MeSHwA: The case for a Memory-Safe Software and Hardware Architecture for Serverless Computing

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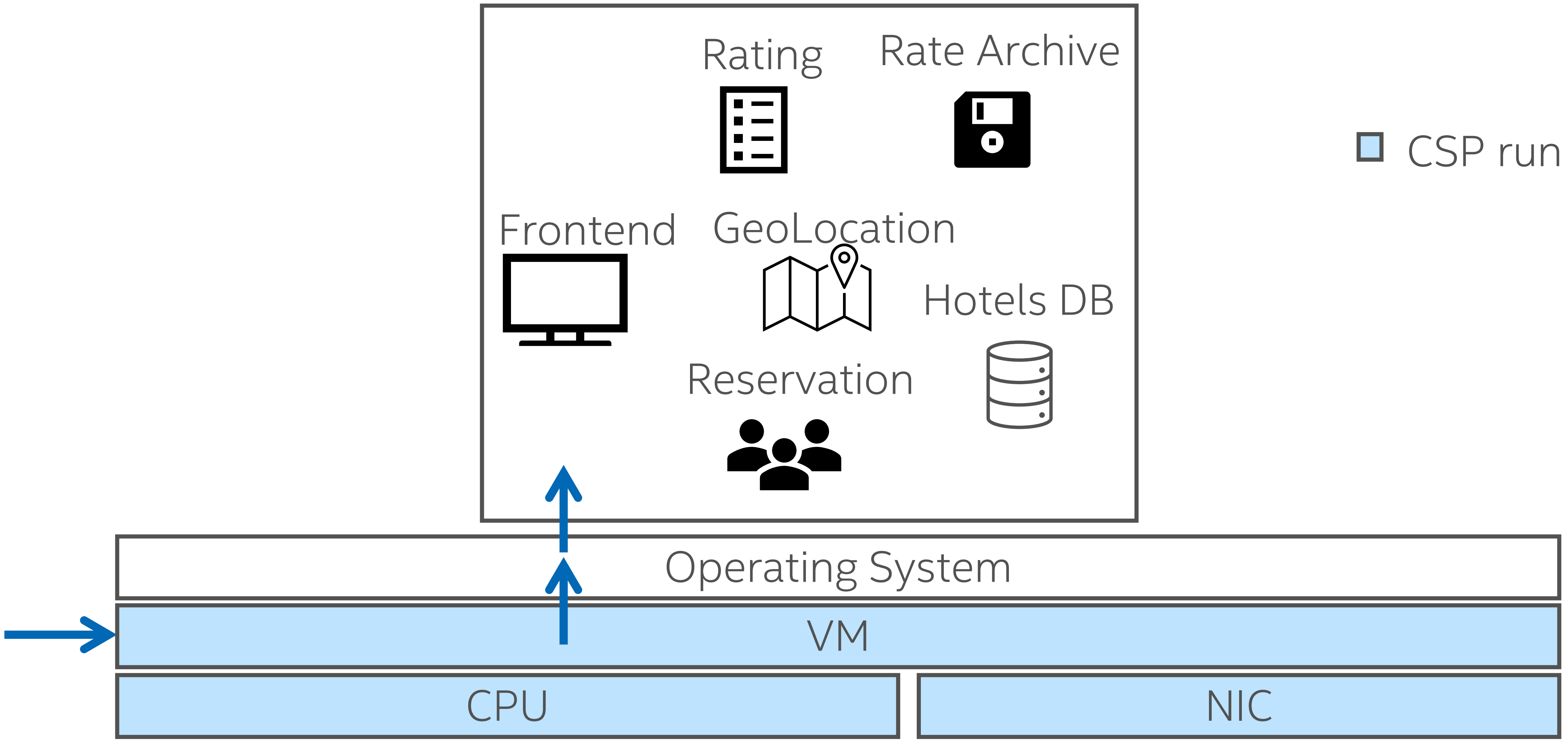
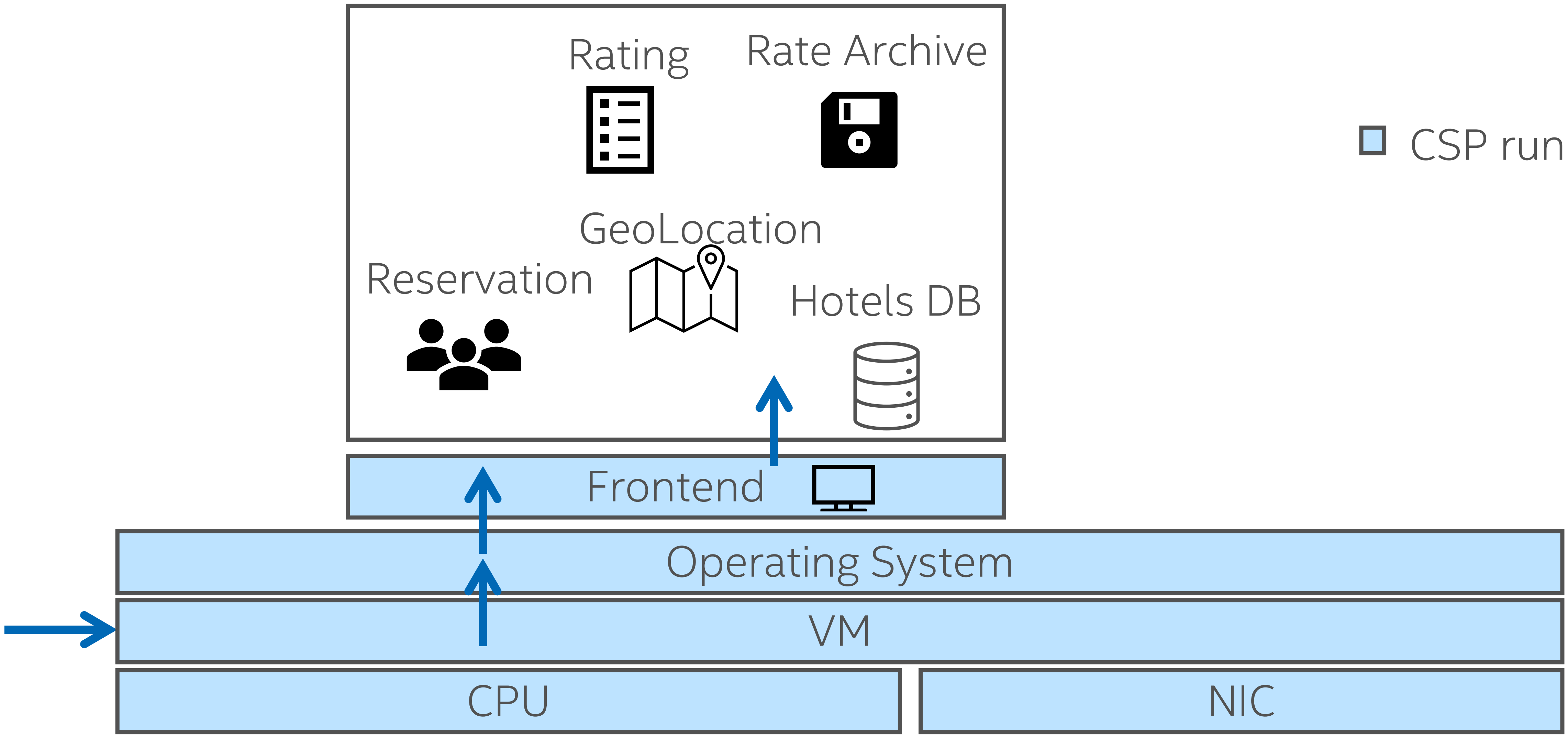
Monolithic Webservices

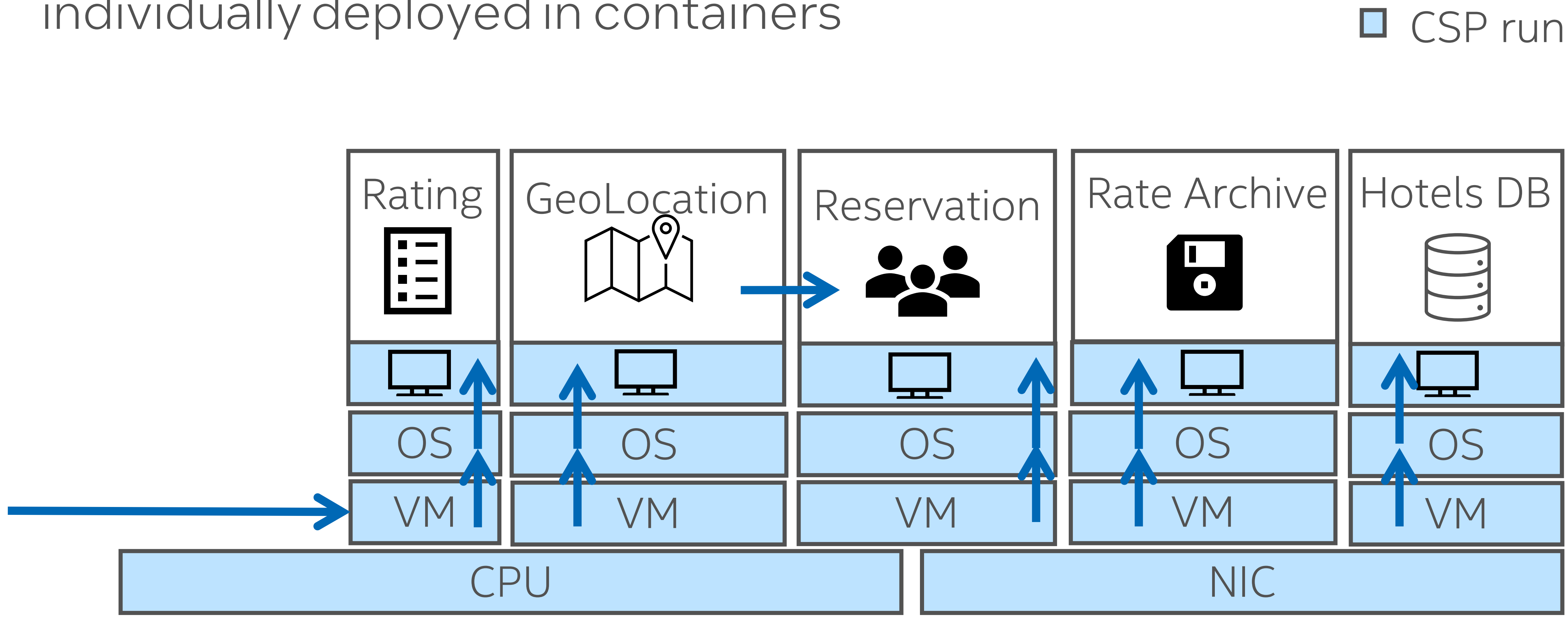


Monolithic Serverless Computing



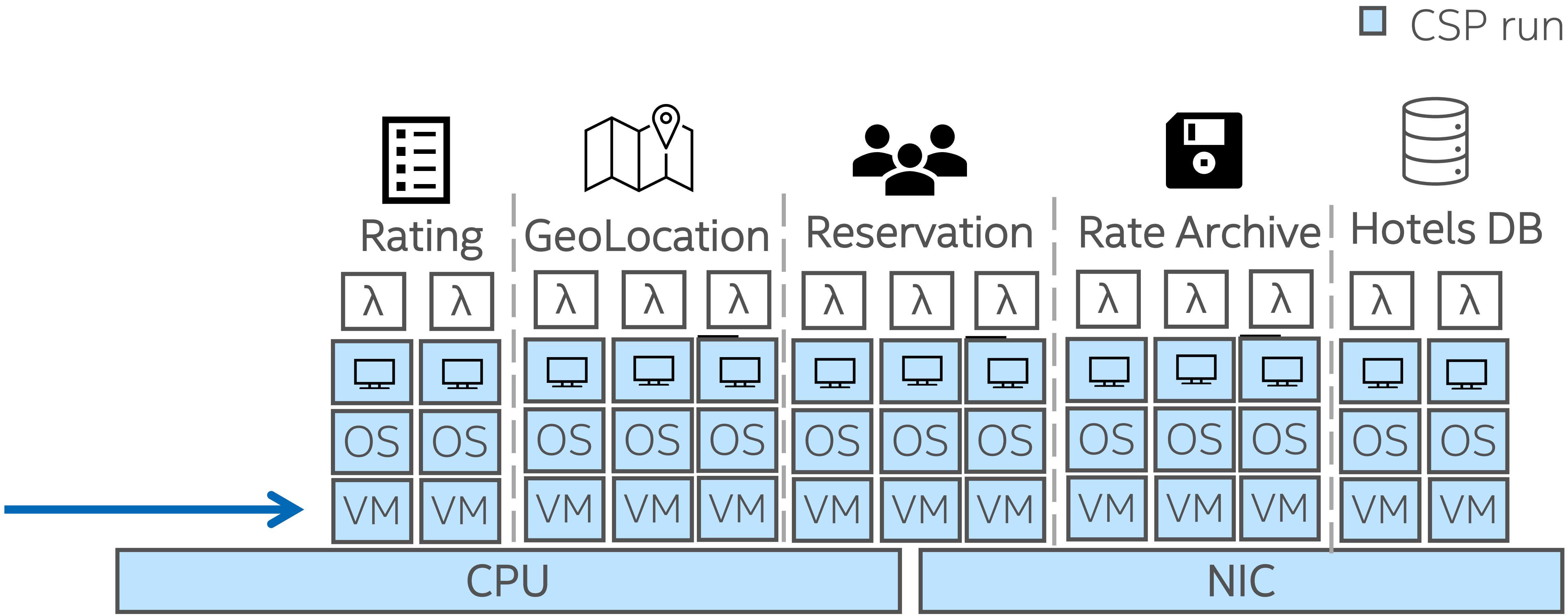
Monolithic to Microservices

Decompose service into communicating functional units individually deployed in containers



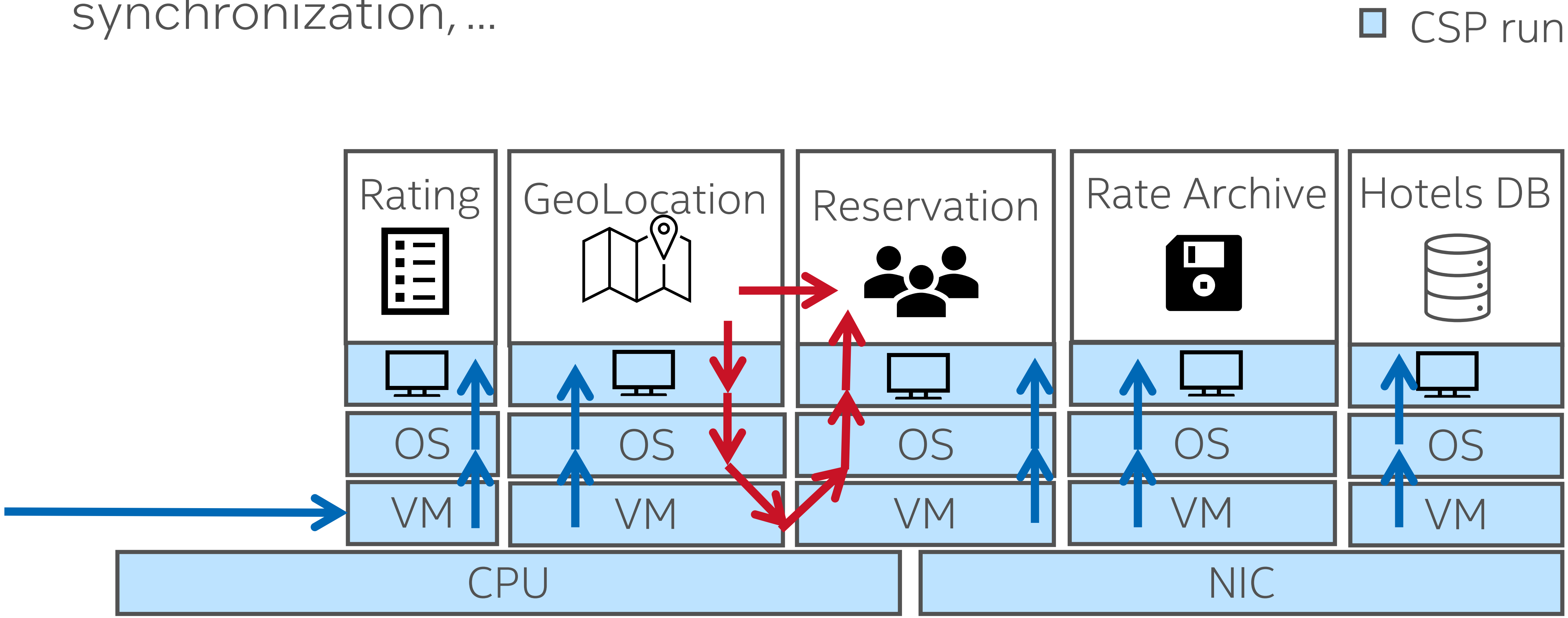
Microservices to Function-as-a-Service (FaaS)

Decompose even further into functions triggered when needed



Emergence of Infrastructure Tax

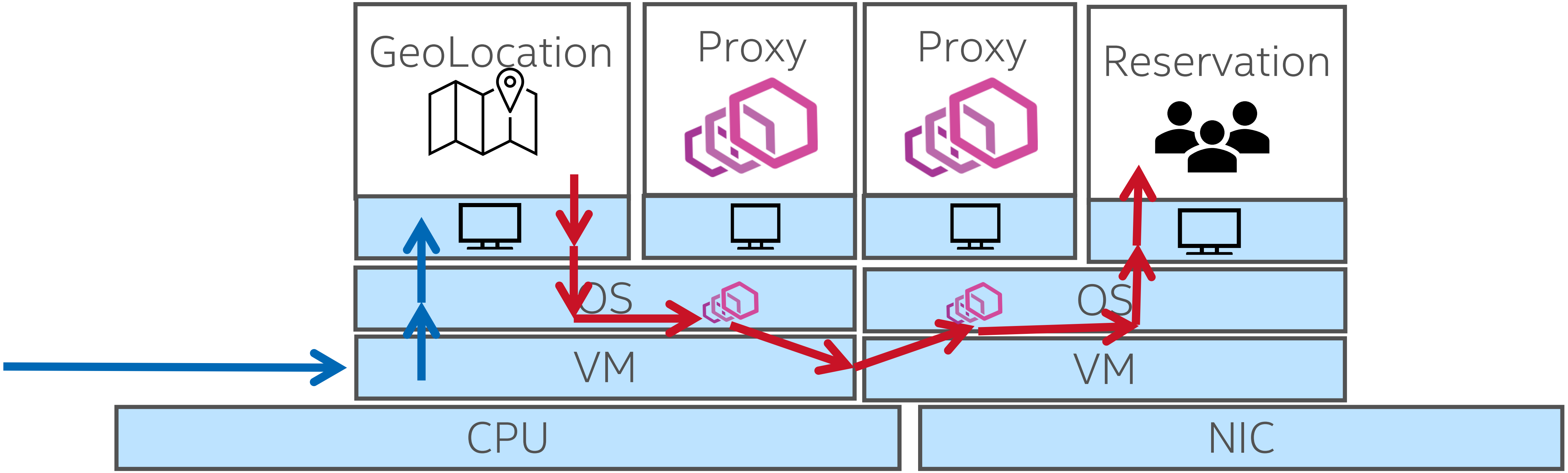
- 25% of CPU cycles spent on marshalling, memory copy, synchronization, …



Service Meshes and Proxies

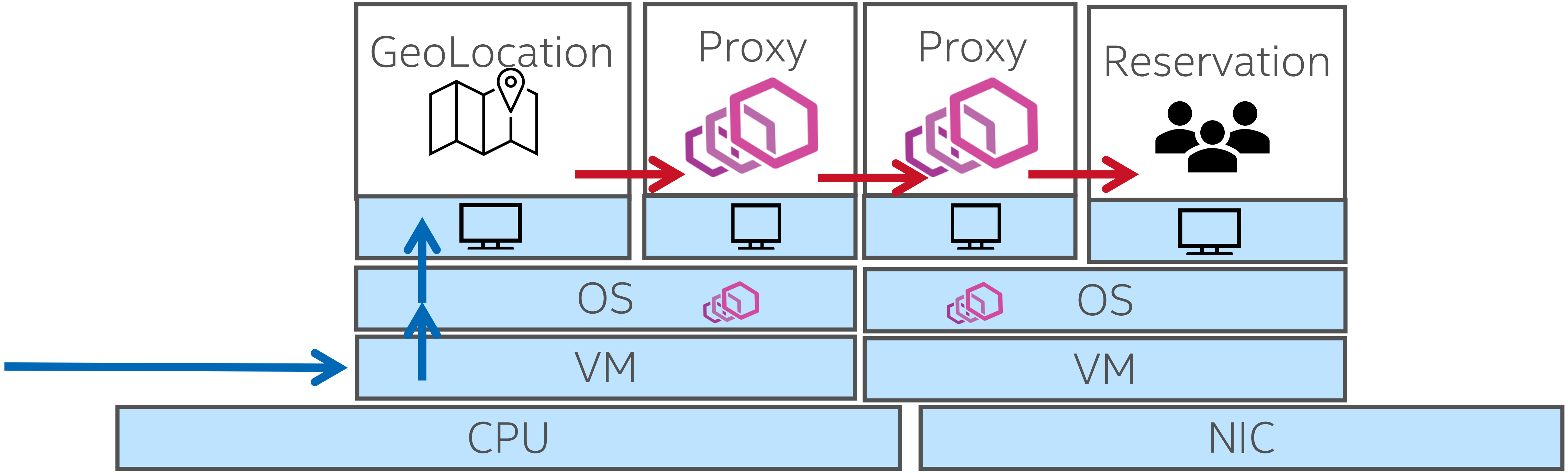
- Proxy encapsulates service functionality (e.g., load balancing)
- eBPF proxies reduced overhead, still observable

CSP run



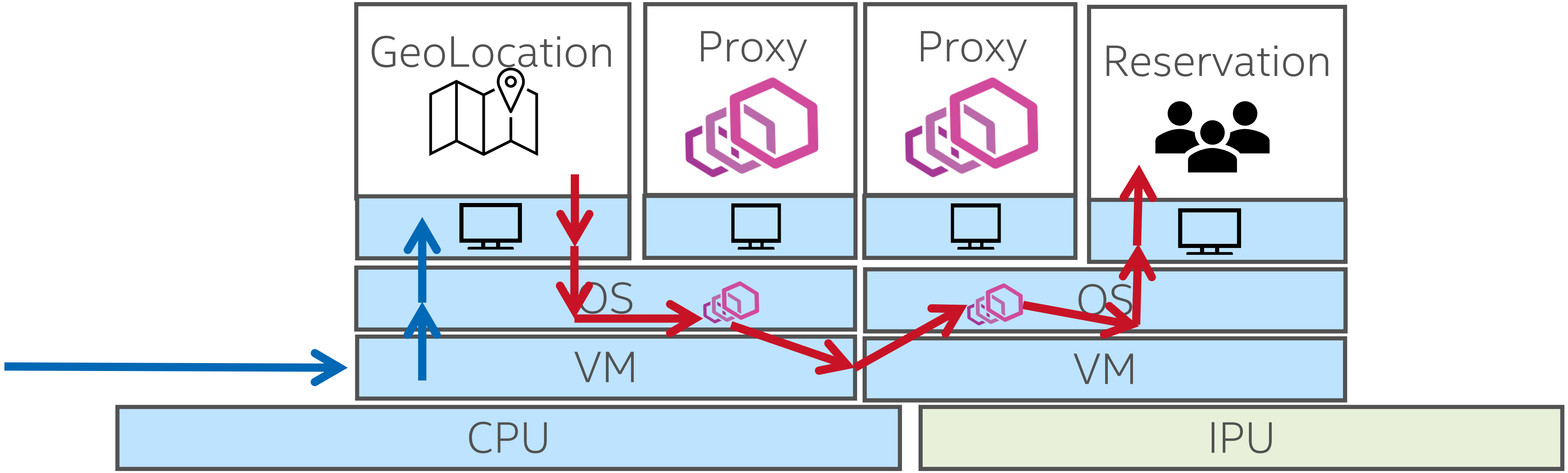
Shared memory as an alternative?

- Involves marshalling and copying of objects
- Needs synchronization or polling
- Needs library capable of regular and shared-mem network



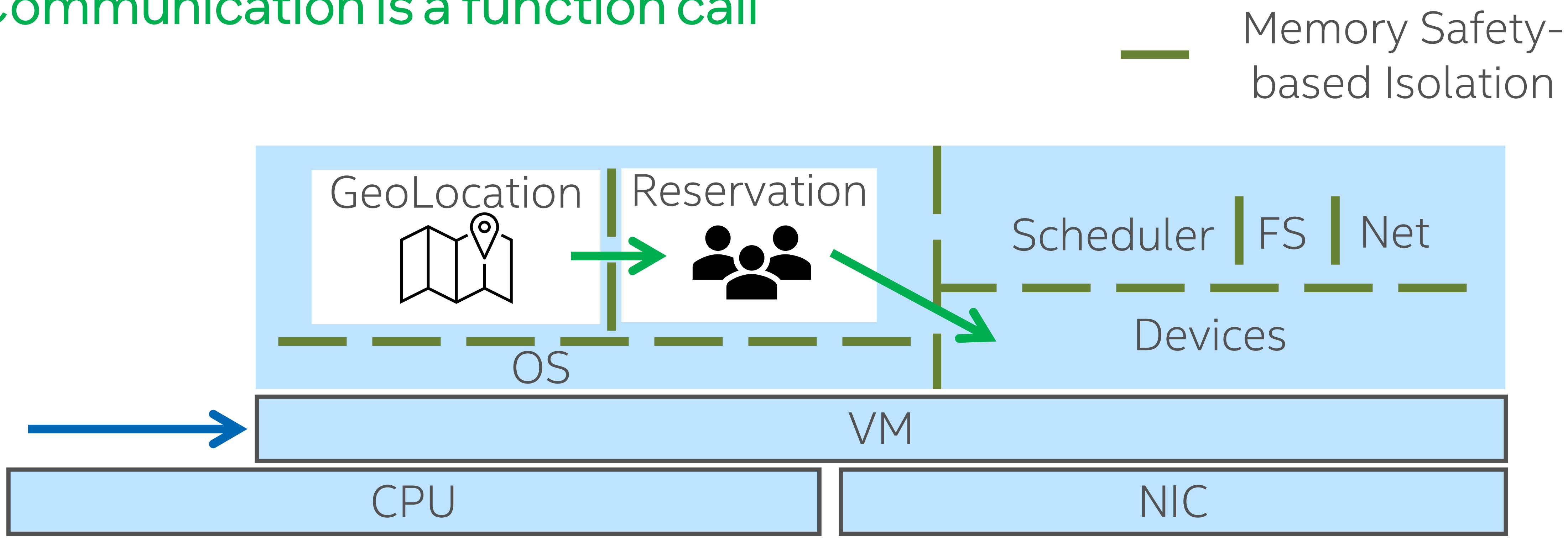
Infrastructure Processing Units (IPUs) as an alternative?

- Offloads cost to cheaper HW, freeing main CPU
- Focused on remote communication



Memory-Safe Software/Hardware Architecture (MeSHwA)

- Execute in single address space
- Isolate using memory-safety guarantees of languages and RT
- ➢ Communication is a function call



Co-Designing the Software/Hardware Tradeoff

Software-only

Software defines computation;
Hardware defines execution abstraction.

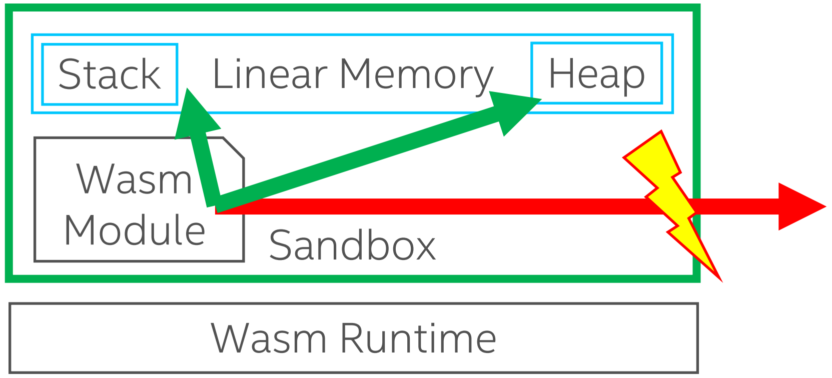
Rise of Memory-Safe Languages and Runtimes

- Provide safeguards for memory accesses and control flow

- Microsoft/Google report 70% of security vulnerabilities caused by memory safety violations
  - Microsoft, Google, Amazon, FB, NSA urge use of memory safe languages

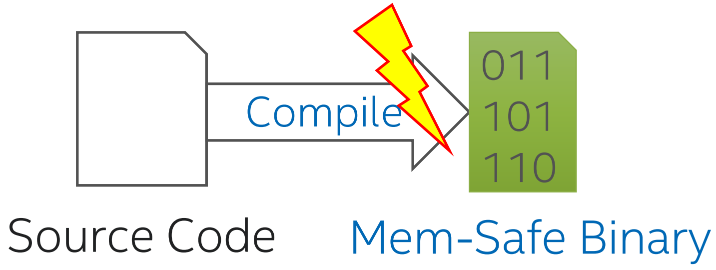
Examples: Webassembly/Rust

WEBASSEMBLY



- Compilation target for common languages (e.g., C/C++, Rust, …) and interpreters (e.g., Python)
- Light-weight isolation to Sandbox memory
- Performance 1.5-2x of native

Rust



- Compiler enforced memory safety
- Incremental adoption
  - Interfaces with legacy software (C/C++)
  - No VM/runtime
- Predictable Performance comparable to C/C++

MeSHwA Isolating Services

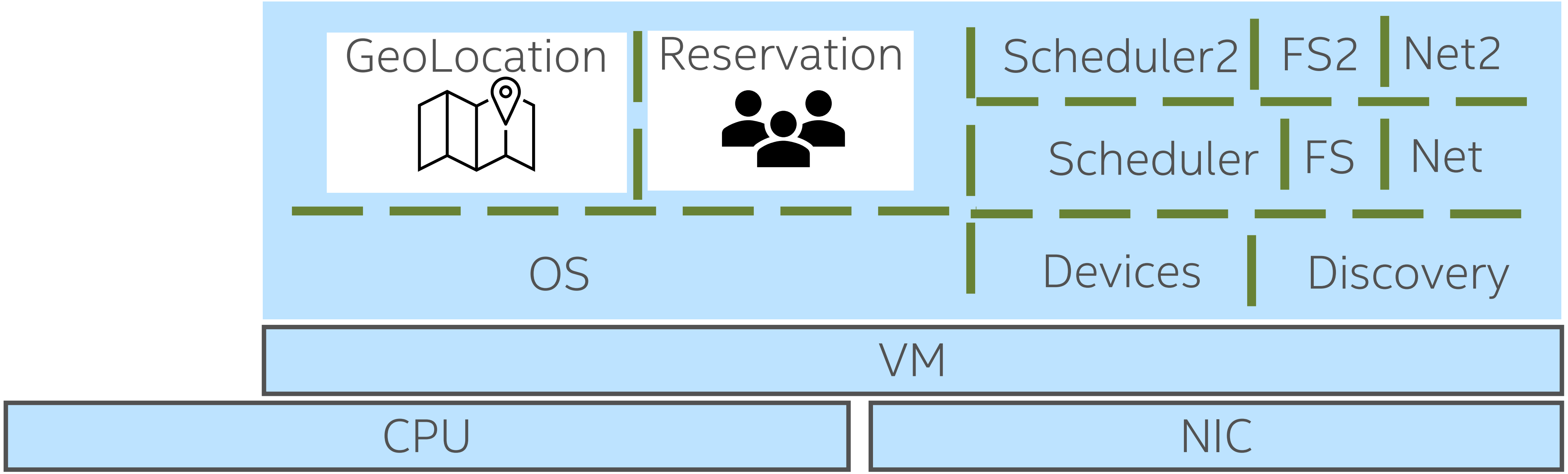
- Unifying abstraction across different languages and runtimes

- Restricting memory view
  - Object-granular languages vs. VM-based runtimes
  - Sharing across multiple memory-safe services

- Restricting execution targets
  - Limited targets within the service
  - Single exit acting as router across services

MeSHwA Software Runtime

- Specialized common services
- Discovery of common services



MeSHwA Hardware optimizations: Sharing

- Software-only drastically improves sharing, but in some cases still requires copying

- Language support for foreign types
  - Rust provides foreign function interface, Wasm provides interface types
  - Memory ownership unclear across services

Extend research in ownership across applications

- Capability-based Hardware
  - CHERI or Cryptographic Computing
  - Hardware pointer represents memory access privilege

Apply capability-based hardware to single address space

Conclusion: MeSHwA

- Serverless Microservice/FaaS development and deployment model demands SW/HW architecture improvement
- Recent advances in memory-safe languages and runtimes suggest stronger reliance on software
- MeSHwA argues for a single address space, memory-safe environment with optimized hardware

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Software-only
Hardware provides
compute only

MeSHwA

Software controls
computation only
Hardware controls