Outline

- Introduction
- Gnutella system
- Peer-Grid structure
- Gridella system
- Future works and conclusions
Introduction

- Client-server-based system
  - Server capacity
  - Network capacity
  - Service reliability
- Some solutions
  - Load balancing
  - Fault tolerance
  - Caching
  - Replication
What is P2P?

- Every participating node acts as both a client and a server ("servent")
- Every node "pays" its participation by providing access to (some of) its resources
- Properties:
  - no central coordination
  - no central database
  - no peer has a global view of the system
  - global behavior emerges from local interactions
  - all existing data and services are accessible from any peer
  - peers are autonomous
  - peers and connections are unreliable
Napster: Communication Model

- Napster Server
  - register (user, files)
  - "Where is X.mp3?"
  - "A has X.mp3"
  - Download X.mp3

A

B
This paper presents Gridella, a P2P system based on Peer-Grid (P-Grid), improves on Gnutella’s search performance while reducing bandwidth requirements.
Gnutella

- Gnutella is a decentralized file-sharing system.
- The host communicates peer-to-peer via the Gnutella protocol.

- http://www.gnutella.com
## Gnutella: Protocol Message Types

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Contained Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ping</td>
<td>Announce availability and probe for other servents</td>
<td>None</td>
</tr>
<tr>
<td>Pong</td>
<td>Response to a ping</td>
<td>IP address and port# of responding servent; number and total kb of files shared</td>
</tr>
<tr>
<td>Query</td>
<td>Search request</td>
<td>Minimum network bandwidth of responding servent; search criteria</td>
</tr>
<tr>
<td>QueryHit</td>
<td>Returned by servents that have the requested file</td>
<td>IP address, port# and network bandwidth of responding servent; number of results and result set</td>
</tr>
<tr>
<td>Push</td>
<td>File download requests for servents behind a firewall</td>
<td>Servent identifier; index of requested file; IP address and port to send file to</td>
</tr>
</tbody>
</table>
Gnutella: Meeting Peers (Ping/Pong)
Gnutella: Searching (Query/QueryHit/GET)
Gnutella’s Problems

- High bandwidth consumption
- High cost of database search on all requested hosts
- No estimate of query duration and probability for success of query
- Free-riding problem
Gnutella: Summary

- Completely decentralized
- Hit rates are high
- High fault tolerance
- Adopts well and dynamically to changing peer populations
- **Protocol causes high network traffic (e.g., 3.5Mbps). For example:**
  - 4 connections C / peer, TTL = 7
  - 1 ping packet can cause \(2 \times \sum_{i=0}^{TTL} C \times (C - 1)^i = 26,240\) packets
- No estimates on the duration of queries can be given
- No probability for successful queries can be given
- Topology is unknown \(\Rightarrow\) algorithms cannot exploit it
- Free riding is a problem
- Reputation of peers is not addressed
- Simple, robust, and scalable (at the moment)
Free-riding on Gnutella [Adar00]

- 24 hour sampling period:
  - 70% of Gnutella users share no files
  - 50% of all responses are returned by top 1% of sharing hosts

- Verified hypotheses:
  - H1: A significant portion of Gnutella peers are free riders.
  - H2: Free riders are distributed evenly across domains
  - H3: Often hosts share files nobody is interested in (are not downloaded)
Can a set of peers without central coordination provide efficient search and small storage space?
CAN

- Content Addressable Network (*SIGCOMM’01*)

![Diagram of 2D space with 5 nodes labeled A, B, C, D, E. Node B's virtual coordinate zone is indicated.]

**Figure 1:** Example 2-d space with 5 nodes
P2P Data Access Structures

- Every peer maintains a small fragment of the database and a routing table
- The peers implement a routing strategy
- Replication can be used to increase robustness
Peer-Grid

- P-Grid is a **virtual binary search tree** that distributes replication over a community of peers and supports efficient search.
- Peers in P-Grid perform construction and search/update operations without any central control or global knowledge in an unreliable environment.
Peer-Grid Properties

- It is completely decentralized
- All peers serve as entry points for search
- Interactions are strictly local
- It uses randomized algorithms for access and search
- Probabilistic estimates of search request success can be given
- Search is robust against node failures
- It scales gracefully in the total number of nodes and data items
Routing

- Every participating peer is represented by its path, the binary bit string representing the subset of the tree’s overall information that the peer is responsible for.
- For each bit in its path, a peer stores the address of at least one other peer that is responsible for the other side of the binary tree at that level.
Data Structure of an Agent
P-Grid Construction Algorithm (Bootstrap)

- When agents meet (randomly)
  - Compare the current search paths p and q
- Case 1: p and q are the same
  - If the maximal path length is not reached extend the paths and split search space, i.e. to p0 and q1
- Case 2: p is a subpath of q, i.e. q = p0...
  - Extend p by the complement of q, i.e. p1
- Case 3: only a common prefix exists
  - Forward to one of the referenced peers
  - Limit forwarding by recmax

0.011 \rightarrow r01.011 \rightarrow 010.011
4. Search and Update

- Search straightforward
  - Follow own path or references
  - At most $k$ steps
  - If multiple references are online, select randomly

- Updates
  - All replicas need to be found
  - Repeated searches
    - Breadth first (limited recursion breadth)
    - Depth first
    - Depth first and contact buddies with same key
Gridella

- Gridella is a P-Grid-based, Gnutella-compatible P2P system.
- Gridella is written in Java and will be released under the GNU general public license.
Gridella Components
Gridella Interaction
Performance Comparison

<table>
<thead>
<tr>
<th>Peers</th>
<th>Gridella messages</th>
<th>Gnutella messages</th>
</tr>
</thead>
<tbody>
<tr>
<td>20,000</td>
<td>61</td>
<td>8,744</td>
</tr>
<tr>
<td>40,000</td>
<td>63</td>
<td>26,240</td>
</tr>
<tr>
<td>60,000</td>
<td>65</td>
<td>26,240</td>
</tr>
<tr>
<td>80,000</td>
<td>65</td>
<td>78,728</td>
</tr>
<tr>
<td>100,000</td>
<td>68</td>
<td>78,728</td>
</tr>
<tr>
<td>120,000</td>
<td>69</td>
<td>78,728</td>
</tr>
<tr>
<td>140,000</td>
<td>68</td>
<td>78,728</td>
</tr>
<tr>
<td>160,000</td>
<td>69</td>
<td>78,728</td>
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<tr>
<td>180,000</td>
<td>69</td>
<td>78,728</td>
</tr>
<tr>
<td>200,000</td>
<td>72</td>
<td>78,728</td>
</tr>
</tbody>
</table>
Future Works

- **New e-commerce models:**
  - Use P-Grid for decentralized storage of reputation data to address security issues such as authenticity and confidentiality.

- **Micro-payment system**
  - Force people to pay for service to avoid free riding.
  - Offers and downloads from a peer would earn credits, which could be used to pay for services requested.
Research Issues

- P2P for reliable E-Commerce
  - dynamic business models
  - trust establishment
  - peer-to-peer transactions
  - decision making
- Quality of service
  - improved fault tolerance
  - archival storage
  - quality guarantees
- Richer data model
  - Relational, XML
  - meta-data model
  - improved search
- Multimedia (MPEF7, MPEG2000)
- Message-based applications
  - scalability
  - improved search capabilities
- Mobility
- P2P Search Engines
Conclusion Remarks

- Considerable research and experimentation remains to make P2P systems feasible for application domains beyond mere MP3 and image exchange, such as creating a new paradigm for decentralized **e-commerce systems**, or for new types of network infrastructures such as **mobile ad hoc networks**.
2. The P2P Cloud

Akamai
FastTrack
DFS
E-Donkey
Intermemory
iMesh
Alpine
Aimster
Gnutella
Napster
Freenet
Gnutmeg
OFSI
Farsite
India
OceanStore
CAN
JXTA
Chord
Gridella
Tornado

... and many more ...
### Summary and Comparison of Approaches

<table>
<thead>
<tr>
<th>Paradigm</th>
<th>Search Type</th>
<th>Search Cost (messages)</th>
<th>Fixed Data Assignment</th>
<th>Common Network Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gnutella</td>
<td>Breadth-first search on graph</td>
<td>String comparison</td>
<td>$2^* \sum_{i=0}^{TTL} C^* (C-1)$</td>
<td>no</td>
</tr>
<tr>
<td>Freenet</td>
<td>Depth-first search on graph</td>
<td>Equality</td>
<td>$O(\log n)$?</td>
<td>no</td>
</tr>
<tr>
<td>Chord</td>
<td>Implicit binary search trees</td>
<td>Equality</td>
<td>$O(\log n)$</td>
<td>yes</td>
</tr>
<tr>
<td>CAN</td>
<td>d-dimensional space</td>
<td>Equality</td>
<td>$O(d n^\alpha(1/d))$</td>
<td>no</td>
</tr>
<tr>
<td>Tapestry</td>
<td>Prefix trees</td>
<td>Equality</td>
<td>$O(\log n)$</td>
<td>yes</td>
</tr>
<tr>
<td>P-Grid</td>
<td>Binary prefix trees</td>
<td>Prefix</td>
<td>$O(\log n)$</td>
<td>no</td>
</tr>
</tbody>
</table>

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Listen — P2P is around

- P2P systems receives currently a lot of attention
  - File-sharing systems
    - Napster, Gnutella, Freenet, etc.
  - Conferences
    - O’Reilly P2P conference 2001 (conferences.oreilly.com/p2p/)
    - Peer-to-Peer Computing Workshop at Networking 2002 conference (http://www.cnuce.pi.cnr.it/Networking2002/)
  - etc.

- P2P is nothing new – see Arpanet