Native Actors: How to Scale Network Forensics

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Problem Statement

Network forensics today suffers from:

- Huge amount of activity to store for later inspection
- Numerous different data formats
- Separate analysis procedures for past and future activity

⇒ Time-consuming and complex process

Goals

Need a better approach with the following properties [1]:

- **Interactive** work flow
  - Sub-second response times
  - Iterative query refinements
- **Scalable** in terms of data and compute
  - Handle distributed ingestion and at high rates
  - Asynchronous query execution
  - Graceful aggregation of older data
- **Expressive** and easy to learn
  - Represent activity in a unified data model
  - Same procedures to analyze past and future data

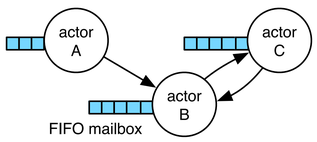
Requirements

To achieve these goals, we need a platform that is:

1. **Distributed**: scale with number of nodes
2. **Reliable**: fault isolation & local recovery
3. **Type-safe**: check protocols statically at compile time
4. **Adaptive**: dynamic provisioning & deployment

⇒ Ideal fit for the **actor model** of computation

- **Actor**: primitive for **parallel computations**
- Network-transparent **message passing**
- Actors can **dynamically** spawn more actors



CAF offers **building blocks** meeting these requirements.

VAST: Visibility Across Space and Time

Use Cases

- **Incident response**
  - Goal: identify scope of security breach
  - Begins with a piece of intelligence
  - Ad-hoc, interactive analysis style

⇒ Concrete start, then widen scope

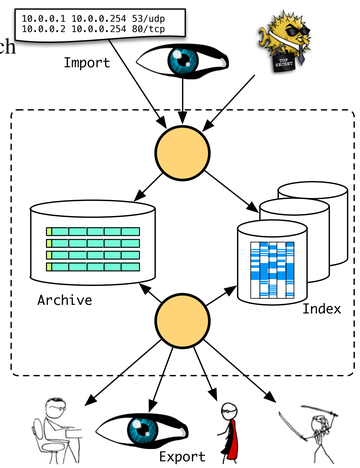
- **Network troubleshooting**
  - Goal: find root cause of failure
  - Only symptoms visible

⇒ Start broadly, then narrow scope

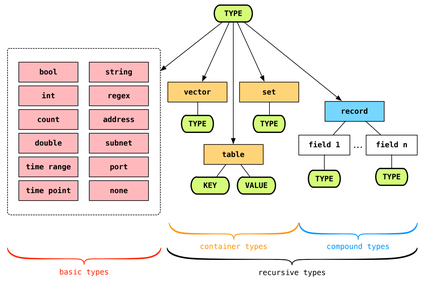
- **Combating insider abuse**
  - Goal: uncover policy violations
  - Attack: chain of *authorized* actions
  - Analysis style: "connect the dots"

⇒ Relate temporally distant events

Architecture



Type System



- **Rich typing**
  - Facilitate domain-specific analyses
  - Expressive and generic
- **Strong typing**
  - Clear and intuitive query semantics
  - Type-specific optimization opportunities

CAF: C++ Actor Framework

Overview

A framework for building high-performance concurrent applications and distributing systems at scale [2]:

- **Lightweight** actor implementation
  - Actors have only a few hundred bytes overhead
  - Spawn millions of actors without performance penalty

- **Type-safe** messaging interfaces, checked at compile time
  - Actor protocol verified during development
  - No type errors at runtime, even in distributed scenarios

- **Adaptive** platform for heterogeneous systems
  - Actors can run on different nodes using different OSes
  - Actors can run on GPUs via OpenCL bindings

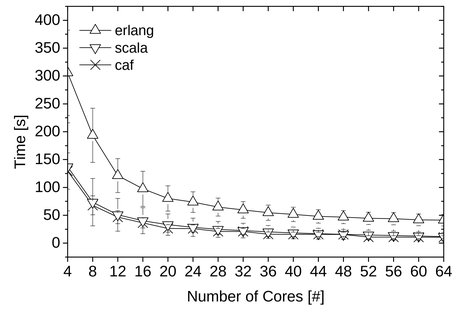
- **Dynamic** and extensible
  - Enables developers to deploy actors at runtime
  - Configurable scheduling to match application needs

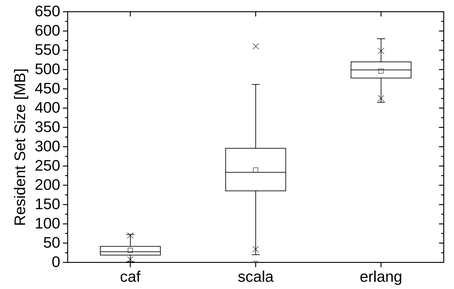
Minimal Example

```
using server =
  typed_actor<replies_to<int,int>::with<int>>;

server::behavior_type adder() { return {
 [](int a, int b) {
  return a + b;
 }
};}

void run(server s) {
 scoped_actor self;
 self->sync_send(s, 40, 2).await(
  [](int result) {
   cout << "40 + 2 = " << result << endl;
  }
 );
 self->send_exit(s, exit_reason::user_shutdown);
}

int main() {
 run(spawn_typed(adder));
 await_all_actors_done();
 shutdown();
}
```

CAF: Performance Example

Use case: CPU-intense tasks & token passing in rings





⇒ CAF scales to **many cores** with **minimal RAM usage**

References

[1] M. Allman, C. Kreibich, V. Paxson, R. Sommer, and N. Weaver, "Principles for developing comprehensive network visibility," in *Proc. of Workshop on Hot Topics in Security (HotSec)*, Jul. 2008.

[2] D. Charousset, T. C. Schmidt, R. Hiesgen, and M. Wählisch, "Native Actors – A Scalable Software Platform for Distributed, Heterogeneous Environments," in *Proc. 4rd ACM SIGPLAN Conf. on Systems, Programming, and Applications (SPLASH '13), WS AGERE!* ACM, Oct. 2013.

VAST
https://github.com/mavam/vast

CAF
http://actor-framework.org