Internet Exchange Traffic Sharing and Market Competition

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Abstract

Traffic behavior in a large-scale network can be viewed as a complex non-linear system. It is very difficult to illustrate the long-term network traffic behavior in a large-scale network. The Internet can be seen as the combination of Internet Service Providers (ISP) and Internet Exchange (IX) providers. Due to market competition among ISPs and IX, Internet users will experience the different kind of quality of services (QoS), which effectively affect the network traffic model.

The paper analyzes the traffic model in the Internet Exchange (IX) environment. The model simulates ISP/IX market competition behavior. Internet exchange providers' market share will be diluted through market competition. Several routing strategy was proposed in the study. The routing strategies vary with the different competing environment.

Keywords: ISP, IX, QoS, Routing Strategy.

1 Introduction

The Internet has been around for over decades now. Though it has become one of the most popular media, our understanding of it is still not yet complete. From topology point of view, the Internet can be seen as the combination of ISPs (Internet Service Providers) and IX (Internet Exchange). ISP provides Internet traffic access and transit to Internet users, IX provides traffic aggregation and exchange. One of the major areas in which we lack understanding of is Internet traffic behavior in IX environment. We address this issue by presenting a paper which models the traffic model in IX environment. In the paper we analyze and present a evaluation appraisal of the model.

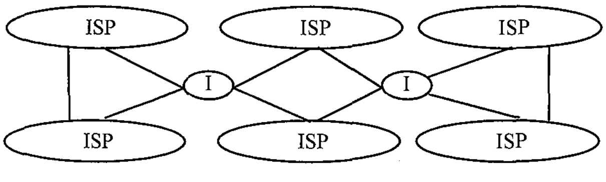

Figure 1 ISP vs. IX : Components of Internet Architecture

Figure 1 illustrates the components of Internet architecture.

The connectivities among ISPs are constructed through either private peering or public peering (IX). Internet traffic engineering is defined as that aspect of Internet network engineering dealing with the issue of performance evaluation and performance optimization of operational IP networks. Traffic Engineering encompasses the application of technology and scientific principles to the measurement, characterization, modeling, and control of Internet traffic [1].

Introduce ISP operation model in IX environment. It is shown that smaller Internet exchange competitors can benefit from the competition even if their Quality of Service (QoS) is worse than the incumbent IX provider.

2 A model of Internet Traffic Exchange

With reference to the case of two IX providers, we establish the following hypothesis to model the behavior of the ISP and the sharing of its traffic between the two IX providers.

- Initial assumption : there are only two IX providers in the market
- The ISP initially chooses one of the two IX providers (indicated as E_1 and E_2) with probability p and 1-p (initial shares) respectively;
- The probably p can take into account all the factors that may lead the ISP to choose one of the two IX providers as its first choice, including the quality of service it offers or business settlement;
- Once the traffic congested, ISP has two choices: it can either switch to transit service provider (TSP) with higher transit cost (with probability p_T) or switch to the other IX for a new attempt;
- Switching between the two IX providers is performed on a route-by-route basis and depends just on the latest route attempt;
- During the repeated routing attempt process, the congestion probabilities C_1 and C_2 (i.e. the congestion

probabilities that the route attempt through the operator E_1 or E_2), and the probability of switching transit service provider p_T stay constant.

- Congestion probabilities C_1 and C_2 can be decomposed into other sub-elements, such as pricing and bandwidth. The decomposition analysis is not covered in this study.

Under these hypotheses the ISP's behavior can be modeled by a four-state discrete-time Markov chain (see Figure 2) in which state E_1 corresponds to the ISP attempting to route traffic through the operator E_1, state E_2 corresponds to the ISP attempting to route traffic through the operator E_2, state Z corresponds to a successful route to destination ISP, and state T corresponds to the ISP leaving the process (internet traffic through transit service provider). Both states Z and T are absorbing, since the completion of an IX route or the transit switching terminates the ISP's attempt process (through IX environment). The transition probabilities are indicated on the arcs connecting the circles representing the chain states. The time is represented by the number of time slots, so that, indicating by X the actual state, $P[X^{(n)} = E_i]$ (i=1,2) is the probability that the n+1th routing attempt is placed through the IX provider E_i, $P[X^{(n)}=Z]$ is the probability that the routing traffic has been completed through Internet exchange environment within the first n attempts, and $P[X^{(n)}=T]$ is the probability that the ISP has given up and switching traffic to transit service provider after no more than n attempts.

The starting conditions (state distribution before the first route attempt) are

$$P[X^{(0)}=E_1] = p \quad , \tag{1}$$

$$P[X^{(0)}=E_2] = 1\text{-}p, \tag{2}$$

$$P[X^{(0)}=Z]=0, \tag{3}$$

$$P[X^{(0)}=T]=0. \tag{4}$$

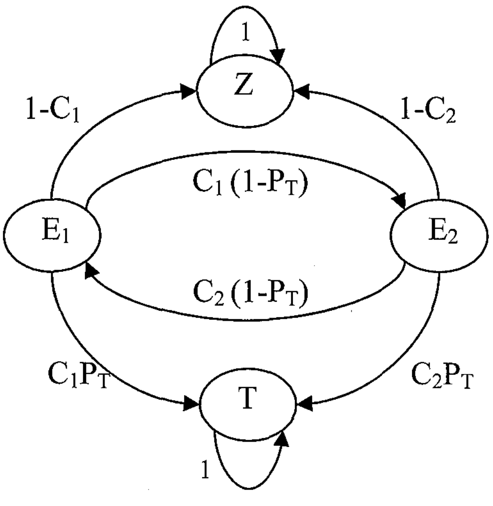

Figure 2 The Markov chain model of the ISP behavior in the two IX providers case

Since the ISP switches from E_1 to E_2 only if its route congested and if it does not switch to transit service provider, the transition probability from E_1 to E_2 is $C_1(1\text{-}p_T)$. Consequently, the probability of a route placed through IX provider E_1 being completed in a single attempt is $1\text{-}C_1$.

The one-step transition probabilities matrix is therefore

$$M = \begin{pmatrix} 0 & C_1(1-p_T) & 1-C_1 & C_1p_T \\ C_2(1-p_T) & 0 & 1-C_2 & C_2p_T \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \tag{5}$$

and, having two absorbing states, is neither regular nor irreducible.

The state probabilities after the first attempt can be obtained by simple relationships:

$$P[X^{(1)}=E_1]=P[X^{(0)}=E_2]$$

$$P[X^{(1)}=E_1|X^{(0)}=E_2] = (1\text{-}p)C_2(1\text{-}p_T), \tag{6}$$

$$P[X^{(1)} =E_2]=P[X^{(0)}=E_1]$$

$$P[X^{(1)}=E_2|X^{(0)}=E_1] = pC_1(1\text{-}p_T), \tag{7}$$

And by the recursive relationships for the subsequent attempts

$$P[X^{(n)} = E_1] = P[X^{(n-1)}=E_2]\ C_2(1\text{-}p_T), \tag{8}$$

$$P[X^{(n)} = E_2] = P[X^{(n-1)}=E_1]\ C_1(1\text{-}p_T), \tag{9}$$

After unwrapping the recursions we obtain the general relationships

$$P[X^{(n)} = E_1] = p\sqrt{(C_1C_2)^n}\ (1\text{-}p_T)^n,\ \text{n even}, \tag{10}$$

$$P[X^{(n)} = E_1] = (1\text{-}p)C_2\sqrt{(C_1C_2)^{n-1}}\ (1\text{-}p_T)^n,\ \text{n odd}, \tag{11}$$

$$P[X^{(n)} = E_2] = (1\text{-}p)\sqrt{(C_1C_2)^n}\ (1\text{-}p_T)^n,\ \text{n even}, \tag{12}$$

$$P[X^{(n)} = E_2] = {}^{pC1}\sqrt{(C_1C_2)^{n-1}}\ (1\text{-}p_T)^n,\ \text{n even}, \tag{13}$$

3 The Quality of Service Experienced by Internet Service Provider (ISP)

From the ISP's perspective the goal is to complete the traffic routing to the destination network. The first quality of service parameter of IX service provider is therefore the congestion probability that ISP experience. In our model the ISP continually toggles between two IX providers until the ISP either completes its connection to destination or switching to transit service provider; such a network design can be labeled the dynamic routing design. For ISP who sticks with the IX provider it has chosen for its first attempt and label the network design the static routing design.

The static routing design always experiences the same congestion probability: C_1 if it has chosen the IX provider E_1, C_2 otherwise. Averaging over these two choices gives us the average congestion probability B_s for the static routing design:

$$B_s = pC_1 + (1-p)C_2. \qquad (14)$$

Instead, ISP will experience a varying congestion probability (B_d) in the dynamic routing design; at the *n*th attempt it is

$$B_d^n = \frac{P[X^{(n-1)} = E_1]C_1 + P[X^{(n-1)} = E_2]C_2}{P[X^{(n-1)} = E_1] + P[X^{(n-1)} = E_2]} \qquad (15)$$

Since the state probabilities for the two states E_1 and E_2 at the *n*th attempt depend on whether n is even or odd, we have two expressions for the congestion probability

$$B_d^{(n,even)} = \frac{C_1C_2}{pC_1 + (1-p)C_2}, \qquad (16)$$

$$B_d^{(n,\,odd)} = pC_1 + (1-p)C_2. \qquad (17)$$

At each odd attempt the dynamic routing design experiences the same congestion as the average one encountered by the static routing design. On the even attempts B_d can be larger or smaller than B_s; the dynamic routing design is favored if the geometric mean of the congestion probability C_1 and C_2 is smaller than their weighted sum, i,e, if

$$\sqrt{C_1C_2} < pC_1 + (1-p)C_2 \qquad (18)$$

or in other terms

$$p > \frac{\sqrt{C_1C_2} - C_2}{C_1 - C_2},\ C_1 > C_2, \qquad (19)$$

$$p < \frac{\sqrt{C_1C_2} - C_2}{C_1 - C_2},\ C_1 < C_2,$$

The ISP can perform its strategy based on Eq(19). For example, in Figure 3 and 4 are shown the regions of the (C_1,p) plane where the dynamic routing design is favored when the IX provider E_2 congestion probability is 0.05 and 0.2 respectively.

Based on Figure 3 and Figure 4, ISP who choose dynamic routing structure can benefit from the regions of (C_1,p) plane with dynamic routing remarked.

4 Traffic Sharing

We now can calculate the ISP traffic sharing between the two IX providers. The process is completed as ISP successfully routes its Internet traffic to the destination network through IX provider E_1. The probability that a route is completed through IX provider E_1 at the *n*th attempt is

$$P_1^{(n)} = P\{X^{(n-1)} = E_1\}P\{X^{(n)} = Z|X^{(n-1)} = E_1\}. \qquad (20)$$

Replacing the expressions (10) and (11) in (20), two different expressions depending on n:

$$P_1^{(n)} = p(1-C_1)(1-p_T)^{n-1}\sqrt{(C_1C_2)^{n-1}},\ n\ odd, \qquad (21)$$

$$P_1^{(n)} = (1-p)C_2(1-C_1)(1-p_T)^{n-1}\sqrt{(C_1C_2)^{n-2}},\ n\ even, \qquad (22)$$

To obtain the cumulative probability that a route is completed through the IX provider E_1 within the first n

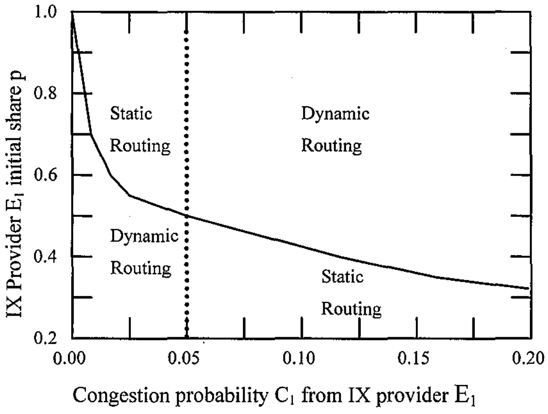

Figure 3 Favored strategies when C_2=0.05

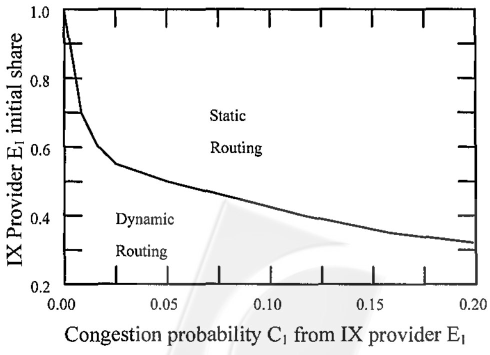

Figure 4 Favored strategies when C_2=0.2

attempts we have to sum over the number of attempts:

$$\overline{P}_1^{(n)} = \sum_{i=1}^{n} P_1^{(i)} = \sum_{i=1}^{n} (1-C_1)P\{X^{(i-1)} = E_1\} = (1-C_1)\sum_{i=0}^{n-1} P\{X^{(i)} = E_1\}$$

$$= (1-C_1)\left[p\sum_{\substack{i=0 \\ i,even}}^{n-1} \sqrt{(C_1C_2)^i}(1-p_T)^i + (1-p)C_2\sum_{\substack{i=0 \\ i,odd}}^{n-1} \sqrt{(C_1C_2)^{i-1}}(1-p_T)^i \right] \tag{23}$$

Alternatively, when n is even expression (23) can be written as

$$\overline{P}_1^{(n)} = (1-C_1)[p+(1-p)(1-p_T)C_2]\frac{1-\sqrt{[C_1C_2(1-p_T)^2]^n}}{1-C_1C_2(1-p_T)^2}, \tag{24}$$

When n is odd, we obtain the expression

$$\overline{P}_1^{(n)} = (1-C_1)\frac{p\{1-\sqrt{[C_1C_2(1-p_T)^2]^{n+1}}\}+(1-p)(1-p_T)C_2\{1-\sqrt{[C_1C_2(1-p_T)^2]^{n-1}}\}}{1-C_1C_2(1-p_T)^2} \tag{25}$$

We obtain the probability that a route is completed through the IX provider E_2:

$$\overline{P}_2^{\,n} = (1-C_2)\left[(1-p)\sum_{\substack{i=0 \\ i,even}}^{n-1} \sqrt{(C_1C_2)^i}(1-p_T)^i + pC_1\sum_{\substack{i=0 \\ i,odd}}^{n-1} \sqrt{(C_1C_2)^{i-1}}(1-p_T)^i \right] \tag{26}$$

These probabilities reflect the proportions by which the overall traffic offered by an ISP is distributed between the two IX providers; We also find the traffic shares of the two IX providers are modified with respect to the initial share probability p and 1-p because of the congestion probability it occurred.

An example of the impact of the route-by-route choice is reported in Figure 5, where the traffic share of the incumbent IX provider falls from 80% to 65% when its congestion probability is 20% and competitor's congestion probability is 5%.

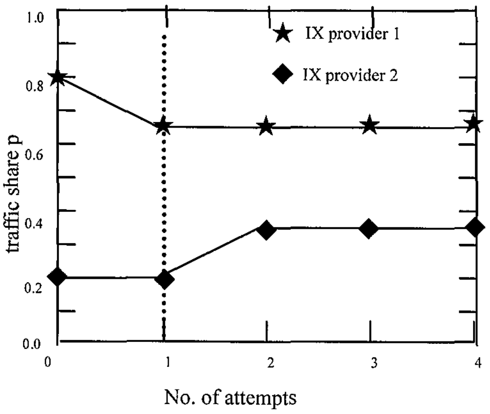

Figure 5 Exchange of traffic share during the route attempt process (p=0.8; C_1=0.2; C_2=0.05; p_T=0.05)

5 Conclusion

Internet traffic prediction plays a fundamental role in network design, management, control, and optimization. Prediction on large scale network is complicated and difficult to perform a precise prediction.

The paper analyzes the traffic model in the Internet exchange (IX) environment. We can simulate the market share dilution through competition between two Internet exchange providers. It is shown that smaller Internet exchange competitors can benefit from the competition even if their Quality of Service (QoS) is worse than the incumbent Internet exchange provider. The paper also proposed different routing strategies which reflect to the competing Internet exchange environment. Pricing and bandwidth are important elements especially in business operation. Assessing pricing strategy and bandwidth allocation in a competing IX environment will be the appropriate research area as the study moving into further development.

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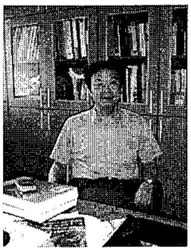
Biographies



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