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OPPORTUNISTIC FORWARDING FOR DUTY-CYCLED WIRELESS SENSOR NETWORKS

Sowmya M[1], S. N Hanumanthappa[2]
[1]M.Tech Student, [2]Assistant Professor
Dept of Electronics and Communication, UBDT College of Engineering, Davangere, India

Abstract: Opportunistic routing, offering relatively efficient and adaptive forwarding in low-duty- cycled sensor networks, generally allows multiple nodes to forward the same packet simultaneously, especially in networks with intensive traffic. Uncoordinated transmissions often incur a number of duplicate packets, which are further forwarded in the network, occupy the limited network resource, and hinder the packet delivery performance. Existing solutions to this issue, e.g., overhearing or coordination based approaches, either cannot scale up with the system size, or suffer high control overhead. We introduce Duplicate-Detectable Opportunistic Forwarding (DOF), with duplicate free in low-duty cycled sensor networks. It enables senders to get the information of all essential forwarders through a slot acknowledgment scheme, so the data packets can be sent to deterministic next-hop forwarder. With light-weight mechanism, DOF explores the opportunities and removes duplicate packets from forwarding process. This paper overcomes the pitfalls in transmission loss. The simulation study is done in ns2 and the results prove that the proposed DOF is improved and efficient compared to existing protocol.

Index Terms: Wireless Sensor Networks (WSN),Duplicate-Detectable Opportunistic Forwarding (DOF).

I. INTRODUCTION

Large-scale sensor networks are deployed in numerous application domains, and the information that we collect are used in decision making for critical frameworks. Information's are rushed from multiple sources through transitional processing nodes that accumulate information. A malicious attacker may introduce additional nodes in the network or compromise existing ones. Therefore, persuade high data trustworthiness is crucial for correct decision-making. Data provenance serves as key factor in evaluating the trustworthiness of sensor data. Provenance management for sensor networks introduces several challenging demands, such as low energy and bandwidth consumption, efficient storage and reliable transmission. Here we mainly focus on minimizing energy consumption and maximizing network lifetime for data relay in 1 D queue network. Following the principle of opportunistic routing, multihop relay decision to optimize the network efficiency is made based on differences among sensor nodes, in terms of their distance to sink and residual energy of each other. Energy saving via opportunistic routing algorithm is designed to ensure minimum power cost during data relay and protect the nodes with relatively low residual energy. The task of designing an energy-efficient routing protocol, in case of sensor network is multifold, since it involves not only finding the minimum energy path from a single node to destination but also balancing the distribution of residual energy of whole network. Furthermore, the unreliable wireless links and network partition may cause packet loss and multiple retransmissions in preselected good path. Retransmission causes significant energy cost. Thus it is appropriate to make tradeoff between minimum consumption and maximum network lifetime. 1-Dimensional queue network is designed and developed for a wide variety of applications. Sensor nodes will send the collected data to relay sensor data nodes and then the relay sensor nodes forward traffic information along the Energy-efficient path to sink node that is one or more hops away. Finally all values are reside at traffic management center, it will select appropriate information and offer it to clients via the network. Based on distance of sensor node to the sink, and residual energy of each node are crucial to determine the optimal transmission distance. Thus it is necessary to consider these factors together for opportunistic routing decision. Wireless sensor networks are usually duty-cycled to prolong the network lifetime. A widely adopted low-duty- cycled media access mechanism is low power listening (LPL). Taking X-MAC as a typical example of LPL, each node periodically wakes up and checks the received signal strength to detect the potential traffic. If the channel is clear, it turns off the radio to sleep for a certain period. Note that the sleep schedule of different nodes is generally unsynchronized. A sender probably has to spend much time waiting for its corresponding forwarder to wake up. During the waiting time, the sender continuously transmits the same data packet (called preamble) until the preset timer expires or an acknowledgment is received. As a result, if the forwarder is deterministic, the end-to- end delay is likely high. Obviously, sender energy is wasted on waiting for the forwarder. The duty-cycled communication nature makes the deterministic forwarding schemes inefficient. To shorten the waiting time, an intuitive idea is to take the earliest forwarding opportunity instead of waiting for the deterministic forwarder, like opportunistic routing. Temporally available links may be exploited to reduce the transmission cost in wireless mesh networks. Landsiedel et al. propose ORW, an opportunistic forwarding protocol for low-duty- cycled unsynchronized sensor networks. In ORW, any forwarder with certain routing progress can acknowledge the preamble transmission in LPL. The first wake-up neighbor that successfully receives the packet is selected as the next-hop forwarder. Nevertheless, ORW cannot support high-traffic- load applications due to channel capacity degradation incurred by the inherent duplicate problem. Most duplicate packets are generated when several forwarders keep awake and receive the same data packet during the same period. In low-duty- cycled sensor networks, the high traffic load will significantly increase the risk of producing duplicates. Although several duplicate suppression mechanisms are proposed, the overhearing-based approaches are not well adapted to the bursty traffic, especially in the large-scale networks with dynamic links. Moreover, according to MORE, the long coordination process diminishes the benefits brought by opportunistic routing. The amount of duplicate packets might increase exponentially along the multihop relay such that the network throughput is significantly degraded. In order to address the above issues, we propose Duplicate- Detectable Opportunistic Forwarding (DOF). Instead of direct data transmission in LPL, a sender sends a probe and asks the potential forwarders to acknowledge the probe respectively in different time-slots. By utilizing the temporal diversity of multiple acknowledgments, the sender detects the quantity and differentiates the priority of all potential forwarders. The sender then forwards its data in the deterministic way to avoid multiple forwarders hearing the same packets. We develop methods to resolve possible collisions among multiple acknowledgments and exploit temporal long good links for opportunistic forwarding. With the lightweight mechanism to suppress duplicates, DOF can adapt to various traffic loads in duty-cycled sensor networks and enhances the system performance with respect to both network yield and energy efficiency. The remaining part of the paper is organized as follows: Section II point to related work. Section III discusses overview of Opportunistic Routing in WSN’s. Design and System Flows are illustrated in Section IV. Section V presents Simulation setup and Results and Conclusions are drawn in Section VI and VII Respectively.

II. RELATED WORK

In this section, we first make a brief summary about the widely used deterministic forwarding protocols, and then discuss related work on opportunistic and dynamic forwarding mechanisms. Moreover, we illustrate the advantage of our adaptive duplicate suppression schemes in unsynchronized duty-cycled wireless sensor networks. Deterministic forwarding protocols, such as CTP [18], have been widely applied in WSNs. Considering the limited energy of sensor nodes, WSNs are usually duty-cycled to prolong the network lifetime. The main two types of duty-cycled media access mechanisms for deterministic forwarding are low power listening, such as X-MAC [6], and low power probing, such as A-MAC [15]. Built upon a duty-cycled MAC, the duty-cycled communication nature makes the deterministic forwarding protocols inefficient, e.g., sleep state of the next-hop node bringing about high forwarding latency and high energy consumption, network dynamics reducing the reliability of deterministic forwarding, etc. To address the deficiencies of deterministic forwarding, scientists have devoted much of their research to opportunistic forwarding. ExOR [7] develops a complete opportunistic routing for wireless networks. ExOR assigns each receiver to further transmit in a distinct time-slot, and the receiver overhears others' transmissions to avoid the duplicates. MORE [10] targets the inefficient coordination process of ExOR and proposes a coding approach to eliminate the overhead. Rather than network coding, DOF takes a lightweight method to mitigate the overhead for wireless sensor networks. BRE [12] develops the overhearing scheme in CTP [18] to capture the temporally good links. The sender changes the next-hop receiver when the opportunity appears to reduce the transmission count. However, BRE does not address the duty-cycle issue, in which the waiting time dominates the energy efficiency. In DSF [19], each node knows the schedule of neighbor nodes by synchronization. DSF dynamically selects multiple next-hop forwarders based on the sleep schedules and routing metrics of the neighbors. [16] further notices the link burstiness to optimize the energy consumption on each packet and improve the network yield. However, DSF and need extra control overhead to stabilize the forwarding schedule, which is vulnerable to dynamic links and network churn. ORW [8] implements the opportunistic routing for unsynchronized low-duty- cycled wireless sensor networks, but shows the limited performance for high-traffic- load applications. DOF extends this work to more general-purpose wireless sensor network applications.
CMAC [9] includes the slotted acknowledgments, but CMAC still determines the unique forwarder by overhearing others’ acknowledgments. In DOF, the sender distinguishes the forwarders, and then considers the link quality to arrange the forwarding schedule. There are also some theoretical works focusing on opportunistic routing [20]–[22] and dynamic forwarding [23], [24] for wireless sensor networks. Although the models and simulation show the efficiency of the opportunistic routing, they neglect the practical issues addressed by DOF.

III. OPPORTUNISTIC ROUTING

Challenged networks where network contacts are intermittent or where link performance is highly variable and there is no complete path from source to destination for most of the time. The path can be highly unstable and may change or break quickly. To make communication possible intermediate nodes may take keeping of data during the blackout and forward it when the connectivity resumes. Opportunistic Routing uses a broadcast transmission mechanism to send packets through multiple relays. Opportunistic routing achieves higher throughput than traditional routing. The main idea behind Opportunistic Routing is select a subset of the nodes between the source and the destination node and the node closest to the destination will first try to retransmit packets. The main two steps are –

1. Selection of the forwarder sets: Selecting only the potential nodes between the source and destination to increase the routing efficiency.

2. Prioritization among these forwarders: The highest priority forwarder should be the closest one to the destination.

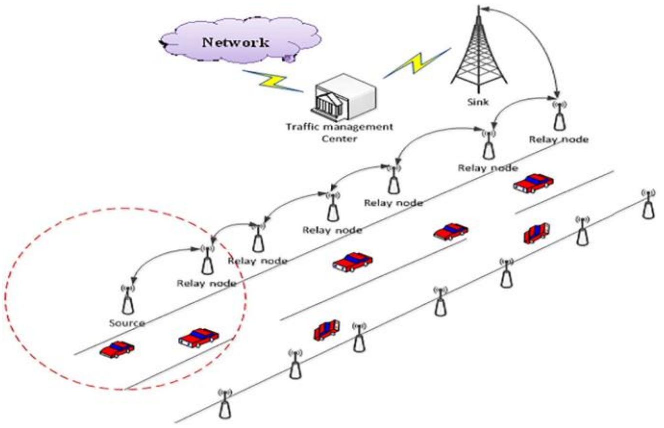


Fig. 1 Relay Node Selection using Opportunistic Routing

Duplicate Detectable Opportunistic Forwarding (DOF)

DOF targets on developing a practical opportunistic forwarding scheme for various duty-cycled sensor network applications. In this section, we discuss several issues: 1) the overview of how DOF detects the potential forwarders by slotted acknowledgment (ACK); 2) the algorithm of ACK slot assignment and forwarding strategy; 3) the adaptive routing metric. For simplicity, we here illustrate the basic design of DOF using X-MAC, a well-adopted unsynchronized LPL MAC as we mentioned above.

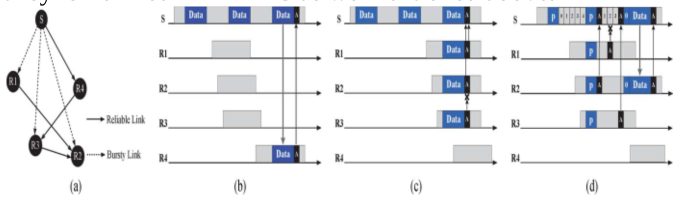


Fig. 2. Different from deterministic forwarding and ORW, in DOF the sender distinguishes the multiple waking forwarders by the temporal diversity of ACKs. Then, it sends the data packet to an exclusive forwarder by adding in the ACK slot information. (a) Topology. (b) Deterministic forwarding. (c) ORW. (d) DOF.

A. Overview of DOF

As Fig. 2(a) shows, sends packets to the intended destination (a destination is the final receiver like the sink node). There are three potential forwarders, , and (a forwarder is one relay node along the routing path). The links are either reliable or bursty, indicated as the solid or dashed lines, respectively. As Fig. 1(b) shows, in traditional deterministic forwarding, continuously sends the data to the predetermined relay node until it wakes up. As Fig. 1(c) shows, ORW takes the early wake-up nodes (R1,R2, or R3) that receive the data and provide routing progress as the next-hop forwarder. However, as Fig. 1(c) shows R1, R2, and R3 may receive the data simultaneously. The duplicates then significantly degrade the system performance as introduced above. DOF detects potential duplicates by using adaptive slotted ACK when multiple forwarders are awake simultaneously. As Fig. 1(d) shows, instead of directly sending data, a sequence of probes is first broadcast by. The interval of two adjacent probes is divided into multiple time-slots. Each slot is long enough to receive an ACK. When R1,R2, and R3 receive one probe and any of them offers routing progress, each of them independently selects a slot (2, 0, and 4) to send the ACK back. According to the slot information of the received ACKs (0 and 4), sends the data packet to a forwarder (R2) by adding in the slot information (0). To minimize the duplicates and keep the benefit of opportunistic routing, the design of DOF faces several challenges:

1) Different forwarders should acknowledge the probe at different slots. In addition, the routing progress of different forwarders should be distinguished because the forwarder with more routing progress should be used with a higher priority.

2) Although the communication overhead caused by probe transmissions for each data packet is little, it should be avoided when the traffic load is high.

3) DOF may explore temporally Fig. 3. DOF splits all the ACK slots into three slightly overlapped priority zones. According to the routing progress, DOF randomly maps each forwarder into a slot in different priority zones. Available links to forward data. However, the data ACK loss over these links may lead to undesirable retransmissions due to the bursty loss. Thus, the short-term link performance should be considered.

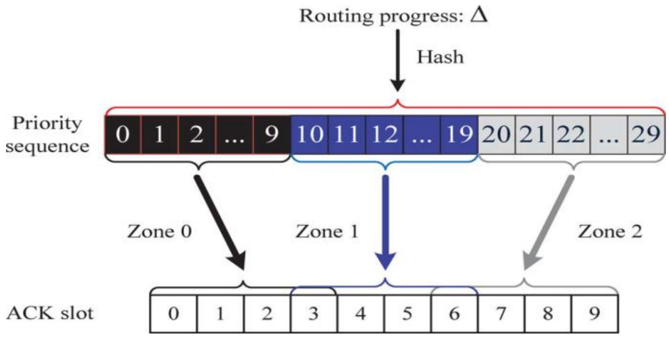


Fig. 3. DOF splits all the ACK slots into three slightly overlapped priority zones. According to the routing progress, DOF randomly maps each forwarder into a slot in different priority zones.

B. ACK Slot Assignment

As we mentioned, the two requirements of ACK slot assignment are that multiple forwarders should be distributed into different slots, and the sender should infer the routing progress of different forwarders by ACK slot distribution. As Fig. 3 shows, the basic strategy is as follows: First, according to a hash function, the forwarder matches its routing progress to a location on the priority sequence. The priority sequence is like a ruler to measure the routing progress Δ then, we split all the ACK slots into multiple slightly overlapped zones, which are matched to different segments of the priority sequence (e.g., zone{ 0 -- >9}); last, according to H sf , we randomly assign one slot in the selected zone. There are six parameters in the calculation procedure. When forwarder receives the probe sent by, the routing progress is calculated by

$$\Delta_{Sf} = W_s - W_f \qquad (1)$$

W s is carried in the probe, and W f is local routing information. If Δ_{sf} is larger than Δ max , we set it as . By (2), the routing progress Δ_{sf} is mapped to a location H_{sf} in the priority sequence. A forwarder with a larger routing progress is mapped into the head area of the sequence

$$H_{sf} = [(1-(\Delta_{sf} / \Delta_{max})* N] \quad (2)$$

f calculates in which ACK zone ($Zone_f$) it should acknowledge the probe and the offset (δ_f) in the segment of priority sequence corresponding to $Zone_f$.

$$Zone_f = [H_{sf} . L / N] \quad (3)$$

$$\delta_f = H_{sf} - [Zone_f . N/L] \quad (4)$$

fk randomly maps H_{sf} into the final ACK slot, $slot_f$, as thefollowing equationshows,

$$slot_f = Zone_f . [M/L] + [\delta_f . L. R / N] + rand() \quad (5)$$

In our design of Fig. 3 with a small number of ACK slots, by using overlapping zones, the number of ACK slots in each zone will be enlarged. Thus, the probability that several forwarders with similar routing progress choose the same ACK slot will be reduced. Moreover, the size of overlapping slots between two adjacent zones is small. With our random mapping algorithm, the probability that several forwarders that select different zones choose the same ACK slot is small. Note that there are still chances (with very small probability) that the ACKs from multiple forwarders collide. On one hand, if the sender still receives other ACKs distributed in different slots, DOF will ignore the collision and select the forwarder that sends the earliest coming ACK. On the other hand, if the sender has not received any ACK, it will keep transmitting the probe to find other forwarding opportunities. Rather than assigning each forwarder a fixed ACK slot, our method is more flexible to utilize all temporarily available links. Moreover, the parameters of our method are predetermined based on the local routing information so that there is no extra communication overhead. The computation complexity of the algorithm is . However, this algorithm does not guarantee that multiple forwarders do not choose the same ACK slot.

C. Forwarding Management

Note that a forwarder may serve multiple senders during a short period. Each forwarder maintains a sender table, which records the ACK slot information to trace the potential senders. Each entry of the sender table includes the following: the sender's address, expected data sequence number (DSN), and the selected ACK slot. When a probe is received, the forwarder first checks the attached routing metric of the sender. If the forwarder can provide routing progress ($\Delta_{sf} > 0$), it selects an ACK slot to acknowledge the sender. Then, if there is a record of the same sender, the forwarder updates the corresponding record in the sender table. Otherwise, the forwarder adds a new entry into the table. Note that the DSN attaching in the received probe copies that of the sender's pending data packet. Upon the acknowledged probe, the sender attaches the DSN and the selected ACK slot number as the virtual intended forwarder address. When the forwarder receives a data packet, it queries the sender table. If there is no matched entry, the forwarder drops the packet and does nothing. Otherwise, it will take the responsibility to forward the data packet. Moreover, although the forwarder acknowledges the received probe, it still receives the duplicate of the same probe. The probe duplicate indicates the sender has not received the ACK for the previous probe due to the asymmetric link or link dynamics. Considering that the ACK collision rate is low by using ACK slot assignment and the potential forwarders are sufficient, DOF makes a tradeoff between making full use of the forwarders in awake state and decreasing the impact of link burstiness and link asymmetry on energy consumption. If thekforwarder receives thekduplicate probe, itkgoes back to sleepkto save energy. On the other hand, the sender may receive multiple ACKs distributed in different slots after sending a probe. According to our ACK slot assignment algorithm, the forwarder corresponding to the earlier coming ACK provides relatively high routing progress. Thus, the sender inserts the DSN and the minimum slot number of ACK received to the pending data packet and sends it. When the sender prepares to send a batch of packets, the intended forwarder will keep awake during the batched sending. Besides the probes of the first packet, the probes of the rest of the packets are not needed. Thus, to save the extra overhead of the probe transmission, the sender directly sends the rest of the packets with the connection (called Tunnel) found by the probes of the first packet until either the loss of data ACK or there are no pending data packets. When the pending data packet is acknowledged, the sender finishes this transmission. However, because of the lossy link or misalignment of the probe ACK slots, the sender may not receive the data ACK from the intended forwarder. Hence, with a larger retransmission limit is inadvisable. Whether we should keep retransmitting the data packet or send a probe again to detect new forwarders is an important problem for the agility and efficiency of the protocol. According to [11] and [12], the packet loss tends to be bursty over temporally available links. We propose the Limited Retransmission Strategy (LRS) to address the data ACK loss. The basic idea is to estimate the available period of those links and then adaptively bound the number of retransmissions.

D. Low-Duty- Cycled Opportunistic Routing

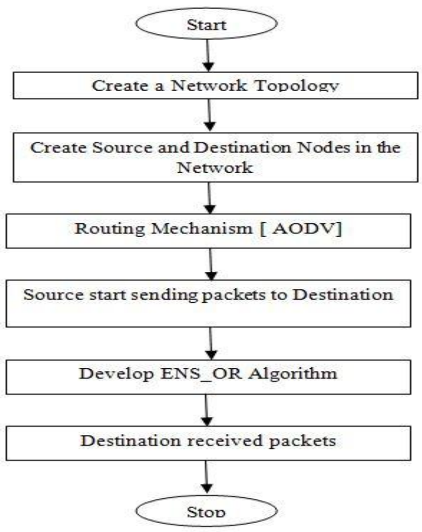
In DOF, a packet is sent to one of the waking neighbors, which provides certain routing progress. As a result, the routing topology toward the sink is not fixed. A packet may be forwarded to the sink along different paths. Moreover, considering the unsynchronized sleep schedule in LPL, DOF drives two requirements on routing. First, the routing metric should reflect the waiting time of the link-layer transmissions. Second, each node should adaptively choose a set of forwarders from all neighbors to determine the local routing metric. Considering the two requirements above, expected duty-cycle (EDC), which is introduced by ORW [8], acts well on the whole. Hence, we adopt the concept of EDC as the routing metric. Our method of duplicate detection can be easily built on other routing metrics as well, such as end-to- end delay or ETX [13]. Briefly, EDC is an adaptive metric of ETX for opportunistic routing in duty-cycled wireless sensor networks (WSNs). EDC describes the expected number of wake-up intervals from the beginning of the transmission to the sink along multihop relay. Hopefully, in unsynchronized duty-cycled schedule, multiple next-hop routing choices decrease the expected waiting time to successfully send the packet to any of them. For node i, giving the next-hop forwarder set F i and the quality q ij of the link with next-hop forwarder j (j € F_i), it defines the single-hop EDC as the inverse of the sum of the link quality of all forwarders in F i , as follows:

$$EDC_i(1) = 1 / \quad (6)$$

IV. SYSTEM DESIGN

In applications like pipeline monitoring and electrical power line monitoring 1-D queue network is been used. In traffic monitoring system also, the 1-D (one dimensional) queue networks are used. The sensor will sense the traffic information in their range, and pass it on to the sink. When it is passed, it should be sent through the energy efficient path.

D Bruckner, proposes a energy efficient routing scheme ENS- OR for such 1-D networks. It introduces a concept called EEN (Energy Equivalent Node). A forwarder list is prepared based on the residual energy of the neighbors. The nodes in the forwarder list rank themselves based on the distance from the EEN. Using ENS_OR algorithm, the next forwarder relay node is selected, and we further analyze the energy consumption of large-scale network under 1-D model. In order to acquire the minimum energy consumption during data transmission in whole network, we introduce the concept of EEN to conduct energy optimal strategy at the position based on the optimal transmission distance dop. However, the optimal energy strategy does not explicitly takes care of the residual energy of relay nodes in the network. For instance, in the case of hop-by- hop transmissions toward the sink node, the relay nodes lying closer to the EENs tend to deplete their energy faster than the others, since dop is a constant. As a consequence, this uneven energy depletion dramatically reduces the network lifetime and quickly exhausts the energy of these relay nodes. Furthermore, such imbalance of energy consumption eventually results in a network partition, although there may be still significant amounts of energy left at the nodes farther away. Therefore, we should readdress the optimal energy strategy for large-scale network. Inspired from the opportunity routing approach, EEN is formed by jointly considering the distribution of real nodes and their relay priority. The specific algorithm to choose EEN is described in the following section.



- One-dimensional queue network is considered, which has been designed and developed for a wide variety of industrial and civilian applications, such as pipeline monitoring, electrical power line monitoring, and intelligent traffic.
- An energy-efficient routing algorithm is proposed for above 1-D queue network, namely, Energy Saving via Opportunistic Routing (ENS_OR). ENS_OR adopts a new concept called energy equivalent node (EEN), which selecting relay nodes based on opportunistic routing theory, to virtually derive the optimal transmission distance for energy saving and maximizing the lifetime of whole network.
- Since sensor nodes are usually static, each sensor's unique information, such as the distance of the sensor node to the sink and the residual energy of each node, are crucial to determine the optimal transmission distance; thus, it is necessary to consider these factors together for opportunistic routing decision.
- ENS_OR selects a forwarder set and prioritizes nodes in it, according to their virtual optimal transmission distance and residual energy level.

Nodes in this forwarder set that are closer to EENs and have more residual energy than the sender can be selected as forwarder candidates.

V. SIMULATION SETUP

In WSN, there is no one-for-all scheme that works well in scenarios with different network sizes, traffic overloads, and node mobility patterns.Ns-2 is a discrete event simulator using in networking research. NS-2 used for wired and wireless network to provides significant support for simulation of TCP, routing and multicast protocols. It is combination of two simulation tools. The network simulator (ns) contains all commonly used IP protocols. The network animator (nam), which is use to visualize the simulations. Ns-2 can fully simulates a layered network from the physical radio transmission channel to high-level applications.

Table: 1 Simulation Parameters

Simulation Parameters	Value
Simulator	Ns-2 (2.35)
Topology	1200*1000
Propagation Model	TwoRayGround
No. of Nodes	User Defined
Bandwidth	3 Mbps
Queue length	340
Packet Size	512 bytes
Simulation Time	20 s
Initial Energy	100 Joules
Routing Protocols	AODV

The initial topology settings required for the setting up of the network environment. First the n numbers of mobile nodes are deployed using ns-2.35 simulator tool to form a WSN structure. Here we have created the network with user defined set of mobile nodes acting as sensor nodes. In the network there is a one Source node. And one (Sink) Node 0 is considered as destination node and also user has to give deterministic forwarder node from source to sink. It is as shown in Fig 4 and it gives the design of the initial topology required to setting up the environment.

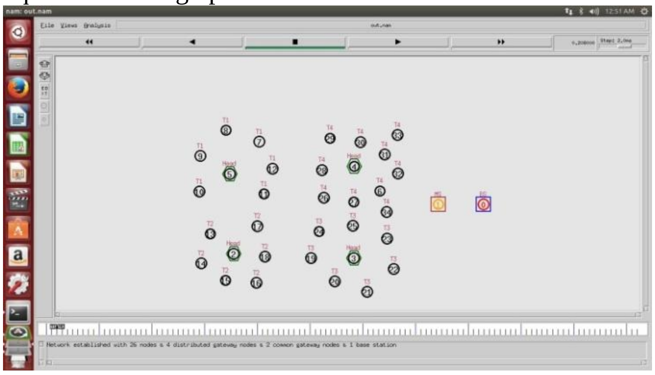


Fig 4 Initial Topology Design for WSN

VI. RESULTS

Here we deployed10 nodes with 2as forwarder. Node1 is considered as Source node and node0 is treated as sink node. for this application both transport layer protocols have been implemented first we tries to implement with TCP and later with UDP. The results are described below.

Using TCP :
The nodes are randomly deployed and TCP agent is provided for communication between source and sink node.

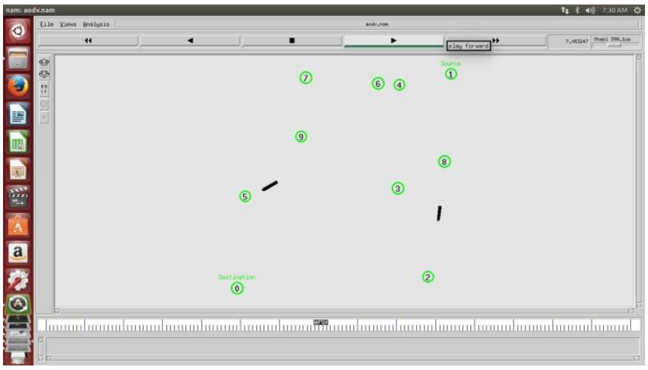


Fig 5 TCP Connection between source and sink node.

Source node 1 selects two different shortest paths based on opportunistic forwarding, in which we need to select one reliable path and with the help DOF routing protocol. A sender sends a probe and asks the potential forwarders to acknowledge the probe respectively in different time-slots. By utilizing the temporal diversity of multiple acknowledgments, the node 1 detects the quantity and differentiates the priority of all potential forwarders. The node 1 then forwards its data in the deterministic way to avoid multiple forwarders hearing the same packets. We develop methods to resolve possible collisions among multiple acknowledgments and exploit temporal long good links for opportunistic forwarding. Fig 5 illustrates with the help of TCP Agent source 1 selects two optimal paths one from 1,6,5,0 and other through 1,2,0. And we select next reliable forwarder as (2) so in this case source node 1 uses 2 as next forwarder and with the help of DOF it neglects path 1,6,5 and 0. Thus efficiency and energy will be consumed.

Using UDP Agent:
The nodes are randomly deployed and UDP agent is provided for communication between source and sink node. In fig 6, source node 1 sends hello (probe) packets to all potential forwarders, then these forwarders forward data to the sink nodes. There by calculating nearest neighbor as Next potential Forwarder. For the above scenario next potential forwarder is considered as Node 2.

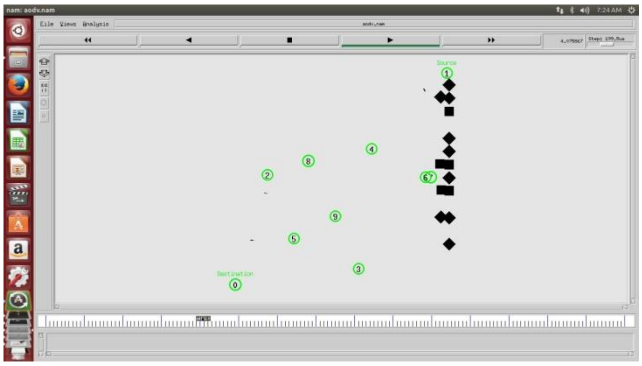
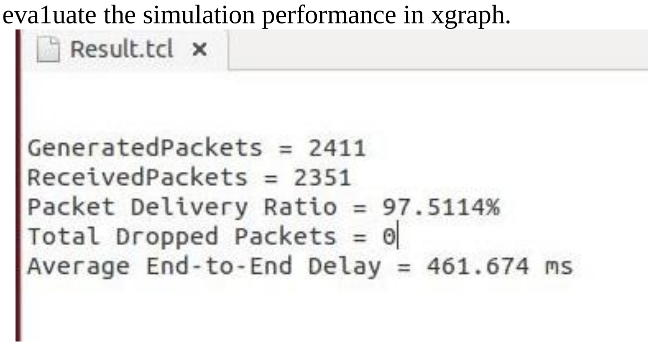


Fig 6 UDP Connection between Source and Sink Node.

Performance Evaluation
In this section, evaluate the performance of simulation. We are using the xgraph for evaluate the performance. We choose the some evaluation metrics: Energy Consumption – the energy consumed by the source node and destination node and also calculate the Throughput and Average End to End Delay. Along these evaluation metrics we have to eva1uate the simulation performance in xgraph.



Result.tcl

GeneratedPackets = 2411
ReceivedPackets = 2351
Packet Delivery Ratio = 97.5114%
Total Dropped Packets = 0
Average End-to-End Delay = 461.674 ms

Fig 7 Result analysis over TCP Network.

Energy Consumption:

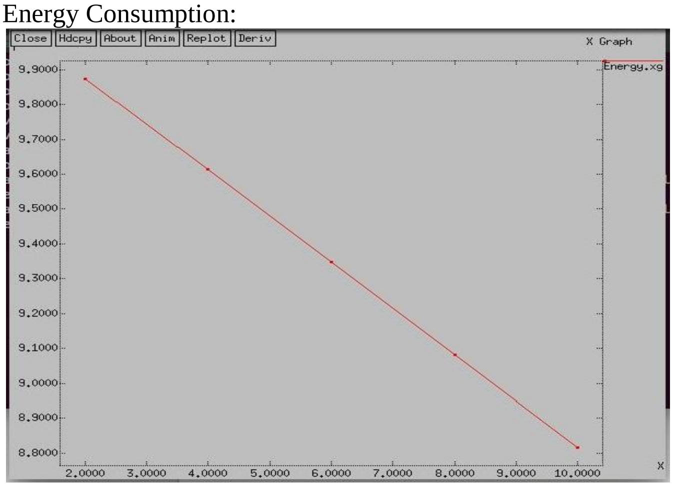


Fig 8 Xgraph of Energy Consumption Throughput:

Fig 9 Throughput (Kb/s)

Average End - End Delay:
Average End to End delay is defined as time taken by the source node to sink node to communicate.

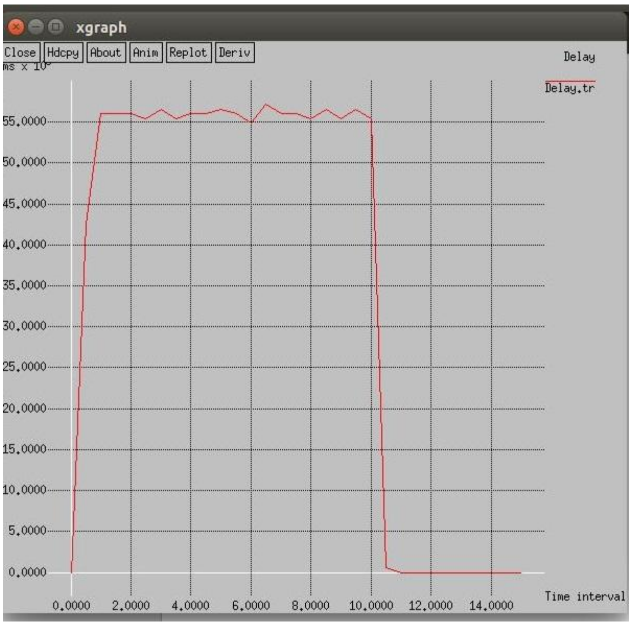


Fig 10 Average End to End Delay from source node to sink node.

VII. CONCLUSION

We proposed opportunistic routing protocol for selecting relay nodes in wireless sensor network to transfer the data from source to sink. The previous approach does not consider the drain rate and other minute details like number of retransmissions, energy consumed by transmitter circuit, receiver circuit etc. The simulation results show that the proposed protocol performs better. In future, the experiment will be done in real world. Developing an adaptive and efficient forwarding protocol is urgent for a duty-cycled wireless sensor network. In this paper, we propose DOF, a duplicate detectable unsynchronized low-power opportunistic forwarding that is adaptive to various traffic loads. Based on the slotted acknowledgment, DOF mainly solves the channel degradation problem incurred by the large amount of duplicates in traditional opportunistic forwarding and retains the benefits of the opportunistic routing as much as possible. The testbed experiments show DOF is more efficient and reliable than state-of- the-art low-duty- cycled forwarding protocols.

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