How Far Can Client-Only Solutions Go for Mobile Browser Speed?

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LOGO

Introduction

- Web browser is one of the most important applications on mobile devices. It is known to be slow, taking many seconds to open a webpage.
- The long delay harms mobile user experience and eventually discourages web-based business:

Background

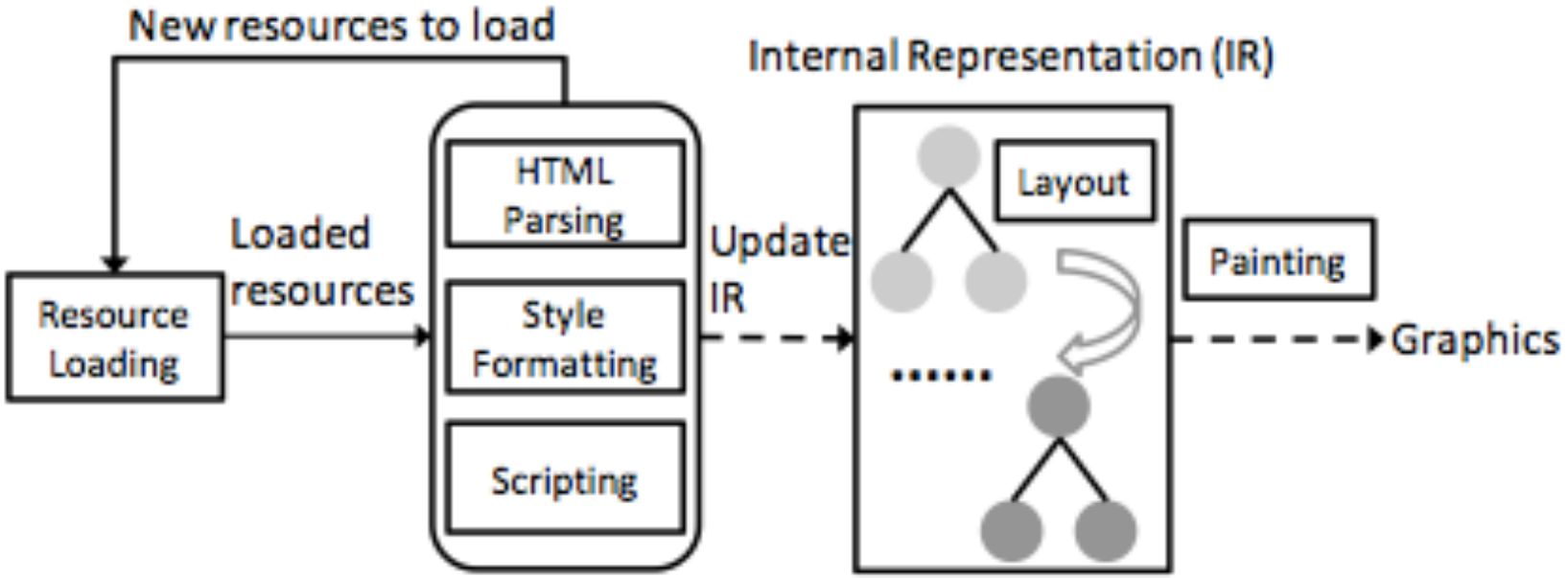


Figure 1: The procedure of opening a webpage

Why are Mobile Browsers Slow?

The bottleneck of mobile browser performance is actually in *resource loading* due to long round trip **time** (RTT) and the large **number** of round trips.

Related Work

- The key to improve mobile browser is to speed up resource loading.
- Many effective solutions require infrastructure support, either from the web server or a proxy.
- Those solutions are hard to deploy, are subject to the ability of the servers, cannot provide end-to-end security or has limited client JavaScript support.

Client-only solutions

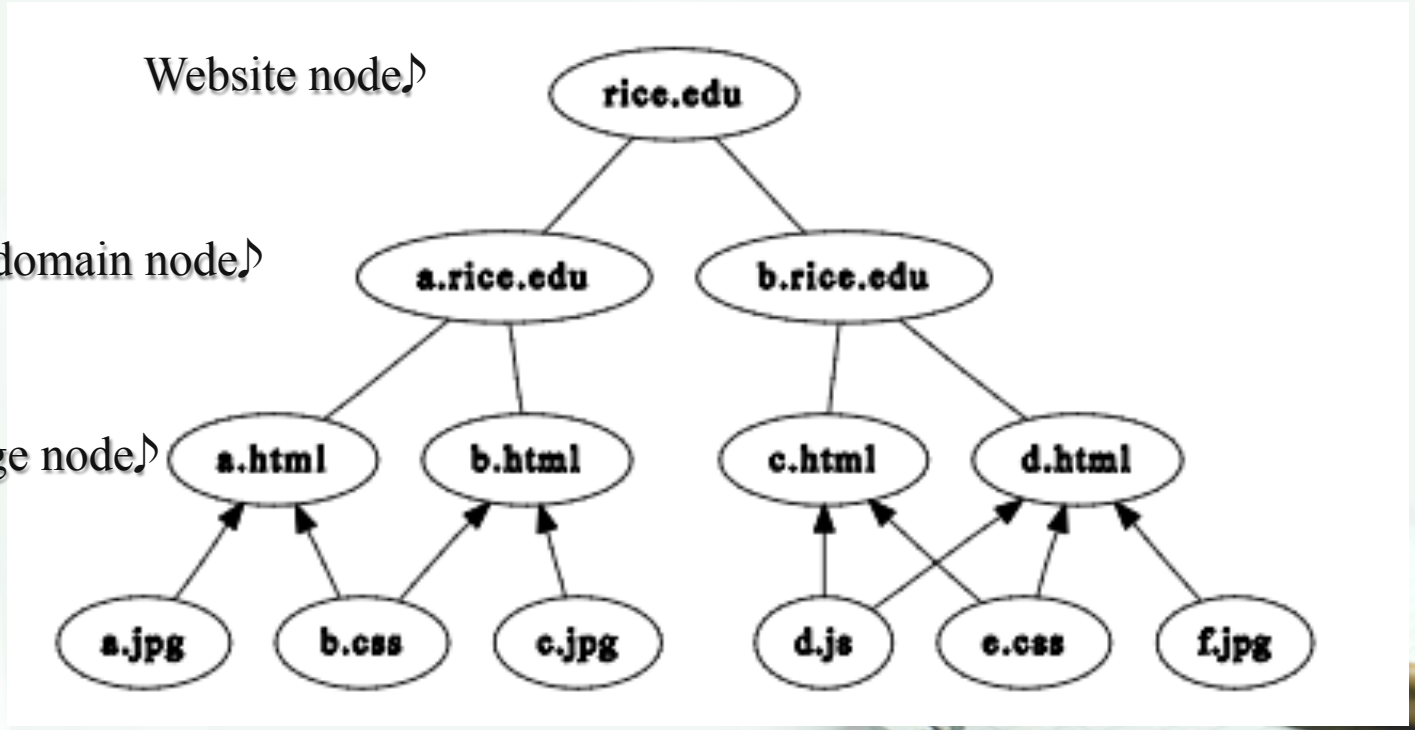
Client-only solutions, are particularly attractive because they are immediately deployable, scalable, and secure.

client-only solutions are likely to be less effective than those leveraging infrastructure supports.

How effective client-only solutions can be for mobile browsers?

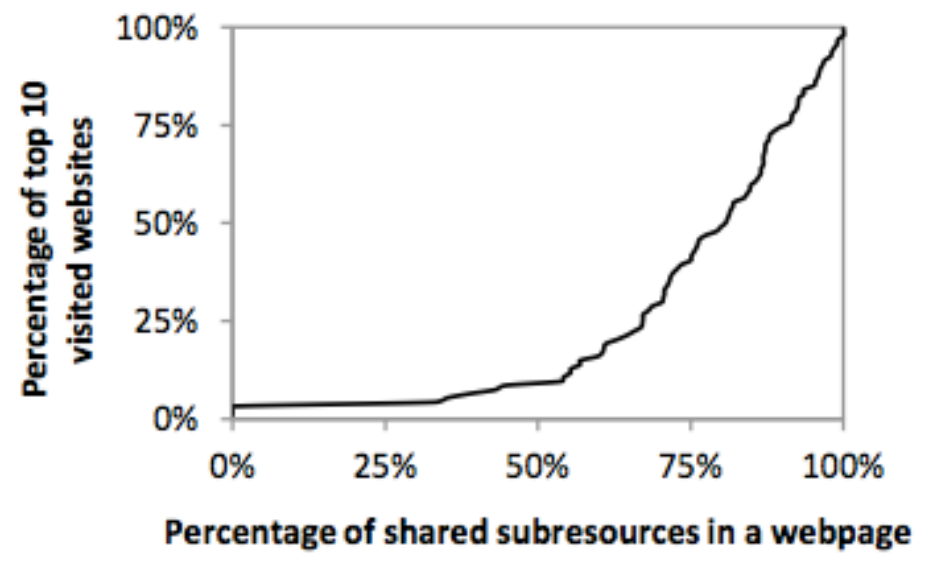
Mobile Web Browsing Characteristics

- **Resource graph:**



Characteristics of Websites

- **Firstly, Webpages from the same website often share a large portion of resources.**



- **Secondly, the structure of a resource graph can change over time.**

Mobile User Browsing Behavior

- The total number of frequently visited websites is usually small.
- Across different users, the web usage is diverse.
- The majority of the webpage visits are new visits.
- Though users tend to visit new webpages, the browser is likely to request a similar set of subresources.

EFFECTIVENESS OF CLIENT ONLY APPROACHES

Caching

- browser saves the subresources of previously visited webpages locally and reduces the resource loading time if the same subresources are requested again.
- A cached resource can have two states: fresh or expired.
- The benefit of caching is marginal

EFFECTIVENESS OF CLIENT ONLY APPROACHES

Web Prefetching

- Web prefetching predicts the webpages that will be visited by the user and downloads their resources beforehand.
- Client-only web prefetching results in significant additional data usage with very little improvement.
  - **Web prefetching cannot predict URLs that have never been visited before;**
  - **On average, 75% of the webpages visited are new visits**

EFFECTIVENESS OF CLIENT ONLY APPROACHES

Speculative Loading

- Load sources for a webpage along with the main resource file *after* a user provides the web URL.

- predicts which subresources to load based on a resource graph of the website constructed using knowledge of the website collected from the past.

EFFECTIVENESS OF CLIENT ONLY APPROACHES

The advantages of Speculative loading:

- Compared with Caching.
- Compared with Prefetching

EFFECTIVENESS OF CLIENT ONLY APPROACHES

- Upper Bound of Improvement

Table 1: Upper bound of the browser delay reduction from speculative loading under different cache states (in ms)

Sites	Fresh Cache				Expired Cache				Empty Cache			
	Legacy	Speculate	Reduction		Legacy	Speculate	Reduction		Legacy	Speculate	Reduction	
ESPN	4557	4557	0	0%	6702	4622	2080	31%	7143	4622	2521	35%
CNN	2382	2382	0	0%	4869	2884	1985	41%	6300	4315	1985	32%
Google	2162	2131	31	1%	3363	2131	1232	37%	3661	2223	1438	39%
Yahoo! Mail	3199	3199	0	0%	4333	3199	1134	26%	4341	3199	1142	26%
Weather	3645	3608	37	1%	6294	3608	2686	43%	6349	3608	2741	43%
Craigslist	1926	1920	6	0%	3034	1920	1114	37%	3103	1920	1183	38%
Neopets Games	3605	3605	0	0%	11505	9002	2503	22%	11843	9340	2503	21%
Varsity Tutors	3313	3313	0	0%	8410	6596	1814	22%	9219	7405	1814	20%
Ride METRO	3826	3826	0	0%	8266	5560	2706	33%	8774	6068	2706	31%
Rice Registrar	3351	3351	0	0%	5865	3541	2324	40%	6427	3541	2886	45%
Average	**3197**	**3189**	**7**	**0%**	**6264**	**4306**	**1958**	**33%**	**6716**	**4624**	**2092**	**33%**

TEMPO:ASPECULATIVEMOBILE BROWSER

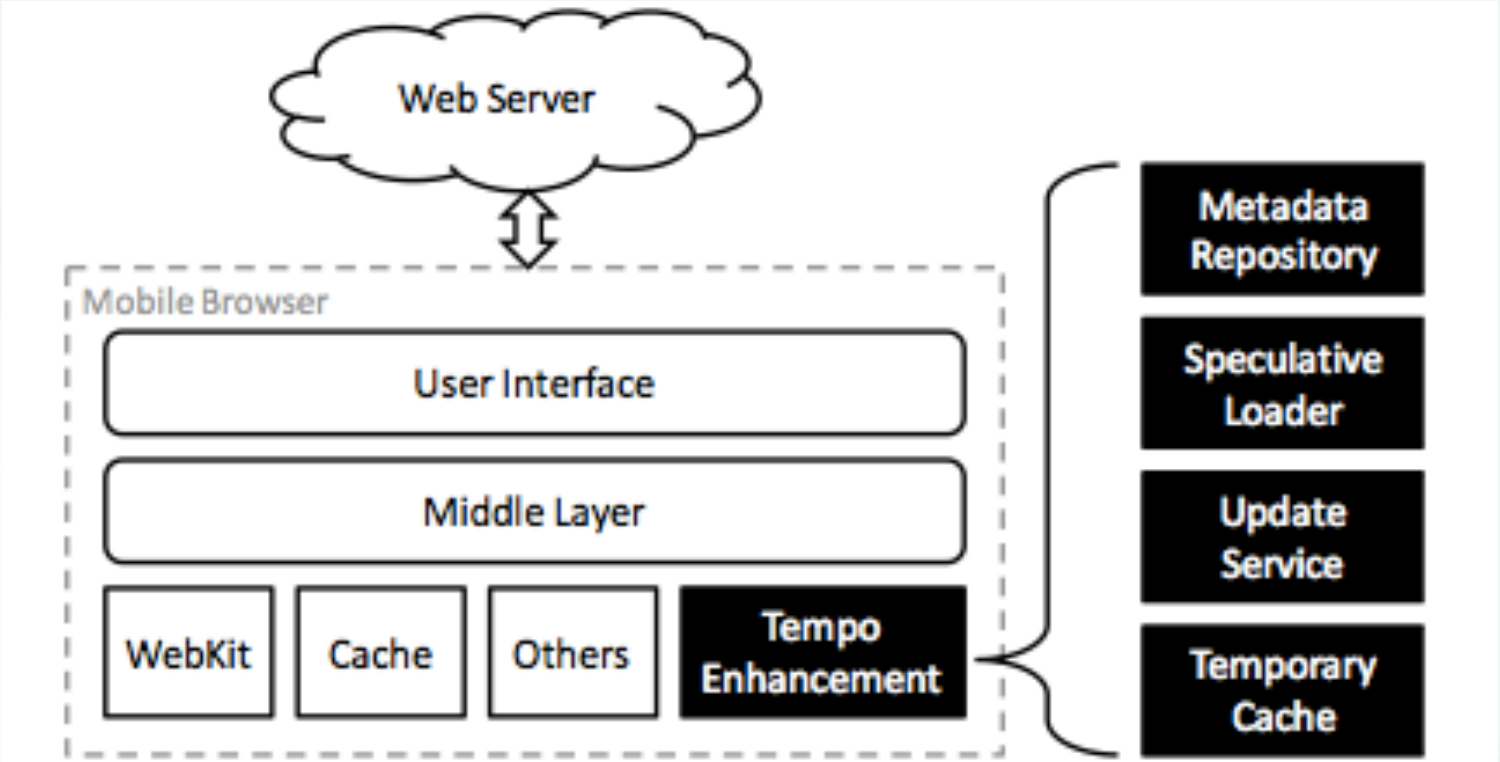


Figure 5: Tempo, a speculative mobile browser. Black components are new additions to the existing mobile browser.

Metadata Repository

Two advantages:

- Firstly, it relates the resources in each website in the corresponding resource graph.
- Secondly, metadata repository only takes several hundred KB of storage on the mobile device

Speculative Loader

```
Input: webpage URL
Output: predicted subresources' URLs
SubresourcePrediction(url):
  candidates = []                  // subresources
  webpage_node = get_webpage_node(url)
  if webpage_node != NULL:  // webpage revisit
    candidates = children_of_webpage_node
    sorted_candidates = Sort(candidates)
    return sorted_candidates
  else:                            // webpage new visit
    subdomain_node = get_subdomain_node(url)
    if subdomain_node != NULL:
      candidates = subres_nodes_of_the_subdomain
    else:
      candidates = subres_nodes_of_the_website
    sorted_candidates = Sort(candidates)
    num_predicted = avg_num_of_webpage_children
    return sorted_candidates[0:num_predicted]
```

Figure 7: Pseudo Code of Subresource Prediction

Update Service

- *Update* operation adds a node if the node does not exist in the resource graph or updates the information stored in the node if the node exists in the resource graph already.
- *Trim* operation removes the nodes that are not visited for more than one month from the resource graph.

Temporary Cache

- Those files should not be stored in the cache.
- After the webpage is open, all the resources in the temporary cache will be deleted.

Evaluation

- **Subresource Prediction Performance**

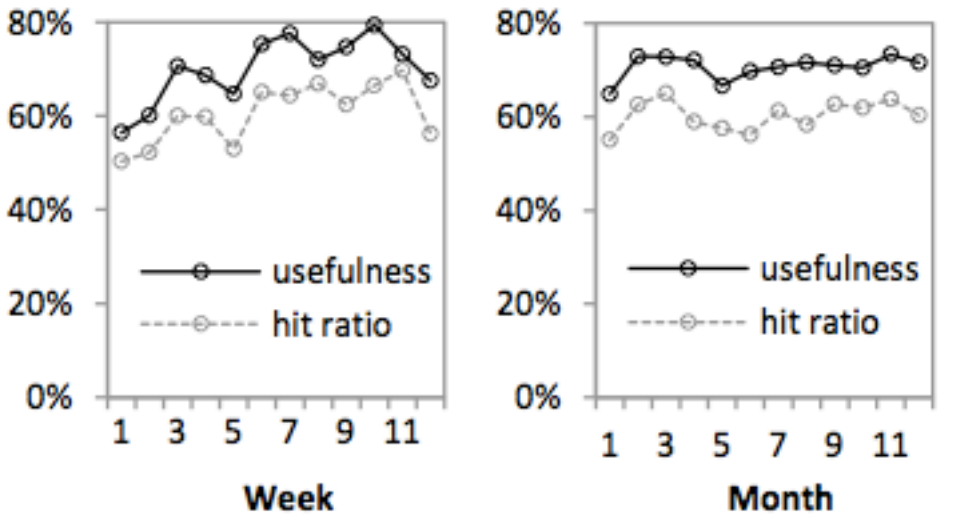


Figure 8: Hit ratio and usefulness of subresource prediction for the first 12 weeks (Left) and the entire year (Right). Each data point is the average value across 24 LiveLab users

Lab Experiments

Table 2: Browser delay reduction from speculative loading for webpage *revisits* under different cache states (in ms)

Sites	Fresh Cache				Expired Cache				Empty Cache			
	Legacy	Tempo	Reduction		Legacy	Tempo	Reduction		Legacy	Tempo	Reduction	
ESPN	3491	3602	-111	-3%	6748	5372	1376	20%	7031	5322	1709	24%
CNN	4873	4507	366	8%	5992	4274	1718	29%	6346	5307	1039	16%
Google	2407	2842	-435	-18%	3411	3073	338	10%	3932	3257	675	17%
Yahoo! Mail	3239	3472	-233	-7%	5083	3265	1818	36%	5083	3442	1641	32%
Weather	5055	4559	496	10%	6109	3835	2274	37%	7167	4716	2451	34%
Craigslist	3123	2400	723	23%	3648	2089	1559	43%	3677	2470	1207	33%
Neopets Games	9041	9076	-35	0%	10639	9280	1359	13%	10660	10220	440	4%
Varsity Tutors	5969	5384	585	10%	8516	6677	1839	22%	9987	7914	2073	21%
Ride METRO	4220	3801	419	10%	6109	4620	1489	24%	6945	5488	1457	21%
Rice Registrar	3046	3609	-563	-18%	4169	3489	680	16%	6027	4084	1943	32%
Average	**4446**	**4325**	**121**	**1%**	**6042**	**4597**	**1445**	**25%**	**6686**	**5222**	**1464**	**24%**

Table 3: Browser delay reduction from speculative loading for *new* webpage visits under different cache states (in ms)

Sites	Fresh Cache				Expired Cache				Empty Cache			
	Legacy	Tempo	Reduction		Legacy	Tempo	Reduction		Legacy	Tempo	Reduction	
ESPN	3152	2587	565	18%	3163	2788	375	12%	6162	4205	1957	32%
CNN	2994	3328	-334	-11%	3519	2438	1081	31%	7091	6054	1037	15%
Google	2982	2295	687	23%	2376	2492	-116	-5%	4638	2945	1693	37%
Yahoo! Mail	5222	5282	-60	-1%	4472	3162	1310	29%	5572	5047	525	9%
Weather	5180	3763	1417	27%	3757	2682	1075	29%	5357	5244	113	2%
Craigslist	1203	1210	-7	-1%	2624	1848	776	30%	5163	3463	1700	33%
Neopets	10105	9795	310	3%	7326	7038	288	4%	6914	6623	291	4%
Varsity Tutors	7126	8013	-887	-12%	10598	7437	3161	30%	14921	12674	2247	15%
Ride METRO	2759	3460	-701	-25%	3352	2602	750	22%	6829	6171	658	10%
Rice Registrar	3929	3708	221	6%	4570	3672	898	20%	6506	5534	972	15%
Average	**4465**	**4344**	**121**	**3%**	**4576**	**3616**	**960**	**20%**	**6915**	**5796**	**1119**	**17%**

Conclusion

- Of solutions for browser speed improvement, client-only ones are immediately deployable, scalable, and secure.
- the upper bound of browser delay reduction for client-only solutions is 1.4 second with today’s typical 3G network.

Thank You!

Q&A