Karlsruhe Institute of Technology

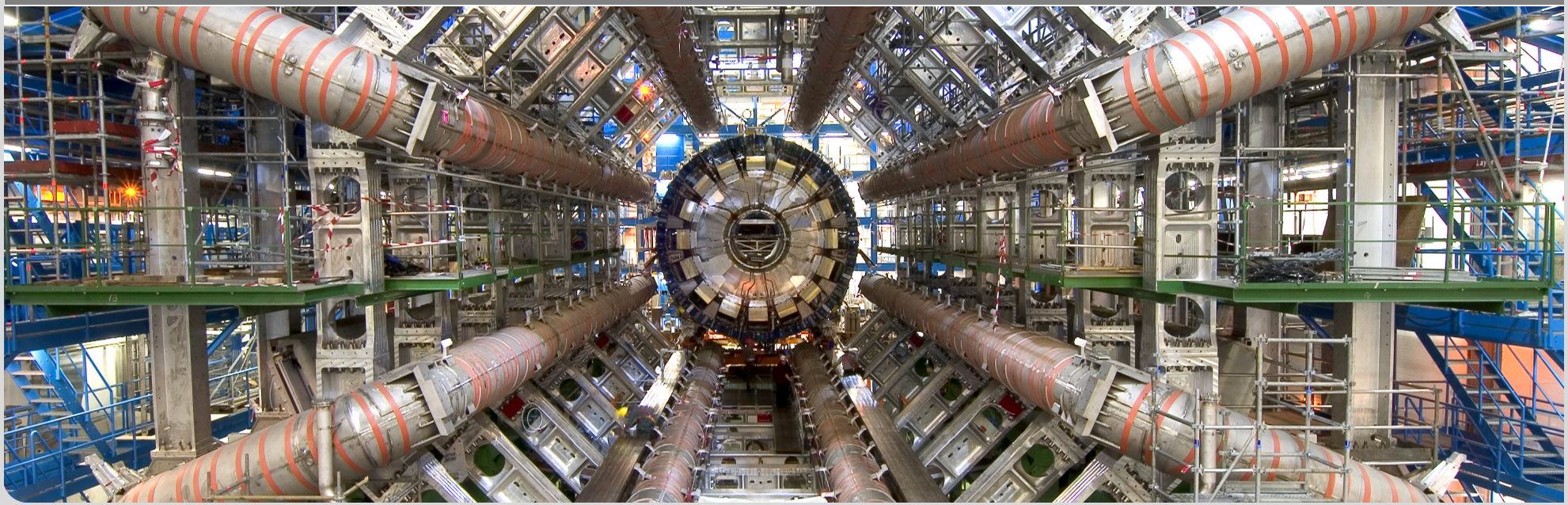
Steinbuch Centre for Computing

rootJS - Functional Specification

PSE - Software Engineering Practice

C. Wolff, M. Früh, S. Rajgopal, C. Haas, J. Schwabe, T. Beffart | December 15, 2015

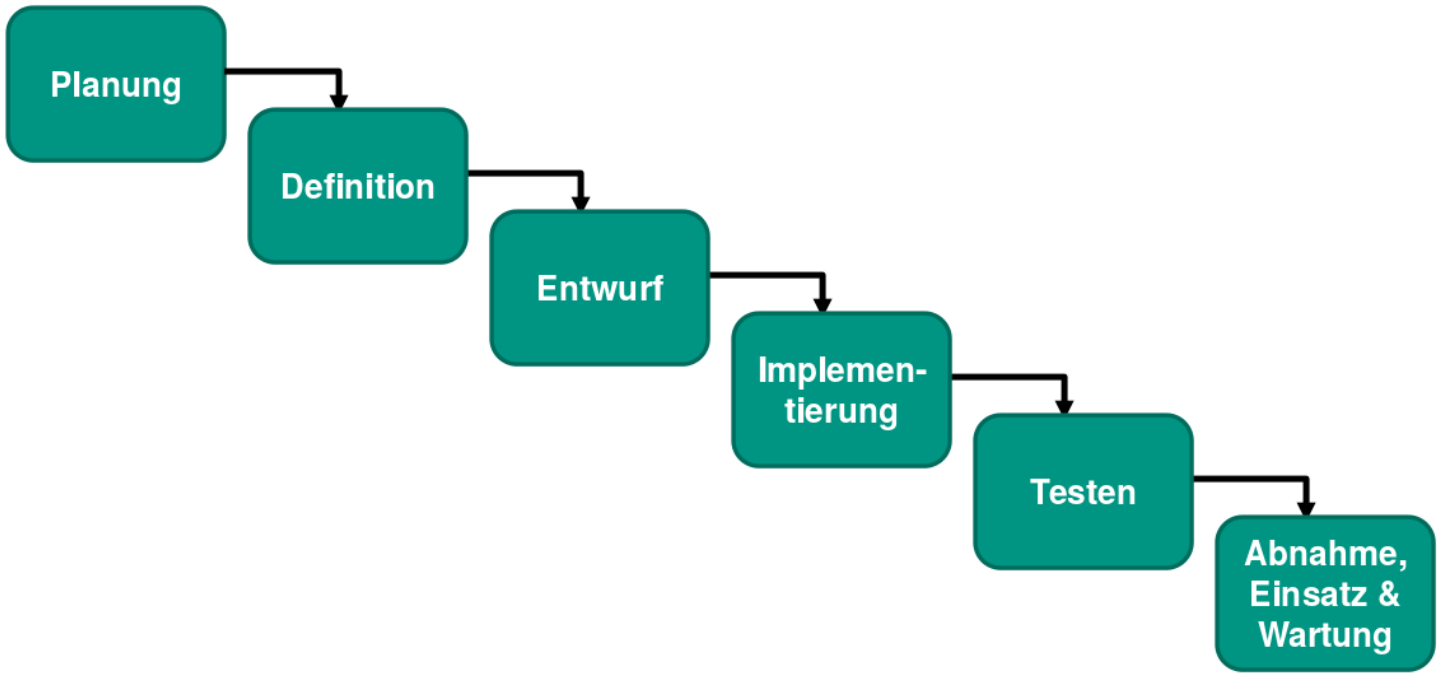
STEINBUCH CENTER FOR COMPUTING



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

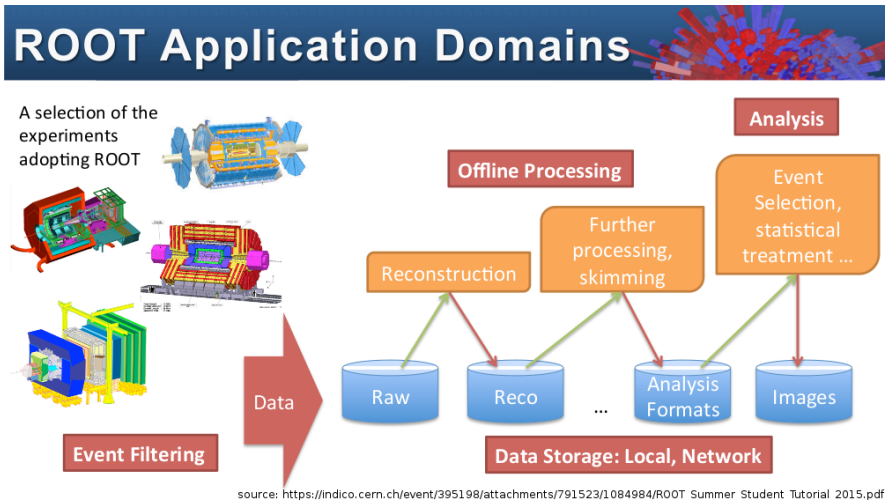
- Scientists (e.g. particle physicists) and Researchers
- Typical user will know ROOT and JavaScript $\rightarrow$ rather technology proficient
- Web-developers

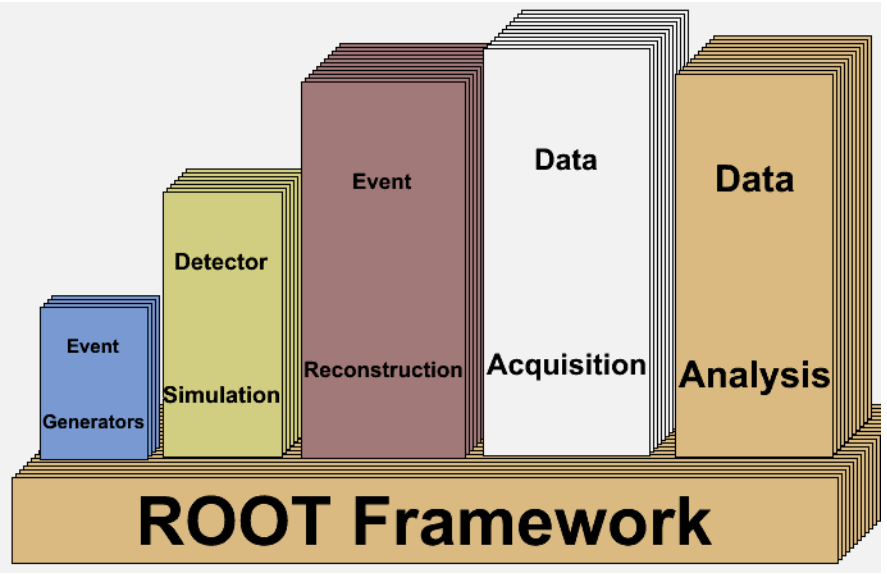
Operating conditions

- 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



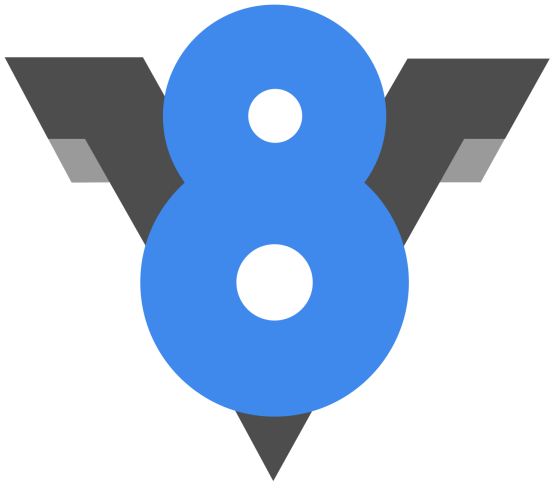


Node.js

- open source runtime environment
  - develop server side web applications
  - act as a stand alone web server

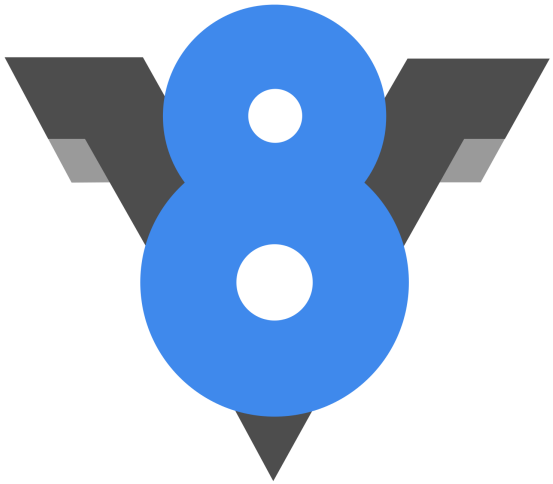
Node.js

- open source runtime environment
  - develop server side web applications
  - act as a stand alone web server
- Google V8 engine to execute JavaScript code



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

Hardware

- Task: encapsulation of ROOT objects and functions
  - → scanning ROOT structures during initialization
  - → encapsulating objects with heavily nested object structures
  - → introduce (proxy) object cache

⇒ generally negligible hardware requirements of the bindings themselves

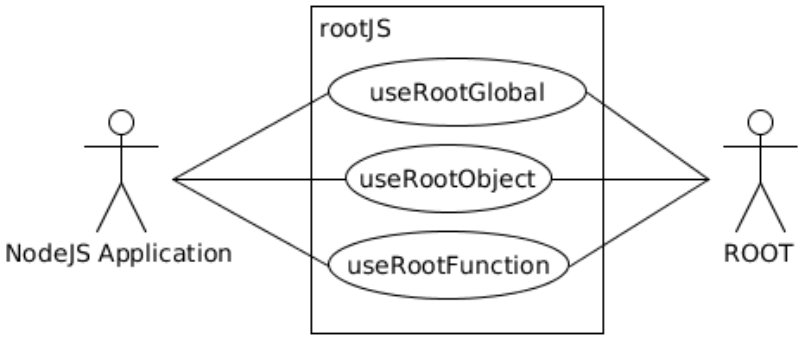
Product data

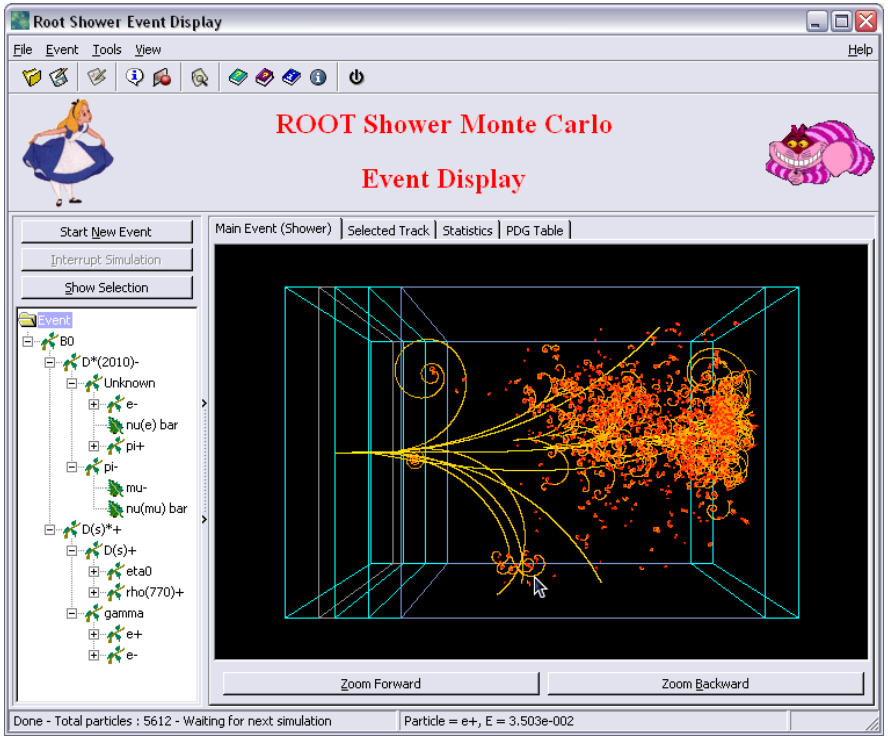
The following data will be stored by the rootJS bindings

- 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

Product interface

Event Viewer





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`

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.
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`
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`.
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`
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`.

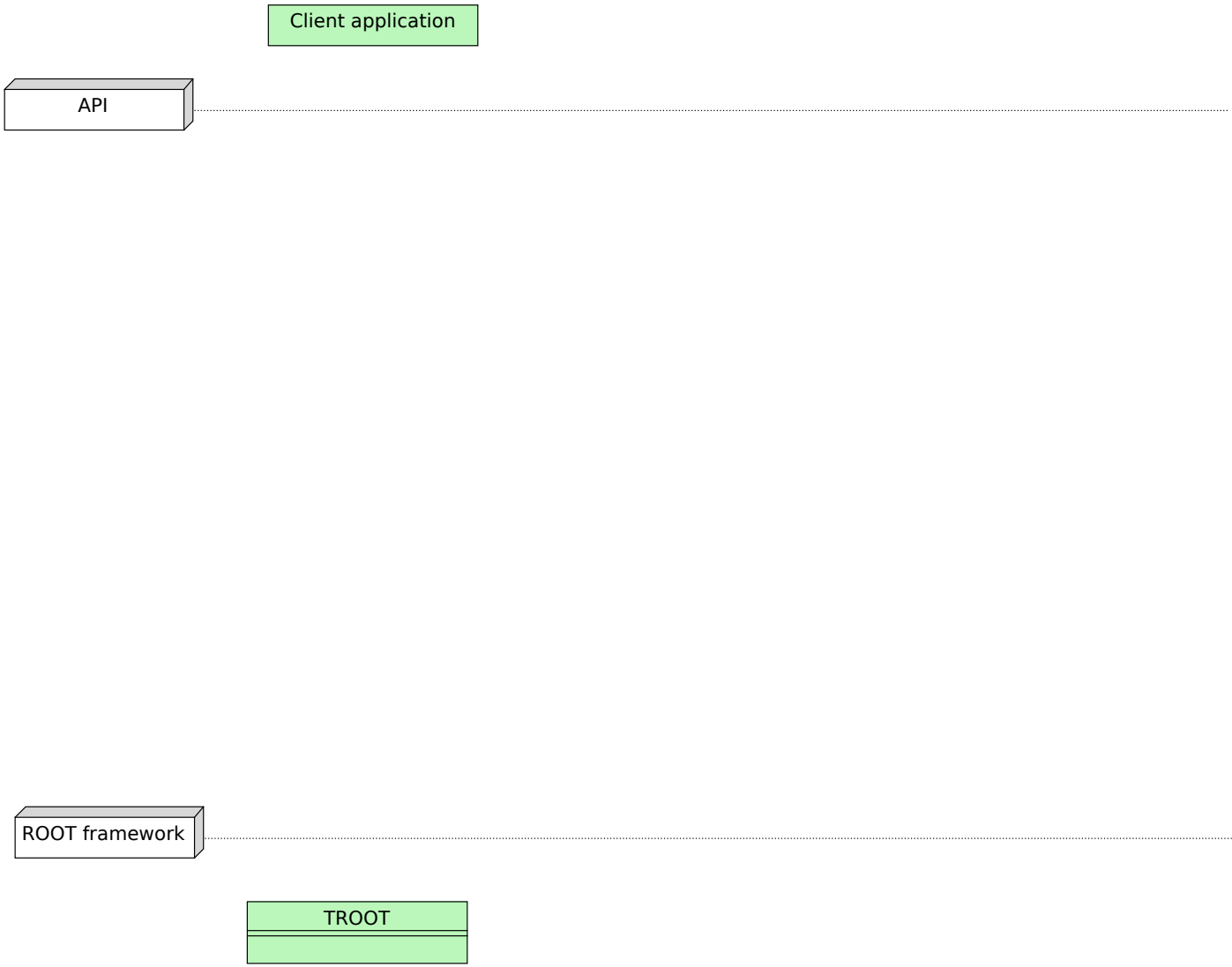
UseJIT

Flow of events

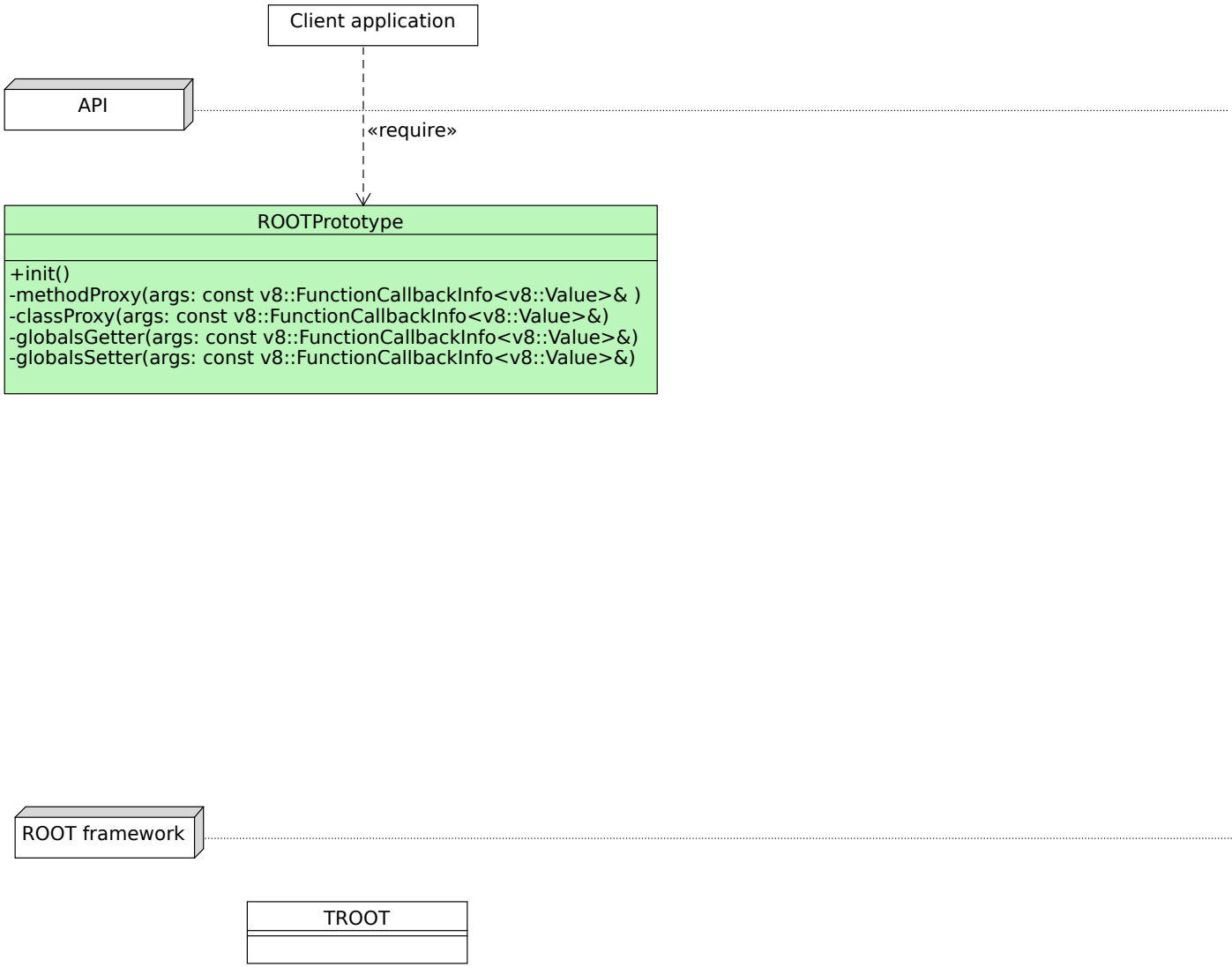
3. `rootJS` takes care of encapsulating exceptions possibly thrown by `Cling` or `ROOT` during evaluation and execution.
4. `rootJS` provides the evaluation results and corresponding return values to the `NodeJSApplication`.

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`.

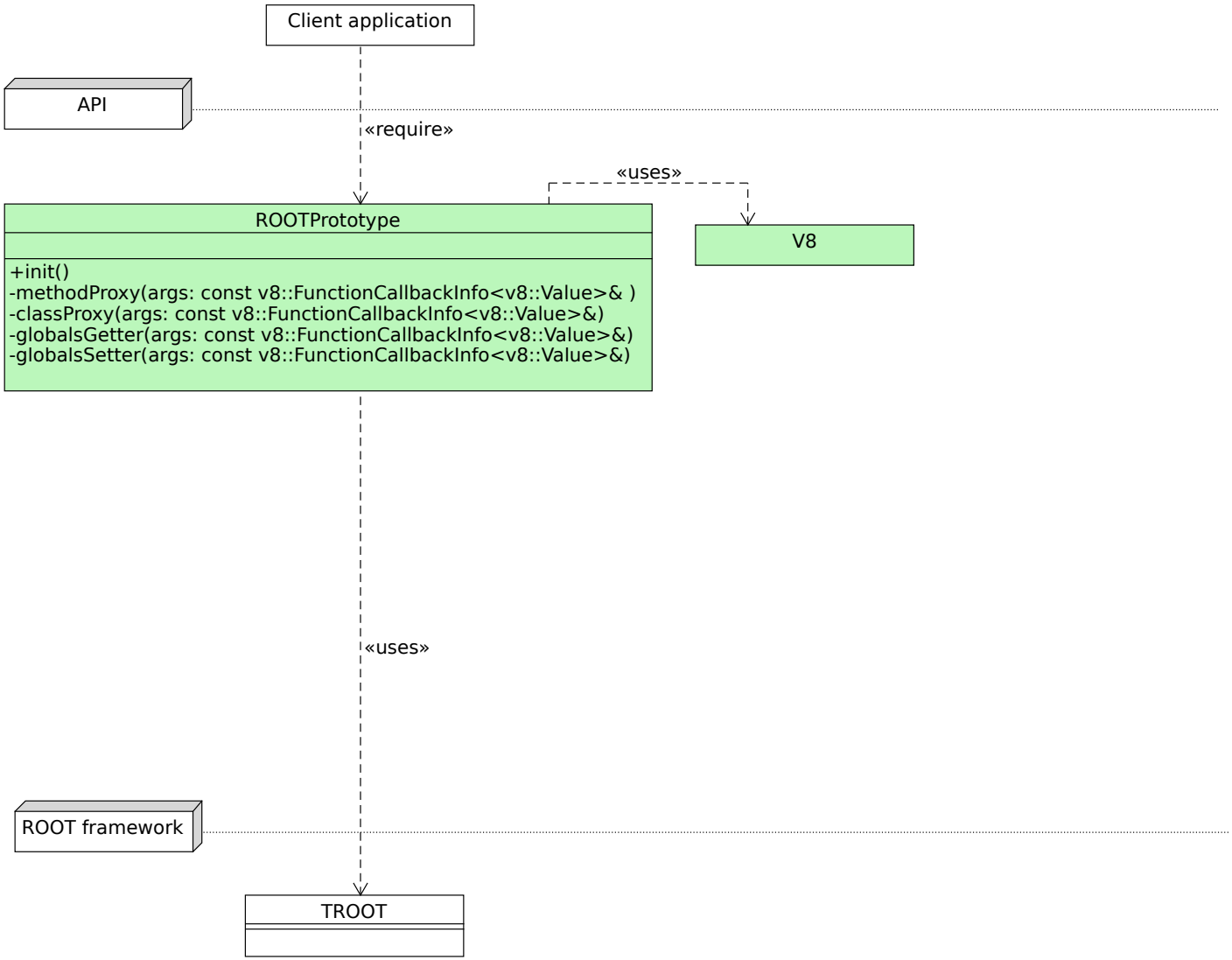
Basic Architecture



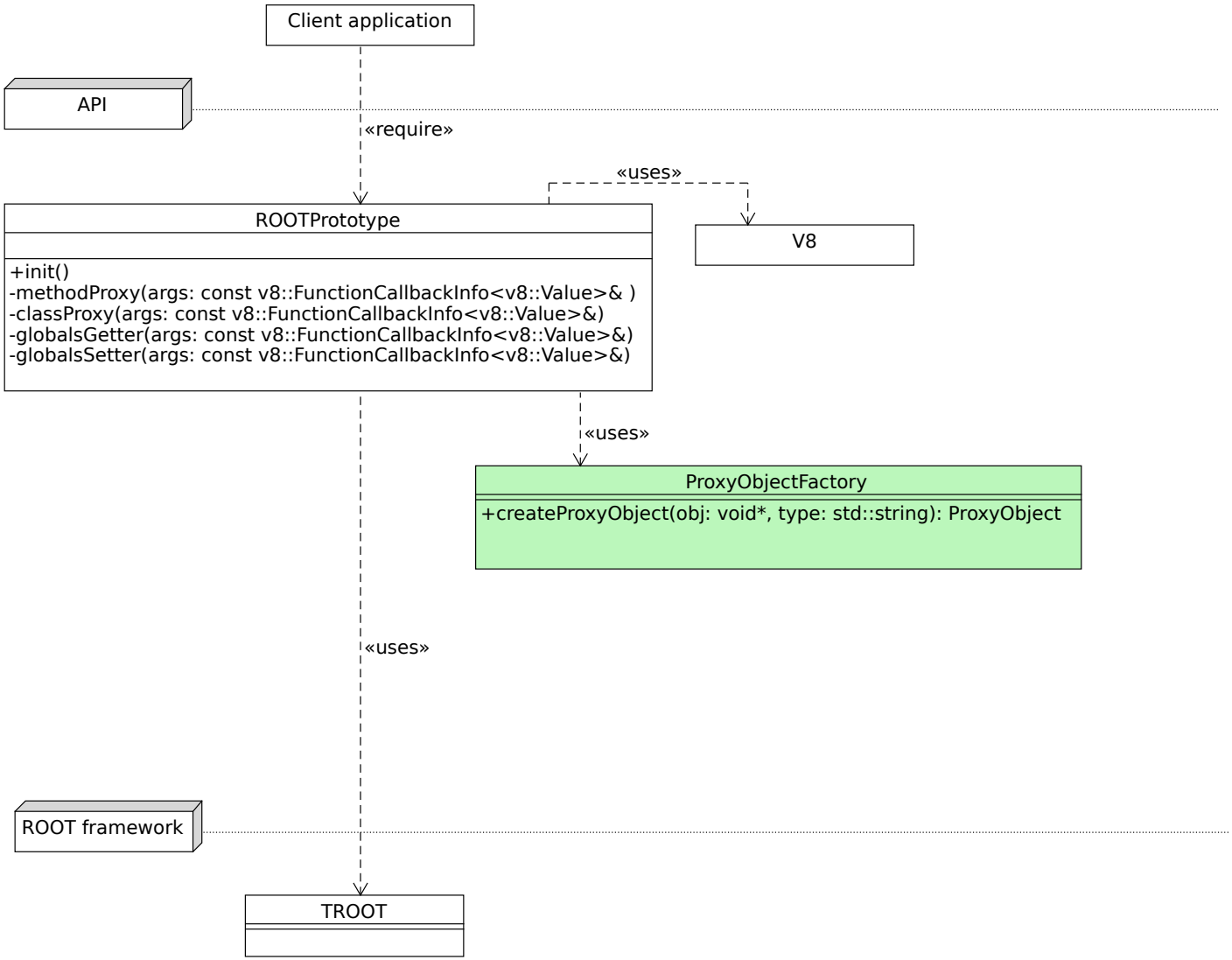
Basic Architecture



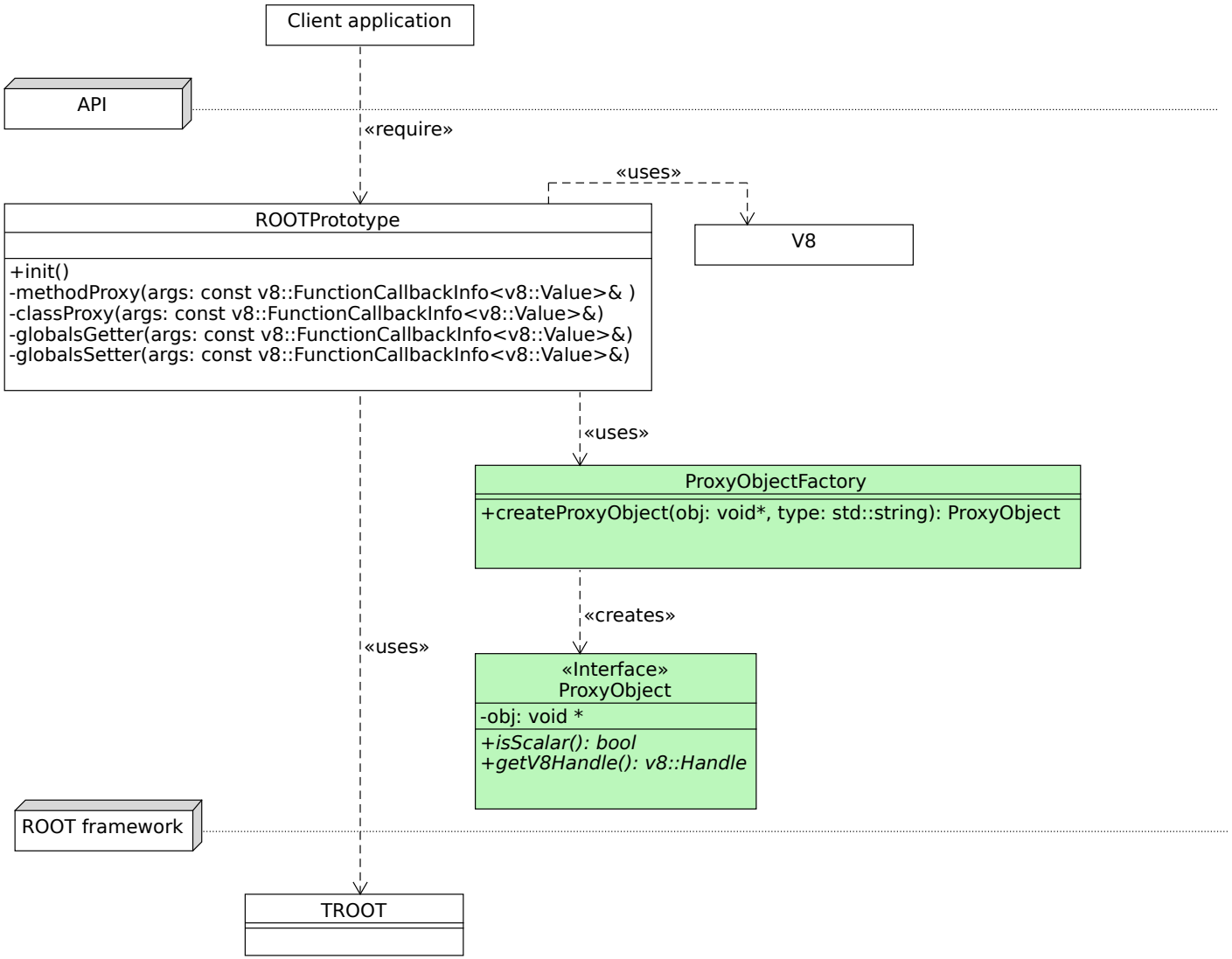
Basic Architecture



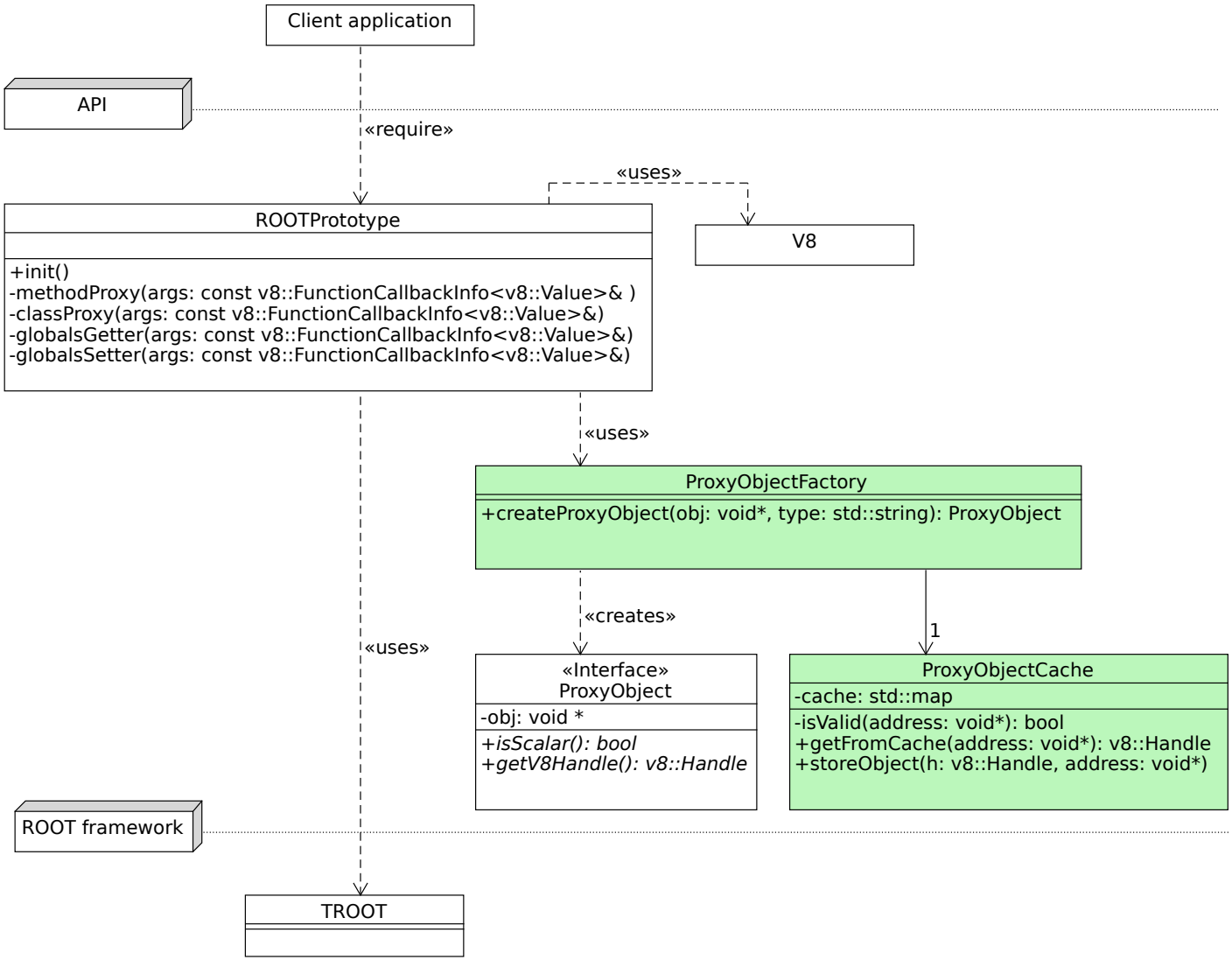
Basic Architecture



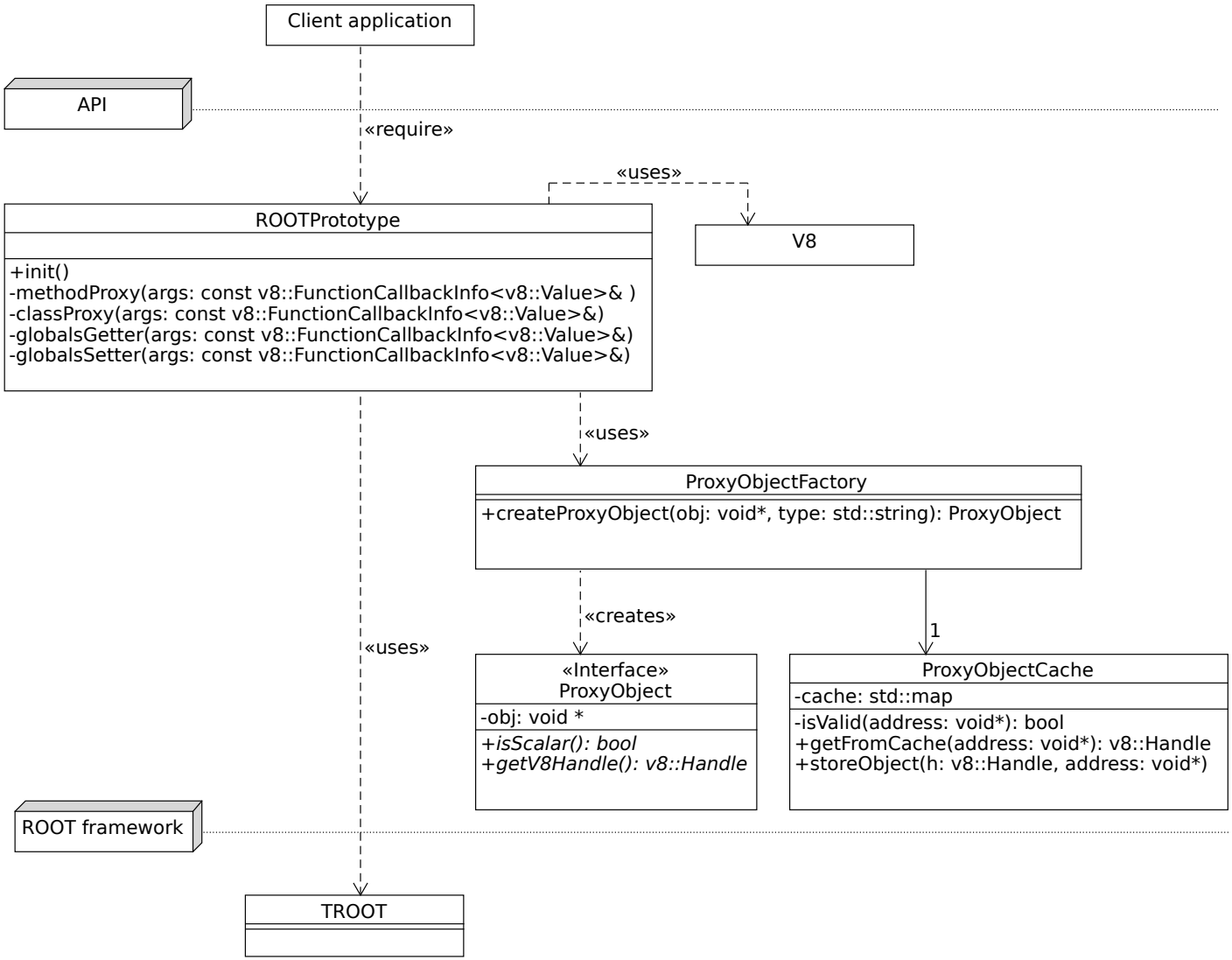
Basic Architecture



Basic Architecture



Basic Architecture



Initialization

- Expose all
  - Global variables
  - Global functions
  - Classes

Initialization

- Expose all
  - Global variables
  - Global functions
  - Classes
- Each are bound to corresponding proxy methods
- An object which members are the exposed features is beeing passed to node

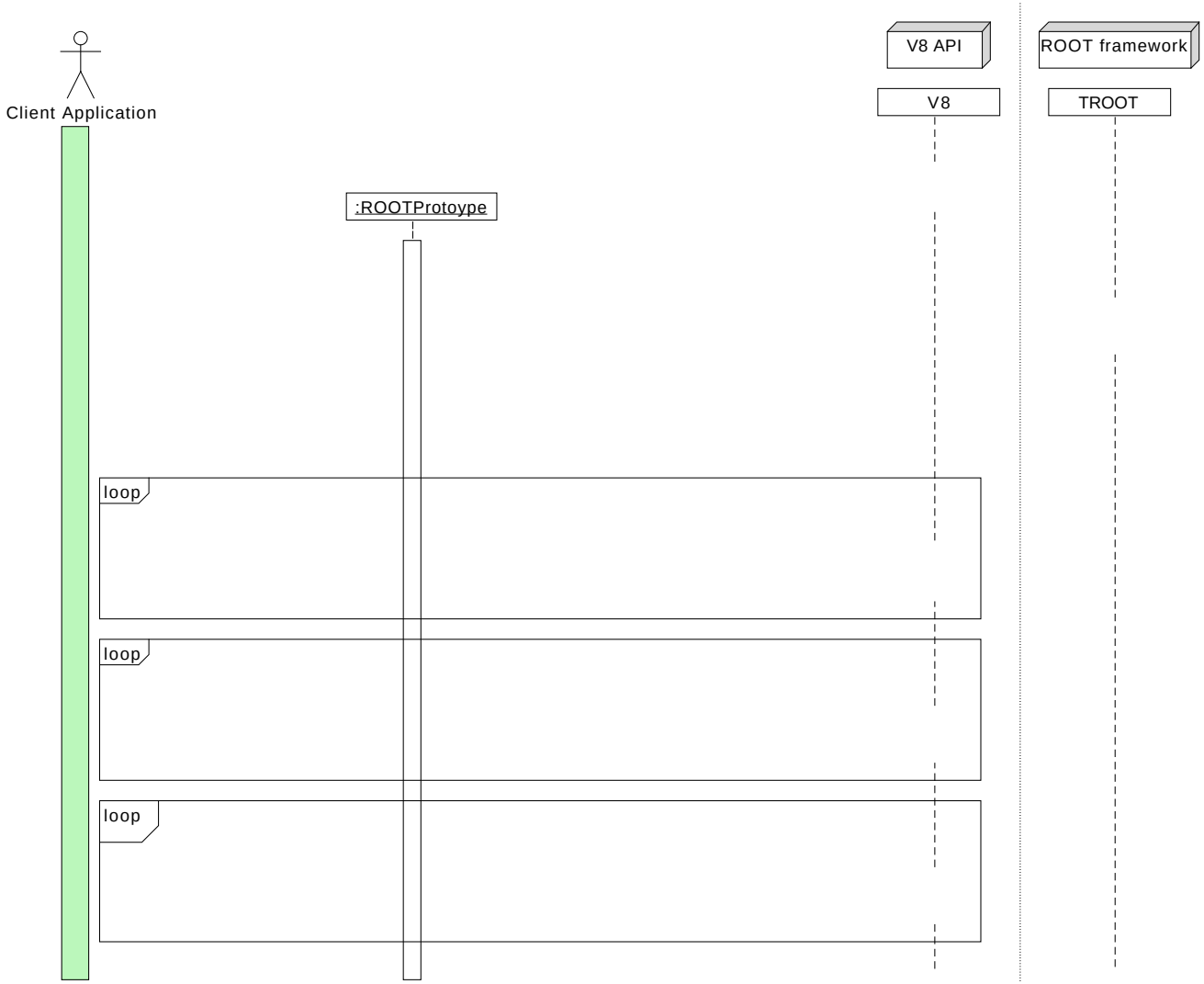
Initialization

- Expose all
  - Global variables
  - Global functions
  - Classes
- Each are bound to corresponding proxy methods
- An object which members are the exposed features is beeing passed to node

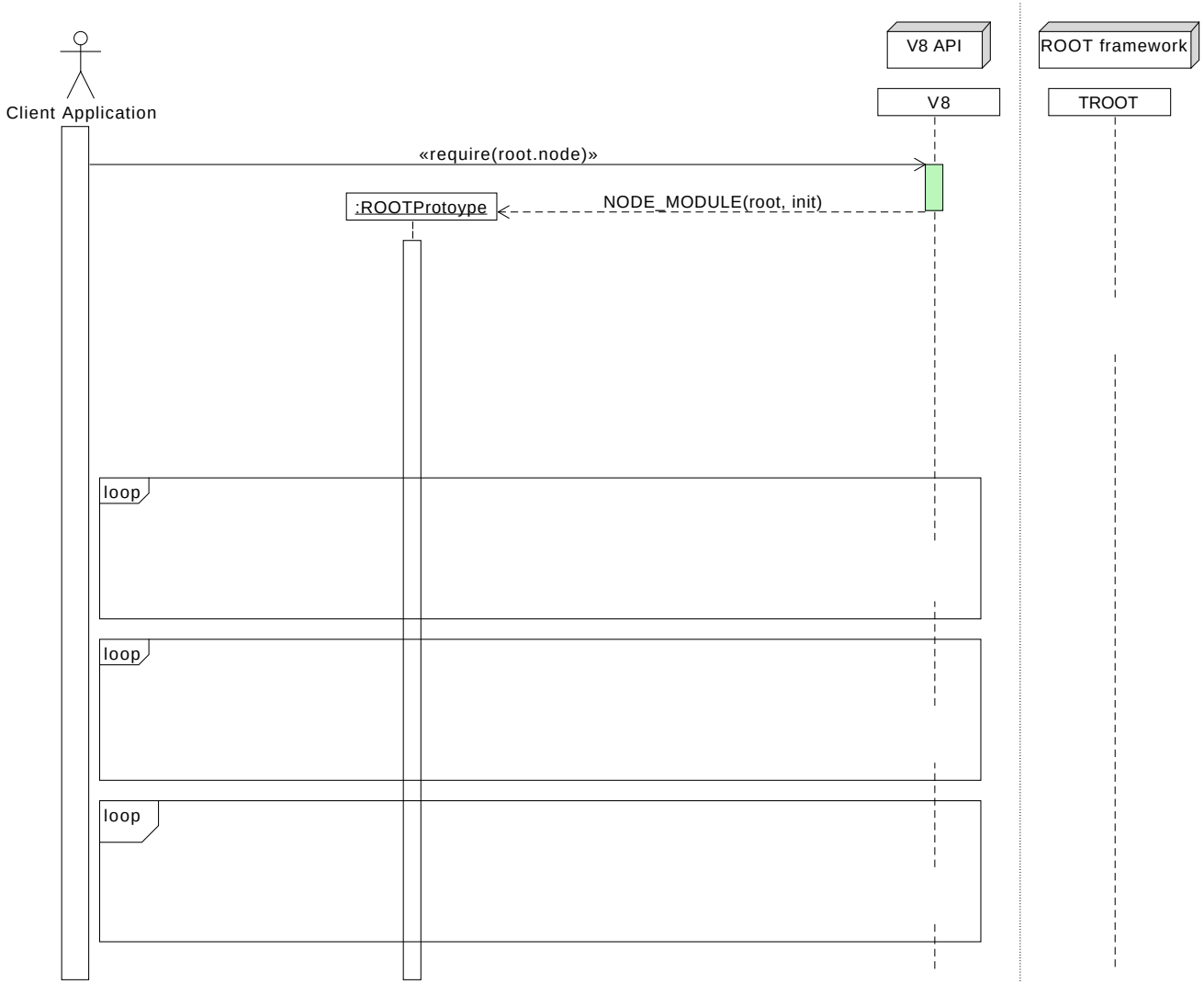
Names

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

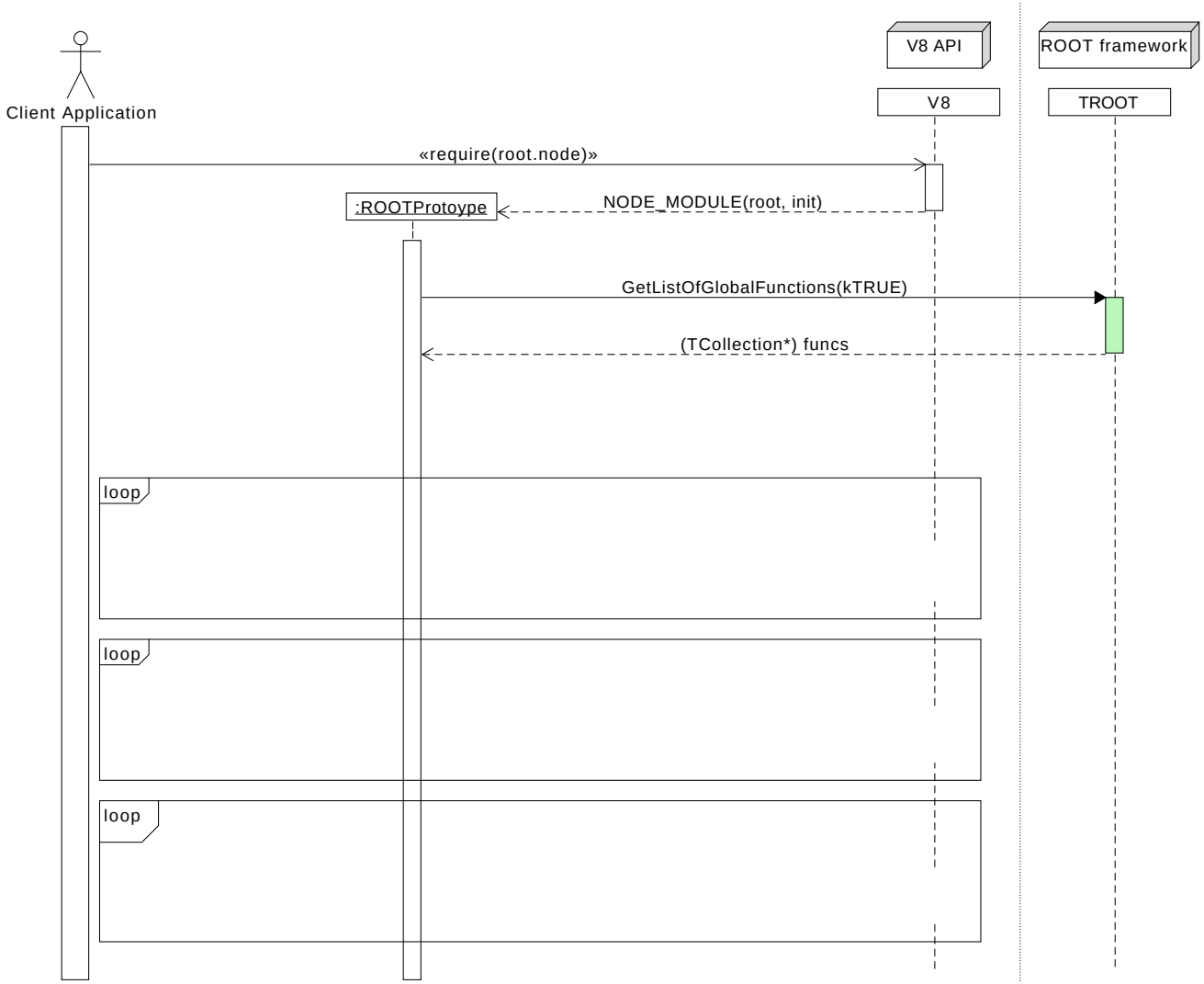
rootJS init


Client Application
V8 API
V8
ROOT framework
TROOT
:ROOTPrototype
loop
loop
loop

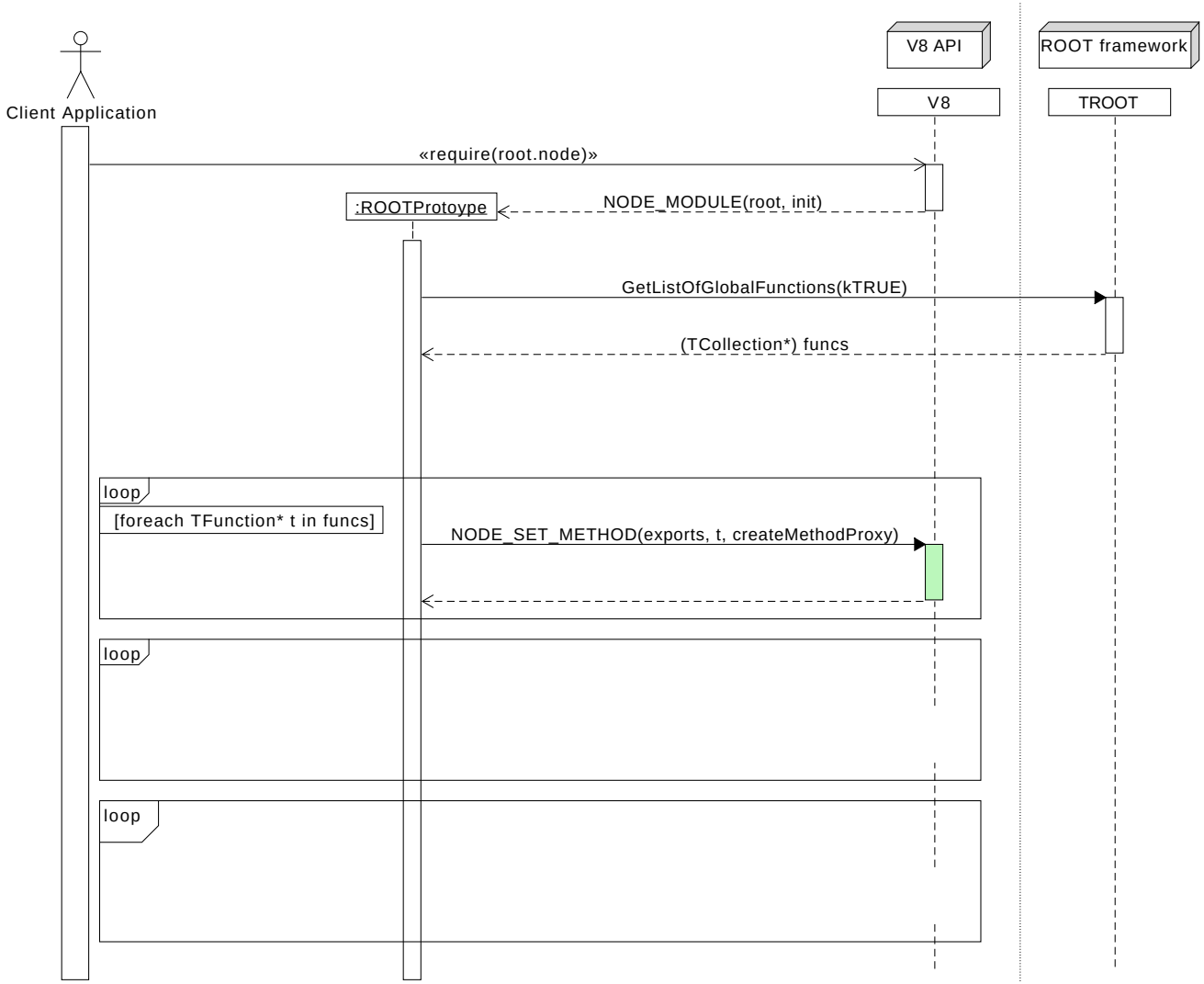
rootJS init


Client Application
V8 API
V8
ROOT framework
TROOT
«require(root.node)»
:ROOTPrototype
NODE_MODULE(root, init)
loop
loop
loop

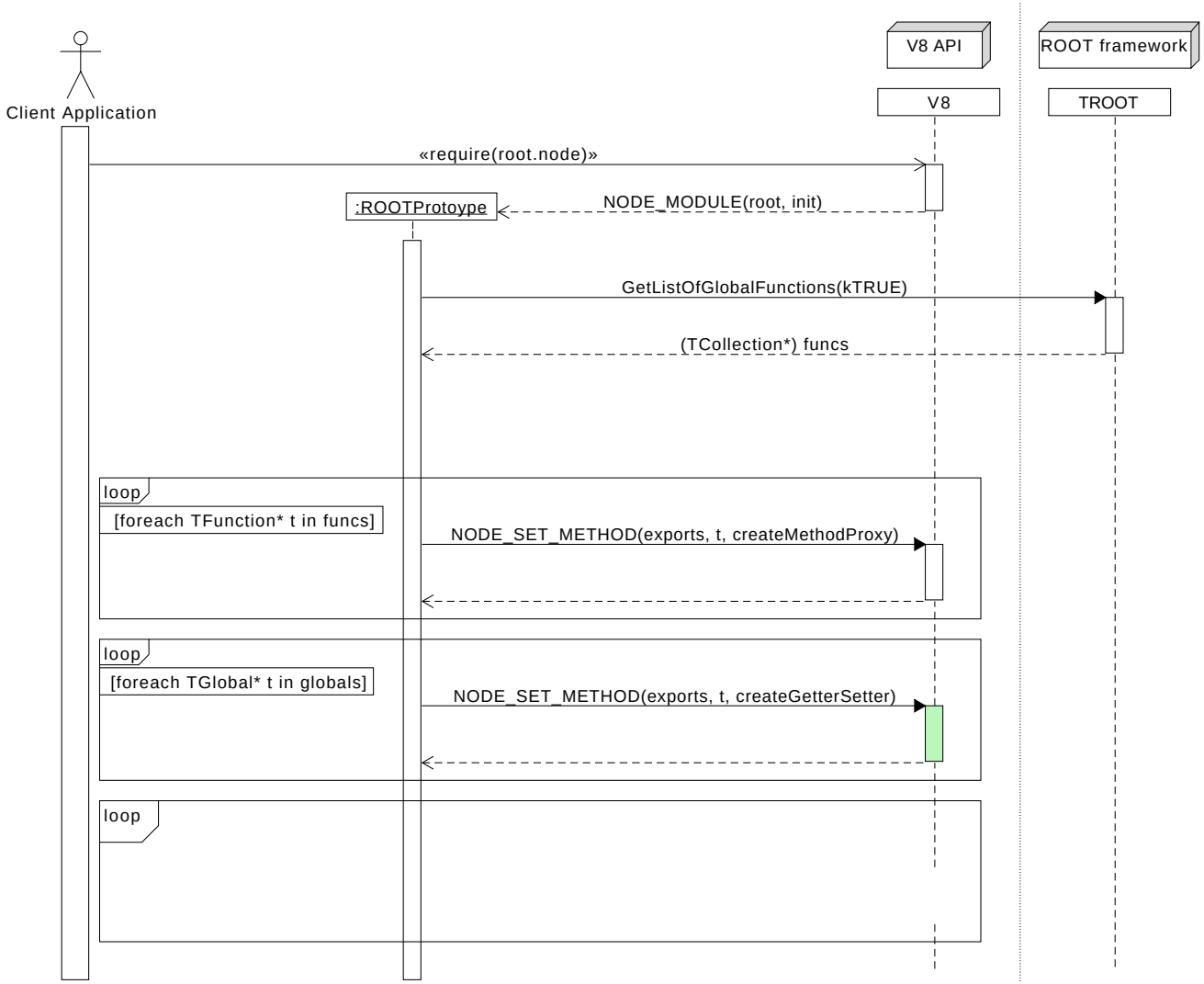
rootJS init


Client Application
V8 API
ROOT framework
V8
TROOT
«require(root.node)»
:ROOTPrototype
NODE_MODULE(root, init)
GetListOfGlobalFunctions(kTRUE)
(TCollection*) funcs
loop
loop
loop

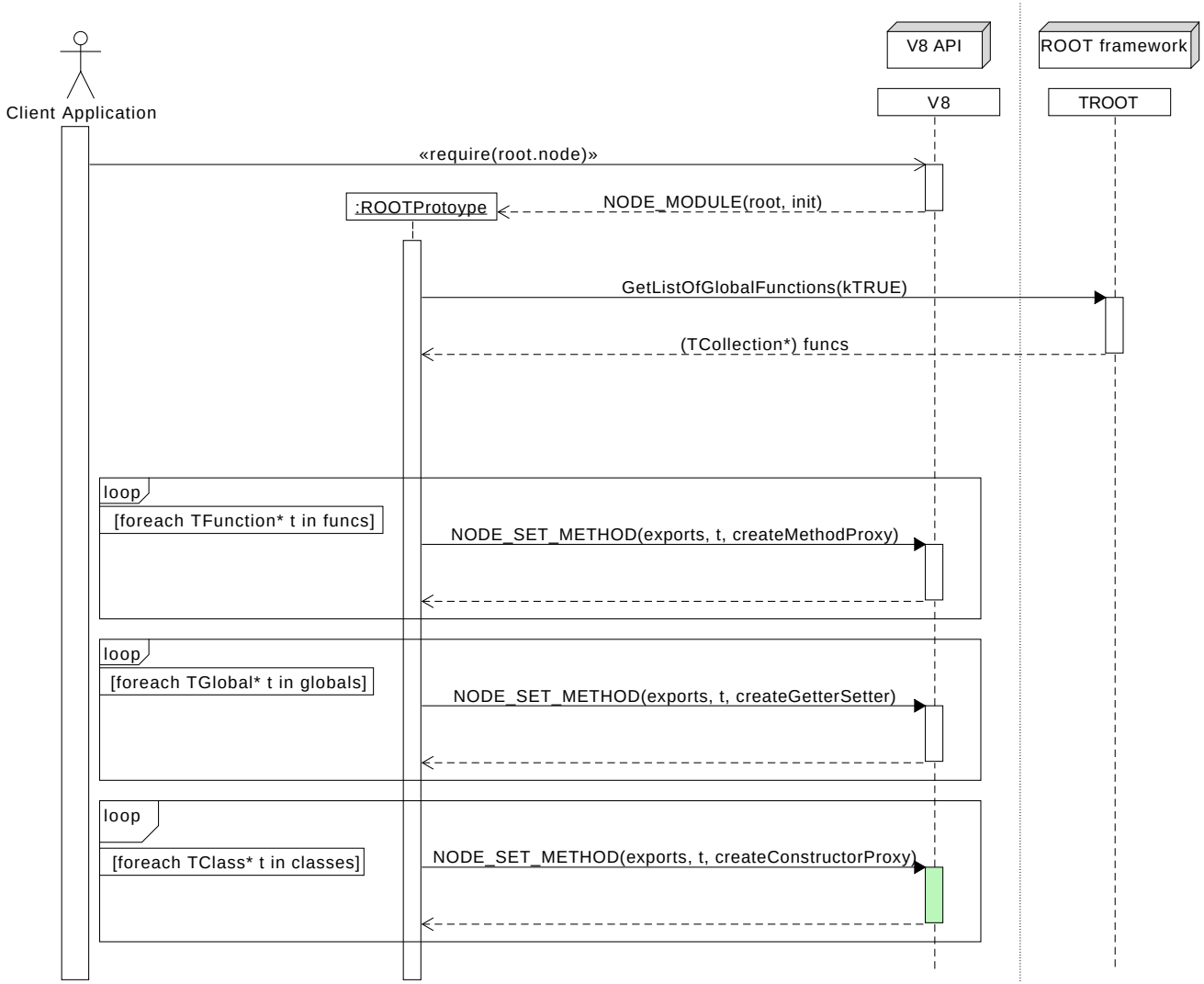
rootJS init


Client Application
V8 API
V8
ROOT framework
TROOT
«require(root.node)»
:ROOTPrototype
NODE_MODULE(root, init)
GetListOfGlobalFunctions(kTRUE)
(TCollection*) funcs
loop
[foreach TFunction* t in funcs]
NODE_SET_METHOD(exports, t, createMethodProxy)
loop
loop

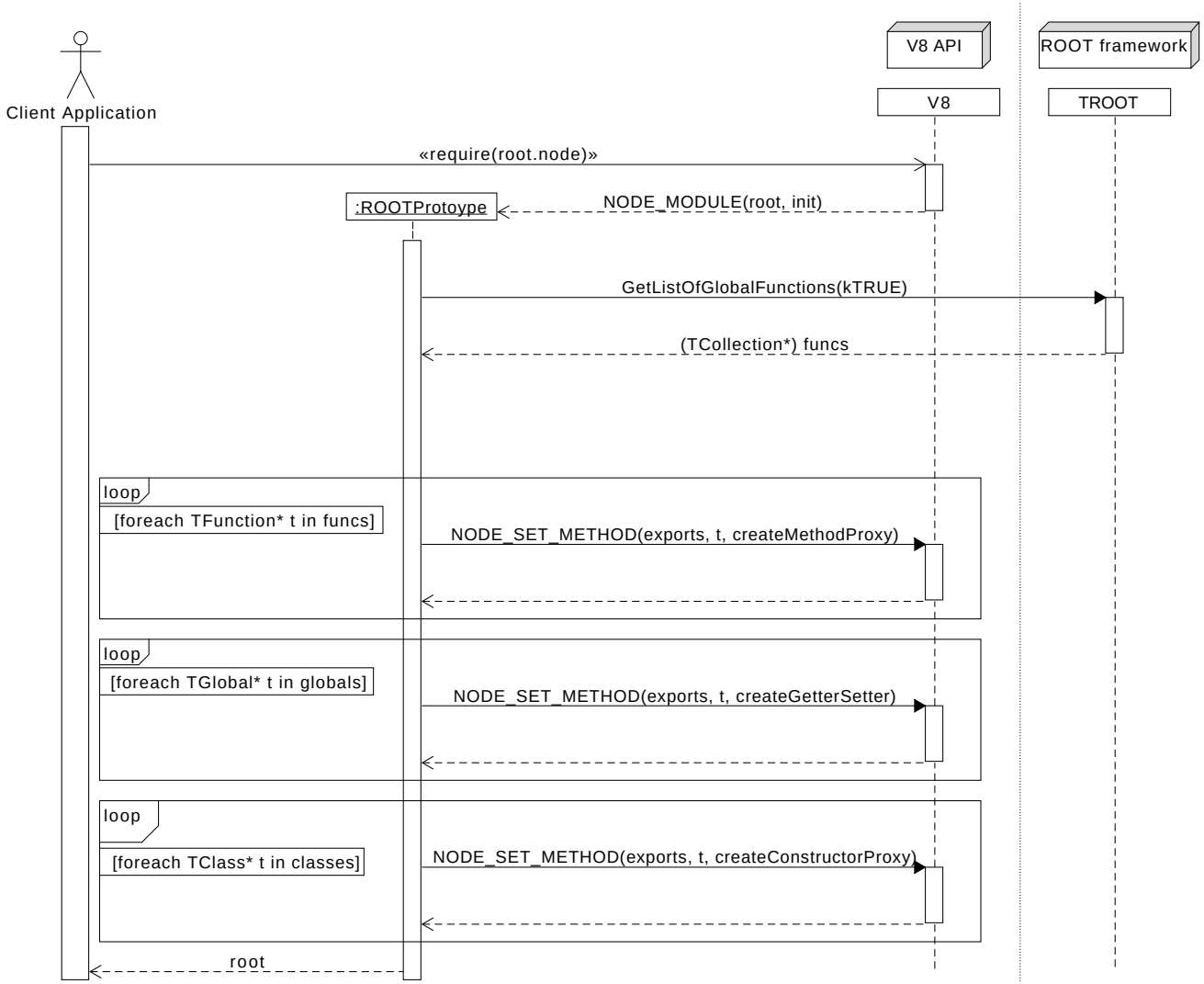
rootJS init


Client Application
V8 API
V8
ROOT framework
TROOT
«require(root.node)»
:ROOTPrototype
NODE_MODULE(root, init)
GetListOfGlobalFunctions(kTRUE)
(TCollection*) funcs
loop
[foreach TFunction* t in funcs]
NODE_SET_METHOD(exports, t, createMethodProxy)
loop
[foreach TGlobal* t in globals]
NODE_SET_METHOD(exports, t, createGetterSetter)
loop

rootJS init


Client Application
V8 API
ROOT framework
V8
TROOT
«require(root.node)»
:ROOTPrototype
NODE_MODULE(root, init)
GetListOfGlobalFunctions(kTRUE)
(TCollection*) funcs
loop
[foreach TFunction* t in funcs]
NODE_SET_METHOD(exports, t, createMethodProxy)
loop
[foreach TGlobal* t in globals]
NODE_SET_METHOD(exports, t, createGetterSetter)
loop
[foreach TClass* t in classes]
NODE_SET_METHOD(exports, t, createConstructorProxy)

rootJS init


Client Application
V8 API
V8
ROOT framework
TROOT
«require(root.node)»
:ROOTPrototype
NODE_MODULE(root, init)
GetListOfGlobalFunctions(kTRUE)
(TCollection*) funcs
loop
[foreach TFunction* t in funcs]
NODE_SET_METHOD(exports, t, createMethodProxy)
loop
[foreach TGlobal* t in globals]
NODE_SET_METHOD(exports, t, createGetterSetter)
loop
[foreach TClass* t in classes]
NODE_SET_METHOD(exports, t, createConstructorProxy)
root

Call a feature

- All features in node are mapped to a proxy method that will be called

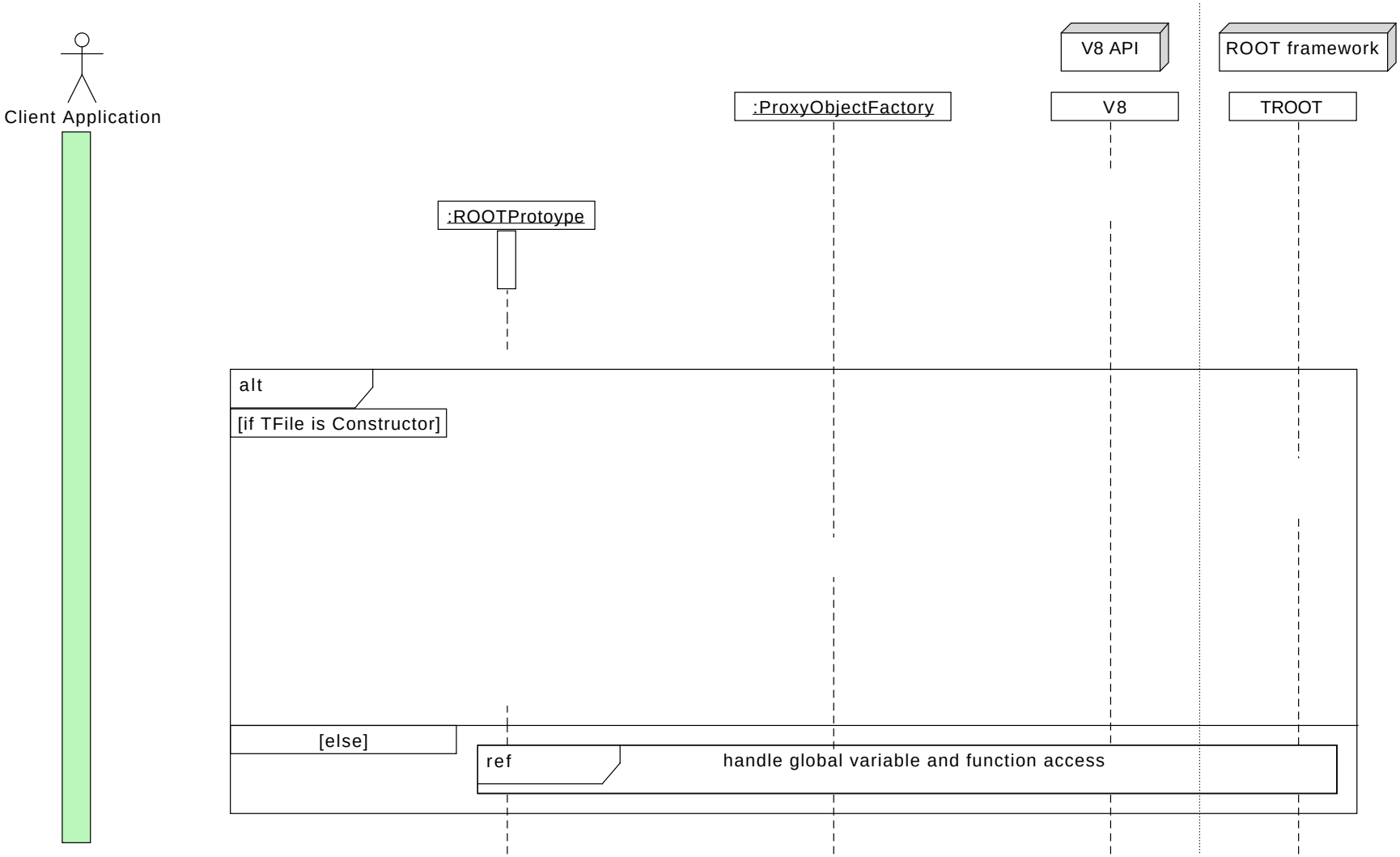
Call a feature

- All features in node are mapped to a proxy method that will be called
- The proxy method will eventually call a root function and pass the result to our ObjectFactory

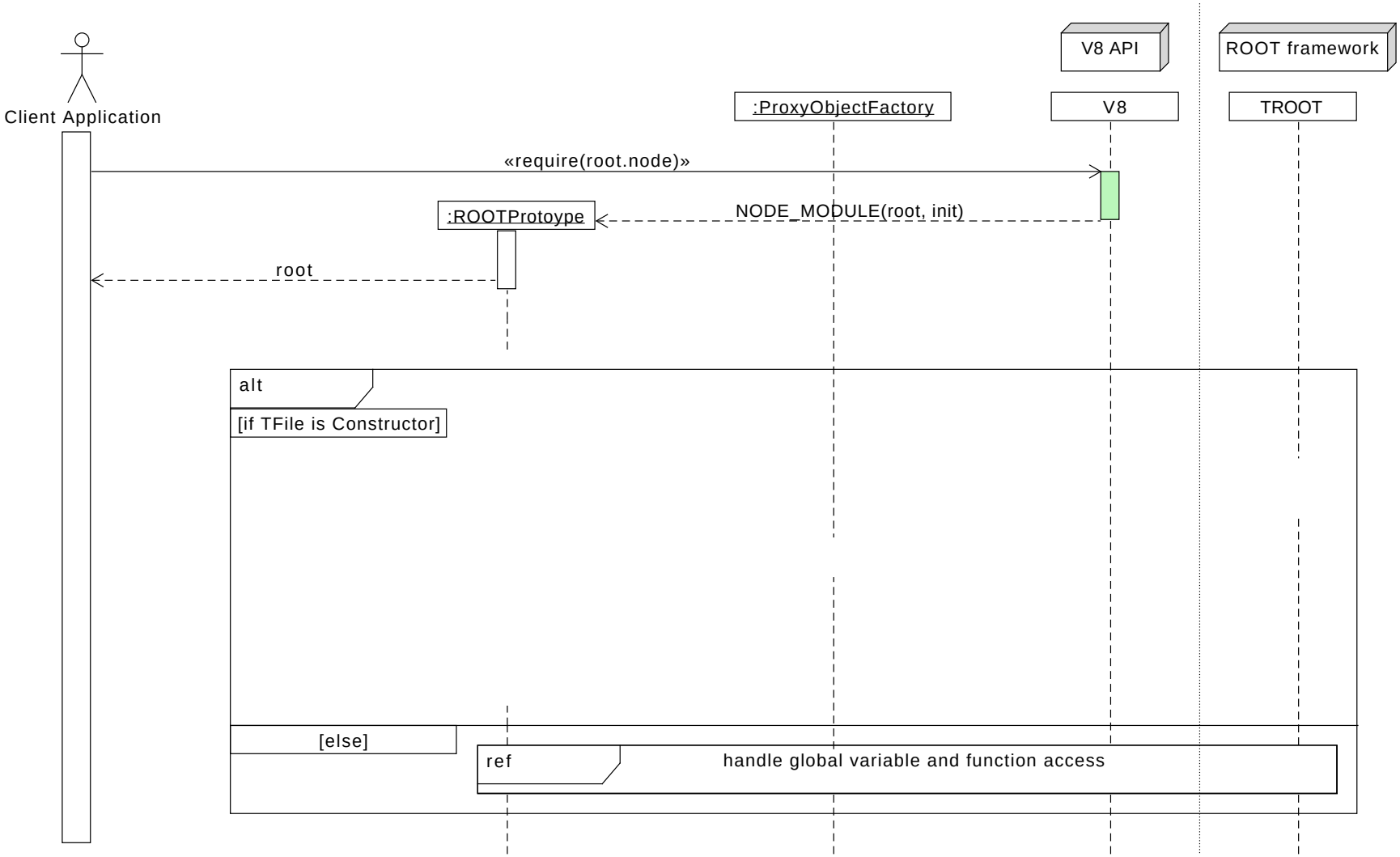
Call a feature

- All features in node are mapped to a proxy method that will be called
- 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

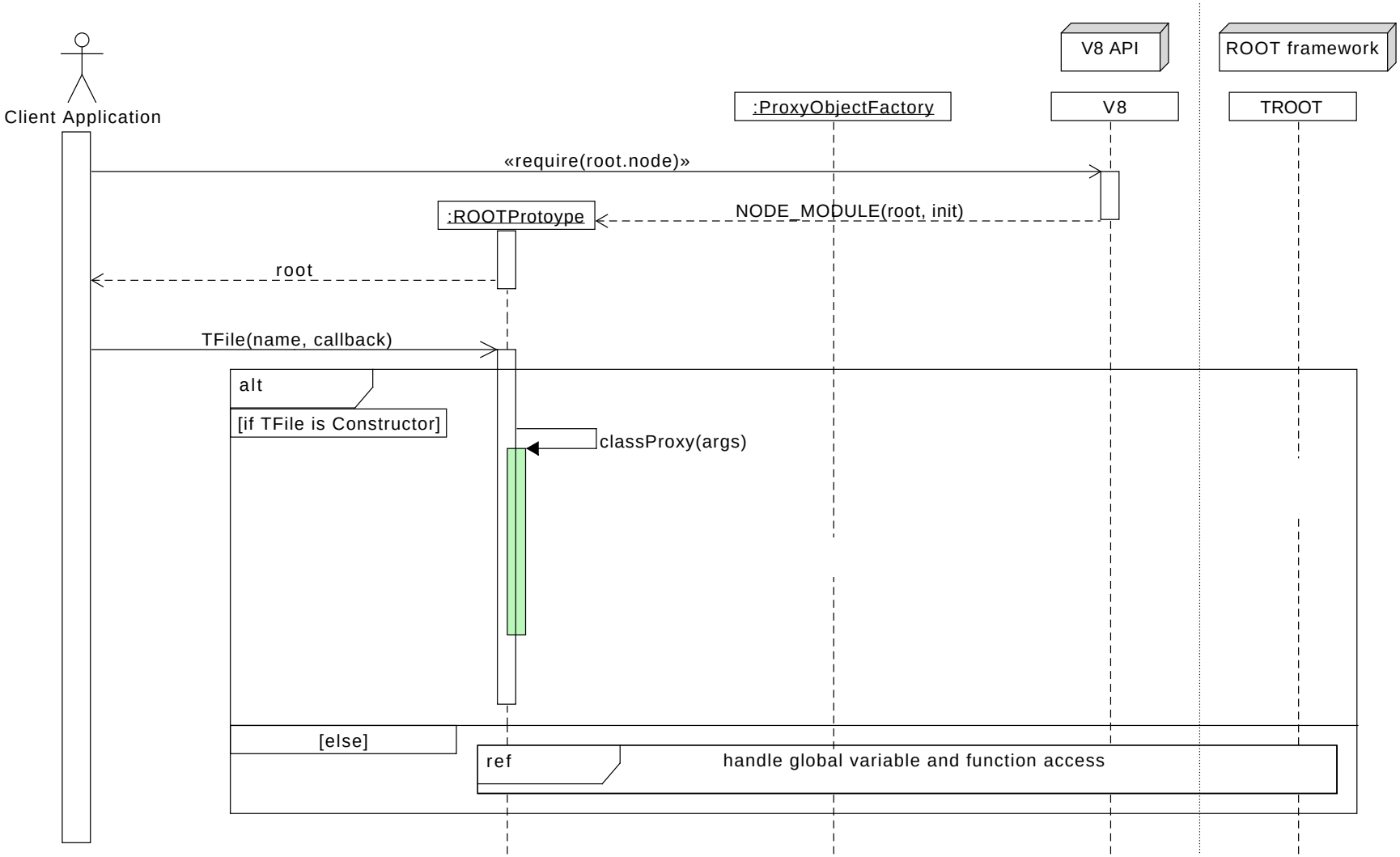
proxied file access



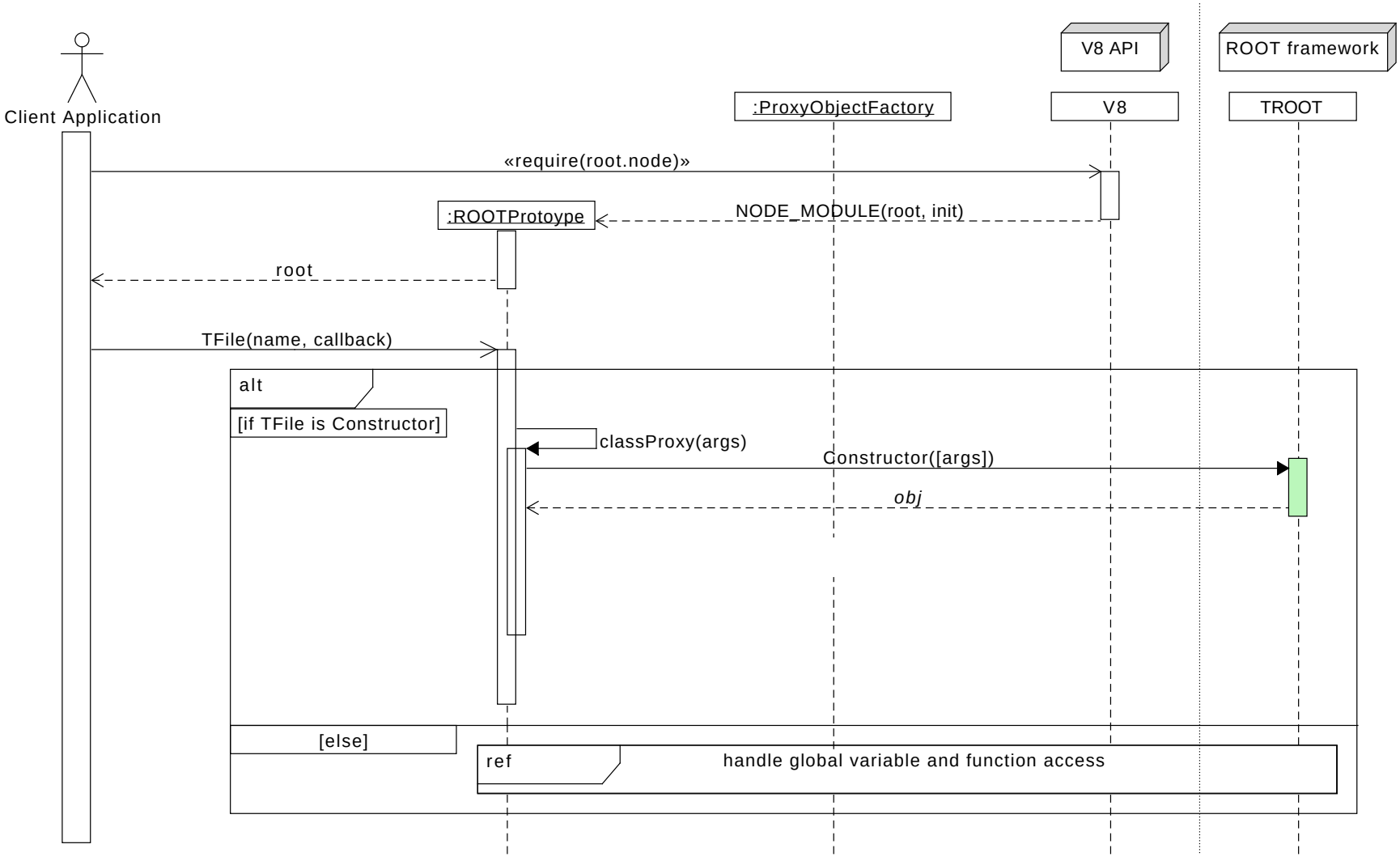
proxied file access



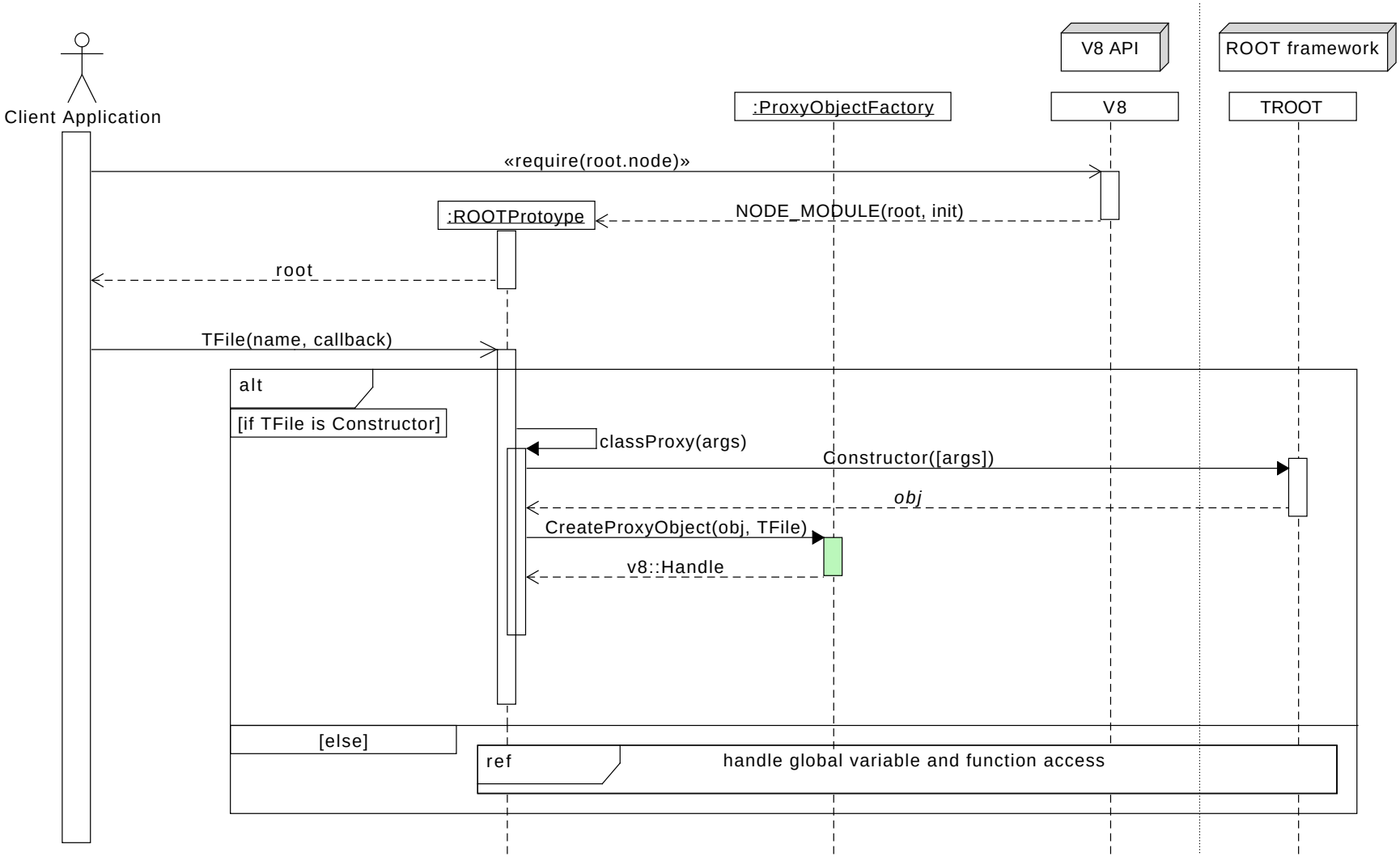
proxied file access



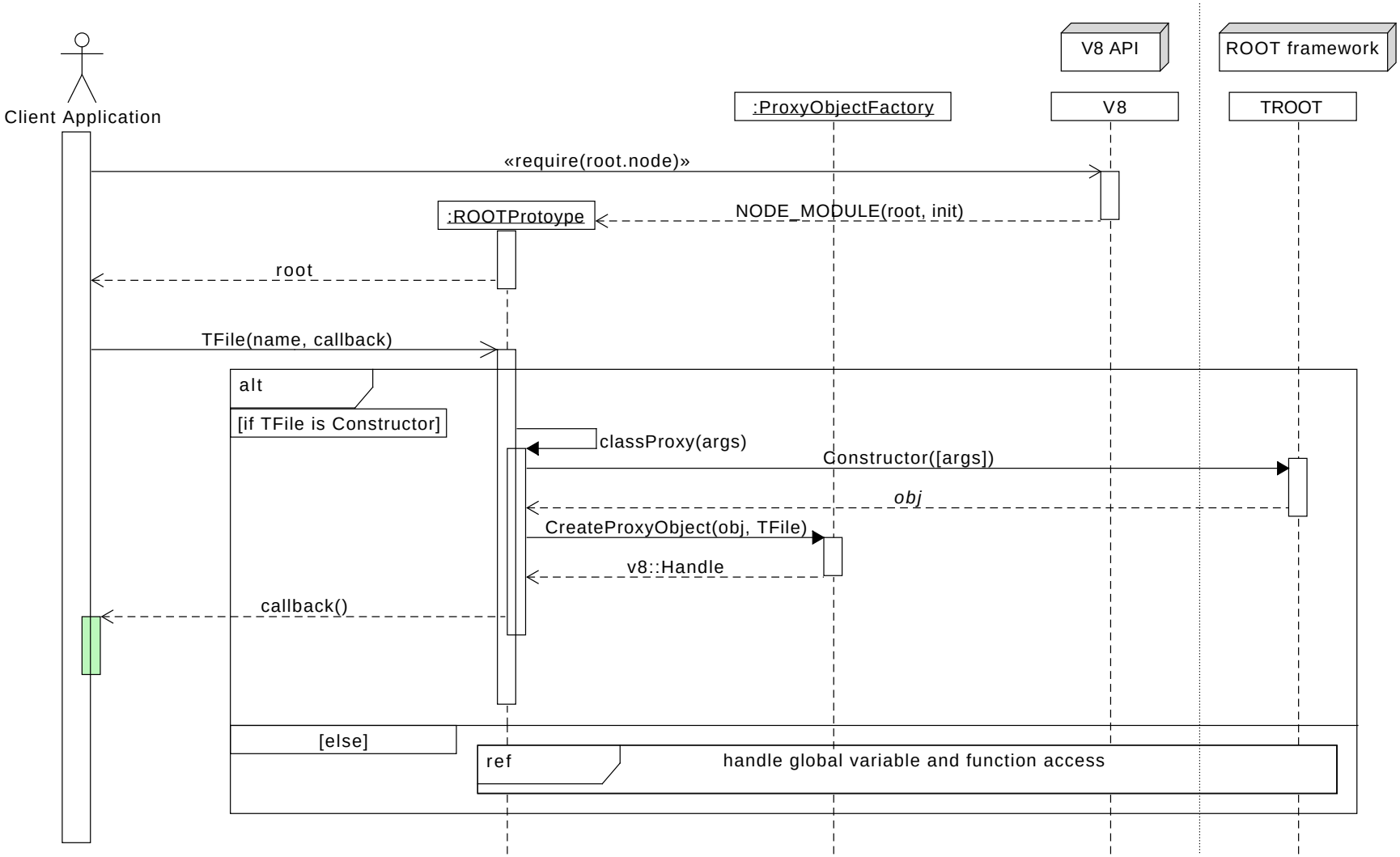
proxied file access



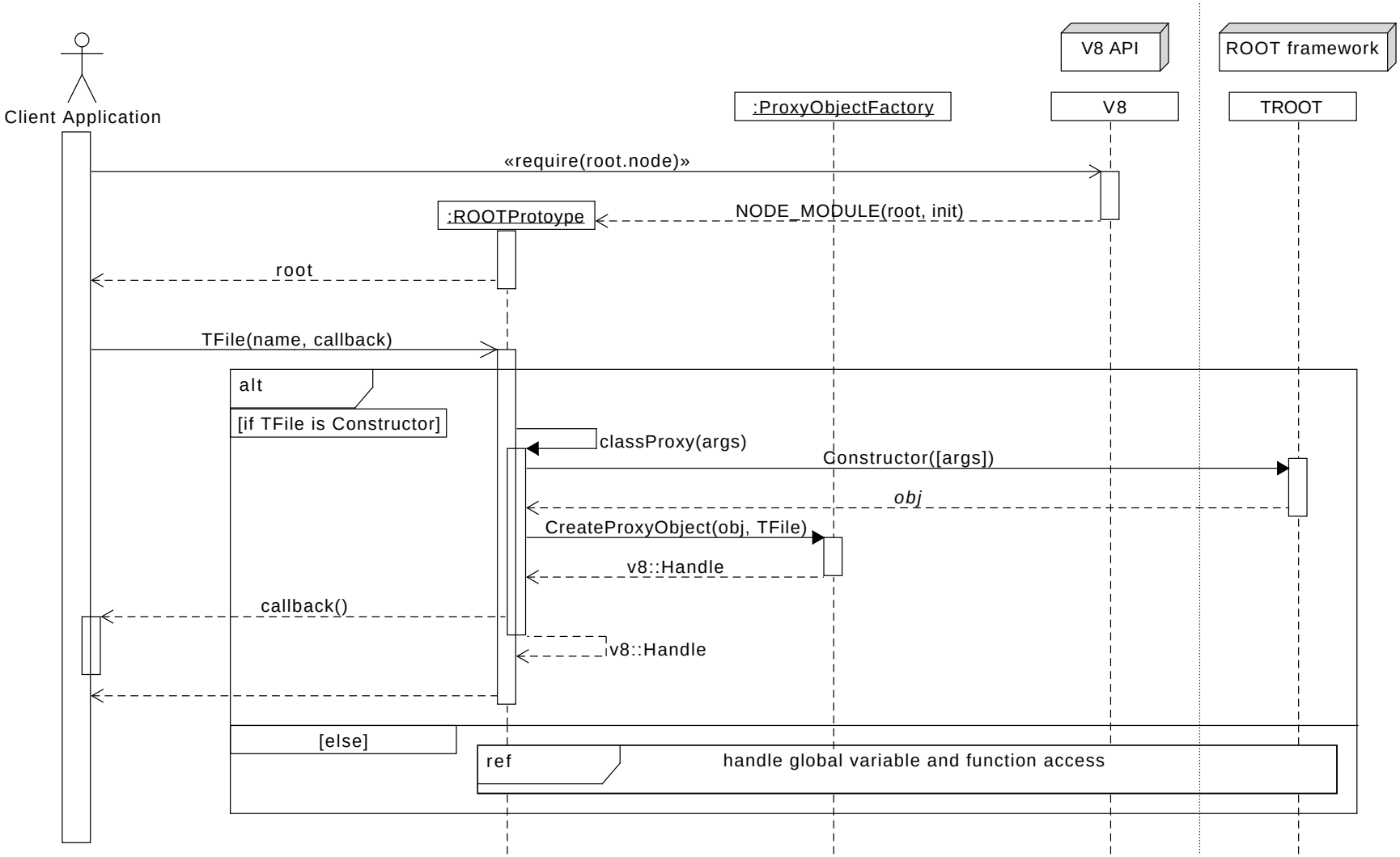
proxied file access



proxied file access



proxied file access



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

References I