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IA-TCP: Improving Acknowledgement Mechanism of TCP for better performance in MANET

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ABSTRACT

A Mobile Ad hoc Network (MANET) is a collection of terminals equipped with one or several wireless network interfaces. In this paper, we suggest an improvement of the Transmission Control Protocol (TCP), called Improvement of the Acknowledgement mechanism of TCP (IA-TCP), to better performance in MANET. IA-TCP delays the acknowledgements packets of TCP according to the number of nodes, their mobility and the communication distance between these nodes. We limited our studies on very important parameters in such networks which are throughput and end-to-end delay because they have great effects on the TCP performance in MANET. The results are satisfactory and showed that IA-TCP can outperform not only TCP standard, but also similar techniques that have been proposed in the literature like LDA and WCCP.

KEYWORDS

MANET, performance improvement, TCP, Acknowledgement mechanism, IA-TCP, throughput, end-to-end delay.

1 INTRODUCTION

Transmission Control Protocol (TCP) [1] still the transport protocol the most used in Mobile Ad Hoc Networks (MANET) [2]. When the parameters of the communication environment are not taken into account, this may degrades MANET performance notably TCP performance parameters (throughput and the end-to-end delay) [3], [4], [5].

In [6], we have shown that the TCP parameters performance (notably throughput) degrades while the nodes number increase in a MANET. In [7], we have proposed solutions to the problem posed in [6], but we have just limited to a chain topology and also to the influence of the nodes number on the TCP performance. In [8], another parameter which is the mobility of nodes is taken into account in addition to the number nodes. Based on the nodes number and the mobility of nodes, we proposed in [8] an improvement to TCP performance in MANET by exploiting the backoff algorithm of Medium Access Control (MAC) protocol. This improvement is IB-MAC (Improvement of Backoff algorithm of MAC protocol) which proposes a new backoff algorithm based on a dynamic adaptation of its maximal limit according to the number of nodes and their mobility.

The works presented in this paper is the following of those done in [8] where we exploited the MAC layer to improve the TCP performance. This improvement is an adaptation of the MAC backoff algorithm according the nodes number and their mobility. Here, we intervene directly on TCP and propose an Improvement of its Acknowledgement mechanism (IA-TCP) for better performance in MANET. IA-TCP is an adaptation of the acknowledgement mechanism of TCP by delaying the transmission of acknowledgment packets according, not only to the nodes number and their mobility, but also to the communication distance between the nodes.

In what follows, after a short presentation of TCP, we present the IA-TCP improvement and study its incidences on TCP performance parameters. we finish with section five which consists on conclusion and perspectives.

2 TCP PROTOCOL IN MANET AND RELATED WORK

In MANET, data transmission failures due to the environment (like mobility, collisions, etc) lead often to the congestion control activation by TCP protocol then the number of packets is reduced. This impossibility to distinguish between sources of losses packets has as consequence the degradation of the TCP performance parameters [9], [10].

In our previous work [6] [7] [8], we confirmed these results by studying the effect of the nodes number and their mobility on TCP performance. Many solutions are proposed in the literature in order to reduce this degradation of TCP performance. In [8], we exposed some important works which try to improve the TCP performance. However, we give some of these works which we find useful to introduce our own IA-TCP improvement.

Yuki and al. [11] have proposed a technique that combines data and ACK packets, and have shown through simulation that this technique can make radio channel utilization more efficient. Altman and Jimenez [12], proposed an improvement for TCP performance by delaying 3-4 ACK packets. Kherani and Shorey [13], suggest significant improvement in TCP performance as the delayed acknowled-gement parameter *d* increases to the TCP window size *W*. Allman [14], conducted an extensive evaluation on Delayed Acknowledgment (DA) strategies, and they presented a variety of mechanisms to improve TCP performance in presence of side-effect of delayed ACKs. Chandran [15] proposed TCP-feedback, with this solution, when an intermediate node detects the disruption of a route; it explicitly sends a Route Failure Notification (RFN) to the TCP sender. Holland and Vaidya [16] proposed a similar approach based on ELFN (Explicit Link Failure Notification), when the TCP sender is informed of a link failure, it freezes its state. Liu et al. [17] proposed an end-to-end technique for distinguishing between packet losses due to congestion from packet loss by a wireless medium. They designed a Hidden Markov Model (HMM) algorithm to perform the mentioned discrimination taking RTT measurements over the end-to-end channel. Oliveira and Braun [18] propose a dynamic adaptive strategy for minimizing the number of ACK packets in transit and mitigating spurious retransmissions. Zhai et *al*. [19] propose a systematic solution named Wireless Congestion Control Protocol (WCCP) which uses channel busyness ratio to allocate the shared resource and accordingly adjusts the sender's rate so that the channel capacity can be fully utilized and fairness is improved. Lohier et *al*. [20] proposes to adapt one of the MAC parameters, the *Retry Limit* (*RL*), to reduce the drop in performance due to the inappropriate triggering of TCP congestion control mechanisms. Starting from this, a MAC-layer LDA (Loss Differentiation Algorithm) is proposed.

The approaches just presented suggest improvements to TCP performance but none of them takes into account the parameters of the communication environment. Our work exploits this lacks by improving TCP performance with taking into account some important communication environment parameters which is the nodes number, their mobility and the distance between them.

3 IA-TCP (IMPROVEMENT OF THE ACKNOWLEDGEMENT MECHANISM OF TCP PROTOCOL)

The reliability provided by TCP is to ensure that each packet issued by the TCP sender will be forwarded to the addressee node through a system of acknowledgements.

The TCP Acknowledgements can return collided with their corresponding data packets especially when the number of nodes considered in the network becomes important. This large number of TCP ACK packets comes into contention with TCP packets, and cause the intra-flow contention. This problem has been well addressed by Oliveira and Braun in [17], then hey proposed a dynamic adaptive strategy for minimizing the number of ACK packets in transit and mitigating spurious retransmissions.

Our IA-TCP solution is an adaptive delayed of the TCP acknowledgment mechanism but, unlike to the previous works; the adaptation is according to the number of nodes, communication distance between them and their speed mobility. The objective of IA-TCP is to reduce the collisions caused by the TCP data packets and their corresponding acknowledgement packets.

We have seen through the works presented in [8], that when the number of nodes in the network increases, the performance of TCP deteriorates. The cause of this degradation is the frequent occurrence of collisions between nodes. More the number of nodes increases, more collisions are frequent. Packets loss can also occur when the distance between nodes increases. Their mobility can be another factor to this loss of packets. These

Collisions can also be produced between the TCP data packets and their TCP acknowledgement packets. The principle idea with IA-TCP is to make the transmission time between these two kinds of TCP packets adaptable to the nodes number, their mobility and the communication distance between them.

We note by:

T_i : delayed time applied by the node i,
n : the number of nodes in the MANET

The first part of the expression of d is given by following expression:

$$G(n) = Log(n) \quad \textbf{(1)}$$

Log () is used here because we found in [8] that the effects of the large values of the nodes number on the TCP performance are almost the same.

We know that the communication distance between nodes and their mobility are significant parameters in the communication environment. For each node i we take its speed of mobility M_i and we calculate its average communication distance D_i as follows:

$$D_i = \sum_{n-1}^{J=1} d_{i,j} / n \qquad \textbf{(2)}$$

$d_{i,j}$: the distance between the node i and the node j;
n: the number of nodes in the MANET

We take into account these two parameters (distance and mobility) to get the second part of our delay time d_i:

$$F(D_i, M_i) = (M_i+D_i)/[\alpha\sum_{N-1}^{J=1} D_j + \beta\sum_{N-1}^{J=1} M_j] \qquad \textbf{(3)}$$

Where:

M_i: the speed mobility of the node i;
D_i: is the average distance between the node i and their communicating nodes. It's calculated with the following function:

The equation **(3)** gives, for the node i, the ration (probability) to get packet loss caused by the distance communication or by the mobility of nodes.
α and β used to make the mobility and the distance parameters more or less important.

Form **(1)** and **(3)**, we can give the expression of the delay transmission time T_i as follow:

$$T_i = F(D_i, M_i) + G(n) \qquad \textbf{(4)}$$

With IA-TCP, each node must have a local image for the variable n. this variable will be constantly updated whenever there is a new mobile node joins the network or leaves it (for reasons such as energy, no availability of processor or memory, etc). The information n is broadcast as well as other information about the MANET with a piggy backing technique. Many diffusion algorithms exist [21] and should be implemented with our solution to ensure the availability of the information n for all the nodes in the MANET.

For the parameter M_i which is the speed mobility of the node, each node can get it; the easiest way to do it is to deduce it by knowing the time spent between two geographical points. There are many solutions for nodes mobiles location such us GPS and power measurement techniques [22] [23]. Same for $d_{i,j}$ which represents the distance between the node i and its corresponding node j. With these location systems it is possible to determine the distance between these tow nodes.

4 INCIDENCES OF IA-TCP ON TCP PERFORMANCE IN MANET

4.1 Simulation Environment

The evaluation is performed through the simulation environment NS-2 (version 2.34) [24], [25]. MAC level use the 802.11b with DCF (Distributed

Coordination Function) and the values of its basic parameters are listed in [8].

Each node has a queue buffer link layer of 50 packets managed with a mode drop-tail [26]. The scheduling packet transmissions technique is the First in First out (FIFO) type. The propagation model used is two-ray ground model [27].

Our simulations are done with reactive routing protocol AODV [28]. We used TCP NewReno [29] which is a reactive variant, derived and widely deployed, and whose performances were evaluated under conditions similar to those conducted here. The simulations are performed for 1000 seconds, this choice in order to analyze the full spectrum of TCP throughput.

We considered two cases: without and with mobility. In the case with mobility, we study a random topology with two cases: weak and strong mobility. The mobility model uses the random waypoint model [30]. In this model the node mobility is typically random and all nodes are uniformly distributed in space simulation. The nodes move in 2200m*600m area, each one starts its movement from a random location to a random destination. Once the destination is reached, another random destination is targeted after a pause time.

4.2 Parameters Evaluation

Since our work in this paper is the following of that done in [8], we keep the same parameters evaluation which are the throughput and the end-to-end delay. The throughput is given by the ratio of the received data on all data sent. The second parameter is the end-to-end delay which is given by time for receipt of data - the data transmission time / number of data packets received.

4.3 Simulation and Results

In this section, we evaluate our IA-TCP by doing the same simulations done in [8]. We compare our solution (IA-TCP) with TCP standard and two other solutions proposed in the literatures which are Wireless Congestion Control Protocol (WCCP) [19] and the Loss Differentiation Algorithm (LDA) [20]. Two cases are also considered, with and without mobility. In both cases we used TCP New Reno version and AODV routing protocol.

Without mobility

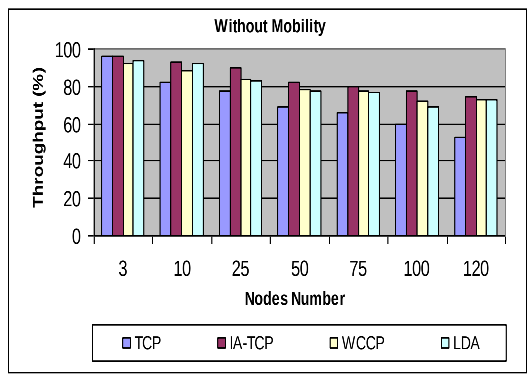

Figure 1. Throughput variation.

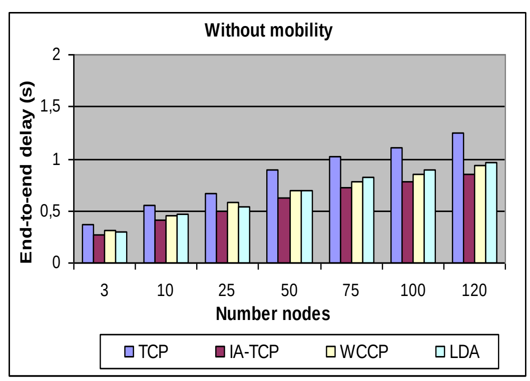

Figure 2. End-To-End Delay variation.

Figure 1 and **Figure 2** show that the nodes number has a great impact on the TCP parameters performance. More the nodes number participating in the network increases, more the throughput decreases and the end-to-end delay increases. This degradation is due to TCP packet loss occurred, and that becomes more important with the increasing of the network size. These losses will be the cause for the frequent start of the congestion avoidance mechanism by the TCP, so that will result in reducing of throughput and the increase of the transmission time or the end-to-end delay.

Even there is degradation of the TCP parameters performance, IA-TCP allows us to get the better results compared to the other techniques used as TCP protocol. This improvement is due to the delaying of the some acknowledgments packets when the number of the nodes increases in the network. IA-TCP mechanism makes the delay time of each node adjustable to the nodes number. This delay time reduces the probability of collisions between the TCP packets data and their acknowledgements packets. Then the both throughput and delay parameters are improved.

Based on these results, we can say that IA-TCP outperform not only TCP standard, but also similar techniques that have been proposed in the literature. The results of the variation of the throughput and the end-to-end delay parameters are better than those of LDA and WCCP solutions.

Weak mobility (W = 5 m/s).

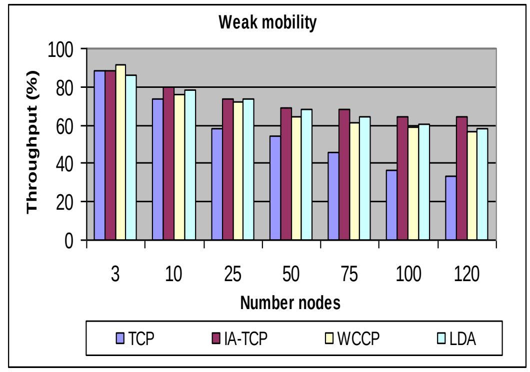

Figure 3. Throughput variation.

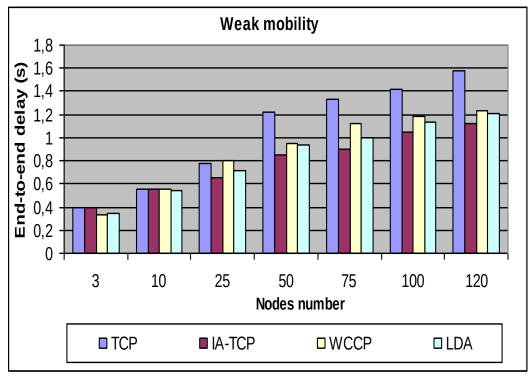

Figure 4. End-To-End Delay variation.

Figure 3 and **Figure 4** showed an important degradation of the throughput and end-to-end delay parameters in comparison to the first case (without mobility). We found that there are also many packets loss due to the increasing of the nodes number and their mobility even it's weak (the used route is outdated, denoted by "NRTE" in the trace file).

The degradation of the TCP parameters performance is recorded with all the techniques tested here. We can say that, in addition to the nodes number, the mobility, although it is weak, has also an impact on the performance of these parameters.

With our IA-TCP solution, we found an important improvement of the throughput and end-to-end delay parameters in comparison to the others techniques tested (TCP standard, LDA and WCCP). Our IA-TCP mechanism makes the delay time adjustable to the nodes number in the network and their mobility. For this reason, even for the case where the nodes are mobiles, the probability of collision between TCP data packets and TCP acknowledgement packets is reduced, and then throughput and the end-to-end delay parameters are improved.

Strong mobility (W = 25 m/s).

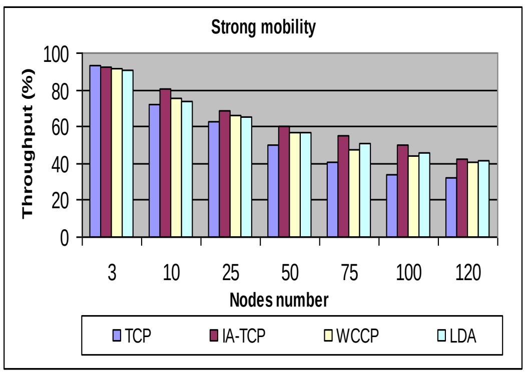

Figure 5. Throughput variation.

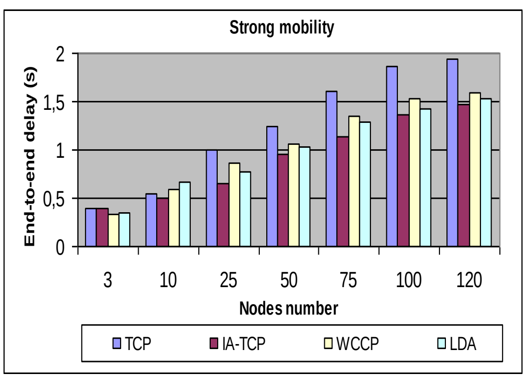

Figure 6. End-To-End Delay variation.

Figure 5 and **Figure 6** illustrate the impact of strong mobility on TCP parameters performance. Here, the degradation of the throughput and end-to-end parameters is more important compared to the previous case (weak mobility). In fact, when the network has a weak mobility (nodes with low speeds), it presents a rather high stability; then links failure are less frequent than the case of a high mobility. Consequently, the fraction of data loss is important with strong mobility.

Although there is more degradation in this case, but with our improvement IA-TCP, we found an important improvement of the throughput and end-to-end delay parameters in comparison to the others techniques tested in first case when TCP standard is used. IA-TCP mechanism makes the delay time of each node adjustable not only to the nodes number but also to their mobility. For this reason, although here the mobility is important (W=25 m/s), the probability of collisions between the TCP packets data and their acknowledgements packets is reduced. In addition to that, with IA-TCP we reduce too the packets loss due to the link broken caused by the mobility. In fact, with our new technique of delaying, the acknowledgement packets are transmitted in separated intervals then we increase the probability that these packets will be send when the receiving node is note mobile.

Based on the last results (weak and strong cases) we conclude that even in the case of a random topology where nodes are mobile (a feature specific to MANET networks) the IA-TCP present better performance for the TCP parameters. IA-TCP outperform not only TCP standard but also LDA and WCCP solutions.

5 CONCLUSION

Our present work is the following of those started previously. We continue to improve the interaction between the

MAC and TCP levels. Contrary to the first case where the MAC layer is used, in this paper we exploited the transport layer to improve the MANET performance. We proposed a new acknowledgement mechanism called IA-TCP which is an adaptation to the number of nodes used in the network, their mobility and the communication distance between them. This adaptation is to reduce the number of collisions between the TCP data packets and their corresponding acknowledgement packets with using delay time after transmission.

IA-TCP is evaluated and compared to the TCP standard and also the others techniques proposed in the literature which are LDA and WCCP solutions. The results are satisfactory and showed that our IA-TCP solution present better performance of TCP parameters.

As perspectives, we will continue our work with the modelling of the maximum number of parameters of the communication environment. We will try to reflect as much as possible the communication environment with a more a realistic set E. also, we plan to conduct a study one the communication environment of MANET to better assign meaningful values to the two constants α and β. In fact, these values must be deduced mainly depending on the complexity of the MANET and the type of the application covered by the network. Finally, our IA-TCP solution will be tested on a real platform; in this case, we really need to produce all the phenomena supposed exist in a real MANET.

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