

# QoS-Aware Routing in Future All-IP Access Networks



**University of London**

**Alexandre Jaron**

Centre for Telecommunications Research

King's College London

A thesis submitted to King's College London in partial fulfilment  
of the requirements for the degree of

*Doctor of Philosophy*

February 2015



I would like to dedicate this thesis to Rana,  
the light of my universe. . .



## Acknowledgements

Never planning before to get here, until the opportunity came, I cannot express my happiness in words for one of the most worthwhile experiences in my life. While tackling the problems during a PhD, one may learn invariable lessons: from self-adjustment to facing the failures; from bitterness of being on the verge of hopelessness, to the beauty of getting the confidence and inclination to question all that is around, and seek out new ways of doing it. Most importantly, the lesson of learning to push yourself out of comfort zone to make progress. Without a doubt, I would not be able to sit and write this acknowledgement today without many people throughout my life, who their presence and true friendship in a times of need have shed the light of beauty into my life. Although not being able to name all, I will never forget any of them. I am and will always be deeply indebted to my Ph.D. Supervisor Prof. Hamid Aghvami, the head of the Centre for Telecommunication Research. I am deeply grateful for the guidance, encouragements and support he provided throughout my Ph.D. A special thanks to Dr. Andrej Mihailovic who helped me greatly during my Ph.D. research study. I have true appreciation for his valuable suggestions and insights and the collaborative works produced towards writing papers. He always had faith in me and supported me throughout my studies which I am very thankful for.



# Abstract

The proliferation of mobile devices over the past several years has created a whole new world of the Internet. The deluge of applications for every aspect of today's life has raised the expectation of having ubiquitous connectivity, with a desired Quality of Service (QoS). Although appealing, it has violated the original Internet design which was not intended to support mobility, neither better than best-effort delivery.

It is also a well-known fact that technology is an ever-advancing need of the human society, and undeniably the Internet forms a major part of our lives now. Everyday more and more users flood the Internet with enormous amount of data and information. As such there is a need to effectively handle all the information and traffic in a way that there is an availability of high speed network routing without any loss in data transmission.

QoS provisioning has been one of the long lasting focuses in the network research community. While designed for fixed networks, the use of QoS protocols in IP-based mobile networks, where hosts dynamically change their point of attachments, imposes new challenges to be studied and analysed. Furthermore, a massive growth in the access network traffic with its highly unpredictable nature can cause bottlenecks in some links while others are under-utilised, rendering the load skewed, and therefore, breaching the QoS provisioning commitments.

The main objective of this research is to propose a novel QoS mechanism for mobile networks. The new scheme is composed of two different approaches accountable for QoS provisioning in next-generation access networks. Firstly, a new method is proposed that minimises the signalling overhead, as well as the interruption in QoS at the time of handover. Through a developed analytical framework and simulation scenario, the performance of the new scheme is investigated thoroughly, with the focus on the figures of merit that affect the efficiency of using QoS signalling protocols in access networks. Secondly, a new QoS-aware routing mechanism is proposed, based on the OSPF protocol, intending to minimise the congestion on the links while at the same time

complying with traffic requirements. OSPF was created for providing flexibility and great scalability, and although not widely used shows strong promises for the future.

This research delves into the study and development of IP-based networking, built upon an extension to OSPF routing protocol, that will foster integrated functioning of technologies that currently lead the vision for the novel telecommunication infrastructures and service provision. This novel QoS-aware approach, Multi-Plane Routing (MPR), is applied in access networks for IP routing. MPR divides the physical network into several logical routing planes, each being associated with a dedicated link weight configuration. Network topology and node degree distribution directly impact the performance of our strategy.

The foundation of the project's vision for networking in the future networks is in the evolution and derivatives of IP routing that are inherited from the native Internet and stand as the solution for networking in the sought 'all-IP' integrated modern telecommunications infrastructures. MPR uses QoS-awareness and policies for plane selection to achieve optimal performance according to criteria selected for traffic engineering in networks.



# Table of contents

List of figures	<a href="#">xi</a>
List of tables	<a href="#">xiii</a>
Nomenclature	<a href="#">xv</a>
<b>1 Getting started</b>	<b><a href="#">1</a></b>
1.1 What is lorem ipsum? Title with math $\sigma$ . . . . .	<a href="#">1</a>
1.2 Why do we use lorem ipsum? . . . . .	<a href="#">1</a>
1.3 Where does it come from? . . . . .	<a href="#">2</a>
<b>2 My second chapter</b>	<b><a href="#">5</a></b>
2.1 Short title . . . . .	<a href="#">5</a>
<b>3 My third chapter</b>	<b><a href="#">11</a></b>
3.1 First section of the third chapter . . . . .	<a href="#">11</a>
3.1.1 First subsection in the first section . . . . .	<a href="#">11</a>
3.1.2 Second subsection in the first section . . . . .	<a href="#">11</a>
3.1.3 Third subsection in the first section . . . . .	<a href="#">11</a>
3.2 Second section of the third chapter . . . . .	<a href="#">12</a>
3.3 The layout of formal tables . . . . .	<a href="#">12</a>
<b>References</b>	<b><a href="#">15</a></b>
<b>Appendix A How to install L<sup>A</sup>T<sub>E</sub>X</b>	<b><a href="#">17</a></b>
<b>Appendix B Installing the CUED class file</b>	<b><a href="#">21</a></b>
<b>Index</b>	<b><a href="#">23</a></b>



# List of figures

2.1	Minion . . . . .	<a href="#">6</a>
2.2	Best Animations . . . . .	<a href="#">9</a>



# List of tables

3.1	A badly formatted table . . . . .	<a href="#">13</a>
3.2	A nice looking table . . . . .	<a href="#">13</a>
3.3	Even better looking table using booktabs . . . . .	<a href="#">13</a>



# Nomenclature

## Roman Symbols

$F$       complex function

## Greek Symbols

$\gamma$       a simply closed curve on a complex plane

$\iota$       unit imaginary number  $\sqrt{-1}$

$\pi$        $\simeq 3.14 \dots$

## Superscripts

$j$       superscript index

## Subscripts

$0$       subscript index

## Other Symbols

$\oint_{\gamma}$       integration around a curve  $\gamma$

## Acronyms / Abbreviations

$CIF$     Cauchy's Integral Formula





# Chapter 1

## Getting started

### 1.1 What is loren ipsum? Title with math $\sigma$

Lorem Ipsum is simply dummy text of the printing and typesetting industry (see Section 1.3). Lorem Ipsum [3] has been the industry’s standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsum [1, 4, 5].

The most famous equation in the world:  $E^2 = (m_0c^2)^2 + (pc)^2$ , which is known as the **energy-mass-momentum** relation as an in-line equation.

A  $\LaTeX$  class file is a file, which holds style information for a particular  $\LaTeX$ .

$$CIF : \quad F_0^j(a) = \frac{1}{2\pi i} \oint_{\gamma} \frac{F_0^j(z)}{z - a} dz \quad (1.1)$$

### 1.2 Why do we use loren ipsum?

It is a long established fact that a reader will be distracted by the readable content of a page when looking at its layout. The point of using Lorem Ipsum is that it has a more-or-less normal distribution of letters, as opposed to using ‘Content here, content here’, making it look like readable English. Many desktop publishing packages and web page editors now use Lorem Ipsum as their default

model text, and a search for ‘lorem ipsum’ will uncover many web sites still in their infancy. Various versions have evolved over the years, sometimes by accident, sometimes on purpose (injected humour and the like).

### 1.3 Where does it come from?

Contrary to popular belief, Lorem Ipsum is not simply random text. It has roots in a piece of classical Latin literature from 45 BC, making it over 2000 years old. Richard McClintock, a Latin professor at Hampden-Sydney College in Virginia, looked up one of the more obscure Latin words, *consectetur*, from a Lorem Ipsum passage, and going through the cites of the word in classical literature, discovered the undoubtable source. Lorem Ipsum comes from sections 1.10.32 and 1.10.33 of "de Finibus Bonorum et Malorum" (The Extremes of Good and Evil) by Cicero, written in 45 BC. This book is a treatise on the theory of ethics, very popular during the Renaissance. The first line of Lorem Ipsum, "Lorem ipsum dolor sit amet..", comes from a line in section 1.10.32.

The standard chunk of Lorem Ipsum used since the 1500s is reproduced below for those interested. Sections 1.10.32 and 1.10.33 from "de Finibus Bonorum et Malorum" by Cicero are also reproduced in their exact original form, accompanied by English versions from the 1914 translation by H. Rackham

"Lorem ipsum dolor sit amet, consectetur adipisicing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum."

Section 1.10.32 of "de Finibus Bonorum et Malorum", written by Cicero in 45 BC: "Sed ut perspiciatis unde omnis iste natus error sit voluptatem accusantium doloremque laudantium, totam rem aperiam, eaque ipsa quae ab illo inventore veritatis et quasi architecto beatae vitae dicta sunt explicabo. Nemo enim ipsam voluptatem quia voluptas sit aspernatur aut odit aut fugit, sed quia consequuntur magni dolores eos qui ratione voluptatem sequi nesciunt. Neque porro quisquam est, qui dolorem ipsum quia dolor sit amet, consectetur, adipisci velit, sed quia non numquam eius modi tempora incidunt ut labore et dolore magnam aliquam quaerat voluptatem. Ut enim ad minima veniam, quis nostrum exercitationem ullam corporis suscipit laboriosam, nisi ut aliquid ex ea commodi consequatur? Quis autem vel eum iure reprehenderit qui in ea

voluptate velit esse quam nihil molestiae consequatur, vel illum qui dolorem eum fugiat quo voluptas nulla pariatur?"

1914 translation by H. Rackham: "But I must explain to you how all this mistaken idea of denouncing pleasure and praising pain was born and I will give you a complete account of the system, and expound the actual teachings of the great explorer of the truth, the master-builder of human happiness. No one rejects, dislikes, or avoids pleasure itself, because it is pleasure, but because those who do not know how to pursue pleasure rationally encounter consequences that are extremely painful. Nor again is there anyone who loves or pursues or desires to obtain pain of itself, because it is pain, but because occasionally circumstances occur in which toil and pain can procure him some great pleasure. To take a trivial example, which of us ever undertakes laborious physical exercise, except to obtain some advantage from it? But who has any right to find fault with a man who chooses to enjoy a pleasure that has no annoying consequences, or one who avoids a pain that produces no resultant pleasure?"

Section 1.10.33 of "de Finibus Bonorum et Malorum", written by Cicero in 45 BC: "At vero eos et accusamus et iusto odio dignissimos ducimus qui blanditiis praesentium voluptatum deleniti atque corrupti quos dolores et quas molestias excepturi sint occaecati cupiditate non provident, similique sunt in culpa qui officia deserunt mollitia animi, id est laborum et dolorum fuga. Et harum quidem rerum facilis est et expedita distinctio. Nam libero tempore, cum soluta nobis est eligendi optio cumque nihil impedit quo minus id quod maxime placeat facere possimus, omnis voluptas assumenda est, omnis dolor repellendus. Temporibus autem quibusdam et aut officiis debitis aut rerum necessitatibus saepe eveniet ut et voluptates repudiandae sint et molestiae non recusandae. Itaque earum rerum hic tenetur a sapiente delectus, ut aut reiciendis voluptatibus maiores alias consequatur aut perferendis doloribus asperiores repellat."

1914 translation by H. Rackham: "On the other hand, we denounce with righteous indignation and dislike men who are so beguiled and demoralized by the charms of pleasure of the moment, so blinded by desire, that they cannot foresee the pain and trouble that are bound to ensue; and equal blame belongs to those who fail in their duty through weakness of will, which is the same as saying through shrinking from toil and pain. These cases are perfectly simple and easy to distinguish. In a free hour, when our power of choice is untrammelled and when nothing prevents our being able to do what we like best, every pleasure is to be welcomed and every pain avoided. But in certain

circumstances and owing to the claims of duty or the obligations of business it will frequently occur that pleasures have to be repudiated and annoyances accepted. The wise man therefore always holds in these matters to this principle of selection: he rejects pleasures to secure other greater pleasures, or else he endures pains to avoid worse pains."

# Chapter 2

## My second chapter

### 2.1 Reasonably long section title

I'm going to randomly include a picture Figure 2.1.

If you have trouble viewing this document contact Krishna at: [kks32@cam.ac.uk](mailto:kks32@cam.ac.uk) or raise an issue at <https://github.com/kks32/phd-thesis-template/>

### Enumeration

1. The first topic is dull
2. The second topic is duller
  - (a) The first subtopic is silly
  - (b) The second subtopic is stupid
3. The third topic is the dullest

### itemize

- The first topic is dull
- The second topic is duller
  - The first subtopic is silly
  - The second subtopic is stupid
- The third topic is the dullest

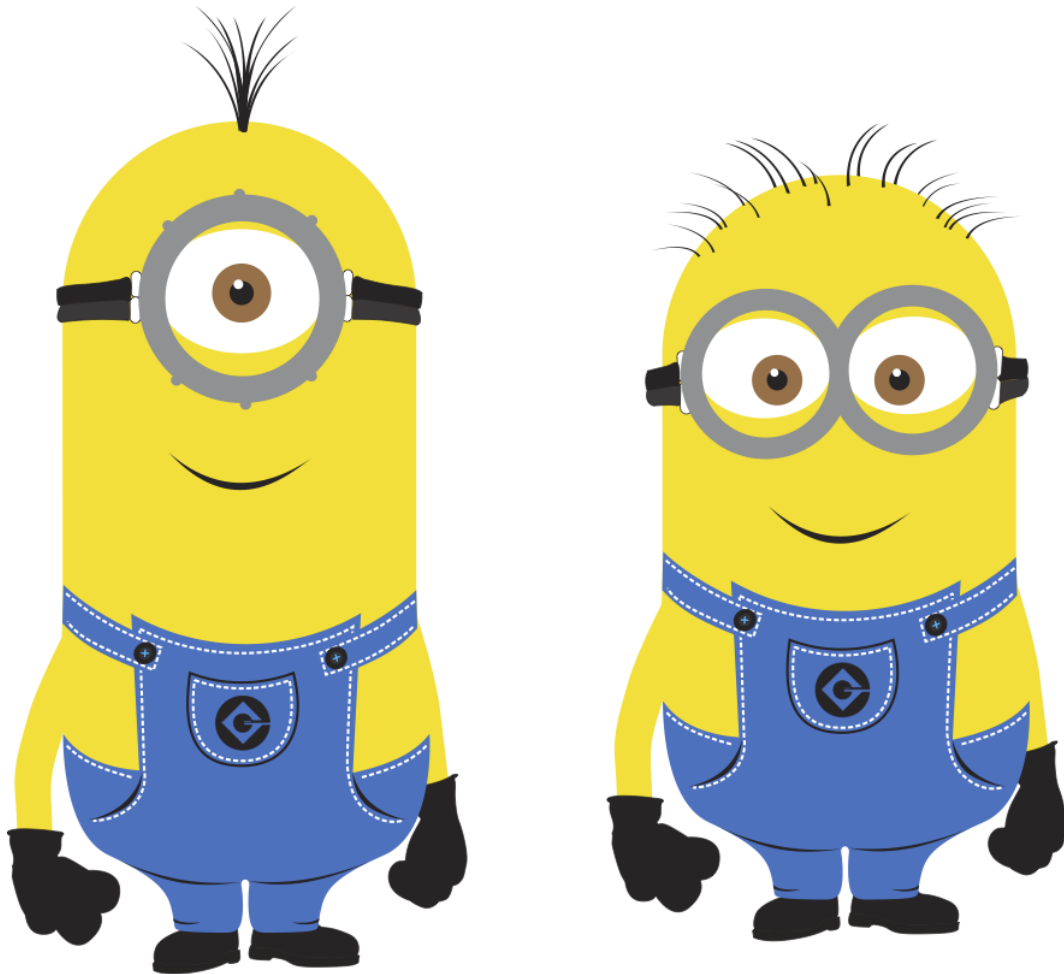


Fig. 2.1 This is just a long figure caption for the minion in Despicable Me from Pixar

## **description**

**The first topic** is dull

**The second topic** is duller

**The first subtopic** is silly

**The second subtopic** is stupid

**The third topic** is the dullest

## 2.2 Hidden section

**Lorem ipsum dolor sit amet**, *consectetur adipiscing elit*. In magna nisi, aliquam id blandit id, congue ac est. Fusce porta consequat leo. Proin feugiat at felis vel consectetur. Ut tempus ipsum sit amet congue posuere. Nulla varius rutrum quam. Donec sed purus luctus, faucibus velit id, ultrices sapien. Cras diam purus, tincidunt eget tristique ut, egestas quis nulla. Curabitur vel iaculis lectus. Nunc nulla urna, ultrices et eleifend in, accumsan ut erat. In ut ante leo. Aenean a lacinia nisl, sit amet ullamcorper dolor. Maecenas blandit, tortor ut scelerisque congue, velit diam volutpat metus, sed vestibulum eros justo ut nulla. Etiam nec ipsum non enim luctus porta in in massa. Cras arcu urna, malesuada ut tellus ut, pellentesque mollis risus. Morbi vel tortor imperdiet arcu auctor mattis sit amet eu nisi. Nulla gravida urna vel nisl egestas varius. Aliquam posuere ante quis malesuada dignissim. Mauris ultrices tristique eros, a dignissim nisl iaculis nec. Praesent dapibus tincidunt mauris nec tempor. Curabitur et consequat nisi. Quisque viverra egestas risus, ut sodales enim blandit at. Mauris quis odio nulla. Cras euismod turpis magna, in facilisis diam congue non. Mauris faucibus nisl a orci dictum, et tempus mi cursus.

Etiam elementum tristique lacus, sit amet eleifend nibh eleifend sed <sup>1</sup>. Maecenas dapibu augue ut urna malesuada, non tempor nibh mollis. Donec sed sem sollicitudin, convallis velit aliquam, tincidunt diam. In eu venenatis lorem. Aliquam non augue porttitor tellus faucibus porta et nec ante. Proin sodales, libero vitae commodo sodales, dolor nisi cursus magna, non tincidunt ipsum nibh eget purus. Nam rutrum tincidunt arcu, tincidunt vulputate mi sagittis id. Proin et nisi nec orci tincidunt auctor et porta elit. Praesent eu dolor ac magna cursus euismod. Integer non dictum nunc.

---

<sup>1</sup>My footnote goes blah blah blah! ...





Fig. 2.2 Best Animations

# Subplots

I can cite Wall-E (see Fig. 2.2b) and Minions in despicable me (Fig. 2.2c) or I can cite the whole figure as Fig. 2.2



# Chapter 3

## My third chapter

### 3.1 First section of the third chapter

And now I begin my third chapter here ...

And now to cite some more people Ancey et al. [2], Read [6]. I can also cite [3].

#### 3.1.1 First subsection in the first section

... and some more

#### 3.1.2 Second subsection in the first section

... and some more ...

##### First subsub section in the second subsection

... and some more in the first subsub section otherwise it all looks the same doesn't it? well we can add some text to it ...

#### 3.1.3 Third subsection in the first section

... and some more ...

##### First subsub section in the third subsection

... and some more in the first subsub section otherwise it all looks the same doesn't it? well we can add some text to it and some more and some more and some more and some more and some more and some more ...

### Second subsub section in the third subsection

...and some more in the first subsub section otherwise it all looks the same doesn't it? well we can add some text to it ...

## 3.2 Second section of the third chapter

and here I write more ...

## 3.3 The layout of formal tables

This section has been modified from “Publication quality tables in L<sup>A</sup>T<sub>E</sub>X<sup>\*</sup>” by Simon Fear.

The layout of a table has been established over centuries of experience and should only be altered in extraordinary circumstances.

When formatting a table, remember two simple guidelines at all times:

1. Never, ever use vertical rules (lines).
2. Never use double rules.

These guidelines may seem extreme but I have never found a good argument in favour of breaking them. For example, if you feel that the information in the left half of a table is so different from that on the right that it needs to be separated by a vertical line, then you should use two tables instead. Not everyone follows the second guideline:

There are three further guidelines worth mentioning here as they are generally not known outside the circle of professional *typesetters* and subeditors:

3. Put the units in the column heading (not in the body of the table).
4. Always precede a decimal point by a digit; thus 0.1 *not* just .1.
5. Do not use ‘ditto’ signs or any other such convention to repeat a previous value. In many circumstances a blank will serve just as well. If it won't, then repeat the value.

A frequently seen mistake is to use ‘`\begin{center}`’ ... ‘`\end{center}`’ inside a figure or table environment. This center environment can cause additional vertical space. If you want to avoid that just use ‘`\centering`’

Table 3.1 A badly formatted table

	Species I		Species II	
Dental measurement	mean	SD	mean	SD
I1MD	6.23	0.91	5.2	0.7
I1LL	7.48	0.56	8.7	0.71
I2MD	3.99	0.63	4.22	0.54
I2LL	6.81	0.02	6.66	0.01
CMD	13.47	0.09	10.55	0.05
CBL	11.88	0.05	13.11	0.04

Table 3.2 A nice looking table

Dental measurement	Species I		Species II	
	mean	SD	mean	SD
I1MD	6.23	0.91	5.2	0.7
I1LL	7.48	0.56	8.7	0.71
I2MD	3.99	0.63	4.22	0.54
I2LL	6.81	0.02	6.66	0.01
CMD	13.47	0.09	10.55	0.05
CBL	11.88	0.05	13.11	0.04

Table 3.3 Even better looking table using booktabs

Dental measurement	Species I		Species II	
	mean	SD	mean	SD
I1MD	6.23	0.91	5.2	0.7
I1LL	7.48	0.56	8.7	0.71
I2MD	3.99	0.63	4.22	0.54
I2LL	6.81	0.02	6.66	0.01
CMD	13.47	0.09	10.55	0.05
CBL	11.88	0.05	13.11	0.04



# References

- [1] Abramovich, Y. A., Aliprantis, C. D., and Burkinshaw, O. (1995). Another characterization of the invariant subspace problem. *Operator Theory in Function Spaces and Banach Lattices*. The A.C. Zaanen Anniversary Volume, *Operator Theory: Advances and Applications*, 75:15–31. Birkhäuser Verlag.
- [2] Ancey, C., Coussot, P., and Evesque, P. (1996). Examination of the possibility of a fluid-mechanics treatment of dense granular flows. *Mechanics of Cohesive-frictional Materials*, 1(4):385–403.
- [3] Aupetit, B. (1991). *A Primer on Spectral Theory*. Springer-Verlag, New York.
- [4] Conway, J. B. (1990). *A Course in Functional Analysis*. Springer-Verlag, New York, second edition.
- [5] Ljubič, J. I. and Macaev, V. I. (1965). On operators with a separable spectrum. *Amer. Math. Soc. Transl. (2)*, 47:89–129.
- [6] Read, C. J. (1985). A solution to the invariant subspace problem on the space  $l_1$ . *Bull. London Math. Soc.*, 17:305–317.





# Appendix A

## How to install L<sup>A</sup>T<sub>E</sub>X

### Windows OS

#### TeXLive package - full version

1. Download the TeXLive ISO (2.2GB) from  
<https://www.tug.org/texlive/>
2. Download WinCDEmu (if you don't have a virtual drive) from  
<http://wincdemu.sysprogs.org/download/>
3. To install Windows CD Emulator follow the instructions at  
<http://wincdemu.sysprogs.org/tutorials/install/>
4. Right click the iso and mount it using the WinCDEmu as shown in  
<http://wincdemu.sysprogs.org/tutorials/mount/>
5. Open your virtual drive and run setup.pl

or

#### Basic MikTeX - T<sub>E</sub>X distribution

1. Download Basic-MiK<sub>T</sub>E<sub>X</sub>(32bit or 64bit) from  
<http://miktex.org/download>
2. Run the installer
3. To add a new package go to Start » All Programs » MikTeX » Maintenance (Admin) and choose Package Manager
4. Select or search for packages to install

## TeXStudio - T<sub>E</sub>X editor

1. Download TexStudio from  
<http://texstudio.sourceforge.net/#downloads>
2. Run the installer

## Mac OS X

### MacTeX - T<sub>E</sub>X distribution

1. Download the file from  
<https://www.tug.org/mactex/>
2. Extract and double click to run the installer. It does the entire configuration, sit back and relax.

## TeXStudio - T<sub>E</sub>X editor

1. Download TexStudio from  
<http://texstudio.sourceforge.net/#downloads>
2. Extract and Start

## Unix/Linux

### TeXLive - T<sub>E</sub>X distribution

#### Getting the distribution:

1. TexLive can be downloaded from  
<http://www.tug.org/texlive/acquire-netinstall.html>.
2. TexLive is provided by most operating system you can use (rpm,apt-get or yum) to get TexLive distributions

#### Installation

1. Mount the ISO file in the mnt directory

```
mount -t iso9660 -o ro,loop,noauto /your/texlive####.iso /mnt
```

2. Install wget on your OS (use rpm, apt-get or yum install)
3. Run the installer script install-tl.

```
cd /your/download/directory
./install-tl
```

4. Enter command 'i' for installation
5. Post-Installation configuration:  
<http://www.tug.org/texlive/doc/texlive-en/texlive-en.html#x1-320003.4.1>
6. Set the path for the directory of TexLive binaries in your .bashrc file

### **For 32bit OS**

For Bourne-compatible shells such as bash, and using Intel x86 GNU/Linux and a default directory setup as an example, the file to edit might be

```
edit ~/.bashrc file and add following lines
PATH=/usr/local/texlive/2011/bin/i386-linux:$PATH;
export PATH
MANPATH=/usr/local/texlive/2011/texmf/doc/man:$MANPATH;
export MANPATH
INFOPATH=/usr/local/texlive/2011/texmf/doc/info:$INFOPATH;
export INFOPATH
```

### **For 64bit OS**

```
edit ~/.bashrc file and add following lines
PATH=/usr/local/texlive/2011/bin/x86_64-linux:$PATH;
export PATH
MANPATH=/usr/local/texlive/2011/texmf/doc/man:$MANPATH;
export MANPATH
INFOPATH=/usr/local/texlive/2011/texmf/doc/info:$INFOPATH;
export INFOPATH
```

### **Fedora/RedHat/CentOS:**

```
sudo yum install texlive
sudo yum install psutils
```

**SUSE:**

```
sudo zypper install texlive
```

**Debian/Ubuntu:**

```
sudo apt-get install texlive texlive-latex-extra  
sudo apt-get install psutils
```

# Appendix B

## Installing the CUED class file

$\LaTeX$ .cls files can be accessed system-wide when they are placed in the `<texmf>/tex/latex` directory, where `<texmf>` is the root directory of the user's  $\TeX$  installation. On systems that have a local texmf tree (`<texmflocal>`), which may be named “texmf-local” or “localtexmf”, it may be advisable to install packages in `<texmflocal>`, rather than `<texmf>` as the contents of the former, unlike that of the latter, are preserved after the  $\LaTeX$  system is reinstalled and/or upgraded.

It is recommended that the user create a subdirectory `<texmf>/tex/latex/CUED` for all CUED related  $\LaTeX$  class and package files. On some  $\LaTeX$  systems, the directory look-up tables will need to be refreshed after making additions or deletions to the system files. For  $\TeX$ Live systems this is accomplished via executing “texhash” as root.  $\text{MiKTeX}$  users can run “initexmf -u” to accomplish the same thing.

Users not willing or able to install the files system-wide can install them in their personal directories, but will then have to provide the path (full or relative) in addition to the filename when referring to them in  $\LaTeX$ .



# Index

Stupid Term, [1](#)

Another stupid term, [12](#)