Understanding the incentives for prefix aggregation in BGP

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C. Kalogiros, M. Bagnulo, A. Kostopoulos

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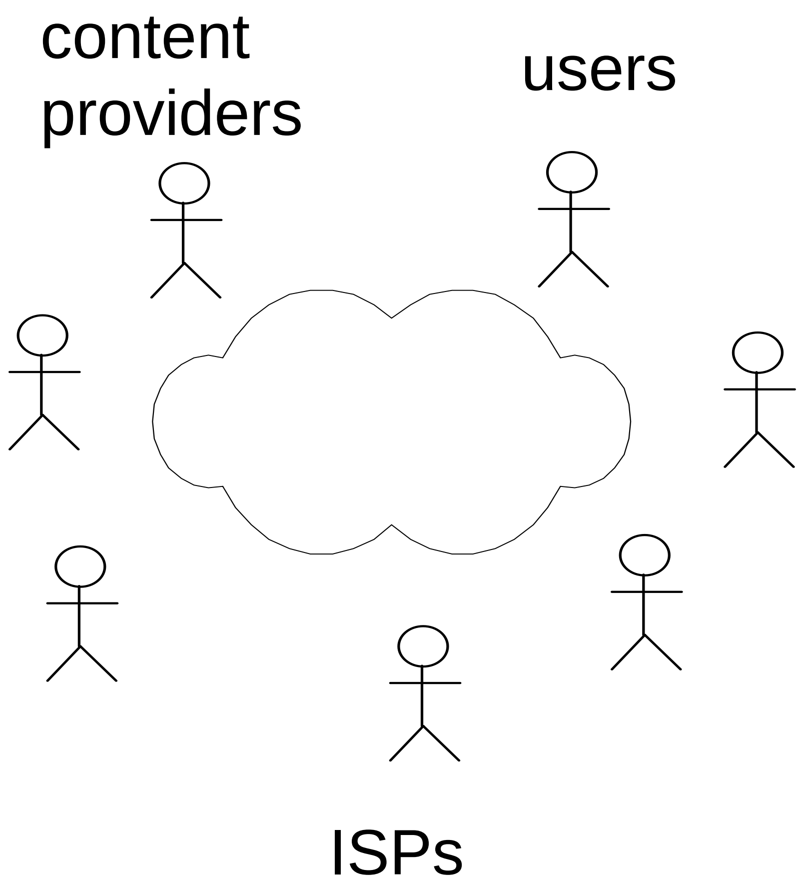
Introduction

- “Tussles” may constitute a threat to FI
- Internet → *victim of its success*
- Global routing system → *scalability challenges*
- BGP global routing table → *growing at a super-linear rate*
- New technology may be required to keep global routing system working

  → *affect the economic viability of the Internet (increased operator's cost)*.



Motivation

- Significant effort of the FI architecture to improve the scalability of the next generation routing architecture.
- Essential to have a deep understanding of the aggregation incentives → *use that knowledge as an input in the design of FIA*.
  - *Understand providers' incentives for prefix (de)aggregation*
  - *Case Study: 2 ISPs compete for attracting traffic (game theory)*
  - *Examine the properties of the game equilibria when providers decide what routes to propagate – equilibrium?*

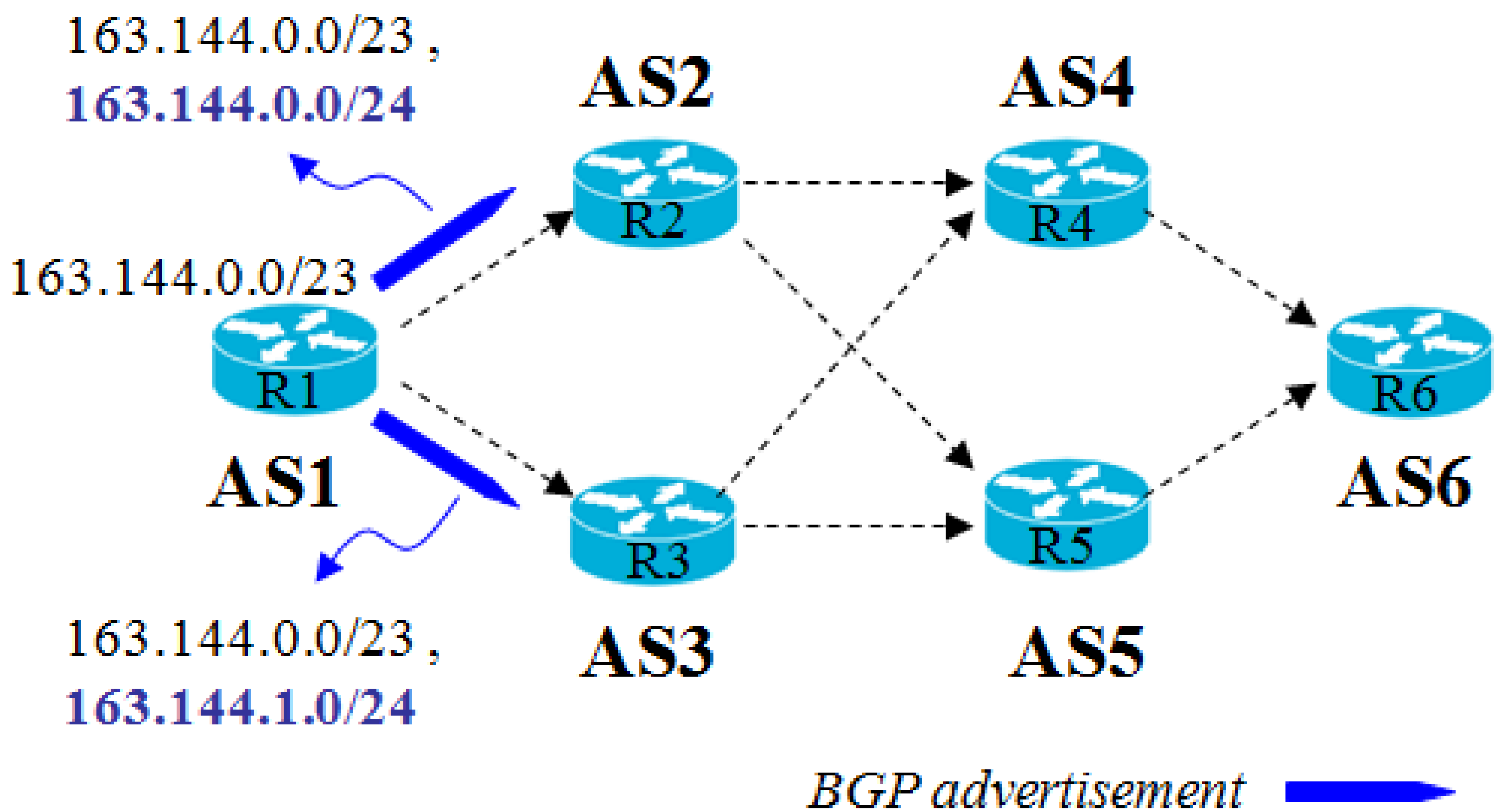
Incentives for prefix aggregation

- Providers' revenues are based on the level of traffic
  → *incentive to make the routes they advertise more attractive*
  → *trade-off: routing table scalability vs. service attractiveness*

A choice for an AS:

- **Aggregation**→*group an address space (single route advertisement)*
  - ☑ ***reduced routing table entries / costs***
- **Deaggregation** → propagate the more specific routes
  - ☑ ***increases the transit attractiveness (l-p rule) / revenues***
  - ☑ ***benefits to the origin ASs (traffic engineering)***
  - ☒ ***scalability of the routing system***

Topology of our scenario



Game Setup

- l_i: *aggregation level*
- r: *average revenues from delivering one unit of traffic to a specific IP address*
- t: *average traffic delivered to a specific IP address*
- $2^{(lmin - lmax)}$: *number of IP addresses that are contained in original prefix B/mask*
- $P_i(l_i,l_j)$: *probability of* AS_i *being selected by* AS_s *to carry traffic*

$$P_i(l_i,l_j) = \begin{cases} 0 & \text{if } l_i < l_j \\ 1/2 & \text{if } l_i = l_j \\ 1 & \text{if } l_i > l_j \end{cases} \quad \text{and} \quad P_j(l_i,l_j) = 1 - P_i(l_i,l_j)$$

- k: *the cost per route*

Payoff matrix of a simple scenario

- *i.e.* AS_i and AS_j have a restricted action space; l_i, l_j є [23,25].

		AS_j		
		23	**24**	**25**
AS_i	**23**	$2^8r - k$, $2^8r - k$	$-k$, $2^9r - 2k$	$-k$, $2^9r - 4k$
	24	$2^9r - 2k$, $-k$	$2^8r - 2k$, $2^8r - 2k$	$-2k$, $2^9r - 4k$
	25	$2^9r - 4k$, $-k$	$2^9r - 4k$, $-2k$	$2^8r - 4k$, $2^8r - 4k$

Players' strategies

- Case I: *Same aggregation level*

		AS_j		
		23	24	25
AS_i	23	$2^8r - k$, $2^8r - k$	$-k$, $2^9r - 2k$	$-k$, $2^9r - 4k$
	24	$2^9r - 2k$, $-k$	$2^8r - 2k$, $2^8r - 2k$	$-2k$, $2^9r - 4k$
	25	$2^9r - 4k$, $-k$	$2^9r - 4k$, $-2k$	$2^8r - 4k$, $2^8r - 4k$

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	25	$2^9r - 4k$, $-k$	$2^9r - 4k$, $-2k$	$2^8r - 4k$, $2^8r - 4k$

Players' strategies

- Case II: *Different aggregation level*

		AS_j		
		23	24	25
AS_i	23	$2^8 r - k$, $2^8 r - k$	$-k$, $2^9 r - 2k$	$-k$, $2^9 r - 4k$
	24	$2^9 r - 2k$, $-k$	$2^8 r - 2k$, $2^8 r - 2k$	$-2k$, $2^9 r - 4k$
	25	$2^9 r - 4k$, $-k$	$2^9 r - 4k$, $-2k$	$2^8 r - 4k$, $2^8 r - 4k$

trilogy

Players' strategies

- Case II: *Different aggregation level*

		AS_j		
		23	24	25
AS_i	23	$2^8r - k$, $2^8r - k$	$-k$, $2^9r - 2k$	$-k$, $2^9r - 4k$
	24	$2^9r - 2k$, $-k$	$2^8r - 2k$, $2^8r - 2k$	$-2k$, $2^9r - 4k$
	25	$2^9r - 4k$, $-k$	$2^9r - 4k$, $-2k$	$2^8r - 4k$, $2^8r - 4k$

Example of pure Nash Equilibrium

$\xrightarrow{l_i = 23} (23,23)$

		AS_j		
		23	24	25
AS_i	23	$2^8r - k$, $2^8r - k$	$-k$, $2^9r - 2k$	$-k$, $2^9r - 4k$
	24	$2^9r - 2k$, $-k$	$2^8r - 2k$, $2^8r - 2k$	$-2k$, $2^9r - 4k$
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Example of pure Nash Equilibrium

$\overrightarrow{l_i = 23}$ $(23, 23) \Longrightarrow (23, \mathbf{24})$

		AS_j		
		23	24	25
AS_i	23	$2^8r - k$, $2^8r - k$	$-k$, $2^9r - 2k$	$-k$, $2^9r - 4k$
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Example of pure Nash Equilibrium

$\xrightarrow{l_i = 23}$ (23,23) ⟹ (23,**24**) ⟹ (**25**,24)

		AS_j		
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trilogy

Example of pure Nash Equilibrium

$$\xrightarrow{l_i = 23} (23,23) \Rightarrow (23,\mathbf{24}) \Rightarrow (\mathbf{25},24) \Rightarrow (\mathbf{25},\mathbf{25})$$

Each provider is willing to deaggregate at the maximum allowed level, in order to attract traffic.

		AS_j		
		23	**24**	**25**
AS_i	**23**	$2^8r - k$, $2^8r - k$	$-k$, $2^9r - 2k$	$-k$, $2^9r - 4k$
	24	$2^9r - 2k$, $-k$	$2^8r - 2k$, $2^8r - 2k$	$-2k$, $2^9r - 4k$
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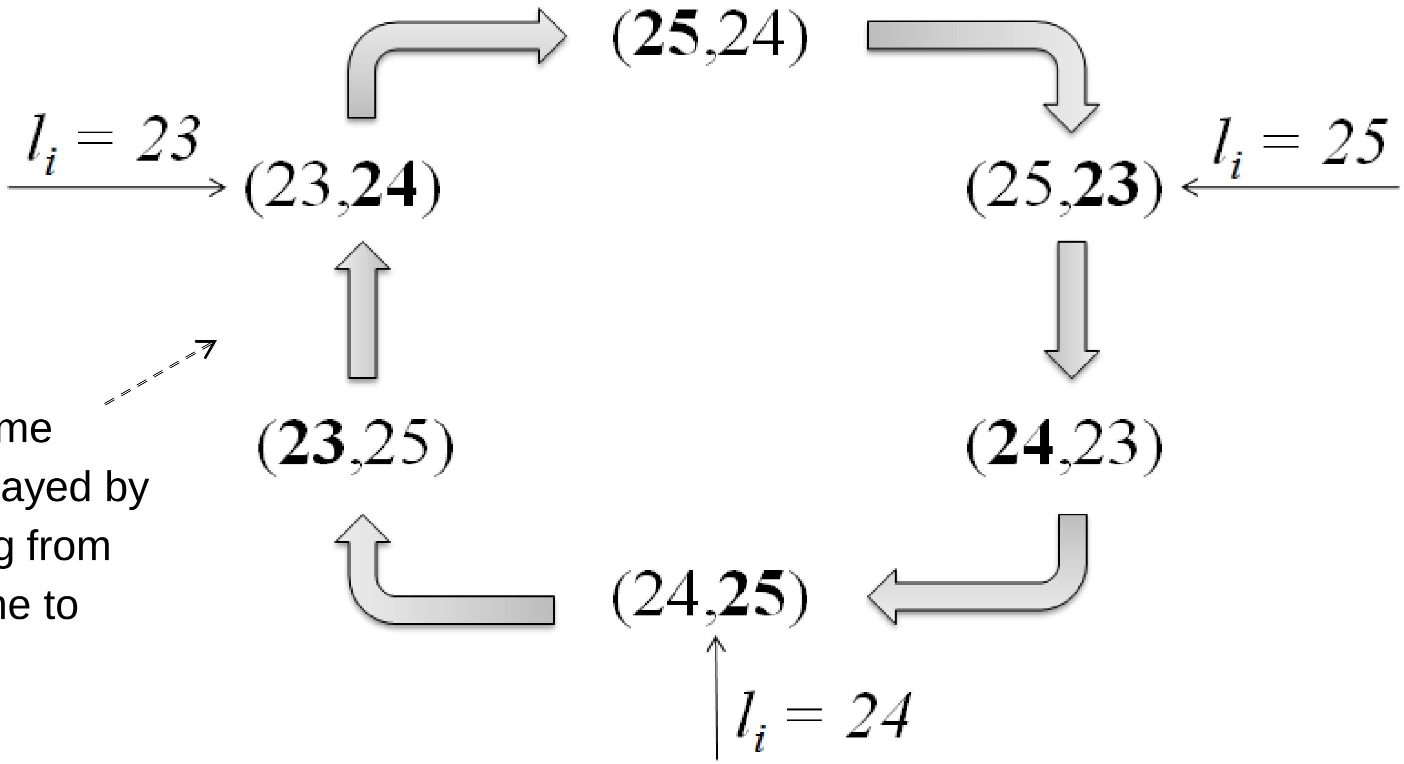
Example of no pure Nash Equilibrium



how the game would be played by transitioning from one outcome to another.

If both providers act aggressively, their cost will exceed revenues (traffic will be split – cost will be increased).
So, if one ISP selects the maximum deaggregation level, the opponent's best response may be the minimum deaggregation level.

Conclusions and Future Work

- Study of providers' incentives to perform (de)aggregation
- A game theoretic model – properties of equillibrium
  - *Repeated game? → collusion*
  - *Assymetry in terms of traffic?*
- A pure equilibrium exists *for a limited range of values*.
  - *Better estimation of parameters r, k*

THANK YOU!!