Time Efficient Shortcut Tree Routing Technique for ZigBee Wireless Network

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***Abstract*—As ZigBee is an emerging industrial standard for ad-hoc networks; it can be used in wireless sensor networks for remote monitoring, home control and industrial automation. In ZigBee networks, end devices having less memory, so instead of using routing tables the ZigBee Tree Routing (ZTR) mechanism is used to send a packet to the destination. Even though, the destination is close to the arbitrary source node some unwanted nodes are being visited before reaching the destination due to the nature of ZTR using one-hop neighbor information to send a packet to the destination from each source or intermediate node forwards a packet to the neighbor node which has the smallest remaining hops in its neighbor table. So, it can afford slake optimal routing path. In this paper we propose a novel technique of Shortcut Tree Routing (STR) along with Open Shortest Path First (OSPF) that provides time efficient routing path and also maintains the advantages of ZTR. This technique discovers each hop in the network to calculate the shortest path and creates neighbor table used to forward the next hop which has the smallest remaining hops on the path to its destination using hierarchical addressing scheme in ZigBee. The precise analysis proves that the hop-by-hop neighbor information improves overall network performance and stimulates time efficient routing path moreover distributed traffic stream concentrated on the tree links.**

***Index Terms*—ZigBee; tree routing; shortcut tree routing (STR); MANET; IEEE 802.15.4; OSPF; Greedy technique**

I. INTRODUCTION

ZIGBEE is a low power spin off of Wi-Fi. It is a specification for small, low power radios based on IEEE 802.15.4 emerging worldwide standard for Wireless Personal Area Network (WPAN) [2], [6], [8] and the main goal to provide cost effective, flexible, reliable and scalable wireless products, especially in the industrial, scientific and medical (ISM) radio band. Zigbee Alliance [4] has been evolving and systematizing the Zigbee network. Different from the other personal area network standards such as Bluetooth, UWB, Wi-Fi and Wireless USB which have been developed for communication of large amount of data with complex structure like the media files, software etc. ZigBee is looking into the needs of communication of data with simple structure like the data from the sensors. Zigbee provides the low power wireless mesh networking and supports up to thousands of devices in a network. Zigbee devices can form networks with star, tree and mesh topologies, self-forming and self-healing as well as more than 65,000 address spaces; thus the network can be easily extended in terms of size and coverage area. A ZigBee network [3] can have three types of nodes: ZigBee Coordinator (ZBC), ZigBee Router (ZBR), and ZigBee End Device (ZBE) each having some unique property. The ZBC in a network, the one that initiates in the first place and stores the information about the network and it would be the main control panel, routing capabilities along with acts as a bridge to other networks. A ZBR is an optional component used to extend the coverage, continuously in active monitoring state and handle local address allocation or de-allocation. A ZBE is optimized for low power consumption and communicates only with the coordinator and the point where sensors are deployed. Based on these characteristics, Zigbee Alliance [5] has extended the applications to the diverse areas such as smart home, building automation, health care, smart energy, telecommunication, and retail services. The ZigBee networks layer, which is the core of the standard, provides dynamic network formation, addressing, routing, and network management functions. Every node is assigned a unique 16-bit short address dynamically using either distributed addressing or stochastic addressing scheme. Based on these applications a system or user can choose the optimal routing strategy owing to the routing protocols of Zigbee are diverse. The rapid growth in the field of mobile computing such as Mobile Ad Hoc Network (MANET) [9] is driving a new alternative way for mobile communication, in which mobile devices form a self-creating, self-organizing and self-administrating wireless network. In MANET, where nodes communicate without any central administration or network infrastructure while they are connected via wireless channels and can use multiple hops to exchange data. Its intrinsic flexibility, lack of infrastructure, ease of deployment, auto-configuration, low cost due to deploy the large efforts of research community and rapid progress.

A. ZigBee Route Discovery Process

A device that has routing capacity will initiate route discovery if there is no proper route entry to the requested destination in its routing table. The route discovery in a ZigBee network is similar to the AODVjr (Ad-hoc On-Demand Vector junior) [8]-[10], [12], [13] routing protocol. In an On-Demand routing protocol, routing paths are searched only when necessary. A route discovery operation invokes a route determination procedure. The discovery procedure terminates when either a route has been found or no route is available after examination for all route permutations. AODV determines a route to a destination only when a node wants to send a packet to that destination. Routes are maintained as long as they are needed by the source. In sequence numbers ensure the freshness of routes and guarantee the loop-free routing. AODV uses symmetric links between neighboring nodes. It does not attempt to follow paths between nodes when one of the nodes cannot hear the other one. Nodes do not lie on active paths; they neither maintain any routing information nor participate in any periodic routing table exchanges.

The route discovery process which will be responsible for an optimal routing path in lieu of the arbitrary source and destination pair. For each communication pair the route discovery process is required; so the route discovery overhead and the memory consumption correspondingly increases with the number of traffic sessions. Moreover, route discovery packets are flooded to the entire network, which obstruct with transmission of other packets even in the spatially uncorrelated area with the route discovery.

B. ZigBee Block Addressing Scheme

On the other hand, ZigBee tree routing (ZTR) [13], [15] protocol, coordinator is responsible to initiate the network by electing certain key of network parameters and thus becomes the parent node. Other nodes can join the network by becoming the children of the current node. In ZTR, the network addresses are distributed in tree structure in which coordinator use zero network address while other nodes have the non-zero address. The addresses are computed by the parent node based on its own network address and the network address of its children. The network addresses are assigned using a distributed address allocation scheme, when the tree address allocation is enabled. By this scheme which is designed to deliver potential parents with a finite sub-block of network addresses to be disseminated to its children. The device simply follows the hierarchical tree by comparing the destination address, which a device has no capability of routing table and route discovery table. The most benefit of ZTR is that any source node can transmit a packet to a destination in a network without any route discovery overheads. Down to this efficiency, ZTR is used in resource constrained devices of diverse applications. Thus, ZTR cannot provide the optimal routing path, while it does not require any route discovery overhead. Our objective is to provide, time efficient routing path like the reactive routing protocol to maintain the leads of ZTR such as no route discovery overhead and little memory consumption for the routing table. As proposed in the Shortcut Tree Routing (STR) that suggestively enriches the time efficient routing path of ZTR by only adding the hop-by-hop neighbor information. Whereas, ZTR only uses tree links connecting parent and child nodes, STR feats the neighbor nodes by focusing that there exist the neighbor nodes shortcutting the routing path in the mesh topology. In other words, in STR, a source or an intermediate node selects the next hop node, which is having the smallest remaining tree hops to the destination nevertheless of whether it is a parent, one of children, or neighboring node. The time efficient routing path selection in STR is decided by individual node in a distributed manner, and STR is fully compatible with the ZigBee standard that applies the different routing strategies according to each node's status. Also, it needs neither additional cost nor change of the ZigBee standard including the creation and maintenance mechanism of hop-by-hop neighbor information.

The main aids of this paper are as follows:

- First, as per propose STR to resolve the overall network performance degradation of ZTR, which are the detour path problem and the traffic concentration problem.
- Second, the hop-by-hop neighbor information on each node used by STR progress to prove the time efficient routing path and assuage the traffic load concentrated on tree links in ZTR.
- Third, analyze the performance of ZTR and STR by differentiating the network conditions for instance network density, ZigBee network constraints, and the network traffic.

II. RELATED WORKS

A. MANET Routing Protocols

As MANET [3], [10] are categorized by a multi-hop network topology that can change repeatedly due to mobility, efficient routing protocols are desired to establish communication paths between nodes, without causing extreme control traffic overhead on the power constrained devices. A number of routing protocols tries to have an up-to-date route to all other nodes at all times. These protocols exchange routing control information sporadically and on topological changes which protocols are called proactive routing protocols. The evocative examples of proactive routing protocols are OLSR, and DSDV. Most of the time, it is not necessary to have an up-to-date route to all other nodes. Thus, reactive routing protocols only set up routes to nodes they communicate with and these routes are kept active as long as they are required. Hence, if there is no data packet to transmit it does not generate the control packet overhead, while it causes long delay to find a routing path. AODV, DSR, and TORA are examples of the reactive routing protocols. However, these protocols are stored all the routing paths in the resource-limited devices so as to the routing table size is too big.

B. Collection Tree Protocol

Collection tree protocol (CTP) [4] is the descriptive tree routing protocol of WPAN protocol. A CTP builds and maintains minimum-cost trees of nodes that advertise themselves as tree roots. Collection is address-free: when there are multiple base stations, it sends to the one with the minimum cost without knowing its addresses. Every node maintains an estimate of the cost of its route to a collection point. The expected transmission count (ETX) as the cost metric. In

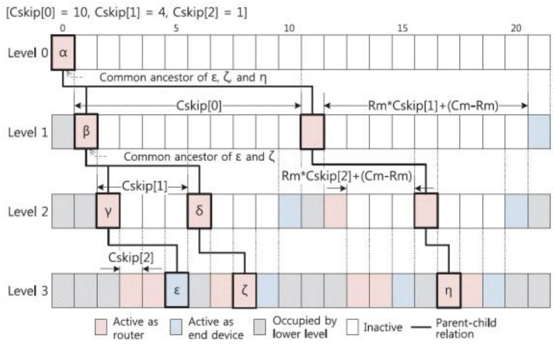

Fig. 1. Address Assignment in ZTR

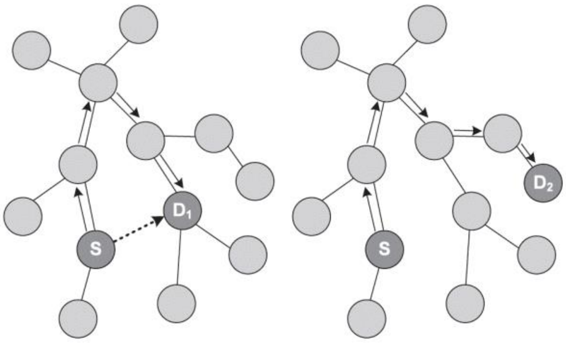

Fig. 2. ZigBee Tree Routing

addition to a node's cost is the cost of its next hop plus the cost of its link to the next hop; the cost of a route is the sum of the cost of its link. Collection points advertise a cost of zero for the root node. In CTP, the base station as a root of the tree builds a collection tree and every sensor node selects its parent node. The CTP maintains the ETX of its neighboring device and selects the node which has the smallest ETX as the parent. This forwarding process is repeated until the base station receives. The routing path of CTP is also slake by traversing along the tree topology and also suffer from detour path and traffic concentration problems like ZTR.

C. Smart Home Networks using ZigBee

Ming Xu *et al* [8], developed a system of Wireless Sensor Networks for Smart Homes also Wireless Sensor Networks enriched indispensable to the insight of smart homes based on ZigBee technology. ZigBee networks would overlay with each other and network of nodes may fail to communicate. The improved Dijkstra algorithm which is realized to overwhelmed the nodes failure in Smart Home. This algorithm delivers an optimal path selection for single source to single destination in multi-hop networks if there is a situation where a source node need to forward data to multiple nodes simultaneously finding the shortest path for each node will become difficult.

D. Hybrid Routing Algorithm of ZigBee Wireless Network

Aiming at the early paralysis of the energy diminution inequity of nodes, which caused the network problem in ZigBee is focused on Yan Li *et al* [15] a hybrid routing algorithm (HRA) is proposed. This algorithm has the combinations of both Cluster-Tree algorithm and AODVjr routing algorithm. The Cluster-Tree algorithm which is helpful for forwarding the packets based on the hierarchical tree structure. AODVjr routing algorithm, however it can simply find the best routing path, from route discovering process to forward route request (RREQ) packet towards all nodes in the network as it has the problem of huge diversity in energy consumption of nodes, it is hard to equilibrium the energy depletion of every ZBC or ZBR. Last but not least, in HRA, if the source and sink within the 1-hop distance the packets are directed through only the cluster head. It adopts unwanted node visits, energy consumption and it increases the probability of node failure in the network.

For the ZigBee standard [11], there have been do research on enlightening the path efficiency of the ZTR. The routing cost of the ZTR would be reduced while applying 1-hop neighbor information. In addition to the inept routing path of ZTR suffer from performance degradation when all the packets are concentrated on the tree links.

The primary version of our paper proposed STR algorithm that selects the neighbor node based on 1-hop neighbor information. STR can reduced detour path problem and traffic concentration problem of ZTR, thus STR is affected by the tree topology due to its integral features. And also the routing overhead increases as the number of session will increases. Since all the nodes between a source and a destination in each pair participate in the route discovery as well as it may cause the packet transmission delay and retransmission will degrade the packet delivery ratio.

III. ZIGBEE TREE ROUTING

A. Address Assignment in ZTR

In Figure. 1 shows ZTR, the devices which utilized the distributed address assignment scheme [8], [12], [13] to assign the network addresses. The ZTR protocol, is disseminated the network addresses in tree structure in which ZBC have a preference of zero network address whereas other nodes have the non-zero address. The ZBC decides the maximum number of children (Cm) of a ZBR, the maximum number of child routers (Rm) of a parent node, and the depth of the network (Lm). Here, Cm ≥ Rm and a parent can have (Cm-Rm) end devices as its children. In this algorithm, the parents which are assigned the addresses of their devices. Intended for the ZBC, the entire address space is logically segregated into Rm+1 blocks. A parent device which consumes Cm, Rm, and Lm to compute a function called Cskip, which computes the starting addresses of its children addresses group. Equation 1 is the Cskip for the ZBC or a ZBR in depth of the node d, unknown node requests to join the network. Hence, the ZBC or ZBR computes Cskip (d) as follows:

$$Cskip = \begin{cases} 1 + Cm.(Lm - d - 1) & if \quad Rm = 1 \\ \dfrac{1 + CM - Rm - Cm.Rm^{Lm-d-1}}{1 - Rm}, & Otherwise \end{cases} \qquad (1)$$

The depth of the subtree is at most Lm-d-1. While, the size of the sub-tree is bounded as in Eq. 2 and Eq.3:

$$Cskip(d) = \frac{1 + Cm - Rm - Cm.Rm^{Lm-d-1}}{1 - Rm} \qquad (2)$$

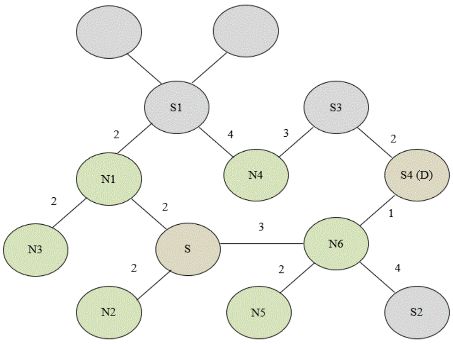

Fig. 3. Time Efficient STR (2-hop range)

$$Cskip(d) = 1 + Cm + CmRm + ... + CmRm^{Lm-d-2} \quad (3)$$

Since every device in the network is a descendant of the ZigBee coordinator and no device in the network is the descendant of any ZigBee end device, any device with address A at depth d has the destination device with address D if the following Eq. 4 is satisfied.

$$A \langle D \langle A + Cskip(d-1) \quad (4)$$

If the target node is successor of the current device, then it is directed to the child node. Or else it is forwarded to the parent node and the address of next hop will be the address of its parental node.

B. ZigBee Memory Allocation structure

Figure. 2 exposed the ZTR [12], if the destination is a successor the device sends the data to one of its children; otherwise it sends to its parent. ZTR has the maximum memory allocated for the one-hop neighbor table size is 116 bytes stored in the ZigBee Coordinator or Router. ZTR allocated 15 bytes for Header, and remaining 101 bytes for an application payload. In the routing path of ZTR, a packet is routed through several hops towards the destination even though it is within the range of sender's 2-hop transmission range. Thus, it induced the detour path problem. To solve this detour path problem, the ZTR has defined the direct transmission rule that allows the ZBC to transmit a packet directly to the destination lacking assessment of the routing protocol. However, this method cannot fundamentally resolve the detour path problem of ZTR, when the destination is positioned more than 2-hop distance away from a source node.

Additionally to the detour path problem, ZTR has the traffic concentration problem due to restricted tree links. Ever since all the packets pass through only tree links, particularly around the root node, severe congestion and collision of packets are focused on the limited tree links. If symptom increases, then it finally causes the degradation of the packet delivery ratio, end-to-end latency, and other network performance.

IV. Shortcut Tree Routing

To avoid the problems, we propose the STR along with OSPF [1] algorithm that solves these two problems of the ZTR using hop-by-hop neighbor information. The STR algorithm

TABLE I. Algorithm to Find Address Range of Destination

Find_AddRange (dstAddr, startAddr, curDepth)

```
Input: dstAddr, startAddr, curDepth
Output: depth_dstAddr, AddrRange [depth_dstAddr]
Begin
    if (dstAddr = startAddr)
    return curDepth
    else
    for i = 1 to Rm
    if (dstAddr is in the address space of ith router)
    store address space of ith router to AddrRange[curDepth+1]
    return Find_AddrRange(dstAddr, ith router, curDepth+1)
    end if
    end for
    if (Cm-Rm > 0)
    if (dstAddr is the end device of startAddr)
    store dstAddr to AddrRange[curDepth+1]
    return curDepth+1
    end if
    end if
    end if
End
```

fundamentally follows ZTR, then before each hop will accept any routing information from another hop, it will built a neighbor table with each other on their connected hops. When this neighbor table is built, the two hops are called a neighbor. Each hop will generate a packet every 10 seconds. If a neighbor is not seen within the dead lag time, which defaults to 40 seconds, the neighbor is declared as dead. The neighbor establishment process begins with hops exchanging Hello packets with each other, thus achieving bi-directional status. This is followed by the exchange of database description (DD) packet. Each hop determines if the neighbor has newer hops by receiving the link state packets (LSP) and then updates its own routing table. Then it will disseminate the link state updates (LSA) to all the available nodes. The area-wide flooding of neighbor hops stay contemporary and harmonized. Fig. 3 shows the intended architecture of Time Efficient Shortcut Tree Routing (Two-hop neighbor information range) in ZigBee wireless network. Link state maintenance mechanism [14] is used to reduce overhead and speed up the convergence time, which can be classified into the following categories:

- Neighbor selection: Rather than establishing neighbor with all the nodes, a hop becomes neighbor with only selected nodes.
- Hello Redundancy Reduction: Incremental Hellos and Differential Hellos are two techniques that can report changes noticed in the neighborhood over the last hello period, instead of full neighborhood information every hello period. However, in doing this, transmission failures may cause hello synchronism loss and may take away nodes' ability to track neighborhood changes properly.
- Topology reduction: Rather than listing all end-to-end neighbours, a hop reports only a subset of its end-to-end neighbor.
- Flooding optimizations: It used to reduce redundant retransmissions.

In algorithm [12] from Table I to get the address space of destination can be finding its predecessor nodes in each level

TABLE II. PSEUDOCODE TO FIND MINIMUM COST OF DESTINATION

```
Procedure Prim (G: weighted connected graph with n vertices)
T: = a minimum-weight edge
For i = 1 to n − 2
Begin
E: = an edge of minimum weight incident to a vertex in T and not
forming a circuit in T if added to T
T: = T with e added
End
Return (T)
```

and calculating the address space according to the ZigBee's address assignment scheme. The Find_AddrRange () is a recursive function that has arguments such as startAddr, curDepth, dstAddr. A startAddr is the address of the predecessor node at curDepth for the given destination dstAddr as well as it's started with startAddr 0 and curDepth 0 by calling from the Find_NextHopAddr () function, and returns the address space of the destination along with its depth.

OSPF is an intradomain routing protocol and the link state maintenance mechanism supports classless routing addressing, sub netting of the larger network with the benefit of VLSM (Variable Length Subnet Masking) techniques as well as it adequate to deliver the periodic changes into the network.

STR (OSPF) with link state mechanism of undirected graph will induced the minimum link cost along with the time metric of minimum distance. Table II. Describes the pseudocode for calculating the minimum routing cost with minimum shortest path for undirected graph. The proposed algorithm [7] establishes greedy techniques and it begins with the hop which is initialized to 1 or many source. At each step, it finds a shortest edge, such that the cost is the smallest among all edges then it will constructed the STR.

Each hop in the network uses the same topology to create routing table, but the routing table for each node is unique because the calculations are based on different interpretations of the topology. The topology must be dynamic, representing the latest state of each node and link. If there are any changes in any point in the network, the topology must be updated for each hop.

Although the global knowledge about the topology is not clear, each hop has partial knowledge. OSPF fast hello packets refer to Hello packets begin sent at intervals of less than 1 second. This feature allow to detect lost neighbors within 1 second. OSPF has 24 bytes to be allocated for the router to store the routing table size. Also 20 bytes to be fragmented for the application payload as well as header to be acquired 5 bytes. The neighbor details are located by remaining 4 bytes; so that the amount of memory required to store the information in the routing table is computed from the following Eq. 5:

$$(N + Nm)E \quad Bytes \qquad (5)$$

The Hello message partitioned into each of 1 byte which are allocated to Hello (1 byte), Database Description (1 byte), Link State Request (1 byte), Link State Update (1 byte), Link State Acknowledgement is 1 byte.

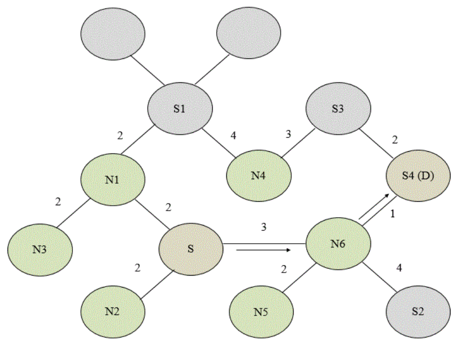

Fig. 4. Time Efficient STR (from S to D)

The Hello packet size will be computed and expressed as in Eq. 6:

$$(20 + 4m) \qquad (6)$$

The routing table size depends on the number of routers in the communication link 'm'. Hence, the 'N' routers to exchange the HELLO packet information in the bi-directional way to all available routers via LSP messages. Thus, the number of database exchange of HELLO message is 'N2'. After the database exchange the router discovered their designated routers and then database exchange of information will be reduced to 'N'. As well as the router maintained the Designated Router (DR) information into the Backup Designated Router and (BDR) it's database exchange will be '2N'. If the DR under failure, then the STR (OSPF) quickly recovered an alternate optimal shortest path for direct the packets to the destination with BDR. The total route discovery process after failure should takes only 180 milliseconds. In the ZigBee network shows from Fig. 4 has minimum of 13 nodes beyond that has 6 routers. Then the calculated hop-by-hop neighbor table size appropriately 44 bytes. So that our proposed system will followed the ZTR addressing scheme expressed in Eq. 1 each of the node has the distance of 10 meters and time is the metric to transmit a packet with available bandwidth.

TABLE III. ROUTING TABLE FOR MINIMUM COST IN STR (OSPF).

V	KNOWN	D_V	P_V
S	1	0	0
N1	1	1	S
N2	1	2	S
N3	1	5	N1
N4	1	4	S1
N5	1	2	N6
N6	1	3	S
S1	1	2	N1
S2	1	4	N6
S3	1	3	N4
S4	1	1	N6

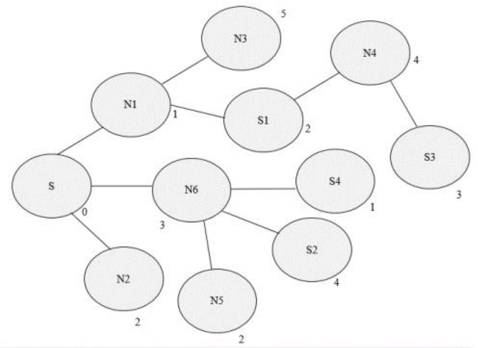

Fig. 5. Minimum transmission cost of STR (OSPF)

In the ZigBee network shows from Fig. 4 has minimum of 13 nodes beyond that has 6 routers. Then the calculated hop-by-hop neighbor table size appropriately 44 bytes. STR (OSPF) will have the routing table as the same but the details resides in each router to be different. From the hop-by-hop neighbor table route the packets to the destination with minimum routing cost. STR (OSPF) will have the routing table as the same but the details resides in each router to be different. The mathematical evaluation forecasts the routing table with all possible hops with minimum cost from Table III. After calculation of minimum shortest path for STR is have the total minimum transmission cost is 27. And the final mathematical evaluation result is shown in Fig. 5 since the mathematical evaluation of routing table, the source (S) to send the packet to destination (S4) with minimum cost is 4.

V. CONCLUSION

This paper introduces the problem of Zigbee Tree Routing and proposes a Time Efficient Shortcut Tree Routing protocol that overcomes the overhead occurred when ZTR (1-hop Neighbor Information). In the proposed algorithm, neighbor table of hop-by-hop neighbor information which enhanced the efficient routing path based on available neighbor information. As well as each of the node in the link has obtained only the partial information about their neighbor node details instead of full topology information.

Through this the proposed methodology can achieve the time efficient STR. The STR (OSPF) link state maintenance mechanism will followed the ZTR addressing scheme and induced VLSM techniques to reduce the routing table size. STR (OSPF) routing algorithm is time efficient in terms of both routing performance and time complexity significantly achieved. Hence, the ZigBee wireless mesh network to follow our Time Efficient STR (OSPF) to send the packets from source to destination is located within the 2-hop distance using minimum cost, minimum time requirement. Furthermore, diminished the memory consumption for route discovery process and maintained up-to-date information about the optimal path for routing. Therefore, we expect the proposed algorithm to be utilized in many ZigBee applications requiring both small memory capacity and high routing performance.

Our future work is to implement the Time Efficient STR (OSPF) in ZigBee Wireless Network and measure its performance characteristics, packet delivery ratio, route discovery, end-to-end latency, network traffic measurements using NS2 simulator.

REFERENCES

[1] Behrouz A Forouzan "Data Communication and Networkiing," Ed. 4, 2006.

[2] S. Chen et al., "A Reliable Transmission Protocol for ZigBee-Based Wireless Patient Monitoring," *IEEE Trans. Infromation Technology in Biomedicine*, vol. 16, no. 1, pp. 6-16, Nov 2012.

[3] Chieh-Jan Mike Liang, Nissanka Bodhi Priyantha, Jie Liu, and Andreas Terzis, "Surviving Wi-Fi Interference in Low Power ZigBee Networks," *ACM 978-1-4503-0344-6, SenSys'10*, Nov 3-5, 2010.

[4] O. Gnawali, R. Fonseca, K. Jamieson, D. Moss, and P. Levis, "Collection Tree Protocol," *Proc. Seventh ACM Conf. Embedded Networked Sensor Systems (SenSys)*, 2009.

[5] http://www.engineersgarage.com(URL)

[6] Han, and J. Lim, "Smart Home Energy Management System Using IEEE 802.15.4 and ZigBee," *IEEE Trans. Consumer Electronics*, vol. 56, pp. 1403-1410, Oct 2010.

[7] P. Merz and S. Wolf, "TreeOpt: Self-organizing, Evolving P2P Overlay Topologies Based on Spanning Trees," *Proc. Comm. in Distributed Systems Conf. (KiVS)*," 2007.

[8] Ming Xu, Longhua Ma, Feng Xia, Tengkai Yuan, Jixin Qian and Meng Shao, "Design and Implementation of a Wireless Senssor Network for Smart Homes" *Ubiquitous Intelligence & Computing and 7th International Conference on Autonomic & Trusted Computing (UIC/ATC) E-ISBN: 978-0-7695-4272-0*, pp. 239-243, 26-29 Oct. 2010.

[9] Onkar Nath Thakur et al., "Enhancing then Communication Range and Reliability of Mobile ADHOC Network using AODV- OSPF Protocol," *Int. Journal of Engineering Research and Applications, ISSN: 2248-9622*, vol. 4, pp. 493-498, Issue 2 (Version 1), Feb 2014.

[10] V.D. Park and M.S. Corson, "A Highly Adaptive Distributed Routing Algorithm for Mobile Wireless Networks," *Proc. IEEE INFOCOM '97*, 1997.

[11] Prativa, P. Saraswala, "A survey on Routing Protocols in ZigBee Network," *IJESIT, ISSN: 2319-5967*, vol. 2, Issue 1, Jan 2013.

[12] Taehong Kim, Seong Hoon Kim, Jinyoung Yang, Seong-eun Yoo, and Daeyoung Kim, "Neighbor Table Based Shortcut Tree Routing in ZigBee Wireless Networks" *IEEE Trans. Parallel and Distributed Systems*, vol. 25, No. 3, Mar 2014.

[13] T. Kim, D. Kim, N. Park, S. Yoo, and T.S. Lopez, "Shortcut Tree Routing in ZigBee Networks," *Proc. In'l Symp. Wireless Pervasive Computing (ISWPC)*, 2007.

[14] V. Vetriselvan, Pravin R. Patil, and M. Mahendran, "Survey on the RIP, OSPF, EIGRP Routing Protocols," *IJCSIT, ISSN: 0975-9646, vol. 5 (2)*, pp. 1058-1065, 2014.

[15] Yan Li, An-na Yuan, Xue Liu, Yong-bin Du, Tian-xin Huang and Hao-xin Cui, "A Weight Cluster-Based Hybrid Routing Algorithm of ZigBee Network," *International ournal of Future Generation Communication and Networking, ISSN: 2233-7857 IJFGCN*, vol. 7, No.2 (2014), pp. 65-72, 2014.