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Energy aware Cluster based data Aggregation Scheme for Wireless sensor Networks

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Abstract - Data transmission plays a significant role in communication, due to the rapid development of electronic devices and information technology. Wireless sensor network is one such communication paradigm. Data aggregation is one of the thrust research areas in the field of wireless sensor networks. Compressive sampling methods are widely used for data aggregation in wireless sensor networks. This research work proposes energy aware cluster based data aggregation (EAC-DA) scheme for wireless sensor networks. Chunk oblique matrix is applied for compressive sampling and the conventional Dijsktra's algorithm is employed for obtaining the shortest path from source sensor node to destination sink node. Performance metrics such as throughput, overhead, average energy consumption of nodes, network lifetime and aggregation latency are chosen. The proposed EAC-DA is compared with the existing data aggregation mechanisms. Simulation results are proved that the proposed EAC-DA outperforms in terms of preferred performance metrics.

Keywords - Cluster, WSN, Communication, Energy Aware, Electronic Devices.

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1. INTRODUCTION

Microelectronic system and low-power radio technology advancements have enabled the production of low-cost, low-power, multipurpose sensor devices that can detect, measure, gather data from the environment, and transmit that data to the user through radio transceiver. Recent developments in micro electronic systems have allowed the creation of these sensor devices. These sensor devices can sense, measure, and gather data from their environment. They can also send the information to the user via radio transceiver. Wireless sensor networks are self-organized multi-hop networks comprised of sensor nodes dispersed throughout a localised or global area to collect and transmit data about environmental or physical parameters. Wireless links connect each of these sensor nodes to the others. [1]

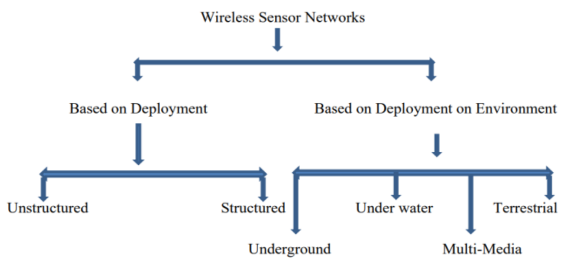

Figure 1: The classification of wireless sensor networks

It is possible to utilise such a network to keep an eye on various physical or environmental parameters. Researchers from a wide variety of fields have recently invested heavily in the wireless sensor network (WSN) sector due to advances in computing, sensing, and communication. Sensor networks are rapidly becoming an essential component of technology due to the benefits it gives consumers with regards to detecting, processing data at regular intervals. This is because of the wide range of practical uses for the technology. A wireless sensor network's (WSN) classification may depend on the design of its nodes, which might be one of two broad categories. [2]

1.1 Unstructured and Structured

A large number of nodes were installed in close proximity to one another in an unstructured WSN and then abandoned to collect data. The primary goal of deploying these nodes was to facilitate two-way communication. To help with the ad hoc placement of the nodes into the sensor field, it provides. Perhaps the biggest drawback of such a layout is that it necessitates the provision of network maintenance, failure detection, and connection management. There are now such a huge variety of

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nodes that completing these tasks is a monumental undertaking. To differentiate itself from an unstructured WSN, a structured WSN has fewer nodes and is implemented in whole or in part according to a strategy that has been established in advance. By considering the conditions of their deployment, wireless sensor networks (WSNs) may be divided into five broad categories. [3]

a. Underground WSN

The wireless sensor network (WSN) sensor nodes may be found in a variety of subterranean tunnels and mines across the world. However, the sensor field that connects these two places is a considerable distance below the surface of the ground. The real base station, on the other hand, is situated at a higher elevation than the surrounding area. The significant costs associated with operating these networks, as well as maintaining existing sensor nodes and installing new sensor nodes,may be attributed to the necessity of deploying sensor nodes at depths below the surface of the earth. This requirement may also be attributed to the necessity of installing new sensor nodes.

b. Underwater WSN

Monitoring the seabed is one of the many uses for submersible sensor nodes, which are the building blocks of the wireless sensor network's underwater component. It is to be anticipated that these sensor nodes will be utilised in maritime settings. The goal of the networks that fall under this category is to collect data from a diverse collection of sensor nodes. To do this, the networks make use of autonomous underwater vehicles. Nodes in these networks have a hard time talking to one another due to problems like the network's limited capacity, signal fading, the failure of individual nodes, and the delay imposed by propagation.

c. Multimedia WSN

Applications such as sensor networks, which provide high bandwidth, high data processing, data compression, high energy consumption, and lowest transmission latency, are some of the applications that are conceivable with these kinds of networks.

d. The WSN operates based on the terrain

A huge number of nodes, or sensors, spread out across a wide area make up these so-called sensor networks. The failure of a single node, or even of a large number of nodes throughout a network, is typical in highly distributed systems, as is the presence of substantial congestion. Furthermore, dense deployment may cause a great deal of retransmission attempts, which may further delay the delivery of vital data to the base station. It's possible the heavy deployment is the blame for this lag. It is common practise to employ such networks all through the procedure of recording a wide range of events, including audio, video, and still photographs. The sensor nodes in such networks are mobile, allowing them to sense and monitor their environment as they move from one location to another. All of the sensor nodes are wired with cameras and microphones, and some of them can even capture sound. Localization, deployment, navigation control, coverage, and self-organization are only some of the challenges that may be handled with the help of such networks. [4]

1.2 WSNComponents

This network's fundamental component may be disassembled into its component pieces, and the bulk of its important component is made up of the sensor unit, processor unit, transceiver unit, and power unit, in that order. [5]

a. Sensing Devices and Equipment

It is common for there to be two components in a single sensing unit: the sensor and the ADC (ADC). A sensor is an apparatus that takes in data from its surroundings and transforms it into a format that can be processed by electrical impulses. Sensors can be classified as either digital or analogue, or even as both types. As of now, a wide variety of sensors may be purchased online. These sensors can measure a wide range of parameters in their surroundings, from temperature to sound pressure to magnetic fields to visual information. Once the sensor's analogue signals reach the ADC, they are transformed to digital signals and either transmitted to or received by the processing unit, depending on the phenomenon being monitored. To complete the process, the ADC takes in the sensor's analogue output and converts it to digital.

b. Processing Unit

There is a heavy burden on the CPU to provide intelligence to the sensor node. It's common for the processing unit to be a microprocessor. It processes the data collected by the sensors using signal processing algorithms and runs the communication protocols necessary to get the data in the first place. It has the authority to take on this duty.

c. Transceiver Unit

It is now possible to have wireless contact not only with the nearby nodes, but also with the nodes situated all over the world, all thanks to the radio. Most commonly, it consists of a short-range radio with a single channel and bidirectional symmetry. Many factors, including the data rate, transmit power, and operating duty cycle, impact the radio's power consumption characteristics. Like microcontrollers, transceivers have several modes of operation, including transmission, reception, inactivity, and hibernation. It was discovered that the great majority of radios waste almost as much power while in their "off" state, when they are not

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actively sending or receiving signals, as they do when they are in their "on" mode, when they are supposed to do so. All sorts of mysteries might be unravelled with this discovery. For this reason, you should always completely switch off the radio rather than merely leaving it in the "off" position. Every time the radio's operating mode shifts due to brief electrical activity, a lot of power is wasted. This is another factor that plays a crucial role in determining the final result. An integral aspect of the WSN's ability to conserve power is its sleep mode. [6]

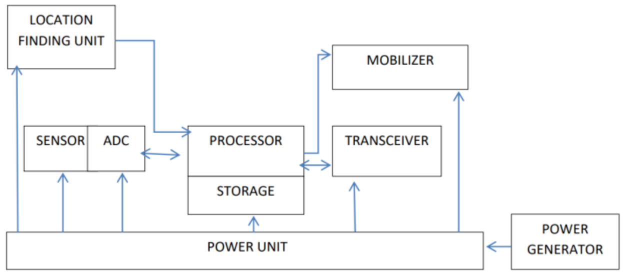

Figure 2: The hardware that is used for wireless sensor networks

d. Battery

The battery supplies the sensor node with the necessary amount of power to function. Since the battery life of the sensor node is directly related to the amount of power it consumes, keeping close tabs on that data is essential. The vast majority of sensor nodes have a constrained battery life because of their diminutive size, light weight, and cheap overall cost.

1.3 Essential Features of Sensor Networks

There are a number of factors and/or restrictions that must be taken into account while launching a sensor network; these factors and/or constraints are, in turn, influenced by the application, design, and ultimate goal of the network. In particular, the characteristics of the network itself define the components and/or limitations that must be applied. [7]

a. Deficiency in the available infrastructure

One of the most important features of a wireless sensor network is the capability of its individual sensor nodes to communicate with one another without the need for a fixed infrastructure. The resulting reduction in communication burden will be significant.

b. Proportional Size of the Network

Individual nodes that make up a wireless sensor network are often spread out across a large area. The number of nodes in a wireless sensor network is likely to vary not just with the type of activity being conducted, but also with the physical location. If the setting is taken into account, this will be the case.

c. Homogeneous Network

The nodes, which are the essential building blocks of a wireless sensor network and are all similar to one another, are the networks' most important components. These nodes are individual units, with each one being an exact copy of every other node in the network.

d. Knowledge of the neighbourhood and its surroundings Locations

Due to the fact that the conveyed data is dependent on the physical distance between nodes, it is crucial for each node to be aware of its position in relation to the others. [8]

1.4 Communication Protocol Architectures

Many factors, including as the structure of the protocol layers and the way in which each layer processes the sensing data, affect the total amount of energy consumed by a single sensor node. Each network node, or "sink," makes use of the following layers of the protocol stack: the Application Layer, the Transport Layer, the Network Layer, the Data Link Layer, the Physical Layer, the Power Management Plane, the Mobility Management Plan, and the Task Management Plan. [9]

a. Application Layer

There is a large variety of application software that may be used, and it is supported, to carry out the many sensing tasks that must be carried out. SQDDP (Sensor Quality Data Distribution Protocol), TADAP (Task Assignment, Data Advertisement Protocol), and SMP (Sensor Management Protocol) are the protocols that constitute this layer (Sensor Query and Data Dissemination Protocol).

b. Transport Layer

This layer helps keep the data flow going when the application layer is needed by offering aid to the application layer. This layer's protocol is notoriously challenging to build because to the wide range of factors, constraints, and limits that impact sensors, such as limited memory and power. As a result, working on the protocol is quite challenging. At this stage, the protocol's architecture introduces a great deal of complexity.

c. Network Layer

With the network layer in place, data may be sent through the wireless communication channel. This layer ensures that the functionality can be implemented. Interest-based routing and attribute-based naming are the two most used methods of data rerouting. There is more than one way to reroute data. The energy metre may also be used to determine the cost of power usage based on actual energy consumption.

d. Data Link Layer

This layer is responsible for a broad variety of tasks, including multiplexing data streams, identifying data frames, media access control (MAC), and problem detection and repair. Power conservation, mobility management, and failure recovery are just a few of the many constraints that must be factored into the design of the MAC layer protocol. Examples of bounds include the following. [10]

1.5 Problems and Challenges in WSN'S

Structure Challenges

The key technological challenge of wireless sensor networks is to carry out detecting, communicating, and controlling tasks when there are severe restrictions on energy resources, computational power, storage space, and communication capabilities of nodes. Therefore, while designing a wireless sensor network's routing protocol, it's important to prioritise maximising the network's lifespan, ensuring reliable data forwarding, and minimising energy consumption. The following is a brief overview of the major considerations that must be made while developing a routing protocol for a wireless sensor network, taking into account the network's topology. [11]

a. Network dynamic

In most network setups, it is safe to assume that the sink node travels while the sensor node stays put. Depending on the specifics of the task at hand, a mobile or fixed monitoring device may be used. Different applications have different monitoring objectives; one may be used to keep tabs on military targets, which are always on the move, while another might be used to keep an eye out for forest fires, which would be a rather static target. These two forms of tracking are actually one and the same programme.

b. Network topology

This topology may be used in either of two possible configurations: one that is already established, or one that is constructed on the fly. In a topology with a fixed topology, the sensor nodes must be put up by hand, and data must be transmitted along a path that has been planned in advance. Nodes in ad hoc topologies are often placed in a random and scattered pattern.

c. Data transmission mode

The data transmitting node can function in one of four modes depending on the requirements of the application: continuous mode, event-driven mode, request-driven mode, or a combination of the two. The sensor nodes deliver a continuous flow of data at periodic intervals that have been established beforehand. The term "mixed mode" is used to denote a combination of the various modes discussed above. Both the event-driven and the request-driven modes of data transmission have their initiation at the sink nodes. They do this by generating either a matching event or a request, depending on the mode in which they are currently functioning.

d. Node type

In every conceivable way, the sensor nodes are indistinguishable from one another. Isomorphic sensor nodes are available to serve as needed in the event that a certain application calls for a sensor that performs a particular function. Recently, the possibility of switching out the sensor node responsible for data transmission, sensing, and gathering with a different node that has fewer constraints on its availability of resources has been discussed.[12]

2. METHODOLOGY

In this part of the study, a WSN with many hops is being considered. Each node in this network is a sensor, and there are n of them. These nodes, indicated by the symbols s1, s2,,...,sn, are spread out throughout an A×A region at random.

In a WSN, the destination sensor node is the node responsible for receiving and assembling the data supplied by the other nodes, and this is indicated by the prefix 0 s. In addition to storing the information, this node is also in charge of sending it to the other nodes in the network. A weighted bidirectional graph denoted as GV,E is used to characterise the system. The graph's vertices, V, are the sink node at the endpoint and all the sensors, while the edges, E, are the two-way wireless connections between them.

If and only if two nodes I and j are within communication range of each other via link I jV, then they can establish a direct connection through that link. Using Euclidean distance as a metric, we can calculate the transmission cost between vertices I and j as wi, j. Sensor node I s sends one data packet I x toward node j s of size L bits, where L is a constant for all nodes, for each single-hop connection I jV with the Euclidean distance dij. Assuming at the start of each cycle that all s I n I 1,..., have data packets to transmit, the primary goal of a data aggregation approach is to reduce the network's power consumption by collecting sufficient data to retrieve the n-dimensional signal vector at the sink node.

2.1 Compressive Sampling

Compressive sampling is used for a variety of data collection methods (CS). The majority of these methods revolve around developing and updating routing trees. Since these methods need a larger amount of energy, they can't be used in real-time sensor networks. However, it is possible that some sensor nodes will still be somewhat far apart from one another, given that the member sensor nodes

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that are put in the terrain region are selected at random. This is due to the fact that the sensor nodes that make up the network are deployed in the field. When this occurs, each measurement collected by compressive sampling contributes to the creation of an assortment tree with several edges. The notation yi,i1,...,m represents these lengths. In turn, this will drive up the cost of the tree.

2.2 Chunk Oblique Matrix (COM)

Sensor nodes in WSNs may employ effective data collection techniques like compressive sensing and chunk oblique matrix (COM) based data gathering. These data retrieval procedures are efficient in terms of both computing power and energy use.

The chunk oblique matrix is a matrix having C n distinct sub-matrices, denoted by k C , k 1,....n, where k is a positive integer between 1 and C n, and m is the number of oblique entries in the matrix.

In order to interpret the signal, it has been split into C n vectors, k n xkR, and for each of them, k1,...nC, a sub-matrix, nkmk k: Measurements from compressive sampling are collected by R by R.

The measurement vector for the gross compressive sample is denoted by, and it is illustrated here for reference.

$$Y = \Phi x \Leftrightarrow \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_{n_C} \end{bmatrix} = \begin{bmatrix} \Phi_1 & 0 & \cdots & 0 \\ 0 & \Phi_2 & \ddots & \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \Phi_{n_C} \end{bmatrix} \begin{bmatrix} x1 \\ x2 \\ \vdots \\ x_{n_C} \end{bmatrix} \quad \ldots (1)$$

It is generally agreed that k is a sparse random measurement matrix if and only if a condition known as the Restricted Isometry Property (RIP) holds. As a result of careful consideration, it has been concluded that this matrix's dimension contains some useful information. The compression basis is used to determine the number of compressive sampling dimensions m, and this basis is differentiated by a low-level signal. A count can't be made without this basis. Though the compression basis is larger as the rationality of the dimension matrix falls, a sparser dimension matrix is produced because Cl n does not increase with m. As a result, the resulting matrix has lower dimensionality and is sparser.

2.3 Working Mechanism of EAC-DA

WSNs have a number of issues, one of the most important being the need for sensor nodes to successfully manage the issue of energy consumption in order to extend the network's lifetime. A word of caution is in need before consuming this test. If we want the network to last for a reasonable amount of time and handle the most pressing problem, we need to figure out how to reduce the energy consumption of individual nodes. The vast majority of sensor nodes rely on extremely tiny batteries for their power source. Given that these batteries have a hard time maintaining their charge, it may be challenging to either recharge or replace the battery. Energy-efficient protocols are being developed to enable sensor nodes in efficiently interacting with one another, which will help mitigate this problem to a greater extent.

3. RESULTS

In order to carry out the simulation, an NS-2 Simulator was required. The WSN's nodes are dispersed at random, with densities ranging from 500 to 1000 nodes per square kilometre. A predetermined number of bits per second is set as the ceiling for packet transmission. Many people assume that all sensor nodes are able to communicate, are aware of their immediate environment, and can locate themselves without human intervention using only GPS.

Table 1: Some of the Simulation's Presets

Parameter Name	Value
Number of nodes	500 nodes to 1000 nodes
Terrain Size	1500 meters X 1500 meters
Initial energy / node	50 joules
Simulation time	1500 seconds
Baseline node power	6mW
Simulation runs	10
Packet size	300 bytes
Radio Propagation	Free Space
MAC Protocol	802.11
Radio Range	200 meters

3.1 Throughput

The node counts used in the simulations span a wide range, from to Some examples of performance metrics are throughput, overhead, average energy consumption, network lifespan, and latency. Longevity is another important indicator of performance.

Table 2: The results of the throughput simulation

Number of Nodes	Existing Method			Proposed Method
	PDA [93]	MAI [94]	FASM [95]	EAC-DA
500	18094	19046	21332	25947
600	17485	18461	19004	23846
700	16835	17946	18563	21001
800	15364	16483	17452	20736
900	14273	15038	16493	19037
1000	13563	14343	15008	17473

Table2 shows that the throughput of the recently created method known as EAC-DA is 500-1000 times higher than that of the previously used protocols known as PDA, MAI, and FASM. Specifically, the throughput of EAC-DA is much higher, proving this point. The results of the proposed EAC-throughput DA are displayed in Fig.

and compared to the performance of several other existing approaches. The results show that the provided EAC-DA is more efficient than previously developed procedures in terms of throughput.

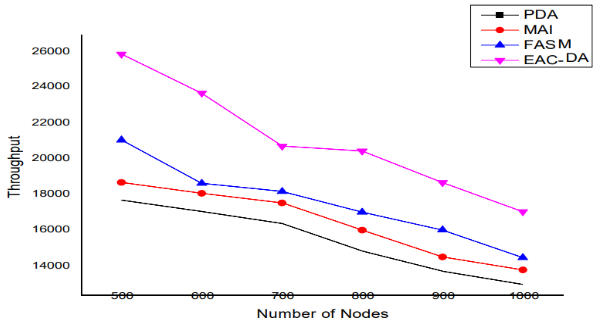

Figure 3: The number of nodes that correspond to each unit of throughput

Figure 3 shows that the current process has a lower throughput compared to the alternatives that are recommended, which have a greater throughput.

3.2 Overhead

A comparison is shown in Table3 between the expected overhead performance of the proposed EAC-DA and that of the various current protocols. The data demonstrates quite clearly that the proposed EAC-DA will get less overhead packets than the protocols that are already in use. The results of the simulations of the overhead costs have been compiled into Table4.3 for your perusal.

Table 3: The Node Proportion in Relation to the Overhead

Number of Nodes	Existing Method			Proposed Method
	PDA [93]	MAI [94]	FASM [95]	EAC-DA
500	658	549	492	399
600	735	631	572	478
700	836	749	601	528
800	903	842	725	627
900	991	901	807	702
1000	1091	992	889	782

Table 3's data indicate that EAC-DA, the presently in use technique, has a lower overhead than the already in use protocols PDA, MAI, and FASM.

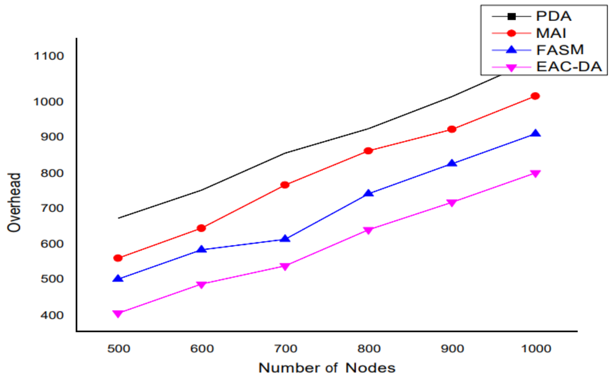

Figure 4: Nodes count versus Overhead

As can be seen in Figure 4, the present approach, known as EAC-DA, has less overhead than the current protocols, known as PDA, MAI, and FASM, respectively.

3.3 Energy Consumption

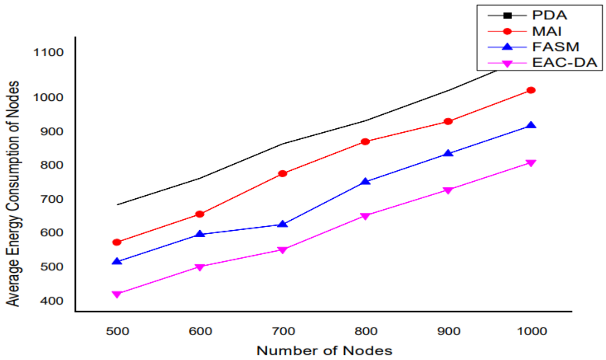

Figure 5: The Relationship Between the Total Number of Nodes and the Typical Amount of Energy Consumed by Each Node (joules)

Figure 5 presents a visual representation of the suggested method's energy usage for the EAC-DA, PDA, MAI, and FASM. The energy needs of the proposed approach are significantly lower than those of the current method, as seen in this figure.

4. CONCLUSION

The main and subordinate cluster heads of two separate clusters are selected using this method's chunk oblique matrix methodology in order to get the required outcomes. A routing protocol is used by a source node to transfer data to a sink when it wants to do so in an energy-efficient manner. This protocol takes a number of factors into account, such as the likelihood that a connection will be lost and the expected overall number of retransmissions. In a sensor network that uses wireless connections, a cluster is a collection of nodes that have been organised into a network and are able to communicate with one another. The nodes frequently auto-organize and communicate wirelessly with one another after being placed ad hoc. It is more challenging to employ older

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technologies since a significant portion of WSNs use hardware that has a restricted capacity. WSNs have a possibility to grow into an important technology that is utilised to address several challenges that are now being encountered by a number of enterprises.

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