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# Oblivious Routing: Static Routing Prepared Against Network Traffic and Link Failures

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orange™

## Internet is very dynamic

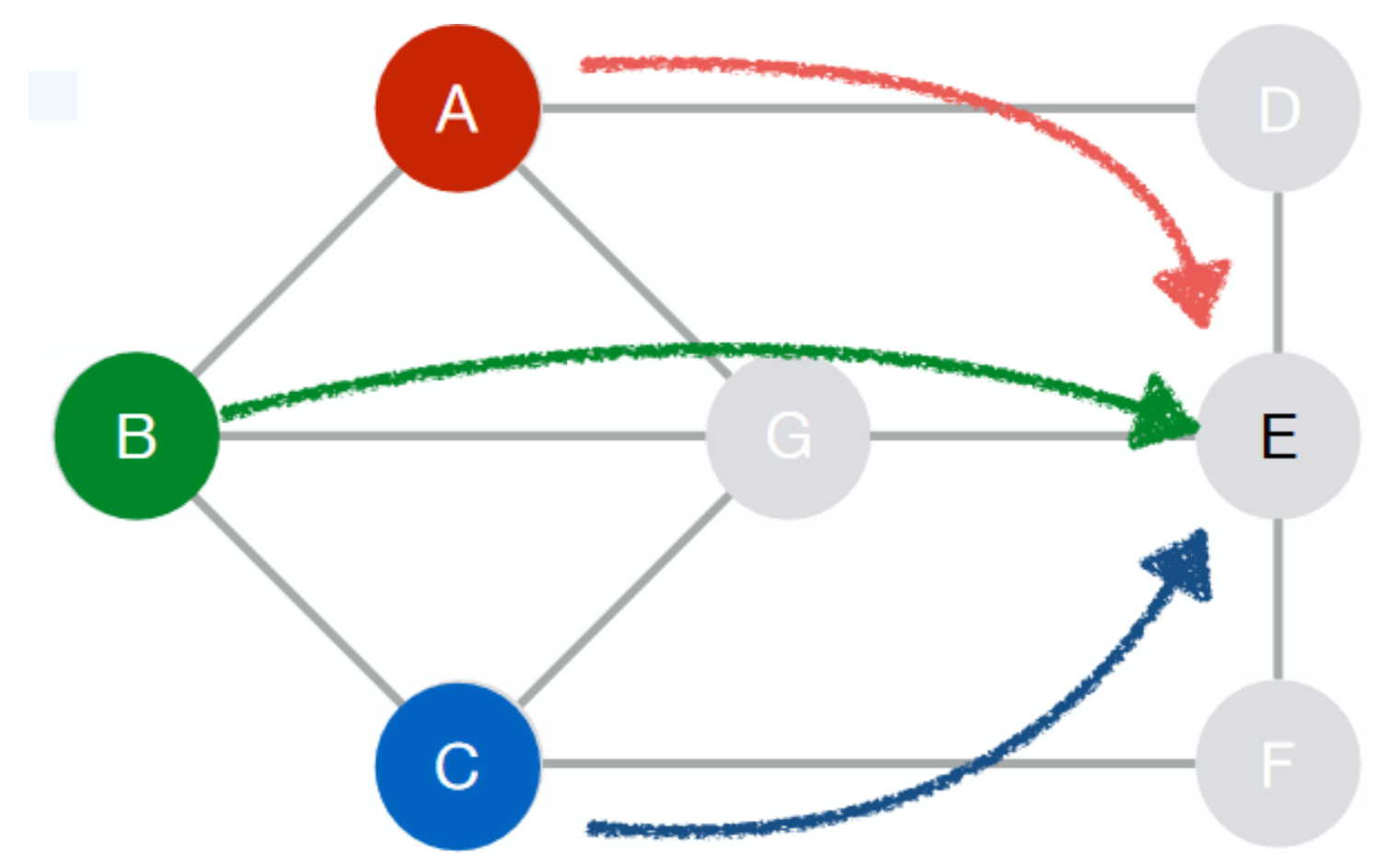
- Routing in Internet challenged by large throughput variations:
  - Day vs. night, week days vs. week ends
  - Popular events (like sports or Black Friday)
- Users expect excellent service around the clock!
- Network operators must fine-tune their routing to guarantee sufficient bandwidth and low enough latency in all conditions

## How to compute a routing?

- Very common approach: IGP protocols and shortest path
  - An administrator chooses the "distance" metric between two routers, according to their own criteria: OSPF, IS-IS, RIP
  - **Often not capacity-aware**: only dealing with connectivity, not traffic
- More centralised traffic engineering using real-time measurements? Promised by SDN
  - Use optimisation tools (mostly linear programming — LP)
- **What about uncertainty?** It lies in traffic and failures
  - Discarded with usual protocols! However, SDN proposes to change the situation

## Multi-commodity flow (MCF) formulation

- Optimisation variables:
  - flow  $f_k(e)$  in each link  $e \in E$  for each origin-destination pair  $k \in K$ , expressed in MB/s
  - $\mu$ , a capacity-reduction factor (reduce the capacity of the links by a factor  $\mu$ )
- Constraints:
  - Link capacity  $C_e$  (scaled with  $\mu$ ):  $\sum_{k \in K} f_k(e) \leq \mu C_e, \quad \forall e \in E$
  - Flow conservation
- Objective: minimise  $\mu$ , i.e. use the links as little as possible, be far below their capacity
  - Taking capacities as low as possible is equivalent to sending multiple times the demand, and to minimising the maximum congestion (defined as *load / capacity* for a link)



## Oblivious routing

- Integrate **traffic uncertainty** into the MCF
- Optimise for all possible traffic matrices respecting the capacities
  - Minimise the worst ratio for all these matrices (congestion oblivious / optimum congestion)
- **Algorithm?** Iteratively limit the capacity of the edges:
  - Compute the demand that leads to the largest congestion for a given edge  $e$ , repeat for all edges, pick the worst one
  - Generate the corresponding capacity constraint
  - Start again until convergence
- Important theoretical result [Räcke, 2008]: for any traffic matrix, the maximum ratio is  $O(\text{polylog } \# \text{ nodes})$

## Capacity variant

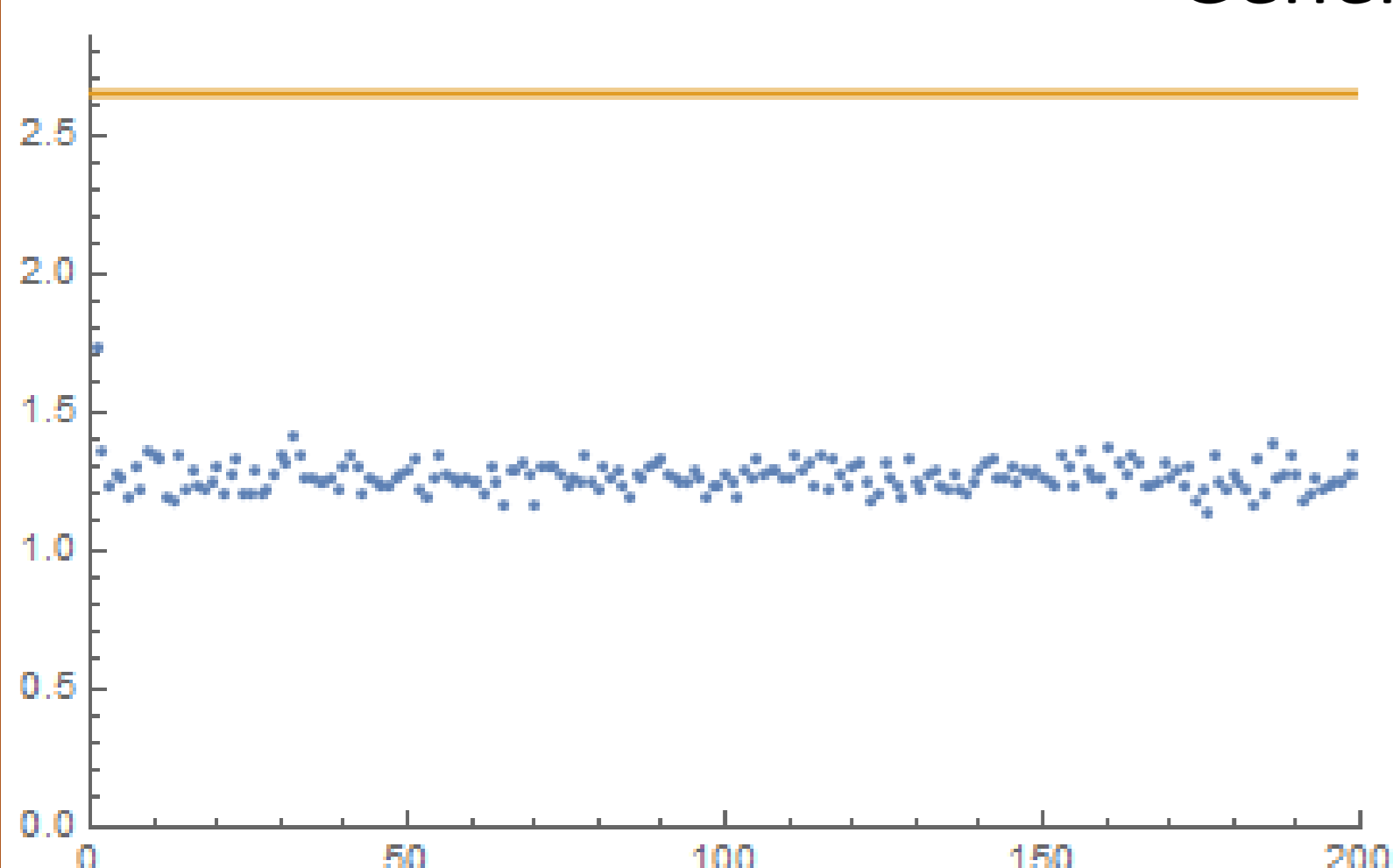
- Integrate **failure uncertainty** into the MCF, i.e. the **capacity** of the links may vary
- Optimise for all possible capacity matrices accepting a given (fixed) demand
  - The routing must maximise the amount of traffic for all these matrices
- **Algorithm?** Iteratively impose minimum of flows for each demand, i.e. demand constraints:
  - Compute the capacity that leads to the lowest amount of traffic for a given demand  $d$ , repeat for all demands, pick the worst one
  - Generate the corresponding constraint
  - Start again until convergence

## In practice

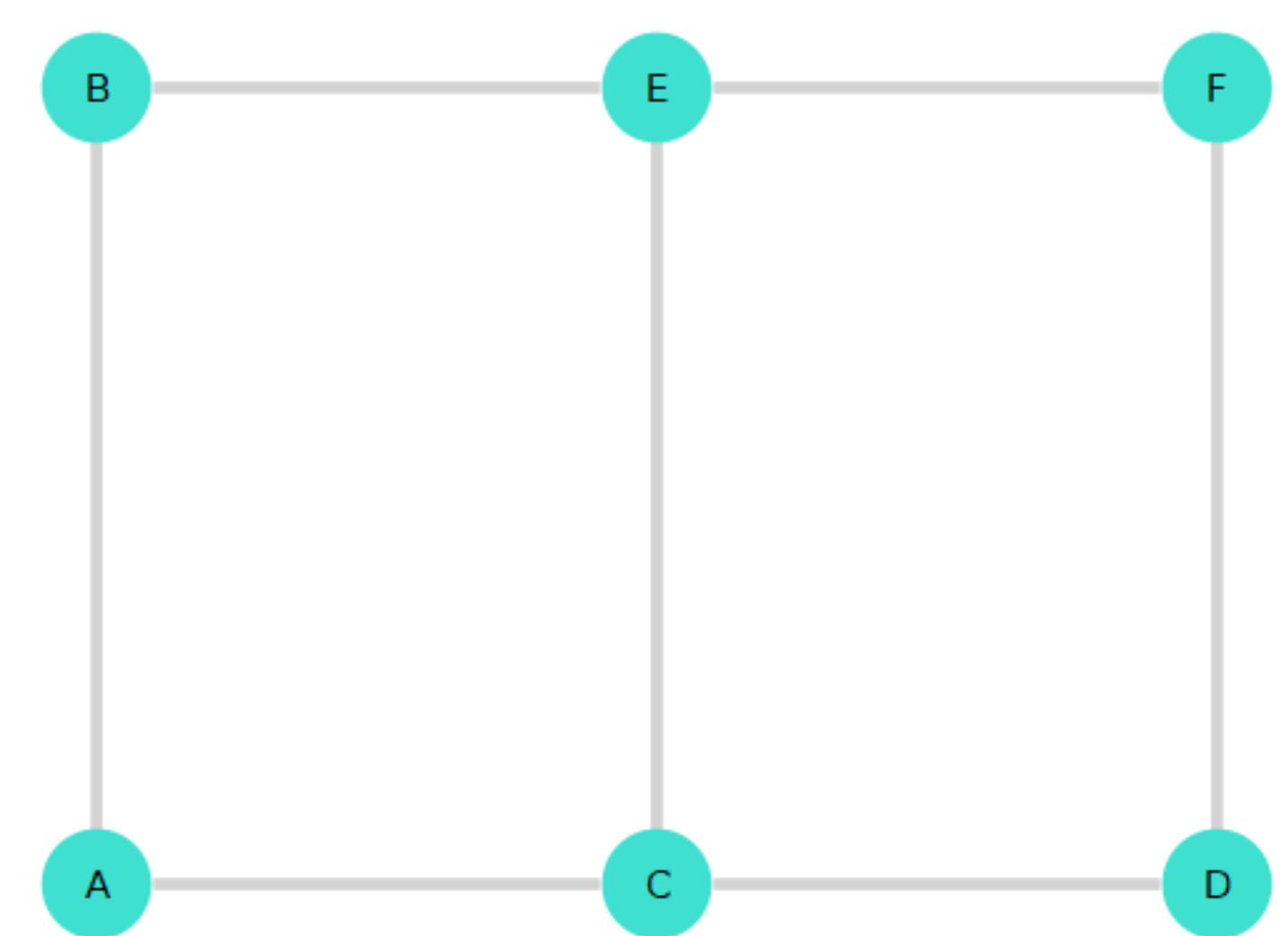
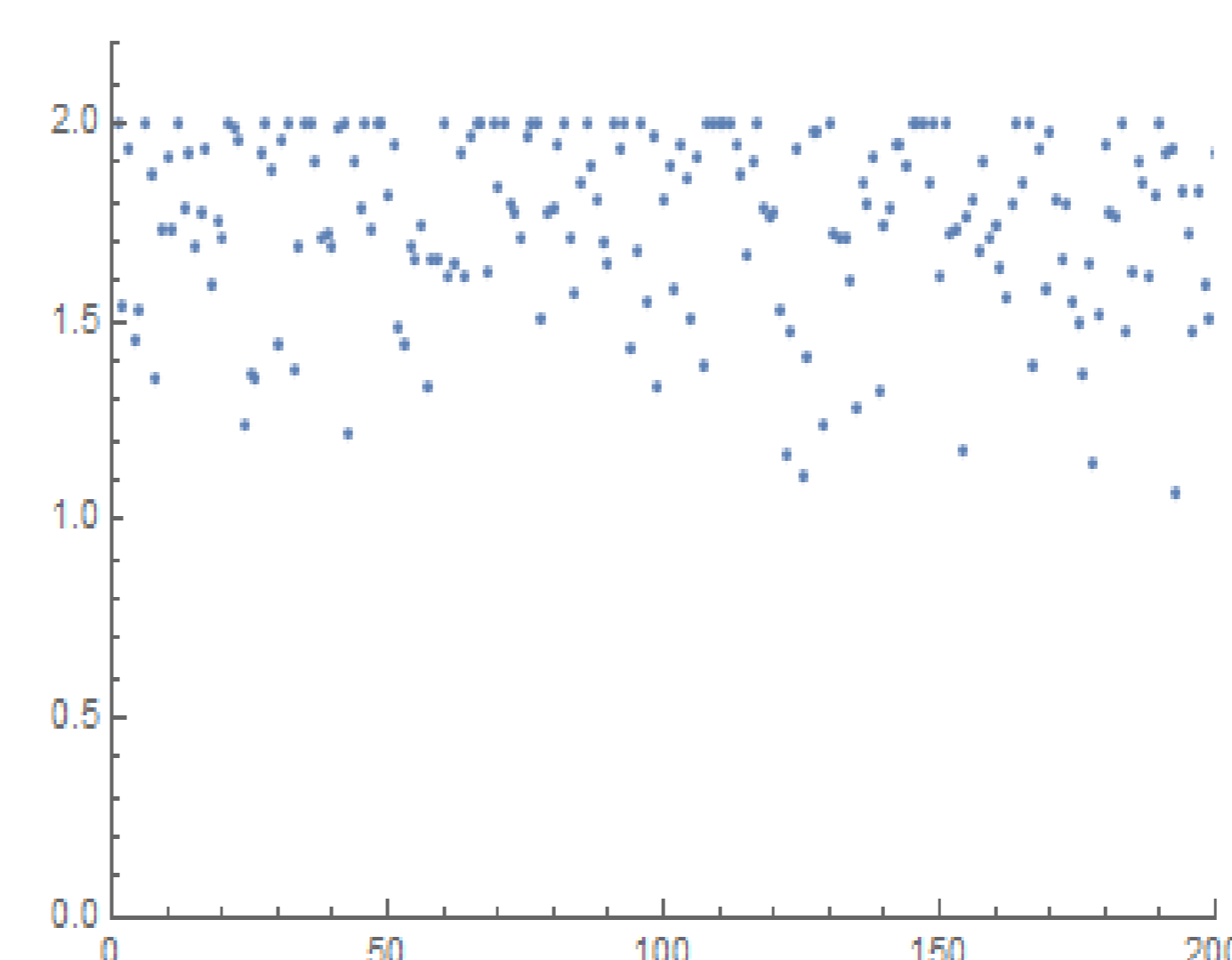
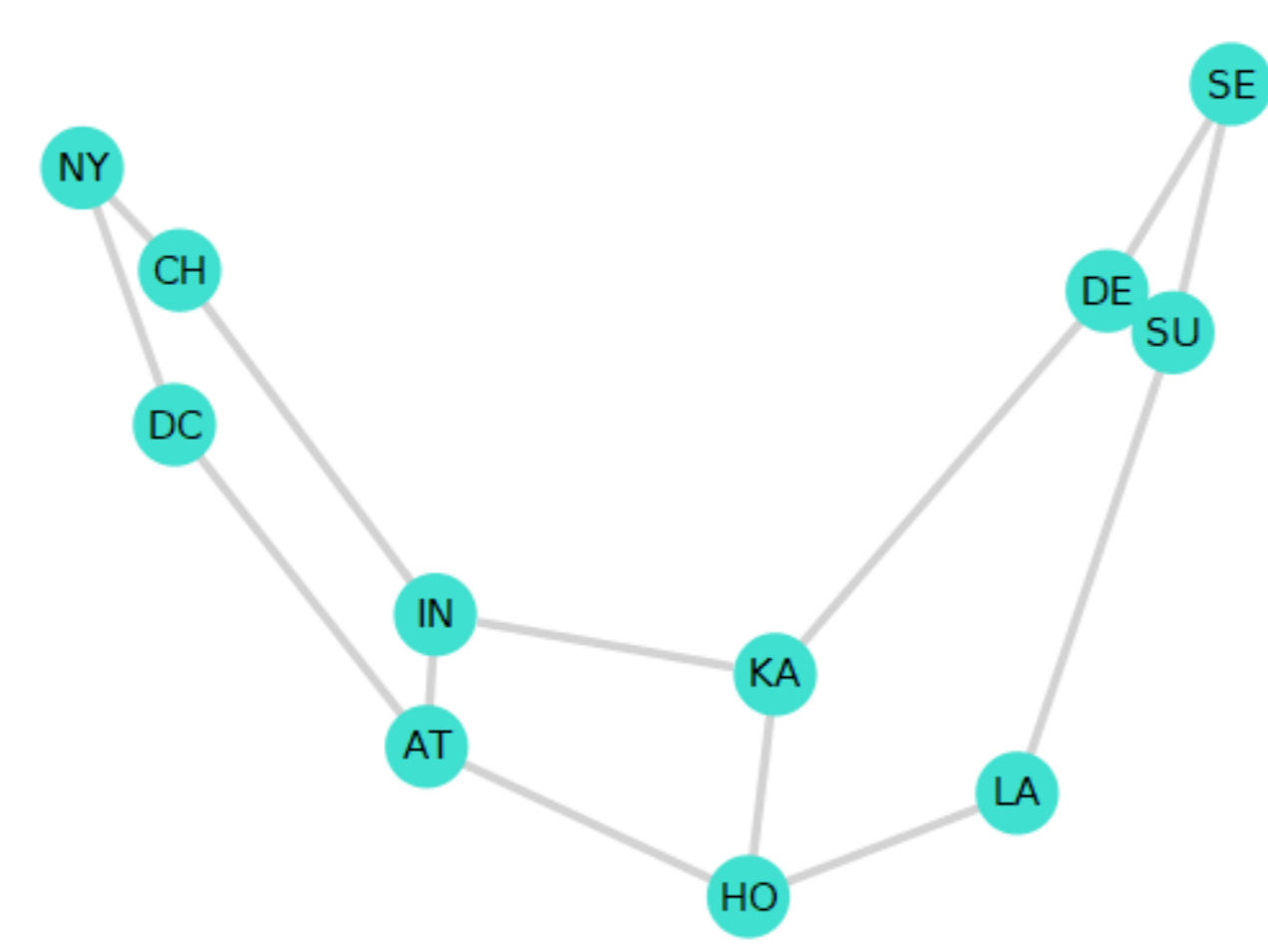
- Oblivious routing can scale (1,000 nodes, 1,000s edges, 10,000s demands) on a high-end laptop
- Abilene network: 3.5 seconds
  - 11 nodes, 14 edges, 103 demands
- AT&T network: 50 seconds
  - 26 nodes, 50 edges, 103 demands
- Real proprietary network: 1.5 hours

## Numerical experiments (demand uncertainty only)

Generate a plausible traffic matrix, compute the ratio, rinse and repeat 200 times



Abilene



## Extensions

- Generalise to other performance metrics:  $\alpha$ -fairness, quality of experience (QoE). What happens to the theoretical guarantees?
- Optimising for all possible traffic matrices that respect the capacity constraints is probably too demanding
  - ⇒ Exploit traffic history to derive a less conservative uncertainty set
  - The traffic matrices must be a convex combination of previously seen matrices, within a "distance" to an average matrix, etc.
- Implement the optimisation algorithm in a distributed fashion (which is probably required by SDN for scalability)