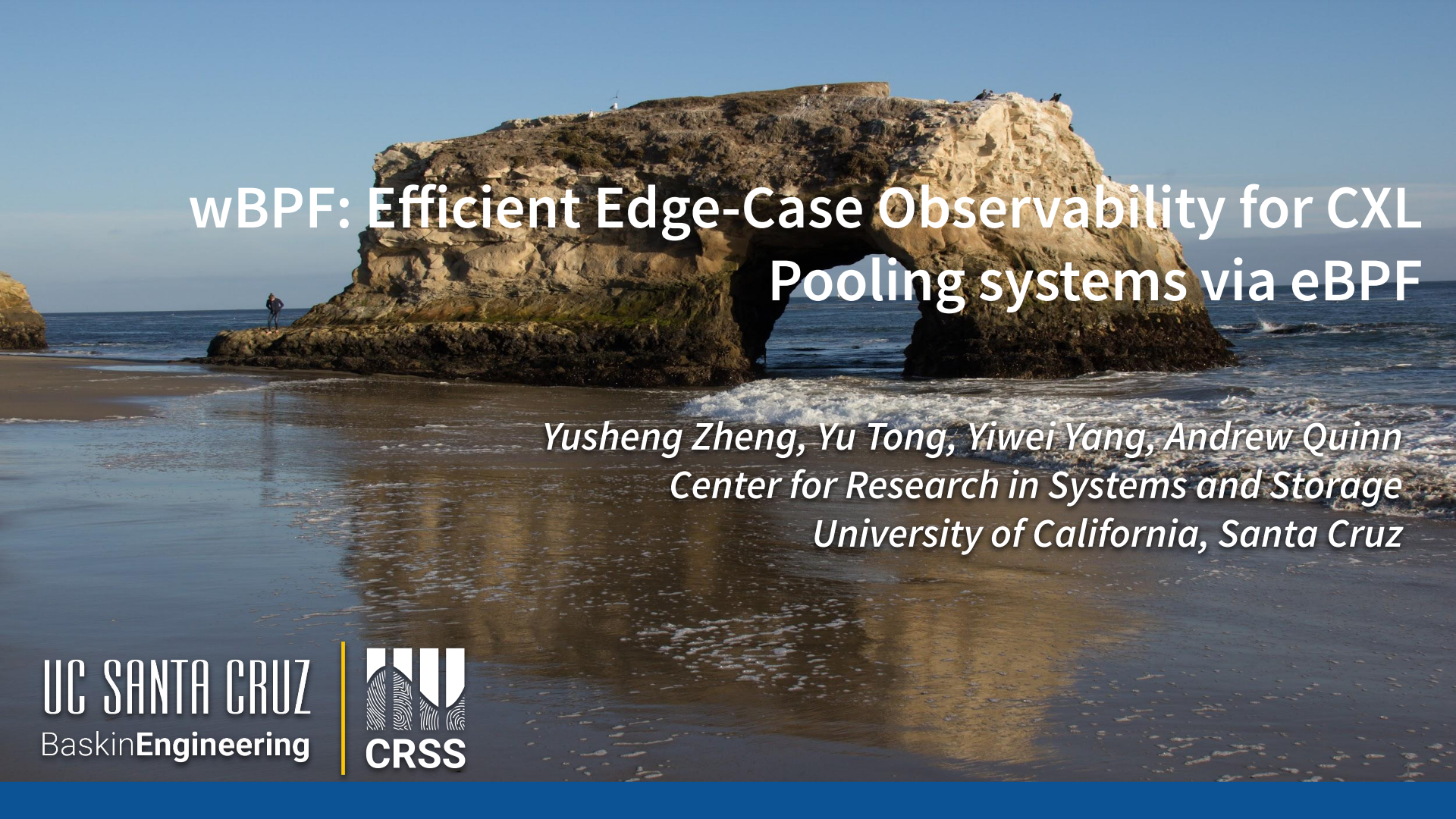

wBPF: Efficient Edge-Case Observability for CXL Pooling systems via eBPF

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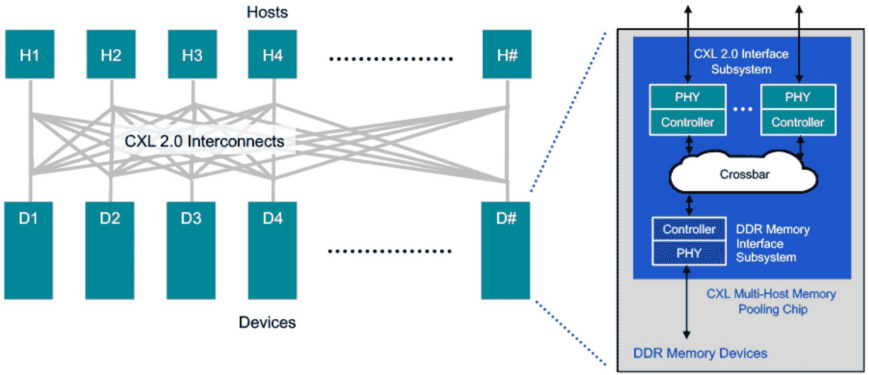
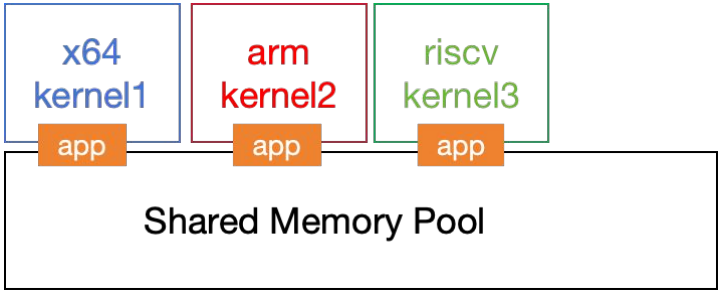
CXL Pooling system is booming…

- High Level idea:
  - Use cache coherency to replace distributed socket calls.
  - No serialization and deserialization cost
  - CXL3.0 memory pooling enables multiple hosts to share pooled memory devices via low-latency interconnects.

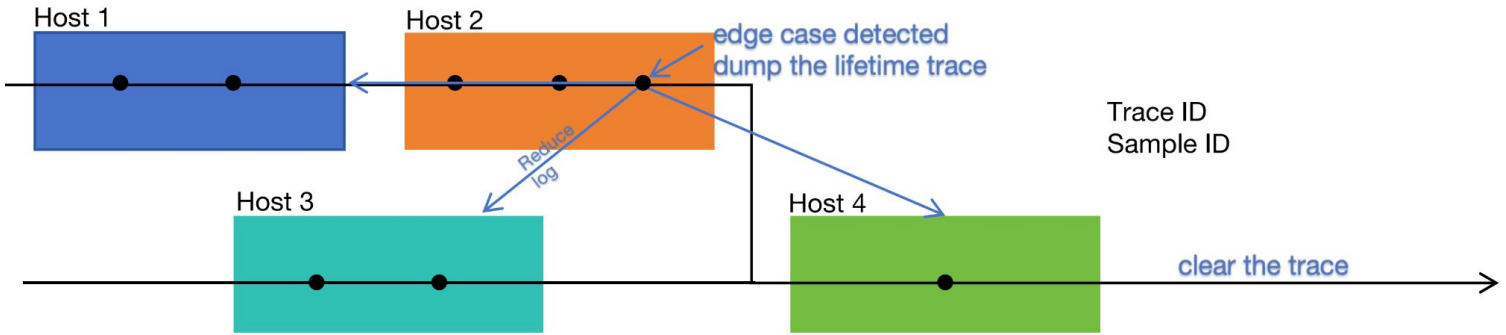




- Global I/O-free Shared Memory Objects (GISMO) by MemVerge
- Concord a FaaS distributed Caching Scheme over CXL by UIUC Jovan

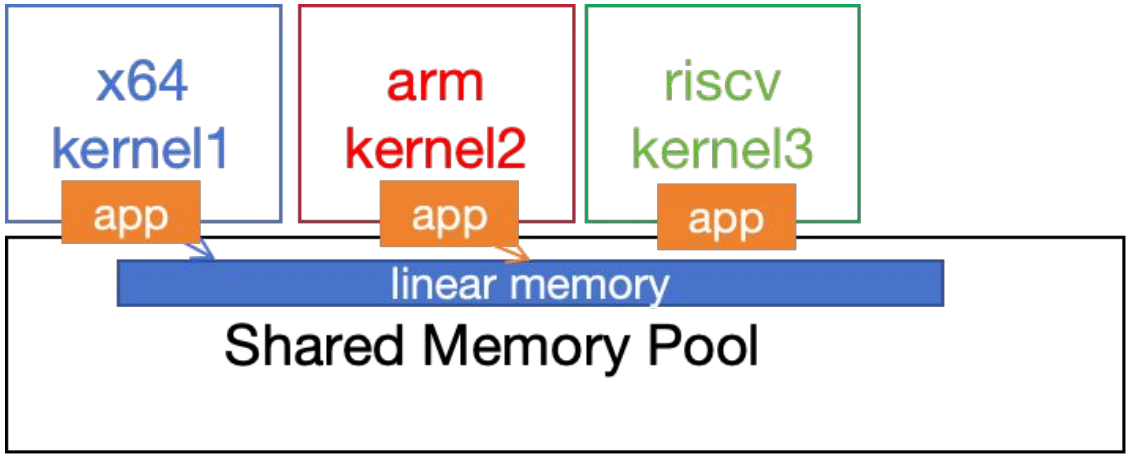
Challenges CXL memory pooling faces

- Unexpected tail latency from CXL pooling (cite).
- Concurrency bugs caused by multi-host memory environments, especially when using multiple memory models (e.g., ARM and x86) (cite)
- Existing academic (e.g., Hindsight) and industrial (e.g., Jaeger) tracing tools are designed for distributed systems and are incompatible with the shared memory setup of CXL pooling.



wBPF Design Overview

- Use lightweight language virtualization, in the form of WebAssembly, to provide a unified platform across heterogeneous systems.
  - Solves the concurrency and consistency problems that arise from sharing memory across heterogeneous hosts.
- Use a on-demand tracing library that captures detailed traces in a small ring buffer locally, and only outputs when anomalies occur.
- It is a fully automated system (i.e., it detects what to put in the ring buffer)



Semantic Probing

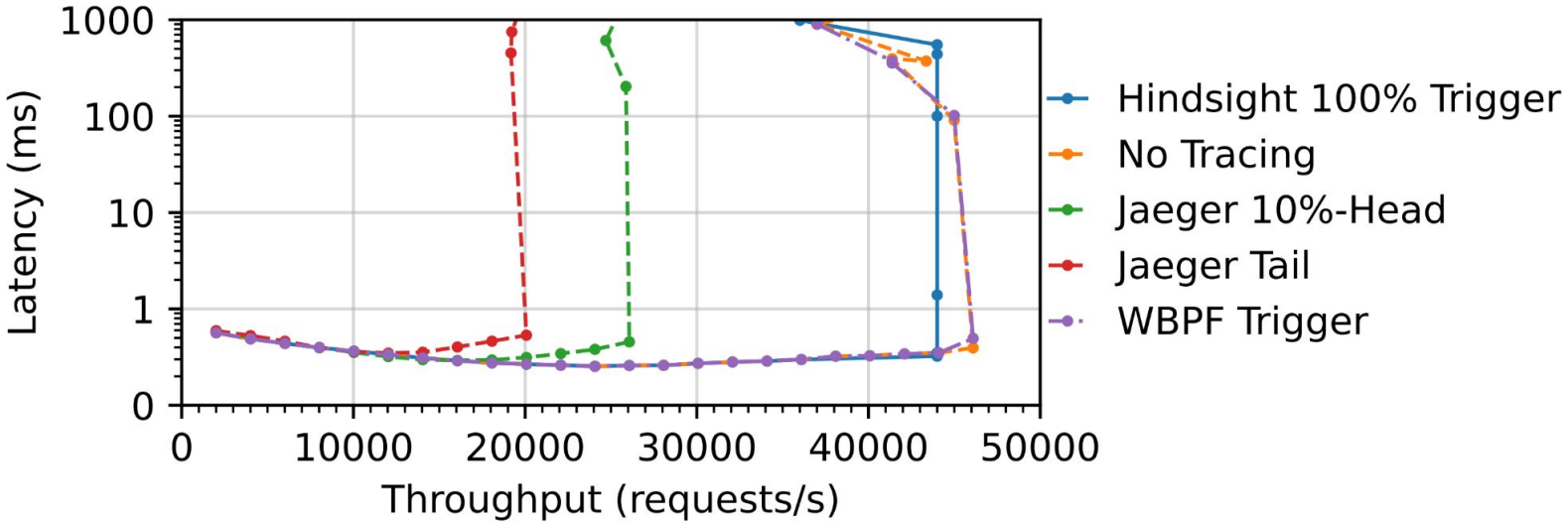
- 1. How does wBPF know what to put in the ring buffer? Applications use a variety of APIs that wBPF needs to support!
- 2. How does wBPF know when an anomaly occurs? The notion of an anomaly is application specific!

- Proposed solution: LLMs!
  - LLM suggests what parts of the program to trace and what relates to an anomaly
  - Run program in testing environment and collect traces.
  - pass traces to LLM to see if it is satisfied that the traces explain the anomalies.
  - Repeat as necessary.

Use Case: Low Overhead Tracing

- **Machine: single socket epyc 7742 with 256GB DDR4 Memory**
  Workloads: 2 services MicroBrick benchmarks

- **Minimal Performance Impact**
- **Throughput vs Latency**



Future Work

- **Scalability** – deploying wBPF in larger, multi-pool environments and ensuring its overhead stays predictably low as trace volume increases.
- Enriching the **semantic analysis**, possibly using more advanced AI models to cover a broader range of invariant violations.
- **Integrating** wBPF with existing distributed tracing ecosystems (like OpenTelemetry), so that memory pool traces can be correlated with application-level traces.
- As CXL technology evolves (e.g., CXL 3.0 with memory sharing between hosts), wBPF could be adapted to trace new usage models, making it a continuous asset for **future heterogeneous, composable systems**.