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Scalability Study of the Hybrid ZigBee Multipath Routing Protocol

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ABSTRACT- Multipath routing is an efficient technique to route data in wireless sensor networks (WSNs) because it can provide reliability, security and load balance, which are particularly critical in the resource constrained system such as WSNs. Multipath routing protocol helps ZigBee network to improve the global throughput. For finding multiple paths this Hybrid Multipath routing protocol uses both hierarchical tree routing and AODV. The first path is always discovered using the TR routing. Successive path are calculated using combination of TR and neighbor table and AODV. Scalability is a main aspect in designing an efficient routing protocol for wireless sensor networks. This paper checks the scalability of hybrid multipath routing protocol for ZigBee e networks.

KEYWORDS IEEE 802.15.4/ZigBee, Wireless Sensor Networks**.**

I. INTRODUCTION

Wireless sensor networks (WSNs) have appeared as one of the promising technologies that combine embedded computing, automated sensing and wireless networking into tiny embedded devices. Although the early research on WSNs has mainly focused on monitoring applications based on low-rate data collection, present WSN applications can support more complex operations like industrial automation, building automation and personal health care. Besides these, the availability of low cost CMOS cameras and microphones where a tiny sensor can be equipped with modules for collecting visual and audio information's have enabled a new class of WSNs: multimedia or visual wireless sensor networks (WMSN/WVSN) [1] which has significantly enhance a wide range of applications like object detection, tracking and surveillance, etc. What is common in these emerging application domains is that performance and quality of service (QoS) assurance are becoming crucial as opposed to the best-effort performance in traditional monitoring applications.

ZigBee is a robust wireless communication standard managed by the ZigBee Alliance [2] and based on the IEEE 802.15.4 physical and MAC layer standard. ZigBee is a standards-based technology for remote monitoring, control and sensor network applications. The standard was created to address the need for a cost-effective, standards-based wireless networking solution that supports low data-rates, low-power consumption, security, and reliability. ZigBee technology suffers from its limited bandwidth (250 kbps at 2.4 GHz) and extending it to meet WMSN requirements is a real challenge.

ZigBee networks include of three components. The three components are ZigBee coordinators, routers and end devices. Each device is responsible for particular roles within the network. ZigBee supports three kinds of networks, namely star, tree, and mesh networks. A *ZigBee coordinator* is responsible for initializing, maintaining, and controlling the network. A star network has a coordinator with devices directly connecting to the coordinator. For tree and mesh networks, devices can communicate with each other in a multi hop fashion.

The communication methods of ZigBee have three models, and they are unicast, broadcast and multicast. The unicast data can just be transferred to some single device. The broadcast data is transferred to all the devices of the network. Multicast data is transferred to all the devices to some group, which can be called groupcast. Group is a notion in Zigbee, and a group is composed by one or many devices, every group is using a group id to be identified. In the

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Zigbee network, the location and data transferring can be received and transferred, so many devices can controlled in one operation.

Because of following characteristics routing in WSNs can be distinguished from other networks. First one is an IP-based design is difficult to be appl ied in WSNs, because of limited available resources and an enormously large scale. Second one is unlike conventional routing protocol, in WSNs; most traffic is routed from nodes to the base station. Next one is in WSNs; the nodes are resource constrained in terms of storage, energy and computational capacity. Well-organized use of resources is important. There are generally two types of routing techniques, single path routing and multiple path routing. Single path routing is scalable and simple but does not efficiently convince the requirements of resource constrained WSNs. It is uncomplicated because the route between the source node and the destination node can be established in a specific period of time. It is scalable because, even if the network changes from ten nodes to ten thousand nodes, the complexity and the approach to discover the path remains the same.

When we consider the characteristics of WSNs, single path routing is not efficient because of following reasons. First is in single path routing, it is easy for the source node to select the inter-mediate data routing nodes from the same part of the network over and over again. This may result depletion of power of those sensor nodes and network partition, which shortens the lifetime of WSNs. Second is in WSNs, failures are common because of inadequate power, limited storage space, undependable wireless communication, or unpredictable environmental interference. In the case of a failure, most single path routing protocols could not successfully deliver sensed data to the sink due to a lack of fault tolerance mechanisms. Third is in single path routing, the presence of a malicious node on the path can manipulate and corrupt the data without catching the attention of the sink node.

Multipath routing is an alternative routing technique, which selects multiple paths to deliver data from source to destination. With the help of multipath routing we can use the available resources at each node more efficiently. Multipath routing can overcome significant drawbacks of a single path routing scheme because it can provide reliable data transmission, even distribution of network traffic, and data security. On the basis of the protocol feature and its specifications, it is possible to classify existing multipath routing techniques in WSN into three categories: A) Infrastructure Based, B) Non-Infrastructure based, and C) Coding Based. The major concern of the protocols within category A is to construct and maintain specific multipath infrastructure by considering location and resource capabilities. Protocols which do not build any specific infrastructure and decide the next hop on the basis of its local knowledge are classified into category B. The category C protocols use variant kinds of coding schemes to fragment the data packet at the source node and then send the chunks through discovered multiple paths.

Multipath routing has been one of the most important current tips in the area of routing. It is known for its advantage to Ad-hoc and WSNs. Multipath routing allows the establishment of multiple paths between source and a destination node. According to the application goal, multipath routing may be proposed in order to increase the reliability of data transmission (i.e., fault tolerance) or to supply load balancing and higher aggregated bandwidth. In fact, numerous research investigations on the performance and benefit of multipath routing technique have shown that the use of such routing can improve throughput, reduce end to end delay, increase reliability, ensure security and also alleviate network congestion. Depending on application requirements, the established paths can be used alternatively where only one path is used at a time or simultaneously by using more than one path at the same time. The earlier approach is more appropriate to ensure failure tolerance while the latter may allow load balancing. A multipath routing protocol can fall in one of the following three classes depending on paths disjointness: link disjoint paths, non-disjoint paths and node disjoint paths.

II. LITERATURE REVIEW

Routing protocols are usually of two types, the reactive and proactive. Reactive protocols are on demand that is routes are calculated based on need. Proactive routing protocols are table driven. AODV junior [4] is one of the reactive routing protocols in zigbee networks. They usually provide optimum path but the problem is route discovery overhead and memory consumption. It should process and forward route RREQ and RREP packets. To overcome this next come a proactive routing protocol called ZTR (Zigbee Tree Routing). It prevents the route discovery overhead in both memory and bandwidth by the distributed block addressing scheme. The most benefit of ZTR is that any source node

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can send a packet to an arbitrary destination in a network without any route discovery overheads. Because of this efficiency, ZTR is considered as a promising protocol for resource constrained devices in diverse applications such as smart grid project and Internet of Things (IoT).

A. *Tree routing algorithm*

Every parent has a finite sub-block of address space for allotting network address to its children. This address space is calculated using a function called Cskip(d),d is the depth. Cskip() function calculation is as follows

$$Cskip(d) = \frac{1 + Cm - Rm - Cm \cdot Rm^{Lm-d-1}}{1 - Rm}$$

Where C_m is nwkmaxChildren, L_m is nwkcMaxDepth and R_m is nwkmaxRouters

For example, the kth router and nth end device shall be assigned the network address by their parent at depth *d* as in the following equation.

$$A_k = A_{parent} + Cskip(d) \cdot (k-1) + 1 \; (1 \le k \le Rm)$$
$$A_n = A_{parent} + Cskip(d) \cdot Rm + n \; (1 \le n \le Cm - Rm)$$

In tree routing, if the destination is a descendant, the device sends the data to one of its children; otherwise, it sends to its parent. The problem with ZTR is that it only forward packet along the tree topology even though the destination is its neighbor. Thus it does not provide an optimal path. To resolve this detour path problem next come Shortest Tree Routing (STR) [3].

STR uses neighbor table information. A neighbor table is maintained by each device in the ZigBee, which has all the neighbor information in the 1-hop transmission range. If users limit the size of the neighbor table, the chosen numbers of neighbor entries are stored in the table. When a node joins to an existing network entries in the neighbor table are created. When a joining node requests a NLMENETWORK-DISCOVERY, it receives response beacons from previously joined nodes. The newly joined node stores neighbor's information from the information enclosed in a beacon packet. When the neighbor node leaves the network it's entry is removed from the table. Nodes can recognize this fact by receiving NLME-LEAVE indication messages. Since the information on the neighbor table is restructured every time a device receives any frame from some neighbor node, the information of the neighbor table can be said to be up-to-date all the time. The contents for a neighbor entry are the network's PAN identifier; node's extended address, network address, device type and relationship. Additional information such as beacon order, depth or permit joining can be optionally included. In STR, a source or an intermediate node selects the next hop node having the smallest remaining tree hops to the destination regardless of whether it is a parent, one of children, or neighboring node.

The above discussed routing protocols are single path routing protocols. ZigBee technology suffers from its limited bandwidth (250 kbps at 2.4 GHz) and for extending it to meet WMSN requirement there comes zigbee multipath routing protocols. Main Zigbee Multipath routing are Zigbee Multipath Hierarchical Tree routing and Hybrid Zigbee Multipath routing.

B. *ZigBee Multipath Hierarchical Tree Routing*

Z-MHTR (ZigBee Multipath Hierarchical Tree Routing)[6] build multiple disjoint paths based on three types of information: (i) the MAC parent-child relationships between IEEE 802.15.4 devices in the cluster-tree topology, (ii) the neighbor links maintained by every node using the neighbors table and (iii) the ZigBee tree path information inspecting multiple paths disjointness property[5].

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III.OVERVIEW ON HYBRID ZIGBEE MULTIPATH ROUTING PROTOCOL

ZigBee Multipath Routing (ZMR)[1] is called hybrid because it uses both Tree routing and AODV. That is the proactive one and the reactive one. It is a hybrid node disjoints multipath routing. In order to reduce the end-to-end latency the proactive part of the protocol is activated first. Also, it starts the route discovery phase which represents the reactive part of ZMR. For finding additional paths it uses light discovery phase that is different from the usual discovery phase of AODV. Usual discovery phase need heavy traffic of control message broadcast.

Procedure for building subsequent paths is as follows: Let S is the source node. At the start S chooses next node as one of the node from its neighbor table. There are two possibilities, it may be sink itself then called it NS or it may be a node belongs to a branch not already used by TR called it NTR. In that case a new path of one link or a path consist of one neighbor node and the parent-child links from NTR to the Sink, can be directly used without triggering the discovery process. Otherwise source sends an Explore message ExploreMsg which is forwarded (unicast and never broadcast) from node to node using forwarding decisions. Whenever a node forwards the ExploreMsg, it records the next node and the node from which it has received the ExploreMsg in its routing table.

Up on receiving an ExploreMsg an intermediate node C at depth d starts searching for the next-hop node among its neighbors. If more than one candidate neighbor exists then the one with the smallest depth is selected. For this three cases are considered: The intermediate node C has a NS or a NTR neighbor node, in this case, the ExploreMsg is not forwarded and the new disjoint path established is the one followed by the ExploreMsg concatenated to either the last link between C and the Sink, or the tree path from the NTR node to the Sink, correspondingly. When such a case occurred the C node sends a ResponseMsg message towards the source node using reverse path already established at the time of discovery phase. If C has no candidate node as its next hop node then it will send an ErrorMsg message to its predecessor node. When an error message arrives at the source if another candidate node is available and a new dis joint path is necessary, then the source can begin a novel discovery process

IV.SCALABILITY STUDY

Scalability is the ability of a routing protocol [8] to perform efficiently as parameters of the network like the number of nodes (N), the average rate of mobility (M), Node Density (D), number of links (L), frequency of connection establishment (F) etc grow to be large in value. So a network is believed to be scalable with respect to the parameter if and only if, as the parameter increases, the network's minimum traffic load does not increase faster than the network rate can bear. Network rate is the maximum number of bits that can be transmitted at the same time. For scalability checking of ZMR here taking the parameter as number of nodes. Here varying the number of nodes as 20,40,60,80 and 100. Simulation is carried using NS2 [7] simulator. And for each set of nodes performance is checked based on the metrics throughput, packet loss rate, power consumption, average end-to-end delay, network life time etc.

V. CONCLUSION AND FUTURE WORKS

ZigBee is a personal area network (PAN) developed for low data rate applications. But with the development of WMSN need for high bandwidth requirements comes. For achieving high data rate zigbee use multipath routing algorithms. This hybrid multipath routing algorithm uses both tree routing and AODV for finding multiple paths. Scalability is a significant factor for designing an efficient routing protocol. This paper checks the scalability of hybrid multipath routing protocol. Path failure detection and recovery while using this protocol will come under future works.

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