On Metrics for Mobility Oriented Self Adaptive Protocols

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Abstract

Mobile networks performance may be enhanced by cross-layer mechanisms. Some of those mechanisms are based on mobility metrics. For example, the establishment of a route by choosing less mobile node could improve the routing protocol. In this paper, we study the ability of mobility metrics to reflect the mobility. The proposed approach evaluates the ability of a metric from its influence over routing protocols. Three routing protocols are considered: AODV, DSR and OLSR. The studied mobility metrics are Frequency of Link State Changes (LC), Link Connectivity Duration (LD) and Link Stability Metric (LS). The metrics are evaluated by simulation, firstly in a general case then in a scenario case.

1. Introduction

We study the mobility metrics for mobile networks, such as mesh or ad-hoc networks. A mobile network must react effectively to the topological changes and to the traffic demands by maintaining an effective routing. The nodes being free to move, the topology of the network may change randomly and quickly. We show in [1] the interest of a mobile self adaptive routing protocol over such environment. In a similar way, others protocols would be enhanced by knowing the *"less"* mobile element. So, an important question is: how to describe the mobility in order to manage the mobile networks effectively?

In [2] we present a synthesis of mobility metrics. Those metrics are interpreted through classifications. The first classification is based on the means of detection of the metrics. A summary of these metrics specifies the functions which they influence. The second classification is based on the brought information. Those metrics that may be obtained from different levels (i.e. at physical, logical link and network level) could be used in a cross-layer mechanism in order to enhance the performance of the overall system.

Works on mobility metrics have been intented to either analyze the mobility models or to compare protocols performance. For example, comparison between protocol performance related to the mobility metrics in the Random Waypoint model are performed in [3, 4, 5, 6, 7]. Many studies [5, 6, 7, 8, 9, 10, 11] investigate in the relationship between the mobility metrics and the mobility models. [12] studies the degree mobility that affects the routing protocol performance.

The aim of our experimental study is to determine the behavior of different mobility metrics rather than the protocol behavior and to appreciate the 'good' value of a metric.

Characteristics of a good mobility metric [6] are: computable in a distributed way without global network knowledge, able to indicate or predict the protocol's performance, feasible to compute (in terms of node resources), independent of any specific protocol and computable in real network.

This paper is organized as follows: section 2 summarizes main considered mobility metrics, section 3 describes the parameters that are tackled for the evaluation by simulation, section 4 highlight the results that are obtained for different MANETs routing protocols. Firstly we consider a general model then we focus on a specific scenario.

2. Mobility Metric

We study the following mobility metrics: Frequency of Link State Changes (LC), Link Connectivity Duration (LD) and Link Stability Metric (LS).

Frequency of Link State Changes (LC) [4, 5, 6, 7, 11] is the number of link state changes. When Node comes into the transmission range of another node, metric is increased by one indicating a link connection. When Node moves out of the transmission range, the metric is increased by one indicating link breakage. The average LC is done over the number of considered nodes.

Link Connectivity Duration (LD) indicates the period a link is in the transmission range of a determined node.

Link Stability Metric (LS) [7, 8] combines the information of both LD and LC. LS capture link longevity as well as frequency of link changes. It is defined as: LS = LD/LC.

Before the use of simulation for metric analysis, we

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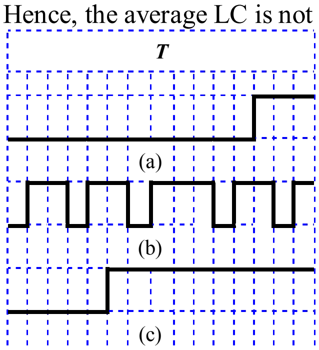
present a non valued analysis. In [7, 8], the authors argue that LS is better than LC and LD. However, we do not consider LS as a *"good metric"* as explained it in Fig 1.

As shown in Fig 1-a and 1-c, LC in both cases is equal but the link duration is different. The routing protocol can work better in the case 1-c than in the case 1-a because of the long duration connectivity. Average LC in Fig 1-b is more frequent than in Fig 1-a. However, the routing protocol can perform better in Fig 1-b than in Fig 1-a because of the long duration connectivity which means that there is a route to the destination (if there is a route the protocol can find it). Hence, the average LC is not the best mobility metric.



	a	*b*	*c*
LC	1/T	9/T	1/T
LD	T/5	2T/3	2T/3
LS	$T^2/5$	$2T^2/27$	$2T^2/3$

(d)

Figure 1. Impact of mobility on three mobility metrics

LS can indicate LD as well as LC. Nevertheless, LS is not really a good metric because it depends on LC. According to Fig 1-d, the value of LS, it ordered by $2T^2/3$ (c) > $T^2/5$ (a) > $2T^2/27$ (b). It appears that LS in Fig 1-a is more stable than in Fig 1-b. Indeed, the routing protocol can work better with LS in Fig 1-b than in Fig 1-a because of the long duration connectivity. Therefore, the average LS does not seem the best mobility metric.

As illustrated in Fig 1-b and Fig 1-c, LD in both cases is equal but the frequency of link change is different. Network goodput can probably be good in 2 cases because of the long duration connectivity. Although, the overhead in Fig 1-b case is higher than in Fig 1-c because of LC value.

The average LD in Fig 1-b is more stable than in Fig 1-a but it is more frequent too. However, the routing protocol can be more efficient in Fig 1-b than in Fig 1-a because of the long duration connectivity.

Hence, the average LD would be the best mobility metric among all three mobility metric.

3. Parameters of evaluations

We use simulation to evaluate the capacity of metric to predict the protocol performance. We focus on routing protocols. Performance of AODV [17], DSR [18] and OLSR [19] according UM-OLSR-0.8.8 [20] are compared to the different mobility metrics.

3.1. Mobility models

To study the effect of mobility on MANET protocol performances, Random Waypoint model (RWP) [13], and Reference Point Group Mobility model (RPGM) [14] are used.

3.2. Performance metrics

Two performance metrics are evaluated: the packet delivery ratio (PDR) [3] and the normalized routing overhead [3, 15]. The first is the ratio of the data packets delivered to the destination to those generated by the CBR sources. The second is the number of "transmitted" routing packets per data packet "delivered" to the destination. Each hop-wise, transmission of a routing packet is counted (in bytes). The routing overhead includes: 1) a Routing Protocol Overhead Packet (in byte) such as Route Request, Route Reply, Route Error, etc. 2) a Routing Overhead on data packet (in byte) because the different routing protocol have different routing header, e.g. DSR has a variable header size upon the number of hops the packet traversed, AODV has fixed size header. Routing overhead on data packet = Packet transmission (RTR) – Packet Original (AGT). Then, we calculate the normalized routing overhead = 100 * (Protocol Routing Overhead on data packet + Routing Protocol Overhead Packet)/(Packet Original (AGT) + transmitted on RTR).

3.3. Simulation models

Network simulator NS2.29 [16] is used with a simulation time of 1000s in an area of 1000m x 1000m.

Firstly, we consider general models. For RWP, we use 2 topologies: 10 nodes and 50 nodes. For RPGM, we use 5 groups of 2 nodes and 5 groups of 10 nodes, which are moving independently to each other and in an overlapping fashion. Both Speed Deviation Ratio (SDR) and Angle Deviation Ratio (ADR) are set to 0.1. The same check point files (the files used to define the movement of group leader) are used for different topology in RPGM.

Secondly, we study a scenario which contains 3 nodes with a simulation time of 1000s in an area of 300m x 300m. Two extreme nodes are fixed at positions (40, 40) and (260, 260) respectively. Because of the too long distance they can not be directly connected. To construct a route between them, another node is used. The characteristics of node movement are similar to RWP.

The pause time is null and the maximum speed Vmax varies from 1 to 5m/s by step of 0.5m/s, then from 10 to 40 m/s by step of 5m/s to generate different

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movement patterns for each mobility model. 15 scenarios in each speed of mobility models are created.

For RWP model 10 nodes and RPGM 5 groups of 2 nodes, the traffic pattern is composed of 6 connections. For RWP 50 nodes and RPGM 5 groups of 10 nodes, There are 30 connections. The source/destination pairs are chosen randomly. Data rate is 4 packets/sec and the packet size is 512 bytes. A nominal bit-rate of 2 Mb/sec and a nominal radio range of 250 meters are used.

For the studied scenario, the traffic pattern consists of 1 connection.

3.4. Expected relations between mobility metrics and evaluation parameters

Because a good mobility metric must be able to indicate or predict the protocol's performance, we first predict the relationship between the mobility metrics and the speed of mobile node as shows in Table 1-a. Then we are going to compare experimental results with the expected results.

We predict relationship between performances and mobility metrics as are in Table 1-b.

Table 1. Relationship of mobility metrics with the maximum speed and the performance metrics

Mobility Metric	*Speed*	
	Low	High
LC	Low	High
LD	High	Low
LS (= LD/LC)	High	Low

(a) the mobility metrics and the maximum speed

Mobility Metric	*PDR*		*Routing Overhead*	
	Low	High	Low	High
Speed	High	Low	Low	High
LC	High	Low	Low	High
LD	Low	High	High	Low
LS	Low	High	High	Low

(b) the performance metrics and mobility metrics

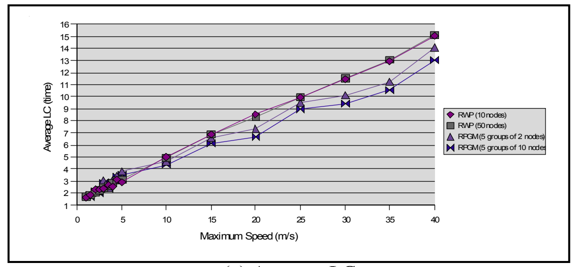
4. Simulation results and discussion

4.1. Mobility metrics and speed relation

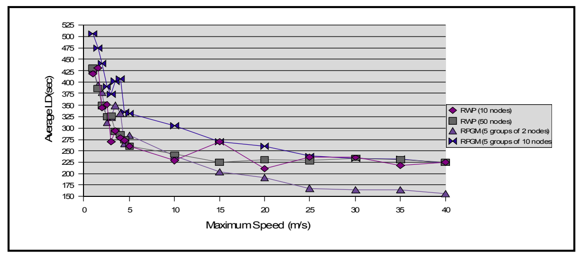
Because our purpose is to test protocols performances in function of metric values, we determine the mean to obtain growing metric values by increasing the speed value in the simulation. The metric values obtained (Fig 2) are reported on the X axis of figures 3, 4, 5, 6 and 7.

In addition, from this simulation we note the comportment of metrics. In Fig 2-a, the speed affects forcefully the average LC. At a very low speed, the average LC is low, while as the speed increases, the average LC increases relatively.

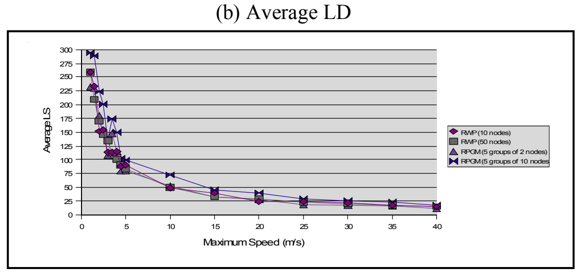
In Fig 2-b, the speed affects also the average LD. For very low speed, the average LD is considerable high. As the speed increases, the average LD increases relatively. Beyond a speed of 25 m/s, the average LD changes a little because the mobile nodes move very fast to a destination, choose the new destination and move to it, and so on. At these speeds, nodes can connect with another node in very short period but very frequently as stated from Fig 2-a. Consequently, the average LD is alike stable when the speed exceeds 25 m/s.



(a) Average LC



(b) Average LD



(c) Average LS

Figure 2. Mobility metrics according to maximum speed

According to Fig 2-c, the speed also affects the average LS. The average LS results from the average LD divided by the average LC. Then the average LS looks like the average LD. Above a speed of 25 m/s, the average LS slightly changes too.

The comportment of LC would seem the most conform to reflect mobility as it linearly increases with the speed. But results show too that *"speed"* is not a good metric of mobility (see section 4.2.). At this step, we can not decide on the best mobility metric

4.2. Performance and mobility metrics relation

The observed protocol performances are PDR and Routing Overhead. Firstly, we study them according to the speed (Fig 3). Secondly we classify the scenarios according to the average LC (Fig 4) and, LD (Fig 5) and LS (Fig 6) and obtain the corresponding performance.

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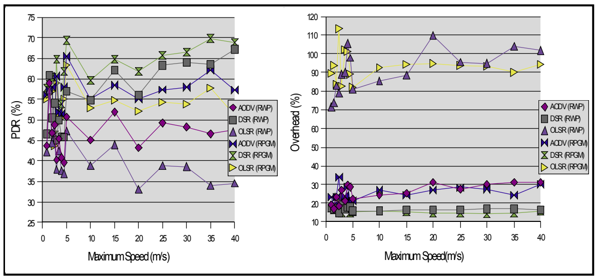
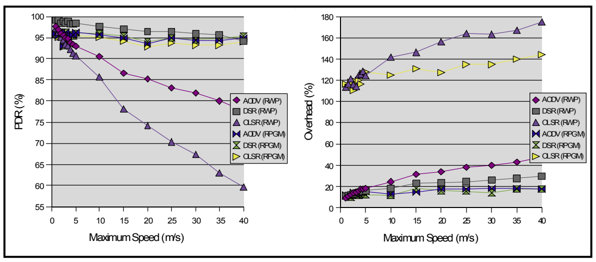


(a) RWP 10 nodes and RPGM 5 groups of 2 nodes



(b) RWP 50 nodes and RPGM 5 groups of 10 nodes

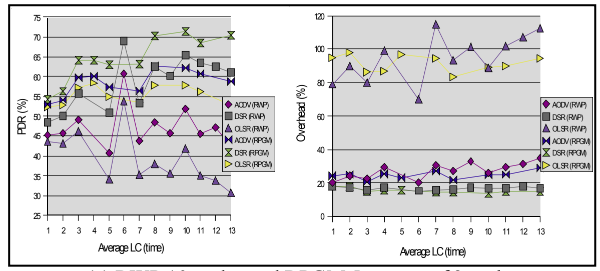
Figure 3. Performances relative with the speed

A first general remark concerns the good aspect of the results. In our study, a result is good if it is conform to the expected results summarized in Table 1-b. As shown in Figs 3 through 6, the performances are not relatively good in RWP 10 nodes and RPGM 5 groups of 2 nodes, in the other hand, the performances are relatively very good in RWP 50 nodes and RPGM 5 groups of 10 nodes. For example, the PDR in RWP 10 nodes and RPGM 5 groups of 2 nodes does not relatively decrease when the speed increases (Fig 3-a), in the same way the PDR does not relatively decrease when the average LC increases (Fig 4-a). Same constitution for the average LD (Fig 5-a) and average LS (Fig 6-a).

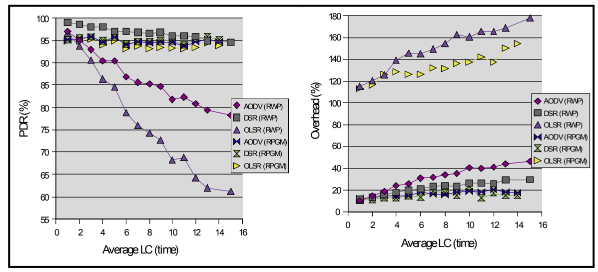
However, for the routing overhead for the RWP 10 nodes and RPGM 5 groups of 2 nodes scenarios, the mobility metrics are relatively better than for PDR. Nevertheless, the PDR and Overhead in RWP 50 nodes and RPGM 5 groups of 10 nodes with all mobility metrics are relatively good (Fig 3-b, 4-b, 5-b, 6-b).

Furthermore, it appears that the node density influences the interest of mobility metric. An explanation may be in the metrics computation process since they are based on average computation when the number of nodes increases the accuracy is better.

Another remark concerns the influence of the routing protocol combined to the mobility models. Especially, comparing DSR and OLSR on high density, mobility metrics have less influence on the PDR of DSR. Probably, it is due to the cache route mechanism of DSR. But for a network with a high load (higher density and traffic), because cache route may contain a lot of stale routes, PDR and overhead would be more affected.

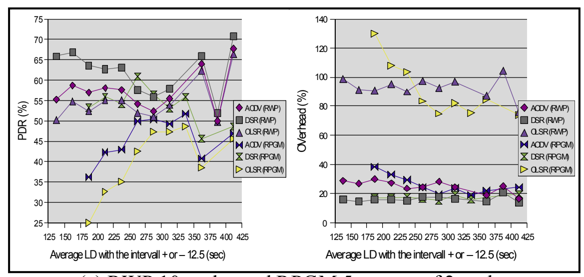


(a) RWP 10 nodes and RPGM 5 groups of 2 nodes

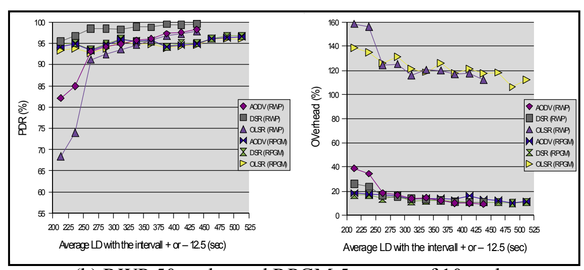


(b) RWP 50 nodes and RPGM 5 groups of 10 nodes

Figure 4. Performances relative with the average LC



(a) RWP 10 nodes and RPGM 5 groups of 2 nodes



(b) RWP 50 nodes and RPGM 5 groups of 10 nodes

Figure 5. Performances relative with the average LD

Moreover, the results show that PDRs in RPGM with 5 groups of 10 nodes slightly change because of the nature of this model. The mobile node sends the packets to any group of nodes directly connected to it.

The PDRs in RWP 50 nodes are very variable (e.g. at the fastest speed, most frequency average LC, least average LD and least average LS, the PDRs of all protocols are the lowest). The reason for this is that the network topology is changed with the speed that affects the LC, LD and LS. Then, the nodes got many routes error, try to find the new route to the destination and so on. This leads to a very high overhead in an unstable network.

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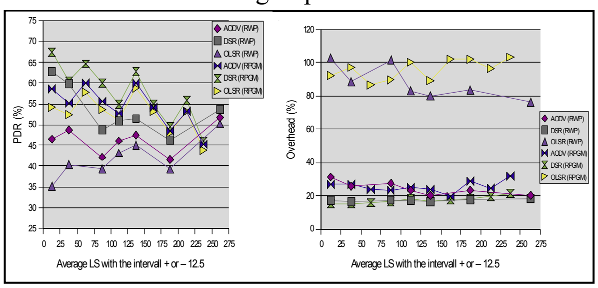
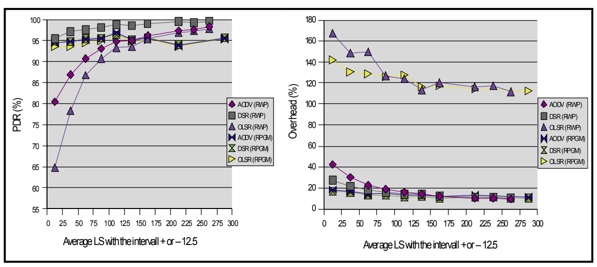
The mobility metrics are not good for RWP with 10 nodes and RPGM with 5 groups of 2 nodes due to the influence of the node distribution, the node density and the methods of calculation. For instance, lets consider two nodes that are connected together during 1000s, the LD and LS is increased but the two nodes can not connect with another node because of the long distance. When the average LD and LS are calculated, they divided by the number of nodes in the simulation. Then, the result is not just.

In addition, we have observed a relationship between the mobility metrics and the correlation coefficient [21] (not reported here) in RWP 50 nodes and RPGM 5 groups of 10 nodes. The correlation coefficient is very high when we use the speed or the average LC in RWP 50 nodes. However, the correlation coefficient is the highest when the average LD is used in RPGM 5 groups of 10 nodes.



(a) RWP 10 nodes and RPGM 5 groups of 2 nodes



(b) RWP 50 nodes and RPGM 5 groups of 10 nodes

Figure 6. Performances relative with the average LS

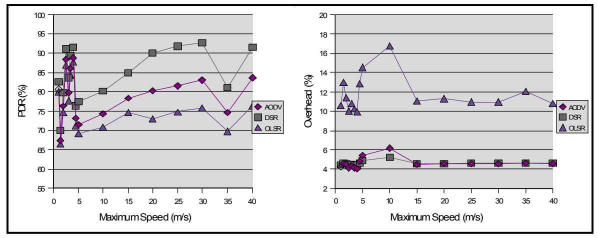
In conformance with performance evaluations done on adhoc routing protocols, in this experiment, the PDR of DSR is the best in all cases. OLSR has the most overhead in all cases because it is the proactive protocol. Furthermore, OLSR has the least performance because of the relatively small size and density of the network simulation (OLSR is intended to large networks).

Important parameters for the accuracy of mobility metrics are the number of nodes and the stability. It is clearly shown in the results that, whatever the routing protocol and the mobility model, best results are obtained with 50 nodes than with 10 nodes. In a same way the metric is more representative when the network stability is high. In the fact the average that is done in the computation leads to some inaccuracy.

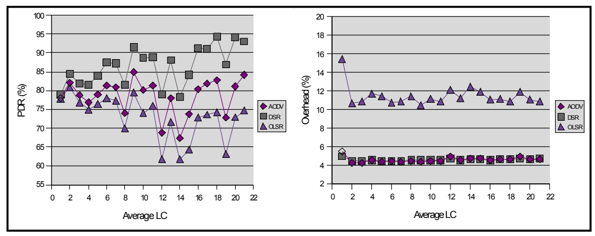
4.3. Mobility metrics effect on a scenario

The previous sub section B highlights the limitation of the analytical formula for the mobility calculation. Therefore, a scenario approach is tested.

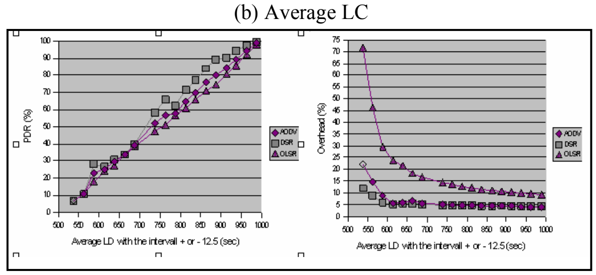
As previously, we focus on the protocol performances. Firstly, they are compared with the speed (Fig 7-a). In addition, all the scenarios of speed are classified in the average LC (Fig 7-b), LD (Fig 7-c) and LS (Fig 7-d) respectively. Then, they are evaluated with the mobility metrics.



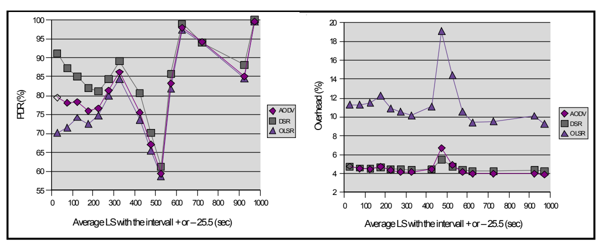
(a) Maximum speed



(b) Average LC



(c) Average LD



(d) Average LS

Figure 7. Performances according to mobility metrics

As shown in Fig 7-a through 7-d, the performances are relatively good only with the average LD. Ideally, the lowest LC should give the best performance. Practically, the performance depends on LD, not on LC. We explain it by the example presented in Fig 1.

The PDR of DSR is the best in all the cases. OLSR has the most overhead in all cases because it is the

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proactive protocol applied. Furthermore, OLSR has the least performance because of the size and the density on simulation. The average LD is the best mobility metric when the proposed scenario is observed.

5. Conclusion

The study indicates that the important parameters for the accuracy of mobility metrics are the node density distribution and the stability. The method of mobility metric calculation affects directly the accuracy metric.

Furthermore, considering an evaluation based on a scenario approach, it appears that the Link Duration metric is the best metric as it impacts in a similar way the routing protocol. Thus, we note that even if there is no universal mobility metric, since study on general model can not decide of a best metric, for a specific case, a best mobility metric can be found. Interest of this result concerns the conception of mobility oriented self adaptive protocols. They have to determine their right metric before to use it. We recommend that, as the concept of quality of service which is implemented by a set of parameters, the mobility concept will be implemented by a set of metrics.

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