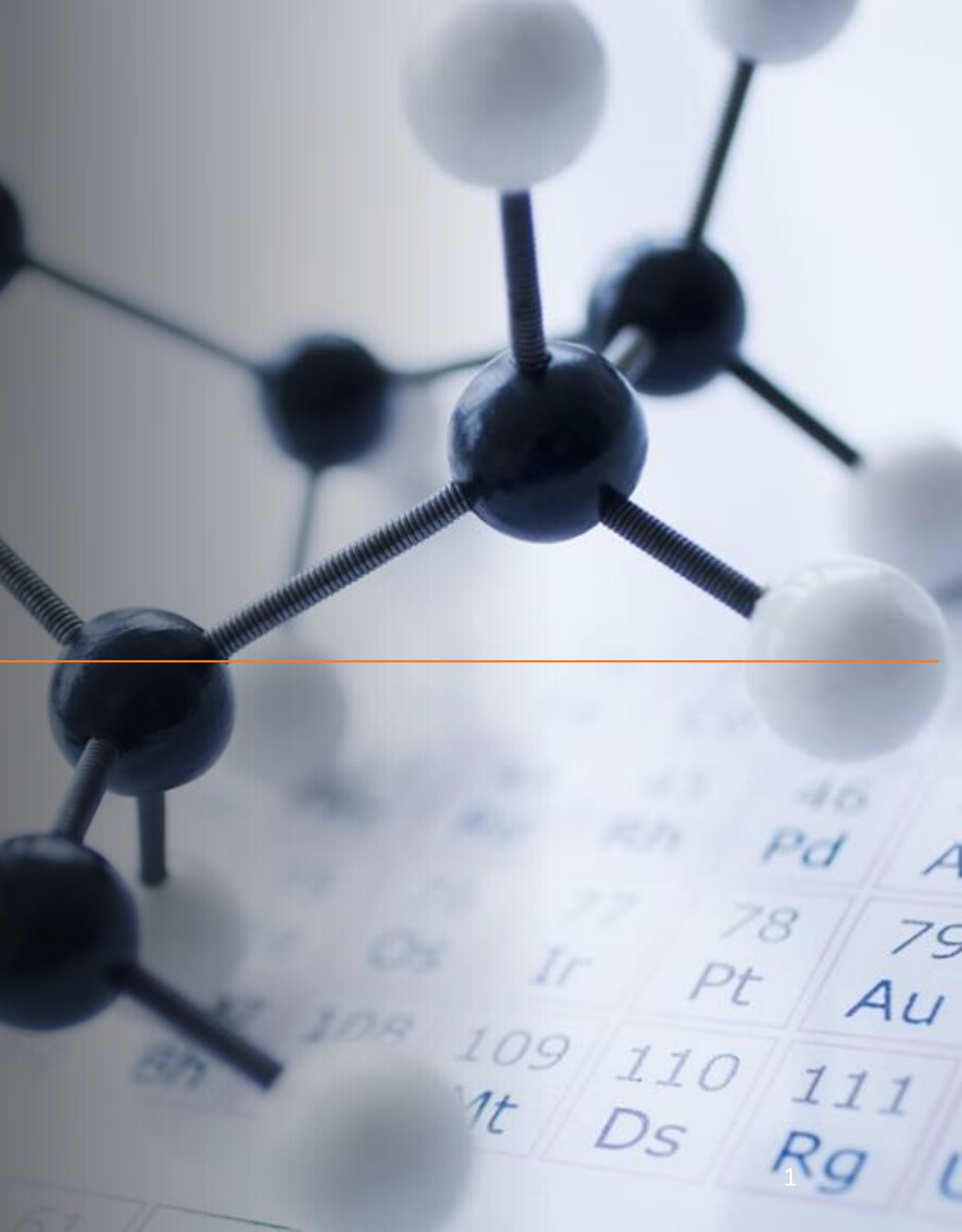
Understanding common concurrency patterns with tricky examples



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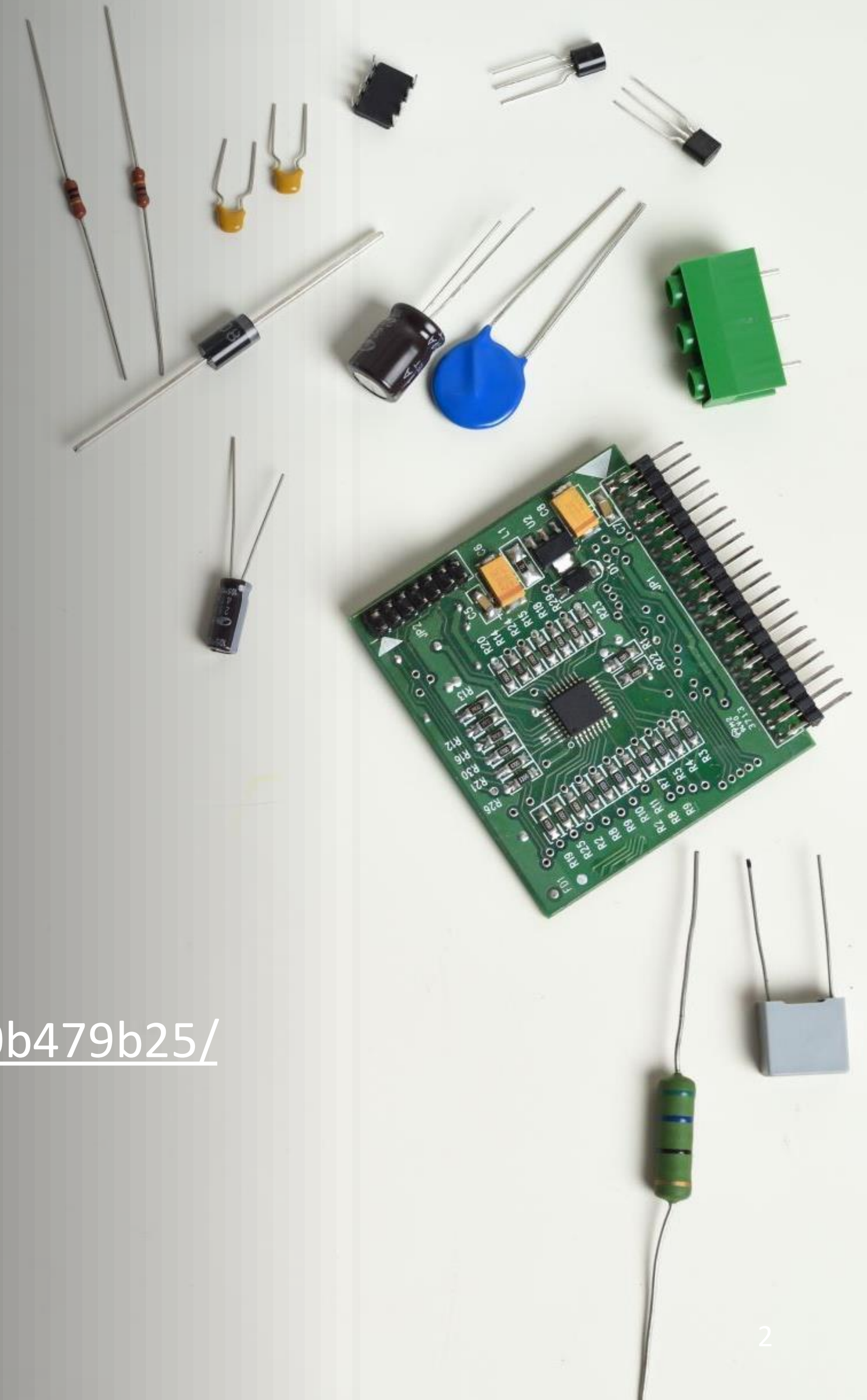


Agenda

- Basics of Concurrency
- Concurrency patterns
- Classic problems and solutions
    - Sleeping barber
    - Dinning philosophers
    - Reader-writer
- Asynchronous I/O
- Reactor pattern (libuv)
- Final thoughts
- References

Basics of concurrency I

- Concurrency is a technique that allows multiple processes to run at the same time by managing access to shared resources on a single CPU core. This is done through interleaved running of processes via context switching.
- One way to achieve concurrency is through **threads**, which are lightweight processes that can switch quickly and share information easily between them.

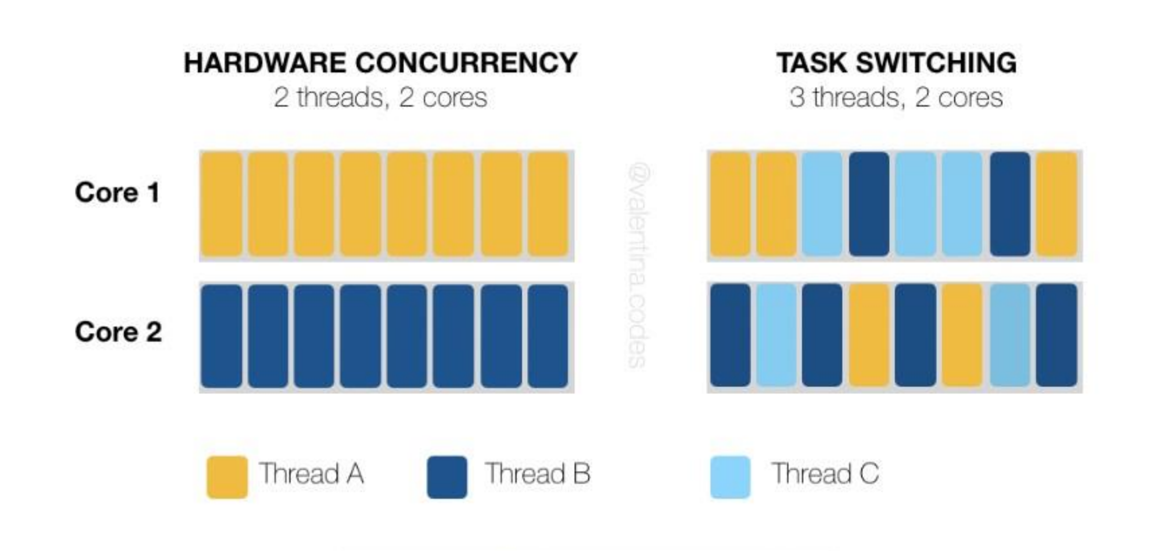


Image from Medium, [C++] Concurrency by Valentina

Basics of concurrency II

Advantages

- Improved throughput and efficiency
- Better CPU utilization
- Concurrent access for multiple users
- Real-time applications

Challenges

- Race conditions
- Deadlocks
- Starvation
- Livelock

Concurrency Patterns

Concurrent Architecture

- Active object
- Monitor object
- Reactor

Synchronization Patterns

- Dealing with sharing
- Copied value
- Thread-specific storage
- Future

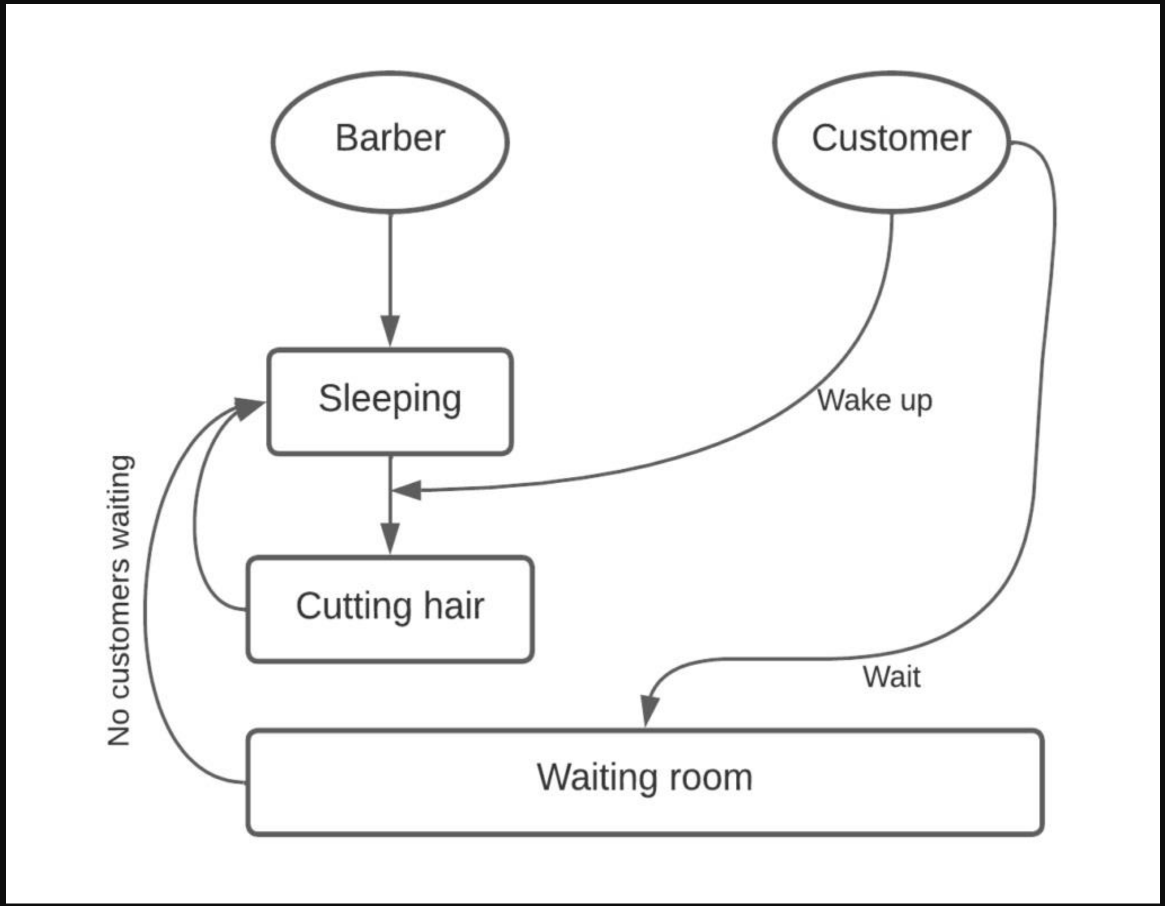
Dealing with Mutation

- Scoped locking
- Strategized locking
- Thread-safe Interface
- Guarded suspension

Sleeping Barber

https://en.wikipedia.org/wiki/Sleeping_barber_problem

- Monitor object: A pattern that encapsulates shared data and its synchronization mechanisms inside a class
- Objectives:
  - No race condition
  - No starvation
  - No deadlock
  - Mutual exclusion
  - Efficient resource allocation



Dining Philosophers

https://en.wikipedia.org/wiki/Dining_philosophers_problem

Objectives:

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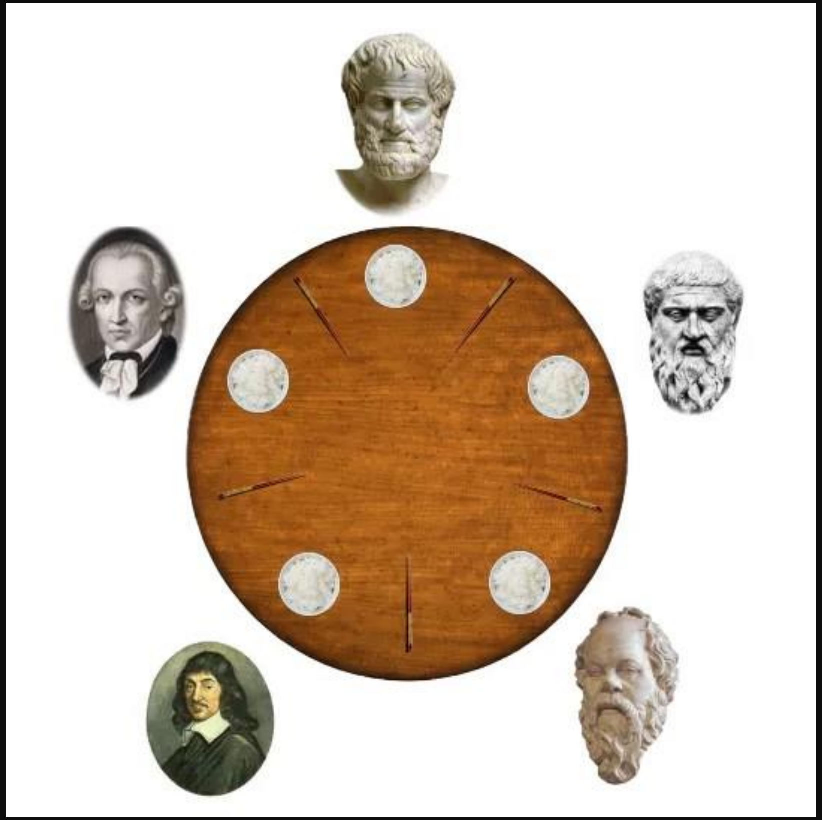
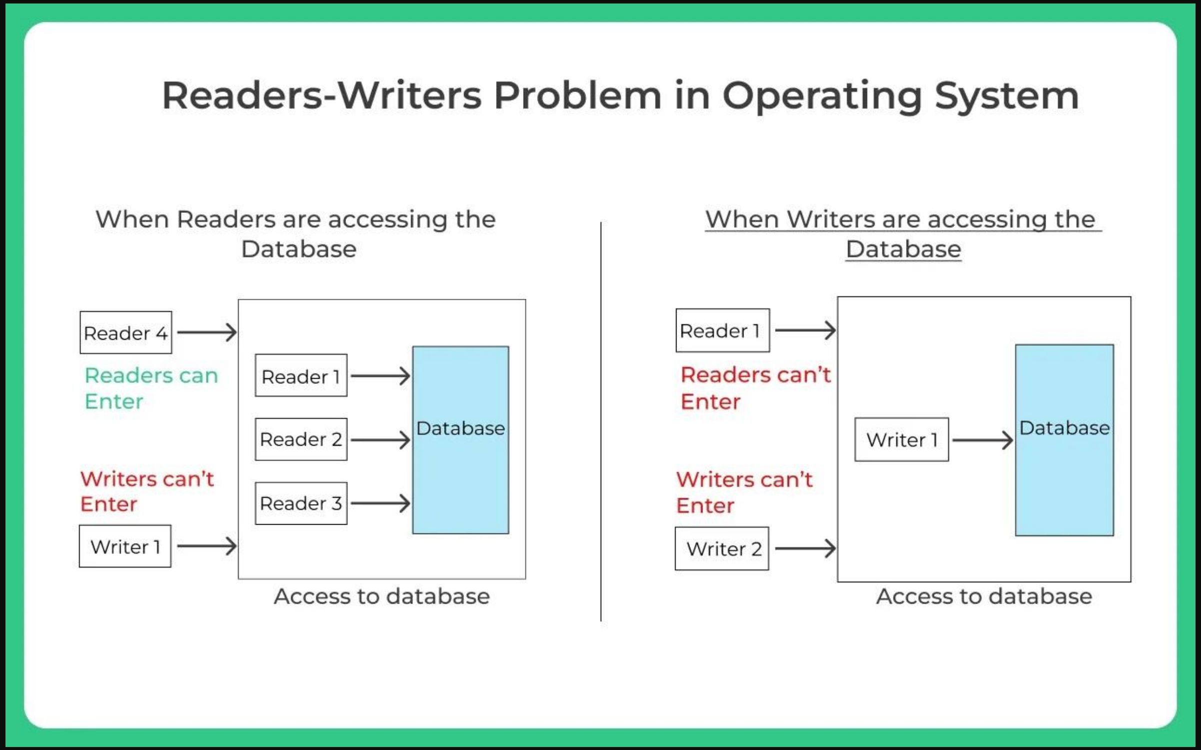


Readers-writers

https://en.wikipedia.org/wiki/Readers%E2%80%93writers_problem

Objectives:

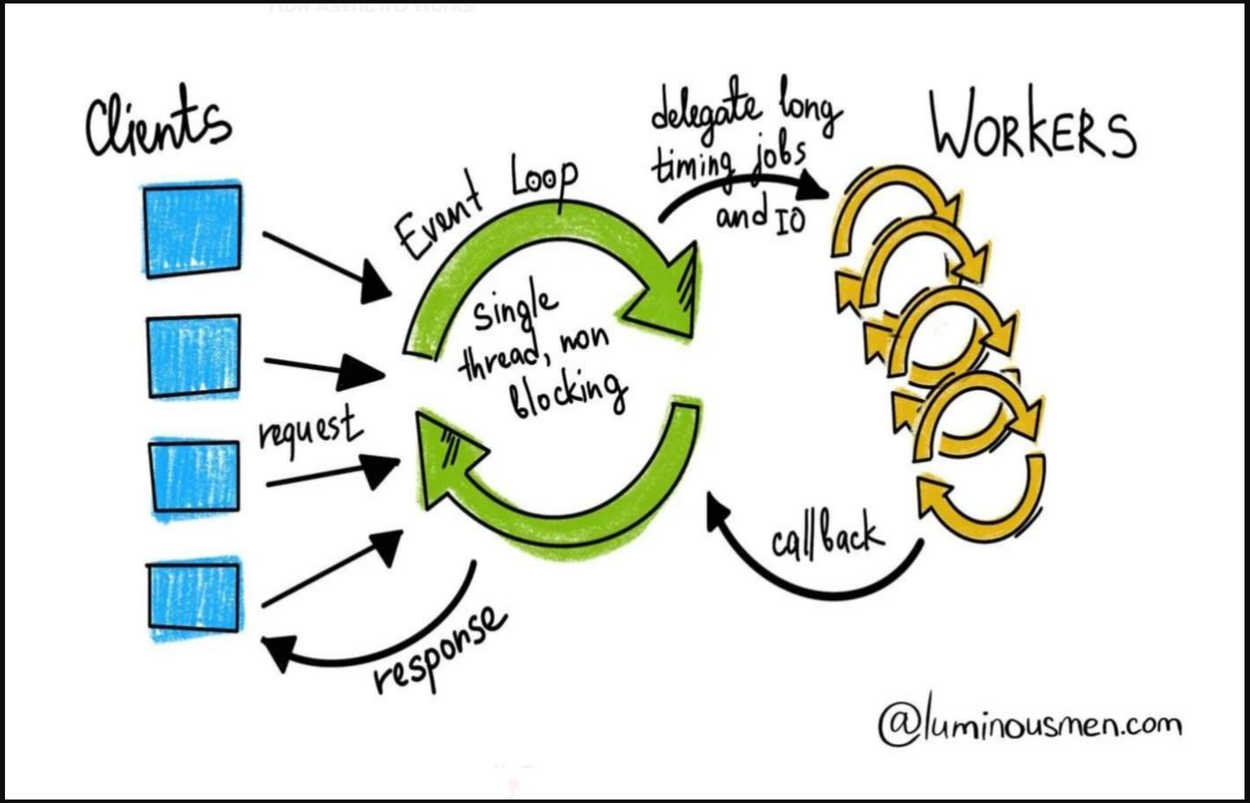
- Mutual exclusion for writers
- No writer starvation
- No reader-writer starvation
- Multiple readers allowed
- Read-Copy-Update (RCU) consistency (handled only in kernel for most cases)



Asynchronous I/O

Asynchronous I/O (also **non-sequential I/O**) is a form of input/output processing that permits other processing to continue before the transmission has finished

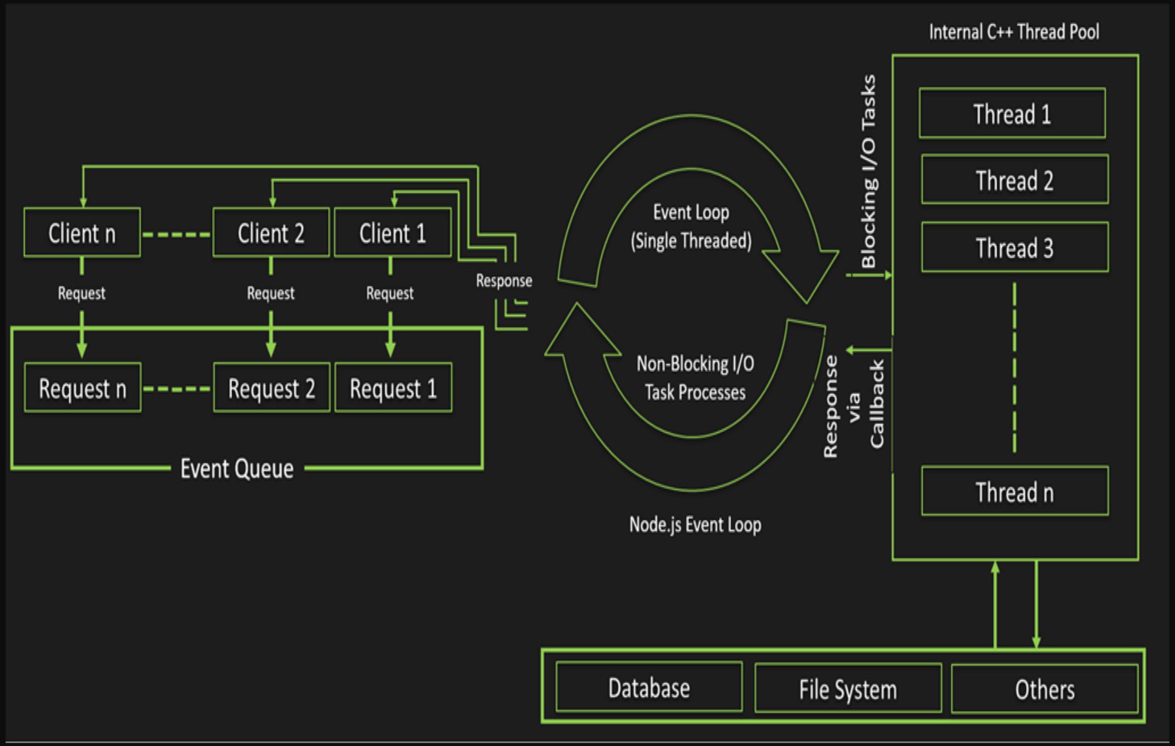
- This provides opportunities for a program to continue running other code while waiting for a long-running task to complete
- The time-consuming task is executed in the background while the rest of the code continues to execute
- https://libuv.org/



Reactor pattern I (libuv)

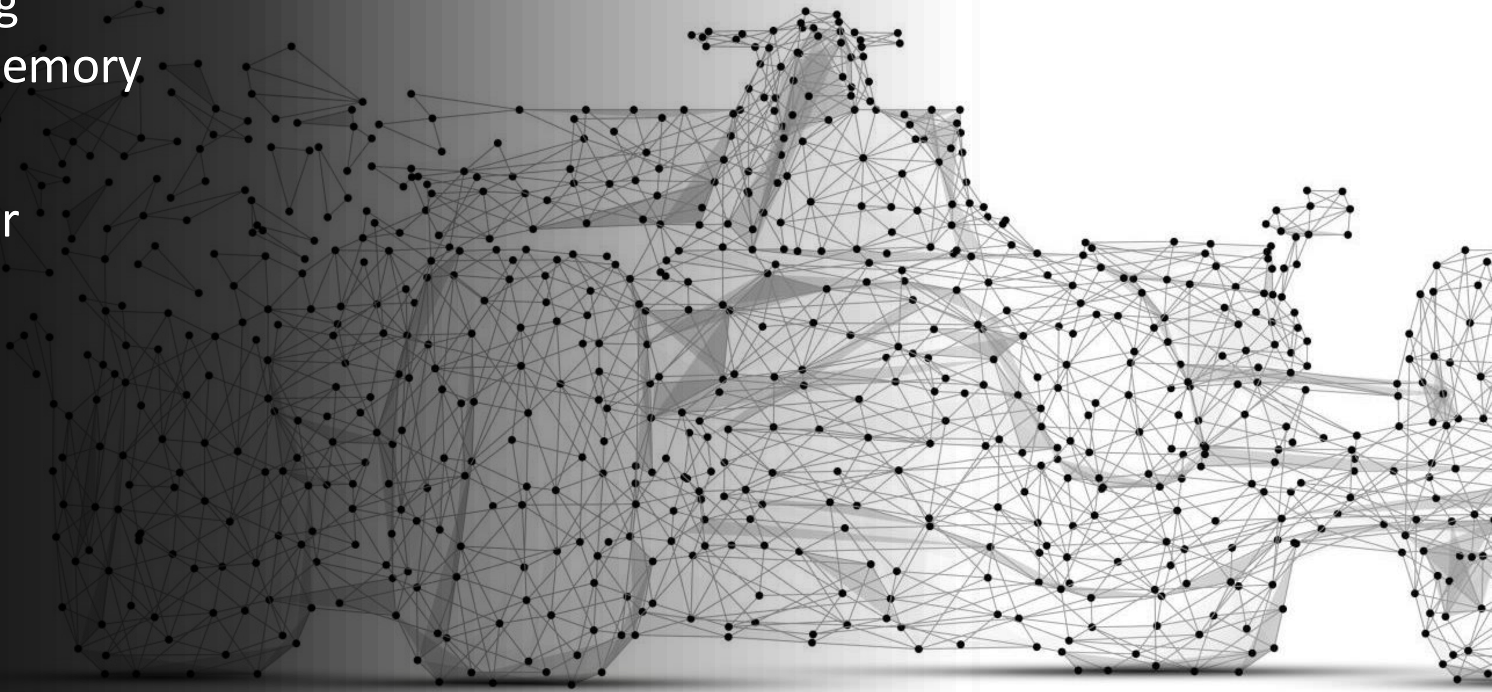
Key components:

- Event loop -> single threaded
- Event queue -> queue requests
- Execution handlers -> callback response



Reactor pattern II (libuv)

- Problem: Design an libuv event loop closing mechanism without race conditions and memory errors
- Examples to study different approaches, for solving the problem



Final Thoughts I

Best practices

- Understand your model
- Minimize shared mutable state
- Design for failure
- Test with realistic workloads
- Identifying critical sections

Techniques

- Futures and promises
- Reactive programming
- Non-blocking algorithms
- Transactional memory
- Immutable data structures

Final Thoughts II

Performance considerations

- Measuring and profiling concurrent applications
- Load balancing and work distribution
- Granularity of locks
- Scaling on multi-core processors

At times, concurrency issues are hard to understand and debug. But solving them gives a big chance to step up the ladder in software design

References

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THANK YOU!