AjaxScope: Remotely Monitoring Client-side Web-App Behavior

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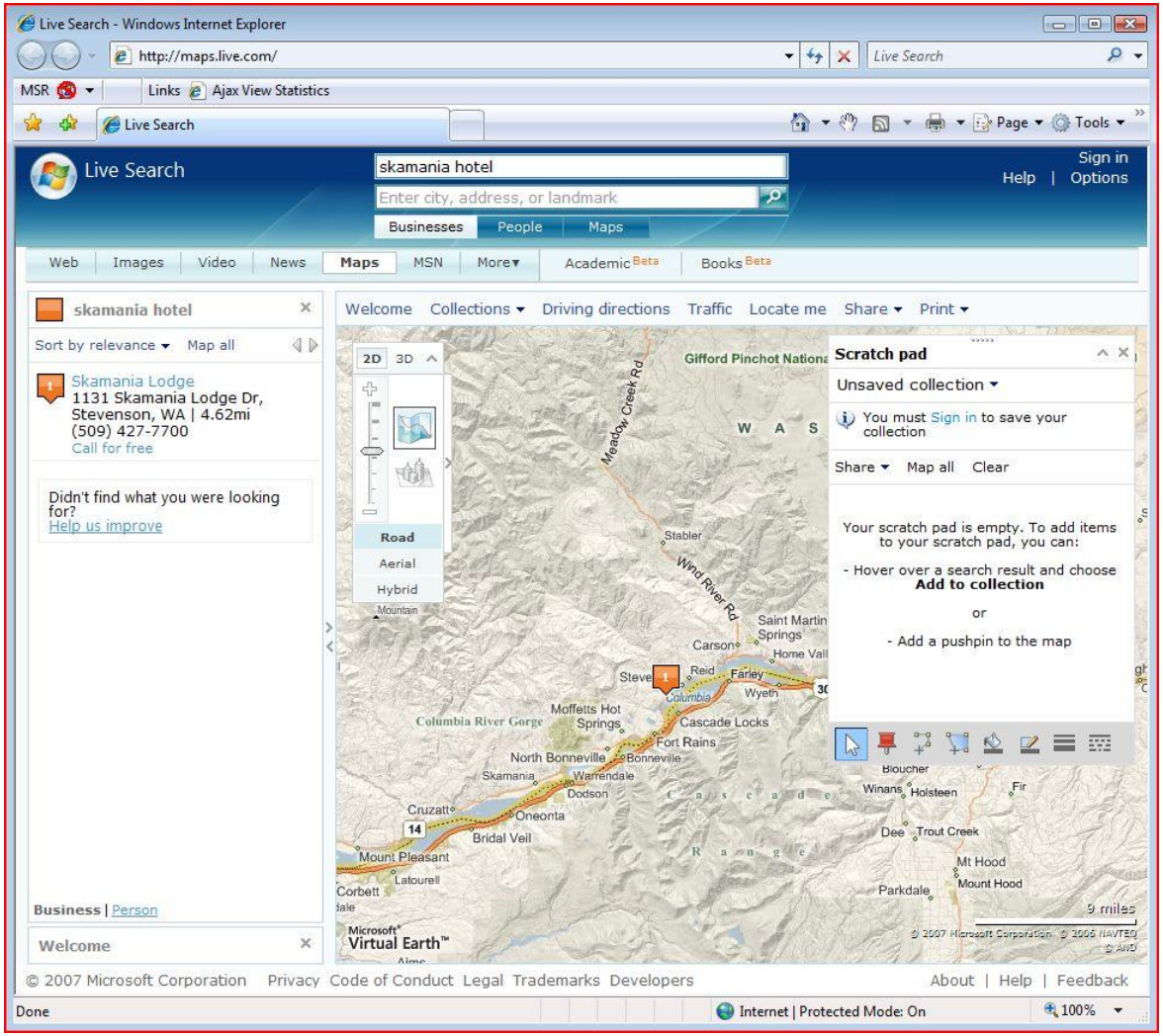
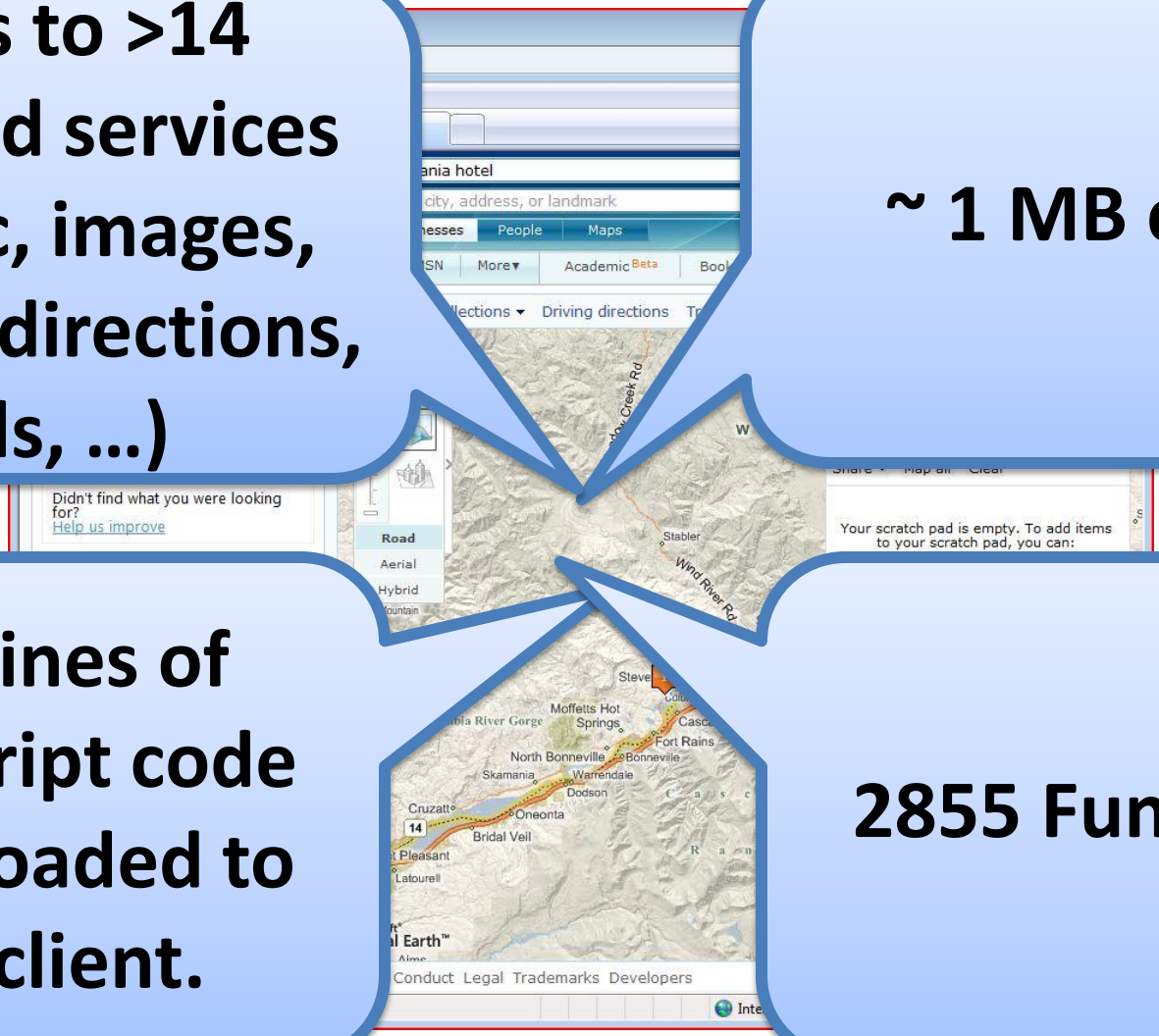
A Web Application



A Web Application

Talks to >14 backend services (traffic, images, search, directions, ads, …)

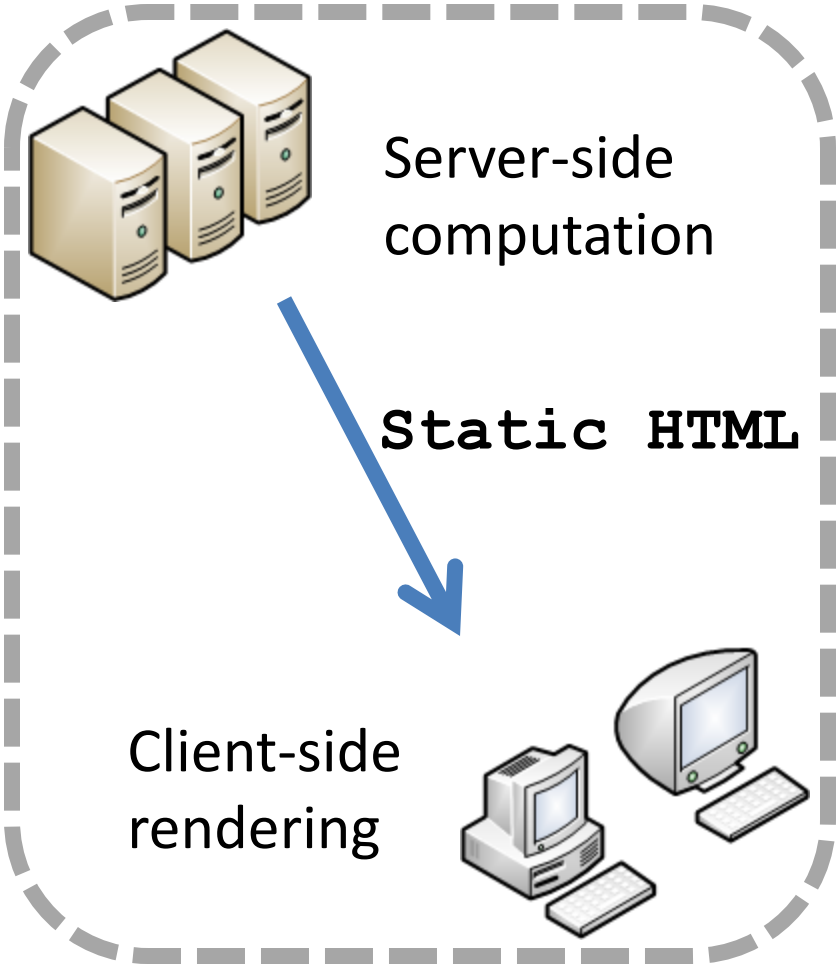
~ 1 MB code



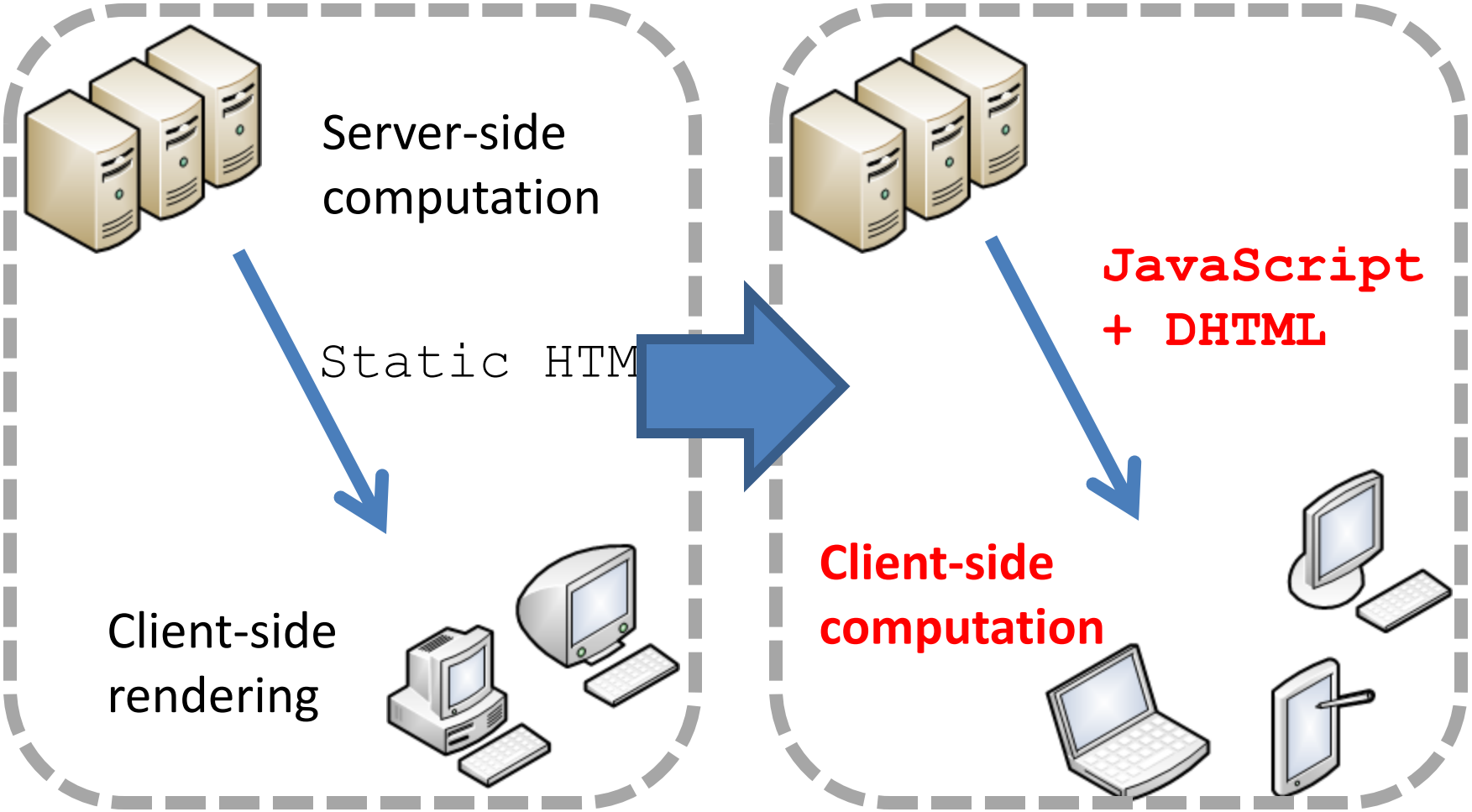
70k lines of JavaScript code downloaded to the client.

2855 Functions

Web 1.0 → Web 2.0


Server-side
computation
Static HTML
Client-side
rendering

Web 1.0 → Web 2.0


Server-side
computation
Static HTM
Client-side
rendering
JavaScript
+ DHTML
Client-side
computation

Web App Challenges

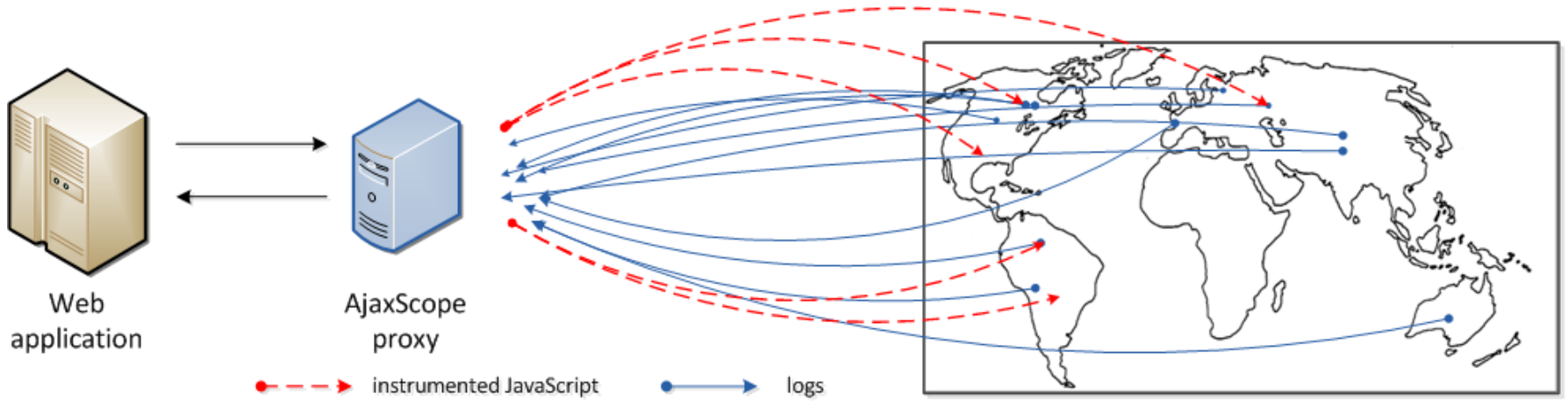
- Code complexity: more client-side code
  - Ex. Maps.live.com: 1MB of code, 70k LoC
  - Bugs, race conditions, memory leaks, …
- Non-standard execution environments
  - Many APIs differ across browsers
  - Perf of simple ops vary 10x-100x across impl.
- Third-party dependencies (*e.g.*, mash-ups)

Missing: Visibility into behavior on clients

Outline

1. Motivation
2. AjaxScope Platform
3. Expt: Adaptive instrumentation
4. Expt: Distributed instrumentation
5. Conclusions

AjaxScope Approach



Goal: Detailed visibility into app behavior in the client

Approach: On-the-fly rewriting to add instrumentation

Key Enabler: Instant re-deployability of web apps

Monitoring Goals

- **Performance Optimization**
  - Performance profiling
  - String optimization; cache placement; …
  - Code splitting and joining
- **Debugging**
  - Report function arguments, app state, errors
  - Memory leak checking
  - Statistical debugging
- **Test**
  - Code coverage
  - A/B tests
- **Operations**
  - Measure RPC network latencies
- **User interaction feedback**
  - What features are being used / discovered?

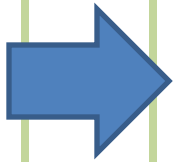
Approach: JavaScript Rewriting

- Simple but powerful monitoring
  - Inspect application state
  - Observe control flow
  - Limited only by JS sandbox
- Easy deployability
  - No changes required to original web app
  - No changes to client-side browsers

Example: Record Function Args

1. Search JavaScript AST for function definitions
2. For each function definition, add a statement to report every argument.

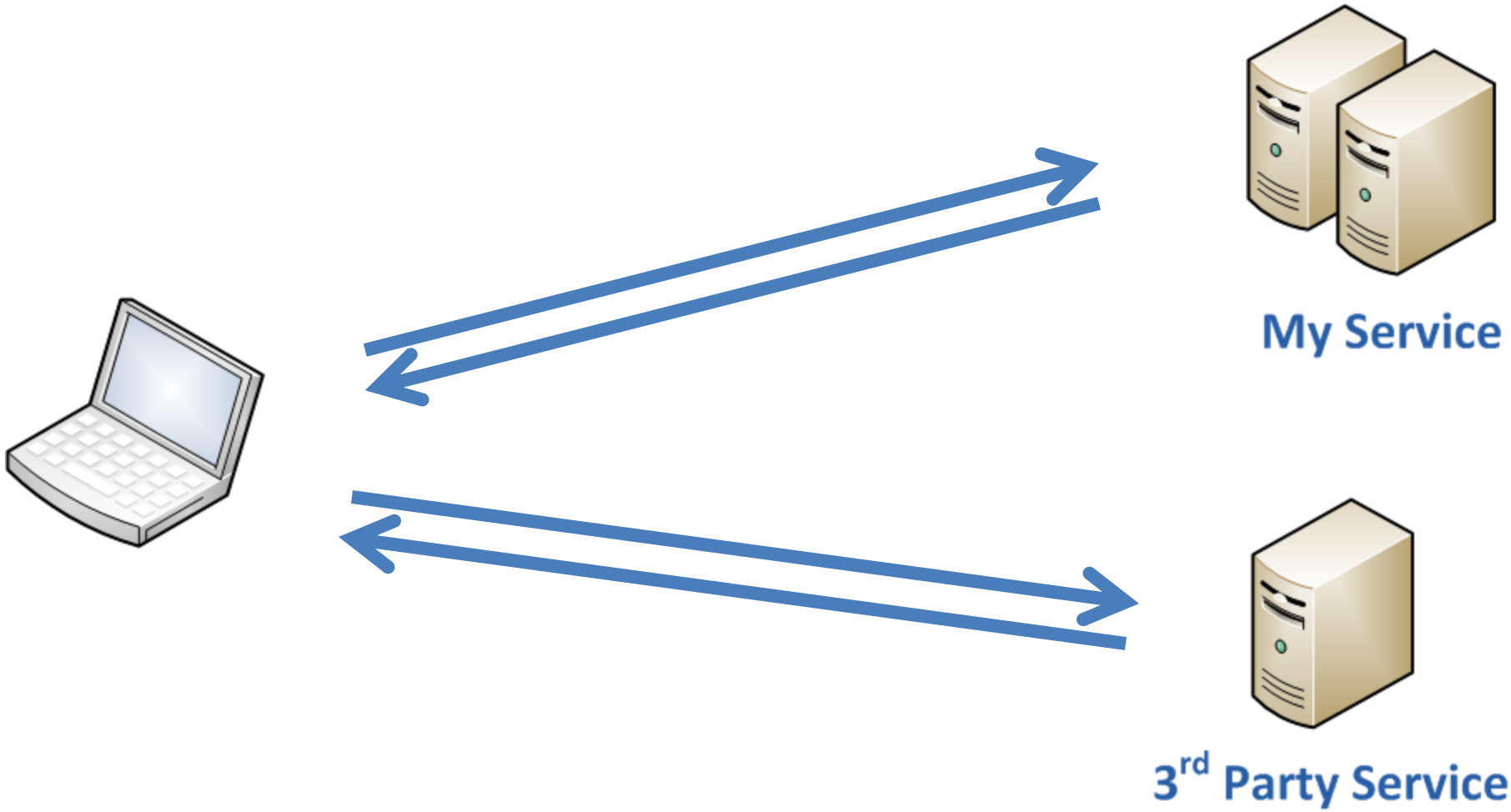
```
function foo(a,b) {
  // do something
}
```



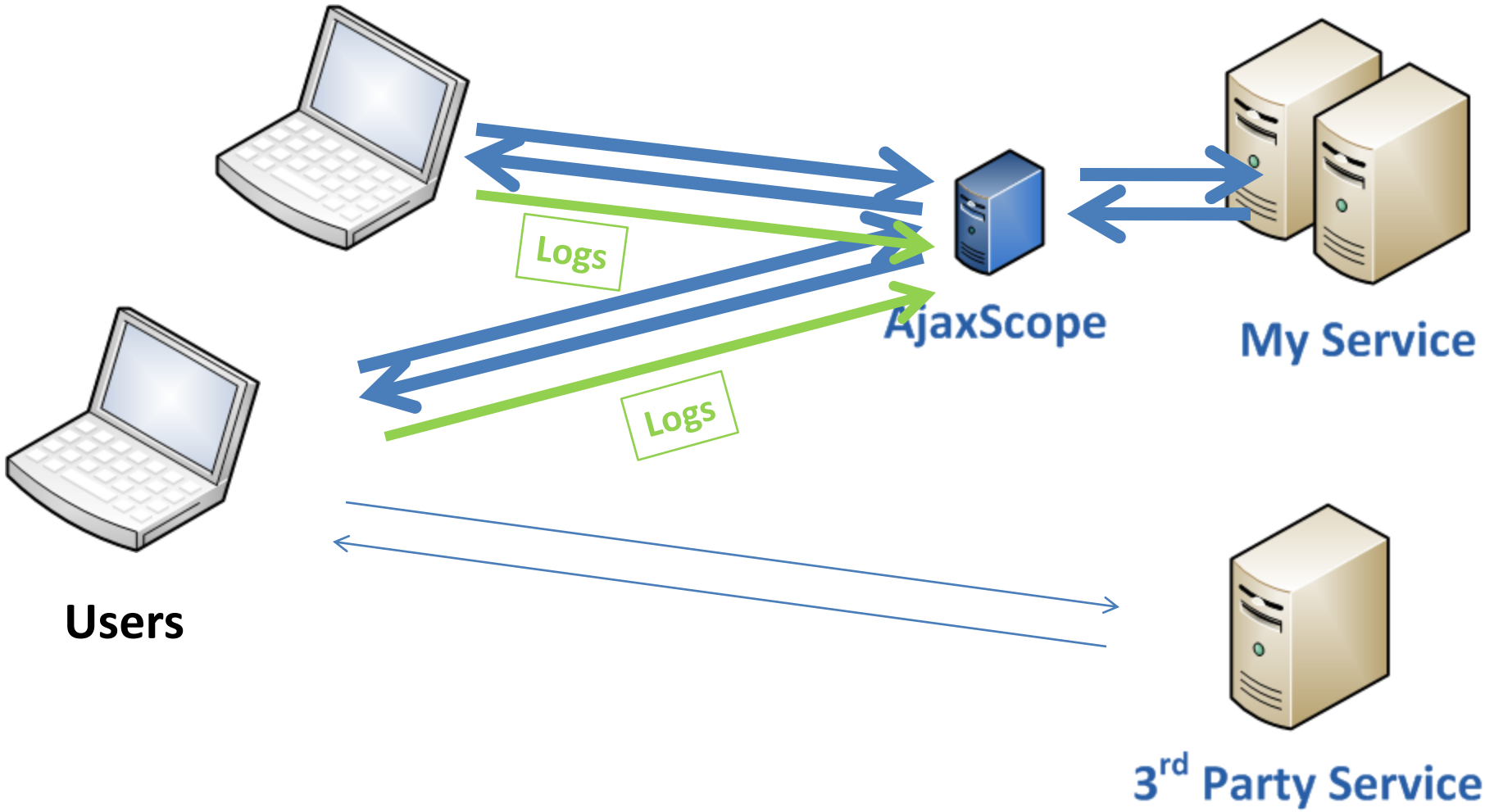
```
function foo(a,b) {
  sendLog("value of a="+a);
  sendLog("value of b="+b);
  // do something
}
```

sendLog() queues up messages for bulk reporting to AjaxScope

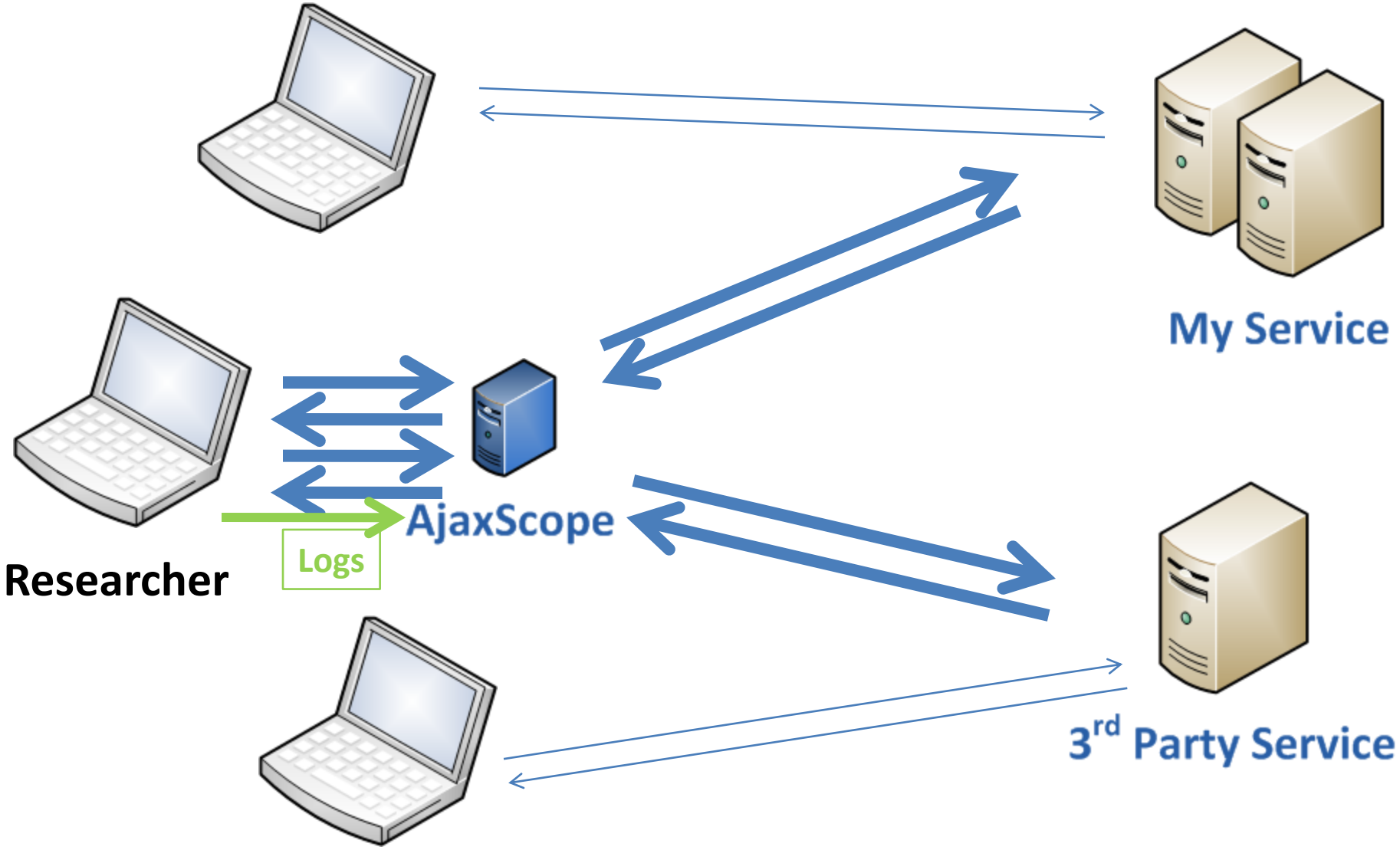
Deploying AjaxScope…



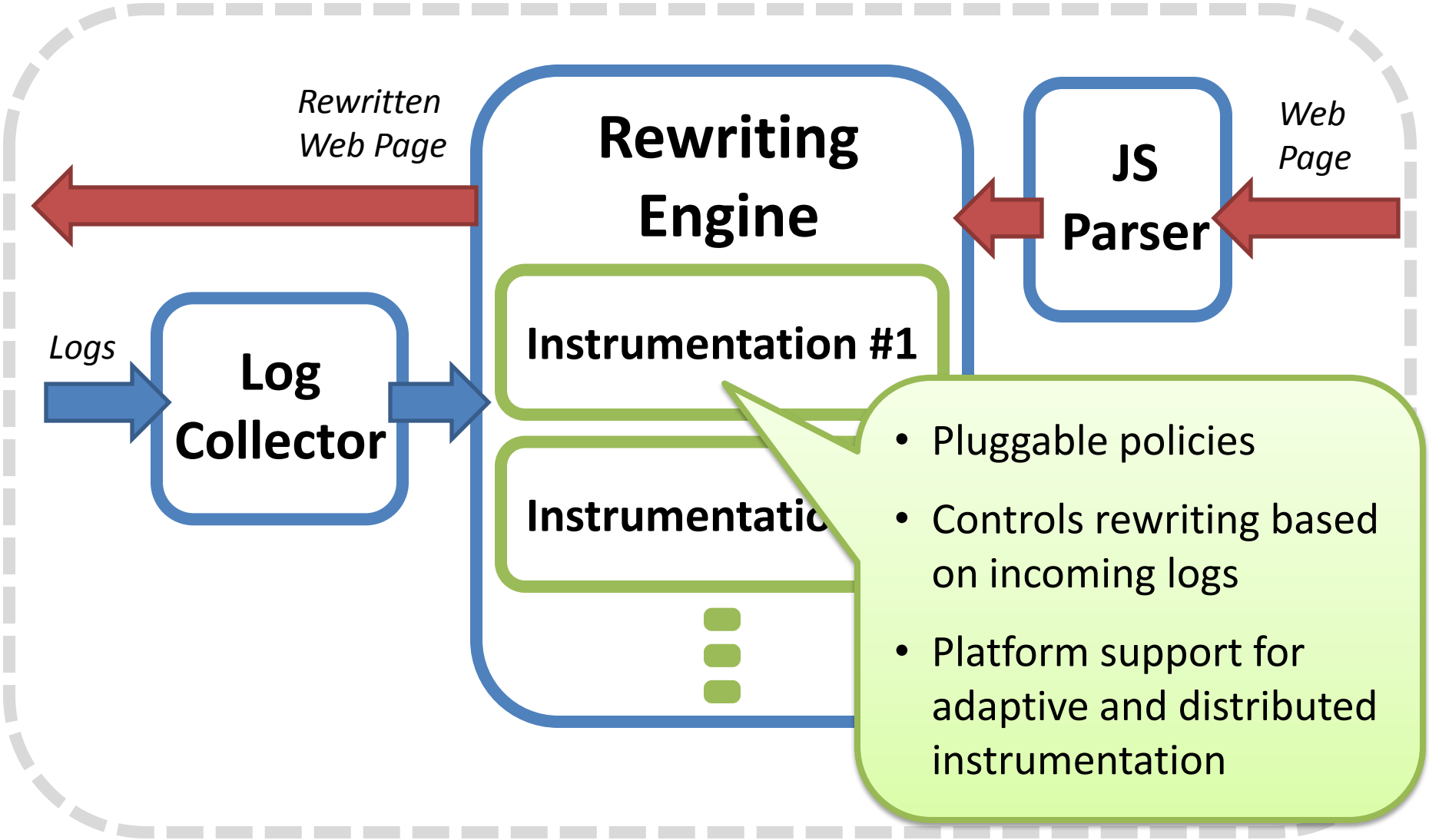
Server-side Deployment



Our Prototype (Client-side)



AjaxScope Proxy



Rewrite “On-the-fly”

- Service has tight control over code running at client
  - Clients always download new version
  - Cache-ability controlled by service
- Enables dynamic instrumentation
- Use to reduce performance overhead
  1. Adaptive instrumentation
  2. Distributed Instrumentation
- Also enables A/B tests to compare versions

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Experimental Setup

- Profile **90** web sites' "startup"
  - Client-side AjaxScope

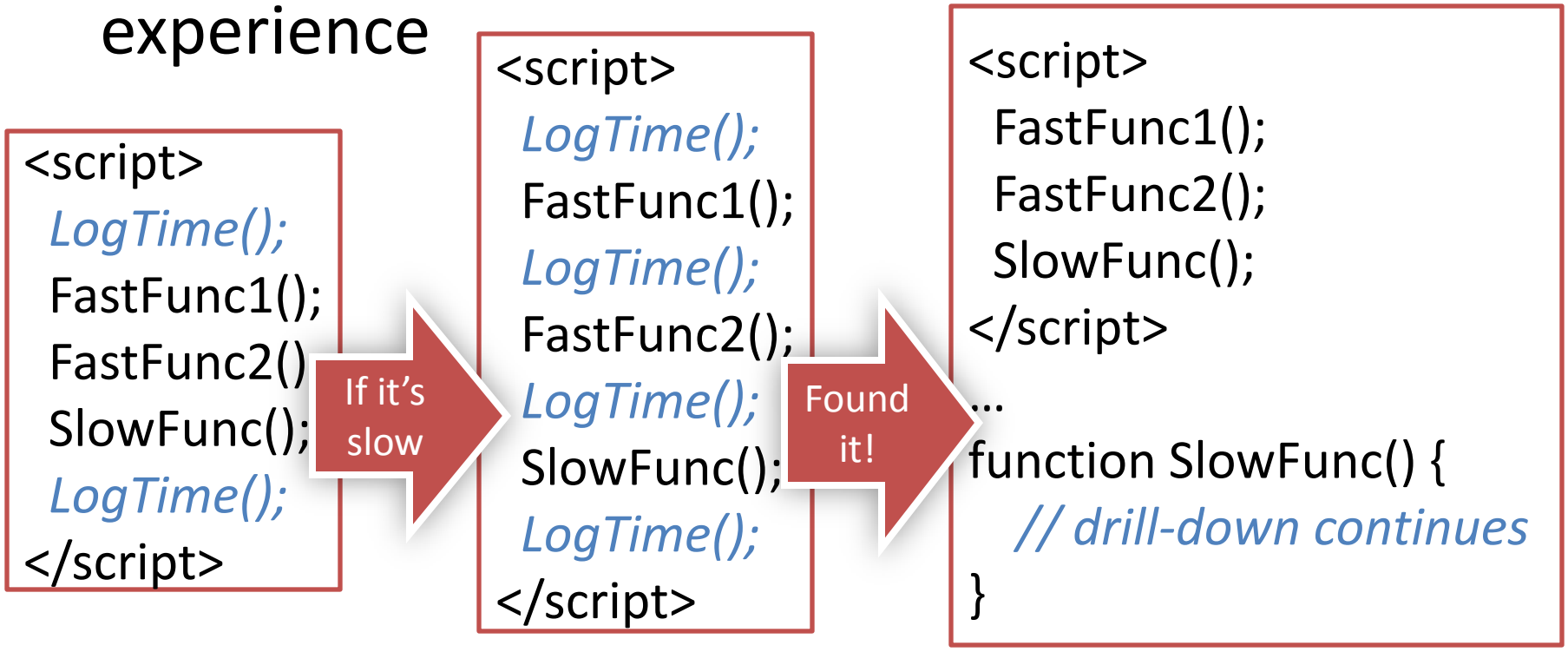
	Site	Code Size (kB)	# of Functions	Exec Time (ms)
Maps	maps.google.com	295	1935	530
	maps.live.com	924	2855	190
Portals	msn.com	124	592	300
	yahoo.com	278	1097	670
	google.com/ig	135	960	190
	protopages.com	599	1862	13780

+ 6 more JS-heavy news & game sites

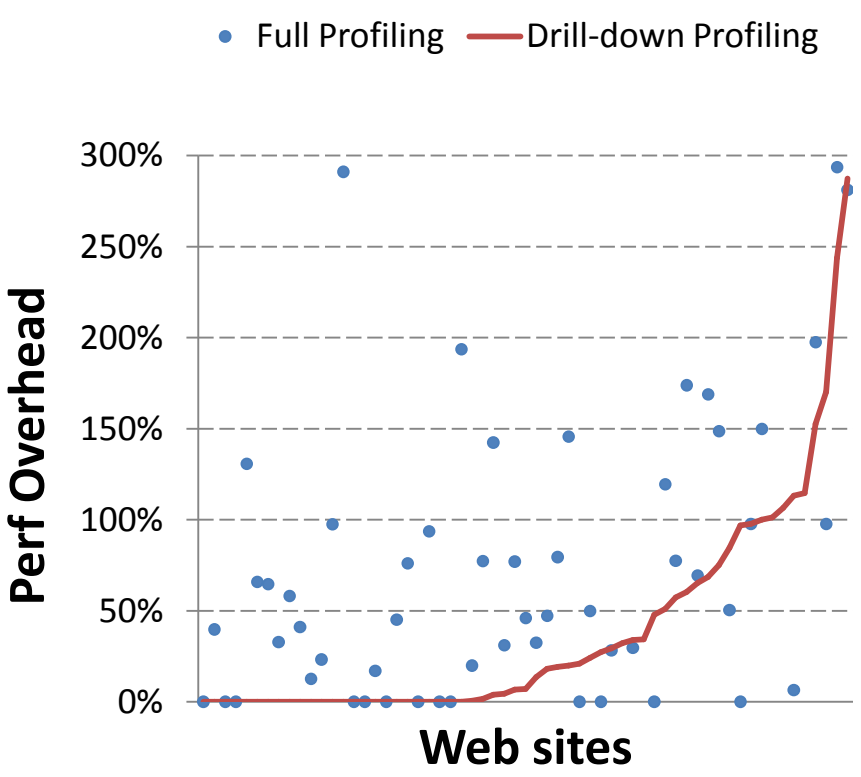
+ 78 sites randomly chosen, weighted by popularity

Adaptation: Drill-down Perf Profiling

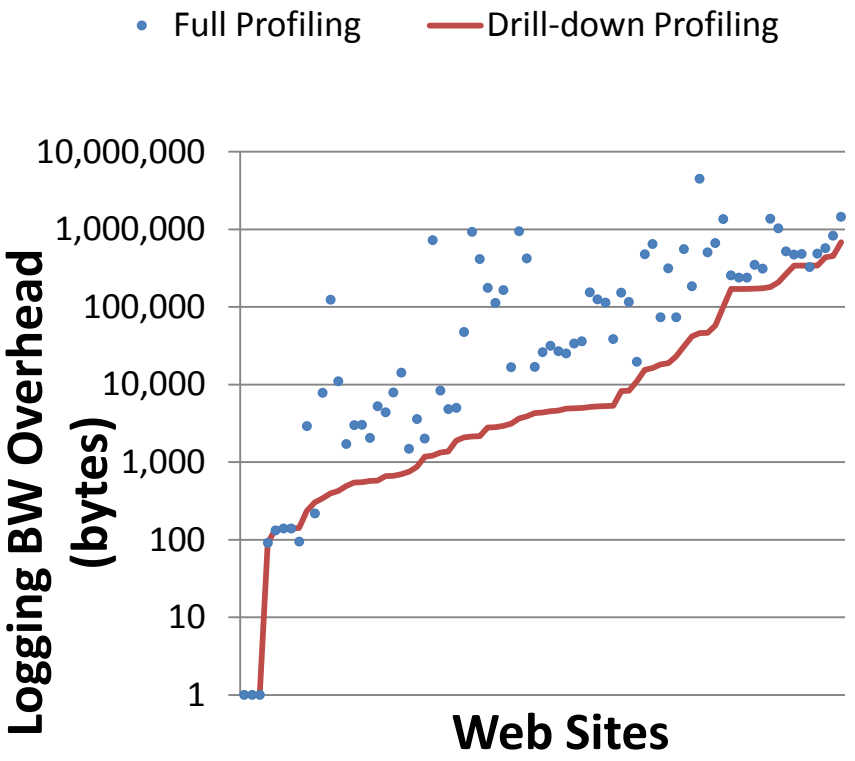
- Naïve: Add timestamps everywhere
  - Too expensive! (both CPU and logging BW)
- Instead, auto-drill-down based on user experience



Adaptation Results



Avg 30% reduction in CPU Overhead



95% Avg Reduction in Logging Bandwidth

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Monitoring for JS Memory Leaks

- Mem leaks major problem in older browsers
  - Web apps can work-around
- E.g., Circular reference across DOM + JavaScript memory heaps

- Instrumentation looks for runtime patterns indicative of leak
- Expensive! Use distribution to reduce per-user overhead

Example: CNN.com

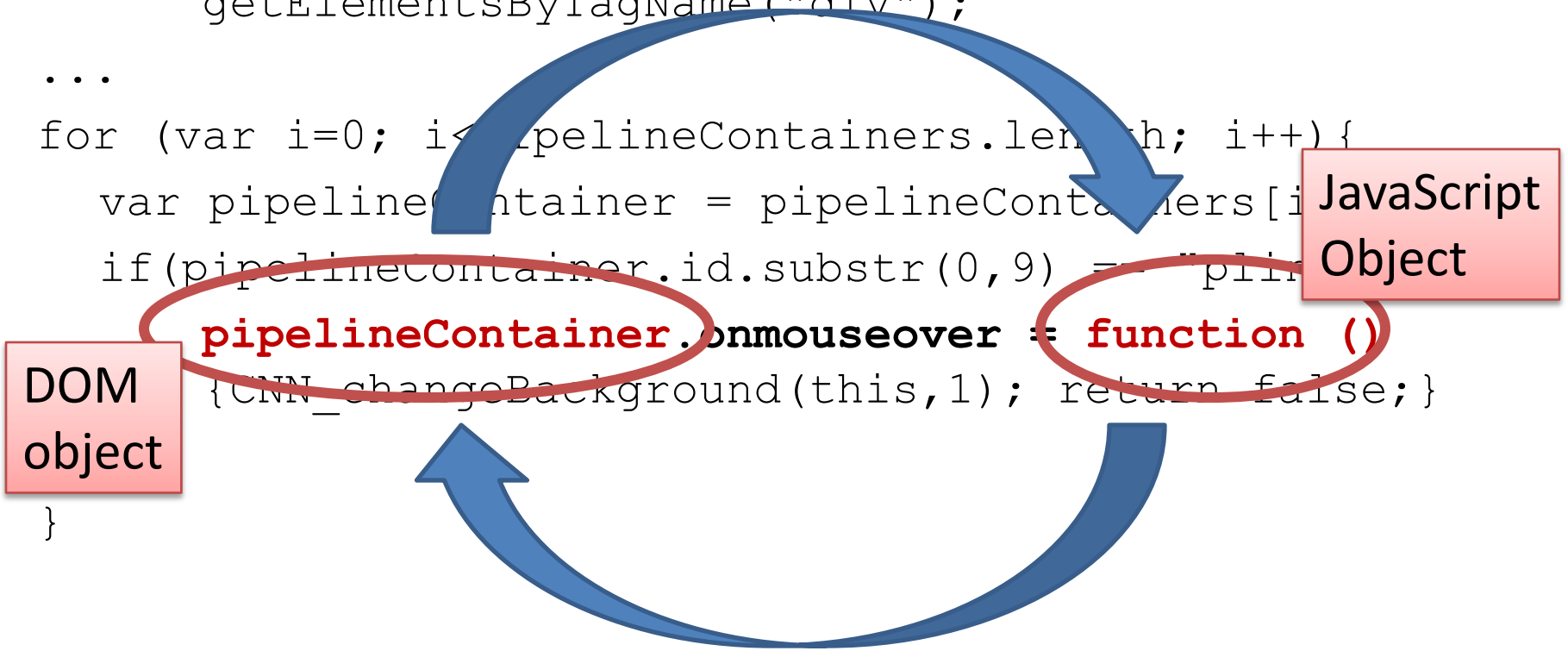
```
var pipelineContainers =
   document.getElementById("cnnPipelineMod
       getElementsByTagName("div");
...
for (var i=0; i<pipelineContainers.length; i++){
   var pipelineContainer = pipelineContainers[i];
   if(pipelineContainer.id.substr(0,9) == "plineCntr") {
       pipelineContainer.onmouseover = function ()
       {CNN_changeBackground(this,1); return false;}
   }
}
```

First, get DOM elements

Then, set their event handlers to a new function

Example: CNN.com

```
var pipelineContainers =
   document.getElementById("cnnPipelineModule").
       getElementsByTagName("div");
...
for (var i=0; i<pipelineContainers.length; i++){
   var pipelineContainer = pipelineContainers[i
   if(pipelineContainer.id.substr(0,9) == "pip
      pipelineContainer.onmouseover = function ()
      {CNN_changeBackground(this,1); return false;}
}
```

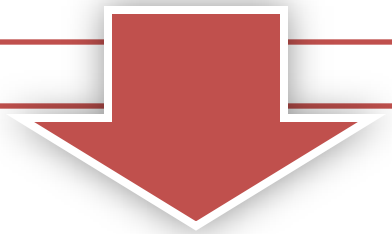


function closure references pipelineContainer

Checking for Memory Leaks

Check all object assignments for potential cycles

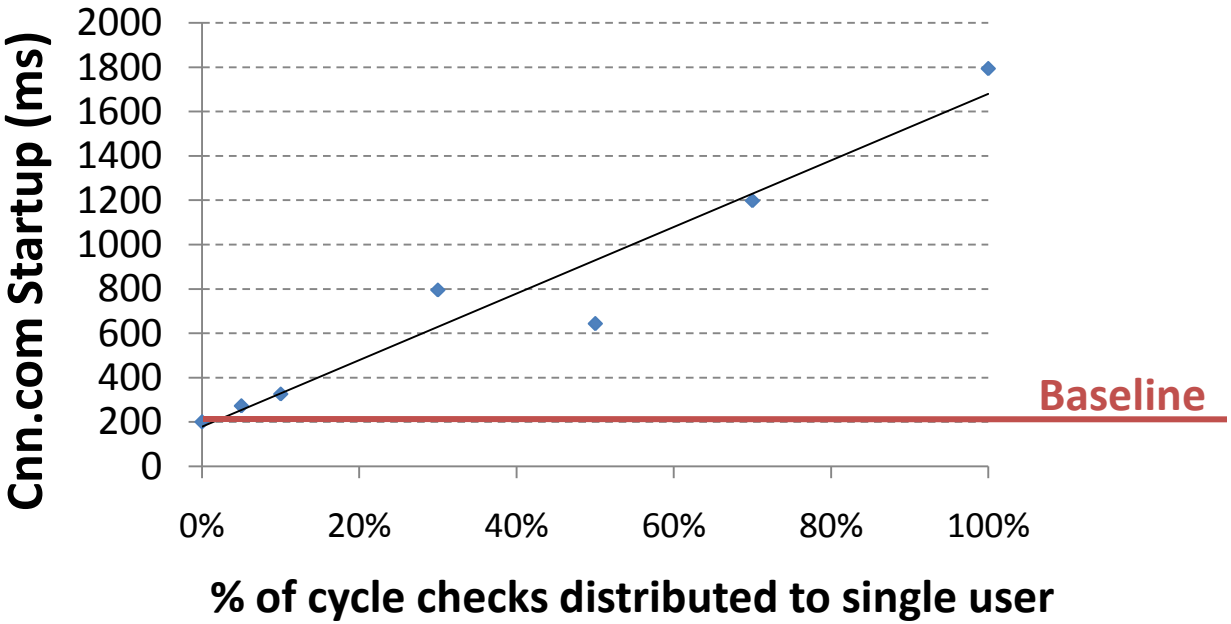
```
a.b = c;
```



```
a.b = c
TraverseHeapAndCheckForCycles(c, a);
```

- Distribute expensive traversals across users
  - Each user gets random N% of checks
  - Controls per-user overhead

Distribution Gives Fine Control of Per-User Overhead



Trade-off per-user overhead vs. detection speed

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Related Work

- JavaScript rewriting for safety & security
  - BrowserShield and CoreScript
- Monitoring and tracing systems
  - E.g., Magpie, Project5
- Dynamic and adaptive instrumentation
  - In parallel computing cluster: ParaDyn
- Runtime program analysis for bug finding
  - Statistical debugging, taint analysis, …

Future Work

- Platform improvements:
  - Integrate caching considerations into rewriting
  - Limit risk of bad rewriting with meta-monitoring
  - Improved information protection

- Collecting data and analysis:
  - Compare executions across users to find outliers
  - Collect dynamic call graphs to inform smart prefetching

Conclusions

- End-to-end visibility into client-side web app
  - Requires no client-side / server-side changes
- Distribution and adaptation controls overhead
  - While maintaining high coverage & detail
- Demonstrated variety of instrumentation policies
  - Performance profiler, memory leak checker, cache placement, …

- Download and extend the prototype
  - http://research.microsoft.com/projects/ajaxview/
  - Supports plug-ins for new instrumentation policies

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