Analysis of Route Discovery in Mobile ad-hoc Network Routing using Information Systems

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Abstract: Mobile Ad hoc NET works (MANETs) are group of wireless mobile nodes that can dynamically form a network without any infrastructures wherein mobile nodes are highly co-operative. In MANETs, the movement of nodes is uncertain may cause links to break and low battery life of mobile nodes may cause nodes to fail. The connectivity of the entire network is uncertain and may not be known to any particular node. The work presented in this studies routing in cache-based ad hoc routing protocols, based on the Information Systems of Rough Set Theory (RST). The Rough Set Theory is a new mathematical tool to deals with vagueness and uncertainty and applied for cache based routing protocols in MANETs. The cache in mobile nodes looks similar to the information system of Rough Set Theory. The direct use of information systems in mobile nodes are used to assist routing of data packets and the decision systems are used to predict the next hop for a destination in MANETs.

Keywords— *MANETs; Dynamic Source Routing (DSR); Rough Set Theory (RST);*

I INTRODUCTION

In the recent years Mobile Ad- hoc network (MANET) [4] has found applications especially to overcome the limitation of Bandwidth in wireless network. Wireless networks play an important role in both military and civilian systems. An ad hoc network is a collection of wireless mobile nodes forming a temporary network with no centralized entity and without aid of any established infrastructure. Messages are exchanged and relayed between mobile nodes. In fact, an ad hoc network has the capability of making communications possible even between two mobile nodes that are not in direct range with each other: packets to be exchanged between these two nodes are forwarded by intermediate nodes, using routing protocols.

A number of routing protocols [1] and [2] has been proposed for MANETs. Most of the routing protocols in MANETs are either proactive, reactive or hybrid. Proactive protocols are table driven. In **Proactive** routing protocols, the mobile nodes are maintaining a table of routes to every destination for this reason they periodically exchange the control messages and hence there is no latency in discovering routes. In **Reactive** routing protocols routing information is acquired only when there is need for it. Each mobile node maintains a route cache of known routes. The needed routes are calculated on demand. Routes are discovered by some global search and hence there is latency in route discovery.

1.1. DYNAMIC SOURCE ROUTING PROTOCOL (DSR)

DSR is a reactive routing protocol which is able to manage a MANET without using periodic table-update messages like table-driven routing protocols do stated in [3]. DSR was specifically designed for use in multi-hop wireless ad hoc networks. Ad-hoc protocol allows the network to be completely self-organizing and self-configuring which means that there is no need for an existing network infrastructure or administration. For restricting the bandwidth, the process to find a path is only executed when a path is required by a node (On-Demand-Routing). In DSR the sender (source, initiator) determines the whole path from the source to the destination node (Source-Routing) and deposits the addresses of the intermediate nodes of the route in the packets. DSR is beacon-less which means that there are no hello-messages used between the nodes to notify their neighbours about their presence.

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DSR contains 3 phases

- Route Discovery (find a path)
- Route Maintenance (maintain a path)
- Route Failure Handling(If the link fails)

1.2. ROUGH SET THEORY

Rough set theory was proposed by Pawlak [5]. It is based on the rules of data mining and artificial intelligent algorithms. It is suitable to discover uncertain and incomplete implied knowledge. A data set is represented as a table, where each row represents an event or an object or an example or an entity or an element. Each column represents an attribute that can be measured for an element. This table is called an information system. The set of all elements is known as the universe.

For example, if the information system describes a hospital, the elements may be patients; the attributes (condition attributes) may be Symptoms and tests; and the decisions (or decision attribute) may be diseases.

In an information system, elements that have the same value for each attribute are indiscernible and are called elementary sets. Subsets of the universe with the same value of the decision attribute are called concepts. A positive element is an element of the universe that belongs to the concept. For each concept, the greatest union of elementary sets contained in the concept is called the lower approximation of the concept and the least union of elementary sets containing the concept is called the upper approximation of the concept. The set containing the elements from the upper approximation of the concept that are not members of the lower approximation is called the boundary region. The lower approximation of the concept is also known as the positive region. A set is said to be rough if the boundary region is non-empty. A set is said to be crisp if the boundary region is empty.

Variable Precision Rough Sets (VPRS) [9], proposed by Ziarko, is a generalization of the rough set model, aimed at modeling classification problems involving uncertain or imprecise information. Using VPRS model, the lower and upper approximations are deduced in probabilistic terms, leading to generalized concepts of rough set approximations.

In RST, the lower approximation of a concept is defined using an inclusion relation. Here in VPRS, the lower approximation is defined using a majority inclusion relation. The β-positive region is the union of elementary sets which are either completely contained in the concept or are almost contained in the concept, with a maximum error of $1 - \beta$. The conditional probability of an element being positive in an elementary set is the probability that the element is positive, given that the element belongs to that elementary set. It is the ratio of the number of positive elements in that elementary set to the number of elements in that elementary set. When this conditional probability is greater than the threshold value β ($0.5 < \beta \leq 1$) the elementary set is said to fall in the β-positive region.

1.3. INFORMATION SYSTEMS AND DECISION SYSTEMS

In Rough Set Theory, [6] a data set is represented as a table, where each row represents an *element*. Each column represents an *attribute* that can be measured for an element. This table is called an *information system*. The set of all elements is known as the *universe***.**

Consider a universe U of element. Formally, an information system I is a quadruple I= (U,A,V,ρ), where A is the non-empty, finite set of attribute;

$V=U_{a\in A}V_a$is the set of attributes, Where V_a is the set of possible values of attribute *a;*

ρ: U*A→V is an information function, Such that for every element x € U, ρ $(x,a) \in V_a$ is the value of attribute a *for element x.*

The information system can also be viewed as an *information table,* where each element $x \in U$ corresponds to a row, and each attribute $a\in$ A corresponds to a column.

I= (U, A U {d}, V, ρ), is known as a *decision system*, when an attribute *d* is specified as the decision attribute. A decision system is used for predicting the value of the decision attribute. A is the known as the set of *condition attribute.*

Regions of the Universe

In Rough Set Theory [7] and [10], An equivalence relation **R**, called *indiscernibility relation*, is defined on the universe **U** as

$$\mathbf{R=\{(x,y) \in U \times U \;\; \forall a \in A, \rho(x,a)=\rho(y,a)\}}$$

In the information system **I**, the *elementary set* containing the element$x \in U$, with respect to the indiscernibility relation **R** is

$$[x]_R = \{y \in U \mid yRx\}$$

The *lower approximation* of the concept $X \subseteq$ U with respect to **U** and equivalence relation **R** on **U**, is the union of the elementary sets of **U** with respect to R that are contained in X, and is denoted as

$$\underline{R_X} = \{x \mid [x]_R \subseteq X\}$$

The *upper approximation* of X is the union of the elementary sets of U with respect to **R** that have a non-zero intersection with **X** , and is denoted as

$$\overline{R_X} = \{x \mid [x]_R \cap X \neq \emptyset\}$$

The *lower approximation* of X is also known as the *Positive region* of X . The set $BN_R(X) = \overline{R_X} - \underline{R_X}$ is called the *Boundary region* of X. The set **U**- $\overline{R_X}$ is called the *Negative region of* X.

The conditional probability that an element in an elementary set is positive is $P(\_|[x]_R|) = \frac{|[x]_R \cap X|}{|[x]_R|}$ **.**

The conditional probability that the element in the elementary set is negative is

$$P(\_ |[x]_R|) = 1 - P(\_| [x]_R).$$

When the context is clear, the *conditional probability* of an elementary set is taken to be $P(\_|[x]_R)$.The β_u-*positive region* is the union of the β_u elementary sets whose conditional probability β_u is greater than or equal to β_u where β_u >0.5. The β_l-*negative region* is the union of the elementary sets whose conditional probability β_l is less than β_l where $\beta_l \leq$0.5. These are based on the definitions in [8]. When $\beta_u = 1 - \beta_l$, we denote it as β, and note that $\beta_l = 1 - \beta$.The range of is β(0.5,1] in the original VPRS definition. It appears that when the decision attribute is multi-valued with k as the number of possible values, the range of is β (1/k,1].

II. RESEARCH BACKGROUND
2.1. INFORMATION SYSTEM WITH LINKS

This section presents the use of thresholds in routing **[8].** The information system captures the links in the route rather than the presence of mobile nodes in the route. Let an information table I_m = (U_m,A_m,V_m,ρ_m) be associated with each mobile node m∈M. Here, Am represents the set of all possible links between the nodes. Each condition attribute aϵA_m in the attribute set corresponds to a particular link in the set of all possible links between the nodes. Each condition attribute is a Boolean attribute, with V_a ={0,1}, and is set to 1 or 0 depending on whether that link is present in the route associated with that element or not, S, V_m={0,1}. A_m is the same in all mobile nodes and hence is denoted as A. Similarly, V_m is denoted as V. ρ_m is the information function.

Consider an element xϵU_m corresponding to a route $m_1 m_2$...., m_k , $m_i \epsilon$M, i=1,2....k. When a row is added to the information table, the values of the condition attributes corresponding to the links $m_1 m_2$,$m_2 m_3$,......$m_{k-1} m_k$ are set as 1.Consider a mobile node m that learns the routes are $mm_1m_4m_5$, mm_1m_5, mm_4m_5, mm_5m_1, mm_4m_1,m_1m_4, $mm_1m_4m_5$, mm_1. Table 1 shows the route cache of mobile node m and Table2 shows the corresponding entries in the information table. In Table 2, the entries x_6, x_7, x_8 correspond to the routes mm_1m_4 ,$mm_1m_4m_5$, mm_1 respectively. These routes or part of the route are already present in the route cache. So these routes are added only to the information table and not to the route cache.

$mm_1m_4m_5$
mm_1m_5
mm_4m_5
mm_5m_4
mm_4m_1

Table 1: Entries in route cache

2.2. DECISIONSYSTEM WITH LINKS

Let the decision system of a mobile node m be $\{U_m, A_m \cup \{d\}, V_m, \rho_m\}$, where d is the decision attribute. The decision attribute d is a Boolean attribute. Let B be a subset of A_m, such that each element in B is a link that has all links to the next hop nodes from the current mobile node m. Let x_i and x_j be members of U_m.

Table 2: Information table with links as attributes

	mm_1	mm_4	mm_5	m_1m_4	m_1m_5	m_1m	m_4m	m_4m_1	m_4m_5	m_5m	m_5m_1	m_5m_1
x_1	1	0	0	1	0	0	0	0	1	0	0	0
x_2	1	0	0	0	1	0	0	0	0	0	0	0
x_3	0	1	0	0	0	0	0	0	1	0	0	0
x_4	0	0	1	0	0	0	0	0	0	0	1	0
x_5	0	1	0	0	0	0	0	1	0	0	0	0
x_6	1	0	0	1	0	0	0	0	0	0	0	0
x_7	1	0	0	1	0	0	0	0	1	0	0	0
x_8	1	0	0	0	0	0	0	0	0	0	0	0

The indiscernibility relation is defined as

R=\{(x_i,x_j)∈ $U_m \times U_m$ ∀ a ∈ B, ρ_m(x_i,a)=ρ_m(x_j,a)\}

That is, among the routes considered by a mobile node m, those that have the same next hop are indiscernible and belongs to the same elementary set. Let X is a subset of U_m such that for each element in X, the Concept X has all routes that have the destination m_t in it. Consider an elementary set $[x_i]_R$ that have all routes considered by m which have the same next hop m_i .

Among these routes, some may have the destination m_t in it. Let the conditional probability P $(m_t|[x_i]_R)$ represent the ratio of the number of routes with m_t in $[x_i]_R$ to the total number of routes in $[x_i]_R$.

That is, P $(m_t|[x_i]_R) = \frac{|[x_i]_R \cap m_t|}{|[x_i]_R|}$. The β −positive region consists of those elementary sets for which the value of $P(m_t|[x_i]_R)$ is greater than β.

III. RELATED WORKS

3.1. ROUTING USING THRESHOLDS IN A DECISION SYSTEM WITH LINKS.

3.1.1. Routing based on thresholds ($DSR_{\beta max}$)

Initially, the values of all condition attributes are set to 0. For each link in the route that is learnt or used, the values of the corresponding condition attributes in the information table are set to one. In the source node, a shortest route cache if available is placed as the source route in the data packet as in DSR and DSR+. If a route is not available in the route cache, a route discovery is done. The decision system is used to find the best next hop (Algorithm 1) in the source node and in any intermediate forwarding node.

When a next hop is to be found from the information system, all possible next hops are first considered. Here, an elementary set has all routes that have the same next hop. For a particular next hop, the ratio of the number of the number of routes that will lead to destination with this next hop to the total number of routes with this next hop (may are may not leads to the destination) is found. If the ratio is greater than a threshold β, then the elementary set falls in the β positive region. If the given destination is next hop, then that node itself is chosen as the next hop. Else, of all the next hops corresponding to the elementary sets in the β- positive region,

The node that will lead to the destination and that use the maximum number of times, for which the number of entries in the elementary set is not one, is chosen as the next hop. If the next hop that is found from the information system is different from the one in the source route that is already in the data packet, this new next hop is appended to the source route in the data packet set the current node and a flag is set in the data packet, to know that the source route taken from the source node has changed.

If a next hop cannot be determined from the information system, or if the next hop found from the in the information system results in a loop, then the data packet is forwarded according to the source route.

Algorithm 1: Finding a next hop in $DSR_{\beta max}$

findNextHopDSRbetamax()
{
foreach *nexthop nh* **do**
ratio[nh] = 0;
nexthopcount[nh]=0;
destnexthopcount[nh]=0;
foreach *row in the information system* **do**
if *the route corresponding to this row has nh as the next hop* **then**
nexthopcount[nh] = nexthopcount**[nh] + 1;**
if *the route corresponding to this row will lead to the destination* **then**
destnexthopcount[nh] =destnexthopcount**[nh] + 1;**

end
end
end
ratio[nh] =destnexthopcount[nh]/nexthopcount[nh];
if *ratio[nh]>β and max(destnexthopcount[nh])* **then**
break;
end
end
return this next hop nh;

3.2. PERFORMANCE EVALUATION

The network simulator ns2 [11] is used for the experiments. The following parameters are ones that have been often used in such studies. The random waypoint mobility model is used in a rectangular field. Constant bit rate traffic sources are used. A transmission range of 250 m is used. The link layer modelled is the Distributed Coordination Function (DCF) of the IEEE 802.11 wireless LAN standard. The source- destinations pairs (connections) are spread randomly over the network.Parameters which are used in simulation are shown in Table

Table 3.1. Simulation Parameters

Simulation Parameters	
Routing Protocol	DSR
Simulation Time	500 secs
Number of Nodes	20
Simulation Area	1500 × 1500
Speed	Min=2.0m/sec,Max=6.0m/sec
Packet Size	512 Bytes
Pause time	20 secs
Traffic Type	CBR

Initial Power	100
Queue Length	50

3.1. The performance of $DSR_{\beta max}$ is evaluated using the following metrics that are normally used in such studies:

(i) Packet delivery ratio: The ratio of the data packets delivered to the application layer of the destination to those sent by the application layer of the source node.

(ii) Average end-to-end delay: The average delay from when a packet is sent by the source node until it is received by the destination node.

A performance comparison of DSR_{β} and proposed $DSR_{\beta max}$ routing protocols for mobile ad hoc network is presented as a function of pause time. Performance of these routing protocols is evaluated with respect to End-to-End Delay and Packet Delivery Ratio**.**

Figure 1. shows the difference in the End-to-End delay of DSR_{β} and proposed $DSR_{\beta max}$ and Figure 2 shows the difference in the Packet Delivery Ratio of DSR and proposed

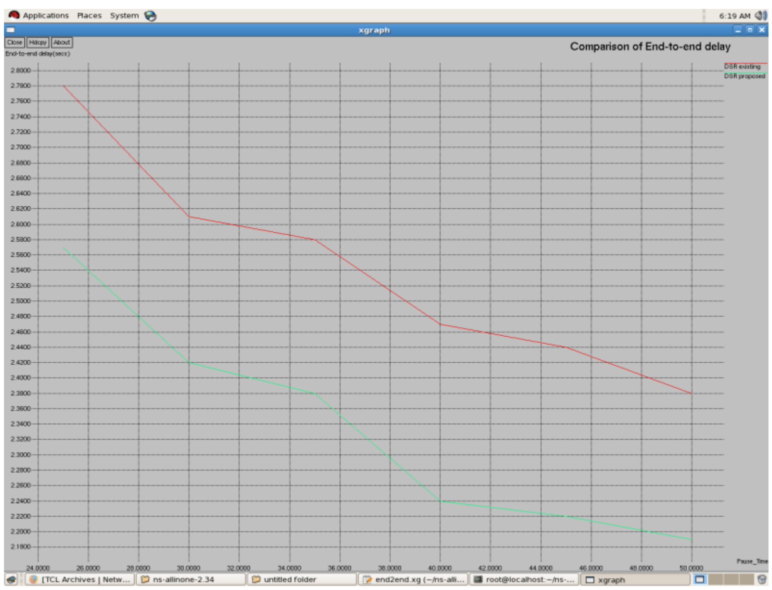

Figure 1: End-to-End Delay vs. Pause_Time

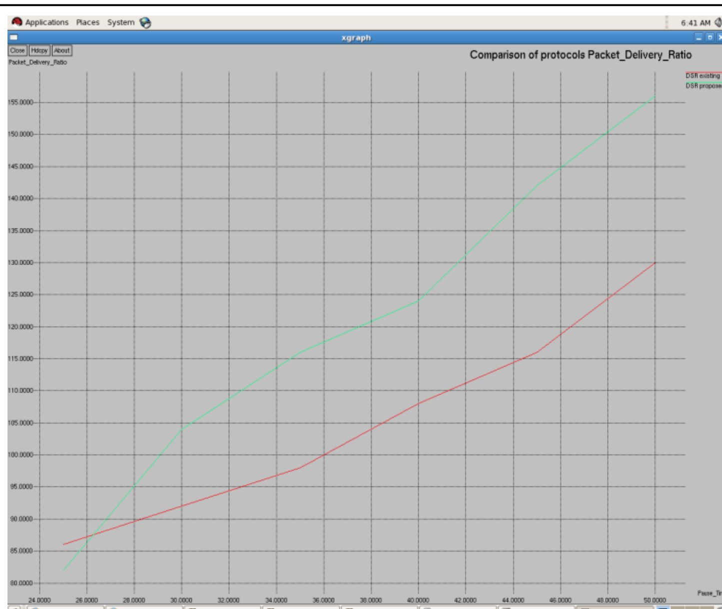

Figure 2: Packet_Delivery_Ratio vs. Pause_Time

IV. CONCLUSION

Thus the information system of RST was first implemented into mobile ad hoc networks and was used similar to a cache in a mobile node. In the routing protocol DSR the information system was incorporated into the mobile node. When choose a next hop DSR_β, the mobile node that will lead to the destination with the minimum number of entry in the cache is used as a criteria from the information system when the number of connection is less. In order to overcome the connection constraint the $DSR_{\beta max}$ is proposed. The performance of DSR and the the enhancement DSR_β was studied with the proposed work. It was seen that $DSR_{\beta max}$ performed better than DSR and DSR_β . The information system in the mobile node was adapted and the attributes of the information system were taken as the links from a route of mobile nodes. $DSR_{\beta max}$ used this information system to choose a better next hop while routing data .

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