High Performance Tor Experimentation from the Magic of Dynamic ELFs

Justin Tracey $^1$ Rob Jansen $^2$ Ian Goldberg $^1$

$^1$University of Waterloo

$^2$U.S. Naval Research Laboratory

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Tor

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High Performance Tor Experimentation from... Magic!
Why does Tor matter?

![Directly connecting users](https://metrics.torproject.org/)

The Tor Project - [https://metrics.torproject.org/](https://metrics.torproject.org/)
### Experimenting on Tor

<table>
<thead>
<tr>
<th>Commit message (Expand)</th>
<th>Author</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Merge branch 'bug23499' <strong>HEAD</strong> master</td>
<td>Nick Mathewson</td>
<td>8 hours</td>
</tr>
<tr>
<td>Rename write_http_status_line, since it does more now.</td>
<td>Nick Mathewson</td>
<td>16 hours</td>
</tr>
<tr>
<td>Make missing reason_phrase into a BUG().</td>
<td>Nick Mathewson</td>
<td>16 hours</td>
</tr>
<tr>
<td>get rid of the scary 256-byte-buf landmine</td>
<td>Roger Dingledine</td>
<td>22 hours</td>
</tr>
<tr>
<td>Make dir servers include a &quot;Date:&quot; http header more often</td>
<td>Roger Dingledine</td>
<td>22 hours</td>
</tr>
<tr>
<td>get rid of a case where we might log a NULL as %s</td>
<td>Roger Dingledine</td>
<td>26 hours</td>
</tr>
<tr>
<td>Merge branch 'maint-0.3.1'</td>
<td>Nick Mathewson</td>
<td>12 hours</td>
</tr>
<tr>
<td>Merge branch 'maint-0.3.0' into maint-0.3.1 <strong>maint-0.3.1</strong></td>
<td>Nick Mathewson</td>
<td>12 hours</td>
</tr>
<tr>
<td>Merge branch 'maint-0.2.9' into maint-0.3.0 <strong>maint-0.3.0</strong></td>
<td>Nick Mathewson</td>
<td>12 hours</td>
</tr>
<tr>
<td>Merge branch 'maint-0.2.8' into maint-0.2.9 <strong>maint-0.2.9</strong></td>
<td>Nick Mathewson</td>
<td>12 hours</td>
</tr>
<tr>
<td>version bump: 0.2.8.15 <strong>maint-0.2.8</strong></td>
<td>Nick Mathewson</td>
<td>12 hours</td>
</tr>
<tr>
<td>version bump: 0.2.9.12</td>
<td>Nick Mathewson</td>
<td>12 hours</td>
</tr>
<tr>
<td>version bump: 0.3.0.11</td>
<td>Nick Mathewson</td>
<td>12 hours</td>
</tr>
<tr>
<td>Remove changes files for items already in release-0.3.1</td>
<td>Nick Mathewson</td>
<td>12 hours</td>
</tr>
<tr>
<td>Merge branch 'maint-0.3.1'</td>
<td>Nick Mathewson</td>
<td>15 hours</td>
</tr>
<tr>
<td>Merge branch 'maint-0.3.0' into maint-0.3.1</td>
<td>Nick Mathewson</td>
<td>15 hours</td>
</tr>
<tr>
<td>entrynodes.c: fix syntax error around BUG() statement</td>
<td>Martin Kepplinger</td>
<td>15 hours</td>
</tr>
</tbody>
</table>
Experimenting on Tor Safely

“1. Use a test Tor network whenever possible.”

—Tor Research Safety Board guidelines
Available Options

- Deployed Networks (e.g., PlanetLab)
- Emulators (e.g., NetMirage)
- Simulators (e.g., ns-3)
- Hybrids (e.g., DCE, Shadow)
Shadow real applications, simulated networks

an open-source network simulator/emulator hybrid

runs real applications like Tor and Bitcoin over a simulated Internet topology

light-weight, efficient, scalable, parallelized, controllable, deterministic, accurate, modular, and more!
Discrete-Event Network Simulation

![Simulation Diagram]

Host 1

Host 2

...

Host m

Simulation time

Rounds
Performance Constraints in Shadow

- Logging
- Loading and running plugins
- No compiler optimizations
- Load Balancing
Performance Constraints in Shadow

- Logging
- Loading and running plugins
- No compiler optimizations
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Logging Performance

![Graph showing the comparison between original and no logging performance over simulation time.

- **Y-axis:** Real Time (h)
- **X-axis:** Simulation Time (m)

- **Original** line
- **No logging** line

The graph illustrates that the real-time performance deteriorates significantly with logging enabled, especially as the simulation time increases.
Performance Constraints in Shadow

- Logging
- Loading and running plugins
- No compiler optimizations
- Load Balancing
Changing Hosts

- Plugin Code
- Active Data
- Plugin Data 1
- Plugin Data 2
- Plugin Data 3
Changing Hosts

Plugin Code

Active Data

Plugin Data 1

Plugin Data 2

Plugin Data 3
Changing Hosts

Plugin Code

Active Data

Plugin Data 1

Plugin Data 2

Plugin Data 3
Lock on Libraries

Library Code

Library Data

links to

Plugin Code

Active Data
The New Design: drow-loader

Namespace 1

Library Code

Library Data 1

Plugin Code

Plugin Data 1

links to

Namespace 2

Library Code

Library Data 2

Plugin Code

Plugin Data 2

links to

Namespace 3

Library Code

Library Data 3

Plugin Code

Plugin Data 3

links to
drow-loader: Memory Overhead

Namespace 1

Library Code

Library Data 1

links to

Plugin Code

Plugin Data 1

Namespace 2

Library Data 2

links to

Plugin Data 2

Namespace 3

Library Data 3

links to

Plugin Data 3
Performance Constraints in Shadow

- Logging
- Loading and running plugins
- No compiler optimizations
- Load Balancing
Time Spent Blocked Per Thread

```
+----------------+----------------+
|                |                |
| elapsed time   | thread 1-6     |
|                | blocked time   |
+----------------+----------------+
| 0              | 0              |
| 10             | 20             |
| 20             | 40             |
| 30             | 60             |
| 40             | 80             |
```

Simulation Time (m)
Real Time (m)

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Problems in Shadow: No Host Migration

thread1:plugin1

thread2:plugin1

Code

Code

data
Problems in Shadow: No Host Migration

thread1:plugin1

```
int x = 0;
```

```
void* ptr = &x;
```

data

thread2:plugin1

```
?
```
Problems in Shadow: No Host Migration

thread1:plugin1

Code

int ? = ?;

thread2:plugin1

Code

int x = 0;

void* ptr = &x;
drow-loader: Memory Overhead

Namespace 1

Library Code

Library Data 1

links to

Plugin Code

Plugin Data 1

Namespace 2

Library Code

Library Data 2

links to

Plugin Code

Plugin Data 2

Namespace 3

Library Code

Library Data 3

links to

Plugin Code

Plugin Data 3
Time Spent Blocked Per Thread

![Graph showing the time spent blocked per thread over simulation time](image)
Time Spent Blocked Per Thread
Small Tor Experiment: 268 Hosts

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Small Tor Experiment: 268 Hosts

Simulation Time (hh:mm:ss)
0
25
50
75
100
125
150

Real Time (minutes)
0
25
50
75
100
125
150

Original
Logging
Loading
Scheduling

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Large Tor Experiment: 22,499 Hosts

Diagram showing simulation time versus real time for different processes:
- original
- logging
- loading
- scheduling

Simulation Time (hh:mm:ss):
- 00:00:00
- 00:16:40
- 00:33:20
- 00:50:00

Real Time (hours):
- 0
- 10
- 20
- 30
- 40
- 50
- 60

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Takeaways

- Tor requires realistic constructed networks for testing
- Shadow provides this, but suffered from performance constraints
- We were able to analyze and address these constraints
  - up to 31% improvement in synthetic benchmarks
  - up to 73% improvement in Tor experiments
- Our changes were merged upstream and are available in Shadow now

shadow.github.io