(Ir)relevance reasoning for software-defined network

Anduo Wang[*] Jason Croft[†] Xueyuan Mei[†]
Matthew Caesar[†] Brighten Godfrey[†]

[*]*Temple University* [†]*University of Illinois Urbana-Champaign*

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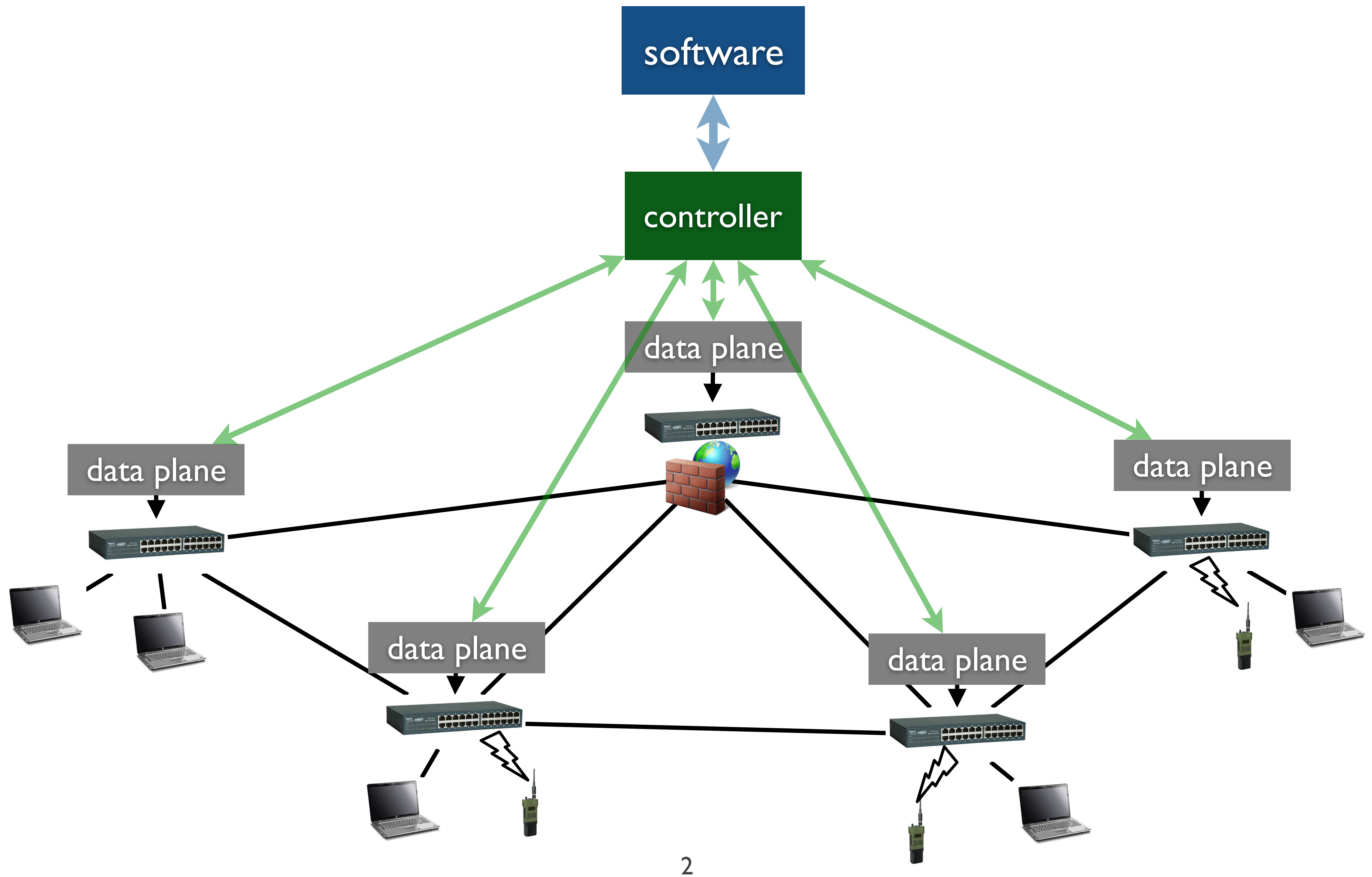
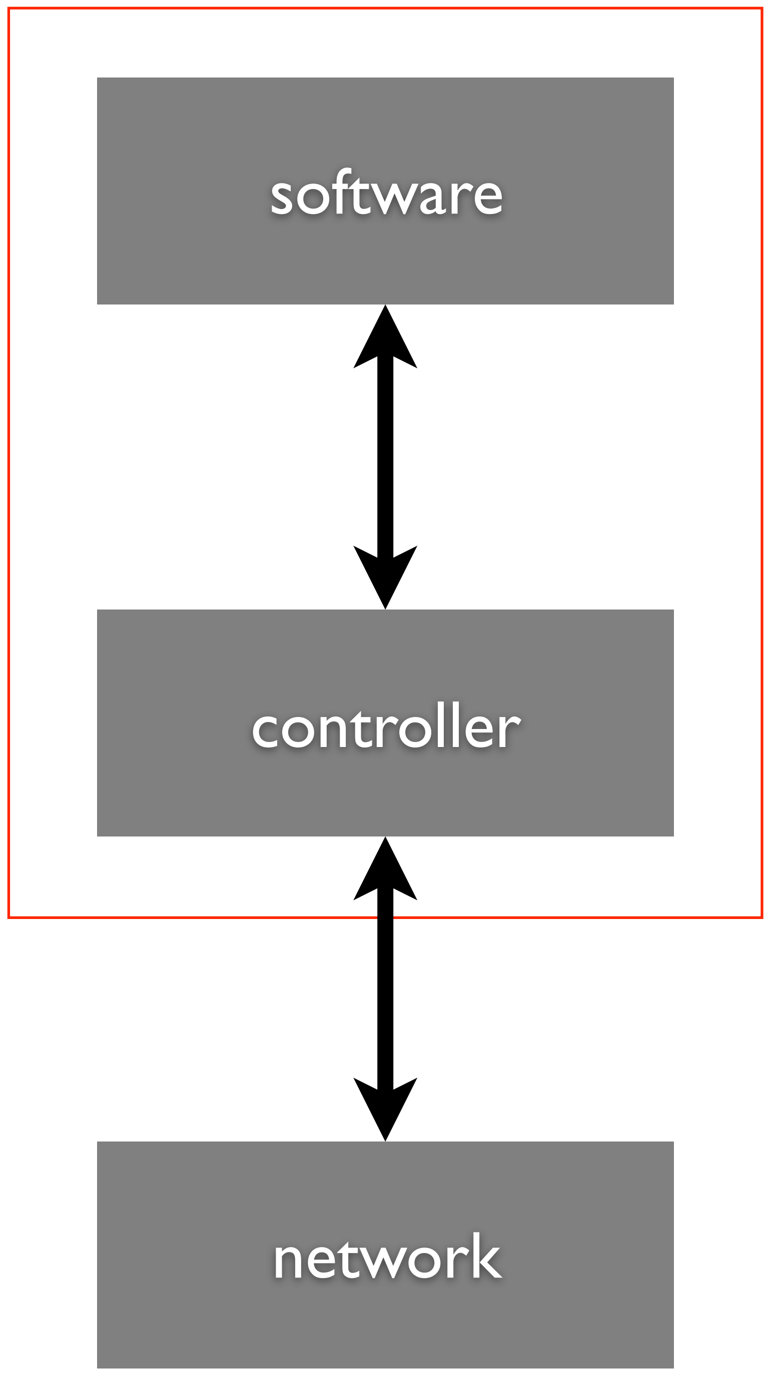
software-defined networking (SDN)

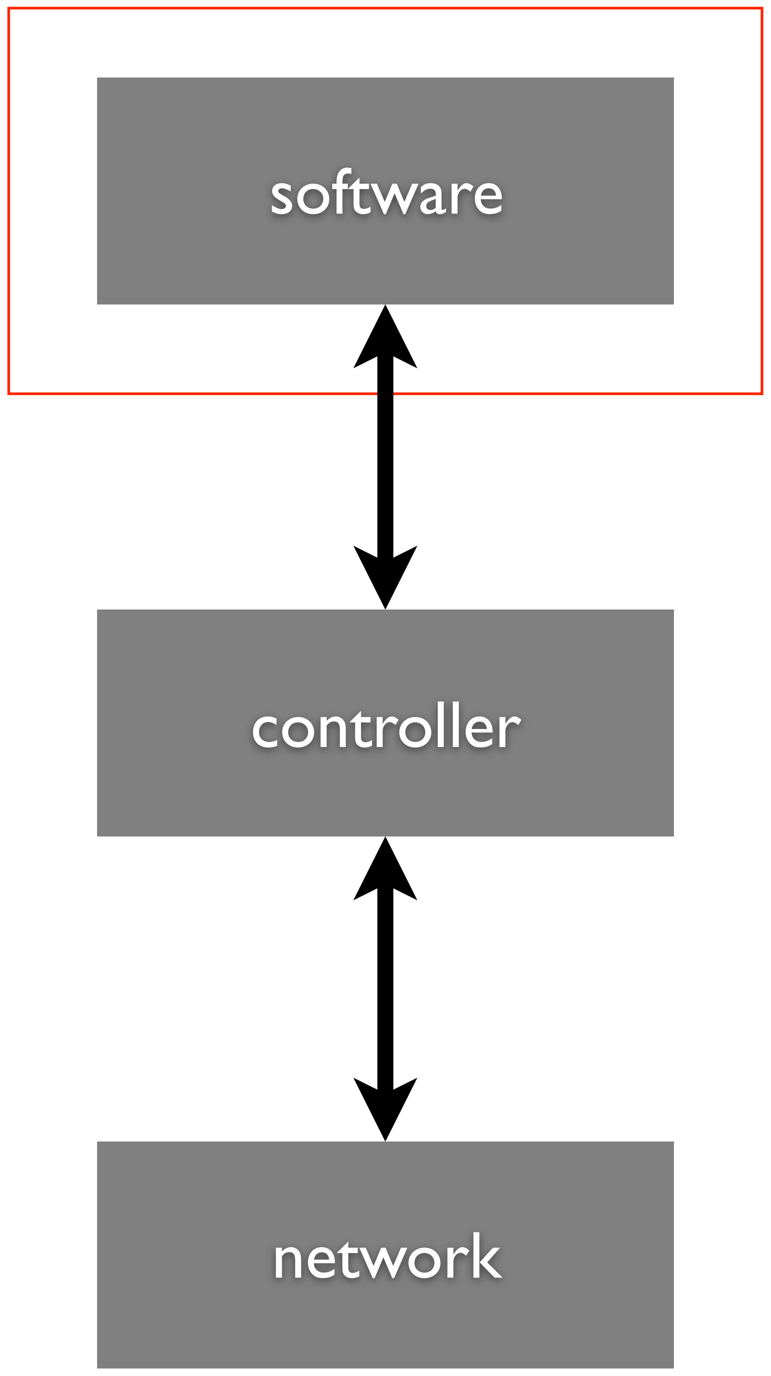


software-defined networking (SDN)



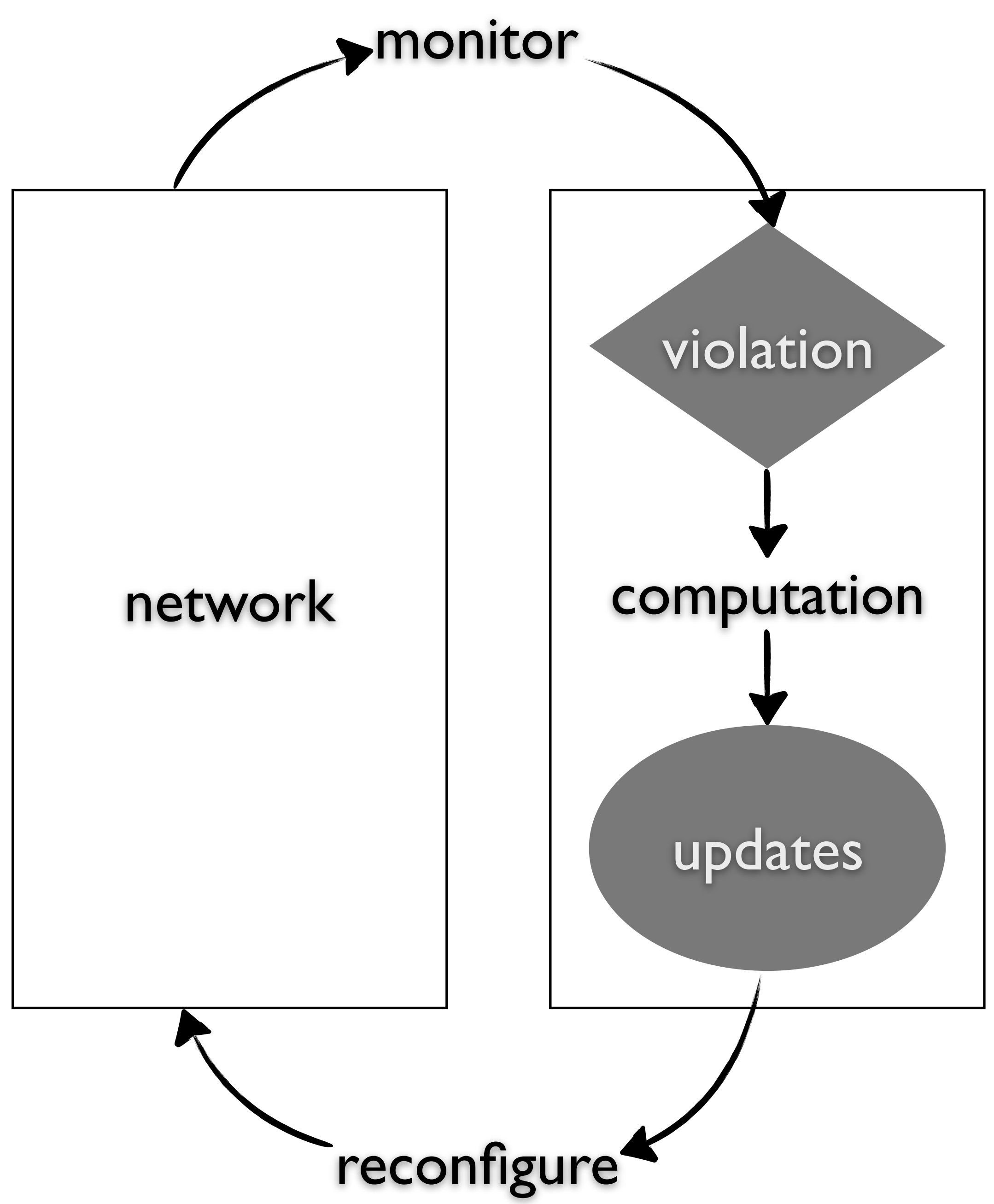
SDN moves complexity to
control software:
an opportunity and challenge

software-defined networking (SDN)



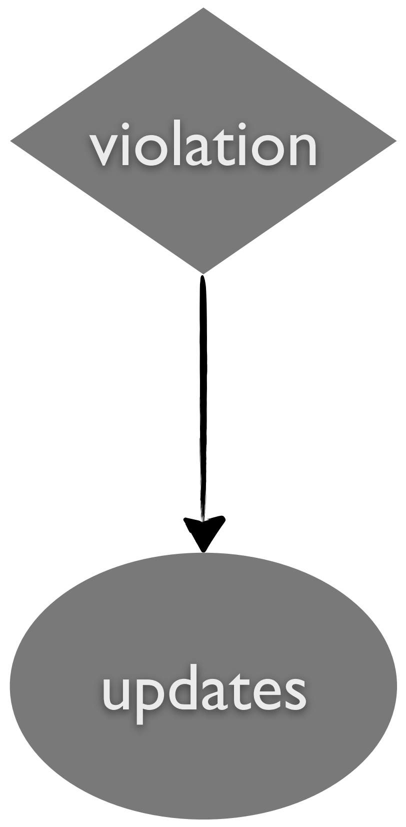
this talk

SDN control software

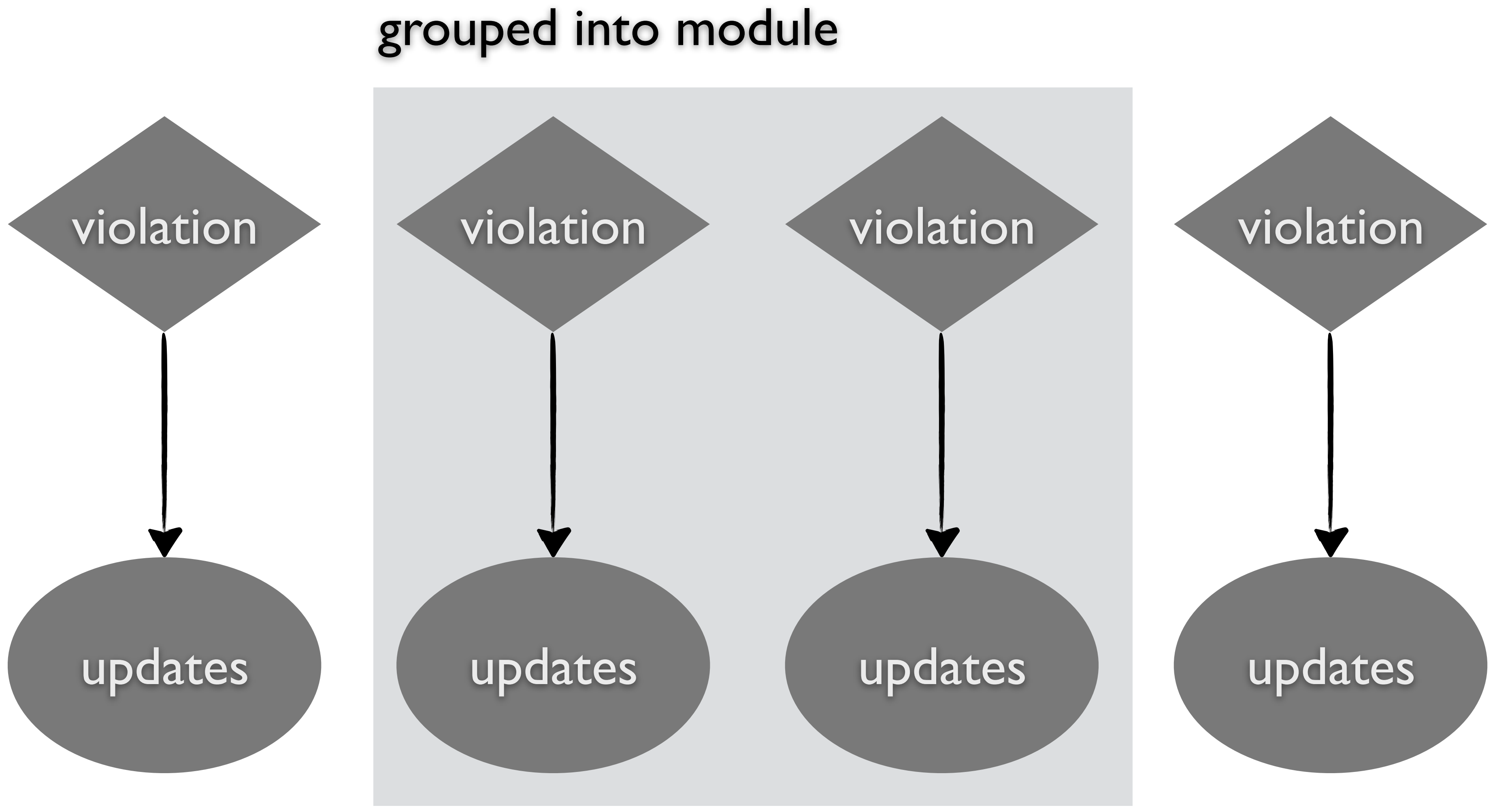


SDN control software

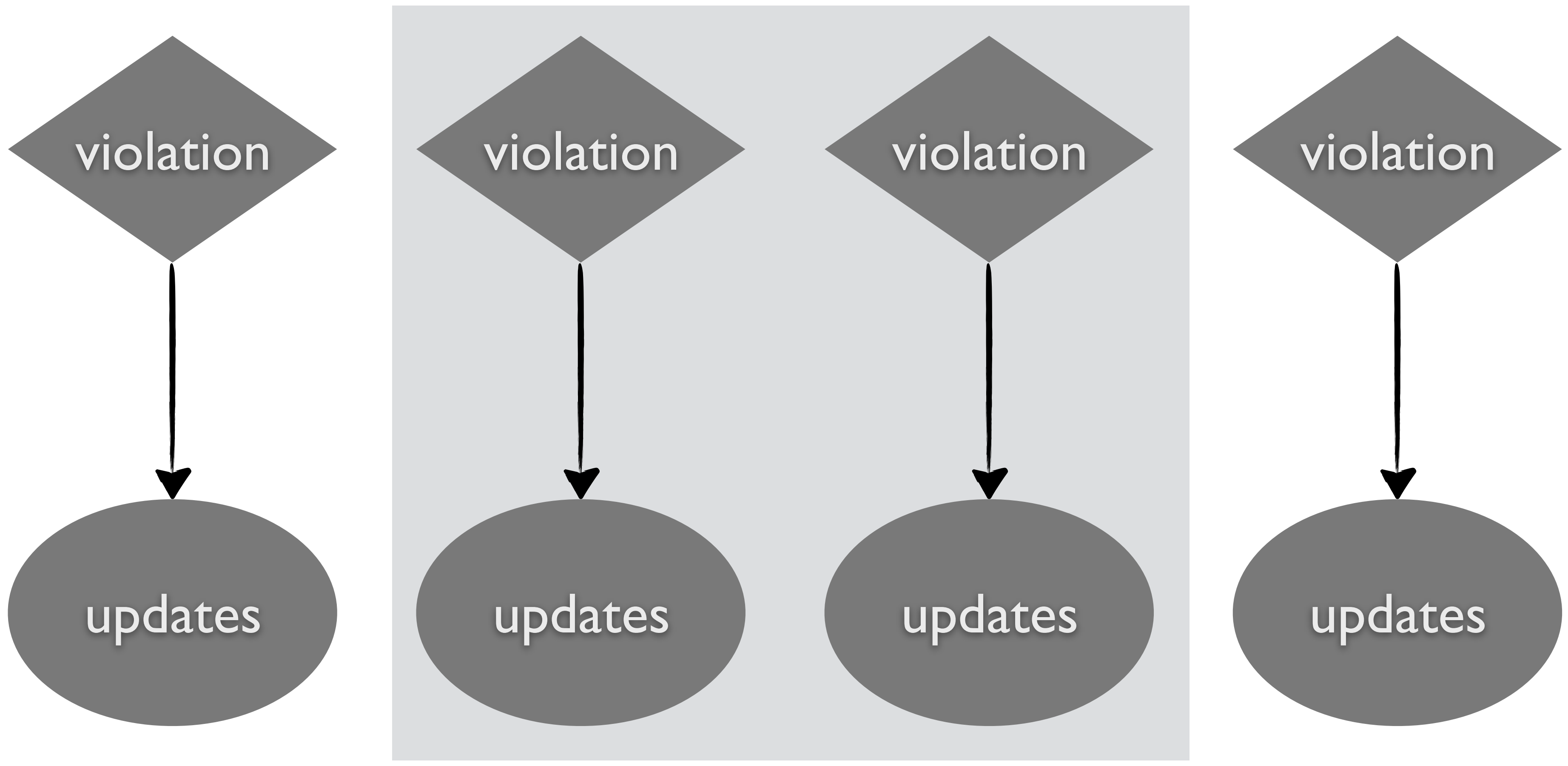
an individual control operation



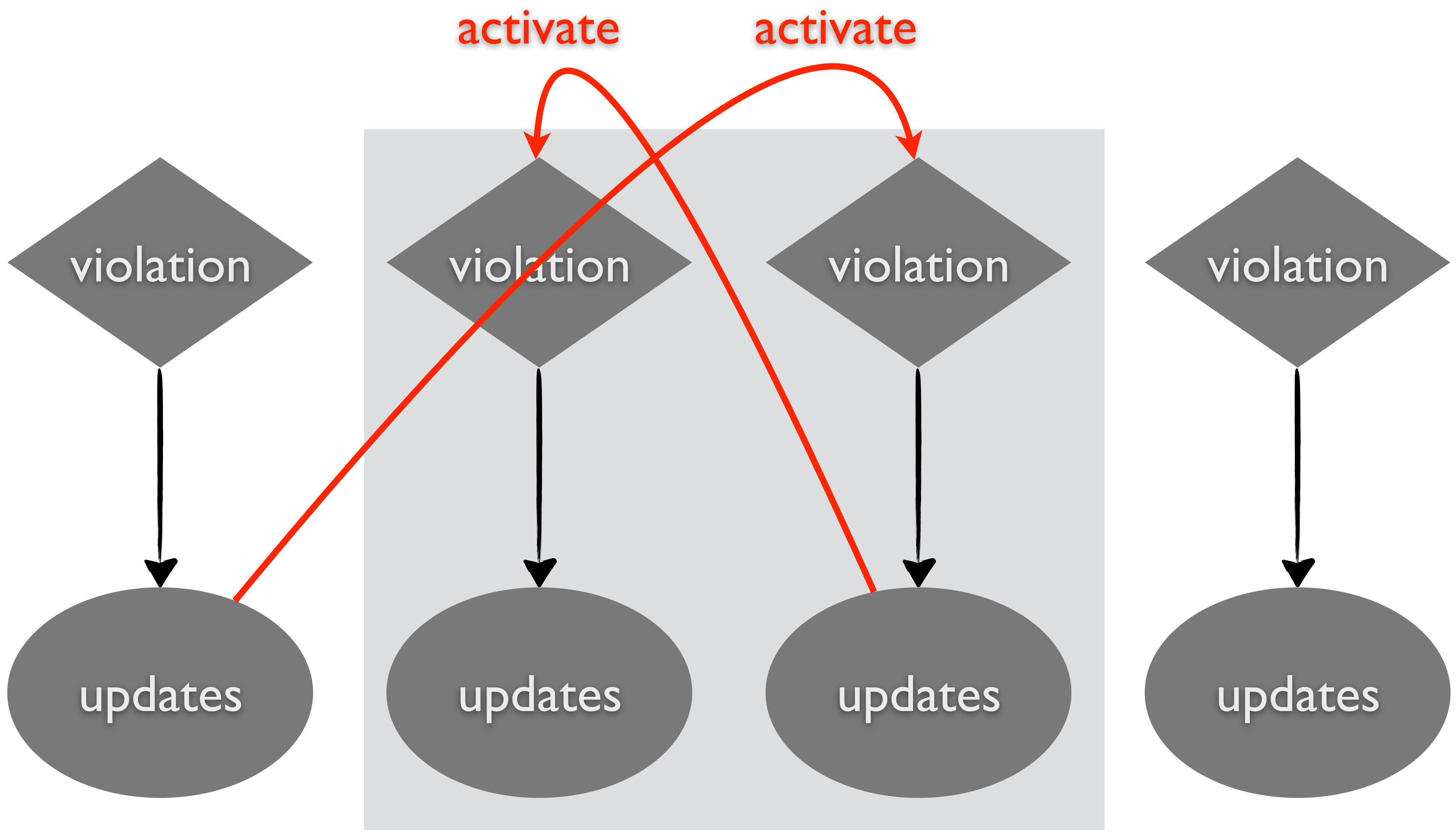
SDN control software



SDN control software



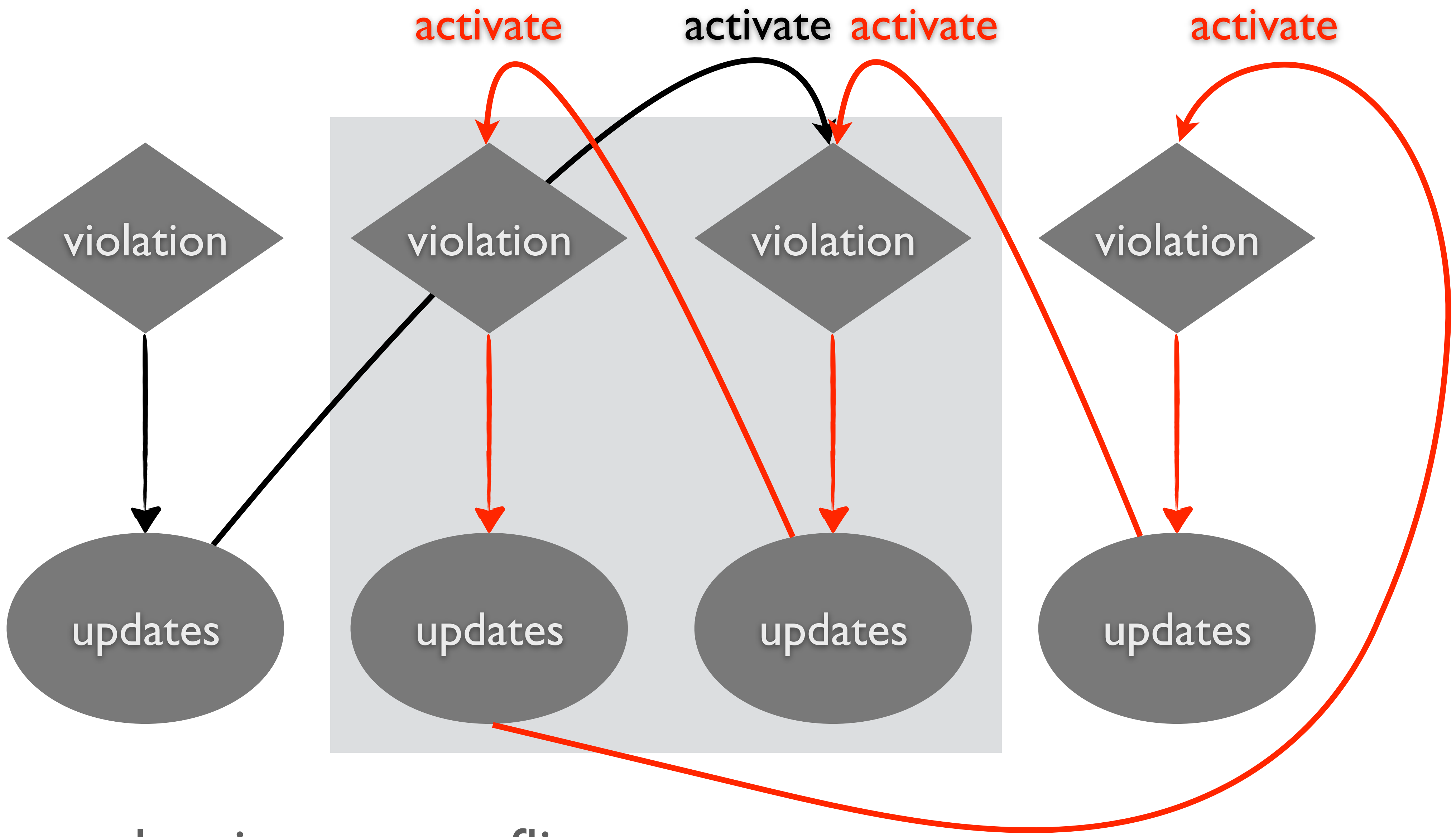
managing complexity in control software



dependency occur within and across modules

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

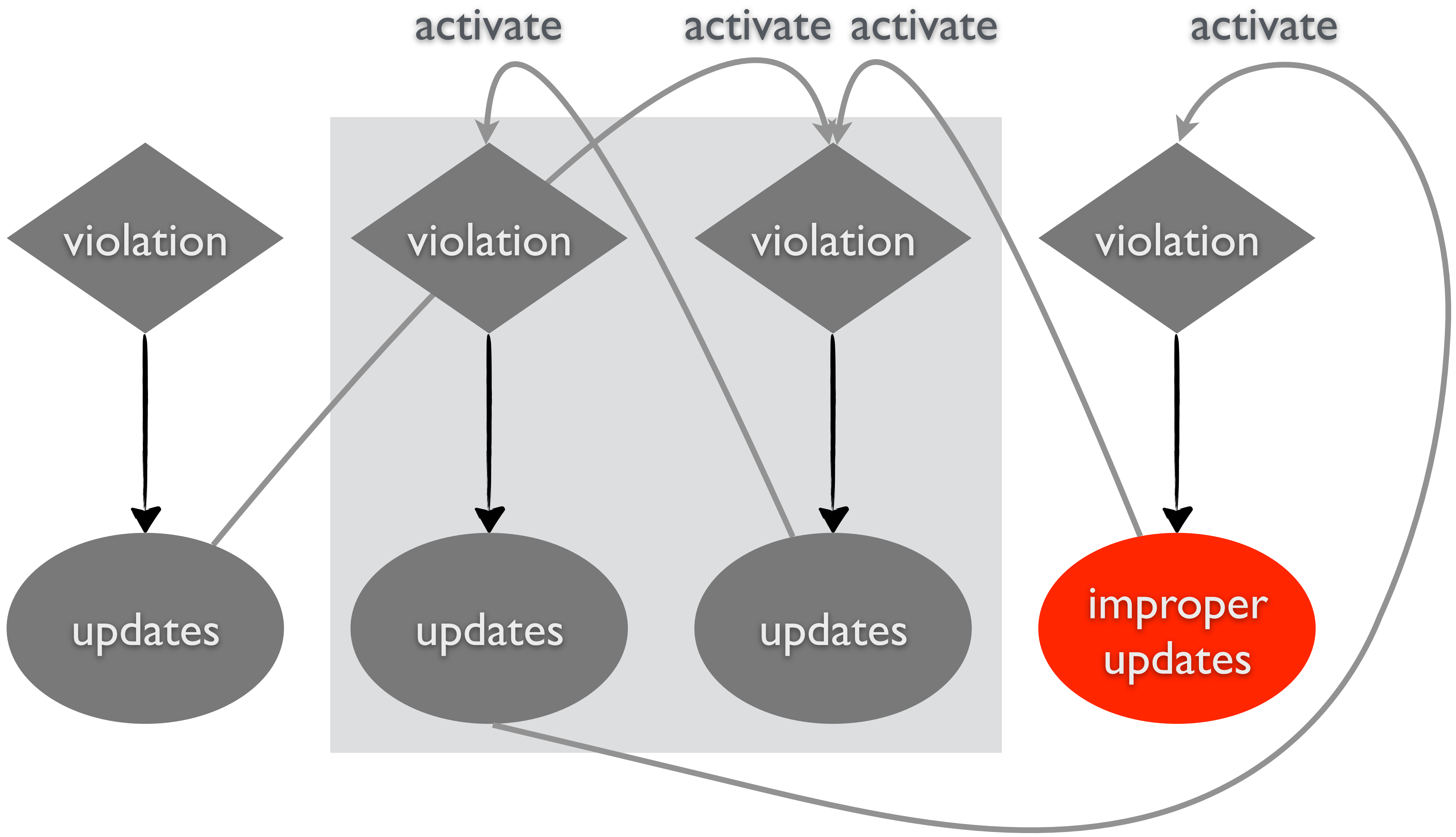
managing complexity in control software



multiple dependencies can conflict

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

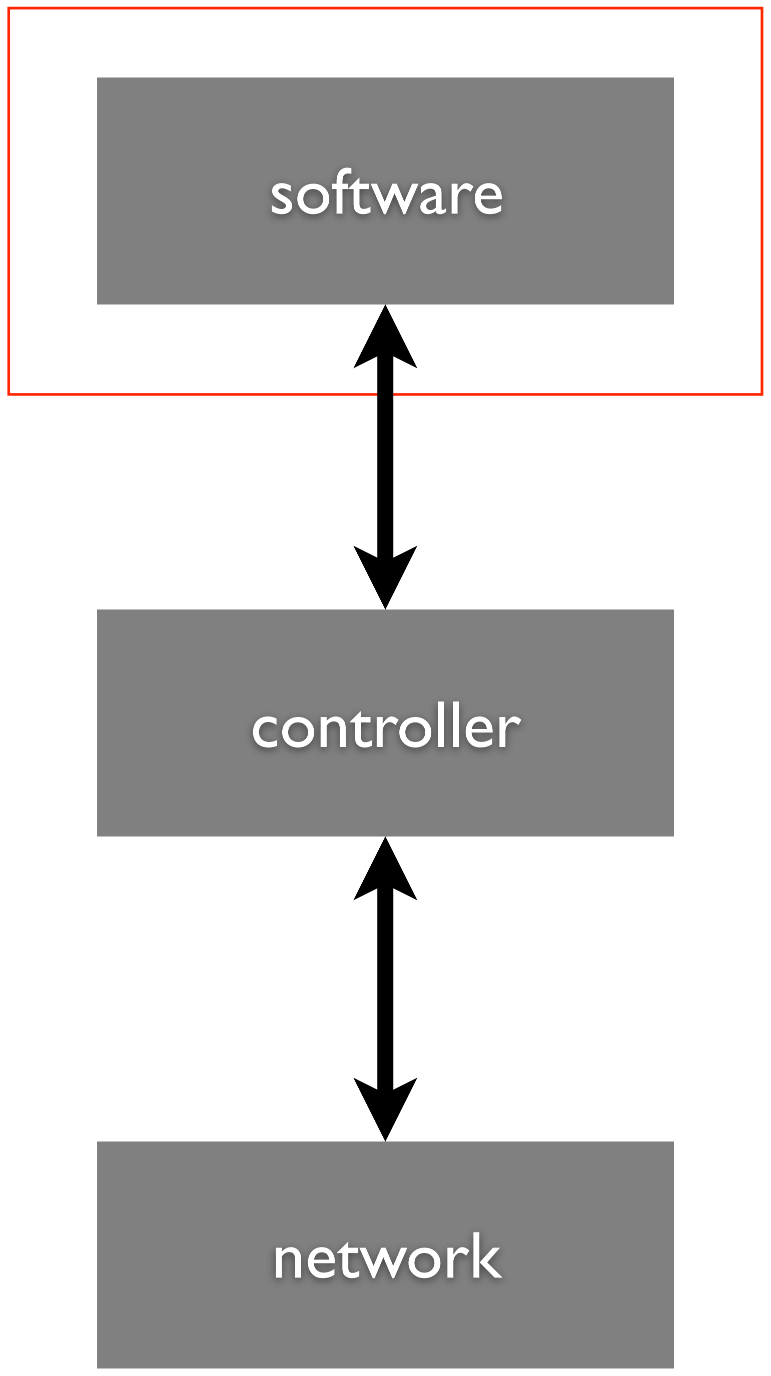
managing complexity in control software



updates can go wrong

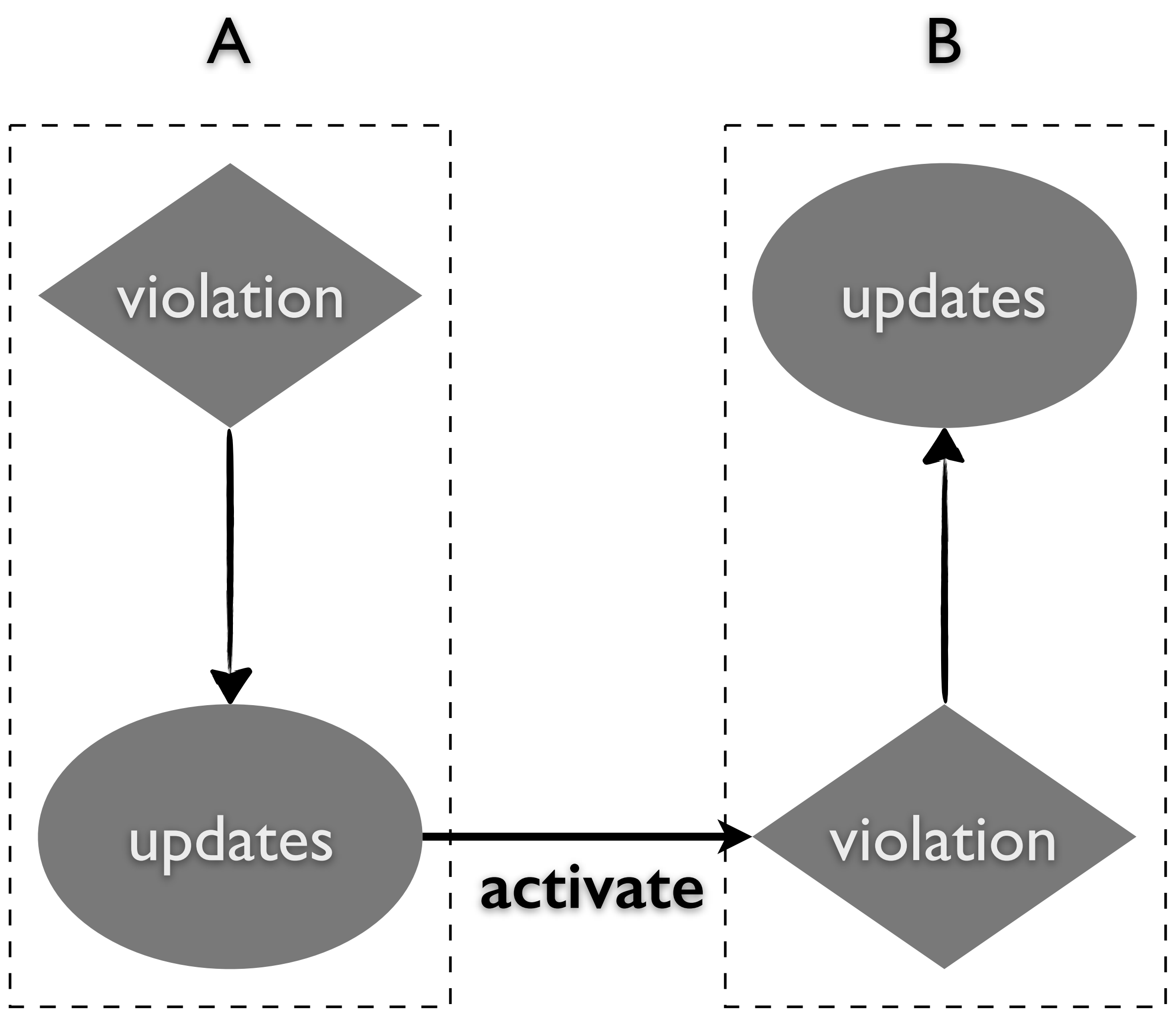
- debugging and verification [SIGCOMM'14, NSDI'13, 15, 16]
- limitation: post-mortem, identify incorrect events/states but not revealing incorrect control logic

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

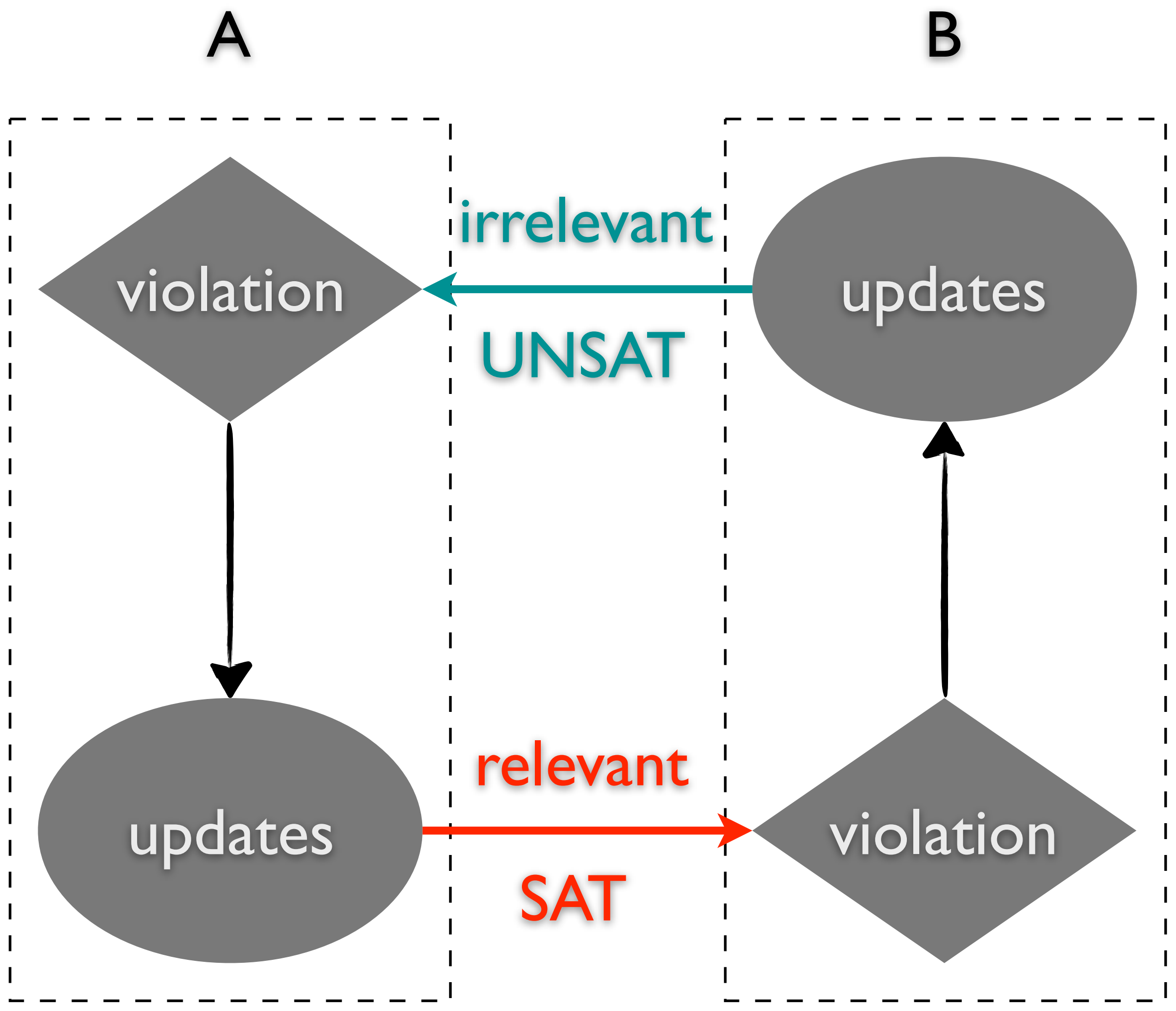


operation **A depends on B**

(1) A update can activate B

(2) B update never activates A

dependency by (ir)relevance reasoning



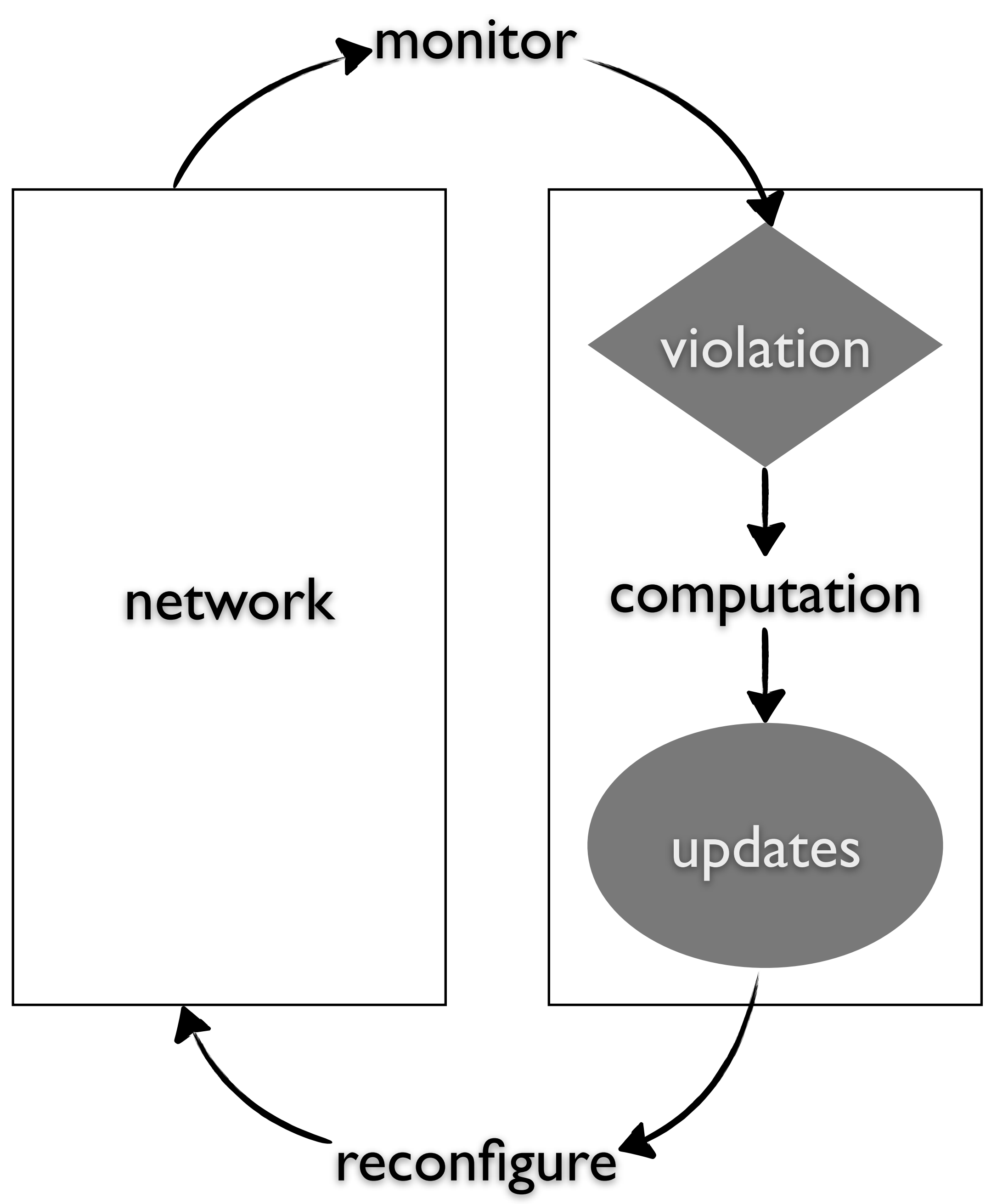
operation A depends on B

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

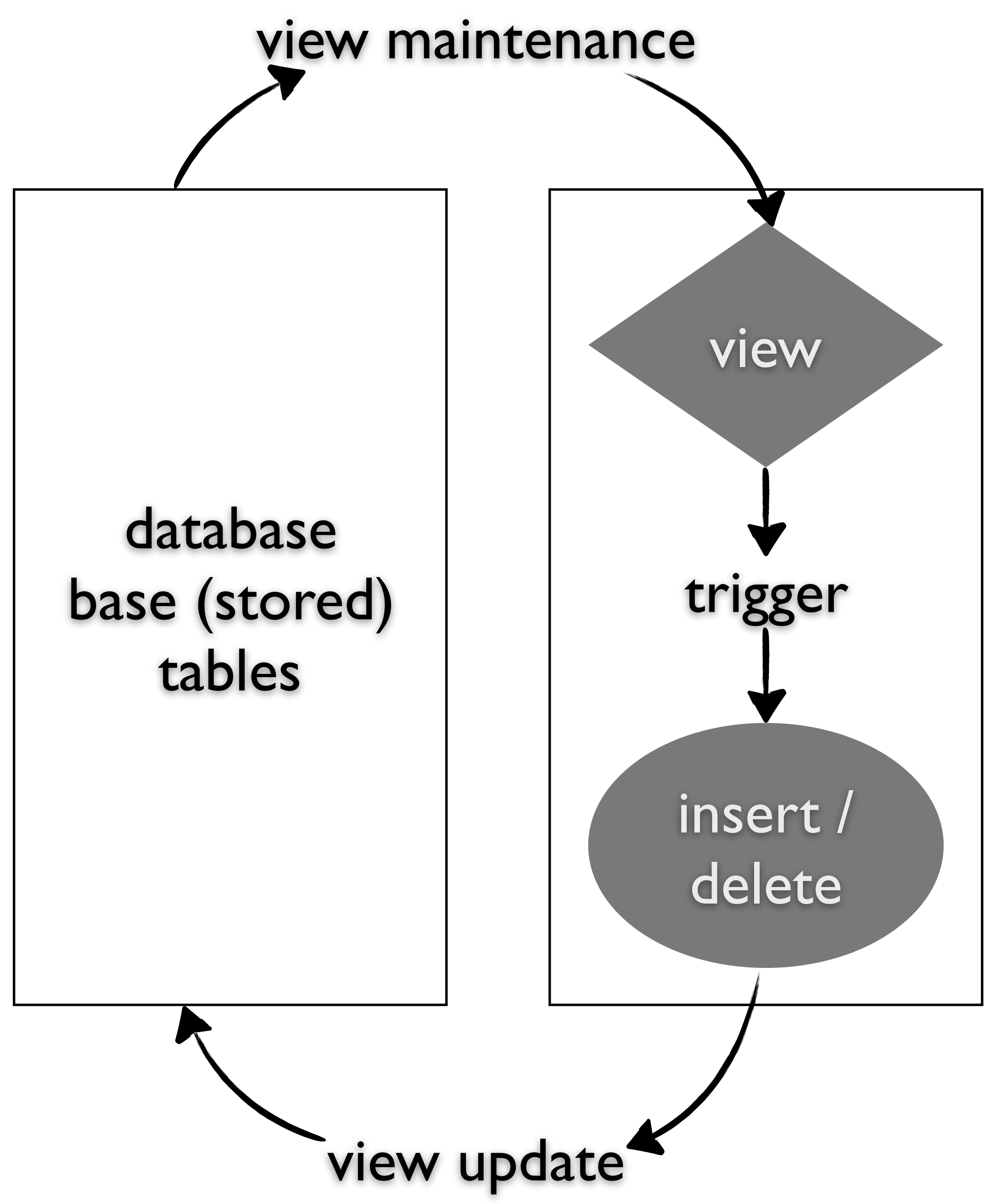
(2) B is irrelevant to A: cannot find a B update that violates A

formal model

SDN control loop



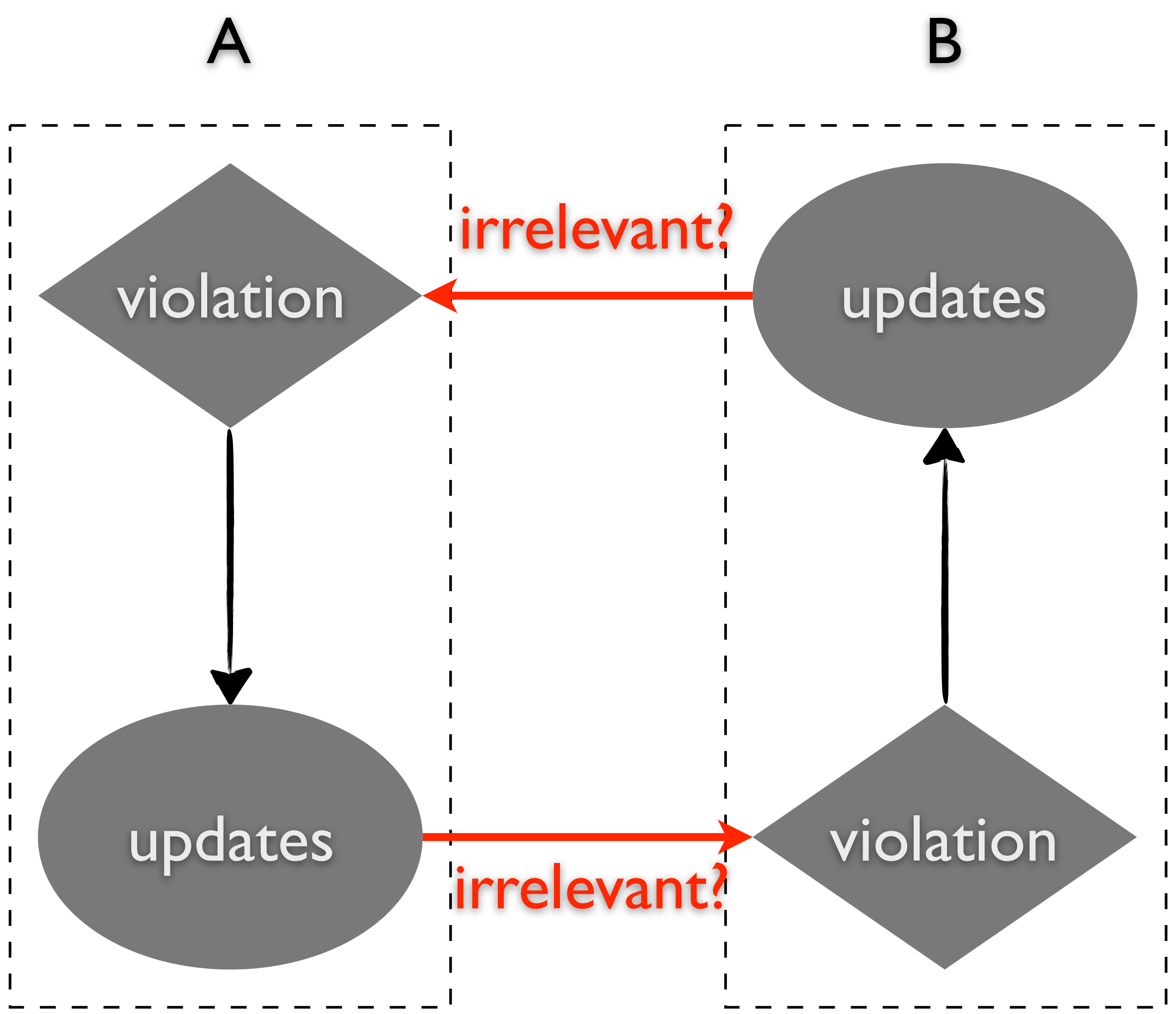
a unified database representation



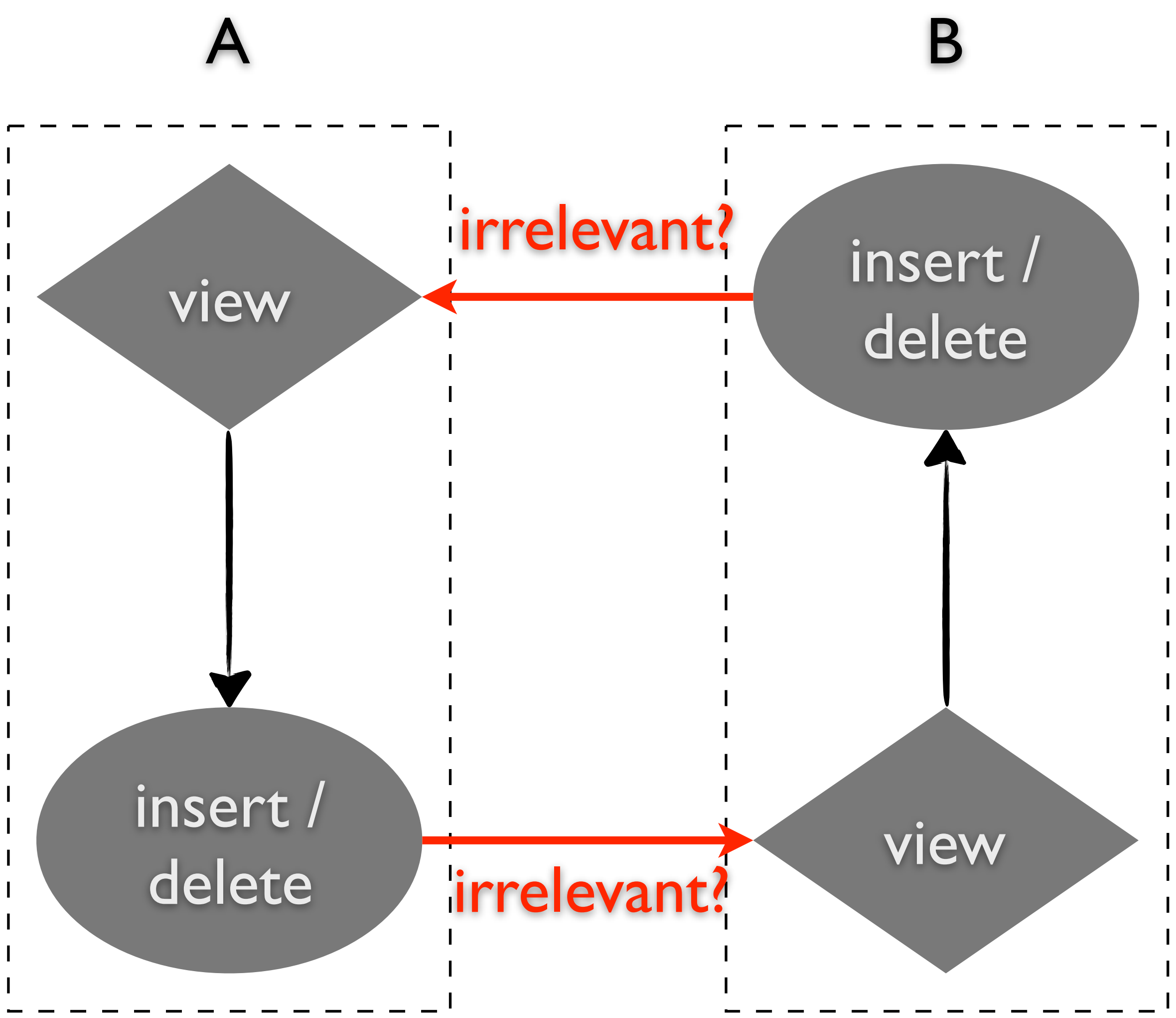
ravel: a database-defined network [SOSR'16]
ravel-net.org

database irrelevance reasoning

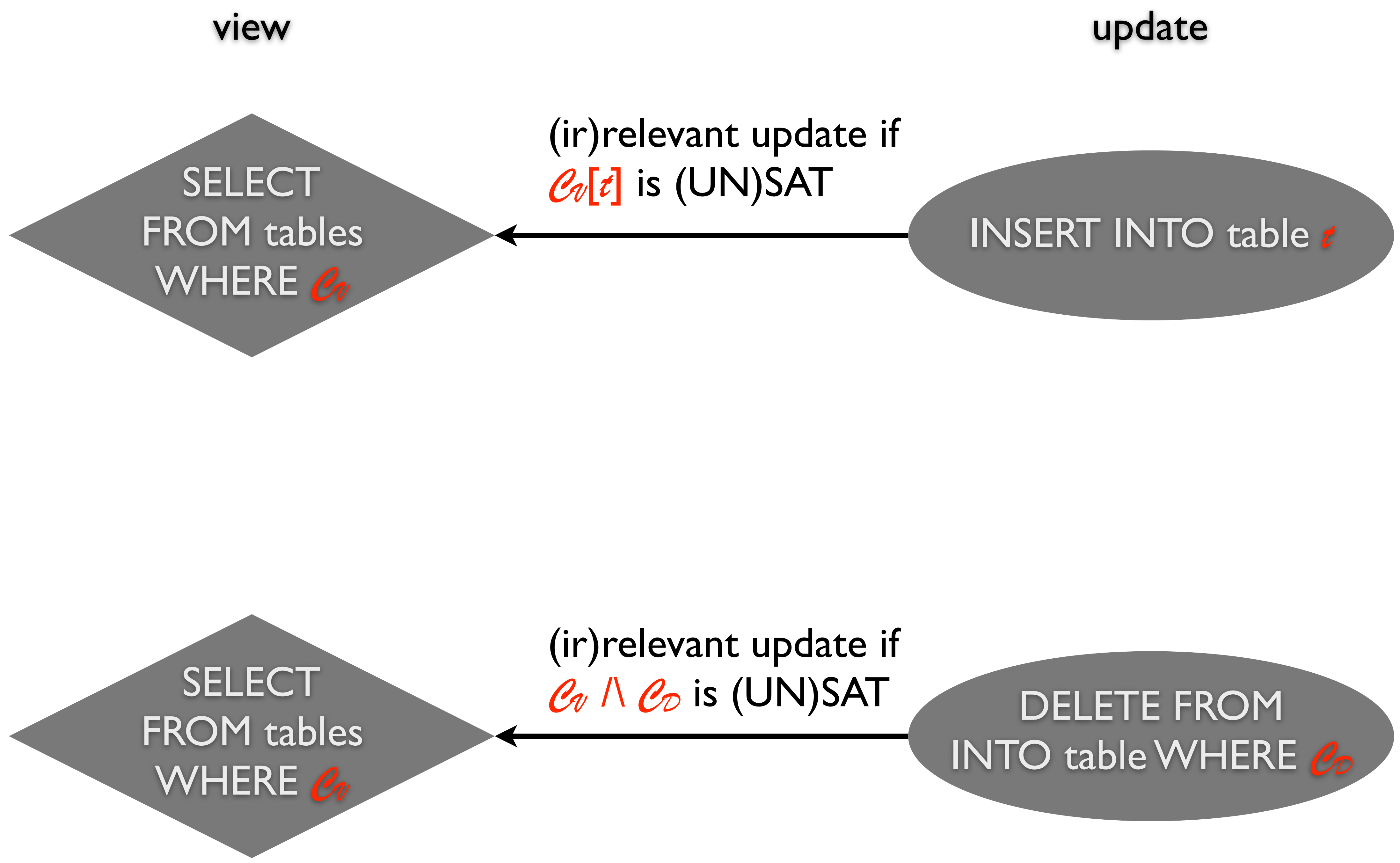
irrelevance reasoning for SDN



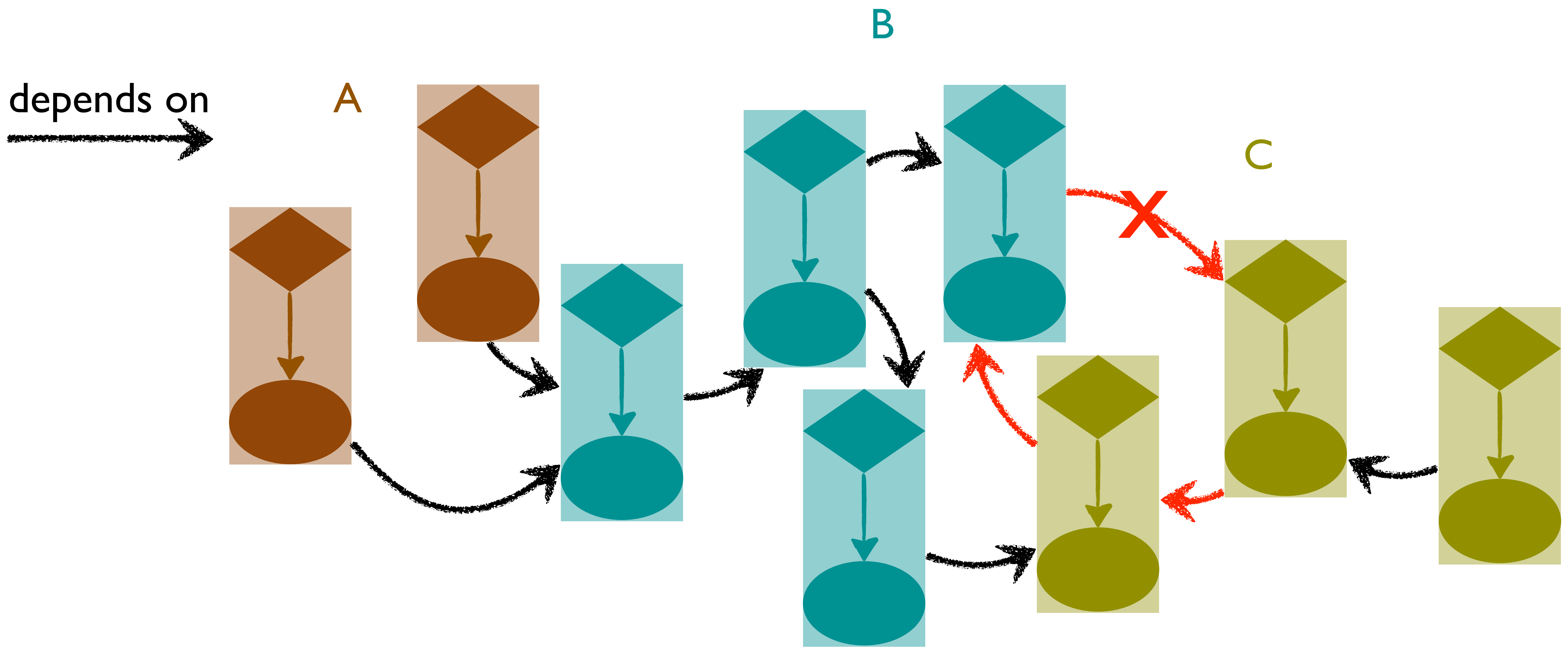
irrelevant database updates



(ir)relevant database update


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

usage: synthesize orchestrator



construct dependency graph

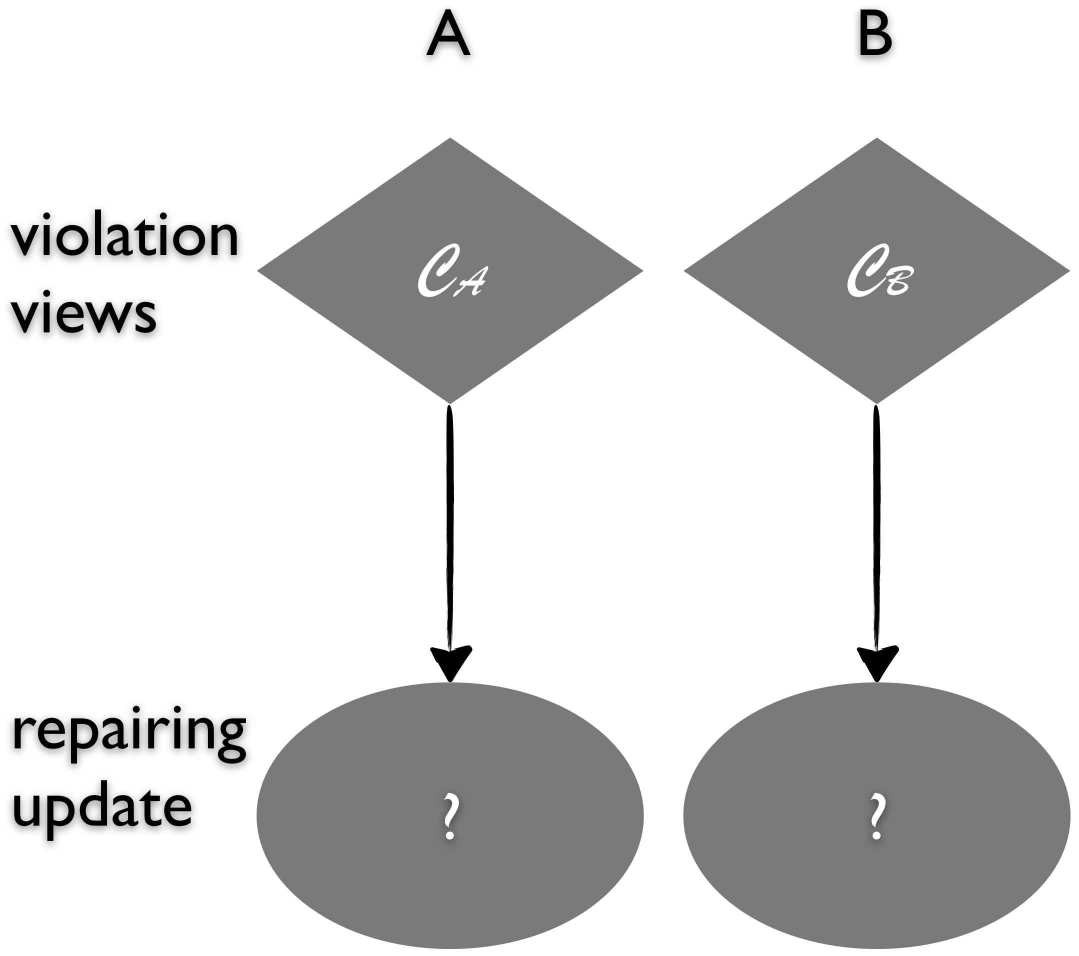
topological sort

- 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?