A Multi-Agent Approach to Reliable Air Traffic Control

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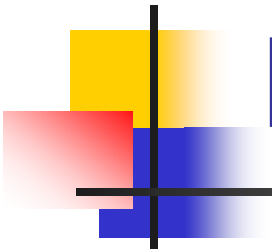


Plan

- Reliability problem
- Air Traffic Control
- Typical example
- Our MAS solution
- Agent-Based Simulation
- Testing scenario
- Conclusion and future work

Reliability problem

- In Air Traffic Control (ATC), controllers will use a large number of distributed software tools
- The reliability of ATC services relies on the availability of the various tools
- The integration of tools in the controllers' daily work currently faces difficulties
  - Controllers have to change their usual, trusted working procedures
  - They need to feel confident in the reliability of their software tools

Our approach

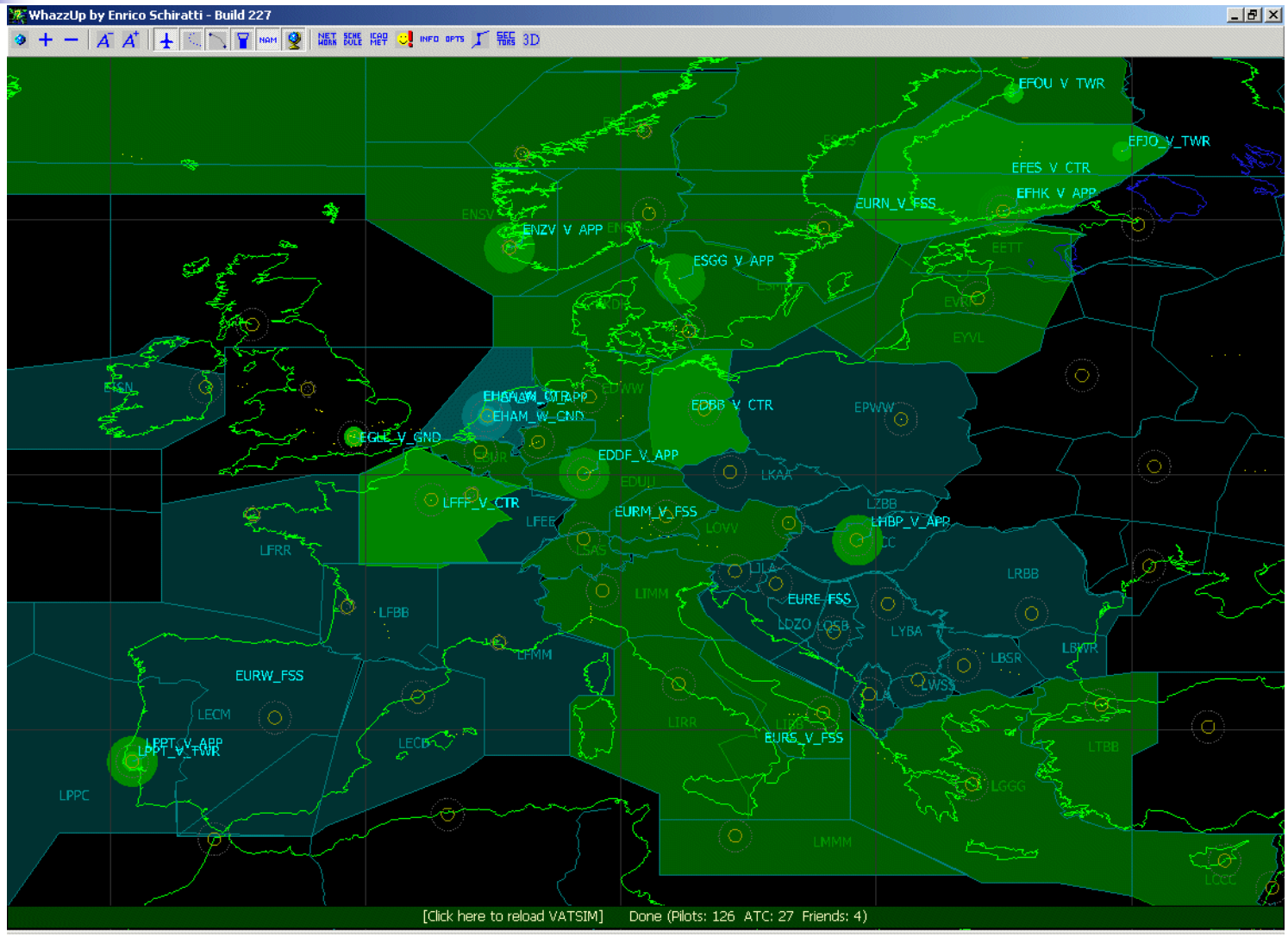
- ATC system can still provide full services when technical incidents suddenly appear
- Controllers can often manage without some of their tools

➔ We need a decision-aided system that helps controllers in using their sophisticated tools,

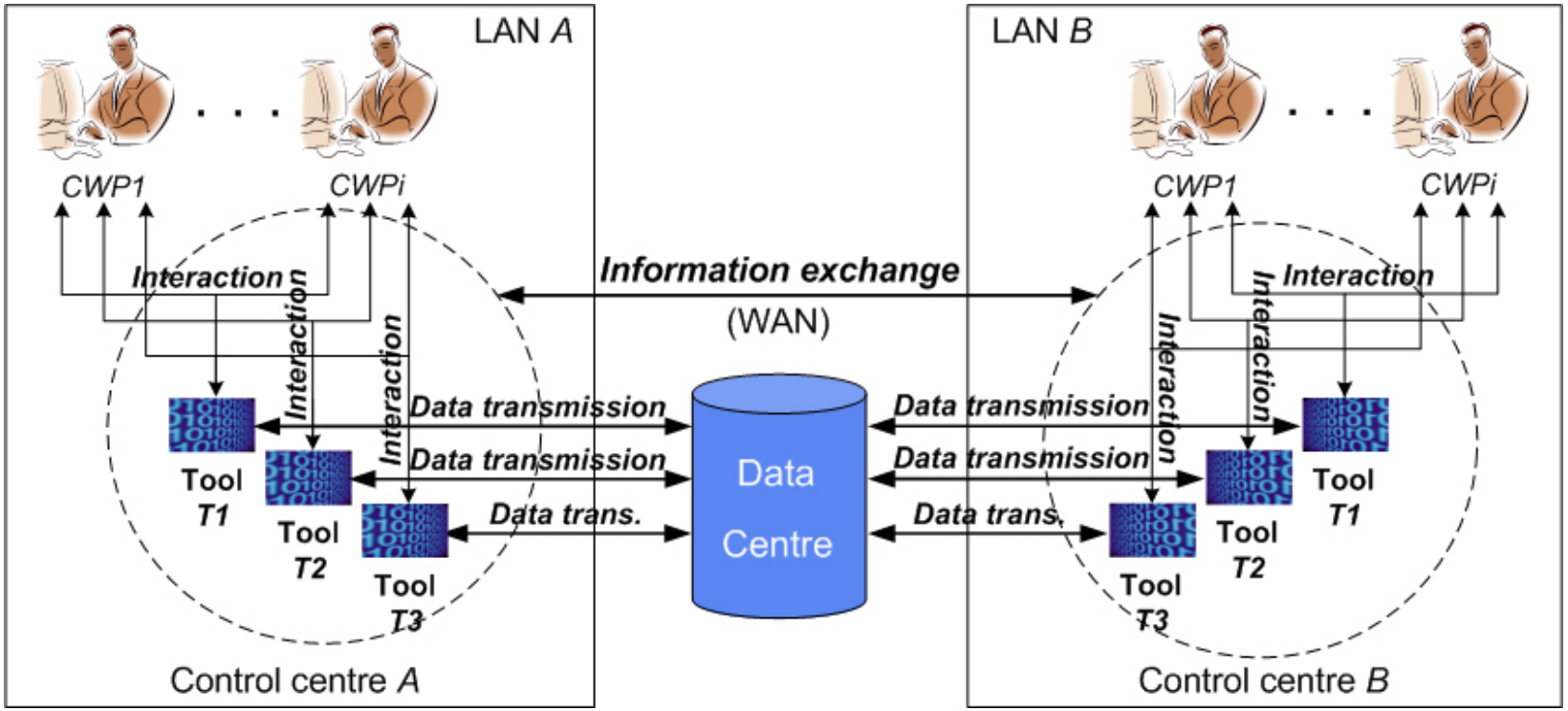
➔ particularly when some tools are not available

➔ A suitable use of multi-agent technology can help in this respect

Air Traffic Control (1)

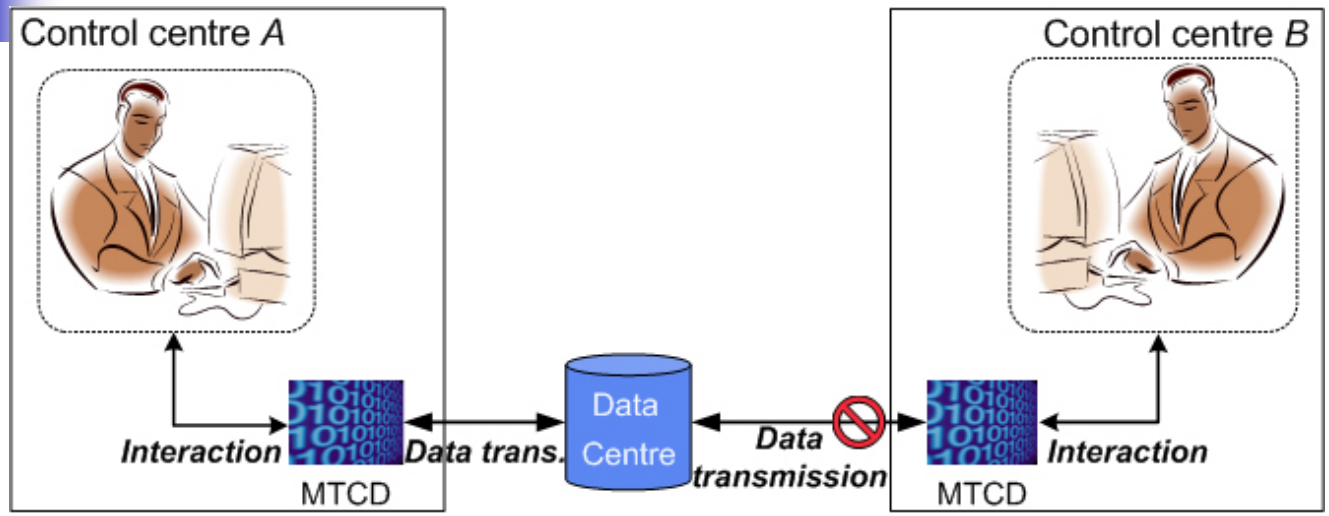


Air Traffic Control (2)



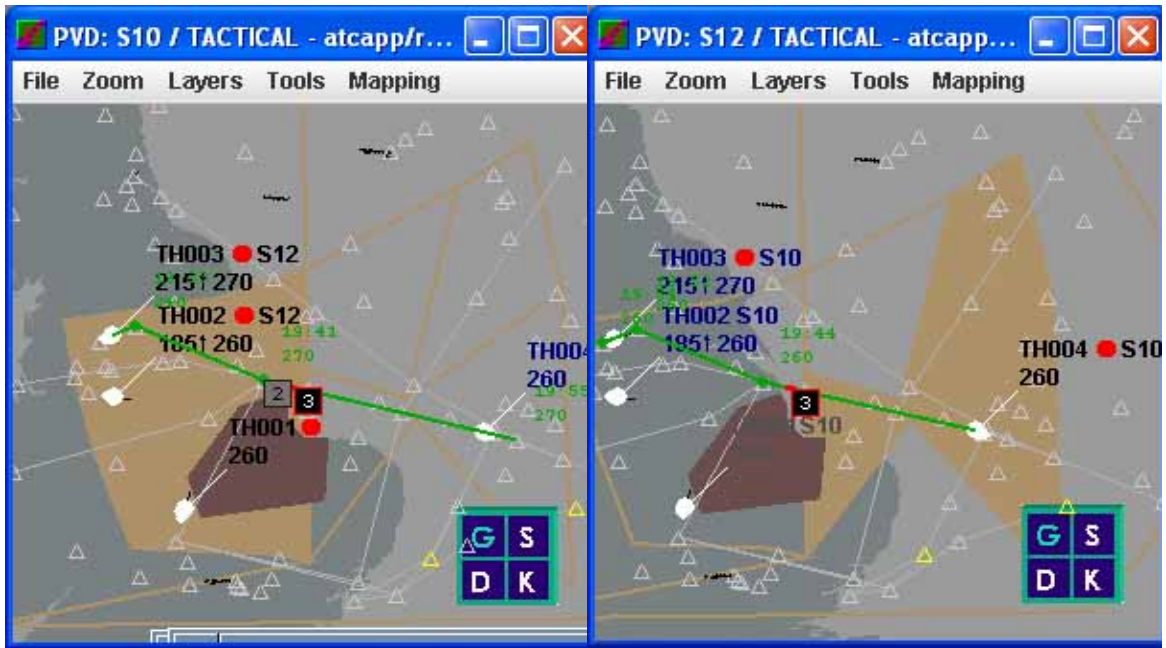
Basic future ATC system architecture

Typical example (1)



MTCD: Medium-term Conflict Detector

- A *handover* situation
- Several potential conflicts
- A disconnection between two control centres
- Partial unavailability of the MTCD in centre *A*



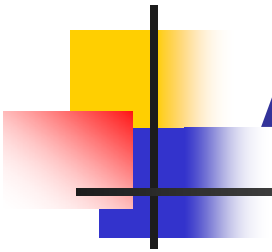
Typical example (2)

- *1st case*: a controller is aware of the unavailability of his MTCD when some potential conflicts are closely going to happen
  - ➔ this will embarrass his conflict sequencing, and can then make him nervous
- *2nd case*: a controller does not know that his MTCD is still “locally available”
  - ➔ an exhaustive manual verification will unnecessarily increase his workload

➔ When some tools are not available, controllers need
- to be timely informed of the unavailability of the tools,
- to obtain adequate information about their state, *e.g.* the “local availability” of MTCD

MAS solution

- An agent-based decision-aided system to response to three major requirements
  - provide controllers a system state awareness
    - ➔ show controllers information of tools' availability
  - mitigate the effects of technical incidents in a distributed environment
    - ➔ monitor software components running on different machines
  - run in real-time
    - ➔ inform controllers of some change of system state as soon as it happens



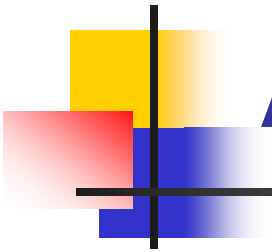
Agent design (1)

- Three monitoring agents for each tool
  - Data sentinel agent

    (observes the input and output data of a specific software tool and communicates with other agents in order to discover data losses)
  - Computation sentinel agent

    (observes the input and output data of a specific software tool and communicates with other agents in order to discover computation faults)
  - Middleware sentinel agent

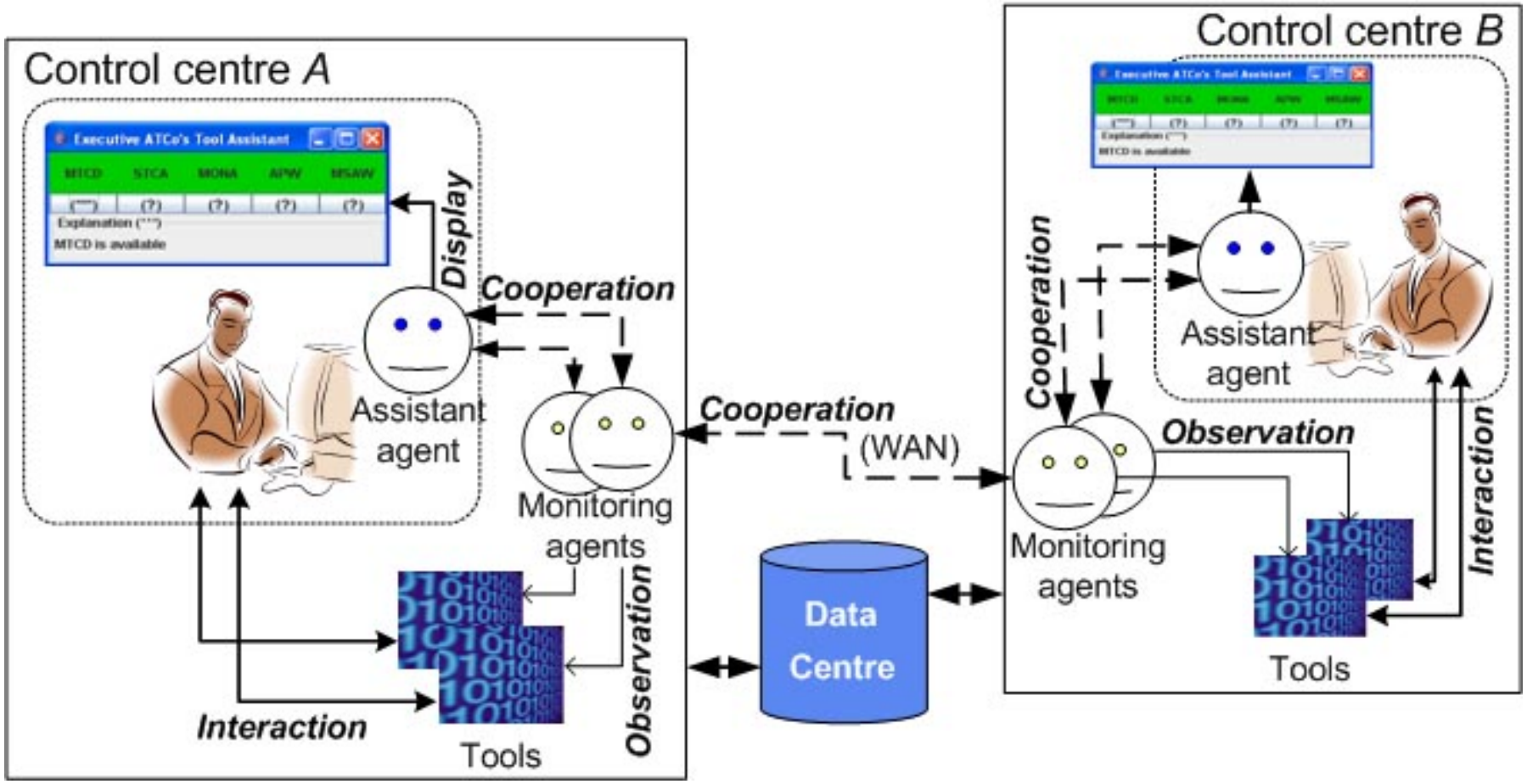
    (receives from the middleware the notifications of faults related to a specific software tool)



Agent design (2)

- An assistant agent for each controller which
  - communicates with other agents in order to determine the availability of tools,
  - informs the controller of this availability,
  - observes the controller's actions,
  - and notify monitoring agents of relevant events concerned with these actions

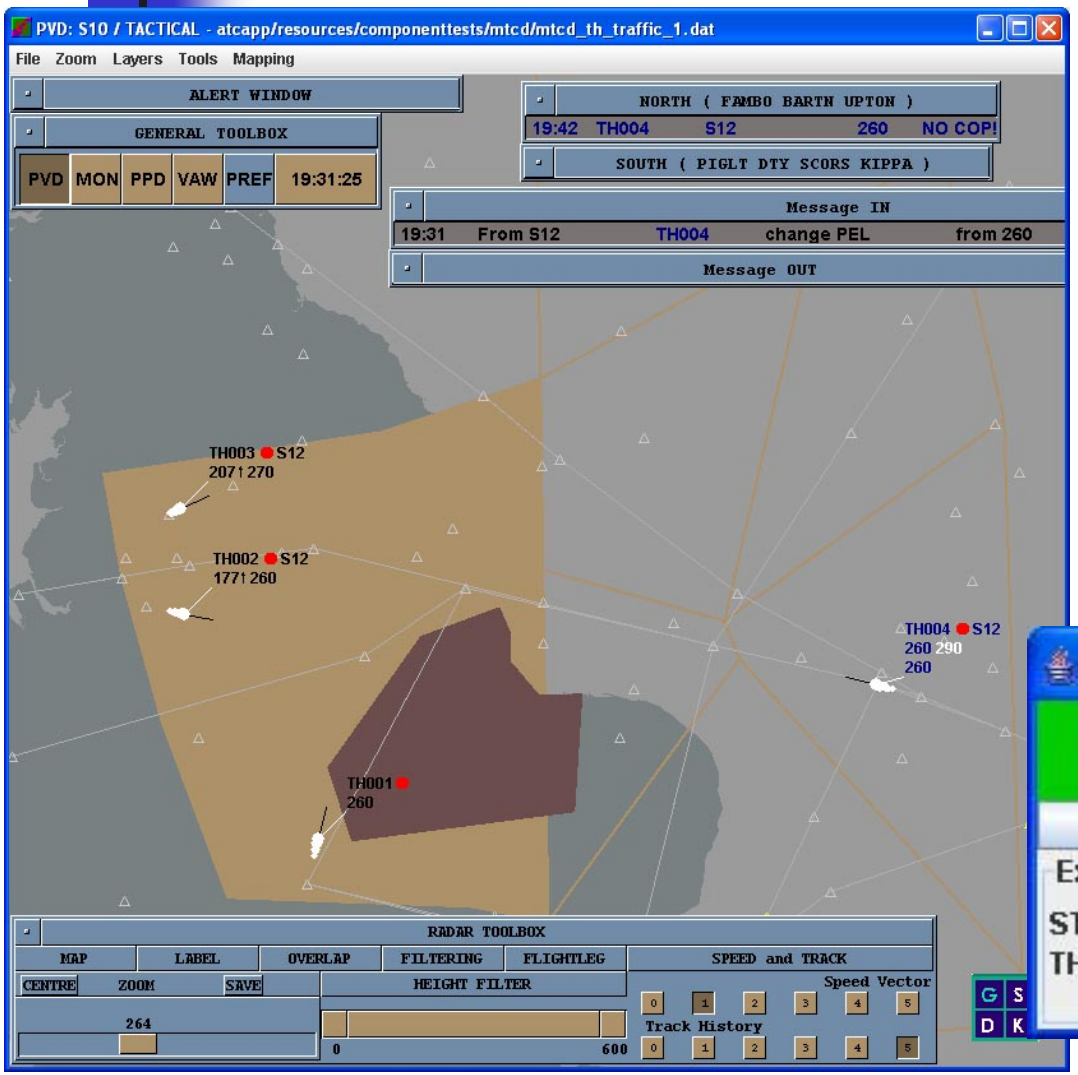
Organization of our MAS

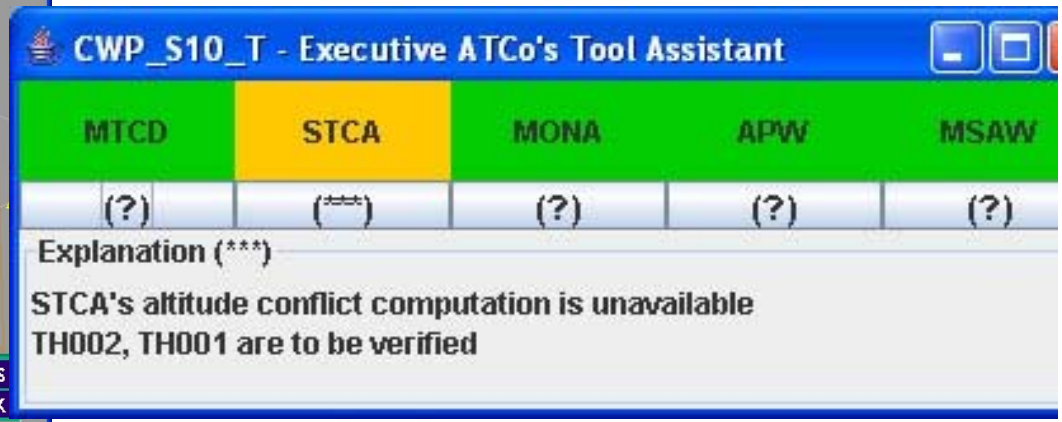


Agent-Based Simulation (1)

- Objective
  - to test our MAS
    - Any novel application to a critical system like ATC has to be tested in simulations before its real world implementation
- Simulation platforms
  - eDEP (*Early Demonstration & Evaluation Platform*) implemented by Eurocontrol:
    - a distributed simulation environment using Java RMI (*Remote Method Invocation*),
    - provides standard ATC elements and software support tools for controllers
  - DimaX implemented by LIP6:
    - a Java programming library,
    - a generic and modular agent architecture,
    - enables the dynamic replication of agents
      - makes MAS fault-tolerant

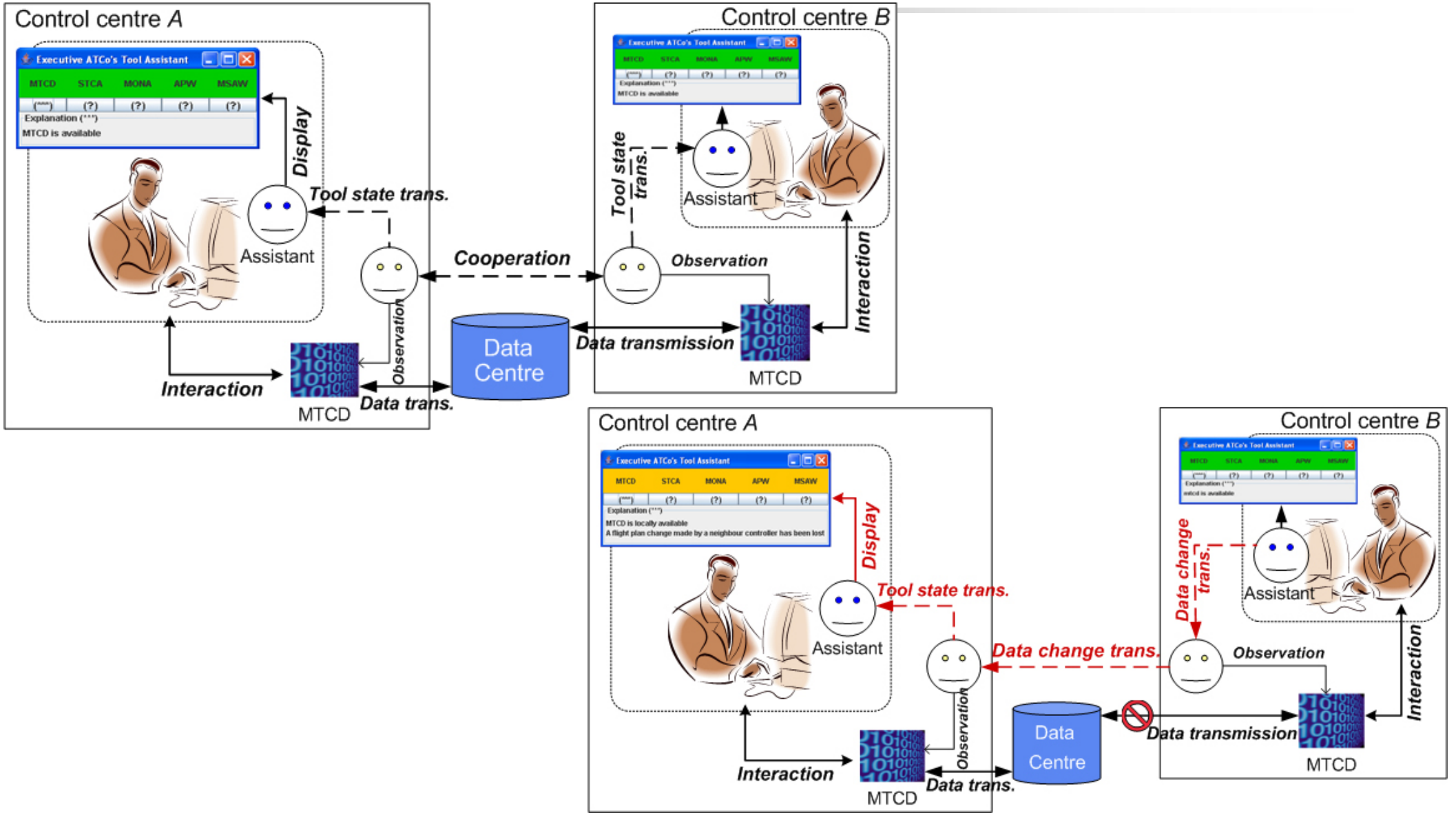
Agent-Based Simulation (2)



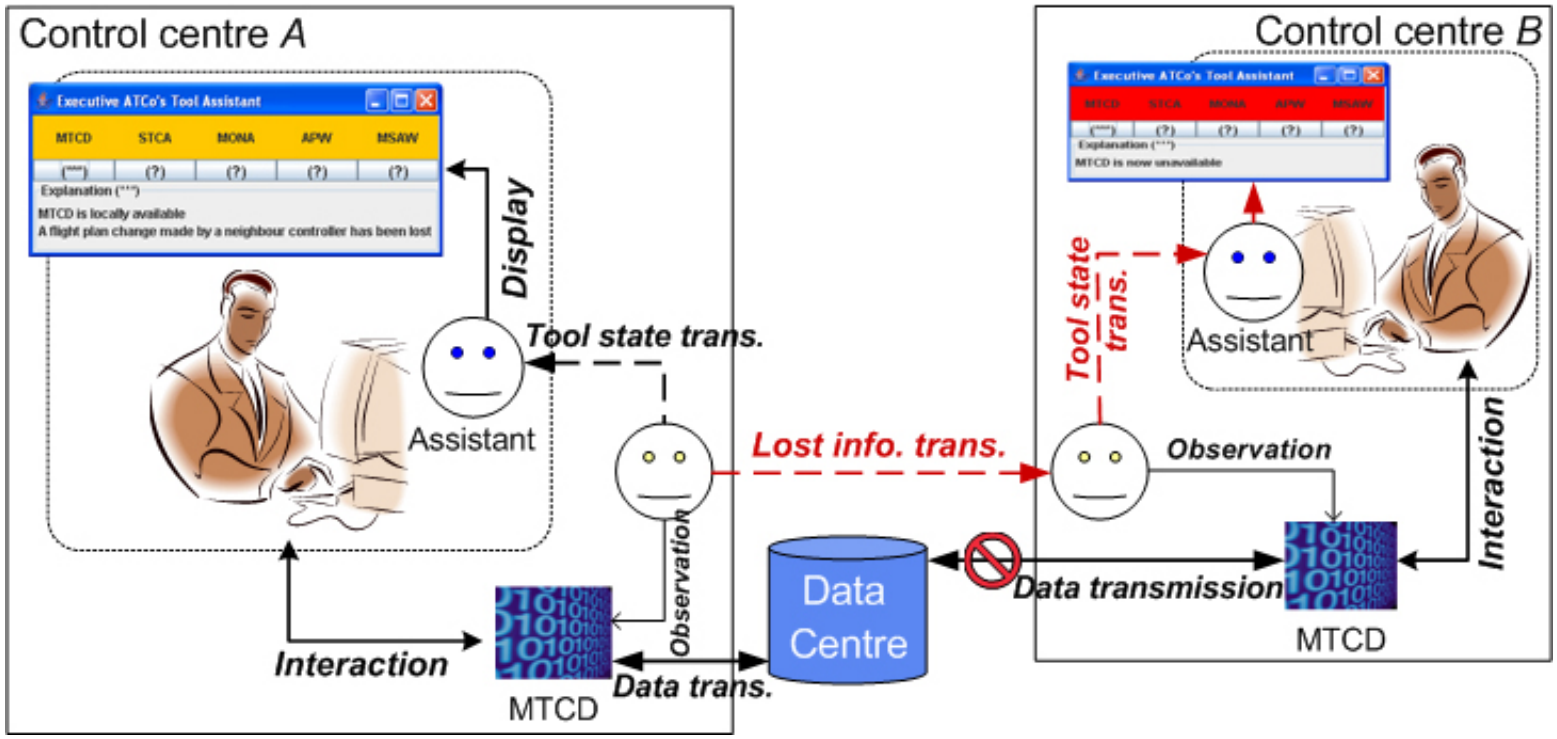


- We use *wrapper agents* (specified by FIPA) to integrate the DimaX platform in the eDEP environment

Testing scenario (1)

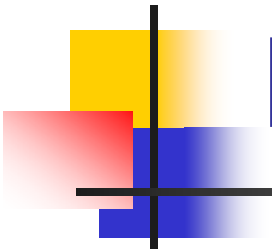


Testing scenario (2)



Experiments

- On technical incidents: network failure, timeout error, machine failure
- Feedback from experts in ATC
  - The validation of this kind of system needs of both points of view, that of professional controllers and that of researchers in ATC
  - They give valuables recommendations on the information controllers require in each situation
    - *e.g.* in a situation of network failure presented above, other tools need to be also notified as totally/locally unavailable



Related work

- Human factors in critical systems:
  - No work has dealt with the daily relation between human operators and their powerful equipments
- Fault-tolerance in critical systems:
  - Methods have mainly solved purely technical reliability problem
- Using “sentinels” in component-based systems and MAS
  - Klein, Dellarocas and colleagues [2003] use complicated “sentinel components”
  - Hägg [1996] employs “sentinel agents” which fully inspect the code of BDI agents

Conclusion and future work

- We have designed a MAS that
  - mitigates the effects of software malfunction in a complex critical system
  - builds confidence for users, *i.e.* air traffic controllers
- We have implemented an ABS based on
  - eDEP, an ATC simulation environment
  - DimaX, a multi-agent platform
- We have demonstrated the usefulness of our MAS to controllers and have got valuable feedbacks
- We plan to set up mechanism for ensuring a degree of fault-tolerance at the agent level
  - ➔ apply adaptive replication and exception handling [Marin et al. 2003]

Thank you very much
for your attention !