Zero-instrumentation observability based on eBPF

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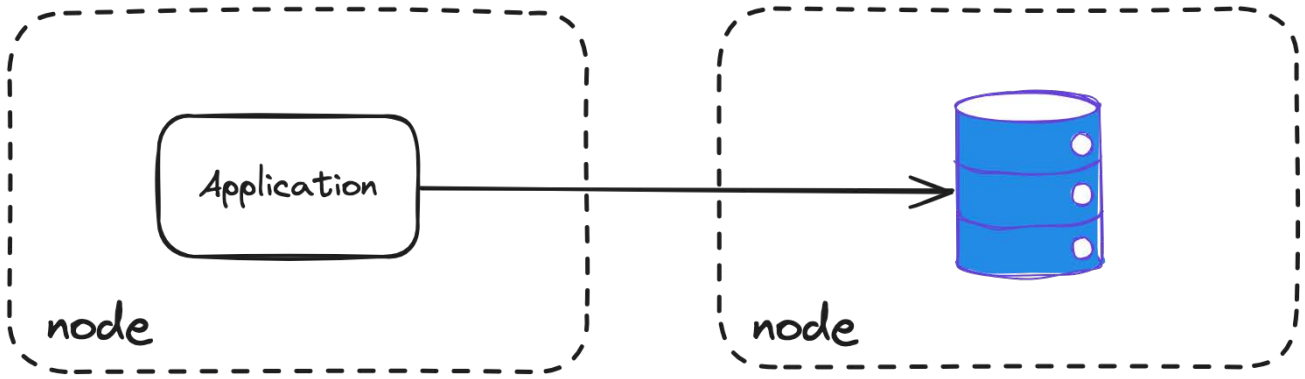
Observability is ...

... being able answer questions about your system:

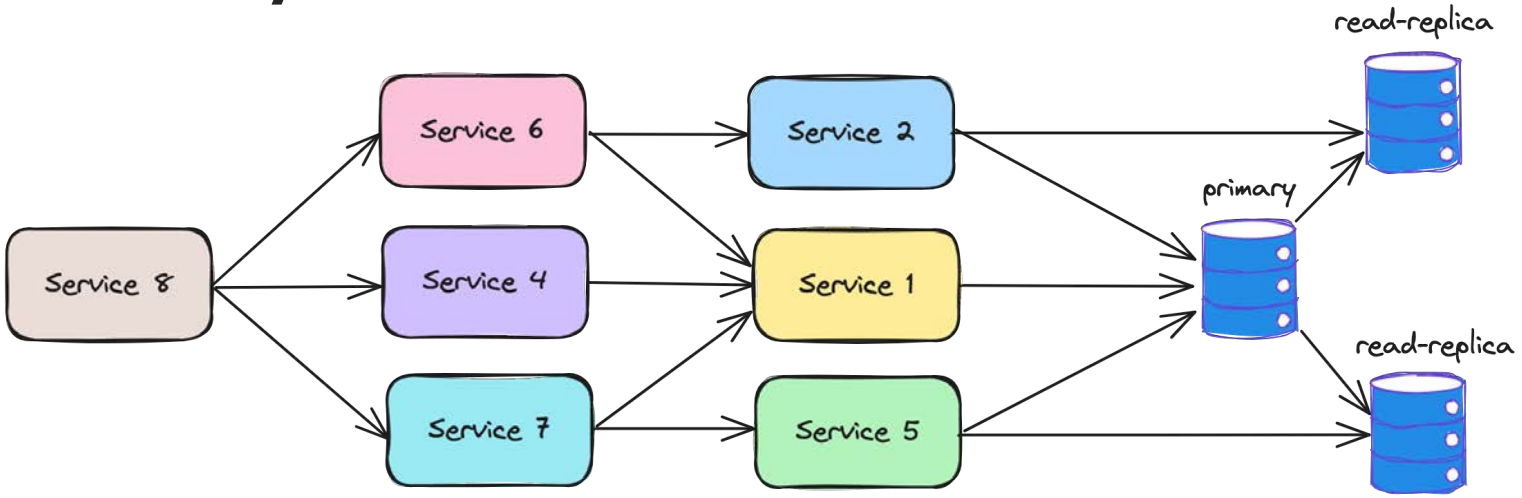
- How is the system performing right now?
- How does its performance compare to an hour ago?
- Why are some requests failing?
- Why are certain requests taking longer than expected?

Systems a while ago



- A monolith application
- DB runs on dedicated nodes
- If something goes wrong:
  - Check the app's logs/metrics
  - Check the DB's logs/metrics
  - Check the hardware

Modern systems



- Hundreds or even thousands of services dynamically allocated to nodes
- Nodes are dynamic and can appear and disappear
- If something goes wrong:
  - Troubleshooting follows the system's topology
  - Analysis of extensive telemetry, from application latency to EBS performance

Making a system observable

- Collecting telemetry data: metrics, logs, traced, profiles
  - Time- and resource-consuming process since it requires adding instrumentation into every application
  - Hard to achieve 100% coverage without blind spots (3rd party and legacy services)
- Storing telemetry data in some databases
- Learning how to troubleshoot your system using all that data
  - The most challenging part

Collecting telemetry data

Before answer HOW to gather, let's discuss WHAT to gather or what we want to know about our apps.

- SLI (Service Level Indicators): requests, errors, latency
- Communication with other services or databases: requests, errors, latency
- Resource-related metrics: CPU, Memory, Disk
- Network-related metrics: latency, connectivity, packet loss
- Node-level metrics and logs
- Runtime-related metrics: GC, Thread Pools, Connection pools, Locks
- Orchestrator-related metrics
- Logs to identify application-specific issues
- Profiles to explain spikes in CPU or Memory usage

Collecting telemetry data

- It’s possible to collect all these data without using eBPF, but eBPF allows to achieve that in **MINUTES**
- There are always legacy and 3rd party services that you can’t instrument. eBPF doesn’t require code changes and redeployments.
- Usually, developers instrument only most critical services, so you can’t be sure that you have no blind spots.
- Instrumentation is a continuous process, so you need to ensure that every new service integrates OpenTelemetry SDKs.

A quick intro into eBPF

- A feature of the Linux kernel
- Allows to run small programs in the kernel-space and call them on any kernel or app function call
- Such programs have access to function arguments and returning values
- Then, they can send some data to a program in the user-space

eBPF is just a way how we can obtain data, we just need to implement kernel-space and user-space programs

How to use eBPF

- **Kprobe** allows to capture any kernel function call
  - Kernel functions can be renamed, deleted, their arguments can change
  - Some functions, in fact, almost never change
- **Tracepoints** – statically instrumented places in the kernel which are relatively stable comparing to **Kprobe**
- **Uprobe** allows to capture user-space programs calls
- **MAPS** allow to store some state in the kernel space
- **PERF_MAPS** allows to share data between the kernel-space and user-space

It's good to know, but you don't have to write your own eBPF programs. There are a lot of ready-made tools, such as **Coroot**

Coroot-node-agent (Apache 2.0 license)

- An open-source Prometheus/OpenTelemetry compatible agent that gathers metrics, logs, traces and profiles
- Discovers containers/processes running on the node
- Discovers their logs (k8s, docker, containerd, journald) and sends them over OTLP
- Extracts repeated patterns from logs and generates log-based metrics
- Monitors TCP connections of every container
- Measures network latency between each container and its peers
- Tracks communications between services (requests, errors, latency), supports HTTP, GRPC, Postgres, MySQL, MongoDB, Redis, Memcached, Cassandra, Kafka, Rabbitmq, NATS

How the agent leverages eBPF

tracepoint/task/task_newtask: tracking new process creation. It reports only a PID, then the agent discovers container metadata using /proc

tracepoint/oom/mark_victim: marking a process as a victim of the OOM killer

tracepoint/sched/sched_process_exit: tracking process terminatio. If a process was terminated by the OOM killer, the event is enriched with the reason of the termination

tracepoint/syscalls/sys_enter_open(at): tracking file openings to identify the logs and partitions used by a specific container

How the agent leverages eBPF

tracepoint/syscalls/sys_enter_connect: tracking FD of a TCP connection

tracepoint/sock/inet_sock_set_state: tracking peers and states of TCP connections

tracepoint/tcp/tcp_retransmit_skb: tracking TCP retransmissions

How the agent leverages eBPF

tracepoint/syscalls/sys_enter_write/writev/sendmsg/sendto: track writes to an FD (socket)

tracepoint/syscalls/sys_enter_read/readv/recvmsg/recvfrom: track reads from an FD (socket)

2-phase L7-protocol parsing:

- Kernel space: high-performance protocol detection
- User—space: protocol parsing for generating metrics and traces

SSL

Capturing the data before encryption and after decryption.

- For apps using OpenSSL:
  - uprobe/SSL_read
  - uprobe/SSL_write

- For GO apps:
  - uprobe/go_crypto_tls_write
  - uprobe/go_crypto_tls_read

eBPF: performance impact

The Linux kernel ensures minimal interruption to kernel code execution by validating each eBPF program before execution:

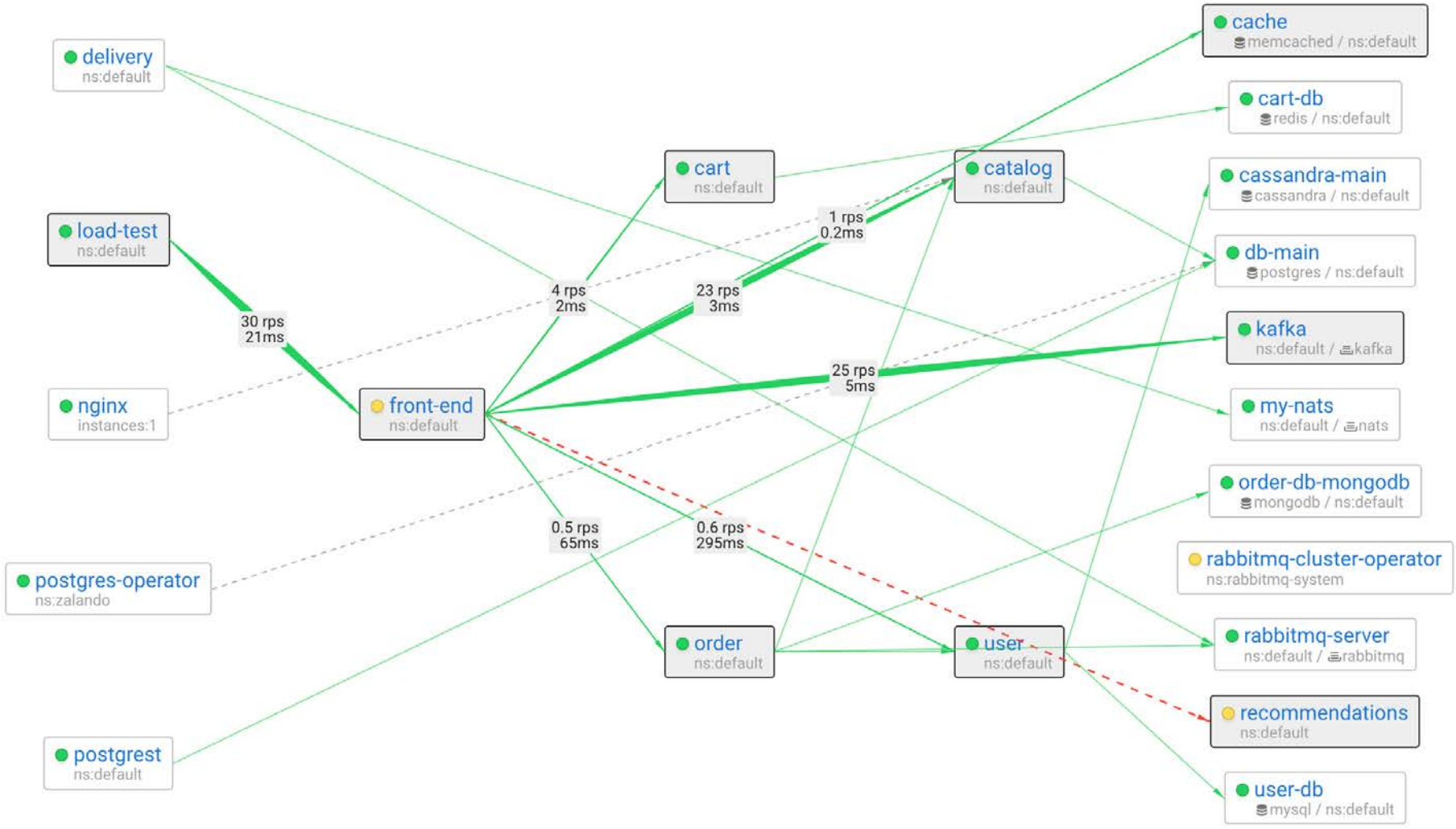
- Program **must** have a finite complexity.
- The verifier evaluates all possible execution paths within configured upper complexity limits

Communication between kernel-space and user-space programs occurs through a ring buffer:

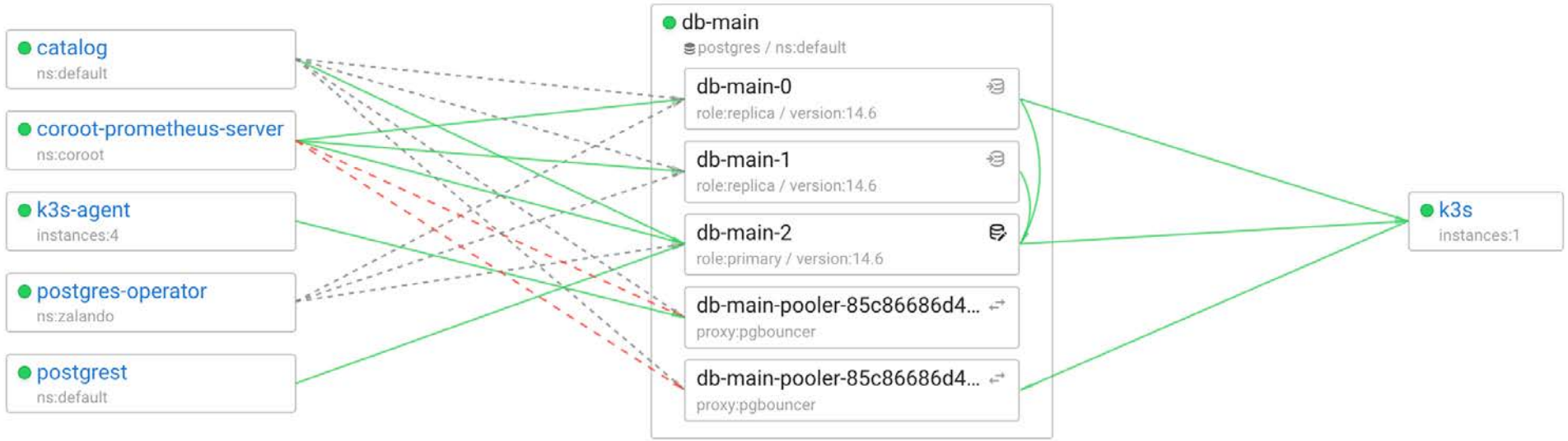
- If the user-space program delays data reading, it may miss data due to overwriting

For observability, it's a great deal: although we might lose some telemetry data, we can be sure that there is no impact on performance

eBPF-based metrics

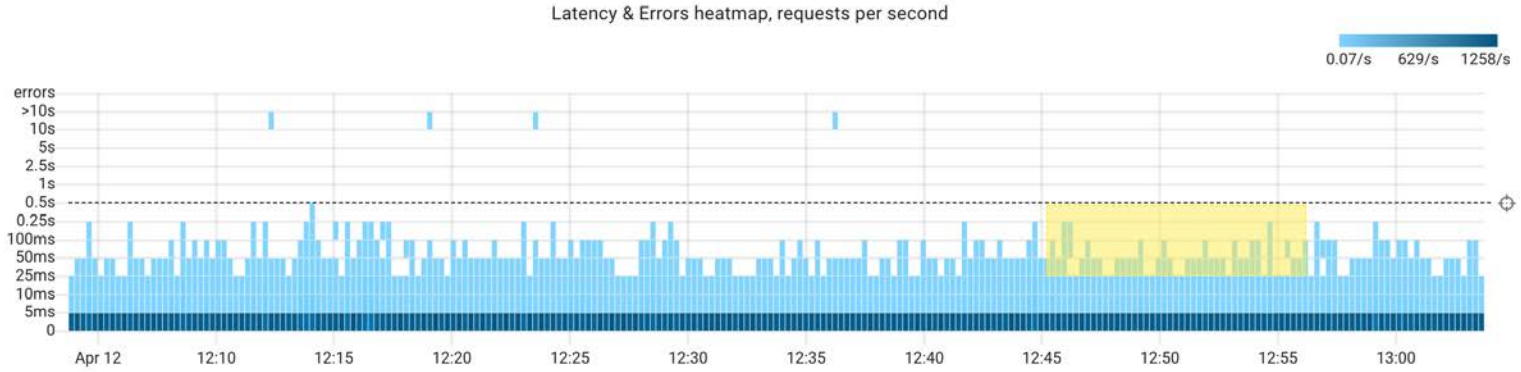


eBPF-based metrics



- L7: requests per second, Errors, Latency
- Network Round-trip-time (RTT)
- TCP: connections, failed connection attempts, retransmissions (can signify packet loss)

eBPF-based traces (spans)



	Client	Status	Duration	Name	Details
	app	OK	27.04ms	query	`PREPARE AS select title, body from articles where id = any ($1)`
	app	OK	53.30ms	query	`insert into articles (created, title, body) values ($1, $2, $3)`
	app	OK	38.06ms	query	`select id from articles where created < $1 order by created desc limit $2`
	app	OK	26.22ms	query	`PREPARE AS select id from articles where created < $1 order by created desc limit $2`

- Traces are extremely useful for identifying the particular requests within an anomaly
- They also provide a more granular distribution of requests by latency and status

eBPF-based tracing limitations

- The OpenTelemetry SDKs generate a TRACE_ID for each request and propagate it to other services

- When using eBPF, TRACE_IDs are not available, limiting us to capturing individual spans (requests) rather than complete traces

- There's a tool that claims to generate TRACE_IDs by intercepting and **modifying** requests, but I think it's not a good idea

Coroot supports both traditional OpenTelemetry integration and eBPF-based tracing methods

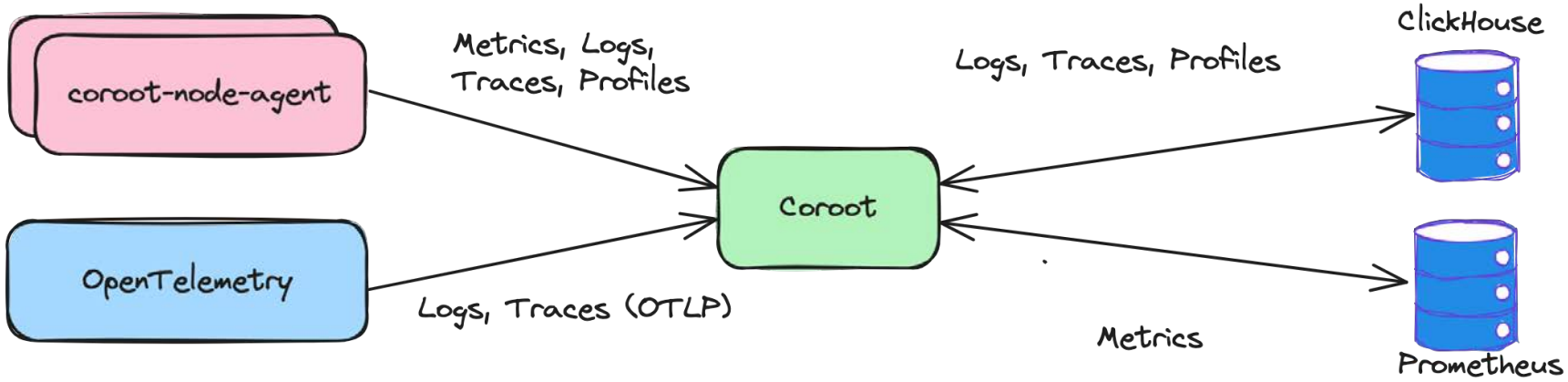
eBPF-based continuous CPU profiling

- Allows to explain any anomaly in CPU usage precise to the particular line of code
- Doesn’t require any code changes
- Gathers per-process call stacks and aggregates them by containers
- Resolution by default is 60 seconds, so you can compare profiles within and anomaly with previous periods

eBPF-based CPU profiling

eBPF-based CPU profiling (comparison mode)

How Coroot works



- coroot-node-agent: gathers metrics, logs, traces, and profiles. Installed on every node in the cluster (k8s, docker, VM, bare-metal)
- Prometheus for storing metrics
- ClickHouse for storing logs, traces, and profiles
- Coroot: UI, alerts, predefined inspections
- You can use Coroot as an OpenTelemetry backend for logs and traces

Conclusion

- eBPF is awesome!
- It enables gathering almost any telemetry data you need without requiring code changes.
- The performance impact on your apps is negligible.
- Want to gain system visibility in minutes? Install Coroot (Open Source, Apache 2.0).

https://github.com/coroot/coroot

Thank you, Let’s connect!

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https://twitter.com/NikolaySivko
https://www.coroot.com
https://github.com/coroot/coroot