Community Detection in Multi layer Networks

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Under guidance of
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Outline:

- ***Introduction***
  - Background
- Related Work
- Motivation
- Objective
- Multilayer Modularity
- Community Detection Algorithm
- Evaluation
- Summary and future work

Introduction

- Background

Communities

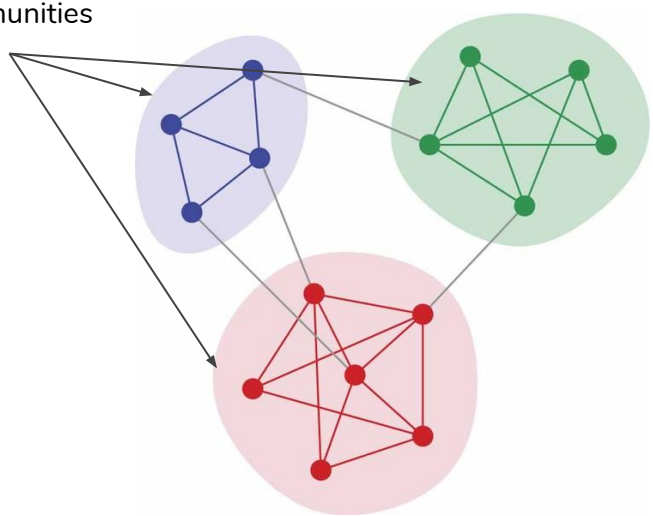

Figure1. Homogeneous network

Community Detection: partitioning the networks into groups of nodes.

Modularity: Reflects the concentration of edges within modules compared with random distribution of links between all nodes regardless of modules

$$mQ = \frac{1}{2m}\sum_{ij}[A_{ij} - \frac{k_i k_j}{2m}]\delta(c_i, c_j)$$

Community detection in homogeneous network has been studied extensively.

Multi-layer network

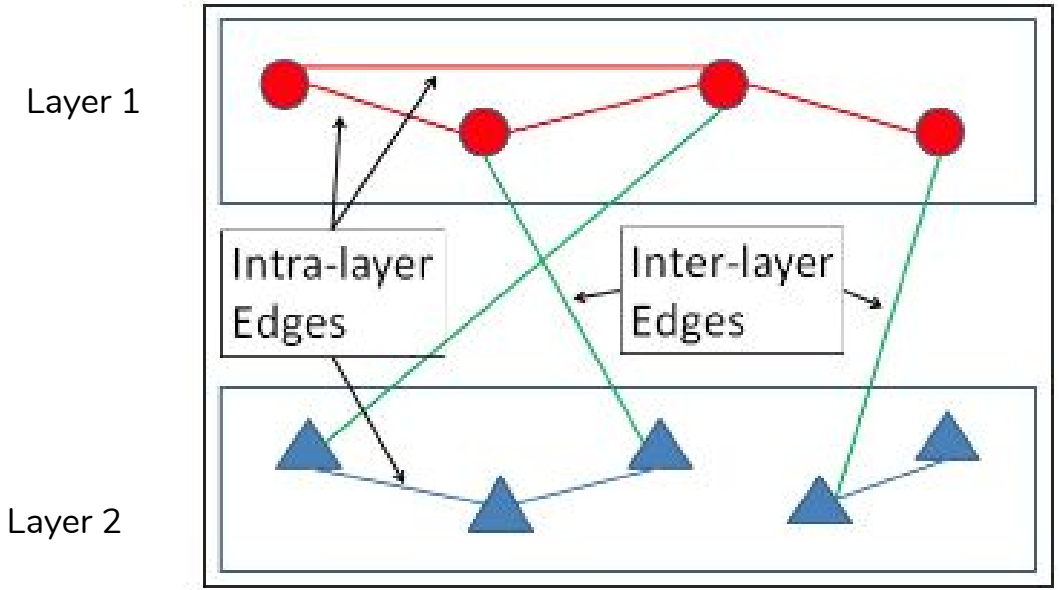

Figure2. Multi-layer network

- Comprises of multiple independent networks.
- Functionality of edges and nodes in different layer is different

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Related Work

Newman, Louvain , 2006	• Used Modularity as the optimization function • Detects communities in a single-layer network
Yu-Ru Lin, MetaFac, 2009	• Used matrix factorization to detect communities.
Kuncheva, CompMod, 2015	• Used the concept of random walk. • Works on multiplex networks.
Pramanik, DSAA , 2017	• Developed modularity index for multi-layer communities. • Used single layer community detection algorithm.

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Motivation

- Can single layer community detection algorithm be used in multi-layer network?

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- Because,
  - Links in multi-layer networks have different meaning.
  - Nodes may represent different entities

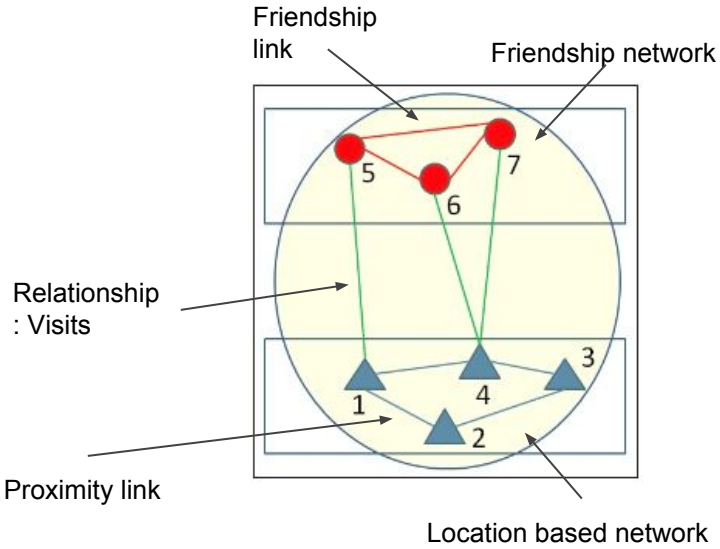
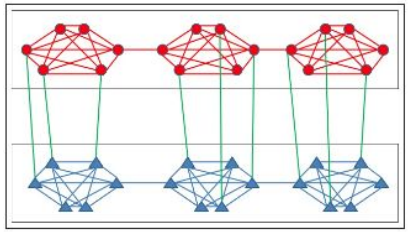
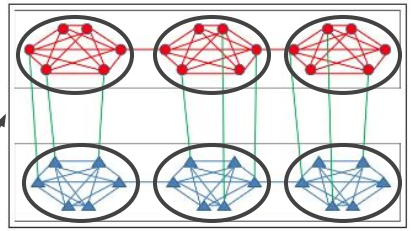


Figure3. Cross layer edges in multilayer networks have a different meaning

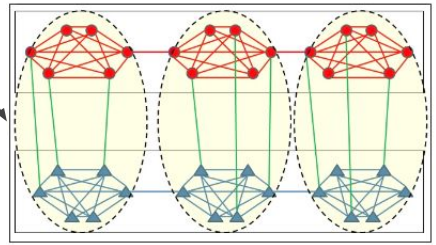
Motivation



Community detection algorithm (Louvain)



Detected community structure



Desired community structure

Figure4.Single layer community detection fails in multi-layer network

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Objective

Detecting communities in a multi-layer network comprising:

- Single type of nodes
- Multiple type of nodes

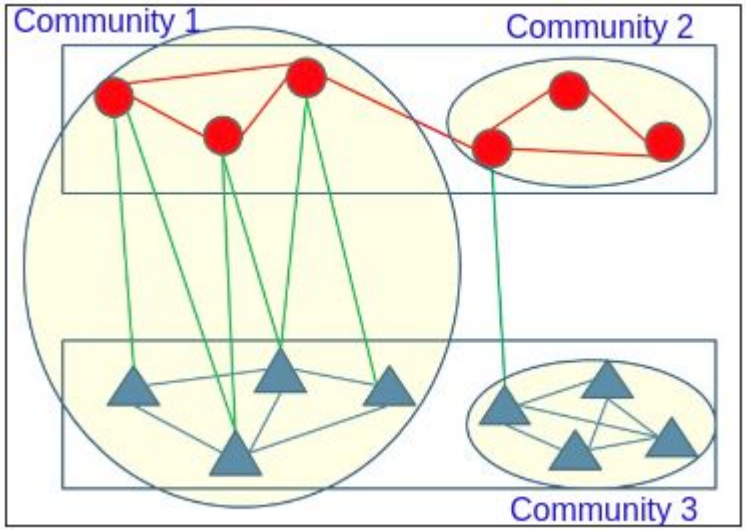

Figure5. Multi-layer community structure

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- **Community Detection Algorithm**
  - Louvain
  - Mixmod
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Methodology

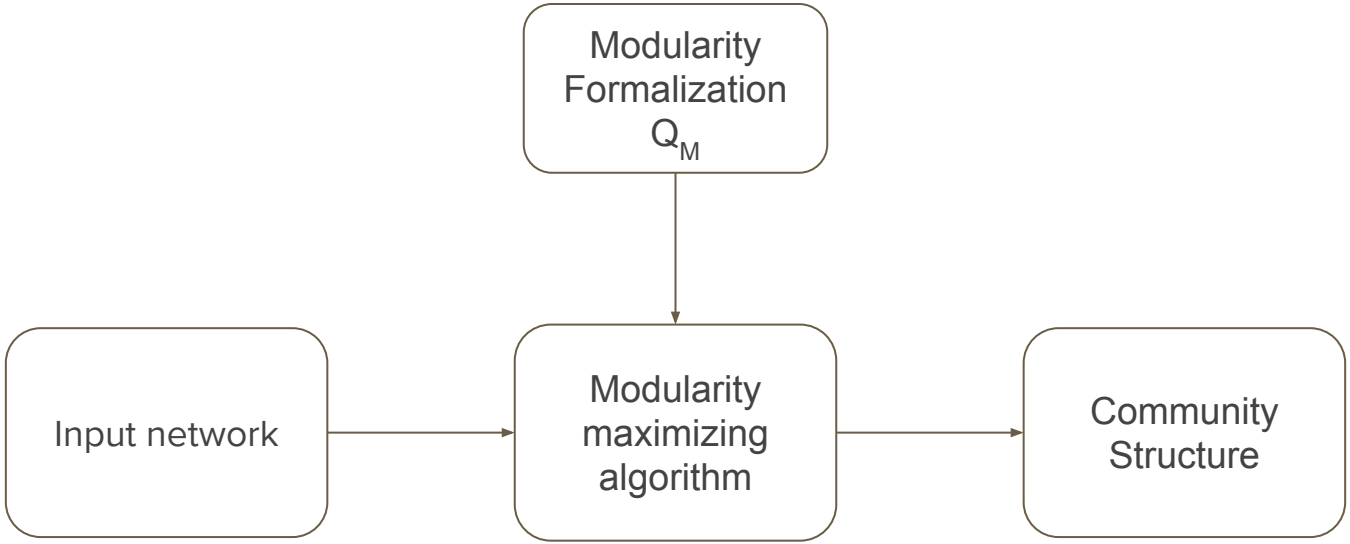


Figure6. Abopted methodology

Louvain Algorithm

1. Assign a different community to each node.
2. For each node i
    a. For each neighbour j of i, consider removing i from its community and placing in j's community.
    b. Greedily chose to place i into community of neighbor that leads to highest modularity gain
    c. If there is no positive gain , than i stays in its own community.
3. Repeat until no improvement can be done

Louvain Algorithm:

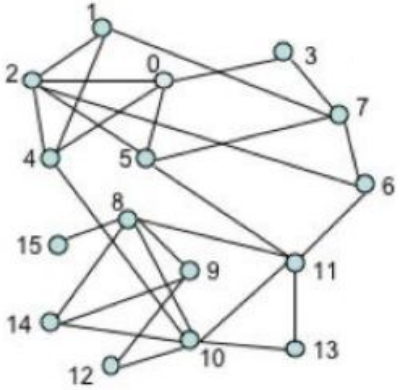
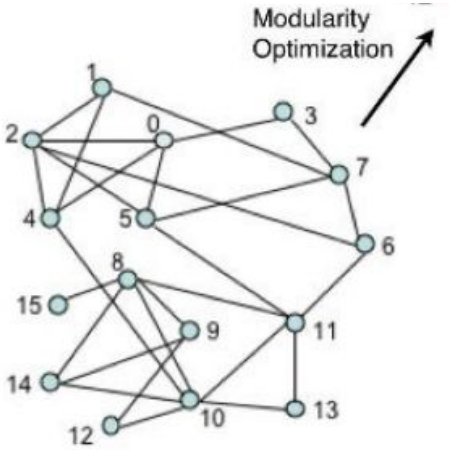


Figure7. Louvain algorithm's steps

Louvain Algorithm:



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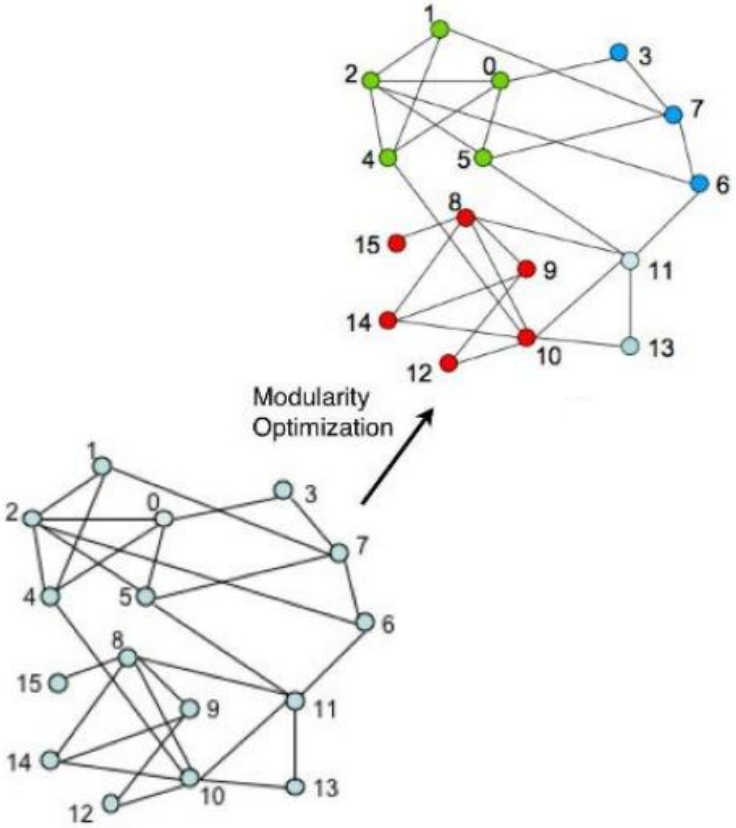

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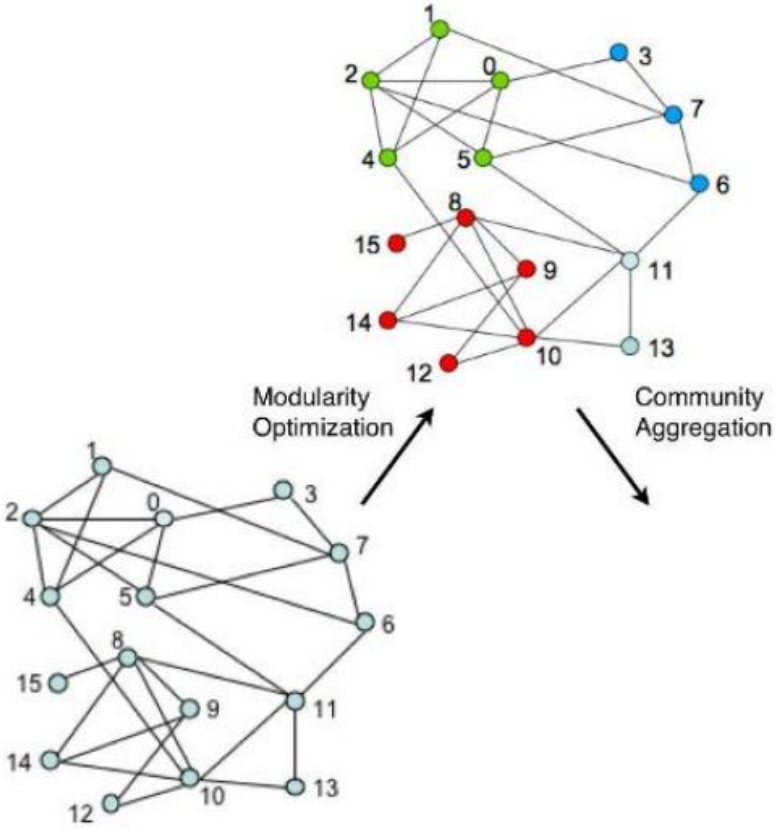

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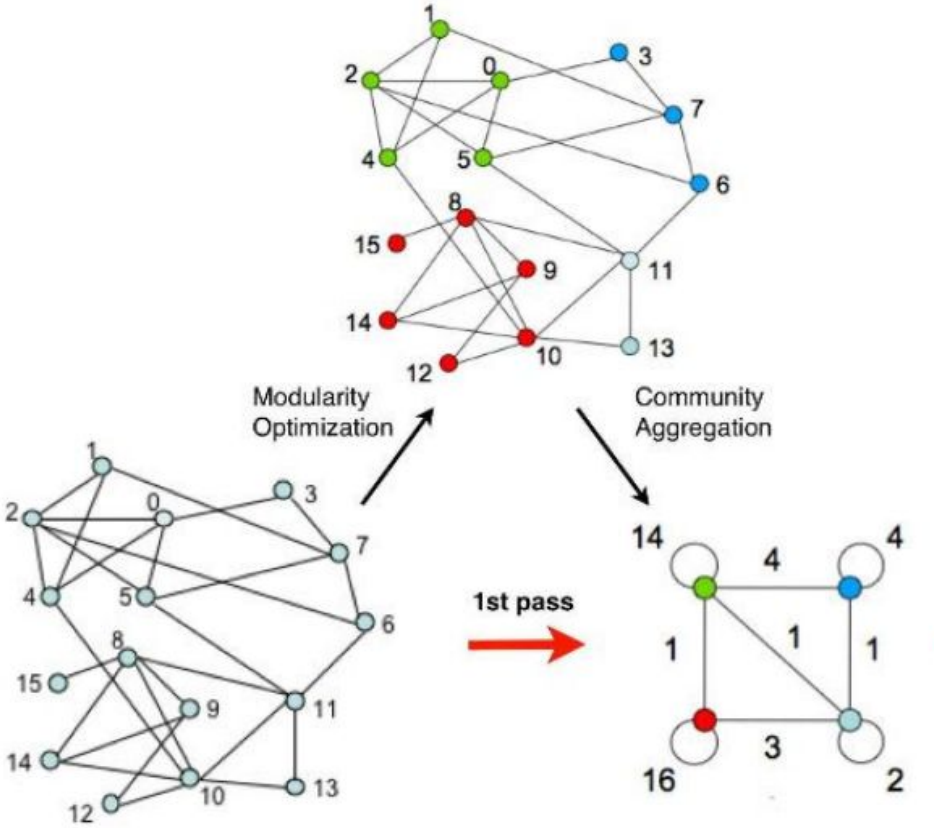

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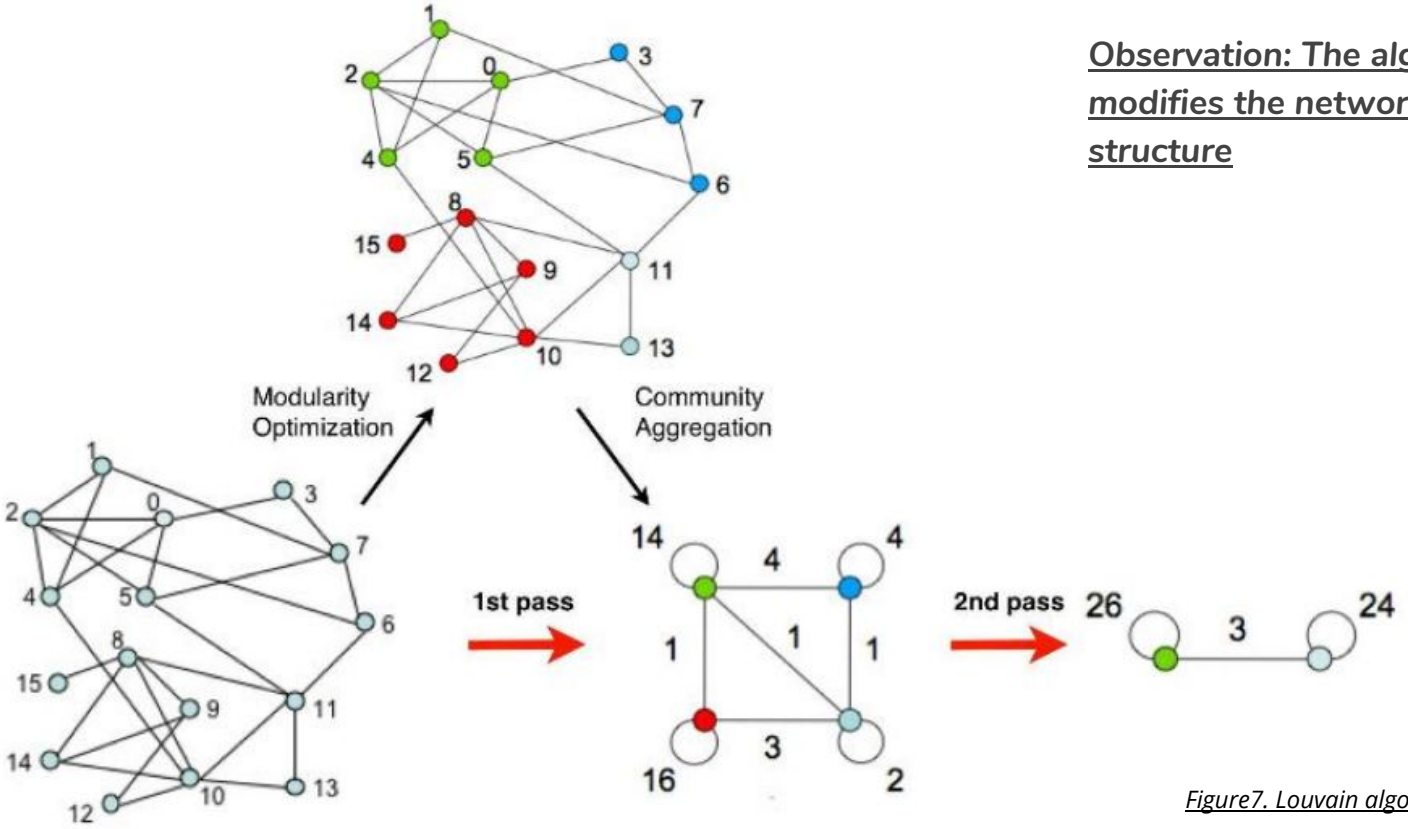

Observation: The algorithm modifies the network structure

Figure7. Louvain algorithm's steps

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- ***Community Detection Algorithm***
  - **Louvain**
  - **Mixmod**
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Algorithm: MixMod

While merging nodes and constructing new network.

- If the community has multiple types of node, we form multiple nodes for each type.
- Keep the information of them being in one community

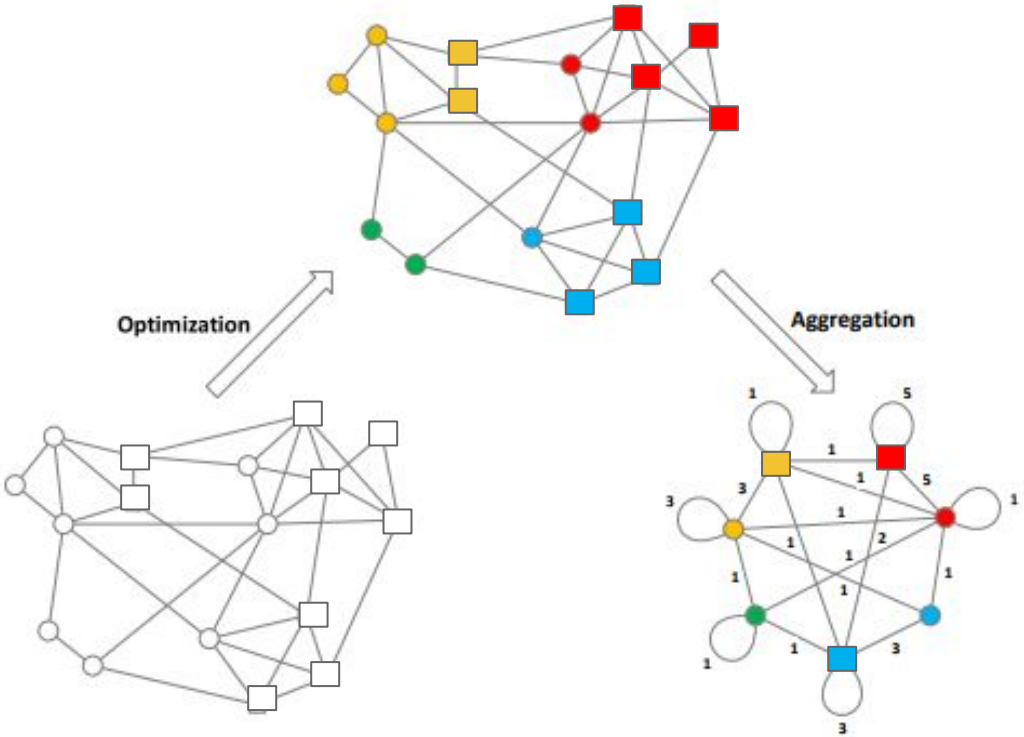


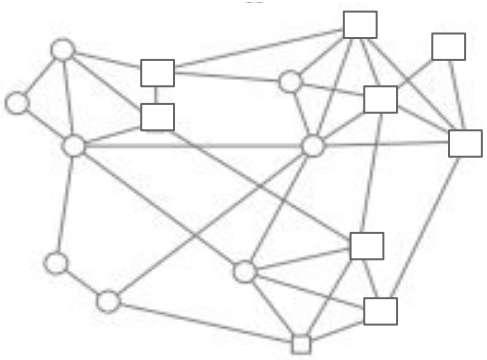
Figure8. MixMod algorithm steps

Algorithm: MixMod

Nodes of layer 1

Nodes of layer 2

All nodes of same colour belong to same community



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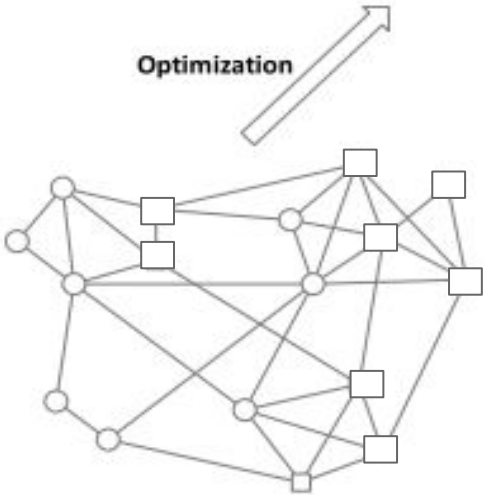

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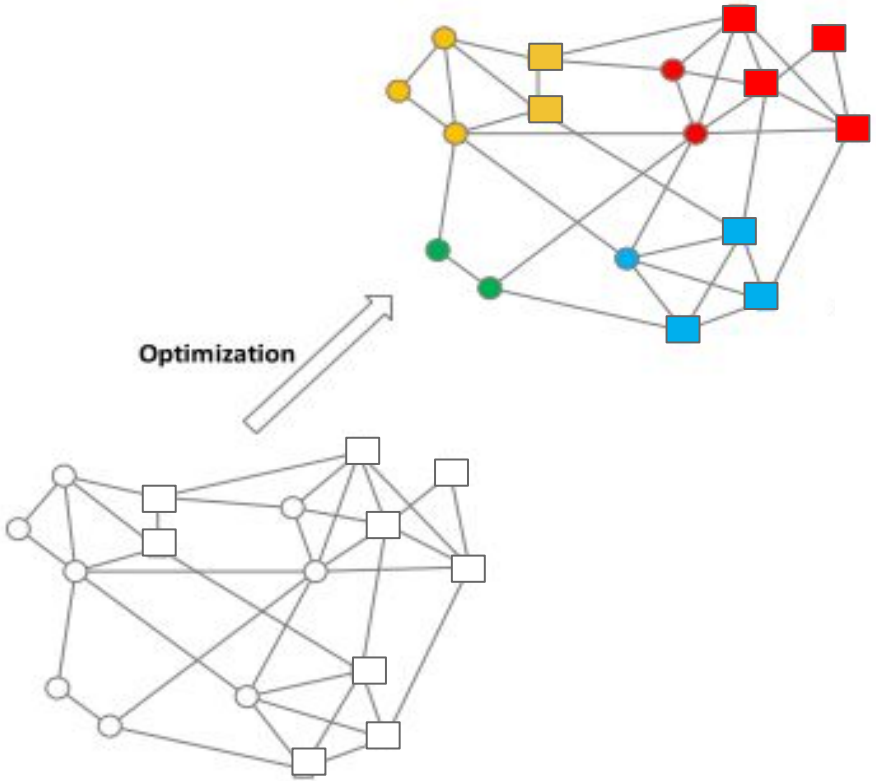

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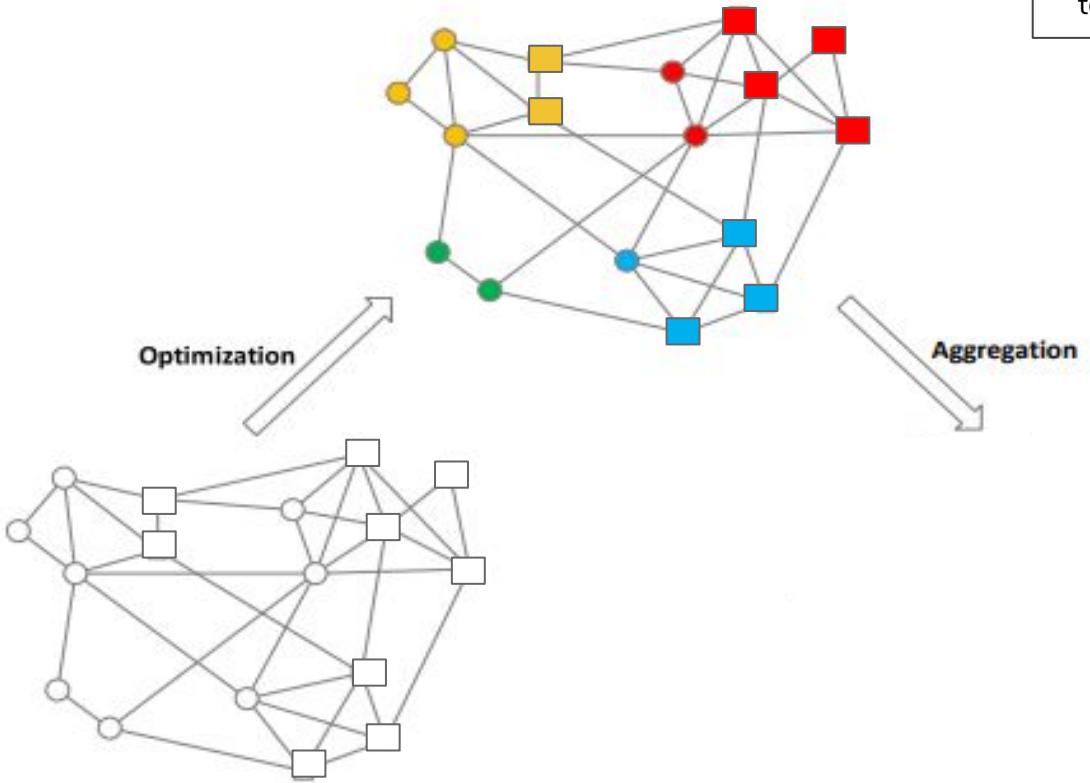

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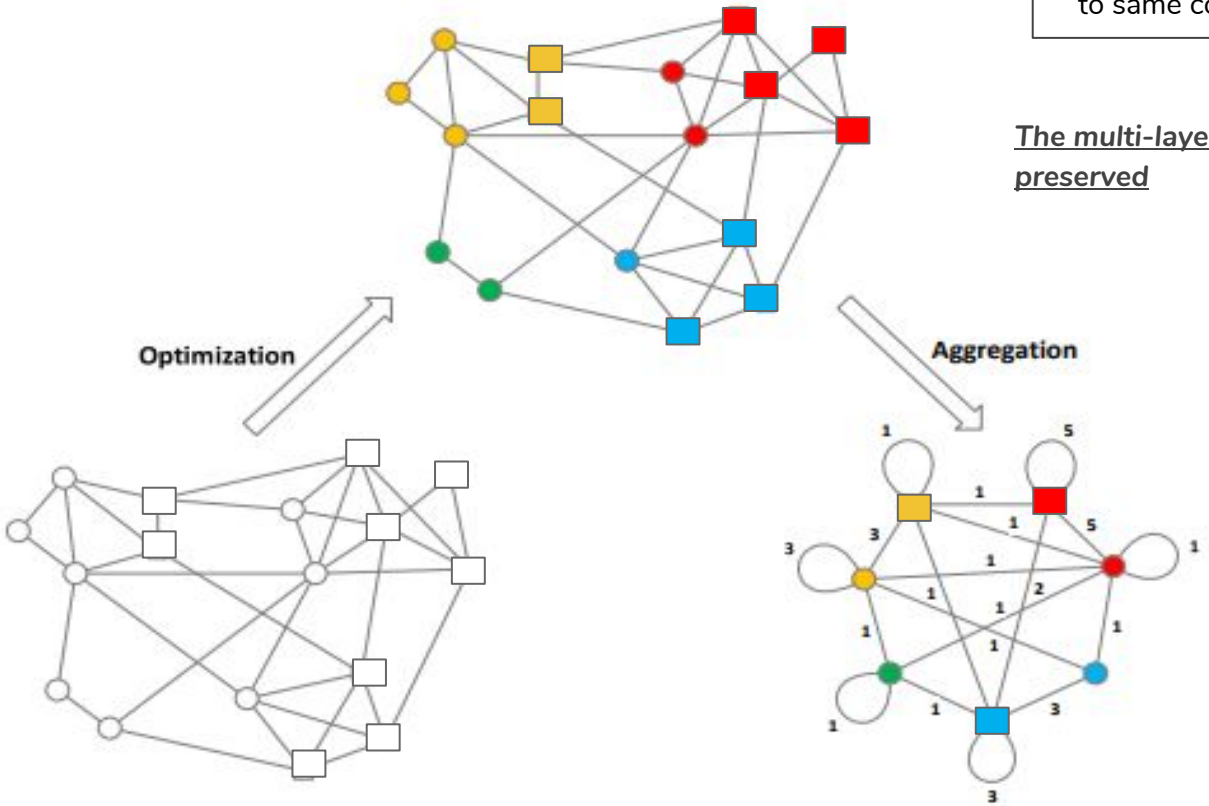
All nodes of same colour belong to same community

The multi-layer network structure is preserved



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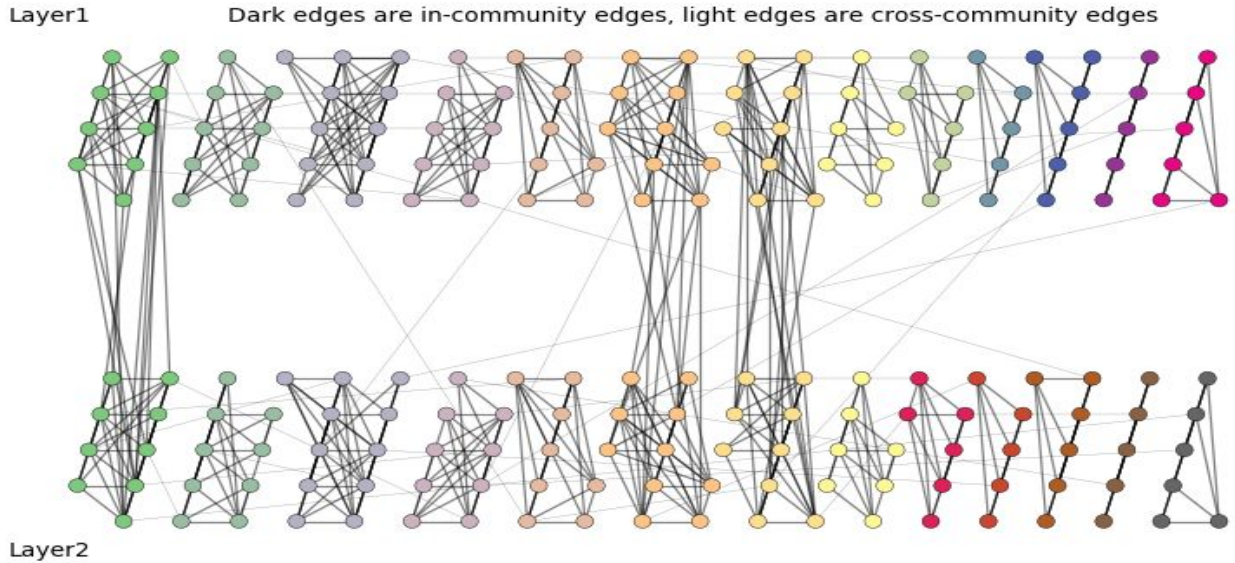
Dataset



Parameters:

- Alpha - denotes the fraction of cross layer communities
- D - density of coupling edges
- P- fraction of coupling edges inside community

Evaluation:

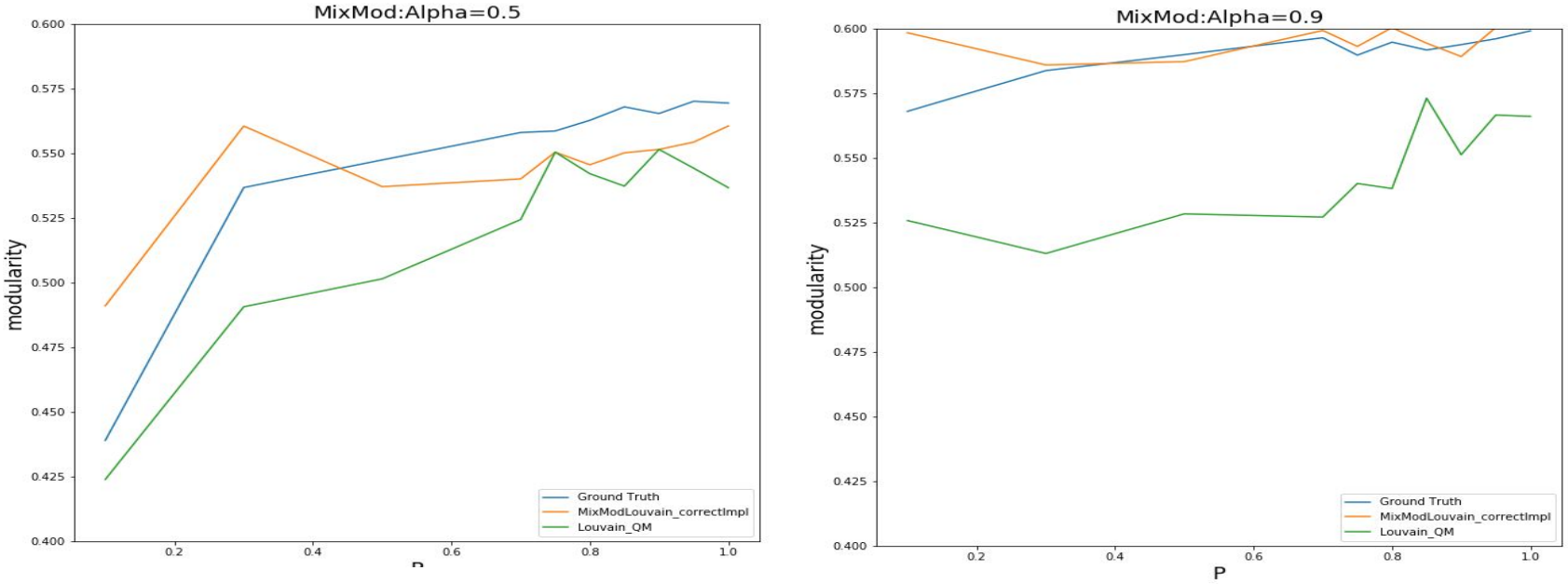


Figure9. Modularity plot for two different values of alpha (0.5,0.9) and varying P

Evaluation:

Gap between the modularity of detected community and ground truth community

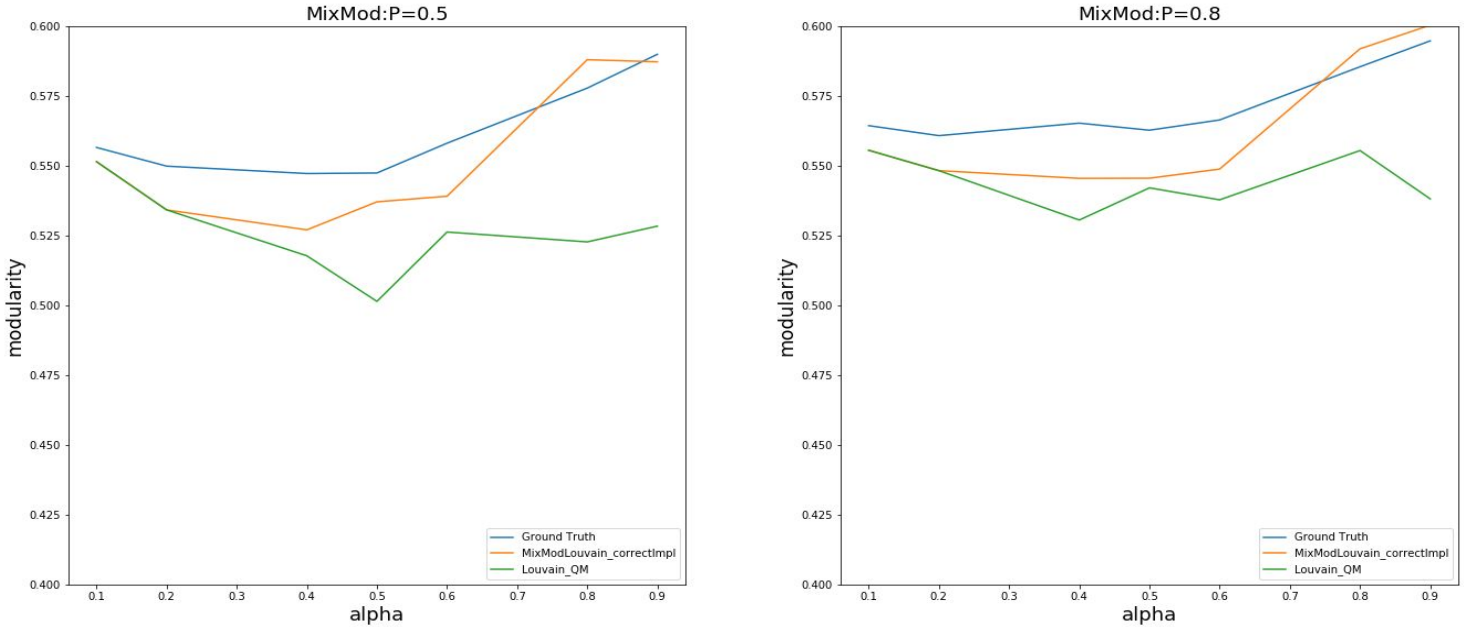


Figure10. Modularity plot for two different values of alpha (0.5,0.8) and varying P

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Summary and Future work:

The MixMod algorithm preserves the multi-layer structure of the network throughout.

The algorithm when pluged with Q_M (MixMod Q_M) performs better than Louvain Q_M

Future Work:

- Analysing the modularity index Q_M.
- Reduce the gap further between the detected communities modularity and the ground truth modularity.

References

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Questions?

Thank You

Algorithm: MixMod

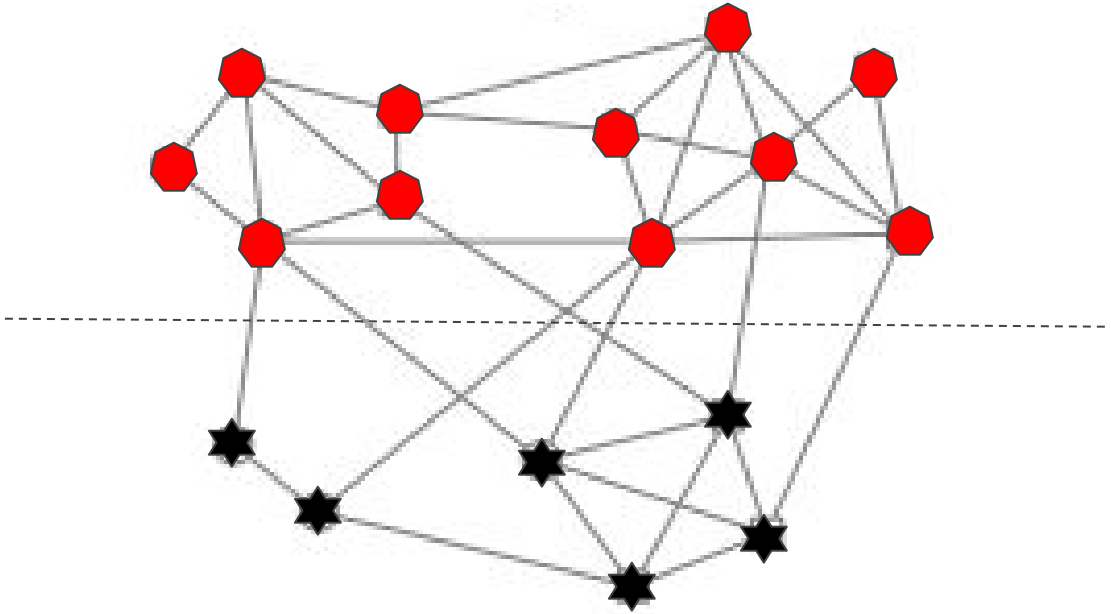
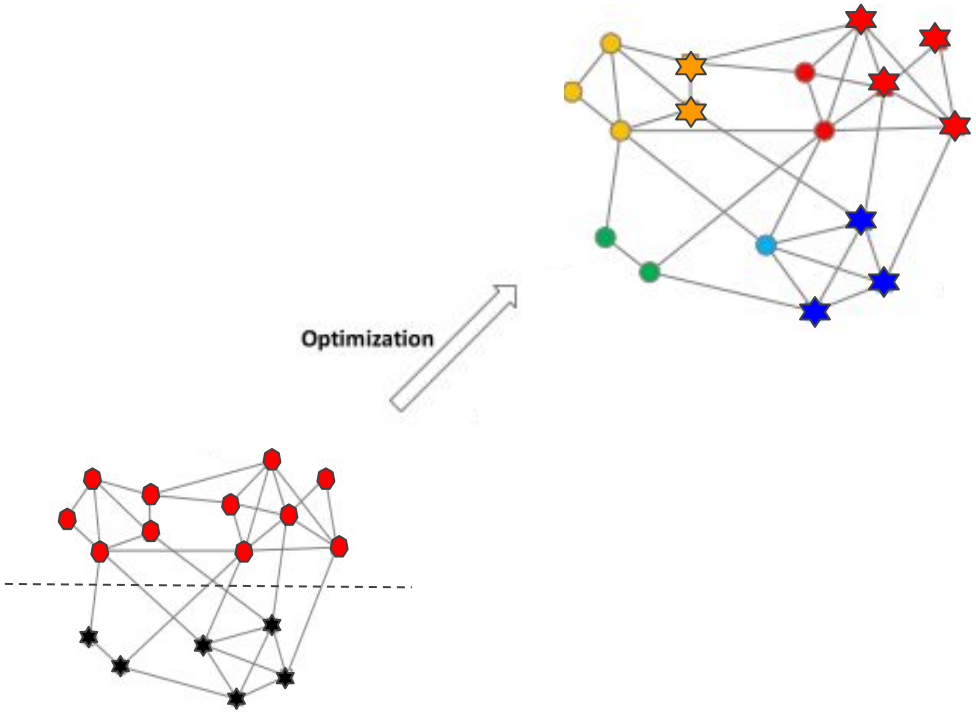


Figure10. Input network

Algorithm: MixMod



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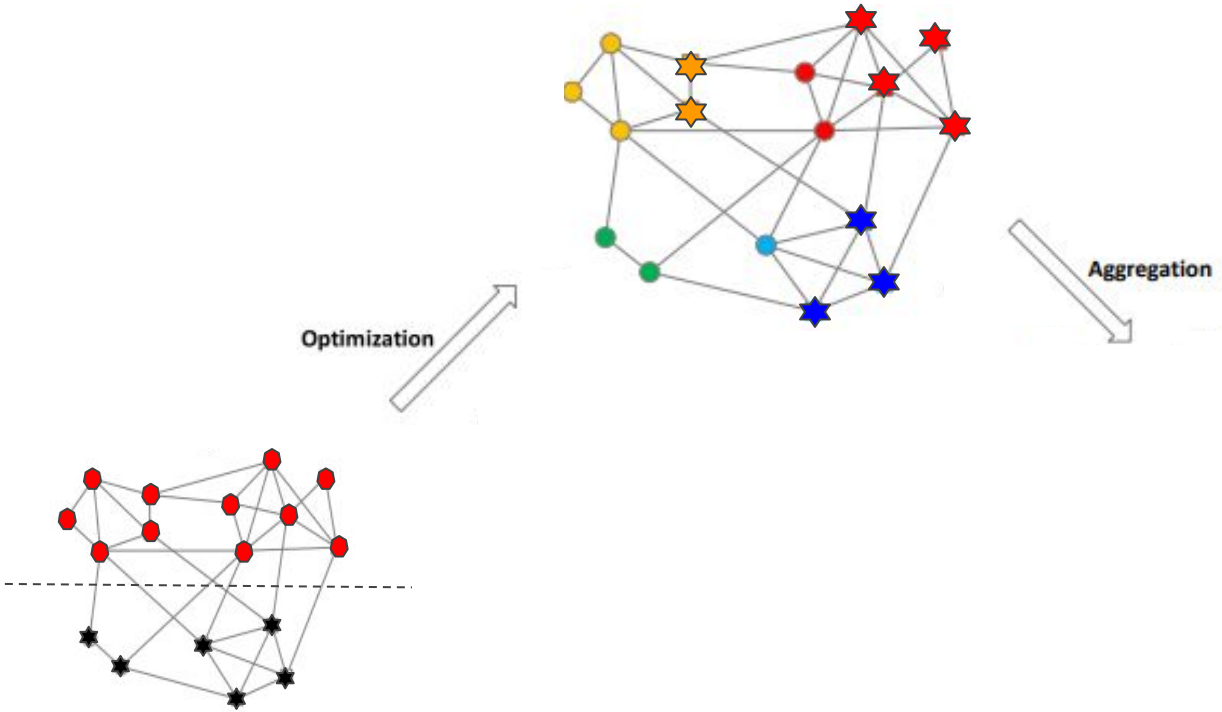

Limitations of DSAA

- The method uses Louvain algorithm for community detection.
- However, Louvain is a single layer community detection algorithm.

Louvain algorithm merges nodes and modifies the network structure, So, if we apply it on multi-layer network:

1. We would lose the layer information after first the merge.
2. The network no more remains multi-layered.