Service Discovery and Provision for Autonomic Mobile Computing

George C. Polyzos, *Chris N. Ververidis, Elias C. Efstathiou*

Mobile Multimedia Laboratory

Department of Computer Science
Athens University of Economics and Business
Athens 104 34, Greece

polyzos@aueb.gr, http://mm.aueb.gr/

Tel.: +30 210 8203 650, Fax: +30 210 8203 325

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Outline

- Introduction
- Context-aware service publishing, discovery, and access for mobile servers with an infrastructure
- Autonomic service discovery in MANETs
- (Autonomic) incentives-based P2P service provision
- Conclusions

Introduction

- Primary goal of Autonomic Systems:
  Self Management
  - Self Configuration
  - Self Optimization
  - Self Healing
  - Self Protection…
- Self Management for **Mobile Communication and Pervasive Environments (MCPE)**

Flexible Service Discovery

& Flexible (& autonomous) Service Provision

encourage cooperation

Service Discovery

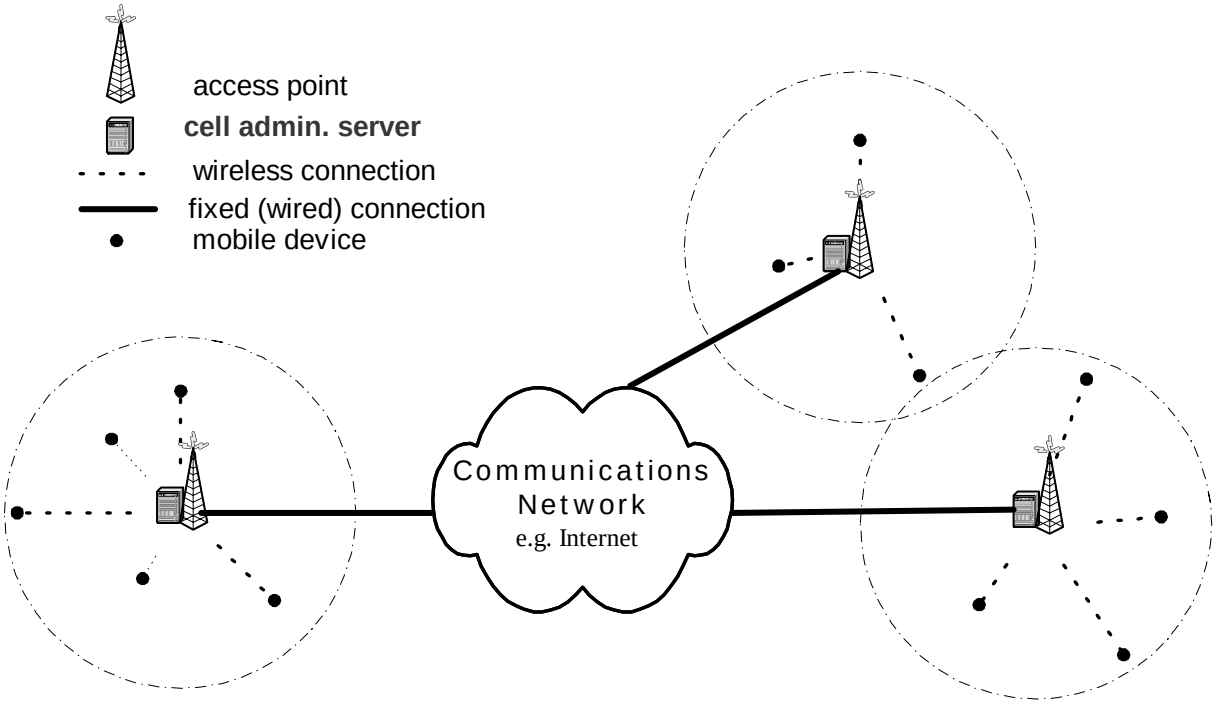
- Basic assumption for Service Discovery
  - All nodes run the ***same discovery protocol***
- However in heterogeneous environments nodes have :
  - ***different capabilities***
    - CPU, Memory, Battery
    - interfaces
  - ***different usage patterns***
  - ***different goals, requirements, etc.***
- ***approach:***

Negotiable Service Discovery

Context-aware service discovery, publishing, and access over a (Global) infrastructure

- The ***MobiShare*** architecture
  - part of project DB Globe (IST/FET FP5)
- Distributed, possibly global, system through which:
  - **Mobile servers** publish services
  - Mobile users discover and access services
- No human intervention for low-level management of the system

The *MobiShare* Architecture



Autonomic Aspects of *MobiShare*

- System Characteristics
  - Self configuration for service publication
  - Self optimization
    - Context based filtering of service replies + semantic matching
  - Self healing
    - Service replication on the infrastructure and/or service provider "handover"
- Use of Ontologies
  - for service description etc.

Autonomic Service Discovery in MANETs

- Distributed
  - Cooperative P2P discovery (no directories)
- Ontology-based
  - Semantic matching (e.g. "currency conversion"="currency exchange")
- Context-aware
  - Adaptation of discovery based on high-level policies (e.g. energy consumption minimization)
- Policy-driven
- Group/election based
- Recoverable

Autonomic Framework for Service Discovery in MANETs

- General Framework for disseminating the way that service discovery should be performed
  - according to the “common” goal of **some** nodes/users
  - different parts of a MANET may have different goals
  - tuned per area, according to the nodes’ needs and capabilities

Autonomic Service Discovery Framework

- **Split service discovery into tunable components**
  - Similar approach to autonomic routing (R. Braden *et al.* 2003)
- **Programmable Components**
  - **Service Advertisement**
    - Query vs. Announcement
    - Flooding vs. Zone-Based
  - **Service Selection**
    - Location Based vs. Energy Conservation Based
  - **Service Recovery**
    - Statefull vs. Stateless

Autonomic Service Discovery Framework: an Example Realization

Goal: "**Minimize**" total **energy** consumption and **avoid** single server drainage

Framework Interpretation:

- avoid use of flooding
- perform localized service discovery (e.g. up to 2 hops)
- use pull techniques
- include current energy constraints and load information data in service replies

Autonomic Service Discovery in MANETs Open Issues

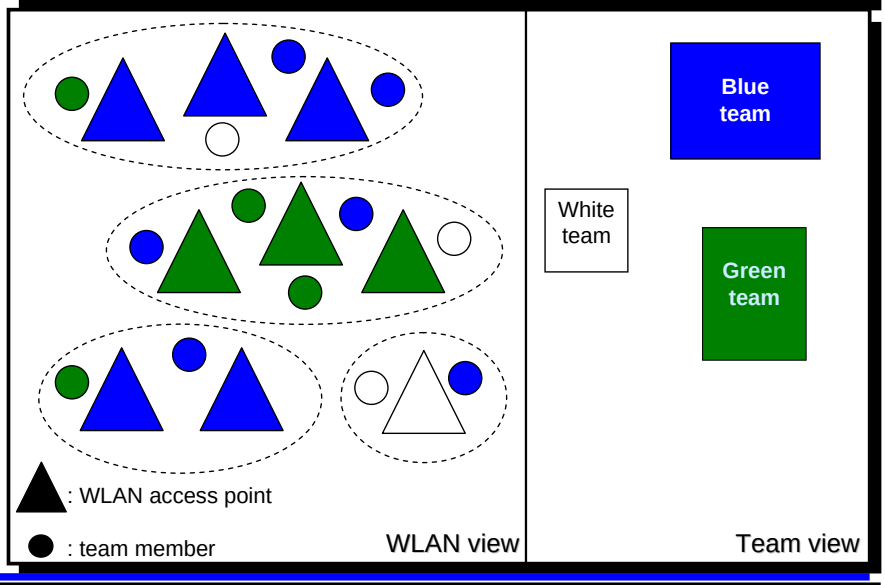
- How do we **select tunable components** to include in the Framework?
- How often can we **refresh** area-wide **policies and goals**?
- How can we allow and support **different deployments** of the service discovery approach in **different areas**?
- How can we **aggregate information** from neighboring areas with **different goals** and hence different ways to perform service discovery?

Autonomic, Incentive-based Service Provision

- The **P2PWNC** Case (= P2P Wireless Network Confederation)
  - totally distributed
    - no CA, cheap IDs ⇒ Sybil attack
  - selfish peers

P2PWNC: An incentives-based P2P system

- Teams provide WLAN access to each other
- Teams should provide in order to consume



Motivation: The Public Hotspot Market

From Gartner:

- 2001: **1200** public hotspots worldwide
- 2003: **71 000** public hotspots worldwide
- 2005: **23 500** WLANs in hotels worldwide

A subscription buys you (June 2005):

- Sprint PCS: **19 000** hotspots worldwide
- Boingo Wireless: **17 400** hotspots worldwide
- T-Mobile HotSpot: **16 663** hotspots worldwide

Sprint. BOINGO WIRELESS T-Mobile HotSpot

SKYHOOK WIRELESS

Skyhook Wireless data (2005):

- **50 000** WLANs in just 5 Massachusetts cities and towns (Watertown, Brookline, Roxbury, Newton, and Cambridge)

P2P Systems

General term

- Usually associated with **file sharing** systems
- Also includes:
  - **Grids** (computation)
  - **(Mobile) ad hoc networks** (packet forwarding)
  - **Distributed Hash Tables** (scalable, fault-tolerant storage)
  - **eBay-like** (electronically mediated communities of providers and consumers)

Distinctive characteristics

- Peers act as both providers and consumers of resources
- System relies on peer cooperation
- Free-riding will prevail if:
  - there is a cost involved with providing resources
  - there are no authorities that can punish or reward
  - exclusion from consuming the shared resources is impossible

Incentive Schemes for P2P

Micropayments

- Digitally signed tokens used as payment
- Requires online bank to check for double spending (and to issue the credits)

Yang, Garcia-Molina, "PPay: Micropayments for P2P Systems," ACM CCS'03

Tamperproof modules

- Each peer maintains its own account balance
- Increase when providing, decrease when consuming

Buttyan, Hubaux, "Stimulating Cooperation in Self-Organizing MANETs," ACM/Kluwer MONET 2003

Multiple account holders

- Other peers maintain a peer's account balance
- Use majority rule in case of disagreement

Visnumurthy, Chandrakumar, Sirer, "Karma: A Secure Economic Framework for P2P Resource Sharing," p2pecon'03

P2PWNC Design Principles

Why P2P?

- A lot of underexploited WLANs out there set up by individuals
- Hotspot operators (in the "centralized model"):
  - operate only a small fraction of the WLANs out there
  - further segregate WLANs by competing for venues among themselves

Micropayments, tamperproof modules, multiple account holders: Why choose another incentive scheme?

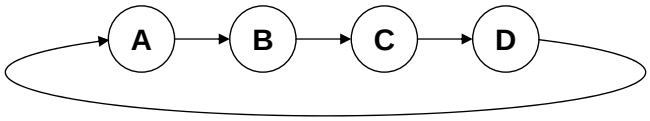
- Require central authority (micropayments)
- Are unrealistic (tamperproof modules)
- Assume peers want to keep accounts for others and/or perform auditing
  - by trying to encourage "account holding" we get back where we started

We need a simple incentive scheme that will encourage participation and cooperation, even at the expense of accurate accounting

N-way Exchanges

Adopt N-way exchanges as the incentive scheme

- A generalization of barter, which retains some of its simplicity
- "Provide to those [who provided to those]* who provided to me"
- A type of **indirect reciprocity** (sociology)
- Scales to larger populations, compared to direct-only exchanges
- Does not require (central or distributed) authorities



Some variants of the basic N-way scheme:

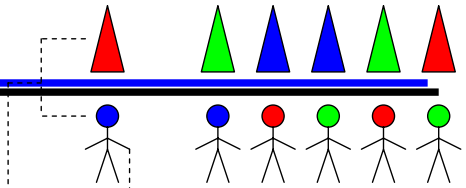
Cox, Noble, "Samsara: Honor Among Thieves in P2P Storage," SOSP'03

Ngan, Wallach, Druschel, "Enforcing Fair Sharing of P2P Resources, " IPTPS'03

Anagnostakis, Greenwald, "Exchange-based Incentive Mechanisms for P2P File Sharing," ICDCS'04

Feldman, Lai, Stoica, Chuang, "Robust Incentive Techniques for P2P Networks," ACM EC'04

System Entities



Team = Members + Access Points (APs)

- Teams := P2PWNC peers
- Assume intra-team trust
- Team ID = (unique) PK-SK pair

PK: public key
SK: private key

Member certificate

- Member ID = (unique) PK-SK pair
- Member certificate binds Member PK to Team PK

Receipt

- Encodes P2PWNC transactions between teams
- Signed by consuming member
- Receipt weight: amount of bytes the AP forwarded

Cooperation Strategies

Three cooperation **strategies** tested so far, each one:

- Uses a different **decision algorithm**
  - Input: the receipt graph
  - Output: a decision of whether to provide service or not
- May use a different **gossiping algorithm** (in the decentralized case)
  - Different ways to choose the receipts that roaming members carry
- May use a different **bootstrap algorithm**
  - New teams need to provide before starting to consume
  - For how long, and to whom?

Specific decision algorithms include:

- **N-WAY** (assumes unit weights on receipts [Efstathiou & Polyzos, "Self-Organized Peering of Wireless LAN Hotspots," *ETT*, vol. 16, no. 5, 2005] **)**
- **maxflow** (borrowed from Feldman, Lai, Stoica, Chuang, "Robust Incentive Techniques for P2P Networks," ACM EC'04)
- **Generalized maxflow**

Progressively more robust against double-spending and collusion

Zero Configuration inter-WLAN service with Linksys WRT54GS APs

Linux-based WLAN access point

- We implemented the P2PWNC protocol (AP side) on it (ECC…)
- 32 MB RAM, 8 MB Flash, 200 MHz CPU
- Retails for less than $70
- Cryptographic, maxflow performance comparable to 200 MHz PC
- Can act as home repository (storing more than 10 000 receipts)

Conclusions

- Enablers for Autonomic Computing and Communications
  - Context sensing / awareness
  - Ontologies
  - Adaptive composition of strategies
  - Local (group) decisions about (distributed) selection of strategy composition (among different **compatible** strategies)
  - Incentives for
    - service provision, but also…
    - information dissemination and adhering to protocols…
  - Interesting General Incentives Mechanisms
    - Indirect Reciprocity or N-way Exchange
    - others…

Thanks!

George C. Polyzos

Joint work with my students

Chris Ververidis & **Elias Efstathiou**

Mobile Multimedia Laboratory

Department of Computer Science

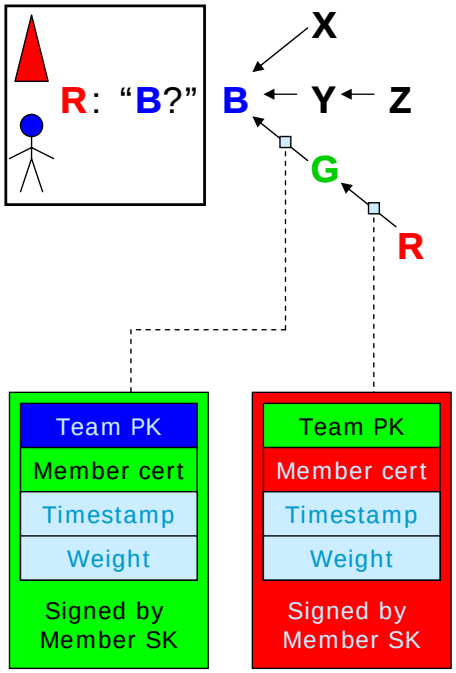
Athens University of Economics and Business

http://mm.aueb.gr/

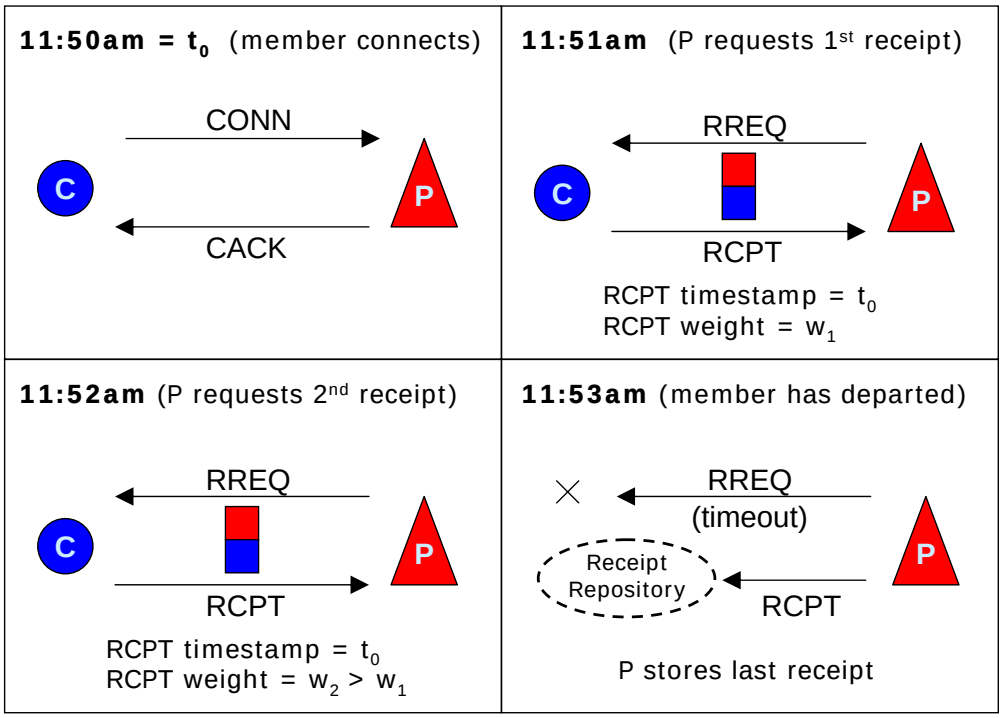
The NWAY Decision Algorithm

Searches for potential N-way exchanges

- **Red** provides to **Blue** if there is a chain of receipts connecting **Red** to **Blue**
- **Red** then **discards** all receipts in the discovered chain

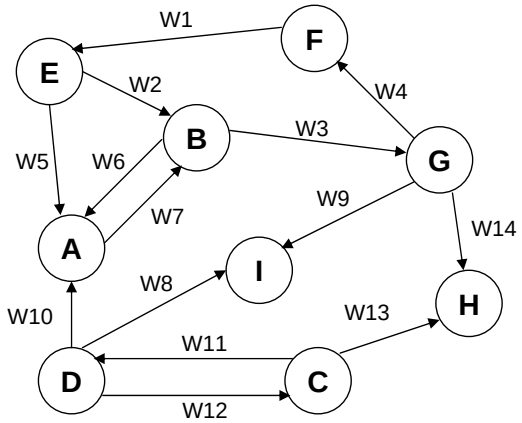


Receipt Generation



The Receipt Graph

Directed weighted graph (with cycles)



Graph security

Free-riders and colluders **can** create an arbitrary number of fake vertices and edges

They **cannot** create fake outgoing edges starting from teams who are outside the colluding group (they do not have the relevant private keys)

Vertices: team public keys
Edge weight: sum of weights of corresponding receipts

Edges point from the consuming team to the providing team

Receipt Repository

Two options:

- **Centralized repository**
  - Requires a well-known server that all teams can agree on
  - All receipts are visible by all teams
  - Server drops oldest receipts when full
  - Mostly used to gauge the effectiveness of decentralized repositories
  - Could have some practical importance
- **Decentralized repository**
  - Each team maintains its own private repository
  - Fills it with receipts it receives during a WLAN transaction
  - And with receipts it receives when **gossiping**

Gossiping algorithm:

- Roaming members carry receipts from their team repositories
- They present them to the teams they visit
- With RSA-1024 keys, a receipt is about 650 bytes long
- With ECC-160 keys, a receipt is about 150 bytes long

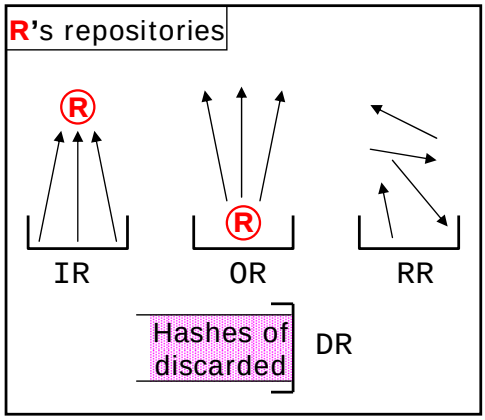
NWAY: Space Requirements

Each team maintains 4 receipt repositories

- IR – Incoming Receipts
- OR – Outgoing Receipts
- RR – Random Receipts
- DR – Discarded Receipts

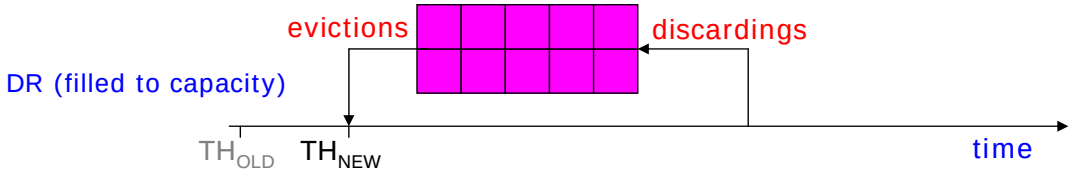
holding up to s_{IR}, s_{OR}, s_{RR}, s_{DR} entries

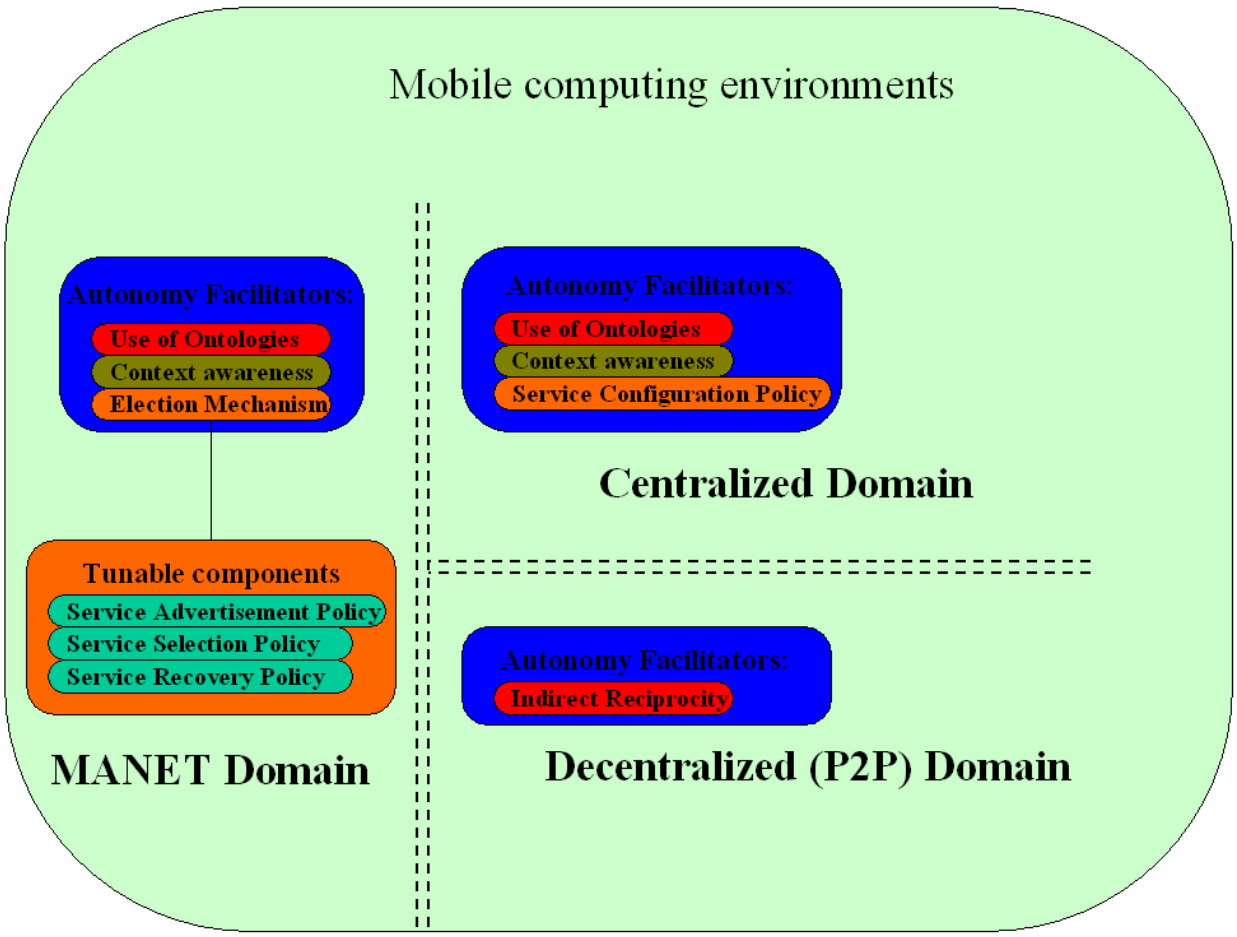
replacement rule: **delete oldest receipt**

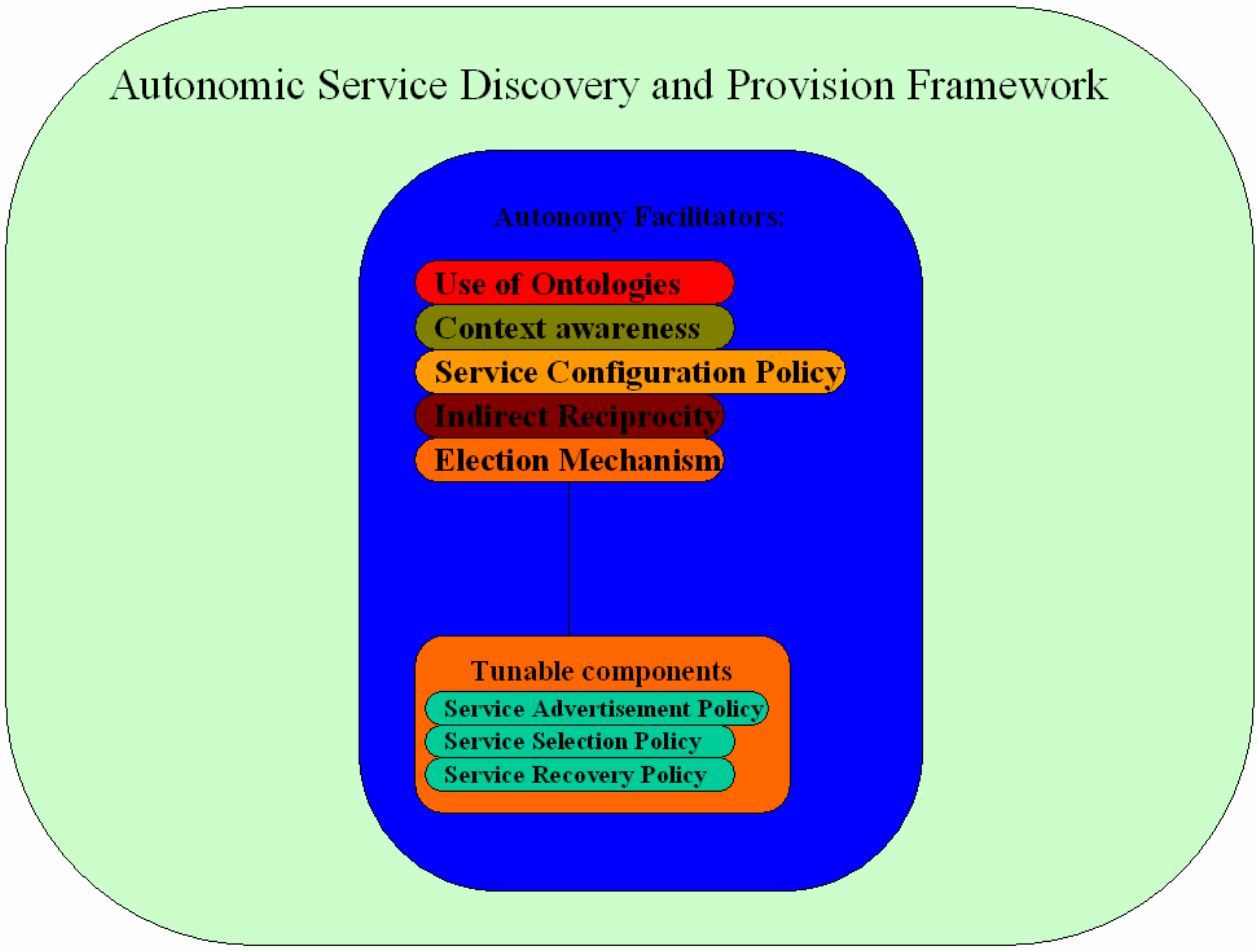


Each team has a Time Horizon (TH)

- When DR overflows, TH holds the timestamp of the receipt that was just evicted
- TH and DR allow ignoring **all** discarded receipts (at a cost…)




Mobile computing environments
Autonomy Facilitators:
Use of Ontologies
Context awareness
Election Mechanism
Tunable components
Service Advertisement Policy
Service Selection Policy
Service Recovery Policy
MANET Domain
Autonomy Facilitators:
Use of Ontologies
Context awareness
Service Configuration Policy
Centralized Domain
Autonomy Facilitators:
Indirect Reciprocity
Decentralized (P2P) Domain


Autonomic Service Discovery and Provision Framework
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