Edge-Cloud Support for Predictable, Global Situational-Awareness and Control for Autonomous Vehicles

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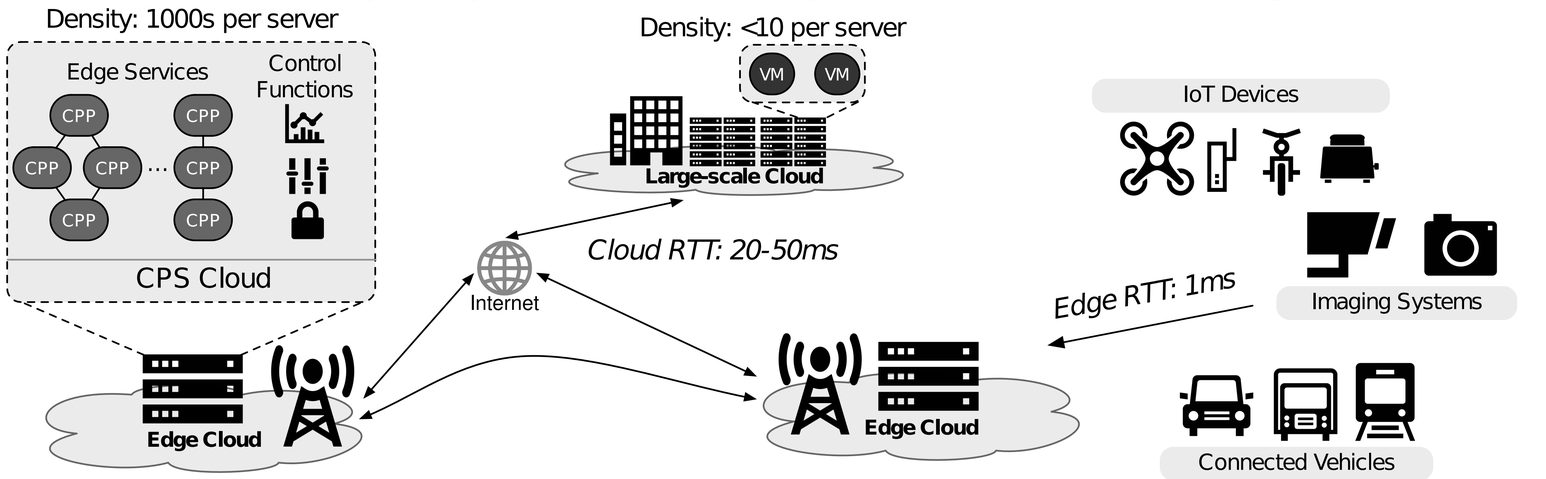
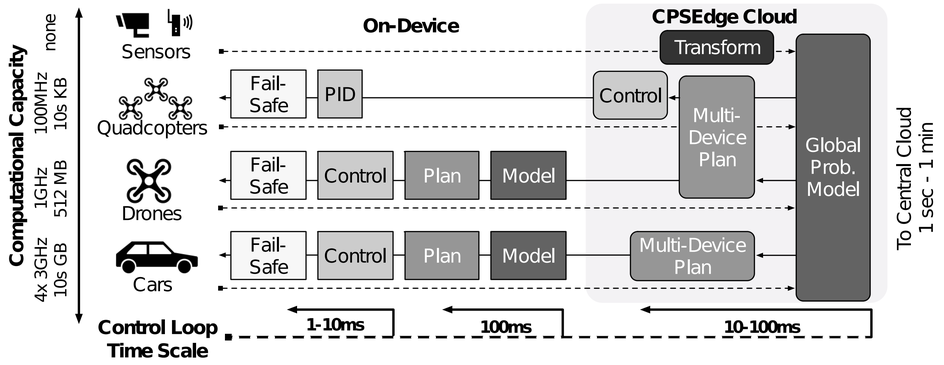
Historically, latencies to the network edge (e.g. basestation) and to the cloud were so high as to make network-accessible planning and control of limited utility. However, with fast city-scale wireless around the corner (5G) with 1ms round-trip times, moving computation to the edge has potential. Adding intelligence at the edge of the network will enable Cyber-Physical Systems by leveraging increased computation at the edge, and harnessing the information from all connected CPSes at the edge to make globally-aware planning decisions. To make the edge CPS-capable, existing cloud infrastructures are insufficient. Thousands of physical devices require edge multi-tenancy on a scale beyond cloud capabilities, and CPSes require tight end-to-end computation latency. CPSEdge is a systems infrastructure for to provide a CPS-aware, multi-tenant execution environment with strong isolation, and low-latency. CPSEdge will provide the next generation of autonomous vehicle control by safely and predictably providing edge-defined logic for global system awareness and control.

Latency Properties at the Edge enable CP offloading!



Integration of the Edge into CPS computations and interactions at various latencies



Key Edge Cloud Goals

- ***Density*** – need to support *per-tenant*, edge computations, and *per-CPS-device* computations – to ensure temporal isolation and optimization.
  → 1000s of time-critical *isolated* computations
- ***Real-time*** – latency-sensitive computation to adhere to the real-time latency requirements of CPSes and AVs.
- ***Security*** – Strong isolation between CP computations to protect the cyber-physical infrastructure.
- ***Global Situation-Awareness*** – sensor aggregation and processing in a shared edge infrastructure.
- ***Throughput*** – best use the limited resources at the edge

Key Abstractions

Cyber-Physical Processes (CPPs)
→ per-physical device, lightweight, high-churn, isolation

End-to-end packet scheduling
→ scale of IoT

Edge physical models and planning

CPS Edge Infrastructures

EdgeOS

- Separate chains of CPPs process each device's packets
- Lightweight, fast creation
  >10x faster than processes, >10000x faster than VMs/containers
- Controlled latency
  3x lower latency than Linux

USENIX ATC

Sledge

- Uses Webassembly and a user-level runtime to provide CPPs *in* Linux
- *3x lower latency than Linux, performance often within 10-30%, creation overhead > 10x faster*

Middleware, EMSOFT

2021 NSF Cyber-Physical Systems Principal Investigators' Meeting
June 2-4, 2021

Award ID#: 1837382