Journal of Discrete Algorithms 24 (2014) 59–67

Contents lists available at SciVerse ScienceDirect

Journal of Discrete Algorithms

www.elsevier.com/locate/jda

Improving time-efficiency in blocking expanding ring search for mobile ad hoc networks

Ida M. Pu [a,*], Daniel Stamate [a], Yuji Shen [b]

[a] Department of Computing, Goldsmiths' College, University of London, London SE14 6NW, United Kingdom
[b] Brain Research Imaging Centre, University of Edinburgh, Edinburgh, United Kingdom

ARTICLE INFO

Article history:
Available online 9 April 2013

Keywords:
Algorithm
Expanding ring search
Ad hoc network
Energy–time efficient
Routing
ERS
BERS
BERS*
tBERS
tBERS*
MANETS

ABSTRACT

We propose a new strategy for reducing the amount of latency and energy consumption in Blocking Expanding Ring Search (BERS) and enhanced Blocking Expanding Ring Search (BERS*) for mobile ad hoc networks (MANETs). BERS and BERS* are respectively energy and energy–time efficient route discovery protocols for MANETs as compared to conventional Expanding Ring Search (ERS). In this study, we identify unnecessary waiting time caused by a STOP/END instruction in BERS/BERS* and explore the potential of further improvement of their time efficiency. This leads to tBERS and tBERS*, the improved BERS and BERS* respectively. In tBERS/tBERS*, a route node may also issue the STOP/END instruction to terminate flooding. We implement this idea in algorithms, conduct analysis, and achieve further latency reduction in both tBERS and tBERS* as well as the energy saving in tBERS*.

1. Introduction

Mobile ad hoc networks (MANETs) rely upon cooperation of mobile nodes to establish communication routes dynamically. Since the nodes are generally powered by batteries, both energy and time efficiency are particularly important for MANETs. Many energy and/or time efficient routing protocols have been developed for MANETs. The Blocking Expanding Ring Search (BERS) [6] and the Enhanced Blocking Expanding Ring Search (BERS*) [9] are two recently developed protocols of route discovery for MANETs.

Both BERS and BERS* aimed at improving the energy efficiency of a widely used search strategy, namely, the Expanding Ring Search (ERS) in popular reactive routing protocols, such as Dynamic Source Routing (DSR) [2] and Ad hoc On-Demand Distance Vector Routing (AODV) [7,4]. BERS was proposed as a new flooding control method to remove an energy-waste act in ERS at the cost of some increased discovery latency (latency in short). To focus on protocols performance, we define the latency as the time required from the moment when a RREQ (Route REQuest) is sent to the moment when the flood is terminated. To improve the overall performance in both energy and time efficiency, the BERS* was developed to reduce the latency in BERS by nearly half with a slight increase of the energy consumption [9]. Among ERS, BERS and BERS*, BERS* achieved the best overall performance in terms of the energy–time efficiency [9].

Both BERS and BERS* use a chase packet, referred to as STOP in BERS and END in BERS*, to terminate the flooding after a route node is discovered. For ease of discussion we refer them to as STOP/END instruction to mean STOP in BERS or END in BERS*. The STOP/END instruction is issued only by the source node in BERS and BERS*. The source node cannot issue

* Corresponding author.
E-mail address: i.pu@gold.ac.uk (I.M. Pu).

1570-8667/$ – see front matter
http://dx.doi.org/10.1016/j.jda.2013.03.006

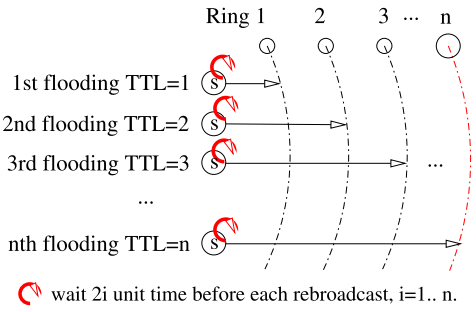

Fig. 1. ERS.

the STOP/END instruction until the first RREP (Route REPly) arrives. In other words, the STOP/END instruction is not issued without a delay caused by waiting for RREPs.

In this paper, we address this problem and propose a new approach. We will demonstrate that such a STOP/END instruction can be sent out as soon as the route node is discovered. Instead of waiting for the source node to issue a STOP/END instruction, the route node may also take part in issuing the STOP/END command to terminate the flooding. We will demonstrate how the route discovery latency of both BERS and BERS* can be reduced without any increase of energy consumption.

We will further demonstrate that the energy consumption for BERS* can also be reduced slightly when applying this new strategy. In the rest of the paper, we first describe briefly the related work in Section 2, including the time-to-live (TTL)-based ERS, BERS and BERS*. We then introduce in Section 3 two new time-efficient protocols referred to as tBERS and tBERS* (corresponding to BERS and BERS* respectively), providing the algorithms for tBERS and tBERS* and comparisons with the original BERS and BERS*. We present the simulation results in Section 5. Finally, we summarise our conclusions in Section 6.

2. Related work

2.1. Expanding ring search (ERS)

The ERS is an effective way of finding a route between a source node and a route node. A route node is referred to as either the destination or the node that can offer the route information to the destination. As a controlled flooding technique, ERS is used frequently in reactive routing protocols. Starting typically in a predefined small searching area, the ERS conducts a new search from the source node in an enlarged searching region each time if no route node is found. This incremental searching process continues until a route node is found or the maximum searching area is reached. The search in ERS is performed with flooding involving rebroadcasts through intermediate nodes in a continuous and relay fashion, and it is like a search zone expanding gradually, ring by ring, from a small ring to a large one.

The source node in ERS initialises the flooding and controls the searching area in each extended flooding as well as the maximum searching area. Two control signals, RREQ (Route REQuest) and RREP (Route REPly), are used in ERS to effectively control the flooding. To minimise flooding, a time-to-live (TTL) mechanism is adopted by ERS. The TTL sequence determines the order of flooding search, and it may be assigned with an increment at a specified value [1], a fixed value of 1 [11] or 2 [8,5], or a random value [3]. Fig. 1 shows how a set of flooding regions are controlled by a sequence of predefined TTL values of $1, 2, 3, \ldots,$ and n.

The TTL-based ERS suffers from an energy inefficiency. As it can be seen from Fig. 1, if no RREP is received by the source node, the source node will rebroadcast a RREQ with an increased TTL value. The rebroadcasting of a new RREQ from the source node each time introduces energy waste. A redundancy happens in the area overlapped with the previously covered searching area. This may happen many times before a route node is found or an entire network is searched.

2.2. Blocking expanding ring search (BERS)

The BERS [6] can be viewed as an energy-efficient ERS. BERS adopts a strategy that the source node passes on the right of re-flooding to the intermediate nodes. The source node in BERS issues a RREQ once only. An intermediate node, acting as an agent, performs rebroadcasting on behalf of the source node. To fulfil this strategy, an extended $2H$ units of waiting time is implemented in BERS, where H is the hop number. The source node, however, is still responsible for the termination of the route discovery process. The source node issues a STOP instruction upon receiving a RREP to terminate flooding. The flooding continues until the chase packet, a STOP instruction, reaches all the nodes on the last flooding ring H_r, where a route node was found.

Fig. 2 demonstrates how the BERS works in the searching propagation from one ring to the next ring. In BERS, the source node issues a RREQ first and waits for RREP. If no route node is found in the first ring, the nodes in the first ring rebroadcast the RREQ with an increased hop number. This process continues until a RREP is received by the source node. The source