A Socially Aware Caching Mechanism for Encounter Networks

Future Internet Architectures: New Trends in Service Architectures, 2nd EuroFGI Workshop

June, 9th 2009

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General Overview

- Mobile information system for ad-hoc groups
- Interdisciplinary research

- Main Idea:
  - People who are near each other often do have some kind of relationship
  - Determine social realtionships and roles within groups
  - Exploit this information to enhance the communication

Communities and Community Support

- **Def. Ad-hoc Community**
  - 2 or more members
  - Shared social territories
  - Ongoing interactions

- **Def. Community Support System**
  - Mobile applications to support ad-hoc groups
  - Micro-coordination ⇔ community state information
  - E.g. navigation and reminder services

Community Support and Encounter Networks

- **Def. Mobile Encounter Networks (MEN)**
  - Mobile peer-to-peer network + ad-hoc network
  - Opportunistic content exchanges
  - Spatial diffusion process

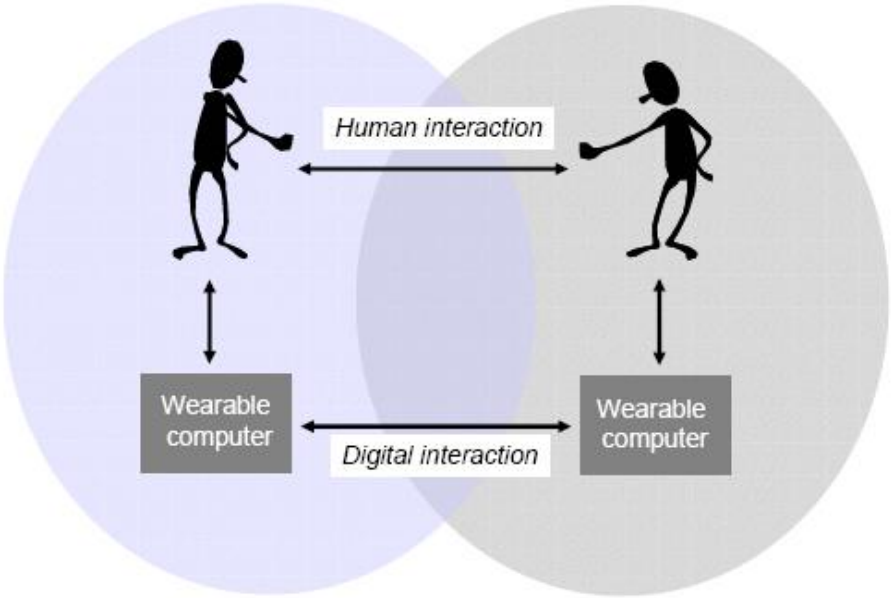


Fig 1. Content Exchanges in MEN

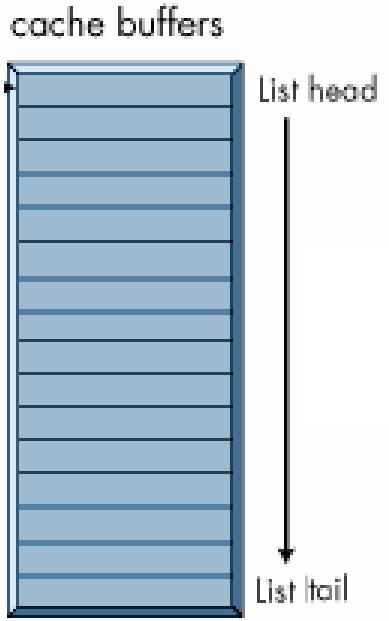
- **Community Support?**
  - Not time critical
  - Small and public contents
  - No subscriptions required!
  - Relevant content from significant people!

Content Management in Encounter Networks

- **Community Contents**
  - Semantic enhancements of real world objects
  - E.g. object descriptions, state information
  - Addressing with metadata

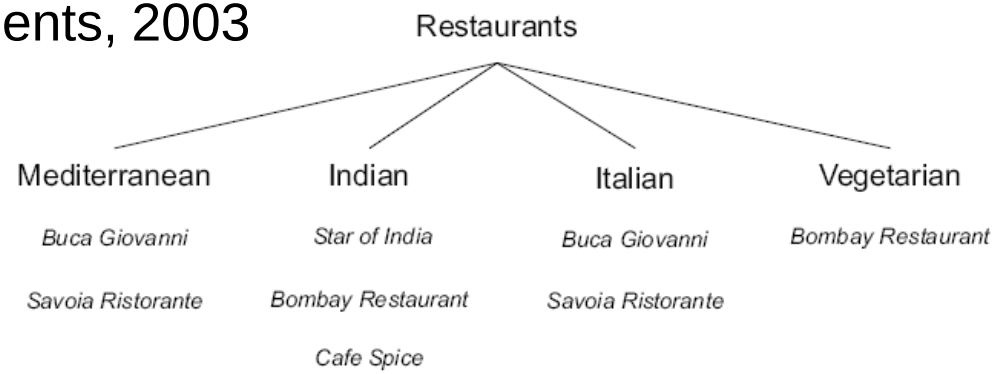
- **Content Diffusion depends on …**
  - available neighbor peers
  - available encounter time
  - available peer contents

- **Peer Cache**
  - Cache Policy
  - Sorting and purge-out of least relevant items!



Related Work

- Heinemann et al: IClouds - Peer-to-Peer Information Sharing in Mobile Environments, 2003



- Datta et al.: Autonomous Gossiping: A Self-Organizing Epidemic Algorithm for Selective Information Dissemination, 2004

Utility := interest x neighbourhood availability

- Wolfson et al.: Opportunistic Data Dissemination in Mobile Peer-to-Peer Networks, 2005

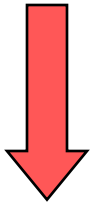
$$R(c) = -\alpha \times t - \beta \times d, \quad \alpha, \beta \geq 0.$$

Our Approach

- Why current cache policies don´t fit?
- How social behavior can improve caching?
- Design of cache algorithms

From Data to Behavior Localities

- **Problems related to urban scenario:**
  - People are members of *several communities*
  - *Local* and *global* information exchanges are mandatory!
    - *Community Networking Effect!*



- **Solution:**
  - Cache policy ~ *acquisition opportunities*
  - Human *behavior histories*
  - *Delegate* caching tasks

Unfamiliar and familiar environments

- Most of the time humans stay in familar environments!
  - Variation seeking almost neglectable!

- Unfamiliar Environments:
  - Contextual information, navigation services
  - Source: co-located community members
  - *Contextual caching* policy for *navigation services*:

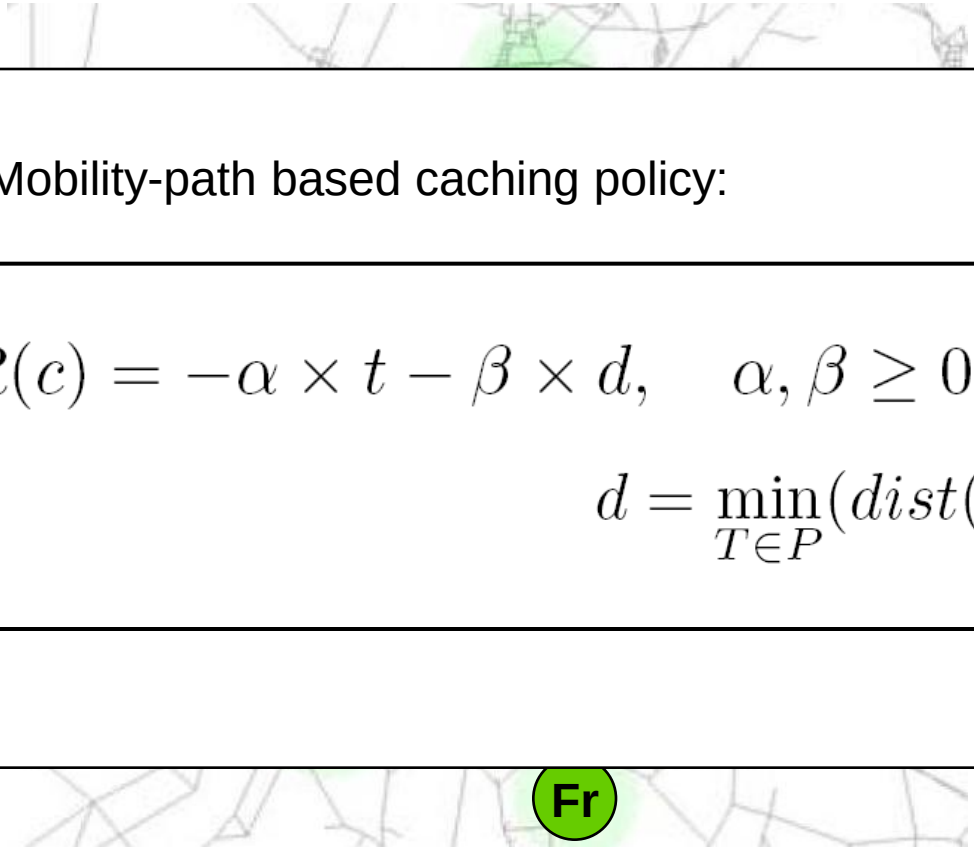
$$R(c) = -\alpha \times t - \beta \times d, \quad \alpha, \beta \geq 0.$$

(See Wolfson et al.)

- Familiar Environments
  - Exploit behavior histories!
  - Reminder Services

Spatio-temporal Behavior Localities – Urban Territories

- People develop **territorial preferences**
  - Biological rythms, opening hours, transport offer etc.



Home

- Mobility-path based caching policy:

$$R(c) = -\alpha \times t - \beta \times d, \quad \alpha, \beta \geq 0.$$

$$d = \min_{T \in P}(dist(O(c), C(T))$$

1,2

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2

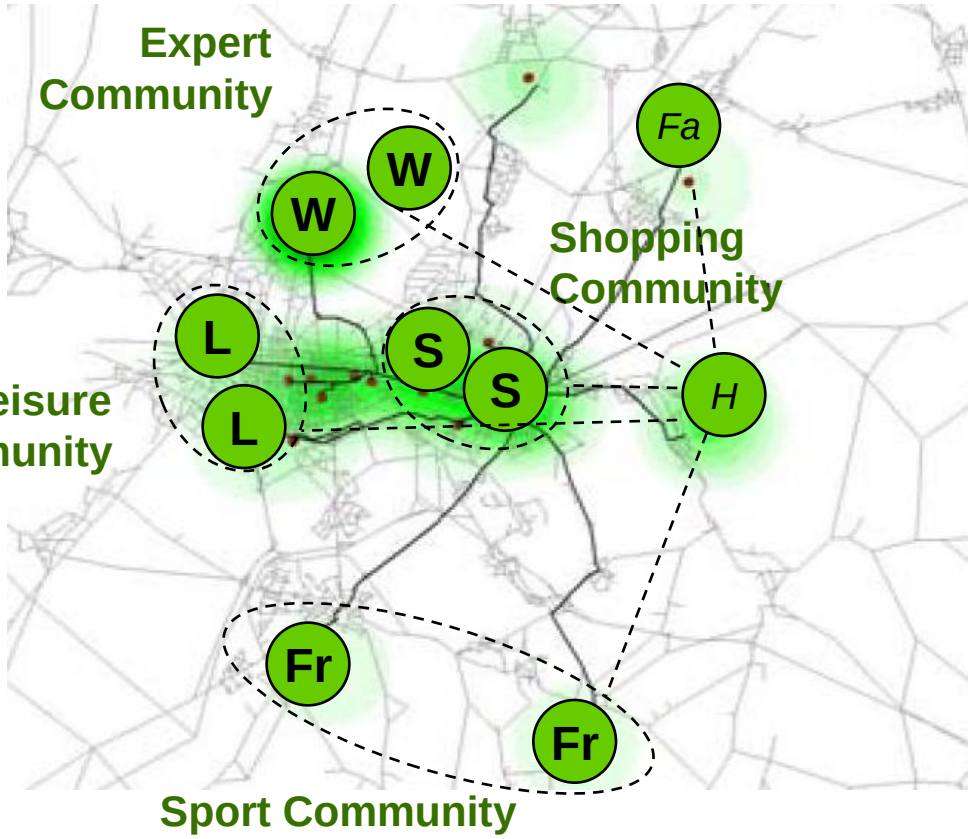
ices:

ts

— sport news
— leisure events

Social Behavior Localities – Urban Communities

- People evolve **social relationships** over time
- Synergies result from community bridging



Interest groups:

- Expert community
- Sport Community
- Theater Community
- Shopping Community

Goal:

— Spreading of information quickly within groups

— Spreading of information across the global community

Achieving Community Integration (Global Knowledge)

Expert Groups:

Community Leader/Bridge Ordinary

- Connectivity based Caching Policy:

$$\hat{R}(c,v) = \alpha \times C_B(v) + \beta \times r, \quad \alpha, \beta \geq 0.$$

$$C_B(v) = \sum_{s \neq v \neq t \in V, s \neq t} \frac{\sigma_{st}(v)}{\sigma_{st}}$$

Spreading of information accross groups

Community Cache Policies

Community Peer

Navigation Services/
Contextual caching:

$$R(c) = -\alpha \times t - \beta \times d, \quad \alpha, \beta \geq 0.$$

Reminder Services

Ordinary Members

Bridge/ Leaders

$$Max(C_B(v)) \cup Max(M(v))$$

$$M(v) = Length(MST(\forall t \in v))$$

Mobility-path based caching:
(Local relevant Contents)

$$d = \min_{T \in P}(dist(O(c), C(T))$$

Connectivity based caching:
(Global relevant Contents)

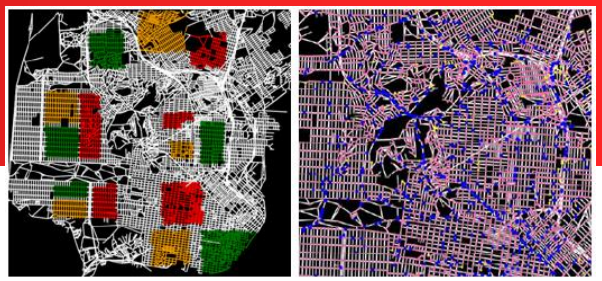
$$\hat{R}(c, v) = \alpha \times C_B(v) + \beta \times r, \quad \alpha, \beta \geq 0.$$

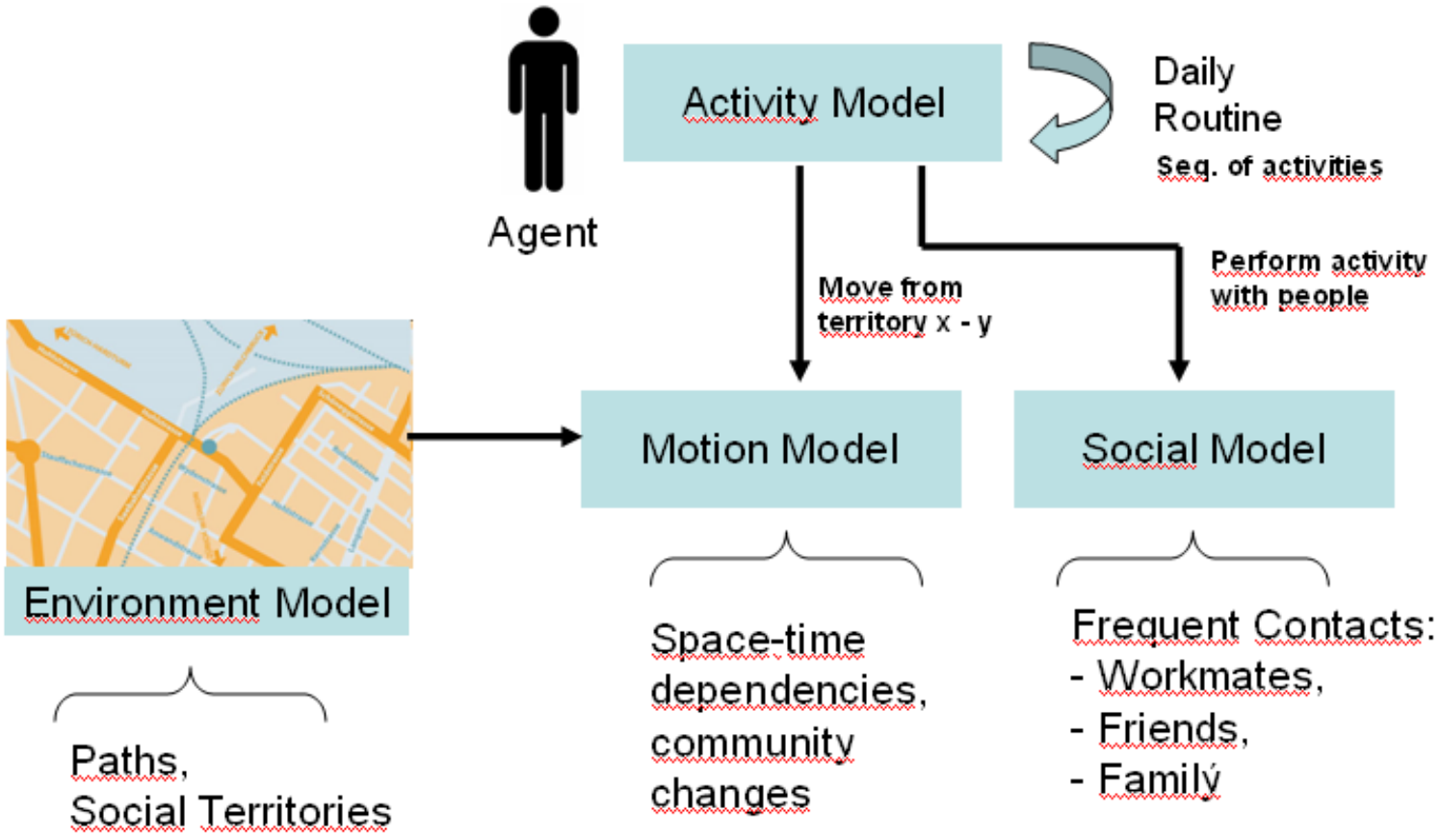
$$C_B(v) = \sum_{s \neq v \neq t \in V, s \neq t} \frac{\sigma_{st}(v)}{\sigma_{st}}$$

Simulation and Evaluation

- Simulator Model
- Measurements
- Results

Simulator – Agent Model





Measurements

- **Precision/Recall Analysis**

$$P_i = \frac{C_{r,i}}{C_{c,i}}. \qquad R_i = \frac{C_{r,i}}{A_r}.$$

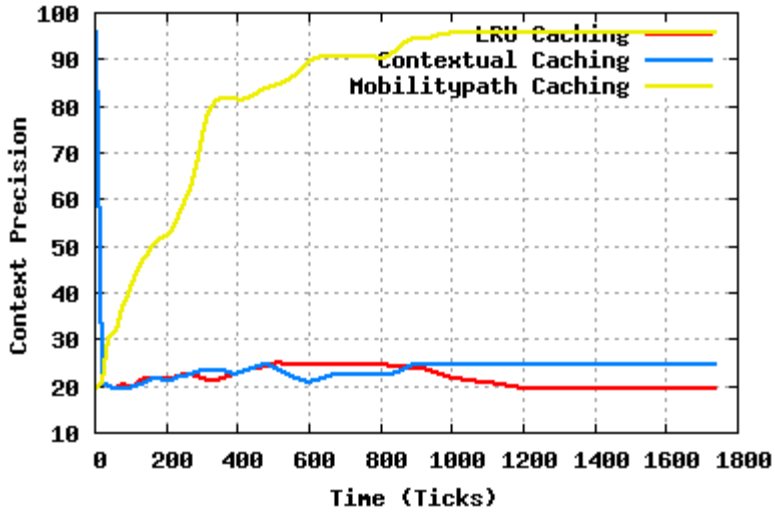
- **Cache Locality Analysis**

$$T_i = \frac{\sum_{k=1}^{N_i} T_{i,k}}{N_i}. \qquad \bar{T} = \frac{\sum_{i=1}^{N} T_i}{N}.$$

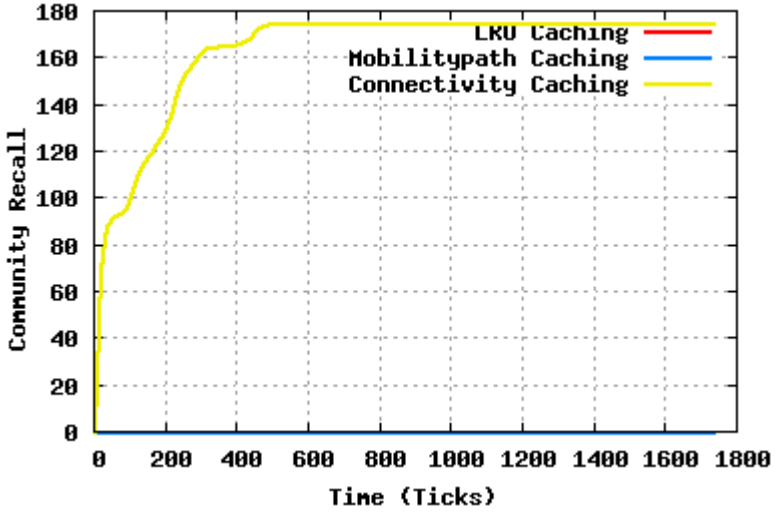
Precision and Recall Analysis

- Local Contents:
  - LRU/contextual policies consider only current user situations
  - Mobility-path based caching ~ multi-community memberships
- Global Contents:
  - Connectivity based caching >> Mobility-path based caching
  - Considers network connectivity & content ratings

Local valid Contents:

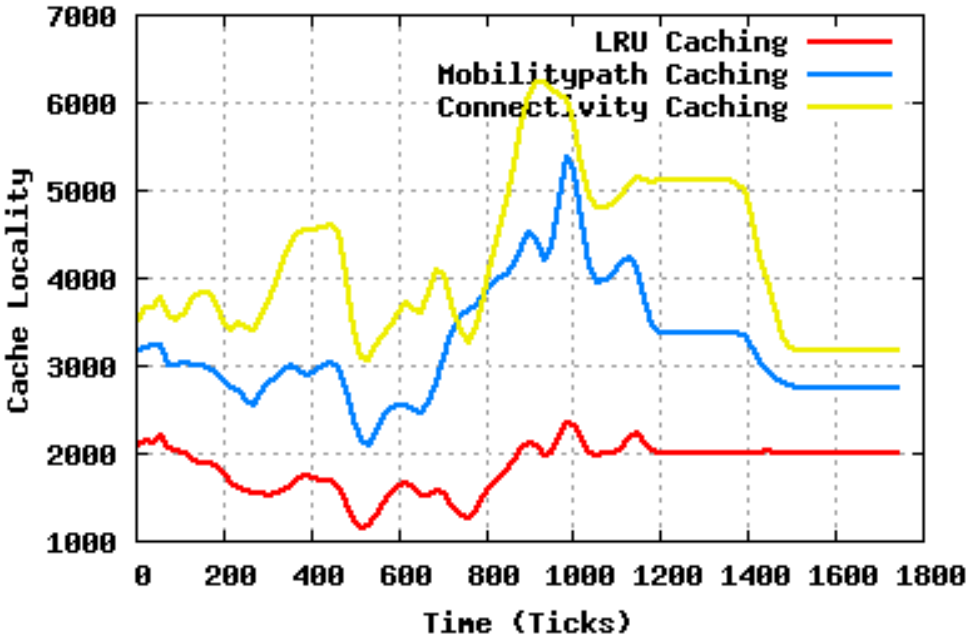


Global valid Contents:



Cache Locality Analysis

- Connectivity > mobility > LRU caching
- Human preferences evolve over time!



Conclusions

Behavior based caching approach:

- ✓ Supports *urban ad-hoc communities*
- ✓ Supports *multi-role* knowledge building
- ✓ Supports *local* and *global* content acquisitions
- ✓ Minimizes storage requirements through *expertise delegation*

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Questions

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