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# APPROPRIATE ROUTING PROTOCOLS FOR HETEROGENEOUS MOBILE AD HOC NETWORKS (HMANETs): A SURVEY

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**Abstract**

Mobile ad hoc networks (MANET) consist of some independent systems that can communicate with each other in a wireless manner. Most routing protocols are appropriate for homogeneous mobile ad hoc networks and in heterogeneous networks (HMANET), they lose their efficiency. Homogenous mobile ad hoc networks (MANET) are nodes in networks that have the same resources and abilities which are the opposite of real MANETs because in real MANET each node is independent and has its own resources and abilities like bit rates, battery life, radio range, bandwidth, extra. In this paper, we introduced some routing protocols that proved to be appropriate for HMANETs.

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*Key words:* Routing protocols, HMANETs, Scalability, Cluster, Flat structure and hierarchical structure.

## 1 Introduction

MANETs are groups of mobility wireless nodes that do not have any special structure. In these networks, each node can play as a router or an end user. Routing is a big challenge in these networks. Many routing protocols are introduced for these networks, but in most of them it is supposed that nodes are the same and have the same resources and abilities and their MANETs are homogenous therefore they lose their efficiency in HMANETs. We have three types of routing protocols: [1]

- Proactive protocols like QOLSR (Qos-based Optimized Link State Routing) [5].

- Reactive protocols like ERORP (Efficient and Reliable On-Demand Routing Protocol for MANET) [3].

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- Hybrid protocols like HOPNET (Hybrid ant colony Optimization Network) [4].

In proactive routing protocols, each node in its routing table has an up-to-date route to any destination at any time. This type of routing has high overload because of broadcasting control messages, but it has a low delay because, when the source wants to send a packet to a destination, it has an up to date route to the destination so for sending the packet it does not need a discovery phase. In reactive routing protocols when a source wants to send a packet to a destination first of all it should find a route to it and then send its packet through the found route. Because of the discovery phase, this type of routing has a higher delay than proactive routing protocols but it has lower overload. Hybrid protocols use a combination of proactive and reactive protocols. For some nodes the source has an up to date route and for some nodes the source should find a route for them and send its packet. An important factor in the efficiency of routing protocols is scalability. A network has Scalability property whenever the number of nodes increases, the network does not lose its efficiency and adjusting itself to the situation, it continues its work without any problem. HMANET routing protocols have more scalability than MANET routing protocols [2]. In this paper, we introduce routing protocols that are appropriate for homogenous MANETs and their improvement in order to be appropriate for HMANETs. For example OLSR and its extended (HOLSR). HOLSR is appropriate for HMANETs and OLSR is appropriate for homogenous MANETs.

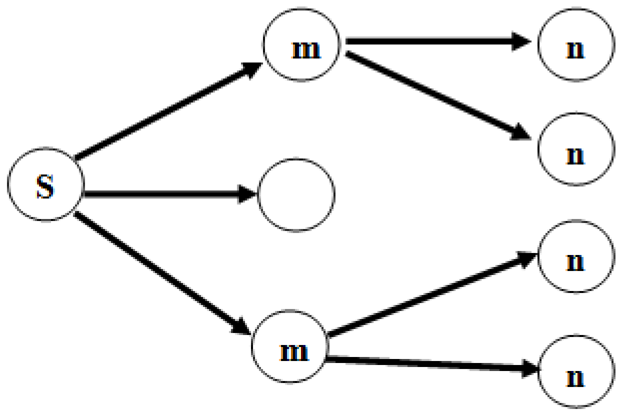
In section 2 we review OLSR [12], HOLSR [10], LANMAR [13], HLANMAR [9], AntHocNet [8], Ant-based [7], AODV [11], HAODV [6] and compare them with each other; for example, compare OLSR with HOLSR, AODV with HAODV and so on in separate tables. Finally, we conclude the paper in section 3.

## 2 Appropriate routing protocols for MANETS and HMANETs

In this section, we introduce routing protocols that have changed in order to be appropriate for HMANETS and their changes. In this section, we introduce routing protocols that have changed in order to be appropriate for HMANETS and their changes.

### 2.1 OLSR (Optimized Link State Routing Protocol)

T. Clausen et al. [12] have introduced OLSR protocol. This routing protocol is link state and is a member of proactive routing protocols. It is appropriate for dense and homogeneous networks. In this routing protocol each node selects a subset of its one hop neighbors independently which are called MPR (Multipoint relays) nodes. Only these nodes should forward its packets through the network and others (the nodes that are not in this subset) only receive and process packets and do not forward them. Each node has to select MPRs among its one hop neighbors whose relation with the node is bidirectional and it can cover its two hop neighbors with them.




The nodes labeled as (m) are MPRs of the node labeled as (s). Node s can communicate with nodes n by its MPRs (nodes m).

Figure 1: selection of MPRs in OLSR

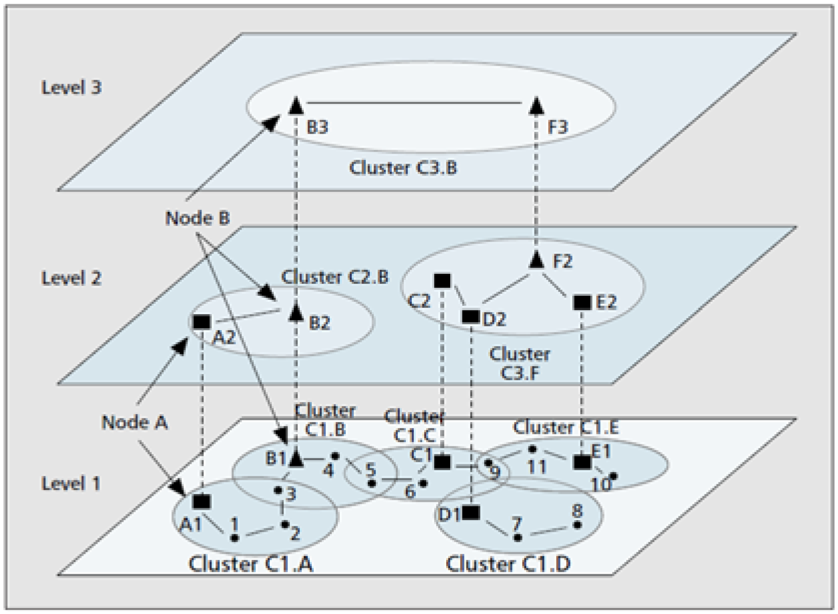
## 2.2 HOLSR (Hierarchical Optimized Link State Routing Protocol)

L. Villasenor-Gonzal et al. [10] have introduced HOLSR. This protocol improved OLSR to be appropriate for HMANETs. It is a member of proactive routing protocols. In this protocol, network components are devised into multi level through their capabilities, resources and their interfaces. Each level consists of multiple clusters, each cluster has a node as cluster head, which is more powerful and has more interfaces than another node in the cluster. Cluster means groups of mobile nodes. Figure 2 shows the procedure of this protocol. The division is done as follows: Level one consists of nodes, which have low capabilities, and has one wireless interface. In figure 2 they are shown by a circle. Nodes having media capabilities and at most 2 wireless interfaces can work at levels, one and two. In figure 2 they are shown by a square. Nodes that have high capabilities and have at most 3 wireless interfaces can work at level one, two and three. In figure 2 they are shown by triangles. If a node with high capabilities it has two wireless interfaces, it can work on both level two and three. In this protocol, clusters are gateways and if a node wants to send packets to the other node, which is not in its cluster, it should deliver packets to its cluster head. Packets go through cluster heads until the destinations cluster head received them and it delivers them to the destination.

Note that:

- The nodes in each level select their MPRs independently without notice to the other levels.

- There is not any relationship between cluster heads on the same level unless they overlap.




Node B has three wireless interfaces and works as cluster head in all levels. C1.A means that node A is the cluster head of c1 cluster, which is in level one.

Figure 2: Clusters, cluster heads and their relationship in HOLSR [10]

- Cluster heads have a relationship with cluster heads in upper or lower level and if a cluster head finds out the packets are not in its cluster it delivers them to its upper level cluster head.

- Cluster heads, which are in the upper levels, have more configuration information than lower levels.

- If there isn't any difference between nodes, then there is no cluster head therefore this protocol behaves like the original OLSR. In table 1 we compare OLSR and HOLSR routing protocols with each other.

Priority of HOLSR in comparison with OLSR:

- It has lower overload than OLSR.
- It has lower computation than OLSR.

## 2.3 LANMAR routing protocol (LANMAR)

G. Pei et al. [13] have introduced LANMAR routing protocol. This protocol is a member of proactive routing protocol. In this protocol, nodes that move together formed a group and each group has a node named as landmark node. Figure 3 illustrates this. The node which covers more nodes introduces itself as landmark node to its group. Nodes in the same group have complete information about their neighbors therefore they can easily communicate with them. The routing protocol that is used in groups is FSR [14]. Every node knows other landmark nodes in the network because the landmark nodes introduce themselves periodically so the

Table 1: Comparison of OLSR and HOLSR

| Routing protocols | Routing structure | Up-to-date frequency | HM (Hello Message) | TC (Topology Control message) | HTC (Hierarchical TC) | Critical nodes | Characteristic |
|---|---|---|---|---|---|---|---|
| OLSR | flat | periodic | yes | yes | no | no | Decrease overload by using MPRs |
| HOLSR | hierarchical | Periodic And Within each cluster independently | Yes Within each cluster independently | Yes Within each cluster independently | Yes Between cluster heads | Yes , Cluster heads | Low overload And Hierarchical structure |

nodes have an up to date route to each of them. IF a node wants to send packets to a far away node, it sends its packets to a landmark which cover destination node, then this landmark delivers the packets to the destination node. If a node moves randomly and doesn't belong to any group, this protocol cannot cover it well and decreases its efficiency. HLANDMAR improved this protocol to solve this problem. We introduce it in 2.4.

## 2.4 Hybrid Landmark Routing (HLANMAR)

Y. Lee et al. [9] have introduced Hybrid Landmark routing protocol. It is like LANDMAR but it is a member of hybrid routing protocols. This protocol combines proactive and reactive routing protocols and uses both of them. This protocol behaves like original LANMAR but when there is a node which does not belong to any group, it uses the reactive routing protocol to find a route to it and sends its packet through the found route to the destination. In table 2 we compare LANMAR and HLANMAR routing protocols with each other.

## 2.5 AntHocNet routing protocol

G. D. Caro et al. [8] have introduced this protocol. The basic idea is obtaining routing information by using small control packets, which are called ants. In this protocol, each node sends multiple ants independently to find a route to a destination and each ant returns to source node through the route that is discovered by it. Therefore, the entire interface nodes in the route, update their information by the ants. In routing tables, a parameter is called Pheromone. This number shows the quality of a route (The larger number, the better route). It is more probable that routes with much pheromone be selected by ants to go to the destination. It

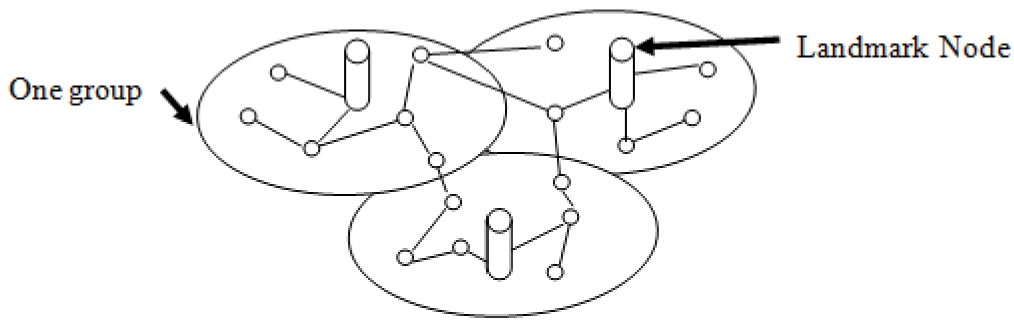



Figure 3: Landmarks and their groups

Table 2: Comparison of LANMAR and HLANMAR

| Routing protocol | RT (Routing Table) | On-demand RT | Landmark RT | Structure | Critical nodes | Characteristic |
|---|---|---|---|---|---|---|
| **LANMAR** | Yes | Yes | No | Flat | No | It uses groups mobility nodes |
| **HLANMAR** | Yes | Yes | Yes | Hierarchical | Yes | It covers both group mobility nodes and single nodes and use combine of reactive and proactive routing protocol |

is only a probability and not a certainty shown in figure 4. Each node finds routing information by sending ants to destinations. It is not necessary for nodes to send routing information to each other. This routing protocol is a member of hybrid routing protocols and uses the combination of both reactive and proactive routing protocols. In this protocol, nodes don't keep all routing to different destinations. They set up paths by using ants only when they want to start a data session, those ants are named reactive forward ants, described below.

The source node randomly sends multiple reactive forward ants through different neighbors to the destination node. Each of them should find a route to destination and return back through it to the source node. When routes are found by ants their pheromone is inserted in the table. When a source node wants to send packets to a destination with more probability it selects a route with more pheromone. These routes are maintained and improved by ants, named proactive ants until the session is on. The route with more pheromone with high probability will be shorter than others. This protocol is a multipath protocol since when a route is failed it will be replaced by the other route.

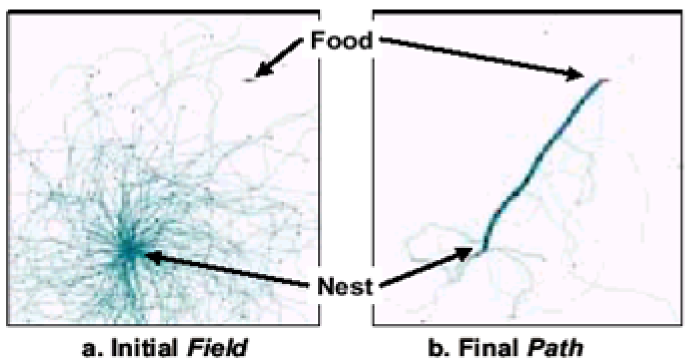
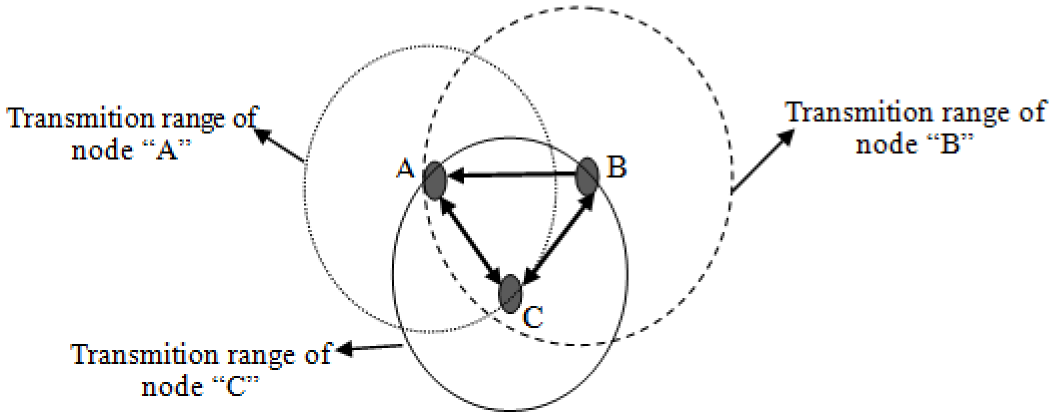



Figure 4: Selected route by ants

## 2.6 An Ant-based Routing Protocol

This routing protocol is introduced by T. Maekawa et al. [7]. It is like the previous routing protocol (AntHocNet). AntHocNet supposes that all routes are bidirectional. On the other hand it first omits unidirectional links and does not use them so this protocol is produced with improved AntHocNet efficiency by using all links (bidirectional, unidirectional). Most routing protocols suppose that all links are bidirectional but it is possible that nodes have different ranges. For example, suppose that node B has a bigger range than node A so it covers node A and because of the shorter range, node A can not cover node B so the link between them is unidirectional (figure 5).

This protocol turns unidirectional link. For example, node B sends ants to node A to find routes to it as we have said before, these ants should return back to node B through the route that they discovered, but return ants from node A cannot turn back to node B through that route because this route is unidirectional. In this case, node A broadcasts backward ants to find a route to node B. As you see in figure 8, BC and CD links are unidirectional and they are turned. Therefore, backwards ants returned to node B. In this case nodes C and D cannot update their routing information by backward ant. To solve this problem, node B broadcasts ants that are named update ants. Each node that has received these ants and sees itself in the list of interface nodes to destination updates its routing information. AntHocNet omits unidirectional links so the long route ABGFEDI is selected as you see in figure 6 but in this protocol the shorter route ABCDI is selected.




In unidirectional BA link, node B is upstream node and node A is downstream node.

Figure 5: A sample of unidirectional and bidirectional links

In table 3 we compare AntHocNet and Ant-based routing protocols with each other.

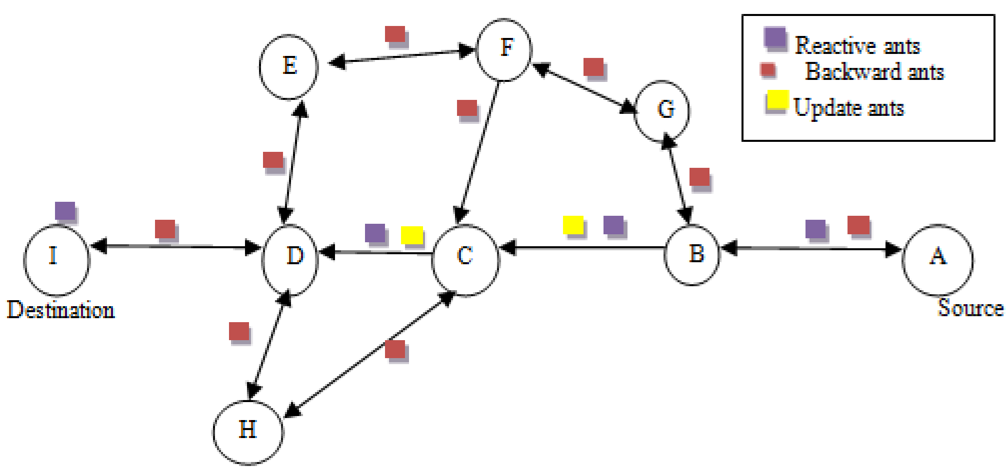



Figure 6: Twanged unidirectional links

## 2.7 AODV (Ad hoc On Demand Distance Vector Routing Protocol)

C. Perkins et al. [11] have introduced AODV. It is a member of reactive protocols, when a source node wants to send a packet to a node (that doesn't have an up to date route in its routing table) operate as below:

Table 3: AntHocNet in comparison with Ant-based

| Routing protocol | Proactive ants | Reactive ants | Backward ants | Update ants | Unidirectional link | Finding shorter path | HM (Hello Message) |
|---|---|---|---|---|---|---|---|
| AntHocNet | Yes | Yes | Yes | No | Yes but omit them | No | Yes |
| ANT-based | Yes | Yes | Yes | Yes | Yes and use them | Yes | Yes, for bidirectional links |

The source node sends an RRAQ (Route Request) message consisting of a source sequence number, destination address, destination sequence number, Broadcast Id, Hop-count to all its neighbors. If a neighbor has an up to date route to the destination and the destination sequence number in its table is bigger than the destination sequence number in RREQ message, it sends an RREP (Route Reply) message to the source node, otherwise it sets up a reverse route in its table and broadcasts an update RREQ message and increases hop-count one unit. This procedure is continued until the destination node receives an RREQ message or an interface node has a better up to date route to the destination and sends RREP to the source node. If a node receives duplicate RREQ, omits it. If a node receives multiple RREP for a destination, one with bigger sequence number and a lower hop-count will be chosen and then its routing table will be updated. RREQ messages consist of source address, destination address, destination sequence number, hop-count and the period of time that this route is active. Each route has a TTL (Time to Live) time and when this time decrease to zero the route is omitted. This protocol finds the shortest route by hop count, (Figure 7).

## 2.8 HAODV (Heterogeneous Ad hoc On-demand Distance Vector)

H. Safa et al. [6] have introduced this routing protocol. Although, in networks different technologies are used by nodes (W/B, Bluetooth and WIFI) and better routes may be found, AODV supposes that nodes use one technology for routing (WIFI) and find the shortest route by this assumption. Because of this AODVs efficiency decreases in HMANETs. HAODV was introduced to improve AODV and makes it appropriate for HMANETs. In HAODV route discovery phase is like AODV but in RREQ and RREP messages have three more parameters (Conversion route (Conv-route), Load Balance (LB), Delivery counter (DC)) that help to find the best route. The DC-route is the summation of all nodes DC in the route. Nodes that use WIFI or W/B technologies have less mobility and more consistencies, having more DC than nodes that use B technology. The LB - route is a summation of nodes LB in the route. A node that uses both technologies (W/B) has lower LB than nodes that use one technology. The conv - route is the summation of the cost of converting B technology to W technology and vice versa for the nodes in the route. In other words, the conversion cost is only considered when a node that

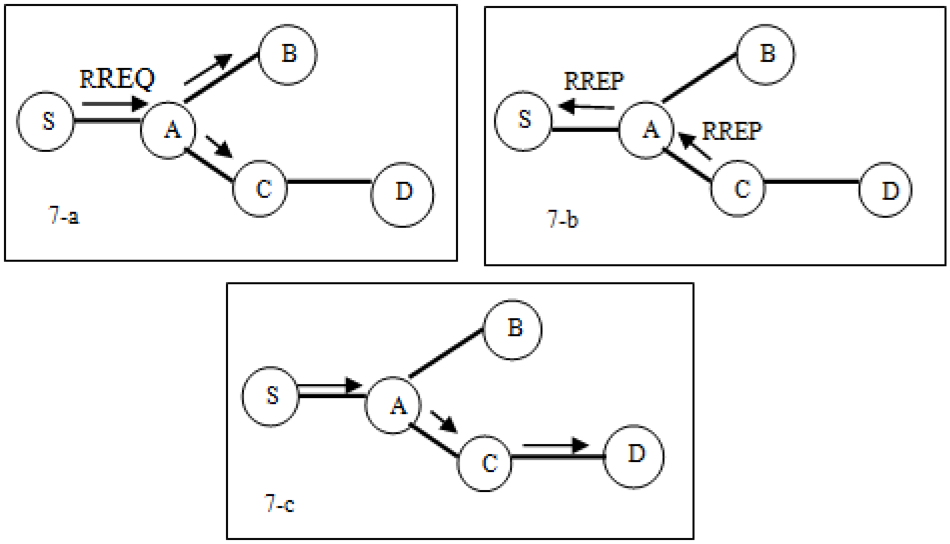



Figure 7: Route discovery and Packet sent in AODV

uses W/B technology receives a packet from a node the uses only B technology and has to forward it to a node that uses only W technology, or when a node that uses W/B technology receives a packet from a node that uses only W technology and forwards it to a node that uses only B technology. Figure 8 explains HAODV. We have another parameter called W.

$W=a_1 *N+1/N\ (-a_2*DC\text{-route}+a_3*LB\text{-route})\ +a_4*Conv\text{-route}$

N is the number of the nodes in the route and $a_1$, $a_2$, $a_3$, $a_4$ are the weights that are considered for each parameter.

The nodes in the route update their routing information when they find a route with smaller W and bigger sequence number because such a route is better.

In figure 8, node n1 wants to send a packet to n10 by using AODV. The route n1,n2,n4,n9,n5,n6,n10 is selected, but by using HAODV the route n1,n2,n3,n6,n10 is selected. As you see this route is shorter than the other. In table 4, we compare AODV and HAODV routing protocols with each other.

Table 4: AODV in comparison with HAODV

| Routing protocol | RREQ | RREP | HM | DC | LB | Conv-route | Routing structure | Finding shorter path | Sequence Number |
|---|---|---|---|---|---|---|---|---|---|
| AODV | Yes | Yes | Yes | No | No | No | Flat | No | Yes |
| HAODV | Yes | Yes | Yes | Yes | Yes | Yes | Flat | Yes | Yes |

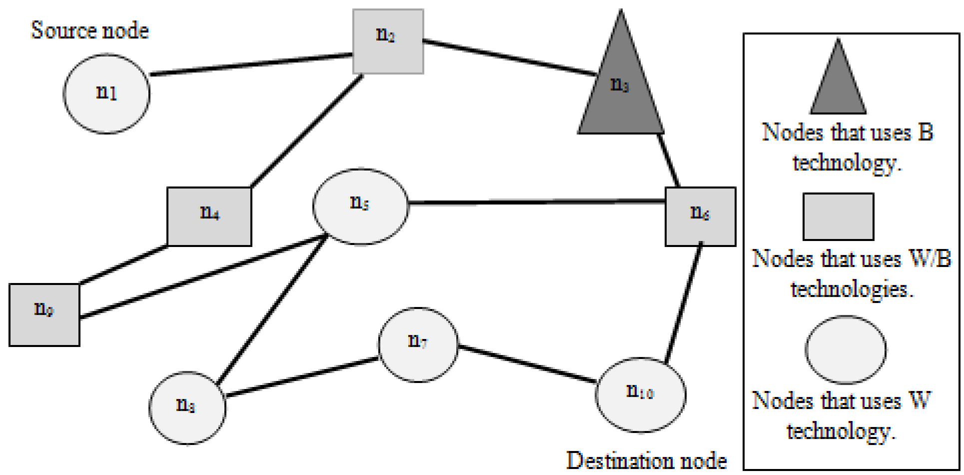



Figure 8: Nodes that use W/B or B technologies.

## 3 Conclusions

Since hierarchical structure divides systems into multiple levels based on their sources and capabilities, it decreases the network traffic and has low overhead. Using all sources and links in the network, the delivery rate of packets in the networks is increased and the delay by using a shorter path is decreased and bandwidth is better used. As we described, HMANET routing protocols have more scalability than homogenous MANET routing protocols; this means that when the network becomes larger, the number of nodes and other changes are increased, but it does not lose its efficiency and is able to adapt to conditions.

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