YAVISTA: A Graphical Tool for Comparing 802.11 Simulators

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***Abstract*—The difficulty to compare network simulators is a major obstacle to the broader adoption of these tools. This problem particularly affects 802.11 simulators because the 802.11 protocol is complex and simulators contain several simplifications that are difficult to evaluate. In this paper, we present a generic visualization system able to interface with the 802.11 protocol implemented in NS-2 and Glomosim. Our tool allows to emphasize the common behaviours and divergences observed between the simulators and the IEEE 802.11 standard.**

Our contribution includes the definition of a new method to compare simulators and the publication of the most complete list to date of modeling differences relative to NS-2 and Glomosim lower layers.

***Index Terms*—Simulator, Comparison, Visualization, 802.11, NS-2, Glomosim**

I. Introduction

Simulation is a common technique used in research to study and design protocols. Once a protocol is developed, its correctness is tested against real observations or analytic models. When developing entire simulators, comparisons with other simulators allow the users to understand the behavioral differences between the simulation models.

The comparison method generally consists in running the simulators under test with the same input values. The simulation outputs are then compared to identify the special working properties of each simulator. The exact nature of these characteristics is determined after analyzing the software sources. The problems with this method are the comparison of incomplete results in different formats and the uncontrollability of the network stack dynamic during simulations.

In this paper, we propose a new comparison method allowing accurate and straightforward analysis of the lower layers of the simulators. We apply it to the 802.11 implementation of Glomosim [1] and NS-2 [2]. As the method logs the entire execution of the MAC layer in a standard format, the trace files contain both the normal behaviours and the simulator characteristics manifestations. With this method, the comparison procedure is the following: when a difference is observed in a frame exchange, the IEEE 802.11 standard [3] is consulted to know which simulator is faulty. Several mechanisms can be used to compare the logs. The tools based on a generic display being the simplest to use, we have extended the timeline representation [4] proposed for NS-2 to Glomosim.

Our main contribution is the definition of a generic comparison method, and a prototype implementation called YAVISTA [5], allowing visual comparison of different 802.11 models. We show how the behaviours of Glomosim and NS-2, despite major modeling differences, can be displayed in the same way and compared. Our contributions also include the publication of the most complete list to date of characteristics relative to NS-2 and Glomosim lower layers. The study particularly reveals important differences between the number of collisions / captures estimated by the two simulators.

The rest of this paper is organized as follows. Section 2 presents our generic visualization system. Section 3 compares the characteristics found out in Glomosim and NS-2. Section 4 addresses related works. Section 5 concludes the paper and presents future works.

II. Yavista processing method

YAVISTA is based on the XML [6] and SVG [7] recommendations developed by the W3C to describe text and graphic information. As shown in fig. 1, the simulation events are initially logged using the XML format. YAVISTA is a specialized tool transforming the XML trace files into the SVG graphical format. The SVG traces are then displayed with Inkscape [8] a free graphic software.

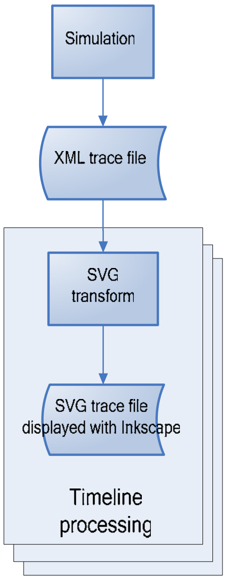

Figure 1. YAVISTA flow chart

A. XML and SVG Formatting

The simulations events are logged into individual XML elements. As an example, the *'PHY_TRANSMITTING'* XML element could be used to indicate a transmission over the channel at the physical level. The XML syntax has the advantage of being very close to SVG, which greatly eases the conversion between both formats.

The SVG transform is performed by a program that translates each XML element into a SVG group composed of a shape and a label. The transformation of the *'PHY_TRANSMITTING'* XML element is illustrated on fig. 2. The element is translated into a SVG group containing a rectangle and a label. The XML attributes *'begin'* and *'nid'* control the group position on the screen through the SVG attribute 'translate'. The XML attribute *'event type'* defines the stroke color to use.

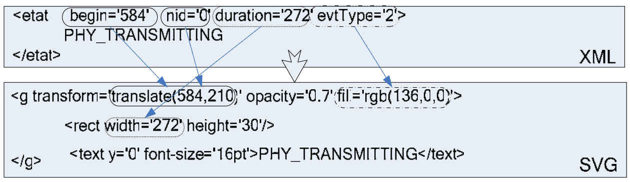

Figure 2. XML to SVG element transformation

A packet exchange between stations A and B at the physical level is represented in fig. 3.

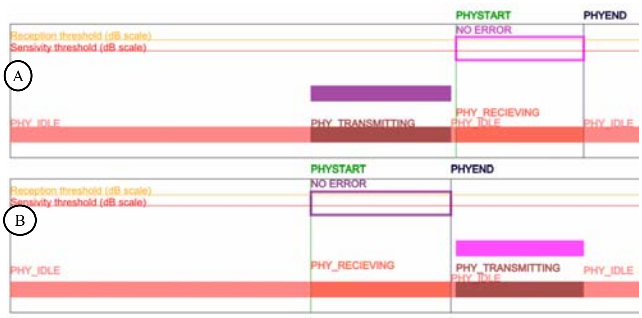

Figure 3. Graphic trace at the radio layer level

For each station, the XML elements are displayed along three lines, each line materializing the temporal execution of a state machine - respectively from top to bottom: the channel perception in reception, the channel perception in transmission and the physical layer state.

B. Generic Representation of the 802.11 Operations

As each implementation has its own internal representation, we must, to compare NS-2 and Glomosim, define a generic declarative language able to represent the whole list of actions performed by the DCF (Distributed Coordination Function) protocol in the simulators.

In this article, we call neutral language, a language simple to understand and able to express the operations carried out by a set E of simulators. We call neutral code, an execution trace written in neutral language. The neutral language elements proposed to represent the MAC layer operations of the MANET simulators are presented in tables I and II. This language has been instrumented into the set E= {glomosim 2.03, NS-2.29, NS-2.30}.

In tables I and II, the yellow elements are related to the MAC's view of the channel (software and physical sensing), to the interframe and backoff waiting periods. The blue elements concern the transmission operations (transmission of an ACK, a RTS, a CTS or a data packet). The red elements refer to the reception operations (reception of an ACK, a RTS, a CTS a data frame, an erroneous packet or a packet addressed to another station). Finally, the grey elements are additional information which indicates when the backoff pauses and resumes.

The start and duration settings of each XML element must respect the DCF specification logic. As an example, the *MAC_DATA* operation must start with the transmission of the first bit of the physical frame and end with the transmission of the last bit. Table II describes the XML attributes associated to each XML elements. As table II shows, each XML element carries, in addition to the *'begin'* and *'duration'* attributes, its own debugging information.

Fig. 4 shows how YAVISTA standard output interface is implemented within the MANET simulators. This one is composed of a module dedicated to the PHY layer and another to the MAC layer. Because of the coupling between the MAC and PHY layers and the allocation of the low level functions in both layers, the implementation of the modules is distributed over all the radio interface.

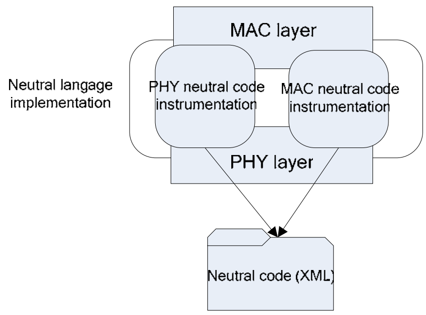

Figure 4. Standard output interface implementation

TABLE I. XML EVENTS DESCRIPTION

Event name	Description of the event
CS_PHY	Physical activity on the channel
CS_NAV	Software activity on the channel
CS_DEFER	IFS period
CS_BACKOFF	Backoff period
MAC_ACK	ACK transmission
MAC_RTS	RTS transmission
MAC_CTS	CTS transmission
MAC_DATA	Data transmission
TX_WF	CTS, ACK or data waiting period
RECV_ACK	ACK reception
RECV_RTS	RTS reception
RECV_CTS	CTS reception
RECV_DATA	Data reception
DROP_ERROR	The received frame is corrupted because of power loss or simultaneous transmission/reception
DROP_NOT_DEST	The received frame is dropped because it is not addressed to the station
START_BO	A new backoff is drawn
PAUSE_BO	The backoff counter has frozen
RESUME_BO	The backoff counter has restarted

TABLE II. XML EVENTS FORMAT

<table>
<tr><th>Event name</th><th>begin</th><th>duration</th><th>Event type</th><th>Node id</th><th>Number of remaining time slots to wait</th><th>Number of time slots spent</th><th>Contention window size</th><th>source</th><th>destination</th><th>Transmission rate</th><th>Packet size</th><th>Packet type</th><th>Packet sequence number</th></tr>
<tr><td>CS_PHY</td><td rowspan="4">×</td><td rowspan="4">×</td><td rowspan="4">×</td><td rowspan="4">×</td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td></tr>
<tr><td>CS_NAV</td></tr>
<tr><td>CS_DEFER</td></tr>
<tr><td>CS_BACKOFF</td></tr>
<tr><td>MAC_ACK</td><td rowspan="4">×</td><td rowspan="4">×</td><td rowspan="4">×</td><td rowspan="4">×</td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4">×</td><td rowspan="4">×</td><td rowspan="4">×</td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="4"></td></tr>
<tr><td>MAC_RTS</td></tr>
<tr><td>MAC_CTS</td></tr>
<tr><td>TX_WF</td></tr>
<tr><td>MAC_DATA</td><td>×</td><td>×</td><td>×</td><td>×</td><td></td><td></td><td></td><td>×</td><td>×</td><td>×</td><td>×</td><td>×</td><td>×</td></tr>
<tr><td>RECV_ACK</td><td rowspan="5">×</td><td rowspan="5">×</td><td rowspan="5">×</td><td rowspan="5">×</td><td rowspan="5"></td><td rowspan="5"></td><td rowspan="5"></td><td rowspan="5">×</td><td rowspan="5">×</td><td rowspan="5"></td><td rowspan="5"></td><td rowspan="5"></td><td rowspan="5"></td></tr>
<tr><td>RECV_RTS</td></tr>
<tr><td>RECV_CTS</td></tr>
<tr><td>RECV_DATA</td></tr>
<tr><td>RECV_NOT_DEST</td></tr>
<tr><td>DROP_ERROR</td><td>×</td><td>×</td><td>×</td><td>×</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>START_BO</td><td rowspan="3">×</td><td rowspan="3"></td><td rowspan="3">×</td><td rowspan="3">×</td><td rowspan="3">×</td><td rowspan="3">×</td><td rowspan="3">×</td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td></tr>
<tr><td>PAUSE_BO</td></tr>
<tr><td>RESUME_BO</td></tr>
</table>

III. Comparison of Glomosim and NS-2 Characteristics

This section compares Glomosim 2.03 and NS-2.30 characteristics. NS-2 is one of the most popular simulation environment used in academic research. It was released in 1996. Wireless support has been added in 1997 in release 2.15. NS-2.30 has been published in September 2006. Glomosim is specifically tailored to wireless systems. It was designed to be scalable to very large networks. Its last version, Glomosim 2.03, was published in 2002.

In the following experiments, the simulators are compared using the same packet size, physical rate, topology, transmit power, frequency band, propagation model and the same reception, sensitivity and capture thresholds. The physical model used in Glomosim is the SNR bounded packet reception model because it was designed to yield the same results as NS-2. The simulators are tested under symmetric channel conditions.

The simulators characteristics are classified into three categories: simplification, error or standard interpretation. The 802.11 standard clauses related to the involved characteristics are provided simply for information.

A. *Interpretations of the IEEE 802.11 Standard*

The interpretations of the IEEE 802.11 standard are listed in table III and discussed in the following sections.

TABLE III. INTERPRETATIONS OF THE IEEE 802.11 STANDARD

	NS-2	Glomo	802.11 standard clause
1) Channel access when medium is free	×		9.2.5.1
2) EIFS use in case of PLCP error	×		9.2.3.4, pp391, pp460

1. Channel Access When Medium is Free

NS-2) When the medium is idle, a station must wait a pre-backoff before transmitting, even if the backoff procedure was already performed at the end of the previous frame exchange. This pre-backoff procedure is indicated by the *CS_BACKOFF* event on fig. 5.a. It includes one IFS period (*CS_DIFS*) plus a random number of backoff slots. The transmission operation is indicated by the *MAC_DATA* event.

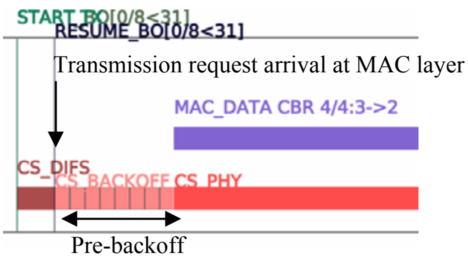

Figure 5.a. Access when medium is free (NS-2)

Glomosim) A closer interpretation of the standard, which stipulates that medium access must be immediate if the channel is free for greater than or equal to a DIFS period, is given in fig. 5.b. The frame is transmitted (*MAC_DATA*) one IFS period (*CS_DIFS*) after the transmission request arrival. Note that if the channel is sensed busy during the IFS period, the transmission is retried one IFS after the channel comes back to idle.

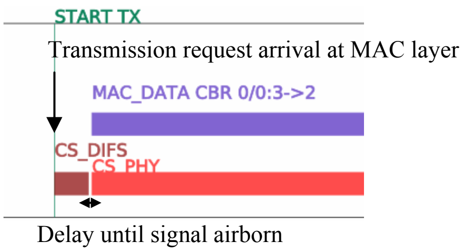

Figure 5.b Access when medium is free (Glomosim)

2. EIFS Use in Case of PLCP Error

NS-2) When a station receives a partial frame without PLCP header, it waits for an EIFS interval when the medium becomes idle again. As the EIFS should only be used after a correct PLCP acquisition this behaviour doesn't comply with the standard. Fig. 6.a illustrates this phenomenon with overlapping transmissions and receptions. Stations A and B are both in range. As B is transmitting at the beginning of the reception of A's signal, it should not be able to acquire its PLCP header. However, this doesn't prevent station B from using the EIFS interval (*CS_EIFS*) at the end of A's transmission.

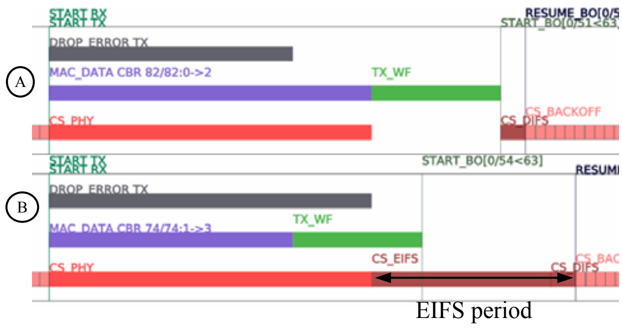

Figure 6.a. EIFS use in case of PLCP error (NS-2)

Glomosim) Contrary to NS-2, Glomosim conforms to the standard because it doesn't use the EIFS interval in this case. The backoff procedure is performed at the ACK timeout (*TX_WF*) expiration as illustrated in fig. 6.b.

Figure 6.b. EIFS use in case of PLCP error (Glomosim)

B. *System Simplifications*

The system simplifications are presented in table IV and detailed in the following sections.

TABLE IV. SYSTEM SIMPLIFICATIONS

	NS-2	Glomo	802.11 standard clause
1) Station behaviour at startup	×	×	pp338, pp457
2) RTS capture	×		N/A
3) Backoff countdown		×	9.2.5.2
4) Capture model	×	×	N/A

1. Station Behaviour at Startup

NS-2, Glomosim) When a station joins the channel, it doesn't perform the standard initialization procedure which consists in waiting for an EIFS interval before transmitting. Fig. 7.a shows how a station having pending traffic to transmit at instant 0, starts up on NS-2 and Glomosim. The access procedure is the same as the one described in section A.1.

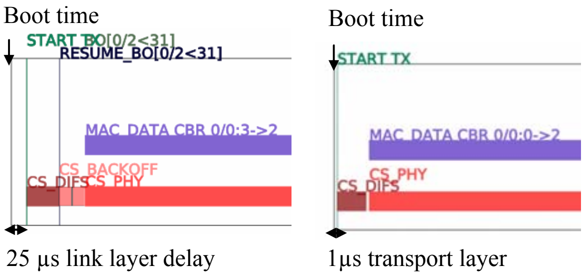

Figure 7.a. Startup phase under NS-2 (at left) and Glomosim (at right)

802.11 standard) On the other hand, fig. 7.b shows how a station complying with the standard would behave. As illustrated, such a station would wait for an EIFS (*CS_EIFS*) plus a backoff period (as indicated by the *CS_BACKOFF* event).

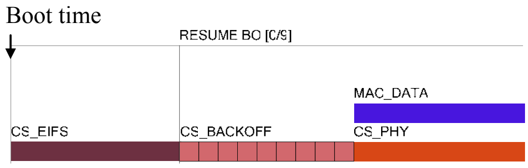

Figure 7.b. Startup phase under the reference model

2. RTS Capture

NS-2) NS-2 does not display capture behaviour if a collision occurs between two RTS packets. In fig. 8.a, stations A and B communicate with station C by using the RTS/CTS mechanism. Two RTS are transmitted and collide at node C. Because of the proximity of stations B and C, the frame from station B is correctly received (*RECV_RTS OCAPTURED*) and the one of node A is ignored (*DROP_ERROR COLL*). But although station C correctly decodes the RTS from station B and medium is idle, C does not reply with a CTS. The reason is that station C must wait the entire completion of the EIFS – started following the collision - before it can transmit. As the EIFS is still not completed at the CTS transmission start time, the CTS response is never sent in this case[1].

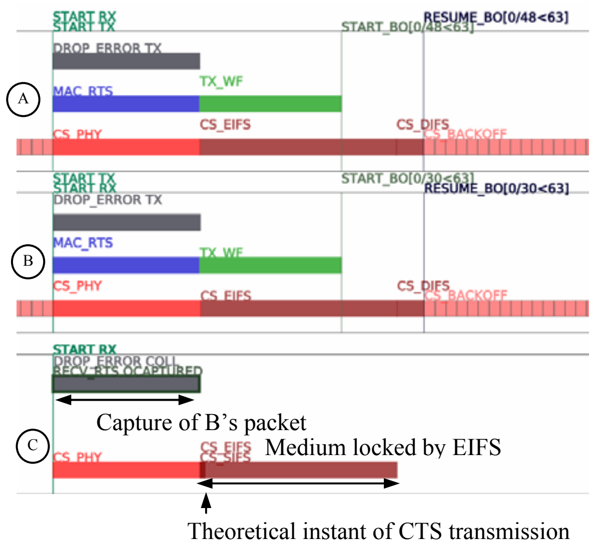

Figure 8.a. Lack of RTS capture (NS-2)

Glomosim) Contrary to NS-2, under Glomosim, station B doesn't abort the RTS procedure as fig. 8.b shows.

Figure 8.b. RTS capture (Glomosim)

3. Backoff Countdown

The backoff countdown brings into play the propagation time over the medium and the receive-to-transmit turnaround time. The way these elements are taken into account has given rise to two different models: discrete (NS-2) and continuous (Glomosim).

NS-2) Under NS, when a frame is transmitted on the medium, all the network stations decrement their backoff by the same number of slots. The proof is geometric: Let B be the station having transmitted the last frame, C the station having transmitted the next to last frame and A a lambda station. Let N_A and N_B be the remaining number of backoff slots of stations A and B before B's transmission ($N_B \leq N_A$). The propagation times t_{AC}, t_{AB} et t_{BC} between the three stations are represented on fig. 9. A, B and C are within transmission range of each other.

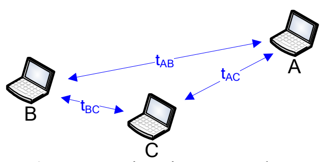

Figure 9. Propagation times over the network

Simple geometric reasoning shows that if B waits $T_B=N_B$*SlotTime before transmitting, then station A will sense the medium idle for:

$$T_A = N_B\text{*SlotTime} + t_{CB} + t_{AB} - t_{AC}$$ [2]

If $t_{CB} + t_{AB} - t_{AC} < 0$, station A waits less than N_B slots. This causes NS-2 to decrement N_A by N_B-1 slots only. Otherwise, N_A is decremented by N_B slots. The proof of the lemma relies on the fact that $t_{CB} + t_{AB} - t_{AC}$ is always positive. Unfortunately, when A, B and C are aligned or when B and C are the same station, the lack of precision of the FPU (Floating Point Unit) in T_A calculation at the backoff timer interruption skews the results (as illustrated in fig. 10.a). In this case, the number of slots to decrement by (N_B-1 or N_B) is random and the number of collisions /captures underestimated compared to theory

[1] The consequences of this phenomenon are studied in [9]

[2] NS doesn't consider the receive to transmit turnaround time

(in theory a collision/capture occurs if A and B transmit in the same slot, that is to say if $|N_A\text{-}N_B|=0$).

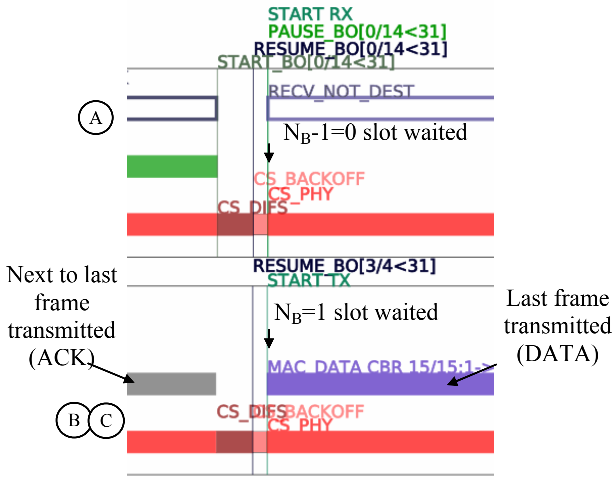

Figure 10.a. Backoff countdown when C and B are the same node (NS-2)

Glomosim) Under Glomosim, two major elements rule the backoff countdown:

a) there is an irreversible time Δ of 5 μsec between the moment when a station decides to transmit a RTS or a data packet[3] and the moment when the first bits of the frame are actually transmitted on the medium.

b) when a frame is sensed on the medium, each station decrement its backoff by the time the medium has been sensed idle. A geometric reasoning shows that if station B waits $T_B=S_B$ before transmitting[4], station A will sense the medium idle for:

$$T_A = S_B + t_{CB} + t_{AB} - t_{AC} + \Delta \;^{5}$$

Owing to the fact that T_A and T_B are real, the stations backoff are not synchronized and expire at time instants approximately multiple of Δ. A collision/ capture occurs between stations A and B if S_A and S_B expire within an interval of Δ. Thus, if A and B transmit in the same slot, the collision/capture probability between stations A and B roughly equals:

$$P = \frac{2\Delta}{SlotTime} = 0{,}5$$

Because of the backoffs desynchronization, this model produces on average twice less collisions/captures than NS-2 when the medium reaches saturation capacity. Fig. 10.b shows the evolution of three backoff counters between the transmission of an ACK and the next data frame. Desynchronization manifests itself by the fact that the slot boundaries of the different stations do not exactly correspond.

The result is confirmed by experimental measurements. Fig. 11 shows the probability of collision under NS-2 and Glomosim. The graphs are obtained by averaging the results of 9 simulations using 3 different topologies[6] and 3 different RNG (random number generator) seeds. A collision is counted each time a transmitted packet does not receive an acknowledgment. The confidence intervals are stated at the 95% level. The MAC PDUs size is set to 76 bytes and the physical rate to 2Mbits/sec. The experiment conditions are the same as in [9]: all nodes are in range, there is no noise, the saturation limit is reached and the load is balanced. Each run lasts 10 sec with the first 5 sec of transient behavior ignored.

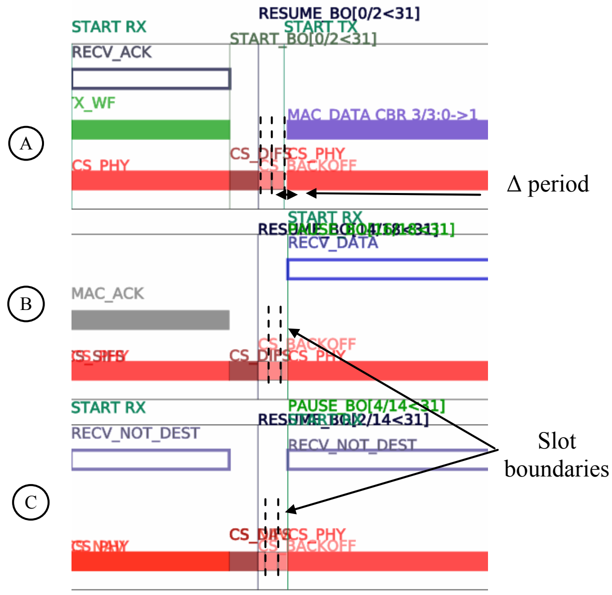

Figure 10.b. Backoff countdown (Glomosim)

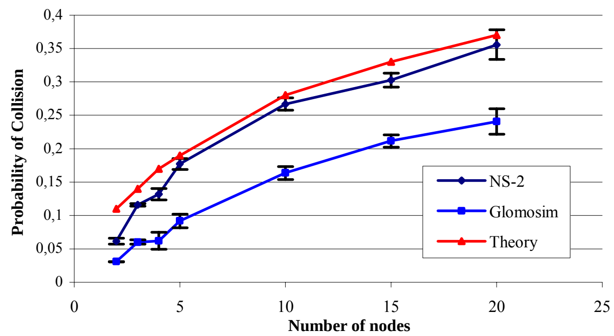

Figure 11. Comparison of the collision probability between NS-2, Glomosim and theory [9]

4. Capture Model

Glomosim and NS-2 don't use the same capture model. As fig. 11 shows, the two simulators only behave the same when the power ratio between the new and the old packet belongs to the interval [0.1-10][7].

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[3] belonging to a DATA/ACK or DATA sequence

[4] S_B is the backoff value in sec

[5] See the NS-2) subsection for the definition of t_{CB}, t_{AB} and t_{AC}

[6] A topology corresponds to the random placement of nodes in 1 meter square. Because of the stations' proximity in this area, the power ratio of the packets transmitted simultaneously is generally close to 1. As a matter of fact, the two simulators' capture model acts the same way and concludes to the loss of the two packets. This configuration also limits the use of the EIFS interframe.

[7] We assume that the capture threshold is set to 10

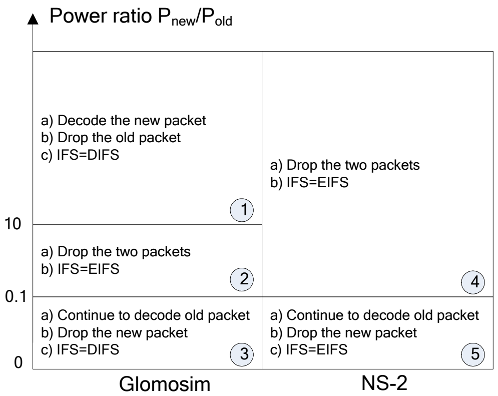

Figure 12. NS-2 and Glomosim capture behaviour in function of the received packets power ratio

Moreover in certain cases, Glomosim and NS-2 present important simplifications as explained below.

Glomosim) In cases 1 and 3, if the packet that finishes last is dropped, the MAC view of the channel directly returns to idle state at the end of the reception of the captured packet. Fig. 13.a and 13.b show two capture scenarios corresponding to cases 1 and 3.

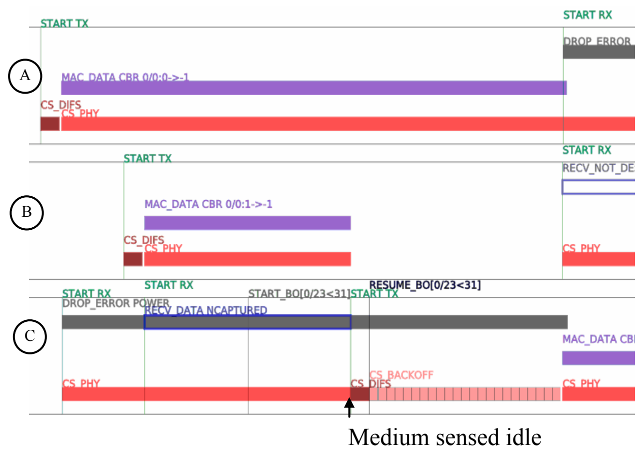

Figure 13.a. Capture (Glomosim) (case 1)

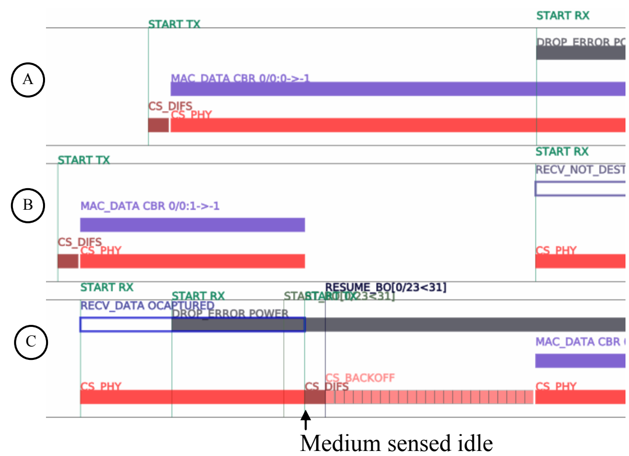

Figure 13.b. Capture (Glomosim) (case 3)

NS-2) In case 5, the EIFS interval could be misused if the new packet ends before the captured packet. Indeed, in this case, the EIFS is started at time t_0 (end of the new frame) instead of time t_1 (end of theoretical carrier sensing). Fig. 13.c shows how two packets broadcasted by stations A and B are handled by station C.

Figure 13.c. Capture model (NS-2)

C. *Modeling Errors*

The modeling errors are presented in table V and discussed in the following sections.

TABLE V. MODELING ERRORS

	NS-2	Glomo	802.11 standard clause
1) Backoff handling when the MAC queue is empty		×	9.2.5.2
2) IFS duration	×	×	9.2.10
3) EIFS synchronization procedure	×	×	9.2.3.4
4) Frame exchange perturbation		×	9.2.5.2
5) EIFS reset		×	9.2.5.1

1. Backoff Handling when the MAC Queue is Empty

Glomosim) Glomosim does not perform the backoff procedure at the end of a transmission if the MAC queue has no more packets to deliver. Fig. 14.a shows how Glomosim behaves when a transmission request comes in whereas the MAC queue is empty. Let us observe the end of the first transmission. It is not followed by a backoff interval and the next packet to come is transmitted directly after a DIFS interval (as indicated by the *CS_DIFS* event).

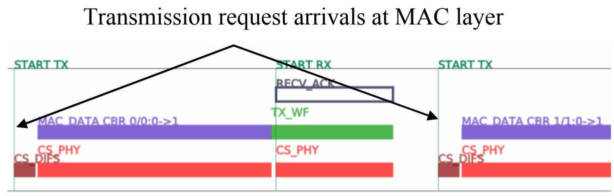

Figure 14.a. Backoff handling (Glomosim)

NS-2) Fig. 13.b repeats the same experiment under NS-2. As depicted, NS draws a new backoff value after the end of the first frame transmission.

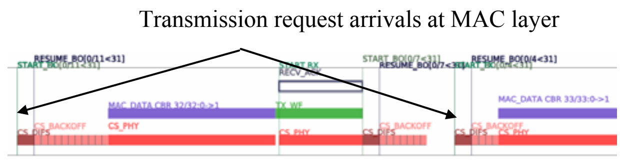

Figure 14.b. Backoff handling under (NS-2)

This dysfunction particularly impacts the estimation of the maximum throughput of a MANET network composed of one CBR sender (node A) and one receiver (node B). The physical rate is set to 2Mbits/sec. Each simulation is repeated three times. We measure A's throughput for different CBR period. The maximum capacity returned by NS-2 and Glomosim differs from 29% when the MAC PDUs size equals 126 bytes. The worst case scenario corresponds to the minimal MPDU size (76 bytes) that can be set in both simulators. In this case, the difference reaches 36% as shown in fig. 15. The discontinuity in the Glomosim performance curve is due to the difference of behavior depending whether the queue is empty or not.

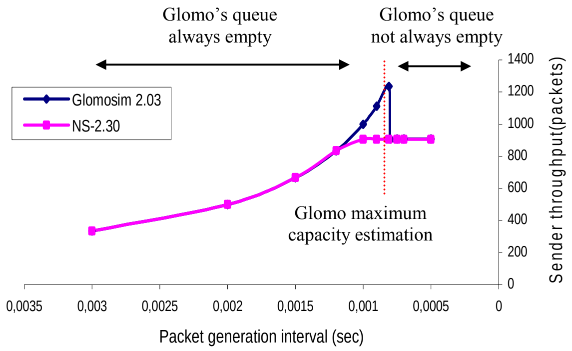

Figure 15. Comparison of maximum communication throughput (MAC PDU size=76 bytes)

2. IFS Duration

Glomosim) In the IEEE 802.11 standard, the EIFS and DIFS durations are set to 364 µs and 50 µs. However, under Glomosim, the EIFS interval is set to 412 µs (see fig. 16.a) and the DIFS to 45 µs (=50-Δ).

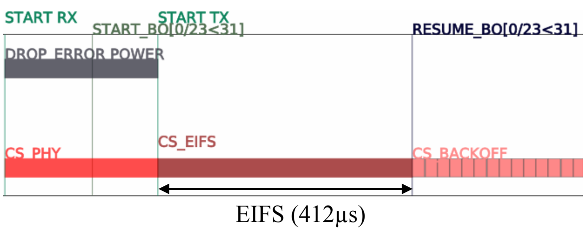

Figure 16.a. EIFS duration (Glomosim)

NS-2) Upon the reception of an erroneous frame, a station waits for a DIFS period in addition to the EIFS interval before counting down its backoff timer. It results that the EIFS duration is 50µs too long under NS-2. Fig. 16.b shows the decoding of an erroneous signal (as indicated by the *DROP_ERROR* label). As we can see, the station waits a DIFS in addition to the EIFS following the reception of the frame.

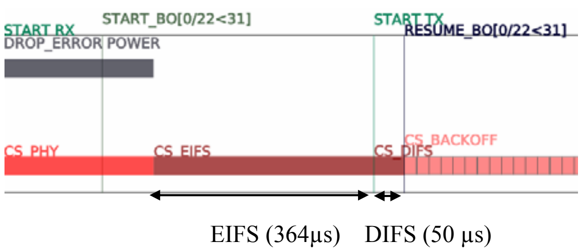

Figure 16.b. EIFS duration (NS-2)

3. EIFS Synchronization Procedure

NS-2) Under NS-2, a station which correctly decodes a frame during the EIFS interval, does not resynchronize. As fig. 17.a shows, station B only achieves to decode the acknowledgment of a DATA/ACK exchange. B performs the backoff procedure following this exchange. But as we observe, the beginning of this procedure is not synchronized with the end of the ACK frame. Indeed, NS-2 forces the station to wait the entire completion of the EIFS - started following the reception of the DATA packet - before it starts its backoff.

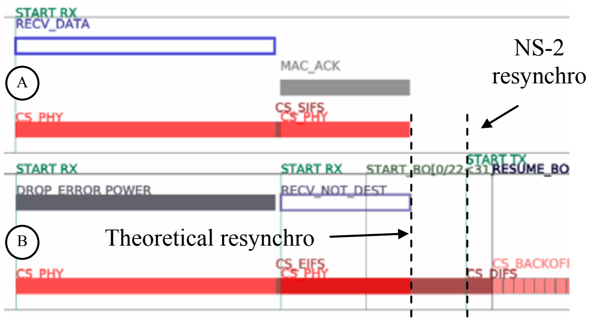

Figure 17.a. EIFS synchronization procedure (NS-2)

Glomosim) Fig. 17.b repeats the same experiment under Glomosim. As station B doesn't succeed in decoding the DATA frame of the DATA/ACK exchange, it sets its IFS timer to EIFS at the end of the DATA reception (as indicated by the *CS_EIFS* event). But as the ACK part of the frame exchange is correctly decoded, the IFS timer is reset to DIFS and the general backoff procedure restarts at the end of the ACK reception.

Figure 17.b. EIFS synchronization procedure (Glomosim)

4. Frame Exchange Perturbation

Glomosim) When a station receives a packet not addressed to itself during one of its own frame exchange, the collision process which follows may differ from the standard[8]. Two case examples underlining this behaviour are presented on fig. 18. In both cases, station A performs its retransmission without drawing a new backoff interval.

[8] This problem concerns both RTS/CTS/DATA/ACK and DATA/ACK exchanges. For it to occur at 2 Mbps, the length of the packets generated by the source stations must not differ for more than 3 bytes. If not, Glomosim behaves correctly.

In case 1, stations A and B transmit simultaneously a data frame to C. As station C is closer from B than from A, B's packet is captured and A's one is lost, C only acknowledges B and A only hears B' ACK.

In case 2, B transmits towards B' and A towards A'. As A' and A are not in range, A only hears the ACK frame sent to B.

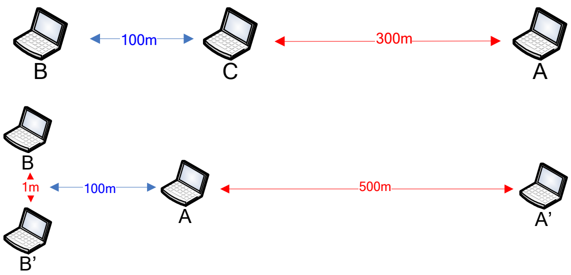

Figure 18. Scenarios used to test simultaneous transmissions

Fig. 19.a illustrates case 1 with a DATA/ACK sequence. As we can see, upon the reception of the ACK frame addressed to B, A immediately retransmits its frame without performing the backoff procedure.

Figure 19.a. Frame exchange perturbation (Glomosim)

NS-2) Contrary to Glomosim, under NS-2, station A correctly restarts the backoff procedure as shown in fig. 19.b.

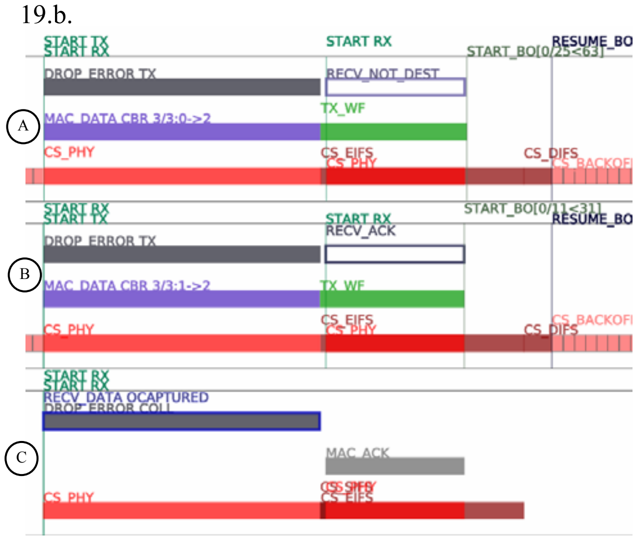

Figure 19.b. Frame exchange perturbation (NS-2)

5. IFS Reset

Glomosim) According to the standard, the EIFS interval is used when the immediately preceding medium-busy event was caused by detection of a frame that was not received correctly. However, under Glomosim, when a STA receives a corrupted frame, it continues to use the EIFS interval instead of the DIFS'one until a correct frame is received. This phenomenon is depicted in fig. 20.a. The *CS_EIFS* event materializes the EIFS interval. The first EIFS complies with the standard because it follows the reception of an ACK frame that didn't lead to correct reception. But that's not true for the second EIFS which is just a resurgence of the first one.

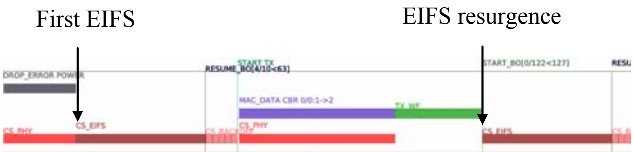

Figure 20.a. EIFS reset (Glomosim)

NS-2) Fig. 20.b displays the same experiment on NS-2. As we can see, the station correctly uses the DIFS interval at the end of the ACK waiting period (*TX_WF*).

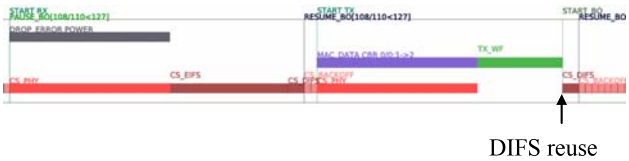

Figure 20.b. EIFS reset (NS-2)

IV. Related Works

Although simulators comparison has been recognized as a powerful protocol validation technique [11], its application is difficult because the simulators behaviour (except NS-2's [4]) is not well known. As a consequence, new questions are regularly rising [12].

Most of comparisons concern the measure of the impact of the simulators characteristics on global performance. Takai et al. [13] compared Glomosim with NS-2 to validate Glomosim. They identified two factors at the physical layer relevant to the performance evaluation of higher layer protocols: the physical preamble transmission rate and the noise computation. While the first factor has been corrected in NS-2.25, we have specially used the SNR bounded packet reception model to neutralize the interference computation feature. Cavin et al. [14] compared the simulation results of NS-2, Glomosim and OPNET. Although they underline significant divergences between the results, no investigation has been done to explain them. The MAC and PHY layer were however suspected to behave differently due to the specific level of details considered at the radio layer and the probable existence of non compliances with the DCF protocol. Reedy et al. [15] compared the outputs of NS-2, Glomosim and GTNetS. Several differences were established between Glomosim and NS-2: the absence of ARP protocol, LLC/SNAP header and pre-backoff in Glomosim and the difference between the transmission rate of the control frames in the two simulators. While the pre-backoff procedure has been described in this paper, we consider the other aspects more as general recommendations to follow when configuring the simulators[9], rather than hard coded characteristics of the MAC and PHY layers.

The major drawback of these works is to rely on very large topology for the effects of the simulators characteristics to manifest on the results. Our comparison method being more accurate, we only need to test a limited number of predefined scenarios with at most five nodes for all the characteristics to appear.

V. CONCLUSION

This paper has proposed a generic framework called YAVISTA and a new method to visually compare 802.11 simulators. As summarized in fig. 21, YAVISTA has allowed to find out and to illustrate eleven different behaviours between the MAC and PHY layers of NS-2 and Glomosim.

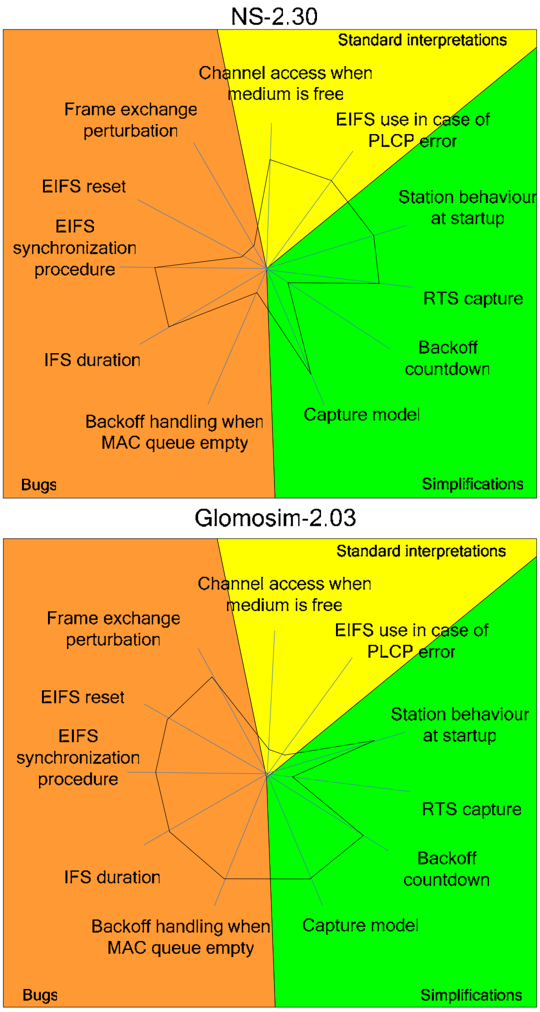

Figure 21. NS-2 and Glomosim characteristics (characteristics are marked with peripheral points)

[9] Note that the basic rate set used to transmit the control frames is not specified in the standard and may also include 5.5 and 11 Mbps

Our observations show in particular how a priori benign simplifications such as 'backoff countdown' can impact the results.

In future works, we plan to identify the worst case scenarios corresponding to each characteristic and to measure their impact on higher layers. An extended framework allowing data analysis and validation of a wider choice of simulators will also be proposed.

REFERENCES

[1] L. Bajaj, M. Takai, R. Ahuja, K. Tang, R. Bagrodia, M. Gerla, "GloMoSim: A Scalable Network Simulation Environment", Computer Science Department, University of California, Los Angeles, Tech. Rep. 990027, 1999 Glomosim 2.03, Available: http://pcl.cs.ucla.edu/projects/glomosim/
[2] NS-2.30, Available: http://www.isi.edu/nsnam
[3] ANSI/IEEE Std, 802.11 1999 Edition (R2003), *IEEE Standard for Information Technology — Telecommunications and Information Exchange between Systems — Local and Metropolitan Area Network — Specific Requirements — Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications*, 2003
[4] R. Ben-El-Kezadri, F. Kamoun, "Graphic Visualization of the 802.11 DCF Protocol Under the NS-2 Simulator", in *Proc. of the 40th Annual Simulation Symposium, (ANSS'07)*, Norfolk, VA, USA, March 2007
[5] YAVISTA, Available: http://yavista.sourceforge.net/
[6] *Extensible Markup Language (XML) 1.0 (Third Edition)*, W3C Recommendation, February 2004
[7] *Scalable Vector Graphics (SVG) 1.1 Specification*, W3C Recommendation, January 2003
[8] Inkscape, Available: http://www.inkscape.org/
[9] Y. C. Tay, K. C. Chua, "A Capacity Analysis for the IEEE 802.11 MAC Protocol", *Wireless Networks*, 7 (2), pp. 159 – 171, Kluwer Academic Publishers Hingham, MA, USA, March/April 2001
[10] A. Kochut, A. Vasan, A.U. Shankar, A. Agrawala, "Sniffing out the Correct Physical Layer Capture Model in 802.11", in *Proc. of the 12th IEEE International Conference on Network Protocols (ICNP'04)*, pp. 252 – 261, Berlin, Germany, October 2004
[11] R. Bagrodia, M. Takai, "Position Paper on Validation of Network Simulation Models", in *Proc of the DARPA/NIST Network Simulation Validation Workshop*, May 1999
[12] T.R. Andel, A. Yasinsac, "On the Credibility of Manet Simulations", *Computer*, 39(7), pp. 48- 54, July 2006
[13] M. Takai, J. Martin, R. Bagrodia, "Effects of Wireless Physical Layer Modeling in Mobile Ad Hoc Networks", in *Proc. of the 2nd ACM International Symposium on Mobile Ad Hoc Networking & Computing (MobiHoc '01)*, pp 87–94, New York, NY, USA, October 2001
[14] D. Cavin, Y. Sasson, A. Schiper, "On the Accuracy of MANET Simulators", in *Proc. of the 2nd ACM International Workshop on Principles of Mobile Computing (POMC'02)*, pp. 38 – 43, Toulouse, France, October 2002
[15] D. Reddy, G. F. Riley, B. Larish, Y. Chen, "Measuring and Explaining Differences in Wireless Simulation Models", in *Proc. of the 14th IEEE International Symposium on Modeling, Analysis, and Simulation (MASCOTS'06)*, pp. 275 – 282, Monterey, CA, USA, September 2006

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