STR: An efficient shortcut tree routing method for ZigBee Wireless Networks

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***Abstract*—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 specifications are unaltered, as STR uses just the addressing scheme and neighbor table in association with the Zigbee standards. The research process illustrates the 1-Hop neighbor communication representation upgrades the overall network performance execution by splitting up of the traffic load concentrated on the tree links. 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.**

***Keywords*—** ZTR- Zigbee Tree Routing, STR- Shortcut Tree Routing, neighbor table, MANET, WSN, and IEEE 802.15.4.

I. INTRODUCTION

Zigbee, a low power and cost effective radio standard accepted widely in association with Personal Area Networks can connect up to 1000 devices through wireless mesh network patterns. Zigbee find its usage in home automation [1], 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. AODVjr [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. Whereas ZTR reduces aforementioned through distributed block addressing scheme [4]. 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 [11] 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 [6], DSDV [7] 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 ODV[8], DSR[9], TORA[10]. Nevertheless of its kind such as proactive or reactive, MANETS provide optimal routing path from a source node to destination node. Hence causing the routing table size to be in a bigger larger manner. To find the routing path, MANETs need to put equivalent control packets in their places of one another and sending of packets may experience a low rate and shorter bandwidth channels.

Regarding communication traffic pattern, they can be segmented into any-to-any, many-to-one and one-to-many [13]. In any-to-any pattern, any node can act as a source and destination. In many-to-one, some nodes i.e. greater than one node will act as a source node and a single node will be acting as a destination node. In one-to-many, a single node acts as the source information node and many nodes will be acting as destination nodes. Many-to-one and one-to-many traffic pattern can be stated through Collection Tree Protocol [CTP] and Routing Protocol for Low Power and Lossy Networks [RPL][15]. CTP deals with a base station, serving as the root which has some nodes connected to it, forming a group of bunch of sensor nodes. The metric through which CTP operates can be explained with Expected Transmission Count [ETX]. With the root nodes, ETX remains zero. The other nodes calculate their ETX through summing up of its link and parent nodes in order to transmit the information fast as the node with low ETX is chosen. CTP is deeply associated with TinyOs[16].

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 C_m, R_m and L_n with their hierarchy expression. As C_m illustrates maximum number of children a parent can have and R_m illustrates maximum number of routers a parent can have as a child and L_m represents maximum tree level of the network.

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

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

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

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

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 tree 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.

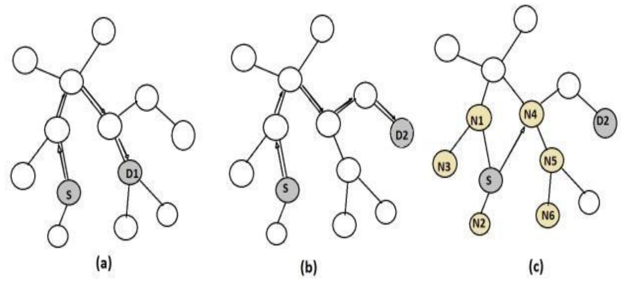

Fig.1 Zigbee Tree Routing and Shortcut Tree Routing

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.

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: Algorithm to find Ancestors at Each Three level Find_Ancestors(devAddr)

Input: devAddr-device‟s network address
Output: level(devAddr)-tree level of devAddr,

A(devAddr)-network addresses of the devAddr‟s Ancestors at each tree level
1: A(devAddr, 0) 0
2: For i=0 to Lm-1
3: If(A(devAddr, i)= devAddr)
4: Return i, A(devAddr)

5: End if
6: rIndex (devAddr-A(devAddr,i)-1)/Cskip[i]
7: if(rIndex < Rm)
8: A(devAddr, i+1) A(devAddr,i)+Cskip[i]*rIndex+1
9: Else if(rIndex>Rm)
10: A(devAddr,i+1) devAddr
11: End if
12: End for

Table 2: Shortcut 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** (nbrRouteCostt<minRouteCost)
11: nextHopAddr Nk
12: minRouteCost nbrRouteCost
13: **end if**
14: **end for each**
15: Transmit packet to nextHopAddr

Tables 1 and 2 illustrates the algorithm and definitions used by STR. Let level(u) represents tree level of node u and A(u) be {A(u,i) | A(u,j) is the network address of u‟s ancestor at tree level i, i < level(u)}. LCA(s,d) [18] can be stated as lowest common ancestor between source node s and destination d.

Table 1 describes the algorithm to find ancestors‟ network address at each tree level together with tree level of given devAddr. Since the network address of device is contained in its ancestors‟ address space in lower tree levels, we can find the rIndex. rIndex is stated as the router-capable child order k in (2) by dividing the size of address space from A(devAddr, i) to the devAddr by the Cskip(i) [21]. If rIndex is less than Rm, then the A(devAddr, i+1) is router device, so the address is derived from the addressing scheme for Ak in (2). If rIndex is greater than or equal to Rm, it states that the A(devAddr, i+1) is network address of the end device and it is same as the devAddr [21].

Finding A(devAddr) process starts with the root node having its network address as 0 and incrementing its value with the significant devAddr which is close to the ancestors‟ address value. A common ancestor address can be found by comparing the source and destination value between the ancestor‟s addresses in each tree level. The common ancestors of the device is found inorder to compute tree routing cost between a source and destination. Considering source node as S and Destination node as D, then the tree routing cost between S and D can be calculated with tree levels of S, D stated as LCA(S,D). The packet from the source node S always goes up to the lowest common ancestor LCA(S,D) through parent node. From the LCA(S,D), the packet directs to the subtree level of node and goes down through the child nodes to the destination. Since the routing hops from S to LCA(S,D) and from LCA(S,D) to D can be calculated using difference of tree levels, the tree routing cost from S to D can be calculated by the equation “level(D)+level(D)-2*level(LCA(S,D))” [21].

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Table 2 illustrates the proposed STR algorithm stating a source or an intermediate node to determine its next hop node that has a minimum remaining tree hop or hops for the given destination. In Table 2, level(dstAddr) and A(dstAddr) for the given dstAddr is computed. Then, for each neighbor entry nk, the remaining tree hops from the nk to the dstAddr, a nbrRouteCost, is calculated, by finding the level(nk) and level(LCA)(nk, dstAddr). 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 [21].

V. SYSTEM MODULES

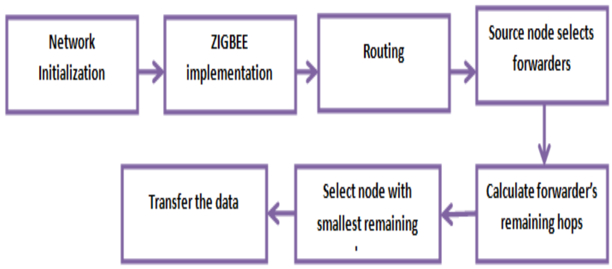

Fig.2 Block Diagram

1. 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 optimalrouting path for source and destination pairthrough the on-demand route discovery. It requires theroute discovery process for each communication pair, so the route discovery overhead and the memory consumption proportionally increases with the number of traffic sessions.

2. Performance analysis

In this module, Zigbee performance is analyzed. Based on the analyzed results X-graphs are plotted. Throughput, allocation delay, energy consumption are the basic parameters considered here and X-graphs are plotted for these parameters.

4. 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.

4. Performance analysis and Result Comparison, Conclusion

In this module, the performance of the proposed addressing scheme is analyzed. Based on the analyzed results X-graphs are plotted. Throughput, allocation delay, energy consumption are the basic parameters considered here and X-graphs are plotted for these parameters.

VI. RESULT ANALYSIS

We use NS2 as our simulating tool. We assigned a network consisting of 25 nodes from node 0 to node 24.Initially, each node find its neighbor node by transmitting HELLO Messages. The HELLO Messages is transmitted periodically for every HELLO period second. The default transmitting range for HELLO Message is 250m. After finding its one hop and two hop neighborhoods, a node start transmitting its packet .The source node sends constant bit rate traffic to destination node. The traffic sources are carried by transport layer protocols User Datagram protocol (UDP) or Transmission control protocol (TCP). At the end of simulation, the trace file is created and the NAM is running (since it is invoked from within the procedure finish{}).Trace file gives the details of packet flow during the simulation.NAM trace is records simulation detail in a text file, and uses the text file the play back the simulation using animation.

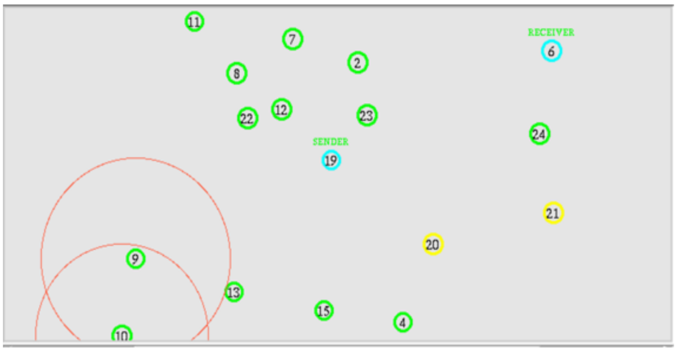

Fig.3 Node Initialization

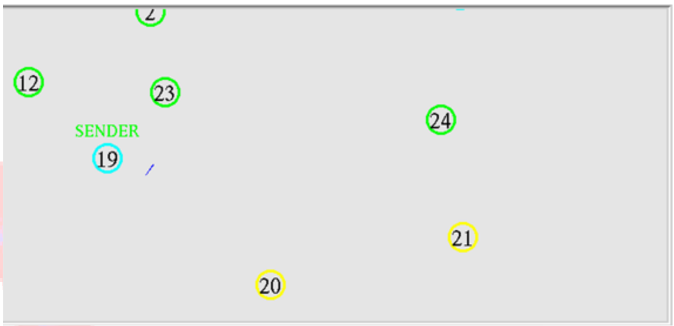

Fig.4 Cbr traffic from node 19

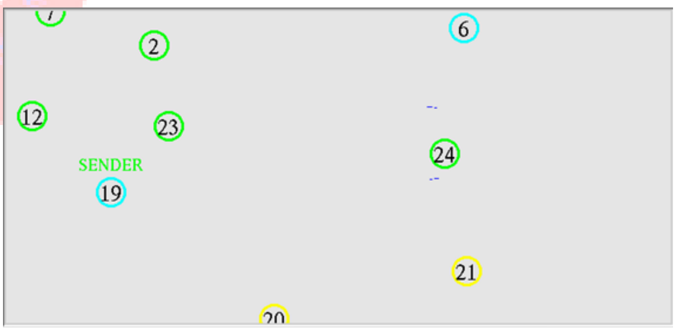

Fig.5 Cbr traffic from node 19 to node 6

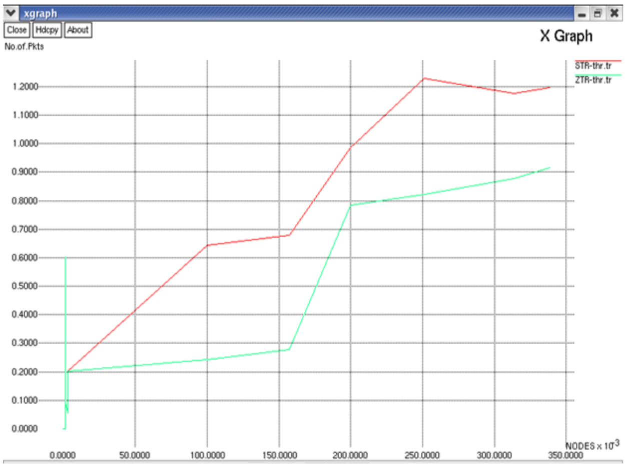

Fig.6 Xgraph for Throughput

Figure 6 shows that the throughput is high when compared to STR and ZTR.

Fig.7 Xgraph for Energy Consumption

Figure 7 shows that the energy consumption is less when compared to STR and ZTR.

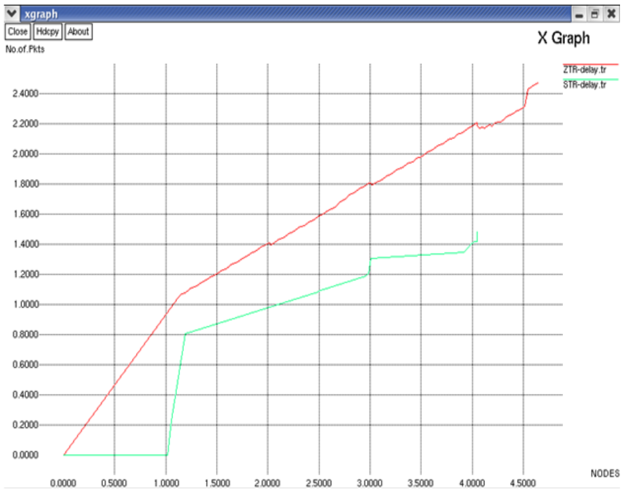

Fig. 8 Xgraph for delay

Figure 8 shows that the delay is less when compared to STR and ZTR.

VI. 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, increase the throughput and also increase the packet delivery ratio.

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