Improving the Efficiency of Future Exascale Systems with rCUDA

Carlos Reaño, Javier Prades and Federico Silla
Technical University of Valencia (Spain)

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Outline

- Introduction
- GPU Virtualization
- Approach proposed
- The NVIDIA Jetson TX1 system
- Performance evaluation
- Conclusions and future work

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- Current supercomputers:
  - √ Performance
  - ✘ Energy consumption

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  - √ Performance
  - ✘ Energy consumption
- **Desired** future supercomputers:
  - √ Performance: exaFLOPS
  - √ Energy consumption: 20 MW

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  - ✘ Energy (~165W)

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- ...plus high-performance accelerators (GPU):
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Introduction

- Current high-performance processors (Xeon):
  - ✓ Performance
  - ✘ Energy (~165W)
- ...plus high-performance accelerators (GPU):
  - ✓ Performance
  - ✘ Energy (~100W)
- Current low-power processors (ARM):
  - ✓ Energy consumption (~15W)
  - ✘ Performance

Introduction

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- Our proposal: heterogeneous platforms
  - Low-power processors (ARM)
  - Accelerated with remote HPC servers (Xeon + GPUs)
  - Remote HPC servers shared among all low-power processors

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- How improving efficiency of future exascale systems?
- Our proposal: heterogeneous platforms
  - Low-power processors (ARM)
  - Accelerated with remote HPC servers (Xeon + GPUs)
  - Remote HPC servers shared among all low-power processors
- How sharing? GPU virtualization
  - ✓ GPUs transparently shared among all cluster nodes
  - ✘ Virtualization framework overhead
  - ✘ Network overhead (high-performance interconnection!!)

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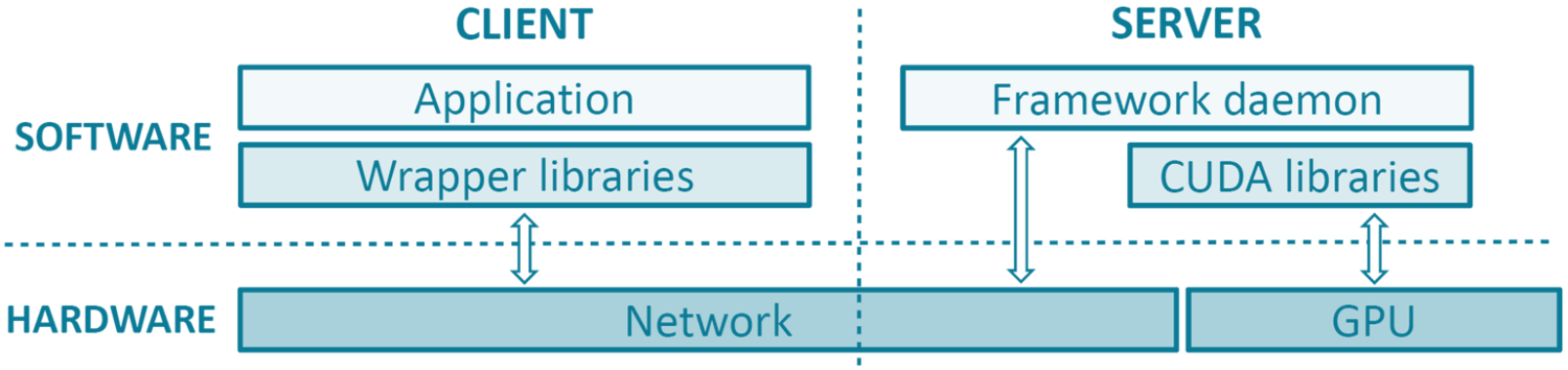
- General architecture remote GPU solutions:



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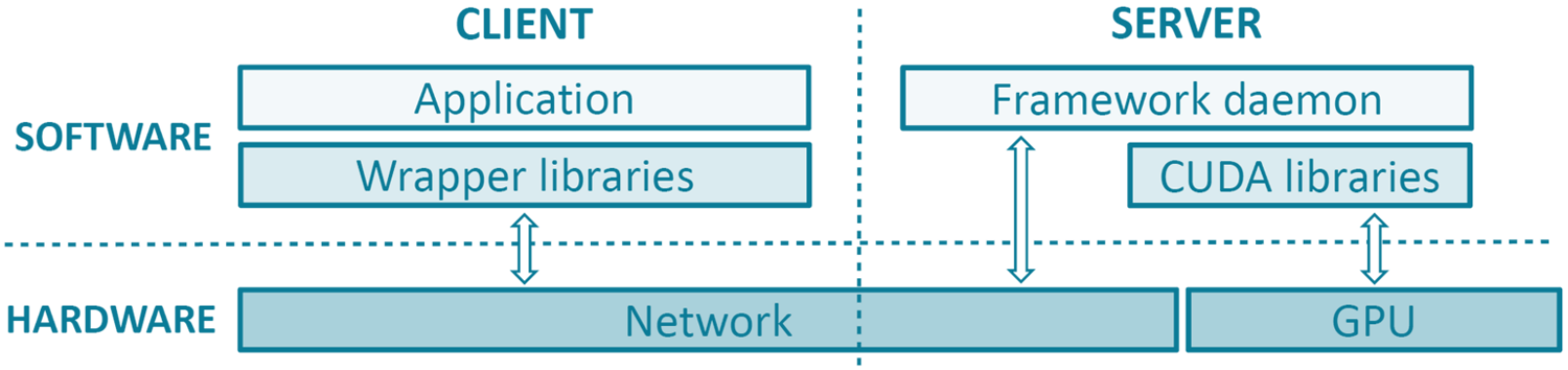
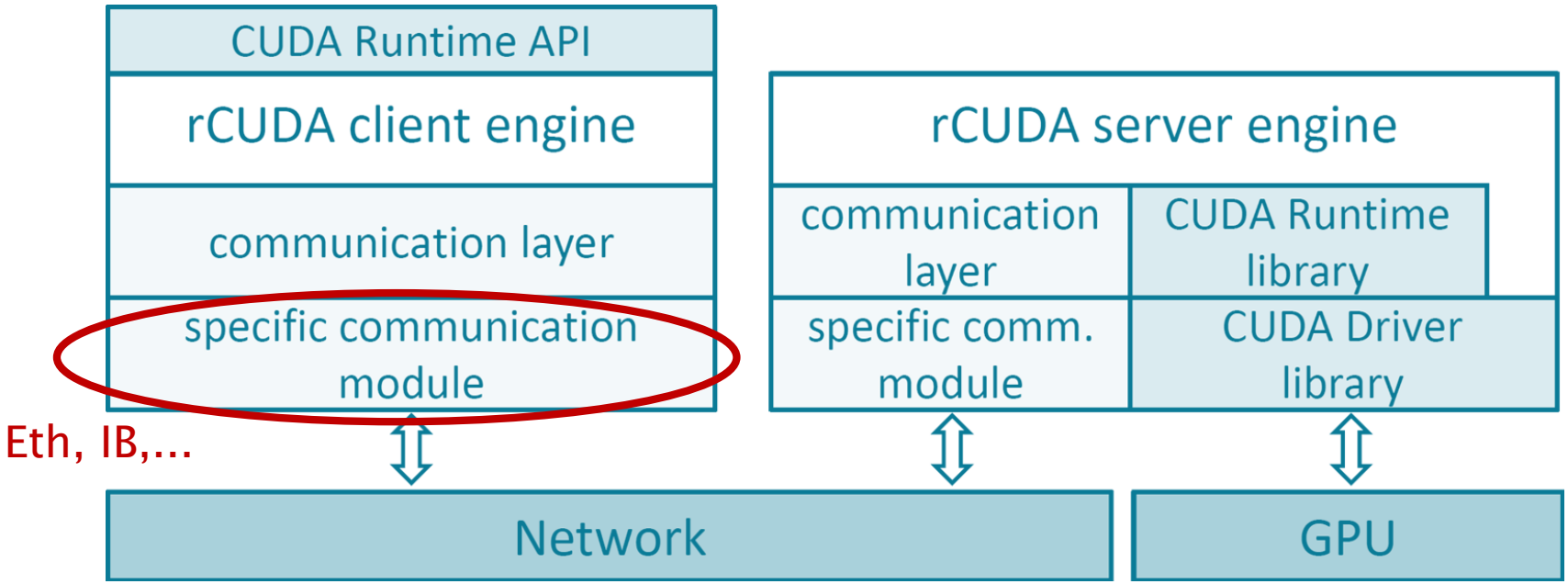


- Existing solutions: **rCUDA (www.rcuda.net)**
  - rCUDA: freely available, supports CUDA 8

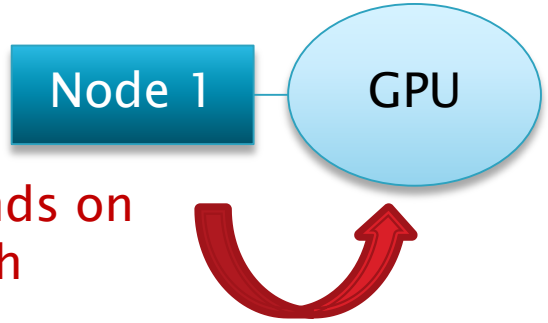
GPU Virtualization

- rCUDA communication architecture:

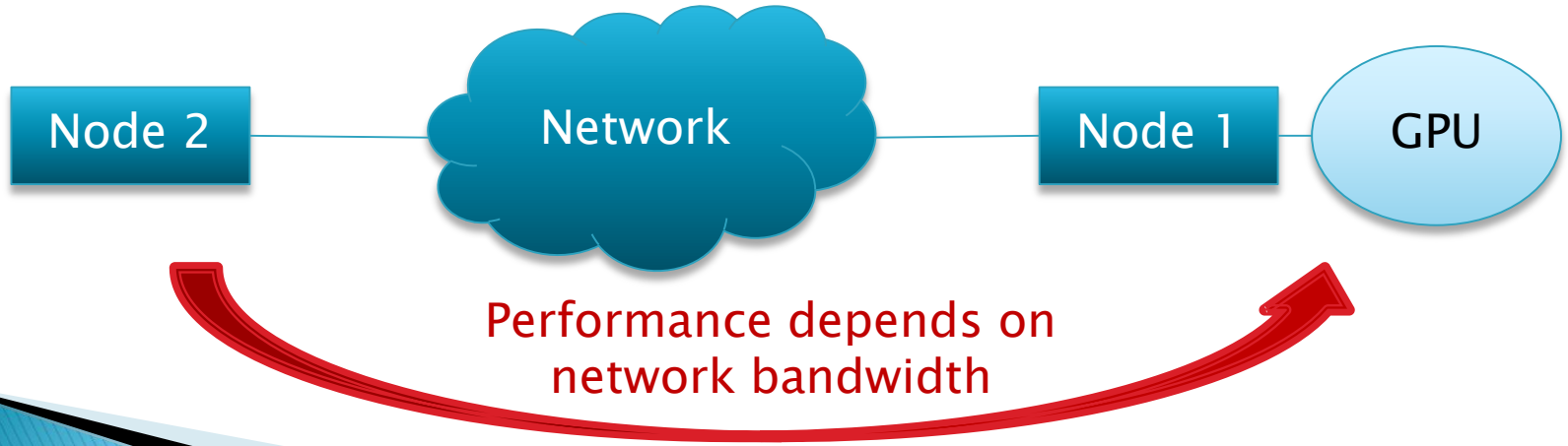


GPU Virtualization

- Local GPU:



- Remote GPU:



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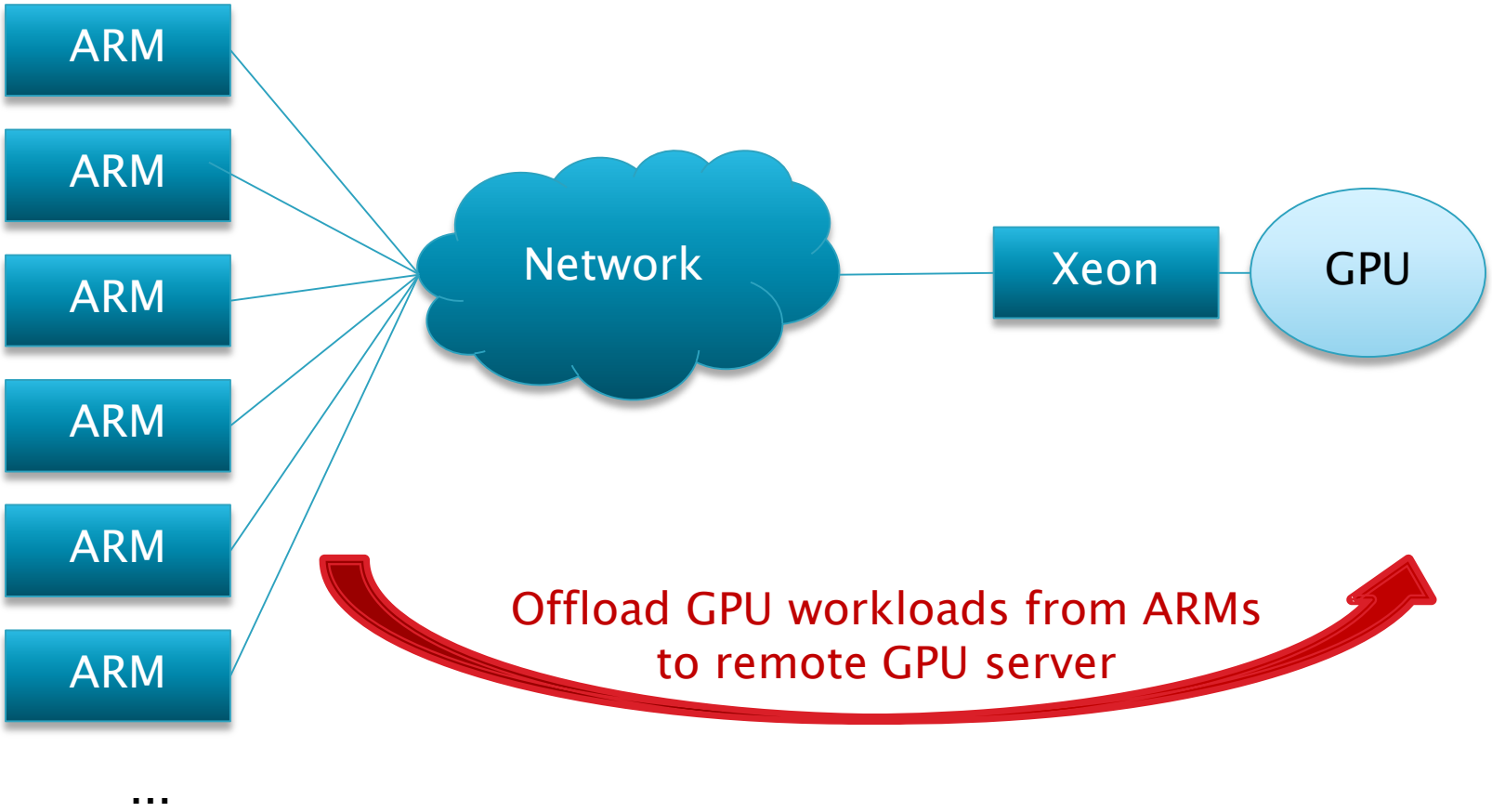
Approach proposed

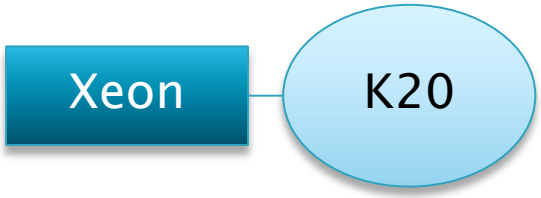


Approach proposed

ARM

- NVIDIA Jetson TX1:
  - 4-core ARM processor
  - 256-core CUDA compatible GPU

- Supermicro 1027GR-TRF:
  - 2 hexa-core Xeon processors
  - NVIDIA Tesla K20 GPU with 2496 CUDA cores



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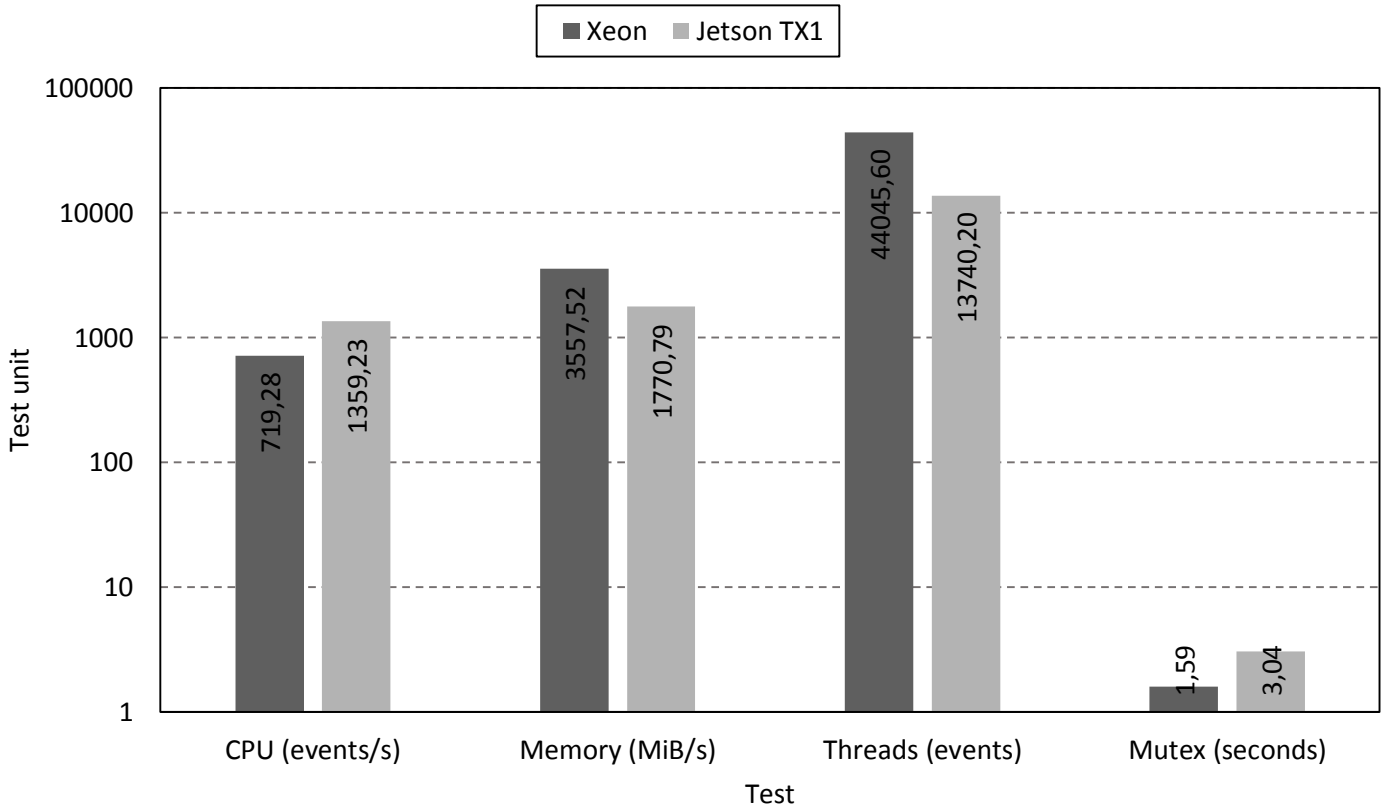

Performance comparison of NVIDIA Jetson TX1 and Supermicro 1027GR-TRF systems using the sysbench benchmark. Notice that the Y-axis is in logarithmic scale.

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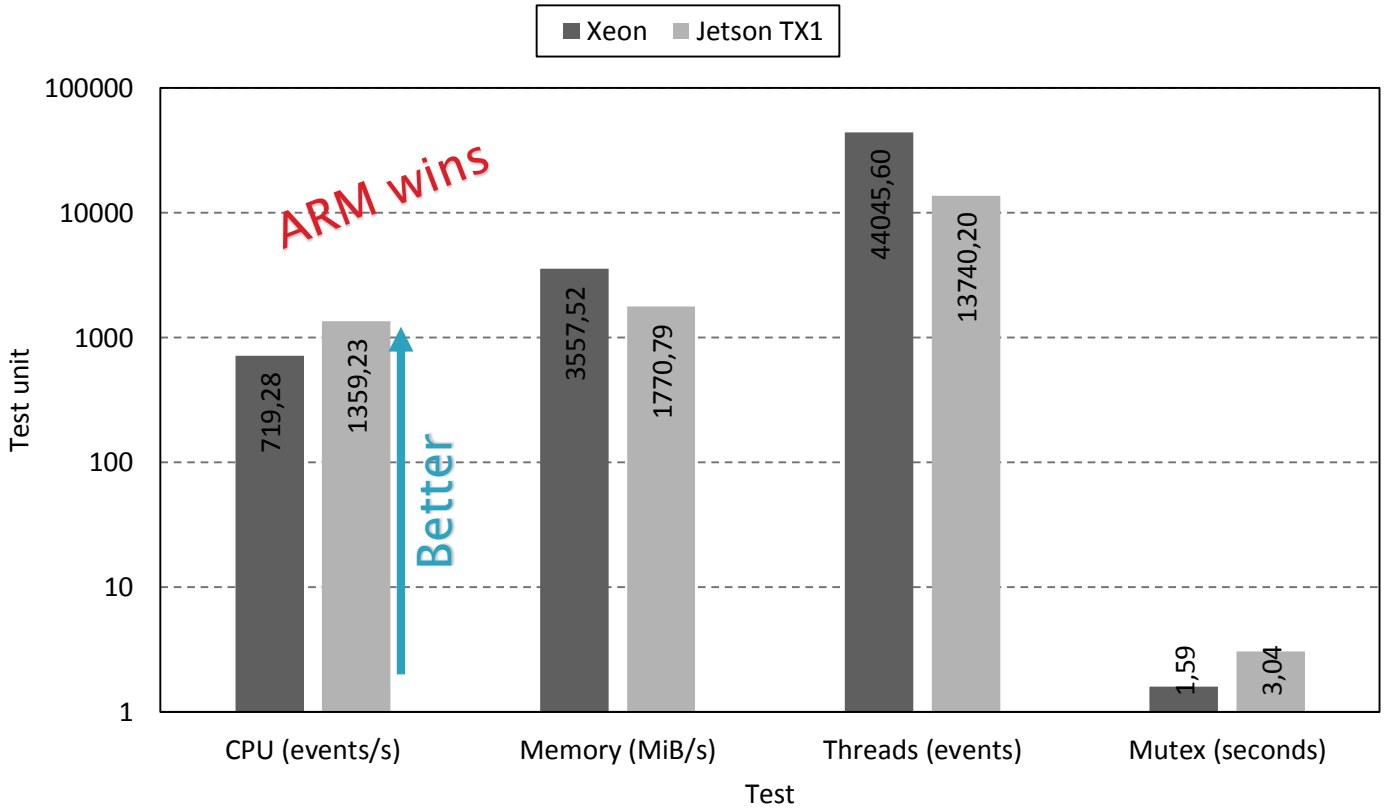

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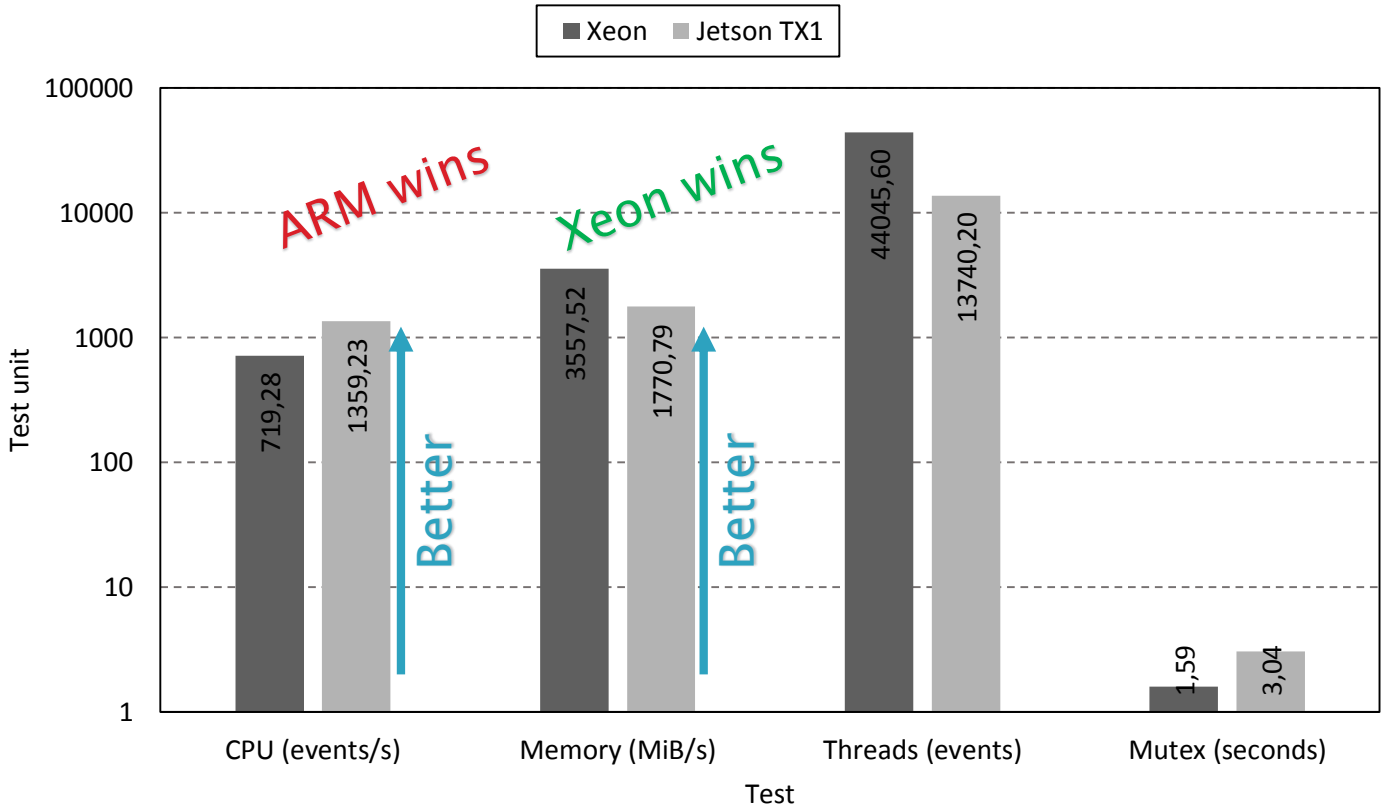

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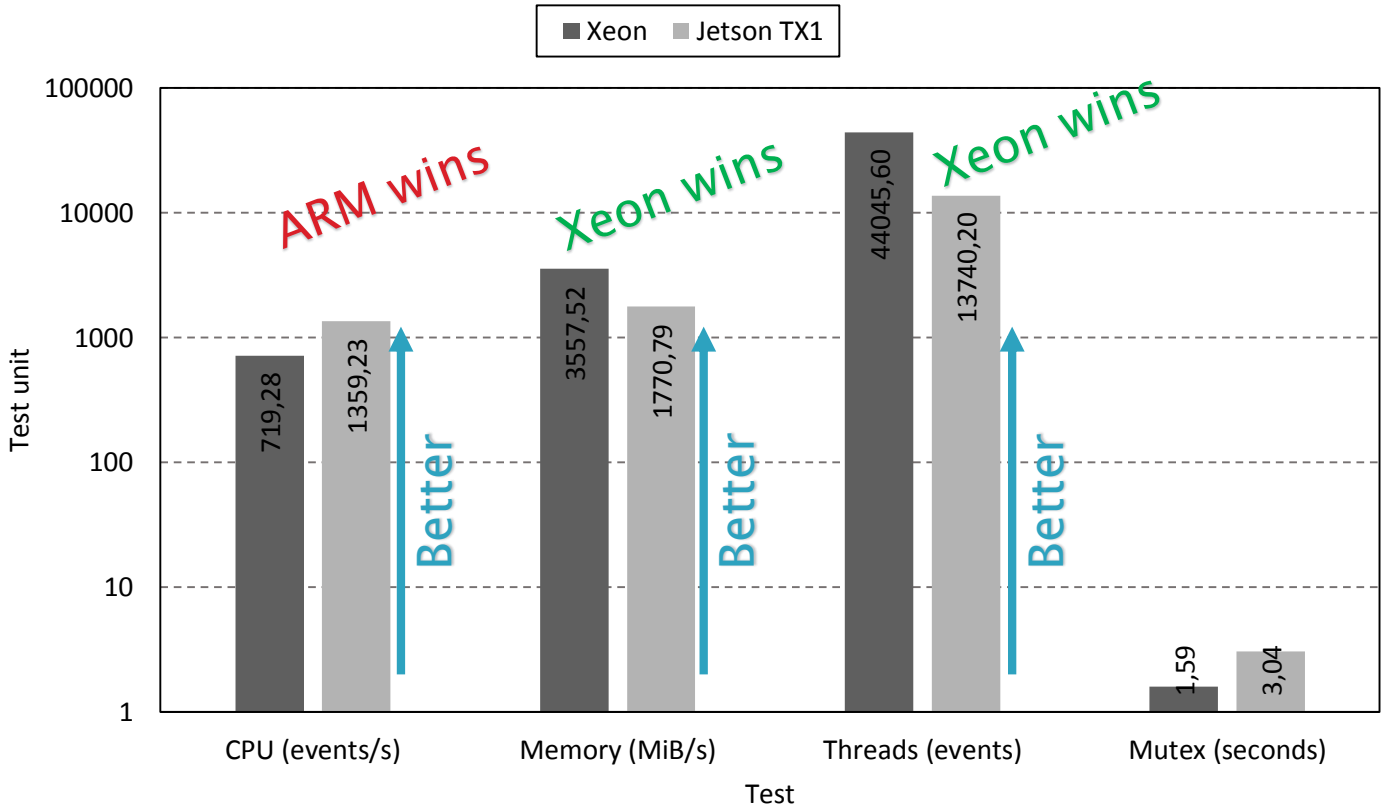

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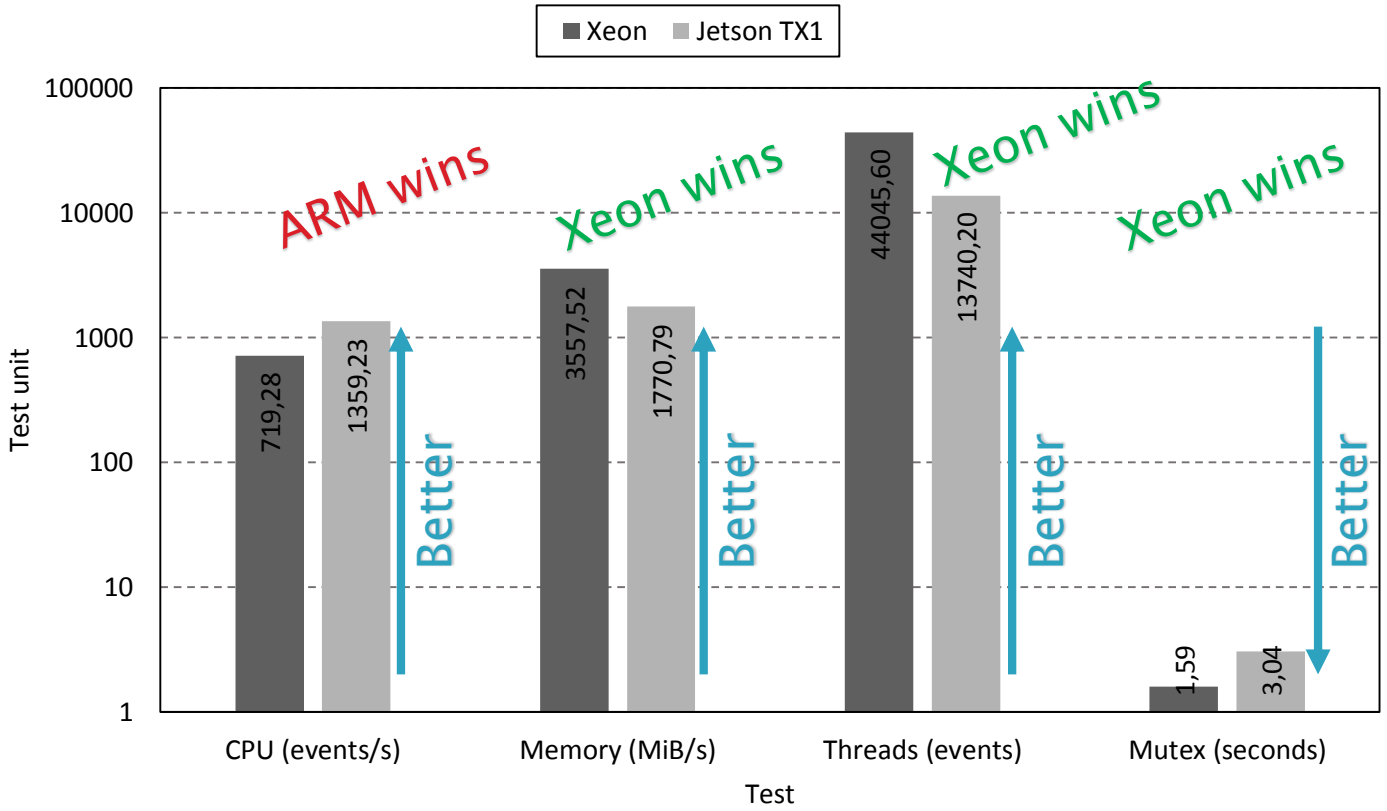

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The NVIDIA Jetson TX1 system

- Performance comparison:
  - ARM CPU vs. Xeon
  - **ARM GPU vs. K20**

The NVIDIA Jetson TX1 system

Attribute	GPU included in Tegra TX1 chip	Tesla K20m
CUDA Capability Major/Minor version number	**5.3**	3.5
Total amount of global memory	3,983 MBytes (4,176,248,832 bytes)	**4,742 MBytes** (4,972,412,928 bytes)
Multiprocessors (MP) - CUDA Cores	2MP - 256 CUDA Cores	**13MP - 2,496 CUDA Cores**
GPU Max Clock rate	**998 MHz (1.00 GHz)**	706 MHz (0.71 GHz)
Memory Clock rate	1600 Mhz	**2,600 Mhz**
Memory Bus Width	64-bit	**320-bit**
L2 Cache Size	262,144 bytes	**1,310,720** bytes
Maximum Layered 1D Texture Size, (num) layers	1D=(16,384), 2,048 layers	1D=(16,384), 2,048 layers
Maximum Layered 2D Texture Size, (num) layers	2D=(16,384, 16,384), 2,048 layers	2D=(16,384, 16384), 2,048 layers
Total amount of constant memory	65,536 bytes	65,536 bytes
Total amount of shared memory per block	49,152 bytes	49,152 bytes
Total number of registers available per block	32,768	**65,536**
Warp size	32	32
Maximum number of threads per multiprocessor	2,048	2,048
Maximum number of threads per block	1,024	1,024
Max dimension size of a thread block (x,y,z)	(1,024, 1,024, 64)	(1,024, 1,024, 64)
Max dimension size of a grid size (x,y,z)	(2,147,483,647, 65,535, 65,535)	(2,147,483,647, 65,535, 65,535)
Maximum memory pitch	2,147,483,647 bytes	2,147,483,647 bytes
Texture alignment	512 bytes	512 bytes
Concurrent copy and kernel execution	Yes with 1 copy engine(s)	**Yes with 2 copy engine(s)**
Run time limit on kernels	**Yes**	**No**
Integrated GPU sharing Host Memory	**Yes**	**No**
Support host page-locked memory mapping	Yes	Yes
Alignment requirement for Surfaces	Yes	Yes
Device has ECC support	Disabled	**Enabled**
Device supports Unified Addressing (UVA)	Yes	Yes

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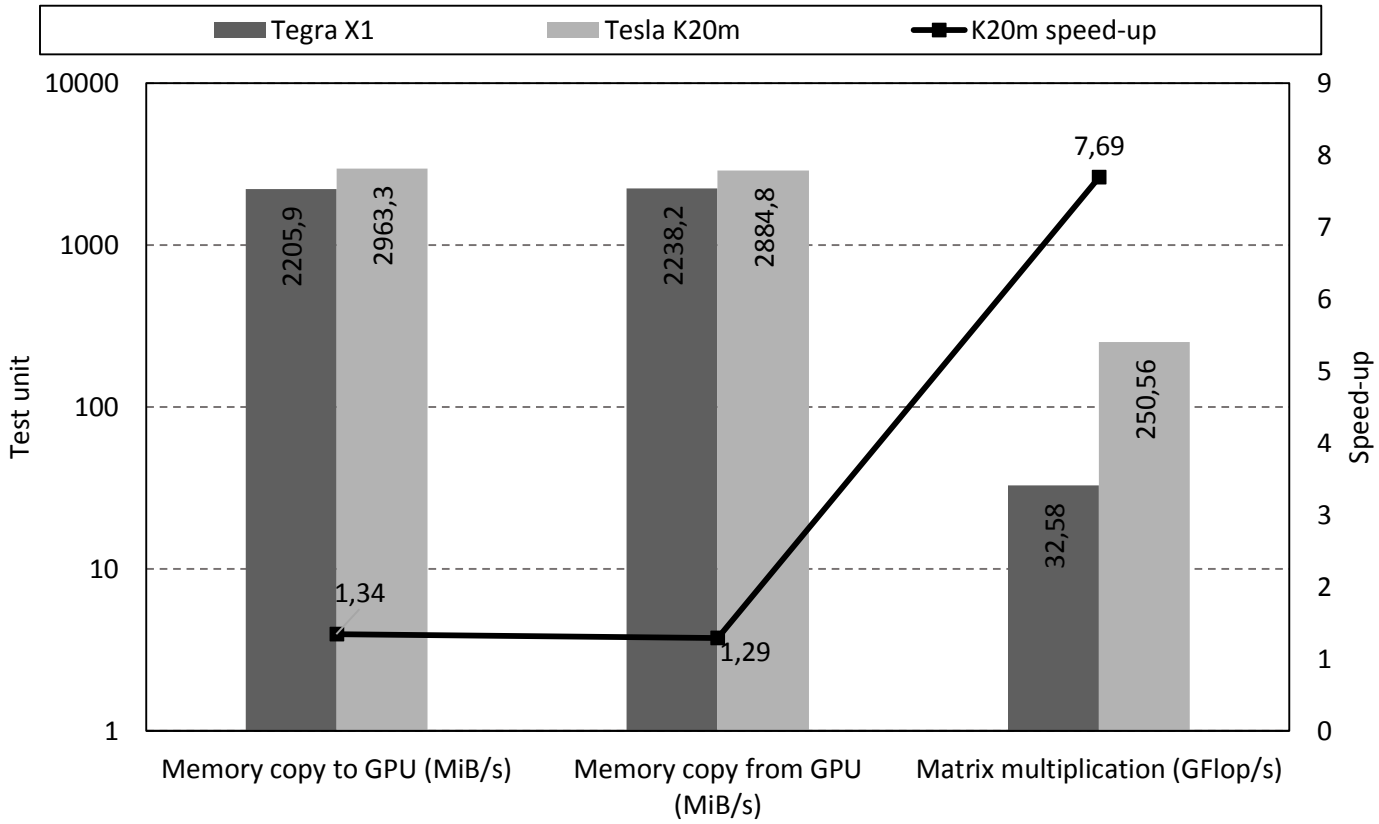

Performance comparison of the GPU included in the Tegra X1 chip and the Tesla K20m GPU in terms of data transfer bandwidth and computational power. Notice that primary Y-axis is in scale.

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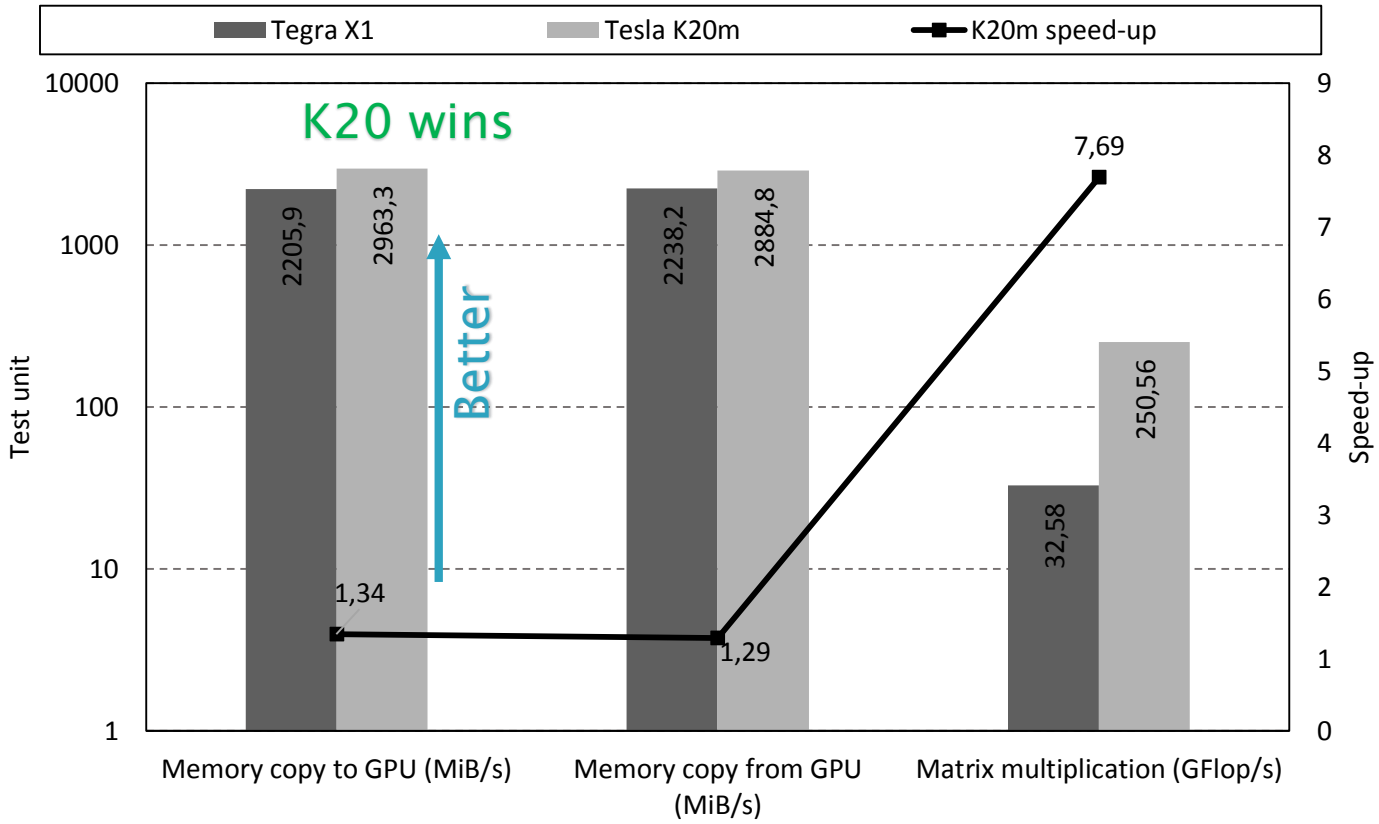

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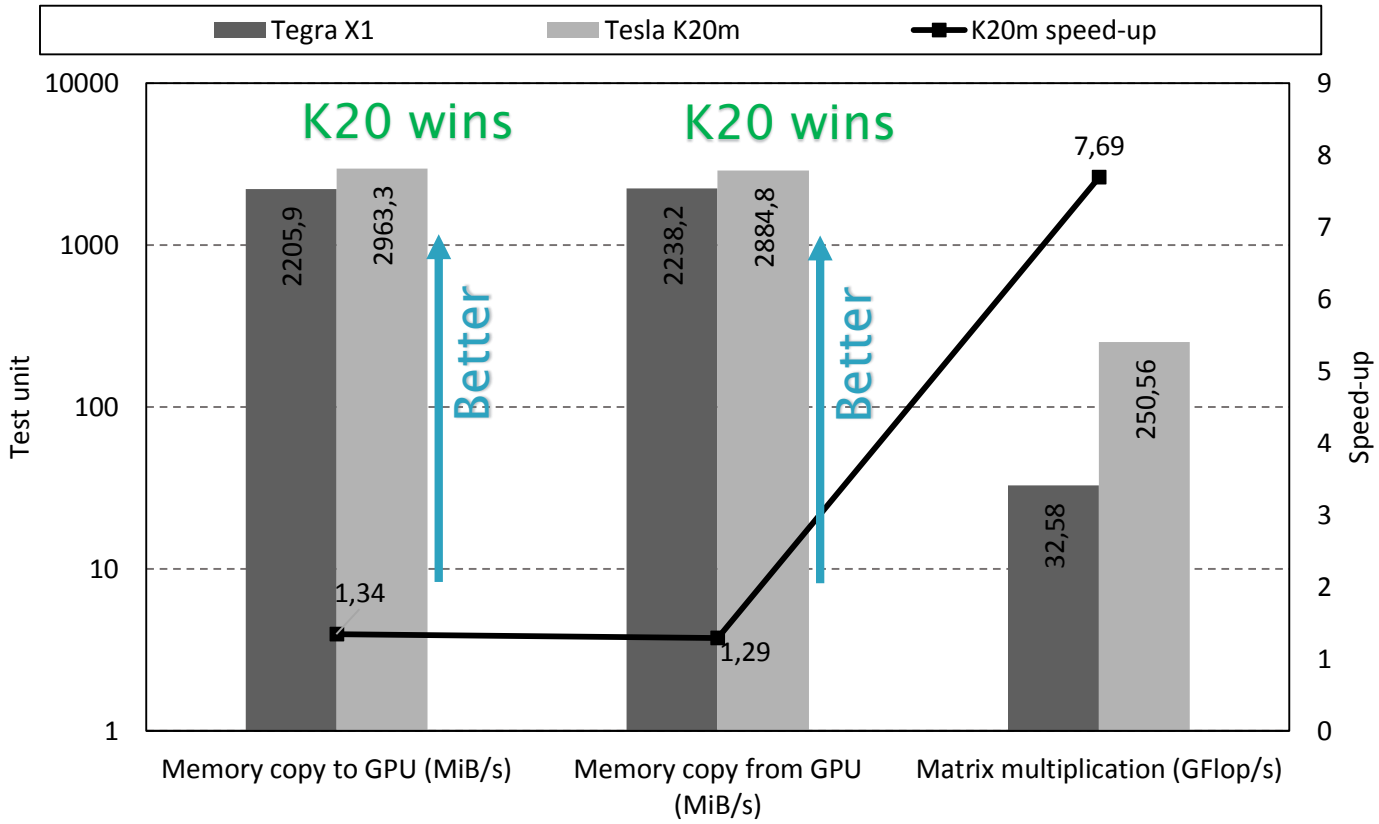

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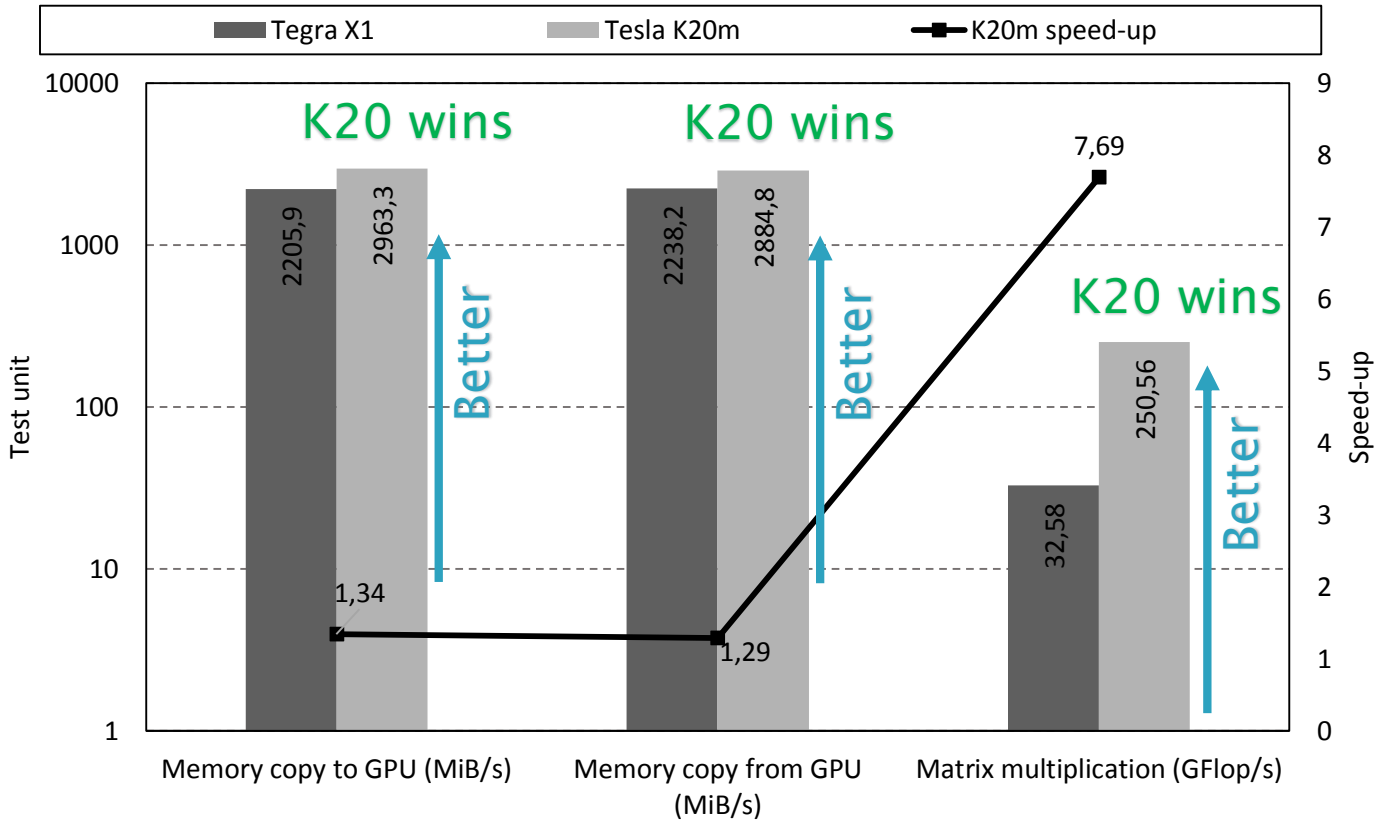

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- Three scenarios:
  1. ARM
  2. Xeon+GPU
  3. ARM+remote GPU

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  - Gaussian benchmark varying problem size
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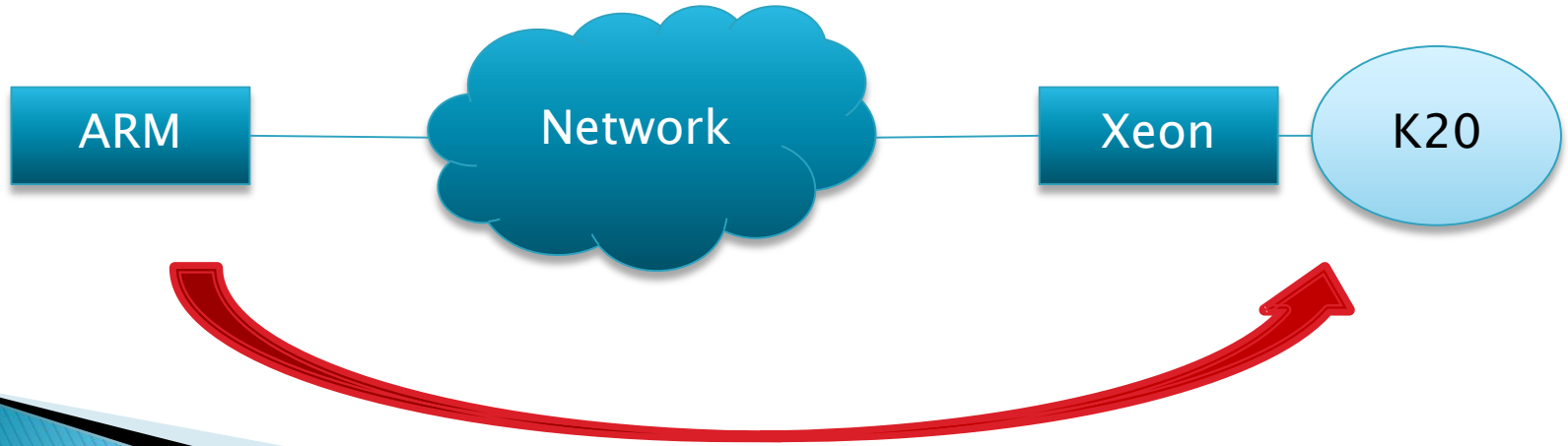

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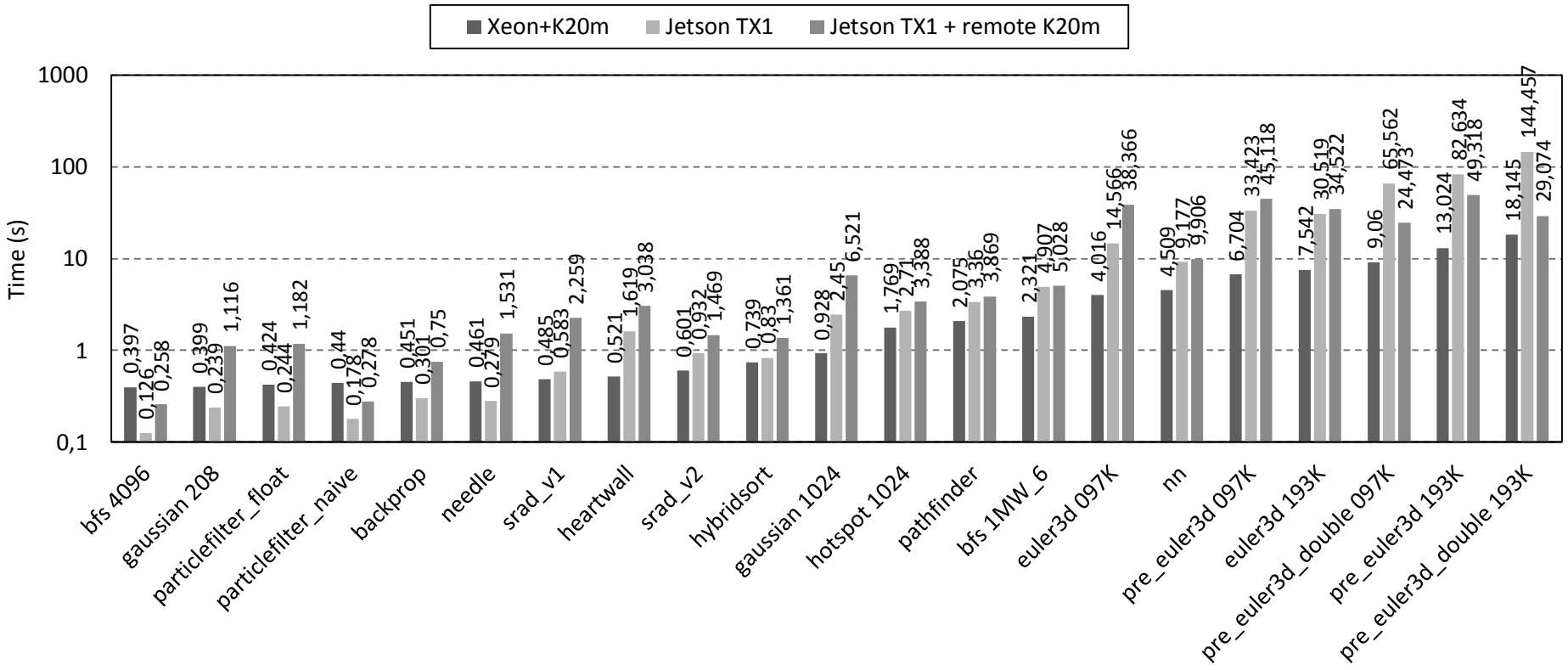

Comparison of Rodinia benchmarks executed in three different scenarios: (i) a regular server with one NVIDIA K20 GPU, (ii) an NVIDIA Jetson TX1, and (iii) an NVIDIA Jetson TX1 offloading GPU work to a remote regular server with one NVIDIA K20 GPU.

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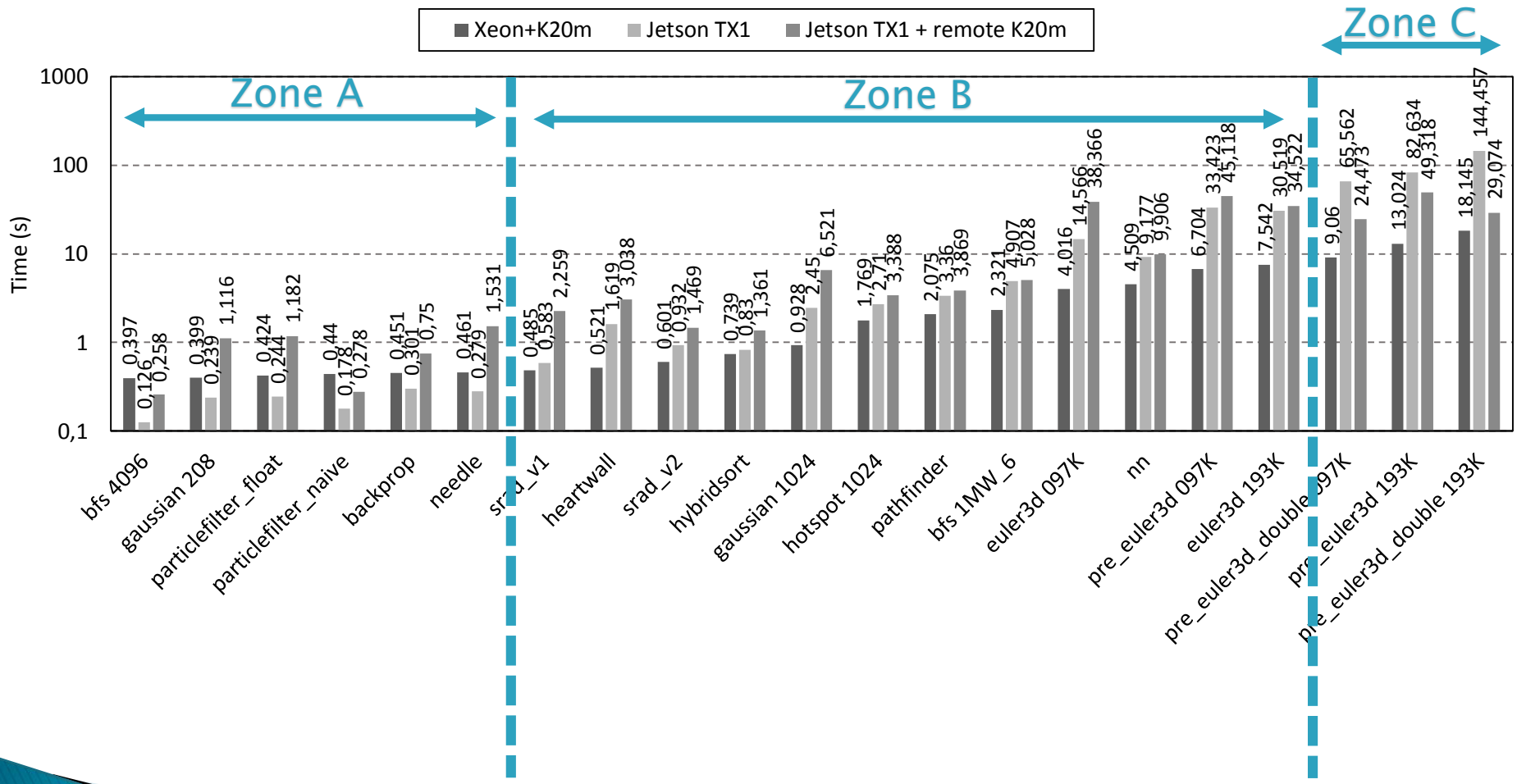

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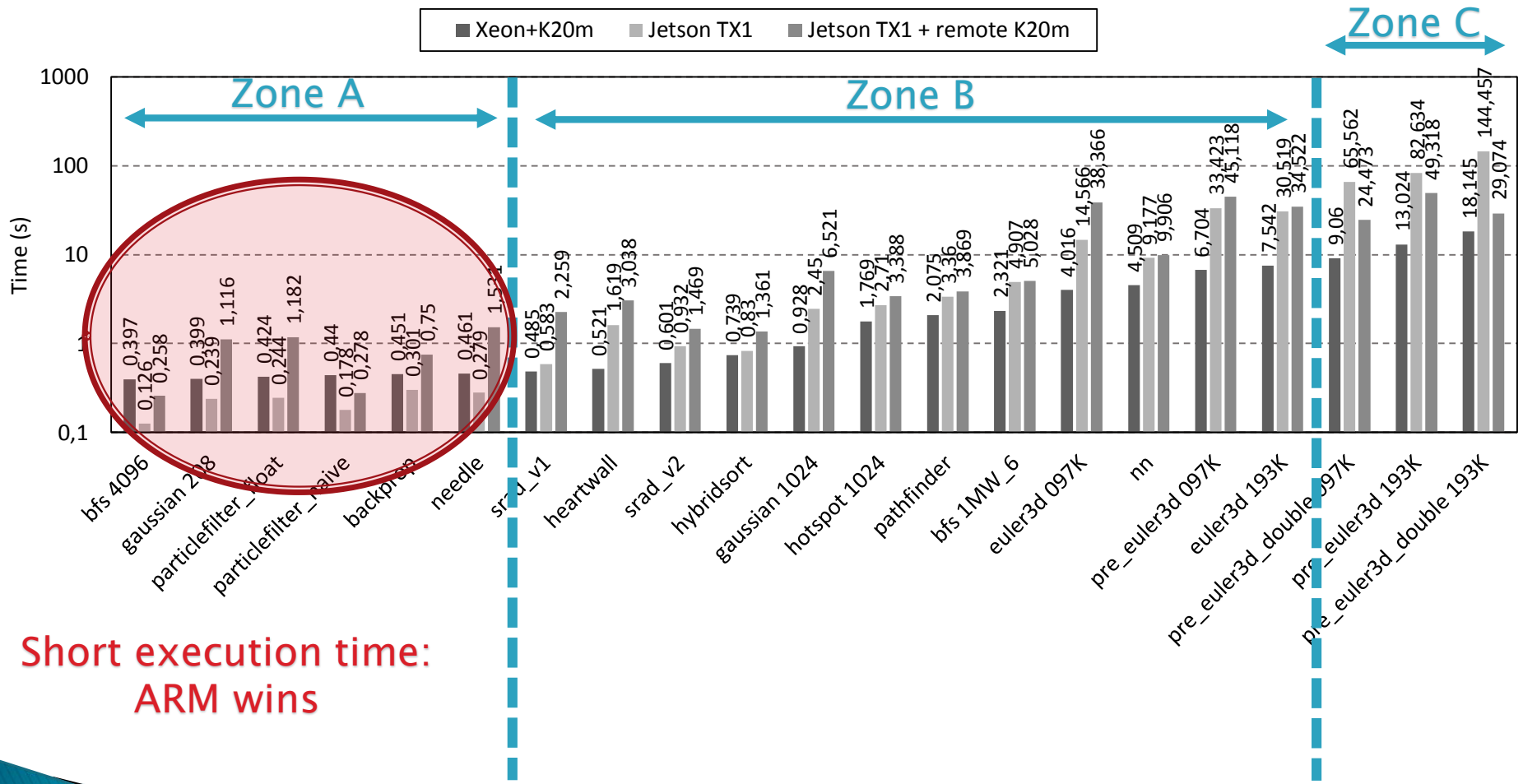

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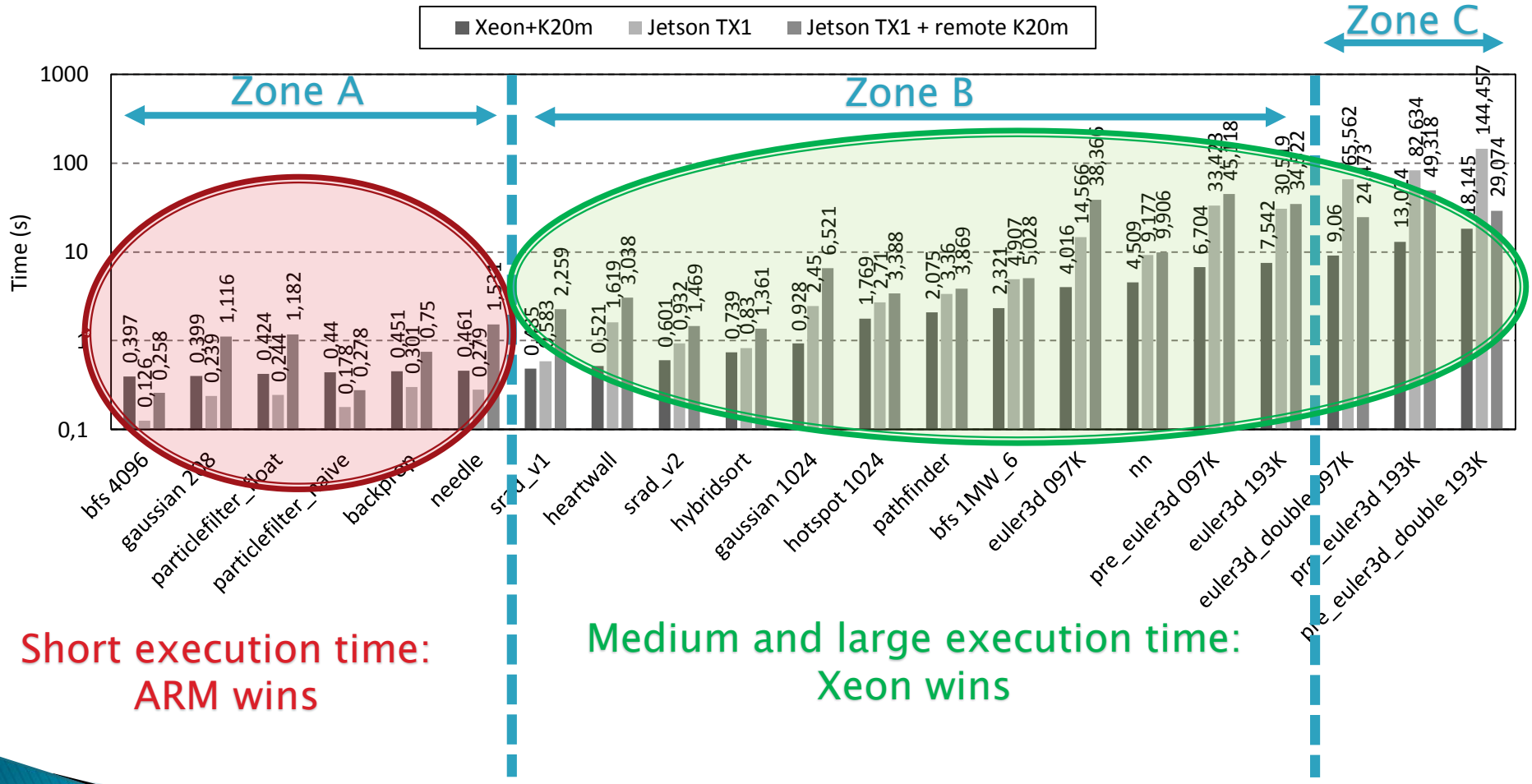

Short execution time:
ARM wins

Medium and large execution time:
Xeon wins

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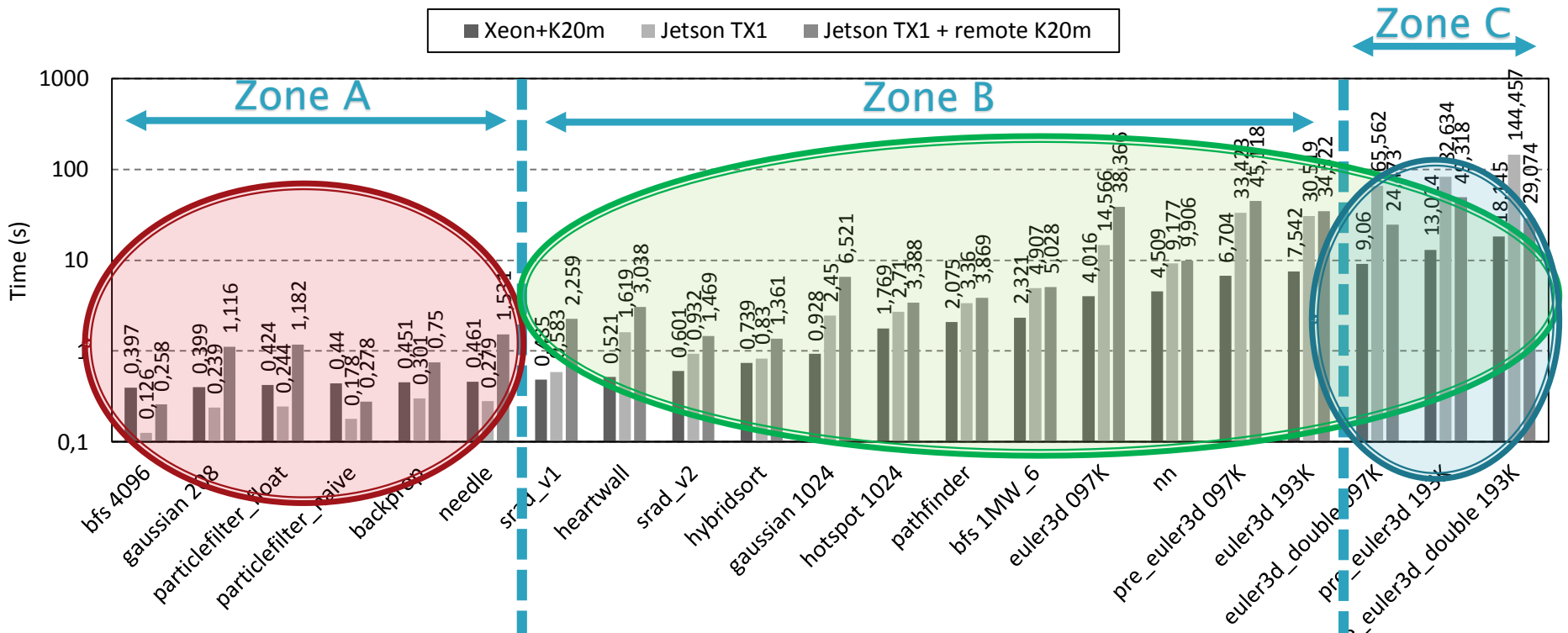

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remote GPU better than ARM

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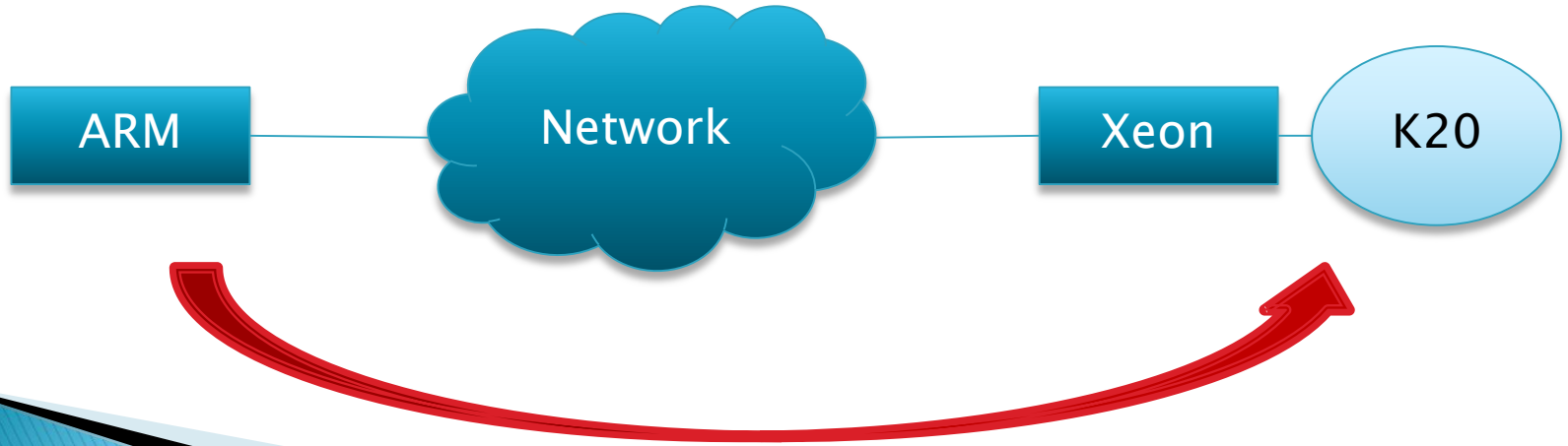

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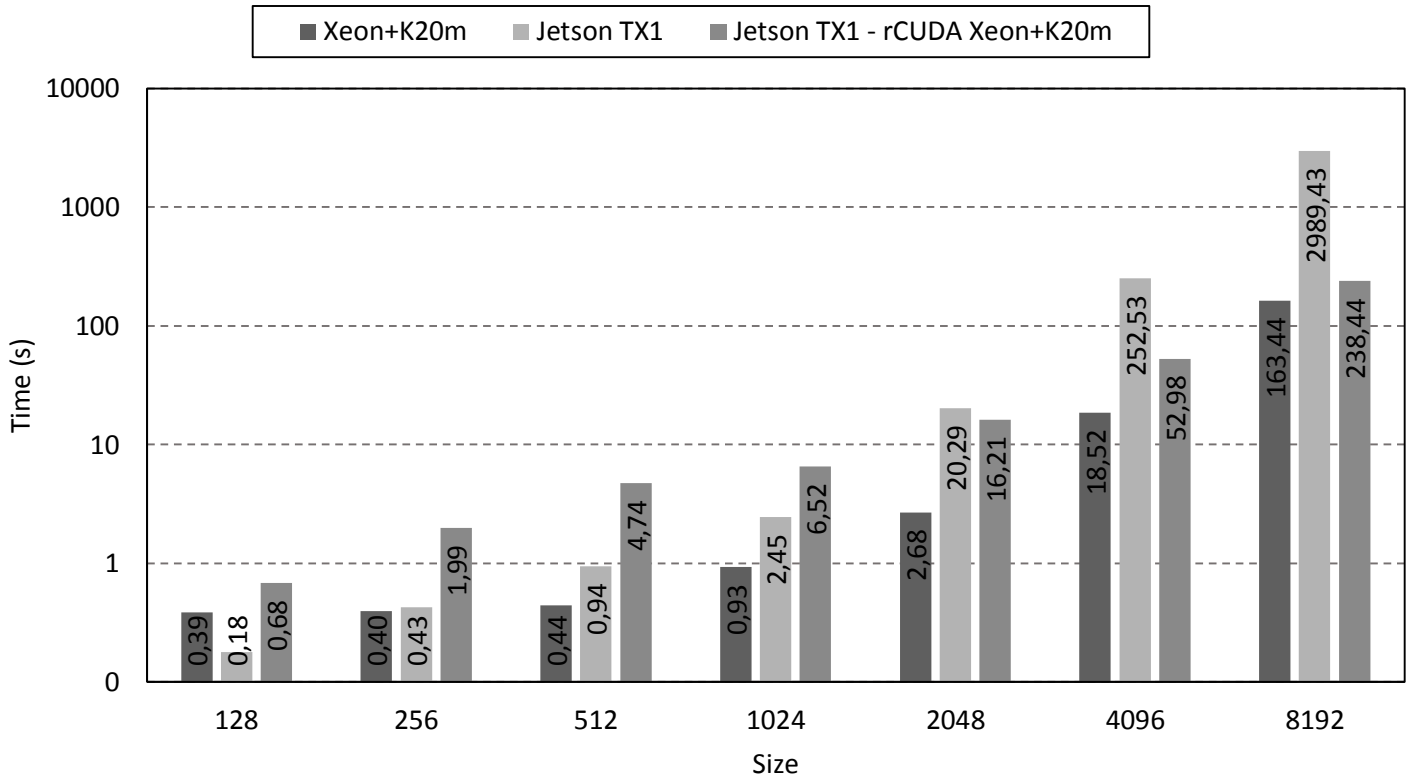

Comparison of Rodinia benchmark "gaussian" varying the problem size, and executed in three different scenarios: (i) a regular server with one NVIDIA K20 GPU, (ii) a NVIDIA Jetson TX1, and (iii) a NVIDIA Jetson TX1 offloading GPU work to a remote regular server with one NVIDIA K20 GPU.

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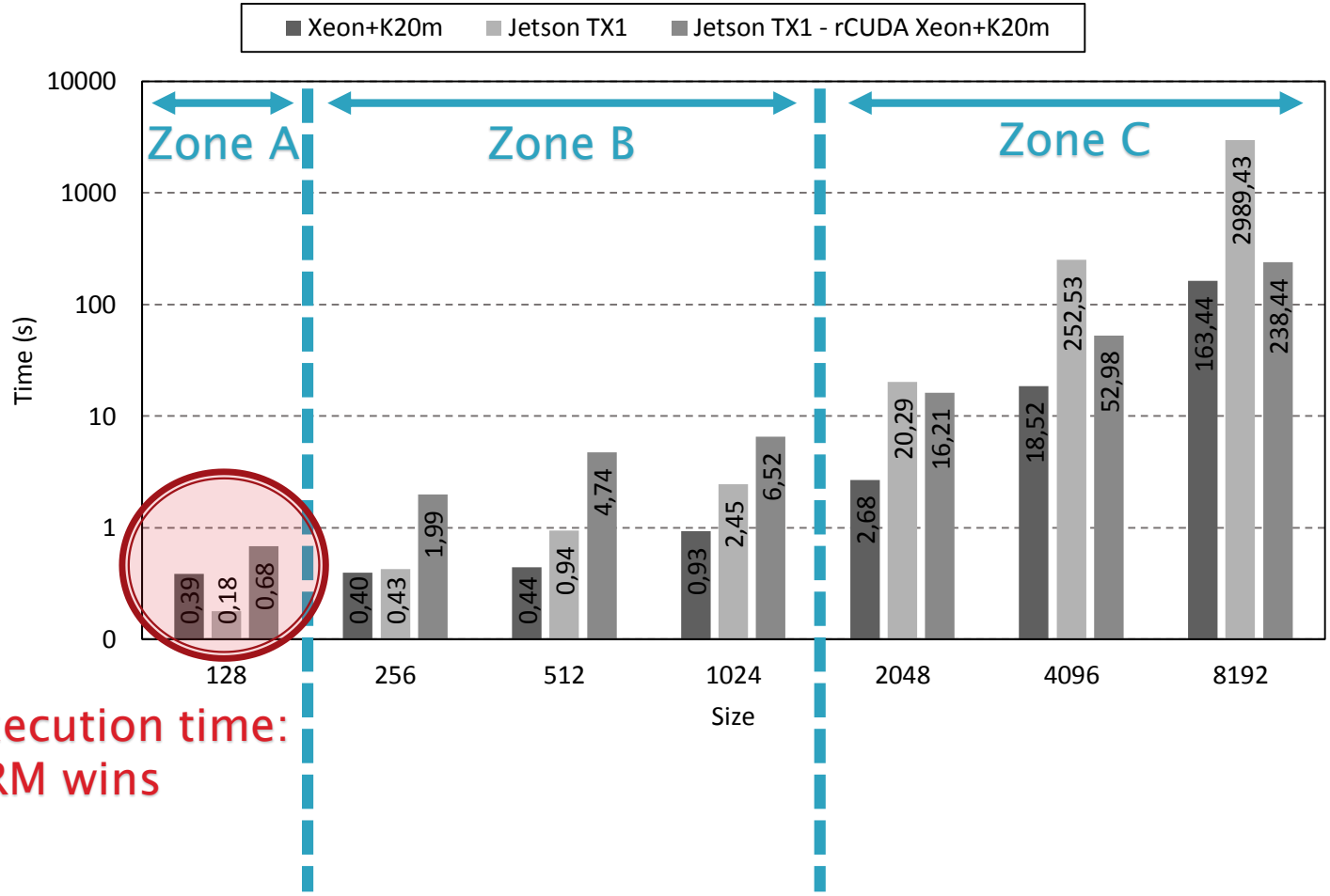

Short execution time: ARM wins

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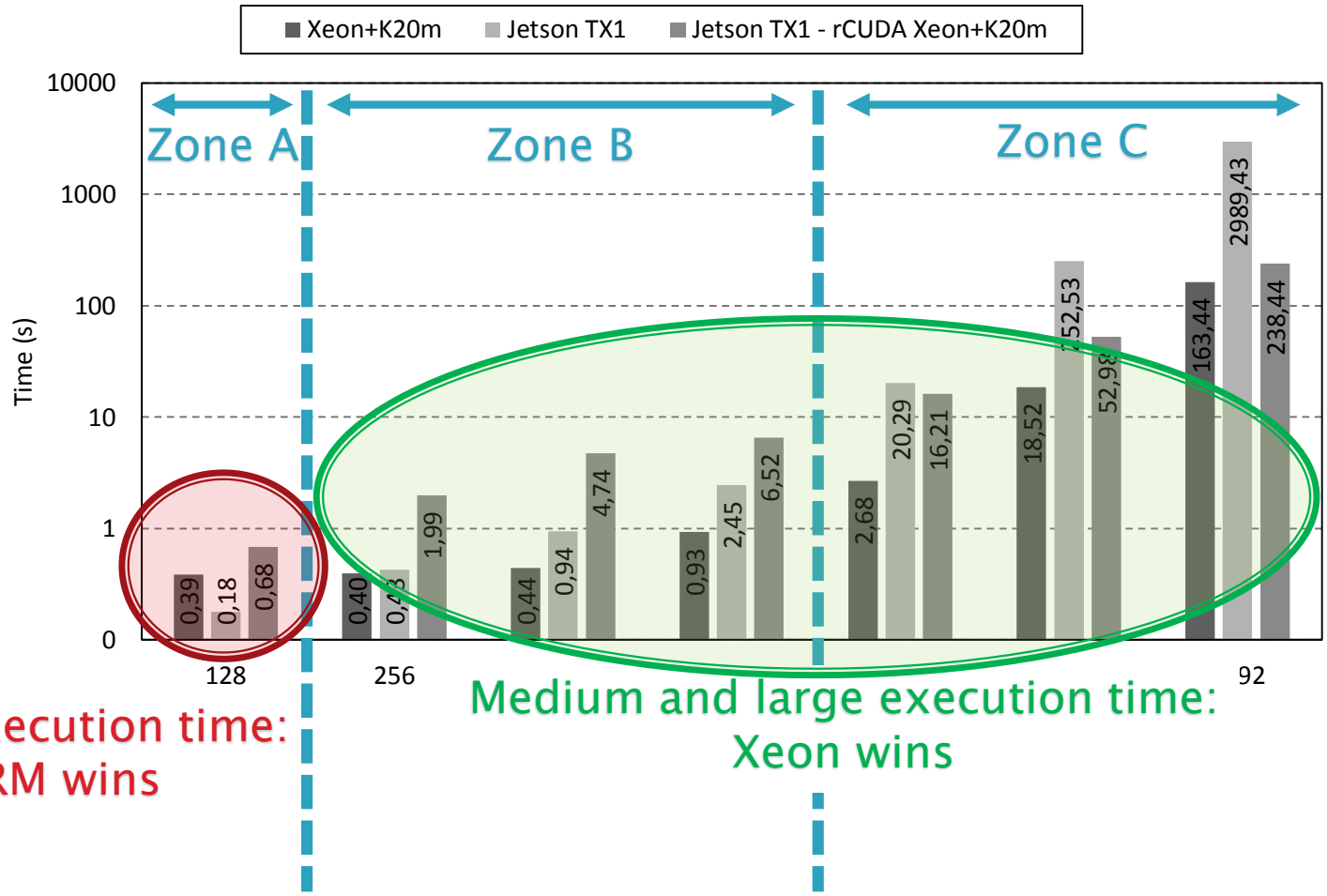

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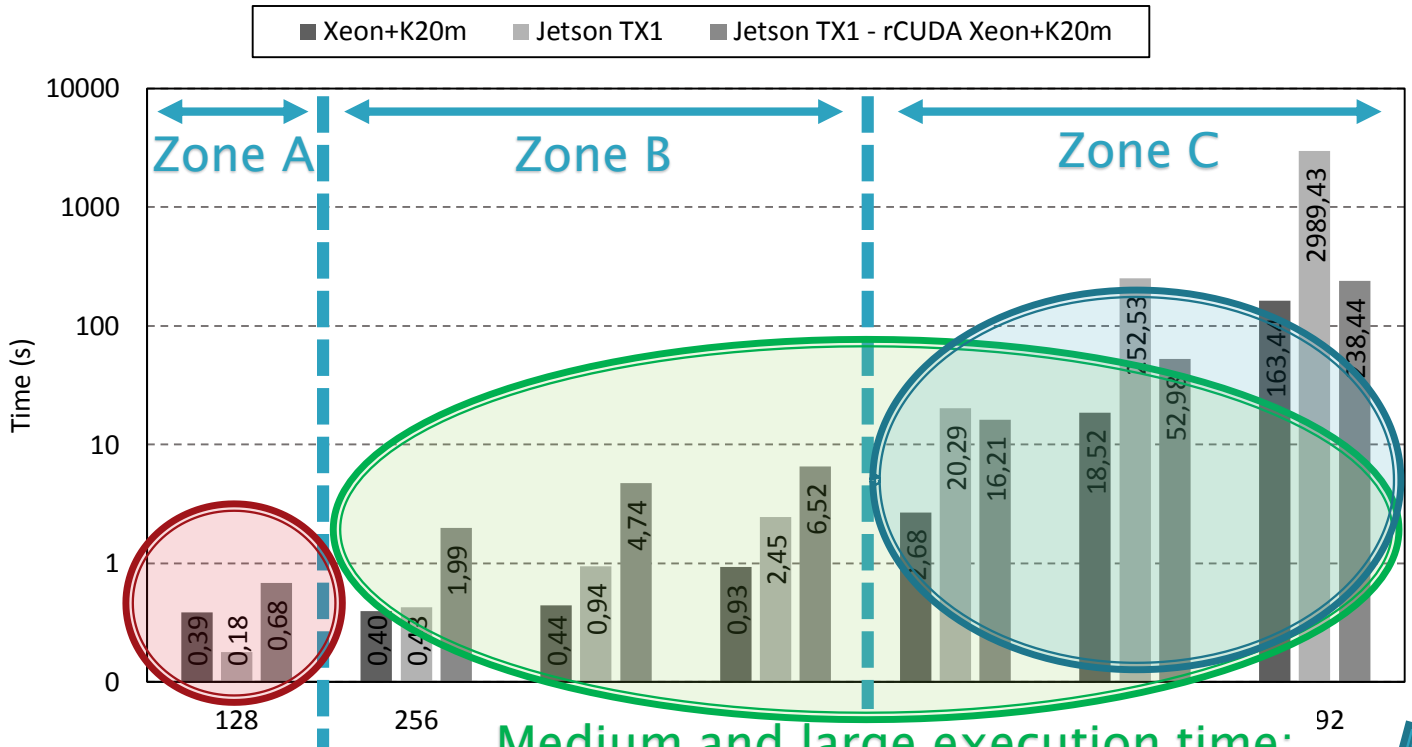

Short execution time: ARM wins

Medium and large execution time: Xeon wins

Large execution time: remote GPU better than ARM

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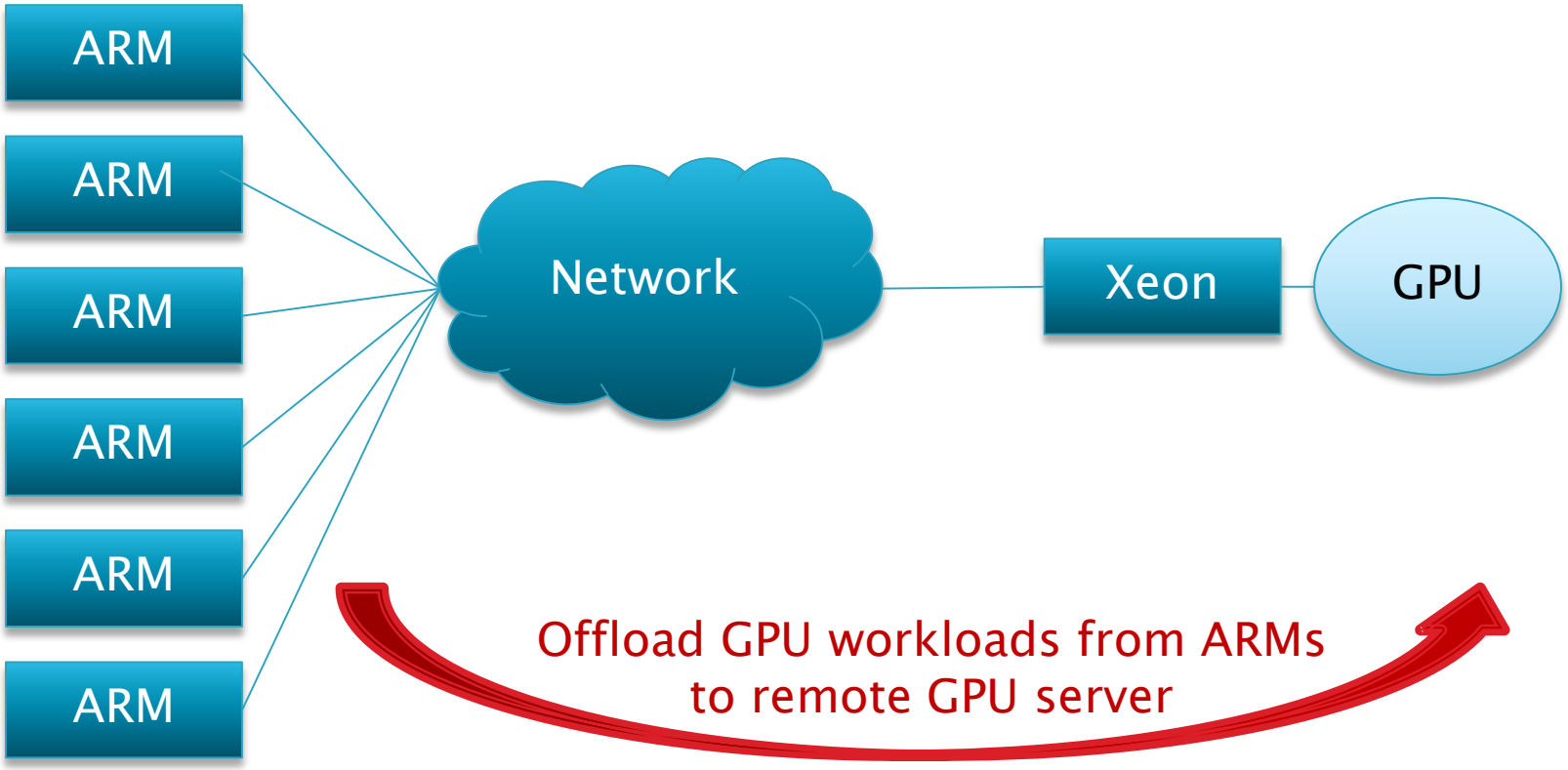

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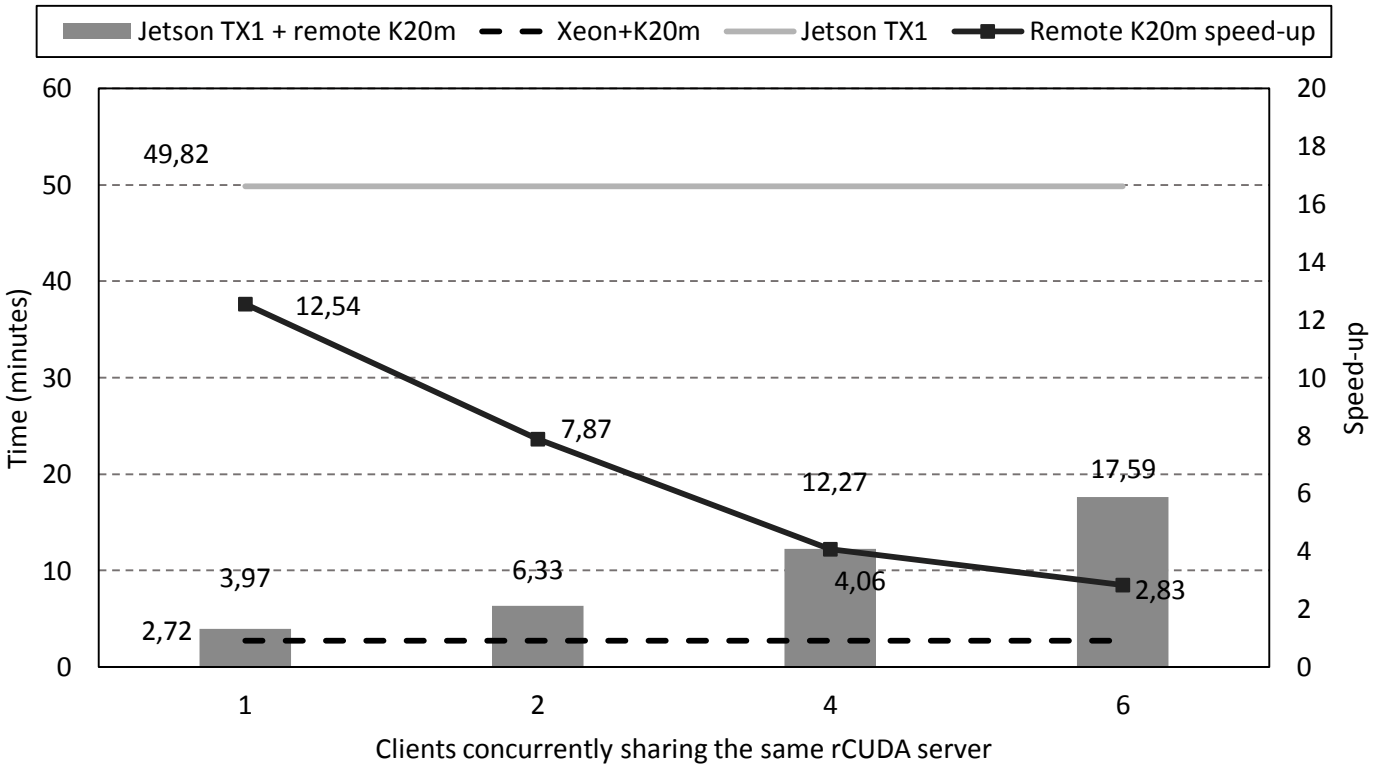

Comparison of Rodinia benchmark "gaussian" with problem size 8,192, executed in three different scenarios: (i) server with one K20, (ii) Jetson TX1, and (iii) Jetson TX1 offloading GPU work to a remote server with one K20 (in this scenario, the number of concurrent clients sharing the same remote server varies from 1 up to 6).

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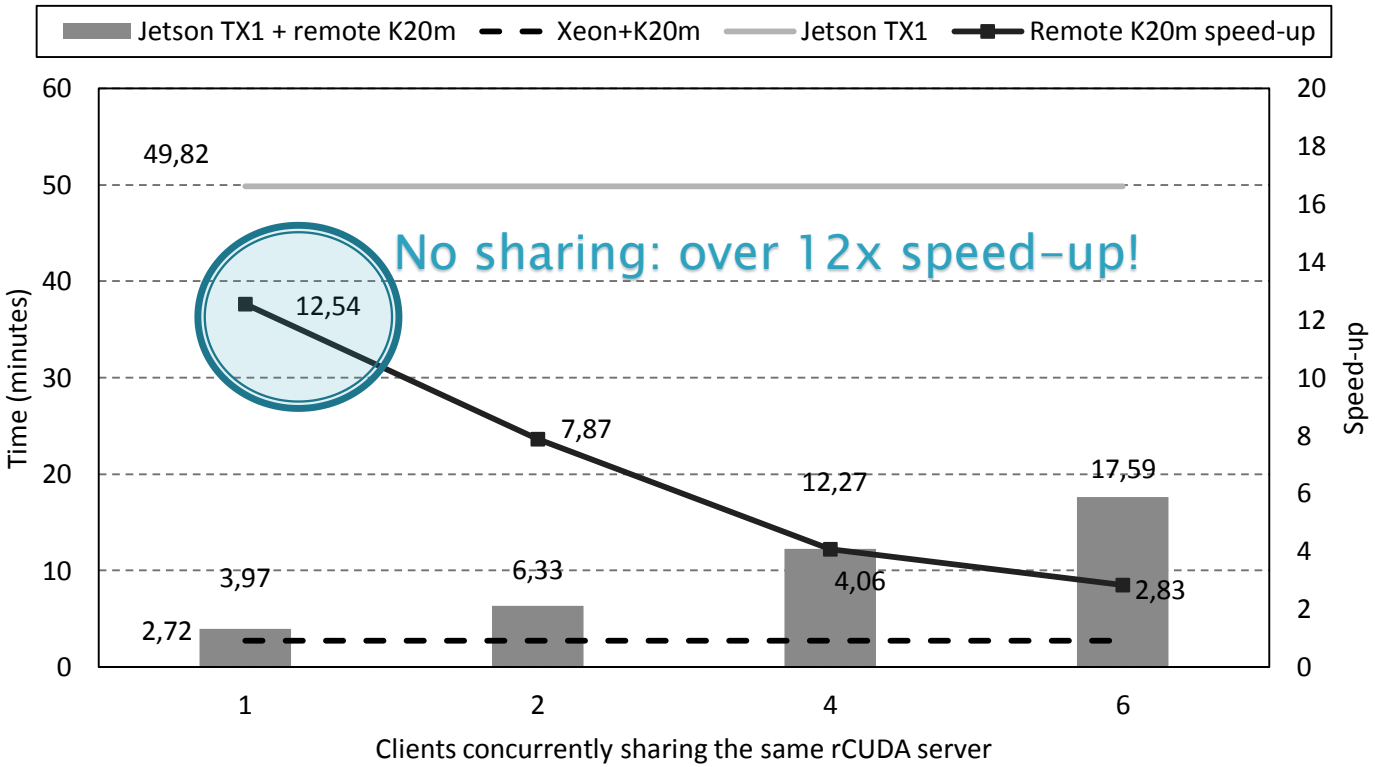

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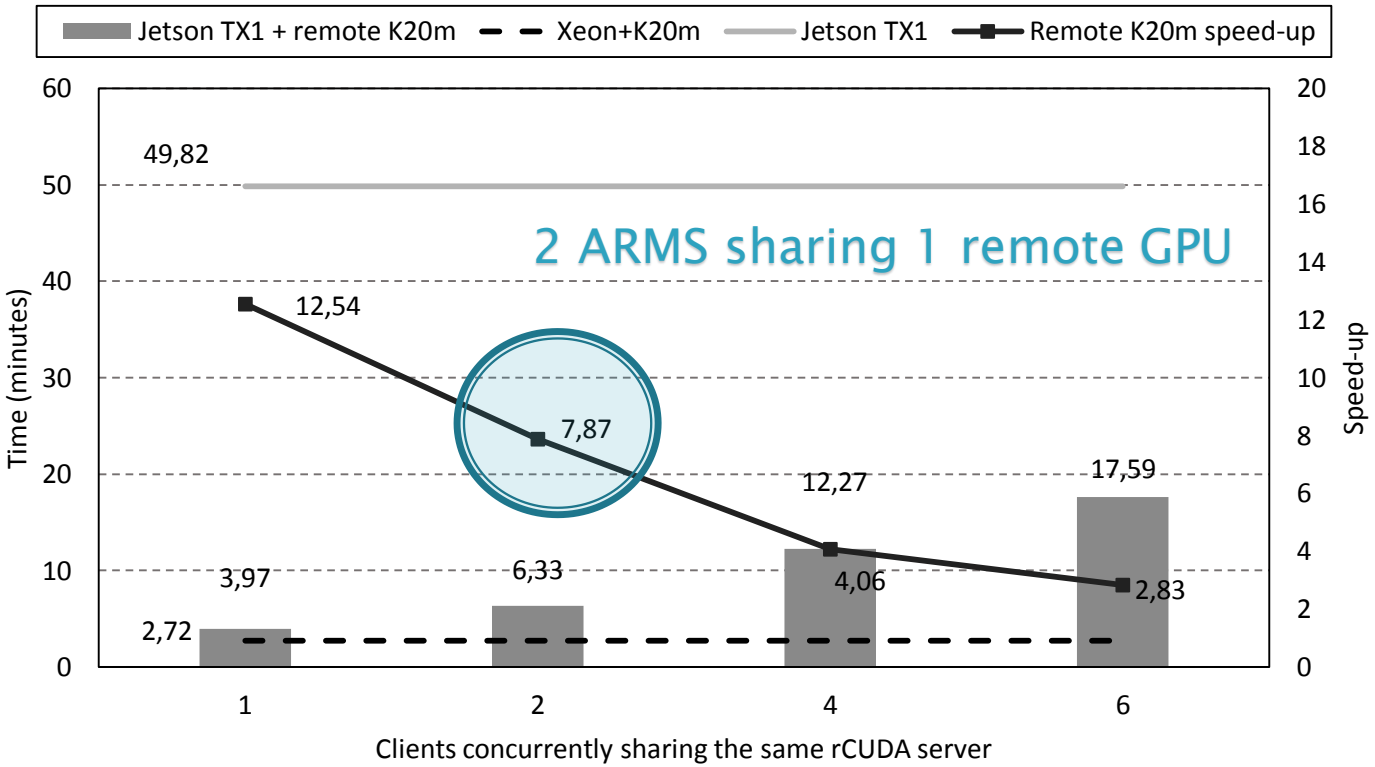

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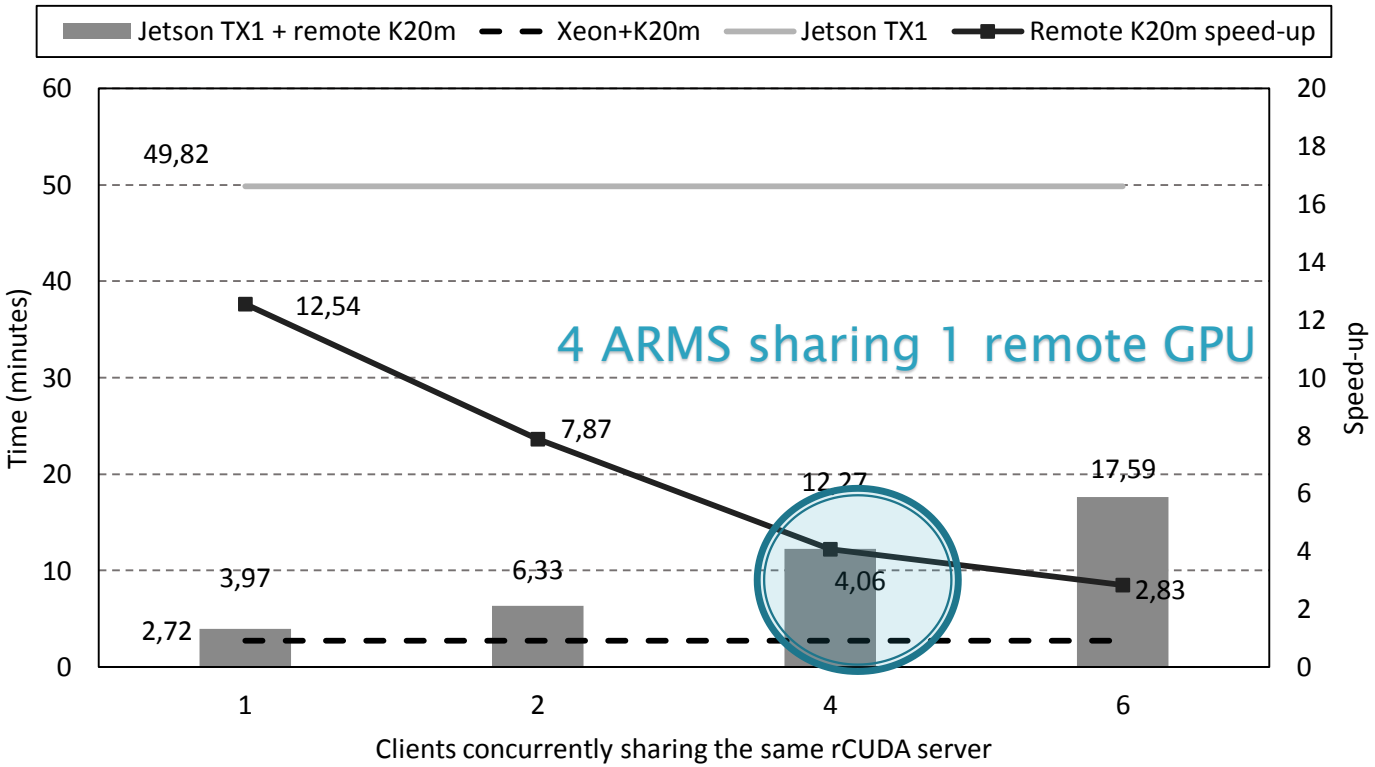

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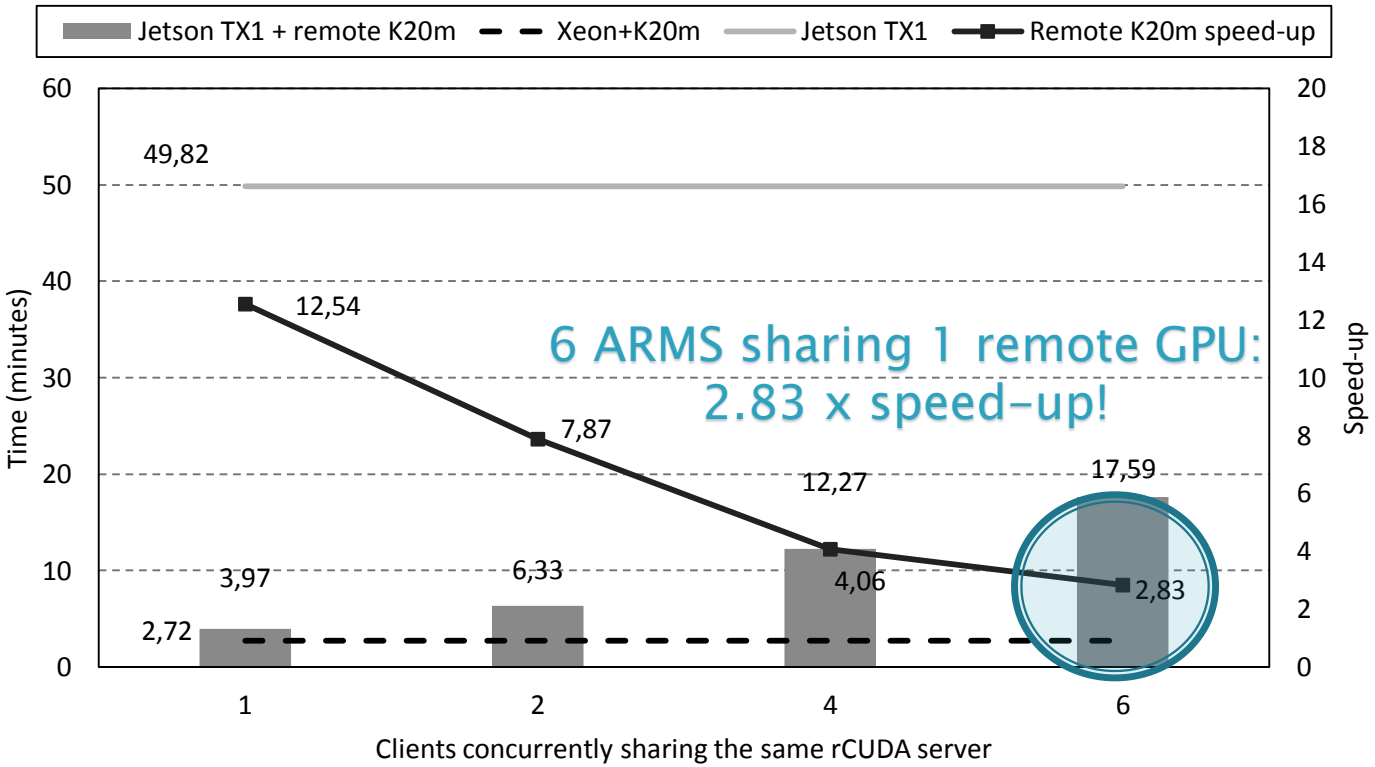

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Outline

- Introduction
- GPU Virtualization
- Approach proposed
- The NVIDIA Jetson TX1 system
- Performance evaluation
- Conclusions and future work

Conclusions

- Proposal for improving efficiency of future exascale systems
- Using rCUDA to provide ARMs access to high-end remote GPUs
- Execution time speed-up by up to 12x
- ARM power efficiency is leveraged along with the high-end accelerators
- Accelerators dynamically shared among multiple ARMs

Future work

- Analysis of this proposal with HPC apps
- Include energy and power measurements
- Validate if our proposal is able to contribute to energy efficiency in future exascale systems

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