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Evaluating the benefit of the core-edge separation on intradomain traffic engineering under uncertain traffic demand ☆

Ke Li [a,b], Sheng Wang [a,*], Shizhong Xu [a], Xiong Wang [a], Haojun Huang [c,d], Jin Ren [a], Bo Zhai [e]

[a] School of Communication and Information Engineering, University of Electronic Science and Technology of China, Chengdu 611731, China
[b] School of Information Science and Technology, Southwest Jiaotong University, Chengdu 610031, China
[c] College of Information Science and Engineering, Wuhan University of Science and Technology, Wuhan 430081, Hubei, China
[d] Department of Computer Science and Technology, Tsinghua University, Beijing 100081, China
[e] Sichuan Expressway Company Limited, Chengdu 610041, China

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ABSTRACT

To address the routing scalability as well as security problems in current Internet, core-edge separation is introduced into many proposals for the architecture of future Internet. Locator/Identifier Separation Protocol (LISP) is used in this paper to evaluate the benefits of such separation on traffic engineering. The main idea of LISP is to split the single namespace for current IP addresses into two subsets, edge network address called Endpoint Identifier (EID) and core network address called routing locator (RLOC), in which a mapping system is required to support the EID-to-RLOC mapping services. Although many researchers have pointed out that EID-to-RLOC mapping assignment (ERMA) could provide enhanced traffic engineering capabilities, little research has been done on the concrete ERMA method. In this paper, we derive an optimizing ERMA (ERMAO) framework and make quantitative analysis of improvement of traffic engineering for multi-homed edge network, where ERMA could be tuned to specify the ingress points of inbound traffic. The framework incorporates two component, traffic demand and link weights, to represent real network. Accordingly, on the condition that traffic demand is uncertain but lies in a defined region, ERMA-only optimization problem in the network with given link weights and joint optimization problem of ERMA and link weights are proposed, respectively. To make the joint optimization problem of ERMA and link weights tractable, one local search algorithm, Optimized Stepsize Algorithm, is presented. Experimental results demonstrate the accuracy of these theoretic models, and the maximum link utilization is decreased by tuning ERMA.

1. Introduction

In the current Internet, Border Gateway Protocol (BGP) is the core routing protocol used to exchange routing information across the Internet. The size of BGP routing table in the Default Free Zone (DFZ) is increasing at a potentially alarming rate due to the continuously increasing user population, as well as several other factors, including multi-homing, traffic engineering, non-aggregatable address allocations and business events (Meyer et al., 2007). Thus, this leads to a serious scalability problem for the current Internet routing and addressing architecture.

The routing scalability problem has been drawing more and more attentions from researchers, including the Routing Research Group (RRG) of the Internet Research Task Force (IRTF). They have discussed and proposed some effective solutions called *core-edge separation architecture* for the future Internet. This architecture suggests that customer networks at the edge should be separated from provider networks at the transit core of Internet. Therefore, the non-aggregateable specific prefixes announced by the edge networks cannot enter into the transit core networks, and the BGP routing table size of the transit core will be reduced. The core-edge separation solutions include Locator/Identifier Separation Protocol (LISP) (Farinacci et al., 2012), enable Future Internet innovation through Transit wire (eFIT) (Massey et al., 2007), Internet Vastly Improved Plumbing (IVIP) (Whittle, 2010), etc. Since LISP is a typical core-edge separation protocol, the rest of the paper is discussed in LISP context.

In LISP, the single namespace for current IP addresses is split into two subsets: one subset is known as edge address called Endpoint Identifier (EID), and the other is known as core address

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* Corresponding author at: School of Communication and Information Engineering, University of Electronic Science and Technology of China, Chengdu 611731, China. Tel.: +86 13981860263.
E-mail addresses: keli@swjtu.edu.cn (K. Li), wsh_keylab@uestc.edu.cn (S. Wang), sz@uestc.edu.cn (S. Xu), wangxiong@uestc.edu.cn (X. Wang), hhj0704@163.com (H. Huang), jinren@uestc.edu.cn (J. Ren), zhaibo73@sina.com (B. Zhai).

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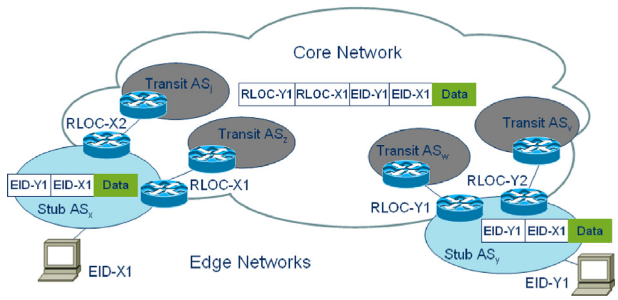

Fig. 1. Example of LISP deployment.

called routing locator (RLOC). Except the ITR (Ingress Tunnel Router) and ETR (Egress Tunnel Router) at the edge of the service provider network, all the routers do not distinguish between the two categories, i.e., the packets addressed to "core" and "edge" addresses are processed in the same way.

Figure 1 illustrates the operation of LISP. When an end-host Y from an edge network sends packets to a remote end-host X within another edge network across the core network, the source and destination address of the end-hosts donated as EID-Y1 and EID-X1 are mapped to the corresponding core network addresses named as RLOC1-Y1 and RLOC1-X1, respectively. Then, such core network addresses are prepended to the original packet at ITR (RLOC-Y1) and the packet is transmitted through the core network. Once the packet leaves the core network, the prepended headers are removed by ETR (RLOC-X1) and the original packet will be forwarded to the destination.

In fact, the transition between EID and RLOC is determined by mapping system, which is used to help ITR map an EID of the destination to an RLOC of an ETR when packets crossing the boundary between edge and core networks. Here, the set of all the EID-to-RLOC mappings of an edge network is called an ERMA (EID-RLOC Mapping Assignment). As shown in Fig. 1, since the edge network X has two border routers, the local EID-X1 address can be reached through one of multiple RLOC addresses (RLOC-X1 or RLOC-X2). In this way, traffic between end-system and routing locators can be redistributed by taking advantage of the ERMA when the destination edge network has several border routers. Therefore, LISP offers another advantage of improved traffic engineering (TE) capabilities in multi-homed environments. To better understand the "improved" TE capabilities, please see the Motivation in Section 2.

Several researchers have suggested the traffic engineering problem in core-edge separation context. Farinacci et al. (2012) mentioned that the separation of EIDs and RLOCs could be used to improve traffic engineering capabilities in LISP. Similar idea is also mentioned by Quoitin et al. (2007). Quoitin et al. (2007) proposed that traffic in an edge network between the edge routers and local hosts can be redistributed by taking advantage of this separation. But no concrete method has been provided about how to make use of this separation in these studies.

As far as we know, there are only three interdomain TE solutions (Saucez et al., 2008; Yannuzzi et al., 2009; Secci et al., 2011) exploiting this separation. Saucez et al. (2008) pointed out that locator/identifier separation offers the possibility of associating several locators to a certain identifier and implies the availability of multiple paths between two hosts of different domains. Yannuzzi et al. (2009) introduced a new control plane for LISP to manage interdomain traffic in Latin America. Besides these two, the routing interaction between distant independent edge networks is modeled with non-cooperative game theory by Secci et al. (2011), and a rationally justified method is proposed to achieve Internet-wide load-balancing. However, the optimization of ERMA for the benefit of intradomain TE is not discussed in these works.

In this paper, we evaluate the enhanced traffic engineering capabilities arising in a core-edge separated routing architecture, focusing on those multi-homed edge networks. In such edge networks, inbound traffic to a particular host must be sent through one specified ingress router, which means the EID of the host must be associated with the RLOC of the ingress router. More specifically, by tuning ERMA in a multi-homed environment, the inbound traffic can be redistributed in an edge network to avoid the heavy loaded links. Thus, the framework of optimizing ERMA (ERMAO) is proposed for edge networks. This framework is intended for improving intradomain traffic engineering, so it incorporates the following two important components of traffic engineering practice (Applegate and Cohen, 2006) in real network.

(1) *Routing protocol*: It is a major factor affecting the design of traffic engineering. Since LISP does not introduce major changes to the routing protocol, the most commonly used shortest path routing mechanism (e.g., OSPF or IS–IS) in current IP network is still feasible to be implemented in our framework. If the set of link weights of an edge network is given, tuning ERMA could be used as a supplementary strategy to achieve the TE objective. Otherwise, ERMA and link weights could be jointly optimized to obtain better network performance.
(2) *Traffic demand*: It specifies traffic load between every source–destination pair in the network. Much work assumed that traffic demand is stable and predictable. In this way, our previous work (Li et al., 2011), optimizing ERMA problem has been formulated as a Mixed Integer Linear Programming (MILP) model, where demand of each node pair is given as a fixed quantity. However, in practice, traffic demand is changing and uncertain (Casas et al., 2008) due to unexpected events, such as network equipment failures, flash crowd occurrences, security threats (e.g. denial of service attacks, virus propagation) and new spontaneous overlay services (e.g., P2P applications). To remedy this situation, we consider traffic variations and uncertainty by introducing a defined set of traffic demand, applying linear programming techniques to compute a stable ERMA for all demands within this set.

The reset of this paper is organized as follows. Motivation is introduced in Section 2. This section provides an overview of traffic engineering and insight into the benefit of EID/RLOC Separation on Interdomain and Intradomain TE. Section 3 describes the optimization framework of ERMA for traffic uncertainty. Two MILP models for ERMA-only optimization problem and joint ERMA and link weight optimization problem are proposed, respectively. A local search algorithm, Optimized Stepsize Algorithm, for the joint optimization of ERMA and link weights problems under uncertain traffic demand is discussed in Section 4. Experimental setup and results are presented in Section 5. Section 6 concludes this work and identifies the future work.

2. Motivation

2.1. Overview of traffic engineering

Traffic engineering (TE) is an important mechanism for Internet network providers seeking to optimize network performance and traffic delivery (Wang et al., 2008). It aims to determine and configure the best routing strategy so that the overall network performance is optimized. From the aspect of traffic optimization scope, TE can be classified into intradomain TE and interdomain TE.