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An improved AODV routing for the zigbee heterogeneous networks in 5G environment

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ABSTRACT

A modified AODV Junior routing protocol is adopted as part of the combined routing strategy in the ZigBee networks. However, its routing overhead caused by the routing discovery and the routing table maintenance needs to be further reduced. Considering the deploying environment, the emerging 5G technology tends to be ubiquitous in the near future. Due to its native support to the smart devices and the M2M communication, the 5G terminals may be used as gateways for the ZigBee networks to improve the existing routing method. The ZigBee coordinator and the 5G terminals, which both have the accessibility to the internet, are defined as associated gateways (AG). Aiming to the higher efficiency and the shorter path, an improved ZigBee AODV (Z-AODV) routing protocol using associated gateways for the heterogeneous networks in the 5G environment is proposed in this paper. Besides the regular ZigBee function, by sharing the neighbour and routing information via IP network, the AGs are also responsible for collaboratively finding the optimum path and transmitting the packets to reduce the consumption for ZigBee devices. Moreover, an additional routing information collecting method is developed to further improve the routing performance. The proposed algorithm is evaluated based on simulation results. It is shown that our routing method outperforms the existing ones by higher picketer deliver ratio, shorter path length, lower latency, fewer packets sent per ZigBee node and lower routing overhead.

1. Introduction

ZigBee specification is a promising wireless standard for low power, low cost, and low data rate applications, since it pays great attention to energy efficiency and communication overheads [1–3]. ZigBee network has been widely applied and studied for the past few years, due to its attractive features of cost effectiveness, reliability, scalability, and simplicity [4–6]. The energy cost of transmitter and receiver in data transmission is the primary overhead in wireless communication, thus the routing mechanism mostly determines the energy consumption. ZigBee specification adopts a mixed routing mechanism combined with ZTR (ZigBee tree routing) and Z-AODV (ZigBee ad hoc on demand distance vector) [7].

The Z-AODV is an on demand routing protocol which is derived from the famous AODV. More specifically, it is essentially a modified AODVjr (AODV junior) protocol in which some minor changes have been made to fit the ZigBee specification. AODVjr is a trimmed down version of the AODV by removing all but the fundamental elements of AODV, and the results show that AODVjr has nearly the same performance as AODV [8]. In Z-AODV, a sending node creates the optimum transmission path on demand by flooding the routing request. So the global shortest path can be acquired, whereas the routing discovery procedure also introduces more energy consumption and higher latency [9].

The combining routing mechanism in ZigBee is designed for different application demands. Nonetheless, the described routing mechanism cannot thoroughly address energy consumption issues due to the limitation of the insufficient resources in ZigBee devices [10]. Therefore the routing improvement has been a main research content for the ZigBee networks. The formation and protocol optimizing is a common solution, and it is another way that to resort to the resources in deployed environment. The coming 5G communication is one of the typical environments which will be ubiquitous in the near future.

5G technology is a term to indicate the forthcoming most important phase of mobile communication standards beyond the 4 G Considering the extremely higher aggregate data rates and the much lower latencies required, several disruptive technologies have been widely regarded the key challenges in the 5G era. Three of them are the native support for the M2M communication, the smarter devices, and the Millimetre wave [11]. For the native inclusion of M2M communication in 5G networks, there are three fundamentally different requirements associated with different classes of low-data-rate services: support of a massive number of low-rate devices, sustaining a minimal data rate in virtually

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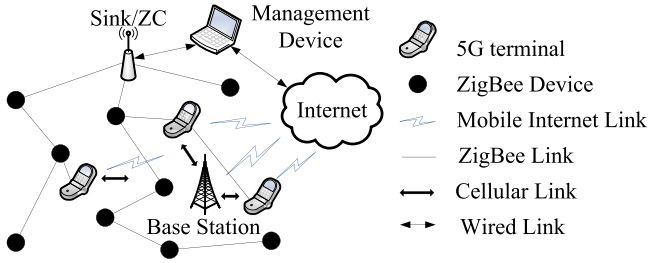

Fig. 1. The ZigBee network in 5G environment.

all circumstances, and very-low-latency data transfer [12]. The smarter devices will allow the 5G terminals have access to different wireless technologies at the same time [13]. Additionally, the instinct of the larger path loss in the propagation for millimetre communication consequentially leads to a higher density infrastructure and relays [14]. Based on the above characteristics, the ubiquitous 5G terminals are capable of taking part in the ZigBee networks; meanwhile they keep the accessibility to other wireless networks. Thus it is rational to take the advantages of the 5G terminals to improve the capability of ZigBee devices.

Thanks to the smarter device and M2M communication features, the 5G terminals are able to join the existing ZigBee network when locating in its coverage. Fig. 1 shows a sample deployment of the heterogeneous wireless network which is composed of ZigBee and 5G devices. The 5G nodes can be regarded as gateways owing to their accessibility to ZigBee networks and abundant resources. Other than the function of forwarding packets in the ZigBee networks, all these devices are able to communicate with each other via IP network. Since the ZigBee coordinator (ZC) is always a fixed sink with sufficient power supply and connected to a PC, we call the 5G terminals, along with the ZC, the associated gateway (AG). Different from the existing relay nodes, note that the AGs are capable of communicating directly without consuming the ZigBee bandwidth. Based on this definition, there is at least one gateway, the ZC, in the ZigBee network. When a foreign 5G terminal joins the network as another gateway, these gateways become associated via internet. And the ZigBee packets can be gathered and conveyed in the IP links.

In this paper, our work is to develop an improved Z-AODV routing method using the associated gateways for the ZigBee heterogeneous networks in the 5G environment. To the best of our knowledge, this is the first work on the Z-AODV routing improvement in the 5G environment. The core idea in the algorithm designing is to maximize the use of the resources in the exotic AGs with the compatibility to ZigBee specification in order to alleviate the overheads in the ZigBee devices.

Here we make two assumptions. One is the symmetric links based on the instincts of wireless channel. The other one is that, considering the features of mobile and WSN devices, the AG (excluding the ZC) has a high degree of mobility while the common ZigBee device has a much lower one. The former one makes it possible to let a certain AG manage the routing information no matter whether it is the sending or receiving device to reduce the cost in ZigBee nodes. And the high mobility of the AGs results in the frequently changing of the route which includes the AG although the path is optimized. Consequently, the improved routing protocol should not only be able to determine the optimum link from source to destination, but also be capable of managing the segmented path consisting of several ZigBee nodes. The required knowledge to implement the described function is defined as the additional routing information, and its mining mechanism is also investigated.

The remainder of this paper is organized as follows: a brief summary of the related work is overviewed in Section 2. In Section 3, some preliminary knowledge of the ZigBee specification is introduced. Section 4 proposes the improved Z-AODV routing protocol using associated gateways in 5G environment. The simulation results and the evaluation of our method is shown and analyzed in Section 5. Finally, Section 6 concludes the paper.

2. Related work

The AODV routing protocol is designed for the ad hoc networks, it has a trustworthy performance in various environments. The on demand routing discovery may bring the global shortest path in any time, but the routing overheads and the bandwidth occupation caused by the flooding are the disadvantages. A feasibility analysis of the ZigBee protocol for the wireless dynamic sensor networks (WDSN) applications is proposed in [15]. The feasibility of adopting ZigBee in the WDSN is proved and the advantages and limitations are well discussed. It is shown that as the node mobility increases, the Z-AODV routing plays a more and more important role in the data transmission. The authors of [16] design a multiple feedback policy by processing key messages during route discovery for the AODVjr routing protocol in the ZigBee specification. Instead of reducing the routing overhead, this work tends to increase the flexibility in the Z-AODV routing. Different from the original algorithm in which the link is decided by the destination node, the sending device would choose the best link based on the multiple replies from each potential path. Although the proposed method may not directly improve the routing, it inspires us to collect the routing information and make other nodes decide the optimal path. In [17], a compliant new model in OPNET simulator is proposed to resolve the node mobility issue in the ZigBee networks. Furthermore, the authors develop an improved AODV routing method. Although the proposed algorithm is proved more fitting for the mobile nodes, it is only able to benefit the end devices and may occupy much extra bandwidth during route discovery/recovery. An improved routing architecture is developed in [18]. The cluster information and network addresses are used to control the transmission range and direction in Z-AODV. Though the routing performance is improved, the routing cost and bandwidth occupation of the algorithm is not well considered. Furthermore, it requires external positioning devices to get accurate positioning information.

As the wireless heterogeneous sensor networks (WHSN) has become a research hotspot with the rapid development of different wireless technologies, there have been emerging some significant works on the routing improvement for the heterogeneous networks which is partly comprised of ZigBee devices. The comprehensive evaluation of AODV in different networks is analyzed in [19]. As a general testing, it explains the performance degeneration as the mobility increases and the heterogeneous devices introduced. However, the protocol is evaluated when the foreign nodes only interfere the channel. In this paper, the AGs are capable of taking part in the existing ZigBee networks to improve the communication. In [20], an improved AODV-based ZigBee routing protocol through pivots is studied. The pivots which are selected by the data sources are the nodes through which the corresponding link must pass. By sending packets in different pivot-determined path, the congestion is reduced. Note that the pivots in this paper are still regular ZigBee devices, which are not able to afford the extra routing overhead. Even foreign nodes with sufficient resources are introduced; the grid-shape deployment is also unpractical for most applications. The authors of [21] propose an integrated gateway node control protocol to extend the network life time. Following the initial flooding, clustering, gateway selection, gateway integration and linking procedure, the gateways are created and applied for transmission optimization. However,