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Optimised relay selection for route discovery in reactive routing ☆

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ABSTRACT

On-demand routing protocols have the potential to provide scalable information delivery in large ad hoc networks. The novelty of these protocols is in their approach to route discovery, where a route is determined only when it is required by initiating a route discovery procedure. Much of the research in this area has focused on reducing the route discovery overhead when prior knowledge of the destination is available at the source or by routing through stable links. Hence, many of the protocols proposed to date still resort to flooding the network when prior knowledge about the destination is un-available. This paper proposes a novel routing protocol for ad hoc networks, called On-demand Tree-based Routing Protocol (OTRP). This protocol combines the idea of hop-by-hop routing (as used by AODV) with an efficient route discovery algorithm called Tree-based Optimised Flooding (TOF) to improve scalability of ad hoc networks when there is no prior knowledge about the destination. To achieve this in OTRP, route discovery overheads are minimised by selectively flooding the network through a limited set of nodes, referred to as branching nodes. The key factors governing the performance of OTRP are theoretically analysed and evaluated, including the number of branch nodes, location of branching nodes and number of Route REQuest (RREQ) retries. It was found that the performance of OTRP (evaluated using a variety of well-known metrics) improves as the number of branching nodes increases and the number of consumed RREQ retries is reduced. Additionally, theoretical analysis and simulation results shows that OTRP outperforms AODV, DYMO, and OLSR with reduced overheads as the number of nodes and traffic load increases.

1. Introduction

Mobile ad hoc networks (MANETs) are composed of a set of arbitrarily distributed and potentially mobile wireless nodes, where any node may act as an information source, sink or router. Such networks present a number of challenging research issues - in particular, that of continuously achieving optimised routing. This subject has received significant research attention and led to the development of numerous routing protocols, which may be classified according to the strategies used for discovering and maintaining routes: pro-active, reactive and hybrid (a combination of pro-active and reactive).

Pro-active routing protocols were among the earliest attempts at determining optimal end-to-end routes in ad hoc networks. These protocols are an extension of traditional distance vector and link state algorithms which were originally designed for wired networks [6,10,11,16]. However, these protocols are only suitable for small networks, since routes are maintained periodically regardless of whether they are required or not. Route updates periodically

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propagate throughout the network using blind flooding, which results in the Broadcast Storm Problem (BSP) [15]. In high density networks, the overhead caused by the BSP can reduce the available bandwidth significantly.

An example of a proactive routing protocol is Optimised Link State Routing (OLSR). The main feature of OLSR is the use of Multi-Point Relays (MPRs) – an optimised set of neighboring nodes that are selected to re-broadcast link state information. This significantly reduces the BSP.

By contrast, *reactive* or *on-demand* routing protocols were proposed in an attempt to improve scalability and reduce overheads compared to proactive routing protocols. This is achieved by performing route discovery at the time when a route is actually needed, rather than continually maintaining a complete set of routes as with proactive protocols. Consequently, a significant reduction in routing overhead can be achieved at the cost of increased first-packet latency [2,5,8,12].

Reactive routing generally occurs in two phases: route discovery and route maintenance. When a node has data to send and a pre-existing route is not available, route discovery is initiated. In this phase, the source node initiates a blind flood of RREQ packets throughout the network. When a RREQ packet reaches a node with an active route to the destination (or it reaches the destination itself), a route reply is sent back to the source either using blind flooding or unicast link-reversal. Unfortunately, the use of blind flooding in route discovery makes reactive protocols subject to the BSP, albeit to a lesser extent than pro-active protocols.

The route maintenance phase is initiated when an active route, which is transporting data, is broken. A broken route may be repaired locally by the node that detects that broken link using a local route repair strategy, or alternatively a Route Error (RERR) packet is sent to the source and a new route discovery initiated.

On-demand routing protocols have the potential to achieve high levels of scalability in ad hoc networks. However, before this can be realised, two major issues need to be resolved. The first is route discovery overhead caused by the blind flooding of RREQ packets. The second is delay caused by the initial route discovery process.

Much of the existing research in the field of on-demand routing has approached the scalability and overhead problems through the use of routing strategies aimed at reducing the scope of flooding, either in direction (for example, location-based protocols such as LAR) or range (such as RDMAR) [3,13]. While this does reduce flooding overhead, topographic changes to the network may result in sub-optimal routes.

In this paper, a novel on-demand routing protocol called OTRP (On-demand Tree based Routing Protocol) is proposed. OTRP is designed to improve scalability and reduce route discovery overhead (and hence the BSP) without the need for a source node to have pre-existing knowledge of the destination node location. This is achieved via an efficient route discovery algorithm called Tree-based Optimised Flooding (TOF) which floods the network through a limited set of nodes, referred to as *branching nodes*. These nodes are selected on the basis of their geographic location with respect to the parent node (determined using Global Positioning System (GPS) information).

To optimise the performance of OTRP, the factors that affect its performance are theoretically analysed and evaluated. The theoretical study demonstrates the efficiency of this protocol comparing to other contemporary MANET routing protocols.

The rest of this paper is organised as follows. Section 2 presents a summary of existing on-demand routing protocols. Section 3 describes the OTRP algorithm in detail. The factors that affect the performance of OTRP are theoretically analysed and evaluated in Section 4. In Section 5, the performance of OTRP is compared to other MANET protocols via computer simulation. Section 6 analyses the results obtained in Section 5 and Section 7 concludes the paper.

2. Related work

Ad hoc On-Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Dynamic MANET On-demand (DYMO), and Location-Aided Routing (LAR) are well-known reactive routing protocols, and will be used as comparative performance benchmarks in the simulation section.

2.1. Common routing protocols

- AODV [1,8], which is one of the earliest reactive routing protocols. AODV maintains only active routes to reduce overheads and contention. When a host does not have a route to a given destination, it floods the network with Route REQuests (RREQs). Intermediate nodes which see a RREQ will retransmit it; duplicates are discarded. When each RREQ arrives at its destination or at any other node with an up-to-date route to the destination, a route reply (RREP) is sent back towards the source. Destination sequence numbers are used to avoid the problem of infinite loops and to evaluate route freshness. Link failure causes a RREP to be sent back to the source with an infinite distance; as this is now the most recent route it will displace the existing route, and since it is invalid it causes the route discovery process to be repeated.
- DSR, which is a reactive source routing protocol in which the full path to the destination is included in each packet [1,12]. It discovers routes on demand using a similar route discovery mechanism to AODV, with each hop progressively added to the route stored in the RREQ, and forwarded back to the source via the RREP. Multiple routes are maintained at the source to achieve load balancing and to increase robustness. DSR operates well with high mobility nodes because it can recover from route failures quickly.
- DYMO, which is based on DSR and AODV [5]. DYMO adapts to network topology changes and mobility patterns by detecting and determining unicast routes to destinations as needed. This protocol can control different patterns of traffic in large networks by allowing nodes to communicate with groups of other nodes.