IMPLEMENTING A DYNAMIC PRICING SCHEME FOR QOS ENABLED IPV6 NETWORKS

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Abstract: Currently the Internet based on IP supports a single best-effort service in which, all packets are queued and forwarded with the same priority. No guarantees are made regarding timely and guaranteed delivery. However, many e-commerce applications, that are delay and loss sensitive, use the Internet as a transport infrastructure because of its reach-ability, and cost efficiency. Challenges faced by ISPs supporting e-commerce traffic include enhancing their traffic flow handling capabilities, speeding the processing of these packets at core routers, and incorporating Quality of Service (QoS) methods to differentiate between traffic flows. These schemes add to infrastructure costs of network providers which can be recovered by introducing extra charges for QoS enabled traffic. Many pricing schemes have been proposed for QoS-enabled networks. However, integrated pricing and admission control has not been studied in detail. In this paper a dynamic pricing model is integrated with an IPv6 QoS manager to study the effects of increasing traffic flows rates on the increased cost of delivering high priority traffic flows. The pricing agent assigns prices dynamically calculated according to the network status for each traffic flow accepted by the domain QoS manager. Combining the pricing strategy with the QoS manager allows only higher priority traffic packets that are willing to pay more to be processed during congestion. This approach is flexible and scalable as pricing is decoupled from QoS decisions and reservations.

1 INTRODUCTION

Traditionally IPv4 incorporates simplistic pricing approaches such as flat rate for unlimited usage and is based on a fair distribution of costs. IPv6 supports QoS by introducing the flow label field which uniquely defines all the packets belonging to the same flow. In IPv6 domains, a QoS manager can take advantage of the flow label and traffic class fields, to handle domain resources and to differentiate traffic flows. This system is capable of negotiating QoS parameters, upon accepting user connection, that includes guaranteeing the quality. Therefore, the resource for delay and loss sensitive traffic is secured and these flows are processed faster than other flows. Such differentiation makes pricing an important, if not critical issue, in today's Internet. In the future the issue of pricing will be more relevant as more E-commerce applications begin to rely on the Internet for their delivery (Faizuullah, 2000). Flat pricing is unfair as it does not differentiate between traffic flows with differing QoS requirements. Proposing appropriate pricing for QoS-enabled networks is a challenging problem as pricing must be integrated with admission control strategies (Tianshu, 2004). Our IPv6 QoS manager uses a combination of a packet's flow ID and the source address (***Domain Global Identifier*** (**DGI**)) (Fgee, 2004), to process and reserve QoS inside a domain. This QoS manger is integrated with a dynamic pricing model (Tianshu, 2003) to study the effects of increasing traffic rates on the increased cost of delivering high priority traffic flows. The pricing agent assigns prices for each traffic flow initially accepted by the domain manager. Pricing is dynamic and calculated based on network status.

Section 2 defines QoS and the parameters used to measure it. Section 3 discusses the new elements of IPv6 needed to enable QoS. Section 4 gives an

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overview of the proposed IPv6 QoS manager (Fgee, 2004). Section 5 discusses how the dynamic pricing model is integrated with the QoS manager. Simulation results are presented to illustrate the feasibility of the integrated approach.

2 QOS REQUIRMENTS

QoS is the ability of a network to provide better services to selected network traffic over different underlying technologies. End-to-end delay, jitter, bandwidth and packet loss rate are the parameters typically used for characterizing QoS of individual connections or data flows (Jha, 2002). The elements commonly involved in providing QoS guarantees are (Jha, 2002): 1) Admission Control determines access to available network resources and keeps track of all reservations. 2) Policing is performed when a flow's actual data traffic exceeds the requested values given in the traffic specifications. In such cases the packets are dropped or downgraded to a best effort service class or marked as non-conforming. 3) Packet classification identifies packets belonging to a specific flow and designates a QoS class for this flow. 4) Packet scheduler ensures that the flows identified by the packet classifier receive the requested QoS. 5) Traffic control implementation involves queuing methods employed to control traffic at routers interfaces. Function 1) and 2) are handled by the domain QoS manager. Functions 3) and 4) are implemented at the edge points.

3 INTERNET PROTOCOL V6

Two components of IPv6 are used to deliver QoS, the first is the 8-bit priority field in the IPv6 header that can be used to identify and discriminate traffic types based on contents of this field. The second component is the flow label which is used to label packets belonging to traffic flows for which the sender requests special handling. Network elements can now classify packets based on IP semantics allowing for efficient mapping of packets to their flows and hence to their flow specification policy. The flow label is chosen by the IPv6 QoS manager and is used for reserving resources, and routing and monitoring traffic flow packets. Also, packets can now be associated with particular service classes and IPv6 routing performed on the basis of these classes, thus improving the performance of core routers. The benefits of this scheme (Fgee, 2004) are its simplicity and speed.

4 IPV6 QOS MANAGEMENT

The proposed QoS scheme handles QoS requests by processing, monitoring, and controlling the traffic flows. Weighted Fair Queuing (WFQ) is used to separate the flows in which separate queues are assigned for each traffic flow. The IPv6 QoS management system uses the DGI and traffic class (TC) field for reserving and tracking traffic flows. This scheme is unique in that the IPv6 network can be managed without invoking any other QoS protocols such as RSVP or MPLS. The end-to-end delay is less as the backbone routers use the DGI for forwarding decisions as compared to the longest match procedure used by other schemes. This technique is scalable as the edge routers handle QoS requests and communicate with other QoS managers. Traffic flows are classified based on the TC field so that each priority level is treated differently. A sender sends its QoS request to the network edge router. Upon receiving requests, the edge router communicates with its domain manager to approve or reject these requests. The edge router forwards the manager's responses, either positive or negative, to the sender. When accepted, the source starts sending data packets to the edge router where traffic flow packets are classified, scheduled and monitored. Packets are queued depending on their TC field and the policies set by the QoS manager. The leaky bucket algorithm is implemented to police incoming traffic. The algorithm parameters for the accepted traffic are setup according to their traffic specifications. When a flow violates its requested specification, its priority level is degraded or its packets dropped.

5 DYNAMIC PRICING MODEL

The pricing model is based on the DiffServ end-to-end pricing scheme introduced in (Tianshu, 2003). In this market based model the value for the base price P^i_{base} and fill factor f^i is set by the network provider for each traffic type. The fill factor is the ratio of target capacity T_i to the maximum capacity $C^i_{\max}$ for a service class *i*. The price $P_i(t)$ for a class *i* at time *t* is computed (Tianshu, 2003, Waog, 2001) by:

$$P_i(t) = P_i(t-1) + \alpha_i (D_i - T_i) / T_i$$

Here, D_i is the demand or current load for class *i* and α_i is the convergence rate factor that determines how the price converges to its maximum. Figure 1 illustrates the general pricing strategy. When the load for a particular service class is lower than its targeted capacity, the price is the base price P^i_{base} for that particular service class. As the load exceeds its target capacity, and when the load is close to the maximum capacity, the price is increased rapidly i.e. we have a dynamic pricing scheme where the price is a function of current network conditions.

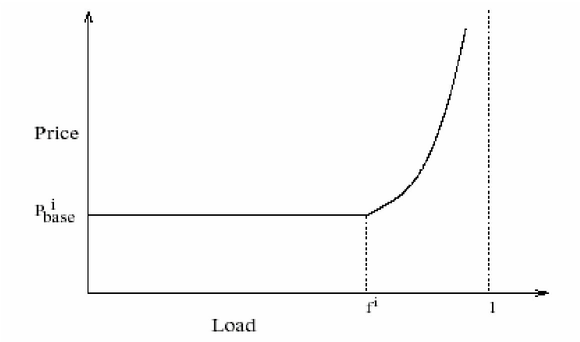

Figure 1: General pricing strategy

During demand increase we adopt the exponential pricing strategy.

$$P_i(t) = \begin{Bmatrix} P^i_{base} & if \quad D_i \le T_i \\ P^i_{base} e^{\alpha\,[\frac{D_i}{T_i} - 1]} & otherwise \end{Bmatrix}$$

A price limit, $P^i_{\max}$, indicates the price when the demand reaches maximum capacity is set for each service class that and is given by:

$$P^i_{\max} = P^i_{base} e^{\alpha_i [\frac{D_i}{T_i} - 1]}$$

Knowing $P^i_{\max}$, P^i_{base} and the fill factor f^i for a service class *i* gives the solution for the convergence factor α_i that determines how the price converges to the maximum.

$$\alpha_i = \log(\frac{P^i_{\max}}{P^i_{base}}) * (\frac{f^i}{1 - f^i})$$

The total revenue is the sum of all classes' prices.

5.1 Pricing integrated QoS manager

Figure 2 shows the flow chart of the proposed pricing model. This figure summarizes the functions performed by the various network entities in implementing the pricing strategy. The source initiates the QoS request and waits for responses that include the acceptance messages and the associated prices. The edge router forwards requests and responses. It monitors all traffic packets entering the domain. The IPv6 QoS manager processes the QoS requests and then sends the network status for each accepted traffic flow to the pricing agent. The pricing agent calculates the price for each accepted traffic flow by first finding f^i using the information received from the domain QoS manager which includes the expected traffic rate (T_i) and the max allowed rate ($C^i_{\max}$). The pricing agent attached to the edge router initiates the price according to the network status and the defined base price (P^i_{base}) for each traffic class accepted by the manager. Prices are sent to the customers that initiated requests who accept or reject the prices.

6 SIMULATION RESULTS

We study the behavior of the integrated pricing model in an IPv6 QoS capable environment using the ns-2 simulator (NS-2, 2004). Figure 3 illustrates the network topology used in simulations and consists of 4 core and 2 edge routers. The Ingress router acts as the pricing agent and handles QoS requests generated by source1 and source2 nodes. The total capacity of each link is 1 Mpbs with a propagation delay of 1 msec. The traffic flow specifications are: Source 1 has a traffic rate of 500 Kbps with priority 15 and Flow ID-15. Source 2 has a traffic rate of 250 Kbps with priority 12 and flow ID 12. Source 3 has a traffic rate is 250 Kbps, is classified as Best effort type with flow ID- 8. The base prices P^i_{base} for each class is set at $0.16, $0.09 and $0.04 per unit time respectively starting with the flow with the highest priority. Simulation was performed on three flows with FID-15 having the highest priority when the total link capacity reaches 50%, FID-12 has the 2nd highest priority when the total link capacity reaches 70% and FID-8 is classified as Best Effort for all link capacities (Tianshu, 2003).

Two simulation scenarios have been tested for each traffic flow, one when the total link load is less than the percentage assigned for each flow and the other one when the traffic exceeds these percentages. Figure 4 shows the change of the prices for traffic flow FID-15.

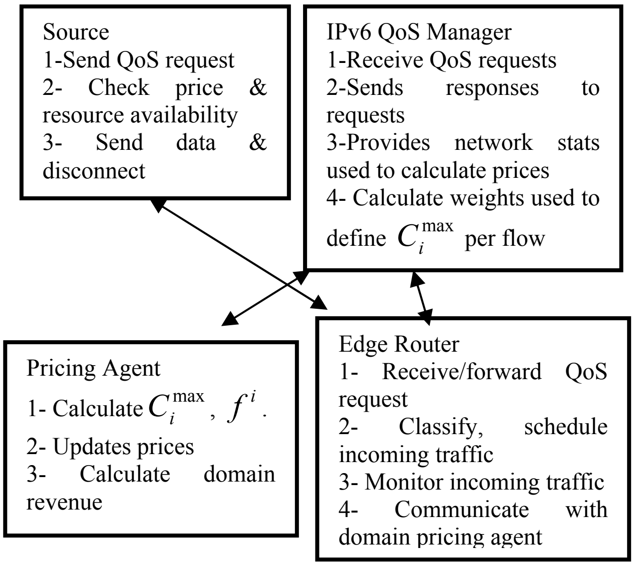

Figure 2: Flow chart for the IPv6 pricing model

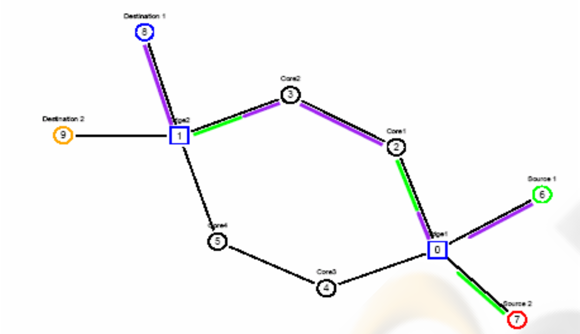

Figure 3: Simulated pricing model network

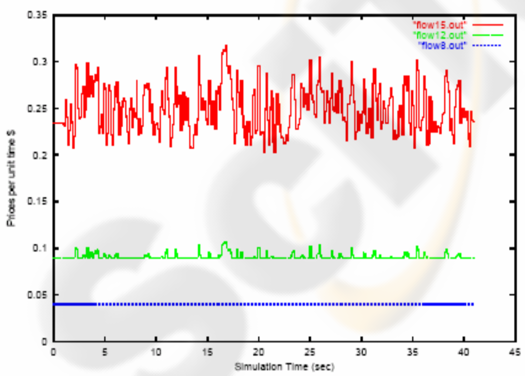

Figure 4: Prices for the three traffic flows FID(15) & FID(12) and FID(8)

From Figure 4 it is seen that the prices change rapidly as the load increases which results in more revenue. We see that the changes in the prices for traffic flows FID-12 does not change much since its percentage is set to 70% and the packets of this flow are not as critical as the first one. This also results in a small increase in the revenue compared with the first one. However, during congestion packets belonging to FID-12 are degraded to best effort as per the policies set by the QoS manager. Best Effort flow packets have no change in prices since the expected load is set to 100%, however, they are the first to be dropped during congestion.

7 CONCLUSION

The main objective in IP billing schemes is to price network resources dynamically, especially during congestion. In this paper, an IPv6 QoS manager was integrated with a DiffServ dynamic pricing model. The manager allows only higher priority traffic packets that are willing to pay more to be processed during congestion. In this approach the pricing is decoupled from QoS decisions/reservations thus avoiding per-flow based messaging for either pricing or admission control. In addition to the scalability and simplicity, more revenues are generated as prices change dynamically according to the network status.

REFERENCES

Fgee, E., Kenney J., Phillips, W.I., Robertson, W., Sivakumar, S., "Implementing an IPv6 QoS management scheme using flow label & class of service fields", *IEEE CCECE 2004.* vol 2 , pp.851- 54.

S. Faizuullah and *Marsic, I*, "Pricing QoS: Simulation and Analysis", *Proceedings. 34th Annual* Simulation *Symposium,* 2001, Pp 193-199.

Tianshu Li, Y. Iraqi and R. Boutaba, "Pricing and admission control for QoS-enabled Internet", *Computer Networks*, 2004 Published by Elsevier.

S. Jha and M. Hassen, "Engineering Internet QoS", Artec House Boston, London 2002.

Tianshu Li, Y. Iraqi and R. Boutaba, "Traffic-Based Pricing and Admission Control for DiffServ Networks", *Integrated Network Management,* 2003. IFIP/IEEE 8th Intl. Symposium, pp. 73-86.

X. Waog and H. Schulzrine, "Pricing Network Resource for Adaptive Applications in a Differentiated Service Network", INFOCOM 2001., Vol 2 , Pp: 943 – 952.

NS-2 The Network Simulator ns-2, Oct. 30, 2004. http://www.isi.edu/nsnam/ns/.