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ANFIS and agent based bandwidth and delay aware anycast routing in mobile ad hoc networks

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ABSTRACT

Anycast is a point to point flow of packets for obtaining services or sending data to one of a multitude of destinations that share one address. To meet needs of real time and multimedia applications, anycast routing in Mobile Ad hoc Networks (MANETs) must provide faster service with better Quality of Service (QoS). This paper proposes an Adaptive Neuro-Fuzzy Inference System (ANFIS) based multiple QoS constrained anycast routing in MANETs by using a set of static and mobile agents. Three types of agents are used in the scheme: static anycast manager agent, static optimization agent, and mobile anycast route creation agent. The scheme operates in the following steps. (1) Optimization agent at the client optimizes membership functions for bandwidth, link delay and packet loss rate to develop Fuzzy Inference System (FIS) by using ANFIS. (2) Anycast route creation agents are employed by the client to explore multiple paths from source (client) to all anycast members (servers) through intermediate nodes. These agents gather intermediate node's information such as available bandwidth, link delay, residual battery power, and stability of anycast servers. The information is passed on to the client. (3) Anycast manager agent at the client performs finding QoS factor by using optimized FIS for every path, and selects QoS anycast path based on QoS and server stability factor, and (4) Anycast route creation agent is also employed for maintaining the QoS path in the event of node/link failures. The simulation results demonstrate reduction in end-to-end delay and control overhead, improvement in packet delivery ratio and path success ratio, as compared to shortcut tree based anycast routing (SATR) in MANETs.

1. Introduction

Mobile ad hoc network (MANET) consists of hand held mobile nodes like personal digital assistants (PDA), laptop computers, cell phones, etc. They communicate through single-hop or multihop paths in a peer-to-peer fashion by using wireless media. The nodes of the MANET operate as end hosts as well as routers (Azzedine et al., 2011; Sunil and Ashwani, 2010). Due to mobility of the nodes, routing path is affected by addition and deletion of nodes. Hence, the topology of the network may change rapidly and unexpectedly. Many different protocols have been proposed to solve the routing problems in ad hoc networks which are roughly classified as unicast, multicast, broadcast and anycast. In unicast (one-to-one), packet is delivered to a particular destination (Hue et al., 2010). In multicast (one-to-many), packet is transmitted to all members of particular group (Rajashekhar and Sunilkumar, 2012). In broadcast (one-to-all), packet is sent to all network hosts. Anycast (one-to-one-of-many) allows source (client) to choose single destination (server) from a set of destination nodes (Dow et al., 2006).

The set of destinations is identified by unique anycast address and provide the same services. Searching for services on networks, often depends on the broadcast or multicast mechanism to acquire the information, which usually results in large overhead. It will be a serious problem in ad-hoc wireless networks, where the bandwidth is limited and each node moves arbitrarily. Anycasting scheme in ad hoc wireless networks can simplify access management in distributed service, improve the robustness and performance of an ad hoc network when mobility and link disconnections are frequent, and reduces the communication overhead. The source node does not need to know about picking a single server and is determined by routing scheme (Shi et al., 2010; Wu-Hsiao et al., 2007).

The server in anycast routing may be chosen by minimum hops, delay or other metrics. Anycasting along the minimum hops path may result in inefficient use of network resources, because it forwards packets along already congested shortest path, and also may not satisfy the Quality of Service (QoS) requirements for multimedia and real time application services. Hence, main objective of

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end-to-end QoS based anycast routing is to find the path that satisfy QoS constraint from client to any one server. To support multimedia applications such as video conference, disaster relief, etc., in MANETs multi-constraint QoS need to be satisfied (such as a bandwidth, delay, delay jitter, packet loss rate and cost) (Jian et al., 2010; Taoshen and Zhihui, 2009). Very few works are done in QoS anycast routing in MANETs as per our literature survey.

The multi-constrained QoS routing is NP-hard and heuristic algorithms are proposed to find solution for the problem . But these algorithms are too complex and cannot obtain best global solution. QoS may be more accurately determined by using fuzzy logic instead of static values. Fuzzy Inference System (FIS) accepts more number of uncertain and imprecise data as inputs and thereby achieves flexibility, robustness, and low cost solution (Mie, 2010; El-Hajj et al., 2009). But, FIS uses human-determined membership functions (MFs) that are fixed. Therefore, they are rarely optimal in terms of reproducing the desired outputs. Tuning membership functions of parameters is a time consuming task. Neural networks overcome most of the complex problems to adapt dynamically to the system operating conditions, and to make correct decisions, if the signals are uncertain. But the integration of neural network into the fuzzy logic system makes it possible to learn from prior obtained data sets (Abraham, 2005).

This paper proposes an approach which integrates both neural and fuzzy techniques to select a server from a number of group members belonging to anycast group by considering QoS constraint route and server with higher stability in MANETs. This section presents some of the related works, software agent concept and our contributions.

1.1. Related works

Some of the related works on anycast routing in MANETs, IPv6, and wireless sensor networks are as follows. Anycast routing is an important mechanism for service discovery and load balancing (Ge and Li, 2011; Ulas and Leandros, 2004; Fernanda and Peter, 2010) in wired and wireless networks.

Density based anycast routing (DBA) considers number of available anycast group members information for routing decision is presented in Vincent et al. (2008). Anycast packets are routed along the steepest gradient at each node. The steepest gradient at each node is determined by evaluating the potential values of their direct neighbours. Packets are forwarded to the neighbour with highest potential value until there are no neighbors left with a higher potential value than its own to guarantees that the steepest gradient is ascending.

k-anycast (KA) discussed in Bing and Jie (2010), deliver a packet to any threshold k members of a set of servers instead of one among the nearest group servers. k-anycast members are selected from a set of servers by three different schemes. Three schemes explain about how to select k servers. The first scheme selects the k-servers out of group servers, by flooding the request to the network depending on the number of responses it receives. The second and third scheme forms multiple components such that each component has atleast k-members and less than k-members, respectively.

In Pei-Jung et al. (2008) clustering and virtual backbone techniques (VBAF) are used to establish anycast tree and forward gate is used to decrease the overhead of responses received from duplicate service packets. A virtual backbone structure is used to set up stable routing paths and clustering scheme is used to reduce the length of the routing paths. Anycast tree is established according to the leaf node on the virtual backbone. When a client node sends out a service request message to the anycast tree, the client is responded by its nearest or best server.

Density of nodes through count of routes (RCBA) is discussed in Martin et al. (2009) to route the packets to anycast group member. Minimum count of hops when forwarding packet and count of routes are the two metrics used to find the best path to the server. The work given in Shyr-Kuen and Pi-Chung (2012) constructs an anycast tree from a cluster-based virtual backbone in a MANET. It finds a path from client to nearest server using anycast tree. For each branch node in the anycast-tree, a routing table is established. The nodes in the routing table are then used to generate a shorter path.

The clustering and virtual backbone techniques to establish anycast tree (SDBA) is discussed in Shyr-Kuen et al. (2008). A virtual backbone structure is used to set up stable routing paths and the clustering scheme is used to reduce the length of routing paths. The Ad Hoc On-demand Distance Vector (AAODV) routing protocol extended to support anycast routing is presented in Jidong et al. (2004).

The work given in Martin and Takuro describes the probability of connected route to anycast member as a function of dynamicity and density of the network. Anycast routing scheme chooses the shortest path routing as well as considers node degree density (NDAR) of hosts in the network through count of routes to the anycast group member. Weight value mechanism is adopted to select an optimal anycast member (OAM) in Wang (2010). Through entropy, the average available bandwidth and the average moving velocity are used to calculate anycast members weight value which can indicate the performance of the routing from the IPv6 ingress gateway to the anycast member.

The combination of ant based routing and clustering models are discussed in Jianping et al. (2009) to solve multi-constrained anycast routing. Anycast QoS routing algorithm based on Genetic Algorithm is studied in Shi and Shen (2010). It adopts the idea of dissimilarity to make population diversity, and the theory of simulated annealing to adjust the fitness function so as to inhibit the premature convergence.

A multi-path multi-gateway wireless mesh network anycast routing protocol based on ant colony optimization is presented in Song et al. (2010). For gateway selection, distributed computing and heuristic searching of ant colony algorithm are used. Multi-sink load balanced reliable forwarding for video delivery in a multi-sinked sensor network for target tracking is proposed in Sinan et al. (2012). To provide load balancing among the sinks, it proposes a sink selection mechanism based on fuzzy logic for the frame forwarding which evaluates the traffic density in the direction of each sink by combining two dynamic criteria which are the number of contenders and the buffer occupancy levels in the neighborhood with the static distance criterion.

Load distribution strategy by adopting distributed resource discovery and dynamic request-redirection mechanisms by using anycast, considering traffic load and network proximity is discussed in Mukaddim and Rajakumar (2009) for content delivery network servers. A distributed algorithm for sink selection in wireless sensor network is discussed in Trivino et al. (2011). Sensor nodes determine goodness of being the next hop for every online transmission. The estimation is supported by fuzzy logic based system which takes into the account the connectivity of the source, the connectivity of the candidate and the candidate's residual energy.

Tables 1 and 2 present the summary and comparison of some of the above mentioned anycast routing in MANETs.

As per literature survey, limitation of the related works are as follows: (1) lack of combination of anycast path and server stability mechanisms in MANETs, (2) multi-constrained QoS anycast routing in MANETs is not supported, (3) lack of robust and reliable route discovery and maintenance, and (4) FIS based routing solutions consider fixed membership functions and does