Integration of Decentralized Economic Models for Resource Self-Management in Application Layer Networks

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Goals of the Presentation

- Make a case for decentralized economic models for self managed resource allocations

- Present an architecture for implementing resource allocation mechanisms

- Highlight challenges and sketch a research agenda

- Avoid too many implementation details
  - Of course, Available upon request!

Outline

- Introduction and Motivation
  - Resource allocation in ALNs
  - A Case for Economics for Autonomic Systems
- Proposed Architecture
  - Conceptual framework
  - Technical platform
- Ongoing Prototype
- Conclusions and future work
- Questions

Application Layer Networks

Large-scale distributed applications that allow the provisioning of **services** using resources from a large, **heterogeneous and dynamic resource pool**, with logical **topologies that emerges** largely from the usage patterns:
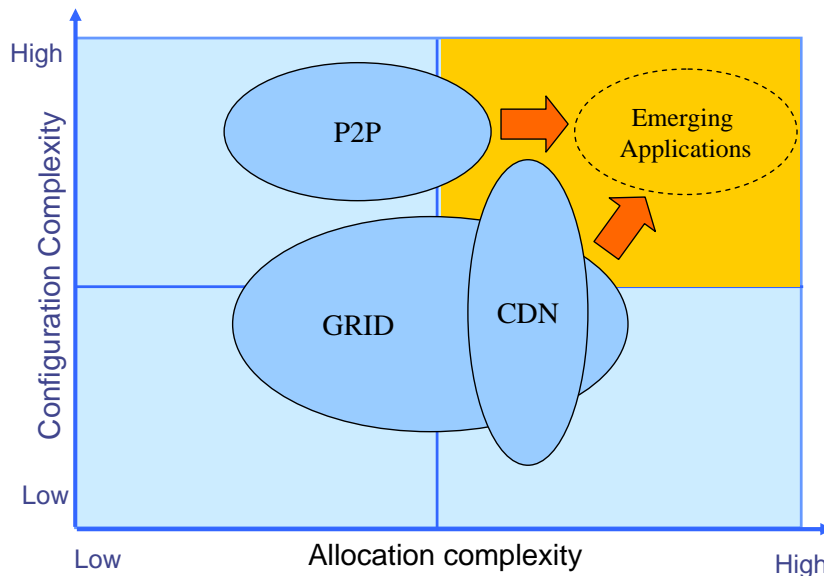
–PlanetLab

–BitTorrent

–Coral

Identified characteristics

–Dynamic environment and configuration

–Diversity of participants

–Large scale

–Partial knowledge

–Complex resource allocation decisions

–Evolutionary

Evolution of Application Layer Networks

Configuration Complexity: dynamics of the configuration, lack of global knowledge and evolutionary environment

Allocation Complexity: Diversity of requirements and complexity of allocation demands

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Requeriments for Resource Allocation

- Situateness
  - Consider location of requestors
  - Be aware of context and environment
- Dynamic (re)configuration
  - Adapt to unpredictable usage patters
  - New instances must be created and located as needed
- Topology neutrality
  - Adapt to different interaction topologies ranging from centralized to fully P2P
- Autonomy
  - Allow for multiple administrative domains with particular policies

Why Economic Based Models?

- What does Economics offer
  - Rich conceptual framework
  - Formal models and analytical insight
  - Theoretical benchmarks

- Decentralized economic models are a promising approach for resource allocation
  - Economy as a **coordination** device (distributed decision making)
  - Can handle **conflicting** needs
  - **Partial knowledge** is a fundamental assumption
  - Participants are **selfish** (don't require cooperation)
  - Price and price changes **synthesizes information** about resources and the environment.
  - Bidding **protocol amenable for standardization** (e.g. Contract net)

Economics versus Biology Inspired Models

Evolution or Intelligent Design?

Biology

- We were made by biology
- Long terms adaptation
- Adaptation of individual from a population
- Might be unfair: unsuited individuals are extinct

Economics

- We made economy
- Short and long term adaptation
- Adaptation by cooperation and competition between populations
- Allows fair treatment of unsuited individuals (subsidized)

Why the Limited Adoption of Economic Models?

- Unsuitable economic models
  - Ad hoc models
  - Too simplistic
  - Not amenable to modern applications (i.e. centralized auctions)

- Lack of standards
  - Bidding protocols
  - Representation of resources and money
  - Agreements (already been addressed)

- Lack of general frameworks to implement models. Existing architectures are:
  - **Our target** — Targeted to specific applications
  - Tied to an specific market model (e.g. Auctions)
  - Rigid architectures, not amenable for diverse ALN architectures


Objectives of Our Research

- Tackle the complexity of implementing decentralized economics models for resource allocation

- We are interested in **Architectures** and **Models**, not specific **Algorithms**

- Proposed approach:
  - Construction of a framework that offers a set of generic mechanism
  - Allow specialized strategies and policies can be dynamically plugged to adapt to specific application domains or market designs

- Requirements
  - Scalability
  - Self-organization to handle lack of global knowledge
  - Full distribution of critical functions among "peer" nodes
  - Flexibility to deploy in diverse architectures
  - Support coexistence of market models
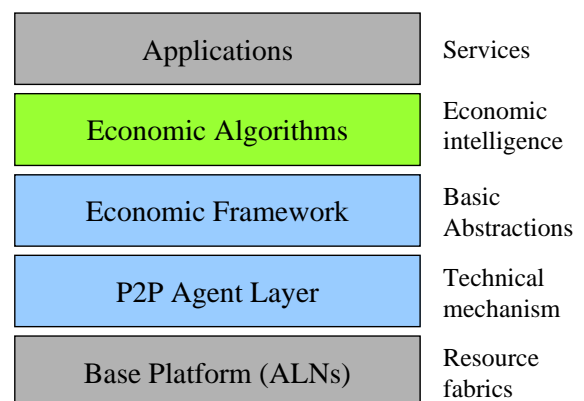
Proposed Resource Allocation Model

- Direct interaction between trading agents under a **"peer to peer"** paradigm
  - Self-organizing
  - No hierarchies
  - No central control
- Model applications under a **Service Oriented Architecture**
- Physical resources are **virtualized**
- Market as a **communication** and **norm enforcement** device
  - No direct participation in negotiations

Resource Allocation Model

ALN
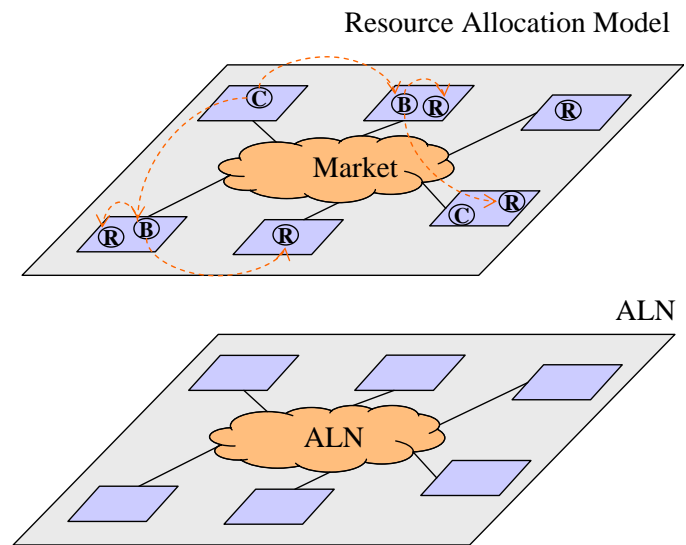
Overview Architecture

Design Principles

- Isolate economic decision from technical complexity
- Give freedom to implement each agent's intelligence (reasoning, strategies) to drive the negotiation process
- Take care of complex "mechanical" tasks at the lowest possible layer
- Use pluggable policies and mechanisms
- Use generic and extensible APIs
- Adopt a P2P architecture for the middleware components
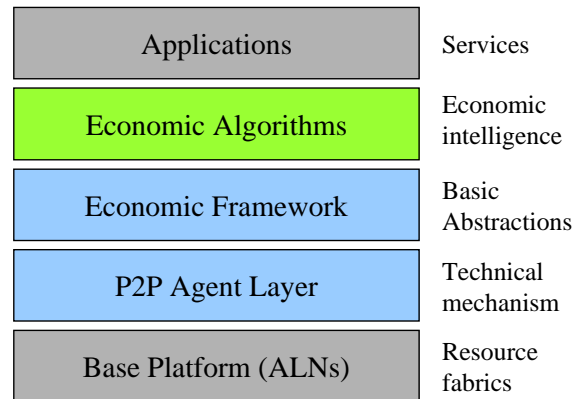
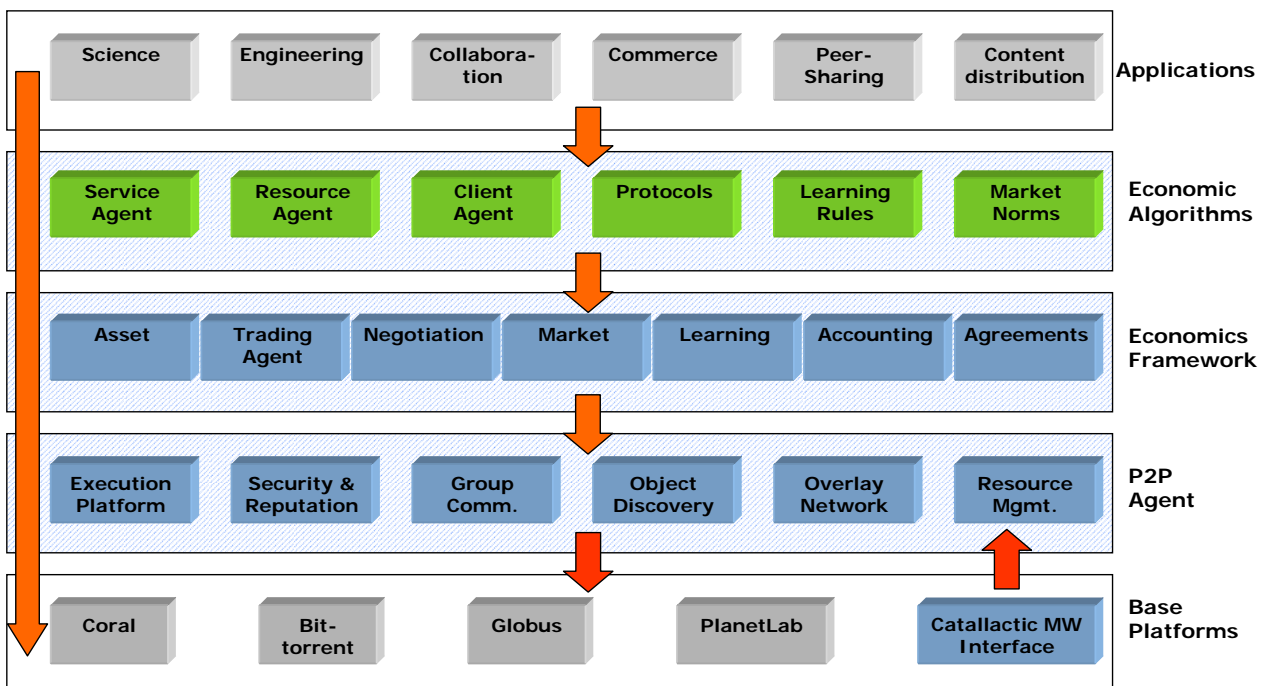|	
Applications	Services
Economic Algorithms	Economic intelligence
Economic Framework	Basic Abstractions
P2P Agent Layer	Technical mechanism
Base Platform (ALNs)	Resource fabrics

Overview Architecture

Economic Framework

- **locate** resources according to complex search criteria
- engage in **negotiations** with other agents
- **learn** and adapt to changing conditions
- **Manage resources** being traded (allocate, de-allocate, monitor, account usage)

P2P Agent Layer

- Rich execution environment for trading agents
- Generic interface to basic middleware and to common mechanisms like communication
- Supply the features not provided by the underlying platform,
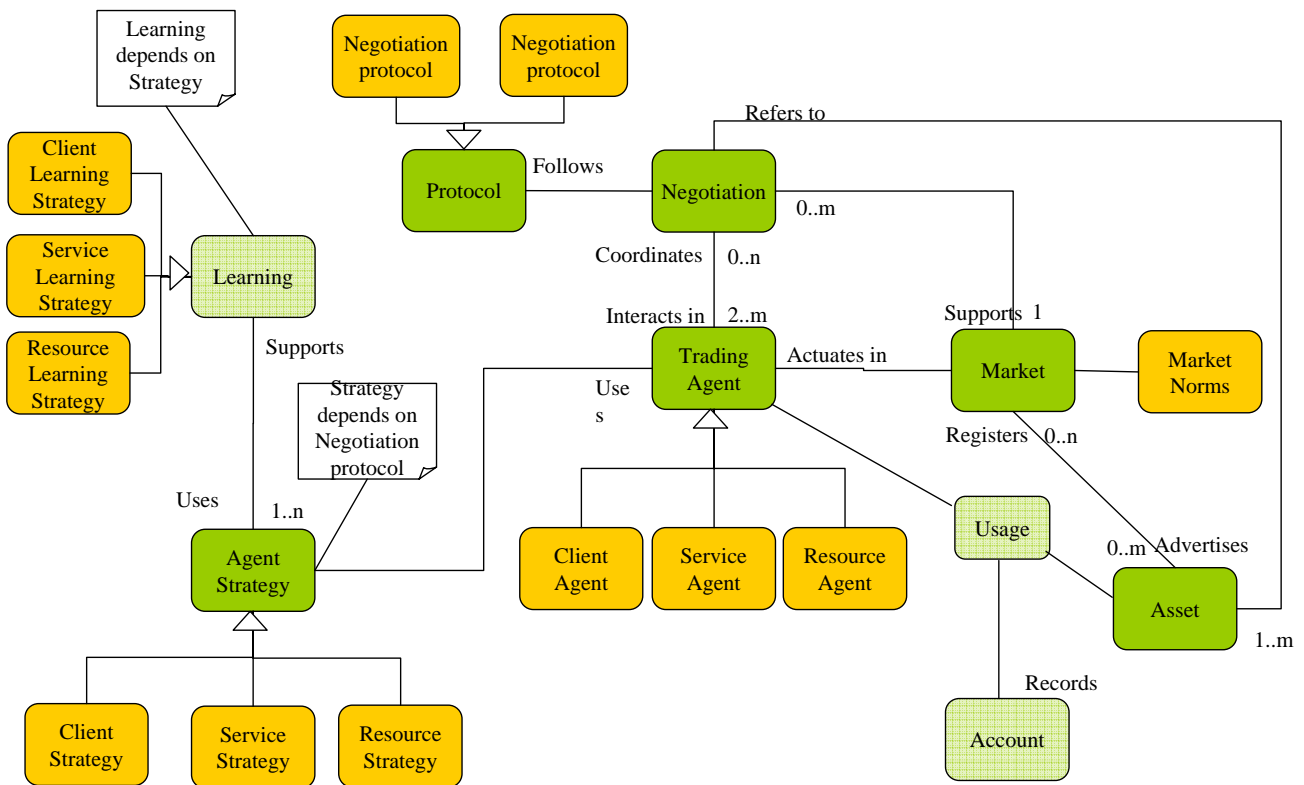- Allow to plug diverse mechanisms for critical functions (e.g. discovery)

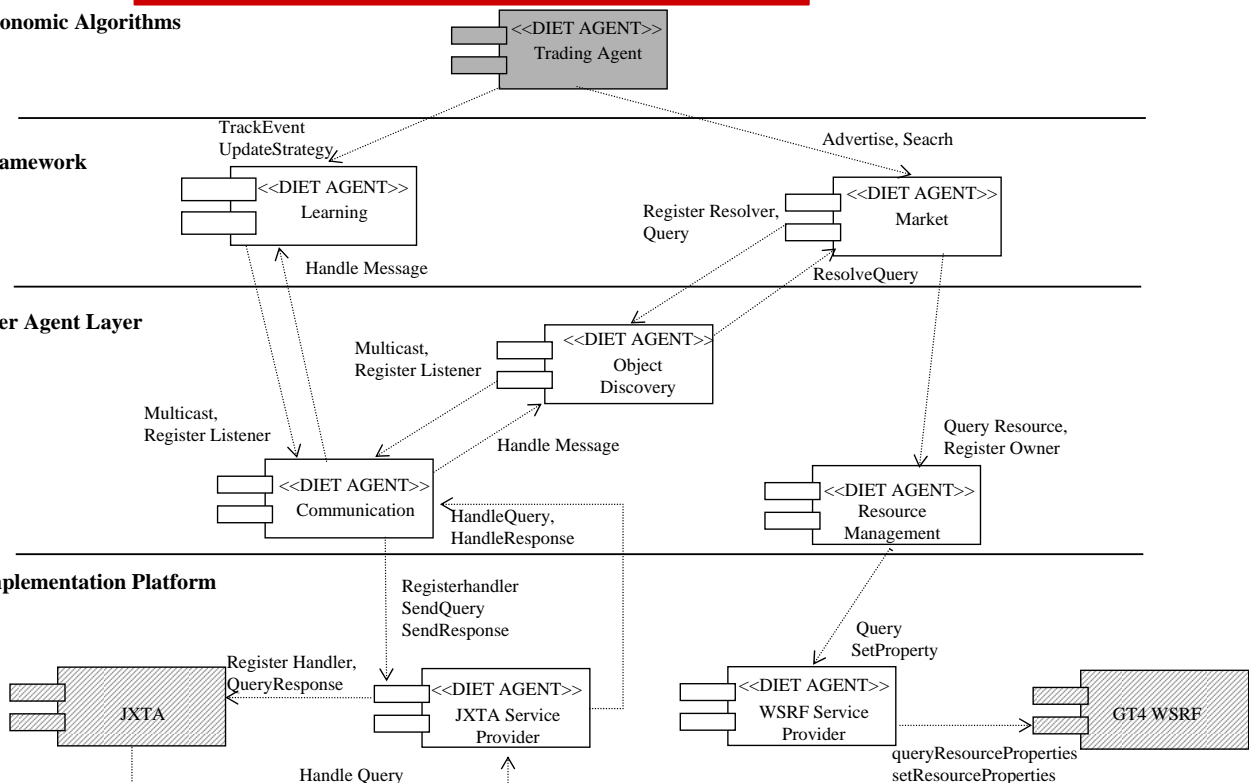| Layer	Description
Applications	Services
Economic Algorithms	Economic intelligence
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Detailed Architecture

Applications: Science, Engineering, Collabora-tion, Commerce, Peer-Sharing, Content distribution

Economic Algorithms: Service Agent, Resource Agent, Client Agent, Protocols, Learning Rules, Market Norms

Economics Framework: Asset, Trading Agent, Negotiation, Market, Learning, Accounting, Agreements

P2P Agent: Execution Platform, Security & Reputation, Group Comm., Object Discovery, Overlay Network, Resource Mgmt.

Base Platforms: Coral, Bit-torrent, Globus, PlanetLab, Catallactic MW Interface

Economic framework

Prototype Implementation in DIET/JXTA/GT4

Challenges

- Cross Layer adaptation
  - From technical to economics and back!

- Standardization of protocols
  - WS Agreements a promising candidate

- Common middleware APIs to develop agents

- Common resource models
  - WSRF a good starting point
  - Handle the virtualization of heterogeneous resources

Some Preliminary Conclusions

- **Separation of concerns** in layers offers the level of flexibility in both the technical implementation and the definition of the market needed to adapt to diverse ALNs.

- **Experience** with early prototype is very encouraging. We are looking towards more **implementation iterations** with different models for further refinement.

- **Models for analysis and interpretation** of results, from both **economical** and **technical** points of view will be needed to obtain some useful insight on the performance of the architecture.

Research Agenda

- Refine the **Economic Framework** to support various decentralized economic models for resource management in order to validate architectural flexibility
- Define **architecture profiles** and blueprints for specific applications and platforms
  - E.g. Grid with GT4, P2P P with Bittorrent
- Develop **models for resource virtualization** in the context of WSRF and other related standards
- Explore options to **automate protocol implementations**
- Integrate a **general resource monitoring framework** to track the state of heterogeneous resources
- Integrate a fully decentralized mechanism for **accounting and payment**

Questions?

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