Research of Fine Granularity Diffserv Mechanism and Optimized QoS Mapping based on Policy Management

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Summary:

Present DiffServ can only provide rough granularity QoS guaranteed for clients since limited PHB classification. In this paper, a policy based Fine Granularity DiffServ mechanism as well as Universal Expression of Differentiated Service is proposed. The core idea of fine granularity differentiated service is that we can obtain different per domain behavior (PDB) by composing multiple per hop behaviors (PHB) in the path they passed. Then a GAs based optimized PHB composition algorithm is designed. The results show that the near global optimal solution can be easily and quickly obtained by this method.

Key words:

QoS Management; policy; DiffServ; QoS Mapping

1. Introduction

It is a hotspot problem to study on how to provide different levels of QoS guarantee over the current IP Network. The Internet Engineering Task Force (IETF) has made a lot of efforts, such as QoS modeling and QoS guaranteed mechanism. Integrated Services (Intserv) and Differentiated Services (DiffServ) are two of the most investigated models[1]. Although DiffServ has the character of simpleness, it is somewhat coarse about the classification of traffic flow since limited service classification cannot satisfy thousands of clients' requirements. In addition, the current QoS management is mostly static, not adaptable. However, the policy based management provided by IETF[2] has the advantage of abstract, automatism, integrity and dynamic, which is broadly used in QoS management and security management domains [3-5]. This paper provided a policy based Fine Granularity DiffServ mechanism as well as an optimized policy-based QoS mapping architecture on DiffServ. We provided Fine Granularity services for clients through an Optimized PHB composition. The experiment demonstrated that the algorithm is practicable.

2. QoS Mapping and Policy based Management

The aim of QoS management is to provide different services according to different data flows as well as efficiently utilize network resource to ensure the service quality of different clients. As to the clients, it is difficult for them to provide specific value of QoS parameters. But they should understand their own QoS requirements explicitly, which can be negotiated through SLA with internet service provider (ISP). On the other side, ISP provides different services for clients, which can be assigned different priority[8]. A data flow with high priority can be preferentially satisfied. Clients only need to select certain service grade, then the QoS management system is responsible for transform clients' SLA into a group of specific QoS parameters. This process is regard as QoS Mapping[6]. The key problem of QoS Mapping is how to minimize the total cost of network and maximize the utilization rate of network on the precondition of satisfying the clients' QoS performance. The paper [6], [7] had given thorough research on QoS mapping and QoS adaptability management.

Policy based management can control the use of bandwidth by predefined policy on the basis of dynamic factors (such as timing, priority and network status). Its distinct character is able to set and implement personalized policy according to clients' requirements, which is coherent with dynamic and adaptable QoS management [3-5]. The framework for QoS mapping based on policy is composed of four layers including application layer, SLA negotiation layer, policy management layer and network layer. Policy controller is the core component of the system. It fulfills the mapping from SLA into specifically QoS parameters and also the mapping optimization. It can evaluate whether the QoS parameters achieving the requirements of clients through QoS mapping. It is a challenging problem to satisfy the QoS requirement for different clients dynamically by assign bandwidth and other network resources based on policies.

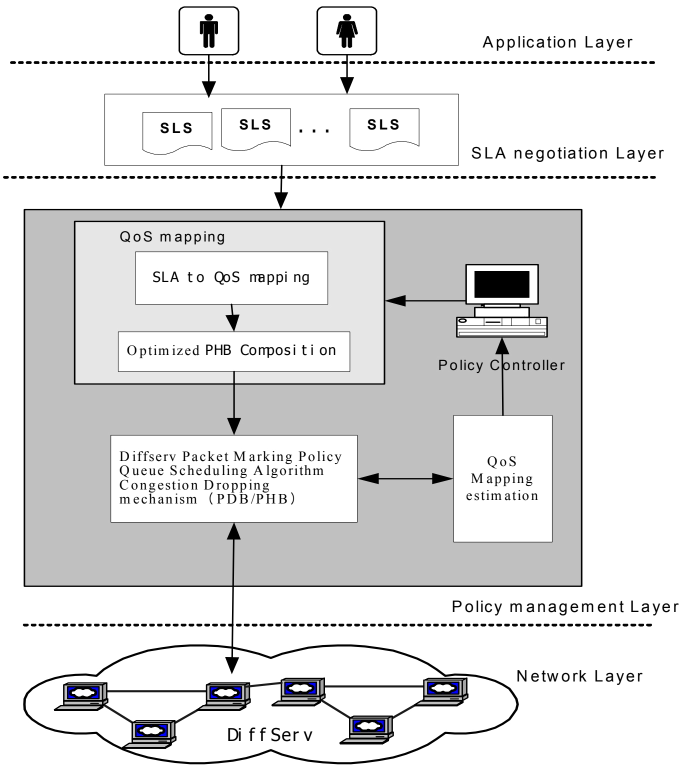

Fig1. Policy based QoS mapping Architecture

3. Policy based Fine Granularity DiffServ Mechanism

Per Hop Behavior (PHB) is an important concept in DiffServ model[8]. PHB describes the transmitting behavior of each DiffServ node. But PHB is only the outer character description. It does not involve the specific mechanism to achieve and can be achieved through queues scheduling and buffer management algorithms. Per Domain Behavior (PDB) means that a special group in DS domain wants to get "peer to peer" service. Every PDB should include one or a group of the corresponding PHB and the means of marking and so on [9]. At first we give the related definitions below:

3.1 Definitions

Differentiated Services Domain(DS domain) ： Domain is a duple $D=(N,L)$, where N is the set of network nodes. L is the set of links between network nodes. Obviously, $\forall l=(n_1,n_2)\in L$, it is satisfied that $n_1\in N, n_2\in N$. Then a domain which supports DiffServ is called a DS domain, namely a contiguous portion of the Internet over which a consistent set of differentiated services policies are administered in a coordinated fashion.

There are many Quality of Service parameters, including time-related parameters such as delay, maximal delay, jitter and maximal jitter. Also include capacity parameters such as maximal throughput, average throughput, bandwidth, maximal bandwidth etc. And reliability parameters such as lose rate, error rate etc. Security parameters such as encryption level etc.

Service Level Specification (SLS) ： SLS is a set of parameters and their values together define the service offered to a traffic stream by a DS domain. It is expected to include specific values or bounds for PDB parameters [9]. Suppose the set of Quality of Service parameters is $Q=\{q_1,q_2,...,q_n\}$. Then SLS is a vector such as $\{v_1,v_2,...,v_n\}$, where $v_i\subset V_i(1\le i\le n)$ and V_i is the set of the value of q_i

Per Hop Behavior (PHB) ： The transmission policy how Packets send from source node n_1 to destination node n_2 through link $l_{1,2}=(n_1,n_2)$ is called Per Hop Behavior. The performance parameters of data transmission between neighbor nodes is determine by

PHB. In other words, there is a map $f: L \times S \rightarrow V$, where $V = V_1 \times V_2 \times ... \times V_n$, S is the set of all transmission policies. $\forall (l,s) \in L \times S$, $\exists (v_1, v_2, ..., v_n) \in V$, satisfy $f(l,s) = (v_1, v_2, ..., v_n)$.

Per Domain Behavior (PDB): A PDB is characterized by specific metrics that quantify the treatment a set of packets with a particular DSCP (or set of DSCPs) will receive as it crosses a DS domain. A particular PHB (or, if applicable, list of PHBs) and traffic conditioning requirements are associated with each PDB[9]. Suppose the path which packets transmitted through DS domain is $(l_{1,2}, l_{2,3}, \dots, l_{m,m+1})$, where $l_{i,i+1} \in L$, $1 \le i \le m$, m is the number of links during the path. Suppose s_i ($1 \le i \le m$) is Per Hop Behavior at $l_{i,i+1}$, where $s_i \in S$. Then $\{(l_{1,2}, s_1), (l_{2,3}, s_2), ..., (l_{m,m+1}, s_m)\}$ is defined as Per Domain Behavior (PDB).

Universal Expression of Differentiated Services: Assured Service (AS) and Premium Service (PS) are two typical service type of DiffServ[1]. The two kind of service respect to differentiated QoS parameters. AS accentuates bandwidth and loss rate, nor parameters such as delay and delay jitter. On the other hand, PS accentuates low delay, low delay jitter, low loss rate and guaranteed bandwidth. Based on this characteristic, a special kind of service can be defined as $W \times Q$. and $W = (w_1, w_2, ..., w_n)$, $Q = \{q_1, q_2, ..., q_n\}$. w_i is the weight of q_i.

3.2 Fine Granularity Diffserv Mechanism

In DiffServ, Service Type and PHB implementing are separate each other in definition. This method is much more flexible. Although PHB can implement different services by different boundary classification adjusters, we need define new PHB if new service type cannot be implemented by existing PHB. IETF has defined three basic PHB: Best Effort, Expedited Forwarding and Assured Forwarding [13,14]. Therefore, present DiffServ network can only provide rough granularity QoS guaranteed for clients. Papers [10-12] has designed related model and function for mapping SLA to PDB in order to satisfy clients' SLA. However, PDB is comprised by a group of the same PHB, which is lack of mechanism to compose multiple PHBs into PDB. Thus, the number of differentiated service grade is limited. On the other hand, the type of differentiated service is closed related with charge. The higher grade means the better guaranteed QoS , but the cost is also expensive. At the same time, if all clients select the higher grade of broader bandwidth, higher transmitting rate and lower delay, it will cause the waste of network resource to some extend, which is not sensible for optimized utilization of resources[6]. The aim of the fine granularity differentiated service based on policy and related optimized algorithm this paper presented is to make the QoS parameters QoS_{PDB} satisfy or approach the SLA parameters of clients in a DS domain and improve the usage of network resources as much as possible.

The QoS of PDB (QoS_{PDB}): Suppose v_i, u_i is the value of QoS parameter q_i in two neighbor hops, $Syn^i(v_i, u_i)$ is defined as the integrated value of q_i in the two hops. For example, if q_i is delay or loss rate, $Syn^i(v_i, u_i) = v_i + u_i$. If q_i is maximal bandwidth, $Syn^i(v_i, u_i) = max(v_i, u_i)$.

Differentiated PDB results in Differentiated QoS parameters when packets passing through a DS Domain. This is called QoS_{PDB} . IF $PDB = \{(l_{1,2}, s_1), (l_{2,3}, s_2), ..., (l_m, s_m)\}$ then

$$QoS_{PDB} = f(l_1, s_1) +' f(l_2, s_2) +' ... +' f(l_m, s_m) \quad (1)$$

$+'$ is a binary operation, if $\forall (v_1, v_2, ..., v_n), (u_1, u_2, ..., u_n) \in V$, $\exists (o_1, o_2, ..., o_n)$, it is satisfied that $Syn^i(v_i, u_i) = o_i \ (1 \le i \le n)$, then we denoted that

$$(v_1, v_2, ..., v_n) +' (u_1, u_2, ..., u_n) = (o_1, o_2, ..., o_n).$$

Objective Function for Fine Granularity DiffServ: The objective function of our system is defined as

$$O(\varphi_i) = \sum_{i=1}^{m} w_i \frac{|v_i - \varphi_t^i|}{v_{\max}^i} \quad (2)$$

Where $\varphi_t (t = 1, 2, ...T)$ is the possible solution. In other words, a group of PHB as so as $\{(l_{1,2}, s_1), (l_{2,3}, s_2), ..., (l_{m,m+1}, s_m)\}$. v_i is the value of QoS parameter q_i in accord with consumer. φ_t^i is a vector of φ_t . $v_{\max}^i$ is the maximum of q_i . w_i is the weight of q_i , and $\sum_{i=1}^{m} w_i = 1$.

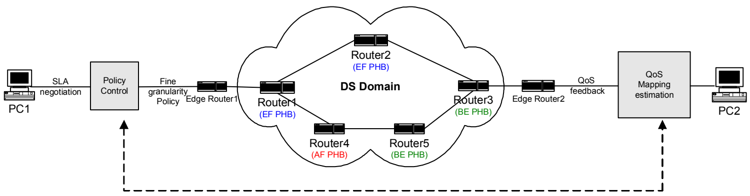

Fig2. Policy based Fine Granularity DiffServ system

The core idea of fine granularity differentiated service is that each hop may have several transmitting policy when the packets passing through a DS domain. Then we can obtain different per domain behavior (PDB) by composing multiple per hop behaviors (PHB) in the path they passed. Assume the path passing the DS domain is $Path = (n_1, n_2, n_k ..., n_p, n_q)$. It can be decided by forward traversal algorithm. The PDB can be presented as $((l_{12}, EF), (l_{2k_2}, BE), ...(l_{pq_n}, BE))$ or, $((l_{12}, AF), (l_{2k_2}, AF), ...(l_{pq_n}, BE))$, therefore we can obtain different fine granularity service quantities QoS_{PDB}, as shown in figure 2. We can compute the optimized PHB composition by genetic algorithm. The goal of PHB optimized composition is that to make the QoS parameters QoS_{PDB} satisfy or approach the SLA parameters of clients, namely $\min O(\varphi_t)$. But if there is no appropriate policy meet to clients' requirement, need to negotiate once again or reduce SLA parameters.

4. GAs in PHB composition

4.1 Coding method and Fitness function

An Optimized PHB composition has many outstanding advantages. It can enhance using of network resources. Also can guarantee the QoS of multimedia applications. In this section, a genetic algorithm based PHB composition policy is presented. We haven't found any similar work in this area until now. An Optimized PHB composition means meet to user's SLA demand proximally and also has a minimum $O(\varphi_t)$. At first, Coding method and initial population are to be defined. The possible solution to the question can be coded as binary digit.

$$\varphi_t = \{R_1, R_2, ..., R_n\}, R_i \in [0, 1, 2] \quad (3)$$

n is the number of core routers during a presumptive path. R_i is the type of specific PHB. In this paper, there are only three typical PHB to be used, such as Expedited Forwarding PHB, Assured Forwarding PHB and Best Effort PHB. When $i = 0$, it means EF PHB to be used at a core router. $i = 1$ means AF PHB. $i = 2$ means BE PHB. In order to start a GAs, it is necessary to create an initial population. We random choose n objects sequence,

$\{0,1,2\}$ as initial population. Because in GAs the maximum nonnegative Objective function is required, we mapping the Objective function to fitness function.

$$A(\varphi_t) = \max O - O(\varphi_t) \qquad (4)$$

$\max O$ is the maximum of Objective function. The goal of the optimized algorithm is to find PHB composition solution as soon as possible. In this GAs, normal mutation operator and crossover operator are adopted.

4.2 Emluator and Evaluation

The applicability of our approach to the Fine Granularity of Differentiated Services networks has been tested on simulated DiffServ networks, using the NS-2. lb9a network simulator. There are groups of C++ class libraries to support DiffServ in NS-2. lb9a, including egde router, core router, adjusters, RED arithmetic, WRED congestion controlling arithmetic etc. Thus can realize various policies such as packet markering, queue scheduling and congestion controlling. In addition, We use C++ to realize GAs PHB composition arithmetic and append it to NS-2. lb9a.

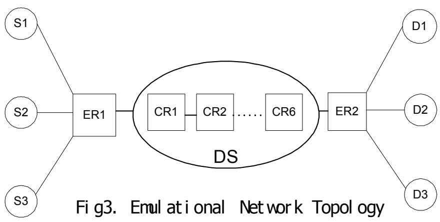

Fig3. Emulational Network Topology

We present results of an experiment based on a simulated typical DiffServ network, with the topology indicated in Fig.3. There are six hosts, two edge router and six core router S1,S2, S3 is source host and D1,D2,D3 is destination host. $(CR1, CR2\ , CR3, ...CR6)$ are the core routers. The parameters between neighbor nodes is that Bandwidth equal to l0Mbps and delay equal to 5ms . We implemented three data flows within this network, CBR flow, TCP flow and UDP flow. Their CIR parameters is 3Mbps， 2Mbps， 1Mbps. RED parameters is {20 30 0. 08} and {10 18 0. 4}. Packet size is 1000 Byte. For the goal of this experiment is not to improve on existing Diffserv arithmetics, we adopt normal AQM/WFQ and WRED arithmetic. Test time is 20 seconds. Emulation result is shown in figure 4.

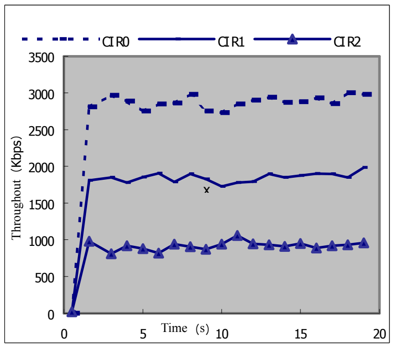

Fig4. Throughput of Individual traffic flows

It indicates that each service flow has get steady bandwidth comparatively by using PHB composition algorithm and above Diffserv arithmetics. Bandwidth is in proportion to their CIR. Although several QoS parameters is not guaranteed better compare to same PHB sequence to PDB，it can get surplus bandwidth

.5. Conclusion and Future Work

This paper provided a policy based Fine Granularity DiffServ mechanism as well as an optimized policy-based QoS mapping algorithm based on GAs. An optimization solution can be achieved in few generations to satisfy fine granularity service. Simulated results shows that the near global optimal solution can be easily obtained by this method, and the solution is definitely satisfactory in PHB composition. We also intend to experiment with Linux based routers as well as commercial routers or switches to evaluate the performance implications of executing policies on routers. In the future work, we will study how to optimize the crossover operator to improve the time performance and convergence precision of the algorithm.

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