Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 46 (2015) 1022 – 1031

Procedia Computer Science

International Conference on Information and Communication Technologies (ICICT 2014)

Enhancing cooperation in MANET using the Backbone Group model (An application of Maximum Coverage Problem)

Md. Amir Khusru Akhtar[a,*], G. Sahoo[b]

[*,a]*Department of Computer Science & Engineering, Cambridge Institute of Technology,Tatisilwai, Ranchi-835103, India*
[b]*Department of Information Technology, Birla Institute of Technology,Mesra, Ranchi - 835215, India.*

Abstract

MANET is a cooperative network in which every node is responsible for routing and forwarding as a result consumes more battery power and bandwidth. In order to save itself in terms of battery power and bandwidth noncooperation is genuine. Cooperation can be enhanced on the basis of reduction in resource consumption by involving a limited number of nodes in routing activities rather than all. To get accurate selection of nodes to define a backbone several works have been proposed in the literature. These works define a backbone with impractical assumptions that is not feasible for MANET. In this paper we have presented the Backbone Group (BG) model, which involve the minimum number of nodes called BG in routing activities instead of all. A BG is a minimal set of nodes that efficiently connects the network. We have divided a MANET in terms of the single hop neighborhood called locality group (LG). In a LG we have a cluster head (CH), a set of regular nodes (RNs) and one or more border nodes (BNs). The CHs are responsible for the creation and management of LG and BG. The CHs use a BG for a threshold time then switches to another BG, to involve all nodes in network participation. The proposed model shows its effectiveness in terms of reduction in routing overhead up to a ratio (n^2: n^2/k) where k is the number of LGs.

Peer-review under responsibility of organizing committee of the International Conference on Information and Communication Technologies (ICICT 2014)

*Keywords:*Backbone group; Locality group; Cluster head; Border node; Regular node

1. Introduction

A mobile ad hoc network (MANET) is a network of cooperation because it does not involve any infrastructure or

* Corresponding author. Tel.:09334718198 .
*E-mail address:*akru2008@gmail.com

Peer-review under responsibility of organizing committee of the International Conference on Information and Communication Technologies (ICICT 2014)
doi:10.1016/j.procs.2015.01.013

routers. Due to the absence of routers nodes are responsible for all major activities such as routing and forwarding. To route packets, these devices discover their neighbors to form a network. If the target node is out of range then it is searched by flooding the network with broadcasts that are forwarded by every node. Unlike an infrastructure network, it has additional characteristics such as self-organization, dynamic topology, energy constrained operation, multi-hop routing etc. Self organization implies that all ad hoc nodes needs to cooperate in network activities and must implement common functions for addressing, routing, power control etc. The dynamic topology is the feature of an ad hoc network in which a mobile node can be moved generously while still be connected to other mobile nodes and cooperate in network participation. Specifically, a mobile node can move in any direction and is still able to participate in any communication. Next, the energy constrained problem tells that a mobile node normally operates with a limited battery power and reduced computational capability to minimize power consumption. For mobile nodes complex calculation and high communication will drain out the battery faster. So, a balance mechanism should be defined in order to use the low resource devices. As far as the communication is concerned, the sender could not communicate directly to the receiver due to the limited radio coverage. Thus, packets are transmitted through multiple hops to reach the destination. For this the intermediate nodes must cooperate in network participation.

In this paper we have presented the Backbone Group (BG) model that divides the network in terms of the single hop neighborhood called Locality group (LG). In each locality group we have a cluster head, a set of regular nodes and one or more border nodes. Regular nodes are accountable for forwarding its data to the cluster head. It has additional responsibility that it has to participate in intergroup routing for a specified amount of time. A regular node when involved in forwarding data to another locality group known as border node. The cluster heads are responsible for the creation and management of LG and BG. It includes the creation of LGs, creation of BGs, inclusion of BGs into option table, exchange of the option table to other CHs and selection of a BG for network activities. The CHs use a BG for a threshold time then switches to another BG, to involve all nodes in network participation. Our model does not assume any reachability constraints because LGs are defined on the basis of single hop distance. A limited number of nodes are used to define a BG which minimizes routing overhead. Thus, it reduces resource consumption which is the real cause of misbehavior and noncooperation.

The remainder of this paper is organized as follows. Section 2, explores the background, literature survey and motivation. Section 3, presents the proposed Backbone Group model to enhance cooperation in MANET through reduction in resource consumption. Experiments and results are discussed in Section 4. Finally, section 5 highlights the conclusions.

2. Background, Literature review and Motivation

2.1. Background

A MANET is a self-governing group of mobile nodes or routers connected by wireless links. In these standalone network nodes have additional responsibilities of forwarding and routing. But, to save its resources nodes drop packets of others either of its honest or malicious causes, called misbehavior[1]. In case of selfish misbehavior nodes drop packet of others for its honest causes i.e. to save battery life or bandwidth. In the case of malicious misbehavior a malicious node deploy wormhole and blackhole attacks to drop packet of others. In spite of that the other reason of packet dropping is network congestion, jamming and burst channel errors due to interference, fading etc. These reasons are accountable for the data dropping attacks[1]. These attacks degrade the efficiency of packet transfer, enhance the packet loss rate, increases packet delivery time and create network partitioning.

2.2. Literature survey

A MANET is most exposed to selfishness. A number of mechanisms are proposed in literature to mitigate routing misbehavior. These mechanisms involve some detection and elimination techniques to enhance cooperation in a mobile ad hoc network. In this paper we are minimizing selfish misbehavior on the basis of reduction in total control traffic overhead. Lots of solutions to overcome from routing misbehavior are proposed in the literature, categorized into the incentive based and reputation-based mechanisms[1,2]. These mechanisms protect a network from attacks and misbehavior with the cost of additional consumption of valuable resources such as battery power and bandwidth. That's why in this paper we have proposed the BG model which involves a minimum number of nodes (BG nodes) in routing activities instead of all which saves battery power and bandwidth the genuine cause of misbehavior or noncooperation.

2.2.1. Reduction enhances cooperation

In the wireless environment the energy constrained problem tells that a mobile node normally operates with a limited battery power and reduced computational capability to minimize power consumption. For mobile nodes complex calculation and high communication will drain out the battery faster. Thus, reduction in resource consumption is essential to enhance cooperation[1]. Lots of work has been proposed to minimize misbehavior on the basis of reduction in routing overhead, they are as follows.

A Partition Network Model for Ad Hoc Networks[3] was proposed by T. Chiang et al. It uses a partition network model to minimize the routing overhead by involving mobile agents. By the reduction in routing overhead it enhances cooperation in ad hoc network.

Subnet Formation and Address Allocation Approach for a Routing with Subnets Scheme in Mobile Ad Hoc Networks[4] was proposed by J. López. The proposed method uses subnetting concepts for the reduction in routing overhead. By dividing a network into several subnets we have minimum number of unwanted packets per subnet. Thus, it saves battery life and enhances cooperation in MANET. The limitation of the subnetting is that it uses an internet type structure to group nodes into subnets. However, it is difficult to use subnetting concept in MANET because of its dynamic and distributed nature. It has various open challenges such as subnet formation and address acquisition, mobility of nodes between subnets and the routing between intra-subnet and inter-subnet.

Several efficient virtual subnet models were proposed in the literature[5,6,7]. These models surely enhance cooperation on the basis of reduction in routing overhead. But, these solutions are not appropriate for low computation power devices. Because these solutions involve certificates for authentication and it involves lots of computation.

A novel approach for securing an ad hoc network using the Friendly Group model[8] was proposed by Akhtar and Sahoo. This model uses border and regular nodes. The border node uses two Network Interface Cards (NICs) to partition a network into several friendly groups (FGs). Thus, the partition of a MANET into several FGs reduces total control traffic overhead and enhances network cooperation.

2.2.2. Prior work on backbone creation and greedy method

Lots of works have been proposed for the construction of backbone, but they have limitations in terms of energy consumption and mobility.

A novel approach for the minimization of communication and computation complexities in a connected dominating set (CDS)[9] was proposed by Wu and Dai which is based on merging the clustering approach and supports varying transmission ranges. It uses cluster heads to form a connected dominating set (CDS) and used to create the backbone of the MANET. But, the limitation of the proposed approach is in terms of mobility because the backbone is created using cluster heads.

The El-Hajj et el. have proposed the fuzzy-based virtual backbone routing protocol[10] to enhances the network lifetime. It uses a fuzzy logic controller to aggregate the network parameters such as residual energy, traffic, and mobility to characterize a wireless node. But, this method has weaknesses in terms of election process of the central processing node (CPN), cluster maintenance algorithm and creation of virtual backbone.

The directional network backbone[11] was proposed by Yang et al. using directional antennas. The proposed algorithm reduces the total energy consumption and interference in broadcasting applications. They have deployed two-phase approach for the directional backbone, the iterative version and the topology control. But, the proposed model has limitation is in terms of energy consumption and mobility.

An opportunistic virtual backbone (VBB) constructing algorithm[12] was proposed by Ma and Jamalipour. It advances the scalability of data communication over intermittently connected mobile ad hoc networks (ICMAN). It was based on the collected partial two-hop mobility statistics due to the intermittent connectivity and delayed message delivery. The proposed VBB construction was presented in a distributed, independent and asynchronous environment. It is highly scalable and compatible with the existing store-carry-forward (SCF) routing protocol. But, this algorithm has several issues such as available storage space, battery level, computing capability etc.

An analysis of approximations for maximizing submodular set functions-I[13] was presented by Nemhauser et al.. They analyzed greedy with local improvement heuristics and a linear programming relaxation for submodular set functions. The results was worst case bounds and the limiting value of the bound is (1− 1/e), where e denotes the base of the natural logarithm.

A Threshold of ln n for approximating set Cover[14] was proposed by Feige in which he proved that ((1 - O(1)) ln n) is a threshold below and cannot be approximated efficiently, with the exception of NP has slightly superpolynomial time algorithms. He has shown that the approximation threshold for a max k-cover is within (1− 1/e), under the assumption that $P \neq NP$.

The greedy sensor selection algorithm[15] was proposed by Shamaiah et al. that give a solution within (1− 1/e). They simplified the novel greedy algorithm to considerably reduce its complexity via Kalman filtering. But, the limitation of the proposed work is in terms of energy consumption because it has computational complexity.

2.3. Motivation

A mobile ad hoc network is a self-organized network that works without any fixed infrastructure or access point. Attacks and misbehaviors are the wall that obstructs the growth and implementation. Modification of routing information can be handled by secure routing protocols but non cooperation is still in its initial stage. Existing mechanisms protect a network from misbehavior at the cost of additional consumption of valuable resources such as battery power and bandwidth. Designing a secured, reliable and applicable design that suits every application is still a challenge. Because the proposed model not only protects the network, but it must consume minimum resources to prolong the life of the network, and this was the foundation for which MANET was actually designed. The motivation behind this paper is to define some new way to confront from misbehavior, by minimizing the routing activities to save battery power and bandwidth. That's why in this work we have presented the Backbone Group model, in which minimum number of nodes participates in routing activities instead of all. Thus, our model minimizes total control traffic overhead which reduces resource consumption the genuine cause of misbehavior or noncooperation.

3. Proposed Backbone Group Model

3.1. Overview

In this section we have presented the Backbone Group (BG) model in which minimum number of nodes participates in routing activities instead of all. At first, a MANET is logically divided in terms of the single hop neighborhood called locality group (LG) shown in Fig. 2. In a LG we have a cluster head (CH), a set of regular nodes (RN) and one or more border nodes (BN). The CHs are responsible for the creation of LGs, creation of BGs, inclusion of BGs into option table, exchange of the option table to other CHs and selection of a BG for network activities. A BG is a minimal set of nodes that efficiently connects the network. The BG used in network activities by the CHs should be taken for a threshold time, so that the responsibility of routing goes to all nodes of the locality groups equally. Our model does not assume any reachability constraints because LGs are defined on the basis of single hop distance.

3.2. Phases of the BG Model

Our model contains two phases i.e. the Custer head selection and Locality Group creation phase and the Backbone creation phase.

3.2.1. Custer Head Selection and Locality Group creation phase

In this phase, a set of CHs is defined on the basis of high computational power and battery lifetime, for instance in the war zone a cluster node could be a captain's laptop[16,17], because it has the high computational power and battery lifetime. In this work we have not discussed the selection of Cluster head, any existing methods[18,19] can be used to select a CH. After that neighboring nodes are examined by cluster heads on the basis of one hop distance to create one or more locality group(s). One hop distance is computed on the basis of the cluster head and the regular node locations as shown in Fig. 1.

Let CH = (p1, p2) and RN = (q1, q2) then the Euclidean distance d is defined as

$$d(CH, RN) = \sqrt{(p1-q1)^2 + (p2-q2)^2} \tag{1}$$

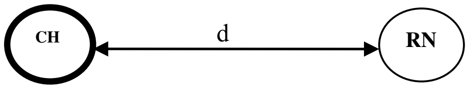

Fig. 1. Euclidean distance (d)

If d<=r then the node is in the coverage area of cluster head and can be taken as a locality group member, where r denotes the communication range. If a RN is within the coverage area of two or more CHs, then, the CHs measure the distance of a RN and share in its neighborhood. To make a member, CHs compare the distances between RN and CHs. The minimum distance is the basis for selecting a RN as a member for the LG. If CHs are at the same distance from the RN then RN is added to any one of the LGs.

Each locality group consists of a set of regular nodes, one or more border nodes under the control of one cluster head. Fig. 2 shows the proposed locality group in which we have one cluster head, a set of regular nodes and one or more border nodes. The backbone group is defined by selecting a minimal set of nodes that efficiently connects the network. The regular nodes that are member of a BG is called border nodes. Fig. 2 shows that nodes of a locality group are arranged in grid pattern but we can use any other pattern as per the requirement and communication range. It also shows that a cluster node of a LG is defined at the center but it could be in the corner or periphery of the network. However, choosing a cluster node at the center covers a large geographical distance.

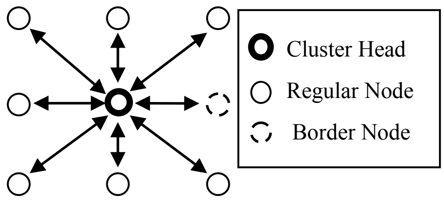

Fig. 2. Locality group

Similarly, on that basis several locality groups are defined as shown in Fig. 3(a) and 3(b). The dotted lines show the backbone link and the dotted circle denotes the member of the BGs called border nodes. We have taken these two patterns to divide a network into locality groups, but it can be arranged in many ways as per the requirements.

3.2.2. *Backbone creation phase*

In a MANET we have n number of nodes which is divided into k number of LGs. The problem is to choose m number of nodes from each LG such that the maximum numbers of LGs are covered, i.e. the union of the selected nodes has maximal size up to the number of LGs and each LG are covered. The problem can be modeled as[20]:

Let the MANET of size n is divided into k number of locality groups $L = \{L_1, L_2, \dots, L_k\}$

Objective is to find a subset $C \subseteq L$ having m number of nodes from each LGs, such that $|C| <= m$

$\left| \bigcup_{L_i \in C} L_i \right|$ is maximized.

The problem can be formulated in linear programming problem as

Maximize the sum of covered nodes from each LG

$$\text{Max} \sum_{L_i \in C} L_i \tag{2}$$

subject to

Select a maximum of m number of nodes from each LG

$$\sum C_i \leq m \tag{3}$$

The above problem can be solved using any greedy approach methods[13,14,15]. In this work we have not focused on the approximation of the maximum coverage problem, here emphasis is given on backbone construction to reduce energy consumption.

3.3. Working of the BG Model

The CHs is responsible for the creation of LGs, creation of BGs, inclusion of BGs into option table, exchange of the option table to other CHs and selection of a BG for network activities. The BG used in network activities by the CHs should be taken for a threshold time, so that the responsibility of routing goes to all nodes of the locality group equally. The proposed BG model working algorithm is defined as follows.

Step 1: [Custer Head Selection]

Select k number of cluster nodes using existing algorithms[18,19].

Step 2: [Locality Group creation phase]

(a) Divide the MANET into k locality groups on the basis of CH location.

(b) Include nodes within a locality group using

$$d(CH, RN) = \sqrt{(p1 - q1)^2 + (p2 - q2)^2}$$

Step 3: [Backbone creation phase]

(a) Create BGs by solving the linear programming problem discussed in section 3.2.2.

(b) Add BGs into option table.

(c) Share option table to other CHs.

Step 4: [Execution phase]

Start network operations on the basis of BG.

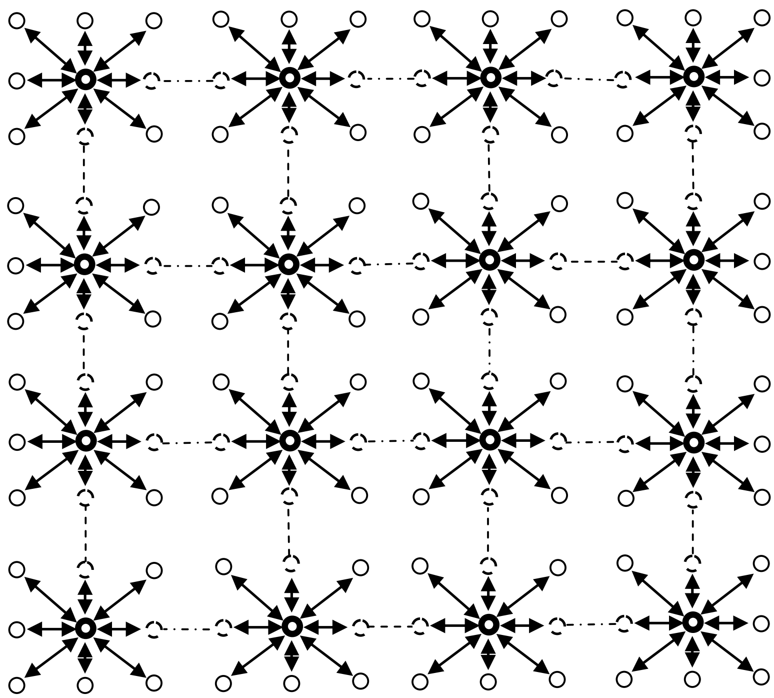

Fig. 3(a). MANET using LGs (Topology 1)

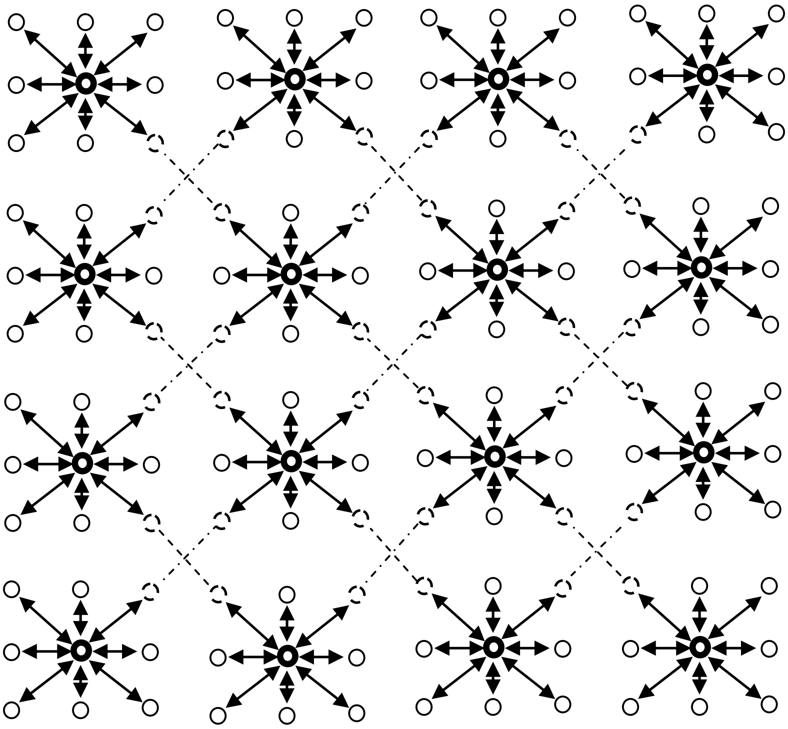

Fig. 3(b). MANET using LGs (Topology 2)

4. Experiments and Results

4.1. Overview

For simulating the work we have used the Global Mobile Information System Simulator (GloMoSim)[21,22,23]. It is a scalable network simulator which supports large wireless and wired communication networks. In order to set up a scenario as per the proposed network four files of GloMoSim[21,22,23] are used and configured.

- The CONFIG.IN file is used for setting up a scenario.
- The APP.CONF file is used for setting up the application layer protocols.
- The MOBILITY.IN file is used for setting up the mobility trace format.
- The NODES.INPUT file is used for setting up the node placement.

Table 1 shows the parameters used in the simulation.

Table 1. Simulation parameters.

Parameters	Values
SIMULATION-TIME	15M
TERRAIN-DIMENSIONS	(1250, 1250)
NUMBER-OF-NODES	121
NODE-PLACEMENT	GRID
MOBILITY	RANDOM-WAYPOINT
MOBILITY-WP-PAUSE	30S
MOBILITY-WP-MIN-SPEED	0
MOBILITY-WP-MAX-SPEED	10
MOBILITY-POSITION-GRANULARITY	0.5
PROMISCUOUS-MODE	YES
ROUTING-PROTOCOL	DSR

In this work a BG is a minimal set of nodes that efficiently connects the network. To create a backbone group a set of nodes are examined (as discussed in section 3.2.2) from each locality group which efficiently connect the network. A BG consists of a set of cluster nodes and border nodes that gives accurate connectivity of the network as shown in Fig. 4, in which a MANET is divided into four locality groups. The nodes of a backbone group are shown in Fig. 4 in which nodes of BG are $\{c_1, (n_5, c_1), (n_4, c_2), c_2, (n_7, c_2), (n_2, c_4), c_4, (n_4, c_4), (n_5, c_3), c_3, (n_2, c_3), (n_7, c_1)\}$.

The BG nodes are responsible for intergroup routing because they efficiently connect the network. The regular nodes which are involved in the BG are called border nodes and are responsible for intergroup routing for a specified amount of time after expiry of the time another BG is responsible for intergroup routing. In this work we have taken several BGs and stored these BGs in the option table shown in Table 2, so that all nodes equally participate in network activity. A different set of nodes can be taken to make a BG, for example from the network given in Fig. 4 these BGs can be taken

$BG_1 = \{c_1, (n_5, c_1), (n_4, c_2), c_2, (n_7, c_2), (n_2, c_4), c_4, (n_4, c_4), (n_5, c_3), c_3, (n_2, c_3), (n_7, c_1)\}$,

$BG_2 = \{c_1, (n_3, c_1), (n_1, c_2), c_2, (n_8, c_2), (n_3, c_4), c_4, (n_6, c_4), (n_8, c_3), c_3, (n_1, c_3), (n_6, c_1)\}$ etc.

A cluster head is denoted by its ID only while a regular node is denoted by an ordered pair (node_ID, CH_ID).

where node_ID is node identity and CH_ID is cluster head identity

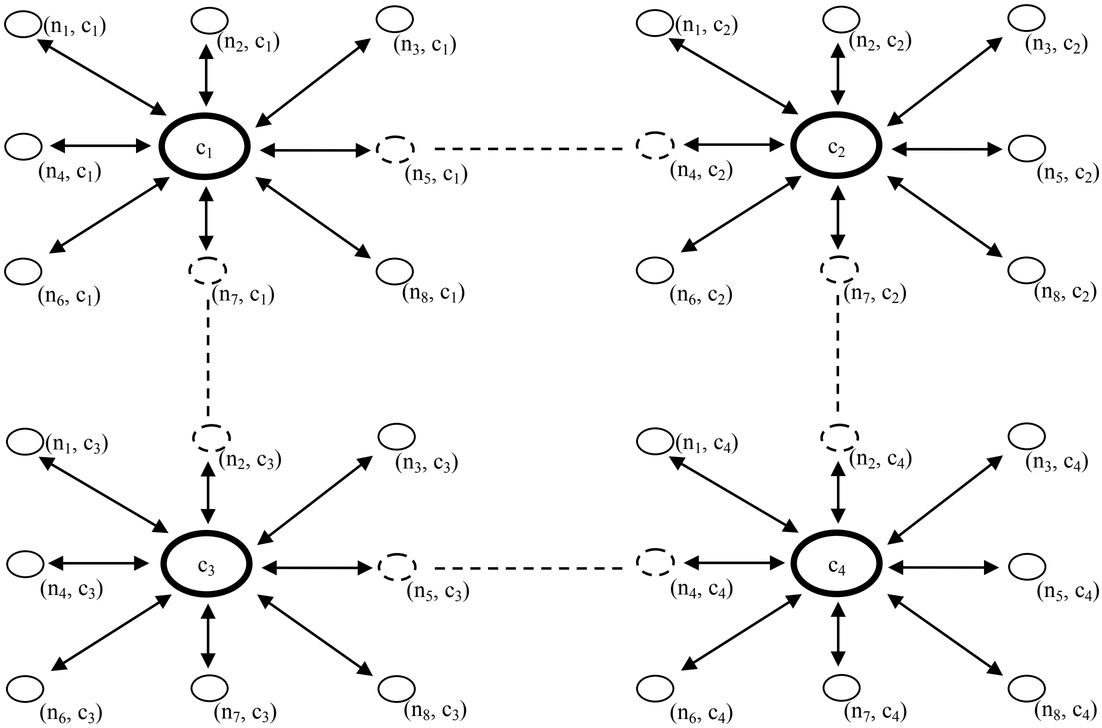

Fig. 4. Nodes of a backbone group

Table 2. Option Table.

BG_ID	BG_Nodes
BG_1	$c_1, (n_5, c_1), (n_4, c_2), c_2, (n_7, c_2), (n_2, c_4), c_4, (n_4, c_4), (n_5, c_3), c_3, (n_2, c_3), (n_7, c_1)$
BG_2	$c_1, (n_3, c_1), (n_1, c_2), c_2, (n_8, c_2), (n_3, c_4), c_4, (n_6, c_4), (n_8, c_3), c_3, (n_1, c_3), (n_6, c_1)$

4.2. Results

The proposed model divides a network into LGs which minimizes resource consumption. The BG model uses only limited number of nodes in network activity instead of all which minimizes total control traffic overhead. The total control traffic overhead for reactive routing protocols[24] is n^2 and our proposed model reduced it to n^2/k, where k is the number of LGs. The control traffic overhead with or without BG model is presented by the graph in Fig. 5.

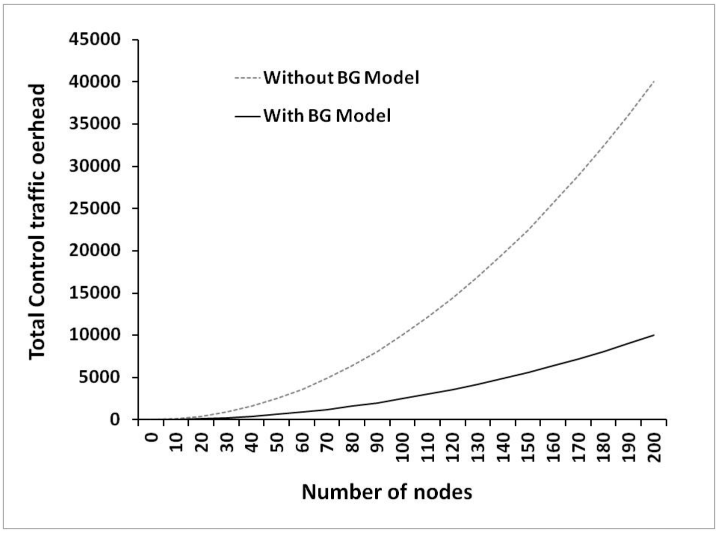

Fig. 5. Reduction in total control traffic overhead

5. Conclusion

Existing mechanisms protect a network from attacks and misbehavior with the cost of additional consumption of valuable resources such as battery power and bandwidth. In order to design a robust and secure system the design not only protects the network from attacks and misbehavior but it must consume minimum resources to prolong the life of the network, and this was the foundation for which MANET was actually designed. In this paper we have proposed the BG model to enhance cooperation in MANET by involving a minimum number of nodes (BG nodes) in routing activities instead of all. Initially the MANET is divided in terms of the single hop neighborhood called locality group (LG). In a LG we have a cluster head (CH), a set of regular nodes (RN) and one or more border nodes (BN). The CHs are responsible for the creation of LGs, creation of BGs, inclusion of BGs into option table, exchange of the option table to other CHs and selection of a BG for network activities. A BG is a minimal set of nodes that efficiently connects the network. To create a backbone group a set of nodes are examined from each locality group which efficiently connect the network. Initial result shows the effectiveness of the model in terms of less control traffic overhead. The total control traffic overhead for reactive routing protocols is n^2 and we have reduced it to n^2/k, where k is the number of LGs. Thus, our model minimizes total control traffic overhead which saves battery power and bandwidth the genuine cause of misbehavior or noncooperation.

Acknowledgements

I would like to express my sincere gratitude to the Prof. (Dr.) Amitabh Bhattacharyya, Coordinator (TEQIP), and Prof. Arshad Usmani, Head, Department of CSE & Nodal officer (TEQIP) of Cambridge Institute of Technology, Tatisilwai, Ranchi who have always encouraged me in my research.

References

1. Anusas-Amornkul T. On detection mechanisms and their Performance for packet dropping Attack in ad hoc networks. *ProQuest*; 2008.
2. Wang Y. Enhancing Node Cooperation in Mobile Wireless Ad Hoc Networks with Selfish Nodes. *Doctoral Dissertation, Paper 602,* University of Kentucky; 2008.
3. Chiang TC, Tsai HM, Huang YM. A partition network model for ad hoc networks. *In IEEE International Conference on Wireless and Mobile Computing, Networking and Communications* 2005; **3**: 467-472.
4. Lopez J, Barceló J M, García-Vidal J. Subnet formation and address allocation approach for a routing with subnets scheme in MANETs. *In Wireless Systems and Network Architectures in Next Generation Internet, Springer Berlin Heidelberg* ; 2006. p. 62-77.
5. Chowdhury MAH, Ikram M, Kim KH. Secure and survivable group communication over MANET using CRTDH based on a virtual subnet model. *In Asia-Pacific Services Computing Conference IEEE APSCC'08*; 2008.p. 638-643.
6. Chang CW, Yeh CH, Tsai CD. An efficient authentication protocol for virtual subnets on mobile ad hoc networks. *In International Symposium on Computer Communication Control and Automation (3CA)* IEEE 2010;**2**:67-70.
7. Vilhekar AA, Jaidhar CD. Modified Authentication Protocol Using Elliptic Curve Cryptosystem for Virtual Subnets on Mobile Adhoc Networks. *In Wireless Communications and Applications Springer Berlin Heidelberg*; 2012.p. 426-432.
8. Akhtar MAK, Sahoo G. A Novel Methodology for Securing Ad Hoc Network by Friendly Group Model. *In Computer Networks & Communications (NetCom), Springer* 2013;**131**: 23-35.
9. Wu J, Dai F. Virtual backbone construction in MANETs using adjustable transmission ranges. *IEEE Transactions on Mobile Computing 2006*; **5(9)**, 1188-1200.
10. El-Hajj W, Kountanis D, Al-Fuqaha A, Guizani S. A fuzzy-based virtual backbone routing for large-scale MANETs. *International Journal of Sensor Networks* 2008; **4(4)**: 250-259.
11. Yang S, Wu J, Dai F. Efficient directional network backbone construction in mobile ad hoc networks. *IEEE Transactions on Parallel and Distributed Systems* 2008;**19(12)**: 1601-1613.
12. Ma Y, Jamalipour A. Opportunistic Virtual Backbone Construction in Intermittently Connected Mobile Ad Hoc Networks. *In Proceedings of the International Conference on Communications (ICC) IEEE*;2011.p. 1-5.
13. Nemhauser GL, Wolsey LA, Fisher ML. An analysis of approximations for maximizing submodular set functions—I. *Mathematical Programming* 1978; **14(1):** 265-294.
14. Feige U. A threshold of ln n for approximating set cover. *Journal of the ACM (JACM)* 1998; **45(4)**: 634-652.
15. Shamaiah M, Banerjee S, Vikalo H. Greedy sensor selection: Leveraging submodularity. *In Proceedings of the 49th IEEE Conference on Decision and Control (CDC)*;2010.p. 2572-2577.
16. Saeed NH, Abbod MF, Al-Raweshidy HS. IMAN: An Intelligent MANET routing system. *In Proceedings of the IEEE 17th International Conference on Telecommunications (ICT)*;2010.p. 401-404.
17. Saeed N. Intelligent MANET optimisation system. *Ph.D. Thesis, School of Engineering and Design, Electronic and Computer Engineering Department, Brunel University*; 2011.
18. Singh AK, Sharma S. Elite Leader Finding Algorithm for MANETs. *In the 10th International Symposium on Parallel and Distributed Computing (ISPDC)*;2011.p.125-132.
19. Mohammed N. Otrok H, Wang L, Debbabi M, Bhattacharya P. Mechanism Design-Based Secure Leader Election Model for Intrusion Detection in MANET. *IEEE Transactions on Dependable and Secure Computing* 2011;**8(1)**: 89-103.
20. Maximum Coverage Problem. http://en.wikipedia.org/wiki/Maximum_coverage_problem
21. Zeng X,. Bagrodia R, Gerla M. GloMoSim: a library for parallel simulation of large-scale wireless networks, *In Proceedings of the 12th Workshop on Parallel and Distributed Simulation (PADS 98)IEEE;*1998.p.154-161.
22. Bajaj L, Takai M, Ahuja R,Tang K, Bagrodia R, Gerla M. Glomosim: A scalable network simulation environment. *UCLA Computer Science Department Technical Report, 990027, 213;*1999.
23. GloMoSim.. Global Mobile Information System Simulator. http://pcl.cs.ucla.edu/projects/glomosim/.
24. Viennot L, Jacquet P, Clausen TH. Analyzing control traffic overhead versus mo-bility and data traffic activity in mobile Ad-Hoc network protocols, *ACM Wireless Networks journal (Winet)*; 2004.