A Deep Dive Into `Sendable`

Tim Condon
@0xTim

BROKENHANDS

Introduction

- Founder of Broken Hands 
- Vapor Core Team 
- SSWG and SWWG Member 
- Server-side Swift Team @ Kodeco 
- Organise ServerSide.swift, NSManchester, Vapor London
- `@0xTim`     

Why

Swift


Fast
Modern
Safe
Interactive

Swift Safety

Optionals

Memory Overflows


C BUFFER
YOUR MEMORY

Swift Safety

Optionals

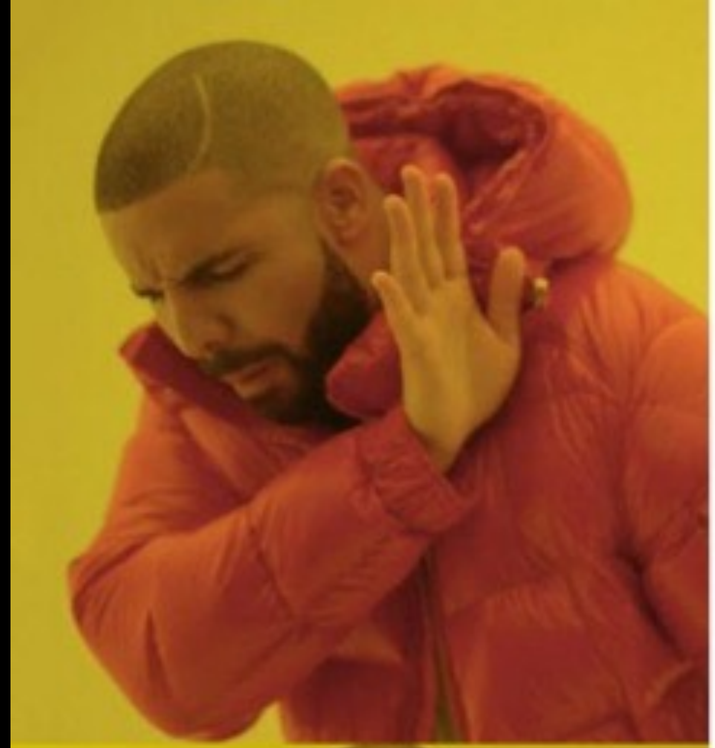
Memory Overflows

Explicit Error Handling

Type Checking

Swift Safety

Undefined Behaviour



RUNTIME ERRORS

COMPILE TIME ERRORS


SHIP IT

Data Races

```
d 1 Queue: com.apple.main-thread (serial)
spatch_async_swift_job
ift_task_enqueueGlobal
ift_task_switchImpl(swift::AsyncContext*, void (swift:...
osure #1 in ViewModel.run()
artial apply for closure #1 in ViewModel.run()
unk for @escaping @callee_guaranteed @Sendable @...
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d 2 Queue: com.apple.root....ooperative (concurrent)
swift_release_dealloc
ol swift::RefCounts<swift::RefCountBitsT<(swift::RefC...
rray.append(_:)
epository.add(value:)
peration.execute(value:)
osure #1 in ViewModel.run()
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unk for @escaping @callee_guaranteed @Sendable @...
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d 3 Queue: com.apple.root....ooperative (concurrent)
swift_release_dealloc
ol swift::RefCounts<swift::RefCountBitsT<(swift::RefC...
rray.append(_:)
epository.add(value:)
peration.execute(value:)
osure #1 in ViewModel.run()
```
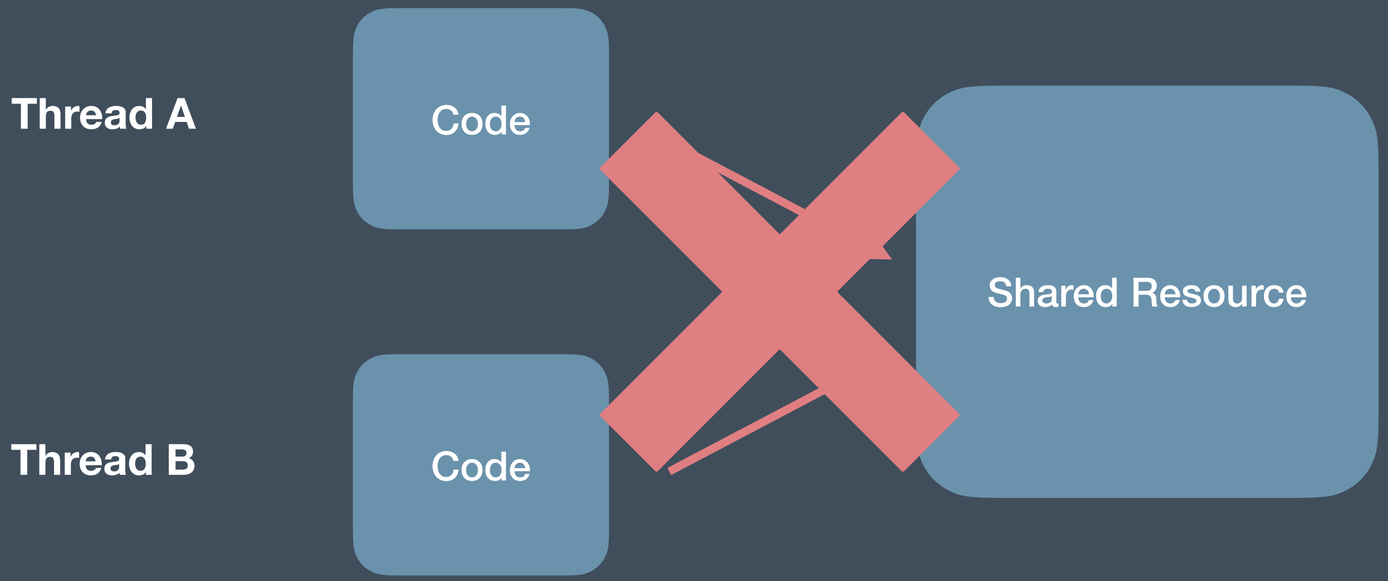

```
1
2  import SwiftUI
3
4  class Repository {
5      var results: [Int] = []
6
7      func add(value: Int) {
8          results.append(value)        Thread 2: EXC_BAD_ACCESS (code=1, address=0xf
9      }
10 }
11
12 @MainActor
13 class ViewModel: ObservableObject {
14     var repository = Repository()
15
16     func run() async {
17         for value in 0..<1000 {
18             Task {
19                 await Operation(repository: self.repository).execute(value: va
20             }
21         }
22     }
23 }
24
25 struct Operation {
26     let repository: Repository
27
28     func execute(value: Int) async {
29         repository.add(value: value)
30     }
31 }
32
```

Data Races



Boto3 1.28.40 documentation

Feedback

improve this website or boto3? Give us feedback.

Quickstart
A Sample Tutorial
Code Examples
Developer Guide
Configuration
Credentials
Low-level clients
Resources
Session
Collections
Paginators
Error handling
Retries
Extensibility guide

```
# S3: Wait for a bucket to exist.
bucket.wait_until_exists()

# EC2: Wait for an instance to reach the running state.
instance.wait_until_running()
```

Multithreading or multiprocessing with resources

Resource instances are **not** thread safe and should not be shared across threads or processes. These special classes contain additional meta data that cannot be shared. It's recommended to create a new Resource for each thread or process:

```
import boto3
import boto3.session
import threading

class MyTask(threading.Thread):
    def run(self):
        # Here we create a new session per thread
        session = boto3.session.Session()

        # Next, we create a resource client using our thread's session object
        s3 = session.resource('s3')

        # Put your thread-safe code here
```

In the example above, each thread would have its own Boto3 session and its own instance of the S3 resource. This is a good idea because resources contain shared data when loaded and calling actions, accessing properties, or manually loading or reloading the resource can modify this data.

Previous Low-level clients

Next Session

READ THE DOCS

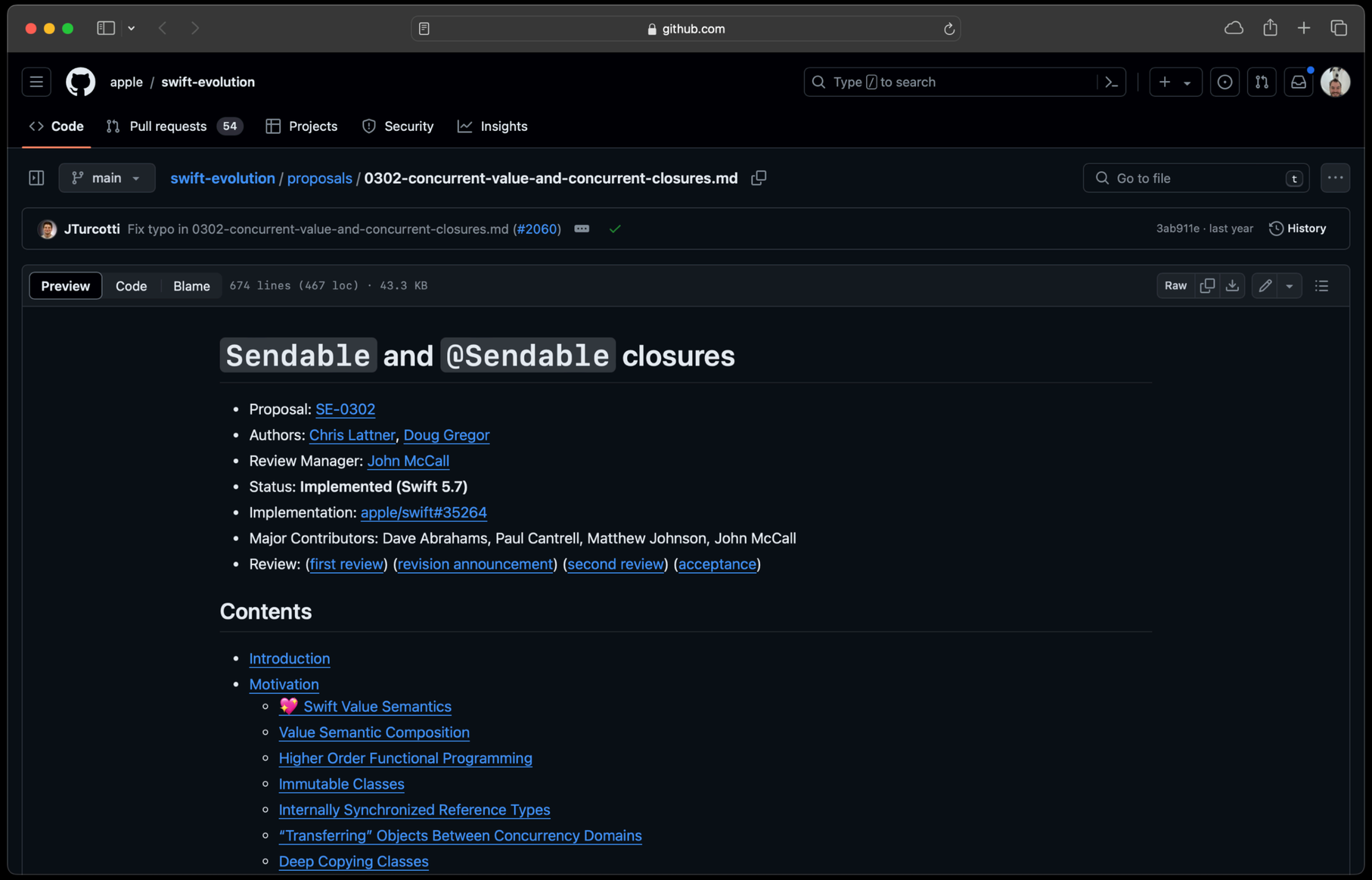
INHERENT KNOWLEDGE

CODE REVIEW

COMPILER ERRORS

What

Sendable


github.com
apple / swift-evolution
Type / to search
Code
Pull requests 54
Projects
Security
Insights
main
swift-evolution / proposals / 0302-concurrent-value-and-concurrent-closures.md
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JTurcotti Fix typo in 0302-concurrent-value-and-concurrent-closures.md (#2060)
3ab911e · last year
History
Preview
Code
Blame
674 lines (467 loc) · 43.3 KB
Raw
Sendable and @Sendable closures
Proposal: SE-0302
Authors: Chris Lattner, Doug Gregor
Review Manager: John McCall
Status: Implemented (Swift 5.7)
Implementation: apple/swift#35264
Major Contributors: Dave Abrahams, Paul Cantrell, Matthew Johnson, John McCall
Review: (first review) (revision announcement) (second review) (acceptance)
Contents
Introduction
Motivation
💔 Swift Value Semantics
Value Semantic Composition
Higher Order Functional Programming
Immutable Classes
Internally Synchronized Reference Types
"Transferring" Objects Between Concurrency Domains
Deep Copying Classes

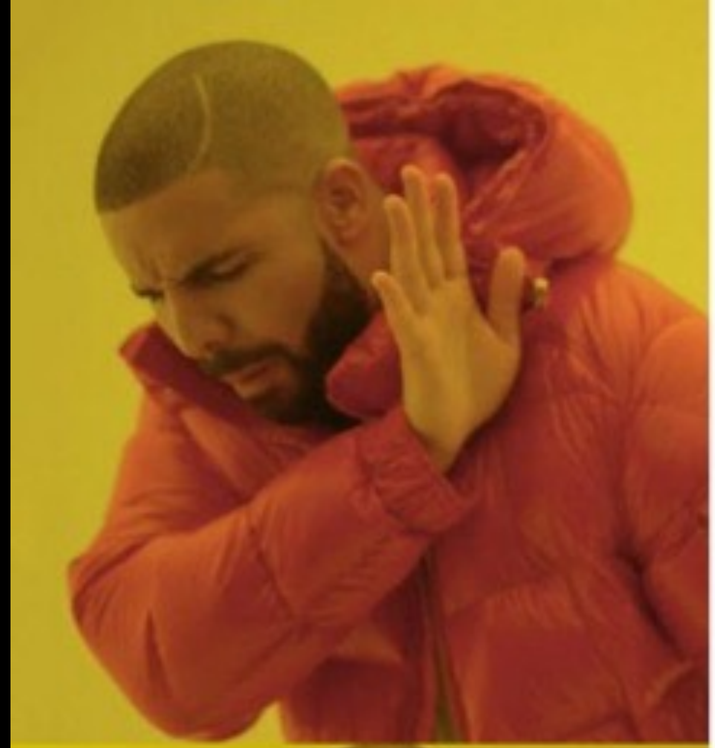
SE-0302

Sendable provides compiler guarantees of data safety in concurrent environments

Sendable ≈ Rust's Memory Safety

Sendable == Thread Safety

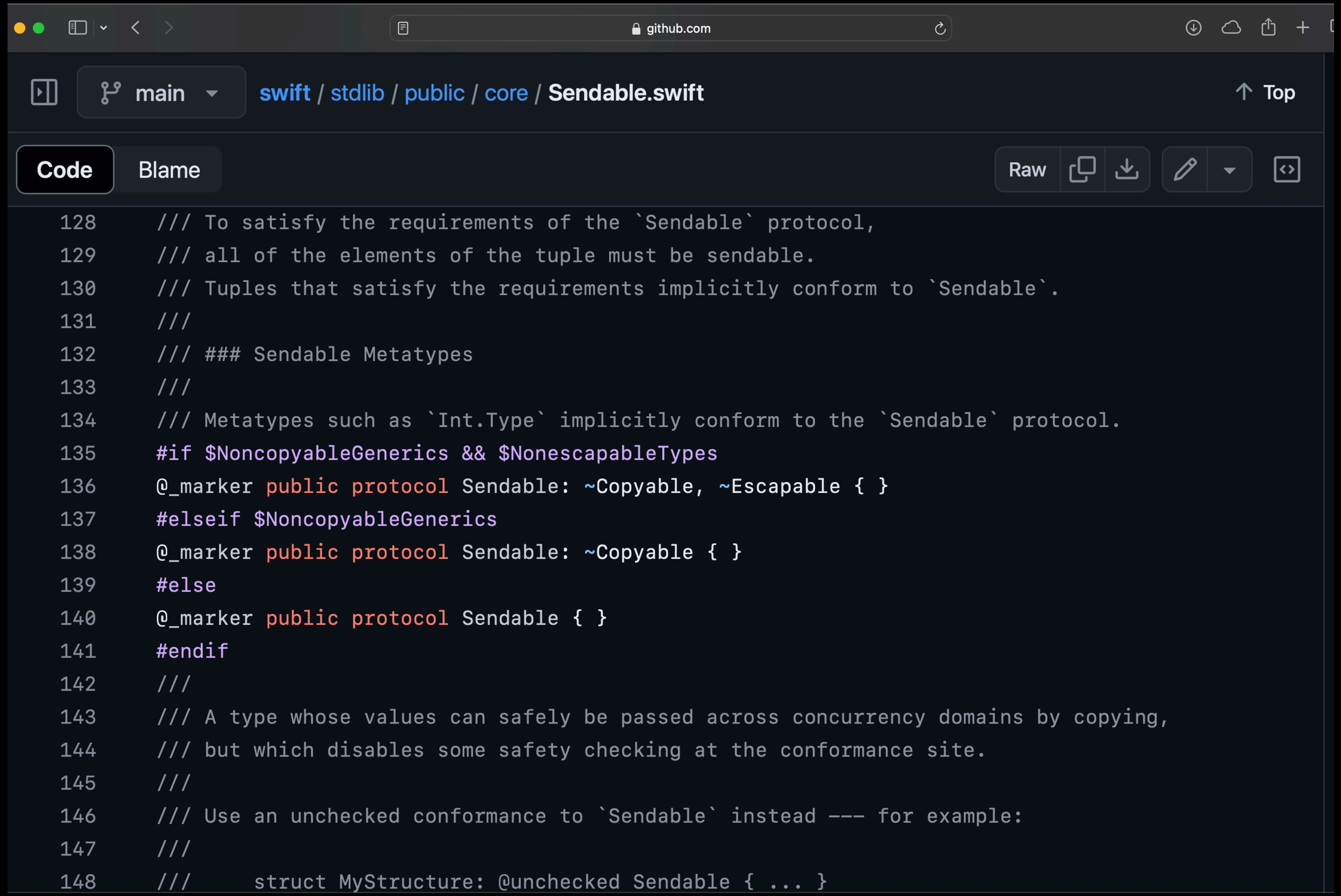

Threads
Tasks
Corporate needs you to find the differences between this picture and this picture.
They're the same picture.
Made with Piñata Farms



RUNTIME ERRORS

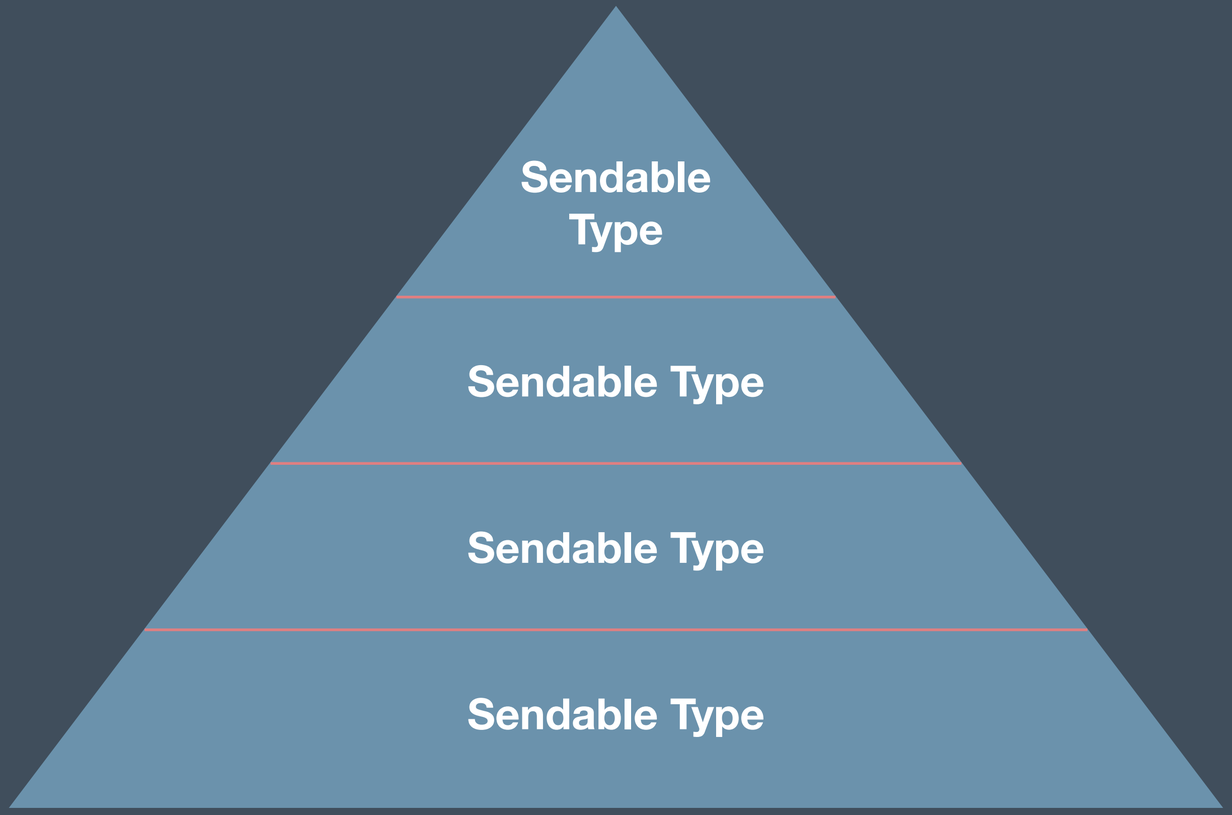
COMPILE TIME ERRORS

How




```
128   /// To satisfy the requirements of the `Sendable` protocol,
129   /// all of the elements of the tuple must be sendable.
130   /// Tuples that satisfy the requirements implicitly conform to `Sendable`.
131   ///
132   /// ### Sendable Metatypes
133   ///
134   /// Metatypes such as `Int.Type` implicitly conform to the `Sendable` protocol.
135   #if $NoncopyableGenerics && $NonescapableTypes
136   @_marker public protocol Sendable: ~Copyable, ~Escapable { }
137   #elseif $NoncopyableGenerics
138   @_marker public protocol Sendable: ~Copyable { }
139   #else
140   @_marker public protocol Sendable { }
141   #endif
142   ///
143   /// A type whose values can safely be passed across concurrency domains by copying,
144   /// but which disables some safety checking at the conformance site.
145   ///
146   /// Use an unchecked conformance to `Sendable` instead --- for example:
147   ///
148   ///     struct MyStructure: @unchecked Sendable { ... }
```

Sendable



```
struct PersonData: Codable, Sendable {
    let name: String
    let age: Int
    let phoneNumber: String
}
```


Sendable Types

```
/// Most base types are Sendable

public struct Date : Comparable,
Hashable, Equatable, Sendable {
    /// ...
}
```


Sendable Types

```
// Value types are Sendable

struct PersonData: Codable, Sendable {
    var name: String
    var age: String
    var phoneNumber: String
}
```


Sendable Types

```
// This is implicit in the same target
extension PersonData: Sendable {}
```


Sendable Types

```
// Anything conforming to this must be Sendable

protocol SuperAwesomeThing: Sendable {
    func doSomethingSafe()
}
```


Sendable Types

```
// All properties must be Sendable

struct SomeGenericThing<T> {
    let theThing: T
}

extension SomeGenericThing: Sendable where T: Sendable {}
```


Sendable Closures

```
public struct Provider: Sendable {
    let run: @Sendable (Application) -> ()

    public init(_ run: @Sendable @escaping (Application) -> ()) {
        self.run = run
    }
}
```


Sendable Reference Types

Sendable Reference Types

```
// MUST be final
final class AReferenceType: Sendable {

    // Cannot be mutable - no CoW
    let nonMutableSendableThing: SomethingSendable

    init(_ aThing: SomethingSendable) {
        self.nonMutableSendableThing = aThing
    }
}
```



SENDABLE
REFERENCE TYPES
SENDABLE
imgflip.com

Sendable Reference Types

```
class Person {
    var name: String
    var age: Int
    var phoneNumber: String

    init(name: String, age: Int, phoneNumber: String) {
        self.name = name
        self.age = age
        self.phoneNumber = phoneNumber
    }
}
```



BLOWN AWAY

Sendable Reference Types

```
class AddressBook {
    var people: [Person]

    init() {
        self.people = []
    }
}
```


Sendable Reference Types

```
// Option 1

@MainActor
class AddressBook {
    var people: [Person]

    init() {
        self.people = []
    }
}
```


Sendable Reference Types

```
// Option 2

actor AddressBook {
    var people: [Person]

    init() {
        self.people = []
    }
}
```


```swift
// Option 3

class AddressBook: @unchecked Sendable {
    private var people: [Person]
    private let lock = NIOLock()

    func addPerson(_ person: Person) {
        lock.withLockVoid {
            people.append(person)
        }
    }

    func getPerson(at index: Int) -> Person {
        lock.withLock {
            people[index]
        }
    }

    init() {
        self.people = []
    }
}
```

@unchecked Sendable

@unchecked Sendable

```swift
// Option 3

class AddressBook: @unchecked Sendable {
    private var people: [Person]
    private let lock = NIOLock()

    func addPerson(_ person: Person) {
        lock.withLockVoid {
            people.append(person)
        }
    }

    func getPerson(at index: Int) -> Person {
        lock.withLock {
            people[index]
        }
    }

    init() {
        self.people = []
    }
}
```

Person is a reference type

```
let addressBook = AddressBook()

let person = Person(name: "Tim", age: 99,
                    phoneNumber: "07123456789")

addressBook.addPerson(person)
await storeAddressBookAsync(addressBook)

person.name = "Alice" // 💥
```

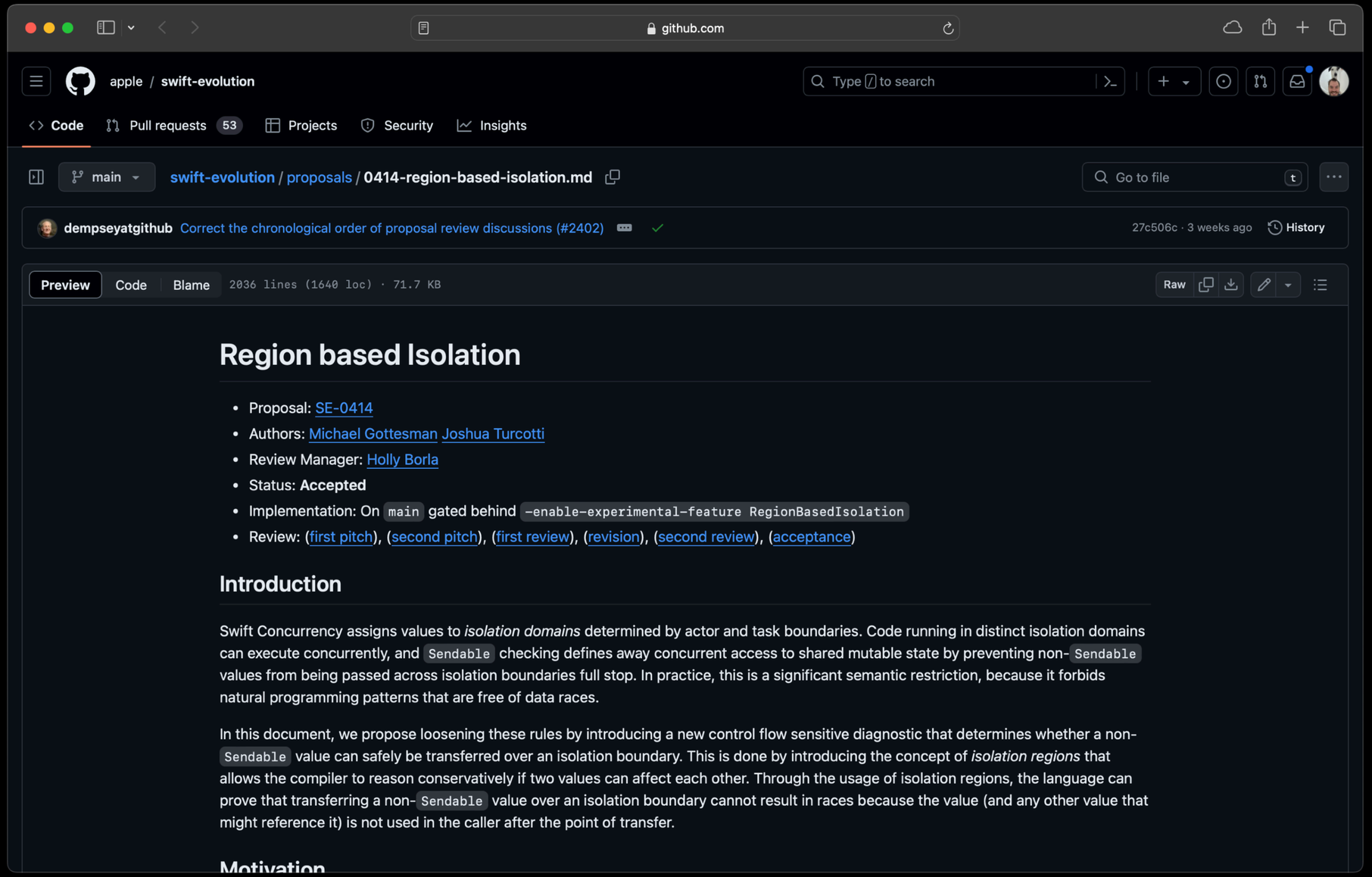
```
actor AddressBook {
    var people: [Person]

    init() {
        self.people = []
    }

    func addPerson(_ person: Person) {
        self.people.append(person)
    }
}

func createPerson(in addressBook: AddressBook) async {
    let person = Person(name: "tim", age: 29, phoneNumber: "1234")
    await addressBook.addPerson(person)
}
```

⚠ Passing argument of non-sendable type 'Person' into actor-isolated context may introduce data races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Code
Pull requests 53
Projects
Security
Insights
main
swift-evolution / proposals / 0414-region-based-isolation.md
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dempseyatgithub Correct the chronological order of proposal review discussions (#2402)
27c506c · 3 weeks ago
History
Preview
Code
Blame
2036 lines (1640 loc) · 71.7 KB
Raw
Region based Isolation
Proposal: SE-0414
Authors: Michael Gottesman Joshua Turcotti
Review Manager: Holly Borla
Status: Accepted
Implementation: On main gated behind -enable-experimental-feature RegionBasedIsolation
Review: (first pitch), (second pitch), (first review), (revision), (second review), (acceptance)
Introduction
Swift Concurrency assigns values to isolation domains determined by actor and task boundaries. Code running in distinct isolation domains can execute concurrently, and Sendable checking defines away concurrent access to shared mutable state by preventing non-Sendable values from being passed across isolation boundaries full stop. In practice, this is a significant semantic restriction, because it forbids natural programming patterns that are free of data races.
In this document, we propose loosening these rules by introducing a new control flow sensitive diagnostic that determines whether a non-Sendable value can safely be transferred over an isolation boundary. This is done by introducing the concept of isolation regions that allows the compiler to reason conservatively if two values can affect each other. Through the usage of isolation regions, the language can prove that transferring a non-Sendable value over an isolation boundary cannot result in races because the value (and any other value that might reference it) is not used in the caller after the point of transfer.
Motivation

SE-0414

```
actor AddressBook {
    var people: [Person]

    init() {
        self.people = []
    }

    func addPerson(_ person: Person) {
        self.people.append(person)
    }
}

func createPerson(in addressBook: AddressBook) async {
    let person = Person(name: "tim", age: 29, phoneNumber: "1234")
    await addressBook.addPerson(person)
}
```

Safe Mutable Values

```swift
public struct NIOLockedValueBox<Value> {

    @usableFromInline
    internal let _storage: LockStorage<Value>

    /// Initialize the `Value`.
    @inlinable
    public init(_ value: Value) {
        self._storage = .create(value: value)
    }

    /// Access the `Value`, allowing mutation of it.
    @inlinable
    public func withLockedValue<T>(_ mutate: (inout Value) throws -> T)
      rethrows -> T {
        return try self._storage.withLockedValue(mutate)
    }
}

extension NIOLockedValueBox: Sendable where Value: Sendable {}
```

Sendable Reference Types

```
// Option 4

final class Person: Sendable {
    let name: NIOLockedValueBox<String>
    let age: NIOLockedValueBox<Int>
    let phoneNumber: NIOLockedValueBox<String>

    init(name: String, age: Int, phoneNumber: String) {
        self.name = .init(name)
        self.age = .init(age)
        self.phoneNumber = .init(phoneNumber)
    }
}
```


Sendable Reference Types

```
// Option 4a

final class AddressBook: Sendable {
    private let people: NIOLockedValueBox<[Person]>

    init() {
        self.people = .init([])
    }
}
```


Sendable Reference Types

```
// Option 4b

final class AddressBook: Sendable {
    private let lock: NIOLock
    // All access protected by a lock
    // Person is now Sendable so it’s ok
    nonisolated(unsafe) private var people: <[Person]>

    init() {
        self.people = .init([])
        self.lock = .init()
    }
}
```


```swift
public struct NIOLoopBound<Value>: @unchecked Sendable {
    public let _eventLoop: EventLoop

    @usableFromInline
    /* private */ var _value: Value

    /// Initialise a ``NIOLoopBound`` to `value` with the precondition that the code is running on `eventLoop`.
    @inlinable
    public init(_ value: Value, eventLoop: EventLoop) {
        eventLoop.preconditionInEventLoop()
        self._eventLoop = eventLoop
        self._value = value
    }

    /// Access the `value` with the precondition that the code is running on `eventLoop`.
    /// - note: ``NIOLoopBound`` itself is value-typed, so any writes will only affect the current value.
    @inlinable
    public var value: Value {
        get {
            self._eventLoop.preconditionInEventLoop()
            return self._value
        }
        set {
            self._eventLoop.preconditionInEventLoop()
            self._value = newValue
        }
    }
}
```

Sendable Reference Types

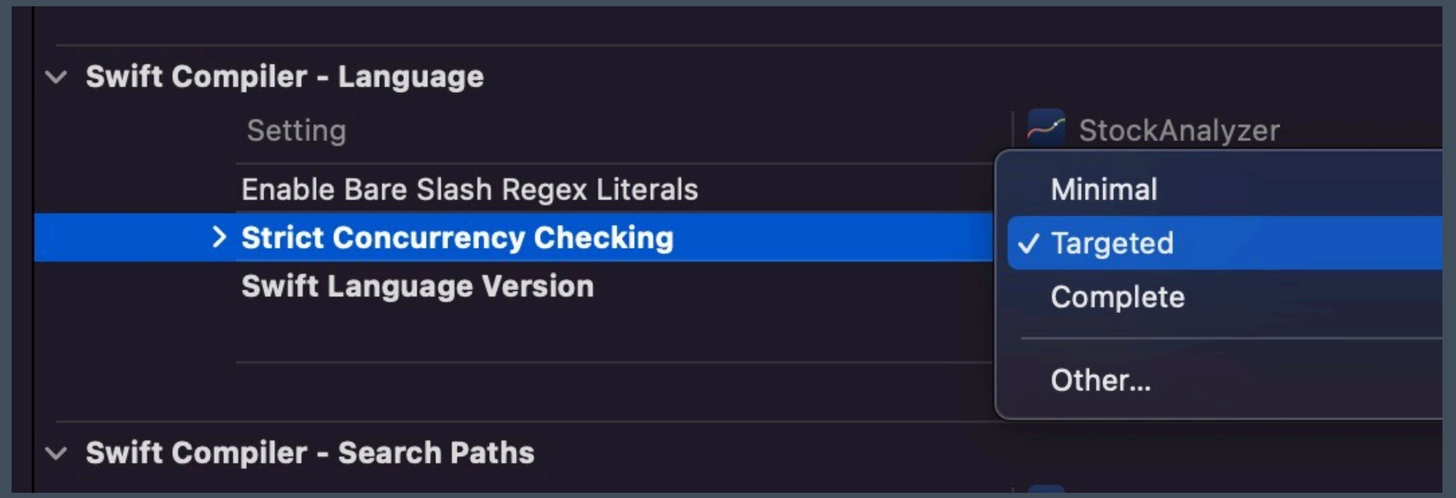
```
// Option 5

final class AddressBook: Sendable {
    private let people: NIOLoopBoundBox<[Person]>

    init(eventLoop: EventLoop) {
        self.people = .init([], eventLoop: eventLoop)
    }
}
```


The Sendable Journey

The Sendable Journey

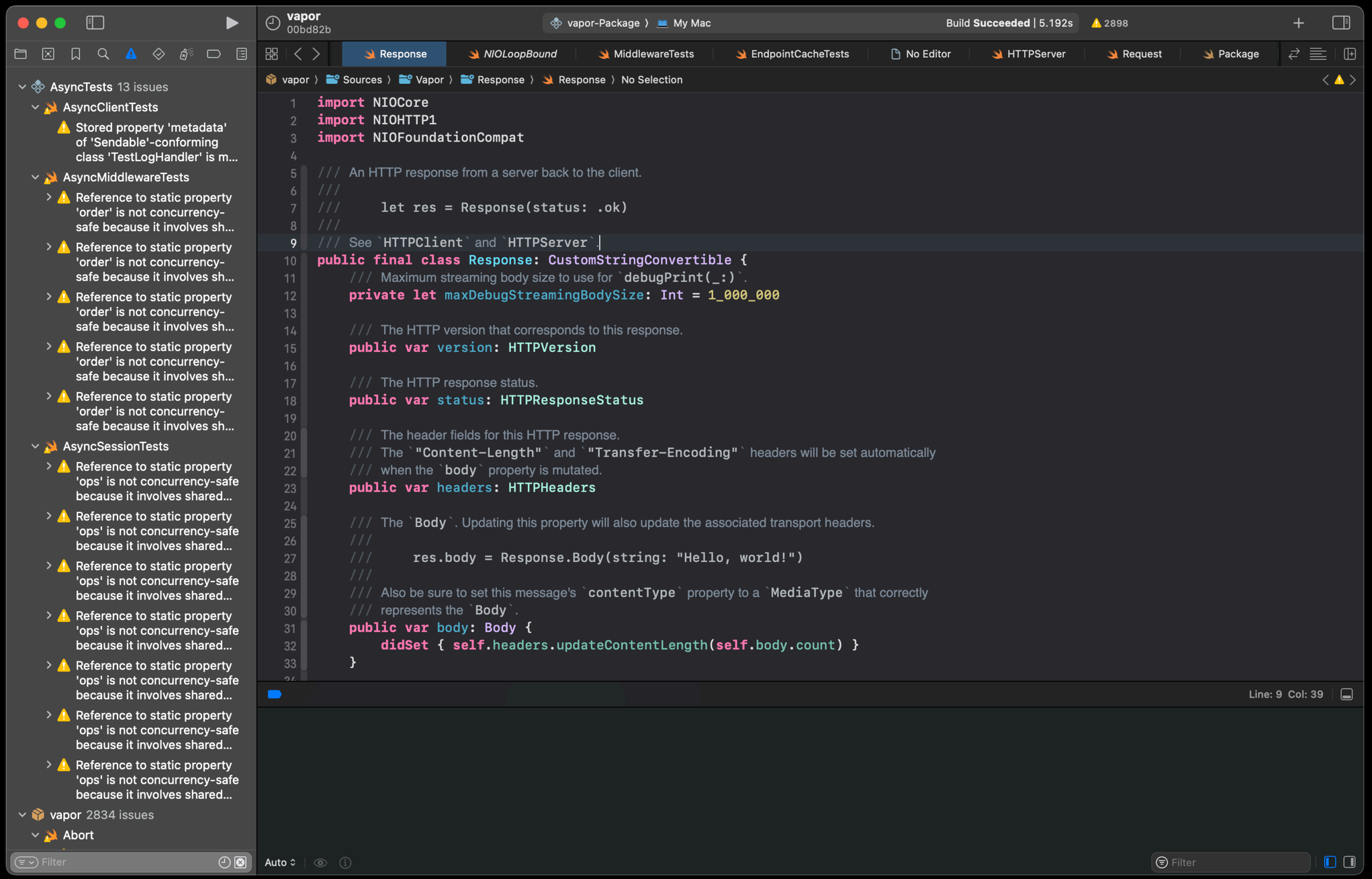


Credit: Antoine van der Lee

The Sendable Journey

```
// swift-tools-version:5.9
import PackageDescription

let package = Package(
    name: "vapor",
    dependencies: [
        // ..
    ],
    targets: [
        .target(name: "Vapor", dependencies: [
          // ..
        ],
        swiftSettings: [
          .enableExperimentalFeature("StrictConcurrency=complete")
        ]),
    ]
)
```



vapor
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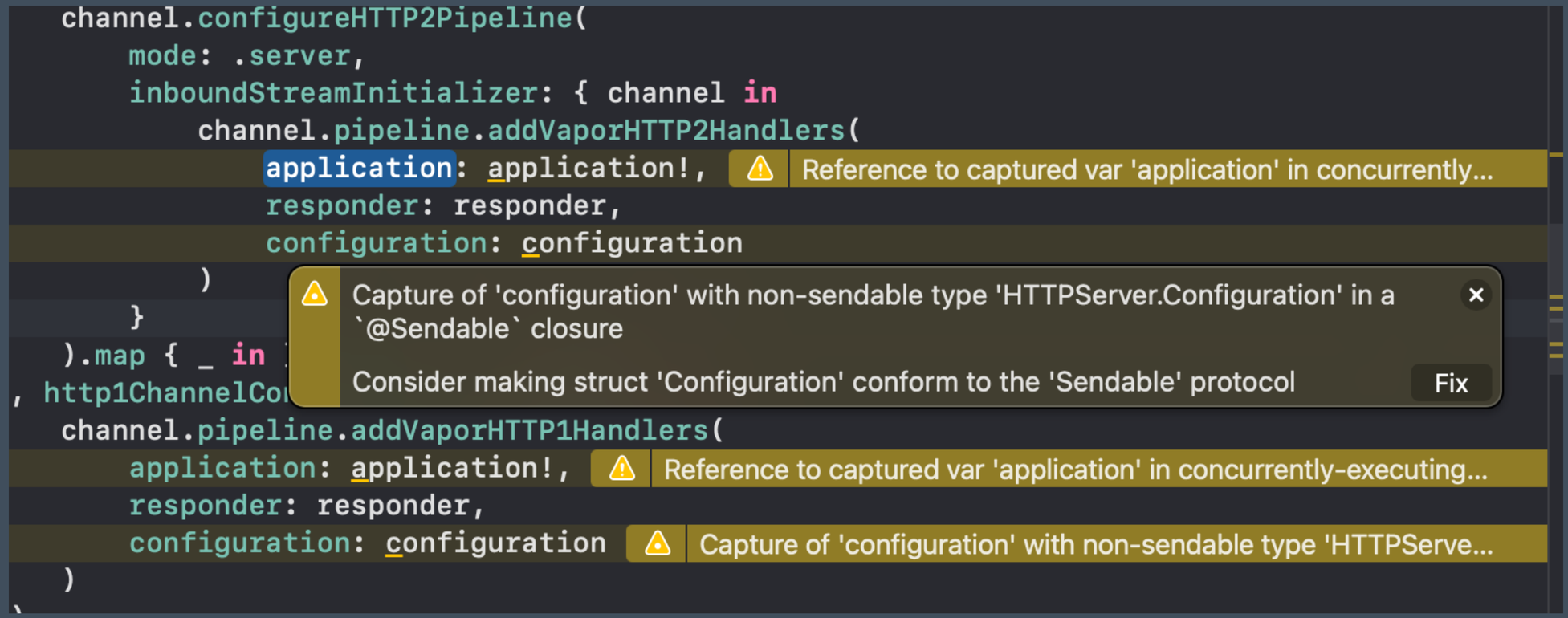
vapor-Package ⟩ My Mac
Build Succeeded | 5.192s
2898
Response
NIOLoopBound
MiddlewareTests
EndpointCacheTests
No Editor
HTTPServer
Request
Package
vapor ⟩ Sources ⟩ Vapor ⟩ Response ⟩ Response ⟩ No Selection
AsyncTests 13 issues
AsyncClientTests
Stored property 'metadata' of 'Sendable'-conforming class 'TestLogHandler' is m...
AsyncMiddlewareTests
Reference to static property 'order' is not concurrency-safe because it involves sh...
AsyncSessionTests
Reference to static property 'ops' is not concurrency-safe because it involves shared...
vapor 2834 issues
Abort
import NIOCore
import NIOHTTP1
import NIOFoundationCompat
/// An HTTP response from a server back to the client.
///
///   let res = Response(status: .ok)
///
/// See `HTTPClient` and `HTTPServer`.
public final class Response: CustomStringConvertible {
/// Maximum streaming body size to use for `debugPrint(_:)`.
private let maxDebugStreamingBodySize: Int = 1_000_000
/// The HTTP version that corresponds to this response.
public var version: HTTPVersion
/// The HTTP response status.
public var status: HTTPResponseStatus
/// The header fields for this HTTP response.
/// The `"Content-Length"` and `"Transfer-Encoding"` headers will be set automatically
/// when the `body` property is mutated.
public var headers: HTTPHeaders
/// The `Body`. Updating this property will also update the associated transport headers.
///
///   res.body = Response.Body(string: "Hello, world!")
///
/// Also be sure to set this message's `contentType` property to a `MediaType` that correctly
/// represents the `Body`.
public var body: Body {
didSet { self.headers.updateContentLength(self.body.count) }
}
Line: 9 Col: 39
Auto
Filter
Filter

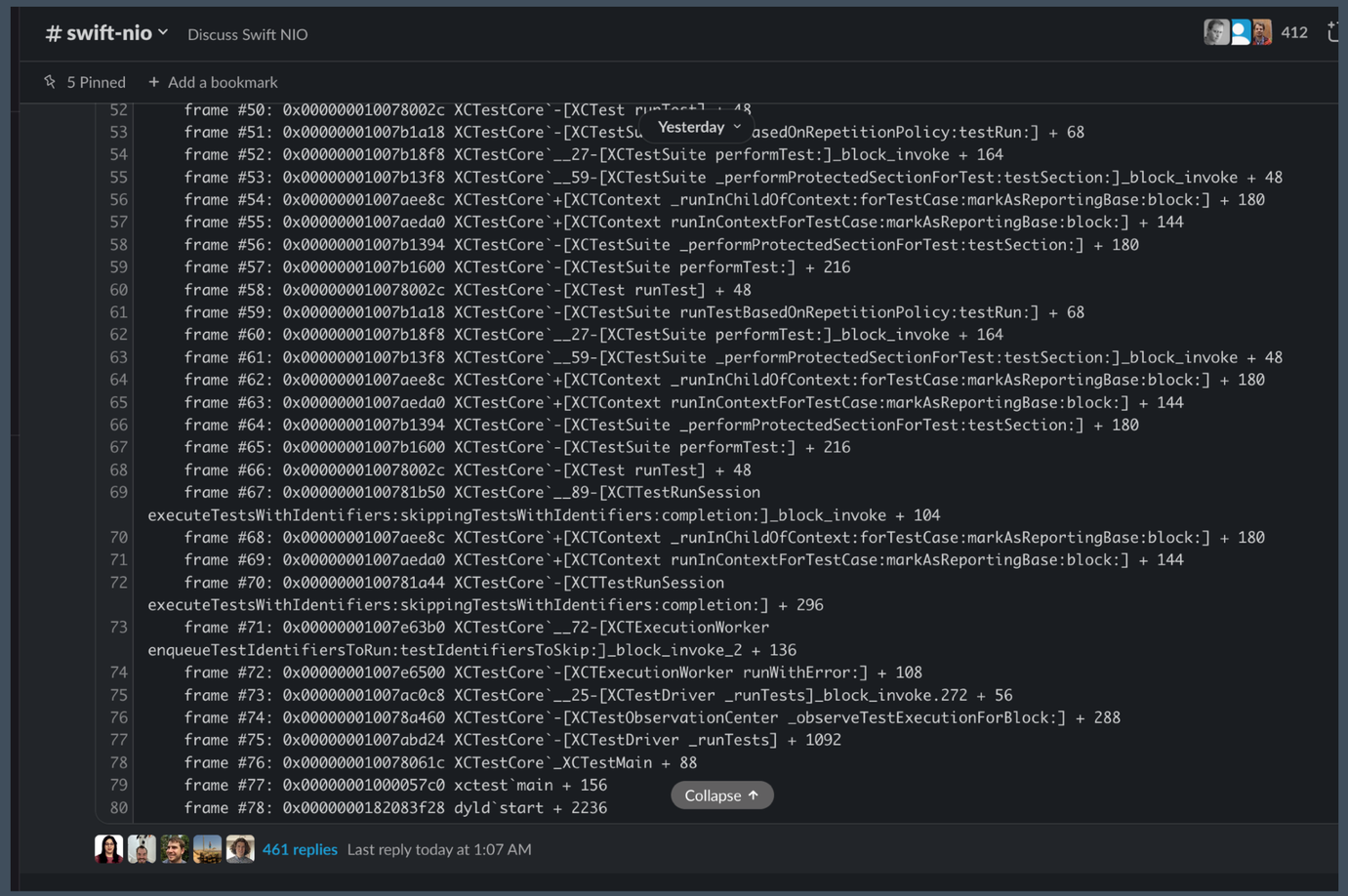
```
func handle(_ req: Request, _ ws: WebSocketKit.WebSocket) {
    var client: Client?

    self.application.ws.knownEventLoop.submit { [weak self] in
        guard let self = self else { return }
        let c = Client(self, req, ws, logger: self.logger)
        client = c
        self._clients.append(c)
    }.whenComplete { [weak self] _ in
        guard
            let client = client,
            let self = self
        else { return }
        self._on(open: client)
        self.on(open: client)
        self.logger.info("[⚡] 🟢 new connection \(client.id)")
    }

    ws.onPing { [weak self] _ in
        guard let client = client else { return }
        self?.log
        self?._or
        self?.on(ping: client)
    }
```

Reference to captured var 'client' in concurrently-executing code

Sendable


channel.configureHTTP2Pipeline(
mode: .server,
inboundStreamInitializer: { channel in
channel.pipeline.addVaporHTTP2Handlers(
application: application!,
Reference to captured var 'application' in concurrently...
responder: responder,
configuration: configuration
)
}
).map { _ in
, http1ChannelCo
Capture of 'configuration' with non-sendable type 'HTTPServer.Configuration' in a `@Sendable` closure
Consider making struct 'Configuration' conform to the 'Sendable' protocol
Fix
channel.pipeline.addVaporHTTP1Handlers(
application: application!,
Reference to captured var 'application' in concurrently-executing...
responder: responder,
configuration: configuration
Capture of 'configuration' with non-sendable type 'HTTPServe...
)

Sendable


swift-nio
Discuss Swift NIO
412
5 Pinned
Add a bookmark
Yesterday
frame #50: 0x000000010078002c XCTestCore`-[XCTest runTest] + 48
frame #51: 0x00000001007b1a18 XCTestCore`-[XCTestSu asedOnRepetitionPolicy:testRun:] + 68
frame #52: 0x00000001007b18f8 XCTestCore`__27-[XCTestSuite performTest:]_block_invoke + 164
frame #53: 0x00000001007b13f8 XCTestCore`__59-[XCTestSuite _performProtectedSectionForTest:testSection:]_block_invoke + 48
frame #54: 0x00000001007aee8c XCTestCore`+[XCTContext _runInChildOfContext:forTestCase:markAsReportingBase:block:] + 180
frame #55: 0x00000001007aeda0 XCTestCore`+[XCTContext runInContextForTestCase:markAsReportingBase:block:] + 144
frame #56: 0x00000001007b1394 XCTestCore`-[XCTestSuite _performProtectedSectionForTest:testSection:] + 180
frame #57: 0x00000001007b1600 XCTestCore`-[XCTestSuite performTest:] + 216
frame #58: 0x000000010078002c XCTestCore`-[XCTest runTest] + 48
frame #59: 0x00000001007b1a18 XCTestCore`-[XCTestSuite runTestBasedOnRepetitionPolicy:testRun:] + 68
frame #60: 0x00000001007b18f8 XCTestCore`__27-[XCTestSuite performTest:]_block_invoke + 164
frame #61: 0x00000001007b13f8 XCTestCore`__59-[XCTestSuite _performProtectedSectionForTest:testSection:]_block_invoke + 48
frame #62: 0x00000001007aee8c XCTestCore`+[XCTContext _runInChildOfContext:forTestCase:markAsReportingBase:block:] + 180
frame #63: 0x00000001007aeda0 XCTestCore`+[XCTContext runInContextForTestCase:markAsReportingBase:block:] + 144
frame #64: 0x00000001007b1394 XCTestCore`-[XCTestSuite _performProtectedSectionForTest:testSection:] + 180
frame #65: 0x00000001007b1600 XCTestCore`-[XCTestSuite performTest:] + 216
frame #66: 0x000000010078002c XCTestCore`-[XCTest runTest] + 48
frame #67: 0x0000000100781b50 XCTestCore`__89-[XCTTestRunSession executeTestsWithIdentifiers:skippingTestsWithIdentifiers:completion:]_block_invoke + 104
frame #68: 0x00000001007aee8c XCTestCore`+[XCTContext _runInChildOfContext:forTestCase:markAsReportingBase:block:] + 180
frame #69: 0x00000001007aeda0 XCTestCore`+[XCTContext runInContextForTestCase:markAsReportingBase:block:] + 144
frame #70: 0x0000000100781a44 XCTestCore`-[XCTTestRunSession executeTestsWithIdentifiers:skippingTestsWithIdentifiers:completion:] + 296
frame #71: 0x00000001007e63b0 XCTestCore`__72-[XCTExecutionWorker enqueueTestIdentifiersToRun:testIdentifiersToSkip:]_block_invoke_2 + 136
frame #72: 0x00000001007e6500 XCTestCore`-[XCTExecutionWorker runWithError:] + 108
frame #73: 0x00000001007ac0c8 XCTestCore`__25-[XCTestDriver _runTests]_block_invoke.272 + 56
frame #74: 0x000000010078a460 XCTestCore`-[XCTestObservationCenter _observeTestExecutionForBlock:] + 288
frame #75: 0x00000001007abd24 XCTestCore`-[XCTestDriver _runTests] + 1092
frame #76: 0x000000010078061c XCTestCore`_XCTestMain + 88
frame #77: 0x00000001000057c0 xctest`main + 156
frame #78: 0x0000000182083f28 dyld`start + 2236
Collapse
461 replies
Last reply today at 1:07 AM

Maintaining Your API

Backwards Compatibility

```
// With @preconcurrency, adopters don’t get warnings
// unless complete currency checking is turned on

@preconcurrency public func onPong(
   _ callback: @Sendable @escaping (WebSocket) -> ()) {
     self.onPongCallback.value = callback
}
```


Backwards Compatibility

```
// With @preconcurrency import, remove warnings
// when using non-Sendable types from dependencies

@preconcurrency import ConsoleKit
```


Maintaining the API

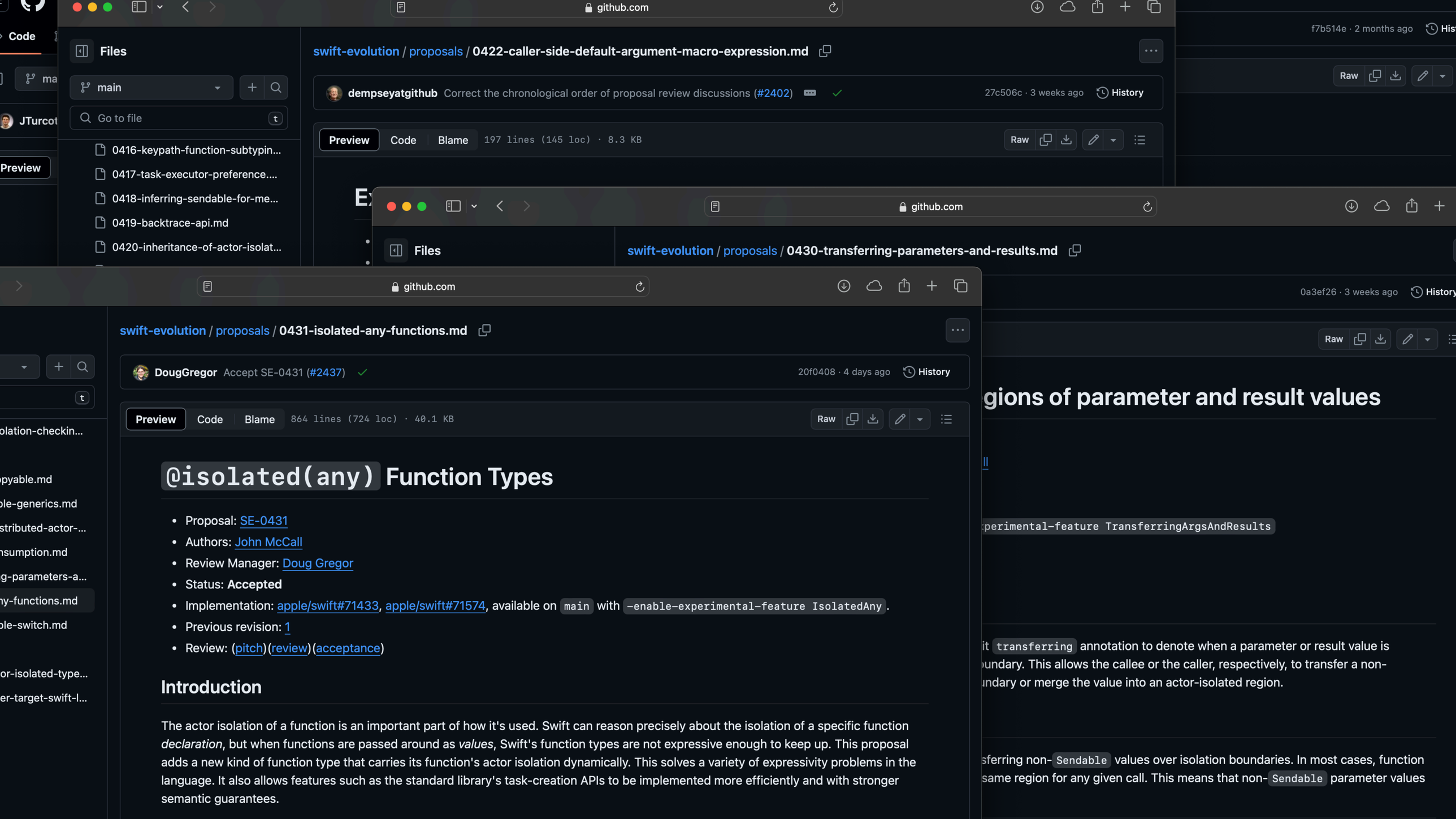
```
// What about mutable properties in a class?

public var method: HTTPMethod
```


Maintaining the API

```
private let _method: NIOLockedValueBox<HTTPMethod>

public var method: HTTPMethod {
    get {
        return _method.withLockedValue { $0 }
    }
    set {
        _method.withLockedValue { $0 = newValue }
    }
}
```


Recap

Sendable provides compiler guarantees of data safety in concurrent environments


github.com
Files
main
Go to file
0416-keypath-function-subtypin...
0417-task-executor-preference....
0418-inferring-sendable-for-me...
0419-backtrace-api.md
0420-inheritance-of-actor-isolat...
swift-evolution / proposals / 0422-caller-side-default-argument-macro-expression.md
dempseyatgithub Correct the chronological order of proposal review discussions (#2402)
27c506c · 3 weeks ago
History
Preview
Code
Blame
197 lines (145 loc) · 8.3 KB
Raw
swift-evolution / proposals / 0430-transferring-parameters-and-results.md
swift-evolution / proposals / 0431-isolated-any-functions.md
DougGregor Accept SE-0431 (#2437)
20f0408 · 4 days ago
History
864 lines (724 loc) · 40.1 KB
@isolated(any) Function Types
Proposal: SE-0431
Authors: John McCall
Review Manager: Doug Gregor
Status: Accepted
Implementation: apple/swift#71433, apple/swift#71574, available on main with -enable-experimental-feature IsolatedAny.
Previous revision: 1
Review: (pitch)(review)(acceptance)
Introduction
The actor isolation of a function is an important part of how it's used. Swift can reason precisely about the isolation of a specific function declaration, but when functions are passed around as values, Swift's function types are not expressive enough to keep up. This proposal adds a new kind of function type that carries its function's actor isolation dynamically. This solves a variety of expressivity problems in the language. It also allows features such as the standard library's task-creation APIs to be implemented more efficiently and with stronger semantic guarantees.
gions of parameter and result values
-enable-experimental-feature TransferringArgsAndResults
transferring
Sendable
Sendable

developer.apple.com

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Thank you!

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ServerSide.swift

26-27 September 2024, London, UK

Questions?

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