readme.md for @push.rocks/smartvm

A TypeScript module that wraps Amazon's Firecracker VMM to create, configure, and manage lightweight microVMs with a clean, type-safe API.

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Install

```
pnpm install @push.rocks/smartvm
```

> ⚡ **Prerequisites**: Firecracker requires a Linux host with KVM support (`/dev/kvm`). Networking features (TAP devices, bridges, NAT) require root privileges.

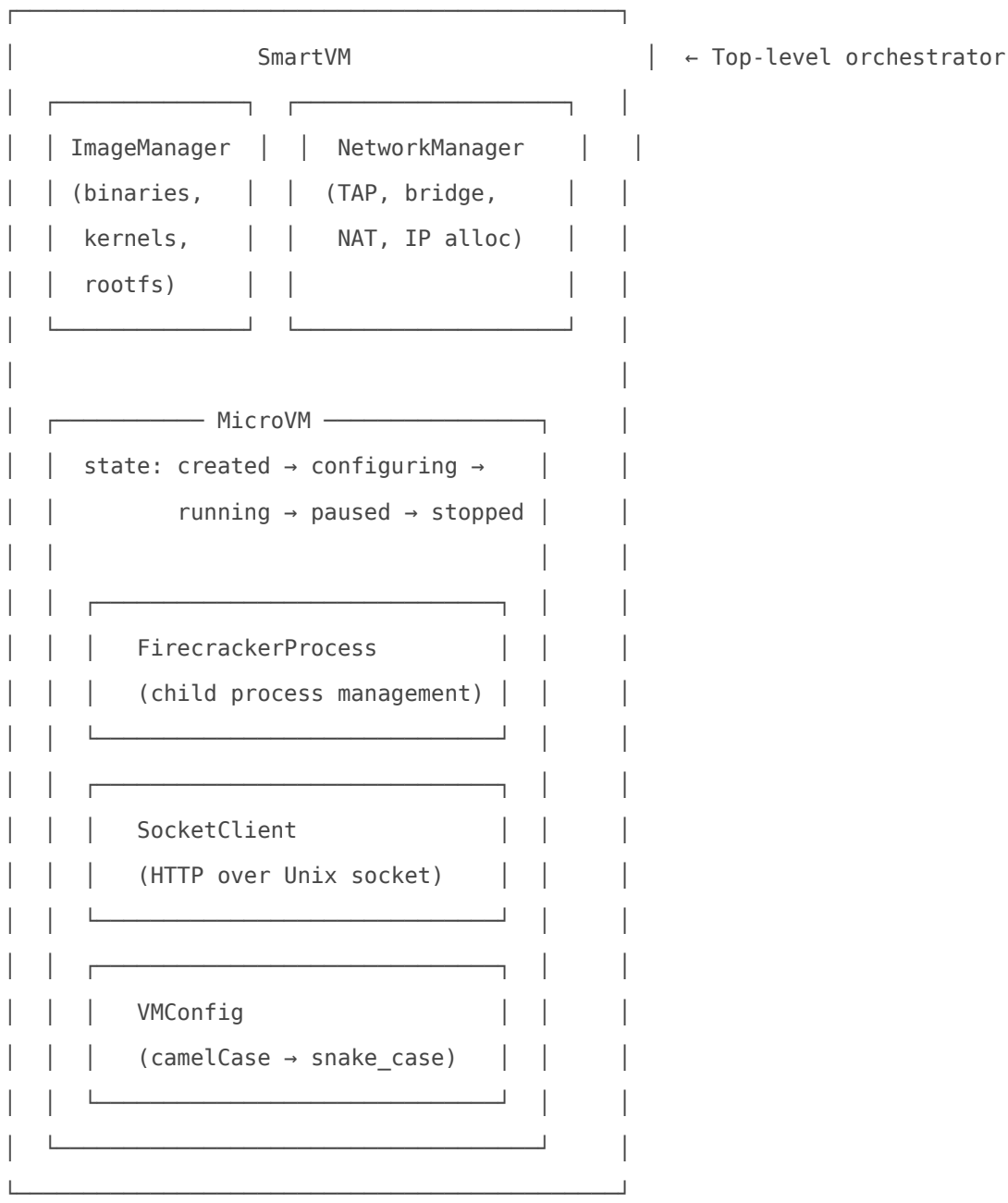
Quick Start

```
import { SmartVM } from '@push.rocks/smartvm';

// 1. Create the orchestrator
const smartvm = new SmartVM({
  dataDir: '/opt/smartvm',         // where binaries, kernels, rootfs are cached
```

```
  firecrackerVersion: 'v1.7.0',  // or omit for latest
  arch: 'x86_64',
});

// 2. Download Firecracker if not already present
await smartvm.ensureBinary();

// 3. Create a MicroVM
const vm = await smartvm.createVM({
  bootSource: {
    kernelImagePath: '/opt/smartvm/kernels/vmlinux',
    bootArgs: 'console=ttyS0 reboot=k panic=1 pci=off',
  },
  machineConfig: {
    vcpuCount: 2,
    memSizeMib: 256,
  },
  drives: [
    {
      driveId: 'rootfs',
      pathOnHost: '/opt/smartvm/rootfs/ubuntu.ext4',
      isRootDevice: true,
      isReadOnly: false,
    },
  ],
  networkInterfaces: [
    { ifaceId: 'eth0' }, // TAP device and MAC auto-generated
  ],
});

// 4. Start it □□
await vm.start();

// 5. Inspect
console.log(vm.state);           // 'running'
console.log(await vm.getInfo()); // Firecracker instance info

// 6. Pause / Resume
await vm.pause();   // state → 'paused'
```

```
await vm.resume();  // state → 'running'

// 7. Stop and clean up
await vm.stop();
await vm.cleanup();
await smartvm.cleanup();
```

Architecture Overview



Firecracker exposes a REST API over a Unix domain socket. This module handles all the plumbing: spawning the process, waiting for the socket, translating your TypeScript config into Firecracker's snake_case API payloads, managing TAP devices, and tearing everything down on exit.

API Reference

`SmartVM` — The Orchestrator

The entry point for everything. Manages binary downloads, VM creation, and global cleanup.

```
import { SmartVM } from '@push.rocks/smartvm';
import type { ISmartVMOptions } from '@push.rocks/smartvm';

const smartvm = new SmartVM({
  dataDir: '/tmp/.smartvm',        // default: /tmp/.smartvm
  firecrackerVersion: 'v1.7.0',  // default: latest from GitHub
  arch: 'x86_64',                // default: x86_64 (also: aarch64)
  firecrackerBinaryPath: '/usr/bin/firecracker', // optional: skip download
  bridgeName: 'svbr0',           // default: svbr0
  subnet: '172.30.0.0/24',       // default: 172.30.0.0/24
});
```

Method	Description
`ensureBinary()`	Downloads Firecracker from GitHub if not cached. Returns path to binary.
`createVM(config)`	Creates a `MicroVM` instance (not yet started). Returns the VM.
`getVM(id)`	Look up an active VM by ID.
`listVMs()`	Returns an array of active VM IDs.
`vmCount`	Number of active VMs.
`stopAll()`	Stops all running/paused VMs in parallel.
`cleanup()`	Stops all VMs, removes TAP devices and bridge.

`MicroVM` — VM Lifecycle

Each VM follows a strict state machine: **created → configuring → running → paused → stopped**.

```
const vm = await smartvm.createVM({
  id: 'my-vm',  // optional, auto-generated UUID if omitted
  bootSource: {
    kernelImagePath: '/path/to/vmlinux',
    bootArgs: 'console=ttyS0 reboot=k panic=1',
    initrdPath: '/path/to/initrd',  // optional
  },
  machineConfig: {
    vcpuCount: 4,
    memSizeMib: 512,
    smt: false,
    cpuTemplate: 'T2',  // optional: C3, T2, T2S, T2CL, T2A, V1N1
    trackDirtyPages: true,
  },
  drives: [
    {
      driveId: 'rootfs',
      pathOnHost: '/path/to/rootfs.ext4',
      isRootDevice: true,
      isReadOnly: false,
      cacheType: 'Unsafe',  // or 'Writeback'
      rateLimiter: {
        bandwidth: { size: 100_000_000, refillTime: 1_000_000_000 },
        ops: { size: 1000, refillTime: 1_000_000_000 },
      },
    },
  ],
  networkInterfaces: [
    {
      ifaceId: 'eth0',
      // hostDevName and guestMac auto-generated if omitted
    },
  ],
  vsock: {
    guestCid: 3,
    udsPath: '/tmp/vsock.sock',
  },
```

```
  balloon: {
    amountMib: 128,
    deflateOnOom: true,
    statsPollingIntervalS: 5,
  },
  mmds: {
    version: 'V2',
    networkInterfaces: ['eth0'],
  },
  logger: {
    logPath: '/tmp/firecracker.log',
    level: 'Debug',
    showLogOrigin: true,
  },
  metrics: {
    metricsPath: '/tmp/firecracker-metrics.fifo',
  },
});
```

Method	Valid States	Description
`start()`	`created`	Spawns Firecracker, applies config, boots the VM
`pause()`	`running`	Pauses VM execution
`resume()`	`paused`	Resumes a paused VM
`stop()`	`running`, `paused`	Graceful shutdown (Ctrl+Alt+Del), then force kill
`cleanup()`	any	Full cleanup: kill process, remove socket, remove TAPs
`getInfo()`	any (after start)	Returns Firecracker instance info
`getVersion()`	any (after start)	Returns Firecracker version
`createSnapshot(params)`	`paused`	Create a VM snapshot
`loadSnapshot(params)`	`created`, `configuring`	Load a VM from snapshot
`setMetadata(data)`	`running`, `paused`	Set MMDS metadata
`getMetadata()`	`running`, `paused`	Get MMDS metadata
`updateDrive(id, path)`	`running`, `paused`	Hot-update a drive path
`updateBalloon(mib)`	`running`, `paused`	Resize the balloon device

Method	Valid States	Description
`getTapDevices()`	any	Returns TAP devices associated with this VM

`ImageManager` — Binary & Image Management

Handles downloading and caching Firecracker binaries, kernels, and rootfs images.

```
const imageManager = smartvm.imageManager;

// Auto-download the latest Firecracker release
const version = await imageManager.getLatestVersion(); // e.g. 'v1.7.0'
const binaryPath = await imageManager.downloadFirecracker(version);

// Download kernel and rootfs images
const kernelPath = await imageManager.downloadKernel(
  'https://example.com/vmlinux-5.10',
  'vmlinux-5.10',
);
const rootfsPath = await imageManager.downloadRootfs(
  'https://example.com/ubuntu-22.04.ext4',
  'ubuntu-22.04.ext4',
);

// Create a blank rootfs or clone an existing one
const blankPath = await imageManager.createBlankRootfs('scratch.ext4', 1024);
const clonePath = await imageManager.cloneRootfs(rootfsPath, 'ubuntu-clone.ext4');
```

Data directory layout:

```
/tmp/.smartvm/
  bin/<version>/firecracker
  bin/<version>/jailer
  kernels/<name>
  rootfs/<name>
  sockets/<vmId>.sock
```

`NetworkManager` — Host Networking

Automatically manages TAP devices, a Linux bridge, and iptables NAT masquerade rules so VMs get internet access out of the box.

```
const networkManager = smartvm.networkManager;

// Manually create a TAP device (usually handled by MicroVM.start())
const tap = await networkManager.createTapDevice('vm-id', 'eth0');
console.log(tap);
// {
//   tapName: 'svvmideth0',
//   guestIp: '172.30.0.2',
//   gatewayIp: '172.30.0.1',
//   subnetMask: '255.255.255.0',
//   mac: '02:a3:b1:c4:d2:e5'
// }

// Generate kernel boot args for the guest
const bootArgs = networkManager.getGuestNetworkBootArgs(tap);
// 'ip=172.30.0.2::172.30.0.1:255.255.255.0::eth0:off'
```

Networking architecture:

- Creates a Linux bridge (default: `svbr0`) with gateway at `.1`
- Each VM gets a TAP device attached to the bridge
- Sequential IP allocation from `.2` onwards
- iptables NAT masquerade for outbound internet
- Deterministic MAC generation (`02:xx:xx:xx:xx:xx` locally-administered)
- TAP names fit Linux's 15-char IFNAMSIZ limit

`VMConfig` — Config Transformer

Converts your camelCase TypeScript config into Firecracker's snake_case API payloads. Also validates configuration before boot.

```
import { VMConfig } from '@push.rocks/smartvm';

const vmConfig = new VMConfig({
  bootSource: { kernelImagePath: '/path/to/vmlinux' },
```

```
  machineConfig: { vcpuCount: 2, memSizeMib: 256 },
});

// Validate
const result = vmConfig.validate();
// { valid: true, errors: [] }

// Generate API payloads
vmConfig.toBootSourcePayload();
// { kernel_image_path: '/path/to/vmlinux' }

vmConfig.toMachineConfigPayload();
// { vcpu_count: 2, mem_size_mib: 256 }
```

`SocketClient` — Low-Level HTTP Client

Direct HTTP-over-Unix-socket communication with Firecracker. You typically don't need this directly — `MicroVM` handles it — but it's available if you want raw API access.

```
import { SocketClient } from '@push.rocks/smartvm';

const client = new SocketClient({ socketPath: '/tmp/firecracker.sock' });

const info = await client.get('/');
const putResult = await client.put('/machine-config', { vcpu_count: 2, mem_size_mib: 256 });
const patchResult = await client.patch('/vm', { state: 'Paused' });

// Check if socket is alive (polls with timeout)
const ready = await client.isReady(5000);
```

`SmartVMError` — Error Handling

All errors thrown by this module are `SmartVMError` instances with structured error codes.

```
import { SmartVMError } from '@push.rocks/smartvm';

try {
  await vm.start();
```

```
} catch (err) {
  if (err instanceof SmartVMError) {
    console.log(err.code);       // 'INVALID_CONFIG', 'SOCKET_TIMEOUT', 'API_ERROR', etc.
    console.log(err.statusCode); // HTTP status from Firecracker (if applicable)
    console.log(err.details);    // Raw error body from Firecracker (if applicable)
  }
}
```

Error codes:

Code	Description
`INVALID_STATE`	Operation not valid for current VM state
`INVALID_CONFIG`	Config validation failed
`SOCKET_TIMEOUT`	Firecracker socket didn't become ready
`API_TIMEOUT`	Firecracker API didn't respond in time
`SOCKET_REQUEST_FAILED`	HTTP request to socket failed
`API_ERROR`	Firecracker returned a non-2xx response
`BINARY_NOT_FOUND`	Firecracker binary not at expected path
`DOWNLOAD_FAILED`	Failed to download binary/kernel/rootfs
`VERSION_FETCH_FAILED`	Couldn't query GitHub for latest version
`BRIDGE_SETUP_FAILED`	Failed to create network bridge
`TAP_CREATE_FAILED`	Failed to create TAP device
`ROOTFS_CREATE_FAILED`	Failed to create blank rootfs
`ROOTFS_CLONE_FAILED`	Failed to clone rootfs image
`START_FAILED`	VM start sequence failed
`NO_CLIENT`	Socket client not initialized

Snapshots

Create and restore VM snapshots for fast cold-start or live migration:

```
// Pause first (required for snapshots)
await vm.pause();
```

```
// Create a snapshot
await vm.createSnapshot({
  snapshotPath: '/tmp/snapshot.bin',
  memFilePath: '/tmp/snapshot-mem.bin',
  snapshotType: 'Full',  // or 'Diff' for incremental
});

// Later: restore from snapshot
const freshVm = await smartvm.createVM({
  bootSource: { kernelImagePath: '/path/to/vmlinux' },
  machineConfig: { vcpuCount: 2, memSizeMib: 256 },
});
await freshVm.loadSnapshot({
  snapshotPath: '/tmp/snapshot.bin',
  memFilePath: '/tmp/snapshot-mem.bin',
  resumeVm: true,
});
```

MMDS (Metadata Service)

Pass metadata to your guest VM via Firecracker's Microvm Metadata Service:

```
const vm = await smartvm.createVM({
  bootSource: { /* ... */ },
  machineConfig: { /* ... */ },
  networkInterfaces: [{ ifaceId: 'eth0' }],
  mmds: {
    version: 'V2',
    networkInterfaces: ['eth0'],
  },
});

await vm.start();

// Set metadata from host
await vm.setMetadata({
  instance: { id: 'my-instance', region: 'eu-central-1' },
```

```
  secrets: { apiKey: 'sk-...' },
});

// Guest can access via: curl http://169.254.169.254/latest/meta-data/
const data = await vm.getMetadata();
```

Graceful Cleanup

The module registers cleanup handlers via `@push.rocks/smartexit` so resources are released even if your process crashes:

- □□ Firecracker child processes are killed
- □□ Unix socket files are removed
- □□ TAP devices are deleted
- □□ Bridge and NAT rules are torn down

You can also trigger cleanup manually:

```
// Stop one VM
await vm.stop();
await vm.cleanup();

// Stop all VMs and clean everything
await smartvm.stopAll();
await smartvm.cleanup();
```

TypeScript Interfaces

All configuration interfaces are fully exported for type-safe usage:

```
import type {
  ISmartVMOptions,
  IMicroVMConfig,
  IBootSource,
  IMachineConfig,
  IDriveConfig,
  INetworkInterfaceConfig,
```

```
  IVsockConfig,
  IBalloonConfig,
  IMmdsConfig,
  ILoggerConfig,
  IMetricsConfig,
  ISnapshotCreateParams,
  ISnapshotLoadParams,
  IRateLimiter,
  INetworkManagerOptions,
  ITapDevice,
  ISocketClientOptions,
  IApiResponse,
  TVMState,
  TFirecrackerArch,
  TCacheType,
  TSnapshotType,
  TLogLevel,
} from '@push.rocks/smartvm';
```

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