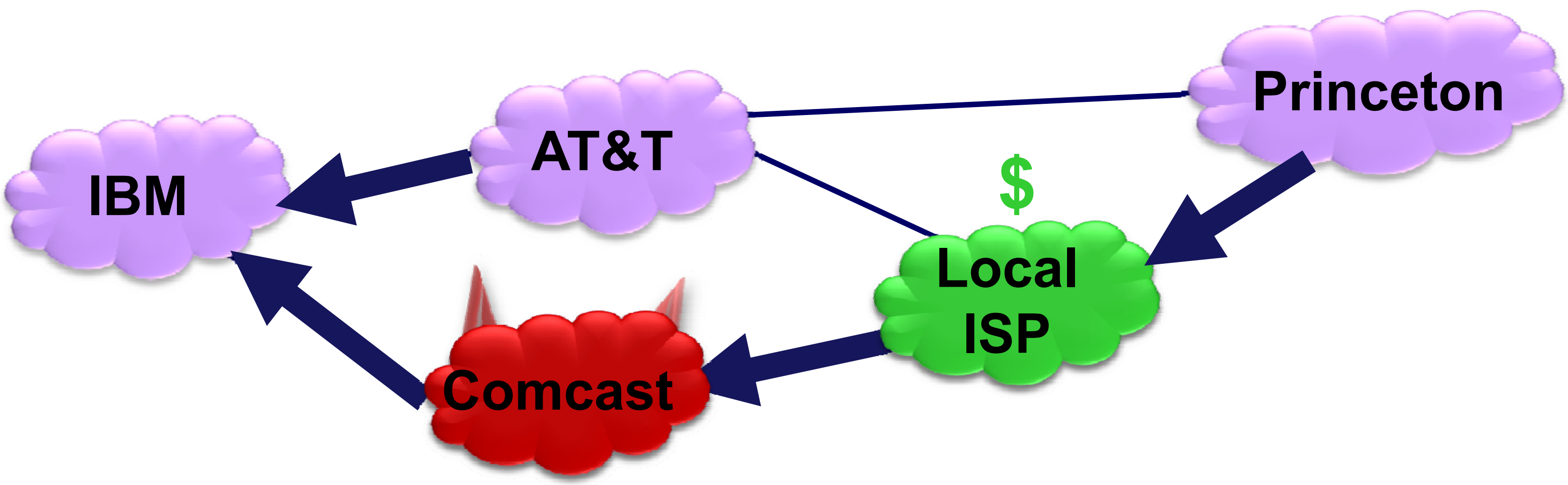
Rationality and Traffic Attraction

Incentives for Honest Path Announcement in BGP



Sharon Goldberg Shai Halevi

Aaron D. Jaggard Vijay Ramachandran Rebecca N. Wright

Cisco Tech Talk, August 1, 2008

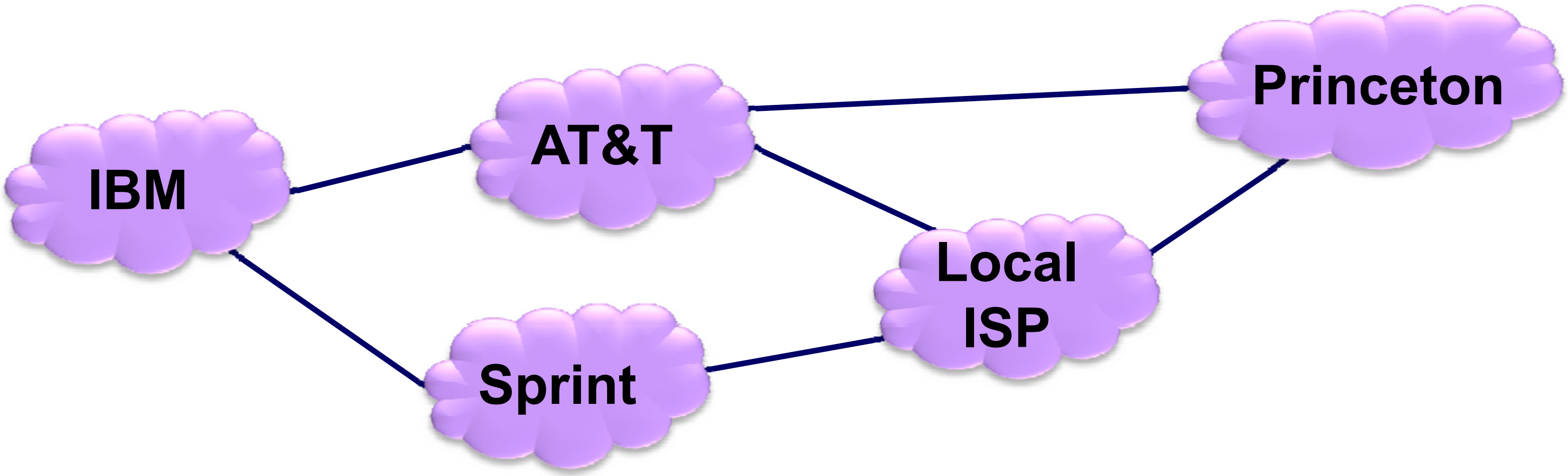
Earlier versions presented at Hebrew University, Berkeley, IBM Research, and DIMACS Secure Routing Seminar

Princeton **University**

Incentives and Security

Do incentives enforce "good behavior" on Internet?

We use game theory to answer a network architecture question - What type of security protocols should we deploy in the network?



We consider interdomain routing with BGP, and ask:

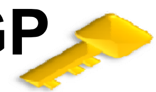
Do rational Autonomous Systems (ASes) have incentives to deviate from "correct operation" of BGP?

Will nodes deviate if we have Secure BGP ?

Overview of Our Results

We ask: Do the paths announced in BGP messages match the paths packets actually take in the data plane?

[LSZ08] implies they match, as long as (roughly)

- Nodes are **rational** – try to maximize utility.
- The network has **Secure BGP** 

This work suggests otherwise.

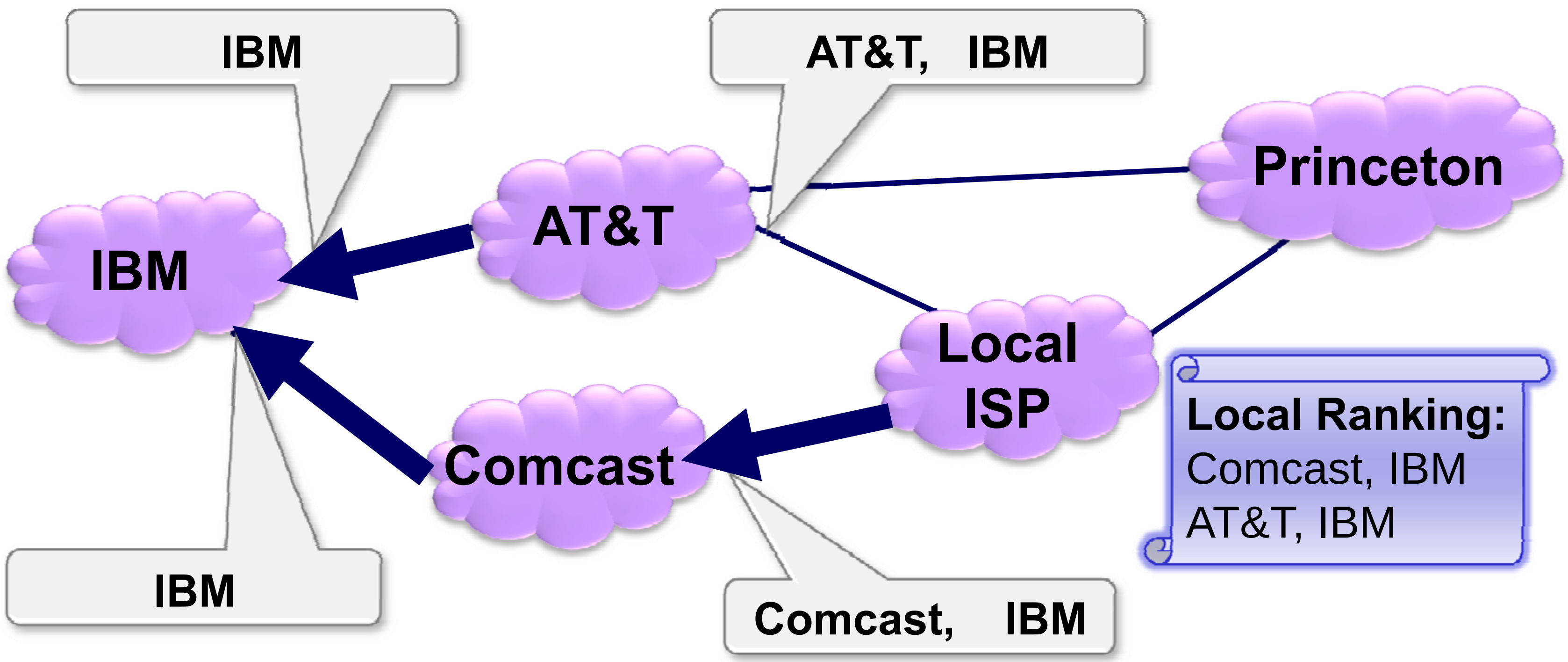
- We use a more realistic model of utility:
- … where ASes also want to **attract traffic**
- We find that **Secure BGP** can help, but in combination
- … with **unrealistic** restrictions on **routing policy**.

This talk

1. BGP Overview
2. Honest path announcements
3. Secure BGP
4. Rational behavior and traffic attraction
5. Volume traffic attraction
6. Customer traffic attraction
7. Conclusion

BGP: The Interdomain Routing Protocol (1)

The Border Gateway Protocol (BGP) is the routing protocol that sets up paths between Autonomous Systems (ASes) in the Internet.



Forwarding: In our model, a node uses a **single** outgoing link for all traffic.

Rankings: Static and local; usually based on economic relationships.

BGP: The Interdomain Routing Protocol (2)

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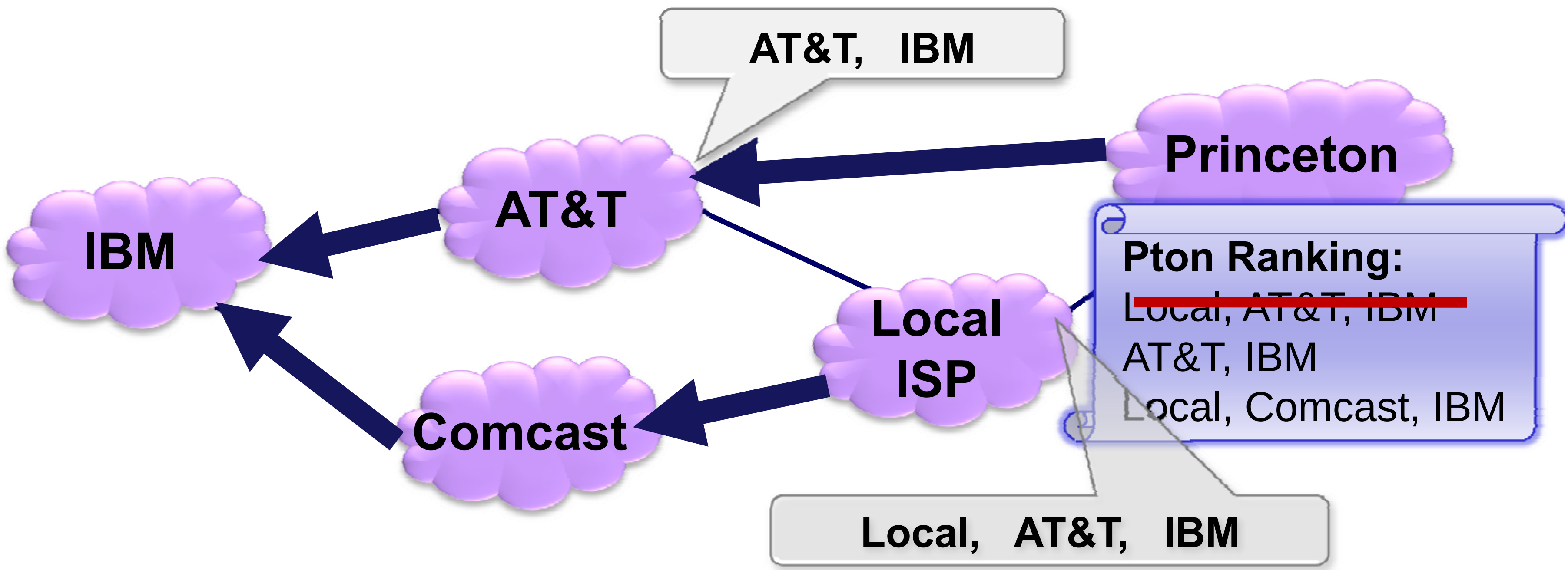

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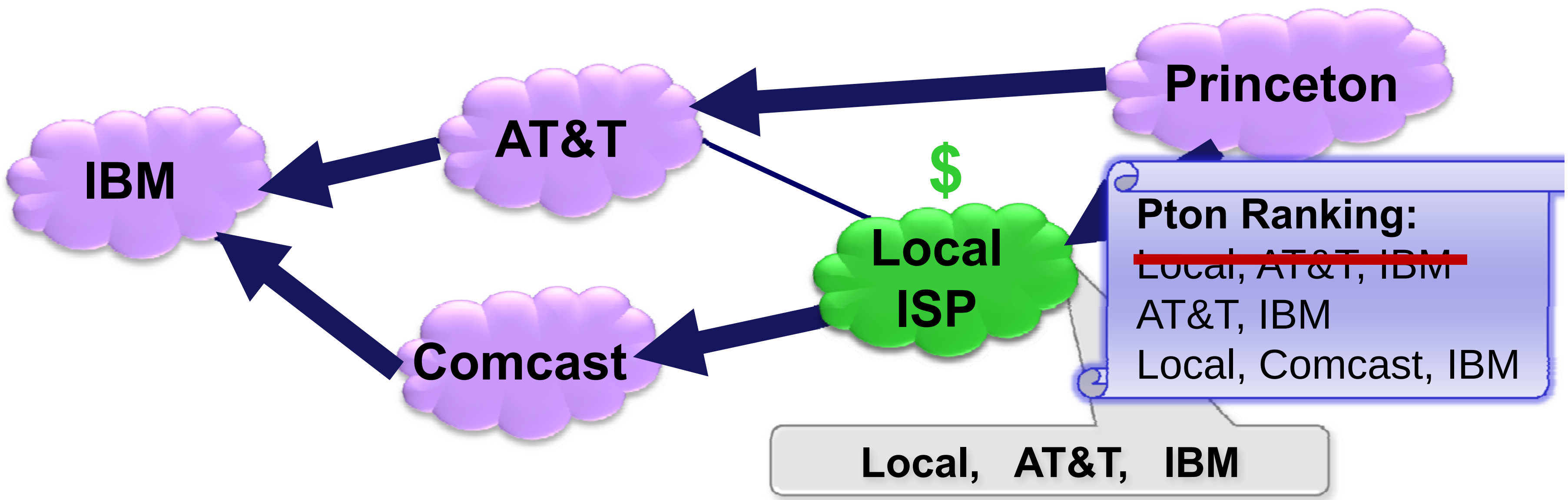
Matching Control & Data Plane (1)

The Control Plane: BGP messages
The Data Plane: The paths packet actually traverse



Goal of this work: Matching the Control Plane and Data Plane
BGP announcements match AS-paths packets take in data plane.

Matching Control & Data Plane (2)

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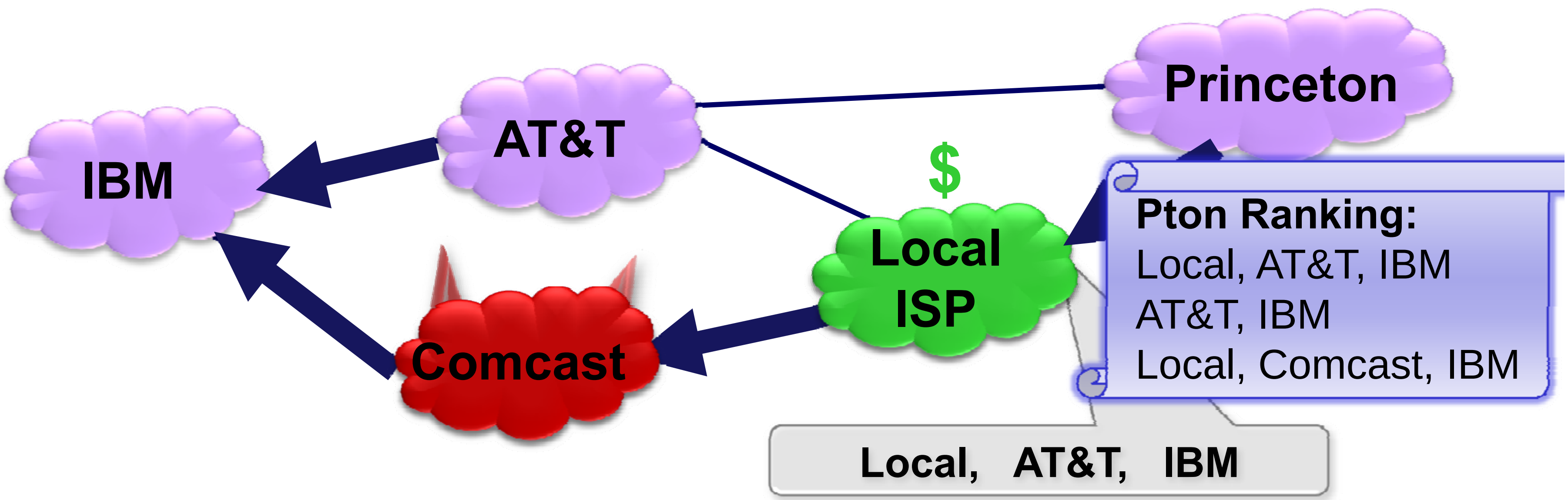
BGP announcements match AS-paths packets take in data plane.



This is useful so that ASes can use BGP messages:

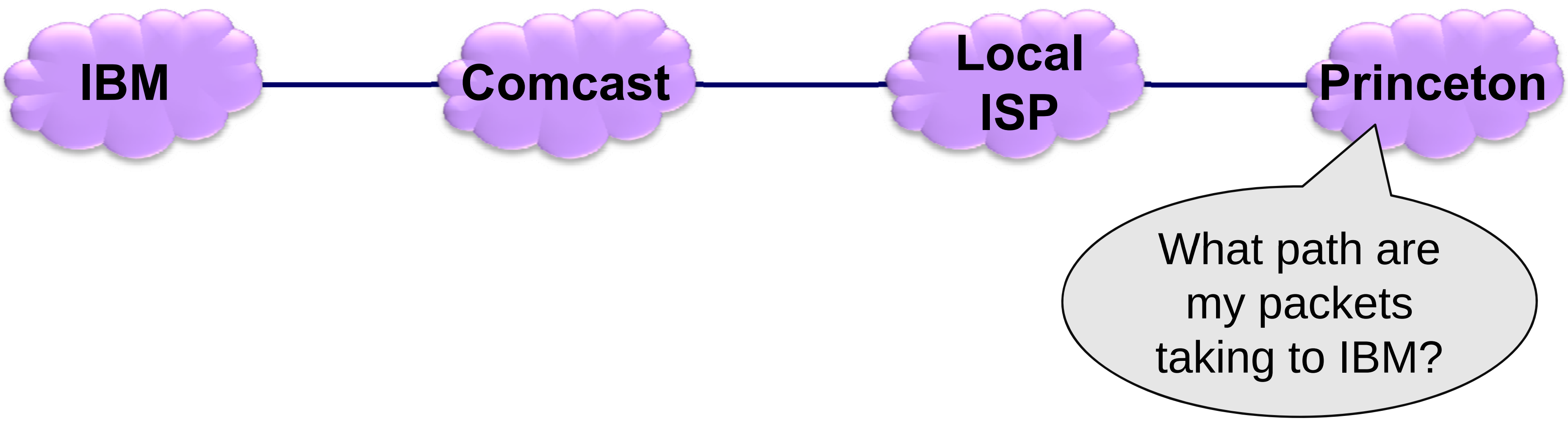
1. To avoid ASes perceived as adversarial / unreliable
2. To choose high performance paths
3. As part of an accountability framework

Approaches for Matching Control & Data Plane

Secure Data-Plane Protocols:

- Packet Passports [LYWA-06] Packet Obituaries [AMISS-07]
  Truth in advertising [WBAGS-07] Failure Localization [BGX-08]

✗ **Secure AS-path tracing protocols incur high overheads**



Approaches for Matching Control & Data Plane

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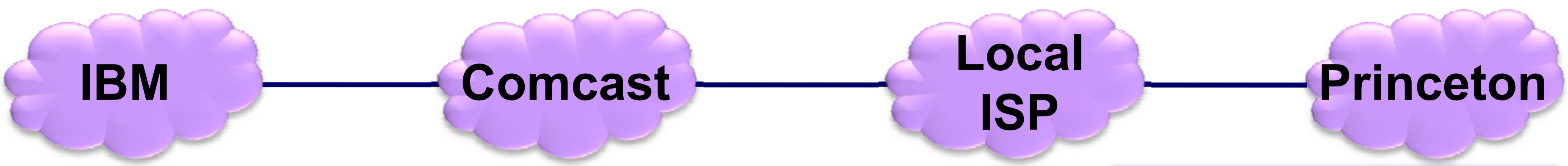

Pton Ranking:
Local, AT&T, IBM
AT&T, IBM
Local, Comcast, IBM

Control-Plane Protocols + Incentives:

- Each AS utility is determined by its ranking
- Find conditions for ASes to incentives to follow specified behavior
  ⇨ Corollary: control-plane matches data-plane

  e.g. **[NR-01], [FPS-01], [FPSS-05], [PS-04], [FKMS-05]**

  Shortest-path routing / Next-hop policy **[FRS-06], [FSS-07]**

  Secure BGP **[LSZ-08]**

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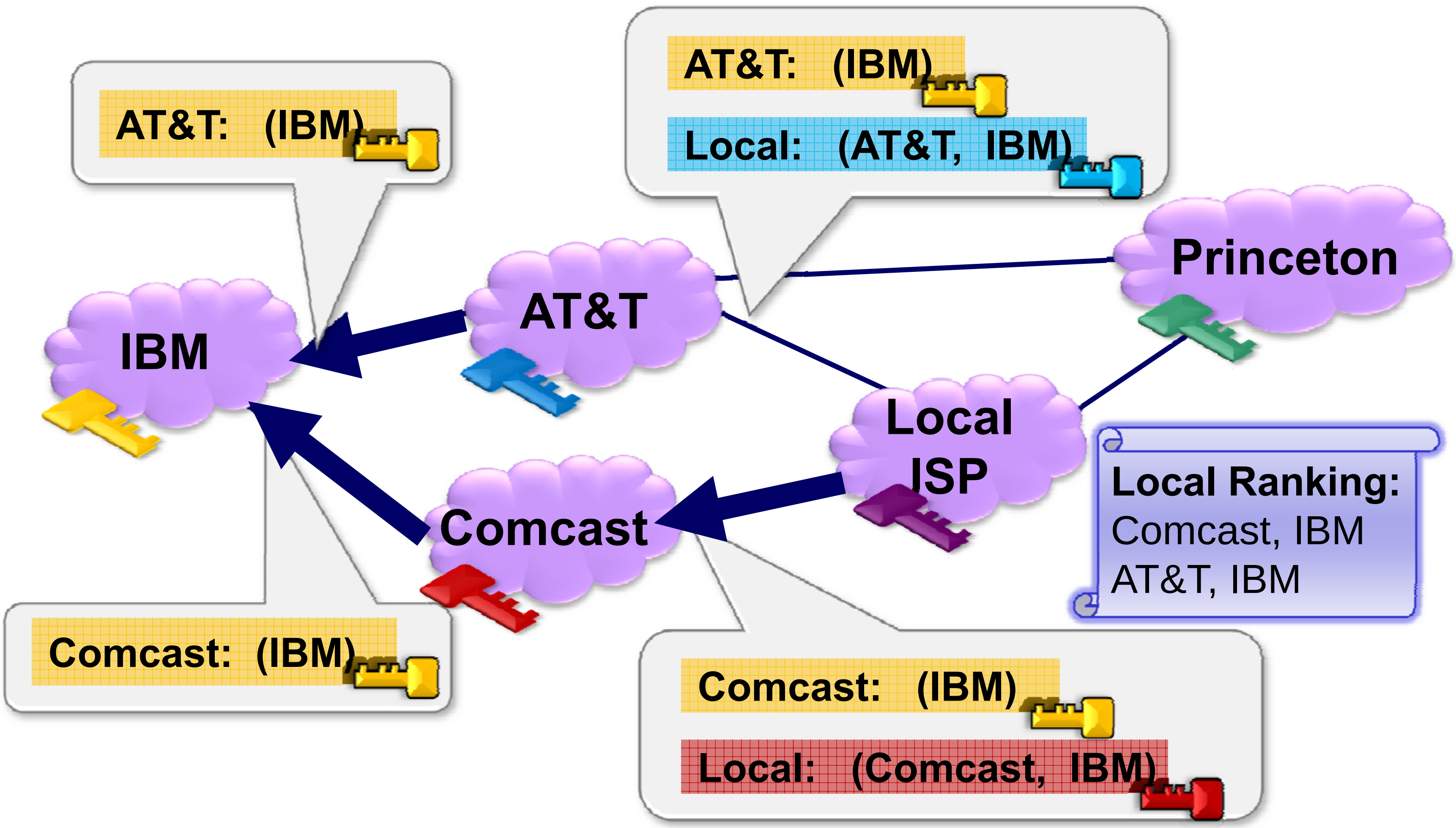
Secure BGP (1)

Secure BGP: If **a** announced path **abP** then **b** announced **P** to **a**
Enforced using cryptographic public-key signatures.



Secure BGP (2)

Secure BGP: If **a** announced path **abP** then **b** announced **P** to **a**
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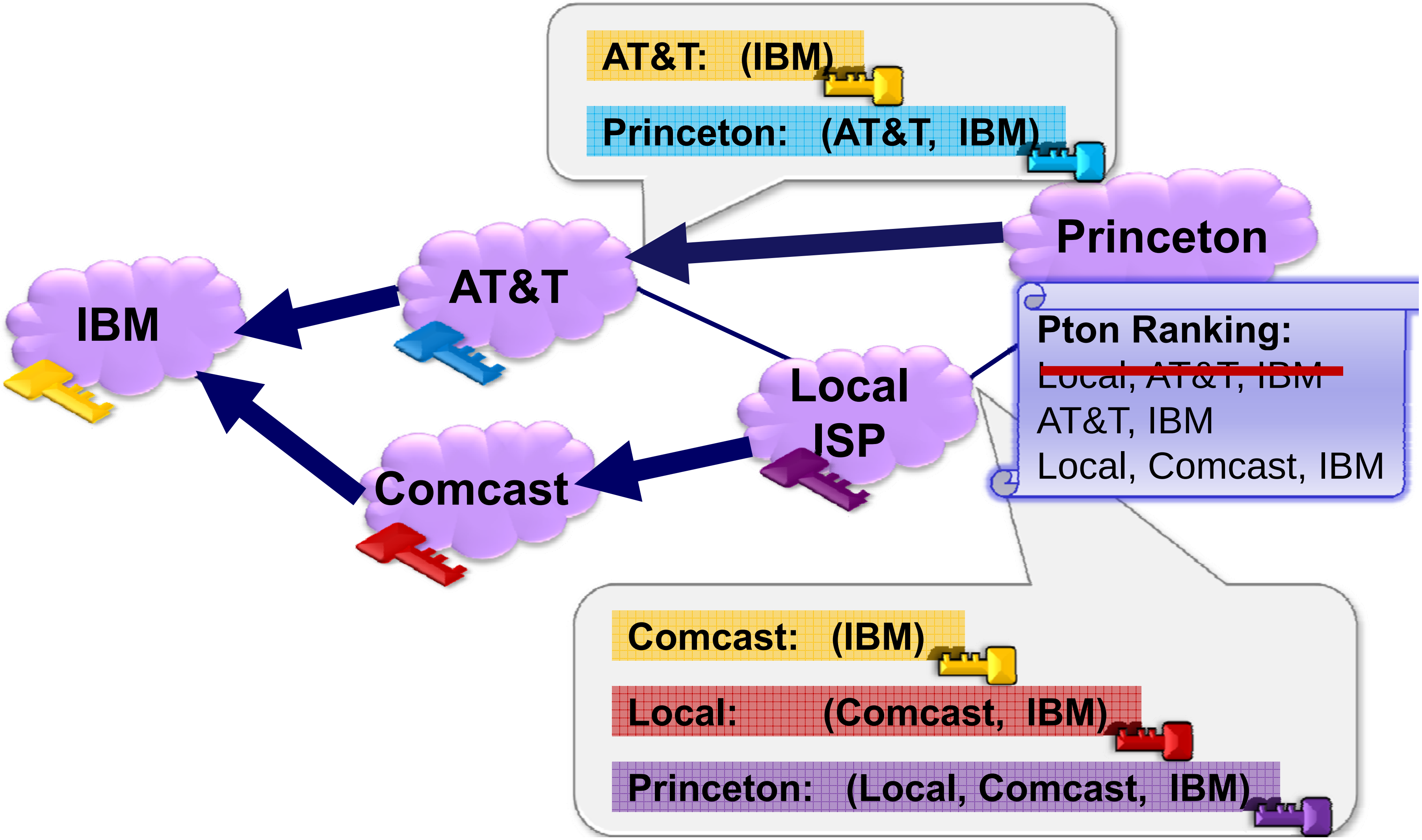

Secure BGP : Matching The Control & Data Plane ?!?

Secure BGP: If **a** announced path **abP** then **b** announced **P** to **a**
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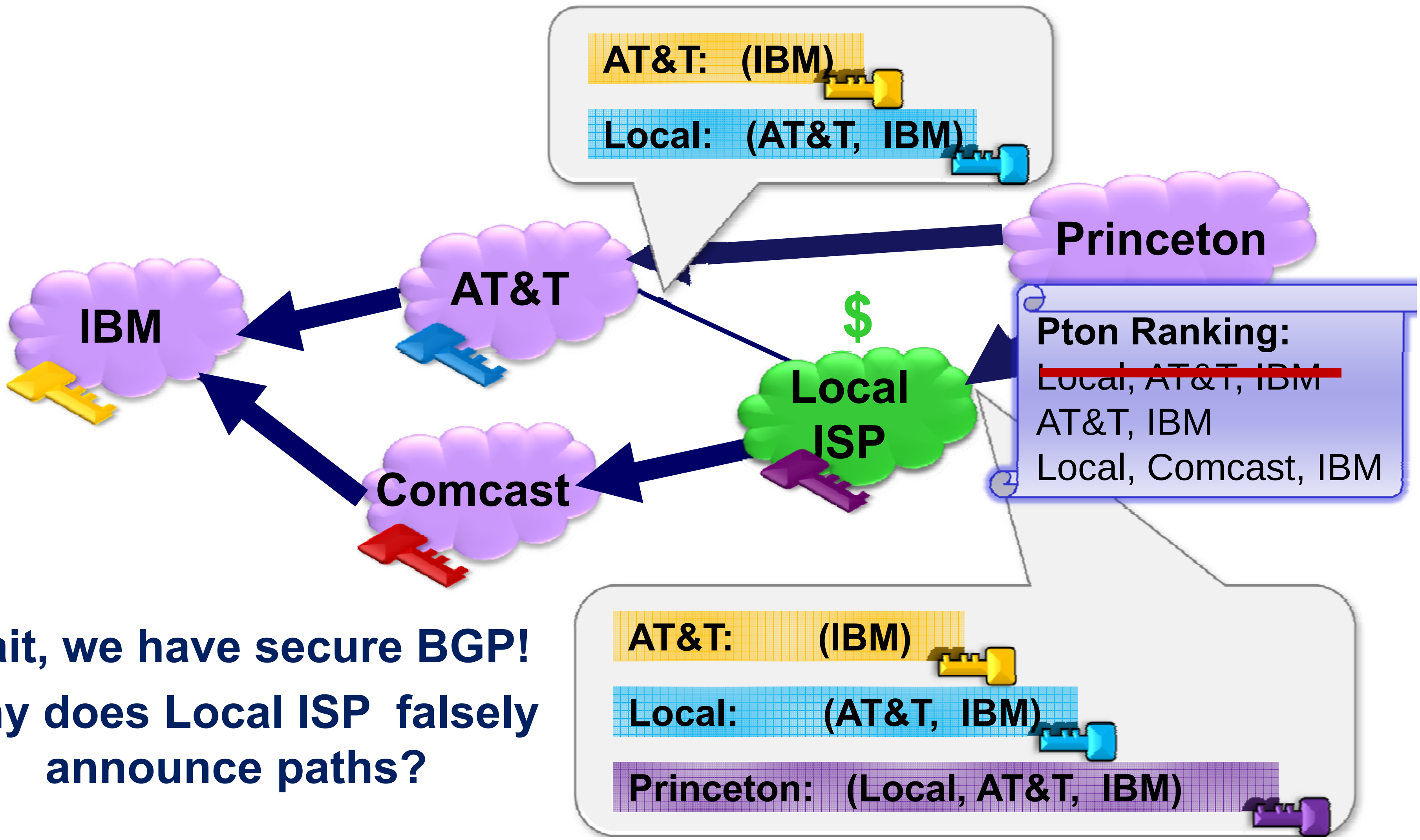

Wait, we have secure BGP!
Why does Local ISP falsely announce paths?

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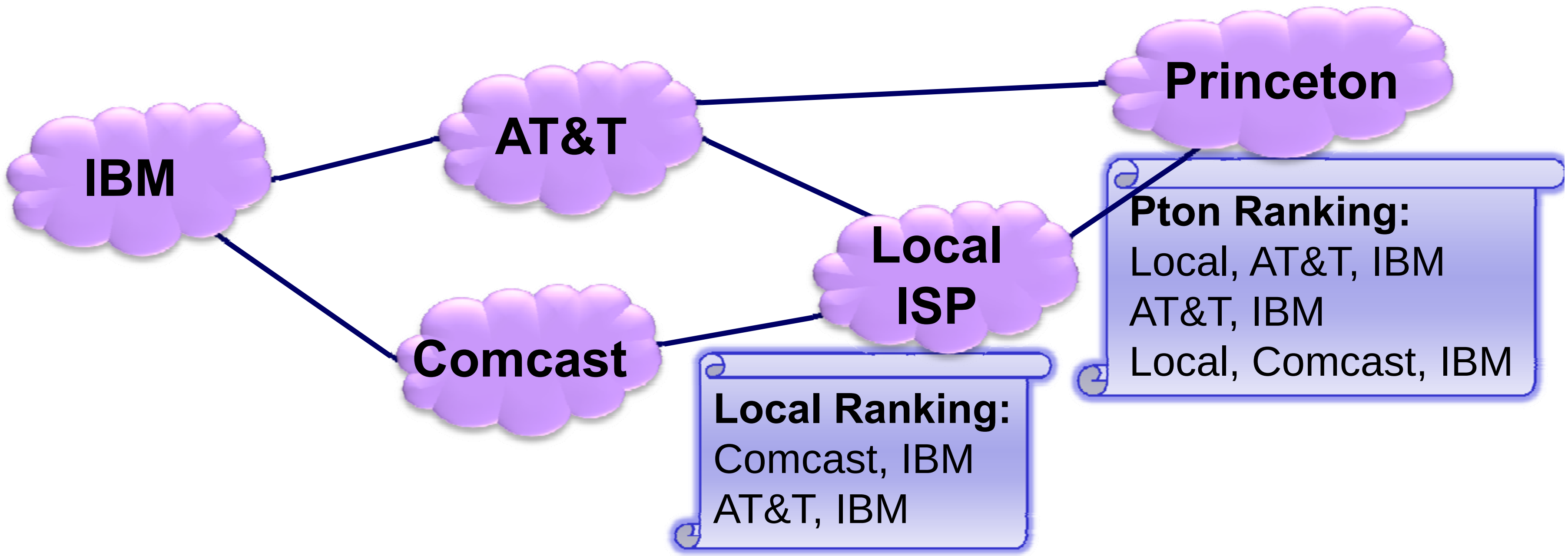
Modeling Utility

Model of utility in prior work:

Utility of **n** **=** Utility of outgoing (data-plane) path

In all prior work: Utility is determined by the ranking function



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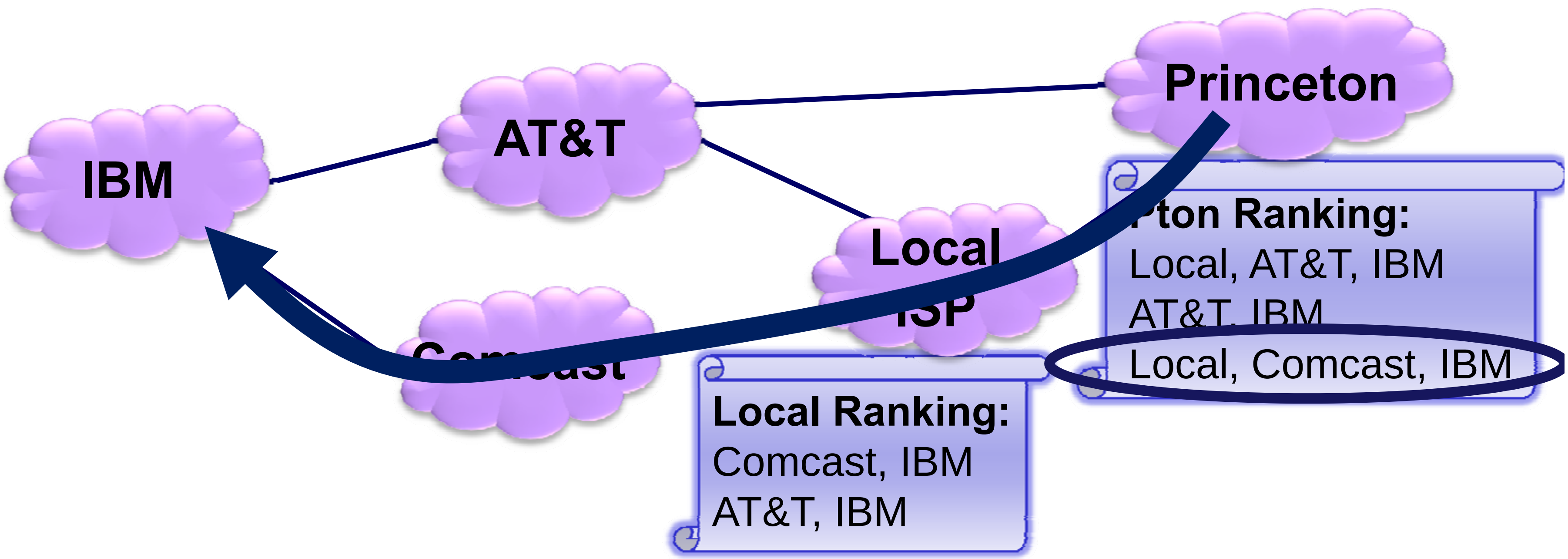


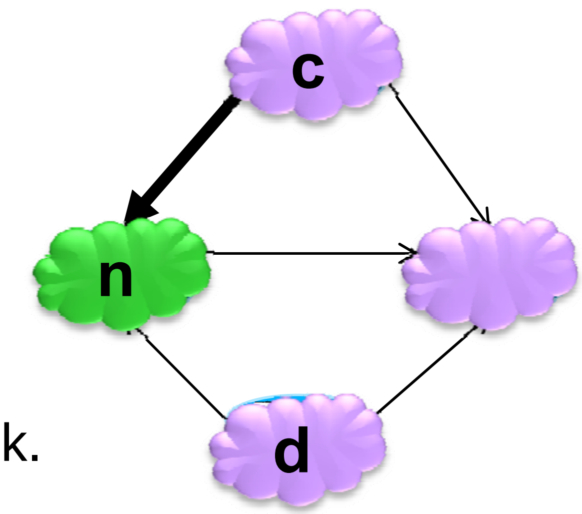
Modeling Utility with Traffic Attraction

Our model of utility:

Utility of **n** **=** Utility of outgoing (data-plane) path **+** Utility of attracted incoming traffic

Traffic-volume attractions:

- **n** only cares which AS originates traffic
- Models AS who wants to snoop / tamper
- … or increase incoming traffic volumes



Customer attractions:

- **n** wants to attract traffic from customers via direct link.
- Models bilateral economic relationships.

Generic attractions:

- **n** wants to attract traffic from specific ASes via a specific path
- Our most general model

Formal model

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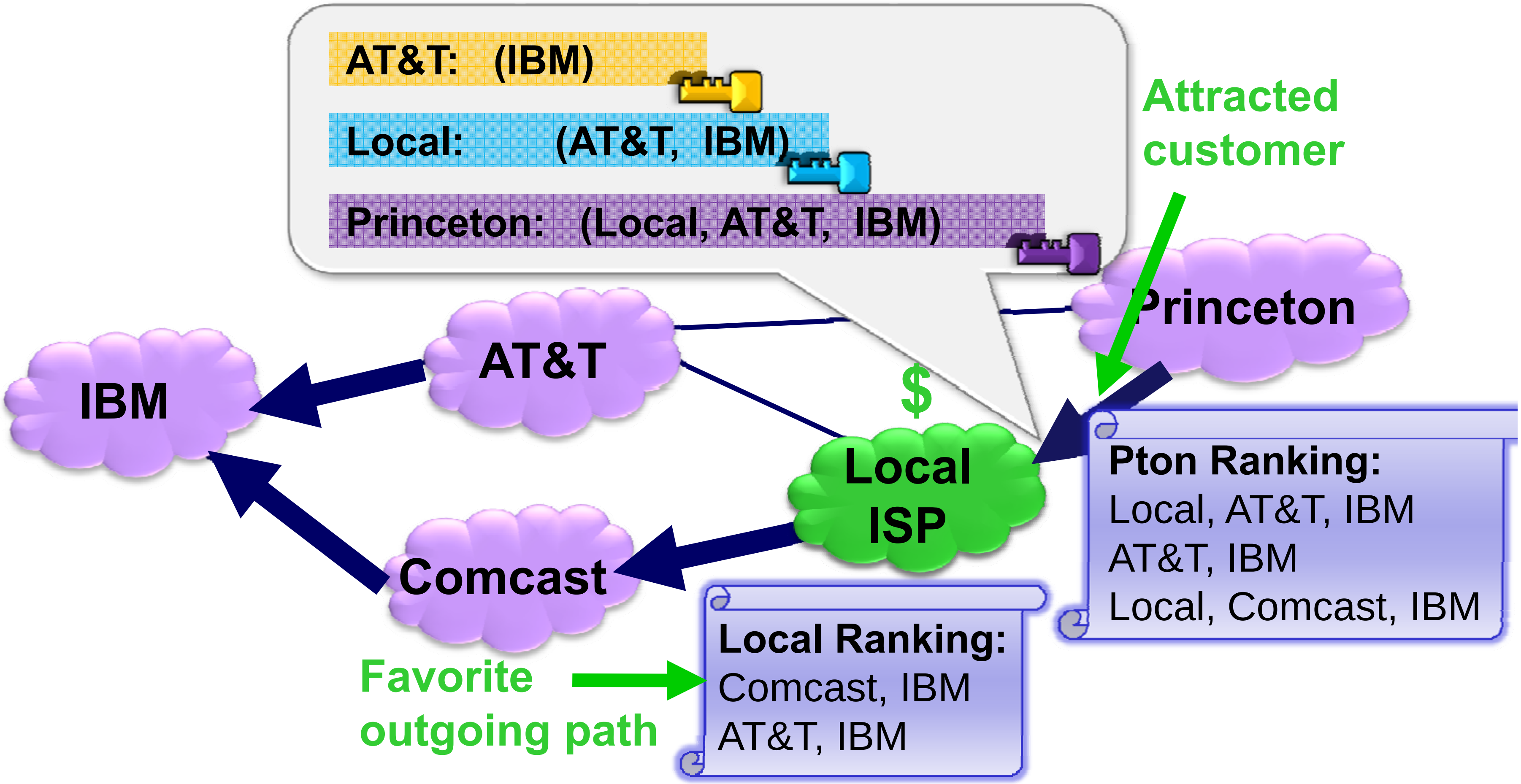
Result: Secure BGP is not Sufficient!

With **traffic-volume** OR **customer** attractions, there can be an incentive to announce false paths, **even with Secure BGP**.



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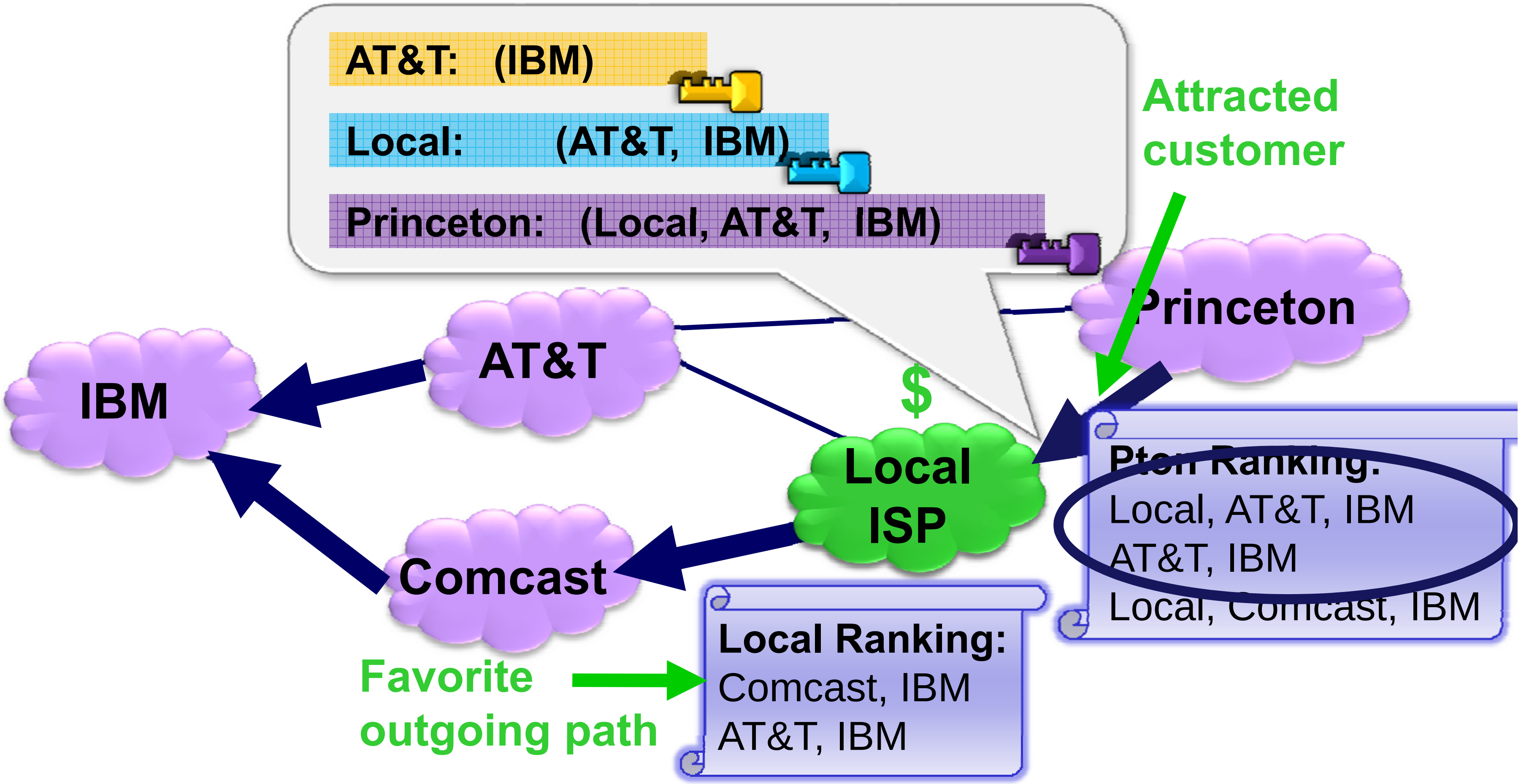
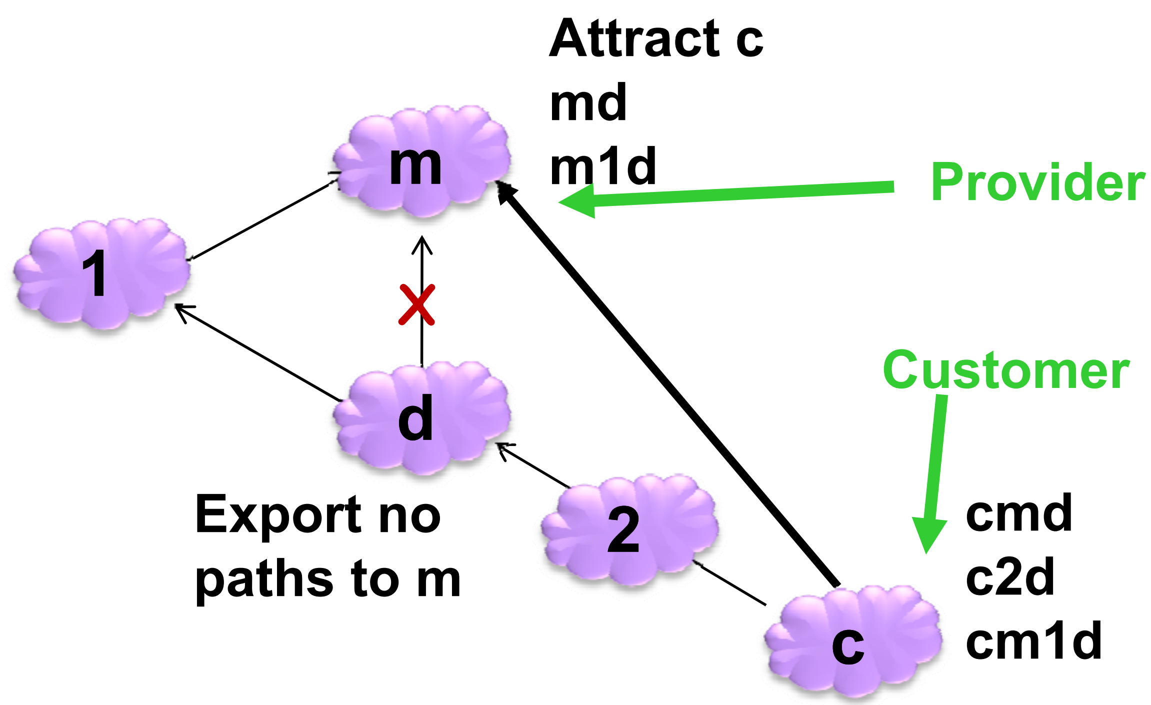


Observation: Princeton does not use a shortest-path policy.

Result: Shortest-Path Routing is not Sufficient! (1)

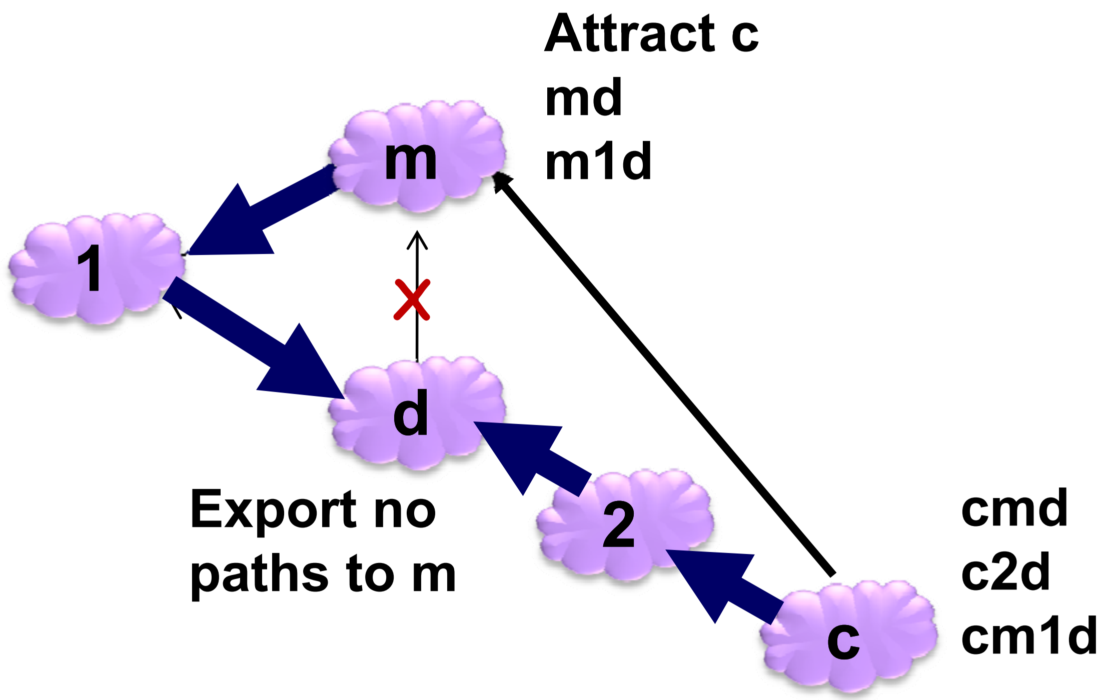
With **traffic-volume** OR **customer** attractions, there can be an incentive to announce false paths, **even with shortest-path policy.**



Result: Shortest-Path Routing is not Sufficient! (2)

With **traffic-volume** OR **customer** attractions, there can be an incentive to announce false paths, **even with shortest-path policy.**

All nodes compile
$r_n( ) = v_n( )$



Result: Shortest-Path Routing is not Sufficient! (3)

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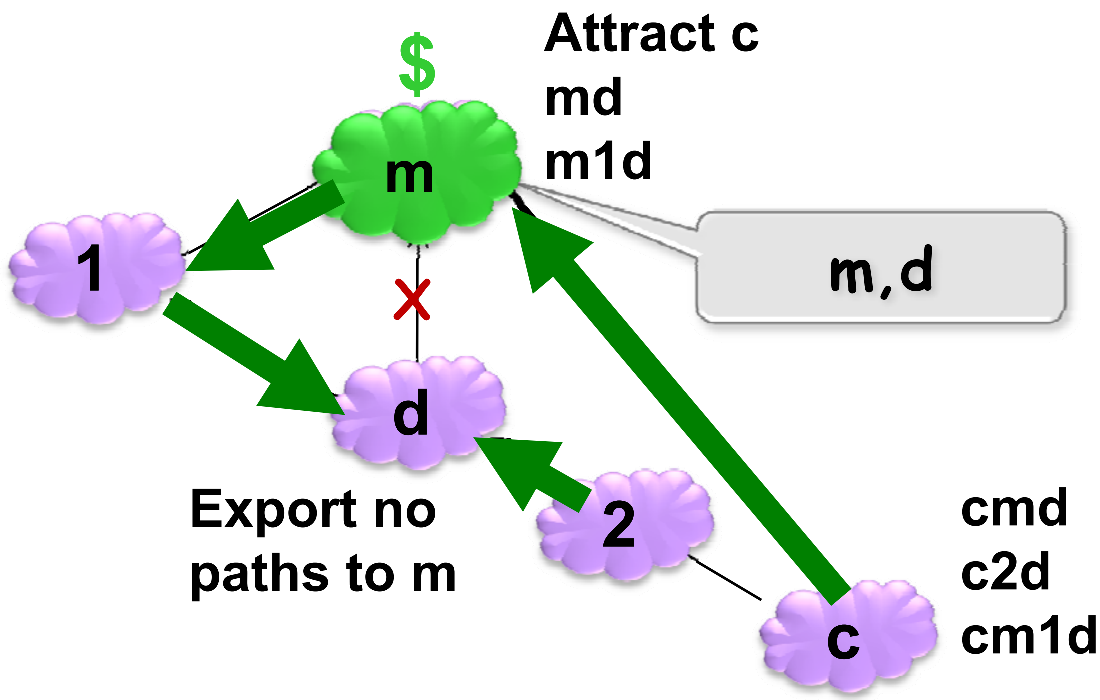

Positive Result for Traffic Volume Attractions

When all attractions are **traffic volume**, there is no **incentive** to **unilaterally** announce false paths if there is no dispute wheel and there is either:

1. **Secure BGP**, and
2. **Shortest-path policies**, and
3. **Consistent export**.

OR

1. **Next-hop policies**, and
2. **All-or-nothing export**.

Utility based only on AS originating incoming traffic, not path traffic takes

Export policy is consistent with preferences.

For each neighbor **n**, either export **all** paths or **no** paths to **n.**

An exact statement of this result is in the paper

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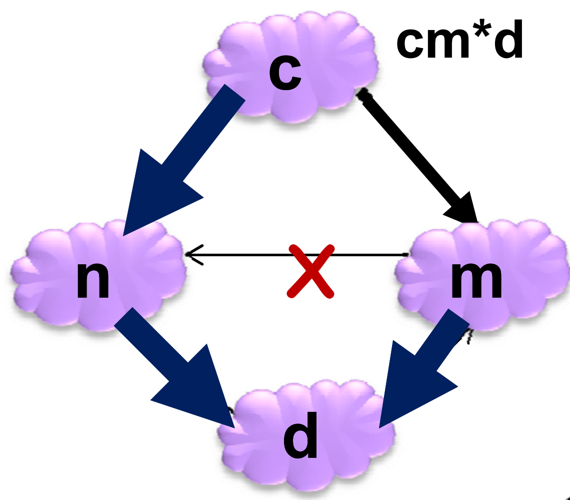
Customer Traffic Attraction (1)

With **customer** attractions, there can be an incentive to announce false paths, **even if all nodes use next-hop policy.**

This was sufficient for traffic volume!

All nodes compile
$r_n(\ ) = v_n(\ )$



For each neighbor **n**, either export **all** paths or **no** paths to **n.**

Observation: All nodes use next-hop policy & all-or-nothing export.

Customer Traffic Attraction (1a)

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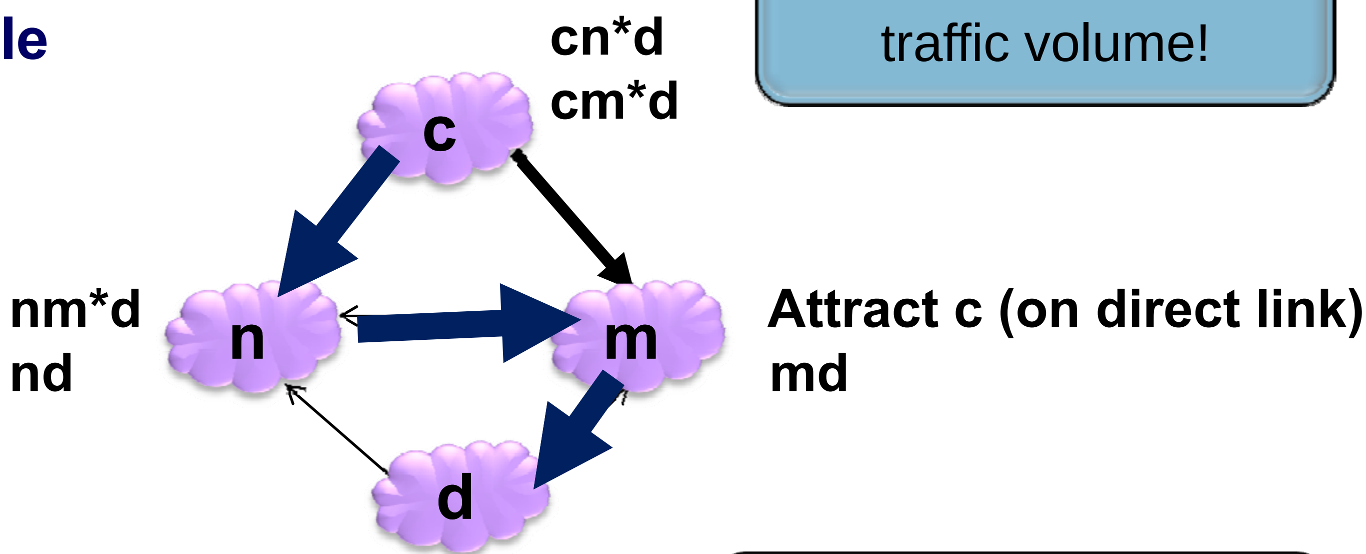
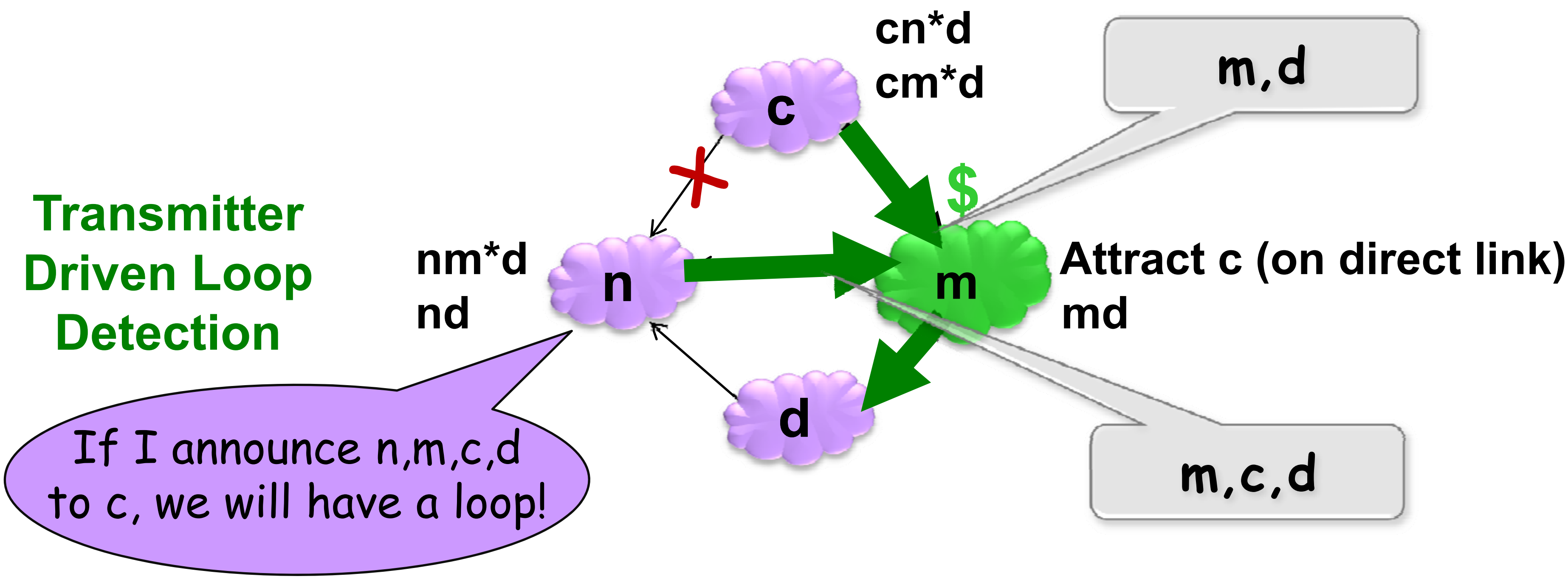


For each neighbor **n**, either export **all** paths or **no** paths to **n.**

Observation: All nodes use next-hop policy & all-or-nothing export.

Customer Traffic Attractions (2)

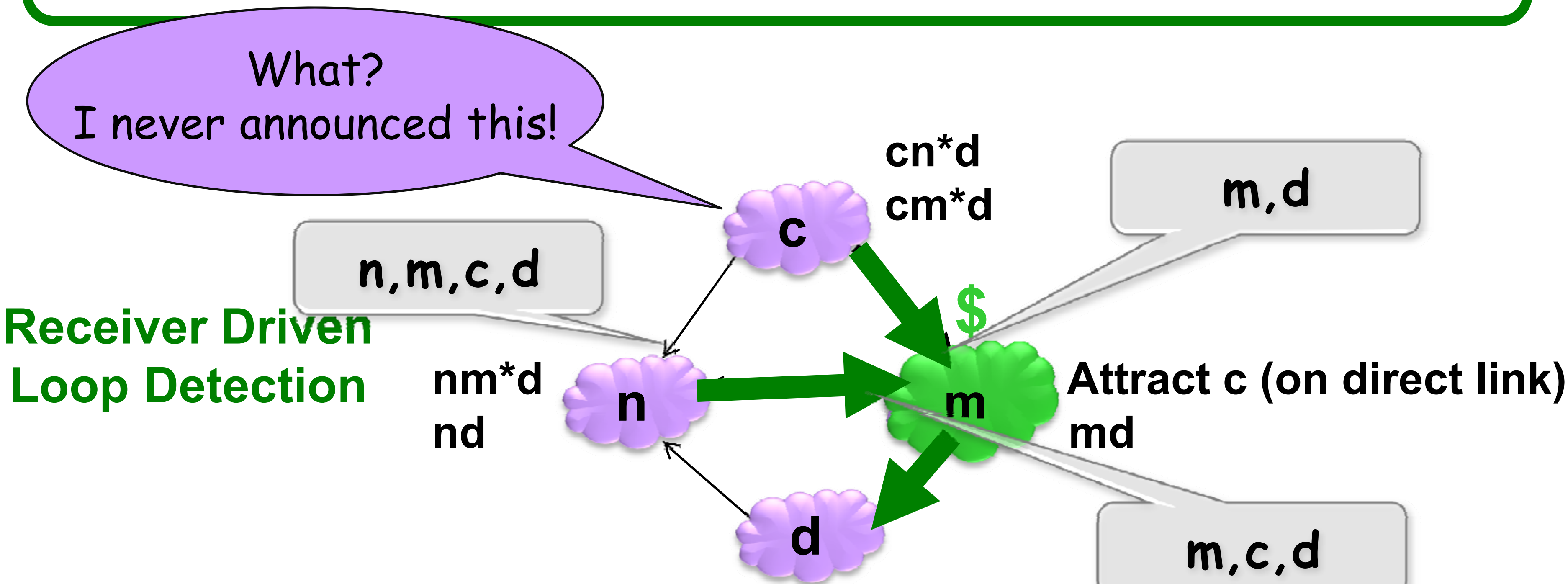
With **customer** attractions, there can be an incentive to announce false paths, **even if all nodes use next-hop policy.**



Observation: All nodes use next-hop policy & all-or-nothing export.

Customer Attractions: Introducing Loop Verification

With **customer** attractions, there can be an incentive to announce false paths, **even if all nodes use next-hop policy.**



Loop Verification:

- If c receives announcement QcR but c did not announce R then the guilty node on Q is punished with zero utility.
- Models “fear of getting caught”. Also, implied by Secure BGP.

Positive Result for Generic Attractions

With **generic traffic attraction**, there exists an honest strategy that obtains the best possible stable outcome for each node (*i.e.* that node has no incentive to **unilaterally** announce false paths), if there is no dispute wheel and there is:

1. **Loop Verification** or **Secure BGP**, and
2. **Next-hop policies,** and
3. **All-or-nothing export.**

But this export rule not compatible with real business relationships.

Sadly, this result is "tight":

Weakening any condition results in a counterexample

The exact statement of this result is in the paper

Conclusions

Should ASes base decisions on BGP path announcements?
How hard is it to make the control- and data-plane match?

Our results suggest that this is hard, since even if we assume

- Nodes are rational but want to attract traffic

we still need unreasonable restrictions on policy and export

- *e.g.* shortest-path policies, or next-hop policies
- and sometimes all-or-nothing export

and usually also control plane integrity checks

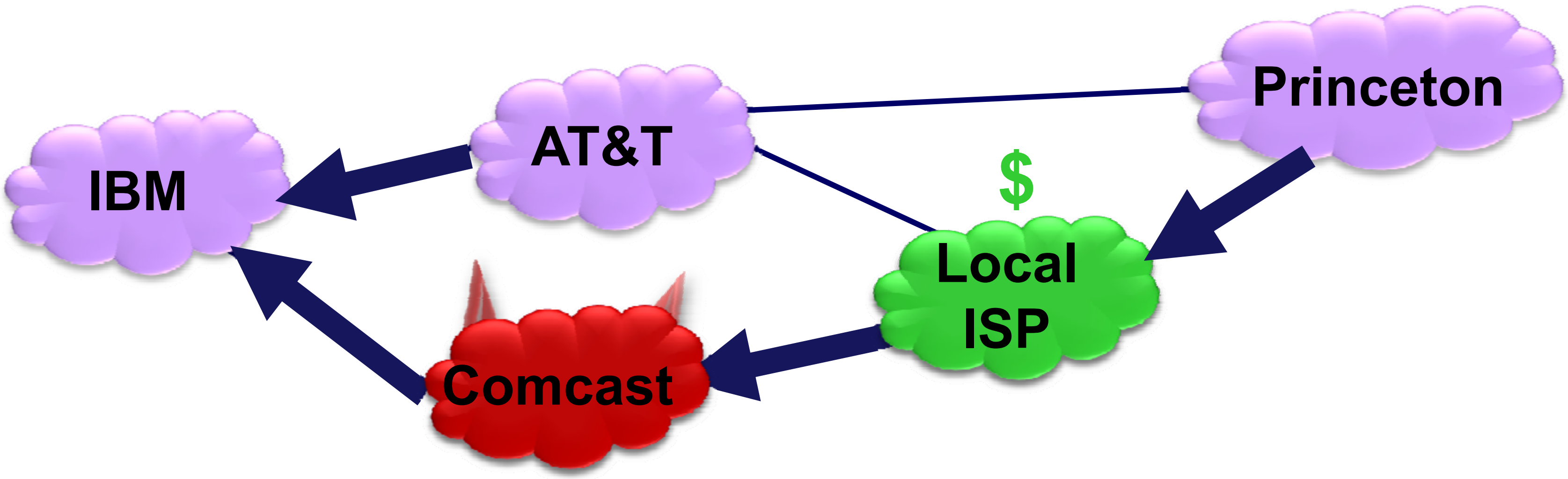
- *e.g.* Secure BGP (or, weaker, loop verification)

And, notice how dependent results are on the utility model!

So, should we use expensive data-plane protocols?

Or just forget about matching the control and data plane, and consider some weaker security goals instead?

Thanks!



This work will appear at SIGCOMM 2008

Full version available:

www.princeton.edu/~goldbe/

Formalizing the Model

Acts on data plane

Acts on control plane

Utility

Satisfaction of node **n** with
a data-plane routing outcome **T**

$$u_n(T) = v_n(T) + \alpha_n(T)$$

$v_n(T)$ is the **valuation function**
Satisfaction of ***n*** is with his
outgoing path in ***T***

$\alpha_n(T)$ is the **attraction function**
Satisfaction of ***n*** with
incoming traffic in T

compile

Ranking

Ranking of **outgoing paths**
Used by **n** in BGP decision process

$$r_n(T)$$

Export

The set of neighbours to which **n** is
willing to announce path **P**

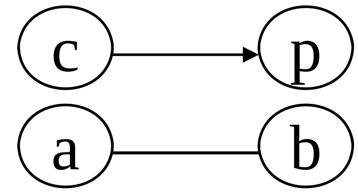
$$e_n(T)$$

Formal model

The Gao-Rexford Conditions

Adjacent nodes have a **customer-provider relationship:**

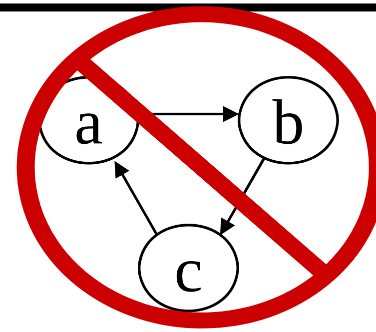
or a **peer-peer relationship:**



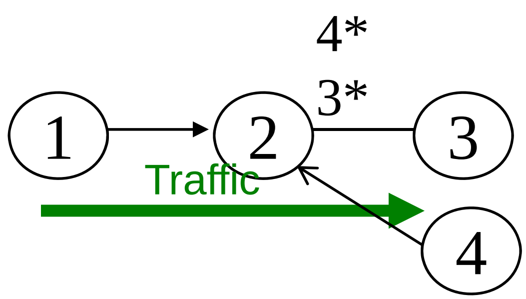
Customer pays provider for service

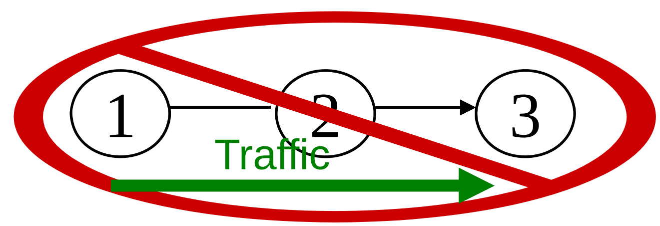
Transit each other's traffic for free.

Topology: No customer-provider cycles in the network.



Transit: Transit traffic only for your customers.



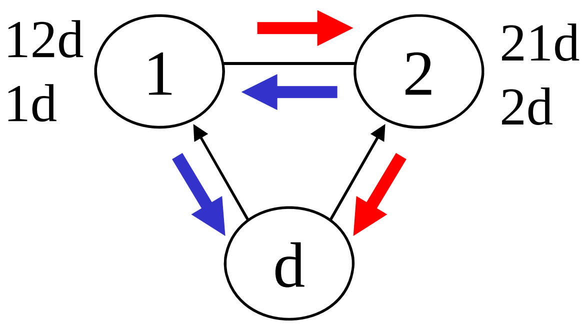


Preferences: Prefer customer routes to peers & providers.

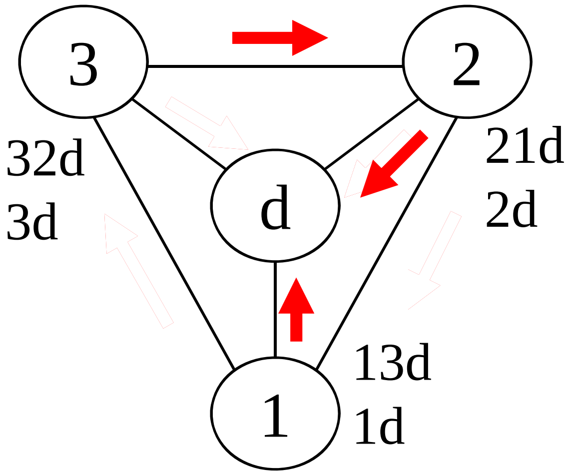
Attractions: Only want to attract traffic from your customers.

Stability: No Dispute Wheel

A dispute wheel is a cycle of nodes with algorithmic rankings that prefer paths through neighbours over direct paths



Disagree: 2 stable outcomes



Bad Gadget: no stable outcomes

Without traffic attraction [GSW01]: The network has a unique stable outcome when there is no **dispute wheel** in the algorithmic rankings.

No Dispute Wheel is a global condition on routing policies.
The Gao-Rexford conditions imply No Dispute Wheel.