Multi-Area Centralized Control Plane of an EON

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Group Meeting

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Overview

- Objectives / Problem Statement
- Previous Work
  - Decentralized Control Plane (GMPLS)
  - Centralized Control Plane (SDN)
  - Elastic Optical Network (EON) – Cent. vs Decent.
- Approach
- Sub-Problems
  - Location
  - Number of areas
  - Number of controllers per area
- Simulation Plan & Formulation
- Conclusion

Objectives

- Describe difference between centralized/decentralized control plane operations in an EON
- Model a single EON subdivided into multiple areas with a centralized control plane framework
- Generate sub-problems (Optimization: ILP)
    - Number of areas in system
    - Number of controllers in area
    - Location of controllers in area

Problem Statement: Propose a logically centralized, physically distributed control plane for fast and efficient EON path provisioning and restoration

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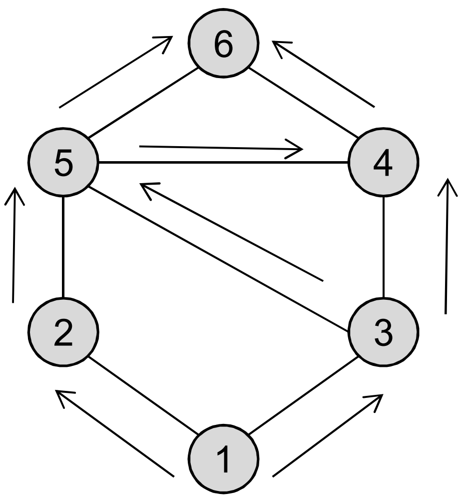
Previous Work

- GMPLS over EON – distributed RMSA
  - Resilient
  - 2 full Roundtrips for complete path provisioning
  - Sliceability

Paths: 1-2-5-6, 1-3-4-6



1)Path Messages are broadcast upon connection request
2)Transit nodes forwards broadcast to destination
3) Multiple paths: 1st path gets RESV message from dest, 2nd gets REQ message
This increases probability that one of the paths will have a contiguous number of required spectral slots
3) Dest returns slot resv./req. along same path, if slots already reserved, tear/error

Fukuda, T., Liu, L., Baba, K.I., Shimojo, S. and Yoo, S.B., 2015. GMPLS Control Plane With Distributed Multipath RMSA for Elastic Optical Networks. *Journal of Lightwave Technology*, *33*(8), pp.1522-1530.

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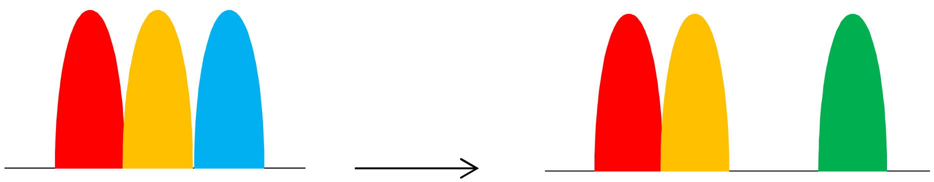
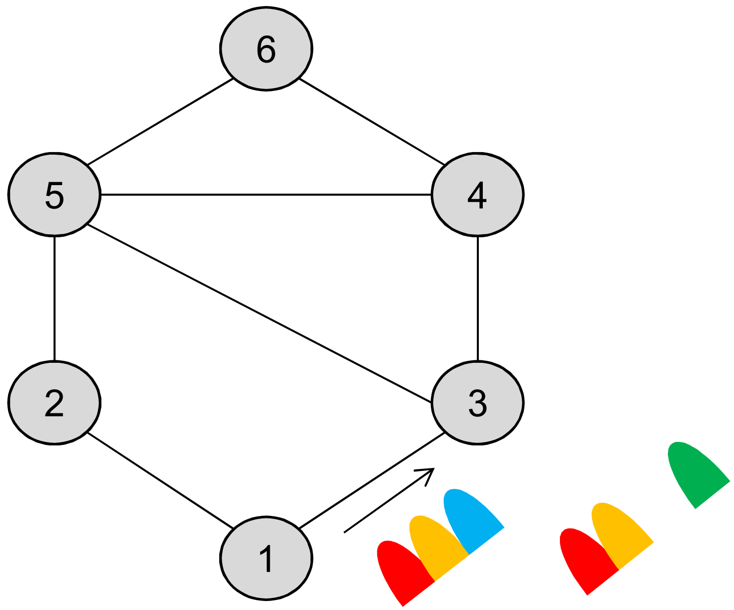
Previous Work (cont.)

- **Sliceability**
  - **Break the connection into multiple smaller slices: provisioning and restoration**
  - **Flexibility with the contiguity constraint**

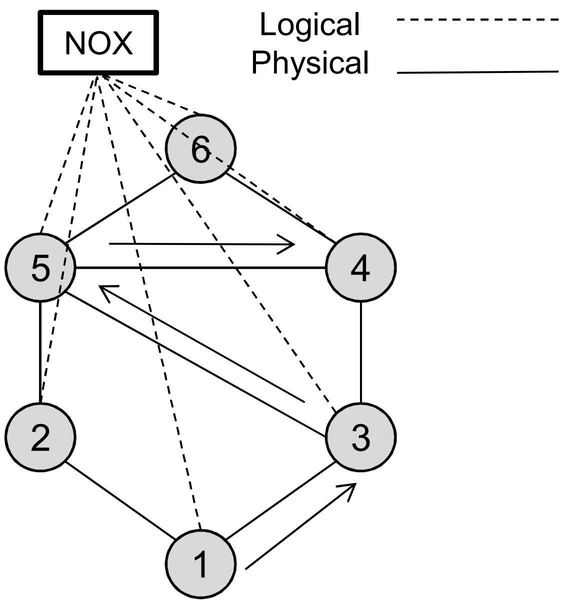




Dallaglio, M., Giorgetti, A., Sambo, N., Cugini, F. and Castoldi, P., 2015. Provisioning and restoration with sliceability in GMPLS-based elastic optical networks [Invited]. *Journal of Optical Communications and Networking*, *7*(2), pp.A309-A317.

Previous Work (cont.)

- Software Define EON (SDEON) – centralized RMSA
  - OpenSlice
  - Less resilient w/ single controller, global network knowledge
  - Appx 3 hop break even point for provisioning latency (GMPLS vs OpenSlice) - 33 ms over NSFnet



Time delay between each node and NOX corresponding to distance
1) Connection request: 1 – 4
2) Path is computed as: 1-3-5-4, Modulation & Spectrum slices also assigned
3) Slice Mod messages sent to all nodes in path With BV-WXCs/BV-WSSs configuration:
4) Connection transmission
Cross-Connect Entry for each OpenSlice switch:

In Port	Cent. Freq	Slot Width	Mod Format
Out Port	Cent. Freq	Slot Width	Mod Format

Liu, L., Muñoz, R., Casellas, R., Tsuritani, T., Martínez, R. and Morita, I., 2013. OpenSlice: an OpenFlow-based control plane for spectrum sliced elastic optical path networks. *Optics express*, *21*(4), pp.4194-4204.

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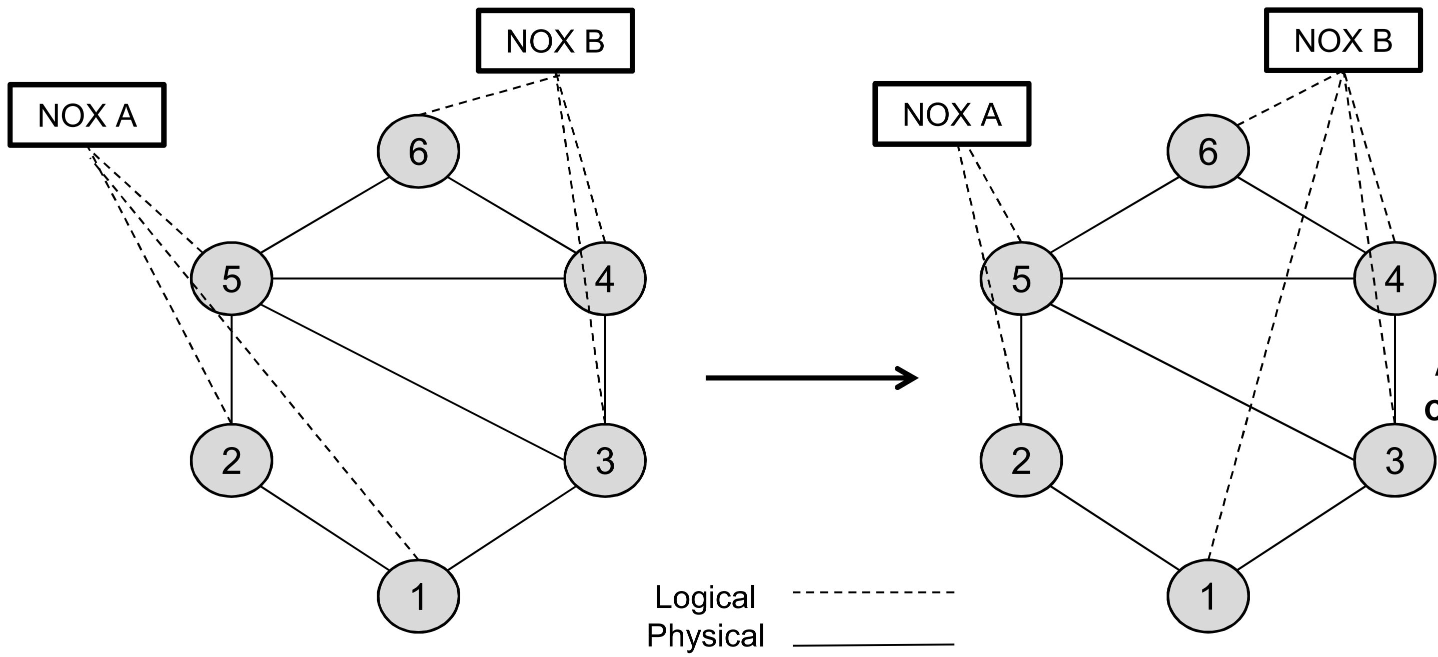
Previous Work (cont.)

- **Distributed SDN Controllers**
  - Proposed for dynamic load sharing; controller migration process;
  - Switches do not belong to group or area
  - Migration based on controller CPU, memory usage, network I/O rate, controller load, aggregated controller load

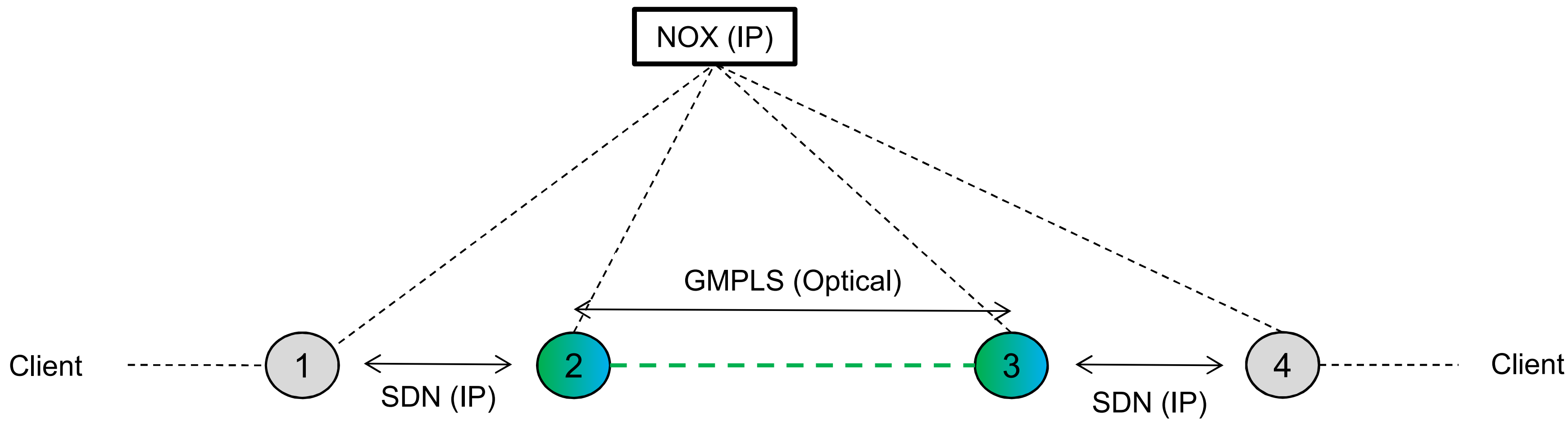


As connection rate of node 1 increased, NOX A & B conducted a hand-off

Dixit, A., Hao, F., Mukherjee, S., Lakshman, T.V. and Kompella, R., 2013. Towards an elastic distributed SDN controller. *ACM SIGCOMM Computer Communication Review*, *43*(4), pp.7-12.

Previous Work (cont.)

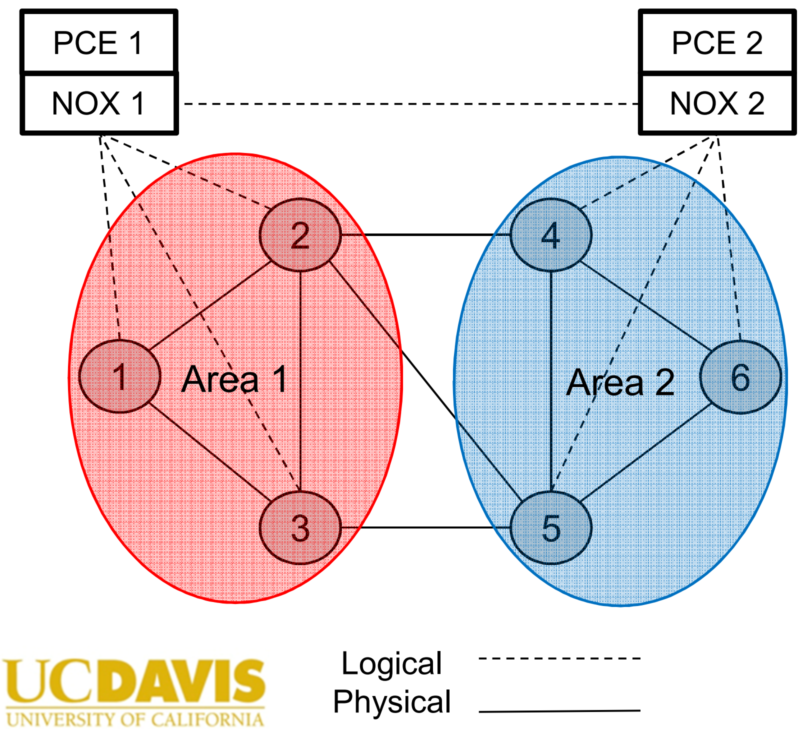
- **Multi-Layer Split Control Plane**
  - Use SDN control plane for IP layer
  - GMPLS for Optical Layer



Liu, L., Tsuritani, T., Morita, I. and Yoo, S.J.B., 2013, June. Optical network control and management technology using OpenFlow. In *OptoElectronics and Communications Conference and Photonics in Switching* (p. TuQ3 1). Optical Society of America.

Approach

- Multi-Area SDEON – each NOX responsible for provisioning for their respective area's nodes
- Each NOX still able to send Slice Mod messages to nodes in other areas
  - PCE provides multiple, X paths



Goal: Minimize the provisioning time as required set of contiguous set of frequency slots are constantly reallocated to new connections. The faster the connection completes the transmission, the lower blocking probability of subsequent connections.

Example: Connection 1 – 6

1) Node 1 sends request to NOX 1
2) PCE 1 computes multiple paths, NOX 1 determines available freq slots at all nodes in path.
3) NOX 1 sends Slice Mod messages to all nodes in path, including nodes in Area 2, NOX 2

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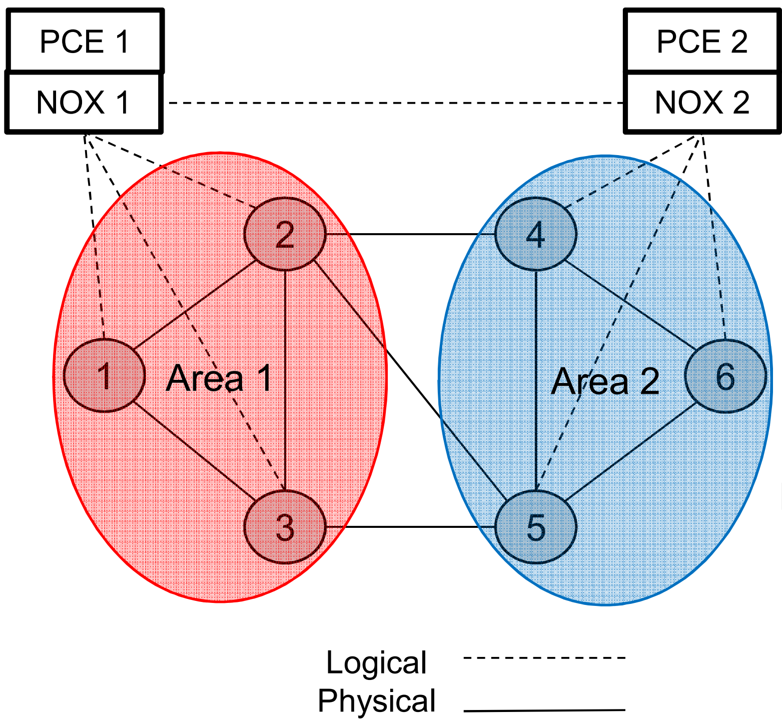
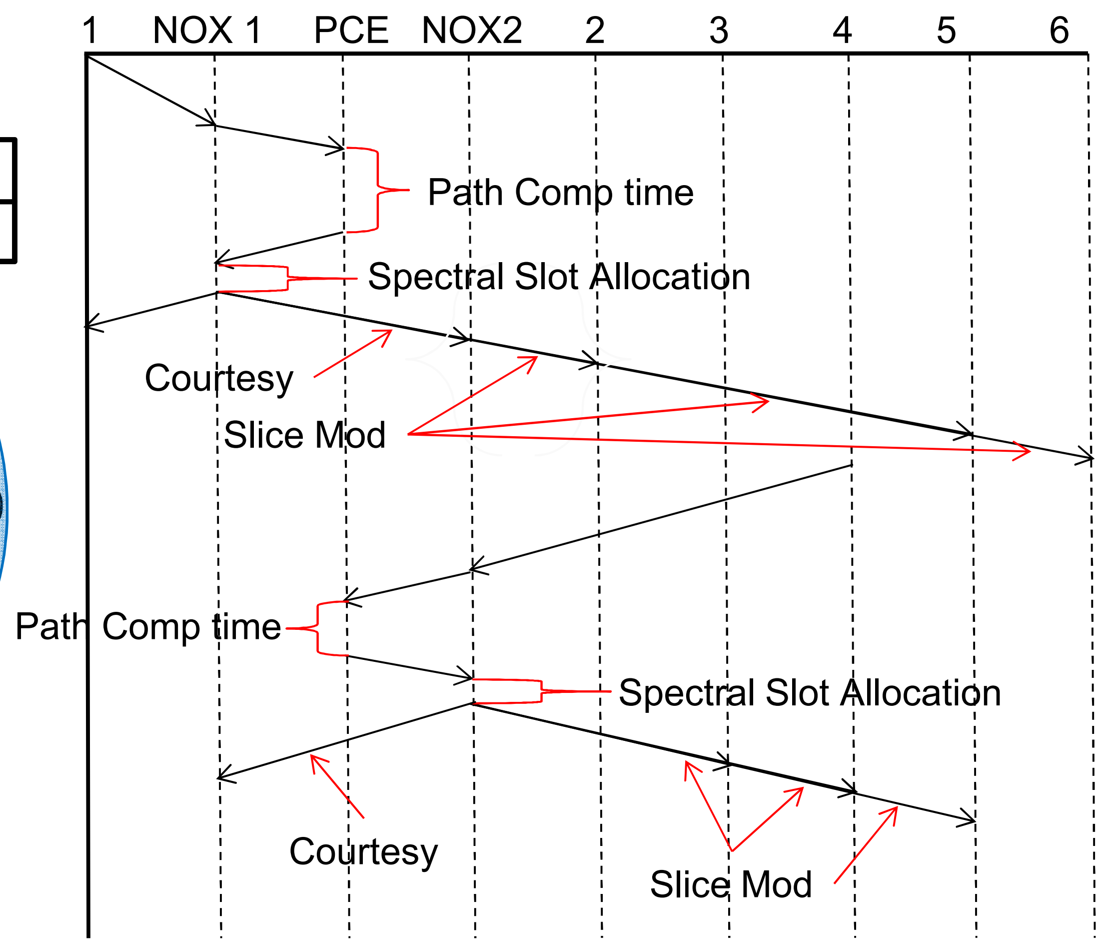
Approach (cont.)

- **Provisioning Timeline**
  - **Conn. 1 – 6, path 1-2-5-6**
  - **Conn. 4 - 3, path 4-5-3**





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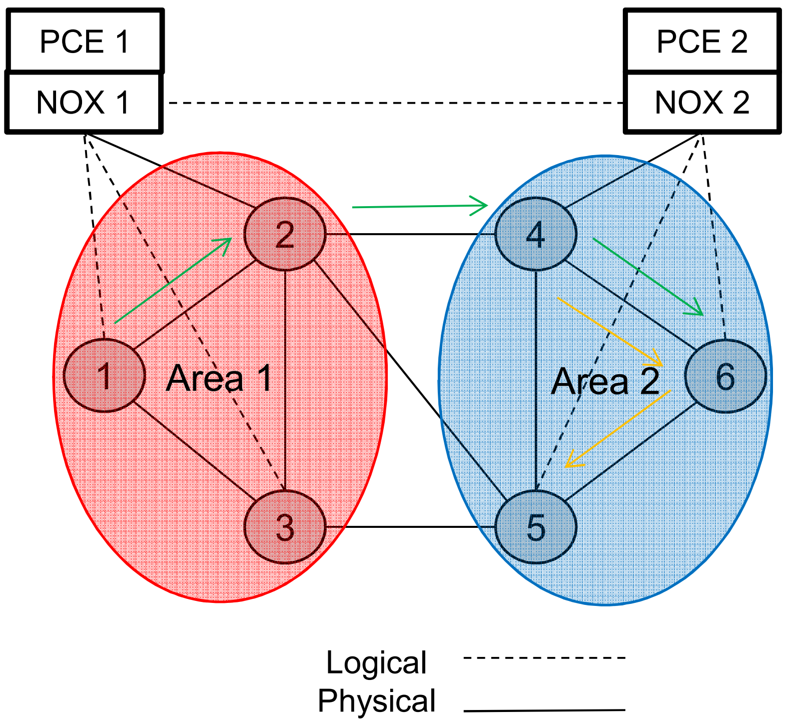
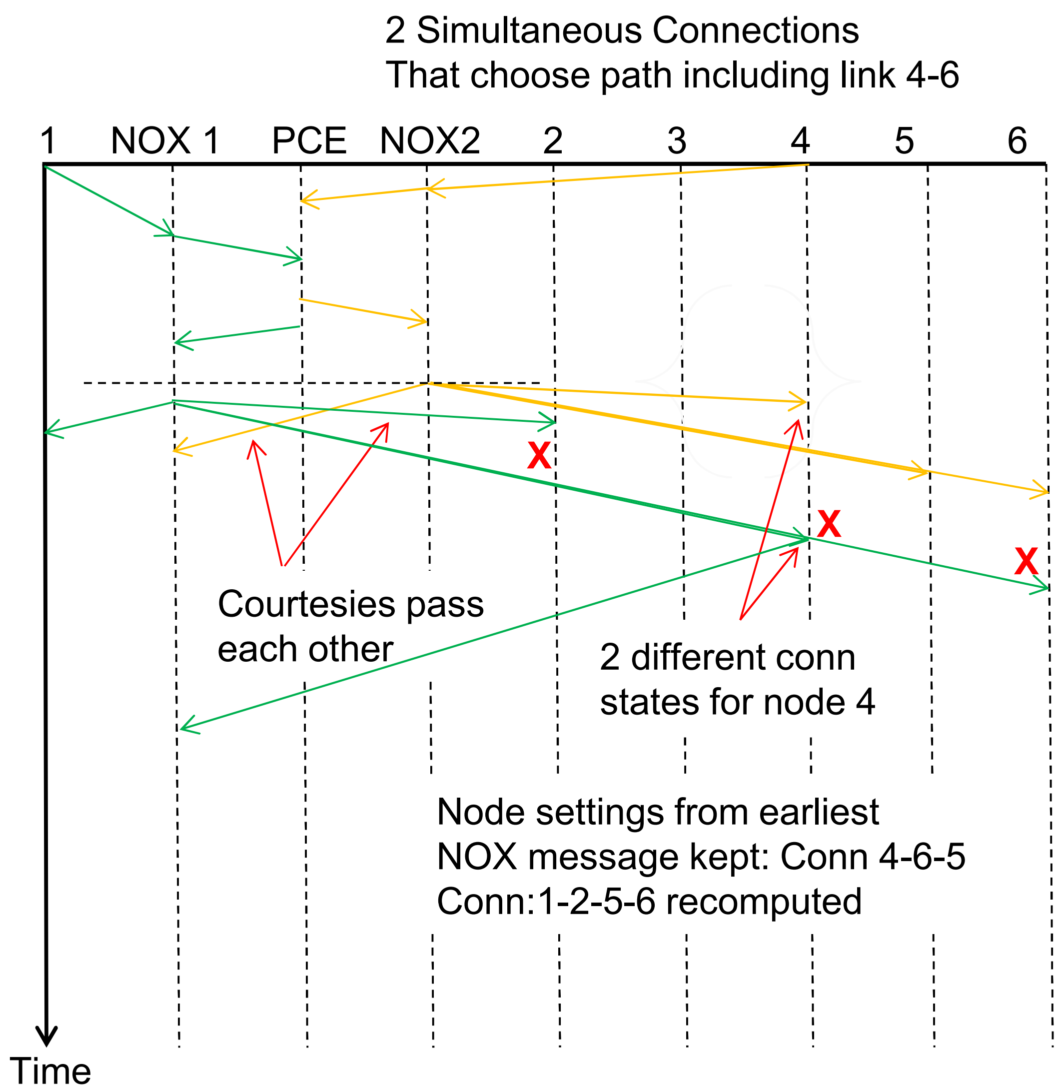
Collisions

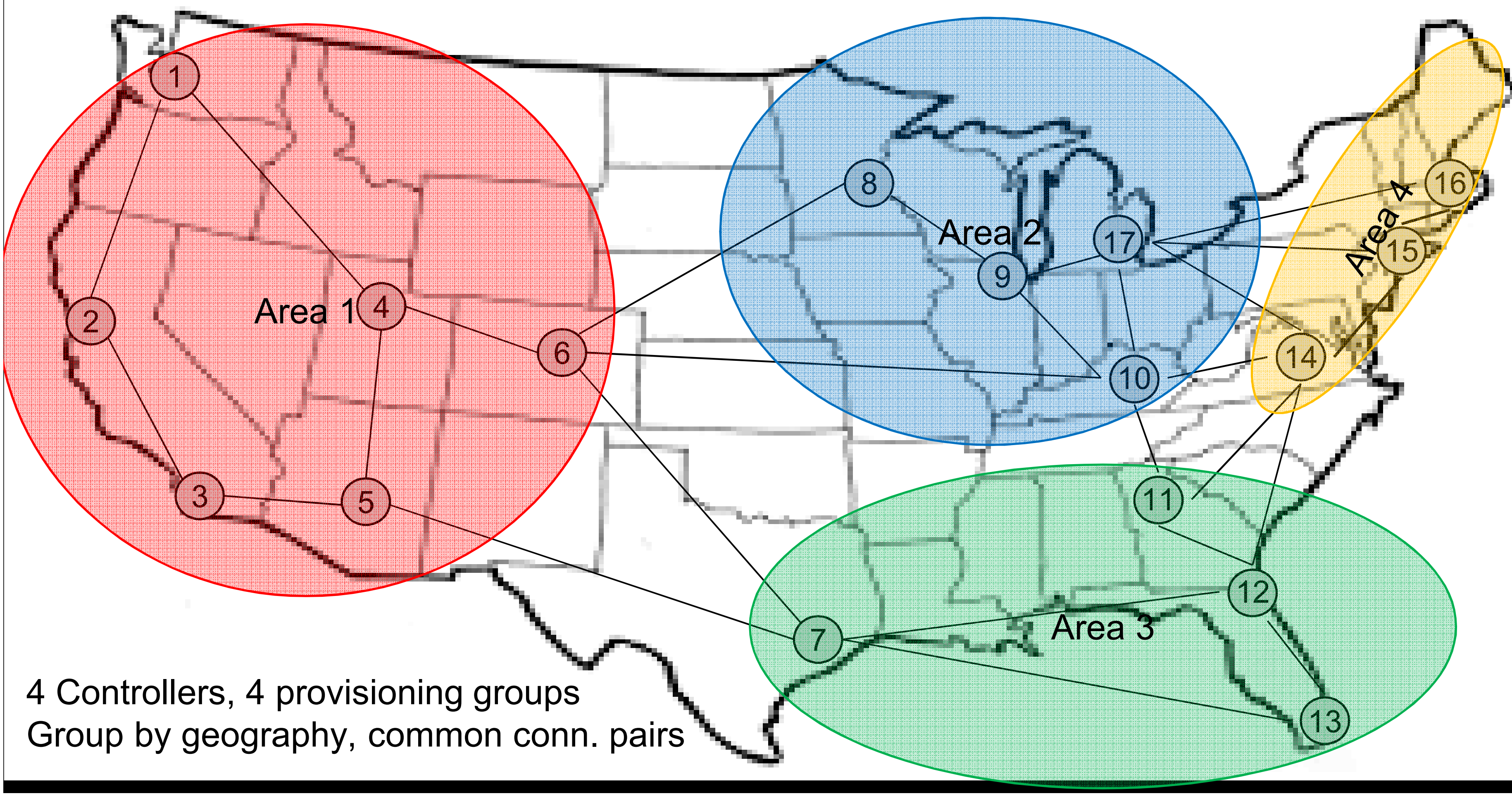
- **Provisioning Timeline**
  - **Conn. 1 – 6, path 1-2-4-6**
  - **Conn. 4-5, path 4-6-5**





Sub-Problems

- **How many areas should compose the Autonomous System (AS)?**



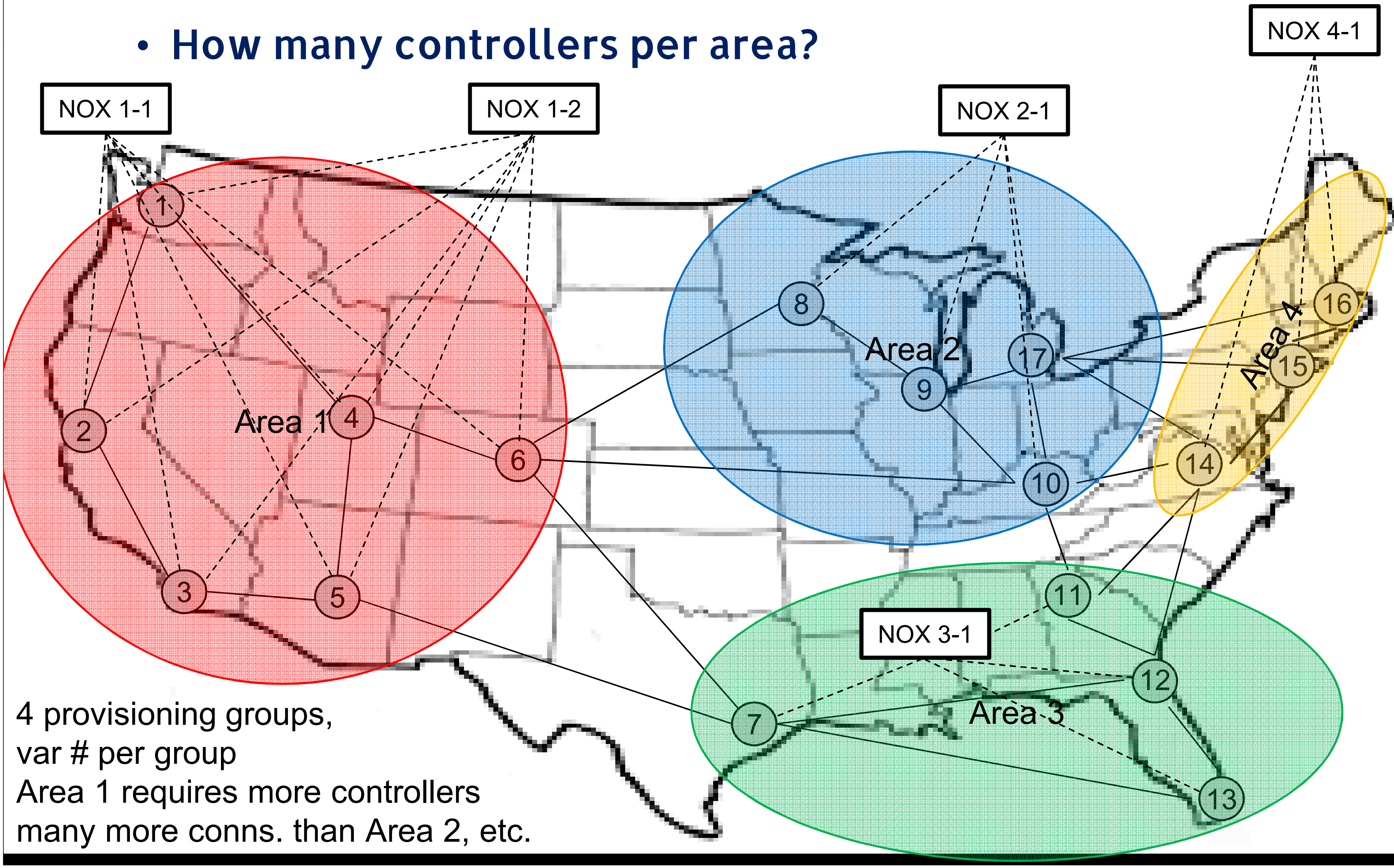
4 Controllers, 4 provisioning groups
Group by geography, common conn. pairs

Sub-Problem Analysis

- Objective Function
  - Minimize the average provisioning delay across the entire network
    - $t_p = \sum_{i=1}^{N} p_i t_{pi}$ (Min t_p)
  - Constraints: Controllers/PCE available (Cost)
    - $\sum_{i=1}^{N} c_i \leq C$ (Controllers available), c_i= 1 if cont at node i
    - Input can also account for traffic matrix, community detection
    - The more uniform the traffic matrix, the more difficult to determine where area boundaries should be
    - Areas dictated by above constraint, physical topology, and connection distribution (traffic matrix)

Sub-Problems

- **How many controllers per area?**



4 provisioning groups,
var # per group
Area 1 requires more controllers
many more conns. than Area 2, etc.

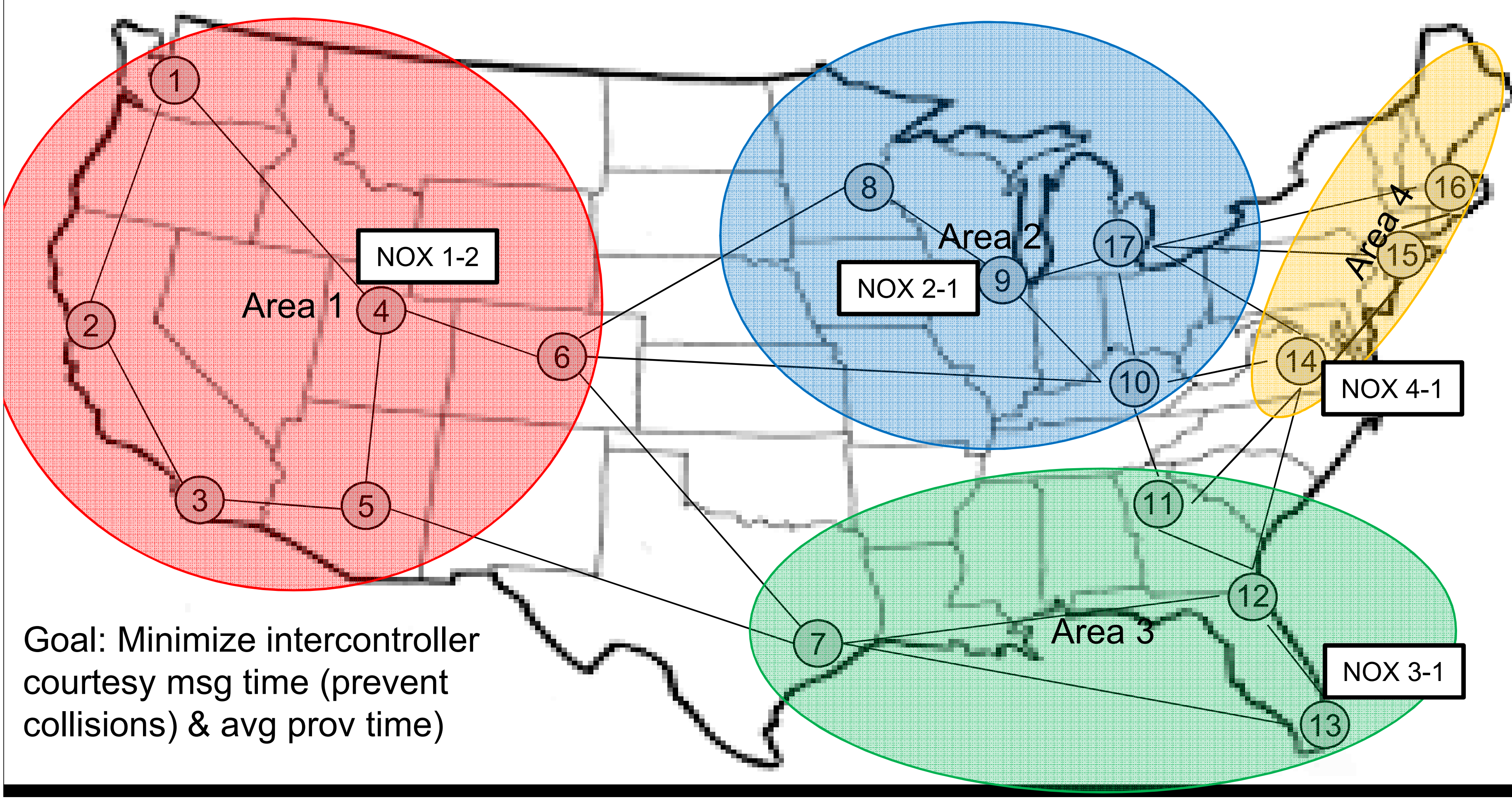
Sub-Problem Analysis

- **Objective Function**
  - **Minimize the average provisioning delay for nodes within the area**
    - $t_{pa} = \sum_{i=1}^{N_a} p_{ia} t_{pia}$ (Min t_p, for each area)
  - **Constraints: Controllers/PCE available (Cost)**
    - $\sum_{i=1}^{N_a} c_{ia} \leq C_a$ (Controllers available), c_{ia}= 1 if cont at node i, area 1
    - Input can also account for traffic matrix, community detection

    - Area's share of all connections roughly proportional to total number of controllers
    - Geographically dispersed/condensed also important

Sub-Problems

- **Controller Location within Area**



Goal: Minimize intercontroller courtesy msg time (prevent collisions) & avg prov time)

Sub-Problem Analysis

- Objective Function
  - Minimize the average provisioning delay for nodes within the area
    - $t_{pa} = \sum_{i=1}^{N_a} p_{ia} t_{pia}$ (Min t_{pa}, for each area)
  - Constraints: Controllers/PCE available (Cost)
    - $\sum_{i=1}^{N_a} c_{ia} = 1$ (Controllers available), c_{ia}= 1 if cont at node i, area a

    - To reduce the blocking probability, we need to balance the time delay between each area node and controller with inter-controller delay, i.e. controllers are placed closer to area border than edge

    - If area has a higher proportion of connections than other areas, controller positioned closer to area center

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Simulation

- Start with small topology, scale number of nodes incrementally, to a large continental network (NSFnet)
- At each topological size, use Poisson arrivals process uniformly across all nodes, measure average path provisioning time with network of 1 area, 2, 3…
- This approach would help determine if multi-area SDEON provisioning is less desirable than GMPLS or single area SDEON in smaller topologies.

- With large, static topology: Set different numbers of areas and compare blocking probability performance to single area SDEON.
- This would also tell us if there is a steady-state number of areas where adding more does not further increase performance

- Also conduct mini simulations within overall topology with different controller locations, controllers per area, etc.

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Conclusions

- GMPLS – distributed signaling w/ RMSA, Sliceability
- SDN for optical layer (SDON/SDEON)
- Distributed SDN, Multi-layer SDN
- Multi-Area SDEON
  - Collisions
  - Sub-Problems: number of areas, number of controllers in area, controller location
- Simulation

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