Abstract— Wireless Sensor Networks (WSN) involves wireless communication of nodes with each other. Code Dissemination in wireless Sensor Networks (WSN) performs wireless propagation of new codes to all target nodes in the network. Flooding is performed to establish a route to the destination for multicast routing by making all nodes in network to receive same message. Trickle one of the important network protocols, performs flooding, by a technique known as Code Dissemination. During broadcast, there may be loss created at each node because of random traffic created between the nodes. This leads to unreliability. This limitation is minimized by implementing Probabilistic and opportunistic flooding algorithm (POFA). Probabilistic and Opportunistic Flooding Algorithm (POFA) minimizes number of broadcasts while satisfying given target reliability using Expected Delivery Probability (EDP), Re-Transmission Policy and Reliability Aware Multipoint Relay Selection (RAMPR).

Index Terms— wireless sensor network, Probabilistic and Opportunistic Flooding, Expected Delivery Probability, Retransmission, Reliability Aware Multipoint Relay Selection.

I. INTRODUCTION

Wireless Sensor Networks (WSN) discovers new applications and requires non-traditional based protocol design due to preoccupied conditions. Admitting to the requirement for low device complexity together with low energy consumption, a balance between communication and signal or data processing capabilities must be discovered. This appreciates huge effort in activities, process, and investments on this field. Wireless Sensor Network consists of automated sensors to monitor physical and environmental conditions to cooperatively pass their data [1] through the network to a main location. Specific concept used in wireless Sensor Networks (WSN) is code Dissemination in which new code is wirelessly propagated to all target nodes [5]. This happens once all the codes gets deployed [2]. Flooding [3] forms basic primitive for Wireless Sensor Networks (WSN). Flooding is achieved by receiving acknowledgements from every receiving node [4]. Flooding affects all operations in the network [6]. The modern specified Wireless Sensor Networks (WSN) are bidirectional, thereby enabling the control of sensor activity. The Wireless Sensor Network (WSN) is built of nodes, where each is connected to one sensor. Each sensor network node has several Parts: radio transceiver with an internal antenna or connection to an antenna, a controller, an circuit for interfacing with the sensors and an energy source which is an embedded form of harvesting. The configuration of the Wireless Sensor Networks (WSN) can vary from a simple star network to an advanced multi-hop wireless mesh network. The technique can be routing or flooding. A Wireless Sensor Networks (WSN) is defined as a network of devices, popularly known as nodes, can sense the environment and communicate the information gathered from the monitored field. The data is carried away, through multiple hops, to a sink that can use it locally or connected to other networks through a gateway. The nodes can be stationary or moving. Scalability is main problem found in single sink scenario. The above specified problem can be minimized by increasing the number of nodes, leading to increase in the amount of data gathered by the sink. This is carried out till maximum limit is reached. Provided with a level node, a huge number of sinks will decrease the probability of isolated clusters of nodes that cannot deliver their data owing to unfortunate signal propagation conditions. As per norms, a multiple-sink can be scalable. There is a popular talk that multi-sink Wireless Sensor Networks (WSN) does not represent a extension of a single-sink case for the network representative. Represented nodes send the data collected to one of the sinks, selected from many, which in turn forwards data to the gateway, to the final user. Presence of multiple sinks ensures better network performance with respect to the single-sink but, communication protocols must be more complex and should be designed according to suitable criteria. Wireless sensor networks perform large numbers of wireless sensor nodes to collect information from terrain. Energy saving is critical to lifetime of a wireless sensor network. Due to availability, diverse flooding algorithms have been proposed in various wireless networks including wireless sensor networks (WSN). Another drawback is that it is hard to achieve high reliability because wireless links generally suffer from high error rates. Thus, to
achieve high reliability, retransmissions are often exploited. It is crucial to decide which node to rebroadcast and how many times to retransmit the message in a flooding mechanism.

II. RELATED WORK

Several approximation algorithms were proposed by different authors for effective broadcast code dissemination in wireless sensor network. Chi-Tsun Cheng [1], Tse, C.K., Lau, F.C.M et.al. indicated that Wireless sensor networks utilize large number of wireless sensor nodes to collect information from their sensing terrain. Yanchao Zhang [2], Yanchao Zhang, LR-Seluge et.al. presented code dissemination concept indicating that code can be propagated wirelessly. Abdallah [3], N.O, Jmaiel, M., Mosbah, M., Zemmari, A. et.al. explained the concept of flooding mentioning that same information is distributed to all target nodes in the network. Ting Zhu [4], Ziguo Zhong, Tian He, Zhi-Li Zhang, et.al. provided flooding protocols indicating costlier acknowledgements is required. Sain Saginbekov [5], Arshad Jhumka, et.al. provided basic definition for Wireless Sensor Networks indicating nodes as constrained devices, communicating wirelessly with each other Sain Saginbekov [6], Arshad Jhumka et.al. proved that number of advertisement messages vary linearly with time.

III. PROBABILISTIC AND OPPORTUNISTIC FLOODING ALGORITHM (POFA)

Probabilistic and opportunistic flooding algorithm (POFA) minimizes number of broadcasts by maintaining the given target reliability. In earlier algorithms, each link is assumed to be error-free and the subset of one-hop neighbours that cover all two-hop neighbors is selected as Multi point Relay Selection from the viewpoint of a sender where as probabilistic and opportunistic Flooding Algorithm (POFA) assumes each link has its own link error rate. The sender has remainder of link error rates between one-hop neighbors and link error rates between one-hop and two-hop neighbors. Link error rates can be mathematically carried out based on periodic message exchanges between sensor nodes for neighbor discovery. Using the stable estimation of link error rate, the exchanges of link information between neighbor nodes need not to be occurred frequently. This implies that piggybacked flooding packets or periodic messages are sufficient to exchange the link state in Probabilistic and Opportunistic Flooding Algorithm (POFA). Owing to cost minimization, incredible effort has been focused on opportunistic forwarding, which appreciates to reduce the cost of forwarding while retaining high routing [7] performance by forwarding messages only to nodes that have high delivery probabilities.

A. Expected Delivery Probability

One-hop neighbors are selected as Reliability Aware Multipoint Selection (RAMPR). Sender (S) broadcasts a message (or to rebroadcast a received message) will be calculating Expected Delivery Probability (EDP). Expected Delivery Probability (EDP) is calculated as the ratio of expected number of close neighbors that will receive the message probabilistically to the number of all close neighbors. In below Figure 3.1, the black circle is the sender (S) and the white circles indicate the close neighbors of Sender (S). Sender (S) calculates EDPm for each close neighbor m. EDPm is a probability that a particular neighbor m will receive the message. For one-hop neighbor i, link error rate from s to i is denoted as lsi, resulting in calculation of EDP given by 1 to lsi. Two hop neighbor j, have to consider two-hop paths from s to j as illustrated in below Figure 3.1. For a close neighbor m, EDPm is given by

$$EDP_{m} = \frac{1 - \prod_{i \in N} l_{si}}{\pi_{km}}$$

if m ∈ N

(1)

Otherwise,

$$EDP_{m} = \prod_{i \in N} [1 - (1-l_{si}) \cdot (1-l_{km})] \text{ if } m \notin N$$

(2)

This module is performed to calculate Expected Delivery Probability (EDP) for close neighbors. It is defined as ratio of close neighbors that will receive message to total close neighbors.

$$EDP = \frac{\text{Close Neighbors that receive message}}{\text{Close Neighbors}}$$

B. Re Transmission Policy

Retransmission policy explains how Sender S selects its Reliability Aware Multipoint Relay Selection (RAMPR) among its one-hop neighbors. As soon as Sender S selects among one-hop neighbors, it considers possible ways to cover all of the two-hop neighbors. As per norms, the goal of Reliability Aware Multipoint Relay Selection (RAMPR) selection is to achieve a given target reliability, not to cover all of its two-hop neighbors. Each and every node selects its own Reliability Aware Multipoint Relay Selection (RAMPR) in a fully distributed manner with its local information. As soon as node receives a message, it checks whether the node itself is a Reliability Aware Multipoint Relay Selection (RAMPR) of the transmitter, and if so, it becomes the sender who rebroadcasts the message. Otherwise, it just receives the message and does not rebroadcast the message. Retransmission thus reduces number of retransmissions performed there by making the algorithm more effective. This leads to effective approach.

C. Reliability Aware Multipoint Relay Selection (RAMPR)

Flooding a message during transmission of message is crucial as objective is to achieve the target reliability and to reduce the overhead of flooding. Number of Retransmissions

Figure 1. Expected Delivery Probability (EDP)
should be carefully controlled so as not to incur too much redundant traffic. The expected number of transmissions can be different from the real number of transmissions since the result of a real transmission will be either a success or failure in contrast to the probabilistic calculation. Actual number of transmissions depends on the situation at the moment reliability. Let us assume target reliability is already achieved after two transmissions. Node then, stops transmitting the message even if the message is transmitted less than N times. To manipulate whether to retransmit the message or not opportunistically, it is crucial to know the transmission results of each broadcast. During broadcast of messages, Acknowledgements (ACK) should be handled carefully due to the Acknowledgements (ACK) implosion problem. There exists two kinds of Acknowledgements (ACK), Explicit and Implicit Acknowledgements (ACK). An explicit Acknowledgements (ACK) indicates Acknowledgements (ACK) packet transmitted by a receiver to confirm successful reception. Whereas implicit Acknowledgements (ACK) happens as follows. Node A sends a data packet to node B, and overhears B’s forwarding the data packet to another node. In this situation, node A can assure that the packet is successfully received by B. To achieve the target reliability in Probabilistic and Opportunistic Flooding Algorithm (POFA), it is significant whether Reliability Aware Multipoint Relay Selection (RAMPR), it is an implicit ACK. When Reliability Aware Multipoint Relay Selection (RAMPR) receives the same message from Sender S twice or more, the Reliability Aware Multipoint Relay Selection (RAMPR) sends an explicit Acknowledgement (ACK) to Sender S. With these two kinds of Acknowledgements (ACK), Sender S can opportunistically figure out whether it should retransmit the message or not to achieve the target reliability. The key mechanism in the retransmission process is online Expected Delivery Probability (EDP) calculation. A-Transmission Policy: For a set of Reliability Aware Multipoint Relay Selection (RAMPR) check, there exists an acknowledgement from each receiving node. If so, the transmission indicates successful. Otherwise, re-transmits message to make it successful. This minimizes number of retransmissions performed, resulting in an effective methodology.

- Re-Transmission Policy: For a set of Reliability Aware Multipoint Relay Selection (RAMPR) check, there exists an acknowledgement from each receiving node. If so, the transmission indicates successful. Otherwise, re-transmits message to make it successful. This minimizes number of retransmissions performed, resulting in an effective methodology.

- Reliability Aware Multipoint Relay Selection (RAMPR): Initialize required variables with N1 indicating set of 1-hop neighbors, NR indicating set of RAMPR, R indicating target reliability, n indicating number of transmissions required by sender for target reliability, EDPn indicating Expected Delivery Probability (EDP) of sender with (n) transmissions, EDPnFull is Expected Delivery Probability (EDP) of Sender with (n) transmissions when NR equal to N1. Increment number of transmissions (n) when condition EDPn = EDPnFull becomes true. Cover 2-Hop neighbors when either of condition EDPn < EDPnMax or EDPn > EDPnMax gets satisfied with (i) covering maximum 2-hop neighbors.

- Throughput: Number of messages transferred from one place to another or processed in a specified amount of time is referred to as throughput.

- Delay: Network delay is a performance characteristic of computer network. The delay of a network specifies how long it takes for a bit of data to travel across the network from one node or end region to other. It is mathematically measured in terms of multiples or seconds. Delay may vary slightly, based on the location of the specific pair of discovering nodes. Representatives usually finalize maximum and average delay, and partition the obtained delay into several parts:

  - Processing delay is the time routers take to process the packet header.

IV. FUTURE WORK

Future work is expected to go with Enhanced Probabilistic Flooding Algorithm (EPOFA). Enhanced Probabilistic Flooding Algorithm (EPOFA) uses connectivity index and lowest delay leading to further efficient approach.

V. RESULTS AND DISCUSSIONS

A. Simulation Setup

Simulation is performed using NS2 simulations. In this simulation, Probabilistic and Opportunistic Flooding (POFA) Algorithm and Enhanced Probabilistic Flooding (EPOFA) Algorithm are performed to assess Expected Delivery Probability (EDP), Re Transmission policy, Reliability Aware Multipoint Relay selection (RAMPR), throughput, Delay in broadcasting, average end to end delay and Energy consumption. Following scenarios were implemented during simulation.

- Expected Delivery Probability (EDP): It is defined as ratio of close neighbors that will receive message to total close neighbors.

  \[
  EDP = \frac{\text{Close Neighbors receiving message}}{\text{Close Neighbors}}
  \]

- Re-Transmission Policy: For a set of Reliability Aware Multipoint Relay Selection (RAMPR) check, there exists an acknowledgement from each receiving node. If so, the transmission indicates successful. Otherwise, re-transmits message to make it successful. This minimizes number of retransmissions performed, resulting in an effective methodology.

- Reliability Aware Multipoint Relay Selection (RAMPR): Initialize required variables with N1 indicating set of 1-hop neighbors, NR indicating set of RAMPR, R indicating target reliability, n indicating number of transmissions required by sender for target reliability, EDPn indicating Expected Delivery Probability (EDP) of sender with (n) transmissions, EDPnFull is Expected Delivery Probability (EDP) of Sender with (n) transmissions when NR equal to N1. Increment number of transmissions (n) when condition EDPn = EDPnFull becomes true. Cover 2-Hop neighbors when either of condition EDPn < EDPnMax or EDPn > EDPnMax gets satisfied with (i) covering maximum 2-hop neighbors.

- Throughput: Number of messages transferred from one place to another or processed in a specified amount of time is referred to as throughput.

- Delay: Network delay is a performance characteristic of computer network. The delay of a network specifies how long it takes for a bit of data to travel across the network from one node or end region to other. It is mathematically measured in terms of multiples or seconds. Delay may vary slightly, based on the location of the specific pair of discovering nodes. Representatives usually finalize maximum and average delay, and partition the obtained delay into several parts:

  - Processing delay is the time routers take to process the packet header.
• Queuing delay is the time the packet spends in routing queues.
• Transmission delay is the time it takes to push the packet's bits onto the link.
• Propagation delay is the amount of time for a processing signal to reach specified destination.
• Average End to End Delay: End to End delay or One-way delay refers to the time taken for a packet to be transmitted across a network from source to destination. Average is calculated as overall end to end transmissions performed by number of transmissions.

• Energy Consumption: Energy is associated with each node in Wireless Sensor Networks (WSN). During broadcasting, there may be a loss in energy at each node. Energy consumption is related with identifying initial Energy at particular node and energy left once broadcast gets completed.

B. Result Analysis

Result Analysis is performed to both Probabilistic and Opportunistic Flooding Algorithm (POFA) and Enhanced Probabilistic and Opportunistic Flooding Algorithm (EPOFA).

Probabilistic and Opportunistic Flooding Algorithm (POFA)

Number of Nodes: NS2 simulation for Probabilistic and Opportunistic Algorithm (POFA) is performed by taking N number of nodes (as N varies from 1, 2, 3…..n). Figure 2 indicates number of nodes taken for specified algorithm.

Expected Delivery Probability (EDP): It is defined as ratio of close neighbors that will receive message to total close neighbors. Expected Delivery for Probabilistic and Opportunistic Flooding Algorithm is performed once message transmission gets completed for assumed N number of nodes. Number of nodes taken here is 50. Figure 3(a) indicates Expected Delivery Probability for Probabilistic and Opportunistic Flooding Algorithm (POFA) when all of close neighbors receives message from sender. Figure 3(b) indicates graph analysis for Expected Delivery Probability (EDP). The graph is simulated as output in simulator by considering simulation time plotted on X-axis and Expected Delivery Probability on Y-axis. The average value of Expected Delivery Probability (EDP) using Probabilistic and Opportunistic Flooding Algorithm (POFA) was found to be 0.6450.

Re-Transmission Policy: For a set of Reliability Aware Multipoint Relay Selection (RAMPR) check, there exists an acknowledgement from each receiving node. If so, the transmission indicates successful. Otherwise, re-transmits message to make it successful. This minimizes number of retransmissions performed, resulting in an effective methodology.

Reliability Aware Multipoint Relay Selection (RAMPR): Initialize required variables with N1 indicating set of 1-hop neighbors, NR indicating set of RAMPR, R indicating target reliability, n indicating number of transmissions required by sender for target reliability, EDP \textsubscript{s} indicating Expected Delivery Probability (EDP) of sender with (n) transmissions, EDP \textsubscript{full} \textsuperscript{n} is Expected Delivery Probability (EDP) of Sender with (n) transmissions when NR equal to N1. Increment number of transmissions (n) when condition EDP \textsubscript{s} = EDP \textsubscript{full} \textsuperscript{n} becomes true. Cover 2-Hop neighbors when either of condition EDP \textsubscript{s} = EDP \textsubscript{max} \textsuperscript{n} or EDP \textsubscript{s} > EDP \textsubscript{max} \textsuperscript{n} gets satisfied with (i) covering maximum 2-hop neighbors.

Throughput: Number of messages transferred from one place to another or processed in a specified amount of time is referred to as throughput. Figure 4 indicates throughput for Probabilistic and Opportunistic Flooding Algorithm (POFA) assuming 50 nodes taken during transmission. Figure 5.4 indicates graph obtained for throughput considering specified number of nodes by taking simulation time plotted on X-axis and throughput on Y-axis. The graph result explains gradual increase as time increases.

Delay: Network delay is a performance characteristic of computer network. The delay of a network specifies how long
it takes for a bit of data to travel across the network from one node or endpoint to another.

Average End to End Delay: End to End delay or One-way delay refers to the time taken for a packet to be transmitted across a network from source to destination. Average is calculated as overall end to end transmissions performed by number of transmissions. Figure 5 indicates graph analysis for average end to end delay by plotting simulation time on X-axis and average end to end delay on Y-axis. The graph decreases gradually with respect to simulation time.

Energy Consumption: Energy is associated with each node in Wireless Sensor Networks (WSN). During broadcasting, there may be a loss in energy at each node. Energy consumption is related with identifying initial Energy at particular node and energy left once broadcast gets completed. Figure 6 indicates graph analysis for energy consumption by plotting Simulation time on X-axis and Energy consumption on Y-axis.

Enhanced Probabilistic and Opportunistic Flooding Algorithm (EPOFA)

Number of Nodes: NS2 simulation for Enhanced Probabilistic and Opportunistic Algorithm (EPOFA) is performed by taking N number of nodes (as N varies from 1, 2, 3…n). Figure 7 indicates number of nodes taken for specified algorithm.

Expected Delivery Probability (EDP): It is defined as ratio of close neighbors that will receive message to total close neighbors. Expected Delivery for Probabilistic and Opportunistic Flooding Algorithm is performed once message transmission gets completed for assumed N number of nodes. Number of nodes taken here is 50. Figure 8 (a) indicates Expected Delivery Probability for Enhanced Probabilistic and Opportunistic Flooding Algorithm (EPOFA) when all of close neighbors receives message from sender. Figure 8(b) indicates graph analysis for Expected Delivery Probability (EDP). The graph is simulated as output in simulator by considering simulation time plotted on X-axis and Expected Delivery Probability on Y-axis.

Re-Transmission Policy: For a set of Reliability Aware Multipoint Relay Selection (RAMPR) check, there exists an acknowledgement from each receiving node. If so, the transmission indicates successful. Otherwise, re-transmits message to make it successful. This minimizes number of retransmissions performed, resulting in an effective methodology

Reliability Aware Multipoint Relay Selection (RAMPR):

Initialize required variables with N1 indicating set of 1-hop neighbors, NR indicating set of RAMPR, R indicating target reliability, n indicating number of transmissions required by sender for target reliability, EDPa indicating Expected Delivery Probability (EDP) of sender with (n) transmissions, EDP\text{full} is Expected Delivery Probability (EDP) of Sender with (n) transmissions when NR equal to N1.Increment number of transmissions (n) when condition EDPa = EDP\text{full} becomes true. Cover 2-Hop neighbors when either of condition EDPa = EDP\text{max} or EDPa > EDP\text{max} gets satisfied with (i) covering maximum 2-hop neighbors.

Throughput: Number of messages transferred from one place to another or processed in a specified amount of time is referred to as throughput. Figure 9 indicates throughput for Enhanced Probabilistic and Opportunistic Flooding Algorithm (EPOFA) assuming 50 nodes taken during transmission. Figure 4 indicates graph obtained for throughput considering specified number of nodes by taking simulation time plotted on X-axis and throughput on Y-axis. The graph result explains gradual increase as time increases.
Figure 9. Throughput

Delay: Network delay is a performance characteristic of computer network. The delay of a network specifies how long it takes for a bit of data to travel across the network from one node or endpoint to another.

Average End to End Delay: End to End delay or One-way delay refers to the time taken for a packet to be transmitted across a network from source to destination. Average is calculated as overall end to end transmissions performed by number of transmissions. Figure 10 indicates graph analysis for average end to end delay by plotting simulation time on X-axis and average end to end delay on Y-axis. The graph decreases gradually with respect to simulation time.

Figure 10. End to End Delay

Energy Consumption: Energy is associated with each node in Wireless Sensor Networks (WSN). During broadcasting, there may be a loss in energy at each node. Energy consumption is related with identifying initial Energy at particular node and energy left once broadcast gets completed. Figure 11 indicates graph analysis for energy consumption by plotting Simulation time on X-axis and Energy consumption on Y-axis.

Figure 11. Energy Consumption

Comparative Analysis of POFA with EPOFA

Expected Delivery Probability (EDP): It is defined as ratio of close neighbors that will receive message to total close neighbors. Expected Delivery for Probabilistic and Opportunistic Flooding Algorithm (POFA) and Enhanced Probability and Opportunistic Flooding Algorithm (EPOFA) are performed using graphical analysis as shown in below Figure 12. Graph infers that EPOFA is found to cover more close neighbors than POFA resulting in an effective approach.

Figure 12. Expected Delivery Probability

Throughput: Number of messages transferred from one place to another or processed in a specified amount of time is referred to as throughput. Figure 13 indicates throughput comparison for POFA with EPOFA assuming 50 nodes taken during transmission. Graph infers that EPOFA is observed to have effective throughput than POFA.

Figure 13. Throughput

Average End to End Delay: End to End delay or One-way delay refers to the time taken for a packet to be transmitted across a network from source to destination. Average is calculated as overall end to end transmissions performed by number of transmissions. Figure 14 indicates comparative graphical analysis for POFA with EPOFA.

Figure 14. Average End to End Delay

Energy Consumption: Energy is associated with each node in Wireless Sensor Networks (WSN). During broadcasting, there may be a loss in energy at each node. Energy consumption is related with identifying initial Energy at particular node and energy left once broadcast gets completed. Figure 15 indicates comparative graphical analysis for POFA with EPOFA.

Figure 15. Energy Consumption
VI. CONCLUSION
Probabilistic and opportunistic flooding algorithm (POFA), handles probabilistic approach to achieve the network-wide target reliability by calculating the expected delivery probability (EDP) opportunistically in wireless sensor networks. Sender selects reliability-aware multi-point relays (RA-MPRs) and determines the number of transmissions to minimize the flooding overhead. Simulation results reveal that POFA achieves the target reliability with the less overhead than the previous approaches in most cases. Specifically, when the link error rate is substantially high, POFA tends to achieve higher reliability than the given target reliability. Future work is expected to go with Enhanced Probabilistic Flooding Algorithm (POFA). Enhanced Probabilistic Flooding Algorithm (POFA) uses connectivity index and lowest delay leading to further efficient approach.

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