
VIRTUAL
THREADS

Traditional Threads

- Java threads = OS threads (1:1 mapping)
- OS threads = expensive (memory + context switching)
- Thread-per-request style = simple, but doesn’t scale

🛑 Result: **Throughput capped by OS thread limits**

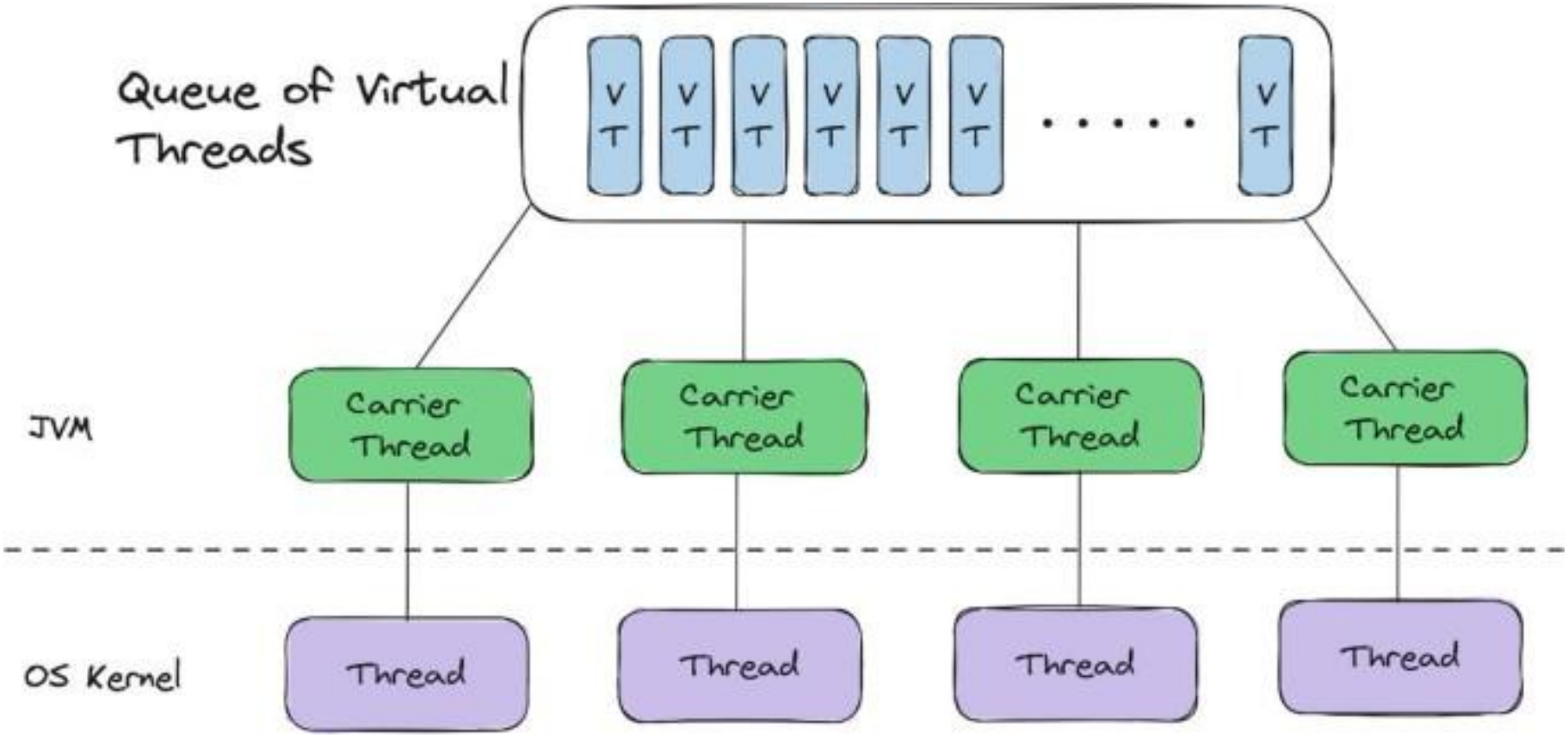
Async / Reactive Programming

- Non-blocking APIs + callbacks (`CompletableFuture`, reactive frameworks)
- Better scalability but…
  - ❌ Harder to read (no loops, try/catch)
  - ❌ Debugging and profiling painful
  - ❌ Stack traces lose meaning

What they are:

- Instances of `java.lang.Thread`
- **M:N scheduling**: Many (M) virtual threads mapped to fewer (N) OS threads
- Lightweight, cheap, and plentiful

📌 **Analogy**: Like OS “virtual memory”, but for threads


Queue of Virtual Threads
VT
VT
VT
VT
VT
VT
VT
JVM
Carrier Thread
Carrier Thread
Carrier Thread
Carrier Thread
OS Kernel
Thread
Thread
Thread
Thread

Virtual Threads - Goals 🎯

- Keep the **thread-per-request** model
- Near-optimal hardware utilization
- Compatible with existing code (`ThreadLocal`, debugging, profiling)
- No new programming model to learn

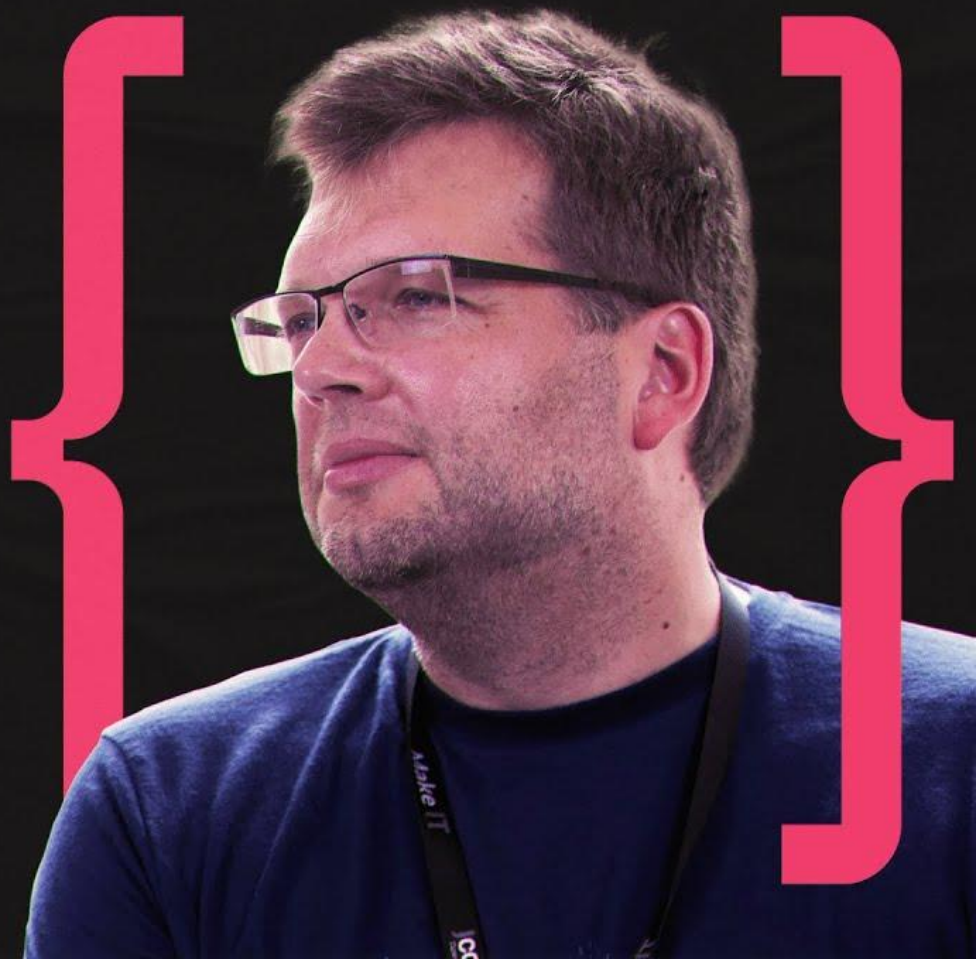
Virtual Threads - Using Virtual Threads (Example)

```
try (var executor = Executors.newVirtualThreadPerTaskExecutor()) {
    IntStream.range(0, 10_000).forEach(i ->
        executor.submit(() -> {
            Thread.sleep(Duration.ofSeconds(1));
            return i;
        })
    );
}
```

✅ 10,000 concurrent tasks → runs fine

❌ 10,000 OS threads → likely crash

The One Billion Row Challenge (1BRC) with Gunnar Morling



podcast

Virtual Threads - When to Use?

Best for **high concurrency I/O-bound** tasks (HTTP calls, DB queries, etc.)

Not faster than platform threads → they give **scale, not speed**

Don’t pool virtual threads — create one per task!

Virtual Threads - Observability 🔍

Virtual threads = fully supported by tooling

Debuggers, profilers, **JFR**

New **thread dumps** grouped by task

JSON export via `jcmd`

Virtual Threads - The Pinning Issue (Java 21 → 23)

- Virtual threads could get **pinned** (stuck to carrier OS thread):
  - Inside `synchronized` blocks
  - Native calls / FFM API

⚠️ Pinned thread = carrier blocked → scalability suffers

Workarounds:

- Replace `synchronized` with `ReentrantLock`
- Monitor with `-Djdk.tracePinnedThreads` or **JFR events**

Synchronize Virtual Threads Without Pinning

- Virtual threads can now acquire/release monitors **independently of carriers**
- ✅ `synchronized` no longer causes pinning
- ✅ `ConcurrentHashMap` and many libraries safe
- 🗑️ `-Djdk.tracePinnedThreads` removed → not needed anymore
- Monitoring only needed for **native calls**

Virtual Threads - Forgive `synchronized` ❤️

In 2023: “Avoid synchronized, use locks!”

In 2025: “Use the best tool for the job”

JEP 491 officially says: choose between `synchronized` and `ReentrantLock`
based on semantics, **not pinning fears**

Virtual Threads - Key Takeaways ✅

Virtual threads = **simple + scalable** concurrency

Ideal for **server apps** (thread-per-request style preserved)

Tooling ready: debugging, JFR, thread dumps

Java 24: **pinning issue solved**

Java 25: Virtual threads are **mature and production-ready**