AntMeshNet:
An Ant Colony Optimization Based Routing Approach to Wireless Mesh Networks

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ABSTRACT

Wireless Mesh Networks (WMNs) are emerging as evolutionary self organizing networks to provide connectivity to end users. Efficient Routing in WMNs is a highly challenging problem due to existence of stochastically changing network environments. Routing strategies must be dynamically adaptive and evolve in a decentralized, self organizing and fault tolerant way to meet the needs of this changing environment inherent in WMNs. Conventional routing paradigms establishing exact shortest path between a source-terminal node pair perform poorly under the constraints imposed by dynamic network conditions. In this paper, the authors propose an optimal routing approach inspired by the foraging behavior of ants to maximize the network performance while optimizing the network resource utilization. The proposed AntMeshNet algorithm is based upon Ant Colony Optimization (ACO) algorithm; exploiting the foraging behavior of simple biological ants. The paper proposes an Integrated Link Cost (ILC) measure used as link distance between two adjacent nodes. ILC takes into account throughput, delay, jitter of the link and residual energy of the node. Since the relationship between input and output parameters is highly non-linear, fuzzy logic was used to evaluate ILC based upon four inputs. This fuzzy system consists of 81 rules. Routing tables are continuously updated after a predefined interval or after a change in network architecture is detected. This takes care of dynamic environment of WMNs. A large number of trials were conducted for each model. The results have been compared with Adhoc On-demand Distance Vector (AODV) algorithm. The results are found to be far superior to those obtained by AODV algorithm for the same WMN.

Keywords: AntMeshNet, Ant Colony Optimization (ACO), Fuzzy Logic, Routing, Swarm Intelligence, Wireless Mesh Network (WMN)

INTRODUCTION

Wireless Mesh Networks (WMNs) are characterized by multi radio, multi hop, self organizing and self configuring wireless technology to offer last mile access to end users. Easy deployment, lower cost, scalability, self configuring and self organizing capability are the features of the WMNs which make it a suitable technique for various applications e.g. broadband home, community, neighborhood and enterprise networking etc. The data packets hop from one

node to another until it reaches the terminal node based upon multi hop transmissions. A detailed overview of WMNs discussing the challenges and open research issues of each layer, security, mobility management, cross layer design etc. is presented by (Akyildiz, Wang & Wang, 2005). Nodes in WMNs are categorized in two classes: (1) Mesh Router (MR); having limited mobility or are fixed and (2) Mesh Clients. Conventional nodes (e.g., desktops, laptops, PDAs, phones, etc.) equipped with wireless network interface cards (NICs) can connect directly to wireless mesh routers. The architecture of WMNs can be classified as:

- **Infrastructure/Backbone WMN:** In infrastructure type WMNs mesh routers form an infrastructure mesh for client nodes.
- **Client WMNs:** Client WMNs provide peer-to-peer networks and client nodes perform routing and self-configuration functions too.
- **Hybrid WMNs:** The most applicable WMN architecture-Hybrid Mesh is the combination of infrastructure and client meshing. Client nodes can access the network through mesh routers or directly meshing with other client nodes either. Popular commercial applications, architectures and key research areas are discussed by Bruno, Conti and Gregori (2005).

WMNs share many common features with Mobile Ad hoc Networks (MANETs). Thus, the routing protocols developed for MANETs can usually be applied to WMNs e.g. Ad hoc On-demand Distance Vector (AODV). However, to design an effective WMN, considerable research efforts are still needed. The existing MAC and routing protocols applied to WMNs do not have enough scalability; the throughput decreases critically as the number of nodes or hops in a WMN increases. Similar problems exist in other networking protocols. Consequently, all existing protocols from the application layer to transport, network MAC, and physical layers need to be re-designed.

Routing and dynamic network conditions critically affect the performance of WMNs. It is required that routing policies must work in a decentralized, self-organizing and self config-uring way while optimizing network resource utilization and fulfilling QoS requirements (Parissidis, Karaliopoulos, Baumann, Spyro-poulos & Plattner, 2009; Zhang, Luo & Hu, 2006). The objective of the routing policies is to maximize probability of data delivery, minimize delay, maximize throughput, minimize energy consumption, dynamically balancing the traf-fic load etc. It is shown by Decouto, Aguayo, Chambers and Morris (2002) that conventional shortest path routing metric is not an affordable criterion to ascertain good paths. The perfor-mance metrics and routing issues in WMNs are discussed in detail by Waharte, Boutaba, Iraqi and Ishibashi (2006). Commonly used performance metrics are hop count, Expected Transmission Count (ETX), Expected Trans-mission Time (ETT), energy consumption and availability of reliable paths. Routing protocols can further be categorized based upon routing philosophy, network organization, location awareness and mobility management.

Due to complexities and constraints in exact reasoning based routing in dynamic wireless networks, there is a parallel increasing inter-est for nature inspired soft computing based techniques. A Genetic Algorithm (GA) based dynamic shortest path routing approach was proposed by Yang, Cheng, and Wang (2010). Soft computing techniques i.e. GA and Neural Networks approach was applied to optimize Quality of Service (QoS) parameters for chan-nel allocation in cellular networks (Narendran & Mala, 2012). A hybrid combination of Multi Objective Particle Swarm Optimization (MOPSO) and GA is proposed by Benyamina, Hafid, Hallam, Gendreau and Maureira (2012) to optimize the performance of WMNs. A detailed description of various nature inspired meta-heuristic algorithms including ACO, bee algorithm, bat algorithm, cuckoo search, firefly algorithm, particle swarm optimization (PSO) etc. is presented by Yang, (2008). An adap-

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