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Performance Comparisons of Different Multicast Routing Protocols: ODMRP and AM Route

Chandra Naik.M*
Asst.Professor
Department of CSE,
L. B.R College of Engineering,
Mylavaram, Krishna (dt)
Andhra Pradesh
srichandra2007@gmail.com

B.G.Obula Reddy
Asst.Professor
Department of I.T
L. B.R College of Engineering
Mylavaram,Krishna(dt)
Andhra Pradesh
gbobulareddy2007@gmail.com

Dr. S. Sai Satyanaraya Reddy
Prof. & H.O.D (C.S.E)
Department of CSE
L. B.R College of Engineering
Mylavaram,Krishna (dt)
Andhra Pradesh
Saisn90@gmail.com

Abstract: Multicasting can be efficiently supported a variety of applications that are characterized by a close degree of collaboration, typical for many ad-hoc applications currently envisioned. Within the wired network, well-established routing protocols exist to offer an efficient multicasting service. As nodes become increasingly mobile, these protocols need to evolve to similarly provide an efficient service in new environment. This paper discusses the performance of two proposed multicast protocols for adhoc networks: ODMRP and AMRoute. AMRoute as logical core and are responsible for initiating and managing the signaling component of AMRoute such as detection of group members and tree setup. Logical cores differ significantly from those in CBT and PIM-SM, since they are not a central point for data distribution and can migrate dynamically among number of nodes. Simulation results (using NS-2) specify that AMRoute signaling traffic remains at relatively low level for typical group sizes. ODMRP maintains mesh based on softstate. The results show that in many scenarios ODMRP achieves a higher packet delivery ratio, but results in much higher overheads.

Keywords: - ODMRP, AMRoute, MANETs, NS2, Multicasting.

I. INTRODAUCTION

A mobile ad hoc network is a type of wireless networks. This type depends on the mobile nodes and no infrastructure in such type. There are no routers, servers, Access points or cable. Nodes can move freely and in arbitrary ways, so it may change its location from time to time. Each node may be sender or receiver, and any node may work as a router and do all router functions. It is the meaning that it can forward packets to other nodes. Many applications of MANET's are implemented, used until today like in meeting conferences; military operations; search and rescue operations, all of them are examples of MANET networks. Multicasting in wireless ad – hoc network is a hot topic in recent years. By multicasting, we mean the transmission of packets from a source or a group of sources to a group of one or more hosts that are identified by a single destination address. Multicasting greatly reduces the transmission cost when sending the same packet to multiple recipients. It can improve the usage of wireless links by sending multiple copies of data packets using inherent broadcast behavior of wireless transmission though reducing transmission overhead and power consumption is a very challenging part in multicasting. There are many applications where one-to-many and many-to-many transmissions are required. The multicast service is employed in areas of collaborative work such as in rescue operations, battlefields video conferencing etc. Protocols used in static networks, for example, CBT, DVMRP, PIM do not perform well in dynamic environment. The approach to do multicasting is basically classified into tree-based and mesh-based approaches. A tree- based multicast routing protocol maintains either a single shared tree for all the transmissions or different trees from different sources to all the destinations of a multicast group. Tree-based routing protocols have only single path from source to destinations, so the broken links need to be repaired. On the other hand, mesh-based routing protocol maintains mesh of the connected components of the network and therefore, has multiple paths from sources to multicast destinations. This reduces repairing overhead due to presence of alternate paths available in the network. Mesh-based routing protocols lead to congestion under the conditions of high traffic load which can result in low packet delivery ratio. This paper summarizes the simulation techniques and analysis of some of the multicast protocols like ODMRP and AMRoute in MANET environment. This paper specifies as follows. A general description of MANET is depicted in section II. The operation of the two protocols, we studied ODMRP [2][6] in III and AMRoute[6] in IV are summarized . The simulations are presented in the section V. We present results in the section 5 and conclude with section VI.

II. GENERAL DESCRIPTION OF MANETS

A MANET consists of mobile platforms such as a router with multiple hosts and wireless communications devices, herein simply referred to as "nodes" - which are free to move about arbitrarily. The nodes may be located in airplanes, ships, trucks, cars, perhaps even on people or very small devices, and there may be multiple hosts per router. A MANET is autonomous system of mobile nodes. The system may be operate in isolation or may have gateways to and interface with a fixed network. In latter operational mode, it is typically envisioned to operate as a "stub" network connecting to a fixed internetwork. Stub networks carry traffic originating at destined for internal nodes, but do not permit exogenous traffic to "transit" through the stub network. MANET nodes are equipped with wireless transmitters and receivers using antennas which may be omni directional (broadcast), highly-directional (point-to-point), possibly steerable, or some combination thereof.

A. ***MANETs have Several Salient Characteristics:***

(a) Dynamic topologies: Nodes are free to move arbitrarily thus, the network topologywhich is typically multihop - may change randomly and rapidly at unpredictable times, and may consist of both bidirectional and unidirectional links.

(b) Bandwidth-constrained variable capacity links: Wireless links will continue to have lower capacity than their hardwired counter parts. In addition to the realized throughput of wireless communications after accounting for the effects of multiple access, fading, noise, and interference conditions, is often much less than a radio's maximum transmission rate.

(c) Energy constrained operation: Some or all of the nodes in a MANET may rely on batteries or other exhaustible for their energy. For these nodes the important system design criteria for optimization may be energy conservation.

(d) Limited Physical Security: Mobile wireless networks are more prone to physical security threats than are fixed cable networks. The increased possibility of eavesdropping, spoofing, and denial of service attacks should be considered. Existing link security techniques are applied within wireless networks to reduce security threats. As benefit, the decentralized nature of network control in MANETs provides additional robustness against the single points of failure of more centralized approaches.

Issues in Providing Multicast in MANET Well established routing protocols do exist to efficient multicasting service in conventional wired networks. These protocols, having been designed for fixed networks, may fail to keep up with node movements and frequent topology changes in a MANET. As nodes become increasingly mobile, these protocols need to evolve to provide efficient service in the new environment. Therefore, MANET, which completely lacks infrastructure, appears less promising. Host mobility increases the protocol overheads substantially. Rather, new protocols are being proposed and investigated that take issues such as topological changes into consideration. Moreover, the nodes of a MANET rely on batteries; thus routing protocols must limit the amount of control information passed between n nodes.

The majority of applications are in areas where rapid deployment and dynamic reconfiguration are necessary and a wireline network is not available. These include military battlefields, emergency search and rescue sites, and conventions where participants share information dynamically using their mobile devices. These applications lend themselves well suit to multicast operation. In addition, within a wireless medium, it is even more crucial to reduce transmission over-head and power consumption. Multicasting improve the efficiency of the wireless links, when sending multiple copies of messages, by exploiting the inherent broadcast property of the wireless medium when multiple mobile nodes are located within the transmission range of a node. However, besides the issues for any ad hoc routing protocol listed above, wireless mobile multicasting faces several key challenges. Multicast group members can move, thus precluding the use of a fixed multicast topology. Transient loops may form during reconfiguration of distribution structure as a result of the mobility. Therefore, the reconfiguration scheme should be kept simple to maintain the channel overhead low. As we can see, providing efficient multicasting over MANET faces many challenges, including dynamic group membership and constant update of delivery path due to node movement.

III. ON-DEMAND MULTICAST ROUTING PROTOCOL (ODMRP)

A. ODMRP [2][6] (On-demand Multicast Routing Protocol) [6] is mesh based, and uses ,a rwarding group concept (only a subset of nodes forwards the multicast packets). A soft state approach taken in ODMRP to maintain multicast group members. No explicit control message required to leave the group.

In ODMRP,a group membership and multicast routes are established and updated by the source on demand. When a multicast source has packets to send, but no route to the multicast group, it broadcasts a Join-Query control packet to the entire network. This Join-Query packet is periodically broadcast to refresh the membership information and update routes.

When an intermediate node receives the Join-Query packet, it stores the source ID and the sequence number in its message cache to detect any potential duplicates. The routing table is updated with the appropriate node ID (that is backward learning) from which the message was received for the reverse path back to the source node. If the message is not a duplicate and the Time-To-Live (TTL) is greater than zero, it is rebroadcast.

When the Join-Query packet reaches a multicast receiver, it creates and broadcasts a Join Reply to its neighbors. When a node receives a Join Reply, it checks if the next hop node ID of one of the entries matches its own ID. If it does, the node realizes that it is on the path to the source and thus is part of the forwarding group and sets the FG_FLAG (Forwarding Group Flag). It broadcasts its own Join Table built upon matched entries. The next hop node ID field filled by extracting information from its routing tables. In this way, each forward group member propagates the Join Reply until it reaches the multicast source via the selected path (shortest). This whole process constructs (or updates) the routes from sources to receivers and builds a mesh of nodes, the forwarding group, After the forwarding group establishment and route construction process, sources can multicast packets to receivers via selected routes and forwarding groups. While it has data to send, the source periodically sends Join-Query packets to refresh the forwarding group and routes. When receiving the multicast data packet, a node forwards it only when it is not a duplicate and the setting of the FG_FLAG for the multicast group not expired. This type of procedure minimizes the traffic overhead and prevents sending packets through stale routes.

In ODMRP, no explicit control packets need to be sent to join or leave to the group. If a multicast source wants to leave the group, it simply stops sending Join-Query packets since it does not have any multicast data to send to the group. If a receiver no longer wants to receive from a particular multicast group, it does not send the Join Reply for intended group. Nodes in the forwarding group are demoted to non forwarding nodes if not refreshed before they timeout.

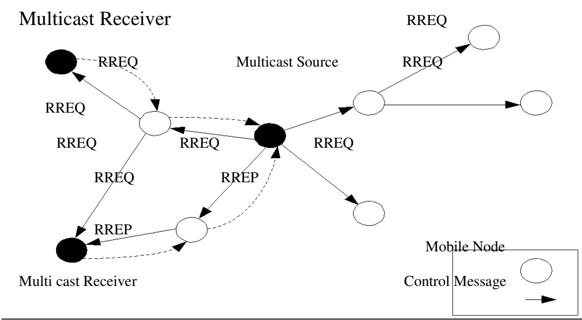


Figure: 1 ODMRP Mesh Creation

IV. AD HOC MULTICAST ROUTING PROTOCOL (AMROUTE)

This document describes the Ad hoc Multicast Routing protocol (AMRoute) [3][10], which enables the use of IP Multicast in MANETs. Existing multicast protocols do not work well in MANETs as the frequent tree reorganization can cause excessive signaling overhead and frequent loss of data-grams. The tree reorganization in MANETs is more frequent as compared to conventional static networks, since the multicast protocols have to respond to network dynamics in addition to group dynamics. AMRoute solves this problem by tracking group dynamics only; the underlying unicast routing protocol is relied upon for tracking network dynamics, which it is required to do anyway. AMRoute emphasizes robustness even with rapidly changing membership or highly dynamic networks; it does not attempt to provide the absolute minimum bandwidth or latency guarantees in a given topology. The two key features of AMRoute that make it robust and efficient in MANETs are:.

(a) User-multicast trees, where replication and forwarding is only performed by group members over unicast tunnels, ,,
(b) Dynamic migration of core node according to group membership and network connectivity...

The user multicast tree includes the group senders and receivers as its nodes. Each node aware of its tree neighbor's only and forwards data on the tree links to its neighbors. Multicast state is maintained by the group nodes only, and is not required by other network nodes. In fact, AMRoute does not even require non-member nodes to sup-port any IP multicast protocol. The elimination of state in other network nodes clearly saves node resources, especially when compared with broadcast-and-prune native multicast protocols that require per source and per group state at all network nodes. More importantly, especially in highly dynamic ad hoc networks, user-multicast trees also eliminate the need to change the tree as the network changes. Neighboring tree nodes are inter-connected by IP-in-IP tunnels, similar to the approach adopted for connecting multicast routers on the MBONE. Consequently, assuming unicast connectivity is maintained among member nodes, the AMRoute distribution tree will continue to function despite network changes.

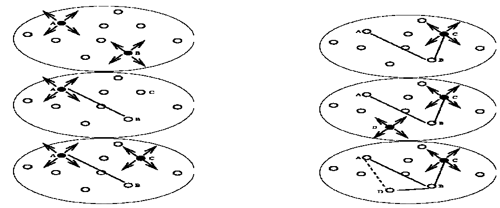


Figure2. Formation of Mesh and Tree (1)
Figure 3. Formation of mesh and tree (2)

Nodes A and B simultaneously join a group, elect themselves as logical cores and start transmit-ting JOIN_REQ with expanding TTL. When either of them receives the other's JOIN_REQ, node B loses the core resolution procedure and is relegated to being a non-core node. There now exists a tree link (tunnel) connecting nodes A and B. Node C now joins the group, elects itself as a logical core, and starts transmitting JOIN_REQ with increasing TTL. Node B is closer to node C, and so will receive the JOIN_REQ from C before it reaches node A. A mesh link will be formed between B and C. The core resolution mechanism at B will determine that C is the winner. B will forward TREE_CREATEs from C to A. A will also deter-mine that C wins, and relegate itself to non-core node. There now exists tree links from C to B and from B to A. Eventually JOIN_REQ from C will reach A, but since A is on the same mesh as B, it ignores this JOIN_REQ. This step is a tradeoff between reducing dynamic tree changes that can result in packet loss, and optimizing the tree structure. A new group member D can now join this mesh by transmitting JOIN_REQ, which are received at B. The core resolution at B results in C remaining the core, and D is grafted onto the tree at B. The JOIN_REQ from D may also have been received by A, but D may receive the TREE_CREATE from B before getting it from A. So the mesh link between A and D does not get converted to a tree link.

A. *State Diagram:*

AMRoute simplicity is illustrated by the state diagram in figure 4, which shows the three main AMRoute states and state transitions (with causing events and resulting actions). The states can be interpreted as follows:,

(a) NON-MEMBER – a node does not belong to the multicast group. ,
(b) CORE: a node currently recognizes by itself to be a logical core.
(c) NON CORE: a node is currently a non-core member in the multicast group,

A node transitions from the NON_MEMBER state when an application on the node joins a group and transitions to it from all other states when the application leaves the group. A node transitions to the CORE state when an application joins a group, and by default sets itself to be a logical core. A logical core sends out periodic JOIN_REQ messages and TREE_CREATE messages. A logical core becomes a non-core node if it loses in the core resolution procedure that ensues when it receives a TREE_CREATE message from another core belonging to the same multicast group, which means the other core becomes the new core. A non-core member expects periodic TREE_CREATE messages from a logical core. If it does not receive one within the specified period, the associated timer expires and the node resets itself to be a core.

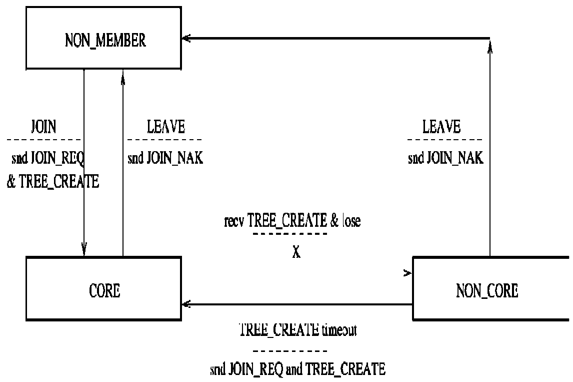


Figure 4. AMRoute state diagram

B. *Qualitative Comparison of ODMRP and AMRoute*

The two on demand protocols share salient characteristics. In particular, they both discover multicast routes only in the presence of data packets to be delivered to a multicast destination. Route discovery in either protocol is based on request and reply cycles where multicast route information is stored in all intermediate nodes on the multicast path. However, there are several important differences in the dynamics of the two protocols, which may give rise to significant performance differences.

First, AMRoute uses a shared bi-directional multicast tree while ODMRP maintains a mesh topology rooted from each source. In AMRoute, the tree is based on hard state and any link breakages force actions to repair the tree. A multicast group leader maintains up to date multicast tree information by sending periodic group hello messages. ODMRP provides alternative paths and a link failure need not trigger the recomputation of the mesh, broken links will time out (soft state). Routes from multicast source to receivers in ODMRP are periodically refreshed by the source. However, a bi-directional tree is more efficient and avoids sending duplicate packets to receivers. Also, depending on the refresh interval in ODMRP, the control overhead from sending route refreshes from every source could result in scalability issues.

Second, ODMRP broadcasts the reply back to the source while AMRoute unicasts the reply. By using broadcasts, ODMRP allows for multiple possible paths from the multicast source back to the receiver. Since AMRoute unicasts the reply back to the source, if an intermediate node on the path moves away, the reply is lost, and the route is lost. However, a broadcasted reply requires intermediate nodes not interested in the multicast group to drop the control packets, resulting in extra processing overhead.

Third, AMRoute does not activate a multicast route immediately while ODMRP does (unless mobility prediction is enabled). In AMRoute, a potential multicast receiver must wait for a specified time allowing for multiple replies to be received before sending an activation message along the multicast route that it selects.

V. SIMULATION-BASED COMPARISON

The performance simulation environment used is based on ns-2, a network simulator that provides support for simulating multi-hop wireless networks complete with physical and IEEE 802.11 MAC layer models.

Experimental Setup and Performance Metrics the simulated environment consists of 50 wireless mobile nodes roaming in a 1000 meters x 1000 meters flat space for 900 seconds of simulated time. The radio transmission range is 260 meters. A free space propagation channel assumed. Group cenario files determine which nodes are receivers or sources and when they join or leave a group. A multicast member node joins the multicast group at the beginning of the simulation (first 30 seconds) and remains as a member throughout the whole simulation. Hence, the simulation experiments do not account for the overhead produced when a multicast member leaves a group. Multicast sources start and stop sending packets in the same fashion (four packets per second, each packet has a constant size of 512 bytes).

Each data point represents an average of at least five runs with identical traffic models, but different randomly generated mobility scenarios. For fairness, identical mobility and traffic scenarios are used across the compared protocols.

One multicast group used for all the experiments. Each mobile node moves randomly at a preset average speed according to a random waypoint model. Here, each node starts its journey from a random location to a random destination with a randomly chosen speed (uniformly distributed between 0 – some maximum speed). Once the destination reached, another random destination is targeted after a pause. By varying the pause time, the relative speed of the mobile are affected. In our experiments the pause time was always set to zero to create a harsher mobility environment. The maximum speeds used were chosen from between 1m/s to 20m/s.

The following mesures were used in comparing the protocol performance. The metrics were derived from ones suggested by the IETF MANET working group for routing/multicast protocol evaluation [3]:

A. Packet Delivery Ratio: The ratio of the number of packets actually delivered to the destinations versus the number of data packets supposed to be received. This number presents the effectiveness of a protocol in delivering data to the intended receivers within the network.

B. Number of data packets transmitted per data packet delivered: “Data packets transmitted” is the count of every individual transmission of data by each node over the entire network. This count include transmissions of packets that are eventually dropped and retransmitted by intermediate nodes. ,

C. Number of control packets transmitted per data packet delivered: This measure shows the efficiency overhead in control packets expended in delivering a data packet to an intended receiver.

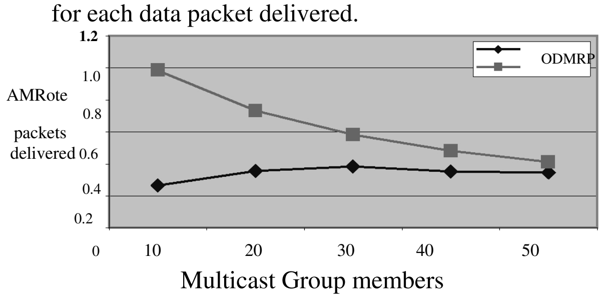
D. Number of control packets and data packets transmitted per data packet delivered: This measure tries to capture a protocol’s channel access efficiency, as the cost of channel access is high in contention-based link layers.

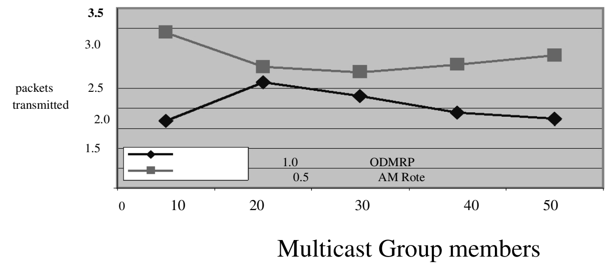
To test the protocols, we performed a number of experiments to explore the performance of ODMRP and AMRoute with respect to a number of parameters: number of senders, node mobility, and multicast group size.

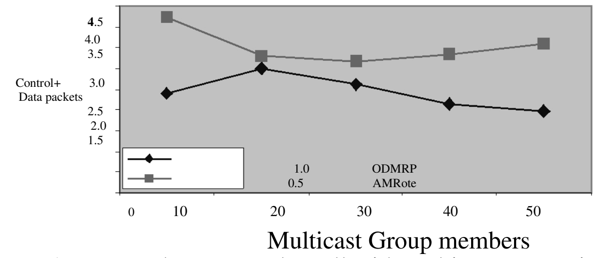
(a) Number of Senders: We varied the number of senders in the multicast group in order to evaluate the protocol scalability with respect to source nodes and the resulting effective traffic load. ODMRP is,over 75% more effective than AMRoute in data delivery ratio as the number of senders is increased from one to twenty. In terms of packet transmission ratio though, at twenty senders, AMRoute sends 59% fewer packets for each data packet delivered than ODMRP. As well, AMRoute sends 59% fewer control overhead packets than ODMRP for each data packet delivered as the number of senders reaches twenty. For both control and data transmissions, AMRoute sends 90% less packets than ODMRP for every packet delivered as the number of senders reaches twenty.We observed that ODMRP in particular does not scale well for packet delivery ratio as the number of senders increases along with the effective traffic load. In ODMRP, every source node will periodically send out route requests through the network. When the number of source nodes becomes larger, the effect of this causes congestion in the network and the data delivery ratio drops significantly. AMRoute, on the other hand, maintains only one group leader for the multicast group that will send periodic Group Hellos through the network. In this manner, it is more scalable than AMRoute.

(b) Node Mobility:We are varied the mobility to evaluate the ability of the protocols to deal with route changes. ODMRP is over 104% more effective than AMRoute in data delivery ratio as the maximum node speed is increased from 1m/s to 20m/s. In terms of packet transmission ratio, ODMRP sends 40% less packets for each data packet delivered at high mobility (>15m/s). As well, for control overhead, ODMRP decreases by up to 74% less than AMRoute for each data packet delivered as the mobility reaches 20m/s. For both control and data transmissions, ODMRP sends 48% less packets than AMRoute for every packet delivered. We see that AMRoute is generally unaffected by increases in mobility, while ODMRP is more sensitive to changes in mobility. The mesh topology of ODMRP allows for alternative paths thus making it more robust than AMRoute. AMRoute relies on a single path on its multicast tree, and must react to broken links, by initiating repairs.

(c) Multicast Group Size:For the third set of simulations, we varied the number of members in the multicast group in order to evaluate the protocol scalability with respect to multicast group size. In Figure 3, ODMRP is 270% to 20% more effective than ODMRP in data delivery ratio as the number of multicast group members is increased from ten to fifty. In terms of packet transmission ratio, in Figure 4, ODMRP sends up to 48% less packets for each data packet delivered. As well, for control and data transmissions, from Figure 5, ODMRP decreases by up to 46% less than AMRoute for each data packet delivered.







AMRoute does not scale well with multicast group size. There is a drastic decline in packet delivery ratio as the multicast group increases to fifty members. This can be attributed to collisions that occur from the frequent broadcasts through the network. Despite the poor data delivery ratio, we see that ODMRP scales better in terms of overall control and data transmissions for every packet delivered.

VI. CONCLUSION

Multicasting can efficiently support a wide variety of applications that are characterized by a close degree of collaboration, typical for many MANET applications currently envisioned. Within the wired network, well-established routing protocols exist to offer efficient multicasting service. As nodes become increasingly mobile, these protocols need to evolve to provide similarly efficient service in the new environment. Adopting wired multicast protocols to MANETs, which are completely lacking in infrastructure, appears less promising. ODMRP belongs to the mesh based protocol and AMRoute belongs to tree based protocol. These protocols, having been designed one for tree based networks [AMRoute], may fail to keep up with node movements and frequent topology changes due to host mobility increase the protocol overheads substantially. Rather, the ODMRP protocols that operate in an on-demand manner are being proposed and investigated. Existing studies and our results show that tree-based on-demand protocols are not necessarily the best choice. In a harsh environment, where the network topology changes very frequently, mesh-based protocols seem to outperform tree-based protocols, due to the availability of alternative paths, which allow multicast datagrams to be delivered to all or most multicast receivers even if links fail. Much room still exists to improve protocol performance (as measured by the packet delivery ratio) while reducing the associated overhead.

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