CADENCE: Community-aware Detection Of Dynamic Network States

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Summary

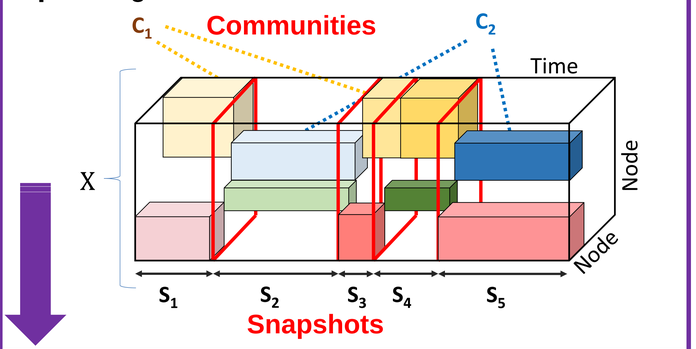
Introduction

- **Dynamic networks** represent interactions over time
- Interactions are often **aggregated** into temporal **snapshots** for downstream tasks (community detection, visualizations, outliers, ML on graphs)
- Typical approach: fixed time window
  - Data-agnostic
  - Does not reflect communities
- ***How to create snapshots that agree with natural communities in the network?***

Key ideas behind CADENCE

- Model interactions as a high-res tensor
- Simultaneously **detect communities** and their **regimes of stable activity**
- Define **snapshots** based on those regimes

input: High-res tensor

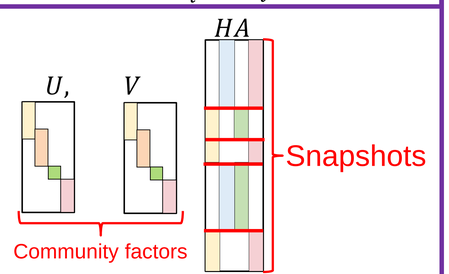


Model: Structured tensor factorization

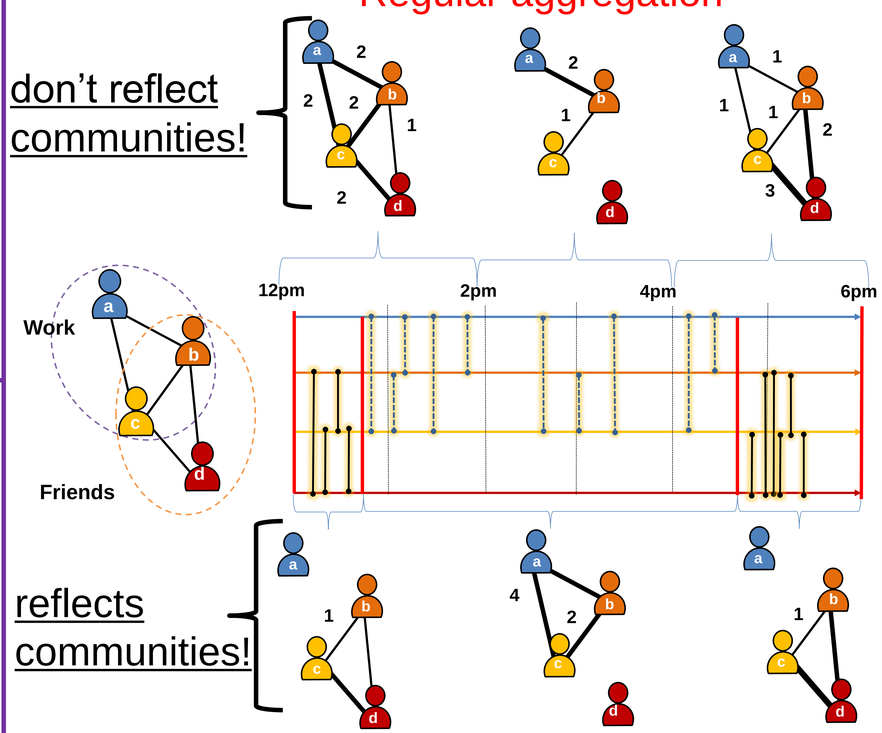
$$arg\min_{U,V,A} \|X - [[U,V,HA]]\|_F^2$$

$$s.t.\ U,V > 0,\ \theta \geq \|A\|_{2,0},\ H_{A_i \neq 0}^T H_{A_i \neq 0} = I$$

Output: Community aware snapshots



What makes a good snapshot in dynamic network data? Follow the activity of communities



Link to code and paper ->

Optimization intuition

$$arg\min_{U,V,A} \|X - [[U,V,HA]]\|_F^2\ \ s.t.\ U,V > 0,\ \theta \geq \|A\|_0,\ H_{A_i \neq 0}^T H_{A_i \neq 0} = I$$

Alternating least squares CPD for U, V

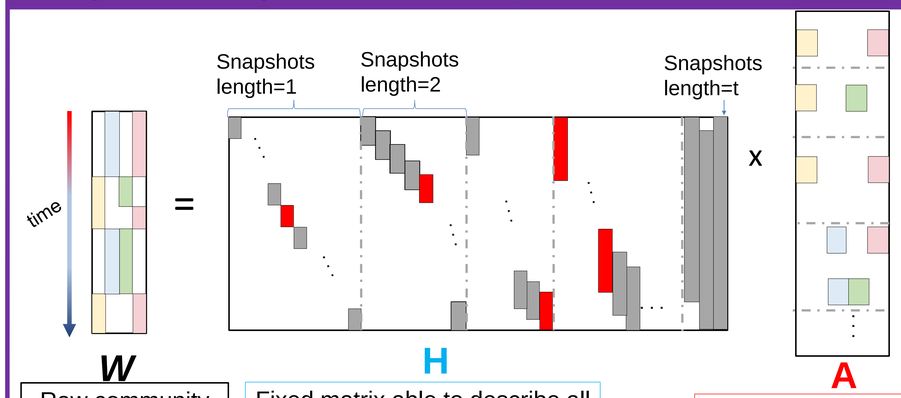
How can we solve for A?

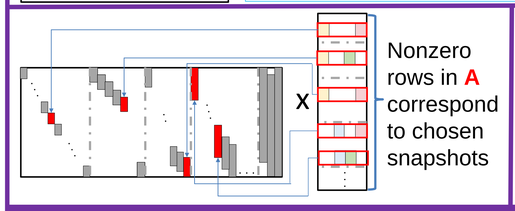
- H is overcomplete dictionary

Thus, to solve for A

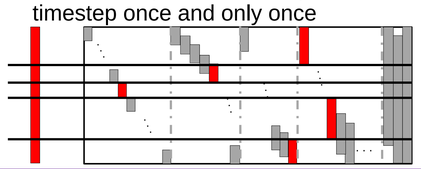
1. Solve for unconstrained W
2. Orthogonal matching pursuit inspired algorithm to solve $W = HA$ $s.t.\ \ \theta \geq \|A\|_0,\ H_{A_i \neq 0}^T H_{A_i \neq 0} = I$

Temporal snapshots via mega matrix H & encoding A



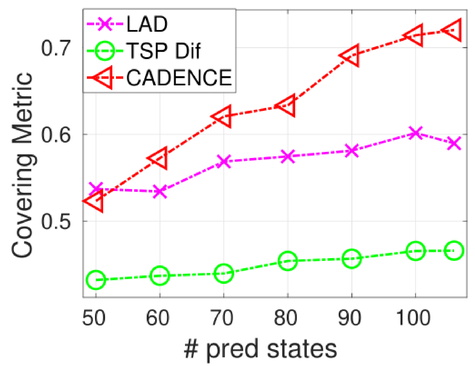


Chosen snapshots must represent each timestep once and only once



Experimental results

Change point detection



GNN Node classification