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IRCAR: Improved Reputation based Context-aware Routing Algorithm for Delay Tolerant Network

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Abstract: *Delay Tolerant Networks are the network where the continuous network connectivity is lacking. R-CAR algorithm[2] addresses the issue of routing in such networks. But the paper fails to address issues regarding newly arrived node in a network, prioritization of low hop count carrier node and sharing and dynamic updation of local reputation tables. This paper gives an Improved version (IRCAR) that efficiently solves these issues.*

1. Introduction

A mobile ad hoc network is an infrastructure less network of mobile devices connected by wireless medium. Such a network has self configuring capabilities. Each device in a mobile ad hoc network is free to move independently in any direction and will therefore, change its links to other devices frequently. When the nodes are mobile, it is possible that, at times, there is no connected path between a pair of devices. In these circumstances, sending data between such a pair of nodes is not very trivial. This lack of continuous network connectivity is addressed by delay tolerant networking (DTN) [3].

Routing in delay tolerant networks is a non-trivial challenge. Popular ad hoc routing protocols such as AODV[4] and DSR[5] fail to establish routes due to the lack of end-to-end paths. Routing protocols in DTN must take a "store and forward" approach, where the data is incrementally moved and stored throughout the network in hopes that it will eventually reach its destination. Replicating many copies of the message maximizes the probability of the message being successfully delivered in the hope that at least one copy will succeed in reaching its destination. Such routing is called epidemic routing [10] and results in flooding of packets across the network.

Probabilistic routing protocol using history of encounters and transitivity (PRoPHET) [8] uses an algorithm that attempts to exploit the non-randomness of real world encounters by maintaining a set of probabilities for successful delivery to known destinations and replicating messages during encounters only if a node that does not have the message have a better chance of delivering it. MaxProp[6], on the other hand, allows many complementary mechanisms that help the message delivery chances in general.

Another approach for routing in DTN is based on intelligently selecting the next node that maximizes the delivery probability of message. Context-aware adaptive routing for delay tolerant mobile network (CAR)[1] chooses the best carrier using Kalman filter[11] based prediction techniques and utility theory. The paper fails to address critical issues including the behaviour in presence of black-holes. Reputation based routing protocol to contrast black-holes in delay tolerant network (R-CAR) [2] is claimed to be an extension of CAR. It proposes a reputation based protocol, where the best carrier node is chosen on the basis of the reputation of that node. Mechanisms like acknowledgements, n-list, s-lists, aging etc make the communication efficient and capable of adapting to the changing environment of DTN.

R-CAR fails to address certain crucial issues like value of local utility function of a newly arrived node, building reputation table of a newly arrived node, prioritization of low hop-count carrier node. This paper answers these questions. The paper is organised as follows. Section 2 briefly discusses the R-CAR protocol. Section 3 discusses the above mentioned issues in R-CAR and tries to solve them. Section 4 summarizes the contribution of this work.

2.Reputation-based routing protocol (R-CAR)

This paper follows a reputation based approach. The forwarding capability of every node is measured in terms of its reputation, i.e., how gud and trustworthy other nodes consider it when it comes to forwarding a message. High reputation value implies high chances of successful message delivery.

R-CAR works on the basis of a single replica of a message. It assumes that a node never refuses to forward a message. Also, if the buffer of a node is full, it leads to message loss.

Depending upon the connectivity of two nodes, a message is delivered either synchronously or asynchronously. The message is sent directly via Dynamic Destination-Sequenced Distance Vector (DSDV) routing protocol [7] in case of synchronous routing, i.e., when the two nodes are in same connected region. However, in case of asynchronous routing, i.e., when the nodes are not connected directly, the message is stored in the buffer of the intermediate node, called carrier node. The next node to forward a message to is chosen on the basis of value of reputation of a node.

Reputation of every node is evaluated and maintained using three concepts: acknowledgements, nodes list and aging. When a node A sends a message to a node B, it waits for an acknowledgement from B. After A has received the acknowledgement from B, it increases the reputation of the node who forwarded its message to B.

Every message carries a list of nodes that it has passes through, called nlist, and a list of digital signatures of those nodes, called slist. Upon receiving a message, a node increases the reputation of all the nodes already present in the nlist and adds itself to nlist and the digital signature to slist.

Since the nodes in a DTN are mobile, therefore, to adapt this dynamic environment of DTNs, reputation of every node is decreased at certain intervals so that it does not times out. A time unit T, not too small and at the same time, not too large, is fixed after which the reputation is decreased by a positive non-zero quantity Y, i.e., R = max(0,R-Y). Quantities T and Y can be changed dynamically when required. This mechanism is called aging. In this way, the reputation is updated timely.

2.1 Mathematical Model

As already described, reputation measures trustworthiness of a node in terms of message forwarding. Reputation of node *i* assigned by node *j*, denoted R_{ij}, lies in [0,1]. Since every node in the network assigns reputation to every other node based on its own experience of network connections and disconnections, it is a local notion and not a global phenomenon.

A lower value of *R* indicates that the node may not be reliable and it may drop all the messages received, in which case it is called a blackhole [9]. However, if a node has successfully forwarded a message, it implies that the node is not a blackhole.

R-CAR calculates Local Utility Function (L_{ij}) that describes how capable node *j* considers node *i* to forward a message. It is defined mathematically as,

$$L_{ij} = R_{ij} \times U_i$$

where U_i is a utility function of node *i* and R_{ij} is the reputation of node *i* at node *j*. Node *j* chooses the node having highest value of L_{ij}.

More intuitively, Let D be the event that “node *i* delivers a message” and B be the event that “node *i* is not a blackhole”. Then, according to Bayes theorem, the probability of successful message delivery *P(D)* is,

$$P(D) = P(B)P\,(DIB)/P\,(BID)$$

Given that node *i* is not a blackhole, i.e., P(B) = one, the probability of a node *i* delivering the message is completely dependent upon the utility of node *i*, i.e.,$P(DIB) = U_i$. Also, *P(B)* is nothing but the reputation of node *i* assigned by node *j*. Thus,

$$P(D) = R_{ij}\, U_i/P\,(BID)$$

But $P(BID)$= one because if *i* forwards messages then it is not a blackhole. Hence,

$$P(D) = U_i \times R_{ij}$$

where $P(D) = L_{ij}$.

For a node *i* which is a black-hole, reputation, R_{ij}, will be zero. And therefore, L_{ij} will also be zero. This implies that node *j* will never consider node *i* for forwarding a message.

3. Improved R-CAR (IRCAR)

R-CAR follows a straightforward and simplified mathematical approach to forward a message. However, it fails to address certain important issues. Whenever a new node arrives, what will be the value of its local utility function in the eyes of other nodes in the network? How this newly arrived node will assign reputation values to other nodes in the network, for which it has zero knowledge base. Also, on receiving the acknowledgement message, every node increases the reputation of its immediate carrier node but it fails to identify a shorter path (if it exists).

3.1 Local Utility Function of a new node

Let us suppose, at time *t,* a new node, (say, n_k) arrives in the network. It comes in the contact of certain already existing nodes of the network. But these nodes will not consider n_k for data transmission unless they don't know the reputation value of this node. As n_k has just arrived, there is no past history associated with it. Thus, the other nodes need to initialize the reputation value of n_k in their local reputation tables(LRT).

In order to calculate the local utility function $L_{n_k j}$, ($L_{n_k j} = R_{n_k j} \times U_{n_k}$), we need to know the values of $R_{n_k j}$ and U_{n_k}. $R_{n_k j}$ is nothing but the probability that n_k is not a blackhole in the eyes of node j. As n_k has just arrived, this probability can be safely initialized to be 0.5.

U_{n_k} is equivalent to the probability of delivering the message, given that it is not a black hole. Without any prior information, this value can also be initialized to 0.5.

Using the values of $R_{n_k j}$ = 0.5 and U_{n_k} = 0.5, the value of $L_{n_k j}$ is calculated and initialized to 0.25. Note that, every existing node j initializes the value of $L_{n_k j}$ to 0.25.

Therefore, the local utility of a new node in the network will be 0.25.

It may appear that the value 0.25 is too high or too low, but its just an initialization value which gets further updated in due course of time, once this node starts getting picked for transmission purposes.

3.2 Reputation table of a new node

The new node n_k cannot assign a constant reputation value to all other nodes in the network. Instead, the algorithm follows a very practical approach. n_k assigns reputation to all other nodes in the network based on the experience of its neighbouring nodes.

Since the node n_k is new in the network, it has no knowledge about forwarding behaviour of other nodes. So it calculates the reputation values using a reputation buildup algorithm, which is described as follows. The new node n_k initializes the reputation value of every other node *i* in the network to 0.5, i.e.,

$$R_{in_k} = 0.5$$

Now, it tries to improvise on this assumption by requesting the LRT of its neighbouring nodes. For every other node *i*, let R'_{in_k} be the mean of reputations assigned to *i* by neighbouring nodes of n_k. Node n_k, then, updates its LRT values as follows:

$$R_{in_k} = 0.8 \times R'_{in_k} + 0.2 \times R_{in_k} \qquad (9)$$

As the network is dynamic, a single exchange is not sufficient. Hence, this entire procedure is repeated after every Δt amount of time over a total span of T time units. Note that, the nodes which are frequently in contact with n_k affects its LRT to a greater extent as compared to the nodes which rarely come in contact with it. The values 0.8 and 0.2 are chosen in such a manner that the history gained over a span of time is given higher weightage as compared to a single iteration.

3.3 Updating reputation

The structure of an acknowledgement message is a bit different from that of the data message. It contains a copy of nlist of the data message. Since a DTN is dynamic in nature, the acknowledgement message might follow a different path from the one followed by the data message in the network, to reach the sender. So, nlist and slist of acknowledgement message indicate the path that it has followed on its way back to the sender.

In R-CAR, when a sender sends the data, it waits for an acknowledgement message from the ultimate destination. As soon as the acknowledgement message arrives, it increases the reputation, say by α, of its intermediate neighbouring node, say n_1, that forwarded the message.

Increasing the reputation of just the immediate carrier node of the sender is not efficient as it fails to identify shorter paths towards the destination. IRCAR handles this by not just increasing the reputation of immediate carrier node, instead it increases the reputation of all nodes through which the message reached the destination.

In order to give priority to shorter paths towards the destination, reputation is not increased by a constant value α, it is increased in a linearly incremental fashion, i.e., α for the immediate carrier, $\alpha+\delta$ for the next immediate carrier, $\alpha+2\delta$ for the third immediate carrier and so on. By increasing the reputation in this manner, we try to prioritize the nodes having shorter paths towards the destination. Note that, the increased reputation is balanced by the aging phenomenon if any node does not come in contact with n_k for a long duration.

4. Conclusion

In this paper, we have improvised R-CAR algorithm to IRCAR to handle crucial issues of local utility function value of a new node, reputation value assigned by a new node to other nodes in the network and prioritization of low hop-count carrier node. The proposed algorithm can be further improvised in future by intelligently replicating the messages like ProPHET and making reputation a global phenomenon.

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