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)
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 a concept to organize IT architectures in a company
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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

- 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…
### Client-Server

1. Server is the central entity and only provider of service and content. → Network managed by the Server
2. Server as the higher performance system.
3. Clients as the lower performance system

Example: WWW

### Peer-to-Peer

1. Resources are shared between the peers
2. Resources can be accessed directly from other peers
3. Peer is provider and requestor (Servant concept)

### Unstructured P2P

#### 1st Generation

**Centralized P2P**

1. All features of Peer-to-Peer included
2. Central entity is necessary to provide the service
3. Central entity is some kind of index/group database
   - Example: Napster

**Pure P2P**

1. All features of Peer-to-Peer included
2. Any terminal entity can be removed without loss of functionality
3. → No central entities
   - Examples: Gnutella 0.4, Freenet

**Hybrid P2P**

1. All features of Peer-to-Peer included
2. Any terminal entity can be removed without loss of functionality
3. → dynamic central entities
   - Example: Gnutella 0.6, JXTA

### Structured P2P

#### 2nd Generation

**DHT-Based**

1. All features of Peer-to-Peer included
2. Any terminal entity can be removed without loss of functionality
3. → No central entities
4. Connections in the overlay are “fixed”
   - Examples: Chord, CAN
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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

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<tr>
<th>company-internal</th>
<th>cross-organizational</th>
<th>production networks</th>
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- Flexible IT architectures are a major requirement:
  - Integration of legacy systems
  - Coupling to IT systems of business partners
Motivation – A Shift of Paradigms

- **Silos of technology**
  - inflexible, complex, imposes limits on business

- **Service-Oriented Architecture**
  - flexible, business-centric, IT responds to needs of business

Level of enterprise adaptability

- Mainframe
- Personal
- Client server
- Internet
- Web services
- Service-centric management
- Service-Oriented Architecture
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
Workflows and Services:

- 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
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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
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

![Diagram showing the relationship between resources, demand, capacity, and unused resources over time. The diagram illustrates how overprovisioning can lead to unused resources when demand fluctuates.]
Risks of Underprovisioning
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
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
- Always!
- Check Customer
- Good Customer?
- Bad Customer?
- Accept Order
- Reject Order
- Customer Address
- Credit Card Information
- Workitem
- Who?
- With?
- What?
Mobile & Context-aware Computing
Autonomic Computing

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

Computing Power as a configurable, payable Service
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:
  - Cloud Computing
  - Service-oriented Computing
  - Elastic Processes
Further Readings