Graph theory in Communication and networks – Spring'16

Dynamic Communities in Evolving Network Graphs

Joseph P. Macker, David J. Claypool

J. P. Macker and D. J. Claypool, "Dynamic communities in evolving network graphs," MILCOM 2012 - 2012 IEEE Military Communications Conference, Orlando, FL, 2012, pp. 1-6.

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Abstract

- Spectral graph partitioning is used to examine potential community structures in evolving graphs.

- Evolving graps: structures vary with time.

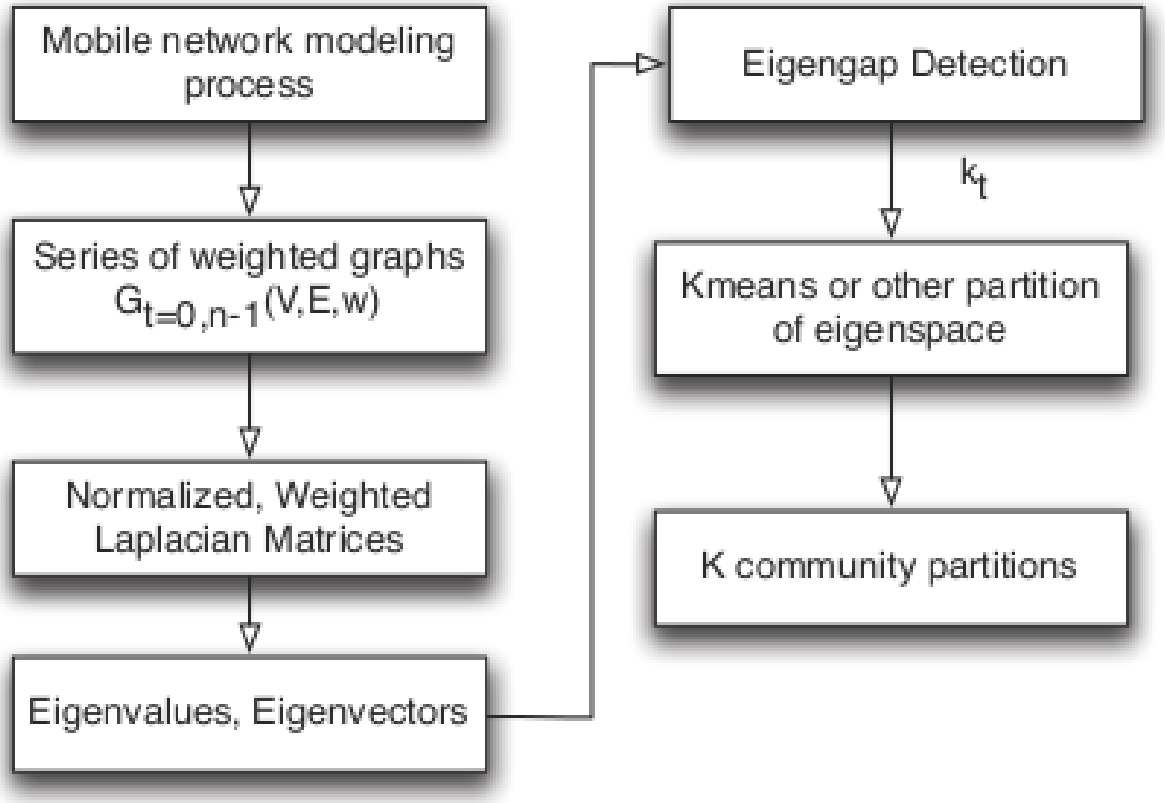
- Set of mobile network scenarios is used to explain dynamic spectral partitioning methods.

- Automatic selection of number of clusters and a measure for partitioning quality.

Motivation

- Clustering is the first step to analyze large datasets or catagorize huge networks.
- Networks such as wireless mobile ad-hoc networks dynamically change their structure with time, grouping of the network nodes with some similarity measure becomes crucial to monitor these networks.
- There is a need for measuring the quality of clusering to trust the results obtained from spectral clustering.
- Authors have used the proposed method for analyzing the mobile network trace models to detect, stabilize and track structural community decomposition

Processing models



Normalized graph laplacian

$$L = D - A$$

$$d_u = \sum_{v \in V} w_{u,v}$$

$$A(u,v) = \begin{cases} w_{u,v} & \text{if } (u,v) \in E \\ 0 & \text{otherwise.} \end{cases}$$

$$L_{norm} = \begin{cases} 1 - (w_{u,v}/d_v) & \text{if } u = v \text{ and } d_v \neq 0; \\ -(w_{u,v}/\sqrt{d_u d_v}) & \text{if } u \text{ and } v \text{ are adjacent;} \\ 0 & \text{otherwise.} \end{cases}$$

$$L_{norm} = D^{-1/2} L D^{-1/2}$$

Eigengap detection

- Disadvantage of spectral clustering with K-means is that we need to input the value of number of clusters.

- For this reason, spectral clustering with K-means cannot be dynamically applied to a series of graph inputs.

- Eigengap detection is used to auto-configure the values of optimal number of clusters k.

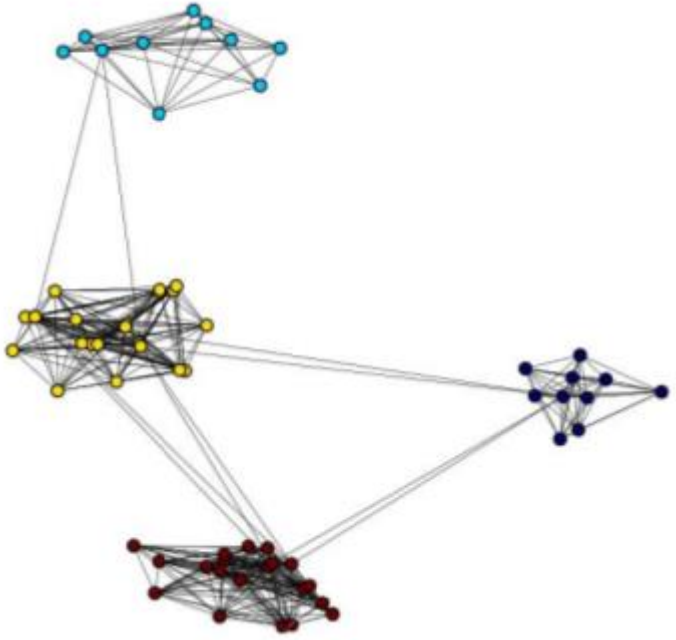
Eigengap detection

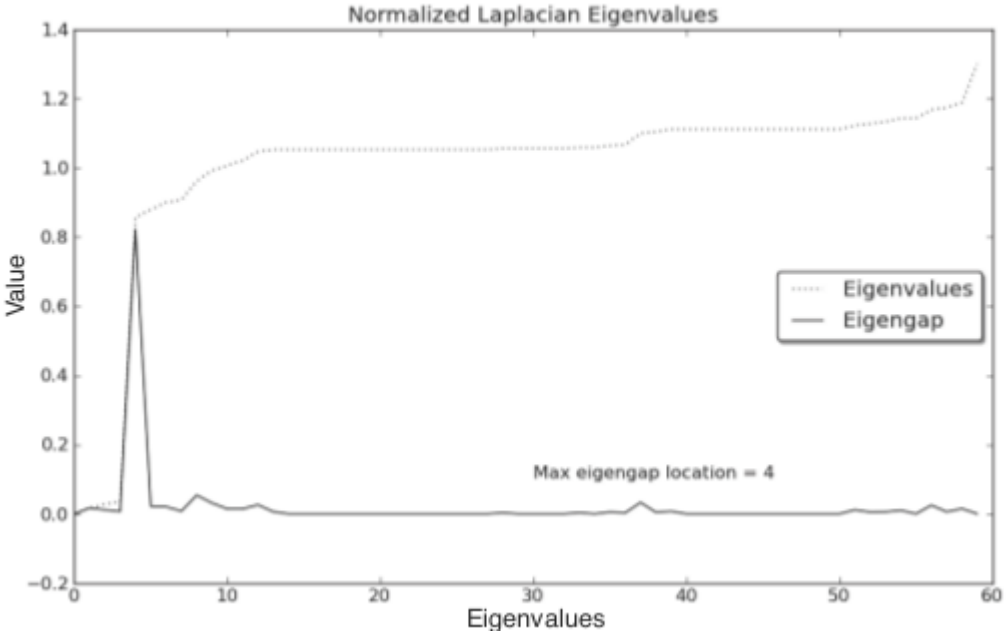
- L_{gap} is defined as the difference between consecutive eigenvalues of the normalized laplacian matrix.
- $L_{gap} = L_{n+1} - L_n$,where L_n represents the n'th eigenvalue

- All the L_{gap} values are calculated and max Lgap is used to decide optimal value of k.

- If $L_{gap,max} = L_{k+1} - L_k$ then 'k' is the optimal number of clusters for input dataset

Eigengap detection





Partitioning quality measure

- Partitioning information becomes less accurate as community structures become more vague such as large grid scenarios or uniform randomly generated networks.

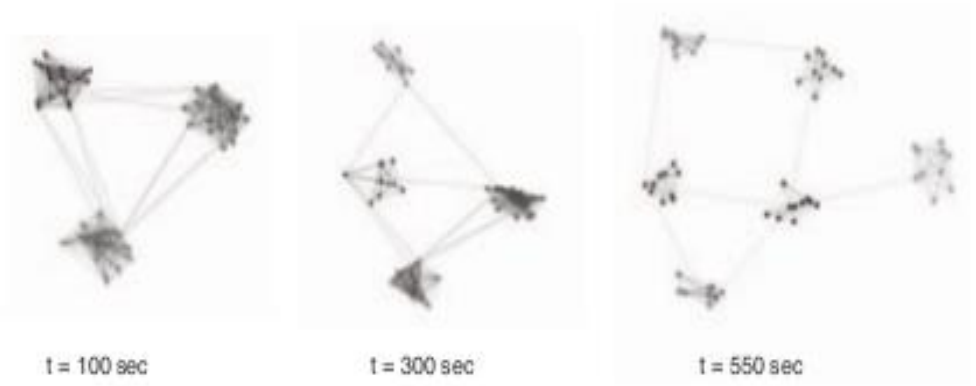
- Pq: peak-to-average ratio – Higher the value better is the quality of clustering.

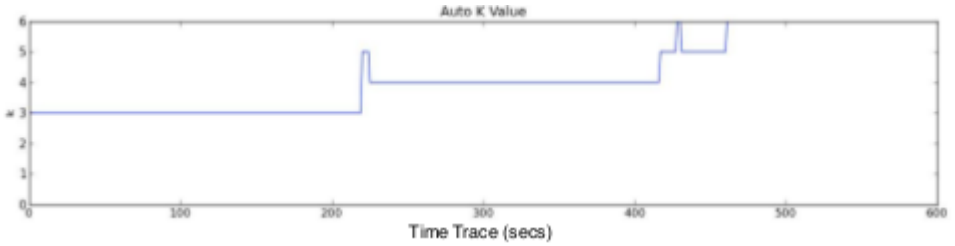
$$P_q = max\lambda_{gap}/((\sum_{i=1,n} \lambda_{gapi})/n)$$

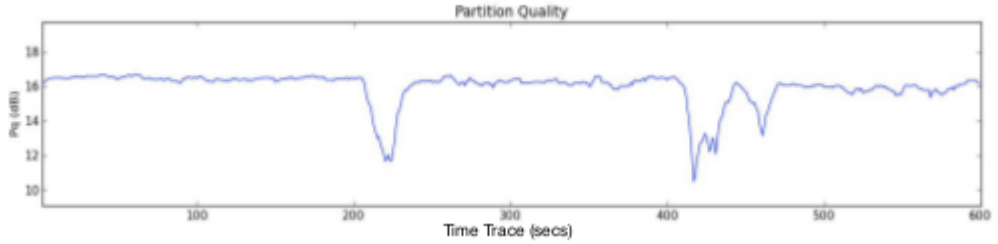
Dynamic mobile cluster scenario

- 60 network nodes
- Total simulation time : 600 seconds
- First 200 seconds: 3 groups of 20
- Next 200 seconds: 2 groups of 20 and 2 groups of 10
- Last 200 seconds: 6 groups of 10

Dynamic mobile cluster scenario



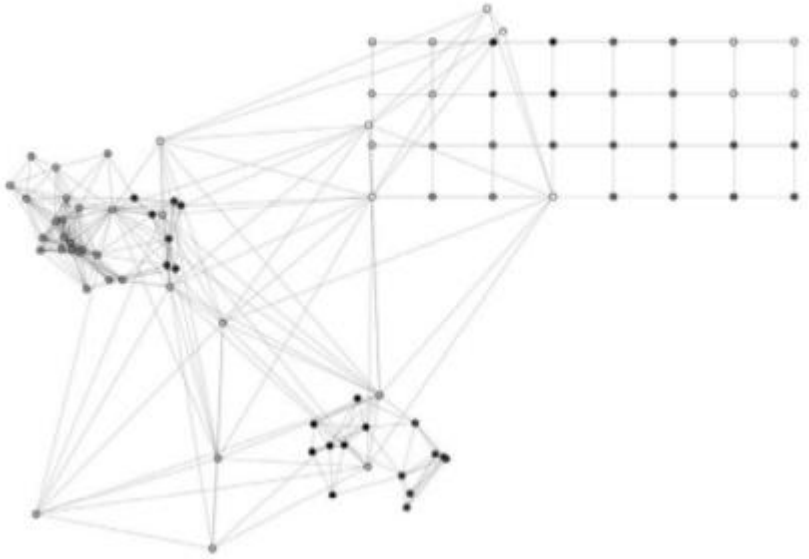


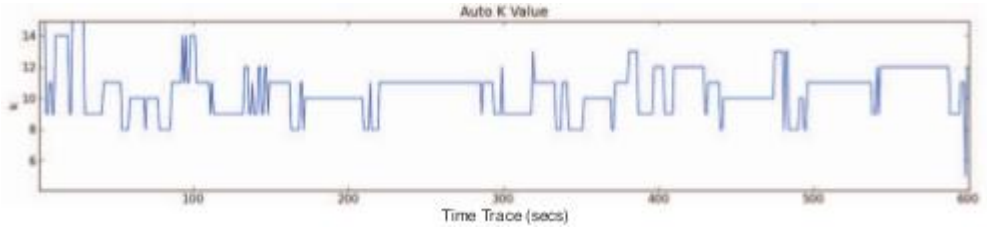


Operationally clustered scenario

- 15 nodes in group A – stationery – west
- 15 nodes in group B – stationery – south
- 15 nodes – move as cluster among groups A & B, forming at times a combined unit with each of the two groups
- 10 high flying aerial units – backhaul network
- East – grid of locally connected stationery 32 nodes with 2 of the nodes in this grid is connected to aerial backhaul network

Operationally clustered scenario





Future work and challenges

- Formulate new metrics for measuring partitioning quality.

- The proposed work could be used to improve the analysis in network planning, design and potential network cognition.

- Analysis of distributed selection in mobile relay nodes based on some node centrality metric.

- For large networks more computationally efficient techniques are required.

Conlusions

- Automated spectral graph partitioning technique is implemented to detect dynamic cluster communities.

- Eigengap detection is used to auto-configure the optimal number of communities.

- Partitioning quality metric is defined.