

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 PhD 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 PhD. A special thanks to Dr. Andrej Mihailovic who helped me greatly during my PhD 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 approached 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 projects 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.

Contents

Contents	v
List of Figures	vii
List of Tables	viii
List of Abbreviations	ix
1 Introduction	1
2 My First Chapter But Note The Numbering ...	3
2.1 First Paragraph	3
2.2 Second Paragraph	3
2.2.1 sub first paragraph	3
3 My Second Chapter	6
3.1 First Section	6
3.2 Second Section	6
3.2.1 first subsection in the Second Section	6
3.2.2 second subsection in the Second Section	6
3.2.3 third subsection in the Second Section	6
4 My Third Chapter	7
4.1 First Section of the Third Chapter	7
4.1.1 first subsection in the First Section	7
4.1.2 second subsection in the First Section	7

CONTENTS

4.1.2.1	first subsub section in the second subsection . . .	7
4.1.3	third subsection in the First Section	7
4.1.3.1	first subsub section in the third subsection	8
4.1.3.2	second subsub section in the third subsection . .	8
4.2	Second Section of the Third Chapter	8
5	My Conclusions ...	9
	Appdx A	10
	Appdx B	11
	References	12

List of Figures

2.1	Airfoil Picture	4
-----	---------------------------	-------------------

List of Tables

List of Abbreviations

Roman Symbols

F complex function

Greek Symbols

γ a simply closed curve on a complex plane

ι unit imaginary number $\sqrt{-1}$

π $\simeq 3.14\dots$

Superscripts

j superscript index

Subscripts

0 subscript index

Other Symbols

\oint_{γ} integration around a curve γ

Acronyms

CIF Cauchy's Integral Formula

Chapter 1

Introduction

And this is how I would like to introduce my piece of work ...

[illegible]

[illegible]

Chapter 2

My First Chapter But Note The Numbering ...

2.1 First Paragraph

And now I begin my first chapter here ...

Here is an equation¹:

$$CIF : \quad F_0^j(a) = \frac{1}{2\pi i} \oint_{\gamma} \frac{F_0^j(z)}{z-a} dz \quad (2.1)$$

2.2 Second Paragraph

and here I write more ...[\[2\]](#)

2.2.1 sub first paragraph

... and some more ...

Now I would like to cite the following: [\[3\]](#) and [\[2\]](#) and [\[4\]](#). Oh and I could cite [\[1\]](#).

I would also like to include a picture ...

¹the notation is explained in the nomenclature section :-)

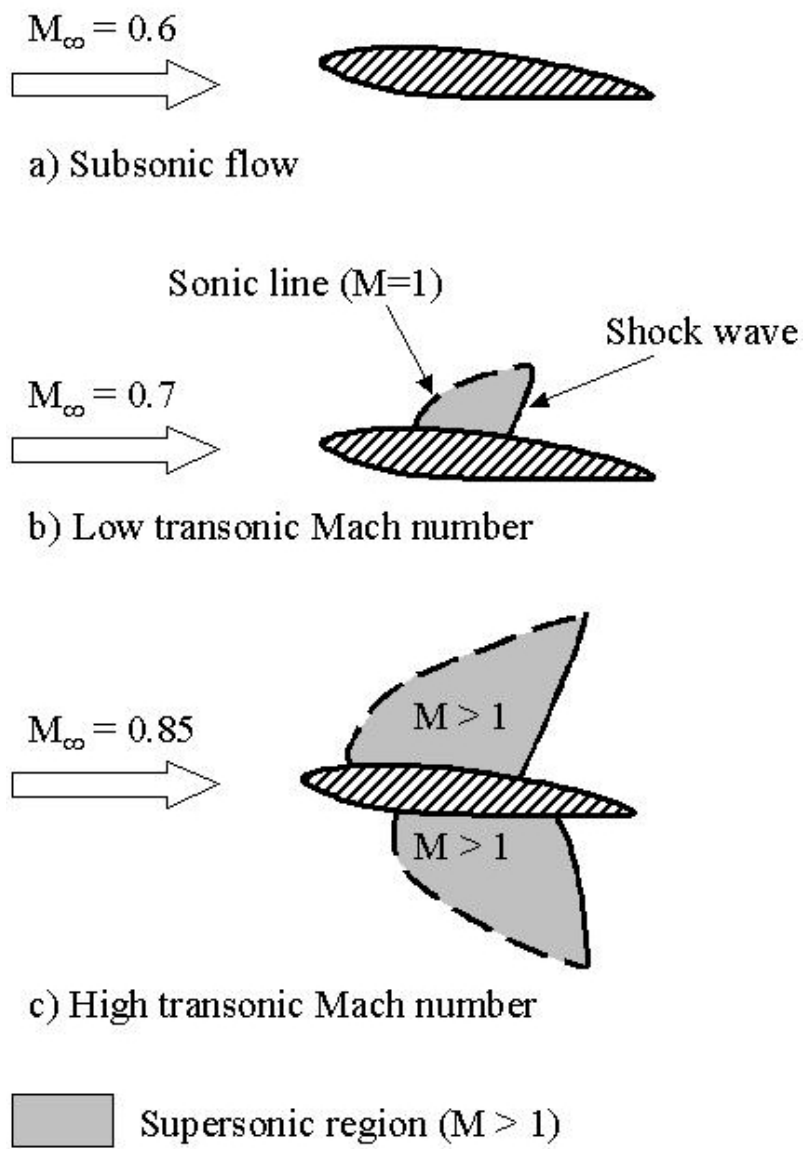


Figure 2.1: Airfoil Picture

So as we have now labelled it we can reference it, like so (2.1) and it is on Page 4. And as we can see, it is a very nice picture and we can talk about it all we want and when we are tired we can move on to the next chapter ...

I would also like to add an extra bookmark in acroread like so ...

Chapter 3

My Second Chapter

3.1 First Section

nd now I begin my second chapter here ...

3.2 Second Section

nd here I write more ...

3.2.1 first subsection in the Second Section

... and some more ...

3.2.2 second subsection in the Second Section

... and some more ...

3.2.3 third subsection in the Second Section

... and some more ...

Chapter 4

My Third Chapter

4.1 First Section of the Third Chapter

And now I begin my third chapter here ...

4.1.1 first subsection in the First Section

... and some more

4.1.2 second subsection in the First Section

... and some more ...

4.1.2.1 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 ...

4.1.3 third subsection in the First Section

... and some more ...

4.1.3.1 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 and some more ...

4.1.3.2 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 ...

4.2 Second Section of the Third Chapter

and here I write more ...

Chapter 5

My Conclusions ...

Here I put my conclusions ...

Appdx A

and here I put a bit of postamble ...

Appdx B

and here I put some more postamble ...

References

- [1] B. AUPETIT. *A Primer on Spectral Theory*. Springer-Verlag, New York, 1991. [3](#)
- [2] DONALD E. KNUTH. *The T_EXbook*. Addison-Wesley, 1984. [3](#)
- [3] LESLIE LAMPORT. *L^AT_EX: A Document Preparation System*. Addison-Wesley, 1986. [3](#)
- [4] W. RUDIN. *Functional Analysis*. McGraw-Hill, New York, 1973. [3](#)