Minimum Disclosure Routing for Network Virtualization

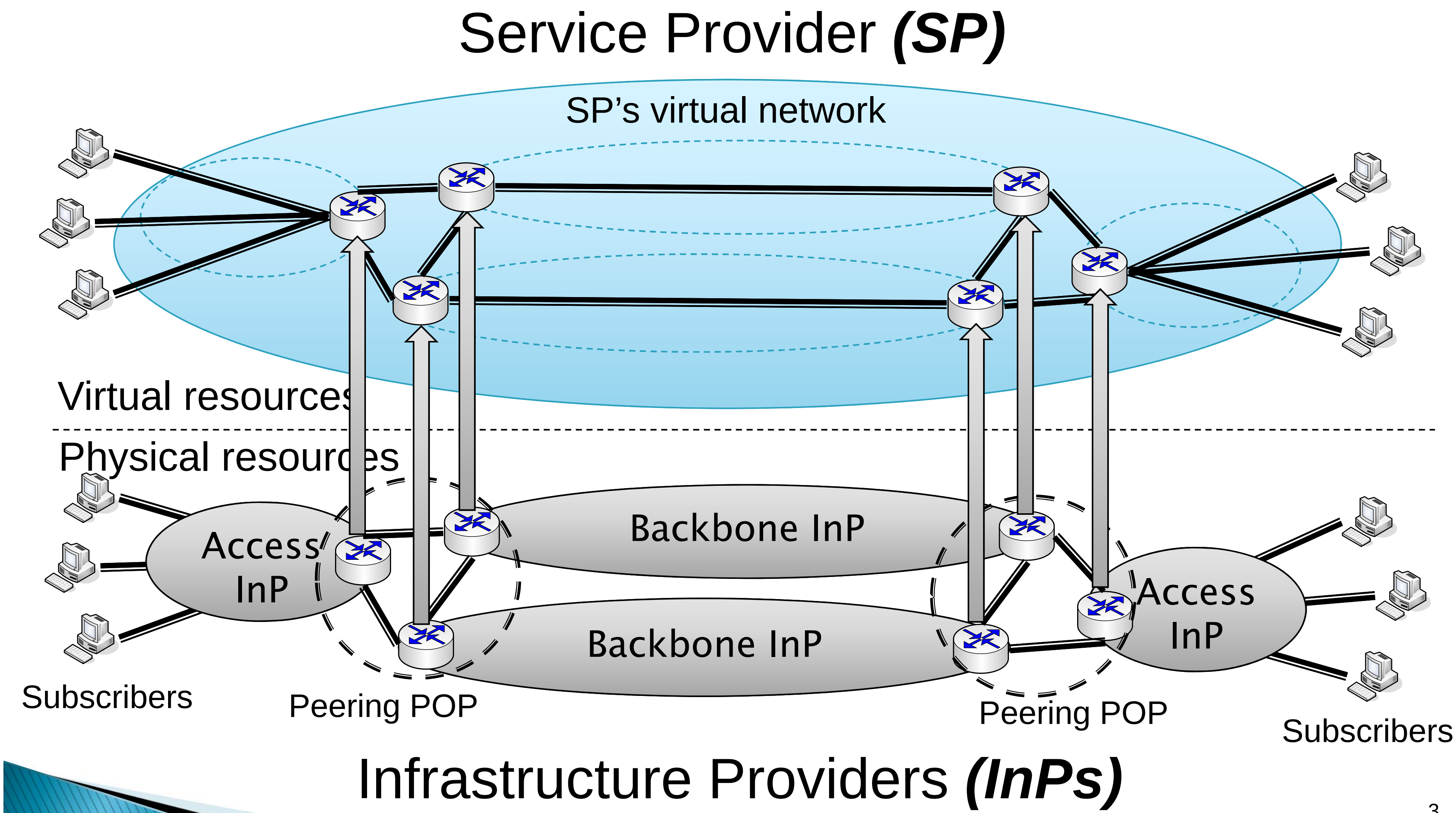
Masaki Fukushima, Teruyuki Hasegawa, Toru Hasegawa
KDDI R&D Laboratories Inc.

Akihiro Nakao
The University of Tokyo

Outline

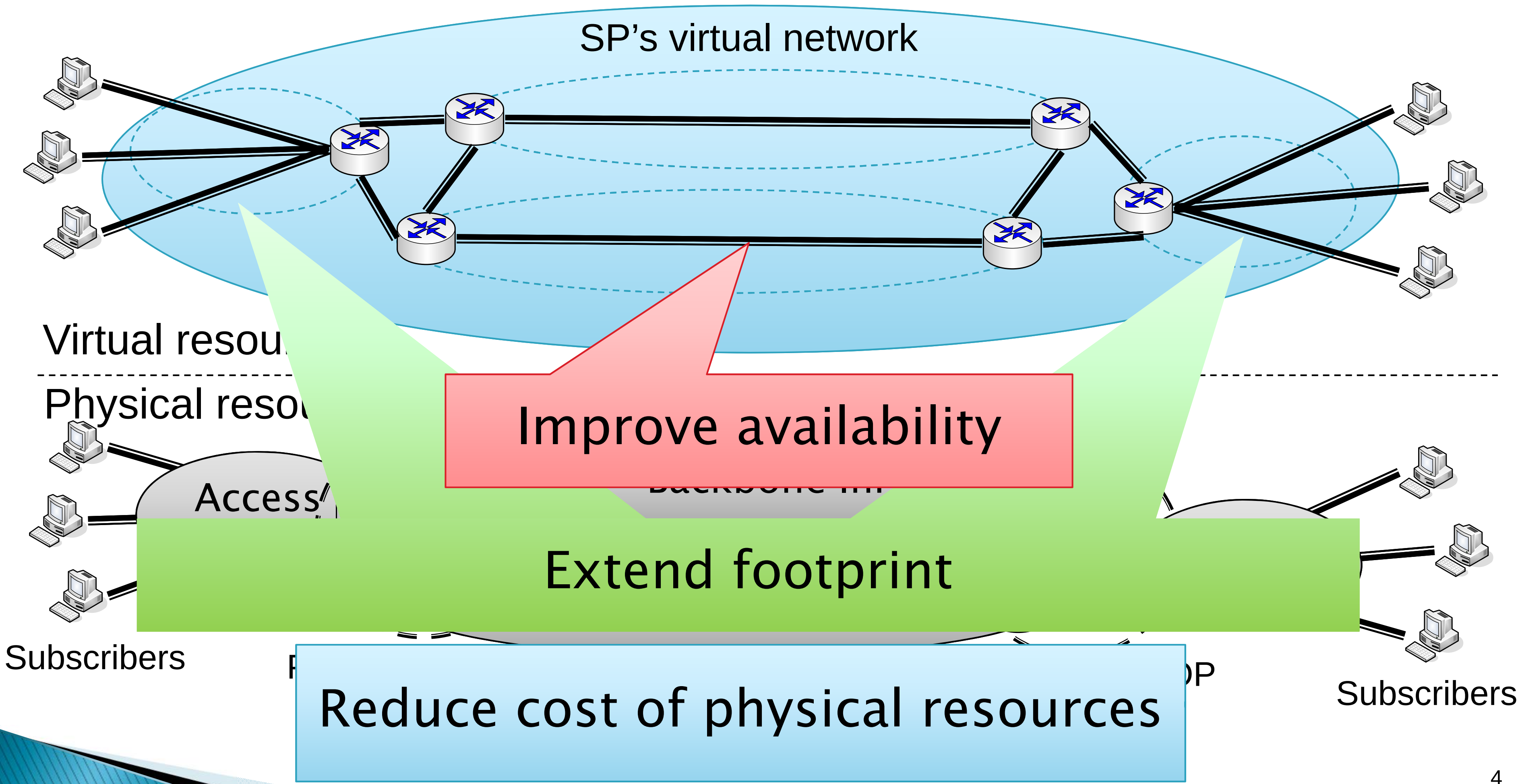
- Background & Motivation
  - Network Virtualization (NV)
- Problem
  - Minimum Disclosure Routing (MDR)
- Related Problem
  - Secure Multiparty Computation (SMC)
- Our solution for MDR
- Feasibility of our solution
- Conclusions & Future work

Background:
Network Virtualization (NV) Environment

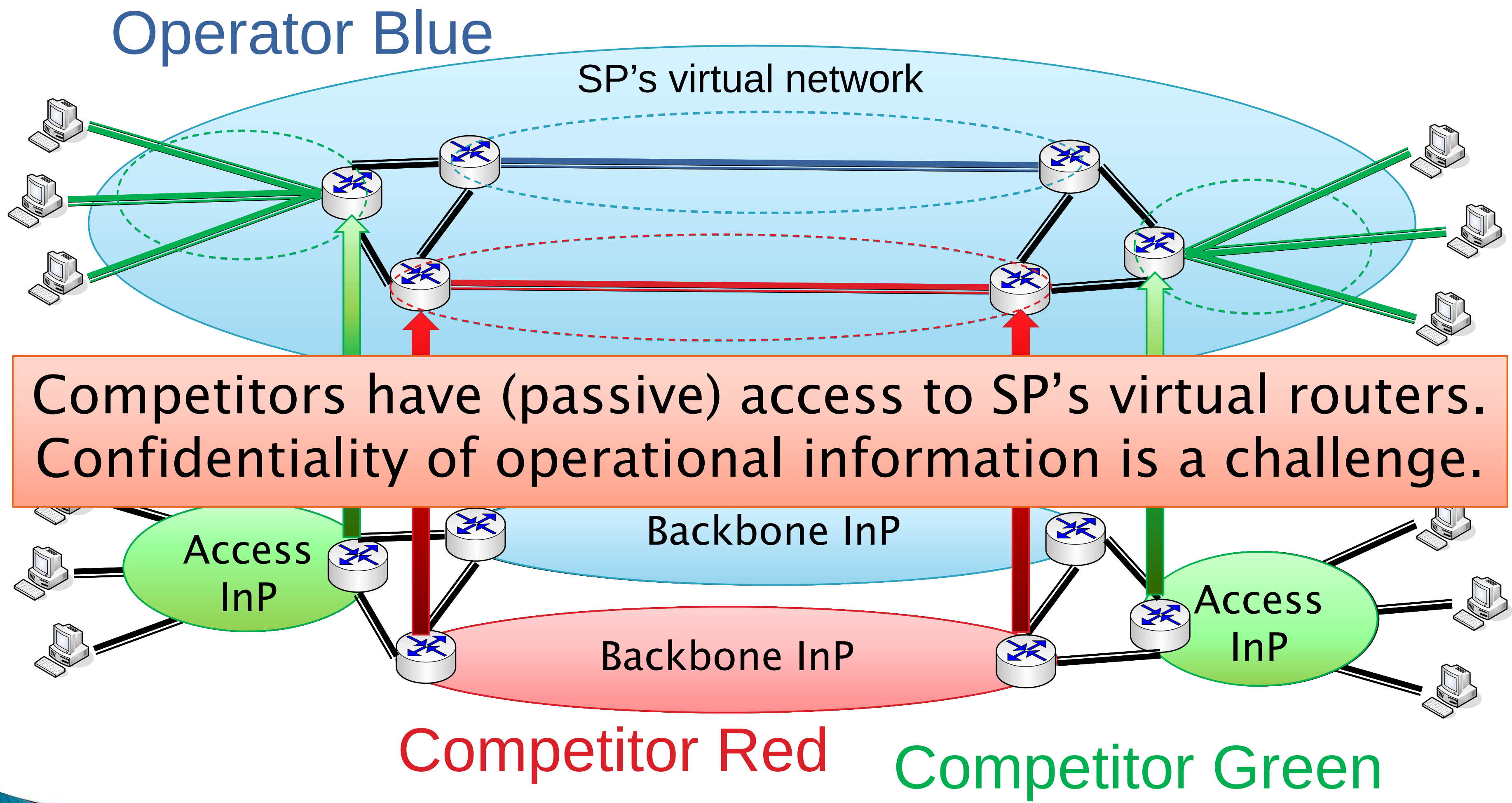


Background: NV brings merits to SP

Service Provider ***(SP)***



Motivation: NV endangers confidentiality of SP



Competitors have (passive) access to SP's virtual routers.
Confidentiality of operational information is a challenge.

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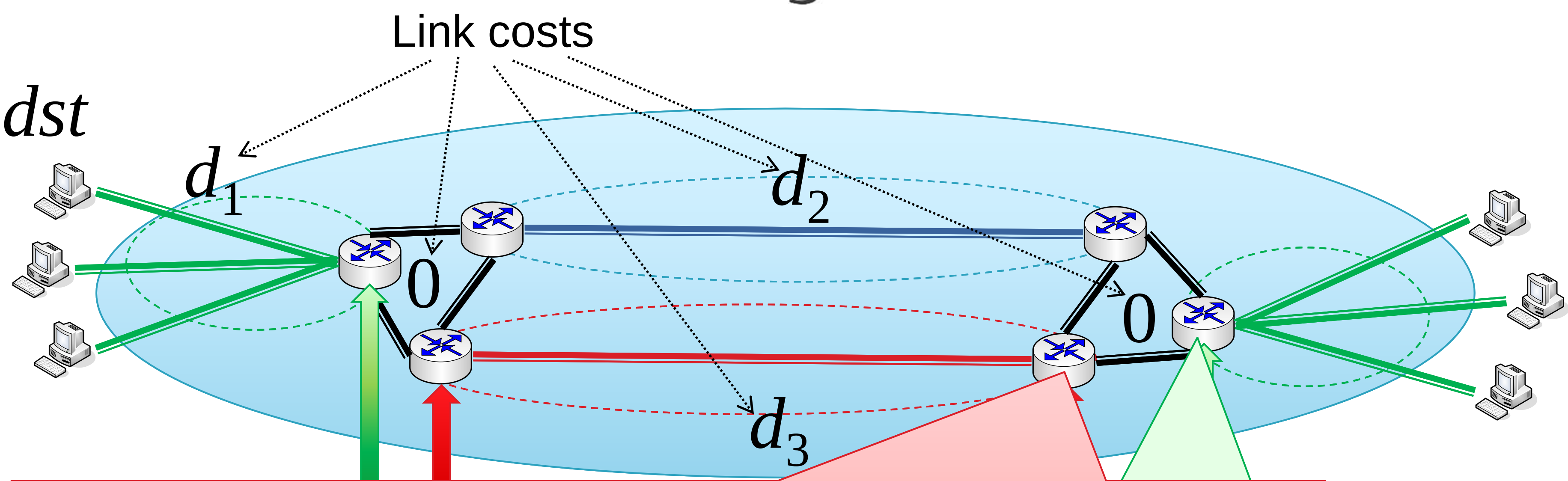
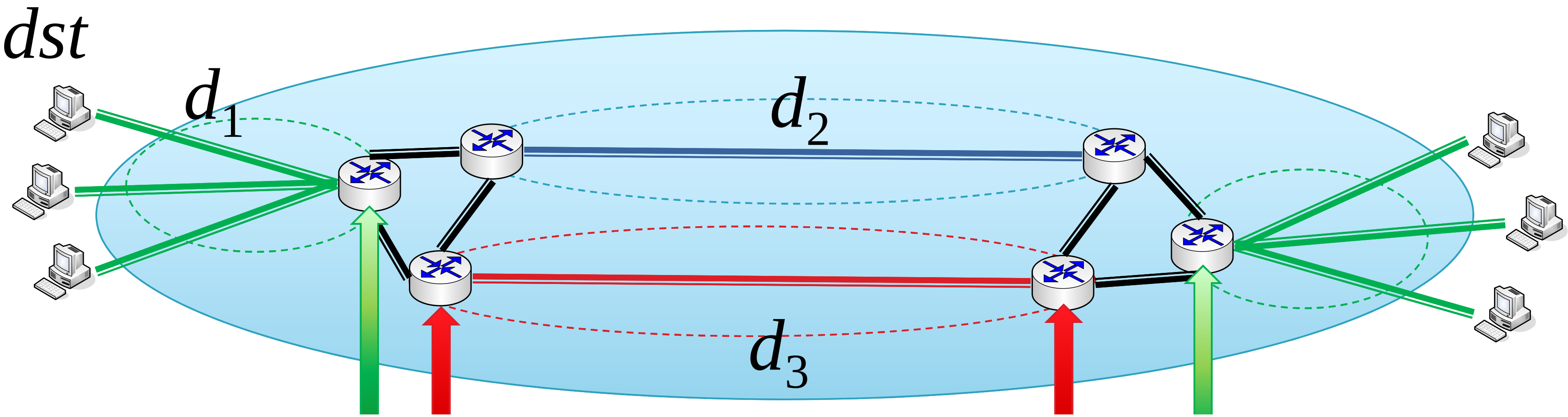
Motivation:
How Blue preserves confidentiality of intra-domain routing?



This router (hosted by Red) needs to compute its next-hop for *dst*, without knowing d_1 and d_2

This router (hosted by Green) needs to compute its next-hop for *dst*, without knowing d_2 and d_3

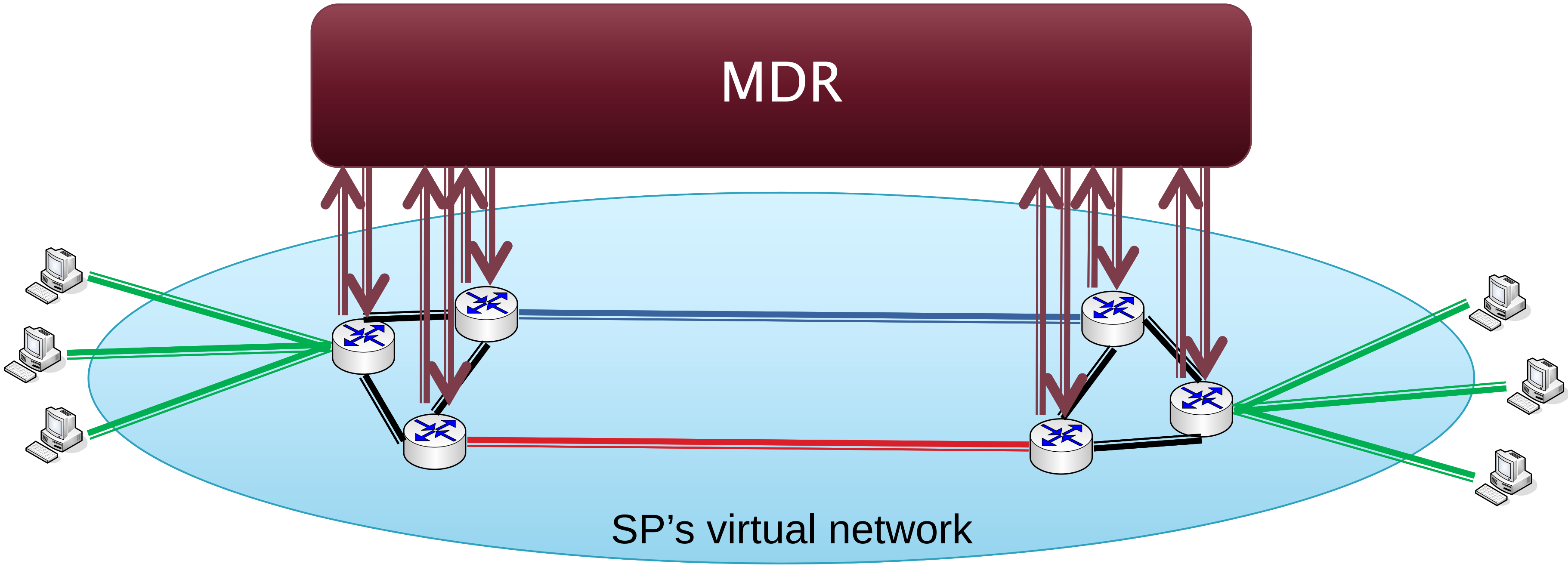
Motivation:
Existing IGPs (OSPF, RIP) do not preserve confidentiality



- Routers exchange routing information
  - including link costs, path costs or even whole topology
- Underlying InPs can observe routing information
- Encrypting IGP messages does not help
  - The InPs also have access to the keys on routers

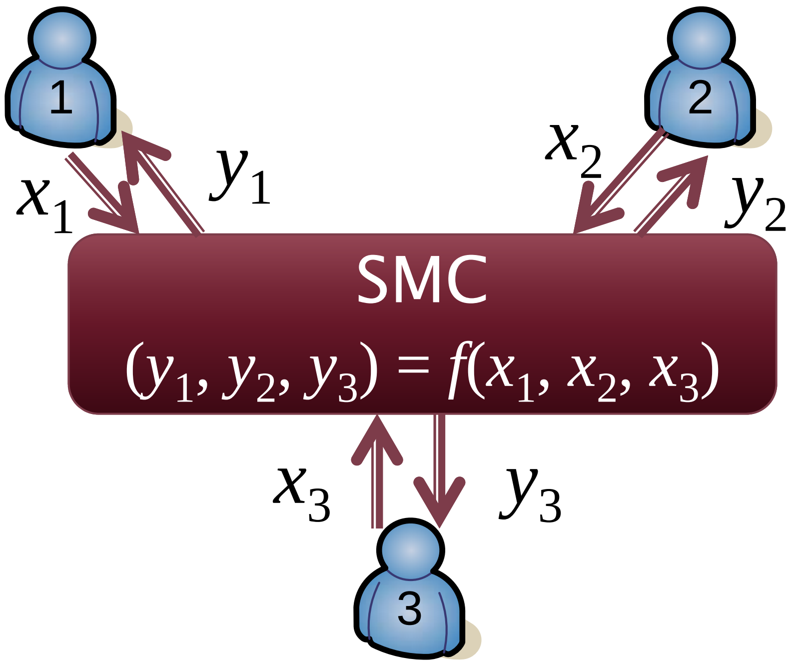
Problem: Minimum Disclosure Routing (MDR)

- SP's intra-domain routing, where each router
  - Provides local topology information as input
  - Learns next-hop information as output
  - *Learns nothing else*



Related Problem: *Secure Multiparty Computation* (SMC)

- An example of Secure 3-party Computation



- MDR is a kind of SMC
- Some generic SMC protocols are known
  - Applicable to any function f

Generic SMC protocol uses secret sharing scheme

- *Secret sharing scheme*
  - Encode a secret information into multiple fragments called *shares*
  - Any single share cannot recover the secret
  - All shares can be combined to recover the secret

Sharing

secret x → share $[x_2]$, share $[x_2]$, share $[x_2]$

Recovering

$[x_2]$, $[x_2]$, $[x_2]$ → x

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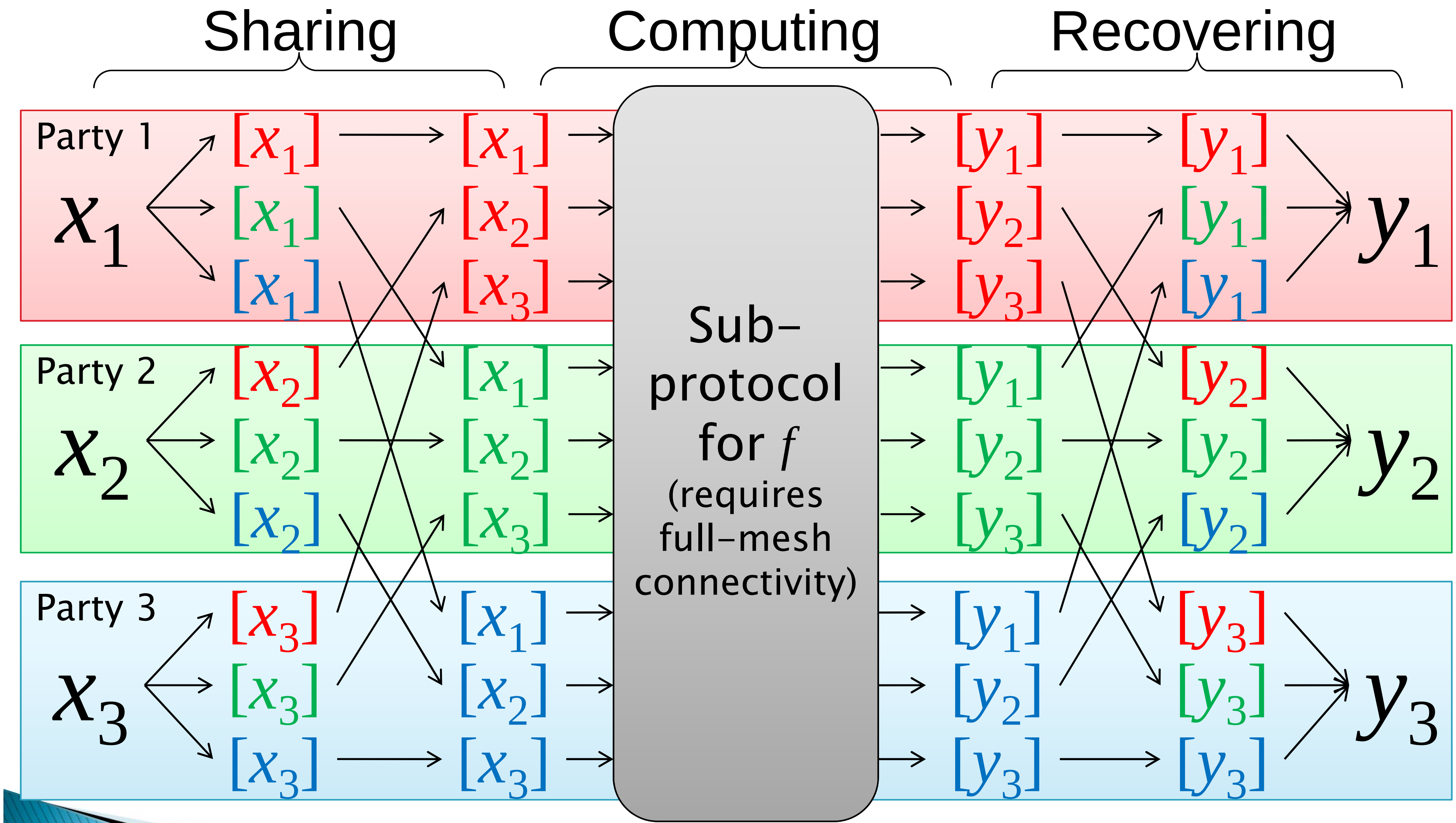
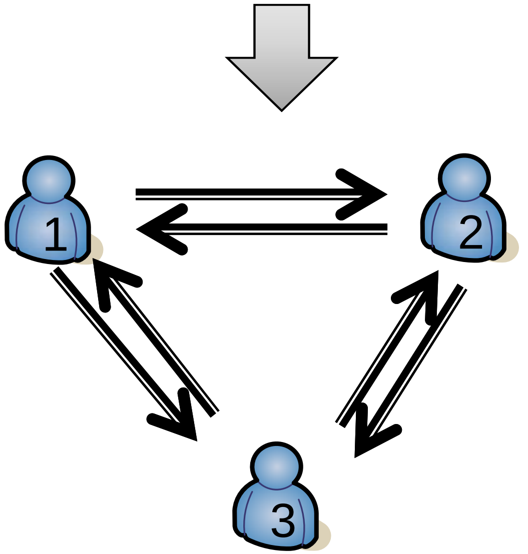
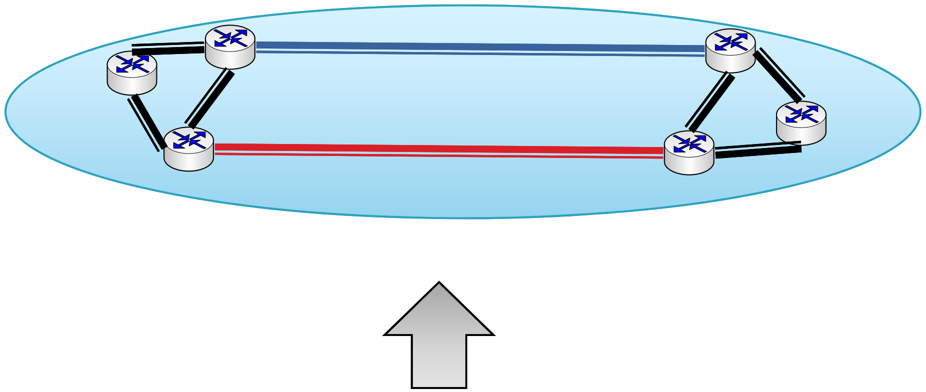
Generic SMC protocol for $(y_1, y_2, y_3) = f(x_1, x_2, x_3)$



Generic SMC protocols cannot be applied to routing

- Generic SMC protocols are applicable only if all parties are fully connected

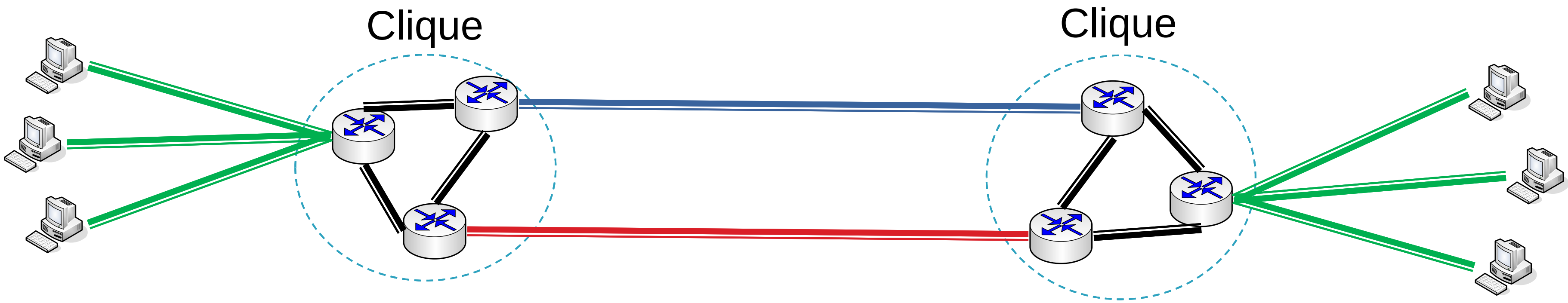




- MDR is a problem for partially connected routers to establish such a full-mesh IP connectivity

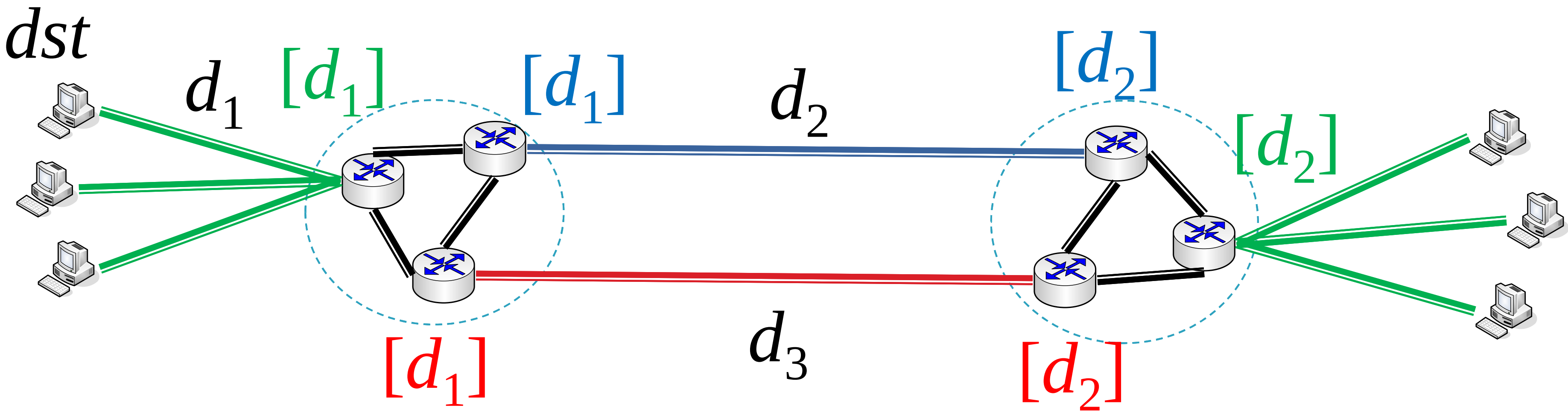
Our solution: Overview

- A *clique* virtually works as a big router
  - Fully-connected routers collocated at a peering POP
- Cliques run a distance-vector routing algorithm
  - In each clique
    - Routing information is encoded into shares
    - Computations are performed by a generic SMC protocol
  - Shares are transferred between neighboring cliques



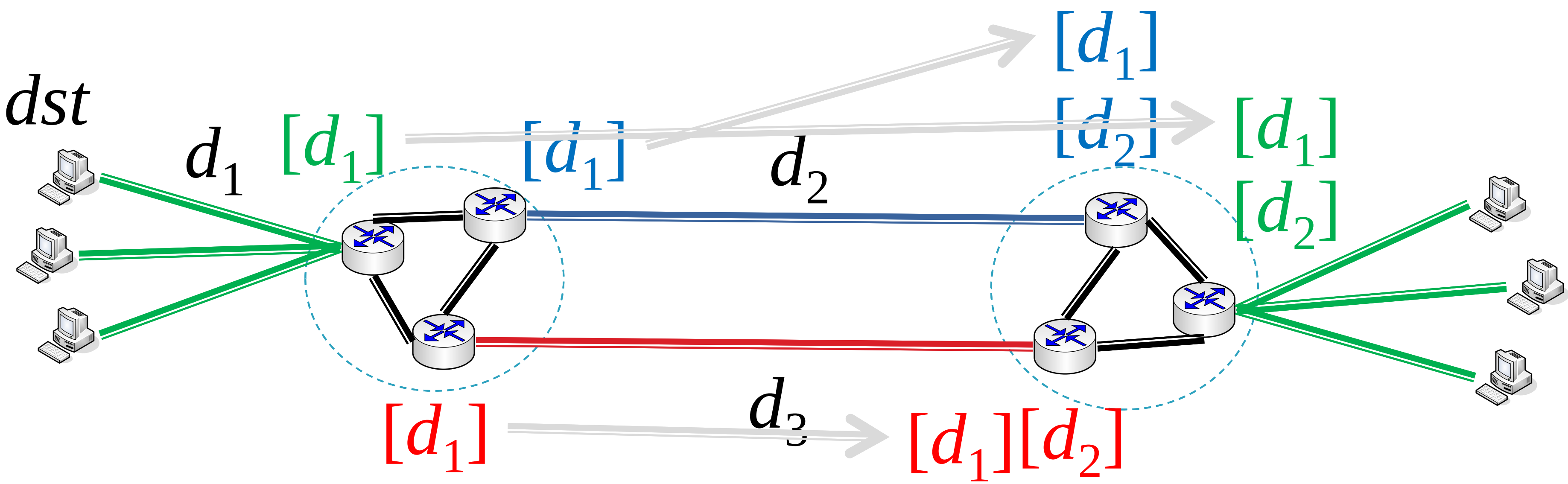
Our solution: A walk-through scenario (1/6)

- How each router obtains its next-hop for dst
- $[d_1]$ = SHARE(d_1), $[d_2]$ = SHARE(d_2)
  - Encode link cost into shares
  - Distribute these shares in a clique



Our solution:
A walk-through scenario (2/6)

- TRANSFER($[d_1]$)
  - Transfer shares of link cost from the left clique to the right clique



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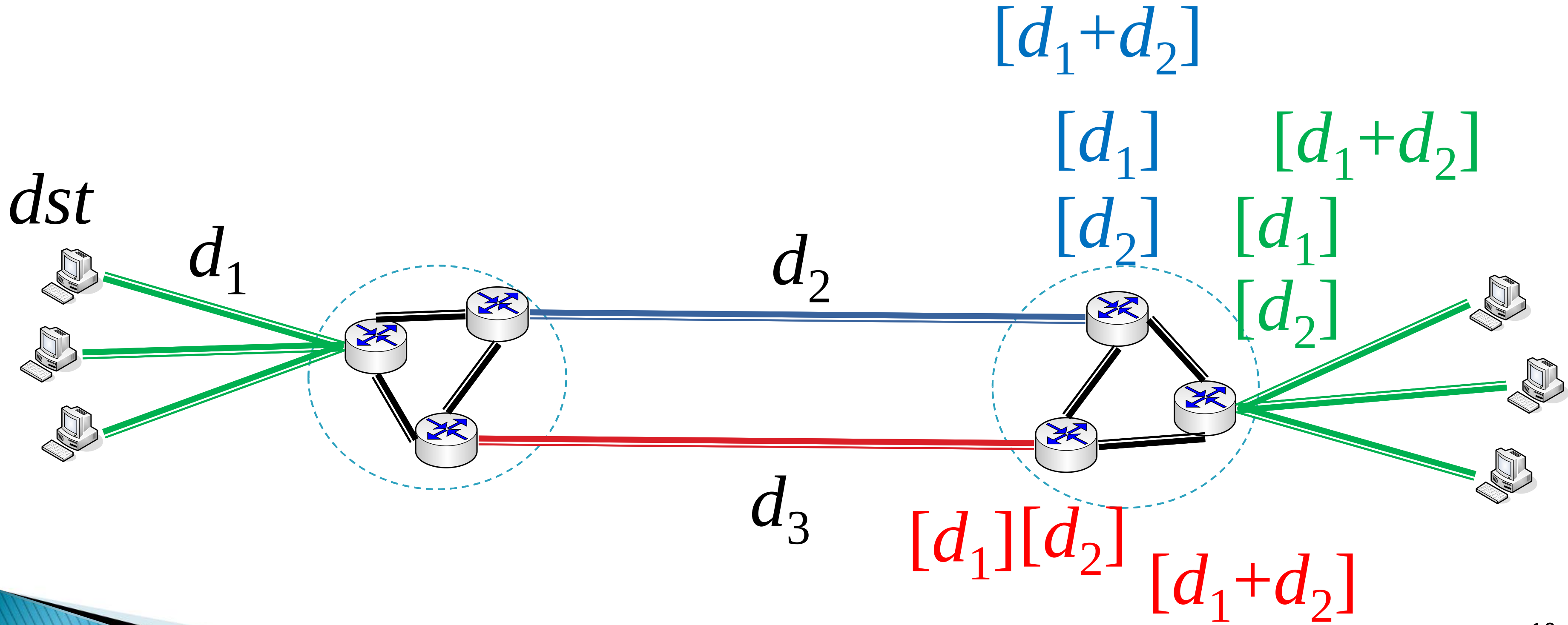
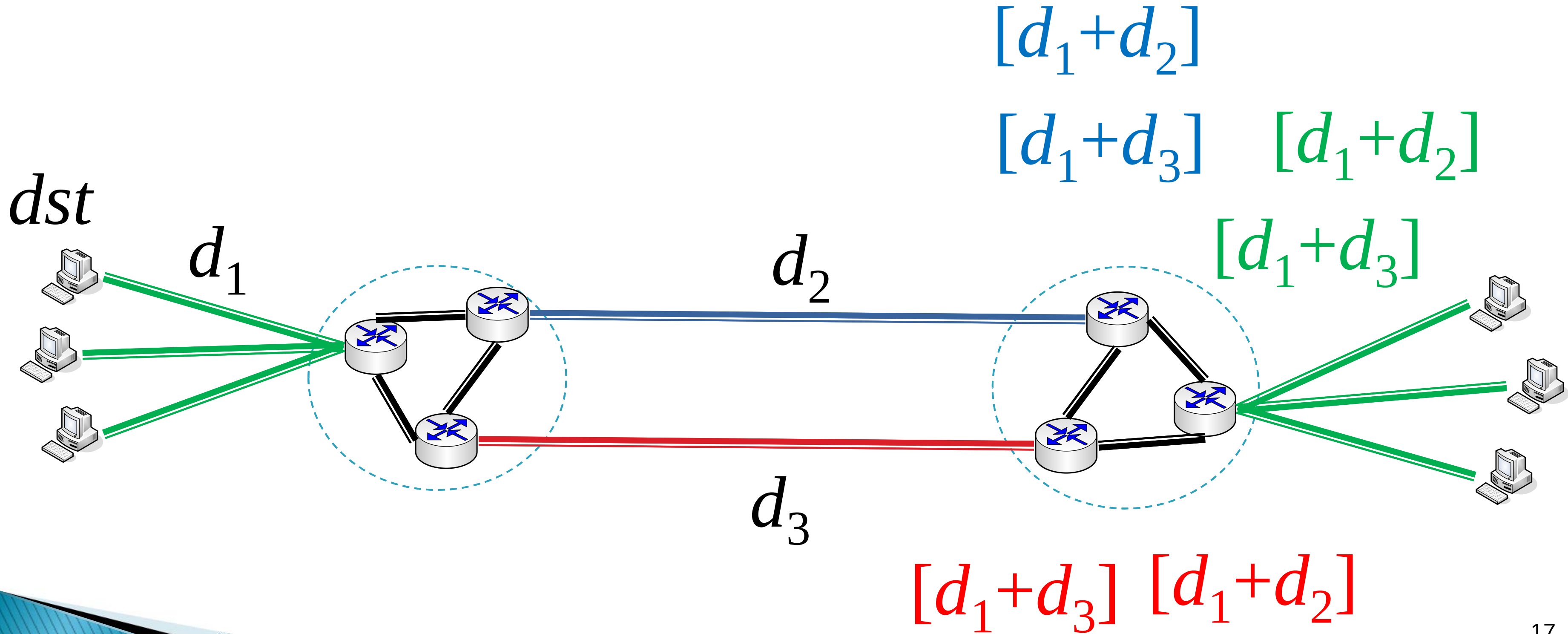
Our solution: A walk-through scenario (3/6)

- $[d_1+d_2]$ = COMPUTE($[d_1]+[d_2]$)
  - The right clique run a generic SMC protocol for addition



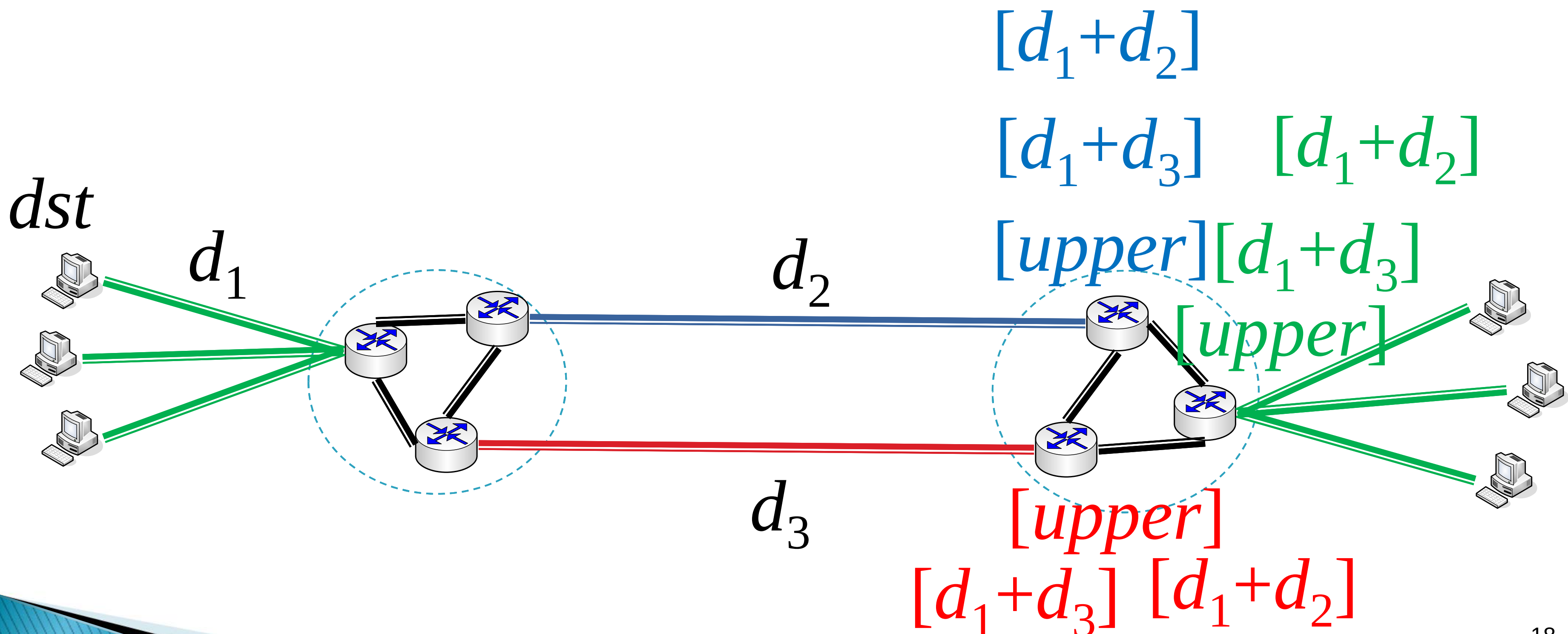
Our solution: A walk-through scenario (4/6)

- Similarly, shares of the distance of the other path [d_1+d_3] is obtained



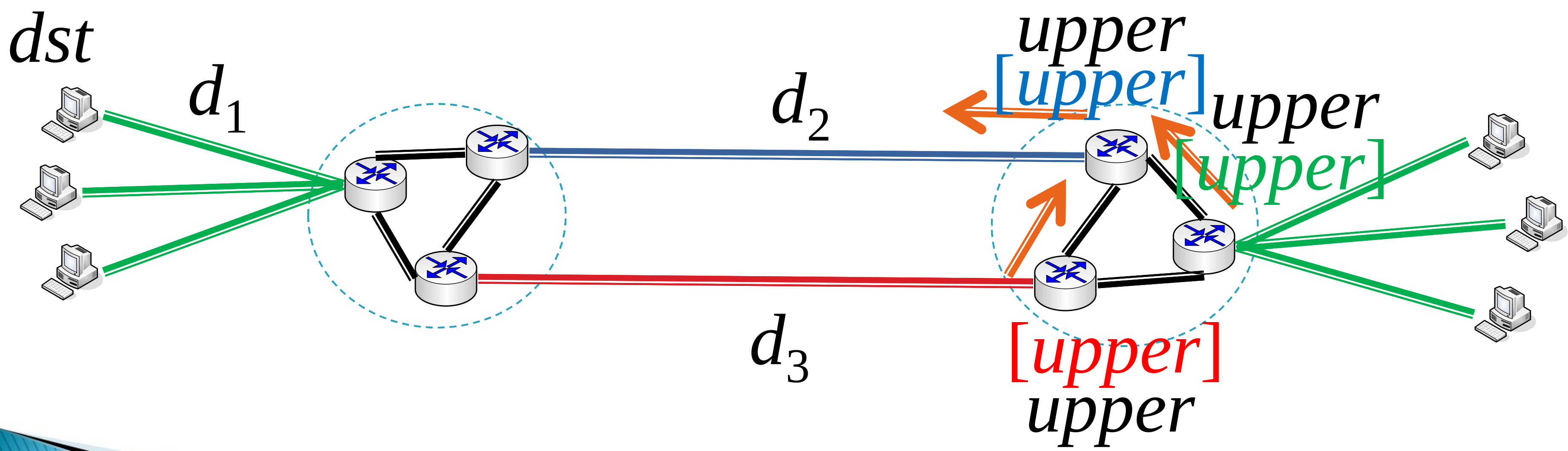
Our solution: A walk-through scenario (5/6)

- Suppose $d_2 < d_3$ (the upper path is shortest)
- $[upper]$ = COMPUTE($[d_1+d_2] < [d_1+d_3]$? $[upper]$: $[lower]$)
  - The right clique run a generic SMC protocol



Our solution: A walk-through scenario (6/6)

- $upper$ = RECOVER ([$upper$])
  - Recover the route in the right clique
- Each router in the clique directs its route towards the upper path

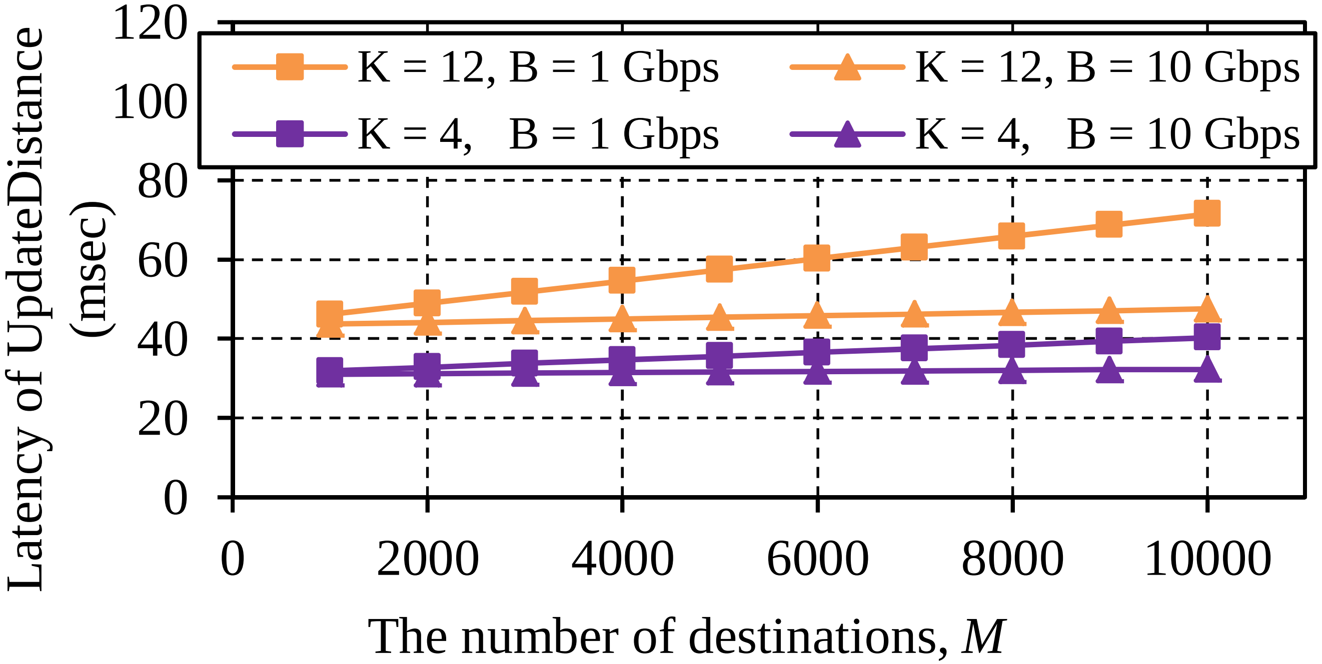


Feasibility of our solution: Assumptions of evaluation

- Generalized version of our solution
  - Arbitrary numbers of cliques and destinations
  - Scalability to the number of destinations
- Metric: latency of SMC protocol to update distances to destinations
  - Most time-consuming part of our solution
- Analysis model and parameters
  - Computation latency (in each router)
    - GPGPU (1.35 GHz, 240 cores)
  - Communication latency (between routers in a clique)
    - One-way delay is 1 msec
    - Bandwidth is 1Gbps or 10 Gbps

Feasibility of our solution: Latency of SMC protocol

- K: number of neighboring cliques
- B: bandwidth of the links within a clique



- An invocation of SMC protocol requires less than 100 msec
- Total Convergence requires less than 1 second
  - Number of invocations are upper-bounded by network diameter
  - Diameter < 10 even in a large Tier-1 network.

Conclusions

- NV poses a new problem, MDR
  - confidentiality of operational information
- None of existing protocols solves MDR
  - Existing routing protocols do not preserve confidentiality
  - Generic SMC protocols cannot be applied to routing
- We proposed a solution for MDR
  - Extend SMC protocol to routing problem
  - Feasible in a large network if it is run on state-of-the-art hardware

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Future work

- Implementation
  - Currently implementing our solution by extending Quagga on Linux
- Evaluation with implementation
  - Preliminary experiment results show that our analysis results are reasonable