Topological arrangement of nodes in wireless networks suitable for the implementation of network coding

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Abstract—This document proposes research on the arrangement of nodes in wireless networks containing network coding suitable topologies. Optimal node placement as well as the boundaries of topologies will be identified. Simulation and implementation of the resulting topologies will follow. The obtained knowledge can be used during the practical implementation of network coding in wireless networks.

Index Terms—Ad hoc Networks, Implementation, Network Coding, Node Placement, Topology Boundaries

I. INTRODUCTION

WIRELESS ad hoc networks offer many advantages over traditional wired networks. This includes increased mobility, ease of usage and easy installation. Transmission rates is however lower when compared to wired networks due to limited bandwidth, interference and the complex routing protocols used, which increases overhead. Therefore efforts are being made to increase communication rates by using new concepts such as network coding. Very little research has been done on the implementation of network coding and the feasibility thereof. In this research project, TeleNet’s previous research and recommendations on “Using Topological Information in Opportunistic Network Coding” [1] is going to be studied and used. Identified network coding suitable topologies will be mathematically analysed, simulated in OPNET and concept implementation will follow on a certified wireless testbed created by Melvin Ferrera at the North-West University.

The rest of the paper is organised as follows: Section II gives an brief background. Section III details the proposed research and Section IV describes the methodology.

II. BACKGROUND

A. Network coding

Network coding refers to the implementation of coding methods to utilize network connections more efficiently. In [2] it is stated that: “With network coding, intermediate nodes may send out packets that are linear combinations of previously received information.” By sending a combined packet in a single time slot, throughput and thus efficiency of the network is enhanced at the cost of having intelligent nodes capable of combining and decoding packets.

B. Wireless Networks

In this project, the IEEE 802.11a/b/g standards will be used in simulations and during implementation. Newly developed MAC methods such as the IEEE 802.11n standard, set to be completed December 2009, will be investigated and possible advantages in the utilization of this standard given [3].

1) Distance vs. transmission rate: In wireless communication, transmission power is lost as the waves propagate through space. This is a result of a number of phenomena including free-space attenuation, multi-path interference, fading and shadowing. Communication distance and transmission rate is influenced by all of these factors. An increase in attenuation causes reliable communication distance to decrease. When the communication speed is increased, the receiver sensitivity decreases and thus also the communication distance. All of these factors must be taken into account when calculating the theoretical communication distance at a certain transfer rate [4].

2) Interference: The 2.5 GHz and 5 GHz open spectrums are divided into different communication channels which can be used for simultaneous communication between multiple radios. When implementing simultaneous communication methods, adjacent channel interference can occur [5]. Interference in wireless networks can also be caused by other equipment such as cordless and cellular phones as well as microwaves. Such sources of interference must be identified and, if possible, removed or the effects lessened for a wireless network to function effectively. Other phenomena such as multi-path interference, which is especially prominent when implementing wireless networks in buildings, must be investigated.

3) The hidden node problem: The hidden node problem occurs when two transmitting nodes are nearby each other, but can not receive the physical header of transmitted packets, thus they are unaware of each other’s transmission. A receiver node can be located between these transmitting nodes receiving simultaneous, and thus interfering, transmissions from the transmitting nodes. To avoid the occurrence of this situation,
C. Mathematical example

An example of the proposed mathematical model is shown in figures 1 and 2. In figure 1, the transmit power, receiver sensitivity, theoretical communication distance and theoretical Fresnel radius is displayed for each IEEE 802.11 standard, set at different transmission rates. The information used to create this model is based on the Atheros AR5112 chipset and takes free-space attenuation and other interference aspects into account. The model will be modified to give an accurate output which can be used as a theoretical platform for the rest of the project.

The output shown in figure 1 is then used as input to create the model shown in figure 2. The areas suitable for the placement of nodes is shown where the necessary circles overlap.

III. PROPOSED RESEARCH

The objective of this project is to find the distance at which communication can reliability be executed in wireless networks given certain hardware, find the speed of communication at these distances and use this information to define the physical dimensions and optimal node placement of a certain network topology, suitable for the implementation of network coding. Other aspects of wireless networks will also be investigated. This includes interference and optimal channel assignment to assure maximum throughput is achieved.

IV. METHODOLOGY

1) Network coding suitable topology identification: M.J. Grobler’s work [1], will be studied and used as a basis for the topology identification stage. Grobler’s work identifies different network coding suitable topologies and methods on finding these topologies in larger mesh networks

2) Distance vs. transmission rate calculations and measurement: The mathematics required to determine reliable communication distance must be studied and used to determine the theoretical communication distance of each node. The distance at which reliable communication can take place at each different packet transfer speed setting must be defined.

3) Effects of interference and possible solutions: Interference from other electro-magnetic wave sources can cause packet loss and induce errors in transmitted data. In severe cases, communication can be lost completely. It is therefore important to be aware of possible interference sources and the impact they may have on communication.

4) Simulate and implement topologies: During the simulation and implementation phase, network coding will not be implemented in its final working state as this is out of the scope of the project. Packets will be transferred form source nodes to the destination nodes as well as the “smart” nodes. At the “smart” nodes, packets will be combined with a simple XOR operation and sent to destination nodes where decoding will take place. OPNET modeler will be used for all simulations.

V. CONCLUSION

The preliminary work regarding boundary identification and optimal node placement in wireless networks, containing network coding suitable topologies, has been presented. Future work will include mathematical model optimisation, OPNET topology simulation and implementation. Results will be investigated and compared to draw conclusions regarding node placement in wireless networks, the implementation of network coding and possible throughput gains that can be achieved.

REFERENCES


Johan-Henry Böning is currently pursuing a M.Eng degree in Computer Engineering at the North-West University. He received his B.Eng degree in Computer and Electronic Engineering (cum laude) in 2008 from the North-West University.