# Serverless Dataflows: ...

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Thesis to obtain the Master of Science Degree in

## Computer Science and Engineering

Supervisor: Luis Manuel Antunes Veiga

## Examination Committee

Chairperson: Prof. Name of the Chairperson
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Member of the Committee: Prof. Name of First Committee Member

**October 2025**

**Declaration**
I declare that this document is an original work of my own authorship and that it fulfills all the requirements of the Code of Conduct and Good Practices of the Universidade de Lisboa.

# Acknowledgments

I would like to thank my parents for their friendship, encouragement and caring over all these years, for always being there for me through thick and thin and without whom this project would not be possible. I would also like to thank my grandparents, aunts, uncles and cousins for their understanding and support throughout all these years.

Quisque facilisis erat a dui. Nam malesuada ornare dolor. Cras gravida, diam sit amet rhoncus ornare, erat elit consectetuer erat, id egestas pede nibh eget odio. Proin tincidunt, velit vel porta elementum, magna diam molestie sapien, non aliquet massa pede eu diam. Aliquam iaculis.

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Donec vestibulum. Etiam vel nibh. Nulla facilisi. Mauris pharetra. Donec augue. Fusce ultrices, neque id dignissim ultrices, tellus mauris dictum elit, vel lacinia enim metus eu nunc.

I would also like to acknowledge my dissertation supervisors Prof. Some Name and Prof. Some Other Name for their insight, support and sharing of knowledge that has made this Thesis possible.

Last but not least, to all my friends and colleagues that helped me grow as a person and were always there for me during the good and bad times in my life. Thank you.

To each and every one of you – Thank you.

# Abstract

Nulla facilisi. In vel sem. Morbi id urna in diam dignissim feugiat. Proin molestie tortor eu velit. Aliquam erat volutpat. Nullam ultrices, diam tempus vulputate egestas, eros pede varius leo, sed imperdiet lectus est ornare odio. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Proin consectetuer velit in dui. Phasellus wisi purus, interdum vitae, rutrum accumsan, viverra in, velit. Sed enim risus, congue non, tristique in, commodo eu, metus. Aenean tortor mi, imperdiet id, gravida eu, posuere eu, felis. Mauris sollicitudin, turpis in hendrerit sodales, lectus ipsum pellentesque ligula, sit amet scelerisque urna nibh ut arcu. Aliquam in lacus. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Nulla placerat aliquam wisi. Mauris viverra odio. Quisque fermentum pulvinar odio. Proin posuere est vitae ligula. Etiam euismod. Cras a eros.

# Keywords

Maecenas tempus dictum libero; Donec non tortor in arcu mollis feugiat;Cras rutrum pulvinar tellus.

# Resumo

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# Palavras Chave

Colaborativo; Codificaçãoo; Conteúdo Multimédia; Comunicação;

# Contents

# List of Figures

x

# List of Tables

# List of Algorithms

# Listings

# Acronyms

**CC**       Cloud Computing

**CDN**      Content Distribution Network

**DASH**     Dynamic Adaptive Streaming over HTTP

**GPRS**     General Packet Radio Service

**HTTP**     Hypertext Transfer Protocol

**LAN**      Local Area Network

**LTE**      Long Term Evolution

**SVC**      Scalable Video Coding

**UI**       User Interface

**UMTS**     Universal Mobile Telecommunication System

# 1

# Introduction

## Contents

## 1.1 Problem/Motivation

## 1.2 Objectives

## 1.3 Gaps in prior work

## 1.4 Proposed Solution

## 1.5 Organization of the Document

RC references to doc sections/chapters are automatic

This thesis is is organized as follows: **??** 2 interdum vel, tristique ac, condimentum non, tellus. In 3 curabitur nulla purus, feugiat id, elementum in, lobortis quis, pede. In 4 consequat ligula nec tortor. Integer eget sem. Ut vitae enim eu est vehicula gravida. 5 morbi egestas, urna non consequat tempus, nunc arcu mollis enim, eu aliquam erat nulla non nibh in 6. 7 suspendisse dolor nisl, ultrices at, eleifend vel, consequat at, dolor.

# 2

# Background

## Contents

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## 2.1  Traditional Streaming Technologies

Cras dictum. Maecenas ut turpis. In vitae erat ac orci dignissim eleifend. Nunc quis justo. Sed vel ipsum in purus tincidunt pharetra [**?**]. Sed pulvinar, felis id consectetuer malesuada, enim nisl mattis elit, a facilisis tortor nibh quis leo. Sed augue lacus, pretium vitae, molestie eget, rhoncus quis, elit [**?**]. Donec in augue. Fusce orci wisi, ornare id, mollis vel, lacinia vel, massa. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas..

Sed pulvinar, "felis id consectetuer" malesuada, enim nisl mattis elit, a facilisis tortor nibh quis leo Table 2.1.

**Table 2.1:** Streaming Technologies Comparison

|  | Dynamic Streaming | Smooth Streaming | HLS |
|---|---|---|---|
| Streaming Protocol | RTMP | HTTP | HTTP |
| Video Codec | H.264, VP6 | H.264 | H.264 |
| Audio Codec | AAC, MP3 | WMA, AAC | AAC, MP3 |
| Container Format | MP4, FLV, | MP4 | MPEG2-TS |
| iOS | NO | YES | YES |
| Android | NO | YES | YES |

Suspendisse vestibulum dignissim quam. Integer vel augue. Phasellus nulla purus, interdum ac, venenatis non, varius rutrum, leo. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas [**?**]. Duis a eros. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Fusce magna mi, porttitor quis, convallis eget, sodales ac, urna [**?**]. Table 2.2 illustrates the use of a Spreadsheet-like table producing calculations by columns and by lines (observe the code).

**Table 2.2:** A nice Spreadsheet using package "spreadtab". Notice the calculations.

| | | |
|---:|---:|---:|
| 22 | 54 | 76 |
| 43 | 65 | 108 |
| 49 | 37 | 86 |
| 114 | 156 | 270 |

## 2.2   Cras lobortis tempor velit

Nunc tincidunt convallis tortor. Duis eros mi, dictum vel, fringilla sit amet, fermentum id, sem. Phasellus nunc enim, faucibus ut, laoreet in, consequat id, metus. Vivamus dignissim [**?**]. Table 2.3 is automatically compressed to fit text width. You can use `https://www.tablesgenerator.com` to produce these tables, and then copy the LATEX code generated to paste in the document.

Cras lobortis tempor velit. Phasellus nec diam ac nisl lacinia tristique. Nullam nec metus id mi dictum dignissim. Nullam quis wisi non sem lobortis condimentum. Phasellus pulvinar, nulla non aliquam eleifend, tortor wisi scelerisque felis, in sollicitudin arcu ante lacinia leo.

**Table 2.3:** Comparison between today's and target Architectures of Telcos

| Today | | Target | |
|---|---|---|---|
| Rigid | Each evolutionary requirement involves development of multiple components, interfaces, platforms,etc. | Flexible | It is possible to modify or add new functionalities rapidly. |
| Slow | Development of a new application takes months or years. | Fast | Development of a new application takes weeks instead of months or years. |
| Closed | Limited integration with external environments. | Open | It is simple to integrate internal, applications with external entities. |
| Complex | Heterogeneous technologies, obsolescence, lack,of standards, high redundancy. | Standardised | Use of homogeneous architectural models. |
| Expensive | High Capex (for new service development) and,high,Opex (to ensure running of IT). | Cost-Effective | Capex and Opex are optimised. |

# 3

# Related Work

## Contents

Donec gravida posuere arcu. Nulla facilisi. Phasellus imperdiet. Vestibulum at metus. Integer euismod. Nullam placerat rhoncus sapien. Ut euismod. Praesent libero. Morbi pellentesque libero sit amet ante. Maecenas tellus. Maecenas erat. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas.

## 3.1   Architecture Design

Example of a Flowchart for a system, in Figure 3.1, created with `https://app.diagrams.net` and then exported as "PDF" crop format (a true vector image that can be scaled to no end, with no pixels or distortion).

Quisque facilisis erat a dui. Nam malesuada ornare dolor. Cras gravida, diam sit amet rhoncus ornare, erat elit consectetuer erat, id egestas pede nibh eget odio. Proin tincidunt, velit vel porta elementum, magna diam molestie sapien, non aliquet massa pede eu diam. Aliquam iaculis. Fusce et
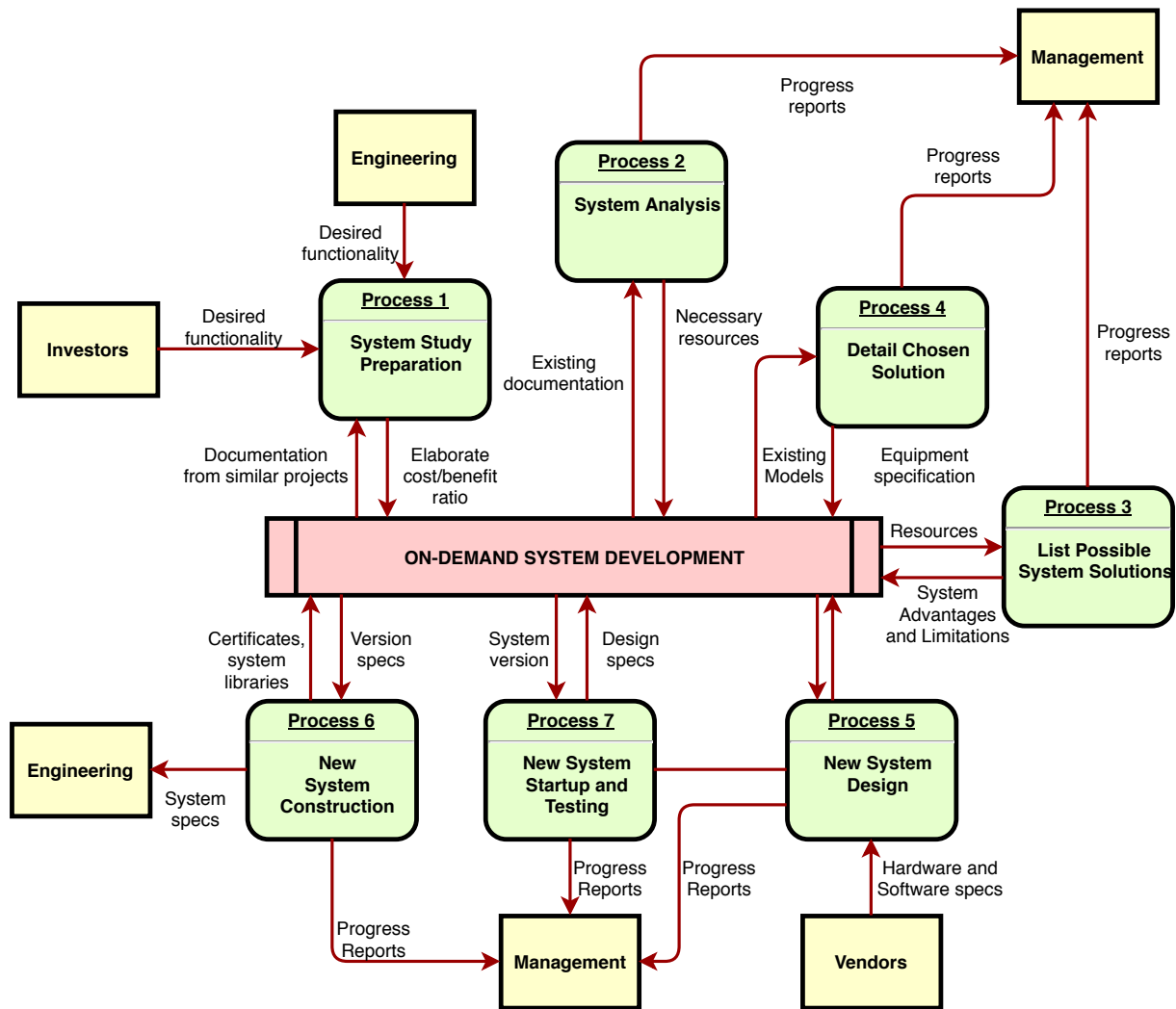
**Figure 3.1:** System Processes

ipsum et nulla tristique facilisis. Donec eget sem sit amet ligula viverra gravida. Etiam vehicula urna vel turpis.

And here another diagram of a network (Figure 3.2) created with https://app.diagrams.net and then exported as "PDF" crop format.

Suspendisse sagittis ante a urna. Morbi a est quis orci consequat rutrum. Nullam egestas feugiat felis. Integer adipiscing semper ligula. Nunc molestie, nisl sit amet cursus convallis, sapien lectus pretium metus, vitae pretium enim wisi id lectus. Donec vestibulum. Etiam vel nibh. Nulla facilisi. Mauris pharetra. Donec augue. Fusce ultrices, neque id dignissim ultrices, tellus mauris dictum elit, vel lacinia enim metus eu nunc:

**Web-streaming:** The client application should support streaming media using cro:HTTPHypertext Transfer Protocol (HTTP) protocols.
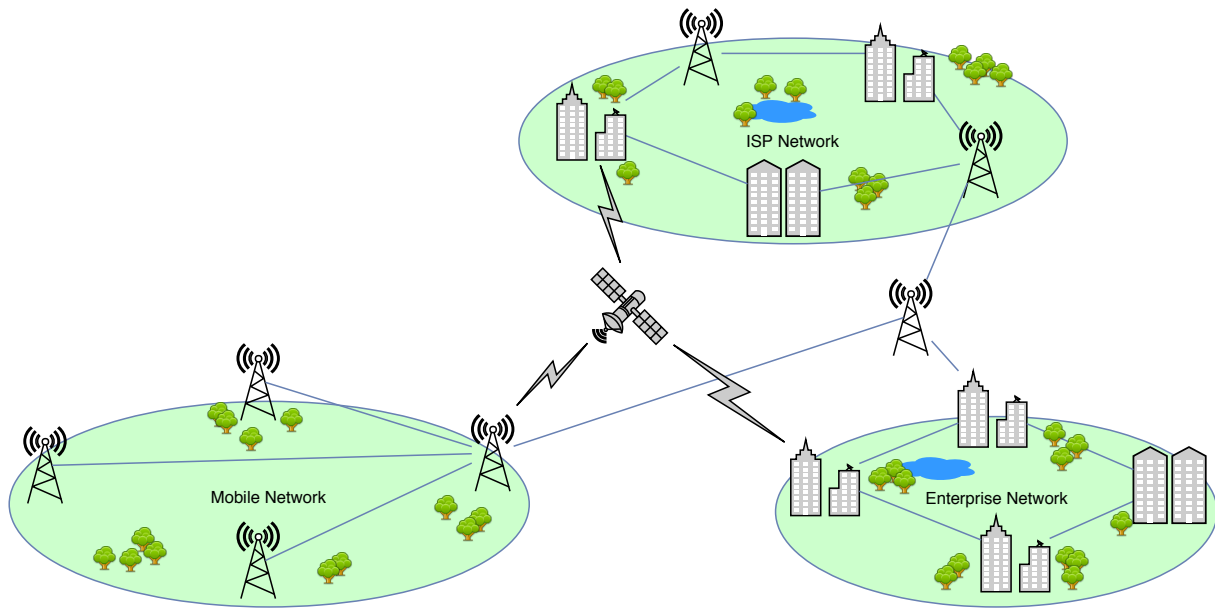
**Figure 3.2:** Network Diagram

**Multi-source streaming:** The client application should support multi-source streaming media, i.e., "simultaneous" streaming of media content components from a network, supported/complemented by cro:CDNContent Distribution Network (CDN)/cro:CCCloud Computing (CC) services.

**Support content Metadata Description:** The client application should support content metadata description in a format similar or compliant with MPEG cro:DASHDynamic Adaptive Streaming over HTTP (DASH) [**?**].

**Scalable and Adaptive Media Contents:** The system should support on-demand streaming of scalable and adaptive contents based on cro:SVCScalable Video Coding (SVC).

**Heterogenous End-User Devices:** The client application should be compatible with current and future generations of end-user devices form factors, irrespective of their performance, screen size and resolution.

**Access Network independency:** The solution should provide the expected service over different types of access networks supported by the end-user devices, such as Wireless cro:LANLocal Area Networks (LANs) (IEEE 802.11) or cellular data networks such as cro:GPRSGeneral Packet Radio Service (GPRS), cro:UMTSUniversal Mobile Telecommunication System (UMTS), cro:LTELong Term Evolution (LTE), etc.

Cras gravida, diam sit amet rhoncus ornare, erat elit consectetuer erat, id egestas pede nibh eget odio. Proin tincidunt, velit vel porta elementum, magna diam molestie sapien, non aliquet massa pede eu diam. Aliquam iaculis. Fusce et ipsum et nulla tristique facilisis.

## 3.2   Architecture Design Requirements

Ut nulla. Vivamus bibendum, nulla ut congue fringilla, lorem ipsum ultricies risus, ut rutrum velit tortor vel purus. In hac habitasse platea dictumst. Duis fermentum, metus sed congue gravida, arcu dui ornare urna, ut imperdiet enim odio dignissim ipsum. Nulla facilisi. Cras magna ante, bibendum sit amet, porta vitae, laoreet ut, justo. Nam tortor sapien, pulvinar nec, malesuada in, ultrices in, tortor. Cras ultricies placerat eros. Quisque odio eros, feugiat non, iaculis nec, lobortis sed, arcu. Pellentesque sit amet sem et purus pretium consectetuer Listing 3.1.

**RC**
A listing for XML code, with syntax highlighting

**Listing 3.1:** Example of a MPD file.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<StreamInfo version="2.0">
    <Clip duration="PT01M0.00S">
        <BaseURL>videos/</BaseURL>
        <Description>svc_1</Description>
        <Representation mimeType="video/SVC" codecs="svc" frameRate="30.00" bandwidth="401.90"
            width="176" height="144" id="L0">
            <BaseURL>svc_1/</BaseURL>
            <SegmentInfo from="0" to="11" duration="PT5.00S">
                <BaseURL>svc_1-L0-</BaseURL>
            </SegmentInfo>
        </Representation>
        <Representation mimeType="video/SVC" codecs="svc" frameRate="30.00"
            bandwidth="1322.60"
            width="352" height="288" id="L1">
            <BaseURL>svc_1/</BaseURL>
            <SegmentInfo from="0" to="11" duration="PT5.00S">
                <BaseURL>svc_1-L1-</BaseURL>
            </SegmentInfo>
        </Representation>
    </Clip>
</StreamInfo>
```

Nam malesuada ornare dolor. Cras gravida, diam sit amet rhoncus ornare, erat elit consectetuer erat, id egestas pede nibh eget odio. Proin tincidunt, velit vel porta elementum, magna diam molestie sapien, non aliquet massa pede eu diam.

# 4

# Architecture

## Contents

Aliquam aliquet, est a ullamcorper condimentum, tellus nulla fringilla elit, a iaculis nulla turpis sed wisi. Fusce volutpat. Etiam sodales ante id nunc. Proin ornare dignissim lacus. Nunc porttitor nunc a sem. Sed sollicitudin velit eu magna. Aliquam erat volutpat. Vivamus ornare est non wisi. Proin vel quam. Vivamus egestas. Nunc tempor diam vehicula mauris. Nullam sapien eros, facilisis vel, eleifend non, auctor dapibus, pede.

## 4.1  Development Process

Suspendisse vestibulum dignissim quam. Integer vel augue. Phasellus nulla purus, interdum ac, venenatis non, varius rutrum, leo. Pellentesque habitant morbi tristique senectus et netus et malesuada

fames ac turpis egestas. Duis a eros. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Fusce magna mi, porttitor quis, convallis eget, sodales ac, urna. Phasellus luctus venenatis magna. Vivamus eget lacus. Nunc tincidunt convallis tortor. Duis eros mi, dictum vel, fringilla sit amet, fermentum id, sem. Phasellus nunc enim, faucibus ut, laoreet in, consequat id, metus. Vivamus dignissim. Cras lobortis tempor velit. Phasellus nec diam ac nisl lacinia tristique. Nullam nec metus id mi dictum dignissim. Nullam quis wisi non sem lobortis condimentum. Phasellus pulvinar, nulla non aliquam eleifend, tortor wisi scelerisque felis, in sollicitudin arcu ante lacinia leo.:

- Technology Research and Related Works

- Requirements Gathering and Study

- Design of the Architecture

- Implementation Process

- Testing and Functional Validation

Pellentesque nibh felis, eleifend id, commodo in, interdum vitae, leo. Praesent eu elit. Ut eu ligula. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Maecenas elementum augue nec nisl. Proin auctor lorem at nibh. Curabitur nulla purus, feugiat id, elementum in, lobortis quis, pede. Vivamus sodales adipiscing sapien. Vestibulum posuere nulla eget wisi. Integer volutpat ligula eget enim. Suspendisse vitae arcu. Quisque pellentesque. Nullam consequat, sem vitae rhoncus tristique, mauris nulla fermentum est, bibendum ullamcorper sapien magna et quam. Sed dapibus vehicula odio. Proin bibendum gravida nisl. Fusce lorem. Phasellus sagittis, nulla in hendrerit laoreet, libero lacus feugiat urna, eget hendrerit pede magna vitae lorem. Praesent mauris.

## 4.2   Development Environment

Cras sed ante. Phasellus in massa. Curabitur dolor eros, gravida et, hendrerit ac, cursus non, massa. Aliquam lorem. In hac habitasse platea dictumst. Cras eu mauris Algorithm 4.1. Quisque lacus. Donec ipsum. Nullam vitae sem at nunc pharetra ultricies. Vivamus elit eros, ullamcorper a, adipiscing sit amet, porttitor ut, nibh.

Maecenas adipiscing mollis massa. Nunc ut dui eget nulla venenatis aliquet. Sed luctus posuere justo. Cras vehicula varius turpis. Vivamus eros metus, tristique sit amet, molestie dignissim, malesuada et, urna..

RC
Notice the reference to the Algorithm construct

**Algorithm 4.1:** Time Control Strategy

**begin**

$nextBitrate \longleftarrow nextDownloadLevel$
$nextBitrate \longleftarrow GetNextBitrate()$
$cpuLoad \longleftarrow GetCpuLoad()$
$bitrateDelta \longleftarrow getBitrateDelta(currentBitrate, nextBitrate)$

**if** $bitrateDelta > maxThreshold$ **then**
    $SetBitrate(nextBitrate)$

**if** $minThreshold < bitrateDelta < maxThreshold$ **and** $numAttemps < 2$ **then**
    $numAttemps \longleftarrow numAttemps + 1$
**else if** $minThreshold < bitrateDelta < maxThreshold$ **and** $numAttemps = 2$ **then**
    $numAttemps \longleftarrow 0$
**else**
    $SetBitrate(nextBitrate)$
**if** $0 < bitrateDelta < minThreshold$ **and** $numAttemps < 3$ **then**
    $numAttemps \longleftarrow numAttemps + 1$
**else if** $0 < bitrateDelta < minThreshold$ **and** $numAttemps = 3$ **then**
    $SetBitrate(nextBitrate)$

## 4.3   Client Application

Cras sed ante. Phasellus in massa. Curabitur dolor eros, gravida et, hendrerit ac, cursus non, massa. Aliquam lorem. In hac habitasse platea dictumst. Cras eu mauris. Quisque lacus. Donec ipsum. Nullam vitae sem at nunc pharetra ultricies.

Vivamus elit eros, ullamcorper a, adipiscing sit amet, porttitor ut, nibh. Maecenas adipiscing mollis massa. Nunc ut dui eget nulla venenatis aliquet. Sed luctus posuere justo. Cras vehicula varius turpis. Vivamus eros metus, tristique sit amet, molestie dignissim, malesuada et, urna.

Quisque lacus. Donec ipsum. Nullam vitae sem at nunc pharetra ultricies. Cras vehicula varius turpis.

```
        return          function        list of formal
      value type          name           parameters


    int puissance (int x, int n) {

                                              local variables
        int i, p = 1;    <- - - - - - - - -   declaration


        for (i = 1; i <= n; i++)
          p = p * x;              <- - - - - -  instructions

                                              instruction
        return p;        <- - - - - - - - -
                                              return
      }
```
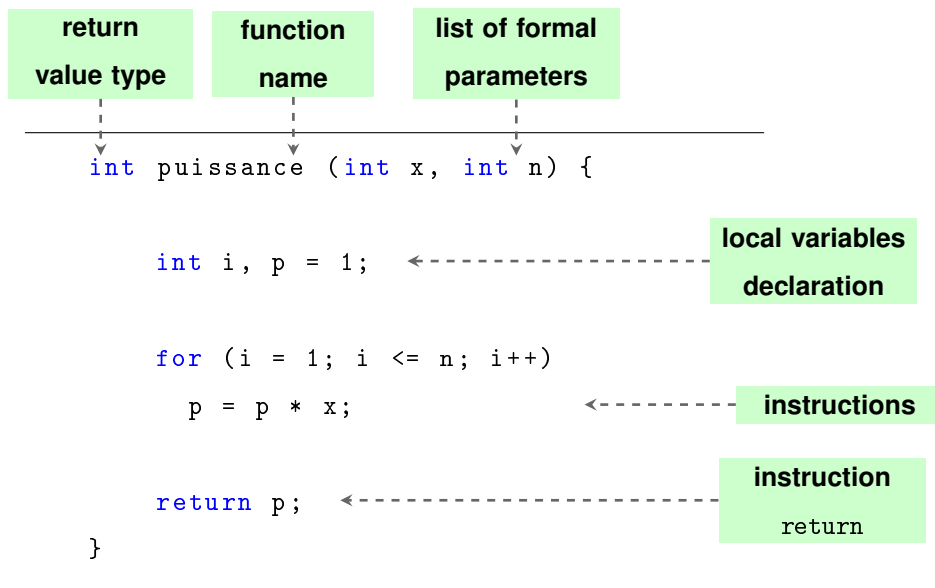
**Listing 4.1:** A listing with a Tikz picture overlayed

And here another method (Listing 4.1) for mixing (overlay) a picture with a listing of code.

### 4.3.1  User Interface

Donec semper turpis sed diam. Sed consequat ligula nec tortor. Integer eget sem. Ut vitae enim eu est vehicula gravida. Morbi ipsum ipsum, porta nec, tempor id, auctor vitae, purus. Pellentesque neque. Nulla luctus erat vitae libero. Integer nec enim. Phasellus aliquam enim et tortor. Quisque aliquet, quam elementum condimentum feugiat, tellus odio consectetuer wisi, vel nonummy sem neque in elit. Curabitur eleifend wisi iaculis ipsum. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. In non velit non ligula laoreet ultrices. Praesent ultricies facilisis nisl. Vivamus luctus elit sit amet mi. Phasellus pellentesque, erat eget elementum volutpat, dolor nisl porta neque, vitae sodales ipsum nibh in ligula. Maecenas mattis pulvinar diam. Curabitur sed leo..

Cras eu mauris. Quisque lacus. Donec ipsum. Nullam vitae sem at nunc pharetra ultricies. Vivamus elit eros, ullamcorper a, adipiscing sit amet, porttitor ut, nibh. Maecenas adipiscing mollis massa. Nunc ut dui eget nulla venenatis aliquet. Sed luctus posuere justo. Cras vehicula varius turpis.

### 4.3.2  Vivamus luctus elit sit amet mi

Nulla facilisi. In vel sem. Morbi id urna in diam dignissim feugiat. Proin molestie tortor eu velit. Aliquam erat volutpat. Nullam ultrices, diam tempus vulputate egestas, eros pede varius leo, sed imperdiet lectus est ornare odio. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Proin consectetuer velit in dui. Phasellus wisi purus, interdum vitae, rutrum accumsan, viverra in, velit. Sed enim risus, congue non, tristique in, commodo eu, metus. Aenean tortor mi, imperdiet id, gravida eu, posuere eu, felis.

Mauris sollicitudin, turpis in hendrerit sodales, lectus ipsum pellentesque ligula, sit amet scelerisque

urna nibh ut arcu. Aliquam in lacus.

Figures 4.1(a) and 4.1(b) proin at eros non eros adipiscing mollis.
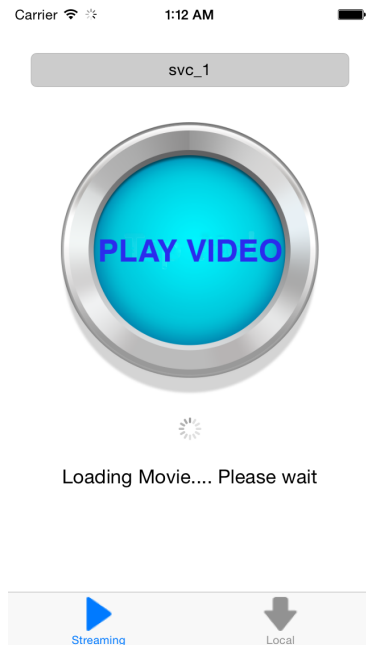
**(a)** Media Loading Window          **(b)** Play-out Session UI

**Figure 4.1:** Complete User Interface

Vestibulum ante ipsum primis in cro:UIUser Interface (UI) faucibus orci luctus et ultrices posuere cubilia Curae; Nulla placerat aliquam wisi. Mauris viverra odio. Quisque fermentum pulvinar odio. Proin posuere est vitae ligula. Etiam euismod. Cras a eros.

# 5

# Evaluation

## Contents

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque, id pulvinar odio lorem non turpis. Nullam sit amet enim. Suspendisse id velit vitae ligula volutpat condimentum. Aliquam erat volutpat. Sed quis velit. Nulla facilisi. Nulla libero. Vivamus pharetra posuere sapien. Nam consectetuer. Sed aliquam, nunc eget euismod ullamcorper, lectus nunc ullamcorper orci, fermentum bibendum enim nibh eget ipsum. Donec porttitor ligula eu dolor. Maecenas vitae nulla consequat libero cursus venenatis. Nam magna enim, accumsan eu, blandit sed, blandit a, eros.

## 5.1 Maecenas vitae nulla consequat

Aliquam aliquet, est a ullamcorper condimentum, tellus nulla fringilla elit, a iaculis nulla turpis sed wisi. Fusce volutpat. Etiam sodales ante id nunc. Proin ornare dignissim lacus. Nunc porttitor nunc a sem. Sed sollicitudin velit eu magna. Aliquam erat volutpat. Vivamus ornare est non wisi. Proin vel quam.

Vivamus egestas. Nunc tempor diam vehicula mauris. Nullam sapien eros Figure 5.1, facilisis vel, eleifend non, auctor dapibus, pede.
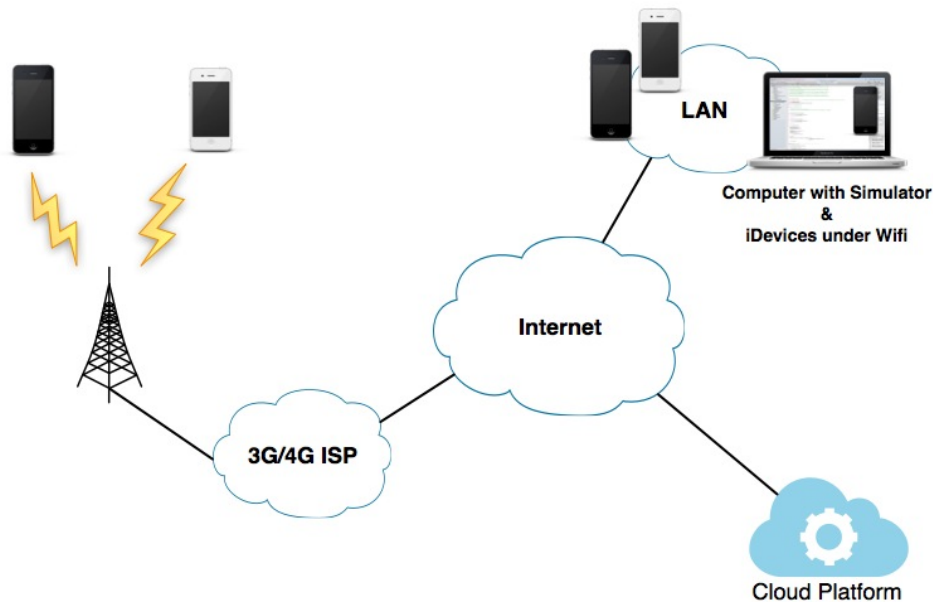


**Figure 5.1:** Test Environment

Aliquam aliquet, est a ullamcorper condimentum, tellus nulla fringilla elit, a iaculis nulla turpis sed wisi. Fusce volutpat. Etiam sodales ante id nunc. Proin ornare dignissim lacus. Nunc porttitor nunc a sem. Sed sollicitudin velit eu magna. Aliquam erat volutpat. Vivamus egestas. Nunc tempor diam vehicula mauris. Nullam sapien eros, facilisis vel, eleifend non, auctor dapibus, pede Table 5.1 used in the tests. The Network Link Conditioner allows to force/simulate fluctuations in fixed network segments.

**Table 5.1:** Network Link Conditioner Profiles

| Network Profile | Bandwidth | Packets Droped | Delay |
|---|---|---|---|
| Wifi | 40 mbps | 0% | 1 ms |
| 3G | 780 kbps | 0% | 100 ms |
| Edge | 240 kbps | 0% | 400 ms |

Aliquam aliquet, est a ullamcorper condimentum, tellus nulla fringilla elit, a iaculis nulla turpis sed wisi. Fusce volutpat. Etiam sodales ante id nunc. Proin ornare dignissim lacus. Nunc porttitor nunc a sem. Sed sollicitudin velit eu magna. Aliquam erat volutpat. Vivamus ornare est non wisi. Proin vel quam. Vivamus egestas. Nunc tempor diam vehicula mauris. Nullam sapien eros, facilisis vel, eleifend non, auctor dapibus, pede.

## 5.2   Proin ornare dignissim lacus

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Et "optimistic" nulla dui purus, eleifend vel, consequat non, dictum porta, nulla. Duis ante mi, laoreet ut, commodo eleifend, cursus nec, lorem. Aenean eu est. Etiam imperdiet turpis. Praesent nec augue. Curabitur ligula quam, rutrum id, tempor sed, consequat ac, dui $G_j$, nec ligula et lorem consequat ullamcorper $p$ ut mauris eu mi mollis luctus $j$, porttitor ut, Equation (5.1), uctus posuere justo:

$N_j$   Is the number of times peer $j$ has been optimistically unchoked.

$n_j$   Among the $N_j$ unchokes, the number of times that peer $j$ responded with unchoke or supplied segments to peer $p$.

$C_{r[j]}$   The cooperation ratio of peer $j$. If peer $j$ never supplied peer $p$, the information of $C_{r[j]}$ may not be available.

$C_{r(max)}$   The maximum cooperation ratio of peer $p$'s neighbors, i.e., $C_{r(max)} = max(C_r)$.

$$G_j = \begin{cases} \dfrac{n_j C_{r[j]}}{N_j} & \text{if } n_j > 0 \\ \dfrac{C_{r(max)}}{N_j + 1} & \text{if } n_j = 0 \end{cases}$$

(5.1)

Cursus $C_{r(max)}$ conubia nostra, per inceptos hymenaeos $j$ gadipiscing mollis massa $N_j = 0$, unc ut dui eget nulla venenatis aliquet $G_j = C_{r(max)}$.

Vestibulum accumsan eros nec magna. Vestibulum vitae dui. Vestibulum nec ligula et lorem consequat ullamcorper. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Phasellus eget nisl ut elit porta ullamcorper. Maecenas tincidunt velit quis orci. Sed in dui. Nullam ut mauris eu mi mollis luctus. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Sed cursus cursus velit. Sed a massa.

Both Figures 5.2(a) and 5.2(b) Phasellus eget nisl ut elit porta "perfect" tincidunt. Class aptent taciti sociosqu ad litora torquent per conubia nostra.

Cras sed ante. Phasellus in massa. Curabitur dolor eros, gravida et, hendrerit ac, cursus non, massa. Aliquam lorem. In hac habitasse platea dictumst. Cras eu mauris. Quisque lacus. Donec ipsum. Nullam vitae sem at nunc pharetra ultricies. Vivamus elit eros, ullamcorper a, adipiscing sit amet, porttitor ut, nibh. Maecenas adipiscing mollis massa. Nunc ut dui eget nulla venenatis aliquet.
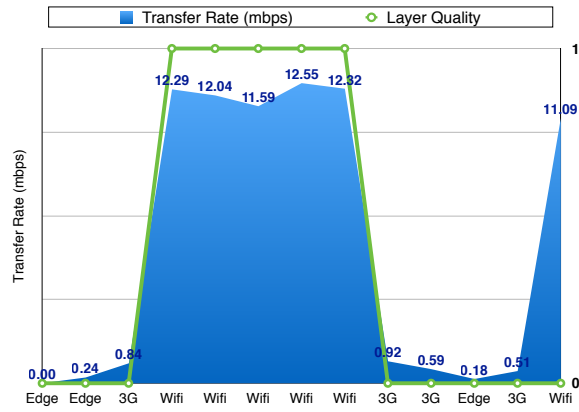
**(a)** Adaptation System Test 4
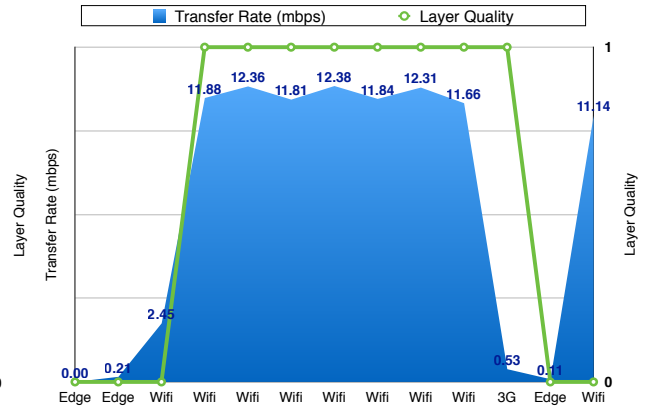
**(b)** Adaptation System Test 5

**Figure 5.2:** Adaptation System Behavior Test

Sed luctus posuere justo. Cras vehicula varius turpis. Vivamus eros metus, tristique sit amet, molestie dignissim, malesuada et, urna.

# 6

# Conclusion

## Contents

Pellentesque vel dui sed orci faucibus iaculis. Suspendisse dictum magna id purus tincidunt rutrum. Nulla congue. Vivamus sit amet lorem posuere dui vulputate ornare. Phasellus mattis sollicitudin ligula. Duis dignissim felis et urna. Integer adipiscing congue metus.

> Rui Cruz
>
> You should always start a Chapter with an introductory text

## 6.1   Conclusions

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## 6.2   System Limitations and Future Work

Aliquam aliquet, est a ullamcorper condimentum, tellus nulla fringilla elit, a iaculis nulla turpis sed wisi. Fusce volutpat. Etiam sodales ante id nunc. Proin ornare dignissim lacus. Nunc porttitor nunc a sem.

Sed sollicitudin velit eu magna. Aliquam erat volutpat. Vivamus ornare est non wisi. Proin vel quam. Vivamus egestas. Nunc tempor diam vehicula mauris. Nullam sapien eros, facilisis vel, eleifend non, auctor dapibus, pede.

# Bibliography

# A

# Code of Project

Nulla dui purus, eleifend vel, consequat non, dictum porta, nulla. Duis ante mi, laoreet ut, commodo eleifend, cursus nec, lorem. Aenean eu est. Etiam imperdiet turpis. Praesent nec augue. Curabitur ligula quam, rutrum id, tempor sed, consequat ac, dui. Vestibulum accumsan eros nec magna. Vestibulum vitae dui. Vestibulum nec ligula et lorem consequat ullamcorper.

**Listing A.1:** Example of a XML file.

```
1  <?xml version="1.0" encoding="UTF-8"?>
2  <StreamInfo version="2.0">
3      <Clip duration="PT01M0.00S">
4          <BaseURL>videos/</BaseURL>
5          <Description>svc_1</Description>
6          <Representation mimeType="video/SVC" codecs="svc" frameRate="30.00" bandwidth="401.90"
7              width="176" height="144" id="L0">
8              <BaseURL>svc_1/</BaseURL>
9              <SegmentInfo from="0" to="11" duration="PT5.00S">
10                 <BaseURL>svc_1-L0-</BaseURL>
11             </SegmentInfo>
12         </Representation>
```

```xml
13    <Representation mimeType="video/SVC" codecs="svc" frameRate="30.00" bandwidth="1322.60"
14        width="352" height="288" id="L1">
15        <BaseURL>svc_1/</BaseURL>
16        <SegmentInfo from="0" to="11" duration="PT5.00S">
17            <BaseURL>svc_1-L1-</BaseURL>
18        </SegmentInfo>
19    </Representation>
20  </Clip>
21 </StreamInfo>
```

Etiam imperdiet turpis. Praesent nec augue. Curabitur ligula quam, rutrum id, tempor sed, consequat ac, dui. Maecenas tincidunt velit quis orci. Sed in dui. Nullam ut mauris eu mi mollis luctus. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Sed cursus cursus velit. Sed a massa. Duis dignissim euismod quam.

Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Phasellus eget nisl ut elit porta ullamcorper. Maecenas tincidunt velit quis orci. Sed in dui. Nullam ut mauris eu mi mollis luctus. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos.

This inline MATLAB code `for i=1:3, disp('cool'); end;` uses the \mcode{} command.[1]

Nullam ut mauris eu mi mollis luctus. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Sed cursus cursus velit. Sed a massa. Duis dignissim euismod quam. Nullam euismod metus ut orci.

**Listing A.2:** Matlab Function

```matlab
1  for i = 1:3
2      if i >= 5 && a ~= b        % literate programming replacement
3          disp('cool');          % comment with some LaTeX in it: πx²
4      end
5      [:,ind] = max(vec);
6      x_last = x(1,end) - 1;
7      v(end);
8      ylabel('Voltage (μV)');
9  end
```

Nullam ut mauris eu mi mollis luctus. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Sed cursus cursus velit. Sed a massa. Duis dignissim euismod quam. Nullam euismod metus ut orci.

---

[1]MATLAB Works also in footnotes: `for i=1:3, disp('cool'); end;`

**Listing A.3:** `function.m`

```matlab
%   Copyright 2010 The MathWorks, Inc.
function ObjTrack(position)
% #codegen
% First, setup the figure
numPts = 300;                % Process and plot 300 samples
figure;hold;grid;           % Prepare plot window
% Main loop
for idx = 1: numPts
    z = position(:,idx);   % Get the input data
    y = kalmanfilter(z);   % Call Kalman filter to estimate the position
    plot_trajectory(z,y);  % Plot the results
end
hold;
end   % of the function
```

Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Phasellus eget nisl ut elit porta ullamcorper. Maecenas tincidunt velit quis orci. Sed in dui. Nullam ut mauris eu mi mollis luctus. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Sed cursus cursus velit. Sed a massa. Duis dignissim euismod quam. Nullam euismod metus ut orci. Vestibulum erat libero, scelerisque et, porttitor et, varius a, leo.

**Listing A.4:** HTML with CSS Code

```html
<!DOCTYPE html>
<html>
  <head>
    <title>Listings Style Test</title>
    <meta charset="UTF-8">
    <style>
      /* CSS Test */
      * {
        padding: 0;
        border: 0;
        margin: 0;
      }
    </style>
    <link rel="stylesheet" href="css/style.css" />
  </head>
```

```
16    <header> hey </header>
17    <article> this is a article </article>
18    <body>
19      <!-- Paragraphs are fine -->
20      <div id="box">
21        <p>
22          Hello World
23        </p>
24        <p>Hello World</p>
25        <p id="test">Hello World</p>
26        <p></p>
27      </div>
28      <div>Test</div>
29      <!-- HTML script is not consistent -->
30      <script src="js/benchmark.js"></script>
31      <script>
32        function createSquare(x, y) {
33          // This is a comment.
34          var square = document.createElement('div');
35          square.style.width = square.style.height = '50px';
36          square.style.backgroundColor = 'blue';
37
38          /*
39           * This is another comment.
40           */
41          square.style.position = 'absolute';
42          square.style.left = x + 'px';
43          square.style.top = y + 'px';
44
45          var body = document.getElementsByTagName('body')[0];
46          body.appendChild(square);
47        };
48
49        // Please take a look at +=
50        window.addEventListener('mousedown', function(event) {
51          // German umlaut test: Berührungspunkt ermitteln
52          var x = event.touches[0].pageX;
53          var y = event.touches[0].pageY;
```

```
54            var lookAtThis += 1;
55        });
56      </script>
57    </body>
58 </html>
```

Nulla dui purus, eleifend vel, consequat non, dictum porta, nulla. Duis ante mi, laoreet ut, commodo eleifend, cursus nec, lorem. Aenean eu est. Etiam imperdiet turpis. Praesent nec augue. Curabitur ligula quam, rutrum id, tempor sed, consequat ac, dui. Vestibulum accumsan eros nec magna. Vestibulum vitae dui. Vestibulum nec ligula et lorem consequat ullamcorper.

**Listing A.5:** HTML CSS Javascript Code

```
1
2 @media only screen and (min-width: 768px) and (max-width: 991px) {
3
4    #main {
5      width: 712px;
6      padding: 100px 28px 120px;
7    }
8
9    /* .mono {
10      font-size: 90%;
11    } */
12
13    .cssbtn a {
14      margin-top: 10px;
15      margin-bottom: 10px;
16      width: 60px;
17      height: 60px;
18      font-size: 28px;
19      line-height: 62px;
20    }
```

Nulla dui purus, eleifend vel, consequat non, dictum porta, nulla. Duis ante mi, laoreet ut, commodo eleifend, cursus nec, lorem. Aenean eu est. Etiam imperdiet turpis. Praesent nec augue. Curabitur ligula quam, rutrum id, tempor sed, consequat ac, dui. Vestibulum accumsan eros nec magna. Vestibulum vitae dui. Vestibulum nec ligula et lorem consequat ullamcorper.

**Listing A.6:** PYTHON Code

```python
class TelgramRequestHandler(object):
    def handle(self):
        addr = self.client_address[0]          # Client IP-adress
        telgram = self.request.recv(1024)      # Recieve telgram
        print "From: %s, Received: %s" % (addr, telgram)
        return
```

# B

# A Large Table

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As Table B.1 shows, the data can be inserted from a file, in the case of a somehow complex structure. Notice the Table footnotes.

**Table B.1:** Example table

| Benchmark: ANN | #Layers $(1)$ | #Nets $(2)$ | #Nodes* $(3) = 8 \cdot (1) \cdot (2)$ | Critical path $(4) = 4 \cdot (1)$ | Latency $(T_{iter})$ $(5)$ |
|---|---|---|---|---|---|
| A1 | **3–1501** | 1 | **24–12008** | **12–6004** | 4 |
| A2 | 501 | 1 | 4008 | 2004 | **2–2000** |
| A3 | 10 | **2–1024** | **160–81920** | 40 | 60$^\dagger$ |
| A4 | 10 | 50 | 4000 | 40 | **80–1200** |

| Benchmark: FFT | FFT size$^\ddagger$ $(1)$ | #Inputs $(2) = 2^{(1)}$ | #Nodes* $(3) = 10 \cdot (1) \cdot (2)$ | Critical path $(4) = 4 \cdot (1)$ | Latency $(T_{iter})$ $(5)$ |
|---|---|---|---|---|---|
| F1 | **1–10** | 2–1024 | **20–102400** | 4–40 | 6–60$^\dagger$ |
| F2 | **5** | 32 | 1600 | 20 | **40 – 1500** |

| Benchmark: Random networks | #Types $(1)$ | #Nodes $(2)$ | #Networks $(3)$ | Critical path $(4)$ | Latency $(T_{iter})$ $(5)$ |
|---|---|---|---|---|---|
| R1 | 3 | 10–2000 | 500 | *variable* | $(4)$ |
| R2 | 3 | 50 | 500 | *variable* | $(4) \times [1; \cdots ; 20]$ |

\* *Excluding constant nodes.*
$^\dagger$ *Value kept proportional to the critical path:* $(5) = (4) * 1.5$.
$^\ddagger$ *A size of $x$ corresponds to a $2^x$ point FFT.*
*Values in bold indicate the parameter being varied.*

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And now an example (**??**) of a table that extends to more than one page. Notice the repetition of the Caption (with indication that is continued) and of the Header, as well as the continuation text at the bottom.

An example of a large Table that autofits the size to the page margins is illustrated in Table B.2. Please notice the text size that is shrunken in order fot the table to adjust to the page:

**Table B.2:** Sample Table.

| URL | First Time Visit | Last Time Visit | URL Counts | Value | Reference |
|---|---|---|---|---|---|
| https://web.facebook.com/ | 1521241972 | 1522351859 | 177 | 56640 | [facebook-2021] |
| http://localhost/phpmyadmin/ | 1518413861 | 1522075694 | 24 | 39312 | database-management |
| https://mail.google.com/mail/u/ | 1516596003 | 1522352010 | 36 | 33264 | Google-Gmail-2021 |
| https://github.com/shawon100 | 1517215489 | 1522352266 | 37 | 27528 | Code-Repository |
| https://www.youtube.com/ | 1517229227 | 1521978502 | 24 | 14792 | Youtube-video-2021 |