Efficient Social-aware Content Placement in Opportunistic Networks

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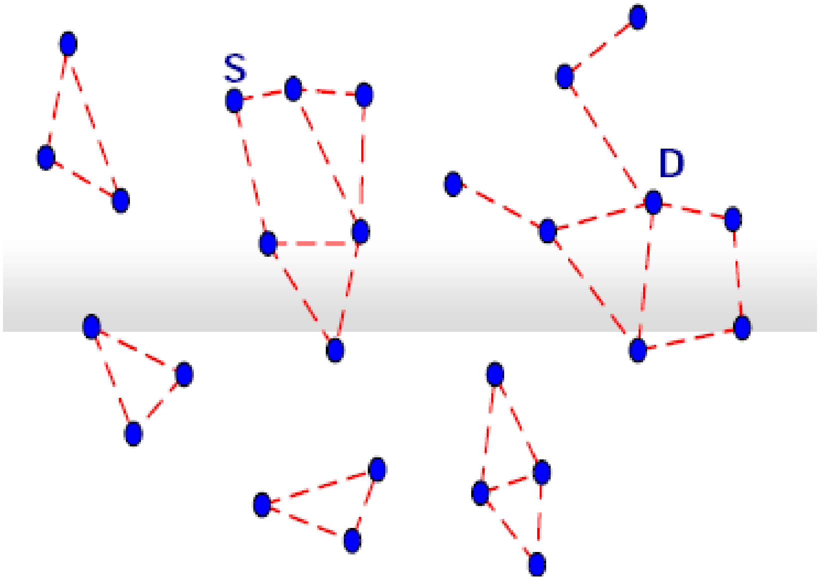
a delay - tolerant environment

A wireless network that is very sparse and partitioned

✓ disconnected clusters of nodes appear



- Nodes are highly mobile making the clusters change often over time
- No contemporaneous end-to-end path

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graph representation of a DTN

A graph that stands for a DTN:

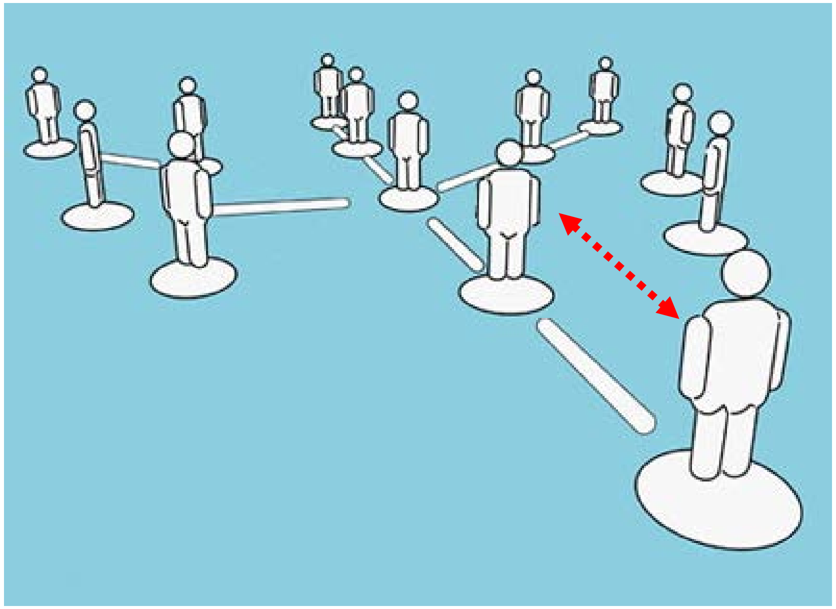
add an edge between two nodes if

- ✓ the frequency of encounters

  or

- ✓ the cumulative time of direct contact

exceeds a pre-defined threshold



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approximate solution to the classic facility location problem*

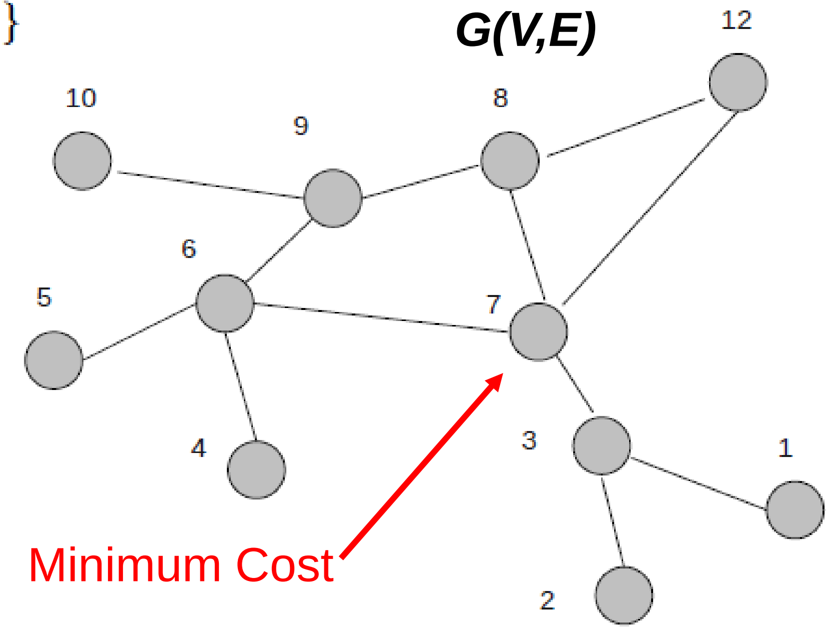
- ***K-median problem*** : given a fixed number of facilities, minimize the total service cost

$$Cost(\mathcal{F}) = \sum_{n \in \mathcal{V}} w_n \cdot min_{x_j \in \mathcal{F}} \{d(x_j, n)\}$$

d **(*k, n*) : cost path between nodes *k* , *n***

w_n : demand generated by node n

Topology represented by ***G(V,E)***



- To cope with constraints, use:

1. Local topology info
2. Local demand info

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* **P. Mirchandani and R. Francis. *Discrete Location Theory*. John Wiley and Sons, New York, NY, 1990**

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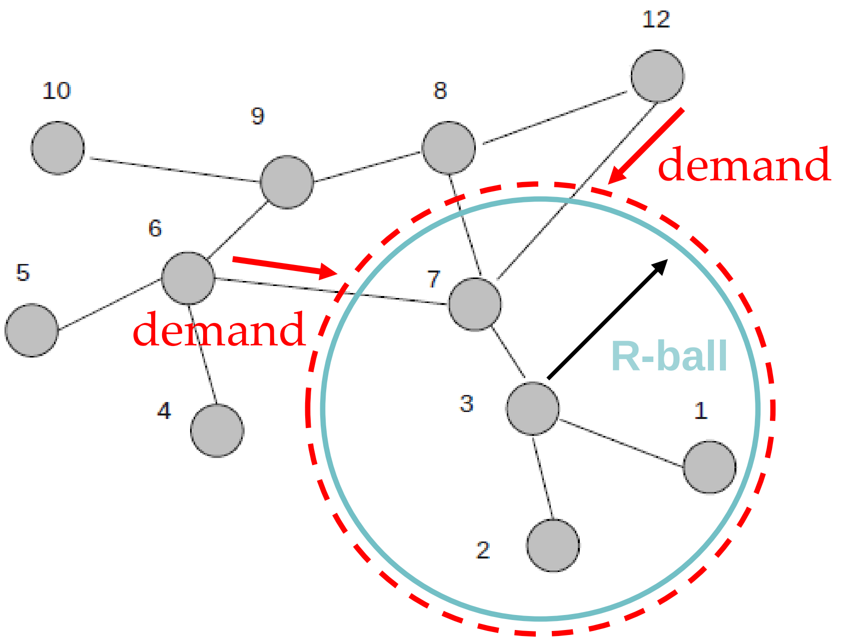
the R-balls heuristic*

- Solve the optimization problem within a limited neighborhood of selected facilities
- Implicit computation of the demand generated by outer nodes

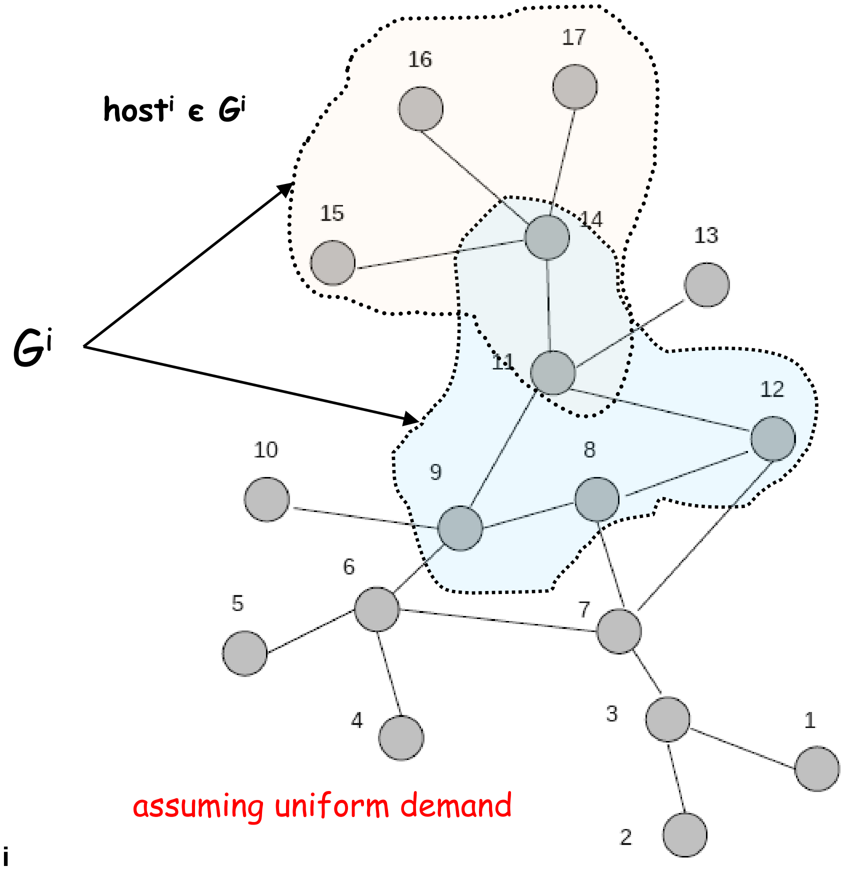


* G. Smaragdakis, N. Laoutaris, K. Oikonomou, I.Stavrakakis, A. Bestavros, ***"Distributed Server Migration for Scalable Internet Service Deployment",*** **to appear in IEEE/ACM T-Net. (2010)**

content placement: a social-aware approach

1-Median* Problem *: Determine the physical location of content's single host, in a way that a cost metric is minimized

- Instead of a **large** optimization problem, solve *iteratively* **small-scale** ones, on subgraphs G^i **є** G, trying to reach the optimal
- Pick G^i nodes around $host^i$ according to a social-inspired criterion
- Criterion should achieve *quantification of demand* from nodes **not** included in G^i



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content placement: a social-aware approach

a measure of the importance of node's *u* social position : lies on paths linking others

Betweenness Centrality (*u*): portion of all pairs shortest paths of G that pass through node *u*

$$BC(u) = \sum_{s=1}^{|V|} \sum_{t=1}^{s-1} \frac{\sigma_{st}(u)}{\sigma_{st}}$$

***Conditional* Betweenness Centrality (*u, t*)** : portion of all shortest paths of G from node *u* to *target t,* that pass through node *u*

$$CBC(u;t) = \sum_{s \in V, u \neq t} \frac{\sigma_{st}(u)}{\sigma_{st}}$$

a measure of the importance of node's *u* social position : ability to control information flow towards *target* node

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content placement: a social-aware approach

CBC criterion

- small-scale *1-median* solution derived from any cost-effective algorithm (i.e. approx., heuristic, enumeration)

Algorithm 1 Social-aware *1-median* in *G(V,E)*

choose randomly node s
place CONTENT in s
$C_{current} \Leftarrow \infty$
$\forall\, u \in G$ *compute* $CBC(u;s)$
let G_s^o *be* $\alpha\%$ *of G nodes with top CBC values*
1-median solution in $G_s^o \rightarrow$ *node Host*
$C_{next} \Leftarrow C(Host)$
while $C_{next} < C_{current}$ **do**
    move CONTENT to Host
    $C_{current} \Leftarrow C_{next}$
    $\forall\, u \in G$ *compute* $CBC(u;Host)$
    let G_{Host}^i *be* $\alpha\%$ *of G nodes with top CBC values*
    1-median solution in $G_{Host}^i \rightarrow$ *node NewHost*
    $Host \Leftarrow NewHost$
    $C_{next} \Leftarrow C(NewHost)$
end while

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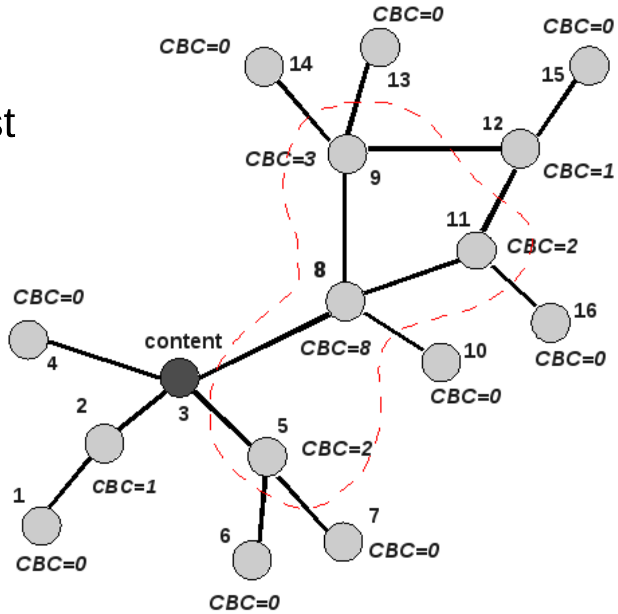
content placement: a social-aware approach



- CBC criterion picks neighboring nodes to the host
- Selected nodes “stretching” in a certain direction
- Solution space moved by selection towards directions populated by capable nodes of transporting information efficiently
- “Socially significant” direction is valid under any demand model but exploited only under uniform demand hypothesis

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simulation settings

- Generate both E-R and B-A random graphs of *N=100* nodes
- 10 simulation runs for any chosen configuration
- Results presented are the averages over the runs
- Regenerate the graph for each simulation run
- Probability of a link to exists approximates the theoretical value of the target graph model

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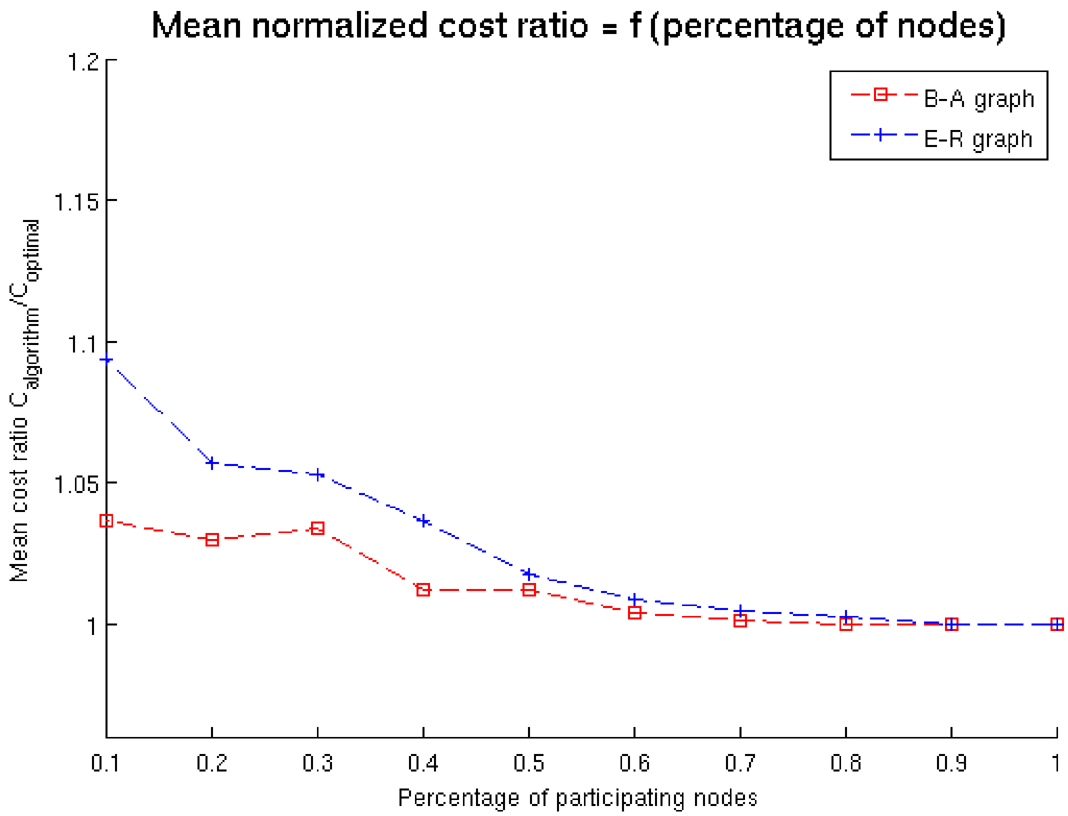
simulation results ($^1/_3$)



Standard Error associated with each mean: 0.07% ≤ SE ≤ 2.88%

simulation results (2 / 3)

- *Random policy* : place the content on a randomly selected node and serve demands

✓ Test the most costly scenario : $\max \beta_{algorithm}(\alpha) = \beta_{algorithm}(0.1)$

$$\beta_{algorithm}(\alpha) = E[\frac{C_{algorithm}}{C_{optimal}}]$$

$$\beta_{random} = E[\frac{C_{random}}{C_{optimal}}]$$

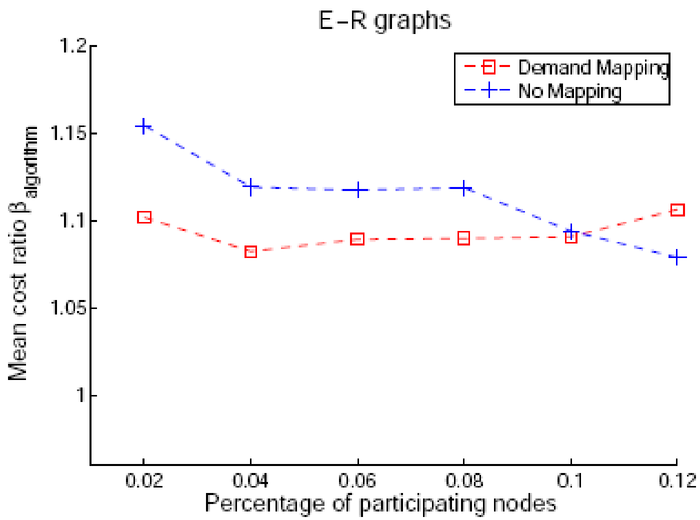
SOCIO-AWARE *1-median* VS SIMPLE RANDOM PLACEMENT

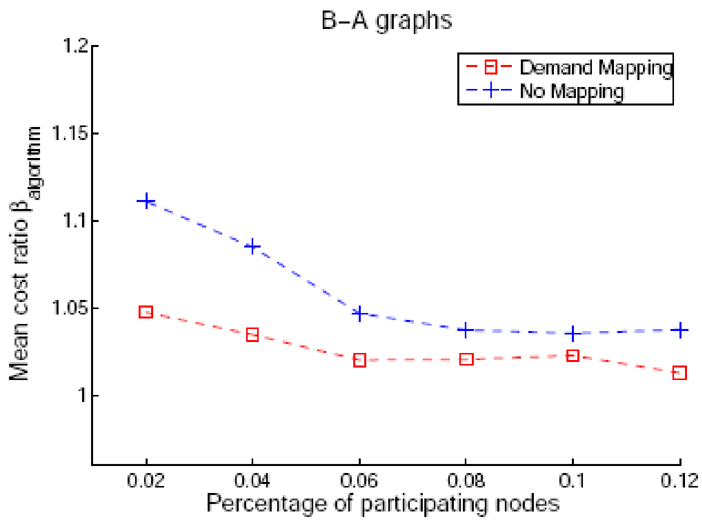
E-R graphs		*B-A graphs*	
max. $\beta_{algorithm}$	β_{random}	max. $\beta_{algorithm}$	β_{random}
1.0938	1.2736	1.0366	1.4953

simulation results ($^3/_3$)

Demand mapping

- New demand model for the small-scale optimization to improve performance
- Mapping between CBC values of subgraph G^i and incoming demand load
- When the percentage of participating nodes $\rightarrow 1$, we solve a different problem





future work

- ✓ study whether such mechanisms can be effectively applied
- ✓ consider the threshold-based mapping of contacts to static graphs
- ✓ expand this work to include non-uniform demand patterns

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Questions ?