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Peer-to-Peer Architectures and Signaling

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Slides based on presentation by Marcin Matuszewski in 2005

Agenda

- **Introduction**
- P2P architectures
- Skype
- Mobile P2P
- Summary

Introduction

- There are various definitions for what peer-to-peer is about

  "A distributed network architecture may be called a Peer-to-Peer (P-to-P, P2P, . . .) network, if the participants share a part of their own hardware resources (processing power, storage capacity, network link capacity, printers, . . .). These shared resources are necessary to provide the service and content offered by the network (e.g. file sharing or shared workspaces for collaboration). They are accessible by other peers directly, without passing intermediary entities. The participants of such a network are thus resource (service and content) providers as well as resource (service and content) requesters (servent-concept)." (Schollmeier, 2002)

  "A peer-to-peer (or P2P) computer network is a network that relies on the computing power and bandwidth of the participants in the network rather than concentrating it in a relatively low number of servers. P2P networks are typically used for connecting nodes via largely ad hoc connections. Such networks are useful for many purposes. Sharing content files (see file sharing) containing audio, video, data or anything in digital format is very common, and realtime data, such as telephony traffic, is also passed using P2P technology." (Wikipedia, ref. 15.2.2006)

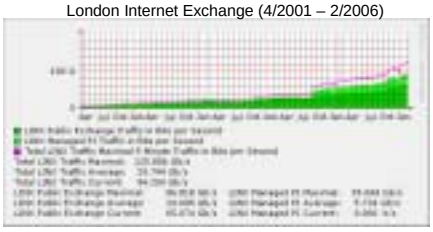
Introduction

- Generally in peer-to-peer communication
  - each communication node (peer) has both server and client capabilities
  - any party can initiate a communication session
  - applications connect with each other directly
- Peer-to-peer paradigm has many uses
  - File-sharing
  - Internet telephony
  - Distributed computing
  - …

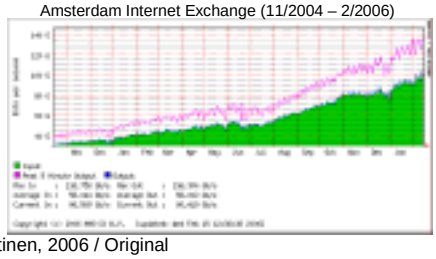
Peer-to-Peer popularity

- File-sharing applications are the most popular form of P2P – at least traffic wise – e.g. BitTorrent, Kazaa, Direct Connect
- P2P accounts for 60 – 80% of all Internet traffic
- Other peer-to-peer applications are also gaining popularity e.g. Skype - Voice over P2P, Mobile P2P

London Internet Exchange (4/2001 – 2/2006)



Amsterdam Internet Exchange (11/2004 – 2/2006)



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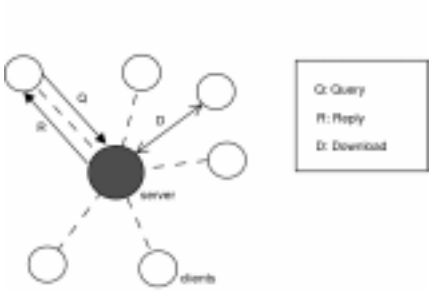
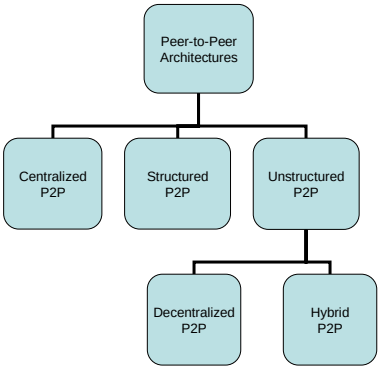
Traditional Client-Server Architecture

- One high-performance server holds all the content in the network
  - Owner of the server has full control on the shared content
- Multiple clients share content via the centralized server



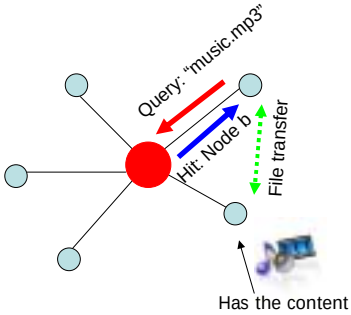
P2P architectures

- Three main architecture types
  - Centralized peer-to-peer
  - Structured peer-to-peer
    - Always decentralized
  - Unstructured peer-to-peer
    - Decentralized peer-to-peer (a.k.a. pure p2p)
    - Semi-centralized peer-to-peer (a.k.a. hybrid p2p)



Centralized P2P architecture

- A centralized server, or a cluster of servers holds information about the files available on the clients
  - Owner of the server has high control on the shared content
- The clients transfer content directly without the server involvement
  - The server is only used for content searches
- Advantages
  - Searches are quick and need very little bandwidth
- Disadvantages
  - Server represents a single point of failure for entire system
  - Can be easily attacked
  - Have limited resources => scalability issue
- Example: Napster

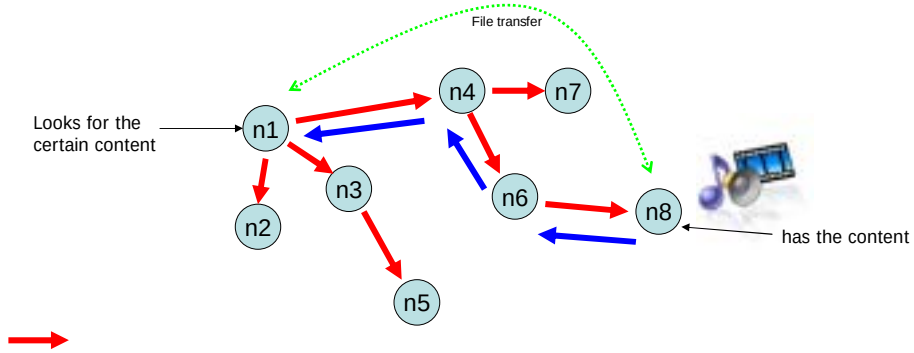


Pure P2P architecture

- All nodes are equal in the network – There is no centralization
  - No single node has control over the content shared by the other users
- Searches are done by flooding search requests in the network
  - Downloads are executed in peer-to-peer fashion
- Control and data are completely distributed
  - No centralized server
- Advantage
  - Resilience to node failures
- Disadvantage
  - Inter-peer connections tend to form a power-law graph (a small number of highly connected peers)
  - Simple broadcast search is not efficient (delay, bandwidth)
  - TTL is used to limit flooding
- Example: Gnutella

Search in pure peer-to-peer architecture

- Requests are flooded in the network
- Reply path may follow query path or be direct



Hybrid P2P architecture

- There are two types of peers in a network:
- Gateways (Super-peers)
  - more powerful peers become gateways to a network
  - form a pure P2P network between themselves
  - handle search requests on behalf of clients
- Clients (Ordinary-peers)
  - less powerful peers act as clients to the gateway peers
  - upload metadata information about shared files to gateways

Hybrid Peer-to-Peer Architecture

- There are two types of nodes in the network
  - **Ordinary-peers** are connected to super-peers as in centralized peer-to-peer architecture
  - **Super-peers** are connected to each other in decentralized manner
- A super-peer has high control on content shared by ordinary nodes connected to it
- Super-peers do not have control on content announced by the other super-peers
- Downloads are executed in peer-to-peer fashion

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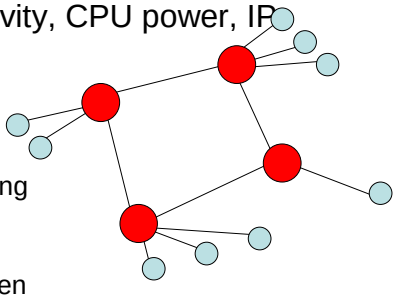
Hybrid P2P - KaZaA

- KaZaA is an example of semi-centralized P2P network
- Super-Peers (SPs) are normal peers that have been automatically elected as the super-peers based on their up time, bandwidth, connectivity, CPU power, IP address (public vs. private)
- Super-peers maintain a database with:
  - file identifiers, their children are sharing
  - metadata (file name, file size, contentHash, file descriptors)
  - corresponding IP addresses of children
- SP maintain long-lived TCP connections with other SPs



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KaZaA cont.

- KaZaA peers frequently exchange list of super-peers
  - Ordinary-Peer (OP) maintains list of 200 super-peers
  - Super-Peer (SP) appears to maintain list of thousands of SPs
- All of the signaling traffic between peers is encrypted
  - Handshaking traffic for connection establishment
  - List of super-peers exchange
  - Metadata upload
  - Queries and replies
- File transfer between nodes is not encrypted
- TCP is used for both file transfer and signaling traffic

KaZaA cont.

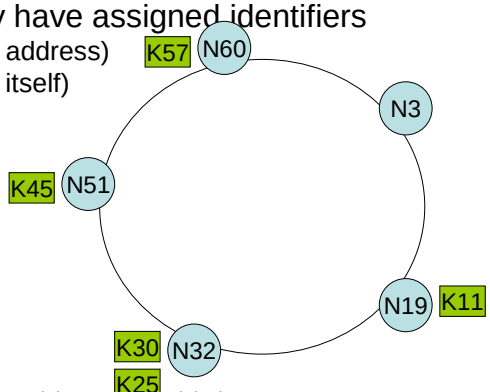
- Files searching
  - OP sends a query with a keyword to its SP
  - SP returns IP addresses and related metadata that correspond to the match from its database
  - SP may forward query to one or more SPs to which it is connected
  - Query visits only a small subset of SPs so the result represent only a small subset of all files stored in KaZaA network
- SPs frequently change their SP-SP connections on a time scale of tens of minutes => Larger part of network can be explored

Structured peer-to-peer architectures

- Are also totally decentralized – there is no single point of control
- Based on Distributed Hash Table (DHT) algorithm
- Wildcard searches are not possible
  - Exact name or has for the searched content must be known
  - Thus unusable for traditional file sharing

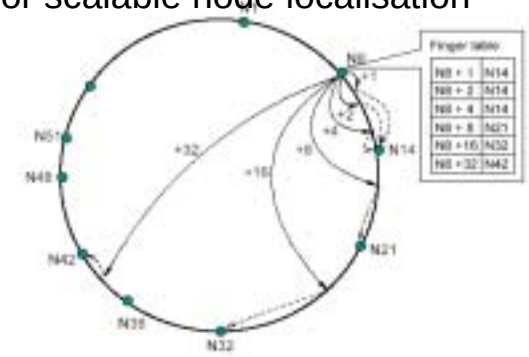
Structured P2P - Chord

- Chord provides improvements to the searching process
- Nodes in a network are organized in a circle
- Each file is identified by a unique key
- Each node and each key have assigned identifiers
  - Node identifiers: SHA1(IP address)
  - Key Identifiers: SHA1(key itself)
- Each key is assigned to its successor

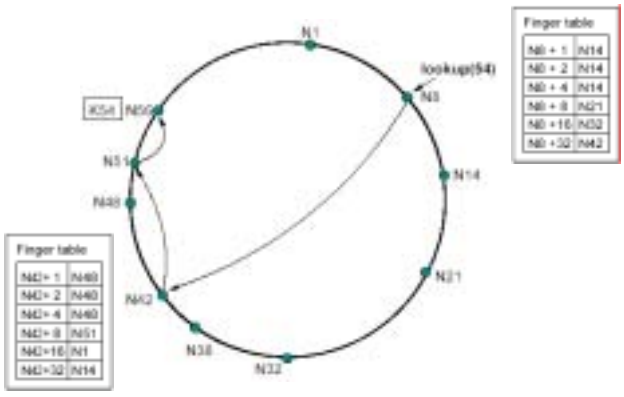


Chord - Finger Table

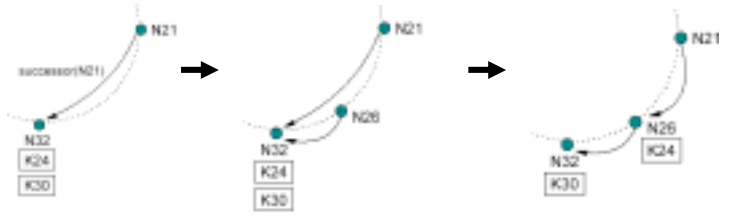
- Chord routing is based on finger table
  - The information stored in the Finger Table is used for scalable node localisation



Chord - key localisation process



Chord – joining node



- Node 21 asks its successor the following question: “Am I your predecessor?”
- If node 26 joins the network an answer to this question is: “NO, node 26 is my predecessor”

Properties of Chord

- Availability
  - Protocol functions very well even if the system is in a continuous state of change
- Scalability
  - Lookup grows only logarithmically with the number of nodes
- Load balancing
  - Keys are spread evenly over the nodes
- Flexible naming
  - No constraints on a key structure
- Not suitable for search engines
  - Chord supports “exact match“, cannot handle queries similar to one or more keys

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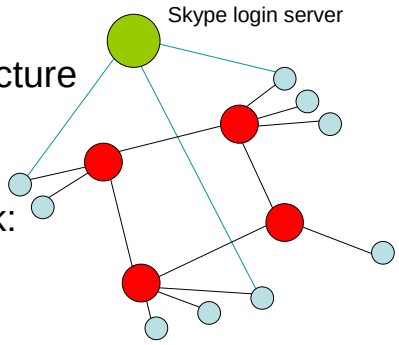
- **Skype**
- Mobile P2P
- Summary

- Skype is another application of peer-to-peer concept
- It provides very successful internet telephony, instant messaging and file transfer services
  - Over 250 million downloads
- Skype is a proprietary protocol in contrast to SIP and H.323
  - No official specifications available – some info acquired by reverse engineering the protocol
- Researchers are trying to apply P2P principle to SIP-based systems

Skype architecture



- Skype has a similar architecture as its predecessor KaZaA
- There are three types of nodes in the Skype network:
  - Ordinary-peers
  - Super-peers
  - Central login server
- The login server stores all of user names and passwords and ensures that names are unique across the Skype name space

Skype – some facts

- It uses TCP for signaling and both UDP and TCP for transporting media traffic
- It uses iLBC, iSAC or a third party unknown voice codec probably developed by GlobalIPSound
- All of the user communication is encrypted using AES 256-bit (Advanced Encryption Standard)
  - Makes wiretapping impossible if there are no backdoors
- It uses a variation of STUN and TURN for NAT and firewall traversal
- Buddy list is signed digitally, encrypted and is local to the machine (not stored on the central server like in case of MSN Messenger)

Skype - login

- After installation a client connects to some bootstrap super-peers, since its Super-Peer list is empty, and acquires the address of the Login Server
- Normal login:
  - Skype client (OP) connects to a Super-Peer
  - OP authenticates the user name and password with the Login Server

Skype - user search

- Client sends an user name to SP and as an answer receives four IP addresses and port numbers
- Subsequently the client contacts these four nodes
- If it cannot find the user it sends request to its SP once again and as a result receives eight IP addresses and port numbers
- The process continues until the user is found
- If the user is behind a NAT and an UDP-restricted firewall, SP searches user on behalf of the client
- Search results are cashed in the intermediate nodes

Skype - call establishment

- If both a caller and a callee have public IP addresses, a caller sends signaling information over TCP to a callee
- If a callee is behind a port-restricted NAT, caller sends signaling information over TCP to an online Skype node that forwards it to a callee
- If both a callee and a caller are behind a port-restricted NAT and an UDP-restricted firewall both exchange the information with an online Skype node

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Mobile P2P (MP2P)

- Faster residential Internet connection, more powerful desktop computers, and cheaper storage were the main drivers stimulating P2P growth
- We can observe a similar technological change in mobile networks
  - Web browsing
  - Email
  - …

Requirements for MP2P (1/2)

- Technical Constraints
  - Memory size
  - CPU performance
  - Screen and keyboard size
  - Battery capacity
  - Access Network Parameters
    - Limited bandwidth shared between multiple users in the same cell

Requirements for MP2P (2/2)

- Special Needs of Mobile Environment
  - Support for various access networks
  - Operator control
  - Feasible bandwidth pricing
- User Requirements
  - Quick response times
  - Rapid downloads
  - Group management features for sharing private content
    - Lot of content is probably self-created, like pictures/videos taken with camera-phone

Optimal Architecture for MP2P

- Hybrid architecture optimal for mobile use
  - Minimizes signaling load on the air interface
  - Allows operator to have control on content by controlling the super-peer
  - Multiple operators can network super-peers in peer-to-peer fashion still retaining quite high autonomy
  - Super-peer can be also operated by private entity, e.g. family or sports club

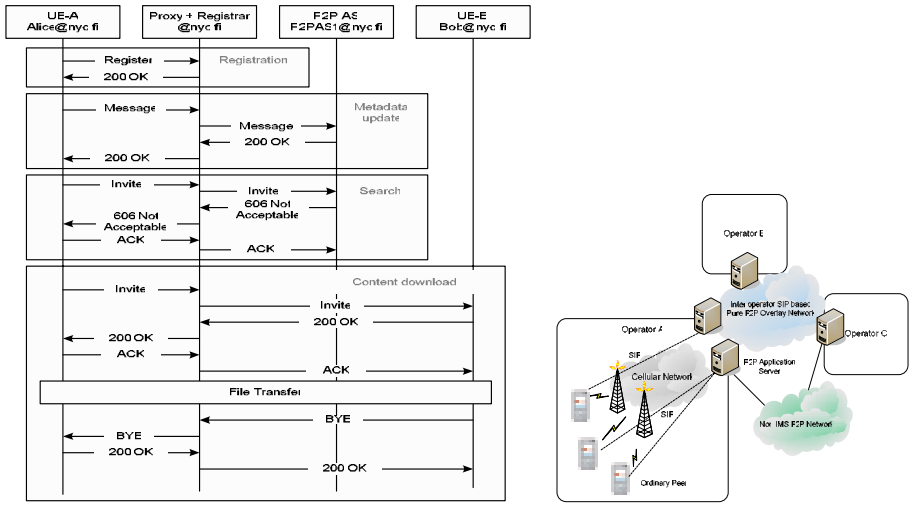
SIP based MP2P application

- SIP based mobile peer-to-peer application has been developed in the Networking Laboratory
  - Uses hybrid peer-to-peer architecture
  - All signaling is in SIP
    - Search
    - File-list update
    - Download initialization
    - …
  - Use of SIP as the signaling protocol allows easy integration with IMS and other SIP aware networks

SIP Requests Used for MP2P Signaling

- INVITE – Content search and download session establishment
- MESSAGE – File-list updates to super-peers
- Search and file-list update messages have all content information encoded in XML to enable easy parsing and extension of the format in the future

Use Case – Register, Search, and Download



Mobile P2P challenges

- Shortage of resources:
  - Battery, CPU, Memory, Network connection
  - Widely used P2P applications/protocols have to be redesigned
- Business issues
  - Understand and analyze the impact of peer-to-peer services on the mobile market and its value chain
  - Identify some key application scenarios that are likely to be attractive to users

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Summary

- P2P architecture offers scalability, robustness and fault tolerance
- Content sharing is a dominant P2P application however other applications, such as Internet telephony, are emerging
- SIP over P2P concept aims to improve scalability and usability of standardized SIP applications – no need for centralized SIP nodes
- In the near future we will see P2P services in the mobile domain

Thank you!

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