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Performance Impact of CSMA/CA on the throughput of IEEE 802.11 Networks

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Abstract— A wireless LAN is a LAN that uses the air as a medium of transmission to permit data transmission among fixed, or moving computers. The MAC layer of 802.11 employs the carrier sense multiple access/collision avoidance (CSMA/CA) to provide reliable frame transmission. This paper presents the impact of CSMA/CA on the performance of IEEE 802.11 networks. We measure the IEEE 802.11 wireless network throughput from a number of hosts to the access point (AP). The paper shows the factors that lead the difference between theoretical and measured throughput.

Keywords— Wireless Network, IEEE 802.11, CSMA/CA, Backoff, INET, and Omnet++.

I. INTRODUCTION

In the last decade, there was a dramatic growth in wireless communication and computing technologies. Wireless systems consist of wireless wide area networks (WWANs) (i.e., cellular systems), wireless local area networks (WLANs) [1], and wireless personal area networks (WPANs) [2]. Wireless networks in comparison to fixed networks as follows:

- Higher loss-rates due to interference: emissions of, e.g., engines, lightning.
- Restrictive regulations of frequencies: Frequencies have to be coordinated, useful frequencies are almost all occupied.
- Higher delays, higher jitter: connection setup time with GSM in the second range, several hundred milliseconds for other wireless systems
- Lower security: radio interface accessible for everyone, base station can be simulated, thus attracting calls from mobile phones

A wireless LAN is a LAN that uses the air as a medium of transmission to permit data transmission among fixed, nomadic, or moving computers. Wireless LANs are categorized into two operational modes: infrastructure mode and ad hoc mode. The majority of wireless LANs operates in infrastructure mode. In infrastructure mode, devices are connected over the air to an AP which in turn connected to a wired network. Ad hoc mode does not require any central to operate. Instead, devices in an ad hoc wireless LAN form a group and communicate with each other in a peer-to-peer fashion.

The MAC layer of 802.11 employs the carrier sense multiple access/collision avoidance (CSMA/CA) to provide reliable frame transmission. A station must first sense the communication channel (the carrier) and make sure it is not occupied. If the channel is idle, it can begin to transmit; otherwise, it will wait for a random amount of time with a contention window and sense the channel again.

This paper presents the impact of CSMA/CA on the performance of IEEE 802.11. This paper measures the IEEE 802.11 wireless network throughput from a number of hosts to the access point (AP). The difference between theoretical and measured throughput can be calculated using Omnet++ simulator[15] and INET [16].

II. IEEE 802.11 MEDIUM ACCESS CONTROL

Wireless LANs uses a shared, high bit rate transmission medium to which all devices are attached. IEEE 802.11 MAC sublayer defines how a user obtains a channel when he needs one. MAC schemes include random access, order access, deterministic access, and mixed access. The random access MAC protocols are: ALOHA (asynchronous, slotted), CSMA/collision-detection (CD), CSMA/collision-avoidance (CA), nonpersistent, and p-persistent. Most WLANs implement a random access protocol, CSMA/CA with some modification.

Backoff is used to resolve contention problems among different stations wishing to transmit data at the same time. When a station goes into the backoff state, it waits randomly selected number of time slots. The random number must be greater than 0 and smaller than the value of the contention window (CW). After it end its wait state, if the medium is still free the station can send its frame.

There is a problem related to the CW dimension. There There is a problem related to the CW dimension. There will be collisions with small value of CW, because the stations may have the same backoff period if they try to transmit at the same time. However, with a large CW, if few stations wish to transmit data they will likely have long backoff delays resulting in the degradation of the network performance. The solution is to use an exponentially growing CW size. The value of CW starts from a small value and doubles after each collision, until it reaches the maximum value *CW* max.

The 802.11 standard defines the following four interframe spaces to provide different priorities.

● *Short interframe space (SIFS):* It is used to separate transmissions belonging to a single dialog.
● *Point coordinate interframe space (PIFS):* It is used by the AP to gain access before any other station.
● *Distributed interframe space (DIFS):* It is used for a station willing to start a new transmission. ● *Extended interframe space (EIFS):* It is used by a station that has received a packet which it could not understand.

III.RESEARCH METHODOLOGY

In order to study the reason for having a difference between theortical and measured throughput there were several simulation tools that could have been used. Examples of these tools are: Global Mobile Information Systems Information Library (GloMoSim) [11] and [12], Optimised Network Engineering Tools (OPNET) [13], Network Simulator (NS-2) [14], and Omnet++ [15]. Omnet++ can support a large number of network components such as different applications, protocols, and traffic models.

Omnet++ is a public-source, component-based, and modular simulation framework. It is mostly applied to the domain of network simulation and other distributed systems. The Omnet++ model is composed of hierarchically nested modules. The top-level module is called the Network Module. This module contains one or more sub-modules each of which could contain other sub-modules. Various Internet protocol model have been developed on the top of Omnet++ such as the Omnet++ Mobility Framework [16] and Castalia [17].

Castalia can be used to test distributed algorithms and/or protocols in realistic wireless channel and radio models. It can also be used to evaluate different platform characteristics for specific applications, since it is highly parametric, and can simulate a wide range of platforms.

MiXiM framework is an OMNeT++ modeling framework created for mobile and fixed wireless networks (wireless sensor networks, body area networks, ad-hoc networks, vehicular networks, etc.). It offers detailed models of radio wave propagation, interference estimation, radio transceiver power consumption and wireless MAC protocols (e.g. Zigbee). It is a merger of several OMNeT++ frameworks written to support mobile and wireless simulations [15]

The INET framework is an open-source communication networks simulation package for the Omnet++ simulation environment. The INET Framework contains models for several wired and wireless networking protocols, including UDP, TCP, SCTP, IP, IPv6, Ethernet, PPP, 802.11, MPLS, OSPF, and many others [16].

A simulation model was built by using both Omnet++ and INET to study the performance impact of CSMA/CA.

IV. SIMULATION RESULTS

Two simulation scenarios are carried out in this paper:

First Scenario (single host simulation)

The first simulation scenario for a single station is connected to an AP and starts sending a message of size of 1000 bytes with 10 Mbps bitrate. Throughput is measured by the "sink" submodule of the AP.. Table 1 shows throughput measured by the simulation, and compares it to the theoretical maximum which is roughly 5.12 Mbps. The theoretical value and the simulation output are very close, the difference being less than 1 kbps.

Second scenario (Multi host simulation)

For the second simulation scenario, we have created a network of ten hosts where each host is sending a message of 1000 bytes with 11 Mbps data rate. The collision is going to be more because the size of the network increases compared to the first scenario. In this case, the average backoff interval on the channel is smaller which would increase throughput, but are also collisions (see table 2).

The difference between the theoretical throughput maximum and the measured throughput for the two scenario is caused by collisions and the inter-frame spacing.

V CONCLUSIONS

The MAC layer of 802.11 employs the carrier sense multiple access/collision avoidance (CSMA/CA) to provide reliable frame transmission. We studied the impact of CSMA/CA on the performance of IEEE 802.11 networks. We measured the IEEE 802.11 wireless network throughput from a number of hosts to the access point (AP). We showed the factors that lead the difference between theoretical and measured throughput.

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NAME	LENGTH (bits)	BITRATE (Mbps)	TIME (us)
DIFS	50	1	50
BACKOFF(avg)	310	1	310
PREAMBLE	192	1	192
HEADER	240	11	21.81818182
DATA	8000	11	727.2727273
CRC	32	11	2.909090909
SIFS	10	1	10
PREAMBLE	192	1	192
ACK	112	2	56
TOTAL			1562
THEORETICAL THROUGHPUT		5.121638924	
DIFFERENCE TO MEASURED		0.005368924	
MEASURED PROPAGATION			0.67208212
TOTAL WITH PROPAGATION			1563.344164
THROUGHPUT WITH PROPAGATION		5.117235336	
DIFFERENCE TO MEASURED		0.000965336	

Table 1: Single host scenario

NAME	LENGTH (bits)	BITRATE (Mbps)	TIME (us)
DIFS	50	1	50
BACKOFF(avg)	150.15625	1	150.15625
PREAMBLE	192	1	192
HEADER	240	11	21.81818182
DATA	8000	11	727.2727273
CRC	32	11	2.909090909
SIFS	10	1	10
PREAMBLE	192	1	192
ACK	112	2	56
TOTAL			1402.15625
THEORETICAL THROUGHPUT		5.705498228	
DIFFERENCE TO MEASURED		0.300778228	
APPROXIMATE PROPAGATION			0.5
TOTAL WITH PROPAGATION			1403.15625
THROUGHPUT WITH PROPAGATION		5.701432039	
DIFFERENCE TO MEASURED		0.296712039	

Table 2: Multi host scenario