Indian Journal of Science and Technology, Vol 9(S1), DOI: 10.17485/ijst/2016/v9iS1/94988, December 2016
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

A Study on Dynamic Address based Routing Protocols for Mobile Ad Hoc Networks

Sanjeev Kumar Prasad[1]*, Karamjit Bhatia[2] and Tripti Sharma[3]

[1]Ajay Kumar Garg Engineerng College, Ghaziabad – 201009, Uttar Pradesh, India; sanjeevkps2002@gmail.com
[2]Gurukula Kangri Vishwavidyalaya, Haridwar – 249404, Uttarakhand, India; karamjitbhatia@yahoo.co.in
[3]Inderprastha Engineering College, Ghaziabad – 201004, Uttar Pradesh, India; tr_sharma27@gmail.com

Abstract

Objective: To present the operational features and to make a comparative study of four major dynamic addresses based routing protocols of mobile ad hoc networks. Further, we discuss the strengths and challenges in dynamic address routing protocol designs. **Methods/Statistical Analysis:** In this paper, we have used packet forward strategy to compare four routing protocols and we have also discussed the operational features of dynamic based routing protocols through their network architecture. **Findings:** Dynamic addressing scheme has been proposed which uses the routing address instead of the node address for selecting the routes in the network. In this scheme, mobile nodes having dynamic routing address is done i.e., its change with movement of the node to reflect the node's position in the network topology. **Application/Improvements:** This study provides new challenges and future research directions to enhance the scalability of MANET using dynamic address based routing protocol.

Keywords: Dynamic Address, Distributed Hash Table, Packet Forwarding Strategy, Scalability

1. Introduction

In Mobile Ad hoc Networks (MANETs) the network topology changes frequently and unpredictably. The connectivity among the nodes may change with time which leads to link breakage and invalidation of end-to-end route. As the network size increases, the transmission performance may be degraded due to network congestion and network splitting. The mobility and density factors also influence the scalability of the MANET routing protocols. Scalability is an essential requirement in the use and deployment of MANETs for this technology to reach to its extreme potential. MANET technology is receiving a lot of interest but it has yet to grow to its fullest extent. Most current research in MANETs focus on performance, energy and power-consumption related issues and less on scalability. The main reason behind the lack of scalability attention is that the existing protocols are based on the flat or static addressing scheme. With scalability as a partial objective, some efforts have been made in the direction of clustering and hierarchical routing[1–3].

MANETs routing protocols are classified into three categories on the basis of their Network Structure:

- Flat Network Structure routing protocols.
- Cluster Network Structure routing protocols.
- Hierarchy Network Structure routing protocols.

The flat and cluster network structure routing protocols are based on static address scheme whereas hierarchical network structure routing protocols are based on static as well as dynamic address schemes. Figure 1 shows the classification of routing protocols. In the routing protocols of a flat network structure, every node plays the same role[4]. Two classes of routing protocols can be further considered that are: Proactive and Reactive; Proactive is a table driven approach while reactive is a source initiated approach. Basically, this classification is based on the responses of the routing protocols towards the topology of the network. The flooding of routing information in the network and the route discovery consumes a lot of bandwidth of channel. Therefore, flat routing protocols create traffic overhead in the network resulting in low

*Author for correspondence

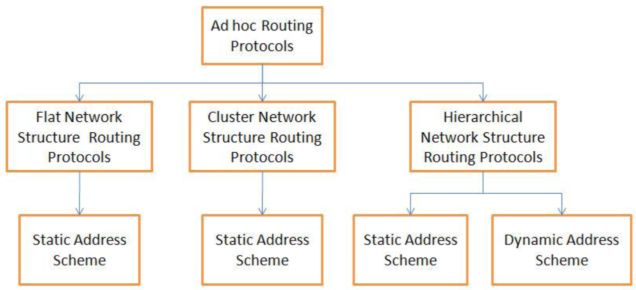

Figure 1. Classification of ad hoc routing protocols.

scalability[5]. These protocols work well in small-scale networks, but it impairs the quality of the performance as the network grows large[6], i.e., they fail to meet a desirable requirement - the scalability.

Besides the flat network structuring, clustering is an alternative way of structuring the network[4]. In this methodology, mobile nodes take different roles, such as anchors, cluster heads, root nodes, and gateway nodes based on the structure used and the organization of nodes in the network[7]. The basic motivation behind development of protocols based on cluster or hierarchical structure is their potential to exhibit better performance considering the scalability issue. The nodes are grouped to make clusters[8–11], so that the route discovery packets can be forwarded by selected nodes only, so as to reduce the redundant traffic in the network[4]. However, the highly dynamic and unstable nature of mobile ad hoc network makes it difficult for the cluster based routing protocol to divide a mobile network into groups and determination of cluster heads for each cluster.

Another solution for enhancing routing scalability is to adopt dynamic addressing scheme[4]in hierarchical network structure. In this scheme a node has two addresses; the address of the route and the address of the node in the network. When the node moves across the network the routing address of the node also changes to reflect the location of the node. The node address is a *global unique number* that remains same till the node is live in the network. The prime issue in this scheme is the strategy to map the identity of node and its address of routing. Thus, there is a need of a *dynamic association* among node location and identification which demands to accomplish this association with a specific mechanism. For this**,** Distributed Hash Table (DHT)[12] has been found suitable and hence adopted as a scalable structure to be responsible for a number of tasks comprising sharing of information, services related to location, and identification which does not based on location but supports to construct many self-establishing systems. The key idea of distributed hash table is to use a hash function to distribute node's location information among the roaming positions throughout the network. The Stability analysis of distributed hash table based multi-path routing protocol under group-based mobility models and entity-based mobility models in MANETs is presented in the paper[13] and further dynamic address translation scheme is presented in the paper[14].

In this paper, we present an overview of the system architecture and packet forwarding strategy in dynamic address based routing protocols. This study focuses on four major dynamic addresses based routing protocols: DART[15], ATR[16], ODR[17], and M-DART[18] which maintain tree (hierarchical) topology in the network and their dynamic addressing scheme is provided by DHT. An overview of packet forward strategy of these routing protocols is briefly discussed. Finally, the strengths of these protocols and important challenges towards research that are vigorous to be considered to attain scalability in mobile ad hoc networks are given.

2. System Architecture of Dynamic Address based Routing Protocols

In this section, the functional description of Dynamic Address based Routing Protocol (DARP) is given briefly. In DARP, the network assigns logical addresses (routing address) to each node on the basis of the node location in network topology. DARP is capable to implement hierarchical routing in a feasible way and reduces the routing state information maintained by each node. The mapping between node addresses and logical addresses is provided by a DHT.

2.1 Network Address Structure

All four routing protocols stated above make the tree topology (*complete binary tree)* in the network. The total number of levels in this tree is $l+1$, where l (bits) is the length of address of leaf node. Other levels share the address prefix of $l - k$ bits represented by a set of leaves. The node with the marker 11X is a level-1 subtree which signifies the leaves 110 and 111. Figure 2 shows the hierarchical network 3-bit addressing scheme and topology. Each leaf has l siblings.

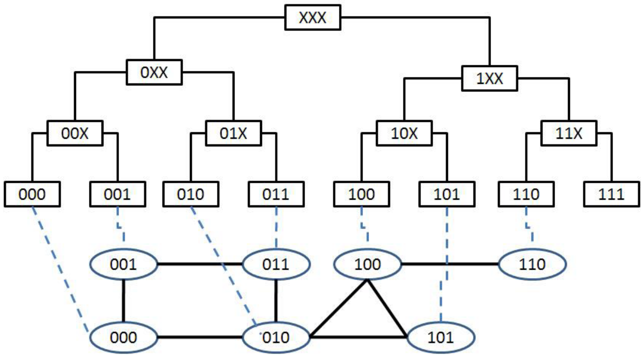

Figure 2. Hierarchical network 3-bit addressing scheme and topology.

To route the data packets every node maintains relationship among its siblings in routing table. *Level-k* sibling of a given address to be the sibling (sibling as leaves, or subtrees, that have the same immediate parent) of the *Level-k* subtree to which a given address belongs. In Figure 2, the siblings of leaf node 000 are 001, 01X and 1XX. In Figure 2, actual physical links are represented by bold lines and dotted lines show the interface between node and routing address.

2.2 Dynamic Address Allocation through DHT

Before the dynamic address allocation of nodes (n), the network computes the level of tree (l+1) and routing address length (l) from equation $l = \log_2 n$. In dynamic address allocation in the multi-level hierarchical network, a node uses its neighbors periodic routing updates (contain the sibling entries) to find an unoccupied virtual routing address, when it joins an existing network.

In detail, each null entry in a neighbor's routing update indicates an empty subtree. This subtree represents a block of free and valid routing addresses[19].

Figure 3 demonstrates the address allocation process for a 3-bit address space in network and the address allocation sequences of nodes. Node L begins with the address [000]. When mobile node M joins the network via L, it receives routing update packet from node L and observes that for the subtree [1xx], L has a null entry in its routing table, and selects the address [100]. Likewise when N connects the network by joining to M, N prefers the address [110]. After that, when O joins the network through L, L's [1xx] routing entry is occupied. Nonetheless, for the sibling [01x], still there is no routing entry and therefore, O node takes the address [010]. Finally, P joins the network

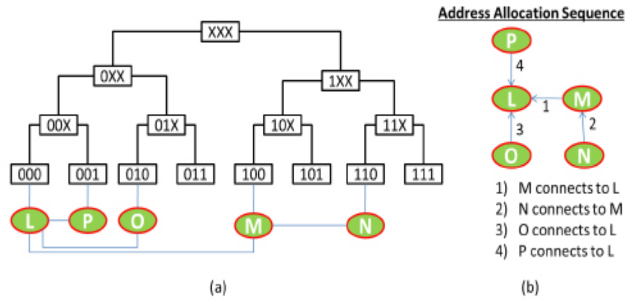

Figure 3. Dynamic address allocation in 3 bit address tree.

via L, L's [1xx] and [01x] routing entry are now occupied. Nevertheless, for the sibling ID [001] still there is no routing entry and therefore P acquires the address [001].

The 3-bit address structure can hold up to 8 nodes, as the network size grows (more than 8 nodes), the number of bits of address structure will also grow with the *level* of tree. Therefore, the tree structure scales the network in terms of network size.

3. An Overview of Packet forwarding Strategy of Dynamic Address based Routing Protocols

The basic purpose of routing protocol is to find the route between a pair of nodes. In dynamic address based routing protocols a route is obtained by employing a packet forwarding strategy. Each mobile node maintains a routing table composed of l segments, one for each sibling. The k^{th} segment stores the route towards a node have its place to the level-k sibling. Each node maintains the routing table and it has five fields: the sibling (the entry refers to), the next hop, the cost required to reach a node belonging to that sibling forwarded via the next hop, the network id (assigned by network) to validate the address, and the path log used by the algorithm applied for avoiding loop. The routing state information is updated via exchanging the routing updates table from neighbor nodes. There are l entries stored in every routing update table and each of them consists of four fields: the sibling id, the cost of route, the network id, and the route log.

3.1 DART Packet Forward Strategy

In DART[15], the packet forwarding strategy uses a hop-by-hop routing based information to refer the network.

Before sending a packet towards the destination, each node performs the bitwise comparison (through most significant bit) of its logical address with the destination logical address. The packet is forwarded towards the route in the segment whose corresponding bit does not match in the comparison. In Figure 2, if the node 000 wants to send a packet to the node 101, then it selects the next hop node stored in the third section (i.e., the node 010) to forward the packet as given in Table 1.

3.2 M-DART Packet Forwarding Strategy

M-DART[18] is a multipath version of DART routing protocol. In M-DART packet forwarding process the route is selected by considering the hierarchy of dynamic addresses, as next hop, the neighbor shares the longest network address prefix with the destination address. The node selects the route having least cost when more than one neighbors being shares the longest address prefix. Table 2 shows the routing table of M-DART for node 000.

Let the node 000 (Figure 2) need to forward a data packet towards the node 101. Here the node seeks for the third segment entries of its routing table as the destination have its place to the level-3 sibling, which is the level 1XX (Table 2). Furthermore, this segment stores two entries: the first through the next hop 010 and the second through 001. Consequently the node chooses neighbor node 010, as next hop, instead of the costs belonging to the paths. In Table 2, the node stored two entries with respect to the next hop 010 and 001, and so both shares the same address prefix, the node chooses the entry having minimum route cost.

Table 1. Routing table of DART for Node 000

Sibling ID	Next Hop	Route Cost	Network ID	Route Log
001	001	1	ID(000)	001
01X	010	1	ID(010)	010
1XX	010	2	ID(100)	100

Table 2. M-DART routing table for node 000

Sibling ID	Next Hop	Route Cost	Network ID	Route Log
001	001	1	ID(000)	001
01X	001	1	ID(010)	001
	010	1	ID(010)	010
1XX	010	2	ID(100)	100
	001	2	ID(100)	100

3.3 ODR Packet Forwarding Strategy

The packet forwarding strategy of ODR[17]is made up of three phases: candidate selection, candidate election, and candidate acknowledgment. To attain these phases, each node depends on two queues in the network: first, the *packet queue*, which holds the data packets which are to be forward, i.e. the data packets for which the node is a candidate forwarder and second, the *ack queue* which holds the acknowledgment of the data packets. At each step, the candidate selection ensures that, only the node which is closer than the forwarder node towards the destination is allowed to forward the packet again[17].

When a node has packet to forward, it stores the logical address and its estimated overlay distance in packet header and then it transmits the packet nearby. The overlay distance is the number of bits included in the network address prefix which are common in the node address and the destination address. When a node receives a packet, it verifies whether its overlay distance to the destination is smaller than the overlay distance from the forwarding node. It also verifies whether the quality of the path (from the Table 3.) is superior to the forwarder node. If the above verifications do not satisfy, it means that the candidate set do not contain the node and the packet will stored in the *ack* queue of the node[17].

3.4 ATR Packet Forwarding Strategy

The ATR[16] is a multipath routing protocol and its routing shows temporal diversity, i.e., the path discovery procedure performs a preventive route discovery prior to the occurrence of route errors[16]. With reference to Table 4

Table 3. ODR routing table for node 010

Destination	Path quality	Route log
011	1.60	001
00X	3.80	010
01X	1.25	010

Table 4. ATR routing table of node with address 001

Level	Sibling ID	Next Hop	Route Cost	Network ID
0	000	000	1	ID(000)
1	01X	000	2	ID(010)
		010	1	ID(010)
2	1XX	000	2	ID(100)
		010	2	ID(100)
		100	1	ID(100)

based on Figure 4, when a node with network address [001] wants to forward a data packet to a node with network address [010], it will take a glance first to the entries associated to the sibling to which the destination address belongs, i.e., the level-1 sibling [01X]. In ATR the routing table consist two entries, so node [001] picks out the one showing the minimum hop count metric, i.e., the node [000]. Else, if there are no entries in routing table for the level-1 sibling, node '001' pursue to examine its higher sibling, i.e., level-2 sibling [1XX][16].

Furthermore, ATR takes benefit of multiple paths described in a cross layer solution to deal with link failures. If a node discovers a link failure after forwarding of data packets and it does not receive any acknowledgement from receiving node, then it will invalidate the formerly used next hop. Then the data packets will be re-directed using another path already discovered by the Route Discovery Process. Obviously this indicates to high delays in packet delivery, conversely it is often more opportune to wait a little more instead of misusing the resources used in packet forwarding[17].

4. The Comparative Study of Dynamic Address based Routing Protocols

Author in[15] examined the Dynamic Address Routing protocols and found dynamic addressing scheme to be a feasible way to achieve scalability in ad hoc network. With dynamic addressing, when the node moves from one location to another location then it changes its logical addresses, so these addresses have a topological meaning. The features of these protocols are summarized in Figure 5.

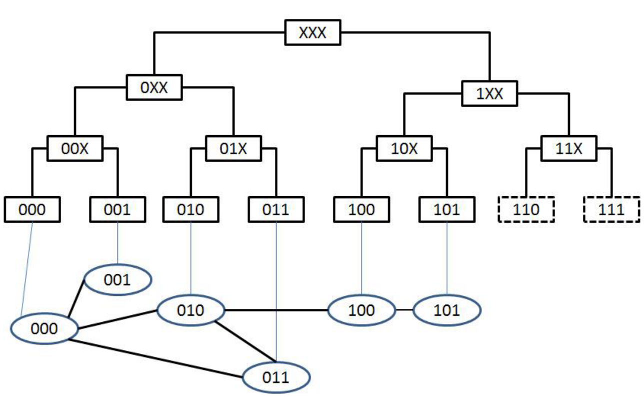

Figure 4. Address structure with physical topology.

Parameters	DART	ATR	ODR	M-DART
Routing Philosophy (reactive & proactive)	Proactive	Proactive	Proactive	Proactive
Routing Metric	Shortest Path	Keeps all possible path	Link Quality & Route Cost	Keeps all possible path
Scalable	Yes	Partially	Partially	Yes
Routing Table Size for n Number of Nodes in the Network	O(log n)	O(n)	O(log n)	Θ(log n)
Control Overhead	High	High	High	High
Logical Structure	Tree	Tree	Tree	Tree
DHT-Based	Yes	Yes	Yes	Yes
Mobility Support	Yes	Yes	Yes	Yes
Routing Forward based On	Logical neighbors	Logical neighbors	Logical neighbors	Logical neighbors
Loop Avoidance	Yes	Yes	Yes	Yes
Multipath Support	No	Yes	No	Yes
Packet Forward Strategy	Minimum cost path	Hop count	Link Quality	Minimum cost path
Link Quality Parameter	ETX	Not Considered	ETX	ETX

Figure 5. Summary of dynamic address based routing protocols.

DART is unipath protocol in which routing is based on hop-count. DART discovers the minimum cost route to a given subtree. The packet forward strategy of DART is discussed in previous section. The availability of single path only between a node and its siblings limits the performance of DART by reducing the fault tolerance, thereby increasing the possibility of route failures[5]. In case of path failure, a path to the given destination address cannot be available, even when network is connected, and all address allocations are accurate. These failures of small period can cause route propagation delay[18]. The nodes could not get the information about the path breakage when the shorter path breaks, and a new longer path has not yet been established. In this situation, the router takes default action to drop the packet, and finds itself without a valid route and potentially send a "there is no path" message back to the sender. Therefore, DART does not have a good mechanism to handle route failures.

A multipath enhancements to DART, called Augmented Tree based Routing (ATR)[16] and Multipath Dynamic Addressing Routing (M-DART)[18] have been proposed in literature. To overcome the limitations of DART, author in[16], proposed a hierarchical multipath ATR routing protocol which is based on Distributed Hash Table (DHT), named Augmented Tree-based Routing (ATR). ATR exploits augmented tree-based address space structure which aims at achieving scalability, gaining flexibility against node mobility, and avoiding link instability in MANETs[16]. As M-DART, ATR proactively maintains all possible routes via its next hop neighbor nodes to reach a destination node in the sibling tree without incurring any additional communication or coordination overhead[5]. In DART, a new node obtains logical address from one of its physical neighbor with the largest unused logical address sets. This process could result in invalid address assignment and slower convergence[16]. However, in ATR, if a new node obtains an invalid logical address from its neighbor because the neighbor's routing table is not updated, the new node examines its other physical neighbors to obtain a valid logical address. Furthermore, ATR uses a caching technique to minimize the traffic overhead associated with the node lookup. This cache mechanism also offers fault tolerance to ATR's routing method.

Another multipath enhancement of DART is M-DART which determines and stores multiple paths to the destination in the routing table. This protocol is able to discover all the available paths for the data-packet forwarding at a node. It adopts a simple policy of using the best available route (based on hop-count where the hops signify the cost associated with a path) until it fails and then switch to the next best available path. M-DART is based on shortest path[18] but it also suffers from other problems like, congestion, consumption of bandwidth[16]. M-DART does not have good mechanism to resolve these problems. The scalability study of M-DART has been carried out in terms of node number, data load, node mobility, channel hostility and also in terms of network address, skewed node distribution.

ODR also extends the location-aware addressing scheme of DART and it depends on a distance metric[20], constructs the link-quality path in the network. These metric goals to estimate the expected number of packet transmissions (including the retransmissions) needed to successfully deliver a packet to the ultimate destination[17]. This metric only tells about the link failure rate not a link bandwidth. ODR produces the high routing overhead due to the hidden terminal problem.

5. Strengths and Challenges of Dynamic Address based Routing Protocols

Dynamic address based routing protocols have following strengths and weaknesses that might be consider for further research.

5.1 Strengths of DARP

- Packet forwarding in DARP does not require route discovery, hence these protocols have less control overhead.
- As the dynamic addresses assigned by the network layer through DHT method, a node can easily find the destination using prefix shared address structure during the packet forwarding process thereby reducing delay in packet delivery at destination.
- DARP organizes the network topology in tree or hierarchal form using logical address assigned by DHT method and there is no requirement of group heads or gateways etc., as required in cluster based routing protocol. This shorted the control overhead.
- With node mobility, subtree identifiers may require to be updated, but these updates are piggybacked on the periodic routing updates at minute extra cost.
- In case of multipath of DARP, a node maintains all possible paths in its routing table for packet forwarding. If the current path fails then a node forwards the packets through the best available path. This reduces end-to-end delay as compared to single path routing protocols.

5.2 Challenges of DARP

- Periodical neighbor updates and routing table updates are required in DARP to maintain the topology and forward the packets. This may increase the control overhead of network.
- Tree topology may not give the exact distance between nodes due to its shared address prefix constraint. Routing distance is expected to be shortening in the network topology.
- Tree expanding (i.e., increment in the tree levels) due to increment in number of nodes and *tree reduction* (i.e., decrement in the tree levels) due to decrement in number of nodes may disturb the physical topology of network. To maintain the relationship between node identifier and its logical address, number of updates is required in the network via update packets such as neighbor updates, sibling updates, routing updates, etc. These update packets may enhance the overhead of network.
- In DARPs, the routing table stores neighbor's logical address for forwarding the packets. A node's logical neighbors may not be its physical neighbors, resulting in a mismatch between the logical structure and physical topology. It may have a negative impact in

MANETs, especially when logical structure is implemented directly at the network layer.

- Some ARPs may produce the high routing overhead due to the hidden terminal problem. ODR suffers with this problem.
- DART, ODR, and M-DART calculate the link-quality via ETX route metric. The ETX metric performs better than shortest path metric. However, it does not necessarily select good routes. ETX metric considers only loss rates on the links and not their bandwidths – an important issue in routing scenario.

6. Conclusion

This paper discussed the network structure and address allocation scheme of dynamic address based routing protocols. An overview of packet forward strategy of various routing protocols is presented. The comparative study of each protocol is described. We also discussed the strengths and challenges in future routing protocol designs. Further, we noticed that the protocols do not considered channel bandwidth for packet forwarding which is required for the real time communication in MANET. To scale the large MANET, bandwidth can be used as additional parameter to the considered routing protocols in future.

7. References

1. Pei G, Gerla M, Hong SX. Lanmar: Landmark routing for large scale wireless ad hoc networks with group mobility. ACM MobiHOC'00; USA. 2000 Nov. p. 11–8.
2. Ramanathan R, Steenstrup M. Hierarchically-organized, multihop mobile wireless networks for quality-of-service support. Mobile Networks and Applications. 1998 Jun; 3(1):101–19.
3. Pei G, Gerla M, Hong X, Chiang CC-C. A wireless hierarchical routing protocol with group mobility. Wireless Communications and Networking Conference, WCNC; 1999 Sep. p. 1538–42.
4. Royer B. Multi-level hierarchies for scalable ad hoc routing. Wireless Networks. 2003 Sep; 9(5):461–78.
5. Abid SA, Othman M, Shah N, Ali M, Khan AR. 3D-RP: A DHT-based routing protocol for MANETs. Computer Journal. 2014; 58(2):1–29.
6. Awad AR, Dressler DG. Exploiting virtual coordinates for improved routing performance in sensor networks. IEEE Transactions on Mobile Computing. 2011 Nov; 10(9):1214–26.
7. Boukerche A, Turgut B, Aydin N, Ahmad A, Boloni B, Turgut D. Routing protocols in ad hoc networks: A survey. Computer Networks. 2011 May; 55(13):3032–80.
8. Devipriya D, Devi BRS, Thenkumari K. Efficiency improvement in wireless sensor networks using ABC algorithm for cluster-based packet forwarding. Indian Journal of Science and Technology. 2016 Aug; 9(30):1–6.
9. Vijayan K, Raaza A. A novel cluster arrangement energy efficient routing protocol for wireless sensor networks. Indian Journal of Science and Technology. 2016 Jan; 9(2):1–9.
10. Sirisha G, Babu RB, Rao KR. Establishing path quality management in wireless sensor networks through cluster head determination. Indian Journal of Science and Technology. 2016 Feb; 9(5):1–9.
11. Thenmozhi E, Audithan S. Energy efficient cluster head selection and data convening in wireless sensor networks. Indian Journal of Science and Technology. 2016 Apr; 9(15):1–6.
12. Eriksson J, Faloutsos M, Krishnamurthy SV. Scalable ad hoc routing: The case for dynamic addressing INFOCOM. 23rd Annual Joint Conference of the IEEE Computer and Communications Societies; USA. 2004 Mar. p. 1108–19.
13. Ibrar M, Ahmad M, Umar M, Habib M, Iqbal M. Stability analysis of DHT based multi-path routing protocol under group-based mobility models and entity-based mobility models in mobile ad-hoc networks. IEEE Conference Information Technology, Networking, Electronic and Automation Control; 2016 May.
14. Jung M, Kim DY, Kim S. Efficient remote software management method based on dynamic address translation for IoT software execution platform in wireless sensor network. Indian Journal of Science and Technology. 2016 Jun; 9(24):1–7.
15. Eriksson J, Faloutsos M, Krishnamurthy S. DART: Dynamic address routing for scalable ad hoc and mesh networks. IEEE/ACM Transactions on Networking. 2007 Feb; 15 (1):119–3.
16. Caleffi M, Ferraiuolo G, Paura L. Augmented tree based routing protocol for scalable ad hoc networks. MHWMN '07: Proceedings of the 3rd IEEE International Workshop on Heterogeneous Multi-Hop Wireless and Mobile Networks; Italy. 2007 Nov. p. 1–6.
17. Caleffi M, Paura L. Opportunistic routing for disruption tolerant networks. AINA09: The IEEE 23rd International Conference on Advanced Information Networking and Applications; 2009 May. p. 826–31.
18. Caleffi M, Paura L. M-DART: Multi-path dynamic address routing wireless communication and mobile. Computing. 2011 Jul; 11(3):392–409.
19. Eriksson J, Faloutsos M, Krishnamurthy S. Book chapter: Routing scalability in MANETs handbook on theoretical and algorithmic aspects of sensor, ad hoc wireless, and peer-to-peer networks. Auerbach Publications; 2006.
20. Couto DSJD, Aguayo A, Bicket J, Morris R. A high throughput path metric for multi-hop wireless routing, Wireless Networks. 2005 Sep; 11(4):419–34.