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Hybrid Geographic and Contact-Based Forwarding in Delay-Tolerant Networks

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Abstract

Delay Tolerant Network(DTN) is a wireless network in which there will be no connectivity exists between source and destination in a given time. Due to the absence of fully connected path between the source and destination, there will be a problem to route a packet from one node to another in DTN .Similarity based techniques relying on contact patterns among nodes provide routing in DTN provides high delivery success rate. This paper is discussing about a PRICE scheme, a greedy forwarding scheme for DTNs that combines geographic oriented forwarding with contact based forwarding by relaying packets according to predictable patterns of location and contacts. Here a throw box is also introduced in the network to store information about frequent contacts and locations used by the network. The simulation result outperforms all other routing solution in terms of cost/delivery success ratio.

Keywords: DTN, throw box,EDTW.

Introduction

Delay Tolerant networking is an emerging paradigm for communication in infrastructure less Network. Intermittent connectivity[21] is the most important parameter for DTN, where communication between nodes can only happen during certain time period. Nodes can make use opportunistic contacts for propagating the information from source to destination node[20]. But the delay in the propagation is potentially large and no guarantees on the delivery can be given[19]. And only delay tolerant applications can be supported. Data forwarding is still a problem in the scenarios. Due to this frequent and long duration partitions between nodes; the network topology may change dynamically and randomly[9]. There are numerous approaches used for data dissemination in DTN[22]. One method is store-carry-forward approach in which there is no guarantee that data can be received successfully. Flooding is another simplest[23] and costly approach based on replicating every single packet at every node met. Although this approach generates large overhead, it is robust. Since it maximizes the chance of final delivery due to replication of data can imply a high delivery delay[16] if a path in the network rarely emerges.

In order to overcome the limitations of these approaches proposed PRICE, a hybrid combination that exploits two forwarding approaches. At first geographic approach[15] is used to forward the packets towards the destination based on the coordinate value of locations. When there is any uncertainty in the location of nodes, a contact based approach is used. It relies on the fact that nodes is able to transmit group of packets to nodes that are frequently in contact with the destination node. In order to store contact patterns and locations [1] coordinate values look up table is used. Each node in the table store the history of its current contacts and coordinates [6] when and where communication takes place. It keeps the node state information.

PRICE is a new approach which combines both geographic and contact based forwarding in DTN. It has the following approaches.

- Geographic based forwarding speed up the forwarding of the bundles towards destination.
- Histories of contacts among the nodes overcome the geographic forwarding[8] limitations.
- Improves the overall performance of the system without any excessive overhead or limitations.

The rest of the paper is organised as follows. In section 2 an overview of PRICE and its performance is evaluated. Performance is evaluated in section 3. Finally the conclusions are drawn in section 4.

Price Operation

In mobile environments, nodes can be inactive and mobility patterns are not fully deterministic. So that probability of losing bundles increases dramatically. One approach to increase the delivery success ratio[11] is to use replicas. But it is important to limit the number of replicas to prevent network flooding. There should be some mechanism to drop the remaining replicas when the bundle reaches the destination. In Price, the source node first transmits a bundle to a node that predicts to move toward the destination. If the source node gets in contact with another node that predicts to move more closely towards destination, a replica of the bundle can be generated and transmitted to that node. Only the source node can generate replicas outside the destinations ecosystem (is the set of nodes with which it is likely to be in contact, according to the periodicity of the mobility[3] behaviour). The source node always keeps a replica of the data bundle within the destination's ecosystem, the source and relay nodes always replicate the data bundles when transmitted to other nodes.

When contact-based forwarding is used, during each contact, the source/relay node evaluates if nearby nodes have the destination node in their agendas of contacts. In this mode, bundle replicas can be transmitted to nodes that are destination's acquaintances to increase the delivery ratio. The aim is to transmit a replica[2] to a node that has a shorter expected window of re-contact with the destination node. In some cases, one predicted contact might not occur. In this case, if it is not possible to re-compute a window of re-contact with the destination node, the replica is simply dropped. Otherwise, if the relay node still has in its agenda of contacts the destination node predicted for another time slot, the relay node re-computes its window of re-contact.

Geographic Forwarding in Price

In order to perform geographic routing[24], all nodes know their own geographic coordinates [5]and aware of their direct neighbours. These neighbour nodes regularly exchange their agendas of locations[13] and contacts. This means that it is possible for a node to evaluate which neighbour is likely to move towards intended destination. The first issue to be addressed is how to characterize the spatial occupancy of destination nodes. In order to identify that depends up on "home location" the place where each node spends more than 50% of its time. But there won't be any information about contacts [18]and locations of external users and temporary visitors.

Now consider a network where nodes are mobile. If some nodes have periodic mobility patterns[17], contacts occurred in predicted places constitute geographic fixed points[12]. By assuming that a place is important for a node and also be an important place for the nodes it is in contact with. Periodic spatial patterns are represented as circles. Locations[6] where two nodes are in contact become vertices in the topology and they are shown as dark spots. There is a link between two vertices if at least one of the nodes involved in the contact visits these two vertices. From the considerations above, it is possible to derive following information: (i) the coordinates of vertices, which indicate the directions towards the bundles, can move to destination and (ii) the existence of a link between vertices within the pattern of each node. Hence, according to the spatial mobility pattern of a node, two faraway vertices may be linked in the same way as two nearby vertices.

There are mainly two advantage of using geographic information[14] to build the topology. First, a node may aggregate successive Contacts when occurred at the same location[4], which provides a significant gain as compared to what happens with contact-based routing. Second, the important information becomes both who has been in contact with and where.

The main algorithmic operations of Price, as introduced below:

Algorithm 1: Contact-based forwarding procedure

```
begin
DTWi deliveryWindow(i, dest);
if (DTWi < EDTW) then EDTW DTWi;
forall neighborNode j do
DTWj bestDeliveryWindow(j, dest);
if DTWj < EDTW then
EDTW DTWj;
sendCopy(bundle, j);
if (DTWi == NULL) then i.drop(bundle);
end
```

Algorithm 2: Geographic forwarding procedure

```
//bundle's EDTW must be NULL //
begin
Di agendaDistance(i,Pdest);
if Di > r then
forall neighborNode j do
Dj bestAgendaDistance(j,Pdest);
if Dj < (Di _ r) and isSource (bundle, i) then
sendCopy(bundle, j);
if Dj < (Di _ r) and isNotSource (bundle, i)
then send(bundle, j);
end
```

Let us consider that node i has to transmit a data bundle to node dest. Assume that it knows the destination's home location, Pdest. There are two possible cases: (1) node i belongs to destination ecosystem and can estimate a temporal window for the next contact based on its own agenda of contacts

(2) i and dest do not belong to the same ecosystem,and i has to use spatial information to choose the contact which will move towards the destination's ecosystem. A bundle is characterized by an expected delivery time window (EDTW), which is null when the bundle is introduced in the network. If node i is currently in contact with dest, it directly transmits the bundles to dest. Otherwise, when i is in contact with any group of potential relay nodes j (j – dest), it evaluates the forwarding opportunity according to the sequence below:

- The relay node j is currently in contact with dest: in this case, i transmit a copy of the bundle to j which, in turn, directly delivers the bundle to dest.
- The relay node j is in dest's ecosystem: in this case, Algorithm 1 is applied; each node computes its delivery time window (DTW) to evaluate whether the relay node can reduce the expected delivery time.

Neither i nor its potential relay nodes have dest in their ecosystems; in this case Price operates in geographic mode, as described in Algorithm 2, where r represents the current distance of the bundles from the destination.

If the selected relay node is no further in the destination's ecosystem as it moved meanwhile, the bundle is dropped[15], given that Price does not allow switching back from contact-based forwarding to geographic forwarding, except for the source node.

Performance Analysis

In this section we present an evaluation study to assess performance of Price as compared to other solutions proposed in the literature. In particular, we evaluate the effectiveness of Price to successfully deliver bundles to destination nodes when considering the combination of geographic and contact based forwarding. This effectiveness is analyzed through three distinct parameters: (i) delivery success ratio, (ii) transmission cost in terms of the number of replicas, and (iii) percentage of bundles sent, lost and correctly delivered.

Efficiency of geographic/contact forwarding

Finally, we investigate on the efficiency of the two forwarding modes used in our hybrid scheme, namely the contact-based and geographic ones, in terms of the percentage of bundles that have been sent, delivered and lost, respectively. Price could take a forwarding decision (i.e., to decide whether applying the geographic or contact-based mode) for 94.3% of the bundles. In particular, 88.5% of all bundles started being sent in the geographic forwarding mode, and 5.8% in the contact based mode. Moreover, 11.1% of bundles that were sent by using the geographic forwarding mode have been then lost before finding the destination, while 36.8% of the bundles sent through geographic forwarding[16] have been directly delivered to the destinations. Also, 40.6% of bundles have switched to the contact- based forwarding mode.

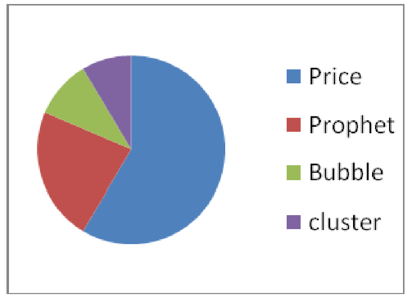

Fig 3.1 Performance Comparison of different Routing Strategies

When summing up this percentage to that of the bundles that have started being sent in the contact- based mode, we see that 46.4% of bundles have exploited this forwarding mode. In this mode, only 0.1% of bundles have been globally lost. If we now consider the performance of geographic forwarding and contact-based forwarding independently, contact-based forwarding alone is proven not to be efficient. In this case, approaches which wait for contact information (e.g. Bubble-C[10]and Prophet) do not ensure high delivery rate. And Cluster[7] delivers bundles on average. This delivery rate is low and is mainly due to the single-copy approach. Accordingly, the combination of geographic and contact-based forwarding helps in circulating bundles in the network. Summarizing, most of the bundles that have been originally sent in geographic forwarding[8] found an acquaintance of the destination node and were eventually delivered. Similarly, almost all of those originally sent using contact-based forwarding successfully got the destination. Thus, we can conclude that the combination of these two forwarding modes definitely leads to improved efficiency.

Conclusion

Price is a hybrid geographic/contact-based forwarding scheme for DTNs. Price combines geographic forwarding with contact-based forwarding by relying on agendas of locations and contacts. In fact, although contact-based forwarding can be very effective when short chains of contacts exist between any pairs of nodes, it becomes costly when we consider chains of more hops. To compensate this overhead, geographic forwarding to move bundles as close as possible to the destination's home location with the hope of finding either the

destination itself or any of its acquaintances. Price outperforms all the other strategies being considered by achieving much better delivery/cost tradeoffs.
As an example, the replication mechanism could result in a significant overhead. Accordingly, this mechanism could be made dynamically adaptable to the ‘‘sociality’’ of the source and destination nodes, for example by further replicating the information to be sent to ‘‘socially-selfish’’ nodes which are expected to have less chances to be contacted. Contact-based forwarding could also benefit from the use of the graph navigation theory which, applied to dynamically changing networks, can lead to exploitation of small world dynamics for information spreading purposes. Throw-boxes [31] are small, inexpensive devices equipped with wireless interfaces and deployed to relay data between mobile nodes. Being small and inexpensive, throw boxes represent a flexible and cost-effective approach to enhance network capacity. Throw-boxes are very effective in improving both data delivery ratio and delay, especially for multi-path routing and environments with regular node movement.

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