Implementing Emulated Communication Models for Hybrid and Dynamic Network Topologies

by

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Abstract

In this thesis, network emulation is presented as a solution to testing, developing, and extending communication systems in a time- and cost-effective manner. Complex hybrid and dynamic wireless networks require extensive testing that is not easily conducted in hardware testbeds and may not be modeled accurately enough in network simulation tools. Network emulation provides the benefits of both hardware testbeds and simulation tools while also minimizing the shortcomings of each. This thesis evaluates the Extendable Mobile Ad-hoc Network Emulator (EMANE) as a network emulation tool by assessing its ability to emulate several complex network models. These models include hybrid wireless rural broadband deployments, an intelligent routing software development environment, and dynamic robot swarm networks. The emulated models were determined to be accurate enough to their hardware counterparts such that EMANE can be used as an effective tool for prototyping and testing communication systems.

Acknowledgements

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Chapter 1

Introduction

1.1 Motivation

As the need Internet and wireless communications grow, more solutions for deploying networks are being conceived. Networks are expensive to deploy and test, especially in rural conditions and when using special networks (MANET) This creates a need for a low-cost, easy method to do initial testing on networks and network technologies to validate viability before spending money on hardware deployments and testing Use network simulation and emulation for preliminary testing as it can require little to no hardware, can be conducted in a lab, and costs less than building physical networks for each new experiment

1.2 State of the Art

Many different software and combination software-hardware platforms exist for testing networks. ns-3, NetSim, OPNET (now called Riverbed)

1.3 Current Issues

Why are these simulators not as good?

- Many are not free or open-source (expensive to use and possibly not as customizable)
- Can be complex to set up

- Often only focus on network layer and abstract MAC/PHY layer, OR model the MAC/PHY layer but does not allow for integration with network software and protocols

1.4 Thesis Contribution

- Propose EMANE as valuable tool that addresses issues with other tools, explain how to install it, and explain how it works
- Develop an initial simple program for maximizing bandwidth in constrained networks
- Basic integration between the robot swarm simulator, ARGoS, and EMANE allowing for more complicated and complete communications simulation

1.5 Thesis Organization

The remainder of this thesis is organized as follows: In Chapter 2, an overview of the network emulator EMANE is presented and the motivation for why this tool was selected is explained. An overview of the subsystems used in EMANE and how to use them is included. Chapter 3 proposes the first use case for testing with EMANE, testing rural broadband deployments. Two similar network topologies are proposed and tested with the help of EMANE. Chapter 4 explores a second use case for utilizing EMANE, development of networking technologies and systems. In this case a program for more intelligent allocated limited bandwidth is developed. Chapter 5 finally details a third use case for EMANE, integrating with other simulation tools to provide more accurate communication models. The paper is concluded with a summary of work completed and recommendations for future work in Chapter 6.

Chapter 2

Overview on Network Emulation and Simulation

2.1 Network Simulation and Emulation

Several tools exist for simulating networks and testing networking protocols and topologies. These tools can vary from modeling the behavior of large-scale networking protocols to modeling the physical characteristics of a single wireless channel.

2.1.1 Evaluation of Network Simulation Tools

One of the most well known, and most used network simulation tools is ns-3. ns-3 is a discrete-event network simulator that was developed to simulate and research wireless and IP networks. ns-3 is not limited to wireless and IP-based networks, as thanks to its open-source nature, many models for simulating other types of networks are also available. This option was inevitably not selected as the software to be used for this research as the physical technologies modeled

The Extendable Mobile Ad-hoc Network Emulator (EMANE) is a network emulation tool originally developed by the Naval Research Lab and currently maintained by AdjacentLink LLC. The software was developed with the intention of creating a platform that could emulate the physical and data link layers of the OSI network model. This focus on

customizability of the physical and link layers is one of the main draws of EMANE because it allows for highly customizable models of physical channels to be used. EMANE consists of several subsystems and components required to create a fully functional test-bed. This creates an initial steep learning curve when using the software, and despite being open-source, the online community around EMANE is rather small with very little active discussion happening about the tool. Despite all this, once the user forms a core understanding of the tools and systems within the software, the tool can be used to effectively and quickly create model wireless networks. For this reason EMANE and combined with the details of the other network simulation tools.

2.1.2 Using EMANE

There are several ways EMANE can installed for use. The primary two methods are to install the bundle of pre-built binaries provided by AdjacentLink or build the tools from source. The precompiled bundle is sufficient for the work completed in this thesis. Compiling the software from source is typically only necessary when

As previously mentioned, there are several systems that make up EMANE. The main three subsystems of note are the emulation processing system, the emulation transport boundary processing system, and the event processing system.

2.2 Network Resource Scheduling

2.3 Routing in Mobile Mesh Networks

2.3.1 Proactive Mesh Routing

2.3.2 Reactive Routing

2.4 Chapter Summary

Chapter 3

Rural Broadband

3.1 What was implemented?

3.1.1 OVERCOME Test-bed

3.1.2 ZoomTEL Test-bed

3.2 How was it implemented?

3.3 Why was it implemented this way?

3.4 Compare EMANE results to real test-bed?

3.5 Chapter Summary

Chapter 4

Intelligent Router

4.1 Intelligent Method of Bandwidth Distribution

4.2 Implementation Methodology

4.3 Why was it implemented this way?

4.4 Effectiveness of the Program

4.5 Chapter Summary

Chapter 5

Robot Swarm Networks

5.1 What was implemented?

5.2 How was it implemented?

5.3 Why was it implemented this way?

5.4 Chapter Summary

Chapter 6

Conclusion

6.1 Research Outcomes

6.2 Future Work

Appendix A

Installation of EMANE