A New Bilateral Arrangement between Interconnected Providers

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Abstract. Cost allocation between interconnected networks is based on measured traffic flows. This principle, however, does not provide a fair way for sharing costs. In this paper, a new bilateral model, called Differentiated Traffic-based Interconnection Agreement (DTIA) for intercarrier compensation is presented. In particular, the approach aims to determine the original initiator of a transmission by means of traffic differentiation into two types and to compensate the interconnection costs. Unlike the existing financial settlements, under which the payments are made based on the traffic flows, the proposed method suggests costs compensation according to the differentiated traffic flows. Further, in order to support the described payment scheme, a simple and scalable traffic management mechanism was designed. The results obtained from the comparative analysis showed that determination of a transmission initiator induces cost sharing between all parties and therefore, reduces the interconnection payments between providers.

Keywords: Interconnection arrangement, intercarrier compensation, Internet economics.

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 a free-settlement basis, called bill-and-keep (BAK), so that the Internet service providers (ISPs) do not pay each other and derive revenues from their own customers [2]. It is fair and efficient under symmetry of traffic flows, termination charges, and costs. Under the transit model, a customer provider pays a transit provider to deliver the traffic between the customers. The outcome of the negotiation process of being a transit or peered customer reflects on the assessment of the actual cost of traffic exchange [3-4]. Peering offers several advantages in terms of interconnection costs and quality of data transmission, but gives access to a part of the entire Internet. According to the estimates in [5], 80% of the Internet traffic is routed via private peering. In

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some cases, however, in order to recover the infrastructure costs, instead of peering with the smaller ISPs, the larger ISPs offer transit arrangements at a certain rate, providing access to the whole Internet. In addition to this, new types of interconnection models, such as paid peering and partial transit, emerged in the market [6].

Traditionally, before interconnecting, a provider calculates whether the interconnection benefits would outweigh the costs [7]. The simple economic principle suggests sharing the costs between all parties. The survey and discussion on interconnection with two-sided benefits are provided in [8-9]. In the case of telephony, the study [10] 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 a peering arrangement is used. However, because no termination cost is charged, BAK is considered inefficient in terms of the cost compensation [11]. Generally, if providers are asymmetric in terms of size, peering model is not appropriate, since providers incur different costs and benefit differently.

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. In bilateral settlements, the payments are done based on the net traffic flow. Considering the Internet hierarchical structure, Internet backbone providers (IBPs) sell the wholesale services to competitive ISPs. As a result, in unilateral settlement agreements, a customer provider pays for sent and received traffic, even though traffic flows in both directions. As cited in [5], it was recommended to establish bilateral arrangements and to compensate each provider for the costs that it incurs in carrying traffic generated by the other network. However, the study [5] 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 performed based on the traffic flows, which provide a poor basis for cost sharing.

Various aspects of interconnection of ISPs have been analyzed by [10], [12-16]. When analyzing economics of interconnection, existing literature considers intercarrier compensation based on the flows of traffic. Analytical studies provided in [17-18] investigated the impact of determination of an original initiator of a transmission on intercarrier compensation, demand as well as profits of the providers in the case of private peering arrangement.

This paper follows the problem of cost sharing between providers and presents a new intercarrier compensation model, called *differentiated traffic–based interconnection agreement* (*DTIA*). The key aspect of the described model is based on the determination of a transmission initiator by means of traffic differentiation into two types, referred to as *native* that is originally initiated by the provider's own customers and *stranger*, which is initiated by the customers of any other network. In comparison to the existing bilateral or unilateral settlements [3], under which the payments are based on the traffic flows, this study proposes to compensate the interconnection costs according to the differentiated traffic flows. In particular, each provider is compensated fully for the costs that it incurs in carrying native traffic and partially for the costs that it incurs in carrying stranger traffic. Unlike telephony, the proposed model does not consider a transmission initiator as a cost causer, who should cover the joint costs. Instead, all parties share the entire costs.

Further, a simple and scalable traffic management mechanism that supports the traffic differentiation approach was designed. A similar mechanism only for private peering arrangements was presented in our earlier work [19]. The major advantage of the described mechanism is that providers have not to inspect the IP header of a packet in order to determine how it should be accounted. The proposed mechanism introduces a membership label, which allows accounting the volume of a particular traffic type. Hence, a significant reduction in computational costs is achieved by using a membership label.

Finally, a comparative study of the agreements based on the traffic flows and differentiated traffic flows compensation was provided. The obtained results demonstrated that the determination of the original initiator of a transmission reduces the interconnection payment between networks.

The rest of the paper is organized as follows. Section 2 discusses the financial settlements between providers. Section 3 describes the motivation for traffic differentiation. Section 4 presents the design of the traffic management mechanism for interconnection arrangements. Section 5 provides analytical studies. Finally, Section 6 concludes this paper.

2 Financial Settlements

Generally, providers arrange financial settlements in order to determine the distribution of the interconnection costs [3], [20]. Before examining financial settlements within the Internet, we consider the telephony system. As an example, assume the scenario, where Alice makes a call to Bob. Accepting the call, Bob incurs termination costs to its provider that should be covered either directly by billing Bob or indirectly by billing the calling party's carrier. As cited in [11], "existing access charge rules and the majority of existing reciprocal compensation agreements require the calling party's carrier, […], to compensate the called party's carrier for terminating the call". Thus, an initiator of the call, i.e. Alice pays to the subscribed provider for the entire call, since Alice asked to reserve the circuit. In contrast to the telephony example, establishing a connection in the Internet does not require any reservation of the circuit. Usually packets between Alice and Bob are routed independently, sometimes even via different paths. Therefore, as cited in [12], "it is very important to distinguish between the *initiator* and the *sender*, and likewise between the *destination* and the *receiver*". The initiator is the party that initiates a call or a session, and the destination is the party 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" for using the terminating network. On 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 the 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 is measured.

Therefore, generally, under unilateral business relationships, providers adopt *service-provider* settlements, where a customer ISP pays to a provider ISP for sent and received traffic, and under bilateral relationship, providers accept *negotiated-financial* settlements, where the payments are based on the net traffic flow. For detailed discussion see [3], [12], [21].

3 Motivation for Traffic Differentiation

The principle that we follow is that both parties derive benefits from the exchange of traffic and, therefore, should share the interconnection costs. Considering a system without externalities [3], [22], the costs should be shared based on the benefits obtained by each party. However, in the real world, it is impossible to measure the benefits of parties and so to share the 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 [23]. As cited in [24], 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 [5], 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. Furthermore, 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" [21].

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 any other network. Indeed, outgoing traffic of ISP_i that is the same as adjacent provider's incoming traffic may be i) either a part of a transmission initiated by a customer of ISP_i, ii) or a part of a transmission initiated by a customer of any other network. In particular, we suggest that a provider compensates the incurred costs i) fully, if the exchanged traffic is native, and ii) partially, if the originated traffic is stranger. More specifically, interconnected networks settle DTIA, whereby each partner is compensated for the costs, which it incurs in carrying traffic 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 throughout the network. The key aspect of the proposed mechanism is the identification the type of traffic based on a two-bit field in the IP packet header, referred to as the *Membership Label* (*ML*).

4.1 Packet Marking by a Transmission Initiator

We assume that all nodes within the network support packet marking, where each node sets the *first bit* of the ML field of native packet to *'1'* and the packet of stranger traffic to *'0'*. The *assignment of the first bit of the label to '1' is done once*, when a node originally initiates a transmission.

A consumer can request a webpage either from a subscribed network or from any other network. This implies that a transmission endpoint, such as the destination can belong to the same network as the transmission initiator or to any other network. Therefore, a packet that appears in the network can be originated either by a local transmission endpoint or by an endpoint, which is located in any other network. Hence, we distinguish the location of a transmission endpoint originated a packet with respect to the network, where the packet appears.

The *second bit* of the label set to *'1'* indicates that the endpoint is local, and *'0'* shows that one is located in another network. The *assignment of the second bit of ML to '1' is done once*, when an endpoint of transmission originates a packet. Consequently, an original initiator of a transmission sets the ML field to *'11'*. Table I presents the description of the four available values of the label, which will be discussed latter in this section.

4.2 Outgoing Packet Re-marking

It is obvious, that native traffic with regard to one network is stranger with regard to the other. Hence, it is necessary to differentiate the exchanged traffic between networks. In order to achieve that we distinguish provider's border nodes, which are trust boundaries and maintain connection with an adjacent network, and refer to as the *Provider-to-Provider Border* (*PPB*) nodes. For calculating the *first bit* of the membership label of outgoing traffic, a PPB node performs the XOR logical operation on both bits of the ML label. Obviously, that the PPB nodes set the *second bit* to *'0'*. Even though packets within a domain can be marked by any available value of ML, interdomain traffic can take on only *'00'* or *'10'* values of the label (i.e. stranger or native traffic originated by a transmission endpoint located in any network).

In addition, in order to carry out intercarrier compensation based on the differentiated traffic (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 its network*. The volume of the other type of traffic can be easily determined by subtracting the counted volume from the total one. Table 2 demonstrates the logic of the PPB nodes for outgoing packet re-marking and for counting outgoing native traffic.

4.3 Incoming Packet Re-marking

As mentioned before, the website requested by a consumer can be subscribed either to the local network or to any other network. As a result, traffic originated by the endpoint of transmission (e.g. destination), can be part of a transmission initiated either by the network's customer or by the customer of any other network. Therefore, the identification the type of traffic (i.e. native or stranger) originated by the transmission endpoint is necessary. For *incoming traffic that is destined to the network* (i.e. destination

IP address is local), the PPB nodes perform the NOT logical operation on the *second bit* of the label and do not change the *first bit*.

A transmission endpoint does not re-examine the label. It sends *response* packets with the same ML field (i.e. the values '01' or '11' are copied from the request packet). It is obvious that incoming network traffic with the first bit set to '1' and destined to the network is a part of a transmission initiated by its own customers. Table 3 shows the logic of the PPB nodes for incoming traffic and for counting incoming native traffic. An example that helps to understand how the described traffic management mechanism works is described below.

Table 1. Available values of the ML field

Values of ML	Description
00	Stranger packet, originated by the endpoint located in another network
01	Stranger packet, originated by the local endpoint
10	Native packet, originated by the endpoint located in another network
11	Native packet, originated by the local endpoint

Table 2. Outgoing packet re-marking and counting

Input	Output	Counter
00	00	counter1
01	10	counter1
10	10	counter1
11	00	counter1++

counter shows the current value of the counter for outgoing traffic

Table 3. Incoming packet re-marking and counting

Input	Output (Counter)	
	If destination IP address is local	Otherwise
00	01 (counter2)	00 (counter2)
10	11 (counter2++)	10 (counter2)

counter shows the current value of the counter for incoming traffic

As an example, consider a model consisting of ISP_i, ISP_j, and their customers as well as the transit network ISP_k, where each provider calculates the volumes of native traffic. Assume that a customer of ISP_i requests data available on ISP_j. Let *N1* be the PPB node of ISP_i, which receives a packet marked by *'11'*. Before forwarding it to ISP_k, *N1* performs the XOR operation on the ML field of the outgoing packet (i.e. sets the label to *'00'*), and increases the counter for outgoing native traffic. The PPB node *N2* of ISP_k reads the destination IP address, however does not re-mark the label (since the packet is not destined to its network), and then forwards the packet to PPB node *N3*, which maintains connectivity with ISP_j. *N3* node performs the XOR operation on the outgoing packet label (as a result, the ML value remains the same, i.e. *'00'*) and forwards it to PPB node *N4* of ISP_j. *N4* node reads the destination IP address, and since the packet is destined for its network, applies the NOT operation on the label of the incoming packet (i.e. sets ML to *'01'*) and forwards it to the destination, e.g. the *N5* node. After receiving the packet, *N5* sends a packet stream with the requested data, where the label remains the same (*'01'* i.e. stranger traffic, which is originated locally). The similar procedure follows on the inverse path with only one difference that ISP_i considers the incoming traffic as native, initiated by its own customers.

4.4 Incentive Compatibility

It is well known that strategic agents have an incentive not to be truthful and, therefore, end-systems or the defined PPBs nodes can perform mendacious packet marking. However, there are several favorable reasons to adopt our approach. First, we considered that PPB is a trust boundary, and therefore, its operations can be recorded and then audited. Second, applying commonly used pricing scheme, such as flat-rate creates no incentive to the end-systems to perform untruthful packet marking, since it does not affect fees and quality of service. Finally, interconnection is a long-term and repeated process, arranged under mutual benefits, and, therefore, sustainable cooperation between interconnected ISPs is a reasonable and natural solution. Nevertheless, we intend to address incentive compatibility in our future work.

5 A Simple Benchmark

In our analysis two types of the customers, namely consumers and websites are considered. Actually, traffic is exchanged 1) between consumers, 2) between websites, 3) from websites to consumers, and 4) from consumers to websites. Generally, traffic between websites and from consumers to websites is negligible. Recently, peer-to-peer (P2P) traffic has increased rapidly. The significant part of the Internet traffic, comprised of FTP, Web, and streaming media traffic, is from websites to consumers. In order to investigate the impact of determination of the transmission initiator on the intercarrier compensation in its simplest way, we focus on traffic exchange i) from consumers to websites, and ii) from websites to consumers. Traffic between consumers and between websites is neglected, since it does not have any significant impact on the results of the analysis. It is worth noting that according to the proposed approach, a node in a P2P network can be considered as a consumer as well as a website simultaneously, since it can act as a server and a client. To simplify the analytical studies the following assumptions were made throughout the paper:

Assumption 1. Let $\alpha_i \in (0,1)$ be a network's market share for consumers and $\beta_i \in (0,1)$ its market share for websites. The market consists of only one transit provider and two customer networks, *i* and *j*, where *i*≠*j*, and $\alpha_i + \alpha_j = 1$, $\beta_i + \beta_j = 1$.

Assumption 2. The number of consumers and the number of websites in the market are denoted as N and M respectively. Each customer chooses only one provider to join, because of homogeneity of the services.

Assumption 3. For simplicity, a balanced calling pattern, where each consumer requests any website in any network with the same probability is considered. Each consumer originates one unit of traffic per request of website and downloads a fixed amount of content.

We examine a scenario, in which ISP_i and ISP_j exchange traffic through the transit provider ISP_k. The amount of differentiated traffic originated from ISP_i with destination ISP_k is given by

$$t_{ik}^{nat} = \alpha_i \beta_j NM \quad (1)$$

$$t_{i\kappa}^{str} = \alpha_j \beta_i NMx \quad (2)$$

where t_{ik}^{nat} denotes the amount of outgoing native traffic (exchanged from consumers to websites) and t_{ik}^{str} the amount of outgoing stranger traffic (exchanged from websites to consumers) with respect to ISP$_i$. The variable x denotes the average amount of traffic caused by requesting a website.

Similarly, the DT volumes originated by ISP$_j$ and destined to ISP$_i$ are given by

$$t_{jk}^{nat} = \alpha_j \beta_i NM \quad (3)$$

$$t_{jk}^{str} = \alpha_i \beta_j NMx \quad (4)$$

Here, t_{jk}^{nat} represents the outgoing native traffic and t_{jk}^{str} represents the outgoing stranger traffic with respect to ISP$_j$. The total amount of traffic from ISP$_i$ and ISP$_j$ are calculated as

$$t_{ik} = t_{ik}^{nat} + t_{ik}^{str} \quad (5)$$

$$t_{jk} = t_{jk}^{nat} + t_{jk}^{str} \quad (6)$$

Since this paper is not about examining how the access charges are defined, therefore, we assume for the purpose of simplicity that access charges between providers are set by an industry regulator and then applied reciprocally. Let ISP$_i$ (ISP$_k$) charges ISP$_k$ (ISP$_i$) a_k^i (a_i^k) and b_k^i (b_i^k) for every unit of received native and stranger traffic respectively, where $a_k^i > b_k^i$ ($a_i^k > b_i^k$), since the providers compensate partially the costs of terminating stranger traffic. For the case of symmetric access charges $a_k^i = a_i^k = a_k^j = a_j^k = a$ and $b_k^i = b_i^k = b_k^j = b_j^k = b$, whereas $b = \varepsilon a$ and $0.5 \le \varepsilon < 1$. However, in order to simplify analysis, we fix $\varepsilon = 0.5$. The net interconnection payments from ISP$_i$ to the transit provider and vice versa are denoted by q_{ik} and q_{ki} correspondingly

$$q_{ik} = a t_{ik}^{nat} + b t_{ik}^{str} \quad (7)$$

$$q_{ki} = b\left(t_{jk}^{nat} + t_{jk}^{str}\right) \quad (8)$$

From (8), it can be noticed that the transit provider is charged based on the rate for stranger traffic, because it does not have any customers of its own. Similarly, the net transfers from ISP$_j$ to the transit provider and vice versa are denoted by q_{jk} and q_{kj} respectively

$$q_{jk} = a t_{jk}^{nat} + b t_{jk}^{str} \quad (9)$$

$$q_{kj} = b\left(t_{ik}^{nat} + t_{ik}^{str}\right) \quad (10)$$

The costs of ISP$_i$ (ISP$_j$) can be interpreted as a composition of two independent components i) one for native traffic business, and ii) another for stranger traffic business.

Proposition 1. *If $\alpha_i = \alpha_j$ and $\beta_i = \beta_j$, then the costs of the customer network providers are the same.*

Proof: From the conditions (1)-(4) follows that $t_{ik}^{nat} + t_{ik}^{str} = t_{jk}^{nat} + t_{jk}^{str}$. As a result, using (7) and (9) it can be obtained that $q_{ik} = q_{jk}$.

Proposition 2. *If* $\alpha_i = \alpha_j$ *and* $\beta_i > \beta_j$ *, then the costs of* ISP_i *are higher than the costs of* ISP_j.

Proof: Observing conditions (1)-(4) it can be obtained that $t_{ik}^{nat} + t_{ik}^{str} > t_{jk}^{nat} + t_{jk}^{str}$. Consequently, from the conditions (7) and (9) follows that $q_{ik} > q_{jk}$.

Proposition 3. *If* $\alpha_i > \alpha_j$ *and* $\beta_i = \beta_j$ *, then the costs of* ISP_i *are lower than the costs of* ISP_j.

Proof: From the conditions (1)-(4) follows that $t_{ik}^{nat} + t_{ik}^{str} < t_{jk}^{nat} + t_{jk}^{str}$. Hence, from the conditions (7) and (9), it can be obtained that $q_{ik} < q_{jk}$.

When $\alpha_i > \alpha_j$ and $\beta_i > \beta_j$, the following cases for traffic volumes are obtained from the conditions (5) and (6): 1) $t_{ik} > t_{jk}$, 2) $t_{ik} < t_{jk}$, and 3) $t_{ik} = t_{jk}$. The cases 1) and 2) are analogous to those described above. The last case when $t_{ik} = t_{jk}$ is analyzed below.

Proposition 4. *If* $\alpha_i > \alpha_j$ *,* $\beta_i > \beta_j$ *, and* $t_{ik} = t_{jk}$ *, then* $\alpha_i = \beta_i$.

Proof: The result is obtained from the conditions (1)-(6).

Corollary 1. *If* $\alpha_i > \alpha_j$ *,* $\beta_i > \beta_j$ *, and* $t_{ik} = t_{jk}$ *, then* $t_{ik}^{nat} = t_{jk}^{nat}$ *and* $t_{ik}^{str} = t_{jk}^{str}$.

Proposition 5. *If* $\alpha_i > \alpha_j$ *,* $\beta_i > \beta_j$ *, and* $t_{ik} = t_{jk}$ *then the costs of the customer providers are equal.*

Proof: The result is obtained from the conditions (7) and (9).

Proposition 6. *If* $\alpha_i > \alpha_j$ *and* $\beta_i < \beta_j$ *, then the costs of* ISP_j *are higher than the costs of* ISP_i.

Proof: Considering conditions (1)-(4) it can be obtained that $t_{ik}^{nat} + t_{ik}^{str} < t_{jk}^{nat} + t_{jk}^{str}$. As a result, from the conditions (7) and (9) follows that $q_{ik} < q_{jk}$.

Table 4. Results of DTIA

Case	α	β	t^{nat}	t^{str}	q
I	$\alpha_i = \alpha_j$	$\beta_i = \beta_j$	$t_{ik}^{nat} = t_{jk}^{nat}$	$t_{ik}^{str} = t_{jk}^{str}$	$q_{ik} = q_{jk}$
II	$\alpha_i = \alpha_j$	$\beta_i > \beta_j$	$t_{ik}^{nat} < t_{jk}^{nat}$	$t_{ik}^{str} > t_{jk}^{str}$	$q_{ik} > q_{jk}$
III	$\alpha_i > \alpha_j$	$\beta_i = \beta_j$	$t_{ik}^{nat} > t_{jk}^{nat}$	$t_{ik}^{str} < t_{jk}^{str}$	$q_{ik} < q_{jk}$
IV	$\alpha_i > \alpha_j$	$\beta_i > \beta_j$	*If* $t_{ik}^{nat} = t_{jk}^{nat}$	*If* $t_{ik}^{str} = t_{jk}^{str}$	$q_{ik} = q_{jk}$
V	$\alpha_i > \alpha_j$	$\beta_i < \beta_j$	$t_{ik}^{nat} > t_{jk}^{nat}$	$t_{ik}^{str} < t_{jk}^{str}$	$q_{ik} < q_{jk}$

Tables 4 and 5 summarize the outcomes of the analytical studies. Table 4 shows how the interconnection payments of the customer providers depend on the DT flows. In addition to this, the results demonstrate the influence of providers’ market shares on intercarrier compensation.

Table 5. Comparative results of the agreements based on traffic flow (TF) and DTIA compensation

Case	α_i	β_i	t_{ik}^{nat}	t_{ik}^{str}	t_{jk}^{nat}	t_{jk}^{str}	q_{ik}		q_{jk}		$q_k = q_{ki} + q_{kj}$		π_k	
							DTIA	TF	DTIA	TF	DTIA	TF	DTIA	TF
I $\alpha_i = \alpha_j$ $\beta_i = \beta_j$	0.5	0.9	1500	52500	1500	52500	27750	108000	27750	108000	54000	0	1500	216000
II $\alpha_i = \alpha_j$ $\beta_i > \beta_j$	0.5	0.9	300	94500	2700	10500	47550	108000	7950	108000	54000	0	1500	216000
	0.5	0.8	600	84000	2400	21000	42600	108000	12900	108000	54000	0	1500	216000
	0.5	0.7	900	73500	2100	31500	37650	108000	17850	108000	54000	0	1500	216000
	0.5	0.6	1200	63000	1800	42000	32700	108000	22800	108000	54000	0	1500	216000
III $\alpha_i > \alpha_j$ $\beta_i = \beta_j$	0.9	0.5	2700	10500	300	94500	7950	108000	47550	108000	54000	0	1500	216000
	0.8	0.5	2400	21000	600	84000	12900	108000	42600	108000	54000	0	1500	216000
	0.7	0.5	2100	31500	900	73500	17850	108000	37650	108000	54000	0	1500	216000
	0.6	0.5	1800	42000	1200	63000	22800	108000	32700	108000	54000	0	1500	216000
IV $\alpha_i > \alpha_j$ $\beta_i > \beta_j$	0.9	0.9	540	18900	540	18900	9990	38880	9990	38880	19440	0	540	77760
	0.8	0.8	960	33600	960	33600	17760	69120	17760	69120	34560	0	960	138240
	0.7	0.7	1260	44100	1260	44100	23310	90720	23310	90720	45360	0	1260	181440
	0.6	0.6	1440	50400	1440	50400	26640	103680	26640	103680	51840	0	1440	207360
V $\alpha_i > \alpha_j$ $\beta_i < \beta_j$	0.9	0.2	4320	4200	120	151200	6420	159840	75720	159840	79920	0	2220	319680
	0.8	0.25	3600	10500	300	126000	8850	140400	63300	140400	70200	0	1950	280800
	0.7	0.35	2730	22050	630	95550	13755	120960	48405	120960	60480	0	1680	241920
	0.6	0.4	2160	33600	960	75600	18960	112320	38760	112320	56160	0	1560	224640

q_k = total costs of the transit provider
π_k = $q_{ik} + q_{jk} - q_k$ provider k's profit obtained from interconnection

The comparison results between the unilateral settlements based on the traffic flows compensation and DTIA, where payments are made on the DT flows are presented in Table 5. In order to calculate specific outcomes, we imposed the following parameter values $a=1$, $x=35$, $N=100$, and $M=60$. The following observations can be made from the obtained results. Firstly, in comparison to the unilateral settlement, under which the customer providers compensate equally, in DTIA the customer provider that sends more traffic compensates more. Secondly, considering transit provider costs, it can be noticed that in DTIA, the transit provider along with the customer providers carries the burden of the interconnection costs. In particular, in contrast to the classical model, compensations of the transit ISP according to the proposed model are different from zero. As a result, determination of a transmission initiator induces reduction in the interconnection payments subsidized by the customer ISPs. And finally, under bilateral DTIA, the profits of the transit provider obtained from interconnection are decreased, since costs are allocated between all parties.

6 Conclusions

In this paper we described a new bilateral model, called Differentiated Traffic-based Interconnection Agreement (DTIA), for intercarrier compensation between providers. We proposed to differentiate traffic into two types, referred to as *native* and *stranger* in order to determine an original initiator of a transmission for calculating intercarrier compensation. In comparison to the existing financial settlement agreements, under which the payments are based on traffic flows, the described model governs cost compensation according to the differentiated traffic flows. More specifically, each provider is compensated fully for the costs incurred from delivering native traffic, which is originally initiated by its own customers, and partially for the costs incurred from carrying stranger traffic that is originally initiated by the customers of any other network.

For supporting DTIA, we designed a traffic management mechanism, in which only border nodes perform packet management. The main advantage of the presented mechanism is its simplicity and scalability that is a basic requirement for a deployment in the Internet. In particular, the provider has not to maintain a 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 low computational complexity (see Table 1). The logic of the border nodes for packet marking and counting is demonstrated as well (see Tables 2 and 3).

Our analytical studies showed how the interconnection payments differ to the existing solution (see Tables 4 and 5). The comparative analysis between the classical model and DTIA indicated that determination of a transmission initiator reduces the payments of the customer providers. This is achieved due to the fact that the transit provider along with the customer ISPs shares the interconnection costs. Overall, it can be concluded that the DTIA model is beneficial for the customer providers, since it outperforms the classical model in terms of payments, which are relatively small and unequal.

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