Measuring and Mitigating Web Performance Bottlenecks in Broadband Access Networks

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Reducing Web page load time

1.2% decrease in Bing revenue with 500ms delay
1% decrease in Amazon revenue with 100ms delay

*Every millisecond counts!*
Performance optimizations

Client-side
  - SPDY, QUIC
  - Browser caching
ISP edge
  - Content and DNS caching
Server side
  - Persistent connections
  - TCP ICW
In modern broadband access networks

What are the bottlenecks of Web response time?

How can we mitigate them?
Page load time

*Time from initial request to all objects retrieved*

DNS lookup time
Time to first byte
  - TCP connection initiation
  - Server response
Object download time
Measuring page load time

Measurements from 5000+ homes
SamKnows and Bismark

Deployed on routers across US
Uses Mirage
Mirage

Used to estimate page load time
Shows breakdown of page load time
Only processes statics objects
Waits to download home page before processing it
After parsing home page, performs all DNS queries before downloading any
Mirage vs Phantomjs

Figure 2: Comparison of Mirage to Phantomjs. We see that Mirage underestimates the page load times: real load times are higher than what we measure.
Higher page load times outside US

(b) BISmark-US

(c) BISmark-nonUS
Throughput not a bottleneck after 16Mpbs
Last mile latency has multiplicative effect

(a) Page load times

- CNN
- Google
- Ebay
- Yahoo
- Facebook
TCP overhead is large on small objects
Where are the bottlenecks?

Low bandwidth (under ~16Mpbs)
   Throughput -> cache content
High bandwidth (over ~16Mpbs)
   Latency -> cache DNS responses, TCP connections
How to optimize for latency

Preemptive, persistent TCP connections
DNS caching
Content caching
DNS resolvers and CDNs stop at ISP edge
  Doesn’t solve last-mile latency problem!

* Caching must be done inside the home*
TCP connections already setup

Figure 8: Connection caching in the home can reduce median page load times by 100–750 ms. (Home Connection Proxy vs. Home DNS Measurements)
DNS Caching in home vs ISP

Maximum times

Figure 7: Caching DNS in the home can reduce the maximum DNS lookup time by 15–50 ms. (Home DNS Measurement vs. No Proxy, ISP DNS Measurement)
Content caching vs. DNS+Connection

Figure 9: Content caching reduces the median page load time by 75–400 ms over connection caching alone. For sites with more cacheable content, the benefit is greater (Home Proxy vs. Home Connection Caching Measurements)
Content caching in home vs ISP

Figure 10: Running a proxy in the home improves median page load times by 150–600 ms versus running a proxy in the ISP. (Home Proxy vs. ISP Proxy Measurement)
Relative improvement of page load time
Popularity based prefetching

Cache size: 20 domains
Timeout threshold: 2 minutes
Improved DNS hit ratios: 19-93%
Improved connection hit ratios: 6-21%
Browser using popularity based prefetching

Figure 12: Average relative improvement in page load times for various optimizations, as observed from the browser. Error bars denote standard deviation.
Conclusion and discussion

Confirms and quantifies

- Last-mile latency problem
- Benefits of caching at the home

Anything novel or surprising?

- Persistent connections and DNS caching at the router happens

Reason to cache at the router instead of browser?
Server load from maintaining longer persistent connections?