A Value-based Framework for Internet Peering Agreements

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with

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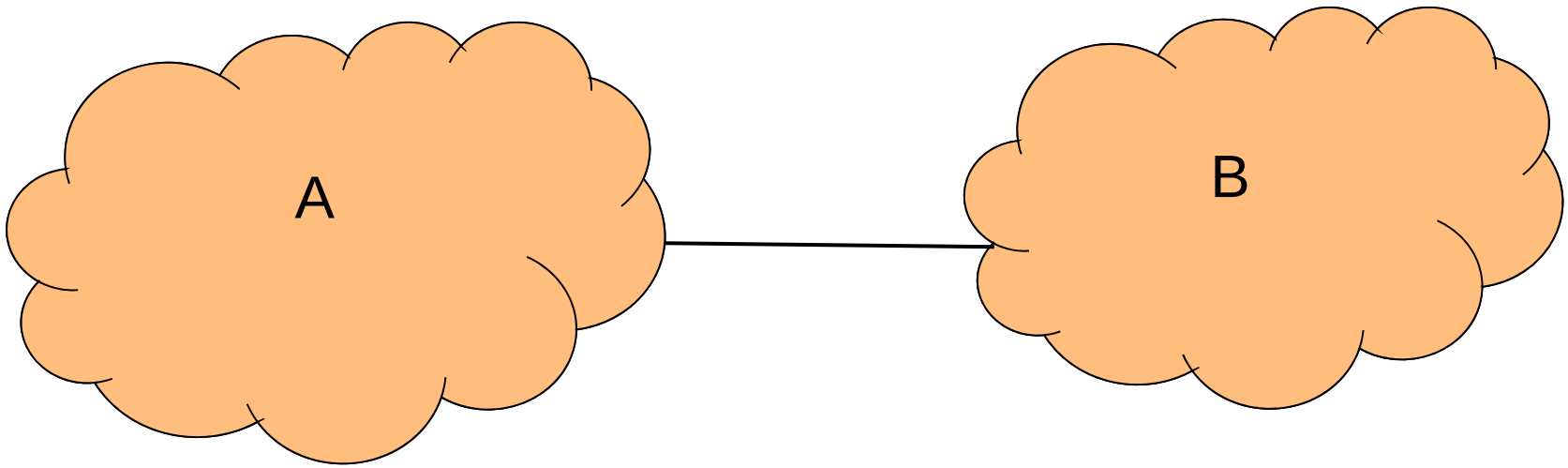
Peering Uncertainty – Current Peers



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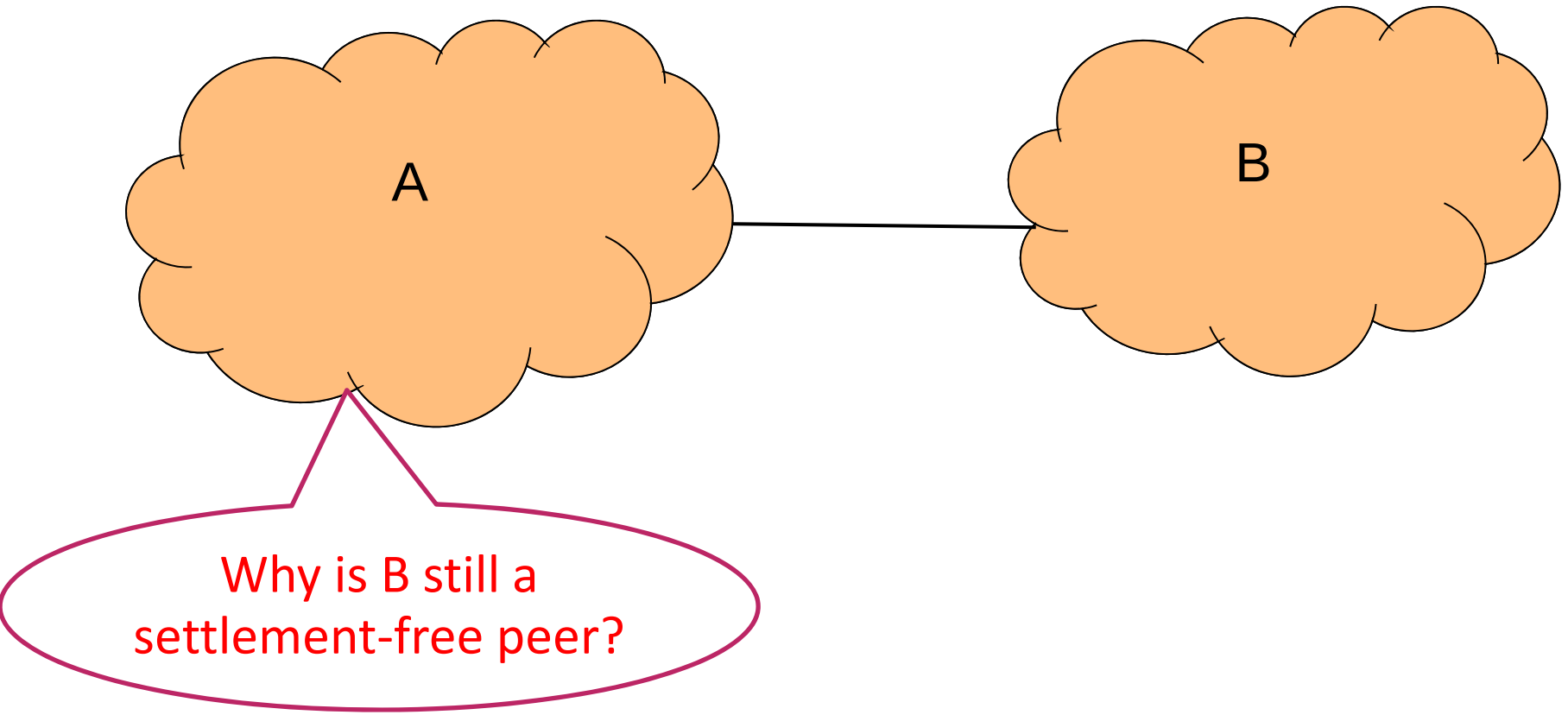

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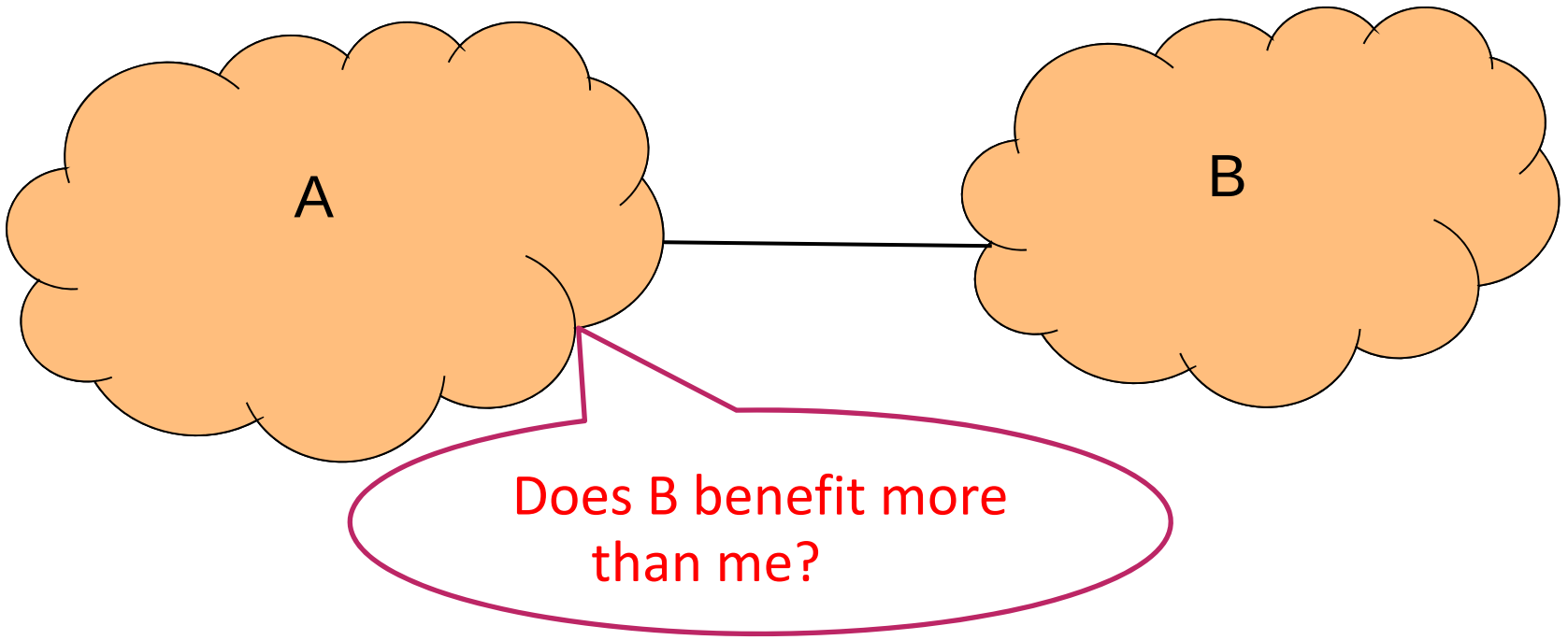

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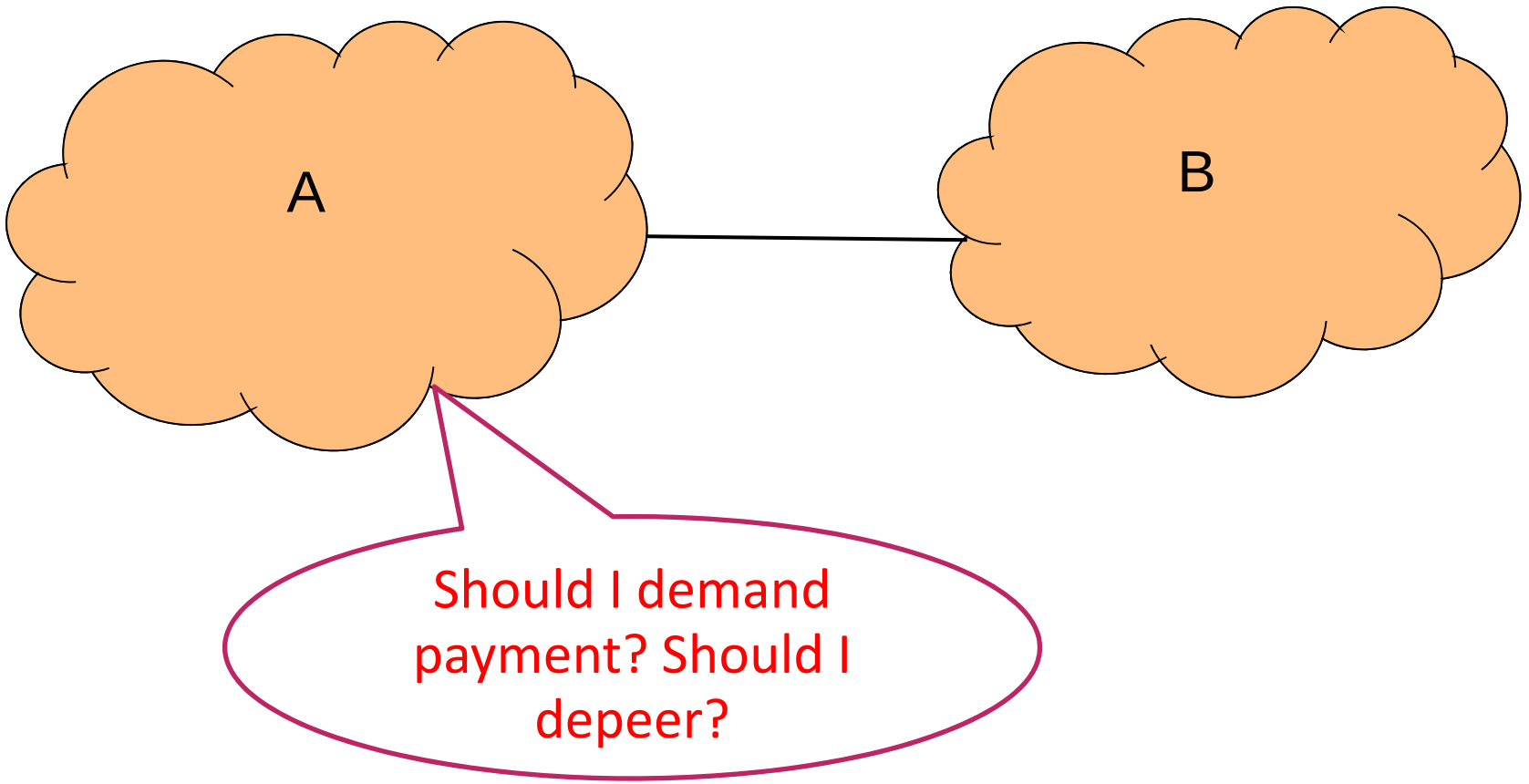

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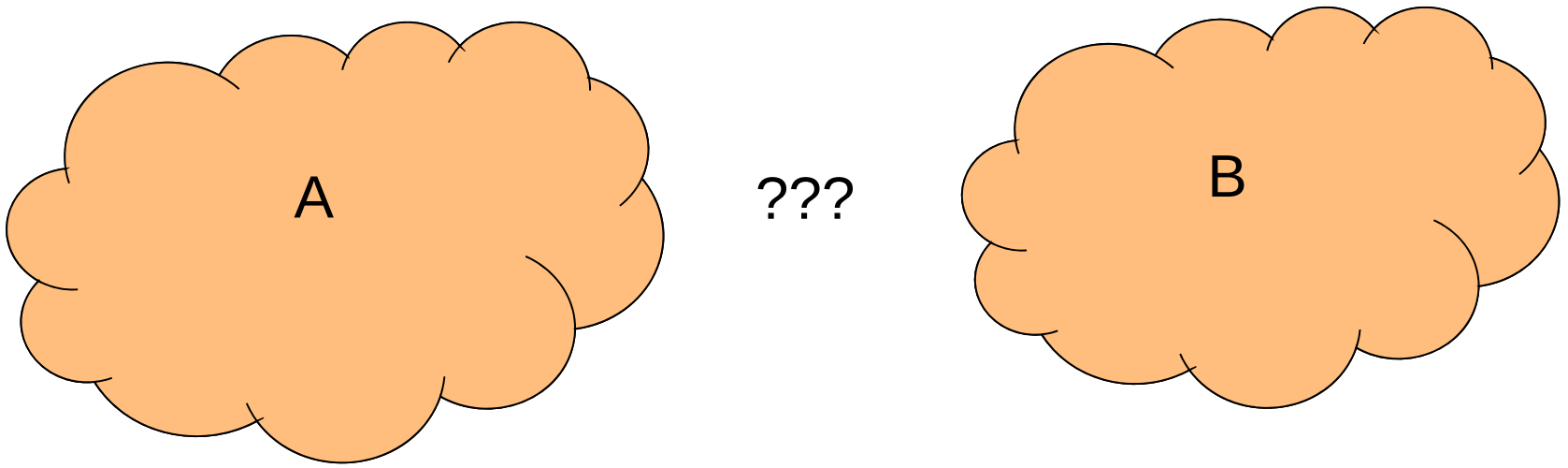

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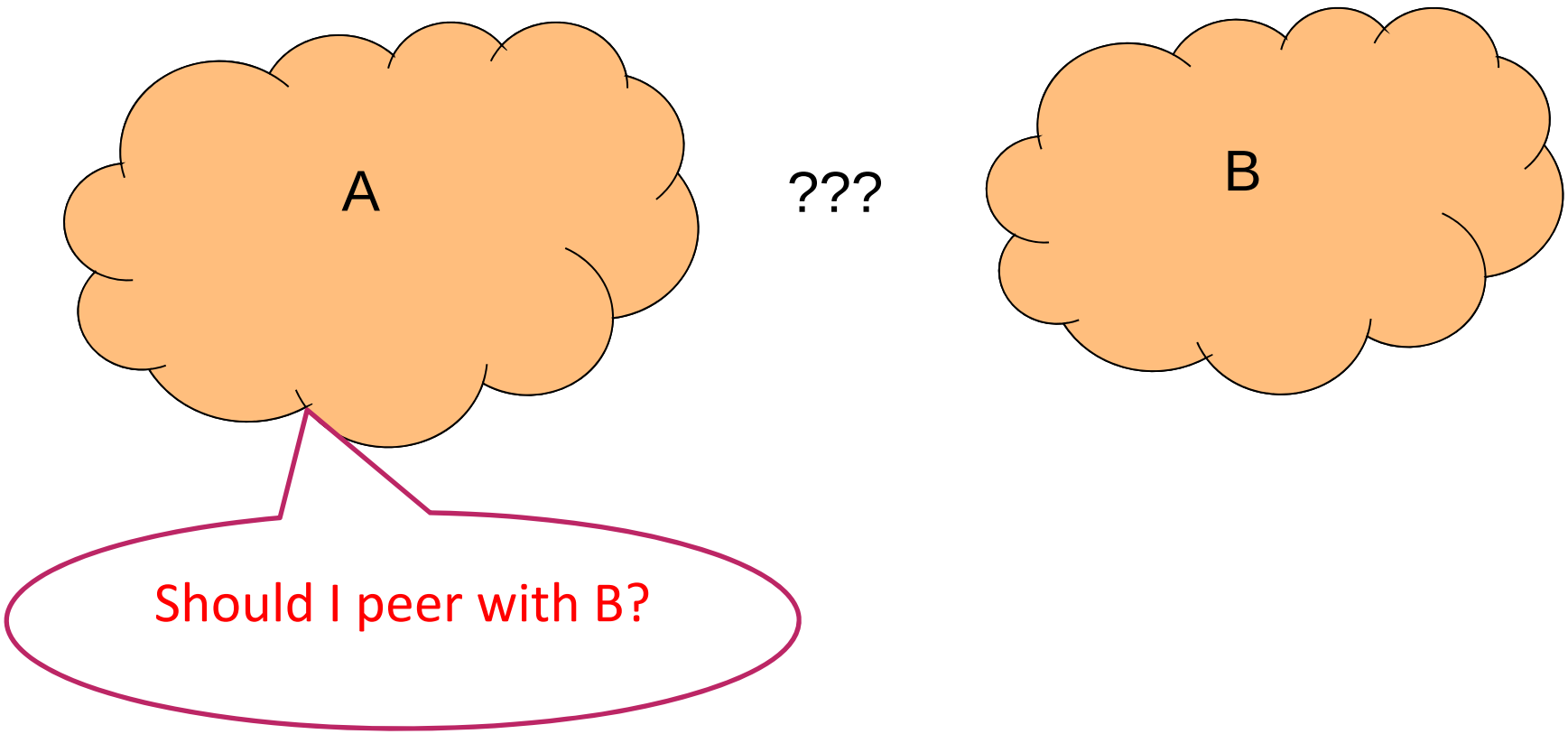

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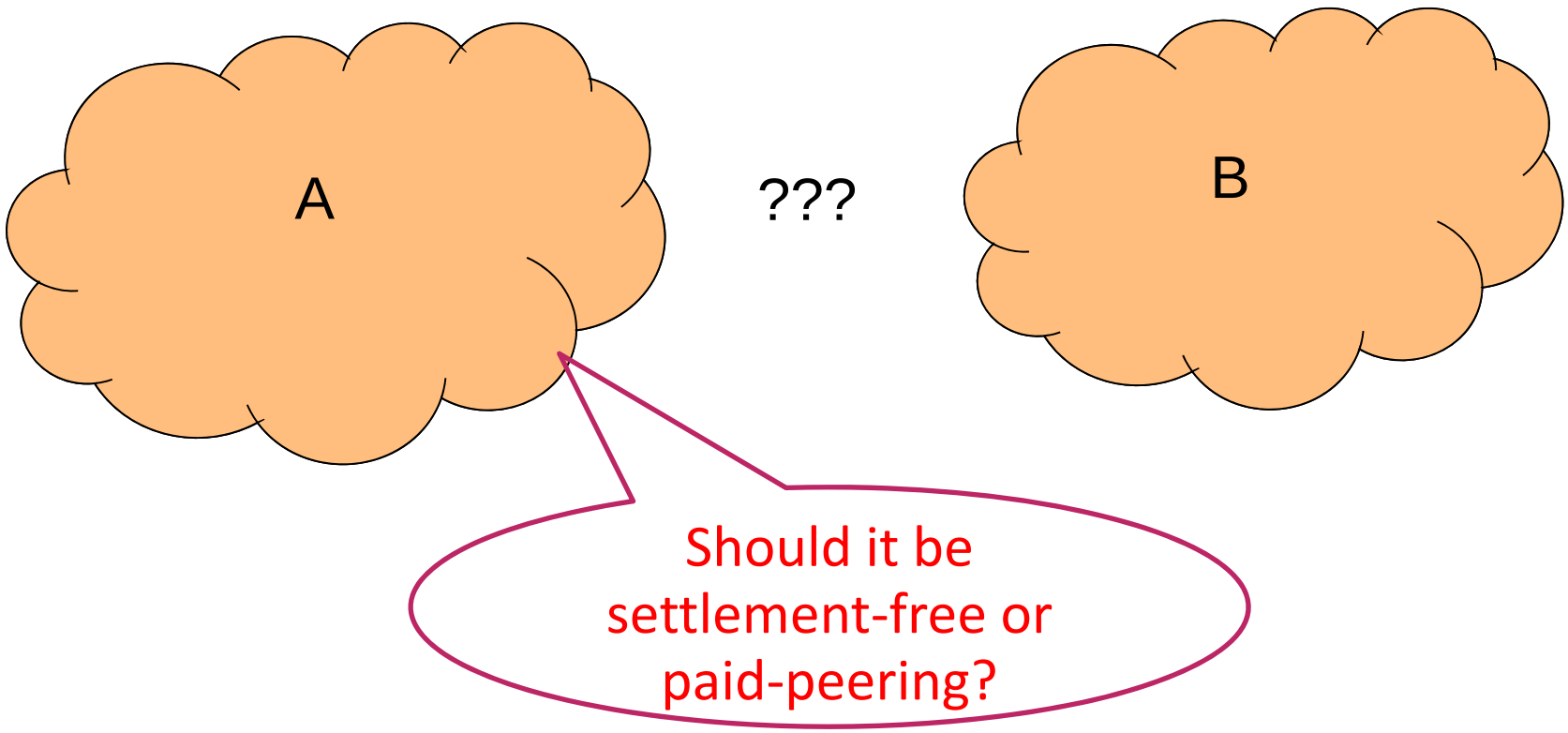

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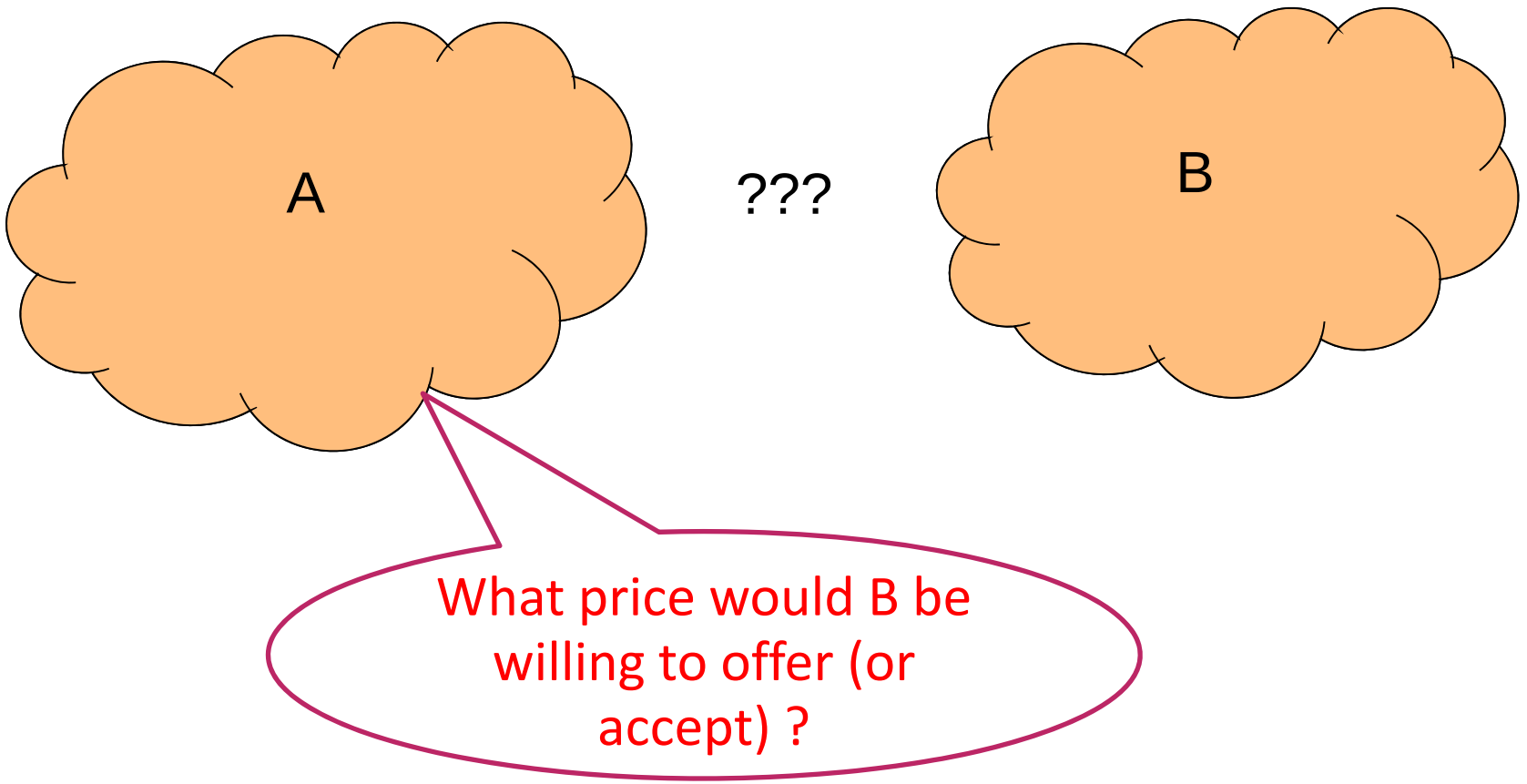

Outline

- What's happening in the real world?
- Our proposed peering model: Value-based peering
- Estimating the value of a peering link
- Global effects of value-based peering

Peering Requirements

- Laundry list of conditions that networks specify as requirements for (settlement-free) peering
  - Traffic ratios, minimum traffic, backbone capacity, geographical spread …
- Heuristics to find networks for which it makes sense to exchange traffic for “free”
  - But when it comes to paid peering..
  - What is the right price? Who should pay whom?
- Are these heuristics always applicable?
  - Mutually beneficial peering links may not be formed

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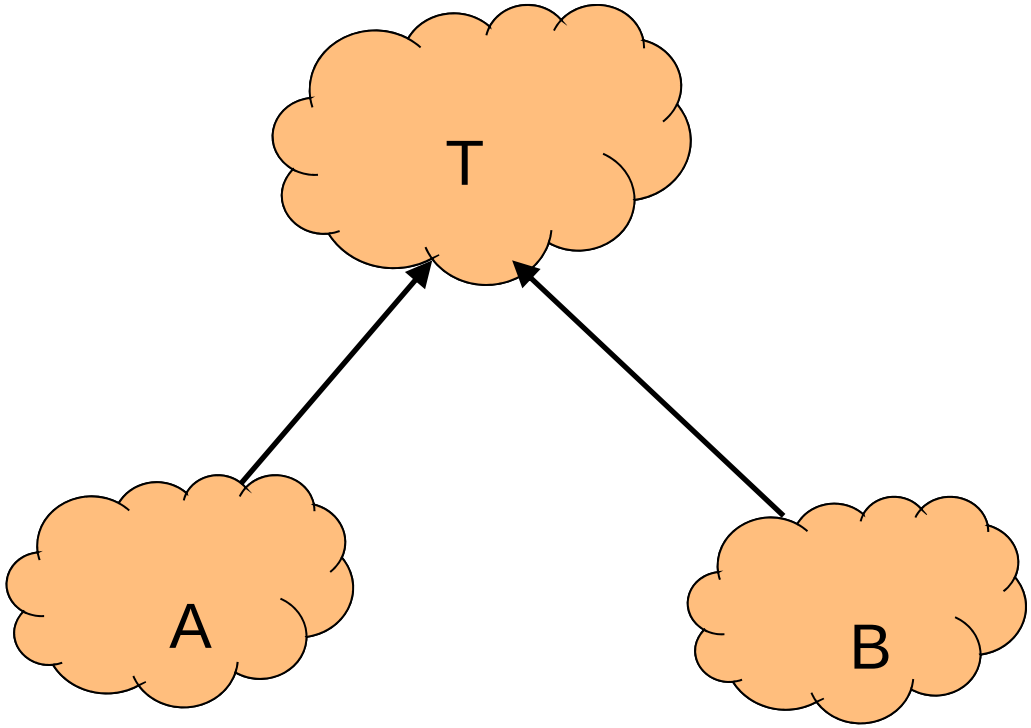
Value Based Peering

- Networks can exchange a price for peering (not necessarily settlement-free peering)
  - Price based on the “value” of the link
- For a network, define the notion of “fitness”
  - f = revenue – interconnect costs – backhaul cost
- Value of the link is the difference in fitness with and without the link
  - $V = f_{with} - f_{without}$
  - Revenue and costs could change on peering/depeering

What Affects Peering Value?



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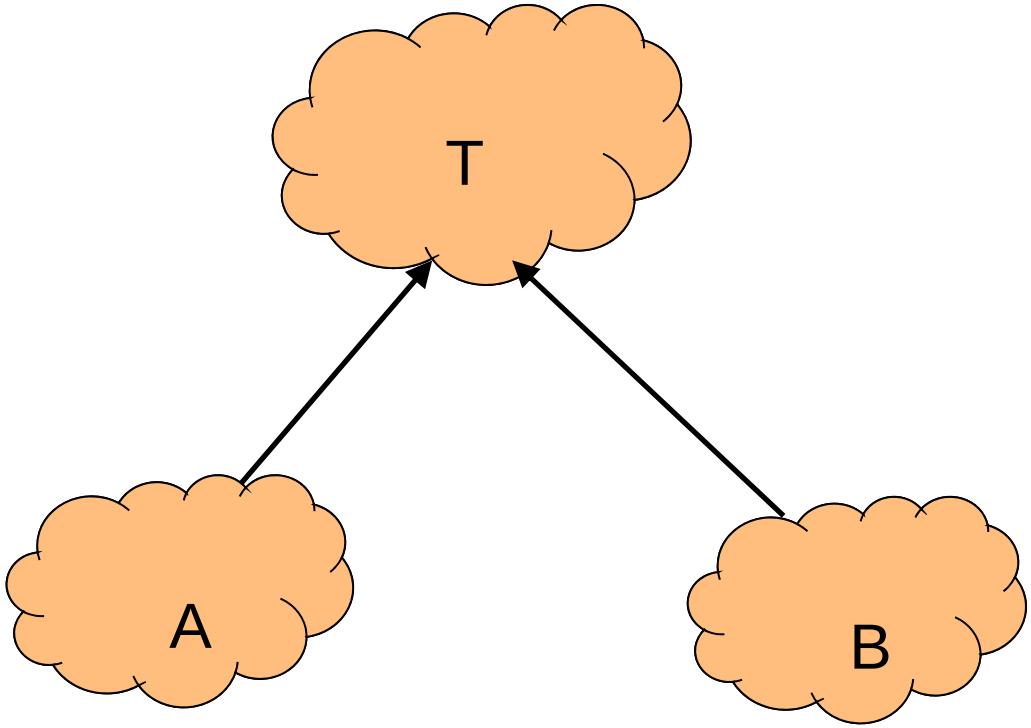

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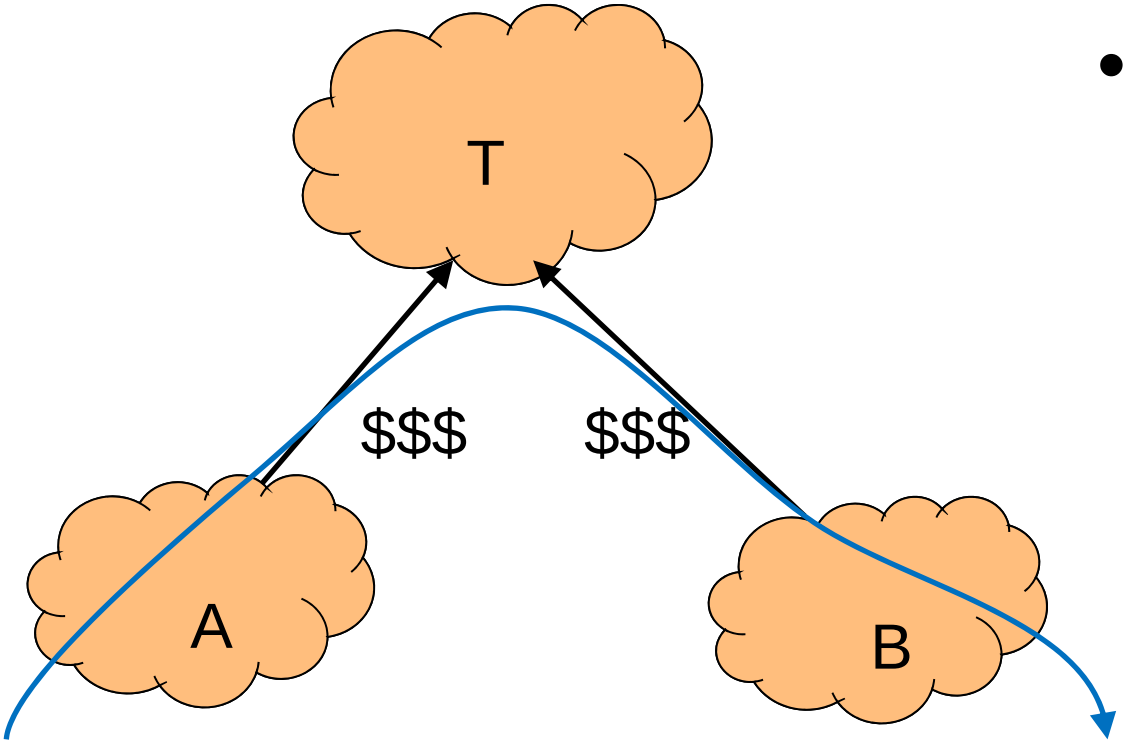

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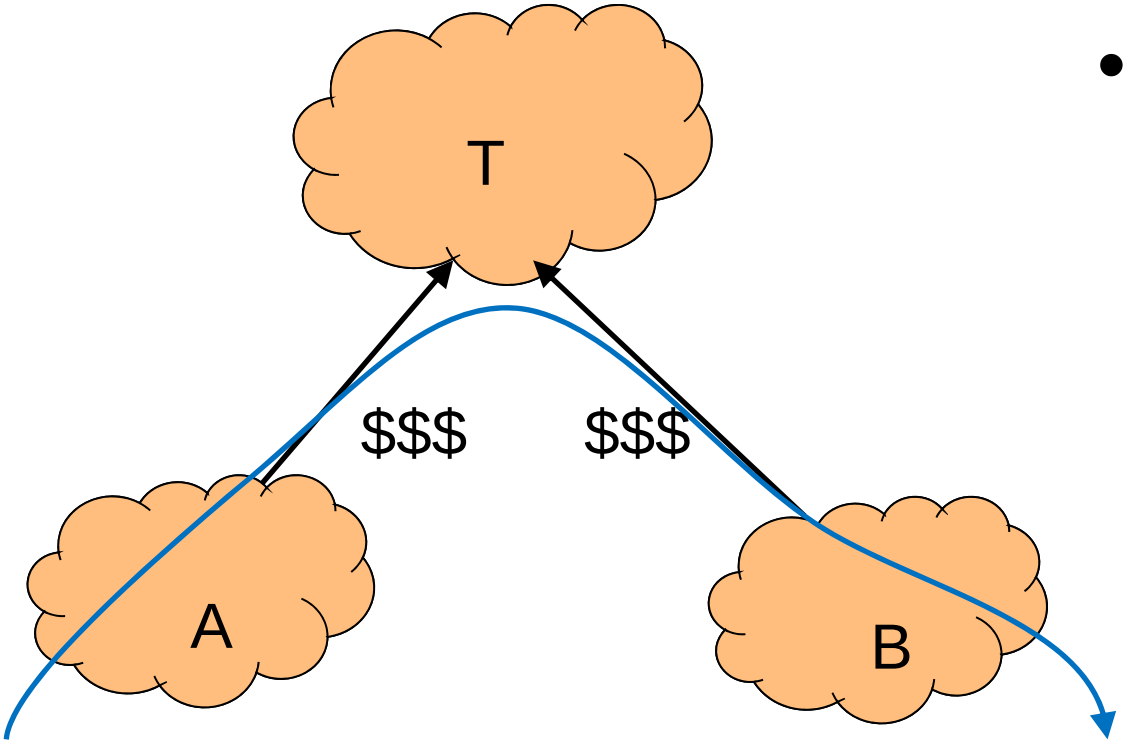

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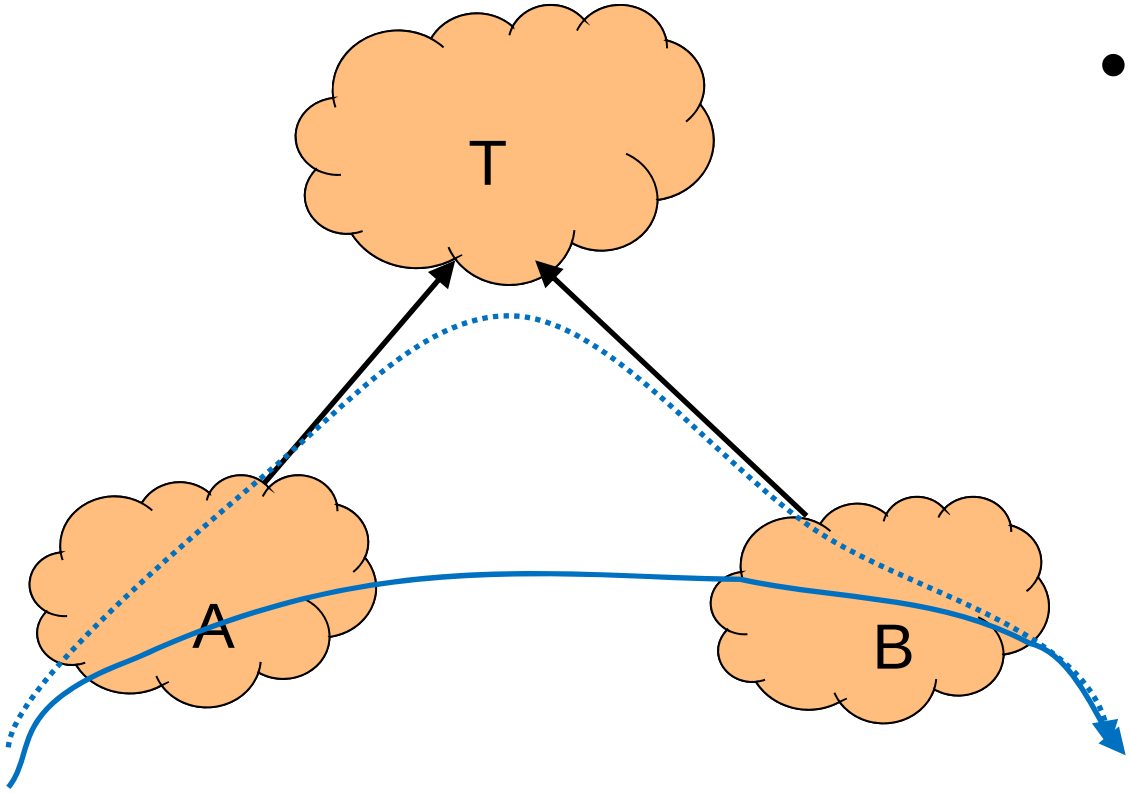

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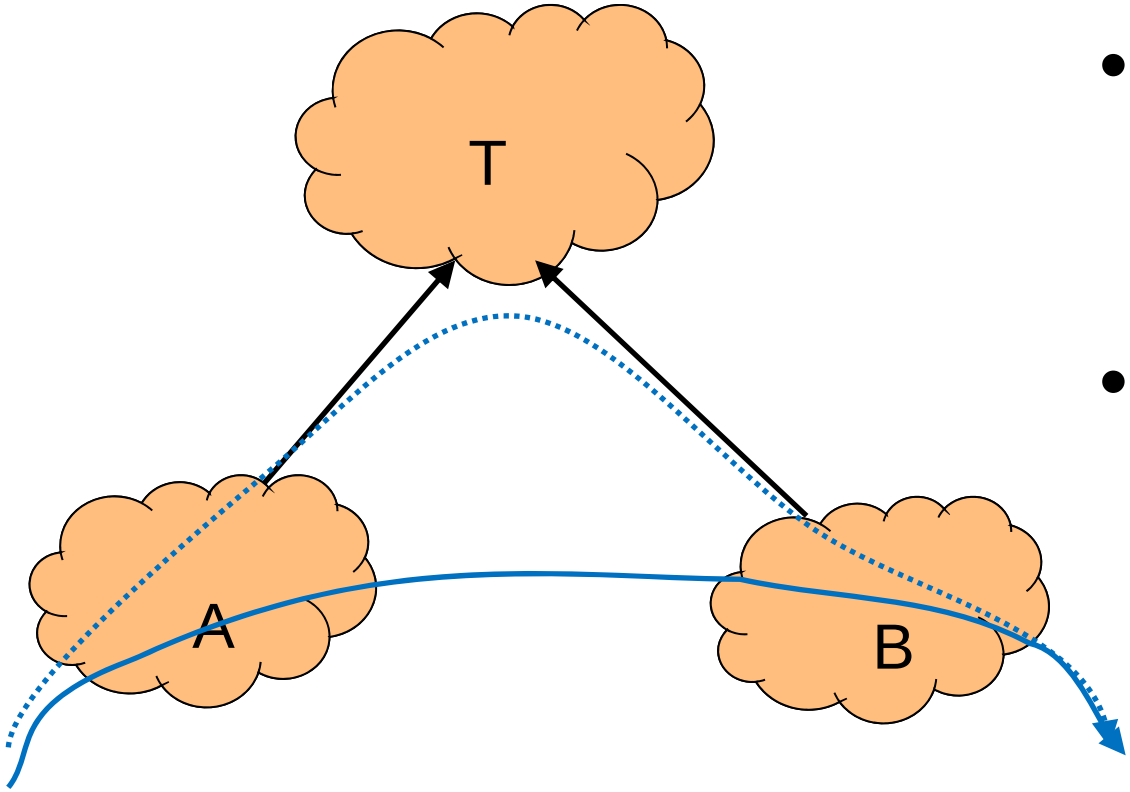

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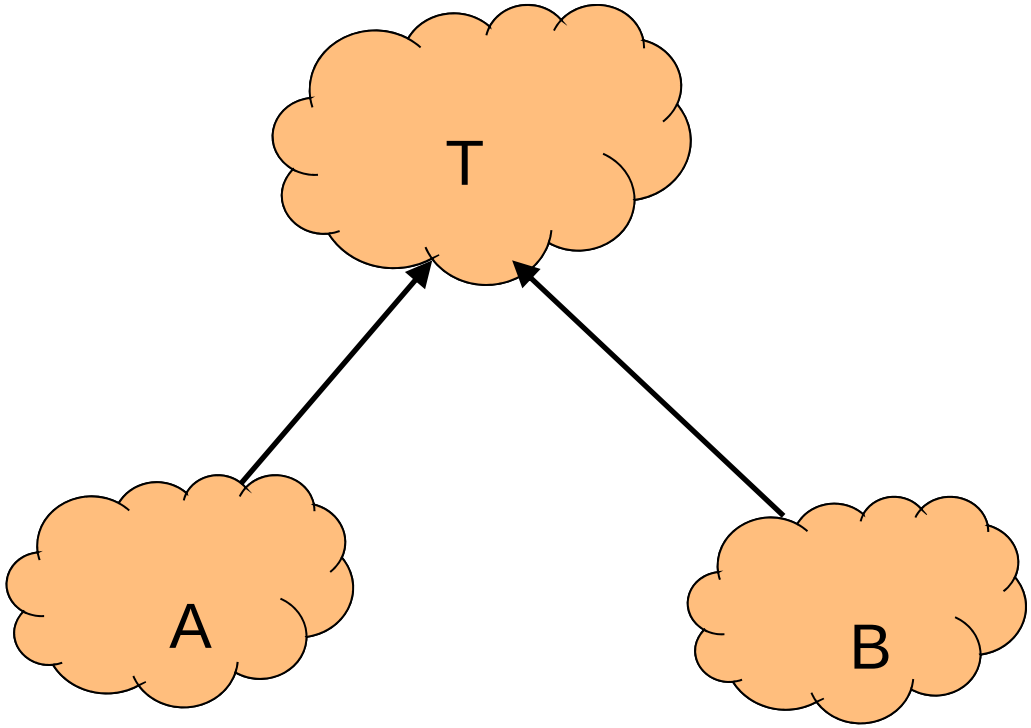

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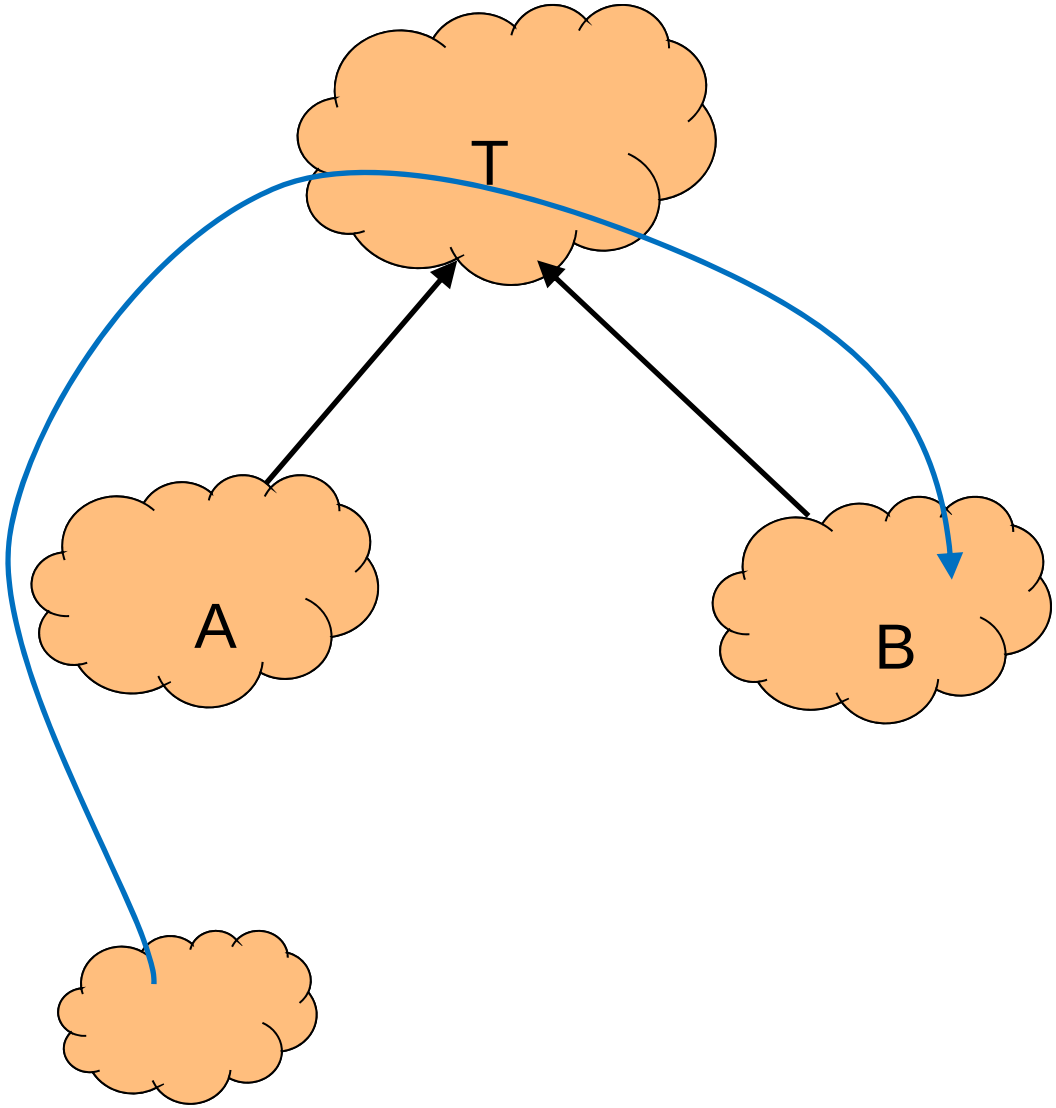

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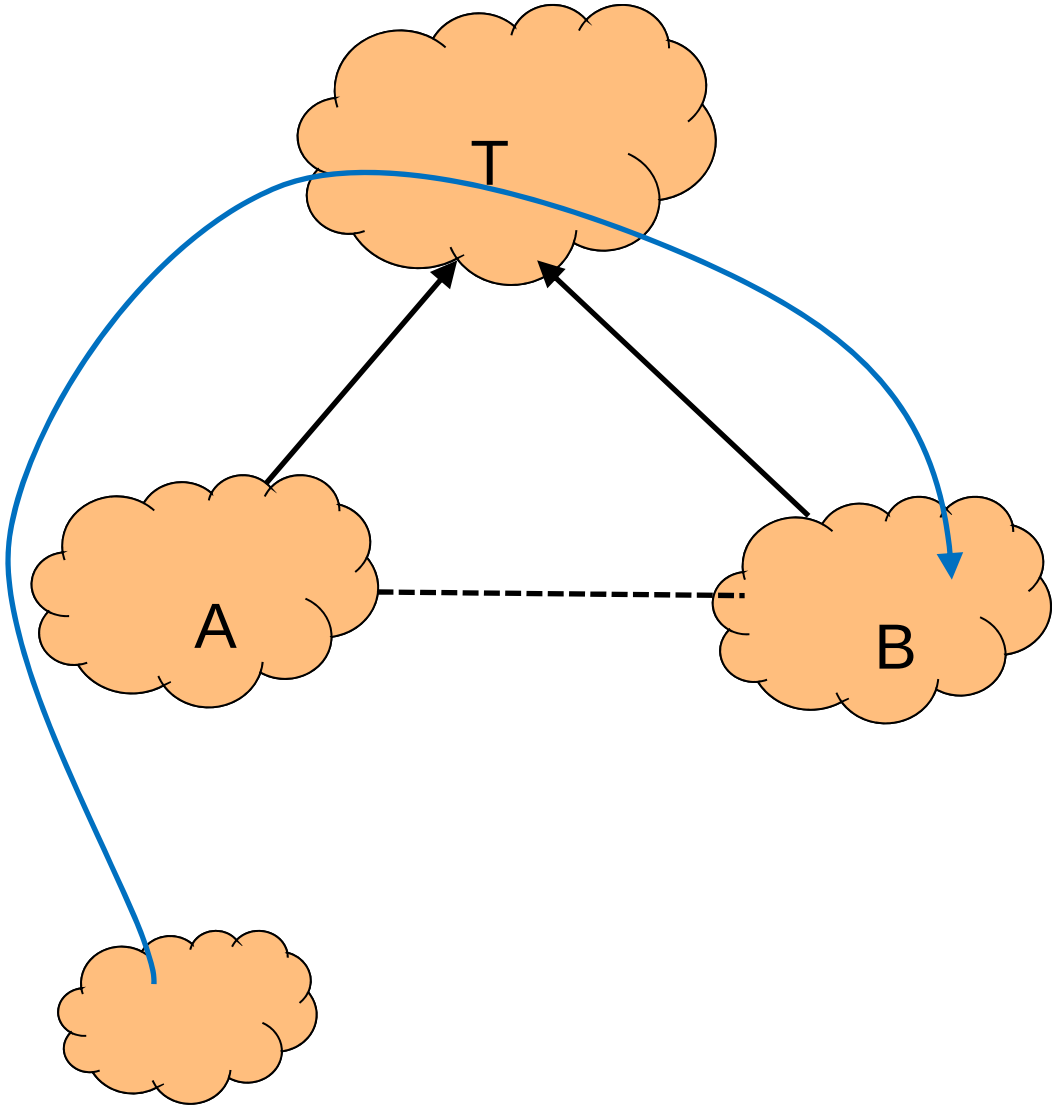

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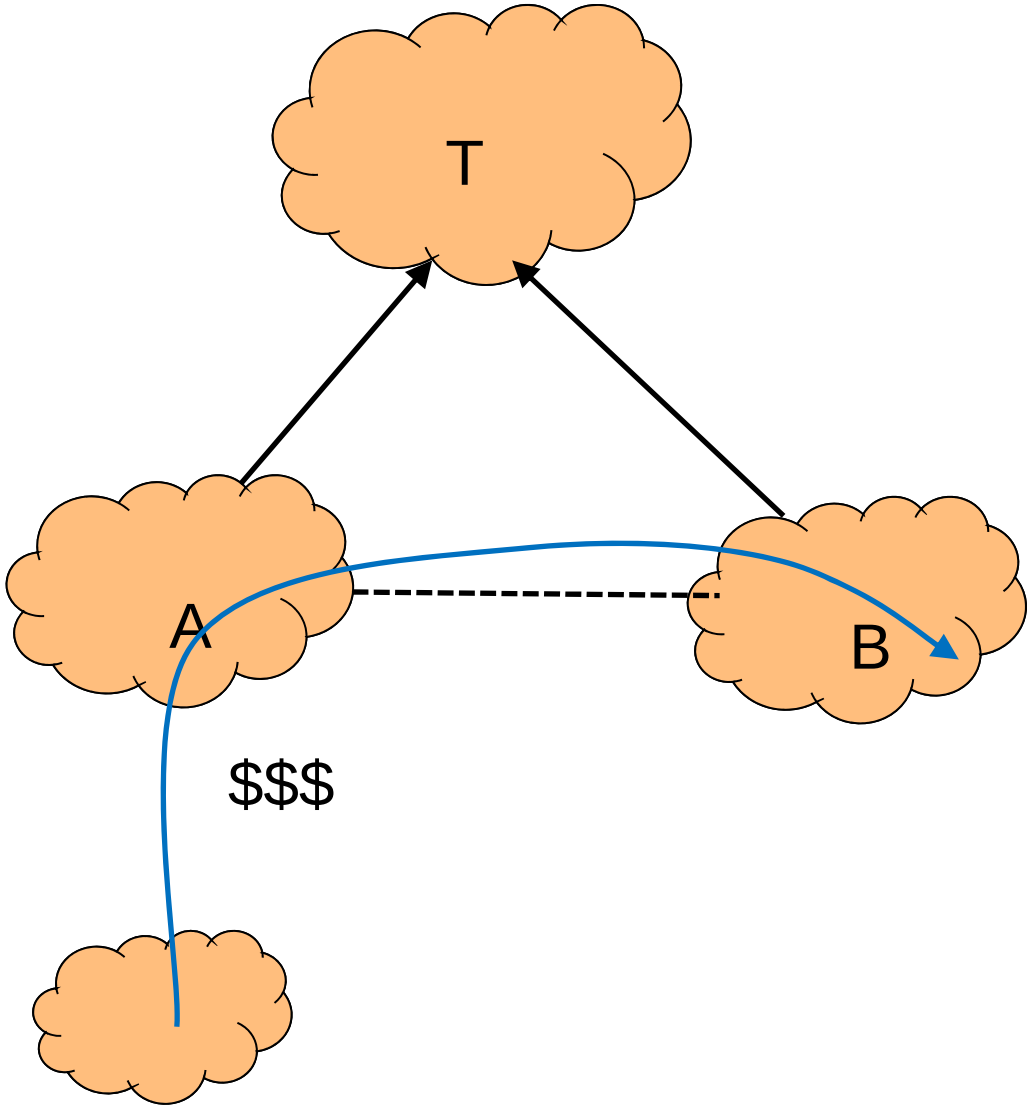

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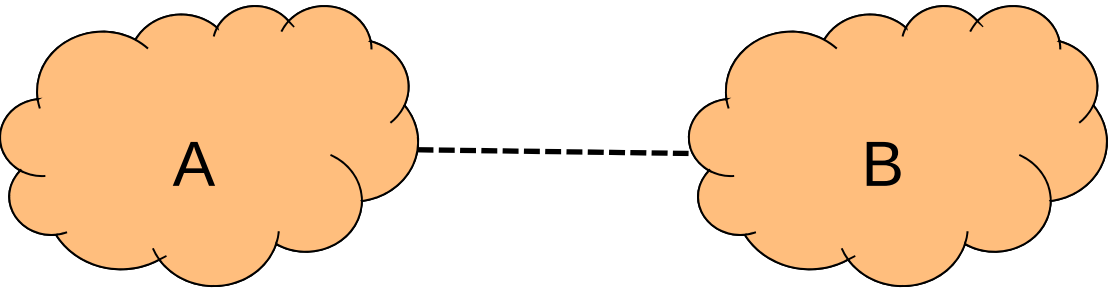
The Fair Peering Price

- An oracle knows V_A and V_B
- Oracle must decide the price for peering



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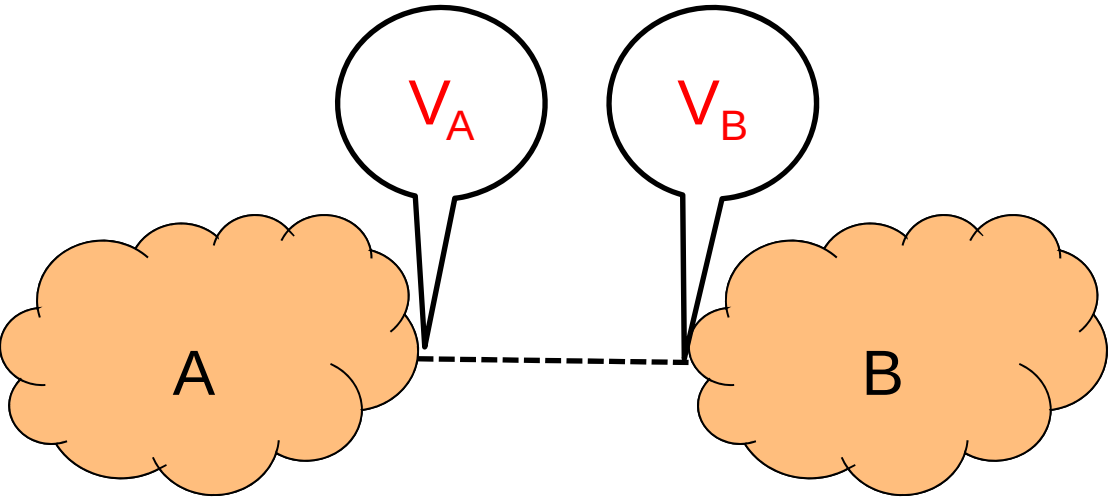

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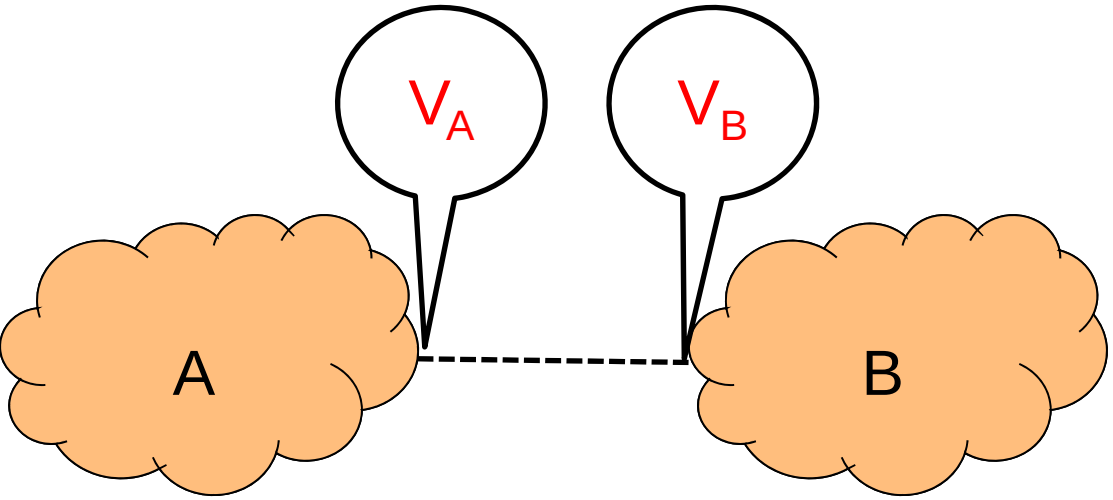

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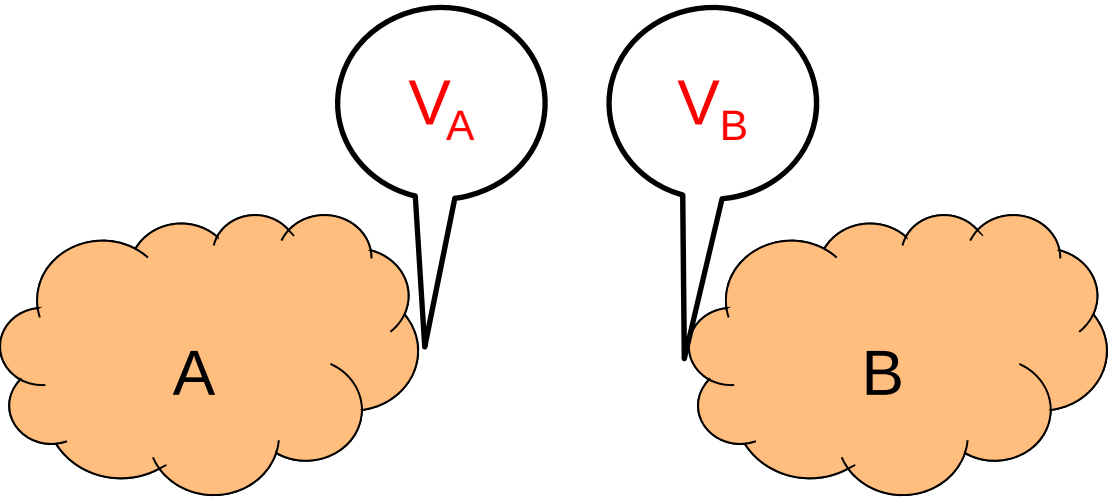

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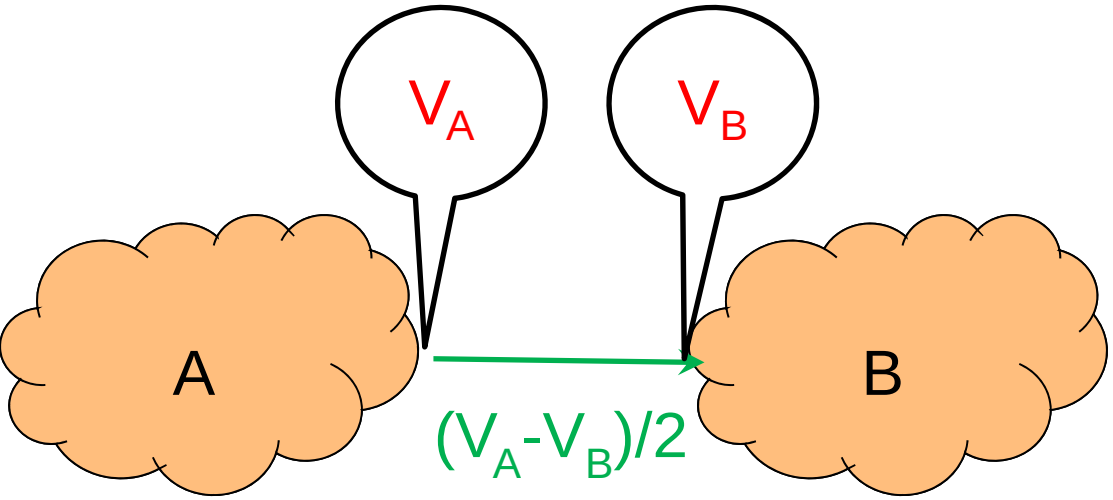

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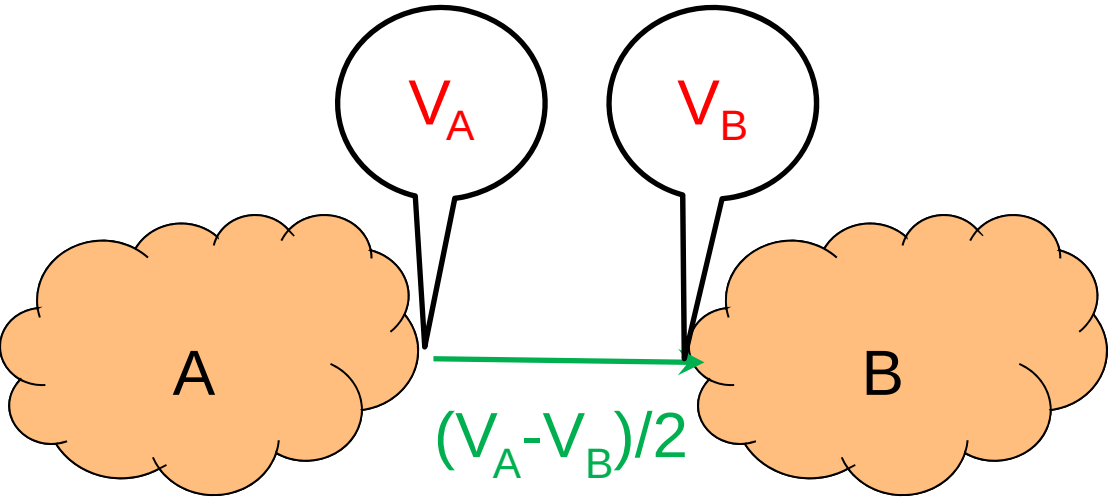

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- Oracle must decide the price for peering
- Fair price is $(V_A-V_B)/2$

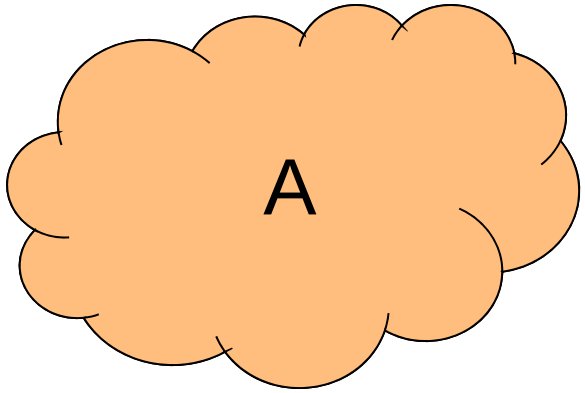
The fair price equalizes the benefit that A and B see from the link

Why Peer at the Fair Price?

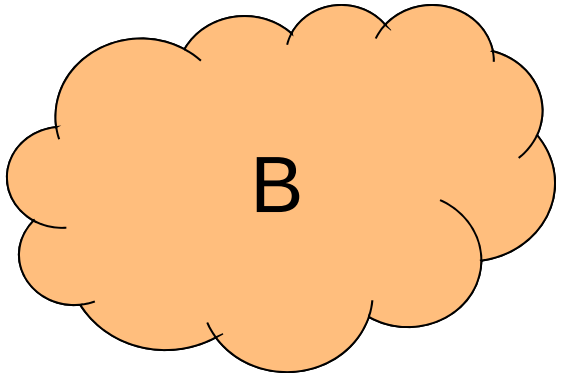
- Peering with the fair price is optimal
  - Both networks see better fitness by peering at the fair price
- Peering with the fair price is stable
  - No network has the incentive to unilaterally depeer the other network
  - Unique Nash Equilibrium
- Optimal and stable as long as $V_A+V_B > 0$
  - Either V_A or V_B can be negative, as long as total is positive
  - For cost-benefit peering, both V_A and V_B must be positive

Negative Peering Value

f_A: \$50k



f_B: \$100k



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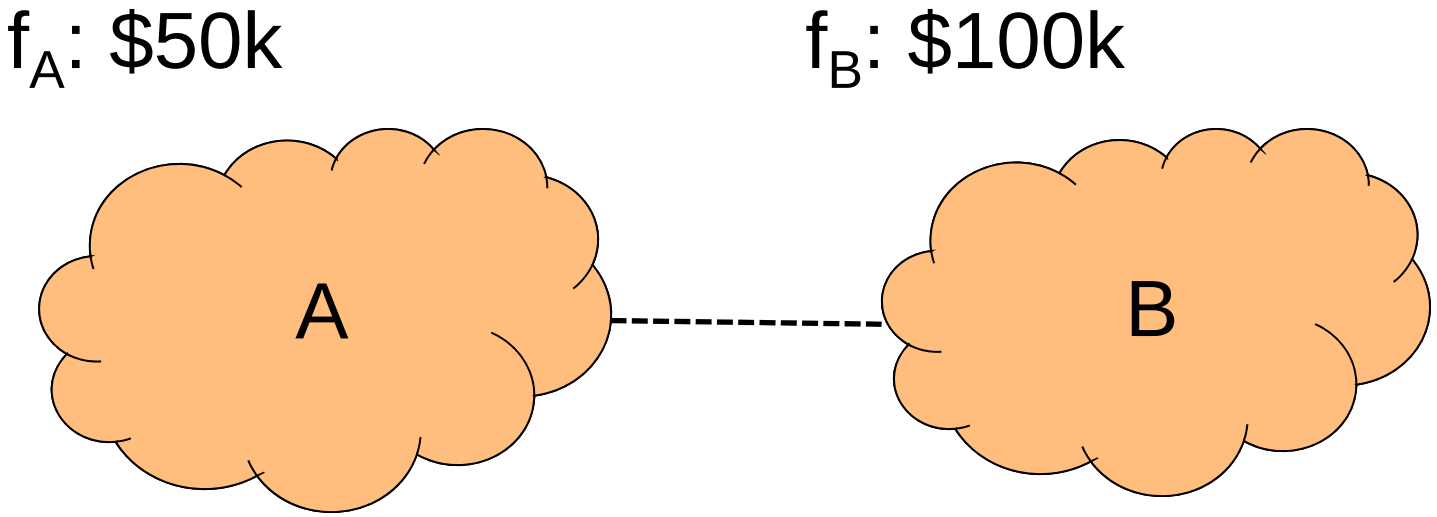

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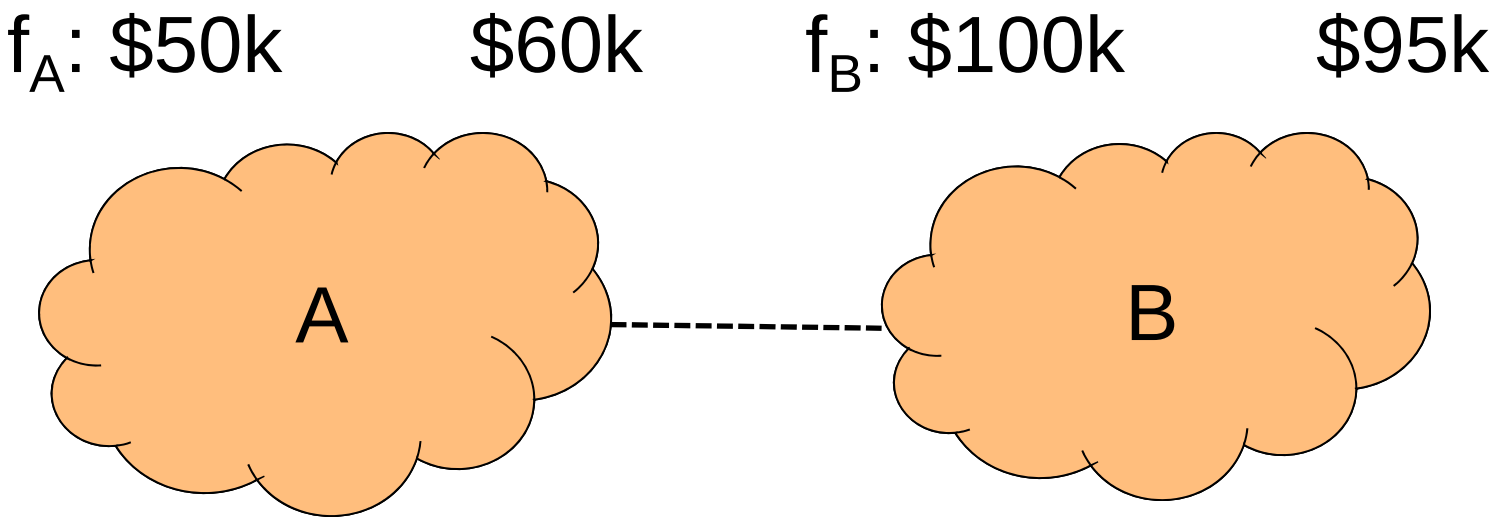

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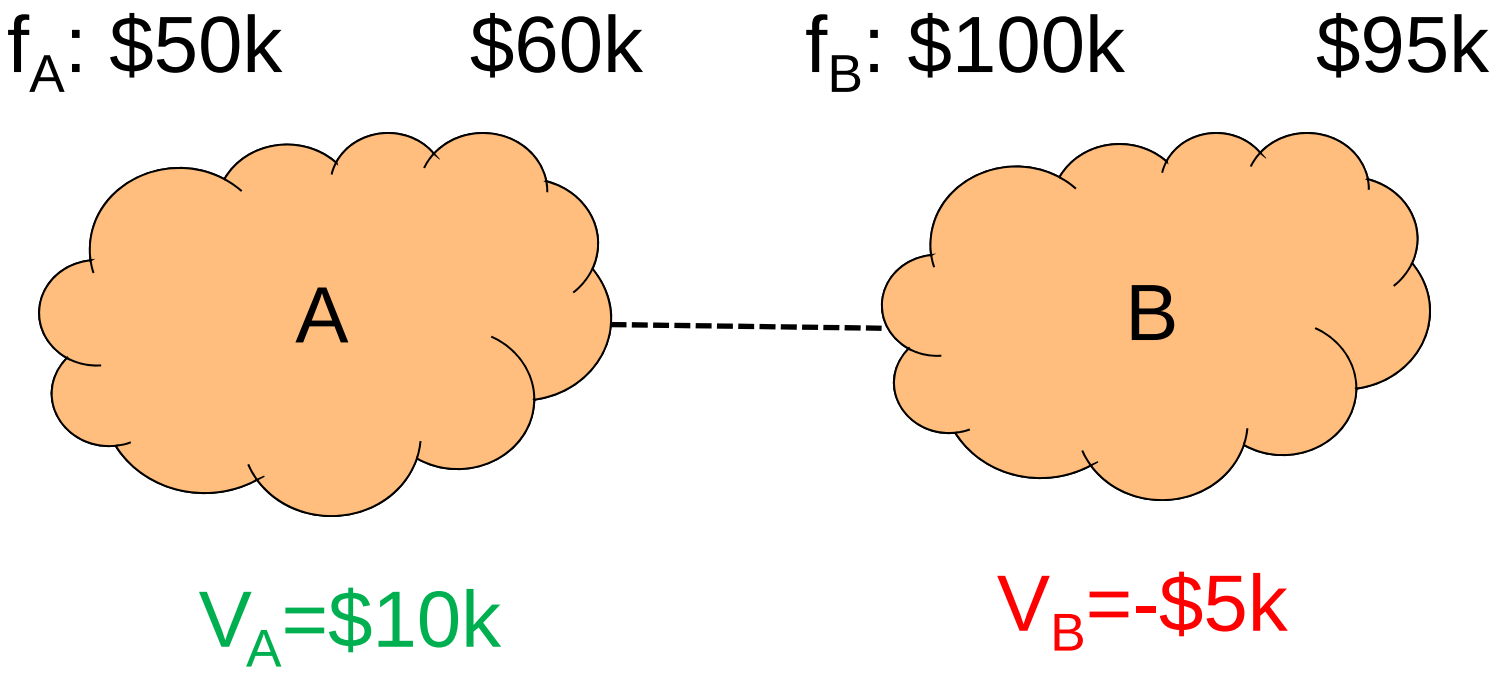

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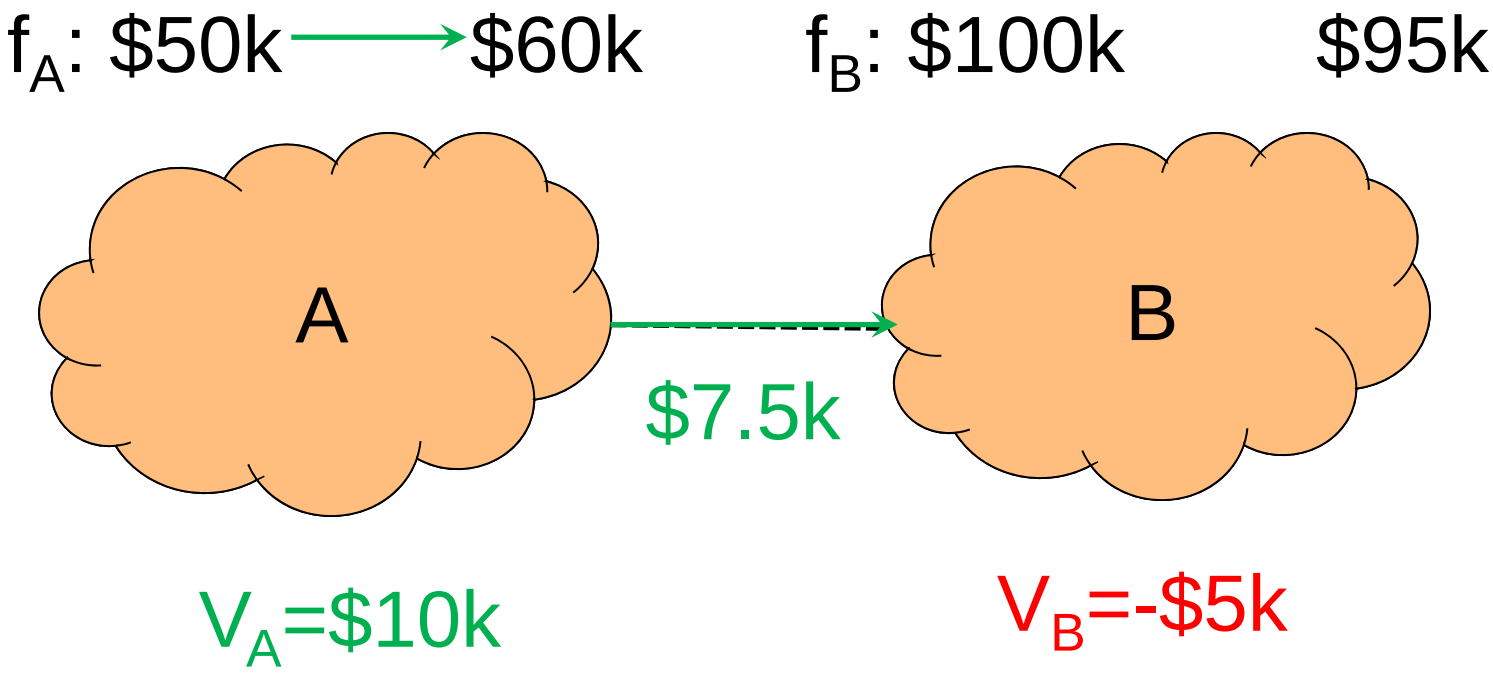

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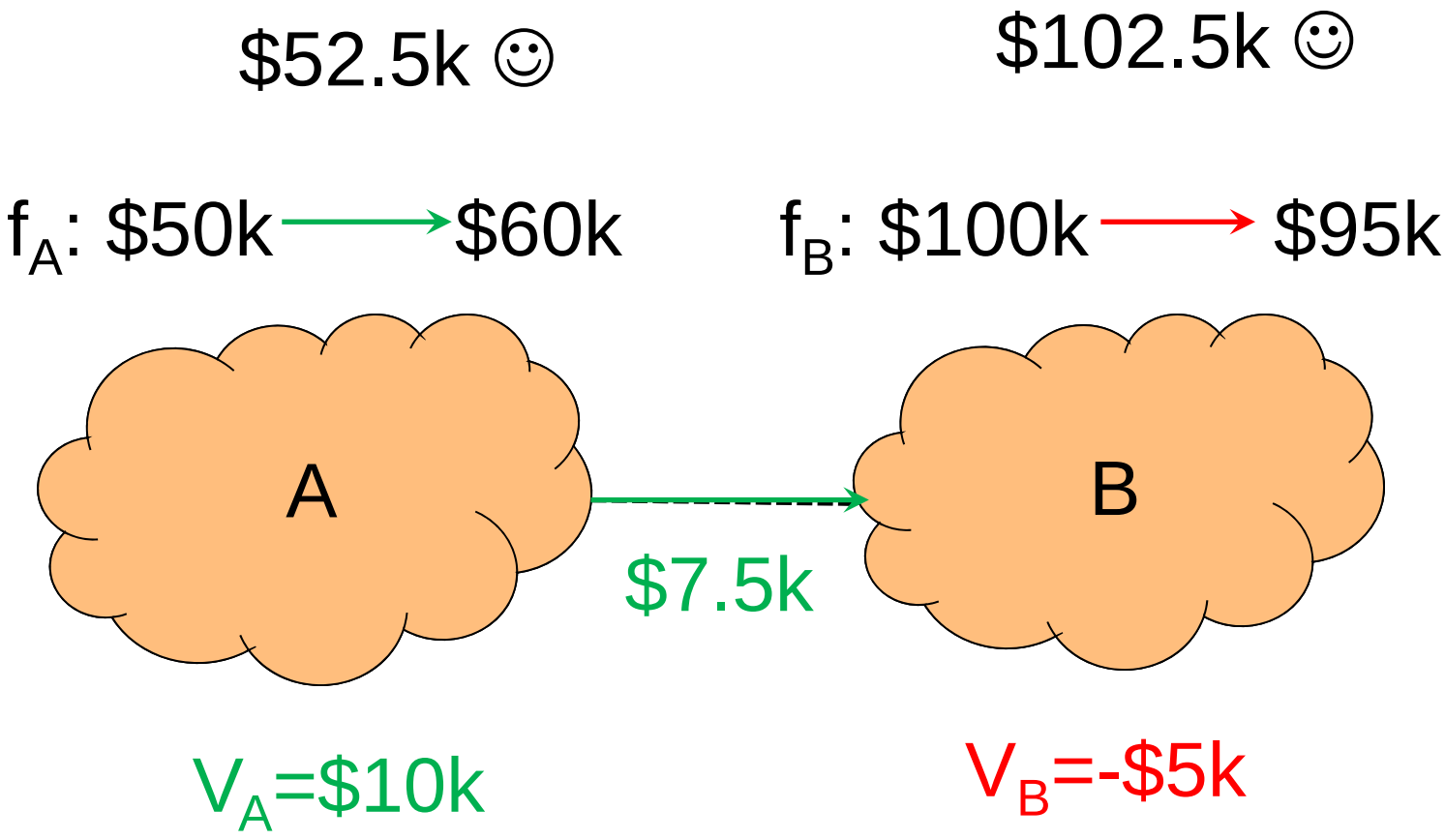

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Measuring Peering Value

- How do A and B measure V_A and V_B?
- With Peering trials:
  - Collect: netflow, routing data
  - Know: topology, costs, transit providers
- With peering trials, A and B can measure their own value for the peering link (V_A and V_B) reasonably well
- Hard for A to accurately measure V_B (and vice versa)

Hiding peering value

- Assume true $V_A + V_B > 0$ and $V_B > V_A$
  - A should get paid $(V_B - V_A)/2$
- If A estimates V_B correctly, and claims its peering value is V_L, where $V_L << V_A$
  - B is willing to pay more: $(V_B - V_L)/2$ ☺
- If A doesn't estimate V_B correctly, and $V_L + V_B < 0$, the peering link is not feasible!
  - A loses out on any payment ☹
- Does the risk of losing out on payment create an incentive to disclose the true peering value?

Some Hard Questions..

- Value-based peering is fair, optimal and stable.
  But is there an incentive to be fair? ☺
- Can a network accurately estimate its own value for a peering link without peering trials? (ongoing work)
- Can a network estimate the value of a peering link for a potential (or current) peer?
- What are the global effects of value-based peering?

Modeling the Internet Ecosystem

- Networks select providers and peers to optimize an objective function
  - E.g., Profit, performance…
- What are the effects of provider and peer selection strategies on the involved networks?
- What are the global, long-term effects of these strategies on the whole Internet?
  - Topology, traffic flow, economics, performance (path lengths)
- E.g., Can we predict what would happen if (fair) paid-peering becomes the common case?

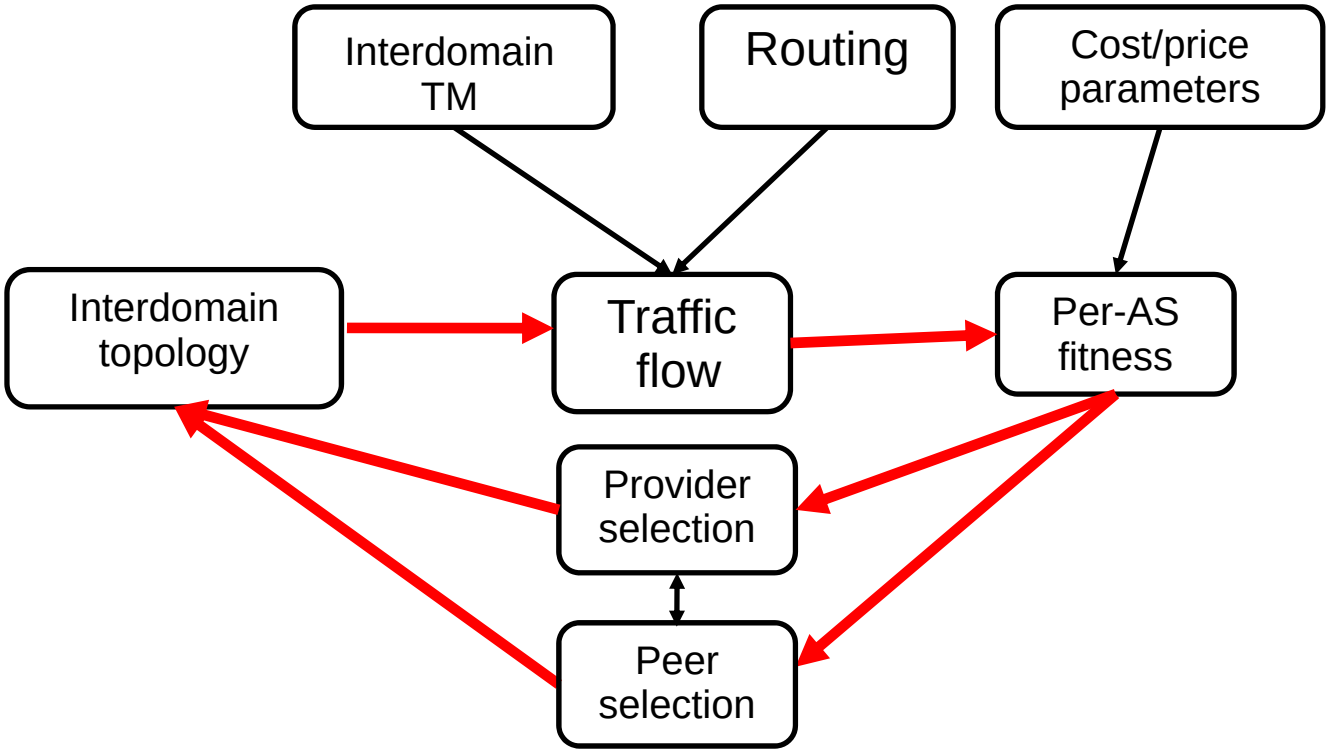
ITER Model

- ITER: Agent-based computational model to answer “what-if” questions about Internet evolution

- Inputs: According to the best available data…
  - Network types: transit provider, content provider, stub
  - Peer selection methods, provider selection methods
  - Geographical constraints
  - Pricing/cost parameters
  - Interdomain traffic matrix

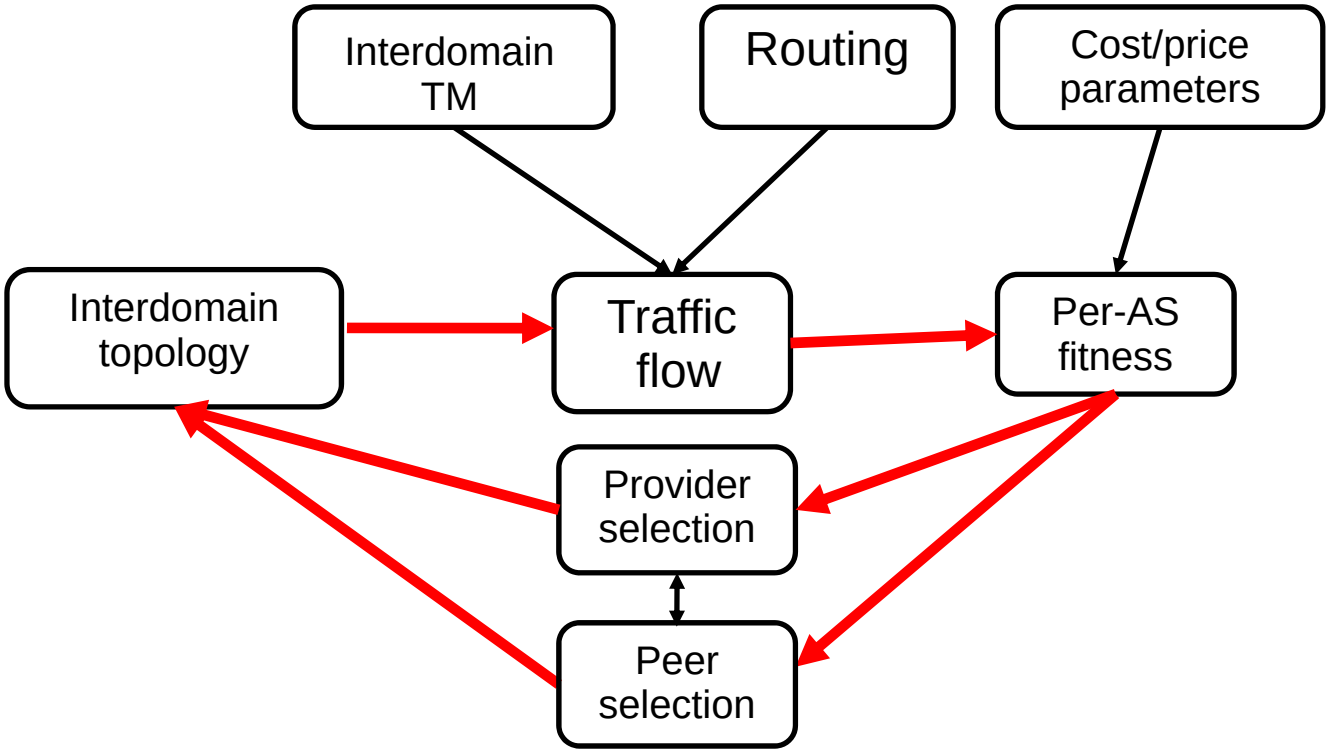
- Output: Equilibrium internetwork topology, traffic flow, per-network fitness

ITER approach



- Compute equilibrium: no network has the incentive to change its providers/peers

ITER approach



- Measure topological and economic properties of equilibrium e.g., path lengths, which providers are profitable, who peers with whom

Using ITER to Simulate Value-based Peering

- Small but realistic internetwork topology with transit providers, content providers and stubs
- Interdomain traffic matrix dominated by traffic from content providers to stubs
- Provider selection for content providers and stubs is price-based – choose cheapest providers
- Simulated value-based, cost-benefit and traffic-ratio peering
- Transit and peering pricing based on best available data

ITER Results for Value-based Peering

- Peering links: Higher density of peering links with value-based peering ➔ Shorter end-to-end paths
  - Links that are not allowed with traffic-ratio or cost-benefit peering are possible with value-based peering
- Payment direction: Content providers end up paying large transit providers, get paid by smaller transit providers
  - Is this happening already?
- Incorrect value estimation can preclude the formation of mutually beneficial links

We need feedback on this model!

- How much foresight goes into provider/peer selection decisions?
  - "What would my customers do if I added this peering link?"
- Insights about paid peering negotiations in the real world
- Would you be willing to share data to help us parameterize ITER?
  - Interdomain traffic matrix, pricing/cost parameters

Thanks!

- More details in the paper
  - www.caida.org/~amogh/depeering_itc10.pdf
- Please email me (amogh@caida.org) for a copy of the ITER paper
- Please send us feedback
  - amogh@caida.org
  - pierre.francois@uclouvain.be
  - dovrolis@cc.gatech.edu

What if there's no middleman?

- Network A
- "requirement" R_A
- "willingness to pay" W_A

- Network B
- "requirement" R_B
- "willingness to pay" W_B

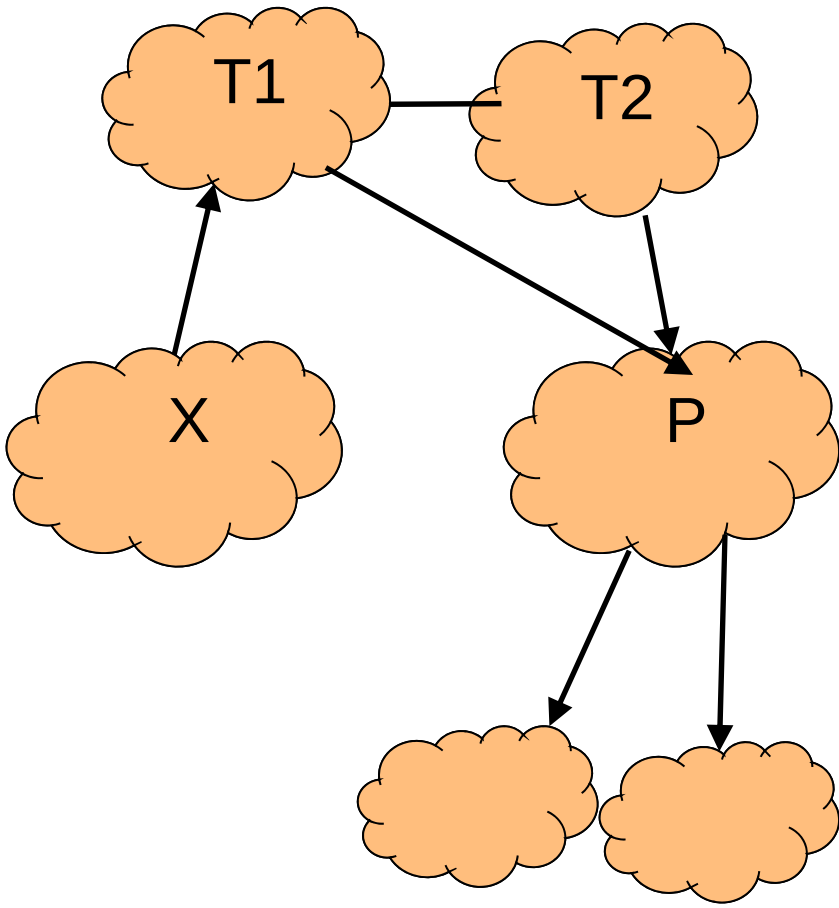
- A and B declare R_A, R_B, W_A, W_B
- Peer if $W_A >= R_B$ and $W_B >= R_A$
- Same solution as middleman case
- With perfect knowledge, price = $|V_A - V_B|/2$

Cost Model

- Optimization problem: Choose (egress AS, egress PoP) for each flow to minimize total cost, satisfy link capacity constraints
  - NP-hard to solve optimally
- Greedy heuristic works well: rerouting 10-20% of the most expensive flows can achieve 60-70% of total saving
- Can be applied to various “What-if” scenarios:
  - Evaluate current/potential peering link
  - Determine which links to upgrade
  - Determine where to add peering locations

Application: Estimating Peering Value

- Apply cost model to current connectivity and traffic flows → total cost C_0
- Identify non-peer P with which X exchanges traffic, and set of flows that traverse P
- Assume X directly connects to P, apply cost model → cost C_1
  - Assume same traffic exchanged with P as before
- Difference $|C_0-C_1|$ is the value of the peering link for X



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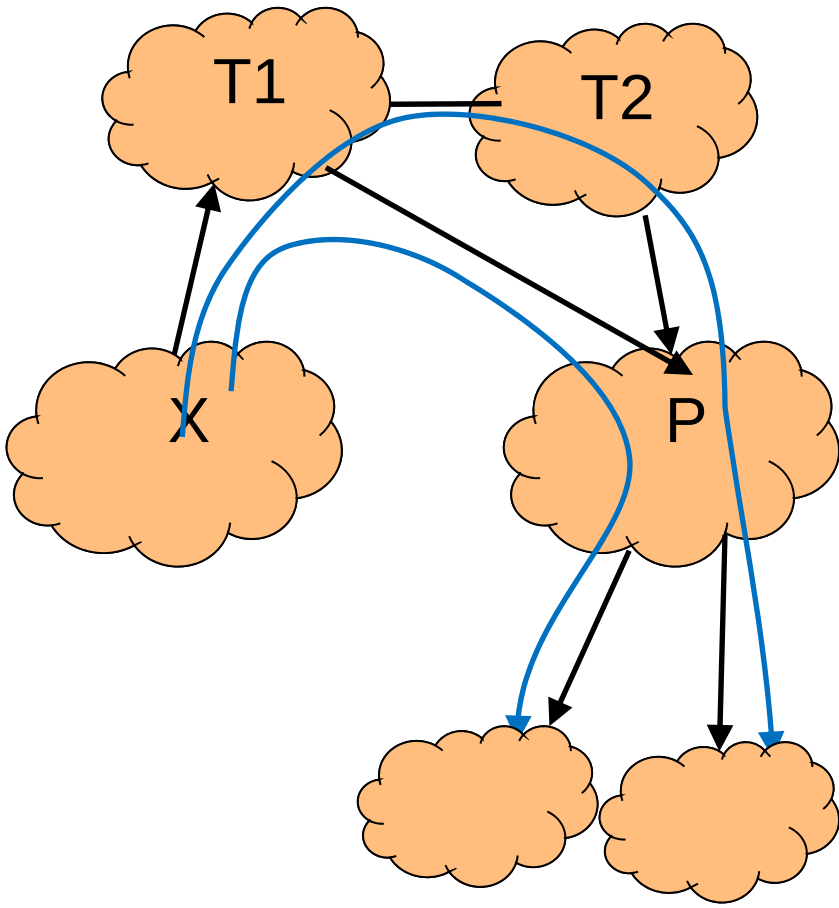

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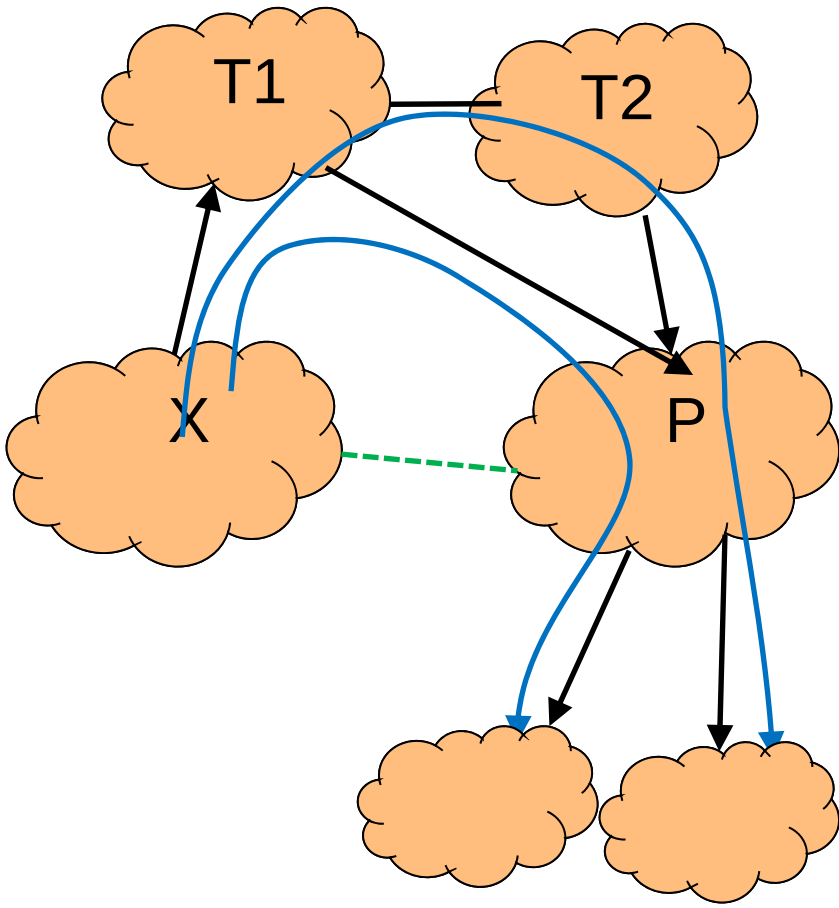

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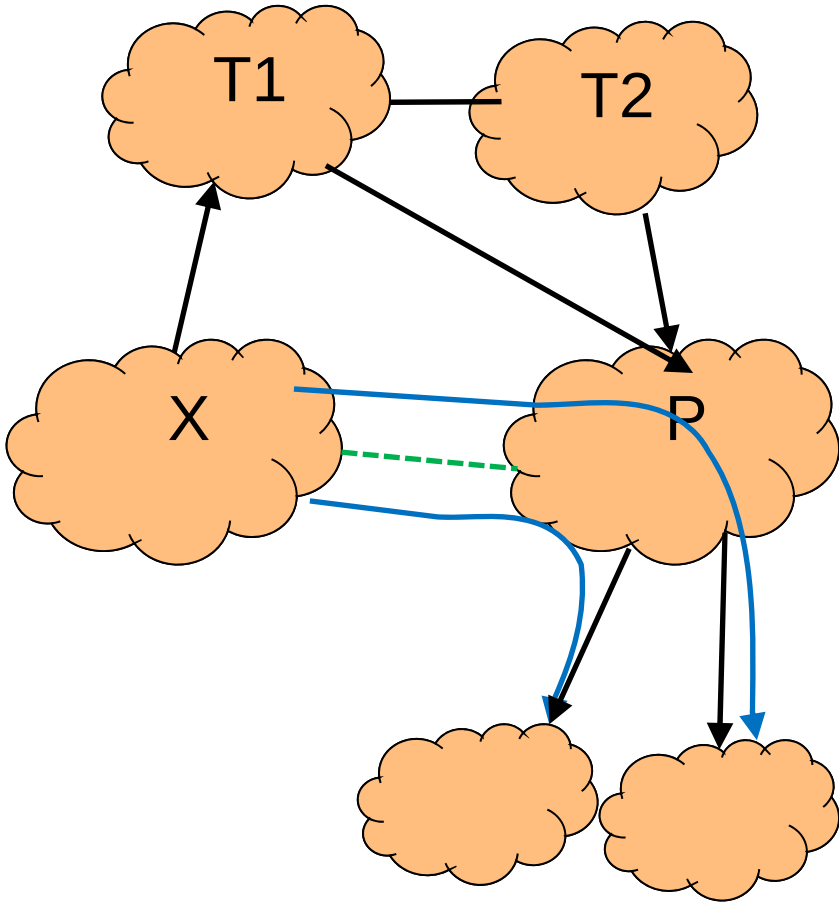

ITER Results – Arbor Study

- Parameterized ITER using recent trends from Arbor study
  - Large fraction of traffic from top content providers
  - increased geographical coverage of content providers
  - peering openness
- Global Internet properties:
- Shorter end-to-end AS paths
- Traffic bypasses large (tier-1) providers
- Revenues decline for all providers
- Does this happen already?