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Campus Guadalajara

Technical Comparison of an IoT System and a Traditional Computing System

Tesis que para obtener el grado de la
MAESTRÍA EN CIENCIAS DE LA COMPUTACIÓN
presenta

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Zapopan, Jal., México a 3 de Mayo del 2016

Agenda

- Motivation
- Justification
- Introduction
- Related Work
- Contributions
- Results
- Summary
- Conclusions

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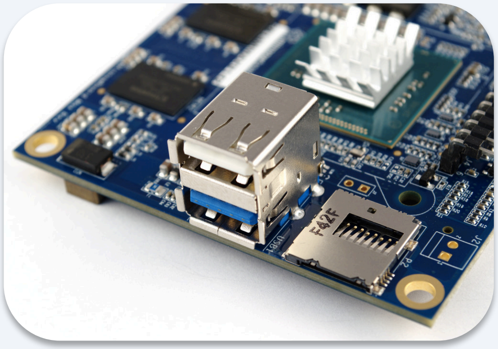
Motivation

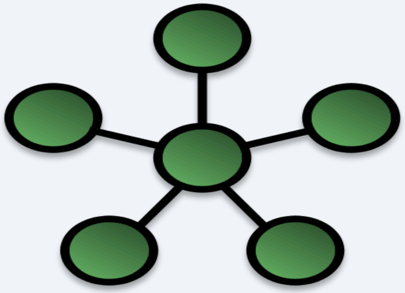
IoT systems: sensors, storage, information processing, display

IoT growth: data volume transmitted, collected and processed

IoT trend: data handling would require 100 megawatts



IoT local processing: process all the data they generate



IoT on real time: are data generated at real time ?

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Justification

Centralized Processing System

- Multiple IoT systems with large processing capabilities
- Avoid sending data to a centralized processing system

IoT systems not using computing resources efficiently

- IoT architectures not using computing resources efficiently
- Lack of standard methodologies to design distributed, self-sustainable networks of IoT systems

Quantitative power efficiency comparison

- Perform quantitative power efficiency comparison of distributed, low-power IoT systems to traditional computing systems

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Introduction

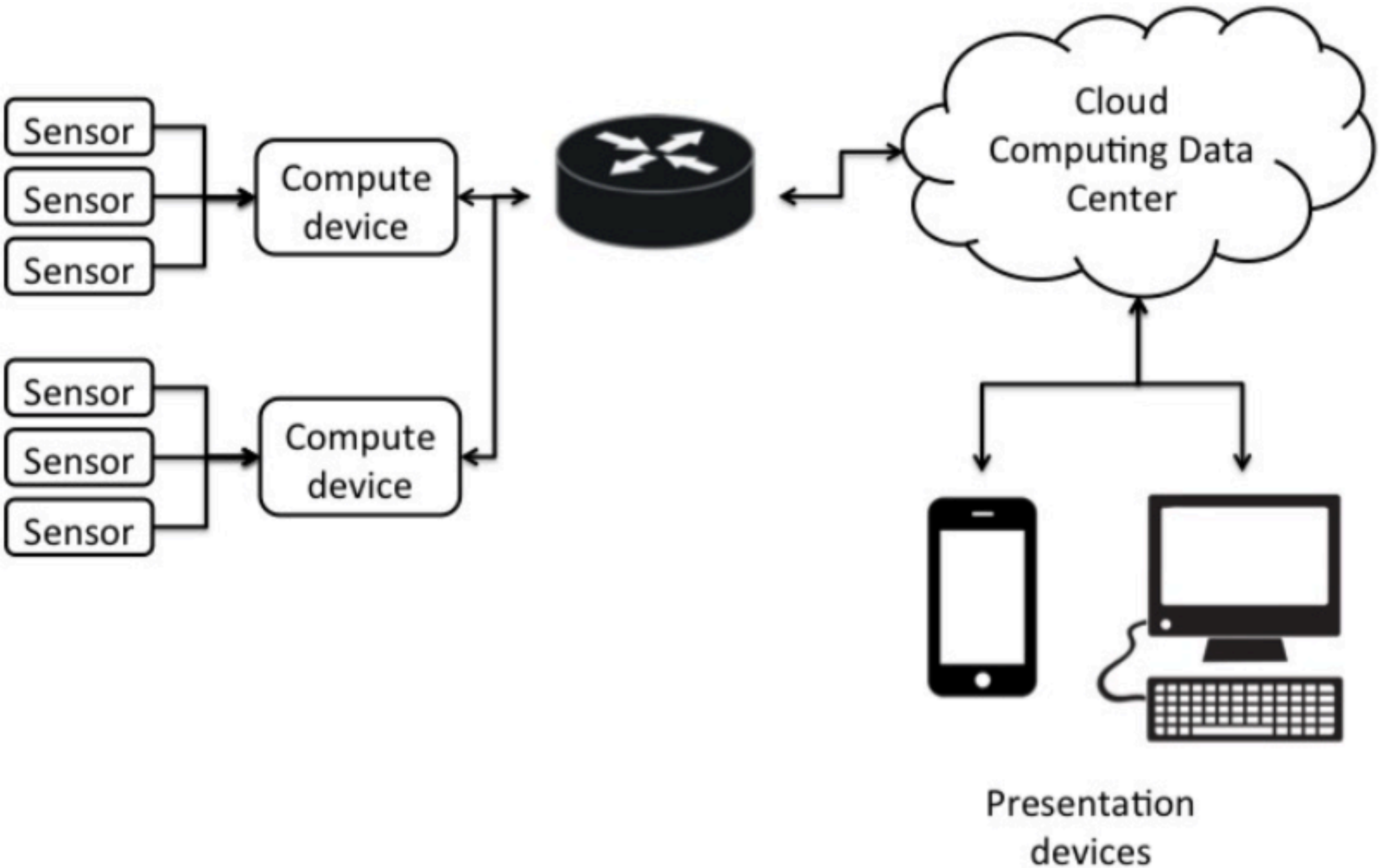


Fig 1.1 An IoT system diagram

Introduction

Power efficiency

$$Perf = \frac{1}{(1-f)+(\frac{f}{n})}$$

<- Amdahl's law

Equation taken from:
D. H. Woo and H.-H. S. Lee, "Extending amdahl's law for energy-efficient computing in the many-core era," Computer, pp. 24 – 31, 2008.

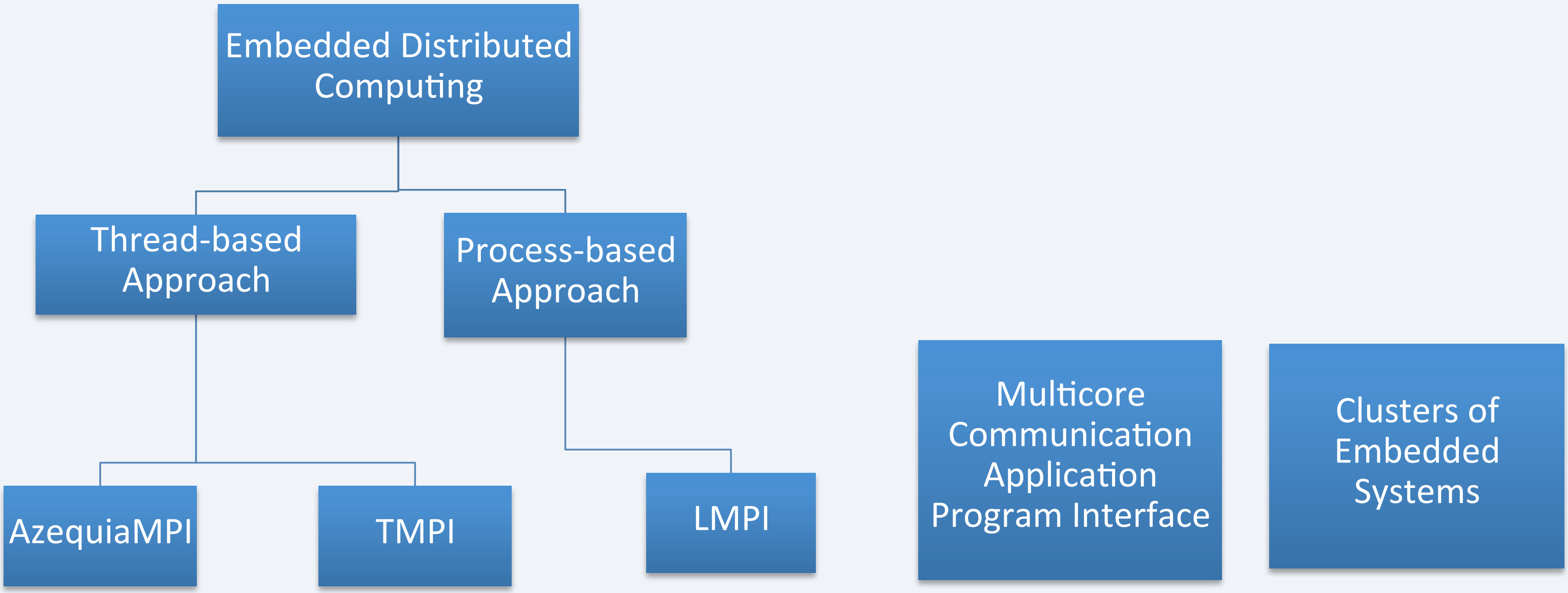
$$W = \frac{1+(n-1)k(1-f)}{(1-f)+\frac{f}{n}}$$

$$PowerEfficiency = \frac{\overline{performance}}{(\overline{watts})}$$

n= number of processors
f = fraction of computation that can be parallelized ($0 \le f \le 1$)
k = fraction of power the processor consumes in idle state ($0 \le k \le 1$)

$$PowerEfficiency = \frac{1}{1+(n-1)k(1-f)}$$

Related Work



J. A. R.-G. et al, "A pthreads-based mpi-1 implementation for mmu-less machines," Reconfigurable Computing and FPGAs, pp. 277 – 282, 2008.

H. T. et al, "Program transformation and runtime support for threaded mpi execution on shared memory machines," ACM Transactions on Programming Languages and Systems, pp. 673–700, 2000

A. A. et al, "Lmpi: Mpi for heterogeneous embedded distributed systems," Parallel and Distributed Systems, pp. 8 pp –, 2006

L. M. et al "Multicore Communications API (MCAPI) implementation on an FPGA multiprocessor," Embedded Computer Systems (SAMOS), 2011 International Conference on, Samos, 2011, pp. 286-293

J. Liu, "Mpi for embedded systems: A case study." [Online]. Available: www.ece.uci.edu/~jinfengl/course/ECE238F02.pdf

Related Work

Conferences where this work has been presented

V. Rodriguez and M. R. de Alba, “Embedded distributed systems: A case of study with clear linux.”, Embedded Linux conference March 2015, San Jose CA [Online]: http://events.linuxfoundation.org/sites/ events/files/ slides/ELC_Embedded_Distributed.pptx_.pdf

V. Rodriguez and M. R. de Alba, “Embedded distributed systems”, Congreso Internacional de Computación y Telecomunicaciones, September 2015, Lima Peru [Online]: http://www.comtel.pe/

Contribution

Hypotesis

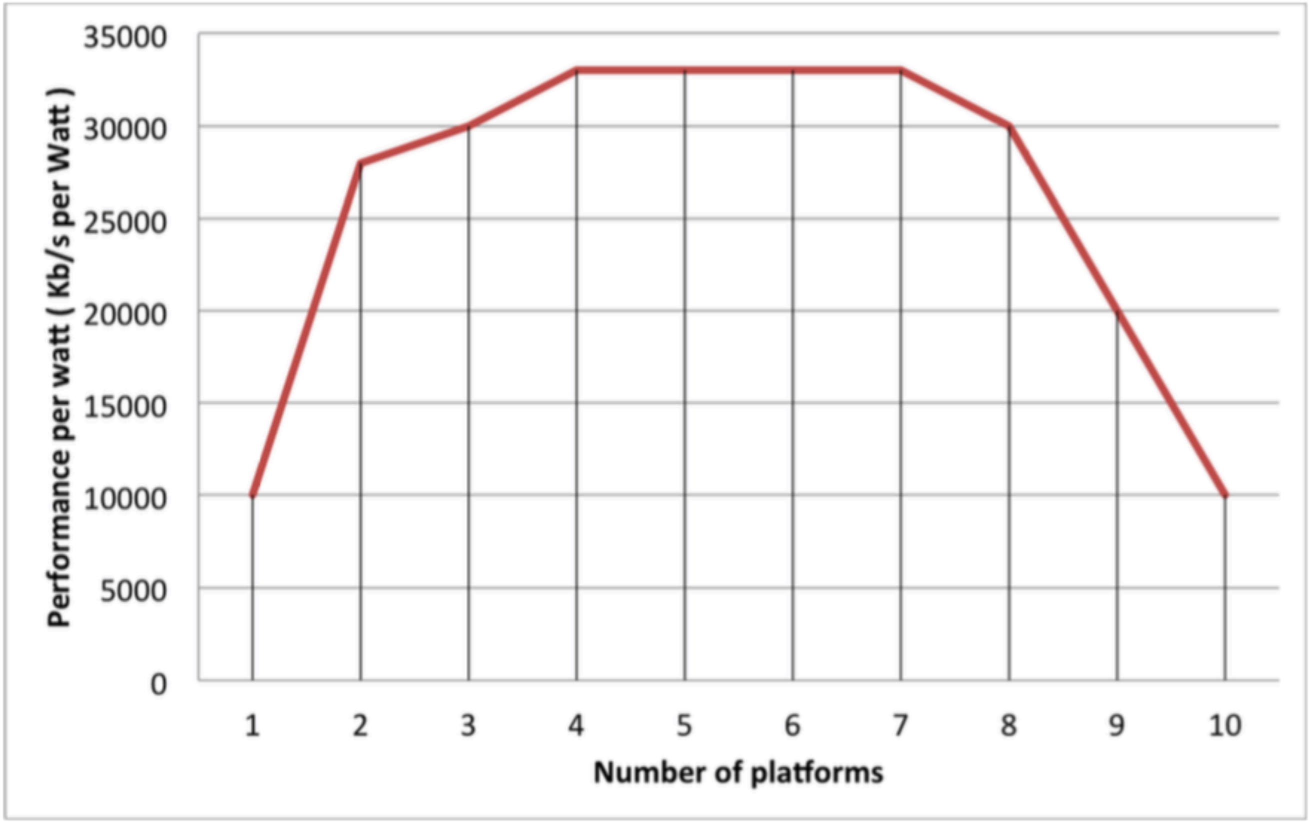


Figure 1.2: Hypothesis of energy efficiency behavior in embedded cluster

Contribution

Methodology

- Select an embedded platform
- Select a set of benchmarks
- Evaluate multiple operating systems
- Measure energy efficiency on embedded clusters
- Find an optimal cluster topology for the highest power efficiency
- Suggest software improvements

Contribution

Embedded Platform

Processor Number	E3825
# of cores	2
# of Thread	2
Clock Speed	1.3 GHz
L2 Cache	1MB
Instruction Set	64 bit

Table 4.1: Intel® Atom Processor E3825 Specifications

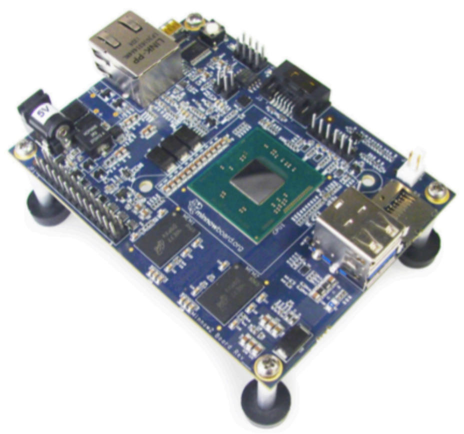


Figure 4.1: Minnow board max platform

Contribution

Traditional Computing System

Processor Number	Intel Core i5-4250U Processor
# of cores	2
# of Thread	4
Clock Speed	1.3 GHz
L2 Cache	3MB
Instruction Set	64 bit

Table 4.2: Intel® NUC D54250WYK Specifications

Contribution

MPI benchmarks selected:

- Bandwidth
- Bidirectional Bandwidth
- Roundtrip
- Application Latency
- Broadcast and Reduce
- AllReduce
- All-to-all

Contribution

Select Operating System

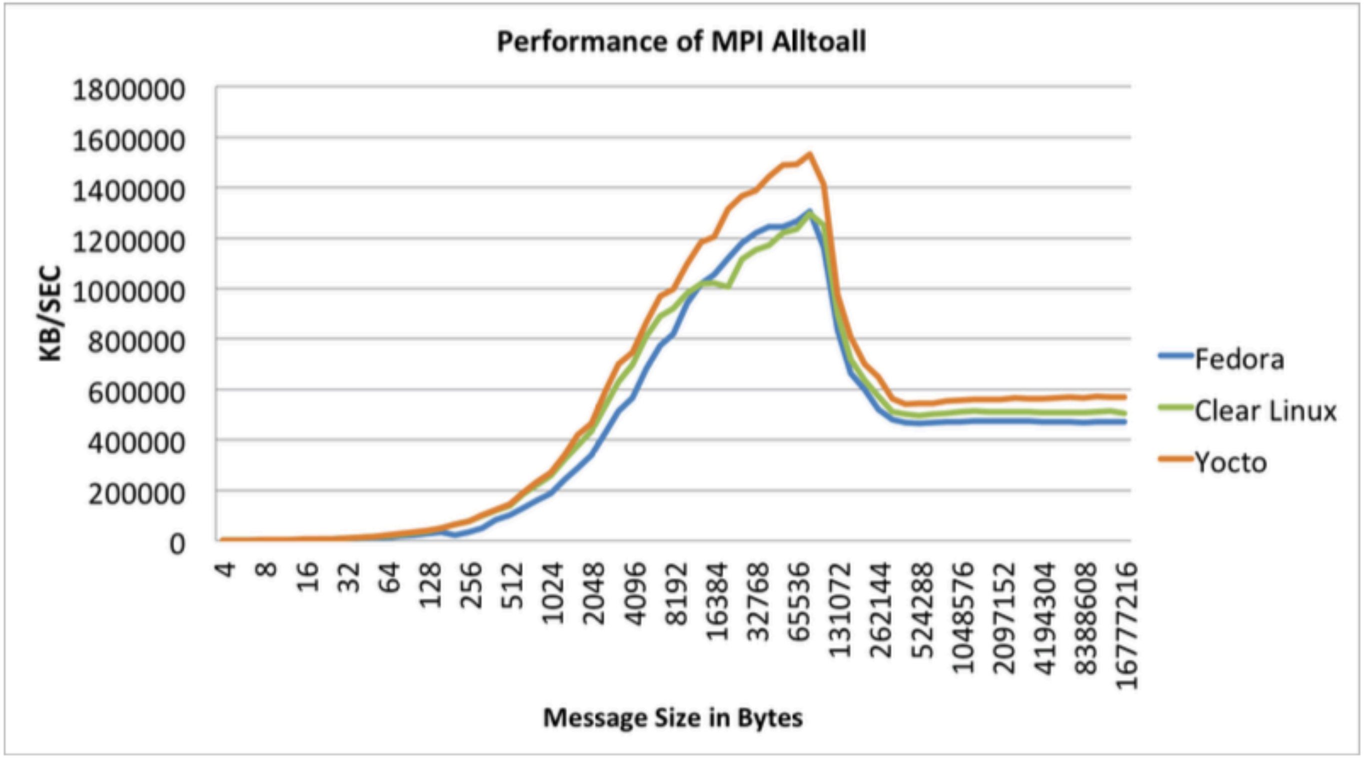


Figure 5.16: *MPI all to all* benchmark running in MinnowBoard MAX with Clear Linux, Yocto and Fedora

Yocto implementation given by Victor Rodriguez and Marcos de Alba
http://cgit.openembedded.org/cgit.cgi/meta-openembedded/tree/meta-oe/recipes-devtools/mpich/mpich_3.1.1.bb?h=master

Contributions

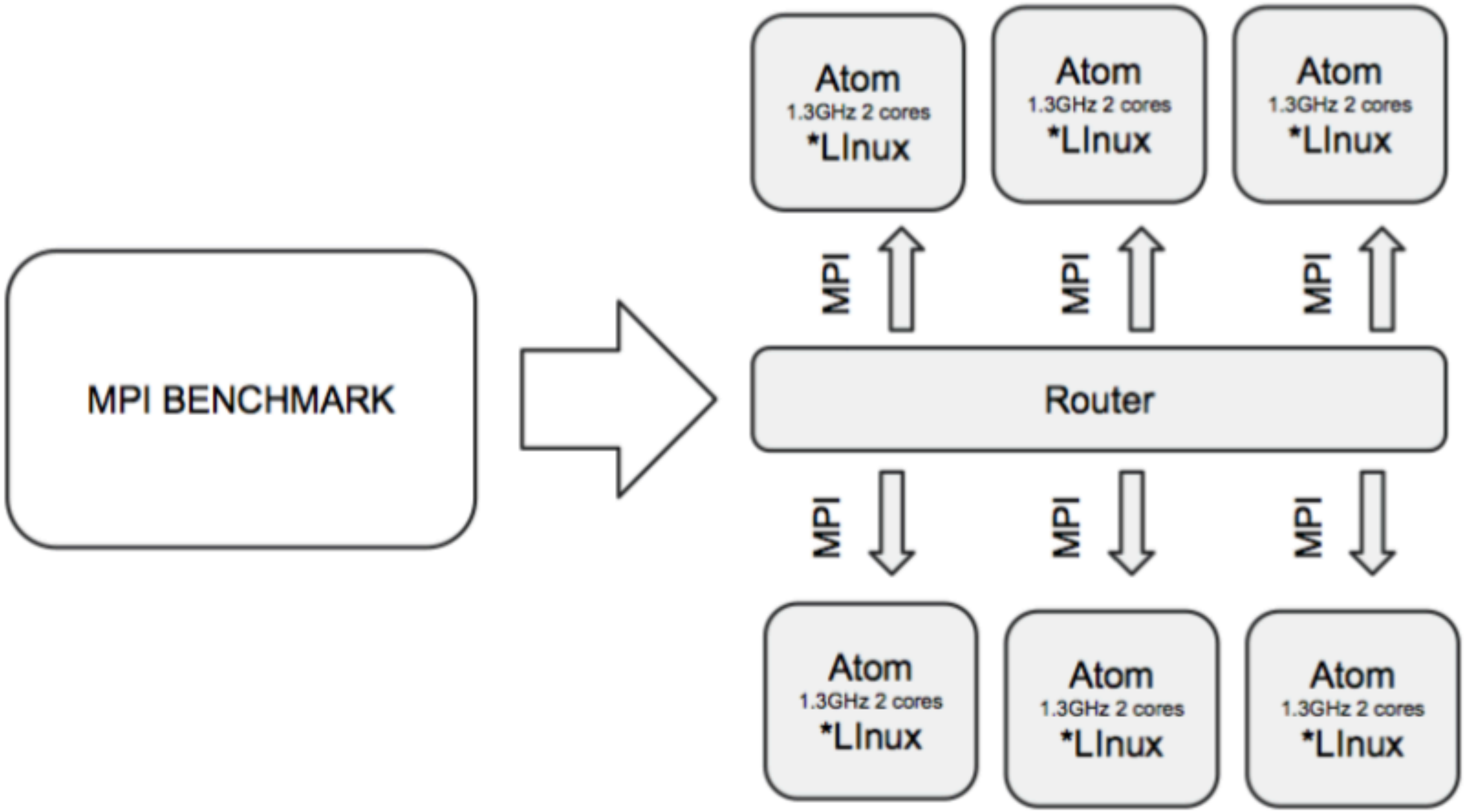


Figure 4.4: System architecture diagram

Contributions

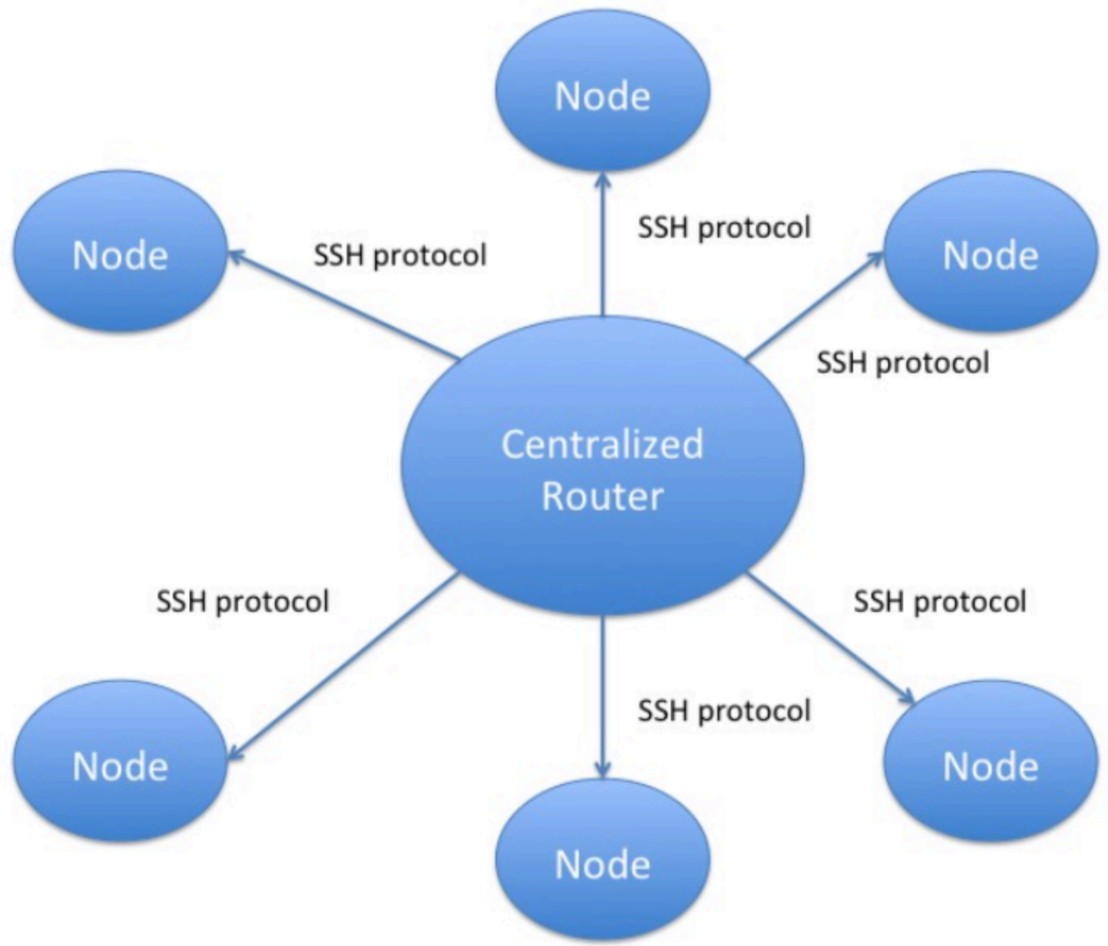
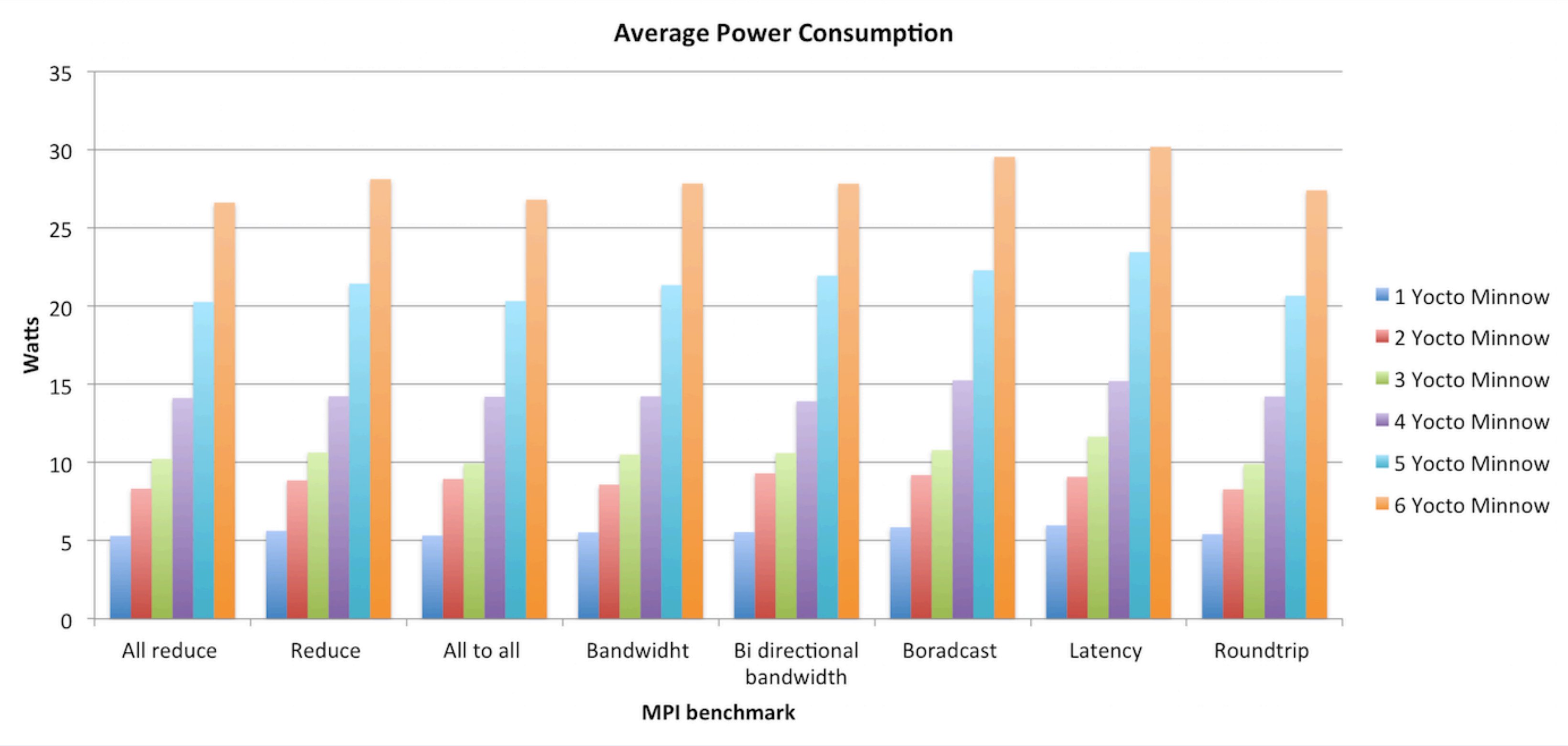


Figure 4.3: Star topology diagram

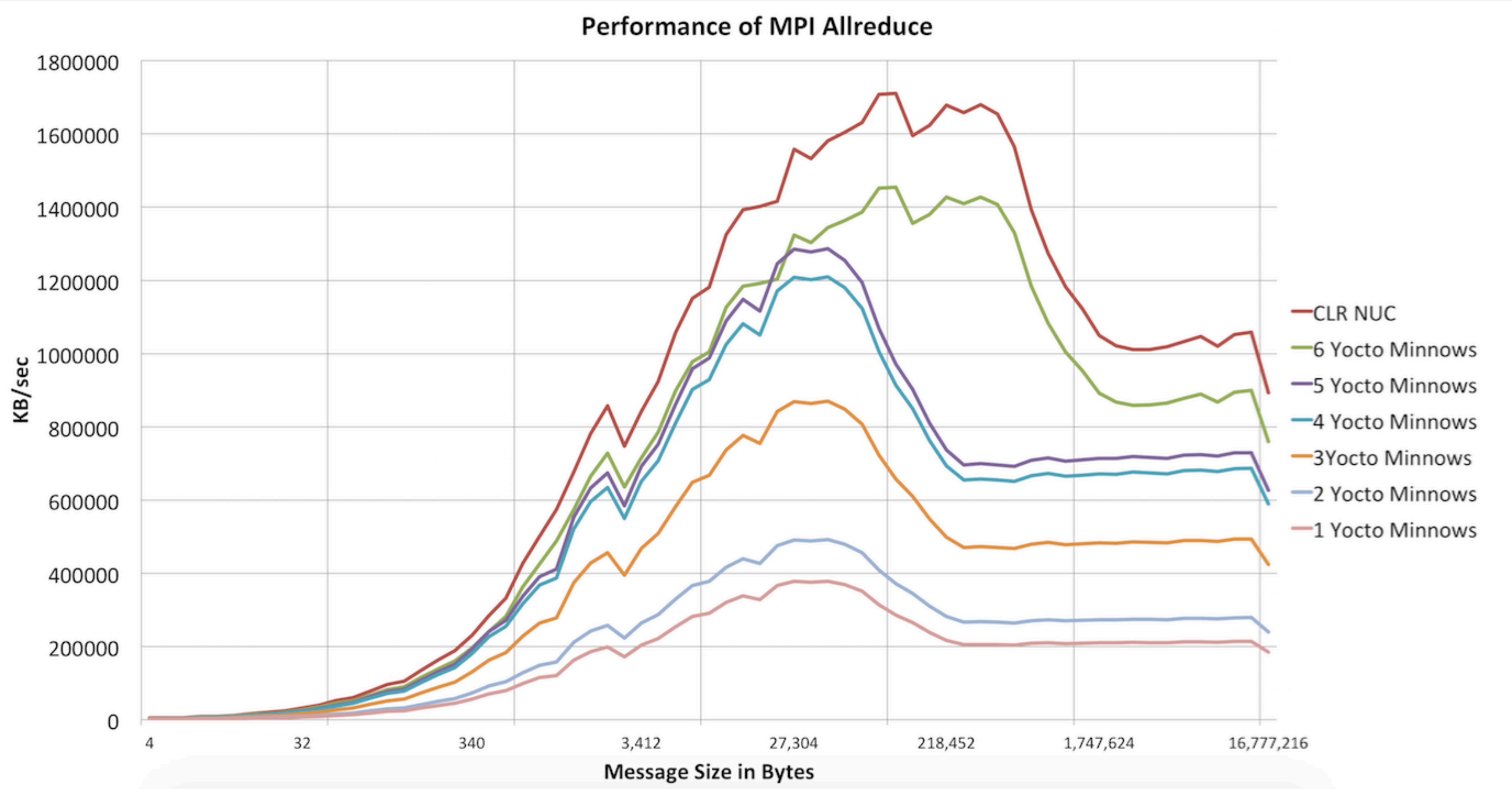
Results

Optimal number of embedded systems/energy efficiency



Results

Performance of MPI Allreduce Benchmark in Cluster



Contribution of this work

Power efficiency

$$PowerEfficiency = \frac{\overline{performance}}{(\overline{watts})}$$

Results

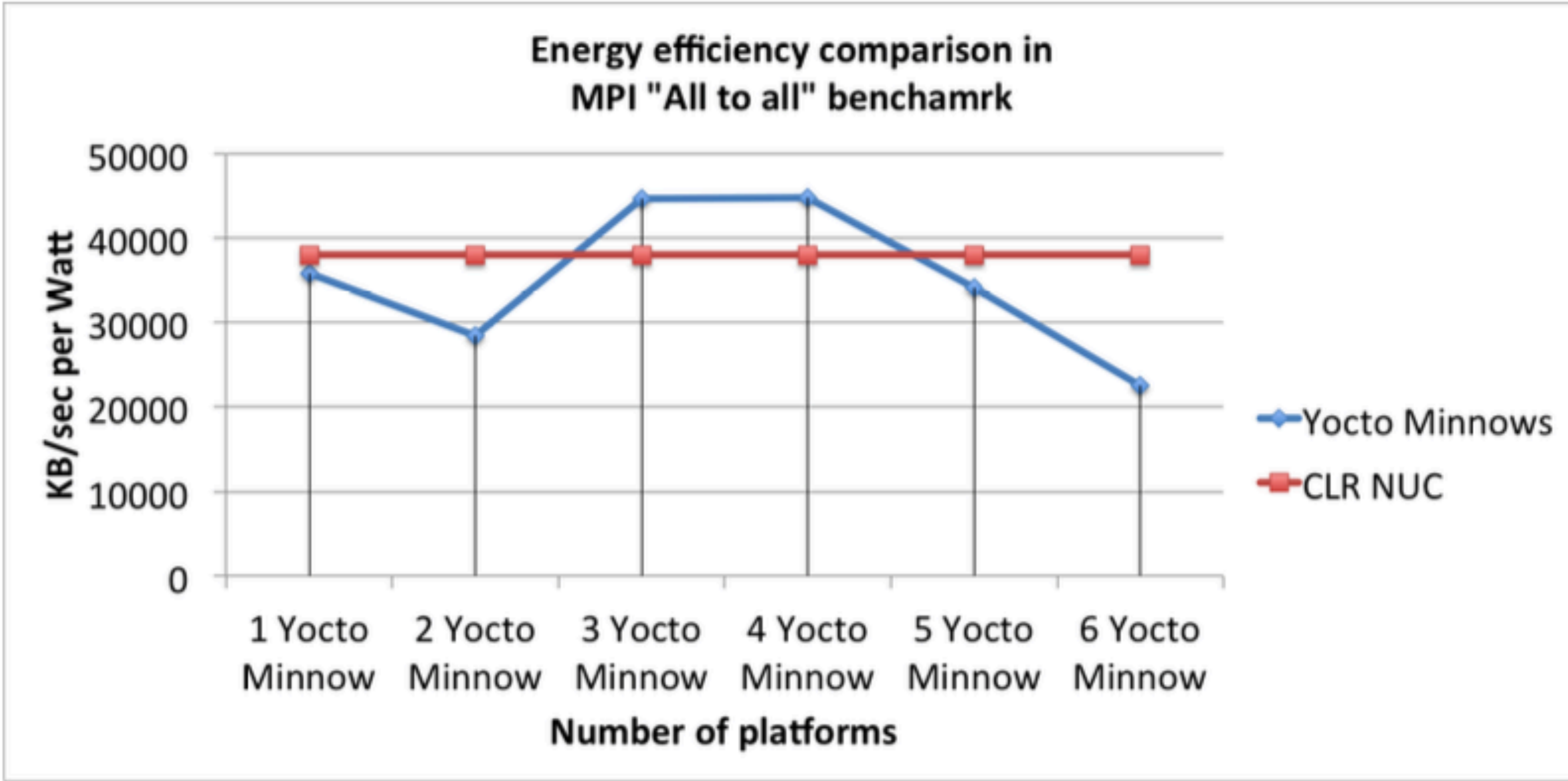


Figure 5.35: Energy efficiency comparison on MPI *All to all* benchmark

Results

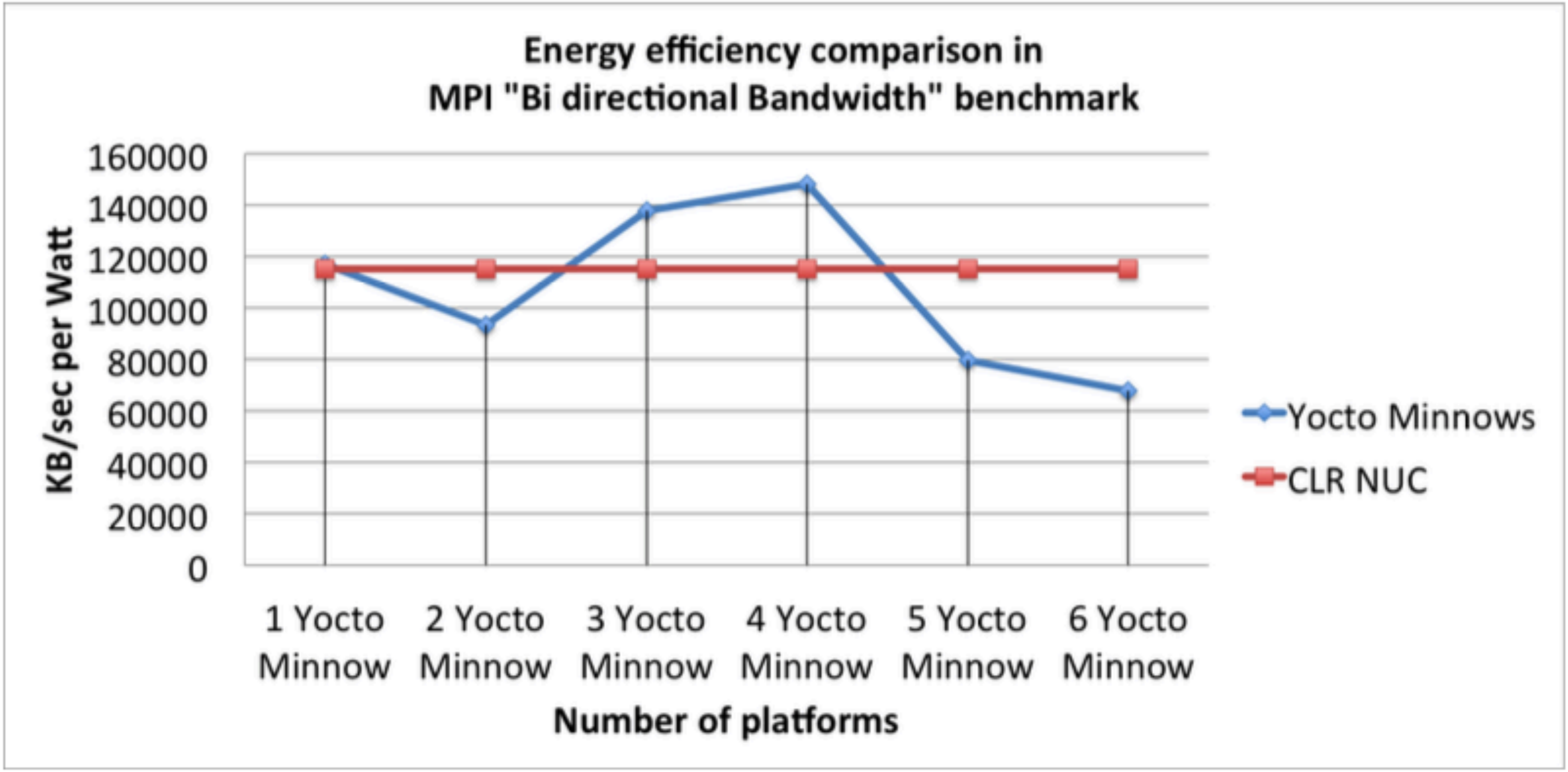


Figure 5.36: Energy efficiency comparison on MPI *Bi directional Bandwidth* benchmark

Results

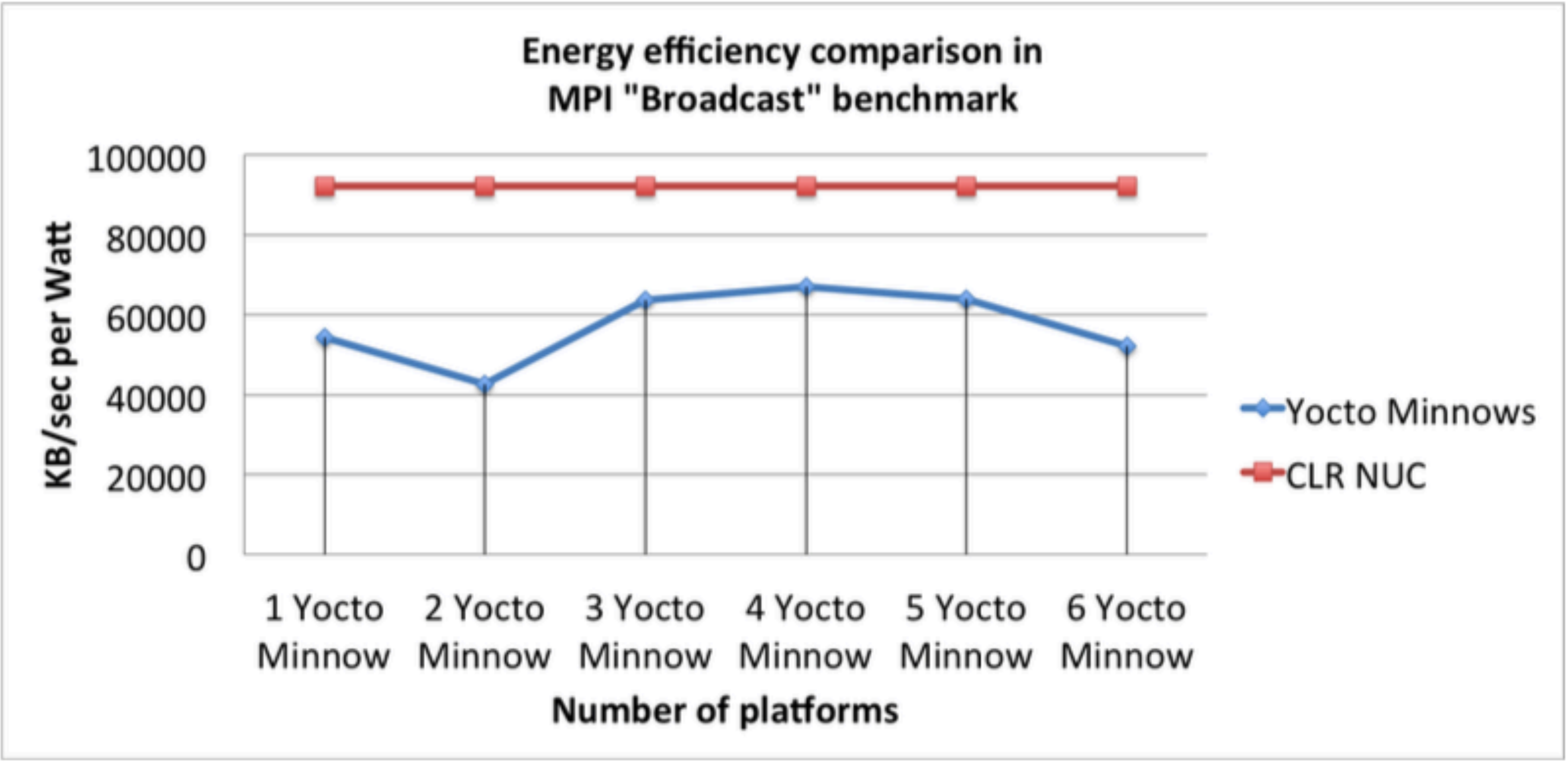


Figure 5.38: Energy efficiency comparison on MPI *Broadcast Bandwidth* benchmark

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Summary

- This research work studies a cluster of embedded boards

- Compares power efficiency of an embedded cluster to a desktop computing system

- Results are compared between multiple operating systems to select the most power efficient

- Evaluates IoT local processing compared to sending data remotely

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Conclusions

- The energy efficiency of a multinode IoT distributed system can be equivalent to that of a traditional computing system
- The workload is distributed between different platforms, as more are added, performance gain starts to minimize
- When the ideal number of platforms is exceeded, power efficiency decreases rapidly

Gracias
¿Preguntas?

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Back up

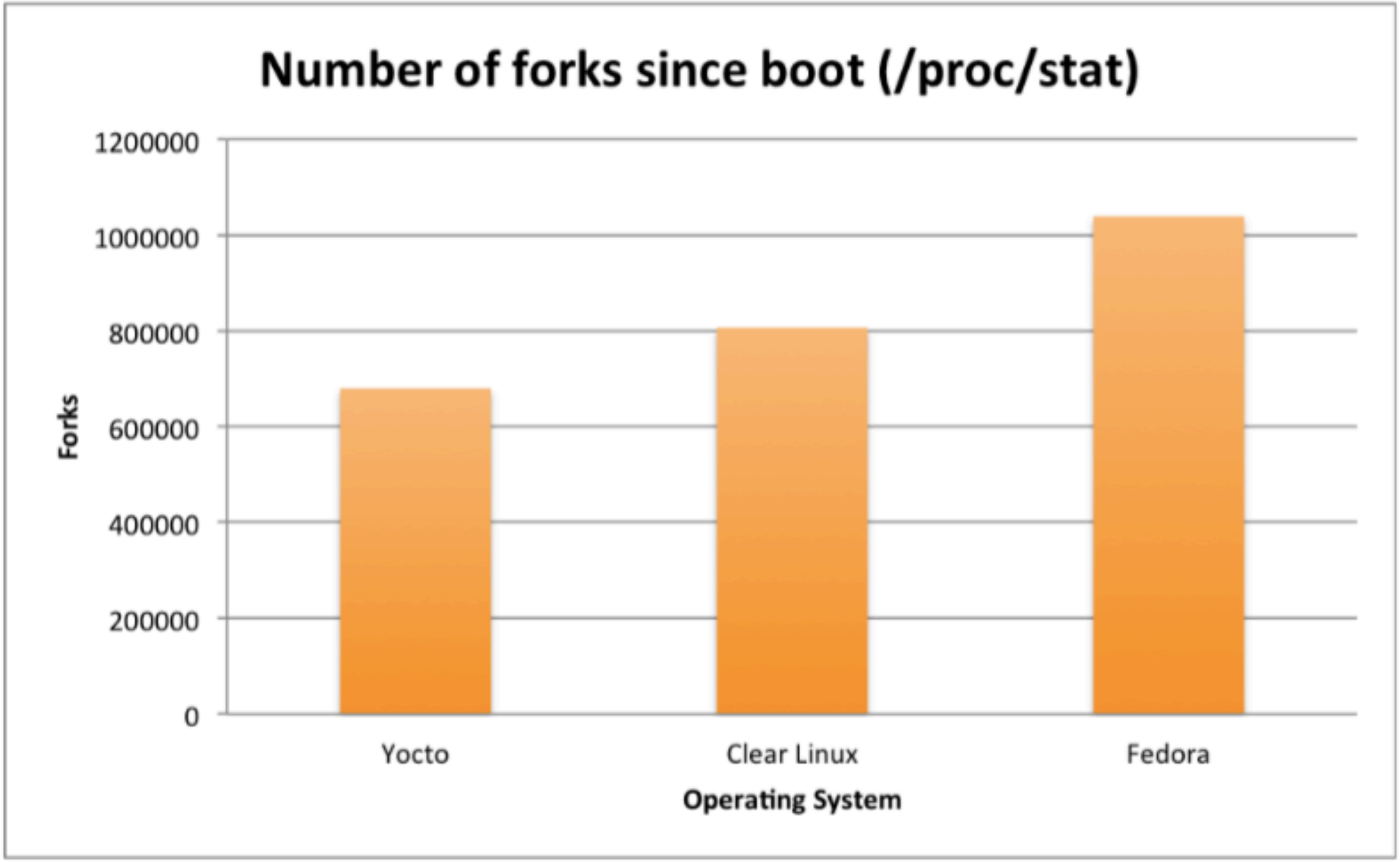

Figure 5.21: Number of forks since booting process reported in /proc/stat file

Back up

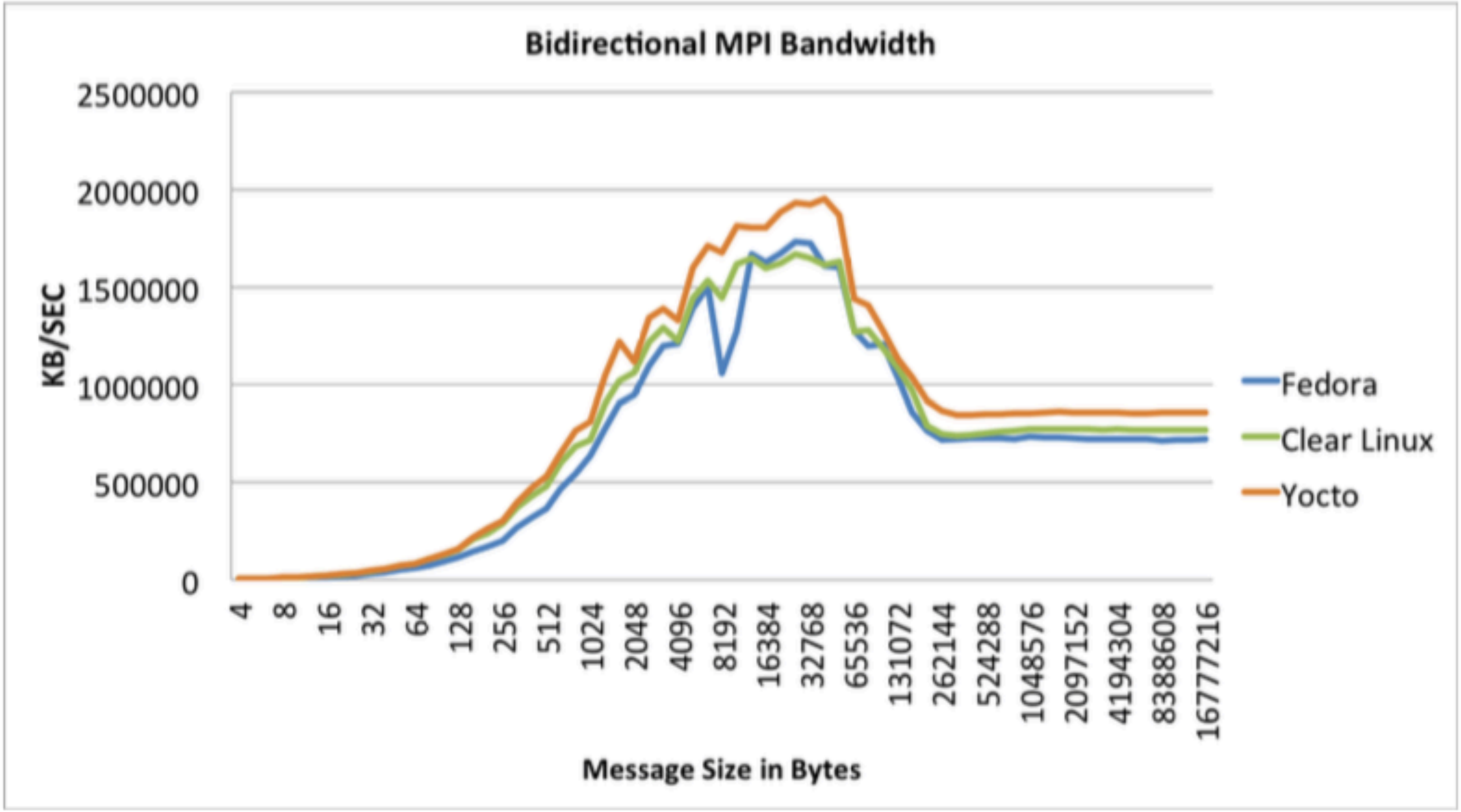

Figure 5.19: *MPI Bi directional* bandwidth running in MinnowBoard MAX with Clear Linux, Yocto and Fedora.

Back up

```
# enable cpu frequency scaling and stats for powertop
CONFIG_CPU_FREQ=y
CONFIG_CPU_FREQ_STAT=y
CONFIG_X86_ACPI_CPUFREQ=y
CONFIG_X86_INTEL_PSTATE=y
CONFIG_CPU_FREQ_GOV_ONDEMAND=y
CONFIG_CPU_FREQ_GOV_PERFORMANCE=y
CONFIG_CPU_FREQ_DEFAULT_GOV_ONDEMAND=y
```

Figure 5.17: Performance improvement in Kernel for Yocto operating systems.

Back up

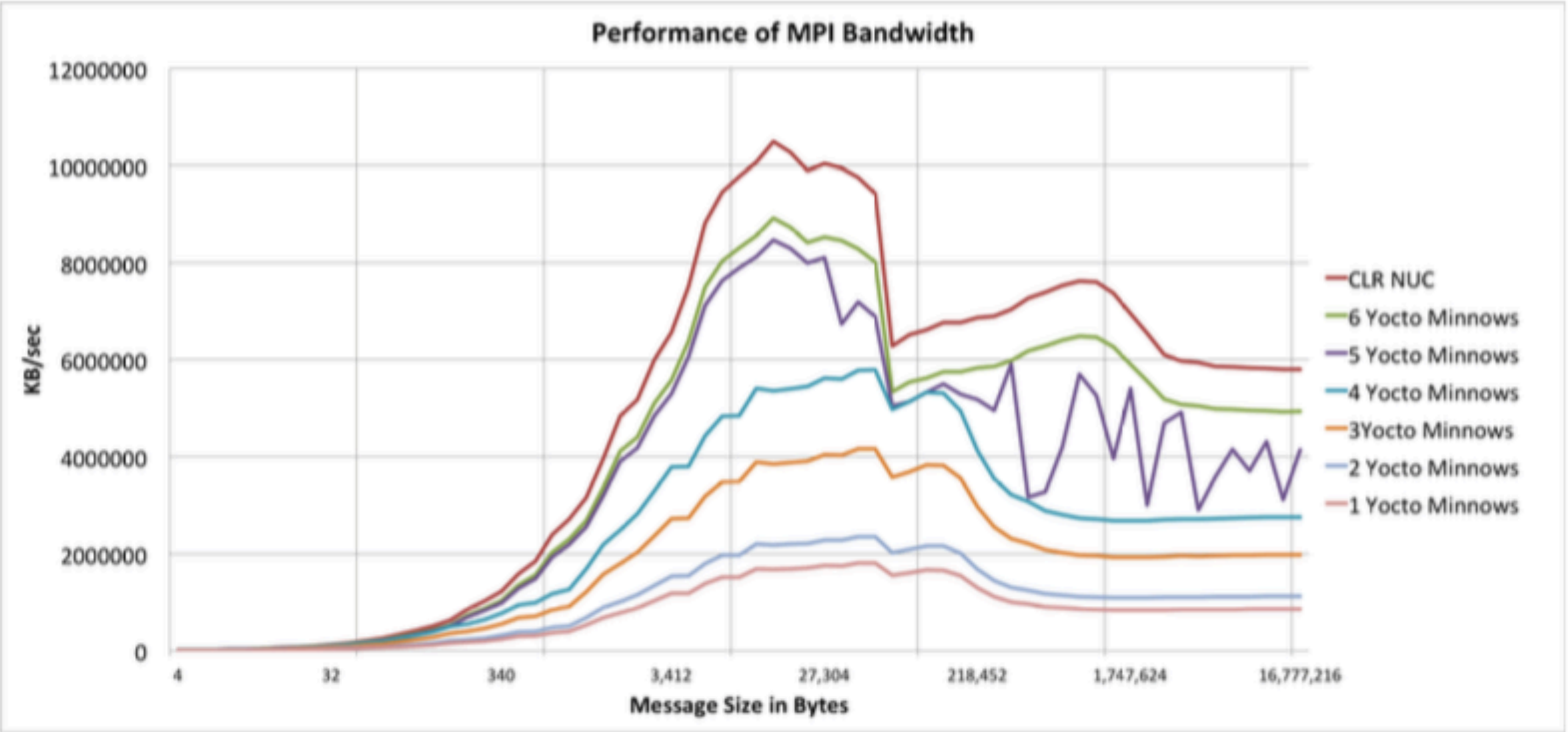

Figure 5.27: *Bandwidth* benchmark in cluster of embedded platforms with Yocto OS and NUC with Clear Linux OS.