ELISA
Enabling Linux in Safety Applications

WORKSHOP

SafetyGurad – Watchdog Software

Elisa Systems WG

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SafetyGuard

A reusable, safety-oriented Linux supervision middleware.

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SafetyGuard Goals

- Zero-copy IPC
- Deterministic timing
- Fault detection + watchdog
- Restart / recovery
- Rust-native core and C based API using FFI for language-agnostic for application
- Scalable toward industrial / automotive-style safety

Architectural Principles

- **Control Plane**

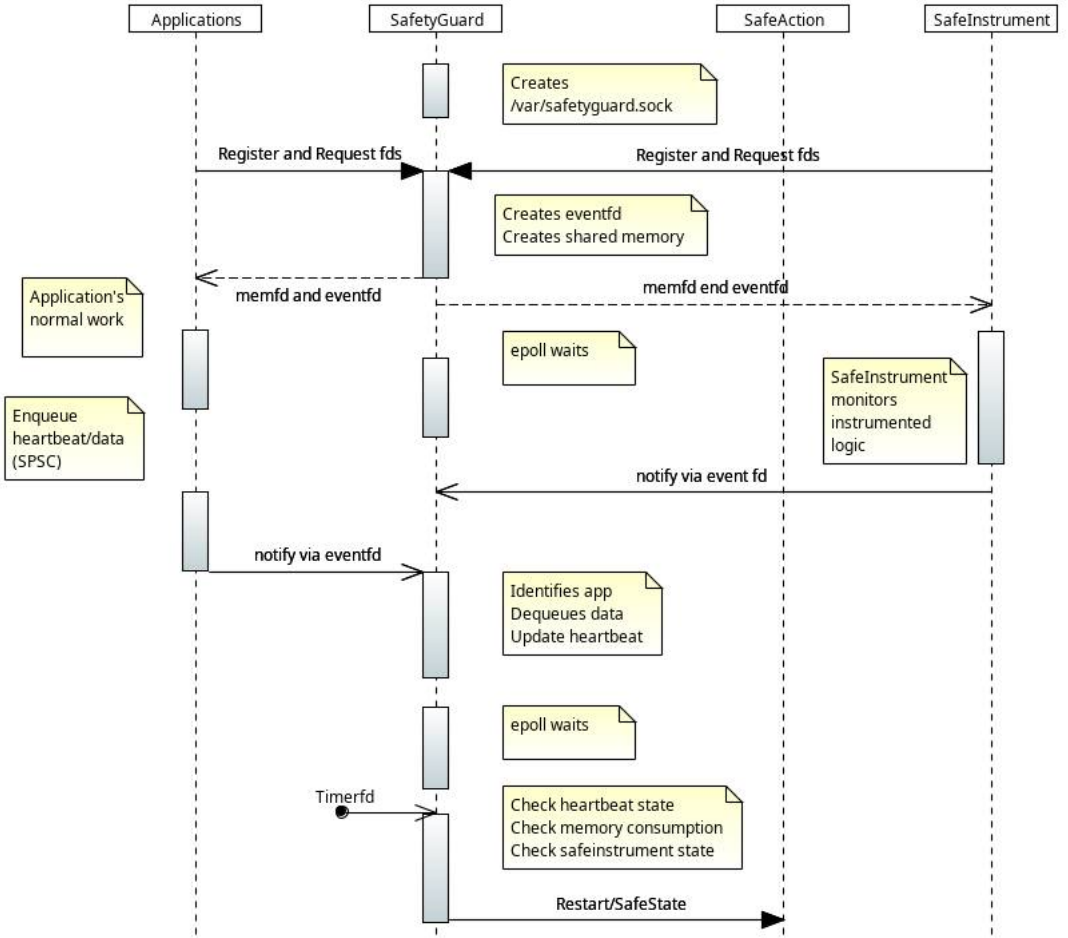
  UNIX socket registration + FD handoff
- **Data Plane**

  Shared Memory (mmap / memfd) + SPSC Ring Buffer
- **Signal Plane**

  eventfd + epoll (Like mosquitto broker, where mosquitto works over tcp socket)
- **Safety Plane**

  Monitor + timerfd watchdog + SafeInstrument + SafeAction (Heartbeat + Memory)

High-Level Architecture Diagram



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SAFE State and Safe Instrument

- Safe State and Safe Instrument are application specific.
- API will be provided.
- One can develop required domain specific safe state application and safe instrument application.
- As part of AGL, we will develop reference safe state and safe instrument apps.

Health Monitoring

Heartbeat

Each thread in app periodically sends: Timestamp and Status

Watchdog

SafeMonitor uses timerfd to check: now - last_heartbeat > timeout

Response

- Restart the app or container
- Enter degraded mode (When one or more apps timeout and restarted. Back to normal, when all apps does sends normal heartbeat)
- Enter safe state (Goal not restart the system, but to move to safesate, as determined by domain)
- Restart system if required (If safe state app sends response to restart)

Why SPSC?

Advantages

- Single Producer / Single Consumer simplicity
- Lock-free
- No mutex overhead
- Fixed-size deterministic memory
- Strong fit for safety arguments

Talk: https://www.youtube.com/watch?v=K3P_Lmq6pw0

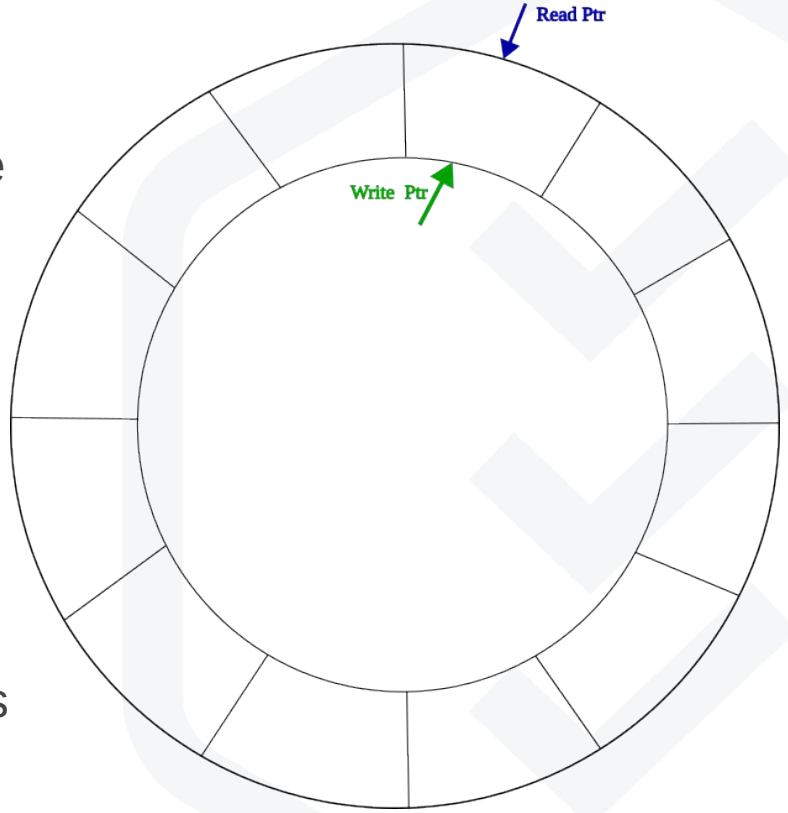
Runtime Data Flow (Fast Path)

Producer App

- ➔ Write Message to SPSC Queue
- ➔ Notify eventfd

SafetyGuard

- ➔ epoll wakeup
- ➔ Identify source app
- ➔ Dequeue all messages
- ➔ Process health / metrics / errors



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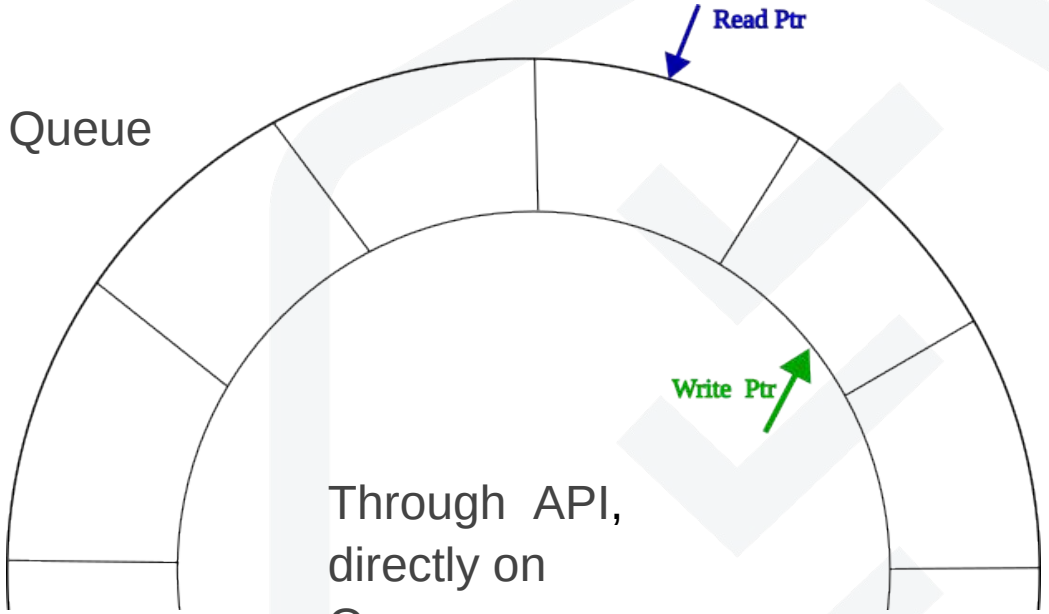

Through API, directly on Queue Message Area

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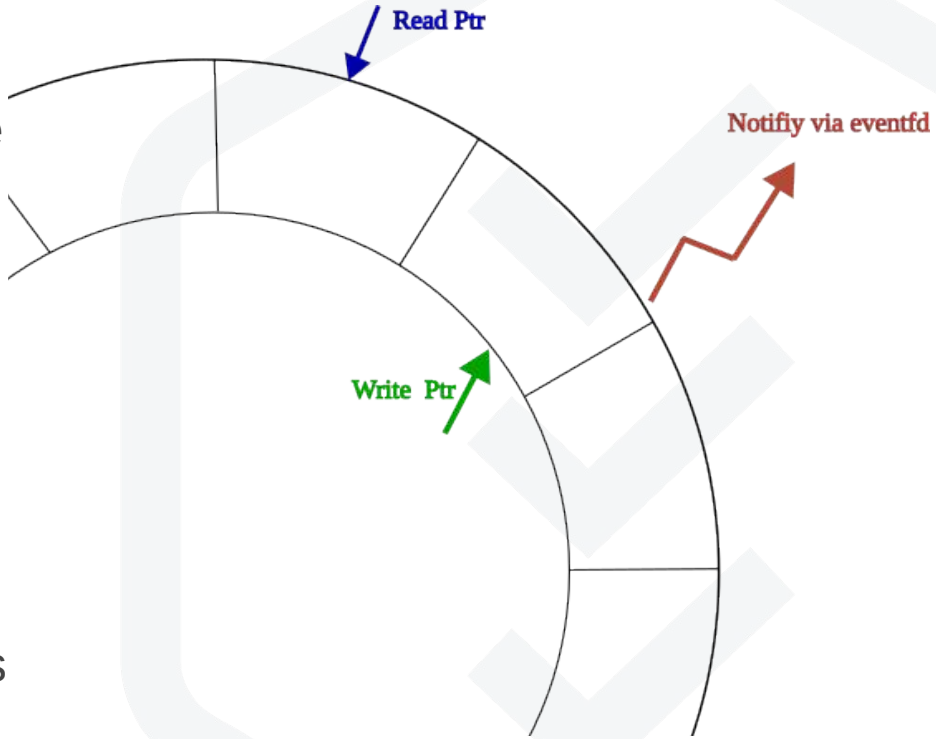

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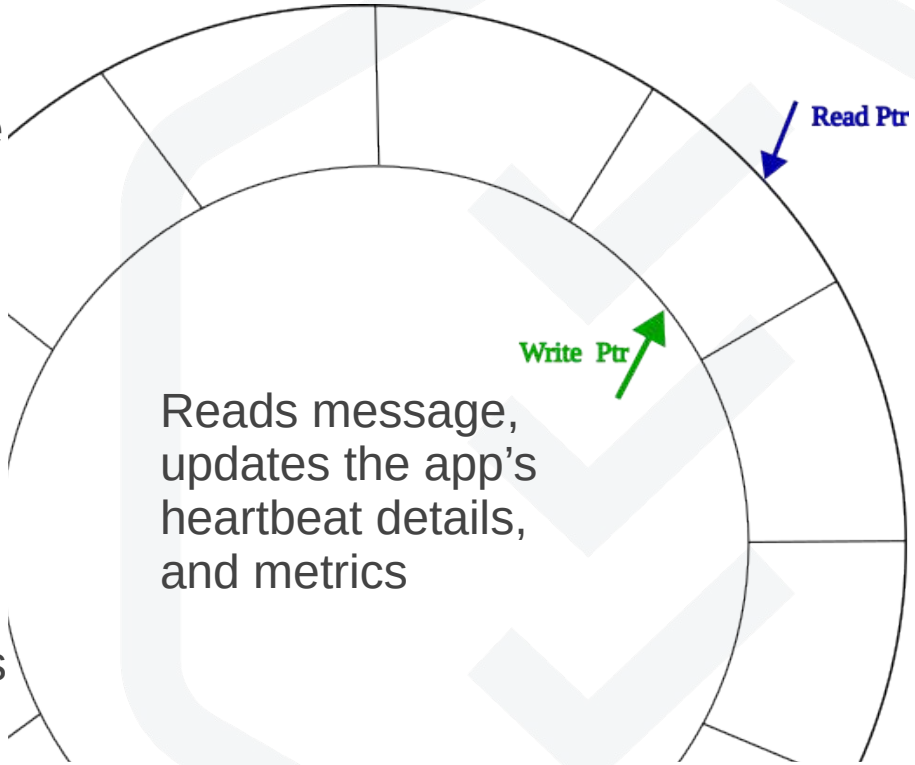

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Benifits

- ✔ Zero-copy
- ✔ No-polling
- ✔ Per-app(thread) isolation
- ✔ With epoll single thread based design in safey-plane of Safetygurad.

Additional Components

Configuration Parser:

- Yaml based configuration parser to user defined parameters.

Configuration Parameter generator:

- Every system is different.
- During development this helps to generate parameters such as heartbeat rate, memory consumption and test safestates

AppManager:

- Generic API for managing the application.
- Act as interface to existing infrastructure to start, restart or stop Application.
- For example:
  - Systemd based AppManager
  - Container based AppManager
  - Limited native AppManager.

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Roadmap

Multi-App Scaling Strategy

Rule:

One App = One Queue + One eventfd for each thread

Benefits:

- Isolation
- Fault containment
- Clear source ownership
- Easy scaling with epoll

Result:

Multiple apps manageable with low overhead (like mosquitto)

Deployment Strategy

meta-elisa:

- Bitbake-class for inheriting dependency
- Generic SafetyGuard application
- Common imporant system apps patches such as systemd, gRPC, Dbus, Wayland(weston)

meta-elisa-agl:

- AGL specific application patches
- Reference SafeState and SafeInstrument Apps.

Embedded Linux / Yocto:

- SatetyGuard being yet another application, it will get launched by systemd
- Journald logging.

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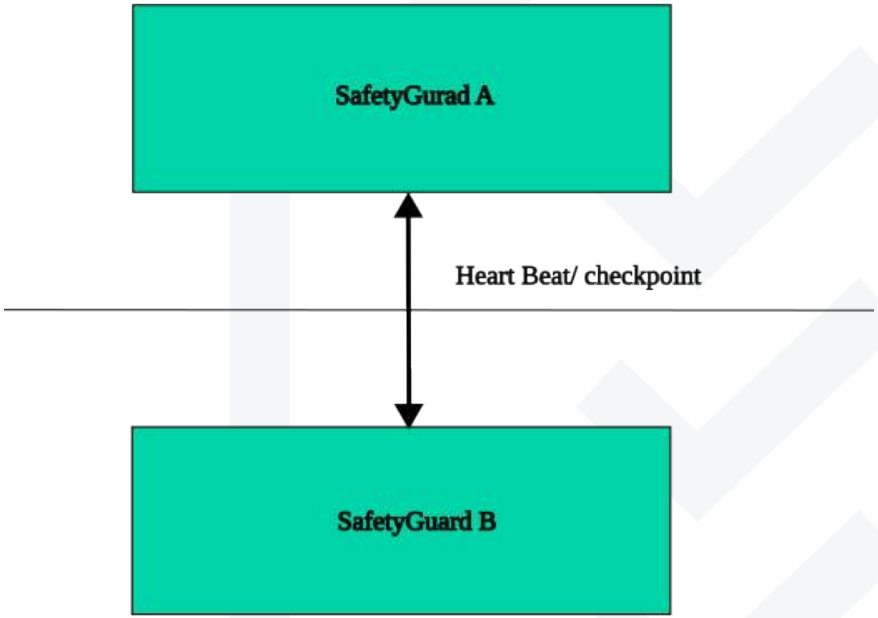
Redundancy Roadmap (Future Safety Expansion)

- Dual Monitor (Primary + Secondary)
- Cross-monitor heartbeat/checkpoint
- Fail-safe state machine

Eg: Xen + dual VM running Linux



Security Considerations

Immediate

- Socket permission control
- App registration validation
- Version compatibility

Future

- Authentication (Require more inputs, can we do during provision of device?)
- Capability restrictions
- SELinux/AppArmor

Milestones

Phase 1 (Immediate)

- Single monitor
- Dynamic app registration
- SPSC + eventfd + epoll
- Heartbeat + memory monitoring + restart

Phase 2

- Logging + metrics
- Support for docker/container engine based applications
- C ABI stabilization
- Tools for system developer to debug and configure

Phase 3

- Redundancy
- Memory partition (Possible via cggroups?)

https://github.com/elisa-tech/safetyguard

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Discussions

Discussions

The architecture technically allows to monitor the kernel threads as well via memfd+eventfd. Any use-cases?

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