Spotify – Large Scale, Low Latency, P2P Music-on-Demand Streaming

Gunnar Kreitz   Fredrik Niemelä

KTH – Royal Institute of Technology
Spotify
gkreitz@kth.se

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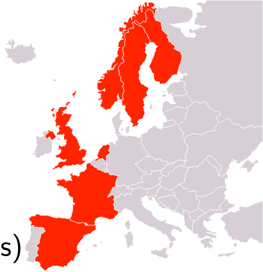
What is Spotify?



- Peer-assisted on-demand music streaming
- Large catalog of music (over 8 million tracks)
- Available in 7 European countries, over 7 million users
- Fast (median playback latency of 265 ms)
- Legal

Image based on Western Europe Map, Wikimedia Commons, CC BY SA 3.0

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User Perspective

- Client software
- Ad-funded (and free), or monthly subscription
- Not included in evaluation data:
    - Can also play local music files (introduced later)
    - Smartphone clients (no P2P)

Comparison with Video-on-Demand

- Lower bitrate
- Shorter objects
- More objects
- Different access pattern
  - More active users
  - Users play their favorite tracks often

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Overview of Spotify Protocol

- Proprietary protocol
- Designed for on-demand streaming
- 96–320 kbps audio streams (most are Ogg Vorbis q5, 160 kbps)
- Relatively simple and straightforward design

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Caches

- Player caches tracks it has played
- Default policy is to use 10% of free space (capped at 10 GB)
- Caches are large (56% are over 5 GB)
- Least Recently Used policy for cache eviction
- Over 50% of data comes from local cache
- Cached files are served in P2P overlay

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Streaming a Track

- Request first piece from Spotify servers
- Meanwhile, search for peers with track
- Download data in-order
- When buffers are sufficient, only download from P2P
- Towards end of a track, start prefetching next one

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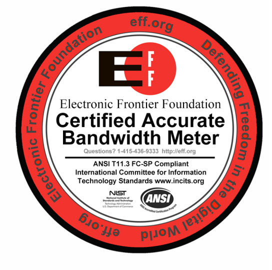
Playout-buffer Adjustment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- Minimize latency while avoiding stutter
- TCP throughput varies
  - Sensitive to packet loss
  - Bandwidth over wireless mediums vary
- Model throughput as a Markov chain and simulate
- Heuristics

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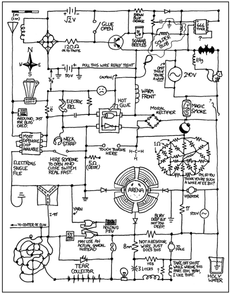
Security Through Obscurity



- ▶ Client must be able to access music data
- ▶ Reverse engineers should not be able to access music data
- ▶ So, some details are secret (and the client is obfuscated)

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P2P Structure

- Unstructured overlay (not a Distributed Hash Table)
- Nodes have fixed maximum degree (60)
- Neighbor eviction by heuristic evaluation of utility
- No overlay routing
- Looks for and connects new peers when streaming new track
- Overlay becomes (weakly) clustered by interest

Brief Comparison to BitTorrent

- One (well, two) P2P overlay for all tracks (not per-torrent)
- Does not inform peers about downloaded blocks
- Downloads blocks in order
- Does not enforce fairness (such as tit-for-tat)
- Informs peers about urgency of request

Finding Peers

- Sever-side tracker (BitTorrent style)
  - Only remembers 20 peers per track
  - Returns 10 (online) peers to client on query
- Broadcast query in small (2 hops) neighborhood in overlay (Gnutella style)
- Client uses both mechanisms for every track

Evaluation

- So, how well does it work?
- Collected measurements 23–29 March 2010

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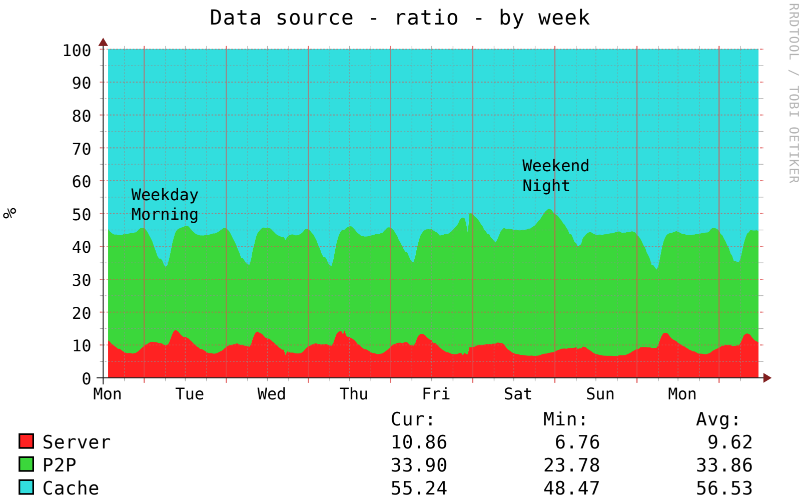
Data Sources



	Cur:	Min:	Avg:
🟥 Server	10.86	6.76	9.62
🟩 P2P	33.90	23.78	33.86
🟦 Cache	55.24	48.47	56.53

Data Sources

- Mostly minor variations over time
  - Better P2P performance on weekends
  - P2P most effective at peak hours
- 8.8% from servers
- 35.8% from P2P
- 55.4% from caches

Latency and Stutter

- Median latency: 265 ms
- 75th percentile: 515 ms
- 90th percentile: 1047 ms
- Below 1% of playbacks had stutter occurrences

Track Accesses

- There is no cost per track for users
- What does the usage pattern look like?
- How is that affected by caches and P2P?

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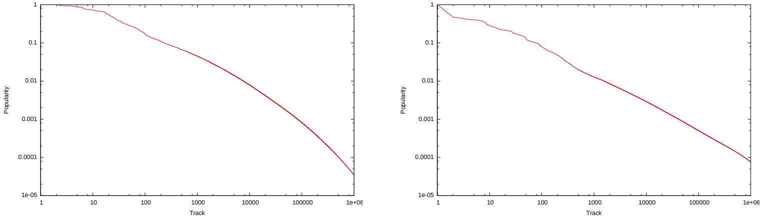
Track Accesses



(a) Track playback frequencies (normalized), log-log scale

(b) Track server request frequencies (normalized), log-log scale

Figure: Frequency of track accesses

- 60% of catalog was accessed
- 88% of track playbacks were within most popular 12%
- 79% of server requests were within the most popular 21%

Finding Peers

Table: Sources of peers

Sources for peers	Fraction of searches
Tracker and P2P	75.1%
Only Tracker	9.0%
Only P2P	7.0%
No Peers Found	8.9%

- Each mechanism by itself is fairly effective

Protocol Overhead

Table: Distribution of application layer traffic in overlay network

Type	Fraction
Music Data, Used	94.80%
Music Data, Unused	2.38%
Search Overhead	2.33%
Other Overhead	0.48%

- Measured at socket layer
- Unused data means it was cancelled/duplicate

Summary

- Commercially deployed system
- Custom protocol for Music-on-demand streaming
- Peer-assisted

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Future Problems

- Playout strategy adapted to P2P streaming
- User satisfaction metrics
- Music-on-demand streaming
- Specialized overlays exploiting similiarty in taste