ON QoS-BASED ROUTING AND RESOURCE OPTIMIZATION IN IP-BASED MULTI-SERVICE NETWORKS

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ABSTRACT

Technology and service convergence is current trend of telecommunication and the guarantee quality of service (QoS) for each application while retaining the best usage of resources is an important criterion for a such network. This leads to a QoS-based optimization process for routing (QoSR) and different aspects with respect to the said are briefly mentioned in this paper as follows: Basis of QoSR technique (II), Bandwith-based QoSR problem (III). A proposed QoSR on MPLS-DiffServ architecture model (IV), Discussions and conclusions with respect to the proposed model (V).

1. INTRODUCTION

The QoS-based routing problem has been recently approached from the IP routing technology, QoS Architectures and Mechanisms and MPLS [1],[3],[4]. In this paper, a model is considered and solutions for traffic routing from the basis of available bandwidth in IP/MPLS network are reported.

2. BASIS OF QoS-BASED ROUTING (QoSR) TECHNIQUE

2.1. A brief on requirements of QoSR [1, 2]

QoSR is an adaptive dynamic routing technique attaining the following targets:

- Selected routes satisfy QoS requirements of all users.
- Network resources are optimally shared among them.
- Traffic load is balanced in the whole network.
- Routing process gains precision, stability, flexibility and shortest time for convergence.
- Routing algorithms are simple, feasible and extendable.
- Routing operation is suited and compatible with existing network.

QoSR is sensitive to updated information and traffic bursty. Routes selected are effective only in a short duration due to property of traffic variation.

2.2. On mechanism of QoSR: Metric methodology [6 - 8]

Route selection and packet forwarding in a network using QoSR take place in the following order:

- QoS requirements from user and network resources state are mapped to metrics (used as criteria for route selection).
- Metrics are exchanged and updated between routers.
- Metric for the whole route from originating user to terminating one is computed.
- If a route is available, signalling between network nodes will be initiated to reserve the resources.
- Packet forwarding is done by lower layer protocols such as ATM or MPLS.

2.3. On recent algorithm for QoSR [5, 9, 10]

Recently algorithm developed for QoSR is seen to consist of two stages: Metric computation in the first one and metrics exchange and update in the second stage.

2.3.1. First stage: Metric computation

Metric pre-computation is initiated periodically or after a number of times receiving updating message while demand dependant computation is only implemented whenever there is a new incoming traffic flow. The following metrics are computed:

- QoS requirements of user (such as delay limit, for example).
- Administrator policy (like cost, ...).
- Network resources and configuration (the number of hops, available bandwidth, ...).

Rules used for computation depend upon characteristics of metrics. For additive, multiplicative and extremum metrics the respective rules are:

$$m(P) = \sum_{1}^{i-1} m(n_i, n_{i-1}),\quad m(P) = \prod_{1}^{i-1} m(n_i, n_{i+1}),\ \text{and}\ m(P) = \mathop{Min/Max}_{1}^{i-1}\ m(n_i, n_{i+1})$$

where, $P = (n_1, n_2 \ldots n_i)$, a route from node n_1 via n_2 ... to n_i, $m(n_i, n_{i-1})$, is a metric of the link between n_i and n_{i-1}, $m(P)$ is a metric of the route P.

Routing algorithm is a combination of metric constraints by several methods as follows:

- Metrics processing in sequence or priority,
- Eliminating links or routes which are not meet at least one constraint,
- Metrics mapping by a function relationship,
- Metrics combination: $m = f(m_1, m_2 \ldots, m_n)$, such as weighting: $m = \sum_{i=1}^{n} w_i m_i$,
- Quantizing values of metrics,
- Estimating and using probability,
- Segmenting the scope or range of metrics.

2.3.2. Second stage: Metrics exchanging and updating

Metrics is related to network topology and to others characterizing QoS requirements and resource states, which are needed to be exchanged by routing protocols. Updating frequency should be chosen according to the compromise between cost and precision.

In a distributed network environment, errors arise in updating information due to: Regular variation of metrics, limitation of updating frequency, combination of metrics, hidden information due to security, error of network nodes or links, and computing errors, etc.

The following solutions can be used for improving precision:

- Historical data combination for estimating current value of metric,
- Using a range instead of a specific value of metric,
- Scanning information from different channels or multi-direction.

3. BANDWIDTH-BASED QoSR PROBLEM

3.1. General model [9, 10]

QoSR problem is mathematically modelled as follows:

- Network is represented by a graph G = <V,E>, in which V ∋ N_i is a set of nodes, E ∋ (N_i,N_j) is a set of links.
- Metrics are represented by n metric values of a link in a diagram: (m_1,m_2,...m_n), in which m_i (N_i,N_j) or m_i (l) is value of metric m_i of link l between node N_i and N_j in a formula.
- Constraints are represented in the matric form (relation or formula): A set of n constraints represented by C = {c_1,...c_n}, in which c_i is a constraint of either type; (i). Limitation, c_i = {MAX ≥ m(l) ≥ MIN}, or (ii). Optimization: c_i ={m(l)→max/min}.
- A set of traffic flows F(l) and a set of available links L(f).

and find an optimal solution {p∈L, f∈F, p=L(f), C={c_1,...c_n}}.

A method for the above QoSR problem with q constraints is extended from the "shortest path first" algorithm with one constraint obtaining from a new concept of "nonlinear path length":

$$\Lambda(p) = \Phi\left(\frac{L_1(p)}{C_1}, \frac{L_2(p)}{C_2}, ..., \frac{L_q(p)}{C_q}\right). \tag{1a}$$

In which, $L_i(p)$ is the i^{th} metric of QoS of link p, C_i is upper or lower limit of i^{th} constraint. By this way, multi constraints are converted to one constraint. In the case C_i is upper limit, (1a) becomes:

$$\Lambda(p) = max\left(\frac{L_1(p)}{C_1}, \frac{L_2(p)}{C_2}, ..., \frac{L_q(p)}{C_q}\right) \tag{1b}$$

Necessary and sufficient condition for p to be a feasible link is: Λ(p) ≤ 1.

In fact, the following conclusions can be drawn from above mathematical model:

- Complexity of QoSR algorithm depends on number of constraint, number of nodes |V| and/or number of links |E|.
- Due to high complexity, it is currently only feasible for a QoSR problem if there is only 01 additive and 01 or more extremum metrics.

3.2. QoSR algorithm for bandwidth guarantee in case of uncertain information [10]

Let f be a traffic flow requiring minimum bandwidth of $B(f)$ on each link $l \in L(f)$, $F_{qos}(l)$, be a set of traffic flows traversing link l, $C(l)$ be bandwidth of link l. Total bandwidth reserved for $F_{qos}(l)$ is defined by $c_{qos}(l) = \sum_{f \in F_{qos}(l)} B(f)$ on satisfying $C_{qos}(l) \leq \lambda C(l)$, with $\lambda < 1$ is a coefficient of useful bandwidth. Redundant or available bandwidth of link l is defined by $Bw(l) = \lambda C(l) - C_{qos}(l)$, then available band-width of route p is found:

$$Bwidth(p) = \min_{l \in p}\{Bwidth(l)\}. \tag{2}$$

Find an optimal route p from a source s to a destination d for an incoming traffic flow requiring a bandwidth of B so that $Pr\{Bwidth(p) \geq B\}$ reaches maximum value.

Denotes B_l an estimated value of $Bwidth(l)$, ΔB_l a maximum variable estimated value of B_l before the next period of updating. These variable are updated periodically as follows:

$$\Delta B_l^{new} = \alpha \times \Delta B_l^{old} + (1-\alpha) \times \left| B_l^{new} - B_l^{old} \right| \tag{3}$$

in which $\alpha < 1$. The estimated available bandwidth of next period meets the condition:

$$B_l + \Delta B_l \geq Bwidth(l) \geq B_l - \Delta B_l \tag{4}$$

It is seen that $Pr\{Bwidth(l)\}$ meets (2), ΔB_l should be large enough. However, if $\beta > 1$ is introduced so that ΔB_l^{new} will converge to $\beta \times \left| B_l^{new} - B_l^{old} \right|$ with a rate $(1 - \alpha)$, then (4) becomes:

$$\Delta B_l^{new} = \alpha \times \Delta B_l^{old} + (1-\alpha) \times \beta \times \left| B_l^{new} - B_l^{old} \right| \tag{5}$$

Each node maintains 02 updated variable of B_l and ΔB_l. Let a random variable $Bwidth(l)$ be steady distribution in $[B_l - \Delta B_l, B_l + \Delta B_l]$ with probability density function defined by:

$$f(x) = \begin{cases} \frac{1}{2\Delta B_l} & x \in [B_l - \Delta B_l, B_l + \Delta B_l] \\ 0 & x \notin [B_l - \Delta B_l, B_l + \Delta B_l] \end{cases} \tag{6}$$

Probability of link l meeting required bandwidth B of new incoming traffic flow will be:

$$Pr\{Bwidth(l) \geq B\} = \int_B^{+\infty} f(x)dx = \begin{cases} \frac{B_l + \Delta B_l - B}{2\Delta B_l} & B \in [B_l - \Delta B_l, B_l + \Delta B_l] \\ 1 & B < B_l - \Delta B_l \\ 0 & B > B_l - \Delta B_l \end{cases} \tag{7}$$

Probability of route p meeting required bandwidth B of new incoming traffic flow will be:

$$Pr\{Bwidth(p) \geq B\} = \prod_{l \in p} Pr\{Bwidth(l) \geq B\} = \begin{cases} \prod_{l \in p} \frac{\min\{B_l + \Delta B_l - B, 2\Delta B_l\}}{2\Delta B_l} & \forall l \in p,\ B < B_l + \Delta B_l \\ 0 & \exists l \in p,\ B \geq B_l + \Delta B_l \end{cases} \tag{8}$$

QoSR algorithm for finding a route p on maximizing $Pr\{Bwidth(p) \geq B\}$ will be as follows.

- *Step1*: Defining a set of links

  $$E^* = \{l \mid (Pr\ Bwidth(l) \geq B) > 0, l \in E\} \text{ or } E^* = \{l \mid B < B_l + \Delta B_l, l \in E\} \tag{9}$$

then eliminating all $l | l \in (E - E^*)$. If no route available in $<V, E^*>$ then reject traffic flow and stop.

- *Step2*: Assigning weighted value

$$w_l = -\log Pr\{Bwidth(l) \geq B\} \text{ or } w_l = -\log \frac{\min\{B_l + \Delta B_l - B, 2\Delta B_l\}}{2\Delta B_l}, \forall l \in E^{*} \quad (10)$$

- *Step 3*: Using Dijstra algorithm to find a route $p \in \langle V^{*}, E^{*} \rangle$ with minimum value of $\sum_{l \in p} w_l$.

4. PROPOSED IP/MPLS - DIFFSERV ARCHITECTURE - BASED QoSR MODEL (QoSPF)

Routing protocol QoSPF and label distribution signalling CR-LDP/MPLS are combined in QoSR to provide more exact routing. System components in a network node are shown in the figure 1.

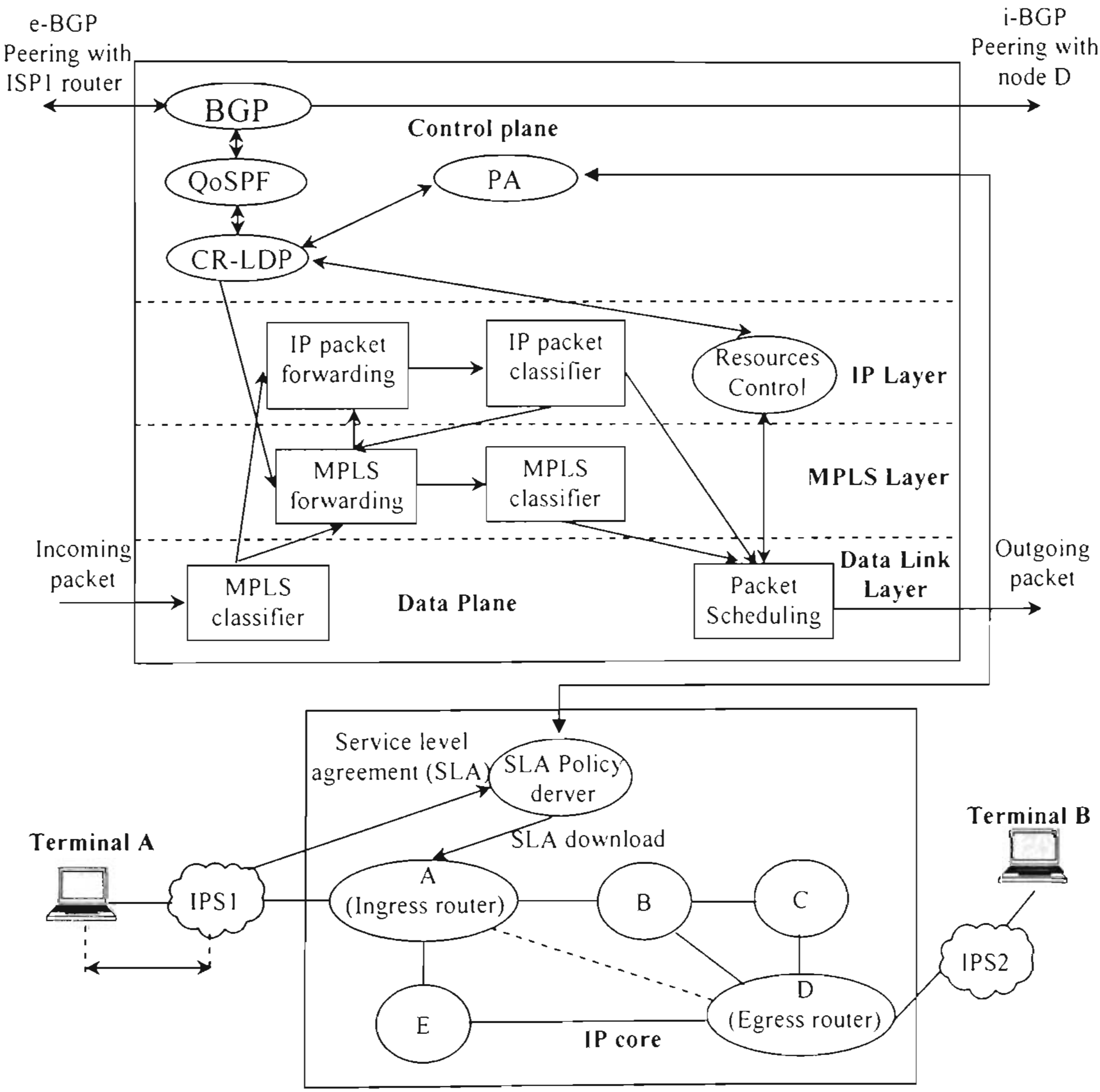

Figure 1. Components of IP/MPLS-DiffServ networks based on multilayer hierarchical QoSR

In the figure, PA (Policy Agent) is to support management of dynamic Service Level Agreement (SLA) between an Internet Service Provider (ISP) and a core network and to balance network traffic, CR-LDP (Constraint Based Routing-Label Distribution Protocol) is to reserve resources for ensuring QoS to aggregate IP traffic flows case, QOSPF (QoS Open Shortest Path First) routing protocol is for IP core network as an autonomous System (AS) and BGP (Border Gateway routing Protocol) is used between AS core network and other, consisting of 02 sections: inter domain (BGP-e) and intra domain (BGP-i). Virtual logical links are allocated dynamically for ensuring specified QoS between users and ISP in SLA. Association between routing and signalling protocols is depicted in the figure 2.

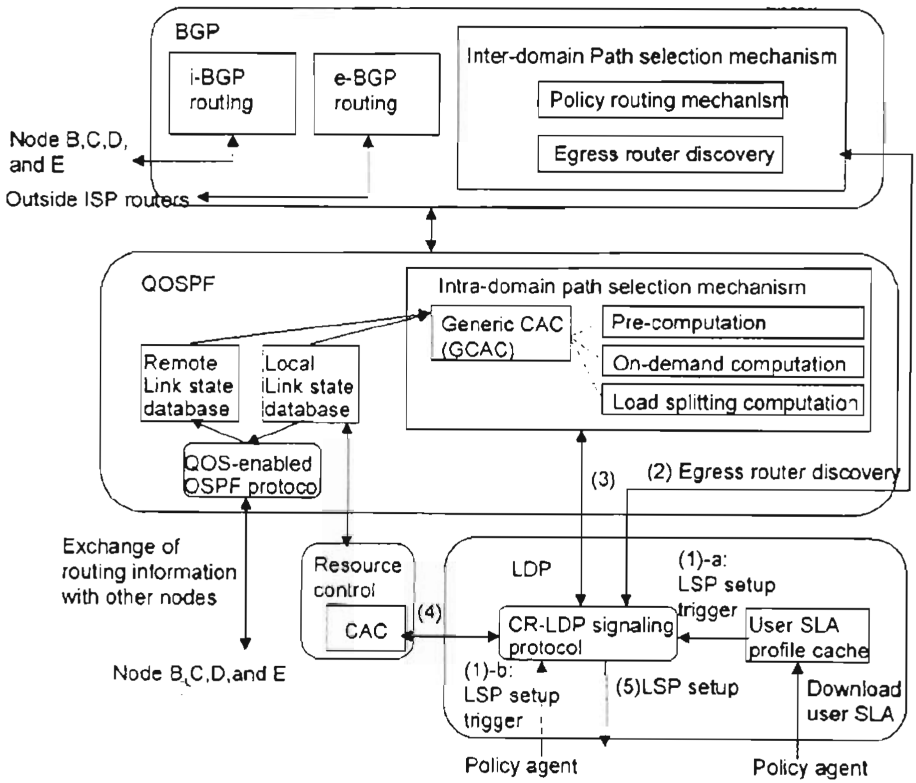

Figure 2. Interworking of CR-LDP, BGP and QOSPF protocols

After receiving an LSP setup initiator, CR-LDP sends a request to BGP resolving address of back-bone area router (D) at egress of anonymous toward destination network, also to QOSPF selecting route for ensuring QoS between ingress and egress routers. After selecting route QOSPF sends route informa- tion to CR-LDP to initiate signalling process (allocated labels and reserved resources). QOSPF supports hierarchical source routing algorithm in an anonymous system. Route computing process is done at each ingress border router in each area network.

Figure 4 illustrates a LSP setup process. At each node, on the basis of QoS constraints, connection admission control mechanism decides if maintaining LSP is setup or not. Updating and advertising QoS information is implemented by QOSPF routing protocol and QoS metrics include maximum available bandwidth, reserved bandwidth integrated in a LSA (Link State

Advertisement message). A QoSR algorithm for an IP/MPLS-DiffServ network can be proposed showing in the figure 5.

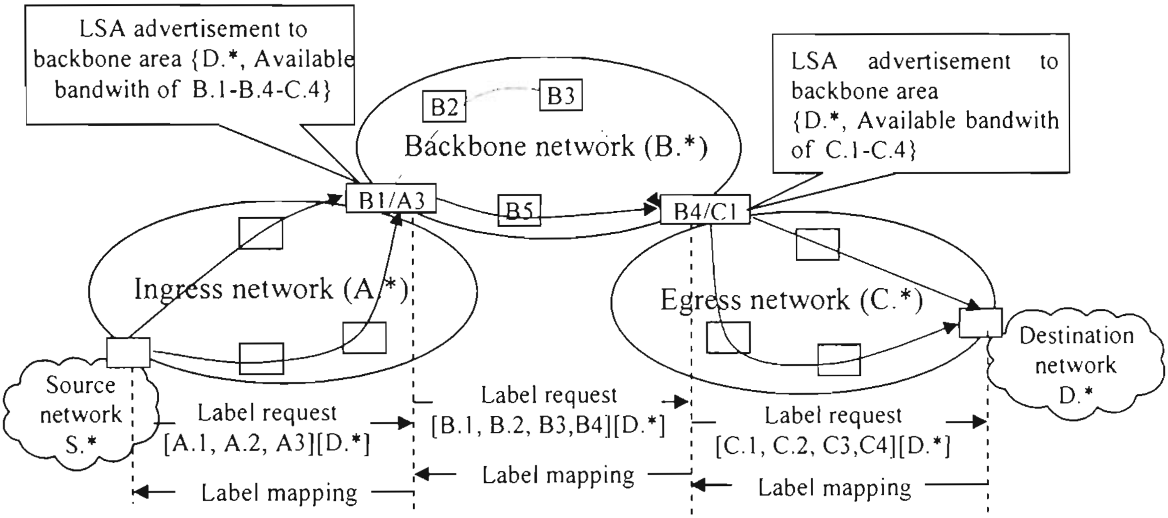

Figure 3. LSP setup process

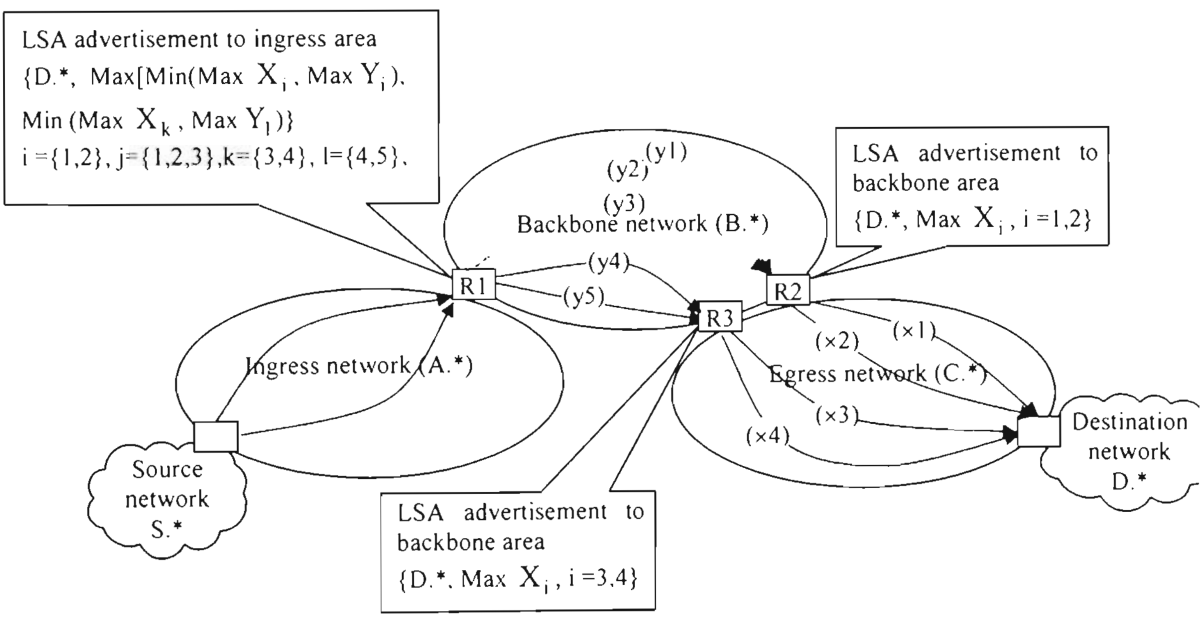

Figure 4. Updating and advertisement routing information

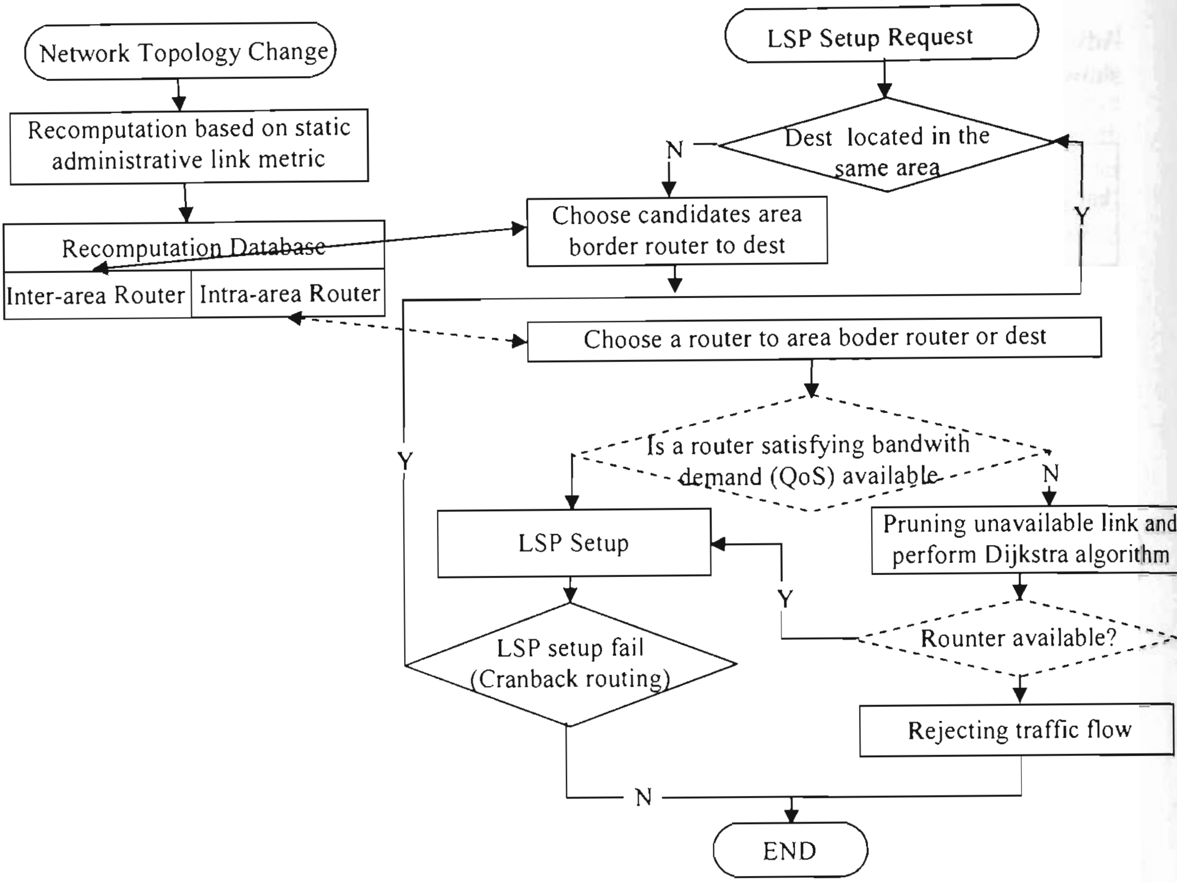

Figure 5. QoSR algorithms in IP/MPLS-Diffserv network

5. DISCUSSIONS AND CONCLUSIONS

Different discussions and conclusions are made with respect to QoSR model as follows.

5.1. On stability of QoSR

Frequency and amount of routing information exchanged in the network have an important impact on stability of QoSR, especially when a lot of resources are allocated or released at the same time. On the other hand, a large number of criteria is used, a higher probability of route variation would cause latency jitter and bad impact on QoS. State change in a network may bring a new, better route for same traffic flow but may harm to network stability as the whole, however. The "route pinning" is therefore needed and intelligent adjustment of parameters can be used for improving stability and load balance.

5.2. On reliability of QoSR

Reliability of QoSR depends on network variation, on precision and timely updating information as well. However, it can show that, precision has little impact on QoSR with bandwith criteria than with others. Several solutions like automatically adjusting initiate time of updating, multi-direction updating or proportional sticky routing can be taken for improving reliability and stability of QoSR.

5.3. On overhead and security of QoSR

Computing cost can be reduced due to technology. However, updating cost is not easy to cut down as its reverse effect to network resource (available bandwidth and archives space). There exists several factors affecting on computing cost (route selection criteria, route selection algorithm) while updating cost depends upon updating frequency and on information amount.

Issues of ensuring integrity of routing protocol in case of conflict or attack from outside should also be considered so that resources exhaustion can be avoided. Authentication of QoS requirements may be taken as a solution for the said.

5.4. On deploying QoSR in practice

Most QoSR models are considered in an ideal homogeneous environment supporting QoS routers. The feasibility of QoSR arises in a heterogeneous network where exists both QoS and normal traffics in the same network. An aspect in realization of QoSR is that the compatibility of QoS routing protocols, the fairness in resources sharing since most QoSR algorithms are extended from the traditional routing protocols versions. It needs to complete and standardize architecture model and operation rule for QoSR based networks.

5.5. Futher QoSR research and development

QoSR is currently still a new topic with a lot of challenges, which are:

- Adaptive mechanism of multi-path alternative routing for traffic to the same destination.
- Complexity reduction of algorithm in multi-criteria QoSR problems.
- Reliability and stability of QoSR based on probability problems.
- QoSR solutions in add-hoc wireless network.
- Compatibility and fairness of resource sharing for both QoSR routing and traditional routing in the same network.

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TÓM TẮT

VỀ GIẢI PHÁP TỐI ƯU HOÁ TÀI NGUYÊN VÀ ĐỊNH TUYẾN TRÊN CƠ SỞ CHẤT LƯỢNG DỊCH VỤ ĐỐI VỚI MẠNG IP ĐA DỊCH VỤ

Hội tụ giữa công nghệ và các dịch vụ đang là xu thế có tính tất yếu của các mạng viễn thông hiện nay nhằm đảm bảo lượng chất lượng đối với mỗi dịch vụ (gọi tắt là chất lượng dịch vụ, QoS) trong quá trình khai thác tối đa tiềm năng mạng (một trong những tiêu chí quan trọng đối với mạng đa dịch vụ thế hệ sau). Điều đó dẫn đến một quy trình định tuyến tối ưu xây dựng trên cơ sở chất lượng dịch vụ QoS và những khía cạnh quan trọng và kết quả nghiên cứu liên quan đến định tuyến tối ưu xây dựng trên cơ sở của QoS được tóm tắt trong bài báo 8 trang này theo các phần như sau.

Trong phần 2, các tác giả tóm tắt những nét cơ bản về kĩ thuật định tuyến tối ưu xây dựng trên cơ sở chất lượng dịch vụ (QoSR), gồm những yêu cầu với QoSR, Cơ chế QoSR theo phương pháp sử dụng mẫu chuẩn (metric methodology) và về thuật trình mẫu chuẩn hiện hành đối với QoSR. Trong phần 3, các tác giả trình bày tóm tắt về kết quả bài toán QoSR được tác giả khác xây dựng trên cơ sở tối ưu về băng thông (bandwidth) gồm quy trình mô hình hoá toán học theo phương pháp mẫu chuẩn xây dựng trên cơ sở lý thuyết hình học (graph), thuật trình đảm bảo cung cấp băng thông trong trường hợp bất định thông tin (liên quan đến đa dịch vụ trong môi trường phân tán IP). Trong phần 4, các tác giả thông báo tóm tắt về mô hình QoSR đề xuất đối với kiến trúc đa dịch vụ, phân tán trên nền giao thức internet (IP). Trong phần 5, những vấn đề quan trọng liên quan đến mô hình đề xuất được các tác giả bàn luận, và định hướng nghiên cứu phát triển tiếp.

Địa chỉ:

Nhận bài ngày 10 tháng 6 năm 2008

Học viện Công nghệ Bưu chính Viễn thông.