Development of a Cross-layer Protocol for the Improvement of Performance in Wireless Networks

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Abstract—Wireless networks are becoming more popular and many network users prefer wireless infrastructure above the wired infrastructure because wireless networks are easy to install, maintain and use. One problem however, is that the network model used to develop protocols for the wireless network is the same layered model used for wired networks. This paper proposes research on cross-layer protocols which will improve the performance of wireless networks. The Open Systems Interconnected (OSI) model will be studied to determine candidate layers for cross-layer interaction and existing cross-layer protocols will be evaluated and considered for the development of a cross-layer protocol which will improve the performance of a wireless ad-hoc network.

Index Terms—Ad-Hoc, Cross-layer, Protocol, Wireless Networks.

I. INTRODUCTION

With the increased popularity and the ease of access supplied using the IEEE 802.11 standard (better known as Wi-Fi) and the comfort supplied with ad-hoc networks we are able to set up a wireless network between nodes that is cost effective, easy to maintain and gives a user mobile access to wired networks without any physical connection to the wired network. These are the main goals of an ad-hoc network which aims to remove the infrastructure between network nodes. As with any other network, the interaction between the nodes involves a strict set of rules on each node which may be illustrated with the Open Systems Interconnected (OSI) model which is a layered network model widely used in network protocol design. The OSI model is well suited for wired networks. However, according to [1] this layered model is insufficient in the wireless environment because the layers in the model communicate in a strict manner and the protocols on the different layers are designed for the worst case scenario instead of adapting to the changing conditions of the wireless medium. According to [2] and [3], the performance and efficiency of wireless networks may be improved with a cross-layer design. The remainder of this paper is organised as follows: Section II gives a brief background. Section III details the proposed research and Section IV describes the methodology which will be followed.

II. BACKGROUND

A. The OSI network model

The OSI model divides a communication system into a set of layers. Each layer performs a set of functions on the information to be transferred before it is passed on to the next layer. These functions are called protocols. Different protocols may exist on one layer and the protocol used for data transfer depends on the application used, the network type, the services provided by the protocol and the nature of the data which needs to be transferred. The protocols on each layer must also be consistent between communicating nodes for information to be transferred between these nodes [4]. Figure 1(a) shows the OSI model and the seven layers of the model. The layers are usually numbered from layer one at the bottom to layer seven at the top. The figure also show that only neighbouring layers can exchange information. This information can not be used by non-neighbouring layers to adapt to the challenging conditions of a wireless network.

B. The cross-layer concept

A cross-layer approach is used to share network status information between non-neighbouring layers on a network node. Layers receiving network status information from non-neighbours should be able to adapt according to the received information [5]. Figure 1(b) is an illustration of cross-layer interaction and graphically shows how information is exchanged across layers. There exist two basic categories for cross-layer interactions [2]:

Fig. 1. (a) The OSI model and interaction between layers, (b) Cross-layer interaction between layers
• **Upper to lower layers:** This interaction allows the upper layers to make information available to the lower layers. An example of this is where the application layer communicates user defined application priorities to layer four, where the protocol on layer four could adapt by adjusting the receiver window and prioritises the receipt of packets for the certain application.

• **Lower to upper layers:** This interaction allows the lower layers to make information available to the upper layers. An example would be where the signal strength and loss probability on layer 2 is made available to higher layers. Layer three could use this information to determine packet fragments, large fragments for a strong signal and low loss probability and small packets for low signal strength and high loss probability.

C. Previous work

Previous research has been done in the past on cross-layer protocols for wired and wireless networks and from this work it seems that the layers mostly used for cross-layer interaction is the media access control (MAC) layer, which combines the physical and datalink layer, and the transport layer. For instance, [6] proposed a path recovery notification mechanism to prevent transmission control protocol (TCP) performance degradation during handoffs. The protocol quickly recovers lost packets by restoring the congestion window, preventing the congestion window to decrease or initiating the slow start algorithm after a handoff. A protocol proposed by [3] is a modification to the standard IEEE 802.11 MAC and the TCP protocol and they claim a significant improvement on the TCP performance. A cross-layer framework for rate adaption in 802.11 networks was proposed by [7] where the rate adaptation is based on loss differentiation mechanisms which identifies the real cause of variations in the channel and takes an action based on that cause.

III. PROPOSED RESEARCH

With this research we want to determine if it is possible to improve the end-to-end delay and increase the packet delivery ratio in wireless ad-hoc networks. From the previous work done by [3], [6] and [7] it seems that making use of cross-layer interaction between layers might aid us in improving the performance and we would also want to determine which layers in the OSI model would be the ideal layers to use in cross-layer interaction.

IV. METHODOLOGY

In order to complete this proposed research we plan on using the following methodology:

**Literature Study:** An in depth literature study on wireless networks, more specific the IEEE 802.11 standards needs to be done. We must study the protocols used on wireless networks and research how they work and on which layer they are implemented. This would help us determine the candidate layers to use for cross-layer interaction and which information we need to exploit from a protocol to other protocols on different layers to improve performance on the network. Previous research on cross-layer protocols will also be studied to help us identify candidate layers and to gain a better understanding of cross-layer interaction.

**Design of the cross-layer protocol:** To develop a good cross-layer protocol we need to investigate the methods for designing cross-layer protocols. Here we must decide which layers will exploit information to other layers and which information they need to exploit to improve the performance of the overall network. The protocol would then be designed according to the above mention criteria.

**Simulation of the protocol:** The simulation would help us to determine if the protocol design show any improvements in performance on the network and would be a good indicator on how the protocol might react when physically implemented.

**Implementation of the protocol:** The protocol will be physically implemented to compare the performance of the protocol to the performance of the standard layered protocol. The implementation would help us to determine if the results obtained from the simulation are an accurate representation of the physical implemented protocol. The protocol will be implemented in the C/C++ environment running in a linux environment.

**Compare and discuss results:** The results obtained from the simulation and implementation will allow one to comment on the following statements:

- The effect of cross-layer design on performance improvement in wireless networks.
- How the results obtained from simulation corresponds with the results obtained from the implementation.

V. CONCLUSION

The preliminary work regarding the development of a cross-layer protocol for the improvement of performance in wireless networks has been presented in this paper. Future work will include the effects on the performance of an ad-hoc wireless network after the implementation of the cross-layer protocol.

REFERENCES


Conraad Maree obtained his B.Eng degree in Computer and Electronic Engineering in 2009 from the North-West University, South Africa. He is currently pursuing a M.Eng degree in Computer Engineering as part of the TeleNet Research Group (in the Telkom-Grintek Centre of Excellence) at the same institution. His areas of interest include, wireless communication systems, hardware development, embedded C programming and TCP/IP networks.