Poster: Protocol-independent Packet Delivery Improvement Service for Mobile Ad hoc Networks*

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Abstract

This poster paper addresses the issue of improving packet delivery for multicast in mobile, ad hoc networks and proposes a reliability improvement mechanism called Protocol-Independent Packet Delivery Improvement Service (PIDIS) to recover lost packets. PIDIS is a non-persistent, best-effort reliability improvement service that exploits the mechanism of swarm intelligence to make intelligent decisions about where to fetch the lost packets from. PIDIS employs the beneficial aspects of probabilistic routing and adapts well to mobility. PIDIS achieves probabilistic reliability and, unlike other gossip-based schemes, does not need to maintain information about group members from which lost packets are retrieved. Further, PIDIS does not rely on any underlying routing protocol or primitive, and can be incorporated into any (unreliable) ad hoc multicast routing protocol. Lastly, because PIDIS is non-persistent, it does not incur any overhead when there is no lost message to be recovered. We incorporated PIDIS into ODMRP, and compared it against Anonymous Gossip (AG) [2] implemented over ODMRP [3], and ODMRP. Our simulation results show that PIDIS+ODMRP, in most cases, is more efficient and performs better than AG+ODMRP and ODMRP in terms of packet delivery, end-to-end delay and MAC layer overheads. We attribute the better performance and lower MAC overheads of PIDIS+ODMRP to the efficient gossiping made possible by using Swarm Intelligence techniques.

1. Introduction

Several multicast routing protocols have been proposed for mobile ad hoc networks [3, 7, 4, 6, 10], but any notion of *reliability* has been a challenge to achieve. For instance, 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. There have been efforts made to provide *reliable multicast* for ad hoc networks [5, 2, 9], however, these schemes, based on either ACK/NACK or adaptive flooding, could easily congest the networks and degrade throughput when network topology changes frequently.

Recently, two gossip-based reliable multicast protocols, Anonymous Gossip (AG) [2] and Route-Driven Gossip (RDG) [5], have been proposed for mobile ad hoc networks. In contrast to aforementioned protocols that suffer from the tradeoff between reliability and scalability, gossip-based protocols exploit the non-deterministic nature of mobile ad hoc networks to provide probabilistic reliability in a scalable manner [5].

In this paper, we address reliable multicast in mobile ad hoc networks via a protocol-independent, reliability improvement *service* that could be incorporated into any (unreliable) ad hoc multicast routing protocol. The service, termed Protocol-Independent packet Delivery Improvement Service (PIDIS), is a gossip-based reliability improvement service and uses the mechanisms of swarm intelligence to decide where to recover lost packets from.

The key to effective gossip is to pick, at all nodes, a hop that would be effective to gossip with. We use Swarm intelligence (SI) to gossip because SI mechanisms allow nodes to learn about the local network around a node, and this information can be used for gossiping efficiently. Using SI mechanisms allow the node to constantly update its view of the local network using any interaction with the neighbor nodes to extract information about the local topology. These SI properties that work together to achieve self-organization are listed in [1].

In comparison to other reliability schemes that use gossip, such as AG [2] and RDG [5], PIDIS does not use or need any membership information or unicast routing primitives. In addition, PIDIS is *non-persistent* and *best effort* – the packet recovery scheme is initiated exactly once. In addition, PIDIS uses a *smartly chosen* gossip path *probabilistically*, choosing from a number of available gossip paths. Lastly, PIDIS, like AG, is a gossip pull mechanism and is a reliability improvement *service* unlike RDG, which is a reliable *protocol*.

PIDIS is concerned with learning which routes give better packet recovery ratios, rather than learning which member nodes help recover the most packets (such as via the use of *member_cache* in AG [2]). In PIDIS, the extent and number of gossip messages are highly restricted, by choosing from a highly restricted set of next hop nodes as gossip partners. Gossip messages in PIDIS are treated as ants; valuable information about the local network is collected during the gossip request phase and processed when the gossip returns as a gossip reply. The effectiveness of PIDIS, as shown in simulation results, attributes to the efficient learning capacity of swarm intelligence.

2. Overview of PIDIS

The provision of PIDIS over a multicast routing mechanism works as follows: (a) an unreliable multicast routing protocol, χ, delivers packets to a node i, and (b) PIDIS service "kicks in" at i to fetch the packets which χ has not been able to deliver to i. In this paper, we discuss an implementation of PIDIS over ODMRP. However, PIDIS can be easily implemented over any other multicast routing protocol with mini-

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mal changes from the implementation over ODMRP.

ODMRP/PIDIS works as follows: When packets belonging to a source/group pair, s/g, are lost at a member node i,

1. i transmits a gossip request (GREQ) to recover lost messages. The GREQ is transmitted to a chosen one-hop destination, the *gossip next-hop*, λ.

2. At any intermediate node X which receives GREQ,

   (a) The id of X is recorded in the GREQ.

   (b) If X is not a mesh node[1], X discards the received GREQ.

   (c) If X is a forwarding group node, but not a member/source node, it forwards GREQ to a newly chosen λ.

   (d) If X is a member/source node, then X checks if it has the lost messages. If X does not have any of the lost messages, X forwards the GREQ to a newly chosen λ.

   (e) If X is a member/source node, and if it has any of the lost messages which were reported lost by i, then X recovers the packets from its cache and prepares a gossip reply message (GREP) for *each* message found. Each GREP backtracks the path of the GREQ to i. The gossip request is then discarded at X.

3. At each node y the GREP visits on the path back to i, the hop previous to y, node z, is remembered (at y) as a useful hop to gossip with when there are lost packets from s/g. This process maintains the *Gossip Table* at y, a data structure used to maintain the information about which next hop nodes were useful in fetching GREPs.

When no information about choosing next hops to gossip is available, only the neighboring mesh nodes information is used, and λ is picked *randomly* from the neighboring nodes. Threafter, information from previous GREPs is available in the Gossip Table, and the choice of λ is made *intelligently* – by choosing λ from the Gossip Table. To aid in the discovery of new routes, GREQs are broadcast with a probability of P_{bi}. The Gossip Table is maintained by using SI mechanisms, and keeps track of the changing topology by a combination of positive/negative reinforcement and amplification of local network topology fluctuations. Thus, choosing λ from the Gossip Table improves the efficiency of gossiping, and there is a good chance that a GREQ sent to λ results in a GREP. In addition, the Gossip Table at a node i maintains multiple routes to recover packets corresponding to a s/g pair and the PIDIS mechanism chooses between these routes probabilistically, to better distribute the recovery efforts.

GREQ/GREPs work as ants – packets traversing the network, collecting information about the nodes they visit, searching and reinforcing the (good) route(s) where lost packets could be recovered from. Information about the nodes a gossip traverses is recovered from a GREP, which backtracks the path of the corresponding GREQ. Since GREPs are only sent in response to GREQs sent, and the GREQs are sent to carefully chosen nodes, rather than randomly, as in AG [2], the overheads of PIDIS due to ant activity is highly controlled.

Details of the implementation of PIDIS over ODMRP and the SI model used in PIDIS can be found in [8].

[1] Since we implement PIDIS over ODMRP, we use the notion of a mesh node to mean either a member node, a source node, or any of the forwarding group nodes.

3. Performance Studies

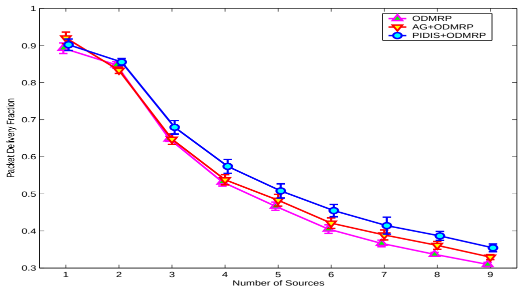
We implemented AG [2] and PIDIS over ODMRP in QualNet, and compared their performance. The simulations used 50 nodes placed uniformly. The mobility model was Random Waypoint with a minimum speed of 0m/s. The MAC layer used 802.11DCF and the physical layer used omnidirectional antennas with a transmission range of 251m using 802.11b. The propagation path loss model used was two-ray and no propagation fading model was used. Gossip replies were source-routed (using a nodes-visited stack) in both AG+ODMRP and PIDIS+ODMRP. For PIDIS, probability of broadcast, P_{bi}, was 0.001.

In our experiment, one group consisting of 5 members was sent 10 packets/s from 1 source to 9 sources, in steps of 1 source in a $2000m \times 500m$ network. The maximum speed was kept constant at 20m/s for the simulations with a pause time of 100s. Both the sources and the group members were chosen randomly. The performance of the protocols ODMRP, AG+ODMRP and PIDIS+ODMRP was recorded and studied.

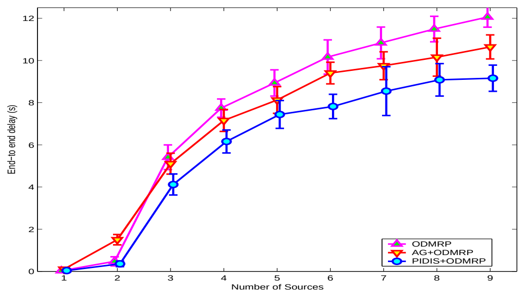
Figures 1(a) and 1(b) show the performance, and Figures 2(a) and 2(b) show the overheads. All figures show the 95% confidence intervals of the measured values. With increasing number of sources, the mesh becomes denser in ODMRP. PIDIS+ODMRP, in most cases, gives better packet delivery metrics along with better delay characteristics compared to AG+ODMRP and ODMRP with increasing number of sources. In addition, PIDIS+ODMRP achieves these goals with substantially lower MAC layer overheads as compared to AG. Note that only GREQs/GREPs are unicast in both AG and PIDIS and ODMRP does not use unicast packets. Thus, a measure of MAC unicast packets is an accurate measure of gossip activity in the network. From the figures, we note that the number of GREQs transmitted by PIDIS is higher than AG. This is because PIDIS *reacts* to a packet loss by sending a GREQ immedialtely, while AG recovers lost packets by means of GREQs which are sent out *periodically*, thus controlling the number of GREQs that can be sent out. Thus, when more packets are lost (with increasing number of sources), more GREQs are initiated by PIDIS. But regardless of more routing overheads in PIDIS+ODMRP, the GREQ transmission is highly controlled. This is because the SI mechanisms working to maintain the Gossip Table see to it that the nodes chosen to gossip with are nodes which have previously recovered packets, guiding the GREQ along nodes which are good nodes to gossip with and decreasing the chances of gossiping with nodes that are not effective nodes to gossip with. Also, when the mesh size increases (when the number of sources increase), the number of neighbor nodes for a member increases, and because AG gossips with a randomly chosen neighbor node, this increases in AG the possibility of gossiping with nodes which are not effective nodes to gossip with. Hence, even though the routing overheads in AG+ODMRP are lower, they translate to much higher MAC layer overheads, owing to unguided gossips. When there is only one source, PIDIS+ODMRP is unable to fetch as many packets as AG+ODMRP because the network is not congested, the persistent action of AG+ODMRP is beneficial to packet recovery, and AG+ODMRP performs best in such a situation.

4. Conclusions and future work

In this paper, we designed and implemented a reliability improvement *service* called PIDIS for multicast routing in mobile ad hoc networks, and studied its performance with an implementation over ODMRP. PIDIS is a non-persistent, best-effort recovery mechanism which uses Swarm Intelligence to gossip for lost packets effectively. PIDIS exploits the positive and negative feedback mechanisms of swarm intelligence to quickly search for good candidate routes from which lost packets could be recovered. PIDIS also utilizes

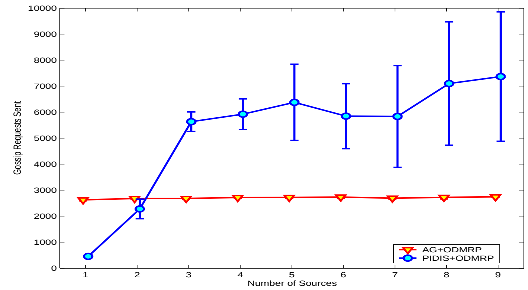


(a) Packet delivery

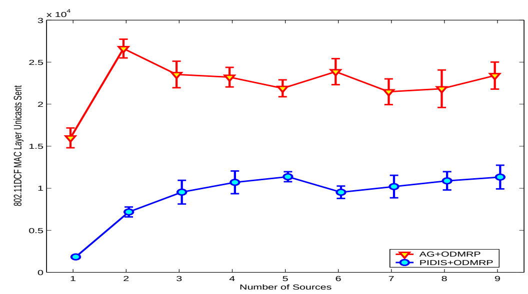


(b) End-to end delay

Figure 1. Performance metrics



(a) Routing overheads: GREQs sent



(b) MAC overheads: MAC unicasts sent

Figure 2. Overheads

the amplification of fluctuation mechanism of swarm intelligence to discover alternate, and possibly better, routes to adapt to changing packet delivery patterns and network topology. ODMRP/PIDIS is shown to have better performance characteristics – packet delivery, end-to-end delay and overheads as compared to a similar reliability improvement mechanism, AG [2] in most simulation scenarios, because it is able to guide the gossip process effectively thus controlling the number of messages traversing the network.

During the PIDIS design, to contain the overheads and end-to-end delay, we constrained the number of times a node gossips for the lost messages. In comparison to other gossip schemes, PIDIS is not "persistent" – a recovery attempt is made exactly once. While this aspect may be suited for low-delay applications like multimedia traffic, some other applications, like file sharing applications, require higher packet delivery metrics, even if it means incurring high delays. To suit a variety of applications, we are currently working on a k-persistent PIDIS scheme in which a maximum of k recovery attempts are made. In addition, we are investigating methods to decrease the variability of the packet delivery metrics across members of a group in a network. Apart from this, our current work includes tuning the PIDIS protocol to use the right parameters under changing network conditions.

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