# Considerations for integrating virtual threads in a Java framework: a Quarkus example in a resource-constrained environment

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## The end of the monolith

- difficult to maintain
- dependency hell
- reboot for every change
- sub-optimal deployment
- limit scalability
- technology lock-in

**from**

Microservices: yesterday, today, and tomorrow - Dragoni & al

- *difficult to maintain*
- split in smaller entities
- *dependency hell*
- less dependencies per service
- *reboot for every change*
- reboot only impacted service

- *sub-optimal deployment*
- per-service deployment
- *limits scalability*
- scale each service
- *technology lock-in*
- per service technology

**Remark**

Transitioning to cloud becomes a thing

# Make microservices cheap

resource-efficiency

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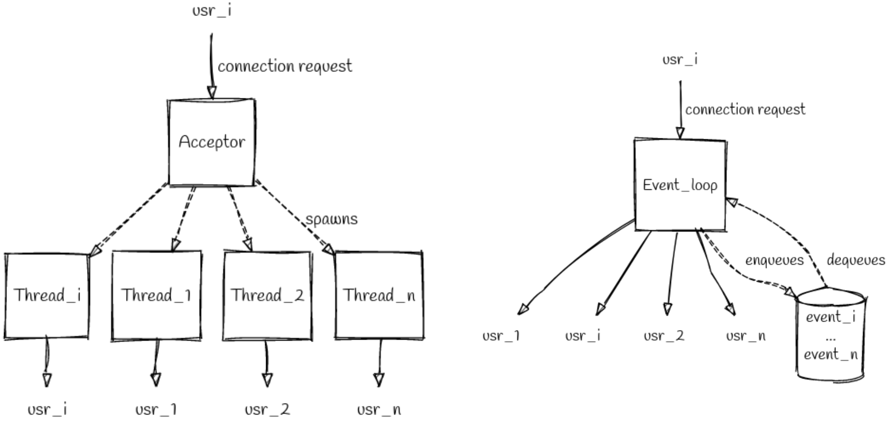
**Problem**

Communications over the network are unreliable and slow.

**Goal**

Achieving efficient and timely communication between services.

# Blocking and Non-blocking programming



- asynchronous callbacks
- promises and futures
- reactive streams
- coroutines
- async functions
- light threads

```
var names = getAll();
var quotes = getQuotes(names.size());
for(int i=0; i < names.size();i ++){
   names.get(i).surname+= "- "+quotes.get(i);
}
return names;
```

```
getAll( names => {
   getQuotes(names.size(), quotes => {
      for(int i=0; i < names.size();i ++){
         names.get(i).surname+= ”- ”+quotes.get(i);
      }
      //continuation
   })
});
```

```
var names = getAll().memoize().indefinitely();
var quotes = names.onItem().transformToUni(list ->
         getQuotes(list.size()));
return Uni.combine().all()
   .unis(names,quotes).asTuple()
   .onItem().transform(tuple -> {
      var nList=tuple.getItem1();
      //can await it since it is already resolved
      var qList = tuple.getItem2();
      for(int i=0; i < namesList.size();i ++){
         nList.get(i).surname += " - "+qList.get(i);
      }
      return namesList;
   });
```

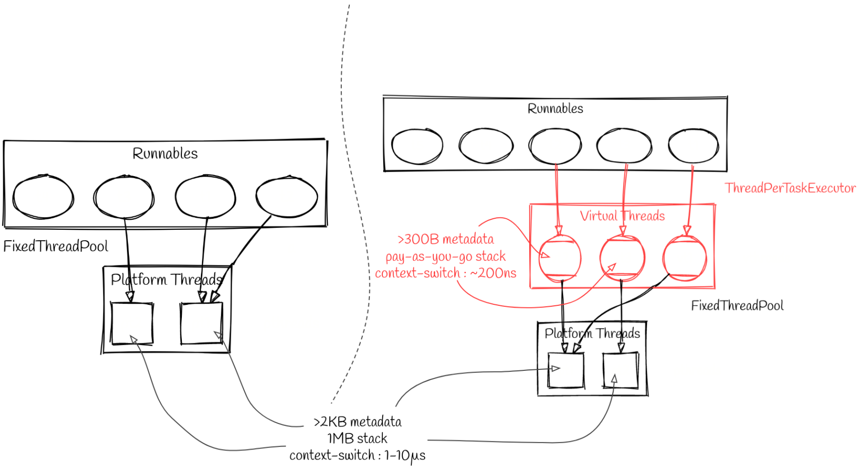
> *We should do (as wise programmers aware of our limitations) our utmost best to shorten the conceptual gap between the static program and the dynamic process, to* ***make the correspondence between the program (spread out in text space) and the process (spread out in time) as trivial as possible****.*

Edgar. J. Dijkstra, 1968

# Code comparison - virtual threads

```
var names = getAll();
var quotes = getQuotes(names.size());
for(int i=0; i < names.size();i ++){
   names.get(i).surname+= "- "+quotes.get(i);
}
return names;
```

# Virtual threads



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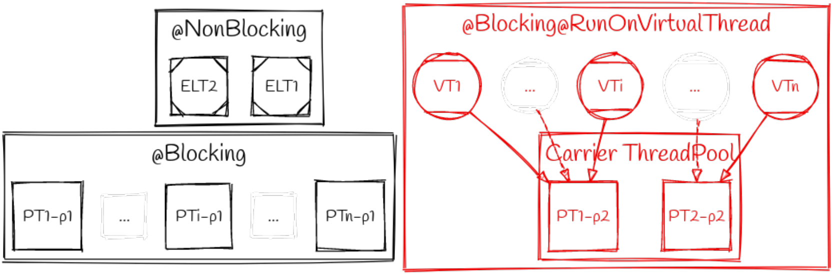
```java
@GET
@Path("/reactive")
Uni<Fortune> reactive() {
   return repo
      .findAllAsync()
      .map(this::pickOne);
}
```

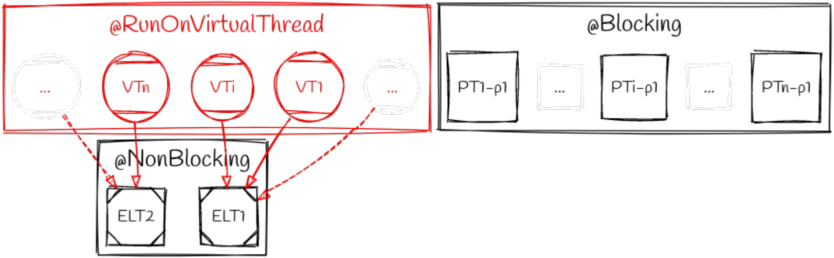
```java
@GET
@Path("/virtual-threads")
@RunOnVirtualThread
Fortune loomWithJdbc() {
   var list = repo.findAll();
   return pickOne(list);
}
```

| Strategy | Pros | Cons |
|---|---|---|
| Forking worker model | Simple, fits virtual threads model | Context switches |
| Using event-loop as carrier | No context-switch, Fewer threads overall | Potential deadlocks |
| Modifying Netty event-loops to be virtual threads | Integration done at the Netty level, Netty-based frameworks would benefit from it | Can't modify Netty up-stream, unpredictable effects |

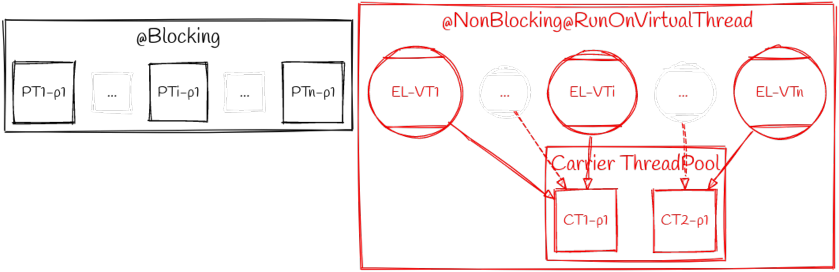
**Table:** Comparison of the different Quarkus-virtual-threads options


@NonBlocking
ELT2
ELT1
@Blocking
PT1-p1
...
PTi-p1
...
PTn-p1
@Blocking@RunOnVirtualThread
VT1
...
VTi
...
VTn
Carrier ThreadPool
PT1-p2
PT2-p2

# Reusing event-loops



# "Virtualizing" Netty event-loops



**Conclusion**

The event-loop can't reuse locks *as a carrier*

| Strategy | Pros | Cons |
|---|---|---|
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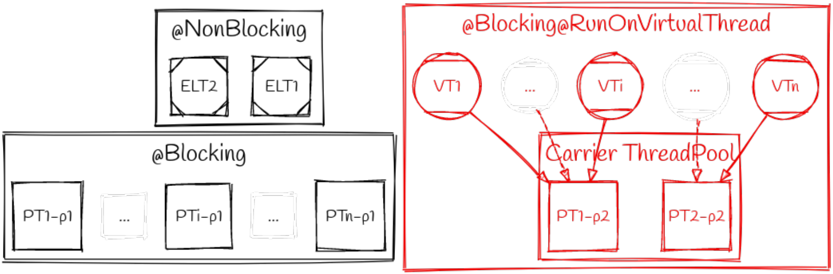
**Table:** Comparison of the different Quarkus-virtual-threads options

# Final Choice: Forking the worker model



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## Goal

Measure how performance of the application is affected by replacing reactive endpoints with virtual-threads offloading

## Hypothesis

**Quarkus-virtual-threads** should perform better than **Quarkus-blocking** but not as well as **Quarkus-reactive**

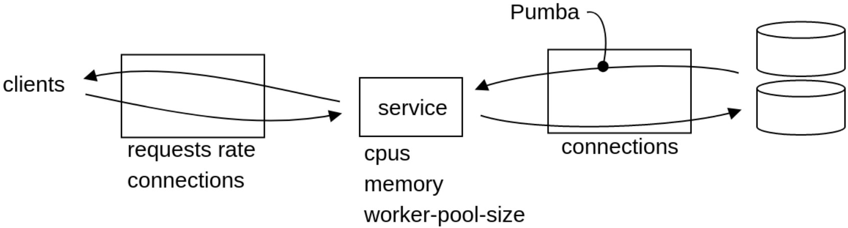
## Limited resources

- 512MB memory
- 0.5 vCPU
- 256MB heap

## Fault-inducing settings

- 200ms of delay between the DB and the server
- Hyperfoil to avoid Coordinated Omission

# Elements of the experiment



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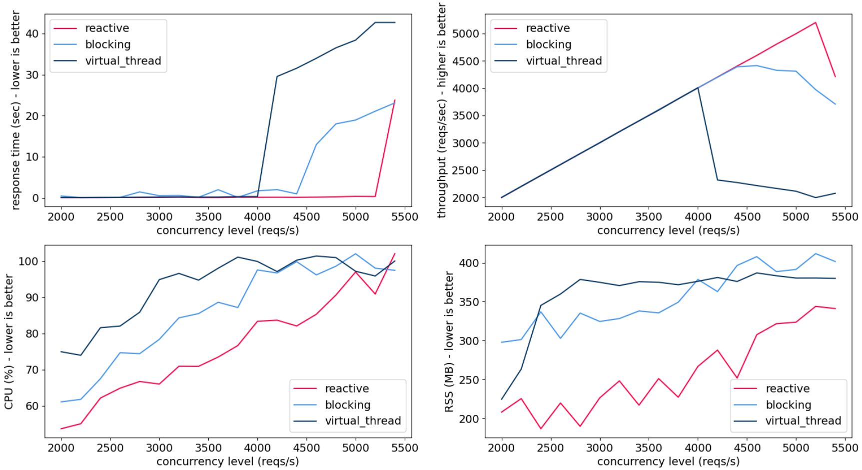
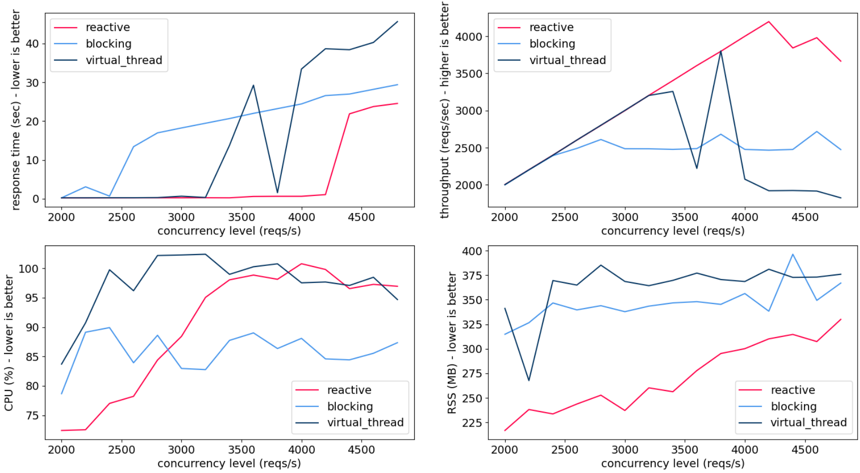
# Results without delay



# Results with 200ms delay



# Garbage Collection detail

| | Quarkus-virt-threads-0 | Quarkus-virt-threads-200 |
|---|---|---|
| Max-latency | 1.44 s | 31.54 s |
| GC count | 275 | 709 |
| Avg pause | 18.662 ms | 92.270 ms |
| Longest pause | 89.723 ms | 520.437 ms |
| Young Collection time | 5.132 s | 41.685 s |
| Old Collection time | N/A | 23.734 s |
| Sum of pauses | 5.132 s | 65 s |

| | Quarkus-reactive-0 | Quarkus-reactive-200 |
|---|---|---|
| Max-latency | 1.08 s | 704.64 ms |
| GC count | 192 | 183 |
| Avg pause | 15.169 ms | 14.968 ms |
| Longest pause | 32.898 ms | 49.312 ms |
| Young Collection time | 3.004 | 2.739s |
| Old Collection time | N/A | N/A |
| Sum of pauses | 3.004 s | 2.739 s |

# Explaining longer Garbage Collection

- Too many virtual threads exist in memory at the same time.
- Data structures generated by Quarkus/Netty pollute memory.

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# Conclusions

- Although *Quarkus-virtual-threads* outperforms *Quarkus-blocking* in the context of the experiment, it still does not scale to the concurrency of *Quarkus-reactive*.
- Memory consumption is especially high for *Quarkus-virtual-threads*.
- Virtual threads are not directly responsible for the high memory consumption.
- Data structures generated by *Quarkus/Netty* are the main memory consumers.

*The integration of virtual threads in frameworks built on top of Netty or that rely heavily on ThreadLocals, presuming a small thread count, is likely to experience significant garbage collection (GC) pressure.*