Grid Economy and Business Models
– from Web to Grids –

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Joint Work with **Torsten Eymann, Björn Schnizler, Dirk Neumann**

Research Projects

- **CatNets**: Catallaxy paradigm for decentralized operation of dynamic application networks
  - STREP in FP 6, duration: 8/2004-8/2007
  - 6 partners within EU
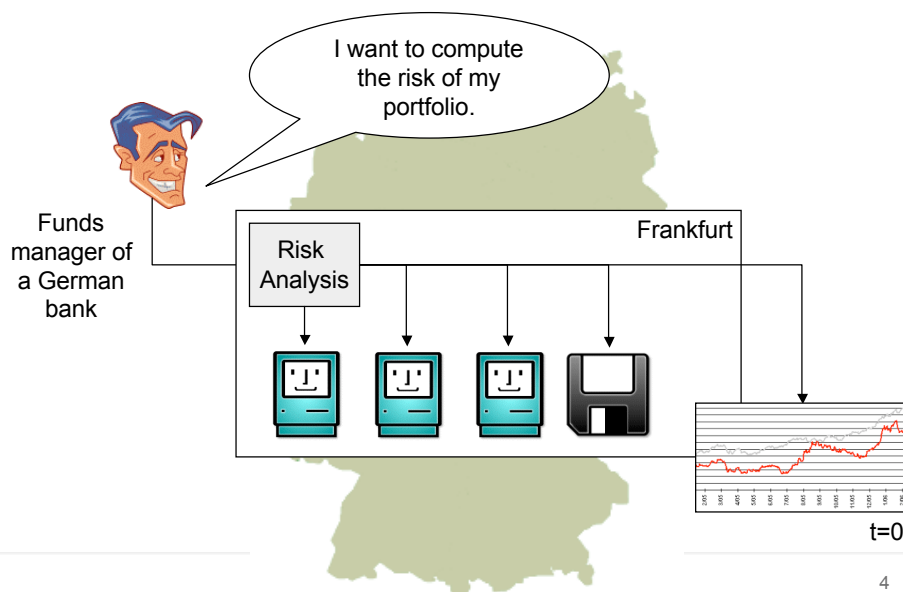 - Web: www.catnets.org
- **SORMA:** Self-Organizing ICT Resource Management
  - STREP in FP 6, duration: 9/2006-9/2009
  - 10 partners within EU
  - 2 partners from Asia/Israel
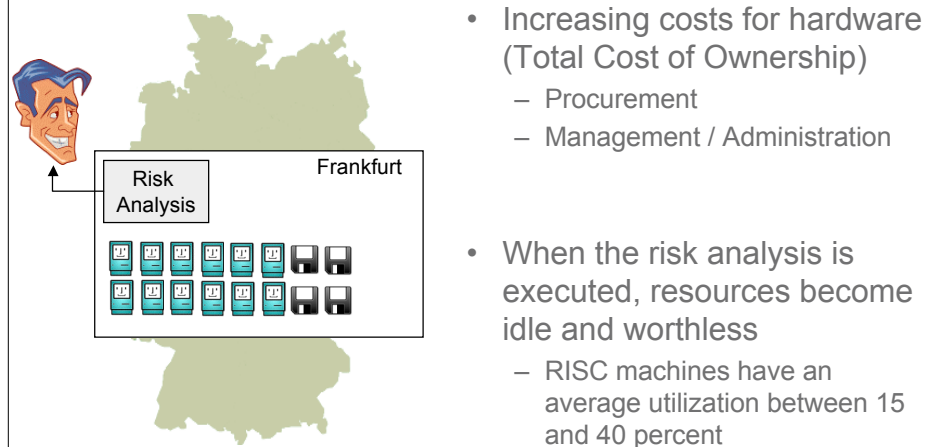 - Web: www.sorma-project.org
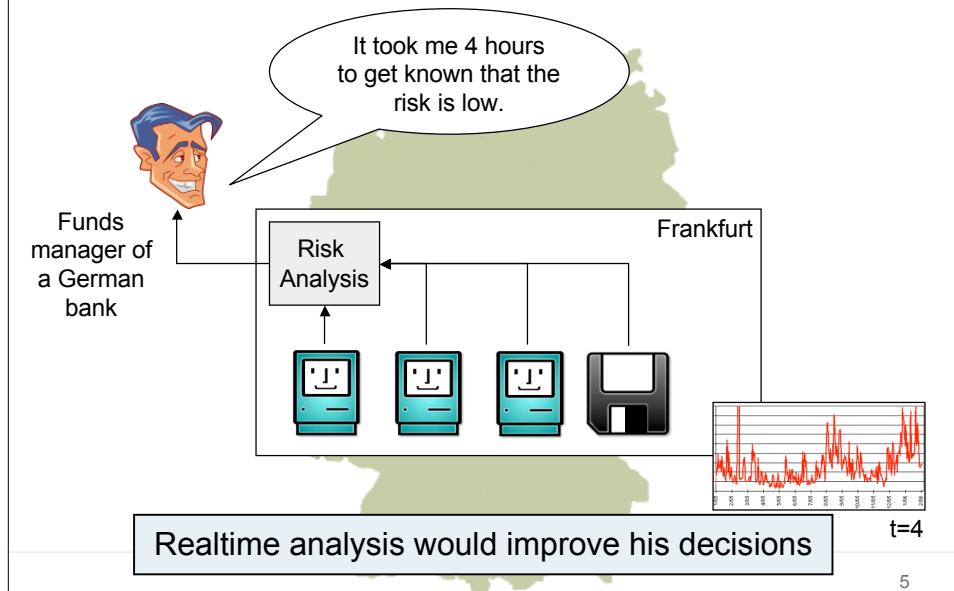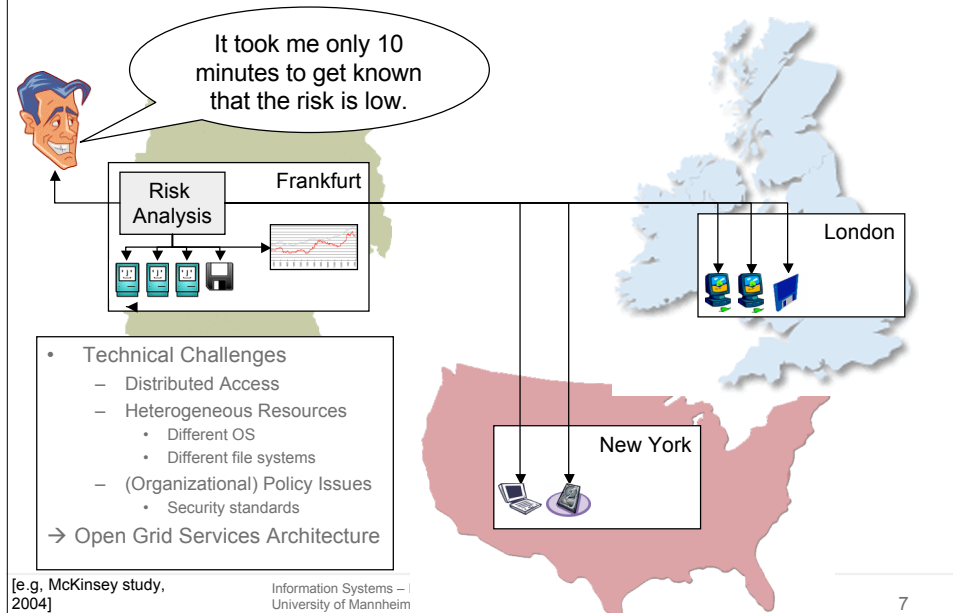
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- **PowerACE:** Effects of emissions trading and the increased use of renewable energy sources on power markets

PowerACE
  - Funded by VolkswagenFoundation, duration 5/2004-8/2007
  - 3 partners from Germany, Web: www.powerace.de

Agenda

- **Motivation**
- **Technical Solution**
- **Economic Challenges**
- **EU Project CatNets: Allocating Grid Resources using Auctions**
- **EU Project SORMA: The Open Grid Market**
- **Wrap up**

Scenario: Financial Risk Analysis

I want to compute the risk of my portfolio.

Funds manager of a German bank

Risk Analysis

Frankfurt

t=0

Scenario: Financial Risk Analysis

It took me 4 hours to get known that the risk is low.

Funds manager of a German bank

Risk Analysis

Frankfurt

t=4

Realtime analysis would improve his decisions

5

Solution 1: Buy more hardware!

Risk Analysis

Frankfurt

- Increasing costs for hardware (Total Cost of Ownership)
  - Procurement
  - Management / Administration

- When the risk analysis is executed, resources become idle and worthless
  - RISC machines have an average utilization between 15 and 40 percent

[Gartner, 2004]

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6

3

Solution 2: Grid Technologies

It took me only 10 minutes to get known that the risk is low.

Risk Analysis   Frankfurt

London

New York

- Technical Challenges
  - Distributed Access
  - Heterogeneous Resources
    - Different OS
    - Different file systems
  - (Organizational) Policy Issues
    - Security standards
- → Open Grid Services Architecture

[e.g, McKinsey study, 2004]

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7

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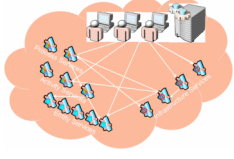- ▪ **EU Project SORMA: The Open Grid Market**
- ▪ **Wrap up**

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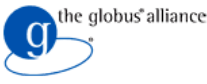University of Mannheim, Germany

8

4

Open Grid Services Architecture (OGSA)

- OGSA is an Open Grid Form (OGF) standardization effort

- OGSA defines all resources (physical and logical) as services
  - Conflation of Web services and Grid technologies
  - Storage-, Computation-, Database service
  - Virtualized IT-infrastructure

→ Grid becomes a *Service Oriented Architecture*
  → Improved interoperability

- Globus Toolkit 4 (GT4) as reference implementation
  - Provides common Grid management services
    - Resource management, Security, Authorization, …
  - Provides the base for deploying Grid applications
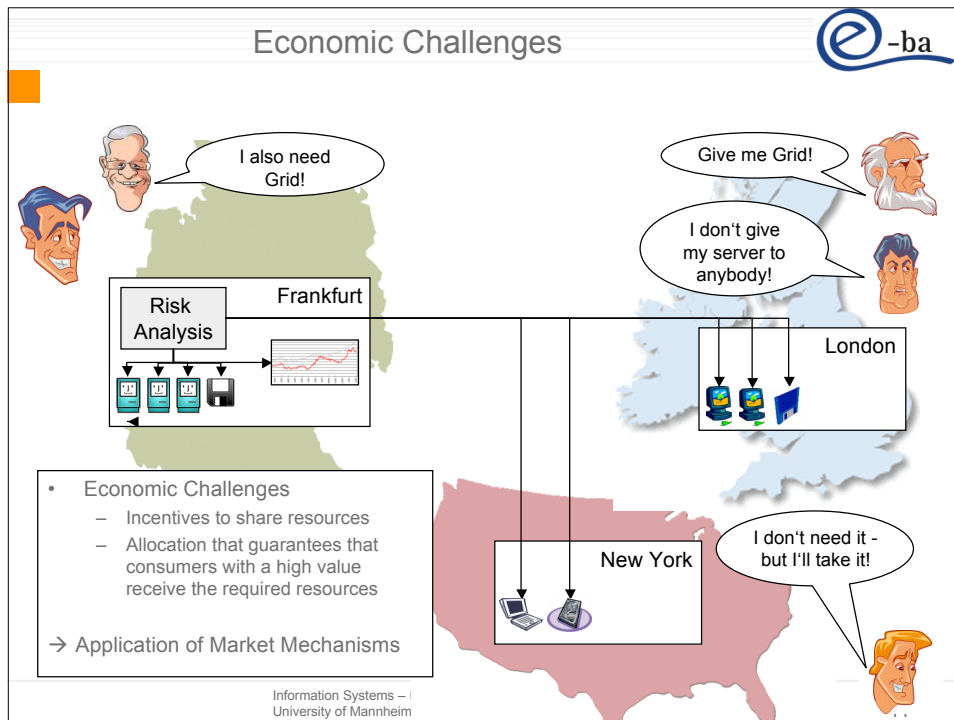

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Economic Challenges

I also need Grid!

Give me Grid!

I don't give my server to anybody!

Risk Analysis

Frankfurt

London

- Economic Challenges
  - Incentives to share resources
  - Allocation that guarantees that consumers with a high value receive the required resources

→ Application of Market Mechanisms

New York

I don't need it - but I'll take it!
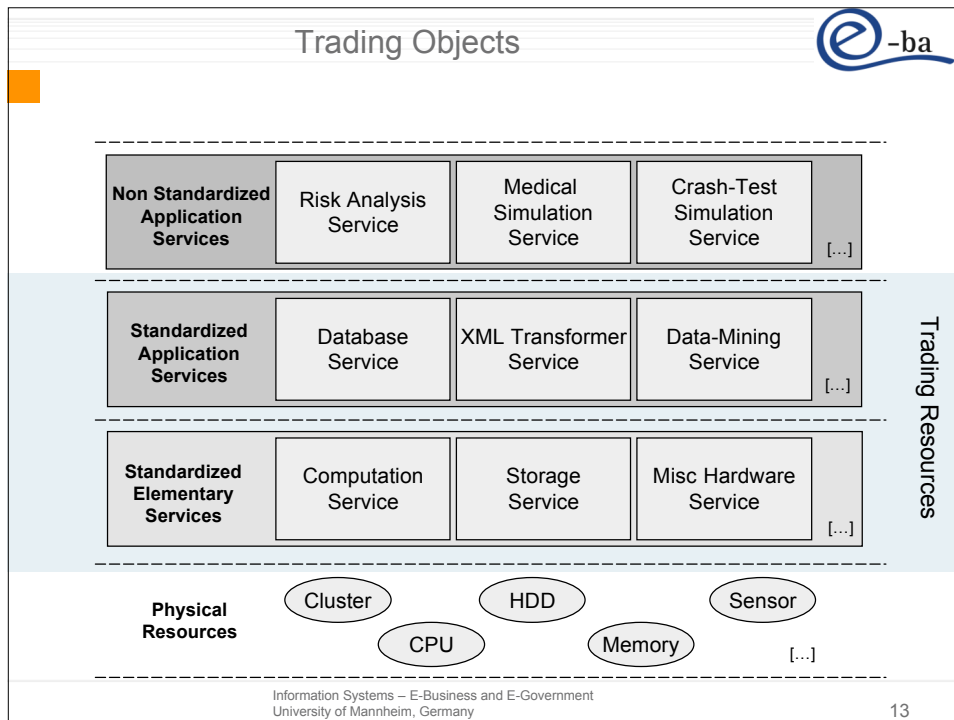
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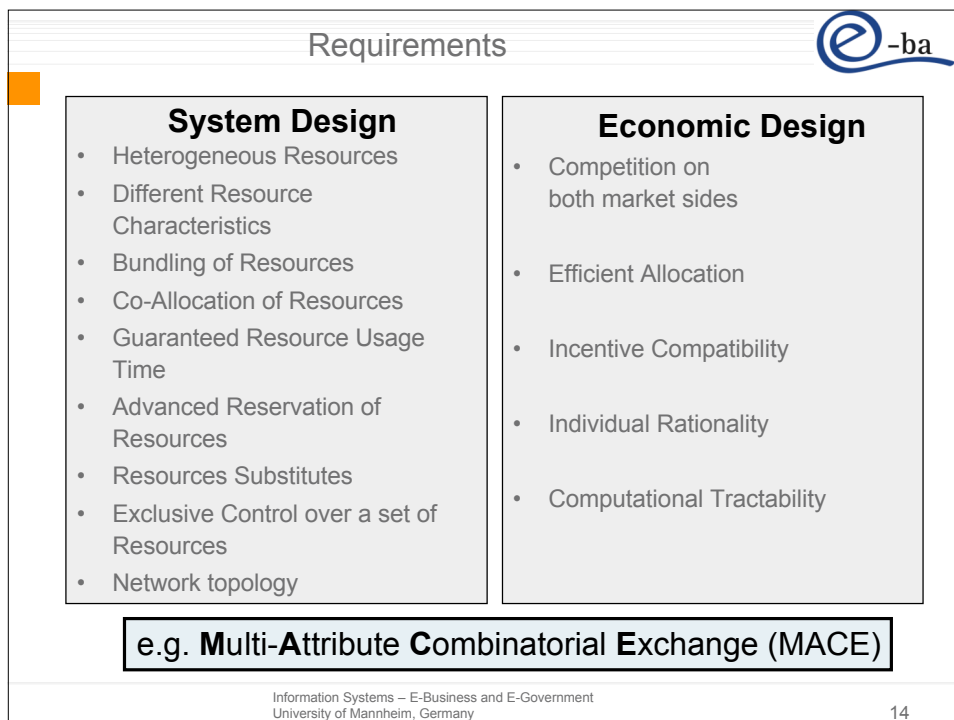University of Mannheim

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Why Engineering a Grid Market?

- **Idea** of applying Markets to distributed systems is old …
  - Ferguson et al. [1988]: Market based load balancing
  - Regev, Nisan [1998]: Popcorn, Market for CPU scheduling
  - Buyya et al. [2002]: Grid economy
  - […]
- **None** of the proposed mechanisms is applied in commercial apps
- **Why?** Lack of a systematic and structured view on
  - System Design Challenges
    - What is traded? What are the technical requirements? How can they be realized in a market?
  - Economic Design Challenges
    - What is the objective of the allocation? What are the economic requirements?

Trading Objects

e-ba

Non Standardized Application Services	Risk Analysis Service	Medical Simulation Service	Crash-Test Simulation Service	[...]
Standardized Application Services	Database Service	XML Transformer Service	Data-Mining Service	[...]
Standardized Elementary Services	Computation Service	Storage Service	Misc Hardware Service	[...]

Trading Resources

Physical Resources

Cluster   HDD   Sensor

CPU   Memory   [...]

Requirements

e-ba

System Design
- Heterogeneous Resources
- Different Resource Characteristics
- Bundling of Resources
- Co-Allocation of Resources
- Guaranteed Resource Usage Time
- Advanced Reservation of Resources
- Resources Substitutes
- Exclusive Control over a set of Resources
- Network topology

Economic Design
- Competition on both market sides
- Efficient Allocation
- Incentive Compatibility
- Individual Rationality
- Computational Tractability

e.g. Multi-Attribute Combinatorial Exchange (MACE)
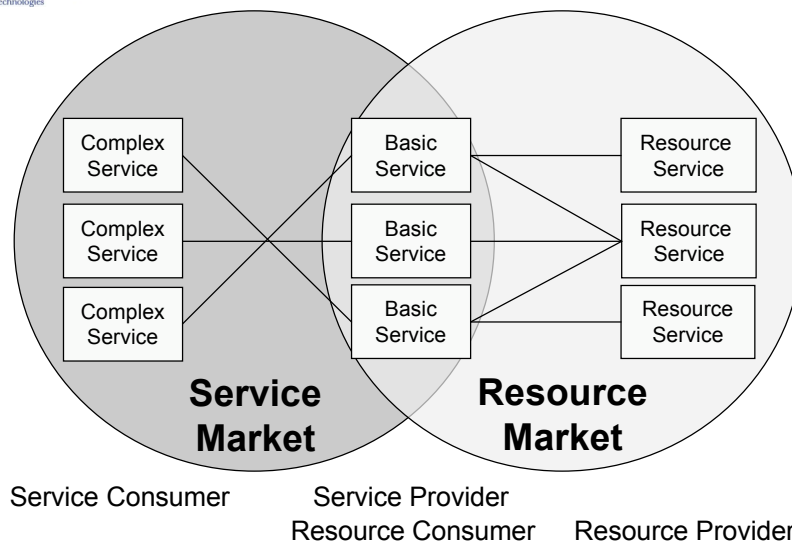
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Information Society
Technologies

Service Market: Complex Service, Complex Service, Complex Service

Resource Market: Basic Service, Basic Service, Basic Service — Resource Service, Resource Service, Resource Service

Service Market **Resource Market**

Service Consumer   Service Provider
                     Resource Consumer   Resource Provider

8

Slide 17

CatNets Facts
- EU IST FP 6
- 2004 – 2007
- 6 European Partners

- **Multi-attribute Combinatorial Exchange**
  - **Supports:**
    - Bundle and XOR bids
    - Quality and time attributes
  - **Requirements:** Bidding Language, Allocation and Pricing Rule
- **Bidding Language**

$$B_n(S_i) = (v_n(S_i), (q_n(S_i, g_1, a_{g_1,1}), \ldots, q_n(S_i, g_j, a_{g_j, A_j}), s_n(S_i), e_n(S_i), l_n(S_i))$$

→ Bundle (e.g. Computation AND storage)

→ Valuation/Reservation prices

→ Quality attributes (e.g. 30GB of free space)

Slots ← Start ← End ←

- Fulfills requirements upon a Grid system **www.catnets.org**
  - Compliant with WS-Agreement specification

Slide 18

- **Winner Determination**
  - Maximize difference between buyers' valuations and sellers' reservation prices
  - Formalized as Linear Mixed Integer Program:

$$\max_{z_{n,t}(S_i), y_{m,n,t}(S_i)} \sum_{n \in \mathcal{N}} \sum_{S_i \in \mathcal{S}} \sum_{t \in \mathcal{T}} v_n(S_i) z_{n,t}(S_i) - \sum_{m \in \mathcal{M}} \sum_{n \in \mathcal{N}} \sum_{S_i \in \mathcal{S}} \sum_{t \in \mathcal{T}} r_m(S_i) y_{m,n,t}(S_i)$$

$$\text{s.t. } feasible(x_n(S_i), z_{n,t}(S_i), y_{m,n,t}(S_i))$$

  - Feasible Means:
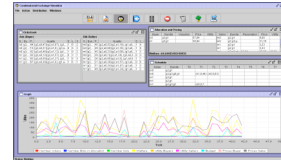   - Logical operators (XOR, AND), quality and time restrictions are met

- **Pricing**
  - Approximated Vickrey Pricing   *(Parkes et al., 2001)*
  - K-Pricing   *(Schnizler, Neumann, Veit, Weinhardt 2006)*

MACE: An Auction for trading Grid Services

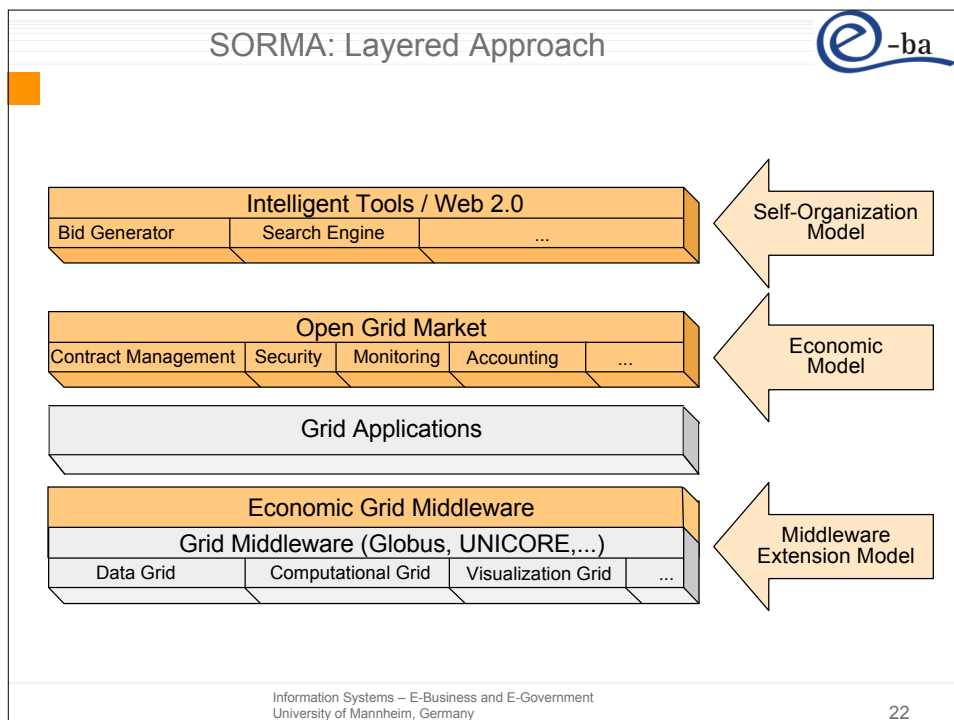- **Implementation**
  - jCase: Java Combinatorial Auction Simulation Environment
  - OptorSim Simulator

- **Evaluation**
  - Incentive Compatibility
    - Can participants gain utility by manipulating bids?
    - → K-Pricing Schema is "approximate" incentive compatible

  - Performance Evaluation
    - Is the mechanism tractable with an increasing number of bids?
    - → For large-scaled settings, approximations are required

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SORMA: Challenges

SORMA Facts
- EU IST FP 6
- 2006 – 2009
- 10 European Partners
- 2 Non-EU Partners

"Development of **methods and tools**
- for establishing an **efficient market-based allocation** for resources
- in order to enable resource **accessibility** for all users
- and to increase **user's satisfaction, profit and productivity**"

SORMA Focus

Requirement Analysis → SORMA system specification → SORMA system implementation → Pilots

Requirement Analysis → MOSIX enhancement → MOSIX implementation → Pilots

Exploration

www.sorma-project.org

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21

SORMA: Layered Approach

Intelligent Tools / Web 2.0
| Bid Generator | Search Engine | ... |

Self-Organization Model

Open Grid Market
| Contract Management | Security | Monitoring | Accounting | ... |

Economic Model

Grid Applications

Economic Grid Middleware
Grid Middleware (Globus, UNICORE,...)
| Data Grid | Computational Grid | Visualization Grid | ... |

Middleware Extension Model

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22

SORMA: Participating in the Market

- **Open Grid Market**
  - Definition and evaluation of market mechanisms
  - Accounting and billing
  - Security
  - Integration of the market into the SORMA system

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Recommendations

- *Recommendation*: Modeling of a two-tiered cost-oriented resource allocation scheme for E-Infrastructures based on a hybrid centralized/decentralized market mechanism for Grids and distributed architectures.

- *Recommendation*: Introduction of a billing scheme for post-allocation resource billing in E-Infrastructures. Enabling of a cost-/profit-center concept for the utilization or computational resources.

Wrap up

- Why "Markets" for Grid resources?
  - Efficient allocation
  - Pricing of scarce computational resources
- Technical versus economic allocation of Grid services
  - Grids become *Service Oriented Architectures (SOA)*
  - *Technical and economical allocation often diverse*
- Strong efforts in commercialization of Grid services
  - Pricing/business/allocation models needed
  - "Convincing" of companies about usefulness of Grid
  - Utilization of Grid technology in E-Business scenarios

Thank you for your attention

contact

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27