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Optimistic Opportunistic Routing Techniques for Wireless Sensor Networks: -A Review

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Abstract: Secure and optimistic routing is very important and significant task in Wireless Sensor Networks (WSN). In multi-hop communication, selection of routing path between the sensor nodes in the sensor field is essential and also important. Based on the coordination, time based, token based and network coding based techniques the data packets are forwarded from the source to the destination through the intermediate nodes in the network called Opportunistic Routing (OR). Compared with traditional routing, the OR uses the broadcast nature of transmission which greatly increases the wireless network throughput, reliability. In order to support higher node density in WSN, the selection of the most optimistic, flexible, dynamic and reliable OR mechanism and OR protocol are important. In this study the various OR mechanisms and OR protocol are identified and design issues like delivery ratio, packet transmission rate, communication pattern, reliability rate, throughput and fault tolerance are discussed and the comparative results are also tabulated.

Keywords: EAX, ETX, ExOR, GeRaF, HARBINGER, MORE, OAPF, opportunistic routing, wireless sensor networks

INTRODUCTION

Sensor networks are an up-and-coming computing platform consisting of huge numbers of small, tiny, low-powered, wireless devices called sensor node. A sensor node is able to perform data processing, data gathering and communicate with other associated sensor nodes in the network. Each sensor node consists sensing, transmission, processing and power units. The sensing unit of sensor node consists of sensors and analog to digital converter (ADC). Processing unit consists of processor and storage unit (Agnius *et al*., 2010). The transmission unit consists of the transceiver. These self-directed devices, or nodes, connect themselves; connect to routers and a gateway to form a typical WSN system. In WSN, relay node is called as the important intermediate node between the source node and the destination node. Some cases relay node acts as the router node in WSN. The sensor field is nothing but the total reporting area where the sensor nodes are fixed. To expand the coverage and reliability, routers are used to increase a supplementary communication link between each node in the sensor field and the gateway in WSN.

Wireless communication (Agnius *et al*., 2010) is facing many unpredictable challenges such as air interference, channel fading, environmental changes. Basically the communication in WSN between sensor nodes, cluster heads to sensor nodes and vice versa and cluster head to base station. WSN are mostly used in critical and non-critical applications like military, environmental monitoring, fire detection, home applications, machine health monitoring and on-site tracking of materials, data logging and data processing centers. Recently many research issues are identified in WSN are topology management, coverage, congestion and flow control, fault-tolerant, transmission power control, secure data aggregation, security and routing.

In WSN, communication uses wireless nature; it faces lots of real time problems like fading and interference. For the most part, communication scenario in WSN (Agnius *et al*., 2010) is single hop and multi hop. Multi hop communication in WSN, efficient routing techniques play a vital role.

Routing involves passing the data through several intermediate nodes. Routing algorithm should always be power aware because sensor network lifetime is equal to sensor node lifetime. Traditional routing techniques do not perform well in WSN because of the bandwidth of wireless network is substantial. The main objective of routing is to achieve optimality, simplicity, minimal overhead, robustness, stability, speed and flexibility. The factors which affect the design of routing protocols in WSN are node deployment, energy consideration and heterogeneity. In routing, data reporting can be classified into time driven or continuous, event driven, query driven and hybrid. The design and development of routing protocol for WSN is most critical and vital one in network management.

In conventional method it preselects one or more route before the transmission starts where as in OR Chachulski *et al*. (2007) the path is determined during

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the packet transmission. First it broadcasts an information packet to communicate candidates. By using a coordination protocol it selects the best intermediate candidate. Then it will forward the data packet so that it greatly increases the transmission range, transmission reliability and network throughput. OR Haitao *et al*. (2009) is the optimistic routing techniques, it uses broadcasting nature of the wireless standard, it follows any path routing techniques and one transmission can be overheard by multiple neighbors. It dynamically chooses the forwarding node based on node availability so it increased link reliability, network throughput and transmission range. To crush the lossy nature of the wireless medium opportunistic routing has been proposed and it is compatible with WSN.

In this study the various opportunistic routing mechanisms, techniques (Haitao *et al*., 2009) and opportunistic routing protocols (Sanjit and Robert, 2004) are reviewed discussed and preferably the conclusion is made based on which opportunistic routing mechanism and opportunistic routing protocols are suitable either for distributed WSN, Hierarchical WSN. The various performance issues of all the opportunistic routing mechanism and opportunistic routing protocols are analyzed.

OPPORTUNISTIC ROUTING MECHANISM

In a WSN numbers of sensor nodes are deployed is relatively more, whenever, the data transmission starts between different numbers of nodes, routing play a vital role. Proper coordination is ensured between source and destination in the network. Many cases direct communication is not possible between source and destination. Before identifying the forward packet candidate, the source node or coordinator must select the best path between sources and the destination. In coordination method (Zhong *et al*., 2006), select the best relay node as candidate to forward the packet from one node to another. For selecting the best node, the communication cost and time are considered, present coordination method is divided into three major categories namely time, token, network coding (Che-Jung *et al*., 2011). In the following section, these three major categories are discussed.

Timer based: The timer based coordination method (Che-Jung *et al*., 2011) is used to select the best relay node from the sensor field. First a data packet is broadcasted. Then the node with the highest priority responds in the first time slot. If it does not respond then the next highest priority node responds in the next time slot. As a result mth priority node responds in the mth time slot only if all the higher priority nodes do not reply. Once a node responds it is selected as the next relay and the same process is continued till the packet reaches the destination. The timer based coordination method is easy to implement and no control packets are needed. The main drawback is the waiting time of the candidate nodes is high and also the candidate order has to be included in the packet header. There may be duplicate transmissions because some of the nodes may not overhear the response of the other nodes.

Token based: In this method (Che-Jung *et al*., 2011) the duplication of packet is overcome, which is the major drawback in time based coordination method. In this method, tokens are generated at the target node and are passed from higher priority nodes (closer to the destination) to the lower priority nodes (closer to the source), finally it will reach the source. Only the candidate node which has the token can transmit the packet. The details (acknowledgements) about which packets have been received and which have not been received are included in the token. The main advantage of this method is that there are no duplicate transmissions. But a large number of control packets have to be exchanged. Thus this kind of coordination method cannot be used when the source and destination are very close.

Network coding: Network coding (Che-Jung *et al*., 2011) is introduced in the opportunistic routing to avoid the duplicate transmissions without having the coordination overhead among the nodes. Here intra flow coding is integrated with routing. The packets which are to be sent by the sender are divided into batches to code and decode. A batch consists of the original packets without coding called native packets. Then the sender encodes the current batch by generating a random linear combination of it. This coded packet is broadcasted to the candidate nodes of the sender and eventually it reaches the destination. The destination decodes the coded packets only when it receives enough linear combinations of the current batch. The main advantages are eliminating duplicate transmissions and there is no coordination overhead, the disadvantages are coding overhead. Wireless devices having high computational overhead and it cannot perform network coding in real time.

Path based forwarding: The primary goal of OR protocols includes how to select the forwarder set and how to allocate priority for them. Forwarder set can be determined through path based forwarding method. In order to find out the best forwarder set the source node has to analyze the delivery ratio of all the nodes. In a path based method (Haitao *et al*., 2009) the source node will calculate the average probability delivery ratio based on next hop and the number of hops. With the help of this analysis, source node will transmit the packet through this predetermined path.

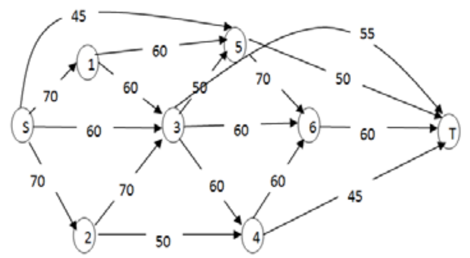

Fig. 1: Path based opportunistic packet forwarding

Table 1: Successful delivery probability from S to T thro Node 1

Number of hops	Path chosen	Delivery probability (%)
3	S-1-3-T	23.1
3	S-1-5-T	21
4	S-1-3-4-T	11.4
4	S-1-3-6-T	15.1
4	S-1-5-6-T	17.64
4	S-1-3-5-T	10.5
5	S-1-3-4-6-T	9
5	S-1-3-5-6-T	8

Table 2: Successful delivery probability from S to T thro Node 2

Number of hops	Path chosen	Delivery probability (%)
3	S-2-4-T	15.75
3	S-2-3-T	26.9
4	S-2-3-6-T	17.65
4	S-2-3-5-T	12.25
4	S-2-3-4-T	13.2
4	S-2-4-6-T	12.6
5	S-2-3-5-6-T	10.29
5	S-2-3-4-6-T	10.5

Consider the following sample network shows in Fig. 1. Which is used to illustrate path based forwarding. This network consists eight nodes shows in Fig. 1, here S is the source node and T is the destination node. There are a number of intermediate nodes namely 1, 2, 3, 4, 5 and 6. The successful delivery ratio (in percentage) between every pair of nodes is also mentioned.

The data can be transferred from the source to the destination by various paths, each of which has varying number of hops. In order to select the next hop, the successful delivery probability of all the routes from source to next possible hops to the destination have to be analyzed. The successful delivery probability of a route says, A-B-C can be determined using the formula $P = (1-(1-P_{AB}*P_{BC}))$ where P_{AB} is the successful delivery probability between Node A and Node B. where P_{BC} is the successful delivery probability between Node B and Node C.

Case 1: Averaging successful delivery probability: The possible next hops from source node S are node1, node 2, node 3, node 5. Consider 1 as the next hop and the following table. Table 1 illustrates the possible paths from 1 to destination along with their probabilities. Average successful delivery probability of the paths = 1-[(1-0.231) (1-0.21) (1-0.114)(1-0.151)

Table 3: Successful delivery probability from S to T thro Node 3

Number of Hops	Path chosen	Delivery probability
2	S-3-T	3%
3	S-3-6-T	21.6%
3	S-3-5-T	15%
3	S-3-4-T	16.2%
4	S-3-5-6-T	12.6%
4	S-3-4-6-T	12.9%

Table 4: Successful delivery probability from S to T thro Node 5

Number of hops	Path chosen	Delivery probability
2	S-5-T	22.5%
3	S-5-6-T	18.9%

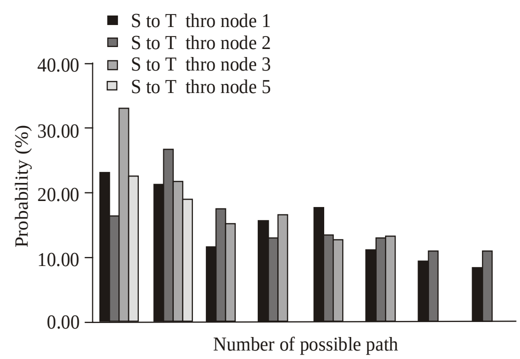

Fig. 2: Successful delivery probability from S to T-path based OR

(1-0.1764) (1-0.105) (1-0.09) (1-0.08)] = 71.4%. The results are discussed in Table 1 to 4.

Considering node 2 as the next hop from the possible paths and their successful delivery probability, The Average successful delivery probability of the paths = 1-[(1-0.1575) (1-0.269) (1-0.1765) (1-0. 1215) (1-0.132) (1-0.126) (1-0.1029) (1-0.105)] = 71.5% Considering node 3 as the next hop from the source node, the possible paths and their successful delivery probability, The Average successful delivery probability of the paths = 1-[(1-0.33) (1-0.216) (1-0.15) (1-0.162) (1-0.126) (1-0.129)] = 70.7%. Considering 5 as the next hop, the possible paths and their successful delivery probability are:

The average successful delivery probability of the paths = 1-(1-0.225) (1-0.189) = 37.1%. Now considering all the possible paths between the source and destination, it is found that S- node 3-T has the highest delivery probability of 33% which takes 2 Hops to reach T. But as the number of hops increases the packet loss decreases and thus the reliability increases. So the average probability based on number of hops should be calculated. This result shows in Fig. 2.

Case 2: Averaging successful delivery probability based on the minimum number of hops: The average successful delivery probability (Haitao *et al*., 2009) of few of the best reliable paths from S to T which takes exactly 2 Hops is 1-(1-0.225) (1-0.33) = 48%. The average successful delivery probability of few of the

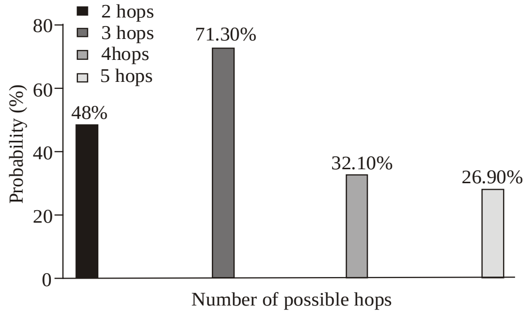

Fig. 3: Successful delivery probability from S to T-path based OR

best reliable paths from S to T which takes exactly 3 Hops is 1-(1-0.216) (1-0.269) (1-0.23) (1-0. 21)(1-0.189) = 71.3%. The average successful delivery probability of few of the best reliable paths from S to T which takes exactly 4 Hops is 1-(1-0.1764) (1-0.1765) = 32.1%. This analysis shows in Fig. 3.

The average successful delivery probability of few of the best reliable paths from S to T which takes exactly 5 Hops is 1-(1-0.09) (1-0.1029) (1-0.105) = 26.9%. With these results it can be concluded that the paths with 3 hops have higher reliability and successful delivery probability of this particular network. So the set of best paths with three hops are S-node 2-node 3-T, S-node1- node 3-T and S-node 3-node 6-T among which S-node 2-node 3-T has the highest successful delivery probability and thus it is concluded that this route is the most optimized route between source nodes to target nodes. This analysis shows in Fig. 3.

OPPORTUNISTIC ROUTING PROTOCOLS

In this section, the different opportunistic routing protocols like ExOR, Opportunistic Any Path Forwarding (OAPF) (Zhong *et al.*, 2006), MAC-Independent Opportunistic Routing (MORE), CAOR (Coding Aware Opportunistic Routing), Hybrid ARQ-Based Intra-cluster Geographically-informed Relaying (HARBINGER) is discussed.

ExOR: ExOR is a combination of routing (Haitao *et al.*, 2009) and MAC protocol and thus this protocol increases the throughput of large unicast transfers in multi-hop wireless networks. Once a node has a packet to send, it transmits to all the nodes that are listening. ExOR then determines which node is closest to the destination, among all the active nodes that received the packet. The MAC protocol ensures that only one of them forwards the packet. ExOR (Sanjit and Robert, 2004) takes advantage of broadcasting to improve the performance also to reduce the number of transmissions when compared to normal traditional routing. The schematic view of this method is shown in Fig. 4.

Consider a network with seven nodes as illustrated in the Fig. 4. When a Source (S) want to send a

Table 5: ETX value of ExOR

Metric	1	2	3	4	5	D
ETX	2.67	2.58	0.33	1.42	1.25	0

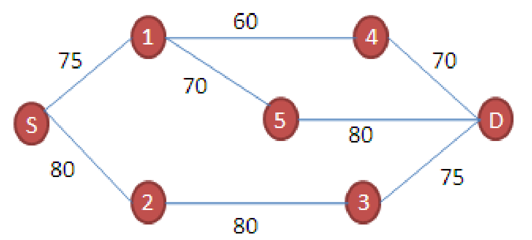

Fig. 4: Illustration of opportunistic packet forwarding in ExOR

message to the Destination (D) it can send through several paths. In this protocol the node having the less ETX (Expected number of transmissions) value is selected as the next forwarder. The ETX values are calculated as the inverse of the delivery ratios. 1, 2, 3, 4, 5 are the intermediate nodes between the source and destination. The ETX value of the nodes is shown in Table 5.

When the source S wants to transmit the packet to the destination D, it can either choose node 1 or node 2 as the next forwarder. But since 2 have the lesser ETX value (i.e., High delivery ratio) than 1 it is selected as the next forwarder to the destination. So the order of transmission will be S->node2-> node 3->D. In forwarding set, the set of next hop candidates for a particular sender from which a forwarder can be selected. Forwarder: A chosen next-hop candidate. This chosen forwarder will become the next sender of this packet. The ETX value is the ETX = 1/delivery ratio. In acknowledging transmissions, the most difficult task is ensuring that the candidate forwarder set nodes agree on which of them should forward the packet. The MAC protocol reserves slots of time for receiving acknowledgements based on node's priority. When a node hears a packet it checks to see whether it is in the forwarder list. If so, the node acknowledges the sender in the order of priority.

Opportunistic Any Path Forwarding (OAPF): In OAPF (Zhong *et al.*, 2006) instead of broadcasting to all the next hops select few good hops to reduce the number of transmissions. A metric used to decide the next hop candidate is EAX (expected any path count) instead of ETX. In this protocol, while calculating the EAX value of a node, the delivery ratios of all the possible next hop paths are considered. EAX also helps to determine the contribution of a candidate to the delivery of packets between nodes. OAPF is mainly used because it minimizes the number of candidates in the forwarder set without adversely affecting the performance unlike EXOR. EAX value helps determine the contribution of a candidate to the delivery of packets. Consider a network with five nodes as

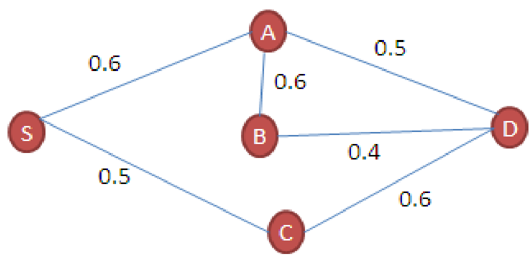

Fig. 5: Illustration of opportunistic packet forwarding in OAPF

Table 6: EAX calculations

Metric	S	A	B	C	D
EAX	3.105	2.18	2.5	1.66	0

illustrated in the Fig. 5. When a Source (S) want to send a message to the Destination (D) through several paths. In this protocol the node in the network having the least EAX value is selected as next forwarder. The EAX values are calculated using the following relationship:

$$\mathrm{EAX}(s,d) = \frac{1 + \sum_i \mathrm{EAX}(C_i^{s,d}, d) p_i \prod_{j=1}^{i-1}(1-p_j)}{1 - \prod_i (1-p_i)}$$

The delivery ratios between various nodes are mentioned in the Fig. 5 and the value shows in Table 6.

Source (S) wants to transmit the data to the destination. It has two next hop possibilities are A and C.S selects the next hop which has the least EAX value and transmits the packet to C. Then C in turn transmits to D. Path: S->C->D. The data packet is then transmitted to the node having the lower EAX value. This process continues till the data packet reaches the destination. Thus during the data transmission using OAPF is more optimistic than EXOR or traditional routing because while calculating the EAX value the probability of all the individual paths from a particular sender to the destination are considered. But the major drawback is that network state information has to be maintained.

MAC-Independent Opportunistic Routing (MORE): Opportunistic routing best utilizes the broadcast nature of wireless networks. If a packet is sent to the destination by broadcast, there are chances of duplicate packets reaching the destination through various paths. MORE eliminates this by encoding the packets. Because of this reason it does not need a node coordination to select the next hop node. As the name suggests this protocol does not depend on the features of the MAC layer. The schematic view of this method shows in Fig. 6. “A” has to send two packets to “D”. “A” broadcasts these packets to “B” and “C”. One of the two packets i.e., P2 did not reach the node “C”. Node “B” has received both the packets. MORE uses coding

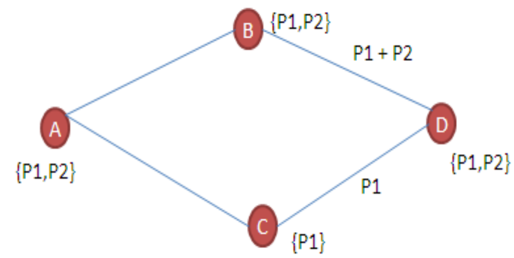

Fig. 6: Illustration of opportunistic packet forwarding in MORE

approach to eliminate the duplication of packets which might occur if both B and C forward the packets to D. So, Node B codes the packets and sends it as P1+P2 to D. D had already received P1 from C. So it decodes that coded packet (P1+P2- P1) to get P2. At the sender node, when a packet has to be sent, the sender creates a random linear combination of packets in the current batch and broadcasts the coded packet. Coded packet is $a_1p_1+a_2p_2+\ldots+a_np_n$ = c, where the ai”s is random coefficients chosen by the node and the pi‟s are native packets from the same batch. The sender attaches a header to each data packet which includes the packet’s code vector. This code vector has the information which should be used by the receiver for decoding the packet.

The sender includes a forwarder list which has the list of nodes that are nearer (in ETX metric) to the destination than itself. The nodes in the list are given such that a node with smaller ETX has higher priority. The sender keeps transmitting coded packets of that batch until all the packets of the batch are acknowledged by the destination.

At the intermediate node, incoming packet which is linearly independent from the packets that the node has previously received from this batch is said to be innovative. The intermediate node stores only the innovative packets and discards the non-innovative packets. This avoids duplicate packets being forwarded. This node creates a random linear combination of the coded packets it has heard from the same batch and broadcasts it. It is generated as “c = ∑j aj cj. At the receiver node, once the destination receives all the innovative packets of the batch, it decodes the whole batch (i.e., it obtains the native packets) using pi = ∑i ai-1 c i” where, pi is an original packet and ci” is a coded packet whose code vector is ai = ai1. . , aiK. As soon as the destination decodes the batch, it sends an acknowledgment to the sender to allow it to move to the next batch.

Ex-OR has certain disadvantages such as low spatial usage and it consumes more time for node coordination. These problems are tackled in MORE. Ex-OR also have some problems with node coordination phase while multicasting a packet, since the same packet has to be sent too many nodes. This is overcome

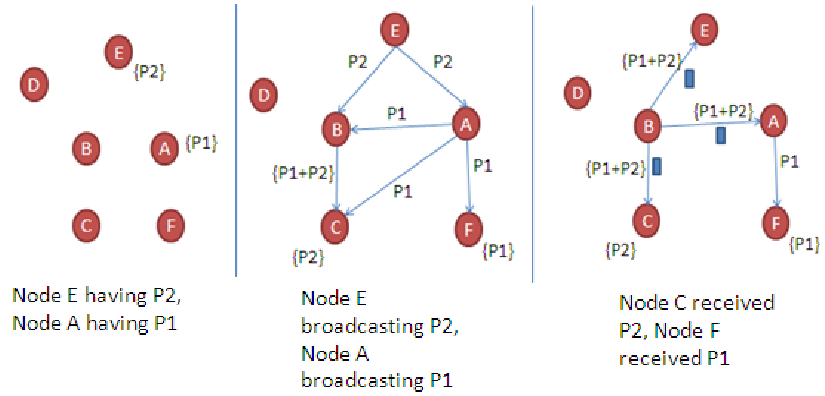

Fig.7: Illustration of opportunistic packet forwarding in CAOR

in MORE and it also reduces the number of re-transmissions by encoding the packets. MORE has less computation compared to the other protocols. It consumes more memory at nodes and it requires more information (code vector) carried in the header of the packet finally leads to high system complexity.

CAOR (Coding Aware Opportunistic Routing): CAOR (Yan *et al*., 2008) takes advantage of coding; the number of transmissions and duplicate transmissions are further reduced than other techniques. In this routing both network coding and opportunistic routing techniques are done. Forwarder set includes all the possible next hop candidates. The conditions that need to be satisfied for forward set selections are, it should be a direct neighboring node to the sender and it should be closer to the destination which may be calculated in terms of the ETX and then all the nodes in the forwarder set should be able to hear each other. While sending a packet the sender also includes the list of nodes in forwarder sets which are ranked based on their distances to the destination. In best forwarder selection, the main problem in CAOR (Lin *et al*., 2008) is in deciding which forwarder has the maximum coding opportunities. A node is said to have more coding opportunities by the number of packets it can send in a single transmission.

The difficult task is ensuring that all the nodes in the forwarder list select the same forwarder for transmission. Example of selecting the best forwarder is discussed in the following section. Consider a network with six nodes described in Fig. 7. Suppose node A has to send packet p1 to F and node E has to send packet p2 to C, the node having maximum coding opportunities forwards it. First node A broadcasts the packet p1 to B, C and F. Since these are the direct neighbors of A. Similarly node E broadcasts the packet p2 to its direct neighbors B and A. At the end of transmission node B receives p1 from A as well as p2 from E, but C and F receives only one packet each i.e., P2 and P1 respectively. The main overhead in CAOR is that each node should maintain local state information.

GERAF: In wireless networks the nodes are usually battery powered. So the routing has to be designed in such a way that the energy is conserved.

In GERAF (Zorzi and Rao, 2003) the relay node is not known in prior by the sender but it is known only after the packet has been transmitted. This is because in wireless medium the nodes are in random motion and a node may not be aware of the topology and the best next node relay. As a result the packet is broadcasted and a contention scheme is required to avoid duplication of packets. The data are transmitted from any node; it broadcasts the packet with its own address and with the address of the destination. All the nodes which receive the packet calculate its priority with respect to its distance from the destination and it checks the address. The relaying node then forwards the packet to the next adjacent node in its coverage area which is closest to the destination along with its own address and the address of the intended destination. This routing scheme then continues till the packet reaches a destination node. If the topology is such that there are no nodes closer to the destination, then the number of hops is incremented by one and the transmit nodes will independently generate the possible set of relay nodes to transfer the packet so that the packet reaches the destination in a finite amount of time.

The key factor of this method (Zorzi and Rao, 2003) is that only the location of the destination is necessary and no other information about the arrangement of nodes in the network is needed. This is a major benefit because the nodes may be stationary or in random motion and thus the topology keeps on changing. It supports node mobility also. If the relay nodes are in sleep mode, they won't be able to receive the packet. In order to avoid this, two types of radio frequencies are present in every node. One of the frequencies is used during data exchange and the

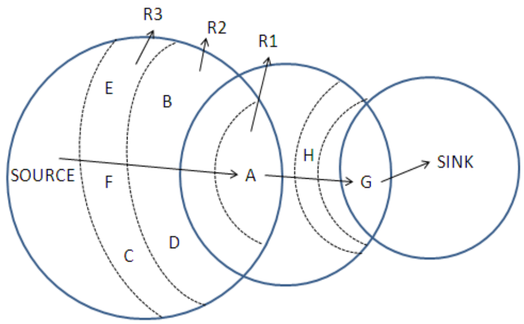

Fig. 8: Illustration of opportunistic packet forwarding in GERAF

other is used to represent busy tone when the node is receiving. The schematic view of this method is shown in Fig. 8.

An RTS (request to send) message is sent from the source to all the nodes (A, B, C, D, E, F). It contains the address of the source and the sink. The nodes who receive the RTS packet act as the relay nodes. Based on the topology of the source, sink and the relay nodes the priority of the relay nodes can be calculated. Based on the priority the relay nodes respond with a CTS (confirm to send) packet i.e., during the first slot, the nodes in the area (R_1) closest to the destination replies with a CTS packet.

Thus the DATA packet is sent to A. If A is in sleep mode, then the nodes B, D in the next coverage area R_2 reply with CTS packets. If more than one CTS packet is received, collision resolution algorithm is used to decide the node with the highest priority. Similarly from A the packet is transmitted to G and then to the sink.

In this method a node need not wait for a specific node (Lin *et al*., 2008) to wake up but can randomly pass the packet to the next available node in its coverage and also no routing tables are necessary for the transmission of data. Coordination among the nodes is also not necessary. In this method one of the drawbacks is that the location information about the nodes are necessary which is very difficult to obtain in many practical applications. This method will be effective even in case there are errors in the node locations.

Hybrid ARQ-based intra-cluster geographically-informed relaying (HARBINGER): A WSN does not come under fixed infrastructure. Since the wireless networks have an unreliable data transmission, the load on each node is always more than calculated. As the load increases the energy also increases. Thereby battery has to be replaced periodically for the node to function continuously. In order to reduce the number of battery replacements, the battery power should be efficiently used. A node simply listening to an idle channel consumes considerable energy for sensing and processing the possible traffic. This can be avoided by turning the nodes ON and OFF occasionally. So the nodes will run into sleep mode when they are not in use. The network topology keeps varying at random because of the mobility of the nodes and their sleep cycle. The node which is in sleep mode for long time has more battery life. So the active node density „d" is mostly less than the total node density of the network. HARBINGER (Zhao *et al*., 2004) helps in data transmission in such networks. It combines the concept of Geographic Random Forwarding (GeRaF) and Hybrid-ARQ Consider the network which has path loss but has no interference and fading. Let the sender has the range R1 initially. Each time a message has to be transmitted the sender encodes the packet with a low rate mother code. Consider M is the rate constraint of the channel. The coded message is rare-compatibly punctured into M distinct packets. Each packet is transmitted to the receiver and the receiver code-combines them to get the original message. Each packet has the sender and the receiver address. Initially the sender broadcasts an RTS packet at the start of the NCI in order to find whether there are nearby active nodes. If a relay node is active within the range of sender R1 it has potential to decode the RTS packet. So it will send back a CTS packet. If many relay nodes responded with CTS packet, the sender has to select a particular relay node using a contention scheme once the relay has been selected the sender will send a data packet to it. Now this relay node act as the sender and the process will start over again. The problem occurs when there is no active relay node in the sender's initial range. If this happens the sender waits for the particular node to be awakened and starts the entire process all over from the beginning with the hope that the transmission would be successful all along the network until the packet reaches the destination. If the network has low active node density, sender will keep re transmitting for several times until it gets back CTS. This wastes the retransmitted packets since they are just discarded. But HARBINGER (Zhao *et al*., 2004) uses the active nodes that are outside the sender's coverage area. With the help of hybrid-ARQ, instead of losing all the information that is obtained by collecting the re transmissions, the active nodes which are outside the coverage area store all the information it had received. Within two or three re transmissions by the sender, the outside node can decode the packet fully by using collected information. Hence the coverage circle of the sender increases after each transmission by the sender. After M transmissions the range of the sender increases from R_1 to R_M.

Slow HARBINGER: The nodes turn ON and OFF at a rate slower than the data transmission rate. The sender sends an RTS packet at the start of an NCI slot. If it gets back CTS the sender sends all the packets in

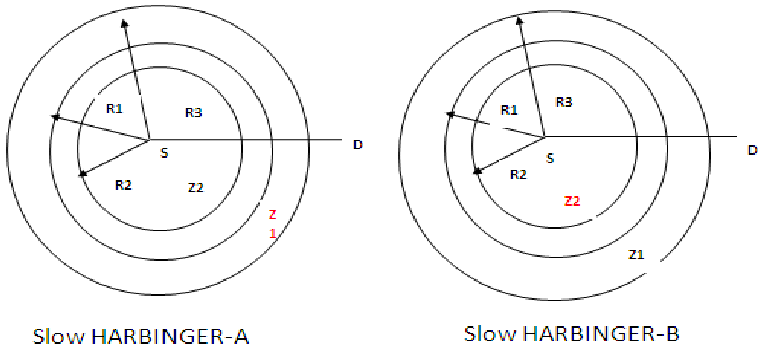

Fig. 9: Illustration of opportunistic packet forwarding in slow HARBINGER

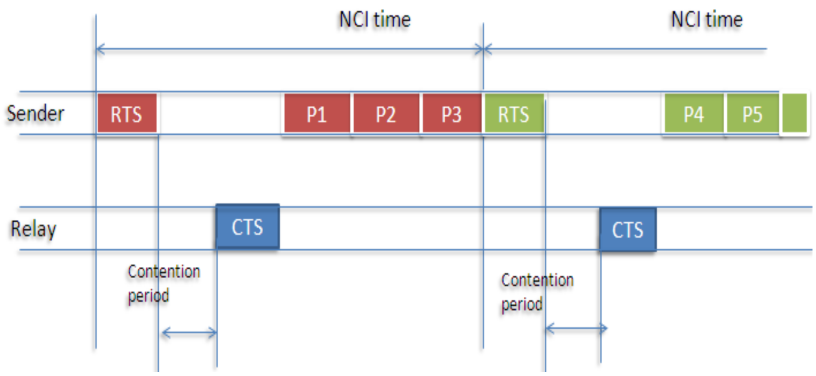

Fig. 10: Timing sequence in slow HARBINGER

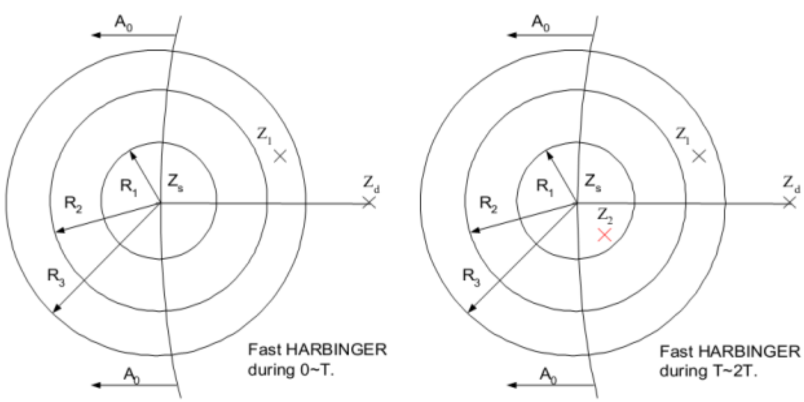

Fig. 11: Illustration of opportunistic packet forwarding in Fast HARBINGER

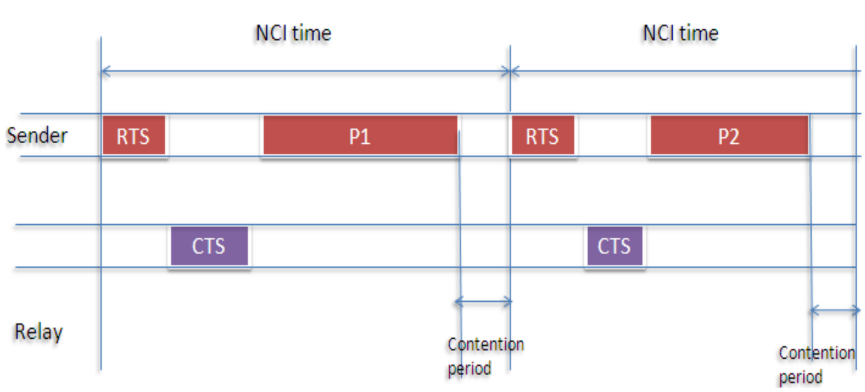

Fig. 12: Timing sequence in fast HARBINGER

the same NCI slot. If the relay node is not detected within the range, the sender has to attempt many ARQ transmissions before the topology changes. If the NCI time is long enough to attempt several M ARQ transmissions then each packet can be delivered to the destination within a single NCI. Otherwise the sender has to wait for the next NCI slot. Since the range of the sender expands from R_1 to R_M after M re transmissions by the sender, there are increased numbers of possible nodes which can be chosen as the next relay node. Based on which relay node is chosen, there are two versions of Slow HARBINGER identified.

In sow HARBINGER-A the node is selects that is closest to the destination. Hence it minimizes the delivery time of a message to the destination. In slow HARBINGER-B selects the path which requires a minimum number of ARQ transmissions (number of hops). Thereby it reduces energy dissipation of the nodes. It described in Fig. 9 and 10.

Fast HARBINGER: In Fast HARBINGER (Zhao *et al*., 2004), the rate of turning the nodes ON and OFF and the data rate are synchronized. The sender starts a session which spans M slots of NCI time. After the M slots, the session expires. M RTS packets are used for M data packets. Each of the M RTS has an identity for its respective data packet. In each NCI slot, the sender broadcasts the corresponding RTS packet.

All nodes within R1 range, able to decipher the first RTS packet. If there are no active nodes within the range R_1 then the sender transmits RTS at the start of the next NCI slot.

This continues till the session expires. So the active nodes within the range R_M respond with a CTS packet if they could successfully decode the RTS packet. Otherwise they will go back to sleep mode. The sender after receiving the first CTS packet transmits the data packet to the relay node. The node which decided to receive packet will keep all the incoming packets so that all the information can be combined and then decoded. It is possible that more than one node decodes the message. After deciding which node has to forward the packet all other nodes flushes its memory. The entire process is described in Fig. 11 and 12. Geraf is just a special case of harbinger with M=1. But in GeRaf, if there are no active nodes within the sender's range it repeats the whole process all over again. But HARBINGER uses Hybrid-ARQ and uses the active which are outside the coverage area. HARBINGER has a better energy trade off at lower node densities because of its dynamic range expansion feature. HARBINGER involves Coding.

CONCLUSION

The selection of routing techniques for WSN is mainly based on the application, the architecture used and system resources involved. The communication patterns among the nodes in WSN either node to node or group communications. In nodes to node communication and group communication, routing play a vital role. Opportunistic routing (Zhong *et al*., 2006) uses the broadcast nature of communication; optimistic forward set selection and got the best coordination between other relay nodes. It uses optimistic route for data communication. It increases the network lifetime based on system resources of sensor nodes and also it supports both distributed and hierarchical WSN. It provides flexible, reliable and optimistic solution for dynamic routing for WSN.

Table 7: Comparison of opportunistic routing protocol

Parameters	ExOR	OAPF	More	CAOR	GERAF	HARBINGER
Optimal route	Moderate	Moderate	Good	Good	Good	Good
Network lifetime	Good	Good	Very Good	Very Good	Very Good	Very Good
Resource awareness	Yes	Yes	Yes	Yes	Moderate	Yes
Use of meta data	Yes	Yes	Yes	Yes	No	Yes
Link/Path	Path	Path	Path	Path	Link	Link
Forwarder candidate selection	ACK based ETX Value	ACK based EAX value	ACK based ETX value with coding	Forwarding area based (code value)	Forwarding area based (geo distance based)	Forwarding area based (geo distance based)
Coordination method	No of hops, ETX	EAX value	ETX value and code	Coding	Distance	Distance

Table 8: Traditional routing Vs opportunistic routing

Parameters	Traditional routing	Opportunistic routing
Architecture	Support Any one from flat, hierarchical, location, QoS and distributed	Support more than one from flat, hierarchical, location, QoS and distributed
Mobility support	Limited	Maximum
Position awareness	No	Yes
Power awareness	Limited	Optimum
Node coordination	Rarely support negotiation	Acknowledgement based
Aggregation	Yes but moderate	Yes but efficient
Communication nature	Unicast, multicast	Broadcast
Multi-path communication	Rarely possible	Possible
Localization	No	Yes
Scalability	Good	Excellent
Complexity	Low	Low
Reliability	Good	Excellent
Fault tolerance	Moderate	Good
No of Hops for Routing	Maximum	Optimum

Table 7 shows summarize the list of opportunistic routing protocol based on Optimal Route selection, Lifetime management, Forwarder Candidate Selection and Coordination Method.

Table 8 shows the comparison result of opportunistic routing protocol with Traditional routing. The opportunistic routing protocols meet all the routing requirements of WSN (Luk *et al*., 2008) and it provides an optimistic solution and better performance than traditional routing techniques of WSN. Based on the analysis and survey (Lin *et al*., 2008), it concludes that in WSN development and applications, an opportunistic routing technique and protocols provides dynamic and optimistic solutions for routing between sensor nodes.

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