Performance Evaluation on Ad-Hoc Network of IEEE802.11 with Considering Multi-Rate and Per-Flow Scheduling in Relay Nodes

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***Abstract*— This paper evaluates throughput characteristics of a multi-hop network, where a relay node itself has own traffic as well as relays transit traffic. In addition, it also has an individual per-flow scheduling such as weighted round-robin scheme to send transit and own data farther. The best route is determined in terms of various QoS criteria such as total throughput and relay node throughput. Novelty of this paper is that the best route is determined by considering both multi-transmission rate property, performance anomaly as well-known in IEEE802.11 wireless LAN and the scheduling scheme. Evaluation results show interesting characteristics of the network.**

Keywords*— *Multi-hop network, wireless LAN, destination selection, throughput

I. INTRODUCTION

Because of per-packet charge or measured rate for LTE/3G and free of charge for Wi-Fi (IEEE 802.11) networks being popular in many countries, accessing Wi-Fi networks are essential for mobile users that care communication cost. Relay network technologies such as ad-hoc network or multi-hop network make it possible to enlarge a Wi-Fi cover range and bring the Interet access to more users. Ad-hoc network is useful in a case where one who has no privileges to directly access an access point (AP) or a hotspot which is set in a public space can connect via someone who can have privileges. This means that a node "A" cannot connect directly to a hot spot but can connect to "B", and "B" can directly connect to the hot spot, then "A" can connect to the hot spot. For better QoS such as throughput, when "A" has multiple candidate relay nodes to the hotspot, "A" should connect to the best candidate. In other words, "A" may virtually connects to all the candidates and takes the best route via the best candidate among them.

There are many researches for ad-hoc network [1]. Incentive problems, however, remain to be unsolved. Moreover, in above case, "B" has two kinds of traffic, own traffic and transit traffic delivered from "A" to the hot spot. "B" should consider a scheduling scheme that gives each traffic some weight to be sent. Multi-transmission rate property that could cause performance anomaly that is well-known in IEEE802.11 wireless LAN should be also considered.

In this paper, effects of the scheduling method on total throughput of the ad-hoc network are investigated. Novelty of this paper is that the best route is determined by considering both multi-transmission rate property and scheduling scheme at a relay node. It is also shown that a relay node "B" can have incentives to avoid performance anomaly when it conveys traffic delivered from a request node "A", in order to maximize throughput of "B".

II. QOS POLICY, SCHEDULING AND THROUGHPUT

A. Multi-Rate and Performance Anomaly

In a wireless LAN, a preferable transmission rate depends on a distance between communicated terminals or between terminals and an AP. Generally, the larger the distance is, the lower the preferable transmission rate is. When multiple different transmission rates are used in a wireless LAN where discrete values of 54, 48, 36, …, 6 Mbps are specified in IEEE802.11g, *performance anomaly* happens in case of saturated traffic [2][3]. As it significantly reduces total system throughput, individual terminal throughput is also reduced. The throughput is estimated by harmonic mean of the transmission rate $\boldsymbol{v_i}$ of the terminals [2][3].

B. QoS Policy and Scheduling

Imagine nodes (called *tenants*) send their traffic through relay nodes (called *owners*) toward an AP as shown in Figure 1. All the nodes are placed in the same carrier sensing range, that is, they share the same single channel in the framework of CSMA/CA. An objective of this research work is to decide the best route for the tenants and evaluate the throughput.

Tenants and owners have their own policies for QoS. A policy may be selfish. The selfish policy for a tenant maximizes the tenant's throughput regardless of an owner's throughput. Note that an owner can have a different policy, for example, it is not selfish. Due to the space limit of this paper, let all tenants' and all owners' policies be selfish. Thus, owners

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decide their scheduling scheme or scheduling weight for themselves, and tenants decide the best route for themselves.

In this paper, it is assumed that each owner advertises its individual weight for own traffic and transit traffic then a tenant decides the best owner to send its traffic based on the weight. It is also assumed that all the nodes can know all the connectivity situation (connectivity information), transmission rate, and any other information enough to calculate total system throughput and individual node throughput. This means that an owners can control a tenant's best route by adjusting their weight parameters. Traffic is assumed to be saturated and includes no higher layer control such as TCP.

III. Throughput and Connection Destination Selection

A. Evaluation Model

A network in Figure 1 is used to evaluate effects of weight parameters of owners and the best routes of tenants. Values beside the link between nodes denote transmission rates. All tenants cannot be connected directly to the AP. For selfish **Owner1**, it looks better to enhance own traffic much more than transit traffic. It is, however, not true. In the case that transit traffic uses the other owner **Owner2**, performance anomaly may happen and reduce **Owner1**'s throughput as well as total throughput. Thus, **Owner1** should not be too selfish and should reasonable weight to transit traffic. This is an incentive of an owner to convey tenants' traffic.

The weight of scheduling is set as [**Owner1**]: [total throughput of tenants through **Owner1**] = *a*:1 and [**Owner2**]: [total throughput of tenants through **Owner2**] = *b*:1. **Tenant** 1 ~ *s* (<= *n*) use the **Owner1**, *t* (= *n-s*) use **Owner2** and *n*=3.

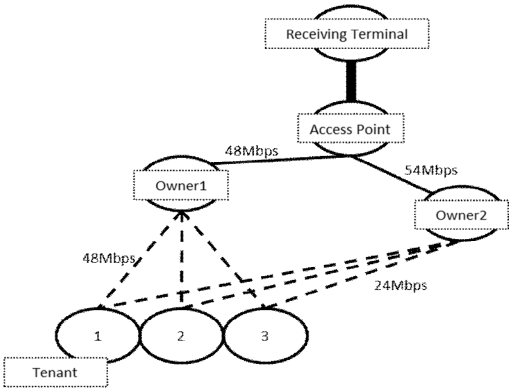

Fig. 1. Evaluation model

B. Evaluation Results

Figures 2 and 3 show the results for the weight parameter *b*=1 and 1<=*a*<=20 for **Tenant1** throughput and **Owner1** throughput, respectively. In Figure 2 therefore, **Tenant1** should use **Owner1** for 1<*a*<6 because 1:2 (green curve) has the largest throughput, and should use **Owner2** for 6<*a*<20 because 0:3 (violet curve) has the largest as shown in the thick curve. Thus, the best parameter for **Tenant1** is *a*=1. On the other hand, **Owner1** has to have its own throughput as shown in the thick curves in Figure 3. The thick curve shows that **Owner1** has the best result by taking 6<*a*. Thus, it is the best for **Owner1** to advertise its weight as 6<*a*.

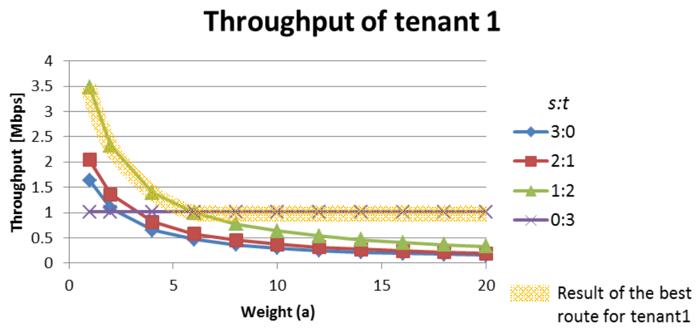

Fig. 2. Throughput of tenant 1

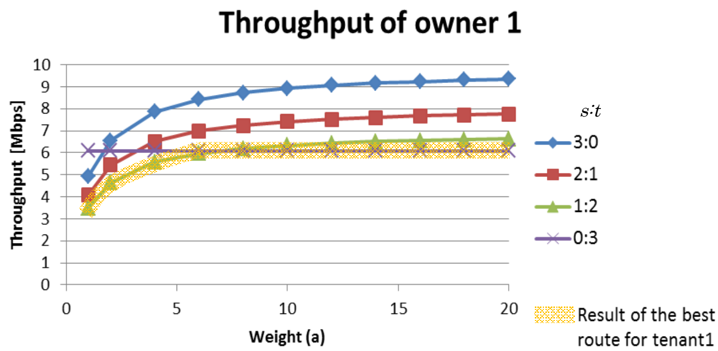

Fig. 3. Throughput of owner 1

IV. Conclusion

This paper describes performance evaluation on ad-hoc network of IEEE802.11 with considering both multi-rate and scheduling scheme for own and transit traffic in relay nodes. With taking account of performance anomaly from multi transmission rate, scheduling traffic in a relay node and selecting the best route significantly affect QoS such as throughput. It is shown that a relay node can control the routing of a node by adjusting scheduling parameters when the node chooses and connects the best relay node among the candidate relay nodes. Evaluation results show that a relay node has a preferable weight based on its QoS policy.

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