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Investigating the Role of a Transmission Initiator in Private Peering Arrangements

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TEMEP Discussion Paper No. 2010:43

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151-742 서울시 관악구 신림동 산 56-1

Technology Management, Economics and Policy Program
College of Engineering, Seoul National University
San 56-1, Shillim-Dong, Kwanak-Gu, Seoul 151-742 ,KOREA
Phone: ++82-2-880-9140, Fax: ++82-2-880-8389

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Editor: Almas Heshmati
Professor of Economics

Technology Management, Economics and Policy Program
College of Engineering
#37-306, Seoul National University
San 56-1, Shilim-dong, Kwanak-gu
Seoul 151-742 Korea

Phone: 0082-(0)2-880-5845
Fax: 0082-(0)2-886-8220
E-mail: heshmati@snu.ac.kr

Investigating the Role of a Transmission Initiator in Private Peering Arrangements

Ruzana Davoyan[1] and Jörn Altmann[2]

[1]Department of Mathematics and Computer Science,
University of Mannheim
68131 Mannheim, Germany

[2]TEMEP, School of Management and Industrial Engineering,
College of Engineering, Seoul National University, South-Korea

ruzana.davoyan@informatik.uni-mannheim.de, jorn.altmann@acm.org

January 2010

Abstract: This paper investigates the impact of determination of an original initiator of transmission on demand as well as profits of the providers. For that purpose we present a new model, called differentiated traffic-based interconnection agreement (DTIA) that differentiates traffic into two types, referred to as native and stranger in order to determine a transmission initiator. In comparison to the existing financial settlement, under which the payments are based on the net traffic flow, the proposed model governs cost compensation according to the differentiated traffic flows. In addition, a traffic management mechanism that supports the presented approach was described. Analytical studies were provided using Nash bargaining solution to explore how the proposed strategy affects the outcome of providers' negotiation. The key consequence of the obtained results showed that determination of an initiator of transmission induces providers to receive higher profits.

Keywords: ISP Interconnection, Peering Agreements, Transit Agreements, Charging, Pricing, Game Theory, Network Provider.

JEL Classification Numbers: C61, C62, C70, D40, D45, D86, L14, L86, L96, M15, M21.

1. Introduction

The Internet is a system of interconnected networks, which are connected either through a direct link or through an intermediate point, called Internet exchange point (IXP) to exchange traffic. Historically, the Internet provides two types of interconnections: peering and transit [1]. Peering is the arrangement of traffic exchange on the free-settlement basis, called bill-and-keep (BAK), so that the Internet service providers (ISPs) do not pay each other and derive revenues from the respective customers. It is fair and efficient under symmetry of traffic flows as well as termination charges and costs. In transit model one party, such as the downstream provider pays the upstream provider to deliver the traffic between the customers. Negotiation process over being a transit or peered customer reflects on the assessment of the actual cost of traffic exchange and was studied in [2-3].

Traditionally, before interconnecting, provider calculates whether the benefits would outweigh the costs [4]. The simple economic principle suggests sharing the costs between all parties. The survey and discussion on interconnection with two-sided benefits are provided in [5]. In case of telephony, the study [6] argued that both calling and called parties benefit from the call, and consequently, should share the interconnection costs. In the Internet, under symmetry of traffic flows, the termination costs are set to zero, since it is assumed that the termination fees are roughly the same and peering is used. However, because no termination cost is charged, BAK is considered inefficient in terms of the cost compensation [7]. Generally, if providers are asymmetric in terms of size and, therefore, incur different costs, the peering model is not appropriate. Therefore, if traffic is unbalanced, interconnection arrangement is governed by the financial compensation in a bilaterally (paid peering) or unilaterally (transit) negotiated basis to recover the costs of the network.

Various aspects of interconnection of ISPs have been analyzed by [6], [8-10]. This work is focused on private peering arrangement and addresses the problem of cost sharing between providers. When analyzing economics of interconnection, existing literature considers intercarrier compensation based on the flows of traffic. However, the study [11] argued that traffic flows are not a reasonable indicator to share the costs, since it is not clear who originally initiated any transmission and therefore, who should pay for the costs. In other words, compensation between providers cannot be solely done based on the traffic flows, which provide a poor basis for cost sharing. Analytical studies provided in [12] investigated the impact of determination of an original initiator of transmission on intercarrier compensation.

This paper explores the influence of determination of a transmission initiator on demand as well as provider's profit considering two-sided benefits. We present a new intercarrier compensation model, called *differentiated traffic-based interconnection agreement* (*DTIA*) that differentiates traffic into two types, called *native* and *stranger*. In comparison to the existing negotiated-financial settlement [2], under which the payments are based on the net traffic flow, this study proposes to determine an original initiator of transmission and to compensate the costs according to the differentiated traffic flows. More specifically, each ISP compensates fully the termination costs incurred from delivering native traffic that is originally initiated by the provider's own customers, and partially the termination costs incurred from carrying stranger traffic, which is originally initiated by the customers of a rival network. Unlike telephony, the proposed model does not consider a transmission initiator as a cost causer, who should cover the joint costs. Instead, both parties share the joint costs.

Further, a traffic management mechanism that supports the traffic differentiation approach was presented. Analytical studies based on the bargaining model were provided to investigate how the outcome of providers' negotiation depends on differentiated traffic (DT) flows. The key consequence of the results obtained from comparative analysis of agreements based on the net traffic flow and differentiated traffic flow compensation showed, that determination of a transmission initiator leads to the increase of the providers' profits.

The rest of the paper is organized as follows. Section II examines financial settlements between providers. Section III describes the motivation for traffic differentiation. Section IV presents the design of traffic management mechanism. Section V provides analytical studies. Section VI concludes this paper.

2. Financial Settlements

Generally, providers arrange financial settlements in order to determine the distribution of the interconnection costs [2], [13]. Before examining financial settlements within the Internet, we consider a telephony system where Alice makes a call to Bob. Accepting the call, Bob incurs termination costs to its provider that usually are covered indirectly by billing calling party's carrier, since Alice asked to reserve the circuit. Unlike telephony, in the Internet, Alice does not make any reservation of the circuit. As cited in [8] "it is very important to distinguish between the *initiator* and the *sender*, and likewise between the *destination* and the *receiver*". The initiator is the part that initiates a call or a session, and the destination is the part that receives a call. In comparison, the sender (the originator) is the part that sends traffic, and the receiver (the terminator) is the part that receives traffic.

In telephony, the initiator is considered to be the originator and is charged based on the transaction unit, namely a "call minute". In the Internet, it might be argued that a TCP session can be considered as a call, where the initiator of a session pays for the entire traffic flow. However, considering actual use of the network resources, financial settlement should be done at the IP level, accounting each packet of a flow. In addition to this, session-based accounting, which faces technical difficulties, is more complicated than simple packet-based accounting, under which the volume of the exchanged traffic in both directions should be measured. Thus, generally, under bilateral relationship, providers accept negotiated-financial settlements, where the payments are based on the net traffic flow. For detailed discussion see [2], [8], [14].

3. Motivation for Traffic Differation

The principle that we follow is that both parties derive benefits from the exchanged traffic, and therefore, should share the interconnection costs. If content is not equally distributed between providers, traffic imbalance occurs, and hence, costs and revenues are not shared evenly. Indeed, the network that sends more traffic incurs lower cost, than the network that receives more traffic [15]. As cited in [16], traffic flow is dominant towards a customer requested the content and generates 85% of the Internet traffic. This implies that inbound traffic is much more compared to outbound traffic of content request. It was recommended to compensate each provider for the costs that it incurs in carrying traffic based on the traffic flows. However, according to [11], traffic flows are not a good meter for costs sharing, since “it is impossible to determine who originally initiated any given transmission on the Internet” and therefore, provide a poor basis for cost sharing. On the other hand, providers are unwilling to inspect the IP header of a packet, since “the cost of carrying an individual packet is extremely small, and the cost of accounting for each packet may well be greater than the cost of carrying the packet across the providers” [14].

In order to determine the party that originally initiated the transmission, we differentiate traffic into two types, referred to as *native*, which is originally initiated by the provider’s own customers, and *stranger* that is originally initiated by the customers of the peered network. Indeed, outgoing traffic of ISP_i that is the same as rival provider’s incoming traffic may be i) either a part of transmission initiated by a customer of ISP_i, ii) or a part of transmission initiated by a customer of the peered network. In particular, we suggest that the provider compensates the incurred costs i) fully, if the exchanged traffic is native, and ii) partially, if the originated traffic is stranger. More specifically, the private peering networks settle DTIA, whereby each partner is compensated for the costs according to the differentiated traffic flows.

4. Traffic Management Mechanism

The traffic management mechanism for interconnection arrangements, which we propose, allows recognizing the packet type between peered networks. The key aspect of the proposed agreement is based on the traffic differentiation into two types, which are identified by a 1-bit field in the IP packet header, referred to as a *Membership Label* (*ML*).

We assume that all nodes within the network support packet marking, where each node sets the ML field of native packet to ‘1’ and the packet of stranger traffic to ’0’. The assignment of the label to ’1’ is done once, when a node originally initiates a transmission. It is obvious, that native traffic with regard to one network is strange with regard to the other. Hence, it is necessary to differentiate the exchanged traffic between the networks. We distinguish a provider’s border nodes, which are trust boundaries and maintain connection with a peered network, and refer to as the *Provider-to-Provider Border* (*PPB*) nodes. For outgoing traffic, a PPB node performs the NOT logical operation on the ML label. In addition, in order to carry out intercarrier compensation based on the DT flows, each PPB node keeps two counters (one for inbound and another for outbound traffic), which calculate the volume of a particular type of traffic, i.e. native or stranger with regard to the network. The volume of the other type of traffic can be easily defined by subtraction of the counted volume from the total one.

The website requested by a consumer can be subscribed either to a local network or to the peered network. As a result, traffic originated by the endpoint of transmission (e.g.

destination) can be part of the transmission initiated either by the network's customer or by the customer of the peered network. Therefore, identification the type of traffic (i.e. native or stranger) originated by the transmission endpoint is necessary. A transmission endpoint does not re-examine the label and sends a response packet with the same ML field (i.e. the value '0' or '1' is duplicated from the request packet). It is obvious that incoming network traffic with the first bit set to '1' is a part of transmission initiated by its own customers. An example that helps to understand how the described traffic management mechanism works is described below.

As an example, consider a model consisting of ISP$_i$, ISP$_j$, and their customers, where each provider calculates native traffic volumes. Assume that a customer of ISP$_i$ requests data available on ISP$_j$. Let *N1* be the PPB router of ISP$_i$, which receives a packet marked by '1'. Before forwarding it to ISP$_j$, *N1* performs the NOT operation of the ML field of outgoing packet and increases the counter for outgoing native traffic. The PPB node *N2* of ISP$_j$ reads the IP header of the received packet and then forwards it to the destination, e.g. the *N3* node. After receiving the packet, *N3* sends a packet stream with the requested data, where the label value of each packet is set to '0'. The similar procedure follows on the inverse path with only difference that ISP$_i$ considers incoming traffic as native, initiated by its own customers.

5. The Model of DTIA

Analytical studies are based on the bargaining process that is explored using Nash bargaining solution. In order to investigate how the profits of the providers depend on determination of an original initiator of transmission, we focus on traffic exchange i) from consumers to websites, and ii) from websites to consumers. To simplify the analytical studies the following assumptions were made throughout the paper:

Assumption 1 Let $\alpha_i \in (0,1)$ network *i*'s market share for consumers and $\beta_i \in (0,1)$ its market share for websites. The market consists of two networks, *i* and *j*, where $i \neq j = 1,2$ and $\alpha_i + \alpha_j = 1$ $\beta_i + \beta_j = 1$.

Assumption 2 A balanced calling pattern is considered.

We examine a scenario, where ISP$_i$ has signed an interconnection agreement with ISP$_j$. Let p_i^S and p_i^R ($\tilde{p}_i^S$ and $\tilde{p}_i^R$) are network *i*'s prices that a subscribed consumer (website) pays for sending and receiving unit of traffic respectively. Therefore, the utility derived by the consumer and the website of ISP$_i$ is defined by

$$U_i = [u(q_i^S) - p_i^S q_i^S] + [u(\tilde{q}_j^S) - p_i^R \tilde{q}_j^S] \tag{1}$$

$$\tilde{U}_i = [u(\tilde{q}_i^S) - \tilde{p}_i^S \tilde{q}_i^S] + [u(q_j^S) - \tilde{p}_i^R q_j^S] \tag{2}$$

where q_i^S ($\tilde{q}_i^S$) is amount of traffic originated by a consumer (website) of ISP$_i$. We assume that the access charges are set by an industry regulator and then applied reciprocally. Therefore, the providers charge each other the same access charges a and b for terminating native and stranger traffic respectively, where $a > b$. The access charge for terminating native traffic is set to the lowest termination marginal cost, and for terminating stranger traffic is defined by $b=\varepsilon a$, $0.5\le\varepsilon<1$. However, in order to simplify analysis we fix $\varepsilon=0.5$. Let network *i*'s marginal costs of origination and termination are $c_i^o>0$ and $c_i^t>0$ respectively, where $c_i^o=c_i^t$. Thus, profit that ISP$_i$ obtains from the interconnection is given by

$$\Pi_i=\alpha_i\beta_j(\gamma-p_i^S)(p_i^S-c_i^o-a)+\alpha_j\beta_i(\gamma-\tilde{p}_i^S)(\tilde{p}_i^S-c_i^o-b)$$
$$+\alpha_j\beta_i(\gamma-p_j^S)(\tilde{p}_i^R+a-c_i^t)+\alpha_i\beta_j(\gamma-\tilde{p}_j^S)(p_i^R+b-c_i^t) \quad (3)$$

The network's outcome according to the bargaining game is

$$\Pi^{NBS}=0.5(\Pi_i+\Pi_j) \quad (4)$$

If $\Pi_i>\Pi_j$ then ISP$_j$ receives the net payment from ISP$_i$ that is

$$\Pi^{NBS}-\Pi_j=0.5(\Pi_i-\Pi_j)=0.5\left[\alpha_i\beta_j\left(\frac{\gamma-c_i^o-a}{2}\right)^2-\alpha_j\beta_i\left(\frac{\gamma-c_j^o-a}{2}\right)^2\right.$$
$$\left.+\alpha_j\beta_i\left(\frac{\gamma-c_i^o-b}{2}\right)^2-\alpha_i\beta_j\left(\frac{\gamma-c_j^o-b}{2}\right)^2\right] \quad (5)$$

The net interconnection charge can be interpreted as two independent components i) one for native traffic business, which is denoted by $\Delta\sigma_{ij}^{nat}$, and ii) another for stranger traffic business that is denoted by $\Delta\sigma_{ij}^{str}$.

The obtained results are presented in Tables 1-4. Table 1 summarizes the outcomes of the analytical studies. Table 2 shows comparison of the demand as well as outcome of providers' negotiation according to DTIA and classical model with two-sided benefits. Table 3 (Table 4) presents results comparison between agreements based on the net traffic flow and DT flows compensation for ISP$_i$ (ISP$_j$). In order to calculate specific outcomes, we impose the following values of termination costs i) $c_i^t=c_j^t=1$ in Case I, IV, and V, ii) $c_i^t=1$, $c_j^t=1.5$ in Case II and III. The demand is given by $q_i(p_i)=10-p_i$.

Table 1. Results of DTIA

α	β	c^t	$\Delta\sigma_{ij}^{nat}$	$\Delta\sigma_{ij}^{str}$
$\alpha_i=\alpha_j$	$\beta_i=\beta_j$	$c_i^t=c_j^t$	$\Delta\sigma_{ij}^{nat}=0$	$\Delta\sigma_{ij}^{str}=0$
$\alpha_i=\alpha_j$	$\beta_i>\beta_j$	$c_i^t<c_j^t$	*conditional*	$\sigma_{ij}^{str}>0$
$\alpha_i>\alpha_j$	$\beta_i=\beta_j$	$c_i^t<c_j^t$	$\sigma_{ij}^{nat}>0$	*conditional*
$\alpha_i>\alpha_j$	$\beta_i>\beta_j$	*if* $c_i^t=c_j^t$	$\sigma_{ij}^{nat}=0$	$\sigma_{ij}^{str}=0$
$\alpha_i>\alpha_j$	$\beta_i<\beta_j$	*if* $c_i^t=c_j^t$	$\sigma_{ij}^{nat}>0$	$\sigma_{ij}^{str}<0$

Table 2. Comparative Results of Demand and Providers' Outcome According to the Net Traffic Flow (TF) and DT Flows (DTIA) Compensation

Case	α_i	β_i	t_{ij}		t_{ji}		Π^{NBS}	
			DTIA	TF	DTIA	TF	DTIA	TF
I: $\alpha_i = \alpha_j$ $\beta_i = \beta_j$	0.5	0.50	2.06	2.00	2.06	2.00	8.52	8.00
II: $\alpha_i = \alpha_j$ $\beta_i > \beta_j$	0.5	0.90	2.11	2.00	1.89	1.88	8.03	7.52
$c_i^t < c_j^t$	0.5	0.80	2.10	2.00	1.90	1.88	8.03	7.52
	0.5	0.70	2.09	2.00	1.91	1.88	8.02	7.52
	0.5	0.60	2.08	2.00	1.93	1.88	8.02	7.52
III: $\alpha_i > \alpha_j$ $\beta_i = \beta_j$	0.9	0.50	2.01	2.00	1.99	1.88	8.00	7.52
$c_i^t < c_j^t$	0.8	0.50	2.03	2.00	1.98	1.88	8.01	7.52
	0.7	0.50	2.04	2.00	1.96	1.88	8.01	7.52
	0.6	0.50	2.05	2.00	1.95	1.88	8.01	7.52
IV: $\alpha_i > \alpha_j$ $\beta_i > \beta_j$	0.9	0.90	0.74	0.72	0.74	0.72	3.07	2.88
$c_i^t = c_j^t$	0.8	0.80	1.32	1.28	1.32	1.28	5.45	5.12
	0.7	0.70	1.73	1.68	1.73	1.68	7.15	6.72
	0.6	0.60	1.98	1.92	1.98	1.92	8.18	7.68
V: $\alpha_i > \alpha_j$ $\beta_i < \beta_j$	0.9	0.10	3.28	3.28	3.48	3.28	13.97	13.12
$c_i^t = c_j^t$	0.8	0.20	2.73	2.72	2.88	2.72	11.58	10.88
	0.7	0.30	2.34	2.32	2.44	2.32	9.88	9.28
	0.6	0.40	2.12	2.08	2.17	2.08	8.86	8.32

$t_{ij}\,(t_{ji})$ = the total traffic volume from ISPi(ISPj) to ISPj (ISPi)

Considering the amount of traffic originated by the providers, it can be noticed that according to DTIA, the demand is higher than that in case of the agreement based on the net traffic flow compensation (Table 2). Specifically, DTIA leads to increase of the traffic volume originated in one network and ready to be terminated in another side. As a result, the provider's retail revenues obtained from consumers and websites are higher in case of DTIA than in case of the classical model (Tables 3 and 4). And eventually, determination of a transmission initiator induces providers to receive a higher profit (Tables 3 and 4).

Table 3. Comparative Results of the Retail Revenues and Profits According to the Net TF and DTIA Compensation for ISP$_i$

Case	α_i	β_i	$\pi_i(p_i^S, p_i^R)$		$\tilde{\pi}_i(\tilde{p}_i^S, \tilde{p}_i^R)$		Π_i	
			DTIA	TF	DTIA	TF	DTIA	TF
I: $\alpha_i = \alpha_j$ $\beta_i = \beta_j$ $c_i^t = c_j^t$	0.5	0.5	6.53	6.00	6.11	6.00	8.52	8.00
II: $\alpha_i = \alpha_j$ $\beta_i > \beta_j$ $c_i^t < c_j^t$	0.5	0.9	1.30	1.20	11.00	10.80	8.93	8.00
	0.5	0.8	2.60	2.40	9.78	9.60	8.83	8.00
	0.5	0.7	3.90	3.60	8.55	8.40	8.72	8.00
	0.5	0.6	5.20	4.80	7.33	7.20	8.62	8.00
III: $\alpha_i > \alpha_j$ $\beta_i = \beta_j$ $c_i^t < c_j^t$	0.9	0.5	11.70	10.80	1.22	1.20	8.10	8.00
	0.8	0.5	10.40	9.60	2.44	2.40	8.21	8.00
	0.7	0.5	9.10	8.40	3.67	3.60	8.31	8.00
	0.6	0.5	7.80	7.20	4.89	4.80	8.41	8.00
IV: $\alpha_i > \alpha_j$ $\beta_i > \beta_j$ $c_i^t = c_j^t$	0.9	0.9	2.35	2.16	2.20	2.16	3.07	2.88
	0.8	0.8	4.18	3.84	3.91	3.84	5.45	5.12
	0.7	0.7	5.49	5.04	5.13	5.04	7.15	6.72
	0.6	0.6	6.27	5.76	5.87	5.76	8.18	7.68
V: $\alpha_i > \alpha_j$ $\beta_i < \beta_j$ $c_i^t = c_j^t$	0.9	0.1	21.16	19.44	0.24	0.24	13.14	13.12
	0.8	0.2	16.72	15.36	0.98	0.96	10.96	10.88
	0.7	0.3	12.80	11.76	2.20	2.16	9.47	9.28
	0.6	0.4	9.41	8.64	3.91	3.84	8.65	8.32

$\pi_i(p_i^S, p_i^R)$ = provider i 퀼 revenue obtained from the subscribed consumers
$\tilde{\pi}_i(\tilde{p}_i^S, \tilde{p}_i^R)$ = provider i 퀼 revenue obtained from the subscribed websites

Table 4. Comparative Results of the Retail Revenues and Profits According to the Net TF and DTIA Compensation for ISP$_j$

Case	$(1-\alpha_i)$	$(1-\beta_i)$	$\pi_j(p_j^S, p_j^R)$		$\tilde{\pi}_j(\tilde{p}_j^S, \tilde{p}_j^R)$		Π_j	
			DTIA	TF	DTIA	TF	DTIA	TF
I: $\alpha_i = \alpha_j$ $\beta_i = \beta_j$ $c_i^t = c_j^t$	0.5	0.5	6.53	6.00	6.11	6.00	8.52	8.00
II: $\alpha_i = \alpha_j$ $\beta_i > \beta_j$ $c_i^t < c_j^t$	0.5	0.1	12.46	11.45	1.30	1.27	7.13	7.03
	0.5	0.2	11.08	10.18	2.60	2.54	7.23	7.03
	0.5	0.3	9.69	8.90	3.90	3.82	7.32	7.03
	0.5	0.4	8.31	7.63	5.20	5.09	7.42	7.03
III: $\alpha_i > \alpha_j$ $\beta_i = \beta_j$ $c_i^t < c_j^t$	0.1	0.5	1.38	1.27	11.70	11.45	7.90	7.03
	0.2	0.5	2.77	2.54	10.40	10.18	7.81	7.03
	0.3	0.5	4.15	3.82	9.10	8.90	7.71	7.03
	0.4	0.5	5.54	5.09	7.80	7.63	7.61	7.03
IV: $\alpha_i > \alpha_j$ $\beta_i > \beta_j$ $c_i^t = c_j^t$	0.1	0.1	2.35	2.16	2.20	2.16	3.07	2.88
	0.2	0.2	4.18	3.84	3.91	3.84	5.45	5.12
	0.3	0.3	5.49	5.04	5.13	5.04	7.15	6.72
	0.4	0.4	6.27	5.76	5.87	5.76	8.18	7.68
V: $\alpha_i > \alpha_j$ $\beta_i < \beta_j$ $c_i^t = c_j^t$	0.1	0.9	0.26	0.24	19.79	19.44	14.79	13.12
	0.2	0.8	1.05	0.96	15.64	15.36	12.20	10.88
	0.3	0.7	2.35	2.16	11.97	11.76	10.29	9.28
	0.4	0.6	4.18	3.84	8.80	8.64	9.06	8.32

$\pi_j(p_j^S, p_j^R)$ = provider j 퀼 revenue obtained from the subscribed consumers
$\tilde{\pi}_j(\tilde{p}_j^S, \tilde{p}_j^R)$ = provider j 퀼 revenue obtained from the subscribed websites

6. Conclusions

In this paper the impact of traffic differentiation on demand as well as profits of the providers was explored. In particular, a new DTIA model was presented, which determines an original initiator of transmission by means of traffic differentiation into two types, called native and stranger. In comparison to the existing financial settlement, under which the payments are based on the net traffic flow, according to DTIA cost compensation is done based on the differentiated traffic flows. Specifically, each provider compensates fully the termination costs incurred from delivering native traffic and partially the costs incurred from carrying stranger traffic.

The technical part of the paper describes the design of a traffic management mechanism that supports the suggested approach. The main advantage of the presented mechanism is simplicity that is significant in the Internet. In particular, the provider has not to maintain complex identification process of transmission initiator and to inspect the IP header of packets in order to determine and record all subsequent packets of the transmission. Instead, the defined membership label (ML) allows accounting the volume of the appropriate traffic type and therefore, leads to computational complexity reduction.

The following conclusions can be drawn from the obtained results based on analytical studies that investigated how outcome of providers' negotiation depend on the DT flows (see Tables I-IV). Firstly, results demonstrated that the total demand (the total traffic volume originated by a particular provider) is higher in case of DTIA than under the classical model based on the net traffic flow compensation (see Table II). Secondly, as a result of demand growth, the retail revenues of the providers settled DTIA also increase (Tables III and IV). And finally, in contrast to the compensation based on the net traffic flow, determination of an initiator of transmission induces providers to obtain greater profit (see Tables II-IV). Thus, the presented model outperforms the classical model in terms of the profits, which are remarkably high.

7. Acknowledgment

The authors would like to thank Prof. Wolfgang Effelsberg and Kristina Davoian for their useful comments and helpful discussions.

8. References

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