Maygh: Building a CDN from client web browsers

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Content exchange and the Web

Web is popular mechanism for content distribution

- News sites, content sharing, movies

Web is fundamentally client-server

- I.e., Web site operator serves every client

Popular Web sites receive millions of hits per day

- Need to handle a large number of requests

How do large, popular web sites distribute content?

Distributing web content

Options for content distribution:

1. Serve on your own
   Purchase machines, network bandwidth

2. Pay content distribution networks (CDNs)
   Akamai, Limelight, Clearway, ...

3. Rent cloud services
   Amazon EC2, Azure, App Engine...

Microsoft

Akamai

amazon web services™

In all cases, *significant monetary burden* on web site operator

How do operators pay?

Operators typically use two models to support site:

1. User subscriptions (e.g., Netflix, New York Times, Rdio)
   Limited user base

2. Advertising (e.g., YouTube, Yahoo, Google*)
   Resort to data-mining user data, privacy implications

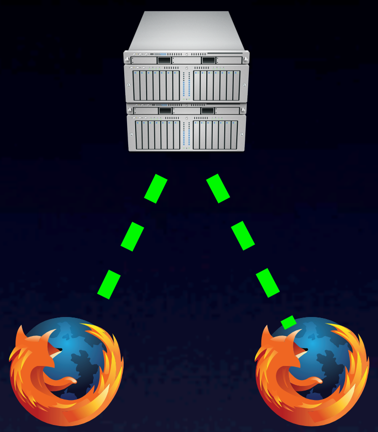
Few choices limit set of sites that can exist
   Free web sites have to accept advertising

Can we give web site operators another option?

Idea: Clients help distribute content

Typical properties of popular web sites:

- Many users
- Same content viewed by many users
- Content are largely static



Insight: Recruit web clients to help serve content

Technically challenging

- Significant user churn
- Web has client-server architecture

But, we are not the first to explore this idea...

Alternate Approaches

1. Browser plugins
   FireCoral, SwarmPlugin

2. Client-side software
   Akamai's NetSession, PPLive

Both require installation of additional software
- Typically with few incentives
- E.g., Adblock Plus, most popular plug-in: 4.2% installations

Can we build a system that does not require additional software?

This talk: Maygh

Goal: Build content distribution system for the Web

- Allow web browsers to assist in content distribution to other users

Requirements:

- Works with today's web sites, browsers
- No client side changes

Maygh

- Serves as a cache for static web content
- Takes advantage of recent HTML5 browser features
- Significantly reduces bandwidth requires for operator

Result: On-demand CDN built from web browsers

Outline

1. ~~Motivation~~
2. Maygh design
3. Security and privacy implications
4. Evaluation

Maygh design overview

Maygh: Drop-in content distribution system

- Serves as a distributed cache
- Assume content always available from origin

Maygh serves static content

- E.g., image, CSS, JavaScript
- Content must be named by content-hash

Key challenge: Browsers not designed to communicate directly

- Browsers distinct from Web servers
- Use new techniques to allow browser to serve content

Protocol: RTMFP or WebRTC

Two peer-to-peer protocols for Web browsers

- Designed for direct audio/video chats
- Both support NAT traversal via STUN

Adobe Flash RTMFP

- Supported in Flash player 10.0 since 2008
- Available in 99% of browsers

WebRTC

- W3C standard, actively under development
- Currently in Firefox and Chrome

Maygh overview

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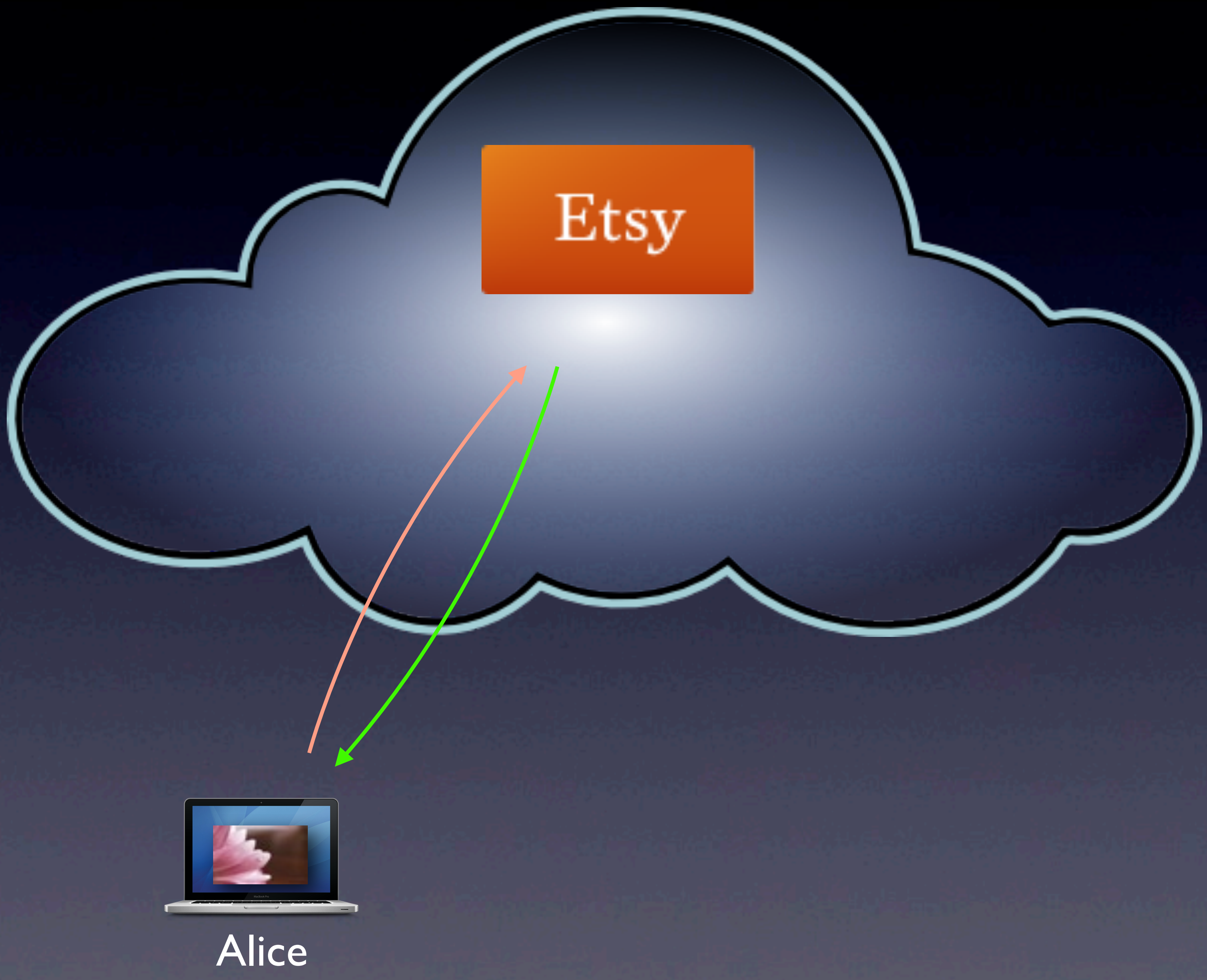

Maygh overview

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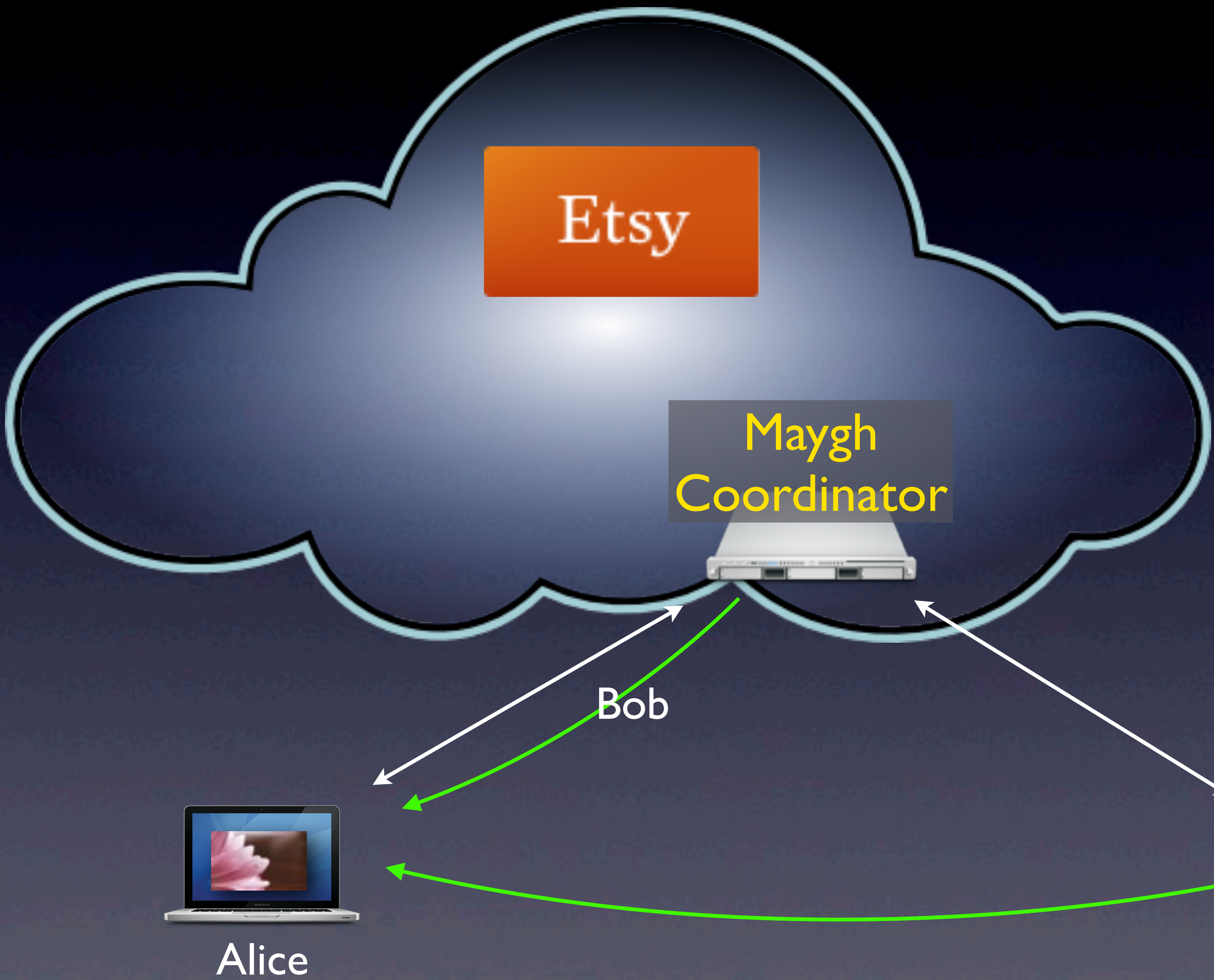


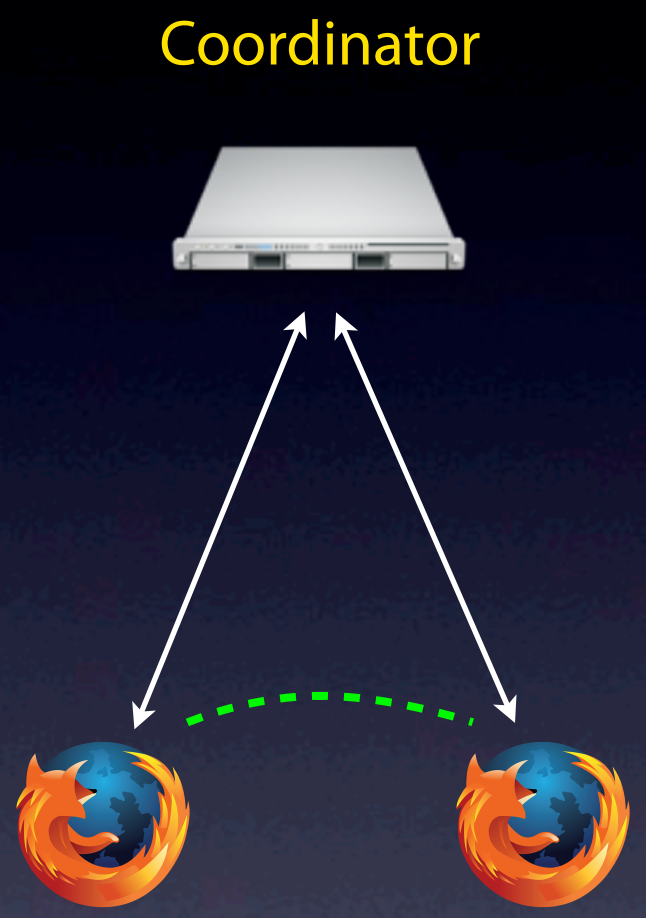
Maygh Coordinator

Introduce a middlebox: Maygh Coordinator

- Run by website operators

Serves two purposes:

1. Serves as a directory for content
   - Keeps track of content in user's browsers
   - Content-hash -> {set of online clients}
2. Allows browsers to establish direct connections
   - Supports NAT traversal using STUN with RTMFP/WebRTC



Techniques to allow multiple coordinators in paper

- Can scale to support high churn, 1000s requests/second

Client-side changes

Implement Maygh client-side library in Javascript

- Add it to the site's pages

Browsers use RTMFP/WebRTC to communicate with coordinator

- Allows bi-directional communication
- Online client is always connected to coordinator

Use LocalStorage to storage browsed content

- Persistent cache, up to 5MB/site
- Easily programmatically accessed

Insert downloaded objects in LocalStorage

- Treat like LRU cache

How does an operator use Maygh?

Web site operators need to do three things:

1. Run coordinator(s)

2. Include Maygh Javascript

```
<script src="maygh.js">
```

3. Change mechanism for loading content

```
<img id="pic-id" src="http://www.foo.com/..."/>
```

replaced with

```
<img id="pic-id"/>
<script>
  maygh.load("pic-hash", "pic-id");
</script>
```

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Security

Can users serve forged content?

- Can detect forged content using content-hash

Can users violate the Maygh protocol?

- E.g., claim to have content, DoS attacks

- Use similar techniques that are in-use today
  - Block accounts, IP address, or subnets
  - Existing defenses against DDoS

Fairness

- Operator controls coordinator, choice of uploading peer
- Maygh tracks content users upload/download
  - E.g., Ensure no user has contributes more resources than they use

Privacy

- Can users view content they are not allowed to?
  - Content secured by its hash
  - Naming content implies access
    - Similar semantics to Flickr, other sites today
- Can users figure out what others have browsed?
  - Client receive information about views
    - Can use cover traffic, pre-fetch requests
    - Or, allow user to disable Maygh for certain content
  - Privacy implications similar to other Hybrid-CDN models
    - NFL's p2p streaming, FireCoral, PPLive

Outline

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Evaluation overview

Implemented Maygh using RTMFP
- Full browser support today, easy to get user base
- Also built proof-of-concept WebRTC client

Includes both Maygh coordinator and client-side library
- Client: 657 lines of Javascript, 214 lines of ActionScript
- Coordinator: 2,944 lines of Javascript

Code open-source, available at

`http://github.com/leoliangzhang/maygh`

How much additional latency?

Accessed from	Served from Maygh LAN (Boston)	Cable (Boston)	DSL (New Orl.)
LAN (Boston)	229 / 87 ms	618 / 307 ms	1314 / 707 ms
Cable (Boston)	771 /283 ms	702 / 314 ms	1600 / 837 ms

Flash RTMFP and WebRTC proof-of-concept implementations

Fetch 50 KB objects from other peer
- Show First/Subsequent object loading time

Overall, latency is sufficient for many Web sites
- Can also be hidden using pre-fetching techniques

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Accessed from	Served from Maygh LAN (Boston)	Cable (Boston)	DSL (New Orl.)
LAN (Boston)	229 / 87 ms 72 / 16 ms	618 / 307 ms 364 / 120 ms	1314 / 707 ms 544 / 354 ms
Cable (Boston)	771 /283 ms 284 / 57 ms	702 / 314 ms 577 / 107 ms	1600 / 837 ms 765 / 379 ms

- Flash RTMFP and WebRTC proof-of-concept implementations
- Fetch 50 KB objects from other peer
  - Show First/Subsequent object loading time
- Overall, latency is sufficient for many Web sites
  - Can also be hidden using pre-fetching techniques

How much bandwidth can Maygh save?

Deploying Maygh to large website is challenging

- Instead, perform simulation

Use 1-week anonymized Akamai access logs from Etsy

- Top-50 US web site, online marketplace
- 205M requests, 5.7M IPs
- 2.77TB total network traffic

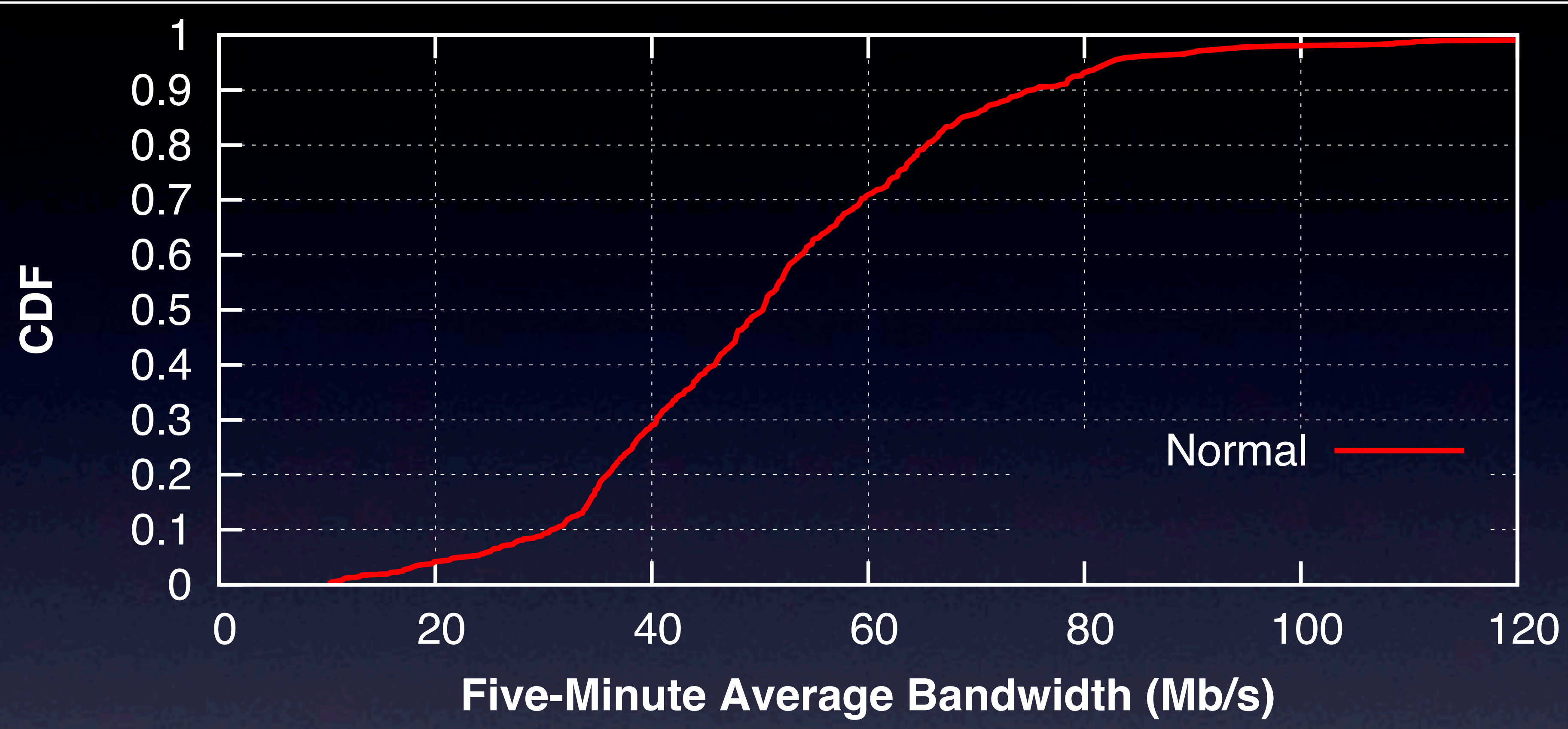
Etsy

85% of Etsy's bandwidth is static images

Simulation setup

- Client stay on page for 10 to 30 seconds
- Ensure fairness
  - Clients never upload more than downloaded, or more than 10 MB

How much bandwidth can Maygh save?



Median bandwidth used drops

- From 50.3 Mb/s to 11.7 Mb/s (a 77% drop)
- Even with significant churn

75% reduction in 95th-percentile bandwidth

- Only requires one 4-core coordinator

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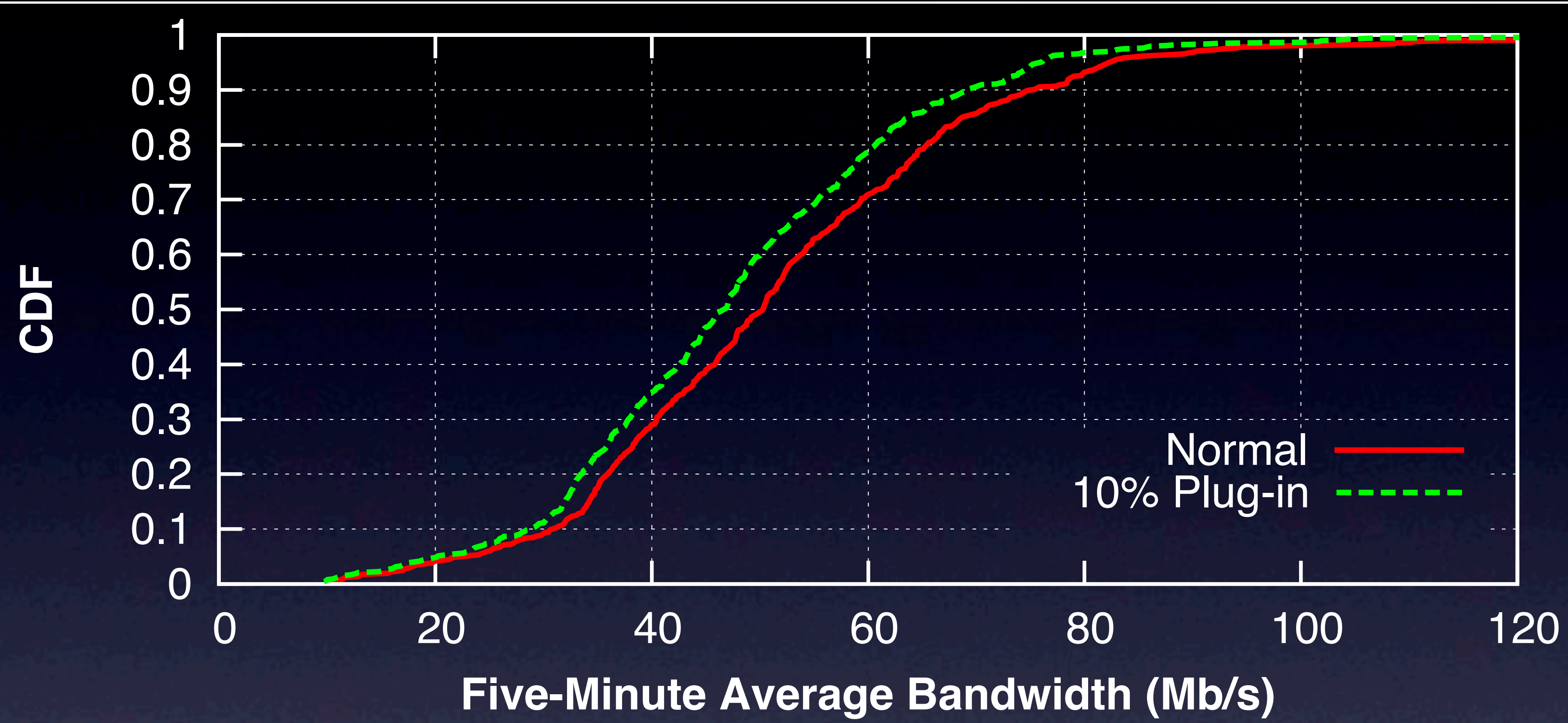

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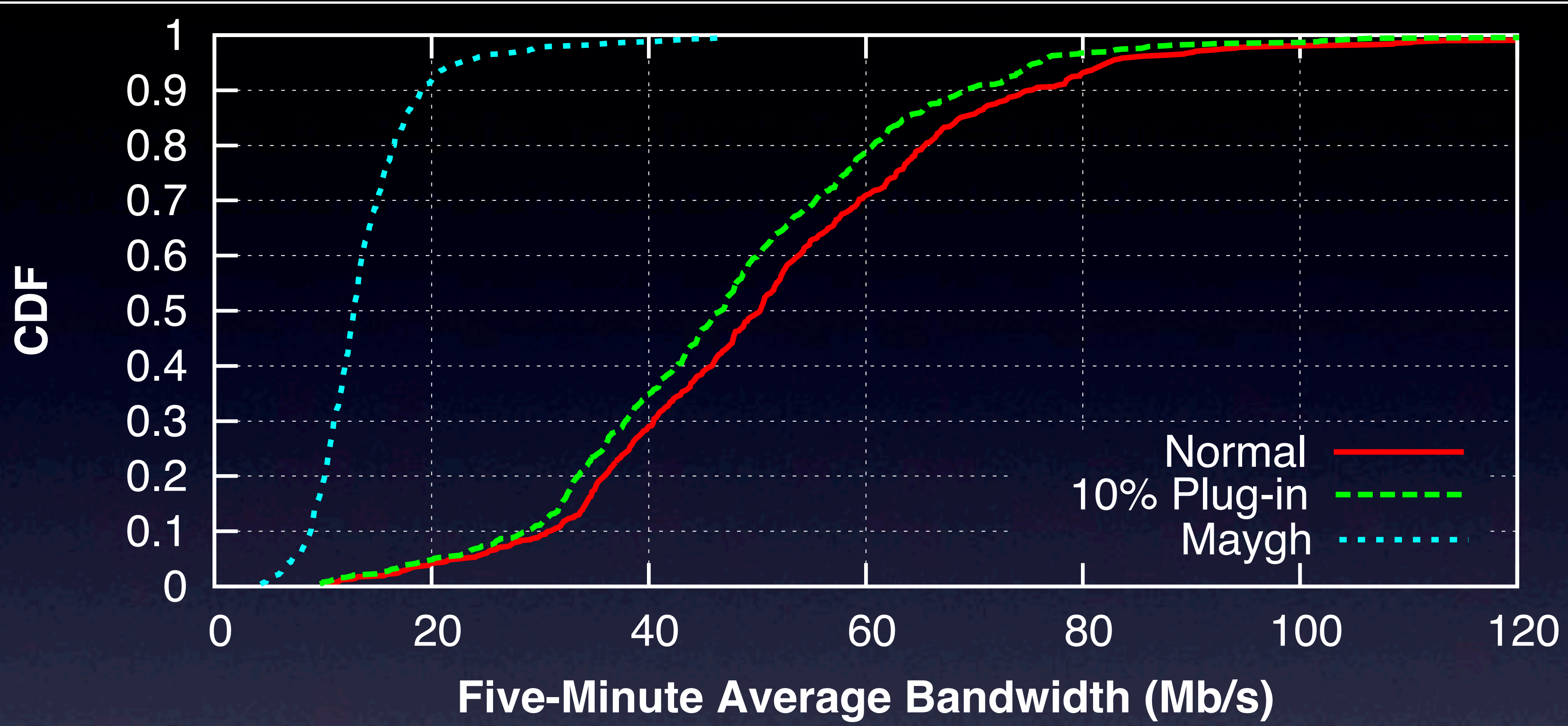

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Real-world deployment

- Set up special version of our department's web server
  - Set up coordinator within our department
- Invite graduate students
  - 18 users for 3 days
  - Total of 374 photos viewed, 24% served from other Maygh client
    - Lower than simulation because more users on Etsy
- Take-away: Compatible with today's
  - Browsers (Firefox, Safari, Chrome)
  - Websites

Summary

Substantial monetary burden to host popular Web site

- Site operators typically resort to advertising to pay bills

Idea: Recruit web clients to help distribute content

- Without requiring any additional client-side software

Maygh

- Serves as cache for static Web content
- Operator runs coordinator, allows clients to communicate

Evaluation demonstrated practicality, efficacy

- Open-source and available to research community

Questions?

http://github.com/leoliangzhang/maygh

Cacheable Web content

Dynamically generated web pages popular

So, how much content is static, cacheable?

- I.e., what is the potential for system like Maygh?

Conduct a experiment

- Consider top 100 websites from Alexa's ranking
- Simulate web browsing via random walk of five pages per site
- Consider content with `Cache-Control: public` cacheable

Result:

- On average, 74.2% of bytes are cacheable
- Maygh could serve a significant fraction of bytes

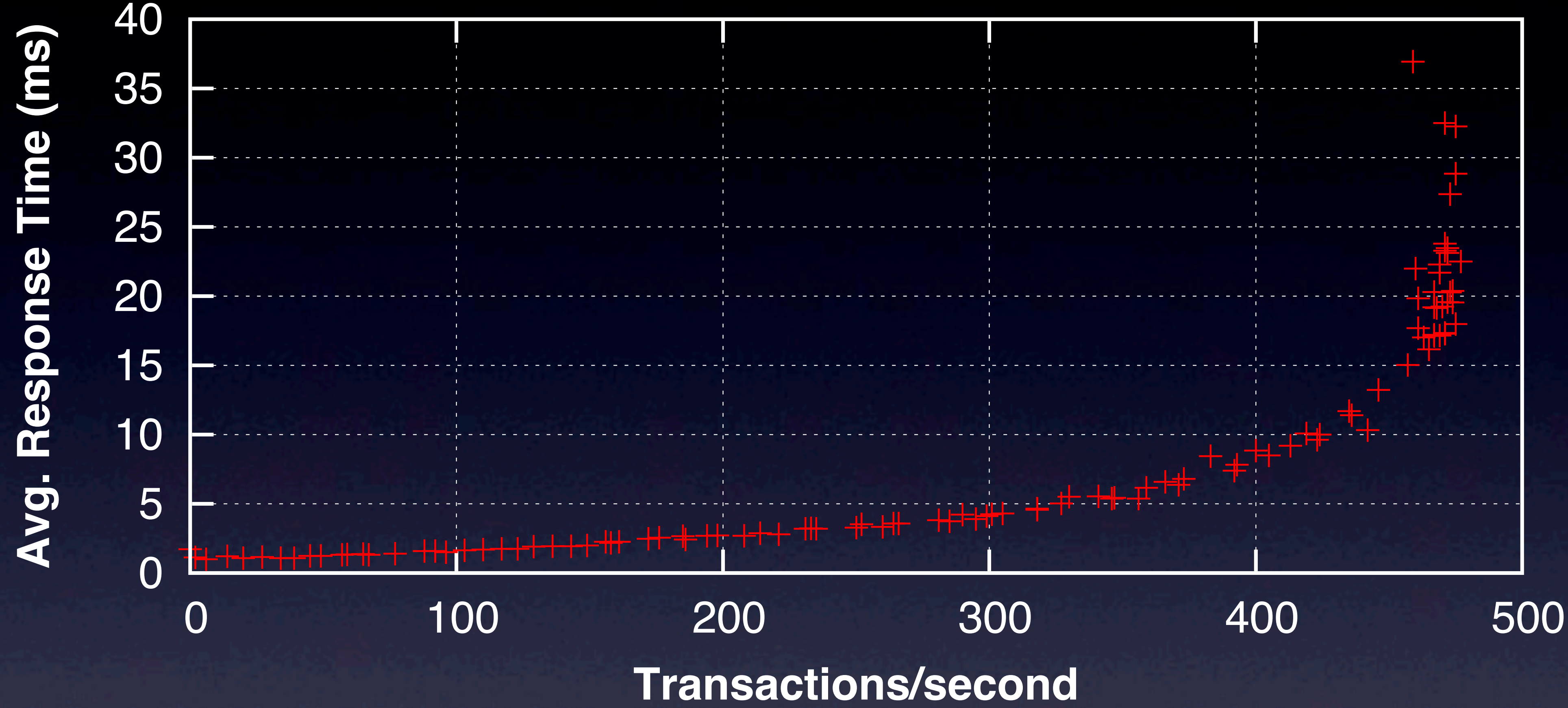
Potential cacheable content

Content Type	% Requests	% Bytes	% Cacheable
Image	70.5	40.3	85.7
JavaScript	13.1	29.0	84.8
HTML	10.7	19.9	30.1
CSS	3.5	8.7	86.5
Flash	0.9	1.3	96.0
Other	1.3	1.0	45.7
Overall	100	100	74.2

Breakdown of browsing trace from the top 100 Alexa web sites.

74.2% of the bytes requested are marked as cacheable
Most static content like images, videos, and SWF are still cacheable

Scalability of Maygh coordinators?

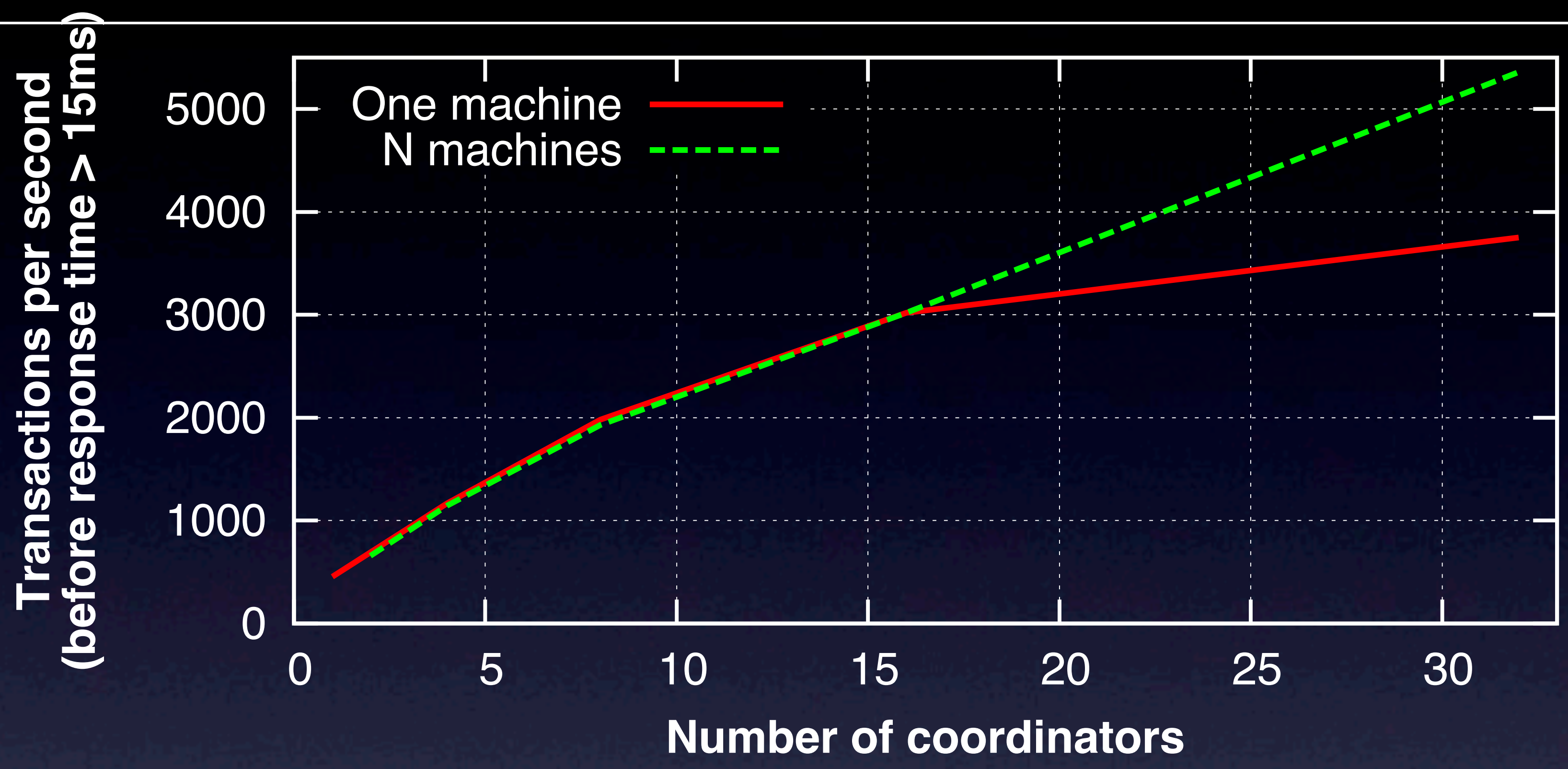


Single coordinator

- Dual 8-core 2.67 GHz Intel Xeon E5-2670 processors
- 454 transactions per second with under 15 ms latency

More details in the paper

Scalability of multiple coordinators



- Multiple coordinators on
  - Single machines, using multiple cores (with hyperthreading)
  - Multiple machines, using only one core
- Close-to-linear scaling
- Single machine performance decreases after 16 coordinators
  - Due to hyperthreading
- A single machine with 4 CPU cores can support Etsy workload