Recovery in Autonomous Robot Swarms

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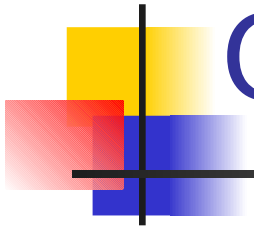

Outline

- Background
- Architecture
- Proposal
- Conclusion

Swarm of robots

- Several simple robots realizing a complex process
- Advantages
  - Low cost robots
  - Adaptability
- Drawbacks: subject to failures
  - Environment (loss, destruction)
  - Hardware

Swarm robots

- No global network!
  - Expensive
  - Global coverage
    - Dead zones
    - Radio interference
  - Hard to deploy
    - Dangerous area
    - Exploration area
- Opportunistic Short-Range Communications (SRC)

Recovery with SRC

- Recovery of the process after a failure
  - Plan repair
- Knowledge for plan repair
  - How to do it
  - Data about past actions
    => Availability?

And when network connection is scarce?

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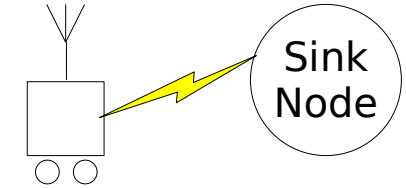
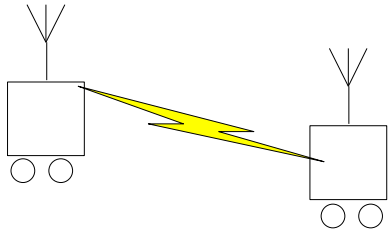
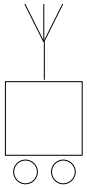
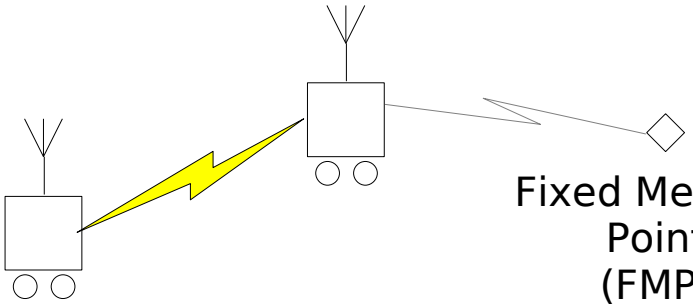
Architecture



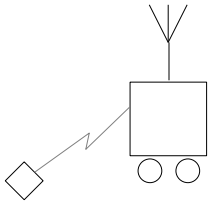
Mobile
Entity



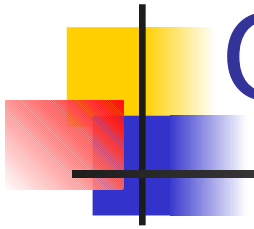




Fixed Memory
Point
(FMP)



Sink Node: Service room with a fail-safe server
Mobile Entity: Robots
FMP: RFID, Motes



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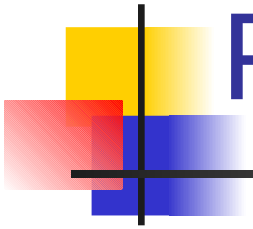
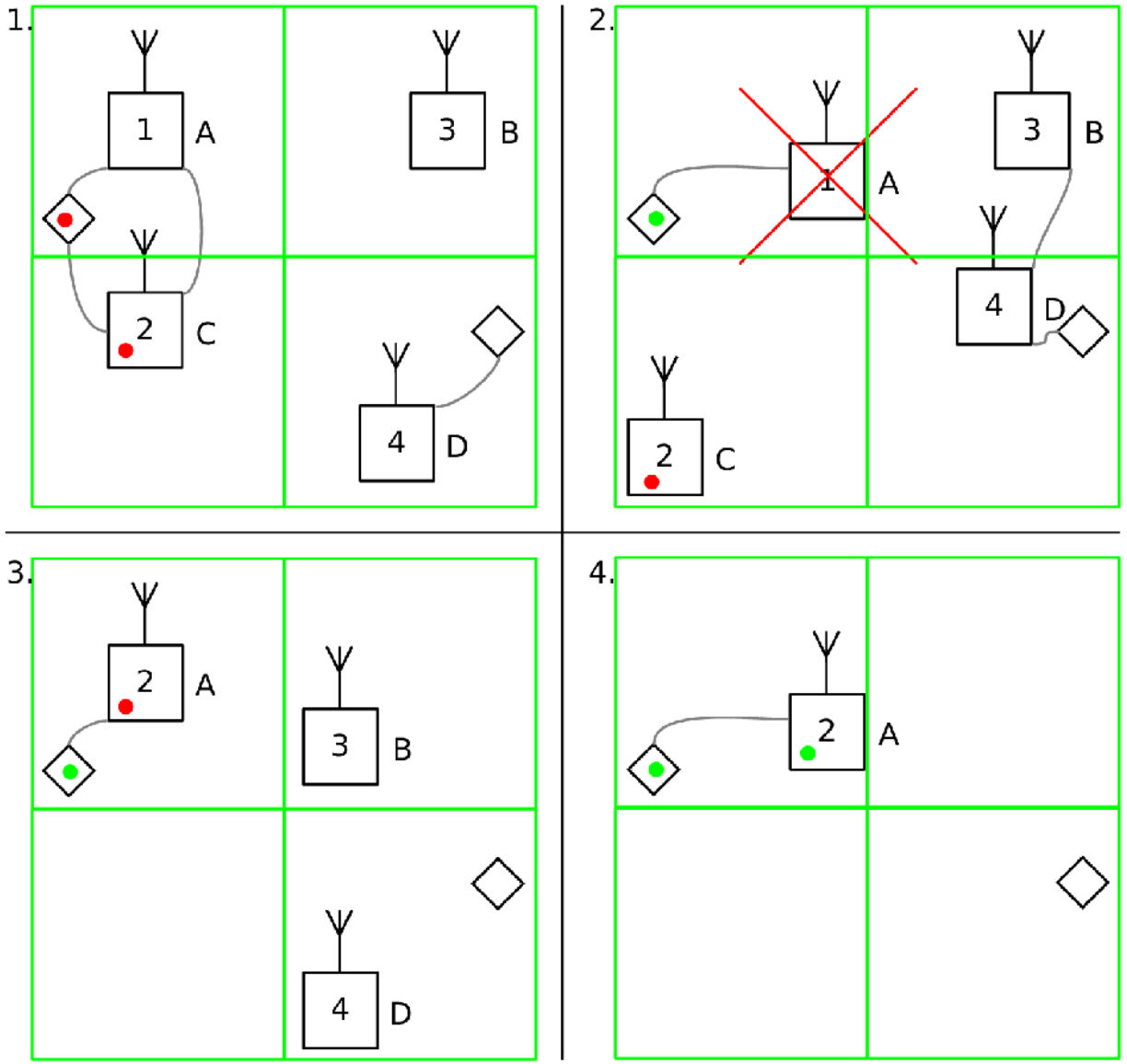
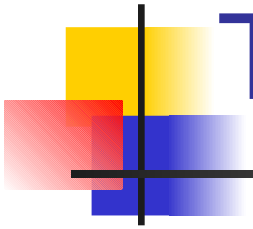


Proposal

- Backup of the state of the swarm
  - Goal: minimal cost of process resumption
  - Using: encounters and spontaneous communications

Proposal

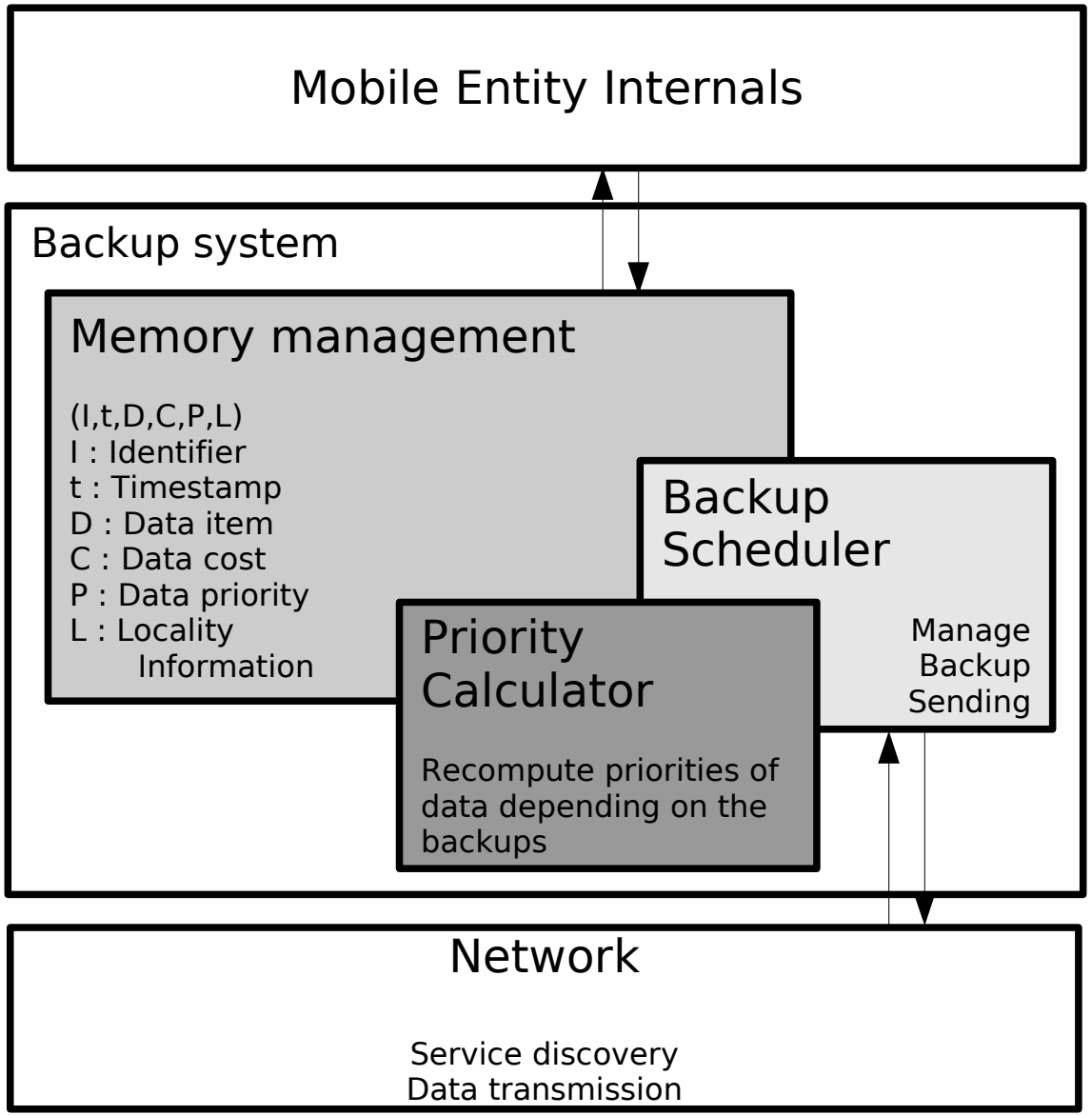




Tasks

- Decomposition into atomic tasks
- Each task has its data
  - Costs: time, energy, consumable
  - Priorities
    - Extracted from the costs
    - Decreased after a successful backup

System Scheme



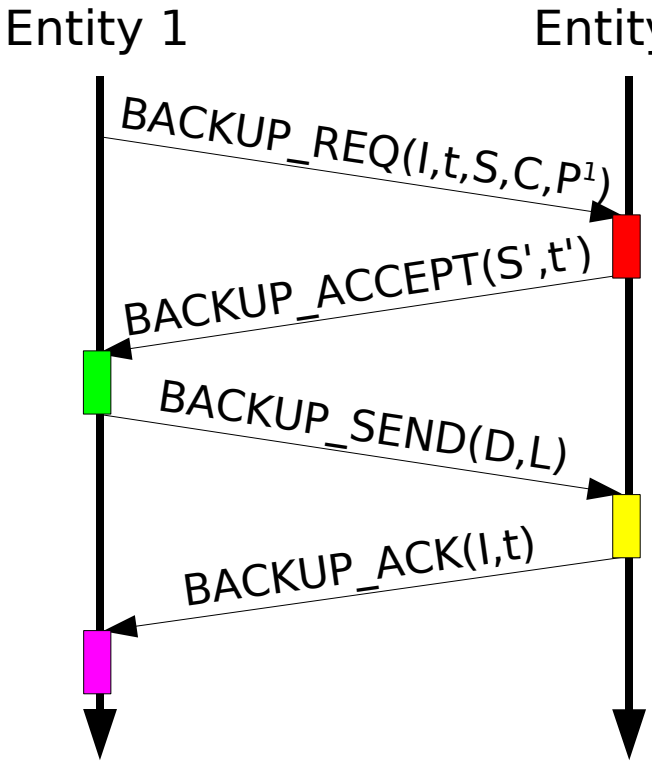
Backup: Memory

- Deletion of old replicas
- Memory space liberation
  - Deletion of lower priority data items
- Data reconciliation

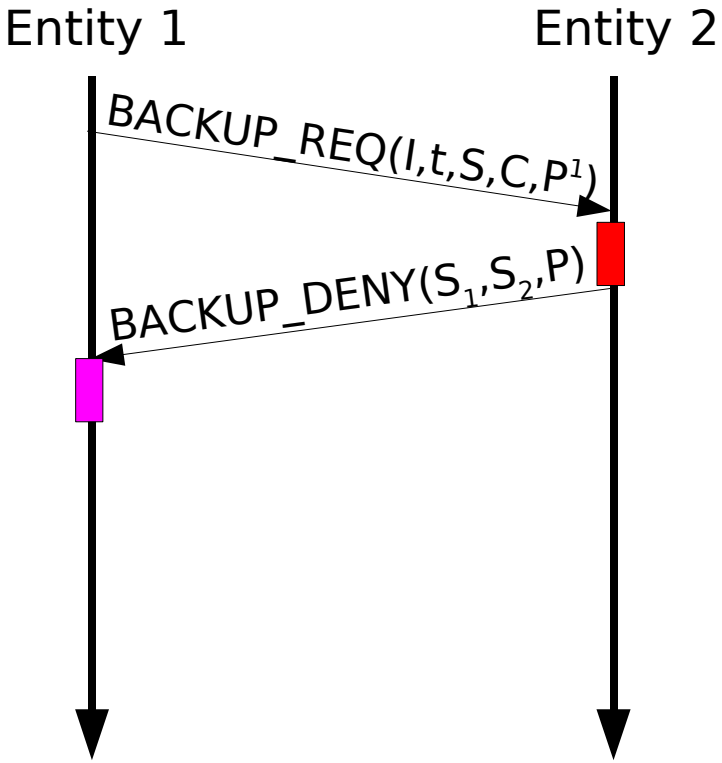
Backup: Scheduling

- When a robot encounters another:
  - Priority of data items:
    - P_i^1: When saved on both entities
    - P_i^2: When deleted from both entities
  - Order of data items:
    - Sent: descending P_i^1
    - Deleted: ascending P_i^2
- Backup acceptance phase is started on reception

Backup: Network



Backup is accepted



Backup is refused

- Backup acceptance
- Backup store
- Backup preparation
- Memory update and next round

Backup: Acceptance phase

- If there is enough memory space for backup update => BACKUP_ACCEPT
- If $\exists j \; s.t. \; (AMS + \sum_{i=1}^{j} S_i < \Delta S) \wedge (\forall i \in [\![1, j]\!], P_i^2 < P^1)$ => BACKUP_ACCEPT
- Else => BACKUP_DENY

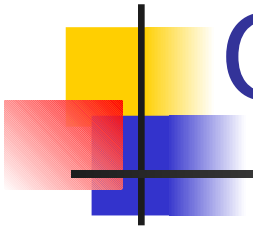
AMS = Available memory space

Recovery

- Data reconstruction
  - Merging the available data
  - Estimation of the final task
  - Continuous updates
    - Newer backup from encountered robots
    - Exploit comparison of costs
- Process reconstruction
  - With standard replanning

Failure detection

- Emergency signal
  - Flooding
  - Global network if available
- Failure to report
- Detection by another robot



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Conclusion & Future Work

- A backup system was proposed for disconnected swarm robots
- Proof of concept simulation
  - 50% reduction of the overhead from the data loss
- Ongoing:
  - Player/Stage simulation
  - Bidding planning system for a map construction process
  - Evaluation: cost and efficiency

Questions?

Back to global coverage

- Cellular coverage
  - Expensive
  - Dead zones
- Satellite coverage
  - Open-space only
  - Dead zones
  - Very expensive
- Short-range coverage
  - Wifi: max. 100 meters indoor, 50 meters outdoor (- interferences).
  - BlueTooth: max. 10 meters (real situations 5 meters)