Computer Communications 31 (2008) 3190–3203

Contents lists available at ScienceDirect

Computer Communications

journal homepage: www.elsevier.com/locate/comcom

A real-time routing protocol with load distribution in wireless sensor networks

Adel Ali Ahmed *, Norsheila Fisal

Telecommunication Laboratory, Faculty of Electrical Engineering, University Technology Malaysia, 81310 Johor Bahru, Johor Darul Ta'zim, Malaysia

ARTICLE INFO

Article history:
Received 1 July 2007
Received in revised form 20 April 2008
Accepted 30 April 2008
Available online 15 May 2008

Keywords:
End-to-end delay
Packet reception rate
Remaining power
Packet velocity
Delivery ratio

ABSTRACT

Wireless sensor network (WSN) is a wireless ad hoc network that consists of very large number of tiny sensor nodes communicating with each other with limited power and memory constrain. WSN demands real-time forwarding which means messages in the network are delivered according to their end-to-end deadlines (packet lifetime). This paper proposes a novel real-time routing protocol with load distribution (RTLD) that ensures high packet throughput with minimized packet overhead and prolongs the lifetime of WSN. The routing depends on optimal forwarding decision that takes into account of the link quality, packet delay time and the remaining power of next hop sensor nodes. The proposed mechanism has been successfully studied and verified through simulation and real test bed implementation.

1. Introduction

WSN may consist of large number of sensor nodes, which are densely deployed in close proximity to the phenomenon. In WSN, sensors gather information about the physical world and the base station or the sink node makes decision and performs appropriate actions upon the environment as depicted in Fig. 1. It is very different from traditional networks as it comprises of a large number of nodes that produce very large amount of data. However, WSNs are not free of certain constrains such as power, computational capacities, and memory. Due to these inherent properties, conventional management schemes are not efficient and effective to manage sensor networks and thus, a new management scheme is needed [1].

WSNs are very data-centric, meaning that the information that has been collected about an environment must be delivered in a timely fashion to a collecting agent or base station. Since large number of sensor nodes is deployed, neighbour nodes may be very close to each other. Hence, multi-hop routing idea is suitable for WSN to enable channel reuse in different regions of WSN and overcome some of the signal propagation effects experienced in long-distance wireless communication [1–3].

Real-time communication is necessary in many WSN applications. For example, in a fire fighting application where appropriate actions should be made in the event area immediately as delay may cause some huge damages further. The sensor data collected and delivered must still be valid at the time of decision making since late delivery of data may endanger the fire fighter's life.

The general research challenges for multi-hop routing in WSN arise primarily due to the large number of constraints that must be simultaneously satisfied. One of the most important constraints on sensor nodes is the power consumption requirement. Sensor nodes carry limited, generally irreplaceable power sources. WSN applications must operate for months or years without wired power supplies and battery replaced or recharged. Therefore, the power consumption must be considered while designing multi-hop routing in order to prolong the WSN lifetime [4].

The real-time routing protocols have time constrain which is important to consider when designing real-time routing in WSN. This paper reports the following main contributions. Firstly, it proposes a new type of communication in WSN called geodirection-cast forwarding based on quadrant. Geodirection-cast forwarding combines geocast with directional forwarding to forward the data packet through multi-path to destination. The multi-path forwarding mechanism increases the delivery ratio of the proposed routing protocol. Secondly, it proposes a real-time with load distributed routing protocol that computes optimal forwarding node based on packet reception rate (PRR), remaining power of sensor nodes and packet velocity over one-hop. Since forwarding nodes with the best link quality are chosen, the data throughput is improved. By choosing the forwarding nodes with the maximum packet velocity, the real-time packet transfer is ensured in the WSN. Additionally, choosing nodes with the highest remaining power level ensures sporadic selection of forwarding neighbour nodes. The continuous selection of such nodes spread out the traffic load to neighbours in the direction of the sink, and subsequently

* Corresponding author. Tel.: +60 017 7621839.
E-mail addresses: adelali3@lycos.com, engadel2003@hotmail.com (A.A. Ahmed), sheila@suria.fke.utm.my (N. Fisal).

0140-3664/$ - see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.comcom.2008.04.030

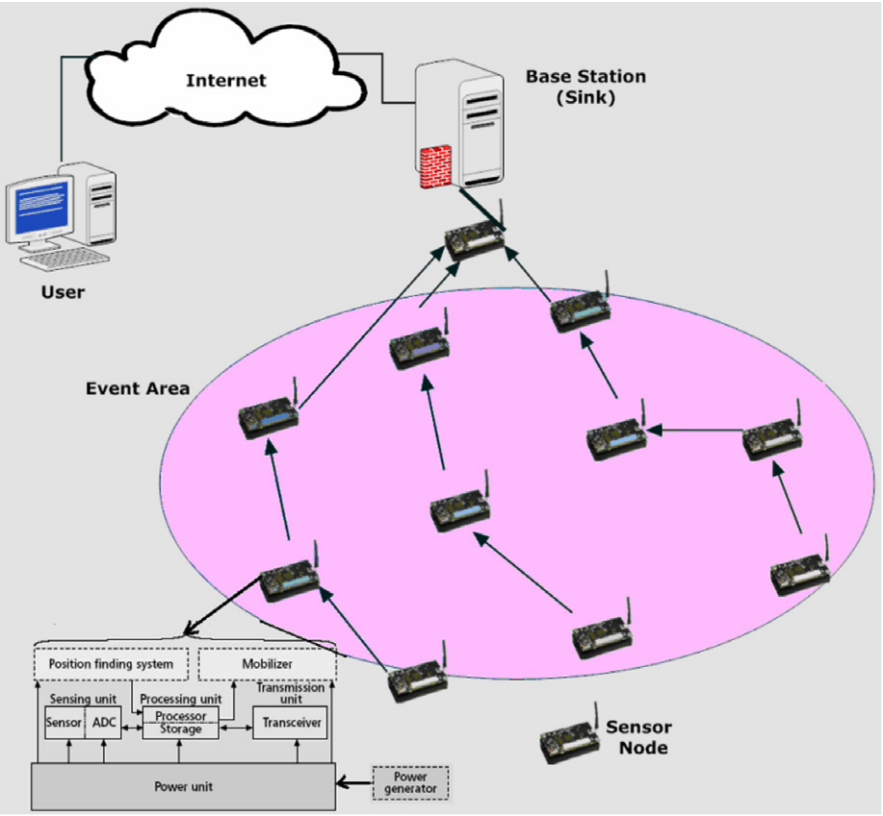

Fig. 1. WSN with multi-hop communication.

prolonging the WSN lifetime. RTLD reports high performance in term of delivery ratio, control packet overhead and power consumption. The performance of RTLD has been successfully studied and verified through simulation and real test bed implementation.

The remainder of this paper is organized as follows: Section 2 will present related work on real-time communication and power control protocols. The design of RTLD will be described in Sections 3 and 4 will describe the simulation study of RTLD. Section 5 will describe the test bed implementation. Finally Section 6 will conclude the paper.

2. Related work

The behavior of routing protocol over WSN has not been addressed and evaluated by many researchers. The related research to this paper can be classified into two categories as describes as follows.

2.1. Geocast forwarding

In global flooding, the sender broadcasts the packet to its neighbours. Each neighbour that does not received the packet, it broadcasts it to its neighbour. This mechanism will continue until all reachable nodes receive the packet including the geocast region nodes. It is simple but has a very high overhead and is not scalable to large networks such as WSN.

GPSR [5] is a geographic routing protocol for wireless networks that works in two modes: greedy mode and perimeter mode. In greedy mode, each node forwards the packet to the neighbour closest to the destination. When greedy forwarding is not possible, the packet switches to perimeter mode, where perimeter routing (face routing) is used to route around dead-ends until closer nodes to the destination are found.

Ko and Vaidya [6] proposed geocasting algorithms to reduce the overhead, compared to global flooding, by restricting the forwarding zone for geocast packets. Nodes within the forwarding zone forward the geocast packet by broadcasting it to their neighbours and nodes outside the forwarding zone discard it. Each node has a localization mechanism to detect its location and to decide when it receives a packet, whether it is in the forwarding zone or not.

GeoTORA [7] integrates temporally ordered routing algorithm (TORA [8]) which is used in ad hoc network with local flooding. It uses a TORA routing protocol to unicast the delivery packet to the region and then floods the packet within the region.

Seada and Helmy [9] proposed two protocols for geocast: geographic-forwarding-geocast (GFG) and geographic-forwarding-perimeter-geocast (GFPG). In the GFG, GPSR is used by nodes outside the region to guarantee the forwarding of the packet to the region. Nodes inside the region broadcast the packet to flood the region. GFPG uses both geocast and perimeter routing to guarantee the delivery of the geocast packet to all nodes in the region. The algorithm solves the region gap problem in sparse networks, but it causes unnecessary overhead in dense networks.

The proposed geodirection-cast is a geographic routing instead of an ad hoc routing protocol. Geographic routing has several advantages: nodes require information only from their direct neighbours so discovery floods and state propagation are not required, and accordingly it has lower overhead and faster response to dynamics. Geographic routing is more scalable than ad hoc routing protocols and more suitable for WSN. Therefore, the proposed mechanism has an advantage than the forwarding mechanisms that are mentioned earlier. Most of the forwarding mechanisms use single forwarding path to send the data packets toward the destination area in geographic region. However, the delivered