STR: An Efficient Shortcut Tree Routing Method for Zigbee Wireless Networks

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Abstract— Zigbee is worldwide standard of wireless personal area network for low power, cost effective, reliable and scalable product and application. It's different from other personal area network standard such as Bluetooth, wireless USB. Zigbee provides the low power wireless mesh networking and supports up to thousands of device in a network. Zigbee Tree Routing, which doesn't need any routing table/route discovery overhead is used in several resource limited devices and applications. ZTR has a basic limitation regarding providing of optimal routing path as it follows tree topology, hence an optimal routing path can't be achieved. In this paper, we proposed a protocol stated as Shortcut Tree Routing (STR) similar to ZTR's entities, such as low memory consumption, no route discovery overhead, providing nearest optimal routing path using hierarchical addressing scheme and calculating the remaining hops from source to destination. The performance evaluation indicates, STR accomplishes the performances of AODV and ZTR in certain conditions of it, such as network density, configurations and network traffic patterns.

Key words: ZTR- Zigbee Tree Routing, STR- Shortcut Tree Routing, Neighbor Table, MANET, WSN, & IEEE 802.15.4.

I. Introduction

Zigbee is worldwide standard of wireless personal area network for low power, cost effective, reliable and scalable product and application. ZigBe Alliance has extended the applications to the diverse areas such as smart home, building automation [1] telecommunication, and retail services.

MANETS, vehicle tracking services etc. Zigbee network layer [4] felicitates with routing network formation specifies and allots a 16-bit short address, dynamically for each node connected. AODV jr [5] finds its presence in the reactive protocol of Zigbee, which depicts MANETS throughout the on-demand route discovery. Communication between the source and destination nodes increases the route discovery overhead, traffic and memory consumption in ordinary Communication protocol. The main factor that distinguishes ZTR over other protocols is its capacity to transfer packets from the source to destination via intermediary nodes; which doesn't require route discovery overhead, as other nodes are issued with hierarchical addresses. This promising factor of ZTR finds its application over IOT, smart grid services, etc.

Even though ZTR uses the tree topology pattern to communicate or transfer packets from one node to another; optimal routing path is yet to be achieved.

In order to preserve the advantages of ZTR such as no route discovery overhead, lesser memory bandwidth consumption and to avoid the tree link communication to nearer nodes, a concept of 1-Hop is introduced in STR. 1-Hop mechanism uses the nearby node's information and shortcuts the tree routing in mesh topology. STR makes use of the smallest remaining tree hops to destination while communication and transferring the packets between the nodes, thus enhancing the speed of the transaction and limiting the usage of time effectiveness. STR finds its process attractive in the field of mesh topology and Zigbee standards, as STR doesn't need any extra offering in mechanism standards but just adding upon the 1-Hop information. This paper furnishes the objectives as, first ZTR has certain issues regarding the network performances, such as detour path problem and traffic concentrated problem as they are rectified by proposed STR. Second, the traffic concentration problem of ZTR is minimized to a great extent by introducing the 1-Hop mechanism by STR. Third, performance analysis of ZTR, STR and AODV is carried forward with criteria's like traffic types, network constraints, and network density.

II. Related Work

MANET routing protocol is said to be proactive and reactive. Proactive routing protocol, as the name itself illustrates has an up-to-date tracking of all the transmission process and will be always active. Topology status and required fields of processing are frequently updated. OLSR, DSDV are some of the examples of it. Meanwhile reactive protocols updates the fields when only a transmission happens and not periodically. Thus the route discovery overhead is used only when a transmission takes place, leading to a later waiting time. Examples are AODV, DSR, and TORA. Regardless of whether it's proactive or reactive routing, these MANET routing protocols provide the optimal tree routing path for given source and destination pair. However the required routing table size of those protocols is too big to store all the routing paths in the resource limited devices.

Moreover, they need to exchange control packets to maintain and discover the routing path, and the interference of these control packets on the other transmissions of the packet may be difficult in the low rate and narrow bandwidth channels.

III. Zigbee Tree Routing

ZTR operates under a circumstance, that the Zigbee devices use multi-hops to transmit information from a node-to-node without any route discovery procedure and based on hierarchical block addressing scheme indicated in (1) and (2). The Following expression illustrates the addressing scheme of Zigbee with Cm, Rm and Lm with their hierarchy expression. As Cm illustrates maximum number of children a parent can have and Rm illustrates maximum number of routers a parent can have as a child and Lm represents maximum tree level of the network.

$$C_{skip}(d) = \begin{cases} 1 + C_m.(L_m - d - 1), & if\ R_m = 1, \\ \frac{1 + C_m - R_m - C_m.R_m \wedge (L_m - d - 1),}{1 - R_m} & otherwise, \end{cases} \quad (1)$$

$$A_k = A_{parent} + C_{skip}(d).(k-1) + 1 \ (1 \le k \le R_m),$$
$$A_n = A_{parent} + C_{skip}(d).R_m + n\ (1 \le n \le C_m - R_m). \quad (2)$$

$$A < D < A + C_{skip}(d-1) \quad (3)$$

The Cskip(d) in (1) represents the address spacing size of each router node at the level „d‟. Following the above illustration, the assignment scheme of network address can be stated as for each Kth router, capable child and Nth end device is given by the parent at tree level d. In this mode of addressing, the available network address space is pre-allocated and divided recursively into spaces as there is an increase in three categories. The Cskip(d) is said as the size of the address space in a tree level „d‟ and Cskip(d+1) is the size of address space with respect to router capable children in definite addressing.

A destination can be easily identified as an immediate or a descendant of each source with this hierarchical addressing scheme. If (3) is met with the resultant, then the destination having the addresses D is said as descendent of a node with address A. ZTR transmits the information to one of the child nodes if the destination node is a descendent, else it is stated as parent.

Fig 1a and 1b deals with the detour path problem of ZTR, which illustrates that the packet is sent through distant nodes even though the destination is available nearby and within a range of 2-Hop transmission. If the corresponding destination is in the neighbor table then the router can send the packet directly to the destination node without the router protocol, through a rule stated as direct transmission rule [6]. Fig 1b illustrates, if the destination node is beyond 2-Hop range, the transmission causes the direct transmission rule to fail and causing traffic concentration problem. Traffic concentration problem is caused due to a single node facing a series of packets passing through the same tree link. This causes collision of the packets leading to packet delivery ratio degradation, network performance degradation etc.

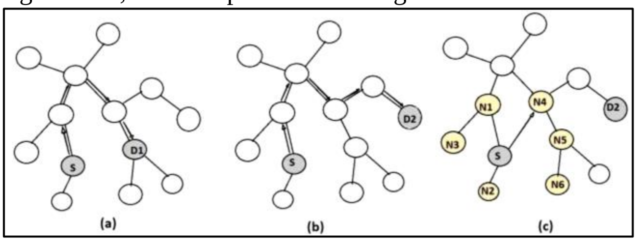

Fig. 1: Zigbee Tree Routing & Shortcut Tree Routing

IV. Shortcut Tree Routing

ZTR faces the above mentioned problem and is rectified in this following algorithm, said as Shortcut Tree Routing algorithm (STR). STR follows ZTR but utilizes the neighbor node as its next destination node using 1-Hop. In fig 2c using the above mentioned methods such as calculating remaining tree hops and Zigbee address hierarchy; STR calculates the next hop node as N4 from source S to the destination D2. This transmission can be illustrated as the levels of tree links when a packet is sent from source, its common ancestor node plays a vital role in transmitting that packet to the nearer or down by node and then to destination D2. Through STR we can compute remaining tree hops from an arbitrary source to a destination using ZigBee address hierarchy and tree structure. Remaining tree hops can be computed using tree levels of source node, destination, and their common ancestor node, because the packet from the source node goes up to the common ancestor, which contains the address of destination, and goes down to destination in ZTR.

Table 1: Shortest Tree Algorithm

Find_NextHopAddr(dstAddr)
Input: dstAddr- network address of the destination
Output: nextHopAddr – next hop address for the destination
1: Initialize minRouteCost with
2: Level(dstAddr), A(dstAddr) Find_Ancestors(dstAddr)
3: For each (neighbor‟s address Nk in neighbor table)
4: Level(Nk), A(Nk) Find_Ancestors(Nk)
5: Level(LCA) = 0
6: While (level(LCA)<min(level(dstAddr),level(Nk))and A(dstAddr,level(LCA))=A(Nk, level(LCA)))
7: ++level(LCA)
8: End while
9: nbrRouteCost-level(dstAddr)+level(Nk)-2level(LCA)
10: if (nbrRouteCost<minRouteCost)
11: nextHopAddr Nk
12: minRouteCost--nbrRouteCost
13: end if
14: end for each
15: Transmit packet to nextHopAddr

Table 2 describes the proposed STR algorithm for a source or an intermediate node to select the next hop node that has the minimum remaining tree hops for the given destination. In Table 2, we first compute the leveldstAddr and AdstAddr for the given dstAddr. Then, for each neighbor entry nk, we calculate the remaining tree hops from the nk to the dstAddr, a nbrRouteCost, by finding the level (nk) and levelLCA nkdstAddr. Finally, a source or an intermediate node selects the neighbor nk as the next hop node, which has the minimum remaining tree hops to the given destination, and transmits a packet to the next hop node.

When there is no neighbor node to reduce the remaining tree hops comparing with ZTR, STR selects the parent or one of children as the next hop node like ZTR. However, Table 1 does not mention selection of the next hop node according to ZTR, because all the parent and children are already included in the neighbor table. Therefore, the upper bound of minRouteCost in Table 2 is the same as the routing cost that is decided when the next hop node is selected by ZTR.

V. Performance Evaluation

In this evaluation, the network simulator NS-2 and IEEE 802.15.4 PHY/MAC Protocol are used for comparing STR with ZTR and AODV. The general parameters setting are summarized in Table 2.

Simulation Parameters	Value
Network size	100*100
Deployment Type	Random
Number of Nodes	50,100,150,200

PHY/MAC protocol	802.15.4
Propagation Model	Two – ray
Network protocol	ZTR/STR/AODV
Cm/lm	3/9
Packet type	CBR

Table 2: Simulation Parameters

The network association procedure and Zigbee addressing scheme are applied to all routing protocol. And also adding a new routing protocol in network simulator.

A. Creation of Wireless Networks

In this module, a Wireless network is created. All the nodes are configured and randomly deployed in the network area. A sample routing is performed to check the connectivity in the network. In this module, ZigBee reactive routing protocol provides the optimal routing path for source and destination pair through the on-demand route discovery. It requires the route discovery process for each communication pair, so the route discovery overhead and the memory consumption proportionally increases with the number of traffic sessions.

B. Performance Analysis

In this module, Zigbee performance is analyzed. Based on the analyzed results X-graphs are plotted. Packet delivery Ratio, Hop Count, End-to-End Delay, MAC level retransmission, and Routing Overhead are the basic parameters considered here and X-graphs are plotted for these parameters.

C. Implementation of Shortcut Tree Routing (STR)

In this module, the shortcut tree routing (STR) is configured in the network. It significantly enhances the path efficiency of ZTR by only adding the 1-hop neighbor information. Whereas ZTR only uses tree links connecting the parent and child nodes, STR exploits the neighbor nodes by focusing that there exist the neighbor nodes shortcutting the tree routing path in the mesh topology.

VI. RESULT ANALYSIS

We use Ns2 as our simulating tool. We assigned a network of 50.100,150,200 nodes respectively. And having the value of cm is 3 from the coordinator it will check all the neighbor node and finding out the value of LCA (Least common Ancestor) value based on the formula as described in table 1 and after calculating the LCA value with 1-hop neighbor selection it will give the available path or the probability of having the path with 1-hop neighbor after that it selects the minimum route cost and then packet store and forward to the source and destination.

After that we calculate the all network parameters such as network density, and network configuration with respect to End-to End delay, MAC level retransmission, HOP count, Packet Delivery Ratio and Routing overhead by comparing all the protocol ZTR, STR and AODV respectively.

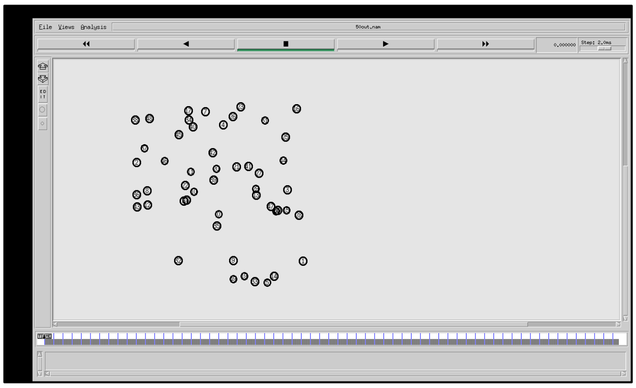

Fig. 2: Creating a Random 50 Nodes

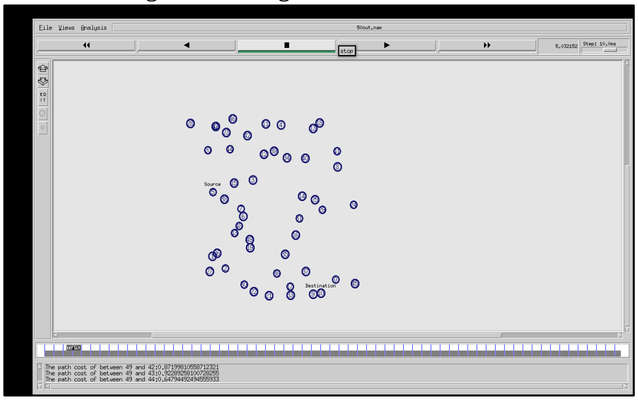

Fig. 3: Finding LCA Value for Each Node

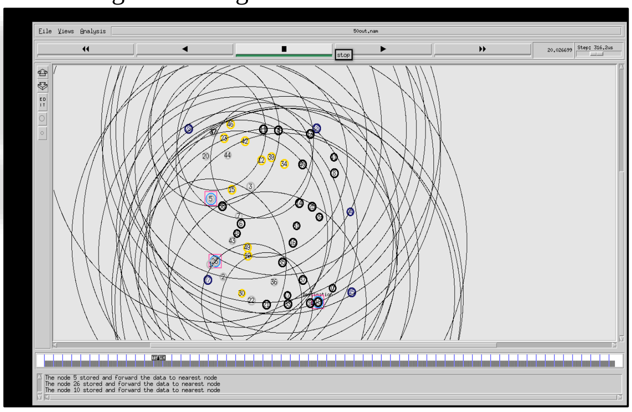

Fig. 4: Nodes Are Communicating

Fig. 5: MAC Level Retransmission

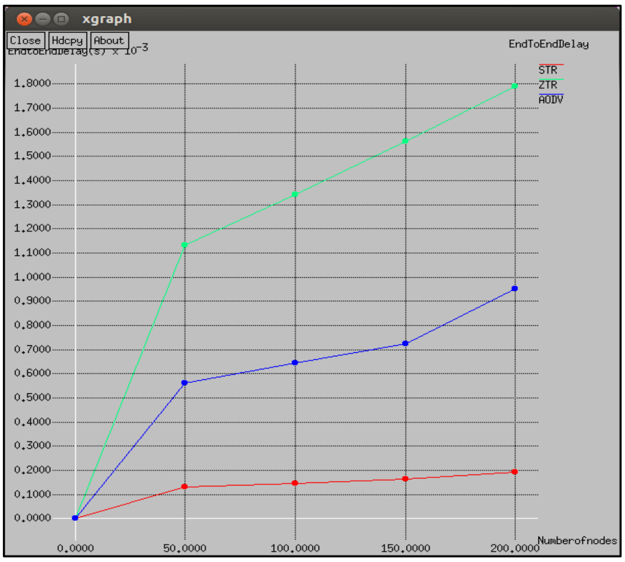

Fig. 6: End to End Delay

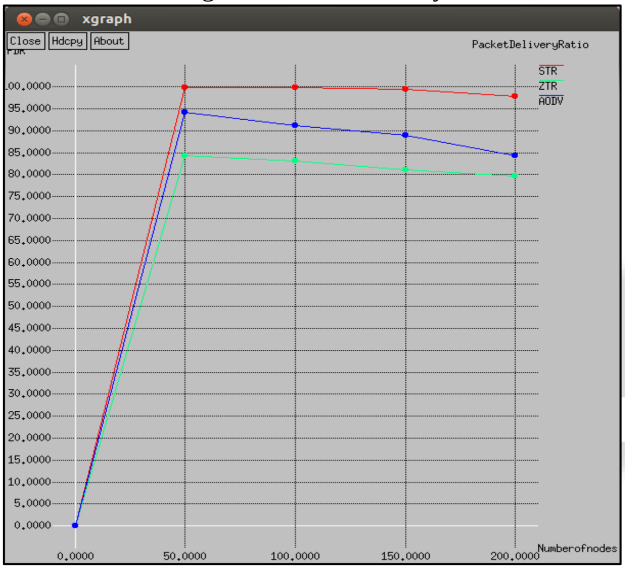

Fig. 7: Packet Delivery Ratio

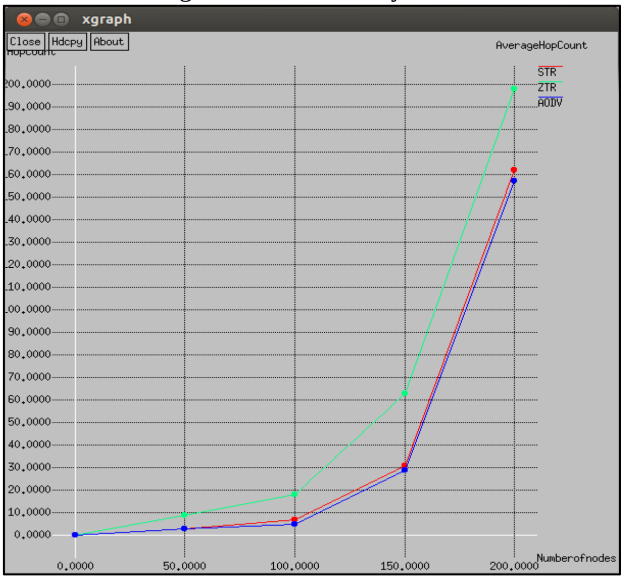

Fig. 8: HOP Count

VII. CONCLUSION

We conclude that the proposed standard protocol termed as STR has remarkably surpass the expenses specifically happened during the operation when specifically following the standard ZTR popular protocol, as this generally basic protocol is going to make use of the neighboring node specific table to search the smallest way to reach to destination node.

The STR is going to improve the routing transmission efficiency generally of the specified ZTR and specifically there is no requirement of finding route for the operation. The proposed protocol i.e. STR maintains the benefits of ZTR and improves its efficiency also, because it does not need to do any route discovery. Because of this improvement in the operation it results into reduce the energy consumption in the network, reduce delay in transmission.

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