QoS Routing with Link Stability in Mobile Ad Hoc Networks [a]

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Abstract. In this paper, in accordance with requirements of different users and supplying effective usage of limited network resources, we propose a stable QoS routing mechanism to determine a guaranteed route suited for mobile ad hoc wireless networks. The manner exploits the received signal strength (RSS) techniques to estimate the distance and the signal change of the velocity to evaluate the breakaway. To ensure the QoS it chooses a steady path from the source to the destination and tries to reserve the bandwidth. Ultimately, it is clear to find that the performance never decrease even the growth of the overhead and the movement of users via the simulated by ns-2.

1. Introduction

Mobile Ad Hoc Wireless Networks (MANET), also called the Ad hoc network, is lots of moving nodes (mobile hosts) communicating with their adjacent mobile node by radio wave. Every node can contact each other without existence infrastructural network. In the Ad hoc network, it differs from cellular wireless networks that need base stations to deliver and receive the packets. Each node plays the role as a router. When one of them wants to deliver packets to destination out of its coverage, intermediate nodes will forward this packet to the next node till the destination node receive it.

In traditional cellular wireless networks, generally we need to establish base stations in advance. Fixed nodes far and near connect to the backbone and become a wireless network environment. In this network the customer who wants to communicate with another must locate in the base station coverage. If user moved out of base

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station’s service scope, he can't take the communication. Consequently, we need to establish enough base stations to achieve the objective. Ad hoc networks do not demand fixed network infrastructures and centralized management mechanisms, as well as can be built anytime, anywhere rapidly. Ad hoc networks also have the feature of self-creating, self-organization and elf-management as well as deploy and remove network easily. Ad hoc network has above advantages. However, the Ad hoc network environment has the following restricts [1], including of Network topology instable, Limited energy constrained and Limited network bandwidth-constrained

In addition, routing protocol is a very important subject at the Ad hoc networks realm. In general, routing protocols categorize into two types: Table-Driven [2] and Demand-Driven [3]. Though, they both need to have a certain cost to look for and maintain the path. To search a stalest path that has a high throughput is more important than just shortest one. How to find out available, stable and accurate paths and efficient dissipation bandwidth and power energy is an important research at Ad hoc networks [4] [5].

In recent years, the multimedia service makes use popularly to wireless communication. Seeking an available path is not enough to satisfy with customer requests. QoS is also the trend of the future communication [6]. In this paper, in according to the characteristics of Ad hoc network, we propose a routing mechanism that can provide QoS. We exploit the signal strength of two nodes to evaluate a stable path and try to diminish the control signal overhead.

Proactive RTMAC (PRTMAC)[7] is a cross layer framework, with an on-demand QoS extension of Dynamic Source Routing (DSR)[8] routing protocol at the network layer and real-time Medium Access control (RTMAC)[9]. It is designed to provide enhanced real-time traffic support and service differentiation to highly mobile ad hoc wireless networks [10]. It is one of Reservation-based QoS solutions and solves the breakaways and clash. Unfortunately, it must combine with particular MAC layer. Actually, there are some difficult in practice.

2. System Model and Assumption

A Ad hoc Network Module

In this paper, we model the Ad hoc network system as a graph G = (V, E). The V is a set of mobile nodes in Ad hoc network, and each node has a unique identifier code. The E is all set of arbitrary couple of nodes i and j, and they can communicate by the radio wave. Since the nodes have mobility, V and E will change dynamically. The other relations with fundamental assumptions in Ad hoc network are described as follows:

1.We assume that there is already a MAC protocol which can hold and resolve the problem of media contention and resource reservation effectively.

2.The signal decay and the background noises caused by transmission medium and geography factor are ignored.

3.We assume each mobile node knows others in its coverage, as well as can monitor the signal strength variation of neighbor node anytime. Only the forwarding nodes will receive the messages from broadcasting and the other nodes will drop those.

4.We assume the moving direction and users' speed are random and not influenced by another user. Its average speed maintenance time is T_s. The arrival procedure of user is Poisson Distribution and its average arrive rate is λ (requests/second). The keep time of user call as well as Exponential distribution and its average is T_d and let $m = T_d^{-1}$.

Every couple of source and destination node is random selected. In order to evaluate the influence of system by different policies, this paper defines the following reference index:

(1). Routing control overhead ($T_{overhead}$): Assume the normal number of packets is N_c, all the number of packets transmitted is N_{all} , and we define the formula.

$T_{overhead} = N_c / N_{all}$.

(2). The transmission success rate of system ($P_{success}$): the numbers of packets that was received successfully of all network is $N_{receive}$, the numbers of real packets was sent is N_{send}, we define: $P_{throughout} = N_{receive} / N_{send}$

(3). $l_{i,j}$: The link between node i and node j that can transmit message again.

(4). T_{adv} : the period of time that each node broadcasts its status packet.

(5). $BW(i, j)$: the maximum available bandwidth of path from i to j, $P_{i,j}$.

(6). $S_{i,j}(t)$: the node i receive the signal strength from node j at time t, the unit of $S_{i,j}(t)$ is dB.

(7). $T_{i,j}^{predict}$: prediction of the invalidity time of link l_{ij}.

(8). $Path_{s,d}(x)$: if the x th path from node i to node d will pass through nodes (s, x, y,…,z ,w ,d) then we define path is $Path_{s,d}(x) = \{l_{s,x} \cup l_{x,y} \cup \mathbf{K}\, l_{z,w} \cup l_{w,d}\}$

(9). $Path_{s,d}^{predict}(x)$: Prediction of the invalidity time of path $Path_{s,d}(x)$ is

$$Path_{s,d}^{predict}(x) = min(T_{s,j}^{predict}, \cdots, T_{w,d}^{predict})$$

(10). $RPath_{s,d}$:if we have k path that fit QoS requirement from node i to node d, the most stable routing path is. $RPath_{s,d} = \max\left(Path_{s,d}^{predict}(x) \mid \forall x = 1,2, \mathbf{L}\,, k\right)$

(11). We have two different traffic types (QoS and Best Effort) in our system; the ratio of QoS is f.

TABLE 1 $Avg(V_{i,j}(t-\Delta t))$ and $V_{i,j}(t)$

Case	$Avg(v_{i,j}(t-\Delta t))$	$v_{i,j}(t)$	Status
1	-	-	Keep approahing
2	-	+	Start leaving
3	+	-	Start approaching
4	+	+	Keep leaving

We can find if the signal strength in distance r_1 is $S(r_1)$, the signal strength in distance r_2 is $S(r_2)$[11], as equation 1:

$$S(r_2) = \frac{r_1^2}{r_2^2}(1 - r_d(h_*(r_2)r_2) \times \Delta r) \times s(r_1) \quad (1)$$

In this paper, we assume the notation $\rho_d = 0$. If number of photons sent was N_p, the signal strength in the distance r from source is S, $S = N_p / A_r$. Then the signal strength in distance 2r will be $N_p / 4A_r = S/4$; in distance 3r will be $S/9$, the rest can be deduced accordingly.

B. The Guarantee Index of Quality of Service

In QoS routing protocol, there are many parameters of QoS guarantee [12][13], such as residual bandwidth, residual buffer space, packet loss probability, delay time and delay jitter, etc. In this paper, we refer to the proposal of Z. Wang [13], only take account of bandwidth to evaluate the efficiency of QoS service. In this paper, we support bandwidth guarantee for QoS type traffic, and we can use some dynamic adaptive technologies to keep the Quality of service.

$$BW_r(s,d) = \min(BW_r(s,x), \mathbf{K}, BW_r(w,d)) \quad (2)$$

3. Proposal of QoS Routing Policy

A. The Prediction Method of Stable Path

In Ad hoc network, we can calculate the variation of signal strength from neighbor link $l_{i,j}$ and predict the broken time with regular beacon signal. In Fig. 1, the signal strength of node j at time t-Δt, t, is $S_{i,j}(t-\Delta t)$, $S_{i,j}(t)$.Then we use equation 1, and we will derive the answer:

$$\mathbf{Q}\, r_{i,j}(t) = R_t \sqrt{\frac{S_t}{S_{i,j}(t)}},\ r_{i,j}(t-\Delta t) = R_t \sqrt{\frac{S_t}{S_{i,j}(t-\Delta t)}}$$

$$\therefore v_{i,j}(t) = \frac{r_{i,j}(t) - r_{i,j}(t-\Delta t)}{\Delta t} = \frac{\sqrt{S_t}}{\Delta t} R_t \sqrt{\frac{1}{S_{i,j}(t)} - \frac{1}{S_{i,j}(t-\Delta t)}} \quad (3)$$

In Fig. 2, we can detect the same variation rate of signal strength. They have same variation rate but their moving ability are not equal in practice. We define the average variation rate of velocity at *t* time $Avg(v_{i,j}(t-\Delta t))$. We divided the average variation rate of velocity into four cases:case1 indicate node ***j*** approach node ***i***, case2 is that node ***j*** go away from node ***i***, case3 is that node ***j*** start to approach node ***i***, case4 shows node ***j*** leave out the range of node ***I***, as in TABLE 1. So we can define a relation equation:

$$Avg(v_{i,j}(t)) = \begin{cases} \dfrac{Avg(v_{i,j}(t-\Delta t)) + v_{i,j}(t)}{v_{i,j}(t)} & ,\text{Case 1 \& 4} \\ & ,\text{Case 2 \& 3} \end{cases} \quad (4)$$

$$T_{i,j}^{predict} = \begin{cases} \left\lfloor \dfrac{R_t - r_{i,j}(t)}{v_{i,j}(t)} \right\rfloor & ,\text{if } avg(v_{i,j}(t)) > 0 \\ T_s & ,\text{if } avg(v_{i,j}(t)) = 0 \\ \left\lfloor \dfrac{R_t + r_{i,j}(t)}{v_{i,j}(t)} \right\rfloor & ,\text{if } avg(v_{i,j}(t)) < 0 \end{cases} \quad (5)$$

Using equation 4, we can derive the relation equation 5 of $T_{i,j}^{predict}$. Using equation 5, we can calculate the predictive lifetime of path, equation 6.

$$Path_{s,d}^{predict}(k) = \min\left(T_{s,l}^{predict}, \mathbf{L}, T_{w,d}^{predict}\right) \quad (6)$$

B. The Method of Stable Path and QoS Routing

The method we propose that each node have to maintain two tables, one is Signal Affinity Table (SAT), the other is Zone Route Table (ZRT). Each node will broadcast a routing information packet periodically with a time period T_{beacon}, when a node receives the packet from its neighbor nodes then it records it in its SAT. We can use equation 2.

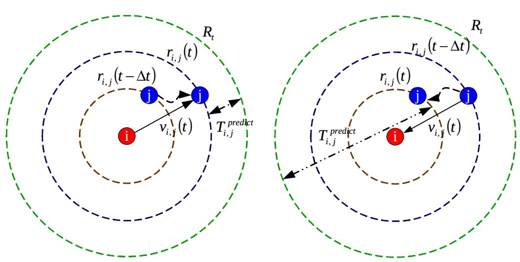


Figure 1 In the condition of uniform motion, the signal strength of node j per t times

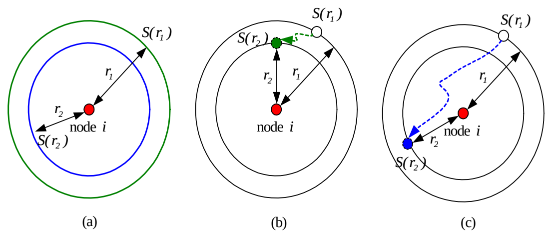


Figure 2 Different conditions but have the same variation rate of signal strength

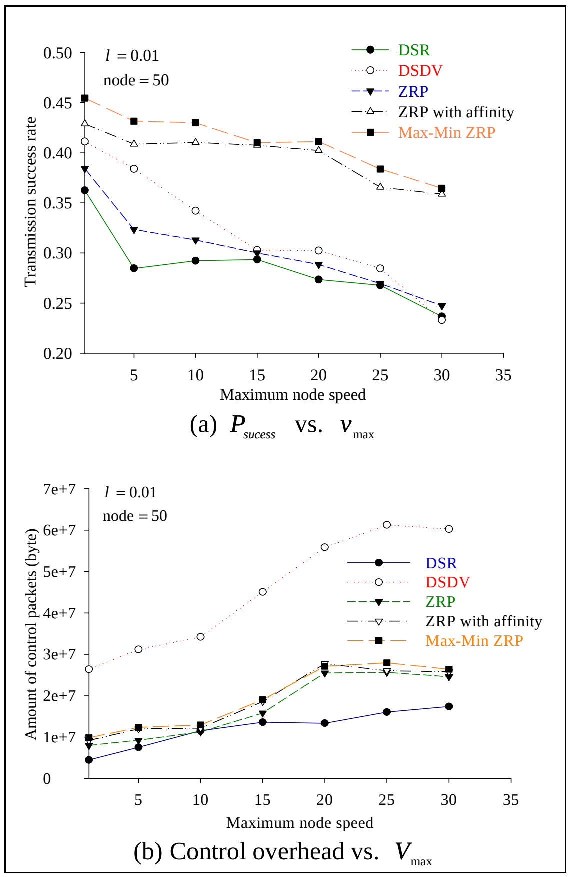


Figure 3 $v_{\max}$ vs. throughput and overhead

Possession of the *BW* and the prediction of invalidity time of path is $Path_{s,d}^{predict}(x)$.ZRT will record the information of hops, next node, sequence number, bandwidth, and signal affinity for prediction time.

When a source node wants to transmit the data to destination, it will find its ZRP first. If the destination did not exist in its table, it will broadcast the request to the far node in its table. The node receive the request packet, they will repeat the step before the destination in they ZRT. When the destination receives the route request packet, it will wait a back-off time; then select the path which has the longest predictive time; then we use this path to transmit the data. Show as equation 7.

$$RPath_{s,d} = \max\{Path_{s,d}(k)\} \quad (7)$$

If has more than one longest path exist, we select the path which has the least number of the hops. When the predictive time of path is equal or less than 1 sec, we will pre-route before the path is failure.If the load of network is heavy, the efficiency of DSDV is better than DSR; otherwise DSR is better than DSDV [14]. In this paper, we attempt to find a QoS routing path using DSR. The destination received the request packet, he will find the path which available bandwidth conformed to the request and it has the longest predictive longest life time. If no path conforms to the request, the destination will decide one with longest predictive time and randomly drop some best effort traffic to reserve the bandwidth whole path.

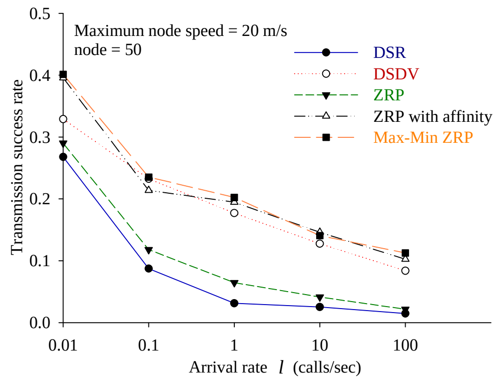
4. Performance Evaluation

A. Simulation Environment

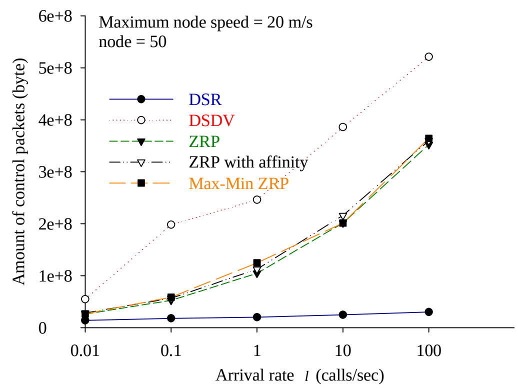
The ***ns-2*** [15] simulator was used in the simulation study, as well as can be exploited for academic research. In the simulation, the environment parameters of the system was refer to the reference [14], Inter-Frame Space (IFS) is 10 ms, Short IFS (SIFS) is 10 ms, PCF IFS is 30 ms, DCF IFS is 110 ms, every time slot is 20 ms. If a packet stays in the queue buffer over 20 ns and was not sent yet, it will be dropped. Contention Window, CW, CW_{min}=32 and CW_{max}=1024. The maximum size of interface queue is 64, all nodes communicate with identical, half-duplex wireless radio that are modeled available IEEE 802.11-based of 2Mbps and a nominal transmission radius of 250 meters. T_{beacon} = 1 ms. The mobility model referred to [2].Our simulation modeled a network of 50 mobile hosts placed randomly using uniform distribution within 1000 meter multiplied by 300 meter area. The minimum and the maximum velocity set zero and 20 m/s, respectively, while each time user velocity is determined previously, and such velocity maintains 100 s, T_s.

In our simulation model, the transmission ratio uses CBR traffic sources between the communications of nodes, as well as data packets are 64 or 1024 bytes long. The velocities of transmission are a packet per second, four packets per second and eight packets per second. The user arrival procedure is Poisson distribution, as well as the average arrival rate is l . That $m = T_d^{-1}$ and user calling duration is exponential distribution. The average duration T_d is 180s.Their are 1000 calling-requests during the simulation.

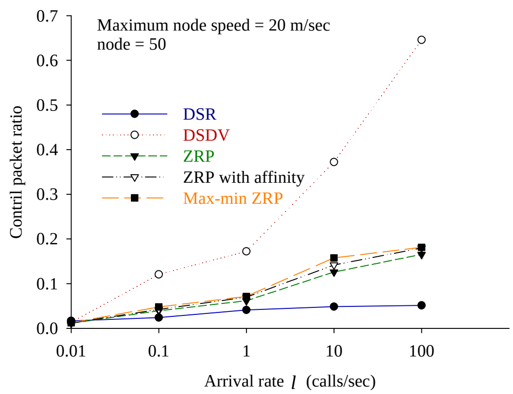
B. Simulation Results



(a) $P_{success}$ vs. λ



(b) Control overhead vs. λ



(c) Control packet ratio vs. λ

Figure 4 λ v.s. P_{sucess} , control overhead and control packet ratio

Fig. 3 shows the influence of transmission success rate and control overhead by the speed of nodes. Because our proposal possesses the ability of prediction invalidity time of path, we can handle it effectively. Fig. 4 shows the influence of transmission success rate, control overhead and control packet ratio by the arrival time $1/\lambda$ (seconds per call), and vice versa the arrival rate defines λ.

We can discover when the arrival rate of user calls increase, the control overhead of DSDV is higher than DSR. Because DSDV must exchange its information with neighbor nodes, so its control overhead will increase, and the ratio of control packet will be higher. The method we propose is based on ZRP. Consequently, the control signal overhead is between those of DSR and DSDV. We simulate the method we proposed with QoS scheme, we divided the zone radius into Z=2. We can discover when the arrival rate is lower, the route discovery latency will be smaller, but when the arrival rate is higher, the route discovery will increase. We can discover the more QoS type traffic that must cause more call blocking rate. If the load of network is very heavy, new calls will be sacrificed; the call blocking probability will be increased. We find out the loss rate is less than all Best Effort traffic with our proposal and just only 30~40% miss rate with our predictive policy. Similarly, the transmission success rate is also higher than ZRP even without pre-route of our method. If the load of network is very heavy, the route discovery latency of network may be long, but they are also much less than 1 sec that is the unit of the predictive time.

Conclusion

The Ad hoc network makes it easy to build up a network environment anytime, anywhere. But the node mobility will break down the paths transmitting data and make the system ineffective. So we propose a method to prediction the broken time of a path and can find a most stable path. According to the simulation results, we can discover if without the QoS service, the transmission success rate of the most stable path we select can increase at most 40% of the ZRP, and its control load can in a certain range. When QoS service is taken into consideration, if the load of network is very heavy, the packet loss rate of network may also stays at 60% below, but new calls will be sacrificed, the call blocking probability will increase. The transmission success rate of our method without the function of pre-route is also better than ZRP. So the Stable path is useful.

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