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Matching Capability of Hierarchical Nexthops to Forward Packets for Qos

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Abstract: The traditional Qos guarantee mechanisms based on a single nexthop cannot provide really differentiated services in network layer. With the various available nexthops generated by multi-nexthop routing protocol, a new Qos guarantee scheme called Matching Capability of Hierarchical Nexthops is proposed in the paper. It chooses bandwidth and reliability of nexthop link as parameters to measure the performance of nexthop links. Using heuristic algorithm for the above parameters to divide multiple available nexthops into three subsets with different link performances, packets are forwarded with the matching relationship between Qos demand and nexthop capability. Simulation results show that the proposed scheme obviously exceeds DiffServ in packet average delay and is promising to improve throughput and resource utilizing rate of network, realizing differentiated services in deed in network layer as nexthop links are optional.

Keywords: Qos; DiffServ; IntServ; Hierarchical Nexthops; Multi-nexthop

1 Introduction

How to meet the Qos requirements of business is a basic problem in the network [1]. To solve this problem, the following Qos guarantee mechanisms based on current single-nexthop routing are mainly used: (1) IntServ [2], each flow requires separate routing and special processing, which contravenes the generality of network transport service, and has poor scalability and high complexity. (2) QoS routing [3], treats each QoS flow in different ways, finds and maintains paths separately. But essentially, path finding in the entire network with multiple-constrained routing parameters is a NP-complete problem. Meanwhile, there is an irreconcilable opposition between using variable parameters to find paths and having no choice but to use static parameters to build paths over the whole network [4]. (3) DiffServ [5], provides different services after the classification and aggregation of data flows to realize data predictable transmission, which marks the packet and offers different service levels to different packet. It is a kind of relative priority strategy that is going with the existing network mechanisms. Compared with the above two mechanisms, DiffServ model is a project that attempts to solve QoS problem universally.

However, DiffServ does not provide a completely differentiated service, as the nexthop link is unique in current single-nexthop routing scheme. Packets are still forwarded through the same nexthop but have different priority. This inherent defect restrains the practical activity of differentiated services mechanism. Multi-nexthop routing mechanism can provide several available nexthops to forward packets to destination [6]. Based on multi- nexthop routing mechanism, this paper proposes a novel QoS guarantee mechanism-Matching Capability of Hierarchical Nexthops (MCHN) which classifies multiple nexthops by their performance and forwards packets meeting flow Qos requirements and performance of next-hop. The current resolving project about MCHN is given in reference [7].

The organization of this paper is as follows: In part 2, the classification of links based on Qos requirement is discussed. The nexthop links are divided into three subsets corresponding to different services; Part 3 discusses the packet forwarding scheme; Part 4 sets a simulation model based on the nexthop set created by the classification algorithm in part 2; The last part summarizes the essay.

2 Link Classification Based on QoS Requirement

This method will continue to use three service types in DiffServ. Expedited forwarding (EF) service, it is similar to private line service on traditional operator network. Assured forwarding (AF) service, it is not just a kind of service, but a cluster of different services. The class of service can be customized in the needs of network development. Best-effort (BE) service, it is similar to the best-effort service on Internet.The set of feasible nexthop links, generated by multi-nexthop routing scheme, are divided into three subsets. Three subsets are respectively named "optimal nexthop subset", "ensuring service nexthop subset" and "best-effort nexthop subset", corresponding to the three service types of DiffServ, so packets with some Qos requirement can be forwarded to corresponding nexthop subset.

2.1 Parametric Representation of Nexthop Performance

Network topology shown in Fig 2.1, all possible paths to reach destination node have been identified through the multi-nexthop routing protocol, which make up the nexthop link sets. Based on multi-nexthop link sets, node forwards packets of different Qos requirements to corresponding subset of next-hop links. For example, define a set $K=\{k_1,k_2,\cdots,k_n\}$, $n\geq 1$ as the nexthop links set of node i , generated by multi-nexthop routing protocol. With this set, packets can be forwarded to the destination node.

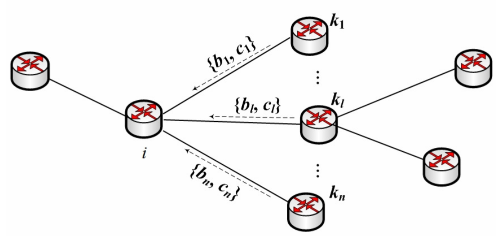

Figure 2.1: Collecting Performance Parameter of Multi-nexthops

Lets tuple $\{b_l,c_l\}$ to describe the performance of nexthop links, which is created by nexthop link set K through a collection mechanism, Where c_l is the link bandwidth, b_l is the rank of link reliability [7], and $c_l>0$, $b_l\in\{0,1\}$, in which "1" is good and "0" means bad. Each node has two states in the network. As the upstream or downstream node of neighbor nodes, node sends a tuple $\{b_l,c_l\}$ to the neighbor nodes, along with another one is received, so the complexity of parameter collection mechanism is $O(2m)$, m is the number of links. As the tuples cannot directly reflect the performance of nexthop links, so the link performance factor is proposed to describe them. The larger coefficient the better link performance, and vice versa. Definition link performance factor

$$r_l=a_0b_l+a_1\frac{c_l-R}{X_0} \tag{2.1}$$

where, $R=\min[c_l,1\leq l\leq n]$, $X_0=\sum_{l=1}^{n}(c_l-R)$, $0\leq a_0$, $a_1\leq 1$. For easy to discuss, let $a_0=a_1=1$, express two factors are well-matched in influence. As above defined link performance factor $r_l>0$ and b_l has greater influence on r_l.

2.2 Link Classification Algorithm Based on Nexthop Performance

In actual network, the number of available nexthops is different from node to node. Therefore, the nexthop set has various forms. If the number of available nexthops $n\leq 2$, the nexthop link set cannot be actually divided, so forwarding packets as following, (1) $n=1$, Implement the DiffServ with the single-nexthop routing mechanism; (2) $n=2$, One with better performance is used to transfer EF service, while another link is used to transfer AF and BE service. The process of forwarding packet could refer to differentiated service mechanism.

While the nexthop link set with $n\geq 3$ available nexthops can be divided into three subsets implementing link classification algorithm with link performance factor. This paper is focus on state of $n\geq 3$. The pseudocode of link classification algorithm is as follows

(1) $S_j^i=\{r_1,r_2,\cdots,r_n\mid r_1\geq r_2\geq\cdots\geq r_n\}$
(2) $r_{sum}=sum\{r_1,r_2,\cdots,r_n\}$
(3) $r_E\leftarrow r_{sum}/n$
(4) $V[l]\leftarrow\mid r_l-r_E\mid$
(5) $mid\leftarrow\{l\mid\min(V[1],V[2],\cdots,V[n])\}$
(6) $A_1\leftarrow(\max S_j^i-r_{mid})/3$
(7) $A_2\leftarrow(r_{mid}-\min S_j^i)/3$

(8) $if\ (r_l > r_{mid} + A_1) \square (r_l \geq r_{mid} \mid l < mid)$
(9) $EF_S \leftarrow r_l$
(10) $elseif\ (r_l < r_{mid} - A_2) \parallel (r_l \leq r_{mid} \mid l > mid)$
(11) $AF_S \leftarrow r_l$
(12) $else$
(13) $BE_S \leftarrow r_l$
(14) $endif$

Implementing link classification algorithm the set of nexthop link can be divided into three subsets, such as "optimal nexthop subset", "ensuring service nexthop subset" and "best-effort nexthop subset", the complexity of algorithm is $O(2n^2)$.

Theorem 2.1. *Link classification algorithm can divided nexthop link set into three non-empty subsets when the number of available nexthops* $n \geq 3$.

Proof: we can get the link performance factor set $\{r_1, r_2, \cdots, r_n\}$ and $r_1 \geq r_2 \geq \cdots \geq r_n$. According as the step (1)-(5) of algorithm, gets the factor r_{mid} has middle value which is subjected to $r_1 \geq r_{mid} \geq r_n$. Factor r_1 meets $r_1 \geq r_{mid} \wedge 1 < mid$, so it can be put into optimal nexthop subset EF_S; In the same way r_n meets $r_n \leq r_{mid} \wedge n > mid$, it is put into best-effort nexthop subset BE_S; While r_{mid} belongs to ensuring service nexthop subset AF_S, so three subsets are non-empty. □

3 Packet Forwarding

Let a real-time flow be specified by the tuple (j, g), where j is the address of destination node and g is service class. Node i has N^i adjacency links and flows forwarded to neighbor nodes are composed of two parts: (1) generated locally by the host attached to node i. It then encodes the destination and class identifier in each packet before it forwards it to next node. At node i, let S_j^i be the set of nexthop links for destination j. Packets received by node i for destination j are only forwarded to neighbors in the set S_j^i. When $n \geq 3$, the set S_j^i can be divided into three subsets with implementing link classification algorithm and $S_j^i = \{S_{j,EF}^i, S_{j,AF}^i, S_{j,BE}^i\}$. According to matching relation between Qos requirement and nexthop capability, packets characterized by class g and destination j can find appropriate nexthops to be forwarded. If the number of link in subset is more than 1, packets select a link discretionarily to go. Thus a routing table entry is of the form $< j, g, S_j^i >$, where destination j and class g uniquely identify a table entry. After recalculating routes and implementing link classification algorithm, routing table is updated. The complexity of selecting nexthop is $O(n)$, where n is the number of nexthops. When $n = 1$, S_j^i has unique link and packets are forwarded with DiffServ. Then $n = 2$, S_j^i has two links and packets are forwarded using operation mentioned in above section.

4 Simulation and Analysis

The network topology in the simulation is as shown in Fig 4.1, which has multiple available nexthops for packets to the destination at node r_0. In actual network, the out-degree of node is small. So let M = 3, the physical bandwidth of links C_1 ~ C_3 are 10Mbps, 9Mbps and 8Mbps respectively. Packet lengths of EF, AF and BE services are 400 byte, 500 byte and 600 byte respectively; the average arrival rates of EF and AF packets are 18%, 72%. The number of packets reached in unit time obeys the Poisson distribution with parameter λ. Bandwidth demand of one EF flow is 0.03Mbps, bandwidth of a single AF and BE is 0.02Mbps and 0.01Mbps respectively. According to the above discussion, implementing link classification algorithm, link C_1 ~ C_3 are used to transfer EF, AF and BE service respectively in MCHN. Single-nexthop Qos assurance mechanism uses differentiated service in which three class services are transferred through next hop C_1 that has best performance.

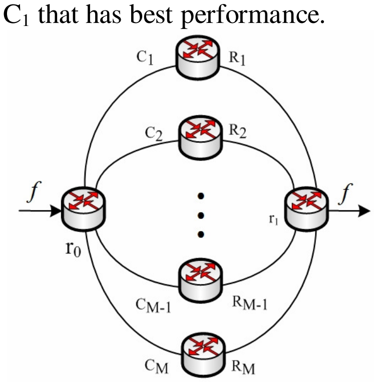

Figure 4.1: Topology of Multi-nexthop for Simulation

In order to evaluate the performance of two methods, packet average delay is selected as the performance evaluation parameter. Let link to be non-preemptive priority queue, average delay of packet belonging to rank g is as follows

$$d_g = \frac{L_g}{C} + W_g \tag{4.1}$$

Where, C is the physical bandwidth of link transfer packets belonging to rank g, L_g and W_g are packet length and queuing delay of packets belonging to rank g. In non- preemptive priority queue each rank flow has a queue.

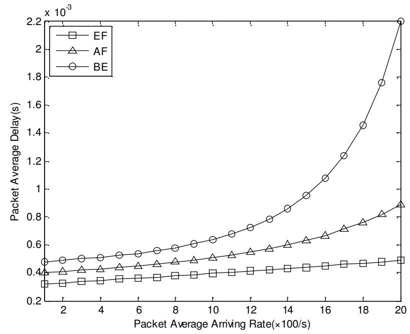

Figure 4.2: Packet Average Delay in DiffServ

Fig 4.2 shows the packet average delay of DiffServ forwarding with single-nexthop. With the increase of packet average arrival rate λ, packet average delay of EF with topmost priority service increases linearly, contrarily packet average delay of low priority service increases quickly. When $\lambda = 2000$ packet/s, packet average delay of AF and BE service are 0.9ms and 2.2ms. Due to multi-class packets transfered in single nexthop link, with traffic increase the bandwidth of unique link is consumed sharply. At the same time high priority service engrosses the service bandwidth of low priority service, so the packet queuing delay of low priority service becomes greatly longer than before. Forwarding packets with single-nexthop which have different Qos requirements, it is inevitable to be that the Qos of low priority service gets worse.

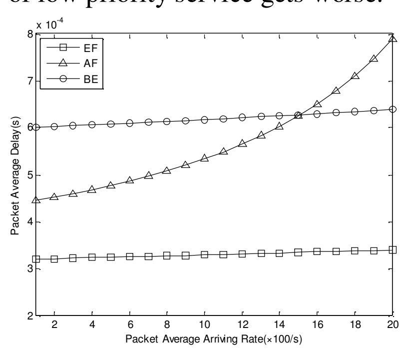

Figure 4.3: Packet Average Delay in MCHN

Forwarding different Qos packets with different links in MCHN, the packet average delay is shown as Fig 4.3. MCHN is different from DiffServ, it provides many optional links not a single to forward packets. This gives packets opportunity to be forwarded with a better service. The proportion of EF and BE traffic is smaller, so their packet average delay increase linearly and when $\lambda = 2000$ packet/s, they are 0.34ms and 0.65ms respectively less than DiffServ. The traffic of AF is much larger than EF or BE, thus packet average delay increases quickly, when $\lambda = 2000$ packet/s, it is 0.8ms less than DiffServ too. Forwarding different Qos packets with different links that terminates interaction of different Qos service and guarantees all Qos service to have a lower bound of packet average delay. But this scheme brings another issue that the packet average delay of AF is still high and bandwidth utilization of nexthop links are disproportioned, optimal nexthop subset and best-effort t nexthop subset are slightly used, ensuring service nexthop subset is heavily used. As a result adjusting traffic between different subsets is very necessary and is our future work to do.

5 Summary

The traditional single-nexthop Qos guarantee mechanism cannot provides real differentiated service in network layer. Therefore, this paper proposes a new Qos guarantee mechanism-MCHN, based on various available nexthops of node generated by multi-nexthop routing mechanism. The fundamental thinking of mechanism is transmitting different class service packets with different class nexthop links because they are optional and have different performance, to achieve real differentiated service in network layer. Simulation results show that because of optionally nexthop links, MCHN mechanism in packet average delay is better than differentiated service obviously. But there are still some problems that some packet average delay is still high and bandwidth utilization of nexthop links are disproportioned, which debases the performance of MCHN. These issues will be resolved in future research.

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