ISSN: 2278 – 1323
International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)
Volume 5, Issue 6, June 2016

On possibility to detect network load burst on MAC-layer of wireless networks

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***Abstract*— A main idea of the paper is to consider a possibility to detect by stations a sudden bursts of wireless network load. Therefore a performance analysis of DCF and EDCA access schemes under bursty wireless network load is done. Influence of the bursty traffic on network throughput, and mean frame delay are shown depending on the network size. As result it was shown that mean frame delay is sensitive to increasing and decreasing of network load and can be used as a factor of mechanism that detects traffic bursts on MAC-layer of wireless networks.**

***Index Terms*— bursty traffic load, DCF, EDCA, performance analysis, wireless networks..**

I. Introduction

In recent years, wireless LANs become very popular and are widely deployed. Inter-net applications over wireless LANs consist of throughput-intensive applications such as email, web surfing or file transfer, as well as of delay-sensitive ones such as voice and video. Technology innovations have significantly increased the transmission rate through wireless environment. At the same time it has been shown in [1] throughput of the 802.11 wireless LANs is bounded by the overhead of MAC protocol. There-fore, there are many studies focused on MAC protocol performance analysis. Most of them are evaluated under saturated or non-saturated traffic following a Poisson-like distribution. This type of traffic is smooth over large time intervals. However, traffic patterns have a significant impact on wireless network performance. Numerous of resent study and measurements have shown that the real network load exhibits bursty arrival nature [2]-[4] with non-uniformly distributed frame destinations [5]-[6]. Such network data flow as web or email traffic, is irregular and is not smooth over large time interval. On the other hand, voice stream flow has a constant bit-rate, is characterized by a continuous rate of data flow and is sensible to the frame delay.

MAC protocol is based on the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) scheme with slotted Binary Exponential Backoff (BEB) algorithm. CSMA/CA scheme, implemented in the early versions of 802.11 MAC, is referred to as Distributed Coordination Function (DCF). Later, with significantly growing multimedia traffic and number of real-time applications that require supporting of a Quality of Service (QoS), DCF has been improved by Enhanced Distributed Channel Access (EDCA) scheme. The EDCA scheme defines four access categories (ACs) that provide support for delivery of prioritized traffic.

This paper is focused on the performance analysis of the DCF and EDCA access schemes under bursty traffic load.

Manuscript received Jun, 2016.

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II. Overview of DCF and EDCA access schemes

Like the original DCF in IEEE 802.11 [7], EDCA enables users to contend for the wireless channel using CSMA/CA and differentiating frames by priorities and map-ping them to specific ACs that are buffered in separate queues at a station. EDCA provides service differentiation by the tuning of various MAC parameters: the mini-mum spacing between packets (Arbitration Inter-Frame Space or AIFS), minimum and maximum contention windows (CWmin and CWmax), and lengths of packet bursts or transmission opportunity limit (TXOP limit). If there is a frame ready for transmis-sion at the AC queue, the station must sense the channel to be idle for a complete AIFS before it can start the transmission. If the channel is idle during this whole time, the frame is transmitted immediately. Otherwise station initializes its backoff counter. Backoff counter is uniformly and randomly chosen in a range [0, CW], where CW is the current contention window. The initial value of CW for each new frame is set to the AC-specific CWmin and after each unsuccessful transmission CW doubles until the maximum AC-specific CWmax is reached. Station decrements backoff counter only if the medium is sensed idle. If the medium is busy, then backoff counter is frozen and reactivated when the medium is sensed idle for AIFS interval. Station is permitted to begin transmission process when backoff counter reaches zero. In case of successful transmission a receiver after a Short Interframe Space (SIFS) immediately transmits a positive Acknowledgement (ACK). If an ACK is not received, the station increases CW as described above, and attempts again until the retry limit is reached. An internal (virtual) collision within a station is handled by providing the access to the AC with the highest priority. The ACs frames with lower priority that suffer from a virtual collision run the collision procedure as if an outside collision has occurred. CWmin and CWmax as well as AIFS are shorter for higher-priority ACs. Therefore, higher-priority frames have a better chance to get transmission opportunity than lower-priority ones.

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III. DCF AND EDCA PERFORMANCE ANALYSIS

The study of network performance can be achieved by three ways: test-bed, simulation, and analytical modeling. The test-bed approach is time consuming and costly, especially for large-scale systems. Analytical modeling requires certain assumptions and restrictions to model. Oversimplified models may lead to inaccurate results that are not desirable. In contrast, simulation can provide accurate results and offers a cost-effective and versatile tool that can be used to investigate the system performance under different design alternatives and various working conditions.

To perform the simulation experiments, we used a developed wireless simulator [8]. Its accuracy has been verified comparing simulated results with the result of different well-known analytical models [9]-[10].

A. Simulation scenario

We consider a wireless network that consists of N wireless stations (STA) and an access point (AP), which are located within a Basic Service Set (BSS), i.e., every station is able to detect a transmission from any other station. The wireless network works in an Infrastructure mode, when all stations send and receive traffic via an access point. The channel condition is assumed to be ideal and each station operates at the transmission rate of 54 Mbit/s. Station generates traffic for each AC equally.

Research scenario considers that average total network load without bursts shall not exceed 20% of network capacity and each station has equal amount of traffic in total network load. The access point transmits all frames that come from stations, so a half of total network load belongs to AP. Therefore, the impact of network load from each station in total network load will be 10/N%.

We assume, that at some moment of time one of the stations produces a traffic burst thus total network load increases to 80% of network capacity and then, after some period of time, station output traffic falls back to 10/N%. Such scenario allows us to analyze network behavior and its characteristics on a simple traffic burst.

B. Performance analysis of DCF and EDCA access schemes

Let us consider the simplest case when the network consists of two stations (STA1 and STA2) and an access point. Using developed simulator a simulation of the network under the defined above scenario was done. In this experiment a traffic burst was generated by the station STA1.

In the Fig.1 a total throughput of the wireless network, that is working using DCF and EDCA access schemes, is shown. Observing the Fig. 1 we can see that there is a burst occurrence in the total network load and that the network unloading interval is approximately 6-7 times longer than the duration of the traffic burst.

In case of DCF access scheme (Fig. 1a) an increase of access point throughput is observed. This increasing is due to the fact that the queue buffer size of stations and access point is unlimited, so the access point buffer accumulates all the frames that are being transmitted from stations while traffic burst. As soon as traffic burst of STA1 is ended and its load is reduced to the level of 5% (10/N) of network capacity the access point gets the opportunity to transmit buffered frames, which causes the growth of its throughput. Similar network behavior is observed for EDCA access scheme (Fig. 1b). After the traffic burst the network throughput growths of STA1 and access point alternates each other. A number of network throughput growths is equal to a number of ACs. During each network throughput growth frames with AC starting from the highest till the lowest one are being transmitted. Thus, we can clearly see how EDCA differentiates frames transmission by priorities.

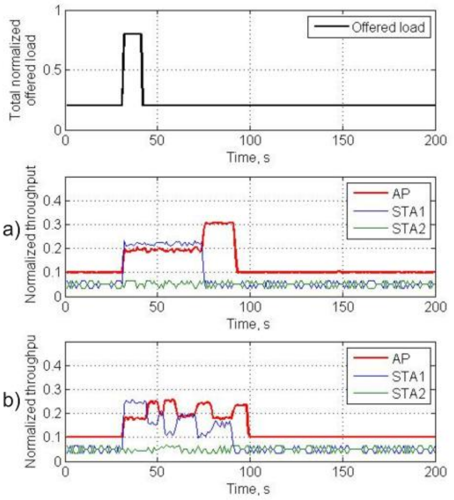

Fig. 1. Normalized total throughput of the wireless network that contains 2 stations and works using a) DCF or b) EDCA access scheme

In the Fig. 2a and Fig. 2b a mean frame delay is shown respectively for DCF and EDCA schemes. For both stations and access point mean frame delay suffers from the traffic burst. In case of DCF scheme mean frame delay during traffic burst increases 1.5-2 times and in case of EDCA scheme – 4-15 times.

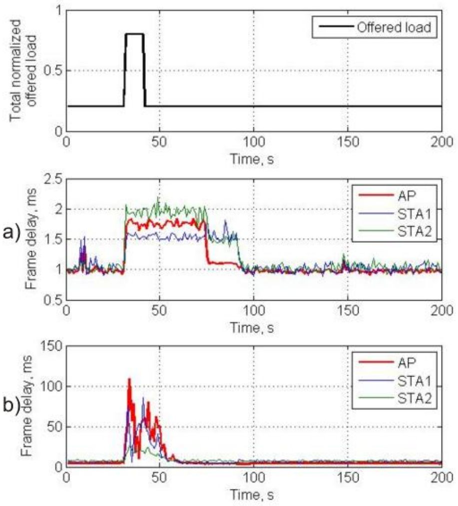

Fig. 2. Mean frame delay respectively for a) DCF and b) EDCA access scheme

A more detailed analysis of impact of the frame priority to the mean frame delay (Fig. 3) shows that a significant contribution to the frame delay growth is done by low priority frames (Fig. 3b).

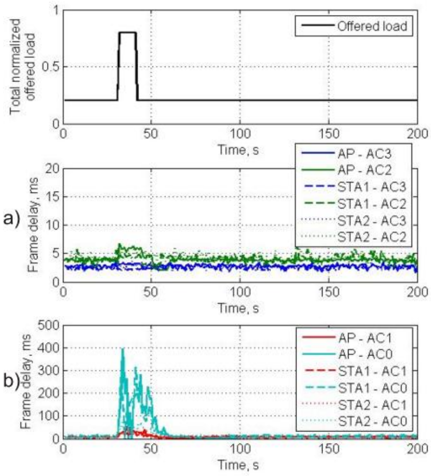

Fig. 3. Mean frame delay for a) high priority and b) low priority frames

Now let us increase network size to 5 stations and then to 10 stations. Simulation experiments were done according to the research scenario described above.

In the Fig. 4 and Fig. 5 a normalized throughputs of the wireless network that contains respectively 5 and 10 stations for DCF and EDCA access schemes are shown. Throughput dependencies are very similar to the throughput dependency in case of wireless network with two stations.

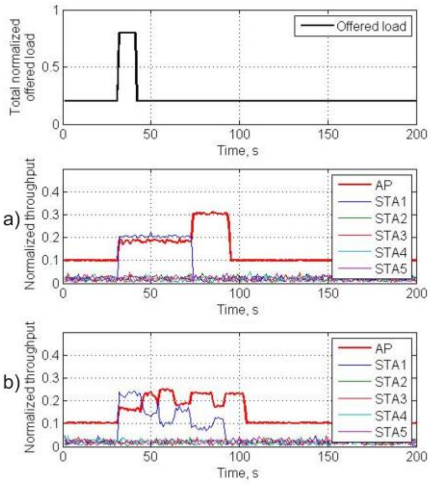

Fig. 4. Normalized total throughput of the wireless network that contains 5 stations and works using a) DCF or b) EDCA access scheme

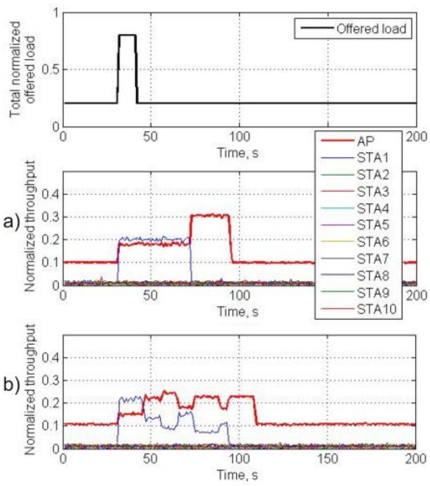

Fig. 5. Normalized total throughput of the wireless network that contains 10 stations and works using a) DCF or b) EDCA access scheme

The only significant difference is that the more stations are in wireless network with EDCA access scheme the longer is unloading interval of access points (Fig. 4b and Fig. 5b). That can be easily explained by a larger amount of buffered frames from larger number of stations.

In the Fig. 6a and Fig. 6b mean frame delay for the network that consists of 5 stations is shown respectively in case of using DCF and EDCA scheme.

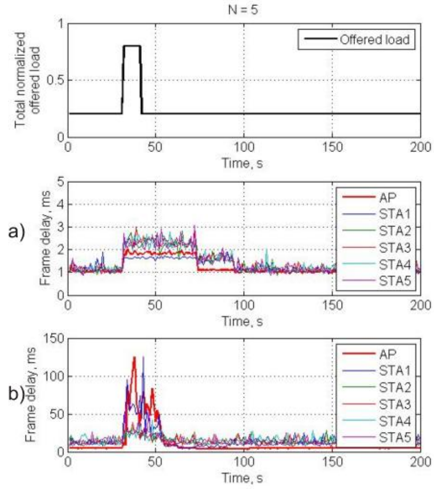

Fig. 6. Mean frame delay for a network of 5 stations in case of using a) DCF and b) EDCA access scheme

In case of using DCF access scheme mean frame delay growths as reaction on the traffic burst for all stations and access point. The edges of the mean frame delay growth are quite sharp; the difference is about 2-2.5 times. For the EDCA access scheme mean frame delay sharply changes for the station STA1 (that is the source of traffic burst) and for the access point (difference is about 8-12 times). For other station of the network mean frame delay reacts smoother on the traffic burst.

If the network size is increased to 10 stations (Fig. 7), then mean frame delay is burstier itself, especially in case of EDCA scheme (Fig. 7b). For DCF scheme increasing of mean frame delay as reaction on traffic burst is still distinguishable and the difference is about 2-2.5 times.

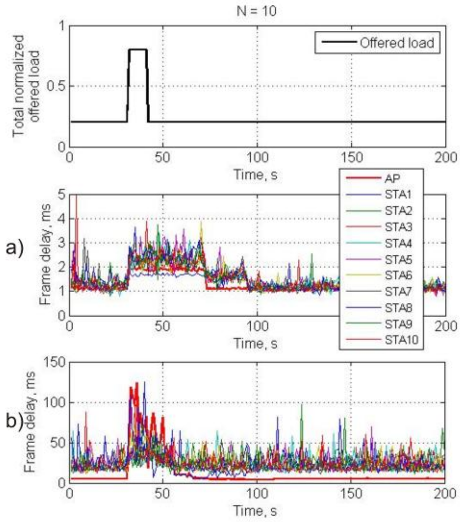

Fig. 7. Mean frame delay for a network of 10 stations in case of using a) DCF and b) EDCA access scheme

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IV. CONCLUSION

Thus, we can conclude that the traffic burst affects not only network throughput, but also mean frame delay. For the wireless network it takes about 6 times longer than the duration of a single traffic burst to unload itself. All the network nodes react on the traffic burst by increasing of mean frame delay 2-2.5 times. In case of DCF scheme the edges of mean frame delay are quite sharp. For EDCA scheme mean frame delay is burstier itself but its increasing on traffic burst is still distinguishable. Therefore, sharp change of mean frame delay may help identify network load condition and may serve as an indicator for decision-making mechanism in adaptive access control scheme of wireless networks.

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