TELKOMNIKA, Vol.11, No.3, March 2013, pp. 1652 ~ 1664
ISSN: 2302-4046

A Novel QoS Routing Algorithm in Wireless Mesh Networks

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Abstract

With the rapid development of information technology, people's daily life becomes more and more dependent on wireless technologies. Wireless mesh network consists of a number of characteristics associated with the return path, with a strong fault tolerance, stability, widely used by the light to the city network construction, military applications, and key service providers and other fields. Compared with traditional wired communication technologies, how to provide qualified QoS routing service is a primary problem for wireless mesh networks waiting for effective solution. Regarding this problem, this paper applys the theory of Evolutionary Game to QoS routing algorithm for wireless mesh networks and proposed a novel algorithm called EGWRA 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*: wireless technology; QoS routing; mesh networks; evolutionary game theory*

1. Introduction

Wireless local area networks are considered as one of the viable solutions for providing Internet connectivity to mobile users. The commercial wireless LANs today, e.g., IEEE 802.11 , provide single hop wireless connection to the infrastructure. All the mobile users need to reside within the access point's reach, i.e., within the basic service set with a radius of 100~300meters. In order to provide full coverage in relatively large size areas we need to deploy a large number of access points (AP). Thus, the conventional infrastructure-based wireless LANs do not scale well with the target coverage area and number of nodes.

We can classify wireless networking architecture as follows 1) point-to-multipoint infrastructure-aided approach like wireless single hop networks (e.g., IEEE 802.11 wireless LAN) and 2) peer-to-peer multihop approach e.g., mobile ad hoc networks (MANETs).

The difference between mesh networks and conventional infrastructure wireless LANs is the fact that mesh networks result in a multihop topology which requires decentralized coordination. The difference between mesh networks and the mobile ad hoc networks resides in the existence of the infrastructure connection. The access points deployed can act both as a peer of the internal wireless ad hoc network and the bridge to the wired network. To provide sufficient infrastructure access bandwidth, multiple access points can be deployed within the network. Traffic balancing can be achieved by the underlying mesh routing protocol. The mesh network features presented above lend themselves to easy scalability.

Wireless mesh networks seamlessly integrate these two network architectures. This integration is obtained by the proposed WMR protocol, implemented in each wireless node. The connectivity to the wired backbone is provided by the wireless infrastructure access points. Each node in the network is both a service provider and a service consumer, i.e., each node has forwarding ability similar to the nodes' functionality in MANETs.

As a new type of wireless network, wireless mesh network [1, 2, 19, 31-34] 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

Received November 5, 2012; Revised January 26, 2013; Accepted February 8, 2013

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. A typical Wireless mesh network can be described like Figure1.

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.

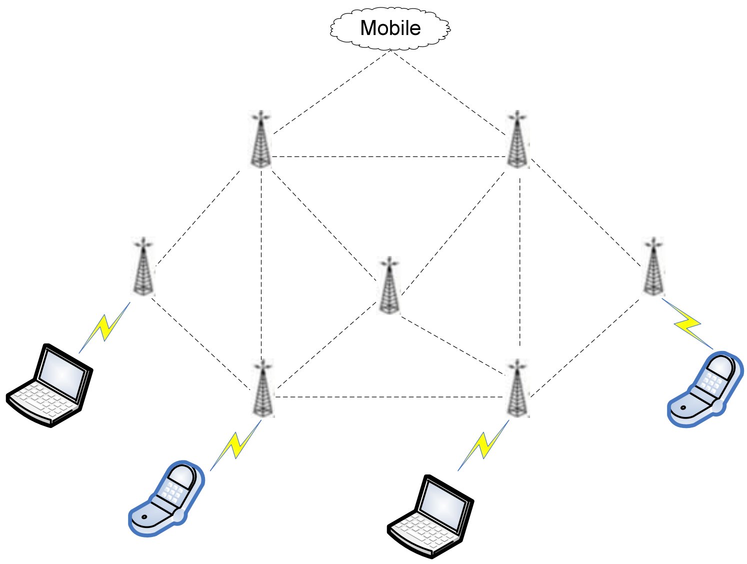

Figure 1. Typical structure of wireless mesh network

2. Related Works

Regarding the Qos problem of Routing Algorithm for Wireless Mesh Networks, lots of scholars in this filed have made some achievements. Some of them with representatives can be listed as follows. Vo, Hung Quoc [3, 4, 16, 17, 18] propose a novel approach to control the traffic to avoid congestion by decoupling forwarding process from the routing process. The proposal is interested in provisioning quality of service guarantees for planned Wireless Mesh Networks which are being used widely as a broadband wireless access network. Zhou, Hao [5, 6, 12, 13] 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 [7, 8, 14, 15] 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. Zhou, Hao [21, 22, 23] 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. In additional, 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. Agarwal, Anjali [24, 25, 26] proposes an Ants-in-Mesh (AIM) routing protocol for wireless mesh networks, which is based on ideas from the nature-inspired Ant Colony Optimization (ACO) framework. AIM agent distributes forward ants on demand to search for the routes to the destination and then activates corresponding backward ants to confirm the routes and update the pheromone. AIM enables only the destination to choose k multiple paths based on Ants Pheromone, which is based on several link-relevant Quality of Service (QoS) metrics. Rong Bo [27, 28, 29, 30] propose a novel network graph preprocessing approach to enable traffic engineering and enhance the performance of QoS multicast routing algorithms. In this approach, we employ prioritized admission control scheme and develop a utility-constrained optimal priority gain policy.

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.

We are going to extract a stable core in MANET in terms of mobility in the goal to serve QoS-aware routing to take network mobility to find the specific resources. Such an extraction can define a subset of MNsin the network where his mobility is low and the links between them are reliable in time. Therefore, the selected path through this core is more stable in terms of mobility, and consequently the required QoS are more guaranteed. Indeed, we can find a path that requests our requirement in QoS such as bandwidth, but the mobility of some intermediate MNs consisting of this path is high. Taking in to account the cooperation between MNs in terms of mobility is a promising idea to find the adequate stable core and consequently a stable path. In this assessment so as to extract this core, we use a cooperative game theory. For this objective, we consider MNs in MANET as players, and we try to find a cooperative coalition (partition) of players that minimizes the mobility criteria in the network.

3. Summary of EGWRA

3.1. The framework of EGWRA

EGWRA, our proposed architecture, is designed to take full advantage of WMN architecture. EGWRA mixes proactive route computation for routers and on-demand path setup for clients. This design eases the management of client mobility and reduces routing table size. Proactive route computation is performed using a Distance Vector (DV) approach. On-demand path setup is performed by new extensions introduced in the routing protocol in order to take advantage of the architecture of WMNs.

In EGWRA, the backbone becomes totally transparent to the clients, which do not need to embed any new feature. This means that if two clients associated to different WMRs wish to communicate, the set of WMRs will forward the traffic at the IP level and not at the link level. To obtain such a behavior, WMRs have to be more than a simple forwarder and more than a simple router. In particular, on the client subnetwork interface, which can be described like figure 2.

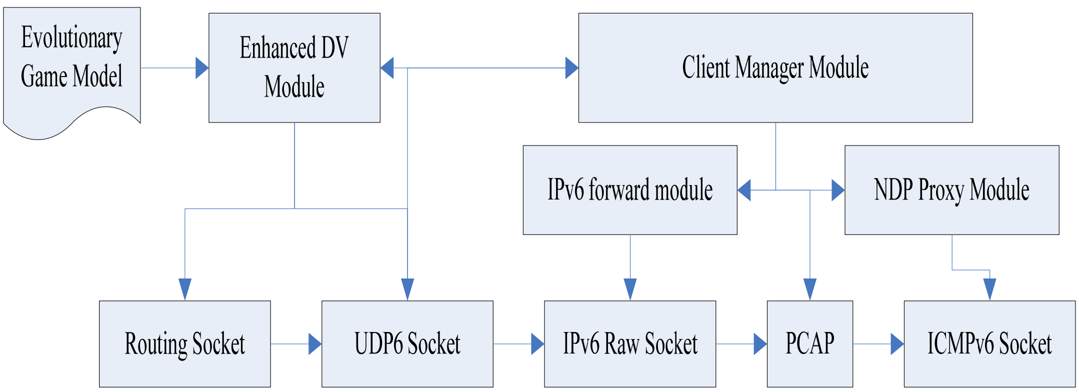

Figure 2.The framework of EGWRA

The WMR acts in such a way to let local clients thinkthat remote clients are in the local WLAN. Then, it is up to the WMRs to find out to which WMR the client is associated and route the packets accordingly.

The basic task of the Enhanced DV module is to maintain proactively a route toward any other WMR present in the backbone subnetwork. This Enhanced DV module is an IPv6 implementation of DSDV, based on existing IPv4 code. Some enhancements have been introduced in order to cooperate with the Client Manager module. This module is the only one that accesses the kernel routing table.

The NDP-Proxy module provides the WMR with theability to act like a Neighbor Discovery Protocol proxy.This allows to transparently forward packets toward the WMR the destination client is associated with. In this way, no particular mechanisms are necessary on the client side, in order to communicate with remote clients. The NDP-proxy module will correctly answer to the ICMPv6 request sent by the local clients.

The IPv6 Forwarder module encapsulates all IPv6 packets in another IPv6 packet, in order to ship packets toward the destination client. This solution, though introducing a certain amount of overhead, avoids keeping state in the WMRs along the path between clients. Indeed, only the WMRs at the edges of the path must be aware that the two clients are communicating. Another significant advantage is the robustness to mobility. If a client changes the WMR to which it is associated, only the WMRs at the edges of the path must update the information (3 WMRs in total). WMRs along the path do not need to make any update, while continuing to relay packets.

The Client Manager module is responsible for discovering which client is associated to which WMR in an on-demand fashion. When a local client wishes to communicate to a remote client (associated to another WMR), it sends a multicast request in order to discover where the client is. The result of this query is stored in the Foreign Client Table. The Client Manager module also manages the reply to requests sent by other WMRs. Furthermore, since MeshDV must be aware of the clients that are associated to the WMR, the Client Manager module monitors the set of clients associated to wlanI and stores them in the Local Client Table.

3.2. Summary of Evolutionary Game Theory

yy 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, which 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 [9, 10, 11, 20], 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.

Set the evolution game located in an N-node MANET, any node with M, that except the node i other than the collection. N_{-i} 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 $u(x,l)$ is a continuous function in domain $X \times L$, 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 $T_I : D_X \to D_X$ and the average selection operator $\overline{T}_I : D_X \to D_X$, the environment, the average fitness function.

According to the statements listed above. The evolution game for WNN can be defined. 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 Table1.

Table 1. The game Matrix between labor nodes in WNN

	successful	failure
The packet reachs node Nj	(B ,C)	(0 , C)
The packet not reachs node Nj	(B, 0)	(0, 0)

3.3. Summary of Evolutionary Game Theory

Assuming the initial time in the game, the use of technical cooperation in supply-side strategy of population ratio of p($0 \le p \le 1$). The proportion of non-cooperative strategies using (1-p).Technology used in cooperation demand-side strategy of population ratio of q($0 \le q \le 1$).The proportion of non-cooperative strategies using 1-q. The technical cooperation strategy for the selection of side population expected to pay for can be expressed with equation 1.

$$\begin{aligned} u_{11} &= q[(1+p)a_1v - c_1] + (1-q)(a_1v - c_1) \\ &= pa_1vq + a_1v - c_1 \end{aligned} \tag{1}$$

Technology suppliers expect to pay for the average population, which can be described with equation2.

$$\begin{aligned} &\overline{U_q} = pu_{11} + (1-p)u_{12} = \\ &p(pa_1vq + a_1v - c_1) + (1-p)a_1v = \\ &pa_1vqp - c_1p + a_1v \end{aligned} \tag{2}$$

Similarly you can calculate the demand-side technology cooperation with non-cooperative population expected to pay u_{21} , u_{22} , and the average expected payoff .

$$\begin{aligned} u_{21} &= p[(1+p)a_2v - c_1] + (1-p)(a_2v - c) = \\ &pa_2vp + a_2v - c_2 \end{aligned} \tag{3}$$

$$u_{22} = pa_2v + (1-p)a_2v = a_2v \tag{4}$$

$$\begin{aligned}\overline{U_2} &= qu_{11} + (1-q)u_{12} = \\ &q(pa_1vq + a_1v - c_1) + (1-q)a_1v = \\ &pa_2vpq - c_2q + a_2v\end{aligned} \tag{5}$$

Therefore, the network equations for the dynamic replication can be described with equation (6).

$$\begin{cases}\dfrac{dp}{dt} = p(u_{11} - \overline{U_1}) = p(pt_1vq + a_1v - c_1 - \\ \quad pt_1vqp + c_1p - a_1v) = \\ \quad p(1-p)(pa_1vq - c_1), \\ \dfrac{dq}{dt} = q(u_{21} - \overline{U_2}) = q(pt_2vp + a_2v - \\ \quad c_2 - pt_2vpq + c_2q - a_2v) = \\ \quad q(1-p)(pa_2vp - c_2)\end{cases} \tag{6}$$

Equation (6) described the group dynamic, to solve this euqations. Set $\frac{dp}{dt} = 0$, $\frac{dq}{dt} = 0$,five steady points can be reached, which can be listed as follows. $E_1 = (0,0)$, $E_2 = (0,1)$, $E_3 = (1,0)$, $E_4 = (1,1)$, $E_5 = (\frac{c_2}{pa_2v}, \frac{c_1}{pa_1v})$.

With $0 \le p,q \le 1$, when $\frac{c_2}{pa_2v} > 1$ and $\frac{c_1}{pa_1v} > 1$, E_5 does not exist. The Jacobi Matrix can be caculated accordingly.

$$J = \begin{bmatrix}(1-2p)(pa_1vq - c_1) & p(1-p)pa_1v \\ q(1-q)pa_2v & (1-2q)(pa_2vp - c_2)\end{bmatrix} \tag{7}$$

When $\det J \ne 0$, The matrix is nonsingular, there is a unique solution.

(1) In steady point $E_1 = (0,0)$, $J = \begin{bmatrix} c_1 & 0 \\ 0 & -c_2\end{bmatrix}$, $\det J = c_1c_2 > 0, trJ < 0$, and the point $E_1 = (0,0)$ is proven at steady state.

(2) In the steady point $E_2 = (0,1)$, $J = \begin{bmatrix} pa_1v - c_1 & 0 \\ 0 & c_2\end{bmatrix}$, $\det J = c_1c_2 > 0, trJ < 0$, and the point $E_2 = (0,1)$ is proven at steady state.

(3) In the steady point $E_3 = (1,0)$, $J = \begin{bmatrix} c_1 & 0 \\ 0 & pa_2v - c_2\end{bmatrix}$, $\det J = c_1(pa_2v - c_2)$, when $0 < \frac{c_2}{pa_2v} < 1$, $E_3 = (1,0)$ is not the steady point of the system, when $\frac{c_2}{pa_2v} > 1$, $E_3 = (1,0)$ is the steady point of system.

(4) In the point $E_4 = (1,1)$, $J = \begin{bmatrix} c_1 - pa_1v & 0 \\ 0 & c_2 - pa_2v\end{bmatrix}$, similarly, when $\frac{c_2}{pa_2v} > 0$ and $\frac{c_1}{pa_1v} < 1$, $E_4 = (1,1)$ is the steady point of the system. when $\frac{c_2}{pa_2v} > 1$ and $\frac{c_1}{pa_1v} > 1$ then $E_4 = (1,1)$ is not the steady state of the system.

(5) for the $E_5 = (\frac{c_2}{pa_2v}, \frac{c_1}{pa_1v})$, only when $\frac{c_2}{pa_2v} > 0$ and $\frac{c_1}{pa_1v} < 1$, E_5 can be considered the steady point.

Evolutionary stable strategy (ESS) is a description of the evolution of the game in the evolution of the concept of steady state, dynamic system to describe the local stability analysis of the above balance.

(1) When $\frac{c_1}{pa_1v} > 1$ and $\frac{c_2}{pa_2v} > 1$, this system has four steady points E_1, E_2, E_3, E_4. Where E_1 is stable node, (cooperate, cooperate) a system of evolutionarily stable strategy, the other three equilibrium points are unstable. At this point, military and civilian technology, supply-side and demand-side populations through long-term evolution of the population will stabilize in the (non-cooperation, non-cooperative) strategy, which does not form a network.

(2)When $\frac{c_1}{pa_1v} > 0$ and $\frac{c_2}{pa_2v} < 1$, this system has four steady points E_1, E_2, E_3, E_4. Where E1 and E4 for the stable node, (cooperate, cooperate) and (co, co) is the system of evolutionarily stable strategy, E2 and E3 for the unstable node, E5 for the saddle point. At this point, network technology, network systems and demand-side supply-side populations through long-term evolution of the population to E5 according to the initial value for the saddle point were stable at different (non-cooperation, non-cooperation) and (cooperation, cooperation) strategy.

Technology supply-side and demand-side species populations under different technologies to get their investment cost and technology benefits of technology, the ratio of benefit-cost ratio can be described as technology,which is under certain technical benefits communication costs.

Figure 3 Described in the plane S system technology for military and civilian populations side and demand-side dynamics of game populations. The system has five partial equilibrium point, the two unstable equilibrium point E2 and E3 and E5 connected into the saddle-point line for the different states the system converges to the critical line, that line the upper right (E2, E5, E3, E4 part) system convergence in partnership, in the line of the lower left (El, E2, E5, E3 part) the system will converge to the co-operative relationship. Because the system's evolution is a long process, probably in a very long time to maintain a cooperative and competitive coexistence.

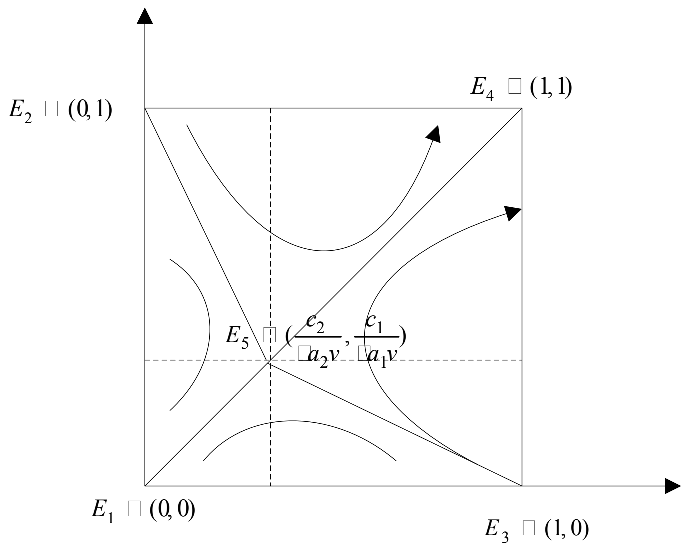

Figure 3. The evolutionary model for mesh network game

4. Workflow of EGWRA

We consider the dynamic nature of MANET as a game with N players, and we call about coalition all non-empty party S of N.

4.1. The Communicating Step of EGWRA

Traffic flowing in a mesh network can be classified into three types:

a) traffic between two clients associated with the same WMR.

b) traffic between two clients associated with different WMRs.

c) traffic between a client and a gateway. All types of traffic are detailed below.

Clients associated with the same WMR. In this case, clients do not need any particular attention, since the wlanl interface automatically bridges the traffic between them. This is an embedded feature of the HostAP mode of wireless card drivers.

4.2. Working Step of EGWRA

The package S may be an element or equal to N. It is assumed given on parts of N, a function which com 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

The aim of the genetic operators is to generate a second generation population of solutions from those selected through genetic operators: crossover, and/or mutation. For each new solution to be produced, a pair of "parent" solutions is selected for breeding from the pool selected previously. By producing a "child" solution using the above methods of crossover and mutation, a new solution is created which typically shares many of the characteristics of its "parents". New parents are selected for each child, and the process continues until a new population of solutions of appropriate size is generated.

4.3. Qos Violation Detection

The route break can not be detected easily. The common approach used in most of existing ad hoc routing protocols is by waiting for a neighbor timeout, i.e., the hello message from a neighbor does not arrive to the node on time. When neighbor timeout is discovered, a route error message is sent to the source notifying about the break. However this kind of route break detection method normally takes several seconds, which is not desirable to time sensitive QoS flows. In our approach, we utilize the bandwidth reservation timeout at the destination to signal possible route breaks. If the destination fails to receive data packets of an active flow 21 before its reservation timeout, route recovery will be triggered at the destination. Using this method, we can detect both types of QoS violations at the same time and handle them identically. The neighbor lost detection will also be used in case the destination that initiated instant recovery can not reach the source because of network partition or packet loss. When a node detects that the downlink node of a reserved route is lost, it will send a route error packet, with its current route sequence number, to the corresponding uplink node. The route error packet is then forwarded upwards to the source to indicate the occurrence of the route break. As a consequence, the reserved bandwidth of the flow will be released at the forwarding nodes.

4.3. QoS Violation Recovery

To provide instant route adaptivity, we use destination initiated route recovery. After the QoS violations are detected, the destination will increase its route sequence number and broadcast an unsolicited route reply packet, also called route update packet, back to the source. The route update packet is treated in the same manner as a route request packet with admission control and loop prevention mechanism, but in the reverse direction from destination to source. Upon receiving the first in time route update packet with appropriate sequence number, the source switches the flow in question to the reverse route on which the update arrives.

On the other hand, a late route update packet or a route error packet, with the valid route sequence, signals the occurrence of QoS violation and the failure of route recovery. In such case, the application can either decide to continue transmitting the flow with the absence of QoS guarantee or suspend the flow and try later.

5. Simulation Experiment of EGWRA

5.1. 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 4, which divided into two parts, mesh network and underlay network.

The MAC layer of each mobile node or AP model uses the default IEEE 802.11 DCF module provided by OPNET with modifications for multihop connection support. Each mobile node or AP has the same transmission range of 200 meters and raw data rate of 2Mb/s. The WMR module is inserted on top of the MAC layer module. In the WMR module, we implemented a sender buffer of 64 packets to buffer data packets waiting for a route, e.g., packets for which route discovery has started, but no reply has arrived yet. Upon discovery failure, the source will back-off for a double time interval and try again until the retry limit of 3 is reached. The maximum packet size used in the temporary bandwidth reservation is set to 1024 Bytes. The hello interval of 1 second is used with neighbor timeout set to 3 seconds.

All the nodes are stationary during the simulation period of 300 seconds. There are 10 external flows with the source nodes spread randomly among the 40 nodes. Since we are interested in the performance of WMR in a mesh network, the connections to the wired network are not included in the simulation. The traffic sink module in the AP model will receive the external data packets as if they are forwarded to the wired network.

To simulate stream media applications we use CBR (constant bit-rate) flows with 10 packets per second and fixed data packet size of 1024 bytes. The sources will keep generating data packets at the fixed rate throughout the simulation. All the flows have the same end-to-end delay bound.

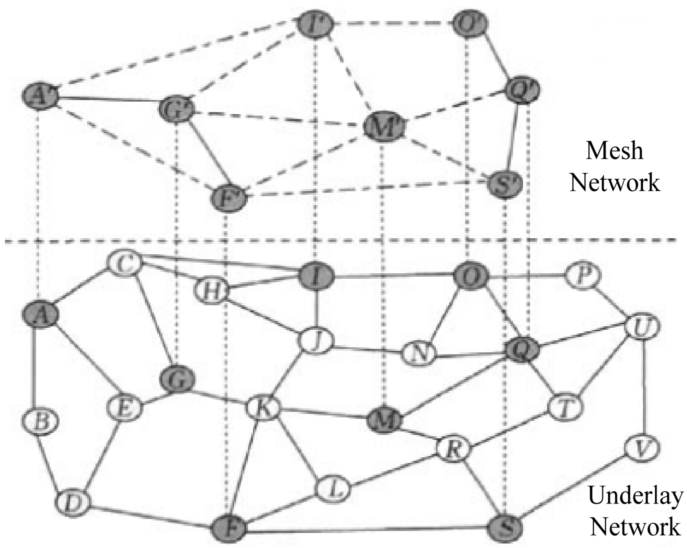

Figure 4.The topology of experiment network

Simulation is 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 ∈ [0,1], the greater the value of a node's NAR. HelpThe 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 ofInitiate another session carved, and the duration of each session 5-10swere uniformly distributed within. These settings will ensure that each node in the networkInteraction between the higher the probability of the relay. Each session is a fixed-speed transmissionRate of 1 Mb / s data stream, packet size is 512byte. Each simulation true continuous 900s, 50 times in the implementation of the statistical average demand.

5.2. Result Analysis of Simulation

Accroding to the parameter we start the experiment and the simulation result can be described like figure 4. At fixed intervals of time, t = 1-75, movement occurs by updating the speed and direction of each MN.We have choose 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 extract 21 MNs as a stable core in terms of mobility which is marked with a read dot.

In the previous section, we modelled a stable core in term of mobility in a MANET by the evolutionary game theory. The solution is the core of game which is the vector of imputation that represents the solution of (PP). We study tatic situation, where MNs are not moving during the evaluation period. In such case, places of the MNs are fixed, hence the assumption is valid. The assumption can also beustified if only a small time frame is inspected. In a smallime frame, the movements of the MNs are negligible.

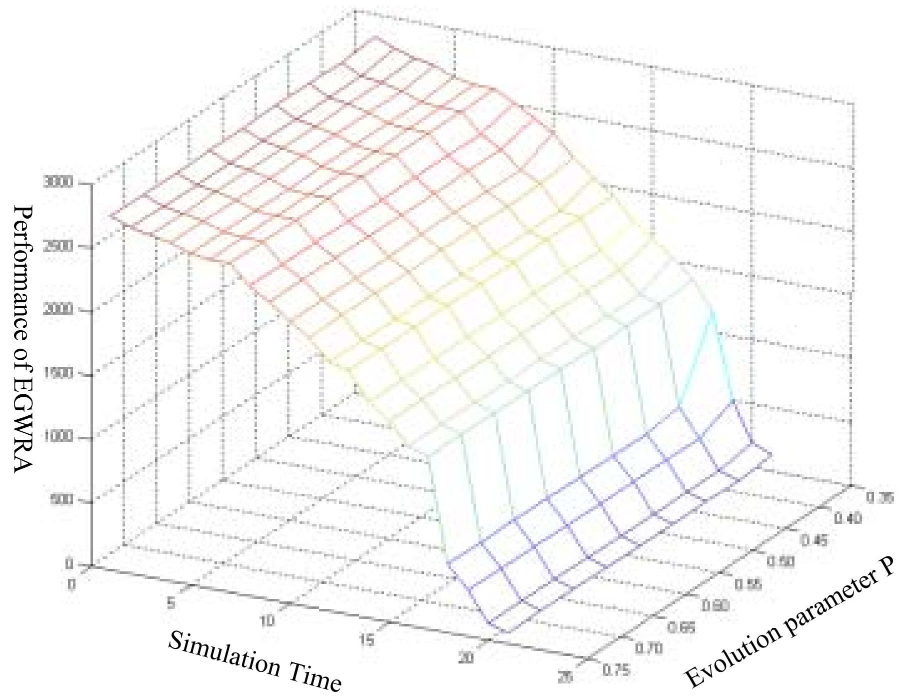

Figure 5. Simulation result of EGWRA

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, which can be described like figure 5.

From the results collected, we know that the proposed mesh network architecture can provide infrastructure access to external flows through multiple APs. The proposed WMR protocol can provide QoS support and react dynamically to the network status changes with low control overheads.

Mesh based wireless LANs are a promising approach to wireless Internet connectivity for mobile users. The mesh wireless LAN architecture provides the advantages of 1) infrastructure based wireless LANs, i.e., Internet connectivity provided by the Access Points (AP) at relatively high speeds, and 2) ad hoc wireless networks which provide a relatively large geographical span without the deployment of a large number of APs. In this paper we have introduced a Wireless Mesh Routing (WMR) protocol which merges these two technologies (infrastructure based wireless LANs and ad hoc wireless networks) seamlessly as well as provides QoS support. The proposed software architecture allows us to deploy WMR protocol with any MAC protocol, fact that leads to easy implementation in existing networks. Our protocol was implemented in NS2 modeler.The simulation results show that the mesh network performance using WMR protocol can provide QoS support and react dynamically to the network status changes with low control overheads.

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

6. 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 applys 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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