
Core C++ 2025
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“Lock me up, Scotty!”
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About Us

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About Fireblocks

Fireblocks powers companies of all sizes to confidently build, run, and grow their business on the blockchain.

$10T+
Transfers Secured

300M+
Wallets Created

100+
Blockchains

2,000+
Global Customers

Reminder: The Mutual Exclusion Problem

Given *N* concurrent threads and a critical section *C*:

- **Safety** Property - at most one thread inside C
- **Liveness** Property - one of the following:

No Deadlocks

No Starvation / Basic Fairness

Bounded Wait / Strong Fairness

(As per prof. Hagit Attiya)

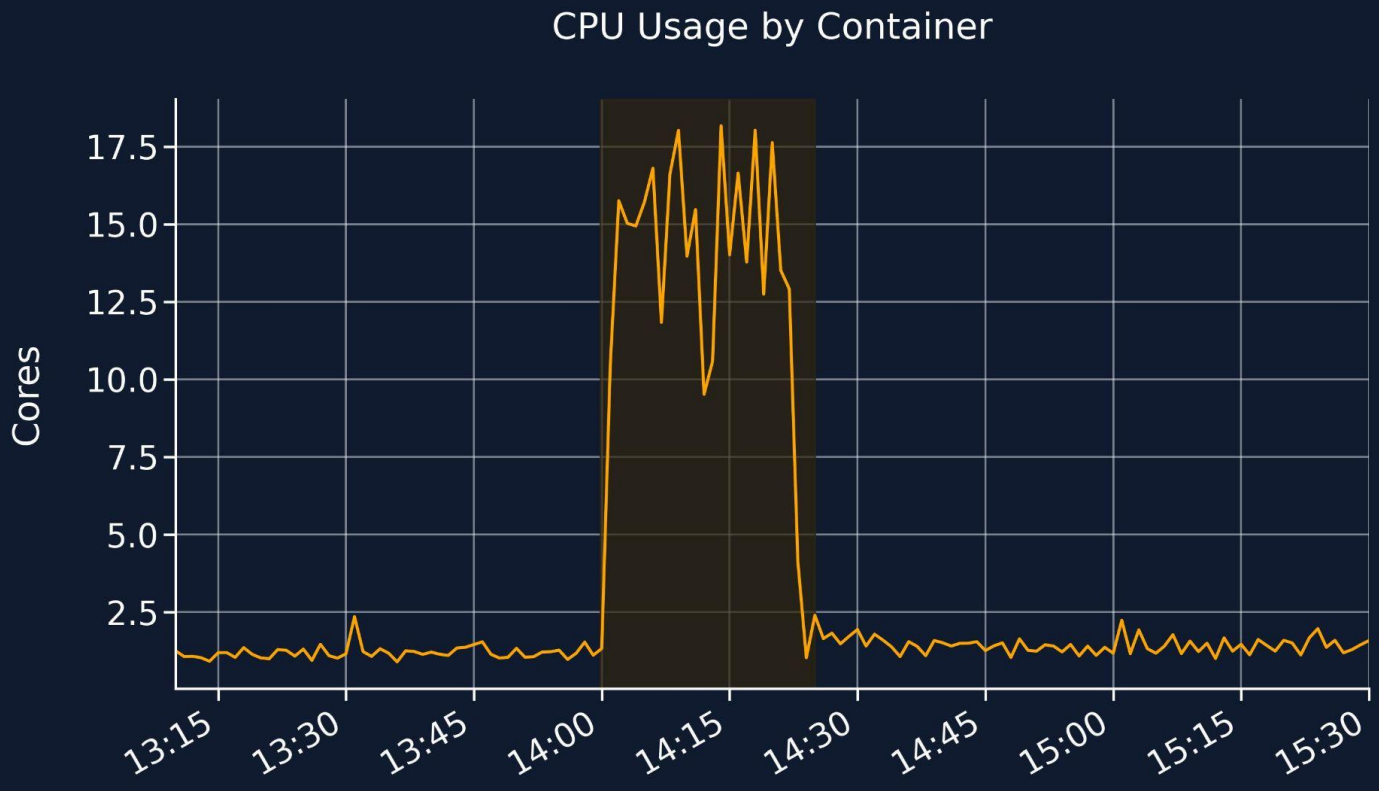
C++ has a Built-in Solution for the MEP

```cpp
static std::mutex transporter_lock;
static Engineer scotty;

void beam_up_crew(const std::string& crew_member)
{
    std::lock_guard lg { transporter_lock };

    scotty.beam_me_up(crew_member);
    std::cout << crew_member
              << " back on the Enterprise!"
              << std::endl;
}
```

It Worked, Until it didn’t…

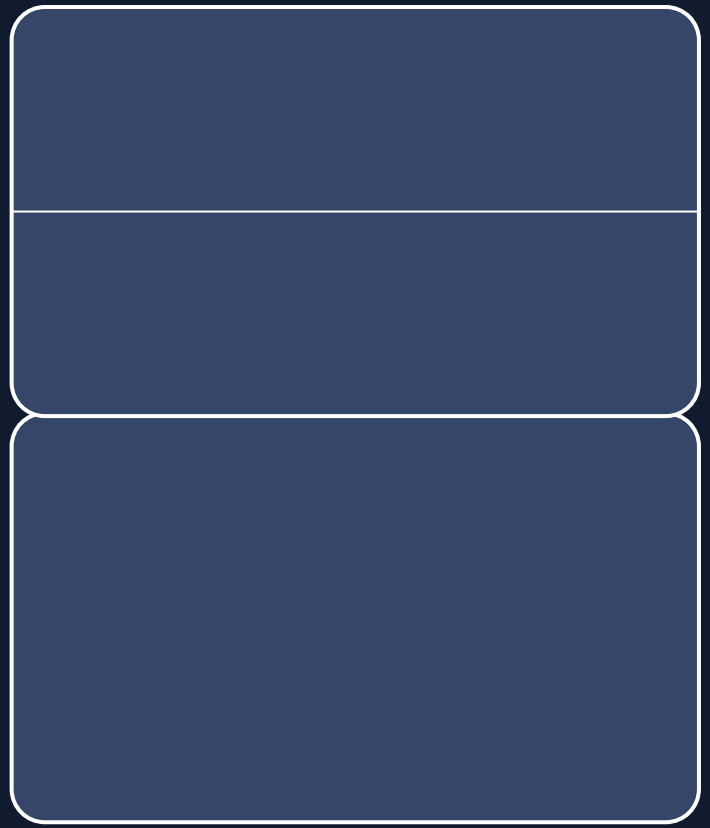


Software Guard eXtensions from 10,000 feet

Kernel

Userspace

Encrypted Memory



Untrusted Host

Trusted Enclave

Software Guard eXtensions from 10,000 feet

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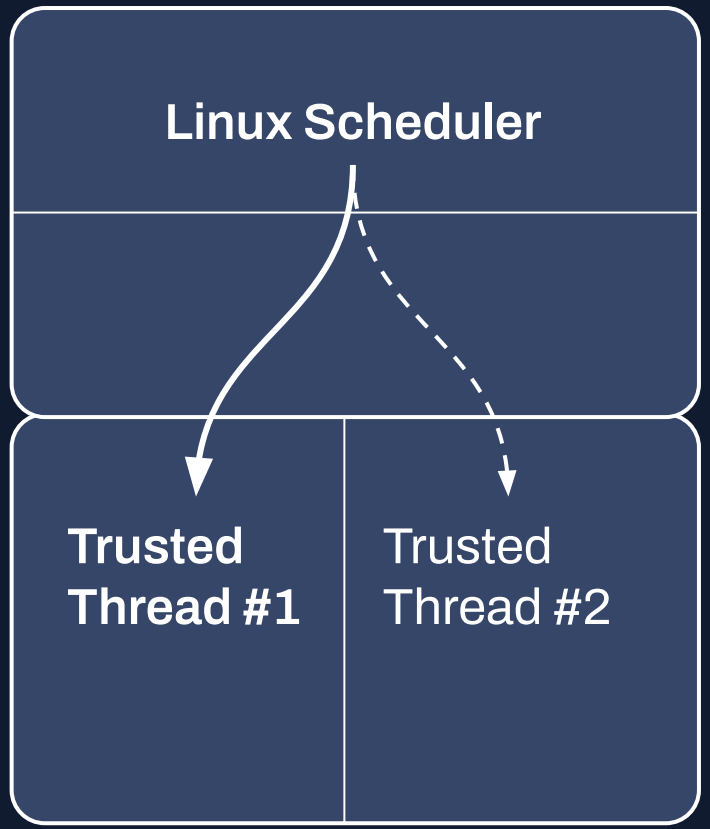
Encrypted Memory



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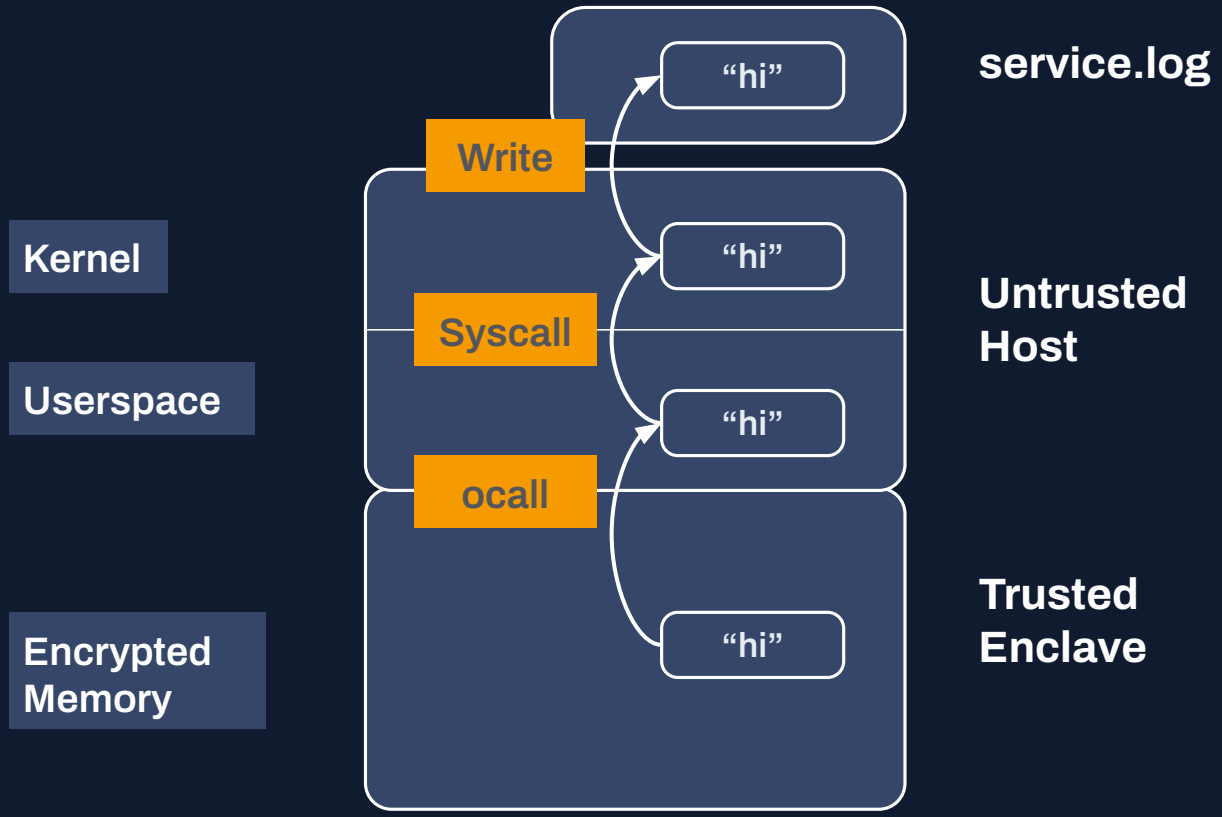


Sources of Mutual Exclusion for Applications

- **Hardware support**
- **Operating system support**
- Pure software algorithms (not practical)

Mutual Exclusion with Hardware Support

```
std::atomic_flag is_locked = ATOMIC_FLAG_INIT;

void lock() {
    while (is_locked.test_and_set(std::memory_order_acquire))
    {
        // Spin!
    }
}

void unlock() {
    is_locked.clear(std::memory_order_release);
}
```

Mutual Exclusion with Hardware Support

- ✔ Safe and deadlock-free
- ✔ All state is inside the enclave
- ✔ Can be good under low contention

- ✗ Starvation
- ✗ Spinning wastes CPU
- ✗ Atomic access has overhead
- ✗ Breakdown under preemptive multitasking

Mutual Exclusion with OS Support (Linux)

```
constexpr uint32_t UNLOCKED = 0;
constexpr uint32_t LOCKED = 1;

alignas(4) uint32_t is_locked = UNLOCKED;
std::atomic_ref<uint32_t> is_locked_ref { is_locked };

void lock() {
    while (is_locked_ref.exchange(LOCKED, std::memory_order_acquire)
           != UNLOCKED) {
        syscall(SYS_futex, &is_locked, FUTEX_WAIT_PRIVATE, LOCKED, NULL);
    }
}

void unlock() {
    is_locked_ref.store(UNLOCKED, std::memory_order_release);
    syscall(SYS_futex, &is_locked, FUTEX_WAKE_PRIVATE, 1); // Wake one
}
```

A Balanced Approach

- We can mix the approaches
- Separate managing the lock state from thread control
- The “Parking Lot” design pattern

What we had

```
int sgx_thread_mutex_lock(sgx_thread_mutex_t *mutex) {
    while (1) {
        SPIN_LOCK(&mutex->m_lock);
        ...
        if (/*mutex is available*/) {
            ...
            mutex->m_owner = self;
            SPIN_UNLOCK(&mutex->m_lock);
            return 0;
        }
        QUEUE_INSERT_TAIL(&mutex->m_queue, self);
        SPIN_UNLOCK(&mutex->m_lock);
        sgx_thread_wait_untrusted_event_ocall(self);
    }
}
```

Critical Section Control

Thread Control

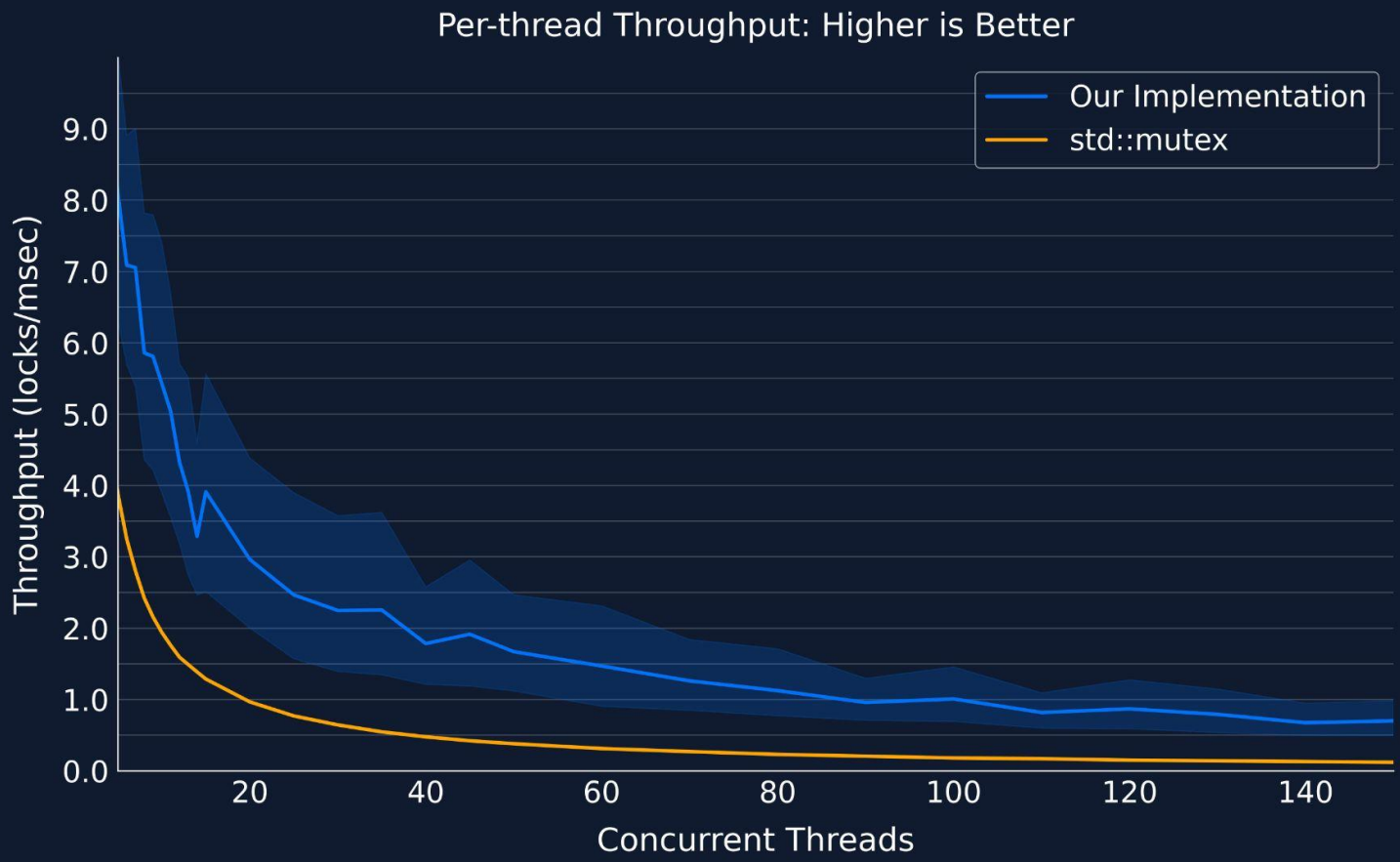
A First Improvement

- We can eliminate the inner spinlock by placing the state in a single trusted atomic variable
- But it doesn’t mean that we shouldn’t spin at all!
- **Adaptive Locking:** Try to set the lock state *N* times before asking the operating system to suspend the thread

Is Fairness Good?

- Satisfying a strong liveness property is a trade-off
- Strong fairness reduces variance of time for entering the critical section, at the cost of both throughput and average latency
- Most platforms do not have a fairness guarantee by default

What we Got


Per-thread Throughput: Higher is Better
Our Implementation
std::mutex
Throughput (locks/msec)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
20
40
60
80
100
120
140
Concurrent Threads

Should I do that too?

- “Locking isn’t slow, contention is”
- Primary effort should be directed at architecture choices that reduce contention
- Understand the guarantees that your specific platform is giving, and compare them to your workloads
- “Insufficient facts always invite danger”

Fireblocks

Thank you!