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Cluster Message Criticality Level Based ZigBee Opportunistic Routing for Smart Energy Home Area Networks

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***Abstract*—In wireless smart energy home area networks, thecluster message criticality level based zigbee routing(CMCLZR) has been proposed for routing the smart energy messages. It employs AODV and zigbee shortcut tree routing(ZSTR) independently for routing highly critical messages and normal messages respectively. As a result of broadcast nature, timevarying and lossy of wireless medium, unicast routing protocols like ZSTR have the basic drawback in wireless environment. On a routing path, even single lossy link may cause unsuccessful end-to-end packet delivery. Thus, this paper proposes Zigbee opportunistic shortcut tree routing(ZOSTR) that inherits the functionalities of both opportunistic routing and ZSTR to improve the reliable packet delivery by applying broadcast mechanism.Also, this paper proposes opportunistic CMCLZR(CMCLZOR)to employ ZOSTR in the place of ZSTR for inheriting the opportunistic feature. It permits all receiving neighbor nodes to compete in packet forwarding using the priority of left-over hops rather than designating a next hop node as in ZSTR. It shows that the significant enhancement in diverse routing performances by suppressing the duplicate forwarding by means of left-over hops and the singlehop neighbor table.**

***Index Terms*—cluster message, criticality level,opport-unistic, smart energy, shortcut tree routing, ZigBee.**

I. INTRODUCTION

ZigBee is one of the wireless personal area network standards for constructing Internet of Things (IoT) [1]. ZigBee spreads its application area to smart grid by linking tens of million devices [2]–[3]. Smart Energy Profile 2.0 [4]and Home Automation Profile [5] have defined ZigBee pro- tocol stack, different zigbee smart energy devices, interfaces and messages for the smart grid networking. In order to colle- ct real-time data from home area, numerous smart energy home area networks are used as the last hop of smart grid network [6]. These networks accomplish dynamic pricing, billing, statistical purposes, system control and load control by establishing the two smart energy services that are Advanced Metering Infrastructure (AMI) and Demand Res- ponse (DR)[7].

As specified in the ZigBee network specification [8], a set of cluster messages transactionsset up a smart energy service among the intended ZSEDs. For this, cluster message critic-ality level basedzigbee routing(CMCLZR)[9] protocol has been proposed. Depending upon the criticality levels specified in the cluster messages, CMCLZR is designed to either zigbee shortcut tree routing(ZSTR) or AODV for utili-zing their strategical routing advantages independently.ZSTR is an enhanced version of zigbee hierarchical tree routing(ZHTR)[9] that has improved the efficacy of multi-hop routing path and lightened the rigorous traffic load on tree links.Since ZHTR does not require any routing table and route discovery mechanism to forward a packet to the destination by using hierarchical address, it has considerableattention due to its resource-less multihop routing compet- ence. To retain the advantages of ZHTR in ZigBee, ZSTR employs the hierarchical addressing scheme and the single-hop neighbor table.

Due to broadcast, time-varying and lossy feature of wire- less medium, efficient and reliable unicast routing protocols have few shortcomings in wireless environment. These short- comings have been discussed in opportunistic routing (OR) protocols [10]–[12]. The OR protocols apply the cooperative diversity that yields benefit of broadcast nature of wireless medium for sending a packet via several forwardercandi- dates. Even though the OR protocols have potential to get better end-to-end reliability and bandwidth utilization, the significant challenges such as the selection of forwardercandidates and their prioritization must be treated. However, it needs more computational resources and communications to face these challenges [10] and cost must be reduced for resource-limited devices in zigbee networks.

In ZigBee, like ZSTR, the proposed zigbee opportunistic STR (ZOSTR) algorithm employs a routing measures that are determined with the leftover hops to the destination by hierarchical addressing scheme. However, instead specifying a next hop node, a sender node just broadcasts a packet and all receiver nodes play to forward a packet using the priority of the left-over hops. Hence, the node nearest to the destination among receiver nodes will be considered as forwardercandidate for forwarding a packet. Furthermore, the prioritization among the set of forwardercandidates is determined with the use of left-over hops and the single-hop neighbor table without using any isolated or centralized technique. Regardless of distributed technique, performance evaluation shows that the unnecessary packets be suppressed from the forwardercandidates efficiently. Thus, opportunistic CMCLZR(CMCLZOR)is proposed in this paper to use opportunistic feature of forwardercandidate selection by employing a combined version of OR and ZSTR instead using ZSTR simply.

Essentially, ZOSTR does not need any resources for discovery of routing path and getting prior knowledge for the selection of forwarder candidate. This nature enables the resource-limited zigbee device to make use of CMCLZORalgorithm and offers reliable and efficient packet

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delivery services. Particularly, OR based algorithm offers reliable end-to-end delivery service and shortens the end-to-end routing path that the receiver node takes a decision whether the packet be forwarded or not.

This paper is organized as follows: Section II presents a summary on the smart energy infrastructure used at residential levels. Section III gives an overview of zigbee tree routings and their problems. Section IV proposes the zigbee opportunistic shortcut tree routing algorithm. The diverse performances of tree routings are depicted in section V and section VI concludes this paper.

II. ZIGBEE ROUTING IN SMART ENERGY HAN

The Smart Energy Profile (SEP) 2.0 [4] and the Home Automation Profile [5] define zigbee protocol stack, interf-aces, clusters and more than 130 types of zigbee smart energy devices (ZSEDs) for establishing smart energy(SE) services in wireless SEHANs. Since each physical home appliances have a built-in software entity ZSED, they would become smart for offering energy and communication services. This section presents residential level communication infrastruc-ture and an overview on SE clusters that are required to per-form the smart grid objective functions of Advanced Meter-ing Infrastructure(AMI) and Demand Response(DR).

A. Smart Energy Home Area Networks(SEHANs)

In order to provide active participation of consumers, SEP has introduced a SE network infrastructure at the residential levels called *SE Network with Utility and Customer Sectors* [13] shown in Fig. 1. It is envisioned by the 8 types of ZSEDs that are *Energy Service Portal (ESP), Metering Device, In-Premise Display (IPD), Pre-payment Terminal Display, Load Control Device, Programmable Communicating Thermostat (PCT), Smart Appliances and Range Extenders*. The inten- sion of an ESP is to bridge the Utility Private SEHAN and the Utility via backhaul network as well as it acts as the in-charge of network coordinator that configures the network, respon- sive to its all constituent nodes and has a repository of security keys.

In order to extend the network range, reduce the network power consumption and increase the network life time, ZSEDs are configured as either *coordinator/router/end-device*. Further, Router and coordinator are *full function device (FFD)* while the end-device are *reduced function device (RFD)*. Since end-device is a RFD and it act as a leaf node in tree network, it requires limited memory and just to make interactions among an intended home appliances and parent nodes. In SEHAN, smart meter should be configured as coordinator and it is linked with a set of smart home appliances via one-hop network for acquiring the home information and transmitting it to the utilities. Other constit-uent nodes are configured as either router or end-device.

B. Clusters and Message Criticality Levels

In Smart Grid framework, ZSEDs are realized by 4 layered network stacks [14]. The SE Application present in the top most layer is capable of instantiating 240 application objects associated with a unique endpoint that acts as the I/O ports. Moreover, endpoints on a local ZSED can be able to interact

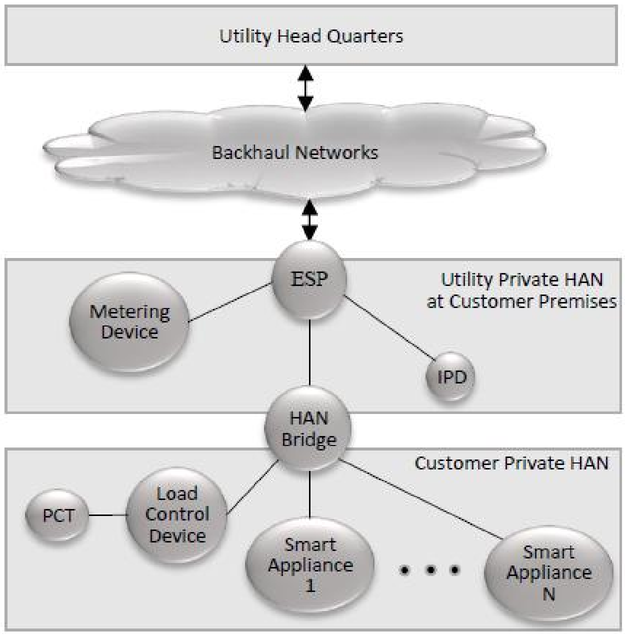

Fig. 1. SE Network with Utility and Customer Sectors

with endpoints on another remote ZSED. In SE networks, all application protocols employ the concept of clusters [13] for establishing the SE services. In order to increase the reusability and reduce the memory consumption during application run-time, an SE-cluster is instantiated by inheriting ZigBee-clusters and SEP-clusters.

For example, AMI uses the following clusters: *Price*, *Metering*, *Message*, *Demand Response*, *Key Establishment* and *Load Control* from SEP and *Identify*, *Time*, *Commissioning* and *OTA Upgrade* from ZigBee. In fact, an event of a SE service can be realized by transacting values of clusters' attribute between the client-server clusters of part-icipating ZSEDs. By handling the events among the SE clusters, objective functions of smart grid can be established in SE networks.

An essential objective function of smart grid, the Demand Response is introduced in smart grid networks to minimize the peak loads. In a real-time basis, DR shifts the load consumption by allowing the appliances to respond the dynamic condition on the grid. Actually, a specific function of DR that handle the number of pertinent events by means of message transactions between the client-clusters and server clusters that are reside within the participating ZSEDs. For conducting *Demand Response and Load Control*(DRLC) [13] in SE networks, participating ZSEDs have one server-side DRLC cluster and four client-side DRLC clusters.

For example, *Load Control Event*(LCE) is the one of important events initiated by the DRLC, actually, it starts from the utility and ends at appliances to schedule their consumption as temporary adjustments and the participations of appliances will be reported back to the utility via ESP. To execute an event, LCE have list of parameters that are *LCE-ID, Target device class and enrolment group, Start-time, Duration, Criticality level, Requiredadjustments and Rand-omization requirementsfor start/end time*.Particularly,*criticalitylevel* statesthe importance of cluster message being transmitted. Similar to LCE, every SE function handles several events and all such events must have criticality level

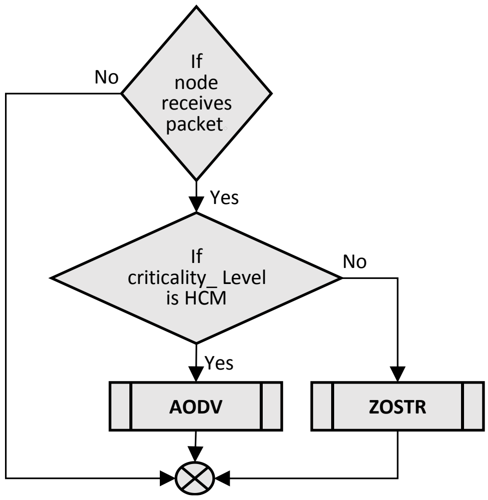

Fig. 2. Opportunistic CMCLZR(CMCLZOR)

in its parameter-list. On account of diverse criticality levels,a message classifier is addressed in [9]. It classifies the messages intoeither *Highly Critical Message (HCM)* or *Normal Message(NM)*.

C. Oppurtunistic CMCLZOR

Indeed, the criticality levels of cluster-messages greatly impact on efficacy of a smart grid functionalities [15]. Hence, Rajeshkanna B et al. [9] has proposed CMCLZR for routing the cluster-messages based on their criticality level in SEHANs. This routing mechanism addressed that HCM deliveries should require a routing protocol with high packet delivery ratio like AODV and a unicast protocol is highly enough for NM deliveries, since NM contains classic data only. Thus, CMCLZR uses AODV for HCM and ZSTR for NM to improve the reliability of routing by exploiting their advantages.

For smart grid applications, many researches [16]–[18] have employed Opportunistic Routing(OR) to neighborhood area network (NAN). In order to improve efficiency and relia-bility, Yoon et al. [16] proposed the OR-centered PLC routing, and Gormus et al. [17] have employed ORPL in AMI mesh networks. Despite a survey [18] says that no opport-unistic technique used in any zigbee routing protocols, different smart grid applications [2]–[3] use zigbee protocols. Since OR based tree routing does not require any resources to find routing path and obtaining prior knowledge for forwarder candidate selection, this paper proposes ZOSTR. Consequently, this paper proposes an opportunistic CMCLZR(CMCLZOR) that can provide reliable any-to-any routing in resource-limited devices, and it is suitable for wireless smart energy home area networks by deploying ZigBee devices.

The proposed CMCLZOREmploys ZOSTR for routing the NMs in SEHANs to achieve OR feature of forwardcandidate selection. Still it uses AODV for routing the HCMs. Fig. 2 shows CMCLZOR algorithm. It selects AODV if cluster-message contains HCM; otherwise it selects ZOSTR. However, practically NM transactions take 80-98%chances for a period of 24 hours during the establishment of different smart energy services.Thus, this paper shows more intention on evaluating ZOSTR and it is presented in section V.

III. ZIGBEE TREE ROUTINGS

Since the zigbee shortcut tree routing (ZSTR) algorithm paved the foundations for the proposed algorithm, this section presents an overview of zigbee unicast protocols ZHTR and ZSTR and lists their difficulties in wireless networks.

A. ZigBee Hierarchical Tree Routing(ZHTR)

ZHTR is aimed at resource-limited zigbee devices for delivering the packets to the destination through multi-hop routing path. It counteracts to the route discovery overhead in both bandwidth and memory by means of the hierarchical bl-ock addressing structure(HBAS) explained in (1) and (2) [8]. The definitions of *Cm(nwkMaxChildren), Rm(nwkMaxRou-ters)* and*Lm(nwkMaxDepth)* are the maximum number of children for a parent node, the maximum number of routers for a parent node as children and the maximum tree level of a network respectively.

$$Cskip(d)=\begin{cases}1+C_m\cdot(L_m-d-1), & if\ R_m=1,\\ \dfrac{1+C_m-R_m-C_m\cdot R_m^{L_m-d-1}}{1-R_m}, & otherwise\end{cases} \quad (1)$$

$$A_k = A_{parent} + Cskip(d)\cdot(k-1)+1 \quad (1\le k\le R_m), \quad (2)$$

$$A_n = A_{parent} + Cskip(d)\cdot R_m + n \quad (1\le n\le C_m - R_m) \quad (3)$$

$$A_k < A_n < (A_n + Cskip(d-1)) \quad (4)$$

As shown in Fig. 3, the HBAS, pre-assigns the network address space at each level of tree. As the tree level increases, the network space is split recursively. At tree level *d,* the *Cskip(d)* in (1) calculates the size of address space allocated by each router node. It covers the *Rm* number of router-capable children and (*Cm-Rm)* number of end devices. Thus, the size of *Cskip(d)* is same as *Rm· Cskip(d+1)+ (Cm-Rm)+1*. At tree level *d,* the parentallocates the network address for each k router-capable child and n end device as explained in (2) and (3) with the help of *Cskip(d)*. If the address of a node satisfies (4), then the target node is descendant of source node or intermediate node [8]. Thus, ZHTR sends the packet to one of its children when the destination is descendant, else, it sends to its parent.

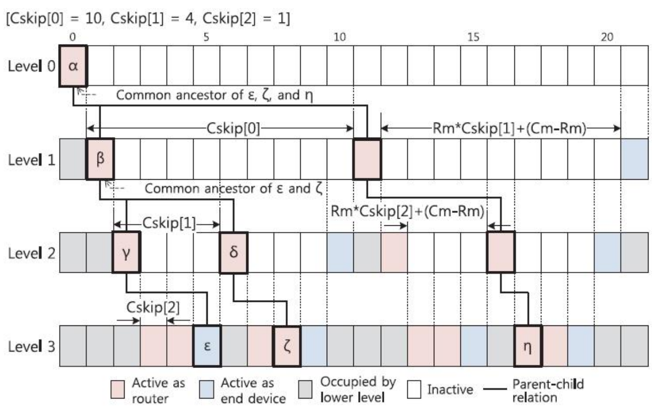

Fig. 3. Hierarchical Block Addressing Structure(HBAS)

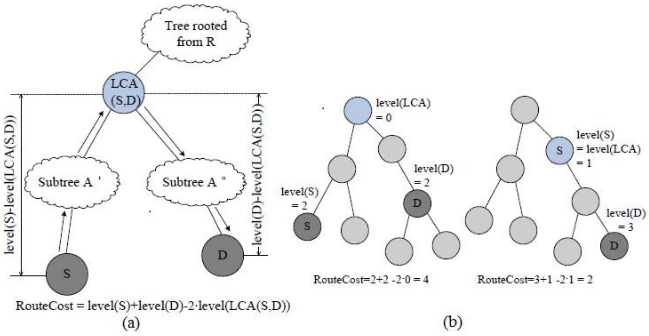

Fig. 4. Calculation of ZigBee tree routing cost between a source and a destination

B. Zigbee Shortcut Tree Routing(ZSTR)

In order to mitigate the packet detour problem in ZHTR, Rajeshkanna et al [9] has proposed ZSTR. Despite ZSTR follows ZHTR, it can select a next hop node among the neighbor nodes with less number of left-over hops to the destination. In fact, the ability to compute the left-over hops towards the destination is the key idea of ZSTR. In a tree topology as shown in Fig. 4(a), the routing cost between source node *S* and destination node *D* can be computed with *level(S)*, *level(D)*, and *level(LCA(S, D))*, where *level(x)* and *LCA(S, D)* are the tree level of node *x*and the lowest common ancestor between *S* and *D* respectively. However, the packet from the *S* reaches *LCA(S, D)* viathe parent nodes irrespec-tive of subtree *A'* then the packet are directed towards the subtree *A''* and goes down via the child nodes to reach the*D*. Since the left-overhops from source *S* to *LCA(S, D)* and from *LCA(S, D)* to destination *D* can be computed using difference of tree levels, the tree routing cost from S to D can be found by equation '*level(S)+level(D)-2·level(LCA(S,D))*'.Fig. 4 (b) describes an example of routing cost computation in a tree between the given *S* and *D*.

Fig. 5. shows the algorithm to compute left-over hops between *S* and *D*, where *A(u)* is defined as {*A(u, i)* | *A(u, i)* is the network address of *u*'s ancestor at tree level *i*,*i*≤*level(u)*}.

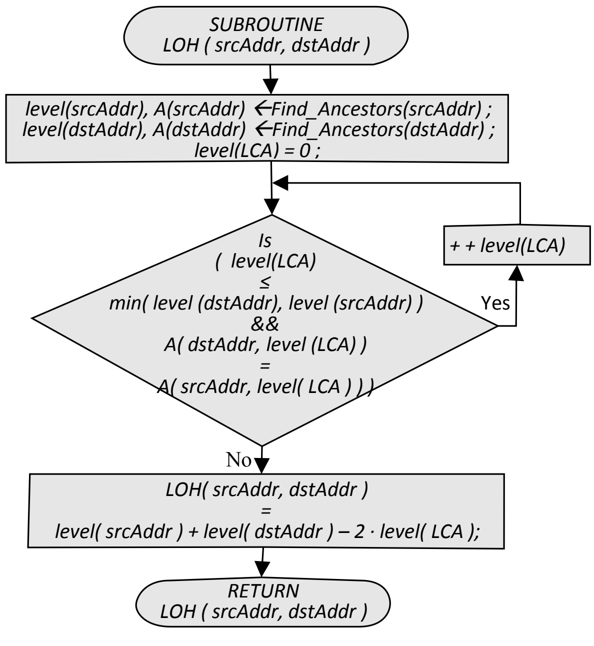

Fig. 5. Left-Over Hops Calculation Algorithm

As described in [9], function *Find_Ancestor(devAddr)* comp-utes the network addresses of ancestors at each treelevel as well as the tree level for agiven *devAddr*. ZSTRselects a neighbor as the next hop node that has the minimum left-over hops towards the destination, then it transmits a packet to the next hop node; However, if there is no neighbor node,ZSTR selects the parent or the direct children as the next hop node similar to ZHTR. An analysis on ZSTR [9] proves that it attains the comparable performance with AODV in all network conditions such as network configuration, traffic and density.

C. Difficulties of ZHTR and ZSTR

A number of works on OR in wireless ad-hoc networks [11]–[13] have addressed that the unicast routing protocols such as ZHTR and ZSTR have difficulties in wireless envir-onment.First, even single lossy wireless link on a path cause the failure of the end-to-end packet delivery, since wireless link is lossy and time-varying [19]. Mainly, unicast routing chooses one routing path. Hence, it is extremely possible to drop a packet in vulnerable link or trafficcongestion circumstances.Second, wireless medium does not allow sim-ultaneous transmission, therefore most of neighbor nodes should not transmit packets in order to avoid interference during the packet transmission even though a sender desig-nates a next hop node in unicast routing protocol. In the case of a nominated next hop node misses a packet, neighbor nodes simply drop the received packet. To surpass these inabilities, the OR algorithms [11]–[13] have suggested that the neighbor nodes participate in packet forwarding, consequently, OR have increased channel utilization, throughput as well as thereliability of end-to-end packet delivery.

IV. OPPORTUNISTIC ZSTR(ZOSTR)

This section proposes Opportunistic Zigbee Shortcut Tree Routing(ZOSTR) to solve the problems of ZHTR and ZSTR by applying the OR technique. Unlike the ZSTR that selects a next hop node, ZOSTR broadcasts a packet from the sender node and receiver nodes make a decision whether to forward the packet or not. Both ZSTR and ZOSTR use tree routing cost as arouting metric. As described in Fig. 4, the tree hop distance from a particular node to the destination can be easily computed by examining thehierarchical addressing structure in ZigBee. Thus, the ZOSTR protocol does not need routing table and route discovery overhead to transmit a packet to the destination. Indeed, it is distinguished feature compared with other OR protocols [20]-[23].

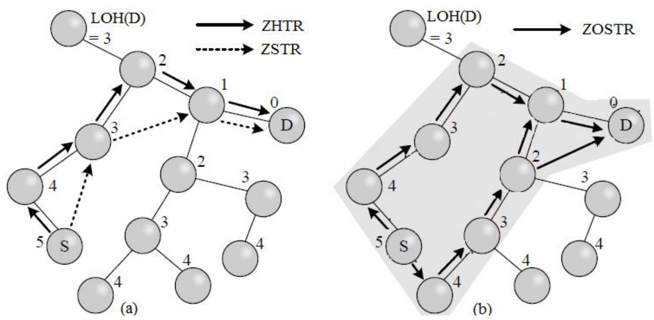

Fig. 6. Inspiration of opportunistic ZSTR(ZOSTR)

Fig. 6 gives an inspiring example of ZOSTR, where a distinguished feature compared with other OR protocols [20]–[23]. *LOH(x)* is meant as the left-over hops to the destination from a node *x*. Since the next hop node is chosen by a sender node in both ZHTR and ZSTR, a routing path cannot be altered even there occurs lossy link or traffic congestion as shown in Fig. 6(a). In contrast, the routing path of ZOSTR in Fig. 6 (b) can be alterable on the basis of link and traffic condition.The nodes inner the gray area in Fig. 6 (b) are forwarder-candidates,suppose a source *S* sends a packet to the destination *D* and the forwarders are selected accordingto the packet reception and the priority of left-over hops to the destination. Due to active involvement of neighbor nodes, ZOSTR can get better reliability of packet delivery and efficiency of channel utilization.The core burden of ZOSTR is how to lessen the packets from the multiple forwarder-candidates and how to minimize the end-to-end latency. In order to handle this issue in ZOSTR, the overhearing and cancellation mechanism are adapted based on the left-over hops to the destination.

A. ZOSTR Algorithm

To inherit the OR feature for ZOSTR, a node broadcasts to forward a packet, and all the receiver nodes take an oppor-tunity to forward this packet. Also, the receiver nodes get the priority on the basis of left-over hops get the destination so as to limit the number of replica packets from forwardercandid-ates.ZOSTRalgorithm is explained in Fig. 7 from the view point of an intermediate node or a destination, since a source node just broadcasts a packet. Note that variables *s*, *x*, and *d*are the network addresses of a source node, a receiver node, and a destination node respectively. If *x* receivesa packet for the first time then it examines whether *x* is an inter-mediatenode or a destination node. If *x* is an intermediate node, it compares the remaining hops (LOH) to the destination from itself and from the previous sender *s*, where *LOH(x)* is calculated using the algorithm shown in Fig. 5 as in ZSTR. The intermediate node that has less number of left-over hops turns into forwarder-candidate. That is to say, it sets broadcast timer proportionally to the length of left-over hops, allowing the nodes with the lesser left-over hops to get greater priority for forwarding a packet. Consequently, before timer expires, if it overhears the same packet then the packet transmission is canceled. Since it is chance that there occur more than one node withthe equal left-over hops,the quantity of timer is randomly selected within*(LOH(x, d) -1, LOH(x, d))-δ* to get around the collision, where *δ* is minimum duration for reliable forwarding. As soon as an intermediate node *x* forwards a packet, it sets timer again until *retryCnt* equals to *maxRetry* for the intention of retransmission. This retrans-mission process is stopped by the rebroadcasting from the node with the lesser left-over hops than *x*, since the rebroadcast packet can be taken as an acknowledgement. For the similar reason, even received packet is destined to *d*,itrebroadcasts the packet as an acknowledgment.

B. Example of ZOSTR

Fig. 8 presents an illustration of an end-to-end routing path suppose source node *S* sends a packetto the destination*D*.Assume that nodes *A*, *C*, and *D* in Fig. 8(a) receive abroad-

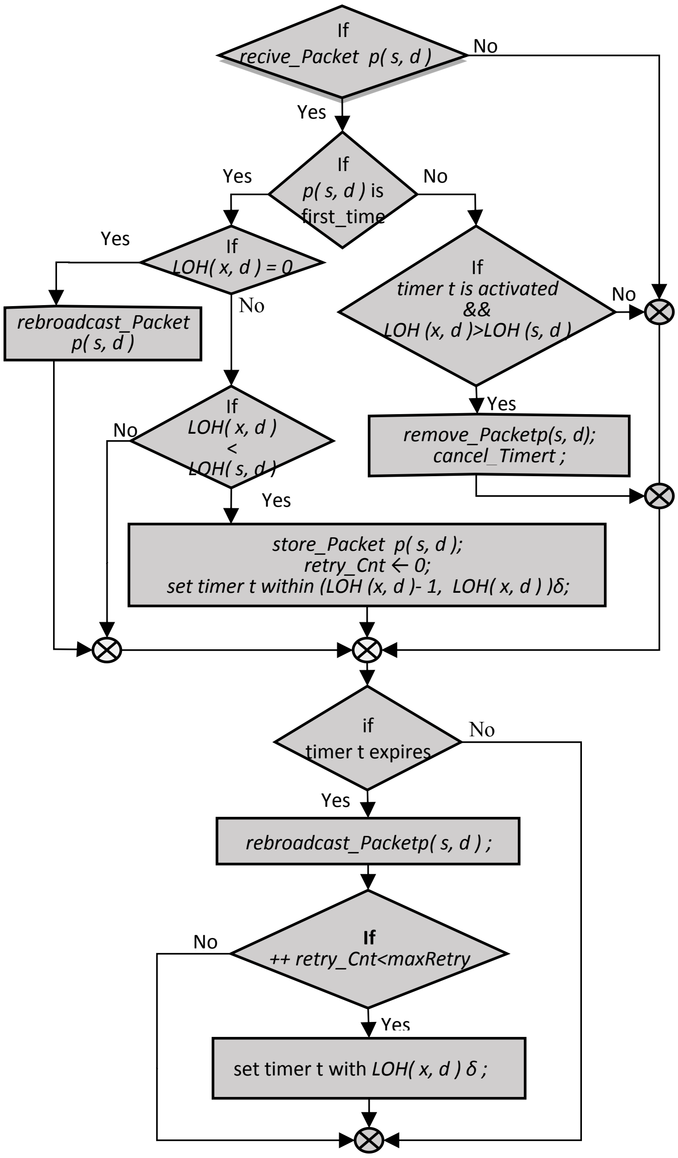

Fig. 7. Zigbee Opportunistic Shortcut Tree Routing Algorithm

cast packet sent by *S*, but node *B* fails. While node *C* and *D* set random delay between [2·δ, 3·δ], and node A sets random delay between [3·δ, 4·δ]. As shown in Fig. 8 (b), since node *C* re-broadcasts the packet at first, node *A* and *D* terminate the timer to forward the packet. At the same time, source *S* also terminates the timer set for retransmission, because *S*consi-ders the packet from *C* as an acknowledgement. Further, node *E*, *G*, and *H* set timer with random delay to forward the received packet, but H forwards the packet in advance than others, since it has the least left-over hops to the destination. As shown in Fig. 8(c), finally the packet is arrived at the destination, and it stops the forwarding process of *E* and *G*. However, the destination rebroadcasts the packet as in Fig. 8(d) so as to notify *H* that it received packet well, and it is different from the unicast centered ZSTR algorithm.

The inherent nature of the ZOSTR is that there are number of forwarder candidates along the routing path that enhance the packet delivery ratio against failures of particular nodes

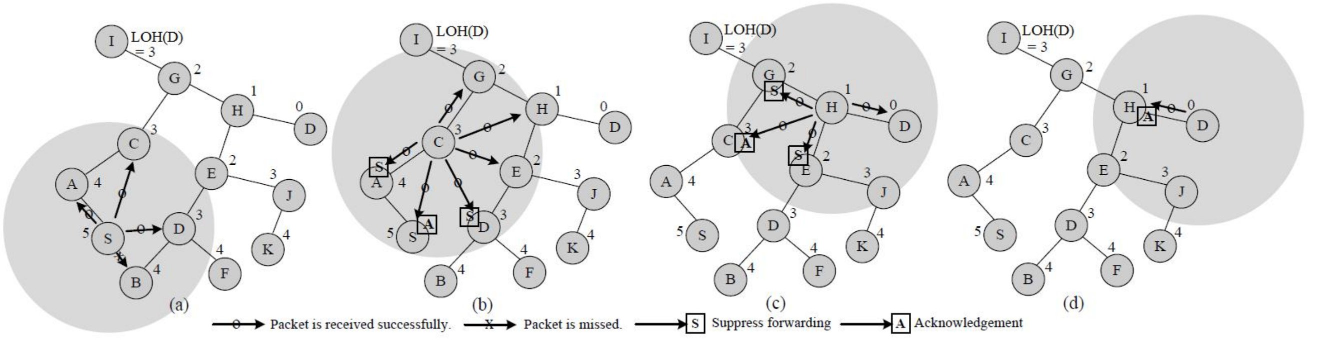

Fig. 8. Example of ZOSTR

along the path. A detailed discussion on the number of forwarder-candidates and the packet delivery ratio is given in succeeding section.

V.PERFORMANCE EVALUATION

This section evaluates the ZOSTR in diverse metrics on the routing performance and overhead compared with ZHTR and ZSTR. For the purpose of evaluation, network simulations are made with NS 2.0 using IEEE 802.15.4 PHY/MAC protocols and the parameters used in simulations are listed in Table I. As shown in Fig. 9, there are 145 zigbee nodes are deployed with address assigned by HBAS for simulating the ZOSTR, ZSTR and ZHTR protocols. Each simulation starts the association procedure during 0-50sec randomly and ends at 50sec after assigning the network address for all nodes. In all simulative scenarios, communication pair(source, destinat-ion) selections are made at random. Also, any-to-any traffic pattern is followed in all application sessions. Application sessions start during80-180secs and they end during 280-330secs randomly. Further, all the outcomes of the simulative scenariosarebased on successfully delivered packets and all the values recorded in Fig.10 are the average metricswith respect to the number of sessions.

The*packet delivery ratio(pdr)* is declined as the number of traffic sessions increases as shown in Fig. 10(a), and it is natural in that collision and congestion of packets increase. It is bit surprising to note that the *pdr* of ZSTR decreases to 73% in 80 number of traffic sessions despite the shortest path. In contrast, ZOSTR shows 84% *pdr*for the same 80 traffic sessions. It evidences that the OR protocol offers reliable communication via various number of candidate paths.

The end-to-end hop count is determined from the succ-essfully delivered path and it shown in Fig. 10(b). It is observed that ZOSTR shows an improvement with 26% less hop count than in ZSTR. The major reason is that the receiver nodes decide the next hop nodes in ZOSTR. But, the hop count in ZOSTR converges with ZSTR when the number of traffic sessions rises. Because the nodes in the shortest path not to overhear the packets due to traffic congestion. However, the other nodes in alternative paths take part in packet forwarding.

TABLE I
SIMULATION PARAMETERS

Simulation Parameters	**Value**
Network Area	80m X 80m
Number of Nodes Deployment Type Position of PAN Coordinator Number of Iterations	145 Random Center 15
PHY/MAC Protocol	IEEE 802.15.4
Propagation Model Max. Rx range Max. Carrier Sensing Range	Two-Ray Ground 25m 30m
Network Protocol	ZOSTR/ZSTR/ZHTR
Lm/Rm/Cm Association Duration	8/7/7 0-50 sec
Application Session Communication Pair Selection Packet Type Packet Interval Session start and end time	 Random CBR 1 packet/sec 80-180/280-330 sec
Traffic Type	Any-to-Any
Number of Sessions	20, 40, 60 and 80

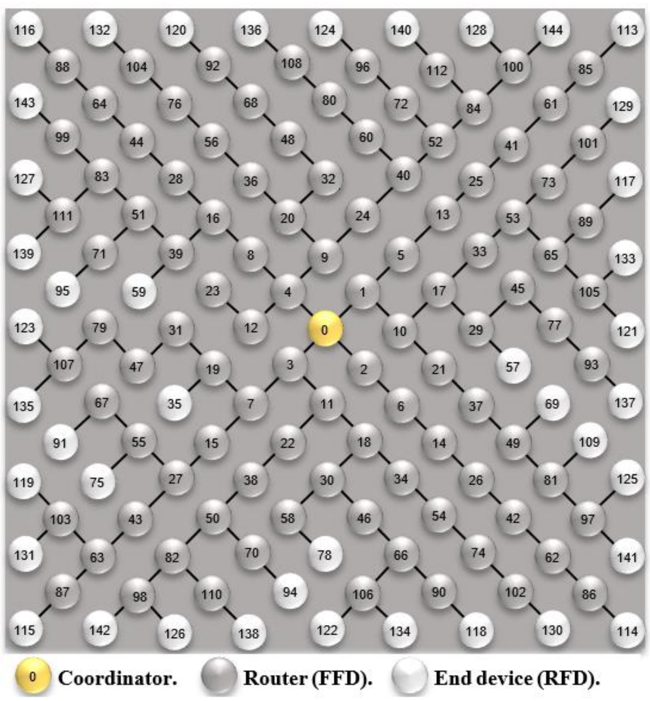

Fig. 9. Deployment of nodes and Network Configurations (145 nodes, Lm = 8, Rm = 7, Cm = 7)

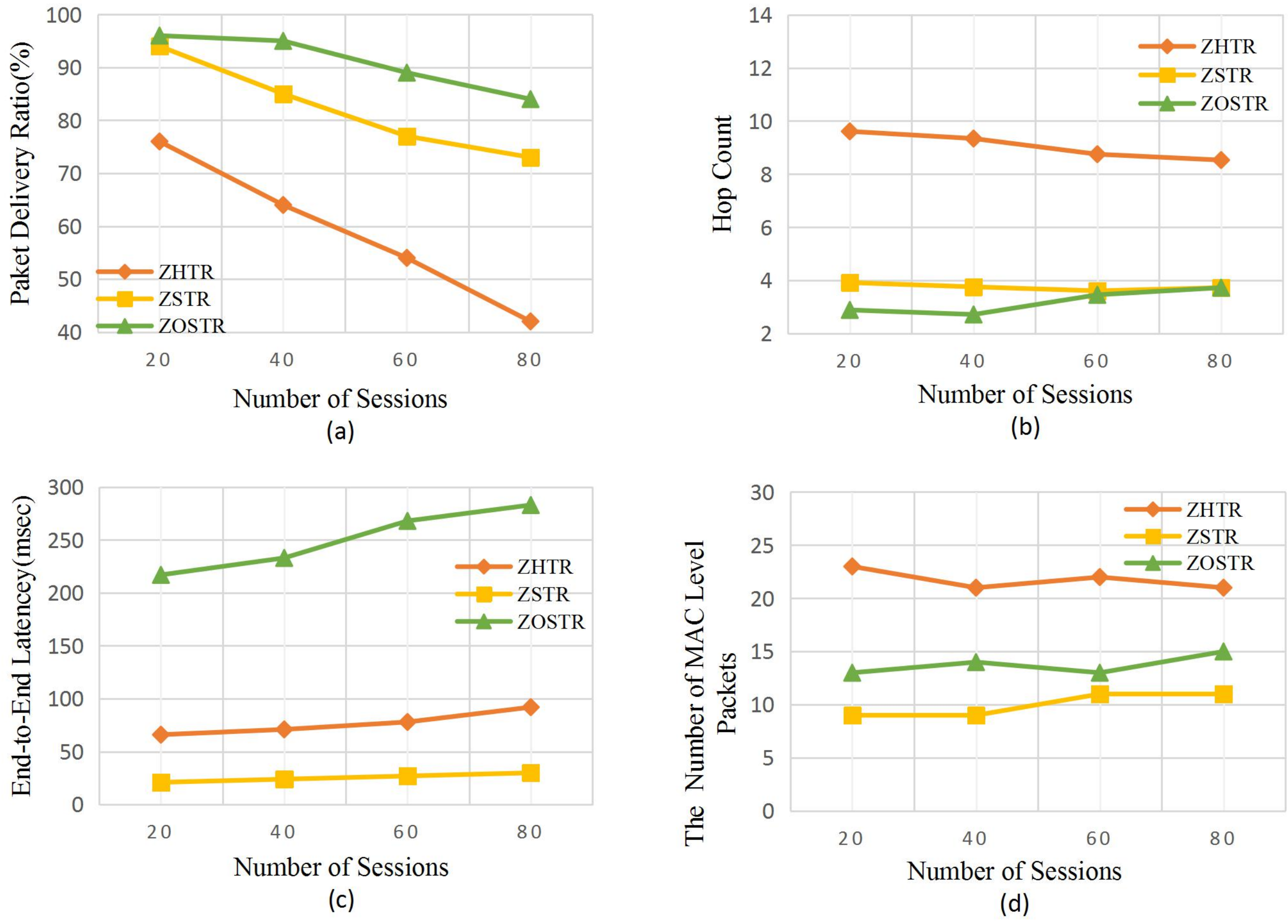

Fig. 10. Routing performance and overhead for the network traffic load (a) packet delivery ratio b) hop count (c) end-to-end latency (d) number of MAC level packets per session.

Fig. 10(c) evaluates the end-to-end latency. ZSTR attains thesmallest end-to-end latency and registers constant latencyregardless of the number of sessions. Reason for that ZSTR offers no queueing delay during packet forwarding. Also, ZHTR does not need any queuing delay, but it spends three times delay more as in ZSTR due to the detour routing path. In contrast, both ZOSTR require long end-to-end latency compared with ZHTR and ZSTR. The key reason for extended latency is the hop delay is spent to prioritize the forwarder-candidate nodes. That is to say, intermediate nodes compete within the assumed δ in ZOSTR algorithm. In this simulation δ is set as 10msec. Hence, the delay for packet forwarding is related to the left-over hops to the destination, and it is assumed with lesser value as it goes close to theto the destination. However, such extended end-to-end latency is unavoidable feature of the OR algorithms.

Fig. 10(d) depicts the total number of MAC level packets for the successfully delivered packets, that include data, acknowledgement and retransmitted packets. It is observed that the total number of packets increases as the number of traffic sessions increases in all protocols. Because of increased congestion and collision trigger the retransmission of data packets. It is surprising to know that ZHTR and ZSTR use acknowledgement packet, whereas ZOSTR does not use acknowledgment packet. Thus, Fig. 10(d) specifies that ZOSTR requires higher number of data packet transmissions than unicast routings.

VI CONCLUSION

This paper proposed the opportunistic routing technique on ZSTR that does not need any route discovery overhead. The existing opportunistic routing protocols need extra route discovery or prior knowledge to limit the number of forwarder-candidates, while the ZOSTR does not force any overhead to locate route path and forwarder-candidate selection. Furthermore, ZOSTR branches out multiple paths towards the destination and goes for the optimal path in accordance with the channel condition. The performance evaluation shows that the ZOSTR attains reliable packet delivery together with moderate end-to-end latency. Therefore, ZOSTR replaces ZSTR in proposed CMCLZOR to inherit the OR feature of forwarder-candidate selection. Thus, the proposed CMCLZOR to be utilized in wireless smart energy home area networks by demanding both less resource facility and high routing performances.

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