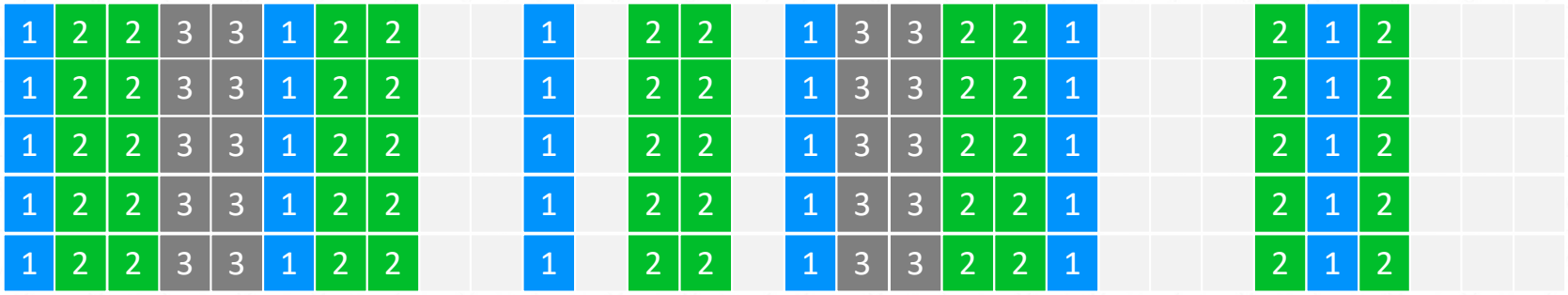
SCHEDULE OBFUSCATION

[RTAS 2016]

- Integrating security in Real-Time CPS
- Prevent attacks by randomizing schedule

"is it possible to reduce the regularity in real-time task schedules while still guaranteeing that the timing constraints (deadlines) are met?"

REAL-TIME SCHEDULE OBFUSCATION



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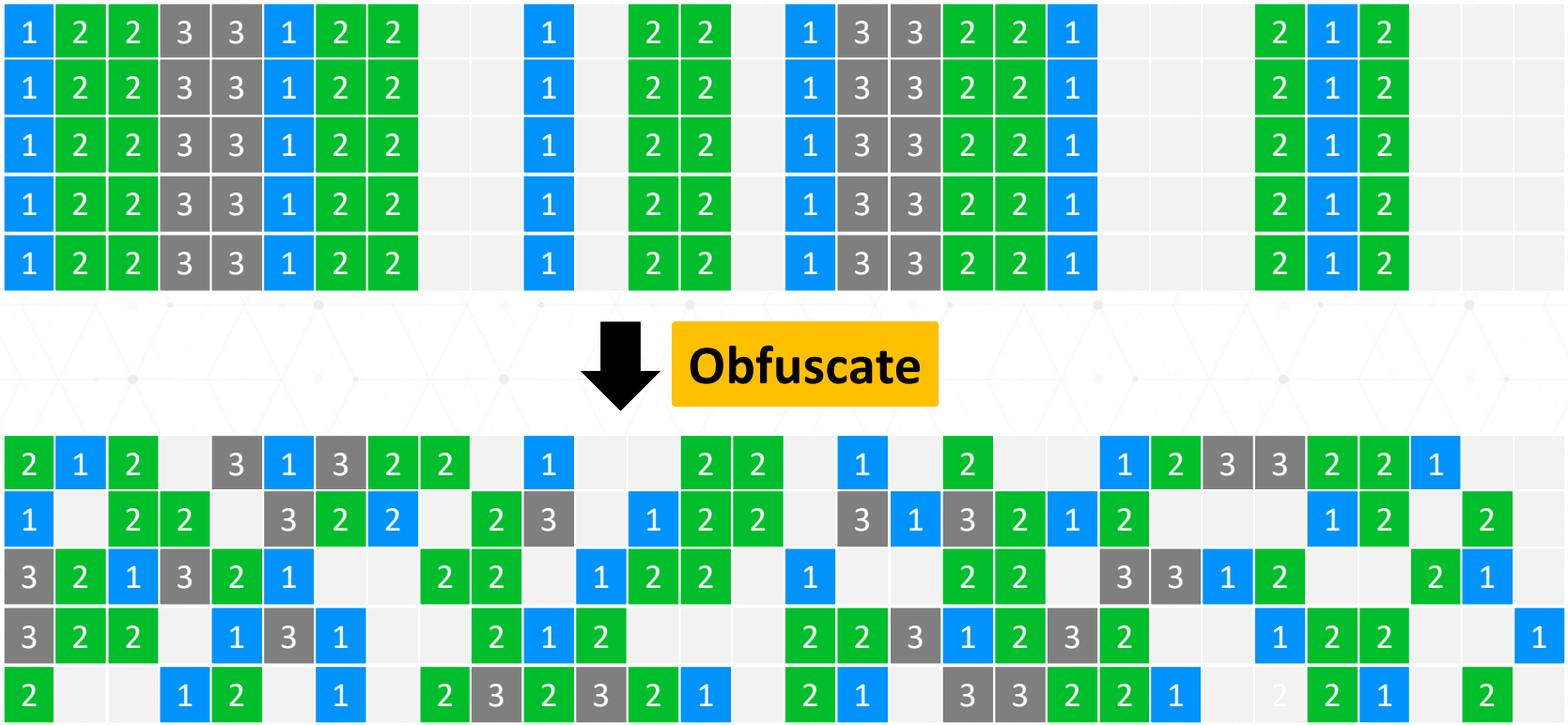
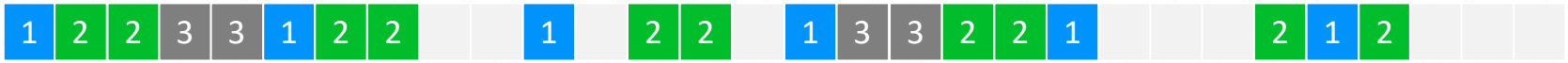


SCHEDULE OBFUSCATION: CONCEPT



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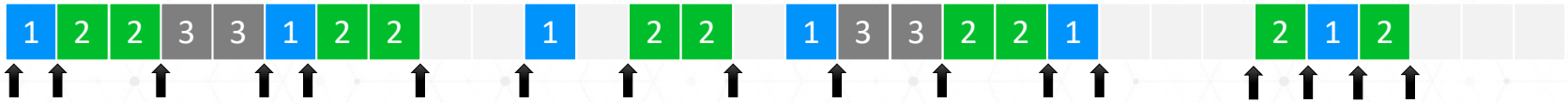
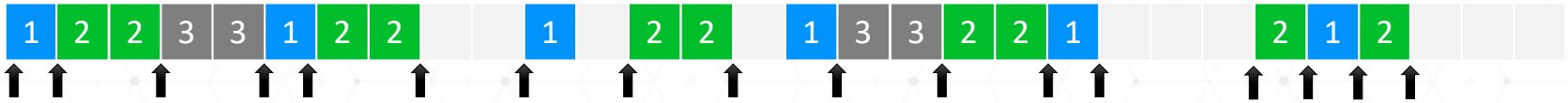


- At each scheduling point

SCHEDULE OBFUSCATION: CONCEPT



- At each scheduling point
  - Pick a random task from the ready queue
  - Not always the highest priority one

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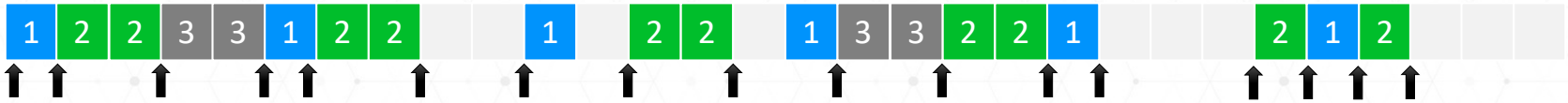

- At each scheduling point
  - Pick a **random task** from the ready queue
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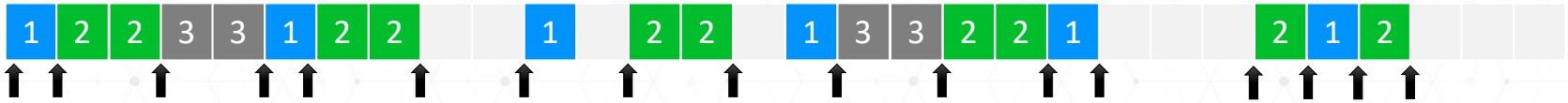
- **Allow priority inversion**

SCHEDULE OBFUSCATION: CONCEPT



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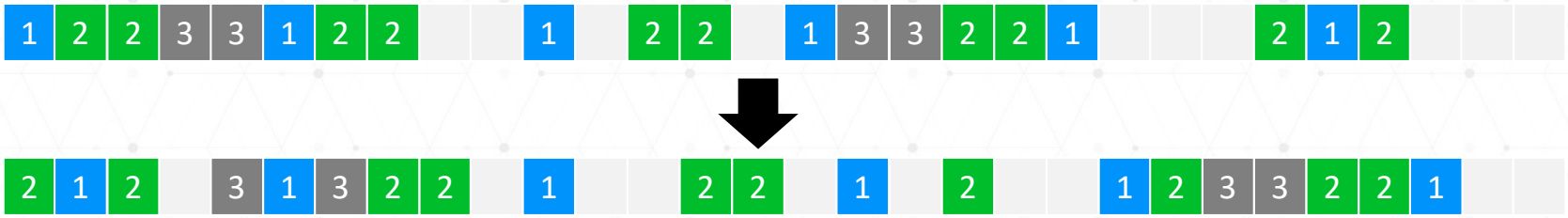
SCHEDULE OBFUSCATION: CONCEPT

- **Hang on a minute…what about deadlines?**



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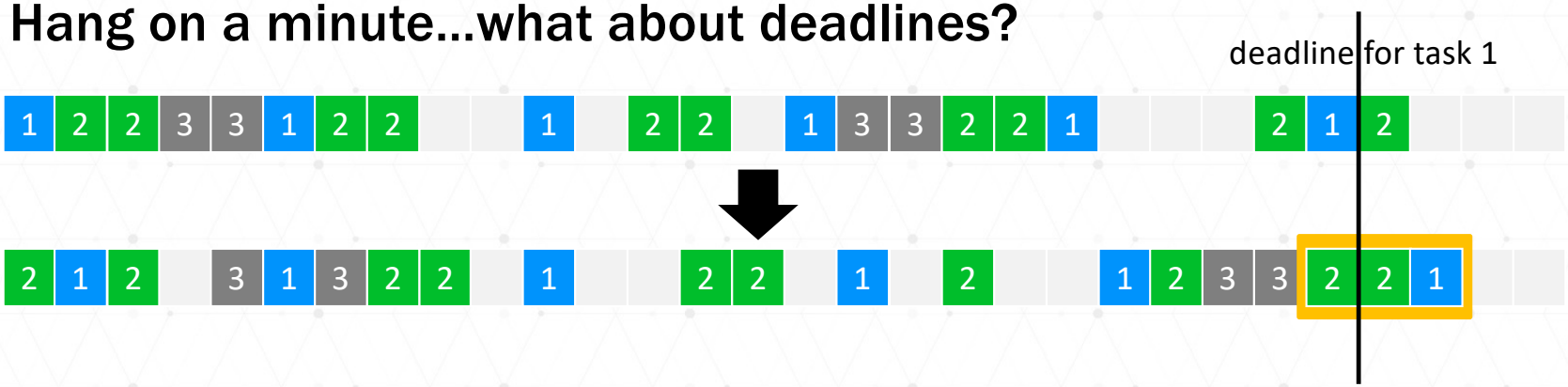

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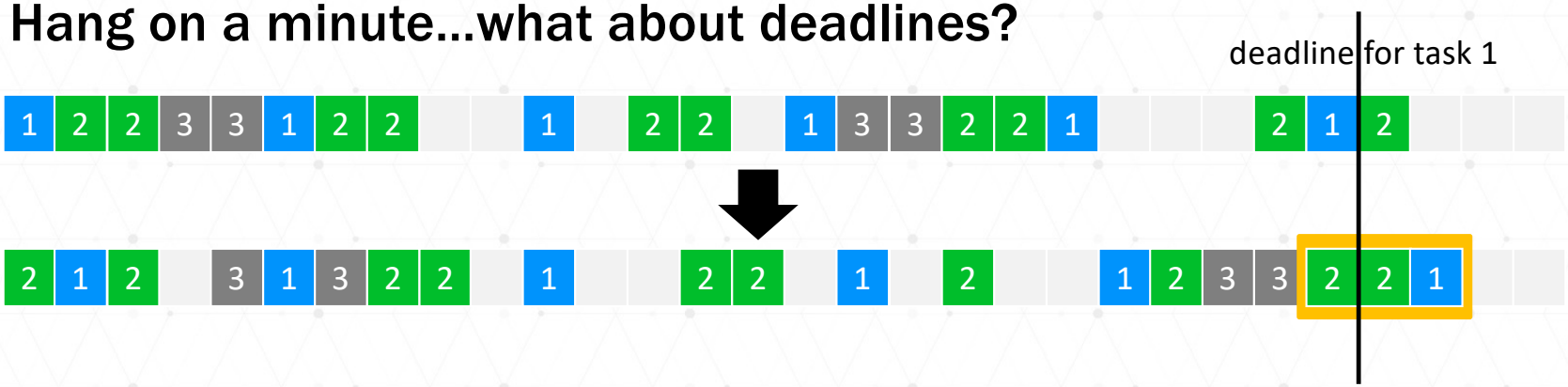
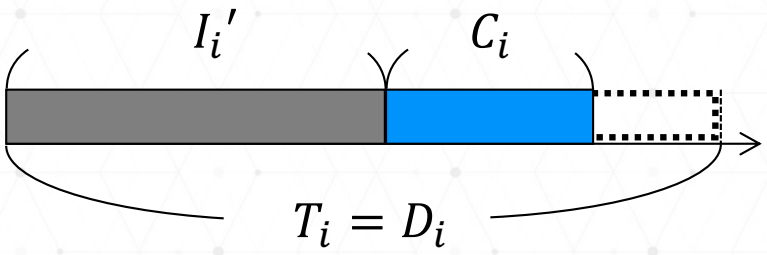


- Allow **bounded** priority inversion
- Tasks should still meet their original deadlines
- We must calculate ‘bounds’
  - how long can a higher priority task suffer inversion?

BOUNDING PRIORITY INVERSIONS

- Let's consider a periodic task τ_i



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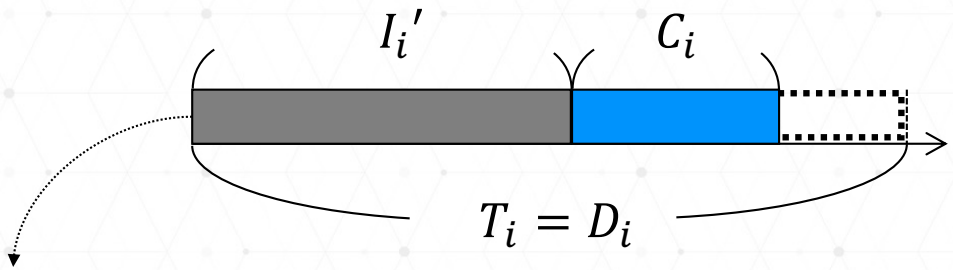

Interference induced by:
- higher priority tasks and
- priority inversion

needs to be taken into account

$$I_i' = \sum_{\tau_j \in hp(\tau_i)} \left(\left\lceil \frac{D_i}{T_j} \right\rceil + 1 \right) \cdot C_j$$

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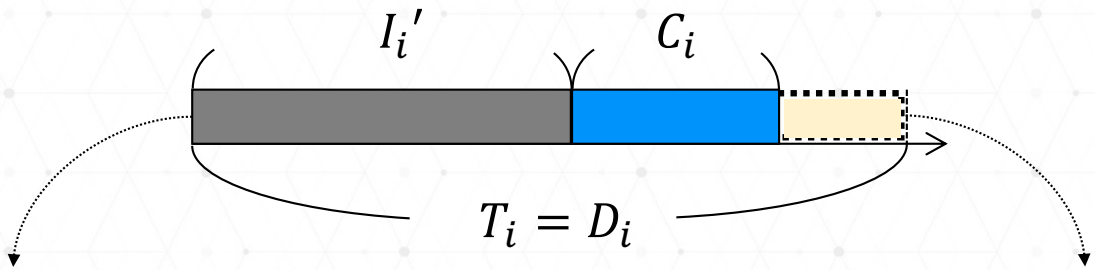

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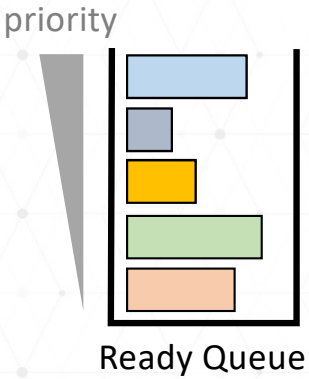
Extra delay that τ_i can tolerate without missing its deadlines

The worst-case inversion budget = V_i

TASKSHUFFLER RANDOMIZATION PROTOCOL

FIXED-PRIORITY SCHEDULING ALGORITHMS

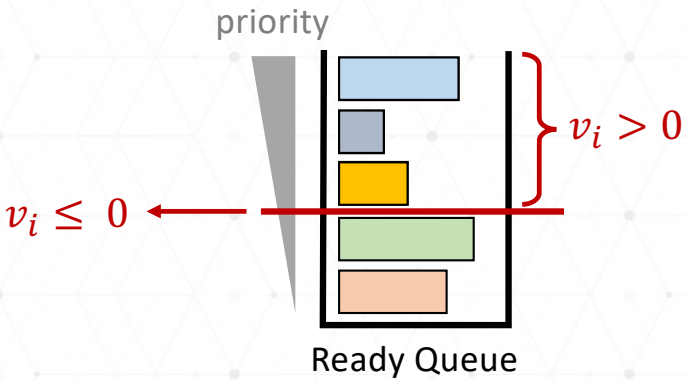
- **At each scheduling point**



TASKSHUFFLER RANDOMIZATION PROTOCOL

FIXED-PRIORITY SCHEDULING ALGORITHMS

- **At each scheduling point**
  1. **Determine job candidates**



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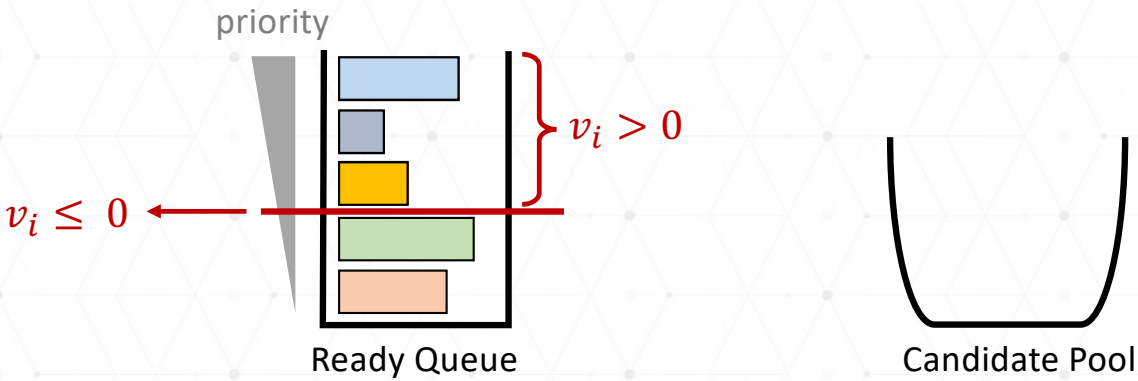

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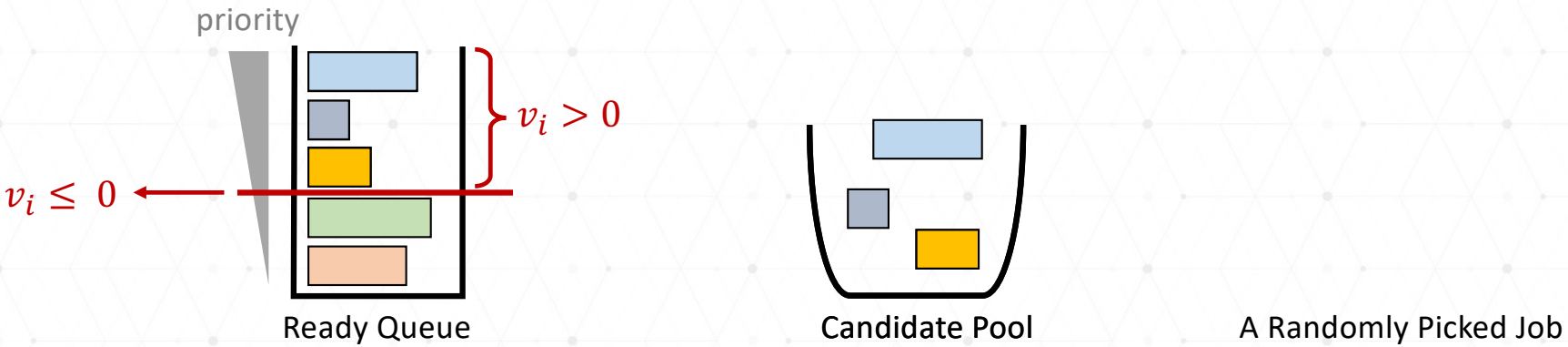

TASKSHUFFLER RANDOMIZATION PROTOCOL

FIXED-PRIORITY SCHEDULING ALGORITHMS

- **At each scheduling point**
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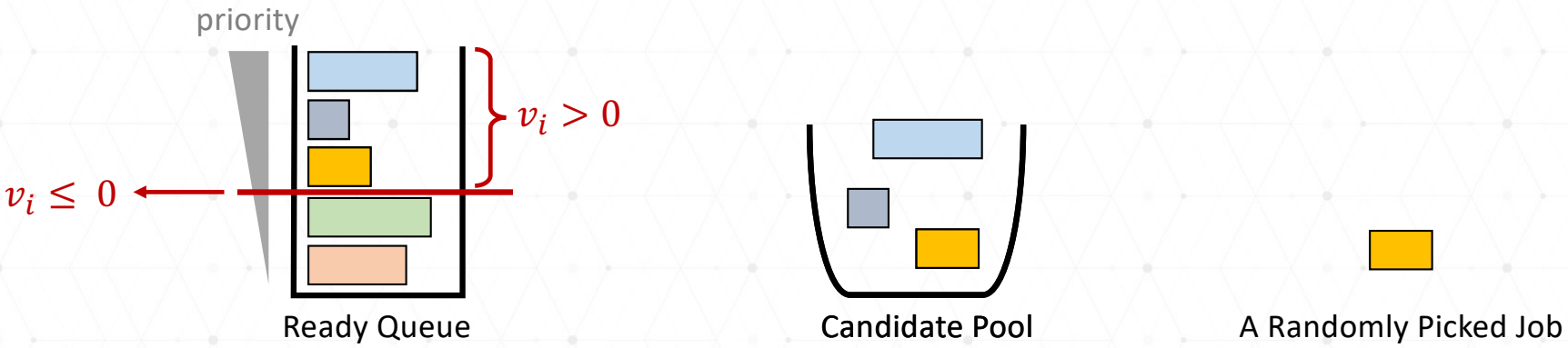
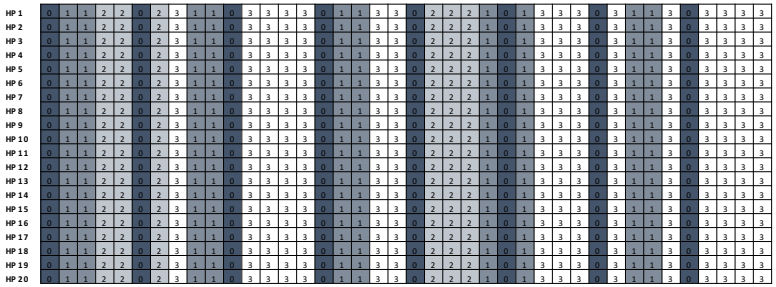
  3. **Set next scheduling point and run picked job**



RANDOMIZATION SCHEMES

- **Without Randomization**



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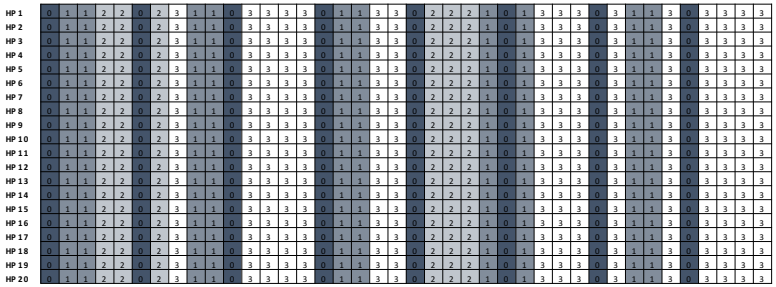

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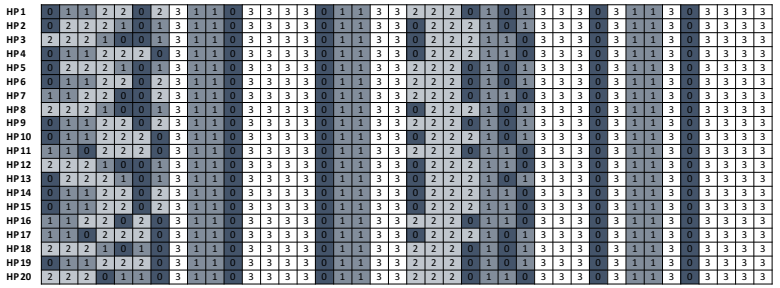

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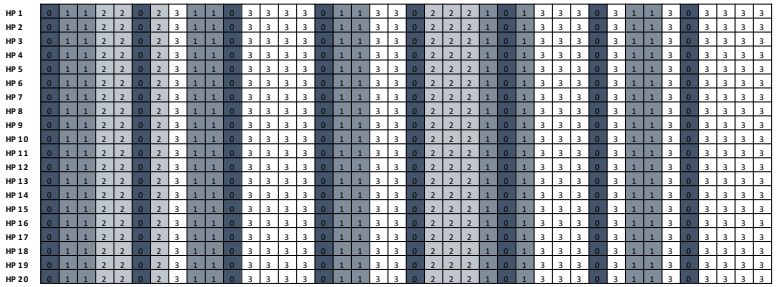

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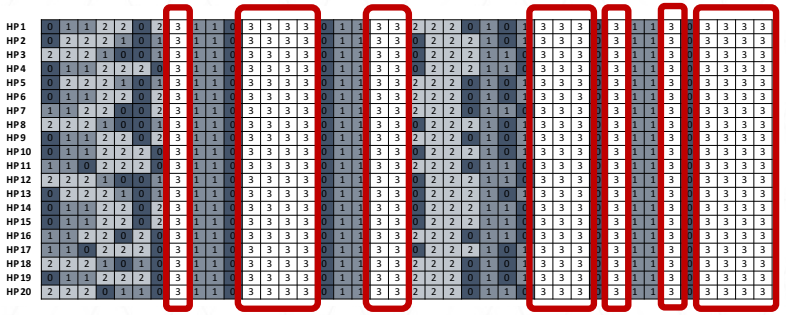

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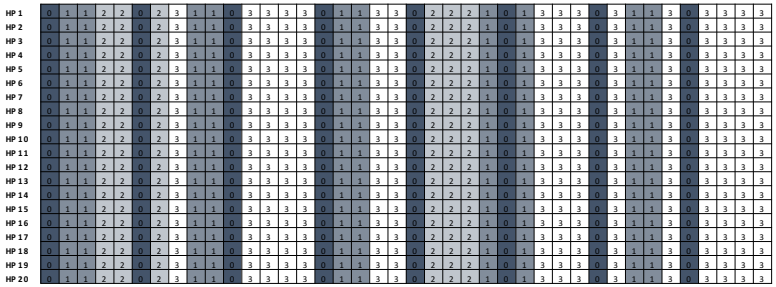
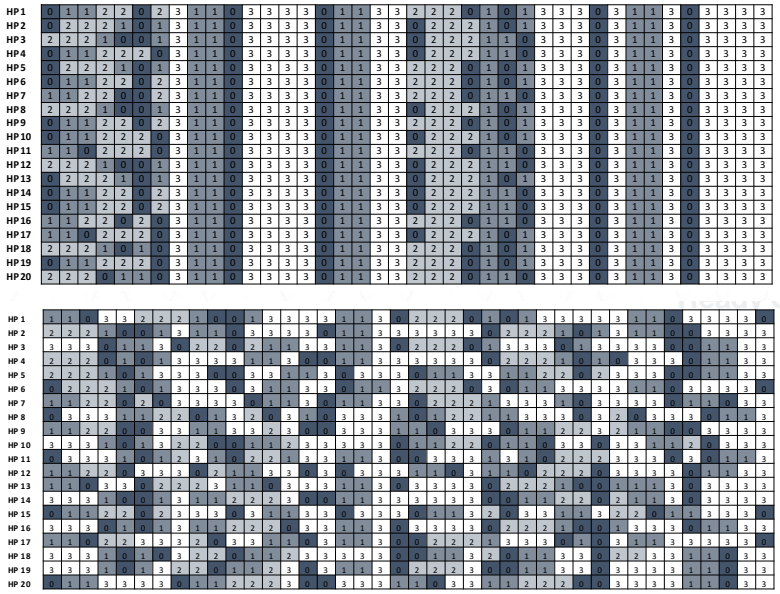


- Task-only Randomization
- With Idle Time Scheduling



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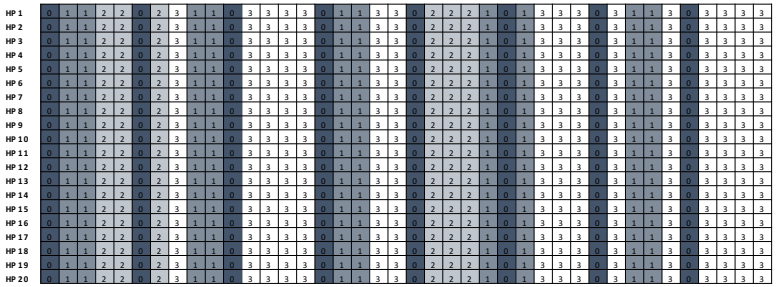
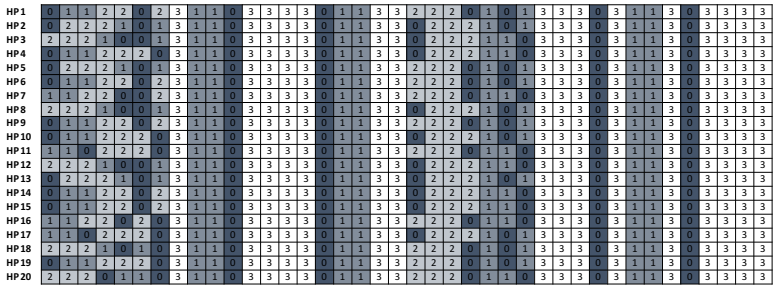
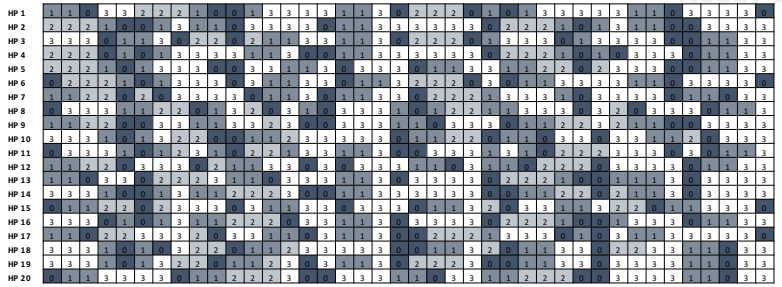
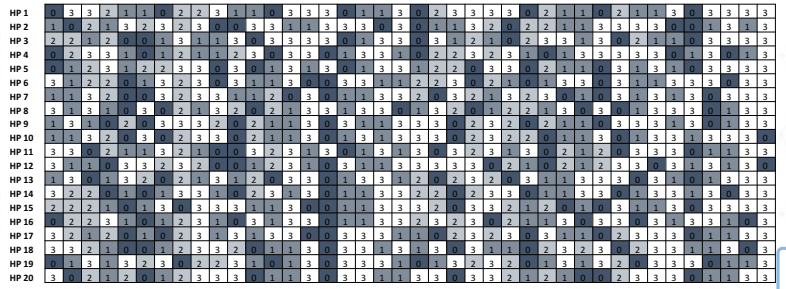


- Task-only Randomization
- With Idle Time Scheduling
- Fine-grained Switching







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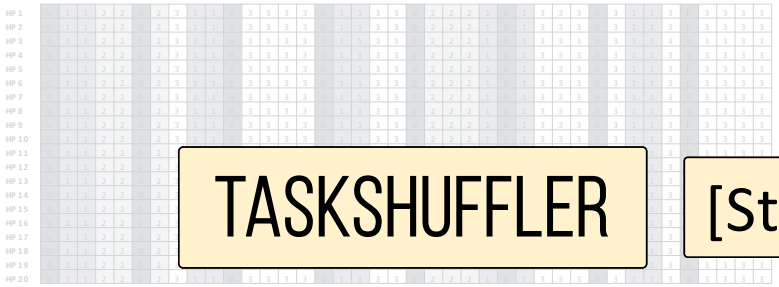


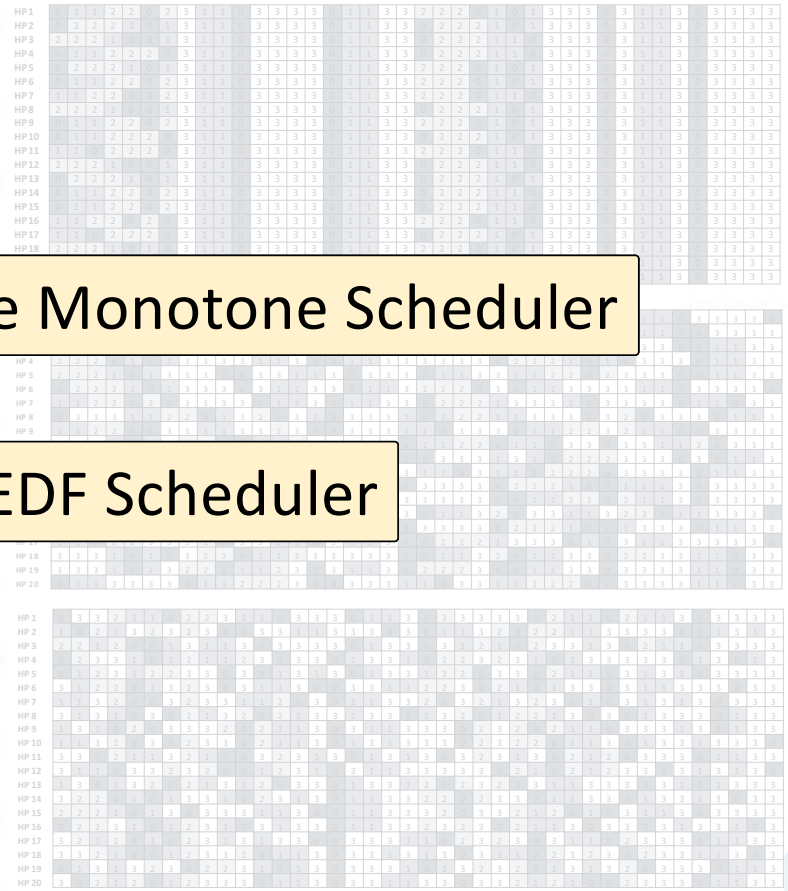
TASKSHUFFLER

[Static] Rate Monotone Scheduler

REORDER

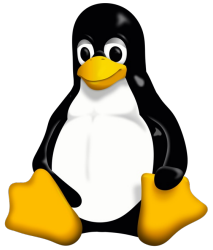
[Dynamic] EDF Scheduler

- Task-only R n
- With Idle Time Scheduling
- Fine-grained Switching



IMPLEMENTATION

- Platform
  - **Raspberry P**i 3 Model B
  - 1.2 GHz 64-bit quad-core ARM Cortex-A53
- Operating System
  - **Linux** kernel version: 4.9.48
  - Raspbian (a variant of Debian Linux)
  - Patched with **PREEMPT_RT**



TASKSHUFFLER VS SCHEDULEAK

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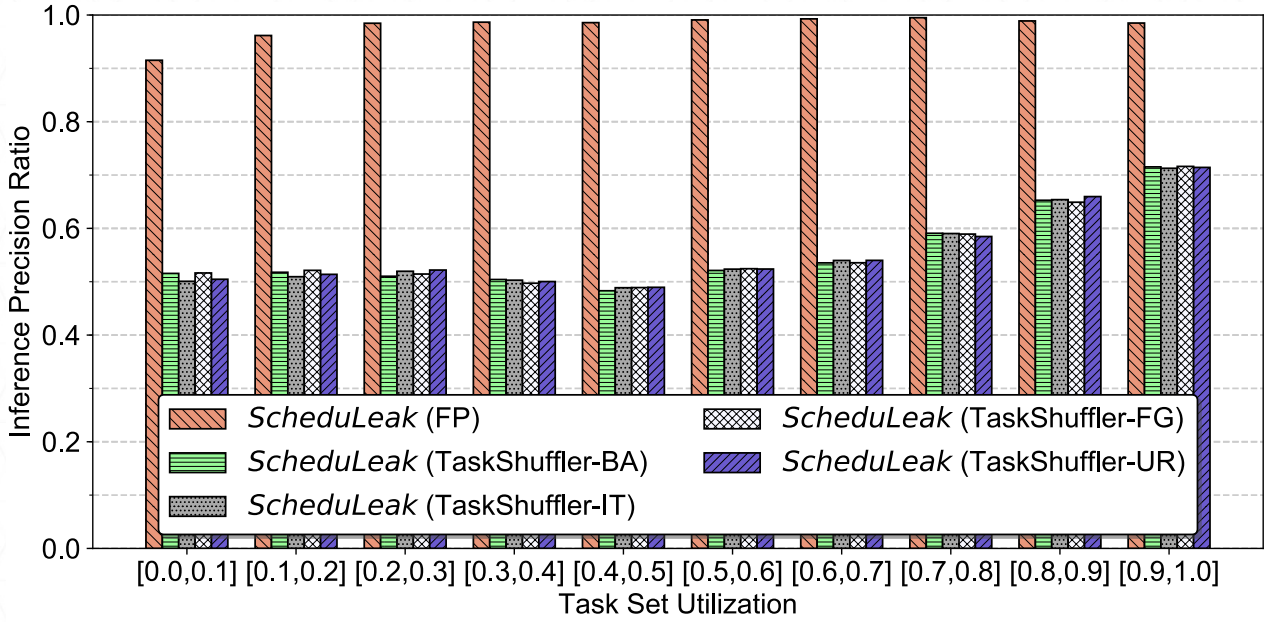

- Experiment Configurations
  - 6000 task sets tested
  - 600 each utilization group
  - 5, 7, 9, 11, 13, 15 tasks per task set
  - Each bar is averaged from 600 task sets

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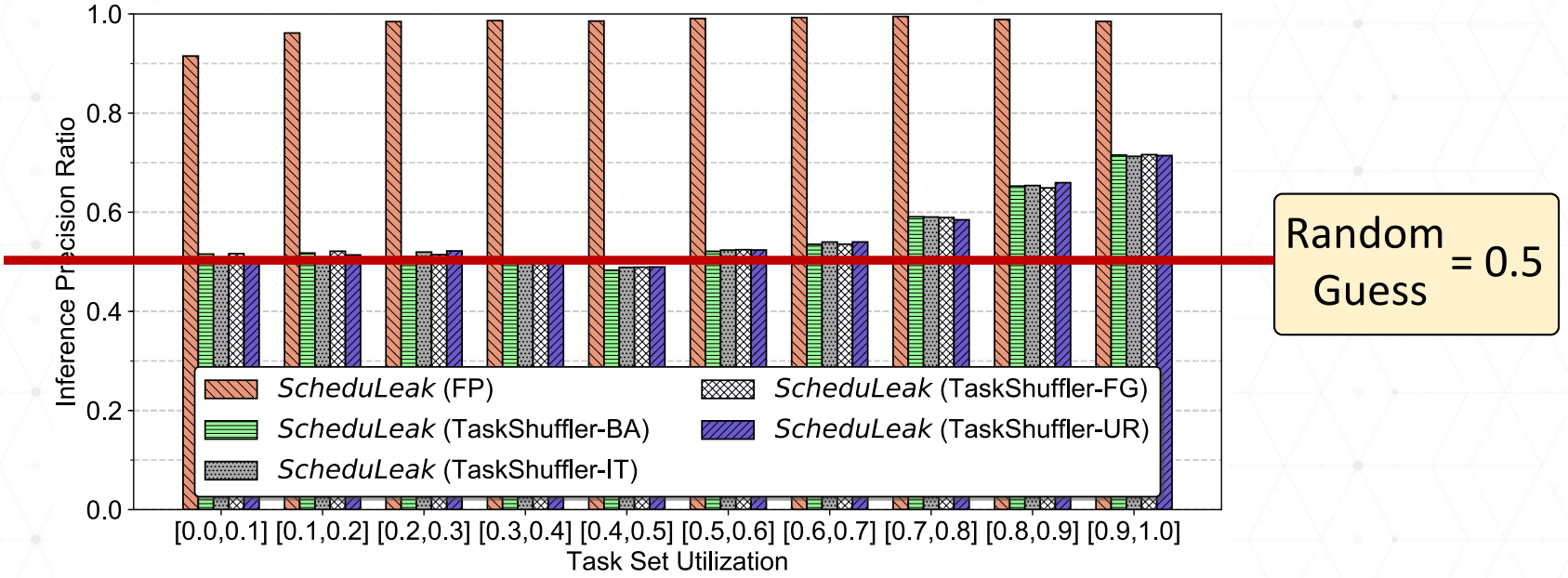

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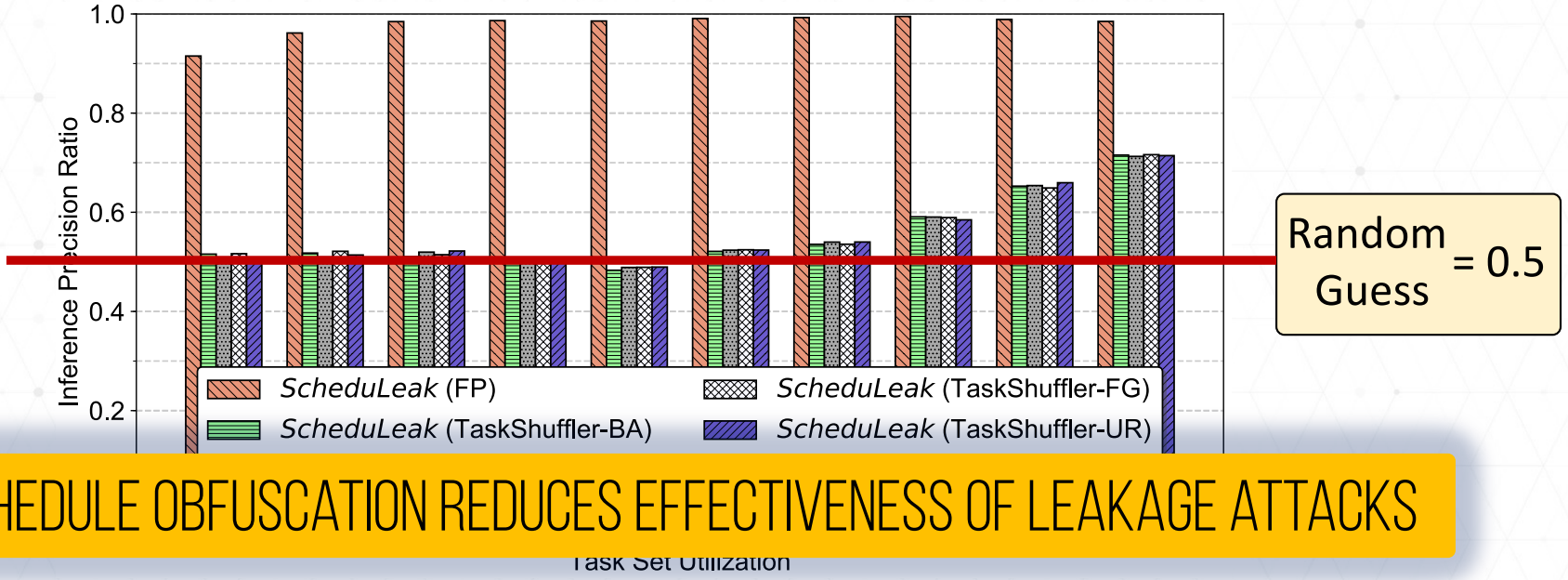

SCHEDULE OBFUSCATION REDUCES EFFECTIVENESS OF LEAKAGE ATTACKS

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