Research Statement

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My Approach to Research

Since childhood, I was always interested in Computing and Machines cum solving complex-problems. I started my journey with computing when I was 8 Years old, when I taught myself programming by typing in programs and making small projects. To my mind, computers were a source of endless possibilities; whatever I could conceive, I could build. Over thirty years later, I still have the same enthusiasm. My interest in computer science research is fundamentally driven by the desire to build smart computing systems- faster, more reliable, secure, sustainable and above all autonomous, that make new things possible, everything looking magical and to support others to help and perform activities.

I love challenges. Nothing satisfies me more than coming up with an elegant solution to a difficult problem. I was fortunate enough to have a solid foundation in theory and practical demonstration of computers and information technology in Masters of Computer Applications from Punjabi University and later by Ph.D from Desh Bhagat University, India. I find theory and formalism indispensable in clarifying ideas, finding unseen corner cases, suggesting new directions to explore, and in the fundamental understanding of any problem.

The combination of engineering theory attached me first to the world of Compilers, Programming, Data Structures and Automata. It is one of the areas in computer science where theoretical results are very often put into practice. Also working in compilers and programming languages, can also improve the existing systems functionalities and make them run better and perform tasks in highly efficient manner. I applied improvements in tons of programs, and impact increased at varied levels. Finally, many challenges problems in terms of compiler design, algorithm analysis and NP-Hard problems can be solved.

My approach towards research is influenced by two-fold approach: Mix of Engineering and Theory. When I search a new research problem, I take a deep dive in thinking about the problem by building some prototype ideas and idea to better understanding and think of steps to solve the problems. After I understand the foundations, I research and learn what others have published and proposed solutions to those problems. With that, I can find and justify that my solution is better and whether the proposed approach from my side is better as compared to existing approaches. After that, I start implementing. My first attempt is rarely successful, but my experience in building the implementation quickly exposes what the real issues are. Then,

I throw away my first implementation and use what I have learned to do it right. Finally, after I have a working implementation, I sit down and try to document and formalize the ideas. I feel it is important to have a working implementation that you can experiment with before you formalize the system because otherwise your formulation may not match reality or miss some key subtleties.

The process of documentation and formalization often suggests new ways of simplifying or improving the implementation and exposes corner cases that I would not have considered. Thus, both engineering and theory play complementary roles in my approach to research.

Finally, I believe strongly in the openness of research and the free flow of ideas. I find communication with others invaluable in the development and understanding of research ideas. Most of my research ideas were not sudden personal inspirations but were the result of interacting with others. I often take ideas from different areas of computer science and apply them to new areas. To facilitate cooperation, communication, and the advancement of research, I release all of my implementations as open source so that other researchers can build upon my work. I use GITHUB repository and Research Networks like: ResearchGate, Publons and SCIRESEARCH for much of my day-to-day research, so anyone can find out what I am working on and have access to my latest research.

Research Philosophy

My Research interests are in the area of : Wireless Sensor Networks, Swarm Intelligence, Internet of Things, Wireless Communications, Artificial Intelligence, Blockchain and Smart cum Sustainable Technologies for development. My Research is driven by strong desire to bridge the digital divide and make computing useful to the significant fraction of the world's population to use smart computing for real-time mission critical applications. My Research focusses on:

a. Design and Development of Internet of Things based solutions with fusion of Big Data, Cloud Computing, Embedded Systems and Artificial Intelligence for real-time implementations.
b. Design and development of new computing solutions by integrating Blockchain and Artificial Intelligence to address real-world problems pertaining to global social and economic development.
c. Understanding complex problems pertaining to Wireless Sensor Networks and Healthcare Informatics and addressing via Real Time Implementations using Artificial Intelligence and Swarm Intelligence based optimization techniques.
d. Solving critical problems in Smart and Intelligent Systems like Drones, Metaverse, Augmented Reality, Game Theory and many more.

Computer science, as a field, has largely focused on problems relevant to the developed world. Bridging this digital divide requires us to address several important and challenging computer science research problems whose solutions will ultimately have significant impact on global development. Conventional computing solutions are often inappropriate in these emerging contexts due to various contextual factors including *lack of infrastructure, limited purchasing power, poor connectivity, limited power, language and literacy issues, and lack of local*

expertise for managing systems. These unique infrastructure, cost, power and connectivity constraints create several new research challenges which often require a fundamental rethinking in the way we design computing solutions.

My research philosophy places a strong emphasis on *"IoT based Smart Computing Solutions- Integrating- AI, Blockchain, Sensors, Cloud Computing, Big Data"* solutions for developmental problems.

I use a three-step research process.

- First, performing strong literature review, towards Problem definitions, solutions design, prototype handling and even studying the related prospects towards the ground realities and identify challenging problems.

- Second, Design and implement cost-effective and appropriate computing systems that address the most difficult problems.

- Third, Deployment and Testing of proposed systems in the developing world (with support from funding organizations), rigorously evaluate the system effectiveness and also perform impact evaluation studies where appropriate.

- In the next stage, if possible and feasible, look for organizations to support for funding and even to seed support from Government for seeding into Kickstarter and doing Patents.

In this research statement, I provide a summary of my Dissertation and an overview of my related works in Section 1. Followed by my General discussion on Current and Future aspects in Section 2 and will include a list of my strong Peer-reviewed papers, best in the class and implementations and abstracts. Finally, I conclude my Research statement with Summary.

1 Prior Research

Till date, the core focus of my research is proposing solutions to Wireless Sensor Networks, Studying and Applying Diverse Nature Optimization algorithms towards discrete problems of computer science, making use of AI based techniques for Healthcare Informatics and above all proposing varied solutions of IoT for mission-critical applications.

My empirical research on routing issues and performance issues in Wireless Sensor Networks left with a set of interesting practical challenges. Based on these, I designed efficient Routing Protocols for optimizing WSN using Swarm Intelligence. This section provides a summary of my dissertation and a summary of key-insights for the practical application of my work.

1.1. Dissertation

My thesis is motivated by the complex and challenges surrounding Wireless Sensor Networks with varied problems like Throughput, Packet Deliver Ratio, Energy Efficiency and Routing Overheads. Indeed, the literature is full of routing protocols proposed by several researchers to optimize sensor networks. Technically, some routing protocols were effective in 1-2 parameters but overall quality of WSN network was not improvised to a greater extent. In addition to this, the proposed solutions have limited novelty in terms of working, applying optimization techniques.

Hence, I conducted an interdisciplinary empirical investigation on the nature of Wireless Sensor Networks. Specifically, I focus on: (1) Energy Efficiency (2) Routing Overhead (3) Packet Delivery Ration (4) Throughput. In addition, I also investigated other issues in WSN like Dynamic Nature, Practical issues of implementations.

Initially, looking at varied protocols, I find that there are commonly prevented by technical mitigations. In contracts, some misconfigurations, and parameters limitations is also not improving the state of the quality of Sensor Networks. Furthermore, an additional literature study also indicates that protocols proposed, were not so efficient as compared to standardized protocols.

So, I proposed a Novel Routing Protocol i.e., IEEMARP (Improvised Energy Efficient Multipath ACO based Routing Protocol) which not only improves energy efficiency but also improvises, Packet Delivery Ratio, Throughput and Routing Overhead. And as compared to more than 12+ Protocols, the IEEMARP outperformed existing protocols by 80%.

In summary, I find that the major objectives for the future are: (1) Introduction of Artificial Intelligence and advanced Swarm Intelligence Optimization Techniques for improvising Sensor Networks; (2) Implement IoT solutions for Smart Computing; (3) Extend the work of IoT towards Healthcare Informatics, Drones and even Smart Building for producing outstanding solutions for Industry 4.0, Smart Cities and Sustainable computing.

2 **Current and Future Research**

Extending my previous works on WSN, I have extended my works on advancements towards IoT, Cloud Computing, Big Data and above all proposing solutions to smart computing.
So, I have published several quality research papers and has strong impacts with Strong citations.

I. Current Research

a. IEEMARP- a novel energy efficient multipath routing protocol based on ant Colony optimization (ACO) for dynamic sensor networks

In the past few years, research and development in Wireless Sensor networks (WSNs) have gained momentum due to its numerous applications in agriculture, industrial manufacturing, military surveillance, environmental monitoring, consumer electronics, medical & healthcare, disaster recovery operations etc. Dynamic WSNs offer a robust blend of distributed sensing, computing and communication. Dynamic sensor networks are characterized by large scale deployment, dynamic and unstructured topology, power limitations, less memory and limited computational capabilities. Sensor nodes deployed in real-time environment's for sensing data have power-limitations which hampers the overall performance of WSNs. So, the only obvious solution is to propose an energy efficient routing protocol to optimize WSN real-time performance. Different specialists have proposed various directing conventions for WSNs dependent on Fuzzy Logic, Genetic Algorithms, Meta-Heuristics, and other improvement strategies. However, every solution suggested till date has its advantages and limitations. In this paper, our primary objective is to utilize Swarm-Intelligence based approach i.e., "Ant Colony Optimization (ACO)", for routing protocol development. Ant colony optimization (ACO) based approach gives optimal solution in terms of efficient routing path determination, energy efficiency and delivering high performance in terms of packet delivery and throughput.

In this paper, we propose a novel energy efficient ACO based multipath routing protocol for WSN i.e., IEEMARP (Improvised Energy Efficient Multipath ACO based Routing Protocol). The proposed protocol works in three phases (Neighbor Discovery via Link Knowledge, Packet Transmission via exponentially weighted moving average method and ACKR packet delivery for assuring end-to-end delivery. To validate the performance of the protocol proposed, extensive simulations were conducted using NS-2.35-allinone simulator on diverse parameters like (PDR), throughput, routing overhead, energy consumption and end-to-end delay. In addition to this, the performance of protocol is compared with traditional routing protocols like Basic ACO, DSDV and DSR and other ACO based WSN protocols like ACEAMR, AntChain, EMCBR, IACR, AntHQSeN, FACOR and ANTALG. Simulation based results, clearly states that as compared to Basic ACO, DSDV and DSR, the performance of WSN network is improvised to around 10% in all performance metrics via IEEMARP routing protocol. And as compared to ACEAMR, AntChain, EMCBR and IACR, IEEMARP performs 20% better in overall functionality and almost 10–12% better as compared to AntHQSeN, FACOR, ANTLAG routing protocols in varied WSN scenarios. It is also observed that IEEMARP protocol is highly efficient in TCP packet transmission from source to destination node.

b. NLFFT: A Novel Fault Tolerance Model Using Artificial Intelligence to Improve Performance in Wireless Sensor Networks

A wireless sensor network (WSN) is a collection of various tiny devices known as sensor nodes, which are also called motes. Due to high-energy consumption, the possibility of hardware, link or node failure, and some malicious attacks, sensor networks are considered error-prone networks. Hence, fault tolerance (FT) in WSN is one of the prominent issues. This article presents a novel FT approach named node-link failure fault tolerance model (NLFFT Model) in WSN, to handle the faults that occur either by link or node failure during data transmission from the sensor to the sink or base station. The NLFFT model consists of an improved quadratic minimum spanning tree (Imp-QMST) approach. This approach helps in finding the alternate link whenever it fails due to various situations and also an improved-handoff (Imp-Handoff) algorithm to support the node failure to the fault tolerance. Improved QMST presents a novel mechanism to find an alternate edge in place of the broken or failed edge in the spanning tree, to improve the fault tolerance in WSN. Imp-Handoff suggests a novel way to find the faulty node owing to less battery power and replaces a defective node by an appropriate neighbor to shift the tasks performed by a faulty node in WSN. Simulation results clearly state that as compared to the basic techniques i.e., Q-MST and Handoff algorithm, the proposed NLFFT model improvises the performance of WSN around by 7%. The results prove that the Imp-QMST gives about 6% improved throughput, 5% less end-to-end delay, and 6% less power consumption than the QMST algorithm. Similarly, Imp-Handoff improves about 4% throughput, 6% less end-to-end delay, and utilizes 7% less power consumption.

c. Proficient QoS-Based Target Coverage Problem in Wireless Sensor Networks

Assuring the coverage towards the predefined set of targets, power-constrained wireless sensor networks (WSNs) consist of sensing devices (i.e., sensor nodes) that are associated with limited battery life and fixed sensing range. All the sensors are collectively responsible for covering these sets of objects. The standard target coverage problem is the one where continuous coverage is provided over a predefined set of targets for the maximum possible duration so that the scarce resource (battery power) can be optimally utilized. Therefore, in order to incorporate quality of service (QoS) in the network and ensure smooth monitoring of the desired target set, the paper addresses target Q-Coverage, which is one of the variants of standard target coverage

problem where a target is covered by at least Q-sensors (pre-defined number) in every cover set. A cover set is a subset of sensors which cover whole targets in a single iteration. In this paper, a greedy heuristic based technique, i.e., maximum coverage small lifetime (MCSL) has been proposed, which restricts the usages of those sensors that poorly cover targets and promotes the usage of those sensors that have maximum coverage and energy. Simulations are performed on static wireless sensor network with varying Q values to test the efficiency of the proposed method. The performance of the proposed heuristic is compared with optimal upper bound based on network lifetime, and results prove that performance is improvised by 94%. The obtained results are further compared with the existing approaches to prove the superiority of the proposed work via extensive experimentations.

d. Simulation-Based Performance Analysis of Location-Based Opportunistic Routing Protocols in Underwater Sensor Networks Having Communication Voids

Recently, Underwater Wireless Sensor Networks (UWSNs) have emerged as a prominent research area in the networking domain due to their wide range of applications in submarine tracking, disaster detection, oceanographic data collection, pollution detection, and underwater surveillance. With its unique characteristics like continuous movement of sensor nodes, limitations in bandwidth and high utilization of energy, efficient routing and data transfer in UWSNs have remained a challenging task for researchers. Almost all the protocols proposed for terrestrial sensor networks are inefficient and do not perform well in an underwater environment. Recently Location-Based Opportunistic Routing Protocols have been observed to perform well in UWSN environments. But it is also observed that these protocols suffer from performance degradation in UWSN networks with communication voids. The objective of this research paper is to discuss the working of major Location-Based Opportunistic Routing Protocols in UWSNs with communication voids and to highlight their issues and drawbacks. We analyzed the Quality-of-Service parameters, packet delivery ratio, end-to-end delay, throughput, and energy efficiency of two major Location-Based Opportunistic Routing Protocols, i.e., Vector-Based Forwarding (VBF) and Hop-by-Hop VBF (HH-VBF) in UWSNs with communication voids using NS-2 simulator with Aqua-Sim extension. Simulation results state that both VBF and HH-VBF protocols suffered from performance degradations in UWSNs with communication voids. In addition to this, the paper also highlights open issues for UWSN to assist researchers in designing efficient routing protocols for UWSNs having multiple communication voids.

e. CT-RPL: Cluster Tree Based Routing Protocol to Maximize the Lifetime of Internet of Things

Energy conservation is one of the most critical challenges in the Internet of Things (IoT). IoT devices are incredibly resource-constrained and possess miniature power sources, small memory, and limited processing ability. Clustering is a popular method to avoid duplicate data transfer from the participant node to the destination. The selection of the cluster head (CH) plays a crucial role in gathering and aggregating the data from the cluster members and forwarding the data to the sink node. The inefficient CH selection causes packet failures during the data transfer and early battery depletion nearer to the sink. This paper proposes a cluster tree-based routing protocol (CT-RPL) to increase the life span of the network and avoid the data traffic among the network nodes. The CT-RPL involves three processes, namely cluster formation, cluster head selection, and route establishment. The cluster is formed based on the Euclidean distance. The CH selection is accomplished using a game theoretic approach. Finally, the route is established using the metrics residual energy ratio (RER), queue utilization

(QU), and expected transmission count (ETX). The simulation is carried out by using a COOJA simulator. The efficiency of a CT-RPL is compared with the Routing Protocol for Low Power and Lossy Networks (RPL) and energy-efficient heterogeneous ring clustering routing (E2HRC-RPL), which reduces the traffic load and decreases the packet loss ratio. Thus, the CT-RPL enhances the lifetime of the network by 30–40% and the packet delivery ratio by 5–10%.

f. An efficient anonymous authentication and confidentiality preservation schemes for secure communications in wireless body area networks

Wireless body area network (WBAN) is utilized in various healthcare applications due to its ability to provide suitable medical services by exchanging the biological data between the patient and doctor through a network of implantable or wearable medical sensors connected in the patients' body. The collected data are communicated to the medical personals through open wireless channels. Nevertheless, due to the open wireless nature of communication channels, WBAN is susceptible to security attacks by malicious users. For that reason, secure anonymous authentication and confidentiality preservation schemes are essential in WBAN. Authentication and confidentiality play a significant role while transfers, medical images securely across the network. Since medical images contain highly sensitive information, those images should be transferred securely from the patients to the doctor and vice versa. The proposed anonymous authentication technique helps to ensure the legitimacy of the patient and doctors without disclosing their privacy. Even though various cryptographic encryption techniques such as AES and DES are available to provide confidentiality, the key size and the key sharing are the main problems to provide a worthy level of security. Hence, an efficient affine cipher-based encryption technique is proposed in this paper to offer a high level of confidentiality with smaller key size compared to existing encryption techniques. The security strength of the proposed work against various harmful security attacks is proven in security analysis section to ensure that it provides better security. The storage cost, communication cost and computational cost of the proposed scheme are demonstrated in the performance analysis section elaborately. In connection to this, the computational complexity of the proposed scheme is reduced around 29% compared to the existing scheme.

g. bSSA: Binary Salp Swarm Algorithm With Hybrid Data Transformation for Feature Selection

Feature selection is a technique commonly used in Data Mining and Machine Learning. Traditional feature selection methods, when applied to large datasets, generate a large number of feature subsets. Selecting optimal features within this high dimensional data space is time-consuming and negatively affects the system's performance. This paper proposes a new binary Salp Swarm Algorithm (bSSA) for selecting the best feature set from transformed datasets. The proposed feature selection method first transforms the original data-set using Principal Component Analysis (PCA) and fast Independent Component Analysis (fastICA) based hybrid data transformation methods; next, a binary Salp Swarm optimizer is used for finding the best features. The proposed feature selection approach improves accuracy and eliminates the selection of irrelevant features. We validate our technique on fifteen different benchmark data sets. We conduct an extensive study to measure the performance and feature selection accuracy of the proposed technique. The proposed bSSA is compared to Binary Genetic Algorithm

(bGA), Binary Binomial Cuckoo Search (bBCS), Binary Grey Wolf Optimizer (bGWO), Binary Competitive Swarm Optimizer (bCSO), and Binary Crow Search Algorithm (bCSA). The proposed method attains a mean accuracy of 95.26% with 7.78% features on PCA-fastICA transformed datasets. The results show that bSSA outperforms the existing methods for the majority of the performance measures.

h. IoT-based green city architecture using secured and sustainable android services

Green and smart cities deliver services to their residents using mobile applications that make daily life more convenient. The privacy and security of these applications are significant in providing sustainable services in a green city. The software cloning is a severe threat which may breach the security and privacy of android applications. A centrally controlled and automated screening system across multiple app stores is inevitable to prevent the release of copyrighted or cloned copies of these apps. In this paper, we proposed IoT-enabled green city architecture for clone detection in android markets using a deep learning approach. First, the proposed system obtained an original APK file together with potential candidate cloned APKs via the cloud network. For each subject software, the system uses an APK Extractor tool to retrieve Dalvik Executable (DEX) files. The Jdex decompiler is utilized to retrieve Java source files through Dalvik Executables. Second, the AST features are extracted using ANother Tool for Language Recognition (ANTLR) parser. Third, the linear features are mined from these hierarchical structures, and Term Frequency Inverse Document Frequency (TFIDF) is applied to estimate the significance of each feature. Finally, the deep learning model is configured to detect cloned apps. The deep learning model is fine-tuned to get better accuracy. The proposed approach is analyzed on five different cloned applications collected from different android markets. The main objective of this system is to avoid the release of pirated apps with various pirated labels in multiple app markets.

i. A Smart Cloud Service Management Algorithm for Vehicular Clouds

Vehicular clouds (VCs) have become a promising research area due to its on-demand solutions, resource pooling, unified services, autonomous cloud formation and transformational management. It makes use of the underutilized resources of vehicles on the parking lot, roadways, driveways and streets, and creates the infrastructure to support various services offered by the cloud service provider (CSP) by deploying virtual machines (VMs). However, these vehicles can leave the coverage/grid of VC due to its mobility and change in the environment. Therefore, the hosted VMs on those vehicles can be transferred to other potential vehicles (i.e., migration) in order to avoid disruption of services. These services can be viewed as user requests (URs) submitted to the CSP by cloud users. Here, the challenging tasks are to map the URs to the VMs (or vehicles) and identify the potential vehicles for migration, and they need immediate attention. In this paper, we propose a smart cloud service management (SCSM) algorithm for VCs and address the above challenges. This algorithm consists of three phases, namely assignment of vehicles to grids, URs to grids and URs to vehicles by considering the mobility pattern of vehicles. The performance of SCSM is assessed using three traffic congestion scenarios and thirty-six instances of four datasets, and compared with round-robin (RR) and deficit weighted RR (DWRR) using seven performance metrics. The

comparison results show that SCSM achieves 58% and 57% (33% and 33%) better than RR and DWRR in makespan (number of migrations) and other performance metrics.

j. Investigation on Security Risk of LoRaWAN: Compatibility Scenarios

The LoRaWAN standard comes from the low-power wide area network (LPWAN) technology suitable for developing Internet of Things (IoT) systems that are poised to disrupt the semiconductor industry. Even as a widespread technology used for diverse applications, security issues of long-range (LoRa) networks and devices remain a major challenge. Although the LoRa Alliance enhanced the security and the network architecture of LoRaWAN from version 1.0 to version 1.1, the last version still faces some drawbacks such as vulnerability to attacks. Some works have assessed LoRaWAN (v1.0 and v1.1) security risks and vulnerabilities. Moreover, all these specifications must coexist with each other, which makes compatibility an important factor in ensuring the sustainability of this technology. For this reason, we study the vulnerability of the LoRaWAN protocol in the context of compatibility. Hence, we consider four compatibility scenarios and possible cyber-attacks when connecting devices from the two mentioned versions. In this paper, we analyze the LoRaWAN architectures and then discuss the basic security concepts related to the compatibility scenarios between homogeneous or heterogeneous systems integrating the two LoRaWAN versions. After that, we investigate and identify the potential security risks and network vulnerabilities in LoRaWAN technology. We establish a catalog of vulnerabilities for LoRaWAN on a methodological framework. The catalog contains five vulnerabilities related to LoRaWAN v1.0.x and v1.1 and seven vulnerabilities related to LoRaWAN v1.0.x. Then, we check if these vulnerabilities could be applied to the compatibility scenarios. We observe that the majority of vulnerabilities mitigated in LoRaWAN v1.1 remain present in compatibility scenarios.

l. Sustainable iot solution for freshwater aquaculture management

In recent years, we have seen the impact of global warming on changing weather patterns. The changing weather patterns have shown a significant effect on the annual rainfall. Due to the lack of annual rainfall, developing countries like India have seen a substantial loss in annual crop production. Indian economy largely depends on agro products. To compensate for the economic loss, the Indian government encouraged the farmers to do integrated aquaculture-based farming. Despite government subsidies and training programs, most farmers find it difficult to succeed in aquaculture-based farming. Aquaculture farming needs skills to maintain and monitor underwater environments. The lack of skills for monitoring and maintenance makes the aquaculture business more difficult for farmers. To simplify the pearl farming aquaculture, we have proposed an Internet of Things (IoT)-based intelligent monitoring and maintenance system. The proposed system monitors the water quality and maintains an adequate underwater environment for better production. To maintain an aquaculture environment, we have forecasted the change in water parameters using an ensemble learning method based on random forests (RF). The performance of the RF model compared with the linear regression (LR), support vector regression (SVR), and gradient boosting machine (GBM). The obtained results show that the RF model outperformed the forecast of the DO with 1.428 mean absolute error (MAE) and pH with 0.141 MAE.

J. **DEICA: A differential evolution-based improved clustering algorithm for IoT-based heterogeneous wireless sensor networks**

With the evolution of technology, many modern applications like habitat monitoring, environmental monitoring, disaster prediction and management, and telehealth care have been proposed on wireless sensor networks (WSNs) with Internet of Things (IoT) integration. However, the performance of these networks is restricted because of the various constraints imposed due to the participating sensor nodes, such as nonreplaceable limited power units, constrained computation, and limited storage. Power limitation is the most severe among these restrictions. Hence, the researchers have sought schemes enabling energy-efficient network operations as the most crucial issue. A metaheuristic clustering scheme is proposed here to address this problem, which employs the differential evolution (DE) technique as a tool. The proposed scheme achieves improved network performance via the formulation of load-balanced clusters, resulting in a more scalable and adaptable network. The proposed scheme considers multiple parameters such as nodes' energy level, degree, proximity, and population for suitable network partitioning. Through various simulation results and experimentation, it establishes its efficacy over state-of-the-art schemes in respect of load-balanced cluster formation, improved network lifetime, network resource utilization, and network throughput. The proposed scheme ensures up to 57.69%, 33.16%, and 57.74% gains in network lifetime, energy utilization, and data packet delivery under varying network configurations. Besides providing the quantitative analysis, a detailed statistical analysis has also been performed that describes the acceptability of the proposed scheme under different network configurations.

K. **System performance and optimization in NOMA mobile edge computing surveillance network using GA and PSO**

Recent years have witnessed the computing process gradually move to the edge network, close to the physical data source, to serve applications that require large computations with very little latency. However, the terminal wireless devices' limited computing and energy resources pose obstacles to the practical implementation of these applications. Mobile Edge Computing (MEC) based non-orthogonal multiple access (NOMA) technology is solving this problem well thanks to its ability to serve many users with high data rates and spectrum utilization efficiency. This study investigates the performance and optimization of MEC surveillance systems using NOMA. Specifically, two camera units (CUs) perform the monitoring task to be accomplished by the MEC access point (AP) through Rayleigh fading wireless links. We then proposed the four-phase protocol for this system. Accordingly, we derive the closed-form exact expressions of the successful computation probability (SCP) and study the impact of the network parameters on the system performance. Furthermore, we propose and compare three meta-heuristic-based algorithms, namely MSCP-GA, MSCP-PSO, and MSCP-HGAPSO, to find the optimal parameters set to help the proposed system achieve the maximum SCP. The results show that the proposed algorithms can significantly improve the system's performance by 40% higher than when the optimal algorithm is not used. Insights into the pros and cons of different

algorithms are also discussed in this study. Finally, we use the Monte-Carlo simulation to verify the correctness of this study.

L. **Hybrid sooty tern naked mole-rat algorithm and Fuzzy Type-2 logic-based trust and energy-aware stable clustering protocol**

With the advent of low-cost circuitry, sensor and communication technologies, it is feasible to sense and communicate the condition of surroundings to end user. The wireless networks of these circuits, called Wireless Sensor Network (WSN) that are utilized in a multitude of applications such as in hospitals, smart industries, environmental sensing and military protection. WSN's main issue is efficient data sharing between various sensors and efficient communication with sink. However, in the real-world sensors have restricted range of communication and resources, which in turn imposes constraints for successful coordination in the design of the communication strategy. Investigating the trust level of a node is also a significant aspect of WSNs using which two sensor nodes can communicate since an untrustworthy node has adverse effect on the reliability and quality of data. The biggest challenge in this domain is to devise a suitable communication system that helps sensors to achieve their target with minimal energy loss and high confidence level transmission of the full exploration data. Clustering is an effective way to extend the network performance parameters. In order to address the restrictions in these protocols such as cluster head (CH) lifetime, cluster quality etc.; an enhanced routing protocol with optimum CH selection algorithm and trust management are required to design an efficient WSN framework. A hybrid sooty tern naked mole rat algorithm (STNMRA) is developed to mitigate the effect of local stagnation problem in classical naked mole rat algorithm (NMRA). In order to evaluate the effectiveness of proposed STNMRA, highly challenging CEC 2019 numerical test problems are taken into consideration and statistical test validates that STNMRA provides better results with respect to competitive algorithms. STNMRA based clustering protocol using a Fuzzy Type-2 logic is proposed in this paper to enhance the trust level and thus the network lifetime. The proposed clustering protocol outperforms state-of-the-art techniques in terms of the efficient removal of malicious nodes together with improved network lifespan and reduced energy consumption.

M. **System design and Optimization of Mobile Edge Computing in the NOMA Wireless Tactile Internet of Things Network**

Mobile edge computing (MEC) is an essential technique in next-generation networks to serve ultra-low latency and computation-intensity applications. At the same time, nonorthogonal multiple access (NOMA) is a technique to help multi-user service, saving energy and increasing spectrum efficiency. In this study, we investigate the NOMA MEC-based wireless Tactile Internet of Things (IoT) network and propose the optimization algorithms for system and users' performance: We propose a network model consisting of a MEC server at the access point that supports computation for two sensor clusters in the Tactile IoT environment. We analyze the performance of the system and cluster heads (CHs) using the successful computation probability (SCP). Asymptotic SCP at high SNRs was analyzed and compared by us to give a better view of the system's behavior. Then, we maximize the SCP of the proposed system and simultaneously maximize the SCP of the CHs to clarify the performance trade-off problem in the NOMA MEC network by proposing low-complexity meta-heuristic algorithms.

Monte-Carlo simulation results show that our proposed approach can significantly improve system performance by up to 30% compared to OMA traditional methods.

II. Future Research

My research has focussed on building IoT systems to solve practical real-world problems. I believe, going forward, IoT systems will form the core of three emerging areas in computing. First, questions of sensing, communication, and inference are integral to the promise of digital healthcare. These digital healthcare systems will glean information from wearables, in-body devices, radio signal reflections, and medical records to reduce risk of health emergencies, ensure better treatment procedures, decrease long-term healthcare costs, and generally produce better healthcare outcomes. In addition, the integration of blockchain technology in Healthcare Systems.

Security and Privacy in Smart Environments: The advent of IoT and cyber-physical systems have forced us to change our existing notions of security and privacy. Security and privacy risks are not limited to digital information that is stored online but encompass our physical identities and environments. IoT systems have the capability to sense information about us and our surroundings and can change our physical environments by controlling devices and objects. As a result, there is an urgent need to rethink our security and privacy solutions. I believe the capability of IoT systems to sense our physical environment presents us an opportunity to rethink our security solutions by incorporating the physical information itself into our security approach.

Specifically, the physical information being sensed and the communication channel will form signatures for verifying next-generation IoT devices. I want to build on this intuition to integrate low-level sensing mechanisms with edge architectures, inference mechanisms, and security protocols to design end-to-end security and privacy mechanisms for IoT systems.

Perimeter-based Security: Due to the closed nature of many IoT devices, we often cannot implement defences directly on the device. This poses a challenge to IoT security. I plan to explore defense mechanisms that define the security state and enforce protection of IoT environments from a distance. First, defense mechanisms will utilize outside sensors in the same environment to estimate the security state of an inaccessible IoT device. For example, power sensor readings could reveal the operating characteristics of another connected device, wireless traffic could indicate malicious behavior, and vehicular sensors could reveal anomalies in the control systems. Second, the defense system will have to thwart an adversary without the privilege of running on the IoT device.

In addition to this, making use of Swarm Intelligence techniques for optimizing real world problems in computer science.

Integration of AI and Deep Learning based techniques for IoT, Smart Cities and Buildings.

Summary

In summary, building future IoT will not only benefit users, but also let us revisit the fundamental questions in networking, computing, data science and security. To this end, I will build a group with members of diverse expertise (networking, distributed systems, data science,

programming languages, security, Artificial Intelligence etc.). I will actively recruit and mentor both graduate and undergraduate students, particularly from the minority and diversity groups. I will aggressively pursue funding from several funding agencies and industries to propel my high-risk, high-gain" research projects. I will assess my research results along multiple dimensions, including top-conference publications, technology transfer to industries via licensing and patents, commercialization via start-up's, open-source software release, and standardization with industry partners.

Top Research Achievements

- **Published 150+ SCI/SCIE/SSCI Papers in Reputed Peer Reviewed International Journals- (Springer, Elsevier, Sage, Taylor and Francis, Emerald, PLOS One) with High Impact Factor. (Q1/Q2/Q3) Journals**
- **Published 27+ Scopus Papers in International Journals with High Cite Score and Impact Factor**
- **Published 100+ Papers in IEEE Conferences, Springer Conferences, ACM Conferences. (All Web of Science, Scopus Indexed)**
- **Published 45 Edited Book Chapters with Top Quality Books with Springer, CRC Press, IGI-Global, Elsevier, River, AAP Publications, Wiley and many more.**
- **Granted 18 Australian Patents, 25 Indian Patents, 4 German Patents, 2 Japan Patents, 1 US Patent, 3 Indian Copyright and 2 Canadian Copyrights**
- **Google Scholar Citations: 9800+ with H-Index: 52 and I-index: 185; Scopus Citations: 4800 with H-Index: 37.**
- **More than 8,50,000+ Reads on Research Gate with H-Index: 50**
- **Completed 3 Grant Projects –2 Industry and 1 Grassroot project from Duy Tan University and Undertaking 1 Grassroot and 1 ASEAN Project**
- **Awarded 40 Awards for Research from Reputed Organizations.**
- **Cited among Top 2% Scientists in PLOS One and Stanford University Rankings (2019, 2020, 2021)**
- **Cited in Research.com (No:2 Rank in Viet Nam) D-Index: 31**
- **Ranked 50 overall (Web of Science) in Publons as Reviewer and Ranked No:1 in Computer Science Reviews-2021, 2022**
- **Ranked in AD Index (No:1 Duy Tan University and No:1 Viet Nam) Overall in Computer Science.**

References

1. Nayyar, A., & Singh, R. (2019). IEEMARP-a novel energy efficient multipath routing protocol based on ant Colony optimization (ACO) for dynamic sensor networks. Multimedia Tools and Applications, 1-32.
2. Menaria, V. K., Jain, S. C., Raju, N., Kumari, R., Nayyar, A., & Hosain, E. (2020). NLFFT: A novel fault tolerance model using artificial intelligence to improve performance in wireless sensor networks. IEEE Access, 8, 149231-149254.
3. Singh, S., Kumar, S., Nayyar, A., Al-Turjman, F., & Mostarda, L. (2020). Proficient QoS-based target coverage problem in wireless sensor networks. IEEE Access, 8, 74315-74325.

4. John, S., Menon, V. G., & Nayyar, A. (2020). Simulation-based performance analysis of location-based opportunistic routing protocols in underwater sensor networks having communication voids. In Data Management, Analytics and Innovation (pp. 697-711). Springer, Singapore.
5. Sennan, S., Ramasubbareddy, S., Luhach, A. K., Nayyar, A., & Qureshi, B. (2020). CT-RPL: Cluster Tree Based Routing Protocol to Maximize the Lifetime of Internet of Things. Sensors, 20(20), 5858.
6. Azees, M., Vijayakumar, P., Karuppiah, M., & Nayyar, A. (2021). An efficient anonymous authentication and confidentiality preservation schemes for secure communications in wireless body area networks. Wireless Networks, 1-12.
7. Shekhawat, S. S., Sharma, H., Kumar, S., Nayyar, A., & Qureshi, B. (2021). bSSA: Binary Salp Swarm Algorithm With Hybrid Data Transformation for Feature Selection. IEEE Access, 9, 14867-14882.
8. Ullah, F., Al-Turjman, F., & Nayyar, A. (2020). IoT-based green city architecture using secured and sustainable android services. Environmental Technology & Innovation, 20, 101091.
9. Pande, S. K., Panda, S. K., Das, S., Alazab, M., Sahoo, K. S., Luhach, A. K., & Nayyar, A. (2020). A smart cloud service management algorithm for vehicular clouds. IEEE Transactions on Intelligent Transportation Systems.
10. Krishnamurthi, R., Kumar, A., Gopinathan, D., Nayyar, A., & Qureshi, B. (2020). An Overview of IoT Sensor Data Processing, Fusion, and Analysis Techniques. Sensors, 20(21), 6076.
11. Loukil, S., Fourati, L. C., Nayyar, A., & So-In, C. (2022). Investigation on Security Risk of LoRaWAN: Compatibility Scenarios. *IEEE Access*.
12. Singh, M., Sahoo, K. S., & Nayyar, A. (2022). Sustainable iot solution for freshwater aquaculture management. *IEEE Sensors Journal*, *22*(16), 16563-16572.
13. Chaurasiya, S. K., Biswas, A., Nayyar, A., Zaman Jhanjhi, N., & Banerjee, R. (2023). DEICA: A differential evolution-based improved clustering algorithm for IoT-based heterogeneous wireless sensor networks. *International Journal of Communication Systems*, *36*(5), e5420.
14. Van Truong, T., & Nayyar, A. (2023). System performance and optimization in NOMA mobile edge computing surveillance network using GA and PSO. *Computer Networks*, 109575.
15. Mittal, N., Singh, S., Nayyar, A., & Singh, U. (2023). Hybrid sooty tern naked mole-rat algorithm and Fuzzy Type-2 logic-based trust and energy-aware stable clustering protocol. *Expert Systems with Applications*, *219*, 119706.
16. Van Truong, T., Nayyar, A., Bilal, M., & Kwak, K. S. (2023). System design and Optimization of Mobile Edge Computing in the NOMA Wireless Tactile Internet of Things Network. *Alexandria Engineering Journal*, *73*, 737-749.