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Routing in Delay Tolerant Mobile Network: A Comparative Analysis

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Abstract

Routing in Delay Tolerant Network has received considerable attention in the recent years. Context-aware Adaptive routing and Reputation based Context-aware Adaptive routing are based on a single copy of the message, whose delivery is based on the choice of a best carrier node. In this paper, we present a comparative analysis of these algorithms and highlight the issues not addressed by any of these algorithm.

1. Introduction

A mobile network is a wireless network distributed over small areas, each served by at least one fixed local base station. Mobile adhoc networks assume that a connected path always exists between sender and receiver node. This assumption is unrealistic in case of mobile nodes in the network which led to extensive research on Delay Tolerant Networks(DTN). Delay Tolerant Networks are opportunistic in nature and follow store-carry-forward approach. When two nodes come in contact of each other, one forwards the packets stored in its buffer depending upon the other node's probability of forwarding the packet.

Popular ad hoc routing protocols such as AODV[6] and DSR[7] fail to establish routes in case of DTN. This is because these protocols first try to establish a complete route and then, after the route has been established, forward the data. Design of routing algorithms for DTN need to consider many more constraints like whether information about future contacts is readily available, if mobility can be exploited and the fact that network resources in DTN are limited.

In Context-aware Adaptive Routing(CAR) protocol for Delay Tolerant Mobile Networks [1], a node forwards a packet to other node depending upon the value of its delivery probability which is calculated on the basis of the mobility of the node and its past collocation (indicating that it will meet the recipient again in the future). A node with the highest delivery probability is considered more trust-worthy in forwarding messages as compared to others. CAR works on Kalman Filter prediction [5] and multi-criteria decision theory.

Another routing algorithm, Reputation-based routing protocol (R-CAR) follows a reputation based approach [2]. Reputation measures trustworthiness of a node in terms of forwarding a packet to other nodes. High reputation indicates high forwarding behaviour. Reputation of all forwarding nodes is increased every time a packet reaches its destination successfully. Aging mechanism is used to decreases the reputation of the nodes over time. The algorithm presented has a protection mechanism against black-holes also.

In this paper, we have compared the two algorithms, CAR and R-CAR, mentioned above. Although the two algorithms are akin in their approaches but there are many dissimilarities. Section 2 and 3 of the paper briefly describes the routing algorithm of CAR and R-CAR respectively. Comparison and contrasts of the two routing algorithm is discussed in section 4.

2. Context-Aware Adaptive Routing(CAR)

Context-Aware Adaptive Routing forwards a packet from a node to other node depending upon the value of its delivery probability which is calculated on the basis of the mobility of the node and its past collocation (indicating that it will meet the recipient again in the future). CAR assumes that a host is unaware of its absolute geographical location and of the location of those to whom it is trying to send a message. It does not assume any previous knowledge of routes of the hosts. CAR works on the basis of a single replica of a message. It also assumes that a node never refuses to forward a message, i.e., nodes neither act in selfish manner nor in byzantine manner.

2.1 Overview

CAR delivers a message synchronously or asynchronously depending upon the connectivity of the nodes. When the sender and receiver are in the same connected region i.e., connected directly via some other nodes, the message is sent synchronously without storing it in the buffer of any intermediate node. The routing protocol used for synchronous routing is Dynamic Destination-Sequenced Distance Vector (DSDV)[8].

Message is sent asynchronously when the two nodes are not in the same connected region. In this case, the intermediate nodes, called carriers, store the message in their buffer until the connection is established with the next carrier (or say, destination) node. The carrier nodes in case of asynchronous delivery are chosen on the basis of the value of delivery probability. High delivery probability indicates high chances of message delivery.

CAR predicts and evaluates the probability of a node to deliver a packet using its context information. Context is defined as the set of attributes describing the system that can be used to drive the process of message delivery. Although context of a node includes many attributes, but CAR utilizes only two attributes, change rate of connectivity and future host collocation. Instead of using just the past history and current information, CAR predicts and utilizes the future values of context attributes so as to make more optimised routing decisions.

2.2 Context Attributes

The context information of a node can be defined as a set of mutually (preferably) independent attributes (X_1,X_2,...,X_n). An attribute, say X_1 is a set of all possible values for the attribute, whereas (x_1,x_2,...,x_n) refers to a particular value within this set. Since the attributes are mutually independent in nature, they can be combined by their sum:

$$U\left(x_{1,}x_{2,..}.x_n\right) \quad {}^{n}\Sigma_{i=1}U_i(x_i)$$

where U_i is a utility function over X_i.

Because the goal is to maximise each attribute and choose the one with the maximum value, the weights method [4] is applied,

$$Maximise\left(f\left(U(x_i)\right) \quad {}^{n}\Sigma_{i=1}w_iU_i(x_i)\right)$$

CAR uses only two attributes, change degree of connectivity and future host collocation. The change degree of connectivity, i.e., number of connections and disconnections of a host *h* during the time interval [*t*-*T*,*t*], normalised by the total number of hosts met in that interval is,

$$U_{cdc_h} = (|n(t-T) \cup n(t)| - |n(t-T) \cap n(t)|)/|n(t-T) \cup n(t)|$$

where *n(t)* is *h's* neighbour set at time *t*.

The collocation of *h* with a host *i* is calculated as follows:

$$U_{col_{h,i}} = \{1 if host h is colocated with host i; 0 otherwise\}$$

Using Kalman Filter Predictors, values for U_{cdc_h} and $U_{col_{h,i}}$ at time *(t+T)*, denoted by $\widehat{U_{cdc_h}}$ and

$\widehat{U_{col_{h,i}}}$ respectively are evaluated and then combined into a single value using multi-criteria decision theory as follows:

$$U_{h,i} = w_{cdc_h}\widehat{U_{cdc_h}} + w_{col_{h,i}}\widehat{U_{col_{h,i}}}$$

The above value represents how good host *h* is for delivering messages to *i*.

The utility function weights are fixed in advance, reflecting the relative importance of different context attributes. However, such a formulation is too static, since it fails to take into account the values of the attributes. In order to have a runtime self-adaptation of the weights, adaptive weights that corresponds to criticality of certain ranges of values, predictability of the context information and availability of the context information can be introduced.

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

R-CAR evaluates the reputation for every node, which measures trustworthiness of a node in terms of forwarding a packet to other nodes. High reputation indicates high forwarding behaviour.

R-CAR also delivers a message synchronously or asynchronously depending upon the connectivity of the nodes. But, the carrier nodes in case of asynchronous routing are chosen on the basis of the value of reputation of that node (in contrast to CARs' delivery probability).

Reputation of every node is maintained and evaluated using three concepts: acknowledgements, nodes list and aging. When a sender sends a message to an intermediate node, it waits for an acknowledgement from the destination node. And when the acknowledgement arrives, it increases the reputation of that forwarding node. Also, every message carries the list of intermediate nodes that it has visited on its way to destination node. Upon successfully receiving the message, every node updates the reputation of all the nodes mentioned in the list. In this way, the reputation is updated dynamically. Since the nodes in a DTN are mobile, so to adapt this highly changing environment, reputation of every node is gradually decreased also. This mechanism is called aging.

3.1 Reputation and Update Protocol

Every node estimates the reputation and in turn, about the forwarding behaviour of every other node. The reputation, *R*, lies in [0,1] and it is a local notion of a node, depending upon its own network experience .

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}.

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.

3.2 Update Protocol and Aging

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.

Reputation of every node is gradually decreased so as to adapt the highly changing environment of DTNs. 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.

4. Comparative Analysis

Both the algorithms, CAR and R-CAR; are based on a single copy of the message and assume that a node never refuses to forward a message. Thus, if the buffer overflows, the message will be lost. Also, the underlying routing protocol for synchronous routing used in both is DSDV.

Kalman Filter prediction technique is used in both the algorithms for mathematically estimating the forwarding behaviour of a node. Though the authors of R-CAR claim it to be an extension of CAR, the mathematical estimation approaches used in these algorithms are very different. CAR evaluates the delivery probability of a node using its context attributes, like change degree of connectivity and future host collocation, whereas R-CAR does not. R-CAR uses the reputation assigned to a node by every other node in the network. Since reputation is assigned by a node to every other node, it is a local notion of a node and not a global phenomenon.

Also, R-CAR deploys the aging mechanism to gradually decrease the reputation in order to adapt the highly changing environment of a DTN, whereas CAR does not.

R-CAR protects against black-holes attacks in contrast to CAR. For a node i which is a black-hole, reputation, R_{ij}, for all nodes j, will be zero. And therefore, the utility L_{ij} will also be zero. This implies that node j will never consider node i for forwarding a message.

5. Conclusions

Surfacially, though the algorithms appear to be very similar, but on a closer look, many technical differences can be identified. R-CAR which calls itself an extension of CAR, does not appear to be so. Instead, it is an entirely different algorithm developed on similar lines as CAR.

Both the routing algorithms fail to address issues of calculation of delivery probability or reputation of a newly arrived node in the network. Also, the algorithms have no communication mechanism to benefit others from their own findings about good, bad, selfish behaviour of any node.

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