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Egwra: Qos Routing Algorithm In Wireless Mesh Networks Based On Evolutionary Game Theory

Yan Weiguang
Department of Information Technology
Hunan Women's University
Changsha, China
E-mail: 173873656@qq.com

Pan Xianmin*
Department of Information Technology
Hunan Women's University
Changsha, China
E-mail: 15974239623@139.com
*The corresponding author

***Abstract*—This paper applies the theory of Evolutionary Game to QoS routing algorithm for wireless mesh networks which can not only improve the performance of traditional QoS routing protocols but also be able to reduce the cost of the routing algorithm.**

Keywords-Wireles Mesh Networks; Routing protocol; Qos Routing; Evolutionar y Game Theory; Routing algorithm

I. INTRODUCTION

As a new type of wireless network, wireless mesh network connect mesh nodes through wireless links to construct a dynamic topology, self-organizing and multi-hop wireless interconnected network. Compared with the traditional single-hop wireless networks, it can extend coverage, enhance robustness, reduce deployment cost and increase capacity. Compared to the traditional switched networks, wireless Mesh network cabling between nodes removed needs, but still has a distributed network provides redundancy and re-routing. In the wireless Mesh network, if you want to add a new device, simply plug in the power on it, it can automatically configure itself, and determine the best multi-hop transmission path. Add or mobile device, the network topology changes can automatically find and automatically adjust the traffic routing in order to obtain the most efficient transmission path. Wireless mesh network's business is usually gathered in the Mesh Router or Gateway, easily lead to local network congestion, making it difficult to maintain network globally optimal routing. Thus routing protocols must be able to adapt to this situation so as to provide better QoS for the users. So, the research of wireless mesh network routing protocol is of great significance. For example, Zhou, Hao[1] focuses on QoS routing with bandwidth constraint in multi-radio multi-channel WMN, and proposes a new multimetric and a QoS routing protocol MMQR. The routing metric has two advantages. First, it replaces the transmission rate of ETT with available bandwidth so that the nodes with light load are more likely to be selected. Second, it takes the channel diversity into account and assigns a weight to each link according to the channels of links within the range of three hops. Sun, Xuemei[2, 3] proposes a QoS routing algorithm based on culture-particle swarm optimization algorithms. The algorithm uses the dual-evolution mechanism of culture algorithms and achieves further improvement on global optimum location mutation particle swarm optimization algorithms (MPSO) by introducing the concept of inertia weight. Traditional QoS routing algorithms like the achievements listed above only considered single objective performance parameters, such as delay bound or bandwidth limitations, or static multi-objective constrained situation. WMN can not meet the needs of General Requirements for some business like dynamic multi-objective performance, such as delay, bandwidth and Frequency congestion.

This paper applies the theory of Evolutionary Game to QoS routing algorithm for wireless mesh networks which can not only improve the performance of traditional QoS routing protocols but also be able to reduce the cost of the routing algorithm.

II. DESCRIPTION OF EGWRA

A. Network Model

In this paper, we consider the WMN with three-tier architecture. The WMN consists of wireless routers and mobile stations. The wireless router serves as an access point in IEEE 802.11 for a number of mobile stations within its transmission range. Moreover, the wireless router also acts as the relay node to transmit packets between it and its neighboring wireless routers. All the wireless routers are located at fixed sites, and they are interconnected via wireless links to form a mesh backbone. The communication of wireless links usually follows the IEEE 802.11 standard [3]. Some wireless routers are designated as gateways to connect the mesh backbone with Internet. The gateways also hold the physical wires to connect with Internet. For the mobile station, it is the end device (e.g. PDA, laptop, etc.) in the WMN, which can randomly move within the WMN. Its packet transmission is through one or more wireless routers in the mesh backbone, and then via a gateway to the Internet. For the packet from Internet to a mobile station, this packet transmission is via the above reversed route.

B. Channels of IEEE 802.11

The IEEE 802.11b/g based WMN model is extensively used in most of WMN literature. This claim is also made in [5]. The IEEE 802.11b/g operates in the 2.4 GHz spectral band, which is split into 11 channels for use in the US. Only three channels (1, 6, and 11) are non-overlapping. The remaining channels are partially overlapping. For each non-overlapping channel, its frequency band is not overlapped with the other two. In contrast, the frequency band of each partially overlapping channel is overlapped with some others. In this paper, we exploit all available (non-overlapping and partially overlapping channels) in IEEE 802.11b/g to perform channel assignment.

C. Related Work

In WMNs, most of existing channel assignment algorithms only use non-overlapping channels to perform channel assignment. In [4-5], the experiment results demonstrated that the throughput of the WMN can be enhanced when all available (partially overlapping and non-overlapping) channels are appropriately used in channel assignment. In [4-5], the authors have also quantified the interference effects of IEEE 802.11b/g in terms of the channel separation and the corresponding interference factor. The channel separation is the difference between two used channels for two nodes. The interference factor is defined as the ratio (I/R) of the interference range (I) to the transmission range (R).

In addition to measuring the channel interference, the research work of [5] also utilizes all available channels of 802,11b/g to propose a channel assignment algorithm called the multichannel multicast (MCM) algorithm. In this algorithm, it gives a channel selection function IR ( ). If channel c is to be assigned for node p, all the neighbors (all the nodes within the transmission range) of node p are first found. Then, the channel separation between node p and each neighbor is a key parameter to respectively calculate the corresponding function IR ( ). Next, all the values of the function IR ( ) are added. After calculating the total value of IR ( ) for each available channel, the channel with the minimum total value of IR ( ) will be assigned for node p. From the above description, we can know that the main idea of the MCM algorithm is to reduce the interference effect between a node and its neighboring nodes. The channel assignment sequence follows the level order. The node on the higher level is earlier than the node on the lower level to be assigned a channel with less interference.

In [5], the channel assignment algorithm is called the minimum interference multi-radio multicast (M4) algorithm. In the M4 algorithm, two-hop interference range is considered in the channel selection to avoid the hidden terminal problem [7]. In the MCM algorithm [4], the interference range is only considered within one hop. For the channel selection metric of the M4 algorithm, it aims to balance the channel separations for the nodes within two hops. This can avoid some node pairs incurring sever interference due to using small channel separations. However, the interference cost is not minimized in the given channel selection metric. In addition, the channel assignment sequence is not discussed in the M4 algorithm.

To compare the above two channel assignment algorithms with the algorithms just using non-overlapping channels, the MCM and M4 algorithms have great improvement in the throughput of the WMN.

D. Summary of Evolutionary Game Theory

Non-cooperative game theory is the decision-making in a distributed environment, the analysis of individual utility maximization Player for the optimal policy choice. Evolutionary game non-cooperative game, a branch of a game strategy for further analysis of game populations in a long-term stability. Evolution of the Nash equilibrium (all Player of the optimal strategy) with groups of stability, that is executed when the other Player balanced strategy, any Player can not be balanced by a unilateral departure from the strategy for more effective; Meanwhile, the implementation of a balanced strategy can reveal the individual proportion of total population.

As the novel achievement in the research field of non-cooperative game theory[8-10], the research on evolutionary game theory attracts great attentions in not only academy but also industry field. Integration of evolutionary game theory, economics and evolutionary biology of rational thought, no longer human model into the game super-rational side, that the human is usually achieved through trial and error method of game balance, and biological evolution is common, the choice The balance is the balancing process to achieve a balanced function, and thus the historical, institutional factors and the balancing process are some of the details of the game will affect the choice of multiple equilibria[11].

Set the evolution game located in an N-node MANET, any node with M, that except the node i other than the collection. denotes the data packets generated by source node i which is called i's group. Data between source and destination nodes transmit a complete data service is called a session; the node mobility will lead to changes in network topology, the completion of a session requires multiple routing paths to create different groups.

The other parameter M trust set up in all the main components of the set of strategies for the real number field on an interval X, strategy by the probability density distribution f (x) to characterize and design the fitness function is a continuous function in domain , which is the environmental parameters, as Environment, the probability density. Note the probability density function of the composition of all the set. The evolution of the network configuration software, game, evolutionary selection is linked with fitness. When given the definition of the conditions of environmental parameters selection operator and the average selection operator , the environment, the average fitness function.

According to the statements listed above. The evolution game for WNN can be defined[12]. So that G = (I, P, U). Where: I = {Ni, N-i} for the Player collection, Ni said node i, and Ni indicates that the network nodes in addition to all the nodes outside i; P is the strategy set P = {pi, p-i}, 1 packet transmission , refused to transmit a message to 0. U is the utility function, the utility function with Ui (si, s-i) to represent. It proceeds B (si, s-i)> 0 from the i (the correct transmission) and costs C (si, s-i) <0 (energy consumption) of two parts. Node i can be the watchdog or other monitoring and feedback mechanisms, that message transmission to the next node if there are Byzantine errors. Whether the benefits or costs i have a strategy with all relevant participants, this is a strategy game or action nodes are the embodiment of interaction, about the Byzantine fault-tolerant WMN classic prisoner's dilemma problems and to link the two adjacent Between nodes Ni and Nj prisoner's dilemma shown in Table 1.

TABLE I. THE GAME MATRIX BETWEEN LABOR NODES IN WNN

	successful	**failure**
The packet reachs node N_j	(B, C)	$(0, C)$
The packet not reachs node N_j	$(B, 0)$	$(0, 0)$

E. *Working Steps of EGWRA*

According to the definition of evolution game , we can design the working steps of EGWRA as follows.

/* Step 1：Finding Available EGWRA-Neighbor */
TCBTC-N(u) □ Φ；TD(u) □ Φ；p(u) □ p0；α = π/3
while (p(u) < P and gap-α(TD(u)))
begin
bcast (u, p(u), (Hello, p(u)))
u receives Ack (ack, p(u)) message from v
if v’s game score is more than the threshold
u calculates the direction of discovered neighbor v dir(u,v), the transmitting power and the direction determines the neighbor v(p(u), dir(u, v))
TCBTC-N(u) = TCBTC-N(u) ∪ { v | discovered neighbor v }
TCBTC-D(u) = TCBTC-D(u) ∪{dir(u, v) | discovered neighbor v }
Pow(u) = Pow(u) ∪ { p(u, v) | discovered neighbor v }
p(u) □ Increase(p(u))
end
/* Step 2：Finding Available DT-Neighbor */
k is the upper bound of node degree, k = 6
Sort all qualified neighbors found in Step1 in order of increasing distance or power
Pow = { p1, p2, p3, ……, pm }，p1≤ p2≤ p3≤ ……≤pm
while (payoff value>threshold)
begin
for(i=1; i ≤m; i++)
begin
u transmits with power pi, 1≤i≤m
draw a perpendicular bisector between u and the node corresponding to the power pi
end
end
TDT-N(u) = TDT-N(u) ∪ { v | v ∈ TCBTC-N(u) and v has corresponding Voronoi Edge }
TDT-D(u) = TDT-N(u) ∪ { v | v ∈ TCBTC-N(u) and v has corresponding Voronoi Edge }
/* Step 3：Filling the α -gap */
Sort TCBTC-N(u) and TDT-N(u) in order of increasing direction
if gap-α (TDT-N(u))
then α □ the smaller direction of the gap
β □ the larger direction of the gap
if dp, dq, dr ∈TCBTC-N(u) and dp ≤ dq ≤ dr and dp =α , dr =β
then dq is dropped in Step 2 and can fill the α-gap
TN(u) = TDT-N(u) ∪ { v | the direction of v is dq }
TD(u) = TDT-D(u) ∪ { dir(u,v) | the direction of v is dq }
Pow(u) = Pow(u) ∪ { p(u, v) | the direction of v is dq }
/* Step 4：Edge Removal */
Suppose node v, w∈N(u)
send(u, p(u, v), relation(v, w), v)
recv(u, relation(v, w), v)
if relation(v, w) is “Y” and | TN(u) | - 1 ≥ 3
then TN(u) =TN(u) - {v}
Procedure gap-α(TD(u))
Suppose TD(u) = {d1,d2,d3,…,dn}
Sort directions in TD(u) in increasing order
TD(u) = {dk1,dk2,dk3,⋯,dkn}, dk1≤dk2≤dk3≤⋯≤dkn, 1≤ki≤n, 1≤i≤n
for(i=1; i ≤n; i++)
begin
if dki+1 - dki ≤ 2π /3 then
continue
end

III. SIMULATION EXPERIMENT OF EGWRA

A. *The Design of Simulation Experiment*

We use the simulation software made by a Ns 2.30 pairs relay cooperation strategy to construct the experiment. The topology of experiment WNN can be described like figure 1, which divided into two parts, mesh network and underlay network.

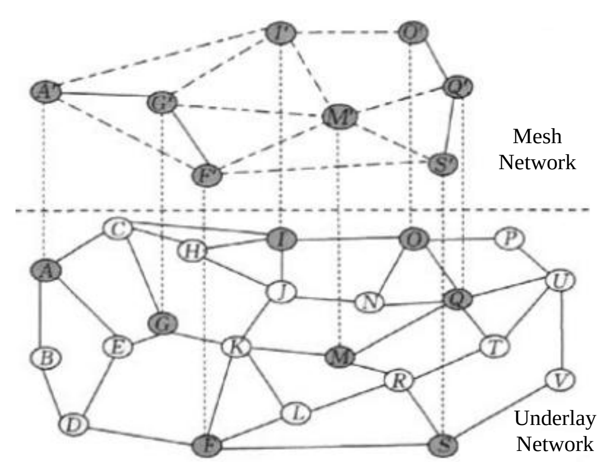

Figure 1. Simulation result of EGWRA.

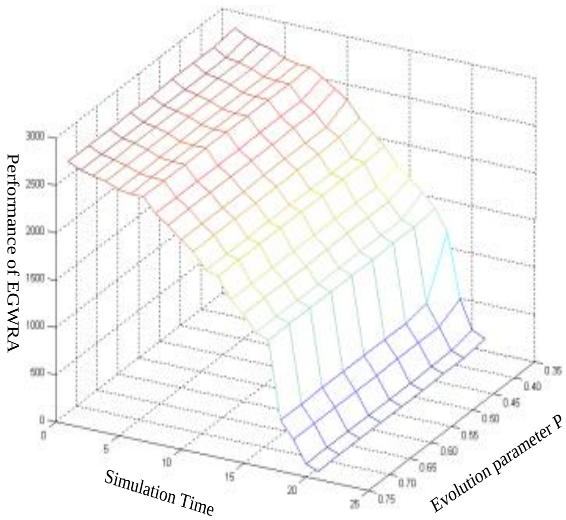

Figure 2. The topology of experiment network.

Simulation using routing EGWRA. Collaboration defined level index node for the network in any of NARMeaning the actual relay nodes and the number of packets following the packet in which the number of requiredVolume ratio. NAR ∈ [o, 1], the greater the value of a node's NAR. Help the higher the degree of collaboration involved in relay. Simulation scenario is set as follows. number of nodes N for a 50, each section Point speed in the 10 ~ 20m/ s were evenly distributed within the mobile rangeWai as a 500m × 500m, each node in a session immediately after the end of Initiate another session carved, and the duration of each session 5-10swere uniformly distributed within. These settings will ensure that each node in the network Interaction between the higher the probability of the relay. Each session is a fixed-speed transmission Rate of 1 Mb / s data stream, packet size is 512byte. Each simulation True continuous 900 s, 50 times in the implementation of the statistical average demand.

B. Result Analysis of Simulation

According to the parameter we start the experiment and the simulation result can be described like figure 2. At fixed intervals of time, t = 1-75, movement occurs by updating the speed and direction of each MN. We have chosen the tuning parameter used to vary the randomness. The speed and direction are chosen from a random Gaussian distribution with mean equal to zero and standard deviation equal to one. For a random chosen instant t in total simulation time, our proposed approach extracts 21 MNs as a stable core in terms of mobility which is marked with a read dot.

This extraction-core based on mobility promotes reliable links between MNs. Therefore, the QoS-aware routing find a path that require QoS through this core, the reliability and lifetime of QoS are more guaranteed in time.

From the experiment we can reach a conclusion that the performance of routing is greatly improved and the cost is not increased very much.

IV. CONCLUSION AND FUTURE WORKS

With the rapid development of wireless technology, some related technologies like mesh network play more and more important roles in working and living process. This paper applies the theory of evolution game to the Qos Routing algorithm and proposes a novel method called EGWRA which integrated multi-step game process into routing decision making process and the performance of routing is greatly improved and the cost is not increased very much.

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