*E*Actors: an actor-based programming framework for Intel SGX

Dr.-Eng. V. A. Sartakov

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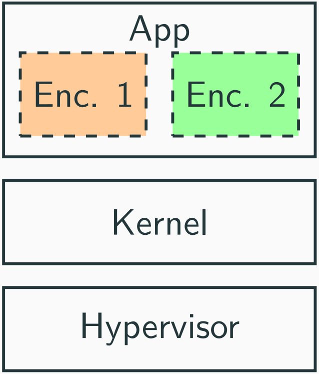
Imperial College London

Plan

New System Component for Trusted Execution

Software Guard eXtensions (SGX) enclaves enable trusted execution in untrusted environment:

- Protect cold-boot [1], platform reset [2] and DMA attacks [3]
- Remove an OS and a hypervisor from the Trusted Computing Base (TCB)
- Special features: remote/local attestation, data sealing



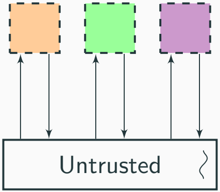
Intel SGX Software Development Kit

Programming approach:

- Invocation of functions

Advantages:

- Low TCB
- Intuitive use



Intel SGX Software Development Kit

Programming approach:

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Advantages:

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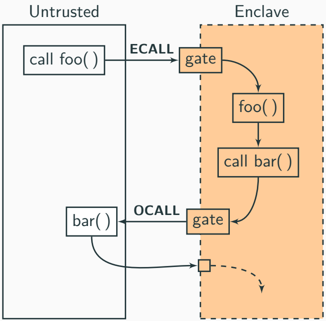
Disadvantages:

- Inflexible partitioning
- High transition costs
  - ECALL, OCALL: ≈50×
  - sgx_mutex: ≈200×



Existing Approaches::LibOS/Shim Layer

Programming approach:

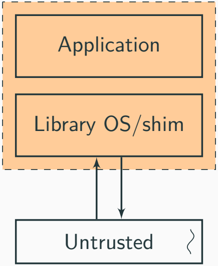
- Enclave the whole application

Frameworks:

- Haven [4], SCONE [5], Graphene-SGX [6], Panoply [7]

Advantages:

- Legacy
- Fast transitions (some)



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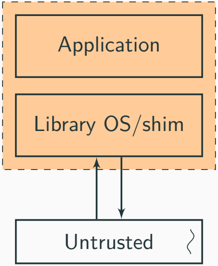
Disadvantage:

- Monolithic design → Large TCB



Towards Multi-enclave Applications

A single process can host multiple enclaves

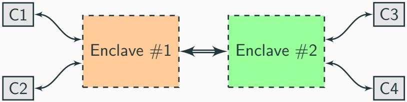
→ Mutually distrusted partitions

Examples:

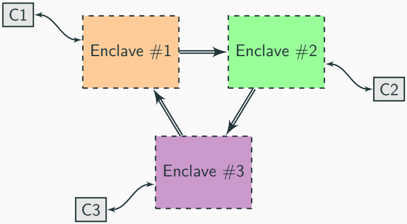
- Instant message service
- Secure-multiparty computation

Programming model should offer:

- Fast enclave-to-enclave communication
- Minimal per-enclave TCB
- Flexible partitioning



Partitioned instant message service



Secure multi-party computation

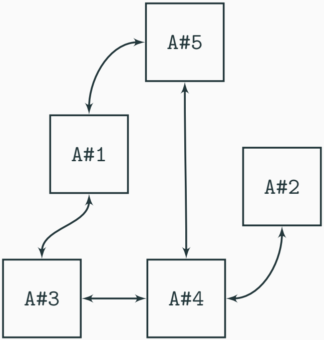
Towards Actors-Based Trusted Computing

Actors:

- Non-blocking
- Use messages

→ Shared-nothing (no locks!)

→ Lightweight (flexible!)



Towards Actors-Based Trusted Computing

Actors:

- Non-blocking
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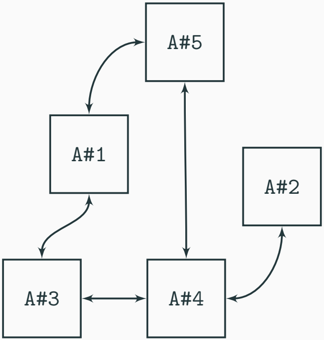
Existing frameworks:

- Heavy runtime (Erlang, Java)
- Do not tailored for enclaves (CAF)

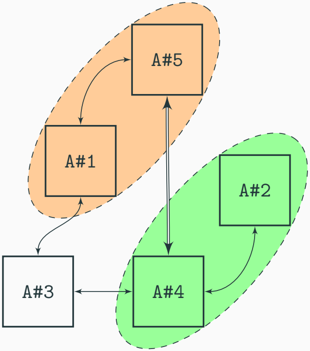
→ **Need another framework**



Plan

*E*Actors: Actors-based Trusted Computing

- What is an *Actor*?
- How actors communicate?
- System support



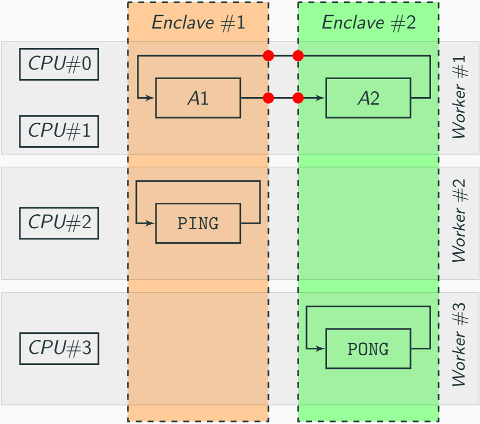
General View

Components:

- *eactors*
- Enclaves
- Workers

Bindings:

- *eactors* to enclaves
- *eactors* to workers
- workers to CPUs



Programming with $_e$*actor*s

An $_e$*actor*:

- Constructor
- Body function
- Private state

Building:

- $_e$*actor*'s source
- Deployment XML
- Framework

Output:

- Enclave's binaries
- Untrusted binaries

```
struct state {struct channel chan[2]; int first;}

void aping(struct actor* self) {
  if(self->state->first) {
    self->state->first = 0;
  } else {
  ^^I/* receive a pong */
    char* msg = recv(&self->channel[0]);
    if(msg == NULL)
      return;
  }
  /* send a ping */
  send(&self->channel[1], "ping");
}

void aping_ctr(struct actor* self) {
  self->state->first = 1;
  connect(self->channel[0]);
}
```

Nodes – a Basis for Messaging

The `node` is a memory object:

- Header, Payload
- Allocated at startup
- Private or public

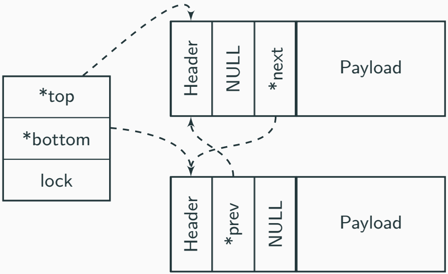
Nodes – a Basis for Messaging

The `node` is a memory object:

- Header, Payload
- Allocated at startup
- Private or public
- Double-linked queues

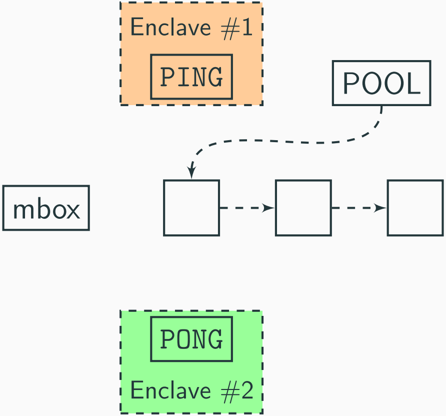
API:

- `pool`: LIFO for empty nodes
- `mbox`: FIFO for message exchange
- push_to/pop_from tail/front



Message-based Communication

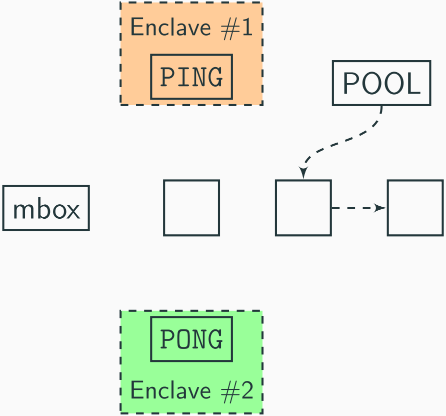
Send/receive:



Message-based Communication

Send/receive:

1. PING: Dequeue a node
2. PING: Write (enc.) data



Message-based Communication

Send/receive:

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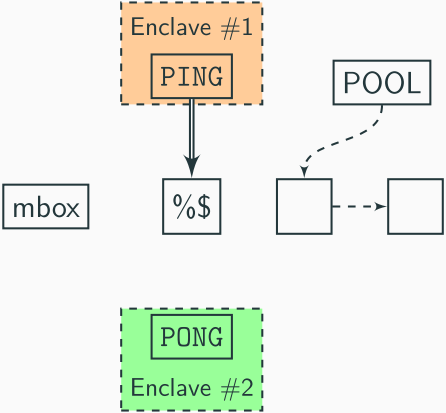

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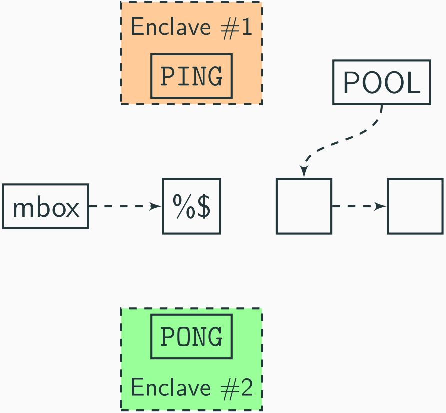

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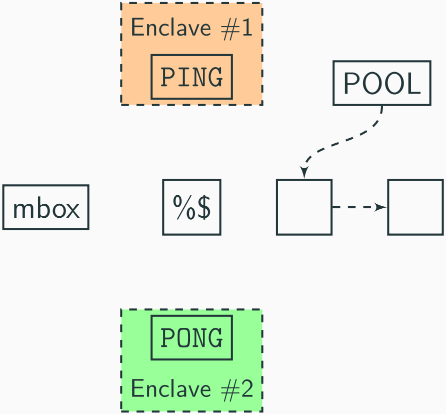

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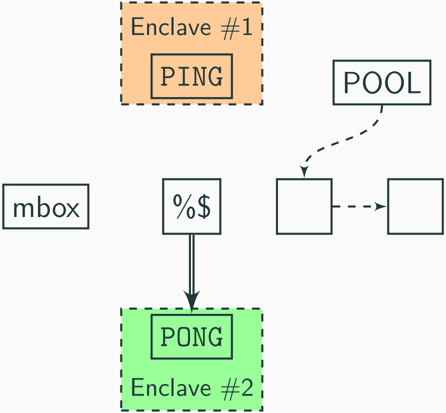

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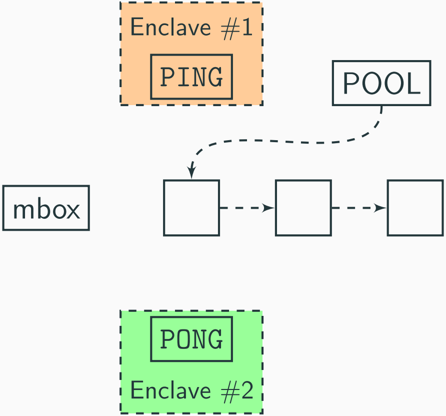

Connectors and Cargos

Nodes and queues are low-level communication primitives

+ Multi-Producer Multi-Consumer
− Plain text

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– Plain text

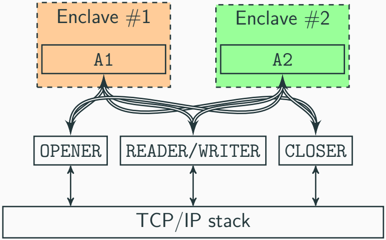
Cargos and Connectors are high-level communication primitives

- Unified interfaces for encrypted and non-encrypted messages
- Based on nodes and queues
- P2P message exchange
- Uses local-attestation for the key-exchange procedure

System Components::System Actors and EOS

System actors:

- $_e$*actor* **cannot** use syscalls
- Multiple system $_e$*actor*s
- Message based interaction



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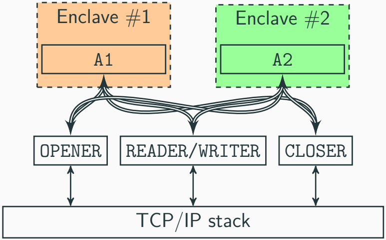
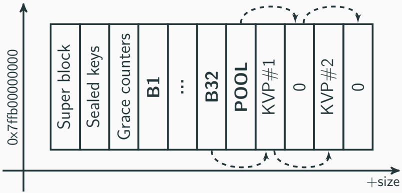


*E*actors Object Store:

- Key-value store
- Can be private or public
- Can be encrypted or non-encrypted
- Persistence on demand



Ping-pong

Ping-pong:

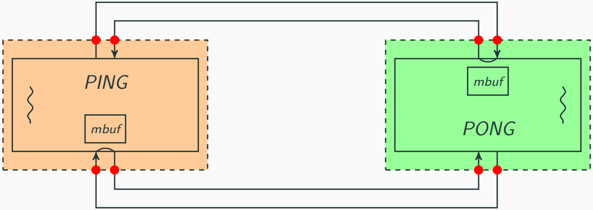
- 1,000,000 messages
- 16–512 KiB

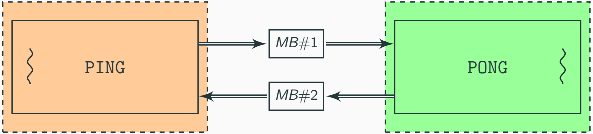
SDK:

- 2 threads, ECALLs

*E*Actors:

- 2 Actors, cargos

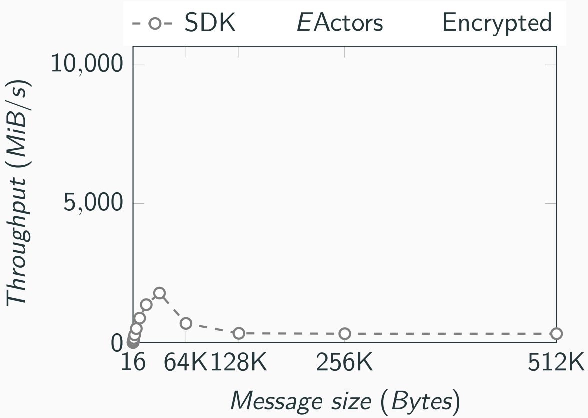




Ping-pong

SDK: 319 (1783 peak)

- 32KiB – L1 cache



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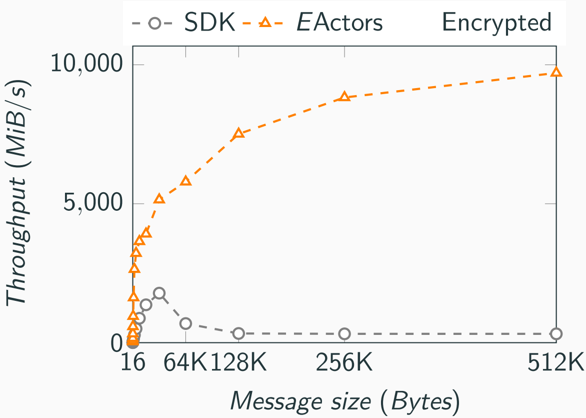
*E*Actors: 9706



Ping-pong

SDK: 319 (1783 peak)

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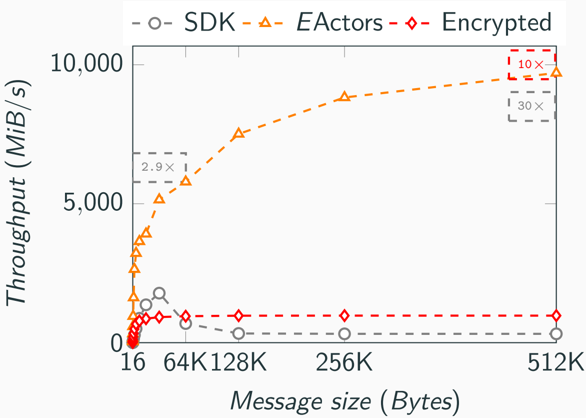
Encrypted: 974



Some Examples and Demos

Sources:
https://github.com/ibr-ds/EActors/tree/master/examples

template	Simple hello-world actor
pingpong	non-encrypted messages
pingpong2	cargo-based messaging
pingpongLA	Local attestation
smc	Secure multi-party computation
eos	EActors object store
http	A simple web server with SSL

https://primate.ibr.cs.tu-bs.de

Plan

*E*Actors:: What is next?

- Hardening – Isolation for actors
- Auto partitioning
- Multi-enclave Applications
- Independent from Intel SGX SDK

Plan

Takeaway

- *E*Actors – an actor-based programming framework
- C, uses the Intel SGX SDK
- Targets multi-enclave use cases
- Provides system components
- High-performance communication primitives

Sources: `https://github.com/ibr-ds/EActors`

Thank you!

References i

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