Experience and Prospects for Various Control Strategies for Self-Replicating Multi-Agent Systems

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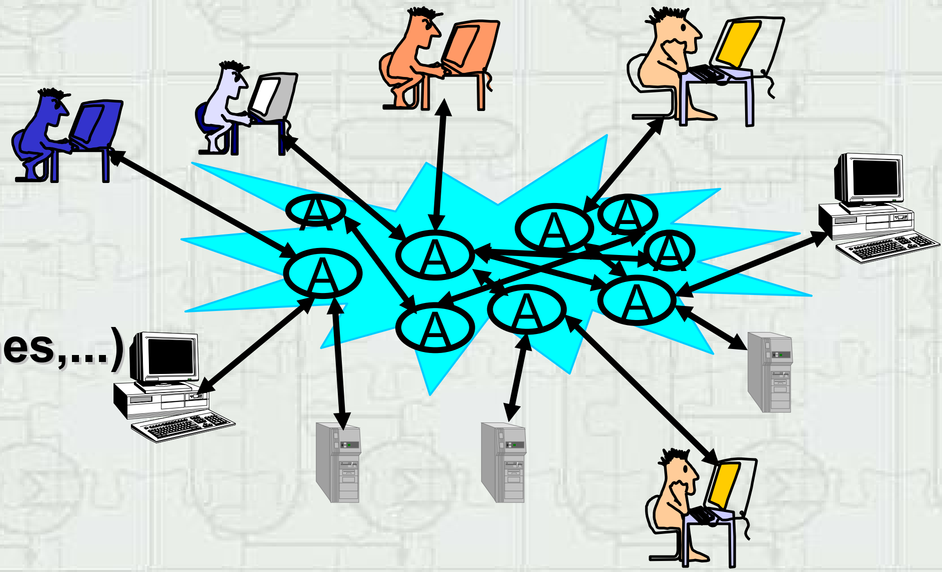
Fault-Tolerant MAS

- **Large-scale multi-agent systems**
  - Physically distributed
  - Dynamic environment (with limited resources)

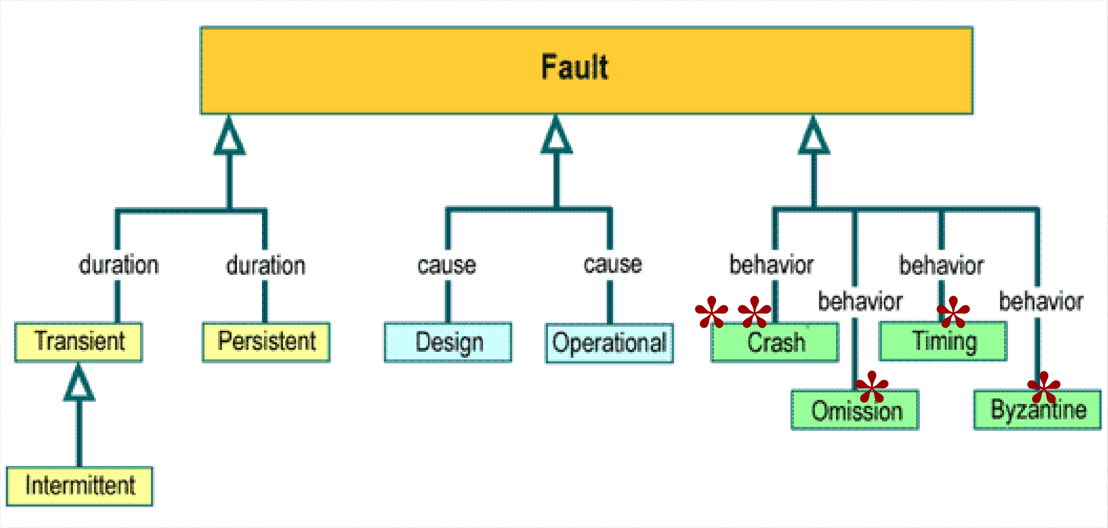


- **Types of failures**
  - Software (bugs, deadlocks, ...)
  - Hardware (Network links, machines,...)

» **How to avoid failures ?**

Fault Classifications

- **Based on how a failed component behaves once it has failed, faults can be classified into 4 categories: crash, omission, timing or Byzantine.**
  - **Crash faults: the component either completely stops operating or never returns to a valid state;**
  - **Omission faults: the component completely fails to perform its service;**
  - **Timing faults: the component does not complete its service on time;**
  - **Byzantine faults: these are faults of an arbitrary nature.**



Replication

- **Existing solution: Replication strategies**
  - Replication of data and/or computation is an effective way to achieve fault tolerance in distributed systems.
  - A replicated software component is defined as a software component that possesses a representation on two or more hosts.

- **Distributed applications:**
  - Small number of components
  - Component criticality is static
  - …

☞ **The number of replicas and the replication strategy are explicitly and statically defined by the designer before run time**

Agent Replication

- **Multi-agent application characteristics:**
  - adaptive agent,
  - large scale,
  - dynamic and adaptive organizational structures
  - …

- **Criticality (the number of replicats and the replication strategy) cannot be explicitly and statically defined by the designer before run time**

  - ***Automatically*** and ***dynamically*** apply replication mechanisms ***where*** (to which agents) and ***when*** it is most needed.

Dynamic Replication

- DarX: a new replication framework
  - http://www-src.lip6.fr/darx/
  - Large-scale distributed systems
  - Replication mechanisms
    - Several replication strategies (active, passive, hybrid…)
    - Dynamic replication: change dynamically the number of replicas and the replication strategy
  - Observation mechanisms
  - Fault detection/recovery mechanisms
  - Encapsulation of the system tasks into the replication group
    - Transparence of the replication regarding the other agents
    - Replication mechanisms are not attached to the DarX servers, they are attached to the replication groups
    - …

Automatic Replication

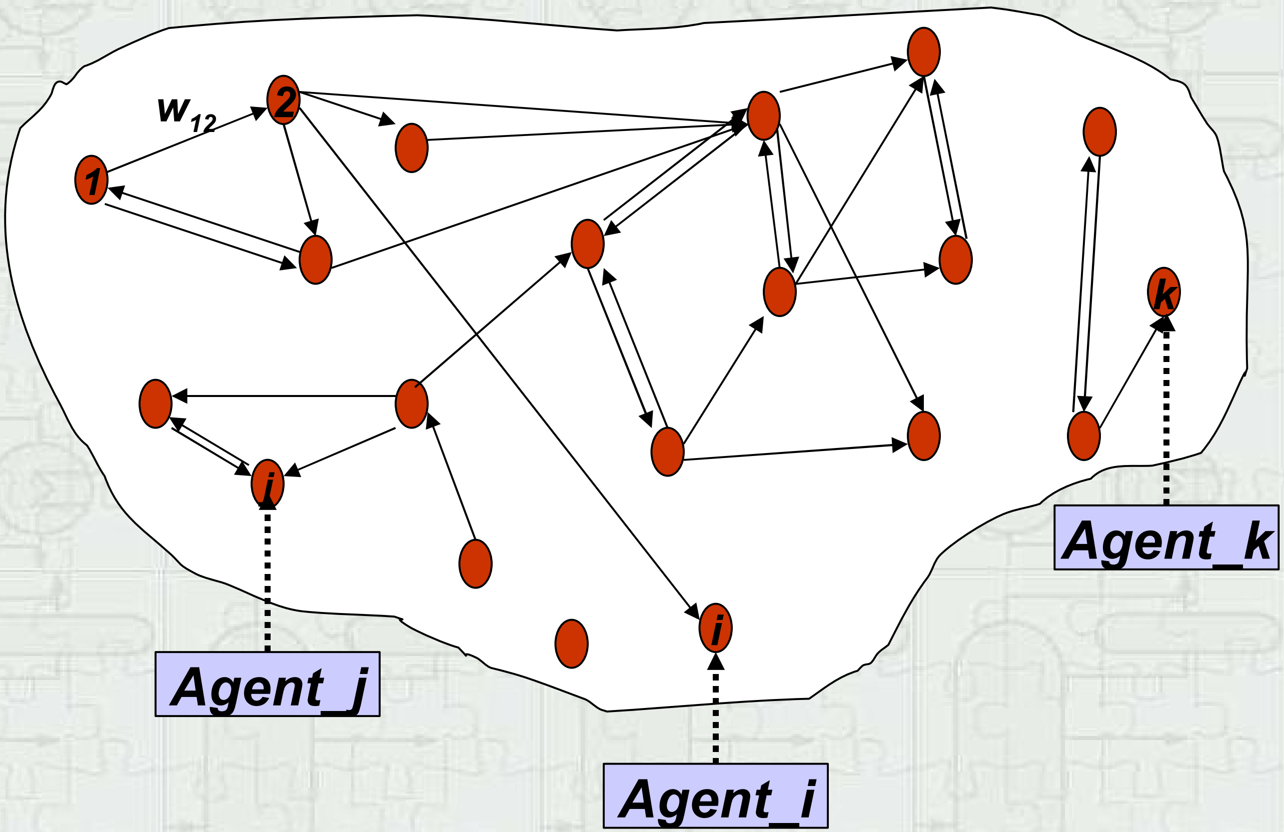
- **Adaptive Replication Mechanism**
  - Which agents need to be replicated and when?
  - What is the number of replicas?
  - Where?

Adaptive Control of Replication

- **Hypothesis and principles**
  - Automatic mechanisms
  - Some prior inputs from the designer of the application
  - Agents can be either reactive or deliberative
  - Agents can be heterogeneous
  - Agents communicate with some ACL (FIPA, …)
- **Agent criticality relies on Semantic-level information**
  - Roles [Selmas'03] [AAMAS'02]
  - Interdependence graph [AAMAS'04] [Selmas'05]
  - Plans
  - …

Interdependence Graph

- The arcs are labeled by any information which is susceptible to enable the detection or anticipation of undesirable behaviors



Interdependence Graph

- **Interdependence may be defined by considering**
  - NbM_{ij}: the number of messages received by *$Agent_i$* from *$Agent_j$*
  - $NbM(\Delta t) = Mop(NbM_{1,1}(\Delta t), NbM_{1,2}(\Delta t)\ldots, NbM_{n,n}(\Delta t))$

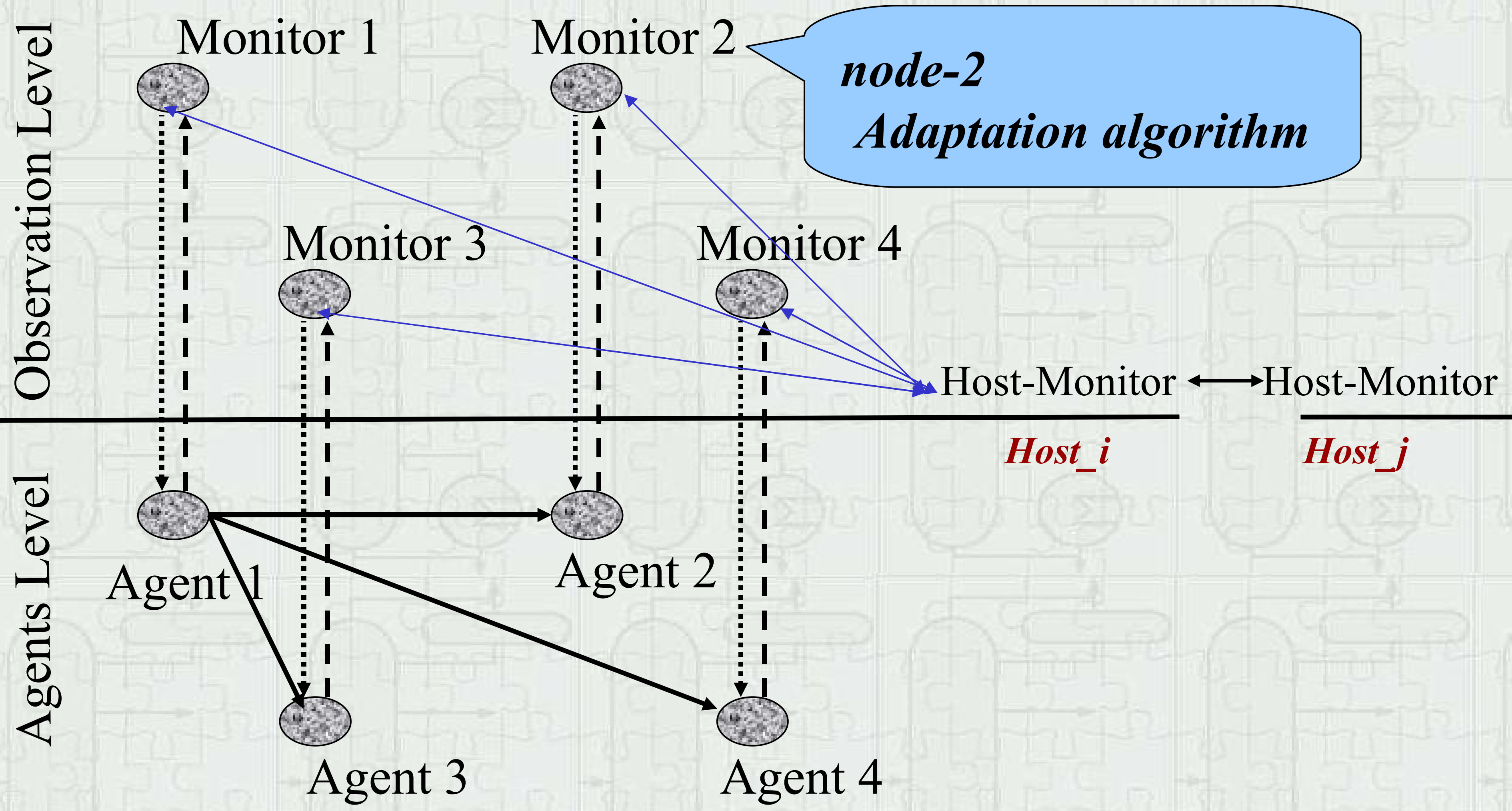
    Mop is the aggregation operator median.
  - Δt: monitoring is activated each Δt

- **A simple adaptation algorithm**

  $w_{i,j}(t0)$ initialized by the designer/user

  $w_{ij}(t + \Delta t) = w_{ij}(t) + (NbM_{ij}(\Delta t) - NbM(\Delta t)) / NbM(\Delta t)$

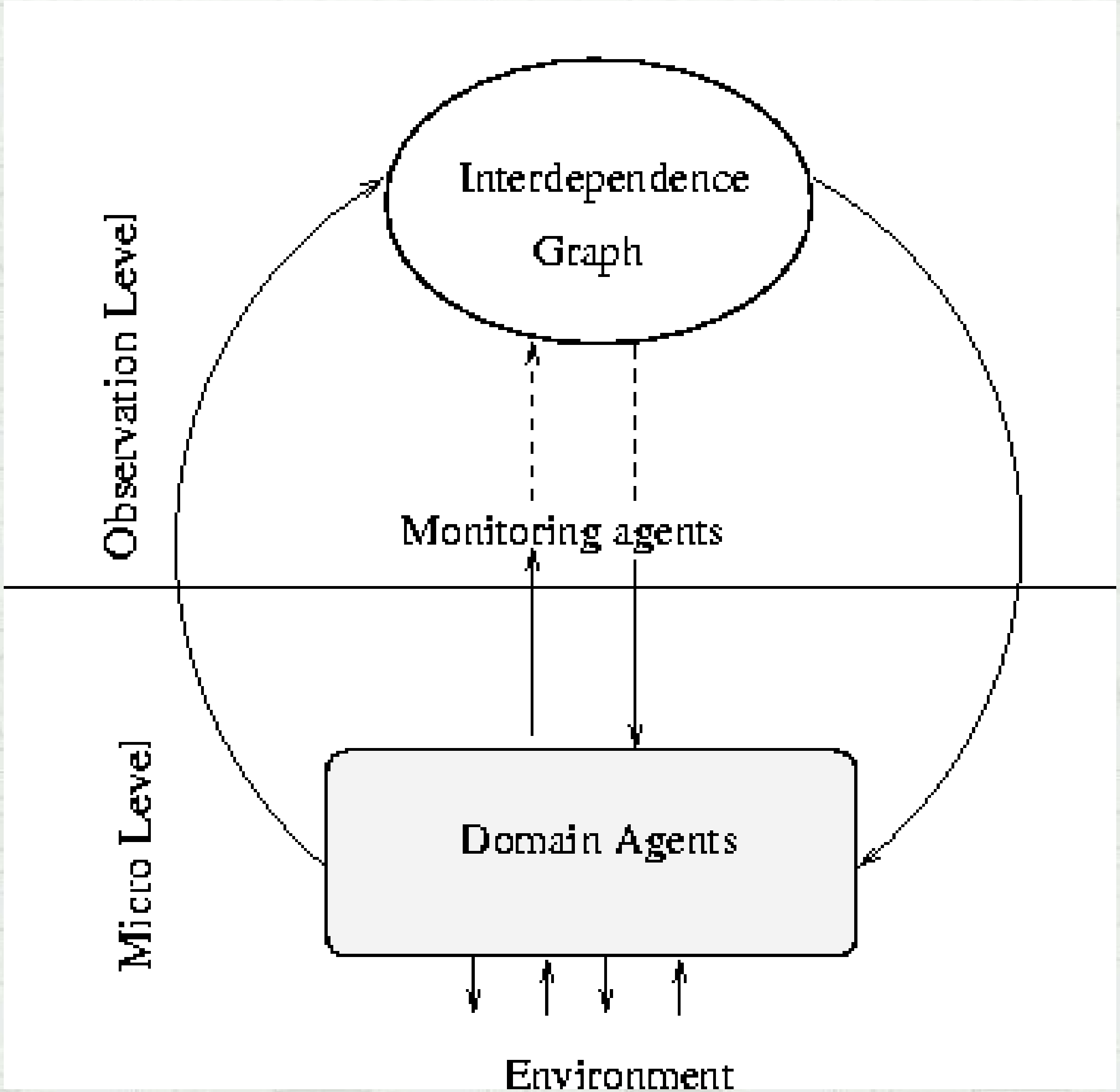
Multi-Agent Architecture



Multi-Agent Architecture

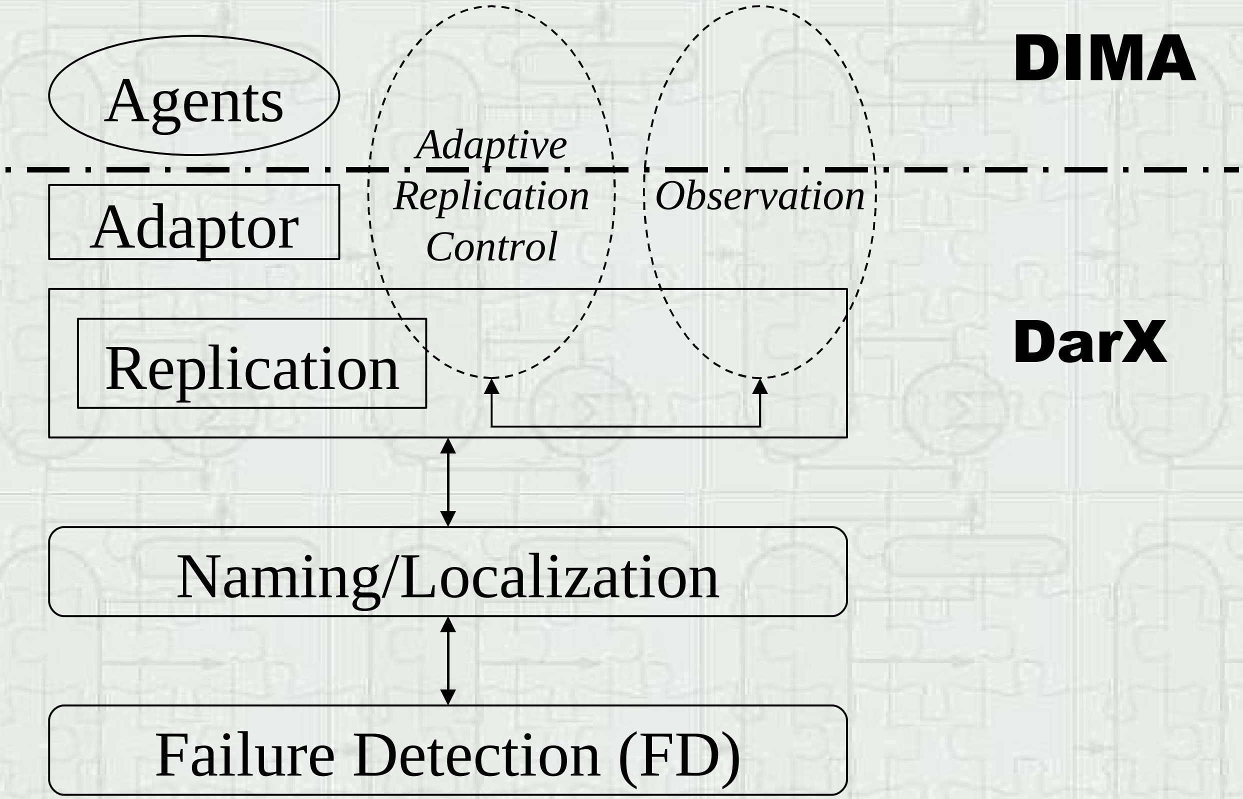
- **Agent-Monitors**
  - observe the domain agents
  - build/update the interdependences of the associated agent
  - control the domain agents
  - …
- **Host-Monitors**
  - aggregate information and dispatche back to agent-monitors
  - manage the resources
  - …
- **Domain Agents (agents of the appliation)**

Multi-Agent Architecture



Implementation

- **DimaX: A Fault-Tolerant Multi-Agent Platform**
  - Various services (naming service, fault detection, replication, …)
  - Agent monitors and host-monitors
  - …



Experiments

- **Technical details**
  - Multi-agent platform: DIMA (Guessoum & Briot 99)
  - Middleware: DarX (Guessoum et al. 2003)
    - Naming localization, observation, replication, failure detection

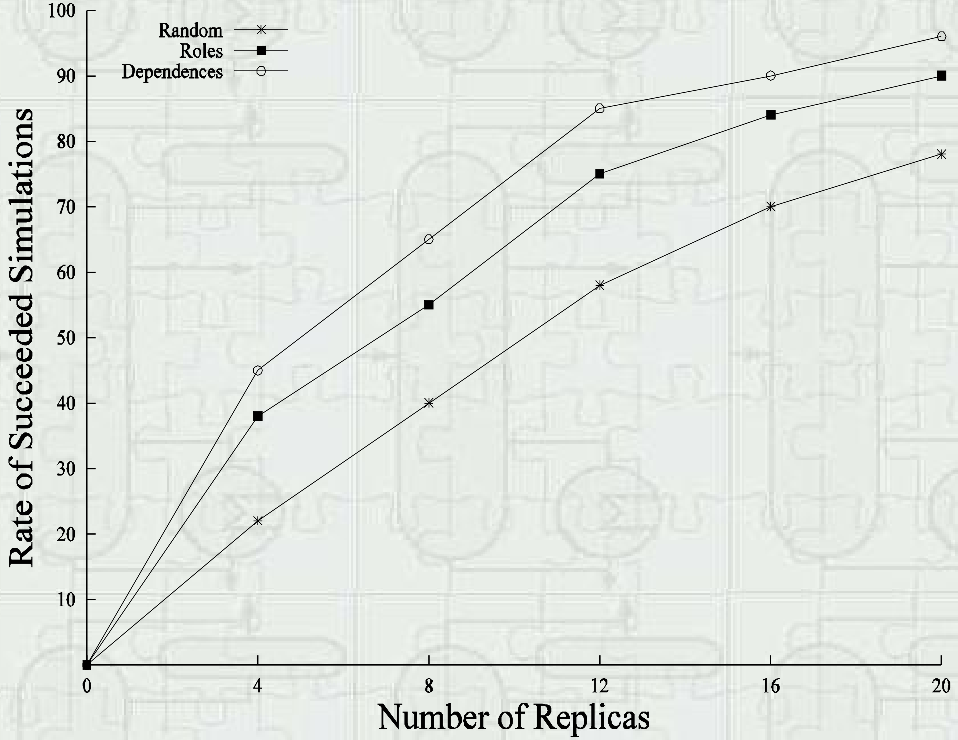
- **Example: Scheduling meetings**
  - Interact with the user to receive their meeting requests and associated information (a title, a description, possible dates, participants, priority, etc.) ,
  - Interact with the other agents of the system to schedule meetings.

Experiments

- **Robustness**
  - 100 agents on 10 machines
  - Failure simulator: randomly stops the thread of an agent
  - Scenario
    - 50 meetings
    - Goal of the MAS: Schedule the 50 meetings
  - Rate of successful simulations
    - Number of simulations which did not fail / total number of simulations
  - 3 replication approaches
    - Random
    - Roles
    - Dependences

Experiments

- **Robustness**



Conclusions and Future Work

- ✓ **A new fault-tolerant multi-agent platform (DimaX)**
  - Based on DIMA and DarX
  - A new approach to evaluate dynamically the criticality of agents
    - Small applications have been developed (meetings scheduling …)
- ☞ **Other categories of faults**
  - Timing, Byzantine
- ☞ **More experiments**
  - To validate the proposed approach
  - To better identify:
    - the potential target application domains (load balancing …)
    - the domains for which the approach is not suited