Self-serving **A**ssets in a **H**ighly **N**etworked **E**nvironment

09 December 2009

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BOEING

Contents

- Vision, aim & objectives
- Programme overview
- Programme outputs
  - Feasibility study and first demo (Year 1)
  - Bring the self-serving asset alive! (Year 2)
- Other Research Highlights
- Next steps

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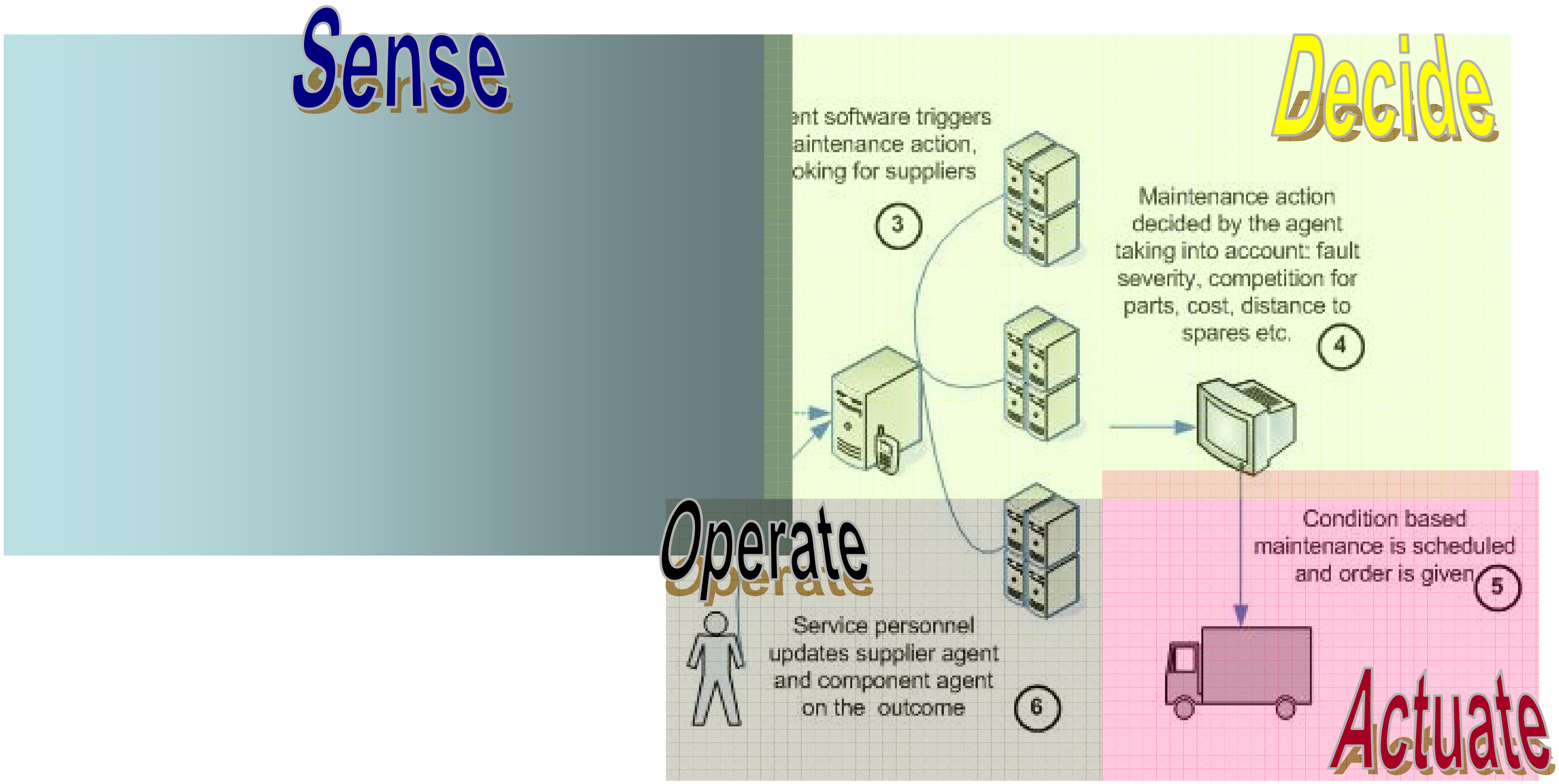
Vision, aim & objectives

VISION:



Vision, aim & objectives

AIM:

Develop suitable software architectures for self-serving assets by embedding service autonomy in parts to manage their own service needs in a scalable and optimal manner

OBJECTIVES:

- Develop a scalable, feasible architecture for self-serving assets
- Enable optimal decision making by coordination and cooperation
- Develop functionality that enables supplier monitoring, service tracking, configuration management, and sensor, expiry, use based service calls

Why self-serving assets?

Current state of affairs:

- parts on plane are monitored via manual testing or through distributed sensors
- information is collated on a central database
- components are then replaced on basis of current health or pre-determined service periods
- spares are sourced manually through a service supply network which includes spares distribution centers, OEMs and manufacturers

labour intensive manual processes; long administrative lead times, frequent data corruption; bottlenecks caused by centralized decision making

- Distribute intelligence – reduce DB maintenance and reliance
- Automated, faster, optimised, objective, traceable decision making
- Tracking supplier reliability
- Simplify and globally optimise the service supply chain
- Maximise availability of the plane and minimize costs to the operator

Assets as intelligent objects

A physical and/or information based representation of an object which*:

Level 1: reactive

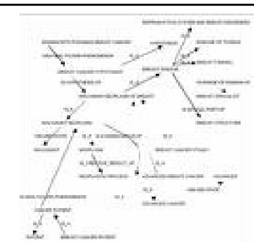
(1) possesses a unique identification

(2) is capable of communicating effectively with its environment

(3) can retain or store data about itself

Level 2: proactive

(4) deploys a language to display its features, and requirements



(5) is capable of participating in or making decisions relevant to its own destiny

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* Ref: (Wong, McFarlane 2002)

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Overview

- Three year programme started in November 2007
- Feasibility study and first demo (Year 1)
  - What is the current state of affairs? What is possible? What considerations should be taken into account? How should the business case be structured?
- Bring the self-serving asset alive! (Year 2)
  - Demonstrate a prototype, embed required functionality, assess performance, push the boundaries
- On the road to a real system (Year 3)
  - Plan integration with Boeing, construct roadmap, continue prototyping
  - Examine compatibility with today's systems

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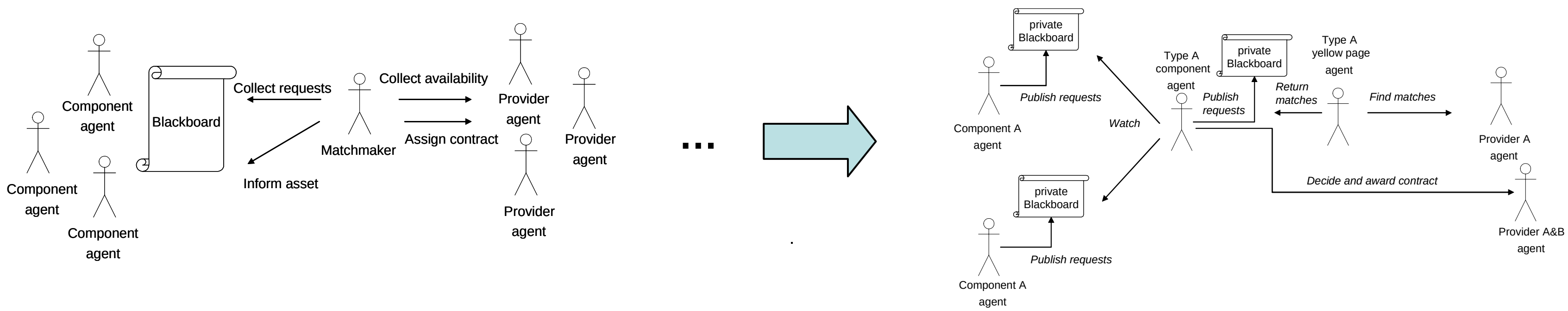
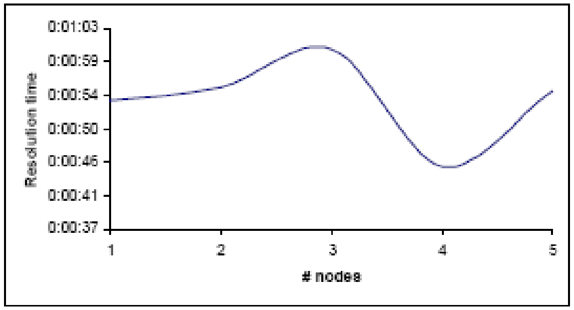
Feasibility Study (Year 1)

- ***What industrial problem are we improving?*** Conducted value stream of current/to be state: Embraer, SR Technic, Boeing
- ***What architecture will be scalable & flexible?*** Carried out architectural re-factoring

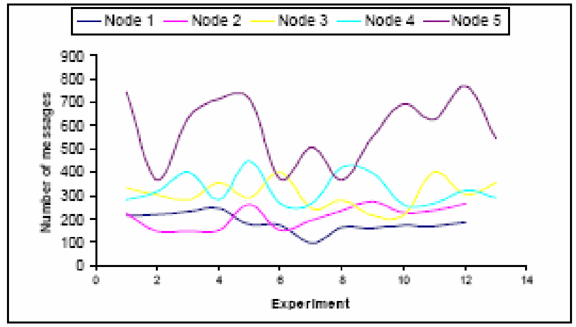


- ***Is its realisation possible?*** Produced proof of concept demonstrator
- ***How will the vision be realised?*** Devised a roadmap to self-serving assets
  - Market drivers
  - Technology enablers
  - Systems, Standards, Adoption
  - Risk factors

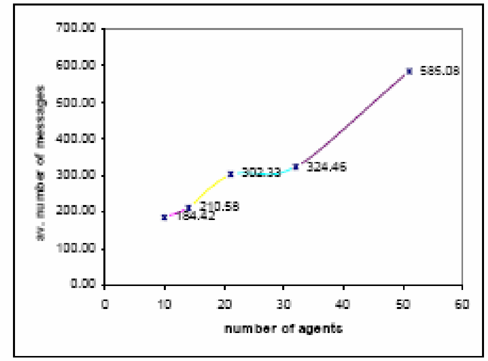
Feasibility Study (Year 1)



(a) Resolution time versus number of nodes

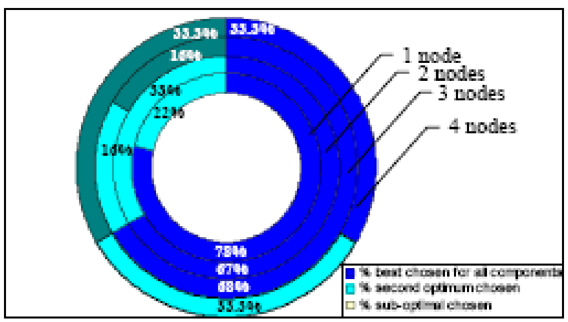


(b) Stability

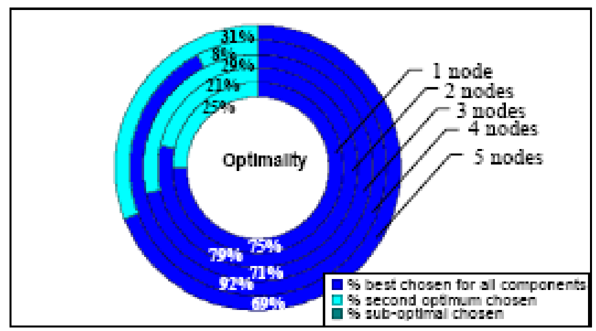


(c) Scalability –based on average number of messages over increasing agent numbers

Resolution time ***Stability*** ***Scalability***



(a) Optimality in decision making versus number of component agents



(b) Optimality in decision making versus number of provider agents

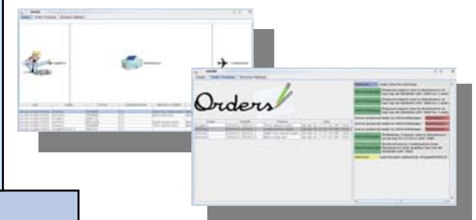
Optimality

Bringing the Self-serving Asset alive! (Year 2)

Functionality wishlist

Make it user friendly

Multi purpose,
user friendly interfaces

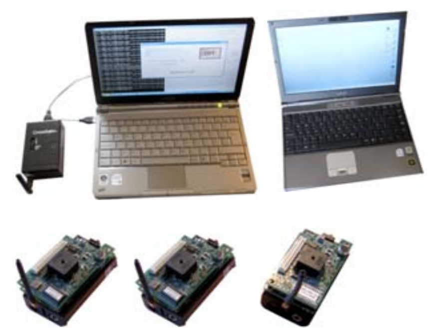


Make it extra smart

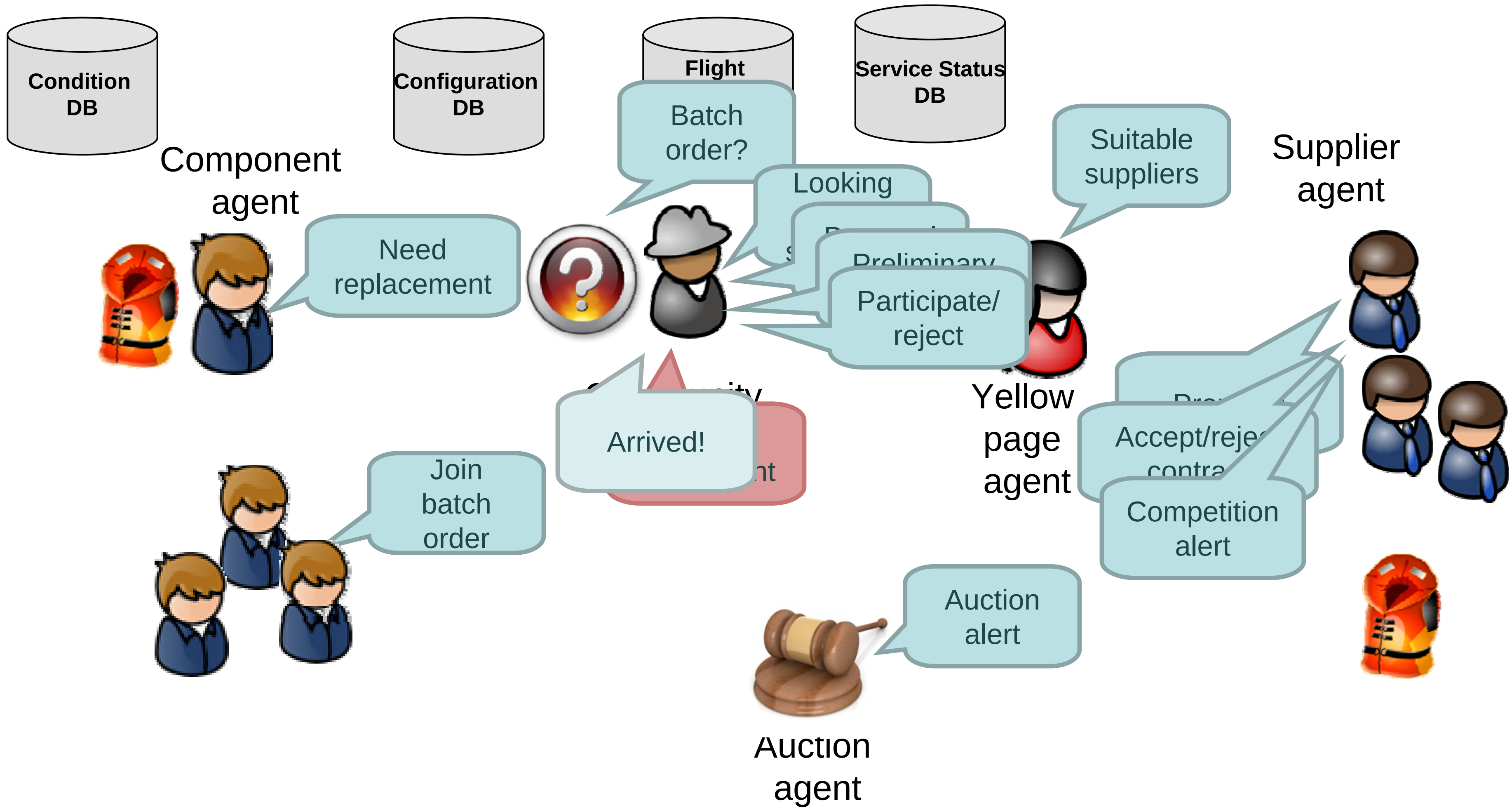
Batch orders
Optimal decision making
Competition management
Service scheduling

Lay the foundations

Dynamic agents & societies
Usage based, expiry based, health based orders
Configuration management
Post-service monitoring



Bringing the Self-serving Asset alive! (Year 2)



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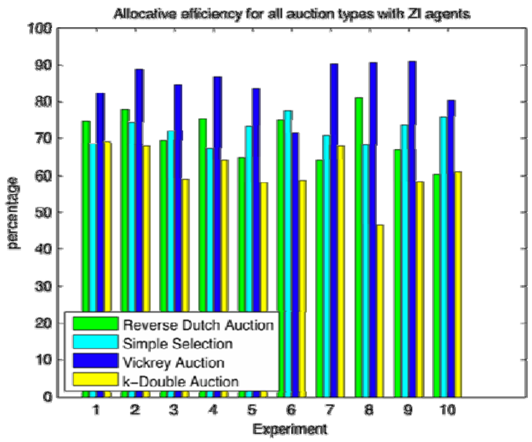
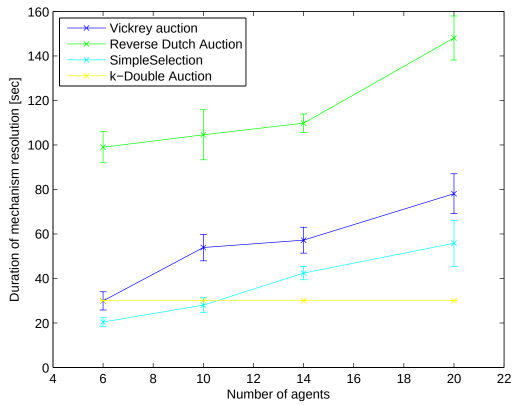
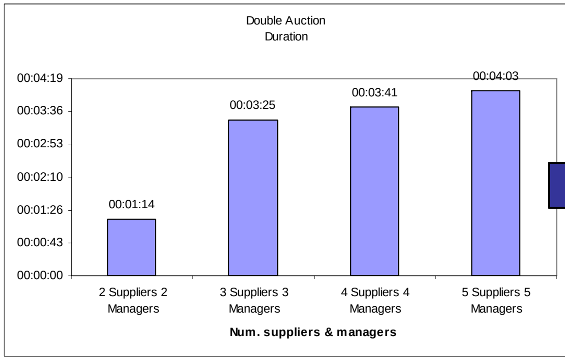
Decision making and competition management

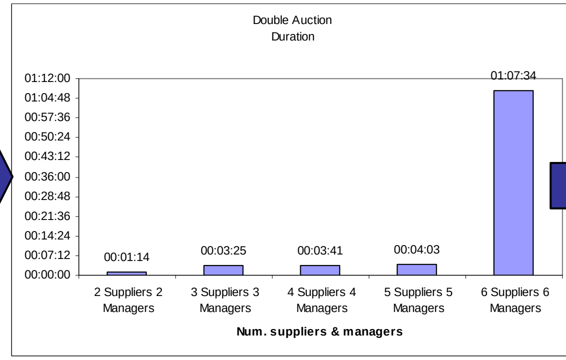
- Evaluating different auction mechanisms for use in competing assets
- Clients decide on Suppliers based on multiple criteria: *location, contractual bindings, price, reliability trail*
- Suppliers decide on clients based on price and availability
- If there is limited capacity at the supplier, competition between airlines may occur
- *Main motivation for auctions*: uncertain market for complex assets, traceability, market efficiency
- Auction design is not straightforward:
  - Truthful bidding – strategy proofing
  - Multi-criteria value determination
  - Both sided competition
- Compare
  - Analytical Hierarchy Process & prioritisation
  - Extended Vickrey
  - Reverse Dutch
  - Double auction
- Outcome: Auctions are useful for:
  - Small markets with stochastic demand
  - Rare high value items are traded
  - Set price of items for the first time
  - The winner is Extended Vickrey

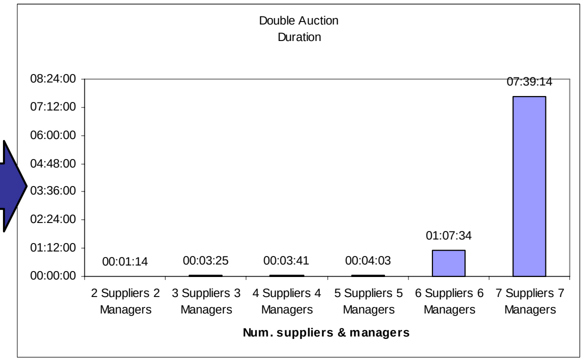




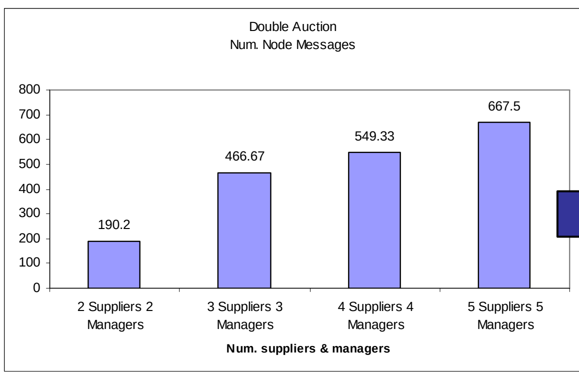
Double Auctions

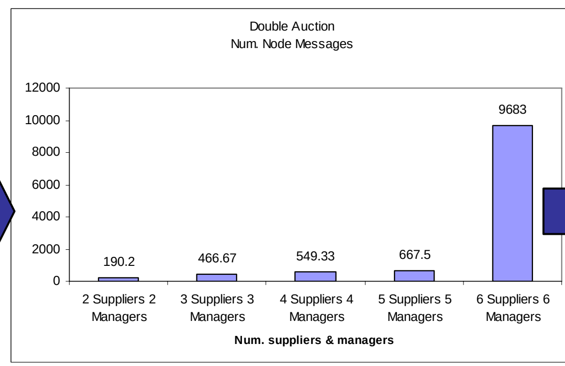


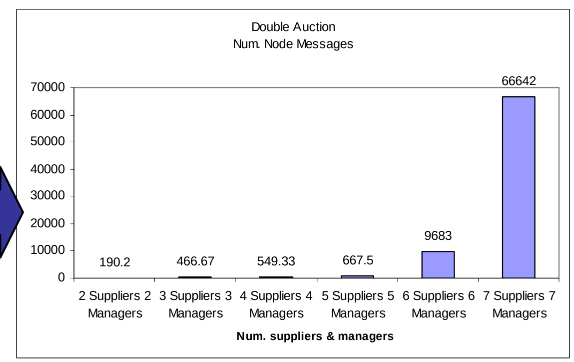




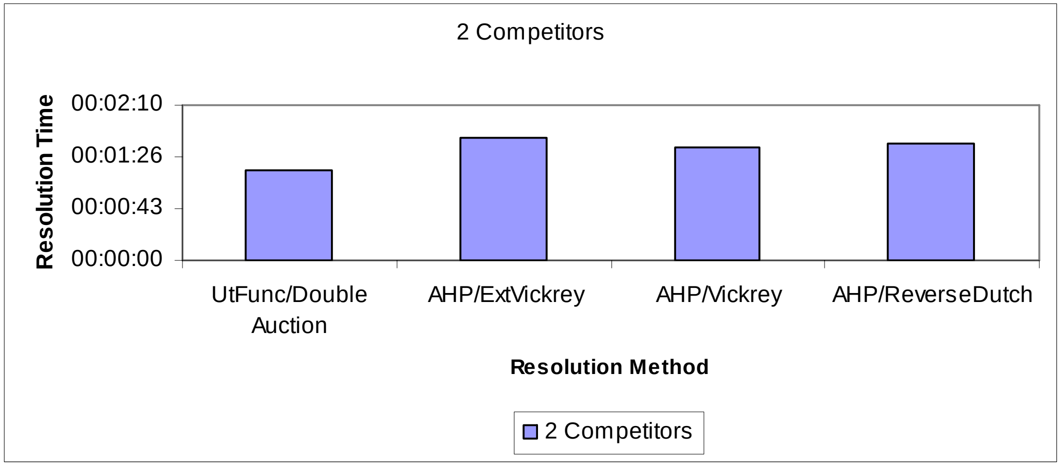
- Always optimal allocation
- Not feasible for more than 5 matches – timing increases exponentially





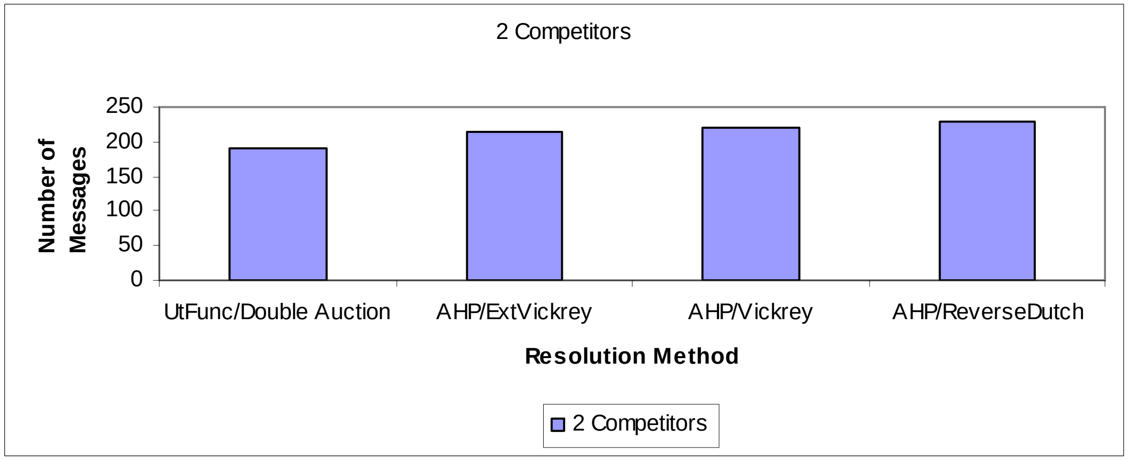


Competition handling

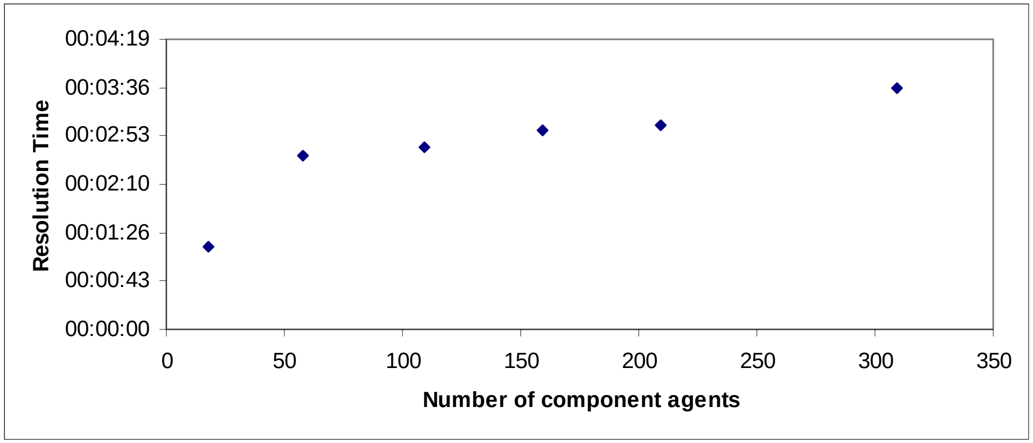


- Resolution time determined by internal timer – should be carefully selected by number of competitors

- Number of messages are approximately same in iterative auctions
- 90% optimal
- Double auctions have relatively small number of message exchange due to central auctioneer

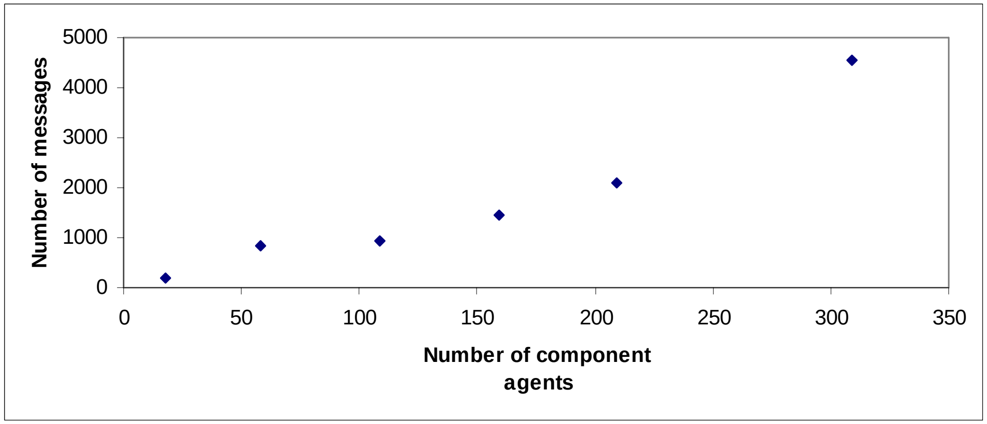


Scalability



- Resolution time is not greatly affected by the number of component agents

- 95% optimality
- Both resolution time and message numbers show a relatively straightforward and predictable increase
- No message leaks

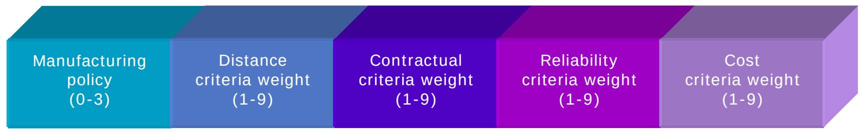


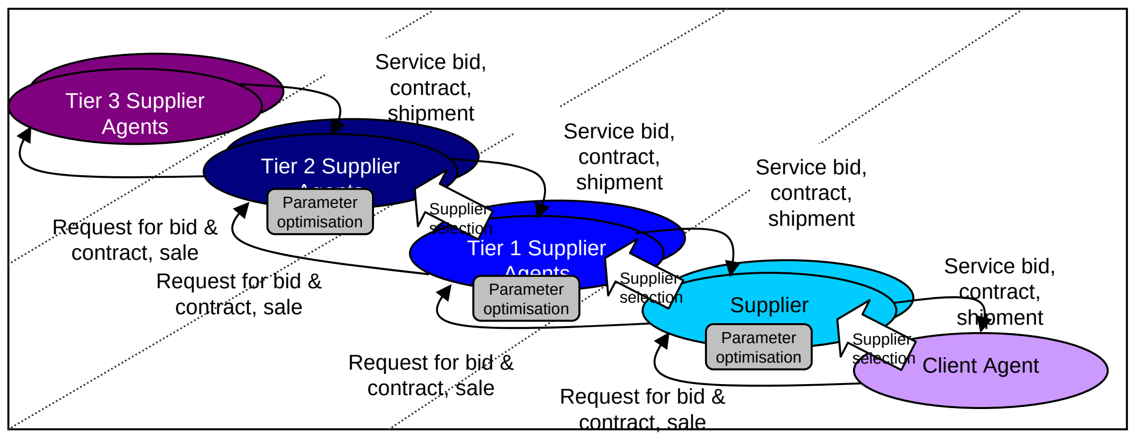
Trade offs in supply chain optimality

- Agent based systems suitable to model/analyse and supply chain
- Examine “emerging” [c.f. designed] Supply chains
- Rising number of practitioners & providers: SAP,Honeywell,Daimler Chrysler
- Investigated 32 research papers in agent based simulation & agent based frameworks for autonomous supply chains (1998-2009)
- Multi-role, multi-objective nature of SCM not considered
- Embed Genetic Algorithms in each agent to play the role of supplier & client

- Embed multi-objective optimisation algorithm to reach to trade off solutions that minimise lead time & maximise revenue

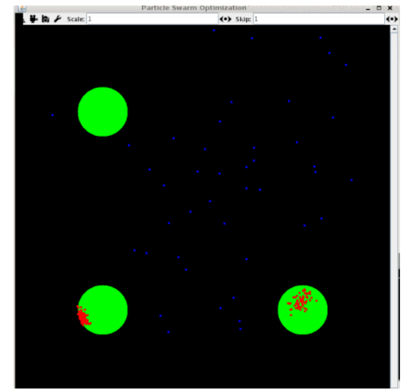
- Reduced the bullwhip effect by converging to strategies in synergy with market



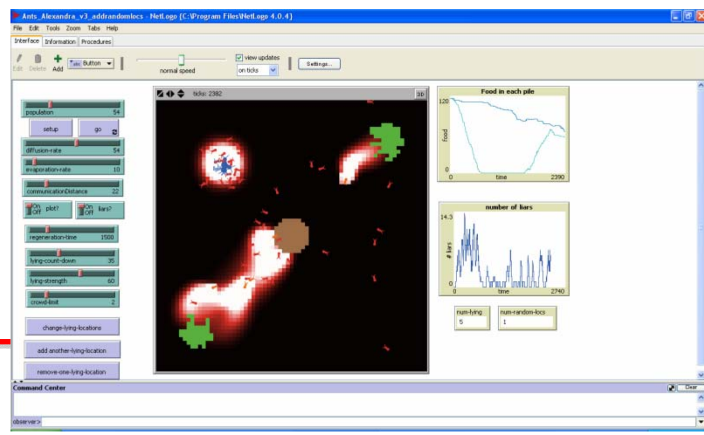


Distributed Control of Emergence

- Liar ants and gossiping swarms
  - How can we prevent unwanted emergence?
  - e.g. Tragedy of Commons
  - Need a distributed and simple strategy
  - Introduce lying ants in the ant colony algorithm
  - Introduce false rumours in particle swarms
  - Effective, yet one solution does not fit all



Equilibrium state in the PSO



Equilibrium state in the ACO

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Next steps - 2

Year 3: focus on risk and performance

Risk Management

- Technology transfer with Boeing secondment
- Scalability analysis with representative network & usage data
- Embed fault tolerance and persistency into system architecture
- Business case
- Compatibility and readiness analysis with today's procurement tools & suppliers

Performance challenges

- Adaptation and learning to allow system to evolve in a changing environment
- Real time coordination under scaled conditions

Publications

- Brintrup A., Multi-agent and multi-objective supply chain behaviour optimisation, in submission, *J. of Computers in Industry*
- Brintrup A., McFarlane D., Owens K., Will intelligent assents fly? Towards self-serving aircraft assets, accepted for publication, *IEEE Intelligent Systems,* http://doi.ieeecomputersociety.org/10.1109/MIS.2009.89 (In Press), 2009.
- Brintrup A., Davis C., Gong T., Ligtvoet A., Robinson E., Willigen W., Distributed control of emergence: local and global anti-agent strategies in particle swarms and ant colonies*, Self-organising and Self-adaptive Systems*, SASO 2009, San Francisco, September 2009.
- Brintrup A., Ranasinghe, D.C., McFarlane, D.C. and Parlikad, A.K.N.(2009), Roadmap for self-serving assets in civil aerospace, *International Academy of Production Engineering Conference* (CIRP IPS2), pp. 323-331, 1-2 April 2009, Cranfield, UK
- Brintrup A., Ranasinghe D., McFarlane D., Parlikad A., A review of the intelligent product across the product lifecycle, *Product Lifecycle Management Conference*, Seoul, July 2008.

Under development:

- Kruse S., Brintrup A., Sanchez Lopez T., McFarlane D., Owens K., (2010) Towards the e - service supply chain: When and how should intelligent assets compete?, *IEEE Transactions on Computational Intelligence and AI in Games*
- Brintrup A., Sanchez Lopez T., McFarlane D., Owens K., (2010) Self-serving assets in civil aerospace

Discussion

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