`libcppa` Now: High-Level Distributed Programming Without Sacrificing Performance

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C++Now
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Outline

1. Example Application: VAST

2. Designing Distributed Applications

3. Thinking `libcppa`
   - Interfacing with 3rd-party APIs
   - Agility Through Network Transparency
   - Behavior Composition
   - Monadic Composition

The Network Security Domain

Network Forensics & Incident Response

- Scenario: security breach discovered
- Analysts have to determine scope and impact

Analyst questions

- How did the attacker(s) get in?
- How long did the they stay under the radar?
- What is the damage ($$$, reputation, data loss, etc.)?
- How to detect similar attacks in the future?

Challenges

- **Volume**: machine-generated data exceeds analysis capacities
- **Typing**: difficult to contextualize minimally typed data
- **Heterogeneity**: numerous log formats and processing styles

VAST: Visibility Across Space and Time
Architecture Overview

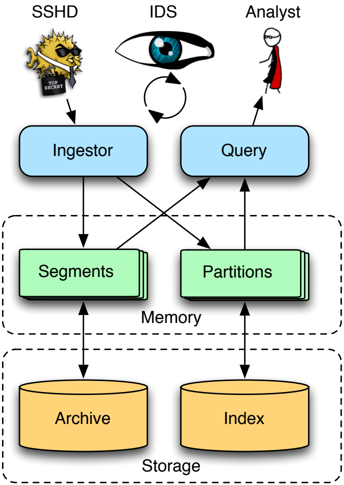
VAST

A **scalable**, **interactive** system to facilitate

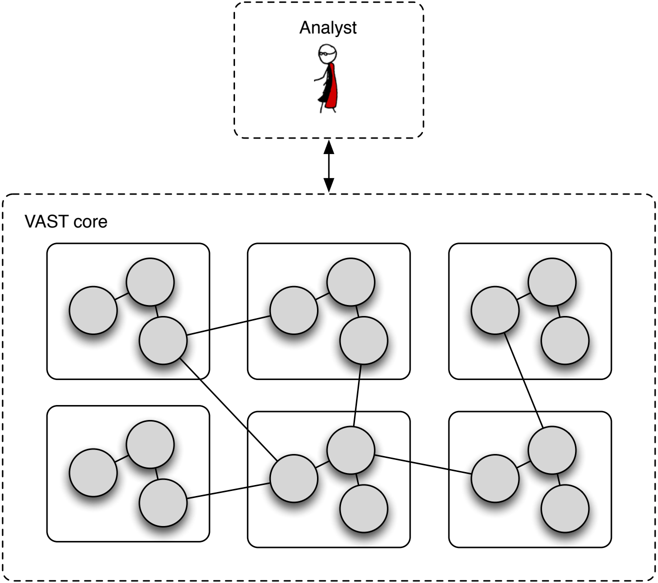
- forensic analyses
- incident response

Components

- **Archive**: Compressed, serialized events
- **Index**: Encoded, compressed bitmaps
- **Segment/Partition**: Data scaling unit
- **Ingestion**: Sources: IDS, syslog, etc.
- **Query**: Sinks: Analyst, IDS, feed, etc.



VAST: Distributed Deployment



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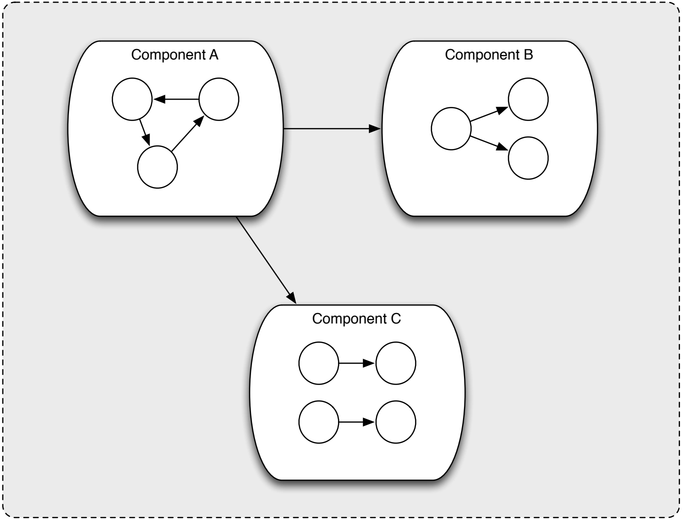
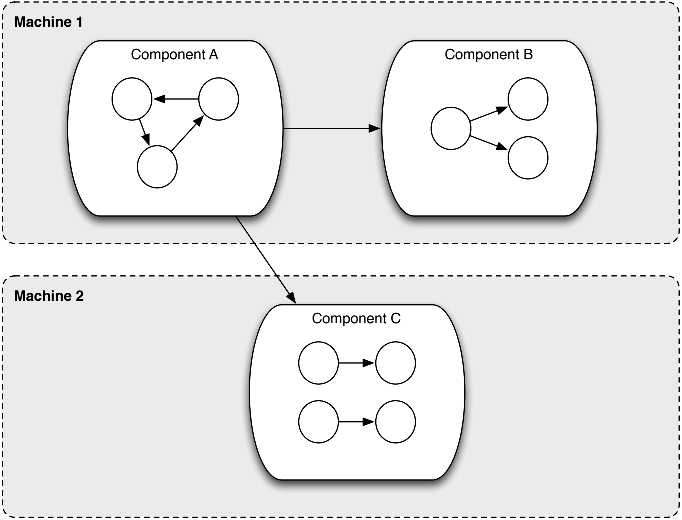
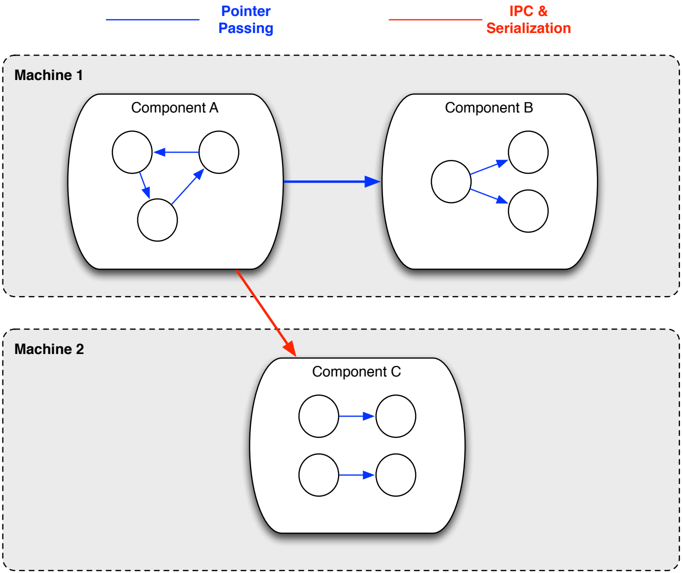
Software Design in Distributed Applications



Challenge: Varying Deployment Scenarios



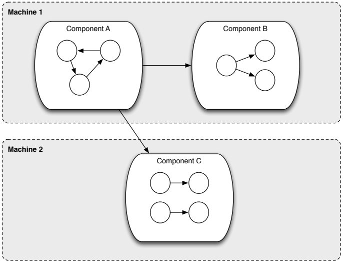
Challenge: Varying Deployment Scenarios



Primitives for Programming Distributed Systems

Desired Building Blocks

- Flexible serialization
- Platform independence
- Network transparency
- Rich-typed messaging
- Asynchronous coding style
- Powerful concurrency model



C++ Reality

No existing
light-weight middle-layer
with high level of abstraction
☹

`libcppa` aims to fill that gap

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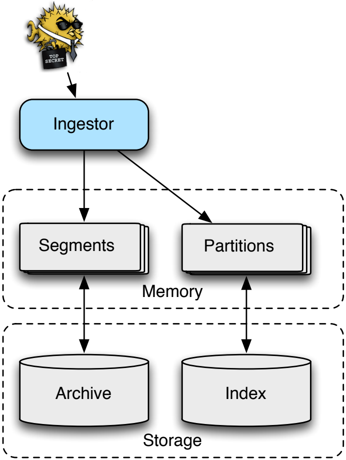
Creating a TCP/IP Server

VAST: Data Ingestion

1. Accept new TCP/IP connection
2. Poll POSIX file descriptor of connection
3. Read from socket when data is available
4. Convert data into internal event format

Existing solutions

- Basic: `accept` & `fork` (or new thread)
- Boost Asio: non-blocking, but IoC



A Generic Asynchronous IPv4 Server

```
template <typename Connection>
void server(uint16_t port, char const* addr, actor_ptr handler) {
  auto acceptor = network::ipv4_acceptor::create(port, addr);
  receive_loop( // libcppa's blocking API
    on(atom("accept")) >> [&] {
        if (util::poll(acceptor->file_handle()) &&
          (auto io = acceptor->try_accept_connection())) {
          auto conn = spawn<Connection>((*io).first, (*io).second);
          send(handler, atom("connection"), conn);
          }
        self << last_dequeued();
      },
    on(atom("kill")) >> [] { self->quit(); }
   );
}
```

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          send(handler, atom("connection"), conn);
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```

Infinite loop that dequeues messages from the actor's inbox

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          send(handler, atom
          }
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}
```

Behavior definition: start the accept loop or shut down the actor

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template <typename Conne
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  auto acceptor = netwo
  receive_loop( // libc
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```

Spawns an **`event_based_actor`** with a pair of streams for reading and writing, then announces the new actor to another actor

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Developing Agile Systems

Provisioning

- Reality: skewed workload distributions

→ Requires *dynamic* provisioning

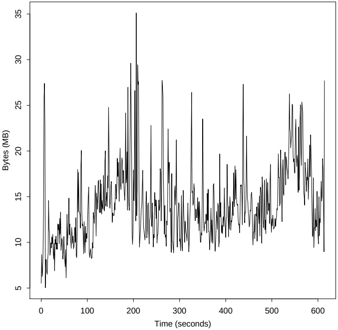
  - **Under**-provisioned: spin up actors
  - **Over**-provisioned: bring down actors

Agility

- Ability to handle/buffer peak loads
- Runtime re-configuration

→ without process restart

→ without losing in-memory state



Wiring Components at Runtime

```
class program {
public:
  void run() {
    auto host = config_.get("tracker.host");
    auto port = config_.as<unsigned>("tracker.port");
    if (config_.check("tracker-actor")) {
     tracker_ = spawn<id_tracker>("/path/to/id_file");
     publish(tracker_, port, host.data());
    }
    else {
     tracker_ = remote_actor(host, port);
    }
    ... // Further similar initializations.
  }
private:
  configuration config_;
  actor_ptr tracker_;
};
```

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If actor should run in this process,
spawn and publish it

Wiring Components at Runtime

```
class program {
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    auto port = con                                 ");
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Otherwise connect to it

Wiring Components at Runtime

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Modularizing Code

Basic Techniques

- Straight-forward to reuse code in OO-style programs
- But how to reuse behavior in `libcppa`?

Object-Oriented Inheritance

```
struct base {};
struct derived : base {};
```

Object-Oriented Composition

```
struct foo {};
struct bar { foo f };
```

Composing behavior in `libcppa`

- Example:

```
partial_function f;
partial_function g;
partial_function h = f.or_else(g);

partial_function i;
behavior j = h.or_else(i);
```

Example: Base Class for Event Sources (simplified)

```
template <typename Derived>
class async_source : public event_based_actor {
public:
  async_source(actor_ptr upstream) {
    running_ = (
       on_arg_match >> [=](event const& e) { /* work */ },
       on_arg_match >> [=](std::vector<event> const& v) { /* work */ }
     );
  }
  void init() override {
    become(running_.or_else(static_cast<Derived*>(this)->impl));
  }
private:
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struct file_source : async_source<file_source> { behavior impl; };
```

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libcppa's event-based actors require implementation of `init()`

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(Stateful) base-class with partial behavior

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Composition of partial functions (or behavior)

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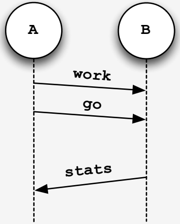
Developing Message Protocols

Asynchronous Messaging

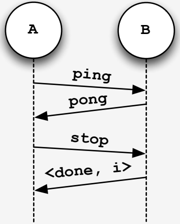
- Decoupled `send` and `receive`
  1. Pattern-match dequeued message
  2. Invoke corresponding handler
  3. Send message (optional)
- libcppa: `send(..)`

→ Loose coupling



Synchronous Messaging

- Lockstep: matching `send` and `receive`
  1. Send a message
  2. Push new behavior to handle reply
  3. Pop behavior
- libcppa: `sync_send(..)`
- How to compose?



The Lack of Monads in C++

Composition

- C++ lacks a powerful language primitive for composition: **monads**
- `(>>=) :: (Monad m) => m a -> (a -> m b) -> m b`

HasC++all

```
sync_send(b, atom("ping"))
  >>= on(atom("pong")) >> [=] { return sync_send(b, atom("stop")); }
  >>= on(atom("done"), arg_match) >> [=](int i) { f(i); }
```

libcppa

```
sync_send(b, atom("ping")).then(
  on(atom("pong")) >> [=] { sync_send(b, atom("stop")).then(
    on(atom("done"), arg_match) >> [=](int i) { f(i); });
  });
```

Summary

Experience using `libcppa`

- Offered abstractions facilitate solving domain challenges
- Asynchronous coding style with local reasoning (no IoC)
- Easy integration with 3rd-party APIs
- Flexible deployment scenarios support highly dynamic systems
- Low overhead (1–3% CPU time)

Future Work

- Improve runtime type debugging and diagnostics

Parting thoughts

- Actor model as natural paradigm to address today's challenges
    - `libprocess`, `jss::actor`, Casablanca, ...
- C++1? wish list:
    - Monads → composition of asynchronous operations
    - Pattern matching → type-safe dispatching

Thank You…Questions?

FIN

`https://github.com/Neverlord/libcppa`
`https://github.com/mavam/vast`

IRC at Freenode: `#libcppa`, `#vast`