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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

19ECT312 – EMBEDDED SYSTEM DESIGN

III YEAR/ VI SEMESTER

UNIT 4 :**Embedded Operating System and Modelling**

TOPIC 4.7 :POSIX Thread Programming

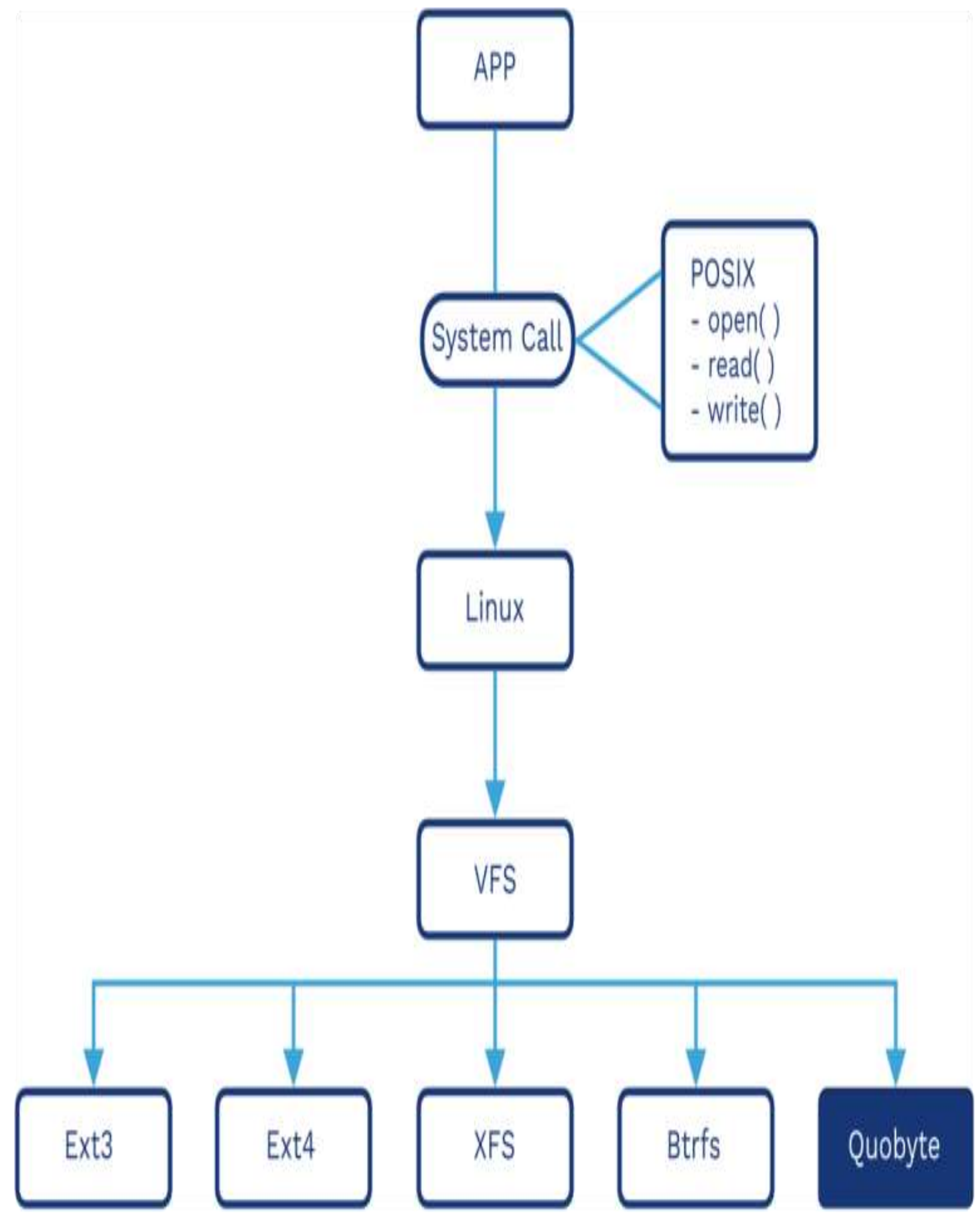
POSIX - Introduction

- **POSIX** (Portable Operating System Interface) is a family of standards created to make sure that applications developed on one UNIX flavor can run on other UNIXes

- The POSIX standard describes how system calls must behave. One particular section of the standard defines the semantics (behavior) of a POSIX compatible file system.

POSIX - Introduction

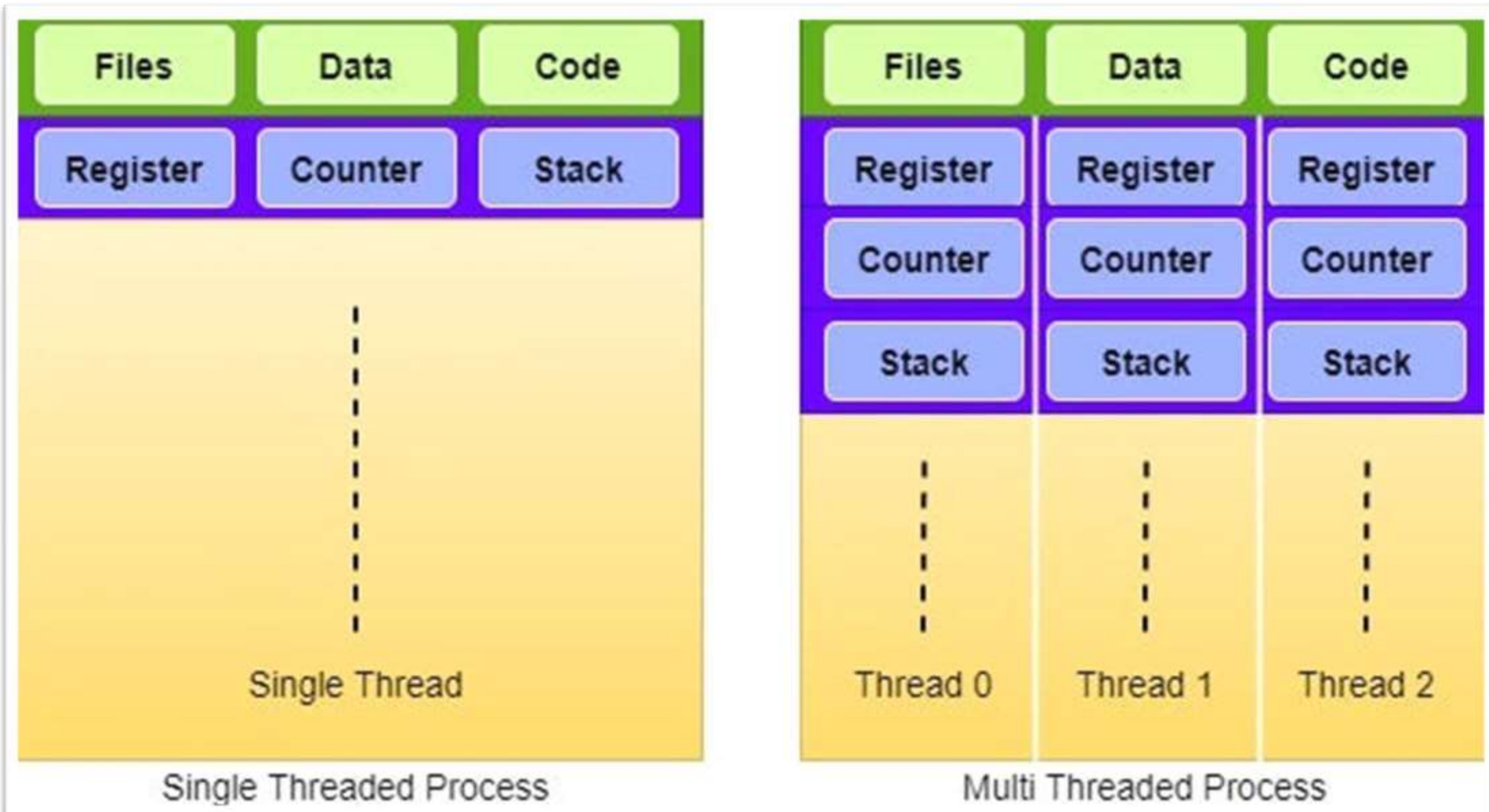
- application makes system calls such as open, read, and write to communicate with the Linux kernel
- the behavior, of the system calls is defined by POSIX
- The Linux Kernel hands the file system-related system calls to the Virtual File System (VFS) layer, which abstracts from the underlying file system implementation, which includes local file systems but also distributed file systems like Quobyte.



POSIX Thread Programming

- POSIX threads, commonly known as Pthreads, are a threading standard that allows multiple threads to coexist within the same process, sharing resources but executing independently
- In embedded systems, Pthreads facilitate concurrent task execution, which is essential for optimizing performance and responsiveness
- Pthreads offer a range of functionalities in embedded systems, such as thread synchronization with mutexes and condition variables, thread management, and real-time scheduling
- These capabilities are crucial for embedded applications where timing and resource constraints are critical.

POSIX Thread Programming



POSIX Thread Programming

Thread Synchronization

- Thread synchronization is a programming concept that ensures the orderly execution of multiple threads within a concurrent processing environment
- It involves coordinating thread access to shared resources to prevent conflicts and ensure data integrity

Mutexes

- Mutexes (mutual exclusion) are synchronization primitives used to protect shared resources from simultaneous access by multiple threads
- In embedded systems, mutexes are commonly employed to prevent data corruption when multiple threads attempt to access critical sections of code or shared variables concurrently.

POSIX Thread Programming

Semaphores

- Semaphores are another synchronization mechanism used in embedded systems
- They provide a way to control access to a shared resource by allowing a fixed number of threads to access it simultaneously
- Semaphores are often used to manage access to finite resources, such as hardware peripherals or memory buffers.

POSIX Thread Programming

Critical Sections

- Critical sections are parts of code that must be executed atomically, without interruption from other threads
- In embedded systems, critical sections are typically protected by mutexes or other synchronization primitives to prevent race conditions and ensure data consistency

Interrupt Handling

- Embedded systems often rely on interrupts to handle time-critical events and asynchronous I/O operations
- Proper synchronization techniques, such as disabling interrupts or using atomic operations, are essential to ensure data integrity when accessing shared resources from interrupt service routines (ISRs) and regular threads

POSIX Thread Programming

Event Flags

- Event flags are used to signal and synchronize between threads in embedded system
- Threads can wait for specific events to occur by blocking on event flags, and other threads can set or clear these flags to notify waiting threads of significant events or conditions

Mutual Exclusion

- Concurrent access to shared resources should be controlled to avoid race conditions
- Techniques such as mutexes, semaphores, or critical sections ensure that only one thread can access a resource at a time, preventing data corruption.

POSIX Thread Programming

Thread Safety

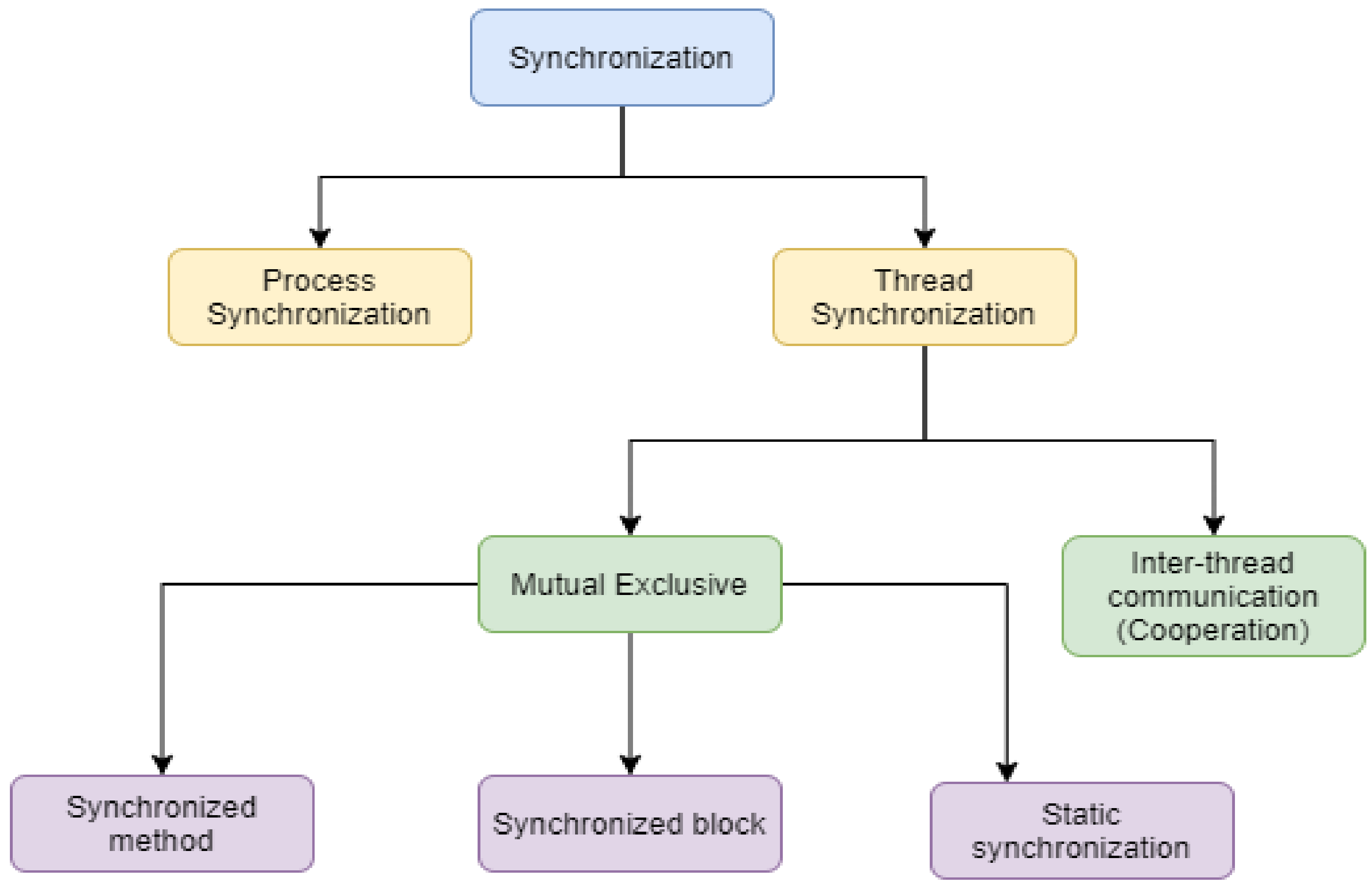
- Thread safety refers to the property of a program or system where it can handle multiple threads executing concurrently without encountering data races, deadlocks, or other synchronization issues
- Ensuring thread safety is crucial in multi-threaded environments to prevent unpredictable behavior and maintain data integrity. Here's a concise overview:

Atomicity

- Operations that involve multiple steps should appear as a single, indivisible operation to other thread
- Atomic operations ensure that threads cannot interrupt each other midway through an operation, preventing inconsistent state

POSIX Thread Programming

❖**Synchronization**: Threads need to synchronize their actions to avoid conflicts and maintain consistency. Synchronization primitives like mutexes, condition variables, and barriers facilitate coordination between threads, ensuring that they execute in a synchronized manner.



POSIX Thread Programming

Visibility

- Changes made by one thread to shared variables should be visible to other threads. Memory barriers, locks, and atomic operations ensure proper memory visibility, preventing inconsistencies due to caching and compiler optimizations.

Reentrancy

- Functions and code segments should be designed to be reentrant, meaning they can be safely called by multiple threads simultaneously without interfering with each other's execution

- Reentrant code avoids issues related to shared data and maintains thread safety.

POSIX Thread Programming

Thread Pool

- A thread pool is a collection of pre-initialized threads that are ready to perform tasks
- Instead of creating a new thread for each task, threads from the pool are assigned tasks as needed
- This approach reduces overhead associated with thread creation and destruction.

Task Queue

- Thread pools often utilize a task queue, also known as a work queue or job queue, to store tasks that need to be executed
- When a task is submitted to the thread pool, it is added to the task queue.

POSIX Thread Programming

Task Submission

- Applications submit tasks to the thread pool instead of directly creating threads
- Tasks can be functions, methods, or any unit of work that needs to be executed concurrently

Task Execution

- Idle threads in the thread pool continuously monitor the task queue for new tasks
- When a thread becomes available, it retrieves a task from the queue and executes it
- This process continues until the thread pool is shut down.

POSIX Thread Programming

Thread Lifespan

- Threads in the pool are long-lived and remain active throughout the lifespan of the application
- After executing a task, a thread returns to the idle state, ready to accept and execute another task

Resource Management

- Thread pools allow for efficient management of system resources by limiting the total number of concurrent threads
- This prevents resource exhaustion and improves overall system stability.

POSIX Thread Programming

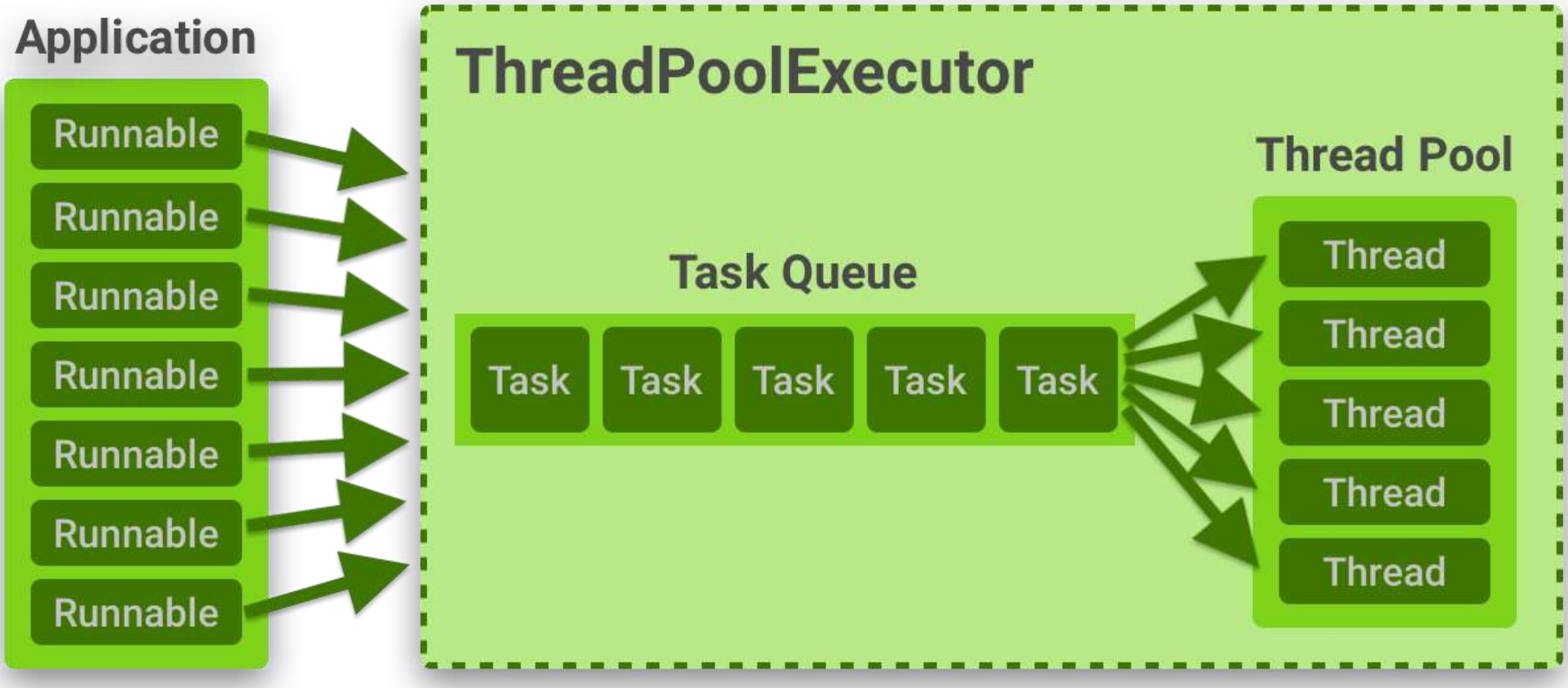
Performance Optimization

- Thread pools help improve application performance by reducing the overhead associated with thread creation and destruction
- Reusing threads from the pool eliminates the need for frequent context switching and thread setup overhead

Dynamic Sizing

- Some thread pool implementations support dynamic resizing, allowing the pool size to adjust based on workload or system conditions
- This flexibility ensures optimal resource utilization without compromising performance.

POSIX Thread Programming



POSIX Thread Programming

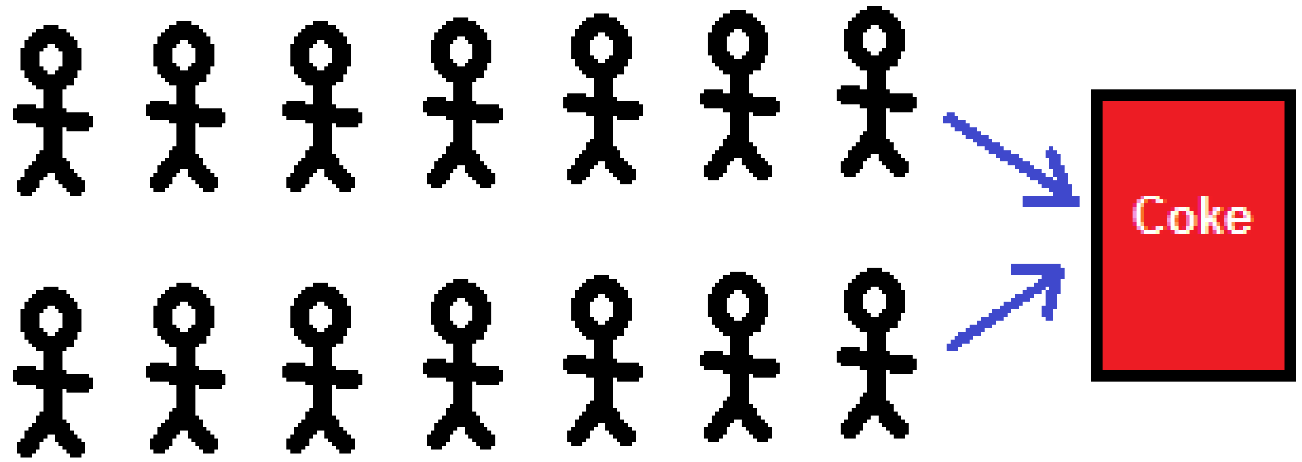
Parallelism

- Parallelism refers to the simultaneous execution of multiple tasks or processes to improve performance and efficiency
- In parallel computing, tasks are divided into smaller subtasks that can be executed concurrently on multiple processing units, such as CPU cores or distributed computing nodes.

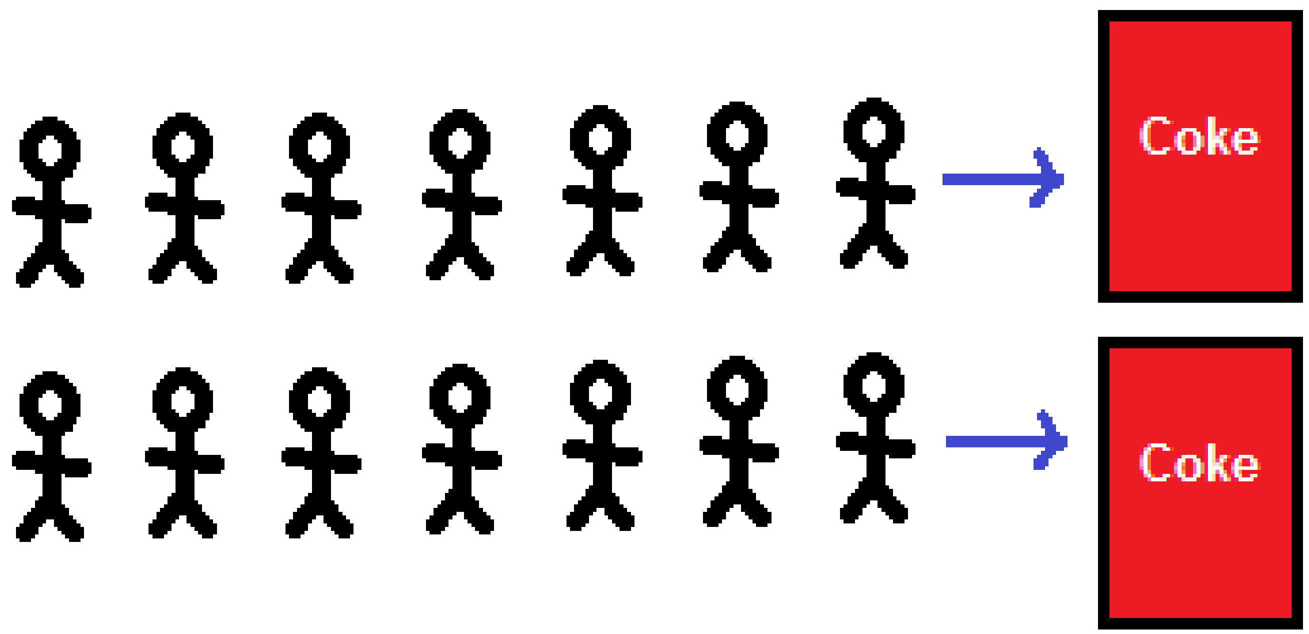
Concurrency

- Concurrency, on the other hand, involves the execution of multiple tasks or processes seemingly simultaneously, but not necessarily concurrently
- Concurrent programming focuses on managing the execution flow of multiple tasks, allowing them to progress independently and make progress concurrently.

POSIX Thread Programming



Concurrent: 2 queues, 1 vending machine



Parallel: 2 queues, 2 vending machines

POSIX Thread Programming

Real World Applications

Web Servers

- Web servers handle multiple client requests concurrently
- POSIX threads can be used to create a pool of worker threads that handle incoming requests, allowing the server to serve multiple clients simultaneously without blocking.

Multimedia Processing

- Applications that deal with multimedia processing, such as video editing software or audio processing tools, often benefit from parallelism
- POSIX threads can be used to parallelize tasks like video encoding, decoding, and rendering to improve performance.

POSIX Thread Programming

Database Systems

- Database management systems (DBMS) need to handle multiple concurrent queries and transactions efficiently

- POSIX threads can be employed to handle query processing, transaction management, and concurrency control mechanisms like locking and transactions.

POSIX Thread Programming

Embedded Systems

- Embedded systems with multitasking requirements, such as real-time control systems or IoT devices, can benefit from POSIX thread programming
- Threads can be used to handle various tasks concurrently, such as sensor data processing, communication protocols, and user interface updates

Parallel Algorithms

- Parallel algorithms, such as sorting, searching, and graph processing, can leverage POSIX threads to divide the workload across multiple threads and exploit parallelism in modern multi-core processors

POSIX Thread Programming

Parallel File Processing

- Applications that involve processing large volumes of data stored in files can benefit from POSIX thread programming
- Multiple threads can be used to read, process, and write data concurrently, improving overall throughput and reducing processing time

Parallel Computing

- High-performance computing (HPC) applications often use POSIX threads for parallel computing tasks like numerical simulations, scientific computing, and data analysis

POSIX Thread Programming

Challenges

- **Concurrency Management**: Effectively managing concurrent execution of multiple threads to avoid race conditions and deadlocks
- **Synchronization**: Ensuring proper synchronization between threads to prevent data corruption and maintain consistency
- **Scalability**: Scaling thread-based applications to handle increasing core counts and workload diversity on modern multi-core and many-core processors
- **Performance Optimization**: Optimizing thread management, load balancing, and task scheduling to maximize performance and efficiency
- **Fault Tolerance**: Implementing robust error-handling mechanisms and fault-tolerant synchronization primitives to enhance application reliability.

Thank you