Deep Dive into Asynchronous Patterns in JavaScript

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What do you mean asynchronous JavaScript?

The execution environment is synchronous!

Indeed, JavaScript does not have a means of performing asynchronous **computation**. (WebWorkers changes this a bit).

There are no constructs for synchronization such as *test and set*. Which is essential for performing parallel computation.

More Info: https://en.wikipedia.org/wiki/Test-and-set

Async in JavaScript really means…

Parallel and **non-blocking IO** (Network access, filesystem access, etc) and **concurrent computation** (running JavaScript).

IO is orders of magnitude slower than computation. By waiting for IO in a non-blocking manor we free up our execution environment to perform logic and manipulate memory.

Relative cost of IO

Computation* is **fast**. IO is slow.

Action	Cost (CPU cycles)
L1 Cache*	3
L2 Cache*	14
RAM*	250
Disk	41,000,000
Network	240,000,000

Borrowed from: http://blog.mixu.net/2011/02/01/understanding-the-node-js-event-loop/

Managing Asynchronous Actions

There are many patterns to choose from

- Callbacks
- Promises
- Generators + Promises
- Async/Await

Callback Functions

simple and familiar

Callbacks Overview

functions to be invoked when IO completes

By convention these functions have the signature:

```
function (err, data) {  }
```

Where `err` is `null` or `undefined` in the event of success.

e.g.

```
fs.readFile('/path/to/file', (err, data) => {
  if (err) {
     return console.error('Error reading file')
  }

  console.log(data)
})
```

Callback Pitfalls

It's easy to forget a `return` after handling an error.

```
fs.readFile('/path/to/file', (err, data) => {
  if (err) { // file does not exist
    /*return*/ console.error('File not found')
  }

  console.log('Found file lets do something destructive!')
})
```

Causing both error and success path's to be executed with possibly undesirable consequences.

Callback Pitfalls (2)

It’s easy to invoke the callback multiple times with different parameters.

```
function doThingAsync(cb) {
    fs.readFile('/path/to/file', (err, data) => {
        if (error) {
            cb(err)
        }

        if (data.toString() === 'special') {
            cb(null, 'special data found')
        }

        cb(null, 'not so special')
    })
}

doThingAsync(function (err, data) {
    console.log('I am executed twice!')
})
```

Avoiding Callback Pitfalls

Use return statements anytime you invoke a callback:

```
if (err) {
    return callback(err)
}

return callback(null, data)
```

Ensure exactly once execution:

```
doMyAsyncThing(_.once((err, data) => {
//    this function can only be executed once thanks to lodash's once
})
```

Callback Tips

Increase readability and avoid name collisions with reduced nesting

```
fetchUser(user_id, (err, user) => {
    fetchPosts(user_id, (err2, posts) => {
        fetchSomethingElse(user_id, (err3, other_stuff) => {
            if (err) { /* OOPS! I meant to use err3! */ }
        })
    })
})
```

Try this instead:

```
function onPostsRetrieved(err, posts) { /* ... fetchSomethingElse */ }

function onUserRetrieved(err, user) {
    fetchPosts(user.user_id, onPostsRetrieved)
}

fetchUser(user_id, onUserRetrieved)
```

Callbacks are old news

use a more modern pattern when possible

Promises

A Promise represents an operation that hasn't completed yet, but is expected in the future.

SOURCE: HTTPS://DEVELOPER.MOZILLA.ORG/EN-US/DOCS/WEB/JAVASCRIPT/REFERENCE/GLOBAL_OBJECTS/PROMISE

Run Demo

Promise.resolve

Creates a `Promise` with the specified `fulfillment value`. This value **never changes** meaning subsequent uses of this `Promise` always return the same value.

```
const foo = Promise.resolve('last')

// then's are always evaluated in a subsequent event loop iteration
foo.then(x => {
    console.log('this happens ' + x)
})

foo.then(x => {
    console.log('this also happens ' + x)
})

console.log('This happens first')
```

Run Demo

Promise.reject

Creates a `Promise` with the specified `rejection value`. This value **never changes** and subsequent uses of this `Promise` always result in `catch` being executed.

```
const foo = Promise.reject('rejection!')

foo.then(x => {
    console.log('this never gets executed because the promise was rejected')
})

foo.catch(x => {
    console.log(x)
})

// Same result with multiple handlers
foo.catch(x => {
    console.log('Another ' + x)
})
```

Run Demo

new Promise()

Provides resolve and reject callbacks to easily interface with callback based functions

Here we create a `Promise` to wrap our usage of the callback based `fs.readFile` function.

```
new Promise((resolve, reject) => {
    fs.readFile('/path/to/file', (err, data) => {
        if (err) {
            return reject(err)
        }

        return resolve(data)
    })
})
.then(data => {
    console.log(data)
})
.catch(err => {
    console.log(err)
})
```

Run Demo

Promises are composable

```
const promiseA = Promise.resolve(5)
const promiseB = Promise.resolve(4)

promiseA.then(a => {
    return promiseB.then(b => {
        return a + b
    })
})
.then(result => {
    console.log(result)
})
```

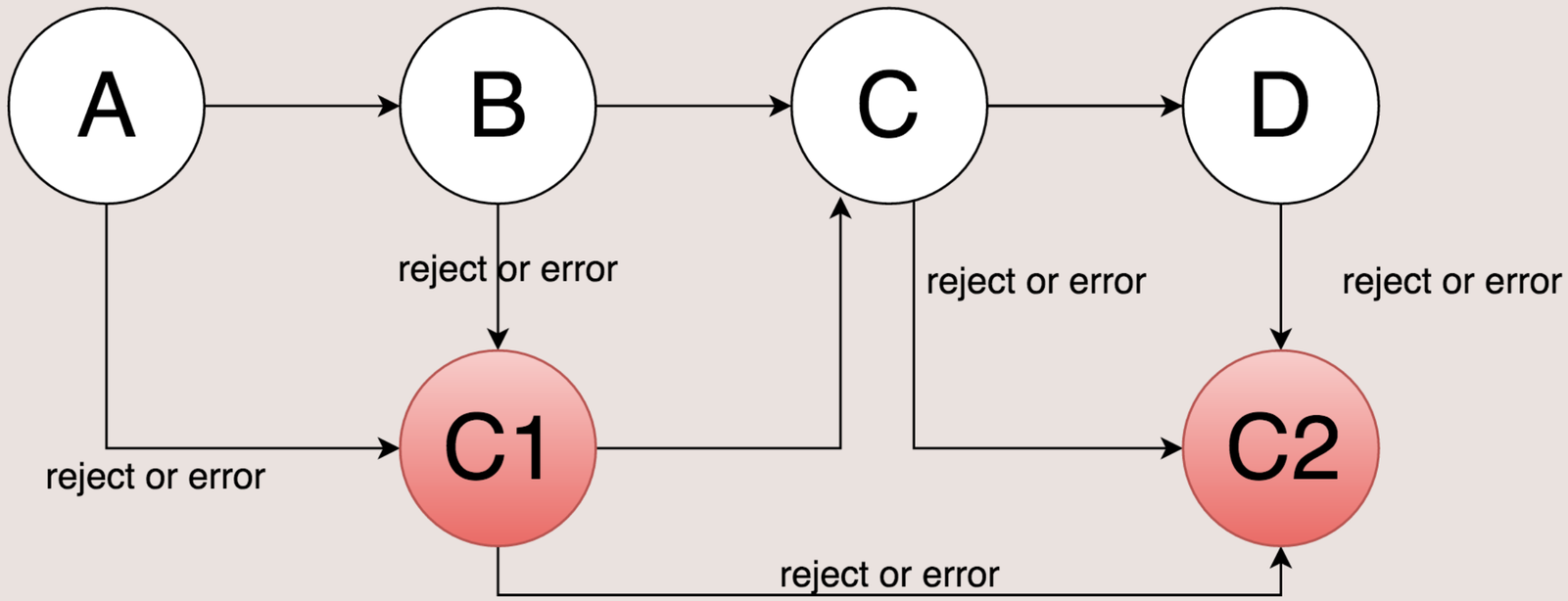
Any value returned from `then` is added to the `Promise chain`.

- `Promise` values are just added to the chain.
- Raw values are wrapped using `Promise.resolve`.
- `throw` or `unhandled error` causes the promise to be rejected.

Run Demo

Promise chain

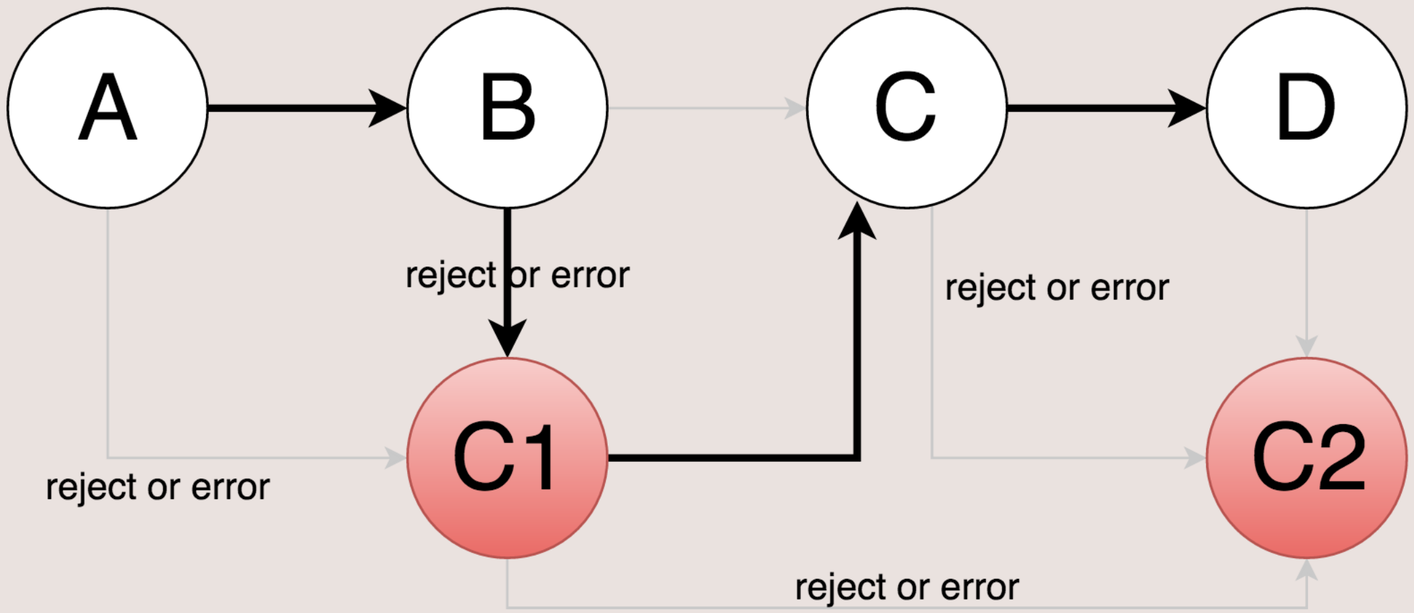
```
promiseA
.then(() => promiseB)
.catch(err => console.log(err)) // C1
.then(() => promiseC)
.then(() => promiseD)
.catch(err => console.log(err)) // C2
```



Run Demo

Promise chain - Example Flow

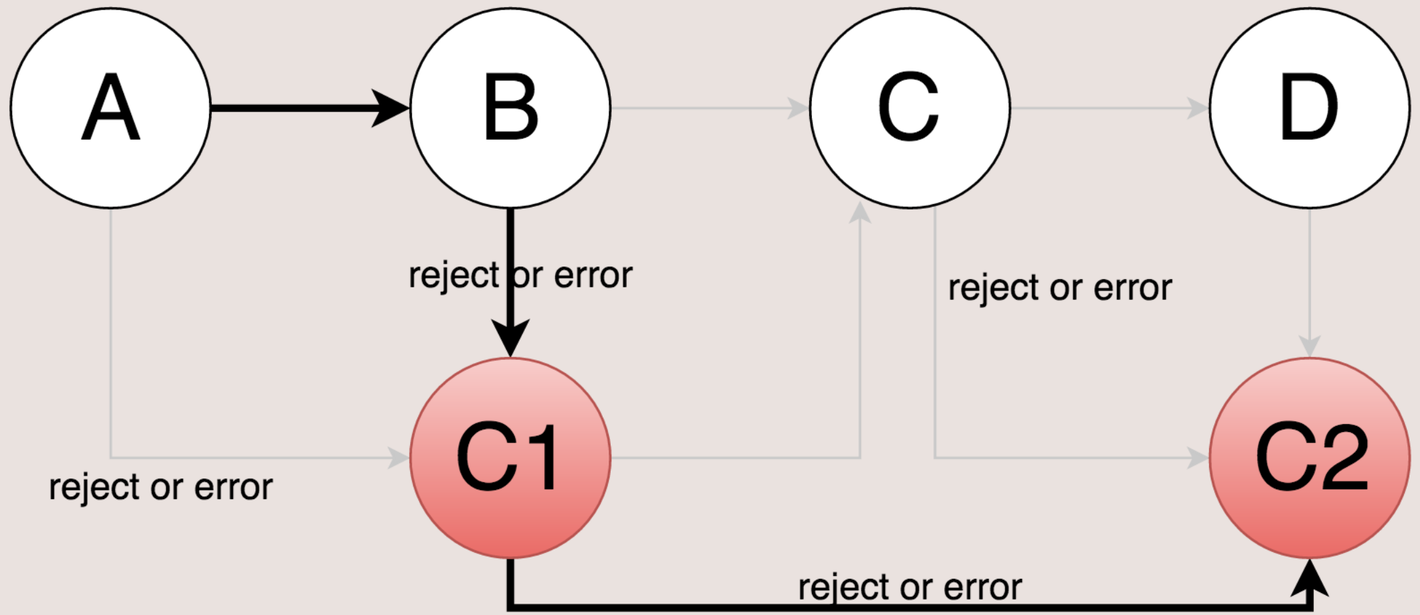
```
promiseA
.then(() => throw new Error('Error')) // Suppose promiseB throws an Error.
.catch(err => console.log(err)) // C1
.then(() => promiseC)
.then(() => promiseD)
.catch(err => console.log(err)) // C2
```



Run Demo

Promise chain - Example Flow 2

```
promiseA
.then(() => throw new Error('Error'))
.catch(err => throw err) // C1
.then(() => promiseC)
.then(() => promiseD)
.catch(err => console.log(err)) // C2
```



Promise.all

waits for all fulfillments (or the first rejection).

```
const userService = require('./services/user')

const users_promise = Promise.all([
    userService.get(123),
    userService.get(555)
])

users_promise.then((users) => {
    const user123 = users[0]
    const user555 = users[1]
    console.log('ALL calls to the userService succeeded!')
})
.catch((error) => {
    console.log('At least one of the calls to the userService failed!')
})
```

Useful when run-order of promises is not important.

Promise.race

receives a collection of promises and resolves or rejects with the value of the first fulfillment

This example illustrates waiting 10 seconds for a service call to complete or timing out.

```
const timeout = new Promise((resolve, reject) => {
    setTimeout(reject, 10000)
})

Promise.race([ timeout, userService.get(123) ])
.then(user => {
    console.log(user)
})
.catch(error => {
    // either error from timeout OR userService.get
    console.log(error)
})
```

Run Demo

Promise Pitfalls

Inadvertently swallowing errors in a catch.

`catch` will either flow you in to the next `then` OR the next `catch` depending on whether the function throws, returns a rejected promise, or succeeds.

```
Promise.reject('original')
.catch(err => {
    return Promise.resolve('default')
})
.then(res => {
    console.log(res) // res -> the value returned from catch
})
```

```
Promise.reject('original')
.then(res => {
    console.log(res) // not executed
})
.catch(err => {
    return Promise.resolve('default')
})
```

Run Demo

Promise Pitfalls (2)

forgetting to return inner promise

```
Promise.resolve('/path/to/file')
.then(filename => {
    /*return*/ new Promise((resolve, reject) => {
        fs.readFile(filename, (err, data) => {
            if(err) { return reject(err) }
            return resolve(data)
        })
    })
})
.then(res => {
    console.log('result: ' + res)
})
```

Flooding the event loop

```
const userService = require('./services/user')

// Imagine if this was a long list of users
const users_to_fetch = [1, 2, 5, 19, ... 9999]

const get_users_promises = _.map(users_to_fetch, (user_id) => {
    return userService.get(user_id)
})

// Note: All promises are already started!
Promise.all(get_users_promises)
```

Run Demo

Avoid flooding the event loop!

use BlueBirds map

```
function timeoutPromise(timeout) {
    return new Promise(resolve => {
        setTimeout(resolve, timeout)
    })
}

const things_to_do = new Array(100)

// Promise.map comes from bluebird (Not available in native implementation) -- finishes in ~2
seconds
Promise.map(things_to_do, () => timeoutPromise(200), { concurrency: 10 })
.then(() => console.log('Batch complete!'))

// As opposed to this which could flood the event loop with large collections
Promise.all(things_to_do.map(() => timeoutPromise(200)))
.then(() => console.log('Flood complete!'))
```

Generators

…functions which can be exited and later re-entered.

SOURCE: HTTPS://DEVELOPER.MOZILLA.ORG/EN-US/DOCS/WEB/JAVASCRIPT/REFERENCE/STATEMENTS/FUNCTION*

Run Demo

Generator example

```
function *oneGenerator() {
    const a = yield 1
    const b = yield 1

    console.log('result 1: ' + a)
    console.log('result 2: ' + b)
}

// Does NOT invoke the function body. Creates a new instance of the generator.
const generator = oneGenerator()

// Invokes the function body for the first time -- the input is ignored
console.log(generator.next('a').value)

console.log(generator.next('b').value)

console.log(generator.next('c').value)
```

Run Demo

Generators don’t block the event loop

this allows us to generate infinite series or defer computation until requested

```
function *myGenerator() {
    let i = 1
    while (true) {
        // suspends execution until the next value is requested
        yield i++
    }
}

const generator = myGenerator()

console.log(generator.next().value)

console.log(generator.next().value)

console.log(generator.next().value)
```

Run Demo

Generators are composable

```
function *oneGenerator() {
    yield 1
    yield* twoGenerator()
    yield 1
}

function *twoGenerator() {
    yield 2
}

const generator = oneGenerator()

console.log(generator.next().value) // run generator to first yield.
console.log(generator.next().value) // now using twoGenerator!
console.log(generator.next().value) // back to oneGenerator
```

Run Demo

How can generators help with async execution?

By taking advantage of composable generators and the power of `Promises`.

```
Promise.coroutine(function* () {
    yield Promise.delay(500)

    console.log('after first delay')

    yield Promise.delay(1000)

    console.log('after second delay')
})()
```

Run Demo

What's this Promise.coroutine business?

It's the precursor to having `async/await`. Generators don't natively understand `Promises`. Bluebird's `Promise.coroutine` delegates to your generator to provide a `Promise` and then invokes `next` on your generator with the fulfillment value.

```
Promise.coroutine(function *() {
    // the fulfilled promise value is unwrapped and provided as the result
    const result = yield Promise.resolve('foobar')

    console.log(result)
})()
```

Run Demo

(Generators + Promises) vs Promises

```
Promise.coroutine(function* () {
    try {
        const resultA = yield Promise.resolve('foobar')
        const resultB = yield Promise.resolve('baz')
        const resultC = yield Promise.resolve('super')
        console.log('GENERATORS: ' + resultA + resultB + resultC)
    } catch (error) { console.log(error) }
})()
```

```
Promise.resolve('foobar')
.then(resultA => {
    return Promise.resolve('baz')
    .then(resultB => {
        return Promise.resolve('super')
        .then(resultC => console.log('NESTED: ' + resultA + resultB + resultC))
    })
})
.catch(error => console.log(error))
```

Run Demo

Generators with Parallel Promises

That's easy, use the tools we've learned already.

```
Promise.coroutine(function *() {
    const results = yield Promise.all([
        Promise.resolve(1),
        Promise.resolve(2)
    ])

    console.log('array', results[0], results[1])

    // Alternatively, using some new syntax to destructure the result:
    const [a, b] = yield Promise.all([
        Promise.resolve(1),
        Promise.resolve(2)
    ])

    console.log('destructured', a, b)
})()
```

Generators Summary

Generators can greatly increase the readability of your asynchronous code. My suggestion is to start using them right away! They are available as of node version `0.12` (with —harmony flag) and on by default in `4+`.

async/await

the beauty of coroutine without the boilerplate

COMING IN ES7 - NOT RECOMMENDED FOR USE YET

Run Demo

From generators to async/await

```
Promise.coroutine(function* () {
    const [a, b] = yield Promise.all([
        Promise.resolve(1),
        Promise.resolve(2)
    ])

    console.log(a, b)
})()
```

Using async/await:

```
async function () {
    const [a, b] = await Promise.all([
        Promise.resolve(1),
        Promise.resolve(2)
    ])

    console.log(a, b)
}
```

Debugging Asynchronous JavaScript

Run Demo

Stacktraces are helpful if you have them

But sadly, stacktraces are lost on the event loop boundary.

```
function doMyThing() {
    setTimeout(() => {
        console.log(new Error().stack)
    }, 100)
}

doMyThing()
```

Run Demo

Maintaining your stacktrace

Capture your stack trace before setting up an asynchronous callback if you want to know where things happened. **Warning: used incorrectly, this can be very memory expensive and cause performance issues.**

```
function doMyThing() {
    const stack = new Error().stack
    // Queues the function to be invoked in 1000ms on the event loop.
    setTimeout(() => {
        console.log(stack)
    }, 1000)
}

doMyThing()
```

There are far more sophisticated ways of capturing the stacktrace. However, what's important to know is that stacktraces are lost on the event loop boundary.

Run Demo

Name function parameters

```
function doMyThing() {
    setTimeout(() => {
        console.log('NOT NAMED: ' + new Error().stack)
    }, 50)
}
doMyThing()
```

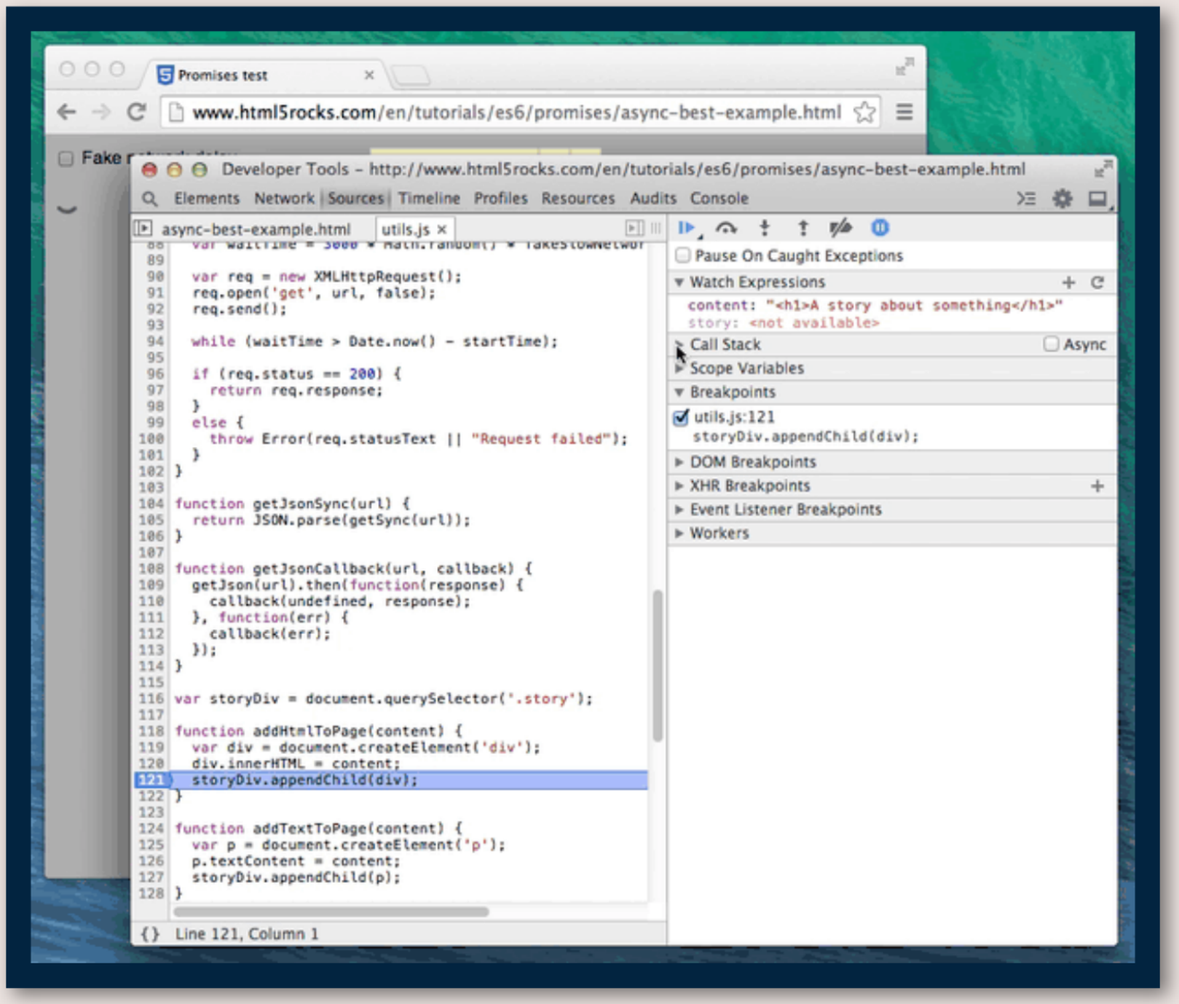
Instead, provide a name for your function parameter to improve stack trace

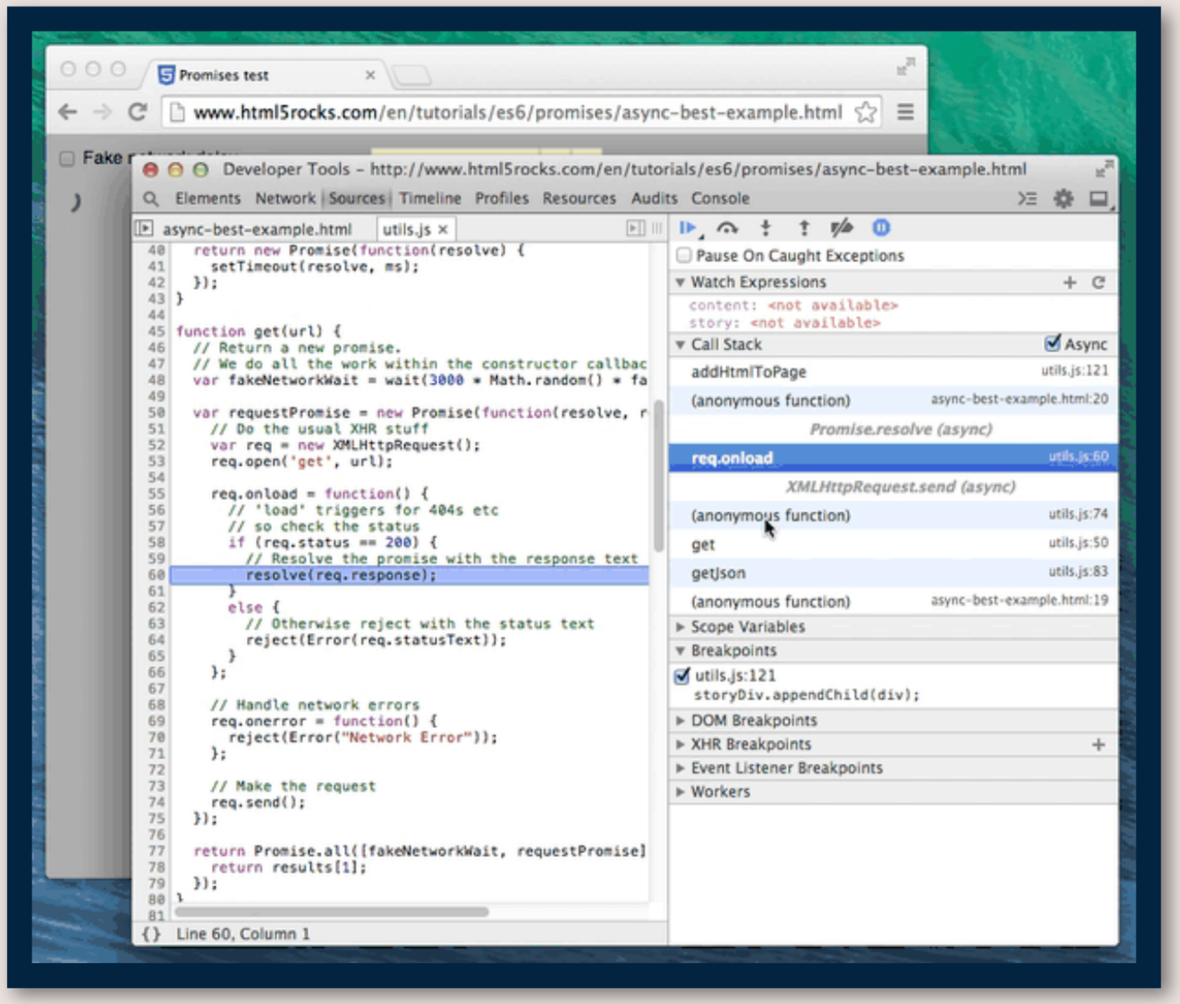
```
function doMyThing() {
    setTimeout(function fooIsMyName() {
        console.log('    NAMED: ' + new Error().stack)
    }, 50)
}

doMyThing()
```

Enable async stacktraces in chrome

source: http://www.html5rocks.com/en/tutorials/developertools/async-call-stack/





Thank you!

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