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Quality of Service evaluation by using Ad hoc on Demand Distant Vector (AODV) in the classroom ad hoc network of the New Generation of Digital Open Universities (DOUNG)

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Abstract

The DOUNG is a recently defined model in [1] with hybrid architecture that was improved in order to extend its covering area. In another side, the technology evolution through the advent of a wide range of electronic devices such as computers, laptops and telephone cells contributes to the DOUNG services development with a new classroom network as illustrate in [2]. In addition to the previous, the document [3] defines the Quality of Service (QoS) parameters and some of them has been evaluated in [2] by using a protocol stack composed of SCTP (Stream Control Transport Protocol) at the transport layer and DSR (Dynamic Source Routing) [4] at the network layer. In order to get a good QoS in the ad hoc zone of the classroom, we are varying the routing protocols. For that purpose in this paper, we use AODV (Ad hoc On-Demand Distance Vector protocol) based on the distant vector algorithm at the difference of DSR even being all in the category of reactive routing protocol. Thus, new simulations are run with the goal to measure the new expected QoS level.

Keywords: Distance education, DOUNG, classroom ad hoc network, QoS, AODV

1. Introduction

When considering the nowadays learners mostly equipped with electronics devices such as computers, laptops and telephone cells, the document [2] improves the DOUNG classroom network through a wireless extension. The new architecture uses a Wi-Fi antenna being a gateway that leads to the ad hoc zone. In addition, a recent work [5] demonstrates the benefit of using these wireless networks by making a comparing analyze between the ad hoc network and the wireless network with infrastructure. In the DOUNG extension, a remaining challenge is to choose an adapted routing protocol since many are available. The choice belongs to the main constraint of ensuring the real time traffic delivery required by learners for following the course alive and imposes to maintain good level of the QoS parameters.

This paper discusses first about the classroom wireless network before presenting the QoS level indicator parameters. For this purpose, the synchronization delay between teacher and learner problematic is defined with also the impact of the amount of data available in the DOUNG and learner buffers. The using of the SCTP/AODV stack allows to highlight their contribution with the balance of degradation factors. After, new scenarios are described and simulation results are provided in curves format before their interpretation.

II. The classroom wireless network

The DOUNG model integrates the innovative m-learning [6][7][8] and cloud computing system with a mixed architecture. In this case, the classroom network is beginning with a wired Ethernet making a server available for learner access. The first extension is designed with a Wi-Fi antenna that federates nearest learner’s mobiles devices in spite of their diversity. The antenna stands as a direct gateway to access to the server. For far learners, the ad hoc network is needed before reaching the antenna and the communication is set through the system operating with standards protocols and web services.

The new architecture of the DOUNG classroom network is divided in two zones. The first called LAN1 covers the Wi-Fi antenna range, the second called LAN2 consists of the ad hoc network that federates learner devices. The LAN2 is set to extend the signal and to avoid the DOUNG to use many no less coasts Wi-Fi antennas. It then becomes possible to extend the course delivery range without additional means but with a main barrier that belongs to the limit imposed by the favorable values of the real time traffic QoS parameters. The extension remains benefit while the QoS parameter are having a "good" value and will not switch and degrade to "bad" level. The LAN2 extension sets the problematic of choosing an adapted routing protocol according to many criterions. In this case, the idea is to measure the QoS gains provided by another reactive routing protocol, the AODV that is based on the distant vector algorithm at the difference of DSR used in [2]. The figure below provides a fair illustration of the architecture given by the classroom wireless network.

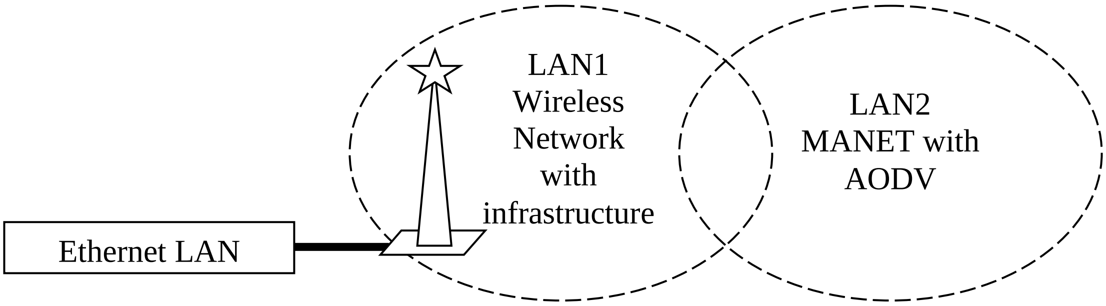

Figure 1: LAN1 and LAN2 positions in the classroom

III. QoS level indicator parameters

The document [3] defines many QoS parameters deriving from the communicating vessels model (CVM) when the course is provided alive. The identified parameters are summarized in the IIMSG (Intelligent Interface of Monitoring the Service Guarantee) used as a dashboard. The QoS problematic is enforced by the routing protocol to be used in the ad hoc zone. In this way, AODV is here put under test in order to evaluate its contribution by simulation. It is a reactive routing protocol based on the distant vector algorithm and uses HELLO_INTERVAL to limit its periodic activities. A favorable factor for routing protocols derives from the classroom ad hoc network that is relatively stable because learners are mostly concentrated to follow the course alive instead of changing their places. Their mobility derives widely from the entrance or the exit of the classroom with also the switching of the devices from “on” to “off” or vice versa. The stability of the ad hoc network is by intuition favorable to the AODV for limiting its periodic activities, allowing thus a fair use of the bandwidth. The final goal is to increase the size of the network (learner attendance). The QoS parameters discussed in [3] used to evaluate the AODV contribution are defined by (1) the synchronization delay between the teacher and the learners without interruption and (2) the amount of data available in the buffers.

III.1. The synchronization delay between teacher and learner

The IIMSG parameters that we firstly consider refer to the synchronization parameters define as follow:

We consider the instant ST_s at which the camera multimedia stream V_s is introduced in the buffer SB (Server Buffer) of the DOUNG.

In the first opposite side, we consider the instant ST_{v1} at which the stream V_s reaches a LAN1 learner.

In the second opposite side, we consider the instant ST_{v2} at which the stream V_s reaches a LAN2 learner.

Then the synchronization delay is defined as the shift of the time from the instant ST_s to the instants ST_{v1} for LAN1 learners and ST_{v2} for the LAN2 learners. The average value of these parameters is considered in our simulation. And in normal case, the intuitive approach assumes that the LAN1 learners will receive the stream V_s before the LAN2 ones. Under that consideration, the double inequality below is stated when following the course alive:

$$ST_s < ST_{v1} < ST_{v2} \qquad (1)$$

The previous parameters give a restrictive delay. In fact, it is necessary to take into account the using of the anticipation windows by the learner's application when using a synchronous course access mode. To integrate this condition, we calculate two additional parameters DG_1 and DG_2 define as follow by using T_δ:

T_δ is the extension of the learner synchronization delay during the transfer of δ bits required by the application before playing the course video.

DG_1 is the global delay used by a LAN1 learner to get the multimedia stream V_s from SB. It is calculated with the equation (2) below:

$$DG_1 = ST_{v1} + T_\delta \qquad (2)$$

DG_2 is the global delay used by a LAN2 learner to get the multimedia stream V_s from SB. It is calculated with the equation (3) below:

$$DG_2 = ST_{v2} + T_\delta \qquad (3)$$

It is important for the DOUNG to establish a threshold giving the limit of the QoS that allow to follow the course in real time. As the far learners impact mostly the average calculated QoS, it is better to consider the global delay of LAN2 learners. If the DG_2.value shows a "good" level of the QoS, it is supposed to be also "good" for DG_1 used for the LAN1 learners. Let assume S_{DOUNG} as the DOUNG QoS threshold that allows to follow a course alive. The intuitive approach considers that the video interruption will not occur only if the stream time to live (TTL_{max}) in the buffer SB does not exhaust. Consequently, we get the inequality (4) below:

$$S_{DOUNG} < TTL_{max} \qquad (4)$$

Then, the QoS level can be discussed as follow.

if $DG_2 < S_{DOUNG}$ the QoS level is "bad" (5)

if $DG_2 >= S_{DOUNG}$ the QoS level is "good" (6)

III.2. The amount of data available in the buffers

The amount of data available in both the server and the learner buffers is an important QoS parameter. The CVM model shows the moving of data from SB to the Client Buffer (CB) at the learner side when the application uses the anticipation windows. Also, the time to live (TTL) of data in SB is limited. An interruption occurs if a stream TTL exhausts without reaching the learners according to the network conditions. It is the case of the time to recover a stream greater than the remaining time to play it by the application. Many conditions that trigger an interruption depend on the amount of data available in SB and CB. We then assume Q_s, Q_{r1} and Q_{r2} being the indicator parameters that are defined with T_V and TTL_{max} as follow:

T_V is the camera bit rate, CT stands for Current Time

TTL_{max} is the maximal duration of a multimedia stream in SB

Q_s is the amount of data available in the buffer SB at the given instant CT. Its value is calculated following this equation:

$$Q_s = T_V * TTL_{max} \qquad (6)$$

Q_{r1} is the amount of data available in CB at the instant CT for the LAN1 learner.

Q_{r2} is the amount of data available in CB at the instant CT for the LAN2 learner.

IV. SCTP protocol of the transport layer

IV.1. Contribution to the positive evolution of the QoS

SCTP protocol offers a total reliability and a partial order through the using of stream and association. If the stream is a sequence of messages that are to be transmitted in order, at the difference, the association regroups many streams with no delivery order. In an association, streams are independent and each stream endpoint is identified by a list of transport addresses that associate the IP (Internet Protocol) address and the port number: SCTP ensures the reliable data transfer through the management of a sending and an acknowledgement timers. It avoids message duplication and adapts the segment size to the path by the fragmentation and reassembly function. The individual message delivery option is available according to their arrival sequence. SCTP operates by grouping many streams that remain independents to avoid that the failure of one impacts the others. It starts an association before transferring data and closes it at the end. During the data transfer, the data send error and the path failure are managed. SCTP uses the congestion avoidance to avoid overflowing the network with in addition the functions of flooding and attack overcoming. Through its multi–domiciliation mechanism, it performs network layer error management.

By ensuring all these reliability functions, SCTP optimizes the learner application, avoiding it to duplicate them. With the stream delivery guarantee, the protocol contributes to maintain a positive level of the QoS. The application is just lead to calculate the time it requires to get the good level of data before starting playing the video and must maintain the required level during the course session without interruption. With the time and the buffer size management, the learner application will make a fair use of the SCTP functions.

IV.2. QoS degradation factors

In the case of the LAN2 learner following the DOUNG course alive, the network is submitted to the constraint of conveying multimedia traffic in real time. So when a data lost occurs, the SCTP develops its reliable function by using retransmissions that can be unsuccessful until the maximal number of attempts is reached. During this time, the learner application continues to play the video available in the buffer CB. The two events will tend to empty the CB. A rank can be reached that triggers the video interruption and its repetition compromises the QoS. So instead of waiting to overcome a lost that occurs at the instant CT, it is better to avoid performing retransmissions without the control of the level of CB. And at a critical threshold, the system must continue with new available streams instead of being late when they are needed by the application. With a low rate, this kind of lost will not compromise the understanding of the message of the teacher.

V. AODV protocol of the network layer

V.1. Contribution to the positive evolution of the QoS

AODV [10] contributes with many functions to a good level of the QoS in the LAN2. It performs the route discovery when the system is having a packet in the sending buffer without the path that reaches the destination. For that purpose, it uses the broadcasting principle toward neighbors with the well-known Bellman-Ford best path selection. In addition to that reactive behavior, AODV builds a local routing table that avoids performing an early route discovery process for the same destination. For building the final routing tables, an AODV node starts with initial table containing immediate neighbors. The using of the distant vector algorithm brings to tables exchange between adjacent neighbors. An active given node is supposed to broadcast its routing table within Hello messages at the frequency of HELLO_INTERVAL (time in milliseconds). The neighbor that receives a Hello message updates if necessary its routing table to reach the message originator.

The AODV route discovery uses two types of messages. The initiator node broadcasts firstly a route request (RREQ) controlled by a frequency of retransmissions and receives the route response (RREP- Route REPly) if the process is successful. For a fair use of the available bandwidth, the node limits its number of unsuccessful retransmissions attempts. Also, it controls the interval between two route discovery attempts for the same destination following a binary exponential back-off for the network congestion reduction. A receiving node N processes a RREQ by creating or updating a route to the previous hop. If N is the destination or is having an active route to the target, it can generate a RREP message.

Through the route discovery and the local connectivity maintenance, AODV performs many mechanisms that allow to ensure a good QoS. The limitation of the overhead in the wireless network and the reduction of the network resource utilization are some factors projected to have a positive effect over the DOUNG real time traffic delivery. In addition, with the stability of the classroom ad hoc network, the period of broadcasting the AODV Hello messages can be extended. An expected positive effect belongs also to the reduction of the overhead that brings to a fair use of the bandwidth for conveying the multimedia stream.

V.2. QoS degradation factors

A the difference of the previous, AODV activities can in some cases impact negatively the need to convey the multimedia stream in real time. The DOUNG QoS can be compromised for example with the flooding in spite of many actions taken to limit its negative influence on the QoS. Same as SCTP, unsuccessful retransmissions attempts between two route discoveries have the consequence of introducing an important delay when conveying a multimedia stream alive. During retransmissions time, the learner’s application tends to empty the buffer CB until the rank of the video interruption that compromises the QoS. Then, retransmissions must be controlled again to avoid the system to reach the critical threshold. With a continuous mode of the system and low lost rate, the QoS is better than the interruption and will not compromise the understanding of the teacher’s message.

VI. QoS Parameters evaluation by simulation

In this new case, we are evaluating by simulations the influence of AODV over QoS parameters ST_{vi}, Q_s, and Q_{ri} (i=1,2) when the ad hoc network is submitted to an increasing attendance of learner. In the global scenario, we use a protocol stack composed of SCTP at the transport layer, IP at the network layer and 802.11 protocols for lower layers. We use the ns–2 environment and set a traffic source representing the Wi-Fi antenna that initiates a Constant Bit Rate (CBR) toward the learners of LAN1 and LAN2. For the CBR model, the inter-arrival time of messages during peak is set to 0.1 second and SCTP is configured to generate 1500 bytes for segments size.

VI.1. Description of scenarios

The same goal of the simulation as in [2] is remaining. We are evaluating the influence of AODV over the synchronization delay between the teacher and the learner and over the size of the buffers SB and CB with an increasing attendance of learners. The size of the SB and CB buffers at the instant CT avoids an interruption to occur during the course delivery alive that can compromise the QoS. Indeed, we evaluate the values of DG_1 for the synchronization of LAN1 learners and DG_2 for the LAN2. The list of QoS parameters evaluated is extended with Q_s, Q_{r1} and Q_{r2} showing the amount of data available at the given time CT in the buffers of the DOUNG, the

LAN1 and the LAN2 learner respectively. We calculate average results from traces file before drawing curves in a two-dimensional mark. The curve helps to determine the contribution of AODV and the capacity of the extended architecture to support the real time traffic of course delivery.

VI.2. Results interpretation Basis

The curves are drawn in the two-dimensional mark. The increasing of the LAN1 and LAN2 learner attendance is set at the horizontal axis within the following values: 10, 15, 20, 25, 30, 35, 40, 45, 50. The dimension of the simulation area is set to 1500 x 300. We divided it into two zones. The LAN1 begins from the left border and has 1/3 of the global area size. LAN2 takes the remaining 2/3 of the area. The position of the CBR source being the Wi-Fi antenna is set to the middle of the left border. By considering the nature of the DOUNG ad hoc network classroom, we set a low node speed in the interval of [1m/s, 10m/s].

The simulations duration is set to 150 seconds. The RWP (Random Way Point) model is used to allow a node to alternate mobility and break time during 25 ms. From the traces file, the average synchronization delay of the LAN1 and LAN2 learners is calculated such as the average amount of data available in their buffers within TTL_{max} set to 10 ms.

VI.3. Curve of the attendance/synchronization delay ratio

The SCTP/AODV stack has an interest which contrasts with that of the previously studied stack using the DSR. Despite their common reactive nature, unlike DSR, the AODV protocol uses the distant vector algorithm and proceeds to regular transmissions of Hello messages according to the frequency determined by HELLO_INTERVAL. Therefore, even with a limitation of this activity, this new protocol adds a significant overhead which tends to decrease the bandwidth available for the binding synchronous course access mode. Thus, taking these factors into account, it is possible to explain the results displayed through the two curves in the figure below. The first measured parameter is DG_1 which translates the evolution of the synchronization of a LAN1 learner during the course. The second parameter is DG_2 used in the case of the LAN2 learner. Same as SCTP/DSR, the observed behavior conforms the intuitive expectations and the mathematical model with an immediate synchronization of the LAN1 learner and a significant delay for the LAN2 learner.

It is possible to explain the obtained results through the behavior of AODV taken in isolation, without even carrying out a comparative study of the two protocol stacks which is left to subsequent work. AODV used in LAN2 because of the limited range of the antenna has a considerable effect on the studied synchronization delay. The calculation of the average value of DG_2 reflects the fluctuations linked both to the routes discovery and to the residual activities of AODV. These are the main components of the routing functionality of this protocol with route maintenance. The two previous functions are in addition to the factors observed in the case of the DSR protocol and cause an extension of the synchronization delay for remote nodes. These factors include the propagation time and the effect of the routing step by step. Thus, the accumulation of the deadlines of these activities can only be increased according to the size of the network to the point of becoming prejudicial to the synchronization of some LAN2 learners in the classroom.

As indicated in the figure below, the evolution of the LAN2 curve presents values which oscillate around 0.6 with a ceiling of 1.2 reached for an attendance of 25. Unlike, the LAN1 curve is always contiguous to the abscissa axis due to an immediate transmission with a zero DG_1 delay. The first observation that emerges for the LAN2 curve is the lack of change as a function of the attendance since the synchronization delay can increase or decrease without the influence of the evolution of the values of the abscissa axis. Up to the limit studied in this paper, the AODV protocol is not influenced by the attendance of learners, which is likely to reflect its ability to allow the size of the ad hoc network of the classroom to be increased. The peaks observed in the figure can be explained by the restarting of the residual activities consuming time and resources of the network while their absence leads to a release of these resources that becomes favorable to the synchronization delay. During these moments, the values of this ratio bring it closer to the abscissa axis when the periodic activity is canceled. These results deserve to be compared with those of other protocols to determine the adaptation of the AODV to the context of the DOUNG wireless LAN of the classroom.

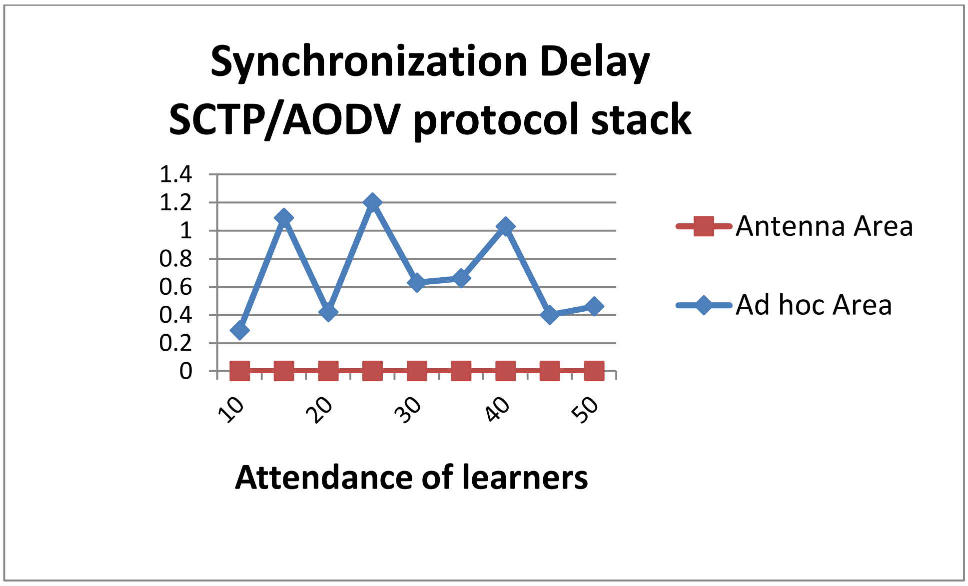

Figure 2: Influence of the attendance over the synchronization delay of SCTP/AODV

VI.4. Curve of the attendance/learner buffers size ratio

The average value of the ratio reflecting the influence of the learner attendance on the size of the buffers in the SCPT/AODV stack is calculated from the simulation trace files and the three curves in the figure below indicate the obtained results. As for SCTP/DSR, the expected intuitive values and the mathematical models are confirmed for the parameters Q_{r2}, Q_{r1} and Q_s. For reminder, this last parameter indicates the amount of data available at a time CT in the buffer of the DOUNG server, Q_{r1} reflects that of a LAN1 learner and Q_{r2} for the LAN2 learner, with a TTL_{max} set to 10 ms. These results show the almost joint evolution of the curves of the Q_s and Q_{r1} parameters. They confirm the intuitive and the mathematical model which ensures their proximity while the sizes of the LAN2 buffer are much smaller as indicated by the third curve. For example, for the attendance 45 to 50, the contents of the SB and of the antenna zone CB are identical and peak around 12000 while the ad hoc zone buffers remain on the floor around 4000. Unlike, the frequentation value of 35 leads to a decrease in the average size of the buffers of LAN1. Equally, the attendance values prior to 35 allow the two curves of Q_s and Q_{r1} to dissociate while the curve of Q_{r2} for the ad hoc network fluctuates around 2000 without much dependence on the influx of learners.

These results can be explained as before by the nature of the wireless networks. If LAN1 has direct visibility of the antenna and benefits from immediate transmission, LAN2 adds a delay linked to the previous parameters mentioned in the case of the synchronization between the teacher and learners. As a reminder, this network is under the influence of the propagation step by step in addition to the routing functionality including the route discovery of the AODV protocol and its residual activities. All these factors are time consuming and, as with the offset observed in synchronization, many packets can be in transit at a given time CT. These packets are counted for the two buffers close to each other, namely, SB and LAN1 CB, while they have not yet reached most of the nodes of LAN2. By comparing the difference between the Q_s and Q_{r1} curves with that of Q_{r2}, the importance of the difference reflects the behavior of AODV in comparison with the DSR, in particular, the emissions of regular messages consuming bandwidth and time. To this must be added the delay of the route discovery and the weight of the propagation in the network. AODV thus takes a considerable time before transferring data and depending on the modifications or events which occur in the network and which have an impact on the routing structures, additional delays can be added as the example of those related to retransmissions.

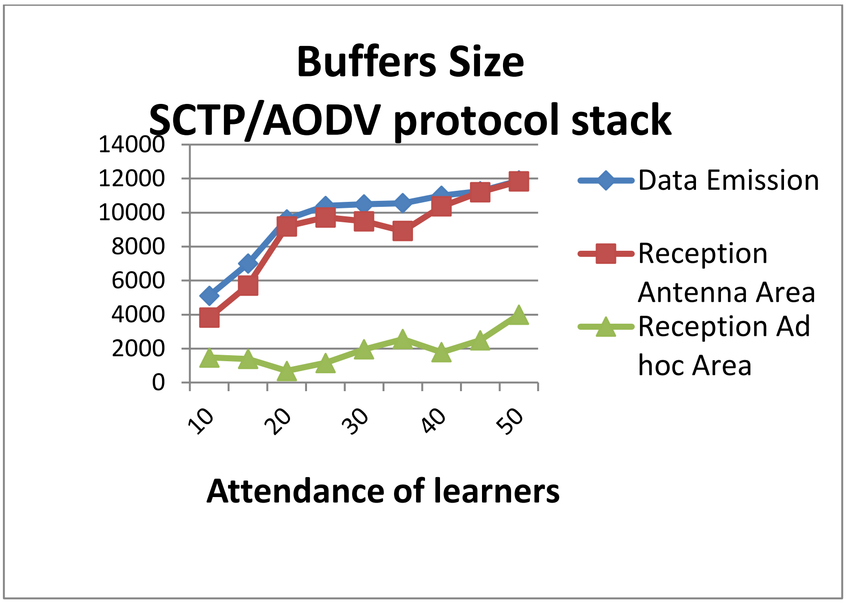

Figure 2: Influence of the attendance over the buffers size of SCPT/AODV

Conclusion

The distance education service offered by the DOUNG requires a good level of QoS for its success both in the proposed initial architecture and in that extended consisting of wireless networks. The nature of these networks limitations requires more optimization and control for the success of their exploitation to benefit learners. By taking advantage of the expansion of new equipments with Wi-Fi and an ad hoc network capacities, in the widely open classroom, the success of the synchronous access of course can only be obtained with the avoidance of interruptions likely to prohibit the good understanding of the teacher message.

In this paper and following previous work that has assessed the QoS gains obtained with the SCTP/DSR protocol stack, AODV is used at the network layer and contributes to resolve one of the basic ad hoc network problems related to the routing of information. We then evaluate the synchronization delay between the teacher and the learners and the size of the buffers when the network is subjected to an increasing number of learners. The results obtained by simulation confirm the mathematical models and the intuitive approach. They highlight the influence of the AODV protocol in the studied context. New curves are drawn with values different from those of the DSR. Their interpretation highlights the nature of the difference which exists between the two protocols. The present work contributes to the consolidation of the basic work subsequently serving to the cross-analyze of the results obtained from different protocols, which is set in perspective complementary to this paper.

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