Introduction to Peer-to-Peer Networks

- The Story of Peer-to-Peer
- The Nature of Peer-to-Peer: Generals & Paradigms
- Unstructured Peer-to-Peer Systems
- Sample Applications

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

A Peer-to-Peer 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.

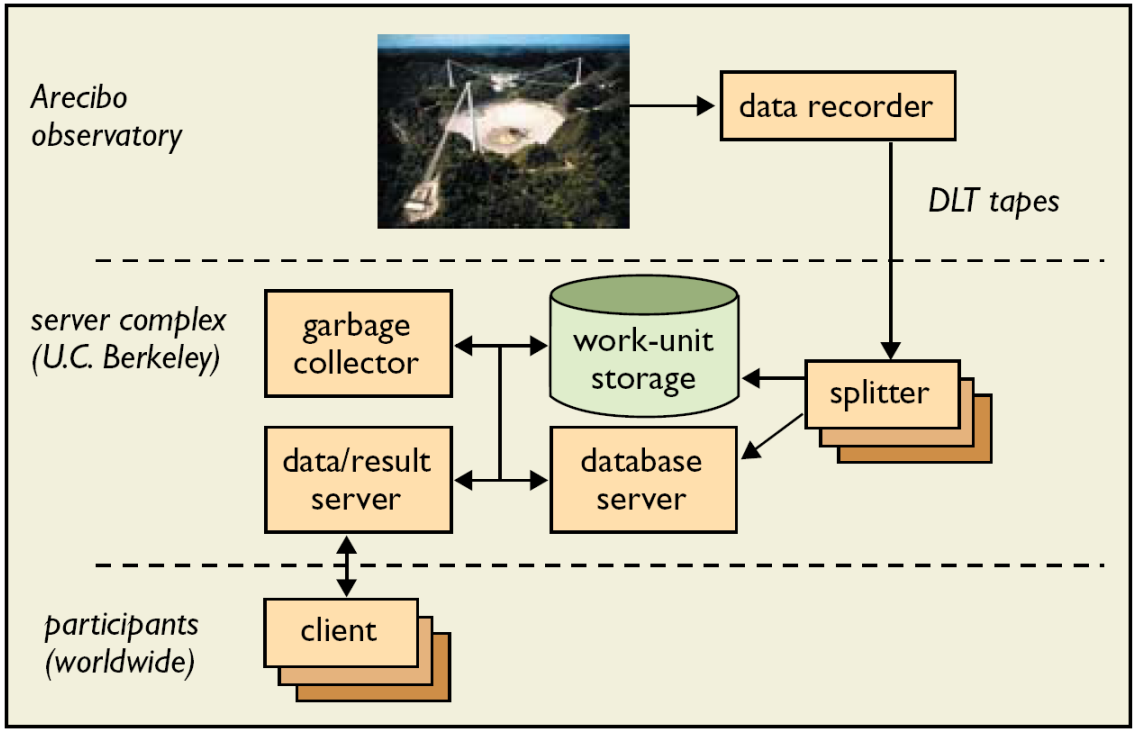
Andy Oram

The Old Days

- NetNews (nntp)
  - Usenet since 1979, initially based on UUCP
  - Exchange (replication) of news articles by subscription
  - Group creation/deletion decentralised
- DNS
  - Distributed delegation of name authorities: file sharing of host tables
  - Name "Servers" act as peers
  - Hierarchical information space permits exponential growth
- Systems are manually configured distributed peers

SETI@home: Distributed Computing

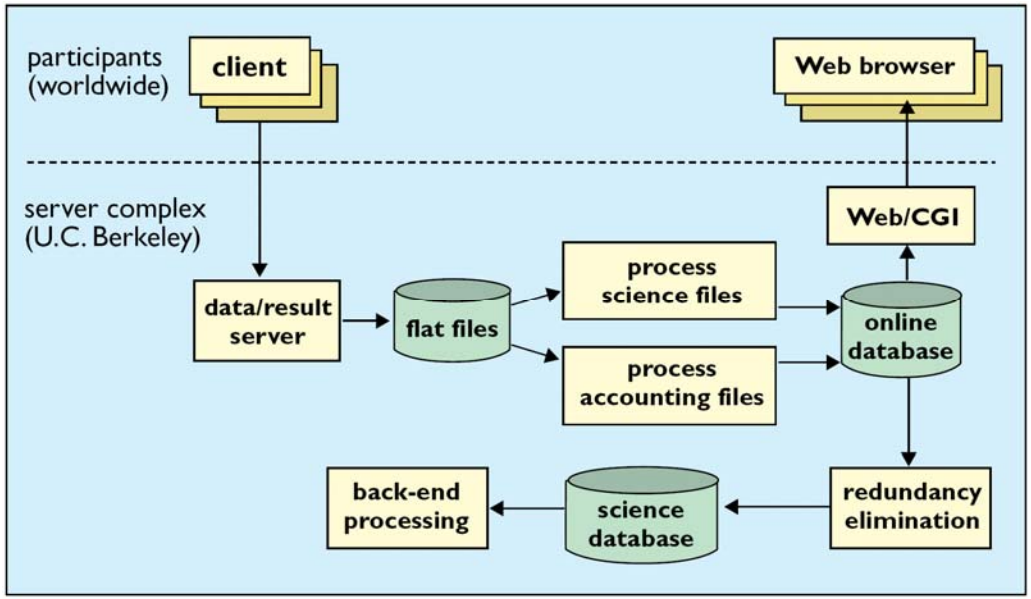
- Search for Extraterrestrial Intelligence (SETI)
- Analyse radio signals from space
- Globally shared computing res.
- Idea 1995
- First version 1998
- 2002 ≈ 4 Mio clnt
- E.g. Screensaver
- http://setiathome.berkeley.edu/ - ongoing



From Anderson et. al.: *SETI@home*, Comm. ACM, 45 (11), Nov. 2002

SETI@home (2)

- http-based client-server model
- No client-client communication
- Data chunks: load & return
- N-redundancy for fault detection
- Attacks: bogus code theft of email addresses



From Anderson et. al.: *SETI@home*, ibidem, Nov. 2002

Napster

- MAY 1999: Disruption of the Internet community
  First Generation of File sharing: Introduction of Napster
  - Users not only consume and download, but also offer content
  - Users establish a virtual network, entirely independent from physical network and administrative authorities or restrictions
  - Basis: UDP and TCP connections between the peers
- Napster provides centralised indexing
  - Clients upload their file list to Napster Server
  - Clients query Index Server and receive full provider list
- Data exchange directly between peers

Napster

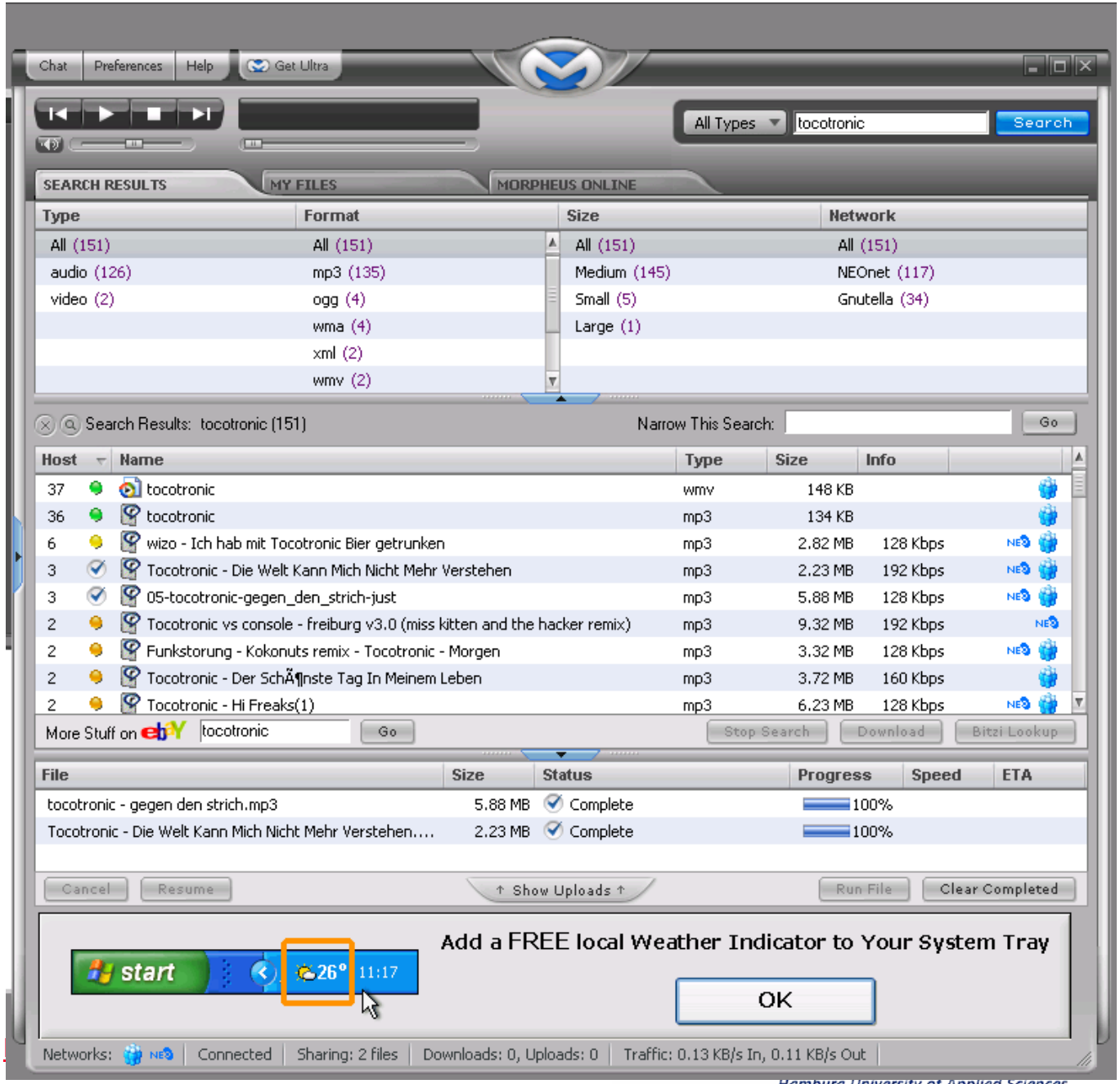
- December 1999: RIAA files a lawsuit against Napster Inc.
- March 2000: University of Wisconsin reports 25 % of its IP traffic is Napster traffic
- February 2001: 2.79 billion files per month exchanged via Napster
- July 2001: Napster Inc. is convicted
  - Target of the RIAA: the central lookup server of Napster
  - Napster has to stop the operation of the Napster server
  - Napster network breaks down
- Napster failed (technically & legally) at its single server point.

Gnutella

- File sharing fully decentralised
- Open source software
- March 2000:

  Release 0.4 – with network flooding
- Spring 2001:

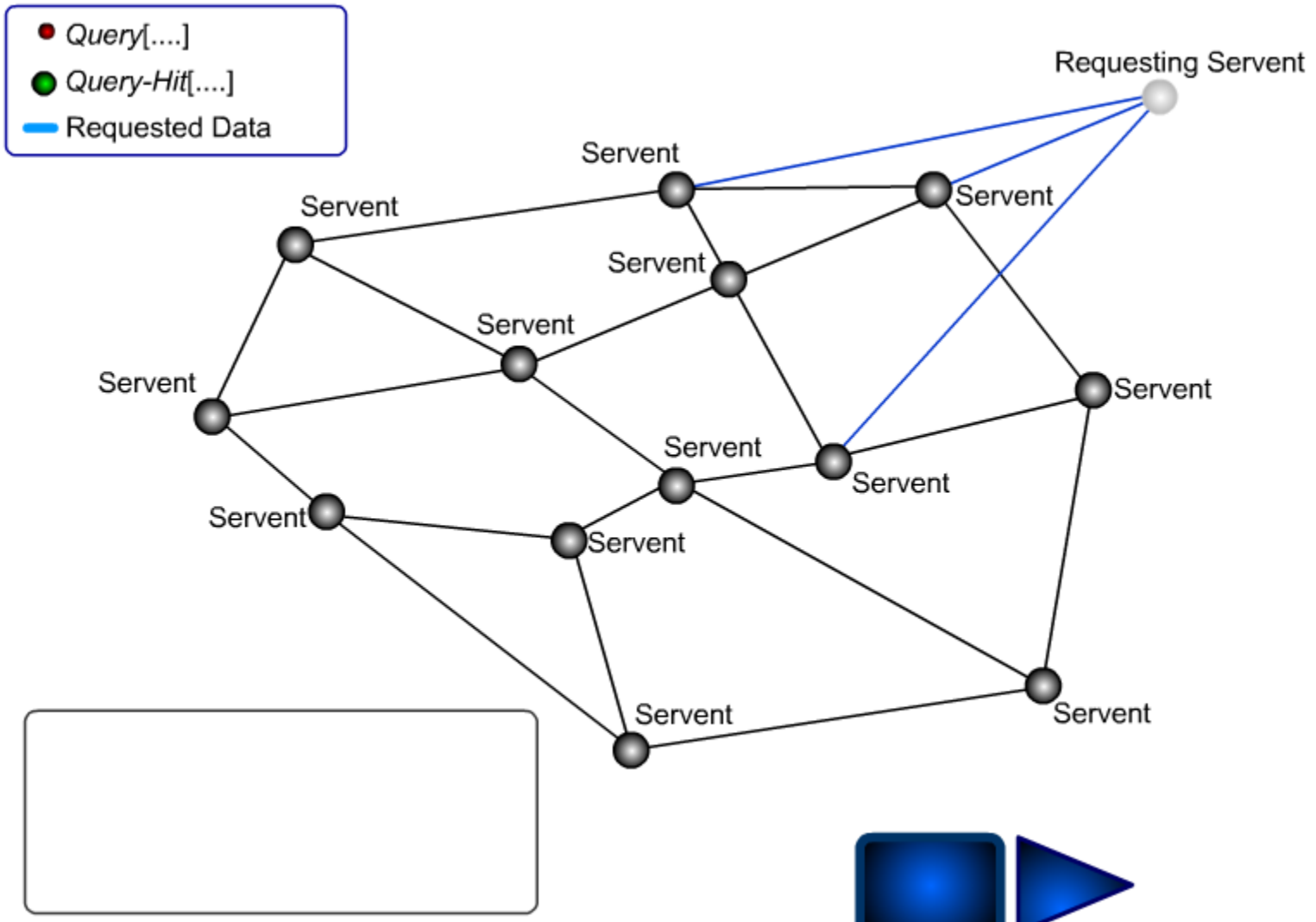
  Release 0.6 – improved scalability



Gnutella 0.4

- Pure P2P system – no central indexing server
- Operations:
  1. Connect to at least one active peer (address received from bootstrap)
  2. Explore your neighborhood (PING/PONG)
  3. Submit Query with a list of keywords to your neighbors (they forward it)
  4. Select "best" of correct answers (which we receive after a while)
  5. Connect to providing host/peer
- Scaling Problems due to network flooding

Gnutella 0.4: How Does It Work



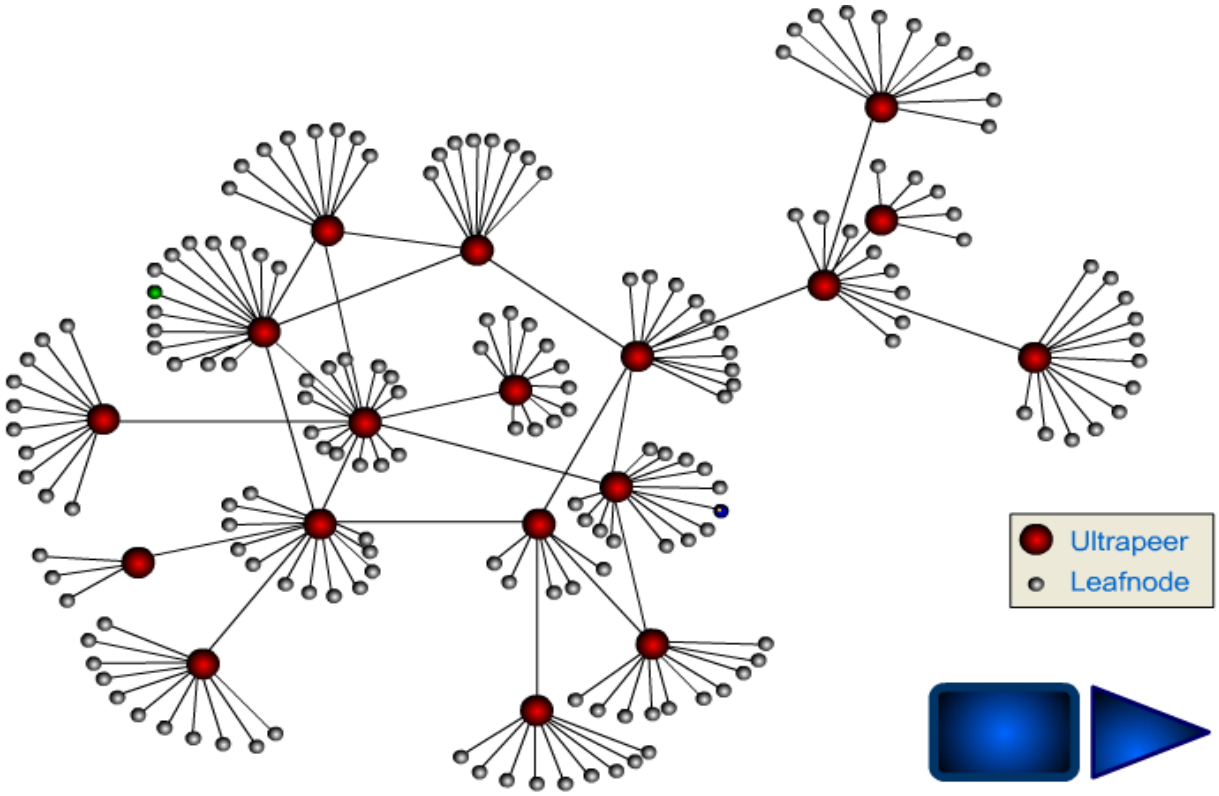
Basic Routing Behavior

- **Request messages:**
  - Include a hop-counter, a GUID and a TTL (Time-to-Live) in the header
  - TTL determines along how many hops a message may be forwarded
  - Are flooded in the overlay network
    - Every node forwards every incoming message to all neighbors except the neighbor, it received the message from
  - Request messages terminate, if
    - Same message-type with same GUID is received more than once (loop!!)
    - Hop-counter=TTL
- **Response messages:**
  - Include a hop-counter, a GUID and a TTL (Time-to-Live) in the header
  - GUID is the same as of the initializing request message
  - Are routed back on the same way to the requestor, the request message had been received
    - every peer has to store the GUID of each request for a certain amount of time
    - No flooding to save resources

Gnutella 0.6

- Hybrid P2P System – Introduction of Superpeers
- Improved scalability: signalling reduced to Superpeers
- Election mechanism decides which node becomes a Superpeer or a Leafnode (depending on capabilities (storage, processing power) network connection, the uptime of a node,…)
- Leafnodes announce their shared content to the Superpeer they are connected to
- Superpeers carry local routing tables

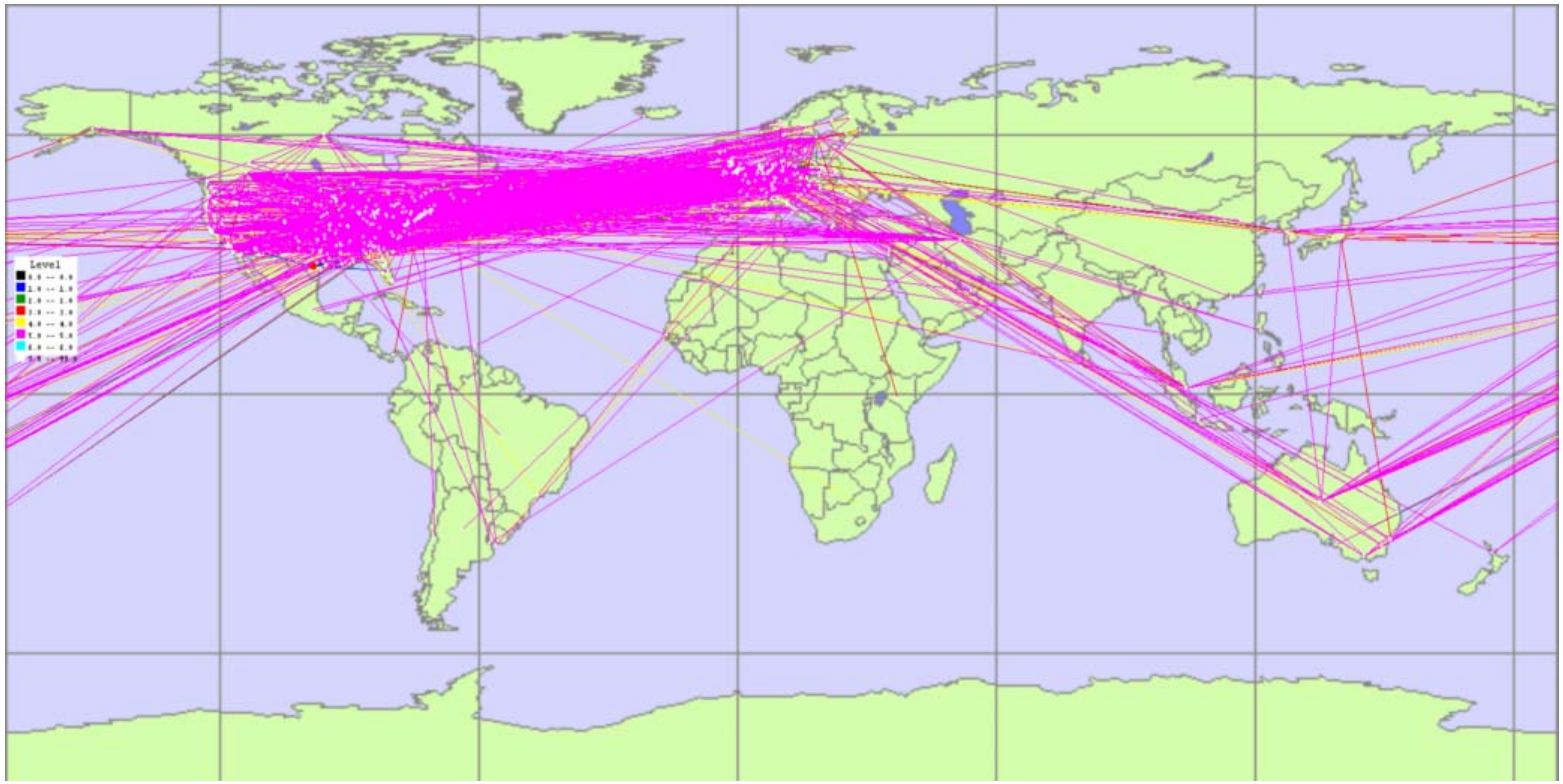
Gnutella 0.6: How Does It Work



From:

J. Eberspächer, R. Schollmeier: *First and Second Generation Peer-to-Peer Systems*, in LNCS 3485

The Gnutella Network



Measurements from May 2002

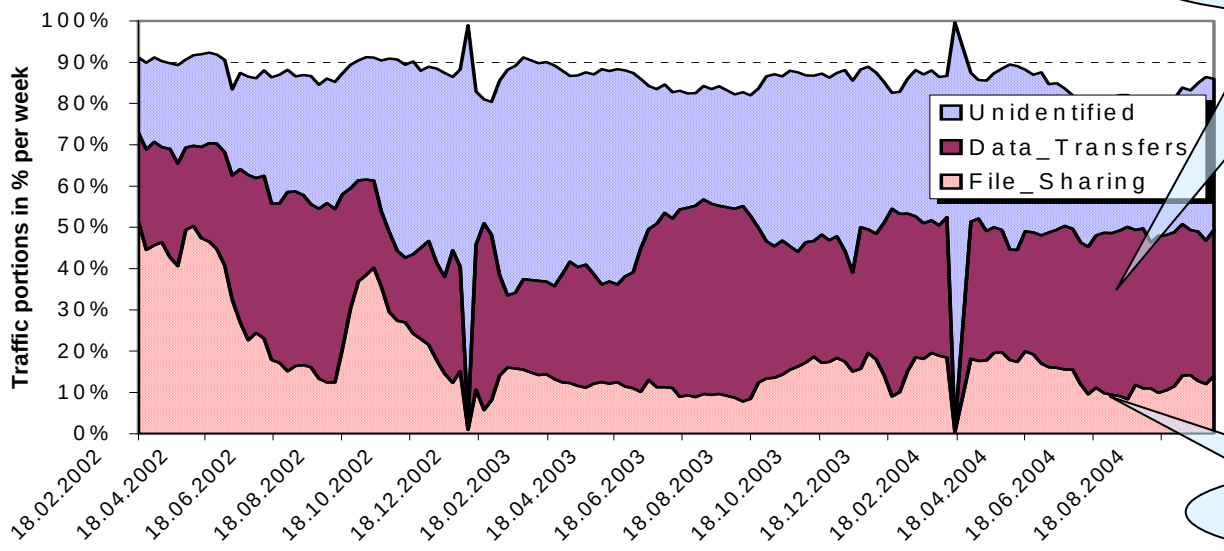
From:

J. Eberspächer, R. Schollmeier: *First and Second Generation Peer-to-Peer Systems*, in LNCS 3485

Impacts of P2P at the Abilene Backbone

- Unidentified + data_transfers + file_sharing causes 90% of the traffic
- Unidentified traffic and data_transfers increased significantly
  - Parts of P2P is hidden (port hopping,…)
  - Some P2P applications use port 80 → data_transfers

Core of Internet2 infrastructure, connecting 190 US universities and research centers

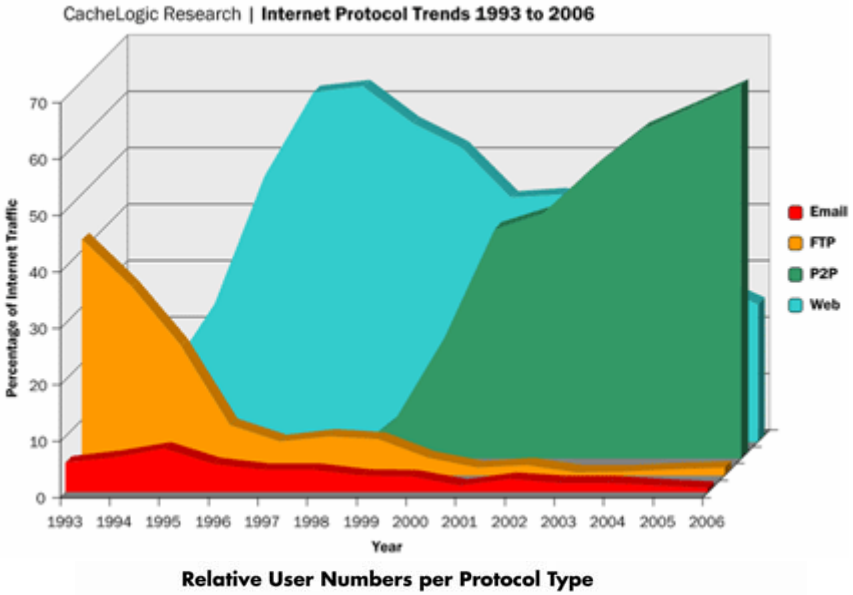


Possible data transfers

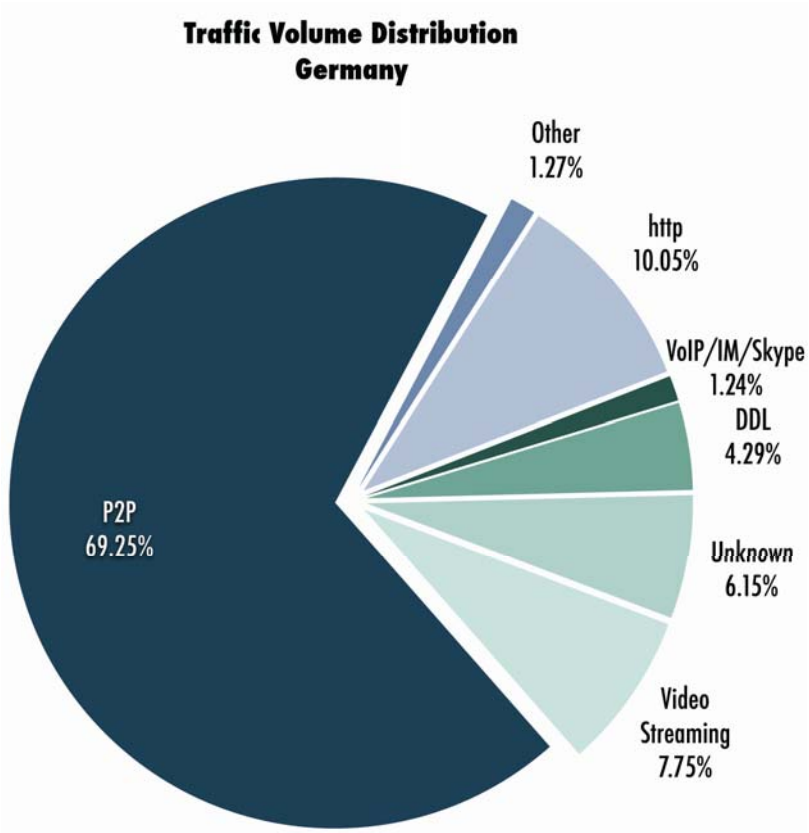
Only Signaling

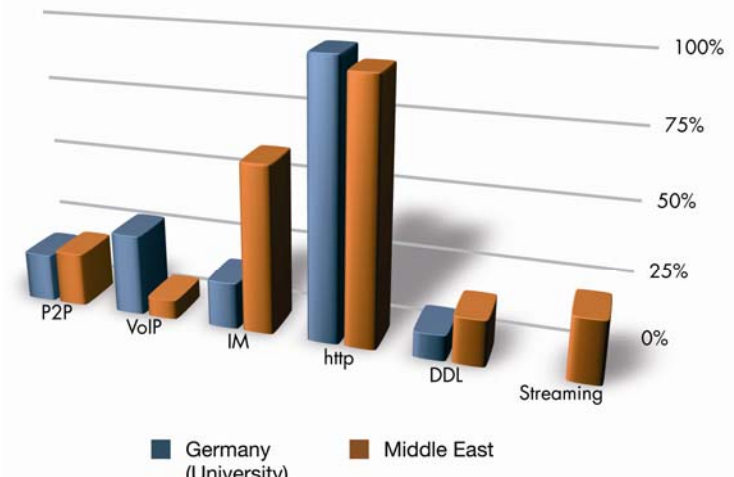
Data source: http://netflow.internet2.edu/weekly/

Internet Traffic Trends



Relative User Numbers per Protocol Type

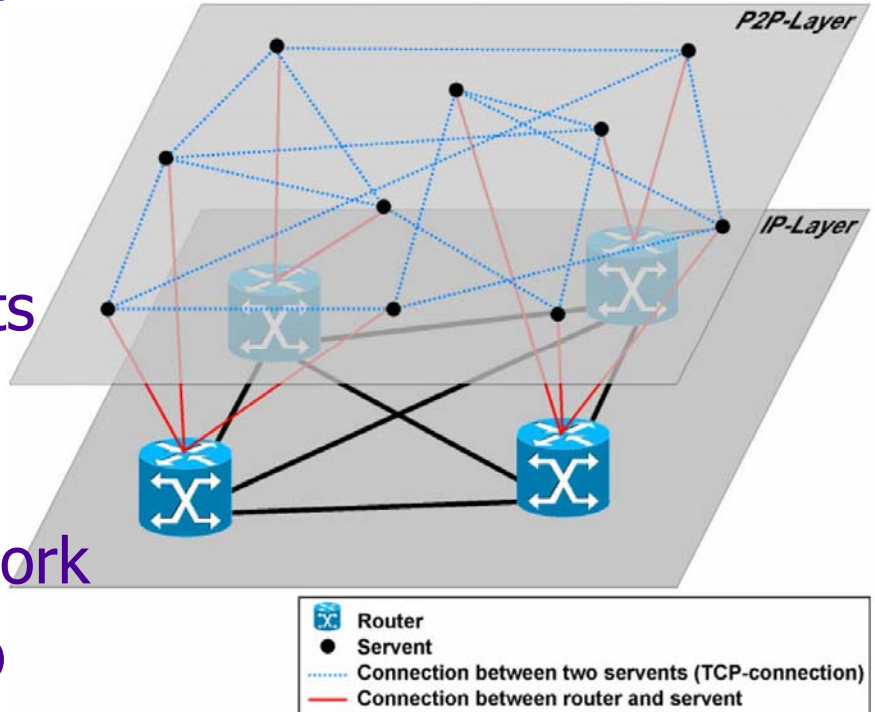




Source:
http://www.ipoque.com/resources/internet-studies/internet-study-2007

The Nature of P2P

- P2P Networks overlay network infrastructure
- Implemented on application layer
- Overlay Topology forms a virtual signaling network established via TCP connects
- Peers are content provider +content requestor +router in the overlay network
- Address: General Unique ID



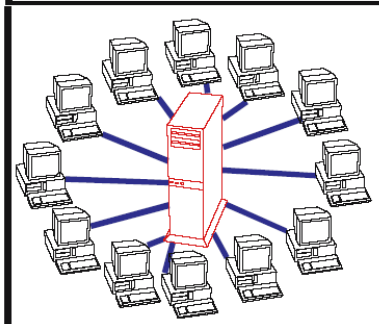
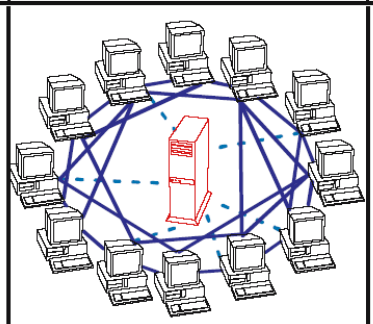
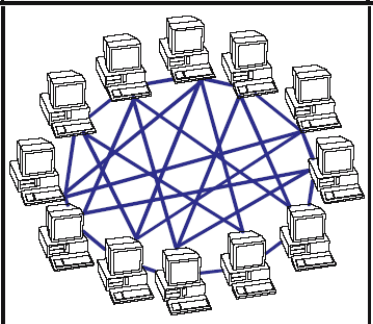
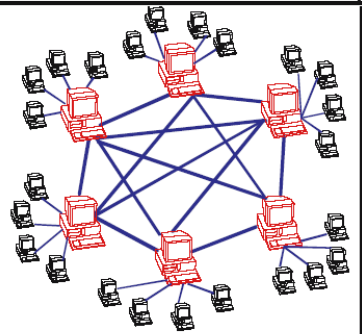
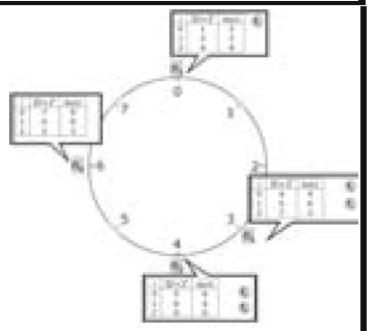
P2P & Distributed Systems Paradigm

- Coordination among equal components
- Decentralised & self organising
- Independence of individual peers
- Scalability over tremendous ranges
- High dynamic from volatile members
- Fault resilience against infrastructure & nodes
- Incentives instead of control

P2P & Internetworking Paradigm

- Loose, stateless coupling among peers
- Serverless & without infrastructural entities
- Dynamic adaptation to network infrastructure
- Overcome of NATs or port barriers
- Client-Server principle reduced to communication programming, not an application paradigm anymore
- Somewhat "Back to the Internet roots":
  - Freedom of information
  - Freedom of scale

But: Freedom of Internet infrastructure & regulation

Client-Server	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 (Servent concept)			
	Unstructured P2P			Structured P2P
	1st Generation		2nd Generation	
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	*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	*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
				

From: J. Eberspächer, R. Schollmeier: *First and Second Generation Peer-to-Peer Systems*, in LNCS 3485

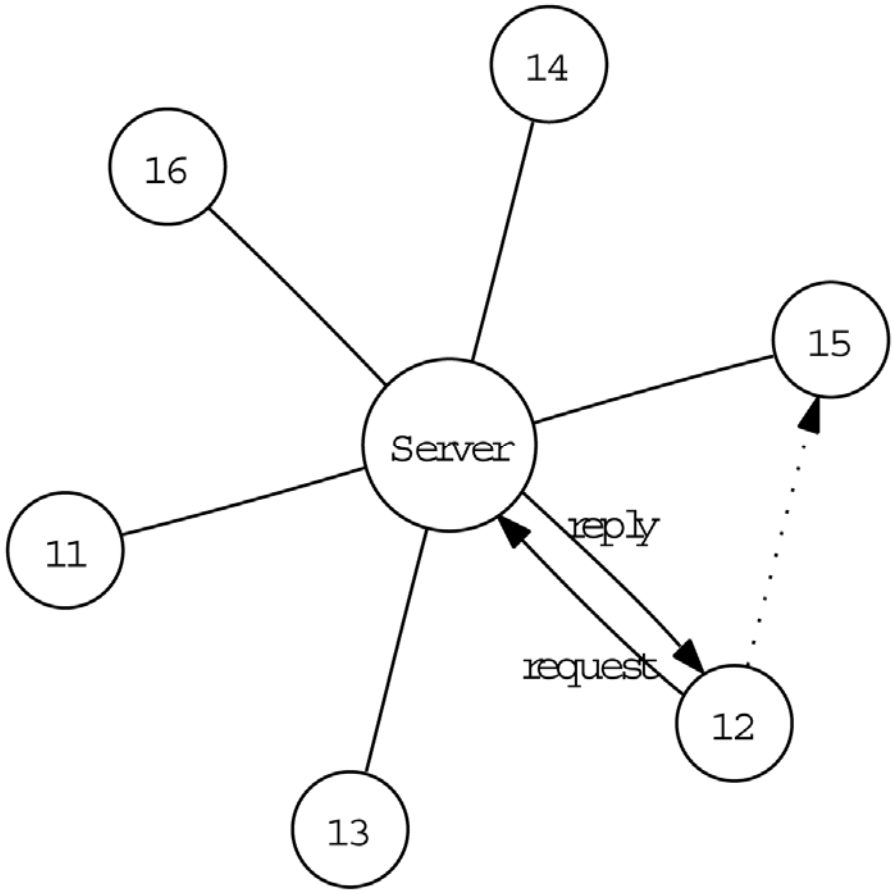
Unstructured Peer-to-Peer Systems

- Decentralized and self organizing (with possible centralized elements)
- Content:
  - Distributed "randomly" on the network, with several replicas
  - content and its descriptions are not structured (stays at the nodes which bring it into the network)
  - Content transfer:
    - Out of band, i.e. on separate connections and not via signaling connections
    - Mostly via HTTP
- Generally two kinds of requests:
  - Content requests: to find content in the overlay
  - Keep-alive requests: stay connected in the overlay
- Initially developed for file-sharing
- Various realizations exist

Basic Characteristics of Centralized P2P

- Bootstrapping: Bootstrap-server = central server
- Central entity can be established as a server farm, but one single entry point = single point of failure (SPOF)
- All signaling connections are directed to central entity
- Peer ↔ central entity: P2P protocol, e.g. Napster protocol
  - To find content
  - To log on to the overlay
  - To register
  - To update the routing tables
  - To update shared content information
- Peer ↔ Peer: HTTP
  - To exchange content/data :

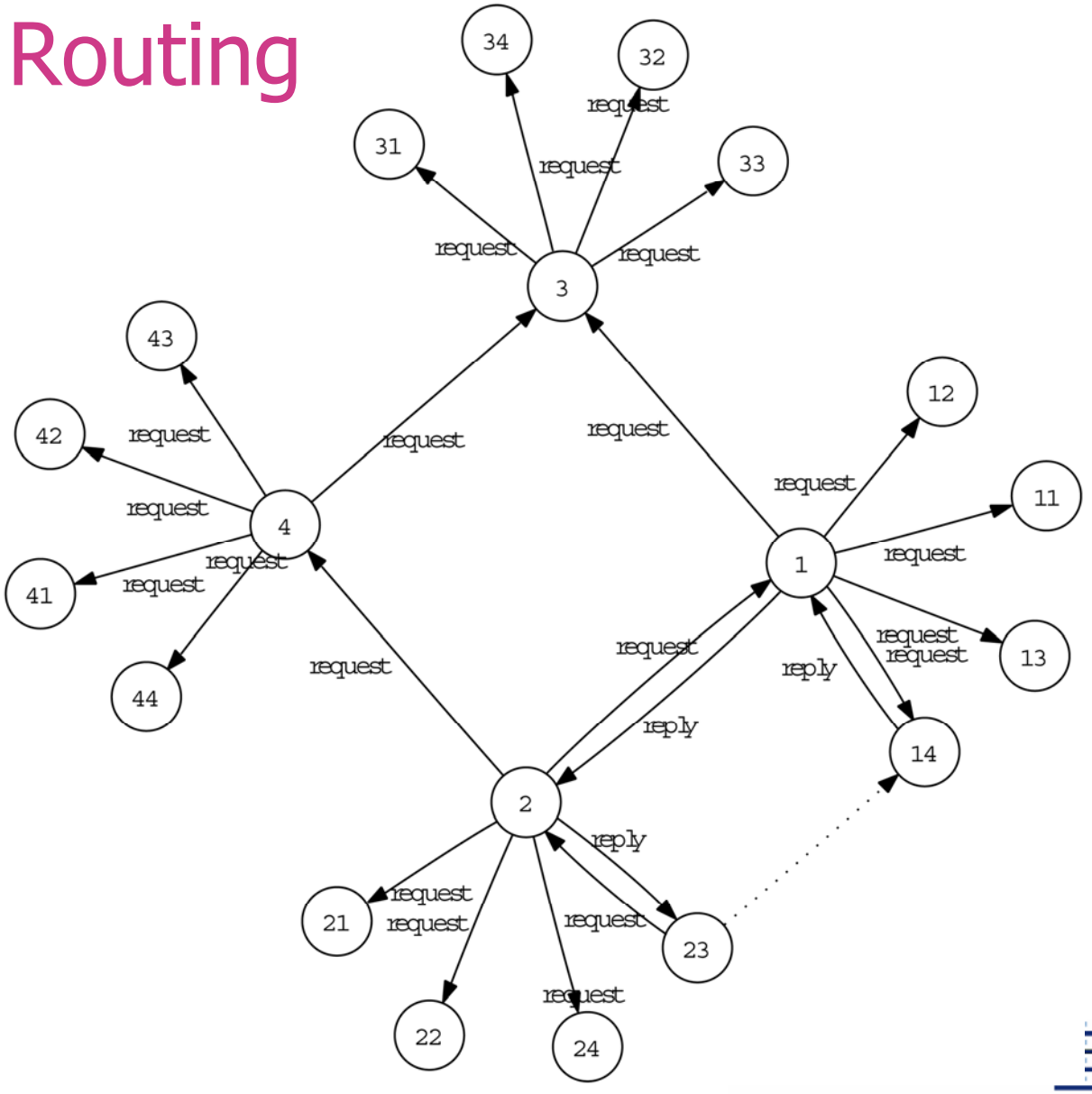
Centralized P2P Routing



Basic Characteristics of Pure P2P

- Bootstrapping:
  - Via bootstrap-server (host list from a web server)
  - Via peer-cache (from previous sessions)
  - Via well-known host
  - No registration
- Routing:
  - Completely decentralized
  - Reactive protocol: routes to content providers are only established on demand, no content announcements
  - Requests: flooding (limited by TTL and GUID)
  - Responses: routed (Backward routing with help of GUID)

Pure P2P Routing



Basic Characteristics of Pure P2P (2)

- 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

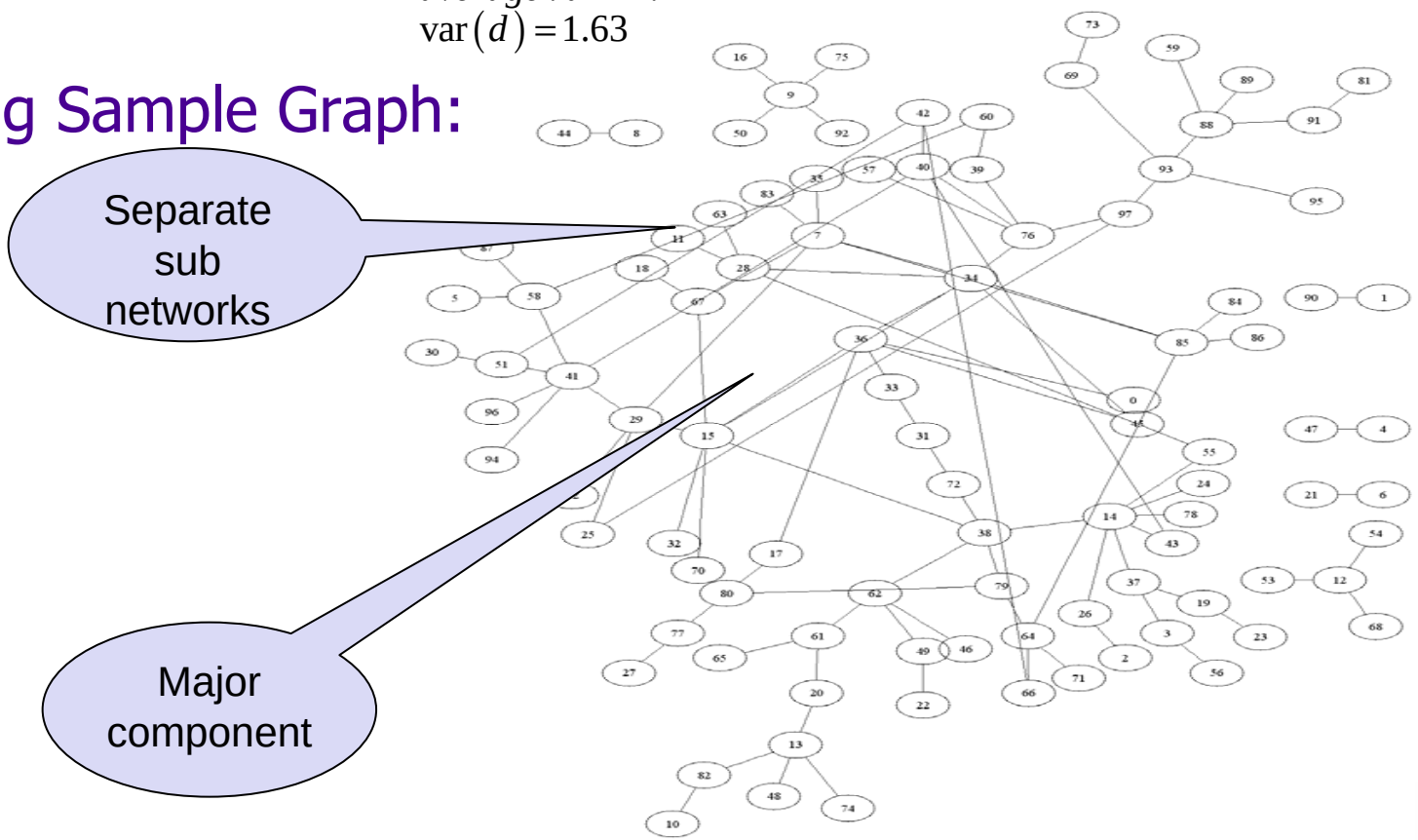
Model of Pure P2P Networks

Degree distribution:

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

$$\textit{average}: \bar{d} = 2.2$$
$$\mathrm{var}(d) = 1.63$$

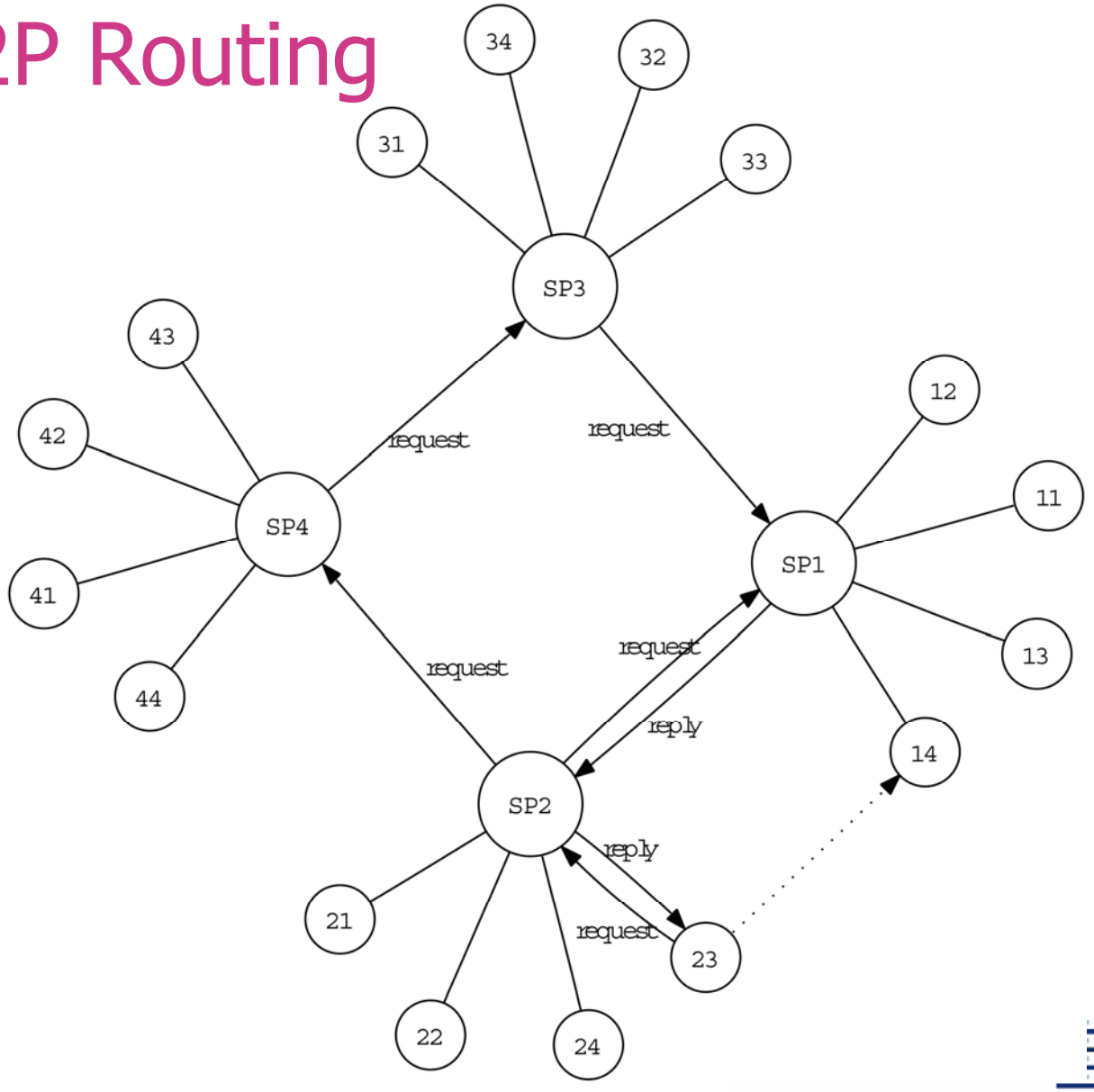
According Sample Graph:



Basic Characteristics of Hybrid P2P

- Bootstrapping:
  - Via bootstrap-server (host list from a web server)
  - Via peer-cache (from previous sessions) or well-known host
  - Registration of each Leafnode at the Superpeer it connects to, i.e. it announces its shared files to the Superpeer
- Routing: Partly decentralized
  - Leafnodes send request to a Superpeer
  - Superpeer distributes this request in the Superpeer layer
  - If a Superpeer has information about a matching file shared by one of its leafnodes, it sends this information back to the requesting leafnode
  - Hybrid protocol (reactive and proactive): routes to content providers are only established on demand; content announcements from leafnodes to their Superpeers
  - Requests: flooding (limited by TTL and GUID) in the Superpeer layer
  - Responses: routed (Backward routing with help of GUID)

Hybrid P2P Routing



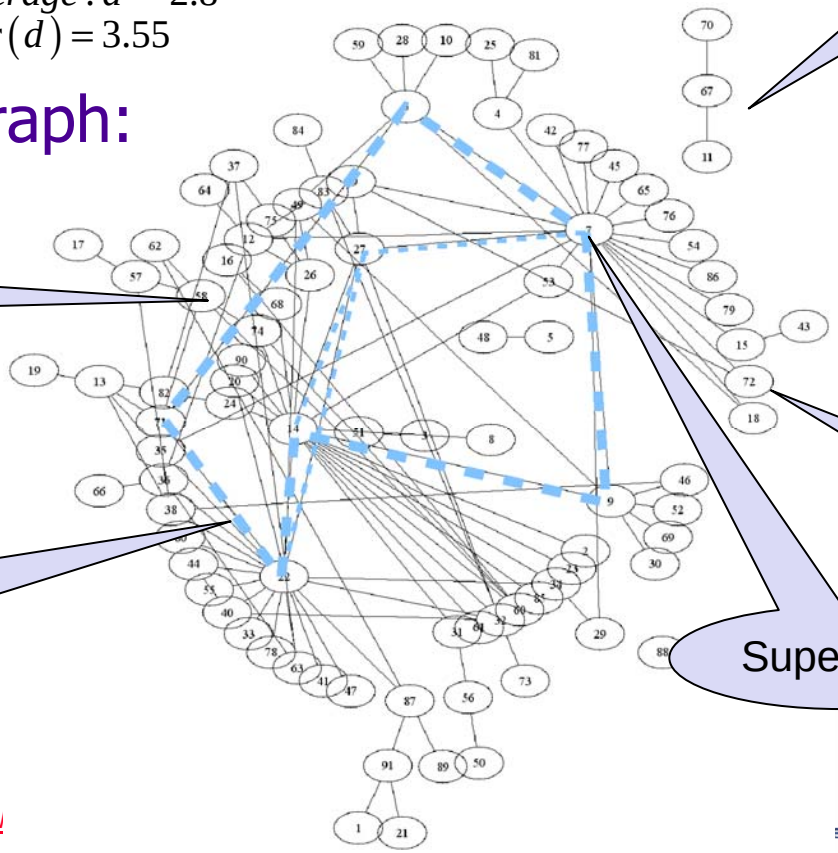
Model of Hybrid P2P Networks

Degree distribution:

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

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

According Sample Graph:



Separate sub networks

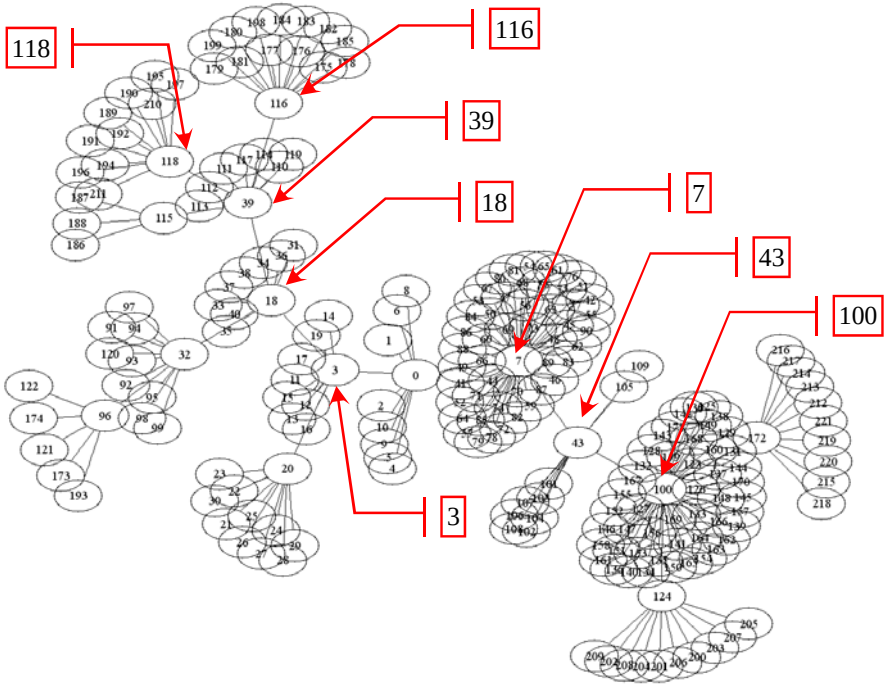
Major component

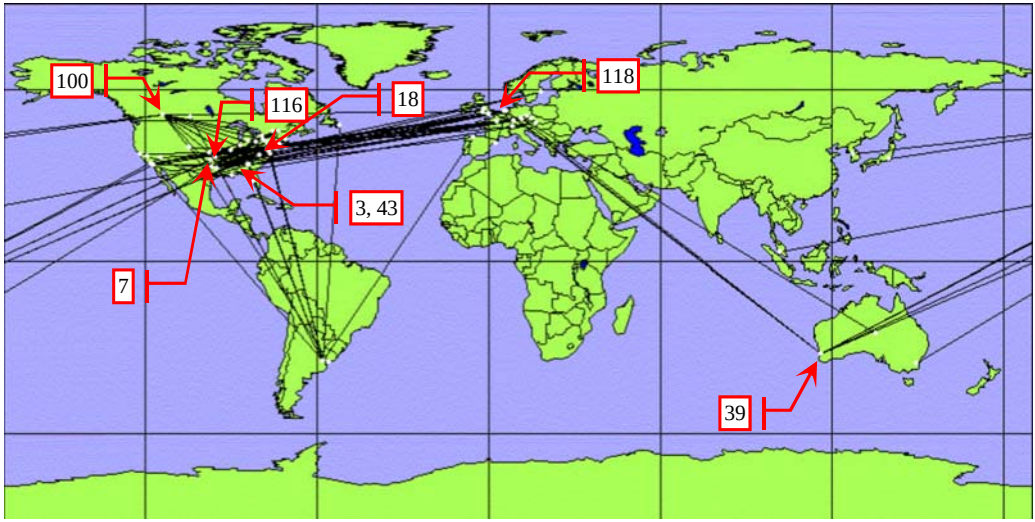
Leafnode

Hub connections (2nd hierarchy)

Superpeer

Topology of Hybrid P2P





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

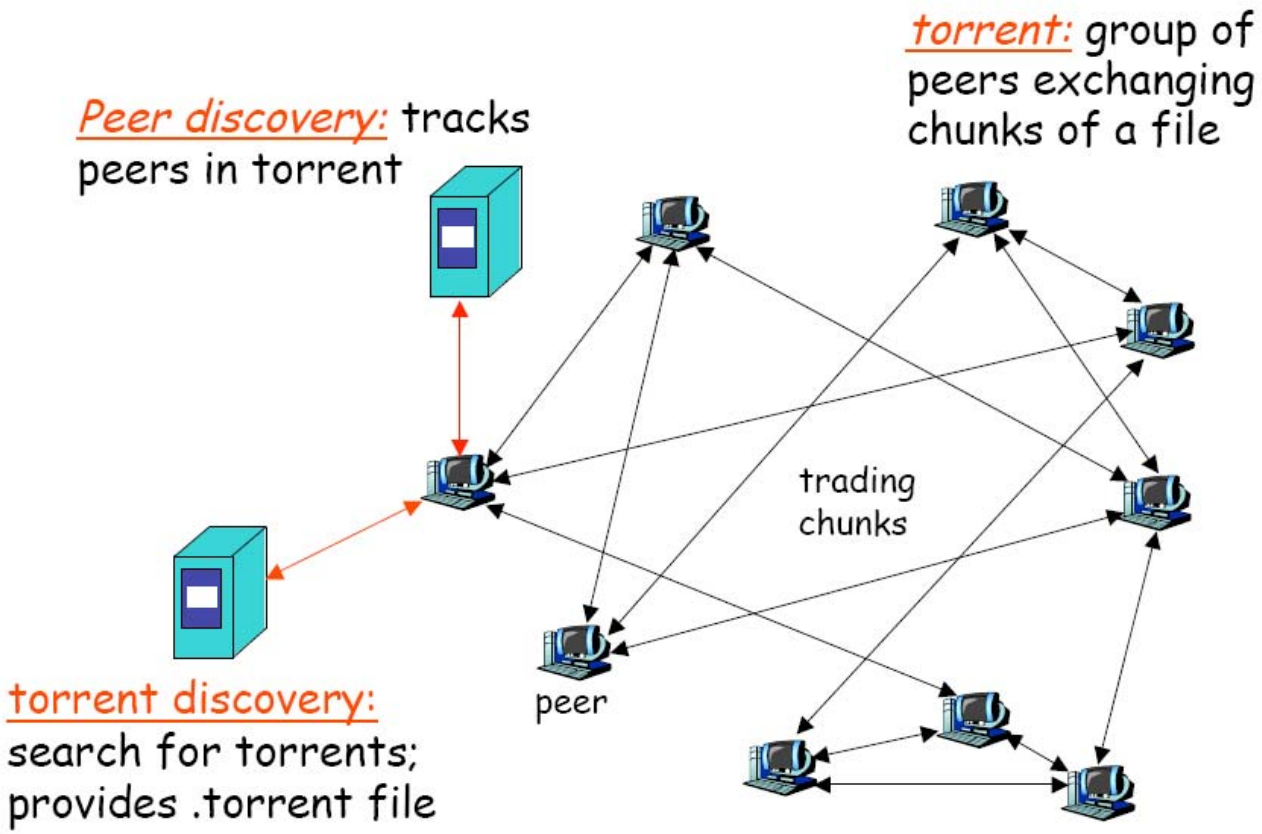
Geographical view of a part of the Gnutella network (222 nodes); The numbers depict the node numbers from the abstract view (Figure on the left, measured on 01.08.2002)

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

P2P Application Areas

- File sharing
- Media Conferencing
- Overlay Multicast: IPTV …
- Resource Sharing: Grids
- Collaborative Communities
- Content based networking: e.g. Semantic Nets
- Mobile Adhoc Networks: e.g. Vehicular Communication
- De-personalization tools: e.g. Tor
- Inspiration for a next generation Internet
- …

File Sharing: BitTorrent



BitTorrent „Eco"-System

Simple Interface:

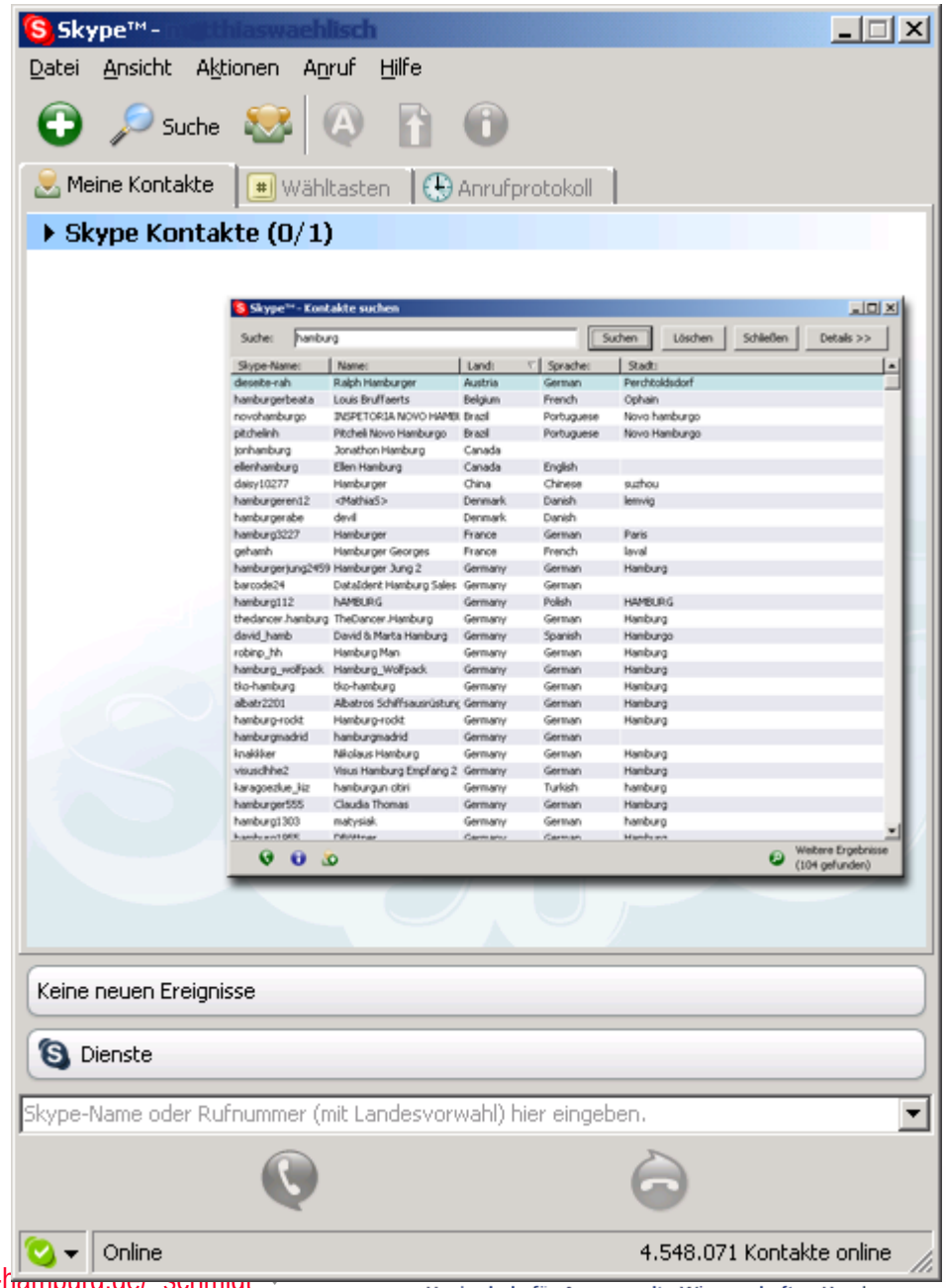
- Publishing – .torrent metainfo file + Tracker
  - Tracker provides download peers
  - Trackerless clients use distributed indexing
- Downloading – use BitTorrent via a Web browser
  - Uploading is started automatically

File exchange incentive:

- Tit-for-tat trade – balance upload and download connection-wise

Skype

- VoIP conferencing system
- Released 2003
- Central login server
- Hybrid P2P system otherwise
- Main focuses:
  - Detect users
  - Traverse NAT & Firewalls (STUN)
- Elects Superpeers according to network connectivity
- Uses Superpeers as relays



IPTV: The Video Tsunami

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Video Road Hogs Stir Fear of Internet Traffic Jam

By STEVE LOHR
Published: March 13, 2008

Caution: Heavy Internet traffic ahead. Delays possible.

Multimedia

For months there has been a rising chorus of alarm about the surging growth in the amount of data flying across the Internet. The threat, according to some industry groups,

E-MAIL
PRINT
SINGLE PAGE
REPRINTS
SAVE
SHARE

Resume

- P2P technologies offer an innovative overlay infrastructure for decentralized and distributed systems
- Due to the distributed nature, the signaling load is very high.
- Signaling load may be decreased by further structures
- Advantages:
  - Simple basic principle
  - Enhanced reliability
  - Redundancy (high replication rate)
  - Unsusceptible against Denial of Service attacks (DOS)
  - No single point of failure
- Problem: Increasing struggle with ISPs

References

- Andy Oram (ed.): *Peer-to-Peer*, O'Reilly, 2001.
- R. Steinmetz, K. Wehrle (eds.): *Peer-to-Peer Systems and Applications,* Springer LNCS 3485, 2005.
- P. Mahlmann, Ch. Schindelhauer: *Peer-to-Peer-Netzwerke*, Springer Berlin/Heidelberg, 2007