Karlsruhe Institute of Technology

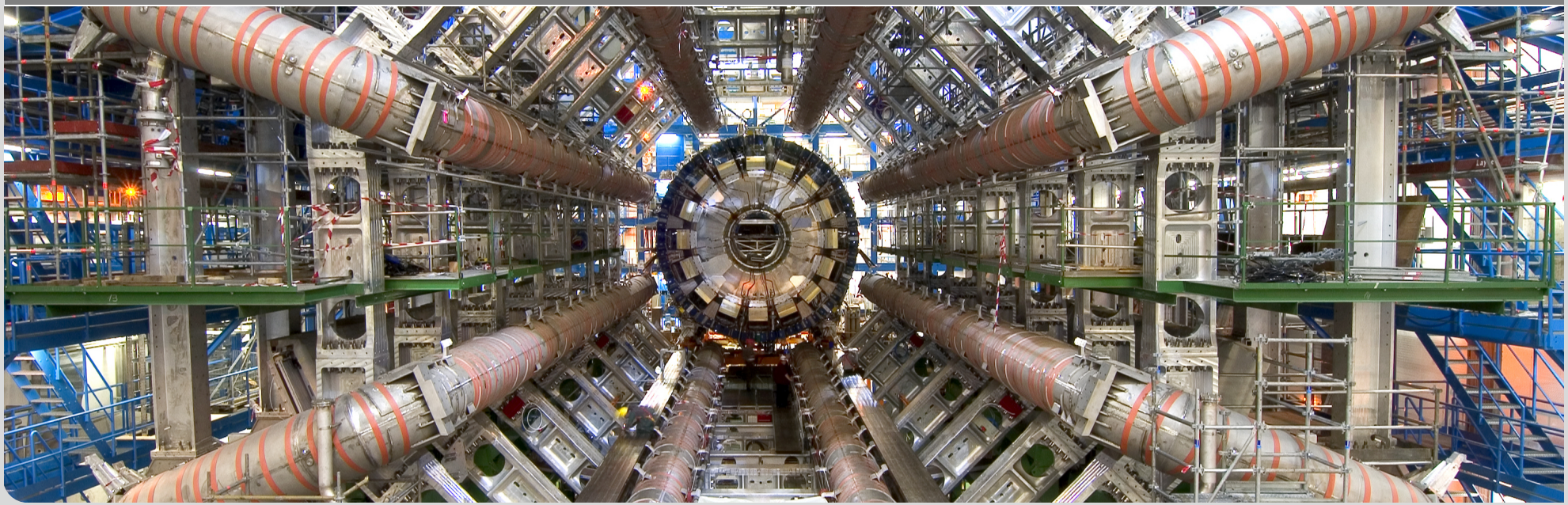
Steinbuch Centre for Computing

rootJS - Functional Specification

PSE - Software Engineering Practice

C. Wolff, M. Früh, S. Rajgopal, C. Haas, J. Schwabe, T. Beffart | December 16, 2015

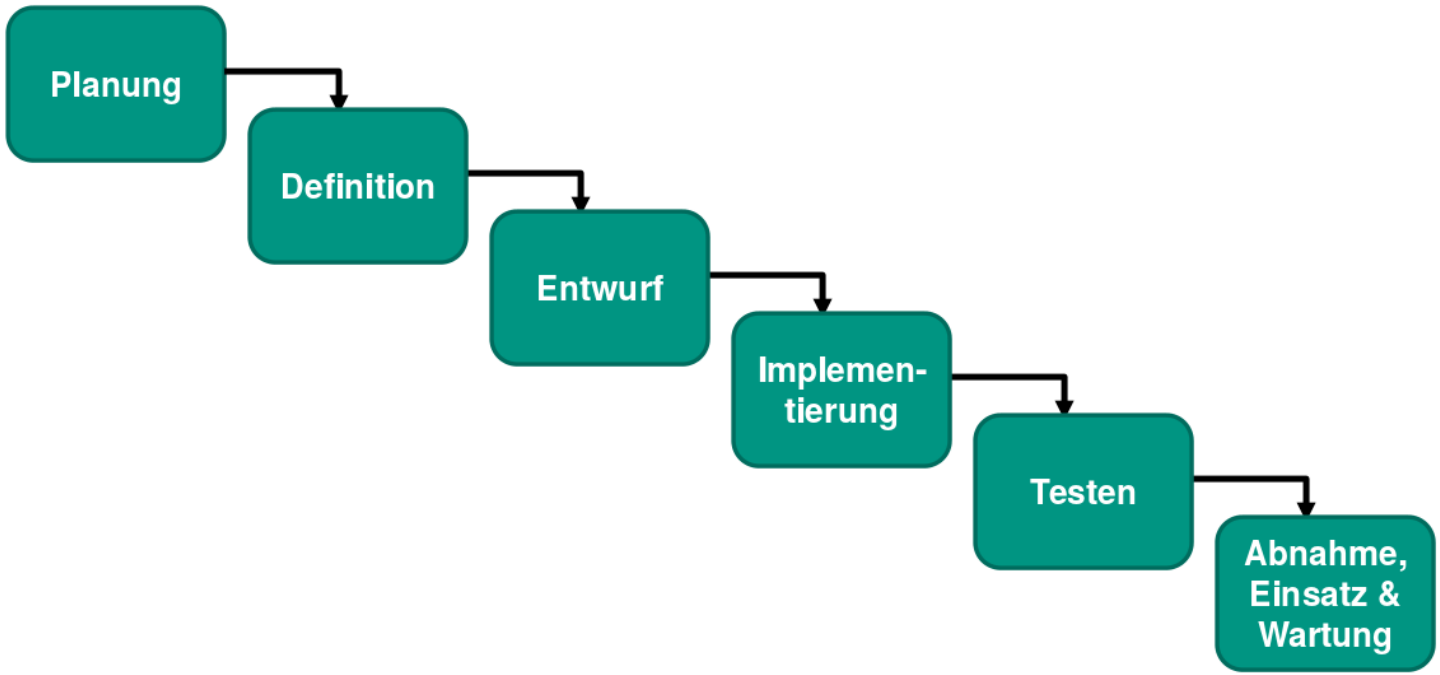
STEINBUCH CENTER FOR COMPUTING



About PSE

Praxis der Softwareentwicklung(PSE) = Software Engineering Practice

- Waterfall model
  - Planning/definition



Purpose

Node.js bindings for ROOT

- Be able to write ROOT code in Node.js programs
- Integrate ROOT into Node.js based web applications

Required Criteria

The bindings must

- Work on Linux
- Allow the user to interact with any ROOT class from the Node.js JavaScript interpreter
- Accept C++ code for just-in-time compilation
- Update dynamically following changes to C++ internals
- Provide asynchronous wrappers for common I/O operations (i.e. file and tree access)

Optional Criteria

The bindings should

- Support the streaming of data in JavaScript Object Notation (JSON) format compatible with JavaScript ROOT
- Implement a web server based on Node.js to mimic the function of the ROOT HTTP server
- Work OS independent (i.e. support Mac OS X, Linux operating systems)

Limiting criteria

The bindings should not

- Add any extending functionality to the existing ROOT framework
- Necessarily support previous/future ROOT versions

Product usage

- It's JavaScript $\rightarrow$ web-applications
- Expose processed data and then visualize it locally
- Interact with remote data (i.e. streamed via RPC)
- Accessible on 'unconvential' devices (mobile phones/tablets)

Audience

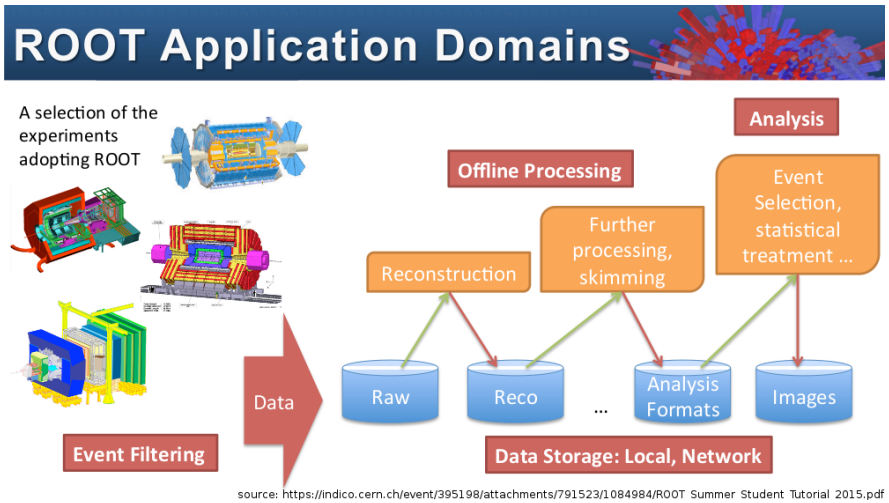
- Scientists (e.g. particle physicists) and Researchers
- Typical user will know ROOT and JavaScript $\rightarrow$ rather technology proficient
- Web-developers

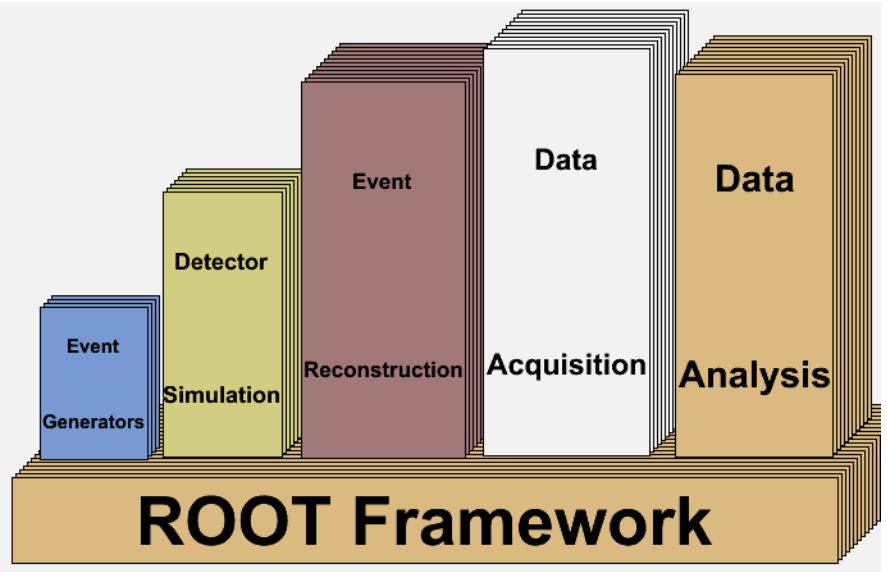
Operating conditions

- Servers that run ROOT
- ROOT6 is currently only available on Mac and Linux, so that's our focus

ROOT

- Process and visualize large amounts of scientific data (CERN)
- Features a C++ interpreter (CLING) - i.e. used for rapid and efficient prototyping
- Persistency mechanism for C++ objects





Node.js

- Open source runtime environment
  - Develop server side web applications
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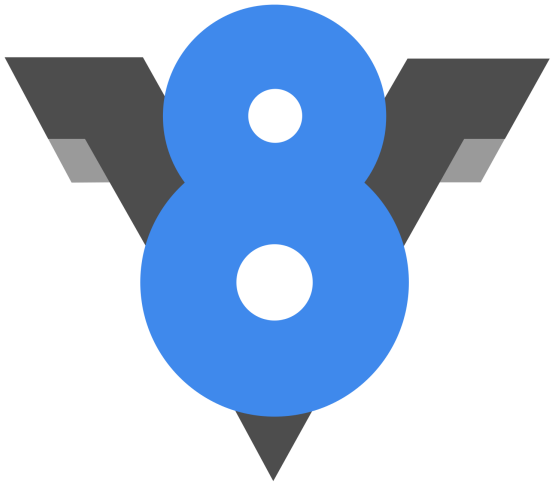
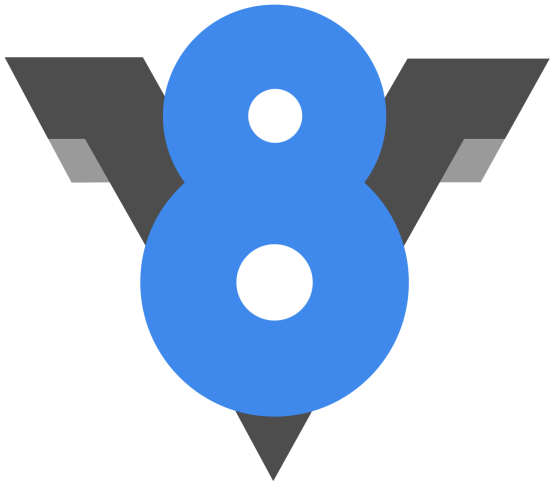


Node.js

- Open source runtime environment
  - Develop server side web applications
  - Act as a stand alone web server
- Google V8 engine to execute JavaScript code
- rootJS bindings realized as native Node.js module written in C++



Hardware

- Task: encapsulation of ROOT objects and functions
  - → Scanning ROOT structures during initialization
  - → Encapsulating objects with heavily nested object structures
  - → Introduce (proxy) object cache

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  - → Encapsulating objects with heavily nested object structures
  - → Introduce (proxy) object cache

⇒ Generally negligible hardware requirements of the bindings themselves

Product data

The following data will be stored by the rootJS bindings

- All ROOT classes and methods as they dynamically mapped to their JavaScript equivalents
- ROOT environment state
- Application context is derived from TApplication
- Map of v8::handles 2 identified by the address of ROOT objects

Scenarios

rootJS is used by applications to access the ROOT framework

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$\Rightarrow$ our users are those applications

Event Viewer

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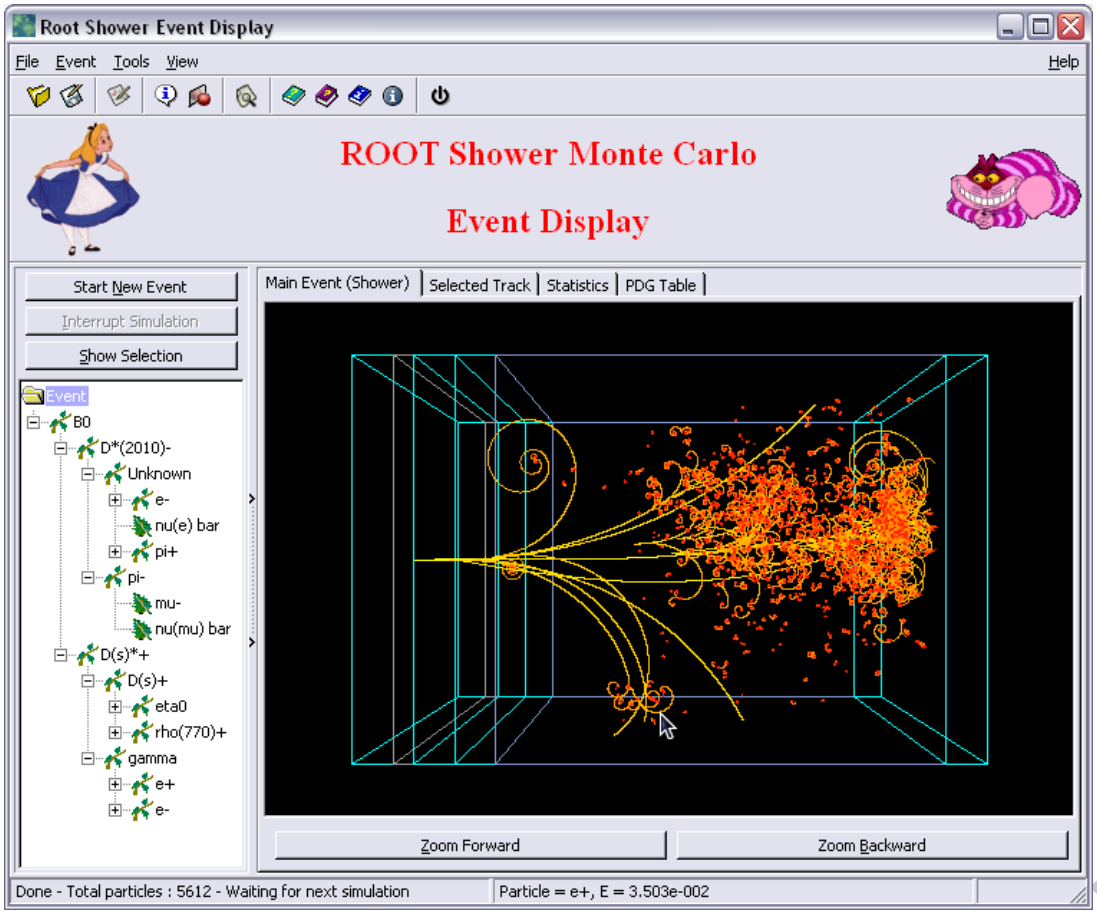

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Conventional ROOT Event Viewer

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- requires ROOT's dependencies
- requires access to data source

$\Rightarrow$ very limited portability and harsh requirements for client system

Event Viewer

Client/Server based Web Event Viewer using rootJS and nodeJS

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- server runs ROOT and its dependencies

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Client/Server based Web Event Viewer using rootJS and nodeJS

- server runs ROOT and its dependencies
- no access to critical data sources required
- no heavy work load on client system
- client only needs modern web browser

$\Rightarrow$ great portability and ease of use as client can be almost any device

Event Viewer

Scenario name	`EventViewer`
Participating actors	Server:EventViewerServer; :ROOT Client:EventViewerClient; :rootJS

Flow of events

- `Client` requests updates from `Server`.
- `Server` interfaces with `ROOT` through `rootJS`.
- `ROOT`'s I/O accesses and processes data
- `ROOT` returns the data to the `Server` using `rootJS`.
- `Server` sends the data to the `Client`
- `Client` renders data locally.

Scenarios

In what ways could these bindings also improve work efficiency for scientists?

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- integrating run logs and quality assurance in ROOT workflow

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- ...

UseROOTGlobal

Use case name	`UseROOTGlobal`
Participating actor instances	Initiated by `NodeJSApplication`; Processed by `rootJS`; Communicates with `ROOT`

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Flow of events

1. The `NodeJSApplication` requests access to a global variable of `ROOT`.

UseROOTGlobal

Use case name	`UseROOTGlobal`
Participating actor instances	Initiated by `NodeJSApplication`; Processed by `rootJS`; Communicates with `ROOT`

Flow of events

1. The `NodeJSApplication` requests access to a global variable of `ROOT`.
2. `rootJS` sends a request to the corresponding `ROOT` variable.

UseROOTGlobal

Use case name	`UseROOTGlobal`
Participating actor instances	Initiated by `NodeJSApplication`; Processed by `rootJS`; Communicates with `ROOT`

Flow of events

1. The `NodeJSApplication` requests access to a global variable of `ROOT`.
2. `rootJS` sends a request to the corresponding `ROOT` variable.
3. `ROOT` returns the requested variable value.

UseROOTGlobal

Use case name	`UseROOTGlobal`
Participating actor instances	Initiated by `NodeJSApplication`; Processed by `rootJS`; Communicates with `ROOT`

Flow of events

1. The `NodeJSApplication` requests access to a global variable of `ROOT`.
2. `rootJS` sends a request to the corresponding `ROOT` variable.
3. `ROOT` returns the requested variable value.
4. The value is passed from `rootJS` to the `NodeJSApplication`.

UseROOTGlobal

Entry condition	`rootJS` has been initialized.
Exit condition	The value has been returned to the `NodeJSApplication`.

UseROOTObject

Use case name	`UseROOTObject`
Participating actor instances	Initiated by `NodeJSApplication`; Processed by `rootJS`, `ProxyObject`; Communicates with `ROOT`

UseROOTObject

Use case name	`UseROOTObject`
Participating actor instances	Initiated by `NodeJSApplication`; Processed by `rootJS`, `ProxyObject`; Communicates with `ROOT`

Flow of events

1. The `NodeJSApplication` requests access to a `ROOT` object by calling a constructor function.

UseROOTObject

Use case name	`UseROOTObject`
Participating actor instances	Initiated by `NodeJSApplication`; Processed by `rootJS`, `ProxyObject`; Communicates with `ROOT`

Flow of events

1. The `NodeJSApplication` requests access to a `ROOT` object by calling a constructor function.
2. `rootJS` encapsulates the requested `ROOT` object within a `ProxyObject` that was created recursively.

UseROOTObject

Flow of events

3. `rootJS` stores the created `ProxyObject` in a cache memory.

UseROOTObject

Flow of events

3. `rootJS` stores the created `ProxyObject` in a cache memory.
4. The `ProxyObject` is exposed to the `NodeJSApplication`.

Entry condition	`rootJS` has been initialized.
Exit condition	The reference of the `ProxyObject` has been return to the `NodeJSApplication`.

UseROOTFunction

Use case name	`UseROOTFunction`
Participating actor instances	Initiated by `NodeJSApplication`; Processed by `rootJS`, `ProxyObject`; Communicates with `ROOT`

UseROOTFunction

Use case name	`UseROOTFunction`
Participating actor instances	Initiated by `NodeJSApplication`; Processed by `rootJS`, `ProxyObject`; Communicates with `ROOT`

Flow of events

1. The `NodeJSApplication` requests access to a `ROOT` function.

UseROOTFunction

Use case name	`UseROOTFunction`
Participating actor instances	Initiated by `NodeJSApplication`; Processed by `rootJS`, `ProxyObject`; Communicates with `ROOT`

Flow of events

1. The `NodeJSApplication` requests access to a `ROOT` function.
2. `rootJS` calls the corresponding `ROOT` function.

UseROOTFunction

Use case name	`UseROOTFunction`
Participating actor instances	Initiated by `NodeJSApplication`; Processed by `rootJS`, `ProxyObject`; Communicates with `ROOT`

Flow of events

1. The `NodeJSApplication` requests access to a `ROOT` function.
2. `rootJS` calls the corresponding `ROOT` function.
3. `ROOT` responds.

UseROOTFunction

Flow of events

4. `rootJS` encapsulates the returned `ROOT` object within a `ProxyObject`.

UseROOTFunction

Flow of events

4. `rootJS` encapsulates the returned `ROOT` object within a `ProxyObject`.
5. The `ProxyObject` is exposed to the `NodeJSApplication`.

Entry condition	`rootJS` has been initialized.
Exit condition	The reference of the `ProxyObject` has been return to the `NodeJSApplication`.

UseJIT

Use Case name	`UseJIT`
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Flow of events

1. The `NodeJSApplication` wants to execute `ROOT` specific C++ code (given as string) during runtime.

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Flow of events

1. The `NodeJSApplication` wants to execute `ROOT` specific C++ code (given as string) during runtime.
2. `rootJS` forwards the instructions to `Cling`.

UseJIT

Use Case name	`UseJIT`
Participating actor instances	Initiated by `NodeJSApplication`; Processed by `rootJS`, `Cling`; Communicates with `ROOT`

Flow of events

1. The `NodeJSApplication` wants to execute `ROOT` specific C++ code (given as string) during runtime.
2. `rootJS` forwards the instructions to `Cling`.
3. `Cling` evaluates the received instructions using JIT compilation concepts and dynamically modifies the state of `ROOT`.

UseJIT

Flow of events

3. `rootJS` takes care of encapsulating exceptions possibly thrown by `Cling` or `ROOT` during evaluation and execution.

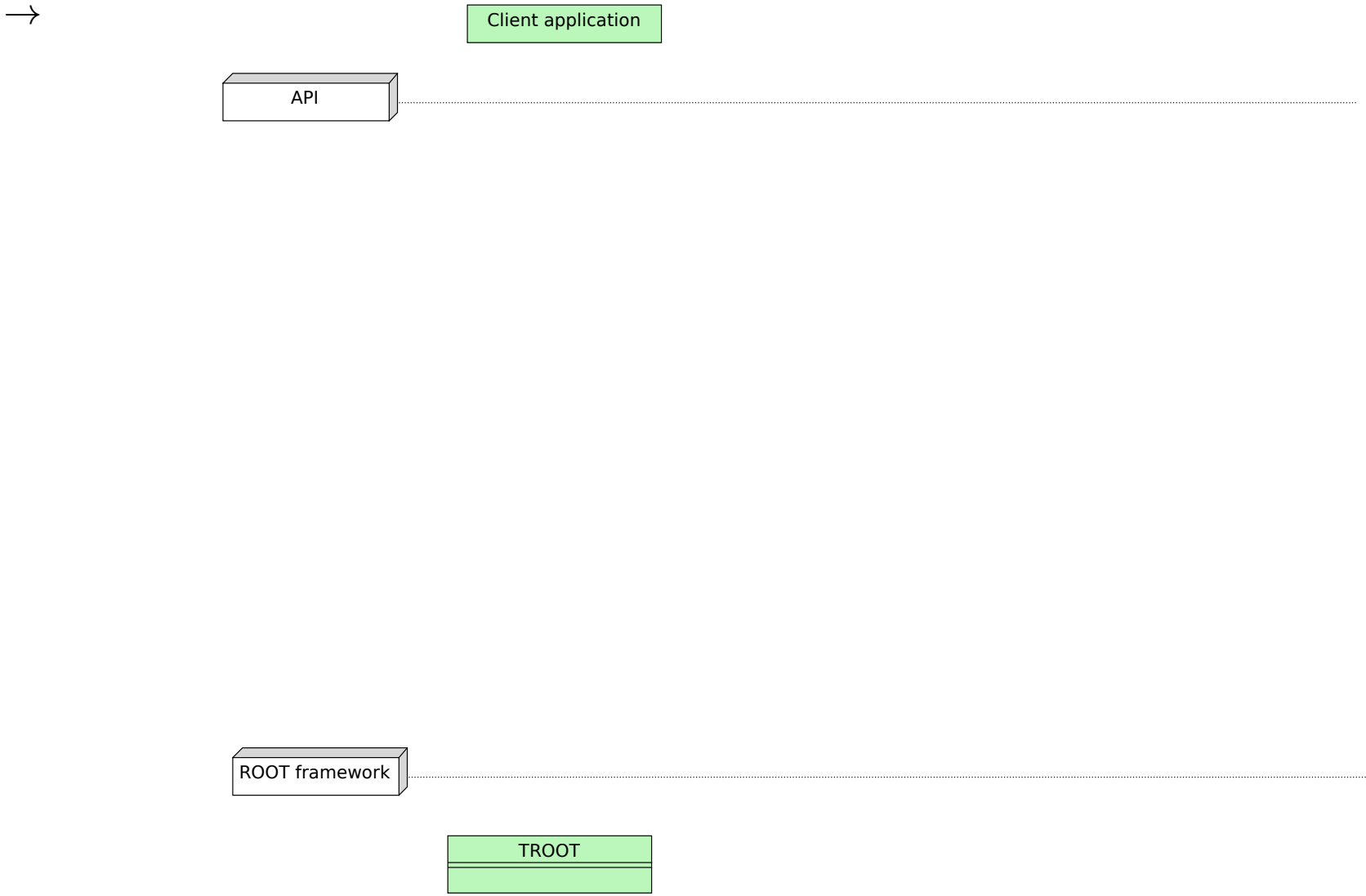
UseJIT

Flow of events

3. `rootJS` takes care of encapsulating exceptions possibly thrown by `Cling` or `ROOT` during evaluation and execution.
4. `rootJS` provides the evaluation results and corresponding return values to the `NodeJSApplication`.

Entry condition	`rootJS` and `Cling` have been initialized.
Exit condition	`rootJS` either confirms the proper execution of the specified instructions or forwards thrown exceptions to the `NodeJSApplication`.

Basic Architecture



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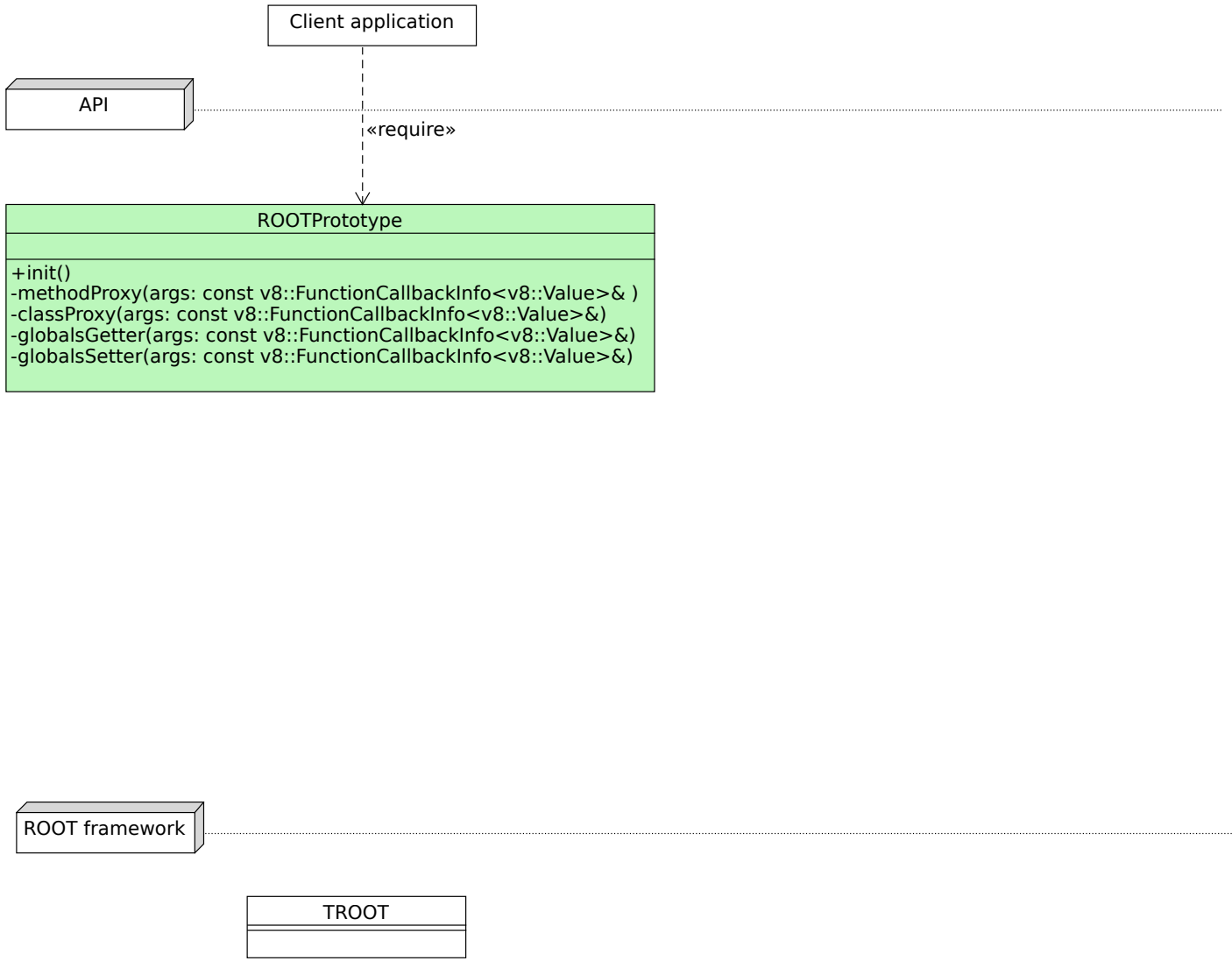

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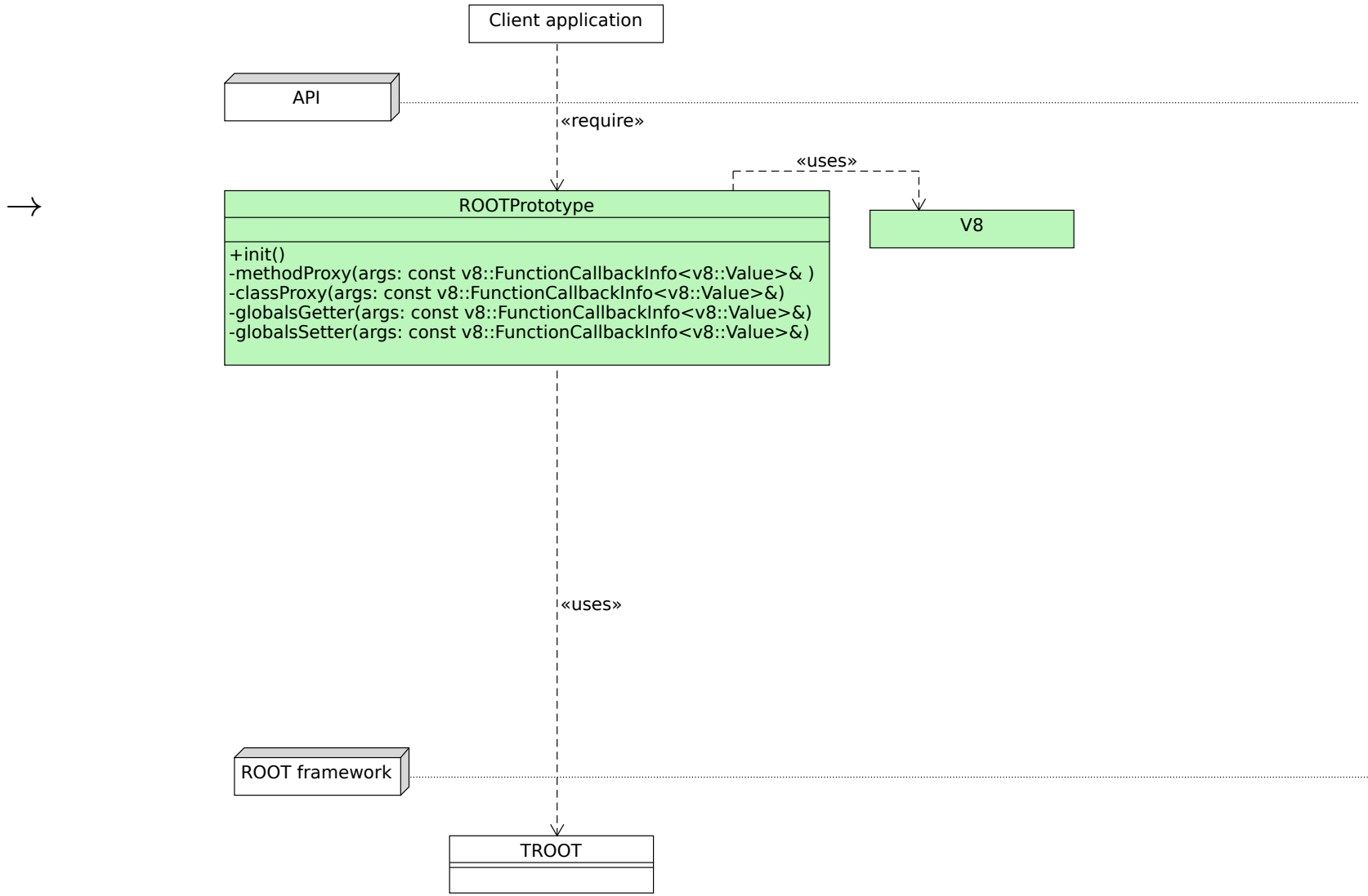

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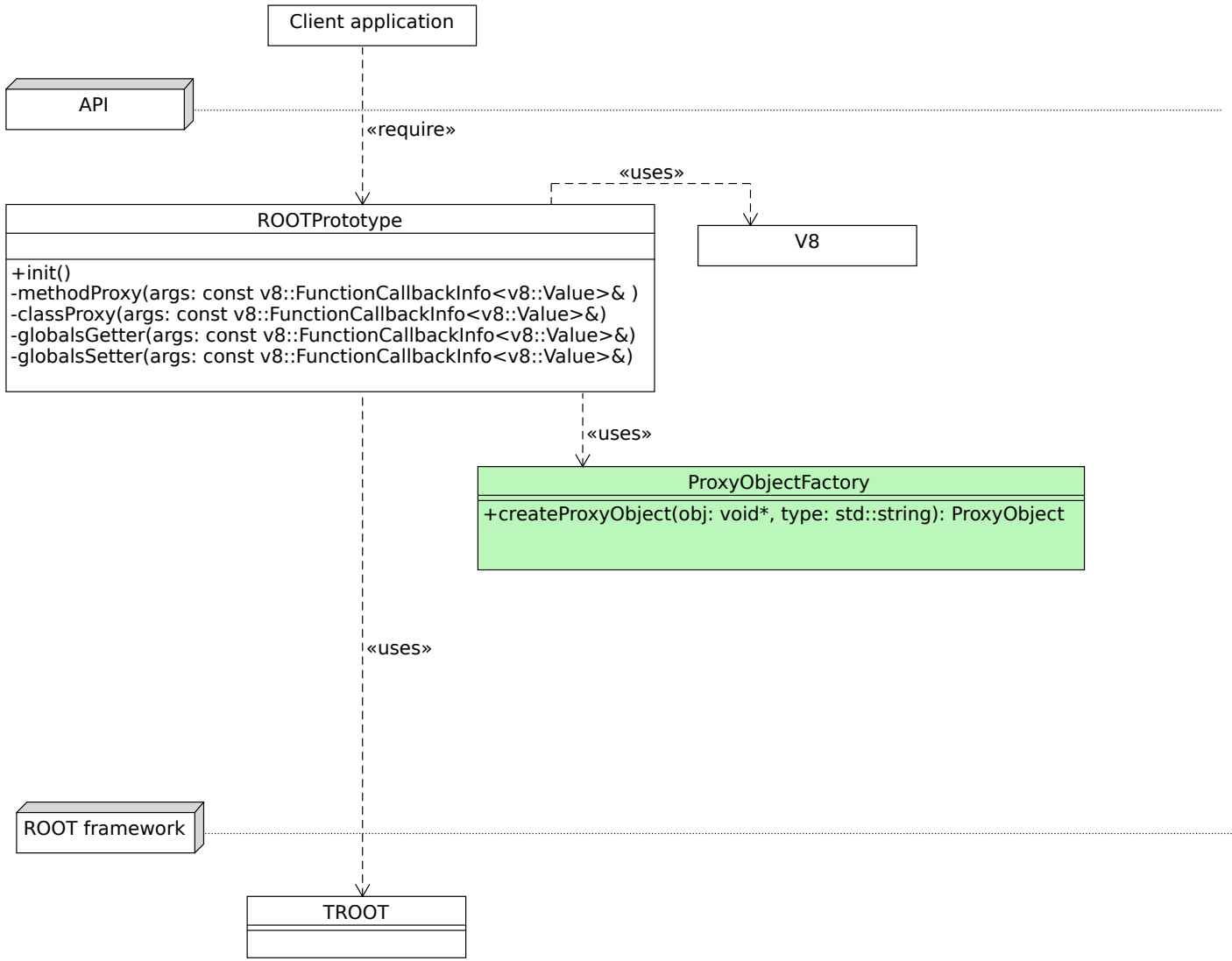

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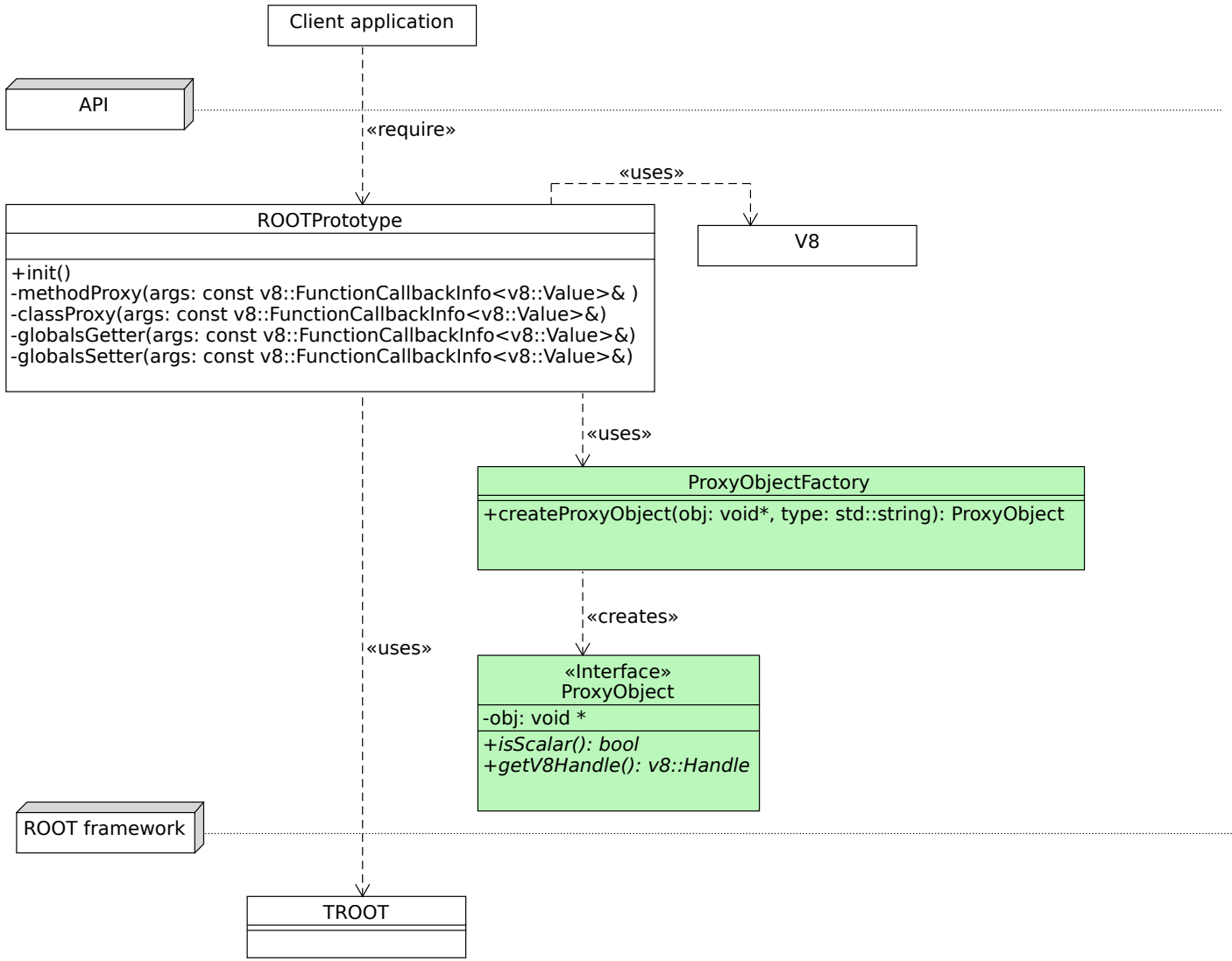

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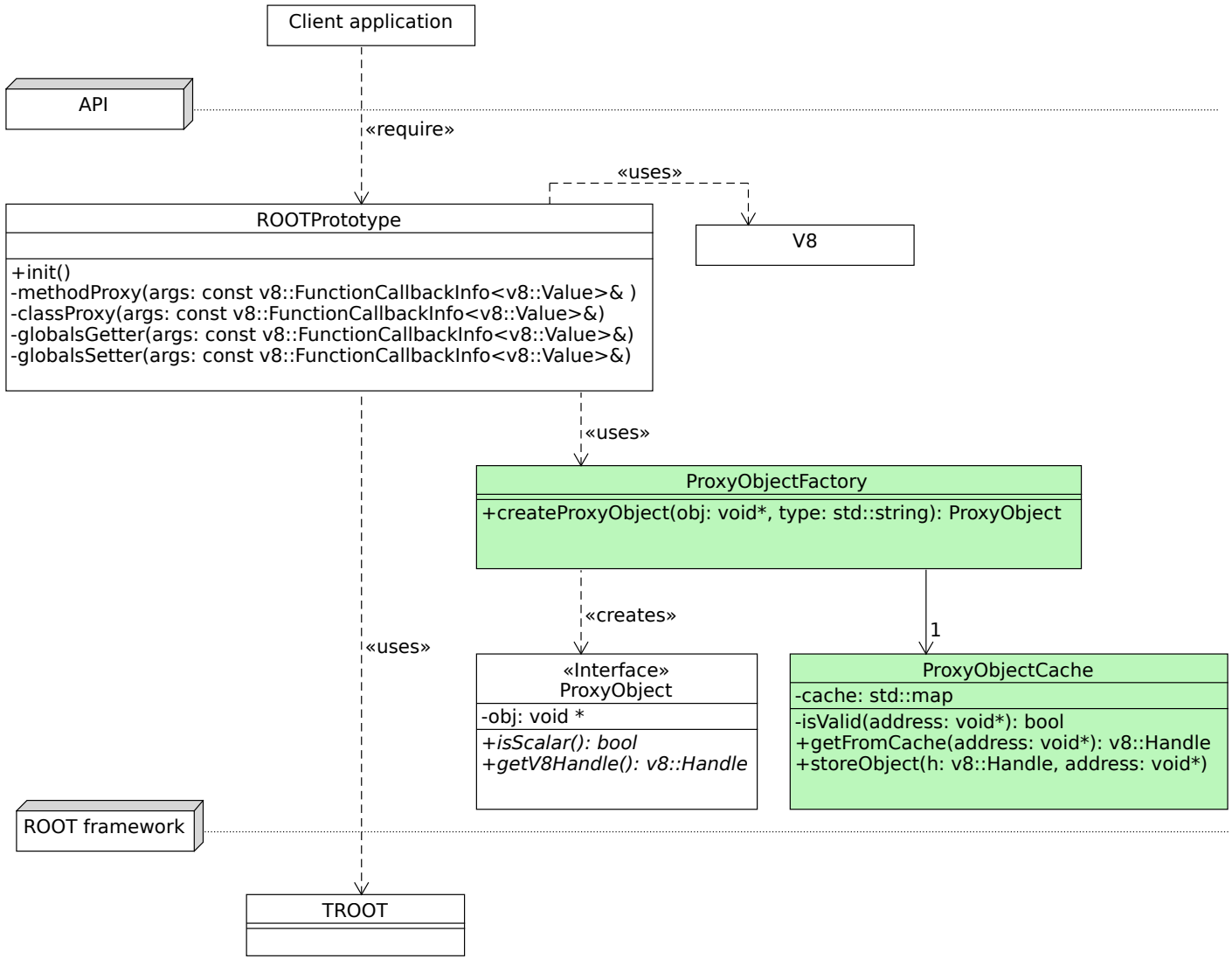

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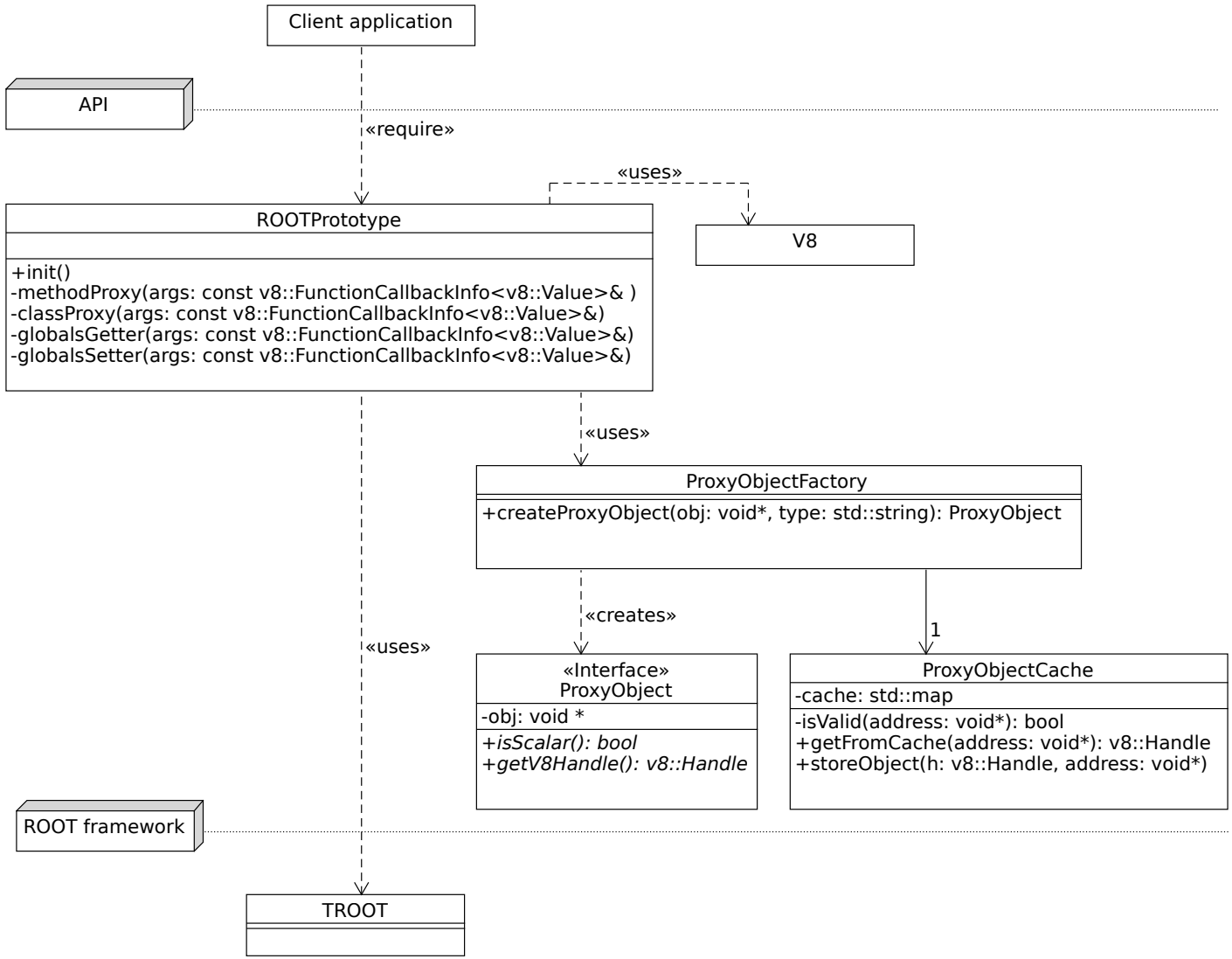

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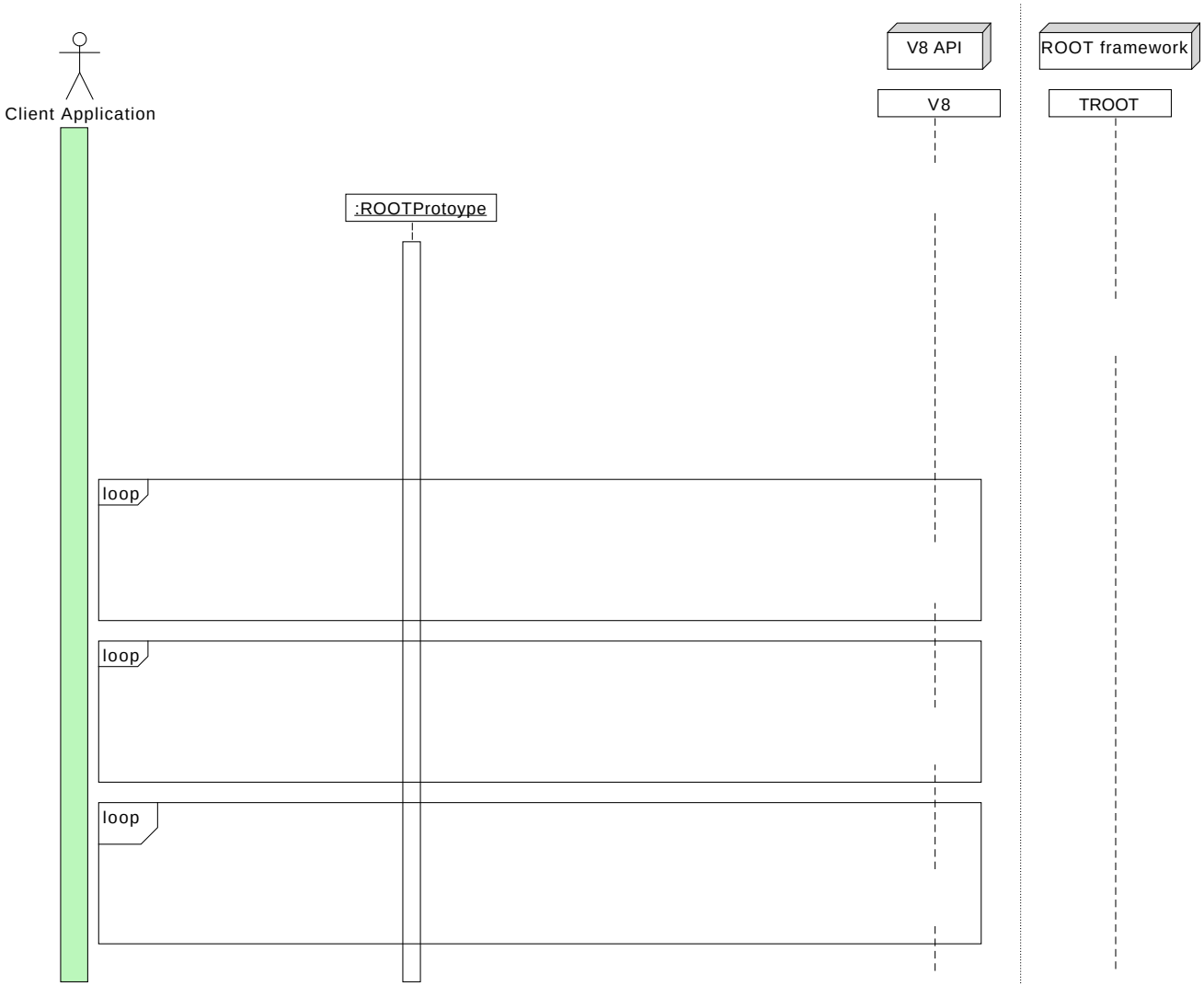
Names

- Functions and classes have the same name as in Root
- Global variables can be called using Get[Variable] and Set[Variable] methods

rootJS init

→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ROOT framework
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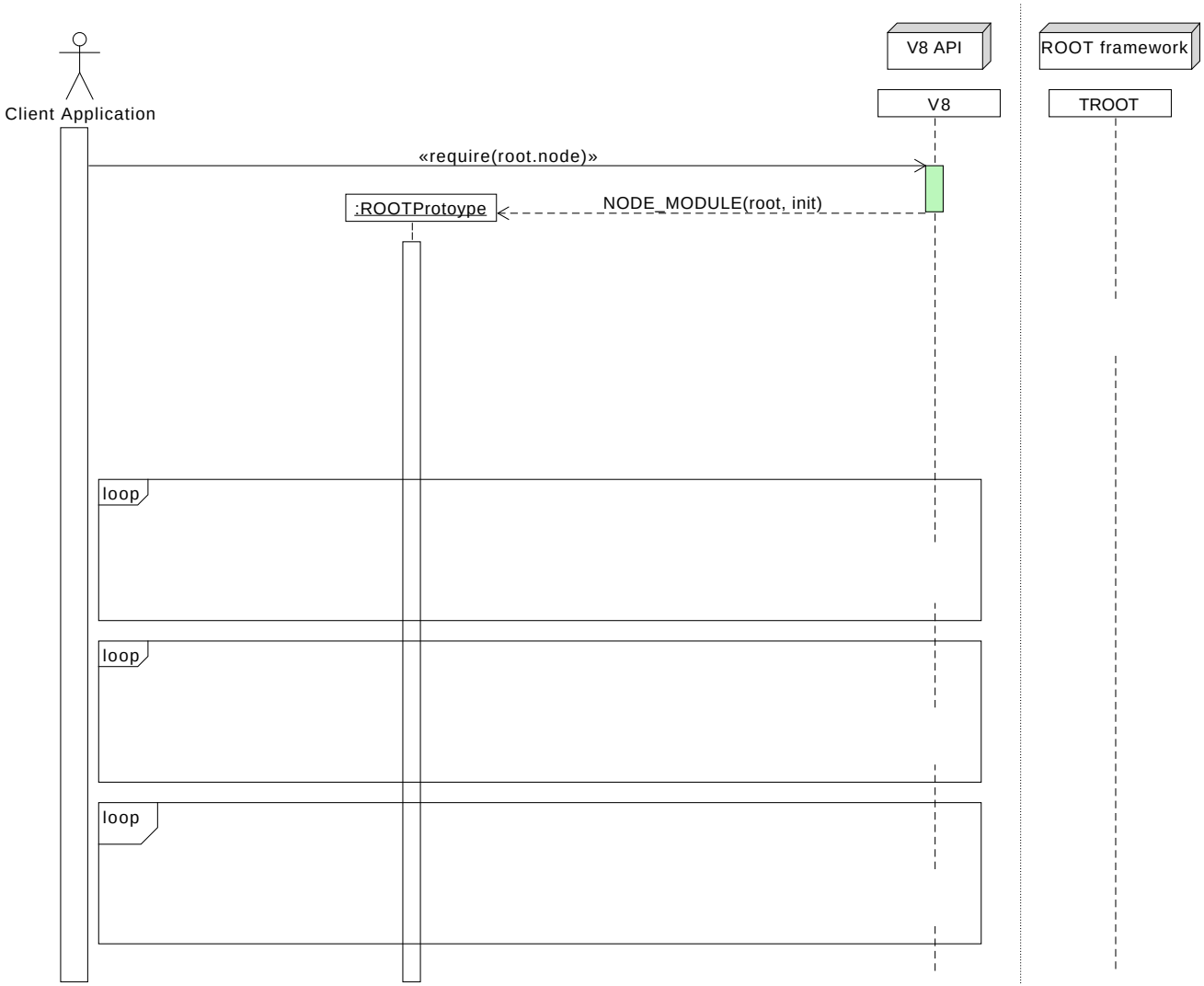
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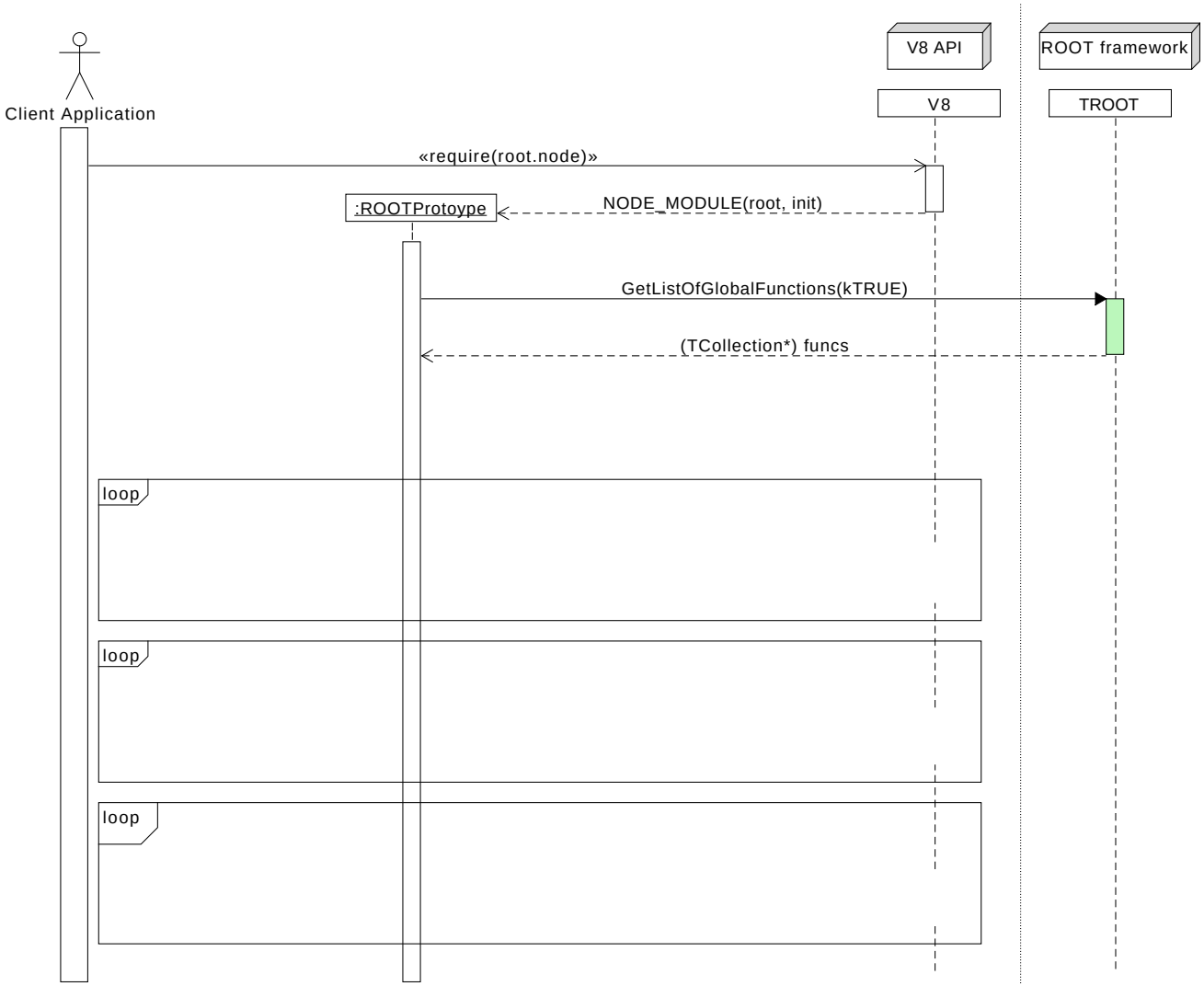
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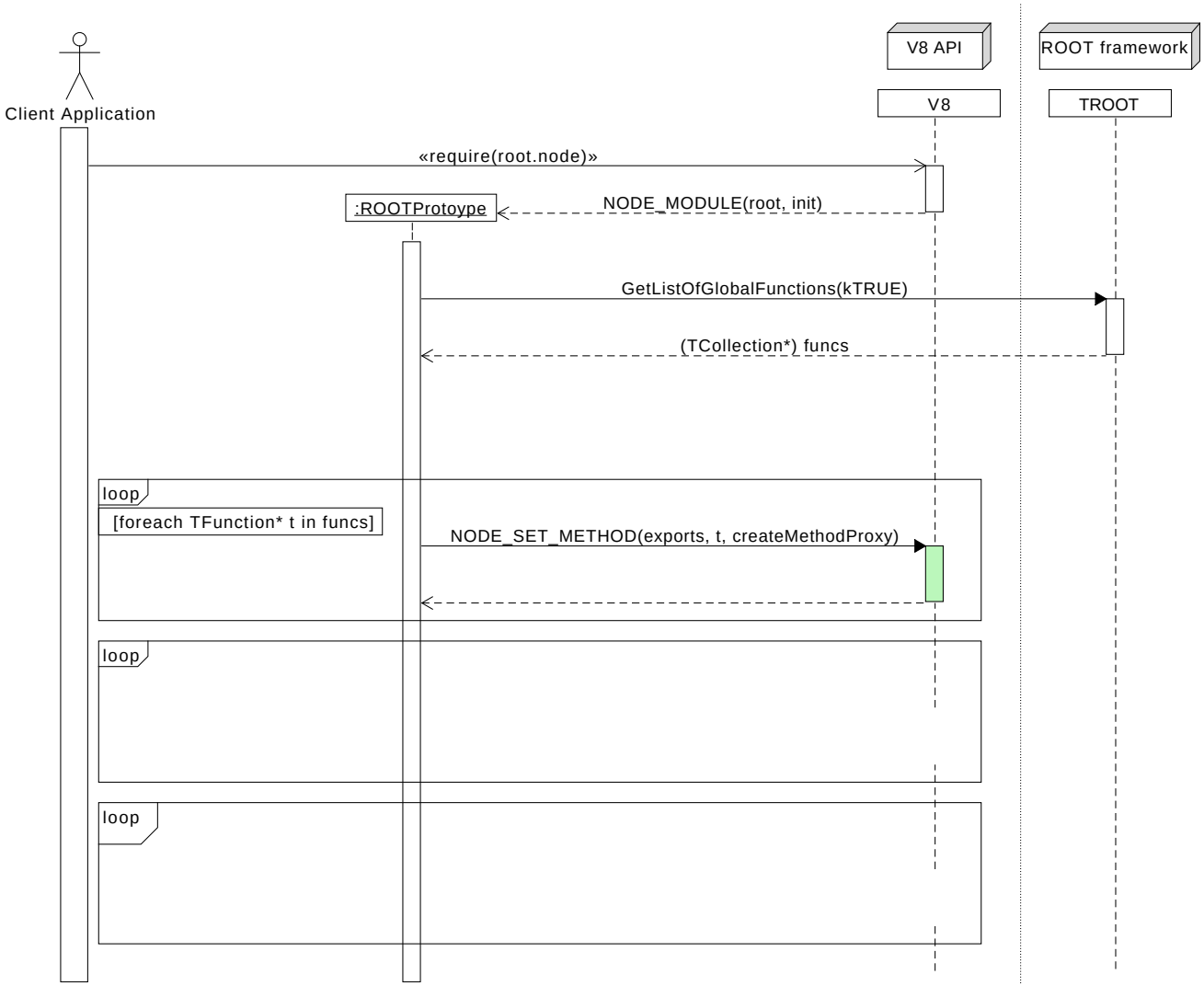
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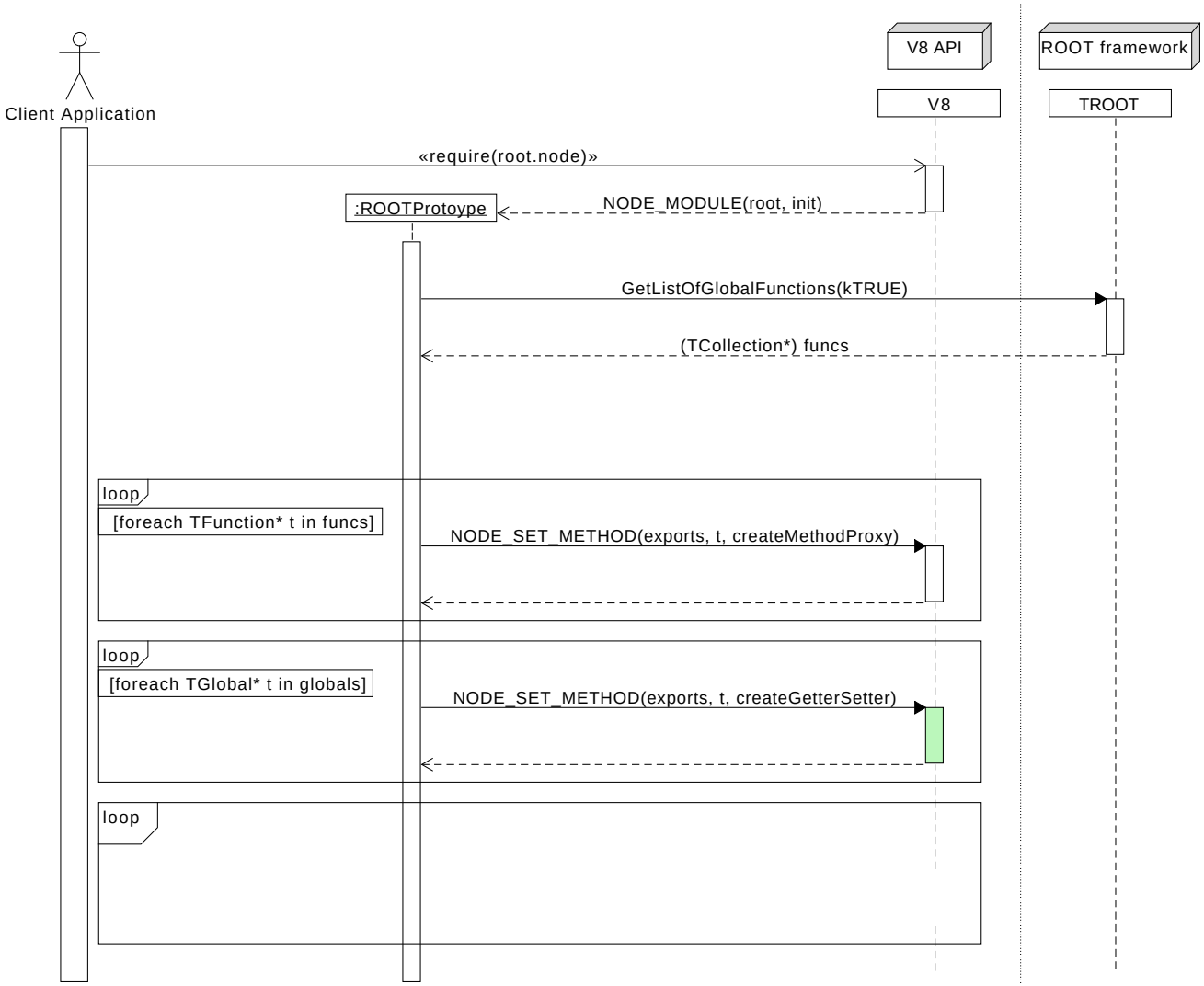
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→

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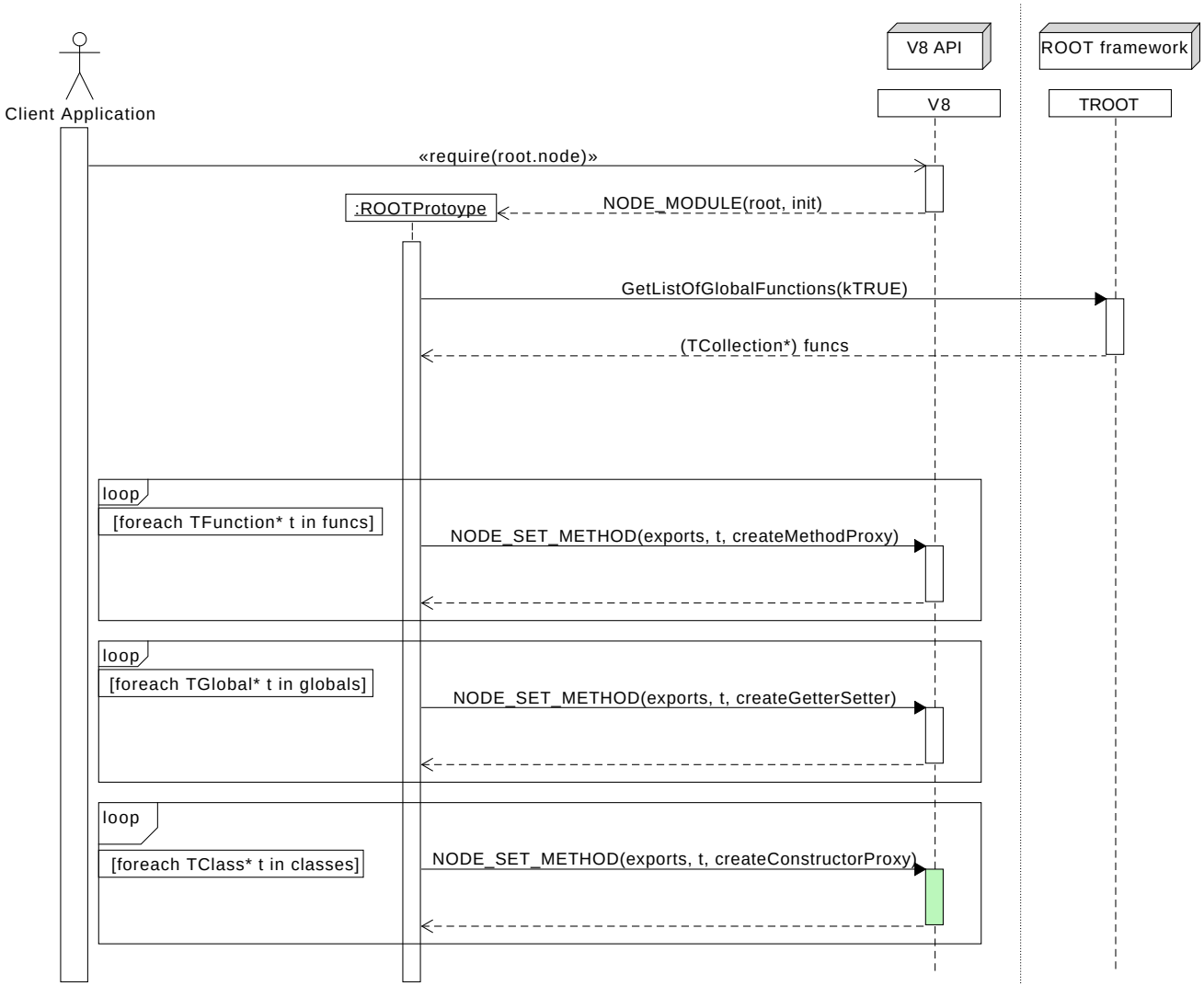
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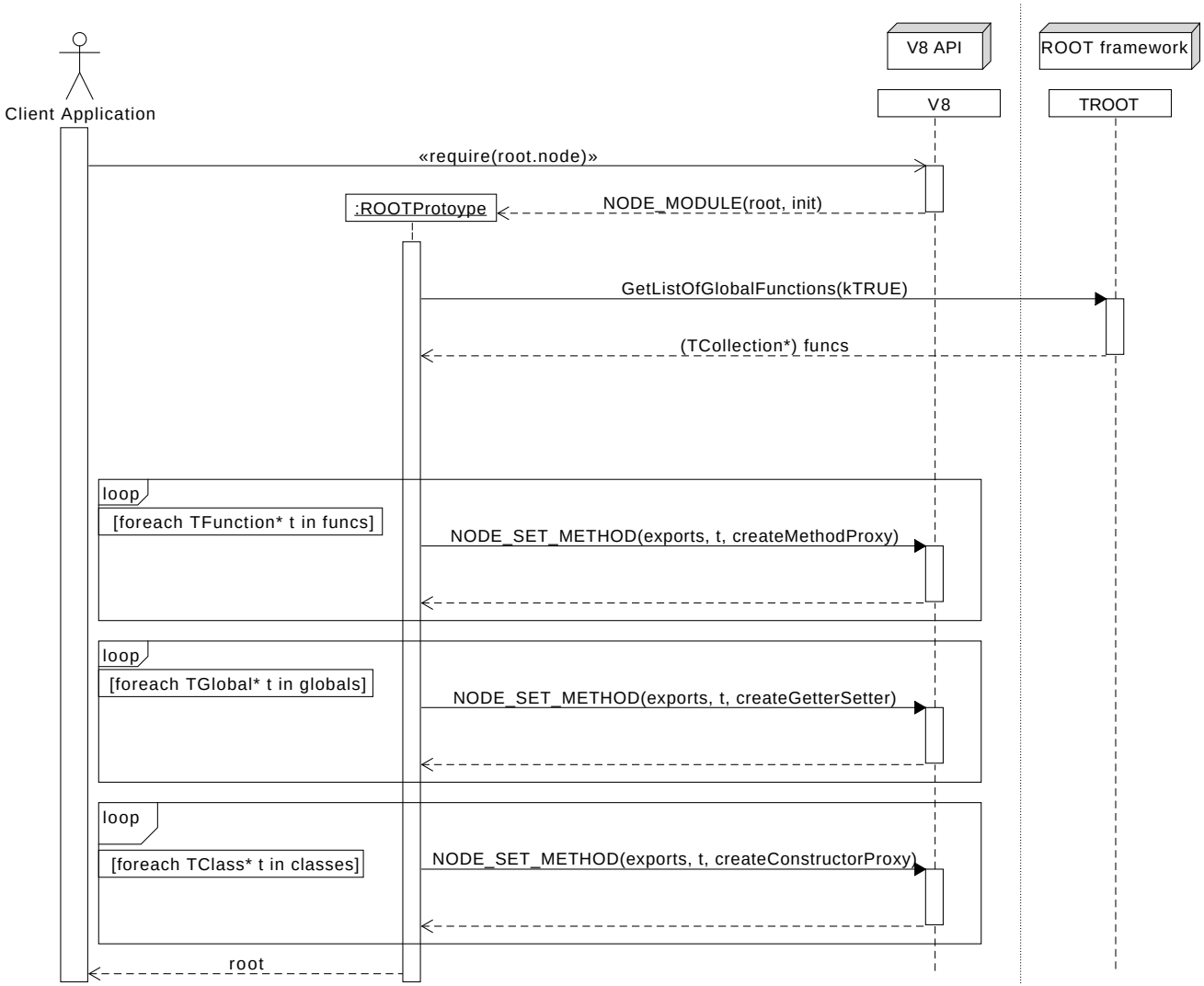
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root

Call a feature

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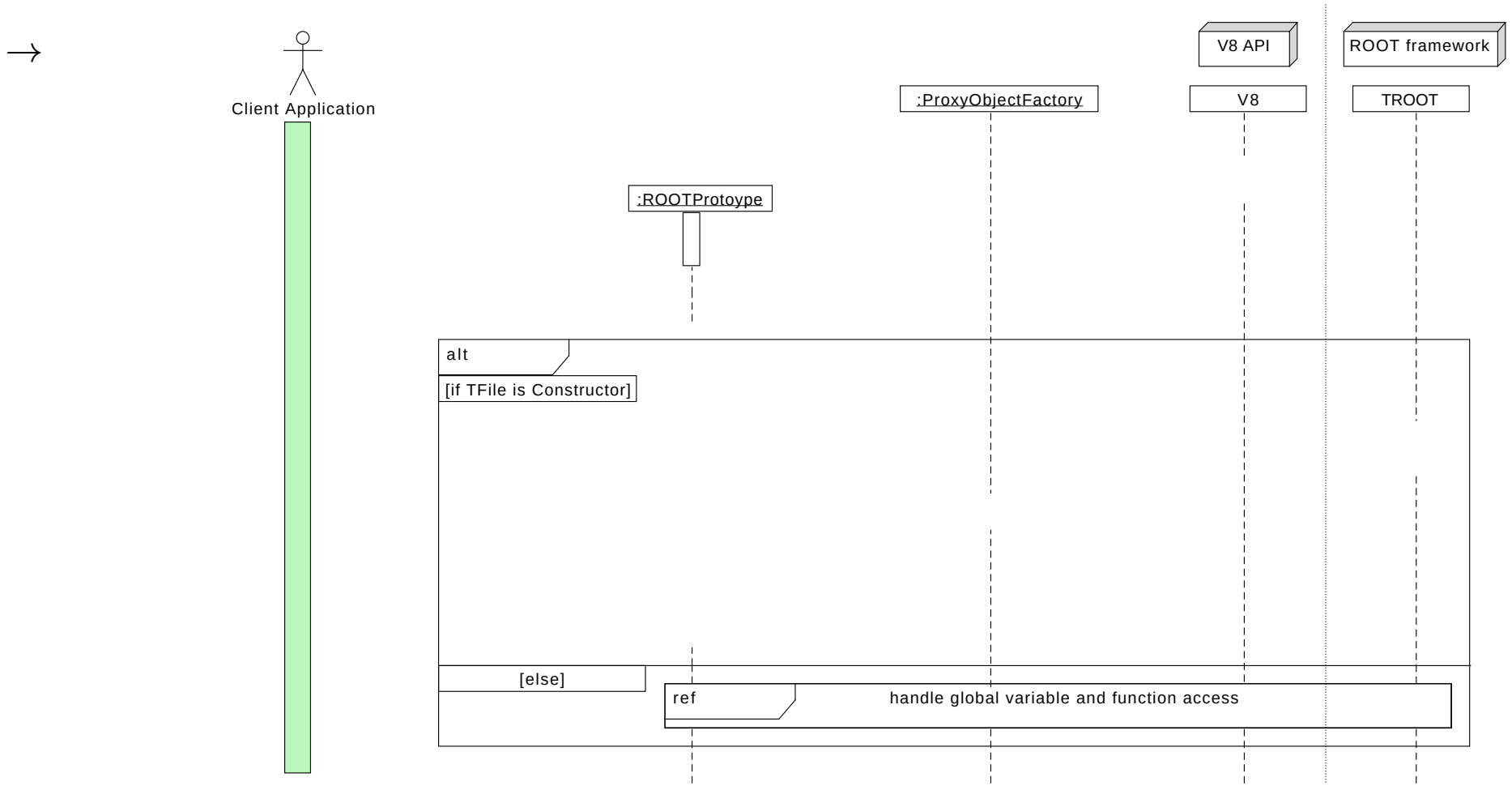
- The proxy method will eventually call a root function and pass the result to our ObjectFactory
- By looking at the object type an corresponding v8::Handle will be generated and returned to node
  - If the result is an object this will be done recursively

proxied file access



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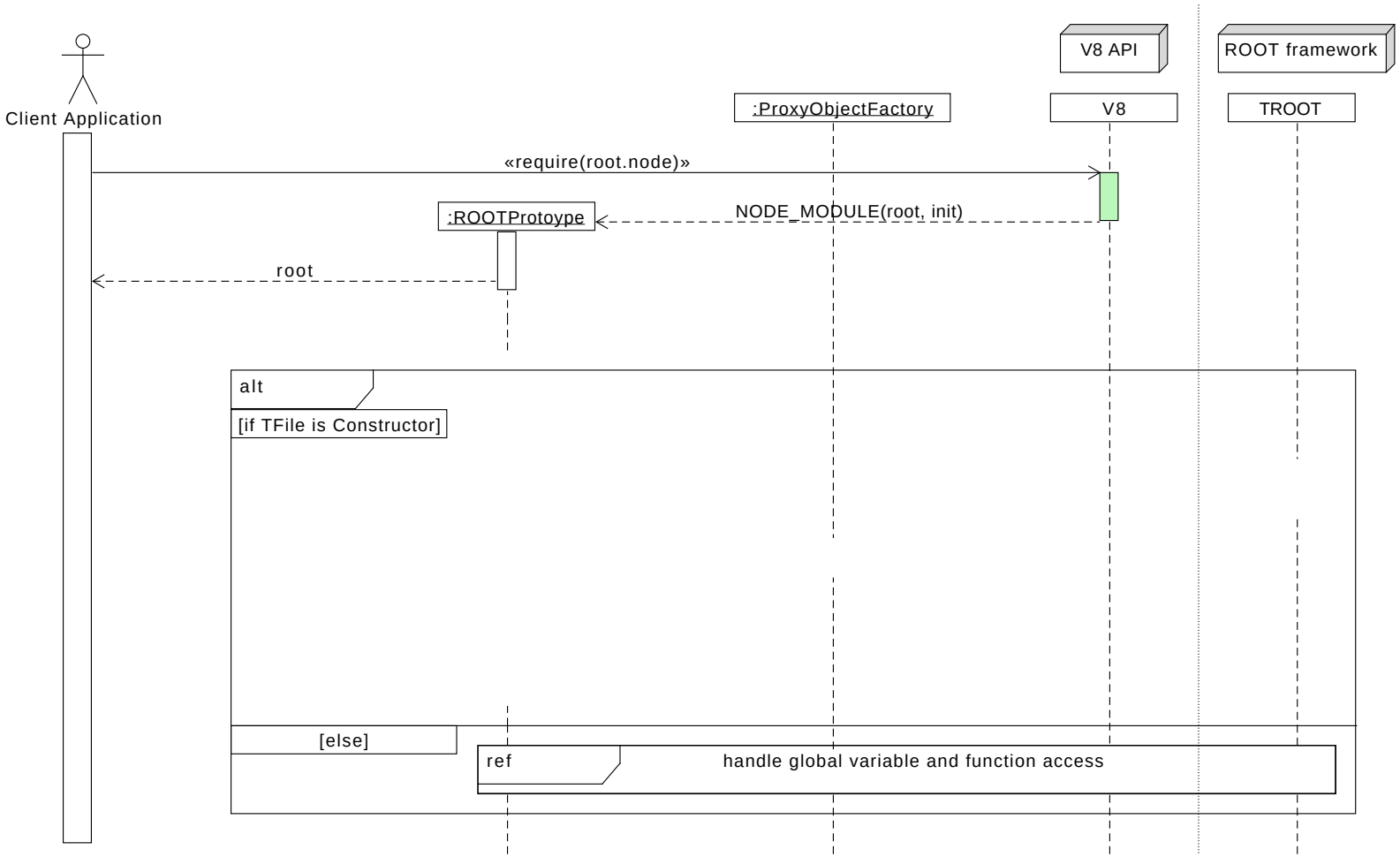
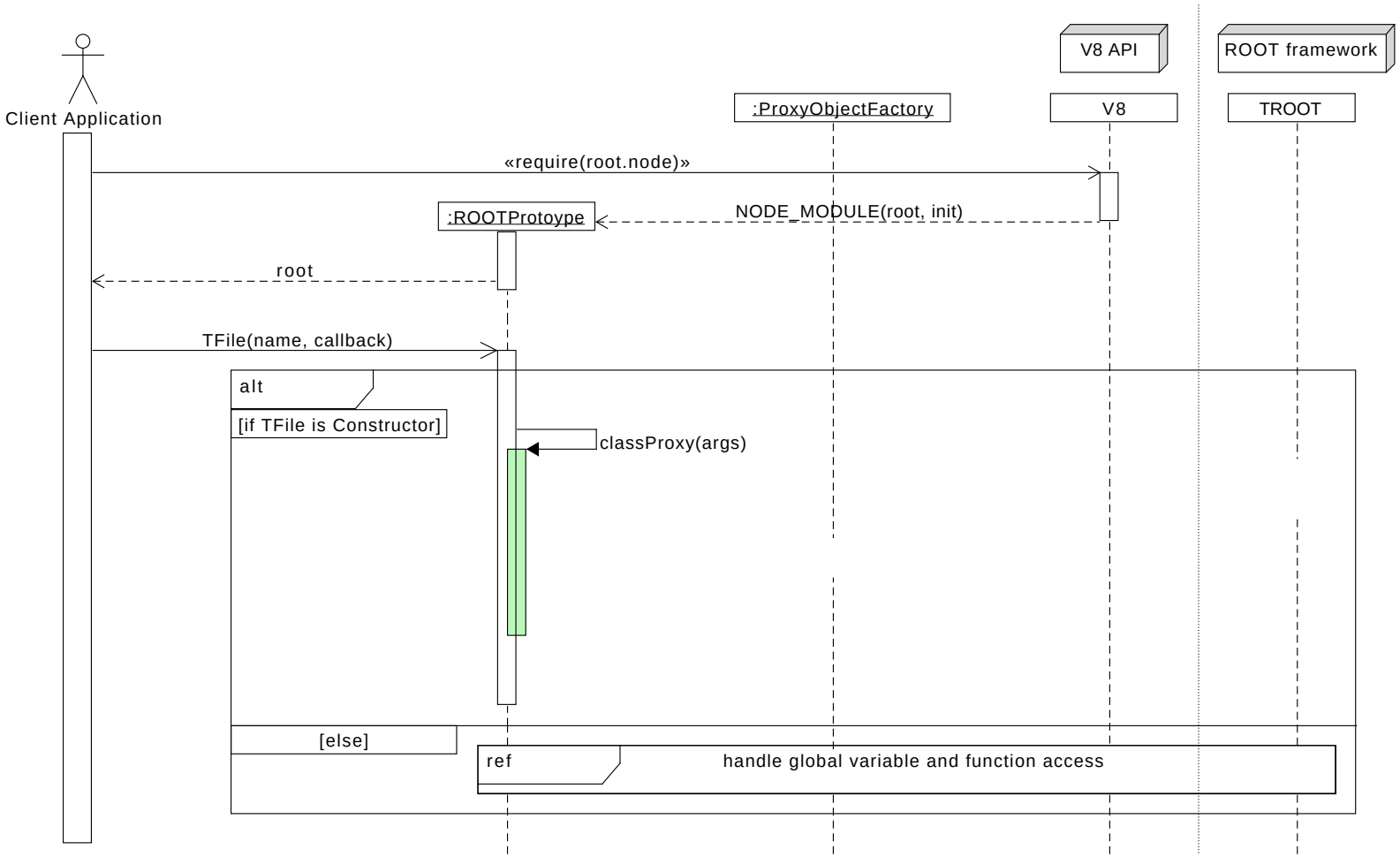


proxied file access



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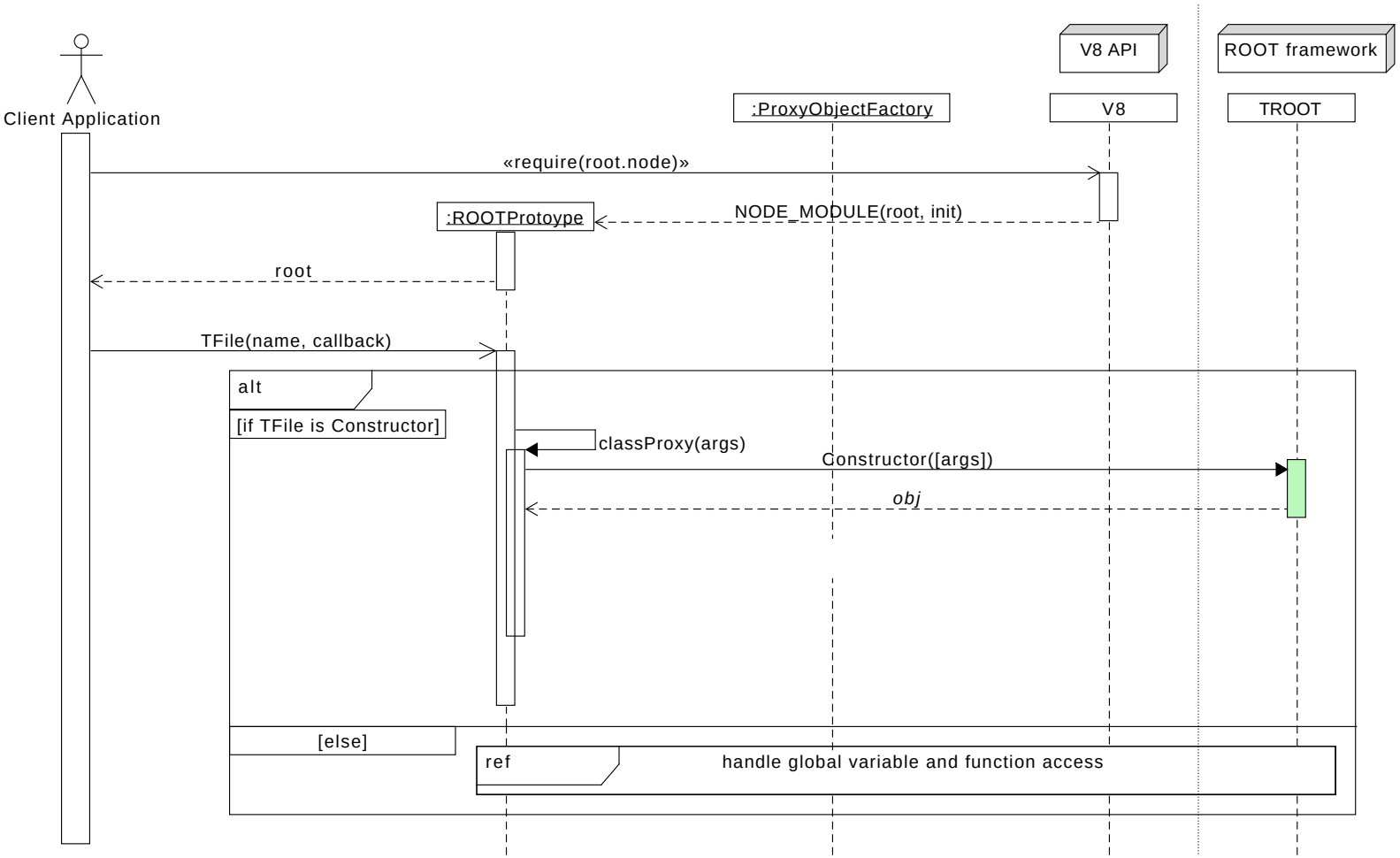

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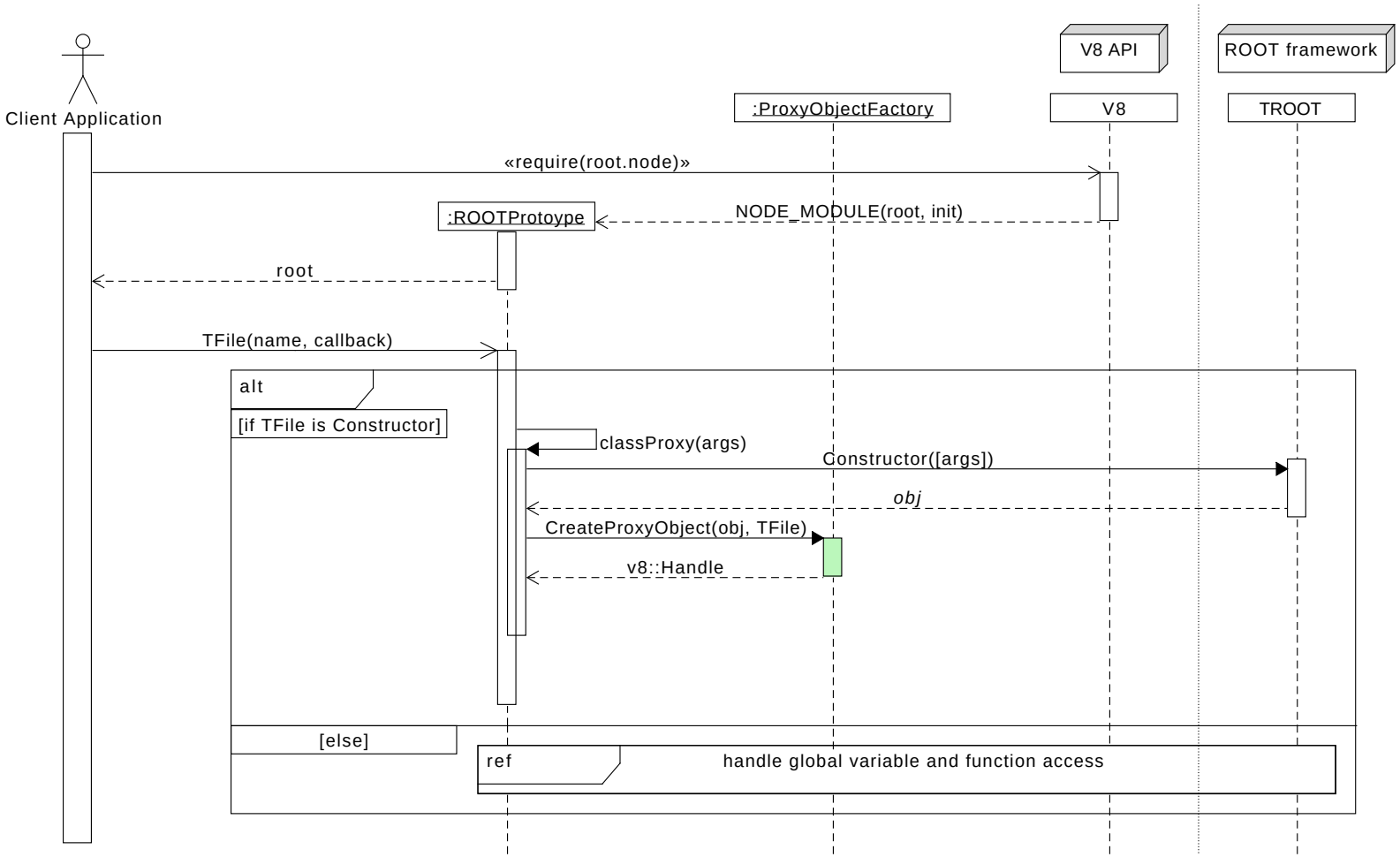

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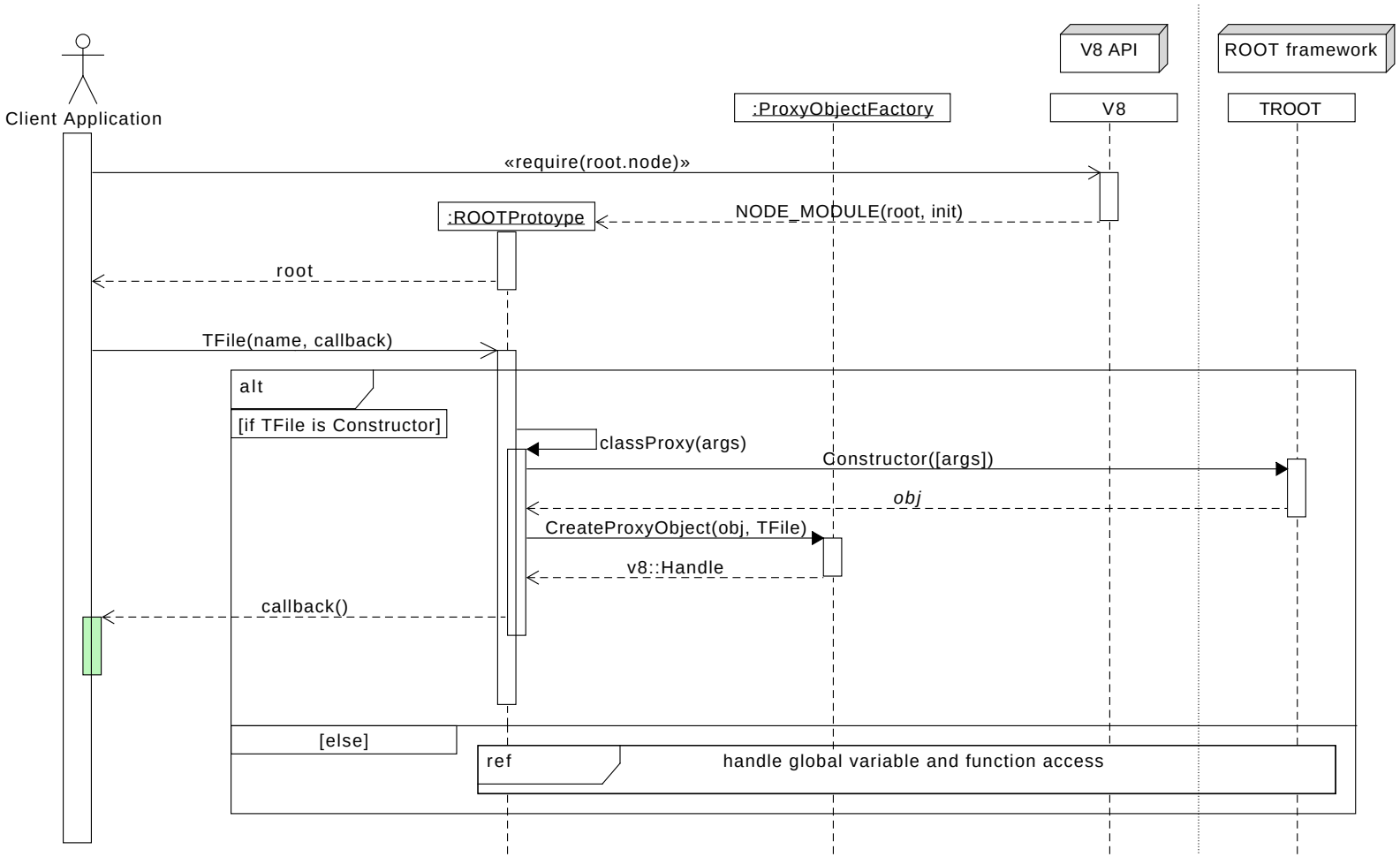

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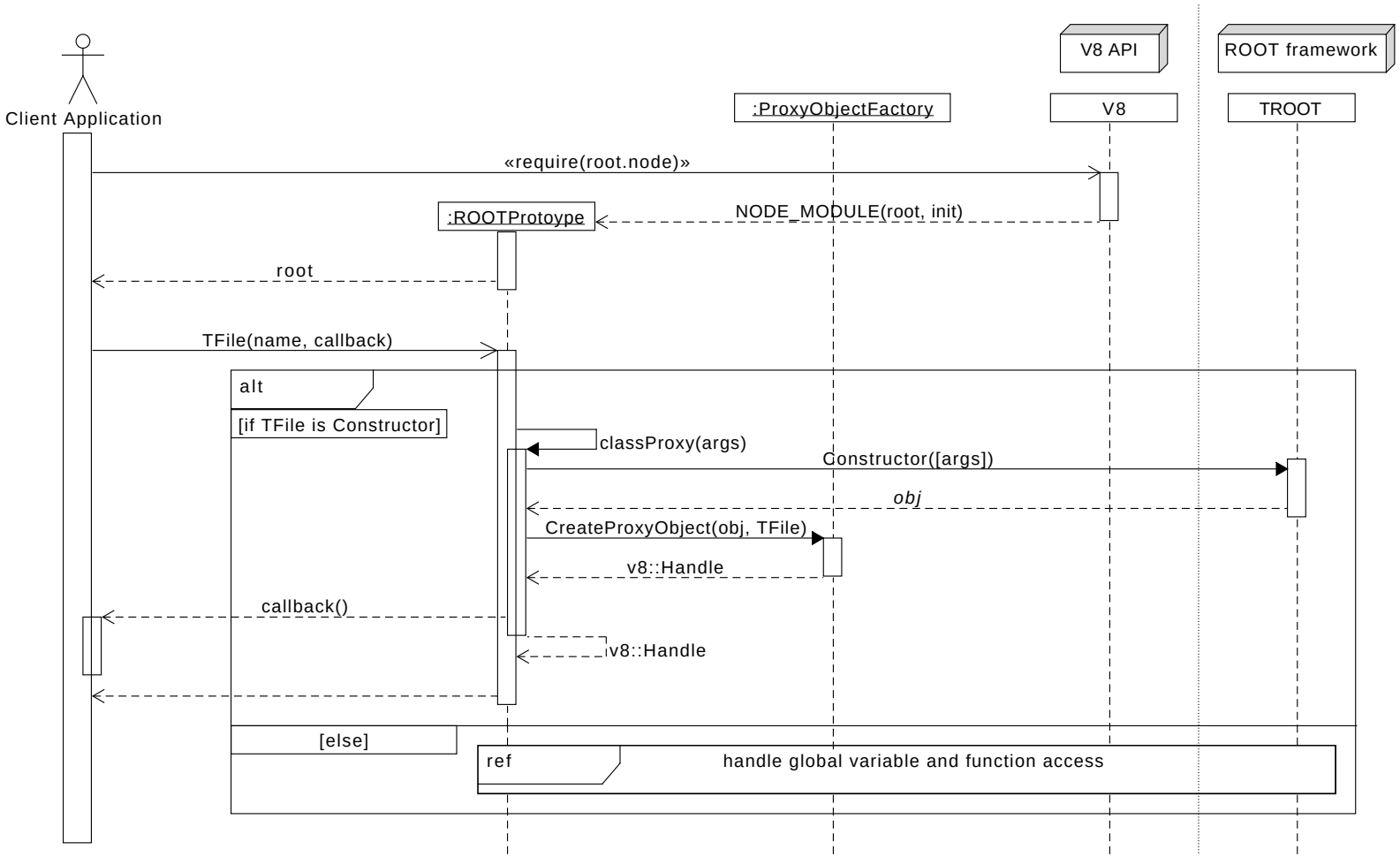

Test Cases

- Make sure all elements are callable without crashing
- To verify results of function calls and calculations, we would need to run ROOT's testcases
- Porting all ROOT testcases would make no sense!
- Only port a subset to make sure the bindings are working and leave the rest to the ROOT developers

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