Malardalen University

Master's Thesis

Innovation Diffusion in Scale-Free Networks : Signal Analysis in Complex Networks

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in the

Research Group Name
School of Innovation, Design and Engineering

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Declaration of Authorship

I, Debajyoti Nag, declare that this thesis titled, 'Innovation Diffusion in Scale-Free Networks : Signal Analysis in Complex Networks' and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Signed: ______________________________

Date: ______________________________

"By the power of the inter-WEB, I am He-Man. Muhahahahah!."

Prince Adam of Eternia

MALARDALEN UNIVERSITY

Abstract

Faculty Name
School of Innovation, Design and Engineering

Master of Science

Innovation Diffusion in Scale-Free Networks : Signal Analysis in Complex Networks

by Debajyoti Nag

The Thesis Abstract is written here (and usually kept to just this page). The page is kept centered vertically so can expand into the blank space above the title too...

Acknowledgements

The acknowledgements and the people to thank go here, don't forget to include your project advisor…

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Abbreviations

LAH **L**ist **A**bbreviations **H**ere

Physical Constants

Speed of Light $c = 2.997\ 924\ 58 \times 10^8\ \mathrm{ms}^{-\mathrm{S}}$ (exact)

Symbols

a	distance	m
P	power	W (Js^{-1})
ω	angular frequency	$rads^{-1}$

For/Dedicated to/To my…

Chapter 1

Introduction

1.1 State of the Art

Everything networks. Studies have shown networks to evolves over time to optimize functionalities, and increase longevity. The most coveted type of network, perhaps, is the kind formed naturally among varied entities, i.e., free scaling networks.

The first model for free scaling networks was proposed by BA , and the works of [REFERENCES] also helped in laying the groundwork.

1.1.1 State of the art in networked devices

IoT - As the almighty Internet steps out of traditional computers to directly link everyday physical objects, overcoming the spatio-temporal boundations, it upgrades a part of our lives to the so called cloud. This makes our lives easier , but also raises confusion as the complexity of processes increase manifold.

CPS and M2M - IoT is but a small part of a larger picture, CPS (Cyber-Physical Systems), where computational devices of all size and shape interact with each other and with everyday objects to perform complex tasks, ranging from temperature control in a modern house, to automatic detection of spread of a potentially fatal epidemic. M2M makes it possible for sensors spread over a large area to share the load of detecting varied signals, while some entirely different processing entity looks into that raw data and extracts meaningful information from it, and then a strong/special link actuates some physical entity to act based on the information just gathered.However, large scale CPS faces a major challenge due to Heterogeneous nature of network elements

1.1.2 Examples of State of the Art networked devices

1. GremlinMusic [REFERENCES]

   Gremlin showed a concept of interconnecting embedded devices in a whole new light. It not only allowed users to carry their music along (like every music player), but it allowed frends to connect their Gremlins and legally share music with each other. An optimization of storage, bandwidth (in p2p form), and monetary resources for the users. Analogy : take an iPod and put facebook and a free Spotify premium on it.

2. p-Cell technology [REFERENCES]

   The new technology by Artemis seems promising, and could have crucial impact on the state of networked devices over time.

3. Swarm robots [REFERENCES]

   Swarm robots are a good example of how even heterogeneous entities can work together. Like the coordination between these Eye-Feet-Hand bots to achieve their goal

1.2 Motivation

Since networks are everywhere, it's important we understand their nature and working so as to exploit and utilize them to our benefit. Going back as far as the 18th century, the "Seven Bridges of Königsberg" might be the most famous networking problem. Ranging from the Travelling-Salesman to Graph-Coloring algorithms, insight into the working of networks have helped greatly in optimizing several issues.

1.2.1 Why Scale-Free Networks

Scale-Free networks are the most prevalent in nature. Hence, it is paramount to model networking of personal devices used by humans on the same topology. This model aims at gaining insight into the workings of such networks, so as to optimize the network elements and make use of their full potential. For eg., by finding the optimal positioning for self-assembling network of satellites, military installations can provide improved security at a lesser cost. Or multiple groups of Swarm networks, like groups eye-hand-feet bots, can work together as a collective with an increased proficiency. Most importantly, due to autonomous nature of most network elements, these networks can be formed anywhere, water, air, or land, and can accomplish a multitude of tasks.

1.2.2 Future Sight

Imagine if your phone was a bit smarter, and it synchronized your calender to include events from your best friend's public calender automatically, or if it alerted you that the person now entering the restaurant is the investor you are supposed to meet so you can be prepared to face him. Or imagine a world where every child has a personal robot, in form of a pet, or a caretaker, and as the children go to the playground in the evening, these bots go with them, now, not only they serve the purpose of monitoring the child, these bots communicate with each other and form a bond, in a most likely manner that the children form bonds, so while your son is busy playing, his robot could find out about the studies he missed at school because he had a stomachache that morning. Networked devices could make life easier and yet more manageable.

1.3 Aim

This thesis aims to find optimal parameters for diffusion of innovation in the society. The author simulates a real-world scenario where companies try to influence it's customers by spreading an idea or publicizing their products, and as an effect the agents tend to lean towards the company if they are successfully , and enough, influenced. However, this campaigning propaganda incurs some costs to the company. The author tries to find a balance between the gain and cost for the company, in order to formulate a strategy which can be effectively used by the company to optimally attract customers.

Chapter 2

Approach and Tools

2.1 Approach

2.1.1 Network Model

It was an obvious choice to select scale-free topologies for modeling the network structure. But B-A model also proposes variants of the scale free structure depending on it's characteristics. These characteristics are :

1. Continuous Growth

   This states that the network grows continuously. i.e., at all times, new nodes are being attached to the the network.

2. Preferential Atachment

   This states the rule any node should follow while making connections. It states that the most connected nodes are most likely candidates to form a connection with.

Now, a scale free network may exhibit either or both of above characteristics. However, the author decided to include both in his model as to make it as close to real life as possible.

2.1.2 Orientation and View of the simulation environment

Initially, an object oriented view was used to give better control over the network agents. But this led to higher time complexity, and the author decide to switch to a connection-view model, where more focus was given to the connections being formed and everything was managed from that view. This resulted in significant decrease in time complexity. Also, focusing on the connections was easier as the whole network could be minimally represented by using the edge list.

2.2 Tools

As a requirement from the University, Matlab was chosen as the programming language, and no special toolboxes were used. The curve fitting app was used occasionally to check the output of the simulation.

The custom formulas used by the author were sometimes first tested as a prototype in Python with NetworkX and Mathematica for mathematical validation. However, any of those implementations do not directly contribute to the result.

Chapter 3

Methodology

3.1 Main Section 1

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3.2 Main Section 2

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Appendix A

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