Leveraging RISC-V to build an open-source (hardware) OS framework for reconfigurable IoT devices

Miguel Silva, Tiago Gomes, Sandro Pinto

miguel.silva@dei.uminho.pt
mr.gomes@dei.uminho.pt
sandro.pinto@dei.uminho.pt

FCT Fundação para a Ciência e a Tecnologia

CENTROALGORITMI

UNIVERSIDADE DO MINHO

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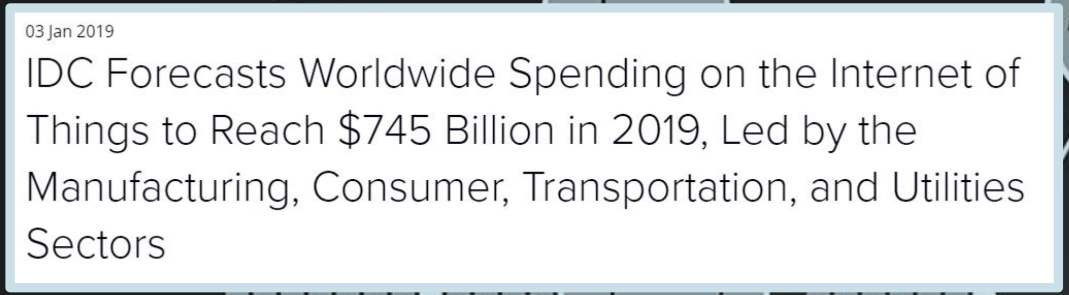
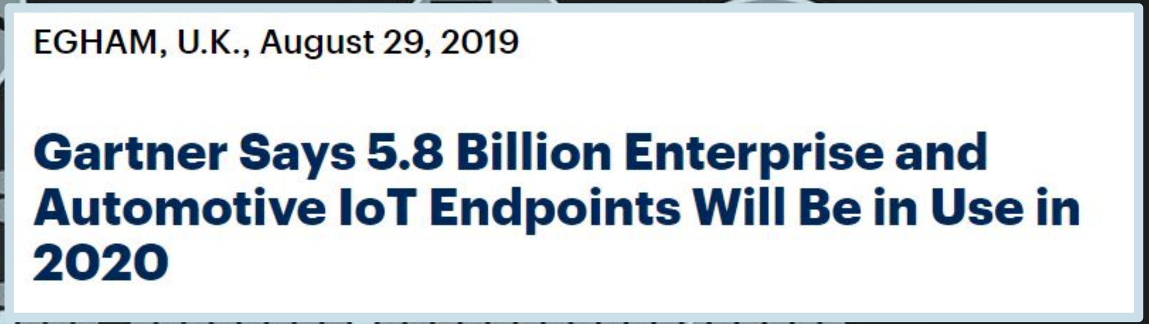
THE INTERNET OF THINGS



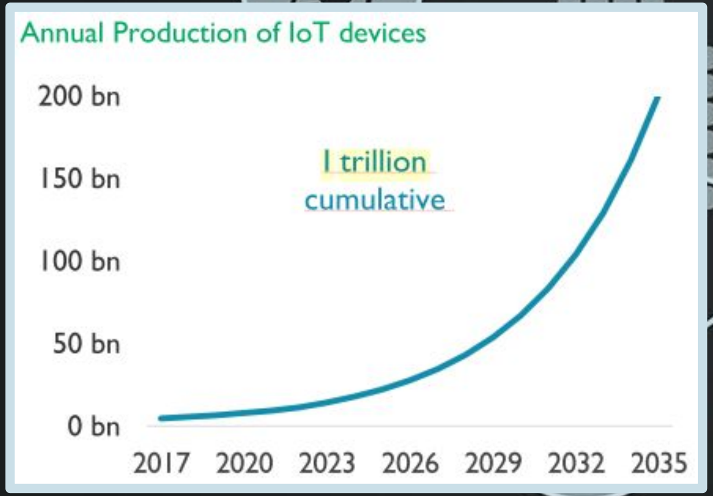
03 Jan 2019

IDC Forecasts Worldwide Spending on the Internet of Things to Reach $745 Billion in 2019, Led by the Manufacturing, Consumer, Transportation, and Utilities Sectors

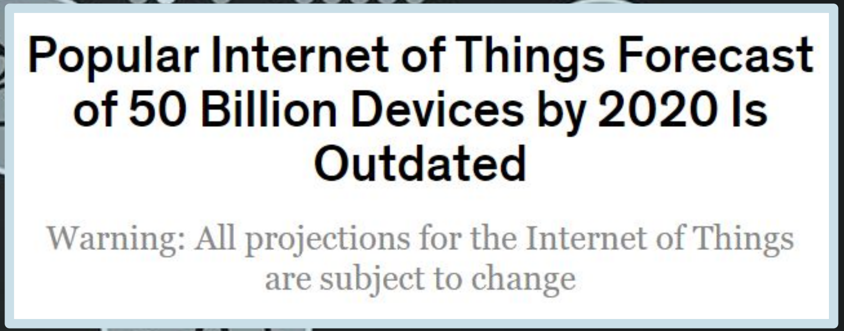


EGHAM, U.K., August 29, 2019

Gartner Says 5.8 Billion Enterprise and Automotive IoT Endpoints Will Be in Use in 2020



Annual Production of IoT devices



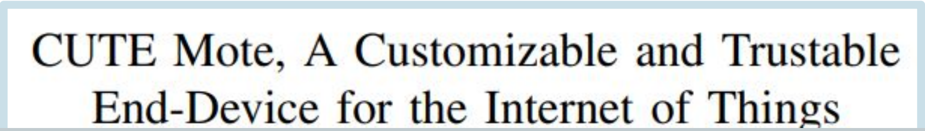
Popular Internet of Things Forecast of 50 Billion Devices by 2020 Is Outdated

Warning: All projections for the Internet of Things are subject to change

RECONFIGURABLE PLATFORMS

As FPGAs get bigger, faster, and cheaper, their presence in the embedded systems market expands.

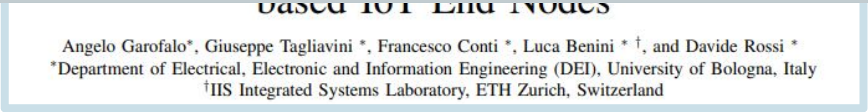
In the IoT industry, these platforms are also gaining traction due to the performance, flexibility, and scalability they provide.



CUTE Mote, A Customizable and Trustable
End-Device for the Internet of Things

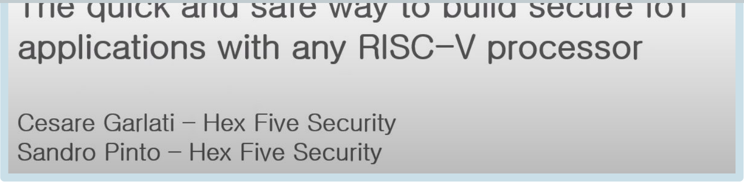
Arnold: An eFPGA-Augmented RISC-V SoC for
Flexible and Low-Power IoT End Nodes

The migration of OS kernel services **failed** in being adopted due to the overwhelming presence of proprietary processor IPs.



based IoT End Nodes

Angelo Garofalo*, Giuseppe Tagliavini *, Francesco Conti *, Luca Benini * †, and Davide Rossi *
*Department of Electrical, Electronic and Information Engineering (DEI), University of Bologna, Italy
†IIS Integrated Systems Laboratory, ETH Zurich, Switzerland



The quick and safe way to build secure IoT
applications with any RISC–V processor

Cesare Garlati – Hex Five Security
Sandro Pinto – Hex Five Security

CHAMELIOT

ChamelIoT is an agnostic hardware OS framework for reconfigurable IoT platforms.

By leveraging the RISC-V architecture, ChamelIoT goals include providing:

- Real-time and Determinism
- Performance
- Agnosticism
- Flexibility and Portability
- Power Consumption

RISC-V®

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ChamelIoT

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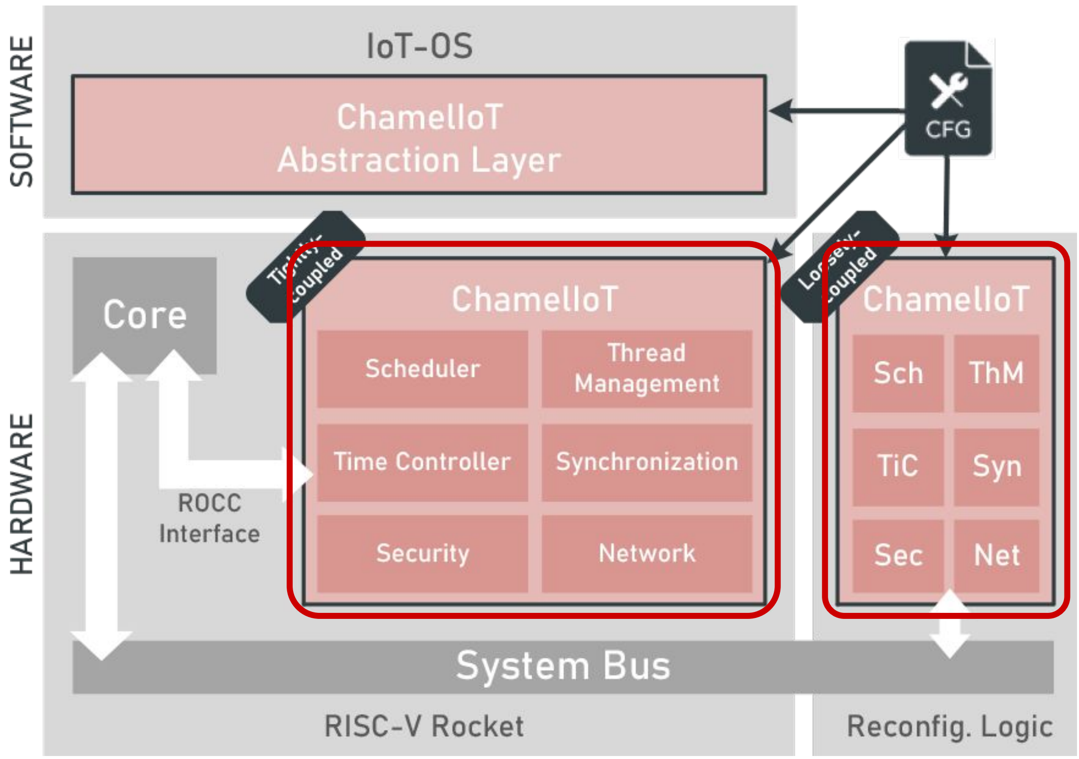
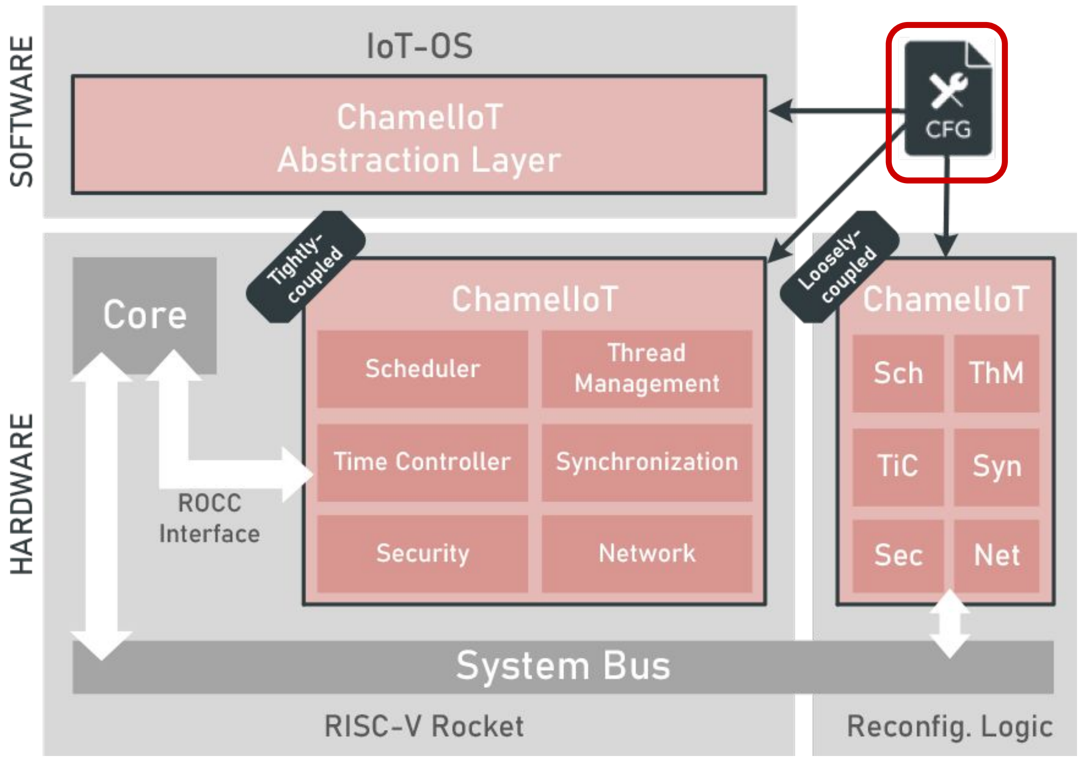
CHAMELIOT ARCHITECTURE



ChamelIoT's hardware component main focus is to accelerate OS kernel services.

ChamelIoT aims at exploring the trade-offs between tightly- and loosely-coupled architectures.

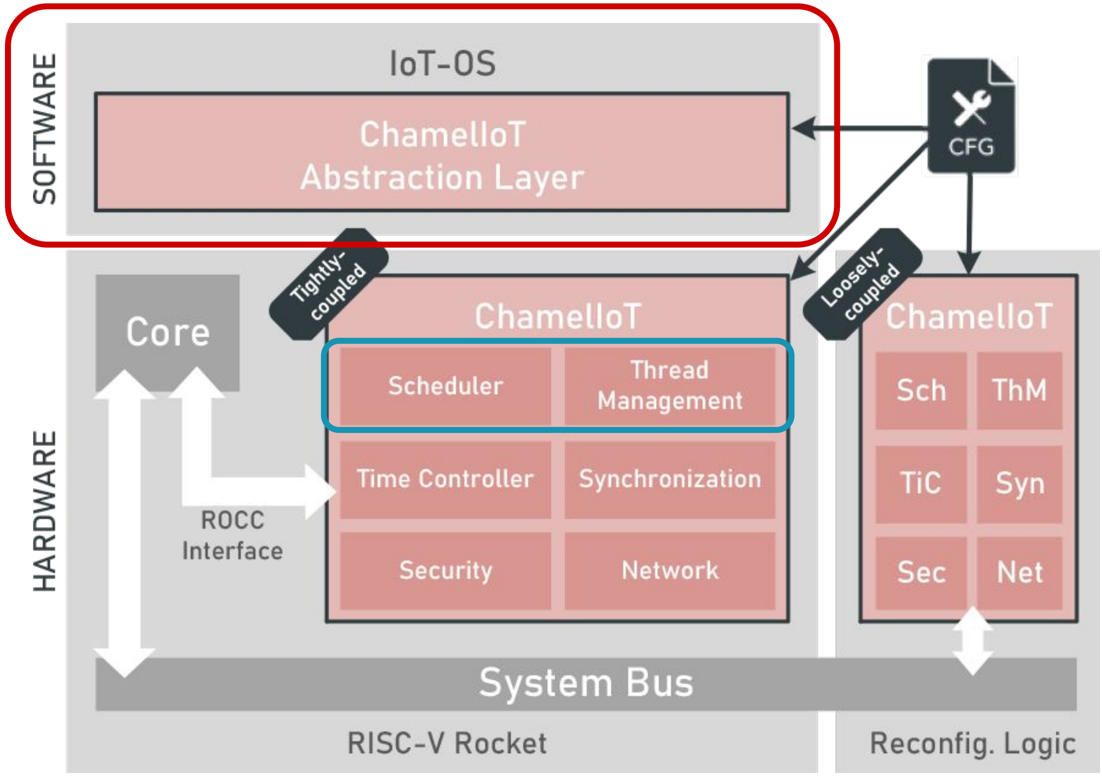
CHAMELIOT ARCHITECTURE



The *External Configuration Tool* can be used to configure and fine-tune the full system.

- Kernel components;
- Fine-grain features of system components;
- Configurations, e.g. tightly- vs loosely-coupled.

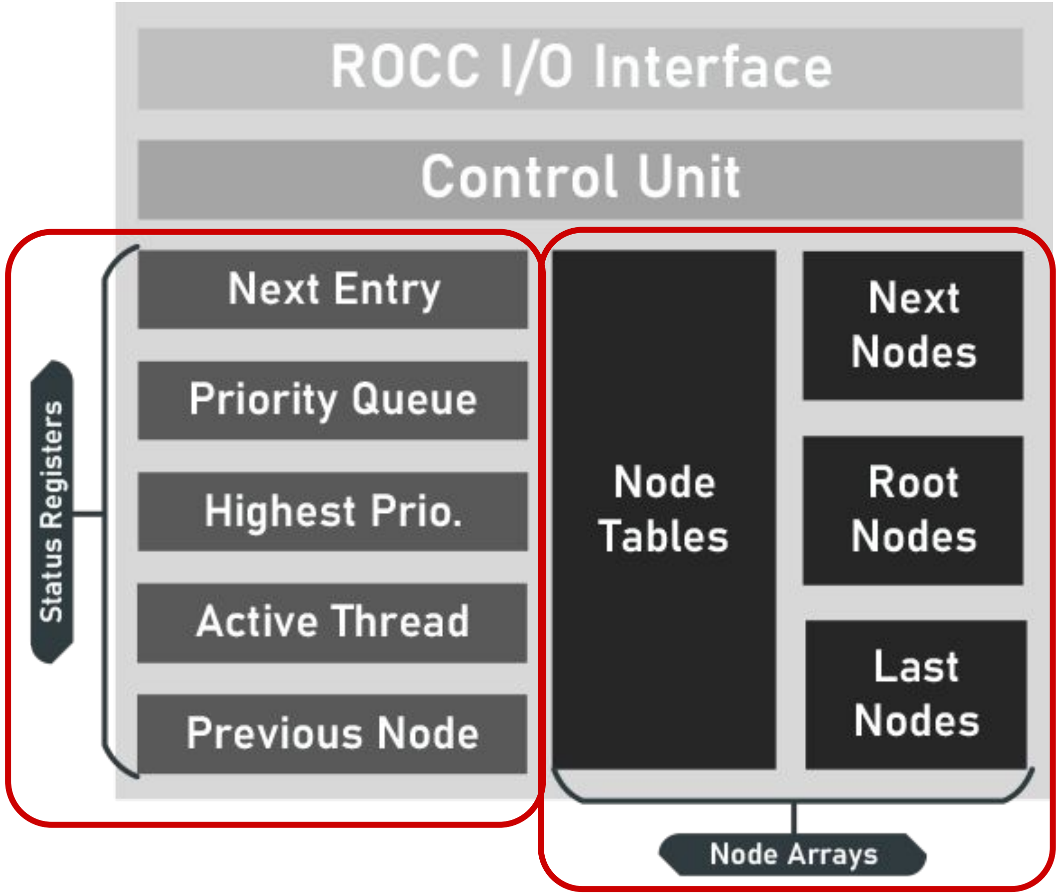
CHAMELIOT ARCHITECTURE



ChamelIoT Abstraction Layer aims at providing agnosticism for applications targeting different OSes.

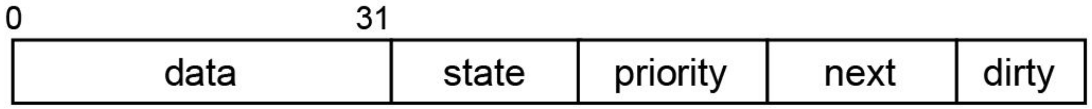
Key aspects	RIOT	Zephyr	FreeRTOS
Ready Queue	Multi-queue	Multi-queue	Multi-queue
States	14	8	4
Scheduling Points	Tickless	Tickless	Tick-based
Priority	Descending	Descending	Ascending

PROOF-OF-CONCEPT IMPLEMENTATION



Status Registers are used to keep track of the state of the multiple linked lists.

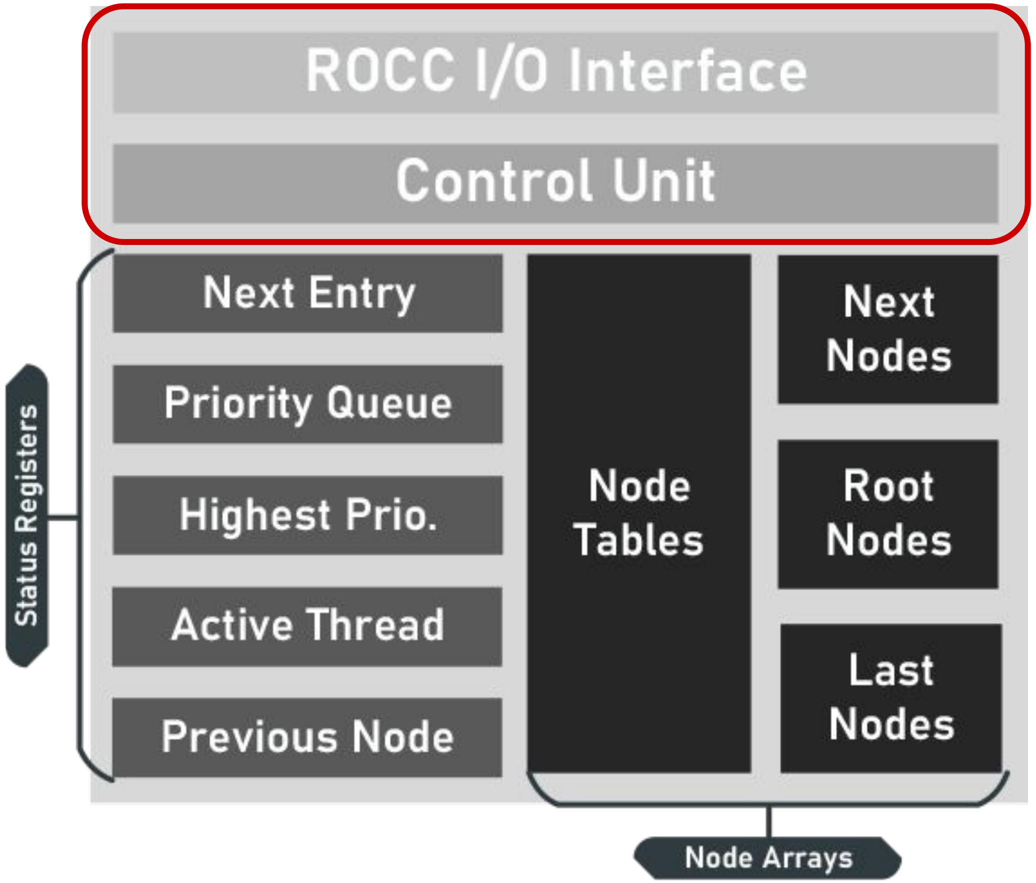
Node Arrays are sets of nodes and registers that constitute the linked lists

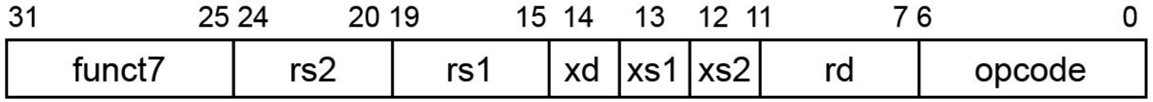


data	state	priority	next	dirty

Linked-List Node

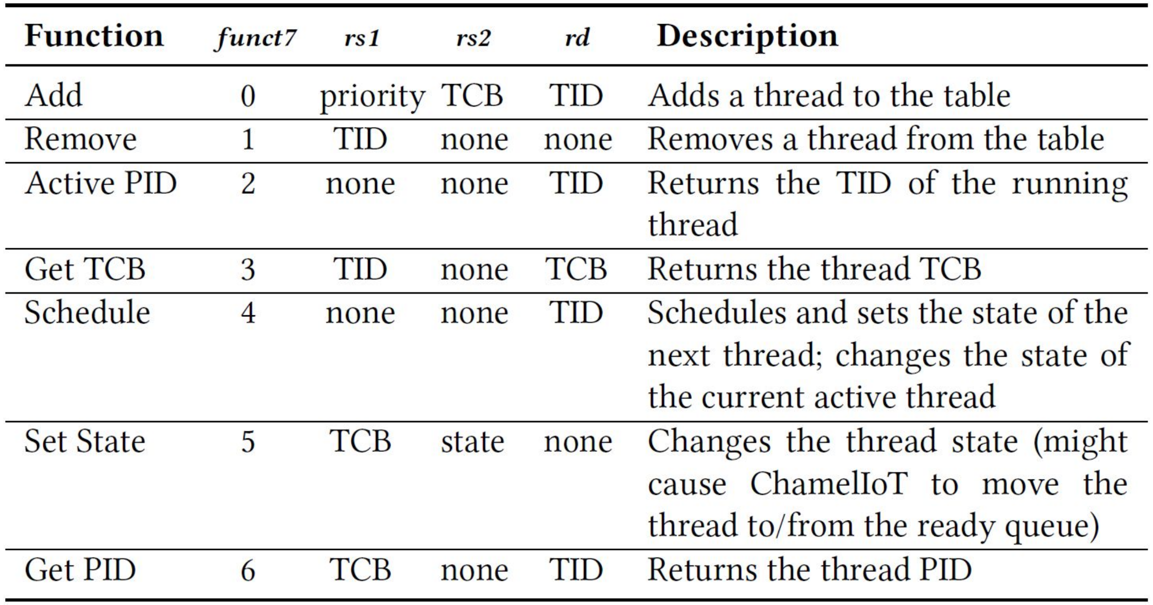
PROOF-OF-CONCEPT IMPLEMENTATION





31 25	24 20	19 15	14	13	12	11 7	6 0
funct7	rs2	rs1	xd	xs1	xs2	rd	opcode

RoCC Instruction Format



Function	*funct7*	*rs1*	*rs2*	*rd*	**Description**
Add	0	priority	TCB	TID	Adds a thread to the table
Remove	1	TID	none	none	Removes a thread from the table
Active PID	2	none	none	TID	Returns the TID of the running thread
Get TCB	3	TID	none	TCB	Returns the thread TCB
Schedule	4	none	none	TID	Schedules and sets the state of the next thread; changes the state of the current active thread
Set State	5	TCB	state	none	Changes the thread state (might cause ChamelIoT to move the thread to/from the ready queue)
Get PID	6	TCB	none	TID	Returns the thread PID

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ChamelIoT

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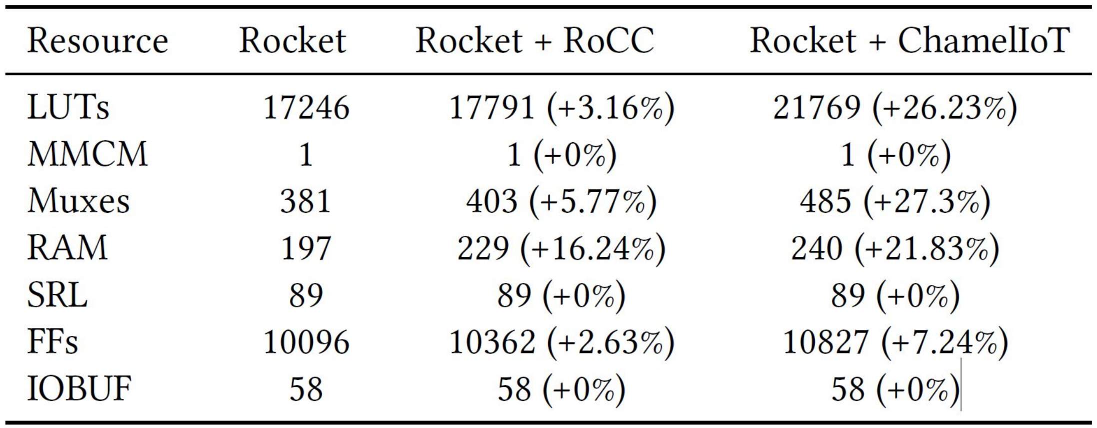
HARDWARE RESOURCES

ChamelIoT PoC implementation was deployed and evaluated on a SiFive Freedom E300 in a Xilinx Arty-35T FPGA board.

- The base configuration supported a total of 8 threads and 8 priority levels:

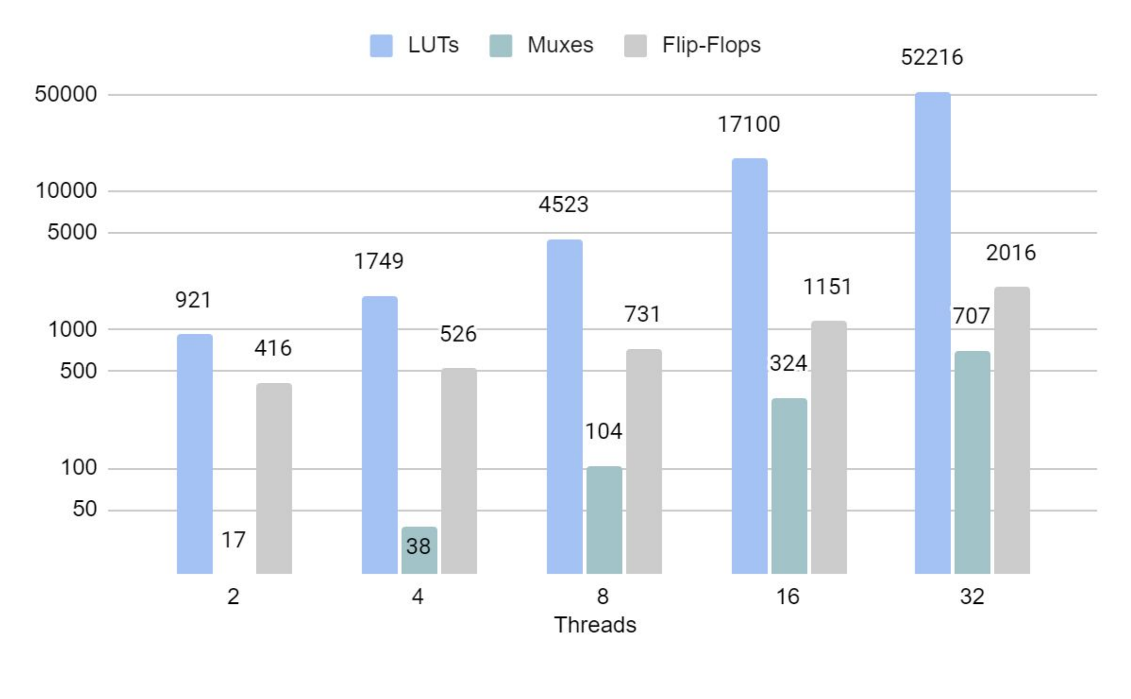


Resource	Rocket	Rocket + RoCC	Rocket + ChamelIoT
LUTs	17246	17791 (+3.16%)	21769 (+26.23%)
MMCM	1	1 (+0%)	1 (+0%)
Muxes	381	403 (+5.77%)	485 (+27.3%)
RAM	197	229 (+16.24%)	240 (+21.83%)
SRL	89	89 (+0%)	89 (+0%)
FFs	10096	10362 (+2.63%)	10827 (+7.24%)
IOBUF	58	58 (+0%)	58 (+0%)

HARDWARE RESOURCES

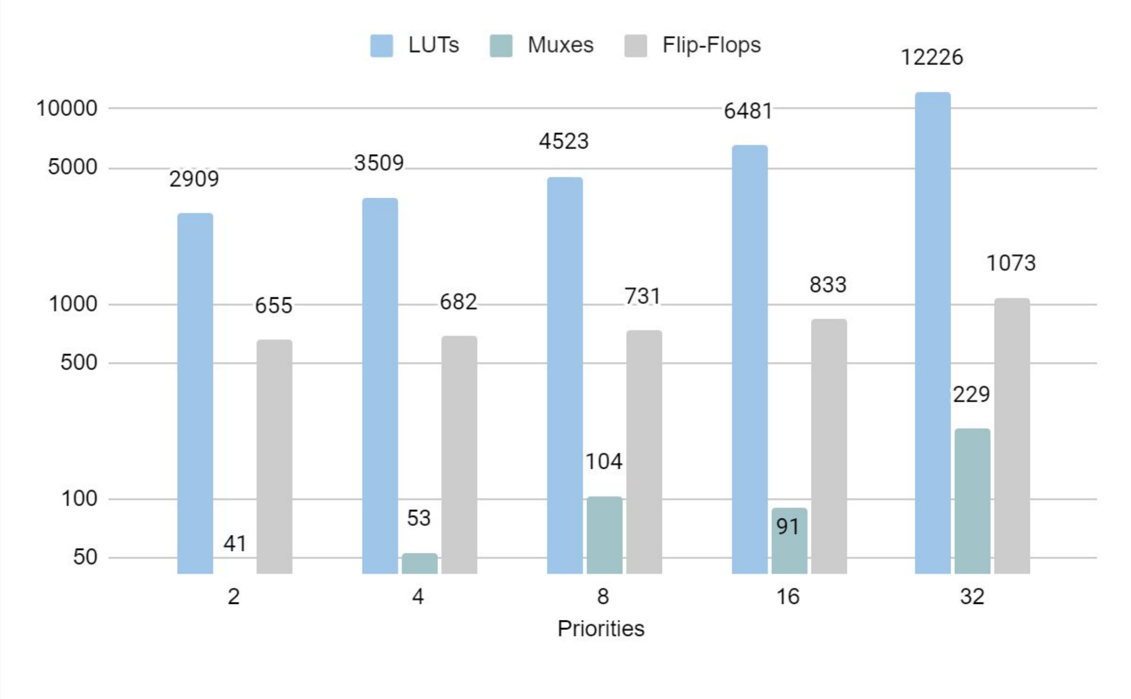
Fixed number of priorities (8)

Varying the number of **threads**



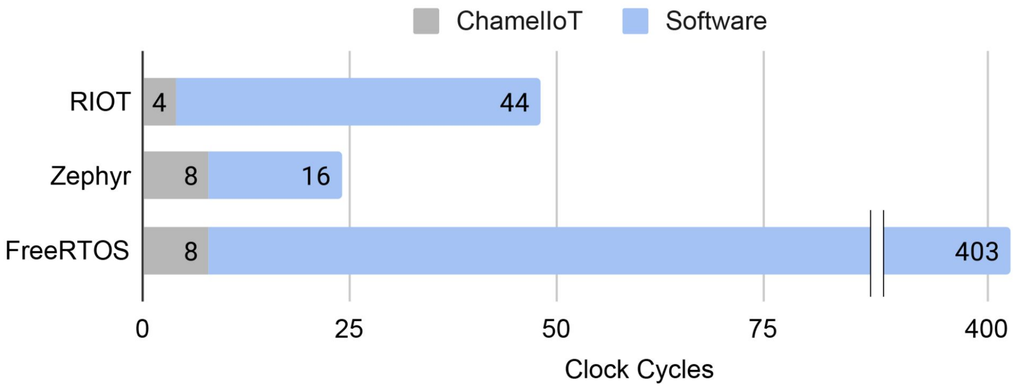
Fixed number of threads (8)

Varying the number of **priorities**



DETERMINISM & PERFORMANCE

We have measured the number of clock cycles required to perform the thread selection algorithm.



- RIOT and FreeRTOS vastly benefit from using ChamelIoT scheduler.
- Despite the impact of ChamelIoT on Zephyr being lesser, our past research proved that Zephyr will benefit from ChamelIoT in other areas.

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NEXT STEPS

Hardware

Thread Management

Timing Control

Synchronization and IPC

Loosely-coupled Accelerator

Software

Operating Systems Integration

Configuration Tool

TAKE AWAYS

1 Accelerating OS kernel services with ChamelIoT brings several benefits in terms of performance and determinism

2 ChamelIoT can be configured to perfectly fit the system's needs

3 Research will focus on providing support to a broader number of kernel features and additional OSes

THANK YOU!

Miguel Silva (UMinho) | Tiago Gomes (UMinho) | Sandro Pinto (UMinho)

miguel.silva@dei.uminho.pt | mr.gomes@dei.uminho.pt | sandro.pinto@dei.uminho.pt

Q&A