SERVICE DISCOVERY IN MOBILE SOCIAL NETWORKS

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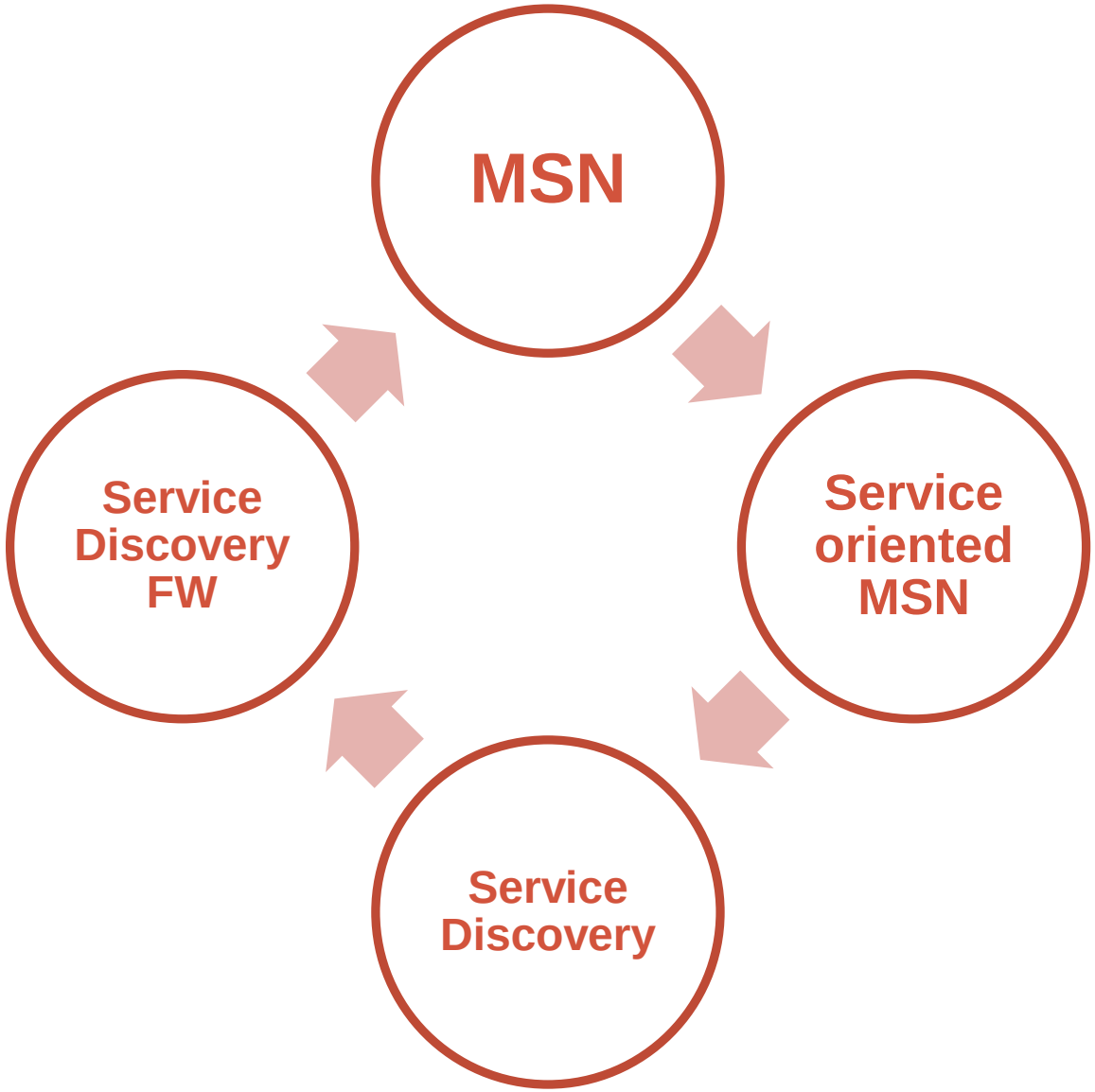
RHS 2015

Layout


MSN
Service oriented MSN
Service Discovery
Service Discovery FW

Objectives of this presention

Layout

1. **Mobile Social Networks**
2. Service-oriented MSN
3. Service Discovery algorithms
   A. SIDEMAN
   B. CORDIAL
4. Service Discovery Frameworks

Mobile Social Networks

Social relationships are deeply studied by researchers

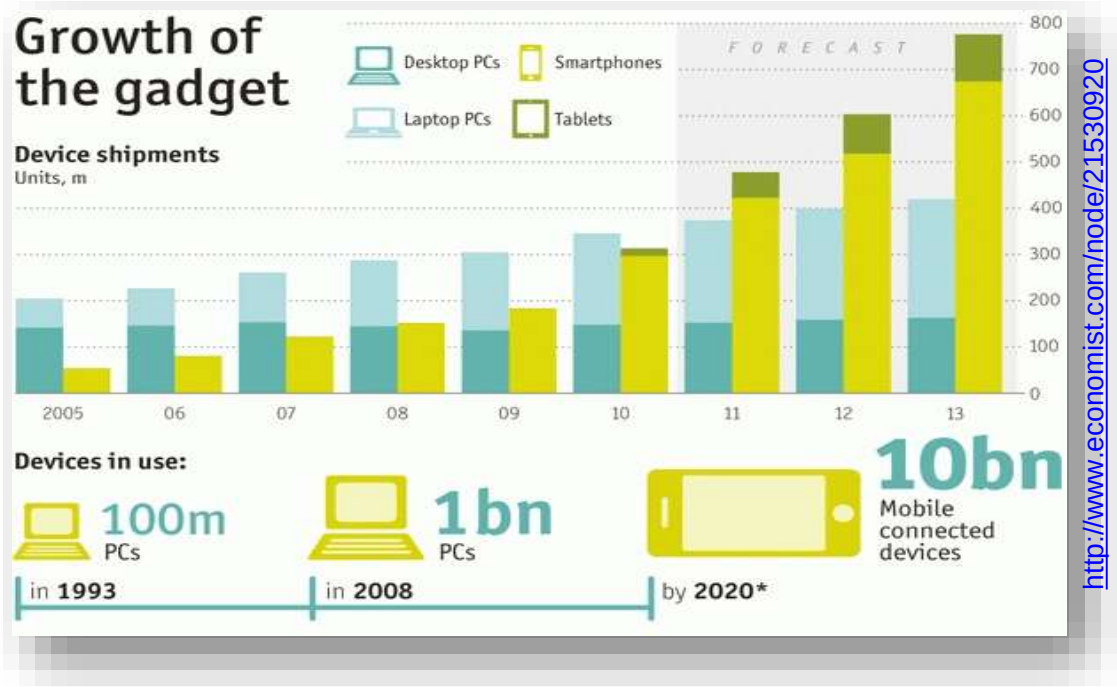
- understand how people interact with each others
- study the nature of human movements
- predict new relationships and human movements

def:

“Social networks are groups of people with some patterns of contacts or interactions between them, forming meaningful social relationships“ [1]

Mobile Social Networks
Technology enablers

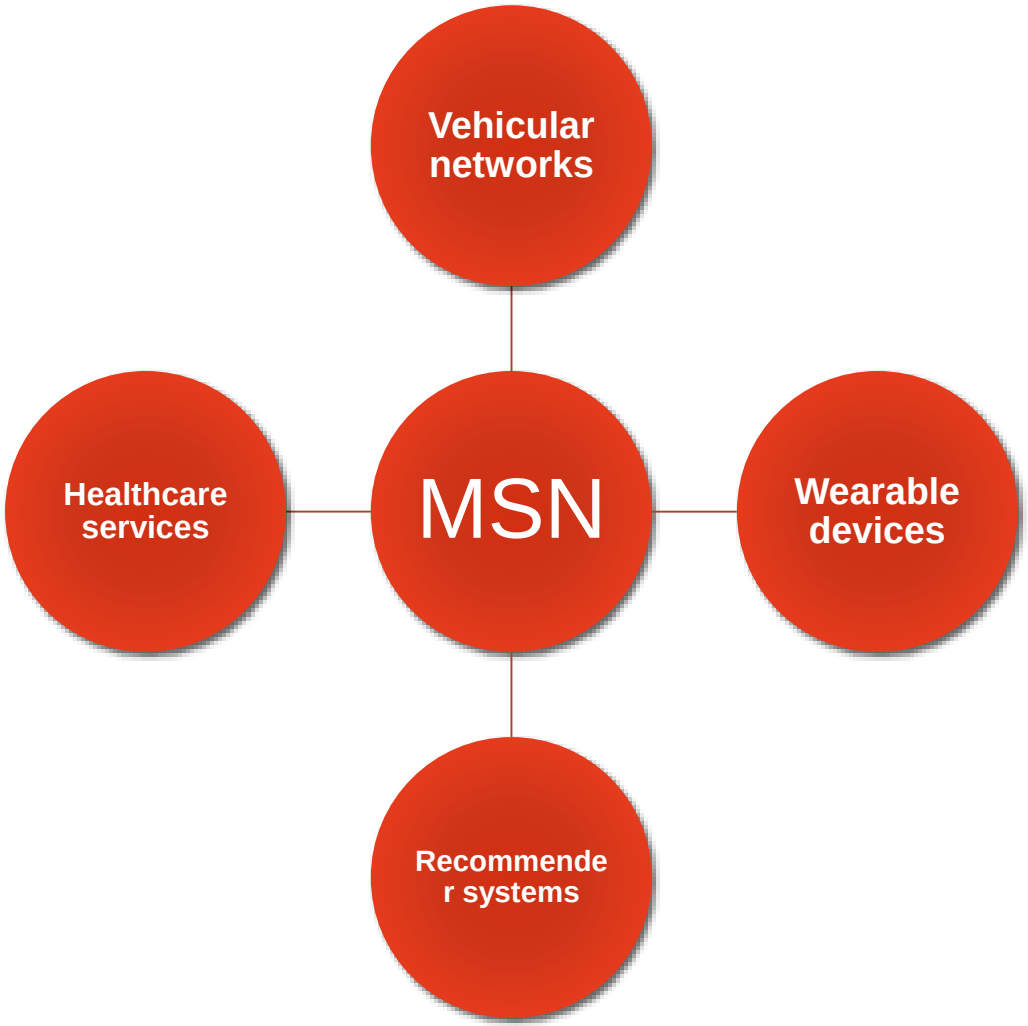
1. People carry pocket devices
2. Mobile devices are pervasive
   - Tablets, Smart Phones, Smart Watch

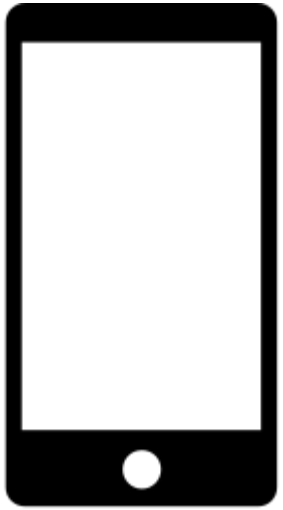


http://www.economist.com/node/21530920

→ **Mobile devices well approximate the position of their owners**

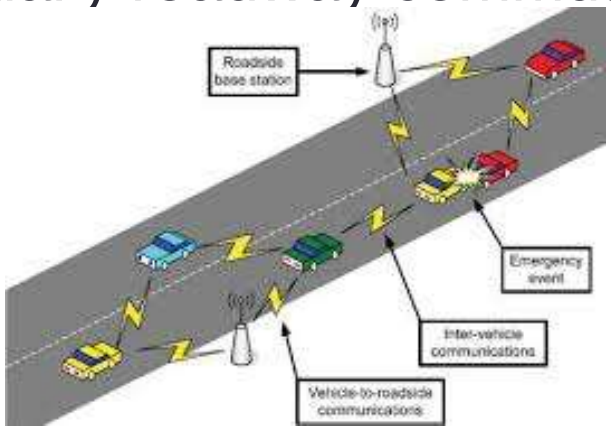
Mobile Social Networks Applications





Mobile Social Networks Applications

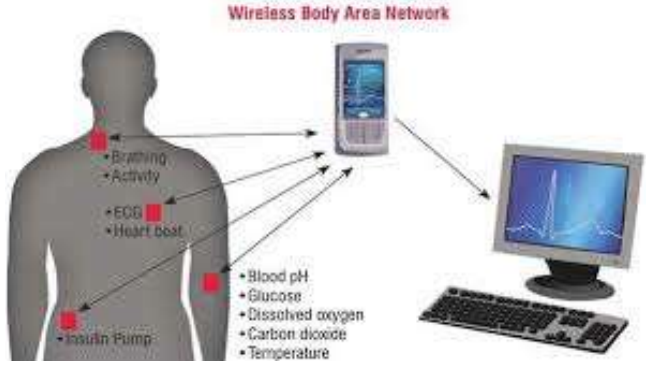
- **Vehicular Networks**: social interactions in daily roadway commute.
  - RoadSpeak
  - Waze



- **Healthcare services**: applications designed to assist patients with special needs
  - PatientSupport [2]

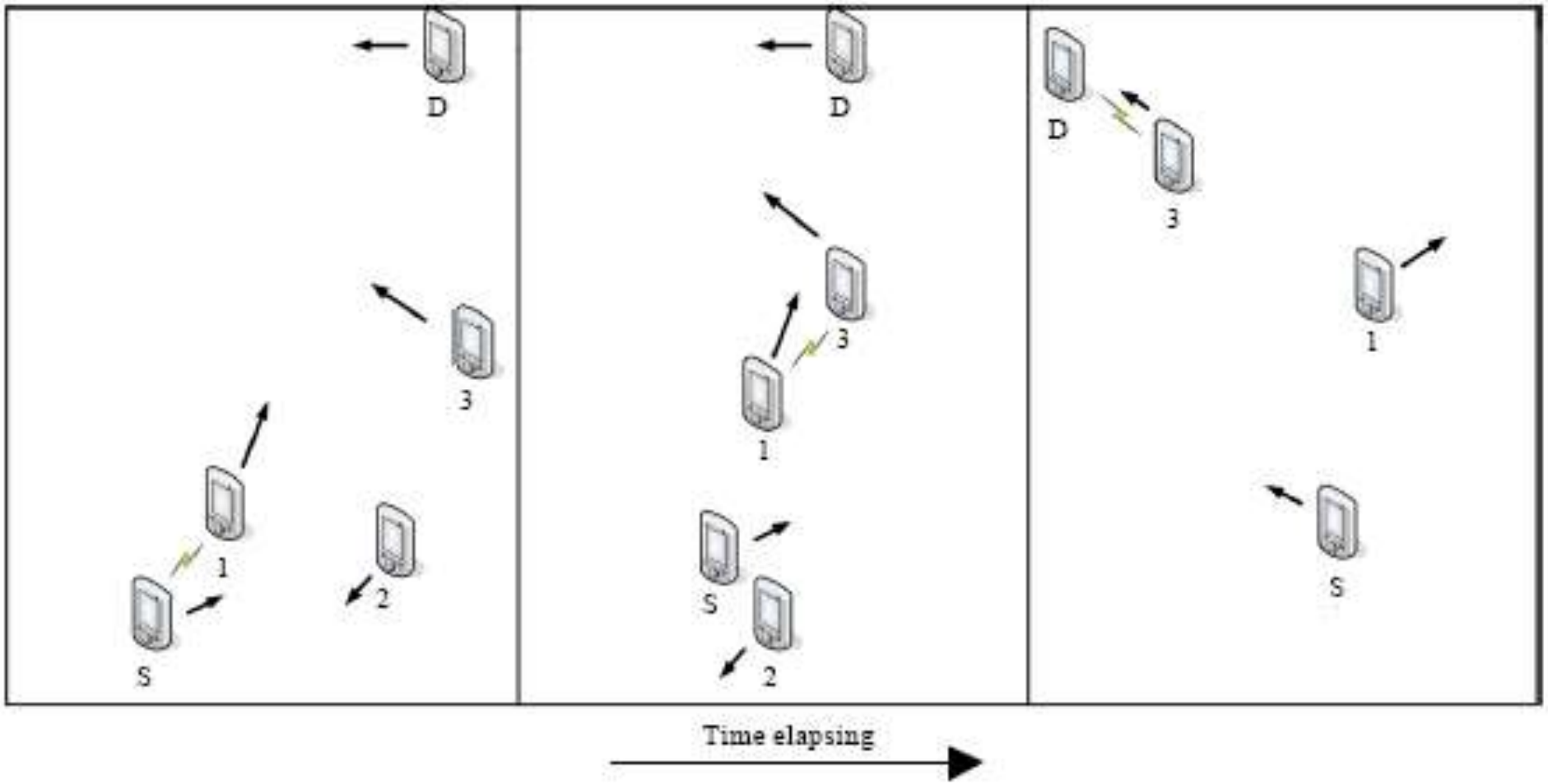
Mobile Social Networks Applications

- **Wearable MSNs**: wearable devices collect information related to social interaction
  - iBand or iMotes



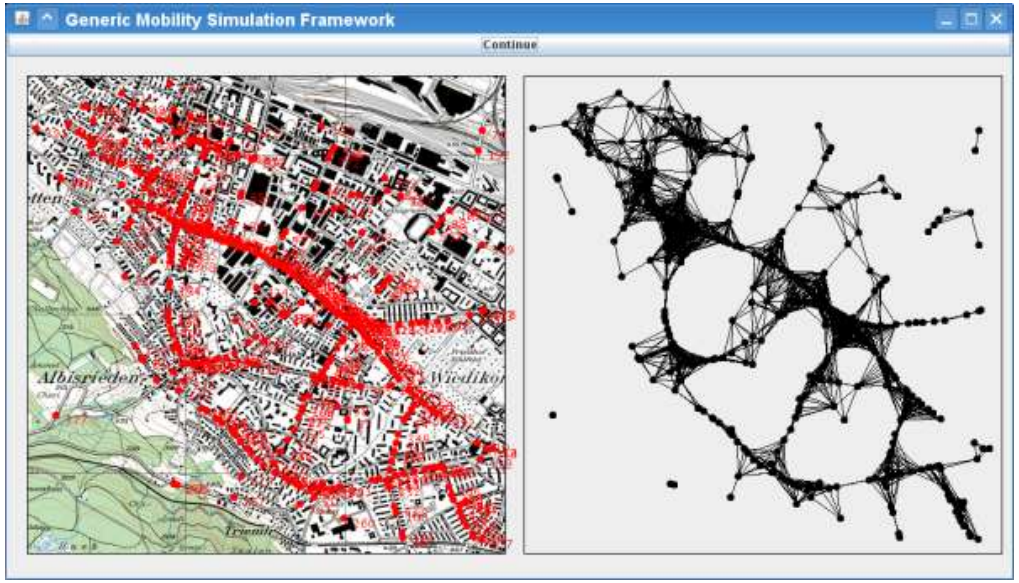
- **Recommender systems**: applications designed to share contents based on: interests, contacts, social behavior
  - ContentPlace, FireChat, Quercia, SIDEMAN

Mobile Social Networks

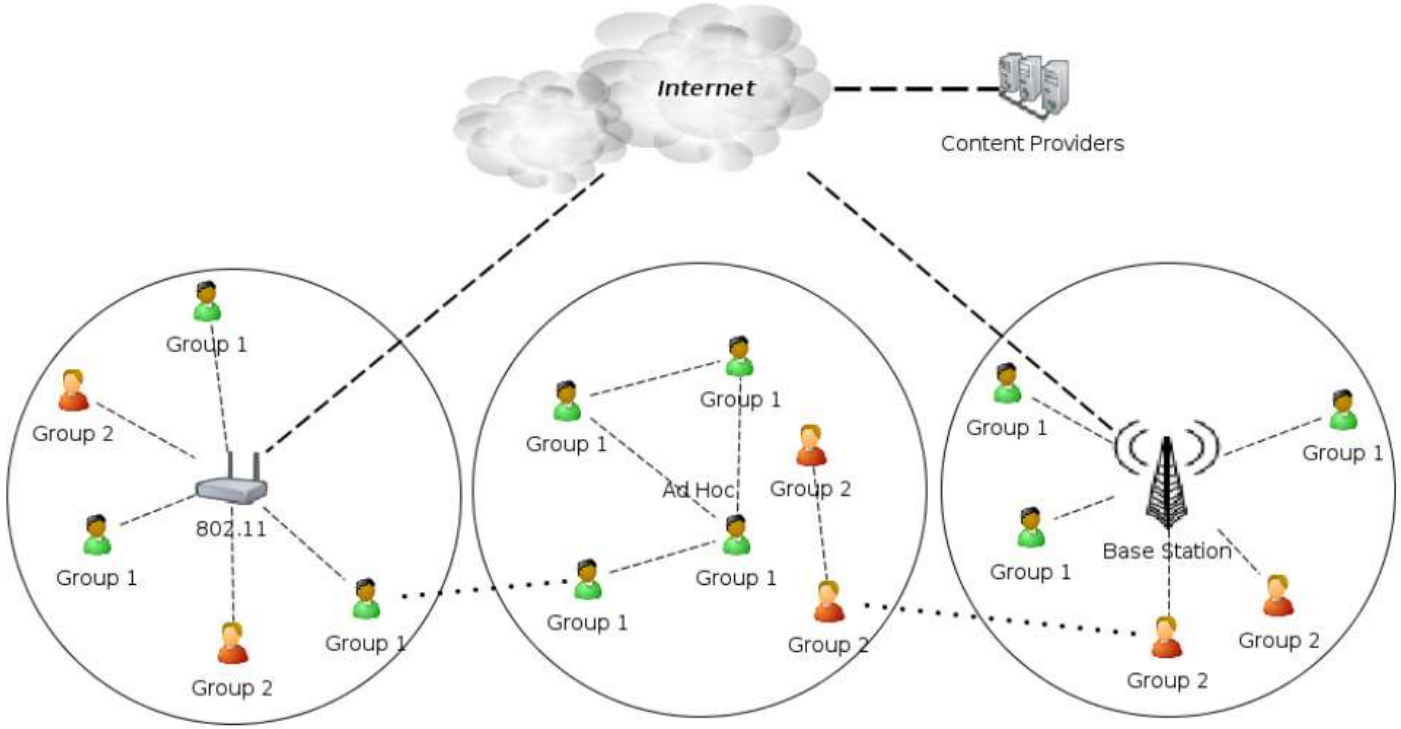


Mobile Social Networks

- Devices are equipped with heterogeneous interfaces
  - Short range: WiFi, Bluetooth
  - Long range: 3,4,5G
- The movement of devices is strictly correlated with the movement of people carrying them



Mobile Social Networks Architectures



centralized distributed hybrid

Mobile Social Networks Communities

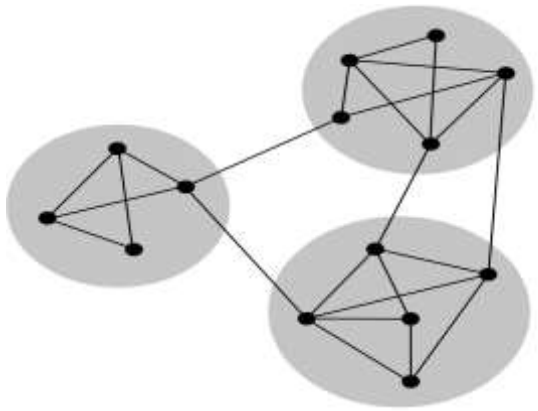
People tend to join to groups

- have social relationships with members of the same group
- have few relationships with other groups

Watts, D. J.; Strogatz, S. H. (1998). "Collective dynamics of 'small-world' networks". *Nature* **393** (6684): 440–442. doi:10.1038/30918. PMID 9623998. edit

Mobile Social Networks Communities

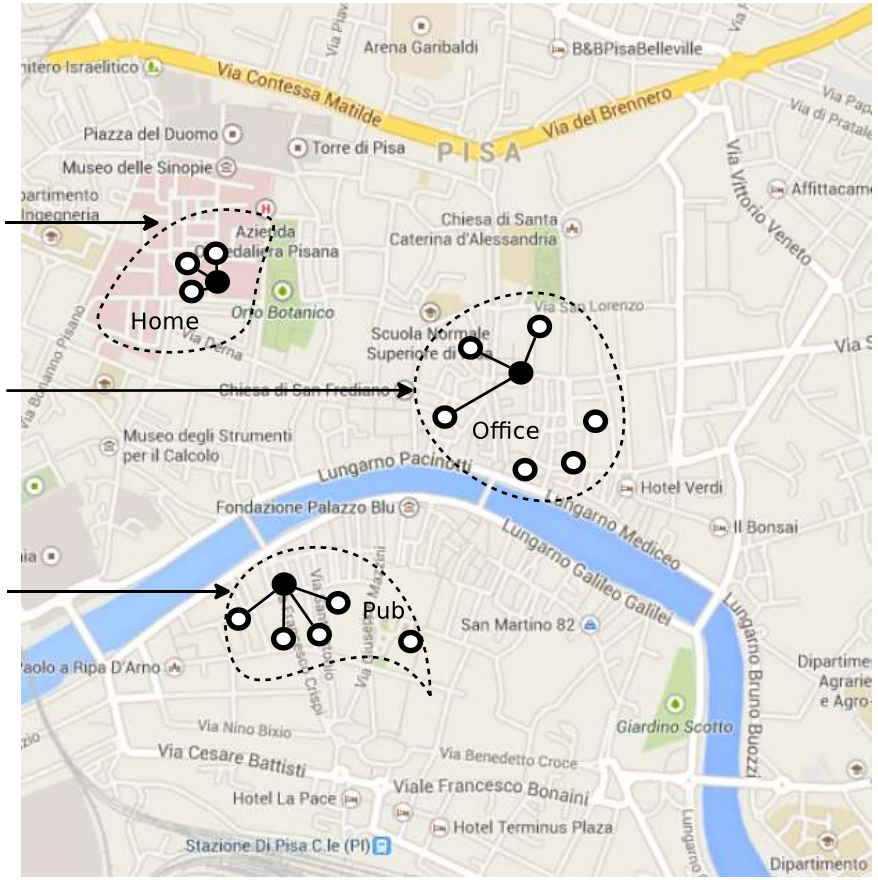
- A community is a clustering of entities that are ”closely” linked to each other
- Centralized and distributed detection algorithms (SIMPLE, k-Clique, Modularity etc…)



Home
8:00 PM - 08:00 AM

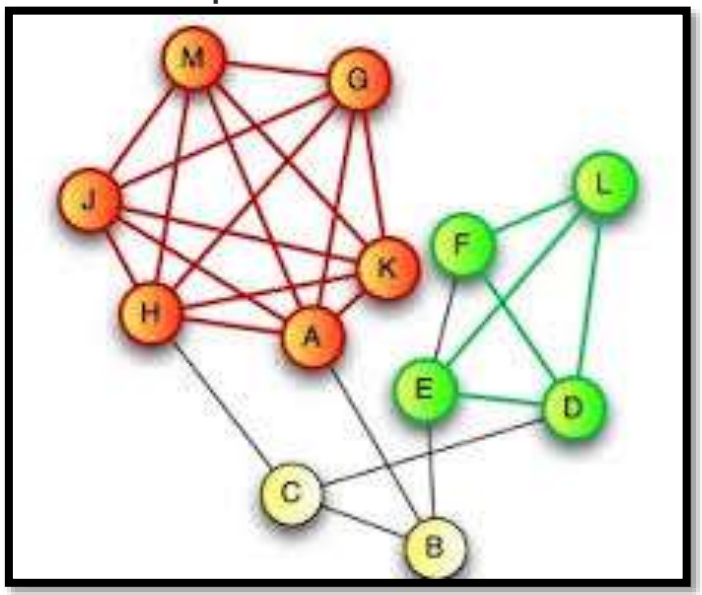
Office
8:00 AM - 5:00 PM

Pub
6:00 PM - 8:00 PM

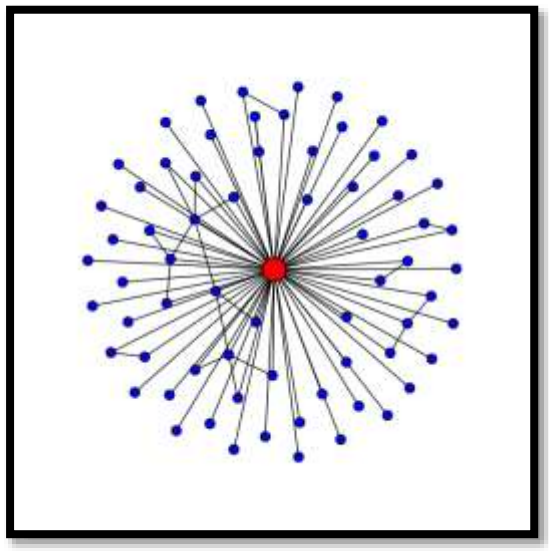


Mobile Social Networks Communities

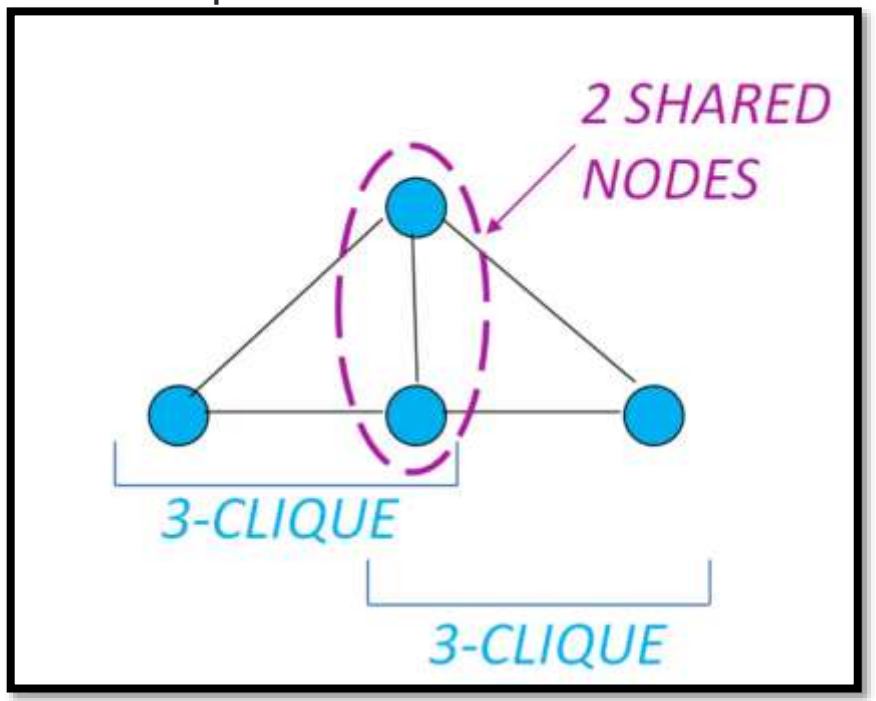
clique



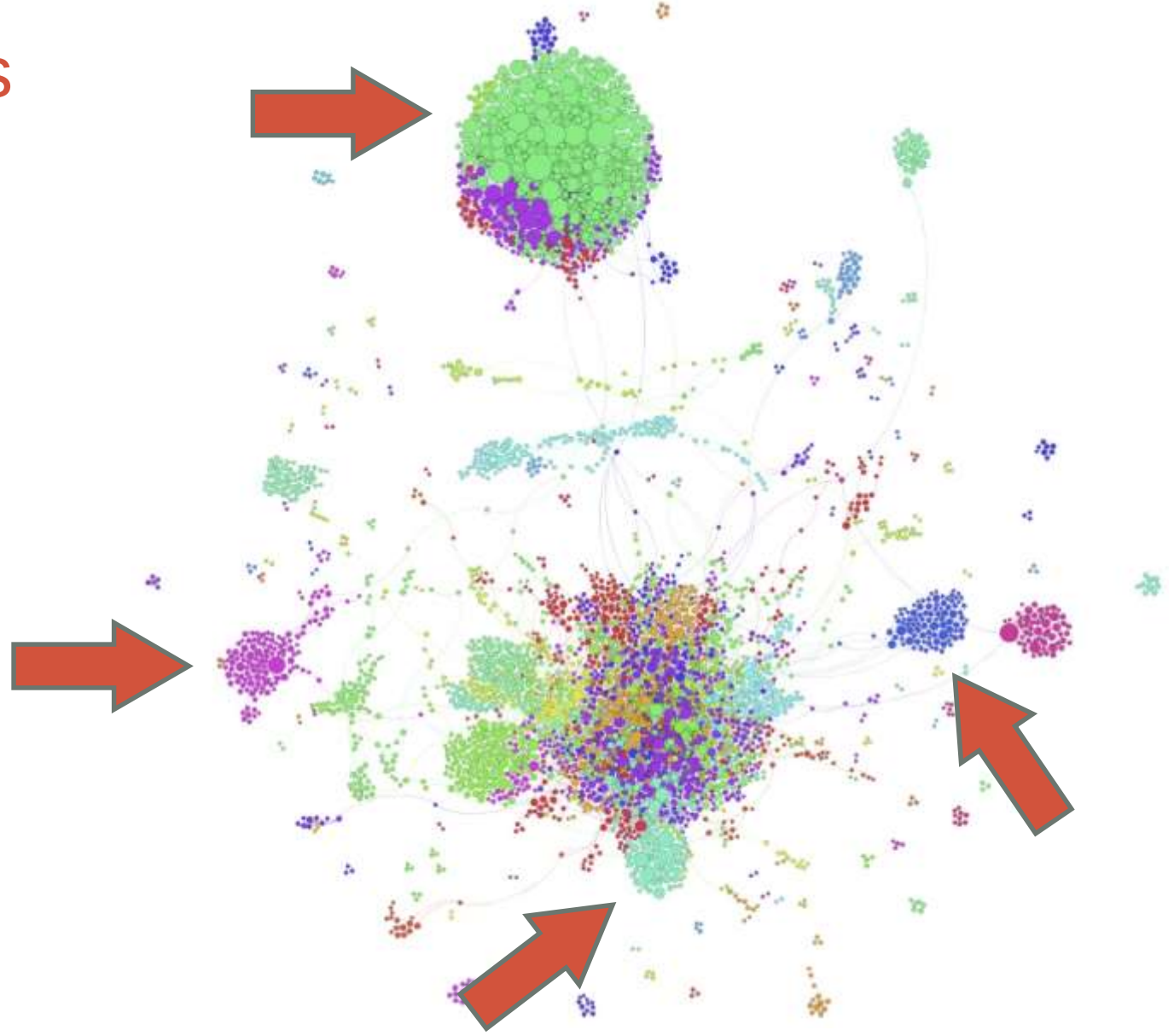
Ego network



K-clique



Mobile Social Networks Communities

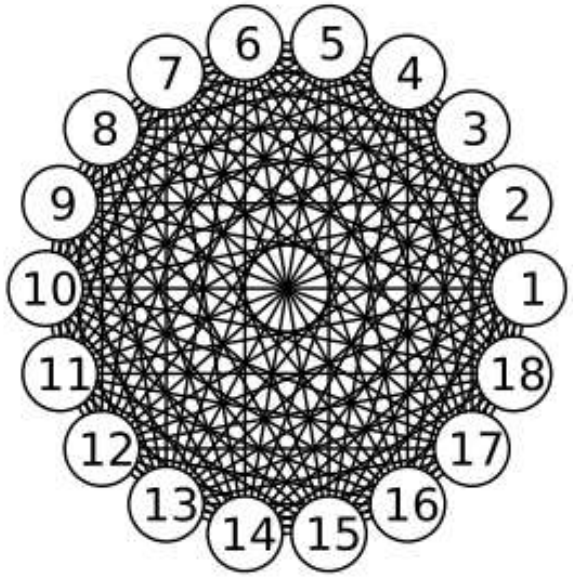


Mobile Social Networks
Network Model

$$G = (V, A)$$

$$V = \{v_1 \cdots v_n\}$$

$$a_{i,j} = \begin{cases} 1 & \text{if } (i,j) \\ 0 & \text{otherwise} \end{cases}$$



Drawbacks of this model

- Contacts among nodes are flattered with the edge: $a_{i,j}$
  - Frequency ?
  - Duration ?
  - Periodicity ?
- The topology changes are not described with this model

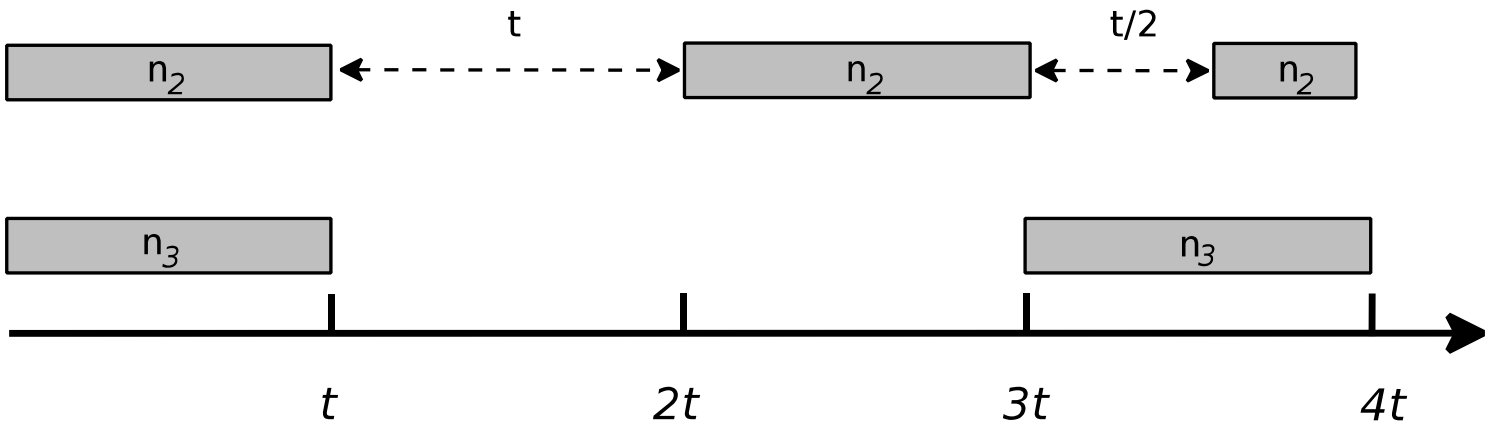
Mobile Social Networks
Network Model

Contacts between nodes are characterize by:

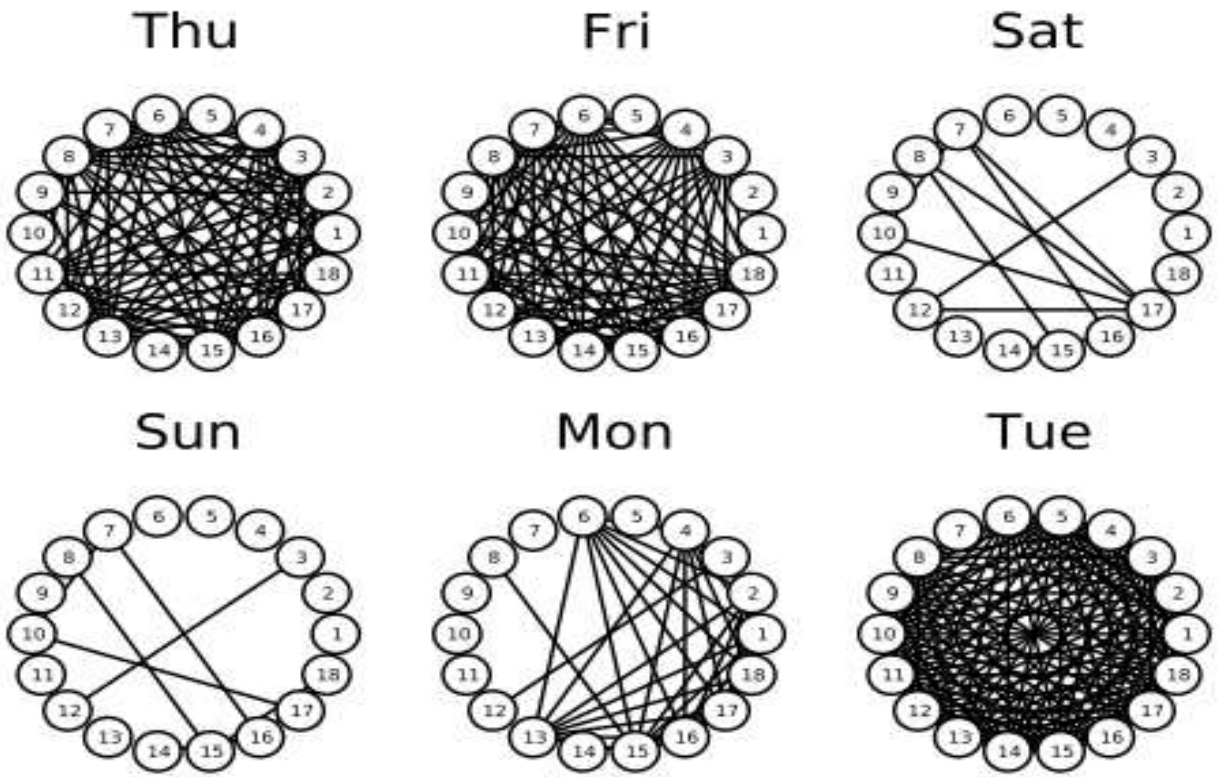
- Temporal features
  - Cumulative contact time
  - Average contact time
  - Inter-contact time

$$a_{i,j} = \begin{cases} 1 & \text{if } (i,j) \\ 0 & \text{otherwise} \end{cases}$$

$$w_{i,j} = \begin{cases} t_{cum}(i,j) & \text{if } (i,j) \\ 0 & \text{otherwise} \end{cases}$$



Mobile Social Networks Network Model



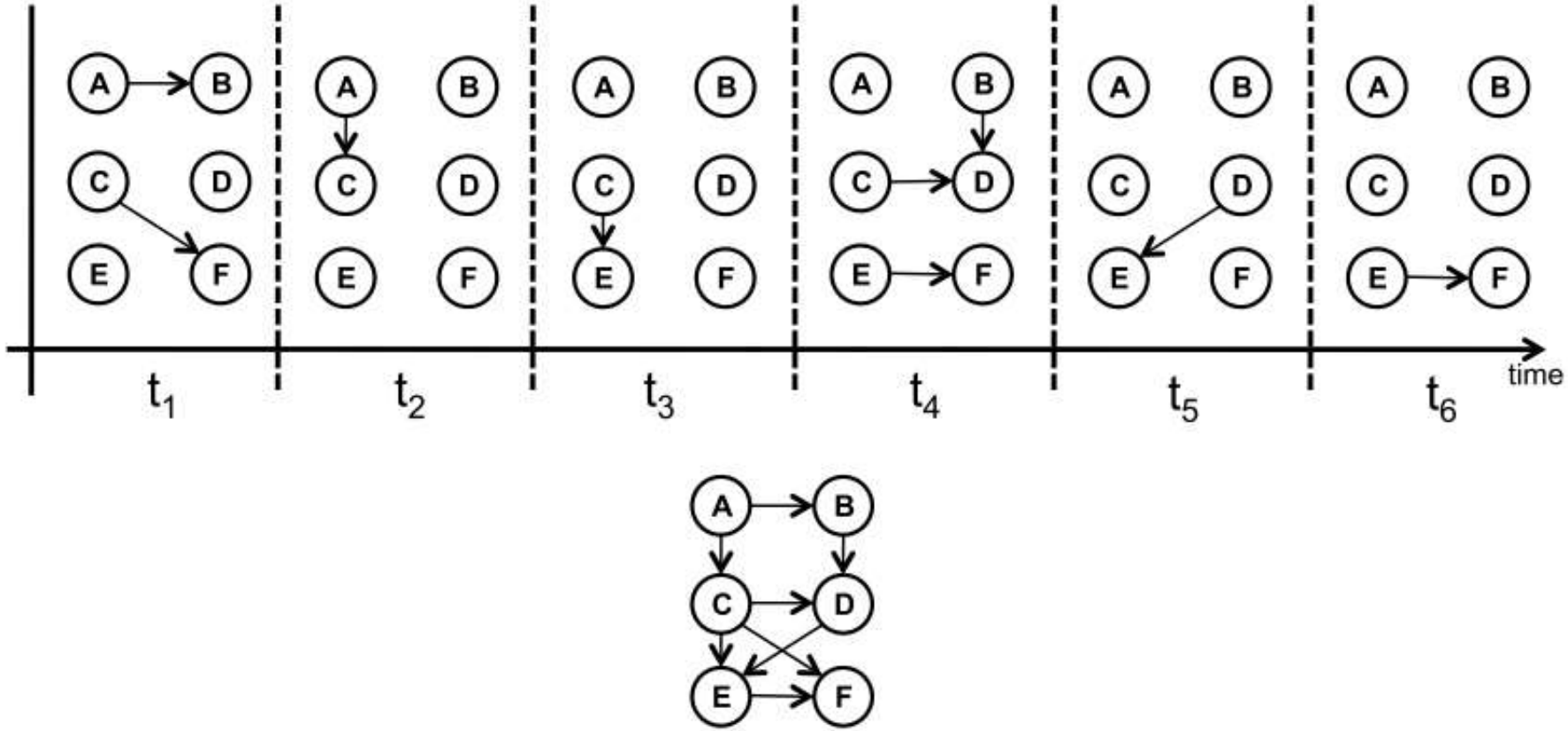
- Contacts among nodes evolve over the time
- Graph metrics change according to the snapshot of the graph
  - Betweeness centrality
  - Closeness centrality
  - Spectral centrality

Mobile Social Networks
Network Model

$$G^w(t_{min}, t_{max}) = (G_0 \cdots G_{T-1})$$

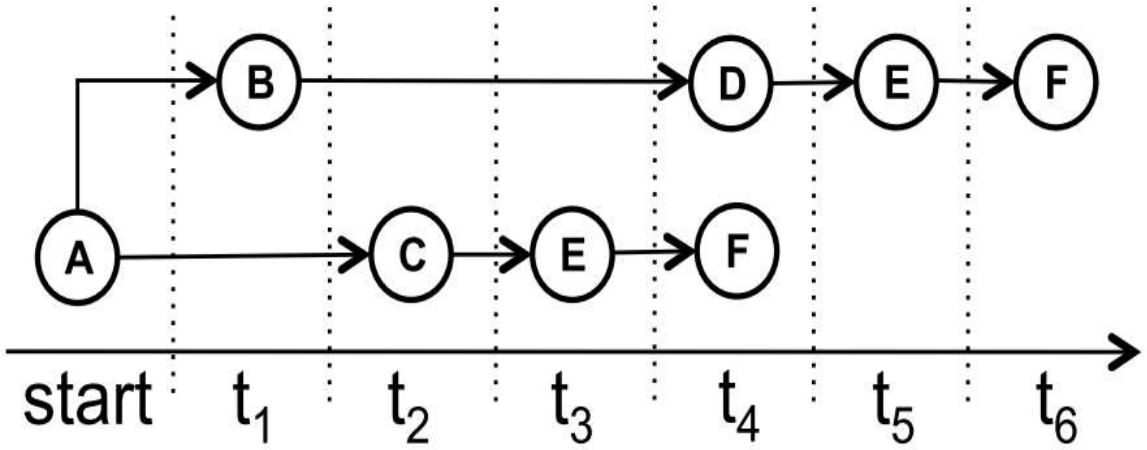
$$[t_{min}, t_{max}]$$

$$T = ((t_{max} - t_{min})/w$$



Mobile Social Networks
Network Model

- Temporal path: sequence of k hops via distinct nodes



$$p_{i,j}^{h} = (n_1^{W_0} \cdots n_k^{W_k})$$
$$i = a, j = F$$
$$W_k > W_{k-1}, 0 \leq W_k < T$$

- Temporal neighborhood

$$N_t^i = \{n_j \in V \mid a_{i,j} \in E_t\}$$

Mobile Social Networks
Mobility and Sociality

MSN can be studied by analysing mobility traces

Mobility Traces

- Real-world
- Synthetic

Infocom6

infocom2006

Cambridge

Cambridge

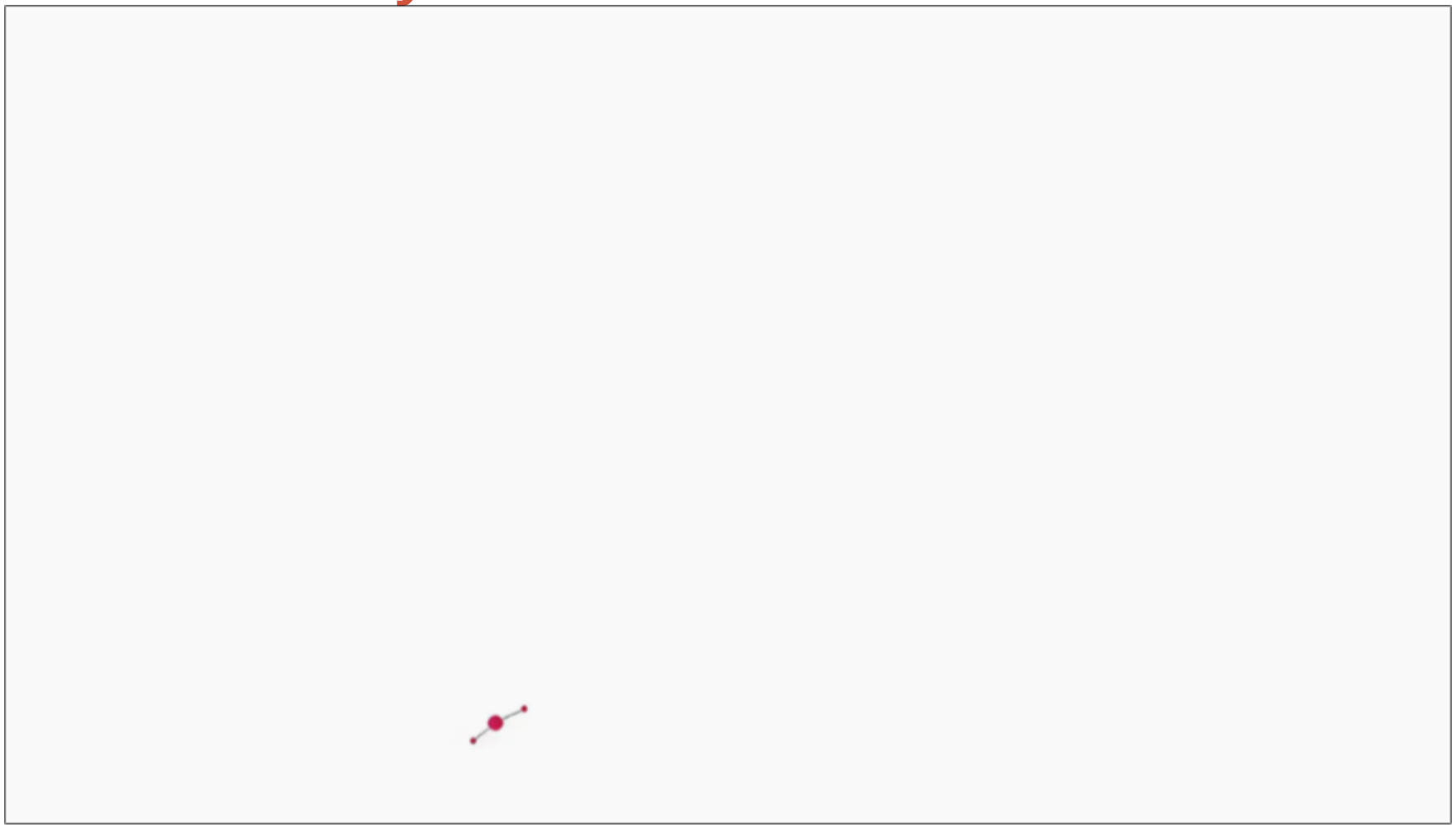
Infocom5

infocom2005

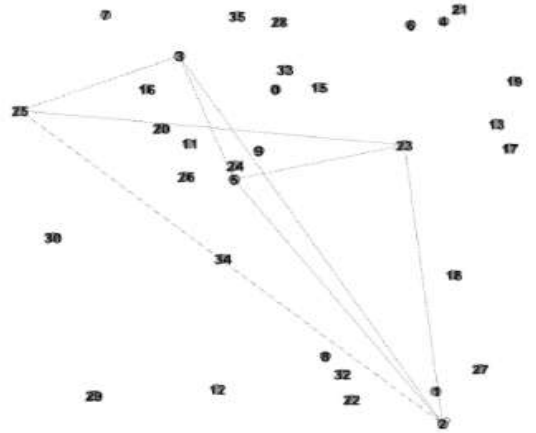
Reality MIT

MIT Reality

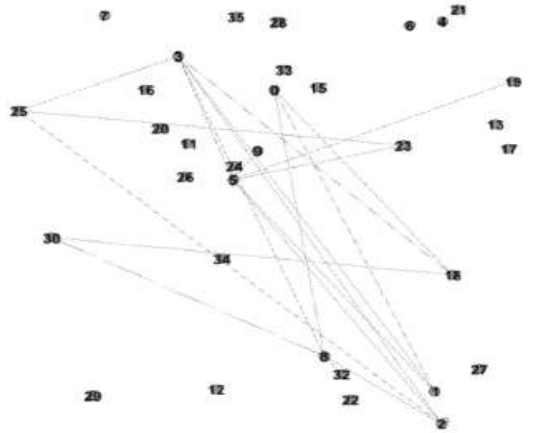
Mobile Social Networks
Mobility and Sociality



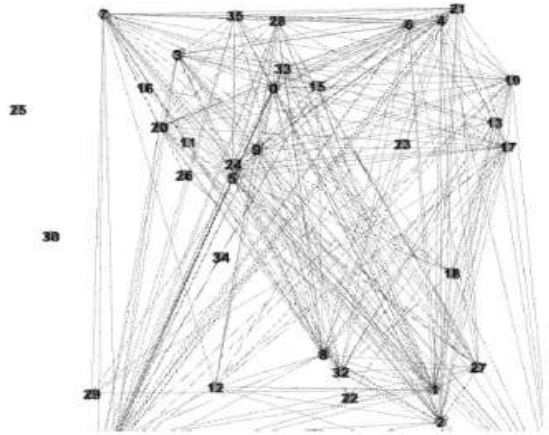
Mobile Social Networks
Mobility and Sociality



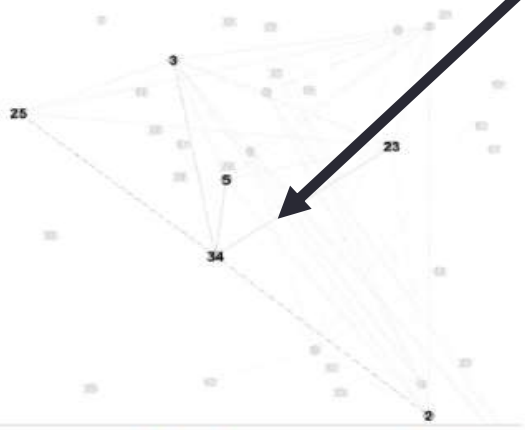
(a) Snapshot 1.



(b) Snapshot 2.



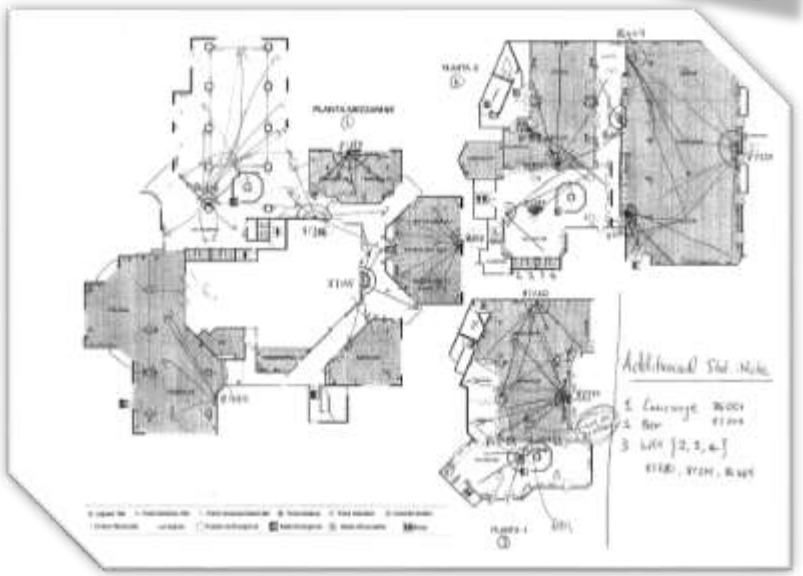
(c) Snapshot 3.



(d) Snapshot 4 at time 51679.00.

```
51679.00 CONN 34 23 up
51679.00 CONN 34 23 down
52218.00 CONN 14 9 up
52218.00 CONN 14 9 down
53517.00 CONN 28 2 up
53517.00 CONN 28 2 down
```

Mobile Social Networks
Mobility and Sociality

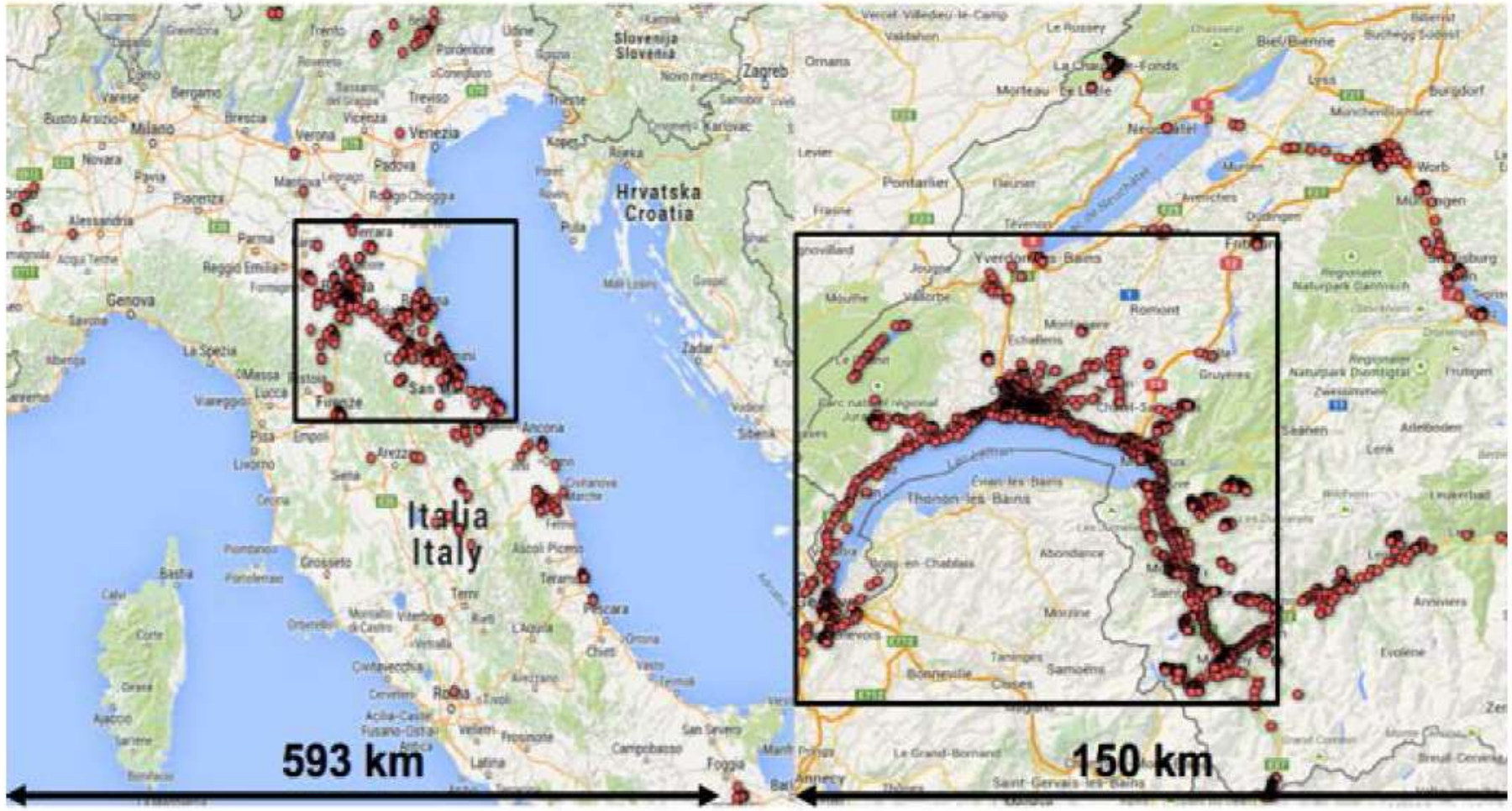


InfoCom 06 traces

- Indoor location
- 4 days

Mobile Social Networks
Mobility and Sociality

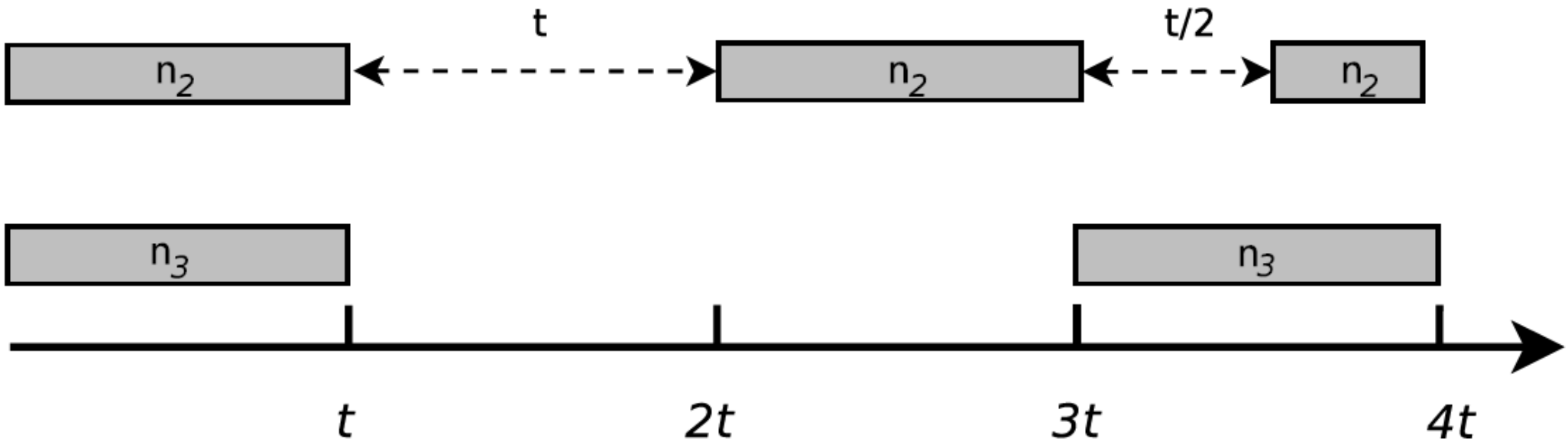
ParticipAct **MDC Nokia**



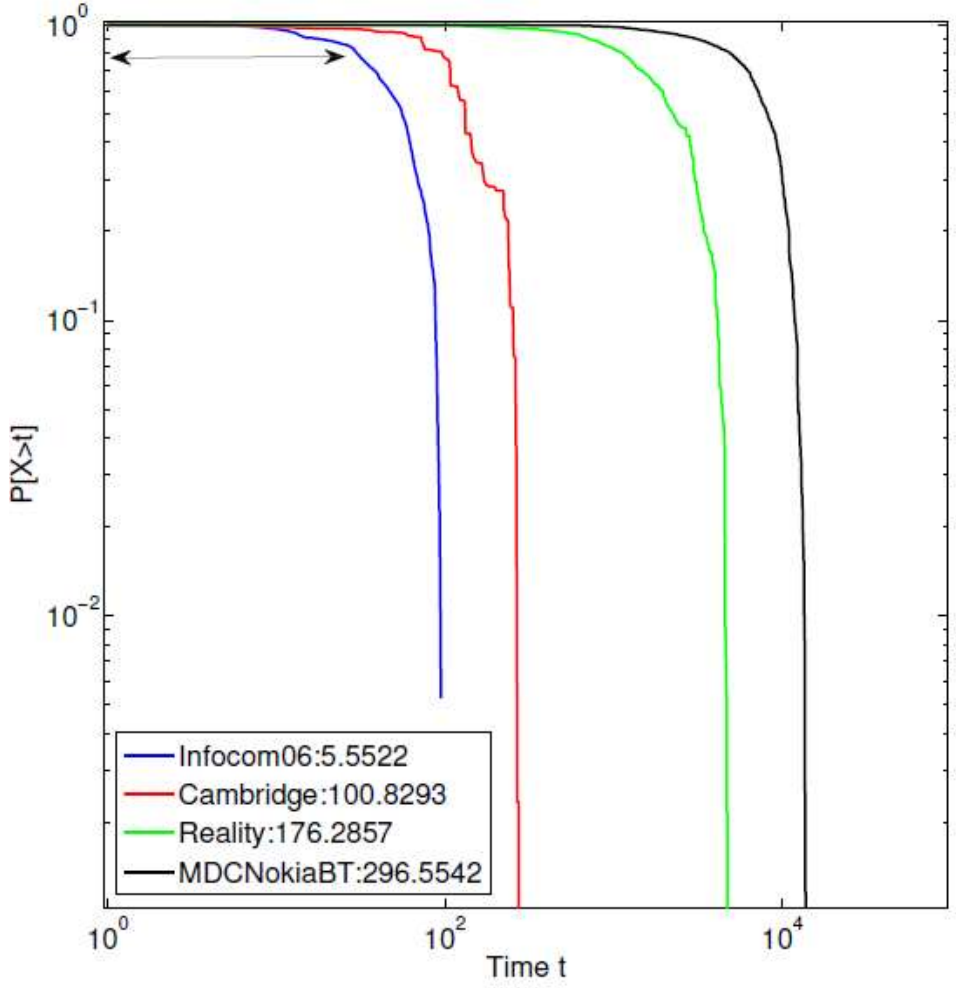
ParticipAct Traces

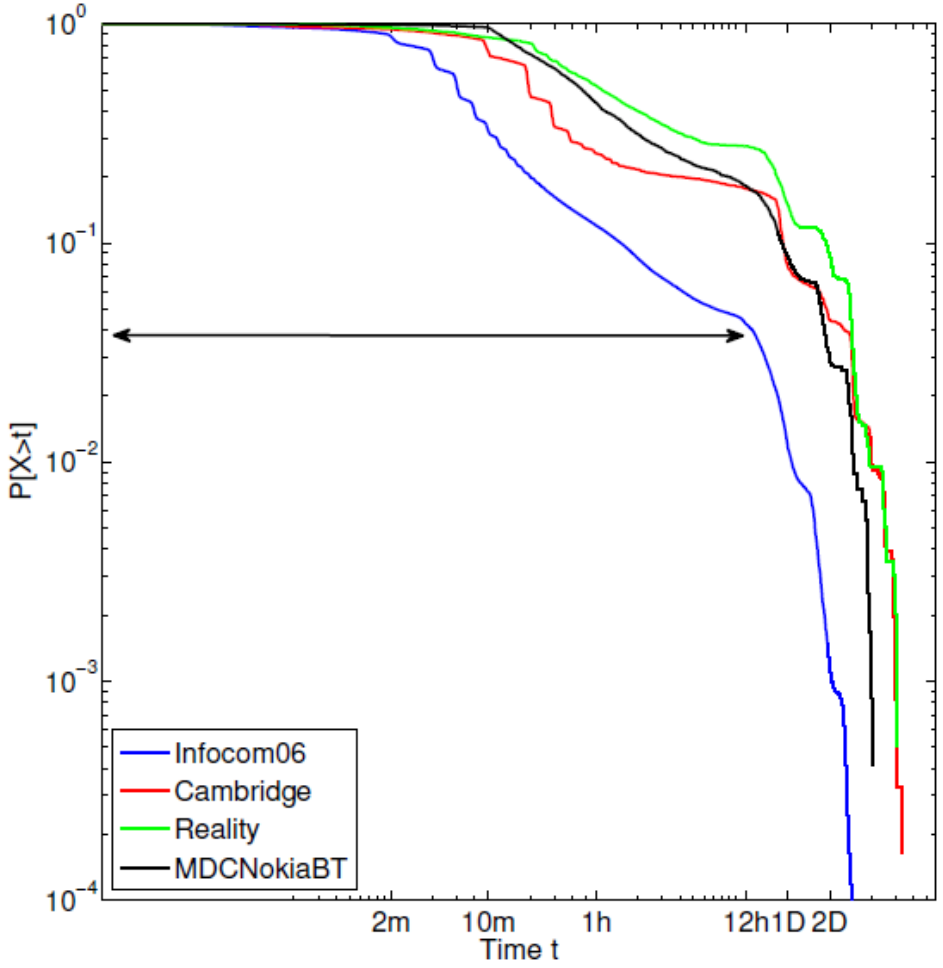
Mobile Social Networks
Mobility and Sociality

- Mobility and sociality in MSN can be measured with specific metrics:
  - Distribution of the inter-contact time
  - Distribution of the contact duration
  - Contact per hours
  - Analysis of the communites

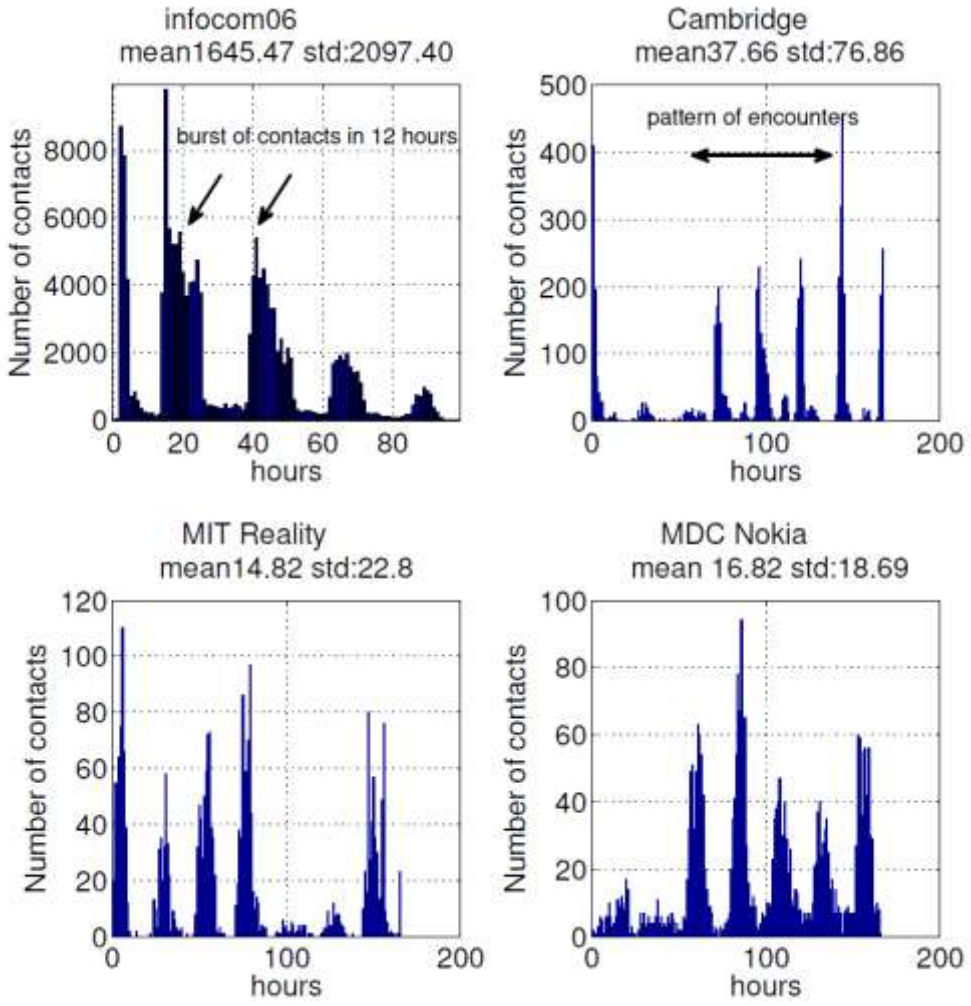


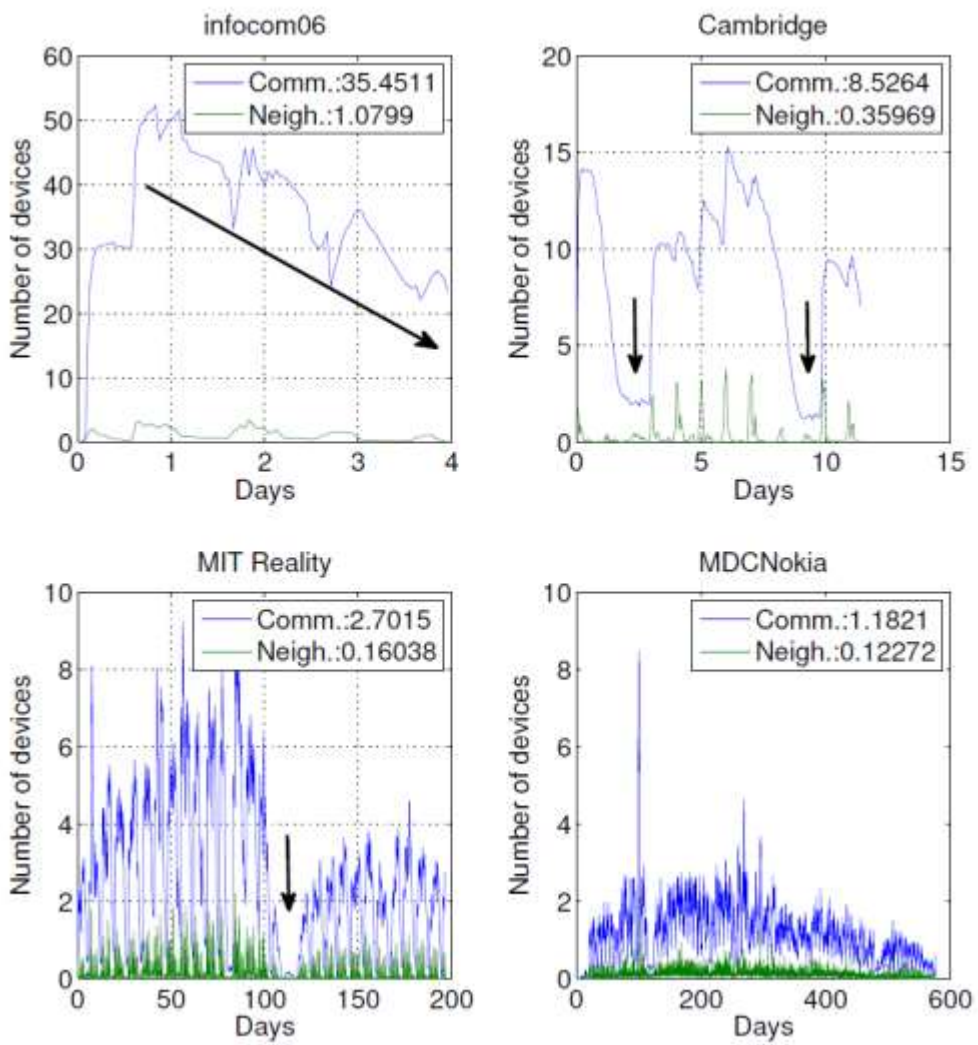
Mobile Social Networks
Mobility and Sociality





Mobile Social Networks
Mobility and Sociality





Mobile Social Networks
Mobility and Sociality

Summary of most important feartures of Human Mobility Traces

	Infocom06	HCMM	Cambridge	MIT Reality	MDC Nokia
Device type	iMote	device	iMote	SmartPhone	Smart Phone
Location	Conference	NA	Campus	Campus	City
Duration	3 days	3 days	11 days	246 days	9 months
Radio	Bluetooth	NA	Bluetooth	Bluetooth	Inferred
Number devices	78	78	36	97	185
Granularity(s)	120	120	600	300	600
Avg. community	25.4	38.68	8.5	2.7	1.18
Avg. neighbourhood	5.50	0.33	0.35	0.16	0.12
Number contacts per hour	1645.47	1754	37.66	14.82	16.82
Duration contacts (s)	5.52	0.34	100.82	176.28	296.55
% of total encounters	91.92	98.71	83.48	67.60	28.27
Routinary mobility	X	X	✓	✓	✓

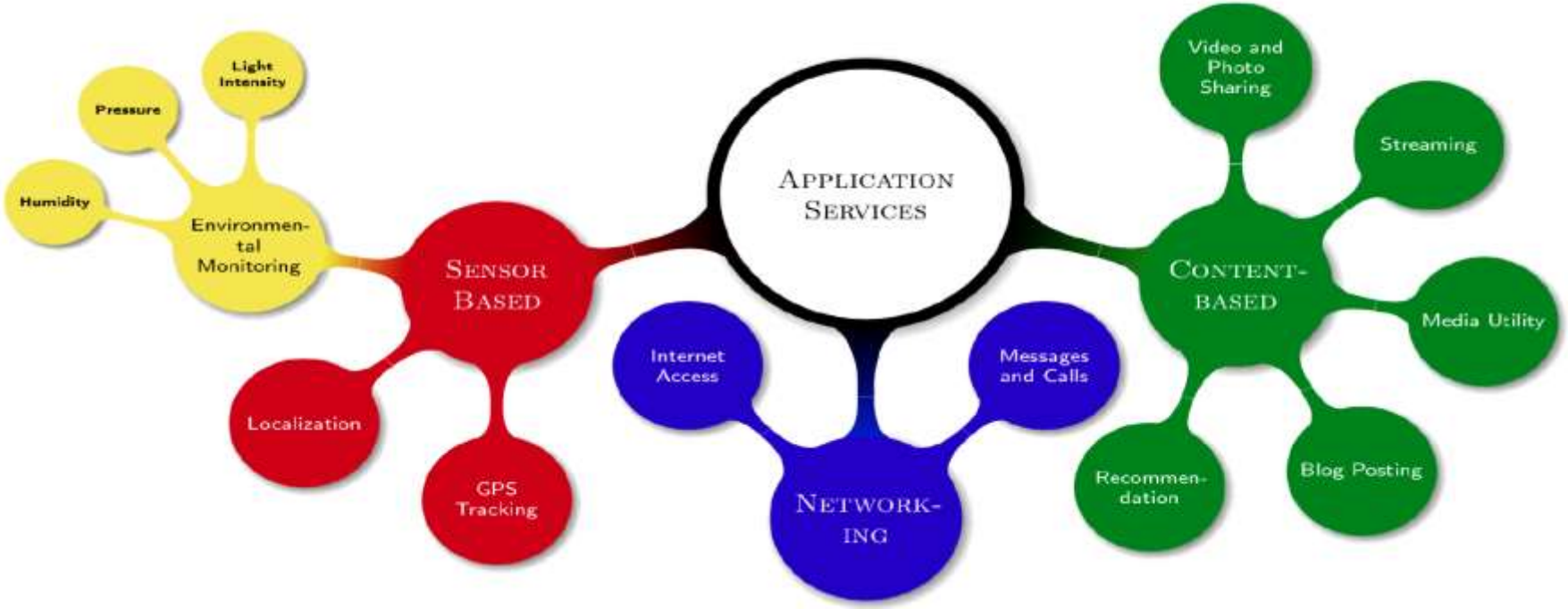
Layout

1. Mobile Social Networks
2. **Service-oriented MSN**
3. Service Discovery algorithms
   A. SIDEMAN
   B. CORDIAL
4. Service Discovery Frameworks

Service-oriented MSN

Devices in a MSN offer different kinds of resources:

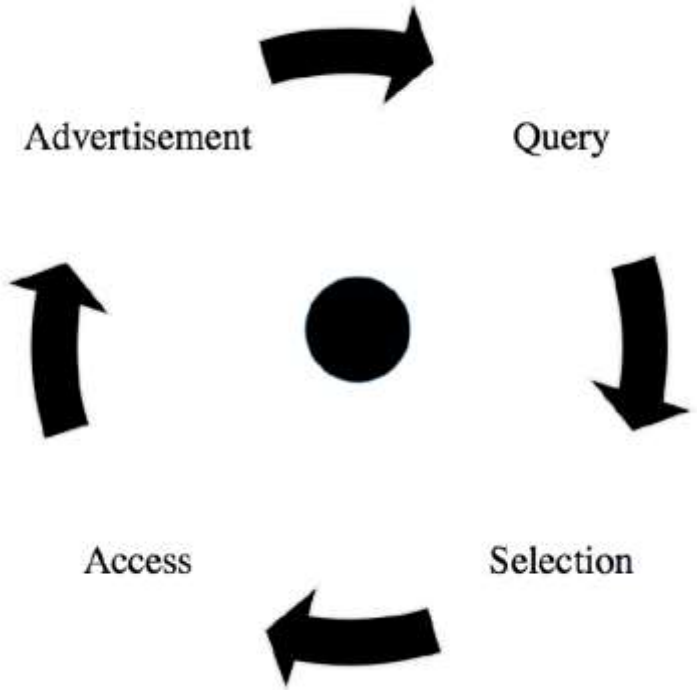
- File-system
- Network connection
- Hardware resources
- Every type of contents that can be shared

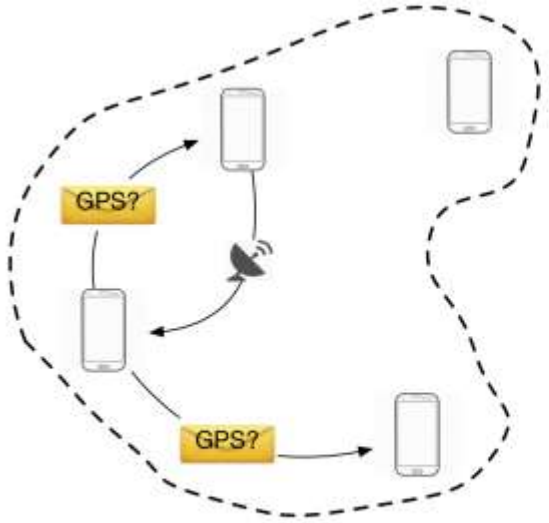


Service-oriented MSN
Service Discovery

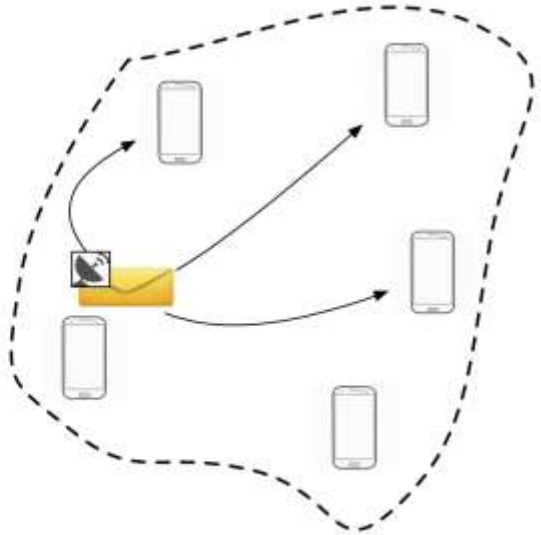
Process composed by 4 steps

1. Advertise the services
2. Query for services offered by the network providers
3. Select the most suitable service
4. Access to the service



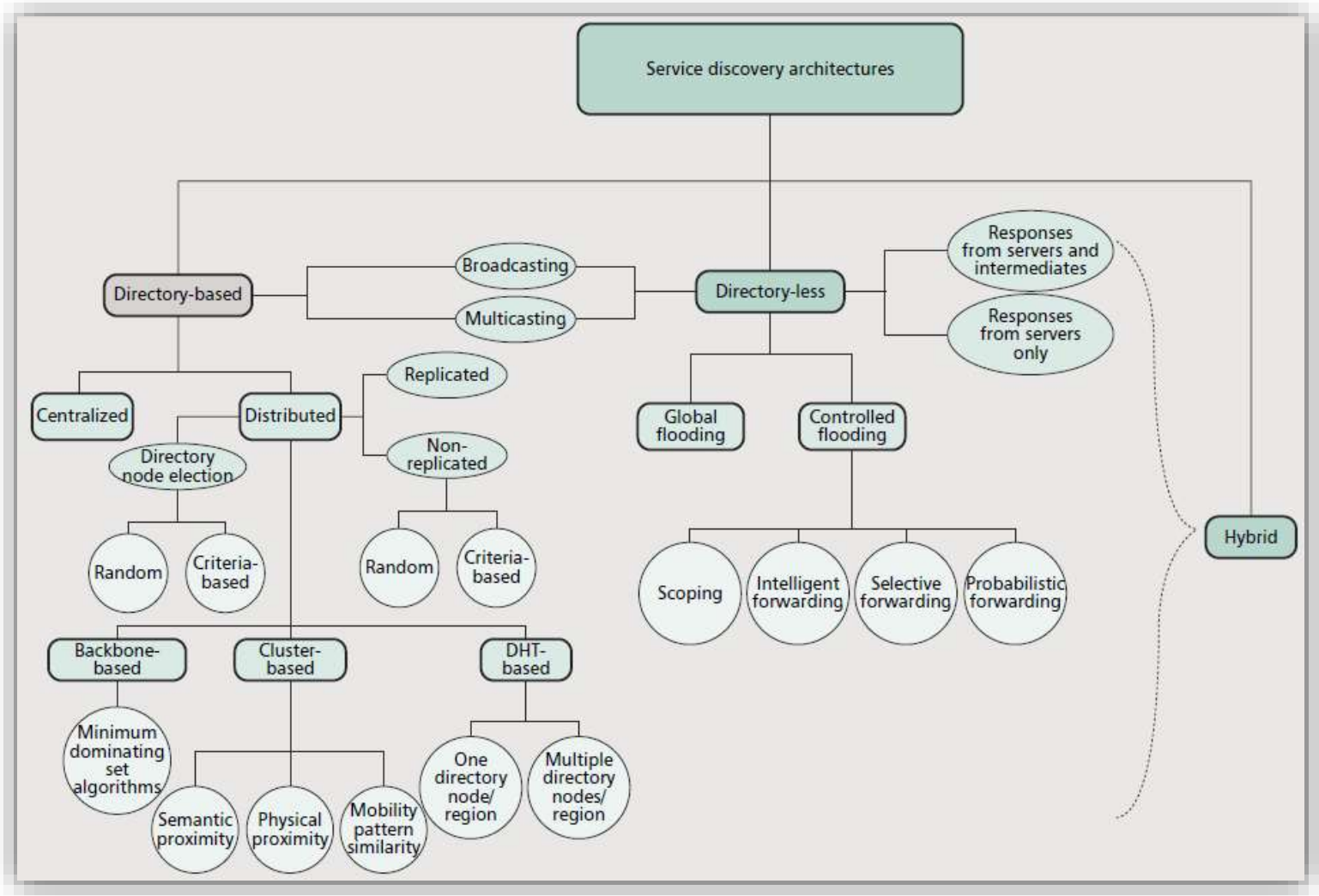


Reactive query



Proactive advertisement

Service-oriented MSN
Service Discovery

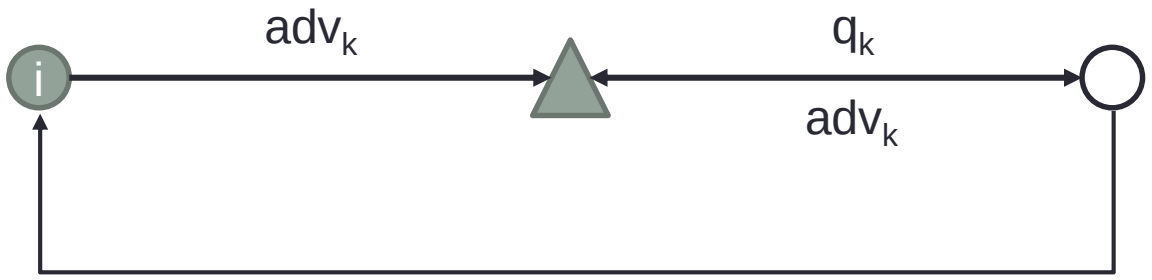


Service-oriented MSN
Service Discovery

Discovery Architectures

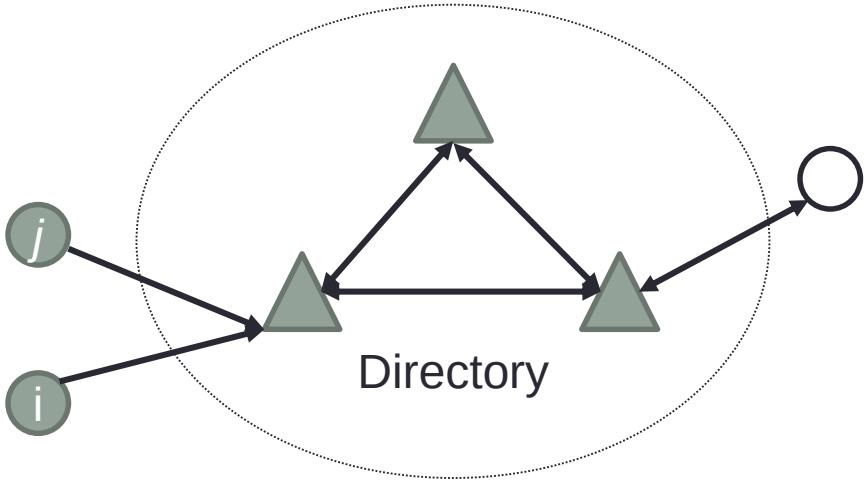
- **Service Directory**: stores the services
- **Service Provider**: advertises the services (*adv*)
- **Service Client**: queries for services

Node	*Advertisements*
i	adv_k, adv_h
j	adv_x, adv_y



Service-oriented MSN
Service Discovery

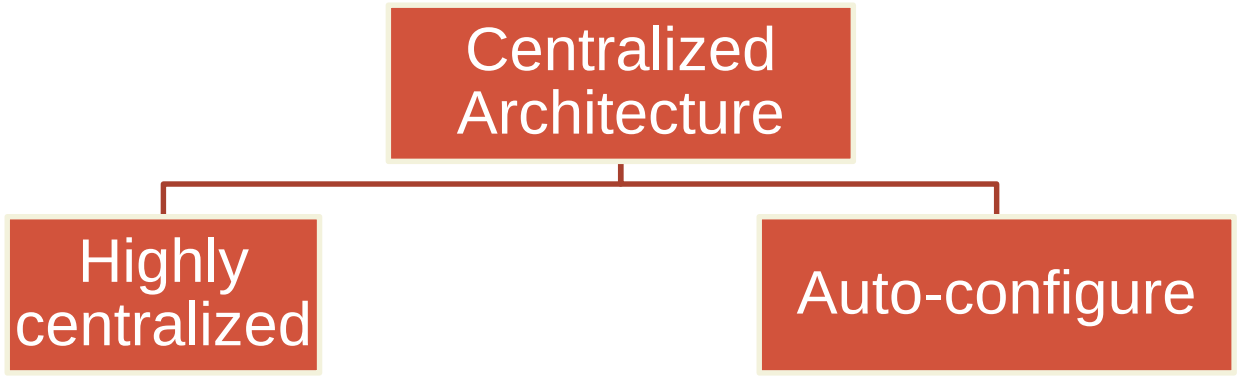
Centralized architecture



Node	*Advs*
i	[…]
j	[…]

- U. C. Kozat and L. Tassiulas, “Service Discovery in Mobile Ad Hoc Networks: An Overall Perspective on Architectural Choices and Network Layer Support Issues,” *Ad Hoc Networks*, vol. 2, no. 1, 2004, pp. 23–44.

Service-oriented MSN
Service Discovery



- directory pre-configured
- nodes know the URLs
- directory must be always reachable

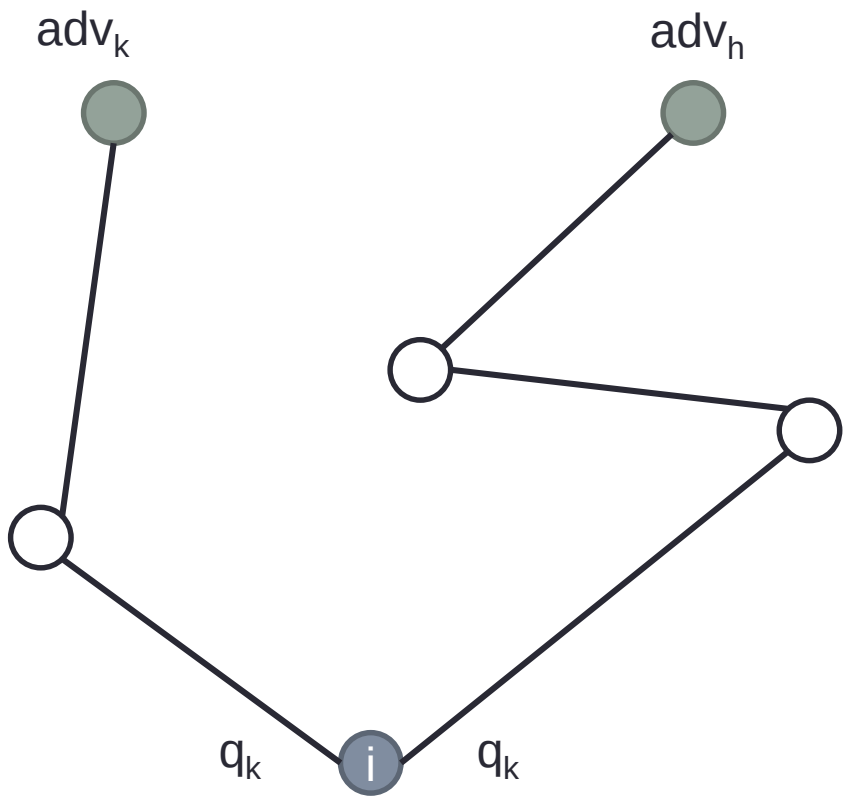
- Variable number of directory nodes
  - dynamically elected
  - synchronization strategy
- Dynamic configuration:
  - Clients discovers the directory with

  ie. m-cast or b-cast announces

Service-oriented MSN
Service Discovery

Directory-less architecture

G^w



Service-oriented MSN
Service Discovery

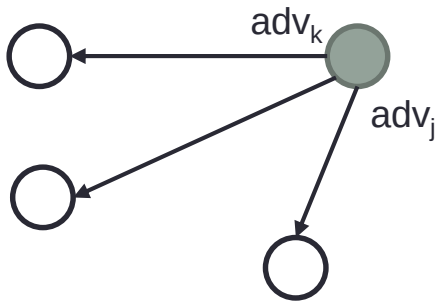
Discovery Modes

Reactive

- Clients send a query to the directory node or to the neighborhood

Proactive

- Clients receive the service advertisements passively
- Providers announce/refresh the services as soon as they are available



Service-oriented MSN
Service Discovery

Piggybacking

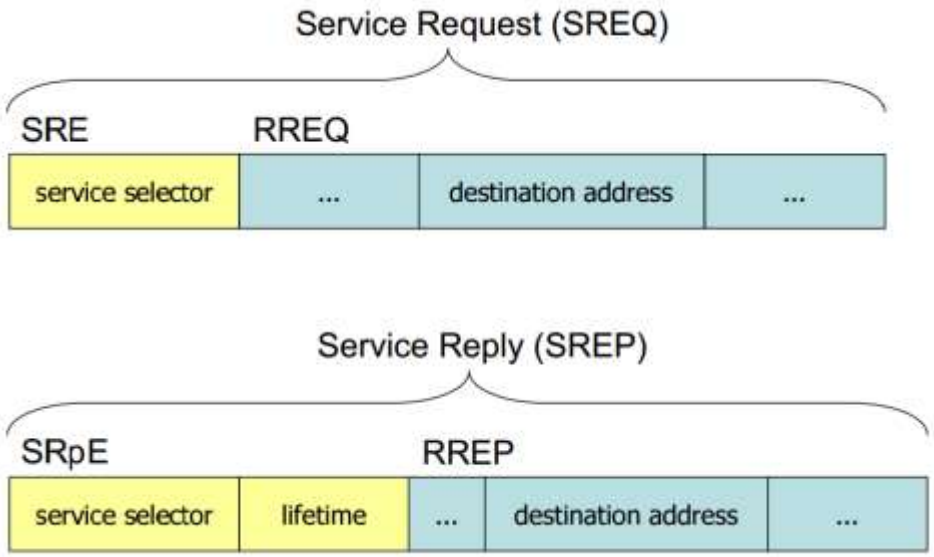
Exploiting existing protocols to deliver information about available/unavailable services:

- routing packets: add an extra payload delivering the information about services
- manage constraints on the maximum packet size used in different environments on physical layer

Sotirios E. Athanaileas, Christopher N. Ververidis and George C. Polyzos, Optimized Service Selection for MANETs using an AODV-based Service Discovery Protocol

Service-oriented MSN
Service Discovery

- AODV popular routing protocol for MANET
  - RREQ
  - RRESP
- AODV messages extended with
  - SREQ: service request
  - SREP: service reply



Service-oriented MSN
Service Discovery

Query Termination

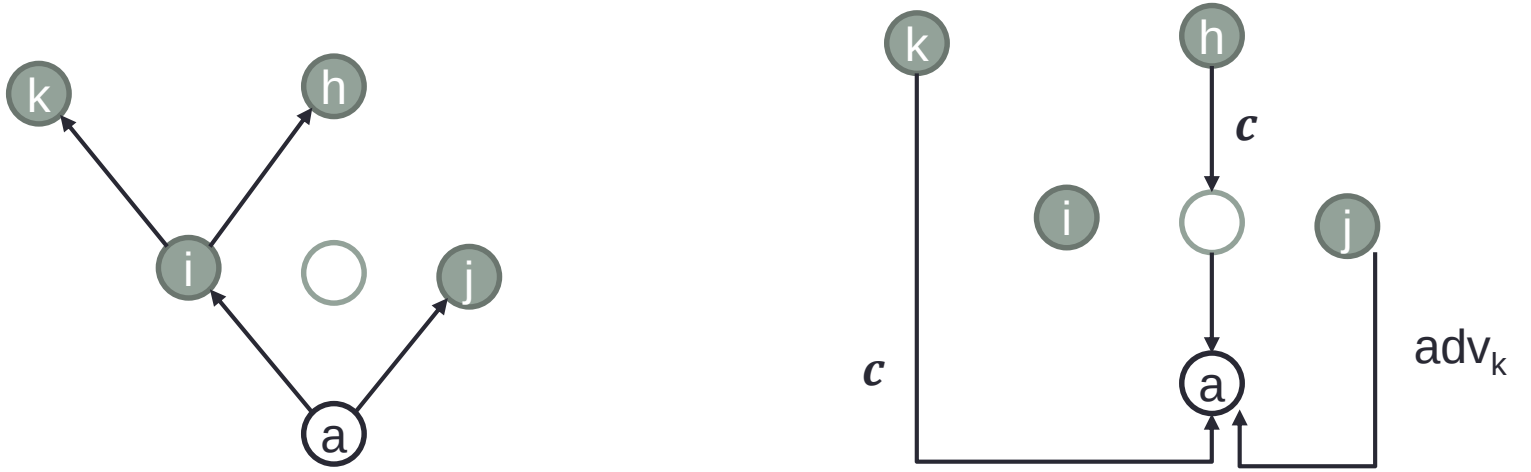
The query propagation injects a number of queries in the MSN

- If the response has been received, all the running queries have to be terminated:
  - network overhead
  - computation of intermediated and target nodes
- If the response has not been already received nothing is done

Service-oriented MSN
Service Discovery

Periodic Checking

TTL = 2



Layout

1. Mobile Social Networks
2. Service-oriented MSN
3. **Service Discovery algorithms**
   A. **SIDEMAN**
   B. **CORDIAL**
4. Conclusions

SIDEMAN: SD in Mobile Social Networks

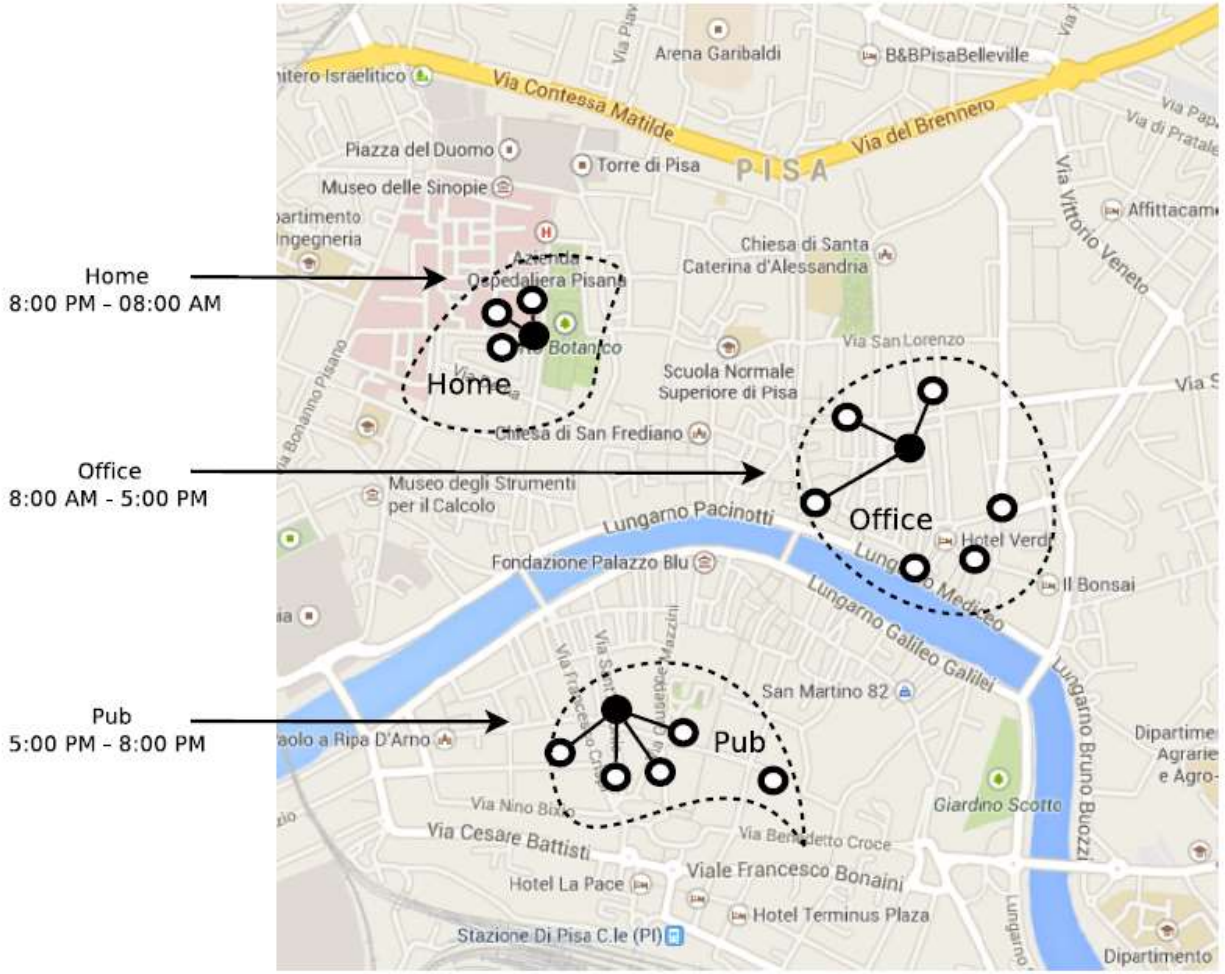
SIDEMAN is a discovery protocol for MSN

- Directory-less discovery architecture
- Implements 2 operations
  - Service dissemination (advertisement)
  - Service query
- SIDEMAN exploits the social nature of MSN

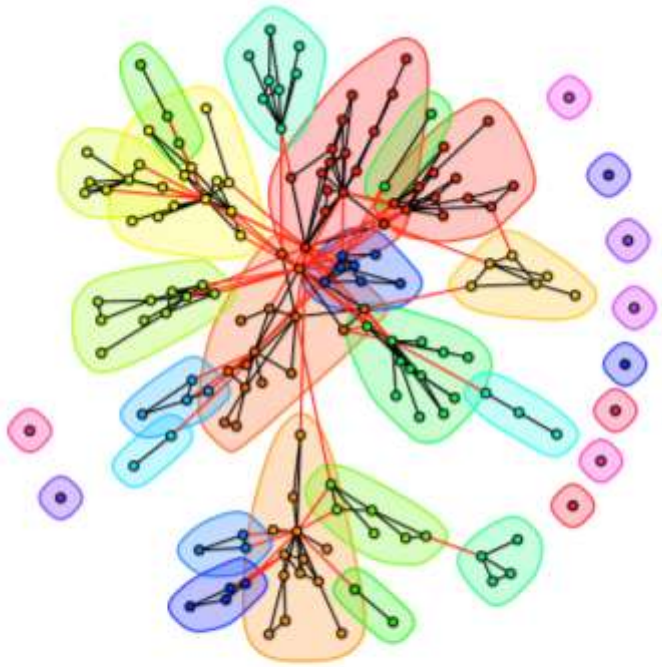
SIDEMAN: SD in Mobile Social Networks

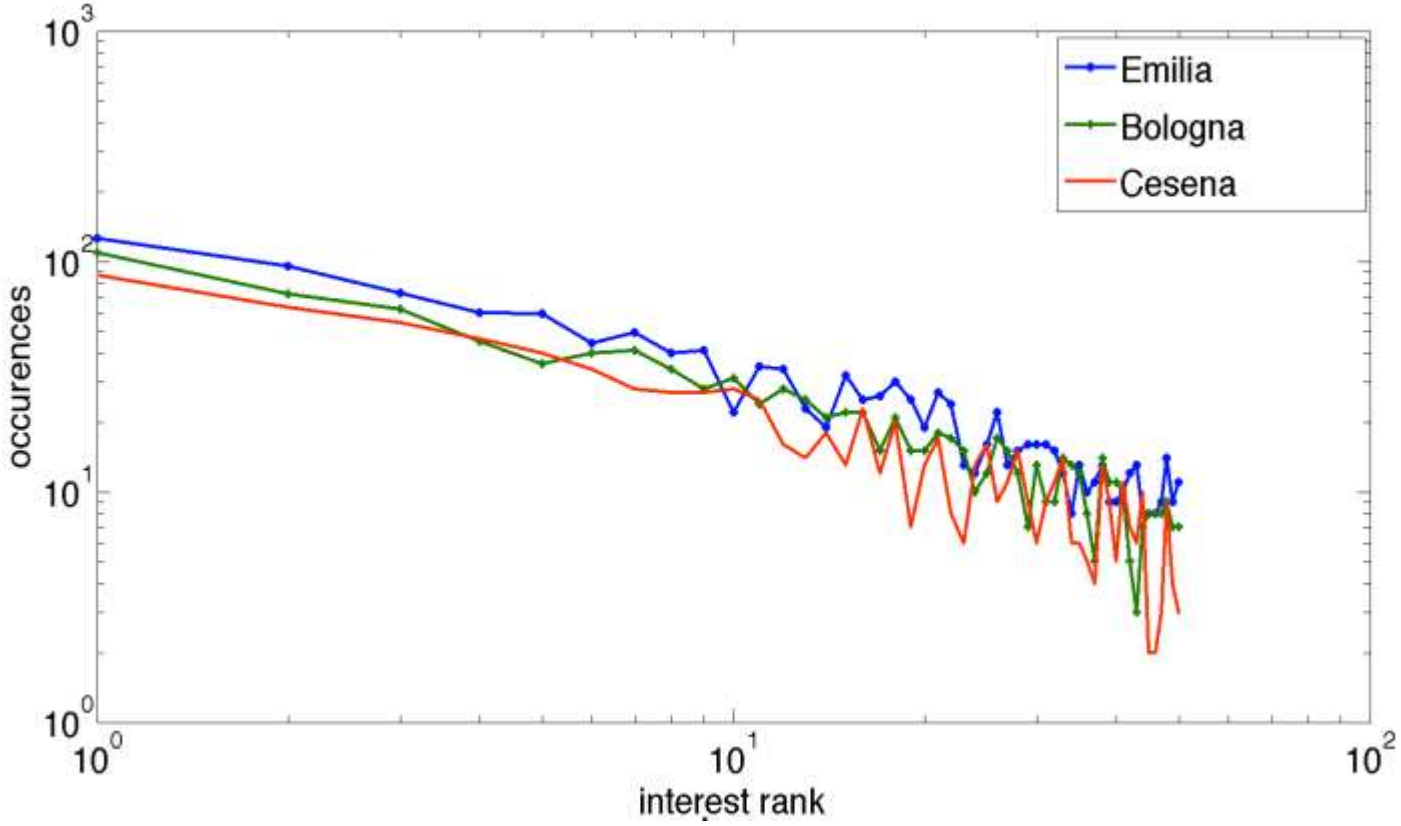
Observations

1. People join communties during the day
    1. Home
    2. Office
    3. Pub
2. Communities are made of people with *Similar Interests*

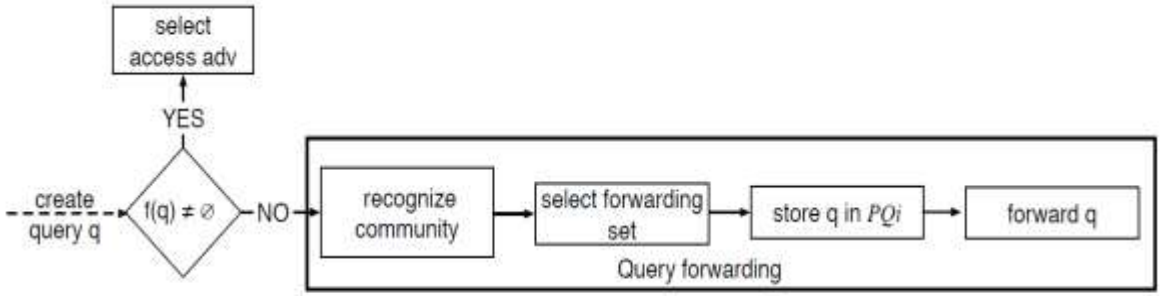


SIDEMAN: SD in Mobile Social Networks

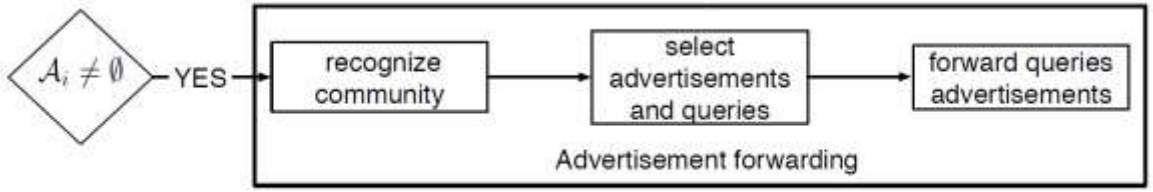




SIDEMAN: SD in Mobile Social Networks

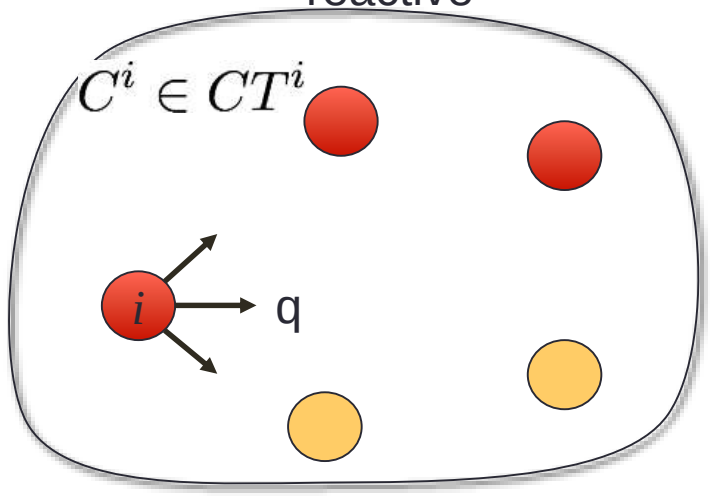


(a) Reactive phase

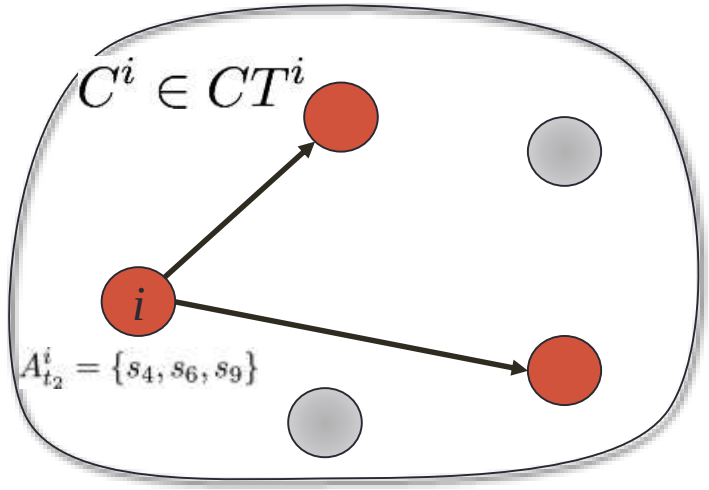


(b) Proactive phase

reactive



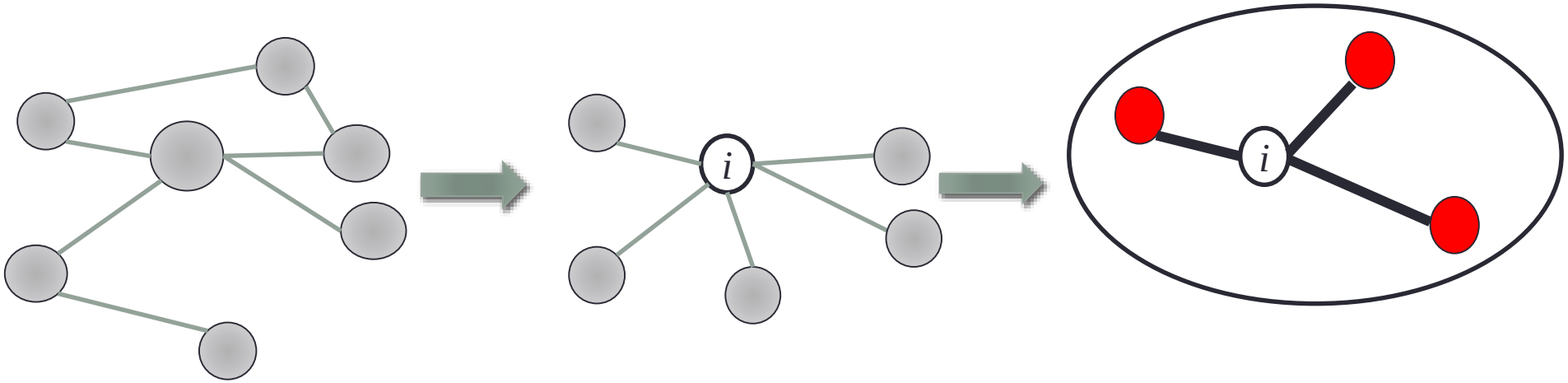
proactive



SIDEMAN: SD in Mobile Social Networks

Community Detection and Recognition

- nodes detect the community they join

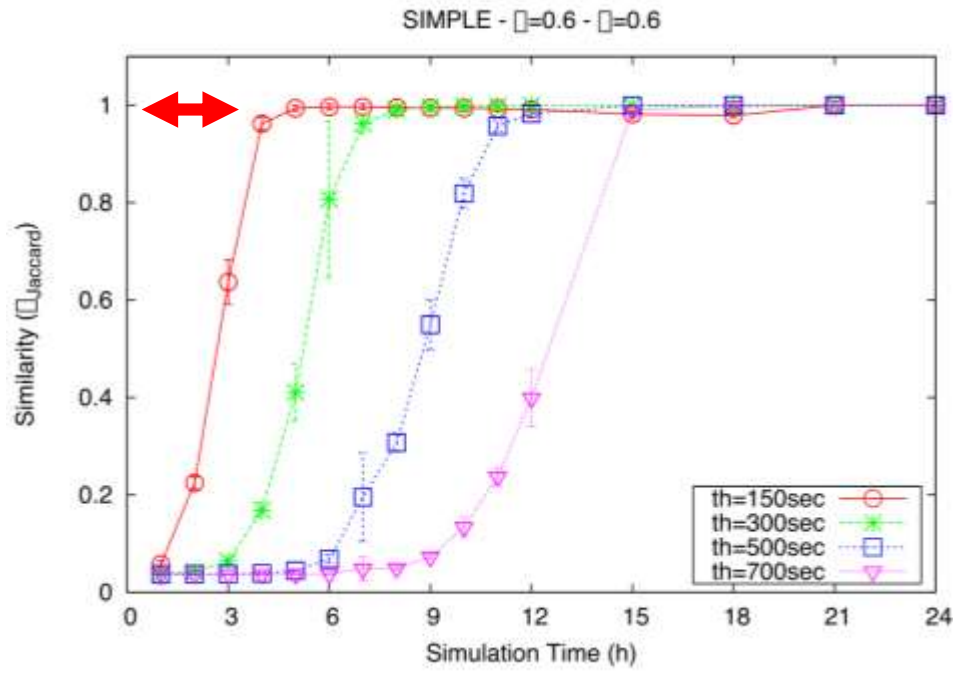


G_T N_t^i $C^i \in CT^i$

SIDEMAN: SD in Mobile Social Networks

AD-SIMPLE keeps track of:

1. Cumulative contact duration of contacts
2. *Similarity* of the contacts



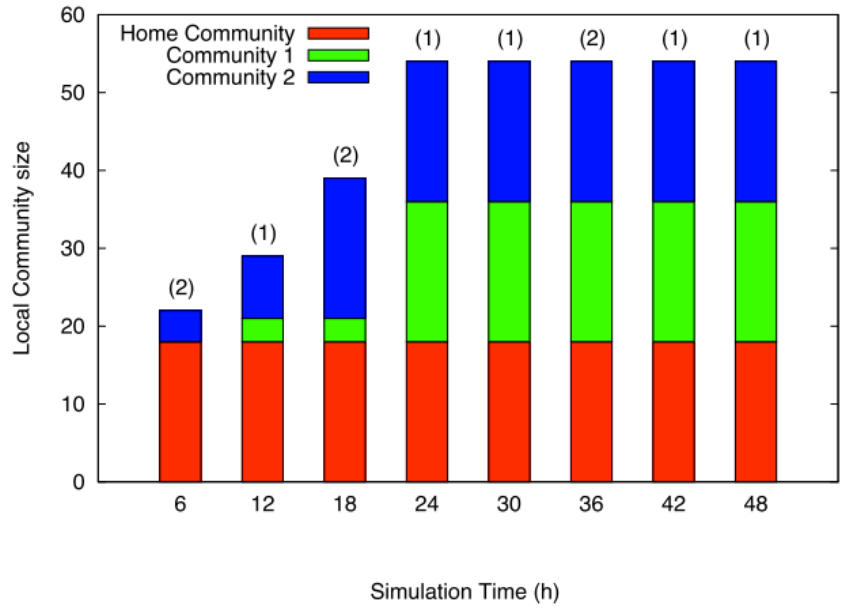
$t_{cum} > \tau$

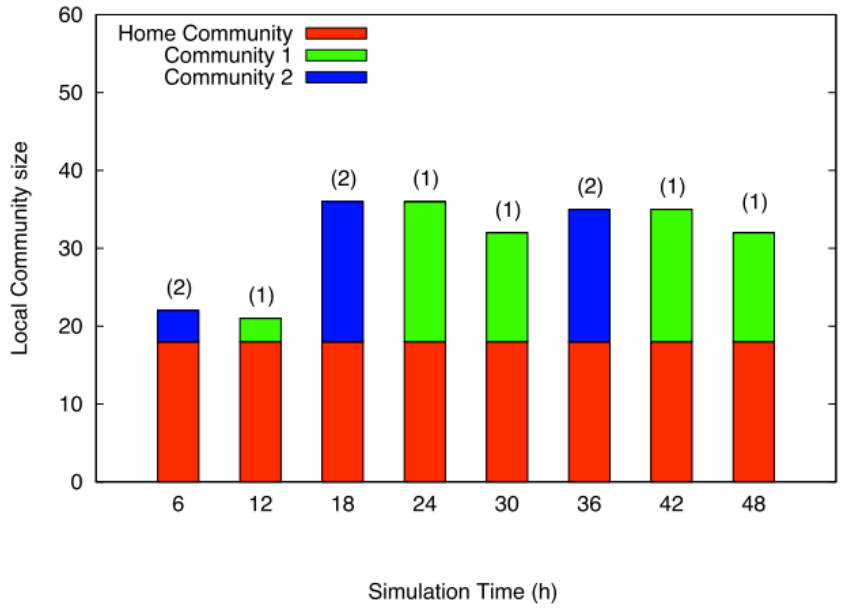
$|C_i \cap F_j| > \lambda \times |F_j| \longrightarrow C_i = C_i \cup j$

SIDEMAN: SD in Mobile Social Networks

AD-SIMPLE

- Longevity and frequency of contacts
- Removes *old* contacts from the communities detected





SIDEMAN: SD in Mobile Social Networks

Service dissemination (advertisement)

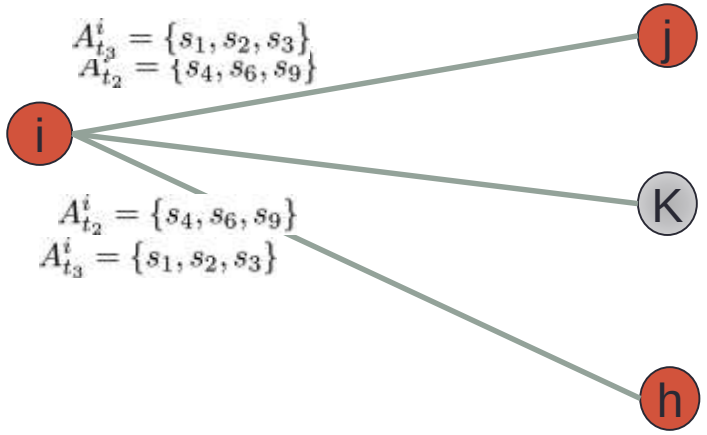
- Proactive mode
- based on the node interests

$SI_i = \{t_1, t_2, t_3, t_6\}$

$SI_j = \{t_2, t_3\}$

$SI_k = \{t_5, t_9\}$

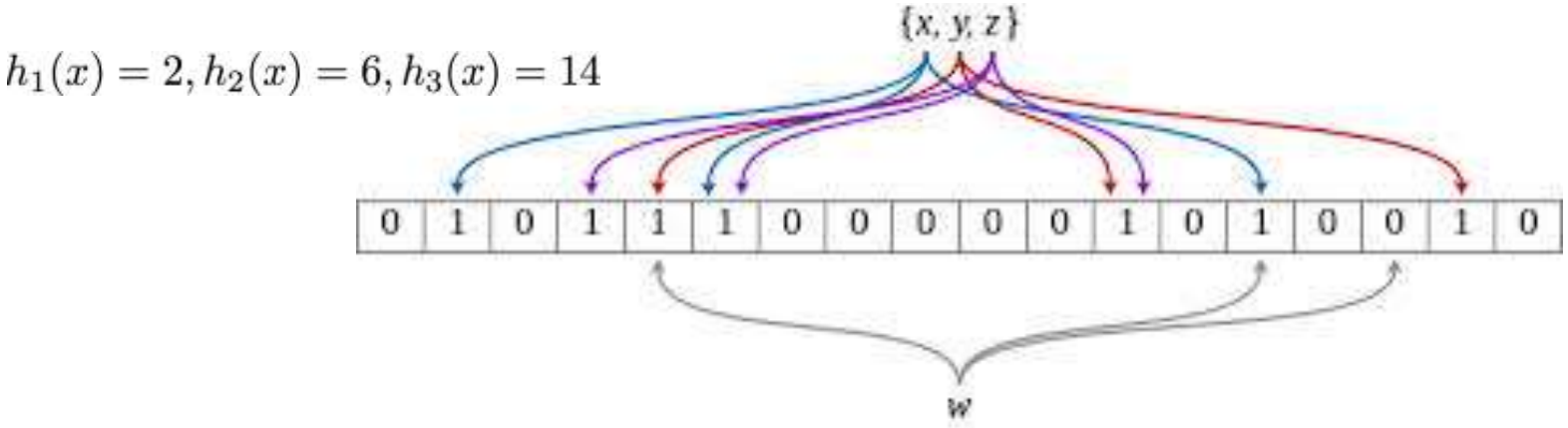
$SI_h = \{t_2, t_3\}$



$$C^i \in CT^i$$

SIDEMAN: SD in Mobile Social Networks

- The set of interests assigned to node are implemented with **Bloom Filters**
  - Membership
  - Insertion



Dimension ‘m’ and optimal number of hash functions ‘k’ is controlled:

$$m = -\frac{n \ln p}{(\ln 2)^2} \qquad k = \frac{m}{n} \ln 2$$

SIDEMAN: SD in Mobile Social Networks

- Watt told us: people tend to visit the same communites
- Exchange the SI is a time and energy consuming task

Detected

$J = \frac{|A \text{Ç} B|}{|A \text{È} B|}^{3} e$

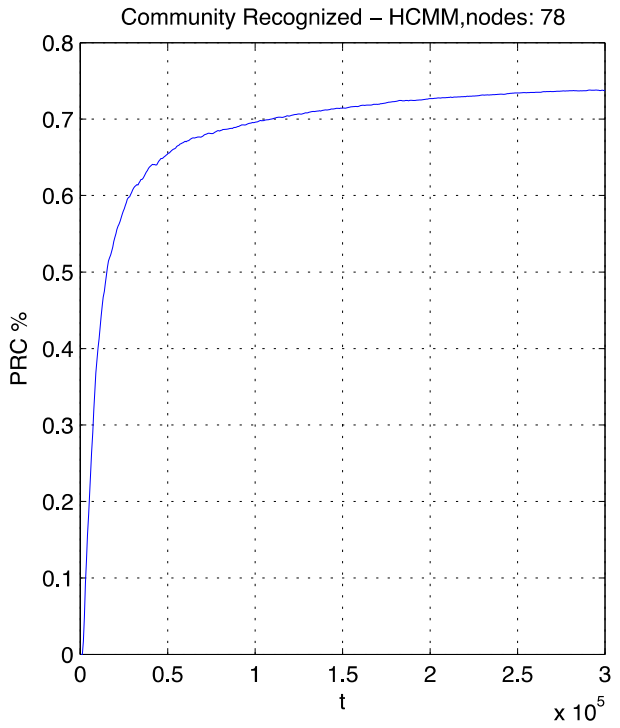
[o,p,m,n] →

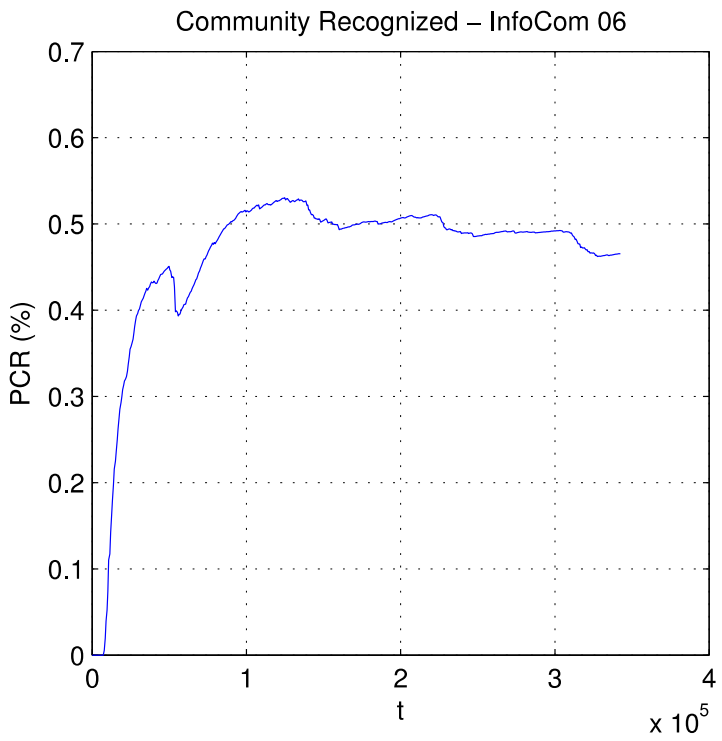
CT^i

Nodes	Interests
[j,h]	[t_1, t_2,]
[a,b,c]	[t_5, t_7, t_8, t_0]
[u,o,p,m,n]	[t_1, t_2, t_3, t_5]
[d,s,w,r,t]	[t_{15}, t_2, t_{11}, t_{10}]

SIDEMAN: SD in Mobile Social Networks

- HCMM: Nodes recognize up to 73%
- Infocom: Nodes recognize up to 52%

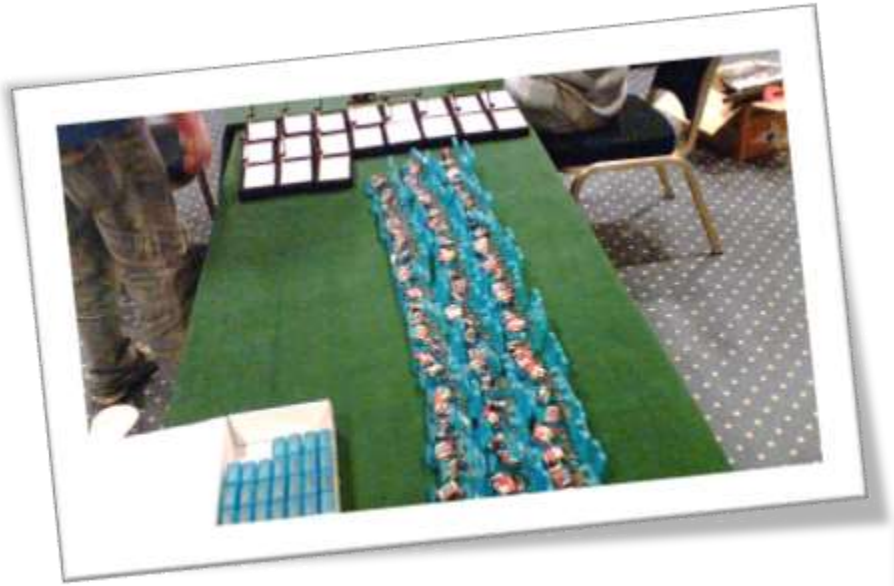




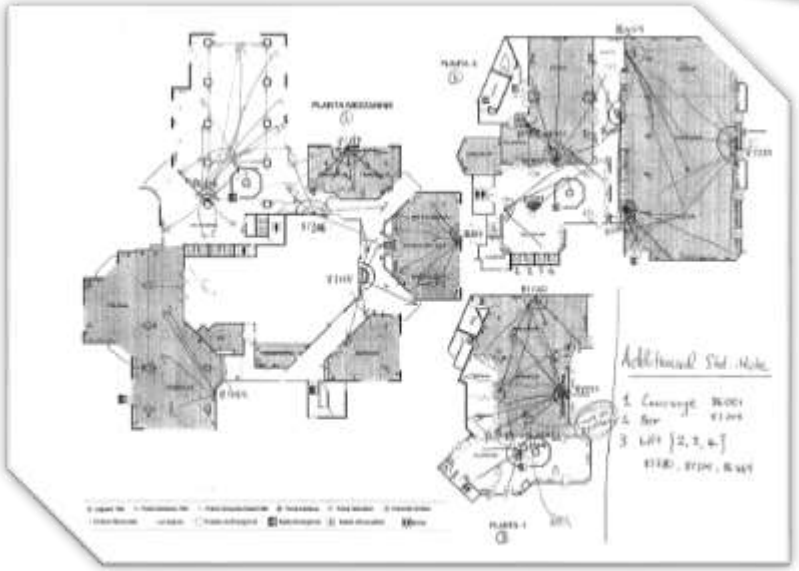
SIDEMAN: SD in Mobile Social Networks
Simulation scenarios

	Infocom 06	**HCMM**
Simulation area side	conference room	800m, 1400m, 2000m
Transmission range	30m	30m
Node speed	n.a.	from 1 to 1.86m/s
Simulated time	$t = 201600$s	$t = 300000$s
Number of nodes	$v = 78$	
Service interests	$n = 35$	
Services	$m = 10000$	
Query rate	$\lambda = 3$	
Service rate	$\mu = 3$	
Community similarity	$\tau = 0.8$	
Community recognition	AD-SIMPLE	

SIDEMAN: SD in Mobile Social Networks
Simulation scenarios

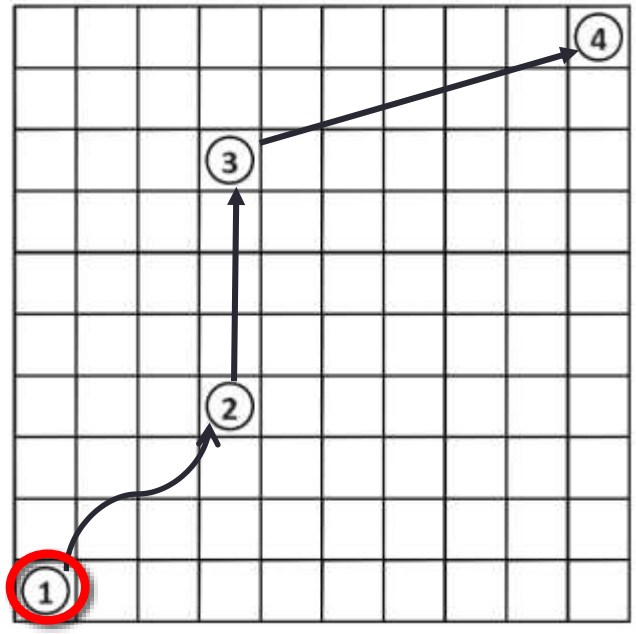


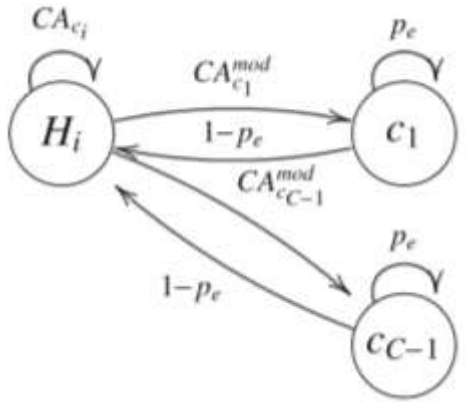
InfoCom 06 traces



SIDEMAN: SD in Mobile Social Networks
Simulation scenarios

HCMM mobility model



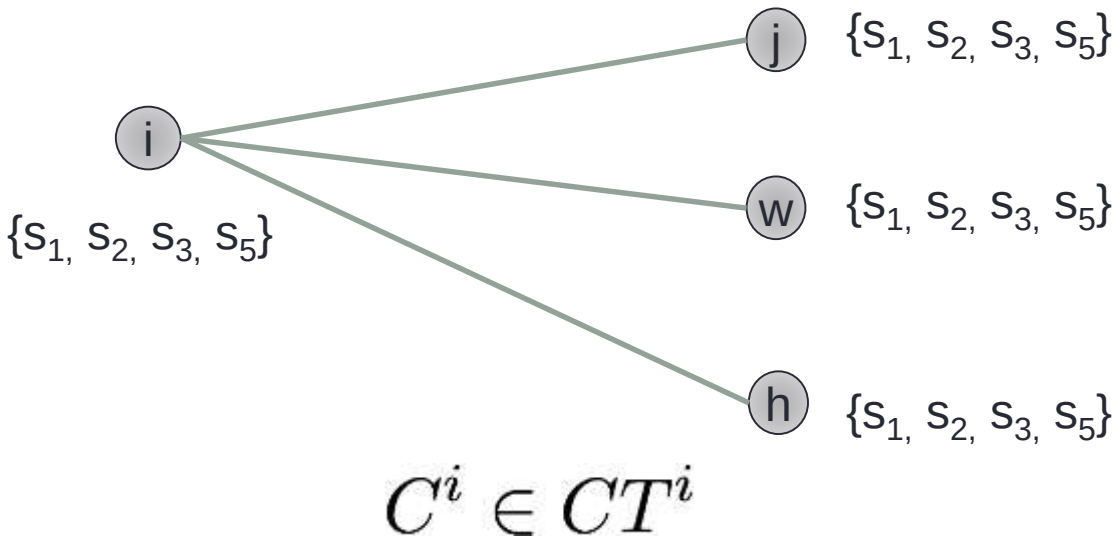


HCMM:

- Nodes move according to social ties
- Nodes move for shorter paths
- Nodes visit few communities

SIDEMAN: SD in Mobile Social Networks
Simulation scenarios

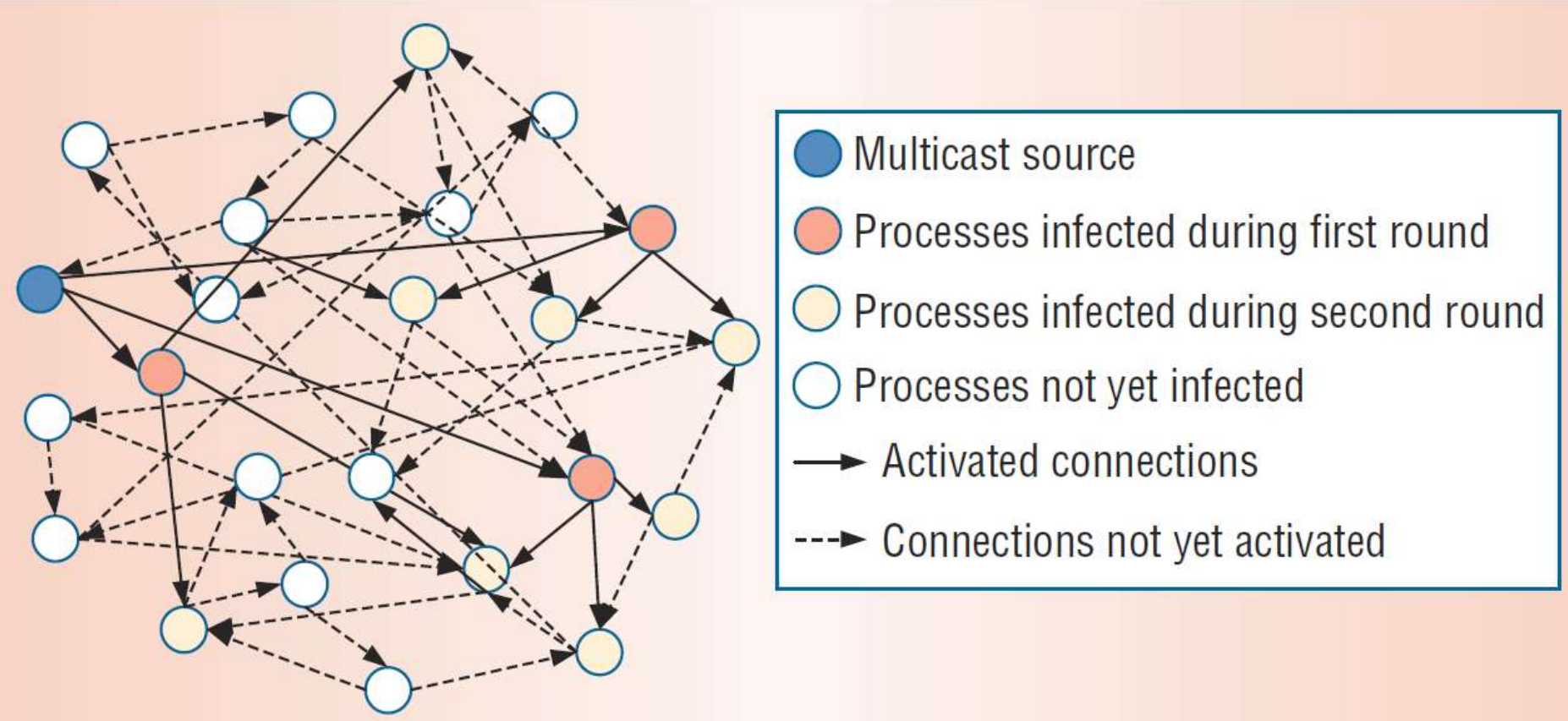
- S-Flooding



$$C^i \in CT^i$$

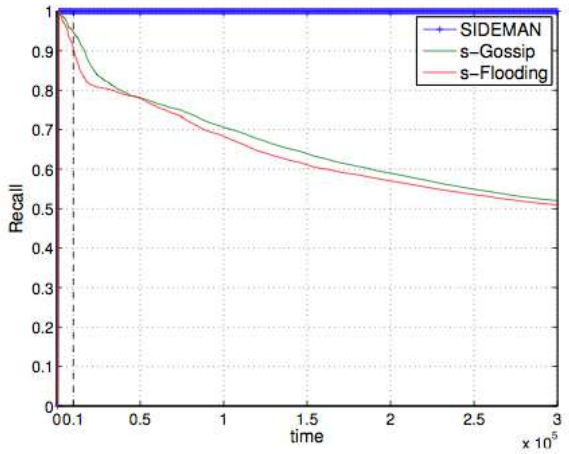
SIDEMAN: SD in Mobile Social Networks
Simulation scenarios

- S-Gossip

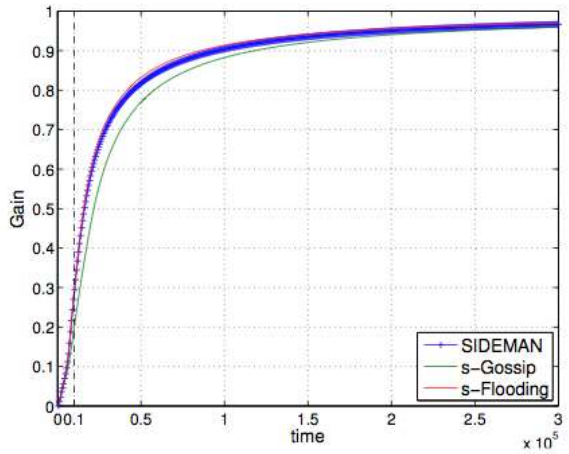


SIDEMAN: SD in Mobile Social Networks Performance Analysis

HCMM scenario



(a) Recall.



(b) Gain.

- 95% of statistical confidence 5% precision
- t=10000s (steady state)

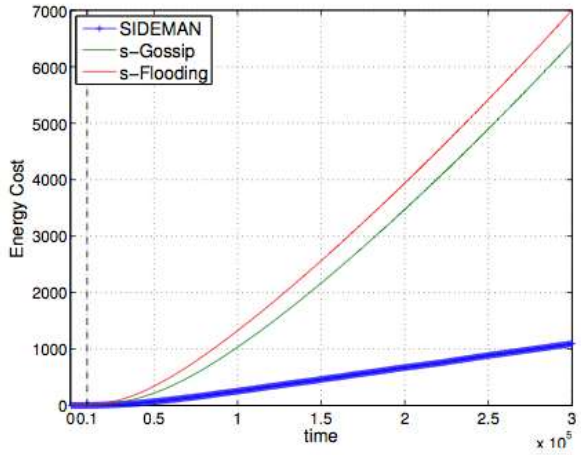
- **Recall**: number of services of interest stored in the node cache, w.r.t. total number of services stored.
- **Gain**: probability that a node finds a service *s* in its cache.

SIDEMAN: SD in Mobile Social Networks
Simulation scenarios

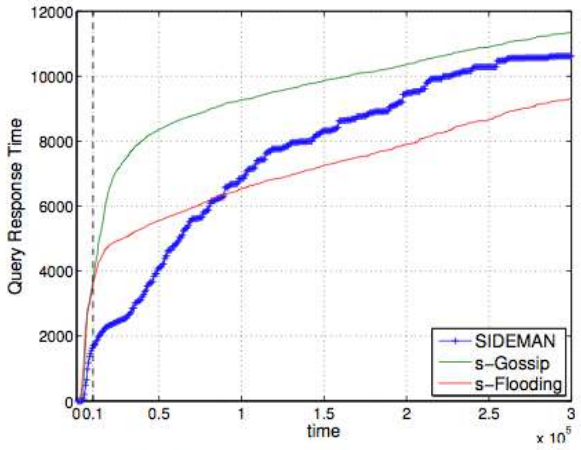
Energy cost: average energy consumption by each node during network operation

- WiFi/ Bluetooth chip Broadcom BCM4330 of the Samsung Galaxy S III smart phone

- **Query response time**: average time elapsed between query and response



(c) Energy cost.

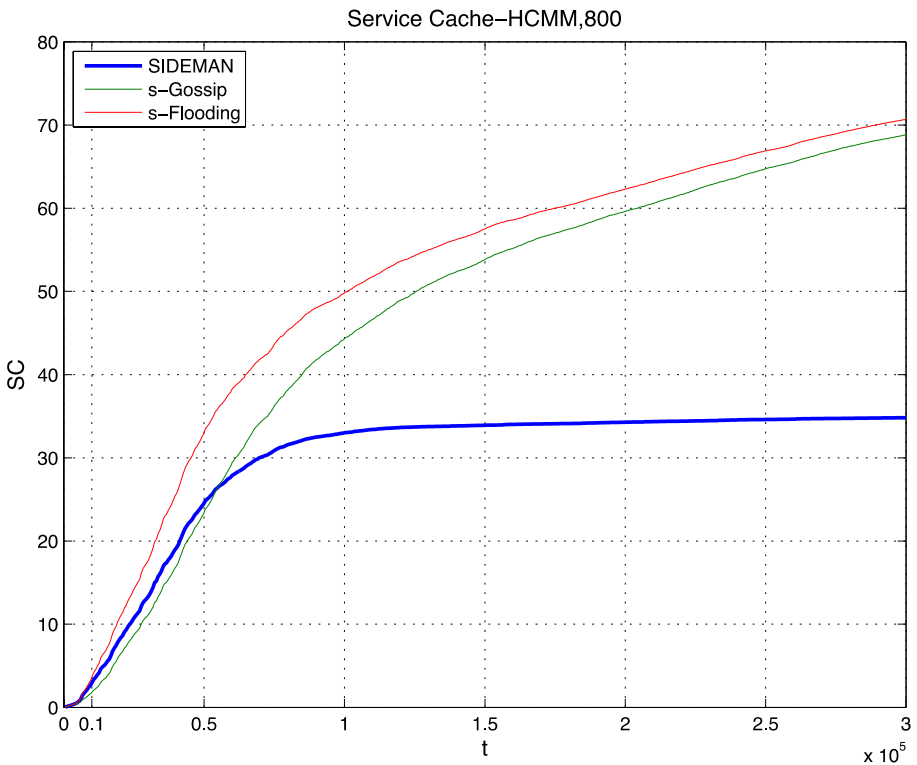


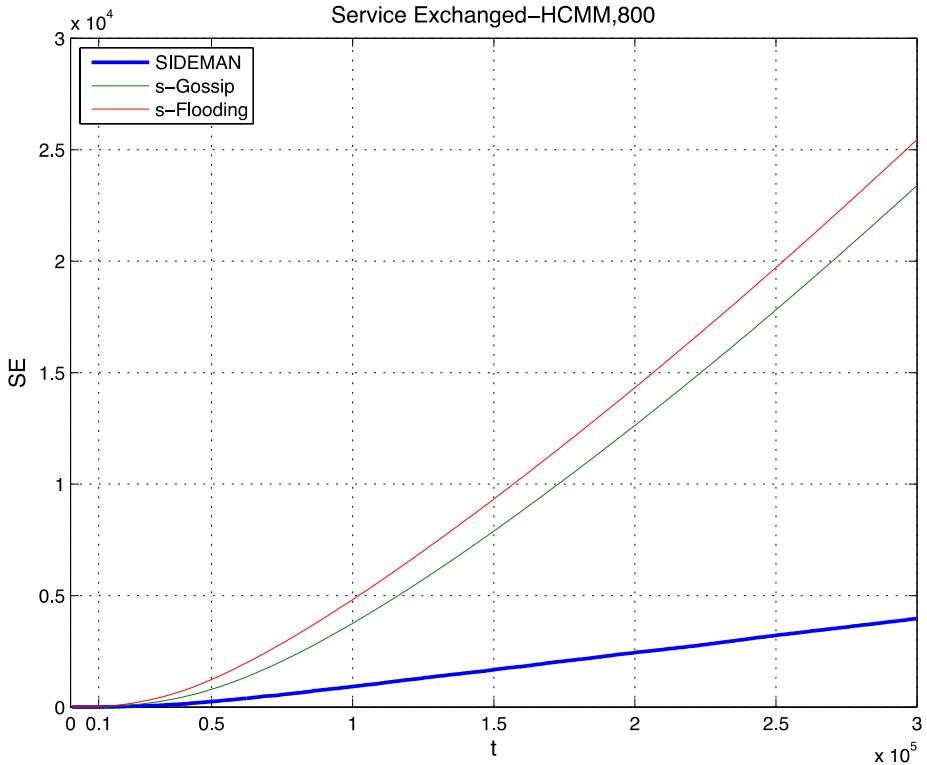
(d) Query response time.

SIDEMAN: SD in Mobile Social Networks
Simulation scenarios

Service cache: average number of services stored locally

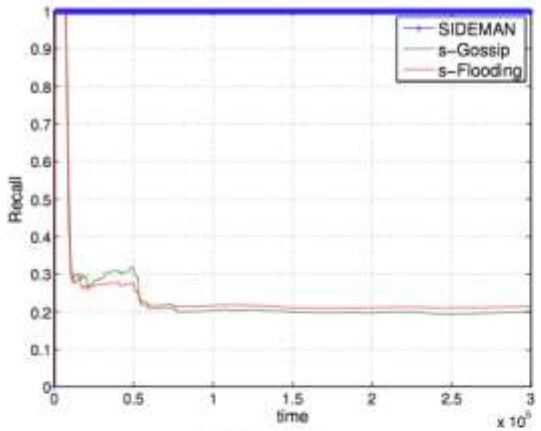
Service exchanged: average number of services exchanged proactively



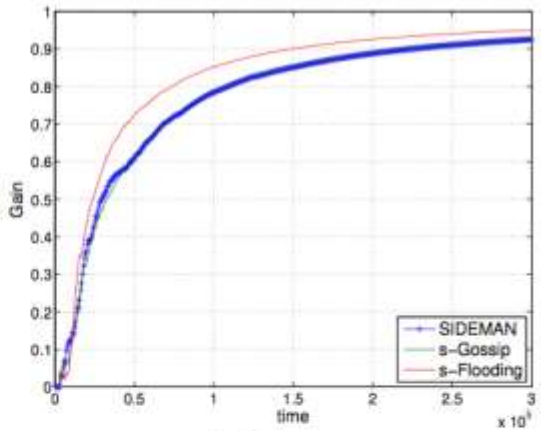


SIDEMAN: SD in Mobile Social Networks
Performance Analysis

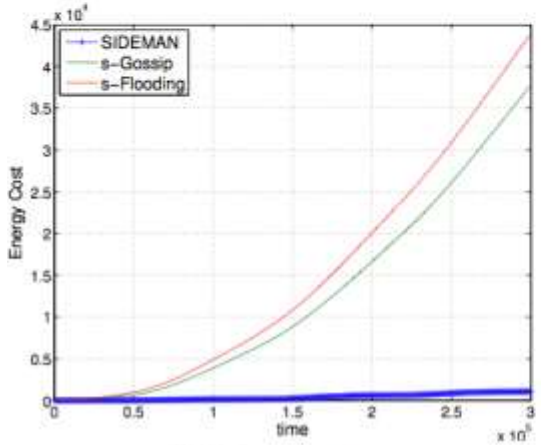
InfoCom scenario



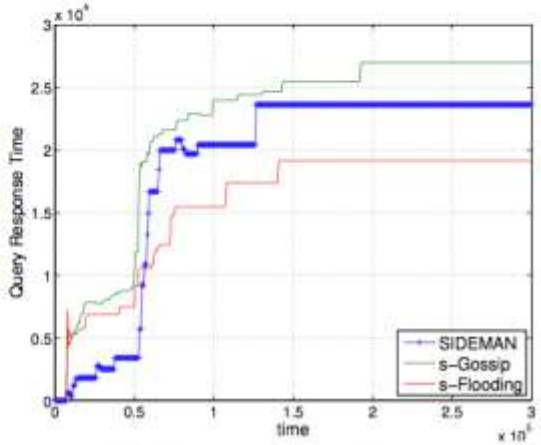
(a) Recall.



(b) Gain.



(c) Energy cost.

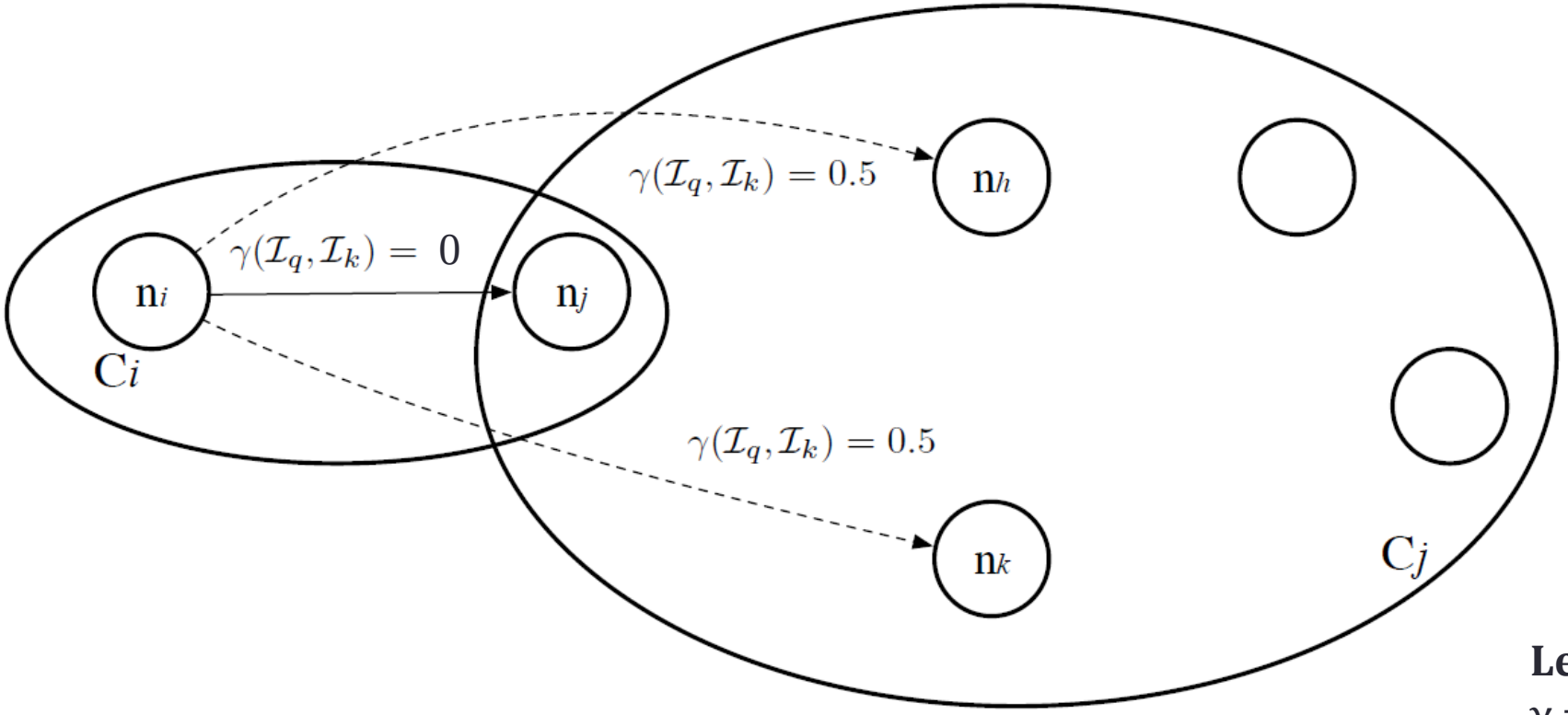


(d) Query response time.

Layout

1. Mobile Social Networks
2. Service-oriented MSN
3. **Service Discovery algorithms**
   A. **SIDEMAN**
   B. **CORDIAL**
4. Conclusions

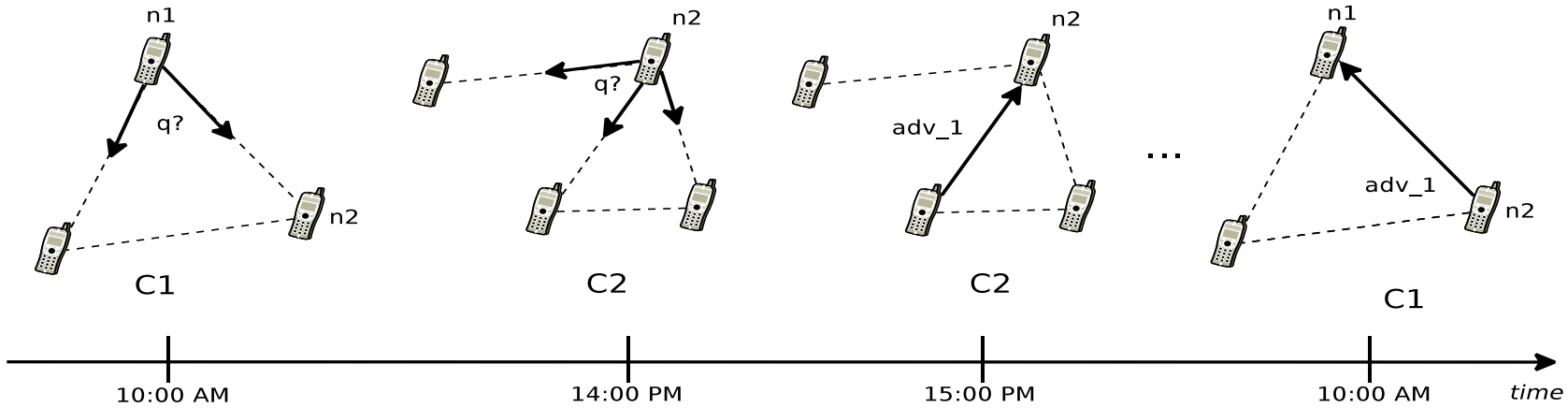
CORDIAL: COllaborative seRvice DIscovery ALgorithm



Legend:
γ = similariy index (ex. Jaccard)
Iq = intereasts of the query (ex. t1, t2, t3)
Ik = interests of node k (ex t1, t4, t5)

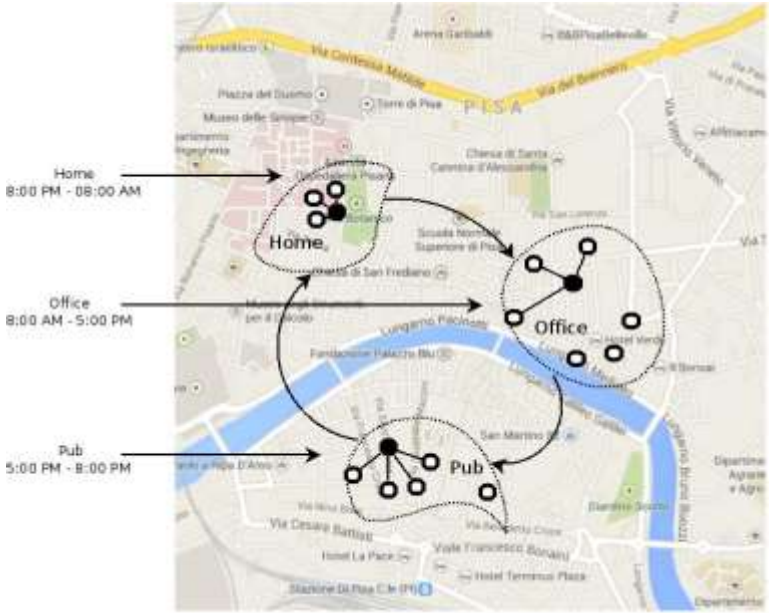
Cj = community of node j
Ci = community of node i

CORDIAL: COllaborative seRvice DIscovery ALgorithm



Mobility features:

- Nodes move according to social ties
- Nodes move for shorter paths
- Nodes visit few communities
- Nodes visit with a repetitive pattern the same communities



Layout

1. Mobile Social Networks
2. Service-oriented MSN
3. Service Discovery algorithms
   A. SIDEMAN
   B. CORDIAL
4. **Service Discovery Frameworks**

Related Works

SD Frameworks

- Review of widely used service discovery frameworks
- Designed for administrated networks (hence not for p2p)
- Centralized and decentralized architectures

1. SLP Service Location Protocol
2. UPnP Universal Plug and Play
3. Bluetooth Service Discovery
4. Bonjour

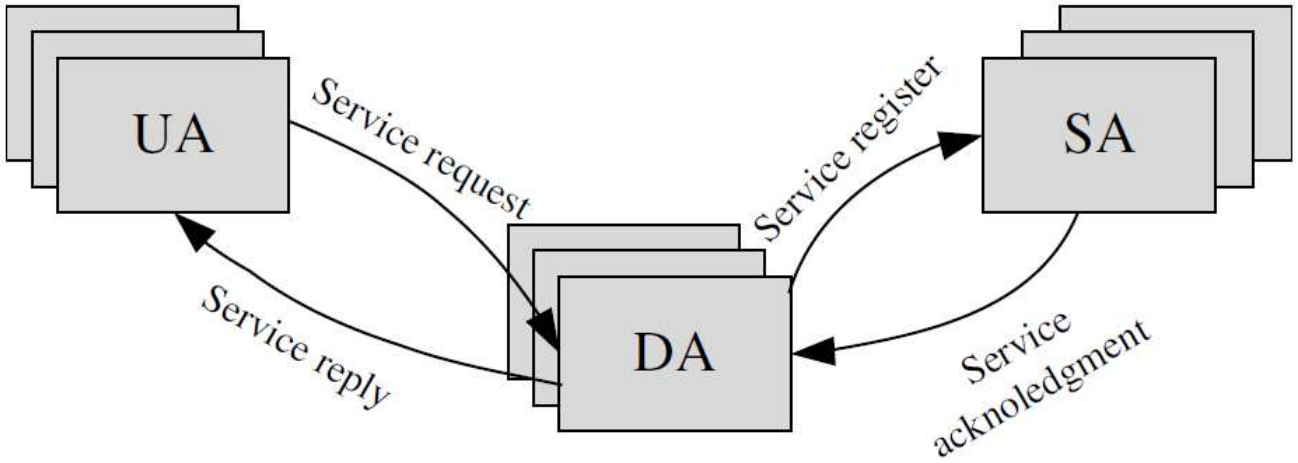
Related Works

SLP

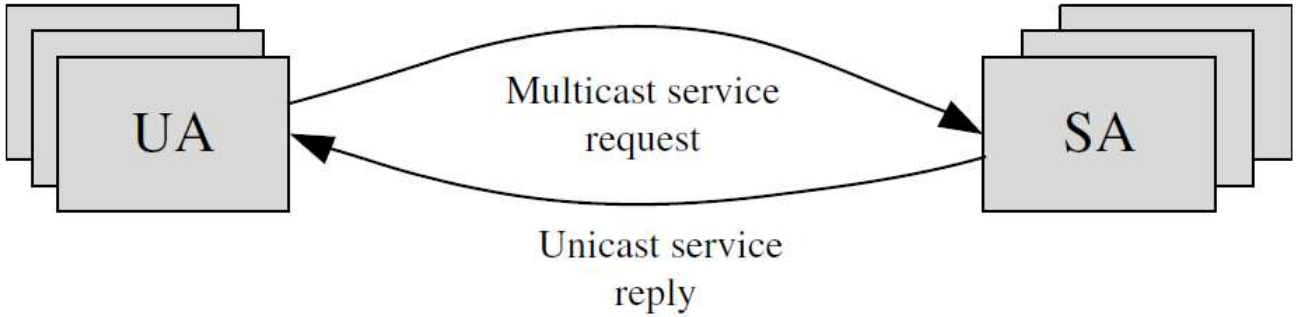
- SLP is an IETF standard
- Defined by a number of RFCs (2165, 2608, 2609 and 2914)
- SLP relies on a centralized architecture suitable for
  - Large-Enterprise networks
  - LAN
- Supports 2 modes:
  - Centralized mode with Directory Agents (DAs)
  - Distributed mode without DAs

Related Works

SLP



A. Centralized approach. SLP with device agents.



B. Distributed approach. SLP without device agents.

Related Works

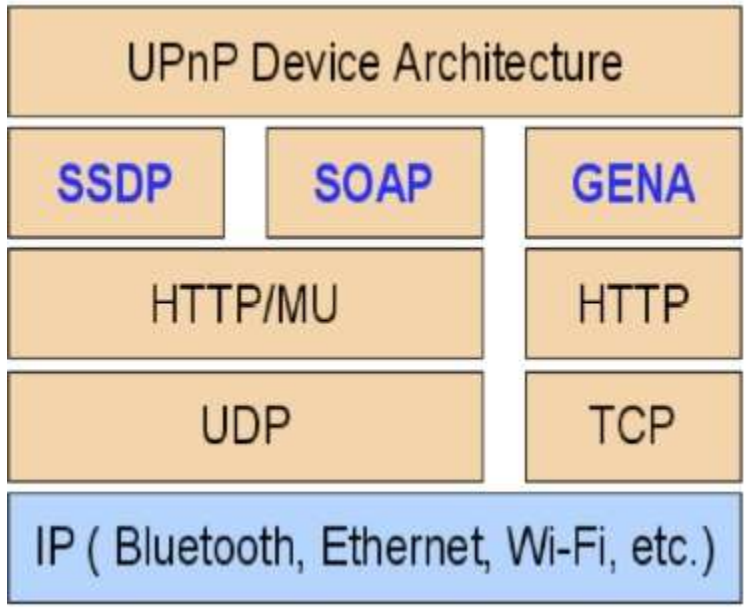
SLP

- The service replies contain:
  - URL **service:servicename:protocolname://hostname**.
  - Attributes: <key, value>
  - Scope: string classifying the services
- UAs query the DA or SAs by specifying:
  - The type of the service
  - A list of attributes
  - The service scopes

Related Works

UPnP

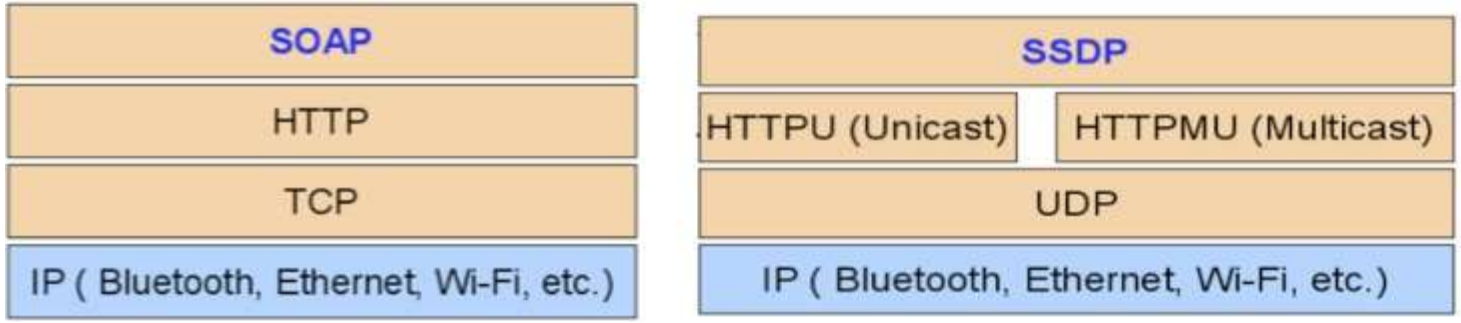
- Universal Plug and Play FW defines a protocol stack for:
  - Addressing
  - **Discovery**
  - Description
  - Control
  - Eventing
  - Presentation



Related Works

UPnP

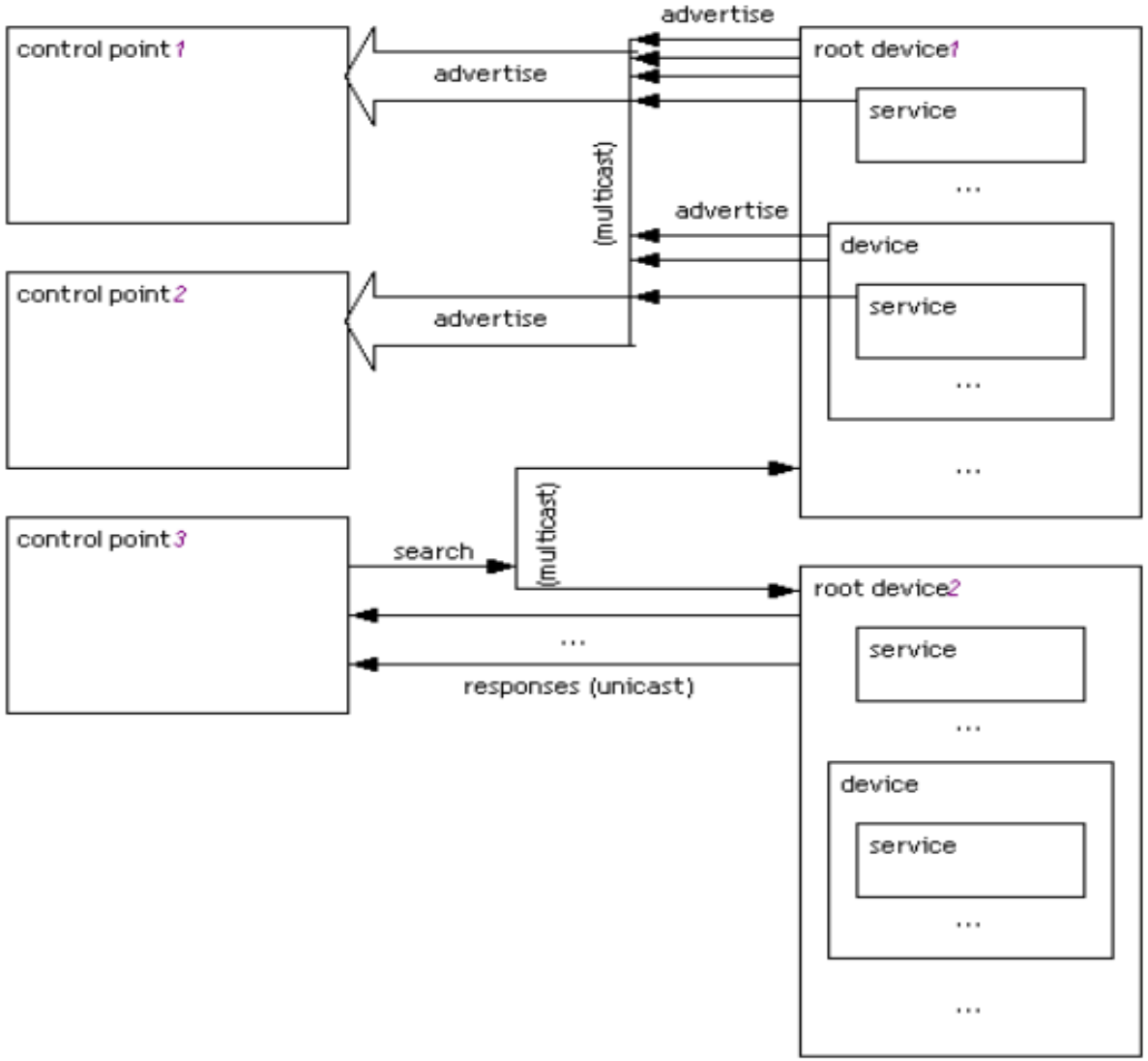
- UPnP relies on the SSDP protocol for the discovery



- Completely distributed query-based
- Roles of nodes:
  - Control Points ($\cong resource\ clients$)
  - Controlled Devices ($\cong resource\ providers$)

Related Works

UPnP



Related Works

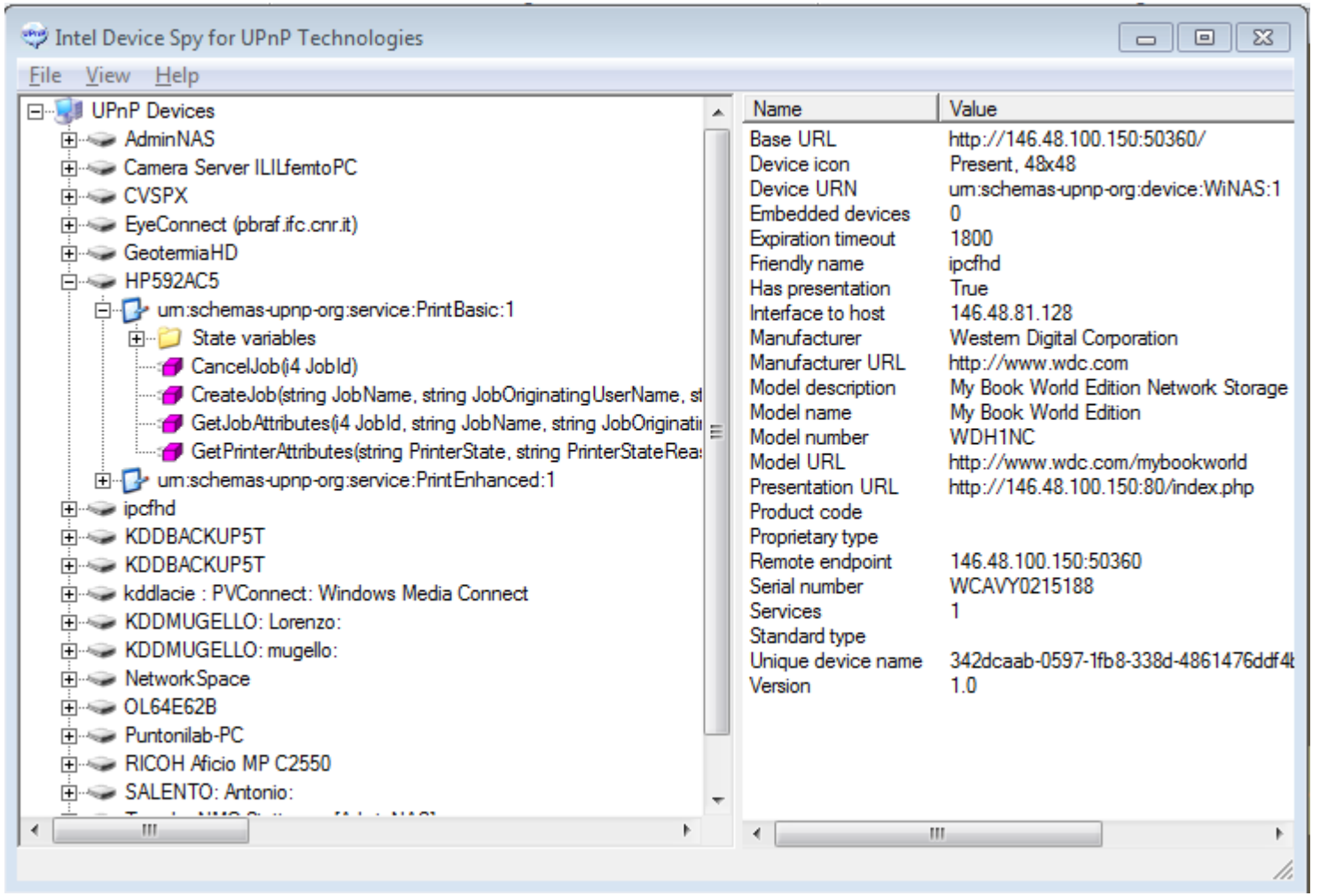
UPnP

- Controlled Devices receive an XML URL describing the Controlled Device
  - Every controlled device runs a HTTP server
  - XML document provides a tree-based description of the device

- UPnP also defines:
  - how to access to the service
    - To invoke remote procedures through SOAP messages
  - how to be notified by the service
    - To register to the control variables and to receive asynchronous HTTP messages

Related Works

UPnP



Related Works

Bluetooth SDP

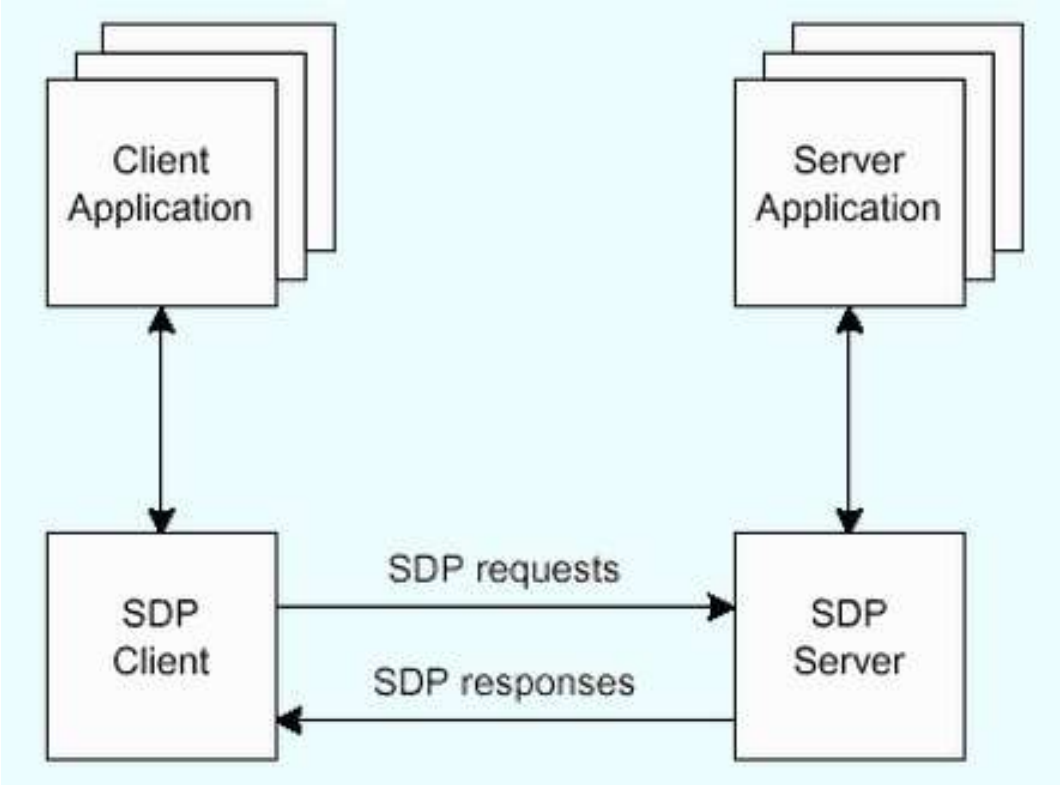
- Bluetooth allows multiple devices to cooperate in a master-slave relationship
  - a Piconet composed of
    - 1 master device
    - n slaves
- Designed for resource-constrained environments and to spend minimal bandwidth
- Bluetooth is not designed for IP-based networks
- Service Discovery in Bluetooth is powered by SDP

Related Works

Bluetooth SDP

- Each device can act as SDP client or server
  - Client discovers services provided by other devices
  - Service provides services
- Every service is described by a *service record (*set of service attributes)
- Every service belongs to a *service class:*
  - Type of the service
  - Set of attributes describing the specific service
- Services and attributes are uniquely identified with pre-defined IDs

Related Works
Bluetooth SDP



Related Works

Bluetooth SDP

- SDP defines 3 search modes
  1. Service Search: to search for a specific service identified by an ID. The client will receive a bunch of service records
  2. Attribute Search: to search for a set of attributes with respect to a specific service
  3. Service and Attribute Search: to search for a service and to fetch a list of relevant attributes

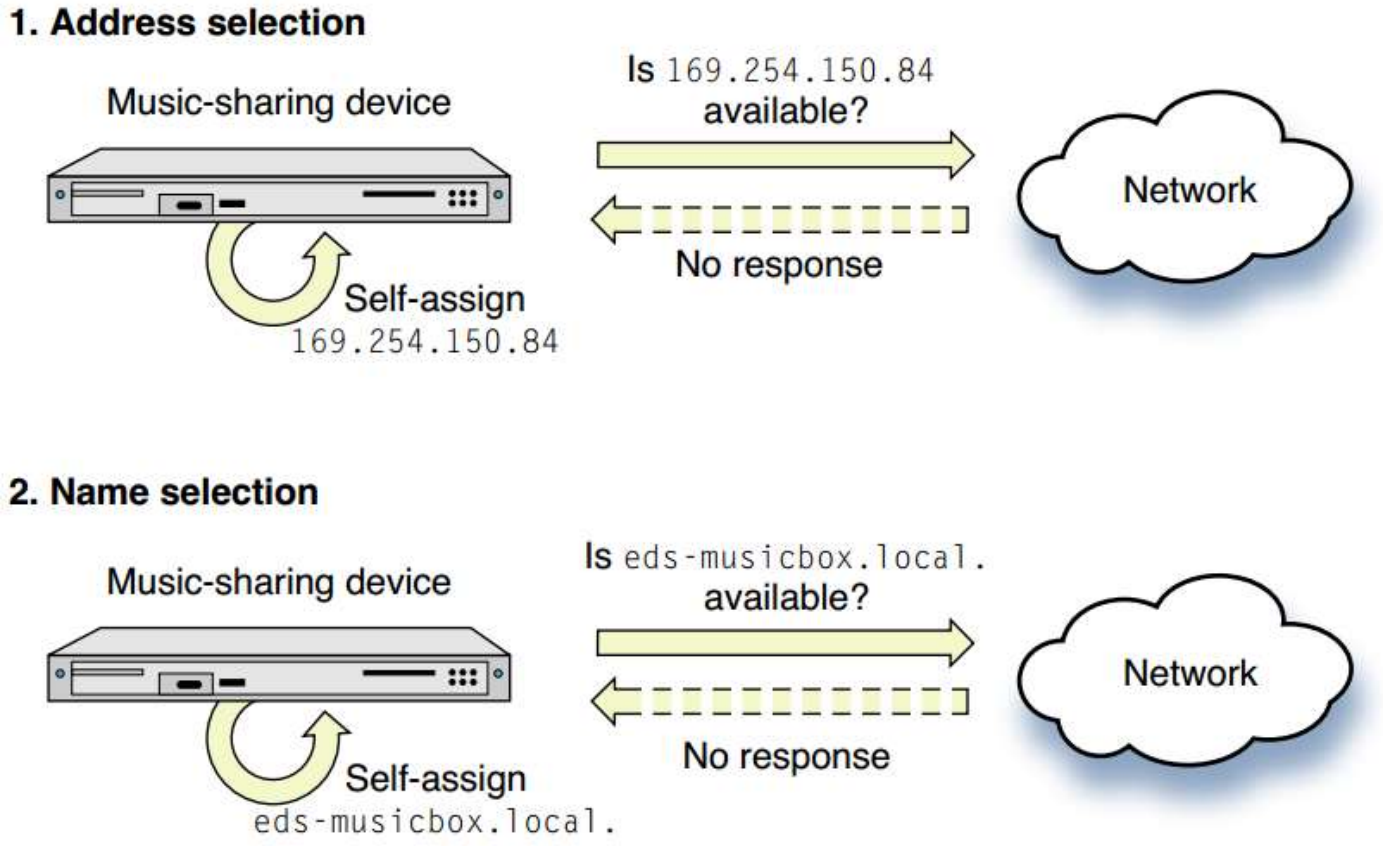
Related Works

Bonjour

- Bonjour protocol is promoted and supported by Apple
  - Successor of Appletalk
  - Implementation of Zeroconf IETF protocol
- Bonjour is designed for local and ad-hoc IP-based networks
  - Decentralized architecture
  - Relies on multicast and DNS technologies
- Bonjour covers 3 areas:
  - Addressing
  - Naming
  - Service Discovery

Related Works

Bonjour



https://developer.apple.com/library/mac/documentation/Cocoa/Conceptual/NetServices/NetServices.pdf

Related Works

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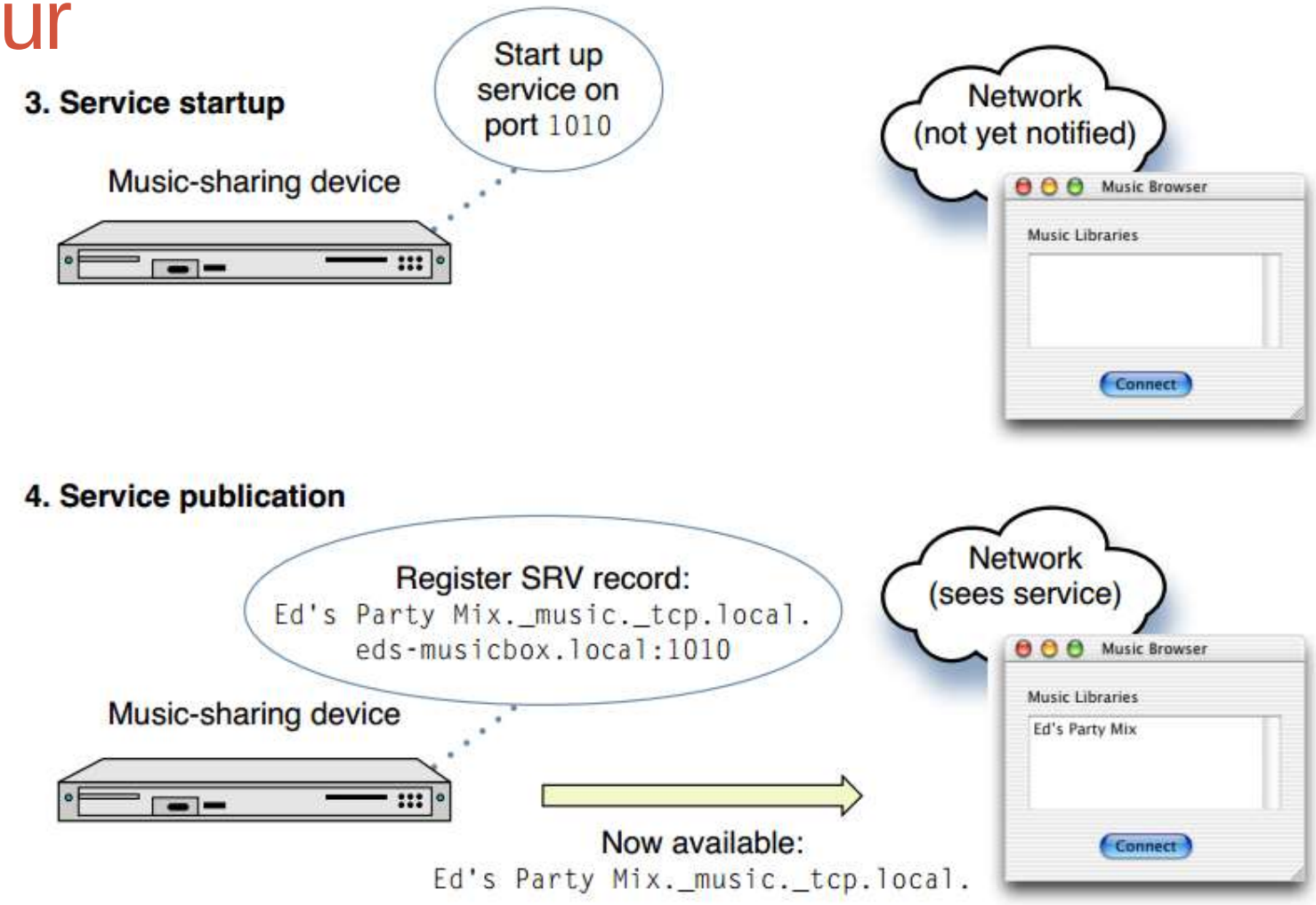

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Related Works

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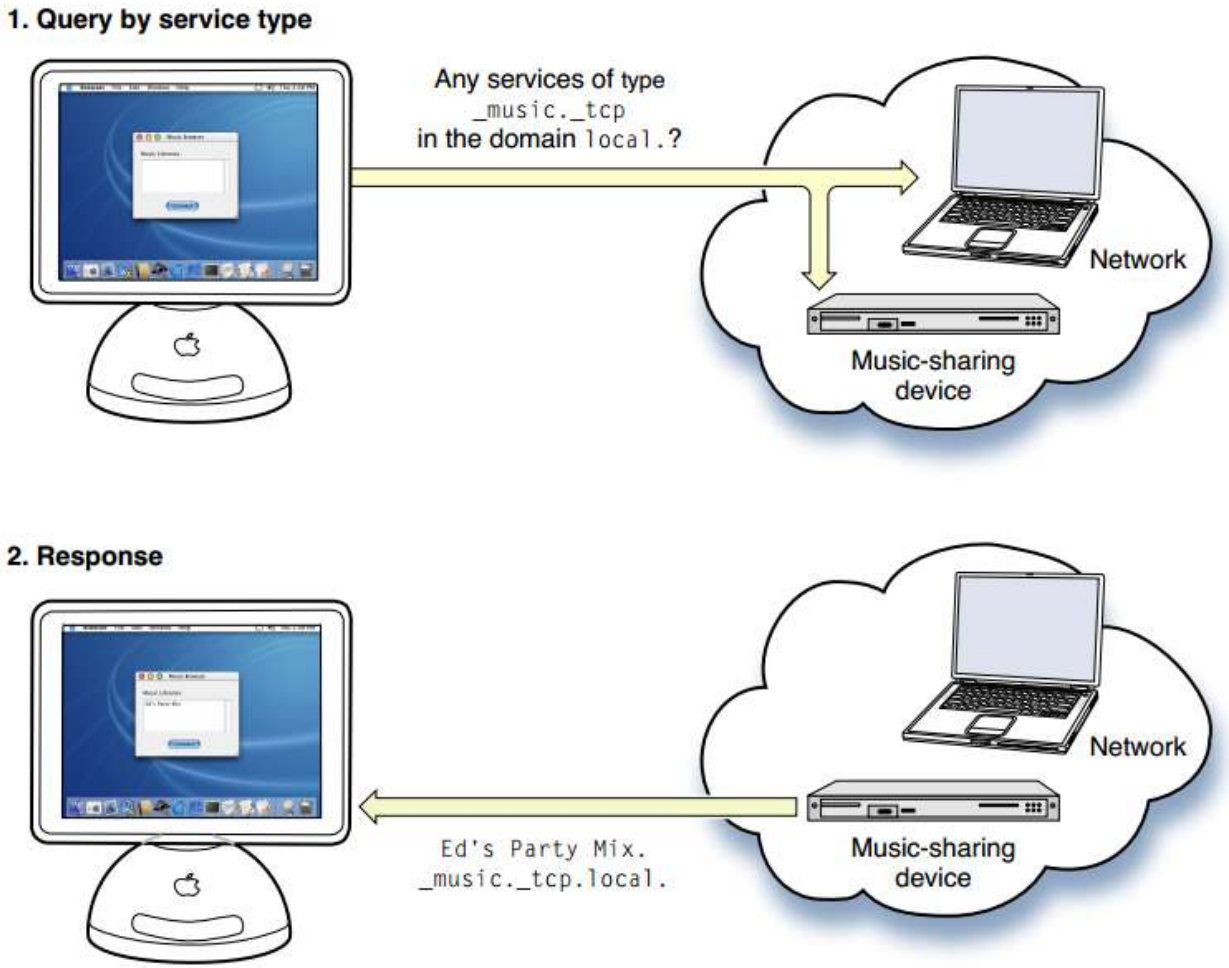

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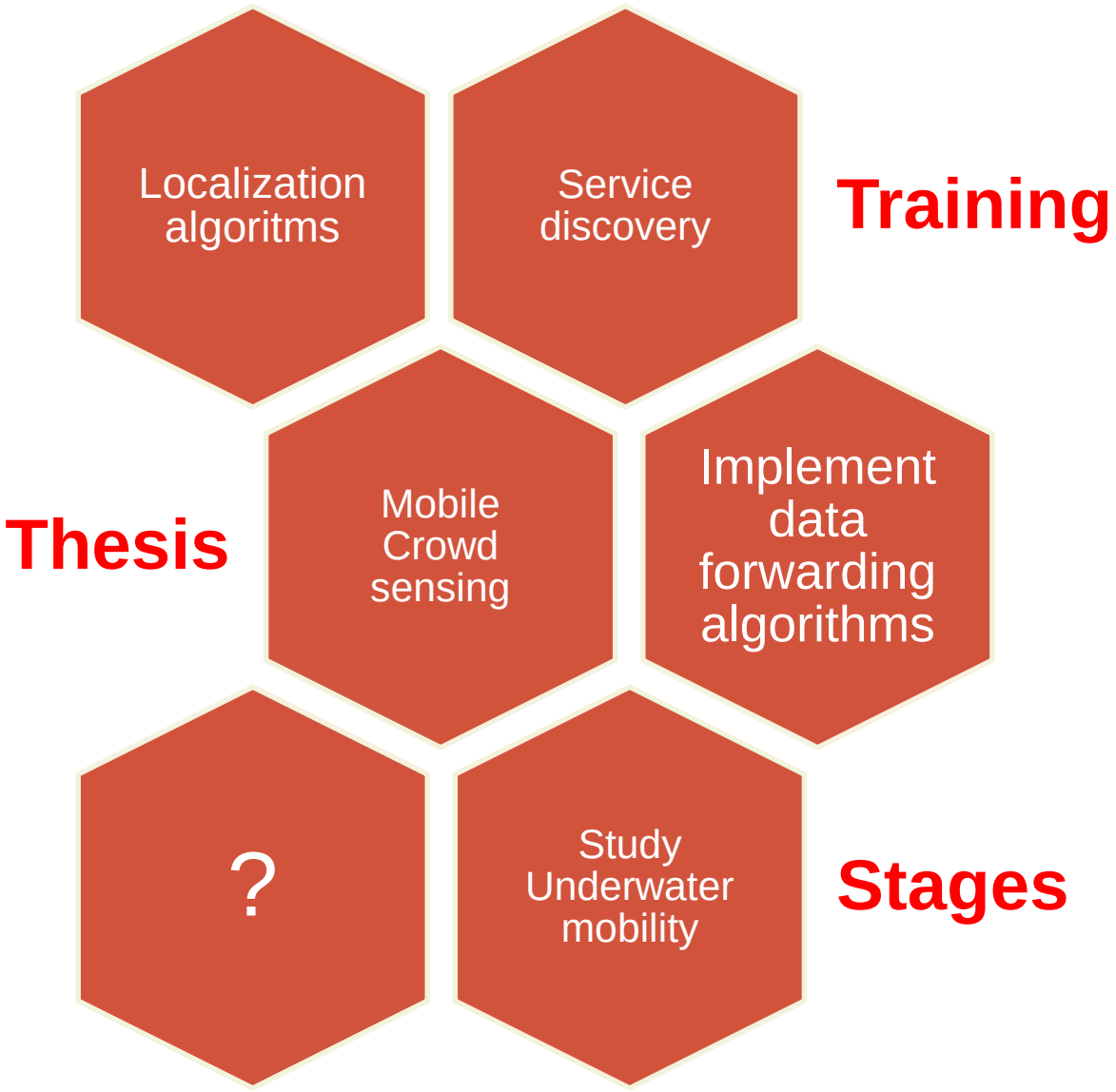
Thesis



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