An Energy Efficient and Reliable Data Aggregation using Elephant Behavior as a Swarm Intelligence in WSN

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Abstract— **A wireless sensor network is a kind of ad hoc network deployed in huge number of nodes in order to sense the physical world. Its applications include both military and civilian services. The sensors are characterized by limited resources and inhibited power hence they experience limited computation, communication and power resources. A major challenge is to provide an improved operational efficiency with limited computational communication and sensing capabilities. In this work we have proposed a clustering technique that groups the sensor node for collaborative processing to enhance the data reliability during aggregation; here we use social behavior of elephants as the biologically inspired swarm intelligence. Simulations are carried out to evaluate the performance of the collaborative behavior that enhances the data aggregation in a resource constrained WSN.**

Keywords— Swarm intelligence, cluster, matriarch, data aggregation, social behavior

I. INTRODUCTION

A wireless sensor network is a system of spatially distributed sensor nodes to collect important information about the target environment**.** A swarm can be viewed as a group of agents cooperating to achieve some purposeful behavior and achieve some goal (Abraham *et al*., 2006). This collective intelligence seems to emerge from what often large group's .Swarm are computing involves numerous devices that work in a coordinated fashion, communicating either with neighboring devices or the environment to accomplish a defined task. The behavior of a single ant, bee, termite and wasp often is too simple, but their collective and social behavior is of paramount significance. The efforts to mimic such behaviors through computer simulation finally resulted into the fascinating field of SI. SI systems are typically made up of a population of simple agents (an entity capable of performing/executing certain operations) interacting locally with one another and with their environment[1],[2]. Elephants are the largest of land mammals living in very advanced social organizations that require good levels of communication between the groups of individuals. This is because they live in a "fluid fission-fusion" society which simply means that their family units are constantly being divided and reunited whilst, at the same time, they are meeting different individuals on a dailybasis.

II. BACKGROUND AND RELATED WORK

Swarm intelligence is a field of artificial intelligence that models the intelligent behaviors observed in creature's swarms by using swarm agents. The agents used to model a swarm are often autonomous and self organizing, following a predefined set of rules that govern individual behavior [3]. Ayon Chakraborty et al [4] have proposed a novel data gathering protocol for enhancing the network lifetime by optimizing energy dissipation in the nodes. To achieve the design objective particle swarm optimization (PSO) with Simulated Annealing (SA) have been applied to form a sub-optimal data gathering chain and devised a method for selecting an efficient leader for communicating to the base station. In the scheme each node only communicates with a close neighbor and takes turns in being the leader depending on its residual energy and location. This helps to rule out the unequal energy dissipation by the individual nodes of the network and results in superior performance as compared to LEACH and PEGASIS [5]. To overcome this problem, a hybrid algorithm based on Genetic Algorithm and Artificial Bee Colony is proposed in this paper. The algorithm resolves the issue through finding the optimal number of clusters, cluster heads and cluster members. Simulation results reveal that this algorithm outperforms LEACH and Genetic Algorithm based clustering scheme. Author [6] discusses about distributed automated sensor deployment algorithms based on swarm intelligence.Author of [7] propose a cluster based private data aggregation, that leverages clustering protocol and algebraic properties of polynomials. Authors of [8],[9],[10] discusses about robust geographical routing algorithm using aggregator nodes to reduce the energy or power.

III. PROPOSED WORK

The work proposed in this paper is an approach for wireless sensor nodes behavior, using biologically inspired swarm intelligence. We try to relate wireless sensor network, using social behavior of elephant's concept in which many players choose to cooperate by forming coalitions. Elephants live in a structured social order. This requires an advanced level of communication and recognition to allow individuals to mediate between the complex relationships that they develop with other individuals. The life of the elephant is very different. As the elephant gets older, it begins to spend more time at the edge of the herd, gradually going off on his own for hours or days at a time. Elephants can communicate over long distances by producing and receiving low-frequency sound, a sub-sonic rumbling, which can travel in the air and through the ground much farther than higher frequencies. It is also their ability to learn from interacting with individuals in their intricate social grouping and to recognize important cues for long periods of time which further adds to their intelligence and complex social network. Our work consists of simulating and applying rule abstraction for SI from the below given behaviors of elephant.

1) Female social structure is similar to concentric rings, with the innermost circle comprising a family unit of adult elephants.

2) The most dominant female is called the matriarch. The matriarch is the backbone of the elephant family unit because she provides stability and determines ranging patterns for the rest of the family.

3) As the elephant gets older, it begins to spend more time at the edge of the herd, gradually going off on his own for hours or days at a time.

4) Elephants have a wide range of sounds that they can emit all with different intensities and for different purposes such as securing their defense, attracting mates, co-ordinating movement and generally announcing their needs.

IV. RULES ABSTRACTION

Abstract Characteristics: We analyze three potential abstract rules for WSN domain: Connectivity, Coverage and Energy. In practical coverage and connectivity depend on energy.

1. **Connectivity**: Connectivity represents the overall functionality of the network. A sensor v is connected to the network G = (V, E), where V is the set of vertices in the network graph and E is the set of edges in the network graph. The more connected a network is, the more sensors it has available to monitor the area and supply data. Connectivity is also related to the degree to which the network is partitioned. The figure below discusses about the connectivity in a WSN.

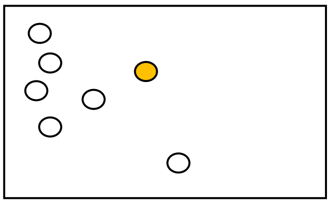

Fig. 1a. Sensors distributed in an Environment. Colored node depicts the sink node

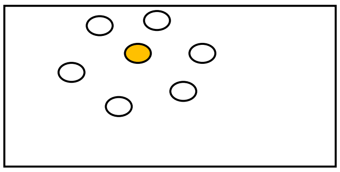

Fig. 1b. Sensors formed in cluster in an environment in a concentric manner with uniform Distribution. Colored node Depicts the sink node.

2. **Coverage**: Coverage measures how efficiently the network monitors the target area. A region in range of a sensor is only covered if that sensor is itself connected to that network. The algorithm used to compute coverage considers every point in the environment is discussed below.

If there are lot of sensors in the target area
  Use a cluster-based protocol
  Compute the number of clusters – Social structure
  Compute the maximum number of nodes inside each cluster
  Elect the cluster leaders - CHs (consider the residual energy and location)
If all cluster leaders are in the range of the Sink Node
  Use a one-level hierarchy of cluster-heads (CHs transmit direct to Sink Node)- matriarch.
Else
  Use a two or more levels of hierarchy (formation of concentric rings as seen in social structure of elephant) of cluster-heads (function of node density and transmission range).

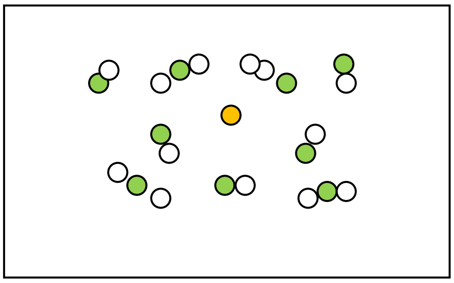

Fig. 2. Cluster of sensors and hierarchy of clusters in an environment. Yellow Colored node depicts the sink node and green color nodes the cluster leaders

3. **Energy**: Energy is used to find the connectivity between the nodes and their coverage for transmission and reception of information from the target area.

Rules:

1. *MoveToBorder* is a conditional rule that a swarm agent follows when it becomes older. By convention, the agent will move towards the border of the environment grid in an attempt to get isolated from the cluster which simulates the behavior of elephants which move away from the herd as they grow older. The swarm agent will eventually get connected with other agents, provided that

the magnitude and sensing/transmission range is reasonable.

2. *Slowdown* is a simple rule that bounds the maximum speed an agent can attain during the movement of the agent toward the border of the environment.
3. *StayatBorders* is a simulation specific rule that prevents the sensor agents from moving outside of the target area. When an agent moves within a specific range of the area border, an energy level still exists in them which helps them to be in clusters/groups. If the energy level is too small a node can escape away from the cluster and get towards the border and escape away from the environment, forever isolated from the swarm. For our simulation the boundary value is set at 100 pixels from the sink.

There are three primary ideas that arise in this work that pertain to data aggregation and energy conservation within sensor network in the below given cases.

1. A large number of nodes/elephants with high energy levels at the initial phase is that sink's attention will strongly be drawn towards those nodes. Thus the nodes with high energy level convey very relevant information.
2. A small number of node/elephants with moderate energy level after a period of transmissions, is the sinks attention will be drawn, but not as much as in Case l.
3. A small number of node/elephants with lowest energy level after a period of transmissions, is the sinks attention will be drawn, less than in above two cases and may even be ignored completely, thinking that the data may be not relevant, because of it low energy level.

V SIMULATION SETUP AND RESULTS

In the simulation network topology distribution wise layout the *slowdown/move to border* values were choosen from the set {0, 10, 20, 30, 40, ------100} with respect to sink where the sink is placed at the centre. Stay *at Border is* where the boundary value is set at 100 pixels from the sink. All combinations of these parameter values were tested with 20 runs for each configuration, each with initial concentric net work layouts to ensure valid results. The graphs in the Fig3 shows that the reliability of data used in data aggregation is high when we use elephant social behavior (ESB) when compared with network without using elephants social behavior, by elimination of data sent by the elephants from the border because of their low energy level. Fig 4 depicts the network life time as the elephants grow older and older they start moving away from the herd and escape from the environment which reduces the lifetime of the network.

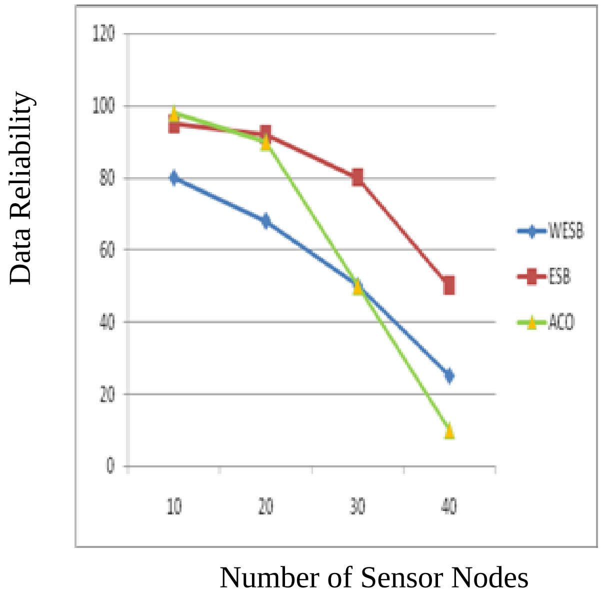

Fig. 3. Graph representing data reliability wrt sensor energy level

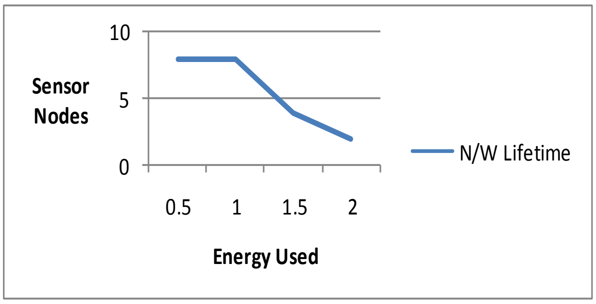

Fig. 4. Graph representing network lifetime

CONCLUSION

Resource constraint environment of WSN requires a energy efficient data aggregation. We have presented a novel swarm abstraction with elephants social behavior model. This model is defined, mapped and applied to wireless sensor network domain, specifically in modeling network characteristics such as connectivity, coverage and energy levels. The above work/investigation has helped to develop new rules and reliability of data for data aggregation with improved energy efficiency and network lifetime.

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