Scientific Journal Impact Factor (SJIF): 1.711
International Journal of Modern Trends in Engineering and Research
ISSN (ONLINE) : 2349 - 9745 ISSN (PRINT) : 2393 - 8161

Shortcut Tree Routing using Neighbor Table in ZigBee Wireless Networks

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Abstract- ZigBee is a worldwide standard for wireless personal area network targeted to low power and cost effective data communications with business and consumer devices. The ZigBee Tree Routing is used in many resource-limited devices and applications. It is not able to require any routing table and route discovery overhead to send a packet to reach the destination. The ZigBee tree routing follows the tree topology. It cannot provide the optimal routing path. The Shortcut Tree Routing (STR) protocol has been provided the near optimal routing path as well as maintains the advantages of ZigBee tree routing that is no route discovery overhead and low memory consumption. The main idea is to provide shortcut tree routing to calculate remaining hops from a source to the destination using the hierarchical addressing scheme. Each source forwards a packet to the neighbour node with the smallest remaining hops in its neighbour table. The shortcut tree routing is fully distributed with ZigBee standard and it utilizes hierarchical addressing scheme. The aim is to find the near optimal routing path with low Route discovery overhead and Low memory consumption.

Keywords- ZigBee; tree routing; shortcut tree routing (STR); neighbor table; MANET

I. INTRODUCTION

ZigBee is the global standards of communication protocol formulated by the relevant task force under the IEEE 802.15 working group. The ZigBee network layer [1] provides dynamic network formation, addressing, routing, and network management functions. Different from the other wireless personal area network standards such as Bluetooth, infrared, and Wireless USB, ZigBee provides the low power wireless mesh and tree networking and supports up to thousands of devices in a network. Every node is assigned a unique 16-bit short address dynamically using either distributed addressing or stochastic addressing scheme. ZigBee is an established set of specifications for wireless personal area networking. ZigBee provides low data rates, consume very low power and long battery life. ZigBee create completely networked homes [3] where all devices able to communicate and controlled by a single unit.

Zigbee tree routing (ZTR) [2] designed for resource constrained ZigBee devices to choose multihop routing path with no route discovery overhead and low memory consumption. By using hierarchical addressing scheme can easily identify whether the destination is reachable of each source or intermediate node. In ZTR, each source node sends the data to one of its child or its parent. ZTR has the traffic conjunction problem due to short tree links. Since all the packets pass via tree links, especially around the root node, congestion and collision of packets are concentrated on the limited tree links. The ZTR follow the tree topology so it cannot provide the near optimal routing path. This symptom becomes worse as the number of data packets increases, and causes the decrease of the packet delivery ratio, and other network performances.

The objective of this paper is to provide the near optimal routing path like the reactive routing protocol as well as to maintain the advantages of ZTR that is no route discovery overhead and little memory consumption for the routing table. The proposed scheme shortcut tree routing (STR) exploits the neighbor nodes by focusing that there exist the neighbor nodes shortcutting the tree routing path in the tree topology. The STR uses 1-hop neighbor information. In STR, a source node selects the next node having the smallest remaining tree hops to the destination regardless of whether it is a parent, one of neighboring, or child node. The routing path selection in STR is decided by individual node in a distributed manner, and STR is fully flexible with the ZigBee standard that applies the different routing strategies according to each node's status. The STR uses only small range and small number of participating nodes. So instead of calculating route dynamically by using control packets a set of predefined paths can be used for forwarding packets.

II. RELATED WORKS

ZigBee is a type of mobile ad hoc networks (MANETs). MANETs enable mobile users to communicate without the use of a fixed infrastructure. MANET [10] routing protocols can be classified into proactive and reactive routing protocols. The proactive routing protocol regularly updates the topology information, so it always has an up-to-date optimal routing path. The reactive routing protocol invokes the route discovery procedure only when an application requests transmission of data. Therefore, it does not generate the control packet overhead if there is no data packet to transmit, while it causes long delay to find a routing path. MANET routing protocols provide the optimal routing path for the source and destination pair. However, the routing table size of these protocols is too big to store all the routing paths in the resource-limited devices.

Dynamic Source Routing [8] in Ad Hoc Wireless Networks shows a protocol for routing in ad hoc networks that uses dynamic source routing. The protocol adapts quickly the routing changes when host movement is frequent, it requires little overhead during in which hosts move less frequently. Source routing is a routing technique the sender can identify the route that a packet should forward through the network. The sender clearly lists this route in the packet's header, identifying forwarding hop by the address of the next node to which to transmit the packet on its way to the destination host. The Disadvantages If only two hosts, located closely together are involved in the ad hoc network, no routing decisions are necessary.

An ad-hoc network is the collection of Mobile Hosts without the required intervention of any centralized Access Point. The highly dynamic destination sequence distance vector routing (DSDV) [6] for mobile computers is a table driven routing technique for ad hoc mobile networks. The basic idea of design is to operate each mobile host act as a specialized router, which regularly advertises its view of interconnection topology with other Mobile Hosts within the network. This amounts to a new sort of routing protocol. Routing information is distributed between nodes by sending full dumps infrequently and smaller incremental updates more frequently.

The AODV [7] (Ad hoc On-Demand Distance Vector) is a reactive routing protocol provides a technique of routing in mobile ad hoc networks. Reactive routing protocols find the path between source and destination only when path is needed. AODV has many features such as built for mobile networks, creates route on-demand, Loop free, Scales well and Fits easily into the existing protocol stack. AODV Junior (AODVjr) [5] is a trimmed down AODV specification which removes all but the necessary elements of AODV. This paper shows that AODVjr has nearly same performance as AODV. AODVjr removes the some items from the AODV specification that is sequence numbers, gratuitous RREP, hop count, hello messages, RERR and precursor lists. The disadvantage of AODV possible large delay from the instance the route is needed.

III. ZIGBEE TREE ROUTING

ZTR is used for resource constrained ZigBee devices to select multihop routing path without any route discovery procedure, and its works on hierarchical block addressing scheme. The tree routing protocol follow only parent and child relationship for routing, avoiding neighbor nodes. Therefore, packets may be routed through several hops towards the destination within sender's 1- hop transmission range. Figure 1 explains the example of described problem. In Figure 1, the packet from the source node to the root node following the parent node, and goes back to the destination. In such a way, 4 hops are needed to reach the destination. However, if the source node sends the packet directly to the destination, it needs 1 hop routing cost. In many cases, the routing overhead of tree routing algorithm cannot be avoided if only parent child relationships are considered in the routing.

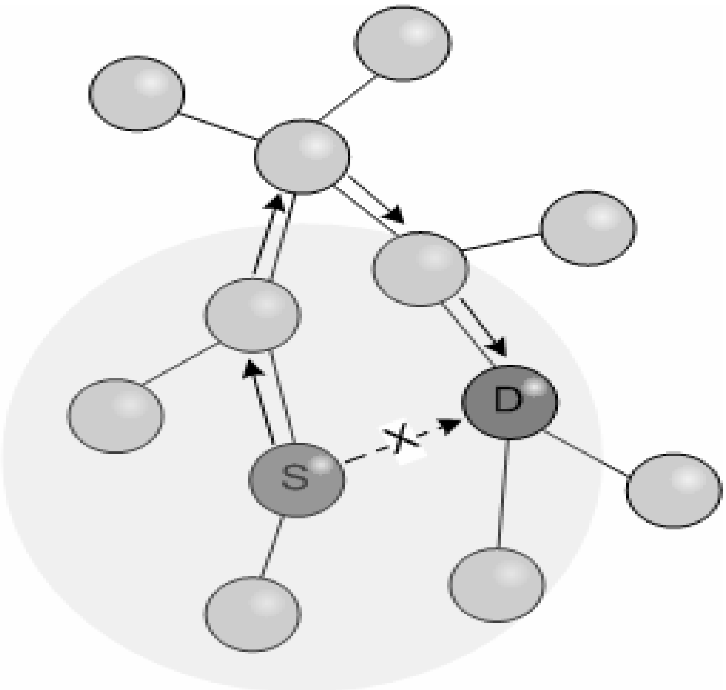

Figure 1 Problem of Tree Routing

IV. SHORTCUT TREE ROUTING

The proposed scheme shortcut tree routing algorithm that improves existing ZigBee tree routing by using the neighbour table. The proposed algorithm basically follows ZigBee tree routing algorithm, but chooses neighbor nodes as next hop nodes if the routing cost to the destination can be decreased. The neighbor table use in the proposed algorithm is defined in the ZigBee specification, so don't need to make an effort to search neighbor list. In order to choose the next hop node that can decrease the routing cost, the remaining hop count from the next hop node to the destination is computed by using all the neighbor nodes including parent and children nodes. In Figure 2, STR computes the remaining tree hops from the next hop node to the destination by using neighbor nodes, and selects the S as the source node to transmit a packet to the destination D. In the Figure 2, the route cost can be minimized if the sender transmits the data directly to the destination.

The main idea of STR is that can compute the remaining tree hops from an arbitrary source to a destination using ZigBee address hierarchy and tree structure. In other words, the remaining tree hops can be calculated by using tree levels of source node, destination node, and their common ancestor node, because the packet from the source node goes up to the common ancestor, contains an address of the destination, and goes down to the destination in ZTR.

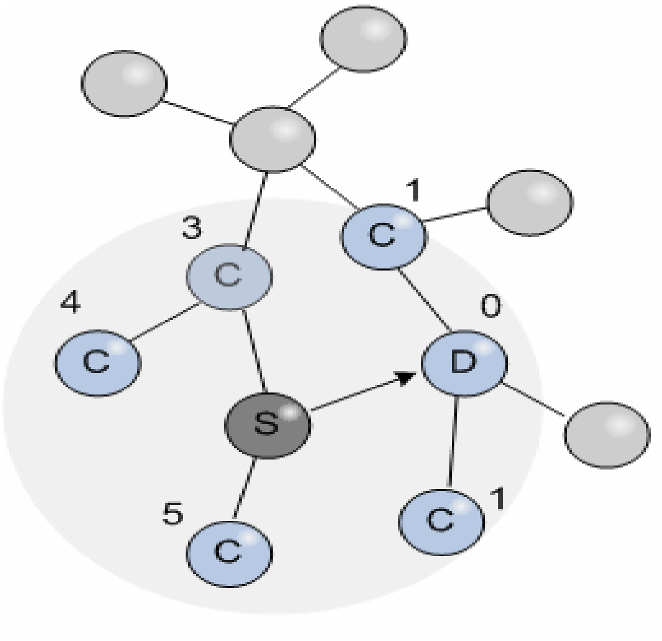

Figure 2 Shortcut Tree Routing

The shortcut tree routing algorithm identifies the next hop node which has the minimum remaining hop count for the given destination. Because the proposed algorithm follows basically the ZigBee tree routing, the parent or child node is selected as the next hop node. The next hop node selected based on minimum routing cost. The remaining routing cost is calculated by using remaining hop count to the destination assuming that the packet goes to the ZigBee tree routing. The hierarchical address structure is used for calculating remaining hop count. By comparing whether the address of a neighbor node that is in the address space [4] that contains the destination address in each level, find the root of the common sub-tree that contain neighbor node and the destination node. The next hop node that has the minimum remaining routing cost of all the neighbors, including parent and children nodes. If there is no neighbour node that has smaller remaining hop count than the parent or child node, the next hop node is determined by the normal ZigBee tree routing. The STR uses only small range and small number of participating nodes. So instead of calculating route dynamically by using control packets a set of predefined paths can be used for forwarding packets.

STR has a limitation the routing path may not be always an optimal one in an aspect of the end-to-end hop distance as next hop node is selected based on 1-hop neighbor table. Maintaining 2-hop neighbor information requires high protocol overhead with high node density. Therefore in order to provide a resource efficient routing protocol as per memory consumption and routing overhead STR is used.

V. RESULTS

In this section, comparison shown between the AODV, Zigbee Tree routing and Shortcut Tree Routing. Figure 3 shows that the comparison with number of nodes over the packet delivery ratio. STR and AODV show high packet delivery ratio about 70 percent even in the 300 nodes, since the routing paths are short enough not to interfere each other and the routing paths are distributed through the neighbor nodes as well.

Volume 02, Issue 09, [September – 2015] ISSN (Online):2349–9745 ; ISSN (Print):2393-8161

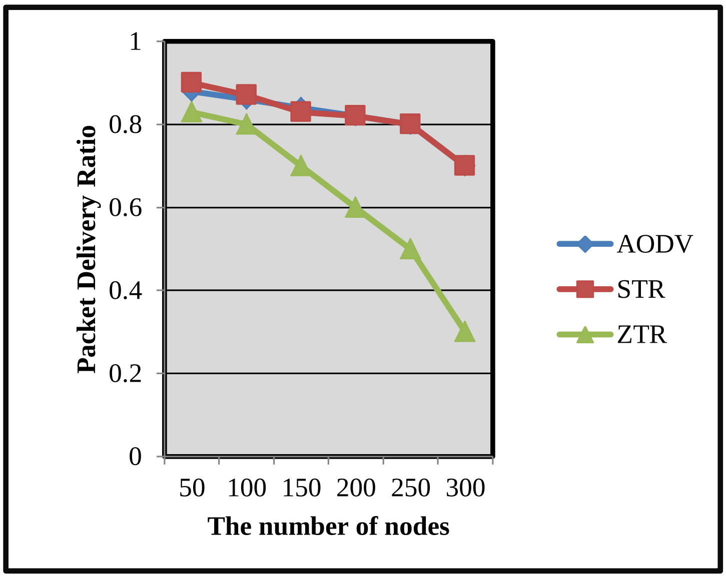

Figure 3 Comparison of Packet Delivery Ratio

Figure 4 shows that the comparisons with number of nodes over the end to end delay. End-to-end delay is mainly affected by the hop distance between the source node and a destination node. Whereas ZTR shows long end-to-end delay about 32-47 ms, STR and AODV show short end-to end delay about 18 and 15 ms per session.

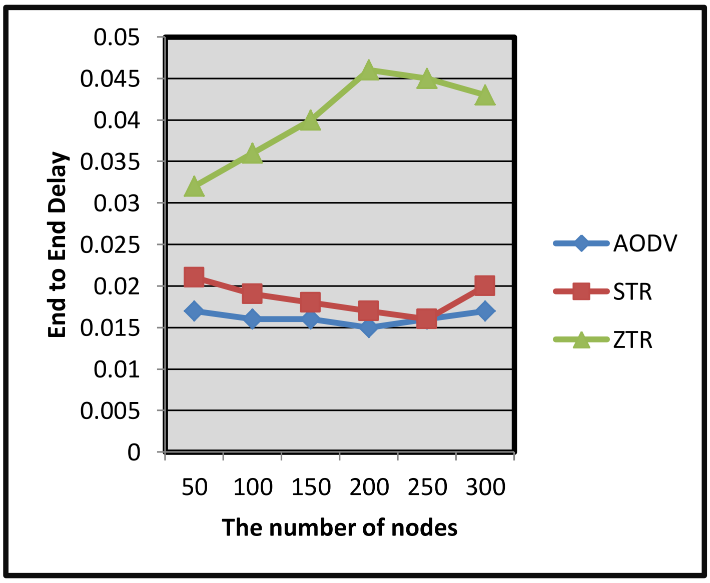

Figure 4 Comparison of End to End Delay

Figure 5 illustrates the routing overhead measurement wherein AODV overhead was increased exponentially due to route request queue that floods the whole network. STR and ZTR acts according to the Zigbee standard protocol and has no or very less routing overhead with the network density has least effect on them.

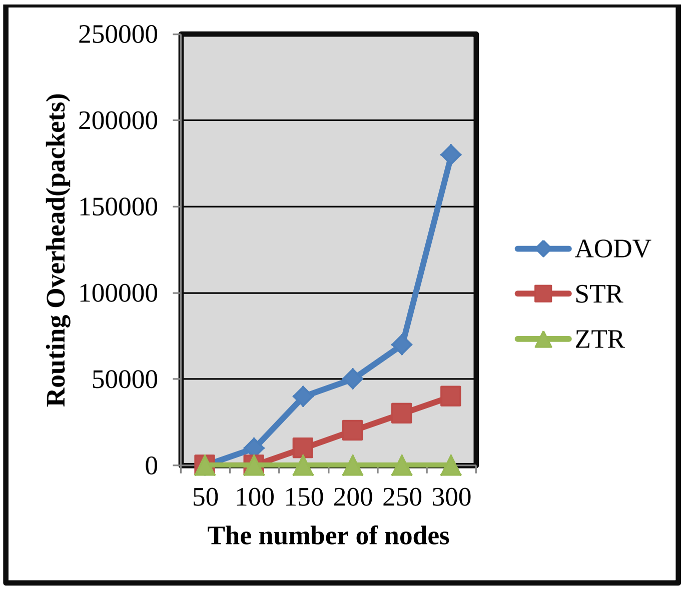

Figure 5 Comparison of Routing Overhead

VI. CONCLUSION

In this paper identify the detour path problem and traffic concentration problem of the ZTR. These are the fundamental problems of the tree routing protocols, which cause the overall network performance degradation. The ZigBee tree routing is used in many resource-limited devices and applications, since it does not require any routing table and route discovery overhead to forward a packet to the destination. However, the ZigBee tree routing has the fundamental limitation that a packet uses the tree topology; thus, it cannot provide the optimal routing path. To avoid these problems, propose STR uses the neighbour table, originally defined in the ZigBee standard. In STR, each node can find the optimal next hop node based on the remaining hops to the destination. STR reduces the traffic load concentrated on the tree links and provides an efficient routing path. The network simulations show that STR provides the comparable routing performance than AODV and ZTR. The number of hops is limited due to the small range and small number of participating nodes. So instead of calculating route dynamically by using control packets a set of predefined paths can be used for forwarding packets.

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