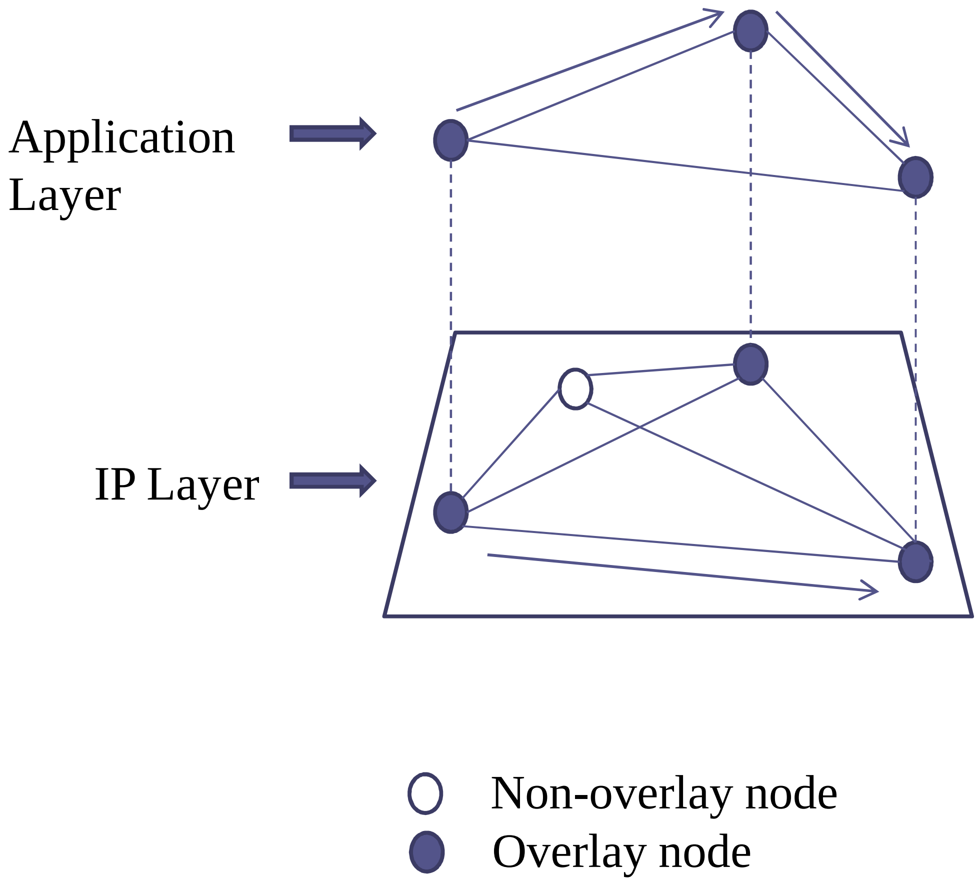
The Implication of Overlay Routing on ISPs' Connecting Strategies

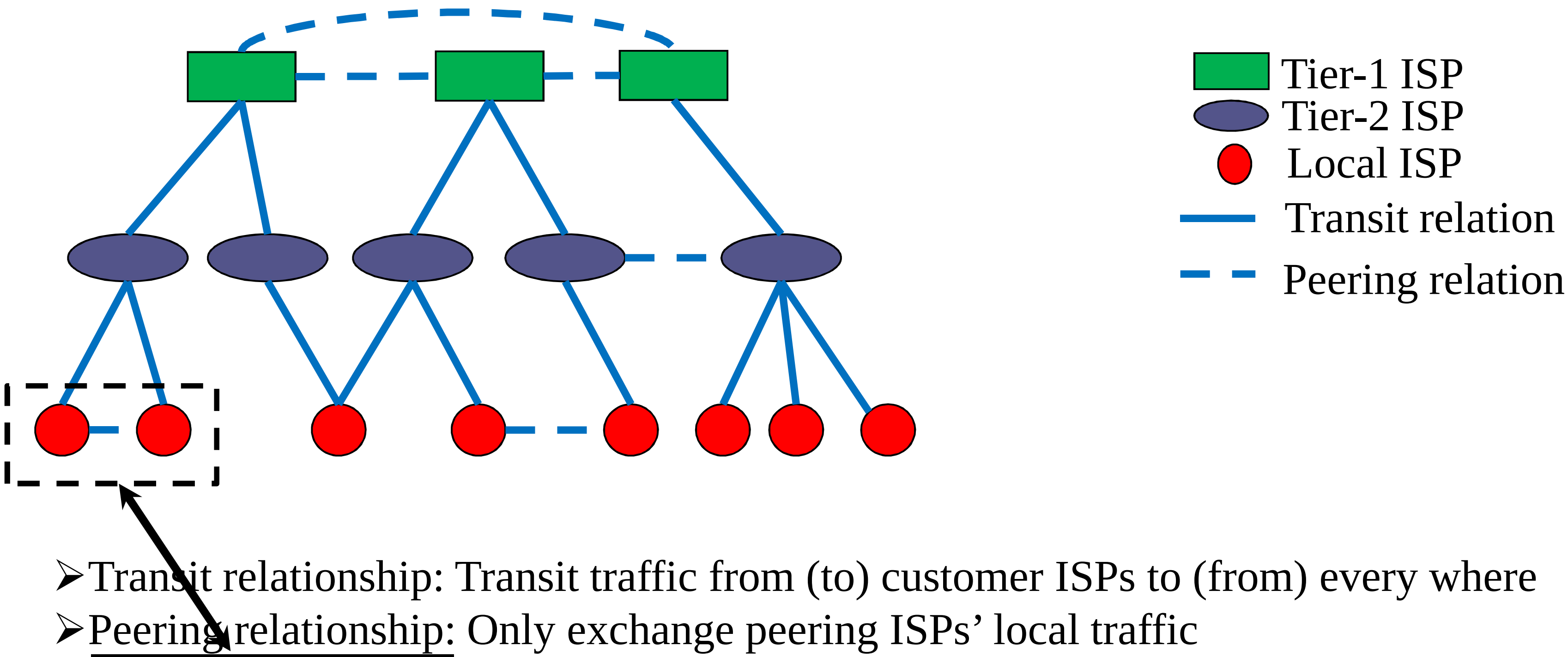
Graduate School of Information Science and Technology, Osaka University
Xun Shao, Go Hasegawa, Yoshiaki Taniguchi, and Hirotaka Nakano

IP layer routing and overlay routing

- Overlay routing may change IP routing at application layer to better satisfy the applications' demands
  - Overlay routing may violate ISPs' routing policies



Tiered Internet architecture



- Transit relationship: Transit traffic from (to) customer ISPs to (from) every where
- Peering relationship: Only exchange peering ISPs' local traffic
  - Bill-and-Peer (BK) peering: No money exchange between peering ISPs
  - Paid peering: One ISP should pay for the other according to agreement

Related researches

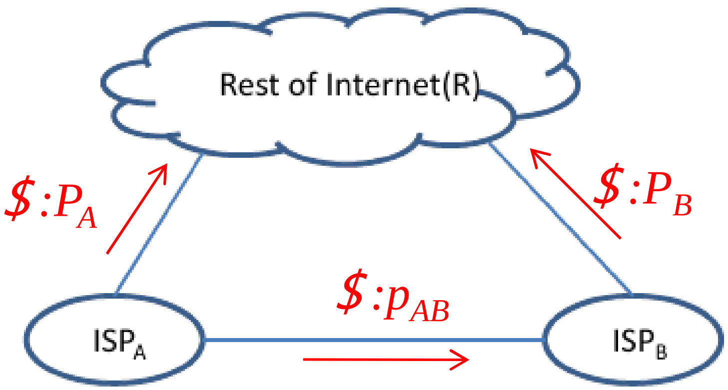
- Researches on overlay routing
  - Performance improvement of overlay networks [1]
- Researches on ISPs' peering settlement
  - Peering of asymmetric ISPs [2]
  - Hot /Cold-potato routing [3]
- An open issue
  - How does overlay routing affect ISPs' peering settlement?

[1] Z. Duan, Z. L. Zhang and Y. T. Hou, "Service Overlay Networks: SLAs, QoS, and Bandwidth Provisioning," IEEE/ACM Transactions on Networking, vol. 11, pp. 1-10, 2003
[2] E. Jahn and J. Prüfer, "Interconnection and Competition Among Asymmetric Networks in the Internet Backbone Market," Information Economics and Policy, vol.20, pp. 243-256, 2006
[3] G. Shrimali and S. Kumar, "Paid Peering Among Internet Service Providers," Proc. GameNets Workshop on Game Theory for Communications and Networks, 2006

Network and business models

- ISPs' monetary costs
  - Transit cost of per unit traffic for ISP_i : P_i
  - Peering cost of per unit traffic (only for paid peering):

$$p_{AB} \begin{cases} > 0, \text{ if } ISP_A \text{ pays } ISP_B \\ < 0, \text{ if } ISP_B \text{ pays } ISP_A \\ = 0, \text{ reduced into BK peering} \end{cases}$$



- ISPs' latency cost
  - Latency function of one link: $D(c, t)$
  - Latency cost of that link: $tD(c, t)$
- ISPs' combined cost
  - Monetary cost + γ(Link latency cost)

Link capacity

Traffic through the link

A parameter translating latency cost to monetary cost

ISPs' costs with no peering and BK peering

- ISPs' costs without peering

$$J_A^{NP} = \gamma(t_{AR} + t_{AB})D_{AR}(t_{AR} + t_{AB}) + P_A(t_{AR} + t_{AB})$$

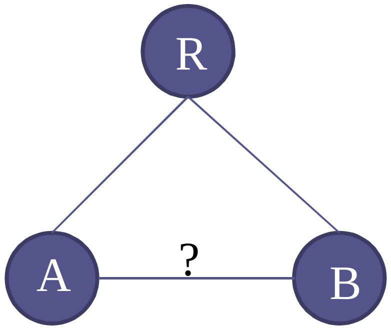
$$J_B^{NP} = \gamma(t_{BR} + t_{AB})D_{BR}(t_{BR} + t_{AB}) + P_B(t_{BR} + t_{AB})$$

- ISPs' costs with BK peering

$$J_A^{BK} = \gamma(\tilde{t}_{AR}D_{AR}(\tilde{t}_{AR}) + \alpha\tilde{t}_{AB}D_{AB}(\tilde{t}_{AB})) + P_A\tilde{t}_{AR}$$

$$J_B^{BK} = \gamma(\tilde{t}_{BR}D_{BR}(\tilde{t}_{BR}) + (1-\alpha)\tilde{t}_{AB}D_{AB}(\tilde{t}_{AB})) + P_B\tilde{t}_{BR}$$

t_{ij}: The traffic demand between *i* and *j*
$\tilde{t}_{ij}$: The actual traffic amont through link l_{AB}
α : The dependence of ISP_A on link l_{AB}



ISPs' costs calculation with paid peering

- Nash bargaining solution
  - Fair and Pareto optimal
- ISPs' costs with paid peering can be got from Nash Bargaining

$$\begin{cases} J_A^{PP} = J_A^{BK} + p_{AB} * \tilde{t}_{AB} \\ J_B^{PP} = J_B^{BK} - p_{AB} * \tilde{t}_{AB} \\ p_{AB} = \arg\min (J_A^{NP} - J_A^{PP})^{\alpha} * (J_B^{NP} - J_B^{PP})^{1-\alpha} \end{cases}$$

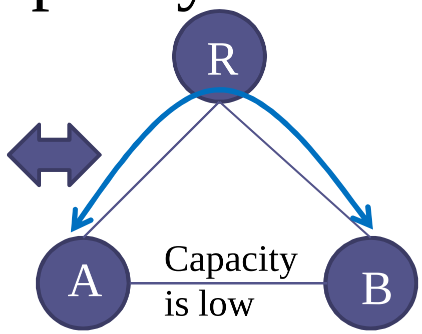
Paid peering cost

Bargaining power of ISP_A

Overlay traffic patterns vs. peering levels

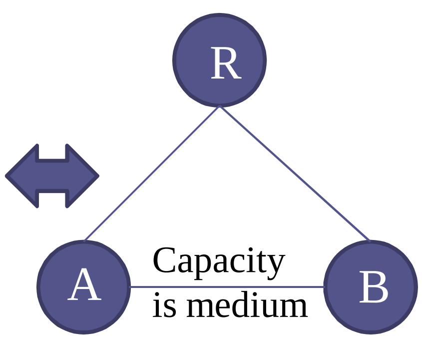
1. Peering capacity is of low level

$D_{AB}=D_{AR}+D_{BR}$



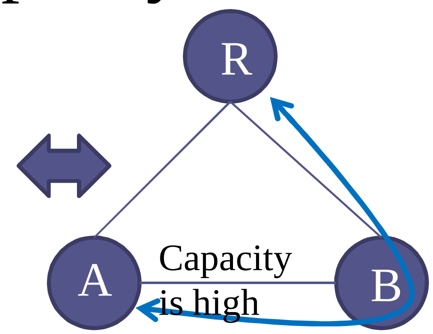
2. Peering capacity is of medium level

$D_{AB}<=D_{AR}+D_{BR}$
$D_{AR}>=D_{AB}+D_{BR}$



3. Peering capacity is of high level

$D_{AR}=D_{AB}+D_{BR}$



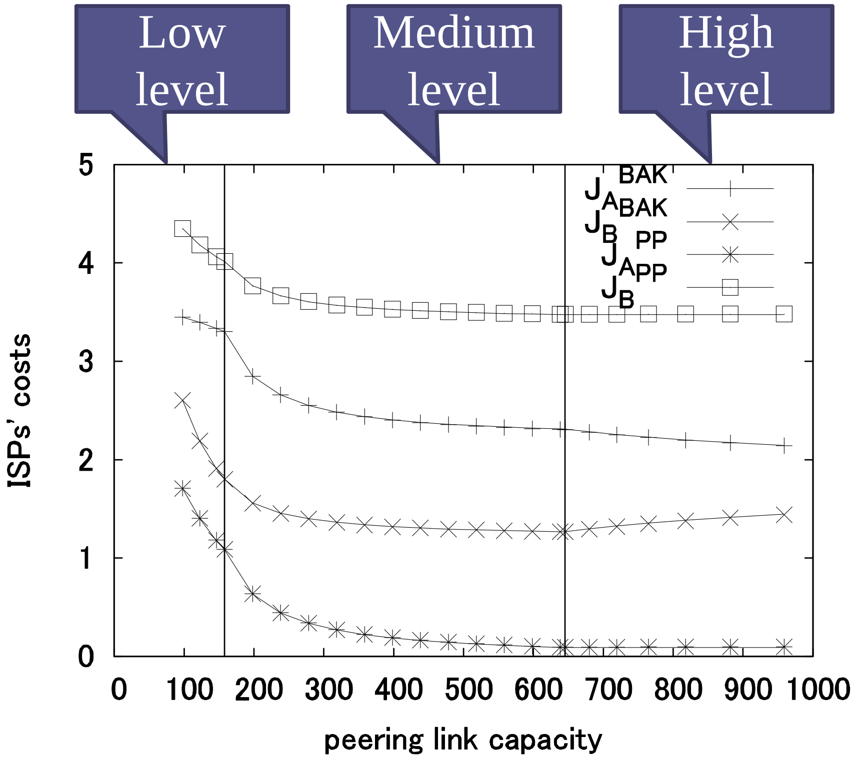
The multi-hop overlay traffic in case 3 is also called "*free-riding*" traffic

⟷ Multi-hop overlay traffic

We assume that: $D_{AR}(t_{AR})>D_{BR}(t_{BR})$

An example of ISPs' costs vs. peering link capacity

- Numerical example settings
  - Latency function of each link (M/M/1 link latency model)
    - $D_{AB} = \dfrac{1}{c_{AB} - \tilde{t}_{AB}} + 0.001$ (c_{AB}: variable)
    - $D_{AR} = \dfrac{1}{500.0 - \tilde{t}_{AR}} + 0.003$
    - $D_{BR} = \dfrac{1}{900.0 - \tilde{t}_{BR}} + 0.001$
  - Traffic amount of each link
    - $t_{AR} = 300.0$, $t_{BR} = 300.0$, $t_{AB} = 100.0$
  - Overlay traffic proportion
    - $\rho = 0.7$
  - Bargaining power of ISP_A
    - $\alpha = 0.5$



Incentives of upgrading peering link with BK peering

- ISP_A always has incentive to upgrade the peering link when the peering level is ***medium or high***

  i.e. $\frac{dJ_A^{BK}}{dc_{AB}} < 0$, if c_{AB} is in medium or high range

- ISP_B always has incentive to upgrade the peering link when the peering level is ***medium***

  i.e. $\frac{dJ_B^{BK}}{dc_{AB}} < 0$, if c_{AB} is in medium range

Incentives of upgrading peering link with paid peering

- Both ISPs always have incentive to upgrade the peering link when the peering level is ***low or medium***

i.e. $\frac{dJ_A^{PP}}{dc_{AB}} < 0$ and $\frac{dJ_B^{PP}}{dc_{AB}} < 0$, if c_{AB} is in low or medium range

> - With BK peering, no ISP prefers peering with low level
> - With BK peering, ISP_A prefers higher peering capacity than ISP_B
> - Paid peering provides a better solution when peering level is low

Conditions in which BK peering is better than no peering

- For ISP_A
  - $\bar{J}_A^{BK}$: The maximum cost when c_{AB} is of low level
  - If $\bar{J}_A^{BK} < J_A^{NP}$, BK peering is better than no peering with arbitrary c_{AB} in all levels
- For ISP_B
  - $\bar{J}_B^{BK}$: The maximum cost when c_{AB} is in low level
  - If $\bar{J}_B^{BK} < J_B^{NP}$, BK peering is better than no peering with c_{AB} in low or medium level

Conditions in which paid peering is better than no peering

- For both ISPs
  - Paid peering is better than no peering with arbitrary c_{AB} in low and medium level

> ➢Free-riding traffic might cause the cost of ISP_B unexpected as well as the total cost of the two

Regime equilibria

- Bilateral Nash Equilibrium (BNE)
  - At BNE, no **player** or a **pair of players** can deviate and benefit from the deviation
- Strategies of ISPs
  - S_i={NP, BK, PP}
  - {NP,NP} is default output, if ISPs prefer different strategies

Regime equilibria

- BNE results
  - If $J_{total}^{BK} > J_{total}^{NP}$, (NP,NP) is the only strategy of BNE
  - Else if
    - $(J_A^{BK}-J_A^{NP})(J_B^{BK}-J_B^{NP})>0$, (BK,BK) and (PP,PP) are two strategies of BNE
    - $(J_A^{BK}-J_A^{NP})(J_B^{BK}-J_B^{NP})<0$, (PP,PP) is the only strategy in BNE

⬇

Paid peering is always BNE if peering level is low or medium

Summary and future work

- Obtained the overlay routing traffic patterns with a simple network model, and revealed the relation between traffic patterns and peering levels
- Showed that with BK peering, the ISP that may free-ride the other prefers peering with medium and high level, while the ISP being free-ridden prefers only medium level
- With paid peering determined by Nash bargaining solution, it is preferred by both ISPs with peering of low and medium level
- Proposed a regime equilibria analysis with BNE theory, and showed that paid peering by Nash bargaining is always a BNE strategy when peering is of low and medium level
- In the future, we are planning to study the implication of overlay routing on ISPs' connection strategies in a more general network

Thank you very much !