International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 02, February-2015

# An Efficient Authentication Mechanism based on ZigBee for Smart Grid Wireless Communication

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***Abstract*—A modern electric power grid infrastructure for enhanced efficiency and reliability through automated control is called smart grid. A vision of smart grid realizing the integration of network information in power system. The critical issues related to the smart grid wireless applications are delivery of information to the destination. Various routing protocols addresses these issues and finds the shortest path. The Tree routing and table driven routing are the most predominant in various routing protocols. In this paper, a modified Short cut Tree routing based on tree routing is proposed. The optimal path discovery solves the limitations in existing methodologies. The proposed shortcut tree routing (STR) maintains the advantages of the existing ZigBee tree routing simulations carried out in network simulator to describe the various performance evaluations like effect of network density in two conditions such as many to one traffic and any to any traffic. The overall network performance reveals the efficient routing path and traffic load on the tree links. Traffic performance in various patterns and network configuration on the basis of STR are compared with the existing protocols.**

***Index Terms*—Block Address Allocation Scheme, Improved Tree Routing, Smart Grid Wireless Communication, Shortcut Tree Routing (STR), Tree Topology, ZigBee Tree Routing.**

## I. Introduction

Smart grid wireless communication is a biggest technology contribution to the mankind in which the integration of network information to the power system to satisfy the major requirements in wireless communication such as security, system reliability and availability. The primary concern for the smart grid is security problem. The control actions and information transmitted via network without the interaction of hacking and diversified information. The explosion in smart grid technology leads to creation of many emergence standards for transmitting information issues and opportunities for discovery of shortest paths.As a result, many companies were forged to create a standard which was acceptable in worldwide. One of the most worldwide acceptable standard created by ZigBee alliance was ZigBee.

ZigBee is a low-cost, low-power, wireless mesh network standard which governs the wireless control and monitoring applications. ZigBee devices have low latency and low average current. The rate of 250 kbit/s suited for the data transmissions. Since ZigBee technology was simpler and less expensive compared Wireless Personal Area Networks (WPANs), it plays a vital role in data transmission. ZigBee network utilized three types of devices such as network coordinator which maintains overall network knowledge, full function device that supports all features described by the standard and reduced function device carries the limited functionality to lower cost and complexity. ZigBee network achieves longer battery life by either continuous network connection or intermittent connection. It also has maximum data rate, high throughput and low latency. The channel accessing technique used in ZigBee was Carrier Sense Multiple AccessCollision Avoidance (CSMA-CA). The ZigBee protocol is fully reliable handshake data transfer protocol employs three types of topologies. They are star, mesh and peer-peer.

Various routing protocols are used in ZigBee network to identify the shortest path routing. The routing protocols of ZigBee diverse so that a system or users can choose the optimal routing strategy according to the applications. The reactive routing protocol in ZigBee was derived from Adhoc On-demand Distance Vector Junior (AODVjr) which is one of the representative routing protocols in Mobile Ad hoc Networks (MANET). Similar with other MANET routing protocols, ZigBee reactive routing protocol provides the optimal routing path for the arbitrary source and destination pair through the on-demand route discovery. When the number of traffic sessions increases, the route discovery and the memory conception is more. So communication pair formed between the traffic which leads to the route discovery process for each communication pair. The route discovery packets flooded to the overall network, which interfere with transmission of other packets even in the spatially uncorrelated area with the route discovery. On the other hand, ZigBee Tree Routing (ZTR) prevents the route discovery overhead in both memory and bandwidth using the distributed block addressing scheme. The optimal route discovery in many applications,resource limited devicescan be found byZTR.

In this paper, the optimal route path can be founded by shortcut tree routing protocol and the advantages of ZTR can be maintained. The ZTR performance can be achieved across various network conditions.The network can be formed according to tree routing protocol. The selection of route process can be carried out using shortcut tree routing algorithm. The performance of the network can be evaluated and the effect of density can be measured upon many traffic patterns.The proposed method improves the lifetime, efficiency and yields lesser delay.

The rest of the paper is organized as follows. Section II presents a description about the previous research which is relevant to the ZigBee network and the possible solutions. Section III involves the detailed description about the proposed method. Section IV presents the performance analysis. This paper concludes in Section V.

## II. RELATED WORK

This section deals with the works related to the ZigBee network and the routing algorithms implemented to enhance the performance of ZigBee.*Dae-Man et al* proposed the design descriptions for smart home device and load management in smart energy applications. They also utilized the sensing device control for smart home interfaces in real time testbet implementation[1]. *Shyr et al* presented transmission protocol based on any cast routing for wireless patient monitoring. The latency of path recovery was reduced by using that protocol and also integration of next generation technologies carried out to achieve the real time patient monitoring [2]. *Peizhong et al* developed practical ZigBee deployment under the interference of WLAN. Two parameters such as 'safe distance' and 'safe offset frequency' were identified for comprehensive approach. They also proposed the frequency agility based interference algorithm for detection of interference and switching to safe node [3]. *Ian et al* examined the performance of AVOD and AVODVjr under various conditions sequence numbers, link layer feedback. The security added easily in AVODVjr since the control packets have no mutable field [4]. *Kiess et al* presented brief survey of real world experiments and the technology required for implementation. Experiments on MANET was carried out in static topologies and the node mobility involving scenario [5].

*Chen et al* presented Adaptive Demand-Driven Multicast Routing(ADMR)protocol for MANET implementations. This was the first no-simulated ADMR implementation of MANET and real world impact path scenario was highlighted [6]. *Wheeler* described the ecosystem emerging ZigBee and the enabling trends [7].*Gnawali et al* presented and evaluated two principles such as data path validation and adaptive beaconing to reduce the rout repair latency [8]. *Jeong et al* presented the standards for research activities for influenzing their design for open source applications [9].*Levis et al* presented the flexible application specific operating system for sensor networks. Qualitative and quantitative measurement was carried out to meet the low memory requirements [10].

*Kim et al* proposed the short cut tree routing protocol to reduce the routing cost of ZigBee routing using the neighbor table. Simulations were carried out and 30 percent of hop count compared with ZigBee routing [11]. Excessive redundancy of messages and the signal collision occurred in MANET. Some flooding algorithms were carried out for the removal of redundancy. But in that algorithm the difficulty was to maintain the neighbor's information. *Liu et al* presented the condition flooding algorithm to perform the 100 percent deliverability based on only 1 hop information [12].The position information for flooding algorithm was required. *Agbaria et al* presented the dissemination protocol called loc cast which utilized positioning information to obtain efficient dissemination [13]. The suitable algorithm was required to handle the unannounced leaving and joining of nodes. Peter and Wolf presented a novel approach for self-organization peer-peer overlays and self-optimization of joining and leaving nodes in spanning trees [14]. The devices in ZigBee network cannot receive network addresses isolated from the network called orphan nodes. *Pan et al* showed that the orphan problem divided into Bounded-Degree-and-Depth Tree Formation (BDDTF) and End-Device Maximum Matching (EDMM) for efficient reduction of orphan devices in ZigBee network [15].

ZigBee cluster-tree network was not able provide the sufficient bandwidth for increased traffic load.*Huang et al* presented an adaptive parent based framework for ZigBee clustering tree for efficient bandwidth utilization. They modeled the process as vertex constraint maximum flow problem compatible with ZigBee standard [16]. *Jonathan et al* derived the simple model to describe the limits of data propagation in wireless networks and the rates for dissemination was argued [17]. *Khatiri et al* addressed the two problems such as more hop count and hot spot problem and proposed a new routing algorithm called Energy Efficient Shortcut Tree Routing to reduce the hop counts and balance the energy [18].*Harbawi et al* presented the enhancement in tree routing Improved Tree Routing (ImpTR) which determines the shortest path to sink node from the neighbor table rather than tree topology [19]. *Qiuet al* proposed enhanced tree routing strategy which have structured node address assignment schemes. Simulations results revealed more energy efficient compared to Tree routing protocol [20].

## III. PROPOSED METHOD

The main idea to implement STR in ZigBee network is that computing the remaining tree hops from the source to destination using ZigBee address hierarchy. The remaining tree hops can be calculated for three nodes source, destination and ancestor node. The block diagram of proposed method is shown in fig.1.

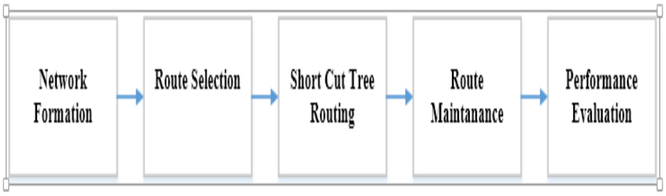


Fig.1.Block diagram.

The proposed method can be evaluated using various modules. The network for analysis formed and the shortest path can be obtained by using short cut tree routing algorithm through iteratively checking and updating process. The overall performance can also be evaluated over existing method. The flow for proposed method consists of successive steps. They are checking neighbor address from the routing table, updating the levels and finding of next hop address.

The flow of proposed method of short cut tree routing as shown in fig.2.

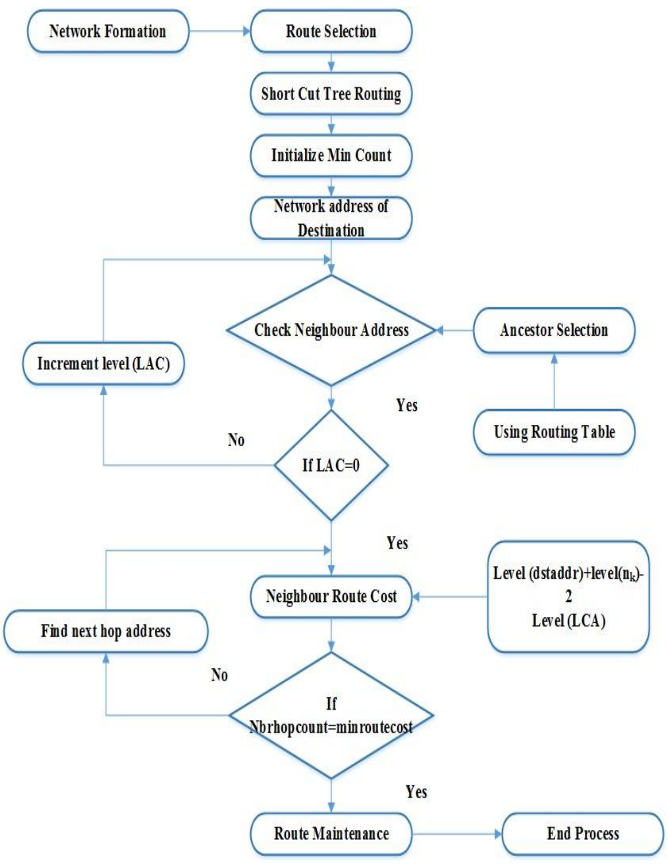


Fig.2.STR Data Flow

## A. *Network formation*

The network formation is done according to the tree routing protocols. The ZigBee network layer, which is the core of the standard, provides dynamic network formation, addressing, routing, and network management functions. ZigBee supports up to 64,000 devices in a network with the multi-hop tree and mesh topologies as well as star topology. Every node is assigned a unique 16-bit short address dynamically using either distributed addressing or stochastic addressing scheme. The routing protocols of ZigBee are diverse so that a system or users can choose the optimal routing strategy according to the applications.

## B. *Route Selection*

The selection of shortest route is done by two protocols such as tree routing and table driven routing.

### *1) Tree Routing*

Tree routing in ZigBee network performed on the basis of *Block Address Allocation Scheme* known as *C,* in which the network address to its children assigned by finite subblock of address space associated with every potential parent.

The size of addressing subblock distributed by each parent node at a depth of d using following equation:

$$c(d) = \frac{1+mC-mR-mC.mR^{mD-d-1}}{1-mR} \quad (1)$$

Where, $mC$- Maximum children,
$mR$- Maximum router,
$mD$- Maximum depth.

The network address assigned to kth router and nth end device from size based on following equation:

$$N_k = N_{parent} + c(d).(k-1) + 1 \; (1 \le k \le mR) \quad (2)$$

$$N_n = N_{parent} + c(d).mR + n \; (1 \le n \le mC - mR) \quad (3)$$

Device in ZigBee network with an address $N$ at $d$has the destination address D only if the following condition was satisfied.

$$N < D < N + c(d-1) \quad (4)$$

The device sends the data to the one of its children only if the condition was satisfied. Otherwise it send the data to parent. This type of tree routing performed between source and destination nodes rather than neighbor nodes hence packets routed through several hops to the destination within sender's 1 hop transmission range.

### *2) Neighbor Table*

Devices in ZigBee contain all information of neighbors in neighbor table. The new joining node received the response beacons from already joined node and also the neighbor entry was removed after the node leaves form the network. So the information in neighbor table called up-date in all time.

This type of table driven provides optimal routes to destination. But the routing cost is high in this method.

## C. *Effective Short Cut Tree Routing*

The short cut tree routing can be enhanced using two processes such as finding of address range and finding of next hop address.

### *1) Calculation of address range*

The function *addrrange()*is the algorithm to find the address range and depth according to ZigBee address allocation scheme.

The arguments for *addrrange()* function was Starting Address(SA) of ancestor node at current Depth (D) for a given destination address (DA). The output of this function was address space and depthof destination which are calculated by iterative processes.

Initially the equality between SA and DA was checked if both are equal then the current depth can be regarded as depth of destination in *line1-2*. Otherwise the address range can be evaluated iteratively until maximum router reached using *line 3-9*.The depth to destination to be updated for maximum no of children in *line 10-14.*

*Algorithm to Find Address Range*

| |
|---|
| *addr range*(DA,SA,D) |
| Input: DA,SA,D |
| Output: d, addrrange(d) |
| Begin |
| 1 if (DA=SA) |
| 2 return D |
| 3 else |
| 4 for i=1 to mR |
| 5 if(DA in address space of ith router ) |
| 6 store the address space of ith router(d+1) |
| 7 return |
| 8 end if |
| 9 end for |
| 10 if ((mC-mR)>0) |
| 11 if(DA is end device of SA) |
| 12 store DA(D+1) |
| 13 end if |
| 14 end if |
| End |

*2) Calculation of next hop address for a given destination Address*

*Next hop addr()* function listed is the algorithm to find the intermediate or source node to select the next hop node with minimum hop count for given destination address.

When selecting the neighbor node as the next hop node source or intermediate node check the remaining routing cost based on remaining hop count to the destination using *line 1-6*. The root of the common subtree can be founded by comparing the address of neighbor node which is contained in the address space. The reference point can be declared as the root of highest common level in sub tree using *line 7-8*. Then the remaining hop count can be calculated by using the equation (level of sourcenode-highest level of sub tree) + (level of destination node-highest level of subtree) using *line 9-14*.

***Algorithm to find Next Hop Address***

| |
|---|
| ***Next hop addr(DA)*** |
| Input: DA |
| Output: next hop address |
| begin |
| 1 depth=addrrange(DA,0,0) |
| 2 Assign the next hop node to next hop address |
| 3 Assign remaining hop count to minroutecost |
| 4 for each neighbor from neighbor table |
| 5 i=0 |
| 6 while (neighbor is in addr range(i+1) && i<depth) |
| 7 ++i |
| 8 routecost=(d-i)+(d(neighbor)-i) |
| 9 if (minroutecost>routecost) |
| 10 nexthopaddr=neighbor |
| 11 minroutecost=routecost |
| 12 store DA(D+1) |
| 13 endif |
| 14 endforeach |
| End |

## IV. Performance Analysis

This section presents the performance analysis of the proposed short cut tree routing in ZigBee network. The evaluation of the routing performance includes hop count, end-to-end latency, packet delivery ratio, and MAC level retransmissions, and the routing overhead is measured with the number of control packets and memory consumption for routing.

The simulation is categorized into four subsections to analyze the effects of throughput, packet delivery ratio, packet sent and packet received.

### *A. Network Throughput Analysis*

The network through put measurement is important to show the proposed algorithm is suitable for optimal path discovery compared to existing methodologies. The network throughput performance analyzed with two parameters such as amount of bandwidth and no of mobile stations used in the network.

*1) Amount of Bandwidth*

The network through put analyzed using NS simulator. The performance of network throughput plotted with various bandwidth constraints shown in Fig. 3.

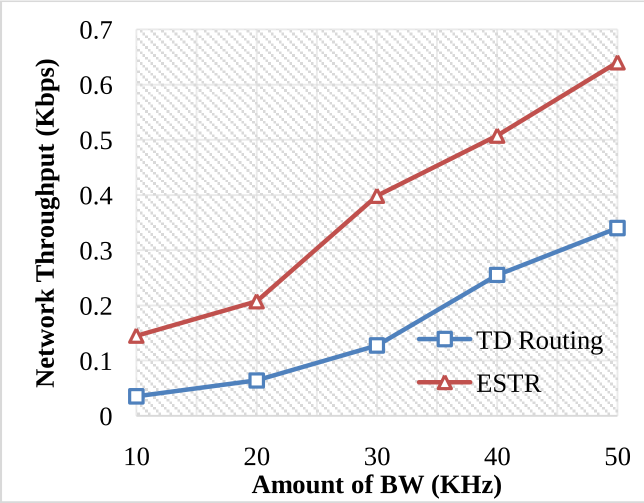


Fig. 3 Network Throughput Vs. Amount of Bandwidth.

Fig.3 describes the relationship between the amount of bandwidth and network throughput. The amount of bandwidth is varied and the network throughput is computed. The proposed ESTR algorithm provide better throughput than the existing approach.

*2) No.of Mobile stations*

When the no of mobile stations increased the network throughput performance measured and variation also plotted in the graph.

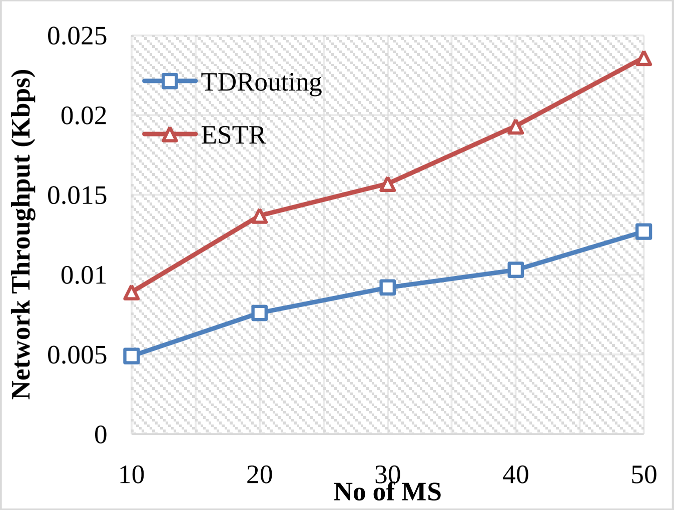


Fig. 4 Network Throughput Vs.No of Mobile stations.

Fig.4 describes the relationship between the no of MS and network throughput. The no of MS is varied and the network throughput is computed. The proposed ESTR algorithm provide better network throughput than the existing approach for no of mobile stations.

### *B. Bandwidth Consumption Ratio*

An amount of the bit rate of available or consumed data communication resources stated in terms of Kb/s, Mb/s etc. called Network bandwidth.

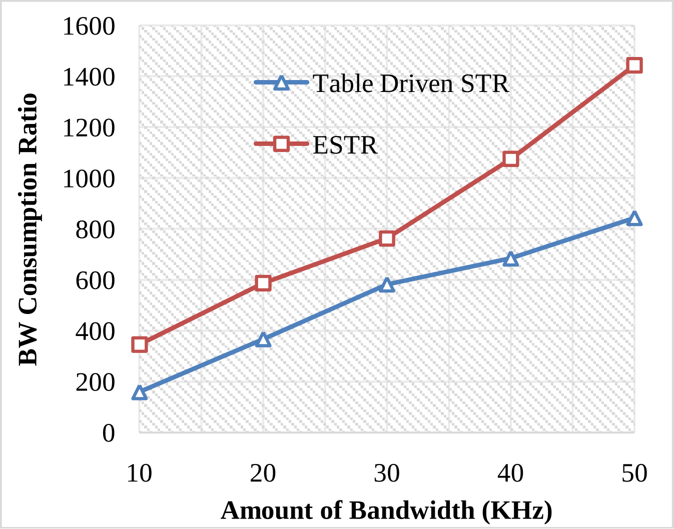


Fig. 4Bandwidth consumption ratioVs. Amount of Bandwidth.

Fig.5 describes the relationship between the amount of bandwidth and bandwidth consumption ratio. The amount of bandwidth is varied and the bandwidth consumption ratio is computed. The proposed ESTR algorithm provide better bandwidth consumption ratio than the existing approach.

## V. Conclusion

In this paper, we have identified the detour path problem and traffic concentration problem of the ZTR. These are the fundamental problems of the general tree routing protocols, which cause the overall network performance degradation. To overcome these problems, we propose STR that uses the neighbor table, originally defined in the ZigBee standard. In STR, each node can find the optimal next hop node based on the remaining tree hops to the destination. The mathematical analyses prove that the 1-hop neighbor information in STR reduces the traffic load on the tree links as well as provides an efficient routing path. The network simulations show that STR provides the comparable routing performance to AODV as well as scalability respect to the network density and the network traffic volume by suppressing the additional route discovery process. The performance analysis proved STR to be utilized in many ZigBee applications in smart grid wireless communication such as minimum delay, maximum efficiency and lifetime.

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