Performance Improvement in Disruption Tolerant Network with Co-operative Caching

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Abstract

Disruption Tolerant Networks (DTNs) consist of mobile devices or nodes that contact each other opportunistically. Due to its high error rates and unpredictable node mobility, only intermittent network connectivity exists in DTNs, and the subsequent difficulty of maintaining end-to-end communication links makes it necessary to use "store-and-forward" methods for data transmission. This paper proposes a novel approach to support cooperative caching in DTNs, which enables the sharing and coordination of cached data among multiple nodes and reduces data access delay. The basic idea is to cache data at specific locations called network central locations (NCLs), which are being easily accessed by other nodes in the network. Due to the limited caching buffer of the central nodes, multiple nodes near a central node may be involved for caching, and ensure that popular data are always cached nearer to the central nodes via dynamic cache replacement based on query history. The NCL selection is based on a probabilistic selection metric. By placing the NCL on the content query path and clustering the nodes together, the data access performance can be improved.

Keywords: Caching, Clustering, Data Access, Disruption Tolerant Network, Network Central Locations

I. INTRODUCTION

The ability to transport, or route, data from a source to a destination is a fundamental ability that all communication networks must have, Disruption Tolerant Networking, Abbreviated as DTN, is a networking architecture that is designed to provide communications in the most unstable and stressed environments, where the network would normally be subject to frequent and long lasting disruptions and high bit error rates that could severely degrade normal communications. However, an end-to-end path are difficult or impossible to establish in DTN, so the routing protocols use a ″store and forward″ approach, whenever two nodes come in contact they establish a link between them and exchange data, this data is stored and forwarded throughout the network till it reaches the destination.

Disruption Tolerant Networks are frequently used in disaster relief missions, peace-keeping missions, outer-space networks, under-water networks, wireless sensor networks and in vehicular networks. Most recently NASA has tested DTN technology for spacecraft communications. Disruption tolerant network is a network which is having a complete different characteristic from normal networks. It doesn't have any end to end connection between the nodes in a network, so it uses store and forward approach for data transmission. For this a new layer called bundle layer is introduced in between the application and transport layer, this uses bundle protocol instead of TCP/IP as in the normal networks. Since it uses store and forwarding for data transmission and not having end to end connection, the data access performance in DTNs are very poor. Data access is an important issue in Delay Tolerant Networks (DTNs), and a common technique used is caching, where data is cached at some locations. Here a novel scheme to support caching in DTNs is introduced, where the data is cached at a set of specific locations called network central locations (NCLs), which can be easily accessed by other nodes in the network. Each NCL is having high popularity in the network and is prioritized for caching data. If too much data is cached at a node, it will be difficult for the node to send the whole data to the requesters during the short contact period between them, thus wasting storage space so, multiple nodes near a central node may also be involved for caching, and ensure that popular data's are always cached nearer to the central nodes.

The detailed contributions are listed as follows,

1) Develops an efficient approach to select NCLs based on a probabilistic selection metric.
2) Data's are cached at the NCLs for ease of data access.
3) Nodes are clustered together based on mobility and, multiple NCLs are selected for caching.

The remainder of this paper is organized as follows. Section II reviews the existing methods. Section III, proposes the NCL selection and caching method, followed by result and conclusion.

II. RELATED WORK

Telecommunication model of the Internet is based on some networking assumptions like it is having a continuous, bidirectional end-to-end path between nodes in the network; ie it assume that there is an end to end connection from the source to the destination, the relatively short round-trip delays; the symmetric data rates; and the low error rates[17]. In a DTN, if two nodes come together a link is established between them, and this link is broken when any one of the move away from other. some of the unique challenges present in DTNs as compared to traditional networks are its, Encounter schedule, network capacity, storage, energy, metrics of interests like, message delivery ratio, delay, number of replicas, energy/power etc . The routing schemes for DTNs are [15], Epidemic routing scheme, Direct contact scheme, Routing based on knowledge oracles, Location based schemes, Gradient based schemes, Controlled replication schemes, Network coding based schemes etc.

One of the main challenges in DTN is to make content available to the interested users in regions of the network where they are present, Users may be interested in different data objects likes files, advertisements, news, etc, and may also be unaware of the users who generate these contents and vice versa. The network may in a way that where the content generator and requester never connect together. So it is important to make content available in the network so as it may reach to interested users. These regions can be identified only by exploiting local information exchanged by nodes when they meet each other [16].

Detecting and dealing with congestion in delay-tolerant networks (DTNs) is also an important and challenging problem. Current DTN forwarding algorithms typically direct traffic towards these nodes of the network in order to maximise delivery ratios and minimise delays, but as traffic demands increase these central nodes may become saturated and unusable. CafRep [6] exploits localised relative utility based approach to offload the traffic from more congested parts of the network to less congested parts, and to replicate at adaptively lower rate in different parts of the network with non-uniform congestion levels.In normal network there exists an end-to-end path between the nodes, so it is easy for data transmission in such a network. The source and destination is always connected together. Data can be forwarded from source to destination via multiple paths. Where as in a DTN, there exists intermittent network connectivity, ie so many delays and disruption in a network. It is difficult to maintain an end-to-end connection in such a network. So it uses store and forward approach, nodes transmit or pass data when they come into contact. And store this data in its buffer until it meets another node. This is the way by which data is forwarded to the destination in a DTN. The source and destination may be far away from each other, and it may take much time to reach its destination. So most of the researches try to find an efficient method by which the data access performance can be improved. And the commonly used method is caching. Data is cached at some locations or nodes. These nodes may be one among the query path or anywhere in the network. If this caching node is far away from the source or destination it will not help much.

III. METHODOLOGY

The data access performance in DTN can be improved by using co-operative caching. Data's are cached at some specific locations called Network Central Location's. These locations or nodes are selected from the network, based on probabilistic selection metric.

A. Network Central Location (NCL):

The network can be considered as a graph with V nodes and E edges, edges means link between the nodes. The contact time between two nodes are exponentially distributed and form a Poisson process with contact rate $\lambda_{ij}.\lambda_{ij}>0$, means j is contacted neighbour of i.

The intercontact time $x_k$between two nodes follows exponential distribution with probability density function (PDF),

$$P_{x_k}(x)=\lambda_k e^{-\lambda_k x} \qquad (1)$$

NCL selection is based on the probabilistic metric, which evaluate the data transmission delay among nodes in DTNs. The metric c_i for a node i to be selected as a central node to represent a NCL is then defined as follows:

$$C_i=\frac{1}{|V|}.\Sigma_{j\in V} P_{ij}(T) \qquad (2)$$

Where $P_{ij}(T)$ indicates the probability that data can be transmitted from node i to j within a time period T. Each node in the network autonomously calculates the metric value c_i and broadcast this information to all other nodes in the network. The node which is having the highest metric value is selected as the central node. This is the node where the data are going to be cached. The nodes also maintain information about the shortest opportunistic path to other nodes when they come into contact.

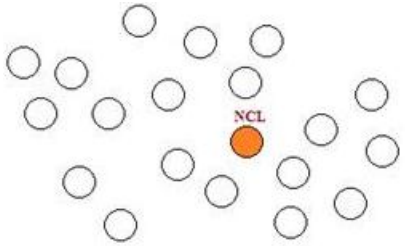

Fig. 1: NCL Selection

The figure (1), shows the selection of Network Central Location from all the nodes of the network. The node which is colored is having the high metric value and so it is selected as the central node for that network.

B. Caching Scheme:

The scheme consists of the following three components:

1) The source node pushes the generated data to the central nodes of NCLs. If the caching buffer of a central node is full, another node near the central node will cache the data.
2) A requester sends the query request to the central node for data access. Upon receiving the query the central node forwards this query to the caching nodes which are nearer to it. And the response is send back to the requester from multiple caching nodes.
3) Utility-based cache replacement is conducted to ensures that popular data are cached nearer to central nodes whenever two caching nodes contacts.

Whenever a source node generates data, it forwards the data to the central node of the NCLs for caching, for this it uses "store and forward" approach in which data is forwarded to a node, one among its neighbours which is having the shortest distance to the NCL. If the buffer space of the central node is full the data is cached at the nearby nodes of the NCL which is having the highest metric value. Thus multiple nodes are involved for caching. By utility based cache replacement it is ensured that most popular data is always cached nearer to the central node. Whenever a data is generated, it carries a life time also. The data cached in anode is of different types, some are short life data's which have no existence after a particular time period, so data's which are expired are removed from the cache which makes space for the new one and also keep the freshness of the content that are cached.

Upon receiving a query the central node checks whether the data is cached locally or not. If it having data in it, it reply back to the requester with the locally cached data. If not it forwards the query to the nearby caching nodes. And response sends back from the caching node to the requester.

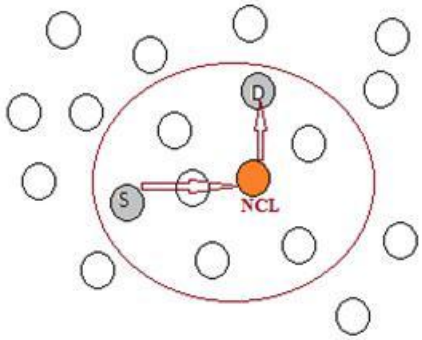

Fig. 2: Co-Operative Caching in NCL

As in the figure (2), the source node 'S' generates data and it is forwarded to the NCL for caching. Upon receiving the query from destination node 'D', data is transferred to 'D' from NCL. The nodes in the network are clustered together based on the mobility and each clusters is having a head which is an NCL so that queries inside a cluster can be responded with less delay and by that way the ratio of query satisfied can be improved.

C. NCL Load Balancing:

The central nodes plays an important role in DTNs, such as it cache the data received from the source, it is responsible for replying to the requester, and also broadcast the received query to all the neighboring caching nodes. However these functionalities may consume its local resources such as battery life and local memory. So the paper proposes an efficient method that can migrate the functionalities of the central node to other nodes whenever any failures or resource depletion occurs.

When a central node fails, another node which is having the next highest NCL selection metric value among the current noncentral nodes of the network is selected as a new central node. Let j be the original central node, a metric is defined as C_i^j for a node i to be selected as the new central node as

$$C_i^j = C^i.p_{ij}(T) \qquad (3)$$

Where C^i is the original NCL selection metric and $p_{ij}(T)$ is the weight of the shortest opportunistic path between node i and j. The original central node is responsible for this selection and it also broadcast this information to all other nodes of the network.

D. Clustering and Performance Improvement:

The nodes in a network are clustered together based on mobility, so that the queries can be responded quickly. A clustering algorithm is having the following steps. First, each node checks its direct contact probabilities to other nodes in the network. Second, a node take decisions about joining and leaving the cluster based on its contact probabilities to other members of that cluster. A node takes its decisions based on its pair-wise contact probabilities to other nodes in the cluster, if the contact probabilities to all existing members are greater than a threshold value it joins a cluster and if it drop below some threshold it leaves the current cluster. To improve the data access each node which is having the highest metric value among them is selected as central node for that particular cluster. The clusters are refreshed after a particular time period, if a cluster is formed at time 'T' the networks refreshes the clusters after 'T+t' time, means it checks the networks and create new clusters, may be some nodes have gone away from the cluster some new ones have there. If the node moved away is a central node, then a new node is selected as central node and the data's are moved to the new one. The figure(3) shows node clustering with central nodes.ie the network is clustered based on the node mobility and the node which is having the highest metric value within a cluster is selected as the central node that cluster and broadcast this information in the network.

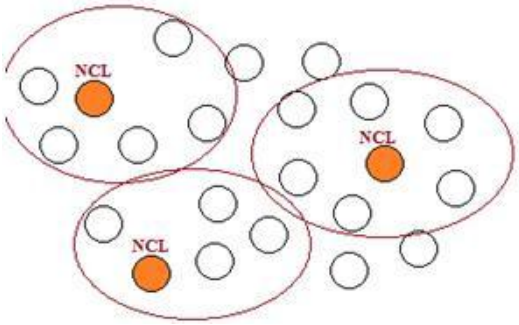

Fig. 3: Node Clustering

IV. RESULT

By this new method of clustering the network and caching the data at specific locations of each cluster improves the data access performance and increases the data delivery ratio. In this new technique the network is clustered based on the node mobility and a node which is having the higher metric value is selected as the central node for each cluster, where the data's are cached. By which the data access performance inside a cluster improves and which also leads to an increase in the whole network data access and data delivery ratio.

V. CONCLUSION

A new method called cooperative caching in DTNs is introduced, Where a DTN is a network which is having high error rates and unpredictable node mobility and also having intermittent network connectivity. In such anetwork data transfer is made by the store, carry, and forward paradigm. The basic idea of data access improvement is caching,cooperative caching is a method where more than one node involves in caching. To improve the data access performance in DTNs the nodes are clustered together based on their mobility . The nodes within a cluster is having high contact probability than others.The cluster head which is having highest metric value is selected as the central node. A network may contain more than one cluster and so it also contains more than one central node. These central nodes are the locations where the data's are cached. Queries are forwarded to these central locations for data access. If the central node is full a neighbouring node which is having highest metric value is selected as new caching node and broadcast this information to the network. By this technique for caching and clustering the data access performance of DTN can be improved.

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