J. Bangladesh Electron. 10 (1-2); 49-56, 2010

Reactive CDS Based Enhancement of Dynamic Source Routing Protocol to Alleviate 'Broadcast Storm' Problem

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Abstract

A Mobile Ad Hoc Network (MANET) is an autonomous system of functionally equivalent mobile nodes, which must be able to communicate while moving, without any kind of wired infrastructure. To this end, mobile nodes must cooperate to provide the routing service. Routing in mobile environments is challenging due to the constraints existing on the resources and the required ability of the protocol to effectively track topological changes. Reactive routing protocols perform well in such an environment due to their ability to cope quickly against topological changes. The paper focuses on analyzing an On Demand Ad hoc Routing Protocols "Dynamic Source Routing (DSR), its broadcast storm problem in the route discovery phase which has the very negative impact on the performance of the protocol. The complete DSR implementation has been studied and also implements a simple, efficient idea on DSR to make a reactive connected dominating set (CDS) in the purpose of reducing the aforementioned problem and enhance the performance thereby. The performance analysis is done by using Network Simulator (NS-2).

Keywords: Routing protocol, DSR, Connected Dominating Set and Network Simulator (NS-2).

1. Introduction

Due to advances in wireless communication technology and portable devices, wireless communication systems have recently become increasingly widespread. Broadcast is an important operation in wireless networks. However, broadcasting by naive flooding causes severe contention, collision and congestion, which are called the broadcast storm or flooding problem. Many exiting on-demand routing protocols [1] suffer from the serious broadcast storm problem in the route detection phase. Routing based on a connected dominating set is a frequently used approach to solve this problem, where the searching space for a route is reduced to nodes in the set. A set is dominating if all the nodes in the system are either in the set or neighbors of nodes in the set. Many protocols have been proposed with some investigations focusing on creation of a backbone or connected set to alleviate the broadcast problem in the route discovery phase yet neglecting the potential problem lies in the heart of the proactive nature of the suggested protocols. Extensive computing of CDS performed in advance without real demand makes these protocols inferior to reactive protocols for routing mobile Ad hoc networks. In the context of the above scenario our intention has propped up to dedicate ourselves in this field. For that purpose a popular reactive protocol dynamic source routing (DSR) has been chosen.

2. DSR and its Flooding Problem

The DSR protocol is composed of two main mechanisms, Route Discovery and Route Maintenance. Route Discovery adopts Route Request (RREQ) – Route Reply (RREP) control packets and is triggered by a node S, which attempts to send a packet to a destination node D and does not have a path into its cache [2]. Discovery is based on flooding the network with a RREQ packet, which includes the following fields: the sender address, the target address, a unique number to identify the request, and a route record.

On receiving a RREQ control packet, an intermediate node can:

- Reply to S with a RREP if a path to the destination is stored in its cache.
- Discard the packet, if already received.
- Append its own ID into the route record and broadcast the packet to its neighbors, in the other cases.

On receiving a RREQ packet, the destination replies to S with a RREP packet. An RREP packet is routed through the path obtained by reversing the route stored in the RREQ's route record (the links are assumed bidirectional) and containing the accumulated path.

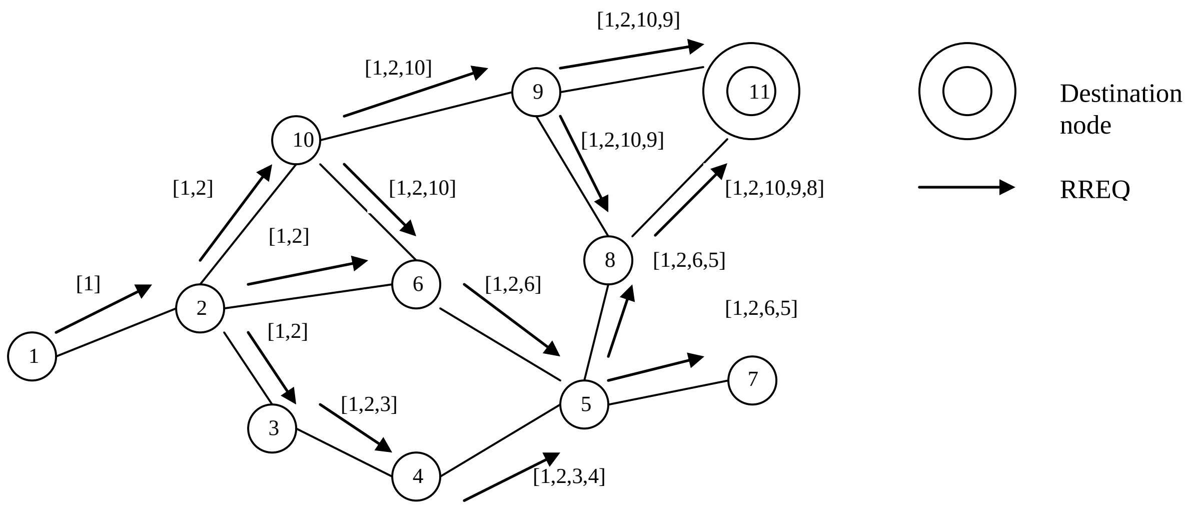

Fig. 1: An example of a routing propagation request in DSR

The above figure shows the propagation of route request massage in DSR that clearly depicts the devastating nature of flooding feature. Node that will not be a part of the route also broadcast the route request packet. So huge packets are generated unnecessarily and their transmission in broadcast manner creates a serious jam over the network. As a consequence the whole network becomes useless for a moment, obviously a very insightful and perceptive issue for ad hoc networking to be focused and to give thought for its recovery.

3. Idea Of CDS

The DSR protocol can provide a satisfactory packet delivery ratio for long-term end-to-end constant bit rate (CBR) connections. However, it is still questionable to deploy such reactive algorithms in scenarios where many spontaneous communications exist. This random and short-lived network traffic can generate heavy overhead and easily trigger a flooding storm due to the broadcasted route discovery messages [3].

The Connected Dominating Set (CDS) protocol is dedicated to reduce this overhead and to addressing this scalability problem. Its distinguishable characteristic is to select only a subset of routing nodes which deal with packet delivery on behalf of the others. These nodes should connect to each other, organizing a backbone that can reach the remaining nodes in the network [4]. By doing so, a CDS algorithm only needs to retain the aggregated backbone's connectivity using local-scale broadcast within a one-hop distance, instead of maintaining individual routes for each source and destination pair using flooding.

4. Design

A number of algorithms have been proposed to achieve a small CDS subset with good approximation quality [3]. These provide useful insights on how to construct and maintain a CDS backbone in mobile ad hoc networks. However, they also share the same unrealistic assumptions that prevent implementation with the existing wireless technologies, IEEE 802.11 in particular. These assumptions facilitate theoretical analysis on these CDS algorithms in terms of approximation ratio, time complexity and message complexity; but also because of them, it is hard to deploy a backbone routing scheme for wireless applications. Obtaining accurate and complete topology knowledge is fundamentally complicated in a mobile ad hoc network without support from any outside infrastructure. Following the idea of the connected dominating set and their problems, designation of our CDS aims to achieve the problem of proactive nature of the CDS which poses serious hindrance to integrate or implement them in DSR. It is necessary to maintain both the primary features: connectivity and domination. We also expect that the reduction in the number of control packets will, in general, improve the traffic by decreasing congestion, which in turn, will increase the delivery ratio.

5. Algorithm for the Reactive CDS

Two threshold values are determined in this algorithm to construct a reactive set of selective nodes which will do the act of broadcast in the route discovery phase of the on demand protocol. They are termed as traffic threshold and mobility threshold. These thresholds distinguish stable nodes, which are included in the reactive CDS from obsolete nodes excluded from CDS. The first threshold determines the eligibility of a node to be in the reactive CDS according to their last data packet forwarding time. The number of these nodes can be controlled by appropriately choosing data paths, which are currently stable, e.g., the data paths that consists of slowly moving nodes or simply recent data paths.

- The first threshold T^{thresh} also named as 'traffic threshold' is to compare the recent time interval from forwarding last data packet by the node up to the current time of receiving RREQ packet.
- And another is the distance M (measured approximately) named as 'mobility threshold' is to compare the distance covered by a node after the event of last data packet forwarding.

We have worked in Route request phase and change it with respect to these two thresholds T^{thresh} and M. Broadcasting feature of the nodes in route request phase is implemented according to the following equations formulated in terms of these parameters:

1. When a route discovery is initiated by a node the route request packet is changed to include the time parameter T^{thresh} which is set to a fixed small value such as 0.1. Each node keeps the time of forwarding its last data packet and the current time of receiving the route request packet denoted by T^{last} and T^{cur} respectively.

When a node receives a route request packet it checks its status of data packet forwarding according to the equation:

$$T^{cur}(N) - T^{last}(N) > T^{thresh}$$

If it is the case that duration between RREQ packet receive and last data send is greater than the threshold value set by the initiator than the respective node will not be a member of the current CDS and . Note that if *N* has a fresh route to the destination in its cash, then *N*, as in standard DSR, will generate Route Reply.

On the other hand if $T^{cur}(N) - T^{last}(N) <= T^{thresh}$, the node has send a data packet in the expected time duration. So this node will be included in the CDS and packet will be propagated as usual.

2. Similarly, the distance covered by the node *N* from the latest data forwarding is measured by $(T^{cur}(N) - T^{last}(N))$.speed (N). Each node calculates this value and compares this with the threshold. If the node moves more than the distance threshold D than it will not be included in the current CDS.

On the contrary if $(T^{cur}(N) - T^{last}(N))$.speed $(N)<M$ than this node will be a part of this CDS and will propagate the first RREQ packet. Thus this algorithm takes the advantages of recently discovered paths.

6. Performance Measuring Matrix

There are two main categories of routing metrics, the first category, performance metrics, describes the outcome of a simulation, or a set of simulations. Scenario metrics is the other class of metrics. These describe the simulation input parameters.

A. Performance Matrix

These metrics are interesting because they can be used to point out what really happened during the simulation and provide valuable information about the routing protocol. In the following sections some metrics of this type are described.

*1. Packet Delivery Ratio***:** The packet delivery ratio presents the ratio between the number of packets sent by constant bit rate sources (CBR, “application layer”) and the number of received packets by the CBR sink at destination.

$$\textbf{Packet delivery ratio} = \frac{\sum \textbf{CBR packets received by CBR sinks}}{\sum \textbf{CBR packets sent by CBR sources}}$$

2. Routing Overhead: The sum of all transmissions of routing packets sent during the simulation. For packets transmitted over multiple hops, each transmission over one hop, counts as one transmission.

$$\textbf{Routing overhead} = \sum \textbf{transmission of routing packets}$$

3. Hop Count: The average path length of data packets measured in hops. This is actually the number of intermediate nodes that act as a router to forward the data packet in the way from source to destination.

$$\textbf{Average Hop Count} = \frac{\sum \textbf{Intermediate Hops}}{\sum \textbf{CBR packets sent}}$$

B. Scenario Metrics

A scenario metric is calculated from the input data to the simulation, or might even be an input variable (such as the pause time and mobility). These metrics are interesting since their value will not be dependent of the routing protocol or the simulation process, as the performance metrics might be. It is crucial that non-biased metrics exists in order to provide a truthful comparison between the different routing protocols.

7. Simulation Model

Simulation model has the two basic components: the movement model and communication model which comprises the topology. Nodes in simulation move according to a “random waypoint” model. The movement scenario files are characterized by a pause time. Each node begins the simulation by remaining stationary for different pause time, which is 0, 30, 60 and 100 seconds. It then selects a random destination in the 1500m × 300m space and moves to that destination at a speed distributed uniformly between 0 and some maximum speed [6]. The entire simulation time is 900 seconds. We experimented with three different maximum speeds 1 meter per second, 10 meter per second and 20 meter per second. For communication model we have chosen traffic sources to be constant bit rate (CBR) sources. We have experimented with sending rate of 4 packets per second, network containing 6 and 10 CBR sources with 8 and 17 connections respectively. Packet size has been chosen to 512 bytes.**VIII. Simulation Parameters**

There are many simulation parameters that are need to be varied in order to perform exhaustive simulations. In this section the simulation parameters used to produce the simulation suite for this work are presented and explained [7].

PARAMETER	VALUE
Transmitter range	250m
Interface queue length	50
Simulation time	900s, 500s
Number of nodes	50, 25
Pause time	0s, 30s, 60s, 100s
Traffic type	Constant Bit Rate
Packet rate	4packets/s
Packet size	512byte

8. Performance Analysis

The aggregation of overhead graph for original DSR and enhanced DSR are shown in figure 2. Relative overhead measures the number of overhead packets (packets that are used for route establishment and for other route controlling purpose) per second. Our CDS-implemented DSR offers improved performance i.e. lower overhead with the traffic threshold (.05), mobility threshold (1) for each of the speed (10, 20 m/s). This is because broadcast storm of route discovery phase is made limited by the act of the connected dominating set.

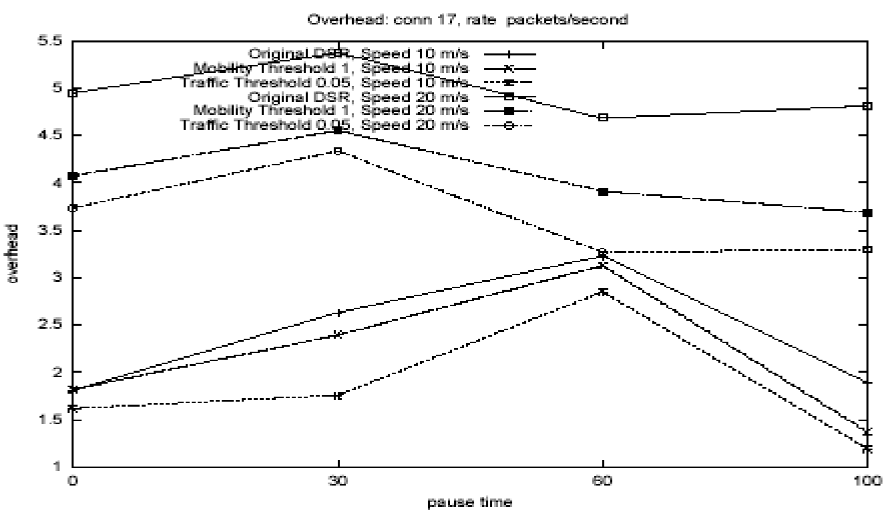

Fig. 2: Simulation result with varying maximum speed and threshold

Experiment-1: Average Hop Count Graph

Figure 3 shows various plot of average hop count of the enhanced DSR for different traffic threshold and speed. Considering the data packet, hop count measures the average path length in terms of intermediate node for forwarding the packet to reach its destination from the source. The average hop count decreased with the increased node velocity and here also the traffic threshold value (0.05) presents the best performance.

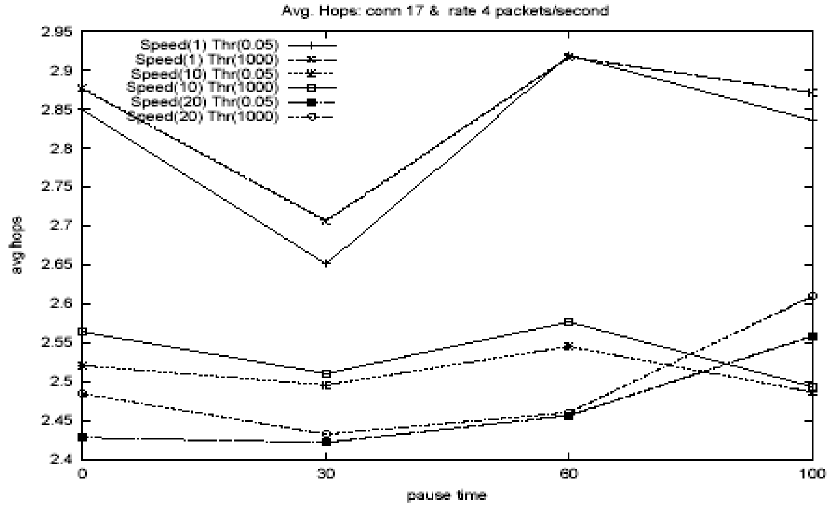

Fig. 3: Simulation result with varying maximum speed and threshold

Experiment-2: Combined Graph with the Original DSR

The combined graph of figure 4 focuses that original DSR simulated with speed 10 m/s needs lower average hops than CDS-implemented DSR with mobility threshold (1). But enhanced DSR with traffic threshold (.05) provides better performance over original DSR in case of speed 20 m/s also.

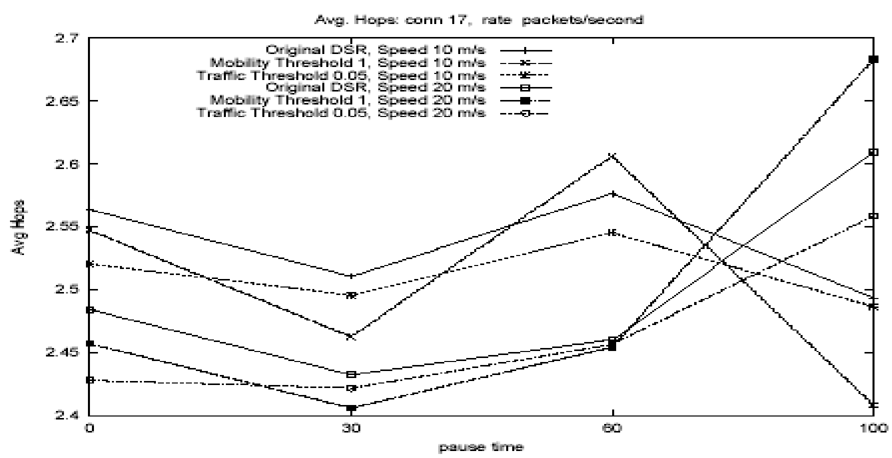

Fig. 4: Simulation result with varying maximum speed and threshold

9. Tabular Representation

The overhead, the delivery ratio and the average number of hops for different values of the mobility threshold M (1, 2, 25, and 10000) are given in Table 1, Table 2 and Table 3. The packet rate is 4 packets/second and the maximum number of connections 17 with 10 sources and the total number of nodes is 50. We may conclude that the mobility threshold 1 is the best and practically for all scenarios (except for the pause time 0 and the speed 10) all characteristics of DSR are improving.

Table 1: Normalized Overhead

Pause Time (seconds)	Normalized Overhead (speed 10 m/s) (Enhanced DSR)		Normalized Overhead (speed 10 m/s) (Original DSR)
	Mobility Threshold=1	Traffic Threshold=0.05	
0	0.589785520241646	0.4470948188017663	0.6620958476223761
30	0.6930784061696658	0.6627564207130299	0.7748807411194995
60	0.5565030572848355	0.3429640689153881	0.5439670160592365
100	0.3561067461392577	0.5595146895260831	0.6541276058348738

Table 2: Delivery Ratio

Pause Time (seconds)	Delivery Ratio (speed 10 m/s) (Enhanced DSR)		Delivery Ratio (Speed 10 m/s) (Original DSR)
	Mobility Threshold=1	Traffic Threshold=0.05	
0	0.970833333333333	0.994573289158003	0.974858450100086
30	0.922873157685085	0.933106144405574	0.935105118829982
60	0.933047249486419	0.946186874749901	0.940629498457672
100	0.962328250813774	0.97049326457348	0.959878621321425

Table 3: Hop Count

Pause Time (seconds)	Hop Count (speed 10 m/s) (Enhanced DSR)		Hop Count (Speed 10 m/s) (Original DSR)
	Mobility Threshold=1	Traffic Threshold=0.05	
0	1.01831343784458	1.03481443013433	1.03617793978669
30	1.09476836841238	1.10589191427684	1.1171771287692
60	1.04996208639706	1.05529189383666	1.06028273684799
100	1.12086765513454	1.11396738993968	1.0992338127822

Conclusion

The dynamic source routing protocol with the idea of CDS has been presented. The enhanced DSR model has been verified through simulation and establishes that in order to have successful integration it is necessary to use a reactive CDS. We formulate requirements for the reactive CDS and give an enhancement of DSR based on using nodes recently used in data packet routing for the reactive CDS. Though it does not fully eliminate the flooding problem, it limits the effect of the broadcast storm in significant manner. Another drawback of this reactive CDS is that it doesn't assure the connectivity of the source destination pair that is exceeded by the dynamic and reactive nature of the CDS. There is no need to retain or periodically exchange overhead information to maintain the connectivity. Although CDS enhancement was targeted to reduce the routing overhead, the resulted protocol improves the original DSR in all three metrics – average decrease in overhead as well as average increase in the delivery ratio and even average decrease in the routing length.

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