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Energy Transmission Protocols for Wireless Sensor Networks: A Review

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Abstract:
Data Routing though being the most basic service provided by the Wireless Sensor Network (WSN) Nodes, it is also the one which consumes the highest amount of energy. Sensor Nodes are usually fitted with power sources that are non-rechargeable and due to the vast application of WSNs they are also usually practically irreplaceable. This makes the longevity of Nodes a critical factor for consideration while designing the routing protocols. In this paper we survey the protocols that are being used and show their efficiency.

Keywords: Wireless sensor network (WSN), LEACH, PEGASIS, GENETIC Algorithm, FUZZY Logic

1. Introduction:

Wireless Sensor Network (WSN) is considered as one of the breakthrough of twenty-first century. This technology has number of applications in numerous fields. From agriculture to military, this piece of technology covers it all. Wireless Sensor Networks (WSNs) are built up of large number of sensor nodes (ranging from hundreds to thousands, as per the need of the application).The sensor nodes are equipped with limited supply of power-source which runs-out as the network goes live. These sensor nodes are used to convert the required data off the ambiance into electrical signals. The sensed data can be either processed or aggregated or directly be sent to the data collector known as Base Station (BS). This routing procedure is the most basic service provided by the sensor nodes. Though being the most basic service, it takes up much of the energy while transferring the data. So the design of a protocol for the data routing should facilitate the maximum lifespan of the sensor nodes. The design of a routing protocol should involve the maximum use of every sensor node before it gets destroyed.

In this paper we present a survey report looking into different protocols that govern the routing process and compare the feasibility that they provide for utmost longevity of Wireless Sensor Networks(WSNs).

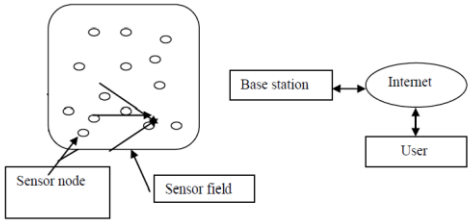

Figure 1: Wireless Sensor Network (WSN)

2. Protocols and Algorithms:

2.1 LEACH:

LEACH (Low Energy Adaptive Clustering Hierarchy) is the first hierarchical or cluster based protocol that governs the routing of data in Wireless Sensor Networks (WSNs) which

also includes data aggregation. A lot of hierarchical based WSN protocols are based on LEACH. LEACH basically works in two different phases: setting up phase and routing phase. [1],[2]

Setting up phase:

In the setting up phase of LEACH protocol, the selection of cluster head is completed. A cluster head can be defined as a sensor node which is selected among a group of nodes or cluster such that the communication between the node and BS can be most effective. For the selection of cluster head, a random number is picked between 0 and 1 by a node. This random number is compared to the threshold values t(n). If the number is less than t(n) then the node becomes cluster head for that round. A round can be defined as the as the time from setting up phase to routing phase and back to the new setting up phase.

The threshold t(n) is calculated using the following:

$$t(n) = \frac{p}{1-p*\left(r*\mathrm{mod}\left(\frac{1}{p}\right)\right)} \quad \text{if} \quad n \in G \qquad (1)$$

$$t(n) = 0 \text{ if } \quad n \notin G$$

Here,

p= the percentage of cluster heads that each node shares

r= the number of rounds

G= the collection of nodes that have not yet been cluster heads in 1/p rounds

By the usage of this threshold value, all the nodes get a chance of becoming the cluster head after 1/p rounds.

Routing phase:

Routing phase includes all the activity after the selection of cluster head. When the cluster heads have been declared for a particular round, now the nodes send the acquired data to the cluster heads using TDMA (Time Division Multiple Access). The cluster heads aggregate the data, i.e. look for any kind of data redundancy and combine them if any. After the aggregation, the data is sent to the BS frame by frame. The frame data transmission helps in increasing the alive time of the routing phase than the setting up phase which in-turn reduces the unnecessary energy loss.

The following figure gives us a clear idea on how effective LEACH is. The representation of number of alive nodes is done in the y-axis and x-axis represents the time-steps. It is clear that LEACH protocol increases the lifetime of the network more than twice as much other transmission methods used before.

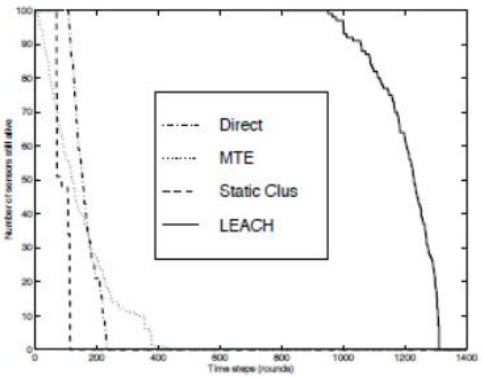

Figure 2: WSN Lifetime in Direct transmission, MTE transmission, static clustering and LEACH

2.2 Genetic Algorithms:

Genetic Algorithm (GA) is a technique that imitates the process of natural selection. This technique originally belongs to a higher class of Evolutionary Algorithms (EAs) which have been used to generate solutions to many kind of optimization problems using various techniques inspired by natural evolution such as selection, mutation, and crossover. GAs hold a wide area of application in computer science, engineering, economics, bioinformatics etc.

Genetic Algorithm is used for the declaration of cluster head in a hierarchical, based WSN. To understand the use of Genetic Algorithm in WSN, we need to first understand the basics of Genetics and Genetic Algorithm. In GA, a population is first created by selecting a group of individuals randomly who are subjected to evaluation. The evaluation is generally done by giving a specific task to the individuals and a fitness score is given to the individuals based on the efficiency that they show in performing the task. Based on the fitness scores acquired by the individuals, two are selected. The height of their fitness level is directly proportional to the chance of them being selected (i.e. the more fitness one has the more chance it has to be selected). These selected individuals are made to reproduce one or more offspring which are then again subjected to random mutation. This whole process is repeated until a predetermined number of times or until a predetermined solution or output is obtained.[3],[4] The selection of cluster head is done using the GA as given below:

So as from above, the whole genetic algorithms can be divided into following:

1. Selection
2. Crossover
3. Mutation

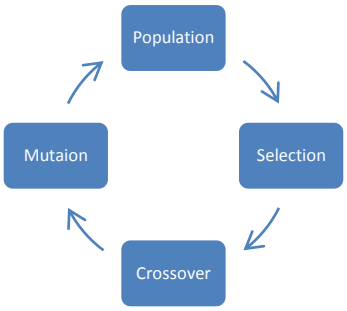

Figure 3: General Representation of GA

2.2.1. Selection:

Selection is the process which helps to determine which of the strings will crossover to give new offspring i.e. new strings. The strings are usually viewed as chromosomes because they relate to the set of characters a particular individual possesses. These newly bred chromosomes again join the population and so the combined new population becomes the basis for the next selection. As mentioned above, the selection of the new individuals is based on the fitness of the individual. The better the fitness of the

individual the better chance of selection. There are many methods of selections available. Some selection methods include Roulette-wheel selection, Proportionate Selection, Linear Rank Selection, Tournament Selection etc.

2.2.2. Crossover:
The GA is based on the concept of generation of offspring. After the selection process is completed and the individuals are selected for the mating, there arises a need of method for the generation of offspring. This is where crossover comes into play. Crossover can be defined as an operator that is used to vary the characters or programming of chromosomes, known as allele, when the generation is succeeded.

In crossover, the locus or a part of chromosome (string) is swapped between the parent strings. This results in two offspring each with a part of both the selected individual.

Though being such an integral part of the algorithm, crossover however does not necessarily occur at between all the selected individuals. The probability of occurrence of crossover is usually between 0.6 and 0.7.

	1		2	
Parent	11001	01100000110	10010	10110001110
Child	11001	10110001110	10010	01100000110

Figure 4: One Point/Single Point Crossover

2.2.3. Mutation:
When the crossover is complete, the new population now contains directly copied individuals and individuals that are generated by crossover. Mutation is now introduced to ensure the individuals in the new population are unique. For mutation, all the alleles of all the individuals are looped through and when selected, they can be mutated in two ways i.e. either by changing a small amount of the alleles or by replacing it with a new value. The probability of a mutation occurring is only about 1 and 2 tenths of a percent. Mutation though having such a small occurrence probability and being fairly simple, it is crucial to be present. It provides the key to genetic diversity.

	Offspring
Original	1100110**1**10001110
Mutated	1100110**0**10001110

Figure 5: Mutation using GA

2.3 Fuzzy Logic:

Fuzzy logic is a logical system which is an extension of multi-valued logic. The basic fundamentals of this logic is to recognize that logical statements are not only true or false but also range from 'almost certain' to 'very unlikely'. It deals with the reasoning that is approximate rather than fixed and exact.

The main key issue to extend the network lifetime is optimal combination of both energy efficiency and energy balanced which is fulfilled by the fuzzy logic rule.

RESEE (Residual Energy Scheming based Energy Equilibrium) is proposed for balancing the energy consumption in WSNs. To maintain the energy consumption, the whole fuzzy gradient classification is based on next hop strategy which has been proposed in RESEE. RESEE holds the capacity to deal with conflicting situations and impressions in data using heuristic human reasoning.

The election of cluster has been found to make it easier to extend life of a network. Hence, this approach is basically based on energy concentration and centrality and is proposed for cluster head election.

Fuzzy logic is used for the cluster head selection process. It is used for the determination of cost of the link between any two sensor nodes by inputting fuzzy variables such as transmission energy, remaining energy, queue size etc. When all the possible links are computed, the shortest path algorithm is used so that the most efficient route to the BS can be determined.

Routing Based On This Logic:
A fuzzy system basically consists of three parts: fuzzifier, fuzzy inference engine and defuzzifier. The fuzzifier maps each unique input value to the corresponding fuzzy sets and assigns it a truth value for each fuzzy set. These values are processed by the inference engine. Inference engines have various methods for inferring the rules and rule base. Rule base can be defined as a set of IF-THEN rules series that relate the input variables with output variables, provided that each of the variables are described by a fuzzy set. The defuzzifier now performs the defuzzification on the population of fuzzy solution space i.e. it finds a single crisp output value from the fuzzy solution space.[5]

The fuzzy rule has been designed not only to minimize the energy consumption but also to balance data traffic among sensor nodes affectively.

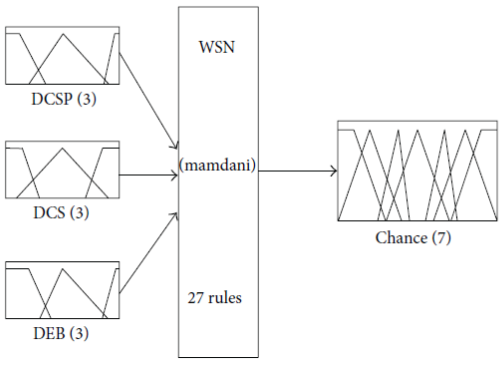

Figure 6: Fuzzy System Model

The above figure shows fuzzy system model. To describe fuzzy logic inference Mamdani algorithm is used.[6]

In the figure:

- DCSP is the degree of closeness of node to the shortest path.
- DCS is the degree of closeness of node to the sink.

- DB is the degree of energy balance.
- DCSP and DCS are used for showing the energy efficiency for selecting one node as the next hop. DEB reflects energy balance major for routing decision.

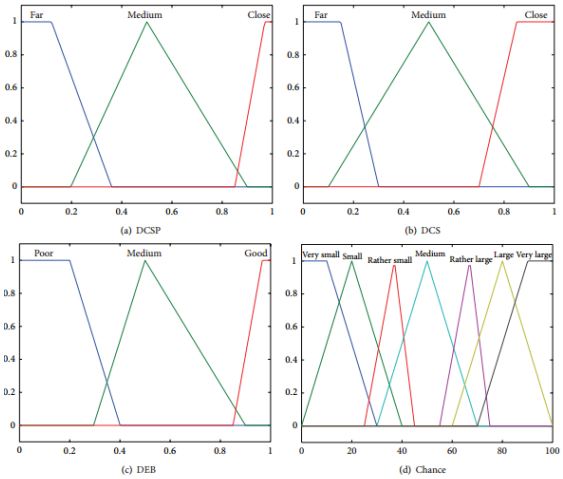

Figure 7: Fuzzy Input And Output

Fig 7 consists of 4graphs in which DCSP and DCS is divided into three levels far, medium and poor. Also, DEB is divided into poor, medium and good.

Mathematically, chance is evaluated as

$$\text{Chance} = \frac{\sum_{i=1}^{27} W_i \mu_A(W_i)}{\sum_{i=1}^{27} \mu_A(W_i)} \qquad (2)$$

Where W is the domain value corresponding to rule I and μA (Wi) is the predicate truth for that domain value

In 4th graph, chance is divided into seven level i.e. very small, small, rather small, medium, rather large, large and very large to represent the node hop election.

The fuzzy rule BASE basically concludes that if DEB is good, then DCSP is close and DCS is close then the next hop to be selected as chance of the node is very large. Now, the currently forwarder is compared on chance basis and the node having maximum chance is selected as the next forwarder

Hence, the above mentioned parameters (DCSP), DEB and DCS are designed for energy optimization in fuzzy logic system.

Simulation result shows that as compared to with similar algorithm for generating different data pattern, the fuzzy logic base routing algorithm extends the life of network more effectively and shows a very good performance in term of energy balance and energy efficiency.

2.4 PEGASIS

PEGASIS is a hierarchical protocol in which the basic idea is that, in order to extend the network lifetime, each node has to transfer data to its nearest neighbor node only and that node fuse that receive data with its own and pass it to its next nearest node by which the data will reach to the BASE STATION.[8] It is also a near chain-based Protocol i.e. improvement over LEACH. In this protocol to increase the network lifetime basic radio model id used.[9]

$$E_{TX}(k, d) = E_{Elec} * k + E_{amp} * k * d^2 \qquad (3)$$

(Where 'k' is a bit at distance d)

$$E_{RX}(k) = E_{Elec} * k \qquad (4)$$

$E_{TX\text{-}Elec}$ = Transmitter Electronic

$E_{RX\text{-}Elec}$ = Receiver Electrionic

$E_{TX\text{-}Elec} = E_{RX\text{-}Elec} = E_{Elec}$

$E_{TX\text{-}Elec}$ = 50nJ/bit

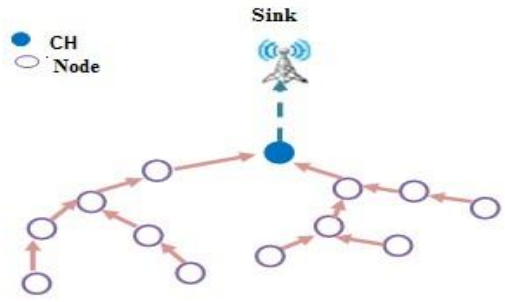

Figure 8: Chain Based Hierarchical Routing.

In PEGASIS we assume that all nodes have same life span and energy level. It also introduces the excessive delay for distant node in the chain. This Protocol has TWO main objectives:

Increase in LIFETIME of each node, results in increases the life span of Networking. It allows only node to communicate with its nearest node which results in to less use of bandwidth during the communication.

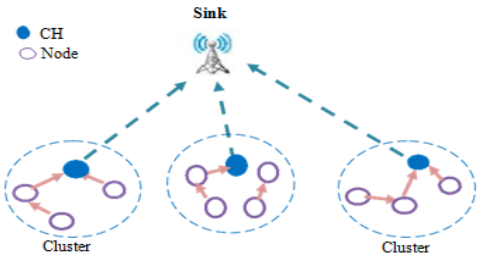

Figure 9: Clustering and Chain Based Hierarchical Routing.

Working of PEGASIS:

Basically in PEGASIS a node from a chain is used to transmit data to BASE Station hence duplication of data is avoided. Each node uses its own signal strength to get the distance of its nearest neighbor node. After which receiver node can be heard only one node.[8]

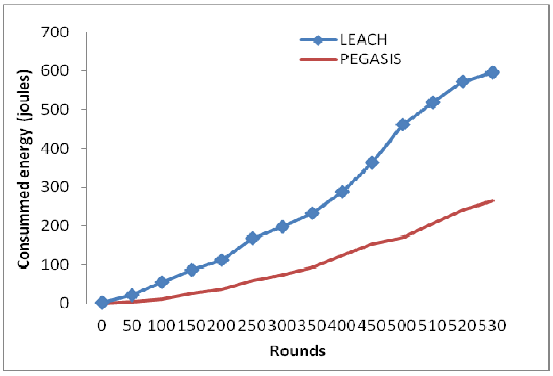

Figure 10: Energy consumed by PEGASIS and LEACH.

For gathering of data, each node receive data from its neighbor node and fused that data with own data after that data is transferred to next neighbor node. Thus in this protocol each node will transmit and receive data at least once in its lifetime and also the last node communicates with BASE Station at least once.

Hence a chain of the nodes that are neighbor node from path to the BASE Station will be formed. When all the data from the very first node reach the BASE Station, then another chain will form and this will continue till the death of the nodes. And this help to reduce the power consumption of node in transmitting data in compare to the previous Hierarchical protocols.

PEGASIS is able to increase the span of a node by 2x i.e. twice as compare to previous protocols. This is due to use of chaining algorithm and avoidance of clustering overhead. But it still requires DYNAMIC TOPOLOGY ADJUSTMENT because each sensor node needs to know about the energy status of its neighbor node in order to route the data in right direction i.e. to the SB. And that such TOPOLOGY ADJUSTMENT in highly utilized networks can introduce significant overhead. It also assumes that very node can be able to communicate with BS and sensor nodes use multi-hop communication technique. After which it also assume in this that all node has all the data regarding the location of all other node present in that particular chain of that network.

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