Role Discovery

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Outline

- Background
- Our Approach
- Complexity Results
- Lower Bounds
- Role Discovery Algorithms
- Results
- Next Steps

Role Based Access Control

- What is it?
  - An alternative to discretionary and mandatory access control, where users' access to permissions is managed directly.
  - A role is a collection of permissions; users are assigned to roles
- Advantages
  - Aligned to business objectives of the organization
  - Rights defined once and applied to multiple recipients
  - Managing access changes for large groups of users
  - Managing individual user's access as job roles change

What's the problem?

- Migrating to RBAC is a huge challenge for large organizations
- The first step is *role engineering*
  - User Identification
    - Typically 10s of thousands in an enterprise
  - Resource Identification (e.g. applications)
    - Typically thousands
  - Constraint Analysis
    - e.g. segregation of duties
  - Design and Optimize
- This is a labor-intensive (expensive) process.

Role Discovery

- A bottom-up approach to discover roles that are implicit in an existing access control environment
  - Input: Existing access control rules
  - Output: A set of equivalent roles
- Goal:
  - Don’t replace role engineering
  - Provide tools to make the role engineering process more efficient

Benefits of Role Discovery

- Faster Results
  - Can help speed the role engineering process
  - Can migrate more of existing access controls to role based system
- Transparancy
  - Provides the organization with a clear view of existing access controls.
  - Exposes "noise" in the system
- Lowers Risk
  - Lowers risk of business disruption and vulernability introduction when role based system is deployed

Related Work

- Acadmic
  - Statistical Analysis (Kuhlmann, et al 2003)
  - Clustering (Schlegelmilch & Steffens 2005)
  - Subset Enumeration (Vaidya, et al 2006)
  - Complexity Results (Vaidya, et al 2007)
  - Merge and Split (Zhang, et al 2007)
- Commercial
  - Eurekify
  - Vaau
  - Bridgestream

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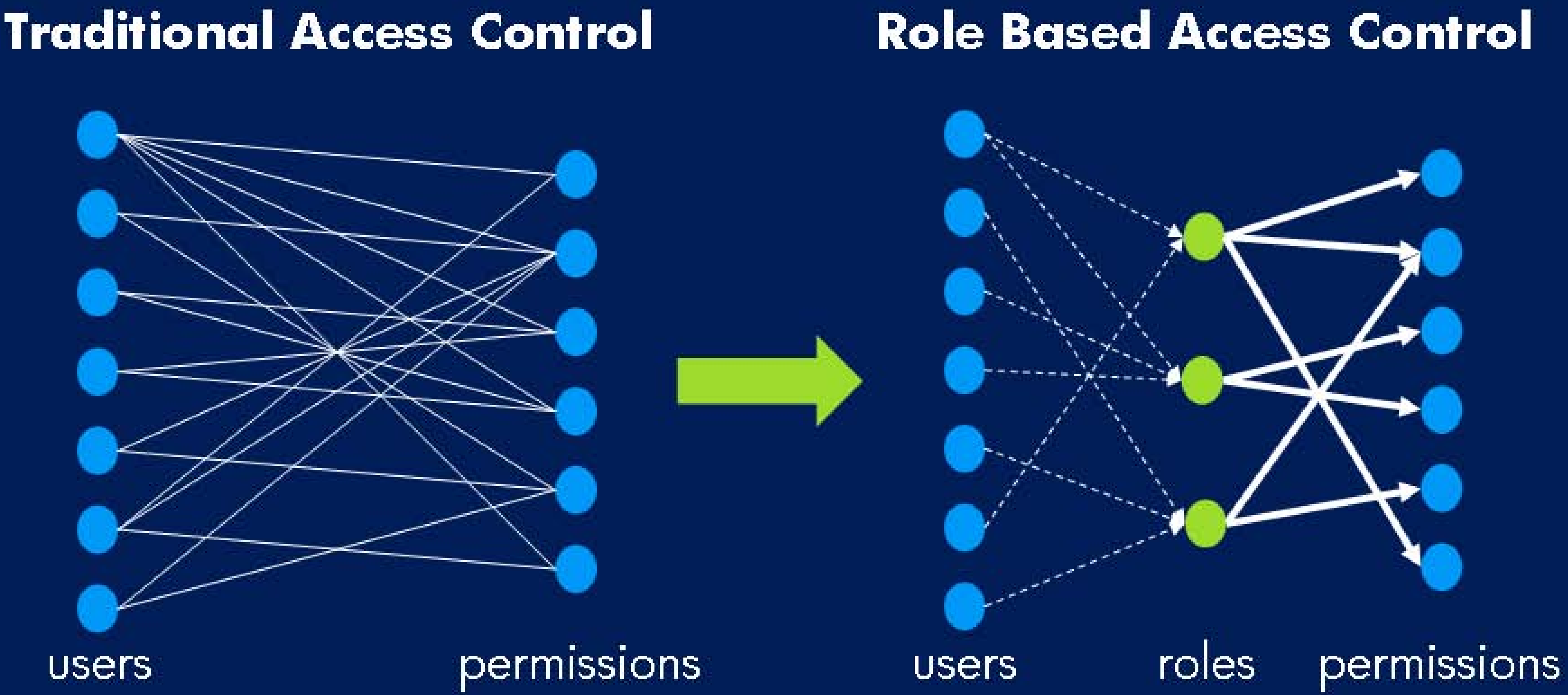
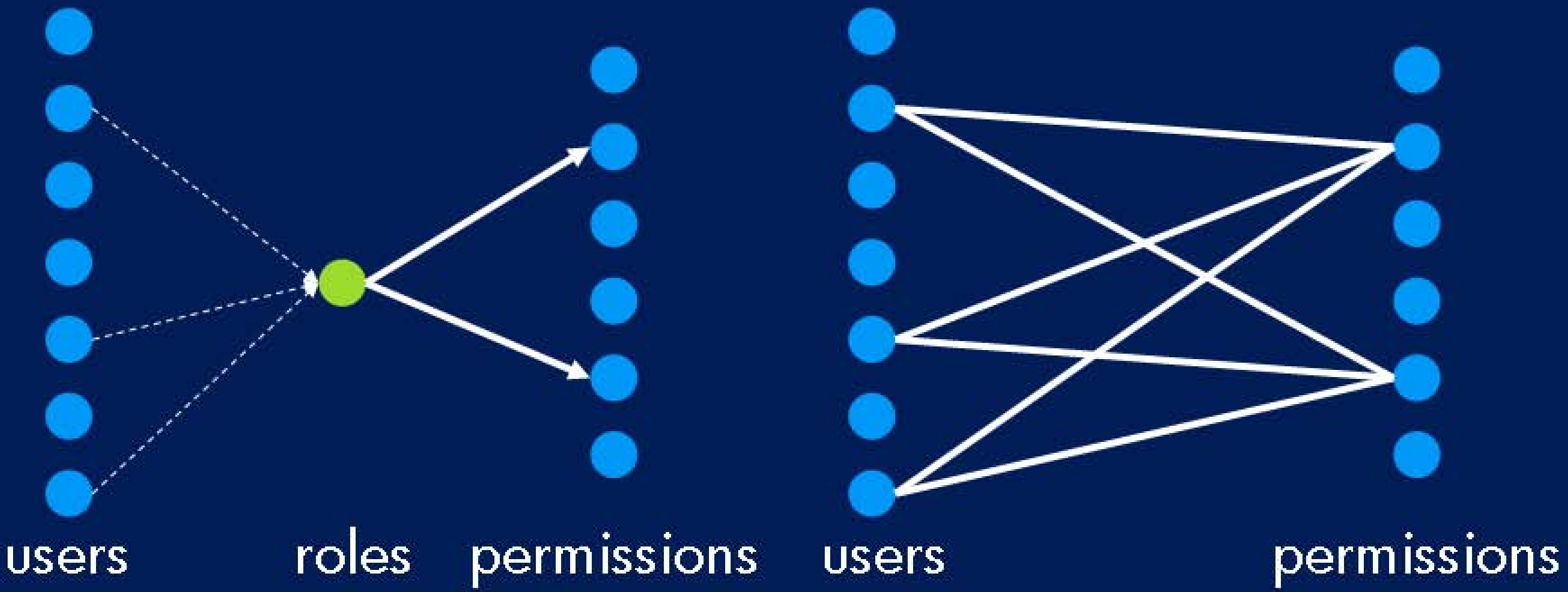
Our Approach



"bipartite" graph

"tripartite" graph

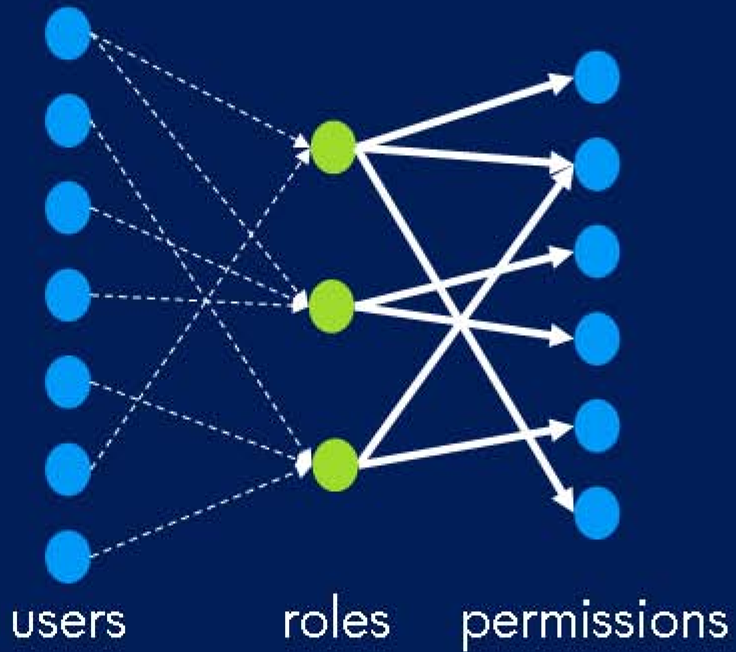
Roles are bicliques



Therefore, discovering a set of roles to explain a set of access control rules is equivalent to covering the bipartite graph with a set of bicliques

Two Goals

- Minimize total number of roles
  - Find the smallest biclique covering
- Minimize total number of edges
  - "Edge Concentration"
  - Find the biclique covering of minimum total order



Complexity Results

- Finding a minimum biclique cover is NP-complete (Orlin,1977)
- Inapproximability (Simon, 1990)
  - The Minimum Biclique Cover problem is inapproximable in polynomial time within a factor n^{δ} for some constant $\delta > 0$, unless P = NP.
  - The Minimum Biclique Cover problem is inapproximable in polynomial time within a factor $n^{1-\varepsilon}$ for any constant $\varepsilon > 0$, unless NP = ZPP.
- Edge Concentration is NP-complete (Lin, 2000)

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Lower Bound on Number of Roles

- Max Independent Set
  - Two edges (a,b) and (c,d) are independent if:
    - a, b, c, and d are distinct
    - not completely connected
  - Independent edges cannot be in the same biclique
  - N pairwise independent edges imply at least N bicliques in the cover

- Finding the max independent set is also NP-complete
- Heuristic algorithm
  - Run algorithm K times
    - Pick an edge randomly
    - Remove dependent edges
    - Iterate until graph empty
  - Choose largest independet set found

Lower Bounds on Number of Edges

- Only bound we know of is trivial
  - Total number of vertices (users + permissions)

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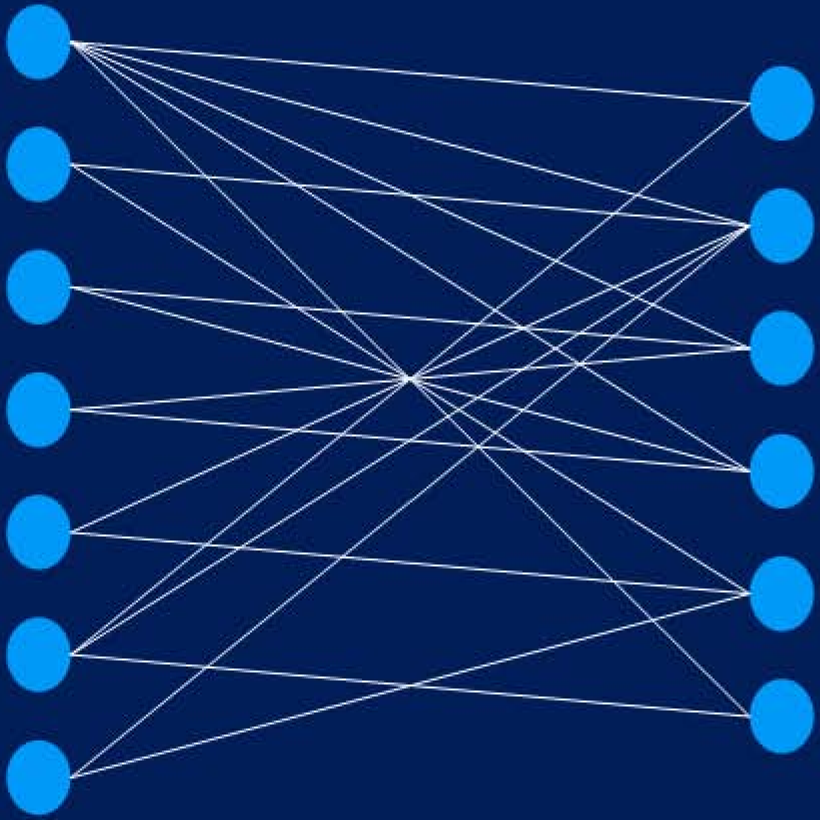
Heuristic Algorithm for Biclique Cover

- Pick some node, n
  - e.g. a node with minimum degree
  - other ways to choose n are possible
- Find its set of neighbors, A.
- Find the intersection of A's neighbors, B.
  - $n \in B$
- (A,B) is a biclique, therefore a role
- Remove those edges from the graph and iterate.

Example



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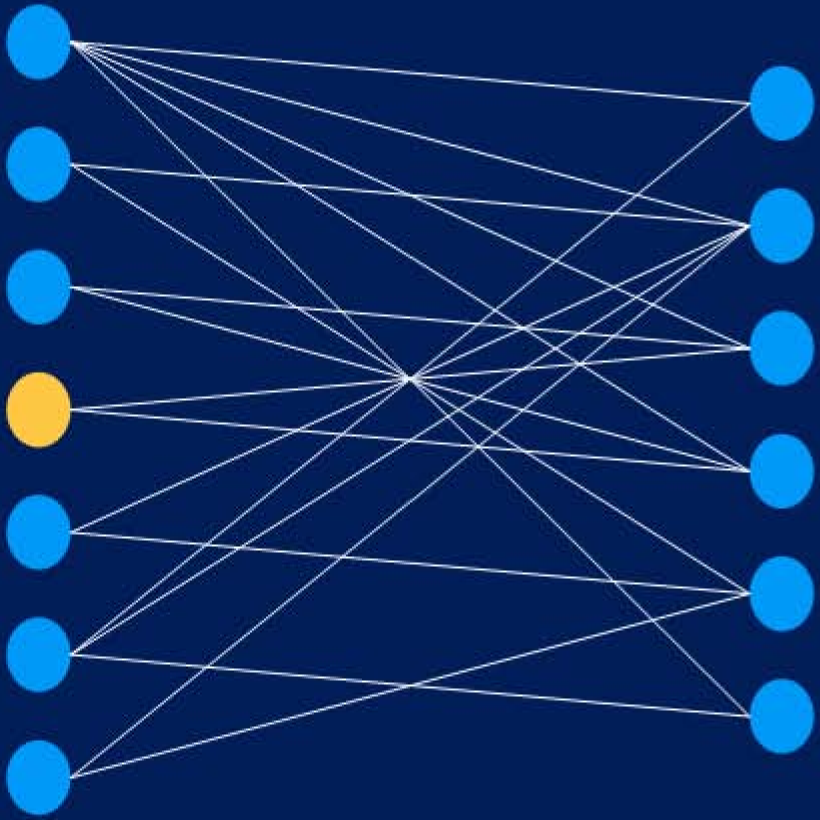

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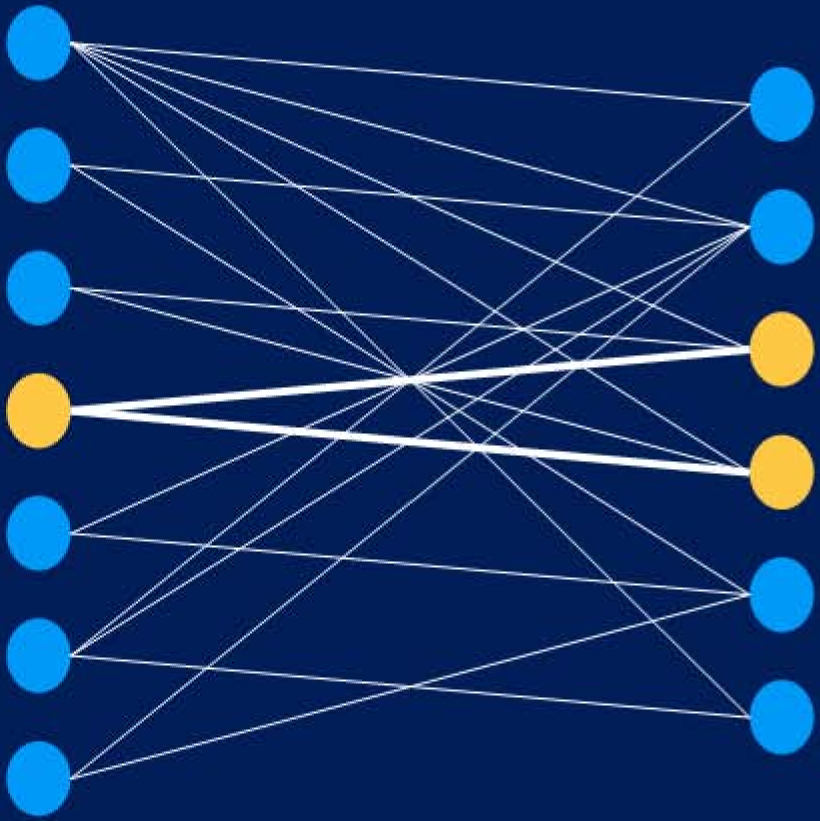

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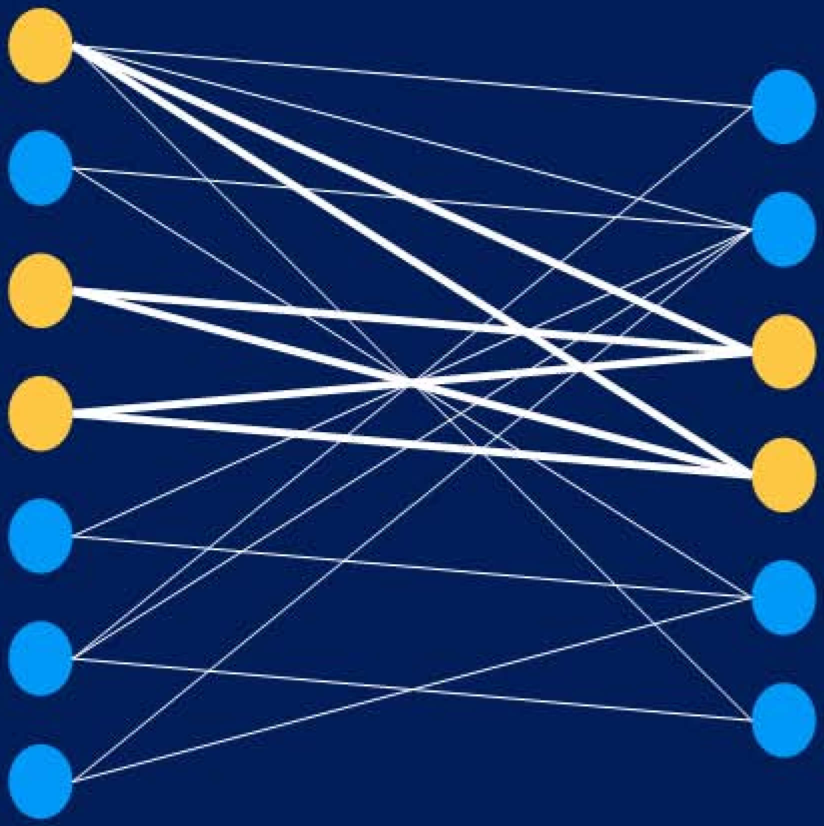

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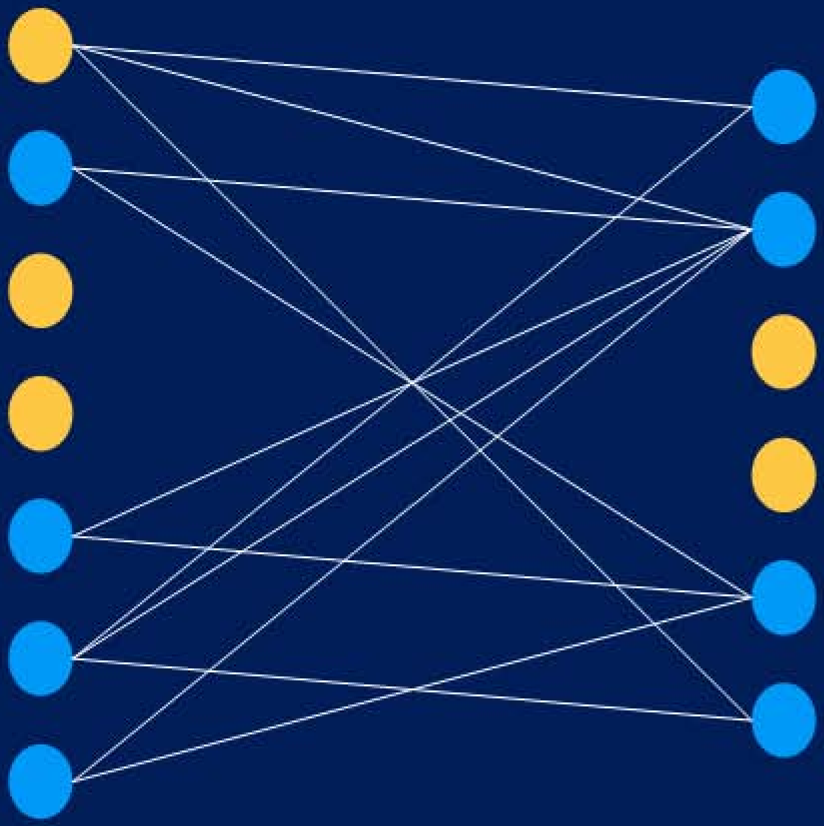

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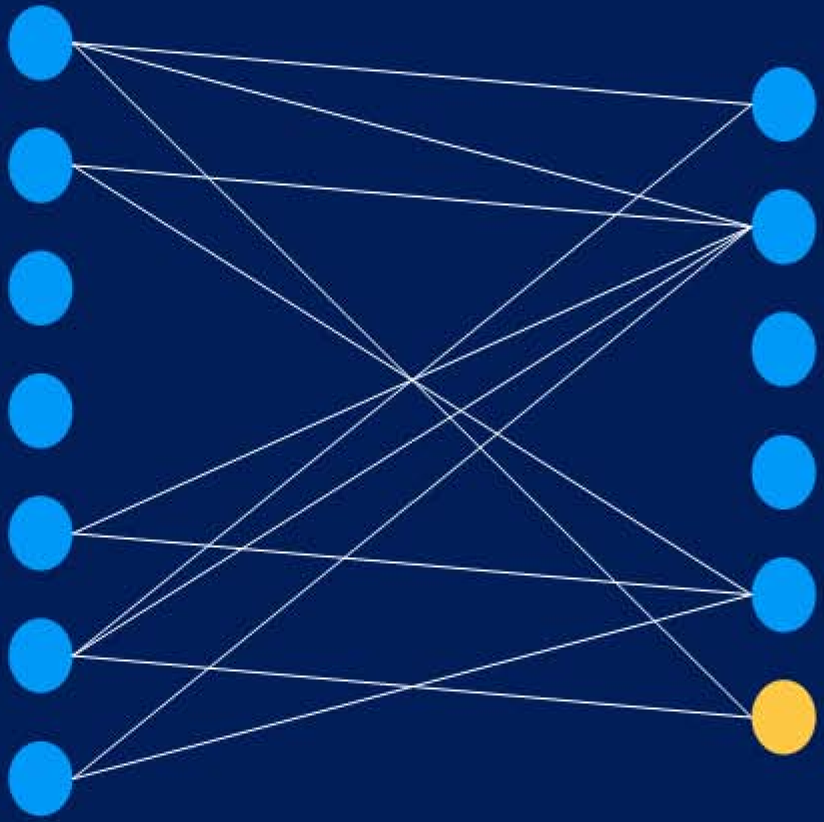

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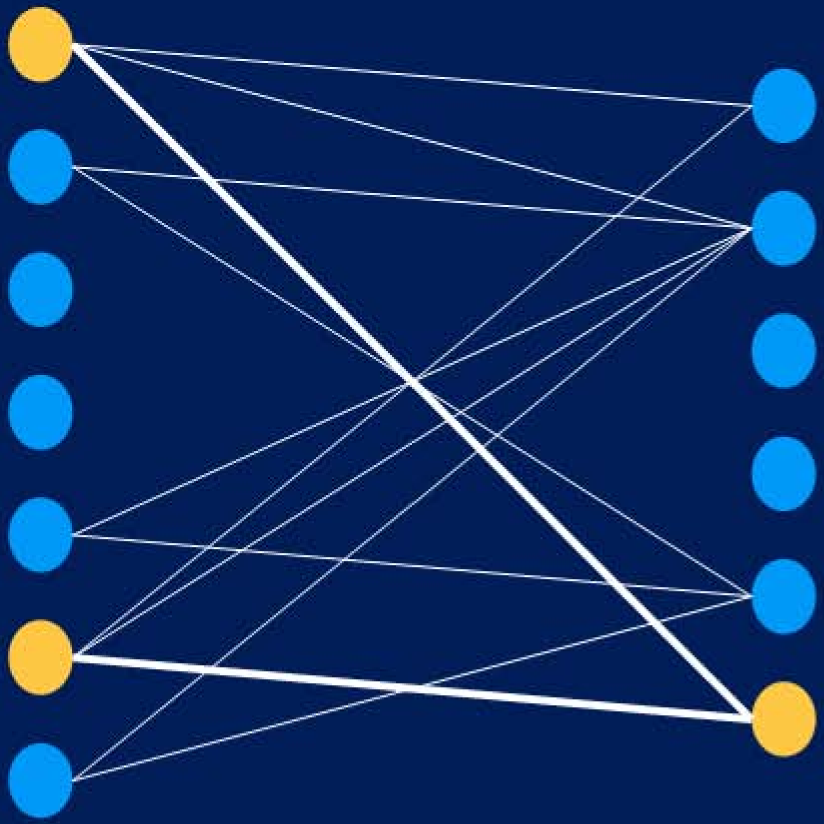

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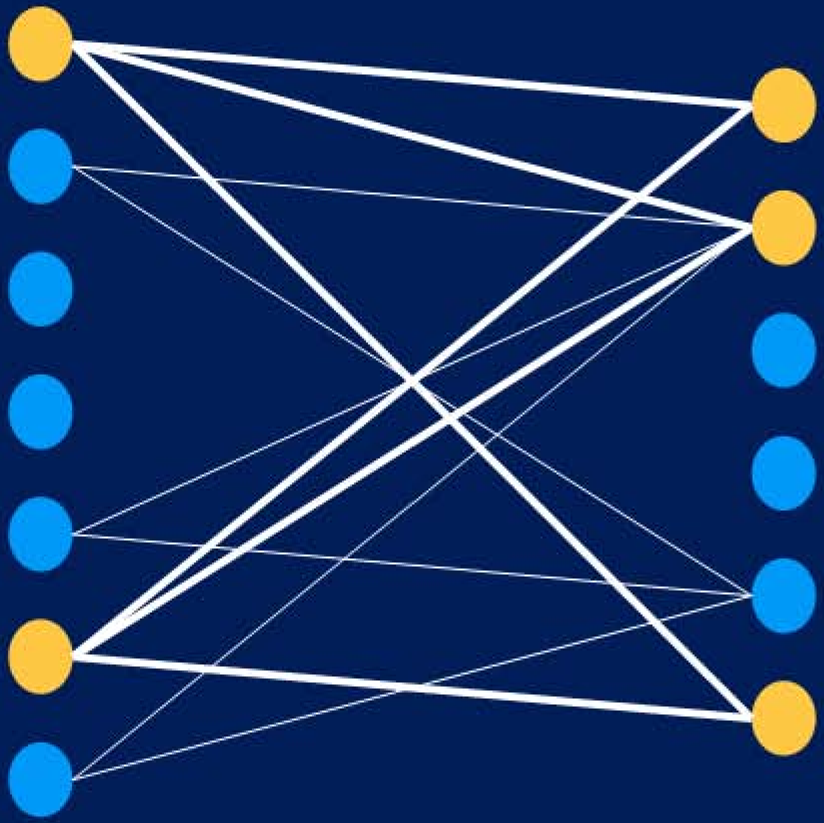

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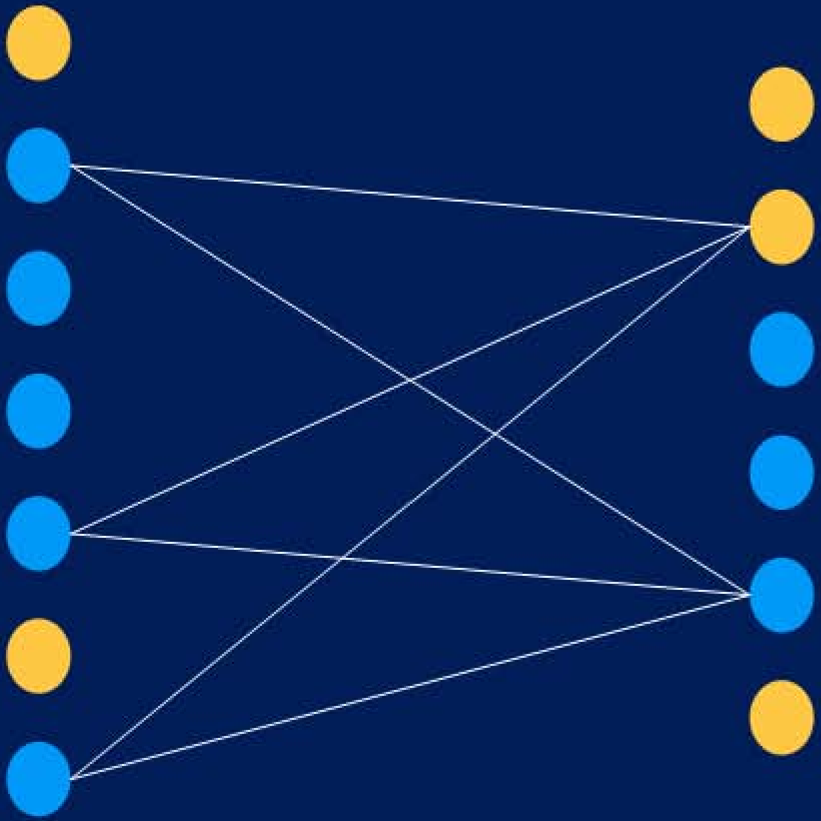

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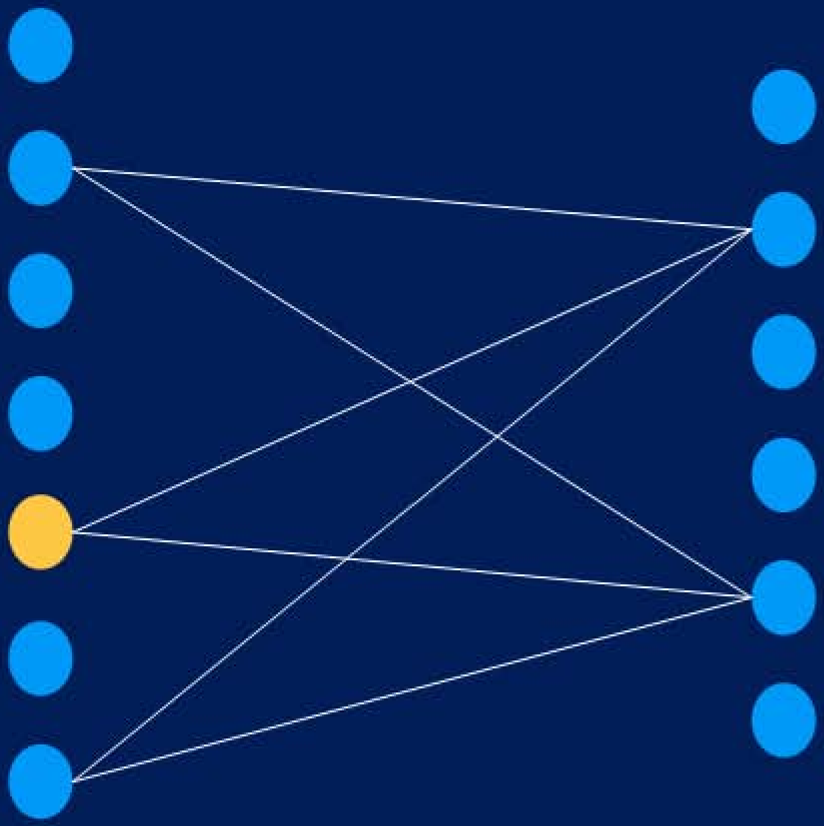

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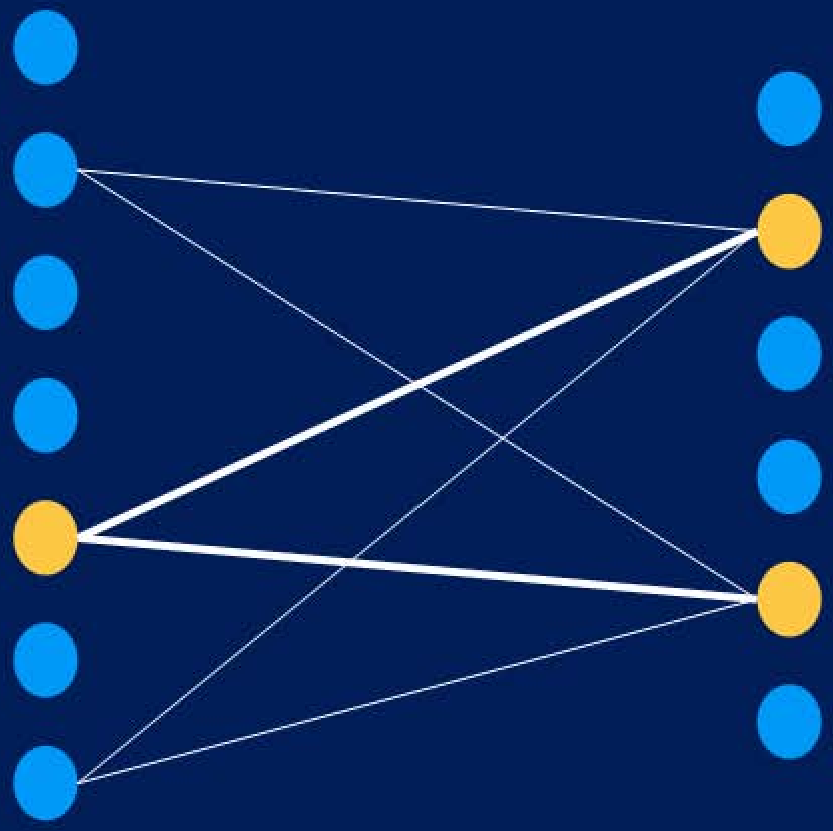

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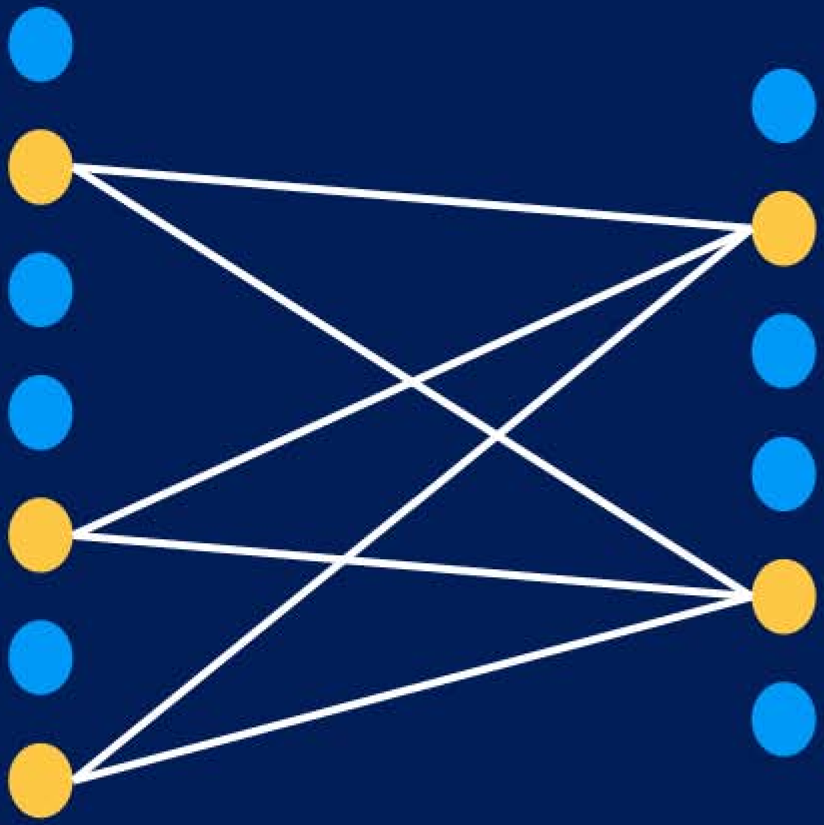

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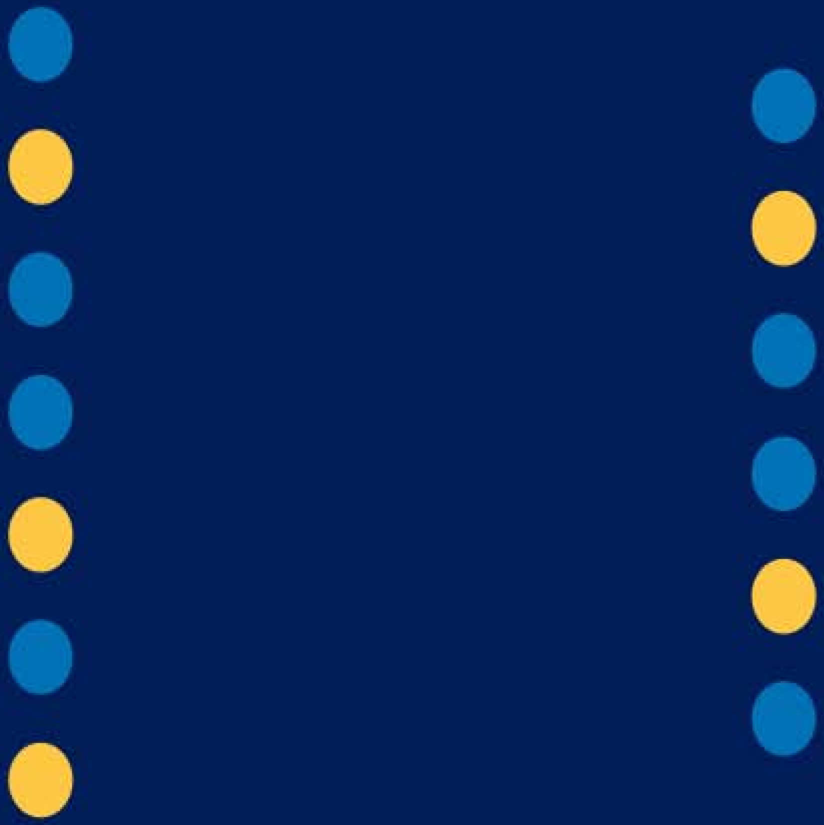
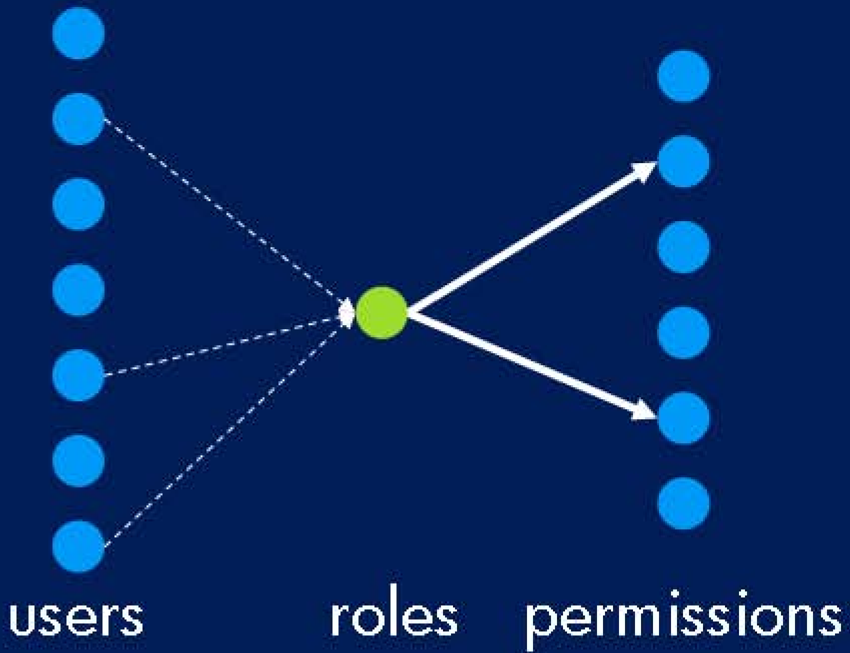
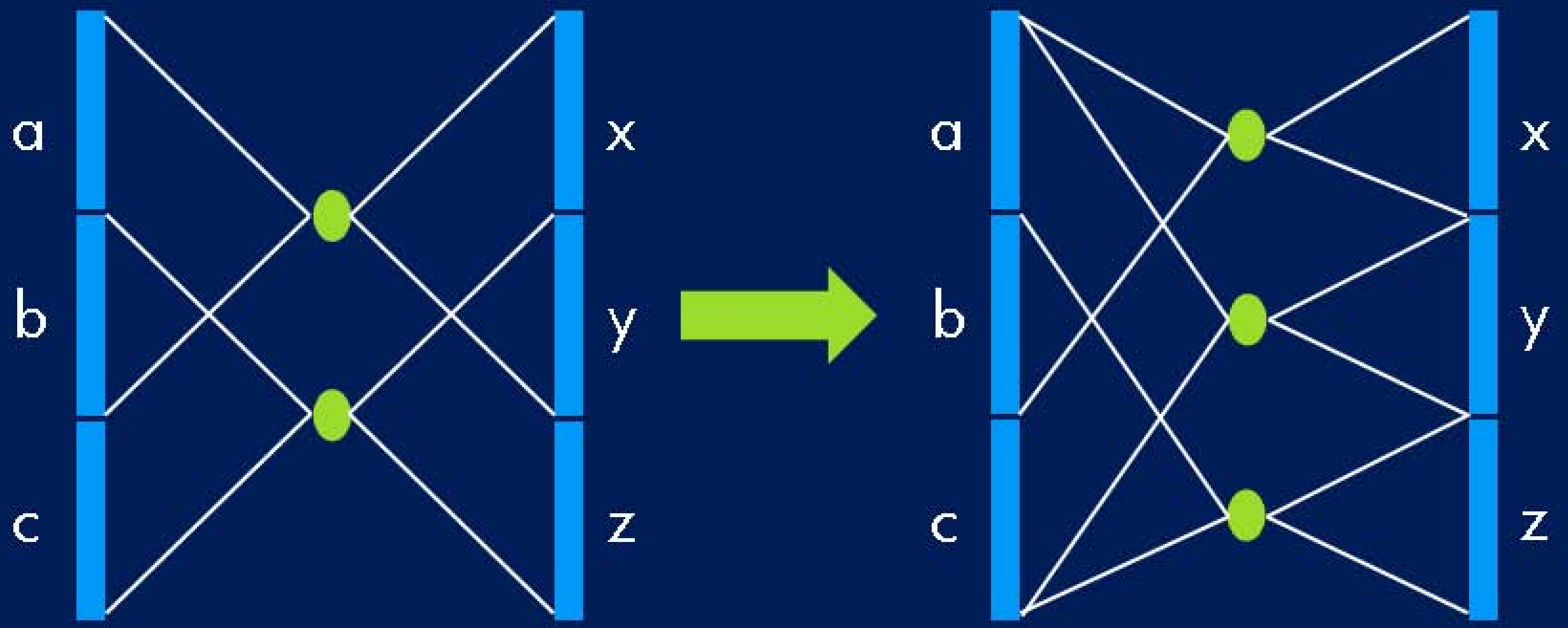


Edge Minimization

- For each role the number of edges is the sum of the number of users and permissions in the role.



Edge Minimization

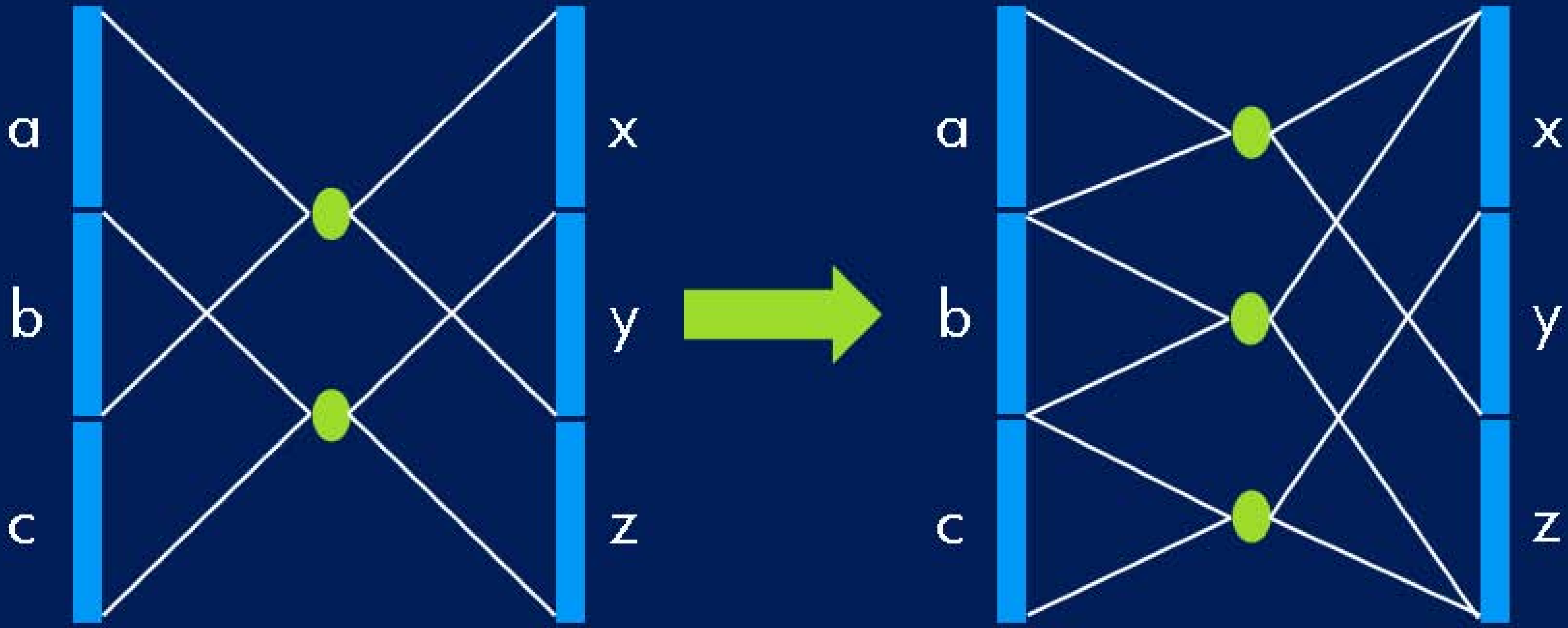


$$\#\text{edges} = [(a+b) + (x+y)] + [(b+c) + (y+z)]$$

$$\#\text{edges} = [(a+b) + x] + [(a+b+c) + y] + [(b+c) + z]$$

$$\boxed{\text{Transform if } y > a + b + c}$$

Edge Minimization



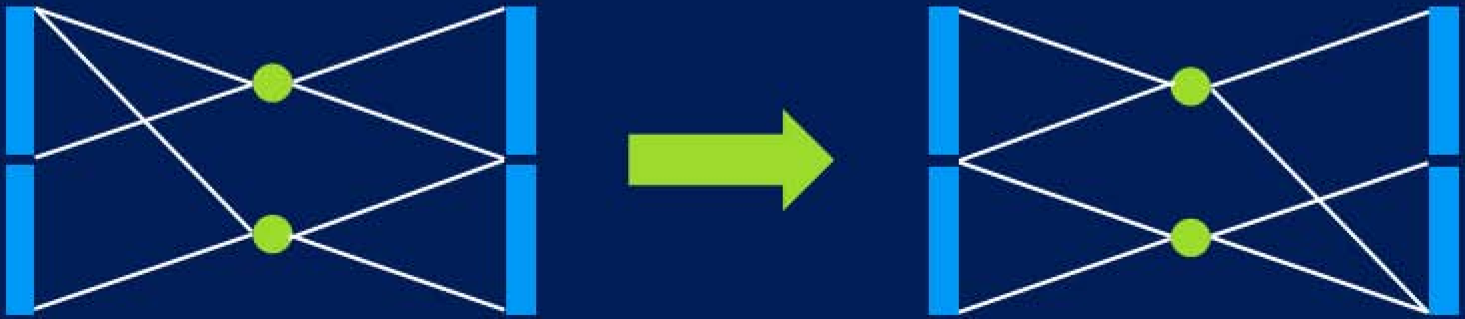
#edges = [(a+b) + (x+y)]
+ [(b+c) + (y+z)]

#edges = [a+ (x+y)]
+ [b + (x+y+z)] + [c + (y+z)]

$\boxed{\text{Transform if } b > x + y + z}$

Edge Minimization

- In certain degenerate cases, no increase in roles occurs



- Algorithm
  - Start with node minimization solution
  - Greedily substitute pairs of roles until no more gains possible

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Application to Real World Problems

- HP IT Partner Connectivity
  - Allows external business partners to connect into internal HP systems
  - ~3,000 partner organizations
  - ~10,000 internal ipaddr/port pairs
  - ACLs on routers and firewalls
- Customer Application Entitlements
  - ~10,000 users
  - ~100 enterprise applications
  - ~1000s of finer grained permissions
  - Access control rules distributed across applications

Sample Results

	dataset	#1	#2	#3
	#users	2044	3485	3477
	#perms	1164	10127	1587
	#edges	6841	185294	105205
	role lower bound	453	390	172
	edge lower bound	3208	13612	5064
role	#roles	456	422	220
min	#edges	4416	74568	8987
edge	#roles	485	929	286
min	#edges	3987	21968	8082

Next Steps

- The real problem is that most organization's existing access controls are too complicated
- Discovered roles are difficult to interpret
- Possible Solutions
  - Approximate covers
  - Roles ⇒ Rules
    - Discovered roles are semanticless
    - Discover rules, based on user/permission attributes to describe roles
    - Dynamic roles

Thank you!

- Want to find out more?
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