COMPUTATIONAL INTELLIGENCE BASED ROUTING SOLUTIONS FOR MOBILE AD HOC NETWORKS

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ABSTRACT

Mobile Ad Hoc Networks (MANETs) refers to a wireless network where nodes dynamically establish and maintain connections with each other, directly without the need for a centralized infrastructure. MANETs are characterized by their decentralized nature, presenting challenges for routing protocols concerning rapid data transmission, minimized delay and Quality of Service (QoS) provisioning. Traditional routing protocols may struggle to perform optimally in MANETs due to frequent changes in network topology and resource constraints. The development of intelligent routing protocols tailored to the specific characteristics of MANETs is vital for dynamic and resource-constrained environments. Computational intelligence (CI) techniques have gained attention for designing intelligent routing protocols for MANETs. This paper provides a comprehensive overview of majorly used CI methodologies in MANETs. The paper reviews existing research on intelligent routing protocols based on CI techniques in MANETs and identifies future research directions in this field to address the unique challenges of MANETs and improve network performance and reliability.

Keywords: Mobile Ad hoc Networks (MANETs), Computational Intelligence (CI), Swarm Intelligence, Intelligent Routing

1. INTRODUCTION

Mobile Ad Hoc Networks (MANETs) denote wireless networks where mobile devices are interconnected via radio links, devoid of predefined infrastructure. It is a self-organizing network where each node can freely move in any direction and form various network topologies due to their dynamic location capabilities [1]. Despite their wide utility, MANETs encounter several challenges, particularly in establishing reliable routes between nodes with minimal overhead due to

the constantly changing topology [2]. Recent technological advancements like 4G, 5G, IoT have revolutionized sensing and computational processing capabilities, poses a significant challenge in providing seamless network connectivity [3]. However, the transmission of real-time multimedia content over wireless links necessitates enhanced capacity, reduced delays and minimal packet loss. Routing protocols are typically necessary to maintain efficient and well-organized transmission from source to destination [4]. Traditional routing algorithms often lack the adaptability needed to accommodate evolving routing requirements in terms of overhead, latency and security attacks, especially as network user volume increases day by day. To address these challenges, researchers have explored the integration of computational intelligence (CI) techniques into MANET routing protocols to enhance their performance and adaptability. With the exponential growth of diverse user and the proliferation of computing technologies, the demand for intelligent routing systems capable of providing seamless connectivity for smart real time MANET applications has become paramount.

The paper is structured as section 2 presents the traditional routing protocols in MANET and their limitations. Section 3 explores the CI techniques, while section 4 discusses the existing CI based routing in MANET, section 5 elaborates future directions in designing intelligent routing based on CI techniques and section 6 presents the conclusion of the study.

2. ROUTING IN MANET

Routing plays a significant role in designing MANET. The role of routing protocol in wireless network is to enable the source to find routes to the destination with the help of other intermediate nodes. MANET routing protocols can be classified into majorly three types:

Proactive Routing Protocols: Nodes in proactive routing protocols, maintains the routing table by storing route information of each and every node in the network [5]. These protocols are suitable for networks with fewer nodes because they require updating node entries in each node's routing table, which adds extra routing overhead [6]. Popular proactive protocols are: Optimized Link State Routing and Destination-Sequenced Distance Vector Routing. *Reactive Routing Protocols:* These routing protocols are also known as On-Demand Routing Protocols i.e. the route will be available only on demand. When a network node has data to send, it first looks in its routing table to see if it has a path to destination. If no viable route is identified, it initiates a route exploration phase to find a path towards destination. The primary benefit of these routing protocols is that they have less routing overhead whereas path discovery latency is the main drawback of reactive routing protocols. Reactive routing protocols include examples

such as Dynamic Source Routing and Ad hoc On-Demand Distance Vector. *Hybrid Routing Protocol:* Hybrid routing protocols integrate reactive and proactive routing protocol capabilities, usually seeking to leverage proactive system's reduced control traffic overhead and reactive system's path discovery delays by retaining a routing table [5]. Majorly used hybrid routing is Zone Routing Protocol (ZRP)

Traditional routing protocols on the other hand possess some limitations in terms of limited mobility support, scalability, inefficient resource utilization and lack of QoS support. Addressing these challenges requires a multidisciplinary approach that combines expertise in networking, optimization and machine learning to develop intelligent, adaptive, scalable and efficient routing protocols that can better accommodate the dynamic nature of modern networks.

3. COMPUTATIONAL INTELLIGENCE TECHNIQUES

Computational intelligence (CI) encompasses a diverse set of methodologies inspired by principles derived from natural and artificial systems. These intelligent techniques have emerged as powerful tools for solving complex real-world problems in data analysis, pattern recognition and decision making. Key pillars of CI include machine learning, evolutionary computation, neural networks and swarm intelligence.

Artificial Neural Networks (ANNs): ANNs are learning models constructed based on the organizational principles of neurons in the human brain. They consist of interconnected nodes, or artificial neurons, organized in layers including input, hidden, and output layers. ANNs operate by adjusting the connections between neurons, a process inspired by the way biological neurons communicate through synaptic connections. *Swarm Intelligence:* Swarm intelligence is inspired by the collective behaviour of social insects and other biological systems [7]. It encompasses algorithms and techniques that involve decentralized, self-organized systems composed of simple agents interacting locally to achieve complex global behaviour. *Evolutionary Computation:* Evolutionary computation is a broad category of algorithms rooted in the principles of evolution and inheritance. In addition to genetic algorithms, it includes other techniques such as evolutionary strategies, genetic programming, and differential evolution. *Machine Learning:* Machine learning is a branch of artificial intelligence where computer systems are designed to learn from data and improve their performance. It involves the use of statistical techniques to enable machines to improve their performance on a specific task over time through experience and data.

4. RELATED WORK

A genetic algorithm-based routing system has been proposed to improve QoS parameters in multicast environments. However, it's important to note that this study evaluates performance using only three metrics [7]. The fuzzy logic approach employs a demand routing method to select stable routes, leveraging independent nodes' cooperation to reduce routing costs. A fuzzy controller selects the route, considering factors such as battery life, node speed, and available bandwidth [8]. An energy-conscious hybrid algorithm has been introduced, integrating cellular automata, african buffalo optimization and genetic algorithm methodologies. Cellular automata are employed to identify feasible routes based on delay criteria, while two optimization techniques are utilized to select the optimal route [9]. The Energy-Aware Ant-Based Routing (EAAR) protocol is proposed to address energy concerns in routing. EAAR evaluates pathway quality using hop count and minimal battery cost metrics of nodes [10]. A hybrid multicast routing algorithm has been introduced by combining Particle Swarm Optimization (PSO) with genetic operators, aiming to leverage the strengths of both PSO and GA. A QoS routing system for MANET, based on ant algorithms, has been developed to facilitate multimedia communications from a specified source to a designated destination. Through diverse probabilities of path selection, the system uncovers multiple routes to reduce delay [11]. A novel multi-agent ant-based routing approach is proposed for MANETs, utilizing an ACO framework. This hybrid algorithm integrates concepts from both multi-agent systems and ant algorithms [12]. Introduced a proactive ant-based routing strategy for MANET inspired by ant colony optimization principles. The algorithm intentionally establishes multiple routes between the source and destination [13].

5. FUTURE RESEARCH DIRECTIONS IN DESIGNING INTELLIGENT ROUTING USING COMPUTATIONAL INTELLIGENCE

The integration of CI techniques with other optimization and learning algorithms holds promise for enhancing the performance and resilience of MANETs. Future research directions for the development of intelligent routing protocols using computational intelligence techniques are as follows:

Context-aware routing: To make more informed routing decisions, future routing protocols should consider contextual information, such as node capabilities, network conditions, application requirements, and environmental factors [14].

Distributed intelligence: Moving towards distributed intelligence models where nodes collaborate and share information to make

collective routing decisions can improve scalability, fault tolerance, and adaptability in smart complex MANETs [5].

Machine learning integration: Incorporating advanced machine learning techniques into routing protocols can enhance their adaptability and performance in dynamic MANETs.

Multi-objective optimization: Considering multiple optimization objectives, such as throughput, delay, reliability and energy consumption, in routing protocol design can better accommodate the diverse requirements of smart complex MANETs.

Edge computing integration: The integration of edge computing with intelligent routing protocols can improve latency-sensitive applications by processing data closer to the source.

6. CONCLUSION

Computational intelligence techniques offer innovative solutions to address the challenges faced by MANETs, including routing, resource management, security and QoS provisioning. By leveraging artificial neural networks, genetic algorithms, fuzzy logic and swarm intelligence, researchers can design intelligent, adaptive and robust routing protocols capable of operating effectively in dynamic and resource-constrained environments. The integration of CI techniques with MANETs opens up new avenues for research and development of intelligent routing solutions, facilitating better throughput, reduced delay and swift communication. This integration paving the way for enhanced connectivity, scalability and reliability in dynamic smart MANET environments.

7. REFERENCES

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