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Minimizing Broadcast Expenses in Clustered Ad-hoc Networks

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Abstract One way to minimize the broadcast expenses of routing protocols is to cluster the network. In clustered ad-hoc networks, all resources can be managed easily by resolving scalability issues. However, blind query broadcast is a major issue that leads to the broadcast storm problem in clustered ad-hoc networks. This query broadcast is done to carry out the route-search task that leads to the unnecessary propagation of route-query even after route has been found. Hence, this query propagation poses the problem of congestion in the network. In particular this motivates us to propose a query-control technique in such networks which works based on broadcast repealing. A huge amount of work has been devoted to propose the query control broadcasting techniques. However, such techniques used in traditional broadcasting mechanisms need to be properly extended for use in the cluster based routing architecture. In this paper, query-control technique is proposed for cluster based routing technique to reduce the broadcast expenses. Finally, we report some experiments which compare the proposed technique to other commonly used techniques including standard one-class AODV that follows TTL-sequence based broadcasting technique.

1. Introduction

Self-configuring structures of randomly moving nodes set up Mobile Ad-hoc Networks (MANETs) in which moving nodes act as mobile-terminals as well as routing stations. These slave-less movements cause the change in the structure of the networks. In such scenarios, route establishment is the primary task to initiate the communication between resources which is very difficult due to their random movements (Yousefi et al., 2006). To achieve adaptability, several routing protocols have been proposed in which different strategies were adopted to acquire the requested route.

The route-query broadcast is the most traditional way of discovering the route in any routing protocol for data transmission (Perkins and Bhagwat, 1994; Perkins and Royer, 1999). This query covers a large area of the network to find the route and propagate even after the route has been discovered. This unnecessary propagation of route-queries in the network poses the problem of congestion. In order to

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minimize such type of congestion, several query control broadcasting techniques came into existence. These techniques reduce the broadcast expenses, and also eliminate one of the causes of network congestion.

Such query broadcast techniques can be classified either as based on selective flooding or as based on bounded flooding (Hussain and Ahmad, 2014; Pu and Shen, 2010). The selective flooding based techniques rely on previously stored routing information to acquire desire route and also require up-to-date topological information. On one hand, the effectiveness of broadcasting increases as up-to-date topological information becomes available. On the other hand, collecting topological information needs periodic link-update broadcasts which are very costly in *ad-hoc* networks, where resources like bandwidth, energy, etc. are scarce. To prevent such periodic broadcast, bounded flooding based query broadcast (e.g. TTL-sequenced based ERS) is needed which reactively places the query control broadcast (Pu and Shen, 2010). Despite controlled broadcasting, some intermediate nodes are used unnecessarily that leads to the unnecessary energy consumption as discussed later in Section 3.

Apart from the single-type routing techniques whether proactive or reactive, hybrid routing techniques were proposed, for example CBRP (Rezaee and Yaghmaee, 2009), ZRP (Haas et al.), etc., which acquire the route proactively within the node proximity and reactively beyond the proximity of the node (Abolhasan et al., 2004). On the one hand, these routing techniques solve scalability issue. On the other hand, they are still prone to the unnecessary query broadcast like single-type routing techniques as discussed in Haas and Pearlman (2001); Park et al., 2006; Ahmad and Hussain. This is because a node may be a peripheral node of more than one node in accordance with ZRP. Consequently, a node may receive multiple copies of same query. In contrast, cluster based routing technique produces the clusters in distributed manner where route-query broadcast is done blindly in the absence of the previous communications. There is no query control mechanism that notifies the relay nodes to cease the query broadcast after the successful discovery of destination node.

Routing techniques, working either as proactively or reactively or as both, need a query control mechanism. The negligent query broadcast may be a major issue for ad-hoc networks, where resources are limited and topology changes frequently. Reactive approach in any routing protocol creates massive traffic by blind-query broadcast in the entire network. As the distance between communicating nodes increases, this overhead again increases. The combination of excessive traffic and larger distance in *ad-hoc* networks rules out the reactive routing technique for real-time communication. Intuitively, hybrid routing techniques inherit the same problem and likewise is not appropriate in such cases as they continuously use the reactive approach to carry out the route discovery. As a result, it becomes challenging to acquire the desired route at minimal cost. Although a large research community has worked and understood that query broadcast in a controlled manner helps improve the quality of the routing techniques in the *ad-hoc* network, no previous work has been done for such a hybrid routing technique. To the best of our knowledge, our work is the first effort to investigate the query control problem for cluster-based routing protocols in *ad-hoc* networks.

In our proposed method, a Distributed Weighted Clustering Algorithm (DWCA) (Choi and Woo, 2006) is devised to form clusters, and select cluster head and boundary nodes based on their metrics. It is free from ripple effect of clusters which works based on the combined weight metric of mobile nodes. In this technique, mobile nodes collectively form a cluster and choose a cluster head based on their weight metric. This cluster head takes care of all the routing decisions both proactively and reactively. Subsequently, a Modified-Blocking Expanding Ring Search (MBERS+) technique is employed for repealing the query broadcast from further propagation. Since broadcast repealing technique is implemented in clustered network, it is called Clustered Modified-BERS+ (CMBERS+) to define proposed technique. The preliminary version of this paper has been published in Hussain and Ahmad (2014). Here, we demonstrated the analytical study of the proposed technique. Now, more clear interpretation of mathematical modeling is presented along with simulation results to evaluate performance of the proposed technique.

The obtained results corresponding to the proposed technique showed better performance against the DWCA (Choi and Woo, 2006), BERS+ (Al-Rodhaan et al., 2008), and TTL-sequence based broadcasting technique (TTL-ERS) that the Ad-hoc On-demand Distance Vector (AODV) (Perkins and Royer, 1999) follows. We noted that like most state-of-the-art broadcasting techniques such as BERS, BERS+, for a communicating pair of nodes, the proposed work followed more or less the same low-cost path in each set of simulation trials and give same results for some other performance metrics. To help avoid such repeated situations used in the previous work, we are currently investigating query forwarding and energy consumption extensions to the technique presented in this research work. This performance analysis is done using 5 performance metrics: average latency, throughput, energy-exhaustion ratio, retransmission ratio, and query-forwarding with varying hop count between resources, and network coverage.

Rest of the papers is summarized as follows: Section 2 describes the previous work related to controlled broadcasting techniques. Section 3 highlights the need for modification in BERS+ and demonstrates the mathematical comparison with this technique. Section 4 represents the design mechanism of clustering used, routing packets, and tables. In Section 5, we discuss the methodology used in route discovery phase, route maintenance technique and also describe the query-control technique. In Section 6, simulation and result of proposed technique are presented and we then conclude our work in last Section 7.

2. Related work

Connecting call at first attempt and smooth communication without interference are always desirable in real world scenarios. It is only possible in congestion free network where one of the communication lines is continuously free for transmission without any interference. In traffic analysis of such networks, it is found that multiple classes of congestion exist in the network (Karenos et al., 2005). It can be either due to heavy data transmission or negligent circulation of route-query. In order to make collision and congestion free networks, several query control broadcasting techniques pertaining to the selective and

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