

Doloto:

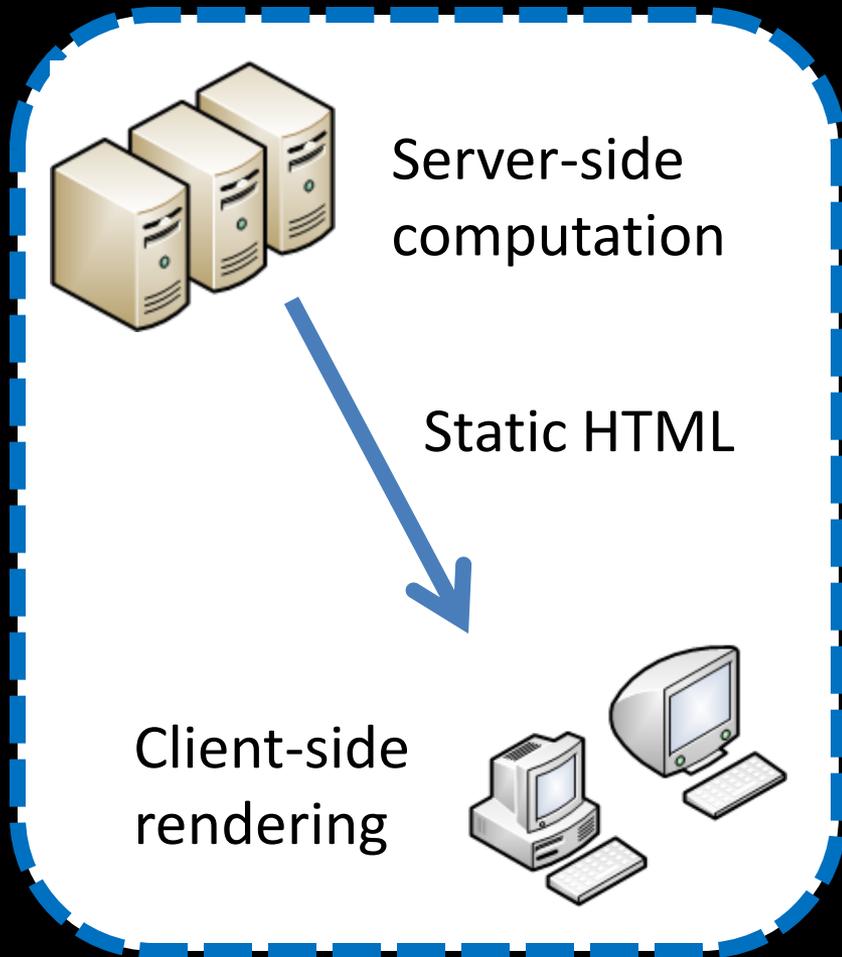
Code Splitting for Web 2.0 Applications

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Web 2.0 is Upon Us



Web 1.0 → Web 2.0



Distributed Applications



Server



Run your code here



Clients

Catch-22



Move code to
client for
responsiveness

Execution can't
start without
the code



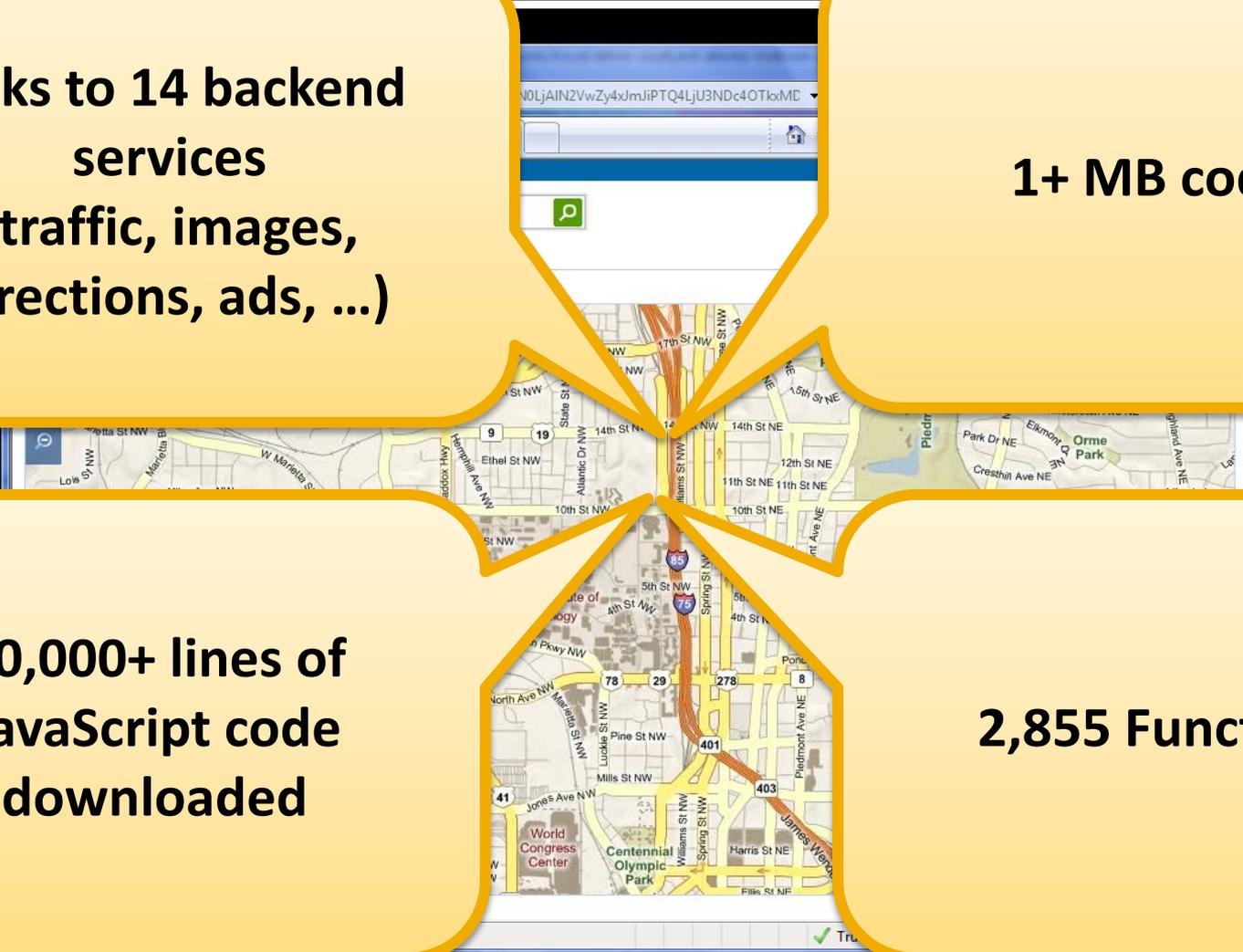
A Web 2.0 Application Disected

Talks to 14 backend services
(traffic, images, directions, ads, ...)

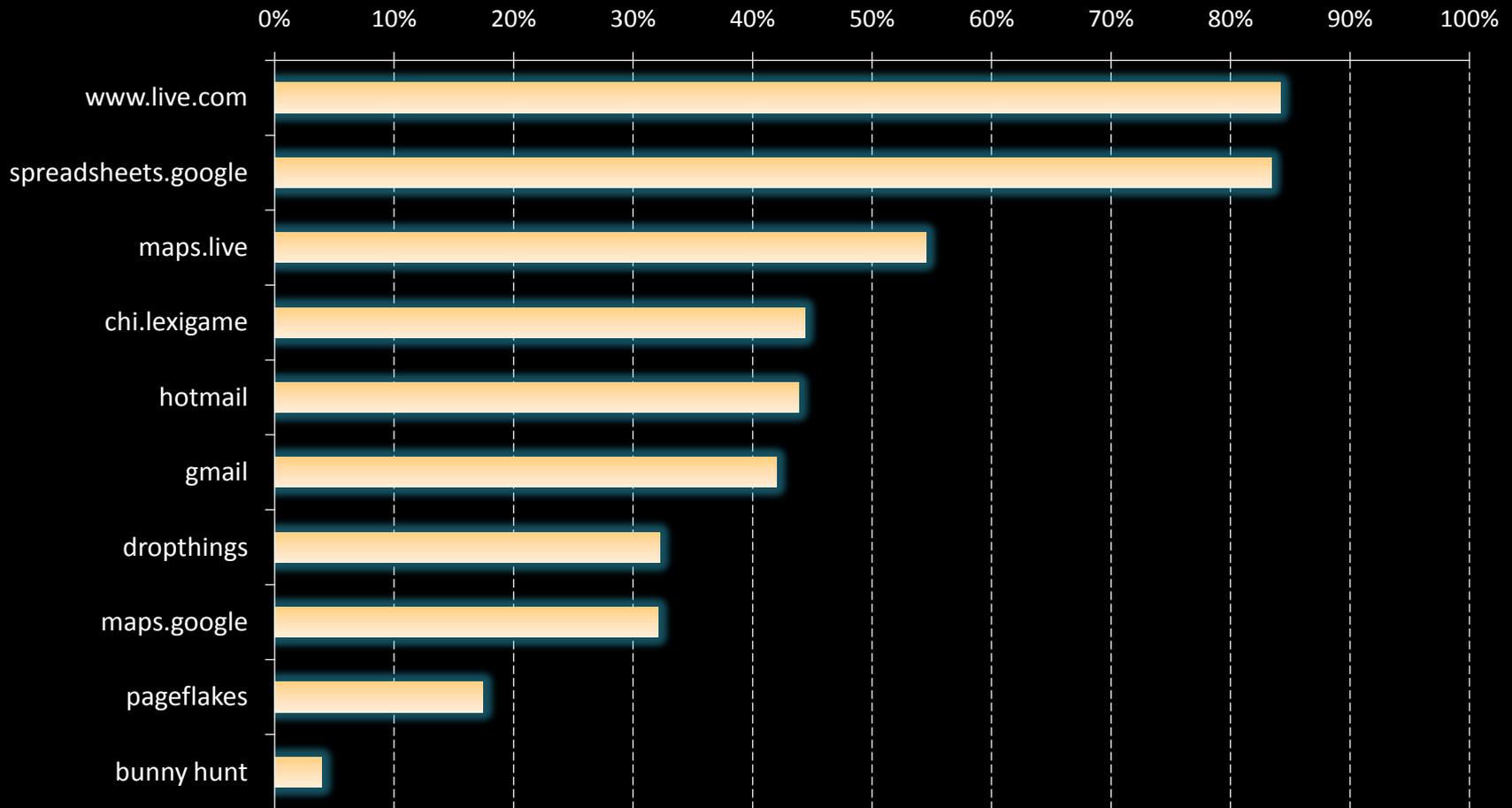
1+ MB code

70,000+ lines of JavaScript code downloaded

2,855 Functions



Lots of JavaScript Code



Motivation for Doloto

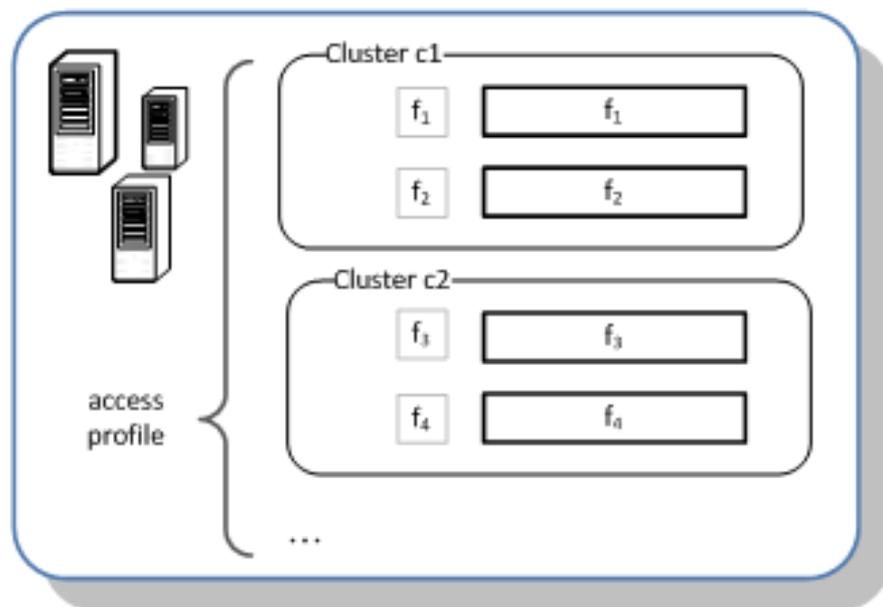
- Idea behind Doloto
 - Start with a small piece of code on the client
 - Download required code on demand (pull)
 - Send code when bandwidth available (push)
- Leads to better application responsiveness
 - Interleave code download & execution
 - Faster startup times
 - Rarely executed code is rarely downloaded

Doloto: the Steps

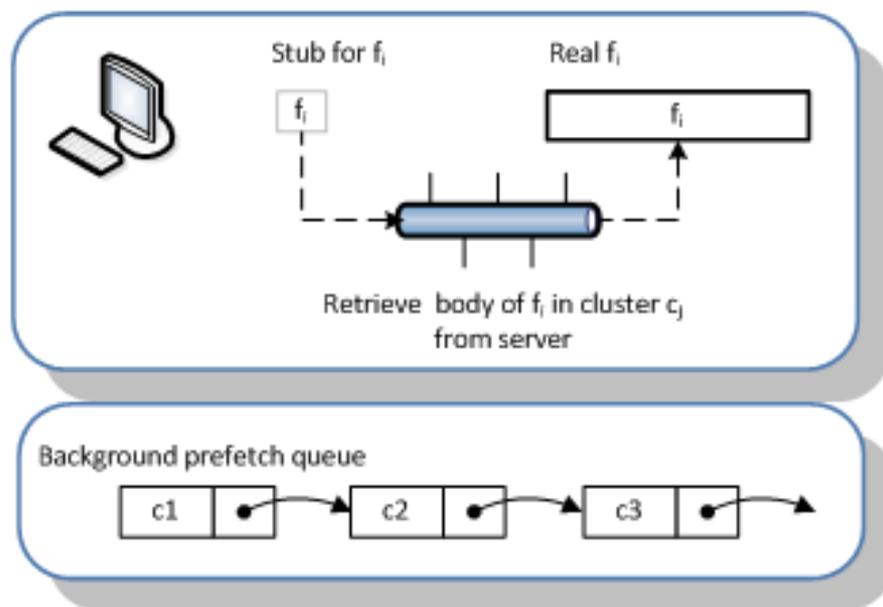
1. [**training**] Runtime training to collect access profile
2. [**rewriting**] Function rewriting or “stubbing” for on-demand code loading
3. [**prefetch**] Background prefetch of clusters as the application is running

Runtime Picture

Server



Client



Training Phase



- Instrument every function
- Record the first-execute timestamp
- Look for gaps to find clusters

Doloto Training Tool

Doloto: Clustering Information Summary

Training summary

There are 6 clusters for <http://maps.live.com/> (window ID 11395600)
 Cluster c1 containing 96 functions with a total size of 26,300 bytes
 Cluster c2 containing 652 functions with a total size of 309,615 bytes
 Cluster c3 containing 188 functions with a total size of 49,569 bytes
 Cluster c4 containing 113 functions with a total size of 25,589 bytes

Training summary Cluster details

Cluster	Function name	URL	First use time	Size	Line	Cha
cluster c1 of size 96						
c1 for winid 11395600	_Anonymous	http://maps.live.com/	1204742171525	69	00	
c1 for winid 11395600	SetLiveDomain	http://maps.live.com/	1204742172509	546	126	
c1 for winid 11395600	IsParentAccessible	http://maps.live.com/	1204742172509	172	113	
c1 for winid 11395600	LaunchSurveyWindow	http://maps.live.com/	1204742172509	1,043	70	
c1 for winid 11395600	Web.Browser._Private.MozillaFilterSub	http://sc1.maps.live.com/js/atlascompat.js	1204742172712	405	99	
c1 for winid 11395600	EstablishMode	http://sc1.maps.live.com/js/atlascompat.js	1204742172712	254	125	
c1 for winid 11395600	Web.Browser.AttachMozillaCompatibility	http://sc1.maps.live.com/js/atlascompat.js	1204742172712	4,501	119	
c1 for winid 11395600	_VERRegisterNamespaces	http://sc1.maps.live.com/js/atlascompat.js	1204742172712	317	10	
c1 for winid 11395600	Web.Browser.isMozilla	http://sc1.maps.live.com/js/atlascompat.js	1204742172712	48	43	
c1 for winid 11395600	_Anonymous	http://sc1.maps.live.com/mapcontrol.ashx?mkt=en-us&v=1.3.20071113130328.94	1204742188681	161	00	
c1 for winid 11395600	_Anonymous	http://sc1.maps.live.com/mapcontrol.ashx?mkt=en-us&v=1.3.20071113130328.94	1204742188681	68	00	2
c1 for winid 11395600	_Anonymous	http://sc1.maps.live.com/mapcontrol.ashx?mkt=en-us&v=1.3.20071113130328.94	1204742188681	40	00	2
c1 for winid 11395600	j	http://sc1.maps.live.com/mapcontrol.ashx?mkt=en-us&v=1.3.20071113130328.94	1204742188681	191	00	
c1 for winid 11395600	c	http://sc1.maps.live.com/mapcontrol.ashx?mkt=en-us&v=1.3.20071113130328.94	1204742188681	141	00	
c1 for winid 11395600	b	http://sc1.maps.live.com/mapcontrol.ashx?mkt=en-us&v=1.3.20071113130328.94	1204742188681	166	00	
c1 for winid 11395600	_Anonymous	http://sc1.maps.live.com/mapcontrol.ashx?mkt=en-us&v=1.3.20071113130328.94	1204742188681	89	00	3
c1 for winid 11395600	_Anonymous	http://sc1.maps.live.com/mapcontrol.ashx?mkt=en-us&v=1.3.20071113130328.94	1204742188681	82	00	4
c1 for winid 11395600	GetManifestUrl	http://sc1.maps.live.com/mapcontrol.ashx?mkt=en-us&v=1.3.20071113130328.94	1204742188681	67	00	4
c1 for winid 11395600	_Anonymous	http://sc1.maps.live.com/mapcontrol.ashx?mkt=en-us&v=1.3.20071113130328.94	1204742188681	57	00	2
c1 for winid 11395600	_Anonymous	http://sc1.maps.live.com/mapcontrol.ashx?mkt=en-us&v=1.3.20071113130328.94	1204742188681	70	00	2
c1 for winid 11395600	_Anonymous	http://sc1.maps.live.com/mapcontrol.ashx?mkt=en-us&v=1.3.20071113130328.94	1204742188681	67	00	3
c1 for winid 11395600	Men VF RnrowserInfo	http://sc1.maps.live.com/mapcontrol.ashx?mkt=en-us&v=1.3.20071113130328.94	1204742188681	454	00	

Clustering granularity presets

Coarse
 Medium
 Fine-grained

Clustering parameters

Gap between clusters: 5.000 seconds

0 seconds 15 seconds

0 ms 1000 ms

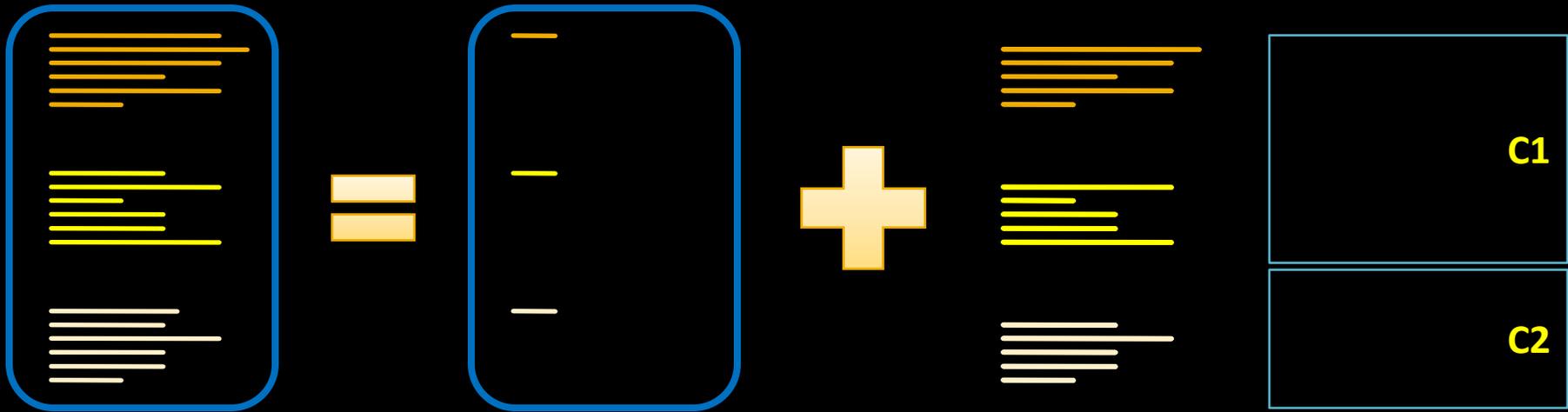
0 KB 100 KB

Cluster size threshold: 25 KB

Architecture of Doloto

1. [training] Runtime training to collect access profiles
2. [rewriting] Function rewriting or “stubbing” for on-demand code loading
3. [prefetch] Background prefetch of clusters as the application is running

Code Rewriting



- Rewrite JavaScript code one file at a time
- Recombine clusters into individual files

Automated Function Splitting

```

var g = 10;
function f1() {
  var x=g+1;
  ...
  ...
  ...
  ...
  ...
  return ...;
}

```

```

var g = 10;

var real_f1;
function f1() {
  if(!real_f1) {
    var code = load("f1");
    real_f1 = eval(code);
    f1 = real_f1;
  }
  return real_f1.apply(this,
                        arguments);
}

```



```

eval($exp("f1"), ""); // 21 chars

```

Architecture of Doloto

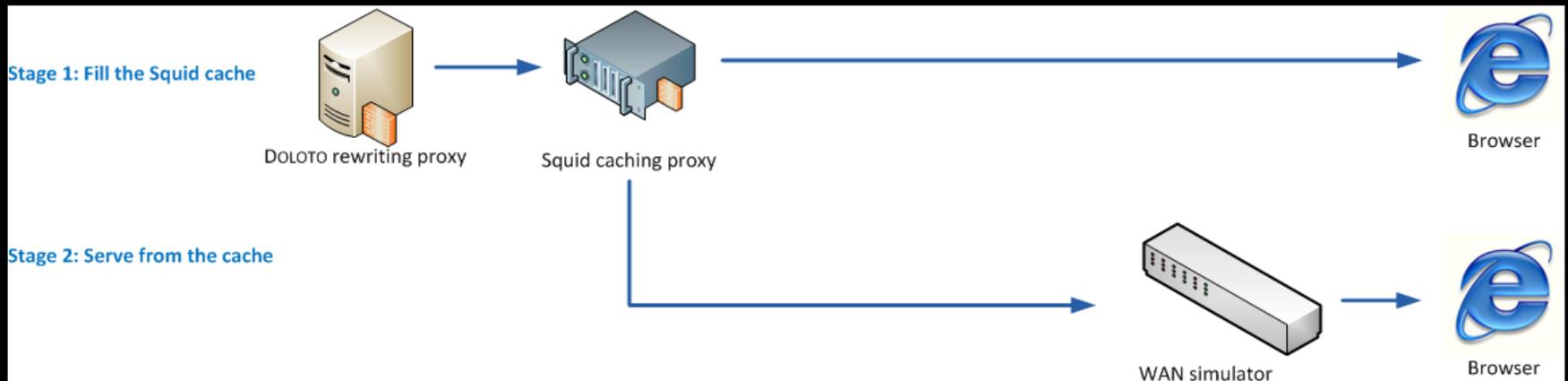
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Cluster Prefetching

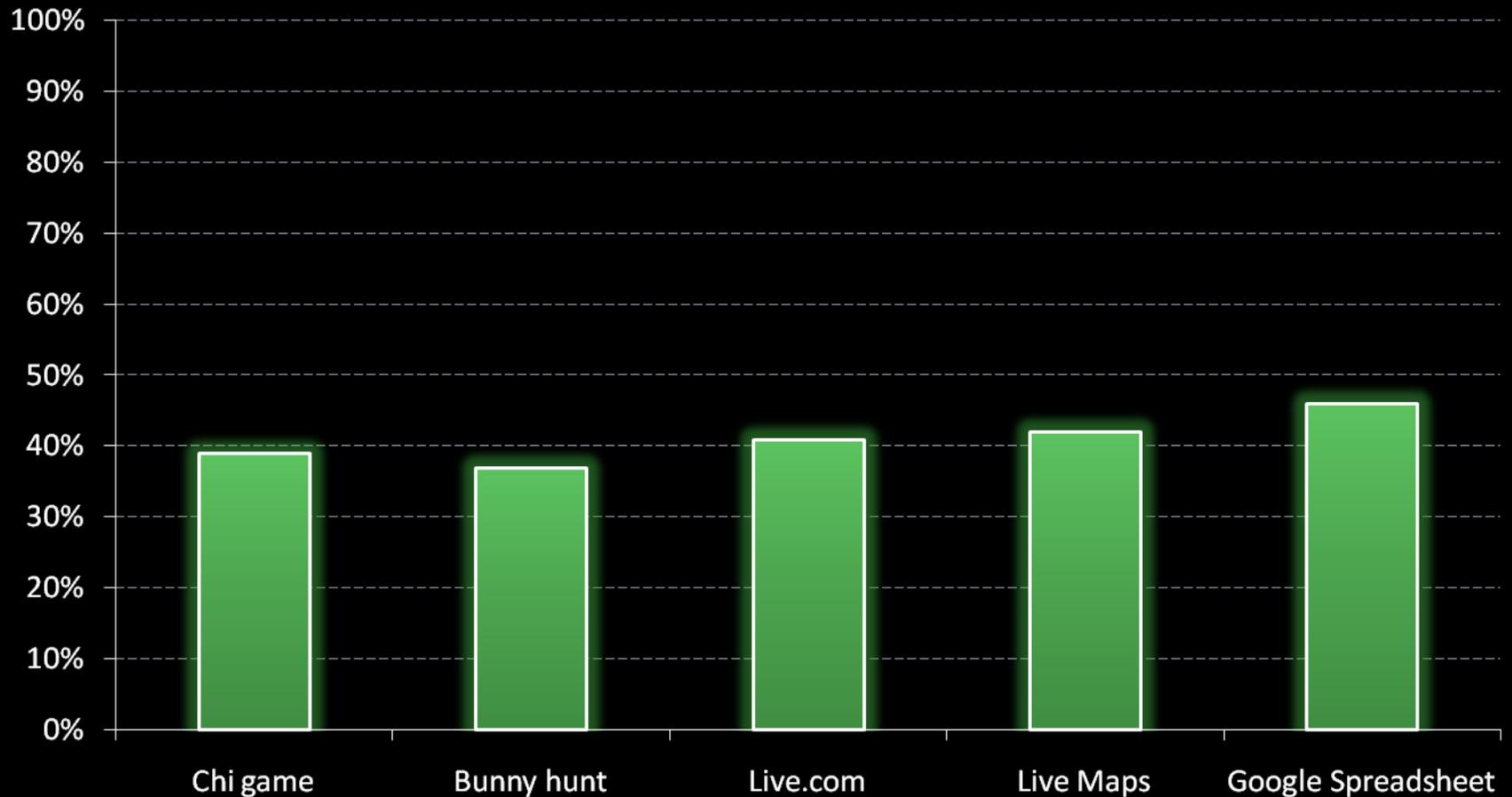
```
1  var xhr = new XmlHttpRequest();
2  function next_cluster(){
3      xhr.open("http://code.server.com/next",
4              /* asynchronous AJAX call */ true);
5
6      xhr.onreadystatechange = handle_cluster;
7      xhr.send(null);
8  }
9
10 function handle_cluster(){
11     if (xhr.readyState != 4) { return; }
12     var code = xhr.responseText;
13     if (code == "") return; // last cluster
14
15     // split code into function bodies
16     foreach(<func_name, func_code> in code) {
17         func[func_name] = func_code;
18     }
19
20     // go fetch the next cluster
21     next_cluster();
22 }
23
24 // initial invocation of next_cluster
25 // after the document is done loading
26 document.attachEvent("onload", next_cluster);
```

Application Benchmarks

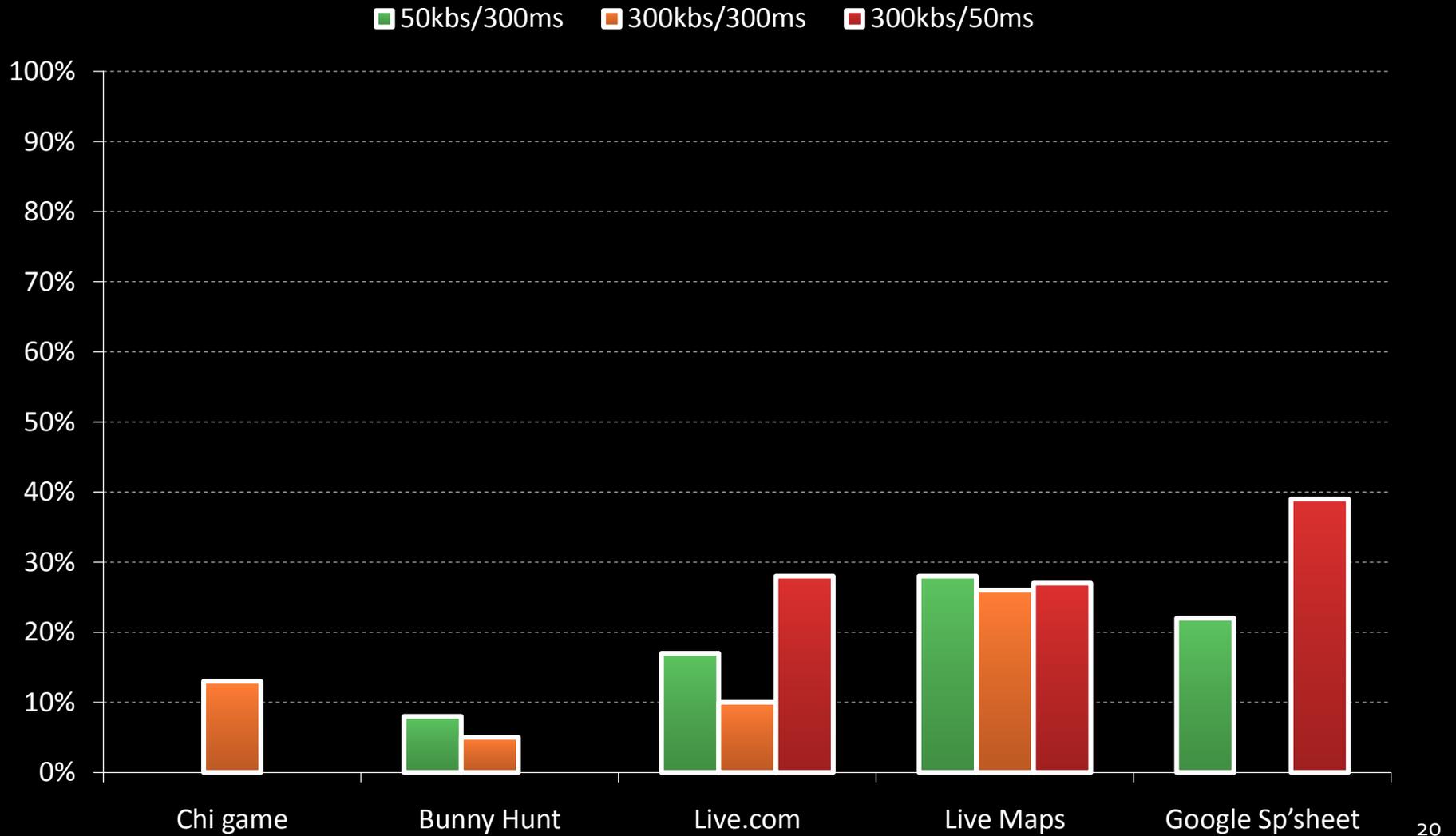
Application	Download Size
Chi game	104
Bunny Hunt	16
Live.com	1,436
Live Maps	1,909
Google Spreadsheets	499



Size Savings with Doloto



Runtime Savings with Doloto



Conclusion

- Doloto: effective profile-driven optimization
- Our approach is general: Silverlight
- Enables larger more complex distributed apps
- Dynamic code loading for distributed applications of the future

Contact us

Ben Livshits (livshits@microsoft.com)

Doloto MSR _



**Doloto: Code
Network-Bound**
Benjamin Livshits
Microsoft Research

ABSTRACT

Modern Web 2.0 applications
look and many others. We
to use AJAX to push a
This improves the
tions, but the sh
to the client
that must
turning
top