NA-LAR : NAV Based Load Aware Routing Protocol for Wireless Mesh Networks

[1]InSoo Lee, [2]ByungDeok Chung
Convergence R&D Laboratory, KT
Seoul, Republic of Korea
[1]insoo.lee@kt.com, [2]bdchung@kt.com

[3]DoHyeun Kim
Dept. of Computing Engineering
Jeju National University
Jeju-Si Jeju-Do, Republic of Korea
[3]kimdh@jeunu.ac.kr

Abstract— In this paper, we propose a load balancing routing protocol for wireless mesh networks based on Network Allocation Vector (NAV) with Directional AODV (D-AODV) to improve network performance. We use a hop count to discover a route between mesh router and gateway because it reduces path discovery over-head, and consider network conditions from NAV, which indicates traffic load in each mesh router, to find load balanced route.

Keywords— Wireless Mesh Networks; Network Allocation; load balancing routing

I. INTRODUCTION

In WMNs most of the nodes are either static or minimally mobile and do not rely on batteries. The goal of routing algorithms is hence to improve network capacity [1] or the performance of individual communications instead of dealing with mobility or minimizing power consumption. The technical challenges in WMNs include load balancing, optimal routing, network auto-configuration, fairness and mobility management. A good routing algorithm needs to balance the load on the entire mesh network as well. Efficient load balancing can help to improve network capacity by avoiding routing traffic through congested areas. In order to achieve load balancing, we need appropriate routing protocols for WMNs. They should be designed carefully to adapt to the above characteristics of WMNs. Most researches considered network traffic load at each node to find load balanced routing path. The node load is measured according to the number of packets buffered in the node, and a routing path is selected through small loaded network nodes. But, they cannot find optimized load balanced routing path since they do not consider traffic interferences.

In this paper, we consider traffic load including traffic interferences calculated from NAV which indicates traffic load in each mesh router, and propose an efficient routing protocol with load balancing for wireless mesh networks to improve network performance.

II. RELATED WORK

In WMNs, most of the nodes are either static or minimally mobile and do not rely on batteries. The goal of routing algorithms is hence to improve network capacity [2] or the performance of individual communications instead of dealing with mobility or minimizing power consumption. Since most traffic in a WMN is destined towards gateways, traffic concentration at a certain node creates a load imbalance which in turn results in network performance degradation. In this section, we describe previous load balancing schemes, analyze and compare each solutions.

Over the years, several load balanced wireless ad hoc routing protocols have been proposed. Most of these protocols are traffic based (Load Balanced Ad Hoc Routing[3], Traffic-Size Aware scheme [4]) while Load-Aware On-Demand Routing is delay based. LARA [5] is considered hybrid based since exhibit features of both traffic- and delay-based protocols.

We shall discuss the operation and features of these protocols in the next section and provide qualitative comparisons. In addition to classifying protocols based on their load balancing techniques, one should also consider the load metrics used by these protocols [6]. The term “load metric” reflects how busy a node is engaged in receiving and forwarding packets over the wireless media. It also refers to processing, memory, bandwidth, and power load on the node.

The DRR (Delay-based RREP Routing) considers the factors of path distance, number of hop-count, intermediate node congestion, and intermediate node neighboring load and finds an optimal path. DRR routing intends to distribute traffic load on wireless routers. The behavior of DRR is similar to AODV in light load. In addition, in the medium load, node-weighted mapping is approximately linear, and this makes DRR acts like the literal load-balanced routing scheme. In the heavy loading region, the node weighted is increasing tremendously, which prevents the routing algorithm from using up the overloaded congested nodes.

LBAR (Load-balanced Ad Hoc Routing) is also an on-demand routing protocol. LBAR’s load metric is based on “active path activity”. However, LBAR considers the activities of neighboring nodes.

CQR (Contention and Queue-aware Routing) is also an on-demand routing protocol. In CQR, the load value includes the contention information from MAC layer and the number of packets in the interface queue along the route. This represents a typical cross layer approach, in which every node collects and processes the contention information from

MAC layer periodically and passes this parameter to the routing agent during the route discovery process.

TSA (Traffic-Size Aware Routing) is an extension to the virtual path routing protocol (VPR). It combines source and table routing [7].

DLAR (Dynamic Load-Aware Routing) [8] is also an on-demand routing protocol. When a route is required but no information to the destination is known, the source floods the ROUTE REQUEST packet to discover a route. When nodes other than the destination receive a non-duplicate ROUTE REQUEST, they build a route entry for the source, destination pair and record the previous hop to that entry thus, backward learning). DLAR considers the load of intermediate nodes as the main route selection metric and monitors the congestion status of active routes to reconstruct the path when nodes of the route have their interface queue overloaded. In the route construction phase, each intermediate node records in the control packet the number of packets queued at the interface and the destination uses that information when selecting the route. DLAR periodically monitors the congestion status of active data sessions and dynamically reconfigures the routes that are being congested. Using the least-loaded routes helps balance the load of the network nodes and utilize the network resources efficiently.

LARA ((Load Aware Routing in Ad Hoc) [5] is hybrid load balanced routing protocol. LARA requires each node to maintain a record of the latest traffic queue estimation of its neighbors. The traffic queue is defined as the average value of the interface queue length measured over a period of time. Traffic density, on the other hand, refers to the sum of traffic queues at a node plus the traffic queues of all the node's neighbors. The traffic cost of a route in LARA is defined as the sum of traffic densities at each node in the route and the hop costs (transmission and propagation delay) on that route.

III. NA-LAR: NAV-BASED LOAD AWARE ROUTING PROTOCOL FOR WIRELESS MESH NETWORK

In this section, we introduce NAV-based Load Aware Routing Protocol (NA-LAR) routing protocol. NA-LAR is basically based on the D-AODV and it uses NAV to reflect each mesh router and neighbor's traffic loads. We describe the operation of NA-LAR focusing on the route discovery with load balancing to gateway.

NA-LAR uses HC and NAV. A HC is the number of hops from a gateway and is used for limitation of RREQ packet forwarding like D-AODV [9]. Each node learns its number of hops from a gateway through hop count discovery procedure. A NAV is traffic load state including traffic interferences, and is used to find load balanced routing path. Each node gets the NAV information by RTS and CTS control frame from neighbor nodes. On receiving RREQ packets, a node compares the NAV value on the RREQ packet with its NAV value. When its NAV value is larger than RREQ packet, it updates NAV field in RREQ packet with its own NAV value. Finally, upon receiving RREQ packet at gateway, it waits certain time to receive more RREQ packets in order to select load balanced route with a smaller NAV value. Thus, NA-LAR can find a lower loaded route, and it leads to network performance improvement.

In the IEEE 802.11, the carrier sensing is performed by method of physical carrier sensing and virtual carrier sensing. The virtual mechanism is referred to as the network allocation vector, NAV in short. NAV blocks other nodes from simultaneous transmission. The most important fact about NAV is that it can be used to monitor the channel busy or channel idle, since a node also transmit its NAV value to its neighbors. Stations set the NAV to the time for which they expect to use the medium, including any frames necessary to complete the current operation. Other stations count down the NAV to 0. When NAV is non-zero, the sensing function indicates that the medium is busy; when NAV reaches 0, the sensing function indicates that the medium is idle. A node will copy another node's NAV when another node actively occupying the medium. This indicates that the neighbor nodes is busy and traffic load.

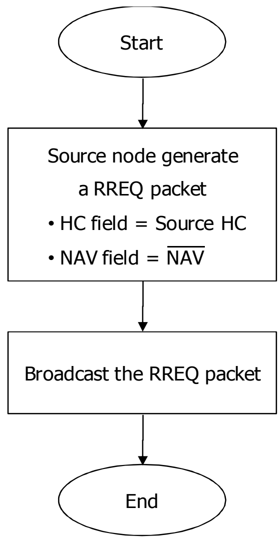

Figure 1. Source mesh routers.

NA-LAR uses the NAV measurements during a specific period as the link's traffic load indicator. This NAV is calculated by equation (2). NAV is used to mitigate the effect of a dynamic traffic load change, and a moving average is used to estimate the traffic load indicator over a period. Each node always calculates NAV value, and it used to routing metric to find load balanced path.

The route discovery of NA-LAR is fundamentally similar to D-AODV. NA-LAR uses modified RREQ packet with HC field to indicate the number of hops from the gateway and NAV field to notify traffic load at bottleneck node. When a source node, which does not have a route to the gateway, desires to send data packets, it broadcasts a RREQ packet with its HC and NAV value as shown in Figure 1.

On receiving RREQ packets at intermediate node, a node compares the HC value in the RREQ packet with its own HC value. If the HC value in the RREQ packet is equal to or smaller than its HC value, the intermediate node discards RREQ packets.

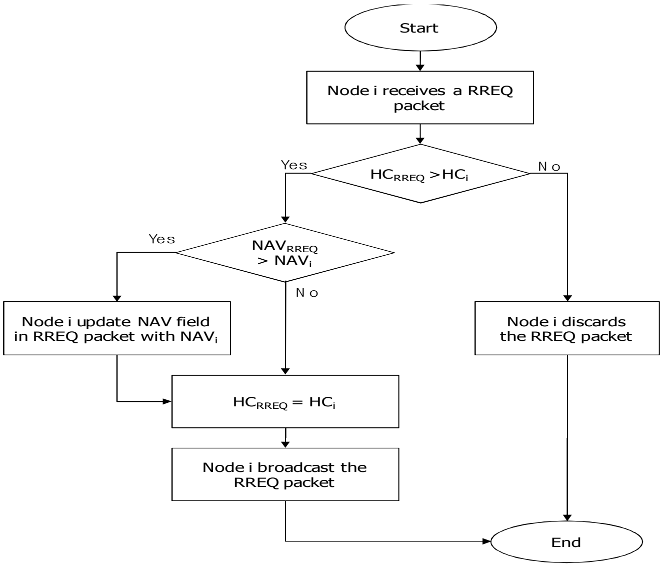

Figure 2. Intermediate mesh routers.

Otherwise, it replaces the HC field in the RREQ packet with its own HC value. Simultaneously, a node compares the NAV value in the RREQ packet with its own NAV value. When the NAV value in the RREQ packet is smaller than the its NAV value, intermediate node updates NAV filed in the RREQ packet with its NAV value and then re-broadcasts the RREQ packet to all neighbors as shown in Figure 2. On receiving RREQ packets at gateway, it selects a route with received RREQ path, and runs RREQ waiting timer to receive some more RREQ packets in order to find a light load path with smaller NAV value. Until the timer expired, whenever the gateway receives RREQ packet, it compares the NAV value on the RREQ packet with its selected route's bottleneck NAV value

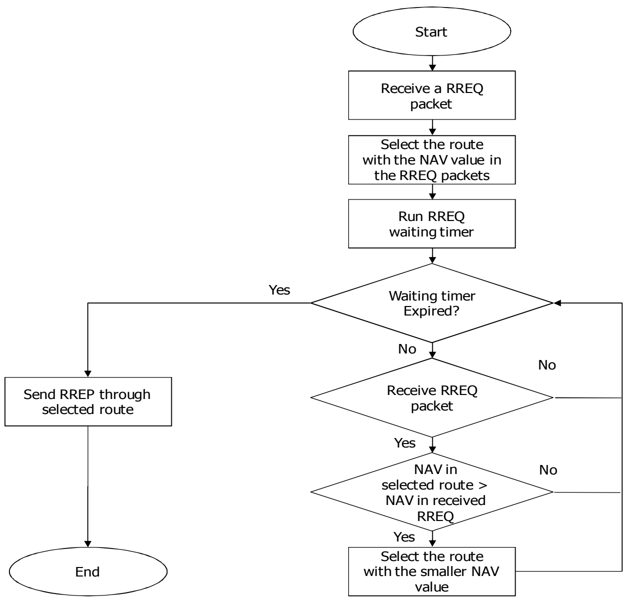

Figure 3. Gateway operation.

If the received NAV value is smaller than previously selected one, it updates selected route with received RREQ path as shown in Figure 2. When the timer is expired, the gateway replies to the source router with RREP packet along selected route. As illustrated above in NA-LAR, RREQ packets with NAV value are directionally flooded toward the gateway to support load balancing. Route maintenance is similar to that of the AODV. An existing routing entry may be invalidated if it is not used within a specified time interval, or if the next hop node is no longer reachable. When a node detects that a route to a neighbor is no longer valid, it removes the invalid entry and sends a route error message to the neighbors that are using the route. Nodes that receive error messages will repeat route discovery procedure. Finally, the source requests a new route if one is still needed toward gateway.

IV. CONCLUSION

This paper proposes NAV-based Load Aware Routing Protocol (NA-LAR) routing protocol. NA-LAR is basically based on the D-AODV and it uses NAV to reflect each mesh router and neighbor's traffic loads. We describe the operation of NA-LAR focusing on the route discovery with load balancing to gateway.

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