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# Energy Efficient Routing Protocols for Wireless Sensor Networks

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**Abstract:** *Designing An Energy Efficient Routing Protocol For Wireless Sensor Network (WSN) Has For Decades, Been An Elusive Goal To Network Developers And Enthusiasts. This Is Due To The Distributed And Dynamic Topology Of WSN Which Introduces Unique Requirements In Routing Protocols That Should Be Met. To Be Classified As Efficient, Wsns Must Maintain Efficient Energy Consumption And An Extended Network Lifetime.TheSynchronization Of Peer Nodes Incurs Some Overhead For Installing The Communication Network. In This Paper, We Study The Various Routing Protocols And Compare Among Them. We Also Study The Trade-Offs Between Energy And Communication Overheads, Highlighting The Advantages And Demerits Of Each Routing Protocol With The Purpose Of Discovering New Research Directions. Based On The Identified ResearchGap,WeProposeAnOptimum Energy Efficient Routing Protocol For Today's Wsns.*
***Keywords:*** *Wireless Sensor Networks; Energy Efficiency; Routing Protocols; Cluster Head*

## I. Introduction

Recent Developments And Sophistication In The Area Of Communication Electronics And Sensor Technology Particularly In The Area Of Green Technology Have Generated Novel Research Interest In Wsns. A WSN Is A Network Of Autonomous Sensors With Capability To Actuate And Sense Some Conditions In The Target Environment. The Inherent Properties Of Wireless Communication, Less Power Requirements And Nano Scale Dimension Make Wsns Suitable For Applications Such As Industrial Automation, Automated And Smart Homes, Military Surveillance, Traffic Monitoring, Medical Device Monitoring, Monitoring Of Weather Conditions, Air Traffic Control, And Robot Control. The Energy Consumption Management For Wsns Is Severely Constrained By Operational Environmental Conditions, Less Energy And Independency From Human Intervention. This Creates The Need To Develop A Routing Protocol That Can Minimize Energy Consumption While Maximizing The Network's Lifetime [1]. While An Array Of Protocols [2] That Address Energy Problem Have Been Developed, None Has Met The Efficiency Level Needed For Optimal Operation Of Today's Wsns. The Inherent Characteristics Which Differentiate WSN From The Other Wireless Networks Such As Ad Hoc Networks Present Big Challenge.[3] To Efficiency Protocol Routing In Wsns. The Growing Number Of Nodes In Wsns Means That The Routing Approaches (Such As UDP And TCP) That Have Worked So Well In Traditional Networks May Not Suffice For This Novel Generation Of Networks. Depending On The Desired Applications, Multiple Numbers Of Protocols Have Been Proposed For Wsns [4]. Central To These Propositions Is Energy Consumption Which Is Closely Connected To The Life Cycle Of The Network. In This Paper, We Review The Various Routing Protocols In Use Today. We Classify These Protocols Into Four Categories Based On Their Application Domain-Mobility Based Protocols, Data Centric Protocols, Location Aided Protocols And Heterogonous Routing Protocols. We Also Identify The Advantages And Weaknesses Of Each Of These Classifications, With A View To Proposing The Most Energy Efficient Routing Protocol In WSN. The Paper Is Organized As Follows: Section 2 Contains The Problem Statement. In Section 3, We Present The Objectives Of Our Study. In Section 4, The Literature Reviews Of Existing Routing Protocol For WSN Are Presented. In Section 5, We Propose A Better Energy Efficient Routing Protocol, Making Recommendations For Future Research Directions. Finally, In Section 6, We Conclude The Paper.

### Problem Statement

The Fundamental Function Of A Sensor Network Is To Sense And Forward Packets To The Desired Destination Or End System, Without Losses. The End System Could Be A Base Station Positioned In A Remote Environment. In The Event Of Energy Constraint In A Sensor Network, Routing Protocol Is Then Used To Tract And Identify The Path To The Destination. The Established Path Then Enables The Nodes In Sending And Receiving Data. Where The Sensed Data Is Only Available To Particular Segments That Are Unable To Forward It To The Desired Destination Due To Energy Constraint Or Depletion In The Sensor Nodes In Those Segments

## II. Literature Review

Routing Protocols Are Classified Based On Network Structure And Mode Of Operation.

**Data Centric Routing**

This Protocol Employs The Sink To Forward Queries To Particular Segments Or Regions Of The Network And Waits For An Acknowledgement Reply. Since Global Addressing Is To Each Node Impossible, Energy Is Conserved Through Data Aggregation, Correlation And Elimination Of Redundant Data [5].

**Sensor Protocol For Information Via Negotiation (Spin)**

In This Protocol, Meta-Data And High Level Descriptors Are Employed For Data Transmission By Exchanging The Meta Data Among Sensors Through A Data Advertisement Mechanism. Spin Offers The Advantage Of Localizing Topological Changes In The Network, As A Node Is Required To Know Only Its Single-Hop Neighbors. The Main Drawback Of SPIN Is That The Advertisement Mechanism Is Prone To Best-Effort-Delivery Of Data.

**Minimum Cost Forwarding Algorithm (Mcfa)**

The Main Objective Of This Protocol Is To Establish The Cost Field Through Routing, And Transmit The Data Through The Minimum-Cost Path. The Energy Consumption, The Battery Life And Hop Count All Follow The Minimum Cost Path Criteria. A Node Routes Its Cost To The Destination Which Broadcasts An ADV Message. The Receiving Node Then Broadcast To Its Neighbor Adding The Cost In ADV To Its Own Cost, And The Cost Field Is Set Up In The Process. It Has The Advantage Of Simplicity As There Is No Need To Maintain A Forwarding Table. Also The ID For A Neighbor Node Need Not Be Known. It However Has The Disadvantage Of Imbalanced Load And Limited Network Size.

**Hierarchical Routing**

This Is Mainly A Two-Layer Routing Characterized By Cluster Heads Selection In Which Nodes Play Different Roles With Focus On Scalability And Communication Efficiency.

**Low-Energy Adaptive Clustering Hierarchy (Leach)**

This Is Based On The Formation Of Clusters Of The Sensor Nodes In Accordance With The Received Signal Strength, And Employing Local Cluster Heads As Routers To The Destination. This Is Followed By Stochastic Change In The Cluster Heads In Order To Balance The Energy Dissipation Of Nodes Following This Model:

$$T_n = \begin{cases} \dfrac{p}{1 - p\left[r \bmod \left({}^{1}/_{p}\right)\right]} & if\ n \in G \\ 0 & otherwise \end{cases} \quad (1)$$

There Are Two Phases In This Protocol-Setup Phase And Steady State Phase. The Clusters Are Organized And Their Heads Are Selected In The Setup Phase While The Data Are Transported To The Base Station In The Steady State Steady Phase. LEACH Has The Advantage Of Improved Performance In Terms Of Energy Dissipation, Configuration Efficiency And Sustained Battery Life In Relation To Conventional Communication Systems.[6].However, LEACH Is Not Suitable For Networks That Are Deployed In Large Regions Because Of Its Employment Of Single-Hop Routing Where Individual Node Directly Transmit To The Cluster-Head And The Destination.

Power-Efficiency Gathering In Sensor Information Systems (PEGASIS)

PEGASIS Is A Chain Based Protocol And Offers Marked Improvement Over LEACH. In This Protocol, Individual Nodes Are Programmed To Interact Only With Their Nearest Neighbor For The Purpose Of Sending And Receiving Data. The Nodes Form Chains Of Sensor Nodes Accomplished By Employing Greedy Algorithm. PEGASIS Offers More Than Twice Performance Capability As LEACH [3][8]. It However Has The Drawback Of Causing Redundancy In Data Transmission Following The Selection Of One Of The Nodes As There Is No Consideration For The Energy Of The Nodes In Relation To The Location Of The Base Station. Also There Is Reduction In The Transmitting Distance Of PEGASIS.

Threshold-Sensitive Energy Efficient Network Protocol (TEEN)

The TEEN Protocol Is Designed To Work Well In Environments Where The Sensed Features Such As Humidity And Temperature Experience Sudden Changes In Attribute. This Scheme Has Members Receive Hard

Threshold (HT) And Soft Threshold (ST) From The Cluster-Head. The HT Is The Value For The Sensed Feature, Being The Absolute Value Of The Attribute. The ST Prompts The Node To Switch On Its Transmitter For The Purpose Of Transmission Following A Small Change In The Value Of The Sensed Attribute. The Main Advantage Of TEEN Is In Its Ability To Work In Conditions Where The Sensed Feature Experiences Changes In Attribute. It Has The Disadvantage Of Increased Energy Consumption With Large Area Networks And When The Value Of The ST Is Small. It Is Also Found Not To Allocate Time Slots As Each Node Turns On Its Transmitter All The Time.

**Location-Based Routing Protocols**

In This Category, We Present Location-Aided Or Position-Oriented Routing For WSN. Here, The Physical Distance And Orientation Of Nodes Action Areas Are Taken Into Consideration. It Functions On The Assumption That That Each Node Recognizes The Position Of Its Neighbor Network And That The Data Source Is Preinformed On The Position Of The Sink. It Has The Good Side Of Operating Without Routing Tables, With Inherent Capability To Localize Data. However, Efficiency Is Dependent On Balancing Geographic Distribution Against Traffic Occurrence.

**Distance Routing Effect Algorithm For Mobility (Dream)**

In This Protocol, Each Mobile Node Keeps A Location Table For All The Nodes In The Network. The Problem Of Overhead With Regard To The Location Packets Is Addressed By The Differentiation Of Nearby Mns From The Far-Located Mns. DREAM Has Efficient Packet Transmission As End-To-End Path Is Always Available. However The Bandwidth Of The Network Is Wasted.

**Geographic And Energy Aware Routing (Gear)**

This Protocol Restricts Flooding In The Network By Leveraging On The Geographical Information And Broadcasting Data To The Target Site By Employing Recursive Algorithm. It Prolongs The Overall Network Lifetime By Localizing Techniques That Result In A Balanced Energy Usage. It Reuses Routing Data Across Multiple User Queries. GEAR Has The Advantage Of Not Only Knowing Its Own Position And Energy Reserve, But Also That Of Its Neighbor Through A ‘Hello Protocol’. Also It Offers Increased Network Lifetime By Balancing Energy Consumption. [7]

**Routing Protocol Based On Protocol Operation**

The Application-Specific Nature WSN Imposes Multiple Functionality Capability On Sensor Nodes. As A Result, Nodes Are Always Under Heavy Energy Constraint In Order To Meet Up With The Burden Of Multiple Operations.

**Multi-Agent Based Itinerary Planning (Mip)**

The Design Of MIP Is Motivated By The Desire To Compensate For The High Delay And Load Imbalance Experienced Through The Use Of Single Agent Based Itinerary Planning (SIP) Protocol. In MIP, The Impact Factor From Each Source Node Will Be Distributed To Other Source Nodes. The Source With The Largest Accumulated Impact Factor Is Selected. From Simulation Results, MIP Is Found To Have Better Energy Efficiency Compared With SIP.

**Negotiation-Based Routing Protocols**

This Protocol Uses High-Level Data Descriptors To Eliminate Redundancy In The Transmitted Data Through A Process Of Negotiation. The Resources Available To The Participating Network Nodes Determine The Decisions That Are Made Following The Negotiation.

Our Proposed Model

We Propose A Hierarchical Cluster Based Routing Protocol. We Assume That The Cluster Head (CH) And Base Station (BS) In Addition To The Node Sensors Are In Reliable Interaction, With Inherent Capability To Know Each Other’s Niche. This Location Awareness Functionality Is Performed In Three Phases By The Proposed Model: CH Election Phase, Steady State Phase And Scheduling Phase. In CH Election Phase, The Reserve Energy Length Vector Denoted By R Is Computed By BS As Follows;

$$R_{ij} = E_{ij} + {}^{1}/_{L_{ij}} \quad (2)$$

Where Rij Is The Reserve Energy-Length Vector, Lij Is The Distance Of Lij Sensor Nodes Taken In The

$(i-j)^{th}$ Sense. The Nodes With The Maximum Rij For All J Clusters Are Selected By BS In Line With The Following Model:

$$CH_j = \max(R_{ij}) \quad (3)$$

Where Chj Represents The Cluster Header For Jth Cluster. The Process Of Energy Election Continues After Default Round Operation Except That The Energy Content Of The Sensor Nodes With Their Corresponding Clusters Will Be Measured By The Last Chs . Each Successive Election Is Followed By Discarding The Energy Information From The Previous Chs . A Time Slot Is Dedicated To Each Sensor Node With Information Relating The Identity Of The Sensor Nodes To Their Separation Distance Provided By The BS. This Scheduling Information Is Then Broadcast To All The Cluster Nodes. Scheduling With Clusters Is Achieved By TDMA While That Outside The Clusters Is Actualized By CDMA. In The Steady State Phase (STP), The Non-CH Node Emulates The CH Nodes By Transmitting Data Via TDMA Scheduling Following A Successful Negotiation With The CH Nodes. The Pulses Required For Synchronizing And Initializing The STP Are Provided To The Nodes By The BS. The STP Is Further Partitioned Into Frames, With The Sensor Nodes Transmitting Data To CH Nodes Within The Assigned Frame. In A1, We Have Implemented Clustering Model Without Employing Data Reduction Prediction Scheme. This Approach Lowers The Cluster Formation Overheads And Provides Pathway For Significantly Reduced Energy Consumption. In A2, Our Model Implemented Using GM (1, 1) Prediction Model Which Has The Capability To Suppress Cluster Formation Overheads Leading To Reduced Energy Consumption. The Incorporation Of Lowered Data Transmissions In Each Sensor Node And Their Corresponding CH Leads To Additional Reduction In The Consumed Energy In A2. Thus A2 Fares Better Than LEACH And A1 In Terms Of Energy Efficiency.

## III. Result And Discussion

**Evaluation Of Parameters**

In The Proposed Model, We Architecture 100 Sensor Nodes On A Unit Area (M X M) Square Field. We Also Divide The Network Into Four Congruent And Optimal Numbers Of Clusters In Order To Cover The Field And The Sensor Nodes. The Table Shows The Simulation Parameters Along With Their Units. The GM (1, 1) Prediction Model Is Used To Compare Among A1, LEACH And A2 On A 3% And 5% Prediction Error Threshold (PET), And The Results Are Analyzed Based On Fig. 1 And Fig. 2.

**Table 1**: Parameters Used In Simulation

| Parameters | Value |
|---|---|
| Number Of Nodes Deployed | 100 |
| Node Distribution | (50,50) To (250,250) |
| Location Of Base Station | (0,0) |
| Initial Energy Of Each Node (In Joule) | 0.1 |
| Data Packet Length (In Bit) | 800 |
| Energy Packet Size (In Bit) | 400 |
| Control Packet Size (In Bit) | 200 |
| $E_{elec}$ | 50 |
| $\epsilon_{mp}^{c}\ (\frac{in\ \frac{nJ}{bit}}{m^4})$ | 0.0013 |
| $\epsilon_{fs}^{b}\ (\frac{in\ \frac{nJ}{bit}}{m^2})$ | 100 |
| $E_{DA}\ and\ E_{Grey}\ \ (in\ nJ/bit)$ | 5 |
| Window Size | 3 |

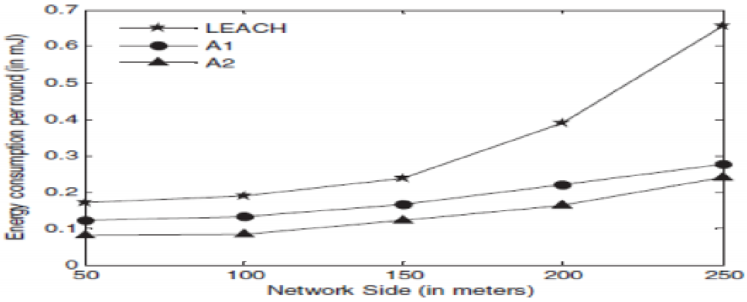


Fig.1. Energy Consumption Comparison Of LEACH, A1 And A2 At 5% PET

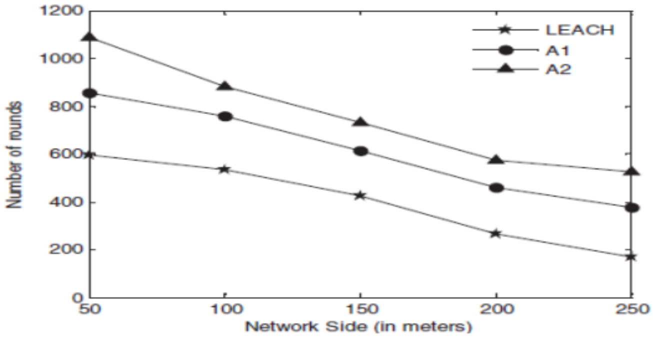


Fig.2. HND Comparison Of LEACH, A1 And A2 At PET

**Simulated Results**

Our Result In Fig. 1 Indicate That The Proposed Model (A1 & A2) Is More Energy-Efficient As Energy Is Depleted At A Slower Rate Compared With LEACH At The Same Prediction Error Threshold, With A2 Eliciting The Best Result Making It A Robust Routing Algorithm For Wsns. As Energy Consumption Is Related To The Network Lifetime, The Simulation Result In Fig.2 Shows That The Proposed Paradigm Offer Improved Network Lifetime In Comparison To LEACH.

## Future Research Directions

CH Election Is Prone To Errors As Marginal Nodes Are Left Out Of Recently Established Clusters. This Problem Can Be Overcome By Putting Into Consideration The Network Topology When Designing New Clusters. One Method Of Achieving This Is To Architecture The Network Map With Location-Aware Algorithm And Ensuring No Node Is Left Out During Creation Of Clusters. Another Method Is To Partition The Network Into Smaller Areas CH And Electing Nodes To Man Each New Area. As Transmission And Reception Of Data Lead To Energy Depletion Of The Sensor Battery, Data Processing Inside The Network Can Be Leveraged And Computation Near Data Sources Can Be Exploited To Minimize Communication. In Addition, Self-Configuration And Reconfiguration Can Be Exploited.

## IV. Conclusion

It Can Be Concluded That A Substantial Amount Of Energy Can CH Be Conserved By Lowering The Overheads In Election Process As Indicated In The Simulation Results, Using The Proposed Paradigm. Energy Consumption Reduction Via Reduction In The Volume Of Transmitted Data Within And Outside The Cluster Region Is Facilitated By Time Series Prediction Based Data Reduction Scheme. The Network Lifetime For The Proposed Model Is Shown To Register Remarkable Improvement Over LEACH. Although Not Explicit In The Above Description, Increasing The Prediction Error Threshold Percentage Leads To A Better Result Both In Energy Consumption And The Network Lifetime.

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