Peer-to-Peer Systems and Applications

Lecture 4: Hybrid Peer-to-Peer Systems

TECHNISCHE UNIVERSITÄT DARMSTADT

Chapter 5 and 21:

Part II: Unstructured P2P Systems
Part VI: Search and Retrieval

*Original slides for this lecture provided by Rüdiger Schollmeier and Jörg Eberspächer (Technische Universität München), and Vasilios Darlagiannis (Technische Universität Darmstadt)

0. Lecture Overview

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1. Hybrid Peer-to-Peer Systems
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   2. Definition and Benefits
   3. Model
   4. Basic Characteristics
   5. Topology
2. Decentralized File Sharing with Distributed Servers: eDonkey
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1. Hybrid Peer-to-Peer Systems

P2P Architectures and Design Dimensions, Definition and Benefits, Model, Basic Characteristics, Topology

1.2. Architectures of 1st and 2nd Generation P2P

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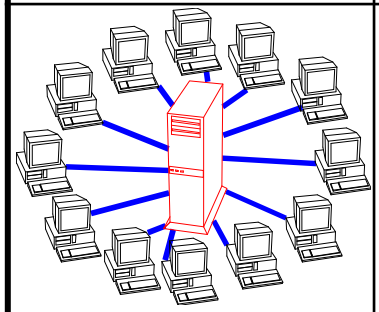
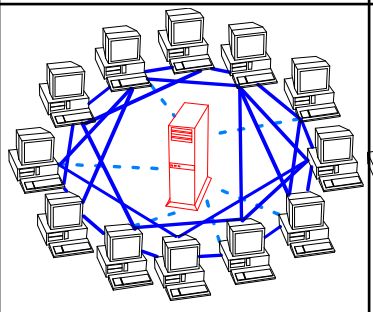
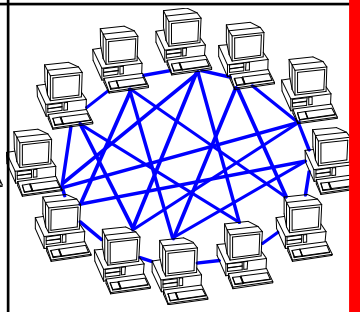
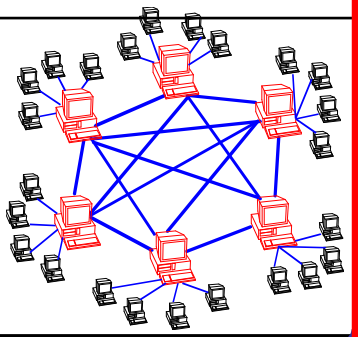
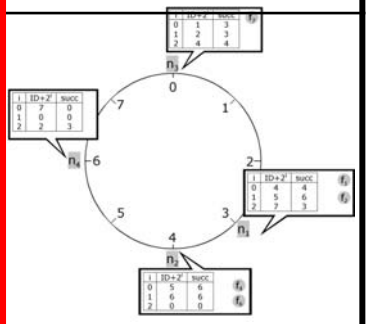
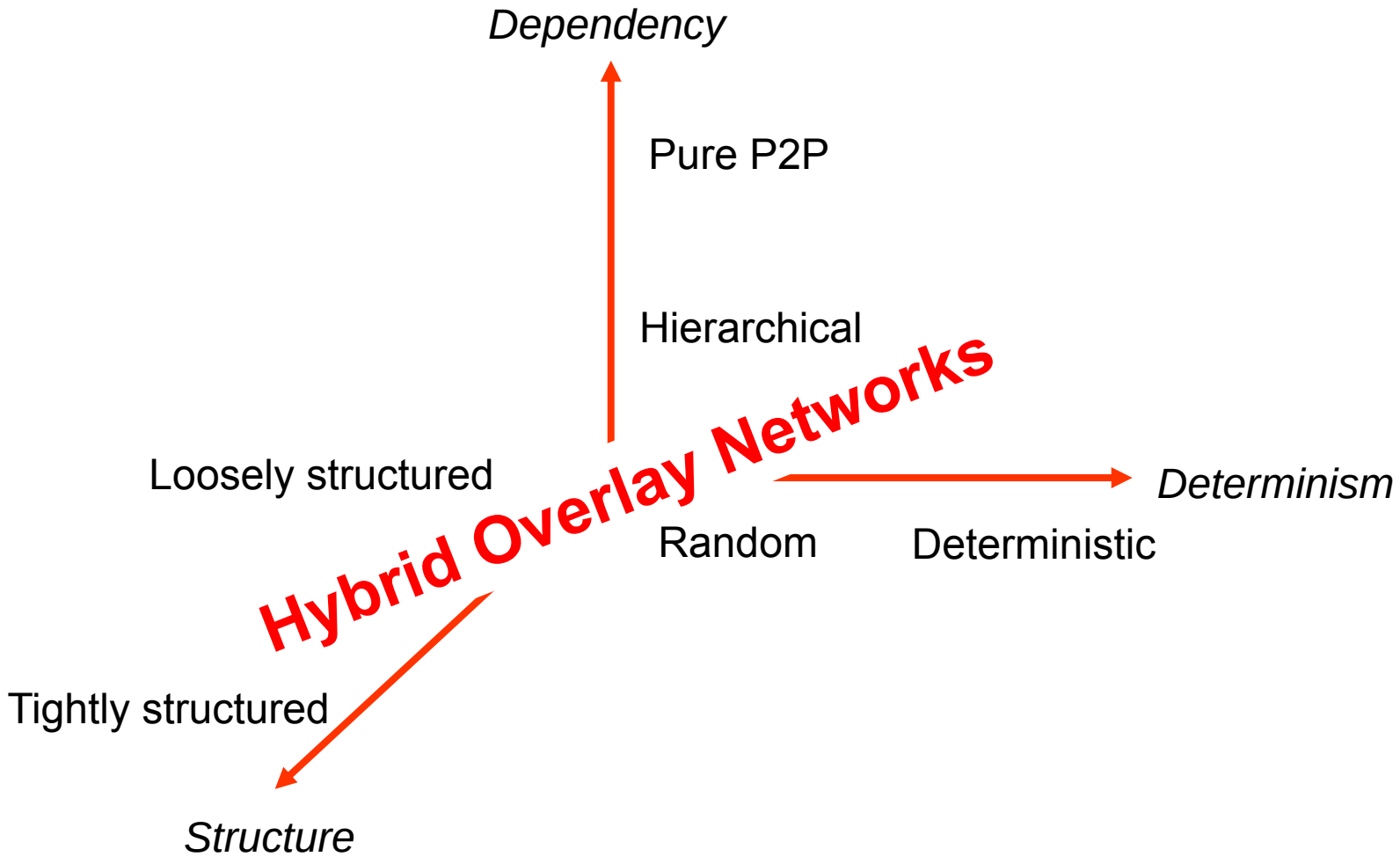
Client-Server	***Peer-to-Peer***			
1. Server is the central entity and only provider of service and content. → Network managed by the Server 2. Server as the higher performance system. 3. Clients as the lower performance system Example: WWW	1. Resources are shared between the peers 2. Resources can be accessed directly from other peers 3. Peer is provider and requestor (Servent concept)			
	Unstructured P2P			***Structured P2P***
	Centralized P2P	*Pure P2P*	*Hybrid P2P*	*DHT-Based*
	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	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	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	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
				
	1st Gen.		**2nd Gen.**	

1.1. Overlay Network Design Dimensions



1.2. Hybrid P2P Systems - Definition

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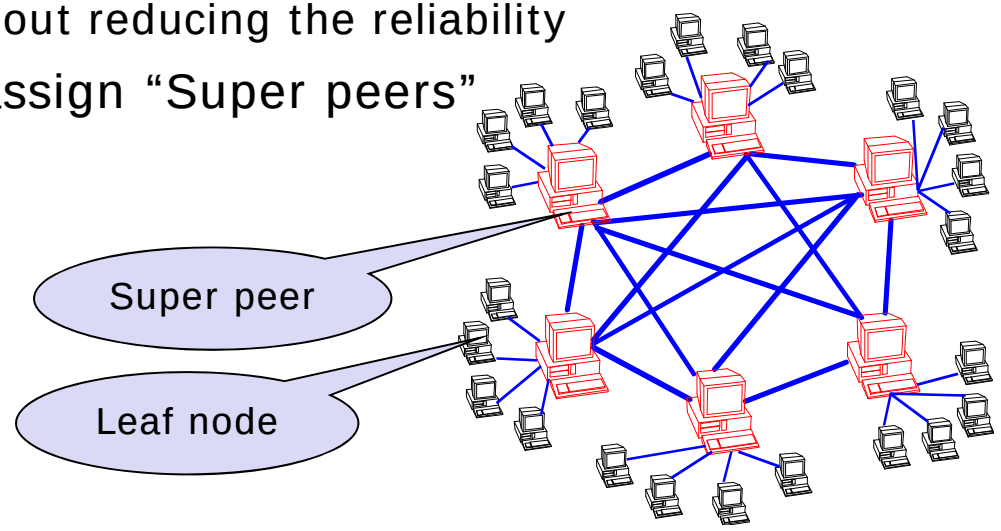
- Definition of “Hybrid”
  - “Something derived from heterogeneous sources or composed of incongruous elements” (Oxford Dictionary)
    - Initially, systems combining P2P and C/S characteristics were called hybrid
- Main characteristic, compared to pure P2P systems
  - Introduction of another dynamic hierarchical layer
- Hub-based network
  - Reduces the signaling load without reducing the reliability
- Election process to select and assign “Super peers”
- Super peers
  - High degree (degree>>20, depending on network size)
- Leaf nodes
  - Connected to one or more Super Peers (degree<7)



1.2. Hybrid P2P Systems - Benefits

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- Intrinsically better than “pure” approaches
  - When heterogeneity is inherent in the deployed systems
- Synergistic combination of techniques
  - With more strengths and less weaknesses than either technique alone
- Meet easier the tradeoffs in conflicting requirements
  - E.g., heterogeneity in physical capabilities versus equal distribution of workload

1.3. Model of Hybrid P2P Networks

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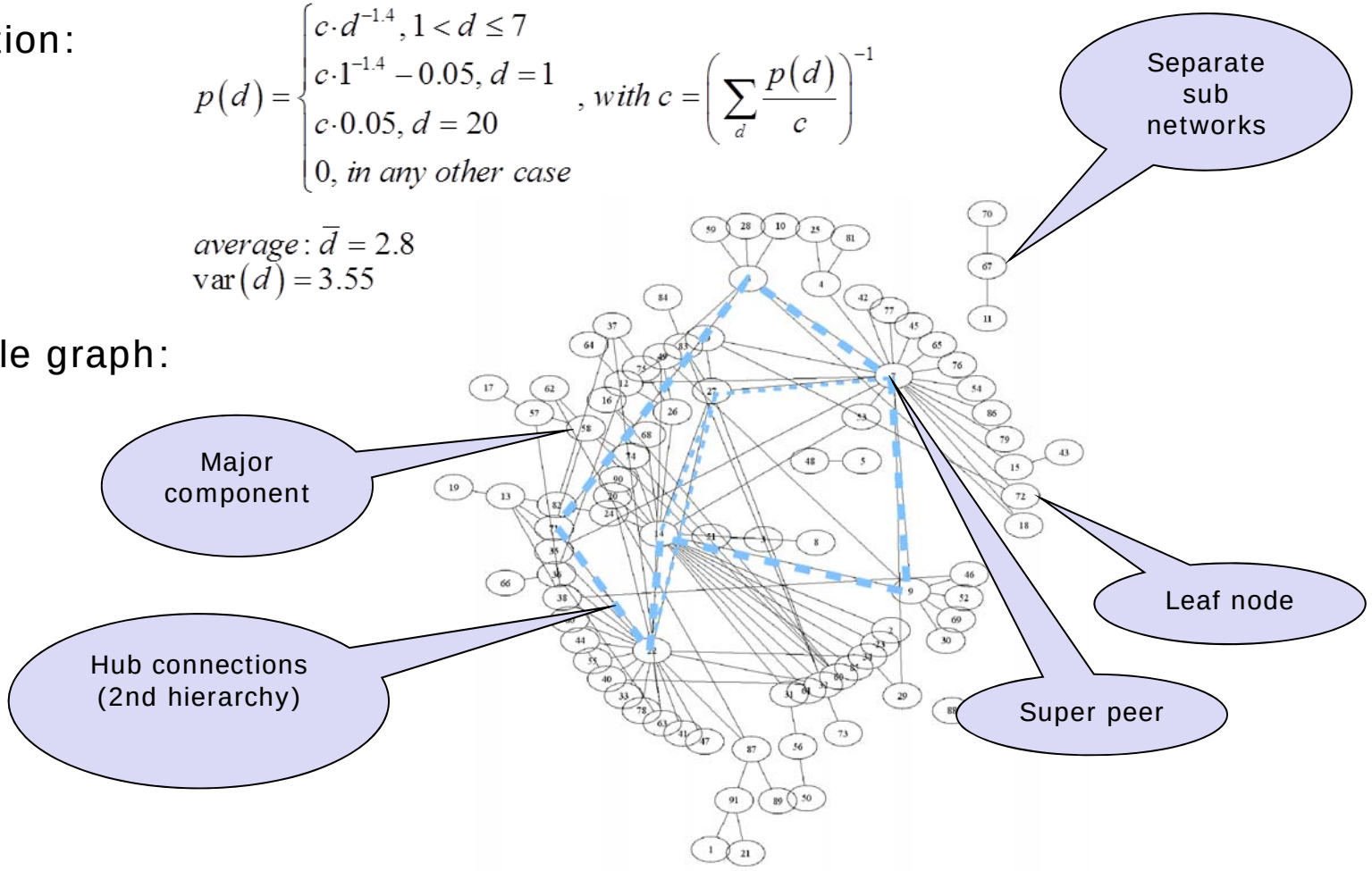
Degree distribution:

$$p(d) = \begin{cases} c \cdot d^{-1.4}, 1 < d \leq 7 \\ c \cdot 1^{-1.4} - 0.05, d = 1 \\ c \cdot 0.05, d = 20 \\ 0, \textit{in any other case} \end{cases}, \textit{with } c = \left(\sum_d \frac{p(d)}{c} \right)^{-1}$$

$$\textit{average}: \bar{d} = 2.8$$
$$\mathrm{var}(d) = 3.55$$

According sample graph:



1.4. Basic Characteristics of Hybrid P2P (1)

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- Bootstrapping:
  - Via bootstrap-server (host list from a web server)
  - Via peer-cache (from previous sessions)
  - Via well-known host
  - Registration of each leaf node at the super peer it connects to, i.e. it announces its shared files to the super peer

- Routing:
  - Partly decentralized
    - Leaf nodes send request to a super peer
    - Super peer distributes this request in the super peer layer
    - If a super peer has information about a matching file shared by one of its leaf nodes, it sends this information back to the requesting leaf node (backward routing)

1.4. Basic Characteristics of Hybrid P2P (2)

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- Routing (cont'd)
  - Hybrid protocol (reactive and proactive): routes to content providers are only established on demand; content announcements from leaf nodes to their super peers
  - Requests: flooding (limited by TTL and GUID) in the super peer layer
  - Responses: routed (backward routing with help of GUID)
- Signaling connections (stable, as long as neighbors do not change)
  - Based on TCP
  - Keep-alive
  - Content search
- Content transfer connections (temporary):
  - Based on HTTP
  - Out-of-band transmission (directly between leaf nodes)

1.5. Topology of Hybrid P2P

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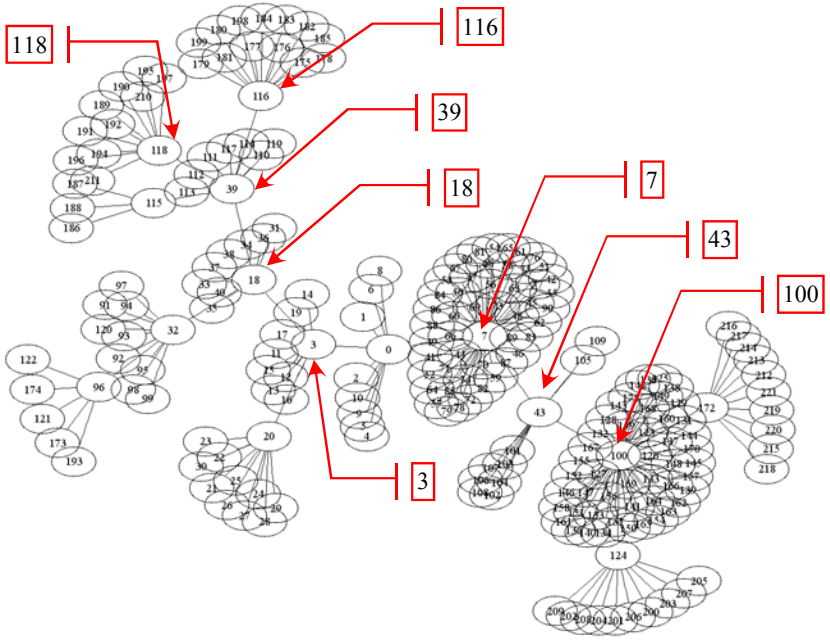
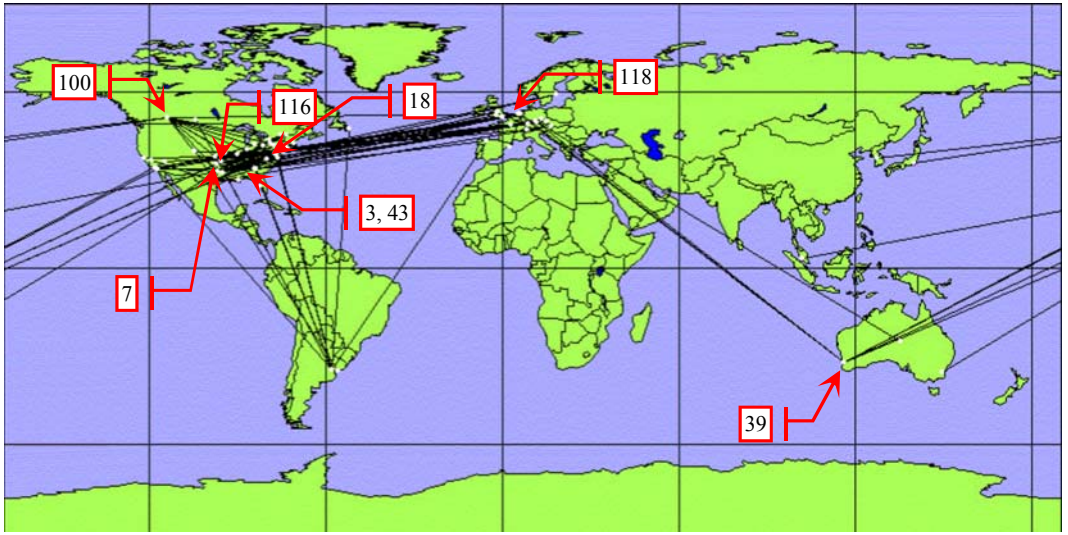


Abstract network structure of a part of the Gnutella network (222 nodes Geographical view given by Figure on the right, measured on 01.08.2002



Geographical view of a part of the Gnutella network (222 nodes); The numbers depict the node numbers from the abstract view (Figure on the left, measured on 01.08.2002)

- Virtual network not matched to physical network. See path from node 118 to node 18.
- Super peer (hub) structure clearly visible in abstract view

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2. Decentralized File Sharing with Distributed Servers: eDonkey

Principle, Procedure, Search, User Behavior

2.0. eDonkey

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- Most successful/used file-sharing protocol in
  - e.g. Germany & France in 2003 [see sandvine.org]
    - 52% of generated P2P file sharing traffic
    - KaZaA only for 44% in Germany

- Stopped by law
  - February 2006 largest server „Razorback 2.0“ disconnected be Belgium police
    - http://www.heise.de/newsticker/eDonkey-Betreiber-wirft-endgueltig-das-Handtuch--/meldung/78093

- See e.g.
  - http://www.overnet.org/
  - http://www.emule-project.net/
  - http://savannah.gnu.org/projects/mldonkey/

2.1. The eDonkey Network: Principle

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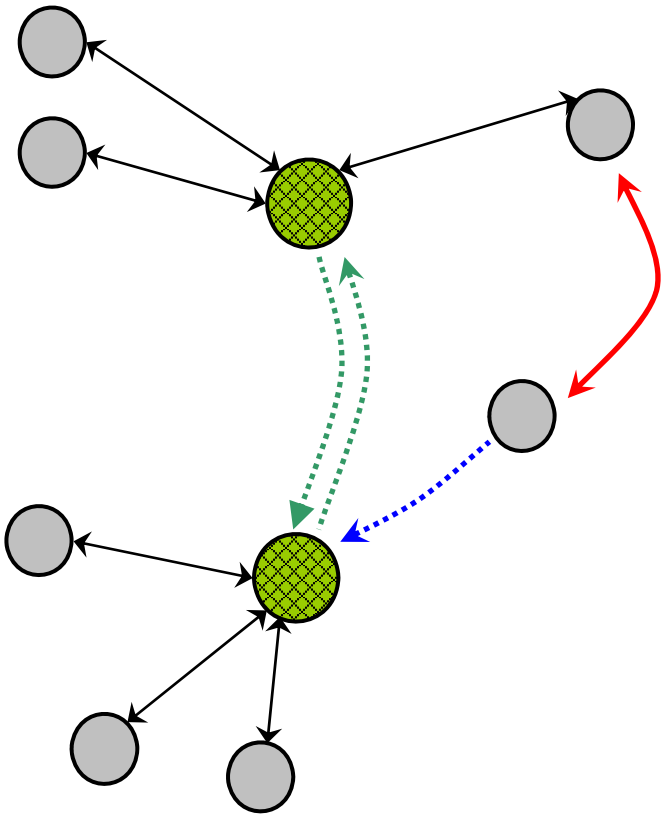
- DISTRIBUTED SERVER(s)
  set up and RUN BY POWER-USERS
  - → nearly impossible to shut down all servers
  - exchange their server lists with other servers
    - using UDP as transport protocol
  - manages file indices



- CLIENT application
  connects to one random server and
  stays connected
  - using a TCP connection
  - searches are directed to the server
  - clients can also extend their search
    - by sending UDP search messages to additional servers

2.2. The eDonkey Network: Procedure

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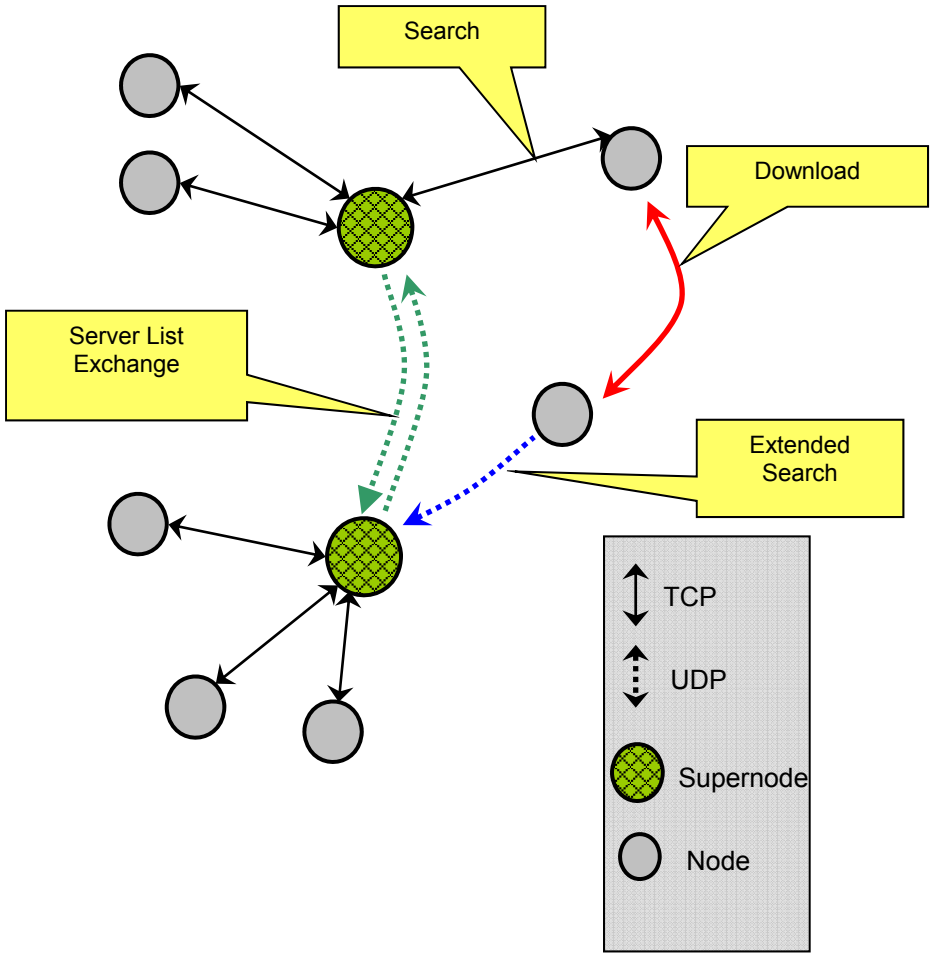
- Procedure
  - New servers send their port + IP to other servers (UDP)
  - Servers send server lists (other servers they know) to the clients
  - Server lists can also be downloaded on various websites
- Files are identified by
  - Unique 16 byte long MD4 (Message-Digest Algorithm4, RFC 1186) file hashes
  - Not identified by filenames
  - This helps in
    - resuming a download from a different source
    - downloading the same file from multiple sources at the same time
    - verification that the file has been correctly downloaded



2.3. The eDonkey Network: Search

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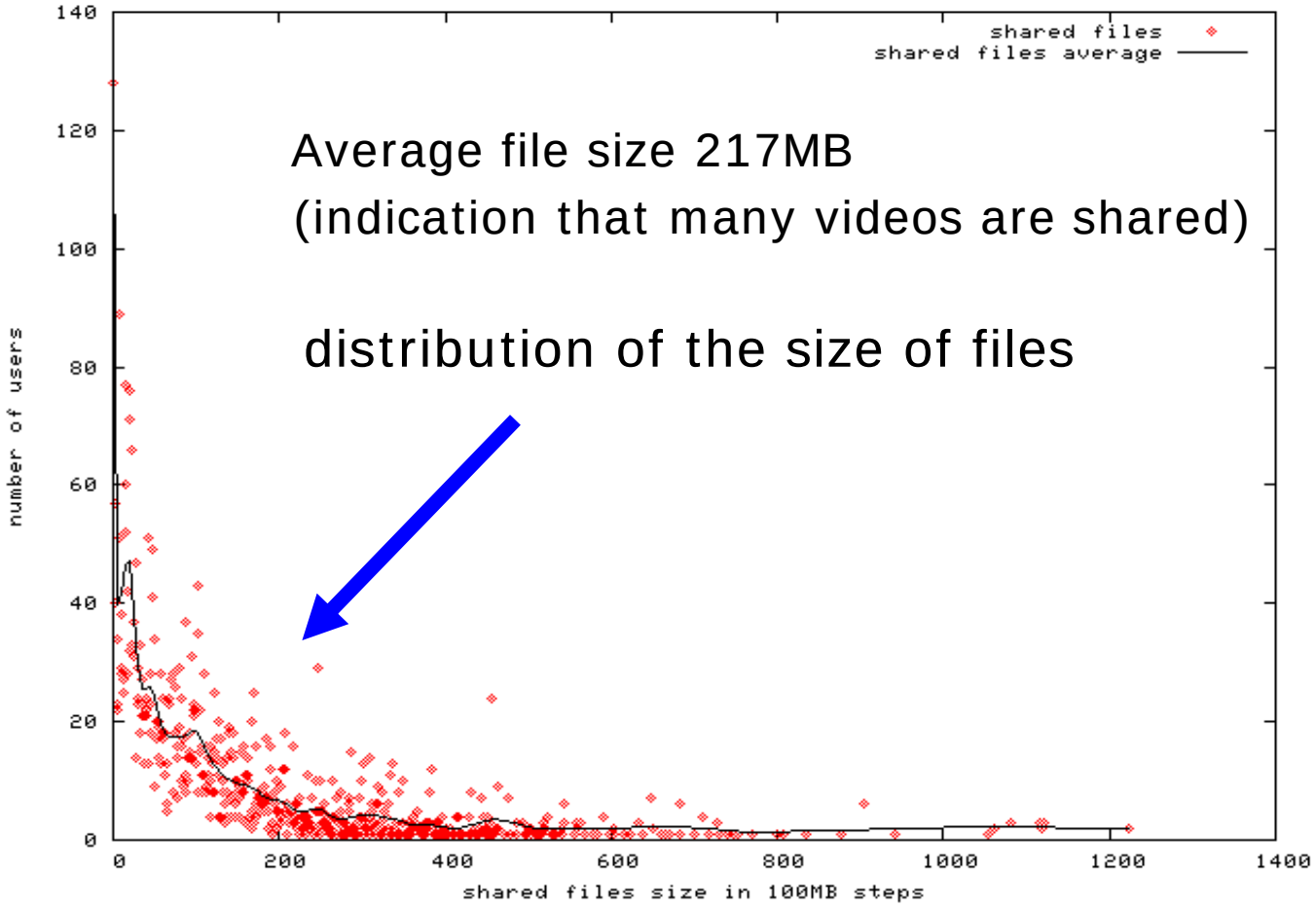
- The SEARCH consists of two steps:
  - 1. Full text search to
    - Connected server (TCP) or
    - Extended search with UDP to other known servers.

    ← Search yields the hashes of matching files
  - 2. Query Sources
    - query servers for clients offering a file with a certain hash
- Later
  - Download from these sources

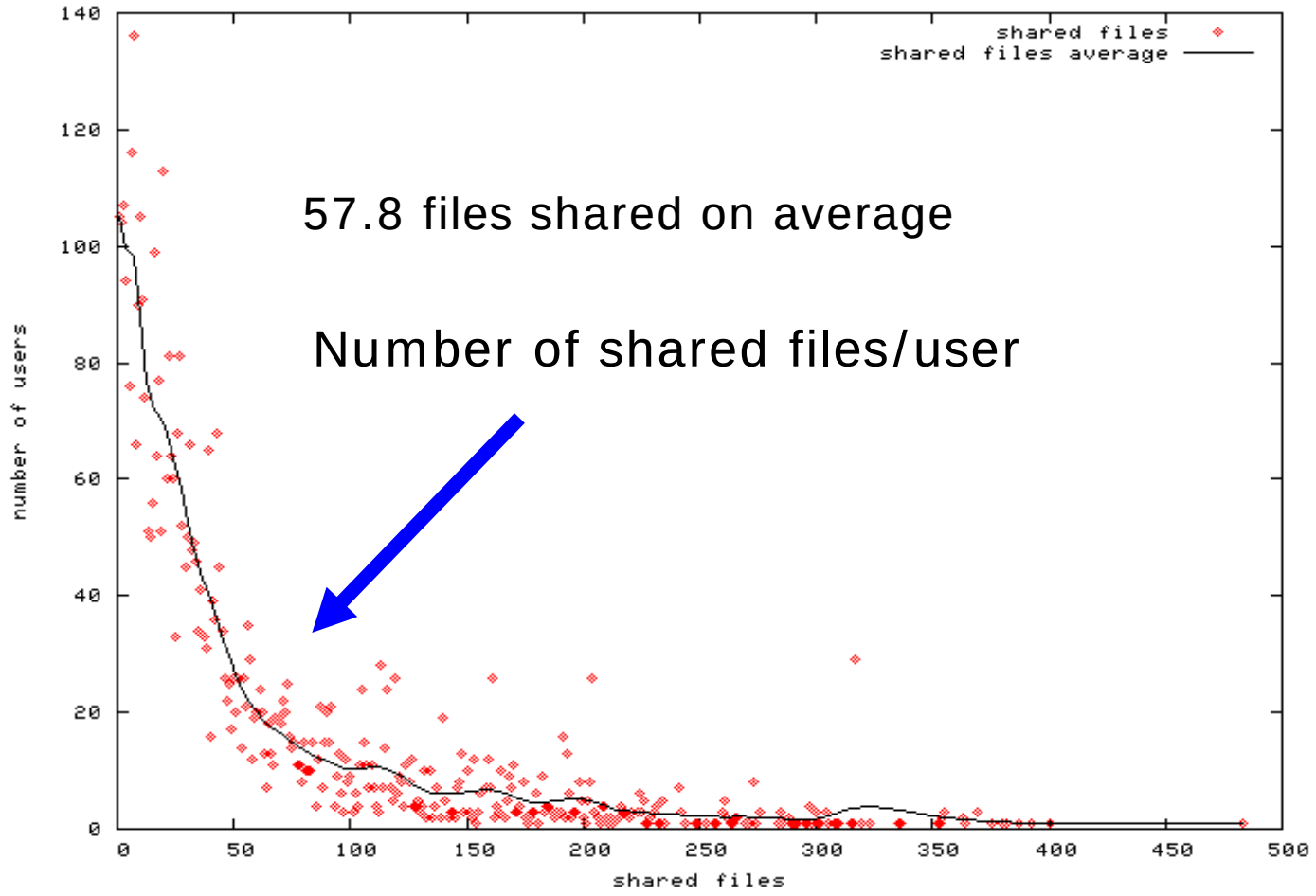
Heckmann et. al. The eDonkey File-Sharing Network. Gi-Informatik 2004

2.4. eDonkey: User Behavior (1)



Heckmann et. al. The eDonkey File-Sharing Network. Gi-Informatik 2004

2.4. eDonkey: User Behavior (2)



Heckmann et. al. The eDonkey File-Sharing Network. Gi-Informatik 2004

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3. Gnutella 0.6

Network Organization, Routing, Messages, Signaling, Demo

3. Gnutella 0.6

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- Program for sharing files over the Internet
- Focus
  - Decentralized method of searching for files
  - Higher signaling efficiency than Pure P2P
  - Same reliability (no single point of failure)
- Basis of many file-sharing applications
- Brief History
  - **Spring 2001**: resulted from Gnutella 0.4 by further developments to improve scalability → Gnutella 0.6 (Hybrid P2P)
  - Since then
    - Available in a lot of implementations (Limewire, bearshare,…)
    - Developed further on (privacy, scalability, performance,…)

3.1. Gnutella 0.6: Network Organization

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- New connection/network setup
  - Upon connection to the network via a super peer, each node is a leaf node
  - It announces its shared content to the super peer it connected to
  - Super peer updates its routing tables
  - Election mechanism decides which node becomes a super peer or a leaf node (depending on capabilities (storage, processing power) network connection, the uptime of a node,…), if
    - Too many nodes are connected to one super peer
    - A super peer leaves the network
    - Too few nodes are connected to a super peer

3.2. Gnutella 0.6: Routing (1)

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- Content requests
  - Leaf node sends request to super peer
  - Super peer looks up in its routing tables whether content is offered by one of its leaf node
    - In this case the request is forwarded to this node
  - Additionally the super peer increases the hop counter and forwards this request to the super peer it is connected to
  - To enable backward routing, the peer has to store the GUID of the message connected to the information from which peer it received the request in the previous hop
  - If a super peer receives such a request from another super peer, this request is handled the same way, as if it would have received it from one of its leaf nodes
  - After the hop counter of the request reaches the TTL-value it is not forwarded any further (prevent circles)

3.2. Gnutella 0.6: Routing (2)

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- Content responses
  - If a leaf node receives a request, it double-checks whether it shares the file (should be the case, as long as the routing tables of the super peer are correct)
  - In case of success, the leaf node sends a content reply back to the requesting peer, by sending it back to that node (super peer) it received the message from (backward routing)
  - Hop by hop the message can thus be routed back to the requesting node

- Content exchange
  - Directly between the leaf nodes, via HTTP connections

3.3. Gnutella 0.6: Messages

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- Content requests and responses
  - QUERY (defined as in Gnutella 0.4)
  - QUERY_HIT (defined as in Gnutella 0.4)
- Keep alive
  - PING (defined as in Gnutella 0.4)
  - PONG (defined as in Gnutella 0.4)
- Announcement of shared content
  - ROUTE_TABLE_UPDATE (0x30), Reset variant (0x0): to clear the routing table and to set a new routing table for one leaf node

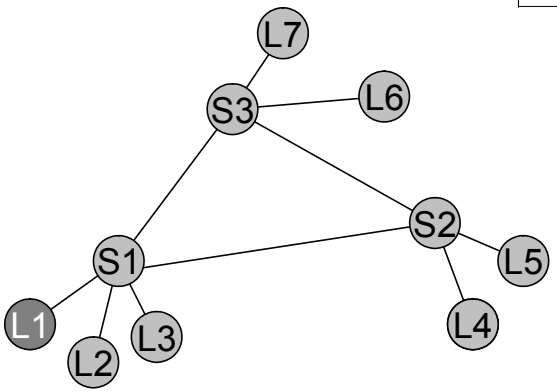
0	1 – 4	5
Variant	Table_Length	Infinity

  - ROUTE_TABLE_UPDATE (0x30), Patch variant(0x1): to update and set a new routing table with a certain number of entries (e.g. new shared files)

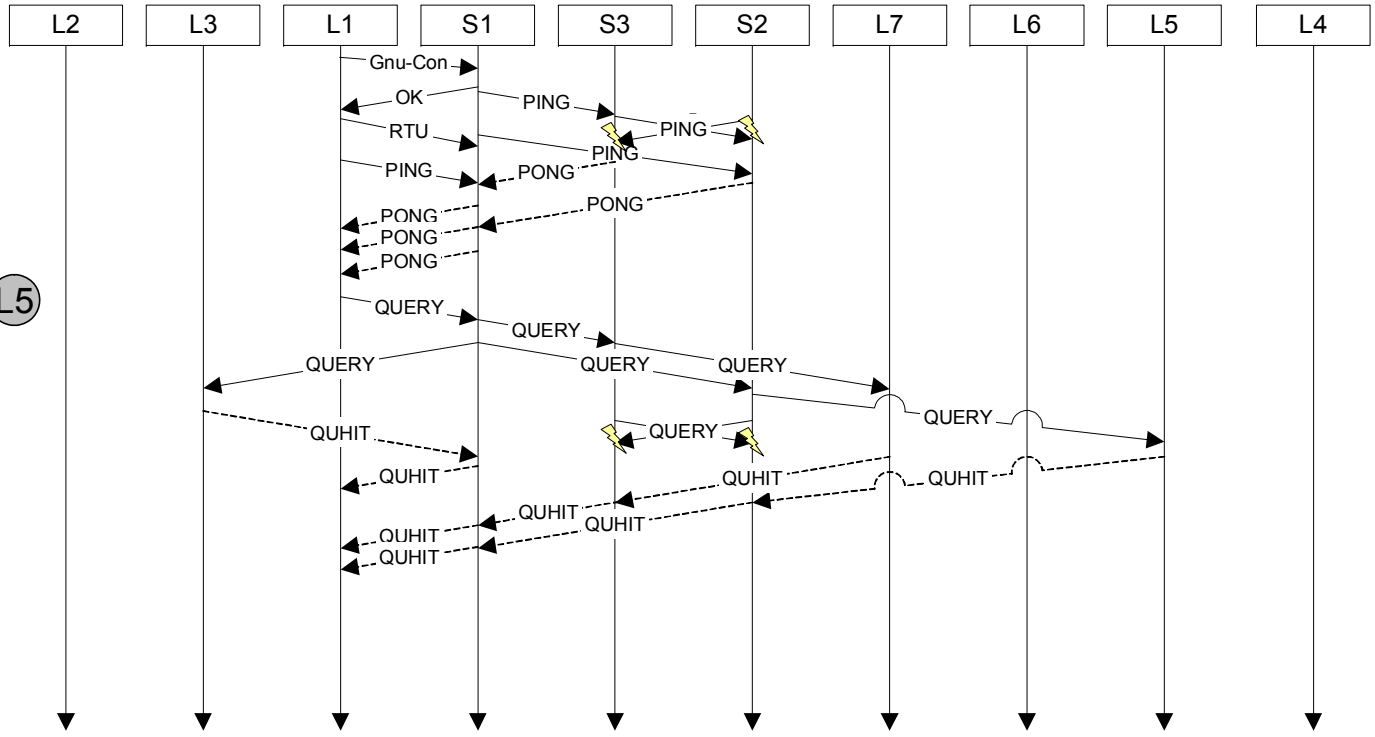
0	1	2	3	4	5 – n+4
Variant	Seq_No	Seq_Size	Compressor	Entry_Bits	DATA

3.4. Gnutella 0.6: Signaling

Sample Gnutella 0.6 network:



Sample message sequence chart according to the sample network:



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4. Decentralized File Sharing with Super Nodes: KaZaA

Basics, Popularity, Super Nodes, Example

4.0. KaZaA

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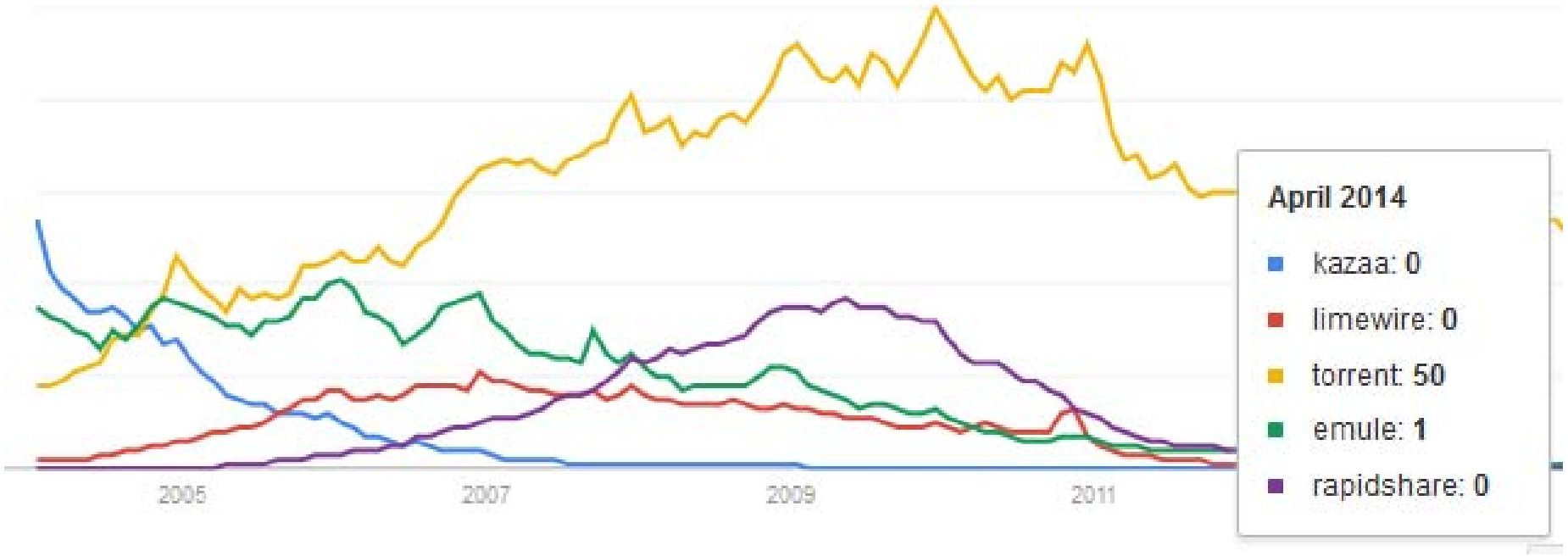
- System
  - Developer: Fasttrack
  - Clients: KaZaA
- Properties:
  - most successful P2P network in USA in 2002/3
- Architecture: neither completely central nor decentralized
  - Supernodes to reduce communication overhead
- See
  - www.kazaa.com, gift.sourceforge.net, http://www.my-k-lite.com/

P2P system	#users	#files	terabytes	#downloads (from download.com
Fasttrack	2,6 Mio.	472 Mio.	3550	4 Mio.
eDonkey	230.000	13 Mio.	650-2600	600.000
Gnutella	120.000	28 Mio.	105	Ca. 525.000

Numbers are from 10‘2002

4.1. KaZaA: Popularity



http://www.google.com/trends?q=kazaa,+limewire,+torrent,+emule,+rapidshare

4.2. KaZaA: Super Nodes

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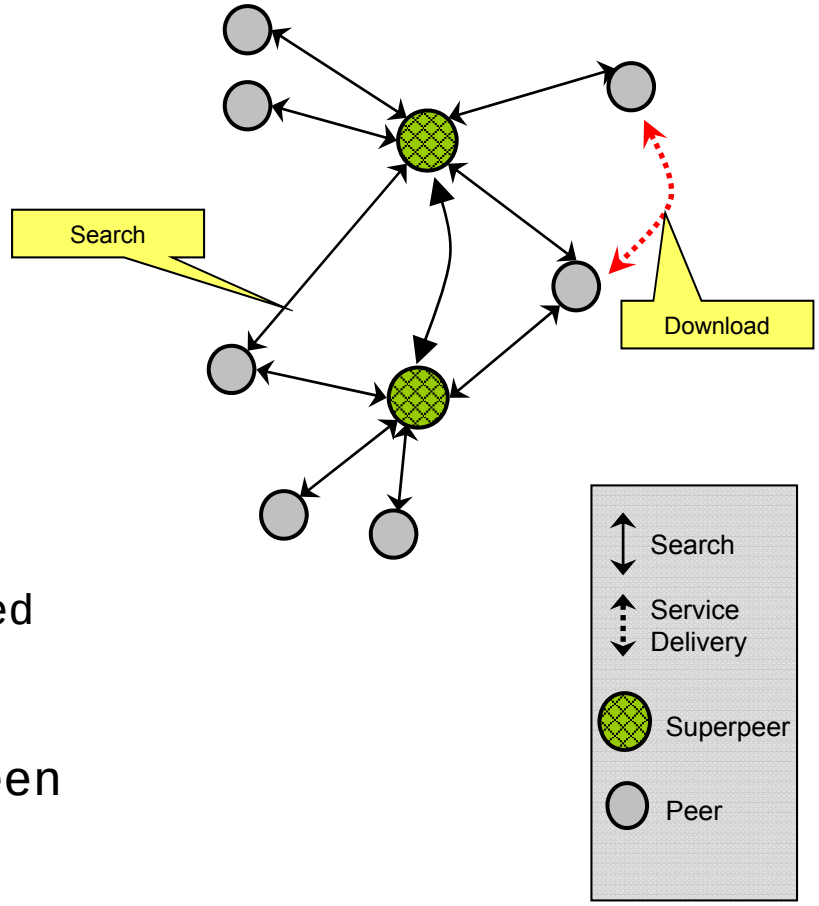
- Peers
  - connected only to some super nodes
  - send IP address and file names only to super peers
- Super nodes - super peers:
  - peers with high-performance network connections
  - take the role of the central server and proxy for simple peers
  - answer search messages for all peers (reduction of comm. load)
  - one or more supernodes can be removed without problems
- Additionally, the communication between nodes is encrypted



4.3. KaZaA: Example

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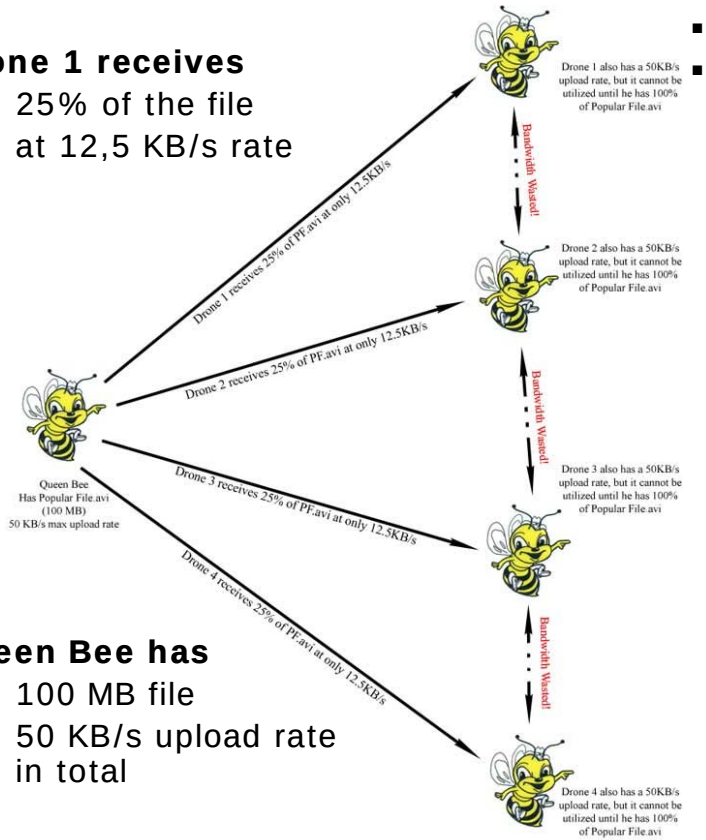
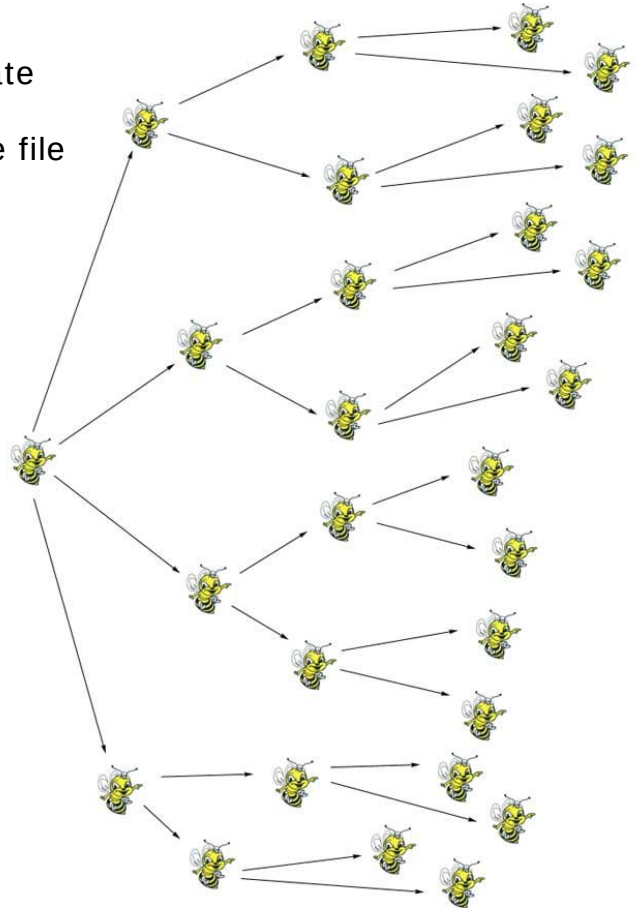
Drone 1 receives
- 25% of the file
- at 12,5 KB/s rate

Drone 1 has
- 50 KB/s upload rate
- not utilized until he has whole file



Queen Bee has
- 100 MB file
- 50 KB/s upload rate in total

At the beginning



later

From www.wtata.com

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5. Unstructured Hybrid Resource Sharing: Skype

Basics, Statistics, Skype vs. Call-by-Call, Network Architecture

5.1. Skype: Basics

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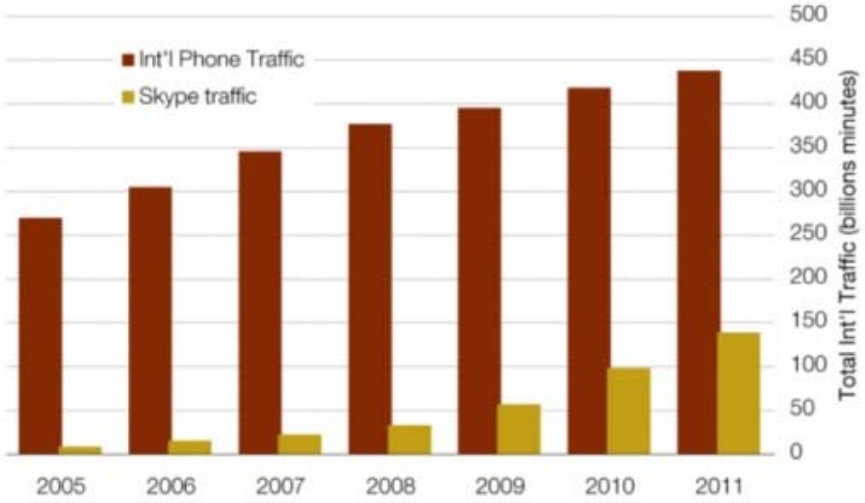
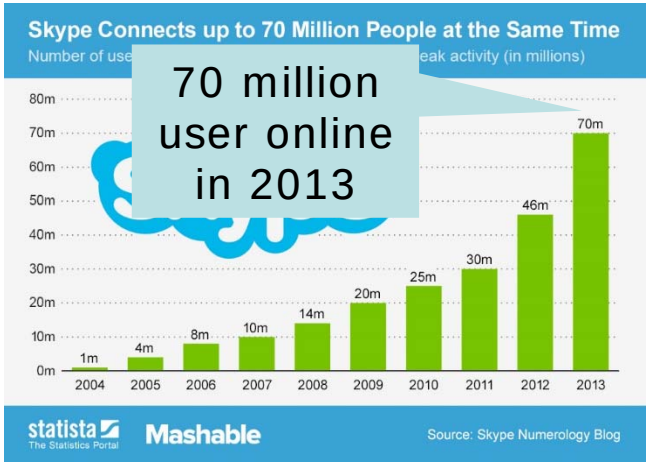
- Offered Services
  - IP Telephony features
  - File exchange
  - Instant Messaging
- Further Information
  - Very popular
  - Low-cost IP-Telephony business model
  - SkypeOut extension to call regular phone numbers (not free)
  - Great business potential if combined with free WIFI
- Features
  - FastTrack technology
  - High media quality
  - Encrypted media delivery
  - Support for teleconferences
  - Multi-platform
- Technical Details
  - NAT Traversal Techniques included
  - Codecs used: G.729, G711, AMR-WB
  - Used AES-256 bit encryption for PC to PC communication
  - API available for developers

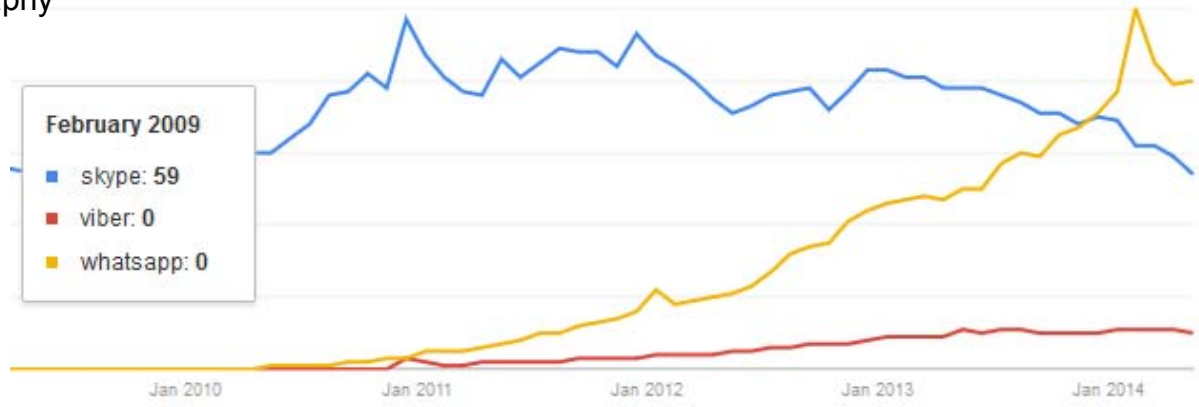
www.skype.com

5.2. Skype: Statistics



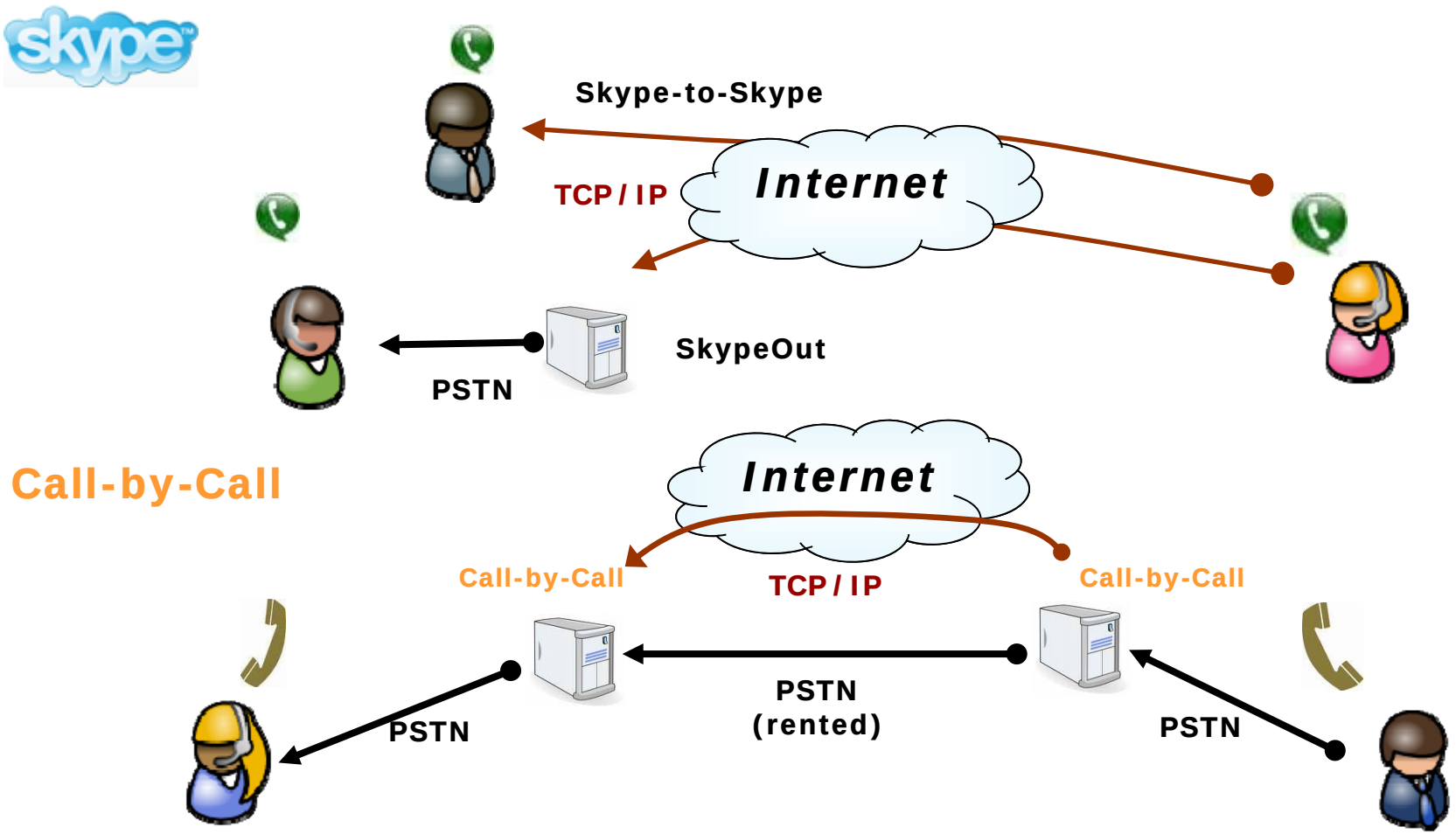
Source: TeleGeography





http://www.google.com/trends?q=skype,+viber,+whatsapp

5.3. Skype vs. Call-by-Call



5.4. Skype: Network Architecture

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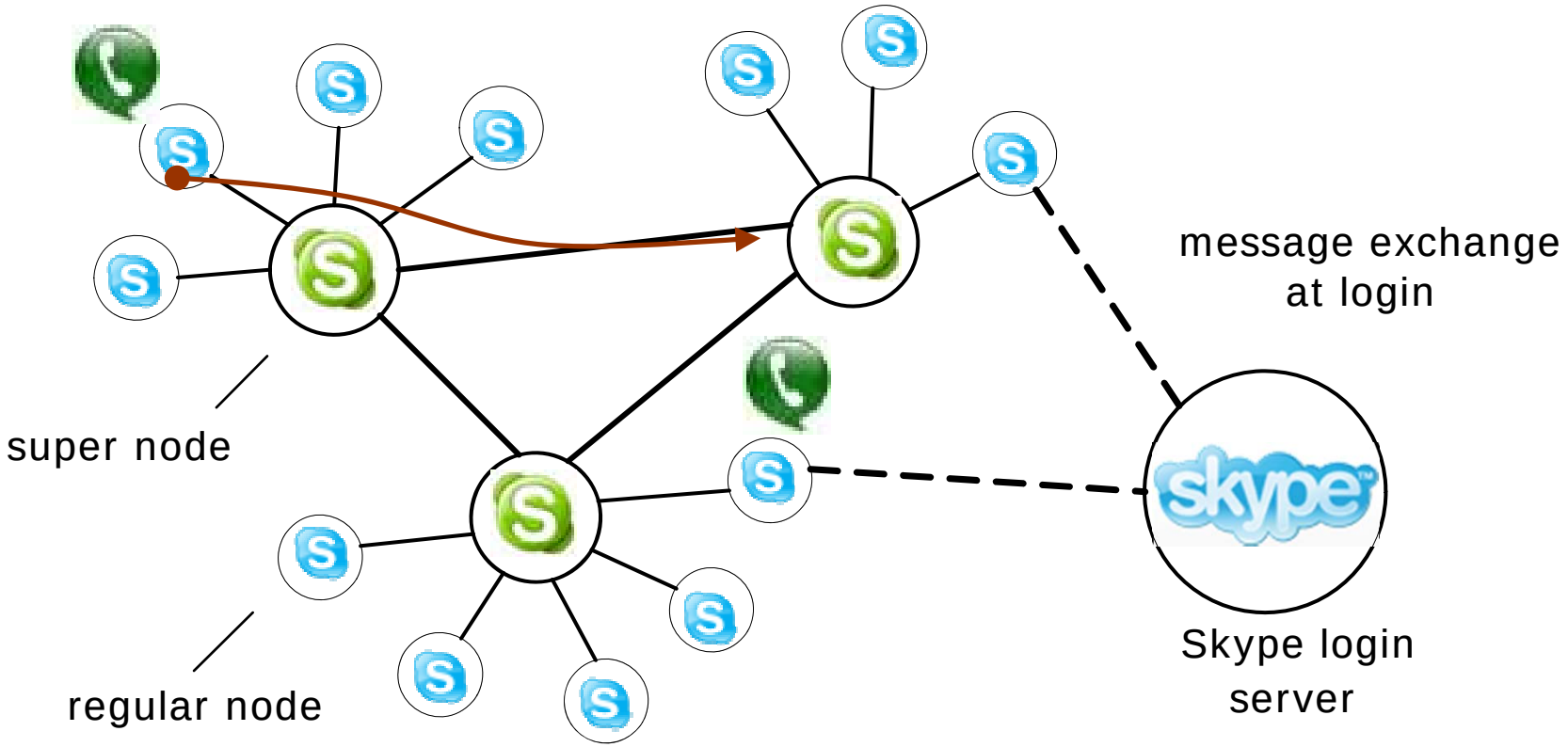
- Formerly KaZaA based



6. Discussion

6. Discussion (1)

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- Drawbacks of Hybrid P2P
  - Still High signaling traffic, because of decentralization
  - No definitive statement possible if content is not available or not found
  - Modem nodes may become bottlenecks
  - Overlay topology not optimal, as
    - no complete view available,
    - no coordinator
  - If not adapted to physical structure delay and total network load increases
    - Zigzag routes
    - Loops
  - Can not be adapted to physical network completely because of hub structure
  - Asymmetric load (super peers have to bear a significantly higher load)

6. Discussion (2)

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- Advantages of Hybrid P2P
  - No single point of failure
  - Can provide anonymity
  - Can be adapted to special interest groups
- Application areas
  - File-sharing
  - Context based routing (see chapter about mobility)