International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 7 (2015) pp. 16885-16897

http://www.ripublication.com

A Highly Adaptive Fault Tolerant Source Routing Protocol For Energy Constrained Mobile Ad Hoc Networks

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Abstract

A mobile ad hoc network (MANET) is a group of mobile wireless devices which are connected with each other in wireless manner in the absence of fixed infrastructure. MANET can form the network in the fashion of “on the fly”. Due to medium is wireless, nodes drain their energy to forward the packet, exchanging network topology information, overhearing packets and also nodes are working in promiscuous mode. To save the nodes from early exhausted state and extends the lifetime of network , Routing protocols play important role and ensure the energy consumption. The existing Optimization algorithms can be done at different layers at different levels and algorithms focused on either improvement of routing schemes or adjust transmission range or control frames or adjust the transmission time interval slot or minimizing flooding of routing packets. This paper discusses about proposed new energy efficient routing protocol MDSR-EBR (Modified Dynamic Source Routing-Energy Based Routing). MDSR-EBR protocol minimizes control overhead with minimum end-to-end delay and Route Acquisition delay.

Keywords- RTS, CTS, Residual Energy, downstream node, Node_Energy_Threshold

1. Introduction
Mobile ad hoc network is an infrastructure-less network where each node is battery operated device and also connected directly or indirectly with other nodes in multi hop fashion [1]. Mobile ad hoc networks can be set up at anywhere at any time

without the need of fixed infrastructure. In MANET, nodes are joining into the network and leaving from the network in an arbitrary manner. Each node will take care of route discovery and route maintenance to set up the communication. Hence, nodes are themselves establish the network in arbitrary manner and more than one path exists between source and destination.

Due to the characteristics of MANET, designing of an efficient and reliable routing protocol for MANET is a challenging task [2]. The aim of this proposed protocol is to maximize network lifetime and free the active nodes from processing of control messages unnecessarily. The proposed protocol efficiently utilizes the control frames such as RTS and CTS at MAC layer and routing overhead (Route Request, Route Reply and Route Error) at Network layer. The aim of this proposed protocol is to maximize network lifetime and free the active nodes from processing of control messages unnecessarily. Also, proposed routing schemes consider parameter such as Node residual energy, Quality of service, network or node lifetime so on.

This paper is organized as follows. Section 2 briefly discusses literature survey of energy efficient routing protocols which improve the performance of DSR Routing protocol. Section 3 presents the algorithm of our proposed MDSR-EBR protocol. Section 4 presents simulation environment model and simulation setup. Section 5 presents simulation results and Section 6 concludes this paper.

2. Literature Review

The goal of Power-aware Source Routing (PSR) [3] is to extend the life time of nodes in the network to avoid the network partition. PSR is extension of Dynamic source routing protocol. In PSR, all nodes in the network except destination compute their link cost and add it to the path cost in the Route Request (RREQ). After this, source node broadcasts RREQ in the network to get the route to destination. If an intermediate node receives a RREQ packet, assign the cost in RREQ packet as min.cost and wait for some time. If it receives any further RREQ packet with the same destination number, it compare the cost in incoming RREQ packet with existing min. cost. If it is minimum value, min.cost is changed to the new value and new RREQ packet is forwarded. If not, new RREQ packet will be dropped. The destination node receives first RREQ packet and wait for some time. If it receives more RREQ packets then selects smallest min.cost from the available RREQ packets and sends RREP to the source when the timer expires.

Energy Saving Dynamic Source Routing (ESDSR) [4] is a modified version of dynamic source routing protocol which combines both the advantages of a transmission power control and load distribution approach to ensure the lifetime of the network. ESDSR works similar to DSR with some modifications. ESDSR uses minimum transmission power control approach to select a route from the set of routes by a source node.

Energy Saving–Dynamic Source Routing (ES-DSR) [5] protocol is the optimization of Dynamic Source Routing protocol. So, ES-DSR is working based on the on-demand routing protocol as well as select the route based on energy of a node. ES-DSR routing protocol adds two new fields such as power aware (‘pa’) and residual energy (‘re’) to the existing DSR Route Request packet and Route Reply packets. These fields are used to mention the energy parameter of current route and minimum residual energy of nodes in the route. ES-DSR selects the route shortest path when there are multiple routes as well as incorporates the idea of CMMBCR and CMRPC while selecting the routes. ES-DSR protocol enables every node maintains a “history list of RREQ” to identify a RREQ message of source node id and request id. ES-DSR routing protocol adds new field maximum power aware (‘max-pa’) field into every entry of history list received route requests. The ‘max-pa’ field is the maximum of ‘pa’ of RREQ packet by same source.

3. Algorithm of MDSR-EBR protocol

MDSR-EBR protocol algorithm:

The Algorithm behinds MDSR-EBR protocol is to avoid the network partition due to node’s energy. MDSR-EBR works as DSR protocol [6] and has a novel idea to deliver the packet without delay. The proposed protocol does not use any additional control messages and tables. MDSR-EBR algorithm was efficiently designed to use the IEEE 802.11 Medium Access Control (MAC) protocol Control packets (RTS,CTS) [7] [8] [9] [10] for knowing the energy level of nodes and Network layer’s Control messages (REQUEST,REPLY, ERROR) only.

As we know, RTS and CTS Packet have limited size. So, the MDSR-EBR Algorithm uses only one bit to know the energy status of next node in active route. MDSR-EBR protocol ensures the mobile nodes to satisfy the Quality of Services (QoS) [11] of networks. In MANET, a node may spend its energy by actively participating in finding out a source route to the destination and also by sending or receiving data or in idle state[12]. But MDSR-EBR algorithm considerably reduces frequent Route Discovery attempts and also minimizes the control messages. MDSR-EBR Algorithm has two major mechanisms such as Route Discovery and Route Maintenance for successful transmission of packets.

- **Route Discovery :**

Source initiates this process for sending data to destination when it has no route to destination. Source node initiates the Route Discovery mechanism by broadcasting Route Request packet by increasing route request packet’s sequence number. This process has two sub process such as

- MDSR-EBR ROUTE REQUEST Generation
- MDSR-EBR ROUTE REQUEST Processing

- **Route Maintenance:**

Source route established from source to destination for data transmission using by previous mechanism and complete source route was stored in Route Record field of each packet. Source node sends RTS packet before sending packet to downstream node which is in active route and waits for CTS packet. Downstream node receives this RTS and processes that packet and sends CTS packet back by stating its energy condition. After receiving CTS packet, node transmits packet and waits for

Acknowledgement (ACK) packet. Downstream node receives the packet and sends ACK packet back to source node. This procedure will be the same for all nodes in the active route from source to destination.

Once active source route has established, nodes in the active route will be down due to energy. Nodes continuously transmit packets without knowing link break and packets will be dropped. MDSR-EBR protocol enables the nodes in active source route updates its energy status in CTS packet before sending to node which sends RTS packet. MDSR-EBR protocol enables node in the active source route to behave intelligently either sending data packet over the established path or to establish the new source route.

MDSR-EBR Route Request Generation & Processing

Algorithm: *Route Request Generation*

Let us assume that

- *S, D is source and destination node.*
- *NODE_ENERGY_THRESHOLD value is 2*
- *E (node) is the remaining energy of a node.*
- *Node is Active node if and only if E (node) > NODE_ENERGY_THRESHOLD otherwise it is a weak node.*

if ((S has packets send to D) || (S does not have route to D in its Route cache))
{
S generates Route request with unique sequence number
S adds its address in route record field of Route request and broadcasts in the network

S waits for Route reply
if (S receives Route reply from either intermediate node or destination node)

S sends packets over the active source route
}

Algorithm: Route Request Processing

if (node is an intermediate node)
{
if (new ROUTE REQUEST)
{
search the route cache for route to D

if (route (D))
Generate ROUTE REPLY and send to S using reverse route

else
Appends its address in route record of route request and forwards route request
}
}

else if (node == D)
{
send ROUTE REPLY with new sequence number to source using reverse route

Intermediate node receives ROUTE REPLY and adds into Route cache and sends packets to destination if it has packets

Intermediate node sends back Route Reply to S
}

else if (!(new ROUTE REQUEST))
{
drop ROUTE REQUEST
}

MDSR-EBR protocol–Route Maintenance

In MDSR-EBR protocol, a node want to send packet to destination then send RTS to next node in active route. MDSR-EBR does not have the policy of broadcasting either 'Hello' message or periodical updating of routing tables to maintain the route. MDSR-EBR protocol efficiently uses the existing control packets to maintain the route and transfer the packet. Based on MDSR-EBR protocol, assume 'NODE_ ENERGY_THRESHOLD' is residual energy of a node and its value is 2. Before sending packet, nodes are in the active route exchanging RTS and CTS to know the status. We will discuss this scenario in two cases.

Case I:

To initiate packet transmission, a node sends RTS to next node in the active route. Next node receives RTS and checks its residual energy level. If energy level is greater than 'NODE_ENERGY_THRESHOLD' value then sends CTS. By receiving CTS, previous node sends packet and waits for ACK. If it receives ACK then that packet is successfully delivered to next node. Packet will be delivered at destination in this fashion.

Case II:

A node sends RTS to next node in the active route. Next node receives RTS and checks its residual energy level before sending CTS. If energy level is less than 'NODE_ENERGY_THRESHOLD' value then it will inform its weak status to Upstream node. To accomplish this, this node will use only one bit of 8 bits size variable named 'cf_energy_st' as shown in Figure 1.

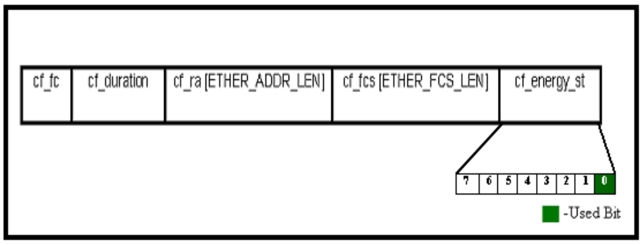

Figure.1- Structure of CTS Frame

where,

cf_fc - frame control
cf_duration - duration time
cf_ra - Receiver address
cf_fcs - frame control sequence
cf_energy_st - Node Residual Energy status

In this case, MDSR-EBR protocol enables nodes to know about downstream node's energy status. If node is energy weak node gets conclusion that next node towards destination will not be used for long time. MDSR-EBR protocol enables downstream node to change 'cf_energy_st' value from '0' to '1' and send CTS to upstream node in the route. By receiving CTS, upstream node concludes that downstream node in the active route is weak and that node will not be used for long time. So, upstream node uses existing route for current packet only and initiates 'Route Discovery' mechanism for remaining packets. So, MDSR-EBR protocol will not drop even a single packet during the packet transmission due to energy parameter. Eventually, MDSR-EBR protocol reduces the control messages such as Route Request, Route Error. The proposed protocol intelligently predicts the link break and establishes the source route in advance with bypassing weak nodes and ensures that the packets delivered at destination with minimum delay compared to existing protocol.

Algorithm:

Node sends RTS frame to downstream node in active route and node receives RTS
if (frame == RTS)
{
Checks its energy level
if (energy level > 'NODE_ENERGY_THRESHOLD')
set cf_energy_st' as 0x00
else if(energy level < 'NODE_ENERGY_THRESHOLD')
set 'cf_energy_st' as 0x01
send CTS and waits for packet
}

Upstream node receives CTS and check 'cf_energy_st' value.
if (frame == CTS)
{
if (cf_energy_st' == 0x00)
send packet over the source route

else if (cf_energy_st' == 0x01)
{
send packet over the source route
upstream node initiates 'Route Discovery' mechanism

if (new route to destination is found)
send packet over new route continuously bypassing weak node.
}
}

MDSR-EBR protocol's Route maintenance mechanism enables the upstream node to take decision that uses the existing route for packet transmission or not. If the next node's energy level is less than 'NODE_ENERGY_ THRESHOLD', then MDSR-EBR activates the upstream node to initiate the Route Discovery mechanism. Simultaneously, upstream node uses the existing route to packet delivery to destination without any delay. After receiving ROUTE REQUEST, either any node or destination will send ROUTE REPLY to source. Once MDSR-EBR found the new route, source will send the packet over new source route free from meeting critical situations like network partition or collision.

4. Simulation Environment Model

To analyze the performance of our proposed MDSR-EBR Protocol, we used Network Simulator-2 (NS-2.34) [13][14] to create a simulation environment. The simulation environment with a size of 3000x 1500 square unit area. The traffic sources were Constant Byte Rate (CBR) with packet size of 512 bytes per packet. Based on the energy consumption model, mobile nodes are equipped with an IEEE Network Interface Cards with 2Mbps. These values correspond to a 2,400 MHz Wave LAN implementation of IEEE 802.11. A wireless network interface [12] can be any one of the following four states such as transmit, receive, idle, sleep and consumes some amount of energy. The number of Connections is 5 in the simulation and source node sends 2 packets per second. To investigate and illustrate the performance of MDSR-EBR protocol under various conditions such as three different routes with different source and destination pairs.

Simulation Setup

We studied the performance of our proposed scheme with a network of 100 number of mobile nodes randomly positioned on a rectangular grid of 3500 meter X 1500 meter area. Radio propagation range for each node uses IEEE 802.11 [12] with 250 m. We have used two-ray ground radio propagation model for simulation. As we have discussed at beginning of this section, proposed MDSR-EBR protocol compared to DSR protocol with parameters as shown in following table.

Parameters	**Value**
Antenna	Omni Antenna
Mobility Model	Random waypoint
Network Interface	Wireless PHY
MAC protocol	IEEE 802.11
Packet size	512 bytes
Number of nodes	100
Transmission Range	250 m
Traffic source	CBR
CBR data rate	2 Pkts/s
Connections	5

5. Simulation Results

End-to-End delay

End-to-End delay is the time taken by a packet travel from source to destination in the network. It includes all delays such as packets waited in send buffer, Route Discovery time and transmission time. An efficient routing protocol should deliver a packet with minimum end-to-end delay. Figure 2 depicts the simulation results of MDSR-EBR and DSR routing protocol for End-to-End delay metric for three source routes. From the figure 2, DSR protocol takes more time to deliver a packet for different source routes compared to MDSR-EBR protocol at the time of any one node is down.

In DSR protocol, a route was established by the source node to transmit a packet and sends packet using source route. As we know, Nodes may lose their energy over a time and a node may be down at some times. DSR protocol ensure node that upstream node try to find out the route to destination to send a packet. DSR protocol makes delay to do local repair once either link or node is down. Failing which, upstream node sends Route Error message back to source node and source node establishes a new route. This delay will be very high in the situations either node are high or node movement speed is high since environment is mobility fashion. As a result, DSR protocol processes these steps and nodes will take considerable amount of time which in turn introduces some delay to deliver a packet to destination. Figure 2 show that, DSR protocol has high End-to-End delay for all three routes compared to MDSR-EBR protocol and very high for Route 2.

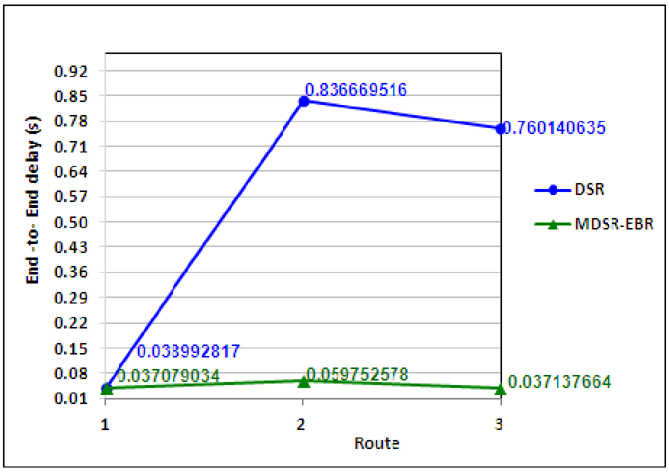

Figure 2- End-to-End delay for diff. source routes

But in Figure 2, MDSR-EBR introduces minimum delay for all routes due to intelligently taking route decisions in advance to deliver a packet. MDSR-EBR protocol ensures node that upstream nodes are continuously monitoring downstream node's energy level by exchanging RTS and CTS Frames. If downstream node's energy goes below 'NODE_ ENERGY_ THRESHOLD' value, then upstream node allows only one packet to travel over the already existing route and also initiates route discovery mechanism to new route at the same time. Then, source node checks its route cache to find the route to destination and permit a packet to use the new route without much delay. As a result, packet introduces minimum delay to reach the destination in either case. Based on figure 2, MDSR-EBR protocol introduces minimum delay compared to DSR protocol for all the three source routes.

Route Acquisition delay

DSR Protocol is a source initiated protocol and establishes a source route whenever there is a demand. Route Acquisition delay is a time taken by a source node to find out route to destination in a situation like either by doing 'Route Discovery' mechanism for sending data to destination or establish a route to destination at 'link break'. This metric is important to consider for former case and most important for second case. Because in first case, packets are in send buffer of source node to send. Source node keeps the packets in its send buffer as safe and continuously try to establish the path and. But in second case, packets are in buffer at intermediate node to reach destination. Intermediate node tries to send packet to destination by introducing more delay. This delay will not be acceptable for sensitive applications like real time data transmission.

An efficient routing protocol should minimize this delay and establishes the route to destination as quickly. Based on simulations conducted, MDSR-EBR outperforms than DSR Routing Protocol. Figure 3 presents the performance of MDSR-EBR and DSR for different source routes.

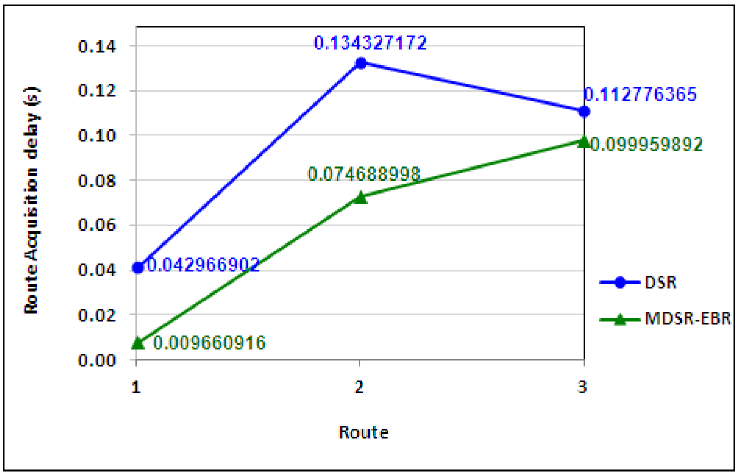

Figure 3- Route Acquisition delay for diff. source routes

Route Acquisition Delay will be more in DSR for all the three routes. But this delay will be more in Route 2. Because, DSR protocol does not have intelligence to know the conditions like 'link break' or 'node down' in advance and initiates Route Discovery process after failure of local repair. So, DSR introduces more delay find out the route to destination. MDSR-EBR protocol monitoring the nodes residual energy and establish the route in advance before packets are placed in intermediate nodes for route to destination node. MDSR-EBR consumes minimum delay to find out the route from source to destination compared to DSR Routing Protocol. The delay of MDSR-EBR is minimum invariably any source to destination pairs.

Number of packets dropped

An efficient routing protocol should achieve maximum packet delivery ratio by means of not dropping a single packet at any time. In this section, we will discuss about number of packets dropped by a protocol. We will consider the time that when a node switch over to the new route when active node is down due to energy. This section explains simulation results obtained for MDSR-EBR protocol and compare it with results of DSR protocol. Figure 4 shows comparison results of number of packets dropped between DSR & MDSR-EBR at the time of switching a new route.

The Packet Delivery Ratio of MDSR-EBR is higher than DSR in this scenario. In Figure 4, we can observe the efficiency of MDSR-EBR protocol and DSR protocol for three different active source routes. These different source routes are comprises of different source destination pairs using different nodes. We should investigate the number of packets dropped not for one route but also for other routes. If a route with more number of nodes, link failure may increase and hence more number of packets drops.

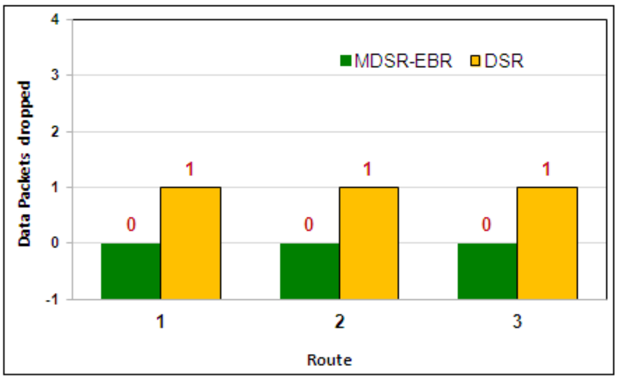

Figure 4- Packets dropped for diff. source routes

Figure 4 depicts that number of Packets dropped of DSR is high when active routes' node is down. If a node in the active route is down due to energy, then DSR protocol will initiate the Route discovery mechanism for new route. Meanwhile, a packet sent by source node is dropped because of link break. DSR drops the data packets whenever the nodes or link in active route break. In DSR, nodes are adjacent to link break send RERR to source about this link break and let source node initiate the action to send the packet. Moreover, the packets in the send buffer will be dropped due to timeout.

But in MDSR-EBR, node in the active source route uses IEEE 802.11 RTS, CTS Frame methodology before initiating packet transmission. MDSR-EBR enable node in the active source route that a node sends RTS frame to downstream node towards destination node. Downstream node sends back CTS Frame to upstream node by mentioning its energy status. Upstream node receives CTS Frame and continuously monitors the next node's energy. When next node's energy goes below 'NODE_ENERGY_THRESHOLD' value, then upstream node permit only one over using existing route and immediately initiate the Route Discovery process to discover the new route. Source node begins to send packet over the new route without dropping of a single packet during this critical situation. From the figure 4, MDSR-EBR Protocol has zero packet drops and DSR Protocol is minimum of one packet dropped for three different active source routes.

Routing Load

An efficient routing protocol deliver packets to destination with minimum control overhead. Routing protocol ensures nods that to use the control overhead at minimum level to deliver the packet. In wireless networks like Mobile ad hoc networks, if this metric is high then these packets will introduce some severe consequences such as network busy, congestion and stale route information. We conducted simulations to estimate the routing load such as IEEE wireless 802.11 RTS and CTS Frames at MAC Layer

RTS and CTS Control Frames

As shown in Figure 5, DSR protocol will use more control frames to packet transmission to solve ‘link error’ due to energy drained node. DSR protocol does not effectively use RTS and CTS Frames and will induce considerable routing overhead. MDSR-EBR protocol effectively uses RTS and CTS frames and consumes minimum routing load compared to DSR at various routes. From the figure 5, Routing load of DSR drastically high compared to MDSR-EBR in all three routes such as route 1, route 2 and route 3. MDSR-EBR efficiently uses existing RTS and CTS frames to know the downstream node’s energy and avoid ‘link break’ due to energy cause which in turn reduces control overhead. Figure 5 depicts that, MDSR-EBR protocol consumes minimum overhead compared to DSR protocol in all the three routes specifically at route 2.

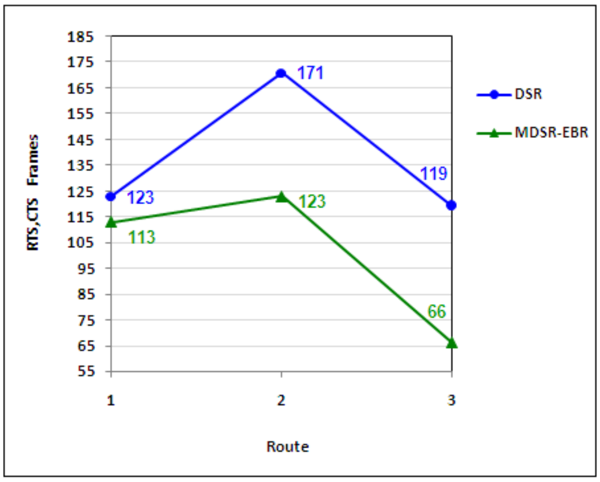

Figure 5- RTS and CTS Frames for diff source routes

6. Conclusion

This paper presented a new energy efficient routing scheme for mobile ad hoc networks that scheme utilizes MAC layer control packets. MDSR-EBR protocol enables source node to establish the source route and initiate the Route discovery mechanism before the link break while packets sending. MDSR-EBR protocol has designed in such a way that node sends the packet over the source route as well as intensively observes energy of next node towards the destination. Further, MDSR-EBR protocol find out the new source route and sends the packets over new route in advance without using either any additional control messages or tables. Simulation results evident that MDSR-EBR protocol outperforms DSR protocol for all different routes irrespective of source and destinations.

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