Mobile Agents based Framework for Routing and Congestion Control in Mobile Ad Hoc Networks

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ABSTRACT
In this paper, we present a Mobile Agents based Framework for Routing and Congestion control in Mobile Ad Hoc Networks (MAFRC). The framework uses a cross-layer design approach where multiple intelligent agents present across the network protocol stack cooperate with each other and aid in finding efficient routes between source and destination pairs and also in controlling congestion in the network. The mobile agents at the network layer moving across the network collect the network connectivity information based on the congestion state provided by the static agent at the link layer. The congestion information brought by these mobile agents is further used in controlling congestion at the transport layer. This multi-agent cross-layer framework has been implemented and a preliminary performance evaluation has been carried out for the congestion aware routing and the cross-layer congestion control scheme in a simulation environment using NS-2 simulator. The results show better performance with respect to the performance parameters such as network throughput, end-to-end delay and routing overhead when compared to the network architecture which uses Ad Hoc On-demand Distance Vector (AODV) as a standard routing protocol and Tahoe TCP.

Categories and Subject Descriptors
C.2.1 [**Network Architecture and Design**]: Mobile Ad Hoc Networks.

General Terms
Algorithms, Performance.

Keywords
MANET, mobile agents, cross-layer design, routing and congestion control.

1. INTRODUCTION
Mobile Ad hoc Networks (MANET) are infrastructureless, ubiquitous wireless and mobile networks that allow "anywhere, anytime" computing. MANET nodes are characterized by limited buffers, low processing capabilities, and low bandwidth. Further the network topology in MANET changes rapidly due to mobility of nodes. Design of efficient routing algorithms and congestion control algorithms is an important challenge. Substantial amount of research has undergone in development of routing protocols in MANETs [1]. The existing routing protocols proposed for MANETs have certain limitations. These protocols use the re-routing strategy which involves route discovery process during situations of congestion and link breakage. Route discovery floods the network with control packets which adds to the congestion in the network and also increases end-to-end delay. The re-routing scheme will fail if the new route goes through the neighbours of the congested node i.e. the congestion domain. A congested node in MANET represents a congestion domain which includes its immediate neighbours also. Since shortest path is the criterion used to select new routes they do not spatially distribute the traffic flows in the network. The research which addresses the problem of congestion control in MANETs has been fairly traveled in recent years. In MANETs, because of mobility of nodes, and wireless links being inherently error prone due to effects such as fading etc., there can be substantial amount of packet losses. If these packet losses are considered by TCP as congestion, then it keeps reducing it's rate by half and will result in poor network performance. The reason for this poor performance is that the congestion control scheme does not consider factors like MAC layer contention, interface queue drops and fairness in setting up of congestion window. Intelligent mobile agent technology has evolved as a solution for several network communication problems like routing, security etc [2,3,4]. The advantages of using mobile agents are that they are highly distributed, cooperative, and flexible enough to adapt to continuous and unpredictable changes. Cross-layer design approach for wireless networks using mobile agents has not received the attention among the researchers. In this paper, we propose intelligent mobile agents based cross-layer routing and congestion framework for mobile ad hoc networks to address the limitations mentioned above and improve the network performance.

2. MAFRC
Mobile Agents based Framework for Routing and Congestion control is shown in Figure 1. There are three main modules in this framework: Agent based Congestion Detection (ACD), Mobile Agents based Congestion Aware Routing (MACAR), and Mobile Agents based Congestion Control (MACC).

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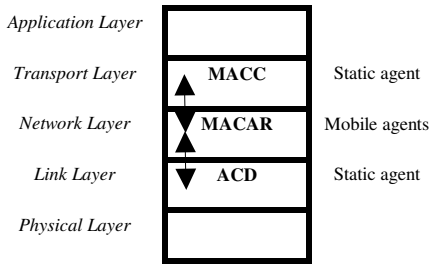

Figure 1. MAFRC Framework.

ACD module at the link layer using a static agent monitors the congestion state of the node in a network. A node is said to be congested in two cases: (i) when the average Medium Access Control (MAC) Drops at a node, due to contention of medium or collision of packets, increases beyond a maximum and (ii) when the average Interface Queue (IFQ) length exceeds a maximum threshold. When a node gets congested, the static agent at the congested node identifies the "culprit flow", <source, destination>, that is causing the congestion. The flow that contributes highest to the congestion is the culprit flow. Once the culprit flow is identified, the static agent sends an "Alert Packet" two hops upstream along the culprit flow. The alert packet indicates that the node two hops upstream should reroute all packets belonging to the culprit flow through a congestion free route. The logic behind sending the alert packet at least two hops upstream is that the chances of avoiding the congestion domain. When a node receives an alert packet with a hop count of one, it forwards it upstream along the culprit flow. When a node receives an alert packet with a hop count greater than one, it looks up its routing table to find a congestion free alternate route. If the routing table does not have the desired alternate route, then the alert packet is forwarded further upstream. The process is repeated till the source node is reached.

MACAR, a hybrid routing module built over AODV routing protocol, uses mobile agents to discovery congestion aware routes by interacting with ACD module. Mobile agents at the network layer move from node to node in the network on a random basis and collect network connectivity and congestion information. The mobile agents update this information in a routing table. A "no return" policy is used to avoid loops and thereby gathering only useful connectivity information. When a mobile agent reaches a node, the node's address and the congestion information is added to the agent history list and forwarded to a random neighbor. When a source node needs to communicate with a destination and a fresh enough route to that destination is not available, currently proposed routing algorithms such as AODV normally initiates route discovery process. In MACAR, the static agent searches the routing table for valid routes brought by the mobile agents to the destination. If such a "ready route" is present then there is no need for route discovery. Further this route is guaranteed to be congestion free. This route establishment mechanism reduces the end-to-end delay experienced by packets in the network and reduces the control overhead on the network. Also, selecting less congested routes at the beginning of the connection achieves better spatial distribution of traffic.

MACC module controls and avoids the congestion in the network with the help of mobile agents present at the network layer and ACD module. Thus mobile agents assist both in finding routes and also in controlling congestion. The congestion information processed and distributed by the mobile agents is used in controlling the setting of the TCP congestion window for a flow in order to influence the overall flow and network performance and also to provide fairness among flows in sharing network bandwidth. At the source node, where congestion window adjustments are to occur, the contribution value for the flows originating from the node are examined by the static agent present at the transport layer, and the flow with the maximum value of contribution is selected for adjusting congestion window.

3. CONCLUSIONS

The mobile agents based cross-layer congestion aware routing which involves ACD module and MCAR module have been implemented and compared with AODV routing protocol in NS-2 simulator [4]. The results show that MCAR performs better than AODV with reduced end-to-end delay as agents brings ready routes, increased network throughput and lesser routing overhead. Also the implementation of the mobile agents based cross-layer congestion control which uses ACD and MACC modules have been tested and compared with Tahoe TCP. MACC performed better than Tahoe TCP because of the congestion avoidance and fairness incorporated among the traffic flows. We are currently working on the joint interaction of all these three modules in NS-2 simulator for efficient routing and congestion control, considering different network scenarios, by varying network size, traffic type, mobility, load, pause time etc and comparing with different routing algorithms and congestion control algorithms. We also plan to implement the same in the Linux kernel and create a mobile agents based mobile ad hoc network communication infrastructure testbed.

4. ACKNOWLEDGMENTS

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