Noncespaces: Using Randomization to Enforce Information Flow Tracking and Thwart Cross-Site Scripting Attacks

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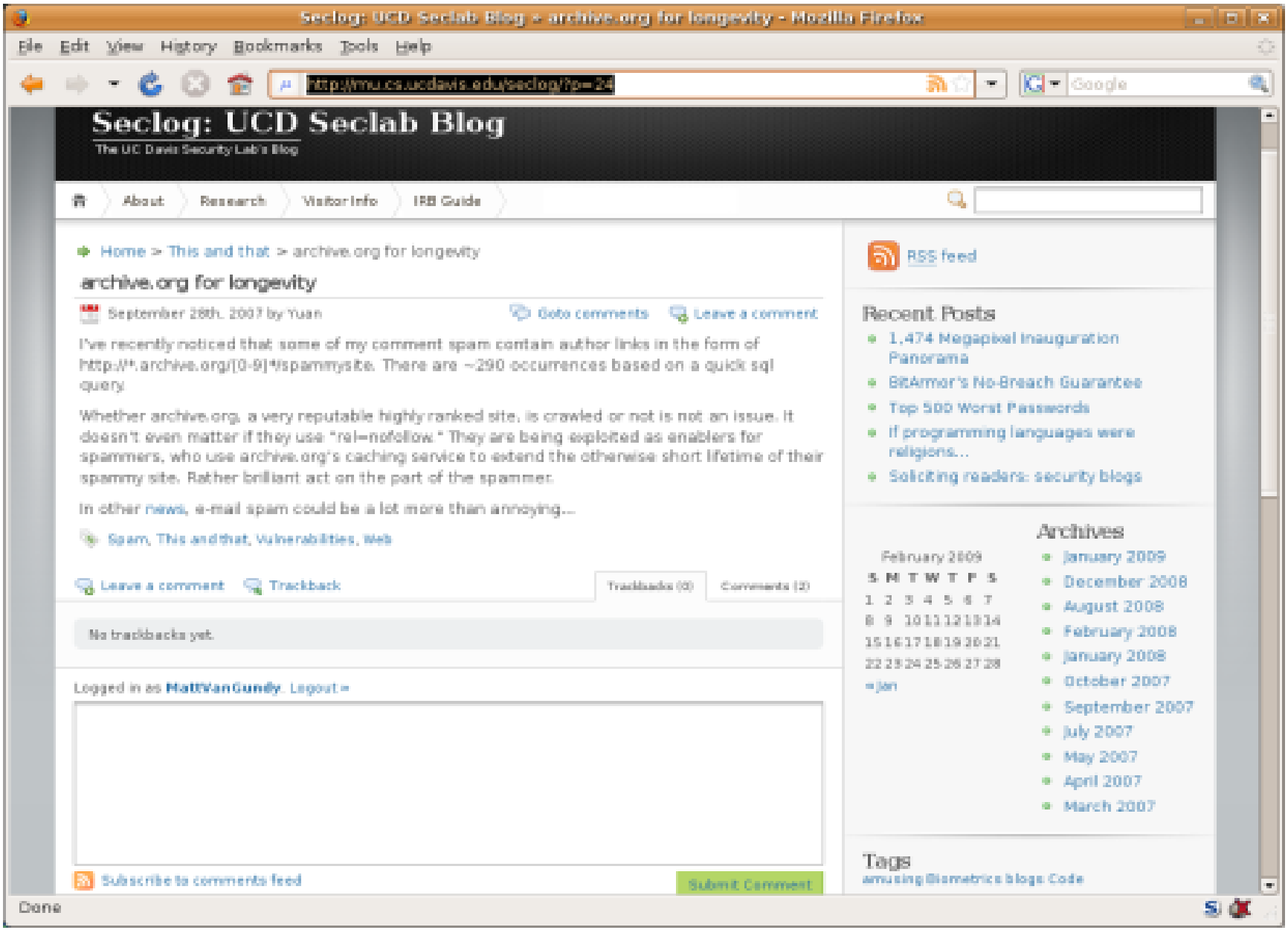
16th Annual Network & Distributed System Security Symposium

Cross-Site Scripting (XSS) Vulnerabilities



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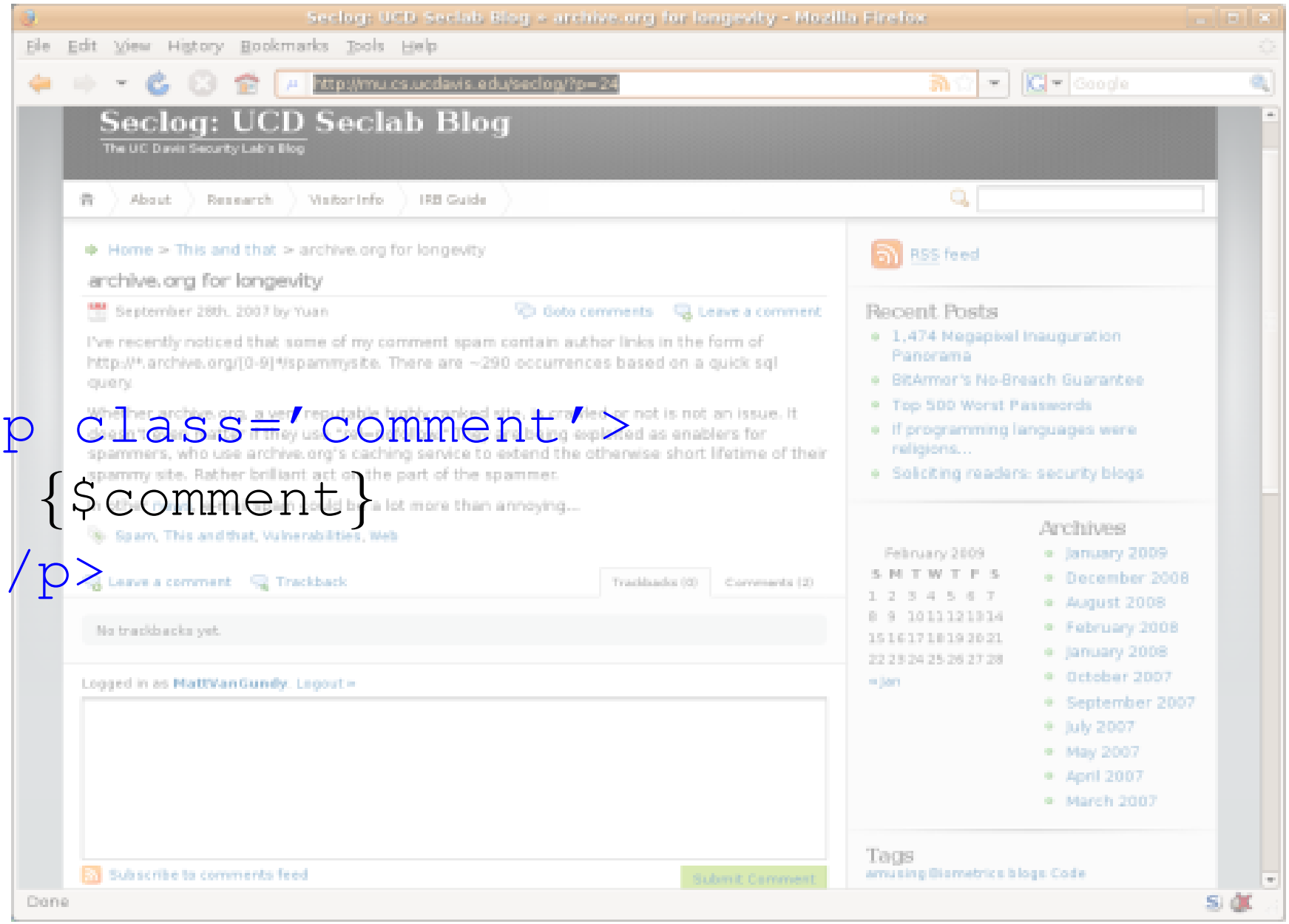

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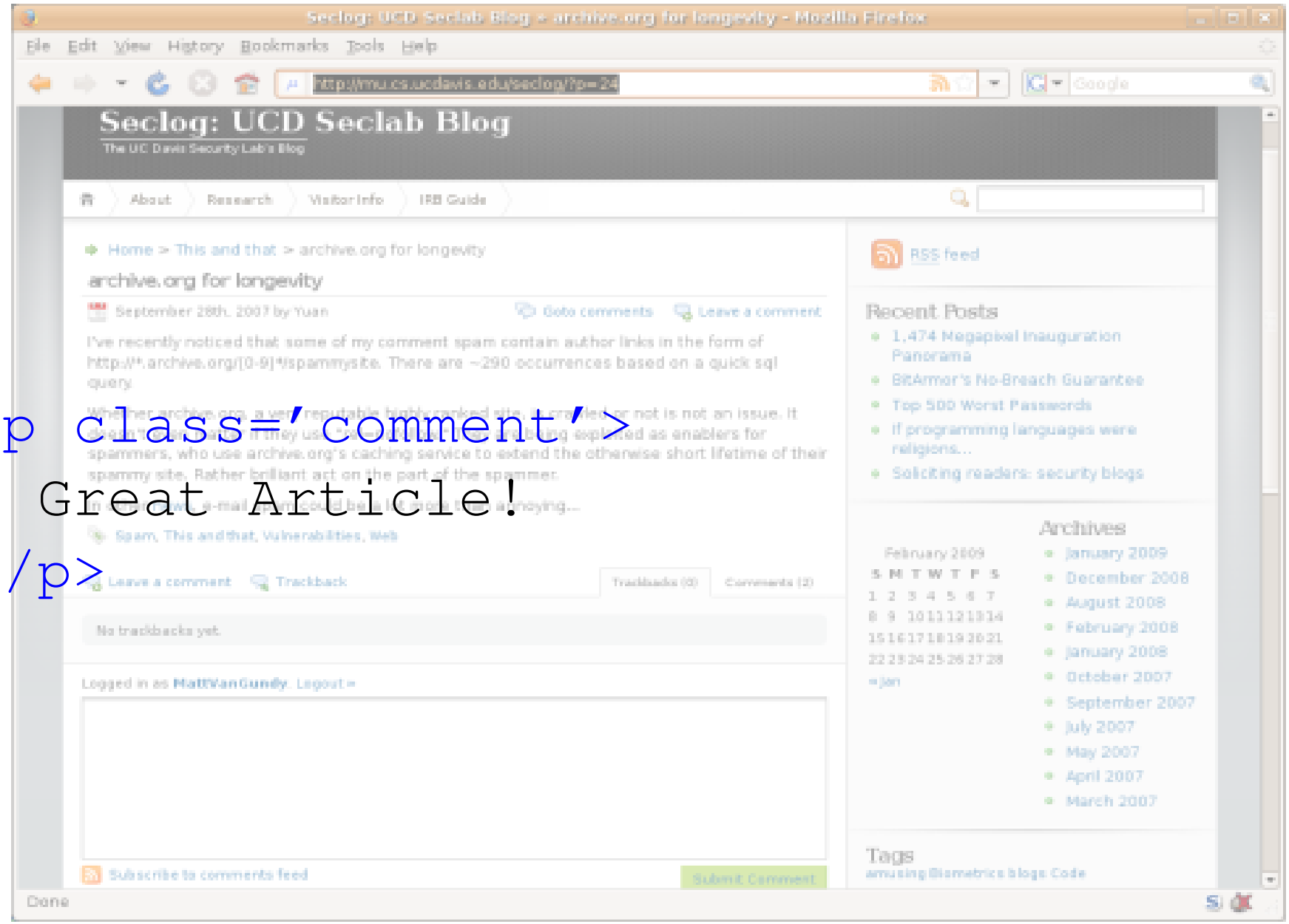
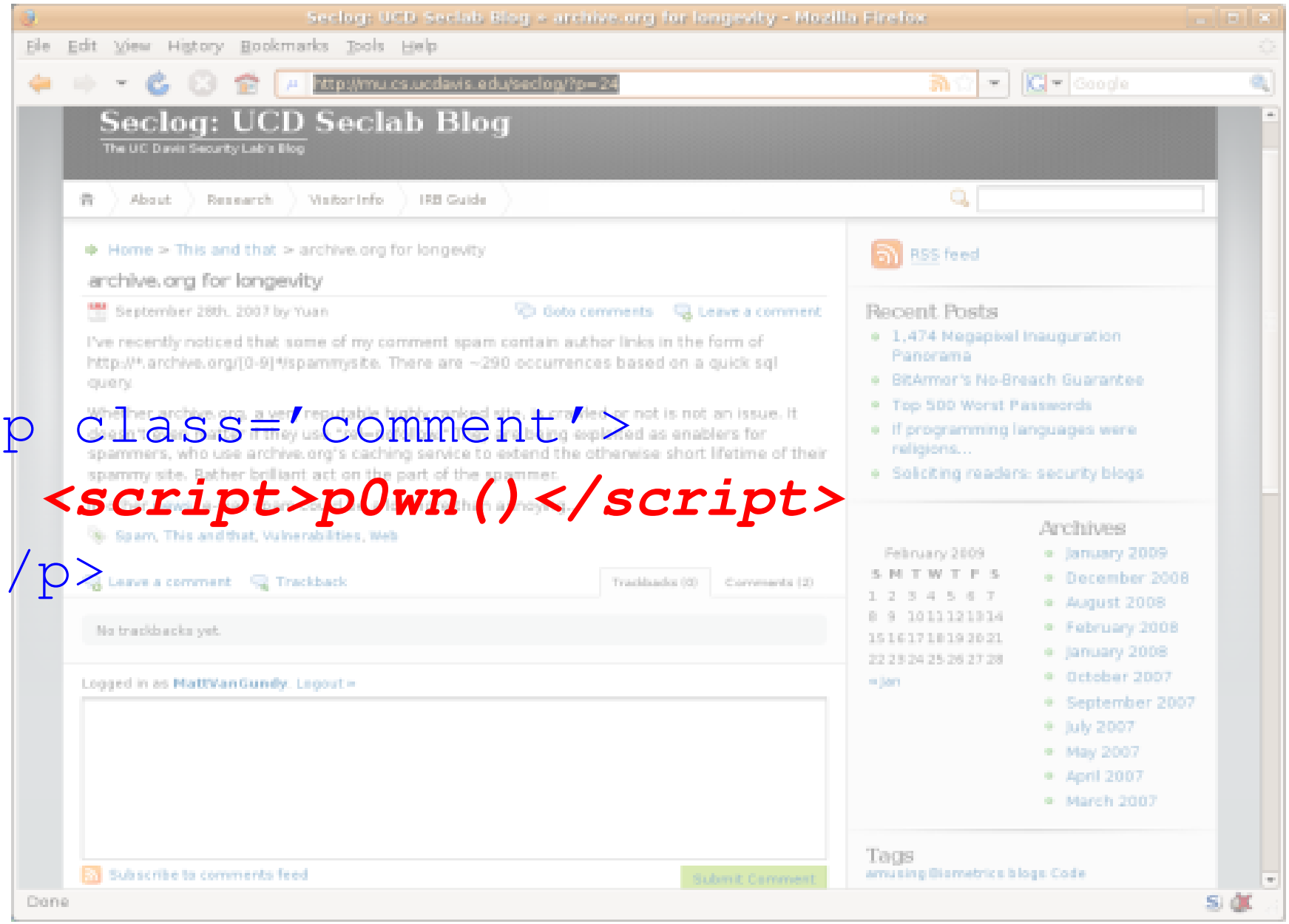



```
<p class='comment'>
  Great Article!
</p>
```

Cross-Site Scripting (XSS) Vulnerabilities



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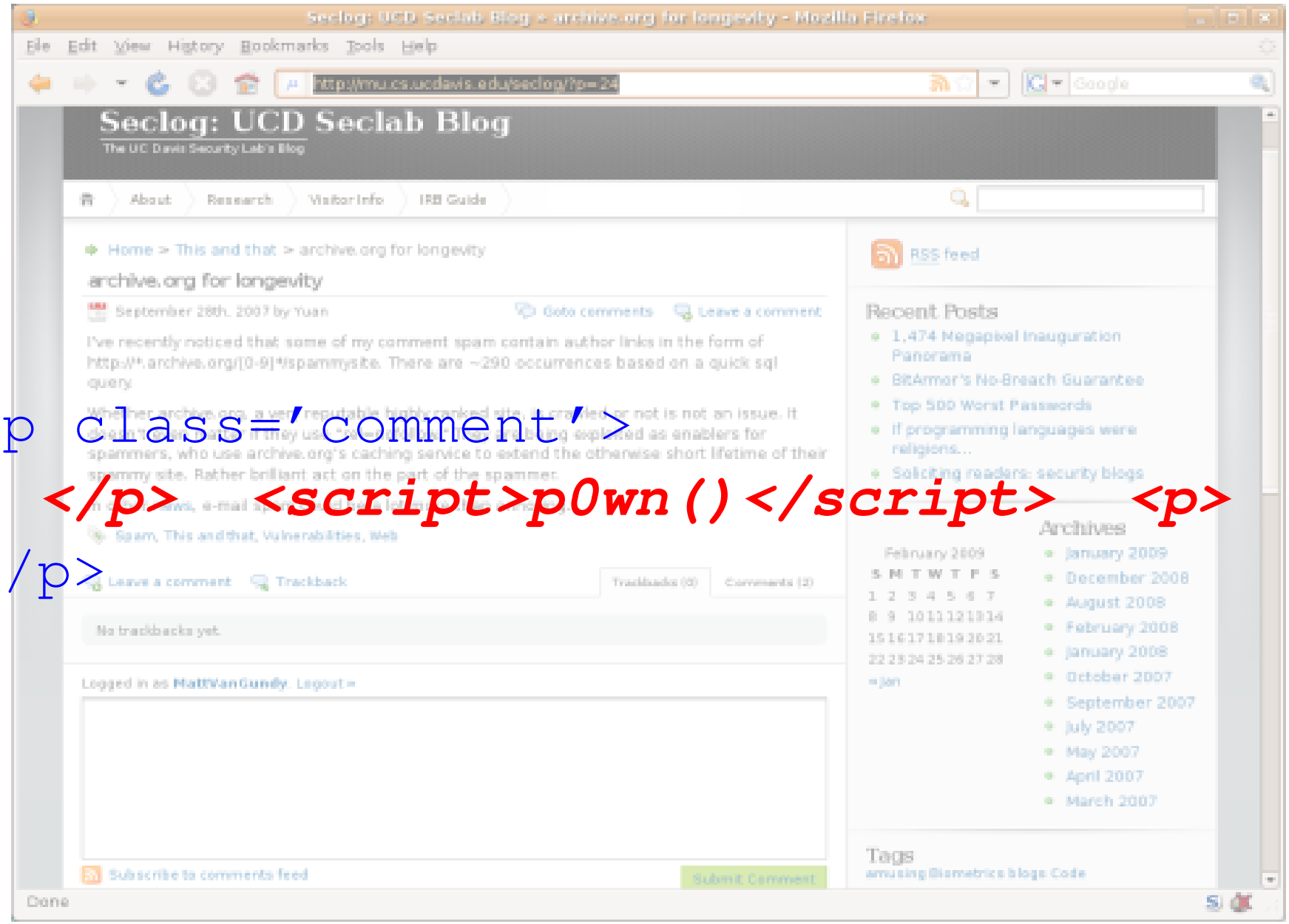



```
<p class='comment'>
  </p> <script>p0wn()</script>  <p>
</p>
```

Threat Model

- An attacker can submit arbitrary content to XSS-vulnerable applications
- An attacker cannot compromise web server or browser directly
- Malicious content must contain XHTML tags and attributes

Limitations of Existing Solutions

Server-side

- Server *sanitizes* untrusted data before sending it to the client
- Client may interpret data in an unexpected way
- E.g. Server replaces `"<script>"` with `""`
  But attacker injects `<script/xss>`

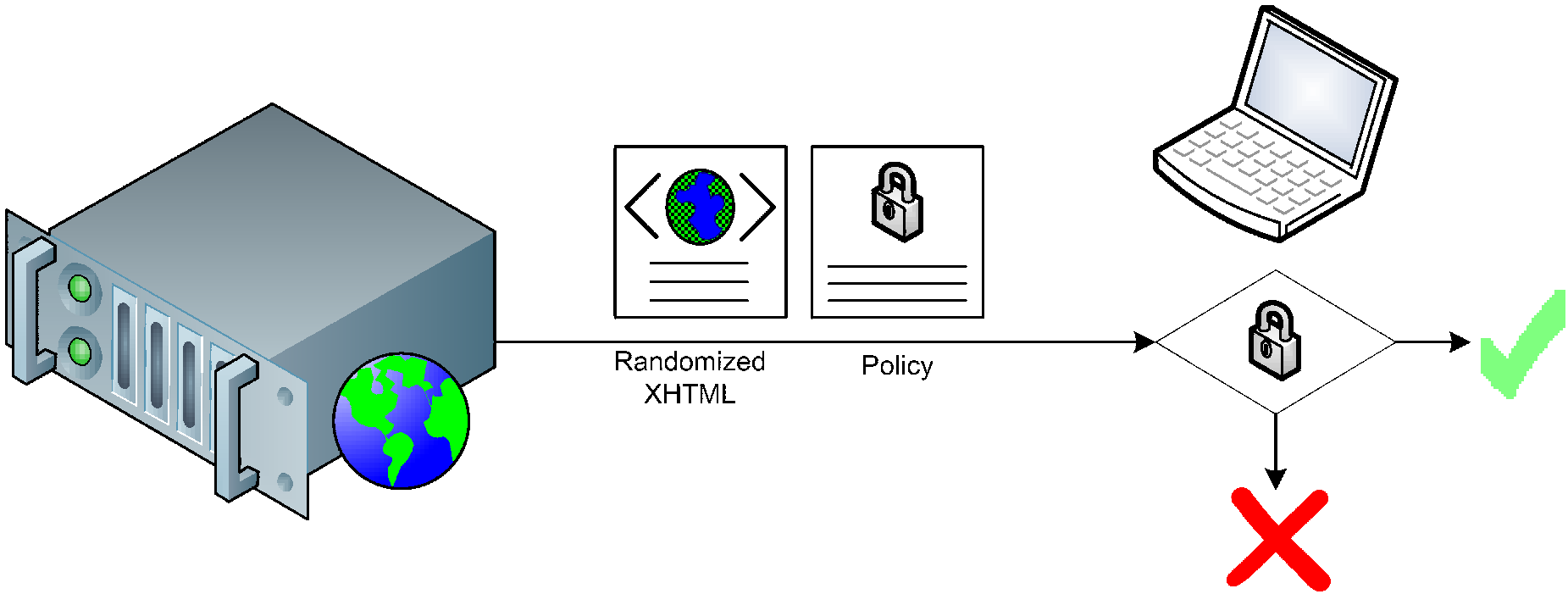
Client-side

- Client enforces a server-specified policy

Challenges

- The client must know whether to trust content
- Attacker must not be able to forge trust metadata

Noncespaces Architecture



- Server partitions content into *trust classes*
- Server randomizes document to prevent forging of trust classification
- Server specifies policy of content permitted for each trust class
- Client displays the document only if it conforms to the policy

Namespaces in XML

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- `<x:q xmlns:x="http://www.w3.org/1999/xhtml">`

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- `<`x`:`q `xmlns:x="`http://www.w3.org/1999/xhtml`">`
  (x: prefix; http://www.w3.org/1999/xhtml: NamespaceURI)

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Defeating Node Splitting

- `<x:a>...</x:a>`

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Encoding Trust Classifications

- Trusted `<a>`

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- Trusted `<a>` ⇒ `<t:a>`

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- Trusted `<a>` ⇒ `<t:a>`
- Untrusted `<a>`

Encoding Trust Classifications

- Trusted `<a>` $\Rightarrow$ `<t:a>`
- Untrusted `<a>`
- Randomly choose trusted prefixes to prevent forgery

Web Page Before Noncespaces

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.1//EN"
    "http://www.w3.org/TR/xhtml11/DTD/xhtml11.dtd">
<html xmlns="http://www.w3.org/1999/xhtml">

<head>
  <title>nile.com : ++Shopping</title>
</head>
<body>
<h1 id="title">{$item->name}</h1>

<h2>Reviews</h2>
<p class='review'>
  {$review}
</p>
</body>
</html>
```

Node Splitting Attack After Noncespaces

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.1//EN"
    "http://www.w3.org/TR/xhtml11/DTD/xhtml11.dtd">
<r617:html xmlns="http://www.w3.org/1999/xhtml"
    xmlns:r617="http://www.w3.org/1999/xhtml">
<r617:head>
  <r617:title>nile.com : ++Shopping</r617:title>
</r617:head>
<r617:body>
<r617:h1 r617:id="title">Useless Do-dad</r617:h1>

<r617:h2>Reviews</r617:h2>
<r617:p r617:class='review'>
  </p>  <script>p0wn()</script>  <p>
</r617:p>
</r617:body>
</r617:html>
```

XSS Attack After Noncespaces

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.1//EN"
    "http://www.w3.org/TR/xhtml11/DTD/xhtml11.dtd">
<r617:html xmlns="http://www.w3.org/1999/xhtml"
    xmlns:r617="http://www.w3.org/1999/xhtml">
<r617:head>
  <r617:title>nile.com : ++Shopping</r617:title>
</r617:head>
<r617:body>
<r617:h1 r617:id="title">Useless Do-dad</r617:h1>

<r617:h2>Reviews</r617:h2>
<r617:p r617:class='review'>
  <script src='http://badguy.com/p0wn.js' />
</r617:p>
</r617:body>
</r617:html>
```

Need for a client-side policy

Innocuous Input

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<b>WARNING:</b>
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<a href='http://useful.com/'>[1]</a>
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Malicious Input

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<b onmouseover='...'>WARNING:</b>
```

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<em>very</em> important

<a href='http://useful.com/'>[1]</a>
```

Malicious Input

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<b onmouseover='...'>WARNING:</b>

<em onclick='...'>very</em> important
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Innocuous Input

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<b>WARNING:</b>
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<a href='http://useful.com/'>[1]</a>
```

Malicious Input

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<b onmouseover='...'>WARNING:</b>
<em onclick='...'>very</em> important
<a href='javascript:...'>[1]</a>
```

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XHTML

```
<b>

<em>

<a href='http:...'>
```

Policy

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XHTML	Policy
`<b>`	`allow //untrusted:b`
`<em>`	
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Determining Trusted Content

- Design patterns separate presentation and business logic
- Templates contain static HTML (presentation)

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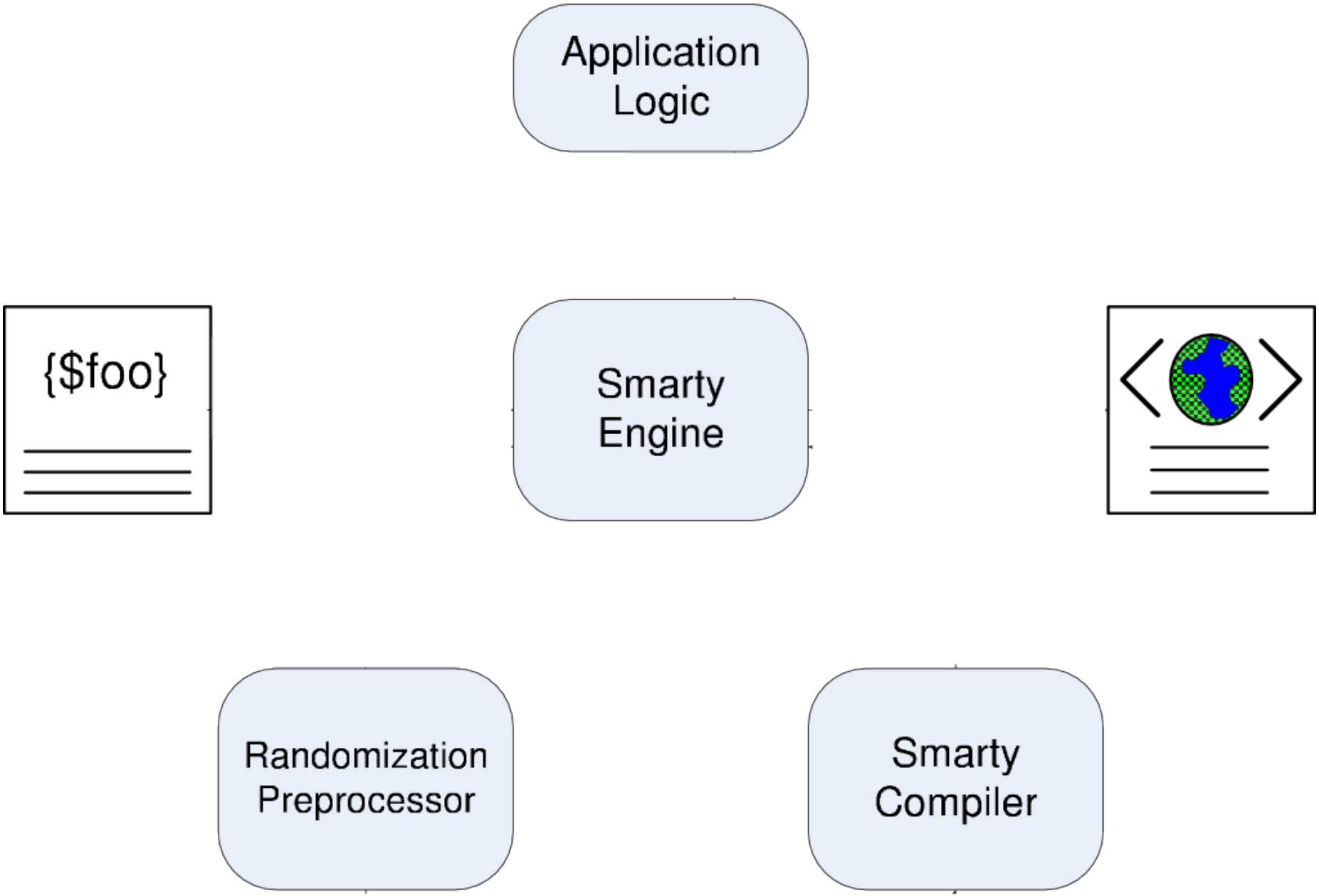
- Templates contain static HTML (presentation)
  - Classify as trusted
- Program creates dynamic content from user input
  - Classify as untrusted

Modifications to Smarty



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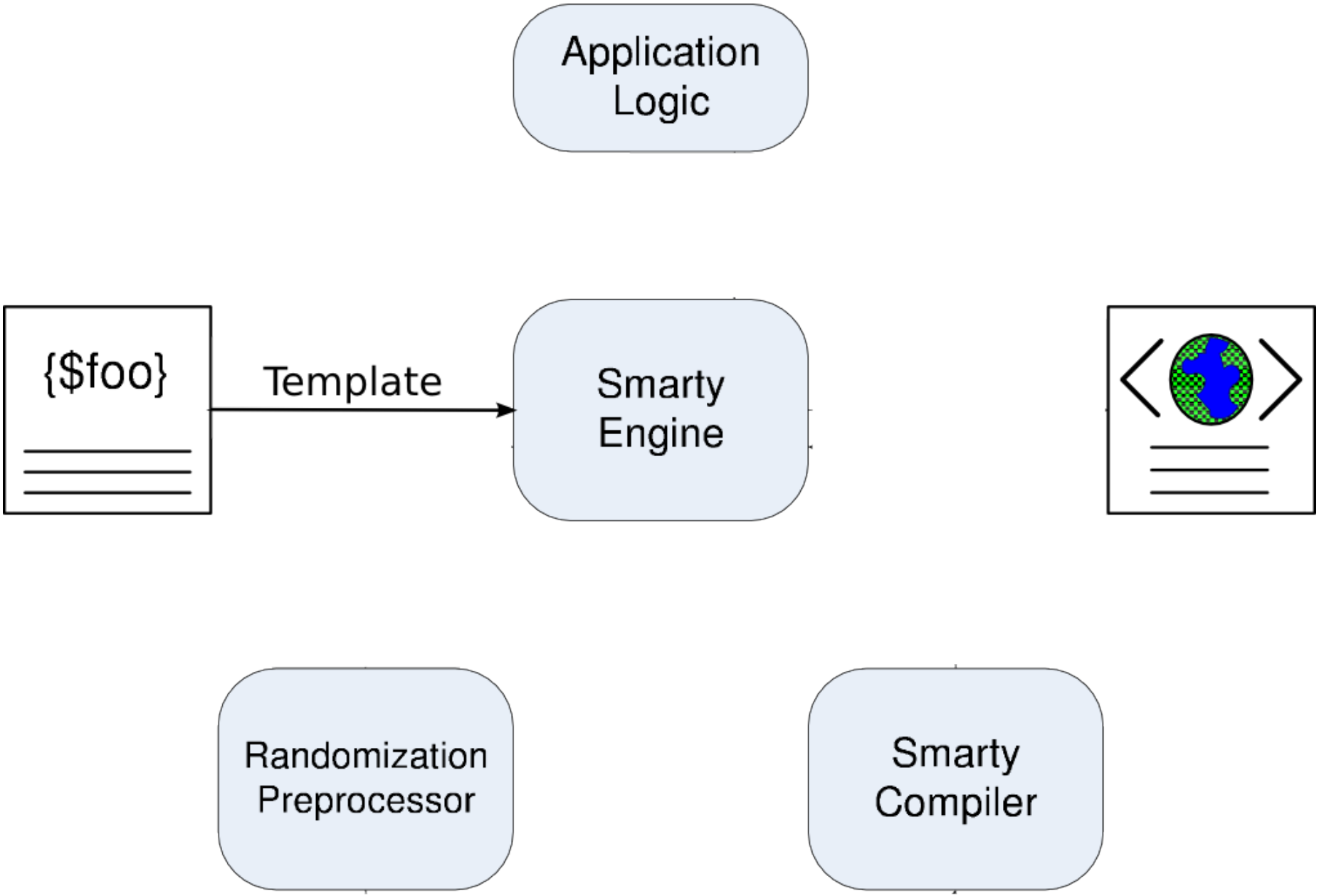

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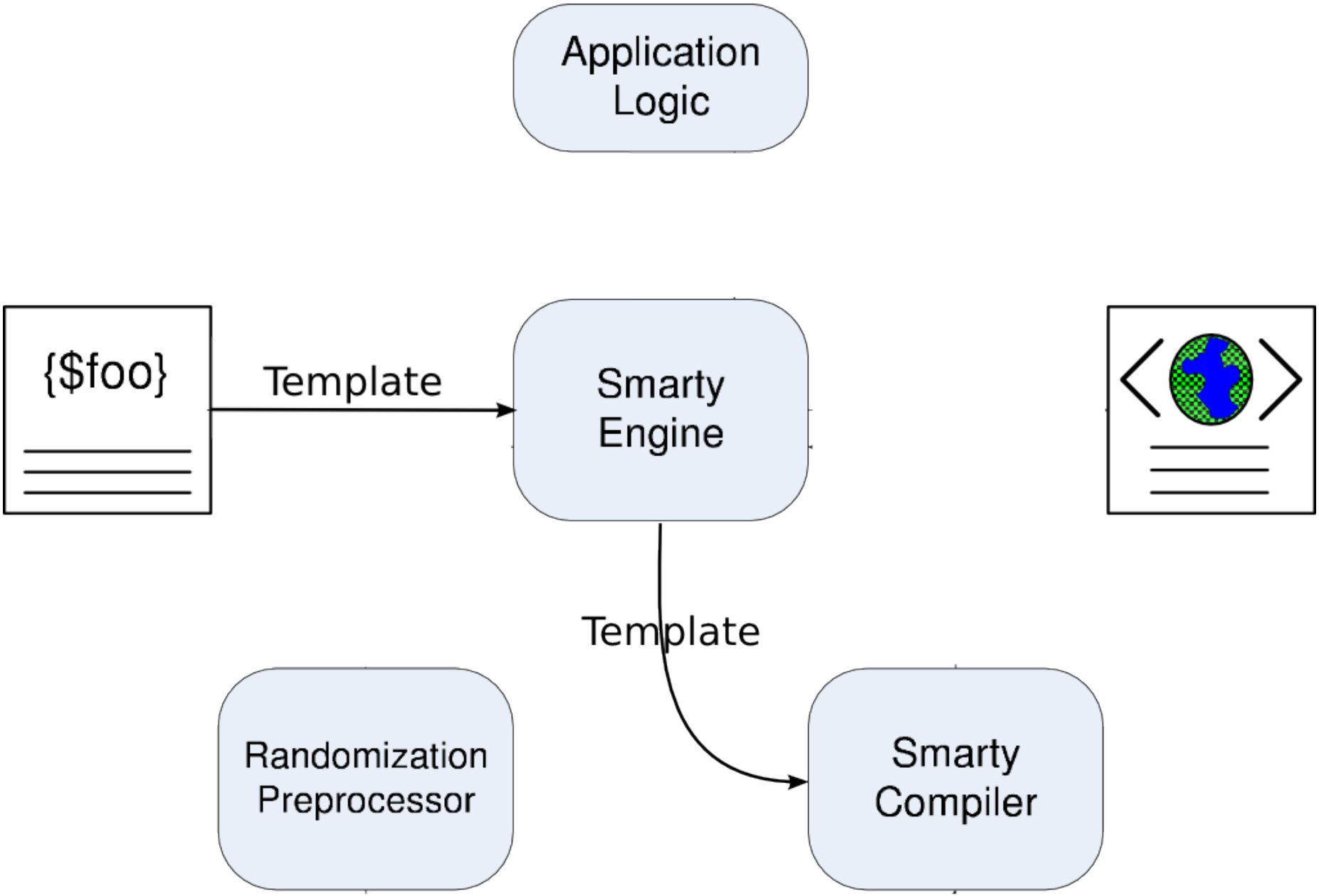

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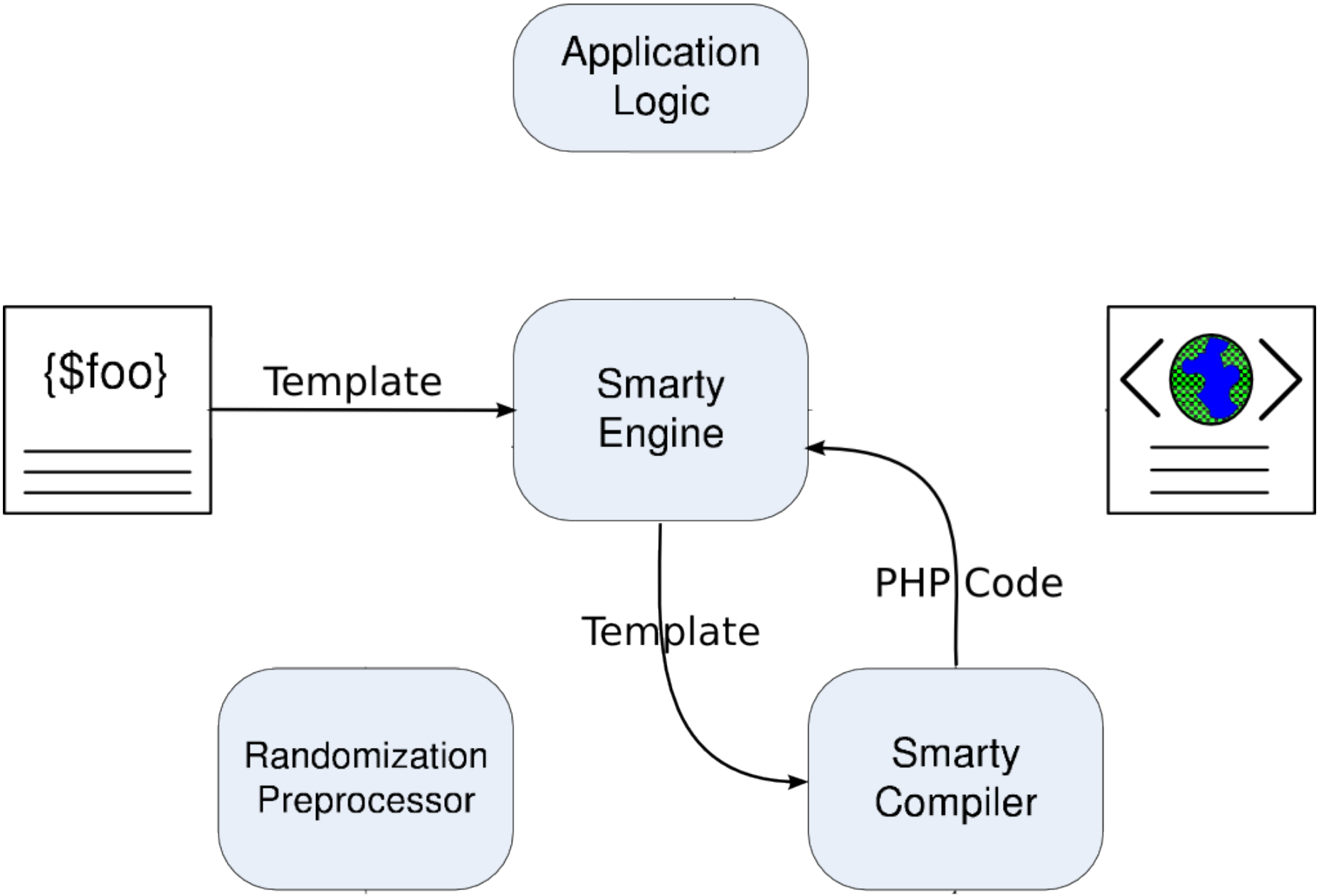

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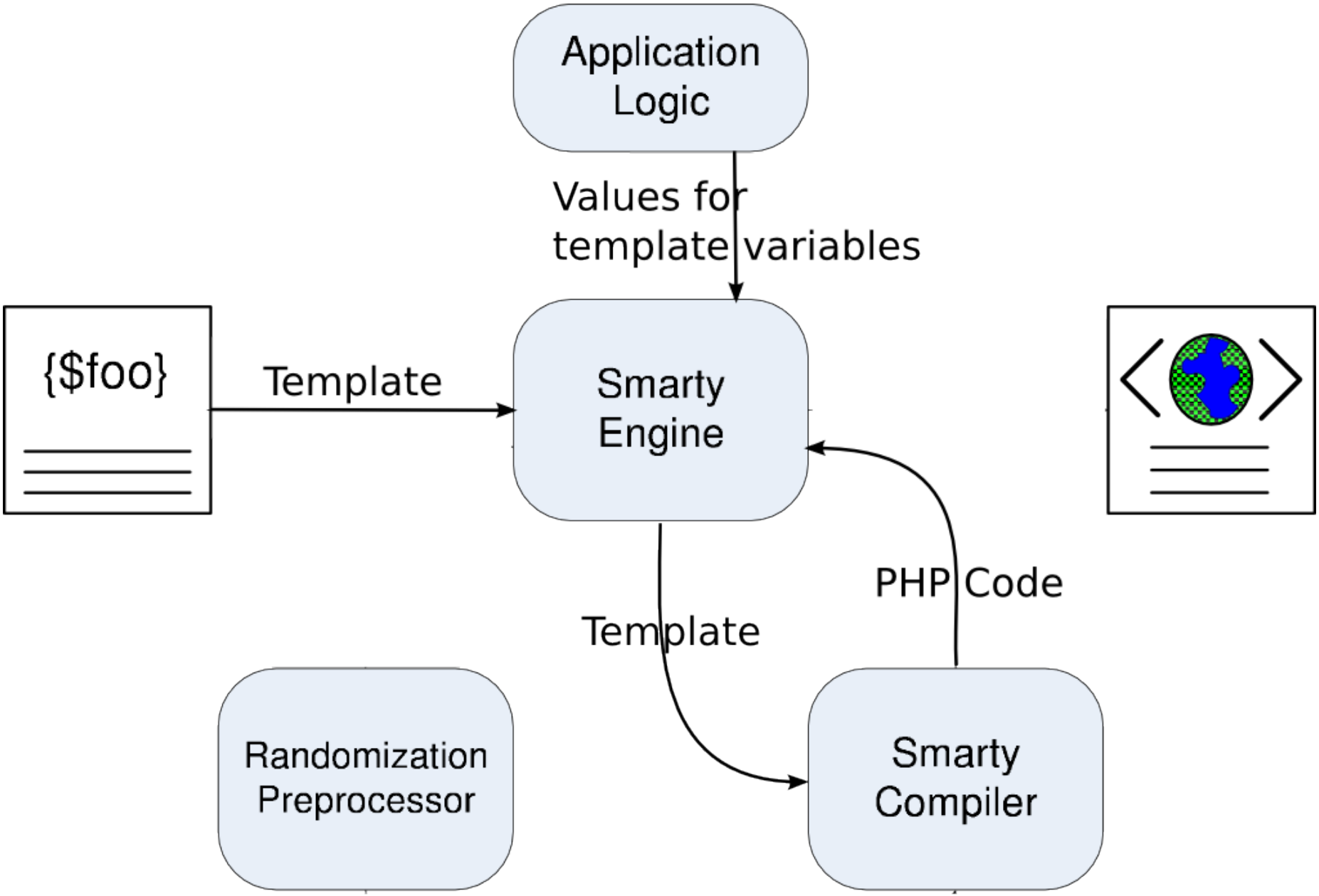

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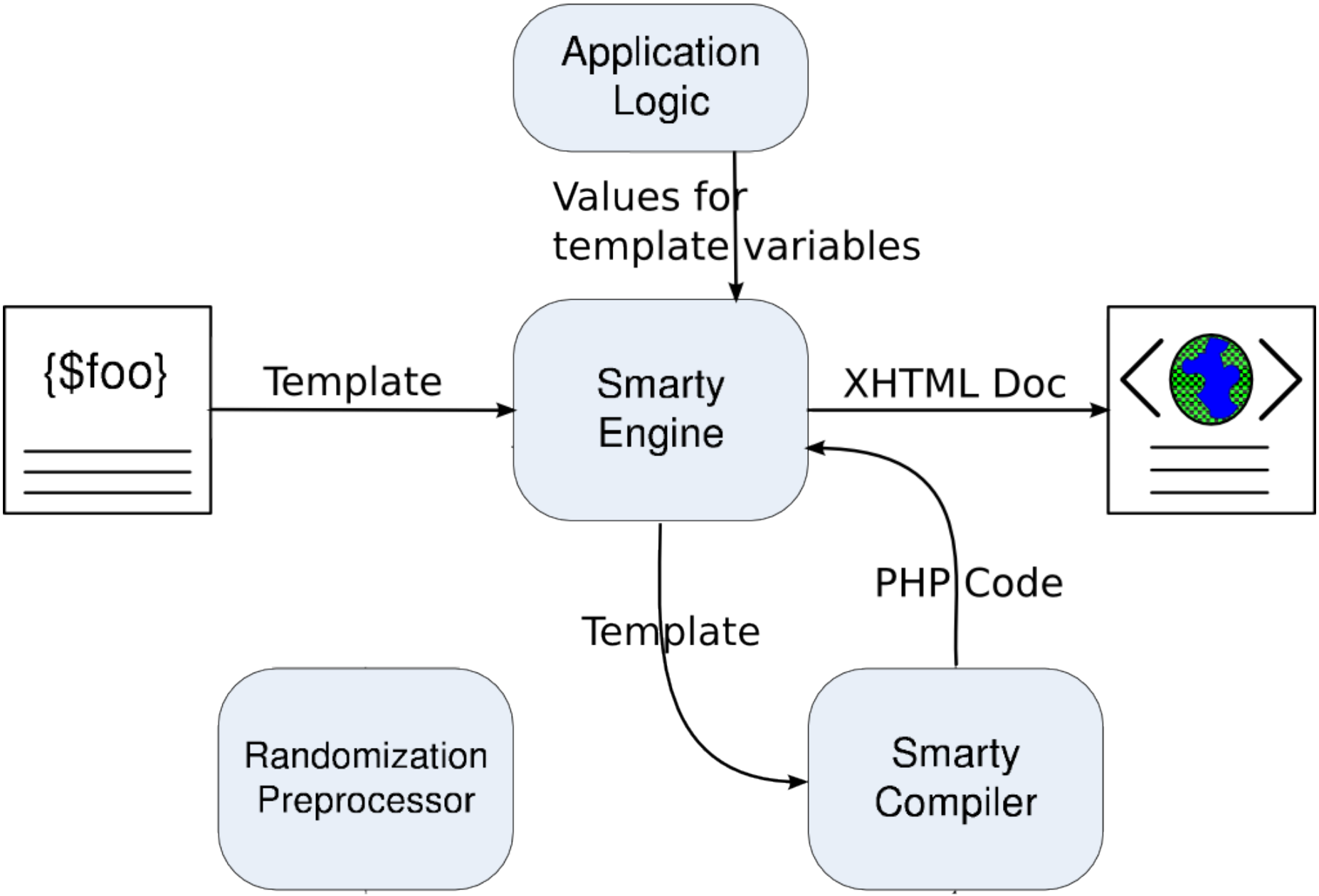

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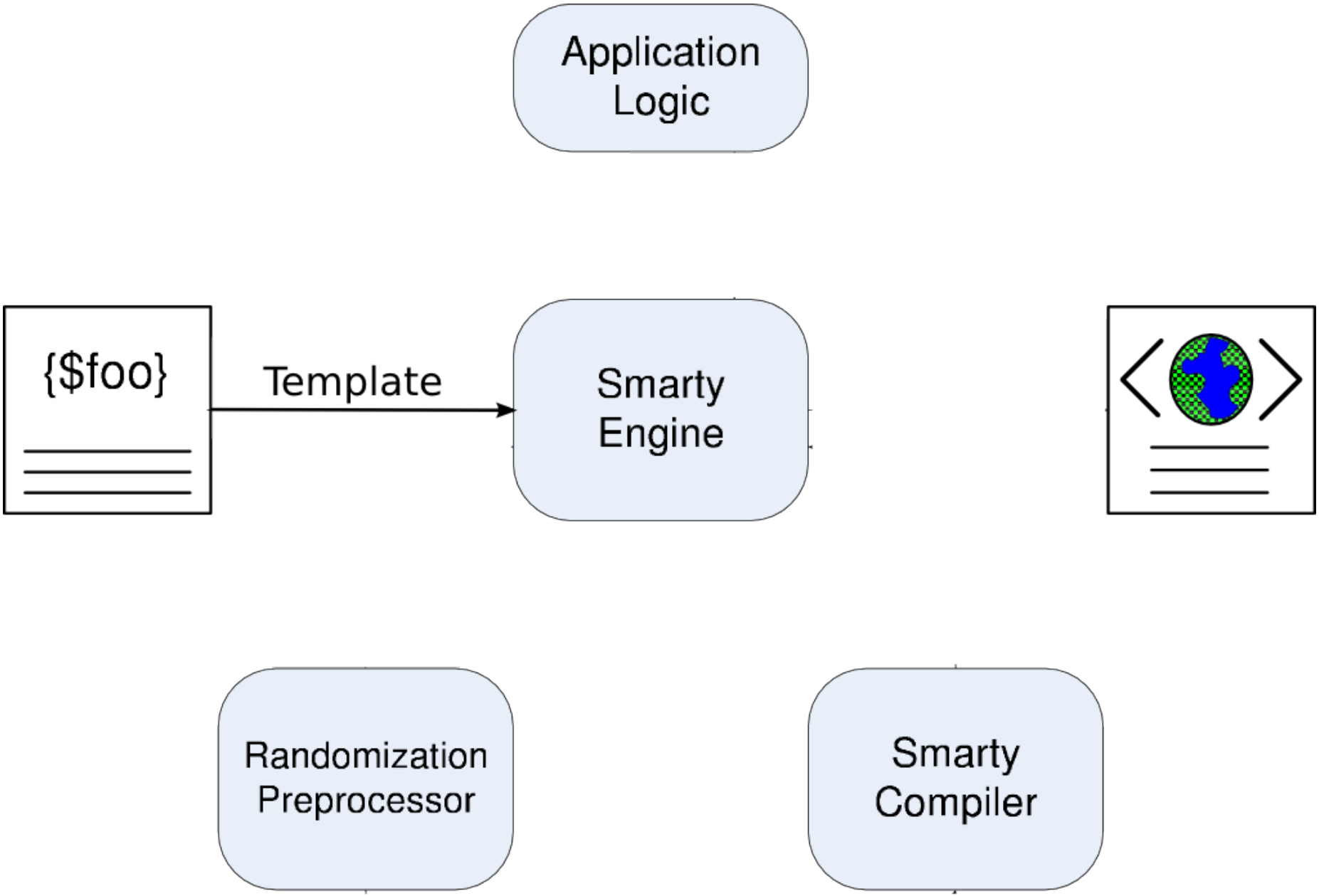

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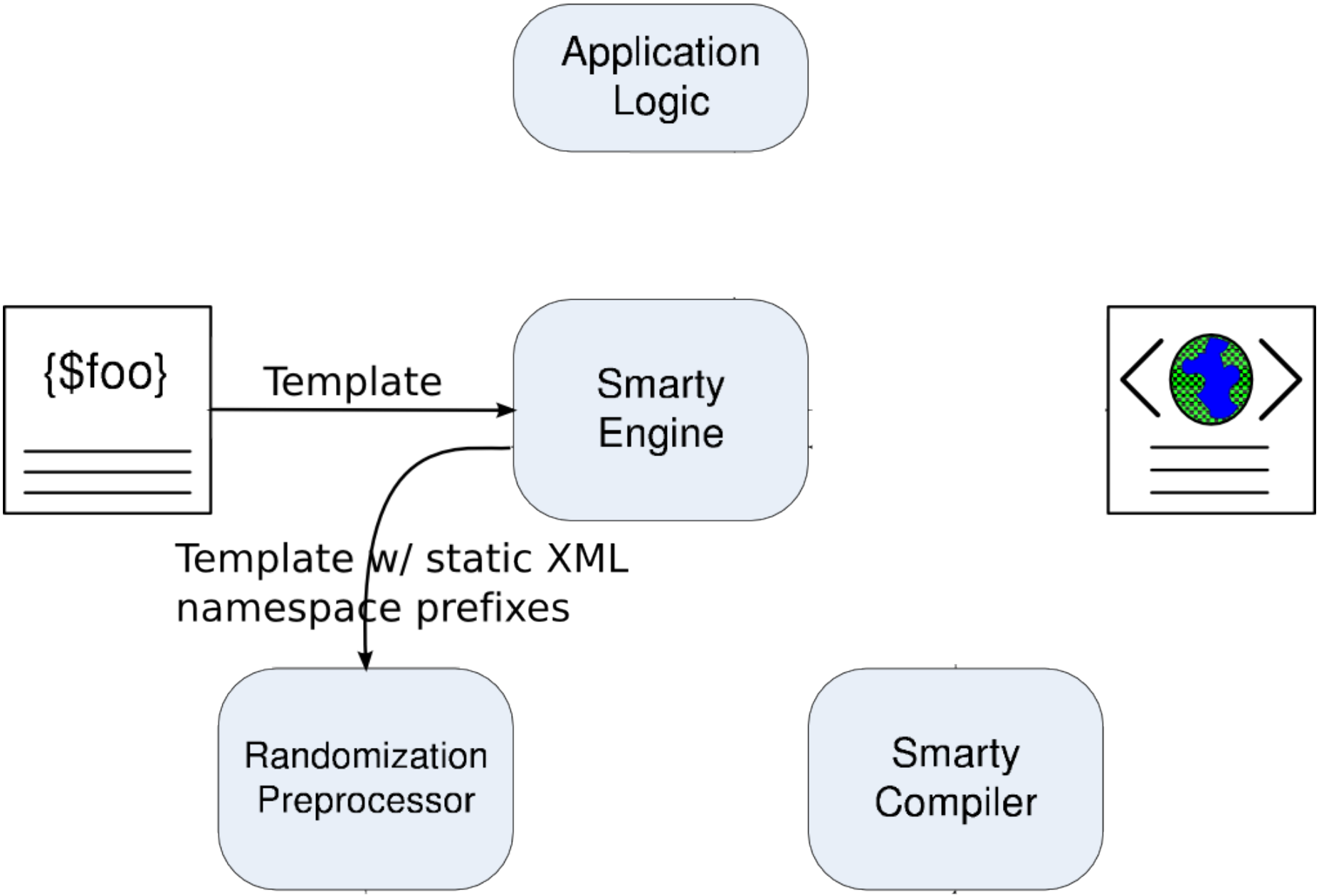

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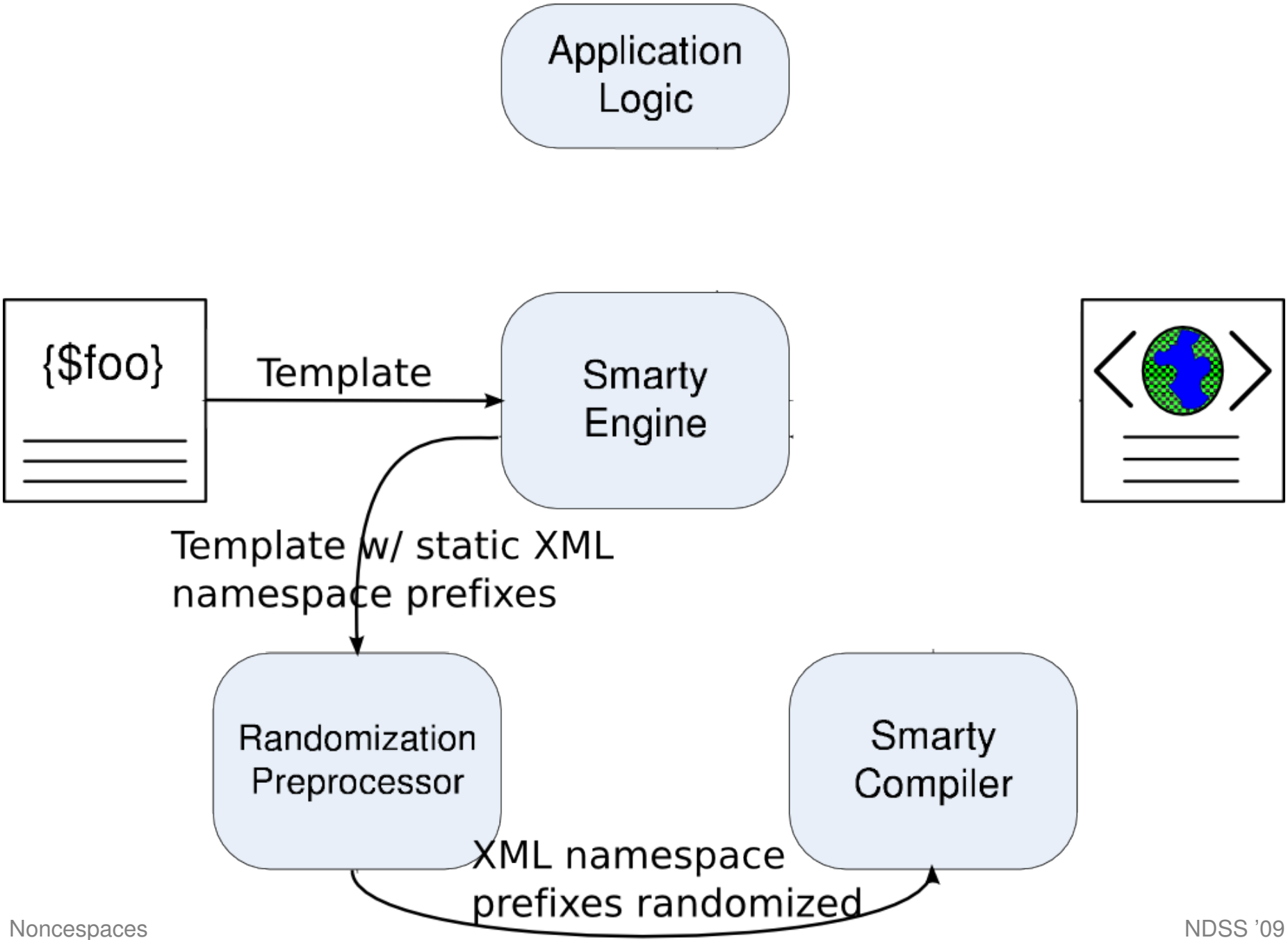

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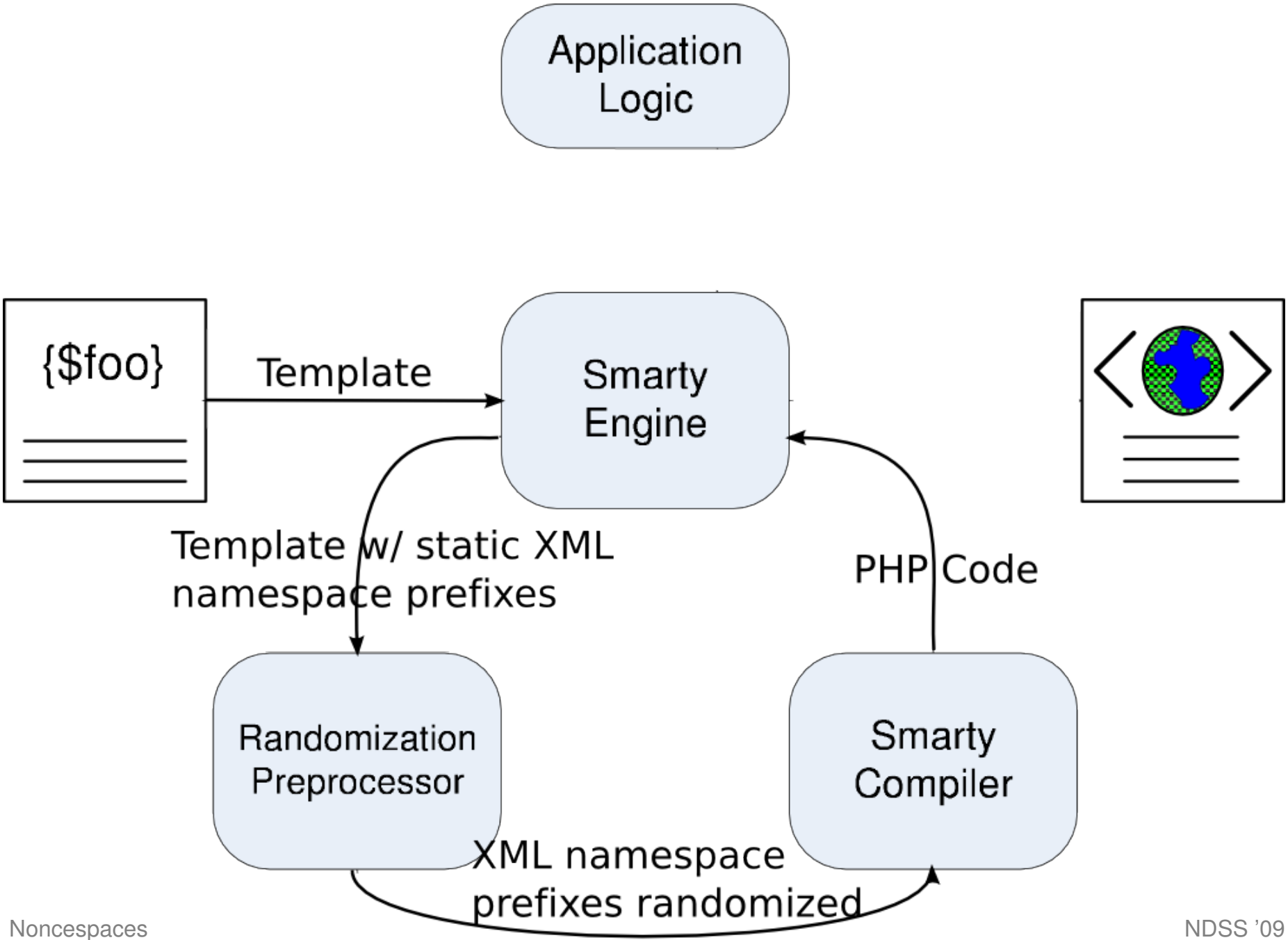

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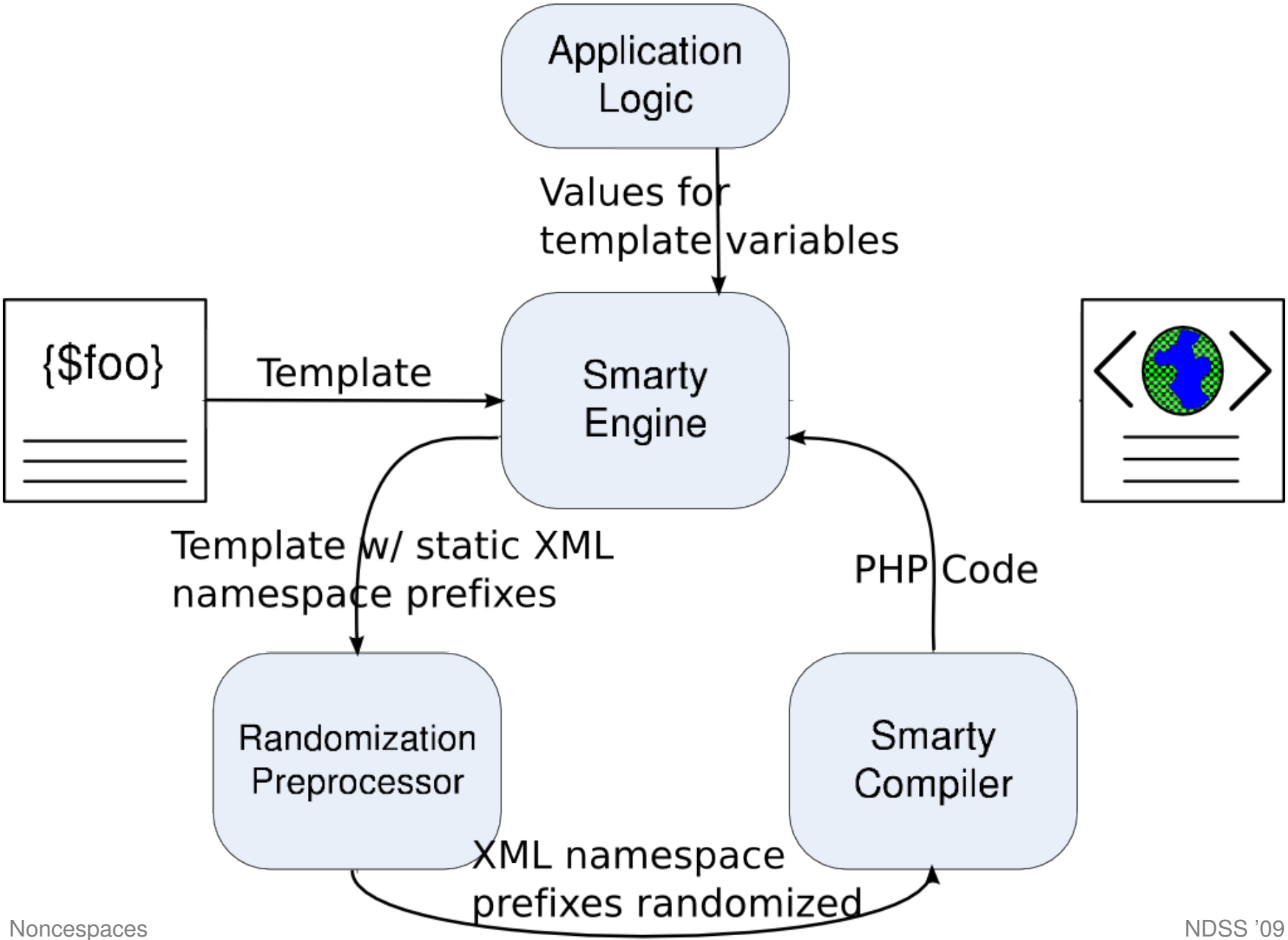

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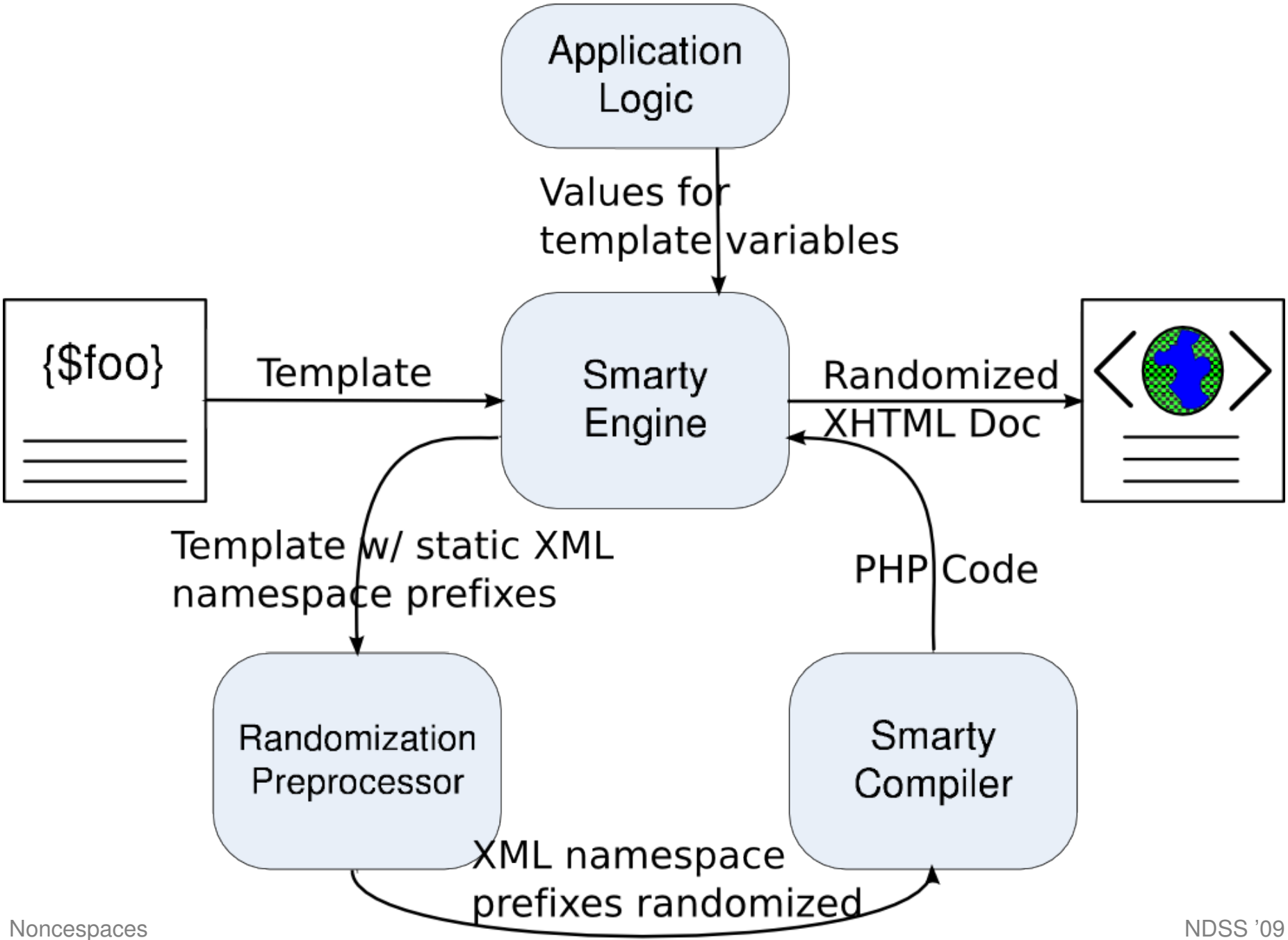
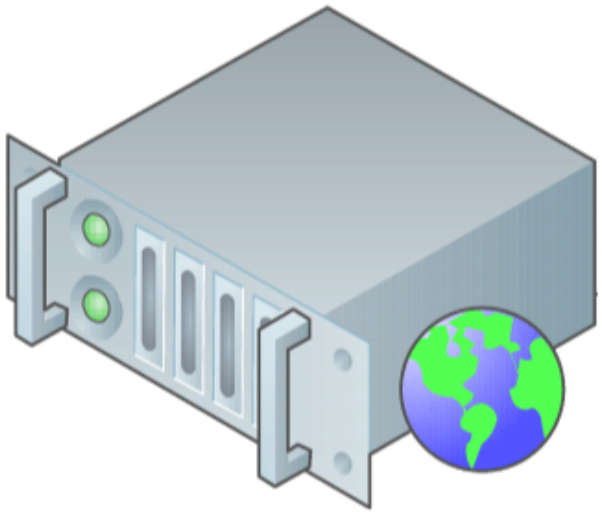
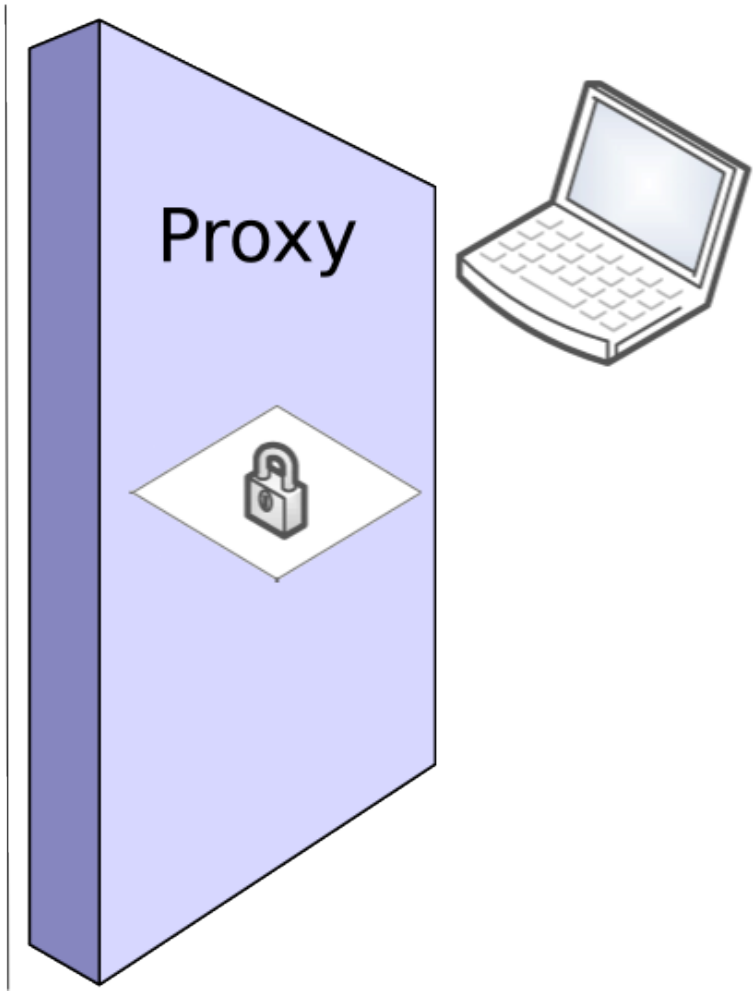


Client-side Modifications





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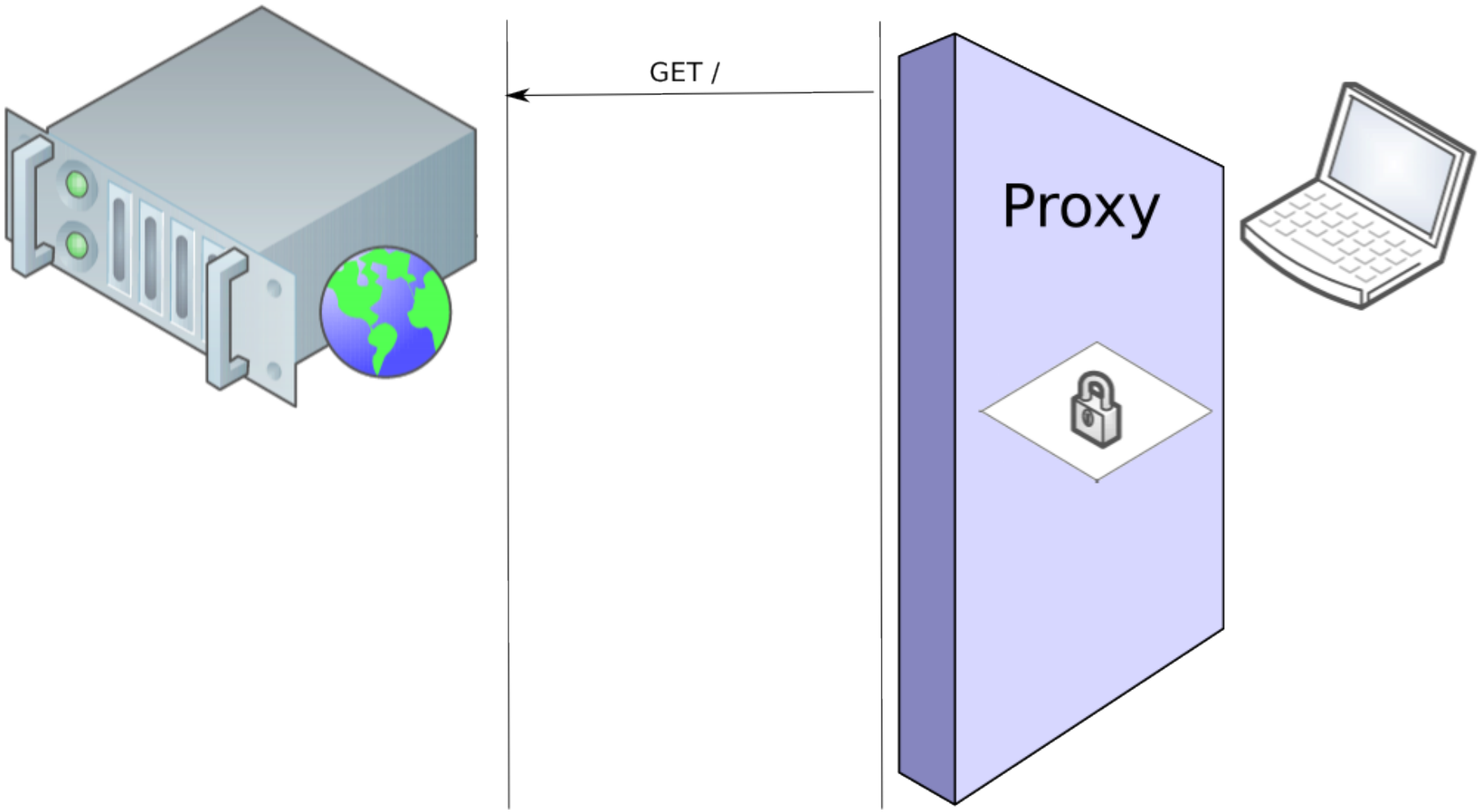

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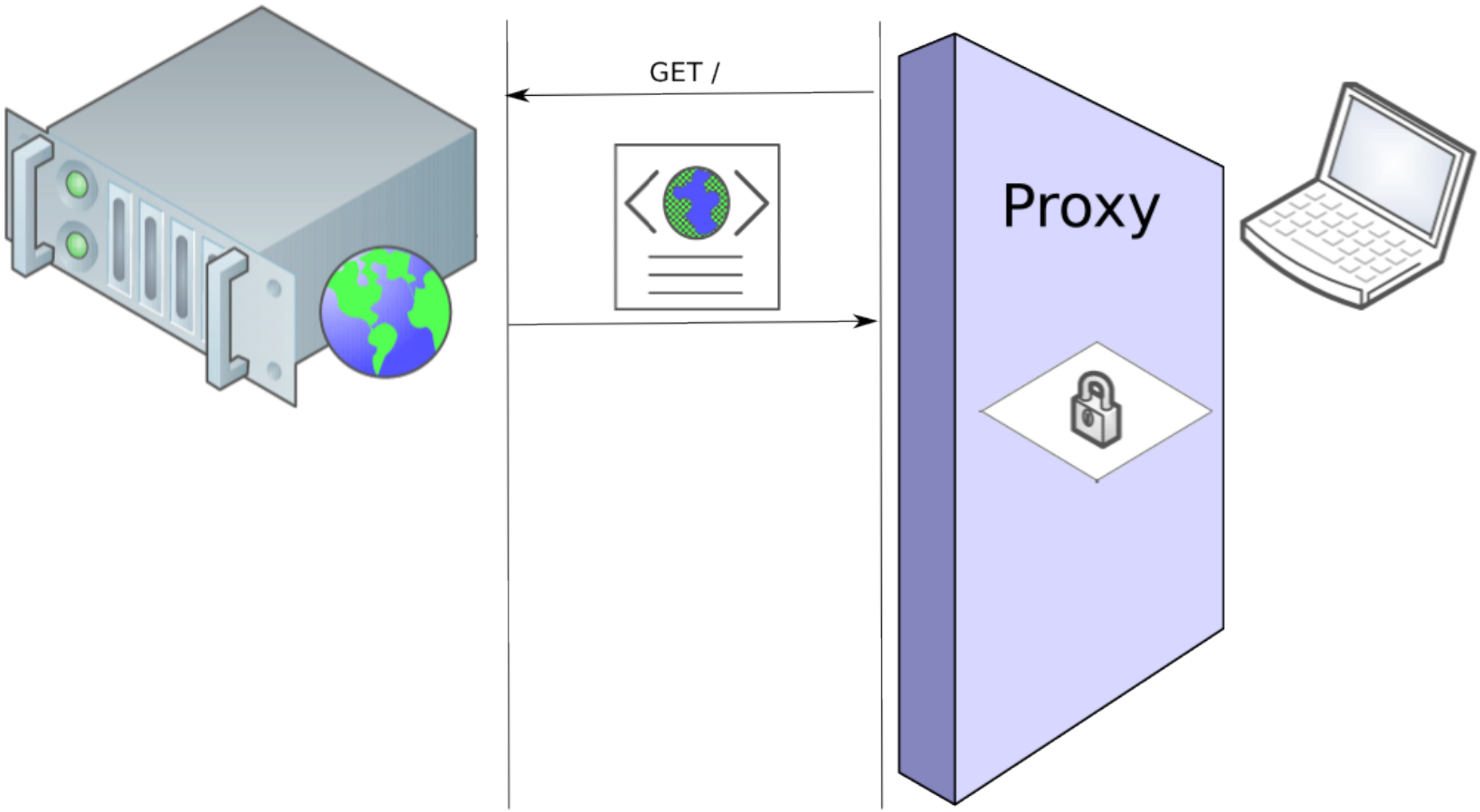

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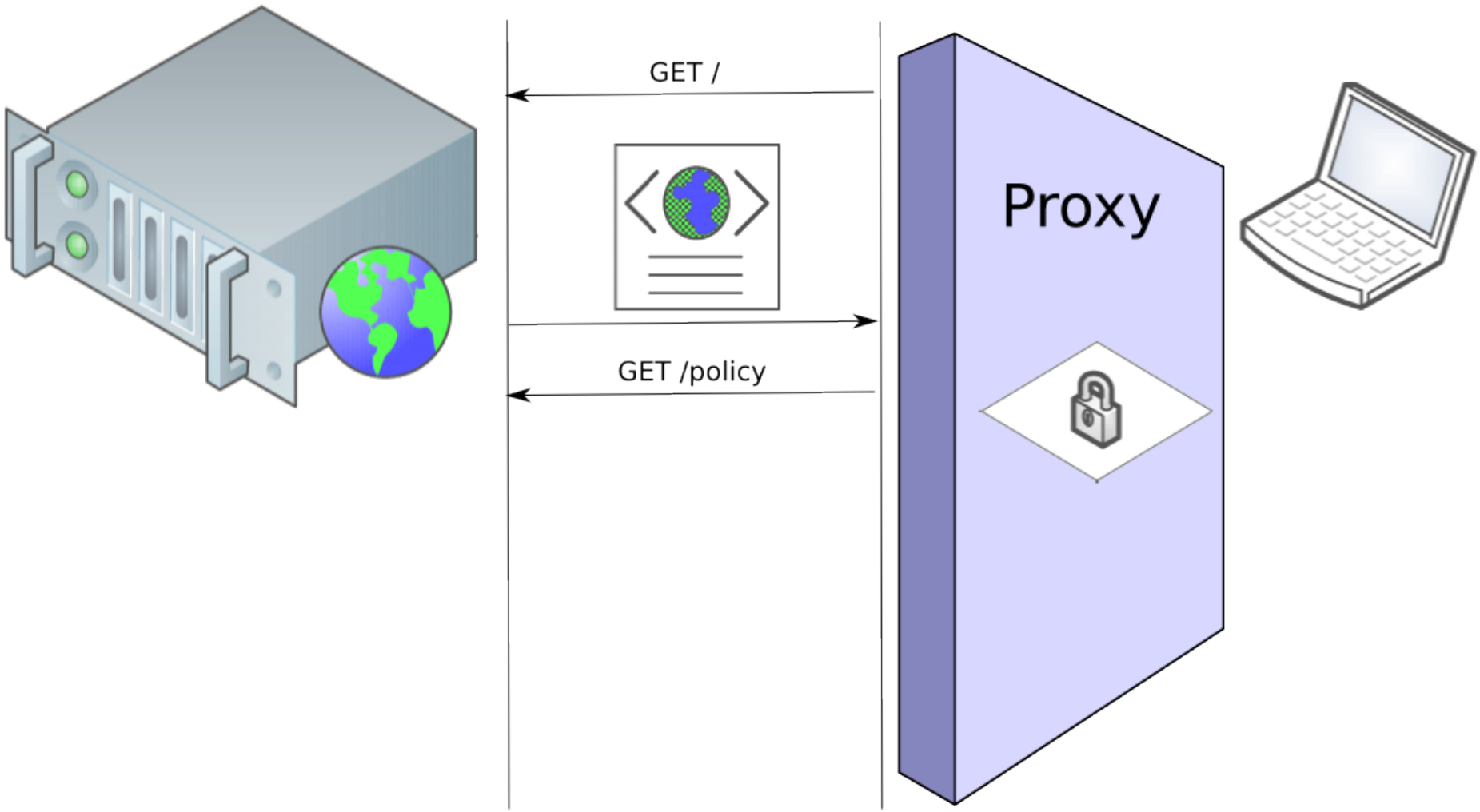

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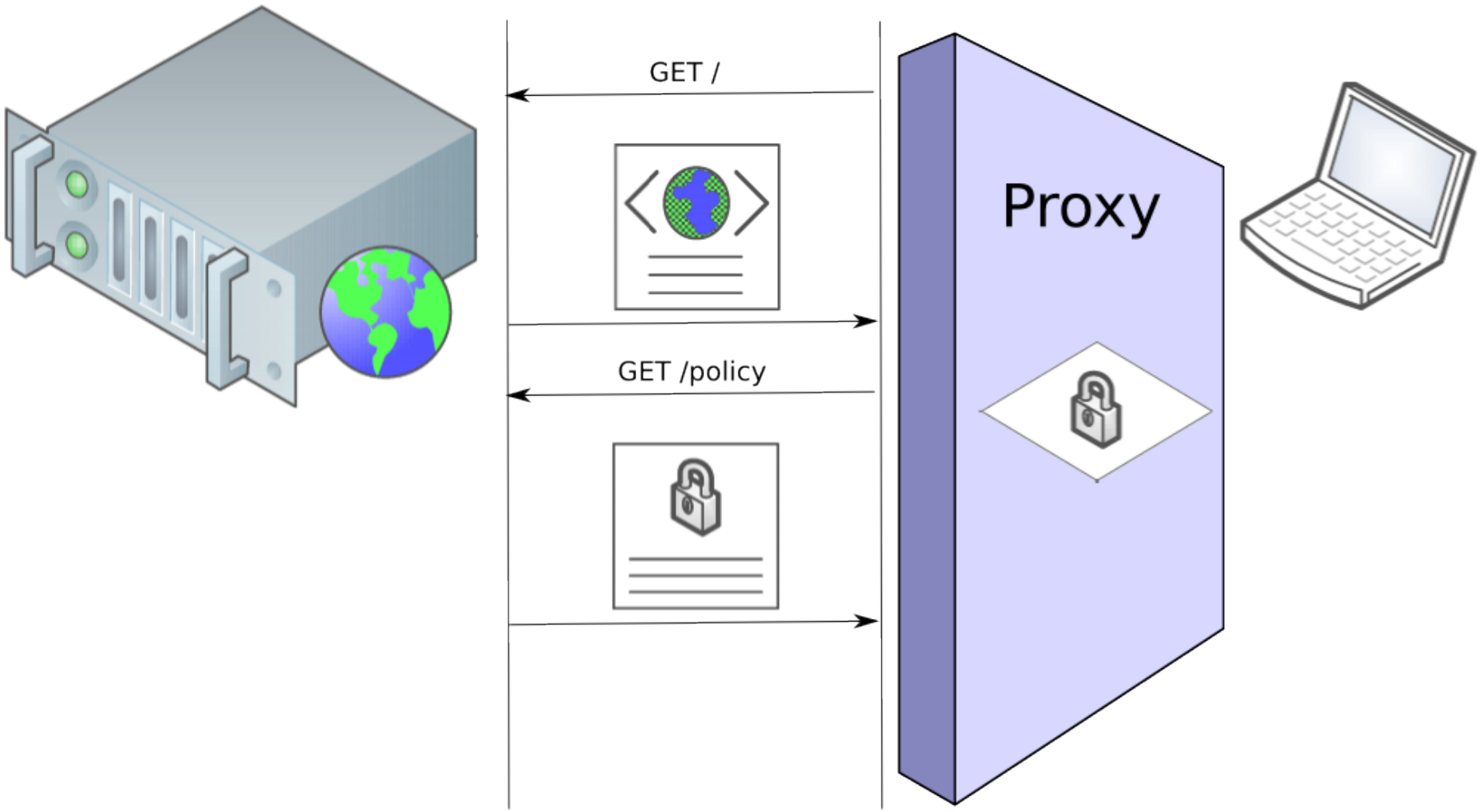

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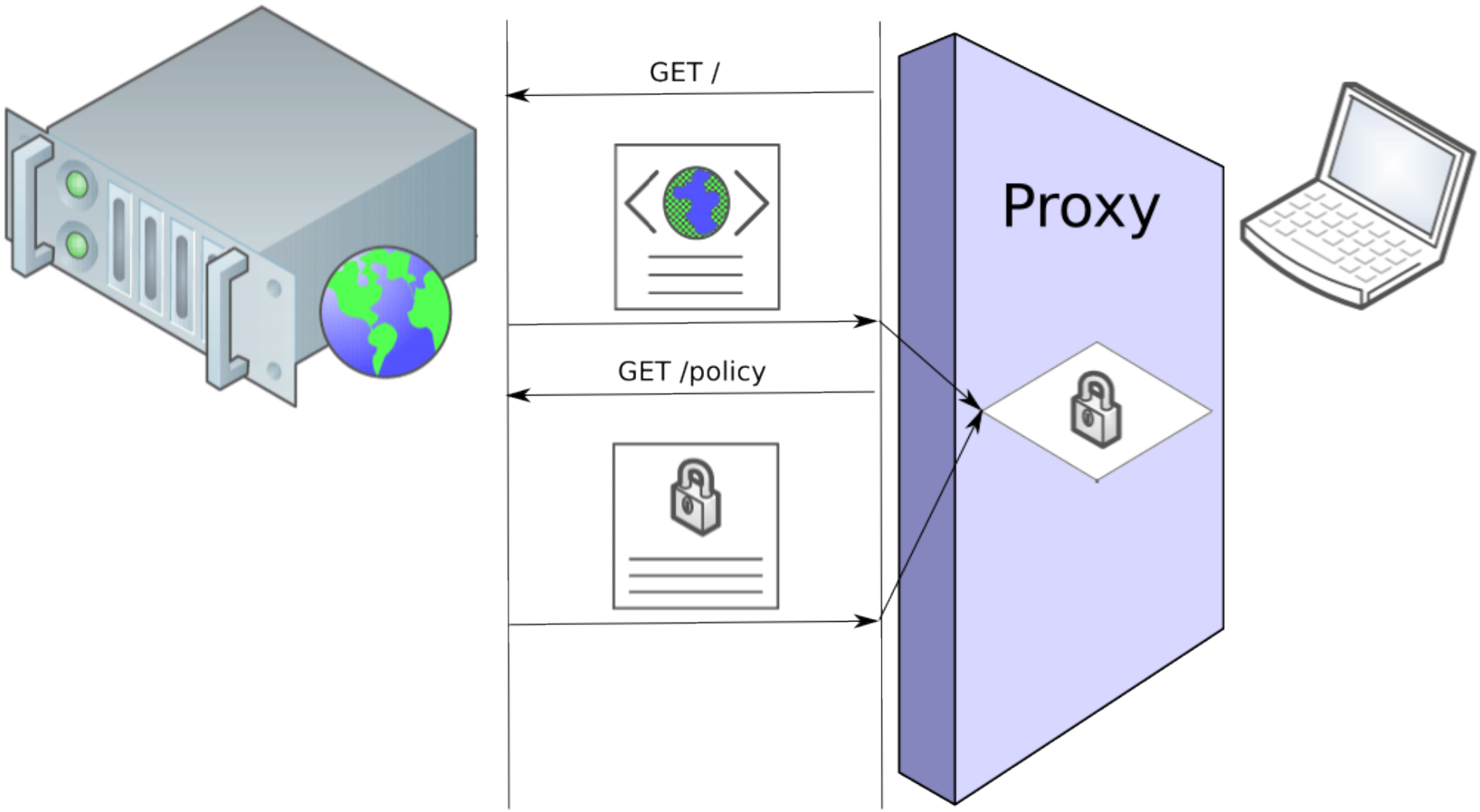

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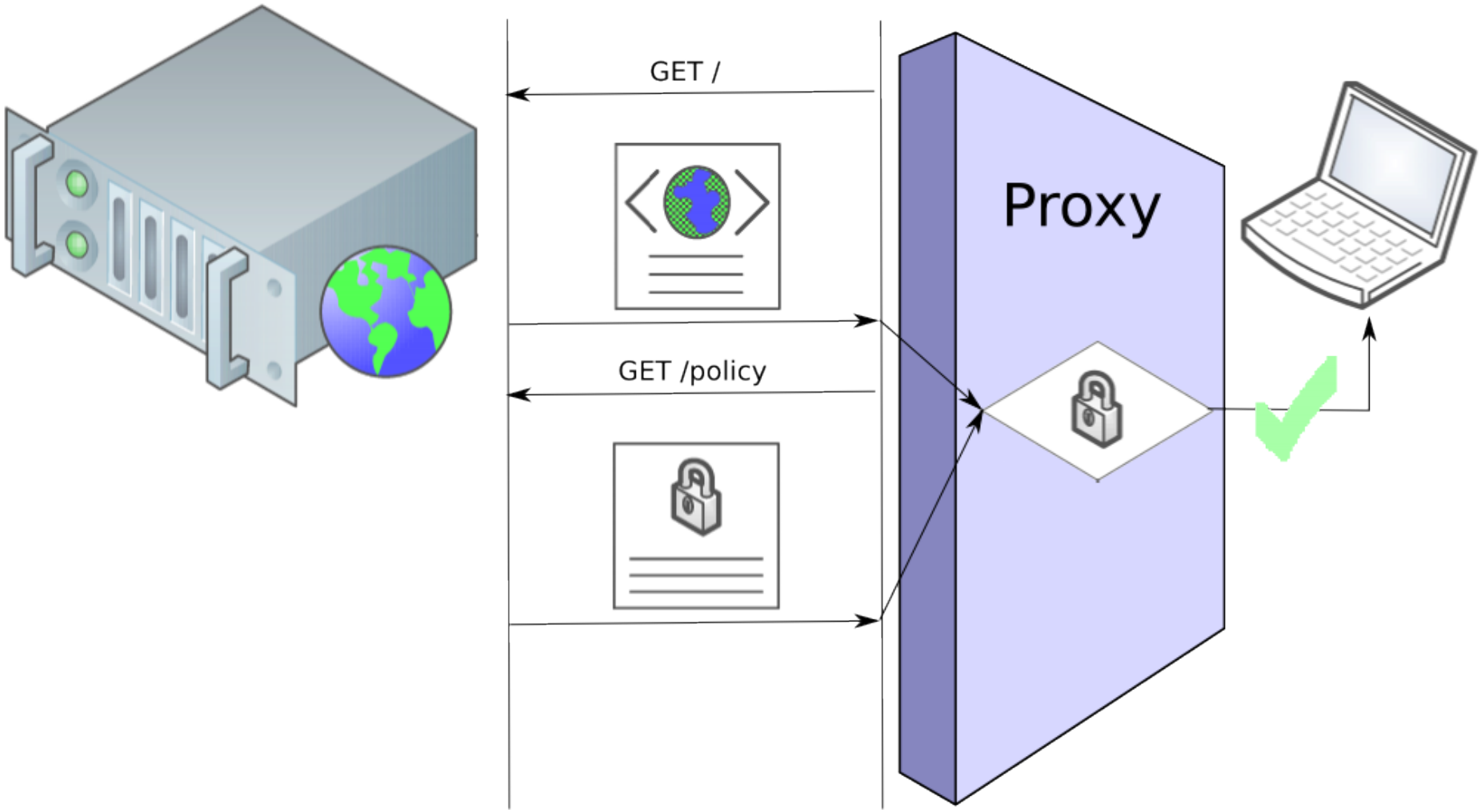

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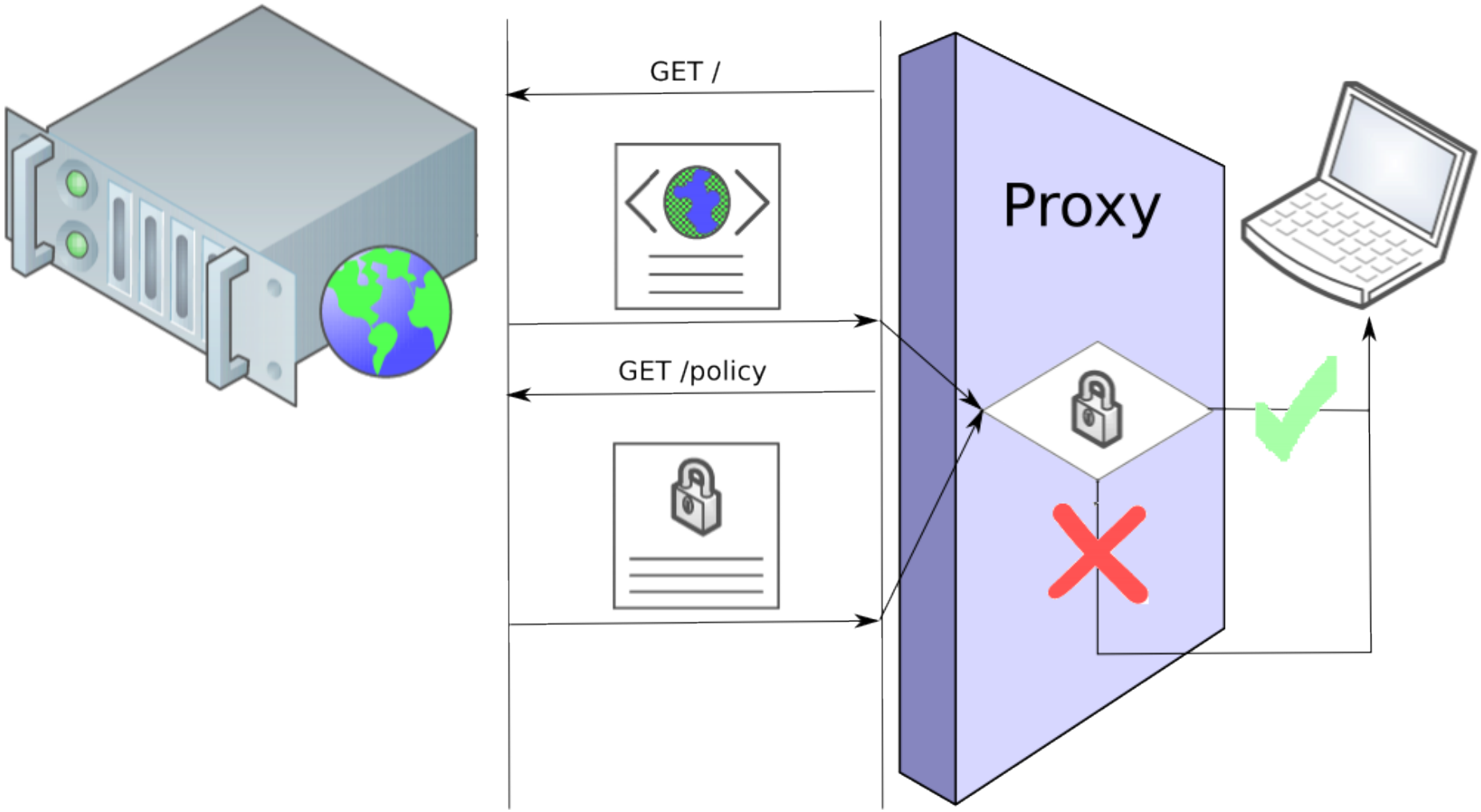
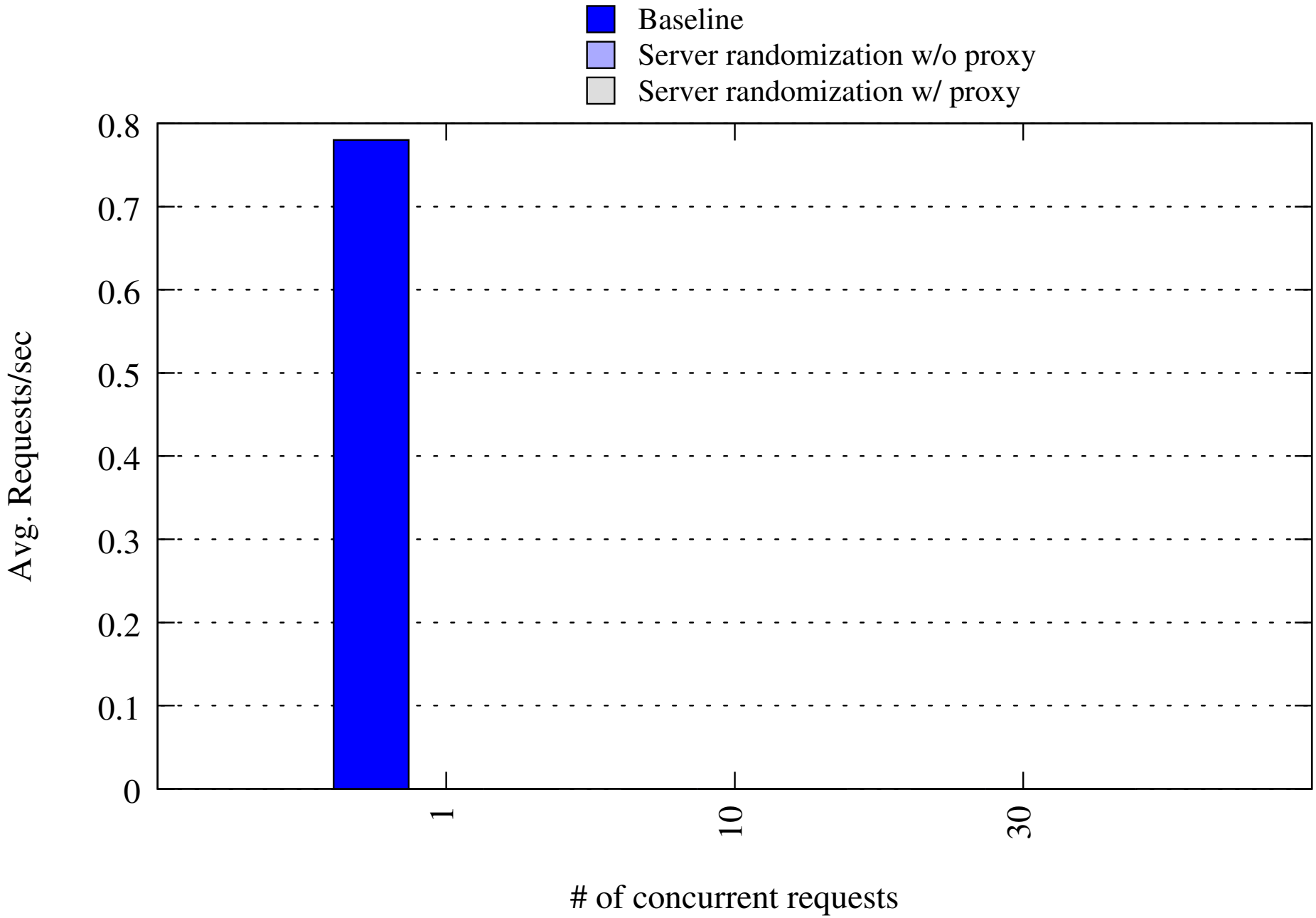


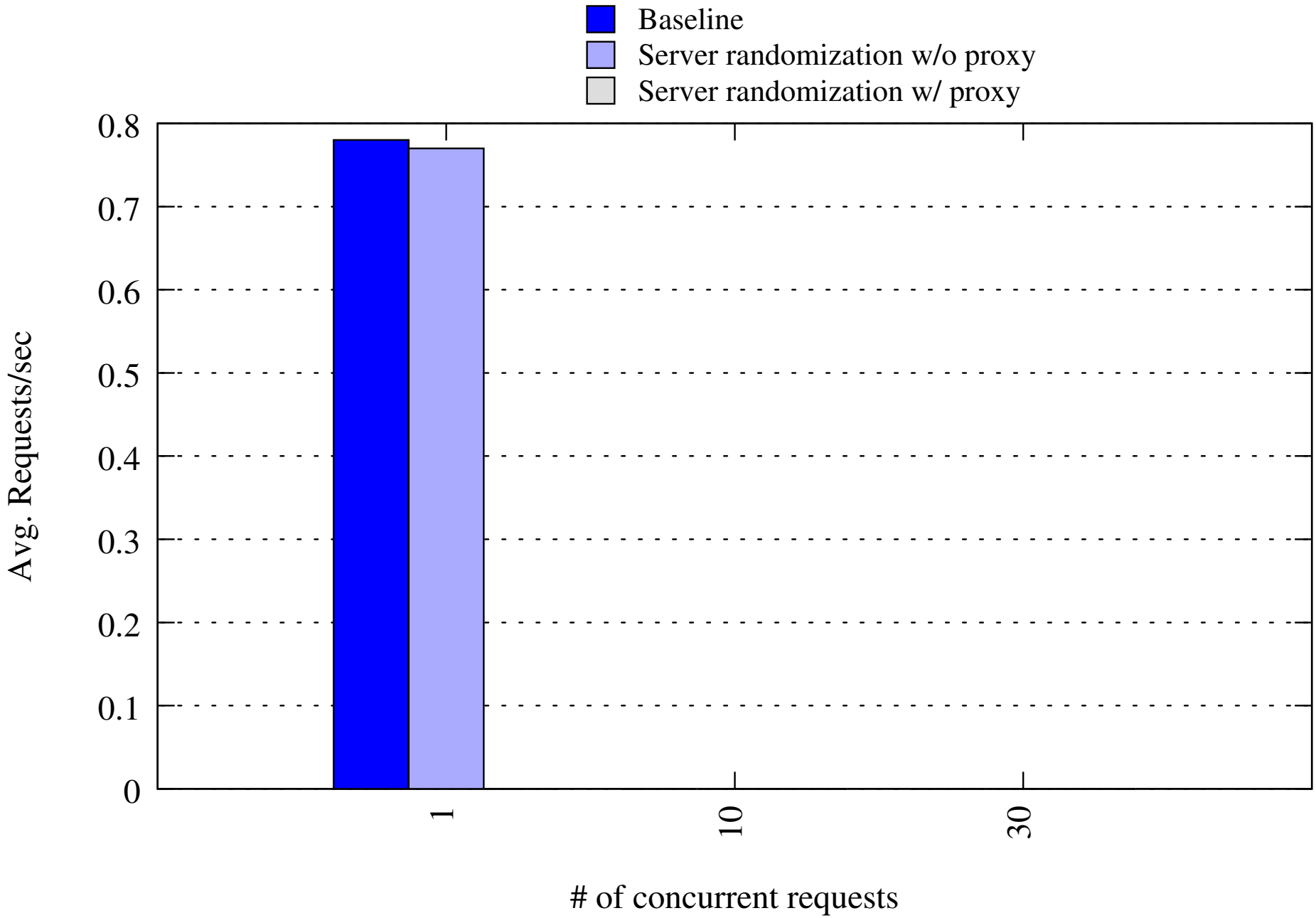
Evaluation

- Tested effectiveness of Noncespaces on 2 applications
- Developed policy for each application
- Ensured that Noncespaces stopped a number of XSS attacks
- Measured performance overhead of both server-side randomization and client-side policy checking

Evaluation


Baseline
Server randomization w/o proxy
Server randomization w/ proxy
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Avg. Requests/sec
1
10
30
# of concurrent requests

Evaluation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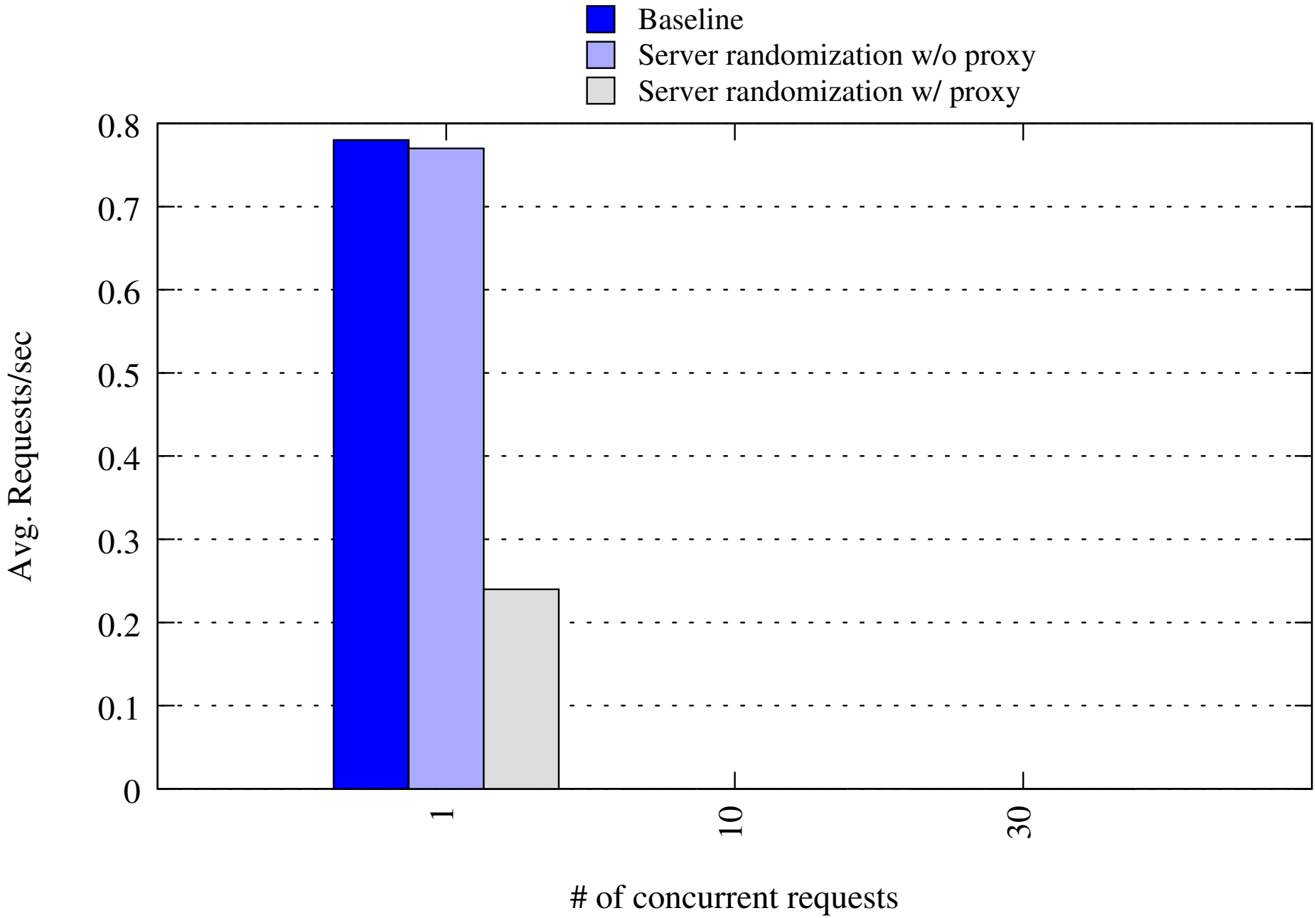
Evaluation


Baseline
Server randomization w/o proxy
Server randomization w/ proxy
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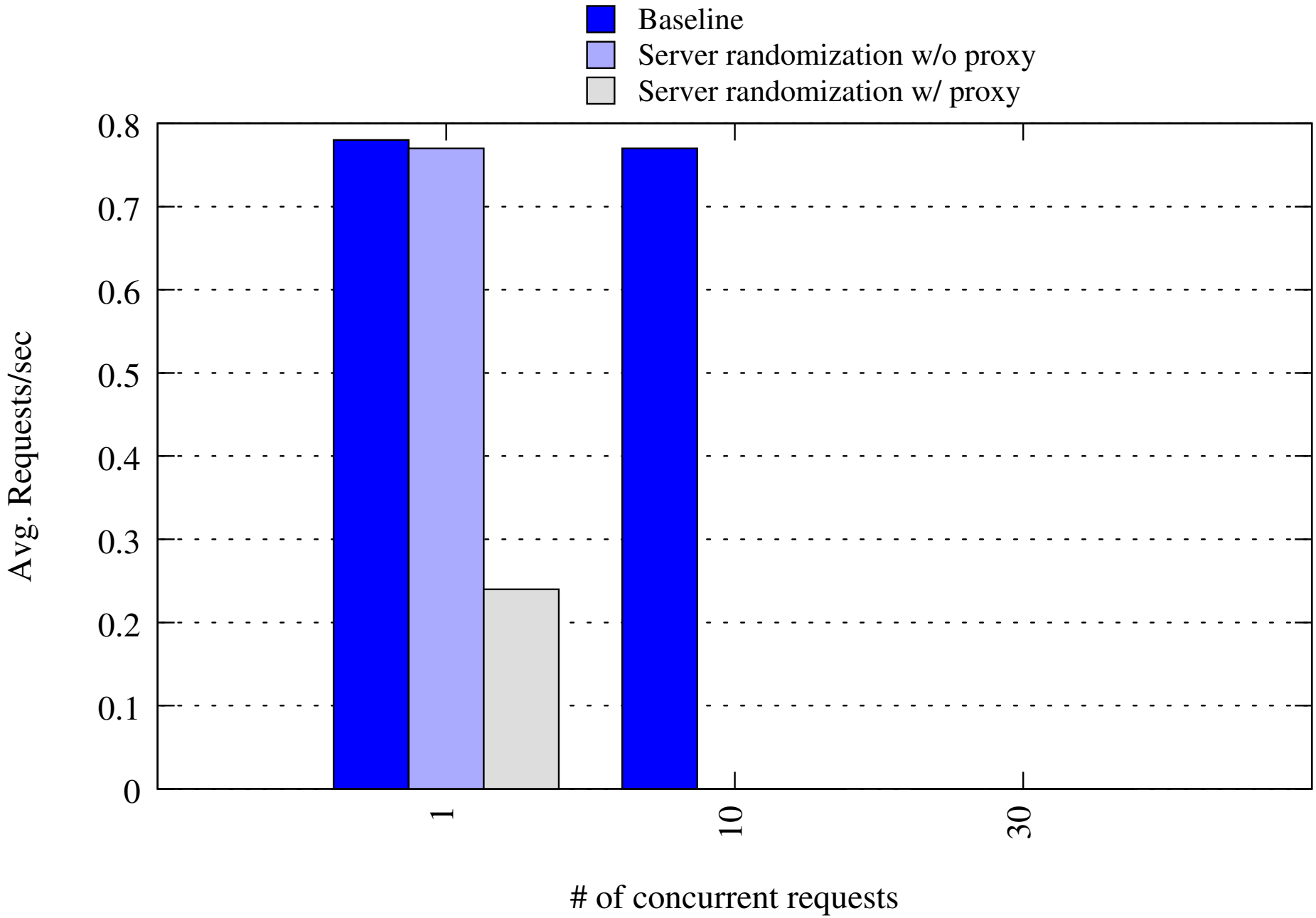
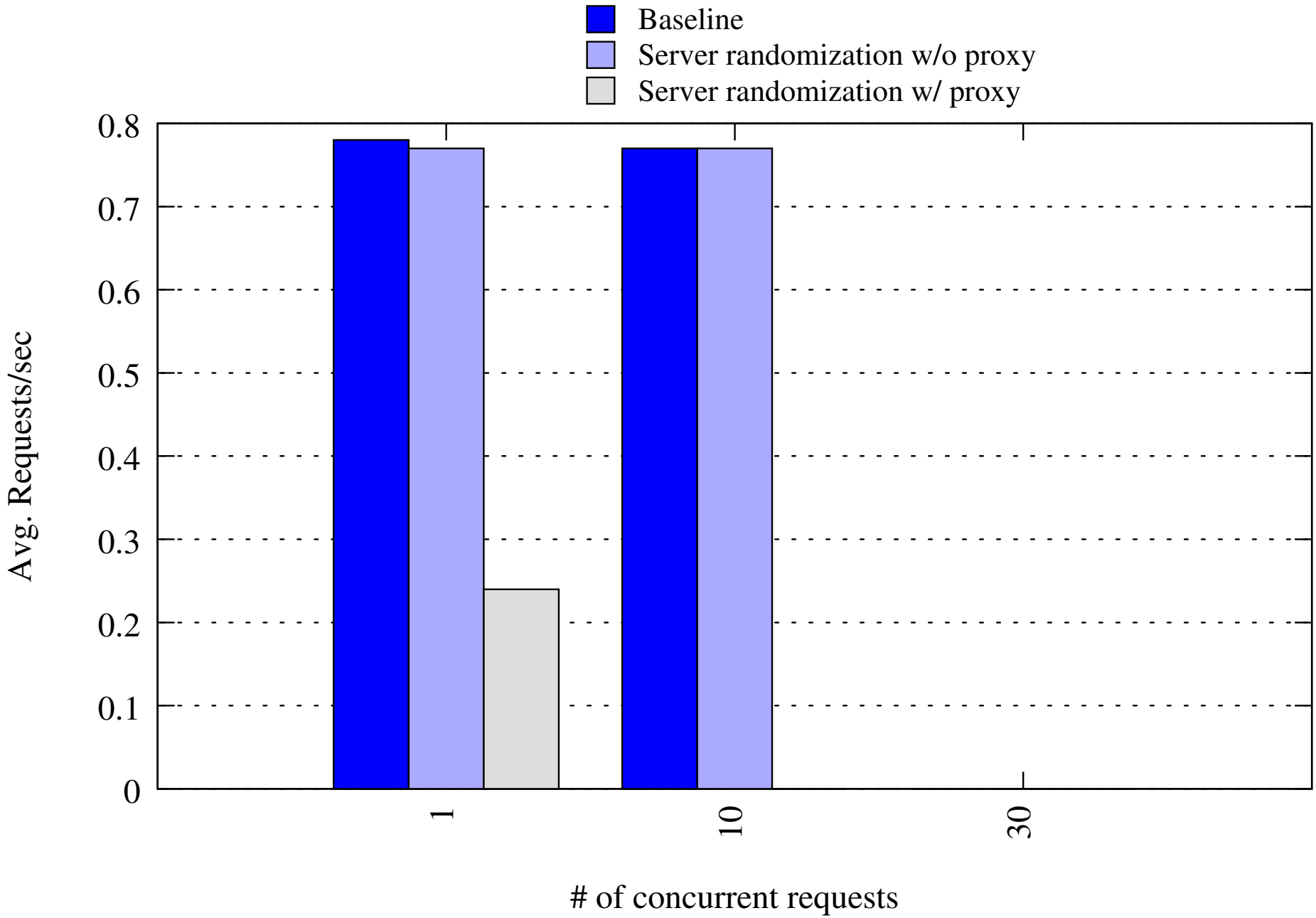
0.4
0.3
0.2
0.1
0
Avg. Requests/sec
1
10
30
# of concurrent requests

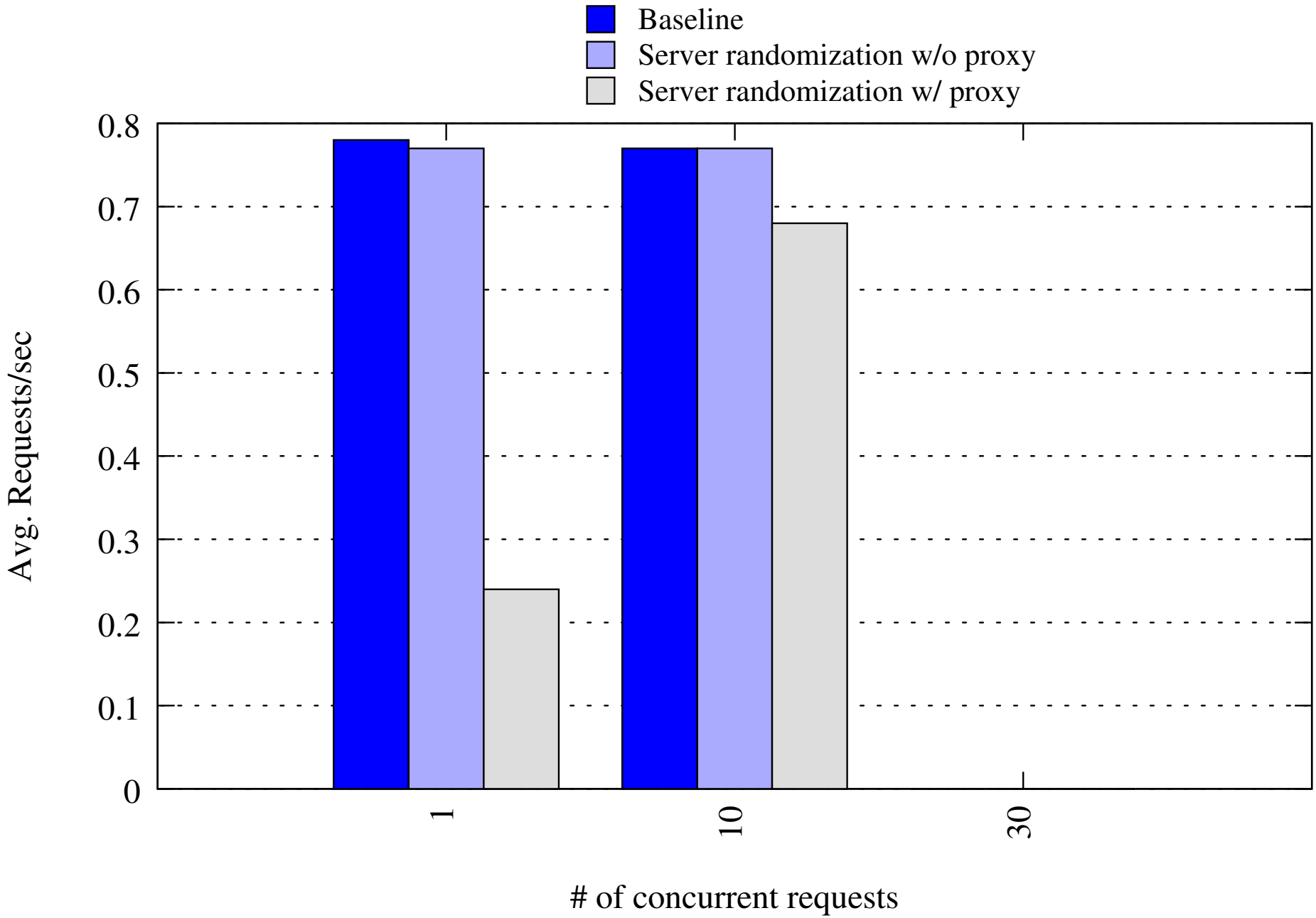
Evaluation


Baseline
Server randomization w/o proxy
Server randomization w/ proxy
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Avg. Requests/sec
1
10
30
# of concurrent requests

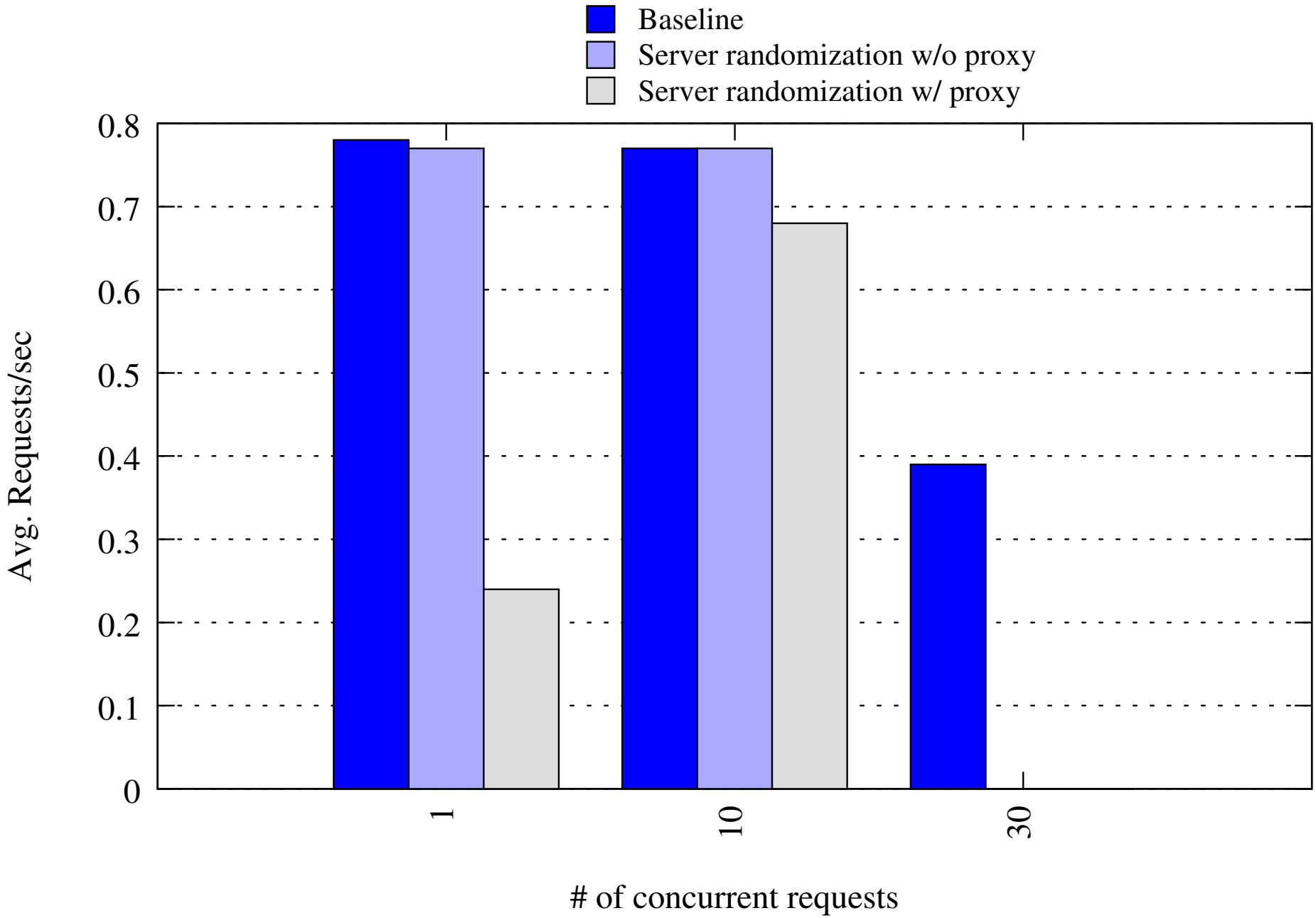
Evaluation


Baseline
Server randomization w/o proxy
Server randomization w/ proxy
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Avg. Requests/sec
1
10
30
# of concurrent requests

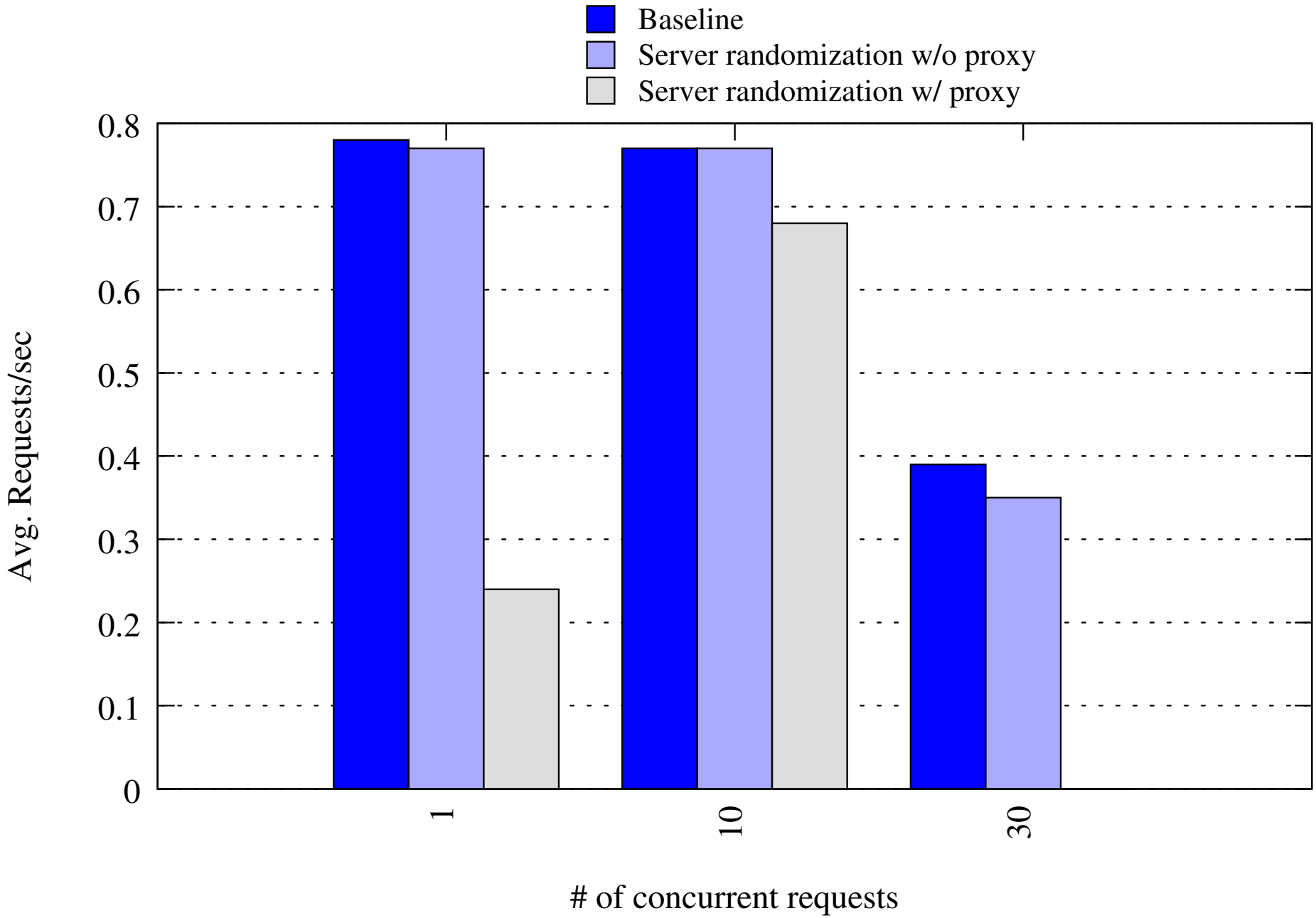
Evaluation


Baseline
Server randomization w/o proxy
Server randomization w/ proxy
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Avg. Requests/sec
1
10
30
# of concurrent requests

Evaluation


Baseline
Server randomization w/o proxy
Server randomization w/ proxy
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Avg. Requests/sec
1
10
30
# of concurrent requests

Evaluation


Baseline
Server randomization w/o proxy
Server randomization w/ proxy
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Avg. Requests/sec
1
10
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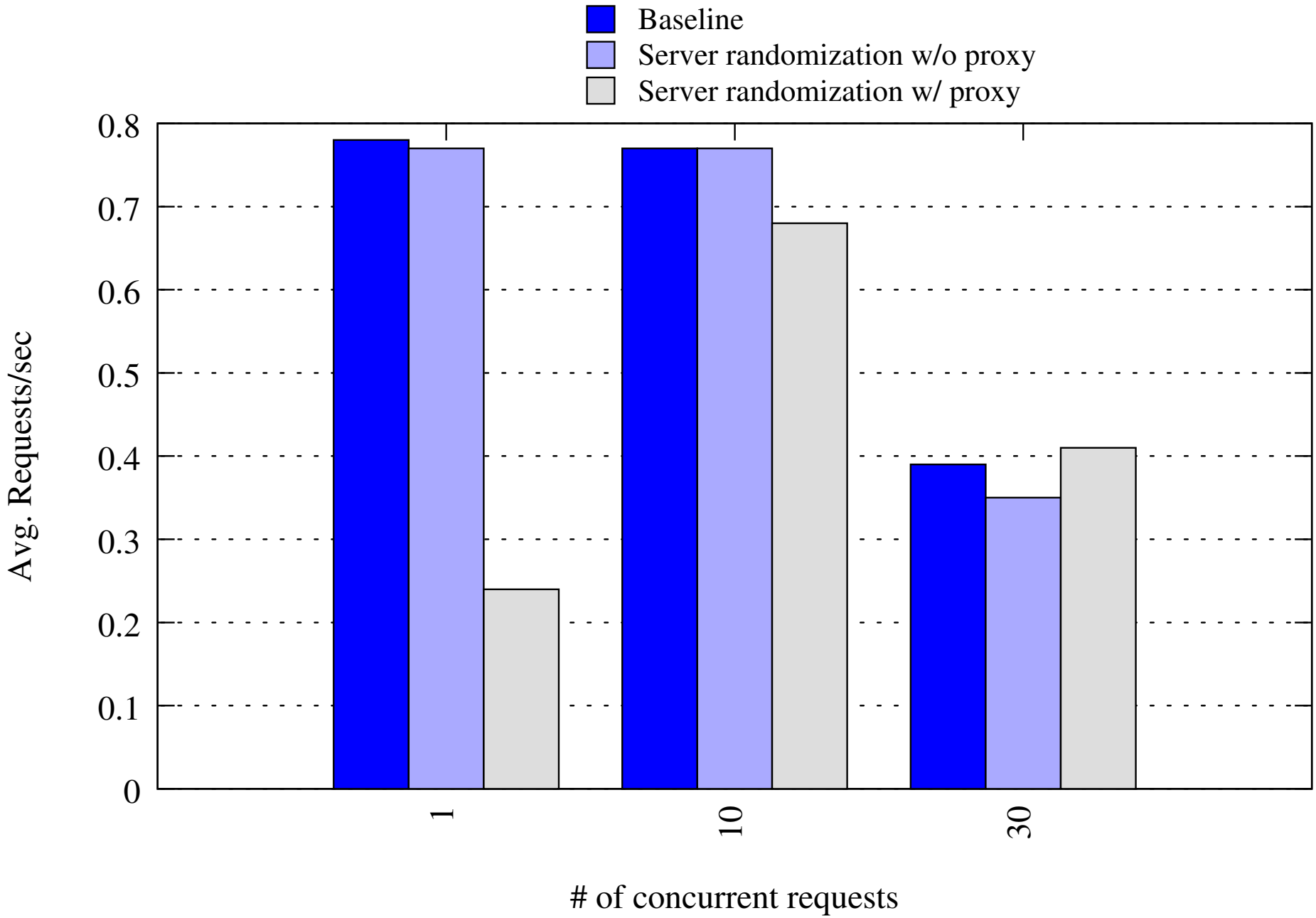
# of concurrent requests

Evaluation


Baseline
Server randomization w/o proxy
Server randomization w/ proxy
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Avg. Requests/sec
1
10
30
# of concurrent requests

Related Work

- Instruction Set Randomization (Kc et al., CCS '03) and (Barrantes et al., CCS '03)
- BEEP (Jim et al., WWW '07)
- Mutation Event Transforms (Erlingsson et al., HotOS '07)
- Noxes (Kirda et al., ACM SAC '06)
- Cross-Site Scripting Prevention with Dynamic Data Tainting and Static Analysis (Vogt et al., NDSS '07)

Conclusion

- We can achieve security without data sanitization on the server
  - Servers classify how trustworthy content is
  - Servers convey trust classifications in a tamper resistant way
  - Clients interpreting the content enforce the policy
- Leverage randomization and XML features to thwart XSS attacks
- Leverage design paradigms to determine trust information without dynamic information flow tracking

Questions?

Example Noncespaces Policy

```
1  namespace trusted
2  namespace untrusted
3
4  allow //trusted:*
5  allow //trusted:@*
6
7  allow //untrusted:b
8  allow //untrusted:i
9  allow //untrusted:u
10 allow //untrusted:a
11 allow //untrusted:a/@untrusted:href[
12     starts-with(normalize-space(.), "http:")]
13 allow //untrusted:img
14 allow //untrusted:img/@untrusted:src[
15     starts-with(normalize-space(.), "http:")]
16
17 deny //*
18 deny //@*
```