Why are Web Browsers Slow on Smartphones?

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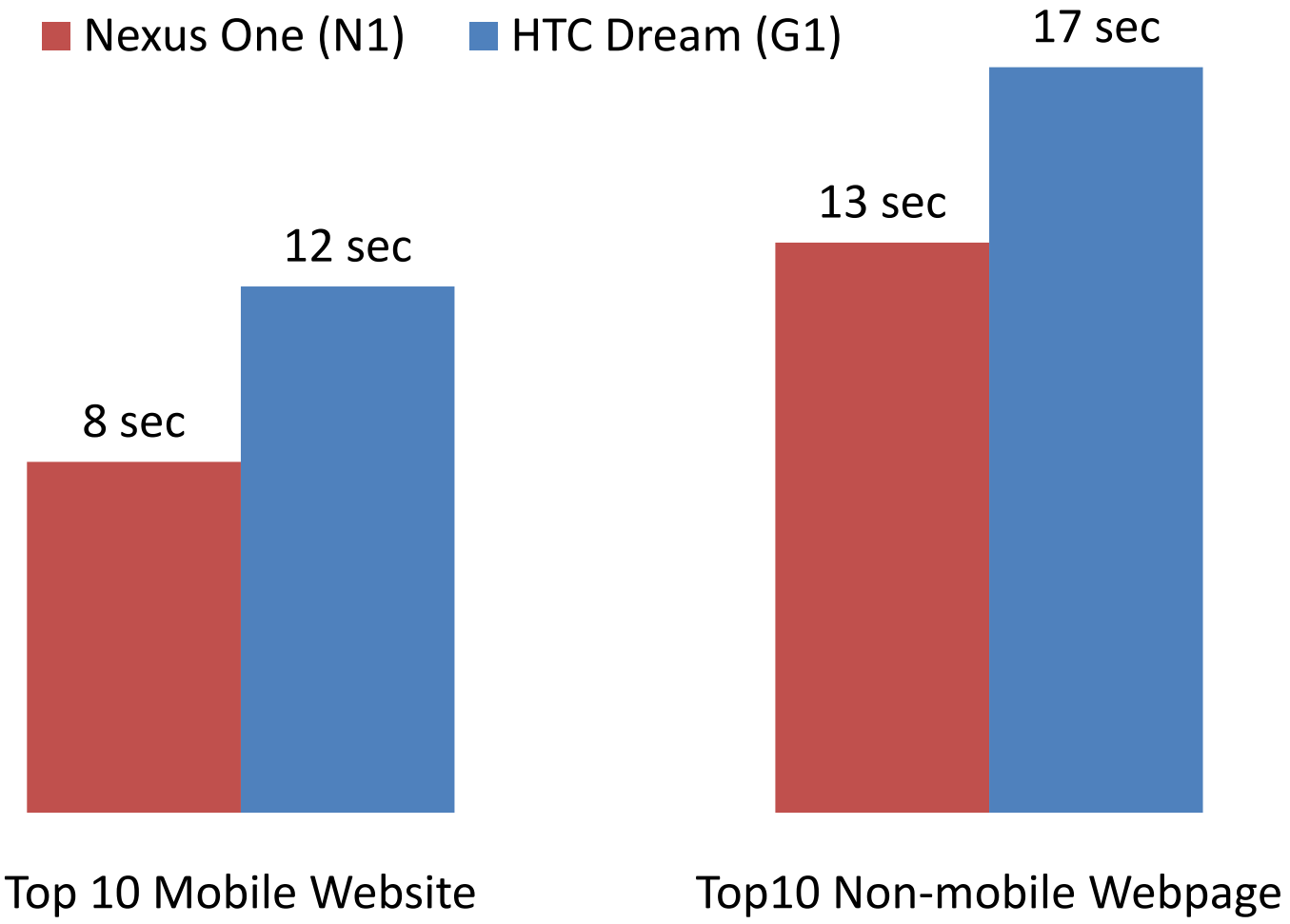
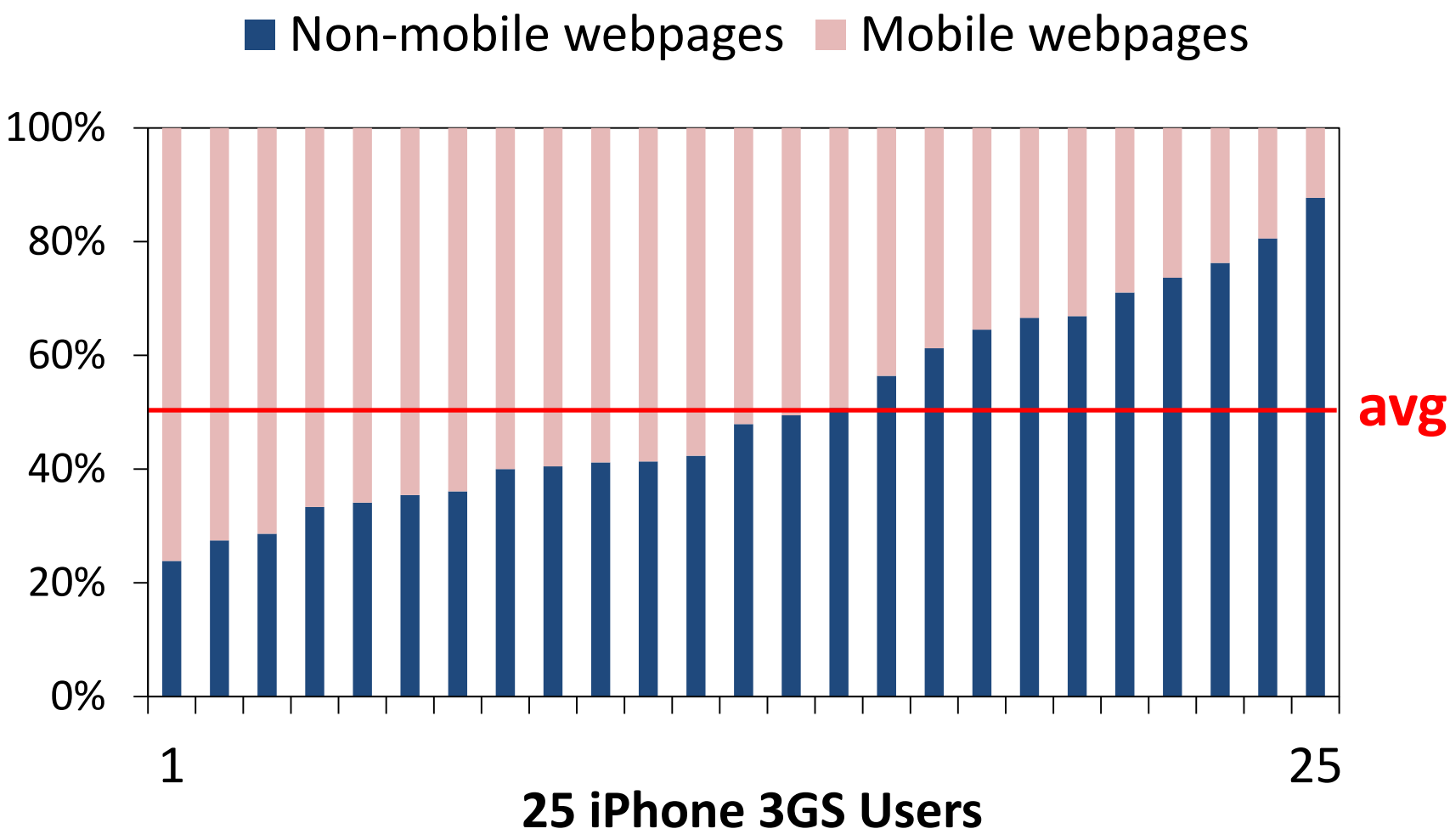
WINDOW TO THE CLOUD

Mobile browsers are slow

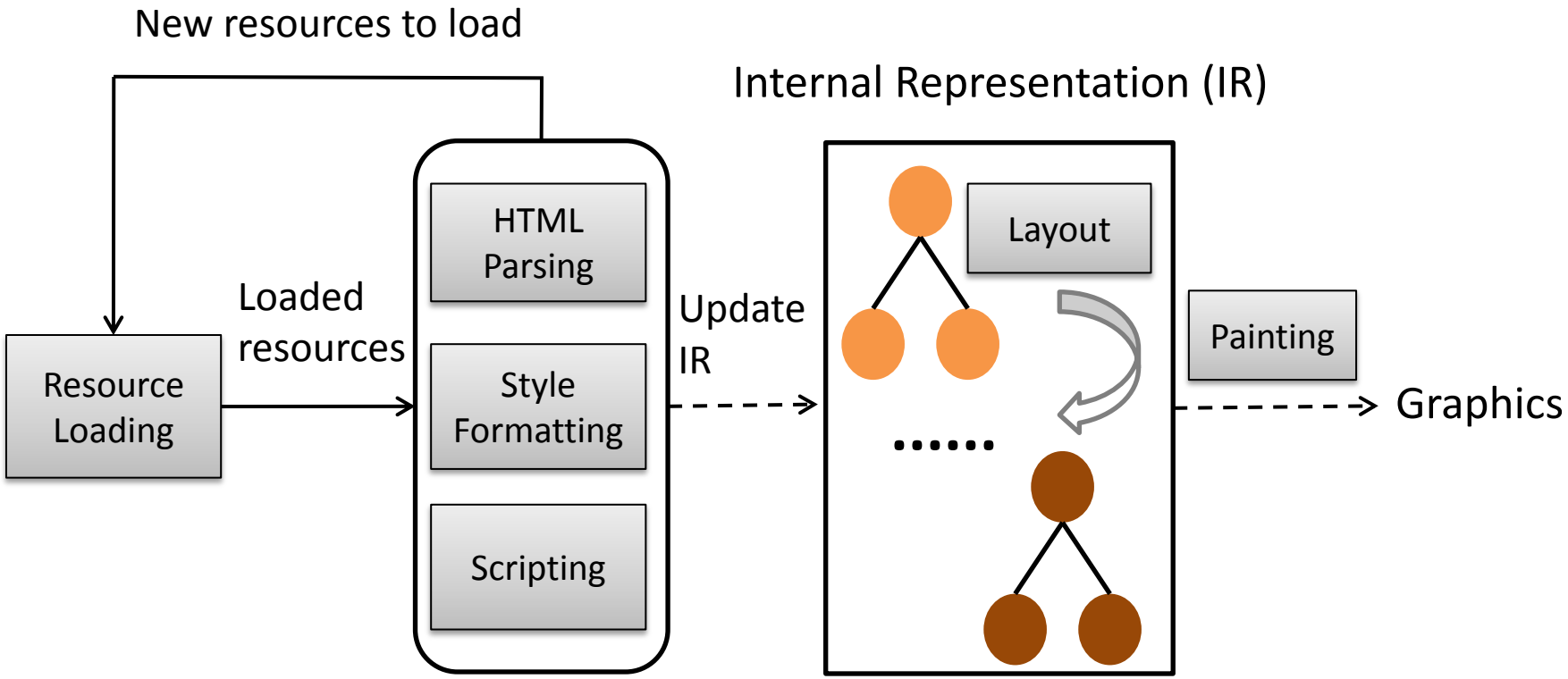


- What does the browser show?
- How does the browser work?
- Where is the bottleneck?

What does the browser show?



How does the browser work?



IR operations: Parsing, Style, Scripting, Layout, Painting

Where is the bottleneck?

- Existing work on PC browsers
  - Layout
  - Style formatting
  - Scripting

1. C. Stockwell, "IE8 Performance," http://blogs.msdn.com/b/ie/archive/2008/08/26/ie8-performance.aspx, 2008.
2. L. A. Meyerovich and R. Bodik, "Fast and parallel webpage layout," in *Proc. Int. Conf. World Wide Web (WWW) Raleigh, North Carolina, USA: ACM, 2010.*
3. K. Zhang, L. Wang, A. Pan, and B. B. Zhu, "Smart caching for web browsers," in *Proc. Int. Conf. World Wide Web (WWW) Raleigh, North Carolina, USA: ACM, 2010.*

Is it true for mobile browsers?

Layout, Style, Scripting

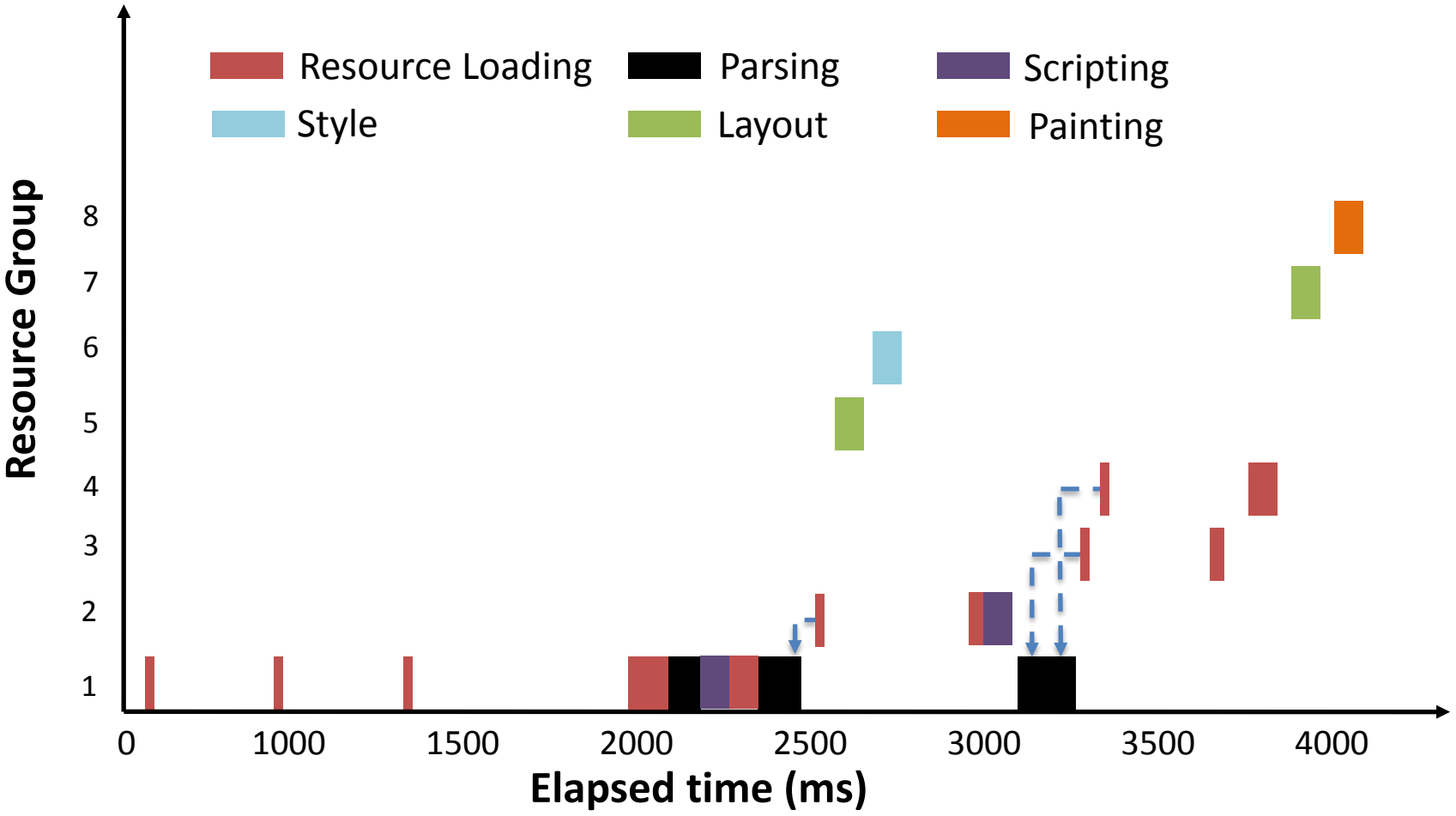
Performance characterization

- Metric: *browser delay*
  - *Starting point*: when the user presses the “GO” button of the browser to open an URL.
  - *End point*: when the browser’s page loading progress bar indicates 100%.

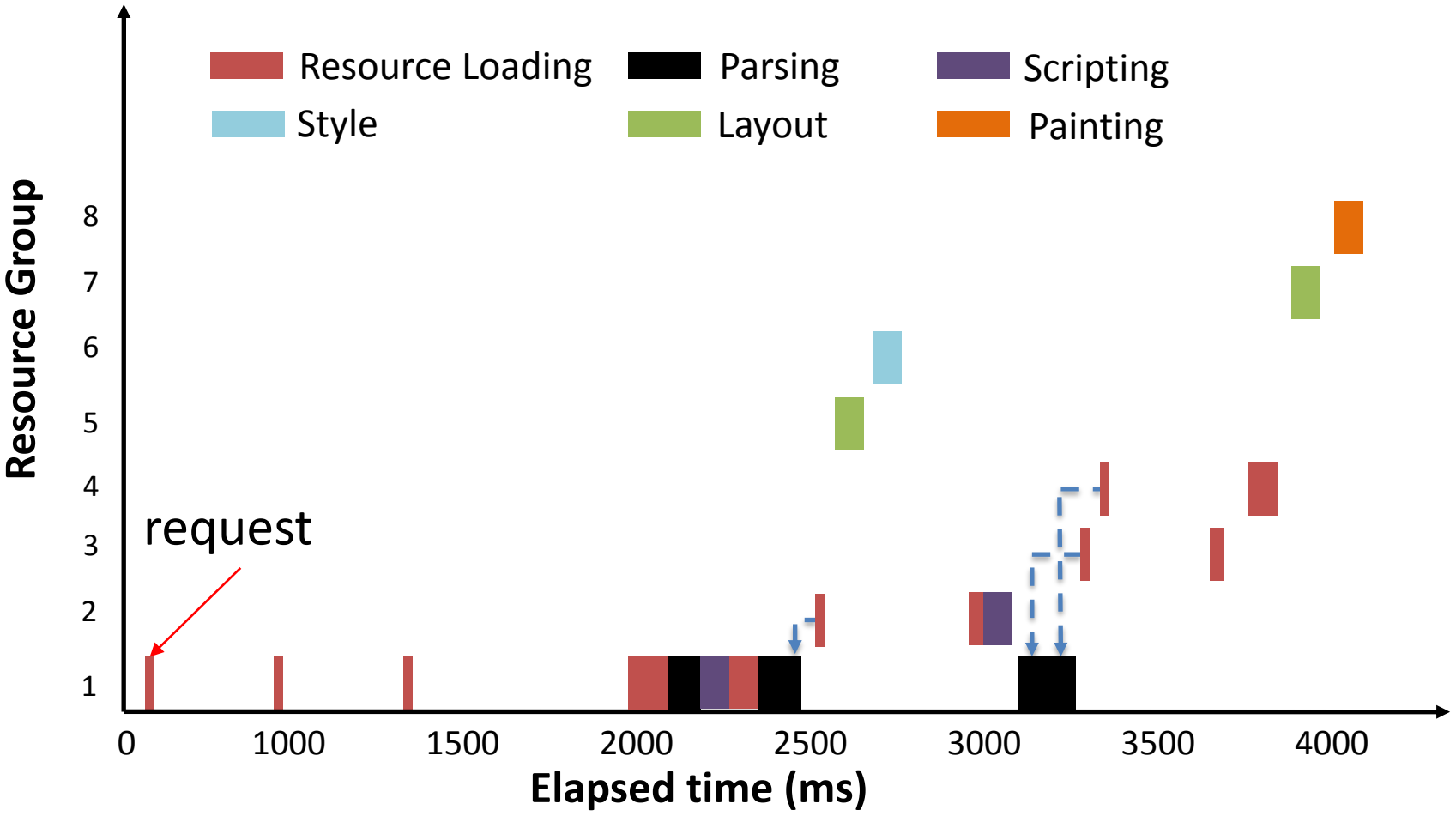
Performance characterization

- Dependency timeline characterization
- What-if analysis

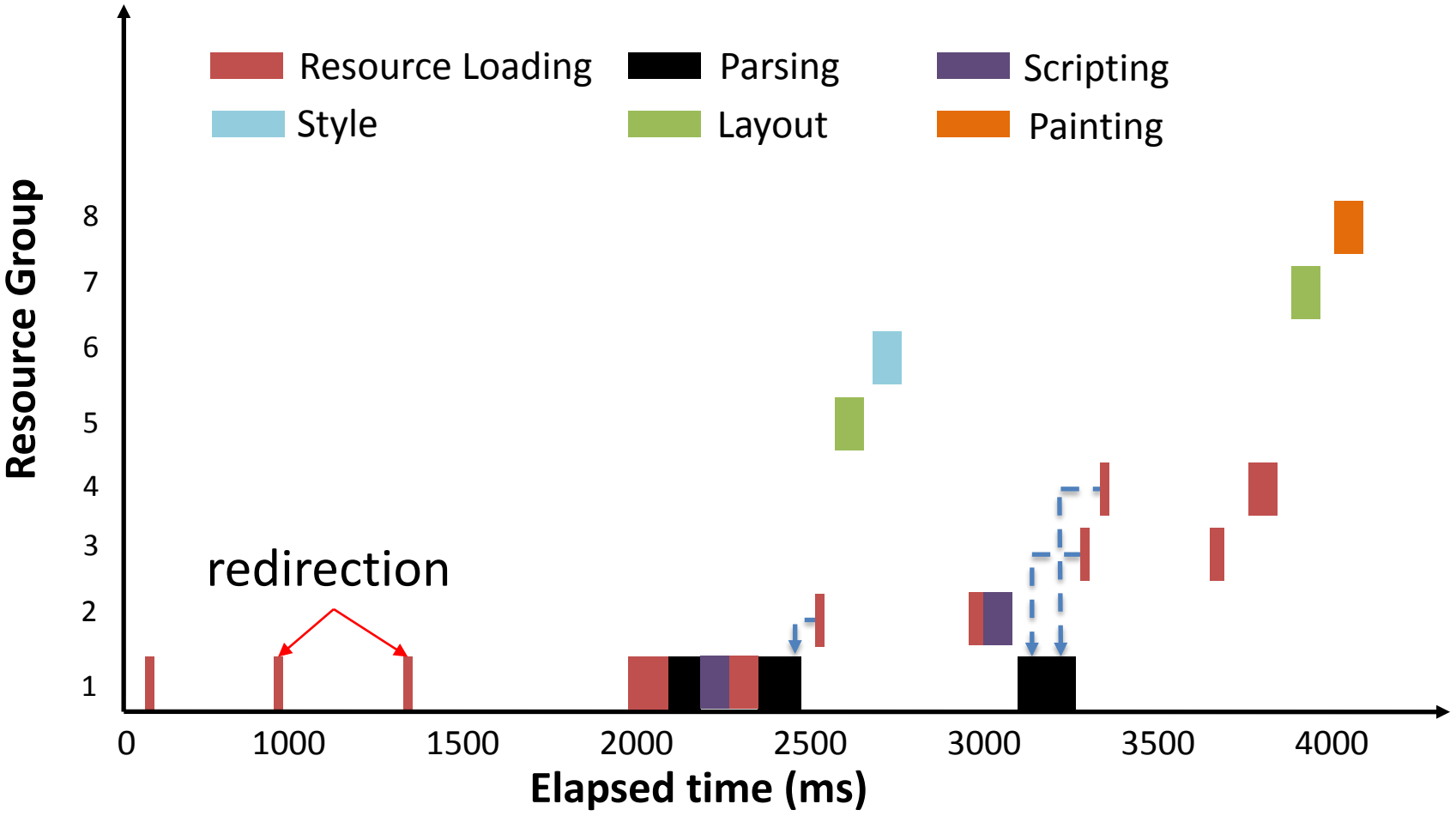
Dependency timeline characterization



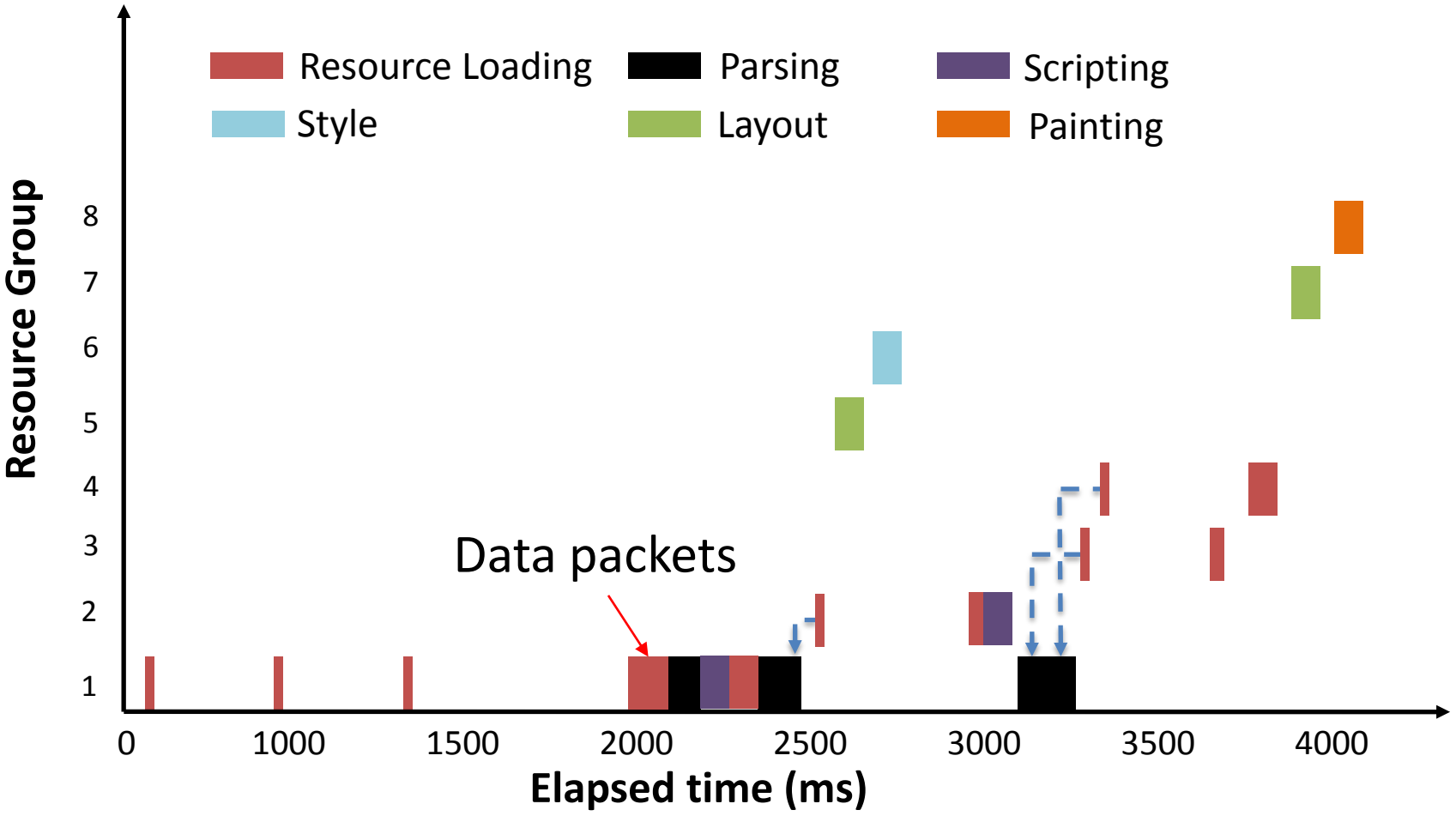
Dependency timeline characterization



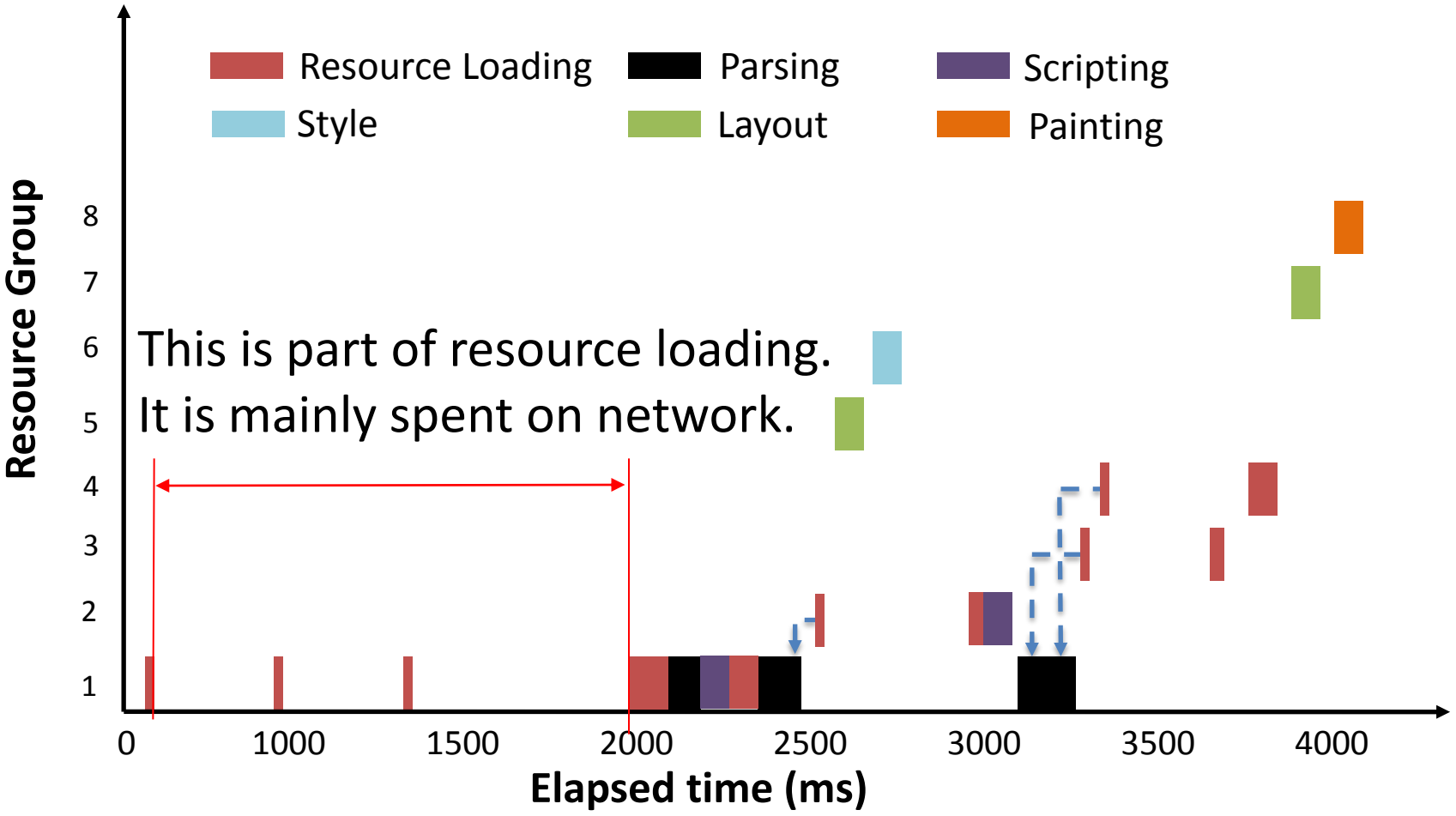
Dependency timeline characterization



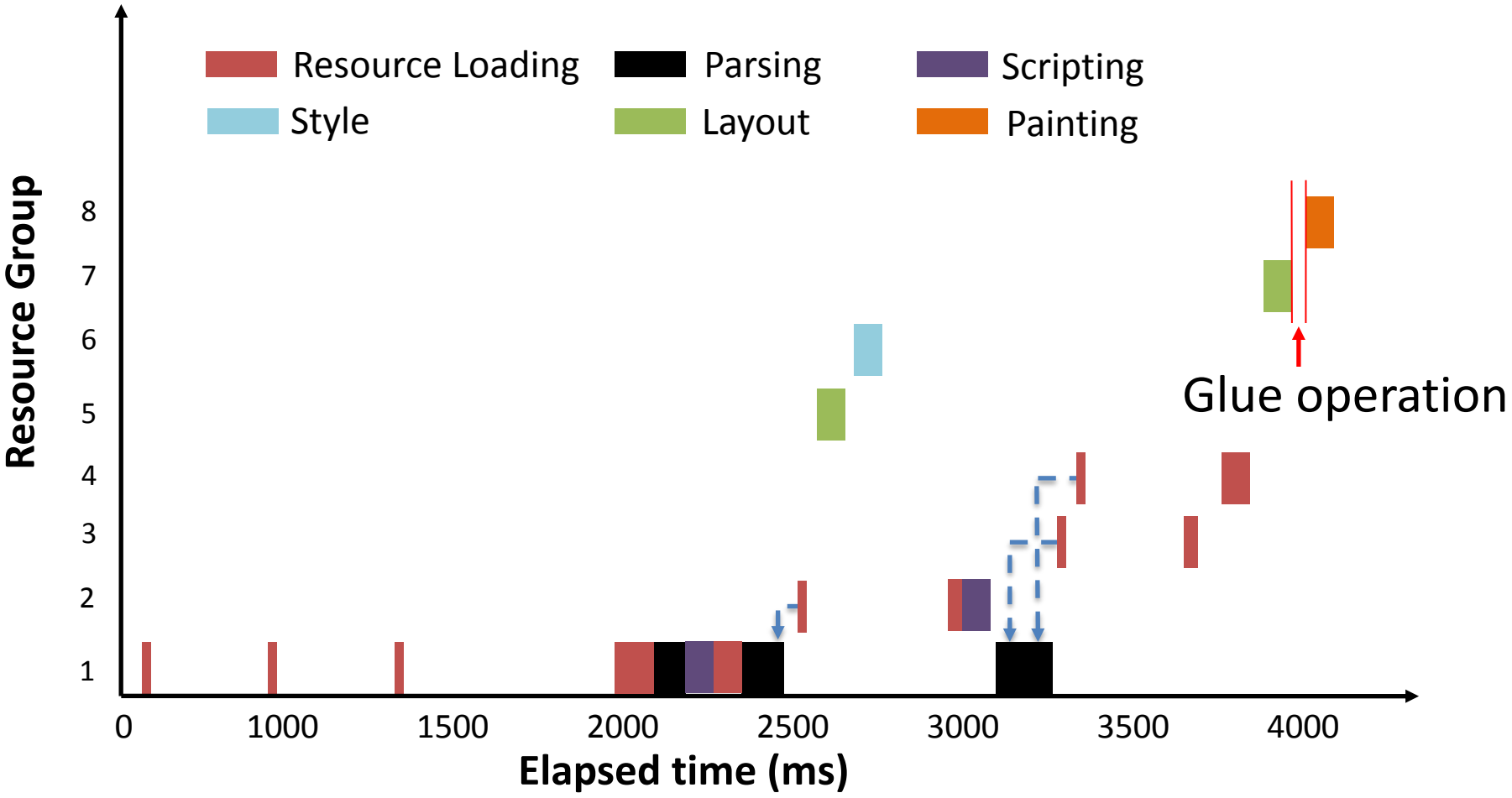
Dependency timeline characterization



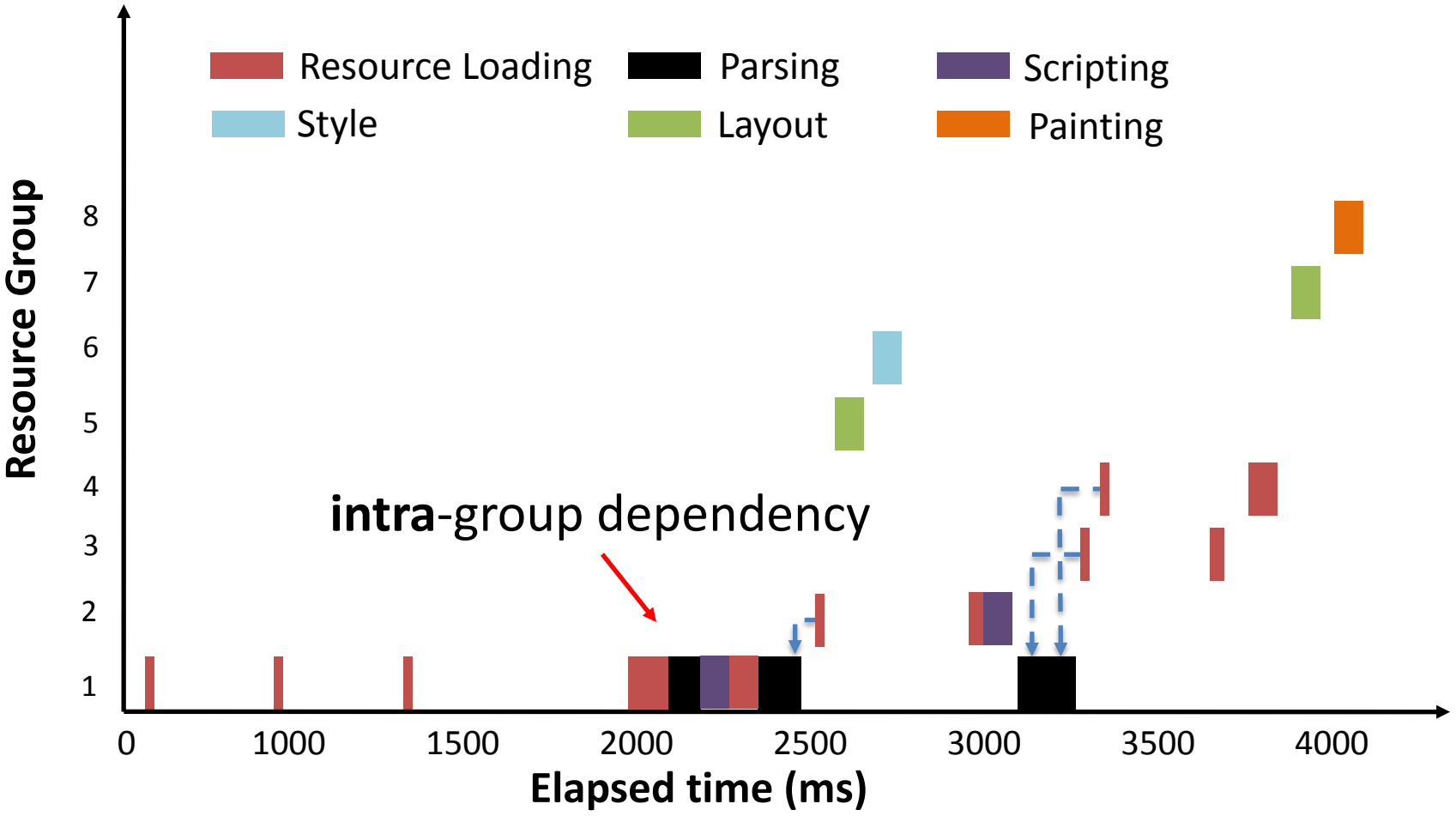
Dependency timeline characterization



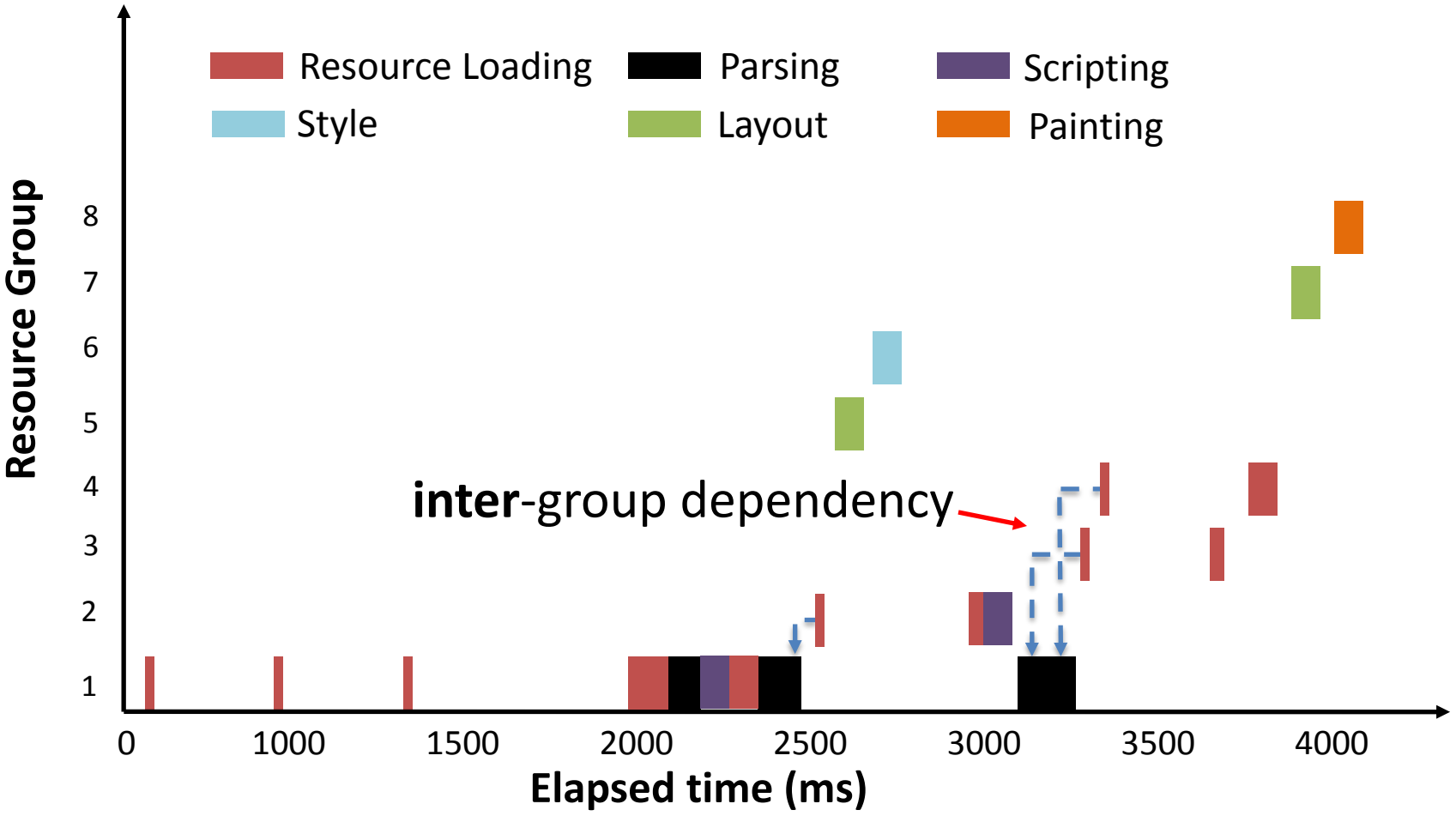
Dependency timeline characterization

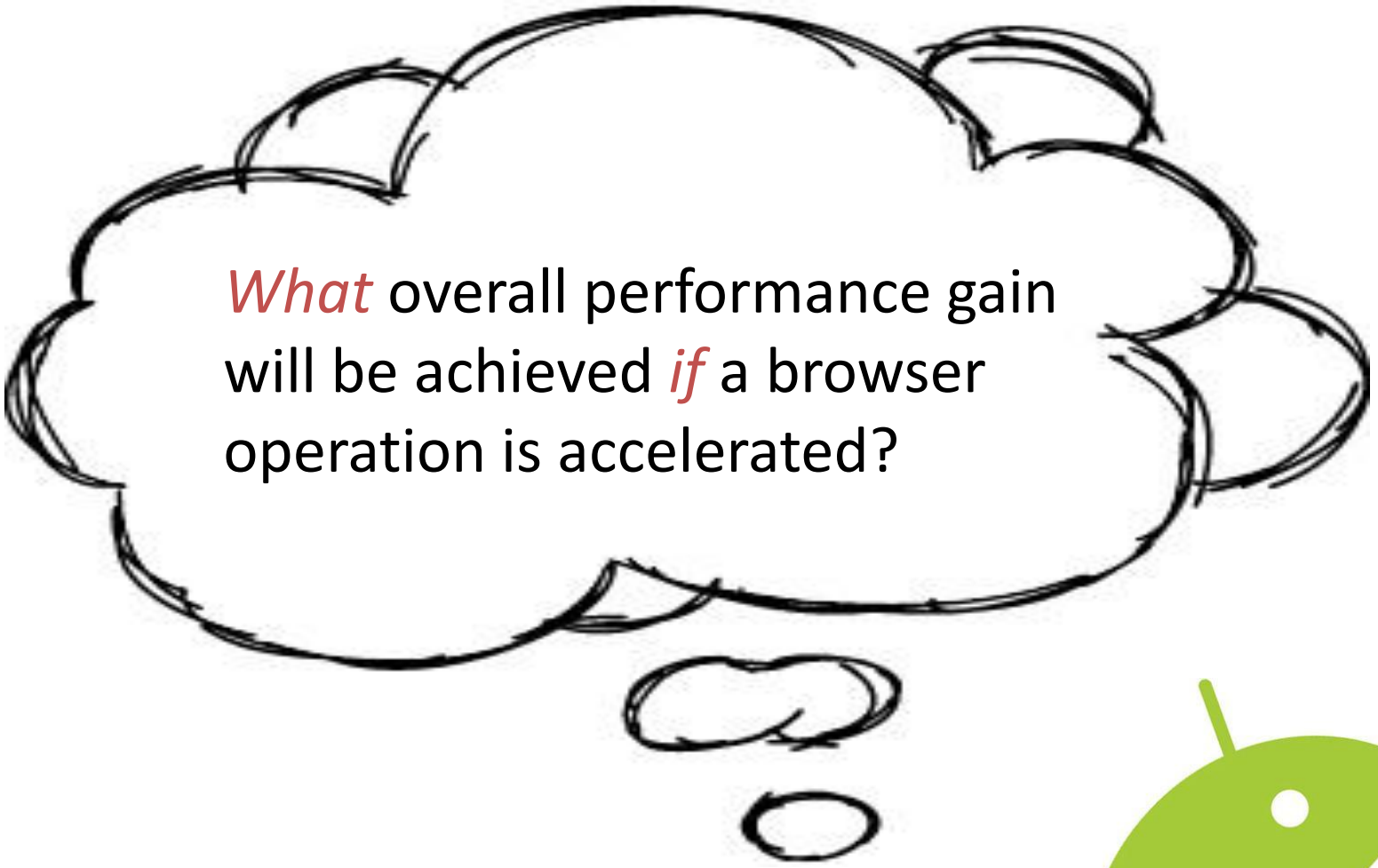


Dependency timeline characterization

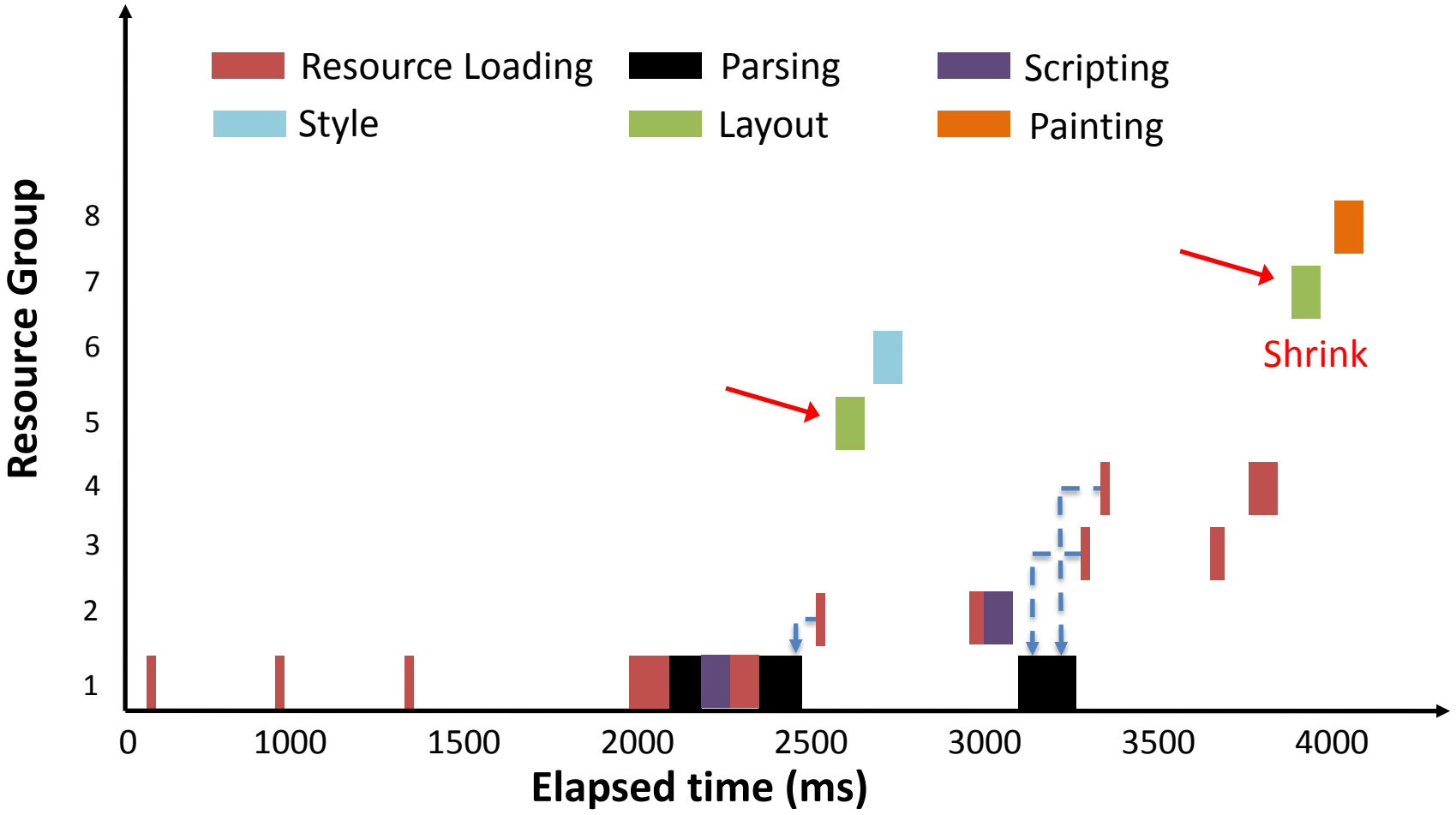


Dependency timeline characterization




What overall performance gain will be achieved *if* a browser operation is accelerated?

What-if analysis



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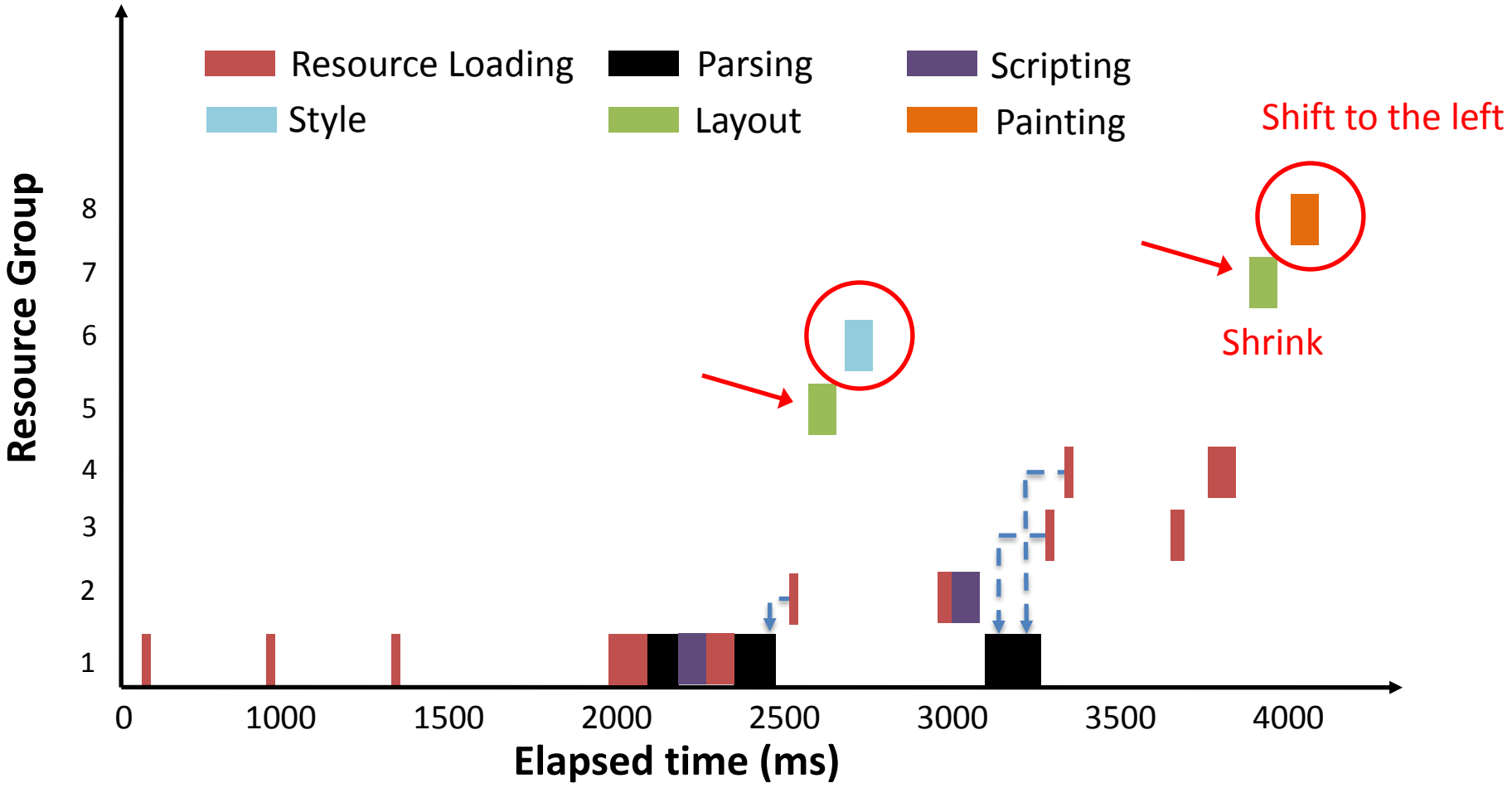

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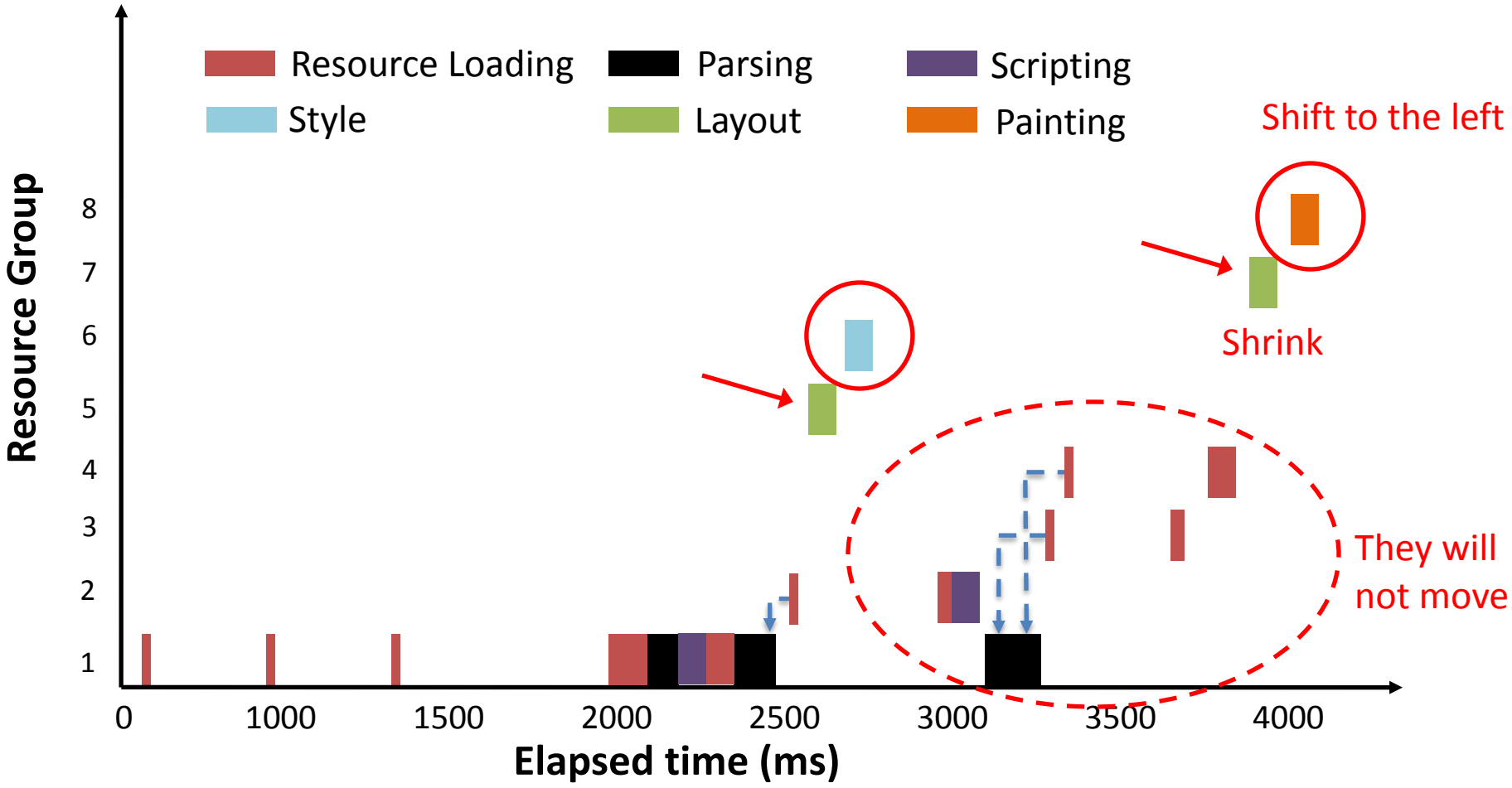

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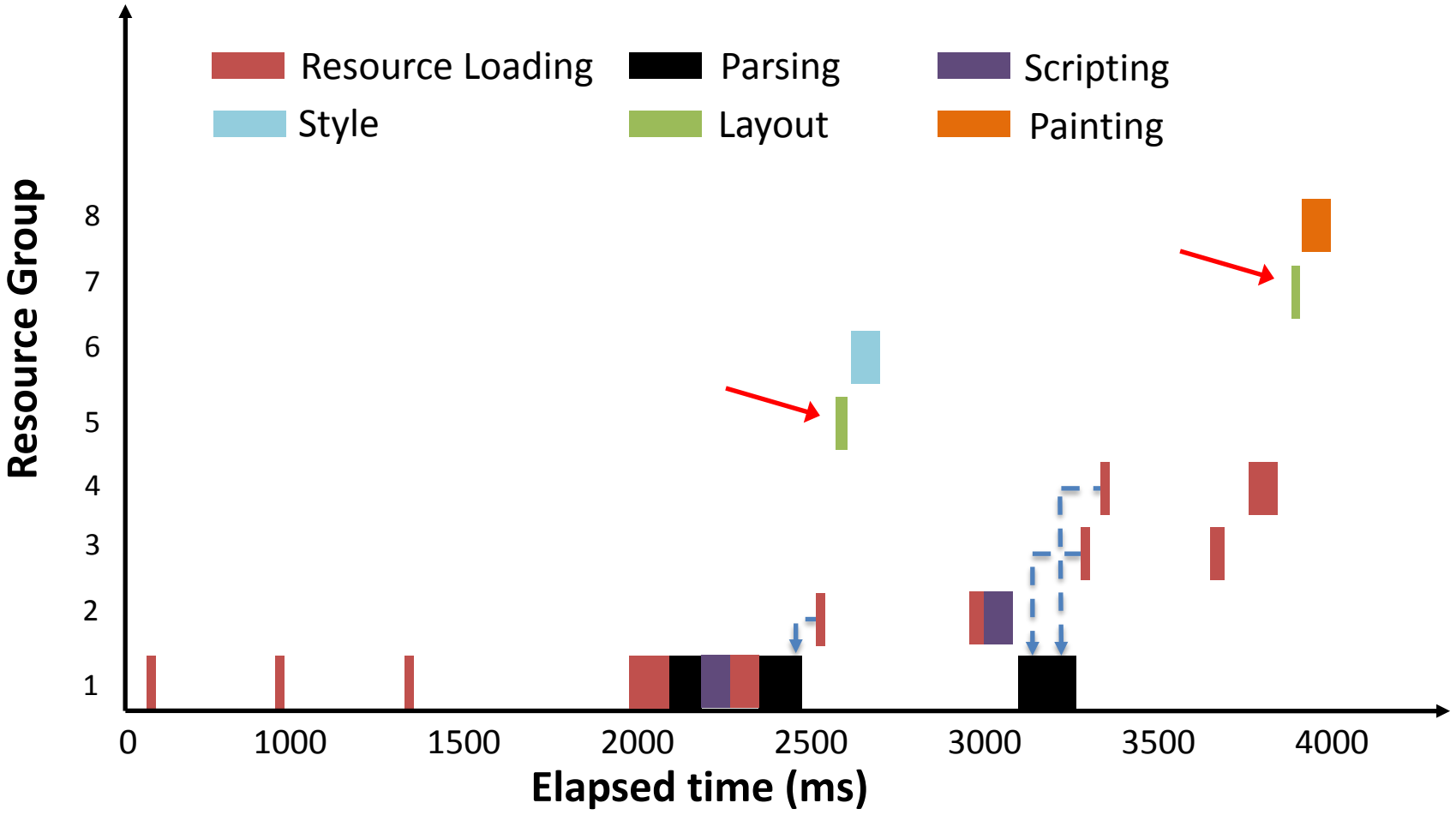

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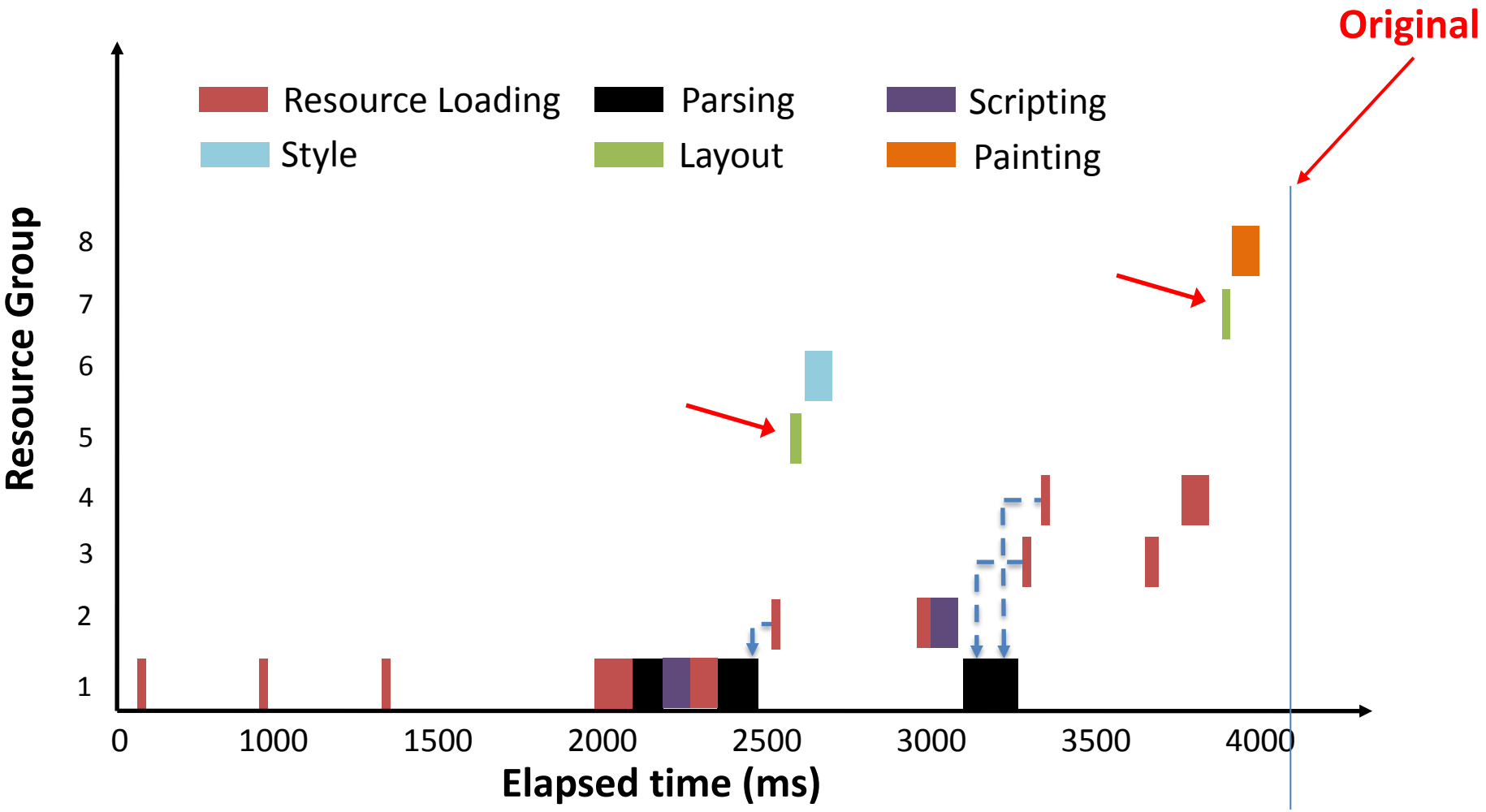

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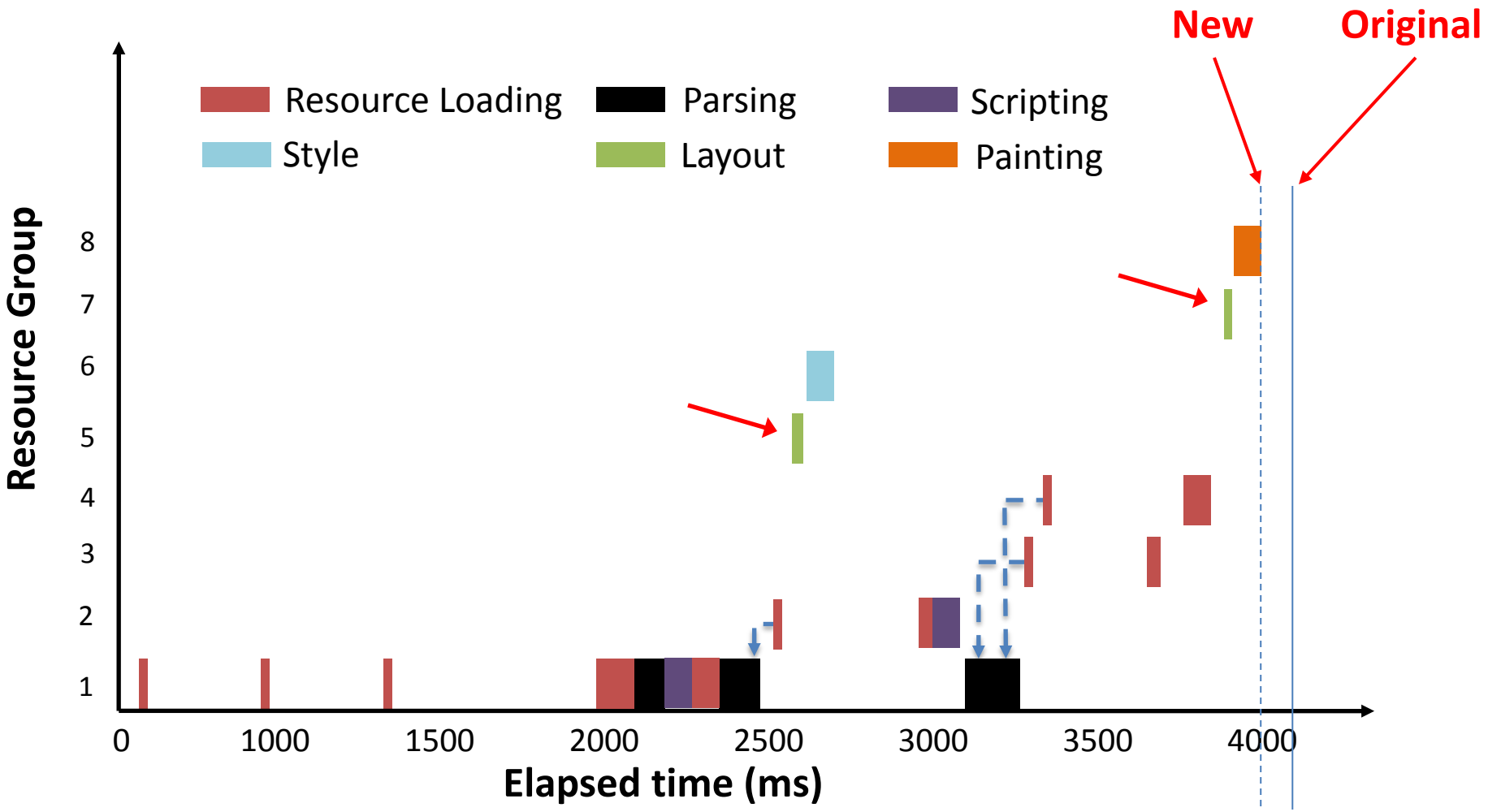


Experimental setup

- Platform:
  - HTC Dream (G1): 528MHz
  - Nexus One (N1): 1GHz
- Operating System
  - Android 2.1 (Eclair)

- Benchmark Webpages:
  - Top 10 mobile websites
  - Top 10 visited non-mobile webpages from LiveLab

1.Nielsen.com, "Top mobiel phones, sites and brands for 2009," http://blog.nielsen.com/nielsenwire/online_mobile/top-mobile-phones-sites-and-brands-for-2009/, 2009.
2.C. Shepard, A. Rahmati, C. Tossell, L. Zhong, and P. Kortum, "Live- Lab: Measuring Wireless Networks and Smartphone Users in the Field," in *Proc. Workshop on Hot Topics in Measurement & Model-ing of Computer Systems, June 2010.*

Experimental setup

- We used three network conditions:
  - Emulated enterprise Ethernet (no traffic control)
  - Typical 3G network (T-mobile)
  - Emulated adverse network
    - First-hop RTT: 400ms
    - Bandwidth (downlink/uplink): 500Kbps/100Kbps

Logging information

- Time stamp for browser operations
  - Overhead: <1%
- Tcpdump
  - Overhead: <2% (CPU); <0.4% (MEM)

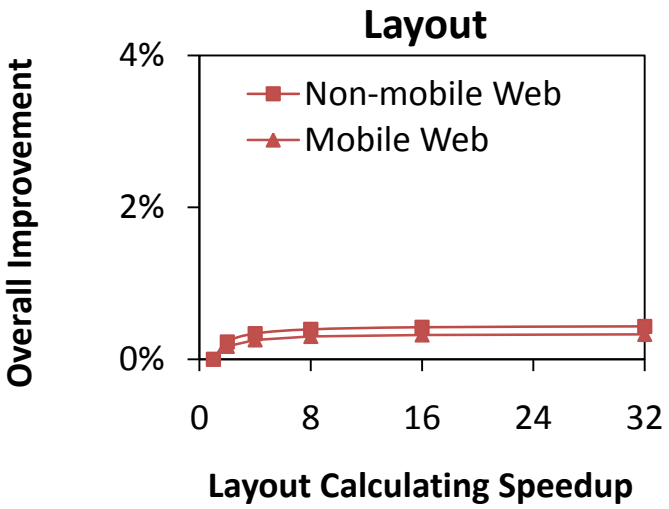
Results

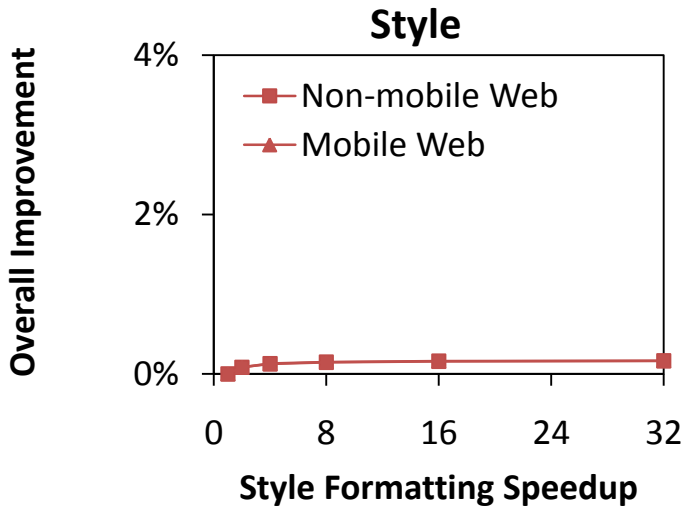
two take-away messages

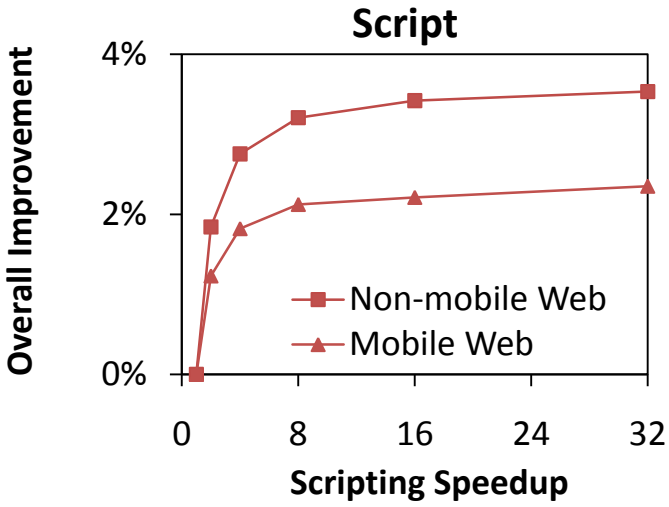
IR operations do not matter much!

Parsing, Style, Scripting, Layout, Painting

IR operations do not matter much







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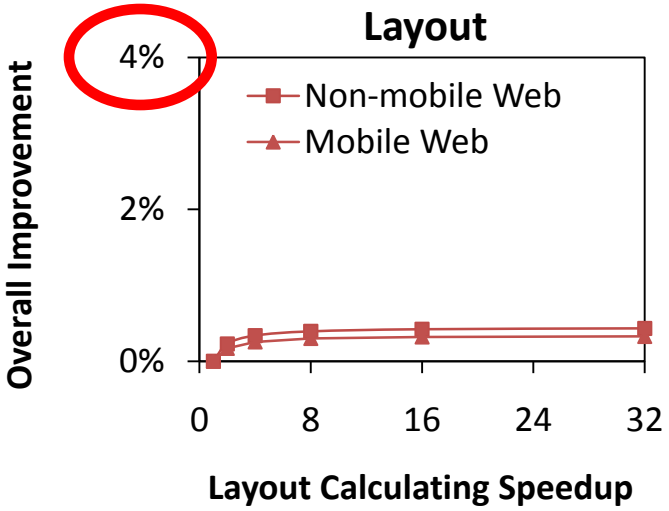

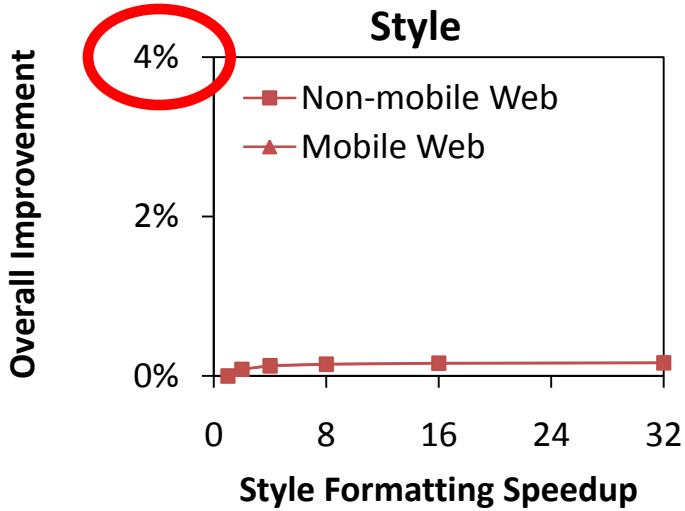

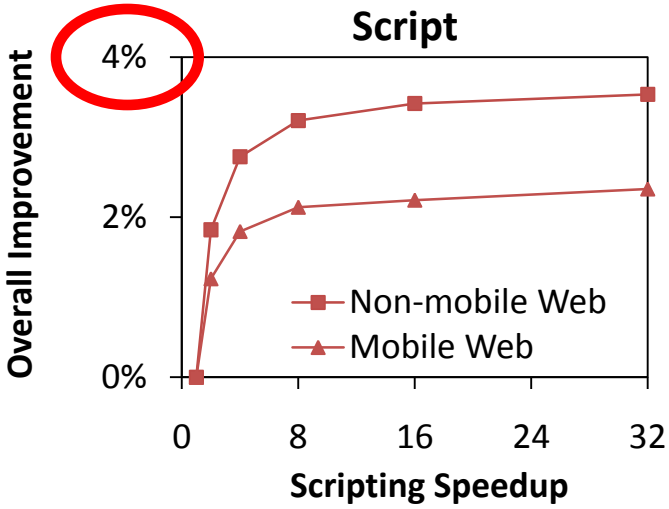

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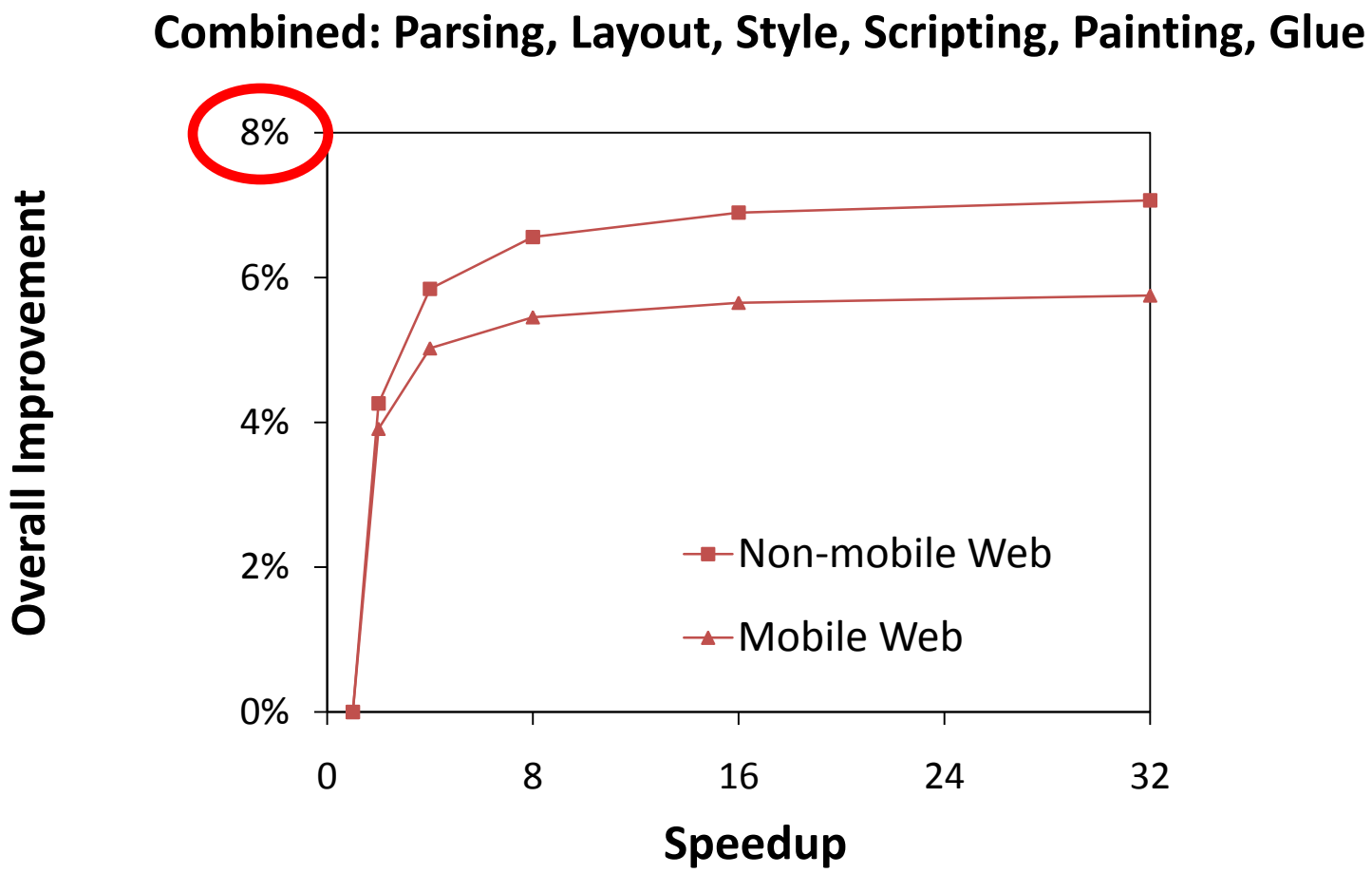

Resource loading is the bottleneck!

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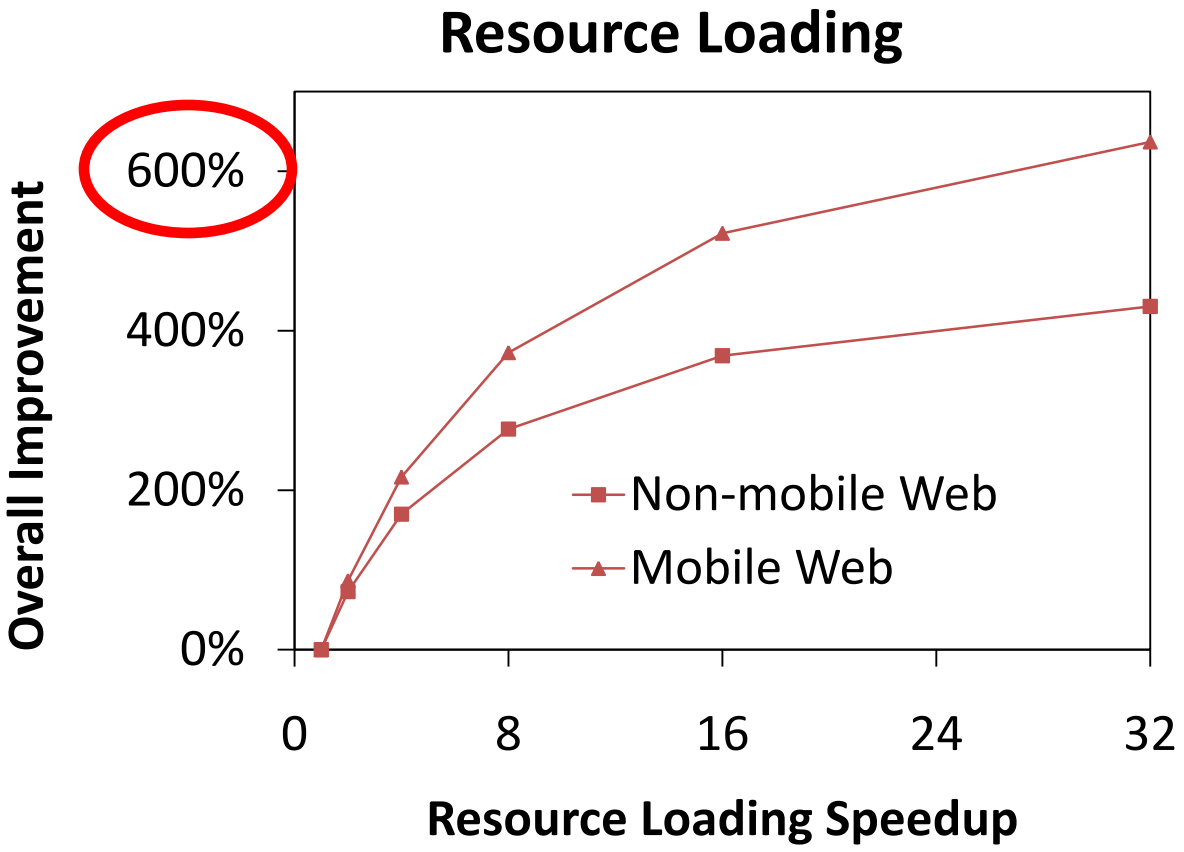

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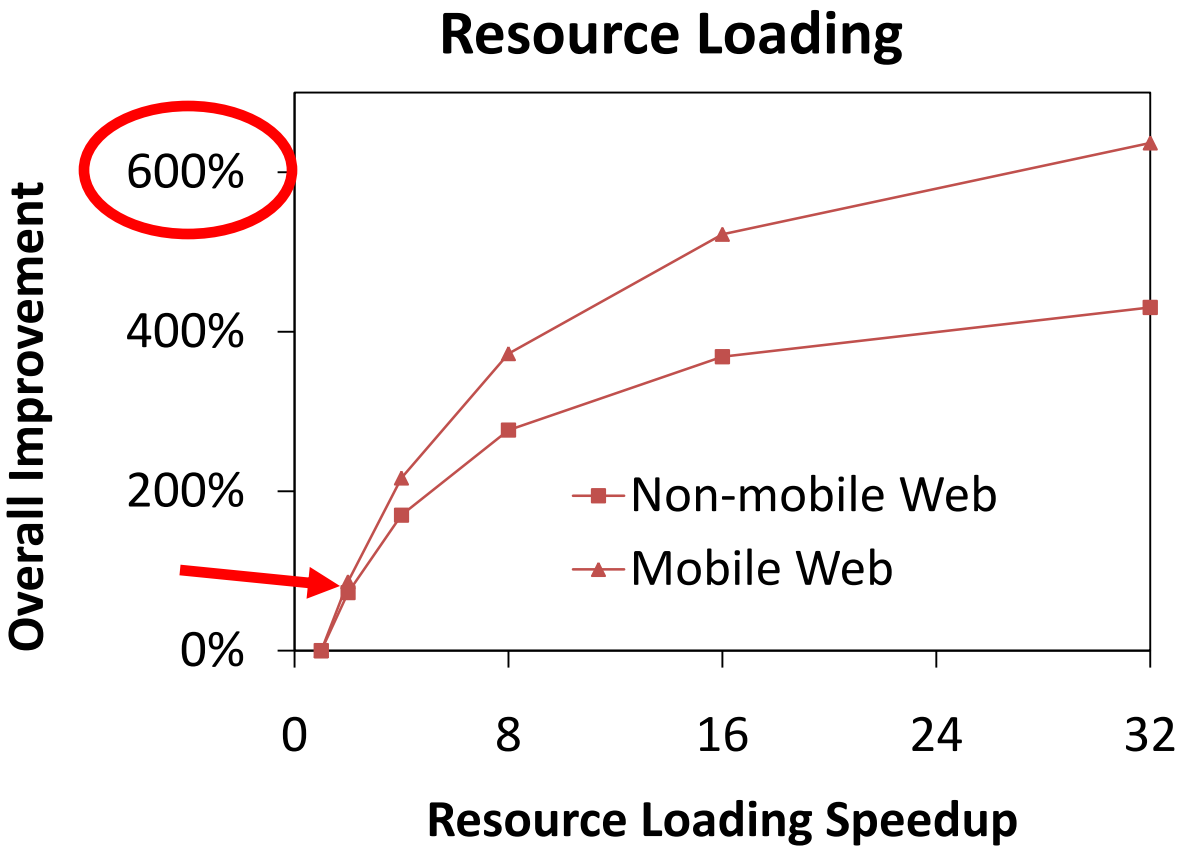
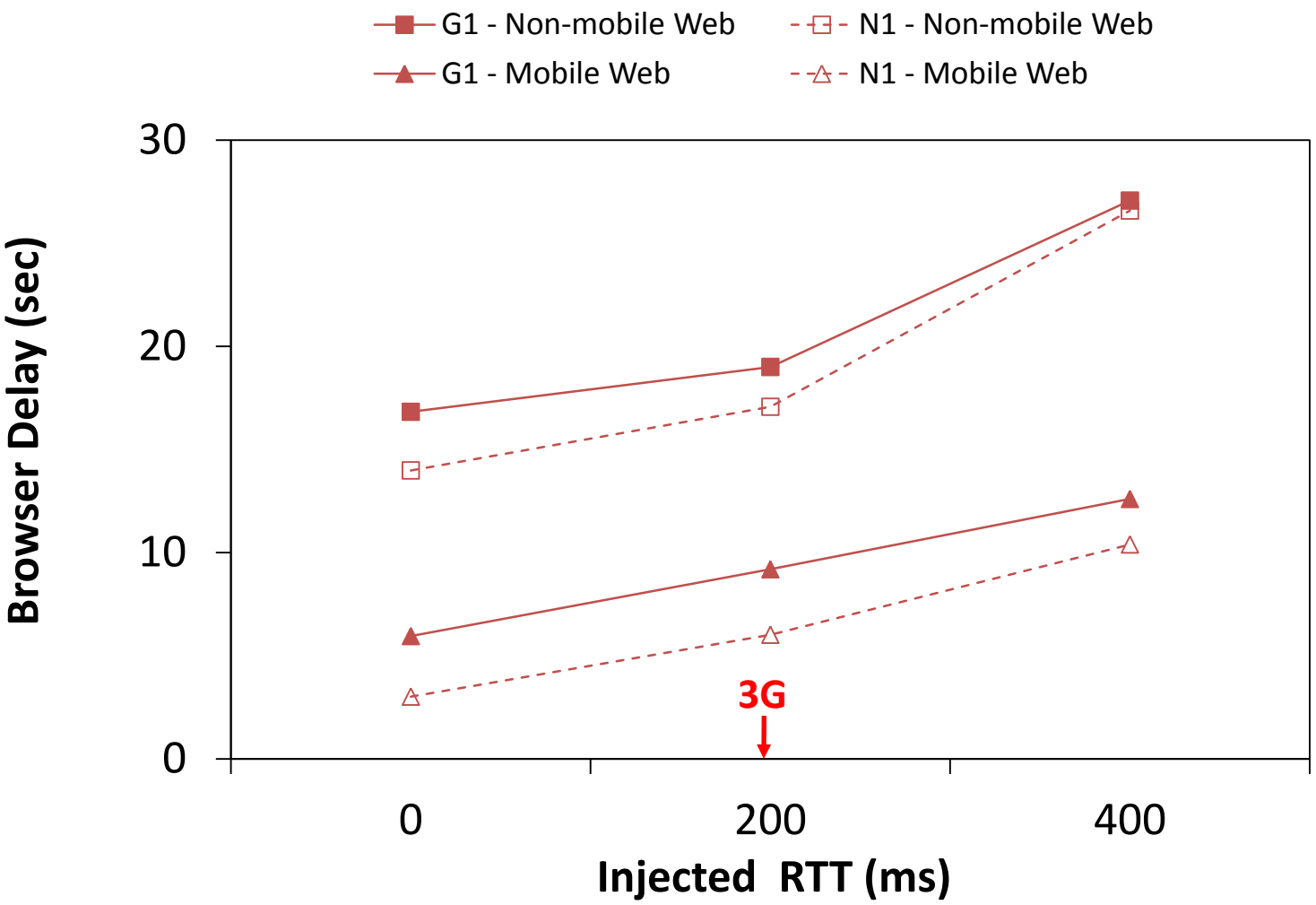


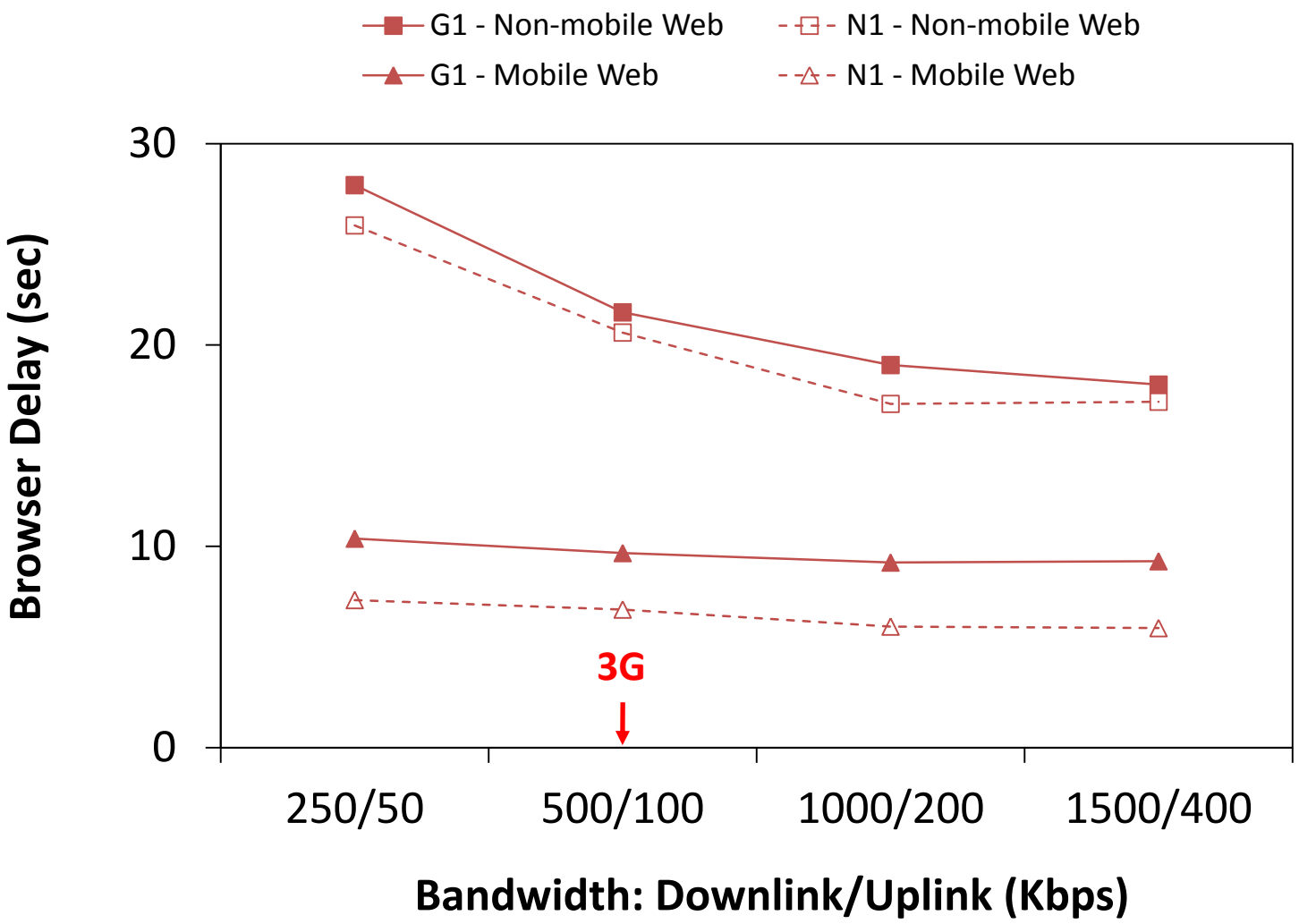
Resource loading is the bottleneck

- Network RTT
- Network Bandwidth
- Browser loading procedure
- Processing power

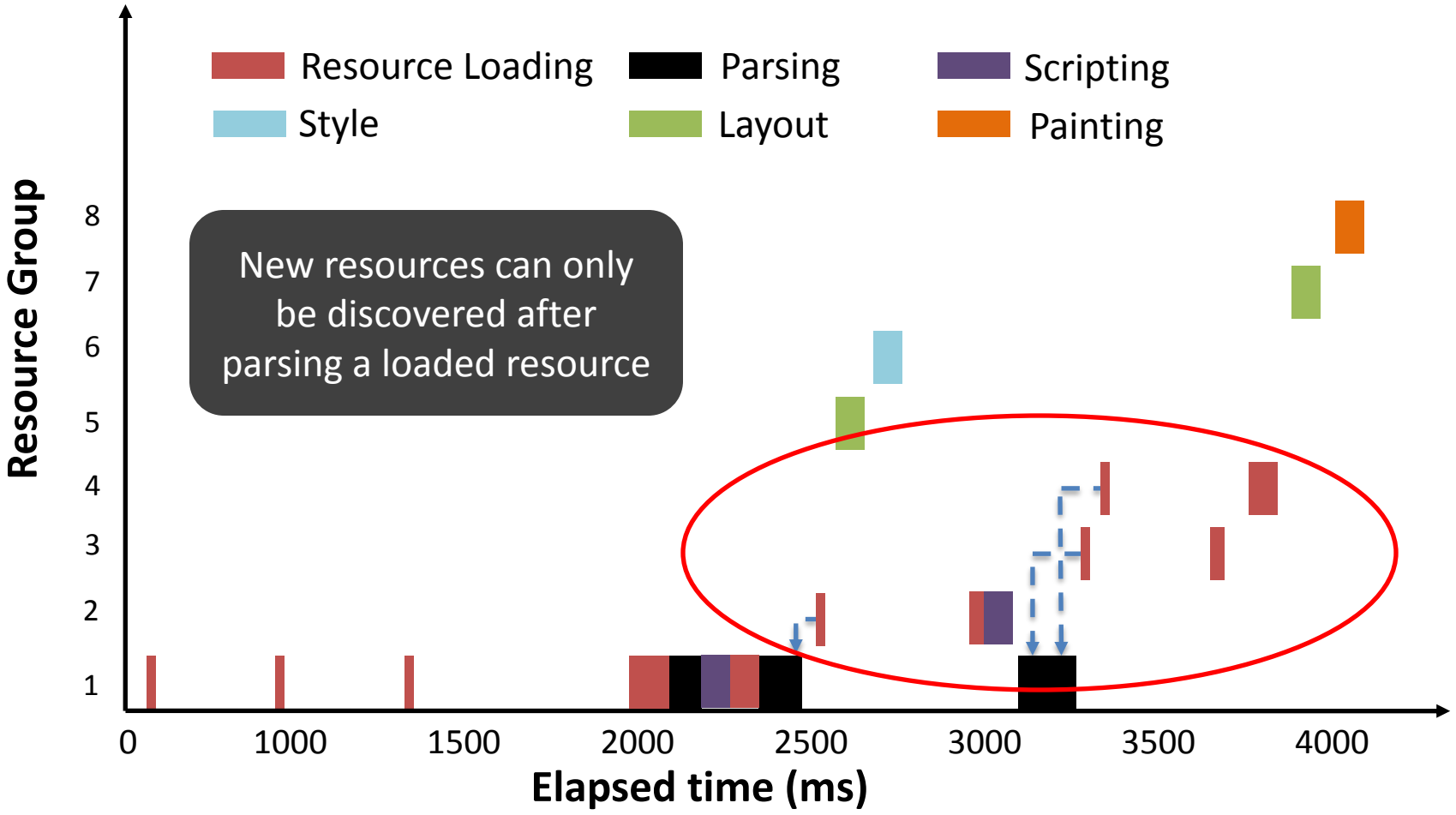
Network RTT matters



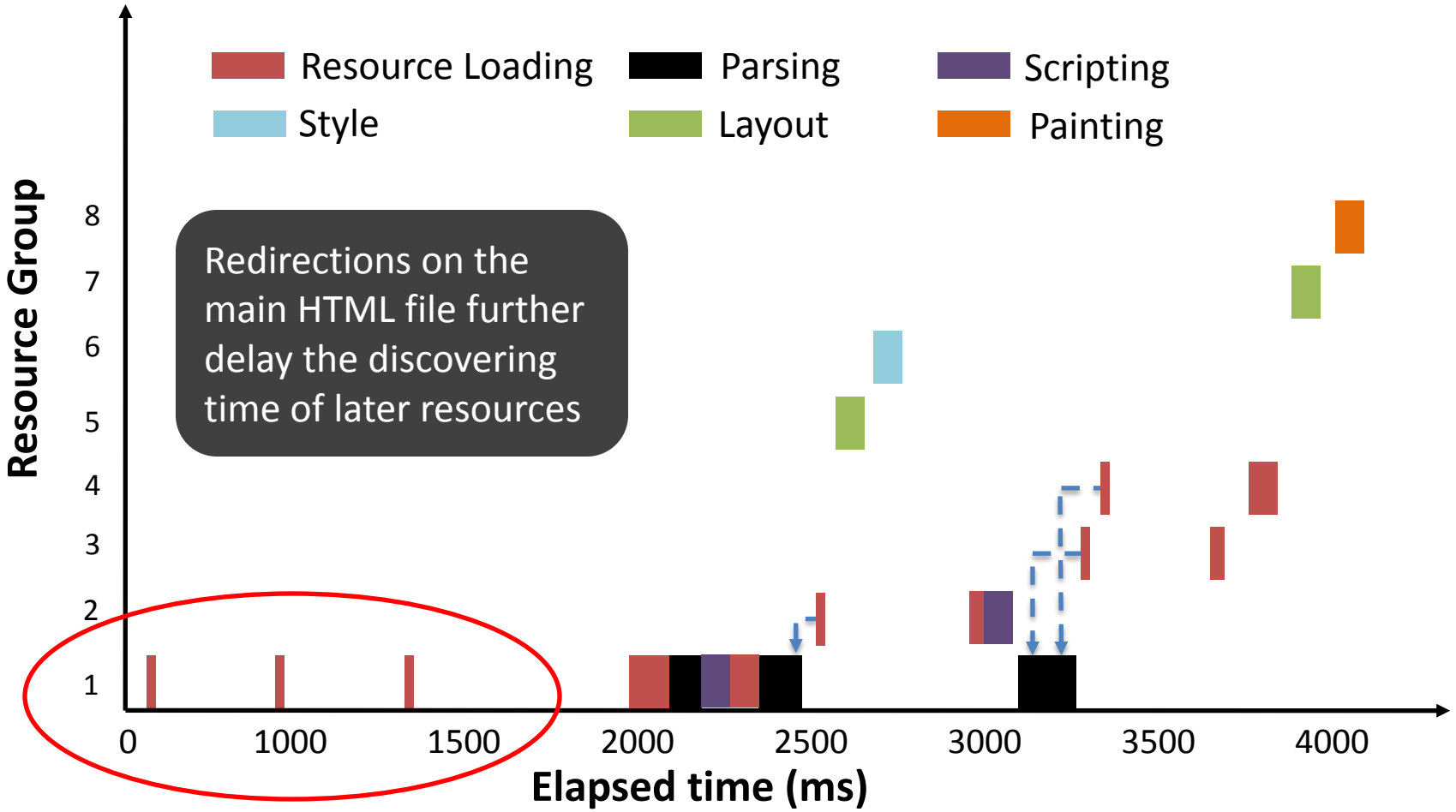
Network bandwidth doesn't matter



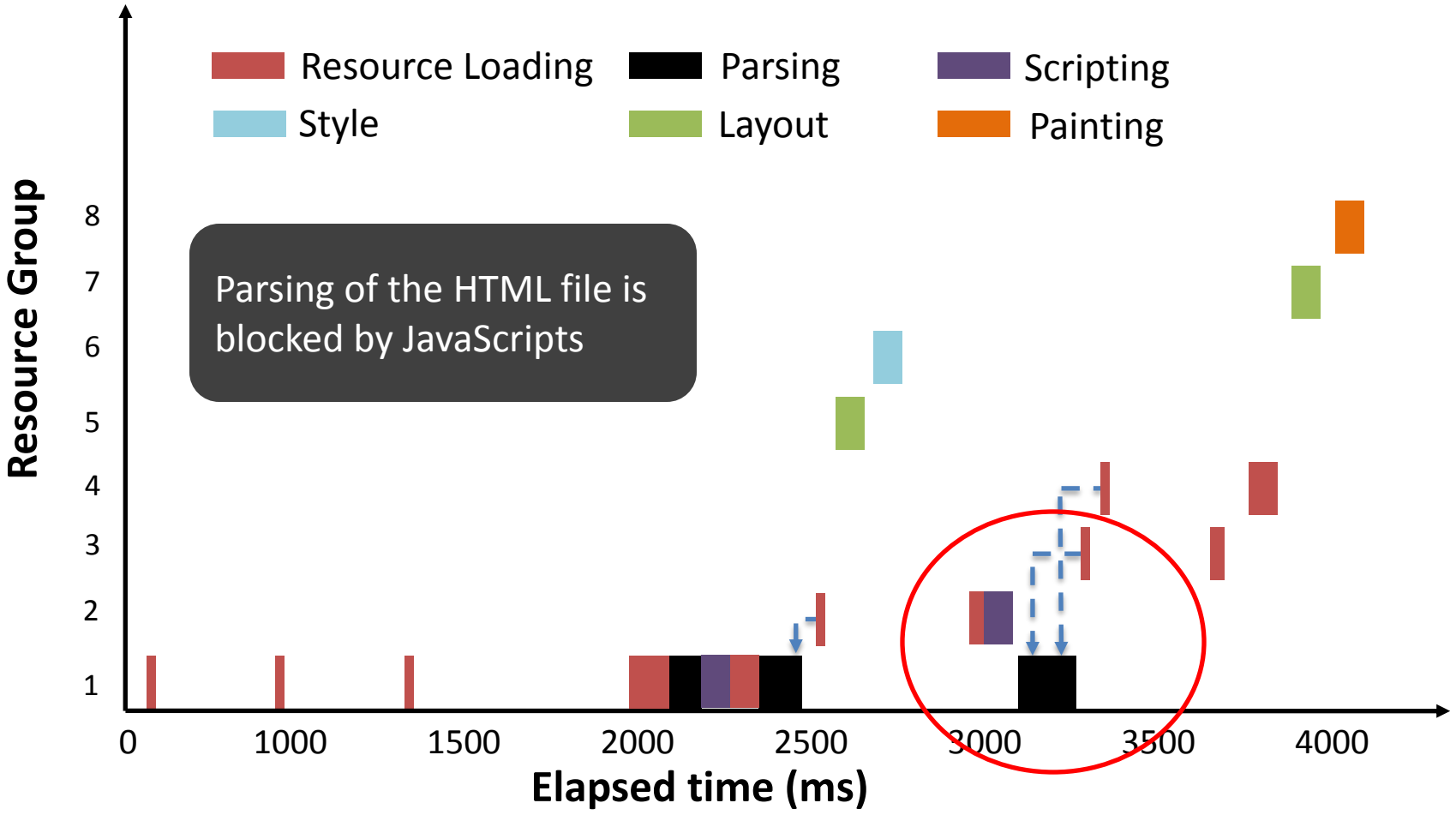
Browser loading procedure



Browser loading procedure



Browser loading procedure



Browser loading procedure

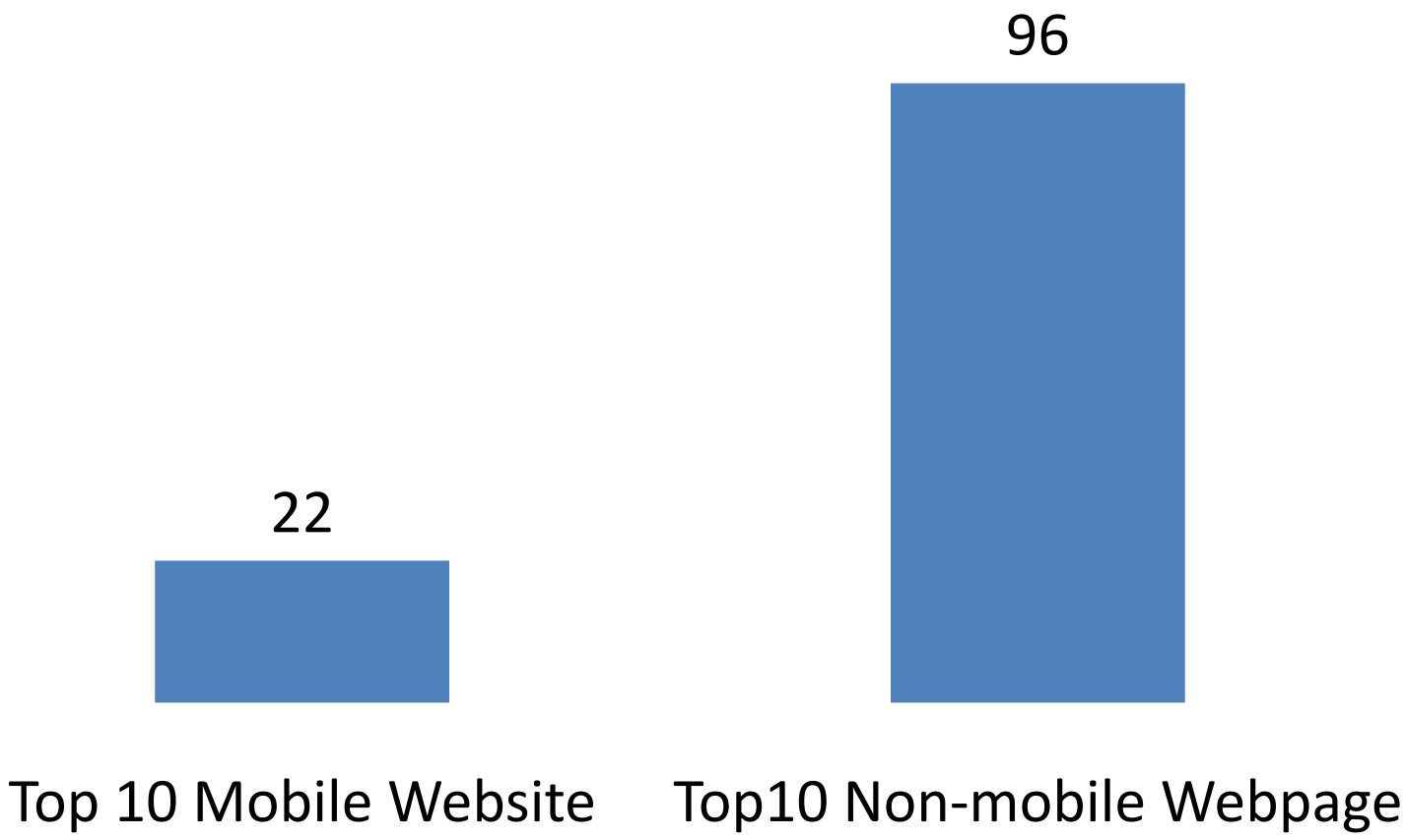
- Up to 25 concurrent requests for top mobile/non-mobile webpages

- Constrains on concurrent TCP connections

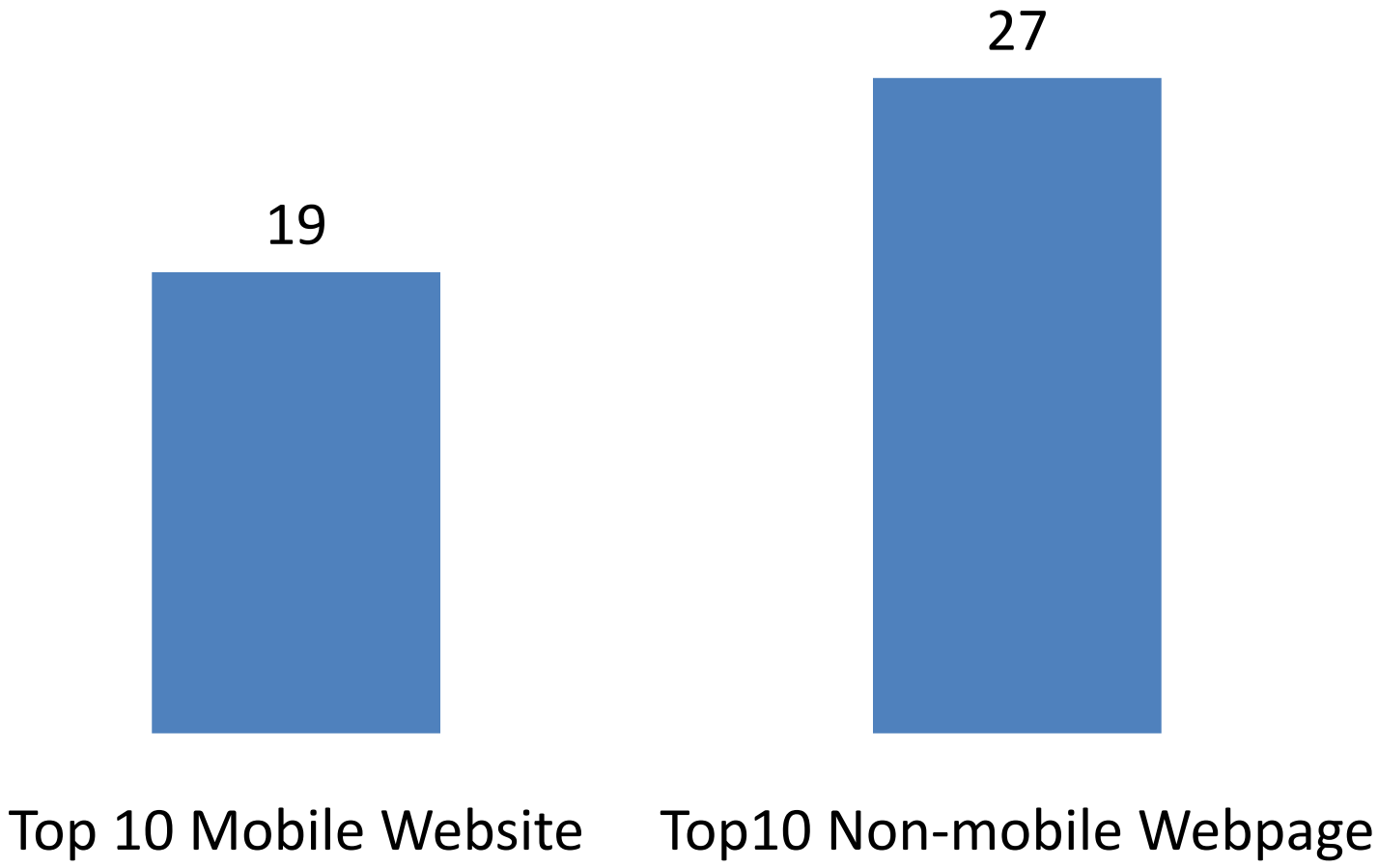
Mobile Browser	Connections/hostname	Maximum connections
Android	4	4
iPhone 4.3	6	35
Blackberry 9700	4	16
Opera Mobile	4	4
Opera Mini	10	60

http://www.browserscope.org/

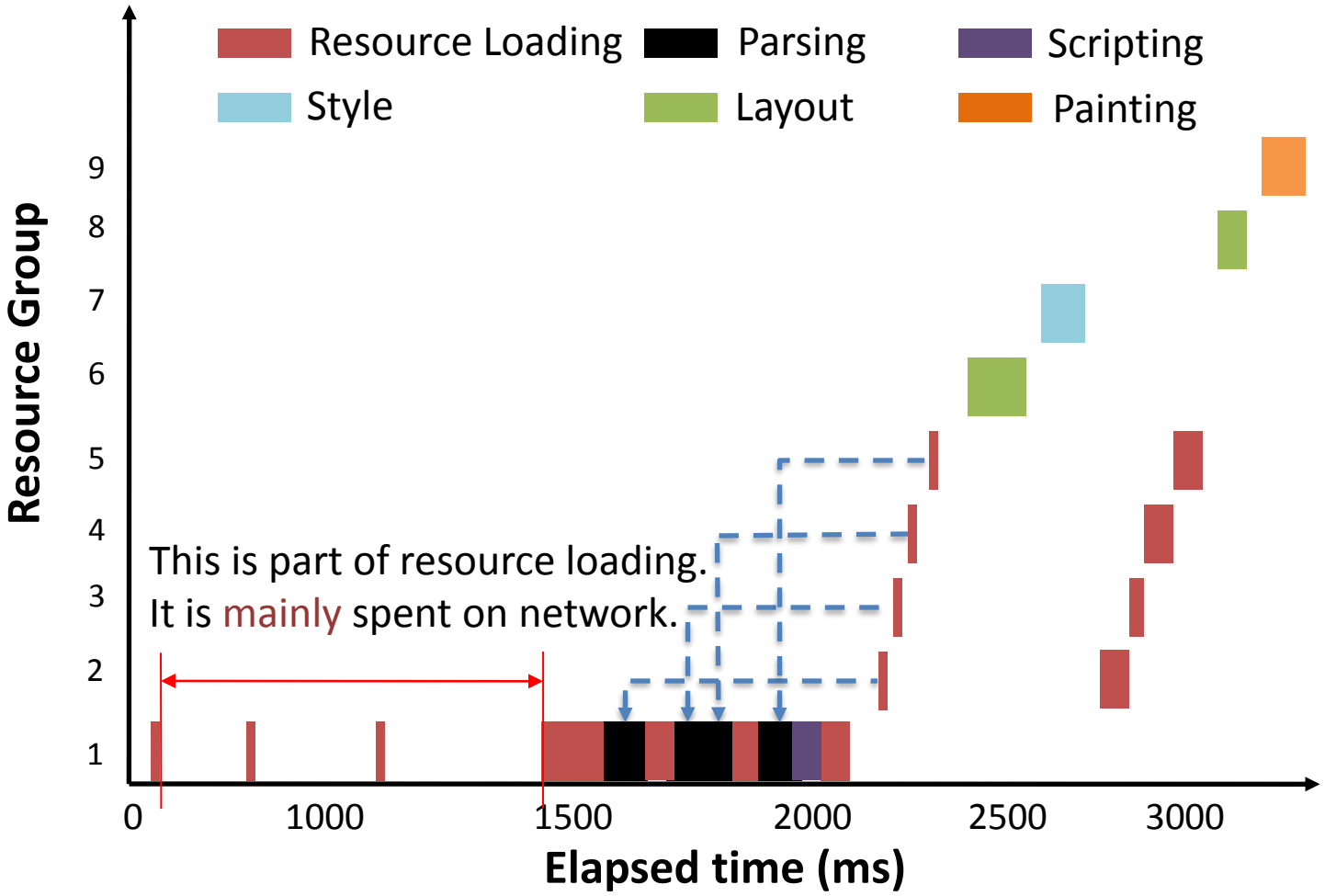
Average number of resources



Average number of network round trips

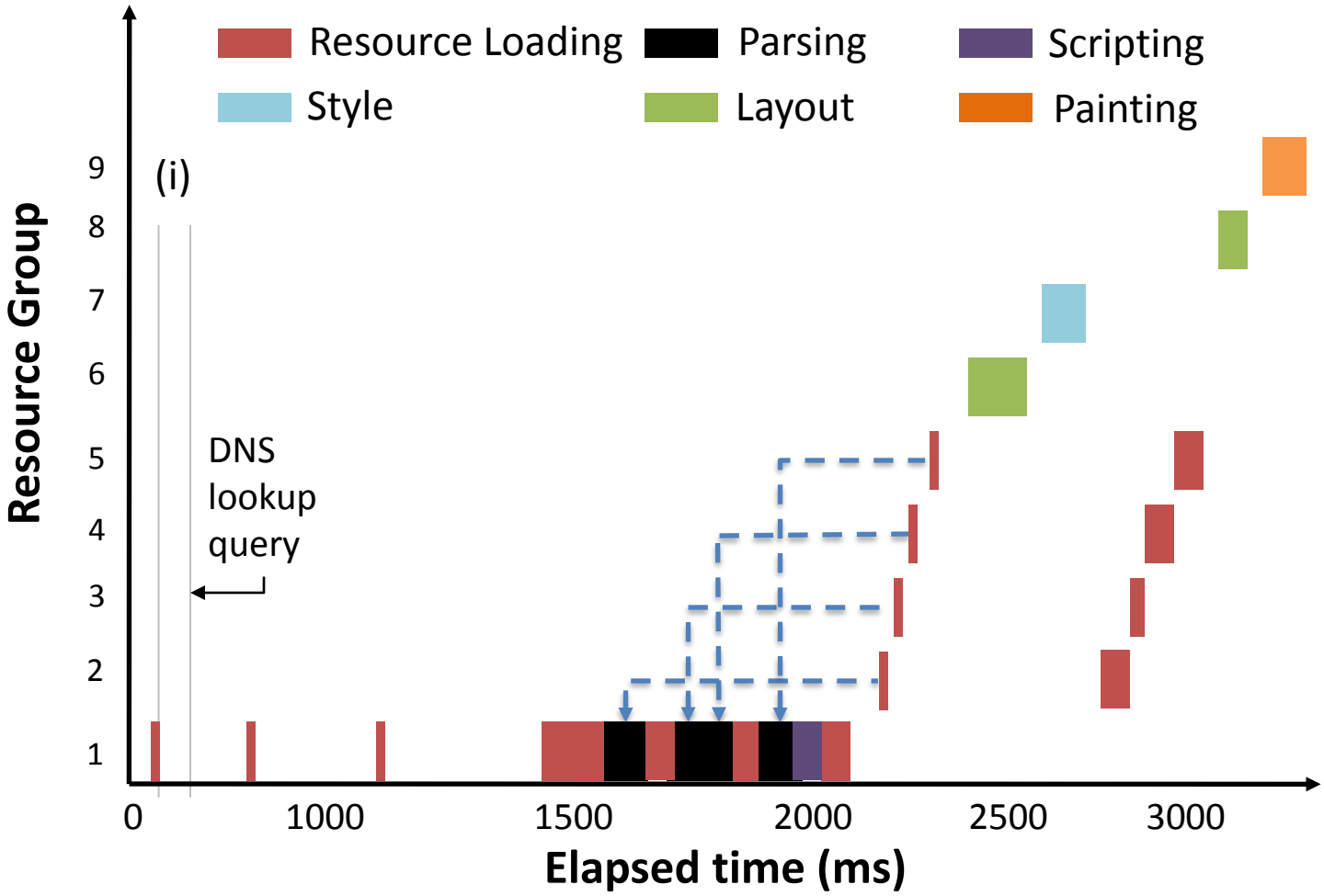


Processing power in resource loading



http://mail.yahoo.com

Processing power in resource loading



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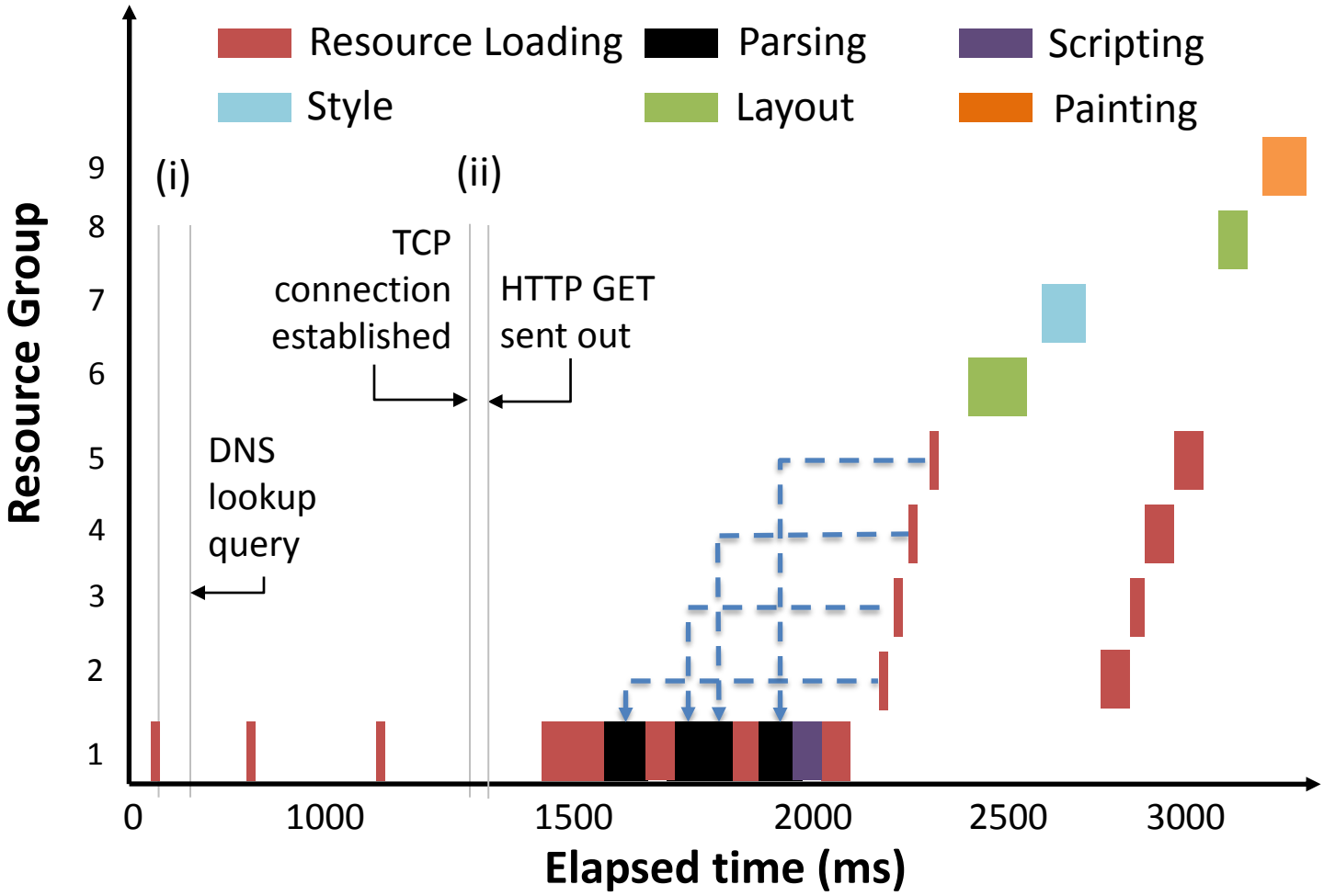

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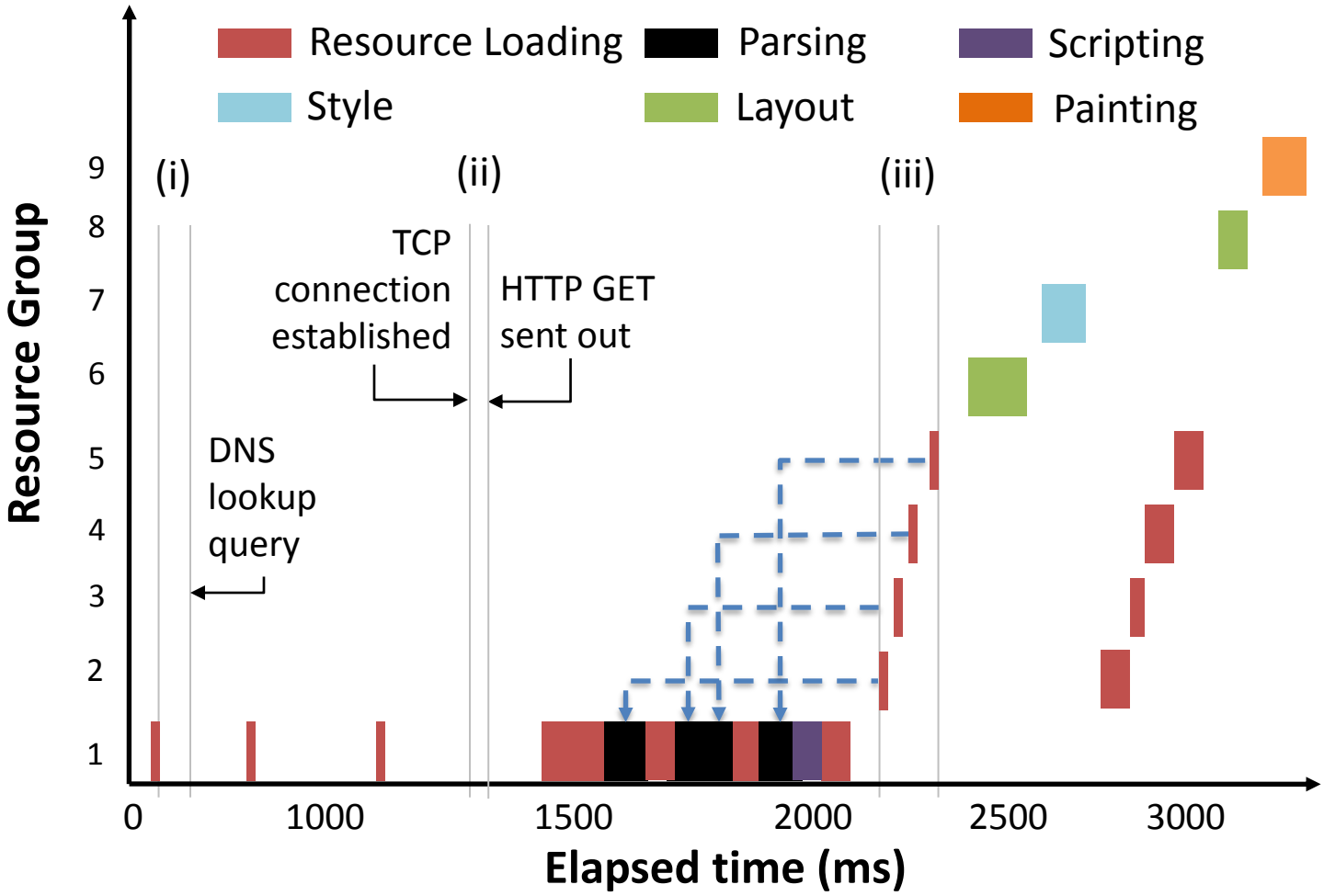
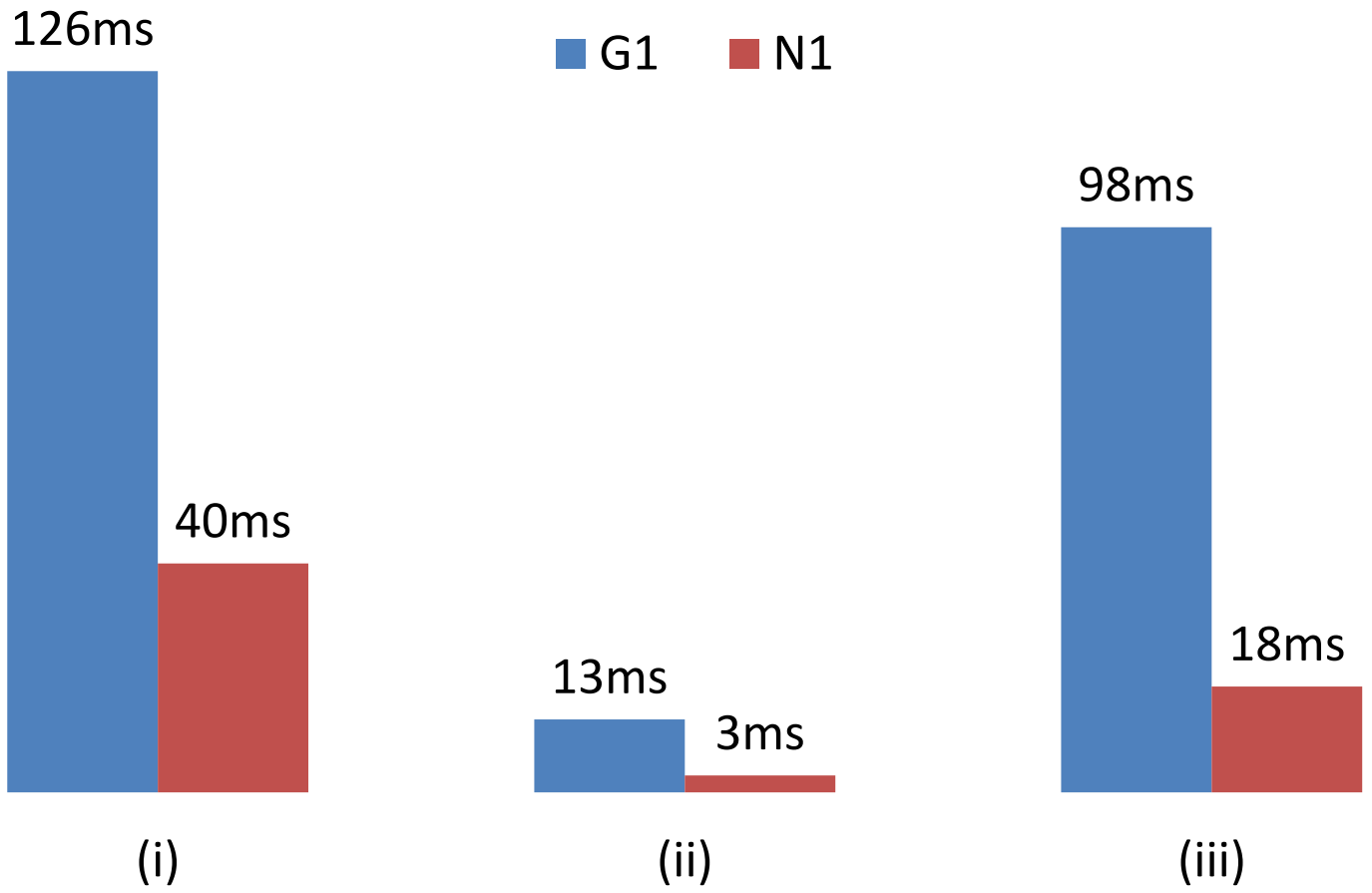
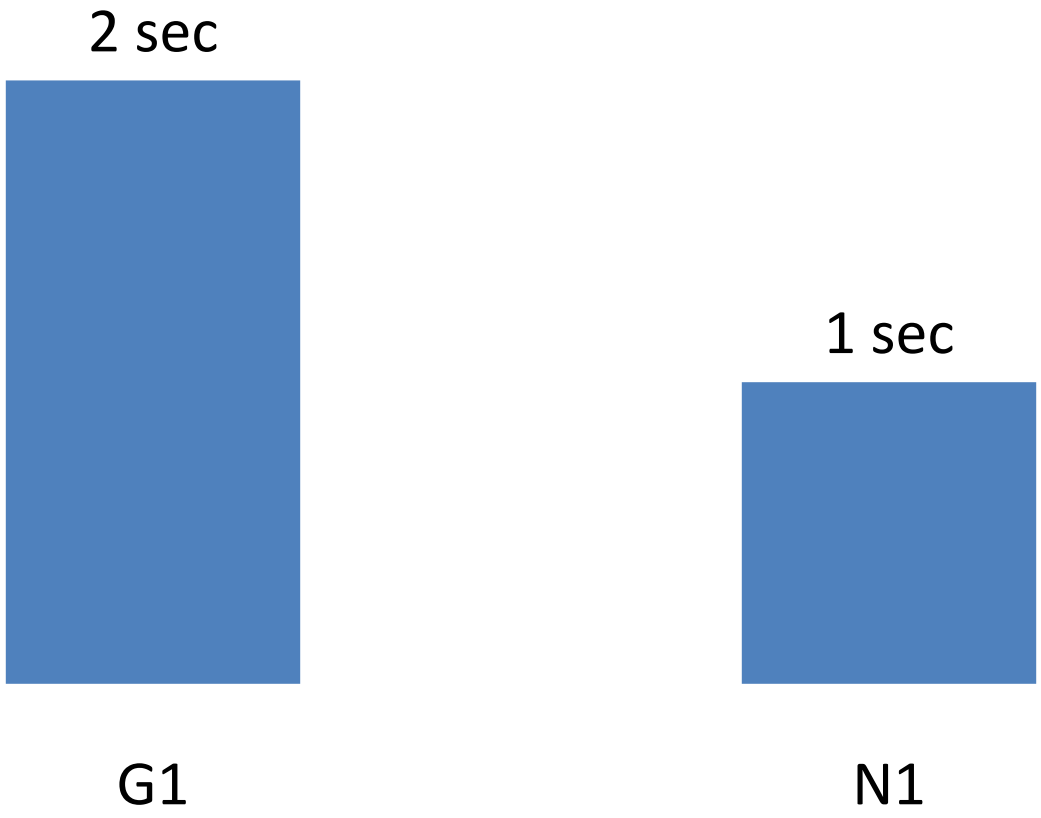


http://mail.yahoo.com

Time spent by G1 and N1 for those three cases



Total time spent in the three cases on average when opening a mobile webpage



Processing power in resource loading

- Other uncategorized processing
  - The OS moves the data from network stack to browser after receiving data packets
  - Computation for secure connection (HTTPS)

More powerful hardware improves the browser delay mainly through faster OS services and network stack instead of faster IR operations.

Performance characterization results

- IR operations do not matter much

- **Resource loading is the bottleneck**
  - Network RTT (**X**)
  - Network bandwidth
  - Browser loading procedure (**X**)
  - Processing power (**X**)

How to improve mobile browser's performance?

Reduce RTT

- Cloudlet
- Data staging

Reduce # of Round Trips

- Web Pre-fetching
- Resource batching
- Data URI scheme
- *Speculative resource loading*

1.M. Satyanarayanan, P. Bahl, R. Caceres, and N. Davies, "The Case for VM-Based Cloudlets in Mobile Computing," *IEEE Pervasive Computing, vol. 8, pp. 14-23, 2009.*
2.J. Flinn, S. Sinnamohideen, N. Tolia, and M. Satyanaryanan, "Data Staging on Untrusted Surrogates," in *Proceedings of the 2nd USENIX Conference on File and Storage Technologies San Francisco, CA: USENIX Association, 2003.*
3.V. N. Padmanabhan and J. C. Mogul, "Using predictive prefetching to improve World Wide Web latency," *SIGCOMM Comput. Commun. Rev., vol. 26, pp. 22-36, 1996.*
4.Skyfire: http://www.skyfire.com/.
5.L. Masinter, "The "data" URL scheme," http://tools.ietf.org/html/rfc2397, 1998.

On-going work

- Speculative mobile browser design
- Fully understand the impact of hardware
- OS and network service acceleration

http://www.owlnet.rice.edu/~zw3/projects_Tempo.html

Benchmark webpages

mobile

http://maps.google.com
http://www.espn.com
http://www.cnn.com
http://www.google.com
http://mail.yahoo.com
http://mail.google.com
http://www.weather.com
http://www.facebook.com
http://www.hotmail.com
http://mail.aol.com

Non-mobile

http://freeappaday.com/
https://owlspace-ccm.rice.edu/portal
http://www.restaurant.com/
http://www.neopets.com/games/
http://arstechnica.com/
http://houston.craigslist.org/
http://houston.varsitytutors.com/
http://www.morewords.com/
http://tripplanner.ridemetro.org/hiwire
http://registrar.rice.edu/