

ROUTING AND CONTROL MECHANISMS FOR DENSE MOBILE ADHOC NETWORKS

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Thesis submitted in partial fulfillment of the requirements for the
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Dedicated to my loving mother



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ABSTRACT

It is not an exaggeration to mention that mobile devices have become ubiquitous and they are used for variety of purposes ranging from personal communication to disaster management and more. These devices are capable of establishing mobile ad hoc networks (MANETs) for multihop communication without the support of infrastructure. This enables more interesting and useful applications of mobile devices, for example for collaborative learners in large classrooms, shoppers in crowded shopping malls, spectators in sports stadiums, online gamers and more.

MANETs have not sufficiently developed to a deployable level yet. Routing in MANETs is a major problem. It is challenging to devise routing protocols for MANETs due to dynamic topology resulting from mobility, limited battery life and impairments inherent in wireless links. Traditional routing approach is to tweak the existing routing protocols that are designed for wired networks. Therefore, it is common to appoint special nodes to perform routing controls and gather global state information such as routing tables. We identify this approach as the *fixed stateful routing paradigm*. Fixed stateful routing does not scale with the density of MANETs because the routes will get obsolete quickly due to the dynamic topology causing frequent routing updates. The overhead for these frequent updates will be unacceptable when the MANETs become dense. For example, the control overhead of routing updates in most of the traditional routing protocols are of magnitude $O(N)$ or $O(N^2)$, where N is the number of nodes in the network.

We name the routing approach that does not require to maintain global network states and does not appoint key nodes for routing and control as *mobile-stateless routing paradigm*. We propose a novel concept called *endcast* that leverages message flooding for end to end communication in MANETs in mobile-stateless manner. However, flooding causes heavy amounts of redundant messages, contention and collisions resulting in a situation known as *broadcast storm problem*. When flooding is utilized for end to end communication, the messages will flood beyond the destination. We call this situation *broadcast flood problem*.

Repetitive rebroadcasting in simple flooding is analogous to biological cell division in the growth of human organs. *Chalone mechanism* is a regulatory system to control the growth of the organs. In this mechanism, each biological cell secretes a molecule called *chalone* and the concentration of chalone in the environment increases when the number of cells increases. When the chalone concentration exceeds a threshold the cells stop dividing themselves. *Counter based flooding* is one of the efficient flooding schemes, in which a node decides not to rebroadcast a received message if the message is subsequently heard multiple times exceeding a predefined threshold during a

random wait period. Inspired by the chalone mechanism in the growth of the organs we selected counter based flooding to unicast messages in a MANET. We proposed an *inhibition scheme* to stop the propagation of message beyond the destination to mitigate the broadcast flood problem. In this scheme, the destination transmits a smaller size control message that we call *inhibitor* that also propagates using counter based flooding but with a smaller random wait period than in the case of data message. Furthermore, inhibitors are limited to the region of the MANET covered by data flooding.

The proposed endcast scheme outperforms simple flooding in such a way that over 45% of redundant messages are saved in all the network configurations starting from 100-node network in ideal wireless conditions when the nodes were placed on a playground of $600m \times 400m$ and each node was configured to have $200m$ of transmission radius. Similarly, the protocol manages to save over 45% of redundant messages for all node densities ranging from 10 to 300 in realistic wireless conditions simulated by IEEE 802.11g standard wireless MAC implementation with power saving transmission radius of $40m$. This saving increases rapidly as networks grow by size in both the ideal and realistic wireless network conditions. The inhibition scheme of the protocol was also found to be effective, for example, redundant messages grow in number at a rate about 8 frames per every 25 nodes added to the network when there is inhibition in operation whereas the growth rate is about 170 frames per every 25 nodes when the protocol operates without inhibition in the simulated network scenario.

The major contribution of this research is the analytical model that we developed to design and evaluate endcast schemes. We developed a graph theoretic model to evaluate the propagation of messages in endcast, based on a preliminary model developed by Viswanath and Obraczka [2]. We modified the model by (i) improving its method of estimating the number of new nodes reached by each level of rebroadcast (ii) modeling the impact of node mobility and (iii) incorporating time domain representation to model the flooding schemes that involve random assessment delays (iii) enabling it to represent efficient flooding schemes such as counter based flooding. We present the process of estimating the area covered by the propagation of flooding messages using a geometric method. Time domain is represented by indexing the edges of the flooding graph by time. The counter value and the threshold in counter based flooding are converted into a rebroadcasting probability and estimated using a probability mass function that we constructed by considering the overlapping of radio range circles of the nodes.

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MANET	Mobile adhoc network
CSMA/CA	Carrier sense multiple access/ Collision avoidance
MAC	Medium access control
N_k	Node k
d_{av}	Average distance between a node and a neighbor
DCF	Distribution coordination function
SNCF	Sequence number controlled flooding
SRB	Saved rebroadcasts
RE	Reachability
CA	Cellular automata
RWP	Random waypoint
P_S	Probability of successful node to node transmission
RTS	Request to send
CTS	Clear to send
TTL	Time to live
N_{ix}	Node x at rebroadcast level i in flooding graph
N_T	Total number of nodes reached by flooding operation
β	Percentage additional area covered by propagation of flooding
P_b	Probability of successful reception at second level rebroadcast



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EAC	Expected additional coverage
RAD	Random assessment delay
ROH	Redundancy overhead
FCT	Flooding completion time
n_i	Number of nodes reached at rebroadcast level i
E	Number of edges in flooding graph
P_{comp}	Probability of complete transmission
T_{RAD}	Random assessment delay time
C	Random variable counter in counter based flooding
K	Random variable threshold in counter based flooding
P_{tx}	Probability of rebroadcast of each node
T_{max}	Maximum value for random assessment delay
P_c	Critical probability



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