A Strategy to Reduce the Control Packet Load of AODV Using Weighted Rough Set Model for MANET

Nagaraju Aitha[1] and Ramachandram Srinadas[2]
[1]Kamala Institute of Technology & Science, Singapur
[2]Department of CSE, Osmania University, Hyderabad

Abstract: *A mobile Ad-hoc networks consists of wireless hosts that may move often, movement of host results changes in path. The well known Ad-Hoc On-demand distance vector routing protocol determines a route when no route exists or route breaks. To establish new path from source to destination, it broadcast control packets (route request packets), which increases the network bandwidth consumption. As mobile Ad-hoc networks have limited bandwidth, it is important to reduce the control packets. We propose a protocol which uses the weighted Rough set model to control the route request packets in the existing Ad-hoc on-demand distance vector routing protocol. Weighted Rough set theory is a mathematical tool to deal with vagueness, uncertainty and it also considers the importance of the objects.*

Keywords: *Weighted roughest, AODV, and route request.*

Received May 14, 2009; accepted August 10, 2009

1. Introduction

A Mobile Ad-hoc Network (MANET) consists of a set of wireless devices that are capable of moving around freely and cooperate in relaying packets on behalf of one another. It does not require any static infrastructure or centralized administration. Instead, it is completely self-healing. MANET's have many potential applications in a variety of fields like military tactical communications, disaster rescue operations, recovery and collaborative group meetings.

Recently, there have been rapid developments in mobile devices and growing interest in mobile communications. Due to this, MANET's have been gaining a great significance in the society during the past few years. Each node acts as both router and host as well (i.e., a node can receive the packet and can forward it to other nodes in the network). Due to increasing demand of mobile devices, effective use of available bandwidth has been a challenging problem. Several existing routing algorithms available in the literature are not zeroing in on the effective bandwidth usage.

A straightforward approach for broadcasting is blind flooding in which each node will be obligated to rebroadcast the packet whenever it receives the same for the first time. Blind flooding [5] will generate many redundant transmissions and broadcast storm problem [19] in which these packets cause contention and collision. To avoid Broadcast storm problem several approaches were introduced by researchers such as selective forwarding [1], LAR [22] and PANDA [2]. Also several heuristic approaches were discovered by researchers which are mainly counter based [19], probability based [19] and function based [8, 9].

In selective forwarding method [1], 1-hop neighbours are selected in such a way that it covers all its 2-hop neighbours in a heuristic manner. Most of these existing protocol proposals can be classified into two main categories: proactive protocols (e.g., DSDV [19]) and reactive (or on-demand) protocols (e.g., TORA [11], DSR [3] and Ad-Hoc On-Demand Distance Vector (AODV) [14]). In general, proactive protocols rely on periodic exchange of routing information and each node maintains knowledge of entire network topology, where as reactive protocols depend on query-based approach in which a mobile node performs route discovery and route maintenance only when needed. Some of the on-demand protocols like DSR and AODV use flooding based query-reply mechanism to search for new route. Location Aided Routing (LAR) [22] is an improvement to DSR and AODV. It attempts to reduce the flooding using information of location of a node.

Positional Attribute Based Next-hop Determination Approach (PANDA) attempts to utilize positional information to determine the rebroadcast delay. In this approach, a node can find the candidate nodes based on velocity and location information. We tried to design a model to find the candidate nodes among the neighbours based on WRS model which is a mathematical concept effectively used for classification of objects (nodes) which use the neighbour knowledge-based methods more effectively.

In our proposed novel protocol, we tried to reduce the existing flooding in Ad-Hoc On -Demand Distance Vector (AODDV) by applying Weighted Rough Set (WRS) model. This model finds the candidate node set by finding the similarity relation among the 1-hop and 2-hop neighbours. Weighted rough set model considers the object (node) importance also and this model gives better results compared to Rough Set model AODV (RAODV) [19]. We compared the results of Weighted Rough Set model AODV (WRAODV) with RAODV. It is found that our model shown improved performance in several important parameters like throughput, energy consumption and number of broken links.

The rest of the paper is organized as follows. Section 2 is the related work. Section 3 comprises WRS mechanism for MANET's. Section 4 deals with WRS model approach to AODV, section 5 presents simulation results of this method, and section 6 presents conclusions and future scope.

2. Related Work

Researchers have just started to develop Fuzzy [6, 17, 23] and Rough set based routing [12, 15, 16] algorithms for MANET's. The existing protocols like Dynamic Source Routing + (DSR +), Dynamic Source Routing β (DSR β) are using the node information to select the next hop to transfer the data packets and RAODV is using the node information to select the neighbour nodes to forward the control packets to search the path to the destination.

Neighbor-knowledge-based algorithms are based on the following idea to avoid flooding the whole network; a small set of forward node is selected. Basically, the forward node set forms a Connected Dominating Set (CDS). A node set is a dominating set if every node in the network is either in the set or the neighbour of a node in the set. The challenge is to select a small set of forward nodes in the absence of global network information. In the literature researchers attempted to find CDS using two ways one is using 1-hop neighbourhood information and the other is using 2-hop neighbour information these are called as self pruning and dominant pruning.

Neighbor-knowledge-based algorithms can be further divided into neighbour-designating methods and self-pruning methods. In neighbour-designating methods the forwarding status of each node is determined by its neighbours. Basically, the source node selects subset of 1-hop neighbours as forward nodes to cover its 2-hop neighbours. In self-pruning methods each node makes its local decision on forwarding status whether to forward or not to forward. Although these algorithms are based on similar ideas, this similarity is not recognized or discussed in depth.

Selective broadcasting in ad hoc networks has been extensively studied [1, 2, 18, 19, 20, 21, 22]. In Jie Wu and Lou [20] proposed Dominant Pruning (DP) algorithm, Partial Dominant Pruning (PDP) and Total Dominant Pruning (TDP). These algorithms use the 2-hop neighbourhood information to find the dominating set. Adaptive Partial Dominant Pruning (APDP) [10] is an extension of PDP which identifies the adjacent and equivalent nodes. In this particular work equivalent nodes are identified using WRS model among the 1-hop and 2-hop neighbours by establishing an equivalence relation.

In our proposed method, we apply WRS model to identify the best RREQ forwarding nodes among the existing neighbours. This kind of WRS mechanism controls the overhead of Route Request Phase (RREQ) of AODV by eliminating the redundant RREQ forwarding towards the destination.

3. Weighted Rough Set Mechanism

3.1. Rough Set Mechanism

Consider a universe U of elements. An information system I is defined as $I = (U, A, V, \rho)$ where A is a non empty finite set of *attributes*; $V = \cup_{a \in A} V_a$ is the set of *attribute values* of all attributes, where V_a is the *domain* (the set of possible values) of attribute a; $\rho: U \times A \rightarrow V$ is an *information function* such that for every element $x \in U$, $\rho(x, a) \in V_a$ and is the value of attribute a for element x. $I = (U, A, V, \rho)$ is known as a *decision system*, when an attribute $d \in A$ is specified as the *decision attribute*. Then $A - \{d\}$ is known as the set of *condition attributes*. These definitions are based on the definition of Rough Set Information System in [12, 13]. In this proposed method we are using node information system at each node of its neighbour nodes and it is converted into weighted information.

3.2. Weighted Rough Set Model

WRS model is an advancement to rough set model, WRS not only considers noise reducing capability of rough set model it also considers the significance of objects (nodes). Object significance can be considered as object weighted factor. This idea is to suit for actual requirement, especially to prioritize the rules. The object information system can be regarded as a record. One record is a rule which is a condition to forward the control information (i.e., RREQ) towards the destination in the proposed protocol. It is depend on the application. In the existing information system there are no parameters to indicate rule's significance and it is characterized by weighted coefficient w.

In the Figure 1 Two sets E_1 and E_2 have elements in each and these are belonging to X's boundary region. Though the element in E1 that not belonging to X and the element in E2 that belong to X may be noise. In Figure 2 after reducing noise E1 is belongs to X's positive region approximately and E2 is belongs to X's negative region approximately. Thus the X's boundary region is reducing and vagueness is decreasing. To improve the accuracy of the approximation in WRS model using weighted coefficient defined in two ways described in the following.

The first one is decided by times of the rule existing information system. Suppose there are n rules for a same domain (for example i^{th} domain) in the same time. If $T_j(x_i) = 1$, means rule x_i is accepted by the j^{th} expert. If $T_j(x_i) = 0$, means rule x_i is refused by j^{th} expert. At last, we sum up all experts opinion $T_j(x_i)$, j = 1,2,3,…n defined as follows:

$$w(x_i) = \sum_{j=1}^{n} T_j(x_i) \quad (1)$$

The second one decided by rule's significance. First let us frame all rules for same domain (for example i^{th} domain). Secondly, according to these rules, assign a relative significance factor for every rule based on available resources. We use $\mu_j(x_i)$ to denote experts assigned rules of x_i s significance for $0 < \mu_j(x_i) < 1$. For rule x_i, we sum up all experts opinions. Rule x_i's significance can be defined as

$$w(x_i) = \sum_{j=1}^{n} \mu_j(x_i) \quad (2)$$

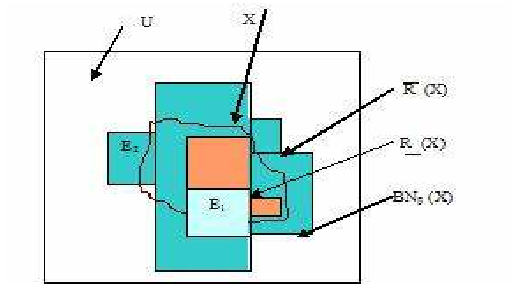

Figure 1. Noise is caused by boundary region

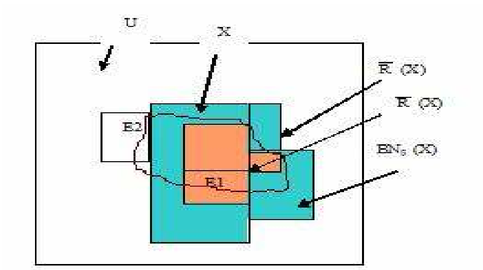

Figure 2. Elimination of noise decreased the boundary

The effectiveness of these two ways is same. Their essence is to assign a relative significance factor for every rule. Every rule should be checked and *w* should be normalized since weighted coefficient is relative factor.

3.3. Weighted Rough Set Model Applications

Mainly Rough Set applications are in decision analysis, data mining and knowledge discovery. One of the main goals of machine learning, pattern recognition, knowledge Discovery and data mining is to synthesize approximations of target concepts from the background knowledge. It usually only possible to search for approximation descriptions of target concepts due to incomplete knowledge about them. Rough set approach divides the incomplete knowledge into lower and upper approximations. The area between lower and upper approximation is boundary region. WRS model trying to reduce the noise in the rough set model.

3.4. Weighted Rough Set Formulation for MANETs

Let M be the set of mobile nodes. A route is a path through mobile nodes in M. It is denoted as sequence of mobile nodes $m_1, m_2, m_3,\ldots m_k$, $m_i \in M$, i =1, 2, 3, …, k and let A be the set of attributes denoted by $x_1, x_2,\ldots x_p$. These attributes are framed for effective routing mechanism. The attributes are like location, pause time, speed...*etc.,* of a mobile node. Every attribute will form a rule based on predefined threshold value. The threshold values are identify based on the available resources at a particular time. Thus every node maintains the neighbour node information Table 1: $M \times A \rightarrow V$, where V is the set of all possible conditional values. The value of I (m, a) is either 0 or 1 based on the attribute values.

Definition 1: Weighted Information System

Weighted information system S is an ordered pair S=< U, A, V, f, w>, in which U is a non-empty and finite set. $A=C\cup D$, where C is a condition attribute set, D is a conclusion attribute set, $C\cap D=\varphi$. V is the attribute's values set, a is an arbitrary attribute, x_i is an arbitrary object, $f(x_i , a)$ is attribute value of x_i and w is object's weighted factor.

Definition 2: Rough Membership

In WIS, let *X be* a non-empty subset of a finite universe *U*. The measure of the relative membership of $x \in U$ with respect to *X* is defined as:

$$\mu^R{}_X(x) = \frac{\sum w_i, x_i \in X \cap [X]_R}{\sum w_i, x_i \in [X]_R}, x \in U \quad (3)$$

when $w_i = 1$, The above formula becomes the basic rough membership.

Definition 3: Lower approximations

The lower approximation of M is defined as

$$\underline{R\alpha}(X) = \{ x \mid \mu^R{}_X(x) \geq 1 - a \},\ 0 \leq a \leq 0.5 \quad (4)$$

Definition 4: Upper approximations

The upper approximation of M is defined as

$$\overline{R\alpha}(X) = \{ x \mid \mu^R{}_X(x) \geq a \}\ \ 0 \leq a \leq 0.5 \quad (5)$$

In our proposed method, the set of neighbour nodes divided into lower and approximation set of nodes based on the relation ship between the 1-hop and 2-hop nodes. The process of finding lower and upper approximations can be categorized into different stages. The first stage would be to select the rules. The second stage is to assign the significance values to the constructed rules. Once the rules are extracted, they can be presented in if CONDITION(S)-then DECISION format. Using WRS the equation representing the mapping between the inputs and the output can be written as y = f (G, N, R) where y is the output, G is the granulization of the input space into weight N is the number of rules and R is the set of rules defined as follows:

If battery power of a node is >= 100
Then return w1
Else
Return 0
If traffic of node is < = 1000
Then return w2
Else
Return 0
If pause time of a node > = 20
Then return w3
Else
Return 0
If relative distance is < = 20
Then return w4
Else
Return 0

3.5. WRS Construction

WRS model converts the existing neighbour nodes into two subsets, called lower and upper approximations. The source or intermediate node will forward the control packets to lower approximation nodes. The lower approximation nodes are the best candidate nodes compared to upper approximation set of nodes. In our proposed model, lower and upper approximations are constructed using the 2-hop neighbour information. The lower and upper approximations are separated depending on the node weight as shown in equation 1 calculated by WRS model. The node weight is normalized between 0 and 1 based on 2-hop neighbourhood information. The classification of nodes as lower and upper approximation is based on equations 2 and 3.

Example: consider an ad-hoc network with twelve nodes. In the Figure 3, neighbours of node 6 are 2, 5, 9 and 7. In the Table 1 we considered node attribute values pause time, traffic, battery power, the relative distance between destination and its different neighbour nodes. The considered Table 1 values are converted in to rough set node information according to rough set mechanism rules. Every rule is assigned a predefined weight (importance). According to equation 1 relative measure is calculated among the 1-hop and 2-hop neighbours with the help of these measures equation 2 and 3 identifies lower and upper approximation sets respectively

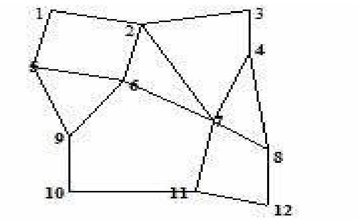

Figure 3. A MANET with 12 nodes.

Table 1. 1-hop and 2-hop neighbor hood information of node 6.

Node	Pause Time (Sec)	Traffic (Bits/Sec)	Relative Distance ΔR_t(M)	Battery Power (Watt)
2	10	1000	10	100
5	20	1500	20	200
9	30	2500	5	500
7	40	2000	40	100
1	11	2000	30	600
3	20	9000	40	700
4	30	2000	23	100
6	40	1002	45	200
8	50	3000	45	300
10	60	2003	24	400
11	20	1000	100	500

Table 2. Rough set node information system.

Node	Pause Time (Sec)	Traffic (Bits/Sec)	Relative Distance ΔR_t (M)	Battery Power (Watts)
2	0	0.5	0.75	1
5	0.25	0	0.75	1
9	0.25	0	0.75	1
7	0.25	0	0.75	1
1	0.25	0.5	0.75	1
3	0.25	0.5	0.75	1
4	0.25	0.5	0.75	1
6	0.25	0.5	0.75	1
8	0.25	0.5	0.75	1
10	0.25	0.5	0.75	1
11	0.25	0.5	0.75	1

Table3. 2-hop neighbours of each node.

V	N(v)	N(N(v))
1	1,2,5	1,2,3,5,6,7,9
2	1,2,3,6,7	1,2,3,4,5,6,7,8,9,11
3	2,3,4	1,2,3,4,6,7,8
4	3,4,7,8	2,3,4,6,7,8,11,12
5	1,5,6,9	1,2,5,6,7,9,10
6	2,5,6,7,9	1,2,3,4,5,6,7,8,9,10,11
7	2,4,6,7,8,11	1,2,3,4,5,6,7,8,9,10,11,12
8	4,7,8,12	2,3,4,6,7,8,11,12
9	5,6,9,10	1,2,5,6,7,9,10,11
10	9,10,11	5,6,7,9,10,11,12
11	7,10,11,12	2,4,6,7,8,9,10,11,12
12	8,11,12	4,7,8,10,11,12

4. Weighted Rough Set Based Routing

In the proposed routing protocol a route is established using the neighbour node information. Also it is updated whenever a change takes place in the topology. When a node is required to send any control information to the next node it uses the neighbour node information. Accordingly, neighbour nodes are categorized into lower and upper approximation nodes using the mathematical tool WRS model WRS. Then the control information is sent to lower approximation set of nodes.

3.4. Weighted Rough Set AODV

The proposed protocol zeroes in on reduction of the redundant flooding in Route Request Phase (RREQ) of AODV. In the existing AODV protocol local connectivity of the mobile node is identified by use of several techniques including local broadcast known as hello messages. Here, we introduced a special hello packet when there is a change in the topology. It carries not only the existing status of the neighbor node but also sends neighbor node attributes. The routing tables within the neighborhood of a node are organized to optimize response time to local movements and to provide quick response time for establishment of new routes. In the present work node relative information is additionally added to the existing routing table. The primary objectives in the existing AODV algorithm are more effectively utilized in the present work as follows. The broadcast of discovery packets takes place only when necessary. Local connectivity management and general topology maintenance are distinguished.Information about changes in local connectivity is disseminated to neighboring mobile nodes which may likely to seek information.

4.1.1.1. Path Discovery

The path discovery process is initiated whenever a source node needs to send information to another node for which it has no routing information in its table. Every node maintains two counters: a node sequence number and broadcast id. The source node initiates path discovery by sending the RREQ packet to selective neighbours. To find selective neighbours each node will maintain the neighbour information in the form of a table. When source node or intermediate node gets the RREQ packet it converts the stored information into lower and upper approximation using WRS with the help of framed rules. Here each rule is assigned a predefined significance value based on the resources available in the network. These approximations are helpful to send RREQ packet from source or intermediate node.

This process will repeat itself in a stipulated number of RREQ retires. If source is not able to get the destination then it will try to send the RREQ to every node in all the neighbour nodes. To achieve this, each and every node additionally has to maintain the neighbour node's attribute information. Even though this is an over head, in some situations like multimedia application and video conferences ad-hoc network is stable for some considerable period of time. In this situation collected neighbor node attribute information will sustain for a long time and this information is helpful to establish reliable path.

4.1.1.1. Reverse Path Setup

AODV maintains two sequence numbers apart from broadcast_id. These are the source sequence number and the destination sequence number known to the source. The source sequence number is used to maintain freshness information about the reverse route to the source, and the destination sequence number specifies how fresh a route to the destination must be before it can be accepted by the source. A reverse path from all the nodes to the source is automatically established during when the RREQ travels from a source to various destinations. In order to establish a reverse path a node records the address of the neighbor from which it receives the first copy of the RREQ. These reverse time for the RREQ to traverse the network and produce a reply to the sender.

4.1.1.2. Forward Path Setup

Forward path setup is handled by RREQ phase along with neighbour table information. The receiving node first checks whether the RREQ was received over bi-directional link. If the intermediate node has a route entry for the desired destination, it determines whether the routing is current by comparing the destination sequence number in its own route entry to the destination sequence number in the RREQ. If the RREQ's sequence number for the destination is greater than recorded one by the intermediate node, then the intermediate node rebroadcasts RREQ instead of using it. The intermediate node can reply only when it has a route with sequence number that is greater than or equal to the contained one in the RREQ. If it has not any current route to the destination and the RREQ has not been processed previously the node then unicasts a RREP back to its neighbour from which it receives the RREQ. A RREP contains the following information.

1. Source Address.
2. Destination Address.
3. Destination Sequence Number.
4. Hop count.
5. Lifetime.

The Algorithm of the Modified AODV RREQ Phase is as follows:

1. Every node collects the attribute values of 1-hop and 2-hop neighbour nodes and verify in a time interval
2. Source or intermediate node converts the collected neighbour node's information into rough set information according to the set of rules.
3. Node weight is evaluated according to the rough membership equitation 1.

RREQ packet is initiated by source node when it needs to find path to destination, RREQ consists of Source Address, Destination Address, Source Sequence Number, Distance Sequence Number, Broad cast ID, Hop Count. All these values are initialized by source node. Later RREQ packet will be forwarded to selected nodes in the network instead of all neighbour nodes.

Selection Process at Source node

If (Source node of any of the neighbour is destination) then
directly RREQ packet is forwarded to destination node.
Else
RREQ is forwarded to one set of approximation nodes

Selection Process at Intermediate node

If the RREQ packet is old then packet will be discarded
Else
If the packet is new and its neighbour is destination then RREQ will be broadcasted to destination node
Else
Then RREQ packet will be forwarded to selected nodes.
This process will continue till the destination node is found in stipulated route request retries.

4.1.2. Neighbour Table and Routing Table Management

4.1.2.1. Neighbour Table

In the proposed protocol a mobile node maintains the 1-hop and 2-hop neighbour table to identify the selective nodes. The neighbour table contains the following information.

- Neighbor node.
- Node pause time.
- Node battery power.
- Traffic along the neighbour node.
- Relative distance with respect to destination.

The above values are identified and stored in the neighbour table. The relative distance parameter is evaluated when a RREQ is reached to a particular node. The neighbour table is modified whenever there is a change in the topology.

4.1.2.1. Routing Table Management

Mobile node which maintains the routing table entry for each destination consists the following entries.

- Destination
- Next Hop
- Number of hops
- Sequence number for the destination
- Active neighbors for this destination.
- Expiration time for the route table entry.

Each time a route entry is used to transmit data from source toward a destination, the timeout for the entry is reset to the current time plus active_route_timeout. If a new route is offered to a mobile node it then compares the destination sequence number of the new route to that of the current route. The route with greater sequence number is chosen. If the sequence numbers are the same then the new route only which has smaller metric to the destination is selected.

4.1.3. Reverse and Forward Path Setup

As the RREP travels back to the source, each node along the path sets up a forward pointer to the node from which the RREP came updates its timeout information for route entries to the source and destination and records the latest destination sequence number for requested destination.

Table 4. Simulation parameters.

Parameter	Value	Description
Number of nodes	45	Simulation Nodes
Field range x	2000m	X-Dimension
Field range y	2000m	Y-Dimension
Power range	250m	Nodes power range
Mac protocol	IEEE 802.11	MAC Layer protocol
Network Protocol	AODV &Rough AODV	Network Layer
Transport Layer Protocol	UDP	Transport Layer
Propagation function	Free-Space	Propagation Function
Node placement	Random	Nodes are distributed in random manner
Simulation time	15 minutes	According to simulation clock
Mobility Interval	10-30sec	Pause time of node
Radio Frequency	2.4e9	Radio layer setting
Bandwidth	2Mbits/Sec	Nodes Bandwidth

A node receiving a RREP propagates the first RREP for a given node towards that source. If it receives further RREPs, it updates its routing information and propagates the RREP only if the RREP contains either greater destination sequence number than the previous RREP or the same destination sequence number with the previous RREP, or the same destination sequence number with a smaller hop count. It discards all other RREPs it receives. We ran each simulation four times with different node pause time varying from 15 to 30sec with a step interval of 5 sec. The graphs are presented in results section.

5. Simulations Results

5.1. Simulation Parameters

We used the simulator glomosim-2.03, [4] to run the simulation Table 4 summarizes the simulation parameters we used. The simulation time was 15 minutes according to simulator clock. A total of 45 nodes were randomly placed in field of 2000 X 2000 m^2.Power range of each node is 250m.

5.2.The Performance Measures

The performance of proposed protocol is evaluated using the following metrics:

- Packet delivery ratio (Throughput): packet delivery fraction is the ratio between the number of packets originated by the application layer CBR sources and the number of packets received by the CBR sinks at the final destinations.
- Number of Collisions: the number of packet loss due to more than one station access the channel at the same time. These collisions are MAC layer collisions.
- Number of Route requests: it is the number of control packets generated by all the nodes in the simulation.
- Energy Consumption: the total energy used by all the transmissions in the simulation.

5.3. Results

Packet delivery Ratio (Throughput) is more for WRS mode AODV than that of Rough set model AODV as shown in Figure 6, which is due to less number of collisions as shown in Figure 7 and less number of broken links as shown in Figure 4.

The number of Route Request packets is less in WRS model as shown in Figure 9 compare to rough set model AODV. The energy used is very less in the WRS model AODV as shown in Figure 5 compare to rough set model AODV. The total number of collisions occurred by different nodes is less in WRAODV than that of RAODV.

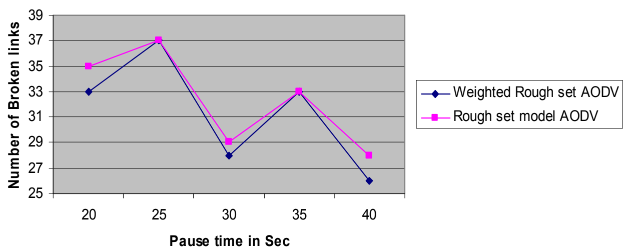

Figure 4. Broken links comparison.

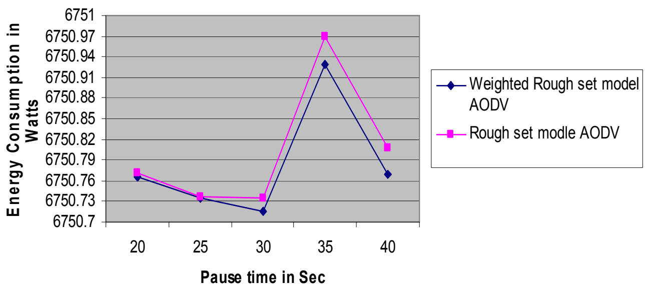

Figure 5. Energy consumption comparison.

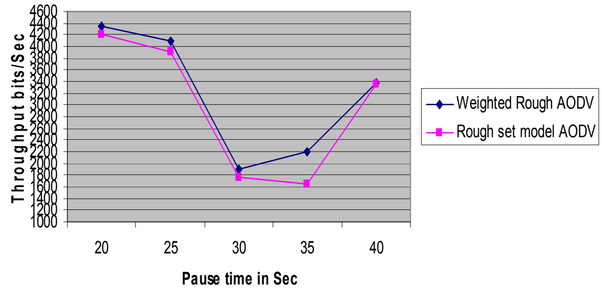

Figure 6. Throughput comparison.

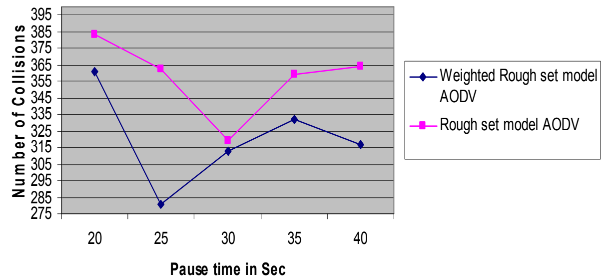

Figure 7. Number of collisions comparison.

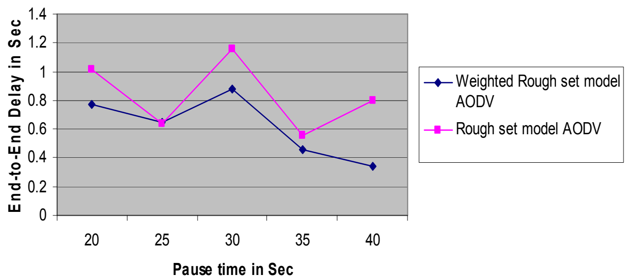

Figure 8. End-to-end delay in sec.

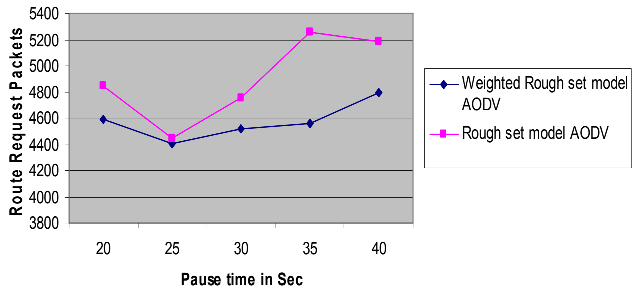

Figure 9. Route request packet comparison.

6. Conclusions

In this paper we discussed a method to reduce the redundant broadcasting. In a particular situation ad-hoc networks are stable for a short stipulated time interval and this stability is made use to collect the neighbour node information which is kept with each node. A node needs to find the destination from the source then the collected node information will be helpful to establish a long term valid path. This long term valid path in turn to reduce the number of unnecessary Route Request control packets. The future scope is to descritize the collected node information. Then

References

[1] Calinescu G., Mandoiu I., Wan P., and Zelikovsky A., "Selecting Forwarding Neighbours in Wireless Ad-hoc Networks," *in Proceedings of ACM Int'l Workshop Discrete Algorithms and Methods for Mobile Computing*, pp. 33-43, 2001.

[2] Jian L. and Mohapatra P., *An Approach to Improve Flooding Based Route Discovery in Mobile Ad-Hoc Networks*, Springer Science, *2006*.

[3] Johnson D. and Maltz D., "Dynamic Source Routing in Ad-hoc Wireless Networks," *in Computer Communication Review Proceedings of SIGCOMM'96*, 1996.

[4] Jorge N., "A Comprensible Glomosim Tutorial," 2004. http://appsrv .cse.cuhk .edu.hk\hndai\ research, Last Visited 2009.

[5] Lim H. and Kim C., "Flooding in Wireless Ad-hoc Networks," *Computer Journal of Communication*, vol. 24, no. 3-4, pp. 353-363, 2001.

[6] Nagaraju A. and Ramachandram S., "Fuzzy Cost Based Multipart Routing for Mobile Ad-hoc Networks," *in the International Journal of Theoretical and Applied Information Technology*, vol. 4, no. 4, pp. 319-326, 2008.

[7] Nagaraju A. and Ramachandram S., "Rough Set Based Ad-Hoc On-Demand Routing Algorithm for MANETs," *in Proceedings of ACM Banglore Chapter Compute*, pp. 156-159, 2009.

[8] Nagraju A., Ramachandram S., and Rao C., "Routing in Mobile Ad-hoc Network by Applying Heuristic Approach to Reduce Broadcasting," *in the 3rd International Conference on Mobile Ubiquitous and Pervasive Computing Obcom*, pp. 369-373, 2006.

[9] Nagraju A., Ramachandram S., and Rao C., "Applying Heuristic Technique to Ad-hoc on Demand Distance Vector Routing to Reduce Broadcast," *in Proceedings of the International Conference of Wireless Networks WCE, London*, pp. 137-142, 2007.

[10] Nagaraju A. and Ramachandram S., "Adaptive Partial Dominating Pruning Algorithm for MANET's," *in Proceedings of ACM Banglore Chapter Compute*, pp. 55-59, 2009.

[11] Park V. and Corson M., "A Highly Adaptive Distributed Routing Algorithm for Mobile Wireless Networks," *in the proceedings of IEEE INFOCOM*, Kobe, pp. 255-257, 1997.

[12] Pawlak Z., "Rough Sets," *International Journal of Computer and Information Sciences*, vol. 11, no. 5, pp. 341-356, 1982.

[13] Pawlak Z., *Theoretical Aspects of Reasoning about Data*, Kluwer Academic Publishers, 1991.

[14] Perkins C. and Royer E., "Ad-hoc on Demand Distance Vector Routing," *in the Proceedings of the 2nd IEEE Workshop on Mobile Computer System and Applications*, pp. 90-95, 1999.

[15] Rajam V., Maheswari V., and Siromoney A., "Mobile Ad-hoc Routing Using Rough Set Theory," *in Proceedings of the International Conference on Hybrid Information Technology*, pp. 80-83, 2006.

[16] Rajam V., Maheswari V., and Siromoney A., "Extensions in Mobile Ad-hoc Routing Using Variable Precision Rough Sets," *in Proceedings of International Conference on Granular Computing*, pp. 237-240, 2007.

[17] Shivanajay A., DiptiSrinivasan M., Chen K., and Althanasios V., "Evolutiony Fuzzy Multi Objective Routing for Wireless Mobile Ad-hoc Networks," *in Proceedings of IEEE Conference*, pp. 321-326, 2004.

[18] Stojmenovic I., Seddigh M., and Zunic J., "Dominating Sets and Neighbour Elimination Based Broadcasting Algorithms in Wireless Networks," *Computer Journal of IEEE Transaction on Parallel and Distributed Systems*, vol. 13, no. 1, pp. 14-25, 2002.

[19] Tesng Y., Ni S., ChenY., and Sheu J., "The Broadcast Storm Problem in a Mobile Ad-hoc Networks," *in Proceedings of the International Proceedings of MOBICOM*, pp. 151-162, 1999.

[20] Wei L. and Jie W., "On Reducing Broadcast Redundancy in Ad-hoc Wireless Networks," *Computer Journal of IEEE Transactions on Mobile Computing*, vol. 1 no. 2, pp. 111-122, 2002.

[21] Wu J. and Dai F., "Broadcasting in Ad-hoc Networks Based on Self-Pruning," *in Proceedings of IEEE INFOCOM*, pp. 277-282, 2003.

[22] Young-Bae K. and Vaidya N., *Location-Aided Routing in Mobile Ad-hoc Network*, Published in Wireless Networks, 2009.

[23] ZHANG X., Sheng C., Mei-yu F., and Wei D., "Fuzzy Logic Qos Dynamic Source Routing for Mobile Ad-hoc Networks," *in Proceedings of IEEE Conference*, pp. 245-248, 2004.

Naga Aitha received his MTech from University of Mysore and MSc (maths) form Central University Hyderabad. He presently works as head and associate professor at Kamala Institute of Technology and Science, Huzurabad, Karimnagar, AP India. His research interests are mobile Ad-hoc networks and theoretical computer science. He is a member in Computer Society of India, ISTE and IAENG.

Ramachandram Srinadas is currently head and professor in the Department of Computer Science and Engineering, Osmania University. He received his BE degree in electronics and communication engineering from Osmania University, MTech degree in computer science engineering and PhD in computer science and engineering from Osmania University. His current research interests include use of mobile databases and designing routing algorithm for mobile Ad-hoc networks. He served on the program committees of several conferences and workshops related to mobile communication.