Prolonging the Network Life Time in WSN through Computational Intelligence

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Abstract—In this paper, key constituents of computational intelligence (CI) are discussed and how different classes come under the paradigm of CI. The very need and importance of CI in the problem solving of different social fabrics of life is comprehensively elaborated in this article and is concluded that CI in turn depicts the nature's supremacy of being the ultimate intelligent optimizer for human made solutions. This concept has become more highlighted due to the discussion about the emergence of computational intelligence from electronics to communication, from signal processing to pattern recognition and from microprocessor design to stochastic system. Wireless Sensor Network is taken as a target domain to implement the computational intelligence for the optimization of different factors involved in energy aware routing. Comparative analysis of different classes in CI paradigm is done to find the most appropriate class for optimization of Clustering design and data aggregation techniques. This analytical survey article can prove as a guiding light for the future researcher to delve into more detail of CI and finding the optimal solution in different social fabric of life. It is concluded that this nature inspired paradigm has the key role for moving to the "optimized solutions" for almost every field of life.

Key Words: Energy Aware Routing, Computational Intelligence, Clustering, Data Aggregation

I. Introduction

Computational Intelligence is a technique which inspired from nature. It is used for complex problem solutions. Computational Intelligence is used to make systems which can work in real time. Computational intelligence is different from artificial intelligence. In artificial intelligence like robots, they are used to do predefined things like they can place things from one place to another, opening or shutting of the door etc. All such things are already fed into the memory of the robot to perform all those tasks. Purpose of CI is to introduce such intelligence in the system that it can take decisions like humans do, like they can select best solution from a set of available options.

According to Shelly et al. [1], the characteristics of Computational Intelligence are written below.

Adaptation: As these systems are designed to work in real time and can react to different situations accordingly like node failure or topology change. They are very adaptive so they can adjust to changing situations.

High Computational Speed: As these systems are working on real time so they must be very fast. For that purpose they have high computational speed so that they meet the requirement of real time applications. Computational intelligence is based on bio-inspired techniques which have distributed control and brings solutions to the problem quickly because of parallel processing.

Versatility: Versatility is another characteristic of CI. They are very adjustable and can handle highly non-linear mappings without external help.

Robustness: Another characteristic of computational intelligence is robustness. It imposes little or no requirements on the objective function.

Self Organizing: Due to many reasons network topology gets changed. Self organization is the characteristic which deals with this problem and also used in the initial stages of network deployment.

Self Learning: Self learning is one of the main characteristic of CI. In self learning systems are given a set of instructions and rules. System then takes the input from environment and then on the basis of that input processing is done. On the basis of that processed information and given set of instructions, system gives output according to real time scenario but that output was not fed into the memory of that system.

Computational intelligence is defined as "*The computational models and tools of intelligence, capable of inputting raw numerical sensory data directly, processing them by exploiting the representational parallelism and pipelining the problem, generating reliable and timely responses and withstanding high fault tolerance*" [2].

The paradigm of computational intelligence (CI) is composed of artificial neural network, artificial immune system, swarm intelligent system, evolutionary system and fuzzy logic system and reinforcement. The intelligent approach which is used to

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solve large scale engineering problems inspired from abundant mechanism of biological systems to solve the computational problems i.e. optimization is bio inspired computing.
Computational intelligence is actually bio-inspired and all classes come under same paradigm because of following the same pattern of nature inspiration. Neural network is the derivation of ideas from human brain system for solving complex problems, evolutionary computing is basically inspiration of natural evolution for generating and evaluating a population of problem for possible solution to a problem, swarm intelligence is also a nature inspired technology the inspiration is basically from the social behavior of insects like foraging behavior of some ants species, fuzzy system are the inspiration of human reasoning, not actually like this, fuzzy system use binary values for decision making. The last class reinforcement learning base is psychology of animal learning; the fundamental idea is that of rewarding the learner (agent) for correct actions, and punishing wrong actions.
The rest of the paper is organized as follows; section II briefly explains the classes which come under the paradigm of computational intelligence along with their key features, their emergence in social fabric of life. The role of computational intelligence paradigm in prolonging the network lifetime in wireless sensor network is discussed section III. More over a discussion on the favorable CI classes for the energy awareness in wireless sensor network along with the optimizing the solution of clustering and data aggregation is also discussed in the same section. Conclusion is mentioned in the section IV.

II. Computational Intelligence Paradigm

Computational intelligence's purpose is to introduce intelligence in the system. When we talk about the classes which come under the paradigm of CI then we came to know that all these classes work on totally different ideas. But the common things between them are
Nature inspired: All these classes which under the CI are nature inspired like Swarm intelligence is inspired from the behavior of swarms like ants, bees etc.
Adaptive: All these classes are adaptive and deal with the real time topology changes very efficiently.
Distributed systems: All these classes have distributed control, they have no centralized control. Each node/member in these systems has its own duty and together they bring solution to a bigger problem.
Intelligent systems: These systems are intelligent e.g. they are self-organizing, self-learning systems etc.
Emergent: Functioning of the system emerges in the form of observable patterns or structures [3].

a. Artificial Neural Networks

Human brain is performing many tasks and doing them faster than computers. Idea of artificial neural networks (ANN) is taken from brain's neural network. ANNs have abilities of learning, memorizing etc.
Huge numbers of nerve cells (neurons) combine to make a biological neural network. Axon, dendrites and cell body makes up a neuron. Axon of one neuron connects with dendrite of another neuron for communication. In same way huge number of neurons gets interconnected. The connection between axon and dendrite is known as synapse. Signal moves from axon of one neuron to the dendrite of another neuron. Inside a neuron signal moves from dendrite to body and then to axon and then axon passes that signal to all connected dendrites. "A signal is transmitted to the axon of a neuron only when the cell "fires". A neuron either can inhibit or excite a signal." [4]. Artificial Neuron is build on the basis of biological neuron. It gathers the information from the environment or connected neurons and transmits the information to the connected neurons only when it is fired.
Applications of ANN includes diagnosis of diseases, speech recognition, data mining, composing music, image processing, forecasting, robot control, credit approval, classification, pattern recognition, planning game strategies, compression and many others [4].
Neural Networks need very high processing and large memory. It usually provides centralized solutions. Solutions are usually slow in speed. It usually provides centralized solutions. It is good for data aggregation and fusion [5]. The emergence of ANN in the social fabric of life is represented in Table 1.

Table 1 Brain in Social Fabrics of Life

Artificial Neural Network inspired by Brain
Institutes\Universities\ Laboratories: Salk Institute, San Diego, U.S.A; University of Arizona, USA; Helsinki University of Technology, Finland; University of Vigo, Spain; Evolutionary Computing Laboratory U.S.A;
Application: [7], [8], [9], [10]
Prominent Researchers: Dr. Stephan, McGlinchey, Dr. Valery Tereshko, Wesam Barbakh, Dr. Jason Teo Tze Wi.

b. Evolutionary Computation

Idea of evolutionary computation is taken from natural evolution where only fittest one survives and weak have to die. Nature is surviving on the basis of reproduction. The key terms used in evolutionary algorithms are Individual, Chromosome, Gene, Allele, Fitness, Culling, Elitism and Phenotypes.
Individual: Individual is referred to as chromosome in a population.
Chromosome: Chromosome defines the characteristic of an individual in a population.
Gene: Each characteristic is referred to as gene.
Allele: The value of gene is referred to as allele.
Fitness: The survival strength of an individual is measured using fitness function which reflects the objectives and constraints of the problem to be solved.
Culling: After each generation an individual can die.
Elitism: After each generation an individual can survive.
Phenotypes: They influence genetic changes and/or behavioral characteristics evolve separately.

Chromosome represents an individual in evolutionary algorithms and these chromosomes combine to make

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population. A chromosome defines the characteristic of an individual and that characteristic is known as gene. The value of gene is referred to allele. There is a competition between individuals and the fit can reproduce offspring. Process of regeneration is known as crossover. An individual can go through changes which can make it weaker. The survival strength of an individual can be measured using fitness function.

Further classes inside evolutionary computing are genetic algorithms, genetic programming, evolutionary programming, evolution strategies, differential evolution, cultural evolution and co-evolution.

Applications of EC are data mining, combinatorial optimization, fault diagnosis, classification, clustering, scheduling etc [4].

Evolutionary algorithms need very high processing and it usually provides centralized solutions. It is good for data aggregation and fusion [5]. Table 2 shows the involvement of evolutionary computation in social fabric of life.

Table 2 Natural Evolution System in Social Fabrics of Life

Genetic Algorithm inspired by Natural Evolution System
Institutes\Universities\ Laboratories:
University of Sheffield UK; Al.I.Cuza University Romnia; Evolutionary Computing Laboratory U.S.A;
Application:
[11], [12], [13], [14]
Prominent Researchers:
K.J. Shaw, P.J. Fleming Prof. Henri Luchian, Dr. Jason Teo Tze Wi

c. Swarm Intelligence

Swarm intelligence is based on the study of swarms that how they live, communicate, forage for food etc. They have no central control, no direct communication but still they manage to find shortest paths, find foods and manage their resources well. Swarm refers the large no of insects or other small organized entities, esp. when they are in motion. Global intelligent behavior to which the individuals are entirely unknown is emerged due to the local, self-organized and decentralized interaction of swarm's agents. Swarm intelligence (SI) is one of the aspiring solutions from bio-inspired computing for such heuristic optimization problems e.g. routing Natural examples of SI include ant colony, bird flocking, animal herding, bacterial growth, fish schooling, drop water, fireflies etc. Examples algorithms under the head of SI are Ant Colony Optimization (ACO), River Formation Dynamics (RFD), Particle Swarm Optimization (PSO), Gravitational Search Algorithm (GSA), Intelligent Water Drop (IWD), Charged System Search (CSS) and Stochastic Diffusion Search (SDS) etc.

Applications of SI are, function approximation, clustering, optimization of mechanical structures, solving systems of equations, routing optimization, graph coloring etc [4]. Swarm intelligence provides solutions for routing in ad-hoc networks. It consumes huge amount of energy on communication when it sends ants for route discovery [5]. Table 3 intuits the importance of swarm intelligence in social fabric of life.

Table 3 Natural Swarming in Social Fabrics of Life

Swarm intelligence Inspired by Global Behavior - Ant colonies, bird flocking, animal herding, bacterial growth, and fish schooling.
Institutes\Universities\ Laboratories:
University of Washington U.S.A; Peking University China; *University* of Canterbury N.Z; University Putra Malaysia; Evolutionary Computing Laboratory U.S.A;
Application:
[15], [16], [17], [18]
Prominent Researchers:
Julia Parrish,William Spears, Dr. Khairulmizam Samsudin,Assoc. Prof. Dr. Adbul Rahman Ramli, Dr. Jason T1eo Tze Wi

d. Artificial Immune System

Artificial immune system is inspired from natural immune system and it models some aspects of artificial immune system. Natural immune system (NIS) is having a great pattern matching ability. It is used to distinguish between foreign cells entering the body (antigen or non-self) and the cells belonging to the body (self). NIS fights the antigens and memorizes their structure for faster future response if they try again to enter the body. The four models of natural immune system are Classic view, clonal selection theory, danger theory and network theory.

Applications of AIS are in pattern recognition problems, classification, clustering, anomaly detection, computer virus detection etc [4].

Table 4 Natural Immune System in Social Fabrics of Life

Artificial immune Network Inspired by Immune System
Institutes\Universities\ Laboratories:
University of York U.K; Institute of Computer Science, Polish Academy of Sciences, Warsaw, Poland; University of Nottingham U.K;
Application:
[19], [20], [21], [22]
Prominent Researchers:
Prof. Johan Timmis, Anna Świtalska, Prof. Uwe Aickelin,Dr. Julie McLeod

Artificial immune system is used to provide security, fault detection, optimization and abnormality detection [5]. Emergence of AIS in social fabric of life is highlighted from table 4.

e. Fuzzy System

Fuzzy means vague, indistinct or difficult to perceive. Unlike Boolean where values are integer i.e. '1' or '0', where '1' represents true and '0' represents false, it (fuzzy) takes continuous values between '0' and '1'. In fuzzy systems '0' represents absolute wrong and '1' represents absolute correct and give continuous values for other conditions.

Let's take an example of fan, if we are using Boolean system then it would either TURN ON or TURN OFF the fan, if it is

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cold or hot. But if we use fuzzy system then it will set the speed of fan from stop to slow, slow to medium and so on, depending on the value of temperature [3].
Applications of FS are in control systems, gear transmission and braking systems in vehicles, controlling lifts, home appliances, controlling traffic signals etc [4].
Fuzzy logic is used in optimization, clustering heuristic and routing. The solutions it provides are not optimal. It is good for security and QoS problems. It usually provides centralized solutions. It is good for data aggregation and fusion [5].

Table 5 Shades of Human Decisions in Social Fabrics of Life

Fuzzy logic Inspired by Shades of Human decisions Definitely, probably, Yes, No
Institutes\Universities\ Laboratories: University South Carolina, USA; De Montfort University U.K; College of Engineering University Park, PA U.S.A;
Application: [23], [24], [25], [26]
Prominent Researchers: Prof. Maja Mataric, Prof. Gaurav Sukhatme, Professor Bob John, Professor John Yen

f. Reinforcement Learning

Reinforcement learning is also bio-inspired technique and obtains information of environment by exploring it. It applies some actions on the environment and then gets the output from it. So there is a sequence of different inputs and gets different outputs. It learns from the experience which it gets from the relations between inputs and outputs.
It use agent for working, agent is learner in this technique. Agent is responsible for applying inputs to the environment. Agent is rewarded for correct actions and punished for wrong actions. RL is good for distributed system where each node should have medium memory and computational strength. It is very adaptive and deals with topology changes effectively. It takes some time to find the solution but it comes up with the optimal one.
Basically its application is found in routing. It is also used in simulated robotic soccer [4].

Table 6 Behaviorist psychology in Social Fabrics of Life

Reinforcement learning Inspired by behaviorist psychology
Institutes\Universities\ Laboratories: University of Massachusetts Amherst, U.S.A;
Application: [27],[28]
Prominent Researchers: Adrew G. Barto,

Reinforcement learning is used for routing and clustering problems. It provides optimal routing solutions. It deals well with node and link failures. It is flexible and distributed. It delivers the data even if topology of network changes. It consumes very little amount of energy for communication [5]. Applications of reinforcement learning are traffic control, environmental monitoring etc [6].

III. Computational Intelligence In Prolonging The Network Life Time

In literature, there are many features considered and discussed that play role in prolonging the network life time. Multi-hop communications, reduced number of transmitted data and control packets, balancing the network load and less computation are few among the feasible solution. To cope up with the proper implementation of the above mentioned solutions, clustering and data aggregation techniques are the most favored techniques in the literature. In the subsequent paragraphs, these techniques are discussed along with their advantages and issues and their optimizing solutions from the nature inspired classes in the paradigm of computational intelligence.

a. CLUSTERING

In terms of computer clustering, the term clustering is for connecting two or more computer to acts like a single computer and is used for parallel processing, fault tolerance and load balancing. In the context of wireless sensor networks clustering can be define as centralize based grouping or clustering of sensor nodes with cluster head (CH) for their management. Each node in the cluster collects information and forwards it to the CH. The CH then communicates with the other CH or directly communicating with base station. In wireless sensor networks there may be hundreds or thousands of sensing nodes communicating with each other and the base station, which consuming more energy in exchanging information, and have problems of load balance, fault tolerance etc. By clustering, these problems can be tackled, so in wireless sensor networks nodes may be divided into groups or clusters. Each cluster has cluster head; non cluster members in the cluster forward the collected information to the CH. The CH work as a gateway between nodes and the base station. The selection of CH changes periodically for the prolong life time of the network [28].
The issue of load balancing can be overcome by clustering that a high energy node known as gateways or cluster head is deployed in the network. Each node in the cluster communicates with the base station via cluster head. Without clustering in sensor networks there may be hundreds or thousands of nodes communicating with base station (base station is also known as command node) [29]. If any node is far away from the base station in the network then sending information to the base station consumes more energy and reduces life time of node. The issue of unbalance distribution of energy is tackle by clustering.
The characteristics of good clustering techniques in wireless sensor networks are: centralize behavior to manage the network, efficient use of energy, scalability, equal distribution of load, and minimization the over heading loads. Clustering give many advantages like scalability, reduce the size of routing table for each node, saves bandwidth, stabilize the network topology, management strategies. With these advantages there are also some issues in clustering techniques.

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In clustering sensor network all nodes send data to the cluster head which cause over loading for CH and consume more energy and sometime exceed. Clustering has major problem such as latency, data accuracy etc.

A successful attempt was made to solve the clustering problem in WSN, but major problem face in traditional clustering algorithms is their high communication overhead for forming the clusters, and selection of cluster head. The reinforcement learning provides better platform for developing good clustering technique by solving the problem by avoiding cluster head selection process over all and assumes the nodes WSN have some clustering information like a simple geographical grid or floor information in a building, further assume that multiple sinks in the network announce via request to network-wide data.[30] During propagation of these request all nodes of network are able to gather single hop neighborhood information consisting of the remaining energy, hops to individual sinks and cluster members. Routing start once data available for sending directly to the sinks, each intermediate node take their own decisions to route the data to or not.

The remaining classes of CI also provide good clustering platform but they have some issues. In neural networks the problems is that it is cost effective of gathering information about the quality of the link by pinging the neighbors nodes.

Fuzzy logic is good in clustering by prolonging the lifetime of the network due to the reduction of energy consumption through cluster head election. The fuzzy logic clustering technique has in issue of overhead at base station by gathering some information before electing cluster head.

Evolutionary algorithms is quite batter in grouping or clustering for small size networks. Clustering maximize life time of the network. This approach has a problem when the cluster head fails it effect the whole cluster to stop operating and nodes in cluster discharge quickly due to over loading.

b. DATA AGGREGATION

Data aggregation is the process of combing data from different sources and present in the form of summary for, say statistical analysis. Data aggregation can be user-based personal data aggregation services, which offers the user a single point for collection of their personal information from other nodes. Wireless sensor networks (WSNs) consist of many sensor nodes. These networks have large application in monitoring, disaster management, security and military, etc. Wireless sensor nodes are very small in size and have limited processing capability with very low battery power. This restriction of low battery power makes the sensor network prone to failure. Data aggregation may be effective technique in this context because it reduces the number of packets to be sent to base station by aggregating the similar packets. Data aggregation increases the life of sensor network by reducing number of packet to be sent to base station. Data Aggregation can be implemented in many ways the simplest data aggregation function is to avoid duplication if source A and source B send same data, Node will send only one of these to forward.

Data aggregation can be categorized on the basis of network topology, network flow, quality of services we can divide data aggregation techniques into two parts. i) Structure based ii) Structure Free. Structure based data aggregation techniques can be further divided into four types; i) Data Aggregation in Flat Network ii) Cluster-Based Data Aggregation iii) Tree Based Data Aggregation iv) Grid Based Data Aggregation. Good aggregation technique for wireless sensor networks needs to meet additional requirements [31]. In particular, they should be very limited processing and energy capabilities of sensor devices, and should therefore be implementable by elementary operations**.** Also, different application may be suitable for different types of operations, depending on their algorithm, execution time which has energy efficient resources and computation capabilities. These facts need to be considered in the design of aggregation functions and routing protocols. The key issues confronted in the data aggregation technique are: delay tradeoffs due to data aggregation, latency tradeoffs, capacity-energy tradeoffs, security tradeoffs.

WSNs have many issues, mainly because of communication failures, storage and computational constraints and limited power supply. Paradigm of computational intelligence (CI) has been successfully used to address various issues such as data aggregation and fusion, energy aware routing, task scheduling, security, optimal deployment and localization. CI provides adaptive mechanisms that exhibit intelligent behavior in complex and dynamic environments like WSNs. CI brings about flexibility, autonomous behavior, and robustness against topology changes, communication failures and scenario changes. CI based solution and methods have capabilities of automatic adjustment and self-adaption require for intelligent fusion of data from different distributed nodes in a multi-sensor network. Data Aggregation are addressed through GA, fuzzy logic, RL and NNs. Some of the approaches focus to determine efficient aggregation paths and the remaining deal with fusion [32]. Good Data Aggregation Technique can achieve in Computational Intelligence Class neural network which is inspired from human brain system, neural network's ability to learn and dynamically adapt to the changing scenarios makes it a natural choice for information fusion application.

IV- Conclusion

Wireless sensor network has many challenges and among those routing is key issue. In this article, we have discussed computational intelligent optimization to achieve energy aware routing by using different clustering techniques. A conclusion has been made by the comparative analysis of CI paradigm classes. We have come up with the result that reinforcement learning is the most appropriate technique for clustering and Neural Network is the best suited for data aggregation. These two factors are the most important among the factors affecting the energy aware routing. Moreover, in this paper, we have mentioned different universities/institutes/laboratories and group of key researchers which are involved in research on CI Classes for their theoretical and applied form, This would be helpful for interested readers as well as researchers.

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