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PL-AOMDV: An Enhanced Energy Efficient Multipath Routing for MANETs

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Abstract

Multipath routing protocols are more prominent in mobile ad hoc networks (MANETs), as they beat certain impediments of single-path routing. Contrasted with single-path routing methodologies they have numerous points of interest in term of lower end-to-end delay, higher throughput, higher energy efficiency and network lifetime. Energy efficiency is essential prerequisites in numerous applications as nodes in MANETs are battery worked. In this paper, Power and Load Aware Ad-hoc On-demand Multipath Distance Vector Routing (PL-AOMDV) is presented. PL-AOMDV is a multipath routing protocol which chooses ways between source-destination pair in light of a consolidated cost function. The cost function is registered by considering remaining battery strength of a node and its present traffic. This article assesses the execution of PL-AOMDV by contrasting it with existing protocol AOMDV. Simulation results recommend that the proposed protocol has lower energy consumption, higher packet delivery ratio and throughput.

Keywords: *Multipath routing, link-disjoint, path load balancing, on-demand distance vector*

INTRODUCTION

A data network or computer network is an information transfer system which permits network devices to trade information. In computer networks, network components trade information with each other along system joins (information associations). The alliance between nodes is set up utilizing either link media or remote media. A remote system is any kind of computer network system that utilizes remote information associations from interfering system nodes. Remote systems administration is a technique by which information transfers systems, homes, and business establishments maintain a strategic distance from the association between different hardware areas or as an excessive procedure of bringing links into a building. Mobile Ad-hoc Networks are one of the usages of Wireless Ad-Hoc network. Versatile specially appointed system (MANET) is a foundation less, consistently self-arranging system of cell phones associated without wires. Each must forward movement random to its own particular use, and in this way be a router [1–4]. The essential test in building a MANETs is preparing every device to ceaselessly keep up the data required to legitimately route movement. Such systems may work without anyone else's input or might be composed with the bigger Internet, which may contain one or various and diverse transceivers between nodes. These outcomes in a profoundly progressive, self-governing topology. MANETs are a sort of wireless specially appointed system that ordinarily has a routable systems administration environment on top of a Link Layer Ad-Hoc system.

Multipath routing approaches are acquainted with find numerous paths between a source-destination sets. Multiple paths between a source-destination pair give a few advantages for example, lower end-to-end delay, higher usage of transmission capacity, higher throughput, higher system life and so on. It moreover applies load balancing in the network via conveying the traffic through multiple paths. It helps to overcome network congestion and route failures. Path discovery method in multipath routings is fundamentally the same as to single path routing in MANETs. At most of the time it picks disjoint paths to convey forward the traffic between source and destinations. Multi-paths can be of two sorts: node-disjoint and link-disjoint. For a given source destination (s-d) match the arrangement of link-disjoint routes includes paths that have no connection in common other than source destination s-d way. Correspondingly, in node-disjoint methodology routes include paths that have no common node (other than the s-d) present in more than one constituent way [5, 6]. MANETs multipath on-demand routing protocols register different quantities of paths between a source-destination pair, in a single route disclosure endeavor. Another route discovery operation is started just when every one of the paths falls flat between a source-destination pair. Energy is a rare asset in specially appointed remote systems and it is of vital significance to utilize it effectively while building up correspondence designs. Energy Management is defined as the way toward handling with the sources and consumers of energy in node or in system completely for updating system lifetime [7–9].

RELATED WORKS

As of late some multipath routing protocols are proposed in writing. Dominant part of them apply on-demand ways to deal with discover the paths between source-destination pair. Numerous augmentation of single path routing protocols are proposed for multipath routing. The greater part of these conventions use hop count metric to choose the path. Being that approaches based on hop-count are not efficient on energy factor. In this segment authors talked about a couple existing multipath routing protocols. The current multipath directing protocols are variations of major directing protocols like AODV and DSR, which are talked about in. Scalable Multipath On-demand Routing (SMORT) is a variations of AODV protocol [10]. The goal of SMORT is to decrease routing overheads. It utilizes safeguard various paths rather than hub disjoint and interface disjoint ways [11]. AODV Multiple Alternative Paths (AODV-MAP) is another augmentation of AODV routing protocol [12]. It utilizes both safeguard ways and in addition node-disjoint and link-disjoint paths. The target of the protocol is to pick more number of elective paths than node-disjoint and link-disjoint paths.

Split Multipath Routing (SMR) is an on-demand multipath routing protocol based on DSR [13, 14]. Principle expectation of this protocol is pick maximally disjoint paths, which reduces the route discovery and control message overhead. To diminish the control message overhead the information movement sent through numerous routes. Delay-Aware Multipath Source Routing (DMSR) is an expansion of DSR [15]. It starts route discovery process by considering collection delay and node delay. Above two delays component is ascertained as metric for path determination. Multipath Source Routing (MSR) is another variation of DSR [16]. The registered node disjoints paths to expand the usefulness of the route discovery and route maintenance stage. By utilizing of source routing system, found paths are put away in route cache with an exclusive index.

Ad Hoc On-Demand Multipath Distance Vector (AOMDV) is a multipath extension of AODV. We have compared our proposed EAOMDV with AOMDV. The working principles of AOMDV protocol is as discussed below:

- It depends on node-disjoint approach and uses the route discovery procedure of AODV. Its center capacity is like AODV. Point of the AOMDV protocol is to discover link-disjoint and loop-free paths and make use of flood-based route discovery process.
- Every node keeps up a variable called advertise hop numbers for destination node. The variety of advertise hop include relies on the advancement done in the sequence number. In the event that the sequence number is changed, then the advertise hop check will change naturally.

- Every duplicates of route request (RREQ) are inspected for exchange reverse paths. Quantities of alternate paths are to be kept up after consent of advertising the longest path. The events of regular link disappointments are disposed off. AOMDV enhances adaptation to internal failure by selecting disjoint paths. The RREQ packet format of AOMDV is appeared in Figure 1.

Destination IP address
Destination sequence number
Advertisement hop-count
Path list (next hop IP 1, hop-count 1), (next hop IP 2, hop-count 2),...
Expiration Route

Fig. 1: *AOMDV RREQ Packet Format.*

- Each node will have novel identifier and all connections are bidirectional. A connection is said to be bidirectional if the connection imparts in both ways.
- Route requests for (RREQ) process are started by source. RREQ comes to the destination D through numerous intermediate nodes.
- Destination gets ready route reply (REEPs) and sends them to source through various paths to source node.
- It keeps routes just for the most elevated destination D sequence number. For each destination, various paths kept up by node have that same destination sequence number.
- Numerous numbers of secondary paths are to be kept after allowable of promoting the longest path.

PROPOSED PROTOCOL

The proposed protocol Power Load aware Ad-hoc On-demand Multipath Distance Vector (PL-AOMDV) is talked about in this segment. The protocol chooses paths based upon a consolidated cost function. The consolidated cost is a function of residual battery power and present traffic load. Some of the methodologies consider remaining battery power as the main way metric to accomplish energy effectiveness. Nonetheless, it may not give any certification to upgrade system lifetime. A node in a path when forward a lot of traffic its battery will exhausts quicker and node kicks the bucket. This will influence the system operation and lifetime. Accordingly, authors have incorporated the traffic load at node alongside remaining battery capacity to process the route cost. The consolidated cost function chooses energy efficient path. Likewise, authors have considered node-disjoint path to deal with select numerous paths between source destination pair.

Protocol Description

The route discovery methodology of PL-AOMDV is especially like AOMDV. Authors rolled out some fundamental improvements to the route discovery period of AOMDV. A node when has some packet to send set up the RREQ. The RREQ packet contains the cost function which is figured by that node. A node on getting the RREQ first figures its cost function. If the cost function value is not more than the value in RREQ packet, then node upgrades RREQ packet by putting its own particular figured cost. Else, it advances the RREQ packet without changing the cost. Along these lines RREQ comes to at the destination through intermediate nodes. Destination nodes on accepting the first RREQ packet run a clock.

All the RREQ got amid this the reality of the situation will become obvious eventually considered for way determination. Any RREQ got after the expiry of the clock will be disposed off. At that point the destination node chooses the paths. The RREP is send to the source through the chosen paths. The consolidated cost function is calculated as follows:

Consolidated Cost Function (CCF)

$$CCF = (\alpha * W_{ad} + \beta * W_{al}) * T_{dc}. \quad (1)$$

Where, W_{ad} states the energy delay weights and W_{al} tells present traffic load. T_{dc} is the arbitrary time delay, and α, β are two constants. Their values can be fluctuates from 0 to 1. The calculation of the above parameters discussed beneath.

Residual Battery Power Consideration

The method to calculate the energy consumption is done as:

$$Energy = Power * Time \quad (2)$$

The energy consumption of a node relies on upon the transmission power as well as its battery power. The time required for taking care of data packet is:

$$Time = 8 * Packet\ size/Bandwidth \quad (3)$$

Hence,

$$E_{tn} = P_{tn} * Time \quad (4)$$

$$E_{rn} = P_{rn} * Time \quad (5)$$

Here, P_{tn} is the transmission power, P_{rn} is receiving power. E_{tn} and E_{rn} show the measure of energy exhausted by a node.

The total energy exhausted by a node sending a data packet E_{total} is:

$$E_{total} = E_{tn} + E_{rn} \quad (6)$$

We expect that the aggregate energy at node is Ea_{total}, and the present leftover energy is $Ea_{current}$, that obeys uniform dissemination on $[0, Ea_{total}]$, the energy delay weights Wad at the node is:

$$Wad = 1 - Ea_{current}/Ea_{total} \quad (7)$$

Where, $0 \leq W_{ad} \leq 1$

Traffic Load Consideration

Let the current load level of a node can hold up to Qa_{max} packets in its buffer space, and the present packet number is $Qa_{current}$ which is present in the buffer space of the node.

Then the present traffic load delay weights W_{al} is figured as:

$$W_{al} = Qa_{current}/Qa_{max} \quad (8)$$

Where, $0 \leq W_{al} \leq 1$

System Architecture

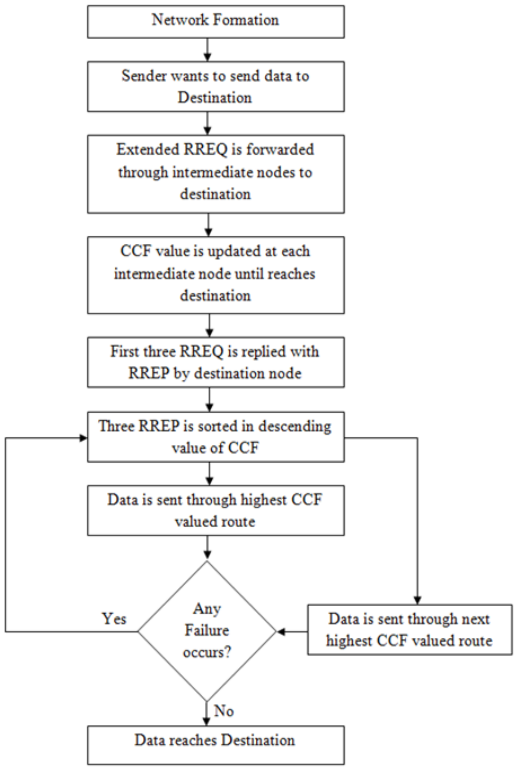

***Fig. 2**: Routing Flow of PL-AOMDV.*

Network formation is the first step in designing of the concept above discussed, with the details of number of nodes, source node and a destination node. In which if the sender wants to send data to the destination node it must send the RREQ packets to intermediate nodes, in which we have altered RREQ by adding CCF value. The CCF value is updated at each intermediate node which finally reaches destination. After first three RREQ reaches the destination it is replied with the RREP to those RREQ which is sorted in descending order. From those sorted CCF valued route highest valued CCF valued is selected to send the data to destination. If later while sending data any failure occurs then next highest CCF valued route is selected for sending data.

Route Discovery

- A source node sends a RREQ message. It first calculates its cost utilizing equation (1). RREQ incorporates the path cost and other data. Subsequent to setting up the RREQ packets, it broadcasts further.
- Intermediate nodes on accepting the RREQ packet calculates their cost. If the calculated cost is less than the cost in the RREQ packet, then it upgrades the RREQ packet by replacing its cost value in the cost field of the RREQ. Further it broadcast. Else, it broadcast the RREQ packet with no changes made. Finally the packet reaches the destination in this way.
- Destination node on getting the main RREQ packet, after it waits until it receives another two RREQ packets. Upon receiving all three RREQ it decides further to choose forward optimal pat among those.
- Optimal path is registered by destination node as below:

  $$P_{opt} = \max_{\forall b \in P*} (P_i(Cost)) \quad (8)$$

  Where, b is path, P* is the collection of paths amongst source and destination and Pi(Cost) is the cost of the path i, (i=1,2,3).
- In the wake of selecting ideal path destination node chooses (K-1) substitute path utilizing the equation (8).
- Destination sends RREP packet utilizing K number of chosen path.
- On accepting of the RREP packets, source select one as primary path and others as backup paths.

Exemplification of PL-AOMDV

We delineate the working of proposed PL-AOMDV through a case. As appeared in the Figure 2, source S set up the RREQ by calculating its cost. Let the calculated cost is 40, it then incorporate this value in the cost field of RREQ packet and broadcast it. Node A on getting the RREQ from S, process its cost. Node A finds its cost as 36 which is not exactly the expense of the RREQ it has gotten.

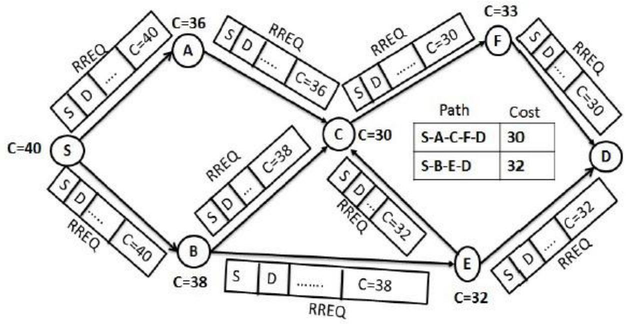

Fig. 3: *Transmission of RREQ from Source S.*

So, A overhauls the RREQ packet by putting its cost and broadcast further. Similarly, node B find the cost as 38 then redesign the RREQ and broadcast it. Hub C gets the RREQ packet from hub A. It figures out its cost as 30 and after that redesign the RREQ packet and broadcast. C may have got RREQ packet from B, however, it will as it were process the first and dispose of other. Node F on accepting RREQ packet with cost 30 and finds its cost as 33. In this way, node F would not upgrade the RREQ packet. Like this, RREQ packet reaches destination node D. On getting the primary first RREQ packet, node D keeps it and runs a clock. It gathers the resulting RREQ bundle till the expiry of the clock. In the given illustration, the cost of the paths recorded at node D are 30 and 32. D chooses way (S-B-E-D) with path cost 32 as primary and (S-A-C-F-D) as the secondary path.

Implementation of PL-AOMDV

The implementation of PL-AOMDV represented as follows:

Residual Energy Attribute

Authors attach the energy attribute E in the routing table section of a node. Let the complete energy of the node is Eatotal, the present leftover energy is Eacurrent which takes after uniform circulation on [0, Eatotal]. A node in the system has two states, active and inactive state. If the present leftover energy of a node is greater than some brink value the node is considered as active. Otherwise the node state is considered as inactive.

Traffic Load Attributes

The load queue is a buffer space kept up by a node. Authors have considered the queue parameter in eaomdv_rqueue.cc. A packet when gotten at a node it is set in the queue and handled later. On the off chance that more packets are pending in the queue then it will process the whole packet and its battery power will exhausts speedier.

Modifications on the Source File

Simulation Test system (NS 2.35) does not naturally empower energy model, so one have physically empower it. Authors have included the accompanying lines in the .tcl script.

```
$ns_node-config
energymodel EnergyModel
initialEnergy $val(initp)
rnPow $val(rnp)
tnPow $val(tnp)
```

where, energy model is energy model, initial energy is introductory energy, rnPow is the measure of energy loss by a node when it gets an information packet, tnPow is the measure of energy loss by a node when it sends an information packet.

In the header record plaomdv.h, include the accompanying code

```
#include<common/mobilenode.h>
#define α 0.5
#define β 0.5
#define Tdc 0.01
```

Where, mobilenode.h is the header record of mobile nodes. Value of α, β shifts between $0 \leq \alpha \leq 1$, $0 \leq \beta \leq 1$. Tdc is a postponement time constant. At that point, include the article pointer of mobile nodes and the object pointer of energy model of mobile nodes in the class.

```
EAOMDV: public Agent;
MobileNode * node;
EnergyModel * em;
```

In the source file plaomdv.cc, following code is added. Function void forward (eaomdv_rt_entry *rt,Packet *p, double delay):

Firstly, define the variables:

```
double T;
int qlen, qlim;
double init;
double remain;
```

where, init variable contains initial energy value of mobile nodes, qlim stores the max buffer size of mobile nodes and qlen stores the present queue length. Also, qlim is calculated by delay time and it is stored in T.

Secondly, in the broadcasting condition if (ih->daddr() = = (nsaddr_t) IP_BROADCAST), following lines are added in the code:

```
em=node->energymodel();
init=em->initialenergy();
remain=em->energy();
qlimit=EAOMDVifqueue->limit();
qlen=EAOMDVifqueue->length();
```

Where, the function energy_model() states the object pointer of energy model, the function initial energy() finds the initial energy of mobile nodes, the function energy() finds the current remaining energy of mobile nodes, the function limit() finds the maximum buffer queue length of mobile node and the function length() finds the current queue length of mobile nodes.

Thirdly, we find the CCF using the formula (1):
CCF = (α*Wad + β*Wal) * Tdc

After doing all the modification in above specified files, to work the changes done we need to recompile NS2.

EXPERIMENTAL RESULTS AND ANALYSIS

These snapshots below are taken from the working project which is run in NS2.35 software running on Ubuntu operating system. PL-AOMDV is the protocol demonstrated.

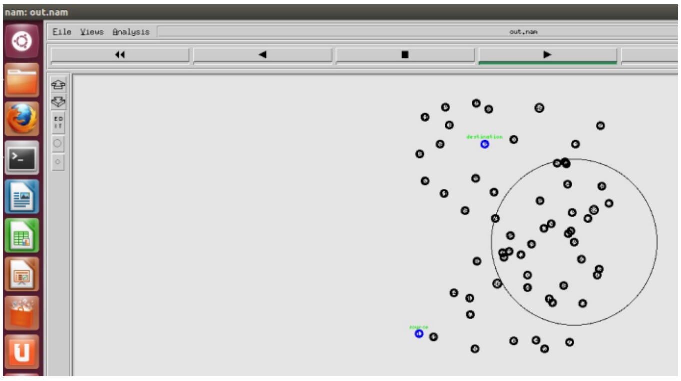

Fig. 4: *Source and Destination Nodes.*

Figure above shows the Source and Destination nodes which are highlighted in blue color. The circular marks show the Hello packet transmission between the nodes in order to establish connection.

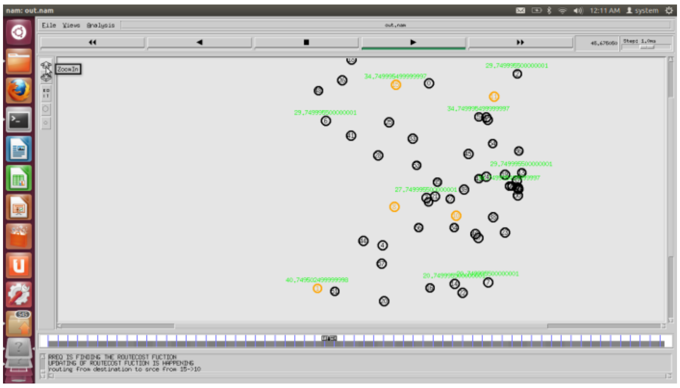

Fig. 5: *Selected Path for Data Transmission.*

As mentioned in Figure 5 Second path is selected for data transmission from the three multi-paths discovered, because it has got the highest CCF value compared to other two paths.

Fig. 6: *Failure in Data Transmission.*

Figure above demonstrates the failure while transmission of packets occurs due to some collusion.

Fig. 7: *Alternate Route for Transmission.*

As shown in the figure above their occurs some link failure an alternate route which has next highest CCF value is selected for transmission.

Performance Graphs

To evaluate the performance of PL-AOMDV it is simulated using NS-2. The results are compared with AOMDV. We considered the four most commonly used quantitative indicators to judge the performance of the PL-AOMDV protocol: (i) Packet Delivery Ratio (PDR), (ii) Throughput (iii) Residual energy. The parameters consider for simulation is shown in Table below.

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Table 1: Simulation Parameters.

Simulator	NS-2.35
Simulation Area	1000m * 1000m
No. of Nodes	70
Traffic Type	CBR
Mobility Model	Random Waypoint
Pause Time	30 sec
Max Queue len	50 packets
Simulation Time	100s

Packet Delivery Ratio (PDR)

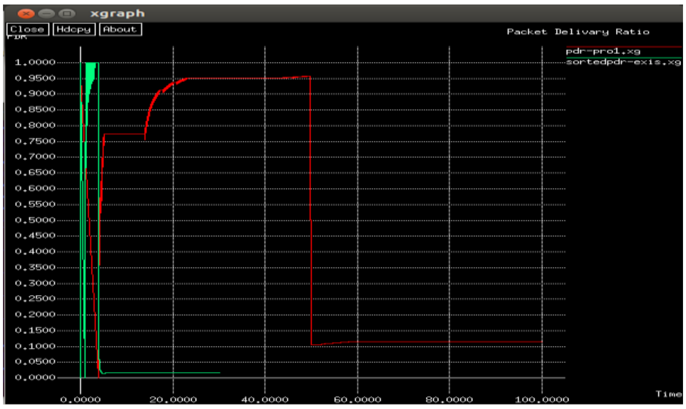

Fig. 8: *Packet Delivery Ratio.*

The above Figure 8 shows that Packet Delivery Ration of the PLAOMDV is greater than the AOMDV protocol.

Throughput

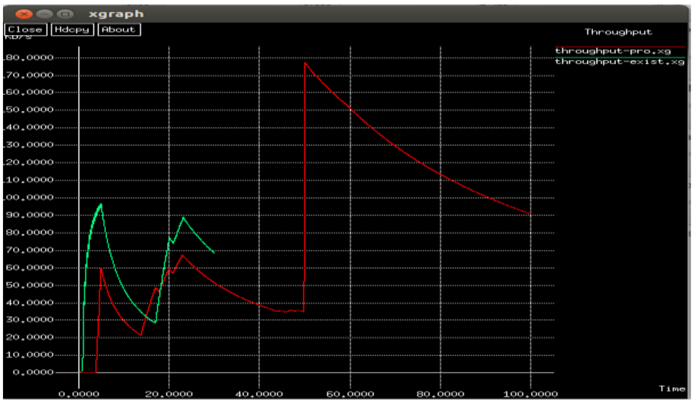

Fig. 9: *Throughput.*

The above graph shows that Throughput of the PLAOMDV is greater than the AOMDV protocol.

Residual Energy

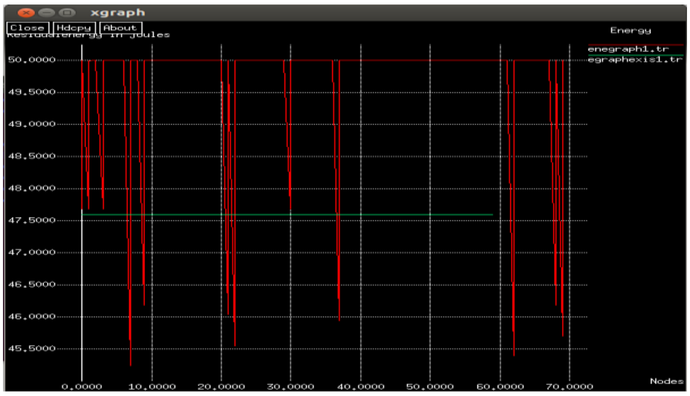

Fig. 10: *Residual Energy.*

The above graph shows that Energy consumption of the PLAOMDV is lesser than the AOMDV protocol.

CONCLUSION

A new routing protocol is proposed. The proposed protocol uses a cost function which considers both residual battery power and present traffic load at a node. Extensive simulation was done using network simulator 2.35 and results are compared with an existing protocol and it is found that the proposed PL-AOMDV performs better in term of higher packet delivery fraction and higher energy efficiency. It has also lower end-to-end delay and lower routing overhead. The proper work can be extending further by using other types of mobility models and at different traffic models.

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