HALBRP: History-Aware Load Balanced Routing Protocol in Delay Tolerant Networks

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Abstract: Delay Tolerant Networks (DTNs) can be defined as groups of moving hosts that form networks with quickly changing dynamic topologies. In such networks, there is no pre-assumed control center or infrastructure. This is so as the network nodes are randomly mobile and located. The nature of such networks makes efficient routing in them an involved problem. This paper presents HALBRP, a new History-Aware Load-Balanced Routing Protocol in Delay Tolerant Networks. The proposed technique uses a precise method (presented in the paper) to measure the load of a node before adding any extra load (in the form of new packets) to the node. The method of calculating the load of a node takes into consideration the history of the node content of messages.

Key–Words: HALBRP; DTNs; History-Aware Routing; Load-Balanced Routing; Delay Tolerant Networks; Routing Protocols.

1 Introduction

The classical routing problem is to design an efficient route from source to destination relying on persistent node to node routes [18]. The nature of routing algorithms depends heavily on the type of the network under study. Therefore classical routing technique are not typically applicable to emerging types of modern networks such as Delay Tolerant Networks [3, 2, 1, 20].

Delay-Tolerant Networks (DTNs) can be considered as models for networks that are marked with often partitioning and infrequent affinity [14]. Energy and mobility aspects of DTNs cause them to frequently have intermittent failure [19]. This is partially due to the fact that the network topology of DTNs is typically an extremely dynamic one [17]. Therefore in DTNs, the challenge is that all long interruptions and delays in node to node routes must be taken into consideration by all network algorithms (including routing). This is the case for many applications and network machinery such as Information-centric networks (ICNs) [13].

It is the case in DTNs that the connection between nodes is intermittent meaning that the node to node routes does always established. This makes the routing problem in DTN a challenging one [18]. The ability to anticipate the node moves in the DTNs does not guarantee the easiness of building a routing technique for boosting the performance in the network. This is partially due to the lack of load data along the DTN [17, 15]. One of the reasons for diversity in routing protocols of DTNs is that a wide range of network kinds are classified as DTN [14].

In this paper, we present a new History-Aware Load-Balanced Routing Protocol (HALBRP) for DTNs. The protocol is History-aware in the sense that a load to each node is calculated in a way that considers the history of messages carried by the node. The protocol is also classified as load-balanced because nodes exchange messages in a manner that balance the load of network nodes. As a result the transfer of a message from one node to another one, in its way to its final destination, is controlled by the condition that the load of the receiving node does not excess a fixed load threshold.

The rest of the paper is organized as follows. Section 2 presents in details the new routing protocol; HALBRP. Section 3 reviews some examples of modern routing methods in DTNs and also reviews modern applications and technologies of DTNs. Finally Section 4 concludes the paper.

2 Routing Protocol

In this section, we present a new routing protocol, HALBRP (History Aware Load Balanced Routing), for DTNs. The protocol is load-balanced in the sense that nodes exchange messages in a way that balance the load of moving nodes. The protocol is History-aware in the sense that load of a node is calculated in a way that considers the history of messages carried by the node. Therefore the transfer of a message from one node to another one is subject to the condition that the load of the receiving node does not excess a fixed load threshold.

For each node, n, we calculate the load of n using the following formula:

$$\text{Node-Load}(n) = \sum_{m_n} 1 - \frac{actv(m_n)}{max(m_n)}. \qquad (1)$$

Equation 1, is a summation over the messages m_n hosted by the node n. The activity of a message m_n is the number of nodes hosted the message so far and is denoted by *actv*(m_n). In the equation above, $max(m_n)$ denotes the maximum number of nodes that m_n is allowed to visit. This number depends on the message level of trust and importance. The substraction from 1 in Equation 1 expresses the fact that the higher the activity of the message, the less the time it is going to spend more on the network, and hence, the less the load caused by the message to the network, in general, and the hosting node, in particular.

Algorithm 1 HALBRP for DTNs

1: **procedure** HALBRP ROUTING
2:     *list*$_1 \leftarrow$ *neighbour-nodes*(n);
3:     **if** *list*$_1 = []$ **then**
4:         *exit*;
5:     **end if**
6:     *list*$_2 \leftarrow$ *sort-load*(*list*$_1$);
7:     **for** each node $n' \in$ *list*$_1$ **do**
8:         **if** $\text{dist}(n, n') \leq max_d$ **then**
9:             **if** n *and* n'*has not met recently* **then**
10:                 *Messages-exchange* (n,n');
11:             **end if**
12:         **end if**
13:     **end for**
14: **end procedure**

Algorithm 1 presents the routing algorithm. This algorithm is to run on each node of the DTN. The frequency of executing the algorithm depends on the amount of message on the network and the mobility of the nodes. The algorithm first (line 2) finds a list of the nodes close enough to the main node, n, via sensors. If this list is empty then the algorithm is finished. Otherwise, in line 6, the list is sorted according to the loads of its element nodes. For each node n' in the list, if n' is still close to the main node n (line 8) and if n and n' have not exchanged messages recently (line 9), then algorithm 1 calls Algorithm 2, Messages-exchange, to attempt exchanging messages between n and n'.

Algorithm 2 presents our proposed method for message exchange between a pair of close nodes, n_1 and n_2. The load of nodes are caudated using Equation 1 (lines 3 and 6). The algorithm uses two variables i_1 and i_2 to mark whether n_1 and n_2, respectively, are overloaded. If this is the case the algorithm is finished (line 10). The messages of n_1 and n_2 are extracted to *list*$_1$ and *list*$_2$, respectively (lines 12 and 13). This extraction includes sorting the message in *list*$_1$ and *list*$_2$ according to their priority and history in the network.

For each message m in n_1 that is not in n_2 (lines 15 and 16), if transferring m to n_2 would not turn n_2 overloaded (line 17), the transfer is carried (lines 18 and 19). This is done provided that n_2 is not overloaded in the first place (line 14).

For each message m in n_2 that is not in n_1 (steps 25 and 26), if transferring m to n_1 would not turn n_1 overloaded (step 27), the transfer is carried (steps 28 and 29). This is done provided that n_1 is not overloaded in the first place (step 24).

If node n_1 has already received some messages (line 34), then messages of n_1 whose final destination is n_1 (lines 35 and 36) are removed (line 37) from n_1 to prevent that they get unnecessarily delivered by n_1 to any other node in the DRN. If node n_2 has already received some messages (step 41), then messages of n_2 whose final destination is n_2 (steps 42 and 43) are removed (step 44) from n_2 to prevent that they get unnecessarily delivered by n_2 to any other node in the DRN.

3 Related Work

Recently, routing in DTNs has gained huge research force. Among the typical DTN routing techniques classifications is that has two categories depending on the way adapted to find the target node; flood-

Algorithm 2 Messages-exchange

procedure MESSAGES-EXCHANGE
    $i_1, i_2 \leftarrow 0$;
    if Node-Load$(n_1) \geq max_l$ **then**
        $i_1 \leftarrow 1$;
    end if
    if Node-Load$(n_2) \geq max_l$ **then**
        $i_2 \leftarrow 1$;
    end if
    if $i_1 = 1 \wedge i_2 = 1$ **then**
        exit;
    end if
    $list_1 \leftarrow calc\text{-}list(n_1)$;
    $list_2 \leftarrow calc\text{-}list(n_2)$;
    if $i_2 = 0$ **then**
        for each message $m \in list_1$ **do**
            if $m \notin list_2$ **then**
                if Node-Load$(n_2 \cup \{m\}) \leq max_l$ **then**
                    $n_2 \leftarrow n_2 \cup \{m\}$;
                    $n_1 \leftarrow n_1 \setminus \{m\}$;
                end if
            end if
        end for
    end if
    if $i_1 = 0$ **then**
        for each message $m \in list_2$ **do**
            if $m \notin list_1$ **then**
                if Node-Load$(n_1 \cup \{m\}) \leq max_l$ **then**
                    $n_1 \leftarrow n_1 \cup \{m\}$;
                    $n_2 \leftarrow n_2 \setminus \{m\}$;
                end if
            end if
        end for
    end if
    if $i_1 = 0$ **then**
        for each message $m \in n_1$ **do**
            if *distination*$(m) = n_1$ **then**
                $n_1 \leftarrow n_1 \setminus \{m\}$;
            end if
        end for
    end if
    if $i_2 = 0$ **then**
        for each message $m \in n_2$ **do**
            if *distination*$(m) = n_2$ **then**
                $n_2 \leftarrow n_2 \setminus \{m\}$;
            end if
        end for
    end if
end procedure

ing techniques [8, 20, 6, 5] and forwarding techniques [12, 11, 10, 9, 14, 4]. Below we review some examples of modern routing methods in DTNs and also review modern applications and technologies of DTNs.

An example of a routing technique for DTNs that is balanced to boost the performance is that presented in [17]. The ABC algorithm, presented in [17], assumes small node buffers and try to balance the buffers usage. Taking into consideration the priority of contents in big DTNs, the problem of cooperative spreading of multiple files was tackled in [16]. The developed technique in this paper assumes that the moving nodes can attempt opportunistic contacts to disseminate two files. And the objective was to deliver the files to the maximum number of nodes giving that one of the two files has more priority than the other. The technique also accepts a delay threshold. In [16], this problem was modeled using concepts of optimal control problem and differential equations. The modeling managed to find routing policies that are captured by simple priority structures [16].

It is common for routing techniques for DTN to decide routes using the contact history of network nodes. In [18], routing routes were decided using both message-characteristics and contact information of nodes. These characteristics include time to live (TTL). Relaying on message-characteristics, [18] proposes a routing protocol (EER) which is encounter based.

The technique in [18] assigns an encounter value to every pair of encounters and then uses this value to disseminate many copies of a message relatively between the pair of encounters. The least accepted arrival delay to destination is used to design the route in case of a single copy of a message. Another routing protocol, (CAR), which is community aware was also introduced in [18]. Restricted to nodes community, CAR utilizes the property of contact frequency.

As a matter of fact, the routing component in some DTNs has records concerning required data traffic and the contact history between nodes. Therefore existing techniques of linear programming can be used to limit the delay of messages in DTNs. However this idea does not perform well for important well-known small applications. In [14], an efficient linear programming algorithm for routing in DTNs was presented using a relatively little number of LP constraints. This algorithm has the advantage of being applicable to column generation applications [14].

Among promising future architectures of Internet is Information-centric networks (ICNs). The idea of ICNs networks is to focus on delivering information among the ends hosts. This is not the case for today's Internet architectures focusing on delivering messages among the end hosts. The potential of merging the two concepts of DTNs and ICNs were discussed in [13]. The combination was in the form of delay-tolerant information-centric network (DTICNs). This paper [13] shows good study of potential design of DTICNs and the involved research challenges.

Security is an important aspect of any DTN routing protocol. However this aspect did not attract enough researchers. Hence many types of attacks are threatening messages moving on DTN. In [19] a defense technique fighting several types of routing attacks was introduced for DTN. This technique extracts and uses routing data from the messages and acknowledgments (ACK). Techniques of evolutionary game theory are used for achieving analysis and enabling routing roles of nodes in the DTNs [19].

4 Conclusion

This paper presented a new routing technique for Delay tolerant networks. The proposed technique has the advantages of being load-balanced and history-aware. This leads to better and more efficient routing decisions by our protocol. There are many directions for developing our technique; for example combing the concept of Information-centric networks (ICNs) [13] with our protocol seems a promising direction.

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