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Node Stability Based Client Routing for 802.11s Networks

A. Prasina, T. Yogamithra and M.A. Bhagyaveni
Department of ECE, Anna University, Chennai 600 025, Tamil Nadu, India

Abstract: IEEE 802.11s is the standard defined for WLAN mesh networks and Hybrid Wireless Mesh routing Protocol (HWMP) is a default routing protocol for 802.11s based Wireless Mesh Networks (WMNs). HWMP uses Air Time Link metric to find out the best path. Air time Link metric outperforms hop count in mono channel mono radio environment. HWMP is affected by path instability and broadcast storm problem. Another main idea behind this routing algorithm is triggered by the routing procedure in partial infrastructure networks. All the existing routing protocols of MANETs can also be applicable for WMNs. But all the MANETs routing algorithms are designed for mobile nodes. But HWMP fails to utilize the partial infrastructure feature of the WMNs. But the proposed algorithm differentiates the stable nodes and mobile clients to make the routing more stable and efficient. The proposed node stability based client routing protocol improves the performance of IEEE 802.11s based WMN. This Protocol identifies new routes by considering stable nodes, Air time link metric and hop count. The simulation results show the protocol achieves improved throughput, packet delivery rate. It has less delay and packet loss compared to HWMP.

Key words: WMNs, IEEE 802.11s, HWMP, stable nodes, air time link metric

INTRODUCTION

A Wireless Mesh Network (WMN) is a multi hop wireless network made up of radio nodes and forms a mesh topology. It can be deployed without any wiring and major infrastructure support. WMNs can self-heal and self-organize in a dynamic environment (Akyildiz, 2005). Hybrid Wireless Mesh routing Protocol (HWMP) and Radio Aware Optimized Link State Routing (RA-OLSR) are defined as the default routing protocol for 802.11s based WMNs. As shown in Fig. 1, IEEE 802.11s based WMNs comprised of three types of nodes such as Mesh Portal Point (MPP) and Mesh Access Point (MAP) and Mesh Point. The HWMP protocol has failed to address the issues such as path instability, broadcast storm problem (Ghannay *et al*., 2009) and it is not considering the mobility of the nodes for routing.

Pirzada and Portmannt (2007) introduced a new routing metric that allows differentiating between node types (Mesh Routers and Mesh Clients). The effect of this new metric is that routes preferentially include Mesh Routers and only involve Mesh Clients when absolutely necessary.

Mhlanga *et al*. (2009) an energy-aware path selection (EAPSM) was proposed. This protocol will increase the survivability of the network. Draves (2004)

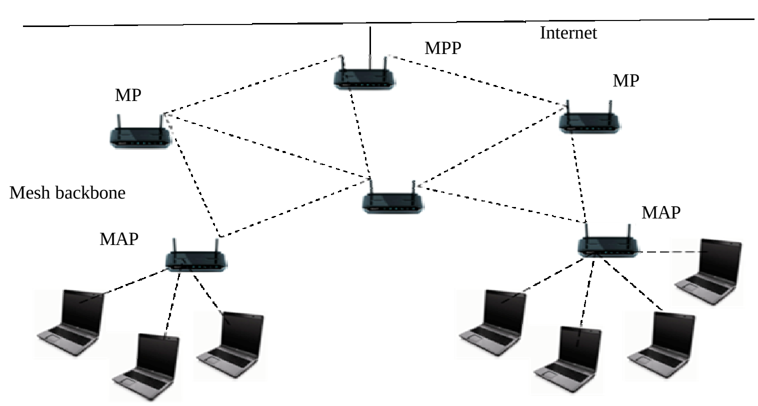

Fig. 1: Infrastructure/backbone WMNs

Corresponding Author: A. Prasina, Department of ECE, College of Engineering, Anna University, Guindy, Chennai 600 025, Tamil Nadu, India

proposed a metric which choose a high-throughput path between a source and a destination based on ETT (Expected Transmission Time) of a packet over the link. The ETT is a function of the loss rate and the bandwidth of the link.

Guerin *et al.* (2007) provided a survey of recently proposed routing metrics for multi radio mesh networks. Cao *et al.* (2009) presented a hybrid anycast routing protocol for heterogeneous access networks which enables Mesh Nodes to select one of multiple eligible access points. Islam *et al.* (2010) proposed a new metric which assigns a weight value, to successfully deliver a packet from a node to the next hop. Oliviero and Romano (2008) proposed reputation-based metric applied to the existing routing protocols that can improve the reliability of the over all network communication. Shen and Fang (2006) proposed a Multi-metric (MM) consisting of the interference and mesh point's transmitting capability in wireless environment based on residual bandwidth, Frame Delivery Ratio (FDR) and mesh point's load. Aure and Li (2008) proposed the radio-aware path selection using airtime as a metric for IEEE 802.11s mesh network.

But none of the above papers deals with the metric which considers number of stable nodes in the path, hop count and ALM together for routing in partial infrastructure network. In this study, we propose a Node stability based Client Routing Protocol which utilizes best path and link of the network and improves routing. The best route is selected by considering the node cost and link cost.

SYSTEM OVERVIEW

Structure of 802.11s mesh topology: Wireless Local Area Networks (WLANs) have become very popular in recent years. The new IEEE 802.11s standard for WMNs is formed by Mesh Points, Mesh Access Points and Mesh Portal Points. MAP, MP and MPP are stable nodes which will form the backbone of mesh network where as clients are mobile nodes. Figure 2 shows the basic structure of 802.11s mesh topology. MPs and MAPs support WLAN mesh services, allowing them to forward packets on behalf of other nodes to extend the wireless transmission range. Mesh clients can associate with MAPs but not with MPs. Mesh portals (MPPs) are MAPs which provides connectivity to other networks.

Hybrid wireless mesh routing protocol: IEEE 802.11s proposes a Hybrid wireless mesh routing protocol which is designed by combining the functionalities of AODV and TBR (Tree based Routing). HWMP utilizes both reactive and proactive routing which makes the protocol more optimal and efficient during path selection in a wide variety of mesh networks both in infrastructure and infrastructure less mode.

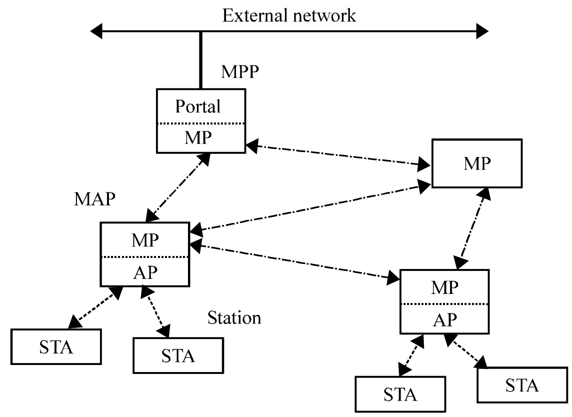

Fig. 2: Structure of 802.11s based WMNs

HWMP is layer 2 path selection protocol since it uses MAC address for its routing instead of IP address which results in faster access to physical layer, faster forwarding and improvement of medium access.

Airtime link metric based routing: The default routing metric of HWMP is the airtime metric where the individual link metrics are added to get the overall path metric. Amount of channel resources consumed to transmit a frame from one node to another through the particular link is represented by ALM (Zhang *et al.*, 2006). A new path metric field is included in the RREQ/RREP message that contains the cumulative value of the link metrics of the path so far. The path with the smallest sum of airtime link metrics will be considered as the best path. Since radio-aware metric changes more often than the hop count metric, it is preferable to have only the destination to answer so that the path metric is up to date. Airtime Link Metric's parameter values are given in Table 1:

$$C_a = [O_{ca}+Op+(B_t/r)]\ (1/1-e_{pt})$$

where, O_{ca} is channel access over head, O_p is protocol overhead and B_t is No. of bits in test frame.

The Fig. 3, illustrates an example on how the airtime metric will provide an efficient path through the network considering the data rate, radio type and frame error probability. All airtime metrics given below include the radio type on each link. Based on the airtime metric obtained, a stationary node is able to select a path towards destination with least total airtime cost. The source node C wants to transmit the packet to the destination E. In hop count based routing, the path will be selected through R since it is going to have only two hops. But in ALM based routing, the individual link cost

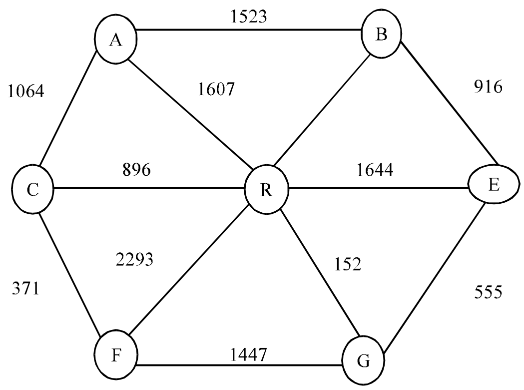

Fig. 3: ALM based routing

Table 1: ALM parameters

Parameter	Value 802.11a	802.11b
Channel access overhead: O_{ca}	75 (msec)	335 (msec)
Protocol overhead: O_p	110 (msec)	364 (msec)
No. of bits in test frame: B_t	8224	8224

of each link will be updated in ALM field of RREQ packet. The destination will check the final cumulative value of each received RREQ packet and select the route which has minimum link cost. In this case, the link C-F-G-E has minimum link cost of 2373 compared to other routes. The link cost of two hop route C-R-E is 2540.So it will be rejected and lowest link cost path is selected.

NODE STABILITY BASED CLIENT ROUTING PROTOCOL (NSCRP)

To solve path instability issue, NSCRP considers hop count, number of stable nodes and the link quality to select the path from any given source to destination. MAP, MP and MPP are considered as the stable nodes in IEEE 802.11s network. The path through stable nodes will be always stable than the path through the clients. Hence NSCRP gives preference to the path with more stable nodes.

Assumptions:

- Mesh nodes such as MAP, MP and MPP are stable nodes and clients are mobile nodes. Since Stable nodes forms the backbone of the network, the topology of the network will not change significantly while a packet is being transmitted
- Wireless Mesh Networks considered are of small to medium sized networks
- All links are bidirectional
- Every node has the knowledge of their position in the network

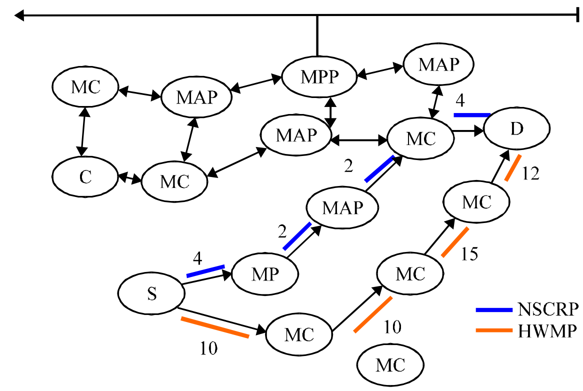

Fig. 4: NSCRP based routing

Algorithm: Whenever a source node has data to transmit, the following steps are executed:

Step 1: The source node initiates route discovery by broadcasting a RREQ packet to its next hop neighbors

Step 2: The nodes receiving this route request packet will check if it is the indented destination or not

Step 3: If so, a route reply RREP is unicasted to the destination

Step 4: Otherwise, the node will check whether it a stable node

Step 5: If so, it will update all the mutable fields except the hop count field

Step 6: If it is the client node, it will update the hop count field since the node cost will be the difference between the number of hops and the number of stable nodes in the route

Step 7: If destination receives RREQ from multiple paths, in order to select the best path, each node will update the link metric field and node cost field. The destination will calculate the link cost from the cumulative link metric field and node cost from the node cost field

Step 8: The destination will select the best route from the path cost and then the RREP will be unicasted to the source by the destination

Step 9: The data packets are transmitted through the selected best path

Figure 4 shows the path chosen by HWMP and the path chosen by the proposed NSCRP. NSCRP selects the best path which has minimum hop count through stable nodes and the best link with minimum ALM cost.

Figure 5 shows the flow of NSCRP protocol. NSCRP will select the optimum route by identifying the route with more number of stable nodes, low air time link cost and less hop count. The client node which needs to transmit the data to the destination should first get associated with the MAP. After the association with MAP, it becomes mesh client and can route the packet to the destination by identifying the best path. For routing, the source will broadcast the RREQ packet to its neighboring nodes. The RREQ packet will have both link metric field and node cost field.

The node cost will be calculated by considering number of hops and number of stable nodes in its path. Node cost is the amount of cost spent to reach the destination through the stable nodes. The link cost field will be updated depending upon the ALM value. At the destination, it will process the received RREQ packet. Destination will calculate the path cost:

$$\text{Path cost} = \Sigma L_i \times Ni$$

where, Li is the link cost, Ni is the node cost:

$$\text{Optimum route} = \text{Min } [\Sigma L_i \times Ni]$$

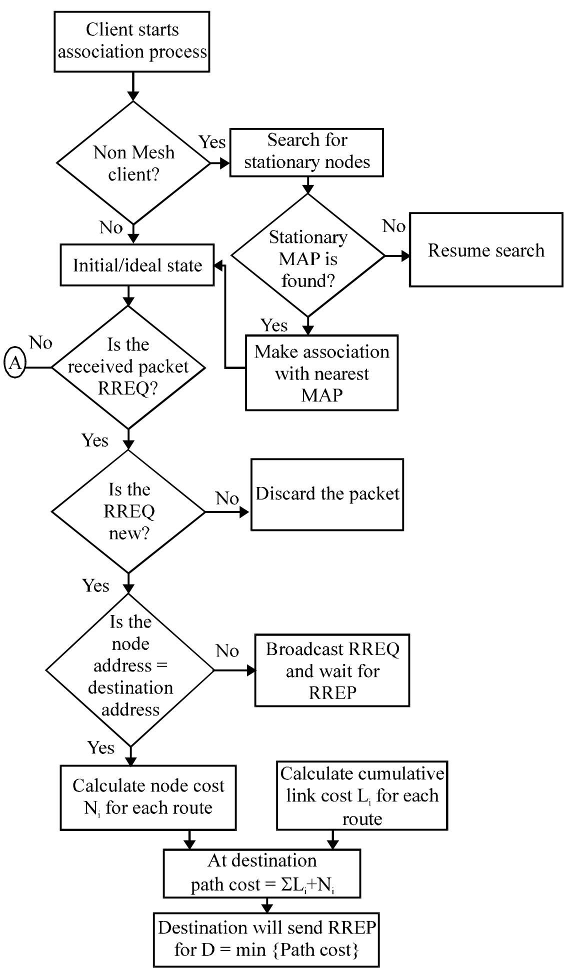

Fig. 5: Proposed system

PERFORMANCE EVALUATION

The proposed node stability based client routing algorithm is simulated and the performance of the protocol is evaluated. The network throughput, average end to end delay and protocol overhead with respect to the network traffic are studied and the results are presented in this section. A network comprised of stable node and mobile clients are placed randomly within 1500×1500 m^2 area is simulated. The radio propagation range of 250 m was chosen for each node. Multiples runs with different seed values were conducted for each scenario and the collected data were arranged over those runs.

Table 2 lists the simulation parameters and environments, which are used as default values unless otherwise specified and Fig. 6 shows the scenario used for the simulation.

Figure 7 shows the Delay performance of NSCRP. Paths selected by NSCRP have been optimized for minimal interference. So packets were sent without excessive contention for the physical medium which will be comparatively high in AODV based routing. NSCRP based routing produces 5 msec less latency than AODV. Initial latency of HWMP was very high. So NSCRP performs well as compared to HWMP and AODV.

Table 2: Simulation parameters

Parameter	Values
Terrain range	1500×1500 square
Transmission range	250 m
Node placement	Random
Mobility model	Random way point model
Propagation model	Free space
Station association type	Dynamic
MAC type	802.11s
Traffic type	CBR
Data payload	512 bytes
Routing protocol	NSCRP

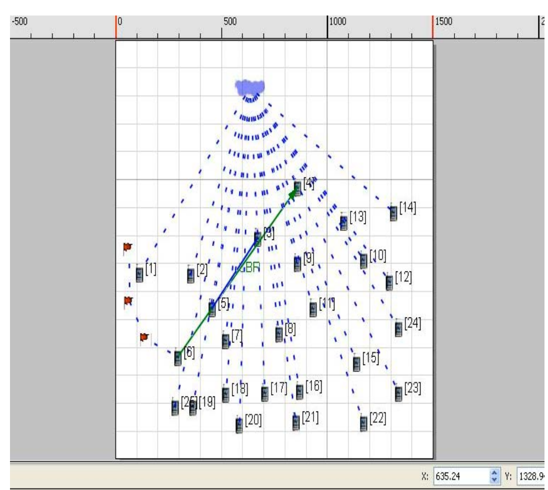

Fig. 6: Scenario

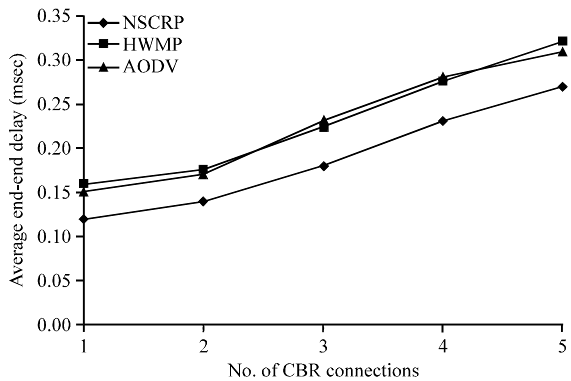

Fig. 7: Number of CBR connections effecting delay

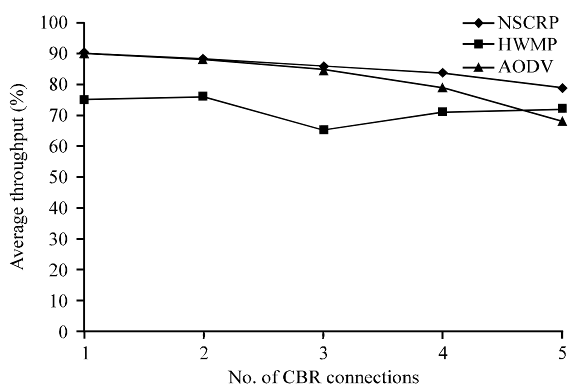

Fig. 8: Number of CBR connections effecting average throughput

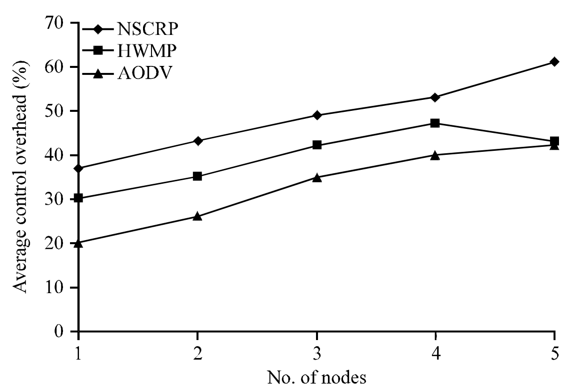

Fig. 9: Number of CBR connections and the average control overhead

Figure 8 gives PDR performance and the results indicate that the NSCRP has lower packet loss rate than AODV and HWMP under increasing traffic loads. This is essentially due to routing of packets through the stable nodes. The PDR performance of NSCRP scheme is found improved by 20% as compared to the HWMP and 10% as compared to AODV. It is also observed that the NSCRP is able to maintain the good PDR performance.

The protocol overhead of NSCRP, HWMP and AODV was shown in Fig. 9. When the traffic load was increased, NSCRP generates more control packets for every received data packet and also NSCRP using three metrics to select the path, the protocol overhead is slightly higher in NSCRP than AODV and HWMP.

NSCRP outperforms HWMP in all scenarios since HWMP considers link loss rate and link bandwidth when selecting a path. It does not attempt to select path through fixed nodes and hop count.

CONCLUSION

In this study, the performance of existing routing algorithm like AODV and HWMP is compared with the proposed protocol NSCRP. The concept of node stability based client routing is proposed and the simulation performance of NSCRP, AODV and HWMP algorithms are presented in this study. From the results obtained, it may be stated that the networks like MANET in which all the nodes are mobile can use the existing protocols such as AODV and DSR. But WMNs which is partially infrastructure should use the routing protocols in which the routing metric should utilize the stability of the network. So the NSCRP would best suit for WMNs which have both stationary nodes and mobile clients. The proposed protocol NSCRP shows improvement in throughput and delivery rate. It reduces the average end to end delay over HWMP. The performance can be improved by implementing this in clustered environment to improve the scalability of NSCRP.

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