An Empirical Study of Artificial Intelligence Performance on Edge Devices

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The Ubiquity of Artificial Intelligence

- Artificial intelligence (AI) is the capability of a machine to make its own decisions without explicit commands
- Applications of AI
  - Autonomous vehicles – drones
  - Search engines – Google Search, Microsoft Bing
  - Intelligent virtual assistants – Siri, Cortana, Alexa
- Benefits of AI
  - Facial recognition
  - Smart manufacturing

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AI in Computing

	Cloud Computing Devices (e.g. AWS p3dn.24xlarge)	Terminal Devices (e.g. Raspberry Pi 4)
Network performance	100 Gbps	1 Gbps
CPU	Up to 96 vCPUs @ 3.1 GHz (turbo)	Quad core Cortex-A72 @ 1.5GHz
GPU	Up to 8 NVIDIA Tesla V100 GPUs (8x 5,120 CUDA Cores and 8x 640 Tensor Cores, double precision performance rated at 7 TFLOPS)	Broadcom VideoCore IV @ 250 MHz
Memory	768 GB, 256 GB (GPU)	8GB LPDDR4-2400 SDRAM
Cost	High $26.928/hour	Low $55 one-time purchase
Real-time processing	Lower (~10s latency AWS Aurora)	Higher (~3600us latency)
Main uses	Training	Inference

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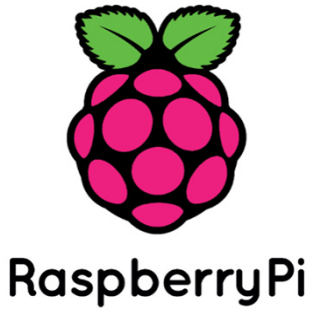
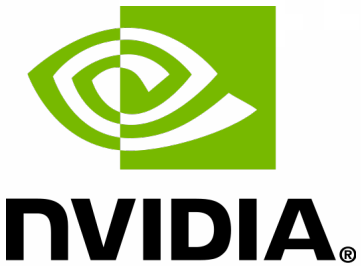
AI Applications and Hardware Manufacturers





The Purpose of Our Research

- We aimed to analyze the performance and resource utilization of AI workloads on edge devices
- The global market for edge computing is expected to reach over $16.5 billion by 2025 [1]
- Top three segments of edge computing expected by 2025 [1]
  - Connected cars
  - Smart grids
  - Security and surveillance

[1] https://www.alliedmarketresearch.com/edge-computing-market

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Our Experiment

- Two edge devices and one cloud instance were used in our research
  - Raspberry Pi 4
  - NVIDIA Jetson TX2
  - Amazon EC2 t2.xlarge
- AI Benchmark and MLMark were the benchmarks used to assess the performance of the devices

- AI Workloads that were evaluated
  - MobileNet v2, MobileNet v1
  - SSD-MobileNet v1
  - Inception v3
  - Inception v4
  - Inception-ResNet v2
  - ResNet-50 v2, ResNet-50 v1
  - ResNet-152 v2
  - VGG-16

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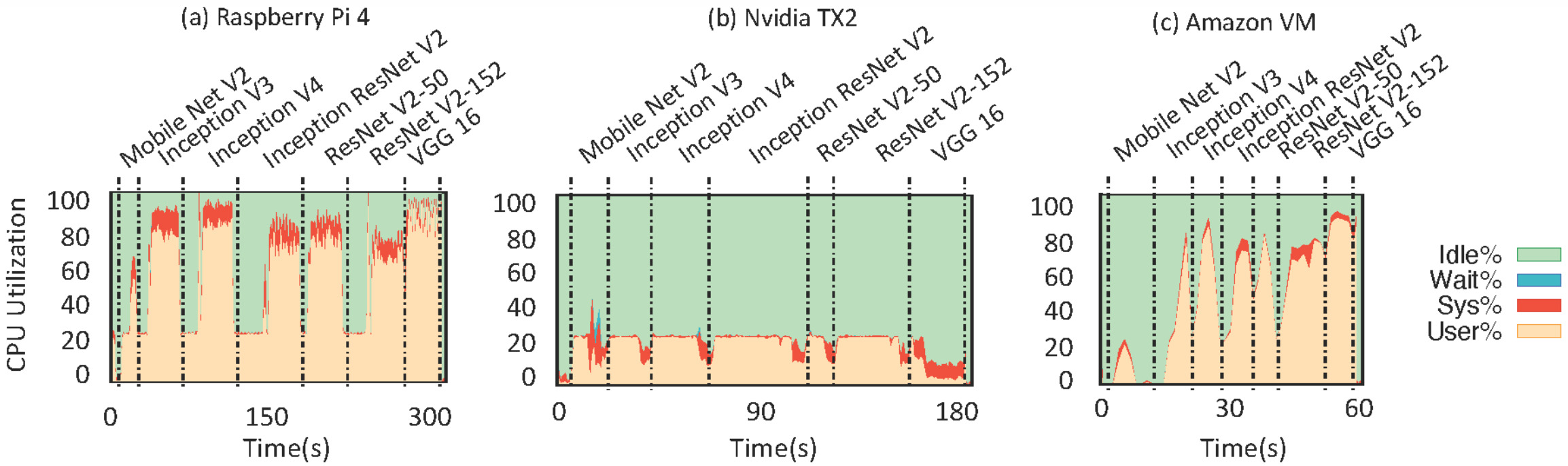
Our Results for CPU Utilization of Object Recognition Applications with AI Benchmark



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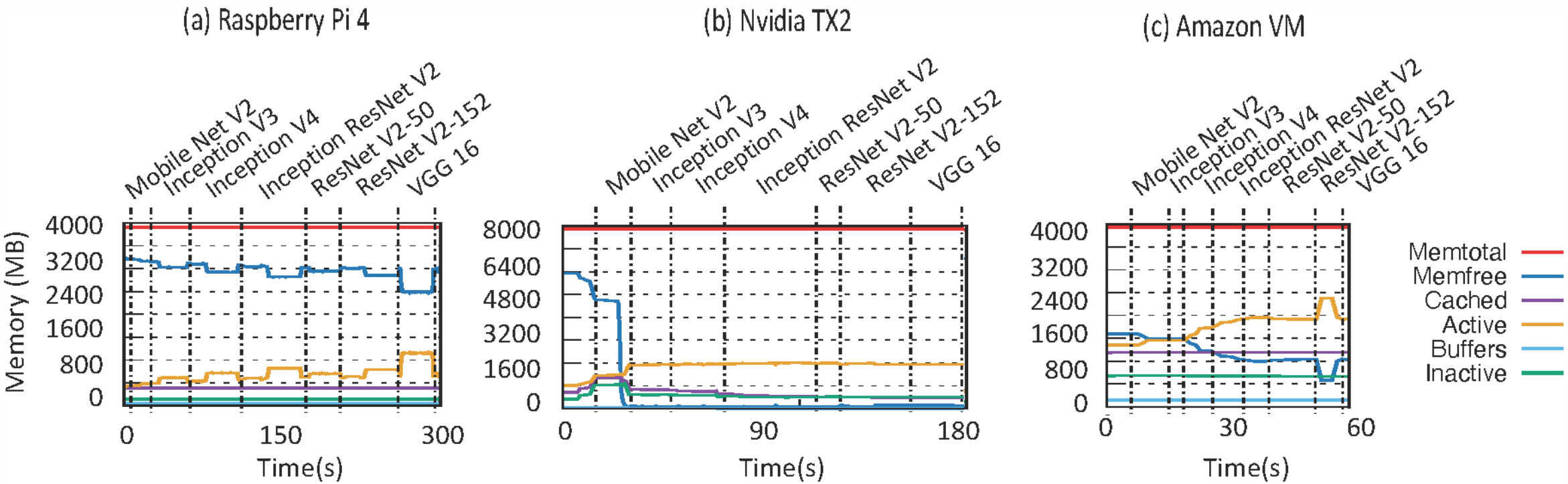
Our Results for Memory Utilization of Object Recognition Applications with AI Benchmark



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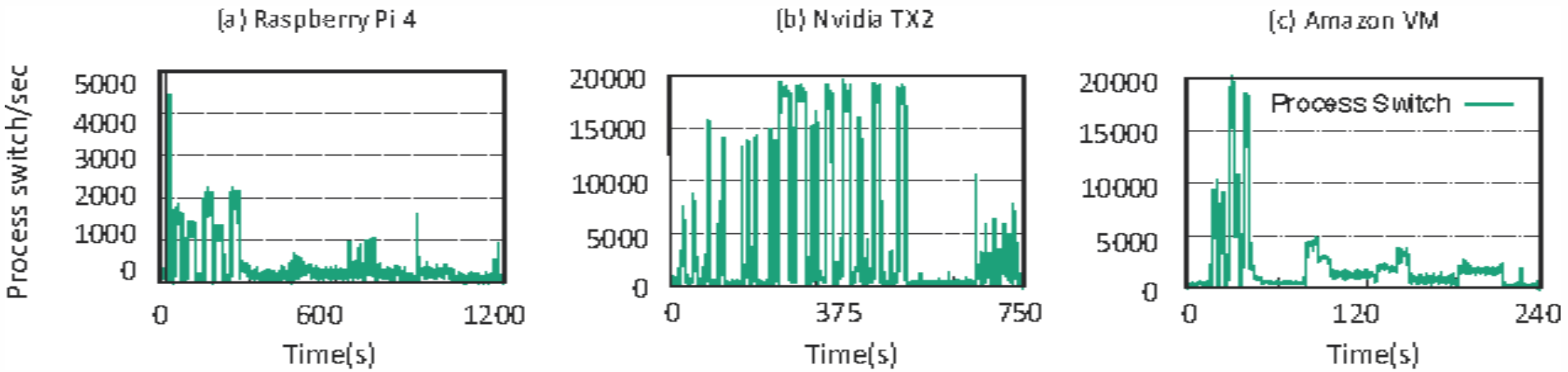
Our Results for Process Switching of Devices with AI Benchmark



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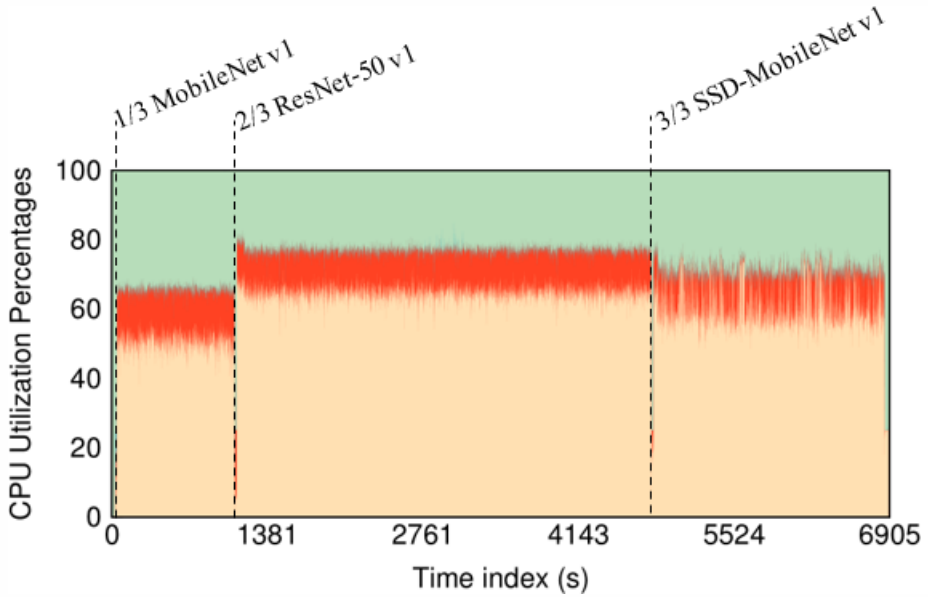
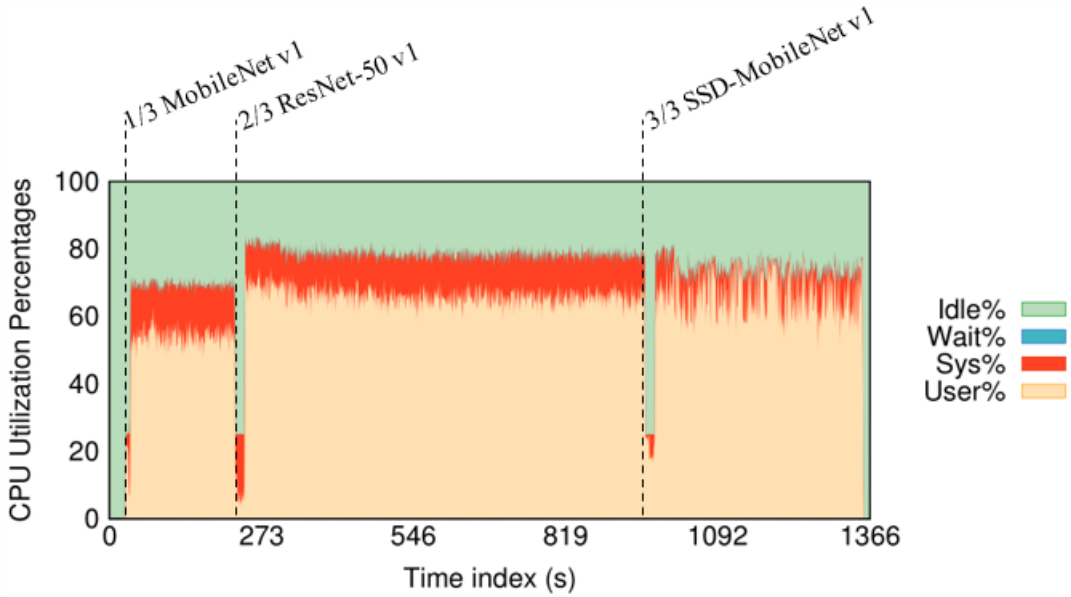
Our Results for CPU Utilization with MLMark on the Raspberry Pi 4



(a) CPU accuracy option



(b) CPU throughput option

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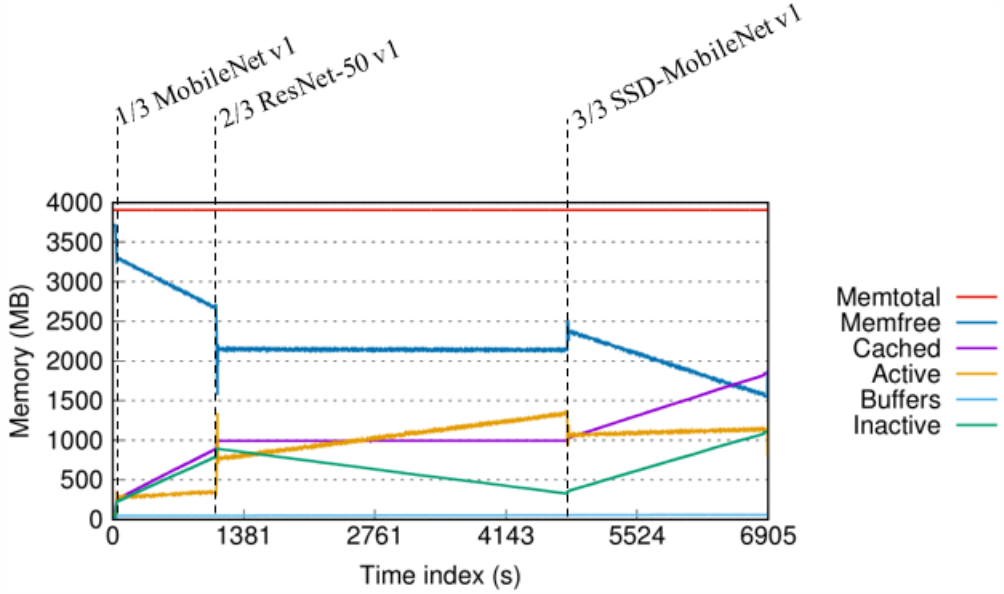
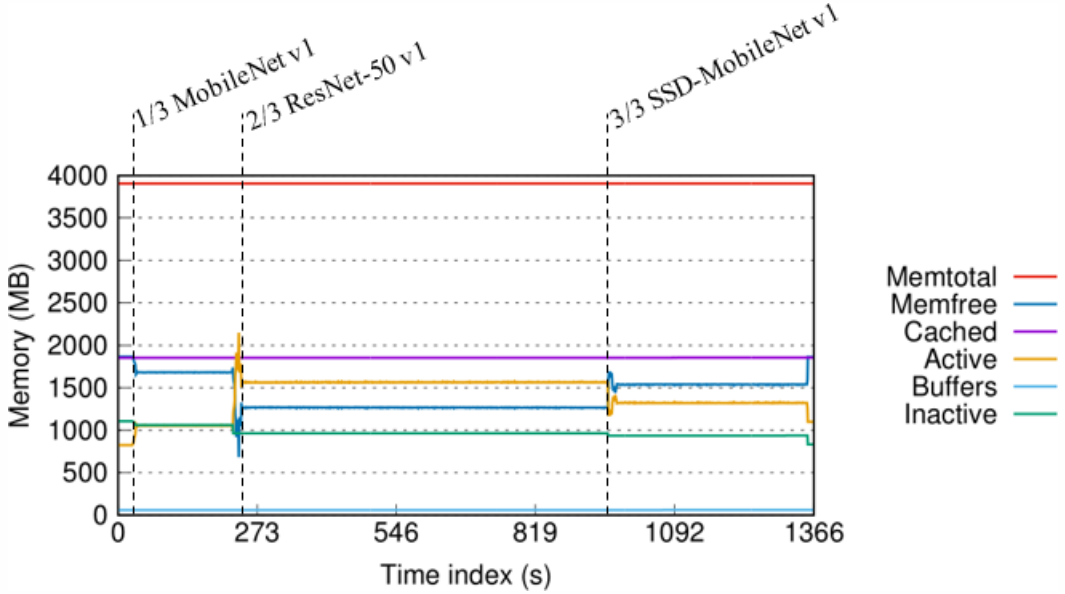
Our Results for Memory Utilization with MLMark on the Raspberry Pi 4



(a) Memory accuracy test



(b) Memory throughput test

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Our Analysis

- Depending on the system's needs, older AI models may perform better than their predecessors
  - MLMark (MobileNet v1) has a lower CPU utilization than AI Benchmark (MobileNet v2)
  - MobileNet v2 is not supported for some of its layers with certain GPUs
  - Newer models consume more memory
- VGG is not recommended to be deployed on edge devices because of its memory requirements
- Edge devices with more powerful GPUs utilize a smaller CPU percentage than cloud instances (NVIDIA Jetson TX2 vs Amazon EC2 tx2.large)

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Security Concerns with Edge Devices

- Default configurations have least restrictive options and minimal security features
  - WEPS/WPA enabled
  - FTP/HTTP enabled
  - Default credentials that are publicly published
- Outdated firmware
- Challenges in managing large-scale systems
- Confusing web user interfaces on networked devices
- Installed backdoors for legal reasons

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Thank You!

I would like to answer your questions

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