Distributed Systems – Current Trends in Distributed Systems

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Outline

1. Overview
2. Peer-to-Peer Computing
3. Service-oriented Computing
4. Cloud Computing
5. Epilogue
Major Trends in Distributed Systems I

- Internet of Things (IoT):
  - Physical objects are seamlessly integrated into the information network
  - Physical objects become active participants in business processes
  - Physical objects become “Smart Objects”
  - Technologies: RFID, sensor networks, Internet Protocol version 6 (IPv6)

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IoT – Example: Factories of the Future

- Combining the power of independent factories
- Achieving complex manufacturing processes
- Providing concrete tools for
  - Process creation
  - Process optimization
  - Information exchange
- Real-time monitoring
Major Trends in Distributed Systems II

- **Internet of Services (IoS):**
  - Software services are provided through the Internet
  - Technologies: REST, WSDL, SOAP
  - Foundation for Cloud Computing

- **Service-oriented Architectures vs. IoS:**
  - IoS = Global SOA?
  - SOA: Originally mainly a concept to organize IT software architectures in an organization
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Slides are based on the book “Peer-to-Peer Systems and Applications”, LNCS Vol. 3485, Springer and lecture “Peer-to-Peer Systems and Applications” (TU Darmstadt)
Peer-to-Peer: Overview

(a) Client/Server

(b) Hybrid

(c) Peer-to-Peer
Peer-to-Peer

- Components directly interact as peers by exchanging services
- Request/reply interaction without the asymmetry found in the client-server pattern – all peers are equal
- Each peer component provides and consumes similar services
What is P2P?

- Definition according to Oram et al.:
  - A Peer-to-Peer (P2P) system is „a self-organizing system of equal, autonomous entities (peers) [which] aims for the shared usage of distributed resources in a networked environment avoiding central services.“
  - „A system with completely decentralized self-organization and resource usage.“

- Derived key characteristics of a P2P system:
  - Equality – All peers are equal (peer = gleichgestellt)
  - Autonomy – No central control
  - Decentralization – No centralized services
  - Self-organization – No coordination from outside
  - Shared resources – Peers may use resources provided by other
Peers

- **Peers**
  - Are nodes running in some P2P overlay
  - Have all the same capabilities (ability to act in any role)
  - Can act as “clients” and “servers” at the same time
Overlay-Network

- Composed of direct connections between peers
- Typically an “overlay“ network on top of a network (e.g., the Internet)
- But completely independent from physical network, due to abstraction of the TCP/IP layer
- Separate addressing scheme
P2P: Application Areas

- Several application areas:
  - VoIP (Skype/FastTrack)
  - Media streaming (Joost)
- In 2006, P2P made up 70% of the Internet traffic (CacheLogic Research):
  - P2P accounts for ~19% of fixed access traffic in North America according to Sandvine (2010/11)
  - Bittorrent is the single biggest application regarding upstream traffic in North America in 2010/11 (52%)
- Obviously, File Sharing is one area where P2P is heavily applied:
  - Napster (1st Generation Centralized P2P)
  - Gnutella 0.4 (1st Generation Pure P2P)
  - Gnutella 0.6, FastTrack/KaZaA (2nd Generation Hybrid P2P)
  - Kademlia (foundation for trackerless BitTorrent and eDonkey) → Structured P2P
Reasons for Application of P2P

- Costs: Computing/Storage can be outsourced (this is the major reason why Skype applies P2P)
- High Extensibility (easy to add further resources)
- High Scalability (system can grow to a very large number of peers)
- Fault Tolerance: If one peer fails, the overall system will nevertheless work
- Resistance to lawsuits...
<table>
<thead>
<tr>
<th>Client-Server</th>
<th>Peer-to-Peer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Server is the central entity and only provider of service and content. → Network managed by the Server</td>
<td></td>
</tr>
<tr>
<td>2. Server as the higher performance system.</td>
<td></td>
</tr>
<tr>
<td>3. Clients as the lower performance system.</td>
<td></td>
</tr>
</tbody>
</table>

**Example: WWW**

<table>
<thead>
<tr>
<th>Unstructured P2P</th>
<th>Structured P2P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1st Generation</strong></td>
<td><strong>2nd Generation</strong></td>
</tr>
<tr>
<td>Centralized P2P</td>
<td>Pure P2P</td>
</tr>
<tr>
<td>1. All features of Peer-to-Peer included</td>
<td></td>
</tr>
<tr>
<td>2. Central entity is necessary to provide the service</td>
<td></td>
</tr>
<tr>
<td>3. Central entity is some kind of index/group database</td>
<td></td>
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<tr>
<td>Example: Napster</td>
<td></td>
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<tr>
<td>Pure P2P</td>
<td>Hybrid P2P</td>
</tr>
<tr>
<td>1. All features of Peer-to-Peer included</td>
<td></td>
</tr>
<tr>
<td>2. Any terminal entity can be removed without loss of functionality</td>
<td></td>
</tr>
<tr>
<td>3. → No central entities</td>
<td></td>
</tr>
<tr>
<td>Examples: Gnutella 0.4, Freenet</td>
<td></td>
</tr>
<tr>
<td>Hybrid P2P</td>
<td>DHT-Based</td>
</tr>
<tr>
<td>1. All features of Peer-to-Peer included</td>
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<tr>
<td>3. → No central entities</td>
<td></td>
</tr>
<tr>
<td>4. Connections in the overlay are “fixed”</td>
<td></td>
</tr>
<tr>
<td>Examples: Chord, CAN</td>
<td></td>
</tr>
</tbody>
</table>

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Motivation

- Major Trend since the 1990s:
  - Globalization, deregulation of markets
  - Cross-organizational workflows and business processes are of major importance
  - Business Process Outsourcing (BPO)
  - Flexibility of business processes is a key success factor

- Flexible IT architectures are a major requirement:
  - Integration of legacy systems
  - Coupling to IT systems of business partners
Motivation – A Shift of Paradigms

- Mainframe
- Personal
- Client server
- Internet
- Web services
- Service-centric management
- Service-Oriented Architecture

Silos of technology: inflexible, complex, imposes limits on business

Service-Oriented Architecture: flexible, business-centric, IT responds to needs of business
Vision of a Service-oriented Architecture

“Loosely Coupled, Process Driven Services and Components”
SOA – Overview and Roles

- **Service-oriented Architectures:**
  - IT architecture made up from single services, i.e., self-contained software components with a distinct functionality
  - Complex applications arise from the coupling of single services, e.g.,
    - Service-based workflows
    - Mashups
  - However, it is also possible to invoke single services

- **Roles in a Service-oriented Architecture**
  - Service Provider
  - Service Consumer
  - Intermediary (optional), e.g., Service Broker

```
1. Publish
2. Find
3. Bind
4. Execute
```
Workflows and Services:
- Workflows are IT-enabled business processes.
- Services can be composed to workflows (2-level-programming).
- Services wrap functionality of legacy systems (e.g. Service A/B).
- Integration external services (e.g. Service C).

Services support rapid composition of distributed workflows.
Example for IoT and IoS: ADVENTURE – The Plug-and-Play Virtual Factory

- Virtual Factory
  - Multiple factories may form a virtual factory
  - Integrated ICT
    - Leverage information exchange
    - Interoperability at a deeper technical level
      - Ensuring that factories can be technically connected

- Plug
  - Factories provide information
    - Semantically enriched descriptions of offered manufacturing capabilities and products
    - Sensor technologies to monitor manufacturing processes

- Play
  - Factories model manufacturing process
    - Manufacturing processes modeled as composition of services
  - Identify particular partners who offer a distinct product
ADVENTURE – The Plug-and-Play Virtual Factory
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Slides are based on “A View of Cloud Computing”, Armbrust et al., Communications of the ACM, Vol. 53, No. 4, April 2010 and The NIST Definition of Cloud Computing
Motivation – Want milk?

- **Buy a cow:**
  - High upfront investment
  - High maintenance cost
  - Produces a more or less fixed amount of milk
  - Stepwise (discrete) scaling

- **Buy bottled milk:**
  - Pay-per-use
  - Lower maintenance cost
  - Linear (continuous) scaling
  - Fault-tolerant

Operating your own IT on-premise

Using IT capacity from the Cloud
Use Cases for Cloud Computing

- Demand for a service varies with time
  - e.g., Peak loads
- Demand is unknown in advance
  - e.g., for new startup
- Batch analytics
  - e.g., 1000 EC2 instances for one hour cost the same as one instance for 1000 hours
Traditional Datacenter vs Cloud

- Traditional datacenter

- Virtual datacenter in the cloud
Risk of Overprovisioning

- Capacity
- Unused resources

Graph showing the relationship between resources, demand, and time.
Risks of Underprovisioning

- Capacity
- Demand

Lost revenue

Lost users
Definition

- According to the National Institute of Standards and Technology (NIST):
  - On-demand self services: Quick, automated rental of capacity using Web interfaces
  - Broad network access
  - Resource pooling: Use of virtualization techniques
  - Rapid elasticity: Virtually unlimited capacity and scalability
  - Measured service: Pay-as-you-go
NIST: 3 Service Models (1)

- Cloud Infrastructure as a Service (IaaS)
  - Deliver computer infrastructure as a service (Virtual Machines, storage, ...)
  - Example: Amazon EC2, Amazon S3

- Cloud Platform as a Service (PaaS)
  - Deliver computing platform and solution stack as a service (execution environment/framework)
  - Example: Google App Engine

- Cloud Software as a Service (SaaS)
  - Example: ERP software as a service, Salesforce.com

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NIST: 4 Deployment Models

- Private Cloud: Operated solely for one single organization
- Community Cloud: Shared by several organizations
- Public Cloud: Open to general public, owned by an organization selling Cloud services
- Hybrid Cloud: Composition of two or more Cloud deployment models (private, community, public)
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Business Processes and Workflows

- Get Order
- Check Customer
- Accept Order
- Reject Order

What?

- Good Customer?
- Bad Customer?

Who?

With?

- Credit Card Information
- Customer Address

Workitems

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Mobile & Context-aware Computing
Autonomic Computing

- Goals:
  - Self-Configuring
  - Self-Healing
  - Self-Optimizing
  - Self-Protecting
Scientific Computing

- Discovery of new galaxies
- Aerodynamic simulation
- Preoperative surgery planning
- Stock exchange simulation
- Large scale weather prediction
Cloud Computing

Computing Power as a configurable, payable Service

**Amazon Web Services**  »  AWS Simple Monthly Calculator

<table>
<thead>
<tr>
<th>Service</th>
<th>Storage</th>
<th>Data Transfer</th>
<th>Requests</th>
<th>Total Monthly Payment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Amazon S3 (US)</strong></td>
<td>$1.50</td>
<td>$2.73</td>
<td>$0.02</td>
<td>$4.25</td>
</tr>
<tr>
<td><strong>Amazon S3 (EUR)</strong></td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
<td>$0.00</td>
</tr>
<tr>
<td><strong>Amazon EC2</strong></td>
<td>$0.00</td>
<td>$0.00</td>
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</tr>
<tr>
<td><strong>Amazon SQS</strong></td>
<td>$0.00</td>
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<td>$0.00</td>
<td>$0.00</td>
</tr>
</tbody>
</table>

Total Monthly Payment: $4.25
The Road User Information System of the Future

- Ubiquitous Web access makes a multitude of information sources available to drivers:
  - Makes it difficult to get exactly the information I am looking for at the time I need it
- Vision: „SIRI for Mobility“

1. Integration of Data from Heterogeneous Sources
2. Building Services on Top of the Data
3. Providing a Unified User Interface to the Services
Some Final Words

- We are always looking for motivated students:
  - Bachelor theses
  - Master theses
  - International internships

- Topics:
  - Internet of Things
  - Cloud Computing
  - Service-oriented Computing
  - Elastic Processes
Further Readings

Thanks for your attention!

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