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Value-Based Resource Management at SoC Scale

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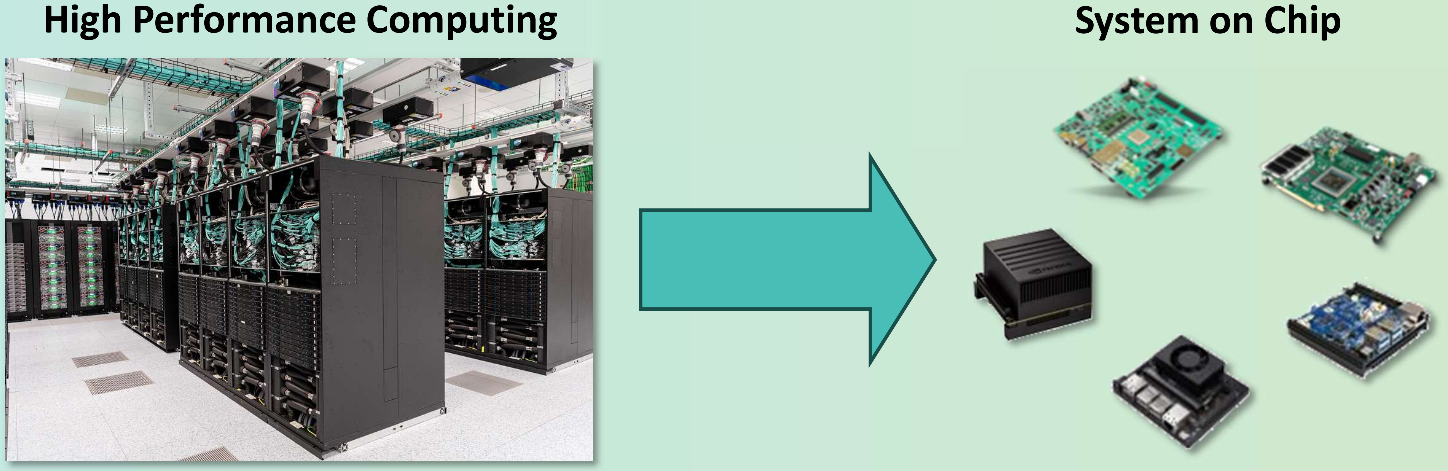
Motivation

- Value-based schedulers have been demonstrated as an effective method in HPC domain
- Challenges in the SoC domain:
    - Dynamic workloads
    - Heterogeneous resource pool
    - Decision-making time
    - Effective utilization of heterogeneous SoC platforms
- First steps to adapt value-based scheduling heuristics to SoC scale



Value Definition

- Value of an application as a function of time:

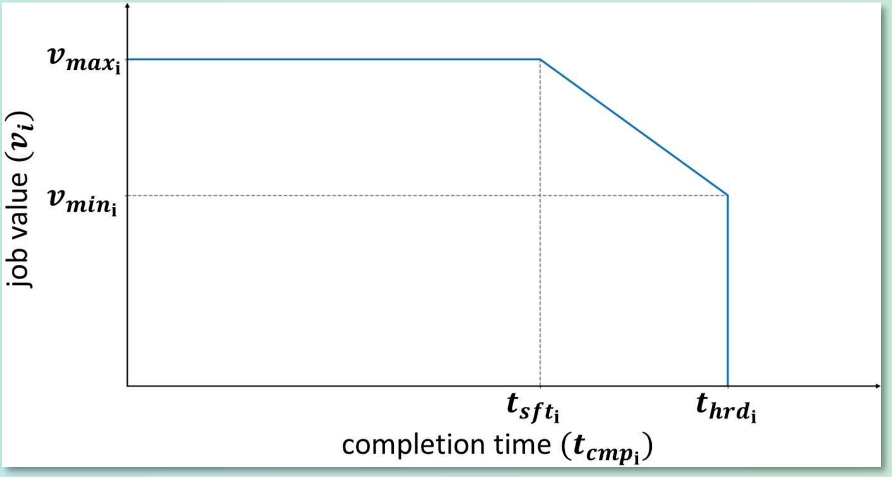
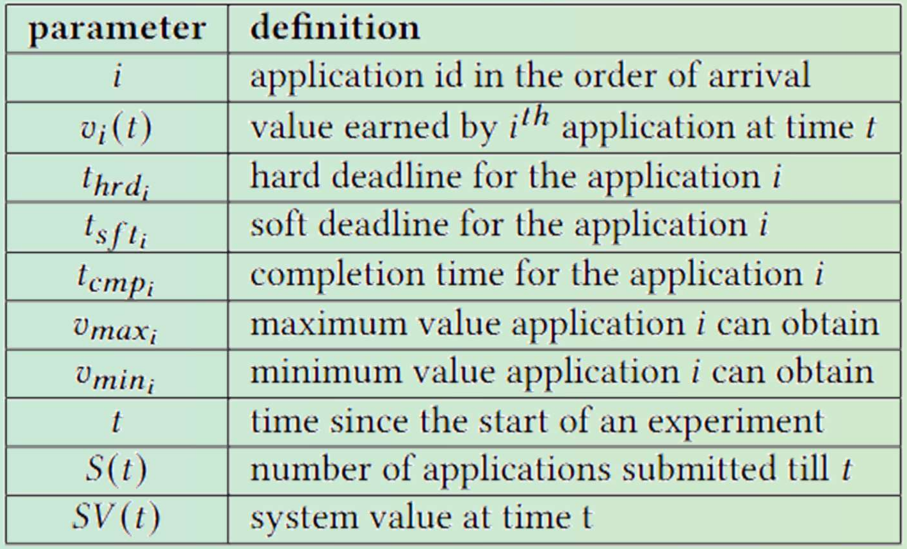


Table 1: Definitions for Equation 1 and 2.



parameter	definition
i	application id in the order of arrival
$v_i(t)$	value earned by i^{th} application at time t
t_{hrd_i}	hard deadline for the application i
t_{sft_i}	soft deadline for the application i
t_{cmp_i}	completion time for the application i
v_{max_i}	maximum value application i can obtain
v_{min_i}	minimum value application i can obtain
t	time since the start of an experiment
$S(t)$	number of applications submitted till t
$SV(t)$	system value at time t

$$v_i = \begin{cases} 0, & t_{cmp_i} > t_{hrd_i} \\ v_{max_i}, & t_{cmp_i} < t_{sft_i} \\ v_{max_i} - \dfrac{(t_{cmp_i} - t_{sft_i}) \times (v_{max_i} - v_{min_i})}{t_{hrd_i} - t_{sft_i}}, & otherwise \end{cases}$$

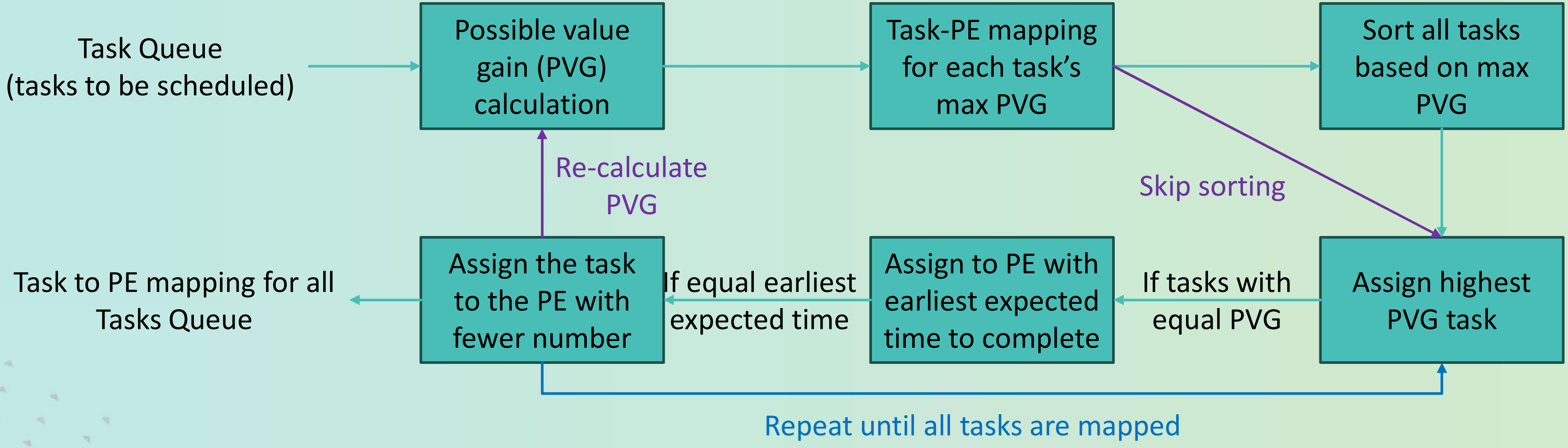
- Systems overall value gain:

$$maximize\ \mathrm{SV(t)} = \sum_{i=1}^{S(t)} v_i(t_{cmp_i})$$

Value per Time Heuristic

- Two variations of value-based scheduling heuristic:
  - Value of Service (VoS)
  - Value of Service (VoS)

At any point, if PVG is calculated as 0 discard the task and mark the application as failed


Task Queue
(tasks to be scheduled)
Possible value gain (PVG) calculation
Task-PE mapping for each task's max PVG
Sort all tasks based on max PVG
Re-calculate PVG
Skip sorting
Task to PE mapping for all Tasks Queue
Assign the task to the PE with fewer number
If equal earliest expected time
Assign to PE with earliest expected time to complete
If tasks with equal PVG
Assign highest PVG task
Repeat until all tasks are mapped

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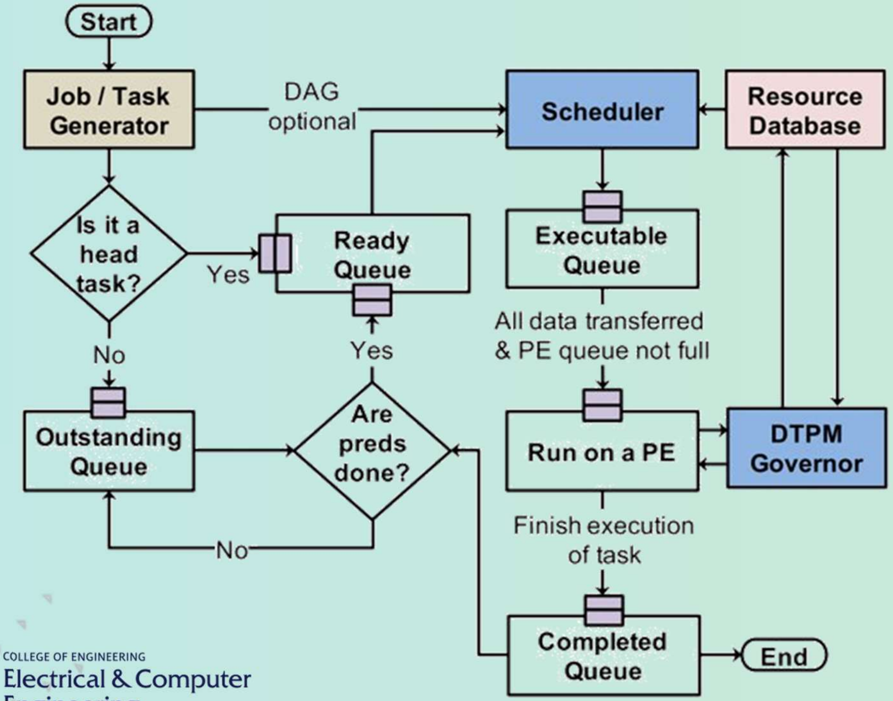
Experiment Setup on DS3 and Applications

Simulation of Jetson AGX MPSoC on DS3[1]:

- 7 CPUs that support all the tasks in the application DAGs
- 1 Accelerator that supports various tasks



Application Setup:

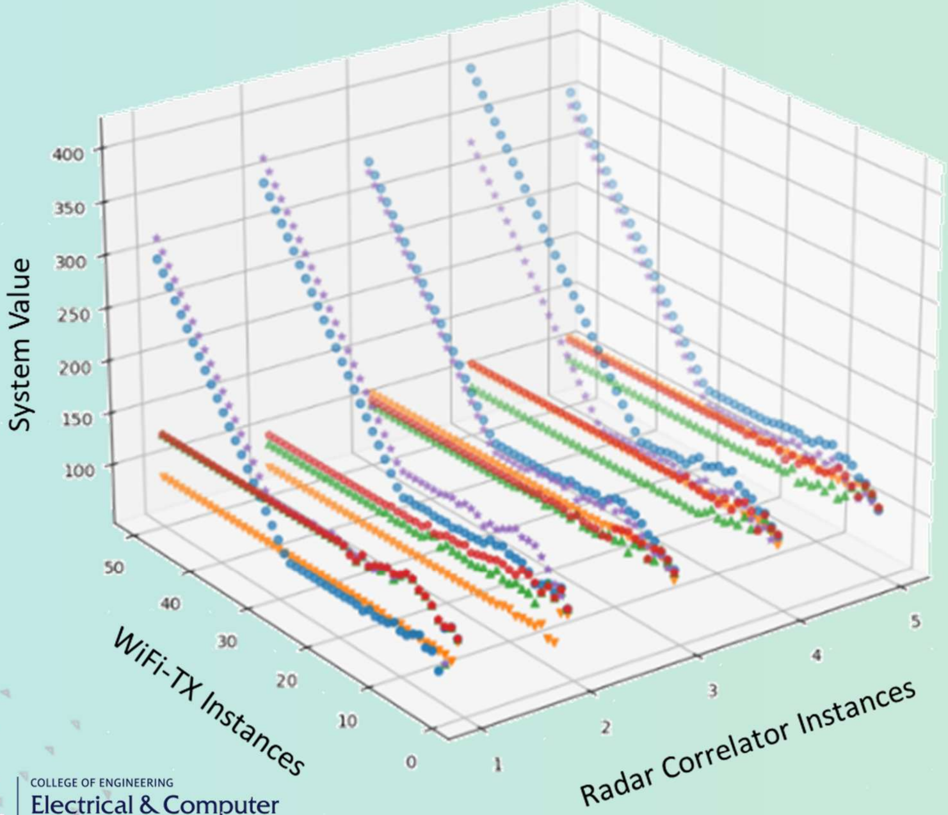
- Hard Threshold scaled as 2.1 ($t_{sft_i} = 2.1 \times EFT\ Exec$)
- Soft Threshold scaled as 1 ($t_{sft_i} = 1 \times EFT\ Exec$)
- v_{min_i} set to 0.5
- Injection rate set to 78.5μs
  - One of each applications injected every 78.5μs

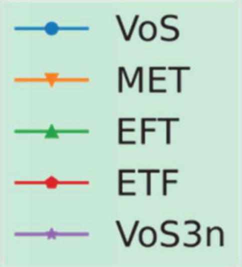
	RC	WiFi-TX	LD
EFT Exec	5,865	61,910	78,522
v_{max}	1	10	100
Maximum Branches	2	5	1
Accelerateable Tasks	3	5	4
Acceleration Gain	10x	10x	15x-8x

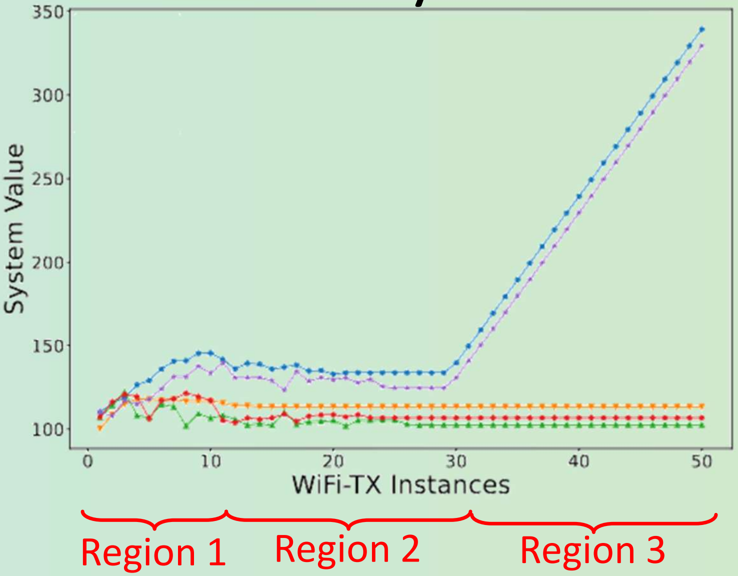
[1] Arda, Samet E., et al. "DS3: A system-level domain-specific system-on-chip simulation framework." IEEE Transactions on Computers 69.8 (2020): 1248-1262.

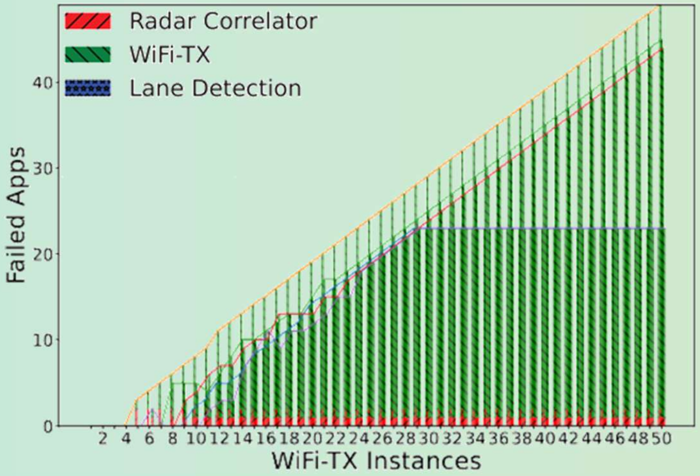
Results 1 – Undersubscribed to Oversubscribed System

- Value-based scheduler is more effective in application prioritization.



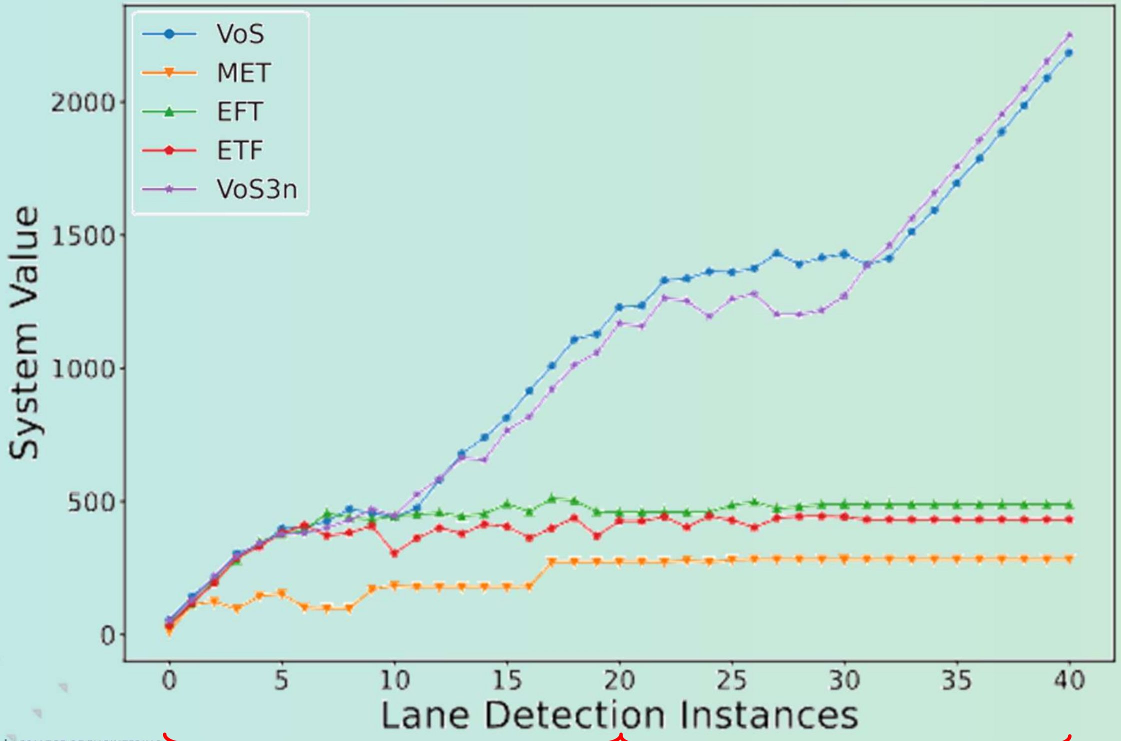






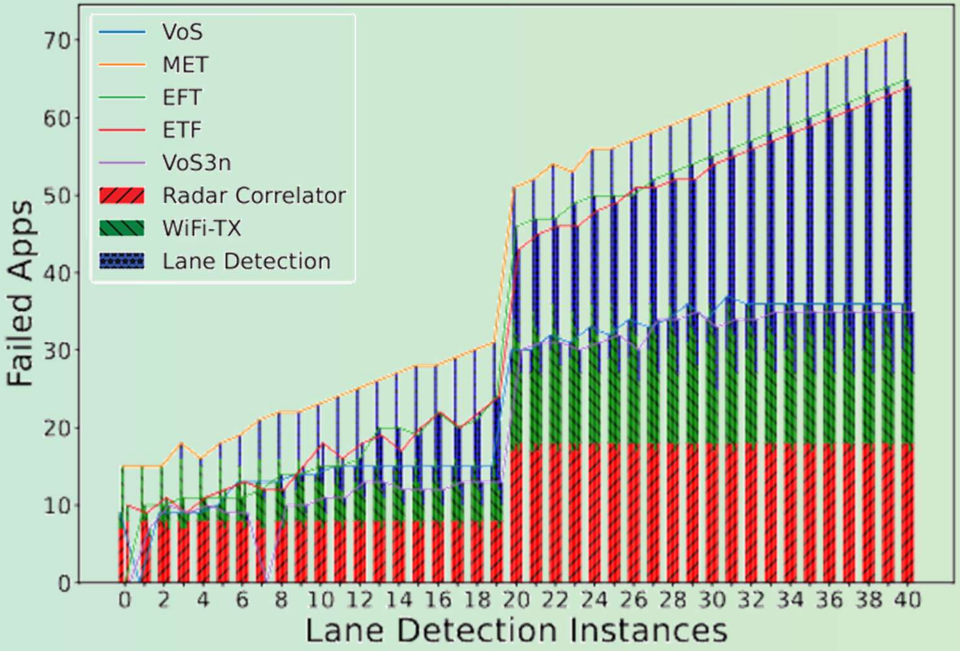
Results 2 – Reproducing Saturation Trends - Robustness and Adaptability

- Value-based schedulers are resilient in managing failed applications



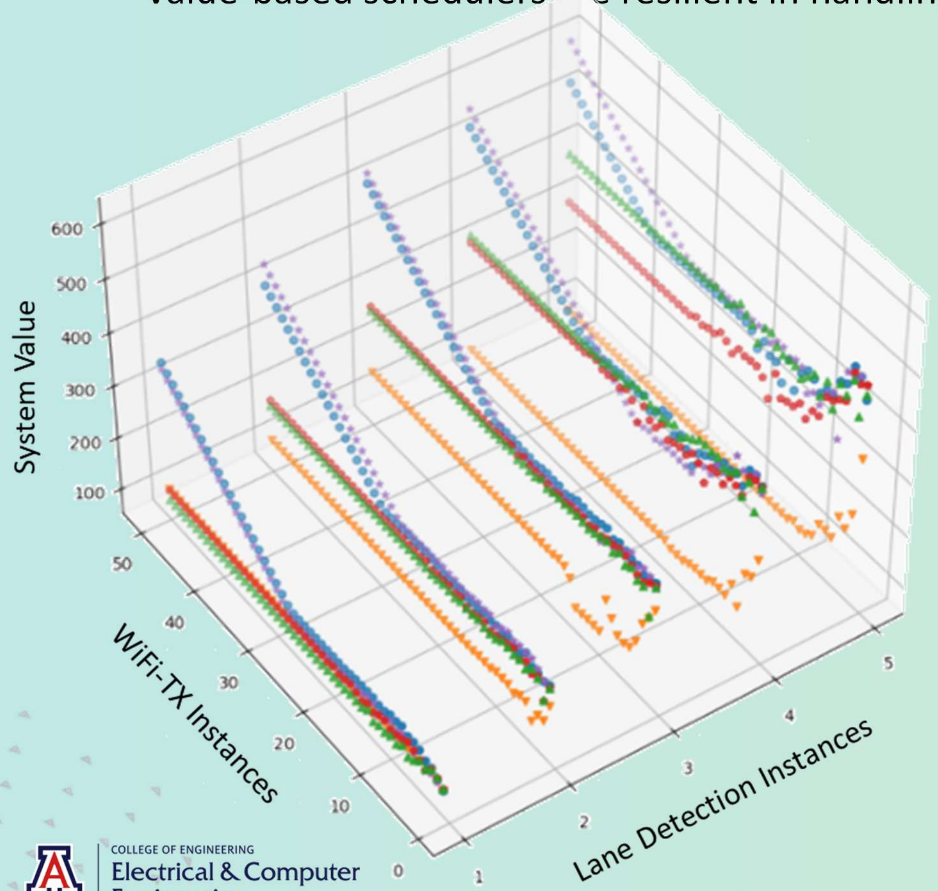
10 WiFi-TX
10 Radar Correlator

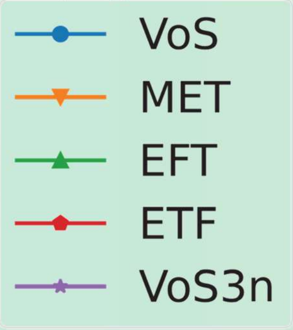
20 WiFi-TX
20 Radar Correlator

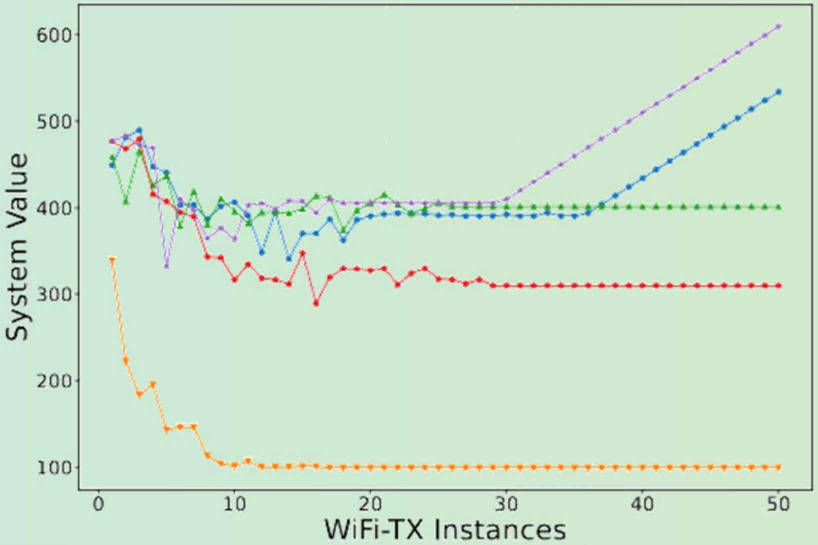


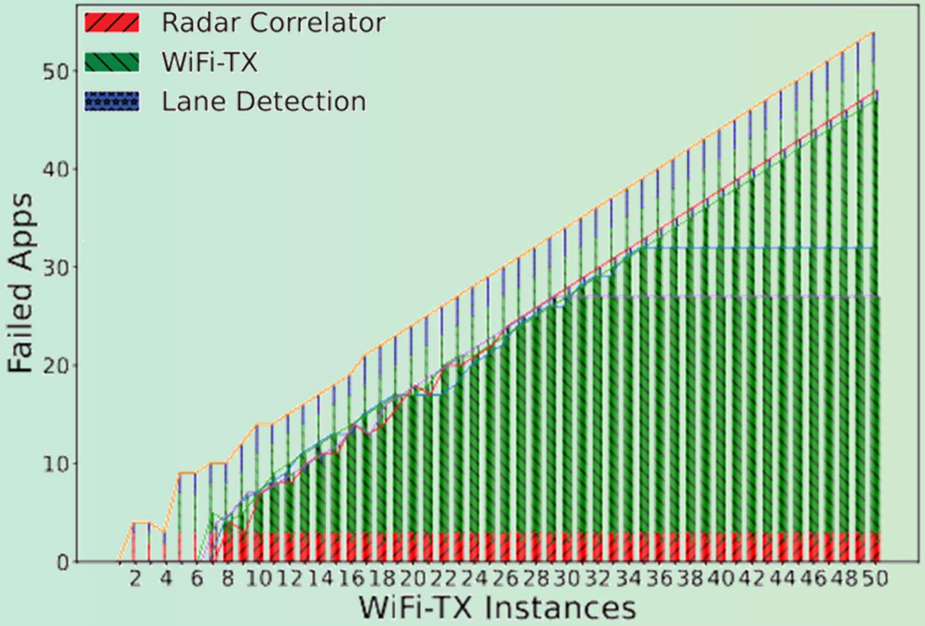
Results 3 – Oversubscribed System

- Value-based schedulers are resilient in handling varying workloads









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Conclusion and Future Work

- Use of value-based scheduling methods in heterogeneous SoC devices to maximize system productivity
- Value-based heuristics outperform traditional approaches
- Enabling the platforms to adapt dynamically to changing execution flows by incorporating task priority
- Dropping low-priority tasks in the decision-making process
- Stays in orders of 120μs scheduling overhead
- Moving toward dynamic priority changes

Thank You!

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Questions?

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