

# Comparing Network Coding implementations on different OSI layers

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# Abstract

Network coding is a technique used to increase the capacity of a network by combining messages sent over the network. The combined messages could be separated by using sufficient original messages which were used to combine the messages. Network coding can be implemented in different layers of the OSI stack, but to date a complete comparison between different implementations of network coding has not been done.

The goal of this dissertation is to implement a wireless node model with network coding in the MAC layer and evaluate the performance characteristics of reference networks that implement the new node model. This will serve as the first step of a greater goal, namely finding the most favourable position in the OSI stack to implement network coding. The characteristics of the different implementations of network coding are presented in this dissertation. Simulations were done in OPNET® to find further attributes concerning the implementation of network coding in the MAC layer.

The simulation process used is presented and explained, and the results from the simulations are analysed. Network coding in the simulations was implemented opportunistically. The results show that the more often different nodes send frames to the coding node, the better network coding performs.

The work contributes to finding the best layer for implementing network coding for its increased throughput. A benchmark network was created so that network coding could be implemented in all the layers of the OSI stack, and then be compared to each other. An implementation of network coding in the MAC layer was simulated and analyzed.

We conclude that, because there are so many different purposes for which networks are used, a single instance of network coding is unlikely to be similarly beneficial to all purposes. There still remains work to find the most favourable position for network coding in the OSI stack for all the different types of network coding.

**Key Words:** MAC, multicasting, network coding, OPNET® node model, OSI protocol stack, wireless ad hoc network

# Opsomming

Netwerkkodering is 'n tegniek wat gebruik kan word om die kapasiteit van 'n netwerk te vergroot deur boodskappe wat oor 'n netwerk gestuur word, te kombineer. Die gekombineerde boodskappe kan uitmekaar gehaal word deur genoeg van die oorspronklike boodskappe te gebruik. Netwerkkodering kan geïmplimenteer word in verskillende vlakke van die OSI stapel, maar daar is nog geen volledige vergelyking tussen verskillende implementerings van netwerkkodering getref nie.

Die doel van die verhandeling is om 'n naatlose node model wat netwerkkodering gebruik te implimenteer in die MAC-vlak, en dan soortgelyke netwerke wat die model implimenteer se werkverrigting karakteristieke te beoordeel. Hierdie karakterisering sal dien as die eerste stap van 'n groter doel, naamlik om te bepaal watter vlak van die OSI-stapel die gunstigste sal wees om netwerkkodering in toe te pas. Die karakteristieke van die verskillende toepassings van netwerkkodering word voorgelê. Om by te dra tot dié kennis, is simulasies in OPNET® gedoen om verdere eienskappe van die implementasie van netwerkkodering in die MAC-laag te vind.

Die simulasieproses word aangebied en verduidelik, en die resultate van die simulasies word geanaliseer. Netwerkkodering is opportunisties toegepas in die simulasies. Die bevindinge wys daarop dat hoe meer gereeld verskillende nodes boodskappe aan die koderende node stuur, hoe meer doeltreffend word netwerkkodering toegepas.

Die werk dra daarby by toe om te bepaal in watter vlak dit die beste sal wees om netwerkkodering toe te pas vir verhoogde deurset. 'n Standaardnetwerk is opgestel sodat netwerkkodering daarin toegepas kon word in al die vlakke van die OSI-stapel, waarna die bevindinge met mekaar vergelyk kon word. 'n Implimentering van netwerkkodering in die MAC-vlak word gesimuleer en geanaliseer.

Die gevolgtrekking uit die werk in hierdie verhandeling gerapporteer, is dat daar soveel verskillende netwerkgebruike is dat dit onmoontlik is om te sê dat 'n enkele toepassing van netwerkkodering gunstig vir almal sal wees. Daar bly steeds werk oor wat gedoen moet word om te bepaal waar in die OSI-stapel die beste posisie is om netwerkkodering toe te pas vir elke tipe netwerkkodering.

**Sleutelwoorde:** MAC, multisending, naatlose ad hoc netwerk, netwerkkodering, OPNET-nodemodel, OSI-protokolstapel

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# Declaration

I, Jacobus Leendert van Wyk, declare herewith that this thesis entitled “Comparing Network Coding implementations on different OSI layers”, which I herewith submit to the North-West University as partial completion of the requirements set for the *Master of Engineering* degree, is my own work and has not already been submitted to any other university.

Signature of candidate: \_\_\_\_\_

University number: 20026277

Signed at: *Potchefstroom* this 10<sup>th</sup> day of July 2011.

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# List of Abbreviations

|                |   |  |
|----------------|---|--|
| <b>MANET</b>   | - | Mobile ad hoc network                                  |
| <b>OSI</b>     | - | Open Systems Interconnection                           |
| <b>DSSS</b>    | - | Direct-Sequence Spread Spectrum                        |
| <b>CCK</b>     | - | Complementary Code Keying                              |
| <b>OFDM</b>    | - | Orthogonal frequency-division multiplexing             |
| <b>BPSK</b>    | - | Binary phase shift keying                              |
| <b>QPSK</b>    | - | Quadrature phase shift keying                          |
| <b>M-QAM</b>   | - | Quadrature amplitude modulation                        |
| <b>MAC</b>     | - | Media Access Control                                   |
| <b>VOIP</b>    | - | Voice Over Internet Protocol                           |
| <b>CSMA/CA</b> | - | Carrier Sense Multiple Access with Collision Avoidance |
| <b>LLC</b>     | - | Logical Link Control                                   |
| <b>CO</b>      | - | Connection orientated                                  |
| <b>CL</b>      | - | Connectionless   |
| <b>IPv4</b>    | - | Internet Protocol version 4                            |
| <b>NAT</b>     | - | Network Address Translation                            |
| <b>AODV</b>    | - | Ad Hoc on demand Distance Vector                       |
| <b>DSR</b>     | - | Dynamic Source Routing                                 |
| <b>OSPF</b>    | - | Open Shortest Path First                               |
| <b>QoS</b>     | - | Quality of Service                                     |
| <b>TCP</b>     | - | Transmission Control Protocol                          |
| <b>UDP</b>     | - | The User Datagram Service                              |
| <b>VOIP</b>    | - | Voice over IP  |
| <b>DES</b>     | - | Discreet Event Simulation                              |
| <b>bps</b>     | - | bits per second  |