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Measurement and modelling of TCP downstream throughput dependence on SNR in an IEEE802.11b WLAN system

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Abstract This paper presents our study on the dependence of TCP downstream throughput ($TCP_{down}T$) on signal to noise ratio (SNR) for multiple users in an IEEE 802.11b Wireless Local Area Network (WLAN) system. The study was carried out in small offices, open corridors and free space environments using an infrastructure based IEEE 802.11b WLAN while transmitting different quality of service (QoS) traffic all corresponding to different wireless multimedia tags. Models describing $TCP_{down}T$ against SNR for different signal categories were statistically generated and validated. Our findings show a large variation in the throughput behaviour of the IEEE 802.11b WLAN system for the different categories of signals. We observed RMS errors of 0.938012 Mbps, 1.047012 Mbps, 0.65833 Mbps and 0.452927 Mbps for the general (all SNR) model, strong signals model, grey signals model and weak signals model respectively which were much lower than that of similar models with which they were compared. Comparing our results with a previous work on TCP upstream throughput showed that it is more accurate to investigate upstream and downstream throughput separately. Our models enable network designers and installers to predict the $TCP_{down}T$ without the need to measure additional parameters other than the observed SNR which is already part of the normal network installation process.

1. Introduction

Today's global activities are increasingly and continuously being influenced by the Internet (Mohammed, 2011). Wireless Local Area Networks (WLANs) have become very useful for providing Internet services to many computers within organizations. The use of LANs, WLANs, Intercom systems, VoIP networks, etc. for communication within an organization and between two or more organizations has greatly helped to

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enhance efficiency and performance of these organizations at only the cost of installation and maintenance of these networks and systems (Oghogho and Ezomo, 2013; Oghogho et al., 2012). The most common architecture of WLANs used by most organizations is the infrastructure based network where one system is used as a server while others are used as clients. The server runs most or all of the application software and programmes while the client systems simply connect to the server through either an Ethernet (wired) interface or a wireless medium to access an application.

Transmission control protocol (TCP) used by WLANs constitutes about 80% of all the traffic on the Internet (Moltchanov, 2012; Loiseau et al., 2010). A good and well-designed network is basically evaluated by the throughput and round trip time (RTT) that the users experience for a given signal to noise ratio (SNR) received (Geier, 2008). Most WLAN implementations must support a minimum throughput before they can be said to provide adequate coverage (Geier, 2008). Predicting the performance of TCP throughput is therefore necessary for better understanding of the performance of WLANs.

From our experience on network design and installation, several network designers only focus on the received signal strength at different locations but do not have the time to deploy several client systems on the network so as to collect large volumes of throughput data at different locations on the network in order to determine the network performance for multiple users (Isiagbona and Obahiagbon, 2013). They however use Internet control message protocol (ICMP) for estimating the throughput. The throughput calculated by ICMP is a rough estimate of the actual value (Mitchell, 2014; Rouse, 2014). This is so because ICMP is a network layer protocol hence the throughput value it predicts is appreciably different from the throughput predicted at the transport layer due to additional overheads. The transport layer is closer to the application layer hence the throughput predicted at the transport layer is more representative of what the users will experience, hence the designed network can fall short of user's expectations after they are commissioned.

By not taking large volumes of throughput data at various locations on the network, the hidden node problem is therefore ignored and not considered in such instances. The hidden node problem occurs when a station attempts to access and use network resources (transmit its own data) because it cannot sense that another station with a weak signal (usually far away from the WLAN radio or the station attempting to transmit its data) is already transmitting its data hence packet collision will occur which degrades the throughput observed (Hung and Bensaou, 2011).

Network designers are constrained to continue to use pinging because available network throughput estimation tools such as Tamosoft throughput test, QCHECK, IxChariot, etc. require lots of time and network resources while available off network throughput models require lots of parameters to be specified (Padhye et al., 2000; Moltchanov, 2010; Gupta et al., 2011; Zhu et al., 2012; Wu et al., 2011; Detti et al., 2011; Loiseau et al., 2010; Ye and Abouzeid, 2010; Hung and Bensaou, 2011; Panda and Kumar, 2012; Tian and Tian, 2012).

Since Network designers presently proceed with WLAN design by measuring received signal strength indication (RSSI) at different positions, can throughput be modelled as functions of SNR only within reasonable accuracy? This will provide a handy tool to WLAN designers without necessarily increasing the parameters they must measure and specify during WLAN design and installation. According to Mahmood et al. (2010), link adaptation process where an increase in the SNR sensed by a station prompts it to use higher data rates for frame transmission changes the throughput behaviour of WLANs appreciably. It therefore follows that by applying cross layer modelling principles (Moltchanov, 2012), the possibility of modelling throughput as a function of SNR only with reasonable accuracy exists. This paper presents our research findings towards providing this tool.

2. Review of past work

To tackle the challenge of providing models for predicting TCP throughput based on observed SNR some researches have applied cross layer modelling principles. Henty (2001) provided models for predicting TCP throughput for single and two users as functions of the received SNR. However their models did not differentiate between upstream and downstream throughput and were limited to two users which does not adequately represent a saturation condition where each client always has a packet to transmit (Wu et al., 2011). Metreaud (2006) also provided throughput models based on received SNR but used UDP traffic. The Author did not also differentiate between upstream and downstream throughput and the models were also limited to a single user on the network. Ikponmwosa et al. (2014) modelled TCP upstream throughput based on observed SNR for a single user while Oghogho et al. (2015a) provided models for predicting TCP upstream throughput as a function of SNR both for single and multiple users. These two models were limited to upstream throughput hence they cannot be applied for predicting TCP downstream throughput with reasonable accuracy as was confirmed in this paper.

Oghogho et al. (2014) provided empirical probability models which predict the probability of having a TCP downstream throughput value depending on the category of signal strength (strong, grey or weak) but do not predict the TCP downstream throughput value for a SNR observed. Oghogho et al. (2015b) developed models for predicting TCP downstream throughput based on observed SNR for a single user on the network. Their model developed for a single user is limited in adequately describing and predicting multiple users' experience in real life scenarios where each client usually has a packet to transmit (saturation condition). None of these works provided multiple users empirical models for predicting TCP downstream throughput as functions of SNR only. This paper fills this gap.

3. Research method

The method used by Oghogho et al. (2015a) was used in this work except that multiple users are considered and TCP downstream throughput is measured and monitored instead of TCP upstream throughput. The number of users is limited to seven due to the findings of Wu et al. (2011) where seven stations (indicating a saturation condition where each client always has a packet to transmit), gave throughput values that were averagely the mid-point from two extremes (1 station and 16 stations).

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