Harjender Singh al. International Journal of Recent Research Aspects ISSN: 2349-7688, Vol. 2, Issue 1, March 2015, pp. 100-103

Efficient Multicast Routing Techniques in ZigBee Provides Efficient Communication between Sensor Nodes to the Same Group through Wireless Sensor Network

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***Abstract*—Data transmission in the wireless sensor network is more unreliable than it is in the wired network whereas the wireless network provides a low data rate and higher bit error rate ratio as compared to the wired network.**
Group communication in wireless sensor network (WSN) requires an efficient multicast routing due to inherent resources and computing constraint of sensor nodes.
IEEE 802.15.4/Zigbee has been considered as a promising technology for wireless sensor network. Zigbee protocol stack provide selectable levels of security using AES-128 mechanism for privacy, sender authentication, message integrity.
In this, a group is defined as a set of nodes that will share the same sensory information. The main contribution of this paper is we will propose an efficient multicast routing mechanism for groups by using favorable algorithm in a cluster of wireless sensor network to increase the efficiency and reliability of the network with the standard specification.

***Keywords*— Zigbee, Wireless Sensor Network, Multicast, Routing, Reliability.**

I. INTRODUCTION

Multicast routing is a challenging problem in wireless sensor networks (WSNs), mainly for supporting group communication. There have been a lot of proposals in this context for ad hoc networks such as [1], [2], [3], [4], [5], which are based on different design principles. However, they are not suitable for direct application in WSNs as they are designed to deal with nodes with higher computation and storage capacities.

The IEEE 802.15.4/ZigBee [6] standard protocols have been shown as prominent technologies for WSNs [7]. However, this standard protocol stack presents some gaps and limitations that were addressed and amended in the literature [8], [9], [10]. In this paper, we address the problem of multicast in ZigBee cluster-tree networks, as it has not been defined in the standard specification. In fact, the ZigBee Network Layer does not define any multicast mechanism neither in terms of routing nor in terms of addressing. This lack of multicast support represents a gap in the standard as far as group communication is considered.

Group communication is an important topic in WSNs and has attracted several research works [11], [12]. However, the grouping semantic may be different depending on the assumptions and objectives of the study. For instance, in [13], the authors have defined a group as a set of sensor nodes that share the same sensory information. The main objective of [13] was to define a secure communication mechanism for a group of nodes sharing the same information in a WSN, but they did not propose any multicast routing mechanism for data transfer among group members. The use of multicast routing is of a great benefit for this type of applications, as it will facilitate the delivery of private data exclusively to group members. However, providing efficient multicast routing in WSNs poses particular challenges as compared to unicast data delivery, especially since the overhead needs to be kept very low due to the limited energy resources of sensor nodes. Using multicast protocols, the bandwidth requirement and energy consumption significantly reduce, as the number of transmissions decreases, which is in-line with WSNs requirements. Group communication is an important topic in WSNs and has attracted several research works [11], [12]. However, the grouping semantic may be different depending on the assumptions and objectives of the study. For instance, in [13], the authors have defined a group as a set of sensor nodes that share the same sensory information. The main objective of [13] was to define a secure communication mechanism for a group of nodes sharing the same information in a WSN, but they did not propose any multicast routing mechanism for data transfer among group members. The use of multicast routing is of a great benefit for this type of applications, as it will facilitate the delivery of private data exclusively to group members. However, providing efficient multicast routing in WSNs poses particular challenges as compared to unicast data delivery, especially since the overhead needs to be kept very low due to the limited energy resources of sensor nodes. Using multicast protocols, the bandwidth requirement and energy consumption significantly reduce, as the number of transmissions decreases, which is in-line with WSNs requirements.ZigBee, defines three types of network topologies, namely star, tree, and mesh networks. All these topologies have a main device that is responsible of initializing, maintaining, and controlling the network, which is referred to as the ZigBee coordinator. The star topology has a ZigBee Coordinator through which all other devices join the network, synchronize themselves and communicate together. For the tree and mesh networks, devices can communicate with each other in a multi-hop fashion. These networks are created and maintained by one

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ZigBee Coordinator and may contain several ZigBee Routers, which provide synchronization services to their neighbor nodes (children), and route their data. A device can join a network as an End-Device (ZED) by associating with the ZigBee Coordinator or a ZigBee Router.

II. LITERATURE SURVEY

Multicast is the transmission of packets to a group of hosts identified by a single destination address and hence is intended for group-oriented computing. This transmission pattern efficiently utilizes the bandwidth and energy. WSNs' multicast communication is usually used between base stations and sensor nodes, for example, reinstalling sensor's sampling rate or base station querying information. multicast communications are rarely used between peer-to-peer sensor nodes [20].

Some multicast routing protocols for ad-hoc networks have been proposed [2], [3], [4], [5]. Multicast routing for Ad-hoc networks can be classified into mesh based and tree based protocol according to the topology.

Mesh-based multicast routing protocols such as [21] and [22] expanded a multicast tree with additional paths that can be used to forward multicast data packets when some of the links fail. However, the maintenance of these structures through periodic broadcasts and the large amount of nodes which are required to forward multicast data messages make them impractical for sensor networks. Tree-based multicast routing protocols such as in [23], [18], [24] require less relay nodes. Multicast tree should be rebuilt when links between nodes become invalid. In addition, periodic flood messages will increase the control overhead, which is unsuitable for WSNs.

Since these works have been proposed for ad hoc networks, they cannot be directly applied in WSNs because they are designed to deal with nodes with big storage capacity and high computation power. There have been therefore a lot of multicast routing mechanisms proposed for WSNs.

In[14], the authors defined a mobile multicast system for wireless sensor networks. This system builds multicast support characterized by hierarchy and mobility. The addressing scheme corresponds to 8 bit ID for nodes and groups. This mechanism uses unicast to do the node-to-base station routing and multicast to perform the base station-to-node routing. Rather than building multicast on top of an underlying unicast network, it is implemented directly on top of the link layer. This approach significantly reduces the router state and the code size. However, the implementation is so specific such that the mechanism cannot be combined with other energy efficient protocols such as data aggregation etc. Moreover, control messages for mobility support and group management are necessary.

In [15], the authors proposed an ad-hoc multicast routing for sensor nodes. They used the common broadcast flooding process for the multicast route discovery. In this proposal, the sender broadcasts a route discovery message to determinate the shortest path to the members of the multicast group. The intermediate nodes compare the hops number of the discovery message with the own maintained number of hops to source. If the message hops count is less than the nodes own hops, the node updates the routing information. In this downstream direction, intermediate nodes only rebroadcast the discovery message to neighbors. However, the path selection with the minimal number of hops may not be the best solution, since it may exist longer links but with the much better characteristics of transmission quality.

In [16], the authors proposed a grid multicast routing Protocol. It consists in routing data between the source and destination via the energy shortest distance. They assumed that the longer hop between the pair of nodes consumes more energy than the smallest one. Therefore, they used the rectilinear hop-by-hop communication in the sensor network formed as grid shape. However, in terms of the number of nodes involved in the multicast tree transmission, this multicast protocol induces a big bandwidth consumption. This is due to the fact that the protocol aims to use a large number of nodes (as the energy efficient solution) which consume the larger bandwidth resources.

In [17], another geographic multicast routing for WSNs was proposed. This mechanism is based on using only the position information for the multicast routing in the network, which avoids the undesirable broadcast flooding. However, the performed simulations in this work only consider a small number of multicast receivers, which raise the question about what results upon the real implementation to the motes with constrained memory space and also how to deal with a bigger numbers of multicast receivers.

In this paper, we particularly tackle the problem of multicast in ZigBee-based networks. The standard specification did not define any multicast data routing mechanism, which represents a limitation to efficiently support group communications in ZigBee-based WSNs. In this paper, we propose a solution to this limitation. The main contributions of this paper are two-folded:

First, we propose Z-Cast, a multicast routing mechanism for ZigBee-based cluster-tree WSNs.

Second, we show that Z-Cast can be easily integrated and implemented into the IEEE 802.15.4/ZigBee standard protocol stack, thus maintaining backward compatibility with these protocol standards, i.e. devices that do implement Z-Cast remain fully interoperable with those that do not

III. ZIGBEE MULTICAST ROUTING

In this section, we present the Z-Cast mechanism, which represents a solution to support multicast in ZigBee-based WSNs. The objective of multicast is to provide an efficient data routing among all group members. We consider a ZigBee cluster-tree WSN with different groups, where members of each group share the same sensory information as defined in [13].

It is clear that simple communication between group members through simple broadcast is not effective and may degrade the performance of the WSN. The use of multicast routing is thus more efficient to improve throughput and reduce energy consumption. It is therefore necessary that a message sent from a group member only reaches the tree leaves that contain the group members. To achieve this objective, we propose to create a Multicast Routing Table (MRT) in the ZigBee

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Coordinator and in each ZigBee Router, to store membership information of all the groups. The proposed mechanism takes into consideration the number of the child routers being members of a certain group to decide about the way that the packet will be forwarded through the rest of the tree. In what follows, we first present the main features of the multicast routing table, then we present the multicast routing algorithm for ZigBee cluster-tree WSNs.

When a group member wants to send a multicast packet to the other members belonging to its group, the request will be sent by unicast to the ZigBee Coordinator passing through all the routers. Then, the multicast packet is sent to the ZC and then to all the multicast group members according to the entries of the multicast routing table and the cluster-tree routing mechanism. The multicast algorithm implemented in the ZC is presented in Algorithm 1.

Algorithm 1 The ZC Multicast routing algorithm

1) **while** Receive a packet **do**
2) **if** destination address is a multicast address **then**
3) *flag <— 1*
4) Route to the direct ZRs according to MRT table
5) **else**
6) Apply the cluster tree routing
7) **end if**
8) **end while**

For the *ZigBee Routers* that receive a multicast frame, the algorithm to be implemented is presented in Algorithm 2.

Algorithm 2 The ZR multicast routing algorithm

1) **while** destination address == a multicast address **do**
2) **if** *flag* = 0 **then**
3) forward the packet to the parent device
4) **else**
5) **if** multicast group address not found in *MRT* **then**
6) Discard the packet
7) **else**
8) **if** multicast group address found in *MRT* **then**
9) **if** *card(GMs_address)* == *1* **then**
10) Apply the cluster tree routing
11) **end if**
12) **if** *card(GMs_address)* >= 2 **then**
13) send to all the direct child nodes
14) **end if**
15) **end if**
16) **end if**
17) **end if**
end while

IV. CONCLUSION:

In this paper, we have to propose Z-Cast, a multicast routing mechanism that ensures efficient communication between sensor nodes belonging to the same group. We showed that Z-Cast is very appropriate for ZigBee Cluster-Tree WSNs. The Z-Cast mechanism guarantees that a multicast message sent from a group member reaches all the group members, while reducing the number of transmitted packets. This is achieved by discarding the messages in the leafs that do not contain group members. We have also demonstrated how to integrate the Z-Cast mechanism in the IEEE 802.15.4/ZigBee protocol stack with only minor add-ons. We have proven that the proposed mechanism is efficient and minimizes considerably the number of messages transmitted between the group members.

We are currently working on the real implementation and validation of Z-Cast with the open source implementations of the IEEE 802.15.4/ZigBee available under TinyOS operating system.

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