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DIRECTIONAL OPPORTUNISTIC MECHANISM IN CLUSTER MESSAGE CRITICALITY LEVEL BASED ZIGBEE ROUTING

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ABSTRACT

The cluster message criticality level based zigbee routing(CMCLZOR) has been proposed for routing the cluster messages in wireless smart energy home area networks. It employs zigbee opportunistic shortcut tree routing(ZOSTR) and AODV individually for routing normal messages and highly critical messages respectively. ZOSTR allows the receiving nodes to compete for forwarding a packet with the priority of left-over hops rather than stating single next hop node like unicast protocols. Since it has inherited benefits of both opportunistic routing and ZSTR, it can offer reliable packet delivery service without any resources for unicast routing and forwarder candidate selection for opportunistic routing. However, ZOSTR has many forwarder candidates on a path in a lossy wireless environment despite the failure of particular node on a path. To detach the out-of-sight forwarder candidates from routing, this paper proposes zigbee directional opportunistic shortcut tree routing (ZDOSTR). It confines the forwarder candidates space along the direction towards the destination to forward the packet by forwarder candidates with minimum left-over hops of single-hop neighbors. The performance evaluation shows that the directional opportunistic approach considerably improves different network performances than ZOSTR by suppressing replicas from out-of-sight terminals efficiently. Thus, this paper also proposes directional opportunistic CMCLZR(CMCLZDOR) that replaces ZOSTR by ZDOSTR for routing normal messages.

KEYWORDS: Directional, HAN, Opportunistic, Routing, Shortcut, Smart Energy, Tree, Zigbee.

I. INTRODUCTION

Zigbee is one of the wireless personal area network standards spreads its application area to smart grid by linking tens of million devices [1]–[2]. For smart grid networking, Smart Energy Profile(SEP) 2.0 [3] and Home Automation Profile [4] have defined ZigBee protocol stack, different zigbee smart energy devices(ZSEDs), interfaces and messages. In order to collect real-time data from residential area, numerous home area networks are used as the last hop of smart grid networks [5]. Exclusively, two smart grid functions Advanced Metering Infrastructure (AMI) and Demand Response (DR) [6] that accomplish dynamic pricing, billing, statistical purposes, system control and load control. Basically, a number of messages transactions among the diverse smart energy applications to establish various services of AMI and DR in smart grid networks. Actually, these services work around a set of clusters that are defined by the ZigBee network specification [7]. Therefore, different cluster message transactions and their criticality levels greatly impact on routing protocol performances. Hence, *Rajeshkanna.B et al.*, [8] has been proposed cluster message criticality level based zigbee opportunistic routing(CMCLZOR) for zigbee smart energy home area networks. It employs AODV for highly critical messages and zigbee opportunistic shortcut tree routing(ZOSTR) for normal messages.

This paper shows intention to reduce the forwarder candidates in ZOSTR for increasing the channel utilization. ZOSTR use routing measures that are calculated by leftover hops to the destination using hierarchical addressing method. However, a sender node just broadcasts a packet and all receiver nodes play to forward a packet without assigning a next hop node as in zigbee shortcut tree routing(ZSTR) [9]. Thus, the node nearest to the destination among all receiver nodes can be designated as forwarder candidate. In fact, left-over hops decide the priority of forwarder candidates. Thus, no resources are desired by the ZOSTR to discover the routing path and no preceding information is required for the selection of forwarder candidate. The inherent feature of the ZOSTR is that many forwarder candidates available on a path and it improves the packet delivery ratio beside the failures of nodes on a path. In this paper, directional ZOSTR (ZDOSTR) is proposed to confine the area of forwarder candidates by using the minimum left-over hops of single-hop neighbors. The performance evaluation shows that the directional

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opportunistic approach considerably enhances diverse network performances by suppressing redundant packets forwarding efficiently with a metric of the left-over hops and the single-hop neighbor table. Therefore, ZDOSTR replaces ZOSTR in CMCLZOR and this directional CMCLZOR named as cluster message criticality level based zigbee directional opportunistic routing (CMCLZDOR).

This paper is organized as follows: Section II presents an overview of residential level smart energy infrastructure. Section III proposes the ZDOSTR algorithm. Section IV depicts the diverse performances of tree routings and this paper is concluded in section V.

II. SMART ENERGY HOME AREA NETWORKS

This section presents a residential level smart energy(SE)network infrastructure that paves a platform to exercise the smart grid objective functions namely Advanced *Metering* Infrastructure(AMI) and Demand Response(DR). In order to encourage the dynamic participation of energy consumers, SEP has introduced a network infrastructure at residential levels [10] as shown in Fig. 1. It is envisaged by the 7 different types of ZSEDs that are *Energy Service Portal (ESP), Load Control Device, In-Premise Display (IPD), Pre-payment Terminal Display, Progr-ammable Communicating Thermostat (PCT), Range Extenders and Smart Appliances*. In these, ESP acts as network coordinator that configures the network and maintains a security key repository. In order to prolong the network life time, all network constituent nodes are configured as either *coordinator/router/end-device* depends their networking responsibilities. In addition, coordinator and router must be *full function device (FFD)* while the end-device may be *reduced function device (RFD)*. Since end-device just links a home appliance and its direct parent node, it requires limited memory. In smart energy home area networks(SEHAN), coordinator have smart meter application that links all smart home appliances via one-hop network to collect home data and it transfers home data to the utilities and vice-versa.

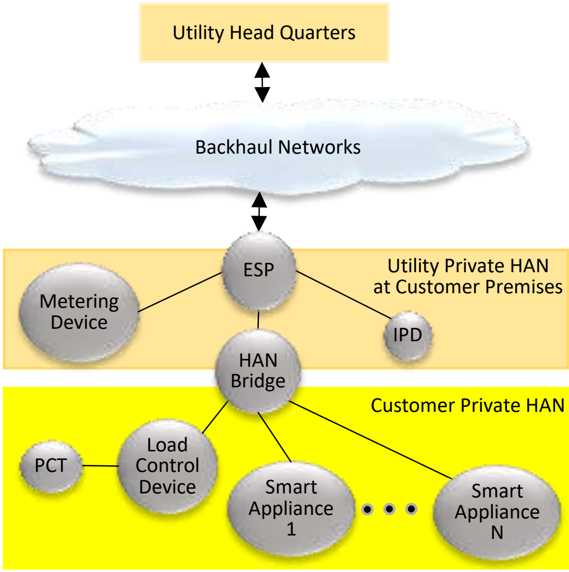


Fig. 1. SE Network with Utility and Customer Sectors

A. SE Clusters and Messages

In zigbee deployed SEHAN, ZSEDs are realized by 4 layered network stacks [11], in which the top most application layer employ cluster concept [10] to provide various SE services. For example, AMI applications are instantiated by inheriting the various clusters. For that, SEP has defined the following clusters: *Price*, *Metering*, *Message*, *Demand Response*, *Key Establishment*, *Load Control* and Zigbee has defined following clusters: *Identify*, *Time*, *Commissioning* and *OTA Upgrade*. In fact, an AMI service can be realized by the number of sequential events that transacts attribute values of various clusters among the client-server clusters of participating ZSEDs. The intention of DR is included in smart grid framework is to minimize the peak loads. Indeed, DR shifts the load consumption in real-time basis by allowing the appliances to respond the dynamic condition on the grid. Actually, various DR services can be realized by handling a number of related events with transacting various cluster messages among the client-clusters and server clusters that are reside within the participating ZSEDs. In particular, a DR function named *Demand Response and Load Control* (DRLC) [10] that instantiates 1 server-side DRLC cluster and 4 client-side DRLC clusters in all participating ZSEDs. For example, *Load Control Eent* (LCE) is the one of important events initiated by the DRLC, actually, this event 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. A parameter, *criticality level* is intentionally included in parameter list of LCE that states the importance of cluster message being transmitted. Similarly, all SE events must include *criticality level* in its parameter-list. On account of diverse criticality levels, a message classifier is modelled in [9] that classifies the messages into either *Highly Critical Message (HCM)* or *Normal Message(NM)*.

B. Directional Opportunistic CMCLZR(CMCLZDOR)

Indeed, the criticality levels of cluster messages significantly impact on effectiveness of a smart grid functions [12]. Hence, Rajeshkanna B et al. [8] has proposed CMCLZOR for forwarding the cluster messages to the destination based on their criticality level. This routing protocol suggested that HCM deliveries must need a routing protocol with high packet delivery ratio like AODV but NM deliveries need just ZDOSTR that requires limited resources for routing. Thus, this paper proposes directional opportunistic CMCLZR (CMCLZDOR) to provide reliable any-to-any routing through resource-constrained devices and it is highly compatible to wireless SEHANs.

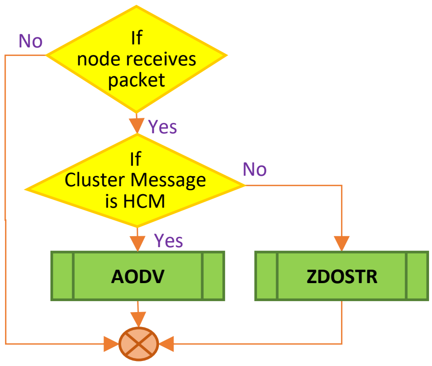


Fig. 2. Directional Opportunistic CMCLZR (CMCLZDOR)

The proposed CMCLZDOR utilizes ZDOSTR for routing the NMs by detaching the out-of-sight forward candidates and allows directional forward candidates only to compete in packet forwarding. Still CMCLZDOR uses AODV for routing the HCMs, since AODV has more pocket delivery ratio than all other zigbee tree routings. Fig. 2 shows CMCLZDOR algorithm. It selects AODV if cluster message is HCM; otherwise it selects ZDOSTR. Perhaps, NM transactions take 80-98% chances for a period of 24 hours SE services. Hence, this paper put more concentration on evaluating ZDOSTR.

III. ZIGBEE DIRECTIONAL OSTR(ZDOSTR)

This section proposes Zigbee Directional Opportunistic Shortcut Tree Routing (ZDOSTR) to solve the redundant packet transmission from out-of-sight terminal problem of ZOSTR. However, both ZOSTR and ZDOSTR utilize tree routing cost as routing metric. In ZigBee, just inspecting the hierarchical block address of a node, the tree hop distance from that node to the destination can be easily computed. Thus, the ZDOSTR protocol does not have route discovery overhead and any routing table to transmit a packet to the destination. Indeed, it is a prominent feature compared with other Opportunistic Routing (OR) protocols [13]-[16].

A. Routing Cost Calculation

In a tree topology as shown in Fig. 3(a), the routing cost between source node *S* and destination node *D* can be determined with the help of hierarchical block addressing structure(HBAS) [9].

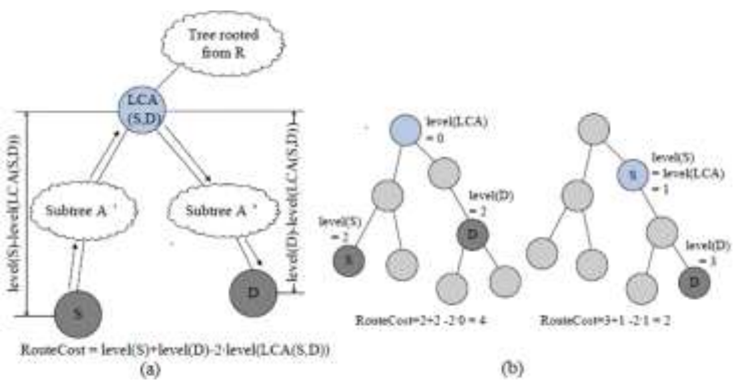
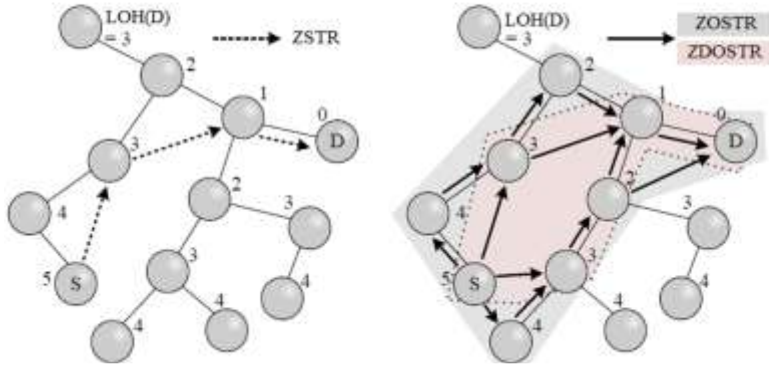


Fig. 3. Calculation of ZigBee tree routing cost between a source and a destination.

Using *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 [9] .However, the packet from the *S* reaches *LCA(S, D)* via the parent nodes regardless of subtree *A'* then the packet are guided to the subtree *A''* and go down via the child nodes to arrive *D*. Since the left-over hops from source *S* to *LCA(S, D)* and from *LCA(S, D)* to destination *D* can be calculated by the difference of tree levels, the tree routing cost from S to D and it can be found by the equation '*level(S)+level(D)-2·level(LCA(S,D))'*. Fig. 3 (b) depicts an instance of routing cost calculation in a tree between the given *S* and *D.*

B. Inspiration of ZDOSTR

Fig. 4 shows an inspiring example of DOSTR, where *LOH(x)* is denoted as the left-over hops to the destination from a node *x*. Actually, the next hop node in ZSTR is decided by a sender node; thus, a routing the contrary, the routing path of ZOSTR can be adjustable according to the link and traffic condition [8] as shown in Fig 4(b). The nodes inside the gray area in Fig. 4 (b) are forwarder candidates assuming a source S transmits a packet to the destination D, and forwarders are dynamically selected based on packet reception and the priority of left-over hops to the destination.



(a) ***(b)***

Fig. 4. Inspiration of opportunistic ZSTR(ZOSTR)

The key idea of ZOSTR is how to reduce the packets from the multiple forwarder candidates and how to reduce the end-to-end latency from a source to the destination node. For that, ZOSTR has adapted overhearing and cancellation tool based on the left-over hops to the destination in order to handle this issue. The intention of proposing the ZDOSTR is to restrict the area of forwarder candidates by utilizing the minimum left-over hops of 1-hop neighbors and node itself. The nodes within the pink area in Fig. 4(b) are the forwarder candidates by ZDOSTR. Hence, ZDOSTR can reduce the number of forwarder candidates compared with ZOSTR by considering the direction of a packet to the destination. Due to dynamic participation of neighbor nodes, ZDOSTR can improve the reliability of packet delivery as well as efficiency of channel utilization. It is noteworthy that ZDOSTR resembles the ZSTR as shown in Fig 4(a) with less number of candidate nodes.

C. ZDOSTR Algorithm

Zigbee directional OSTR (ZDOSTR) is a modified version of ZOSTR from a vision of decreasing end-to-end latency and redundant data transmission. For that, it confines the area of forwarder candidates by applying the minimum left-over hops of single-hop neighbors. Algorithm of ZDOSTR is explained in Fig. 5 from an intermediate node or a destination, since a source node merely broadcasts a packet. Note that the notations *s*, *x*, and *d* are the addresses of a source node, a receiver node, and a destination node respectively. To ease the implementtation of ZDOSTR, each packet header encapsulates a new field named *minimum Left-over Hops* (*minLOH*) and it will be updated by each forwarder candidate node *x*, where *LOH(x)* is calculated by an algorithm that has been proposed in [8]. If *x* receives a packet for the first time then it examines whether *x* is an inter-mediate node or a destination node. If *x* is an intermediate node, it compares the left-over hops to the destination from itself and from the previous sender *s*. The intermediate node that has minimum left-over hops turns into forwarder candidate and updates the minimum left-over-hops field in packet header. That is to say, it sets broadcast timer proportionally to the length of left-over hops, allowing the nodes with the minimum left-over hops to forward the 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 with the equal minimum 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 retransmission process is stopped by the rebroadcasting from the node with the more left-over hops than the value of *minLOH* of packet header, since

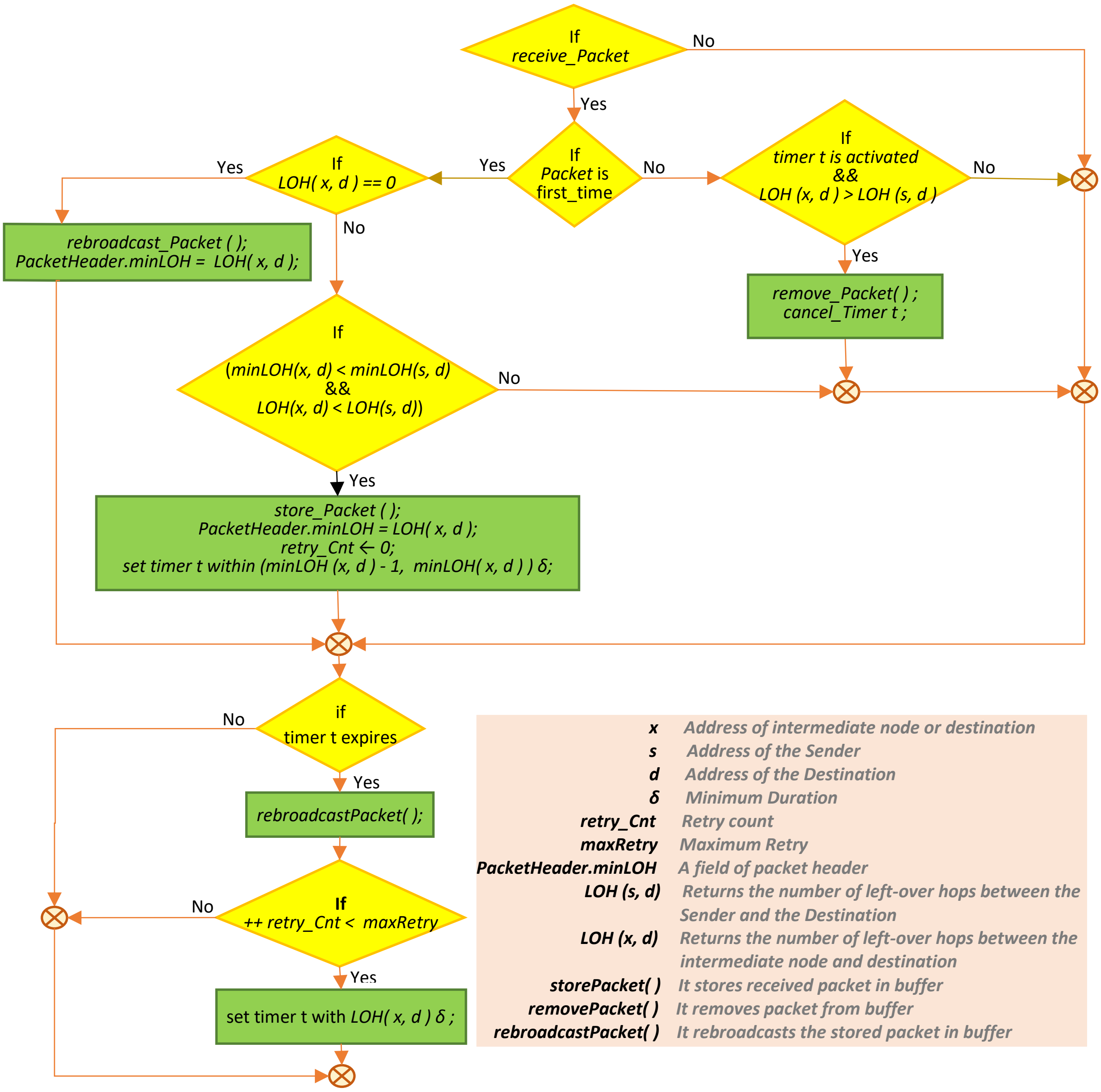


Fig. 5. Zigbee Directional Opportunistic Shortcut Tree Routing (ZDOSTR) Algorithm

the rebroadcast packet can be taken as an acknowledgement. For the same reason, even received packet is destined to *d*, it rebroadcasts the packet as an acknowledgment. node with the more left-over hops than the value of *minLOH* of packet header, since the rebroadcast packet can be taken as an acknowledgement. For the same reason, even received packet is destined to *d*, it rebroadcasts the packet as an acknowledgment.

D. Example of ZDOSTR

In this subsection, ZDOSTR is described with the help of an example in a vision of reducing end-to-end latency and unnecessary data transmission. Say that B receives the packet while D fails to receive the packet in Fig. 6 (a), node C has the lowest left-over hops may forward the packet. In this situation, H receives the packet sent by C. In spite of this, B rebroadcasts the received packet when the timer expires, since B is not able to overhear the packet forwarded by C. Suppose that D previously overheard the packet from C, the same packet received from B can be discarded by D. However, if D also fails to receive the packet from C, D drives rebroadcast for the same packet.

In this way, ZOSTR may produce needless redundant packets, and it is triggered by lossy link environment and out-of-sight terminal situation type association between B and C. In other words, the redundant packet from D is

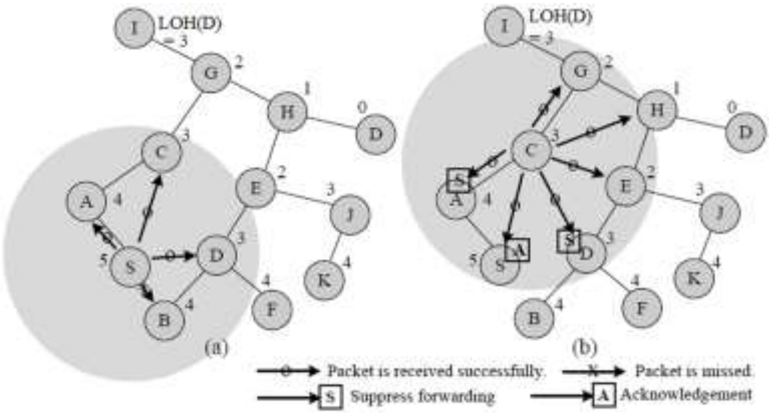


Fig. 6. Example of ZDOSTR

due to lossy link environment, and that from B is due to out-of-sight terminal problem. The redundant packet transmission from out-of-sight terminal problem can be eased by confining the area of forwarder candidates as shown in Fig. 6 (b). The core conception of ZDOSTR is to confine the area of forwarder candidates by using the minimum left-over hops of 1-hop neighbors. For doing this, each packet header encapsulates a field, namely *minLOH*, and each source or inter-mediate node *x* updates this field with the minimum left-over hops among *x*'s 1-hop neighbors. In ZDOSTR, the node can be forwarder candidate only when it can reduce both of left-over hops to the destination and the minimum left-over hops of 1-hop neighbors, while ZOSTR makes node *x* with lesser left-over hops than former sender to be forwarder candidate. For instance, in Fig. 6 (a), source node S has the minimum left-over hops with 3, since C and D are single-hop neighbors of S. Suppose S broadcasts a packet, the nodes A, B, C, and D are the forwarder candidates in ZOSTR. But, in ZDOSTR, only C and D are act as forwarder candidate, since they have reduced the minimum left-over hops to 2. By examining the *minLOHs* of 1-hop neighbors and node itself, it is possible to confine the nodes within the direction to the destination by having an opportunity to forward the packet.

IV. PERFORMANCE EVALUATION

In this section, ZDOSTR is evaluated in various metrics on the routing performance and overhead compared with ZOSTR and ZSTR. Zigbee tree topology network scenarios are simulated using the network simulator NS 2.0 and IEEE 802.15.4 PHY/MAC protocols. Table I lists the parameters used in this evaluation.

Table I Simulation Parameters

Simulation Parameters	**Value**
Network Area	80m X 80m
Number of Nodes	145
Deployment Type	Random
Position of PAN Coordinator	Center
Number of Iterations	15
PHY/MAC Protocol	IEEE 802.15.4
Propagation Model	Two-Ray Ground
Max. Rx range	25m
Max. Carrier Sensing Range	30m
Network Protocol	ZDOSTR/ZOSTR/ZSTR
Lm/Rm/Cm	8/7/7
Association Duration	0-50 sec
Application Session	

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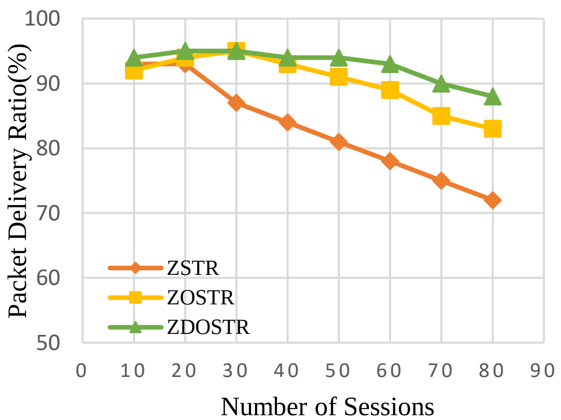
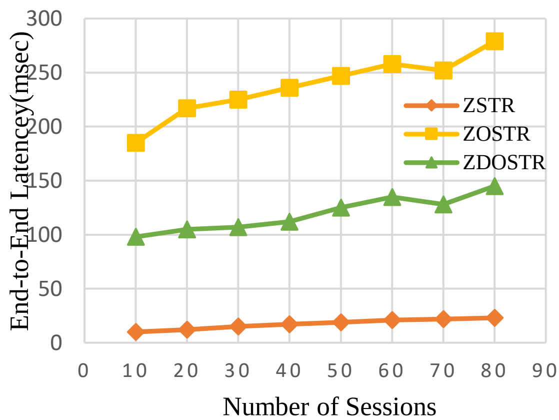
Communication Pair Selection	Random
Packet Type	CBR
Packet Interval	1 packet/sec
Session start and end time	80-180/280-330 sec
Traffic Type	Any-to-Any

There are 145 zigbee nodes deployed in zigbee network and HBAS used for assigning the network address for probing ZDOSTR, ZOSTR and ZSTR protocols.The association procedure starts between 0-50sec randomly for each simulation and ends at 50sec with assignment of network addresses. During the conduction of each session, *communicationPair (source, destination)* is chosen randomly and any any-to-any traffic pattern is applied to all network scenarios. However, all the application sessions start within 80-180secs and they end within 280-330secs randomly. In addition, all the outcomes from the simulations are based on successful end-to-end delivery of packets. Further, recorded values in Fig. 7 are the average metrics with respect to the number of sessions.
From Fig. 7(a), it is confirmed that the packet delivery ratio(PDR) falls as the number of traffic sessions growths due to collision and contention of packets. It is noteworthy that the PDR of ZSTR falls to 72% in 80 traffic sessions despite the shortest path. In contrast, both ZOSTR and ZDOSTR show 83% and 87% PDR in 80 traffic sessions. It upholds that the OR protocol offers reliable communication many forwarder candidates on diverse paths. Furthermore, ZDOSTR shows better performance than ZOSTR at all times, since ZDOSTR can cut down the number of candidate nodes by using the *minLOH* in 1-hop neighbor information. Moreover, by considering the hop delay proportional to *minLOH* instead *LOH* and viewing from 2-hop coverage, the closer node to the destination can be assigned the highest priority. This is why ZDOSTR also shows better performance in end-to-end latency as shown in Fig. 7(b). Prompt that ZDOSTR look like ZSTR. It is because both apply *minLOH* of 1-hop neighbors.
One more important routing metric, end-to-end latency is evaluated from Fig. 7(b). ZSTR attains the lowest end-to-end latency and shows same latency regardless of the number of sessions. It is since there is no queueing delay during packet forwarding. In contrast, both ZOSTR and ZDOSTR need prolonged end-to-end latency competed



(b)



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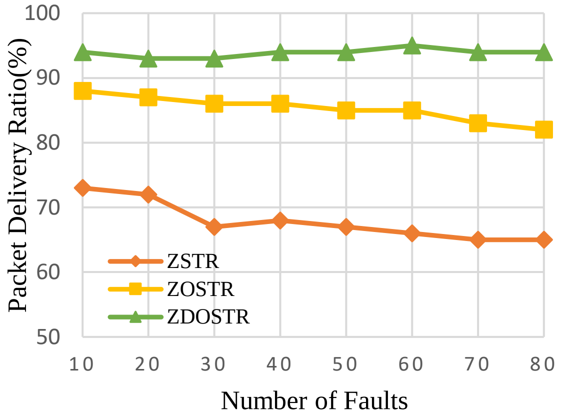
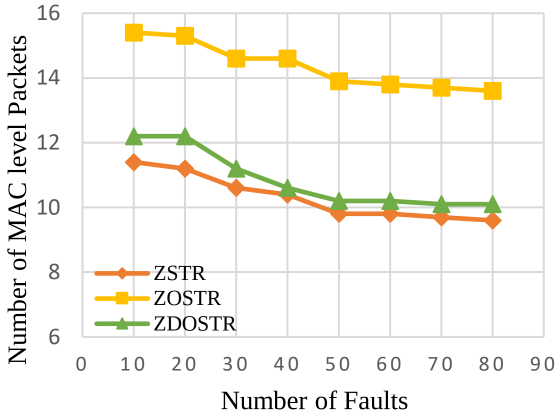


(c)



(d)

Fig. 7. Routing performance and overhead (a) Number of Sessions Vs Packet Delivery Ratio (b) Number of Sessions Vs End-to-End latency (c) Number of Faults Vs Packet Delivery Ratio (d) Number of Faults Vs Number of MAC level packets per session

with ZSTR. The key reason of prolonged latency is the hop delay which is applied to prioritize the candidate nodes. That is to say, intermediate nodes compete within the δ in ZOSTR, which is set with 10msec in these simulations. Hence, the delay for packet forwarding is relative to the *LOHs* to the destination, and it is reduced as it goes near to destination. In spite of this, such prolonged end-to-end latency is unavoidable feature of the OR algorithms.

Dissimilar to the previous evaluations aiming on the influence of the number of traffic sessions, Fig. 7(c) and 7(d) analyze the performance on the number of faults in a network. Fig. 7 (c) and 7(d) authenticate the robust packet delivery of ZOSTR and ZDOSTR by setting the number of traffic sessions as 60 and varying the number of faults in a network. Fault implies that node cannot exercise any routing service for instance receiving and forwarding a packet. At random time, the faults are occurred during the application traffic sessions in these simulations. As shown in Fig. 7 (c), the PDR of ZSTR shows a trend of decreasing for higher number of network faults. It is because ZSTR nominate a next hop node; hence, the end-to-end packet delivery is unsuccessful if the nominated next hop node is faulted. It is upheld by the number of MAC level packet in Fig. 7 (d) falls for the growing node faults. In contrast, both ZOSTR and ZDOSTR have robustness to the node faults, since there are number of forwarder candidate nodes to substitute faulted nodes. Thus, both the PDR and the MAC level packets manage to be constant with the growing number of node faults. Thus, it is concluded that the ZOSTR and ZDOSTR offer reliable packet delivery irrespective of network traffic, network density and node fault.

V. CONCLUSION

This paper has proposed CMCLZDOR for performing the efficient routing in wireless smart energy home area networks. Formerly, it employs ZOSTR and AODV individually for routing normal messages and highly critical messages respectively. Since ZOSTR has many forwarder candidates on a path in a lossy wireless environment, it offers out-of-sight terminal problem. To solve this problem, this paper has proposed ZDOSTR that confines the forwarder candidates space along the direction towards the destination to forward a packet. Thus, the performance evaluation shows that the directional opportunistic approach considerably enhances different network performances by suppressing the redundant packets from out-of-sight terminals.

REFERENCES

[1] H. Y. Tung et al., "The Generic Design of a High-Traffic Advanced Metering Infrastructure Using ZigBee," IEEE Trans. Ind. Informatics, Vol. 10, No. 1, pp. 836–844, 2014.
[2] M. Setiawan et al., "ZigBee-Based Communication System for Data Transfer Within Future Microgrids," IEEE Trans. Smart Grid, Vol. 5, No. 1, pp. 27–36, 2015.
[3] ZigBee Alliance, SEP 2.0 Application Specification 0.9 Document, pp 1-352, Jul. 2012
[4] NXP Laboratories, ZigBee Home Automation, pp. 1-226, June 2013
[5] M. Balakrishnan, Smart Energy Solutions for Home Area Networks and Grid-End Applications, pp. 1-7, Jan. 2012.

[6] U.S. Dept. of Energy, What the Smart Grid Means to Americans Washington DC USA, Tech. Rep., 2007.
[7] ZigBee Document, "ZigBee Specification," pp. 1–378, 2004.
[8] B.Rajeshkanna and M.Anitha, "Cluster Message Criticality Level Based ZigBee Opportunistic Routing for Smart Energy Home Area Networks", International Journal of Advanced Research in Electronics and Communication Engineering, Vol. 7, No.2, pp. 133-140, Feb 2018.
[9] B.Rajeshkanna and M.Anitha, "Cluster Message Criticality Level Based ZigBee Routing for Smart Energy Home Area Networks", International Journal of Computer Networks and Wirless Communication, Vol.7, No 6, pp. 29-37, Nov-Dec. 2017.
[10] NXP Semiconductors, ZigBee PRO Smart Energy API, pp. 1-380, Apr.2013.
[11] ZigBee Alliance, ZigBee Specification, pp. 1-604, Jan. 2008.
[12] Mohamed Kasraoui, Adnane Cabani, Joseph Mouznam, ZBR-M: A New Zigbee Routing Protocol, *International Journal of Computer Science and Applications*, Vol. 10, No. 2, pp. 15 – 32, 2013.
[13] Nessrine Chakchouk, "A Survey on Opportunistic Routing in Wireless Communication Networks," IEEE Commun. Surv. Tutorials, 2015.
[14] Y. Li et al., "Optimal forwarder list selection in opportunistic routing," 2009 IEEE 6th Int. Conf. Mob. Adhoc Sens. Syst. MASS '09, pp. 670–675, 2009.
[15] A. Darehshoorzadeh et al., "On the Number of Candidates in Opportunistic Routing for Multi-hop Wireless Networks," in MobiWac'13, 2013, pp. 9–16.
[16] J. Luo et al., "Opportunistic routing algorithm for relay node selection in wireless sensor networks," IEEE Trans. Ind. Informatics, Vol. 11, No. 1, pp. 112–121, 2015.