Available Online at www.ijcsmc.com

International Journal of Computer Science and Mobile Computing

A Monthly Journal of Computer Science and Information Technology

ISSN 2320–088X

IJCSMC, Vol. 2, Issue. 7, July 2013, pg.385 – 390

RESEARCH ARTICLE

Scalable Heat Routing Protocol for Wireless Mesh Networks

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Abstract— Wireless Mesh Network is a wireless network consisting of nodes in a mesh topology. As compared to routing in other networks, wireless mesh network faces a lot of problem. Routing in wireless mesh network is a challenging task. Field based routing uses a little information to route the packets in the network. Due to this characteristic, field based routing algorithms are less expensive and mainly effective, but such algorithms also face different types of efficiency and scalable issues. Many existing unicast routing protocols like AODV are not well adapted in wireless mesh networks as the messages are flooded across large number of mobile nodes and a few access points with Internet connectivity. As these mobile nodes have limited resources like limited CPU, memory, size and battery, many such routing protocols were suggested. In this paper, the cluster head chaining scheme is used to solve this problem, and is designed to scale to the network size with the use of realistic mobility patterns. HEAT depends on temperature field for packet transmission towards the Internet gateways. It does not require flooding of control messages. The packets are routed along the increasing energy or temperature value of the nodes. Another feature is designing an efficient protocol with respect to throughput and packet delivery ratio in a dense network, which is also scalable to the number of packets. The results clearly show that the benefit of Heat in terms of scalability and it is also more efficient in their packet delivery ratio and throughput. This approach is been analysed through NS2 simulations there-by study the trade-offs between scalability and congestion control.

Key Terms: - Wireless Mesh Networks; NS2 simulation tool; MANET; Heat

I. INTRODUCTION

Wireless mesh architecture is a first step towards providing cost effective and dynamic high-bandwidth networks over a specific coverage area. Wireless mesh architectures infrastructure is, in effect, a router network minus the cabling between nodes. It's built of peer radio devices that don't have to be cabled to a wired port like traditional WLAN access points (AP) do. Mesh architecture sustains signal strength by breaking long distances into a series of shorter hops. Intermediate nodes not only boost the signal, but cooperatively make forwarding decisions based on their knowledge of the network, i.e. perform routing. Such architecture may with careful design provide high bandwidth, spectral efficiency, and economic advantage over the coverage area.

The envisioned scenario is a city-wide wireless mesh network consisting of fixed access points with Internet connectivity and mobile nodes that are typically pedestrians or people moving in a vehicle and carrying a mobile device.

The mobile nodes in this mesh network serve as relays, forwarding traffic for other mobile nodes and thus maintaining network-wide Internet connectivity. The advantage here is only few gateways are required to provide a ”city-wide” Internet coverage when the density of the mobile users is large enough. Wireless mesh networks (WMNs) have the potential to eliminate many of these disadvantages by offering low cost, wireless

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broadband Internet access both for fixed and mobile users. The thesis shall present many of the problems that have to be solved in order to produce a high-performance, efficient and scalable protocol.

The problem appealed in this project is routing the data packets from the mesh network to the gateway. The routing includes the traffic from mobile nodes to whatever access point (called Internet gateway) and the response traffic back to the mobile nodes. This routing problem is different from what MANET routing protocols like AODV, OLSR, DSR, DSDV, or ZRP were originally designed for, these protocols were designed to provide end-to-end paths between two communication hosts (unicast-type of communication).

The primary contribution of the project is Temperature Gradient, an anycast routing protocol for wireless mesh networks. The higher the temperature of a node, the routing is towards that access point. The packets are forwarded along the nodes with the highest temperature until they eventually reach any heat source (an Internet gateway).

The temperature value of the node is decreased when a node receives or sends a message or if it is idles. The packet is always sent to the gateway through the neighbouring node of the highest temperature value.

The hierarchical routing protocols are proposed to solve this problem. It divides mesh network into several clusters and cluster-heads are selected in the every cluster. The cluster-head is responsible for the gathering and aggregation of the information in its cluster. In general, they have better performance than flat routing protocols on the energy consumption. However, the hierarchical routing protocol has an assumption that a cluster-head can communicate with the base station which is located outside of the wireless mesh networks by a one-hop routing. Especially, if the network size become larger, this protocol is unsuitable for the vast mesh networks because of a long distance can cause serious communication problems. Therefore, considering restricted resources of the mesh node, this assumption is inappropriate for applications in massive mesh networks. In general, the hierarchical routing protocols have this assumption.

Here, the cluster-head chaining scheme is proposed to overcome this problem. It is suitable for massive mesh networks and it was found from the simulation result that the proposed scheme shows better performance in their throughput, packet delivery ratio and is scalable to network size.

In this, some group of nodes form a cluster and cluster head is chosen from the group with higher energy value. All the nodes have to communicate through this cluster head to other cluster heads until it reaches the gateway. If the nodes are more than one hop distance ahead then it takes an intermediate node to reach the cluster head. Initially all the nodes send their RTS and CTS in each cluster to their neighbours as well as cluster head. The routing table will be updated in that cluster head. And whenever the packet is to be sent only those nodes which are involved in the transmission will send RTS and CTS to the cluster head and hence unnecessary flooding of control messages are less.

Clustering can be normally separated into two phases, cluster formation and cluster maintenance. Cluster formation means how to choose the CHs and CMs to form the initial cluster structure at the very beginning. Cluster maintenance refers to how to subsequently maintain and update the cluster structure so as to achieve some goal or accommodate the underlying topology change caused by node mobility. In the mobile mesh networks, cluster maintenance mainly focuses on timely updating the cluster structure according to the continuously dynamic underlying topology incurred by nodes movement.

The simulations show that the protocol is more efficient in terms of throughput, scalability and packet delivery ratio. Temperature Gradient algorithm is contrived to scale to the size of the network and to be well defined to node mobility. Furthermore, the packet delivery ratio of HEAT remains above 98% even for large and dense networks with nodes moving at typical pedestrian speeds. The protocol does not require oversupplying of control messages is one of the distinguishing features.

The rest of this paper is organized as follows. The next Section II highlights the related work. Section III, explains the concept and implementation of HEAT. Section IV discusses about evaluation of proposed scheme, in Section V showing the simulation results, we conclude the paper in Section VI.

II. RELATED WORK

The existing HEAT [1] has no good load balancing and congestion control capability, so planning to extend the HEAT to support those capabilities as well, and there by study the trade-offs between scalability and congestion control, and to strike a balance between all those aspects to achieve maximum gains.

A multitude of unicast routing protocols for MANETs have been proposed (e.g. [2]–[6]). These protocols have been extended with gateway discovery functionality [6]–[12] to allow their use for wireless mesh networks. Since these protocols provide unicast routes, individual routes must be maintained between every mobile node and one of the gateways. Therefore, these protocols scale poorly to the number of nodes in the mesh network.

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scalability to the number of mesh nodes is improved with the use of location information; however, this kind of information is typically not available in our target scenario where the mobile nodes in the mesh network are commodity laptops or hand-held devices.

The different wireless mesh network protocols and standards plays an increasingly important role in the future generations of wireless mobile networks proposed by Yan and Luo [7]. A problem that is common to most MANET and mesh routing protocols is that gateway announcements or gateway requests are prone to vanish due to route breaks, and the recovery procedure is often as expensive as establishing a new route.

In contrast M. Mosko and J. J. Garcia-Luna-Aceves, "Ad hoc routing with distributed ordered sequences," in IEEE INFOCOM 2006, Barcelona, Spain, April 2006[8]. , proposes an efficient mechanism to fix broken routes locally. With HEAT, all control messages are local and routes can easily be repaired locally. Moreover, since routing is based on scalar potential fields and not on route entries, alternative routes can most of the time be determined without additional overhead when the primary route fails.

Literature survey has shown that HEAT has no good load balancing and congestion control capability, so planning to extend the HEAT to support congestion control capabilities as well, and thereby study the trade-offs between scalability and load balancing and congestion control, and to strike a balance between all those aspects to achieve maximum gains.

Field-based or gradient-based routing has been proposed in the past for various types of applications including routing in MANETs, load balancing in the Internet, data collection in sensor networks, sensor node placement, guided navigation, or service discovery in MANETs [9].

The basic forwarding principle of HEAT which consists of forwarding along the steepest gradient is similar to these works. However, the method to establish and maintain potential fields after link breaks is unique and uses only local information from the direct neighbors by mimicking how heat dissipates.

The authors H. Ju and I. Rubin, "Backbone topology synthesis for meshed wireless LANs," in IEEE INFOCOM 2006, Barcelona, Spain, April 2006, propose a single-hop mesh network where mobile clients connect directly to the gateways. Compared to our approach, where mobile users also relay packets on behalf of their neighbours, this requires a much higher mesh node density for a comparable wireless coverage.[10].

This Protocol, proposes an efficient mechanism to utilize bandwidth efficiently and improve performance. With HEAT Protocol, all control messages are local and routes can easily be repaired locally. Moreover, since routing is based on scalar potential fields and not on route entries, alternative routes can most of the time be determined without additional overhead when the primary route fails.

III. CONCEPT AND IMPLEMENTATION OF HEAT PROTOCOL

This project, proposes HEAT, a method to establish the scalar field for field-based routing. Routing is based on scalar potential fields and not on route entries i.e., based on the heat vale of the cluster heads. Here the protocol implementation is explained.

A. Gathering information about Nodes

When the nodes have been created, a cluster set is formed with a group of 10-15 nodes to create 2 or more clusters. Then it is required to select the source and destination node from the regions, which are ready for transmission of the message to destination. When the source starts sending the packets, every packet first checks whether it has one hop distance to the cluster head. If so the packets transmits to cluster head. If the node is more than one hop distance, then it uses intermediate node to transfer the packet every time. Since the nodes are mobile not static, It is required to update the information in the routing table of its cluster-head.

Then every cluster head periodically transfers its temperature value to other cluster heads. Based on these messages, all the cluster heads build and maintain a data structure table which contains an entry for every cluster head which embodies the address, the last reported temperature and timestamp value of the corresponding cluster head.

Based on these the packets are transmitted till it reaches the gateway. For every packet the acknowledgement is been sent.

Even though there are a multitude of options for routing the packets, most of them are not useful because they degrade the scalability properties of the temperature field approach. Striving to preserve the scalability properties that is gained from using anycast routing, here I propose to record the paths of packets being forwarded towards the gateways and use the reverse path to route packets back. This approach can be viewed as some sort of source routing and has the advantage that there is no need for additional control messages. On the other hand, two issues pertaining to source routing arise:

(i) A path to a mesh node is only available after this node has sent a packet to a gateway. Since the vast majority of communication is initiated by mesh nodes, this should not be a critical limitation in practical applications. Should a mesh node act as a server, a dedicated addressing mechanism is necessary to enable

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reachability from the Internet? Any mechanism providing this reachability requires periodic registration messages from the mesh node, which allows keeping the path up-to-date.

(ii) The path to a mesh node is only updated whenever packets are sent to gateways. Since most applications generate bidirectional traffic, it should not be a show stopper in practice. Even most streaming applications require periodic keep-alive messages from the receiver. In the rare case where a mesh node only receives data, provisions need to be taken at the application level to ensure periodic updates of the path information.

IV. EVALUATION OF PROPOSED SCHEME

The implementation of the routing protocol consists of three parts:

The scripting language known as TCL (tool command language). C++ for the implementation of our temperature gradient concept. Simulation is done using the network simulator NS2.

The simulation results show the efficiency of the protocol in its throughput, packet delivery ratio, performance and also checks the scalability in large and dense network.

To evaluate the performance and scalability of this approach, simulations are performed with NS2, a network simulator for wireless networks. The complete implementation of HEAT protocol is done in NS2. The relevant parameters of this protocol are described.

These include the HELLO beacon interval, the HELLO beacon timeout, the delay of early HELLO beacons, and the conductivity value. As a reference for the performance of the implementation, an extended version of AODV is used .The settings and assumptions we used for our simulations are described

As first reference for the performance and scalability of our implementation, we extended the standard implementation of AODV included in NS2 to support gateway discovery in mesh networks. As proposed in the paper, all gateways are connected to a dedicated router that acts as a proxy to the Internet. This router has two tasks: (i) on the forward path, it sends route replies on behalf of hosts in the Internet; (ii) on the backward path, it initiates route requests for nodes in the wireless mesh network. Thus AODV does not have to distinguish between the different gateways and only a common route to the Internet has to be maintained, the route to the dedicated router.

An energy model is been implemented to assign every node and cluster head with some joules of energy value.

This Temperature value is reduced by number of packets sent in that transmission time times the temperature value decreased when a packet received or transmitted by that node.

V. SIMULATION RESULTS

Presenting the following metrics to compare the performance, throughput and packet delivery ratio related to scalability.

Packet delivery ratio - The number of packets that are successfully received to the total number of packets sent. This metric includes all data packets from the mesh nodes to the gateways as well as packets from the gateways back to the mesh nodes.

Routing overhead - The number of routing control messages that every node sends on average per second.

Scalability with the Network Size

In this let's first experiment; we look at how the performance is affected when increasing the network size which forms n number of clusters.

The results for a static scenario with randomly placed nodes, like 20 nodes, 46 nodes and 76 nodes in the form of clusters.

The packet delivery ratio of all these simulations remains almost around 97%-98% as the network size increases.

Throughput –Here the throughput efficiency is compared with scalability of nodes as shown in the below fig.1

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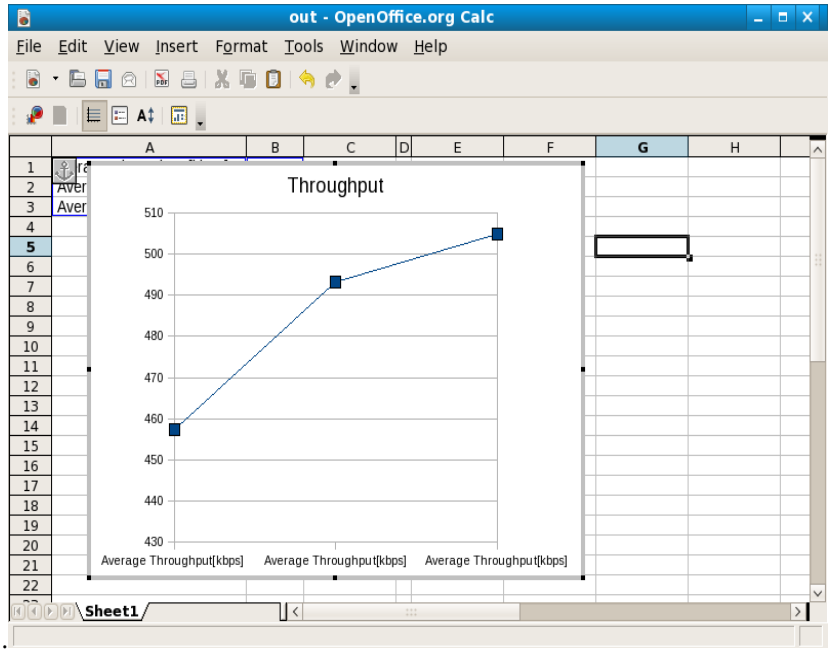

Fig.1.Throughput efficiency

By analysing the graph for packet delivery ratio for 22 nodes, the packet loss is very less.

Generated Packets	2247
Received Packets	2179
Packet delivery ratio	97 %

By analysing the graph for packet delivery ratio for 46 nodes, the packet loss is very less.

Generated Packets	2171
Received Packets	2122
Packet delivery ratio	97 %

By analysing the graph for packet delivery ratio for 76 nodes, the packet loss is very less.

Generated Packets	4712
Received Packets	4624
Packet delivery ratio	98 %

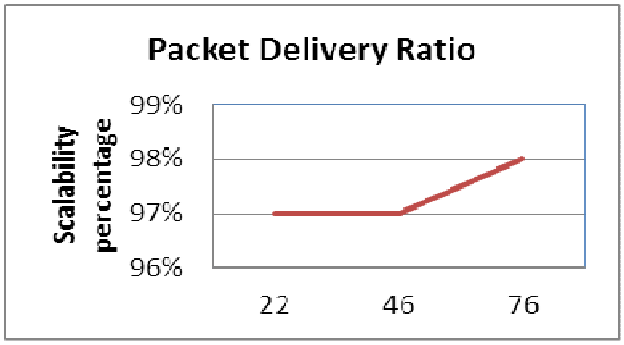

Fig.2.The packet delivery ratio is constant as the number of nodes increases

VI. CONCLUSIONS

I have investigated the problem of routing between mobile user nodes and Internet gateways in wireless mesh networks and have proposed a new anycast routing protocol that is based on temperature fields. This protocol makes use of local beacon exchanges to establish routing state and is thus particularly scalable for large and dense networks.

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The results show that Temperature Gradient achieves packet delivery ratios in static dense and large mesh networks which are above & more than the other protocol. In mobile scenarios this protocol also shows better performance in its throughput and packet delivery ratio as number of nodes increases.

Finally, it is shown that Temperature gradient is able to overcome the problems of congestion and how it performs load balancing by grouping the nodes into clusters and how cluster head is responsible for routing information by reducing unnecessary exchange of packets

We conclude that Temperature Gradient as a scalable routing protocol is best suited for city wide wireless mesh network.

VII. FUTURE ENHANCEMENT

The following are the future enhancement of the project:

A. Link-Diversity Routing

In this thesis, it presents Temperature gradient, a scalable anycast routing protocol for wireless mesh networks. Link-diversity routing incorporates the amount of alternative paths along the delivery path in the forwarding decision and thus manages to route around broken links more often than traditional minimum hop-count routing.

B. Toward Realistic Simulations

The mobility model should be extended with an agent-based behaviour model. In addition to pedestrian and car mobility, it should also consider public transport systems such as trains, buses and trams as well as fixed nodes in buildings. Finally, plan to incorporate these realistic models with simple models such as random waypoint in a public web-based trace generator.

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