(Ir)relevance reasoning for software-defined network

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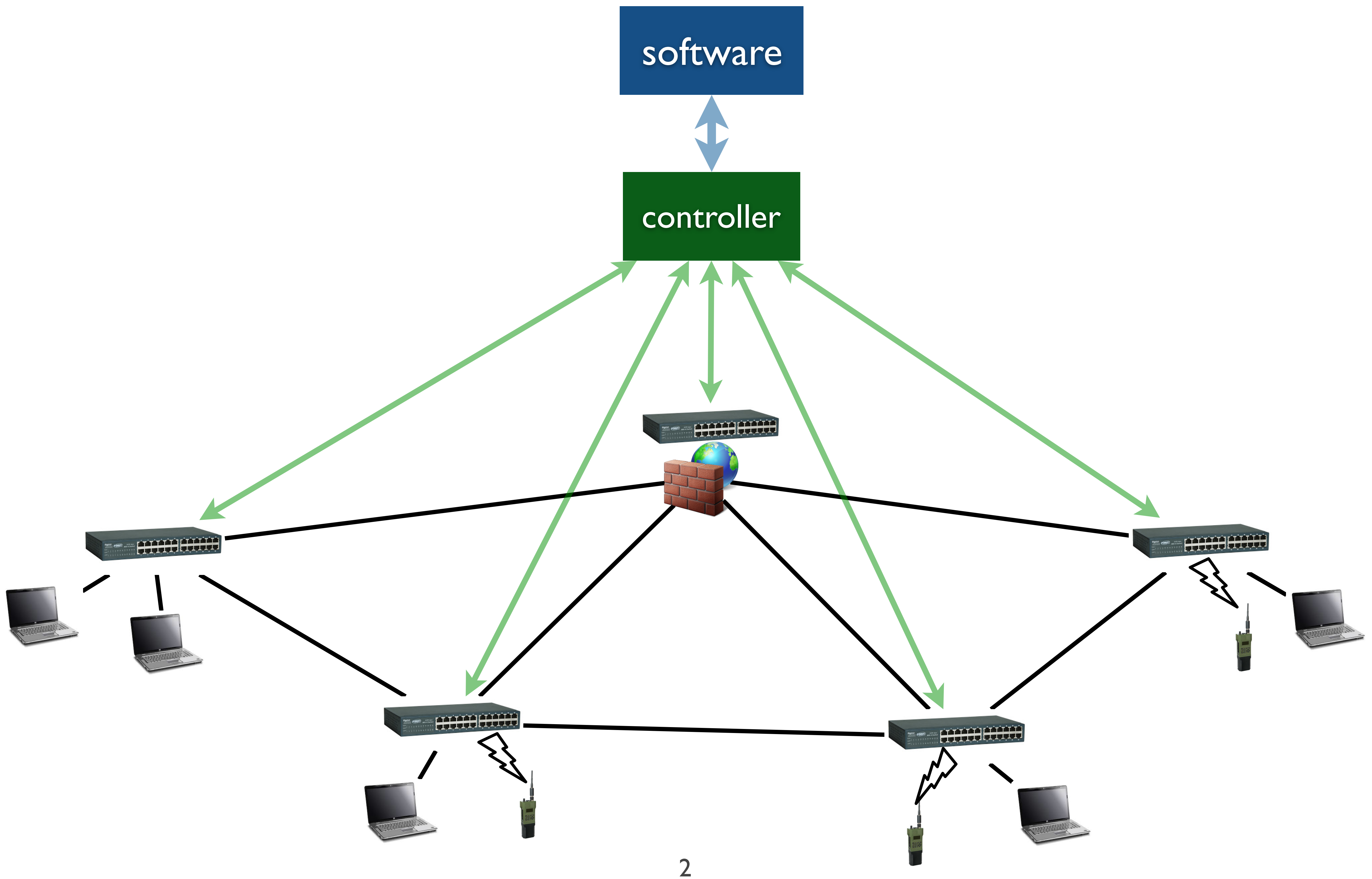
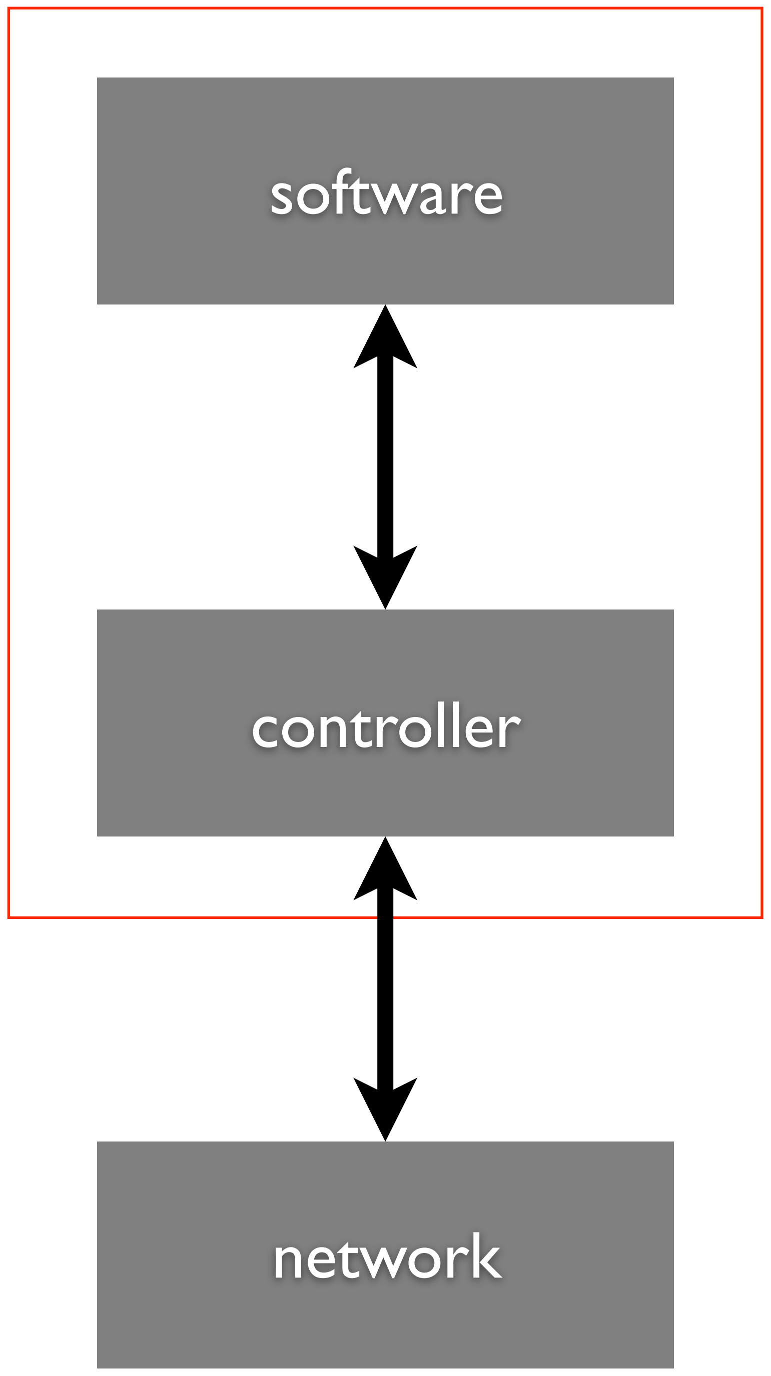
software-defined networking (SDN)

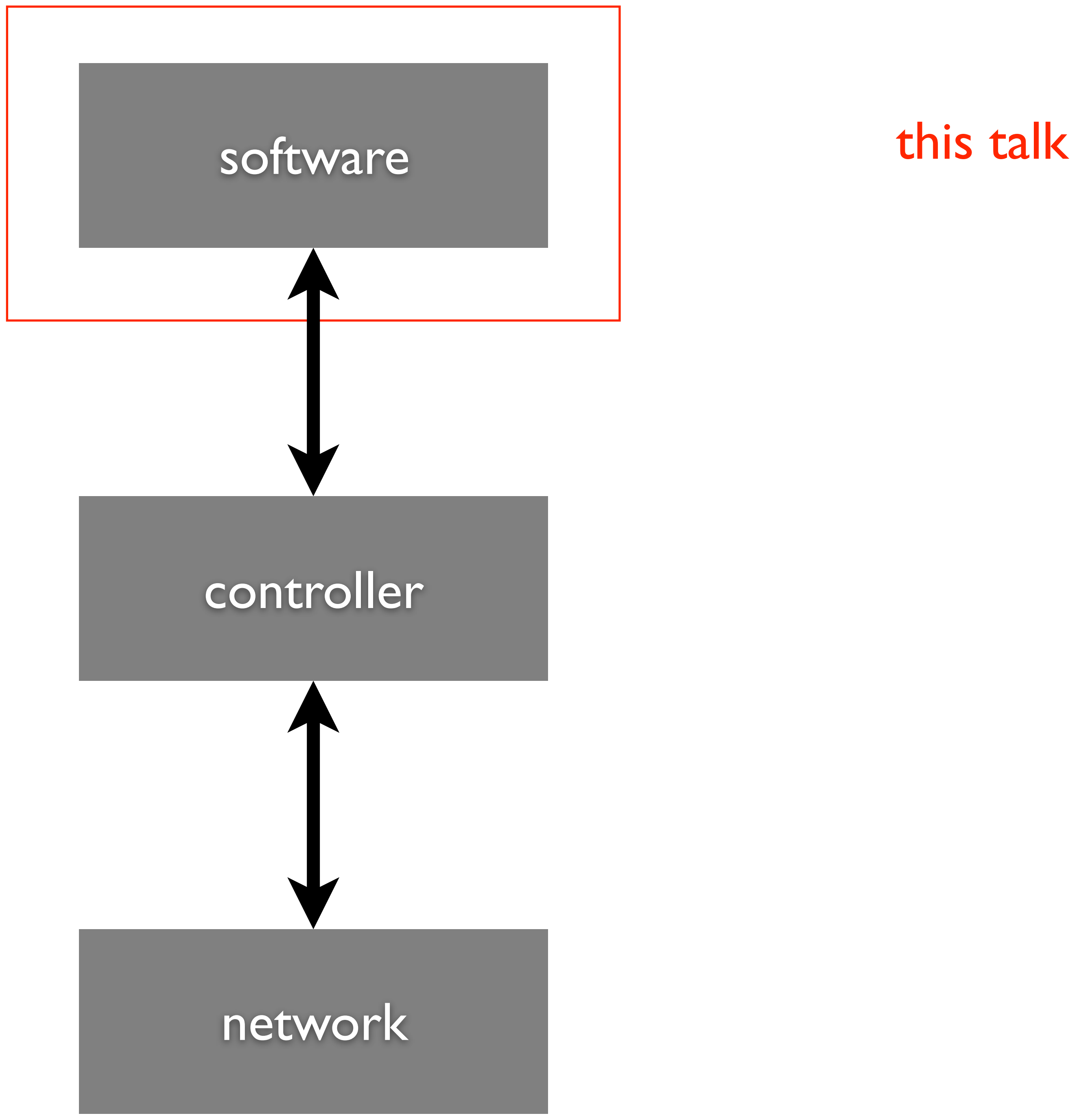


software-defined networking (SDN)

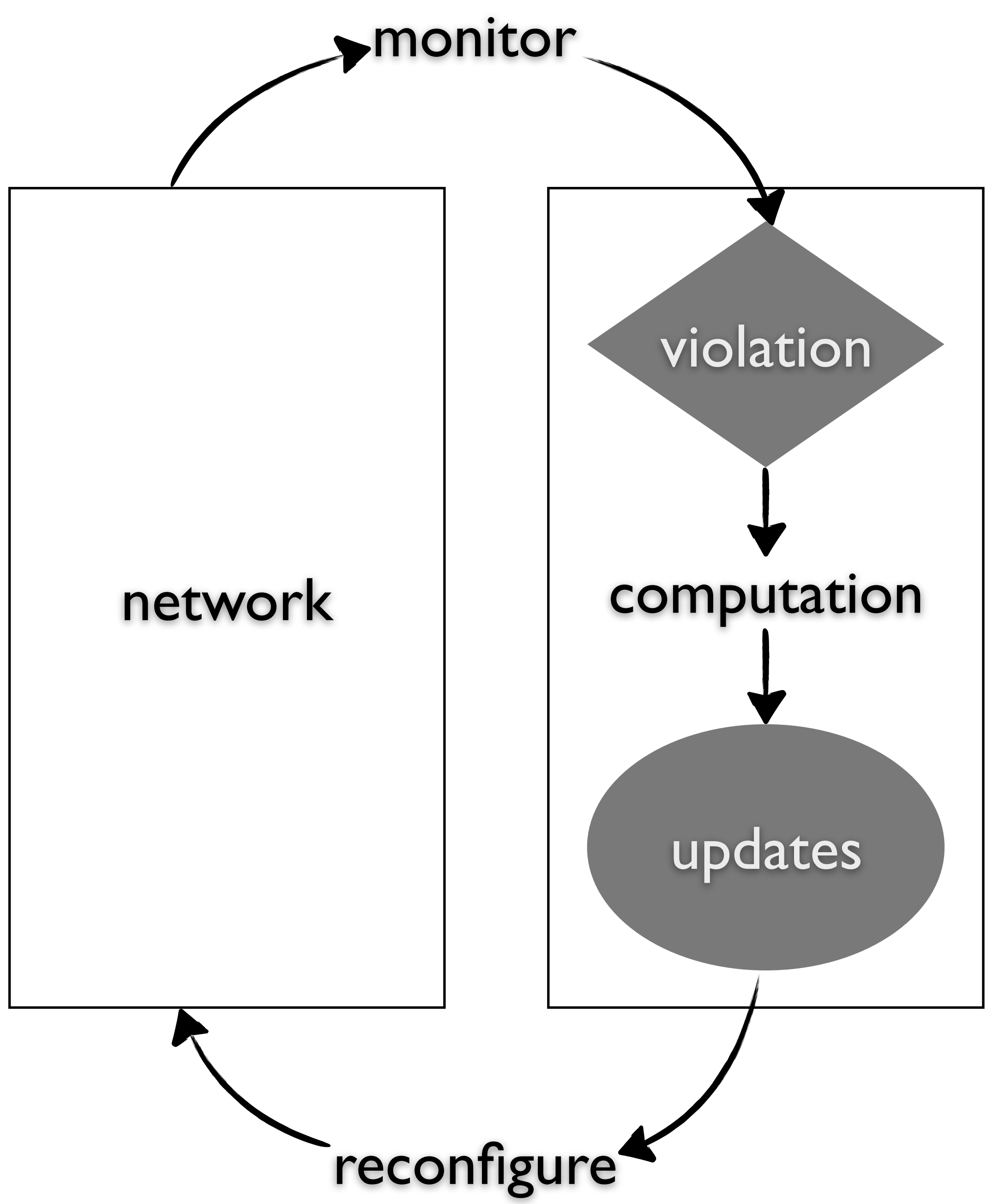


SDN moves complexity to
control software:
an opportunity and challenge

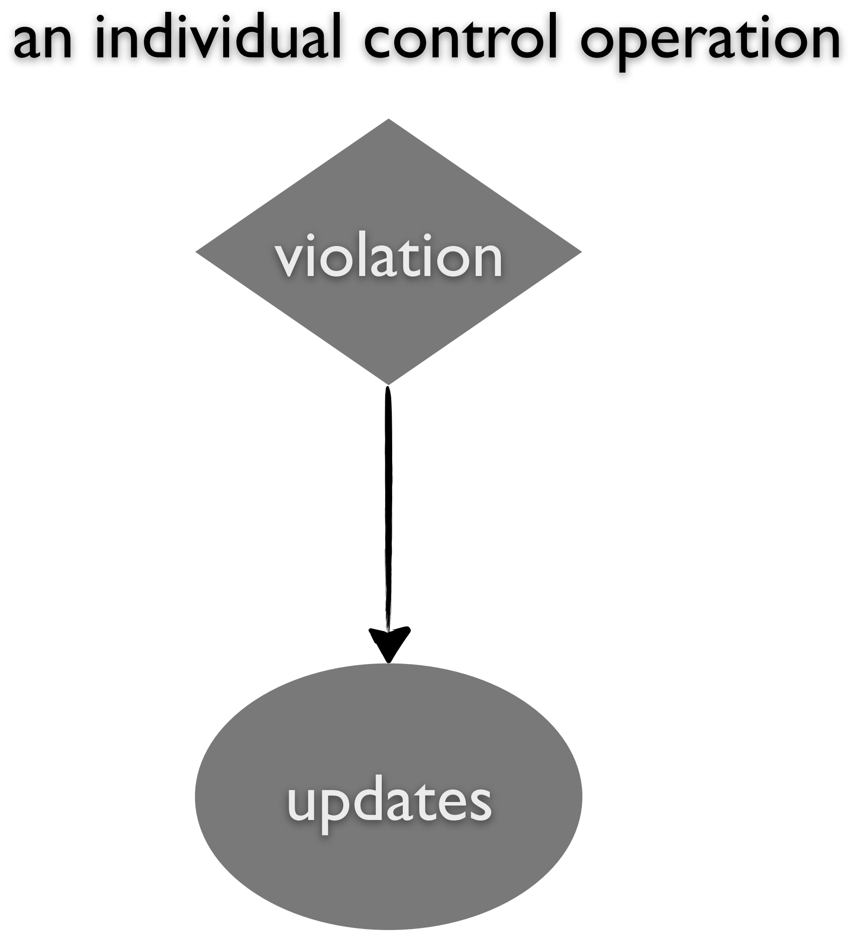
software-defined networking (SDN)



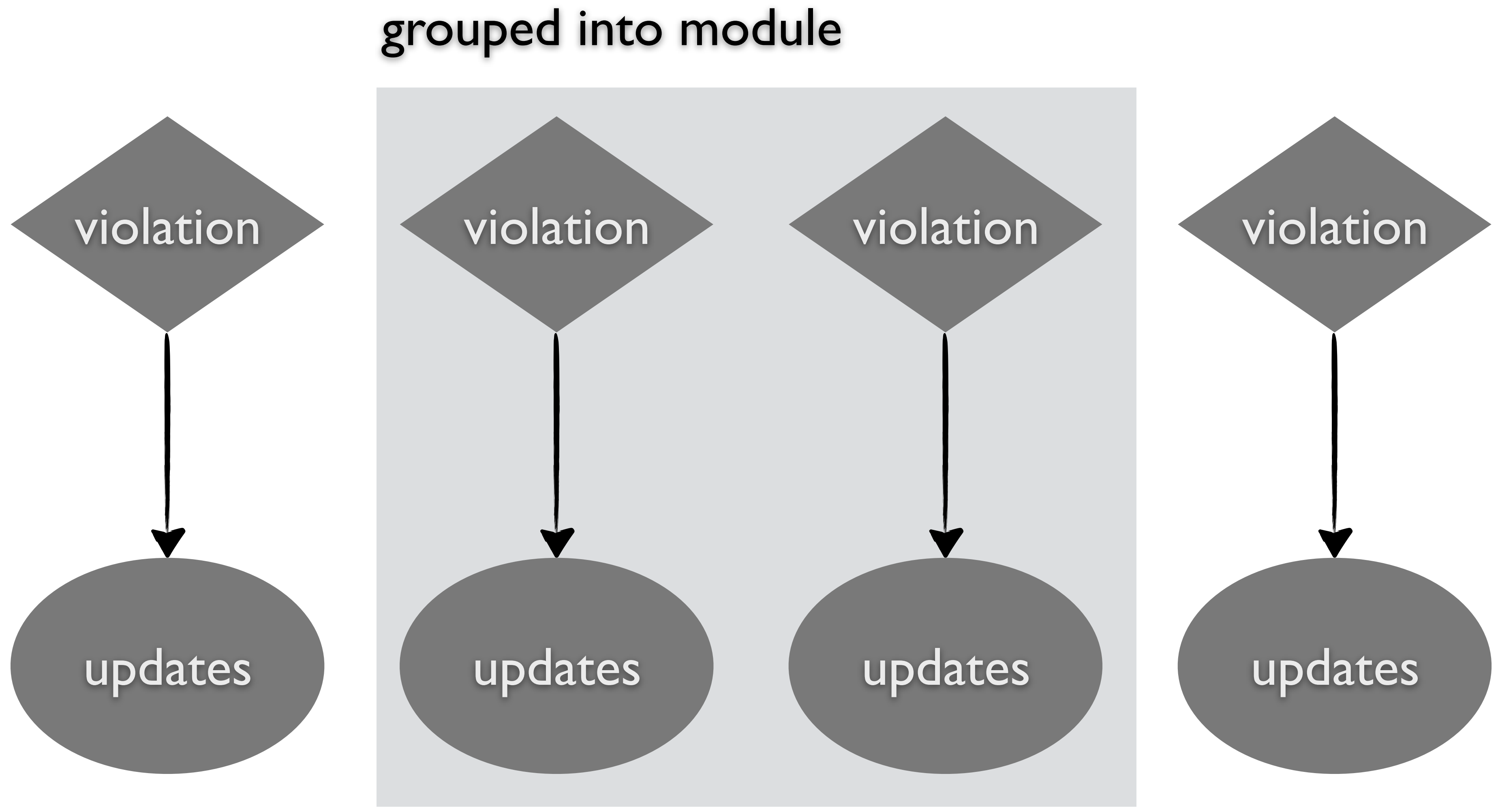
SDN control software



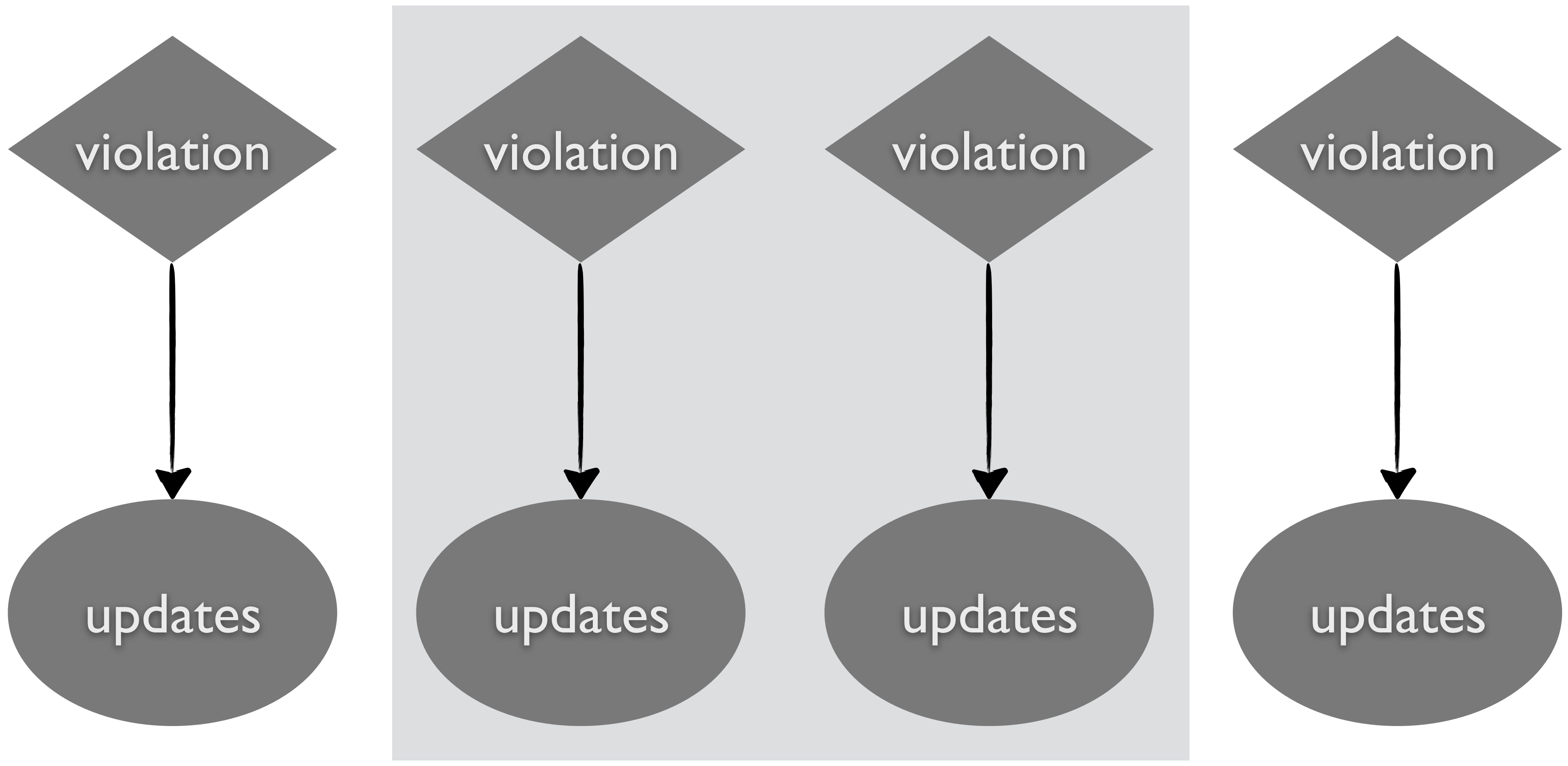
SDN control software



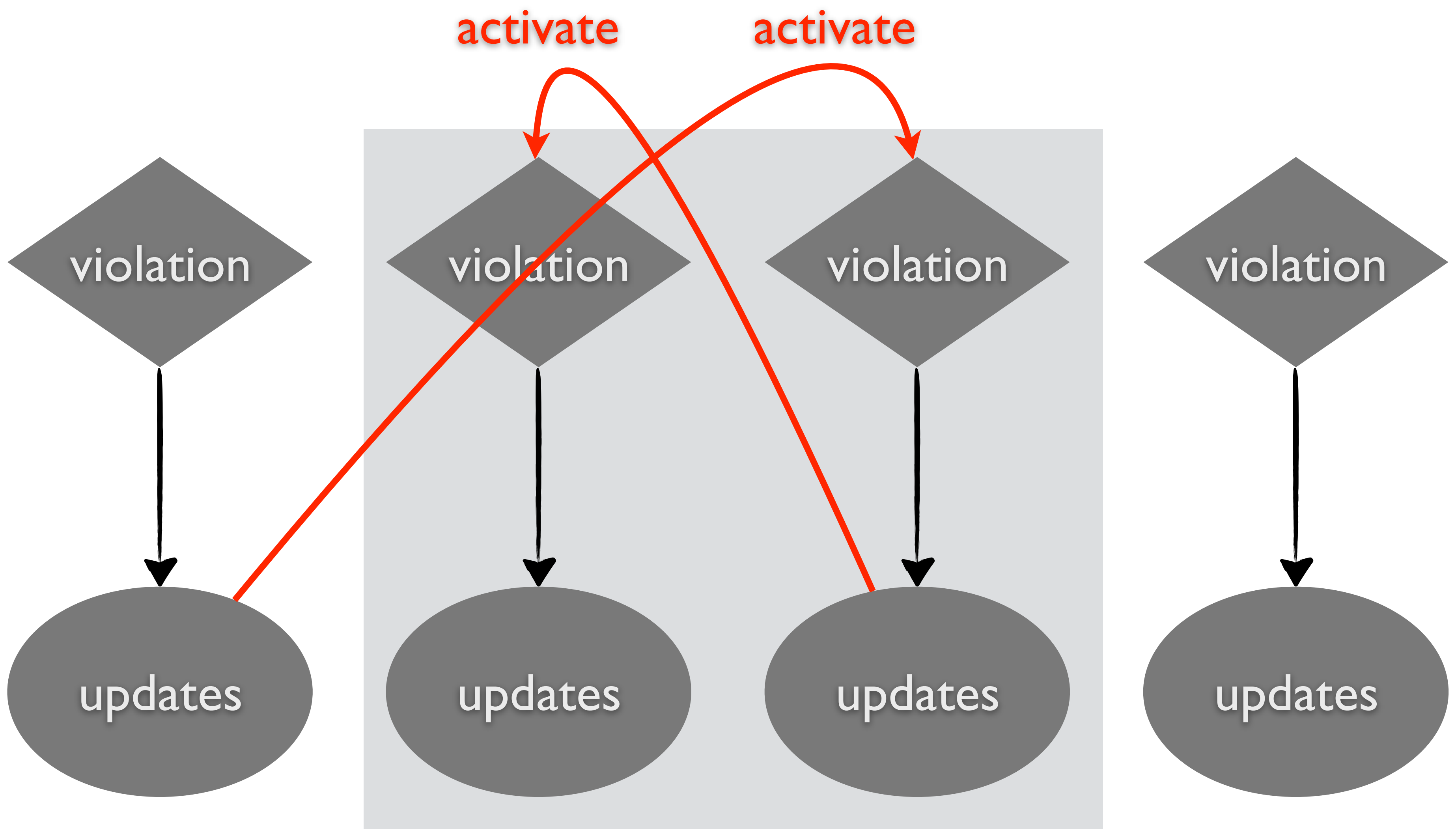
SDN control software



SDN control software



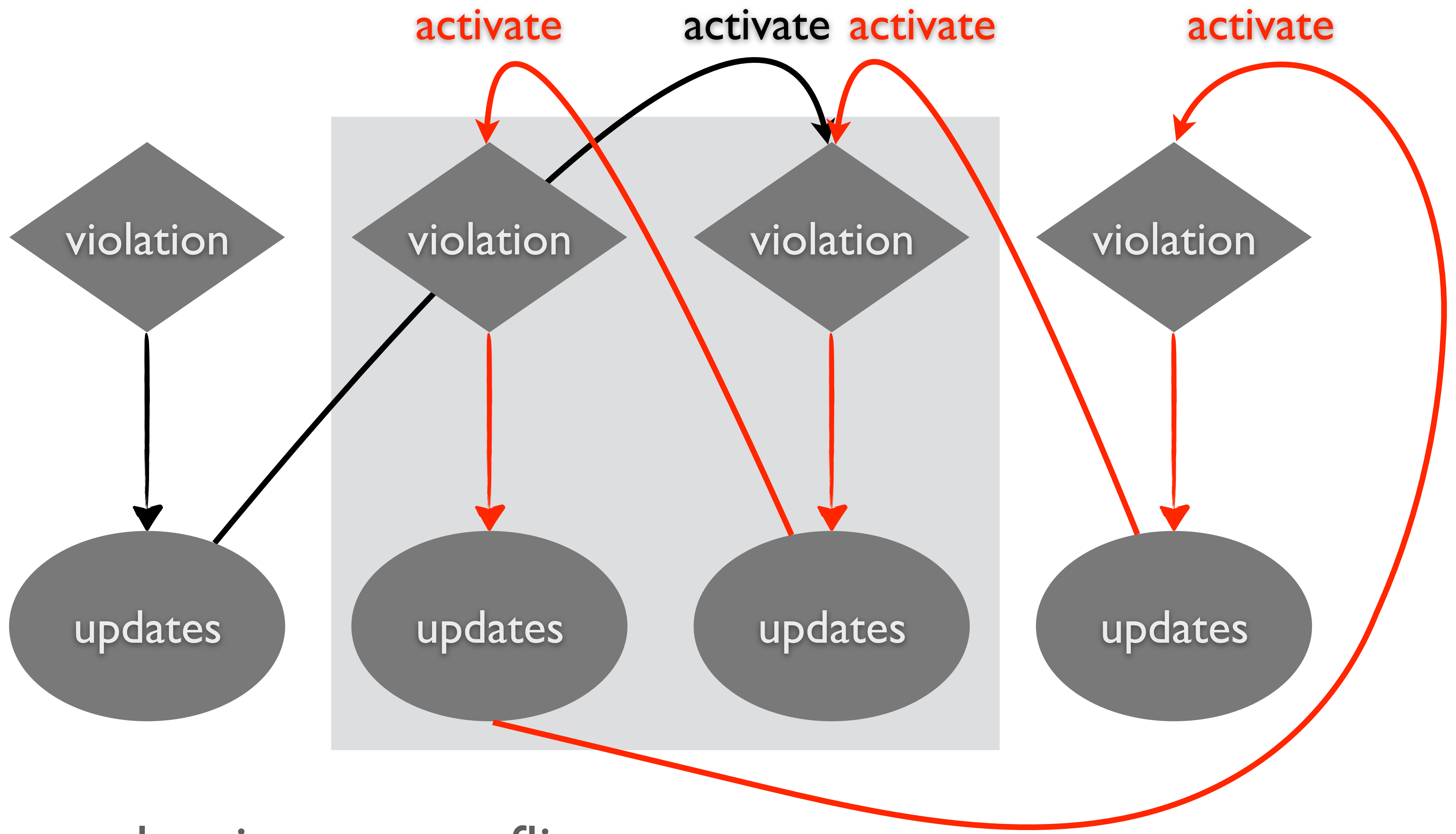
managing complexity in control software



dependency occur within and across modules

- modular programming abstraction [NSDI'13, 15; SIGCOMM'14,15]
- limitation: manual, requires understanding of module internals

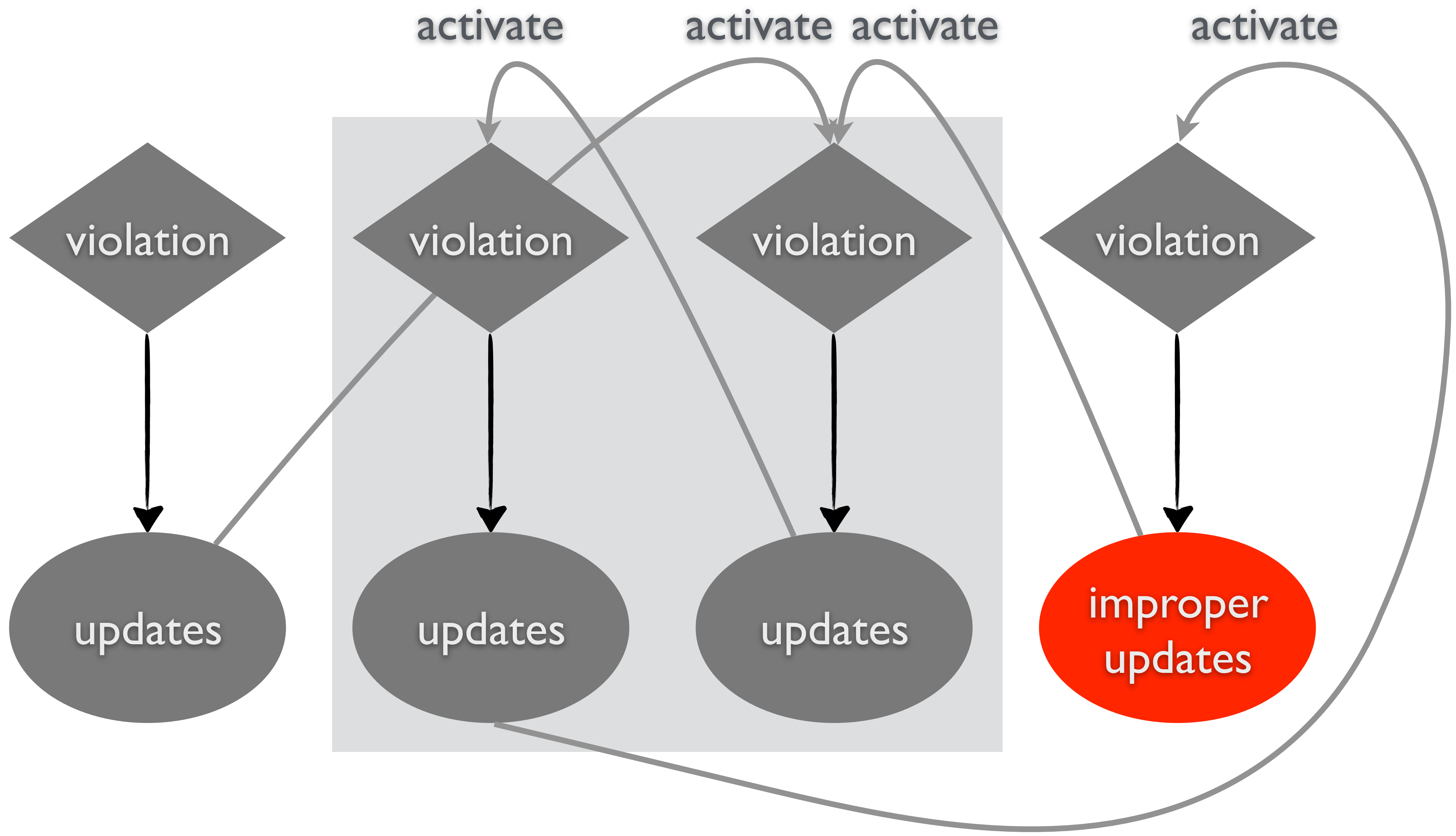
managing complexity in control software



multiple dependencies can conflict

- conflict resolution: module-level priority [many popular control platforms]
- limitation: coarse-grained, manual

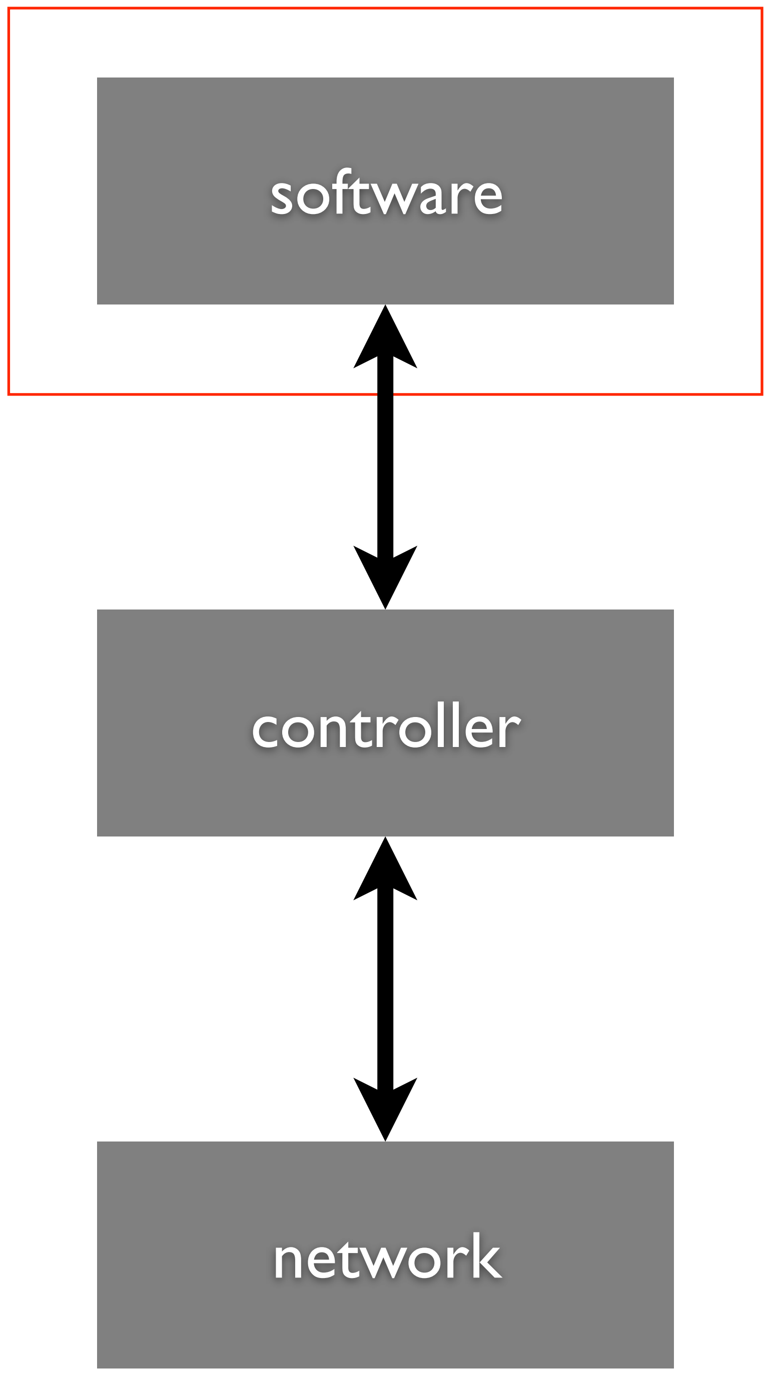
managing complexity in control software



updates can go wrong

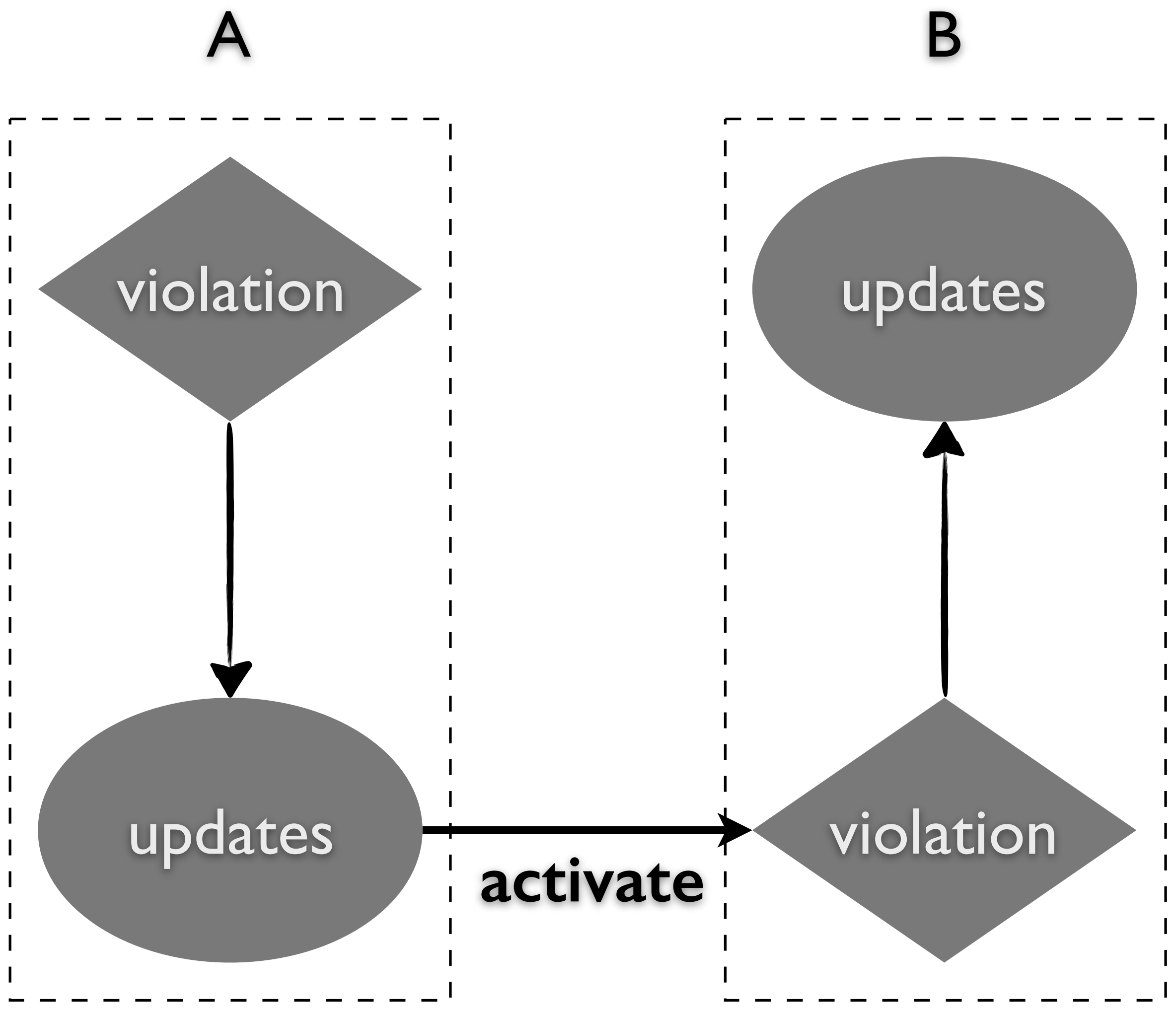
- debugging and verification [SIGCOMM'14, NSDI'13, 15, 16]
- limitation: post-mortem, identify incorrect events/states but not revealing incorrect control logic

automated reasoning support



- **automated:** reduce human involvement with formal tool (SMT solver)
- **finer-grained:** operation-level
- **static:** prior-to deployment,
- **logic based:** derive proper interactions among controls

dependency

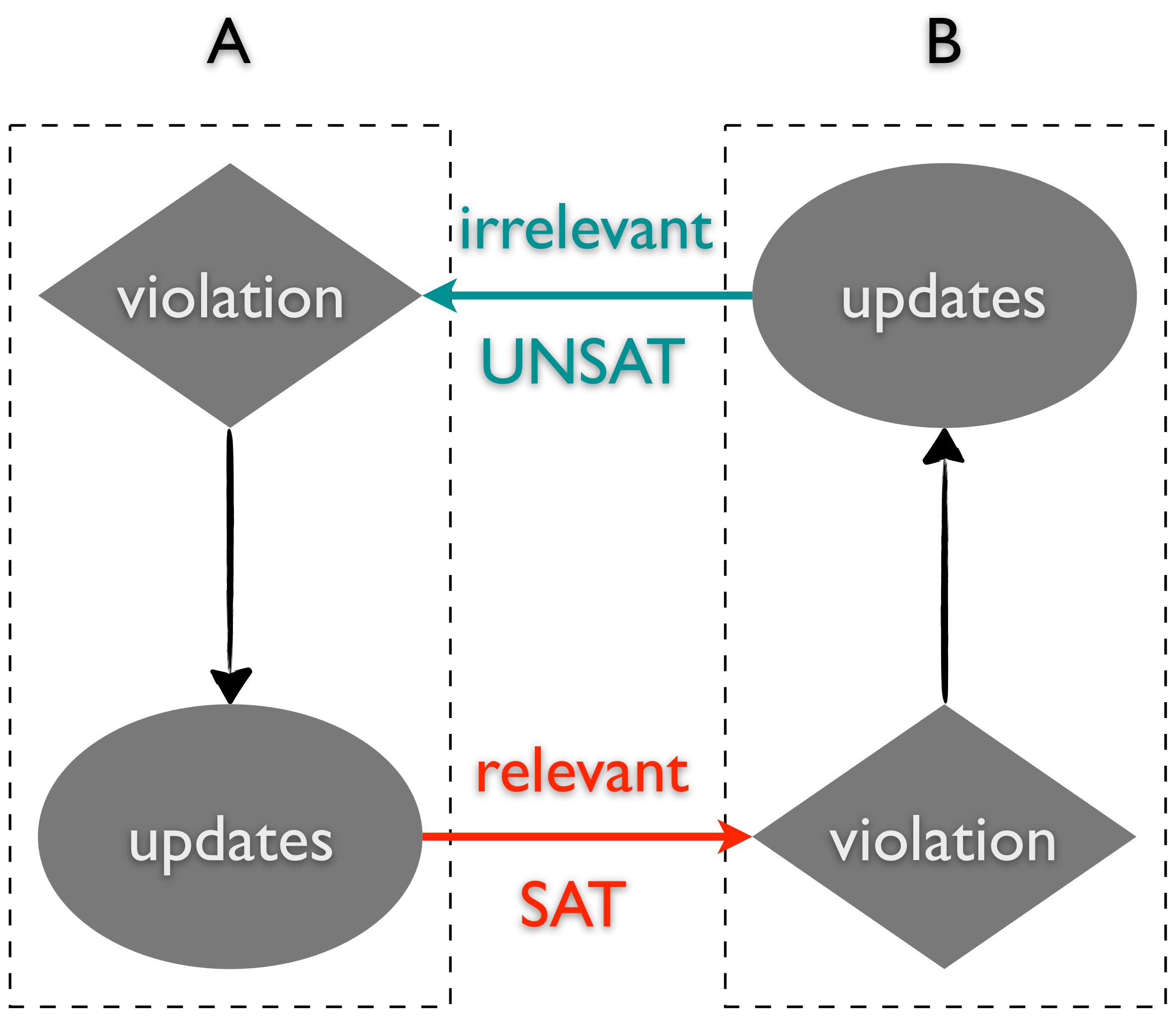


operation **A depends on B**

(1) A update can activate B

(2) B update never activates A

dependency and (ir)relevance reasoning



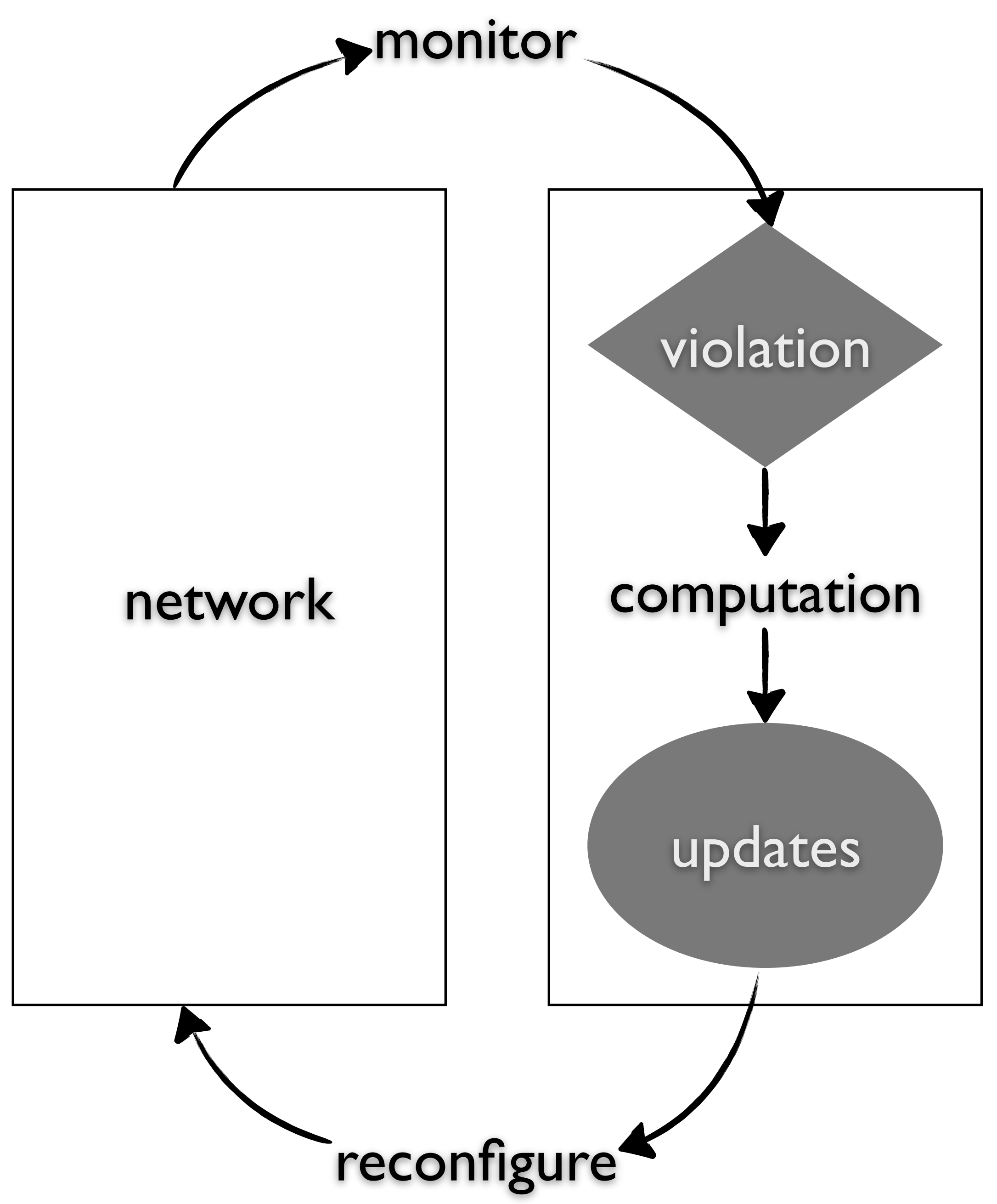
operation A depends on B

(1) A is relevant to B: can find a B update such that violates A

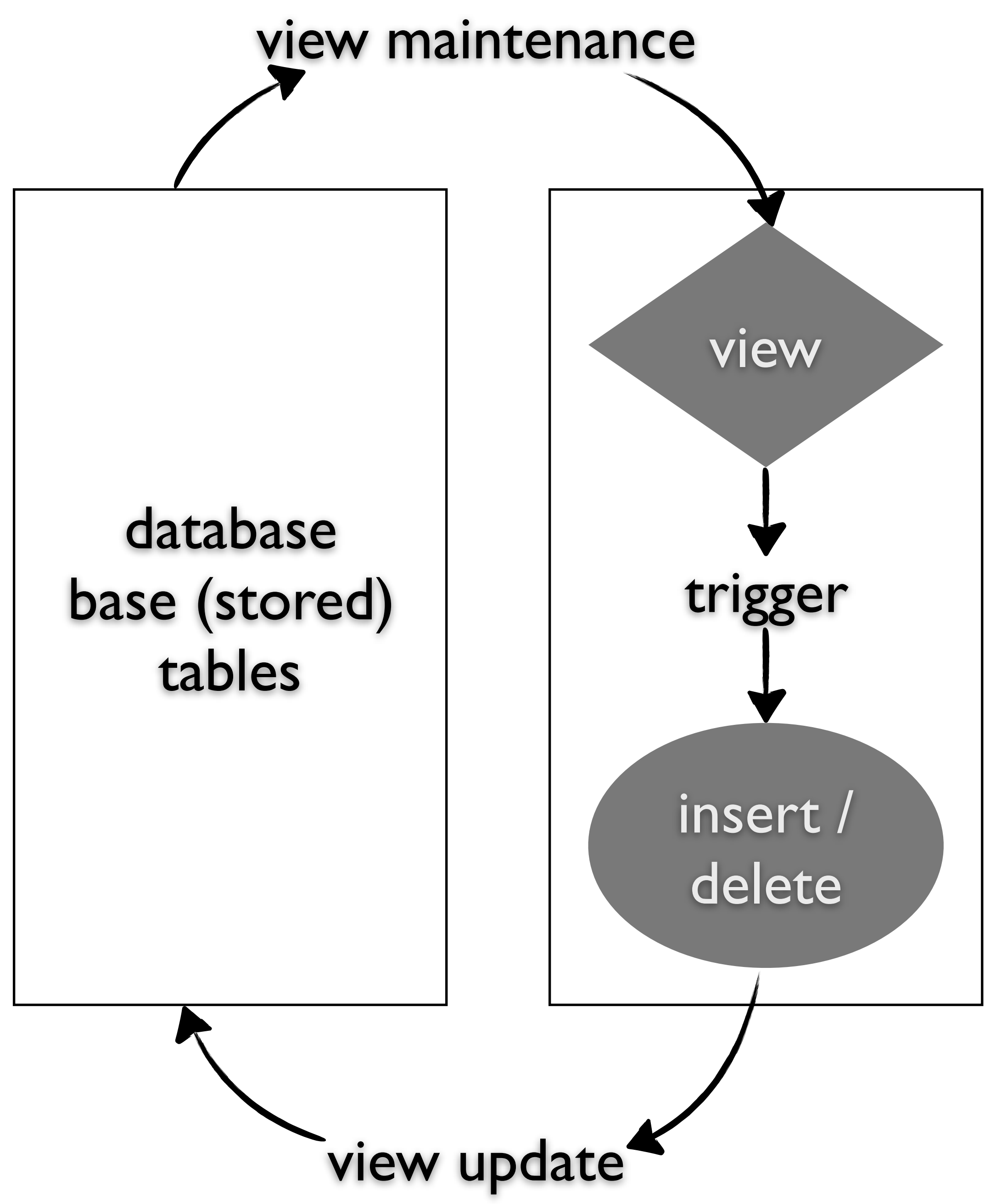
(2) B is irrelevant to A: cannot find a B update that violates A

formal model

SDN control loop



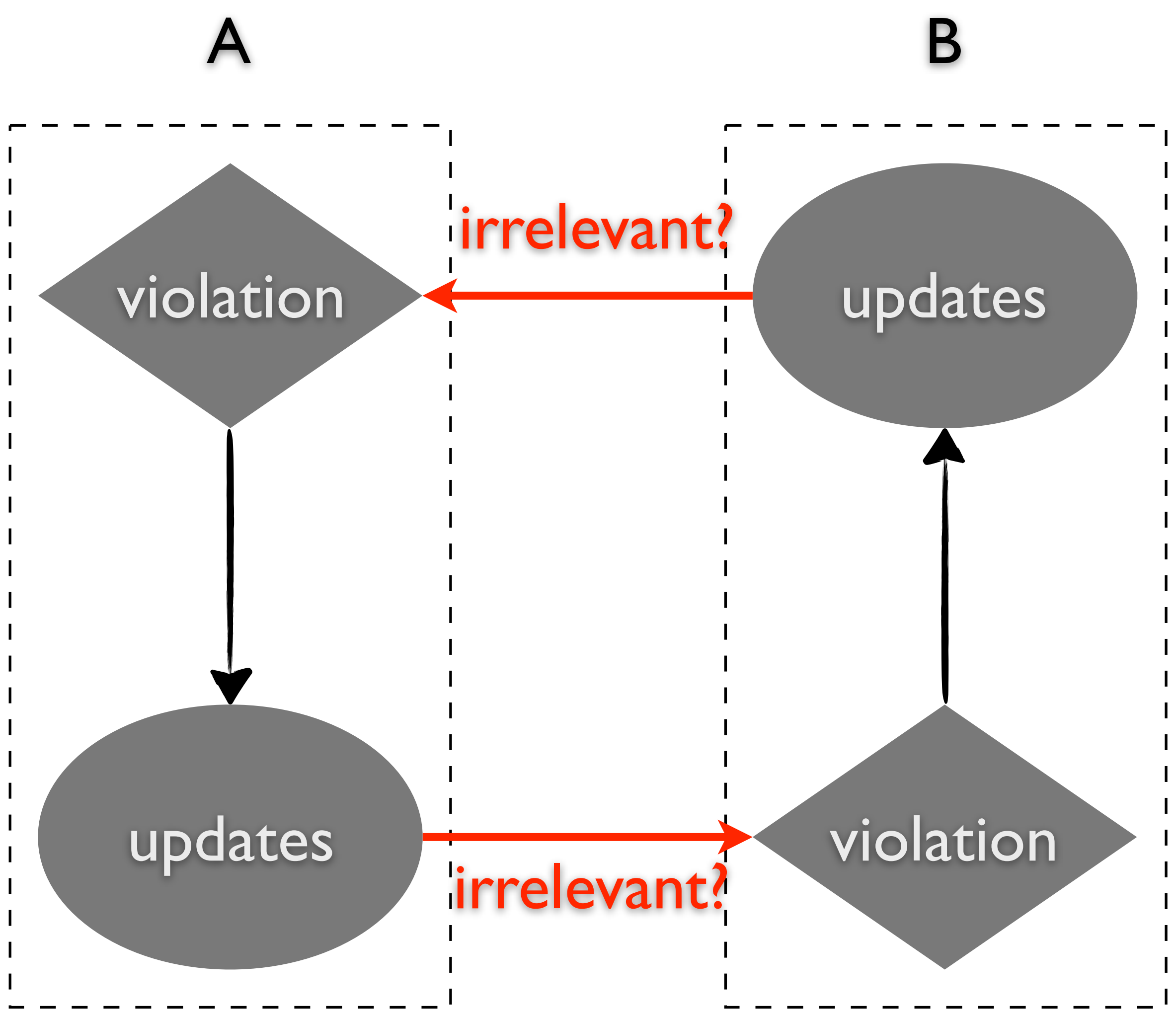
a unified database representation



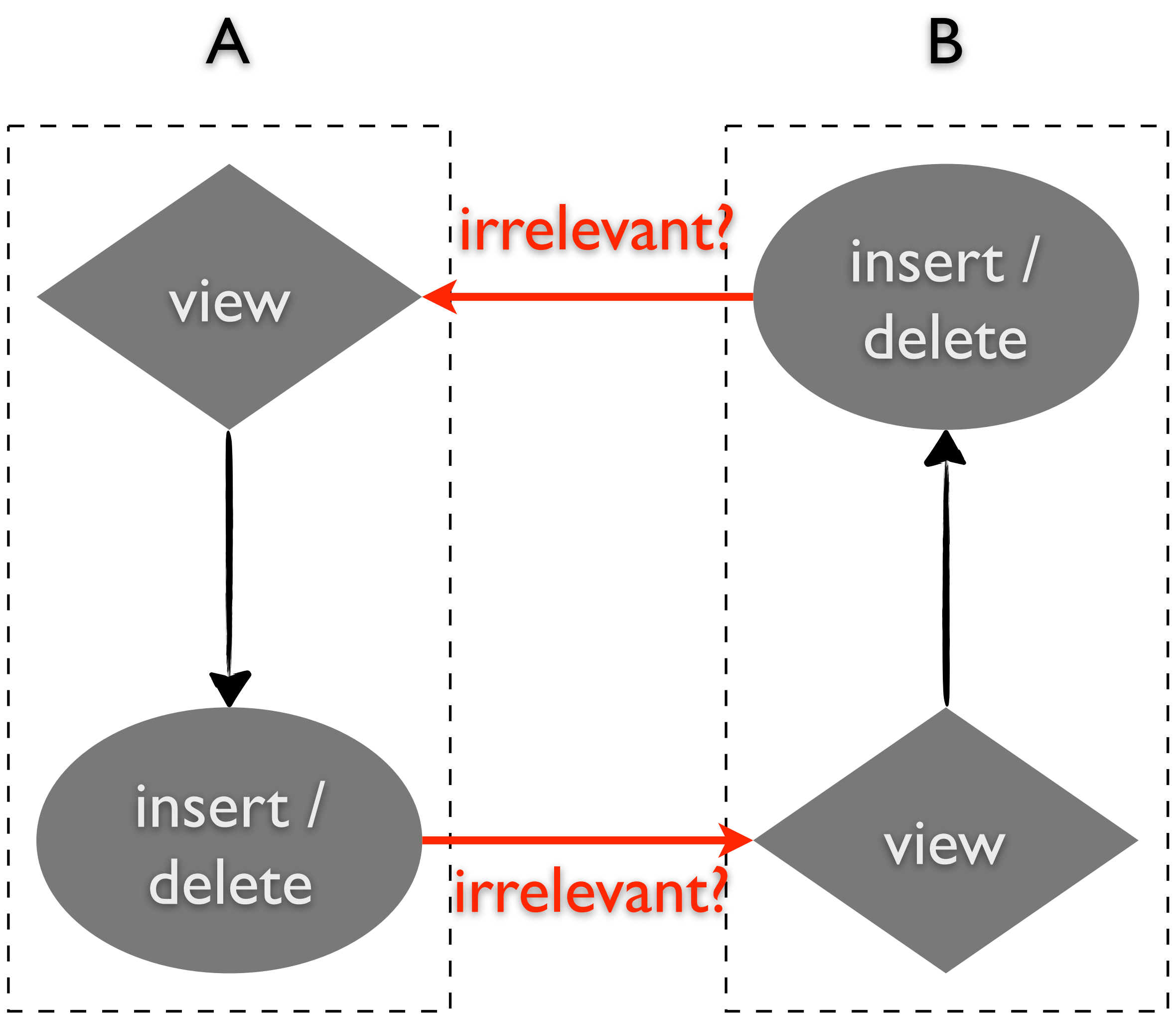
ravel: a database-defined network [SOSR'16]
ravel-net.org

database irrelevance reasoning

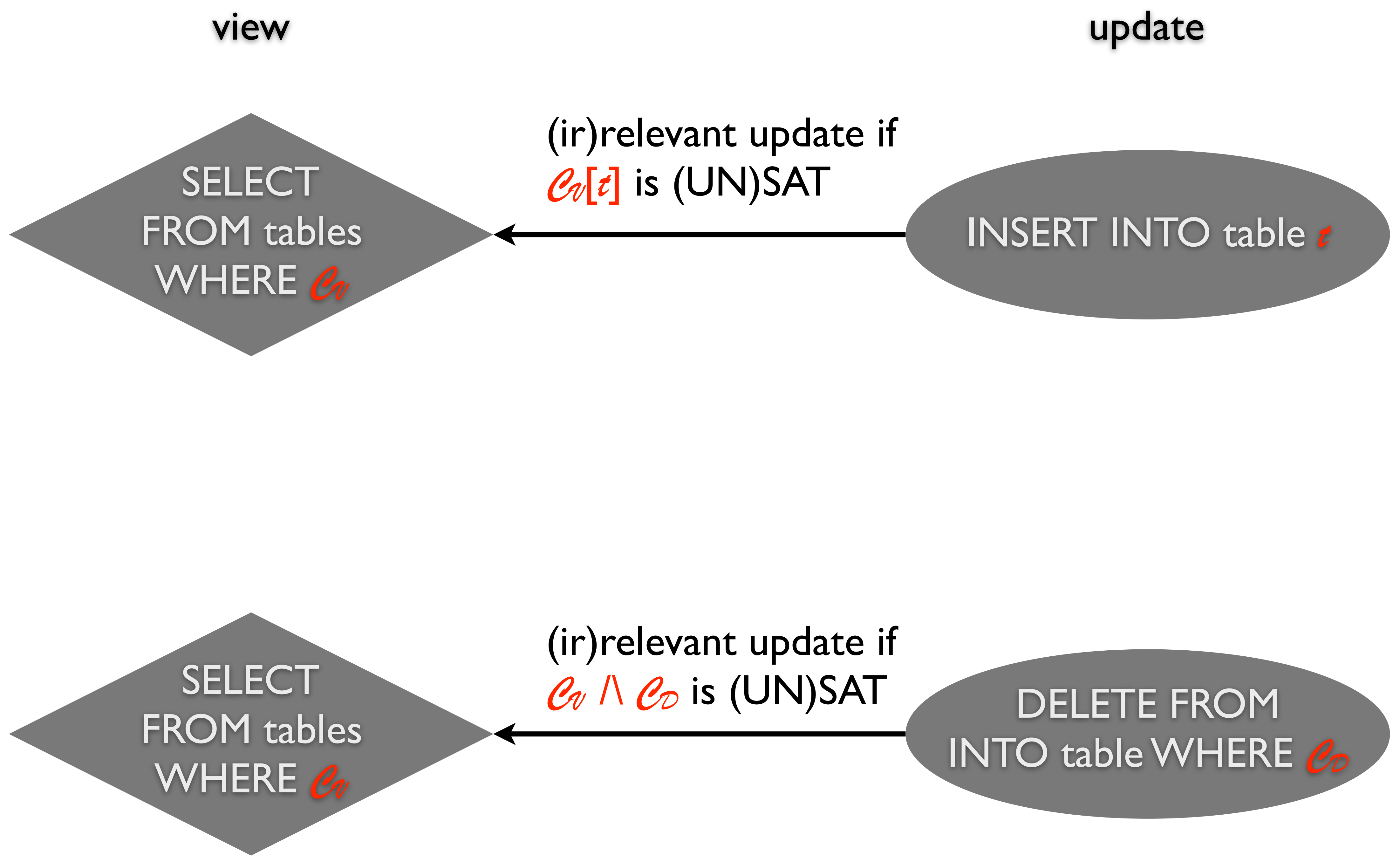
irrelevance reasoning for SDN



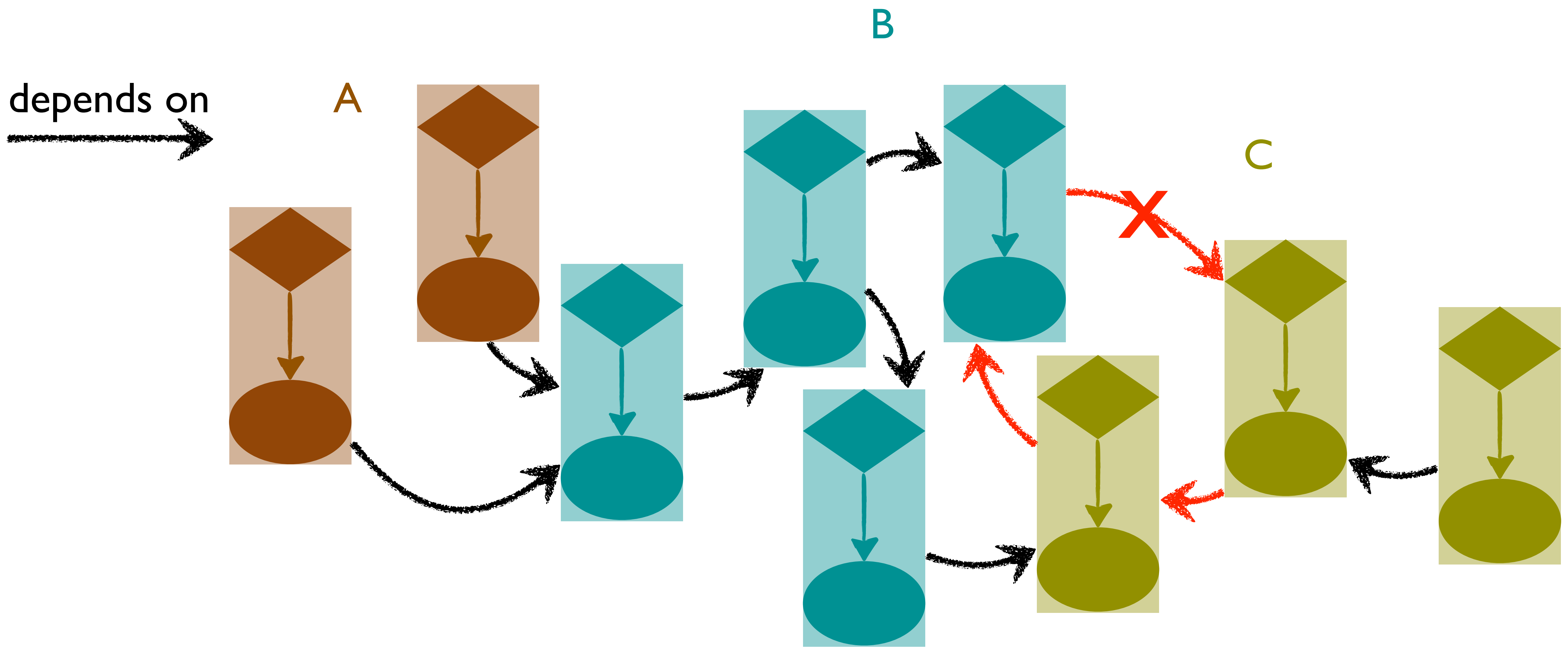
irrelevant database updates



(ir)relevant database update


view
update
SELECT FROM tables WHERE $\mathcal{C}_V$
(ir)relevant update if $\mathcal{C}_V[t]$ is (UN)SAT
INSERT INTO table t
SELECT FROM tables WHERE $\mathcal{C}_V$
(ir)relevant update if $\mathcal{C}_V \wedge \mathcal{C}_D$ is (UN)SAT
DELETE FROM INTO table WHERE $\mathcal{C}_D$

usage: synthesize orchestrator



construct dependency graph

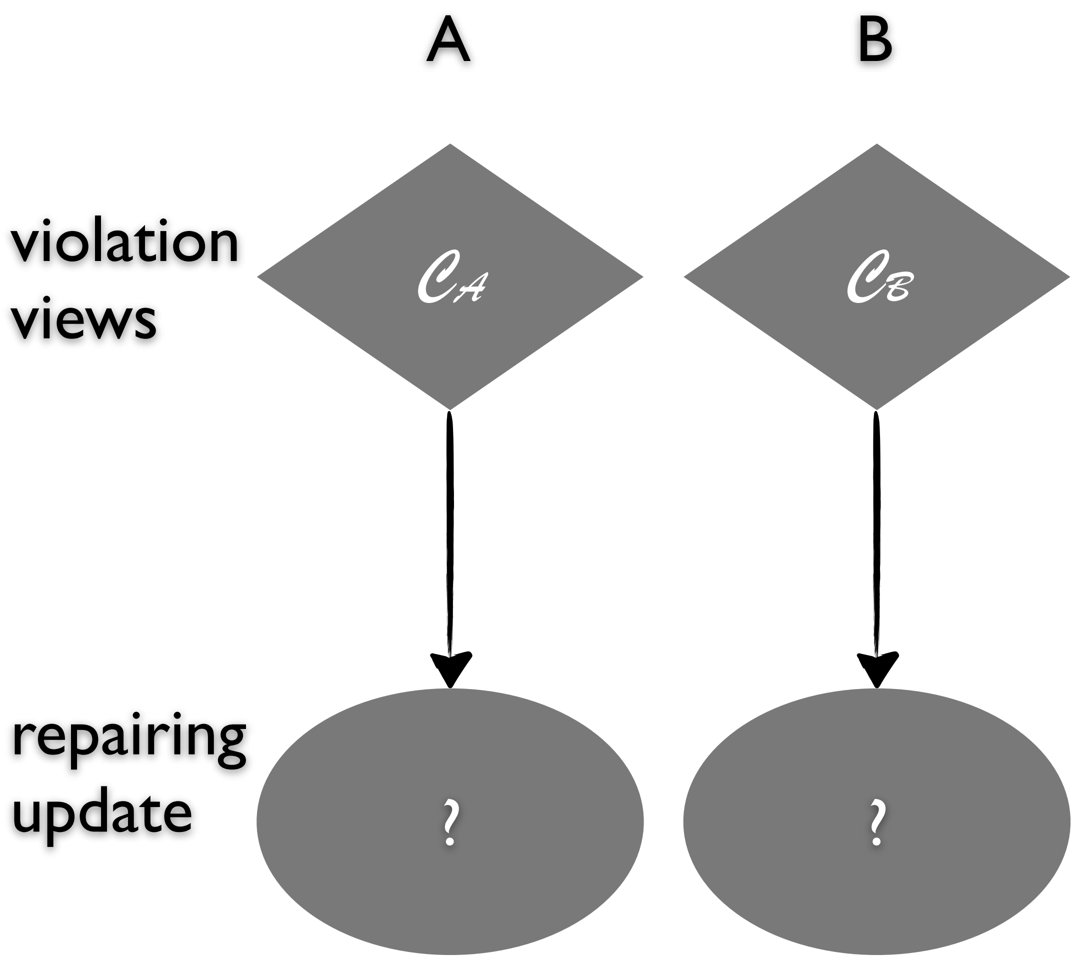
topological sort

- remove conflicts with user guidance
- assign each update a stratum number

synthesize a master orchestrator

- activate an update only when all updates with smaller stratum numbers have completed

usage: reasoning with partial information



conflict-free guarantee

if $\neg C_A \supset \neg C_B$, A is guaranteed to be irrelevant to B

(corollary: synthesize conflict-free updates for A regarding B by rewriting C_A to $C_A \vee C_B$)

feasibility of conflict-free update

if $\neg C_A \wedge \neg C_B$ is SAT, there exists some A update that is irrelevant to B

infeasibility of conflict-free updates

if $\neg C_A \wedge \neg C_B$ is UNSAT, no A update exists that is irrelevant to B

thank you

backup

open questions

obtain the database representation

- use *Ravel*, a database-defined control platform
  - ravel-net.org

extract the database representation from arbitrary control software

- manually construct a map between data objects and database tables
- automatically convert data updates to DB write with conditions?
- extract view condition?

limitation

distribution and concurrency

- the network data plane is a distributed system with concurrent updates
- SDN relies on multiple controller for scalability

combine DB concurrency control and irrelevance reasoning?