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Correlation Based Energy Efficient Routing in Wireless Sensor Networks

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ABSTRACT—A new clustering algorithm and event-driven cluster head rotation mechanism is proposed to solve the energy balance problem in original RPL (IPv6 Routing Protocol for Low Power and Lossy Networks). Even though energy consumption is reduced and life time increased in this approach, the approach cannot reduce the number of packets transmission. In this work, correlation based adaptive transmission is added to clustering approach, as an extension of the original work, in which the transmission process of a node is controlled. By this way of controlling transmission, the lifetime of sensor can be further enhanced.Experimental results show that in comparison against the original E2HRC, the correlation based energy efficient routing protocol more effectively reduces wireless sensor network energy consumption, thus decreasing both node energy consumption and the number of control messages.
Index Terms—Clustering, Cluster head rotation, Energy efficiency, Wireless Sensor Networks.

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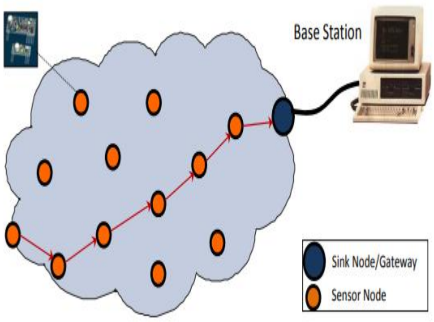
I. INTRODUCTION

WSN are applied in many applications like tsunami detection, ocean boarding alarming for fisherman. Typical WSN consist of nodes connected through wireless infrastructure. The nodes scattered with the objective to sense some environment parameters and route these parameters to base station to realize application logic. The sensors are battery powered and energy depletes during the operation of nodes. At one point of time sensors fails to operate due to very low or no battery energy. In most cases sensors are deployed in unattended environment and it may be costly or not possible to replace the sensor nodes. This necessitates prudent use of energy in the nodes so that longevity of network increases.

Wireless Sensor Networks (WSN) consists of spatially distributed autonomous sensor nodes which are organized into a cooperative network.



A wireless sensor network is composed of wireless sensor nodes and a sink node. Nodes are wirelessly interconnected to one another and to the sink. These networks are characterized as Low-power and Lossy Networks (LLNs), as individual nodes possess limited power and operate in harsh environments. If a node is not in direct communication range with the sink, the data it captures is reported in a multi-hop manner. In this way, nodes located closer to the sink end up relaying data for nodes that are farther away, thus creating hotspots near the sink. These hotspot nodes tend to deplete energy faster, thus reducing the wireless sensor networks lifetime. Considering of LLN characteristics and possible applications, the Internet Engineering Task Force (IETF) Routing Over Low-power and Lossy networks (ROLL) group has standardized a low-power and lossy network routing architecture called RPL. This protocol is an open and accepted technical standard in regards to wireless sensor network IP-based development. The salient design feature of RPL is a routing framework that allows the use of different routing metrics and objective functions (OFs) to manage LLNs, including limitations and heterogeneous application requirements

Many other RPL-based routing protocols have been proposed for different optimization objects. Clustering based routing is proposed in this work.

II. RELATED WORK

RPL (IPv6 routing protocol for low power and lossy network) is a routing protocol specially designed for LLN(Low Power and Lossy Networks) that have limited resources, LLNs are compliant with the 6LoWPAN protocol. O. Gaddour.et.al.[1] lack of surveys on RPL is the motivation behind this paper. In RPL a connection tree called Destination Oriented Acyclic Graph (DoDAG) is constructed, this helps in relaying traffic.

The DoDAG is built by calculating the objective function. Various messages are exchanged between the nodes. The nodesfrequently broadcast DIO message (DoDAG Information Object) to advertise graph characteristics. The nodes broadcast a DIS message (DoDAG Information Solicitation) when it needs to join the DoDAG and immediately receive DIO. The DAO (DoDAG Destination Advertisement Object) is transmitted by each node to validate the path choice and to notify the selected parent. This parent then sends a DAO acknowledgment to the sender node when it receives the DAO.

Many large-scale markets still carry out manual updating of price tags, this leads to errors and inaccuracies. Low-power display techniques such as electronic-ink can be used to automate this process. Kim et al.[2] proposedMarketNet,an asymmetric transmission power-based network for densely populated, obstacle-rich, downwards traffic-oriented environments, where the root directly transmits downlink packets to destination nodes using higher transmission power than low power nodes possess.

Support for mobility in wireless sensor networks has always been a challenge.O. Gaddouret al. [3] proposedCoRPL as an extension to RPL based on the Corona mechanism to support mobility, it functions by using multiple route selection to improve the original RPL object function. CO-RPL exhibits better energy consumptions and packet pass rates when compared to the original RPL, but packet congestion and control packet flooding may still take place in large-scale wireless sensor networks.

Ko et al. [4] proposed the interoperability problem of two operation modes (MOPs) defined in the RPL standard, ultimately demonstrating that there is a serious connectivity problem when two MOPs are mixed within a single network. The DualMOP-RPL, which allows nodes with different MOPs to communicate gracefully in a single network while preserving the high bi-directional data delivery performance, was established to solve this problem.

RPL allows bi-directional end-to-end IPv6 communication on resource constrained LLN devices, leading to the concept of the Internet of Things (IoT) with thousands and millions of devices interconnected through multihop mesh networks. H.-S. Kimet al. [5] investigated the load balancing and congestion problem of RPL. It shows that most of packet losses under heavy traffic are due to congestion, and a serious load balancing problem appears in RPL in terms of routing parent selection. To overcome this problem, this study proposes a simple yet effective queue utilization based RPL (QU-RPL) that achieves load balancing and significantly improves the end-to-end packet delivery performance compared to the standard RPL. QU-RPL is designed for each node to select its parent node considering the queue utilization of its neighbor nodes as well as their hop distances to an LLN border router (LBR). Owing to its load balancing capability, QU-RPL is very effective in lowering queue losses and increasing the packet delivery ratio.

As the collected information increases, the computing performance of single-core sink node for Internet of Things (IoTs) cannot satisfy the demand of large data processing. Hence, the sink node which based on embedded multi-core SoC for IoTs and maximizing its computing performance has brought into focus. T. Qiuet al.[6]proposed a multi-core Task-Efficient Sink Node (TESN) based on heterogeneous architecture and the Weighted-Least Connection (WLC) task schedule strategy has been proposed to improve its efficiency. There are two types of cores in the sink node, master core and slave cores. The master core deals with tasks allocation and the seven slave cores deal with data processing. All of the cores are communicating with each other through mailbox. By considering each core's real-time processing information and computing performance, the proposed WLC can balance each core's load and reduce network congestion.

A multi-father node routing strategy was proposed for the original RPL by Iova et al. [7] that can increase wireless sensor network redundancy, increase stability, balance energy consumption, and extend lifespan. Even with this routing maintenance and routing reconstruction, the network is still congested by a large number of packets; node memory becomes exhausted with an increase in redundant routes, necessitating more node memory to satisfy the performance requirement.

Research indicates that hierarchical networks have unparalleled advantages over other networks. Yu et al. [8] proposed an energy-aware clustering algorithm to solve unbalanced energy dissipation accompanied by a new routing algorithm based on this clustering algorithm; the routing algorithm operates by dividing a nodes competitive radius when attempting to join a cluster. The node with the most energy is then selected.

Yan et al. [9] built a clustering topology control algorithm based on a wireless sensor network with an uneven gradient. Other nodes calculate their own weight and send these weights to their neighbors to participate in cluster head selection based on global parameters transmitted by the sink. Nodes with powerful communication capabilities are effectively selected as cluster head nodes, however, this causes nodes to send too many campaign control messages, resulting in a flood ofcontrol messages to the wireless sensor network and essentially wasting node energy.

Liu et al. [10] proposed the EDUC algorithm based on the probability model with regards to energy and distance. To be specific, the avoiding time message that the candidate cluster heads send to campaign control is calculated according to node energy and distance: The more energy a node has and the closer it is to the sink, the shorter the avoiding time. It is thus likely that a certain node becomes a real cluster head. This algorithm may cause a large number of nodes close to the sink to become cluster head nodes, however. When cluster head nodes are unevenly distributed in the wireless sensor network, the traffic is increased in the clusters; further, the routing convergence time is longer due to low network power and low loss.

Wenbo Zhang et al. [11], a heterogeneous ring domain communication topology with equal area in each ring is presented in this paper in an effort to solve the energy balance problem in original IPv6 routing protocol for low power and lossy networks (RPL). A new clustering algorithm and event-driven cluster head rotation mechanism are also proposed based on this topology. The clustering information announcement message and clustering acknowledgment message were designed according to RFC and original RPL message structure. An energy efficient heterogeneous ring clustering (E2HRC) routing protocol for wireless sensor networks is then proposed and the corresponding routing algorithms and maintenance methods are established. Related messages are analyzed in detail. Experimental results show that in comparison against the original RPL, the E2HRC routing protocol more effectively balances wireless sensor network energy consumption, thus decreasing both node energy consumption and the number of control messages.

III. PROPOSED WORK

The proposed system is an extension on to E2HRC[11].

The correlation between aggregated packet from the cluster head is found using ARIMA model. Auto-regressive (AR(p)) model is time series model where value at time t is a linear combination of past p values together with a residual error term.

Using previous values of aggregated data from the cluster heads, correlation model is built for each cluster head. When the future values of cluster head can be predicted with high correlation, then cluster head node can be stopped from transmission of packets.

The System architecture is shown below.

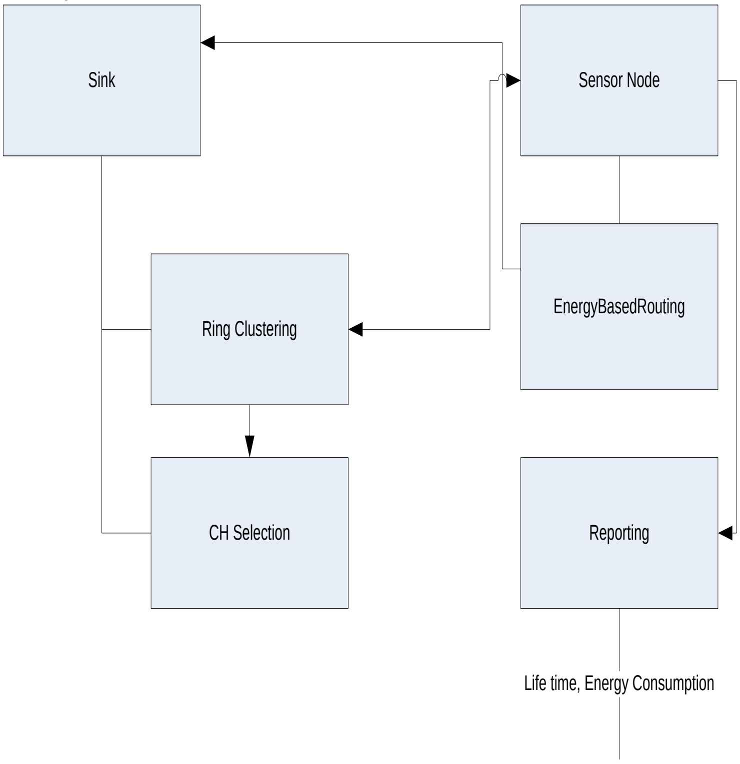


Fig 1: System Architecture

There are two important components in the architecture
1)Sink
2)Sensor Node

Sink: Sink creates Ring clustering of network based on the position information of nodes. After clusters are established, energy efficient cluster heads are selected for each cluster and sensor nodes advertised about the cluster head node.

Sensor Node: Sensor node generated packets at periodic intervals and forward via energy based routing module to the sink. The sensors report their current energy consumption and remaining energy to the reporting module,through which reporting module calculates the life time of the network.

The rest of the modules are explained below.

Ring Clustering

The sensor network is split is four ring clusters. The clustering is done based on the distance between the sink and the sensor nodes. The nodes at every 100m distance is considered one ring cluster: the nodes that are at 100m distance is Cluster 0, the nodes at 200m distance is Cluster 1, the nodes at 300m distance is Cluster 2 and the nodes at 400m distance is Cluster 4. Then the cluster head is selected for each ring cluster.

The flow chart for ring clustering is shown below.

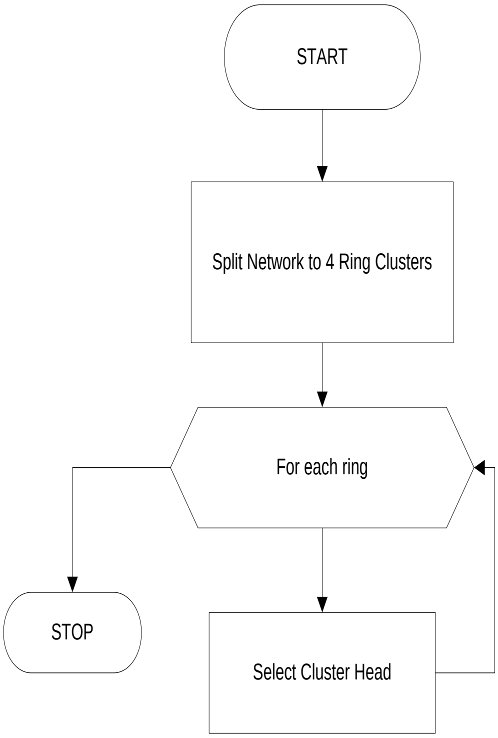


Fig 2: Flowchart for clustering

Cluster Head Selection Mechanism

Once the ring cluster formation is completed, the next step is to select the cluster heads for each ring cluster. The node which has the highest residual energy is selected as the cluster head for that ring cluster. All the nodes forward the messages to the cluster head, the cluster head is responsible for aggregating all the messages and the cluster head finally forwards it to the sink node.

Cluster Head Rotation Mechanism

If a node is not in direct communication range with the sink, the data it captures is reported in a multi-hop manner. In this way, nodes located closer to the sink end up relaying data for nodes that are farther away, thus creating hotspots near the sink. These hotspot nodes tend to deplete energy faster, thus the node my die. In order to avoid this, the cluster head rotation mechanism is introduced. In the cluster head rotation mechanism, the node with the next highest residual energy is nominated as the cluster head. The cluster head rotation mechanism takes place every 2 seconds.

Energy Based Routing

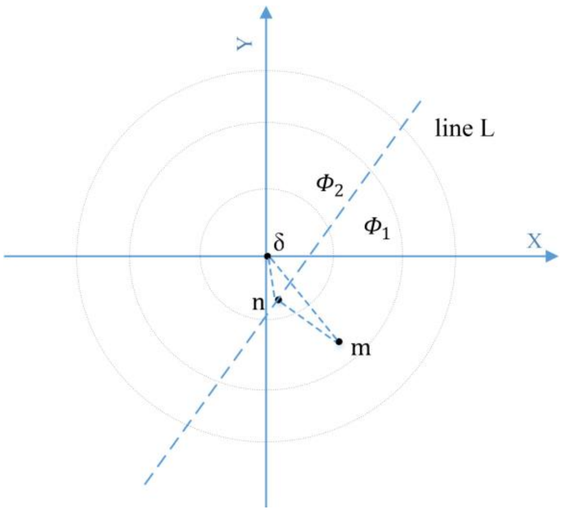


Fig 3: communication area

Optimal Direction Angle, DA: a straight line is drawn from the sink to the relay node and joined the relay node to source node in another straight line. If the included angle between those two lines is less than or equal to 180° and greater than or equal °, this included angle is the optimal direction angle.

The proposed routing algorithm is a stepwise process.

The optimal direction angle is chosen as the path to route the packets.

If there are multiple paths with the same optimal direction angle then the nodes in that path are taken into consideration, whichever path has the least number of nodes is chosen to relay the packets to the sink node.

The routing is carried out in a multi-hop manner.

Data Correlation and Prediction

E2HRC efficiently balances the energy consumption, to further reduce the energy consumption and decrease the number of packets being sent, data correlation and prediction techniques are introduced here.

The sink collects the data from the nodes and finds the correlation between them, when the correlation value is below the set threshold(2.00) then it means that there is a high correlation and the nodes can temporarily stop sending the data and the sink itself predicts the data. If the correlation value exceeds the set threshold value, then the nodes will have to continue sending the messages.

By this way energy consumption can further be reduced and the lifetime of the network can be increased.

The flowchart for correlation and prediction is shown below.

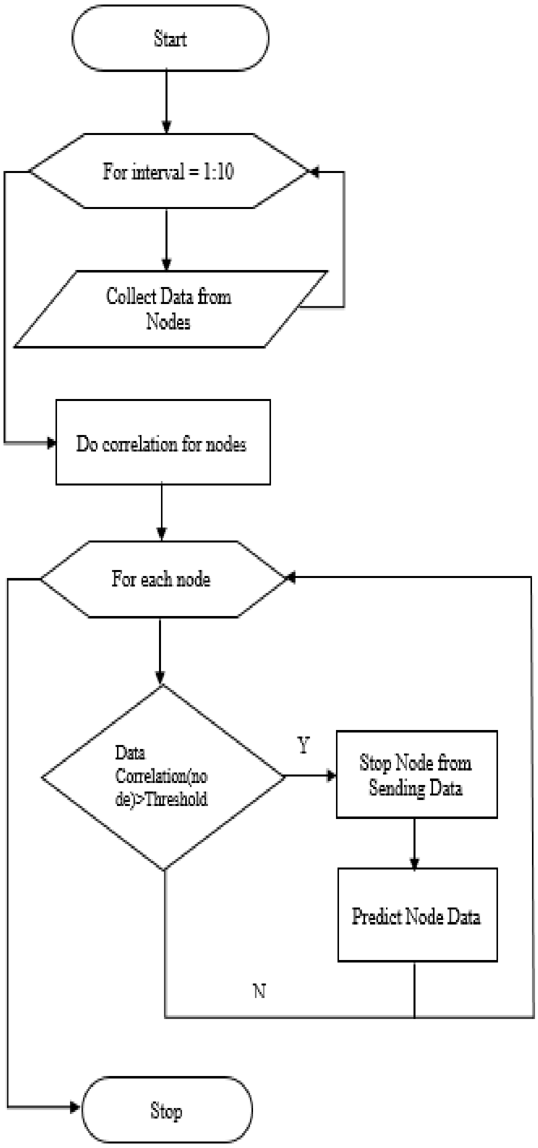


Fig 4: Flowchart for correlation and prediction

IV. EXPERIMENTAL ANALYSIS

A region of size 500m ∗500m with 120 nodes (one sink node and 119 route notes) randomly distributed throughout is considered in this setup. The network topology was formed based on the most common sink topology (radial distribution around the network). A list of specific simulation environment parameters is provided in Table 1.

No of nodes	120
Simulation area	500m*500 m
Simulator	NS2
Operating System	Ubuntu
Transmission range	400 m

Table 1: Simulation Parameters

The original work (E2HRC) is represented by the red line in the graph and is labelled as Cluster Routing. The proposed work is represented by the green line and is labelled as Optimized cluster routing.

Fig 5 shows the comparison of the delivery ratios in the original work and the proposed methodology. In original work the delivery ratio decreases as the number of nodes in the network increases. But in the proposed methodology the delivery ratio increases with the increase in number of nodes.

Fig 6 compares the energy consumption in the original work versus the proposed work. In the proposed work, the energy consumption is lower in comparison with the original work.

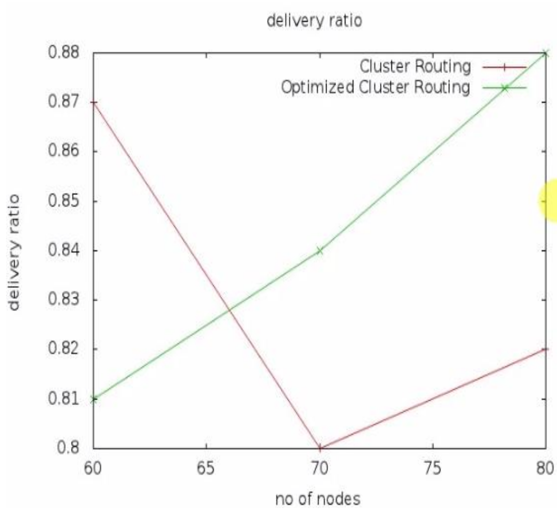


Fig5: Comparison of delivery ratio

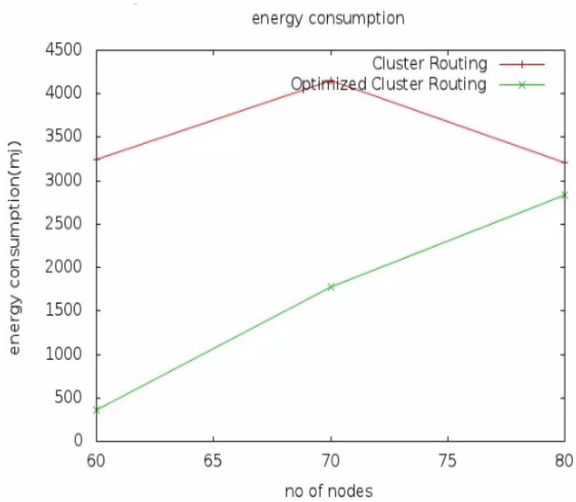


Fig 6: Comparison of energy consumption

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V. CONCLUSION

This study discusses an overview of the existing energy efficiency techniques in clustering environment. Finally, it is concluded from the literature studies that most of the models does increase the energy efficiency but might fail under certain scenarios. In these models, we consider different parameters, such as cluster formation, selection of head, regional energy source for isolated nodes, battery life-time, drain of energy, noise and location uncertainty on wireless link reliability all the techniques work better when the number of packets are limited but the performance decreases as the number of packets increases and in very large network coverage.The proposed approach aims at reducing the number of packets transmitted by using the correlation technique, which in-turn reduces the energy consumption and increases the lifetime of the nodes.

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