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Protocol-independent multicast packet delivery improvement service for mobile Ad hoc networks ☆

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Abstract

This paper addresses the issue of improving multicast packet delivery in mobile ad hoc networks and proposes an adaptive mechanism called Protocol-Independent Packet Delivery Improvement Service (PIDIS) to recover lost multicast packets. PIDIS provides its packet-delivery improvement services to any multicast routing protocol for mobile ad hoc networks by exploiting the mechanism of swarm intelligence to make intelligent decisions about where to fetch the lost multicast packets from. PIDIS is a gossip protocol, and nodes using PIDIS are only concerned with which neighbor nodes to gossip with to recover the most lost packets, rather than which member nodes to gossip with. Thus, it does not rely on membership information in a multicast scenario, which is often difficult to get. PIDIS employs the beneficial aspects of probabilistic routing and adapts well to mobility. PIDIS achieves probabilistic improvement in multicast packet delivery and, unlike other gossip-based schemes, does not need to maintain information about group members from which lost multicast packets are retrieved. Further, the operations of PIDIS do not rely on any underlying routing protocol or primitive, and can be incorporated into any ad hoc multicast routing protocol. We incorporated PIDIS over ODMRP [On-Demand Multicast Routing Protocol in Multihop Wireless Mobile Networks, Kluwer Mobile Networks and Applications, 2000], and compared it against Anonymous Gossip (AG) [International Conference on Distributed Computing Systems (ICDCS 2001) Phoenix, Arizona, April 2001] implemented over ODMRP, and ODMRP itself. Our simulation results show that ODMRP + PIDIS is more efficient and performs better than ODMRP + AG and ODMRP in terms of multicast packet delivery, end-to-end delay, and MAC layer overheads. We attribute the better performance and lower MAC overheads of ODMRP + PIDIS to the efficient gossiping made possible by using the swarm intelligence techniques.

Keywords: Multicast; Mobile Ad hoc networks; Packet delivery improvement; Swarm intelligence

1. Introduction

Ad hoc networks consist of mobile nodes that autonomously establish connectivity via multihop wireless communications. In many ad hoc applications, nodes need to collaborate to achieve common goals and are expected to communicate as a group rather than as pairs of individuals (point-to-point).

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For instance, a group of soldiers roaming in the battlefield listen to their group commander (point-to-multipoint), and a group of commanders exchange current mission scenarios with one another (multipoint-to-multipoint). Multicast communication is a critical capability to support these applications.

However, severe operating constraints such as mobility of nodes, limited energy, memory and wireless bandwidth, jamming, interference and other environmental impairment prevent reliable packet delivery and result in high variation in the number of packets received by different member nodes. Although several multicast routing protocols have been proposed for mobile ad hoc networks, for example, [12,18,13,15,22], improving packet delivery has been a challenge. There have been efforts made to provide *reliable multicast* for ad hoc networks, however, these schemes, based on either ACK/NACK [21] or adaptive flooding [20], could either easily congest the networks and degrade throughput when network topology changes frequently, or may need to maintain state information about other members in the network. There have also been *transport* layer approaches to the problem of reliable multicasting in mobile ad hoc networks. In ReACT [17], the authors outline a transport layer protocol which achieves very high reliability by the use of transport layer mechanisms with end-to-end purviews.

Recently, two gossip-based approaches have been proposed to facilitate the notion of reliable multicast for ad hoc networks. Anonymous Gossip (AG) [6] provides a reliability improvement *service* that runs atop unreliable multicast protocols, and Route-Driven Gossip (RDG) [14] is a reliable multicast protocol. In contrast to [20,21] which suffer from the tradeoff between reliability and scalability, gossip-based approaches exploit the non-deterministic nature of mobile ad hoc networks to provide probabilistic reliability in a scalable manner [14].

In this paper, we address the problem of improving multicast packet delivery in mobile ad hoc networks via a protocol-independent, packet delivery improvement *service* that could be incorporated into any ad hoc multicast routing protocol. The service, Protocol-Independent packet Delivery Improvement Service (PIDIS), uses the mechanisms of swarm intelligence to decide where to recover lost packets from. Notice that PIDIS itself is not a reliable multicast *protocol*, but a *service* which improves multicast packet delivery of an ad hoc multicast protocol that incorporates it.

Swarm intelligence (SI) [3] refers to complex behaviors that arise from very simple individual behaviors and interactions, which is often observed among social insects such as ants and honeybees. Although each individual (for instance, an ant) has little intelligence and simply follows basic rules using local information obtained from the environment, (globally) optimized behavior[1] *emerges* when they work collectively as a group. In essence, swarm intelligence incorporates the following three components:

- positive/negative feedback, which search for good solutions and stabilize the results,
- amplification of fluctuation, which discovers new solutions and adapts to changing environment, and
- multiple interaction, which allows distributed entities to coordinate and self-organize.

Together, these components comprise an adaptive search mechanism that facilitates PIDIS to quickly converge to good candidate *routes* (leading to other group members) through which lost multicast packets could be recovered with the greatest probability, while discovering alternate routes for packet recovery to adapt to changing packet delivery patterns and network topology.

PIDIS is a gossip protocol and is adaptive to network usage and may gossip several times for lost packets. PIDIS continuously gauges the network conditions to control the extent of gossiping and number of gossips sent for a lost packet. PIDIS does not depend on membership views, either partial or total. Also, PIDIS is concerned with learning which neighbor next hop nodes give better packet recovery ratios when gossiped with, rather than learning which member nodes (when gossiped with) help recover the most packets (such as the use of *member_cache* in AG). Thus, in PIDIS, the extent and number of gossip packets are highly restricted by choosing from a highly focused set of next hop nodes as gossip partners. In PIDIS, gossip messages are treated as ants; valuable information in the gossip collected during the gossip request phase is processed when the gossip returns as a gossip reply. The effectiveness of PIDIS, as shown in simulation

[1] An example of these is that ants often find a shortest path from their nest to a food source.