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MAC-Layer QoS Evaluation Metrics for IEEE 802.11e-EDCF Protocol over Nodes' Mobility Constraints

Khaled Dridi¹, Boubaker Daachi¹ and Karim Djouani^{1,2}

¹*Laboratory of Images Signals and Intelligent Systems, Paris-East University*

²*F'SATI Institute of Technology/TUT University*

¹*France*

²*South Africa*

1. Introduction

Although wireless networks suffer from limit bandwidth, higher bit-error rates (BER's), significant amount of delay, and lower security than wired networks, still they have been emerged as an existing technology for the broadband wireless access, like IEEE 802.11 WLAN. Being fair for sharing medium resources considers the main reason for these weaknesses. Furthermore, Quality of Service (QoS) mechanism, in the recent version of the standard, should improve service differentiation among various types of traffic. It challenged to manage collisions and to support channel variation. Beside, wireless networks are more likely to have higher-ranking on flexibility by allowing easy setting up. If the IEEE 802.11 standard family provides the guarantee for connectivity, sufficient local coverage, required security and enough compatibility with the existing technologies, it is highly expected to carry on real-time applications requirements (Andreadis, 2006). Particularly, the EDCF MAC protocol, which improved a set of parameters, defines the classes of priority for the channel access mechanism during the contention-based period (CP). This can subsequently be declined to a variation of network dynamicity. In fact, when a mobile node crosses the overlay area with other connected nodes, the data transfer can be affected during the handoff intervals. The MAC process fails synchronization and it will be considerably corrupted by generating an amount of packets loss. This effect can be highly intensive depending on the increase of node's mobility rate. Consequently, EDCF protocol loses capacity for QoS delivery and can be reverts to a DCF behaviour reached the threshold limit of stability. Reliability analysis of different traffic classes (video, voice and data), without considering both network topology and node's mobility constraint, is not well appropriated. Dealing with this recent constraint, we propose a study which allows to know how EDCF react facing nodes mobility referring to the MAC protocol stability region. The functional analysis allowed us to follow the mobility of the node and identify the high-rated packets loss areas. To reduce this impact, we specify an algorithm, which operates in different network topology, called multi-coverage algorithm for approving the medium access mechanism. This approach can support overlapping adjacent coverage wireless ranges. For performance evaluation, we studied the most common measured metrics: effective

throughput, end-to-end delay and jitter bound. To complete the study, we proposed a mobile scenario, between two adjacent and overlapping wireless stations, within three ranges of mobility rates: low, medium and high. Furthermore, we project to present some issues to improve the behaviour of the protocol by correcting session time BS's hand-off association. Evaluation of the simulation results within three modes of mobility combining the main MAC metrics are detailed and summarised as a user's guide based-on traffic priority scheme.

2. IEEE 802.11 MAC legacy

The standard WLAN IEEE 802.11 used Best-effort service model built on FIFO queuing mechanism. The access mode is based upon two different access methods; the mandatory Distributed Coordination Function (DCF) operates in Contention Period (CP) and Point Coordination Function (PCF) for the polling during Contention Free Period (CFP) (IEEE Std. 802.11-1999).

2.1 DCF

Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol is used to regulate the access in the shared medium. So, all wireless nodes have simultaneous access to the same channel resources. If a node wants to transmit, it first senses the medium. The frame is transmitted when the medium is idle for at least a DCF inter-frame space (DIFS) period of time. If the wireless medium is busy, the node chooses a backoff time slot, B , consisting of a random number within the Contention Window (CW) interval values (0 to CW). This counter, according to each station, is decremented by one when the medium is detected idle for at least one DIFS. Now, when the medium is busy, the B timer is frozen (the backoff value is paused to the current value till the state of medium will change). It will be reactivated when the medium becomes free for the next DIFS space. The MAC layer frame is transmitted only when the backoff timer reaches the zero bound.

If a node does not receive the acknowledgement (ACK) frame, it is considered that collision has occurred and the contention window, W , is doubled, as:

$$W_n = 2^{c+n-1} - 1 \quad (1)$$

Where n is the number of transmission attempts along with the current one for the frame.

c is a constant, which defines the minimum contention window, as:

$$c = \log_2(W_{min} + 1) \quad (2)$$

To start a new backoff process, a new backoff time is chosen. Before sending a new frame after a successful transmission, the backoff mechanism is once more activated. When a transmission is successful, the contention window will reset to W_{min} .

2.2 PCF

This coordination function is related to an Access Point (AP) based network topology. The AP performs as Point Coordinator (PC). So, PCF corresponds to a centralized and polling-

based access mechanism. The condition for the coexistence of both DCF and PCF is the support of PCF. Within a super-frame, to start a CFP, the base station transmits a beacon frame. Once CFP is started, PC maintains a list of the nodes which have demanded to be polled for transmitting data and then it sends poll frames to the nodes. On response, the nodes transmit data packets. A Shorter IFS space is introduced between the PCF data frames to prevent interfering with the DCF mode.

2.3 Quality of service and the IEEE 802.11 standard

Service differentiation is one of the most required strategies to manage and improve peak-time network congestion of diverse class of traffic which combining voice, video and data flows. As, IEEE 802.11 standard initially provided a wireless transmission operation mode for the closed local network area, it shows very poor performance regarding link utilization during the competitive applications access (Visser & El-Zarki, 1995). To overcome this weakness and satisfy the service performance across the network, Quality of Service (QoS) concept is proposed. It refers to the ability of a network for providing desired handling of the traffic requirements which meets the expectations of the end applications (Mellouk, 2009). If a network supports a set of traffic specifications, as: bandwidth, transmission delay, jitter-bound, data path-loss, etc then it is supposed to support QoS delivery. Several new mechanisms for service differentiation have been proposed (Dongxia & al., 2009) (I-Shyan & Jheng-Han, 2008) (Whe-Dar & Der-Jiunn, 2008). The quality of traffics including video streaming is getting better performance when the characteristics of the wireless networks are taken into account. The earlier IEEE 802.11 standard treats packets of all traffic categories at the same priority level. Therefore, delay-dependent traffics suffer from network congestion and bandwidth variations.

2.3.1 DCF QoS limitation

DCF coordination function is based on "Best-effort" service model. All nodes compete with the same priority for access to the channel. Moreover, time-bounded multimedia applications require strict bandwidth, delay, and jitter guarantee. Accordingly, there is no service differentiation mechanism to specify and offer better service for prioritized applications than the rest of the traffic.

2.3.2 PCF QoS limitation

PCF mechanism itself weakens QoS; Firstly, IEEE802.11a creates a delay of 4.9 ms because this access process uses beacons frames to separate the two access modes CP and PCF. Secondly, all types of traffics must pass through AP. This condition causes decrease in bandwidth. Thirdly, Mac Service Data Unit (MSDU) size is affected by the transmission of data in different sizes, which makes QoS uncertain for remaining CFP period.

2.4 Toward supporting QoS in IEEE 802.11

As discussed above, the original IEEE 802.11 has not the capacity for frames differentiating priority rather it offers an equal chance to all nodes contending for the channel access at the same time. The access method in MAC layer for the new IEEE 802.11e is called Hybrid Coordination Function (HCF), it combines functionalities of both DCF and PCF (IEEE Std.

802.11-1999). Eventually, in order to enhance the contention-based access mechanisms during a CP period of the IEEE 802.11, Enhanced DCF Coordination Function (EDCF) was proposed as well.

Fig. 1. shows the super-frame of HCF (Dridi & al., 2008). The great challenge was to make sure that EDCF should be well-matched with the old DCF since large number of devices complying with the old standard had been deployed.

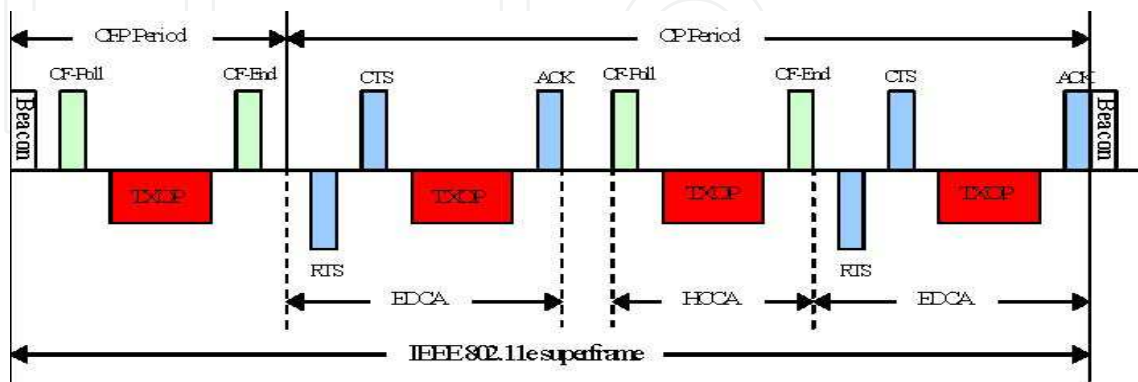


Fig. 1. HCF Super-frame Structure.

The new mechanism classifies the traffic into 8 user classes, with the modified size of contention window (CW_{min}) and the inter-frame spaces. Smaller the contention window then shorter will be the backoff intervals. Therefore, the traffic priority will be greater. A new inter-frame space called Arbitration Inter-frame Space (AIFS) is introduced to start decrementing the backoff timer as in ordinary DCF. Besides, AIFS is used to stop waiting a DIFS period of time before trying the access to the medium. AIFS is associated with each traffic class and is evaluated as a DIFS plus a number of time slots. It implies that traffic using a large AIFS will be assigned lower priority. The following scheme in **Fig. 2** depicts the dissimilarities between the IEEE 802.11 coordination functions depending on with vs. without QoS support mechanisms.

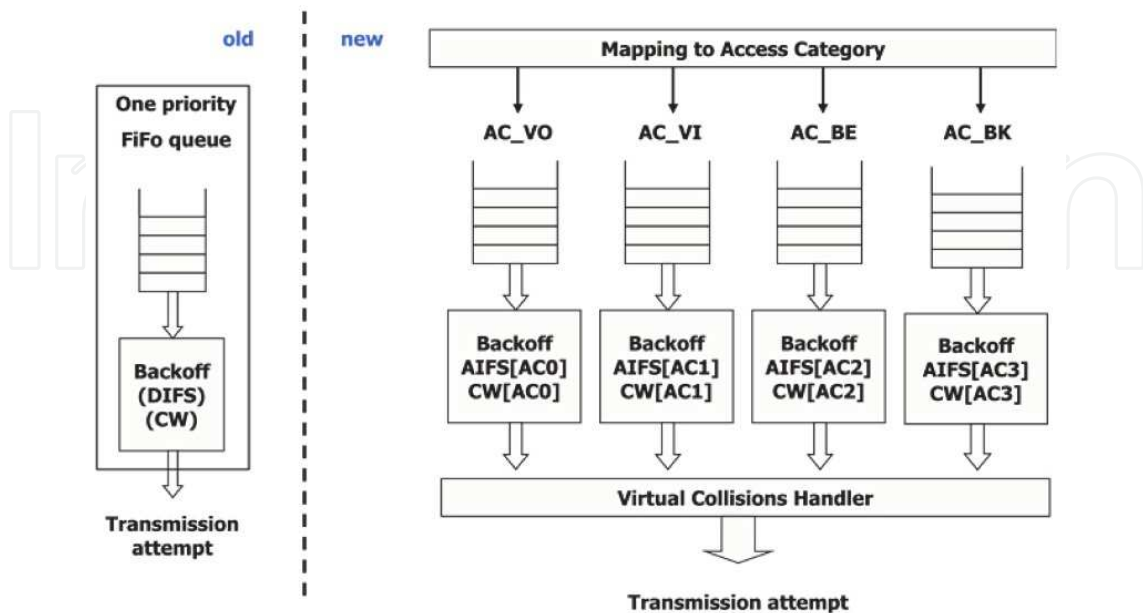


Fig. 2. Advanced QoS improvement mechanism in IEEE802.11e

Toward a better use of the wireless medium, the MAC protocol of IEEE 802.11e should operate in packet bursting mode. It consists of allowing a station to send more frames once it has gained the access to the idle medium through ordinary contention during TXOP-Limit (Dridi & al., 2008). The packet burst is terminated, if a collision occurs or no acknowledgment frame is received, as packet bursting can possibly increase the jitter. The most priority traffic operates with Short Inter-frame Space (SIFS), which is the small time interval between data-frame and Ack-frame.

2.5 IEEE 802.11e-EDCF mechanism

To make more efficient for the existing mechanisms of IEEE 802.11, EDCF has been proposed, which aims to enhance the access mechanism by providing the distributed access for the service differentiation. The IEEE 802.11e working group brought an extension to enhance the access mechanisms of earlier standard and provide a distributed access mechanism for service differentiation (Wiethölter & al., 2006). Because a lot of devices have been deployed to improve the DCF, Enhanced DCF (EDCF or EDCA) is the new IEEE appellation. Currently, an intense care aimed to carry on high level of compatibility with the previous generations of the IEEE 802.11 standard.

The MAC protocol of 802.11e standard divides the traffic into eight classes. Each class has different W_{min} and interframe space for the transmission of data. If a node, for example, requires higher priority for data transmission, it would be having smaller W_{min} and hence shorter backoff. If more nodes have the same W , the traffic classes are differentiated by having different inter-frame spaces. An inter-frame space called as Arbitration Inter-frame Space (AIFS) is introduced to avoid waiting a DIFS before accessing the medium or like DCF to decrement backoff timer. As mentioned above that EDCF has eight traffic classes with different AIFS but operates with the same DIFS period of time. Fig. 3. displays access mechanisms for DCF and EDCF.

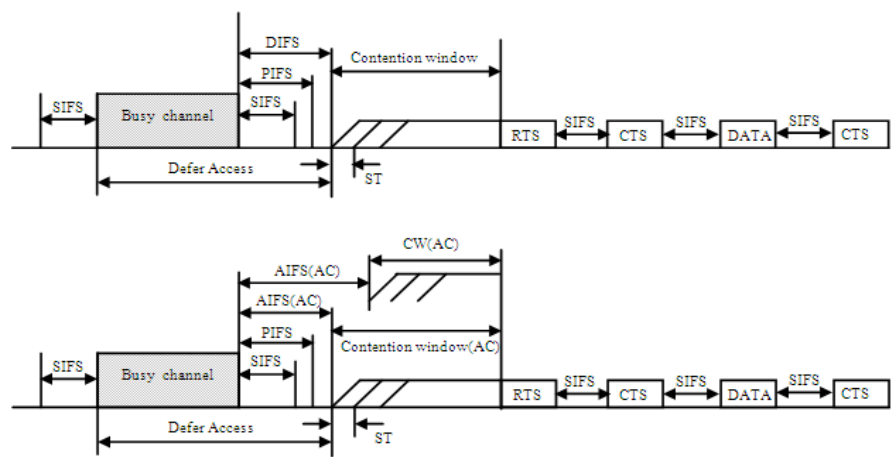


Fig. 3. DCF vs. EDCF access mechanisms.

2.6 Mobility

With wireless imbedded devices and high requirement for spreading data transferring, offer facilities for several applications aiming to investigate and control WLAN networks.

Moreover, new connected devices as: PDA, smartphones and tablet are continuously constrained by the mobility. Embedded systems in ground transport (during walk, on cycle, on car, etc) can disturb communication systems which can not follow the small devices. The increase of more requirement for internet keeping a high level of QoS and security, make the wireless network as a big challenge. That's why; we proposed to evaluate the IEEE802.11, as a wide-spreading known network. We focus on the study of the EDCF QoS support mechanism constrained by the node's mobility. We present the analysis of EDCF behaviour through the measurement of the MAC layer metrics: effective throughput, End-to-End delay and jitter.

To avoid several outside varying parameters according to the fact of mobility, we operate on fixed topology scenario while a node in mobility, as a user, connects to the first BS1, passes through the range of BS1, disconnect from BS2 when it will be out of range, detect the coverage of the second BS2, connect with BS2 and keep data transmission (Walke & al., 2006).

Depending on the node's velocity and the EDCF behaviour in QoS stability region, we suggested three ranges of node's mobility domains:

- Low Mobility [5-12] m/s,
- Medium Mobility [15-30] m/s,
- High Mobility [40-60] m/s.

Exceeding the range of 60 m/s, the EDCF will be unsteady and high level of loss-packets is generated. No detection of any kind of QoS delivery which present the limit of the proposal study.

To manage data transmission between wireless stations BS_n, an algorithm depending on the position and the quadratic neighborhood distance is proposed. It operates for controlling the data connection with BS's during the node's mobility. The Multi-coverage algorithm is given as follows:

An example of two BS's network topology

```

1  $m_n(x, y) \leftarrow \text{mobile node}$ 
2  $b_{s_1}(x_1, y_1) \leftarrow \text{base station 1}$ 
3  $b_{s_2}(x_2, y_2) \leftarrow \text{base station 2}$ 
4  $\check{R}_1 \leftarrow \text{range of } b_{s_1}$ 
5  $\check{R}_2 \leftarrow \text{range of } b_{s_2}$ 
6  $d_1 \leftarrow |m_n b_{s_1}| // \text{distance } (m_n -- b_{s_1})$ 
7  $d_2 \leftarrow |m_n b_{s_2}| // \text{distance } (m_n -- b_{s_2})$ 
8  $d_1 \leftarrow \sqrt{(x - x_1)^2 + (y - y_1)^2}$ 
9  $d_2 \leftarrow \sqrt{(x - x_2)^2 + (y - y_2)^2}$ 
10 for  $\{m_n(x, y) \subset (\check{R}_1 \cap \check{R}_2)\}$ 
11 if  $(d_1 \leq d_2)$ 
12 then connect  $m_n$  to  $b_{s_1}$ 
13 else
14 connect  $m_n$  to  $b_{s_2}$ 
15 for  $\{m_n(x, y) \notin (\check{R}_1 \cap \check{R}_2)\}$ 
```

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16 if  $\{m_n(x, y) \subset \check{R}_1\}$ 
17 then connect  $m_n$  to  $b_{s_1}$ 
18 else
19 if  $\{m_n(x, y) \subset \check{R}_2\}$ 
20 then connect  $m_n$  to  $b_{s_2}$ 
21 for  $\{[m_n(x, y) \not\subset \check{R}_1] \&\& [m_n(x, y) \not\subset \check{R}_2]\}$ 
22 then no  $b_s$  connection

```

3. MAC-layer metrics

A *metric* is a parameter value assigned to each wireless link (path or route) to be used by the respective algorithm or protocol. When the protocol starts processing, this value is measured and evaluated for selecting the better available link to be allocated for data transmission. EDCF protocol is based on shared bandwidth. As we have different composition of traffic, three kind of metric are selected. In each instance of simulation scenario, the values of the metrics are calculated, saved and updated for following continuously the variations of the protocol behaviour. To complete the study, we combine different mobility levels with the main MAC-layer metrics: throughput, end-2-end delay and jitter.

3.1 Effective throughput

The amount of data in (bits or Bytes) successfully transferred from source to destination (or it can be measured on hop-to-hop network points), is called throughput. Throughput actually acts as a gauge to measure the amount of data successfully transferred from the source point to the destination point during a specific period of time. The units bits per second (b/s), Bytes per second (B/s), frames per second (f/s), and symbols per second (s/s) are the typical measuring variety of throughput.

$$\text{Throughput} = \frac{\sum_n \text{Received Packets}}{\sum_t \text{Time}} \text{ (B/s)} \quad (3)$$

To estimate this metric, only the received packets values are considered in our computation.

3.2 End-2-end delay (E2ED)

E2ED is the time that a packet spends from source to destination. E2ED or latency can rightly be considered as propagation delay between two network points without any extra time processing involved, as the packetization delay at the generator or the packet's analyzer at the destination.

$$E2ED = \text{Arrival Time} - \text{Departure Time} \text{ (s)} \quad (4)$$

Another possibility can be used to evaluate the E2ED delay; it is obtainable by the average value of a round-trip-time calculation.

$$E2ED_{avg} = \frac{\sum_n RTT_n}{n} \text{ (s)} \quad (5)$$

3.3 Jitter formulas

Variation in the end-2-end delay measured, either at source or destination, for the corresponding packets is called jitter. The time-sensitive applications, as video or voice streaming, are affected due to the high variations in the jitter. This is why jitter can better measure the performance of traffic-sensitive applications.

Depending upon the requirements, there are numerous ways to measure the jitter.

3.3.1 Jitter combined with E2ED

Here, jitter is measured by calculating the difference in the maximum and minimum E2ED. Most of the equipments deployed up-to-date provide these two delay values. Accordingly, it is considered the easiest and the most convenient method for evaluating jitter.

$$Jitter = Max\ E2ED - Min\ E2ED\ (s) \quad (6)$$

3.3.2 Jitter relating to arrival time of packets

Here, jitter is measured by evaluating the difference in the arrivals time of two packets in the destination point instead of E2ED values.

$$\delta a_n = a_n - a_{n-1}\ (s) \quad (7)$$

Where, n shows the current packet, a_n is the arrival time of the current packet and a_{n-1} is the arrival time of the previous packet.

$$Jitter_n = \delta a_n - \delta a_{n-1}\ (s) \quad (8)$$

3.3.3 Jitter relating to successive packets time

Here, jitter is calculated by measuring the difference in the E2ED of current packet and the previous packet.

$$Jitter_n = E2ED_n - E2ED_{n-1}\ (s) \quad (9)$$

E2ED can also be expressed as:

$$E2ED_n = a_n - d_n\ (s) \quad (10)$$

As: $a_n > d_n$, $E2ED_n$ is always positive.

From Eq.(4), jitter can be rewritten as:

$$Jitter_n = (a_n - d_n) - (a_{n-1} - d_{n-1})\ (s) \quad (11)$$

$$Jitter_n = (a_n - a_{n-1}) - (d_n - d_{n-1})\ (s) \quad (12)$$

$$Jitter_n = \delta a_n - \delta d_n\ (s) \quad (13)$$

If we look closely, the jitter measured in the third method with Eq.(9) is similar to the Eq.(6) of the second method with δd_n as an additional factor. This later is obviously related to the

difference between the departure times. If the source point sends the packets with varying rate, the term δd_n will compensate this error.

3.3.4 Jitter relating to current and average packets delays'

Here, jitter is measured by computing the difference in the E2ED of n^{th} packet. It is worth noting that average $E2ED$ is measured over the required duration of analysis.

$$Jitter_n = E2ED_n - E2ED_{av}(s) \tag{14}$$

4. Scenario and network simulations

4.1 Setting mobility on wireless LAN

We started to analyze the impact of the network variations topology and dynamicity on the stability of EDCF mechanism using NS-2 a discrete event simulator targeted at networking research (Fall & Varadhan, 2011). Results of the comparison study between static scenarios, took as a reference and dynamic scenario show the degree of sensitivity of QoS service delivery to the mobile environment. The degradation rate is important where the EDCF can reach the instability region. Consequently, it loses significantly its service differentiation quality and looks like DCF in the worst case of simulation, as shown in Fig. 4 and Fig. 5. The present study focuses on the stability region of EDCF under mobility constraint. QoS scheme is evaluated depending on three domains of velocity (Low, Medium, and High) through the set of MAC-layer metrics.

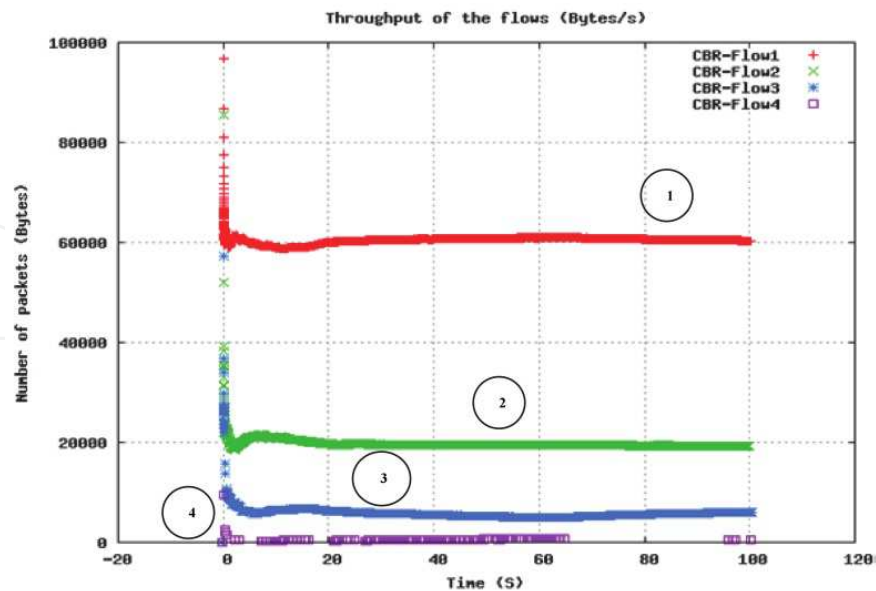


Fig. 4. Throughput without mobility

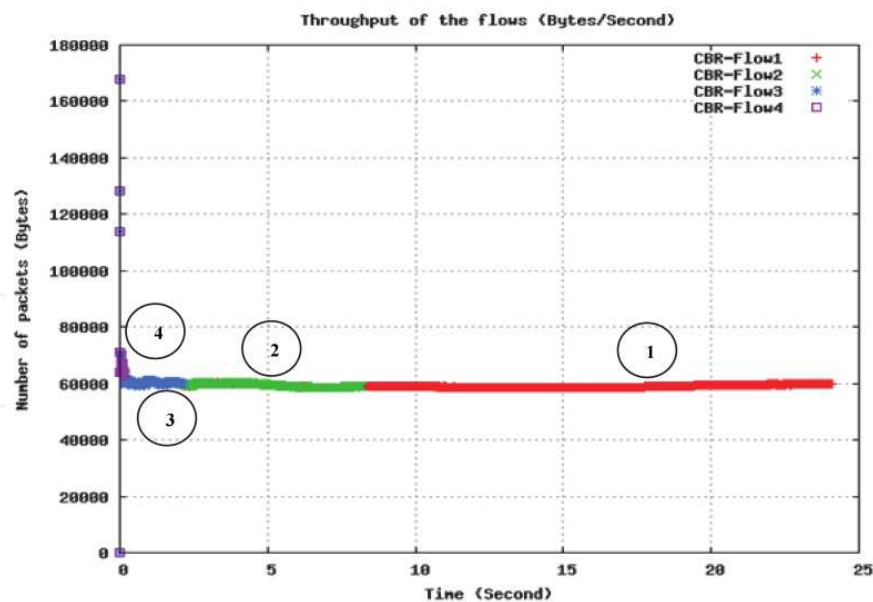


Fig. 5. Throughput with mobility

We proposed a scenario within hybrid network, which is composed of wireless and wired nodes, which can communicate through Base Stations (BS's, b_{s_1} & b_{s_2}). We specified a solution with two BS's observe that what happens when a Mobile Node (m_n) moves out from one BS to another (Fig. 6). At this time, EDCF mobility behaviour can be well evaluated.

For the different Access Categories (AC's) of service and to avoid TCP control packets exchanges', 4 CBR-traffics based on UDP transmission protocol are used.

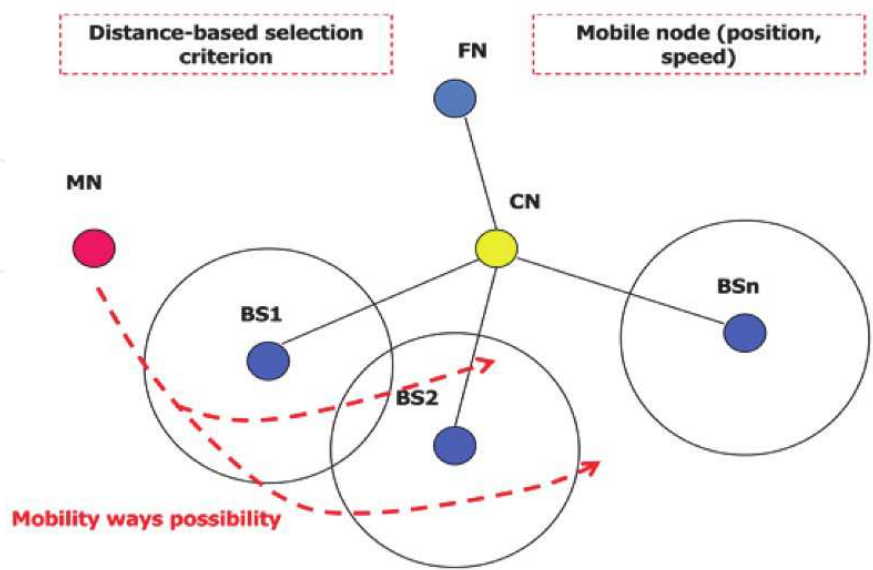


Fig. 6. Mobility scenario through multiple BS's handoff

4.2 Environment and simulation parameters

Within a table, the environnement of the proposal scenario and the parameters used for developing the mobility scheme are presented (Tab. 1).

Physical radio-propagation model	Two Ray Ground
MAC-level type on Data-Link layer	IEEE 802.11e
Queuing class interface	Priority Queuing strategy
Max queue length	50 packets
Routing Protocol	DSDV
QoS Access Categories	AC0, AC1, AC2, AC3
Wireless Data-Rate	1Mb (80% shared between AC0 & AC1)
Mobile node & Network topology	MN, BS1, BS2, CN, FN
Wired to Base-Station links	5Mb / 2ms / FIFO-DropTail queuing scheme
Development tools:	Win-32 on Cygwin environment NS-2, Nam, trace-file format, Xgraph ConTXT program editor, Gnuplot

Table 1. NS-2 simulation parameters & development tools

5. Results analysis

To focus only on the impact of mobility, the present study doesn't take care of the fading effect related to the wireless channel and the non-stationary flows in high data-rate. 5 Mbps are supported by the wired links, and 1 Mbps of data-rate in wireless medium is shared by the different classes of traffic.

As our work focuses on MAC layer, so, without making any comparison of network layer protocols, we used the same Destination Sequenced Distance Vector (DSDV) routing protocol for all the simulation scenarios. To appear congestion event, we preferred limiting the size of the queues at 50 packets. This can allow dropped packets generation, as assuming in a real network, specially when the scheduler is out of its own capacity (Dridi & al., 2010).

5.1 First case: EDCF – Behaviour over “low mobility” domain

5.1.1 Throughput

During low mobility and connection with the BS1, throughput achieves levels 60 Kbps and 20 Kbps for AC0 and AC1 respectively. These tow traffics share 80% of total bandwidth is depicted in (Fig. 7).

During connection with the BS2, the traffic switches to the half level of the top start throughputs (30Kbps & 10Kbps) and increases during the range of mobility. In this class of mobility, there is no rapid saturation event and the EDCF has enough gap to follow the mobility rhythm by increasing the level of the throughput application adequately. By no need of high throughput network resource, VOIP applications can well transmitted without be thresholded by saturation. QoS is maintained and the behaviour remain the same in both ACs traffic categories with a slight rapid has expected in AC1 to reach the top (in the border of 12 m/s).

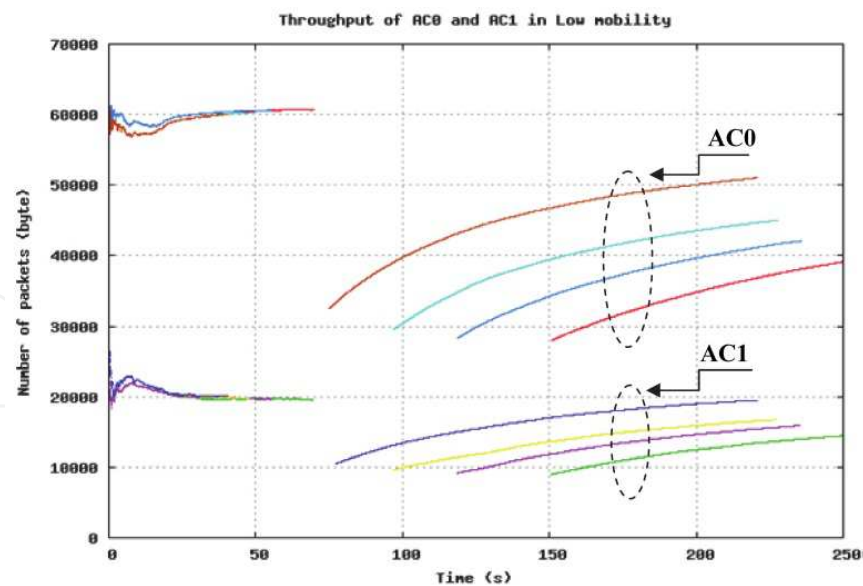


Fig. 7. Throughput for low mobility

5.1.2 End-to-end delay

During the connection with BS2, the AC0 stays around 0.2s, this is very convenient for real-time and almost delay-dependent applications, like audio and video streaming. Unfortunately, EDCF shows this capability only for the AC0 class. On the other hand, during connection with BS2 in AC1, EDCF shows some weakness and remains still sensitive to the fact of mobility, as depicted in the graph in (Fig. 8), level of 0.8s is reached for several times. The limit of 0.2s for a reasonable VoIP conversation is exceeded. Fortunately, the value of 0.5s is rapidly bounded which can be welcomed for CBR-MPEG video stream applications.

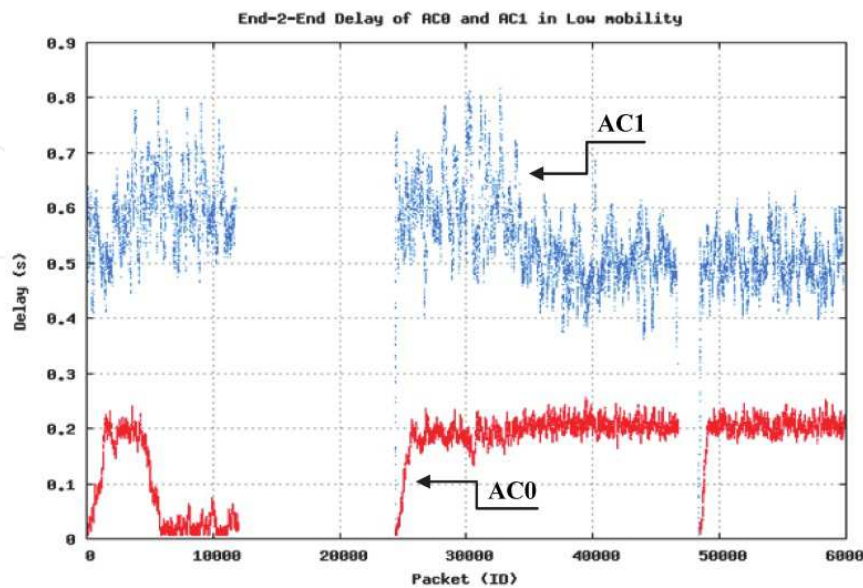


Fig. 8. E2ED for low mobility

5.1.3 Jitter

The graph in the Fig. 9 shows the jitter plotted in two sides of x axis. The negative peaks for packets arrive early, and positive peaks for packets arrive late. The variation of the intensity of jitter in both sides identifies the quality of transmission (ex. degradation quality during a call in VoIP).

For AC0, the jitter is bounded around 0.01s for the all transmissions. An interesting behaviour of EDCF is observed at the negative side. The flow stays quite steady before and after the switching period between the BS's. It shows the ability of the EDCF scheduler to track jitter measurements and adjust buffer size to reduce the jitter impacts. Unfortunately, as we can see in the same graph, this behaviour raises the jitter impact of AC1 (it can reach 0.06s with 0.12s peak-to-peak of variance). Outside this region, EDCF with CBR flow is quite steady.

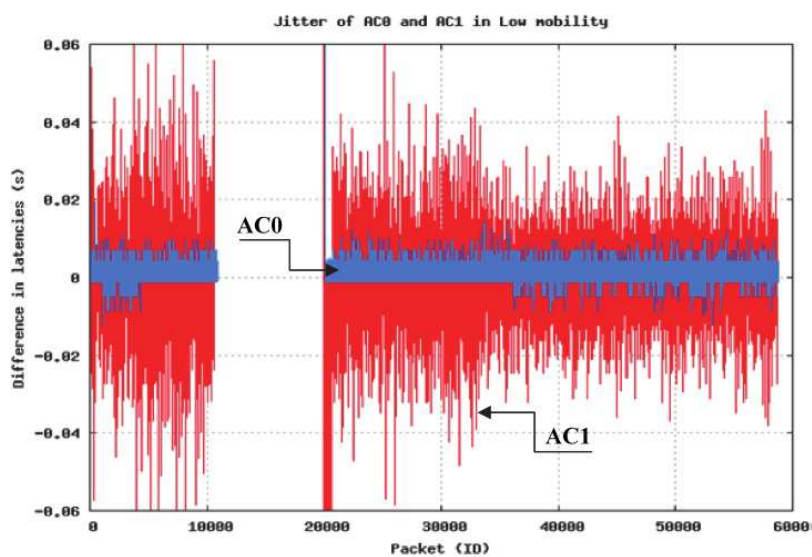


Fig. 9. Jitter for low mobility

5.2 Second case: EDCF – Behaviour over “medium mobility” domain

5.2.1 Throughput

At the start during connection with BS1, the top AC0 and AC1 throughputs stay unchanged. In AC0 traffics with the increase of the node's mobility, the throughput slightly increases. Comparing to the previous mode, the graph for this case (Fig. 10) and previous case are much closer and can't grow over 57 Kbps (start of saturation bound). Even the start top level is not reached; EDCF is not capable to increase throughput for the highest priority traffics. In contrast to AC0, AC1 can gain more flexibility and it increases over the top start level even the curves saturation is expected (more than 20Kbps reached in 30m/s).

In this mobility mode, EDCF guarantees for the maximum throughput. This is highly required variation for the throughput sensitive application (VBR flow) (Rong & Xuming, 2009), as they need robustness over user mobility. Comparing the connections with both of the BS's, we can observe that AC1 does not waste the bandwidth between two connections as AC0 does.

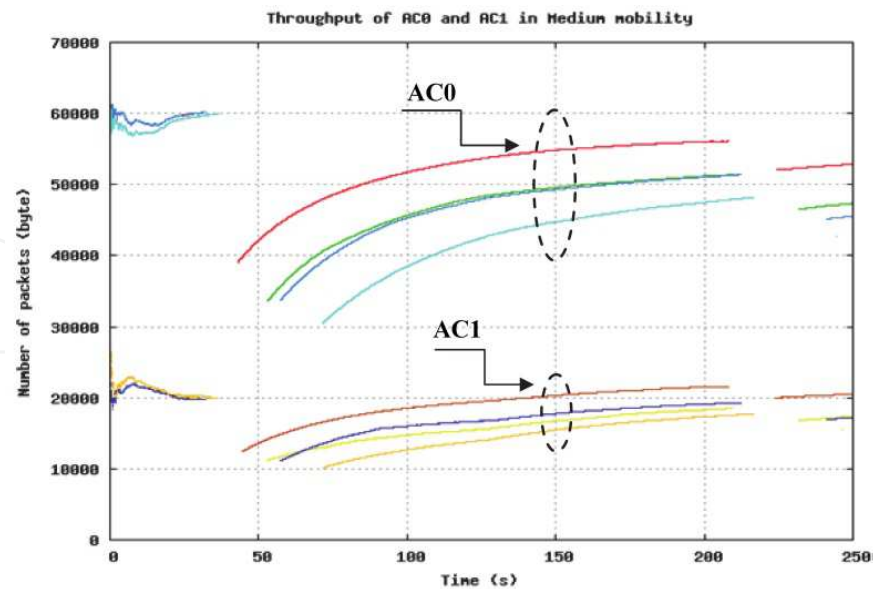


Fig. 10. Throughput for medium mobility

5.2.2 End-to-end delay

AC0 delay gains more stability after connection with BS2 down to 0.1s, and up at ~0.2s. This zone can be reserved for high sensitive traffics for the brief period of time (as in Burst mode). The AC0 in the graph depicted in Fig. 11, shows that less than 30000 packets are allowed for one burst. AC1, after establishing the connection (0.5s) attains an average delay and stays steady for the rest of transmission. This is the most important characteristic of this mode that it can bring to high priority traffic in the same transmission with a small shift of delay but granting a maximum stability. We find the best result at 30 m/s.

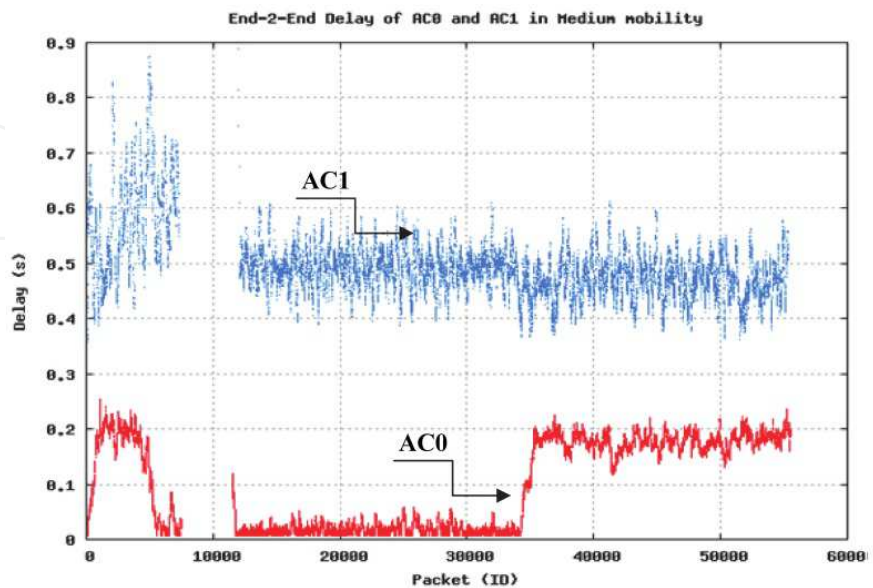


Fig. 11. E2ED for medium mobility

5.2.3 Jitter

As shown by **Fig. 12**, high stability of the negative side of AC0 (before the range of 35000 packet ID) shows that there are no packets coming early. AC1 proves E2ED stability with a reasonable level of jitter (<0.5s) after connection with BS2, with 0.1s peak-to-peak of variance. Almost all of the traffics can support the range of mobility of this mode with a condition of burst (as explained previously).

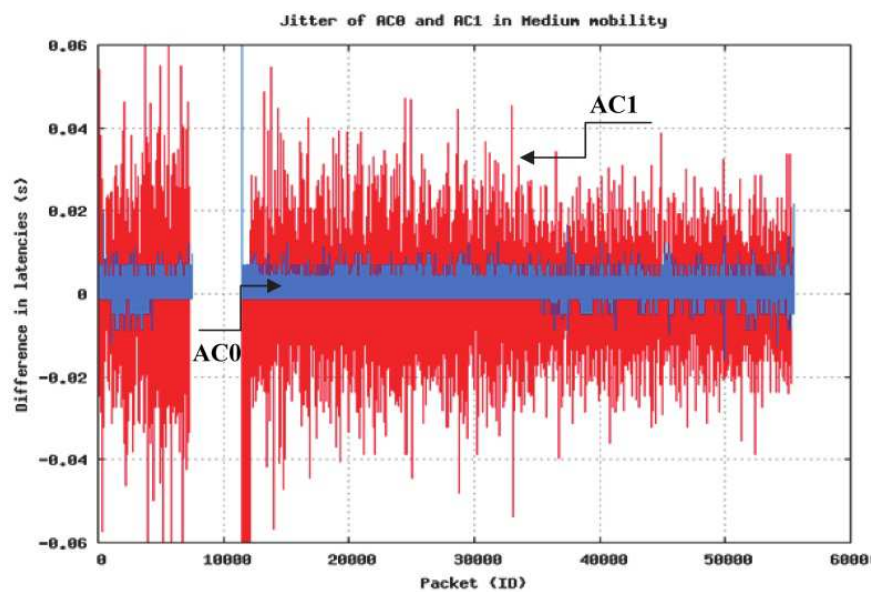


Fig. 12. Jitter for medium mobility

5.3 Third case: EDCF – Behaviour over “high mobility” domain

5.3.1 Throughput

Within this mode, AC0 and AC1 keep the same behaviour independently to the node’s mobility, as shown in **Fig. 13**. EDCF lasts the throughput level comparing to the other modes (15 Kb/s, 30 Kb/s for AC0 and AC1 respectively). It cannot follow the rhythm of the mobility to adjust the throughput accordingly. This behaviour is mainly involved to the size of buffer of the scheduler which is not able to support higher speeds (40 m/s as a critical). All of the traffic classes are penalized with fixed level of throughput, depending on the defined buffer parameters (the size of queue and the used queuing scheduling strategy) (Rong & Xuming, ICCSN-2009).

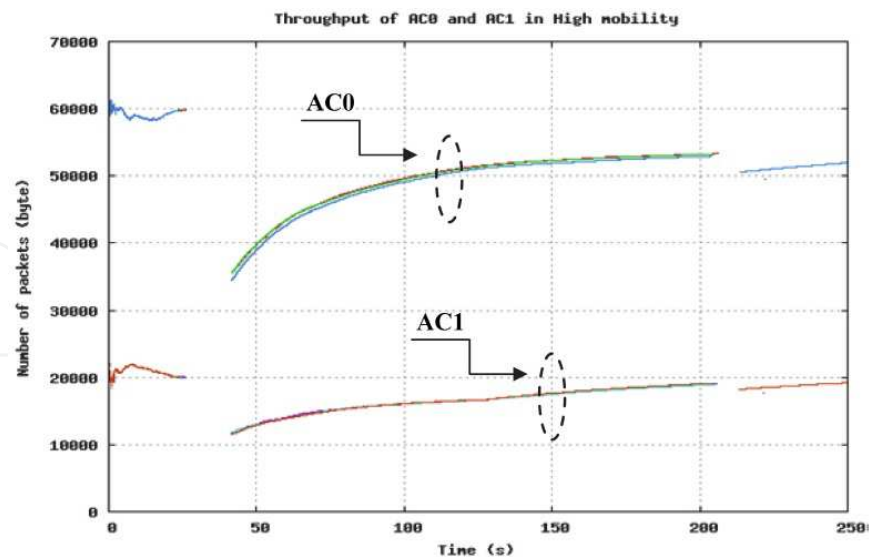


Fig. 13. Throughput for high mobility

5.3.2 End-to-end delay

AC0 stays in fixed position (0.2s) as the previous mode. AC1 shifted with high delay (0.9s) and stays in the same level independently of the network mobility. As we can see in (Fig. 14)

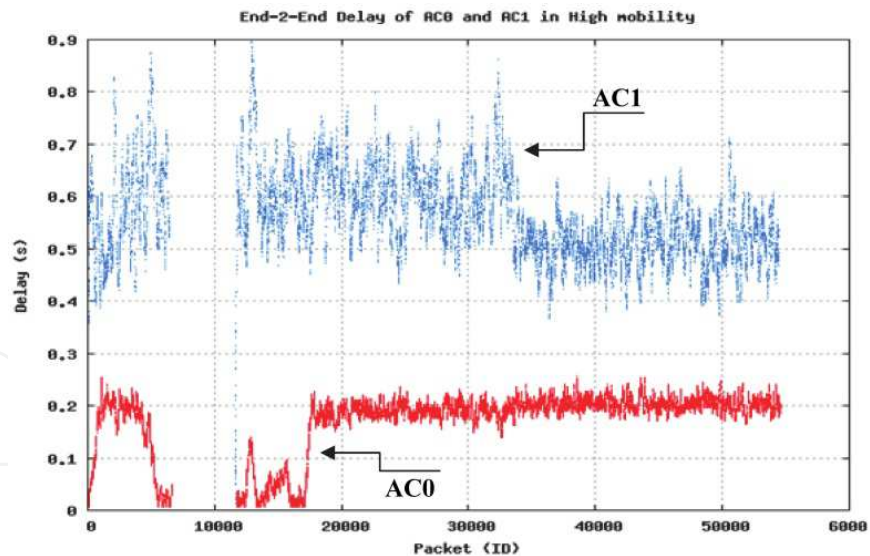


Fig. 14. E2ED for high mobility

5.3.3 Jitter

AC0 is in the worst case than the medium mode, as stability is decreased (less than 10000 packets for burst). AC1 keeps the same levels of jitter (0.06s with 0.12 peak-to-peak of variance in Fig. 15) with random concentration is slightly appeared discerned in the path of mobility.

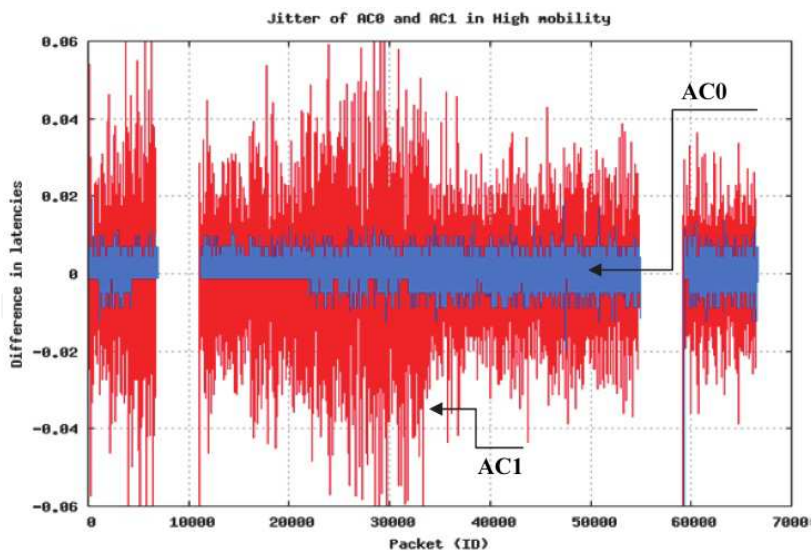


Fig. 15. Jitter for high mobility

The three metrics are worth studying and discussing where the table (Tab. 2) Summarizes the behaviour of EDCF under the three mobility domains according to the traffic aware-MAC metric pertinency.

Mobility/Metric	Low	Medium	High
Throughput	Best ! for real-time applications & video conferencing	Satisfactory for Data transmission	Satisfactory for Emails, SMS, MMS
E2ED	Good for all streaming traffics	Satisfactory for CBR-MPEG	Not satisfactory for almost traffic
Jitter	Good for VoIP traffic	Good for no-streaming traffic	Worst ! Critical level of dropping packets

High performance

Poor performance

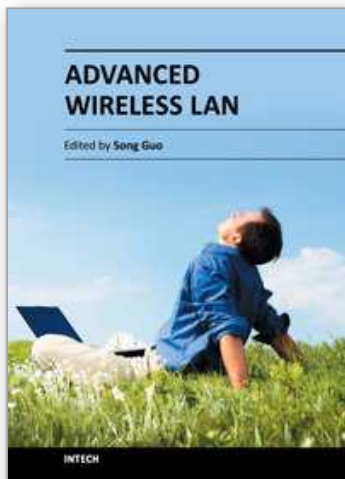
Table 2. EDCF behaviour for the MAC metrics constrained by three levels of Mobility

6. Conclusion

The proposed study of this chapter focuses on the performance of the EDCF protocol under the node's mobility constrains. The IEEE 802.11 standard reveals high sensitivity to the nodes' position and velocity. These can significantly decrease the standard QoS service ability. By looking for QoS stability region of the MAC protocol, several tests are performed over the main layer-link metrics; throughput, End-2-End delay and jitter in order to quantify the mobility effect. Therefore, different classes of traffic are defined. We ended the study by proposing a benchmark which summarized the impact of these metrics according to three zones of stability. Furthermore, the QoS mechanism behaved differently depending on the rhythm of mobility apply in each scenario using NS2 network simulator. The study of MAC protocol, even the range is limited by PHY layer, allows extension since it can operate easily within cooperation topology. The approved results can help users to identify the borderline of service's steadiness depending on the requirements of the traffic flow. Following this optimistic approach, the study will be expanded for supporting channel fading effect, multipath distortion and BER vs. SNR links' quality within node's cooperative diversity network.

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The past two decades have witnessed startling advances in wireless LAN technologies that were stimulated by its increasing popularity in the home due to ease of installation, and in commercial complexes offering wireless access to their customers. This book presents some of the latest development status of wireless LAN, covering the topics on physical layer, MAC layer, QoS and systems. It provides an opportunity for both practitioners and researchers to explore the problems that arise in the rapidly developed technologies in wireless LAN.

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University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China

Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

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