned with the *queuing* delay part.

## 2.2 Bufferbloat

A common cause of latency in packet switched networks is bufferbloat. It occurs when a router, with a large buffer gets congested. the tcp **Congestion Control (CC)** will fill up the entire buffer, before it starts backing off. Packets become queued for a long period of time, untill the buffer is drained, **CC** resets and TCP connection ramps back up to speed to fill the buffer again.

This causes high and variable latency, in addition to "blocking" the bottleneck for other flows when the buffer is full and packets are dropped. Several technical solutions exists, that try to solve the problem of bufferbloat and we will outline some of them in this section.

## 2.3 Network Congestion

TODO: write about congestion...

## 2.4 Transmission Control Protocol

**Transmission Control Protocol (TCP)** is the one of the main protocols for transmitting data on the internet. It is a connection based, reliable protocol and is used by for instance World Wide Web (WWW), email, File Transfer Protocol (FTP) and streaming media. TCP requires that the sender and receiver establishes a connection through a three-way handshake before transmission starts. All segments sent have a sequence number, and the receiver sends an **ACK** for every segment it receives. This, in addition to retransmission and error-checking ensures reliable transfer, but also lengthens latency.

### 2.4.1 Congestion Control

To help reduce congestion on the links TCP maintains a **Congestion Window (CWND)**, which limits the total number of unacknowledged packets that it can send at a time. This is done in multiple phases.

In the slow start phase, right after a connection is established. the congestion window starts as a small multiple of **Maximum Segment Size (MSS)** and is effectively doubled for every **Round Trip Time (RTT)**. When it reaches the slow-start threshold (ssthresh), **CWND** is reduced by half and a new phase starts, congestion avoidance. In this phase **CWND** is increased linearly by one **MSS** every **RTT**. If loss occurs, it could mean there is congestion, and steps will be taken to reduce load on the network. The steps depend on what exact congestion avoidance algorithm is used.

## 2.5 Active Queue Management

## 2.6 Explicit Congestion Notification

**Explicit Congestion Notification (ECN)** is an extension to TCP that allows routers to notify end points on impending congestion without dropping packets.

### 2.6.1 Legacy ECN

In legacy ECN, the router notifies end hosts of congestion by setting a Congestion Encountered (CE) flag in the IP header on ECN enabled packets when experiencing congestion. The receiver of the packet then reflects this back to the sender by setting an ECN-Echo (ECE) in the TCP header. It keeps doing this until the sender responds back with a segment with Congestion Window Reduced (CWR) set, indicating that the sender has backed off.

## 2.7 Alternative Backoff with ECN

# Methodology

## 3.1 Network Topology

### 3.1.1 Raspberry Pi 4 Cluster

## 3.2 TCP Experimentation with TEACUP

### 3.2.1 Exposing TCP State with web10g

## 3.3 Achieving Low Latency with ABE

## 3.4 Improving ABE by Adapting Its Reduction Factor $\beta$

## Chapter 4

# Results



# Conclusion

# The PI4-Cluster Testbed

## A.1 Setting Up Dual Boot

First install Ubuntu. When asked for partitioning the disk, choose manual, select the disk and confirm creating a new empty partition with yes. Select the newly created empty partition followed by create a new partition and set a size for it. The type should be of primary, location at beginning and mounting point root. Finish off with done setting up the partition followed by finish partitioning and write changes to disk.

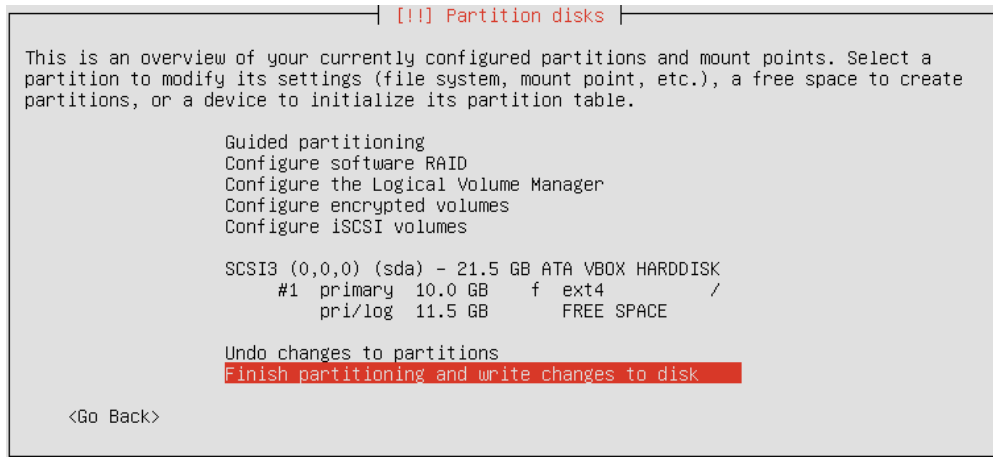


Figure A.1: The partition editor for Ubuntu.

Next, install FreeBSD. When asked for partitioning the disk, choose **auto** (UFS) followed by partition. Set a size, hit ok and finish.



Figure A.2: The partition editor for FreeBSD.

After installing both systems, only Ubuntu is presented in the **GRand Unified Bootloader (GRUB)**. To add FreeBSD as an option, run `sudo nano /etc/grub.d/40_custom` in Ubuntu, and add the following entry:

```

1 menuentry "FreeBSD" {
2     insmod ufs2
3     set root=(hd0,2)
4     kfreebsd /boot/loader
5 }
```

Then update **GRUB** with `sudo update-grub`. The FreeBSD option should now be available when rebooting. If the bootloader won't display, hold the RIGHT SHIFT key upon booting.

To enable a one-time reboot into FreeBSD from Ubuntu, run the command `grub-editenv /boot/grub/grubenv` set `next_entry="FreeBSD"` and reboot with `sudo reboot`.

## A.2 Compiling Mainline Kernel 5.5 for Raspberry Pi 4

## A.3 Patching web10g on Mainline Kernel 5.5

# Terms

**Acknowledgement (ACK)** A signal that is passed between communicating processes, computers, or devices to signify acknowledgement, or receipt of message, as part of a communications protocol.

**Congestion Control (CC)** The process of managing the sender's packet rate to not overwhelm the network.

**Congestion Window (CWND)** A TCP state variable that limits the amount of data the TCP can send into the network before receiving an ACK.

**Explicit Congestion Notification (ECN)** An extension to IP and TCP that allows end-to-end notification of network congestion without dropping packets.

**GRand Unified Bootloader (GRUB)** A Multiboot boot loader. It was derived from GRUB, the GRand Unified Bootloader, which was originally designed and implemented by Erich Stefan Boleyn.

**Maximum Segment Size (MSS)** The largest specified amount of data (in bytes) that a communications device can receive in a single TCP segment.

**Operating System (OS)** System software that manages computer hardware, software resources, and provides common services for computer programs.

**Round Trip Time (RTT)** The time it takes for a signal to be sent plus the time for an ACK of that signal to be received.

**Transmission Control Protocol (TCP)** One of the main communication protocols of the Internet that defines how to establish and maintain a network conversation through which applications can exchange data.

# References

- [1] Naeem Khademi et al. "Alternative Backoff: Achieving Low Latency and High Throughput with ECN and AQM". In: (2017), p. 9.