Extension of Probabilistic Routing Protocol using History of Encounters and Transitivity for Information Centric Network
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Abstract

This document proposes extension of probabilistic routing protocol using history of encounters and transitivity (PRoPHET) for information centric network.

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1. Introduction

In Information centric network (ICN), a node requests Data by sending Interest packet and this Interest packet is forwarded through ICN routers. A router with the requested Data replies to the Interest to the requester and the Interest is delivered through a reverse path of the forwarded Interest. ICN router manages content store (CS), pending interest table (PIT), and forwarding information base (FIB) [George2014]. In CS, cached data is stored for future use. In PIT, the information of Interest, the incoming and outgoing faces of the Interest are stored, and this information is used to deliver Data to the requester using the reverse path of forwarded Interest. FIB is used to forward Interest to appropriate faces.

ICN is considered important for communication of urgent messages in disaster situations [Edo2014]. In disaster situations, communication infrastructure is destroyed and networks are fragmented. In
fragmented networks where connectivity between the nodes at different fragmented networks is not possible, opportunistic network such as delay tolerant networks (DTN) can be used to deliver messages. In DTN, a message is delivered to a destination node via opportunistic contacts between intermediate nodes in a store-carry-forward way.

Since forwarding of Interest and Data should be carried out opportunistically using DTN in fragmented networks, forwarding schemes of Interest and Data in connected ICN networks should be extended to accommodate the disruptive characteristics of DTN. In this draft, we consider probabilistic routing protocol using history of encounters and transitivity (PRoPHET)[RFC6693] for extension. Then, we propose forwarding schemes for Interest and Data of ICN.

2. Conventions and Terminology

2.1. Conventions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

2.2. Terminology

TBD

3. Forwarding of Interest and Data for ICN

3.1. Delivery predictability of PRoPHET

In PRoPHET, delivery predictability is defined between any two nodes. The delivery predictability between node A and node B i.e., $P(A,B)$, increases whenever node A and node B contact as follows:

$$P(A,B) = P(A,B)_{\text{old}} + (1 - \delta - P(A,B)_{\text{old}}) \times P_{\text{encounter}}, \quad (1)$$

where $\delta$ sets an upper bound for $P(A,B)$ and $P_{\text{encounter}}$ is a scaling factor to control the rate of increase [RFC6693].

Also, it decreases as time elapses since the last contact as follows:
\[ P(A, B) = P(A, B)_{old} \times \gamma^K, \]  

where \(0 \leq \gamma \leq 1\) is an aging constant and \(K\) is the elapsed time.

Finally, the delivery predictability has a transitive property, i.e., if node A and B encounter frequently, and node B and node C encounter frequently, then node A probably encounters node C.

### 3.2. Extension for Interest forwarding

Conventional DTN routing protocol is based on push model and the destination of a message is a specific node. However, pull model is used in ICN and Interest is forwarded based on content name, rather than node ID. In order to forward Interest to appropriate nodes which have the requested Data in its CS, the delivery predictability of a node A for the Interest \(i\) corresponding to the requested Data is defined as \(P(A, N(d_i))\), similar to Eq. (1) as follows:

\[ P(A, N(d_i)) = P(A, N(d_i))_{old} + (1 - \delta - P(A, N(d_i))_{old}) \times P_{encounter}, \]  

where \(N(d_i)\) represents a set of nodes with the Data corresponding to Interest \(i\) in its CS.

In Eq. (3), \(P(A, N(d_i))\) increases whenever node A contacts another node which has \(d_i\) in its CS, where the number of nodes having Data \(d_i\) is generally larger than 1, since \(d_i\) can be cached in multiple nodes by adopting the ICN approach. Similar to Eq. (2), the delivery predictability of a node to a node set \(N(d_i)\) decreases as time elapses since the last contact. We note that if node A has Data \(d_i\), \(P(A, N(d_i)) = 1\).

When node A and node B contact, Interest \(i\) stored in node A is forwarded to node B, if \(P(A, N(d_i)) < P(B, N(d_i))\), since node B is a more probable node to deliver Interest \(i\) to a node having \(d_i\) than node A. In this case, the information of requester nodes for Interest \(i\) is also delivered to node B. The information of requester nodes for the same Interest \(i\) stored in both node A and node B is shared, irrespective of the comparison of delivery predictabilities. For example, if node A has Interest \(i\) with requester R1 and if node B has Interest \(i\) with requester R2, both node A and node B have information of requesters R1 and R2 for Interest \(i\) after contact.
3.3. Extension for Data forwarding

For the delivery of Data in DTN, there is no known reverse path like the one using PIT in ICN. Therefore, Data also should be delivered using DTN routing protocol, too. In the proposed extension, the information of requesters for the considered Data is used to forward the Data. If the number of requesters for the Data corresponding to Interest i is only one, the forwarding scheme of conventional PRoPHET can be applied directly since the destination of the Data is a requester node and forwarding is carried out based on node ID. That is, if \( P(B,R(d_i)) \) is larger than \( P(A,R(d_i)) \), the Data \( d_i \) is forwarded to node B, where \( R(d_i) \) is defined as the requester node for the Data corresponding to Interest i.

If there are multiple requesters for the Data corresponding to Interest i, current forwarding scheme of PRoPHET should be extended, too, based on the delivery predictability relationship of two contact nodes for each requester. In this draft, three forwarding schemes for multiple requesters are presented as examples. If node A and B contact and node A has Data with multiple requesters, the Data can be forwarded to node B if any of the following condition is met depending on the selected policy:

1) if the delivery predictability between node B and a requester is larger than that between node A and the corresponding requester for any requester,

2) if the delivery predictability between node B and a requester is larger than that between node A and the corresponding requester for all requesters,

3) if the average of the delivery predictabilities of node B and requesters are larger than that between node A and the corresponding requesters.

For example, if node A has Data \( d_i \) with requesters R1 and R2 and if node B does not have Data \( d_i \) already when node A and node B contact, Data \( d_i \) in node A will be forwarded to node B depending on a Data forwarding policy as follows:

1) if \( P(A,R1(d_i))<P(B,R1(d_i)) \) or if \( P(A,R2(d_i))<P(B,R2(d_i)) \); (4)

2) if \( P(A,R1(d_i))<P(B,R1(d_i)) \) and if \( P(A,R2(d_i))<P(B,R2(d_i)) \); (5)

3) if Average\( (P(A,R1(d_i)),P(A,R2(d_i))) \)

\[ < \text{Average}(P(B,R2(d_i)),P(B,R2(d_i))). (6) \]
Information on requesters is also delivered if Data is forwarded. If both node A and node B have the same Data, the information of requesters is shared between node A and node B.

3.4. Operation of the proposed extension

In the proposed forwarding scheme, whenever node A and node B contact, they exchange Interest list and Data list. Interest list contains all the Interests that they receive from other nodes, where information for the requesters for Interest i is also managed in Interest list. Data list contains all Data that they cache in their CS for future delivery. Also, the information for the destination nodes of the Data, i.e., requesters, is also managed in Data list. Then, node A compares its Interest list with node B’s Interest list and forwards Interest i to Node B if node B does not have the Interest and \( P(B,N(d_i)) \) is larger than \( P(A,N(d_i)) \). The information of requester nodes for the same Interest i stored in both node A and node B is shared between both node A and node B after the contact.

For Data forwarding, node A checks Data list. If node A has only one requester information for the considered Data, node A forwards Data \( d_i \), which corresponds to Interest i, if node B does not have the Data and \( P(B,R(d_i)) \) is larger than \( P(A,R(d_i)) \). If node A has multiple requesters information for the considered Data, Data can be forwarded to node B if any of forwarding condition for multiple requesters defined in this draft is met, as proposed in Eqns. (4)–(6). Information on requesters is delivered if Data is forwarded. If both node A and node B have the same Data, the information of requesters is shared between node A and node B after the contact.

4. Security Considerations

TBD

5. IANA Considerations

TBD
6. References

6.1. Normative References


6.2. Informative References


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