Haggle: Pocket Switched Networks – Social Based Approach

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Haggle Project: http://www.haggleproject.org

Distributed Community Detection: http://www.cl.cam.ac.uk/~ey204/Haggle/Vis/mobility.html

USE of SOCIAL CONTEXTS for FORWARDING

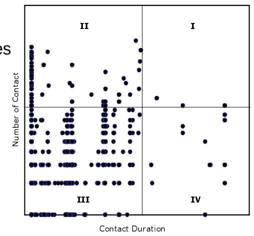
We seek to improve understanding of the human social context and use it in the design of forwarding algorithms for Pocket Switched Networks (PSN). From human mobility traces taken from the real world, we discover the heterogeneity in human interactions including communities and hubs. Society naturally divides into communities, and individuals have varying popularity. We propose various social based forwarding algorithms, which are shown empirically to improve the forwarding efficiency significantly. We describe our centralised community detection algorithms from complex network studies to human mobility studies, which opens a new aspect in human mobility trace analysis. We also introduce our novel decentralised community detection methods that enable these algorithms to be practically used in online applications.

MULTIPLE LEVEL HUMAN HETEROGENEITY

Third generation of human mobility models: understanding heterogeneity at multiple levels of detail

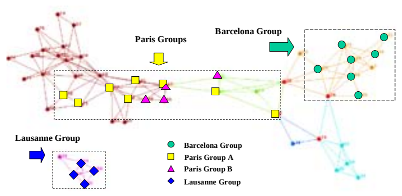
- Local community structures
- Diversity of centrality in different scales
- 4 Categories of human relationship

I Community
II Familiar Stranger
III Stranger
IV Friend



K-CLIQUE COMMUNITY DETECTION

- Union of k-cliques reachable through a series of adjacent k-cliques
- Adjacent k-cliques share k-1 nodes
- Members in a community reachable through well-connected well subsets. For example:
  - 2-clique (connected components)
  - 3-clique (overlapping triangles)
- Overlapping feature
- Percolation threshold



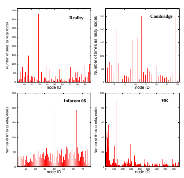
K-CLIQUE Communities in INFOCOM 2006 Dataset (K=4)

CENTRALITIES

- Social hubs, celebrities and postman
- Betweenness, closeness, inference power centrality

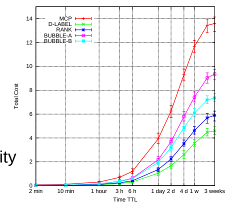
Centrality in Temporal Network

- Large number of unlimited flooding
- Uniform sourced and temporal traffic distribution
- Number of times on shortest delay deliveries



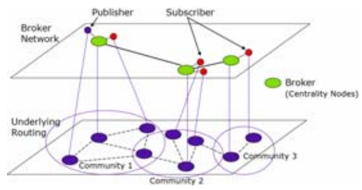
HETEROGENEOUS FORWARDING ALGORITHMS

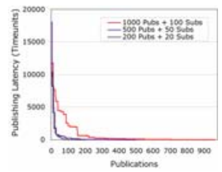
- RANK (centrality based forwarding)
- LABEL (community based forwarding)
- BUBBLE RAP (centrality meets community)
  - Population divided into communities
  - Node has a global and local ranking
  - Global popular node like a postman, or politician in a city



SOCIO-AWARE OVERLAY FOR PUBLISH/SUBSCRIBE

- Subscription Propagation during Community Detection
- Closeness Centrality Nodes Creates Overlay



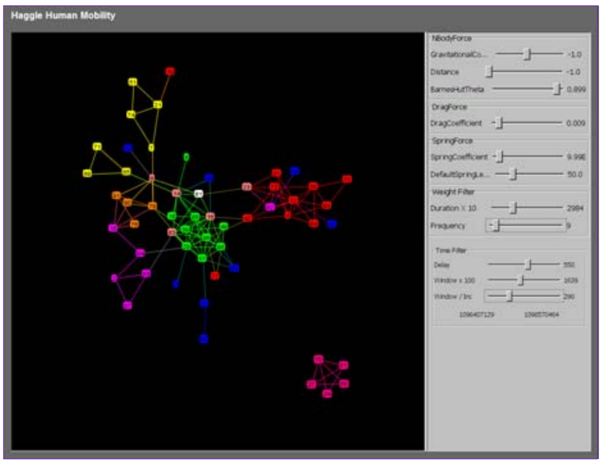


DISTRIBUTED COMMUNITY DETECTION

- SIMPLE O(n)
- K-CLIQUE O(n^2)
- MODULARITY O(n^4)

Experimental data set	SIMPLE	k-CLIQUE	MODULARITY
Reality	0.79/0.76	0.87	0.82
UCSD	0.47/0.56	0.55	0.40
Cambridge	0.85/0.85	0.85	0.87

- Empirical approach with real world human mobility traces
- Contact duration and number of contacts for defining node pair relationship



Connection Map

FUTURE WORK

- Apply Complex Social Contexts
  - Temporal/Spatial (e.g. specific time of the day)
  - Network Locality (e.g. ego-centric, socio-centric)
- Further Experiments with City Scale Human Mobility Data

Visualizing Community Detection in Opportunistic Networks

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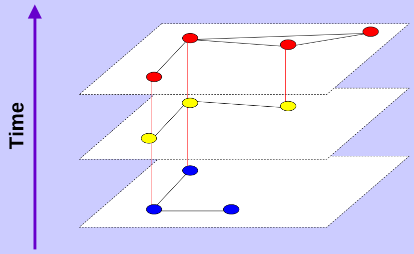
Visualization of Community Detection: http://www.cl.cam.ac.uk/~ey204/Haggle/Vis/mobility.html

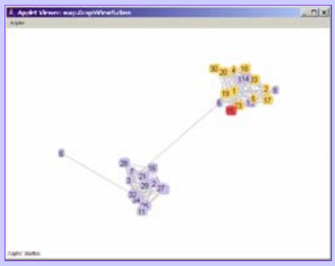
TIME CONNECTED GRAPH AND COMMUNITY DETECTION

- Human connectivity trace can be seen as a time dependent graph
- Topology changes every time unit
- Community Detection
  - Recalculate every time unit
  - Different detection criteria

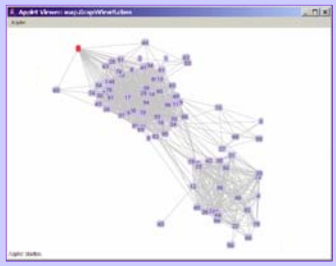


DEGREE BASED CONNECTION MAP

- Simple connection map based on degree
  - Highlight group of nodes → Community
  - Clustering dependent on nodes (= people)
    - CAMBRIDGE → two distinct groups
    - MIT → two large groups but difficult to detect sub-groups



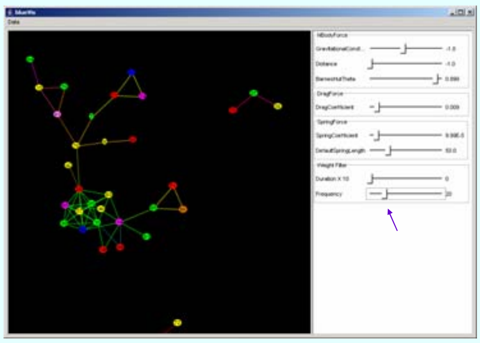
CAMBRIDGE – 36 nodes



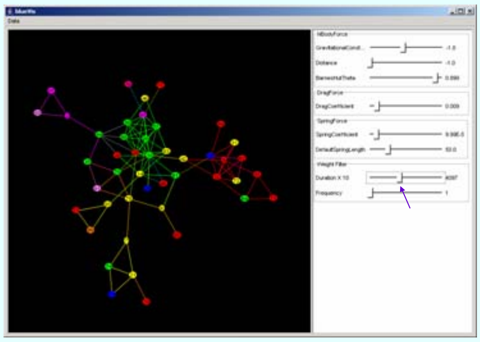
MIT – 100 nodes

BLUE VISUALIZATION

- Visualize detected communities with different criteria
  - Contact duration
  - Frequency (Number of contacts)
- Community detection algorithm: **SIMPLE, K-CLIQUE**



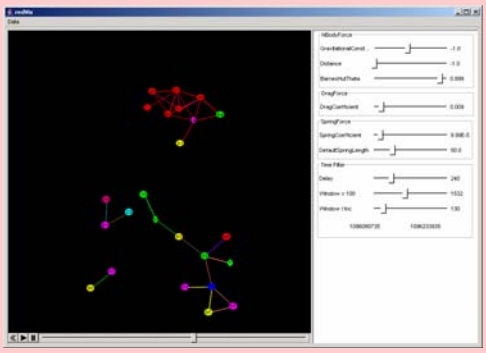
Detection Criteria: Larger Frequency



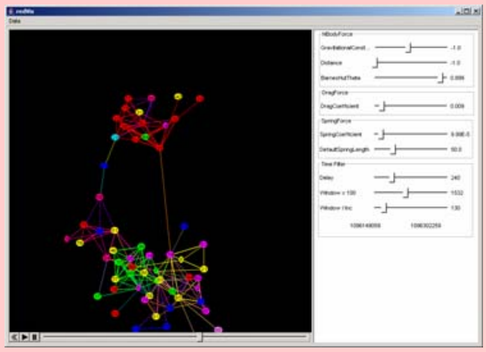
Detection Criteria: Larger Duration

RED VISUALIZATION

- Visualize detected communities within a **SLIDING WINDOW**
- Change time window setting
  - Window size
  - Window Increment size
  - Delay of animation



Loosely Connected Time Window



Tightly Connected Time Window