

Modeling and optimizing Random Walk content discovery protocol over mobile ad-hoc networks



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ABSTRACT

Content discovery is one of the challenges over mobile ad-hoc networks. Peer to peer content discovery techniques including structured and unstructured can be employed in MANETs by considering its special characteristics and limitations. The most important characteristics of MANETs are the mobility of the nodes, power consumption limitations and transitive links which create a dynamic topology. Unstructured techniques present higher performance compared to the structured ones over MANETs and among unstructured peer to peer protocols, Random Walk delivers less energy consumption and satisfactory hit rate awhile. This paper proposes an adaptive method to optimize the random walk unstructured content discovery protocol. First, it models this protocol using the G-network which is a queuing system with two types of customer, negative and positive. Then, it optimizes this protocol by the gradient descend technique based on a cost function which consists of three parameters. Two of these parameters are hit rate and response time which are derived from the content discovery protocol performance metric. The other parameter is energy consumption which is one of the most important performance metrics in MANET.

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1. Introduction

Recently Peer to Peer networks (P2P) have become popular and high internet traffic has been allocated to these networks [1]. Contrary to client/server networks, server and client machines cannot be differentiated and each machine is both a server and a client. This communication pattern can be implemented on any underlay network including wired, wireless, and even the mobile ad hoc network (MANET) [2]. It means that establishing communication among computers in an application layer is independent of physical connection among them. Different applications such as file or resource sharing, content distribution networks, cooperative applications and so on [3] have been applied in these networks. Exploiting P2P applications in MANET, considering its ever rising development and special challenges, has attracted the attention of many researchers.

One of the most important challenges is the mobility of nodes which leads to the over dynamic topology of network and the limitation of energy consumption in nodes [4–7].

In the P2P network, communication between peers leads to the formation of a network in an application layer which is called the overlay network. According to Fig. 1, after running the P2P application, each node becomes a member of this layer. Therefore, each link of overlay network is supported by a path in an underlay network.

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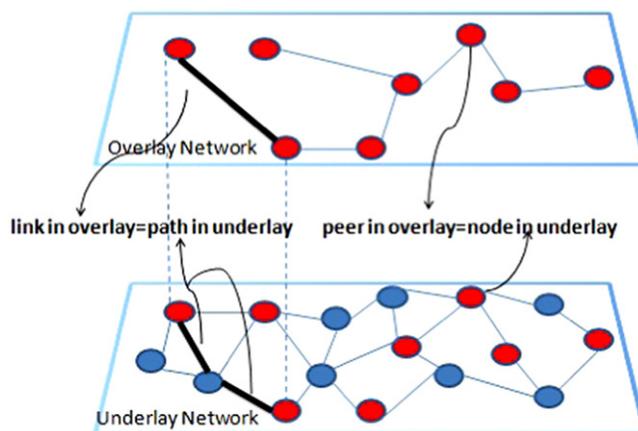


Fig. 1. Overlay network and underlay network.

Based on the manner creation of communication among peers, P2P networks are divided into structured and unstructured ones [8]. In unstructured networks, there are not any regulations for assigning neighborhood among nodes and also there is not a predefined place for indexing contents. On the contrary, in structured networks, the manner of creating neighborhood among nodes and the indexing place of data are clearly defined by a specific routine.

Content discovery is one of the most important applications in P2P networks. For content discovery in the unstructured P2P network, the controlled or uncontrolled flooding method is usually applied. It means a flooding query message in a network for finding the desired content that causes heavy traffic in a network which is usually the main drawback of these networks [9]. In structured P2P networks, the cost of leaving and joining nodes and also the cost of maintaining overlay network are higher because of following a predefined routine. Instead, better and more efficient algorithm for routing and content discovery can be presented by applying a different sample of the distributed hash table (DHT) [10]. Among unstructured content discovery techniques, random walk [11], FreeNet [3], Gnutella [12] and Napster can be referred. There are some examples of structured content discovery techniques such as Chord [10], CAN and Pastry [3].

The efficiency of content discovery protocols over MANET has been evaluated in [13–15]. It has been shown that for searching content in a mobile network with the consideration of their special limitations, unstructured techniques are more efficient than structured ones. Lower efficiency of structured content discovery protocols over MANET is the result of weak communications among nodes of this network [13]. This weak connectivity leads to weak links creation in an overlay network, because each overlay network link is supported by a path including one or some links in an underlay network [7,14]. Therefore, the instability of each link from this path results in the instability of the path and the related overlay link finally.

In such conditions, unstructured techniques over MANET can deliver higher performance by spending more overhead as a result of applying flooding methods. Among unstructured techniques, the random walk content discovery protocol is more appropriate for MANETs. According to [15], compared to other P2P unstructured protocols, random walk has the lower hit rate and consume much less energy. As the amount of energy consumption in MANET is really significant, random walk could be a suitable P2P content discovery protocol for MANET, if it is optimized.

In random walk protocol [11], the peer that sends a query creates n walkers or the same query messages with fixed time to live (TTL). Then, it selects n neighbors from its neighbors with a uniform probability and sends a walker to each one. When a peer receives a walker, if it can provide a response for the query, the walker is deleted from the network and the peer unicasts its response to the query originator. But if it does not have requested content and walker TTL is not zero, it forwards the walker to a random neighbor and reduces one of its TTL. In this protocol, one cache is used to avoid accepting one query several times [11].

In order to improve the efficiency of the random walk protocol over MANET, its behavior must be improved considering momentary traffic conditions of an underlay network. For instance, according to Fig. 1, the relay peer should select a neighbor that the supporting route between them, compared to other neighbors, is more stable and efficient in an underlay structure.

Hence applying the G-network queue network [16], considering the MANET underlay network, the behavior of random walk protocol has been modeled and some metrics for its performance evaluation have been demonstrated. Based on the presented modeling, in addition to peers, MANET nodes and their links and also overlay links can be modeled.

For random walk optimization, first, the composite cost function based on the average response time of the queries, the average hit rate of queries, and the amount of energy consumption for query distribution has been introduced. Then, the behavior of each node at the time of forwarding query has been optimized based on this cost function with $O(n^3)$ by the application of gradual descent.

This method is selected because of its evolutionary process and also its decision making based on the instant traffic of the network. Regarding the dynamic topology of MANET, this issue can be efficient. There are two reasons for the application of G-network to modeling computer networks and also the random walk content discovery protocol in this paper: first, there are two types of customers in the G-network including a positive customer that can be considered as an application packet

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