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# Unicast Routing for CWSB Pest Identification in Coffee Plantation using WSN: Energy Aware Approach

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***Abstract***

*This paper proposes a Unicast Routing in Coffee Plantation (URCP), an energy aware approach for forwarding the information of Coffee White Stem Borer existence in Coffee Plantation using Wireless Sensor Networks. Acoustic signals that are made with biting sound by the pests inside the stem are captured by the nodes, and the information is aggregated at Cluster-Head (CH) which is to be conveyed to sink node in an energy-efficient way. Event-driven routing of the aggregated data is carried out by the CH which follows a Poisson distribution and maintains energy conservation by reducing the number of control packets for route establishment. Simulation analysis of URCP is compared with data routing for in-network aggregation and energy-efficient hierarchical clustering routing protocol in terms of packet delivery ratio, control overhead and energy consumption. The URCP simulation results outperform set alongside the corresponding techniques.*

***Keywords:*** *Clustering, Aggregation, Routing, Energy-efficiency*

## 1. Introduction

Coffee production is one of the effective agricultural commodities in the global world [1]. Two varieties of coffee, namely, Coffee Arabica and Coffee Robusta, are cultured on economic proportion. Due to the product quality that Arabica possesses, it is mainly preferred above the other coffee in the global scenario [2-3]. Coffee White Stem Borer (CWSB) is known as a substantial menace to the Arabica Coffee. The CWSB activity schedule commences with the first deposit of 50-100 eggs on the stem, combined with the incubation period of about 10-12 days constituting the grub. These grubs bore in a number of ways inside the stem attaining utilization to the food and water resources used by the stem for a period of 11 months [4]. In the metamorphose level, the grub transforms into a beetle and exists from the stem through the exit hole leading to porous stem that triggers loss of life of the plant. Based on the extensive research on the coffee plant, the damage is exclusively due to CWSB no other pest activity is noticed within the coffee stem. By acquiring the pest and prevent its existence, the population surge could be inhibited. The complete life cycle of the infestation within the entire process is one-year [5-6].

The identification of CWSB in the coffee plantation is a sparingly challenging task that may be solved by adopting sensor technology over the coffee field [6-18]. Wireless Sensor Network (WSN) is a primary principle for such detection, made up of one or multiple Base-Station (BS) and a couple of sensor nodes deployed within an area called sensing field like a coffee field [7]. The challenges involved in WSN design are proficient usage of restricted energy, identifying efficient interference avoidance mechanism, designing proper security management services, and deployment of nodes in a large-scale effective sensor field. Sensor nodes are higher resource-constrained, with finite control power, space for storage, bandwidth, and battery [8]. Duration of the sensor nodes in WSN is highly allied to the power

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consumption of its battery [8]. Developing optimized hardware, embedded software, data gathering and routing algorithms reduce the energy consumption in WSN [6].

Radio communications used for data gathering and routing are the major sources of energy consumption [6-8]. Data gathering involves data computation and its transmission. Higher level of energy is consumed for data transmission, and sparingly lesser energy is consumed for data computation [9]. Solution to optimize the energy consumption during data transmission is by lowering the communication overhead through data aggregation that reduces redundancy and unneeded data forwarding, hence cutting down the energy consumption in communications from the nodes to the BS [9-10]. Routing involves the process of finding and retaining routes in WSN which is nontrivial since energy limitations and node inability cause repeated and unstable topological changes [11]. In this paper, we propose a unicast routing for CWSB pest identification in coffee plantation, called URCP for a cluster-based WSN that addresses all the issues mentioned above. In our methodology, all the sensor nodes are arranged in distinct clusters. Data aggregation is carried at the CH using Kolmogorov’s zero-one law to eliminate redundancy [6-7]. Event-driven routing of the aggregated data is carried out by the CH which follows a Poisson distribution and maintains energy conservation by reducing the number of control packets for route establishment.

### 1.1. Related Works

The authors in [12] proposed a cluster based routing with TDMA-based MAC mechanism in cross-layer operation for transmission power control. In [13], the authors proposed DRRP, a routing protocol with the power of dynamic reconfiguration. The authors in [14] proposed LEACH for clustered aggregation routing in WSN. Cluster formation is random, adaptive and self-clustering. In [15], on the detection of an event, cluster formation begins with the allocation of the CH and presenting responsibility to each member node in the cluster. The authors in [16] proposed DRINA that is targeted at establishing data synchronization among the transmitting nodes. A node forwards the data only after looking towards a while for data from its neighbor. As there are certain extra number of aggregation points, waiting period of the aggregator to obtain the data from other nodes becomes important. The authors in [17] proposed EEHCRP, whereby using various power levels at BS the network is partitioned into annular rings. These rings contain various sensors programmed such that they extend the network lifetime with a reduction in the energy consumption and faulty nodes.

## 2. Energy Aware Approach for Pest Detection using WSN

In our proposed methodology, for a set of nodes we employ cluster-based data aggregation that requires selection of Cluster-Head (CH). The coffee field is split into small non-overlapping areas (called as a cluster) with all areas possessing a couple of nodes that cover the coffee stem. Each sensor node belongs to only one CH [6]. The Ultrasonic Active Sensor (UAS) is placed in the field that sense the CWSB around the cavity area and confirms the grub existence in the coffee stem as shown in Figure 1. The location of each node placed is according to the communication range of the selected UAS as a CH and the member nodes in such a way that 10-12 coffee plants are covered. Each cluster with one CH and many cluster members eventually sense the change in the sound wave attributable to pest existence in the coffee stem environment. The UAS on deployment within the respective cluster follow the Doppler's phenomenon by spreading across acoustic waves of frequency about 40 KHz and covering a distance of 10-15 meters. Reflected sound waves are picked by the receiver and are analyzed. The changes observed in the received sound wave is considered a shift in frequency which further triggers an alarm [6-18]. Since, it is just a homogeneous network the clustering scheme uses the concept of inner-band and outer-band selection for selecting cluster members as shown in Figure 2.

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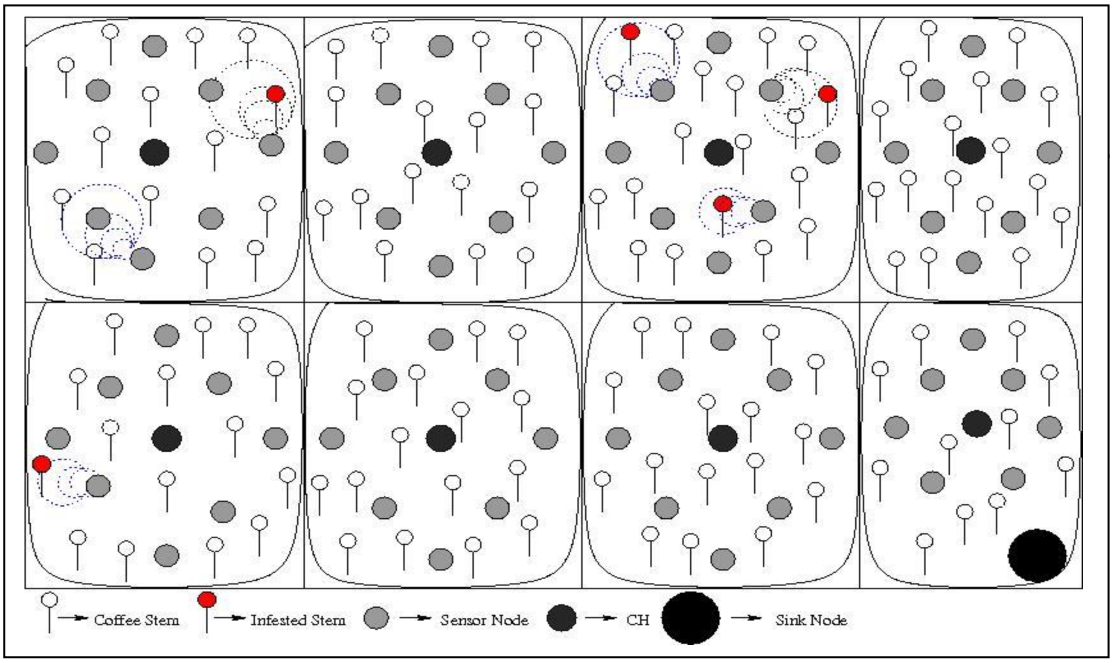


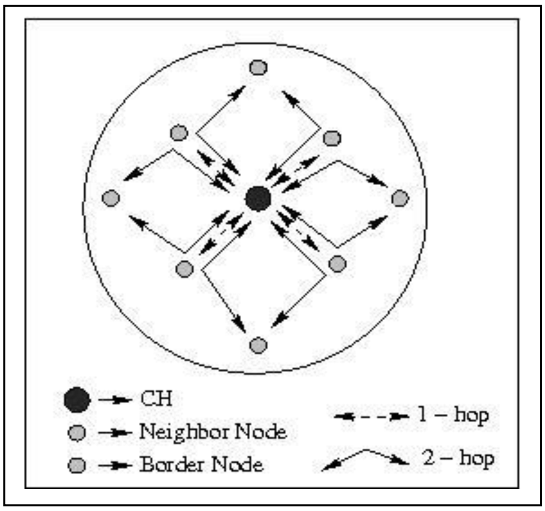


Figure 2. Fixed Deployment of UAS

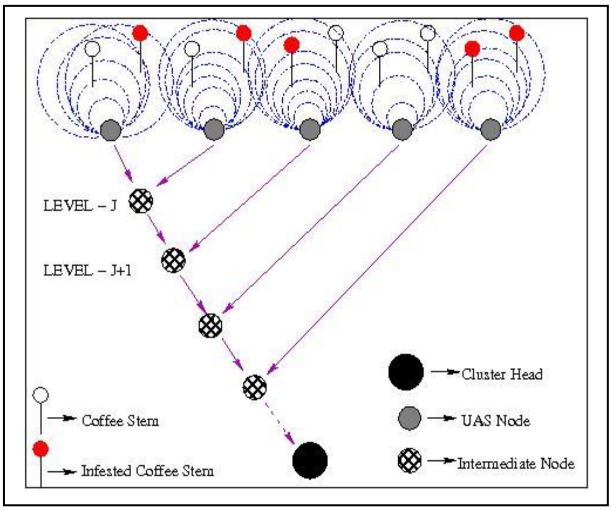


Figure 3. Data Aggregation in Coffee Plantation

To initiate this process flooding is carried out by the CH applying the RREQ packets. These RREQ packets traverse over the 1-hop and 2- hop nodes of a cluster and also to the remaining clusters till it finds its destination node. At the destination, the sink node analyzes the contents of the RREQ's received that contain information on the packet buffer capacity, percentage energy of the nodes, number of hops and timestamp. A better route would be decided on by the sink node and directed to the source CH in the form of RREP packets. On receiving the RREP packet by the source CH, the intended information would then be destined to the sink node.

### 2.1. Data Aggregation with Redundancy Elimination

The model for WSN is discussed in [6-7]. Let S = {S[1], S[2], ...,...., S[n]} represent the set of nodes sensing the event. At each time slot, the sensors are arranged in a sequential order within a cluster. The data gathered is either '0' or '1' indicating the absence or presence of the

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CWSB in the coffee stem respectively. More than one sensor node within the cluster may detect the CWSB pest at the same time at the same location or different locations. To reduce the redundant data transfer, the information received by the CH applies the Kolmogorov's zero-one law as shown in Figure 3. Depth of the level is unusual at the distinctive time during this combining process that is decided to use the OR function.

$$D_{aggregate}(A_i, A_j) = \begin{cases} 1, & \text{if } [(A_i < A_j) || (A_i > A_j)] \text{ } and \text{ } [A_i = A_j \text{ } where \text{ } i, j \neq 0] \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

### 2.2. Route Request and Route Reply Packet

The elements of RREQ and RREP prepared in the form packets are as follows. (1) *Source Node Id (Src_ $Nd_{Id}$):* The address of the source node willing to establish routes to the sink node. (2) *Destination Node Id (Dst_$Nd_{Id}$):* The address of the sink node, where the data is to be delivered. (3) *Visited node address ($N_{visit}$):* The address of the intermediate node on the path from source to sink node. (4) *Hop Distance ($Hop_{Dist}$) in meters*: The distance between the node and its one hop neighbor. (5) *Route Distance ($Route_{Dist}$) in meters*: The distance between the source node and its visited node. (6) *Timestamp ($T_S$):* The time period when the packet is active within the network. (7) *Node Packet Buffer Capacity ($P_{BC}$):* The memory space set aside for storing packets awaiting transmission over the network. (8) *Residual Energy ($E_{res}$) in %:* The remaining energy status of the node. (9) *Route Establishment Flag (REF):* For an RREQ packet, REF=1 and for an RREP packet REF=0. (10). *Sequence number (Seq_no):* The number assigned for every RREQ/RREP packet by the respective source node.

### 2.3. Sequence of Actions Performed

On acquiring the data packets from the neighbor nodes, the CH initiates data aggregation with redundancy elimination. The aggregated data, thus obtained at the CH has to be delivered to the sink node. To initiate this process of data forwarding a path has to be established by the CH. For path establishment, the CH broadcasts the RREQ packets to the neighbor nodes that happen to be in 1-hop connection with the CH that further traverses along the 2-hop nodes and further as shown in Figure 4.

At the initial stage when the RREQ packets traverse their happen to be instants where in fact the neighbor nodes would have the same RREQ’s. In case a node gets both RREQ packets of same *Seq_0* from its neighbor node, then the node must consider the RREQ packet predicated on enough timestamp of the packet.

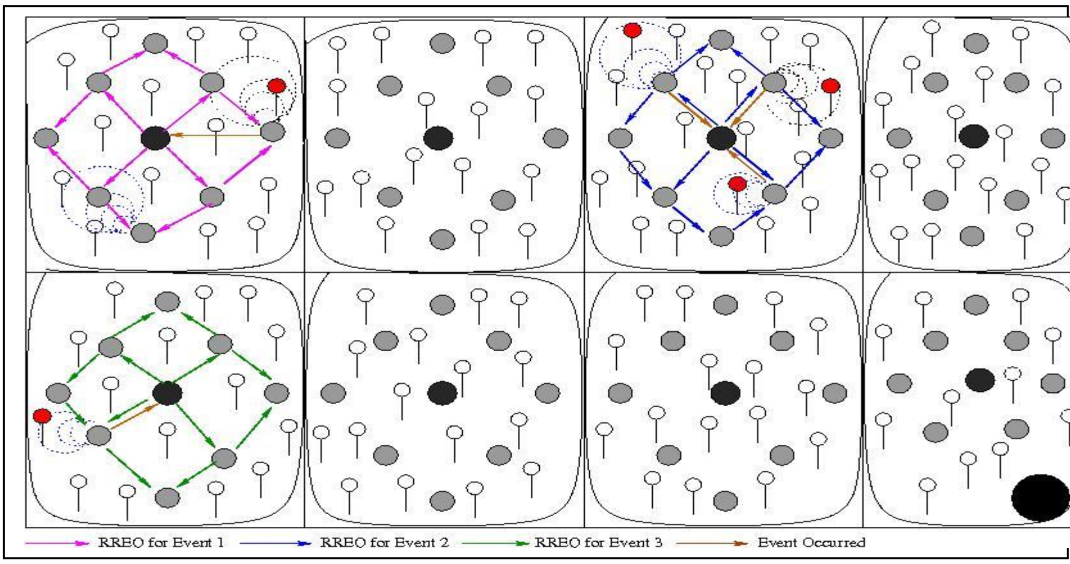


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**Figure 4. Flooding by the CH's using RREQ Pkt**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $Src\_Nd_{Id}$ | $Dst\_Nd_{Id}$ | $N_{Visit}$ | $Hop_{Dist}$ | $Route_{Dist}$ | $T_S$ | $P_{BC}$ | $E_{res}$ | REF | Seq–no |

**Figure 5. RREQ Packet Format**

All the neighbor nodes have already been created with forwarding and a discarding policy plan of packet predicated on the *Seq_0* and the $T_S$. The RREQ packet containing the given information is as shown in Figure 5. On reception of the RREQ packets by the neighbor nodes, the packet field information is collected and stored.

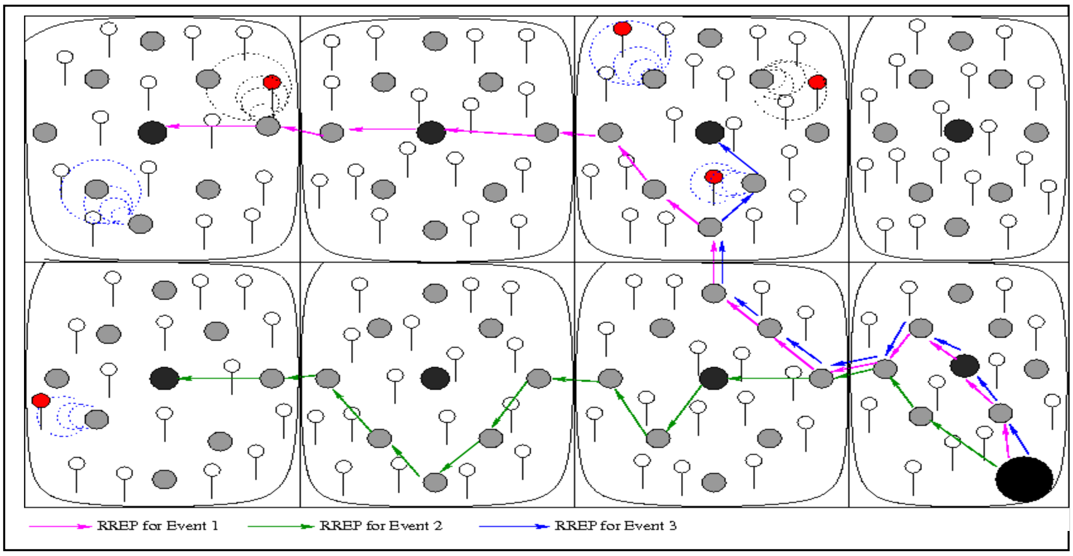


**Figure 6. Providing the Various Path using RREP Pkt**

| | | | |
|---|---|---|---|
| $Src\_Nd_{Id}$ | $Dst\_Nd_{Id}$ | $T_S$ | REF |

**Figure 7. RREP Packet Format**

The number of nodes the RREQ packet traverses is maintained in the list of visiting nodes that appropriates the hop distance count until it reaches the destination for route distance to be registered. For the node to take part in path establishment its node buffer capacity should be less than the buffer threshold ($P_{bc} < P_{th}$), else the node starts dropping the packets transmitted towards it. The percentage residual energy at each node where the RREQ traverses are calculated by using the equation 2. The labels ($E_{rem}$) represents the actual energy availability, ($E_{th}$) represents the threshold below which the node does not operate and ($E_{total}$) is the total energy availability of the node. Percentage residual energy obtained in the packet field indicates whether the node is able to participate in the route establishment process or not. The time instant for the RREQ generation at the source till it reaches the sink is maintained in the field $T_S$.

$$E_{res}\% = \frac{E_{rem} - E_{th}}{E_{total}} * 100 \tag{2}$$

At the destination, the sink node will accept all the RREQ's received at the instant $T_S$ from same CH. The $T_S$ is initially set to a maximum value *x*, as the RREQ packet traverses the $T_S$ gets decremented ($T_S-1$) till it reaches the sink node. The $T_S$ on reaching the value zero, if still in the loop the packet drops. Sink interval ($S_{imax}$) is defined that maintains the time between two RREQ's received from the same source. Suppose, if $RREQ_1$ is received at time $T_i$ and next $RREQ_2$ is received at time $T_l$, then $\{S_i = (T_l - T_i)\}$, where $i$ get incremented. The reception of the RREQ packet at the sink node cannot be for an infinite time, we define the maximum $\{S_i=S_{imax}\}$. After $S_{imax}$, all RREQ's are ignored. The RREP packet is generated at the sink node once the RREQ packet is collected on $(S_i=S_{imax})$ and path to the source has been found as shown in Figure 6. The structure of RREP is as shown in Figure 7. The parameters in the packet field direct the RREP to reach the source CH based on the minimum amount of resource parameters obtained at the sink node. On receiving of the RREP the acquired data at the CH gets forwarded till it reaches the sink through the specified pathway by RREP.

## 3. Simulation Model

The outlined scheme was evaluated using simulation. To decide the performance and competence of the approach, URCP simulation is carried on QualNet 5.2 Network Simulator. URCP simulation environment uses these models: Network model, Propagation model and Traffic model.

### 3.1. Simulation Results

**3.1.1. Analysis of PDR:** In Figure 8, we have compared PDR of URCP with DRINA and EEHCRP for various packet arrival rate. Since the transmission delay in URCP is less, there are fewer chances of congestion and hence packet drops are reduced with enhanced PDR. This is because URCP uses, inner-band and outer-band ranges to communicate within a cluster thereby isolating the congestion point in these bands. In DRINA and EEHCRP, the congestion rate is higher as the delay involved is more. In all these cases, it is observed that the PDR decreases with an increase in transmission rate.

**3.1.2. Analysis of CO:** CO is plotted with varying number of nodes as shown in Figure 9. The number of control packets for URCP is less compared to DRINA because the former uses selected nodes for establishing the routes whereas DRINA and EEHCRP use all the nodes and hence increasing the number of control packets. For more value of node threshold, there are less number of control packets that are generated as less number of nodes are involved in routing.

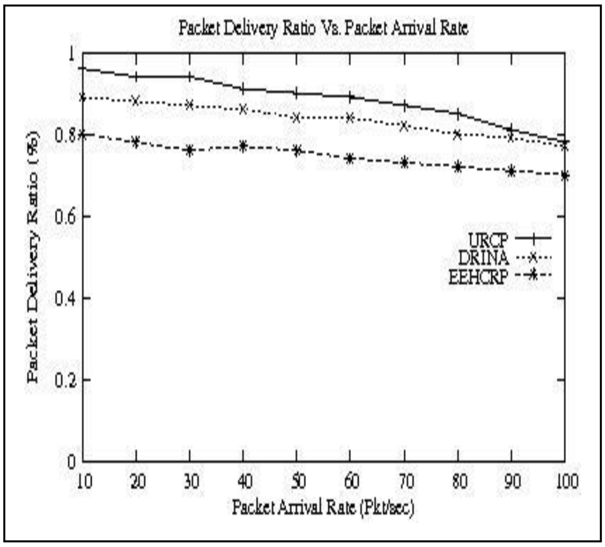


Figure 8. PDR Vs. Packet Arrival Rate

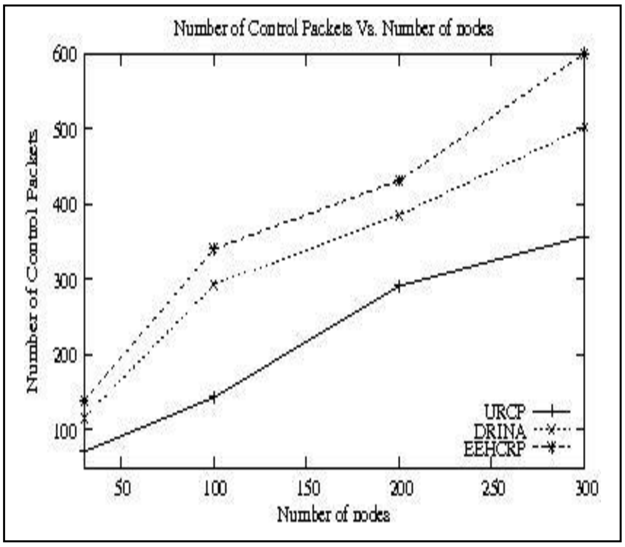


Figure 9. No. of Control Packets Vs. No. of nodes

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**3.1.3. Analysis of EC:** The EC is a crucial factor for communication in WSN. The power consumed by sensor nodes for clustering and data aggregation in URCP is kept at minimal as shown in Figure 10. The reason behind this is the reduction in the number of message packets from CH to BS due to usage of our aggregation method.

## 4. Conclusion

In this paper, we have considered a URCP model for transmitting the obtained CWSB pest identification by the CH in the Coffea Arabica plant. Ultrasonic Active Sensor (UAS) assists in identification of the pest that further more help in lowering the redundant data incoming to the CH through multiple nodes. The technique involves data aggregation with redundancy elimination and unicast routing for route establishment utilizing packet buffer capacity, percentage energy of the nodes, number of hops and timestamp acquired from the model. Simulation analysis performed illustrates the potency of the scheme.

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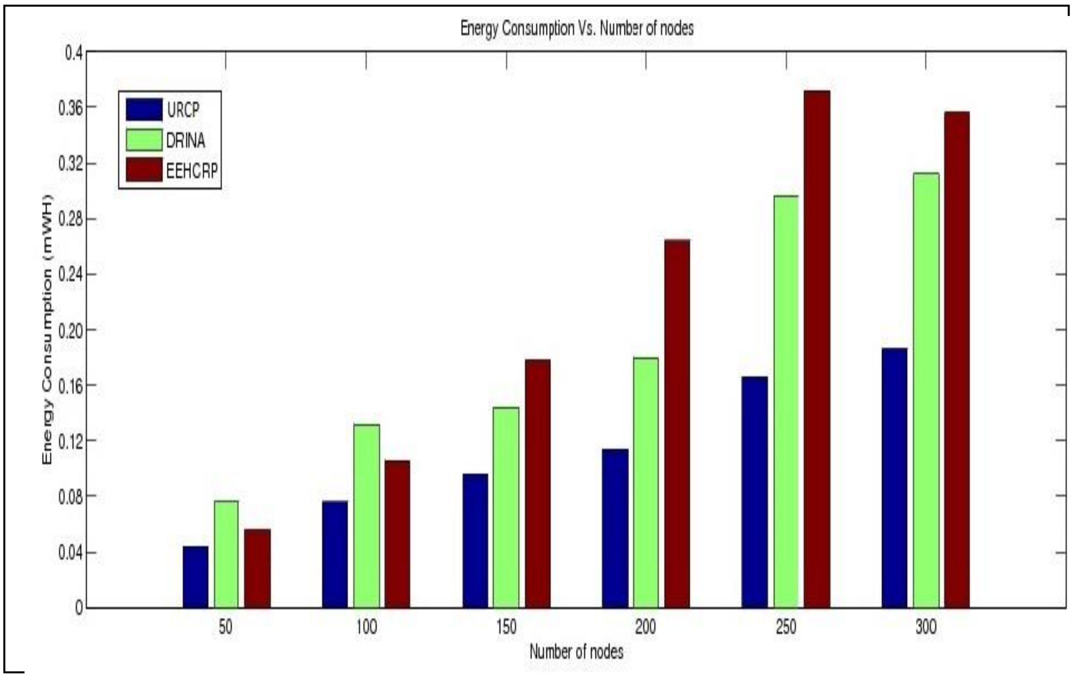


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