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Peer-to-Peer networking in heterogeneous, mobile environments

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Abstract

An increasing number of applications in the Internet are provided through **Peer-to-Peer (P2P) technologies**. These applications are not only concentrating around classical file sharing, but include telephony services and collaborative work as well. However, P2P technology is regarded as being **disruptive for traditional fixed and mobile operators**. Nevertheless, it can also be considered as an **opportunity for new ways of networking for service provisioning**. First, P2P concepts allow a more efficient usage of existing platform resources through relying on existing infrastructure including even the customer equipment and thus provide a low cost service platform. Second, P2P technology brings new business opportunities through extending the service portfolio to user provided services and to ubiquitous environments. Whereas existing P2P systems are focused towards a broadband fixed network Internet characterized by homogeneous desktop PCs, new challenges emerge for the application of P2P technologies in the real networked world. Especially **mobile networks**, which are considered to be an integral part of the next generation Internet, pose new requirements regarding signalling overhead, churn, network capacity and terminal capabilities. This presentation describes a new P2P overlay network that not only **compensates heterogeneity based on a hierarchical networking approach**, but even takes advantage of it to support an efficient information exchange. This P2P system consists of a DHT-based core overlay network interconnecting high capability **super peers that interface to low resource leaf peers.** Based on analytical evaluation and simulations the efficiency of this architecture as well as its optimal design is presented. This system constitutes a basic building block for an **overlay networking infrastructure supporting the lookup and distribution of distributed resources in heterogeneous networks**. Further building blocks address reliability, scalability, controllability, bootstrapping as core building blocks, and further application-specific components such as reputation management and complex query handling. An outlook on P2P based future generation networking concludes the talk.

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Motivation

- **Peer-to-Peer (P2P)** systems and applications …

… **challenging** traditional fixed and mobile operators

- Is this **lost ground** or can we make use of P2P technologies in a favorable way?
- Does P2P **open a new opportunity** for service provisioning? A new service platform paradigm?
- **Are current technologies applicable** for *mobile environments*?

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P2P - potential benefits

Resource efficient

- Infrastructure cost saving
  - through relying on existing infrastructure (e.g., the equipment of users)
  - with high availability and scalability
    - Example: Subscriber management (VoP2P)

Content Search

- New business opportunities and extended service portfolio
  - Services provided by users
    - Example: info sharing
  - Spontaneous emergence of a service overlay
    - Example: Community services

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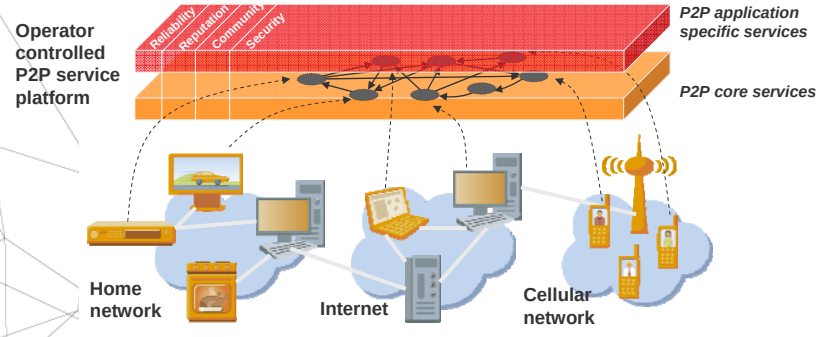
Challenge: "Mobile P2P"

- The original Peer-to-Peer definition aims at homogeneous peers, all having the same tasks!
- Mobile P2P definition:
  Mobile Peer-to-Peer systems involve mobile communication systems for the exchange of data, in which, at least for some peers, the last hop of the communication path is via a wireless link
- Heterogeneity of peers is the key characteristic of mobile P2P.
  - Devices
  - Access (last mile)
  - Wireless, wired, ad hoc

[Kellerer, etal. in Steinmetz, Wehrle (Hrsg.), LNCS 3485] 5

Objective: Operator-driven P2P service platform

- Develop building blocks for an operator-grade service platform based on P2P technology for low cost and rapid service provisioning



- and for any kind of user access incl. mobile

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P2P platform requirements (1)

Mobility, heterogeneity →

- Reduce the P2P lookup traffic overhead as much as possible, in order to overcome low transmission data rates of mobile devices
- Address high churn rates (causing maintenance traffic) due to frequent joins and leaves of nodes
- Considering limited resources of mobile devices addressing the heterogeneity of nodes and their distinct device capabilities

[Kellerer, A.D. Joseph, Dagstuhl 2006]

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P2P platform requirements (2)

Operator driven →

- Guarantee reliability
  - E.g., "99.999%" availability
- Support system management/controllability
  - Monitoring the network operation and collecting (assessing) all relevant parameters: Network size, session times, etc.
  - Tune appropriate parameters to provide satisfactory application operation
- Provide trust and incentive models to support users' willingness to comply to protocol
- Security, interoperability, access control, …

[Kellerer, etal., IEEE SPMS/SAINT 2007]

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Problem 1: heterogeneity

- Problem: efficient lookup of resources in heterogeneous networks and through diverse devices

- Basic concept: structured P2P
  → reduced lookup traffic
- Heterogeneity
  → hierarchical architecture

[Kellerer, etal., Elsevier AEÜ 2006]

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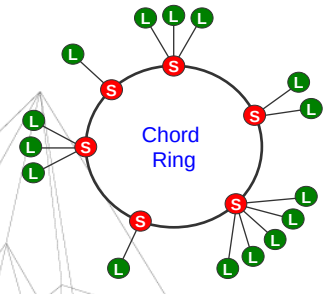
Our solution: Chordella



Chordella

S: Superpeer
L: Leafpeer

- Hierarchical P2P Overlay
  - Superpeers
    - Structured P2P (we use Chord)
    - Routing of all lookup requests
  - Leafpeers
    - Devices with limuted resources interfacing to a superpeer
    - No routing
- [Ganesan, ICDS04]: hierarchical Chord adapting to network topology
- [Garces-Erice, Biersack, Euro-Par03]: reducing the lookup path length
- Chordella:
  Total cost optimized design

[Zöls, Kellerer, Despotovic, IEEE P2P 2006]

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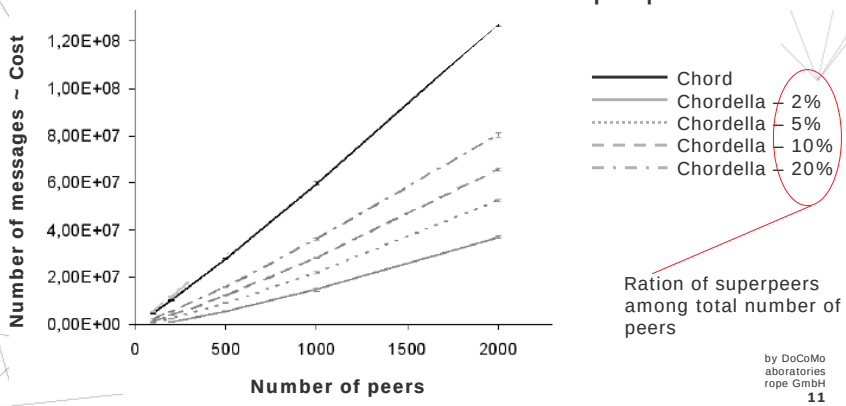
Evaluation

5 peer classes with different data rates, stability, shared objects,...

→ Improved cost compared to Chord

→ Variation with the number of superpeers



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Problem 2: Minimization of operation cost

- Criteria:

  Find optimal superpeer ratio α:

  $$\alpha = \frac{\text{Number of superpeers}}{\text{Number of peers}}$$

  → Minimize the total overlay network costs (in terms of generated messages)

  → Avoid overloaded superpeers

- Method:

  Analytical determination of operation cost in respect with the superpeer ratio

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Cost analysis

- Total cost in overlay network:
  $C = \{C_{Lookup\_SP}, C_{Lookup\_LN}, C_{Maintenance}, C_{Republish}\}$
  dependent on timer values, number of superpeers, number of leafnodes, lookup frequency, number of shared objects…
- Individual cost per superpeer:
  $c_i = \{C_{Lookup\_SPi}, C_{Maintenance\_SPi}, C_{Republish\_SPi}\}$
- Definition:
  Highest observable load factor
  HLF = max (c_i / limit{c_i})
  - takes individual superpeer capacities into account
  - focuses on weakest superpeer in the system

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Determine optimal superpeer ratio α_{opt}

$$\alpha = \frac{\text{Number of superpeers}}{\text{Number of peers}}$$

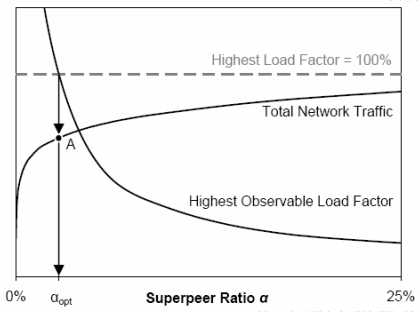
Determine minimal necessary α_{min} to avoid overloaded superpeers:

$$\alpha_{min} = \min(\alpha \in]0;1] \mid \text{HLF} \leq 100\%)$$

Total network traffic is increasing mono-tonically with α

$\Rightarrow \alpha_{opt} = \alpha_{min}$

→ Minimize total cost without overloading superpeers!



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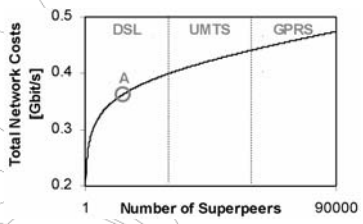
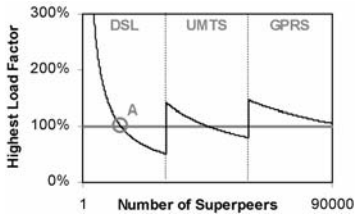
Example

- *N* = 90’000:
  30’000 DSL / 30’000 UMTS / 30’000 GPRS
- Modeling of peers:

	DSL	UMTS	GPRS
Lookup rate	1 / 60s	1 / 30s	1 / 30s
Shared objects	500	100	50
Upstream [kbit/s]	256	92	50





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Summary & outlook

P2P in heterogeneous environments

- The real world is heterogeneous
- Hierarchical systems provide solution
- **Control**: Cost efficiency & reliability
- Current work: distributed algorithm for maintenance of α_{opt}

Outlook

- General P2P overlay (layer?) as part of the future Internet → application specific overlays → move down
- From a "TCP-Internet" to an application-aware Internet (eg. P2P for content)

Thank You!

Dr.-Ing.

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