Rethinking Network Policy Coordination — A Database Perspective

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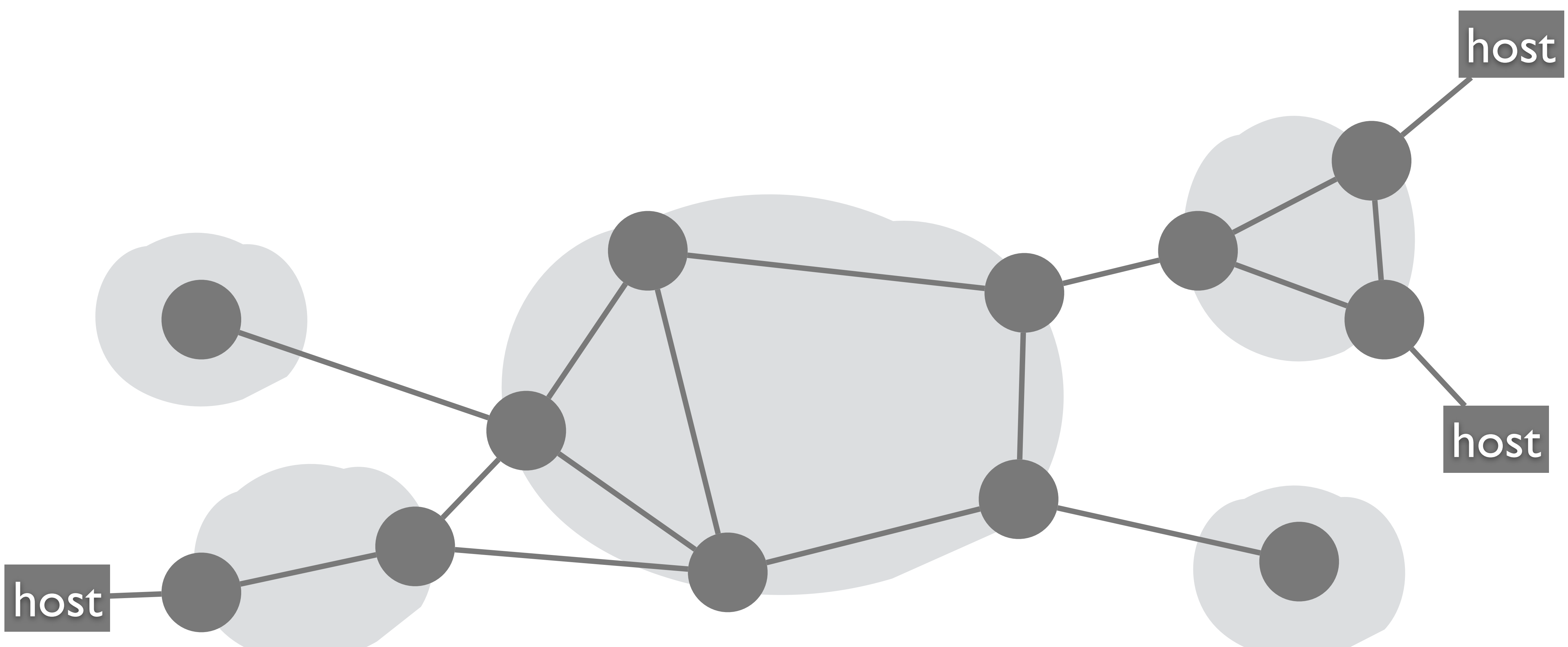
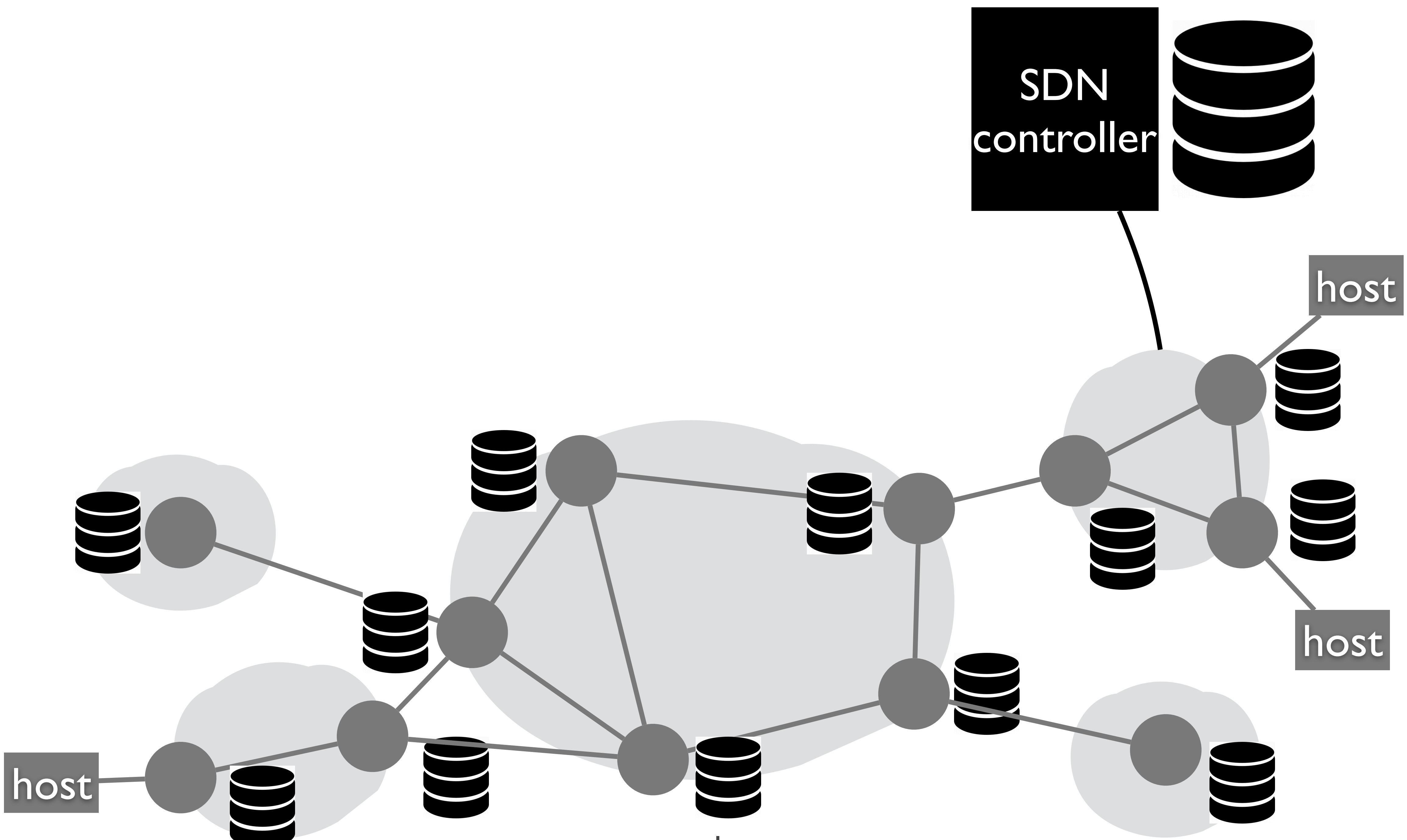
database usage in networking

great for managing network state



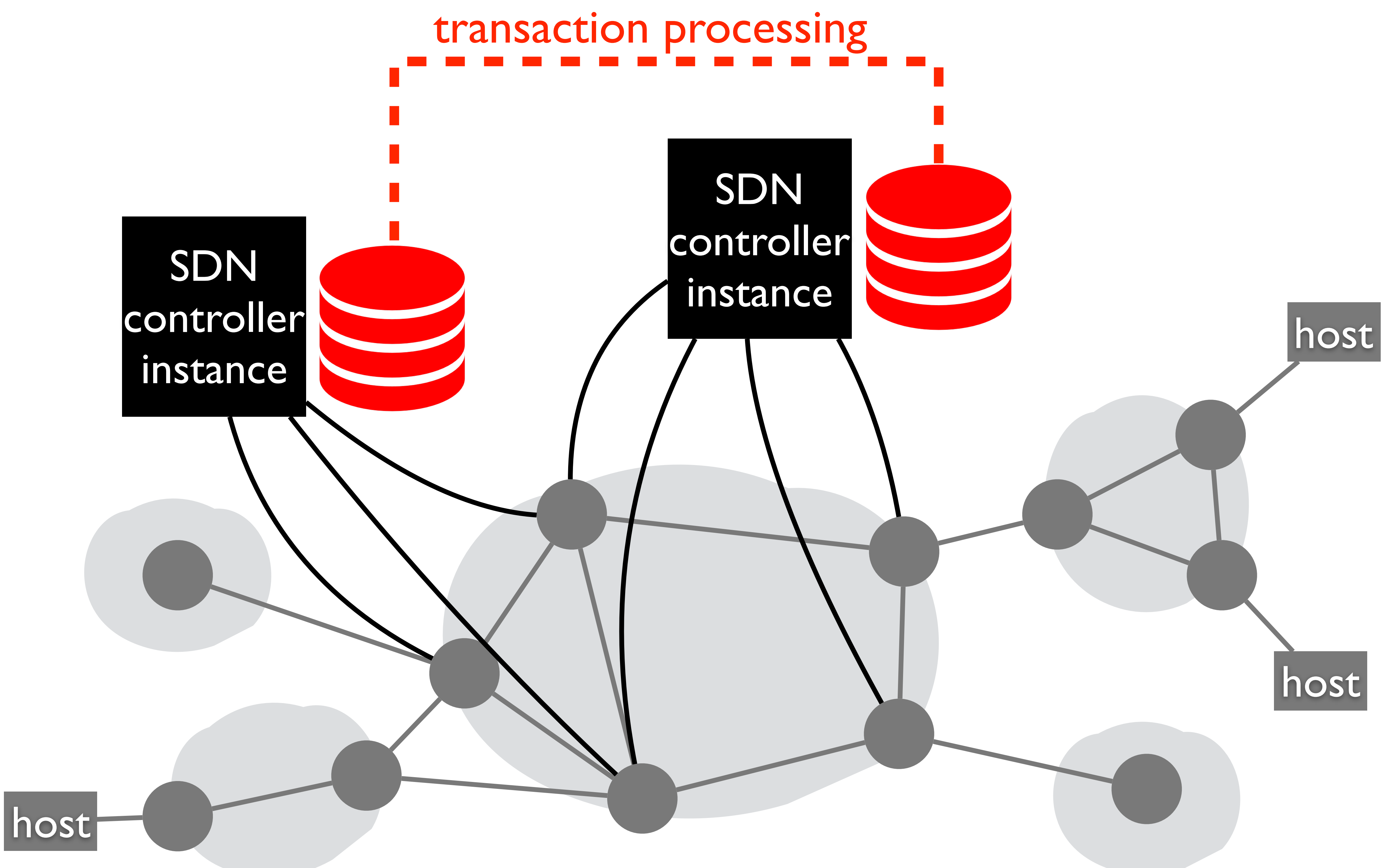
database usage in networking

great for managing network state — *factual* data



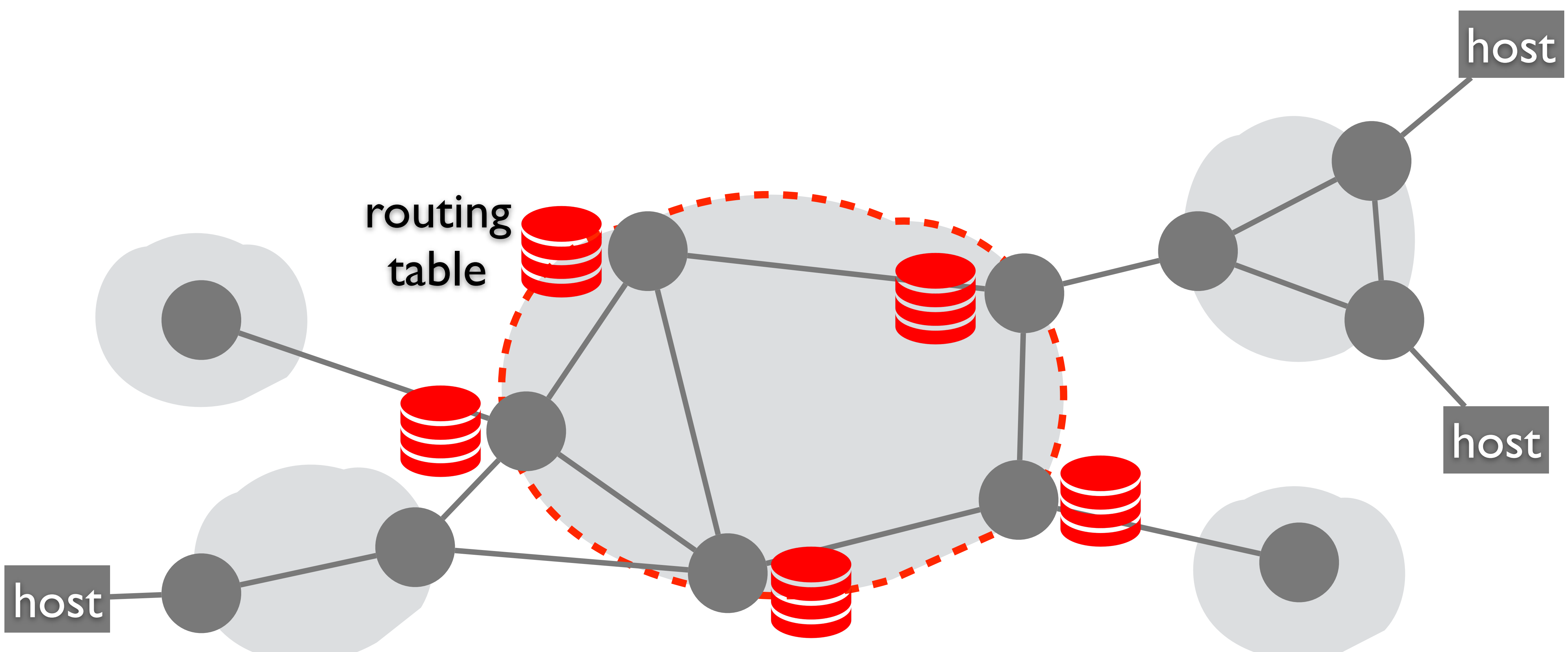
database usage in networking

data synchronization



database usage in networking

data query



database usage in networking

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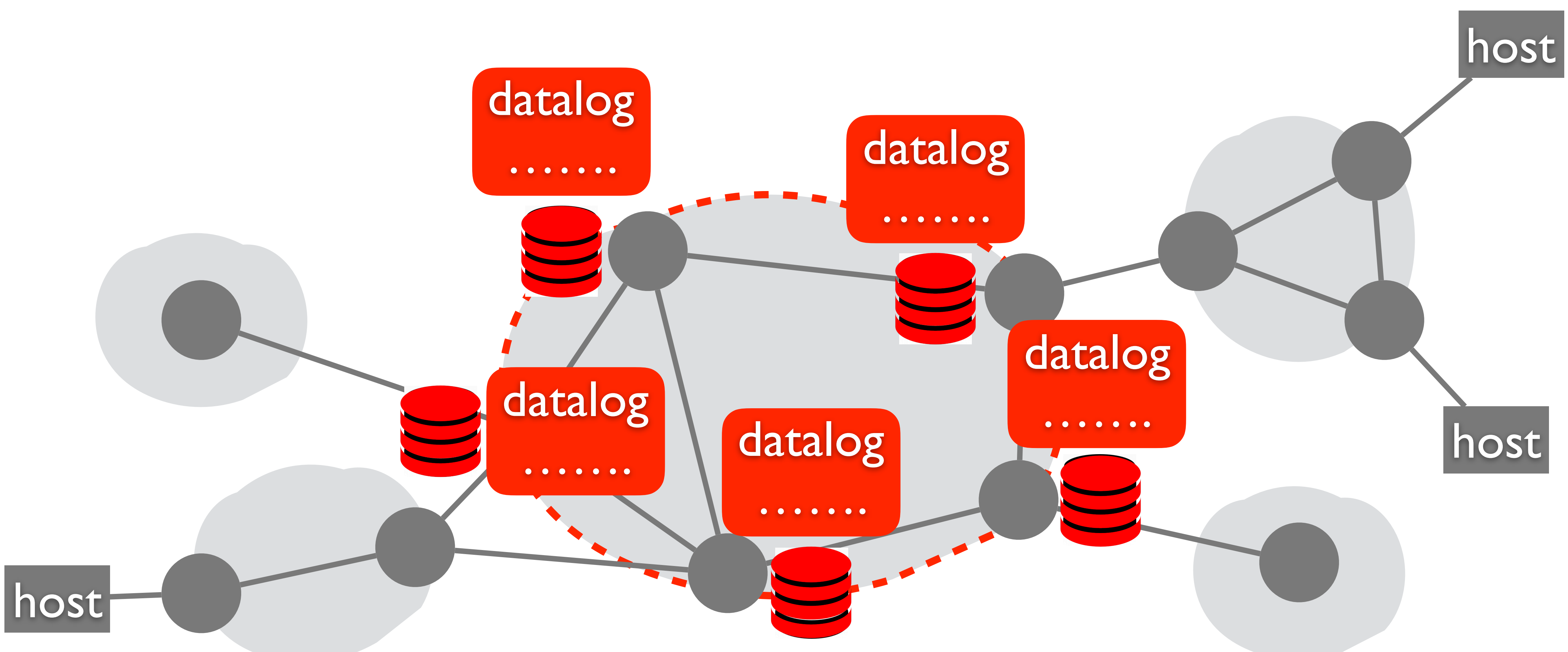
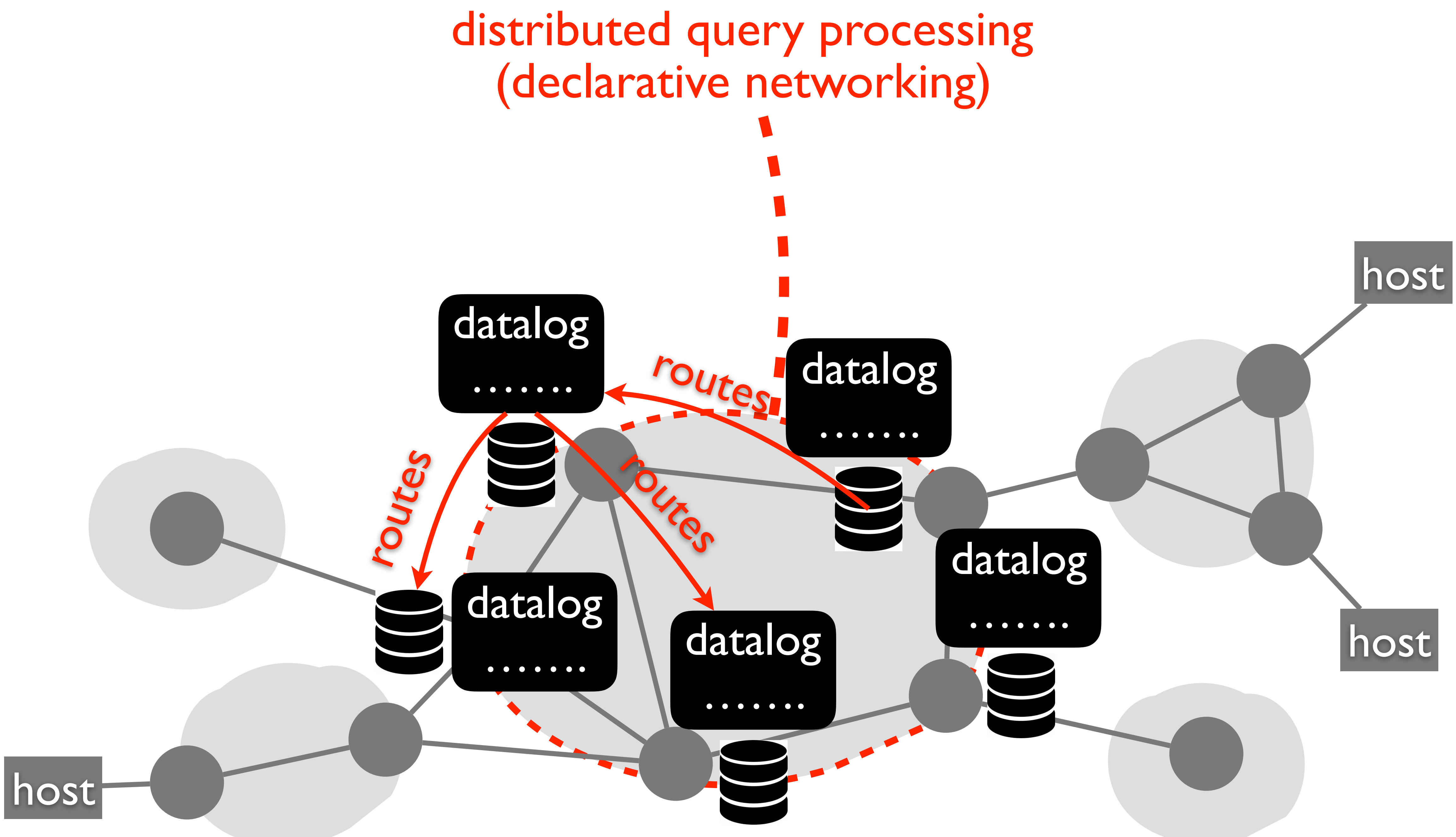


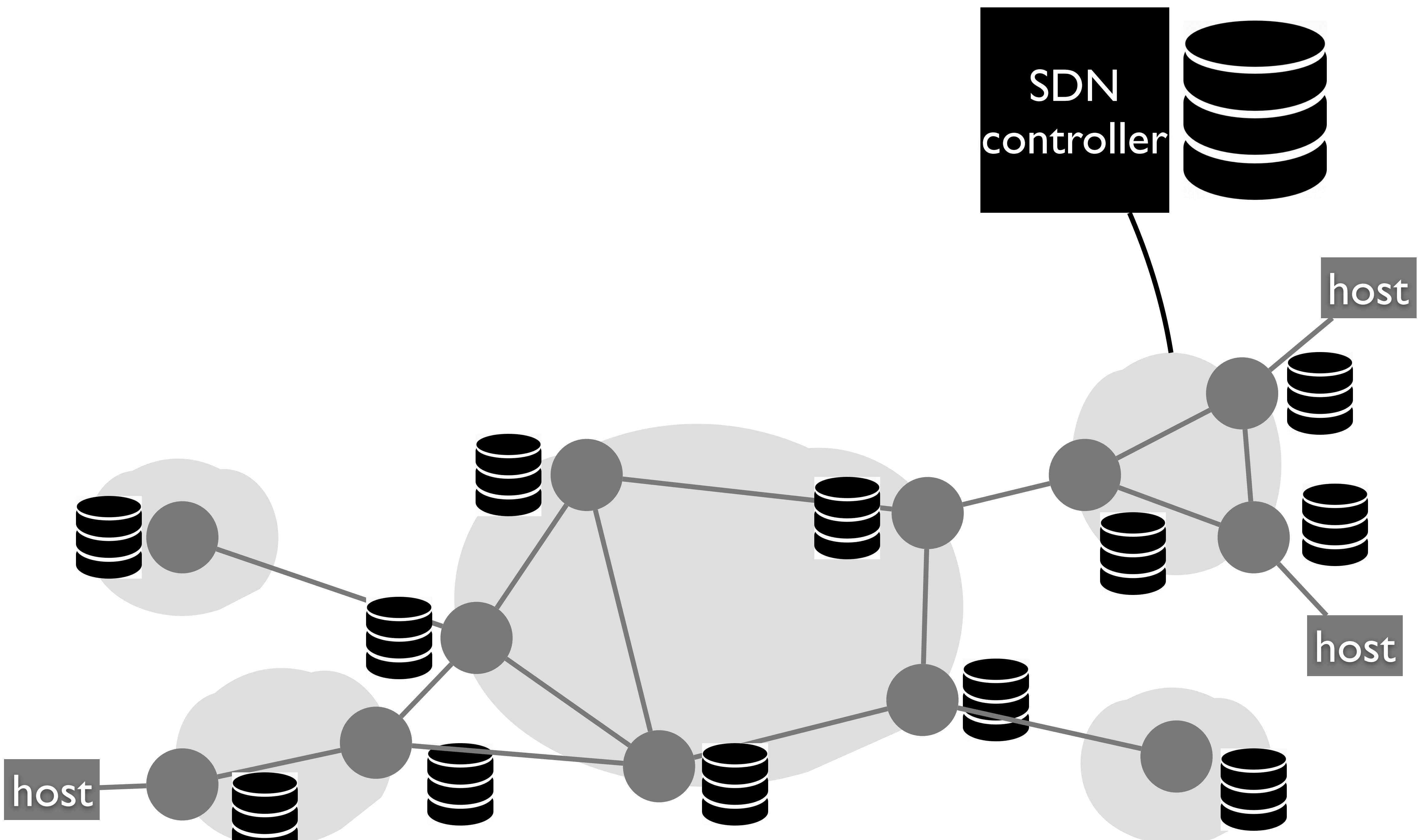
database usage in networking

data query



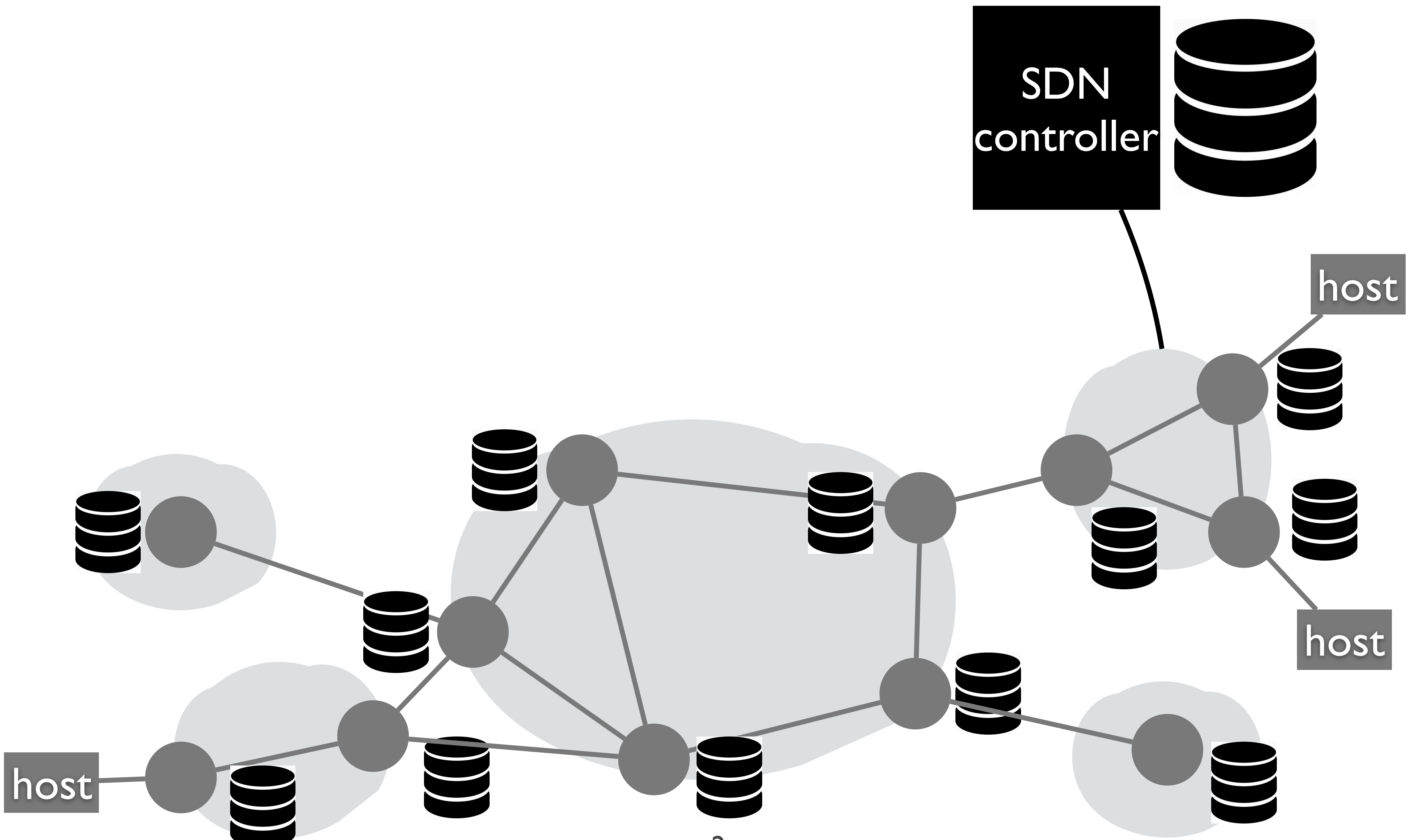
database usage in networking

focus on managing *factual data*



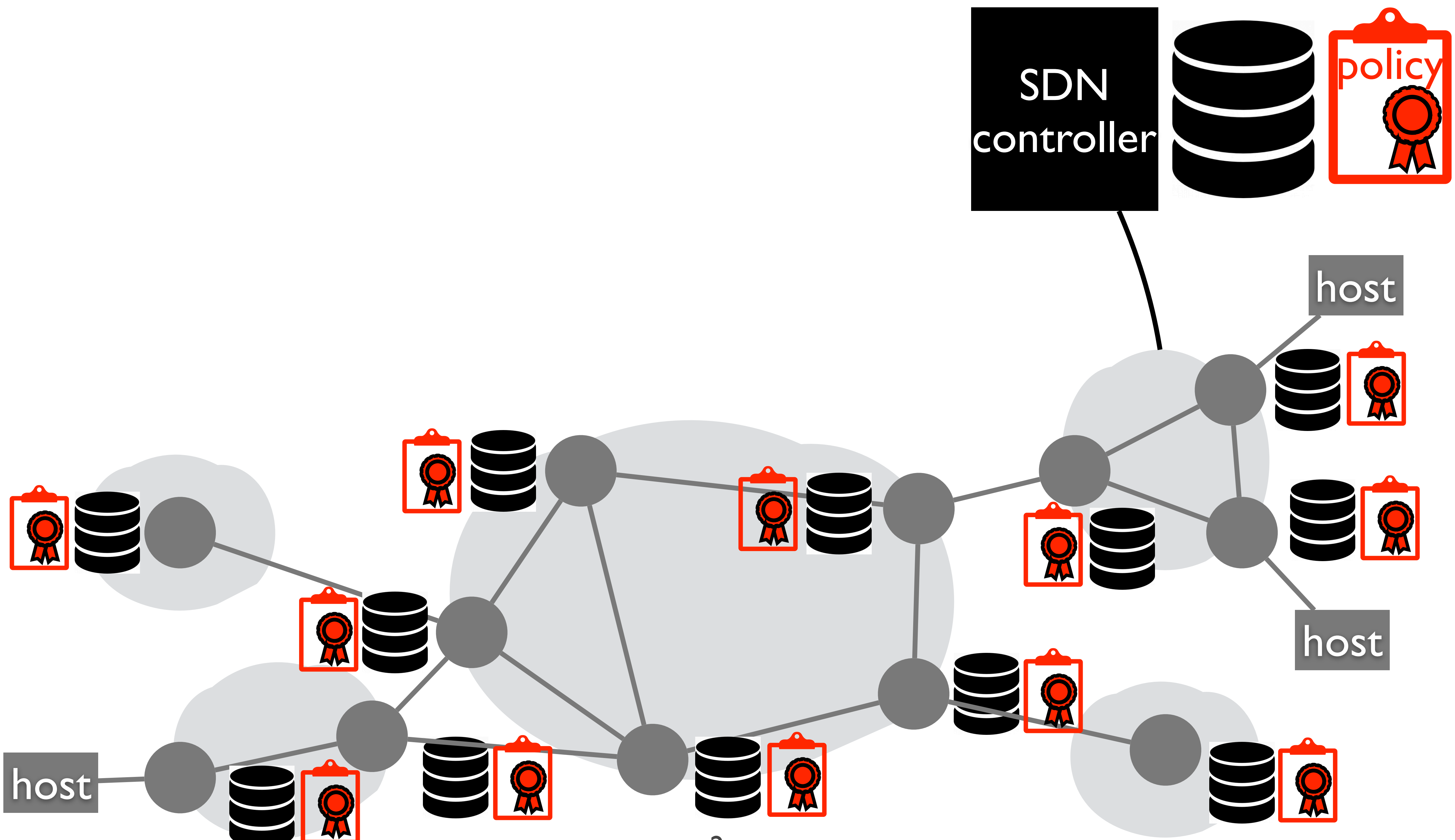
database usage in networking

but database is also renowned for *mediating semantic data*



database usage in networking

but database is also renowned for *mediating semantic data — policies* about what are the acceptable data



this talk

if and how can database systems help with managing network policies that can interact in complex ways

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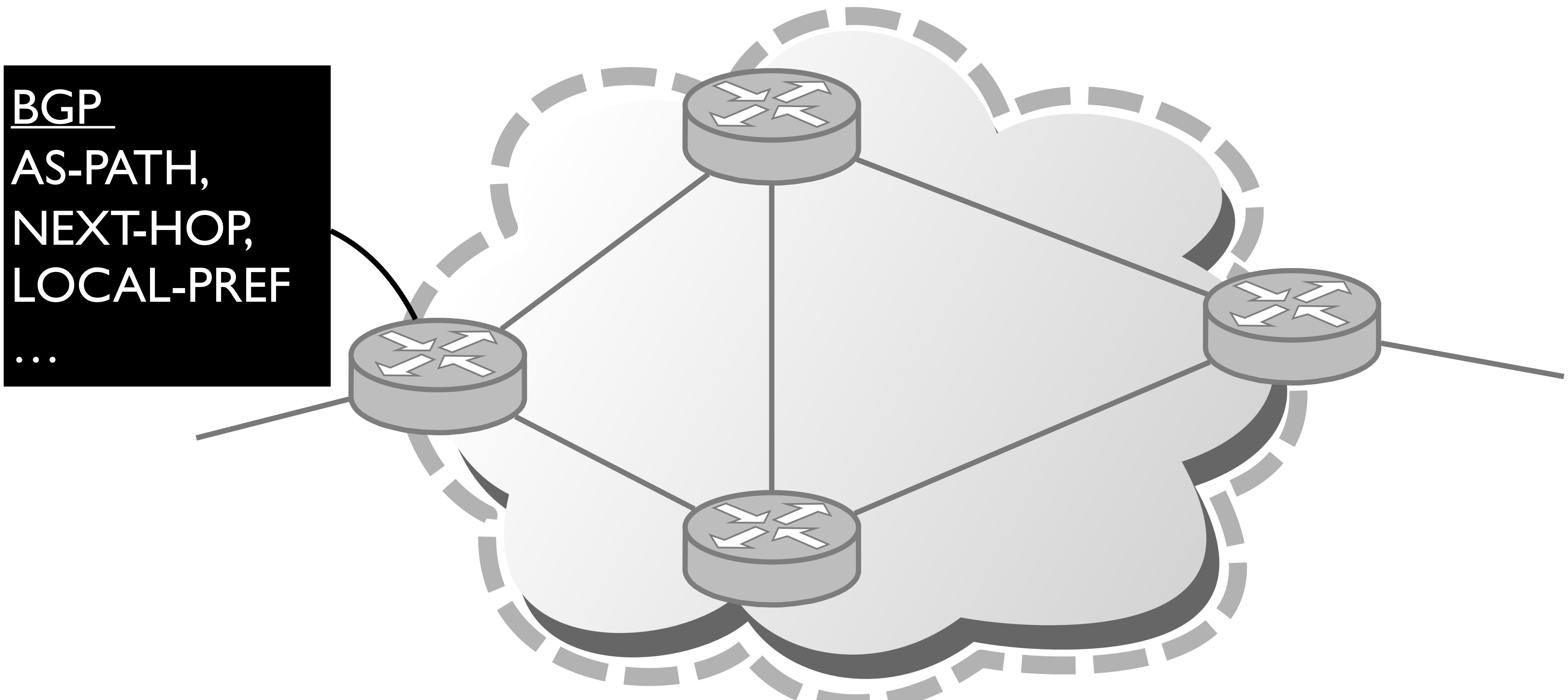
the policy interaction problem

disparate representations buried in the network



the policy interaction problem

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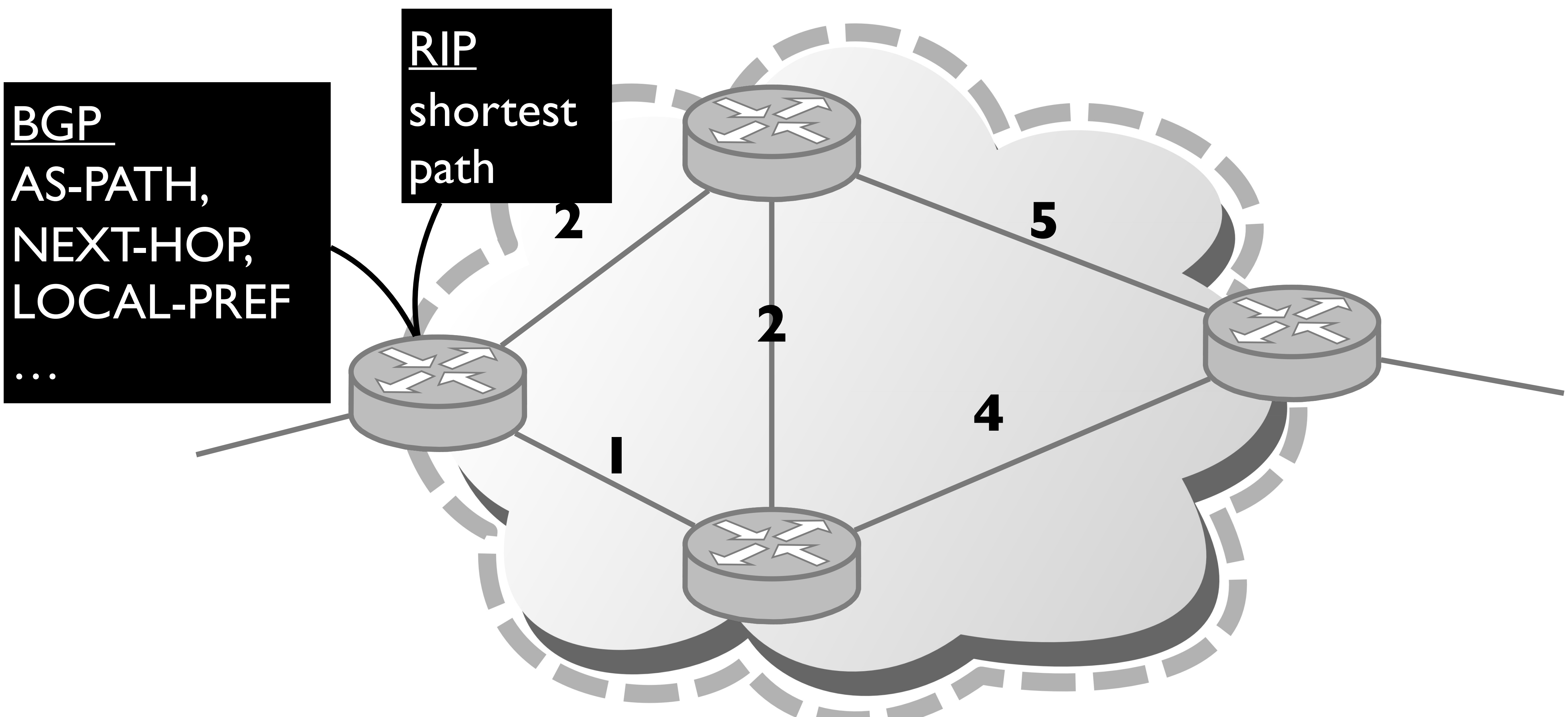
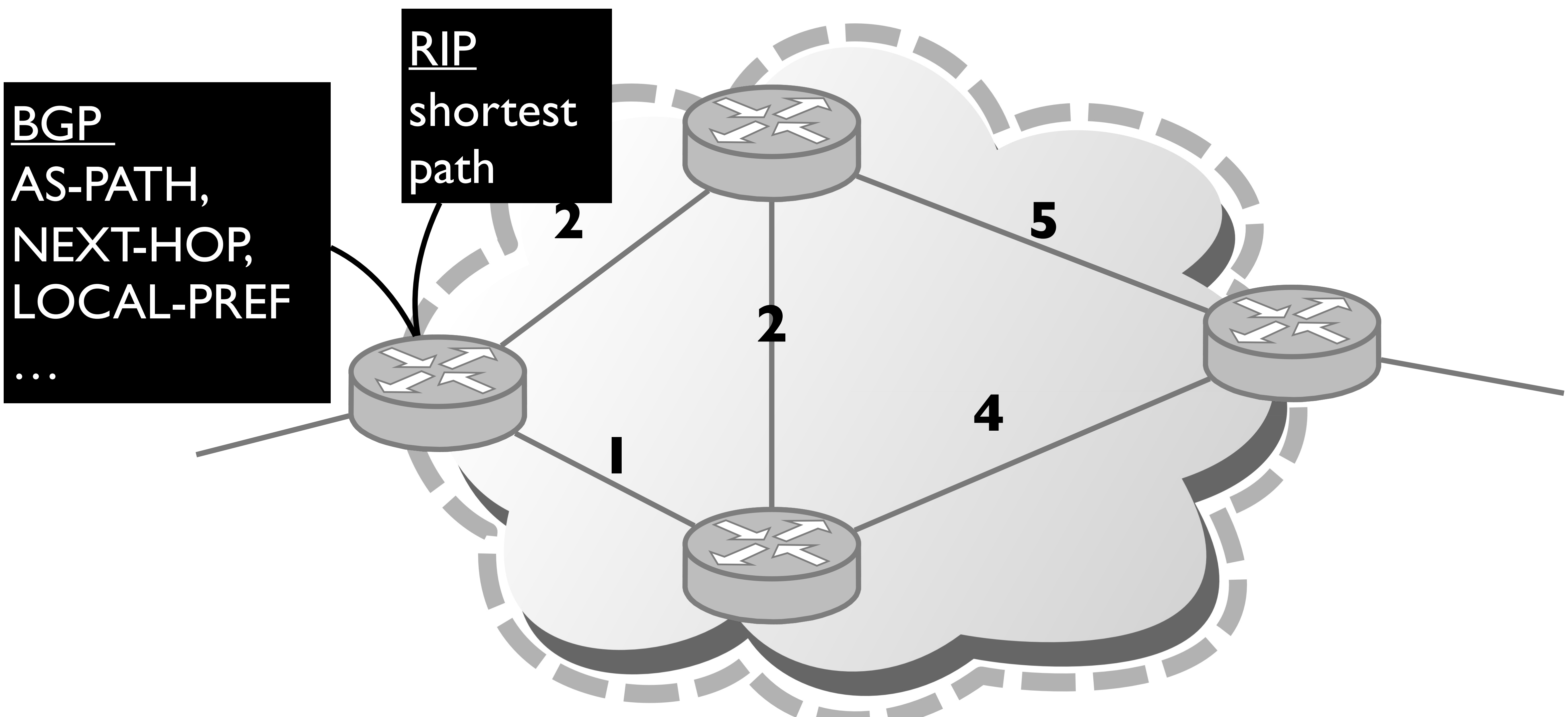


the policy interaction problem

disparate representations buried in the network

- hinders rather than facilitates interaction



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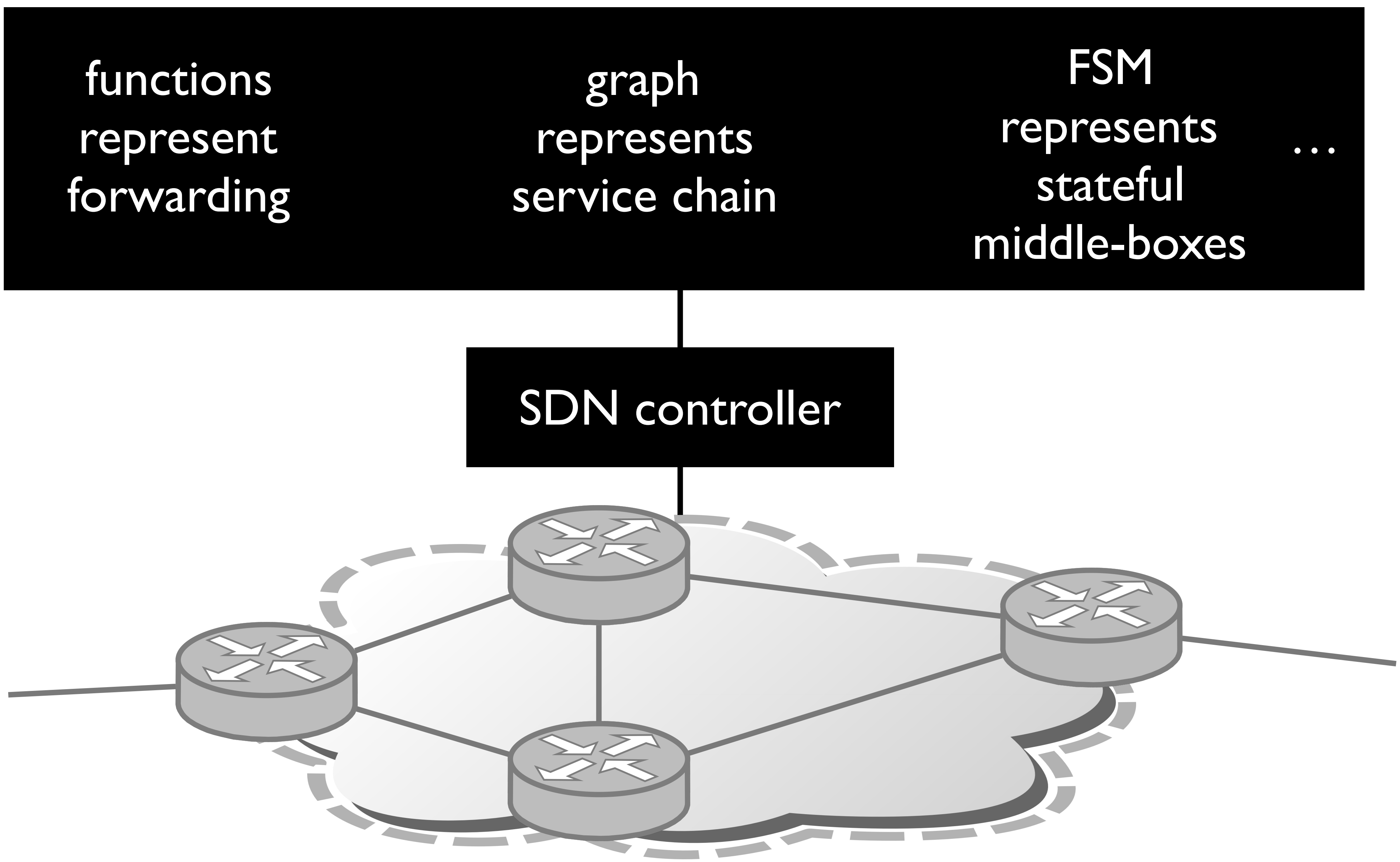

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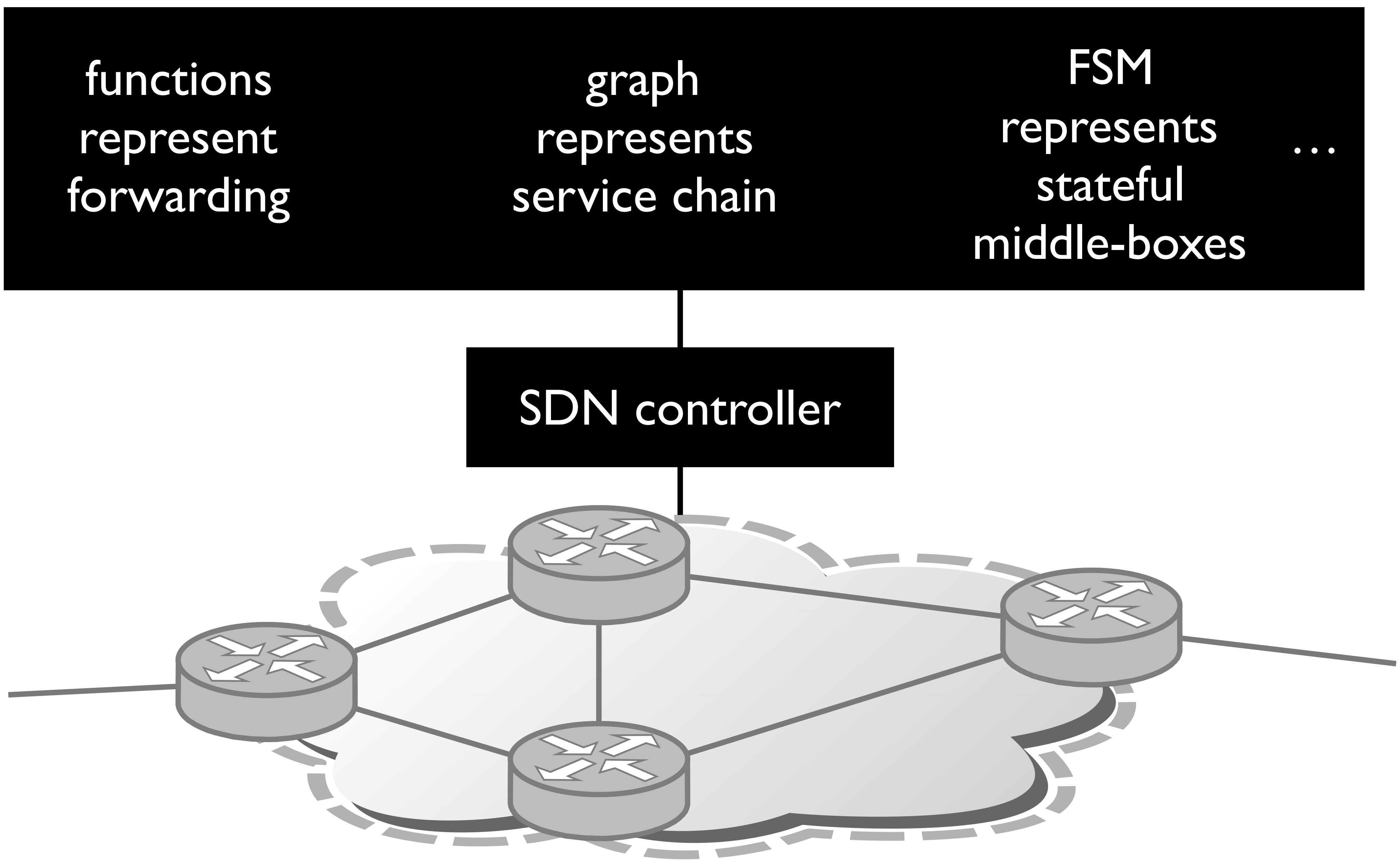
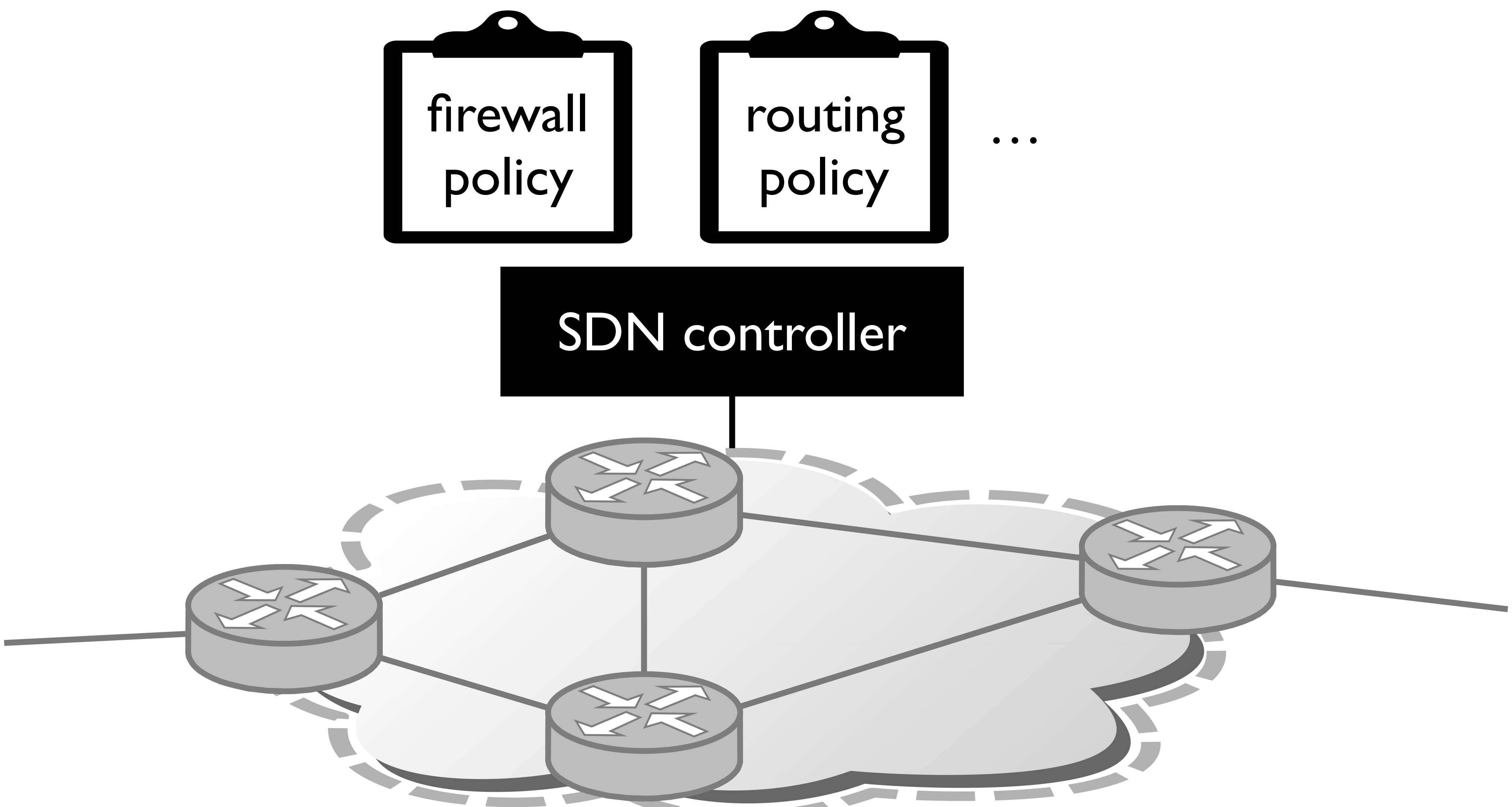


the policy interaction problem

complementary policies in SDNs

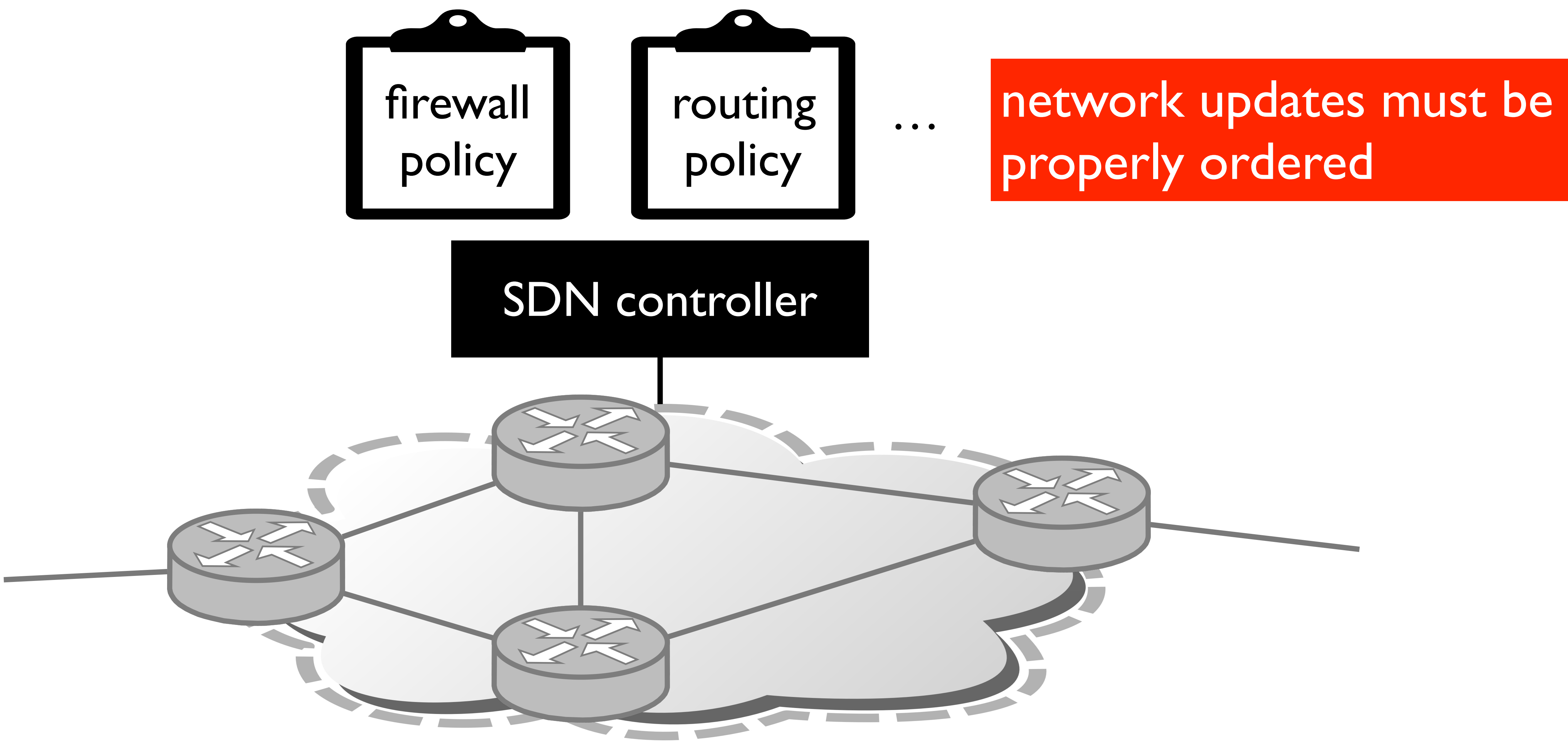
- jointly satisfiable



the policy interaction problem

complementary policies in SDNs

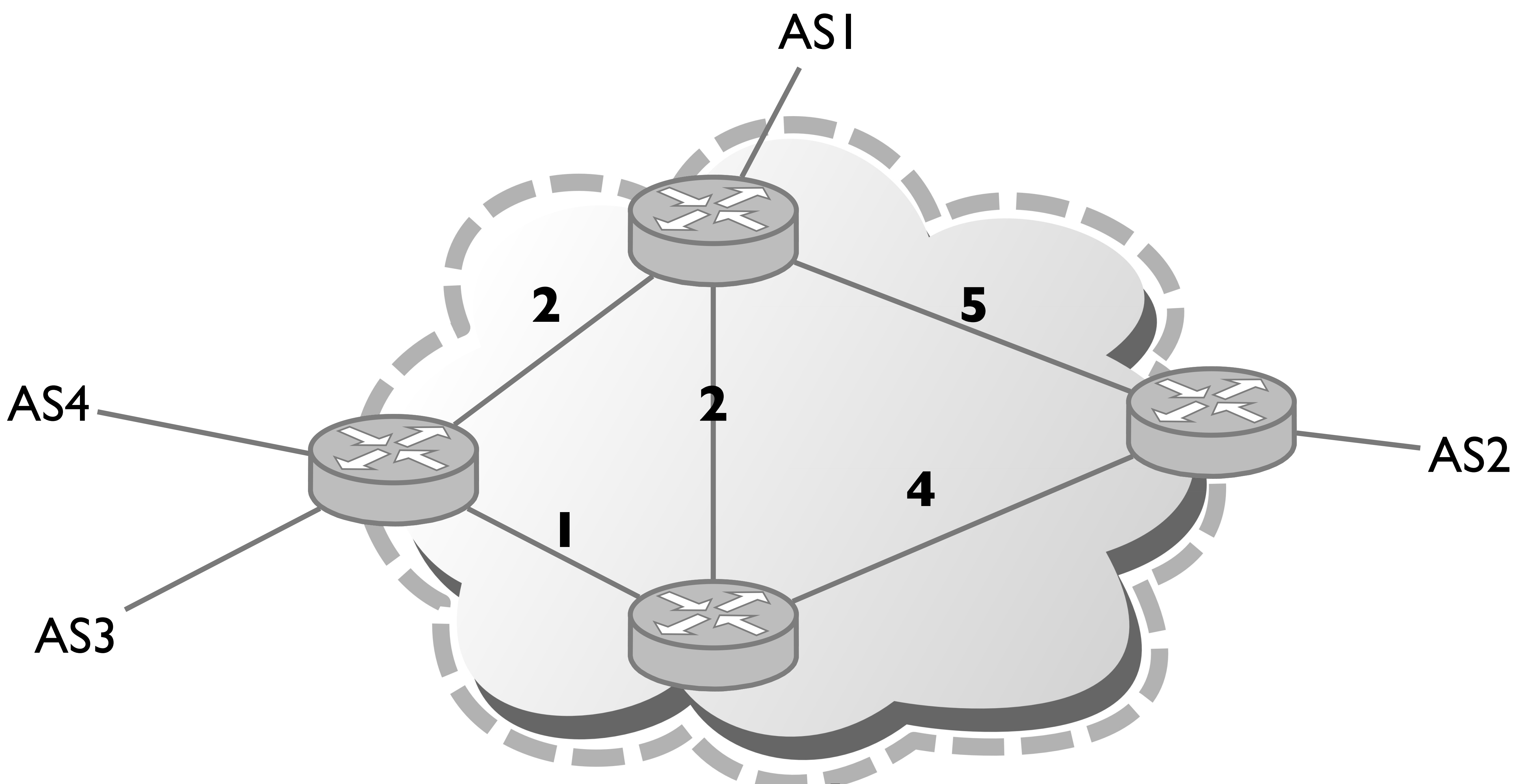
- jointly satisfiable *but not independent*



the policy interaction problem

conflicting policies in inter-domain routing

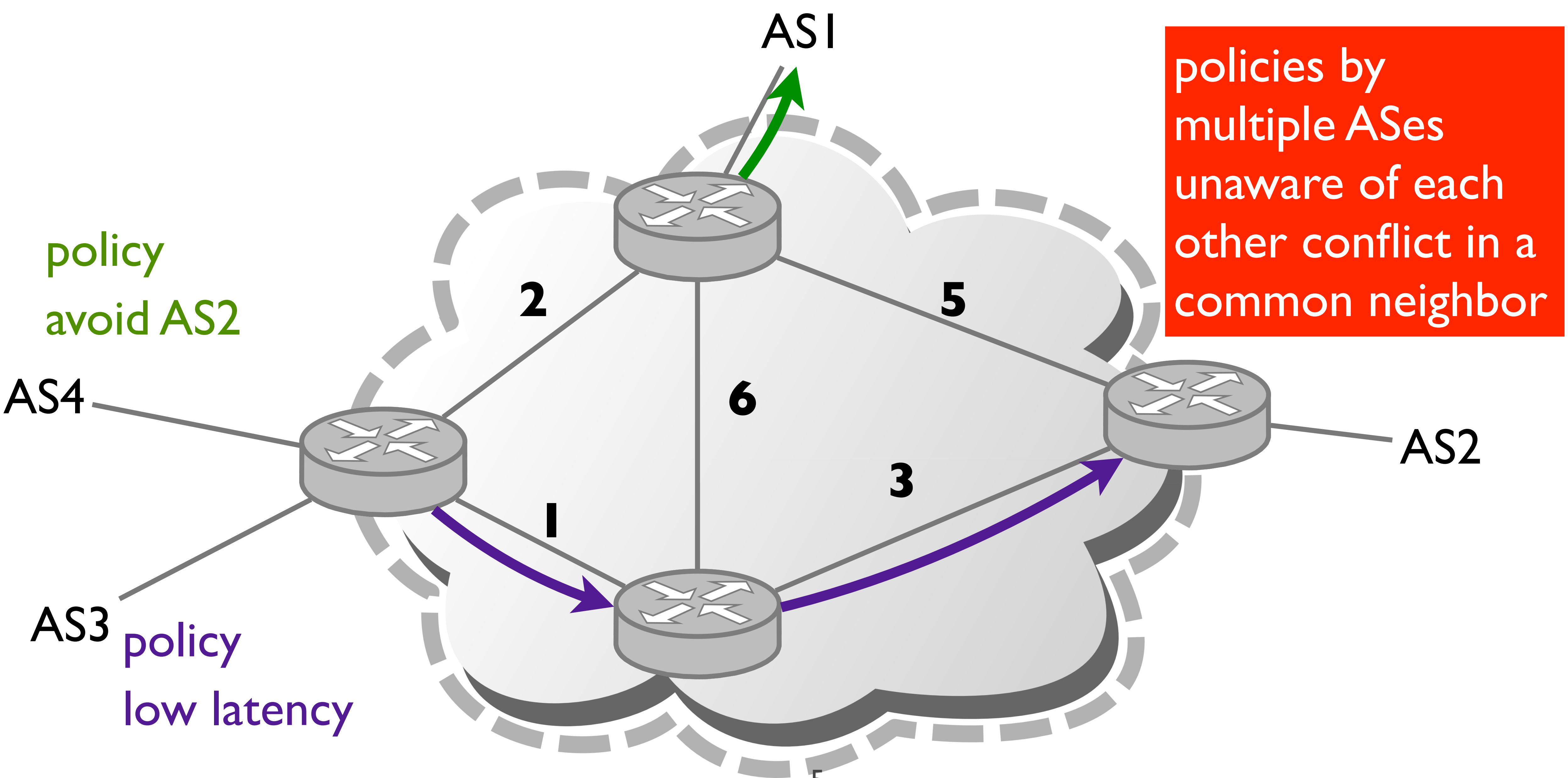
- overlooked conflicts within an autonomous system (AS)



the policy interaction problem

conflicting policies in inter-domain routing

- overlooked conflicts within an autonomous system (AS)
  - AS3 and AS4 attempt to influence route selection of the middle AS



the policy interaction problem

disparate representations buried in the network

complementary policies in SDNs

- jointly satisfiable but not independent

conflicting policies in inter-domain routing

- overlooked conflicts within an AS

a database solution

disparate representations buried in the network ➡ a unified knowledge representation

- policy as integrity constraints (ICs)

complementary policies in SDNs

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a database solution

disparate representations buried in the network ➡ a unified knowledge representation

- policy as integrity constraints (ICs)

complementary policies in SDNs ➡ update orchestrator

- jointly satisfiable but not independent
- dependency analysis of policy ICs

conflicting policies in inter-domain routing

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policy interaction — a database solution

disparate representations buried in the network ➡ a unified knowledge representation

- policy as integrity constraints (ICs)

complementary policies in SDNs ➡ update orchestrator

- jointly satisfiable but not independent

- dependency analysis of policy ICs

conflicting policies in inter-domain routing ➡ policy negotiator

- overlooked conflicts within an AS

- deriving and merging impacts of policy ICs

a unifying representation

network state — factual data — as relations

- example schema

```
% intradomain tables
tp(sid,nid)                  % topology
rm(fid,sid,nid)              % end-to-end reachability (matrix)
cf(fid,sid,nid)              % configuration (forwarding table)
path(pv,cost,iid,eid)        % internal path

% interdomain tables
aspath(did,rid,apv)          % AS level path
```

a unifying representation

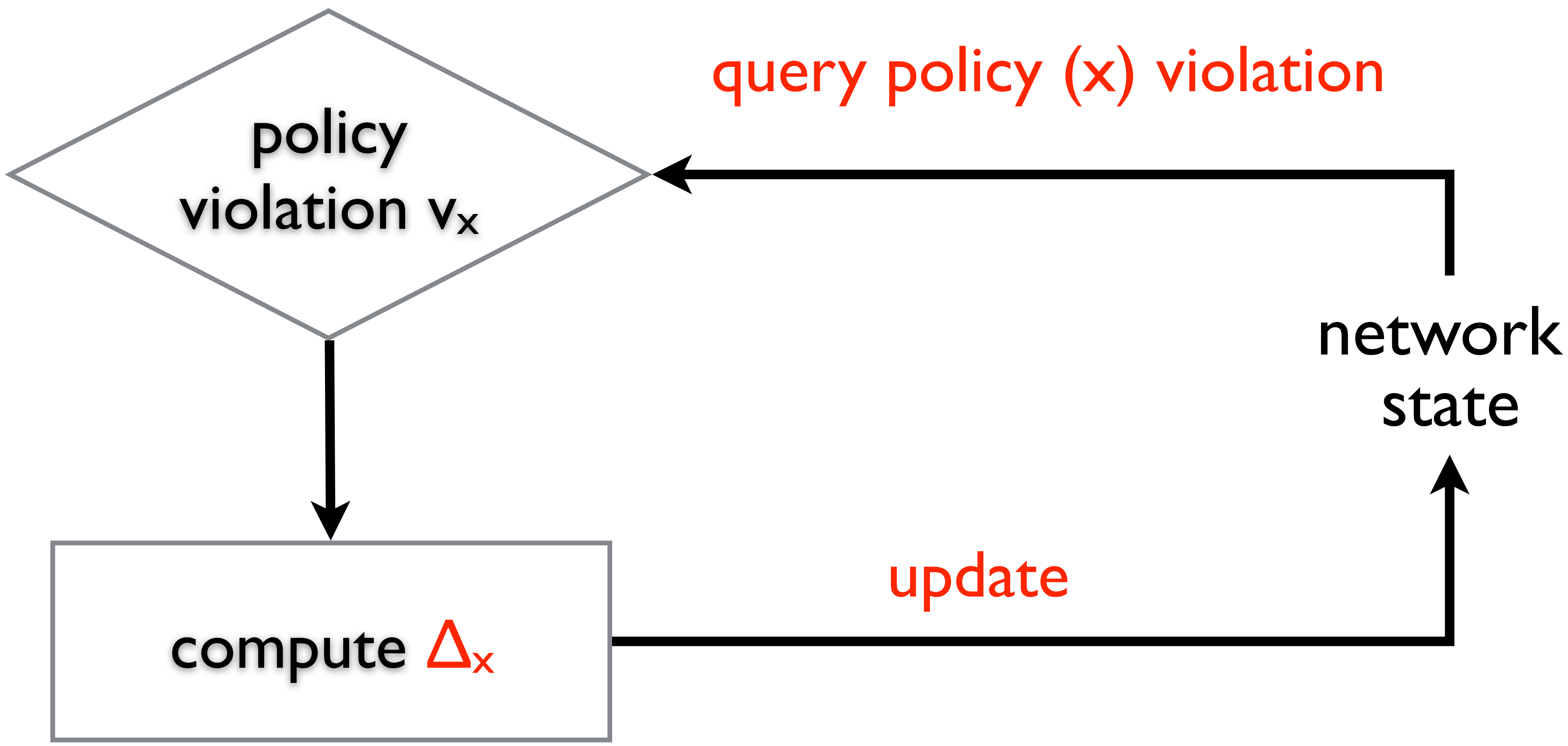
policies — semantic data — as integrity constraints (ICs)

- *denial* form: `:- b1, b2, ..., bn` ($\bot \leftarrow b_1 \wedge b_2 \wedge \ldots \wedge b_n$.)
- meaning: `b1,b2, ...,bn` cannot be simultaneously true.
- example

```
% routing policy
IC1 :- ¬rm(F,S,D),cf(F,X,Y).
IC2 :- rm(F,S,D),¬cf(F,X,Y).

% security policy
IC3 :- rm(F,S,D),blacklist(S,D).
```

relating network state & policy

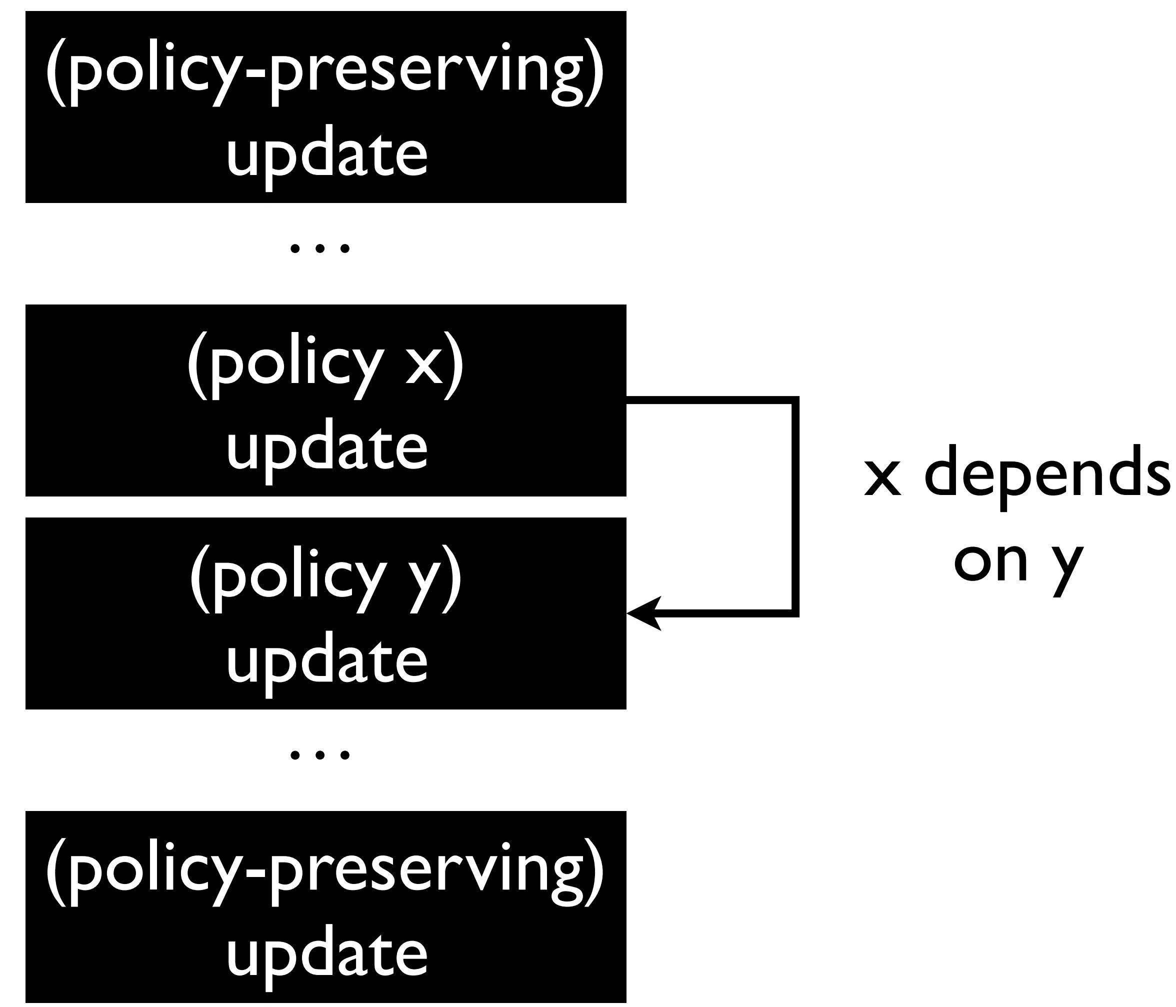


update orchestrator

manage complementary policies in SDNs

- multiple disjoint policies oversee a single task

arrange network updates into a semantic layering

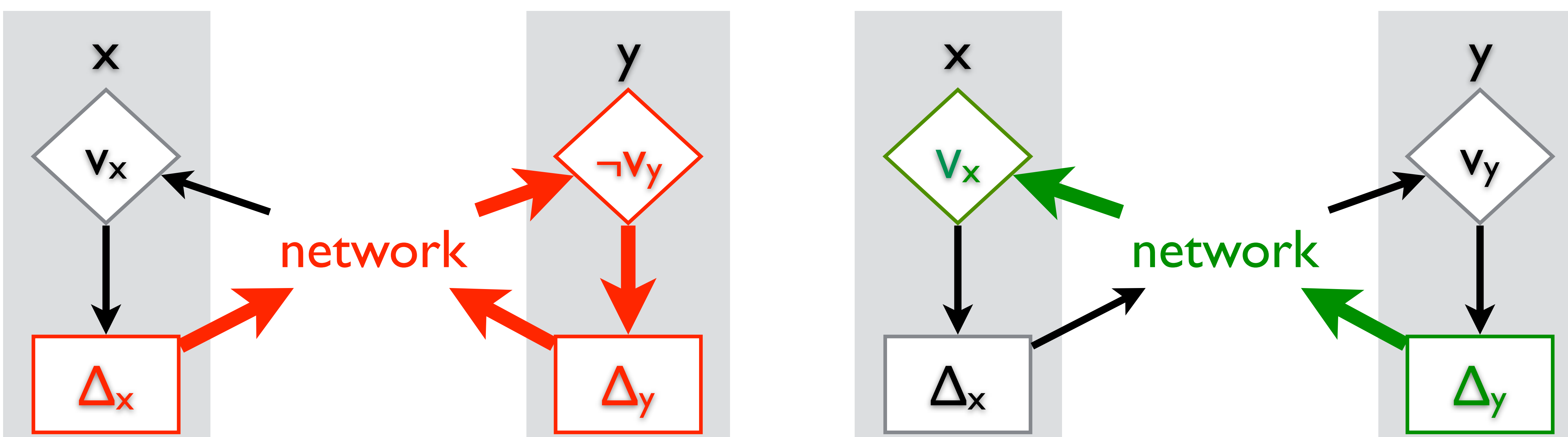


semantic dependency

policy x depends on y if

x update can violate y policy and trigger y action

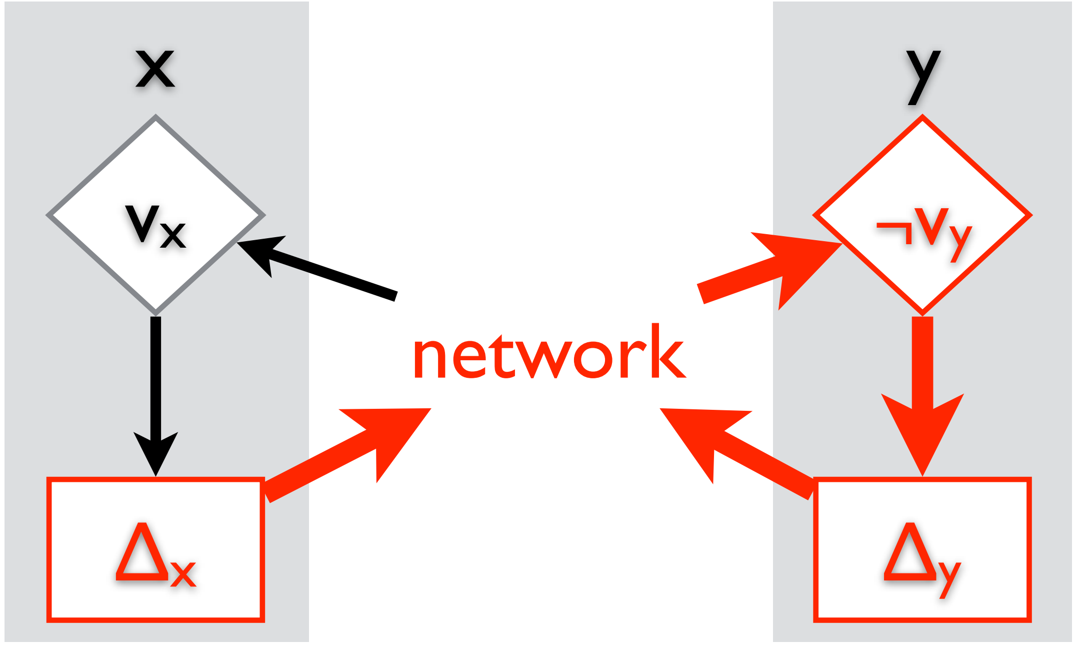
but y can not affect x



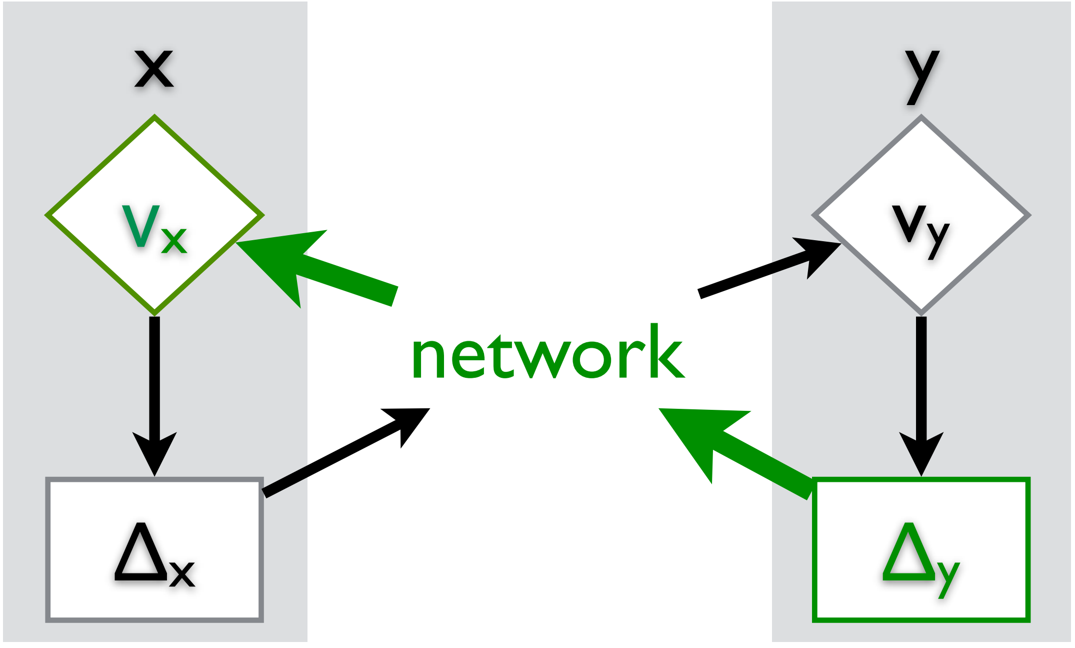
determine semantic dependency

dependency analysis by satisfiability reasoning

check whether Δ_x can alter the result of v_y



check whether Δ_y cannot alter v_x,

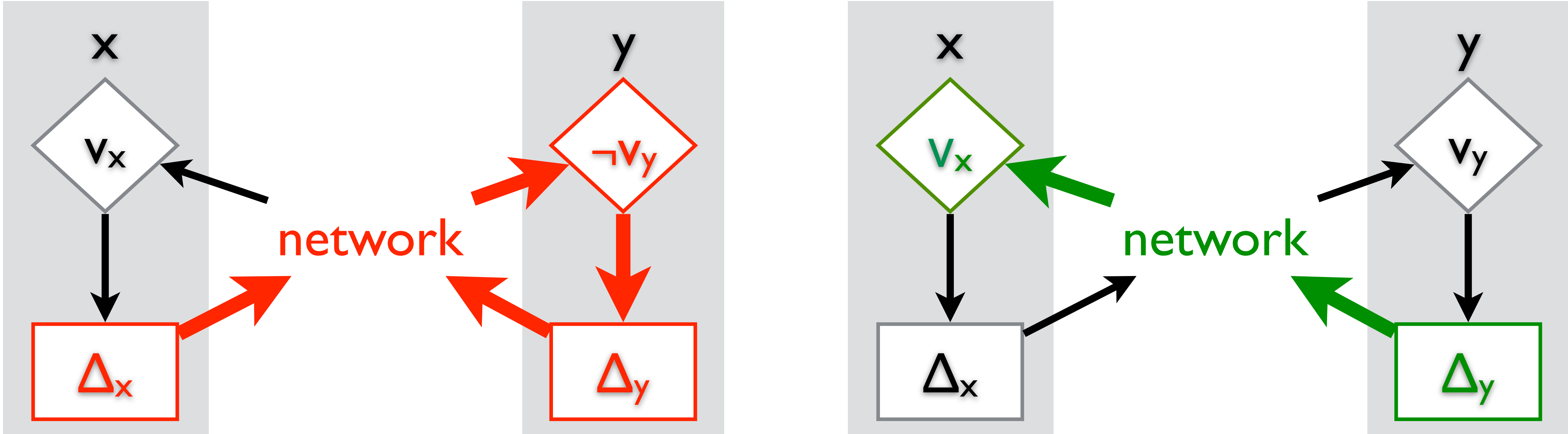


determine semantic dependency

dependency analysis by satisfiability reasoning

(Δ_x condition) $\wedge$ (v_y condition) is SAT

(Δ_y condition) $\wedge$ (v_x condition) is UNSAT



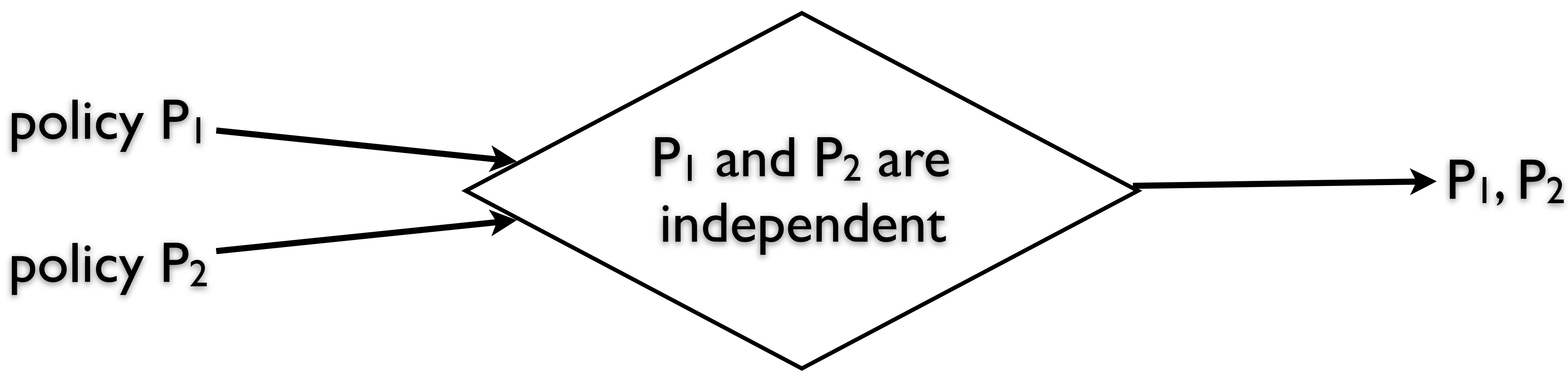
policy negotiator

manage conflicting policies within an AS

- under the influences of multiple neighbors unaware of each other
- derive and merge policy impacts

derive and merge policy impacts

an AS under the influences of p_1 and p_2



derive and merge policy impacts

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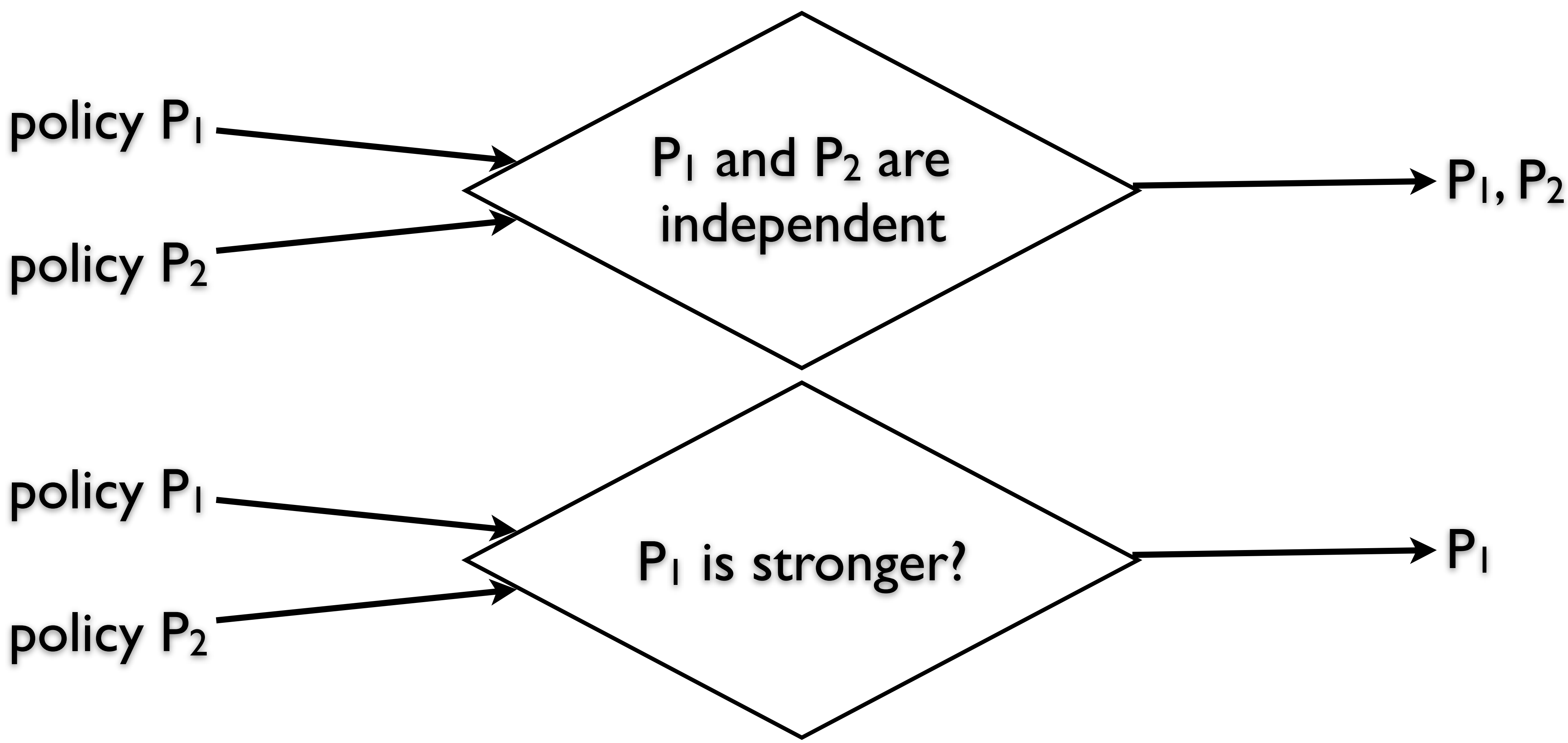

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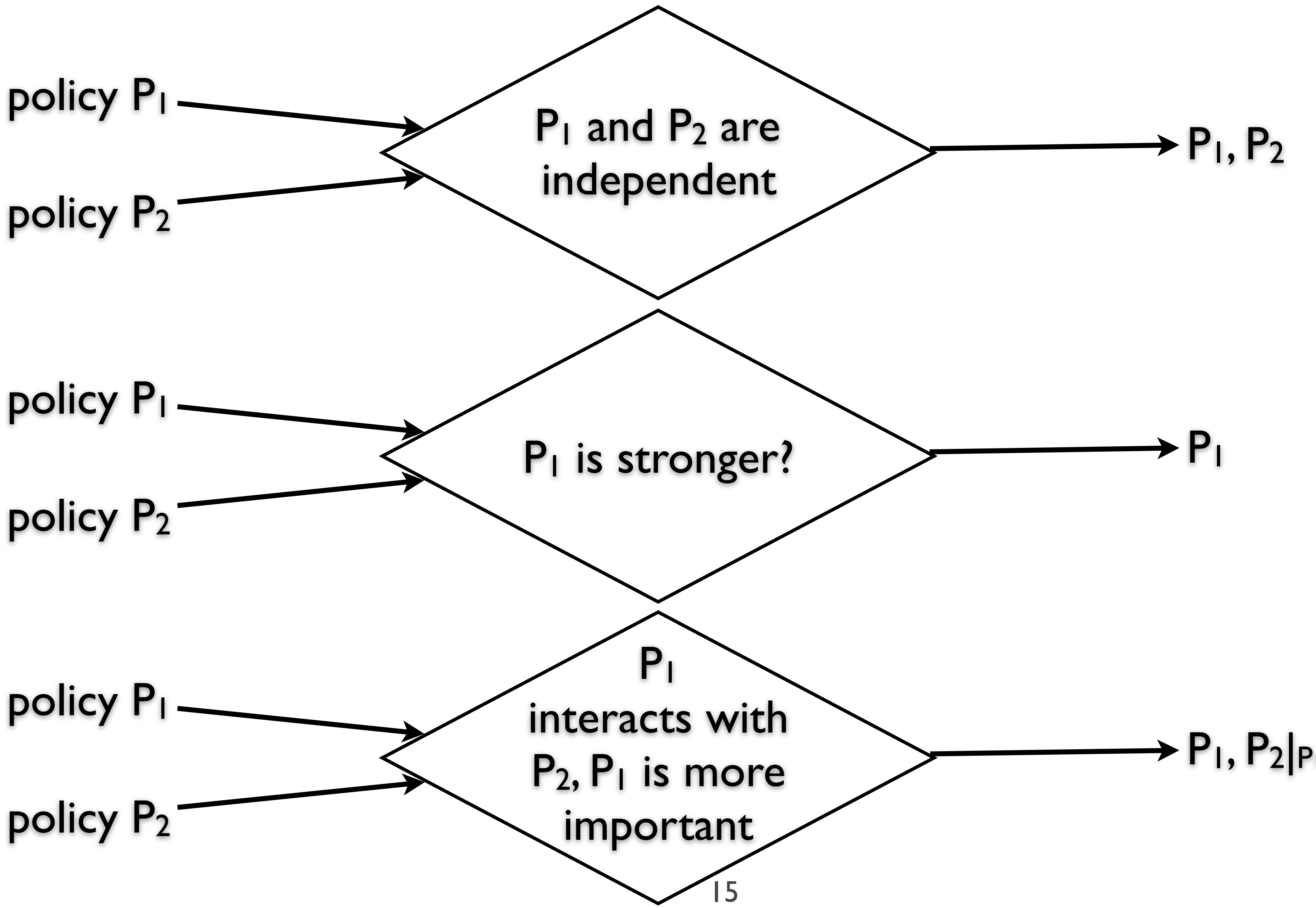
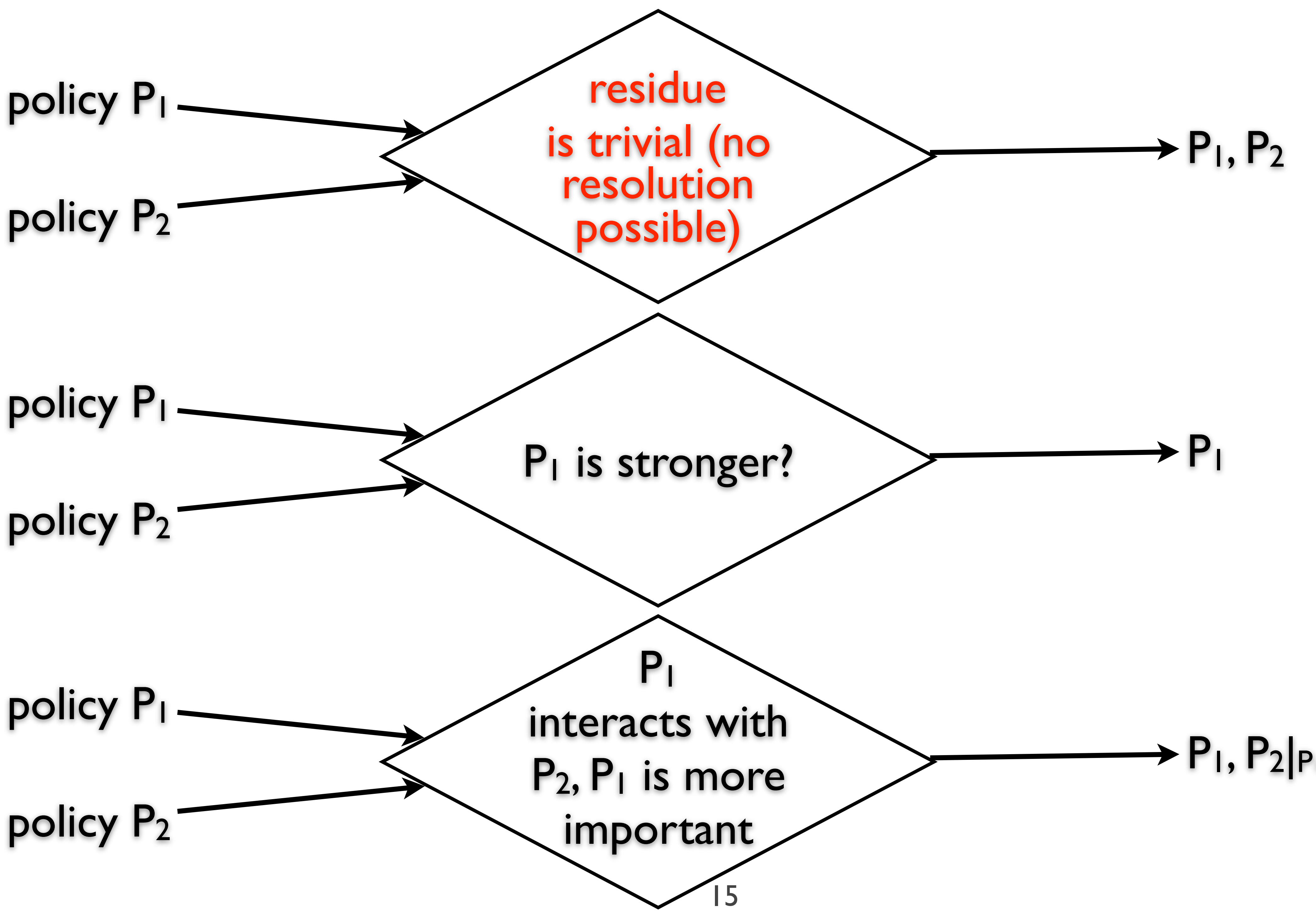


residue method

residue — syntactic fragment that anticipates impact, computed by partial subsumption



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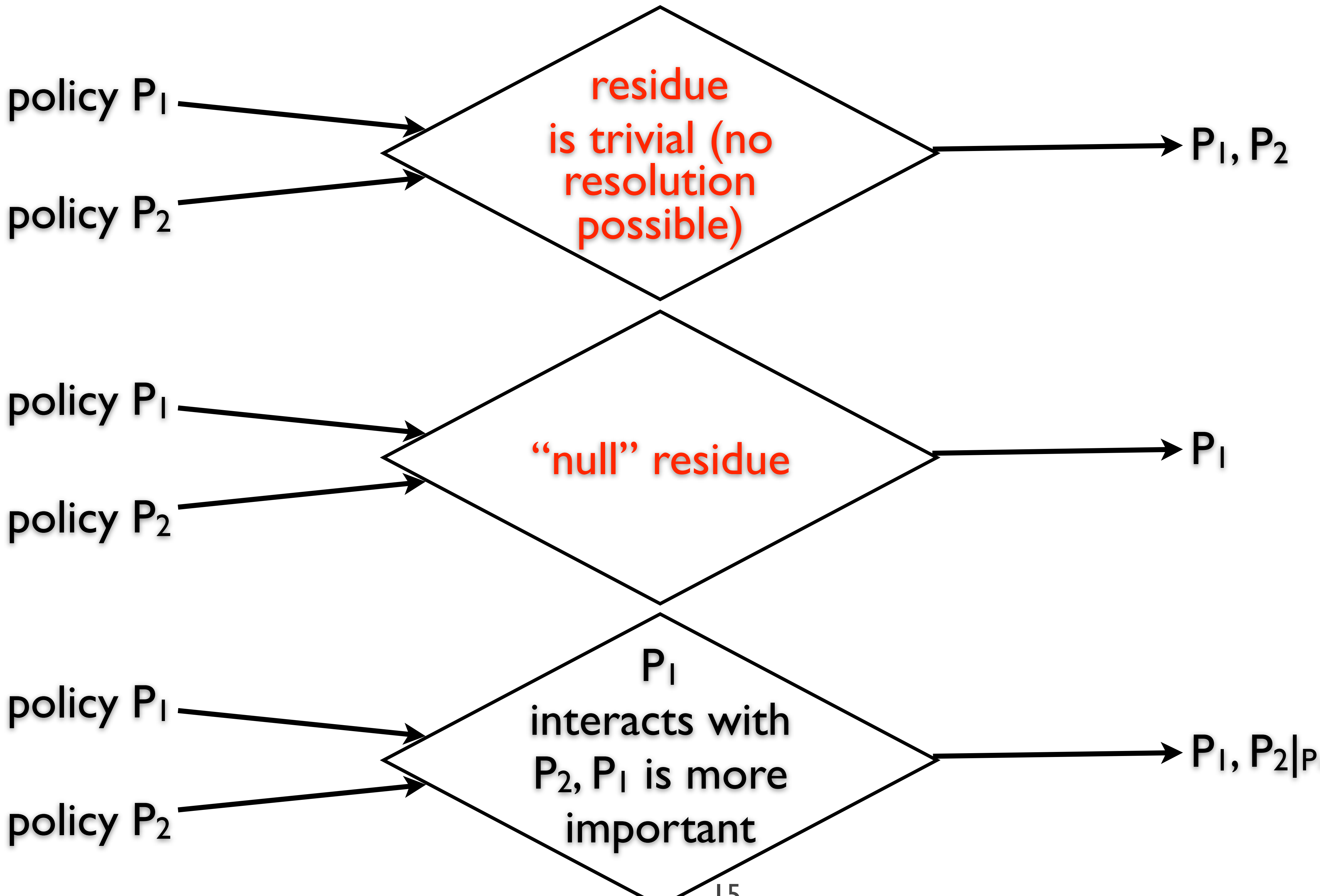

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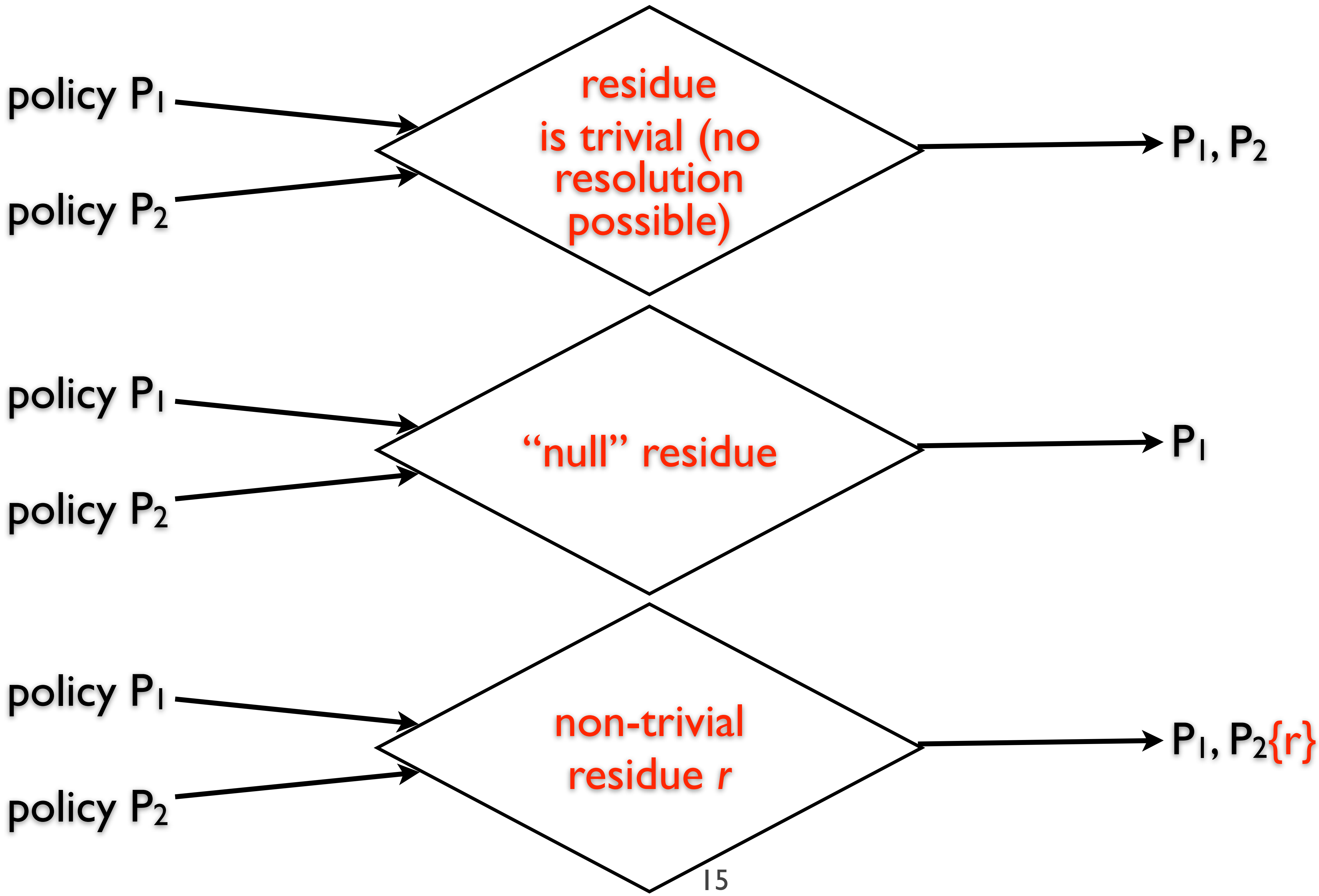

moving forward

expressiveness of the IC representation

- facilitating template, translating tool

cyclic dependency in SDN

- break cycles

policies are private in interdomain

- obfuscate policies

recap

disparate representations buried in the network ➡ a unified knowledge representation

- policy as integrity constraints (ICs)

complementary policies in SDNs ➡ update orchestrator

- jointly satisfiable but not independent

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conflicting policies in inter-domain routing ➡ policy negotiator

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thank you

part of "Ravel database-defined networking" ravel-net.org

backup

residue computation by example

%% shortest path

$\mathtt{IC_{sp}}$ `:-` $\mathtt{r_o(x,y,z),\ r_i(x,y_2,z_2),\ l(z)>l(z_2).}$

%% explicit path policy

$\mathtt{IC_{ep}}$`:` `z=a :-` $\mathtt{r_o(x,y,z),}$ `x=d.`

$\mathtt{IC_{ep}}$

`z=a :-` $\mathtt{r_o(x,y,z),}$ `x=d.`

elements of $\mathtt{IC_{sp}}$

`:-` $\mathtt{r_o(x,y,z).}$

$\boxed{\mathtt{z=a\ :-\ x=d.}}$

a non-trivial residue prescribes the impact of $\mathtt{IC_{ep}}$ —
additional conditions that must be taken into account for $\mathtt{IC_{sp}}$

$\mathtt{IC_{sp}}$ affects $\mathtt{IC_{ep}}$, as anticipated by the residue