CHAP - Credit-based Home Access Point for Overall Application QoS Improvement

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1. INTRODUCTION

Wireless APs have become very popular in networking multiple devices at home and allow multiple individuals to share the Internet connections, doing different tasks simultaneously. People use not only desktop and laptop computers but also many other devices with network capabilities. These devices include gaming consoles, portable gaming consoles, Voice-over-IP (VoIP) phones, video streaming servers, cell phones, PDAs, etc. Each application run on these devices has its own Quality-of-Service (QoS) requirements. For example, a user playing a game on a Playstation 3 would like to have low latency to enjoy the online game. A user downloading a high-definition (HD) quality movie trailer would like to get consistent, high throughput. Multiple activities done over the same Internet connection cause congestion and degrade application performance for some of the users. A typical example is when a user tries to voice chat online while another user downloads a huge file, the voice chat suffers from choppy sound and increase in one-way delay.

Increase in latency for delay sensitive applications is an indication that there is a queue buildup somewhere along the network path. In a typical Internet connection setup, there are three places of interest for congestion: ISP gateway, modem and wireless AP. The link between the ISP gateway and modem depends on the Internet subscription and connection type. The link between the modem and the wireless AP is 100 Mbps to 1 Gbps. And devices at home connect to the wireless AP at speeds up to 270 Mbps over 802.11n. The queue is most likely to build up over a bottleneck link and this depends on the connection capacity of the Internet from the ISP. The fastest Internet access offered in the US is 50 Mbps downstream and 20 Mbps upstream from Verizon. However, ISPs are trying to push faster broadband access to homes worldwide. Hong Kong, Japan, The Netherlands have deployed or is in the process of testing 1 Gbps. Sweden tested 40 Gbps connection to a home. With such high bandwidths available to homes, it is most likely that the wireless AP is bound to the source of the bottleneck. Historically, wireless communication capaticy has been lower than wired capacity and will likely remain thus.

There are some solutions that are implemented by the manufacturers for wireless APs to provide basic QoS support. Some wireless APs support prioritizing physical ethernet ports for a specific device connected over a cable. They also support prioritizing flows based on their protocol type and port for known traffic. However, average users have considerable difficulty understanding and configuring wireless APs. Even with experienced users, these solutions have some limitations. For port-based priorities, users need to know the protocol and ports applications use. It is also difficult for new applications to receive appropriate treatment. These limitations have prompted research in classification of flows to provide specific QoS needs for them.

Classification of flows removes the need for users to configure their wireless APs to prioritize their traffic. Instead wireless APs will examine the flows and classify them atomatically. However, there are some limitations to current classification approaches due to the dynamic nature of wireless conditions. Change in the wireless network connectivity can bring down the overall performance and QoS of the home network if flows with poor connectivity are given higher priority. In such a situation, it is recommended to move away from giving priority to flows with poor connectivity despite their classification.

This extended abstract proposes a credit-based queue management technique for wireless APs to classify flows implicitly based on their wireless connectivity and QoS requirements and treat them accordingly to improve overall application QoS. A full presentation of this technique and evaluation of its performance is an ongoing work for the thesis [1].

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2. USER ACTIVITIES AND THEIR CHARACTERISTICS

Network applications can be characterized based on their bandwidth usage, delay constraint, burstiness, duration, etc. Popular user activities involving network are web browsing, audio/video streaming, Voice over IP (VoIP), instant messaging, online games, emails and file downloads. Bandwidth usage and delay constraint are the characteristics of interest to us.

Figure 2 depicts the bandwidth usage and delay tolerance of different types of user activity based on our survey of various papers. It demonstrates that there is a direct relationship between activities' bandwidth usage and delay tolerance as shown by the grey rectagle. The more bandwidth a user activity uses, the more delay tolerant it is. In other words, the activities that require more bandwidth tend not to have strict delay constraints.

3. PROPOSED APPROACH

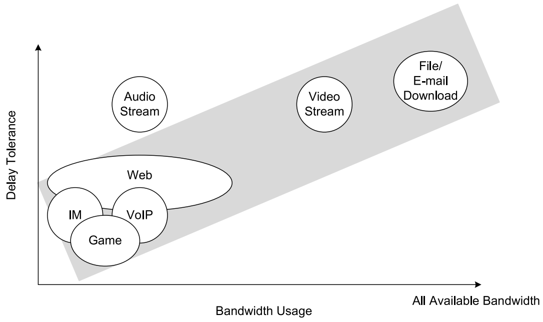

Figure 1: Characteristics of Network Applications

Our proposed approach, Credit-based Home Access Point (CHAP) exploits the property demonstrated in Figure 2. Bandwidth usage can be observed easily at the AP because every packet that arrives and leaves the home network must go through the AP. Since the AP is responsible for routing traffic to the right host within the home network, it keeps track of the Network Address Translation (NAT) table with 5 tuple per entry: source address, source port, destination address, destination port and protocol. This is the same set of information used to identify a flow and we propose adding credits to this set of information. Credits are decremented by cost of transmission and therefore reflects which flow is least costly to serve. Cost is a combination of bandwidth usage and wireless condition.

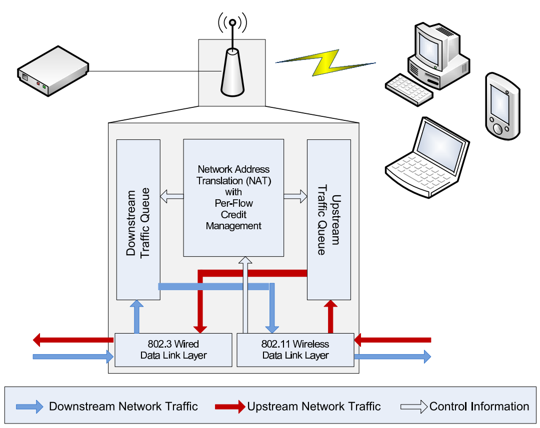

Figure 2: Block Diagram of CHAP

Figure 2 depicts the components of CHAP inside an AP. The solid arrows show the downstream and upstream network traffic in and out of the home network. The major difference from the current APs is that the downstream and upstream queues get control information from the enhanced NAT component with credits to prioritize the packets in the queue. In addition, the NAT component requires control information from the 802.11 data link layer to update the credits.

In order to consider both bandwidth usage and wireless conditions, CHAP uses transmission time of a frame as the cost for credits. The more frames a flow needs to transmit, less credits it will have. The more time frames take for a flow, less credits the flow will have. Therefore, the flow with lowest credit draining rate gets the highest priority. This mechanism is to balance nodes with poor connectivity even though they use delay sensitive applications.

In addition to cost of credits, CHAP needs a mechanism to boost the credits when everyone runs out of them. The basic form of credit boost formula used in Linux process scheduler ($C'_i = \frac{C_i}{2} + I$) where i is the flow index, C_i is the credit of flow i and I is the increment. This mechanism is used when every backlogged flow has 0 or less credits and applied to every active flow's credit. The parameter I is in units of time, consistent with the unit of credits and the value is currently to be determined. The status of active flows is determined by the last time a packet was served from a particular flow and the timeout is also to be determined.

dequeue()

1 find k such that $\alpha_k = max[\alpha_1, ..., \alpha_n]$ and $k \in$ set of backlogged flows

2 if $\alpha_k \leq 0$ then $\alpha_i = \frac{\alpha_i}{2} + I$ for all $i \in$ active flows

3 dequeue p from kth flow

4 $\alpha_k = \alpha_k - cost$

enqueue(p)

1 add p to the end of the queue

Figure 3: CHAP Algorithm for Downstream Traffic

Figure 3 summarizes the algorithm for downstream traffic in a pseudo code format. Step 1 in dequeue() finds the flow with the highest credits. Step 2 checks if the credit boost is necessary and boosts credits for all active flows. Step 3 dequeues the packet from the flow picked in Step 1 and the credit is decremented according to the transmission time spent at the wireless data link layer.

The IEEE 802.11 shares the same space for both downstream and upstream traffic. Therefore, the credits need to reflect how much wireless resources a flow uses in both downstream and upstream. Upstream traffic is impossible to measure exactly how long the transmissions took. At this time, we make an assumption that most of the traffic in home network is downstream and ignore the upstream traffic. Investigation on how to account for upstream traffic is ongoing.

The mathematical model has been developed to estimate the range of credits of flows with different bandwidth usage and how they affect the latency of the flows. The delay analysis of probabilistic priority discipline from [2] has been used to calculate the average queueing delay. The range of the credits has been used to calculate the probabilities needed for the analysis. The full derivation and analysis are available in the thesis [1]. Analysis based on two flows with different bandwidth usage shows that CHAP can provide lower queueing delay for a flow with lower credit draining rate than the other.

4. REFERENCES

[1] Choong-Soo Lee. CHAP - Credit-based Home Access Point for Overall Application QoS Improvement.

[2] Yuming Jiang and Chen-Khong Tham and Chi-Chung Ko. Delay Analysis of a Probabilistic Priority Discipline, Nov./Dec. 2007.