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ROUTING OPTIMIZATION FOR FORCES BASED ON TRAFFIC MATRIX

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ABSTRACT

The research of the ForCES technology has made a great progress. However current research of ForCES mainly focuses on architecture and techniques. In order to ensure ForCES architecture network works well, it is significant to take account of routing optimization for ForCES architecture. In this paper, we will introduce the minimizing sum of path-cost model based on multiple traffic matrices to optimize the routing at FE sides in ForCES architecture. At last, through simulation experiment we prove that it achieves good results in routing optimization.

Keywords: *ForCES, Traffic Matrix, Routing Optimization*

1. INTRODUCTION

Routing optimization is the major application of traffic matrix in traffic engineering. Routing optimization adapts traffic distribution by adjusting routing, to achieve the goal of bandwidth allocating, network congestion relief, link load balancing. The algorithm for routing optimization optimizes the routing by adjusting the routing parameters (link weights, routing fraction) when the traffic matrix has been known [1]. Given that different routing protocols adopt different optimization techniques, routing protocol can be divided into single path routing protocol and multi-path routing protocol.

Nowadays, Internet mainly base on single path routing protocol [2], so data is transmitted along a single path. Algorithm for single path routing protocol is easy to manage and configure but network cost and delay is high. Further more, it is easy to cause congestion and costs quite a long time to find a new path to recover data transmission when the path is unavailable.

Multi-path routing will be more popular in Internet application as it can improve the network performance. To optimize the multi-path routing techniques has practical and far-reaching meaning in the aspect of improving network performance and communication QOS, and contenting users' increasing demand of high quality of service.

2. FORCES ARCHITECTURE

ForCES (Forwarding and Control Elements Separation) in IETF is a new generation of network architecture based on open programmability [3]. Network ware is divided into CE (Control Element) and FE (Forwarding Element) according to ForCES protocol, which is used for collaboration and interaction between elements to improve the scalability and manageability of the network system and enhance the expansibility and flexibility of network ware. As Figure 1 shows, ForCES architecture consists of at least one or several CE and more than hundreds of FE, which conforms to ForCES protocol standard. The interaction between CE and FE implement on network. Packet in network ware is processed by one or more FE and come out, while FE communicates with others through some network.

In ForCES architecture, the topology is the key of constraining the process performance of total system. We should put more attention on ForCES routing optimization problem in order to make ForCES message between CE and each FE be transmitted timely and reliably, provide optimal processing solution for FE forwarding, and make ForCES architecture network ware works well.

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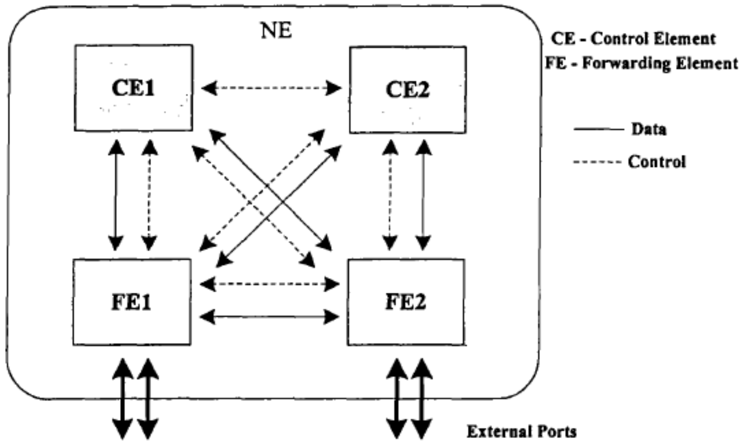

Figure 1 *ForCES Architecture*

Considering the characteristic of ForCES architecture communication channel and topology between CE and FE or among FE, we may regard all the FE nodes as edge nodes, i.e. origin nodes and destination nodes. In spite of internal traffic forming between CE and FE nodes and among FE nodes, the internal traffic of ForCES architecture can be simplified into the traffic among FE nodes. This article plan to propose a method based on IP routing and minimizing sum of path-cost model with multiple traffic matrices to solve routing optimization problems among FE in ForCES system.

3. ROUTING OPTIMIZATION RAINING OF ANN PARAMETERS

Routing optimization is the strategy that used for balancing the network traffic. If congestion occurs at some link, routers automatically adjust the traffic between OD pairs and the probability of packets forwarded at different paths in order to decrease network cost and increase network bandwidth utilization. In this paper, the routing optimization is carried out based on network traffic. Routing optimization can be divided into three categories according to different optimized targets: minimize the maximum link utilization model、minimizing sum of link-cost model and minimizing sum of path-cost model. In the network, it is difficult to estimate traffic matrix accurately because of the inherent challenge of traffic matrix estimation [3][4]. Meanwhile, network traffic's variability has also lead to a high cost for getting a set of routing optimization that adapt to changes in network traffic, and frequent routing updates make it even worse. However, the routing matrix updates slower than traffic matrix, so it is desirable to use multiple traffic matrix to estimate sets of routing during routing updating. In summary, it can only be solved by obtaining a set of routing optimization to adapt to different traffic situation [5]. This article plan to propose a method based on IP routing and minimizing sum of path-cost model with multi-traffic to solve routing optimization problems among FE in ForCES system.

Now let's have a brief look of routing optimization based on multiple traffic matrices:

Network model is assumed that: IP network is displayed by digraph G (N, A). Here N refers to set of routers; A refers to set of links among routers; directed link's capacity c(a) is defined as the maximum bandwidth that link can withstand. Traffic matrix displays the traffic demand for every OD pair (s,t), so routing problem can be defined as the traffic distribution of the path of non-zero D(s,t) from s to t. The result of traffic routing can be expressed by a matrix R, while the traffic proportion of load D(s,t) in the link a can be expressed by R(s,t,a). Then the load of link a can be expressed by $l(a)=\sum_{s,t\in N} R(s,t,a)\bullet D(s,t)$, and the bandwidth utilization is l(a)/c(a).

We define that routing variable $\phi_{kl}(i,j)$ represents the percentage of the traffic, which comes from router i to router j and forwarded by link (i,j) at router k. And $\phi_{kl}(j)$ represents the percentage of the traffic, which reached router j and forwarded by link (i,j) at router k, while ratio variable $B_{kl}(i,j)$ represents the percentage of traffic comes through the link (i,j) in the traffic

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which comes from source node i to destination node j.

Cantor et al. [6] proposed a centralized algorithm using ratio variable $B_{kl}(i,j)$ as control variable and making use of convex optimization to solve this problem. And to increase effectiveness, link cost is estimate to be a piecewise linear function [1]. In addition, Gallager [7] proposed a distribute algorithm based on gradient which using routing variable $\phi_{kl}(i,j)$ as control variable.

In multiple traffic matrices, we make the problem of obtaining routing optimization set in traffic matrix formulized and we use router variable ϕ or ratio variable B as control variable.

Given: network $G=(V,E)$, link capacity C, traffic matrix of n dimensions.
Minimize: cost A
Condition:

- Routing condition: F_y described by ϕ set or B set.
- Feasibility condition: $F_y \le C$.
- When the link cost is estimated to piecewise linear function, they can be described by additional conditions.

Sub-condition: for $y \in \{1,\dots,n\}$,
$D_{kl}(f_{y,kl}) \ge k_i \frac{f_{y,kl}}{c_{kl}} + b_i$, $(k,l)\in E$, $i\in\{1,\dots,6\}$.

Network topology

$G=(V,E), V\in(1,2,3,\dots,|V|),(k.l)\in V^2$, which is composed of a set of nodes V and direct links E. Here E is $(k.l)\in V^2$. Link capacity $C=\{c_{kl}\}$, c_{kl} >0. Traffic matrix set $R=\{R_1,R_2,R_3,\dots,R_n\}$, whose positive weights is $w=(w_1,w_2,w_3,\dots,w_n)$, here $\sum_y w_y = 1$. In the traffic matrix $R_y=[R_y(i,j)], i,j\in V, y\in\{1,2,\dots,n\}$, $R_y(i,j)$ represents the data rate of out source flow moving from node i to node j at bps, and w_y is the weight of matrix R_y.

Link date rate: $F_y=\{f_{y,kl}\}$, $(k,l)\in E$, $y\in(1,\dots,n)$, $f_{y,kl}$ stands for the date rate through link $(k.l)$ in traffic matrix R_y.

$$f_{y,kl}=\sum_{i,j} t_{y,k}(i,j)\phi_{kl}(i,j)$$

$$f_{y,kl}=\sum_{i,j} R_y(i,j)B_{kl}(i,j)$$

Network cost: A_y represents traffic matrix R_y's cost, $y\in(1,\dots,n)$, then $A_y=\sum_{(k,l)\in E} D_{kl}(f_{y,kl})$, $A=\sum_{y=1}^{n} w_y A_y$.

4. ALGORITHM VERIFICATION

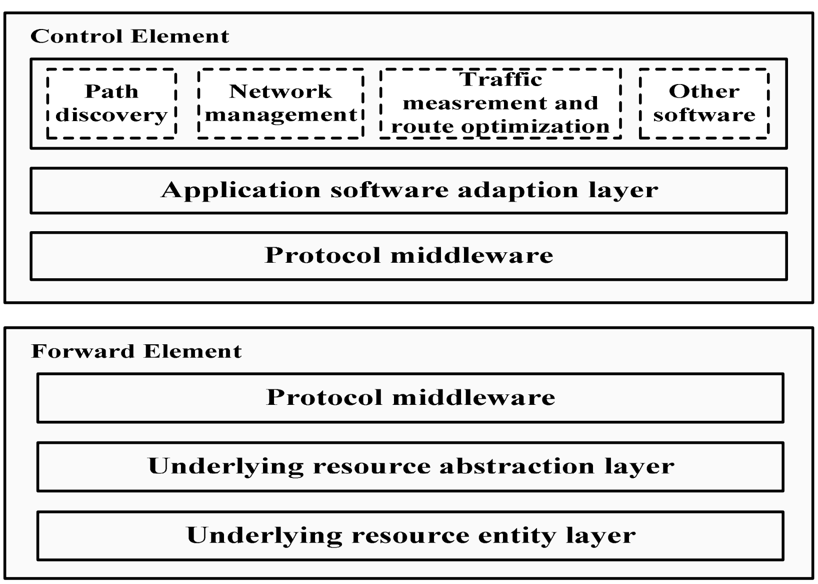

***Figure 2** The software architecture for ForCES router*

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The software architecture model for ForCES router is shown as the figure. CE communicates with FE by standard middleware. Kinds of application software, such as SNMP network management software, MPLS routing protocol software and service control software, are operated in the CE side, while FE side mainly consists of logic components LFB that show different function, such as decapsulation LFB, classify LFB, forwarding LFB. Forwarding LFB forwards packet by inquiring routing table, adding a traffic measurement and routing optimization module to CE side, and distributes the optimized routing information to all of FE. This section only discusses the routing optimization algorithm for FE.

We built a network topology figure, as follow shows, and let C（A,B）=200，C(B,C)=300，C(C,D=200),C(A,E)=300 ,C(E,F)=200 ,C(F,D)=500 to represent link bandwidth. When we calculate link cost and choose routing paths by OSPF routing protocol we can see that all the packet sent from router A,B,E to router D will come through link CD, which will be bottleneck link, while link AE,EF and FD is idle, which will cause low bandwidth utilization and link congestion.

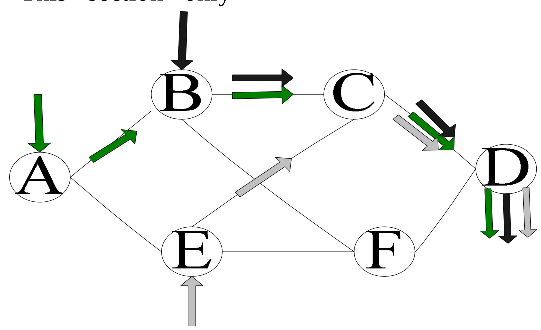

Figure 3 *Network topology*

We use algorithm for minimum network cost based on negative valence loop [8] to adjust the link cost which allow packet uniformly distributed in every paths. The routing path of adjusted packet is shown in the figure. At this time the link utilization is relatively uniform.

5. PERFORMANCE TEST

Test purpose: Validate if the algorithm for minimizing network cost based on negative valence ring can optimize each link's traffic of FE sides.

Test content: For ForCES routers with routing optimization function and those who forward packets directly by OSPF routing discovery protocol, we will make a comparison of their FE side's maximum link utilization.

- Test environment: NS simulation software, Linux operation system.
- Teat result: maximum link utilization at different time showed as the figure follows:

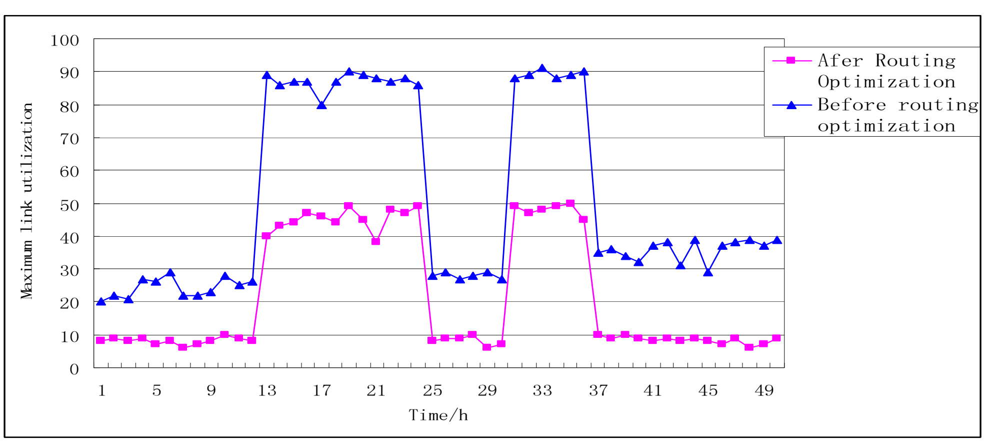

Figure 4 *Simulation results*

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Test result analysis: From the figure, we may conclude that the maximum link utilization got from the algorithm for minimizing network cost based on negative valence ring is obviously lower than that without routing optimization, which shows that in the case of same network traffic the utilization at each link is relatively similar using the algorithm we introduced.

6. CONCLUSION

With the rapid development of network, open and reconfigurable network facility can well achieve the goal for multi-network integration, so that the facility for NGN (next generation network) will be more and more popular. And router with ForCES architecture is one of the most important means for NGN. So it seems particularly important to measure and monitor the traffic inside of ForCES architecture.

In this paper, we mainly discussed the routing optimization and traffic balancing for FE sides in ForCES architecture based on estimated traffic matrix. After analyzing different kinds of routing protocols and algorithms for touting optimization, we introduced a minimizing sum of path-cost model based on multiple traffic matrices estimated by gravity model, combined with negative valence ring algorithm, to balance the traffic of all the links in the FE topology which at last confirmed by simulation experiment.

However considering that the traffic matrix estimated by gravity model is not so accurate sometimes that may not fully reflect the traffic characteristic, and that the model and algorithm we put forward is still not perfect, so at the next period we intend to find a far more accurate estimation for traffic matrix and consummate the traffic balancing model and routing optimization through experiments.

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