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Full Length Research Paper

Enhanced multi-radio AODV in hybrid wireless mesh networks

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Wireless mesh networks (WMNs) have became the focus of many researchers as a promising technology for a broad range of applications due to their self-organizing, self-configuring and self-healing capability, in addition to their low equipments and deployment cost. WMNs are not mobile ad hoc networks (MANETs); instead they can be considered as a superset of traditional mobile ad hoc networks (MANETS). WMNs may exist in the absence of a central infrastructure taking the form of a MANET. However on the other hand, they may exist as networks comprised of an infrastructure connecting extended ad hoc networks. One significant area of research within ad hoc networks is routing and in particular, the efficient thereof. Owing to the characteristics of WMNs, routing algorithms designed for ad hoc networks however may not always be applicable to WMNs. Moreover, traditional ad hoc routing protocols which disseminate routing information by flooding, a technique which requires a significant consumption of energy and bandwidth, cannot achieve optimal performance especially in hybrid WMNs. In this paper, we use a technique to reduce the cost of disseminating information in a power-constrained environment by limiting the cardinality of the subset of nodes which retransmit a packet. This technique can improve the performance of AODV in hybrid mesh networks.

Key words: Wireless mesh networks, multi-radio, routing, hybrid mesh networks, limited forwarding, AODV.

INTRODUCTION

Networks may be one of two paradigms: centralized and decentralized. Traditional wireless networks represent the centralized paradigms where clients directly connect to an access point, while the mobile ad hoc networks (MANETs) represent the decentralized paradigms where clients themselves uphold the network in the absence of a central infrastructure. Wireless mesh networks (WMNs) is a technology to merge these two paradigms into a single transparent network. Routing requirements should be treated differently when addressing different components within a WMN. WMNs generally fall under one of three types:

(i) Infrastructure mesh.
(ii) Client mesh.
(iii) Hybrid mesh (Akyildiz et al., 2005, Asherson and Hutchison., 2006).

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Infrastructure mesh

It is typically a mesh comprised of routing/ access-point devices. The client nodes themselves do not form the mesh; instead they connect to the mesh like regular wireless clients. The routers form a mesh by connecting to one another and are responsible for routing client data. The data may travel via multiple router hops before reaching its final destination (Jones et al., 2001).

Client mesh

It resembles a MANET; there is no central infrastructure available to perform regular networking functions. The clients themselves perform these responsibilities and uphold the network connectivity.

Hybrid mesh

A hybrid mesh is simply a network that incorporates an

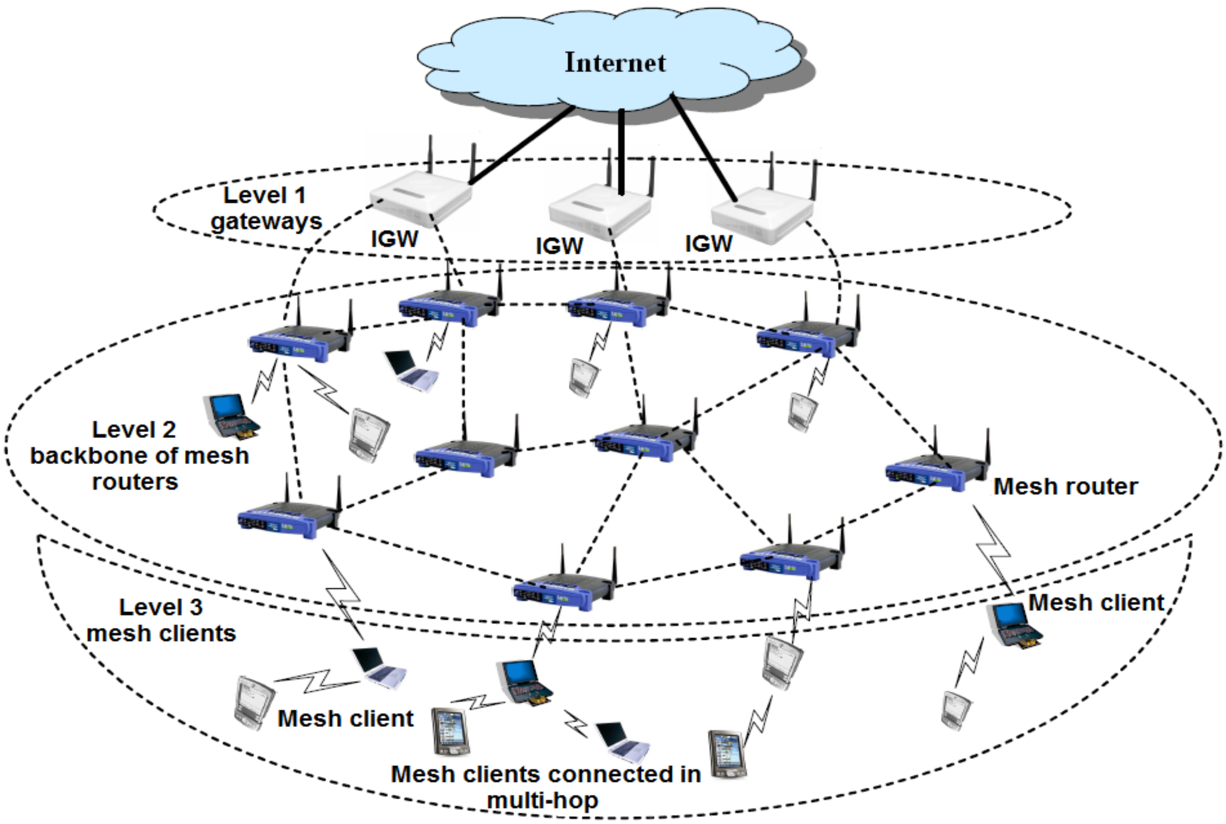

Figure 1. Hybrid wireless mesh network.

infrastructure that is also extended by one or many ad hoc networks. Hybrid meshes should be able to support regular wireless clients, wired clients via ethernet bridging, and mesh clients. This introduces additional challenges in terms of protocol usage for the support of heterogeneity in the network. Hybrid mesh networks would probably be the most applicable model in a realistic environment.

We differentiate between two types of nodes in a WMN: MESH-ROUTERs and MESH-CLIENTs. MESH-ROUTERs are relatively powerful and static nodes, which have either access to mains power or are equipped with high capacity batteries. Also, MESH-ROUTERs typically have multiple radio interfaces, which significantly increase the transmission capacity if the radios are operated on orthogonal channels. In contrast to MESH-ROUTERs, MESH-CLIENTs are relatively resource constrained mobile client devices, such as WiFi-enabled PDAs. These devices usually have only a single radio interface and their key constraint is limited battery power (Avudainayagam et al., 2003).

A WMN that is entirely comprised of MESH-ROUTERs is referred to as an infrastructure WMN, whereas a client WMN is a network made up of client devices only. A client WMN is essentially identical to a pure mobile ad-hoc network (MANET), and we can therefore consider WMNs a superset of MANETs. A hybrid WMN, such as illustrated in Figure 1, consists of both MESH-ROUTERs and MESH-CLIENTs, with both types of nodes performing routing and forwarding functionality. In this case, MESH-ROUTERs form the (wireless) backbone of a hybrid WMN, whereas MESH-CLIENTs can be seen as a dynamic extension.

In this paper, we use a technique to reduce the cost of disseminating information in a power-constrained environment by limiting the cardinality of the subset of nodes which retransmit a packet. This technique can improve the performance of AODV in hybrid mesh networks (Wang et al., 2004).

Problem statement

Hybrid WMNs are characterized by a high level of heterogeneity, since static MESH-ROUTERs are typically much less resource constrained than mobile MESH-CLIENTs, and are often equipped with multiple radio interfaces. Traditional ad-hoc routing protocols do not differentiate between these types of nodes and therefore cannot achieve optimal performance in hybrid WMNs.

A simple extension to the ad-hoc on-demand distance vector (AODV) routing protocol was proposed (Pirzada et al., 2007), which aim to take advantage of the heterogeneity in hybrid WMNs by preferentially routing packets via paths consisting of high capacity MESH-ROUTERs. In addition, it implements a simple channel selection scheme that reduces interference and maximizes channel diversity in multi-radio WMNs.

Despite the fact that this version of AODV has improved its performance somewhat over hybrid WMNs, but it still to disseminate its routing information using traditional flooding, a technique requires a significant consumption of energy and bandwidth. This will not allow it to achieve an optimal performance especially in our case -hybrid WMNs (Akyildiz et al, 1999).

To imagine the situation, mesh topology provides multiple links between devices. A true mesh topology would have a link between each device on a network. So a network of six devices would have 15 connections. True mesh networks have exponential growth in connections. So flooding will cause a serious traffic in the Network (Roemer and Mattern, 2004).

RELATED WORK

Hybrid mesh ad-hoc on-demand distance vector routing protocol

Hybrid WMNs consist of a mix of mobile MESH-CLIENTs and static MESH-ROUTERs. These two types of node differ considerably in terms of their capacity to forward packets. MESH-ROUTERs are typically much less resource constrained than mobile MESH-CLIENTs, and can be assumed to be equipped with multiple radio interfaces. Current WMN routing protocols do not differentiate between the types of node in a WMN, and are therefore not able to exploit the inherent heterogeneity in hybrid WMNs.

This paper, proposed a simple extensions to the ad-hoc on-demand distance vector (AODV) routing protocol, to increase its efficiency in hybrid MNs. It defined a new routing metric that allows more efficient use of high capacity MESH-ROUTERs by preferential routing of packets via paths traversing the MESH-ROUTERs. In addition, it integrated a channel or interface selection scheme to maximize channel diversity and therefore minimize interference on end-to-end paths. (Kyasanur et al., 2006)

Performance analysis of multi-radio AODV in hybrid wireless mesh networks

One of the key challenges that WMN technology faces is the limited capacity and scalability due to co-channel interference, which is typical for multi-hop wireless networks. A simple and relatively low-cost approach to address this problem is the use of multiple wireless network interfaces (radios) per node. Operating the radios on distinct orthogonal channels permits effective use of the frequency spectrum, thereby, reducing interference and contention. This paper, evaluated the performance of the multi-radio Ad-hoc On-demand Distance Vector (AODV) routing protocol with a specific focus on hybrid WMNs. Simulation results show that under high mobility and traffic load conditions, multi-radio AODV offers superior performance as compared to its single-radio counterpart. It proved that multi-radio AODV is a promising candidate for WMNs, which need to service a large number of mobile clients with low latency and high bandwidth requirements (Draves et al., 2004).

Improving routing performance through m-limited forwarding in power-constrained wireless ad hoc networks

This paper presents m-limited forwarding, a technique to reduce the cost of disseminating information in a power-constrained environment by limiting the cardinality of the subset of nodes which retransmit a packet. It has been shown how this technique can be used to improve the performance of ad hoc routing protocols. m-AODV applies m-limited forwarding to the AODV routing protocol, and was used for networks with symmetric connections. The benefits of the enhanced routing protocols were quantified. It concludes that m-AODV outperforms plain AODV in general scenarios.

Ad hoc routing protocols use nodes with limited power reserves for forwarding packets. Most routing protocols disseminate routing information by flooding, a technique which requires a significant consumption of energy and bandwidth. m-limited forwarding (Pirzada et al., 2008) is a technique to reduce the cost of disseminating information in a power-constrained environment by limiting the cardinality of the subset of nodes which retransmit a packet. In case of flooding, the number of messages increases geometrically with the distance from the source while for m-limited forwarding the increase is only linear. In this paper, we analyze m-limited forwarding and report on a simulation study in networks with symmetric and asymmetric links. Our performance studies report on power savings and packet loss for a location-aware mobile ad hoc network.

Proposed solution

To overcome the high traffic generated from re-forwarding RREQ packet through the mesh network during flooding process, which is the case still exist in AODV-HM.

We used a limiting forwarding technique (Wang et al., 2008) to reduce the cost of disseminating information in a power-constrains environment by limiting the cardinality of the subset of nodes which retransmit a packet. This technique can improve the performance of AODV in

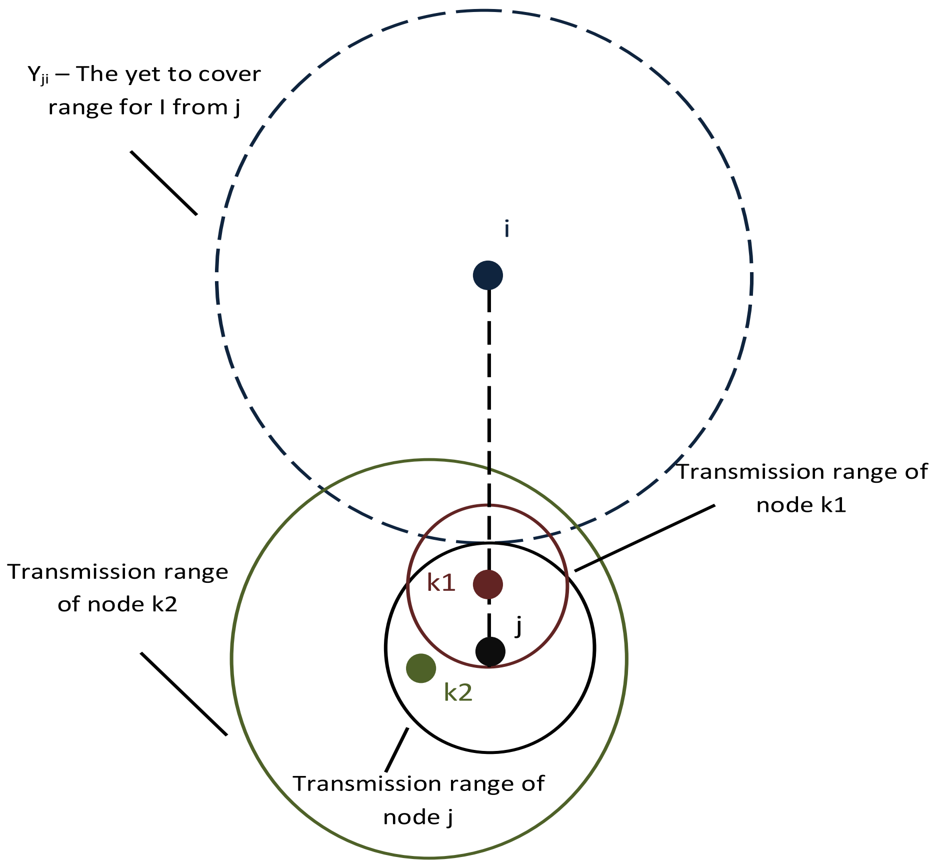

Figure 2. A configuration including the sender j, the destination i, and two candidate nodes k_1 and k_2 as the next hop on the path from j to i.

hybrid mesh networks. Figure 2 shows a configuration including the sender j, the destination i, and two candidate nodes k1 and k2 as the next hop on the path from j to i.

Each node k determines if it belongs to the selected subset by evaluating its own forwarding fitness function $F_k(i,j)$ related to the current transmission and compares the value of this function with the forward cutoff. The node k forwards the packet if and only if its fitness is higher than the forwarding cutoff. Figure 3 shows the flowchart of RREQ processing in AODV-LFHM.

We used the area-based forwarding fitness function in an attempt to optimize the number of “favorably located” nodes towards the destination reachable from the new node, but not from the current one. We define as “favorably located” the nodes which are closer to the destination than the maximum range of the current node (Wang et al., 2008).

$$F_k^a(i,j) = \begin{cases} 0 \\ \dfrac{R_k^2(\theta - \sin\theta) + r_{ij}^2(\varphi - \sin\varphi)}{2} \\ \pi . r_{ij}^2 \end{cases}$$

SIMULATION RESULTS

In this paper, several simulation experiments have been done, by varying node mobility, and network connections, to evaluate the efficiency of the AODV-EHM protocol. Table 1 summarizes the performance metrics which is provided by the simulation.

Node mobility simulation

In Simulation I, we have varied the maximum speed of the MESH-CLIENTs from 0 m/s to 10 m/s (Breslau et al., 2000).

Results shown in Figure 4, indicates that the packet loss is consistently lower for AODV-EHM with FS=4 compared to standard AODV, and AODV-HM.

The packet loss ratio of 1-limited forwarding is noticeably greater than all other schemes as the network mobility increases. Figure 5 illustrate the average power consumption function of node mobility.

Results indicate that with AODV-EHM consumed more power due to transmitting and handling of hello packets, and location-update packets. Figure 6 illustrate the routing packet overhead as a function of node mobility.

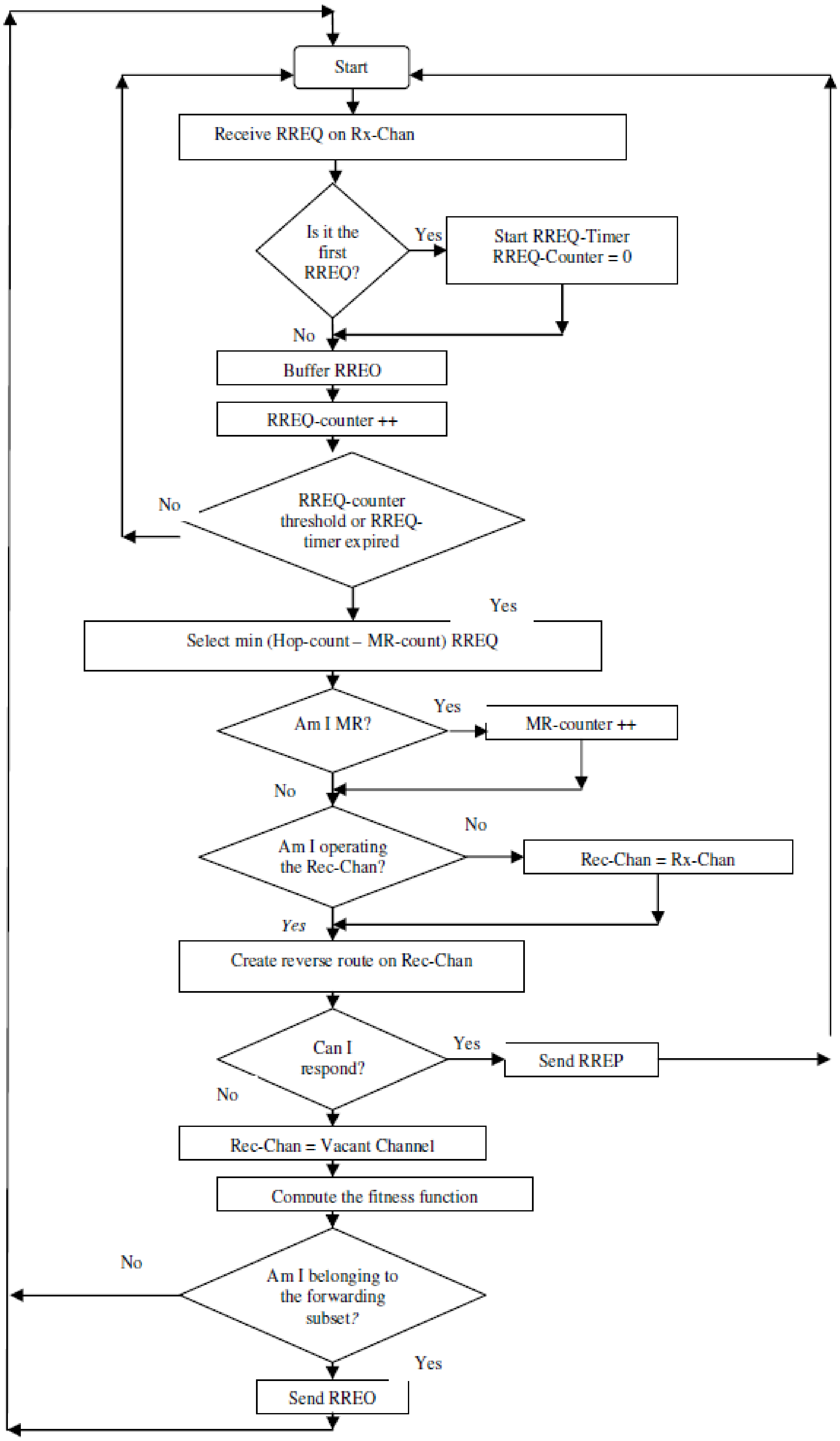

Figure 3. RREQ processing in AODV-LFHM flowchart.

Table 1. Performance metrics.

Performance metrics	Description
Packet loss ratio (%)	The ratio of all data packets received to the number of data packets sent during the simulation.
Average power consumption(j /node)	The ratio of total power dissipated by all nodes to the number of nodes in the network
Routing overhead	The ratio of the total number of control packets generated to the total number of received data packets
Average latency	The mean time in seconds taken by data packets to reach their respective destinations

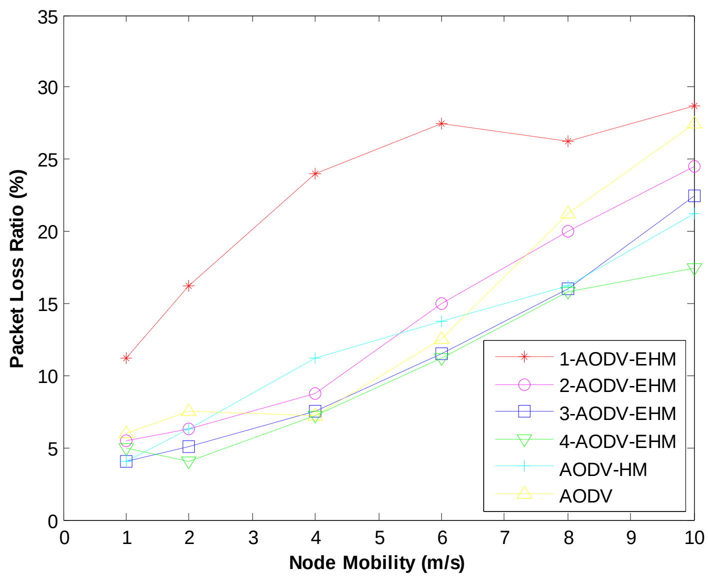

Figure 4. Packet loss ratio versus node mobility.

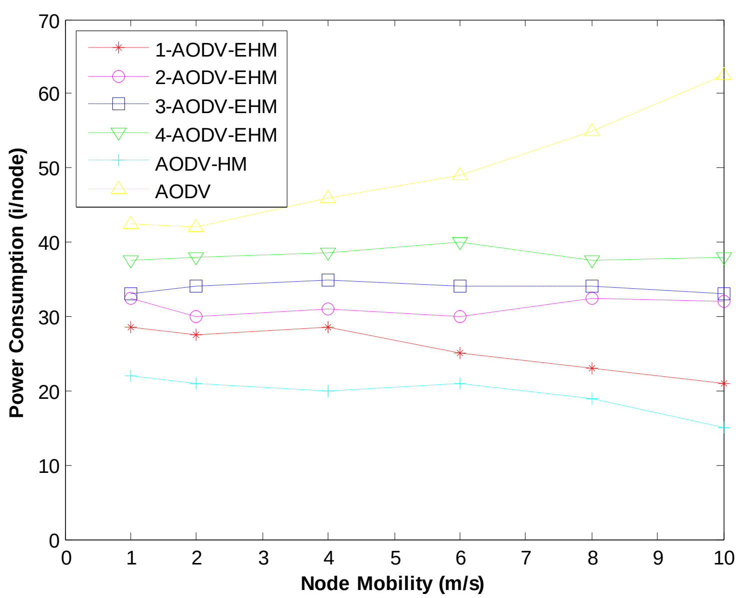

Figure 5. Power consumption versus node mobility.

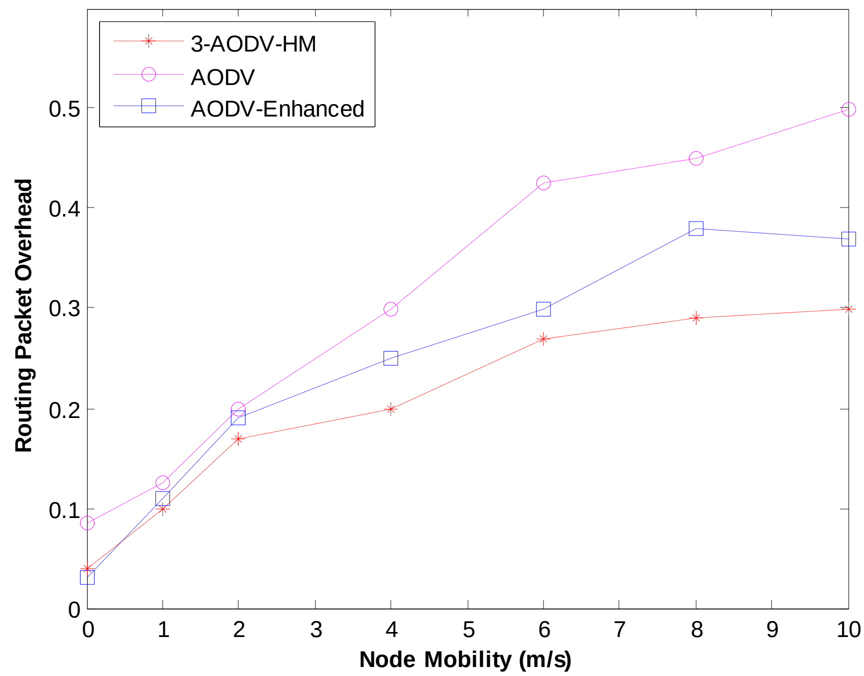

Figure 6. Packet Overhead versus Node Mobility

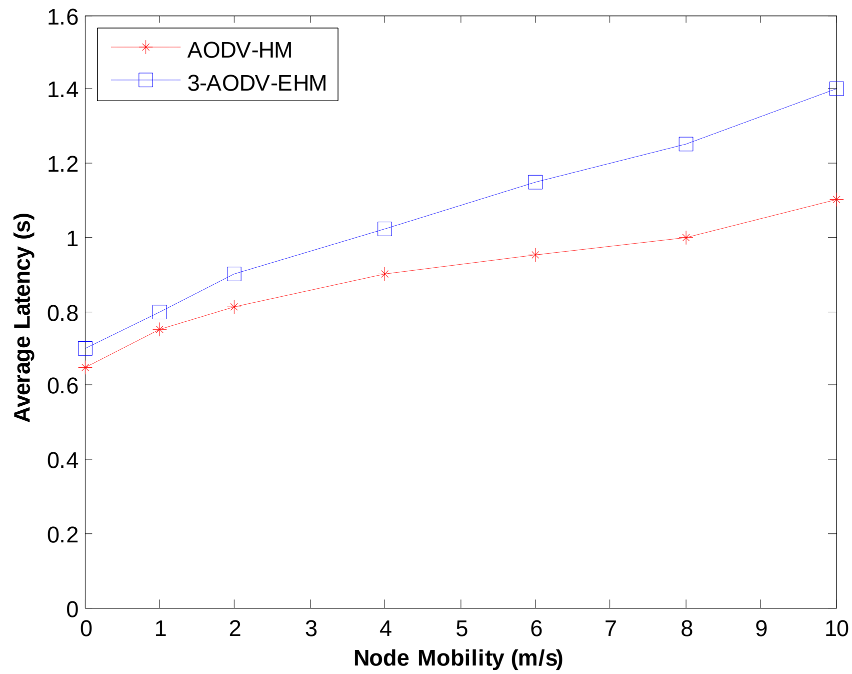

Figure 7. Average latency versus node mobility.

The control packet overhead per received data packet for AODV-EHM is significantly larger than for AODV-HM. This is due to that AODV-HM does not incur any additional byte overhead, since the MR-Count and Rec-Chan already exist at the AODV RREQ header, on the other hand, AODV-EHM, introduce infrequent broadcasting location update packet. Figure 7 illustrate the Average latency function of node mobility.

Results indicate that, AODV-HM's route selection mechanism along with the dynamic channel carried out

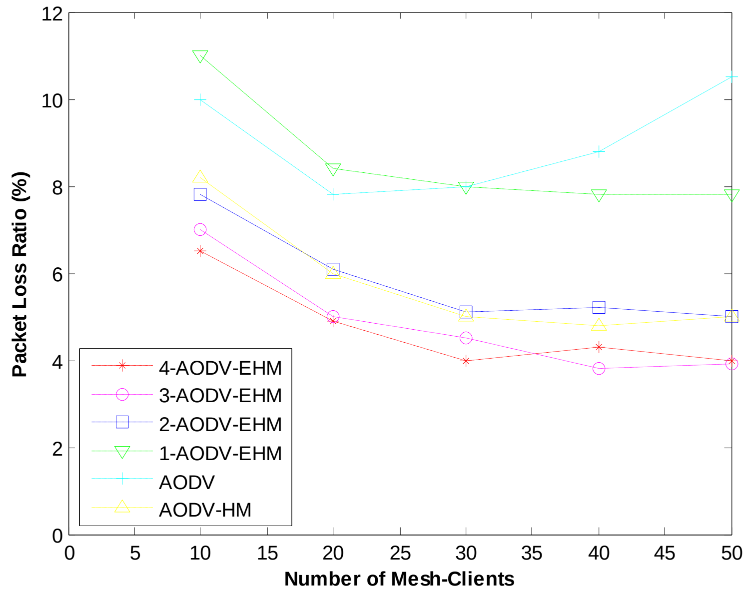

Figure 8. Packet loss ratio versus number of mesh clients.

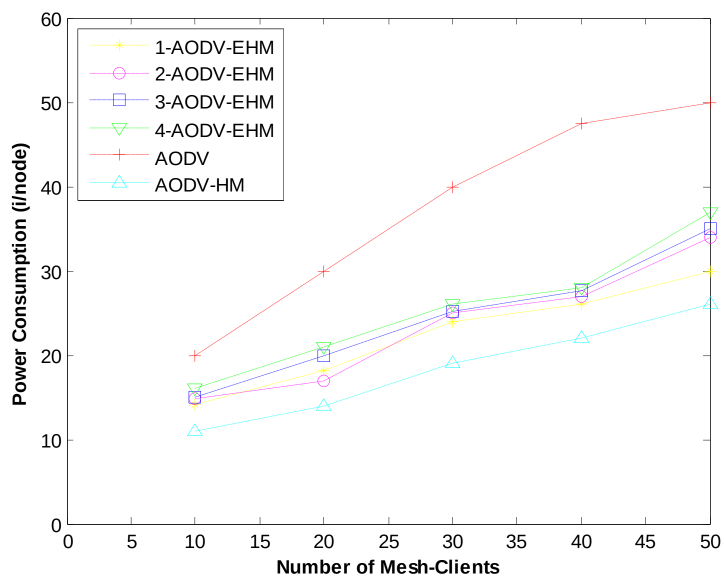

Figure 9. Power consumption versus number of mesh clients.

during the route discovery process is faster than AODV-EHM.

Number of connections simulation

In Simulation II, we have varied the number of simultaneous connections between the MESH-CLIENTs from 15 to 75.

Results, shown in Figure 8, indicate that the packet loss is consistently lower for AODV-EHM with FS=4 compared to standard AODV, and AODV-HM.

Figure 8 illustrates that at the low connectivity, packet loss ratio of all schemes is high. For higher connectivity, we note that AODV-EHM with FS=3 has a lower packet loss ratio than others, and AODV-HM packet loss ratio is comparable with AODV-EHM with FS=3.but, this case is not happened at FS=4, this is due to higher number of forwarding collisions. Figure 9 illustrate the average power consumption function of nodes connections.

Results indicate that with AODV-EHM consumed more power due to transmitting and handling of hello packets,

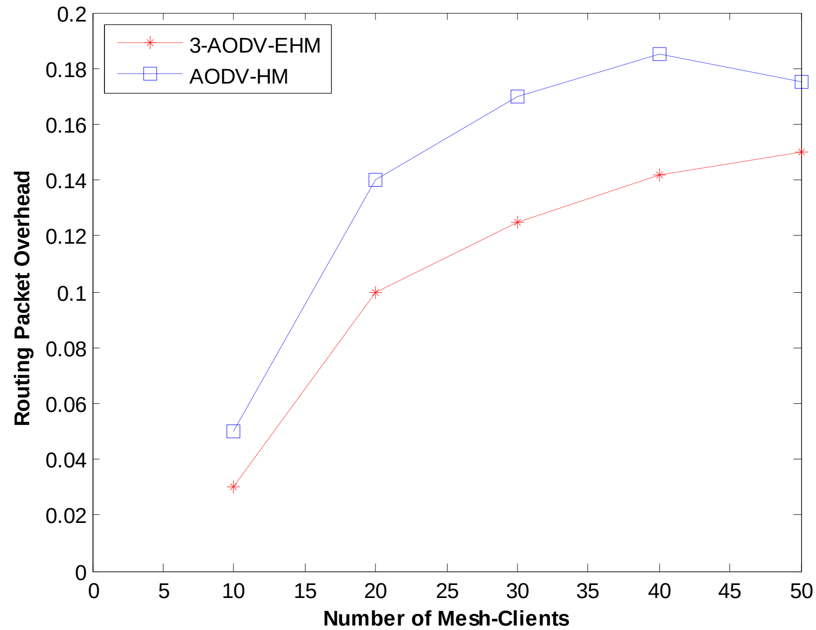

Figure 10. Routing packet overhead versus number of mesh clients.

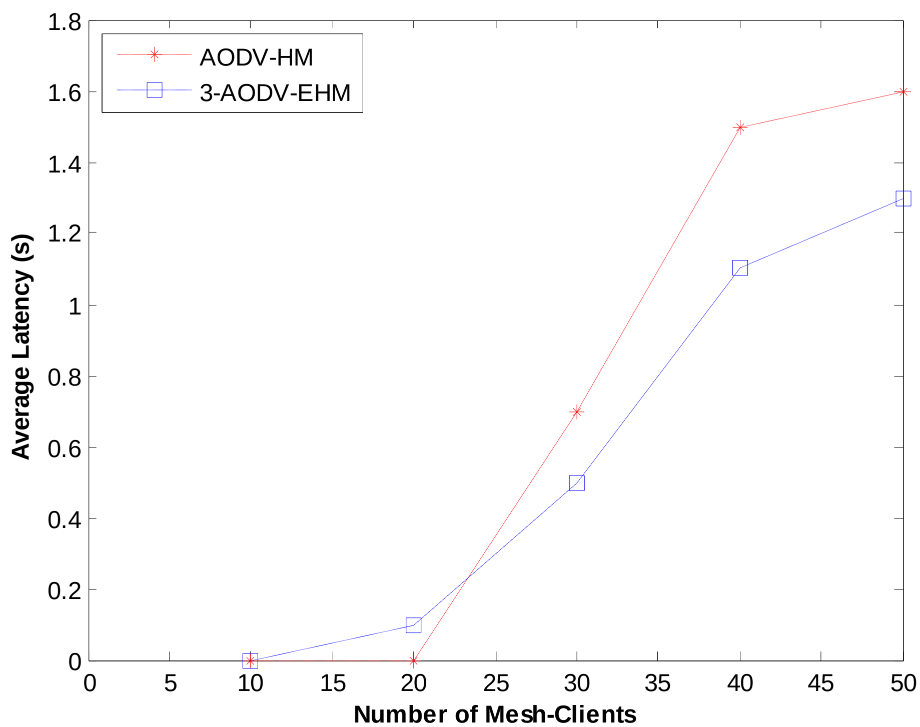

Figure 11. Average latency versus number of mesh clients.

location-update packets by more nodes. Figure 10 illustrates the routing packet overhead of nodes connections.

Results indicate that with AODV-EHM routing packet overhead is higher, due to transmitting and handling of hello packets, location-update packets by more nodes. Figure 11 illustrate the average latency function of nodes connections.

Results indicate that, AODV-EHM has lower latency than AODV-HM; due to its limited flooding packets in network, then it reduces the contention for the wireless medium by nodes.

Conclusion

In this paper, we propose a new version of AODV that is based on AODV-HM, we use a technique to reduce the cost of disseminating information in a power-constrains environment by limiting the cardinality of the subset of nodes which retransmit a packet. Simulation results show that this technique can improve the performance of AODV in hybrid mesh networks.

REFERENCES

Akyildiz IF, Wang X, Wang W (2005). Wireless mesh networks: a survey. Computer Network.

Akyildiz IF, McNair J, Ho JSM, Uzunalioglu H, Wang W (1999). Mobility Management for Next Generation Wireless Systems, 87: 1347-1384.

Asherson S, Hutchison A (2006). Secure Routing for Wireless Mesh Networks. In Proceedings of the Southern African Telecommunication Networks and Applications Conference (SATNAC).

Avudainayagam A, Lou W, Fang Y (2003). Dear: a device and energy aware routing protocol for heterogeneous ad hoc networks. J. Parallel Distrib. Comput. 63(2): 228–236.

Breslau L, Estrin D, Fall K, Floyd S, Heidemann J, Helmy A, Huang P, McCanne S, Varadhan K, Xu Y, Yu H (2000). Advances in network simulation. IEEE Comput. 33(5): 59–67.

Draves R, Padhye J, Zill B (2004). Routing in Multi-Radio, Multi-Hop Wireless Mesh Networks. Proceedings of the 10th Annual International Conference on Mobile Computing and Networking, ACM Press, pp. 114-128.

Jones CE, Sivalingam K, Agrawal P, Chen JC (2001). A survey of energy efficient network protocols for wireless networks. Wireless Netw., 7(4): 343–358.

Kyasanur P, Vaidya NH (2006). Routing and Link-layer Protocols for Multi-Channel Multi-Interface Ad Hoc Wireless Networks, SIGMOBILE Mobile Comput. Commun. Rev., 10(1): 31-43.

Pirzada A, Portmann M, Indulska J (2007). Hybrid mesh ad-hoc on-demand distance vector routing protocol. ACM International Conference Proceeding Series, p. 244.

Pirzada A, Portmann M, Indulska J (2008). Performance analysis of multi-radio AODV in hybrid wireless mesh networks. Computer Commun., 31(5).

Roemer K, Mattern F (2004). The design space of wireless sensor networks. IEEE Wireless Commun., 11(6): 54-61.

Wang G, Ji Y, Marinescu DC, Turgut D (2004). A routing protocol for power constrained networks with asymmetric links. Proceedings of the ACM Workshop on Performance Evaluation of Wireless Ad Hoc, Sensor, and Ubiquitous Networks (PE-WASUN), pp. 69–76.

Wang G, Turgut D, Blni L, Ji Y, Marinescu D (2008). Improving routing performance through m-limited forwarding in power-constrained wireless ad hoc networks. Parallel Distrib. Comput., 68(4).