

Survey of bio inspired algorithms in edge computing

¹Hariharan Ramalingam, ²Dr.V.Prasanna Venkatesan,

¹Research Scholar – PhD, ²Professor

¹Department of Banking Technology, School of Management

¹Pondicherry University, Puducherry, India

Abstract : Nature has its influence in the scientific methods that contributed to various technologies used from consumer to Industrial applications. The focus in this paper is to consolidate the Bio inspiration concepts, algorithms that are used in smart systems used in edge computing or last mile computing environment. These smart systems range from sensing applications in the edge or last mile working with large computing server applications, cloud based IT infrastructure. This paper also highlights the comparison with conventional problems and resolving it with nature inspired / Bio inspired methods. With wider range of application contributing to the data explosion in the today's IT ecosystem, conventional mechanism of data processing is a challenge which drives the need to look for opportunities in nature inspired methods.

IndexTerms – Bio inspired algorithms, Internet of things, Edge computing, Survey, Optimization.

I. INTRODUCTION

Bio inspired computing, a field of study inspired by biology, social behavior and emergence from nature related sciences has imparted lot of knowledge to the scientific community through inspiration that resulted in fusion of mathematics, computer science and biology [1]. Models are created using computers about the study of life and there by extracting algorithms for scientific challenges, economics, social sciences etc. Two main sets govern this category of works and they are

1. Algorithms with Bio inspiration and their characteristics targeting Optimization.
2. Applications where the above can be applied for solution [2].

One of the important research area iis Bio inspired algorithms due to the intent of emulating nature to solve complex problems. Bio inspired algorithms has their applications spanning across knowledge discovery, optimization big data analytics, control systems, image processing, Computer networks, Robotics and security. Industrial, scientific, social or natural discipline can be linked to Bio inspired systems. The terms and representations associated with bio inspired algorithms [2] are

- Nature inspired algorithms
- Evolutionary computing
- Heuristic algorithms
- Collective intelligence

The four pillars such as a population, diversity, heredity and selection are base for Bio inspired algorithms. Though the bio inspired algorithms follow the theory of natural evolutions it is getting subjective to progress made in the living organisms and their working mechanism.

II. ALGORITHMS REVIEW IN BIO INSPIRED COMPUTING

Operations of entities like neurons, bacteria and similar biological organisms drive bio inspired algorithms like neural networks, genetic algorithms or swarm intelligence function. Majorly algorithms in evolutionary, swarm and ecological category are three main categories in bio inspired algorithms. The above has sub categories of naturally occurring processes involving ants, fireflies, bacteria, bees, birds etc which in turn contribute to the bio inspired algorithms.

Bio inspiration driven heuristics algorithm which give quicker solution compared to long iterations of traditional methods in scientific challenges came up from 1970 onwards where the Neural networks, Genetic algorithms, Leaping frog algorithm, Ant colony optimization algorithm, Particle swarm optimization added to computing solutions. And then given the complexity of scientific challenges with dynamic data processing in multi dimensions the meta heuristic algorithms in mid 1980s came in which solves imperfect information related challenges - Ex: Bacterial foraging optimization algorithm, Cuckoo search algorithm. Finally in 2000 hyper heuristics based algorithms came in which are combination of methods to approach in solving a problem Ex: Firefly algorithm, Flower pollination algorithm, Bat algorithm etc. Figure below shows the development focus of bio inspired algorithm over the years.

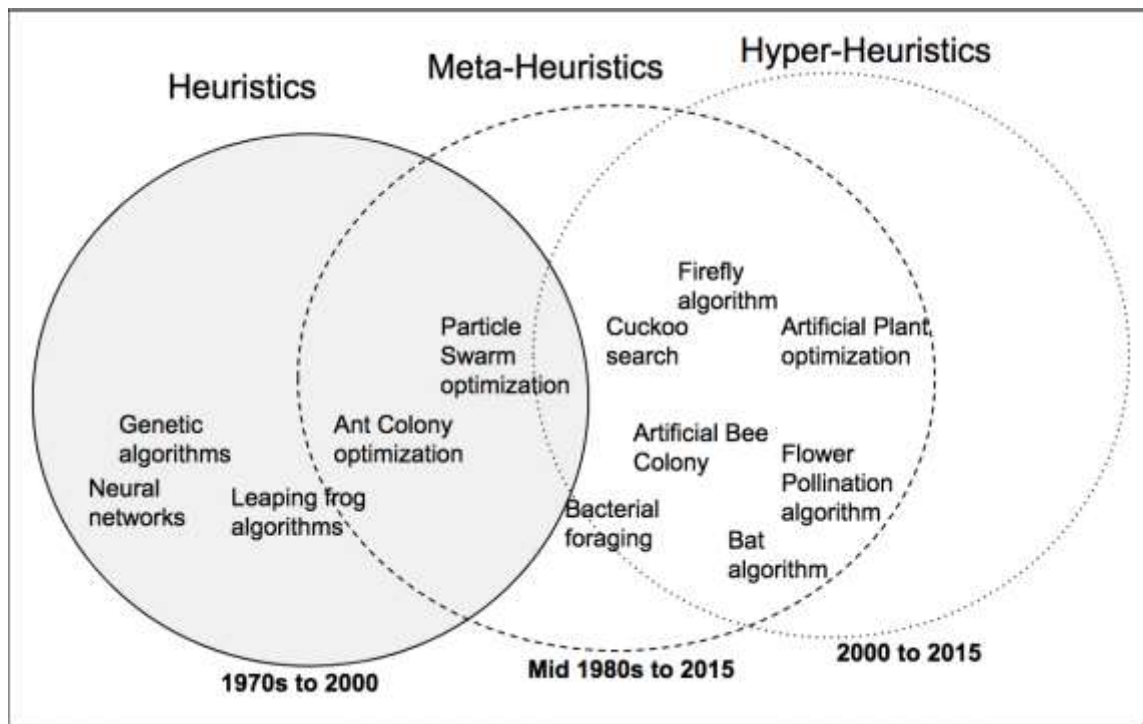


Figure 1: Evolution of bio inspired algorithms over the years

Figure 1 as inspired from Arpan Kumar Kar’s paper [1] highlights over the years the evolution of bio inspired algorithms, the drive for optimization in complex systems has driven the need for heuristics, meta heuristics and hyper heuristics category of algorithms to be developed.

Few of the relevant Bio inspired algorithms [1] and their opportunities are discussed in the table below

Table 1: Description of Bio inspired algorithms and their applications

SN	Algorithm	Description	Application domain areas and opportunities
1	Neural network	Self-learning, Self-organizing, nonlinear data processing algorithms with ability to adapt based on inputs and feedbacks from ecosystem.	For solving <ul style="list-style-type: none"> • Nonlinear problems • Probabilistic problems Used in <ul style="list-style-type: none"> • Pattern classification, • missing data prediction, sequence mining, • bayesian and deep learning, • control of nonlinear systems • switching networks.
2	Genetic Algorithm	Heuristic based evolutionary search algorithm which uses nature inspired operations for solutions.	For Solving <ul style="list-style-type: none"> • Single or multi objective problems. Used in <ul style="list-style-type: none"> • Search, • Maximization • process scheduling, • network analysis, • anomaly detection • network path routing
3	Ant colony optimization algorithm	Algorithm is Inspired by ants which uses Pheromones for traceability. Based on probabilistic search experience and related numerical information solutions are constructed.	For Solving <ul style="list-style-type: none"> • continuous optimization problems. • multi-variable and mixed variable problems. Used in <ul style="list-style-type: none"> • network analysis • scheduling

			<ul style="list-style-type: none"> ● routing ● clustering ● data compression ● parameter estimation
4	Particle Swarm optimization algorithm	Swarm based algorithm which are large number of agents governed by decentralization, homogeneity as characteristics. For a global optimal solution, they interact locally internal to the group and with their environment.	<p>For Solving</p> <ul style="list-style-type: none"> ● population based multi-dimensional multi objective problems. <p>Used in</p> <ul style="list-style-type: none"> ● Path optimization ● Distributed resource management ● adaptive learning ● job scheduling ● resource allocation ● network training ● location identification
5	Artificial bee colony algorithm	The collective foraging behavior of the honey bees drives the base for this algorithm. When there is large number for alternatives driving for a optimal numerical solution this ABC algorithm is used. The entire behavior of honey bees is mimicked for this algorithm.	<p>For Solving</p> <ul style="list-style-type: none"> ● unconstrained and constrained optimization problems ● multidimensional and multi-modal problems. <p>Used in</p> <ul style="list-style-type: none"> ● multilevel thresholding ● network routing ● search ● benchmarking ● optimization for discrete, continuous and numerical parameters.
6	Bacterial foraging optimization	Algorithm is based on the time spent is search for food by a group of organisms that is in desperate need for food.	<p>For Solving</p> <ul style="list-style-type: none"> ● distributed optimization problems ● nonlinear low complexity multi objective problems, gradient based domains. <p>Used in</p> <ul style="list-style-type: none"> ● Optimization domain related to multi optimal function, numerical and global ● gradient based search ● forecasting models ● Clustering ● minimization and maximization
7	Cuckoo search algorithm	Search algorithm based on breeding behavior of Cuckoos. The laying of eggs other birds nest and later remove the eggs of the other bird to ensure higher probability of hatching.	<p>For Solving</p> <ul style="list-style-type: none"> ● Problems with single or multi objective under complex nonlinear constraints. <p>Used in</p> <ul style="list-style-type: none"> ● search ● optimization among designs ● gradient based optimization ● multi objective allocation ● path identification for network analysis
8	Firefly algorithm	The Bioluminescence signalling of fireflies to other fireflies and for deterring predators drives the base for this algorithm. The swarm intelligence of the fireflies drives the self-organizing and decentralized decision making.	<p>For Solving</p> <ul style="list-style-type: none"> ● NP (non deterministic polynomial time) hard problem. ● dynamic environment problems. <p>Used in</p> <ul style="list-style-type: none"> ● job scheduling, ● structural and continuous optimization ● clustering price forecasting ● network analysis, ● non-linear optimization

9	Bat algorithm	Echolocation is a function used by bats to navigate their surroundings. It's basically sound emitted by bats and based on the reflection they navigate. This behavior is the base for this algorithm.	<p>For solving</p> <ul style="list-style-type: none"> • Complex, non-convergent, non-linear and multimodal problems. • adaptive learning problems <p>Used in</p> <ul style="list-style-type: none"> • Numerical, Multi objective and Structural design optimization. • network path analysis • scheduling • effort estimation
10	Flower pollination	The spread of pollens from flowers to other flowers drive pollination which results in germination. The catalyst for the pollination is insects or agents. The algorithms is based on flower with single pollen and drive for the germination of the fittest.	<p>For Solving</p> <ul style="list-style-type: none"> • Optimization problems - continuous, single objective and multi objective <p>Used in</p> <ul style="list-style-type: none"> • energy management • data reduction • classification and search • array synthesis • large scale linear programming
11	Artificial plant optimization	Based on survival techniques of the plants in the natural environment. Assumptions are based on availability of resources for the plant survival as whole and branch wise within the same plant. Each of this will act as a candidate solution.	<p>For Solving</p> <ul style="list-style-type: none"> • Optimization problems with multiple criteria <p>Used in</p> <ul style="list-style-type: none"> • network configuration • overage optimization • simulation analysis • telecom sensor networks

Further categorization of the algorithms [1] is highlighted in the figure below based on scope of research. Figure 2 is an inspiration from Arpan Kumar Kar's paper [1] which shows the categorization of algorithms based on research scope.

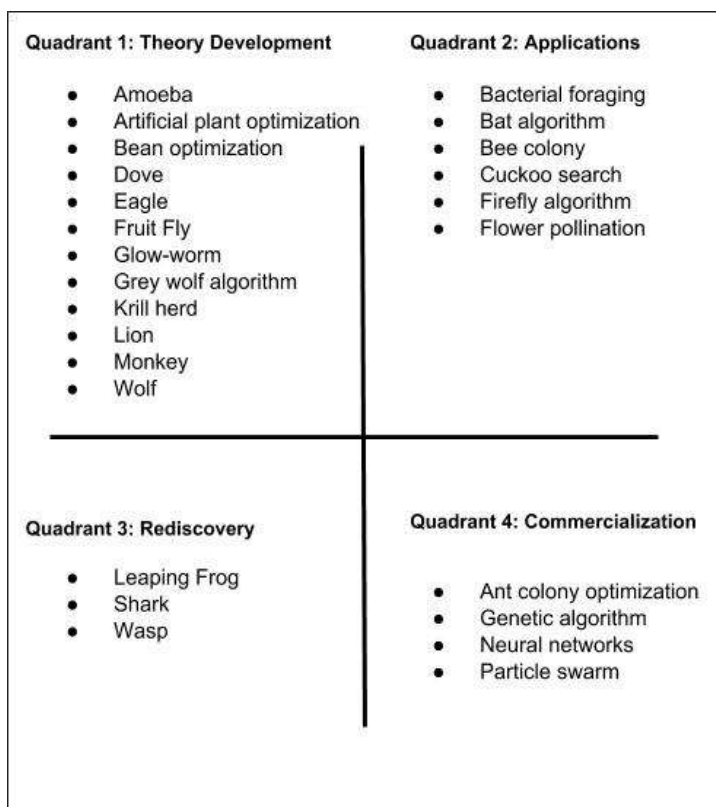


Figure 2: Four Quadrants for Research based classification of Bio inspired algorithms

Quadrant 1 algorithms support theory development, Quadrant 2 algorithms support Applications, Quadrant 3 supports re-discovery, Quadrant 4 supports Commercialization. Overall the survey till now gave highlights on the available bio inspired algorithms for Bio inspired computing. Now let's get to the focus on the Edge computing-based applications where Bio inspired algorithms are used

III. BIO INSPIRED ALGORITHMS IN EDGE COMPUTING

Edge computing is a distributed computing paradigm in which computation or processing is close to where the data is being generated i.e. from the various edge devices. Internet of things (IoT) devices are referred as edge devices based on the geographic distribution of devices. In the case of IoT, an edge device could be the sensor itself with a small microcontroller or embedded system capable of WAN communication [11]. Edge processing is usually referred to in a machine to machine context where there is tight correlation between the edge and a server located elsewhere. The motivation is to provide compute resources, data analysis and artificial intelligence closer to data collection sources. Edge computing exists to resolve issues with latency and unnecessary bandwidth consumption and to add services such as denaturing and security close to the data source. Here considering the complexity level and processing challenges, the need for bio inspired algorithms arise to reduce the complexity and drive optimization. It influences at data quality level, network latency level, Service improvement etc. The heterogeneity of computational nodes is another important challenge which has to be dealt with adequately balancing the load for the different computing units [5]. The case is subjective i.e. based on the compute requirement such as variable compute is performed among the nodes with different quality level that needs to be improved. Let's review few bio inspired algorithms which are used in the edge computing, fog & mist computing to improve their power and processing.

3.1 RTM for IoT based service discovery application

Bio inspired model called RTM [3] - response threshold model is inspired from threshold exhibited by decentralized insect colonies in response to stimuli associated with specific elements and in a group. The individuals with the lowest threshold for an element stimulus will be attracted to it more often. So based on intensity of the stimuli the probability of response is high. In IoT settings this RTM is mapped to resolve service discovery and selection problem, taking advantage of decentralized behavior of the insect colonies which brings the flexibility and robustness as desired by Artificial systems.

3.2 Genetic algorithm for managing distribution of data in Fog and Mist computing

The dynamism of the infrastructure related to resources like storage, processing, power and networking pose a significant challenge for fog and mist computing (FMC)[4]. The transitory permanence of the device poses challenge for data persistence and dissemination locally in the FMC environment. Here a bioinspired computing model is proposed to manage the data handling devices in the network. Using genetic algorithms, the above challenge will be resolved maintaining the local connectivity with devices around and data interactions between devices. The idea is that the objectives of disseminating and maintaining the data in the environment are an emergent behavior of the simple interactions between the devices that are part of the network.

3.3 Ant Trail algorithm for managing Wireless mobile network performance in a multi terrain environment

With use of Pheromones ants get the ability to find the shortest path to a food source without visual sense. Based on this technique the ant trail algorithm is made to serve many applications that requires optimization, search related problems to be resolve. Here in the case of Wireless mobile network which suffers connectivity loss in terrain environment which has obstructions from rocky hills. Basically, the line of sight is interrupted, or range is exceeded which causes signal degradation or loss of signal [6]. An adaptive, configurable, hybrid system is proposed to resolve this network problem and maintain performance. Network packets are routed automatically along the best path between multiple modules and available in different locations. This system requirement drives the need for using inspiration from biological systems and the proposal is to use ant trail algorithms. The algorithm with multi layered information maps to determine the best route through ad-hoc networks at real time and adapt to changes using very little information related. Based on these inputs an ant trail model is created and applied to to solve the connectivity issue.

3.4 Cuckoo algorithm for Cloud Computing service composition in IoT applications

The challenges of power consumption, storage capacity and bandwidth drive issues in IoT applications which results in poor IoT based services. So, to overcome these constraints the sensor networks requires effective communication mechanism and resources [7]. Cloud computing integrated with IoT helps to process & analyze edge data generated by IoT devices. However, one cloud service cannot fulfill complicated user service request and hence more services are need which can be enabled by integration of multiple cloud services from different clouds. Here QoS varies from service providers who offer their respective cloud service which drives the need for identity or location of the needed service within the multi cloud environment and providing with acceptable performance. Such integration of multiple service into one service is a complex combinatorial problem known as service composition. Here bio inspiration algorithm for service composition in a multi cloud environment is used to resolve the challenge of QoS. The cuckoo inspired algorithm where the cuckoo birds follow a breeding strategy i.e. cuckoo bird lay the eggs in host bird's nest. To get the eggs hatched the cuckoo tries to get rid of the host bird eggs and thus allowing the baby cuckoo to hatch from the eggs. The Multi Cuckoo algorithm uses the technique of combining clouds in a composition process while reviewing a minimal number of clouds to reduce the communication costs and shorter execution time.

3.5 BSCA for Multi objective optimization of IoT based Services

Executing ubiquitous services is the goal of internet of things. To achieve this goal a bio inspired self-learning coevolutionary algorithm (BSCA) is proposed for dynamic multiobjective optimization of IoT services with improvement in energy consumption

and service time [8]. Major classification of IoT services are related Identity, Information aggregation, ubiquitous and collaborative awareness. Here the algorithm will focus on resolving challenges in ubiquitous services related to heterogeneous, dynamic and uncertainties.

BSCA is based on consideration that IoT service systems is like a living system such as human beings. In a living organism, three major systems i.e. nervous, endocrine and immune (NEI). All the three cooperate with each other to achieve balancing and stabilization. NEI systems can be seen as complex network control structures which regulate the functions of various organs by means of cytokines, hormone and chemical transmitter. Inspired from the working mechanism of human NEI systems, the integral model of BSCA i.e. having three layers where the bottom most is the execution layer and top 2 layers are decision making layer is modelled.

3.6 Physarum optimization algorithm for router deployment in IoT network

IoT networks are always challenged by resource constraints. The need for energy efficiency drives the use of energy efficient transceiver like Zigbee based router in the infrastructure for IoT edge network. Here a bio inspired algorithm i.e. Physarum optimization algorithm is proposed for deployment of Zigbee router node which minimizes the number for communication hop [9]. Here the method aims to provide communication service to all points of interest with minimum number of Zigbee routers. Physarum algorithm is inspired by amoeboid slime mold organism named Physarum Polycephalum which has intelligence in searching the food source as it can solve a maze problem. It retains a single link which is the shortest path to the food resources and removes the unnecessary links.

3.7 Ultra swarm method for resource management in Internet of things deployed Mesh networks

Internet of things (IoT) deployment using mesh networks has governing parameters such as power, density of nodes, communication and environment conditions. M2M communication is the engagement model for IoT devices in a mesh topology [10]. Here though the mesh topology is known for its low power, flexible model of M2M communications, as the density of nodes increase the governing parameters face challenge in power consumption, traffic density. Using bio inspired ultra-swarm method of computing i.e. integrating wireless cluster computing and swarm intelligence-based algorithms optimization is driven to the resources required for localized efficient operations in dense set of cluster nodes optimizing the latency, power consumption of nodes in the network.

IV. RESEARCH OPPORTUNITIES

Interaction of systems, sub systems, micro systems and nano with connected performance will drive the need for optimization, decision making in a linear and nonlinear system based on use cases. This in turn drives the demand for algorithms that are created to application requirement and as mentioned in this paper the bio inspired algorithms serve the heuristics, meta heuristics and hyper heuristics category. As referred in figure 2 there is a larger scope for research, applications development, prototyping and commercialization which could be leverage for further advancements in complex system design & deployment. Further growth of edge computing systems drive decision based algorithm for enabling Context aware, Pervasive computing, Artificial intelligence applications for larger domain applications like smart cities, Smart grid, Health care, Geo spatial etc.

V. CONCLUSION

The growth of data and related processing has witnessed lot of change in computation and bio inspired algorithms are taking the lead based on optimization potential and opportunities. Bio inspiration is open topic related to nature and organisms related and the recent interest in Starfish, Octopus, Axolotl have attracted more interests recently and potential inspiration towards computing are growing. In this paper the focus is to survey and discuss the available bio inspired algorithms for computations and highlight the ones uses in Edge computing. Given the opportunities in nature inspired methods there is lot of scope for researchers to explore in bio inspired computation domain. As we take the inspiration from nature to solve complex computing problems, we must consciously give back to nature in form of discipline to preserve and nurture the biological eco system contributing to a harmonious bond with nature, resist and suggest alternative to harmful systems that threaten nature and its existence. To conclude bio inspired algorithms are already integral part of the existing technology infrastructure and expanding in areas where optimization and improvements are needed.

VI. ACKNOWLEDGMENT

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REFERENCES

- [1] Arpan Kumar Kar, 2016. "Bio inspired computing - A review of algorithms and scope of applications", ELSEVIER - Experts systems with Applications 59.
- [2] Nancy Arana-Daniel, Carlos Lopez-Franco, Alma Y. Alanis, 2018. "Bio inspired algorithms for Engineering", ELSEVIER, Butterworth-Heinemann Publications.
- [3] Elli Rapti, Catherine Houstis Elias Houstis, Anthony Karageorgos, 2016. "A Bio inspired Service discovery and selection for IoT application", IEEE International conference on services computing.

- [4] Danilo Reis Vasconcelos, Valdenir S. Severino, Rossana Maria De Castro Andra, 2018. "Bio-inspired model for data distribution in Fog and Mist computing", 42nd IEEE International conference on Computer Software and Applications.
- [5] David Camacho, Raul Lara-Cabrera, J.J. Merelo-Guervos, Pedro A. Castillo, Carlos Cotta, Antonio J. Fernández-Leiva, Francisco Fernandez de Vega, Francisco Chavez, 2018. "From ephemeral computing to deep bio inspired algorithms: New trends and applications", ELSEVIER, Future Generation Computer systems 88.
- [6] Richard L. Alena, Charles Lee, 2005. "Adaptive Bio-inspired Wireless Network Routing for Planetary Surface Exploration", IEEE Aerospace Conference.
- [7] Heba Kurdi, Fadwa Ezzat, Lina Altoaimy, Syed Hasssan Ahmed, Kamal Youcef Toumi, 2018. "MultiCuckoo: Multi-cloud Service Composition using a cuckoo-inspired algorithm for the IoT applications", IEEE Access.
- [8] Zhen Yang, Yaochu Jin, Kuangrong Hao, 2018. "A Bio-Inspired Self-learning Coevolutionary Dynamic Multiobjective Optimization Algorithm for Internet of Things Services", IEEE Transaction on evolutionary computation.
- [9] Lukman Rosyidi, Muhamad Asvial, Riri Fitri Sari, 2017. "Efficient Router Node deployment of Zigbee based Internet of things network using Physarum optimization algorithm", IEEE, International conference on Information and Communication technology convergence.
- [10] Hariharan Ramalingam, Dr.V.Prasanna Venkatesan, 2016. "Ultra swarm method for resource management in Internet of things deployed Mesh networks", International Conference on Distributed and Intelligent computing.
- [11] Perry Lea, 2018. "Internet of things for Architects", Packt Publishing.

AUTHORS PROFILE

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Hariharan Ramalingam – Research Scholar – PhD in Department of Banking technology, Pondicherry University. Received B.E. (ECE) from University of Madras, M.Tech (ECE) from Pondicherry University, PGDM from Indian Institute of Modern management. Has Industry experience of 18+ years with core strengths in Research and development of Information technology products ranging from Chip design to complication SW stack development. Currently practicing as consultant in Smart IT infrastructure and services. His research interests are Distributed computing, Wireless sensor networks, Artificial intelligence, Machine learning, Computer vision, Block chain, Internet of things, Bioinspired algorithms, Big Data, Data Science, Banking technology management. He can be reached via email – hariharan.ramalingam@gmail.com

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Dr.V.Prasanna Venkatesan, Professor, Department of Banking technology, Pondicherry University. He has more than 26 years of teaching and research experience in the field of Computer Science and Engineering. His research interest include Software engineering and Architecture, Business Intelligence, Internet of Things (IoT) and Information security. He has development a compiler for multilingual languages, he can be reached via email – Prasanna_v@yahoo.com