PERFORMANCE ISSUES IN CLUSTER BASED SOLUTIONS FOR NETWORKING FUNCTIONS OF MOBILE AD-HOC NETWORKS

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ABSTRACT

Mobile ad-hoc network (MANET) is a self-configuring infrastructureless network of mobile devices in which neither a wired backbone nor a centralized control exists. The network nodes communicate with one another over scarce wireless channels in a multi-hop fashion. With the expanding scope of applications of MANETs, the need for improving the performance in these networks is becoming crucial. The network is expected to guarantee a set of measurable pre-specified service attributes to users in terms of end-to-end performance, such as delay, bandwidth, probability of packet loss, and delay variance (jitter). The goal of improving MANET performance is to achieve more deterministic networking functions, so that the information carried by the network can be better delivered and the network resources can be better utilized. Due to the mobility and traffic dynamics, achieving good performance in key MANET networking functions like routing, service discovery, congestion control and topology control is a challenge. Hence, it is necessary that these functions should be considered in order to improve the overall performance of MANET.

Keywords – Manet, Routing, Service Discovery, Congestion, Topology

I. NETWORKING FUNCTIONS OF MANET

Networking functions consist of a set of activities that help to establish and maintain an efficient communication between the source and destination. A basic requirement for keeping an ad-hoc network operational is to enforce ad-hoc nodes that can contribute to network functions such as packet forwarding, routing, service discovery, network monitoring, congestion control, fault management, topology control and security management. Unlike the networks that use dedicated nodes to support the networking functions, in MANET these functions are carried out by all available nodes. Enhancing networking functions is essential to support the wide-spread use of ad-hoc applications. Among these networking functions, the performance of routing, service discovery, congestion control and topology control are crucial in determining the overall performance of the MANET [1].

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1.1 Routing

In MANET, routing is required to find a path between the source and the destination and to forward the packets appropriately. The destination node might be out of range of a source node while transmitting packets. So each node must be able to forward the data for and to other nodes.

1.2 Service Discovery

The service discovery function allows the networked entities to advertise their services, query about services provided by other entities, select the most appropriately matched services and invoke these services [2]. Significant computational resources are being deployed within the network infrastructure and this computational infrastructure is being used to offer diverse and innovative services to users.

1.3 Congestion Control

Congestion occurs in the network when the amount of data sent exceeds the available network capacity. In a network with shared resources, where multiple senders compete for link bandwidth, it is necessary to adjust the data rate used by each sender, in order not to overload the network. Due to the limited bandwidth availability and intensive use of resources in mobile ad-hoc networks by a growing number of mobile stations, minimizing the traffic congestion will enhance the performance of MANET [3].

1.4 Topology Control

Topology control is a problem of assigning power levels to the nodes of a mobile ad-hoc network so as to maintain a pre-specified network topology while minimizing energy consumption [4]. In MANET, where nodes move freely, the network topology is formed based on the node's transmission ranges and the routes of node movement.

II. PERFORMANCE ATTRIBUTES OF NETWORKING FUNCTIONS

The task of the MANET networking functions is to establish and maintain an efficient communication that will have necessary resources available to meet the performance requirements of the desired service [5]. The key performance attributes of MANET networking functions are measured in terms of end-to-end delay, packet delivery ratio, control overhead, service success ratio, packet loss, throughput, alive nodes and power consumption. These metrics determine the overall performance of the communication.

(i) End-to-End Delay

End-to-end delay relates to the time taken by a data packet to reach the destination. This metric is calculated by subtracting the time at which the first packet was transmitted by source from the time at which the first data packet arrived at the destination.

(ii) Jitter

Jitter is the variation in the delay of received packets. At the sending side, packets are sent in a continuous stream with the packets spaced evenly apart. Due to network congestion, improper queuing, or configuration errors, the delay between each packet can vary, instead of remaining constant.

(iii) Packet Delivery Ratio (PDR)

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PDR is measured as a ratio of data packets delivered to their eventual destinations with respect to those generated by the traffic sources. The greater the packet delivery fraction is, the more reliable the routing protocol and the less the probability of data packet drops.

(iv) Routing Control Overhead

This attribute refers to the total number of routing control packets normalized by the total number of received data packets. It determines the efficiency of the routing protocol in bandwidth utilization.

(v) Service Discovery Control Overhead

The total number of service discovery packets normalized by the total number of received data packets is termed as service discovery control overhead.

(vi) Service Success Ratio

The number of successful service discovery to the number of service requests is termed as 'Service Success Ratio'. This metric is used to evaluate the rate of utilizing the network resources.

(vii) Packet loss ratio

It is the ratio of transmitted packets that may have been discarded or lost in the network, to the total number of packets sent. This metric quantifies the congestion control capability of a protocol.

(viii) Throughput

Throughput is the measure of the number of packets successfully transmitted to their final destination per unit time. The throughput is usually measured in bits per second or data packets per second. It measures the effectiveness of the network in delivering data packets.

(ix) Alive nodes

It illustrate the number of traffic sources that remain alive over a period time. This metric is used to evaluate the effectiveness of a protocol in controlling the topology of the network.

(x) Power consumption

Power consumption includes the energy consumed by the nodes in receiving and sending the packets. Since the wireless nodes have only limited battery power, this metric determines the energy efficiency of a protocol.

III. NETWORKING FUNCTIONS OVERHEAD

Nodes in MANET carry out basic networking functions like routing, service discovery, congestion control and topology control without the help of an established infrastructure. Nodes rely on one another in forwarding a packet to its destination, due to the limited range of each mobile host's wireless transmission. The performance of such networking functions is limited by various overheads in MANET that need to be addressed for effective performance [6].

- **No centralized administration**

In contrast to the wired networks that have fixed infrastructure, with centralized network management system in place, nodes in mobile ad-hoc network operate in a distributed manner by exchanging control information among them. This helps to establish and maintain the network effectively.

- **Frequent and unpredictable network topology changes**

As the nodes move in and out of range with respect to other nodes, the topology changes frequently, and this information needs to be exchanged between the mobile nodes.

- **Bandwidth limitation and estimation**

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The wireless bandwidth and capacity in MANET is scarce, and the channel is not reliable as it is affected by interference, noise and multi-path fading.

- **Node Mobility and Heterogeneity**

The frequent movement of nodes in MANET often leads to route failures. The nodes in MANET are heterogeneous with varying characteristics such as wireless interfaces, battery capacity and node mobility patterns.

- **Limited battery life**

Mobile devices generally depend on finite battery sources. So resource allocation must consider residual battery power and the rate of consumption of the battery corresponding to resource utilization.

IV. CLUSTERING FOR NETWORKING FUNCTIONS

To support scalability and to enhance the availability, clustering of nodes provides an efficient solution. If a cluster can be established, nodes typically remain within a cluster. When the topology of a cluster changes, the changed information is conveyed only to the nodes of the cluster[7]. This approach basically hides all smaller details within the cluster, and they are maintained by clusterheads. The neighbouring cluster need not be updated about these changes. Instead, it can contact the corresponding clusterhead for reaching a node of that cluster. The clusterhead periodically updates the topological information to all the nodes of the cluster. Such of those clusters can be combined to form super clusters to build up a larger hierarchy. The size of the cluster (the number of nodes in the cluster) depends on the transmission range of the nodes in a single hop cluster and the number of hops made by the cluster in multi-hop clusters. There are three types of nodes in clustering networks, namely ClusterHeads (CH), gateway nodes and normal nodes [8]. The clusterhead is responsible for organizing and establishing the cluster. A clusterhead normally serves as a local coordinator for its cluster, performing intra-cluster transmission arrangement, data forwarding, and so on. Clusterhead selection algorithms are used to select these clusterheads. Gateway nodes with inter-cluster links can access neighbouring clusters and forward the information between clusters. A normal node is a non clusterhead node without any inter-cluster links that send or relay data to the CH which transfers the collected packets to the next hop. Clusterheads take on a special role in performing the MANET networking functions that include routing, service discovery, congestion and topology control. MANET stability starts from partitioning the network into clusters. Once the clusters are established, the route stability between a source-destination pair is based on the clusterheads involved in that route. Among the nodes in the MANET, the node with efficient resource utilization may be given priority to become the Clusterhead. The cluster based approach in MANET facilitates, effective network management, improved routing efficiency and scalability, reduced power consumption, simpler and stable topology, improvement of vulnerability due to a node joining and leaving, link failures, reduced interference, effective network capacity and reduces the end-to-end delay.

V. PERFORMANCE ISSUES

In the earlier cluster based approaches for MANET networking functions, the selection of the clusterhead was based on these factors, namely highest degree heuristic, Lowest Identifier (LID) heuristic and node weight heuristic. Highest degree and LID approaches have a common assumption that the nodes do not move while the

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cluster formation is in progress. This is a major drawback of highest degree algorithm because the degree of a node changes very frequently. So the CHs are not likely to play their role as clusterheads for very long duration. In addition, as the number of ordinary nodes in a cluster is increased, the throughput drops and system performance degrades. The lowest identifier approach shows bias towards the group of nodes with lower IDs, to be selected as clusterhead. In Distributed Clustering Algorithm (DCA) [9], the nodes are grouped following a weight based criterion. It allows the choice of the nodes that coordinate the clustering process based on node mobility related parameters. DCA needs only knowledge of the local topology at each node, and allows each ordinary node to have direct access to at least a clusterhead, thus guaranteed faster inter and intra cluster communication between each pair of nodes. A Weighted Clustering Algorithm (WCA) [10] takes four factors namely node degree, neighbour distance, mobility and remaining battery power to compute the node weight. In terms of the number of clusterheads and dominant set updates, WCA shows improved performance than the existing approaches. Flexible Weight Based Clustering Algorithm (FWCA) proposed with the goals of yielding low number of clusters, maintaining stable clusters, minimizing the number of invocations for the algorithm and maximizing lifetime of mobile nodes in the system. Each node computes its weight value to select a clusterhead based on the degree difference, actual transmission power, average speed, remaining power. Secured Clustering Algorithm (SCA) algorithm selects the clusterhead based on the weight factors of trust value, degree, battery, max value, and stability. It overcomes limits in other algorithms by defining new mechanisms as cluster division, merging diminution and extension. The Flexible Weighted Clustering Algorithm based on Battery Power computes node weight based on spreading degree, local clustering coefficient, average speed and battery power. In FWCABP, a predefined threshold for the number of nodes to be created by a clusterhead exists, so that it does not degrade the MAC function.

VI. CONCLUSION

In the existing approaches, factors like node mobility speed, distance to other nodes, trust value, accumulated time of being a clusterhead, connectivity, joining time in the cluster and remaining power level have been used in different combinations to select the clusterheads. The combination of stability, connectivity and power level that are crucial in determining the life-time of a node, are considered together in the proposed approach, to select an effective clusterhead.

- **Stability**: The stability of a node determines its potential to sustain within the cluster. It is computed based on the longer durability of connectivity between its neighbour nodes while in mobility. Its metrics are time and consistent neighbours.
- **Connectivity**: Identifies the number of neighbours of a given node, within a given radius. This parameter is used to choose as cluster-head, the node having maximum number of neighbours, in order to serve more number of nodes.
- **Power level**: Indicates the remaining energy available with a node. Since clusterhead has additional responsibilities, it must communicate as long as possible, thus it must be the most powered node.

Frequent clusterhead changes will limit the performance of MANET networking functions. Hence, improving the performance of networking functions namely routing, service discovery, congestion control and topology control, with the selection of an effective clusterhead remains an open problem.

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