CISPA
HELMHOLTZ CENTER FOR
INFORMATION SECURITY

# Link Stealing Attacks on Inductive Trained Graph Neural Networks

Bachelor Thesis Introduction - Philipp Zimmermann

# Outline

- Graphs
- Graph Neural Networks
- Our Approach: Link Stealing Attacks on Inductive Trained Graph Neural Networks
- Experimental Setup
- Goal

# Graphs

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- Data Structure
  - Model large data and relationships between entities
  - Nodes with features
  - Edges

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- Chemical Networks
  - Protein-protein interactions

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- Social Networks
  - Instagram
  - Facebook
  - Twitter

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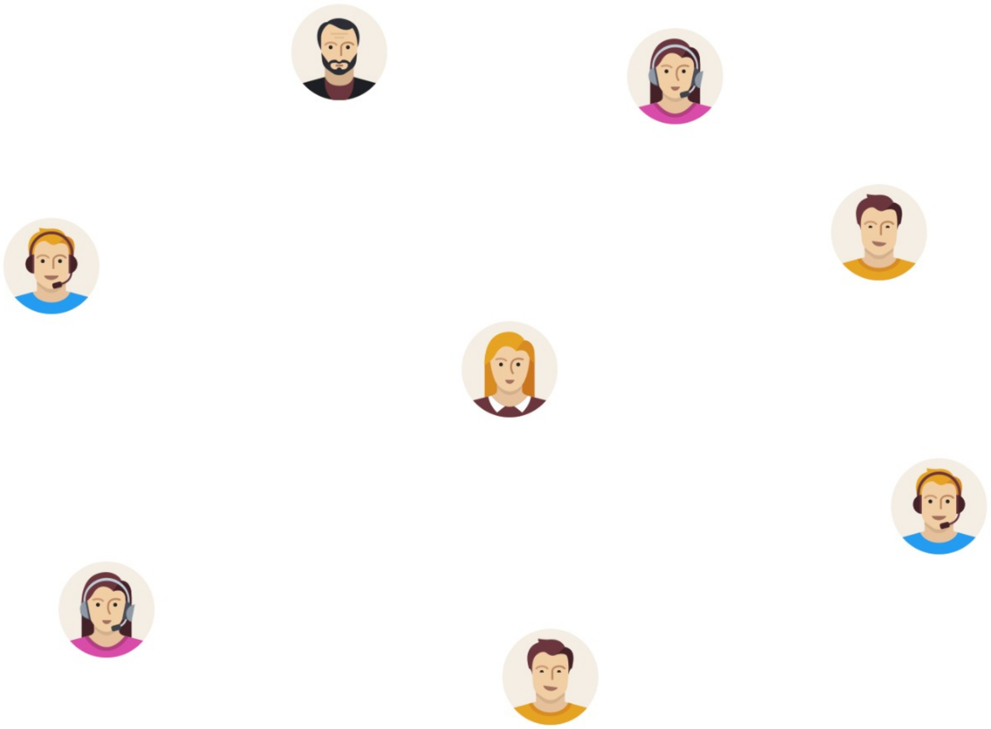

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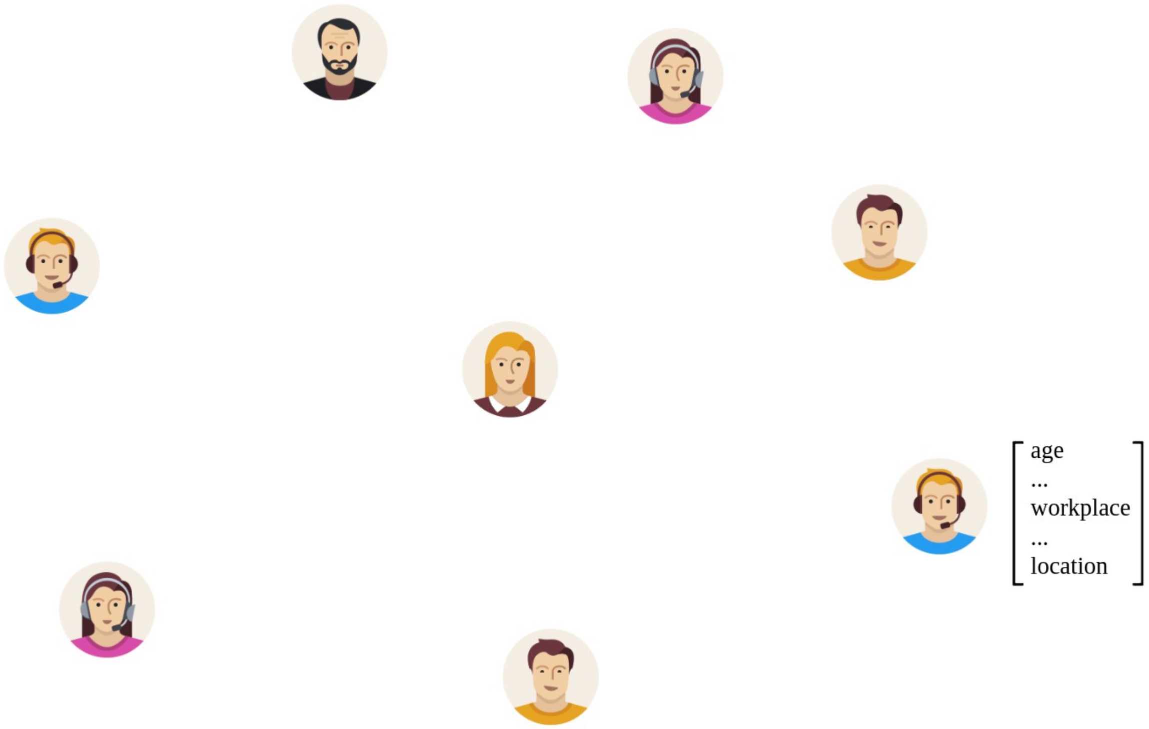

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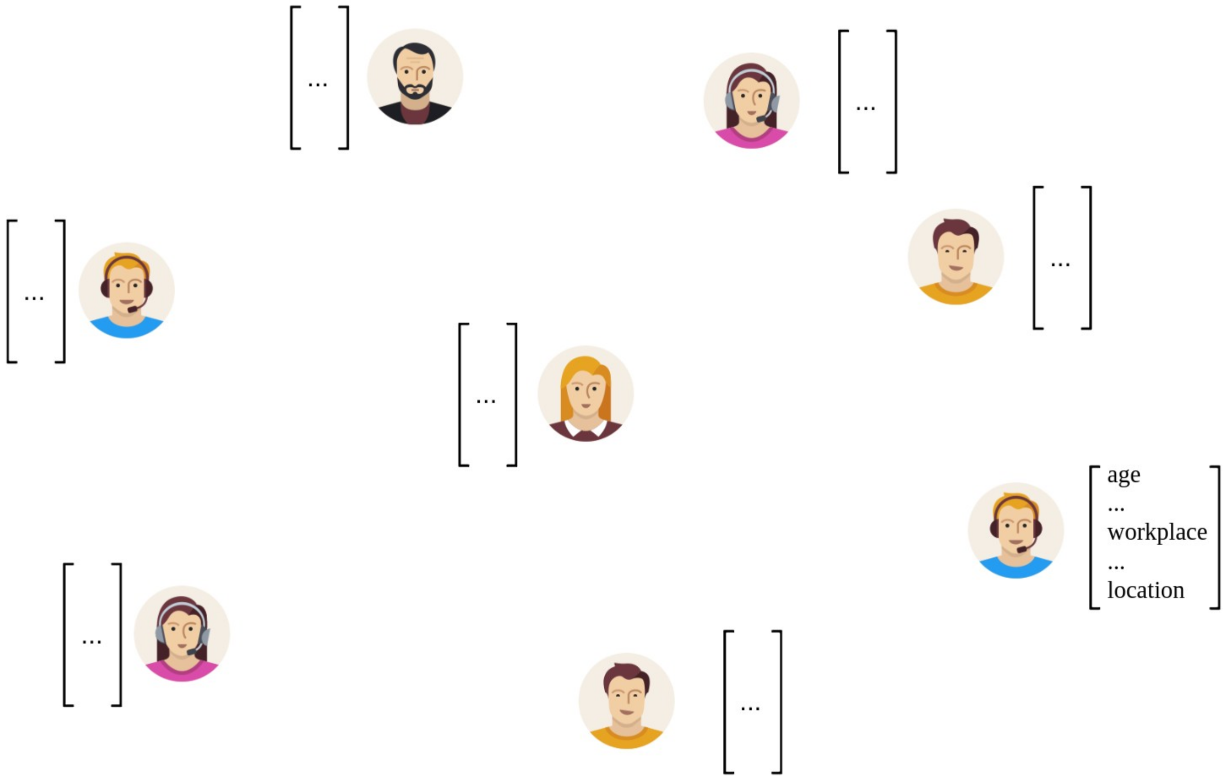

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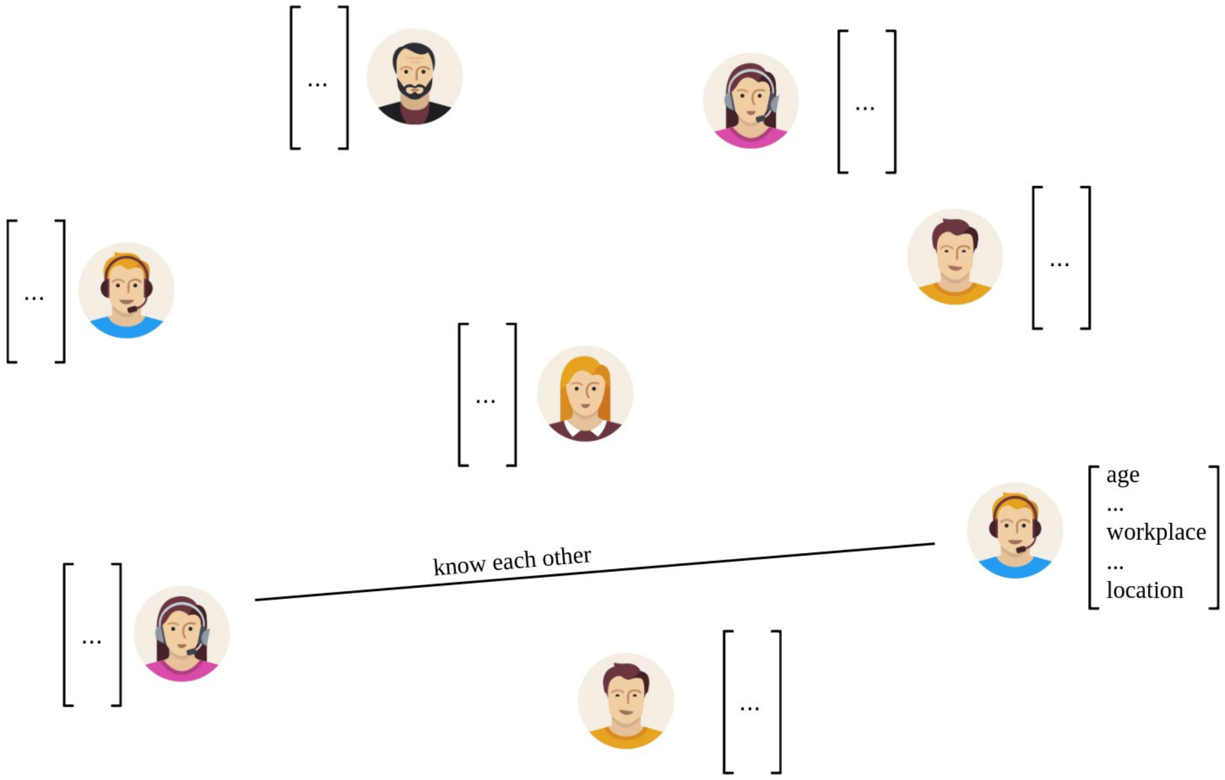

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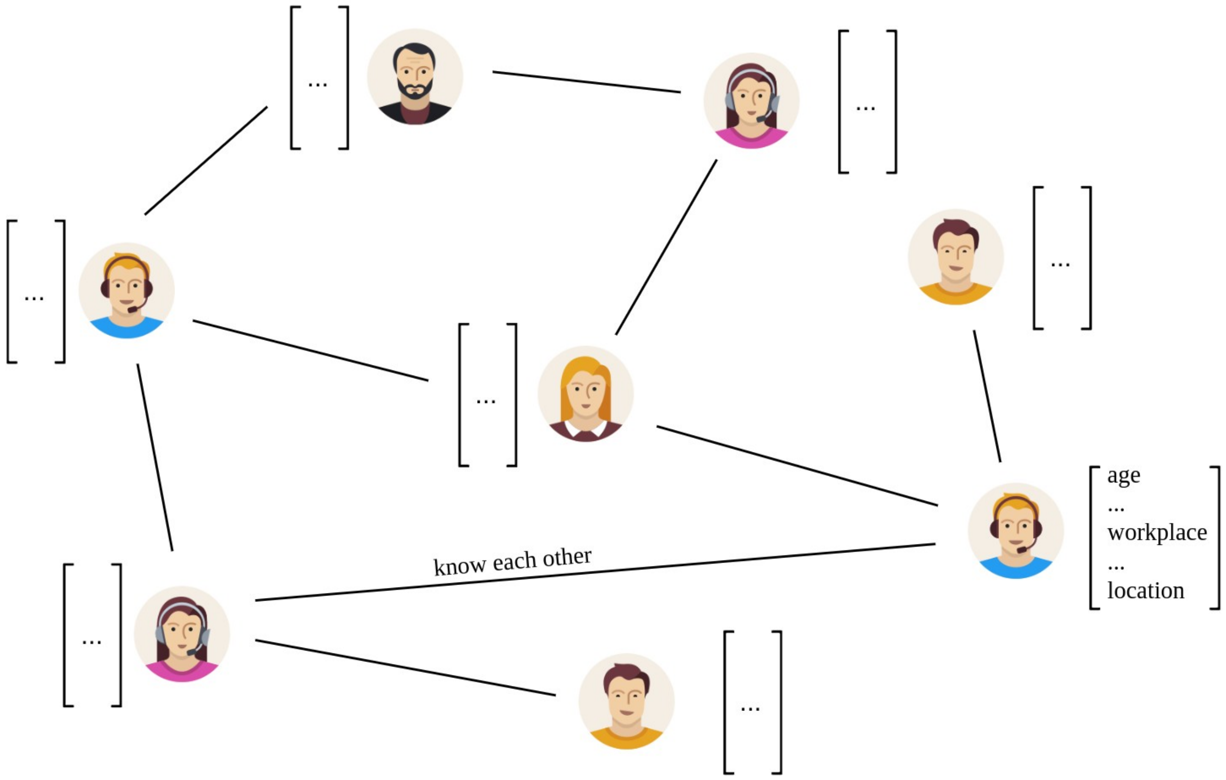
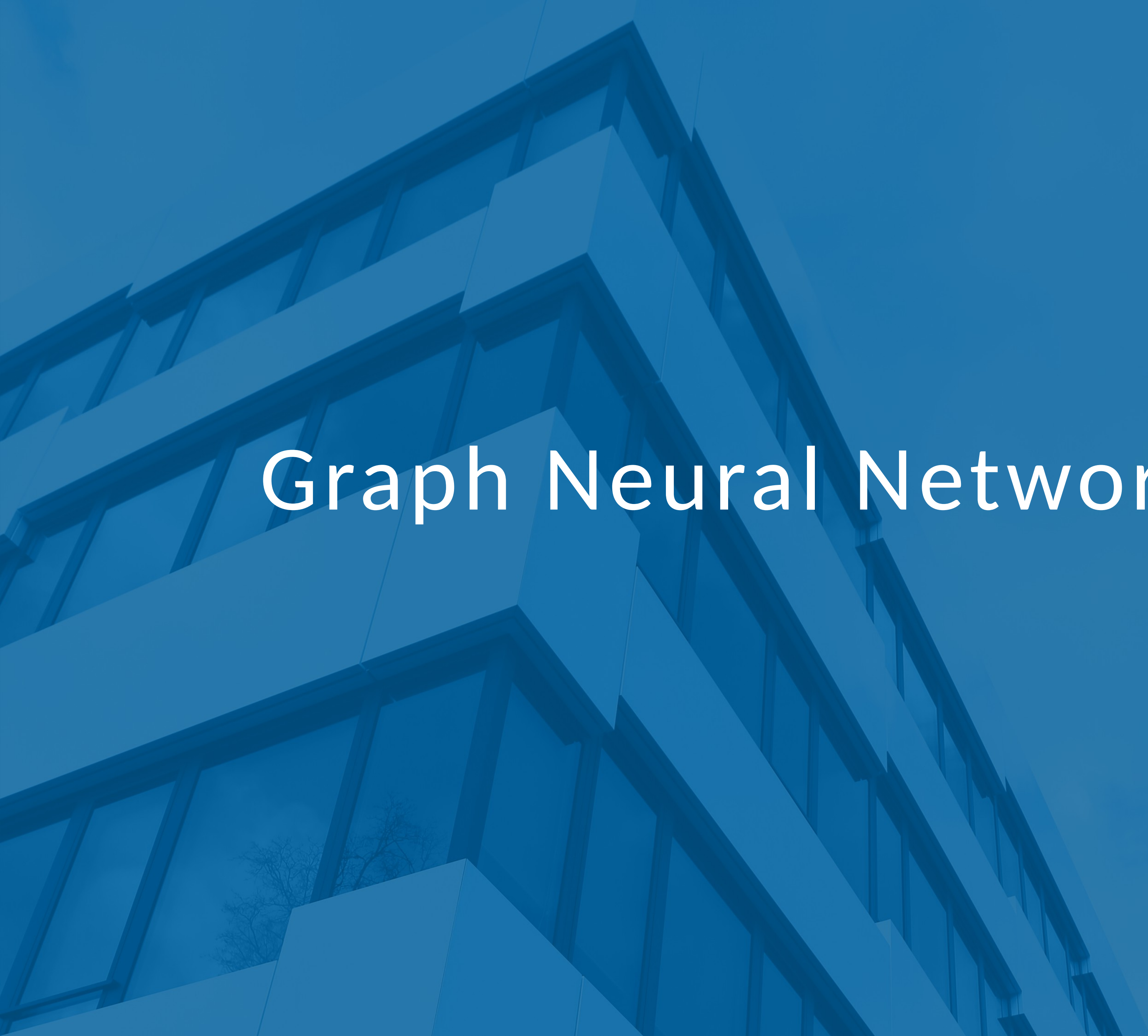




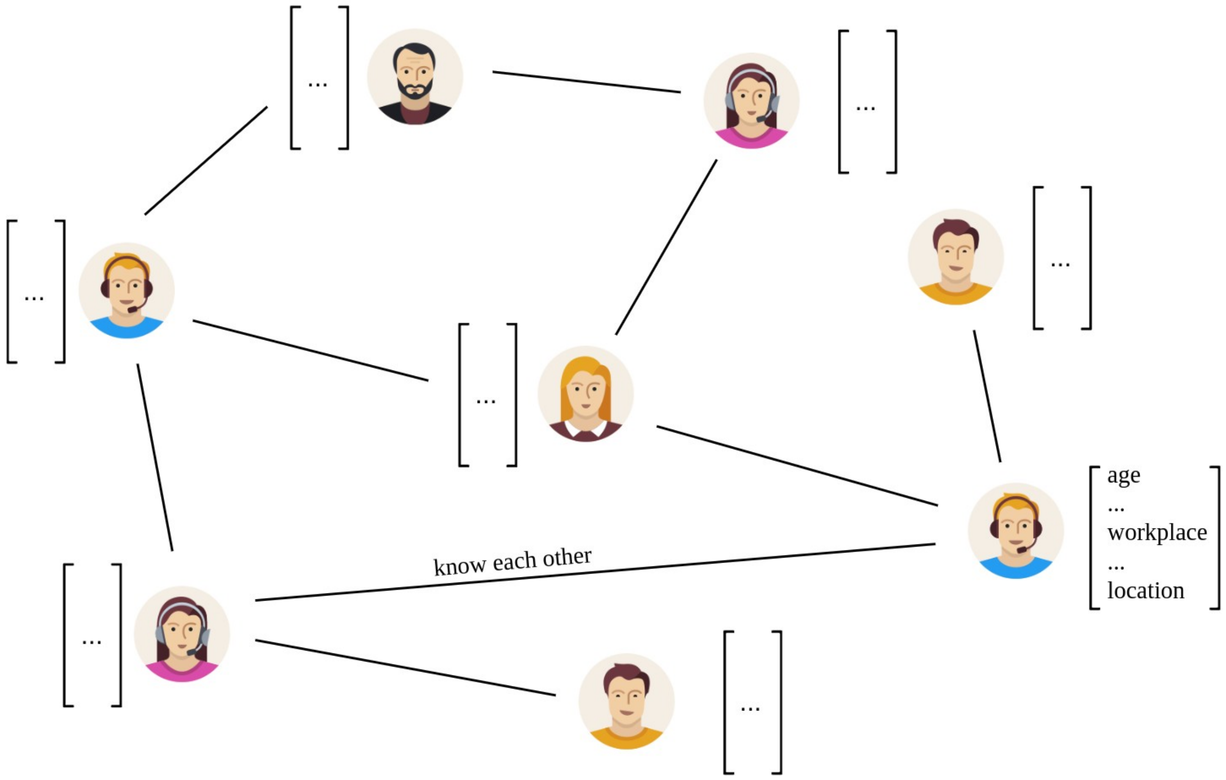
# Graph Neural Networks (GNNs)

# Graph Neural Networks

- Machine Learning Model over Graphs

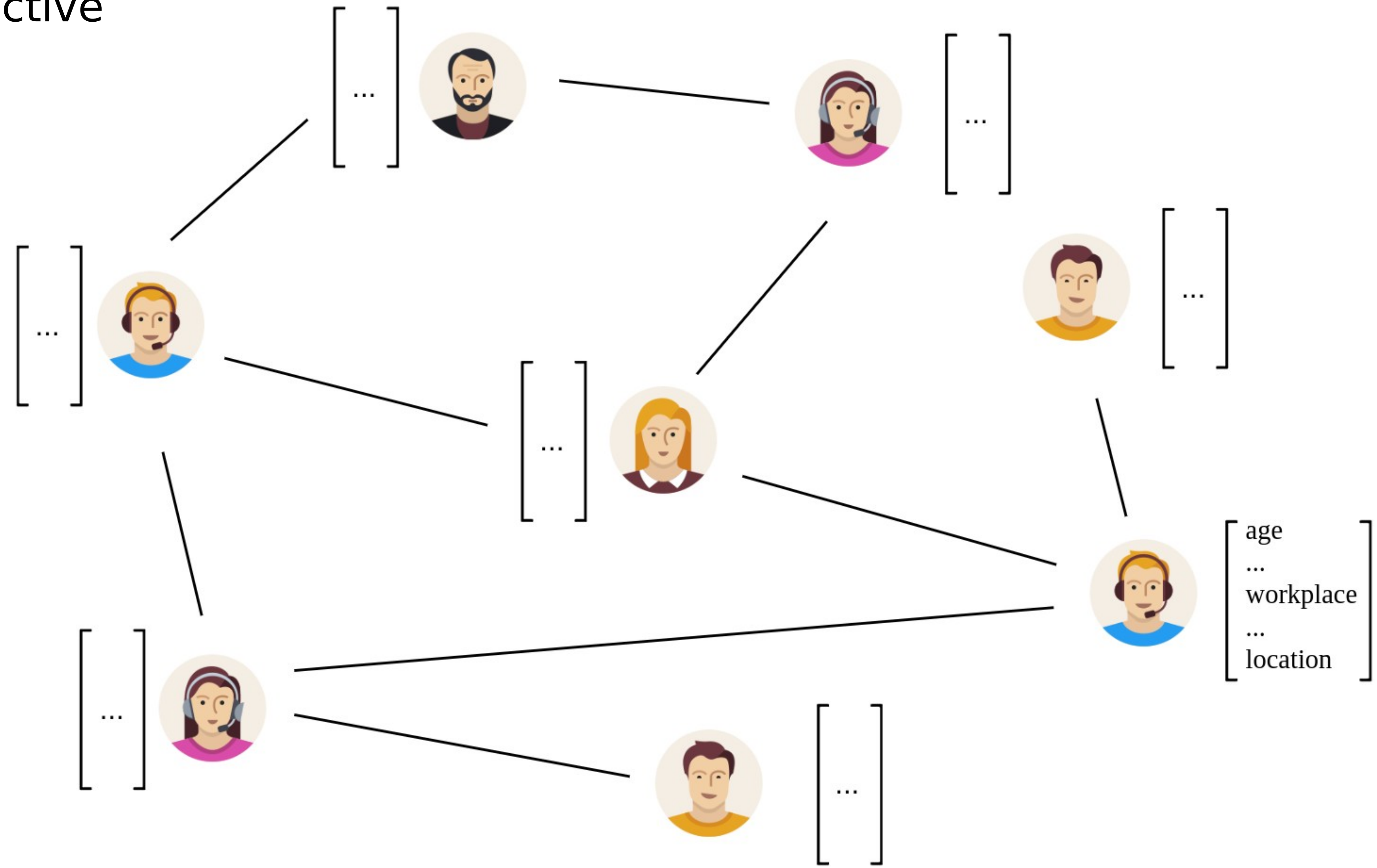
- Different Tasks
  - Node classification
  - Graph classification
  - Link prediction

- Different Learning Methods
  - Transductive
  - Inductive



# Graph Neural Networks

- Transductive



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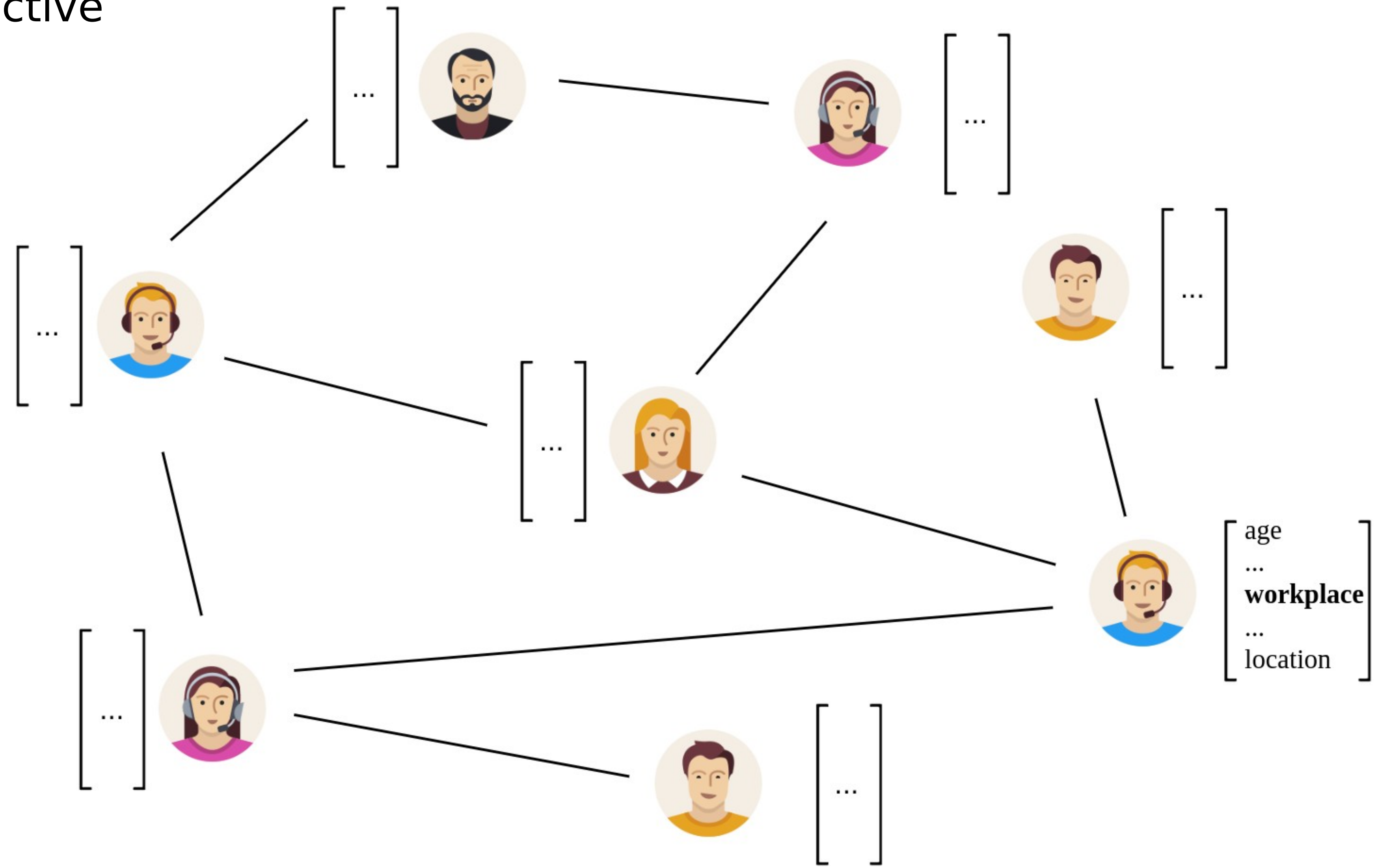
- Transductive



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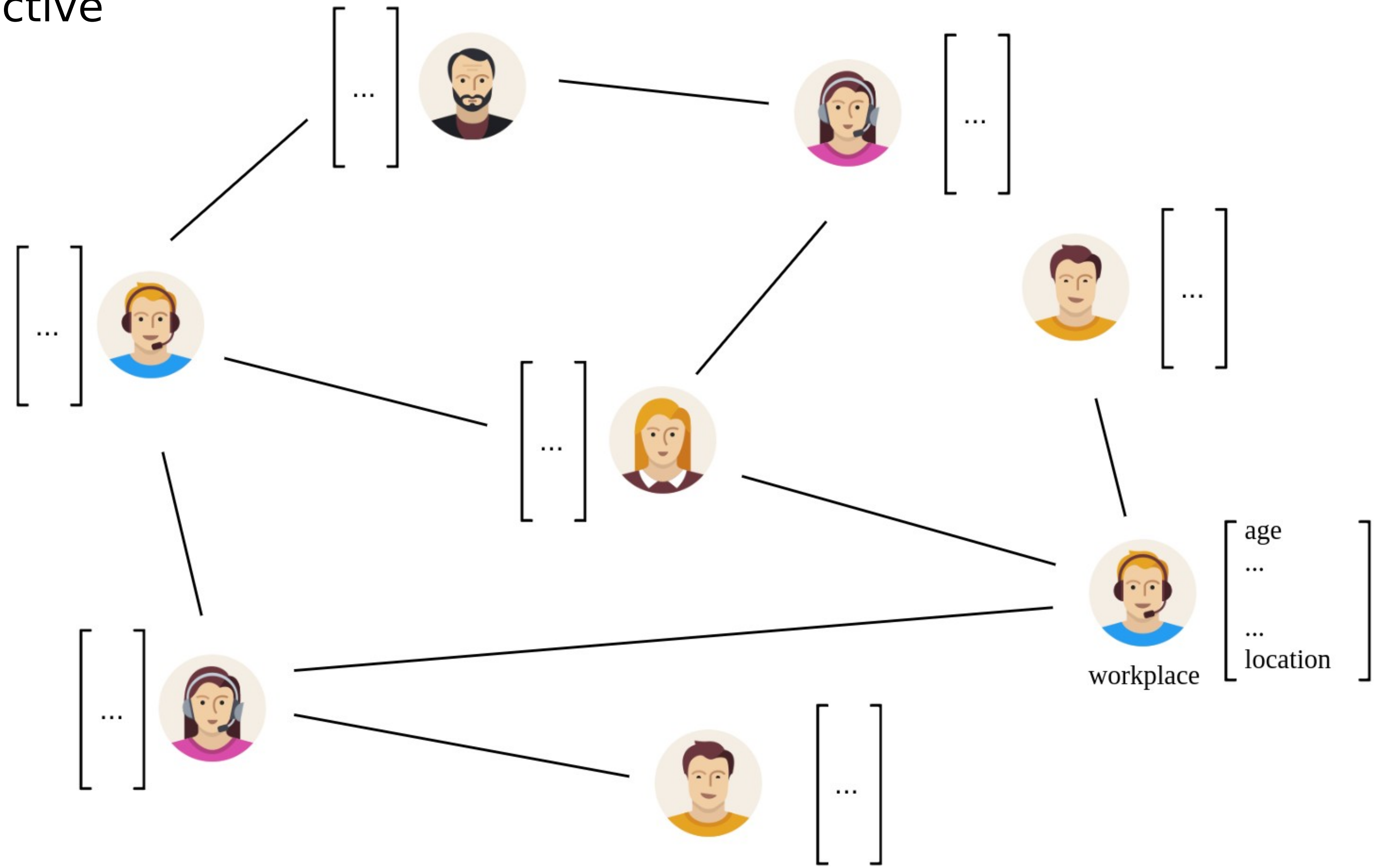

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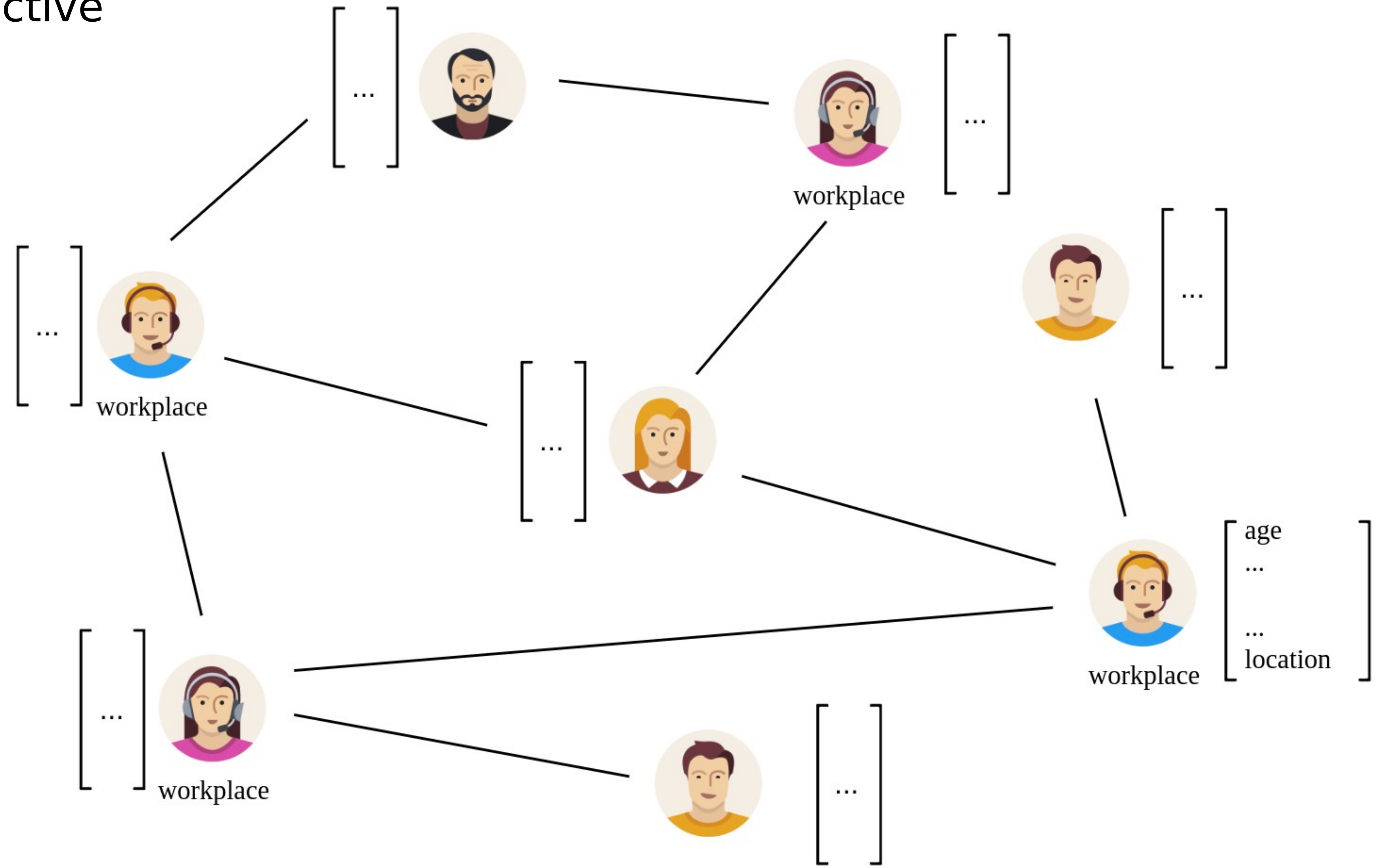
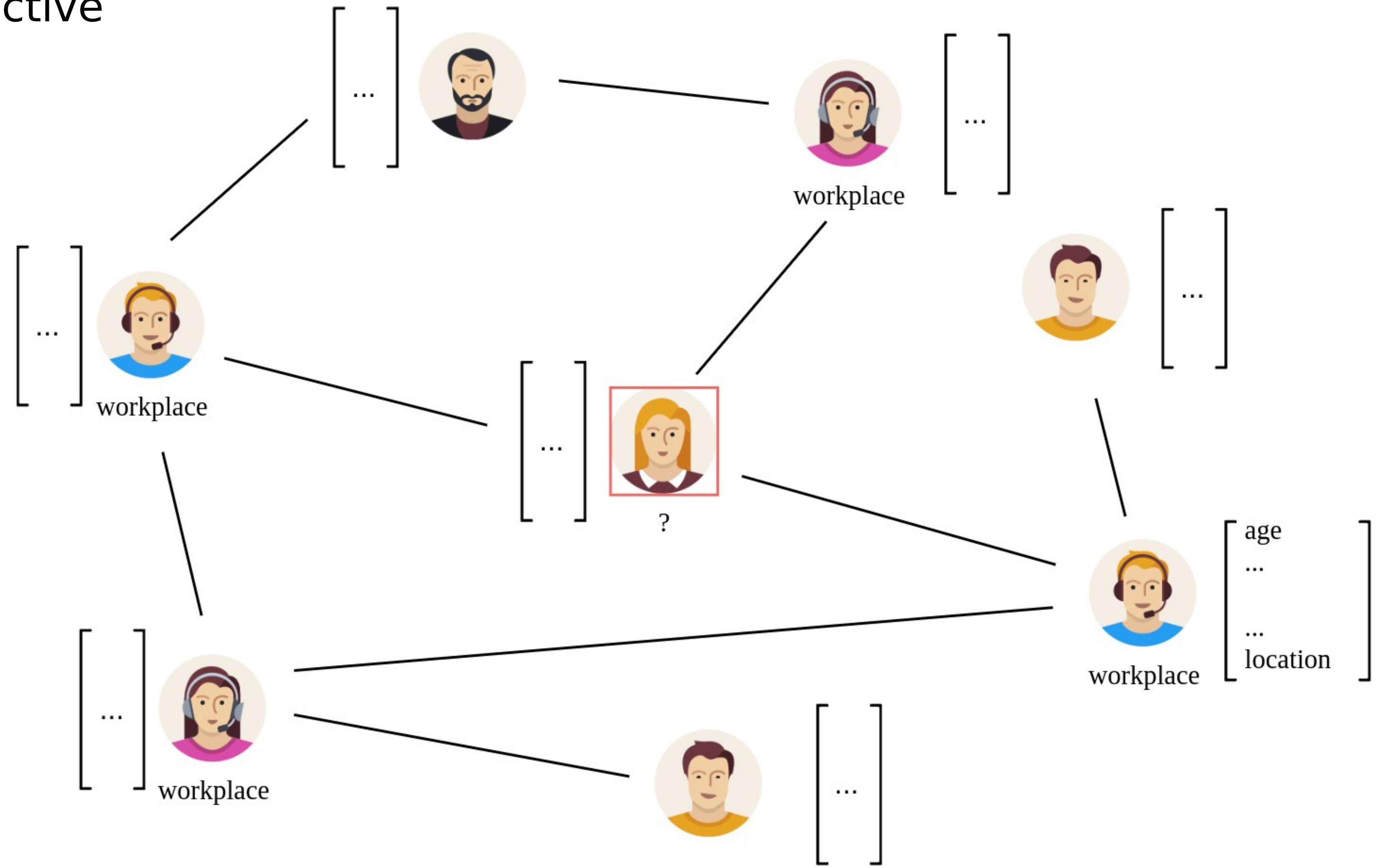


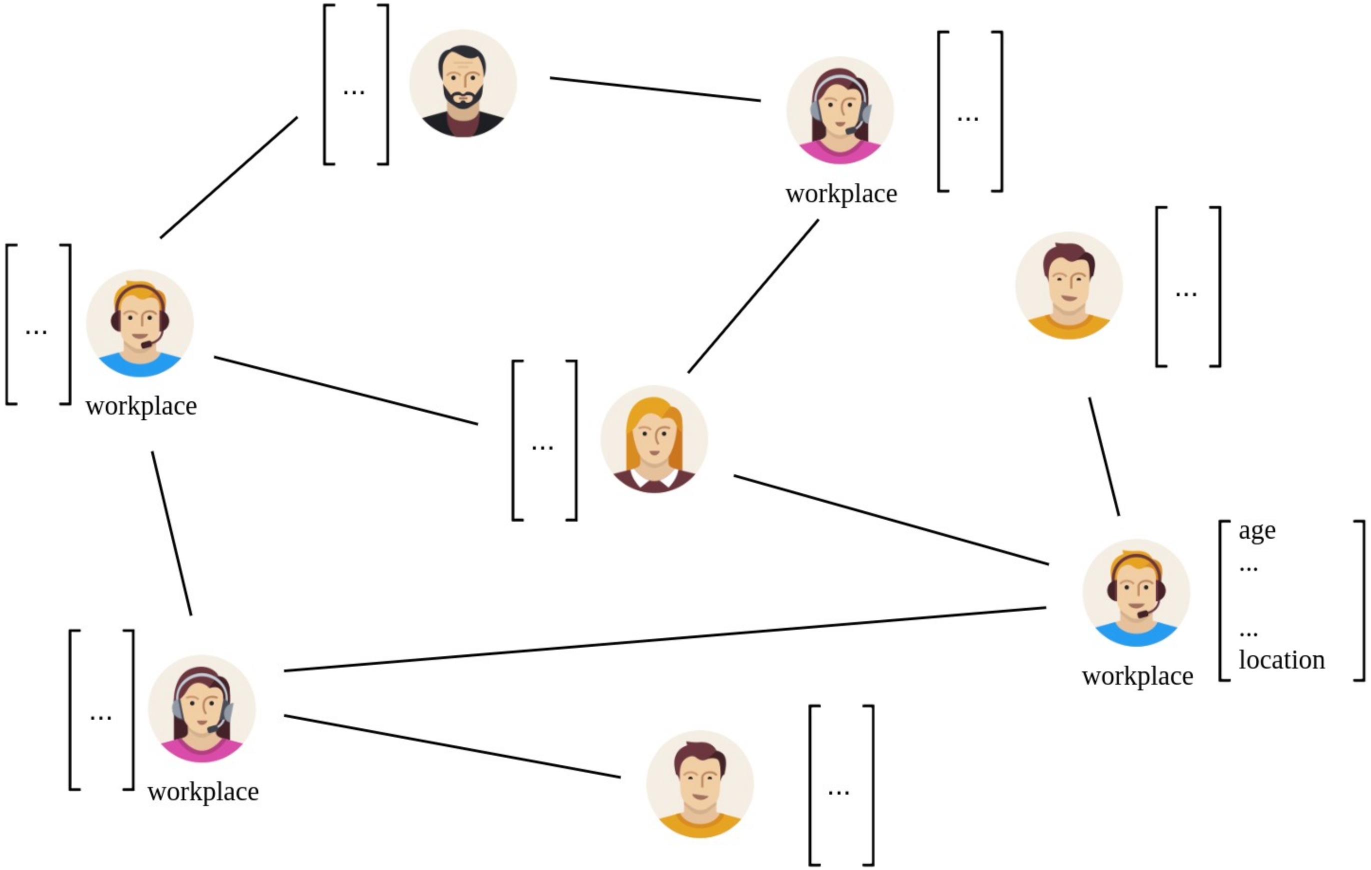
# Graph Neural Networks

- Transductive



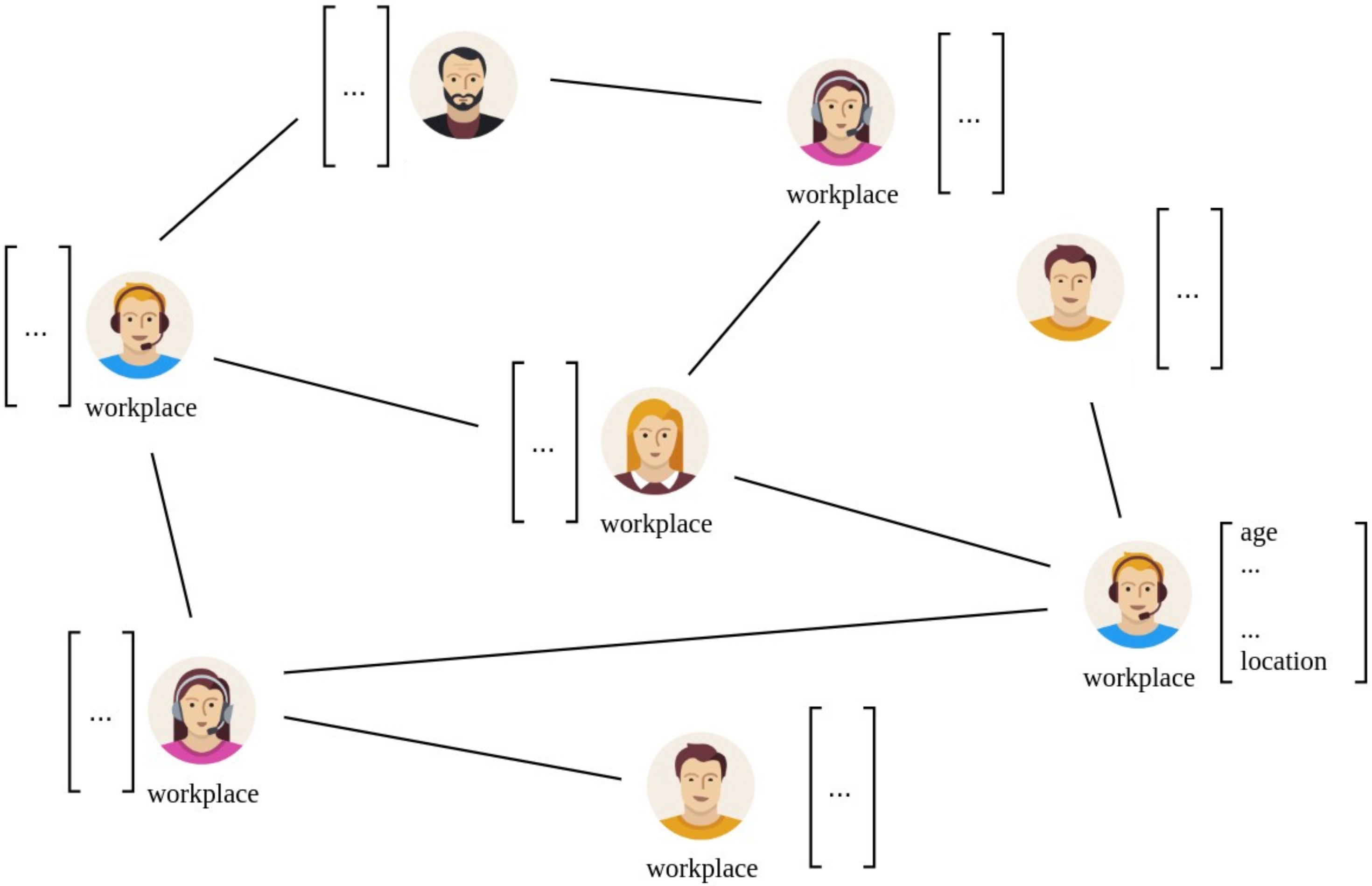
# Graph Neural Networks

- Transductive
  - Fix graph (features and link)
  - Some nodes’ labels are missing
  - Limited scenario



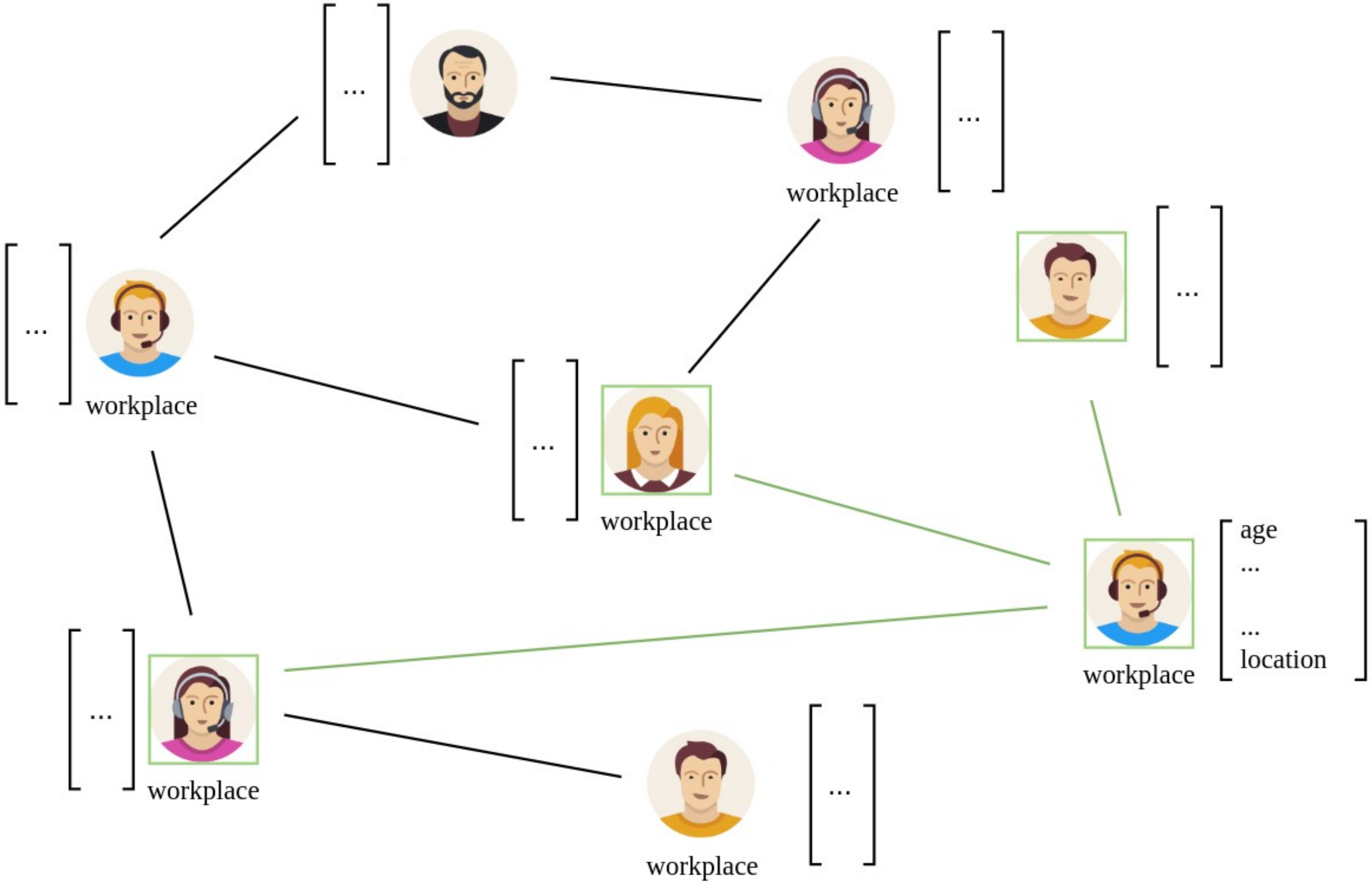
# Graph Neural Networks

- Inductive



# Graph Neural Networks

- Inductive



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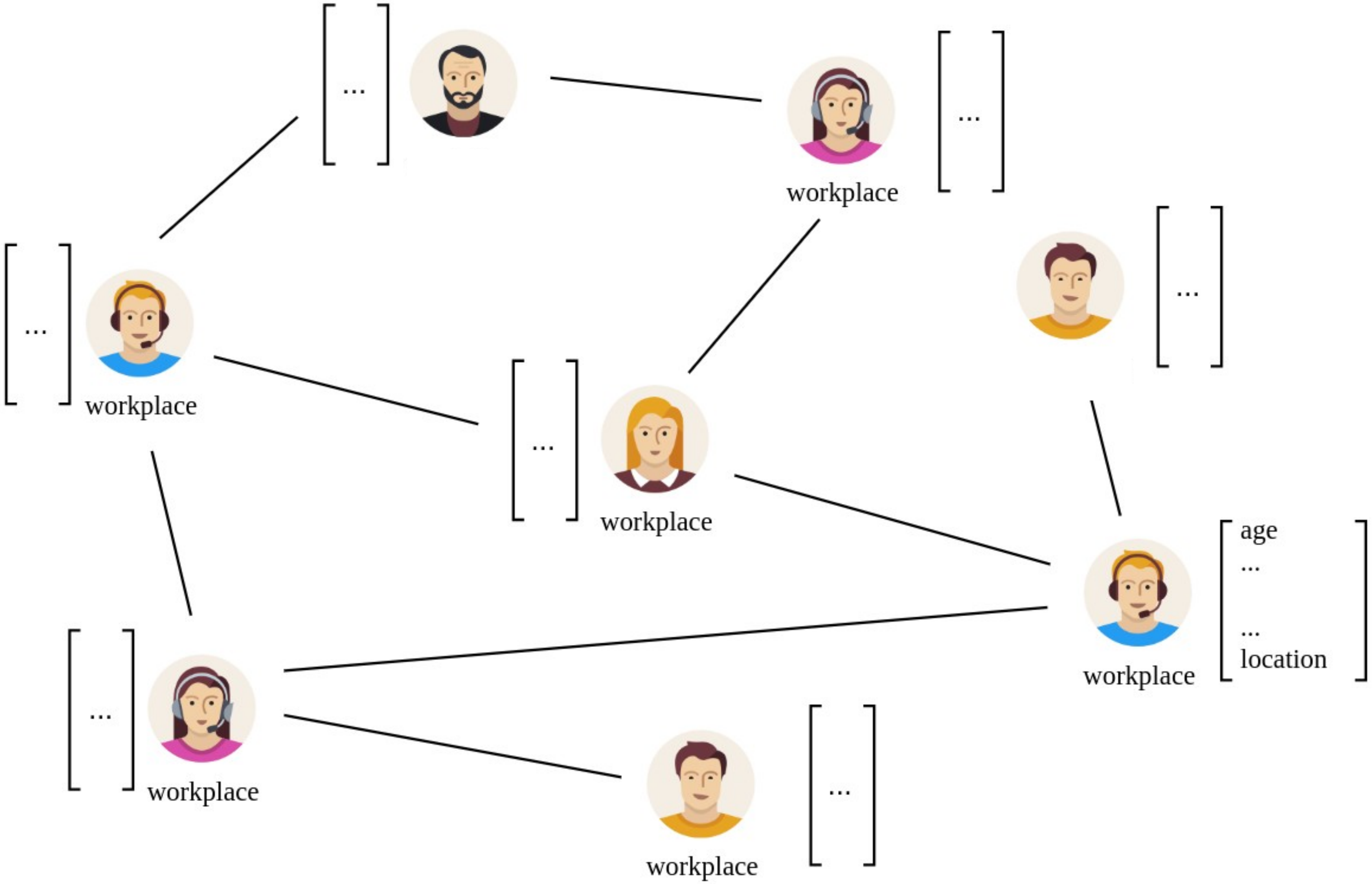
- Inductive



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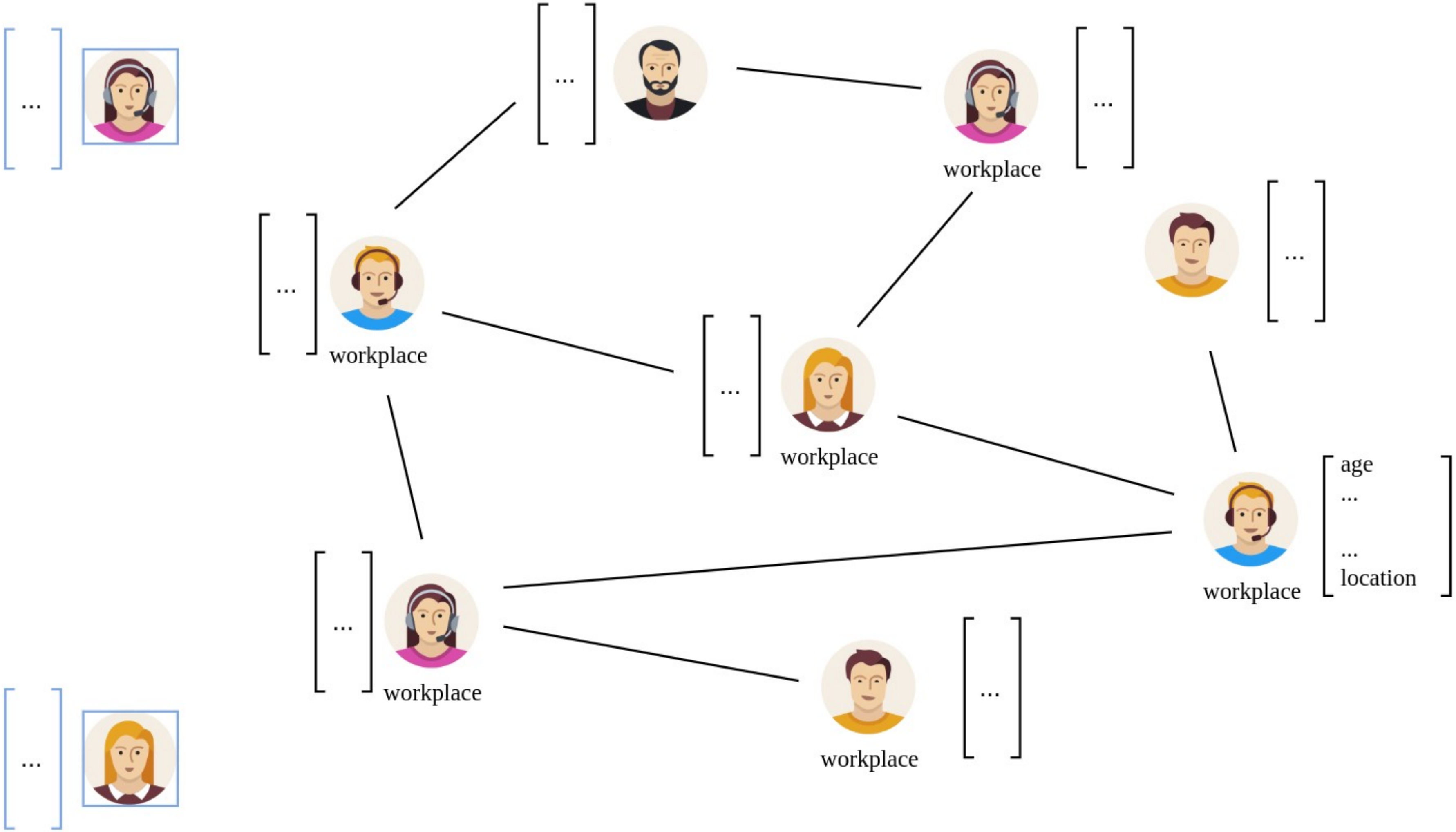
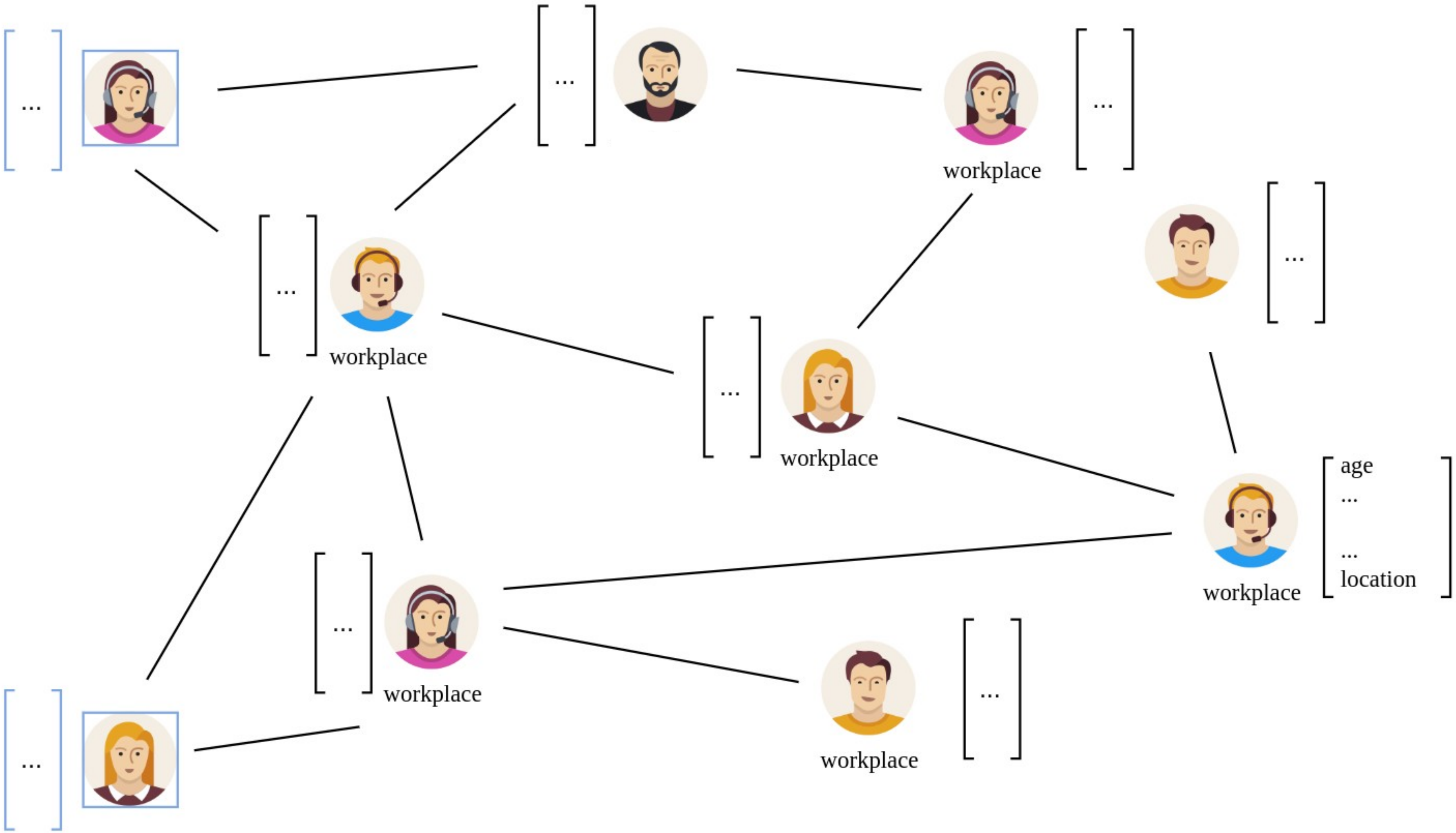
- Inductive



- Inductive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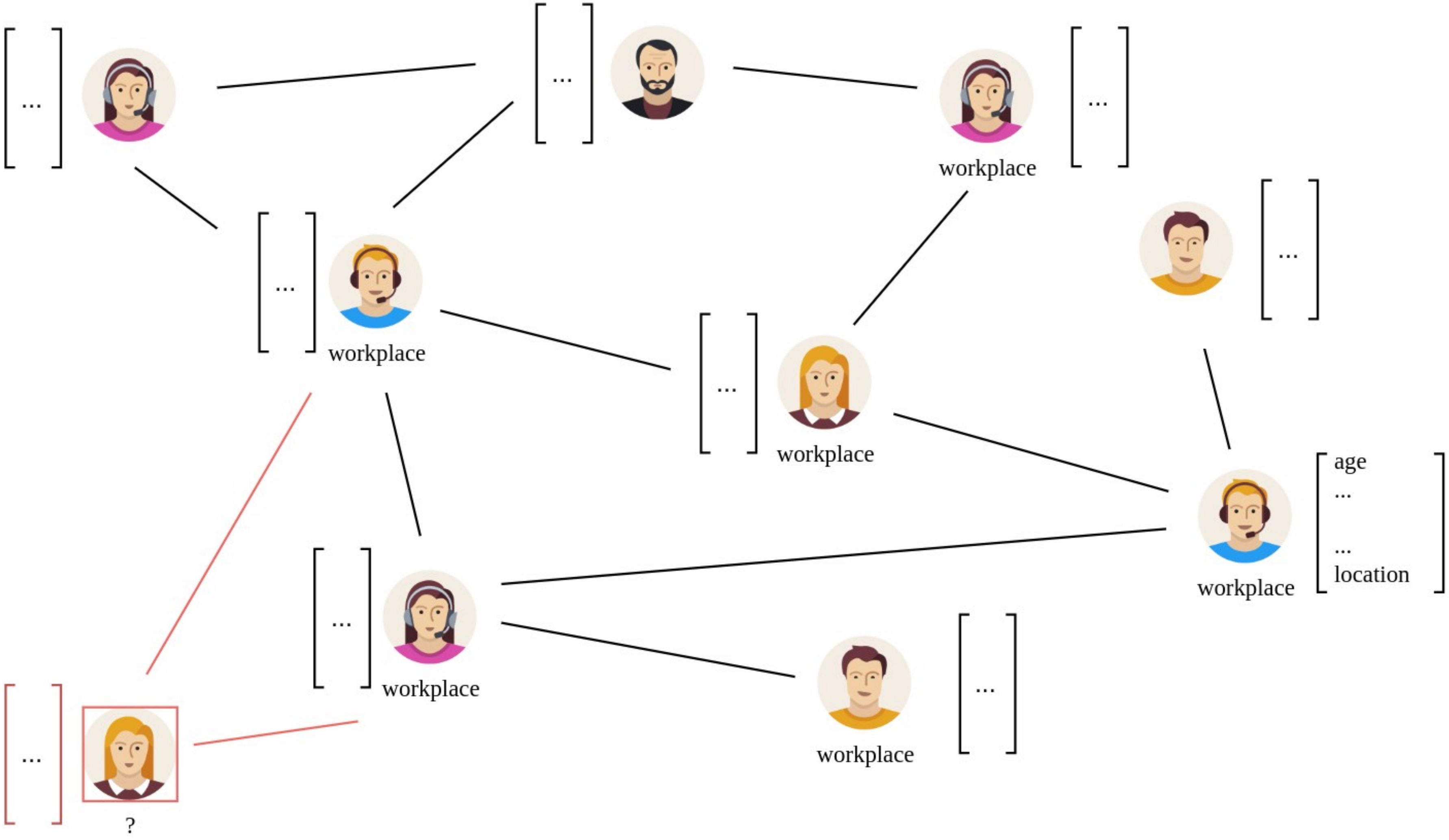
# Graph Neural Networks

- Inductive



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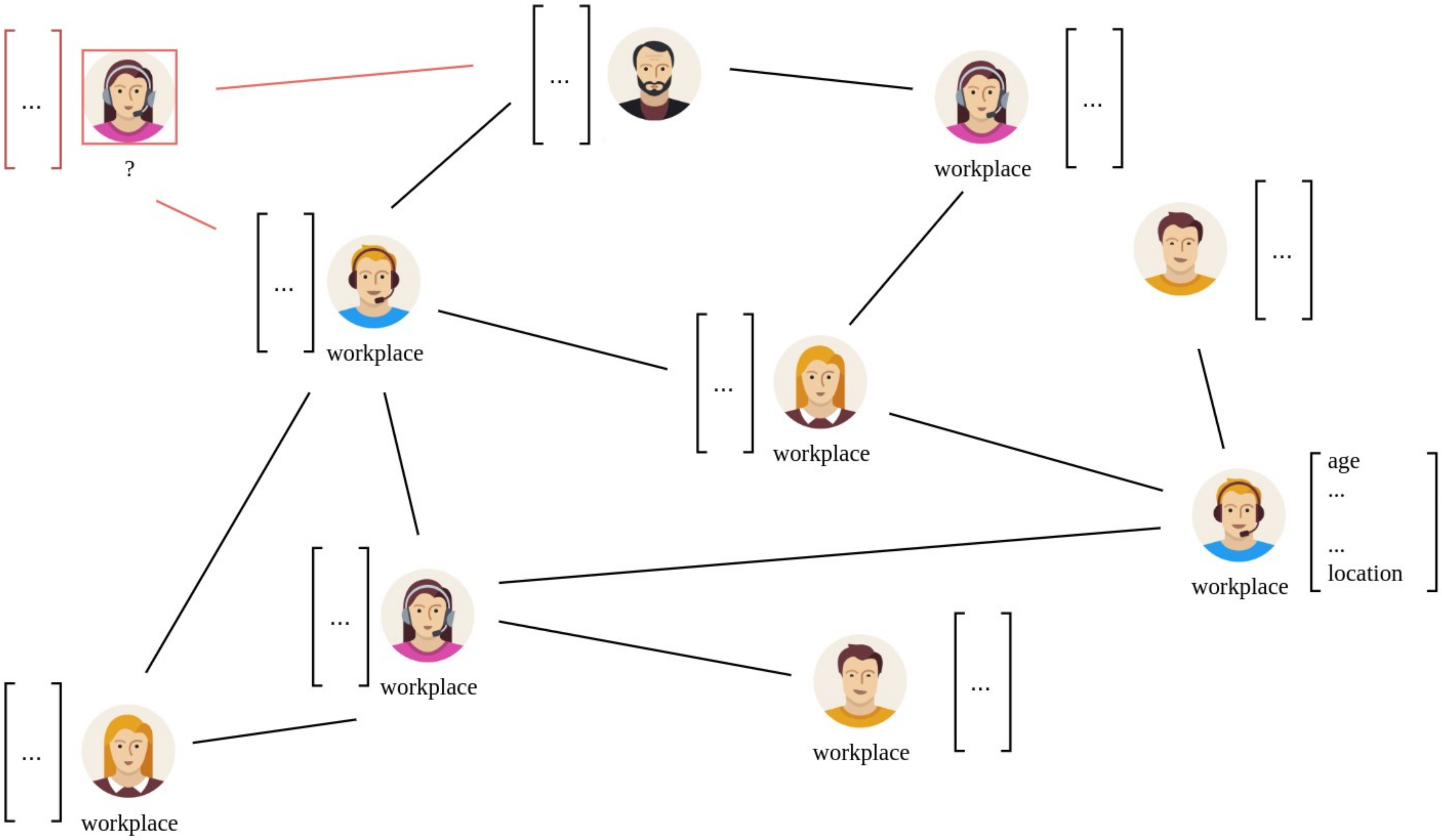
- Inductive



# Graph Neural Networks

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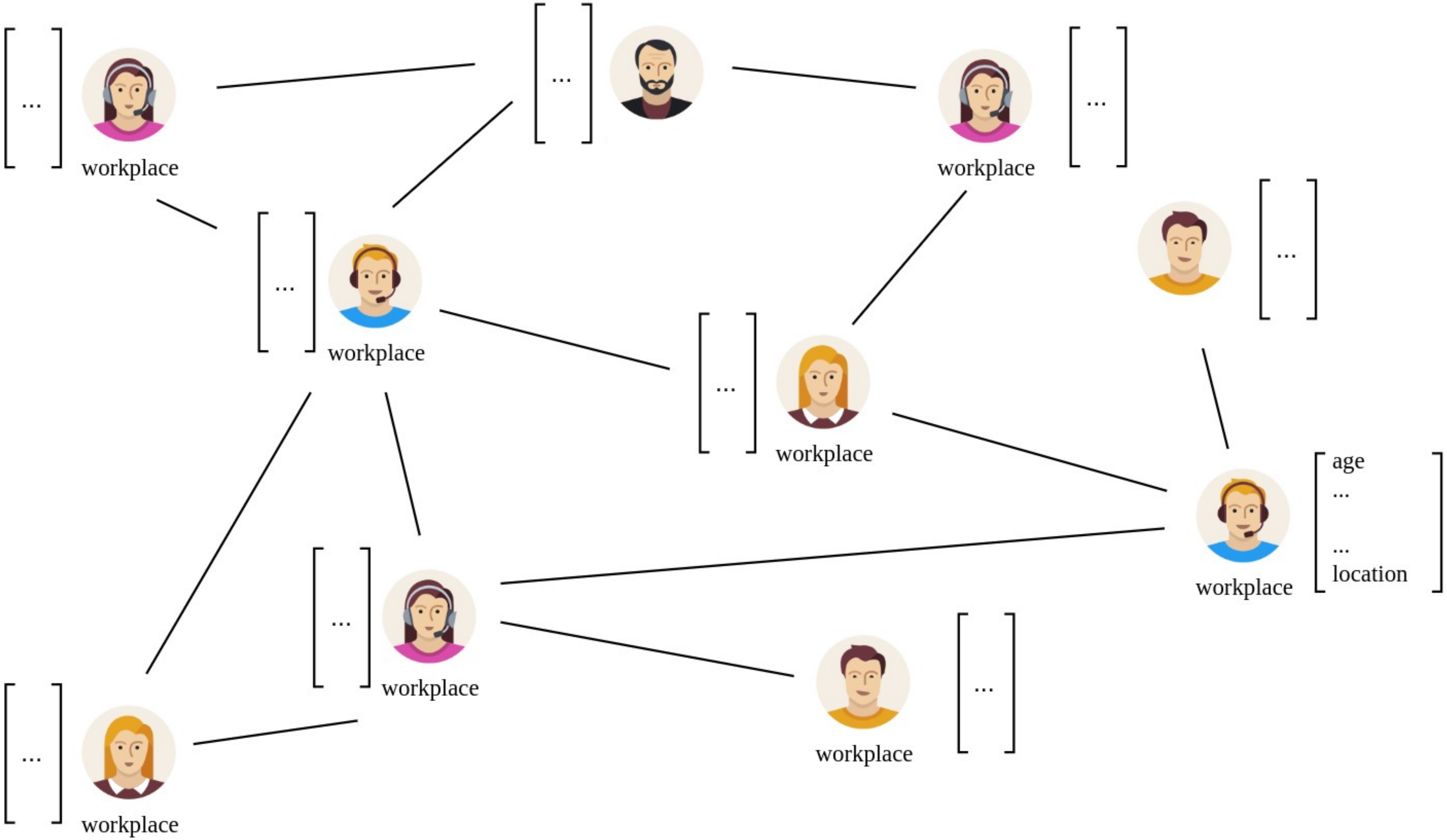


# Graph Neural Networks

- Inductive
  - Extends transductive setting
  - Able to generalize to unseen nodes
  - Unnecessary to retrain the model
  - Broader scenario

# Our Approach:
# Link Stealing Attacks

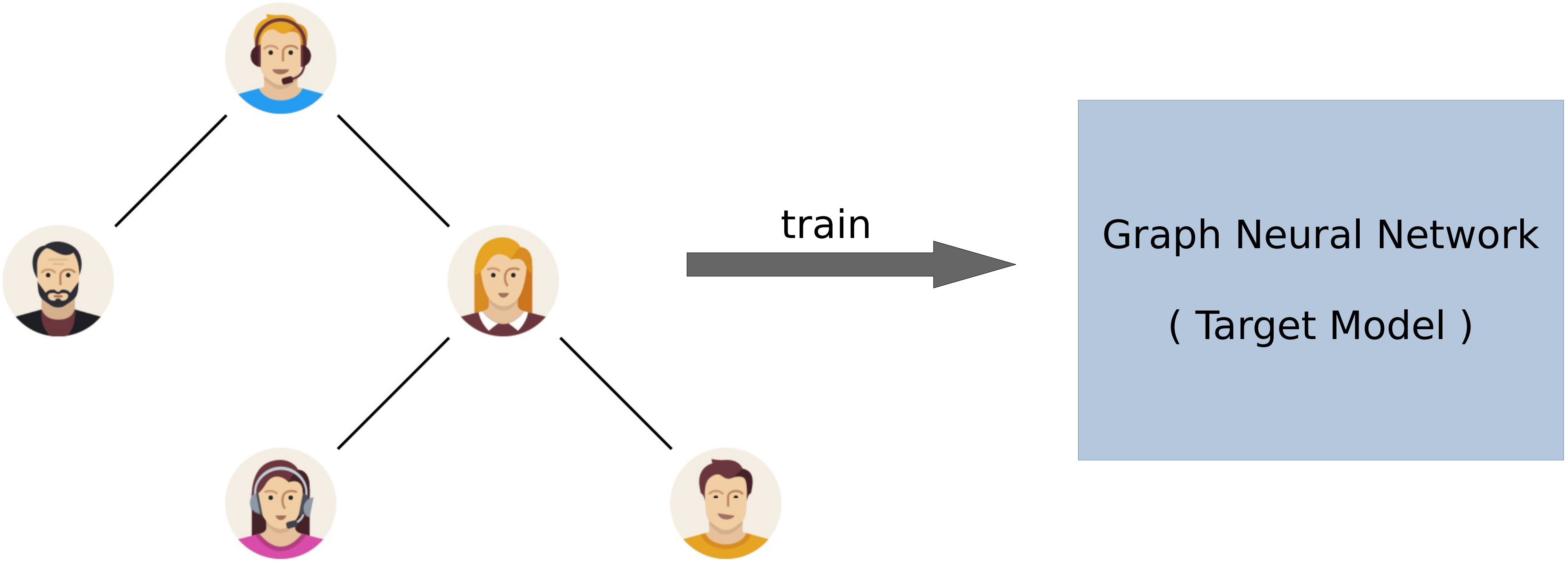
# Link Stealing Attacks

- First Introduced by Dr. Yang Zhang and Xinlei He in 2020
  - Attacks on transductive trained GNNs

- Scenario:
  - GNN trained on graph G to perform downstream task
  - Attacker
    - Black box access to target model
    - Partial graph with incomplete set of edges

- Goal:
  - Recover missing links from partial graph

# Link Stealing Attacks

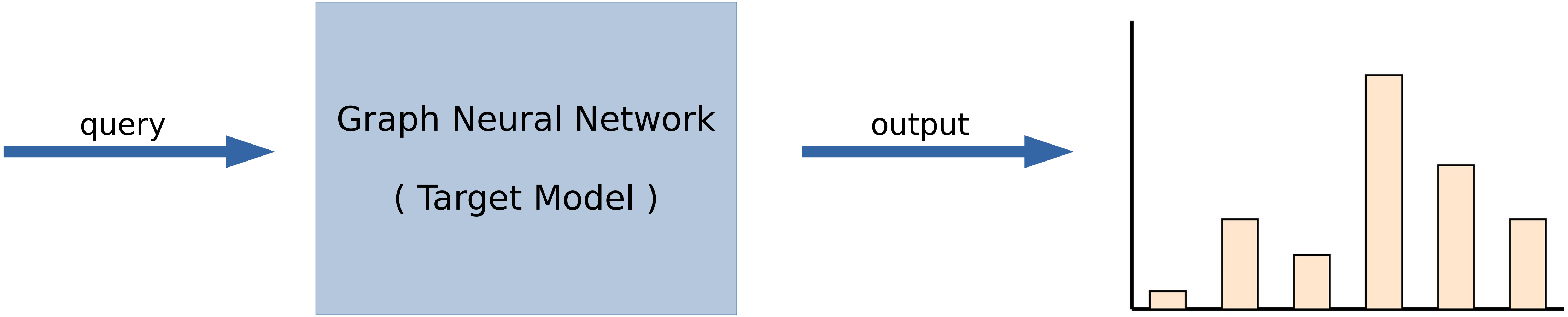


train

Graph Neural Network

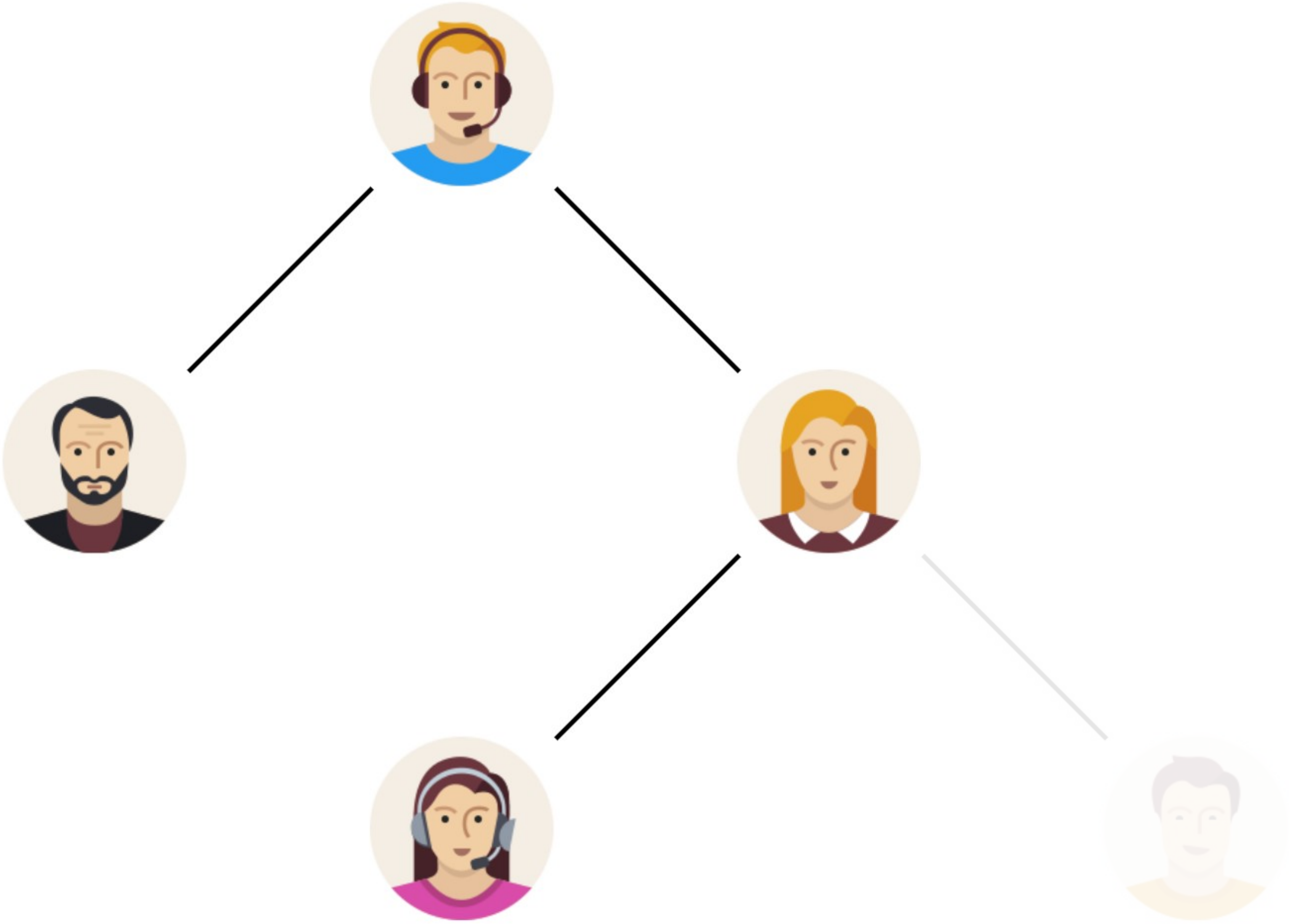
( Target Model )

# Link Stealing Attacks



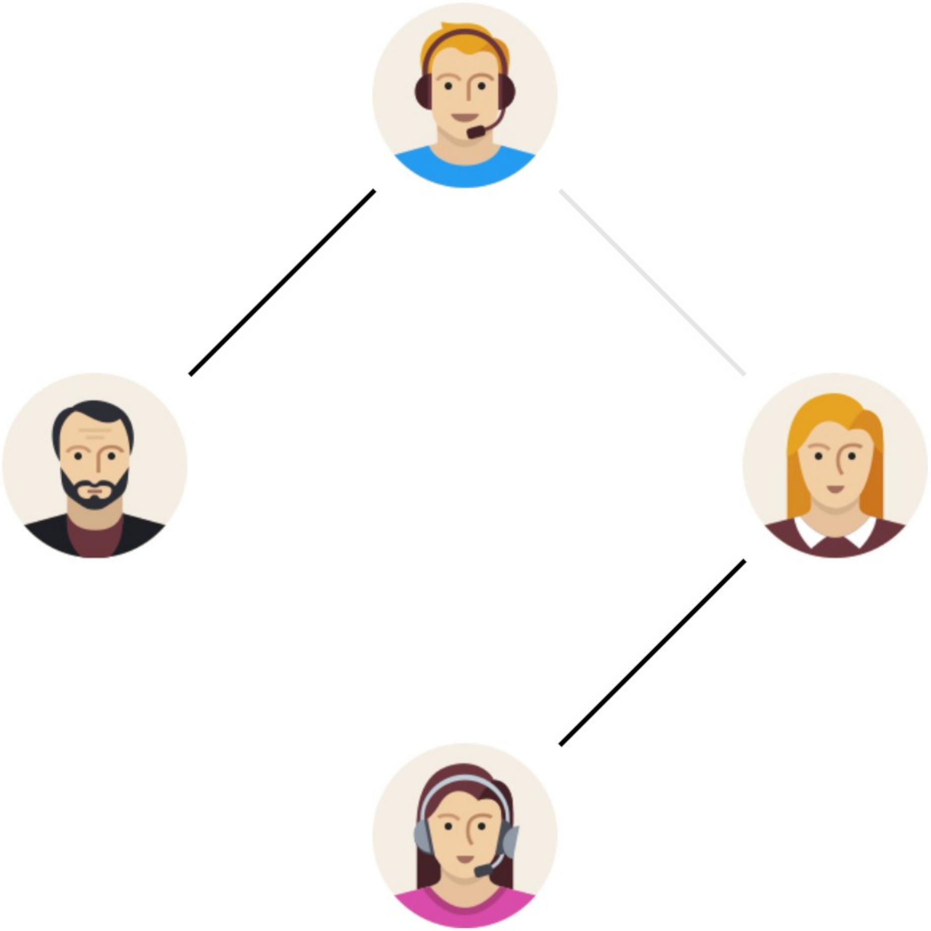
# Link Stealing Attacks

- Attacker Graph



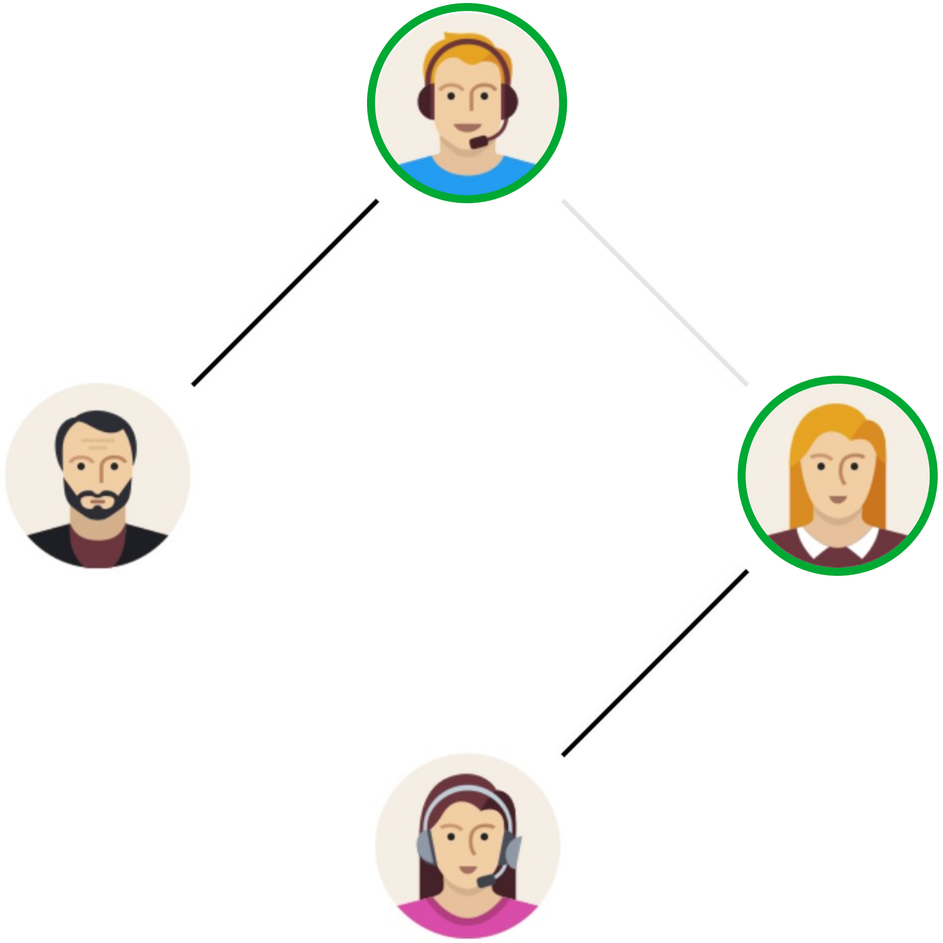
# Link Stealing Attacks

- Attacker Graph with One Missing Link



# Link Stealing Attacks

- Attacker Graph



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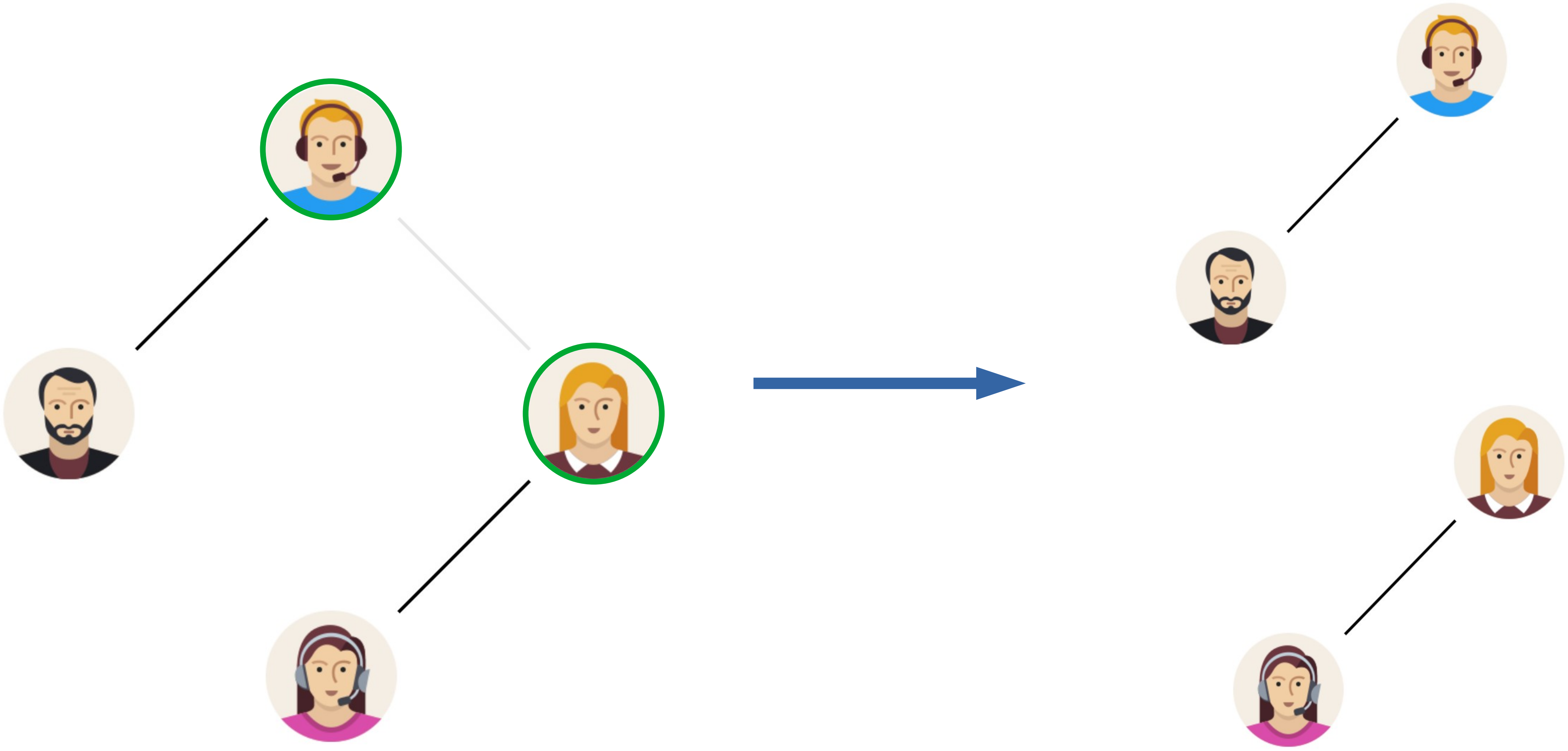

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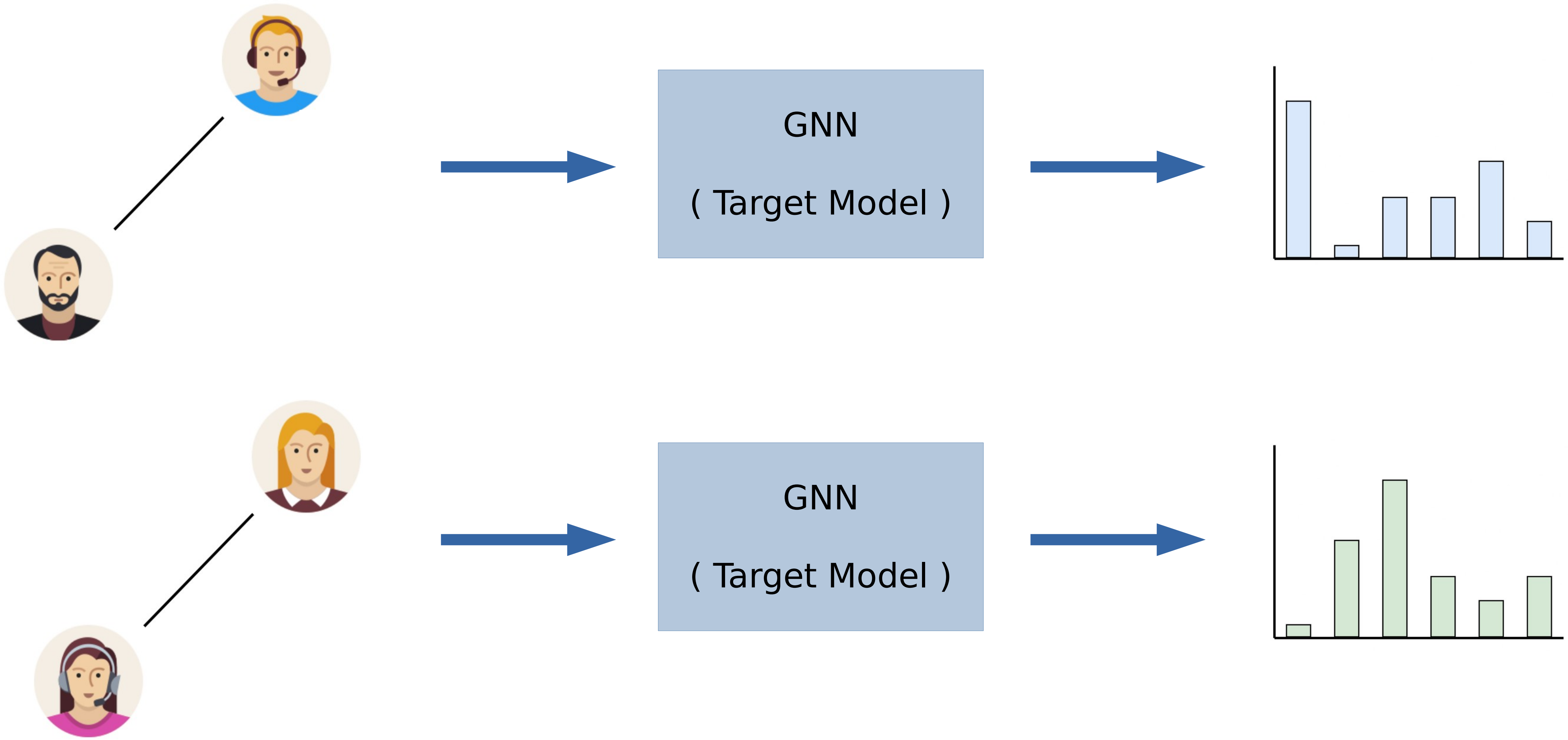

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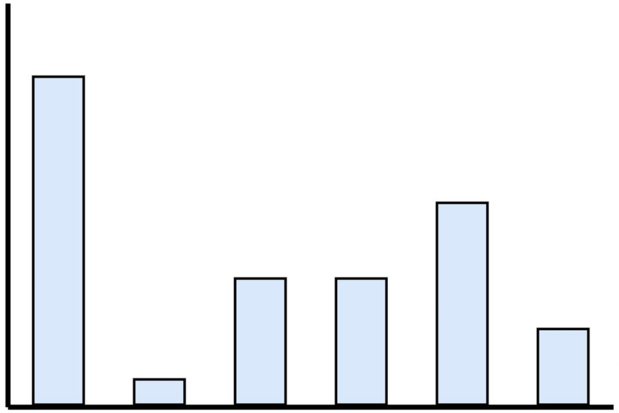

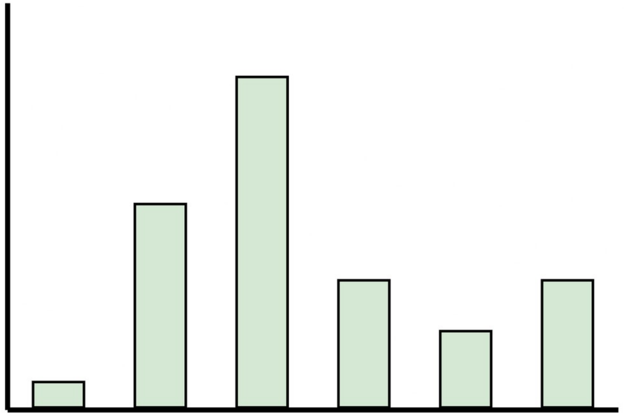

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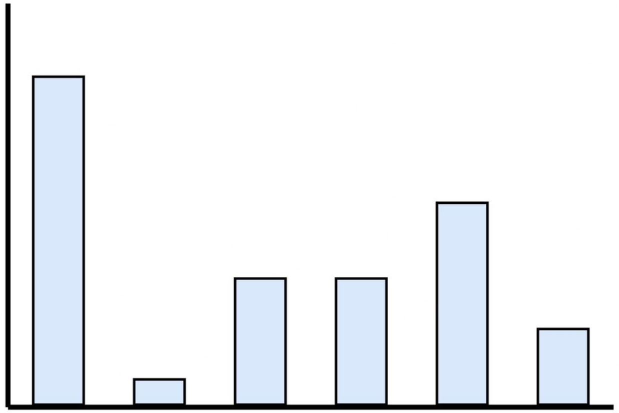
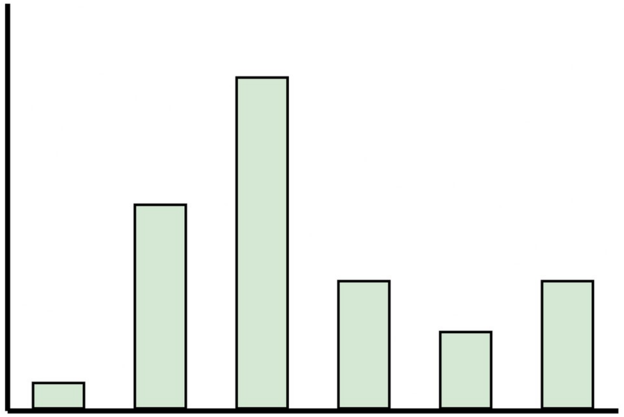


[ 0.3, 0.2, 0.3, …, 0.1 ]



[ 0.2, 0.1, 0.4, …, 0.1 ]

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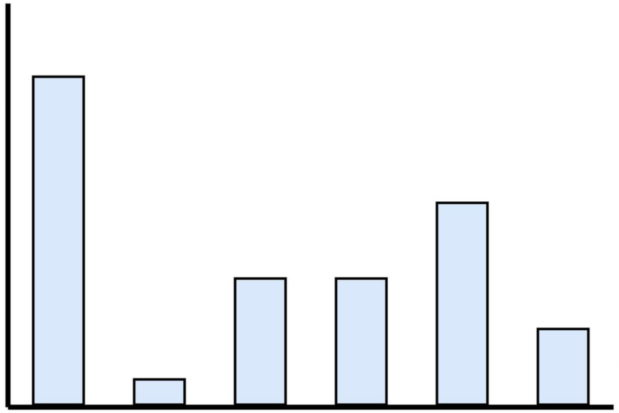

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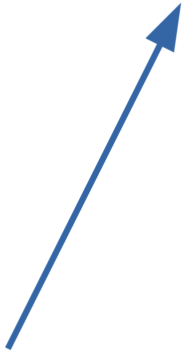

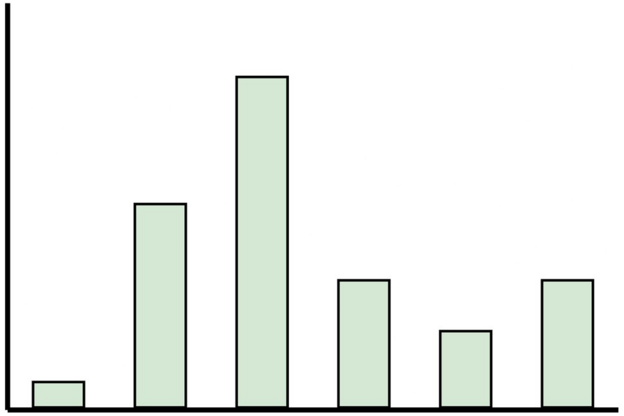

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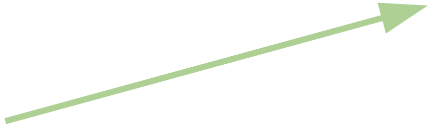

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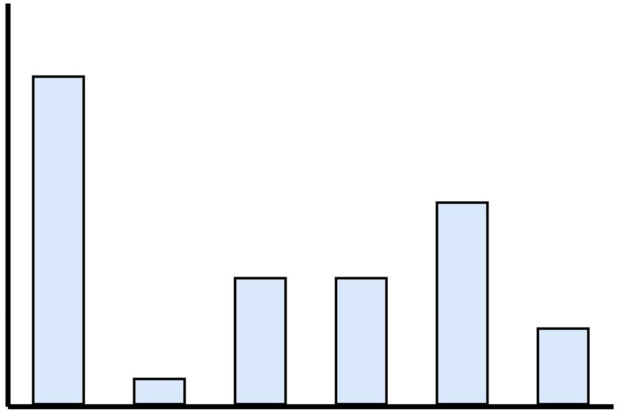

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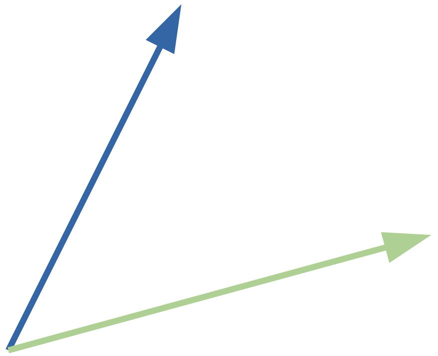

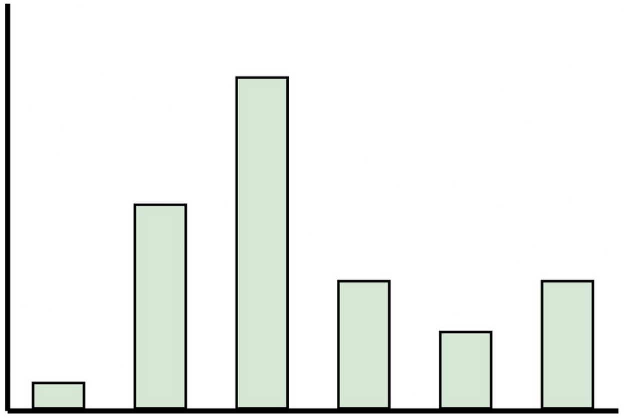

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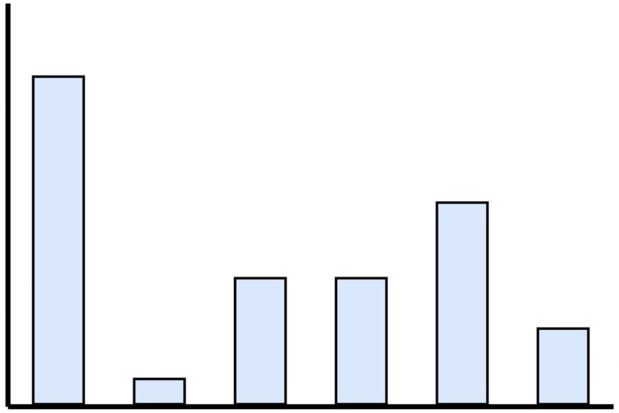

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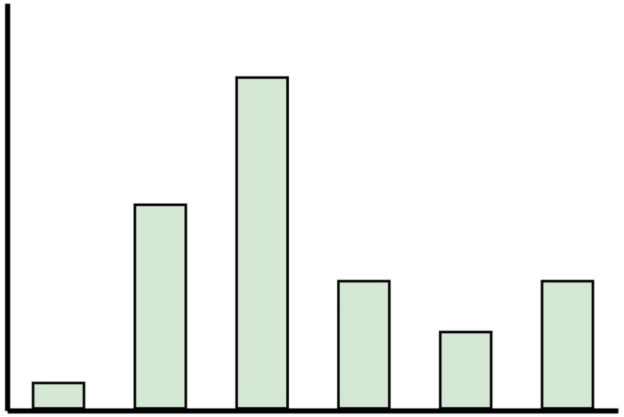

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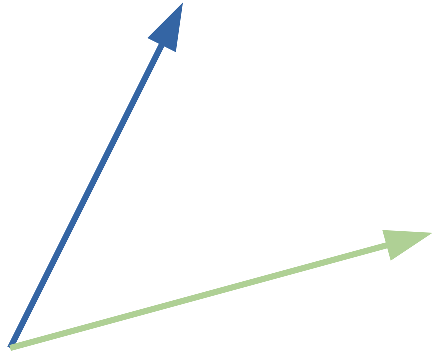

[ Cosine, Manhattan, …, Euclidean ]

# Link Stealing Attacks

[ Cosine, Manhattan, …, Euclidean ]

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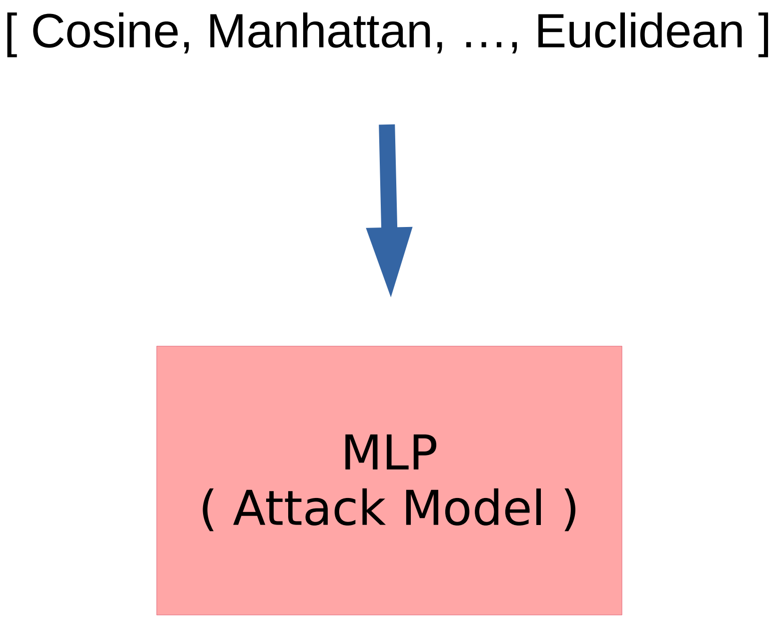
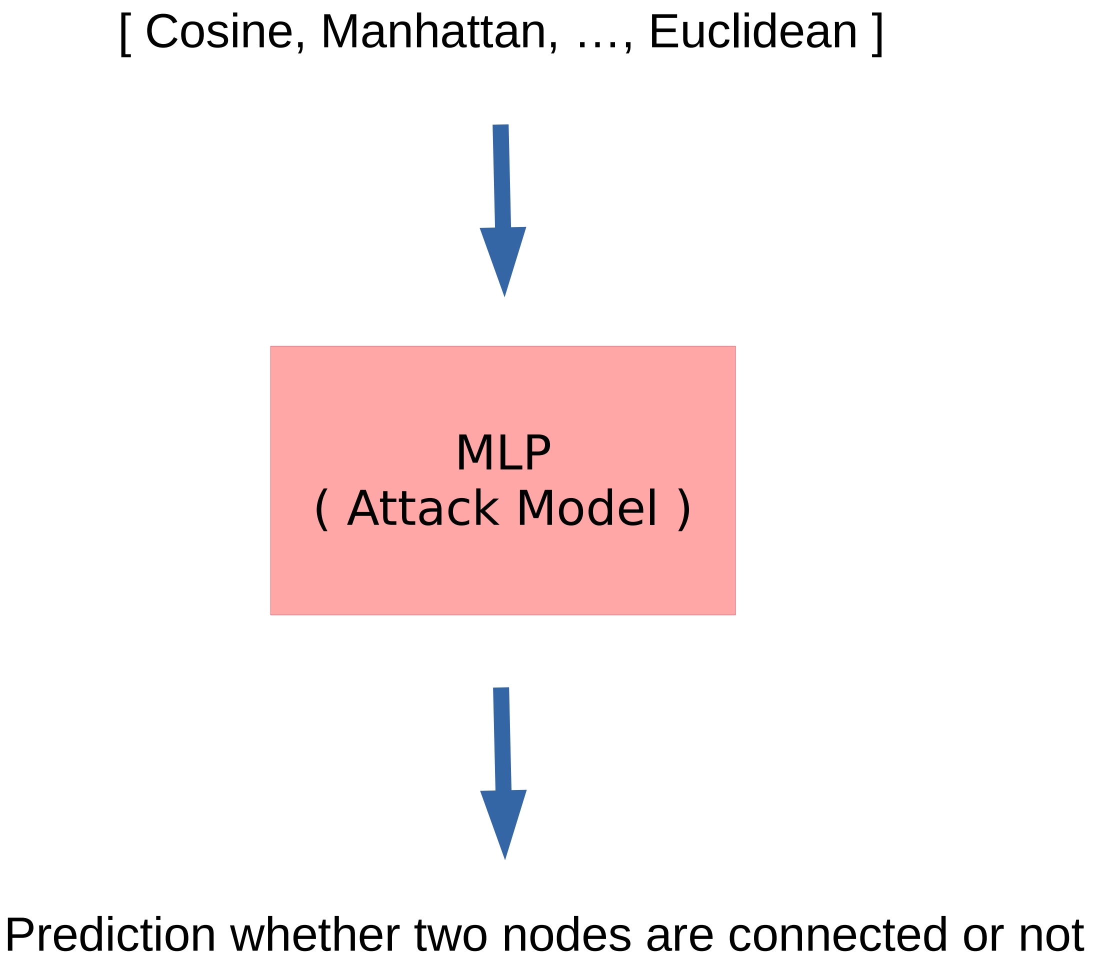


[ Cosine, Manhattan, …, Euclidean ]

MLP
( Attack Model )

# Link Stealing Attacks



[ Cosine, Manhattan, …, Euclidean ]

MLP
( Attack Model )

Prediction whether two nodes are connected or not

# Experimental Setup

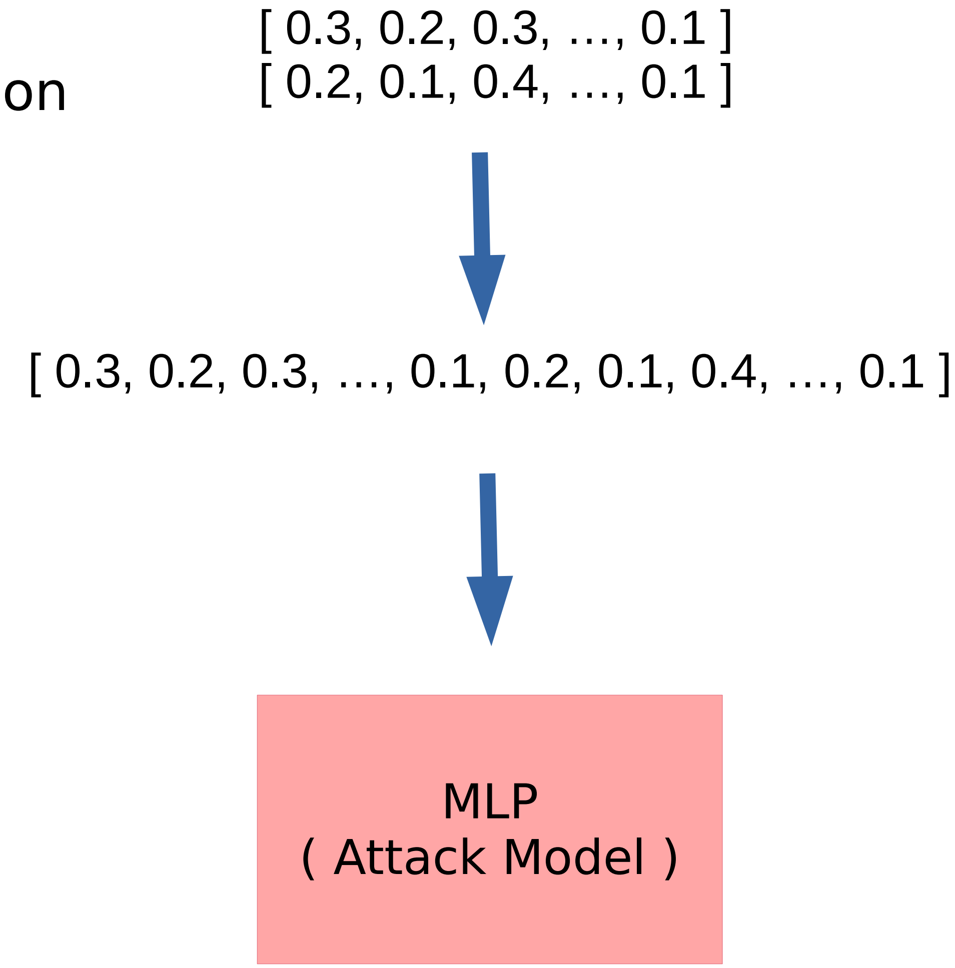
# Experimental Setup

- Three Datasets
  - Cora
  - CiteSeer
  - Pubmed

- Three Graph Neural Network Types
  - GraphSAGE
  - GAT
  - GCN (inductive)

# Experimental Setup

- Attack 1
  - Same distribution



[ 0.3, 0.2, 0.3, …, 0.1 ]
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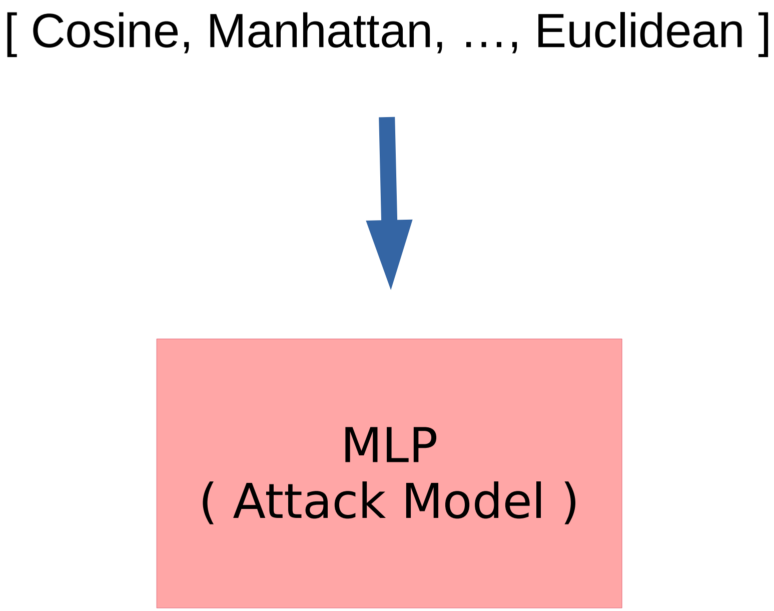
[ 0.3, 0.2, 0.3, …, 0.1, 0.2, 0.1, 0.4, …, 0.1 ]

MLP
( Attack Model )

# Experimental Setup

- Attack 2
  - Same Distribution

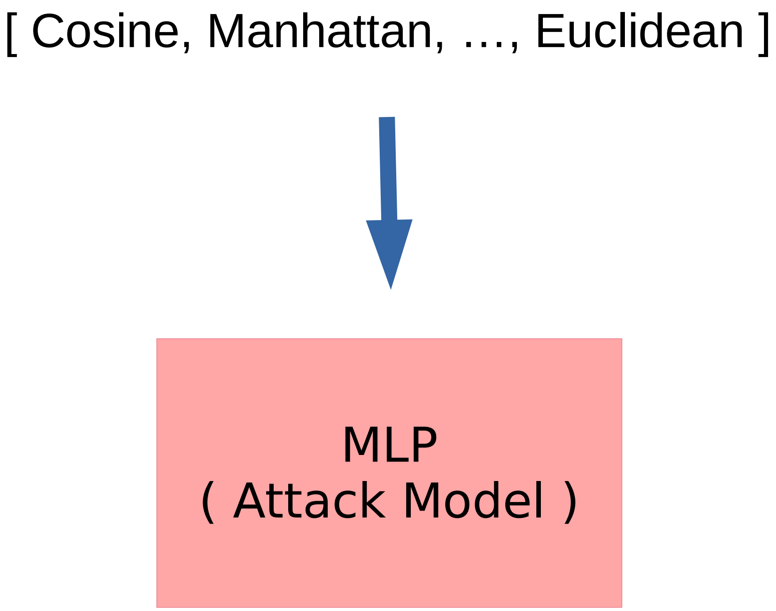


[ Cosine, Manhattan, …, Euclidean ]

MLP
( Attack Model )

# Experimental Setup

- Attack 3
  - Different Distribution



[ Cosine, Manhattan, …, Euclidean ]

MLP
( Attack Model )

# Goal

# Goal

- Observation
  - Inductive trained GNNs are likely to reveal sensitive information about their training graph

- Serious Concerns
  - Intellectual property
  - Confidentiality
  - Privacy

# Questions?