CS528
Energy Efficient Task Scheduling

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Outline

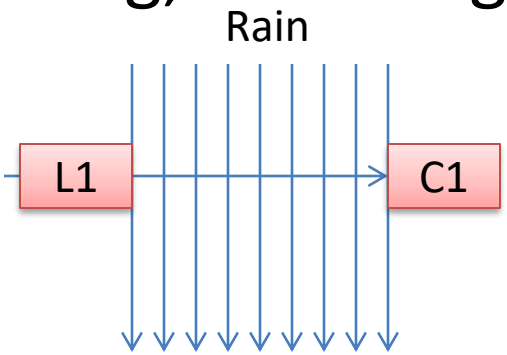
- Power Aware
- Task with Hard Deadlines
- Energy Efficiency
- Energy Efficient Scheduling
- Real Time Tasks

Power Aware Scheduling Vs Energy Aware Scheduling

- Power Budget should not exceed
  - Minimized
  - Monthly Expenses: CAP ===> Solution is EMI
  - Power CAP: If your system have 100 design, at any instance of time you should not run things above 100W
    - Suppose you have 3KW wiring in your home, you have 3 AC with each of 1.5KW rating, At a given time, you can run maximum of 2 AC.
- Total energy budget should not exceed
  - Battery capcity, mah (mobile), AH (UPS)
  - Minimized: EC
  - Power and Time

Speed Matters or Not : I

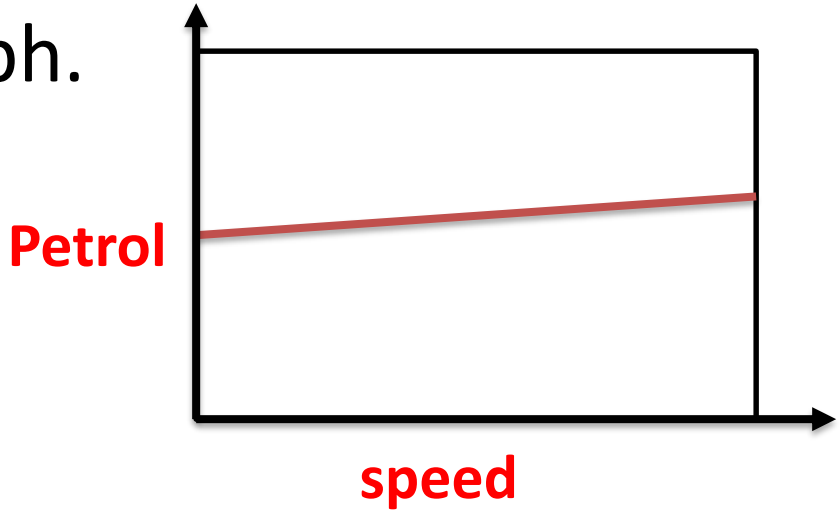
- Assume it is raining, need to go to L1 to C1 of IITG urgently



- Assume rain drops are **falling vertically, uniformly** and you need to walk/run **horizontally**
- **Do you get wetter if you run or walk in the rain?**
- Physics answer: Speed does not matter
  - Surface area cover by your body by traveling from L1 to C1 is same, it does not depend on speed

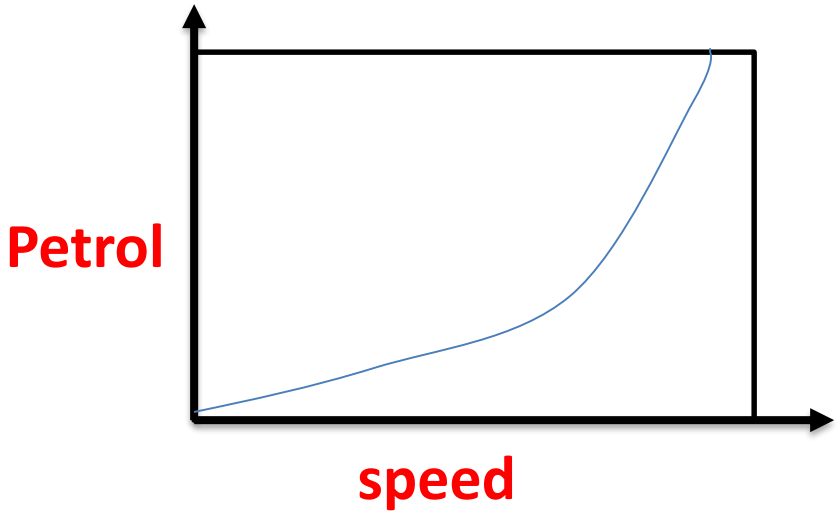
Speed Matters or Not : II

- Assume you have an Royal Enfield Bullet, you need to go from IITG to GS road, 30KM in 1 hours
- Petrol consumption is almost same at any speed. Example it 2ml/minute at 10kmph and 2.1ml/minute at 100kmph.
- How to save petrol ?
  - Sol: Go at higher controllable speed



Speed Matters or Not : II

- Assume you have an Bike, you need to go from IITG to GS road, **30KM in 1 hours**
- Petrol consumption is exponentially/quadratic increasing with speed. Example it 2ml/minute at 10kmph and 20ml/minute at 100kmph.
- How to save petrol ?
  - Sol: Go at slower speed to meet the deadline
  - Above example 30kmph
  - **Critical Speed**



Power and Energy Consumptions

- CPU: dynamic power $P_d = C_{ef} * V_{dd}^2 * f$
  - C_{ef} : switch capacitance, V_{dd} : supply voltage
  - f : processor freq → linear related to V_{dd}

$$P \ \alpha \ f^3$$

  - Battery Powered System Reduce Energy usage

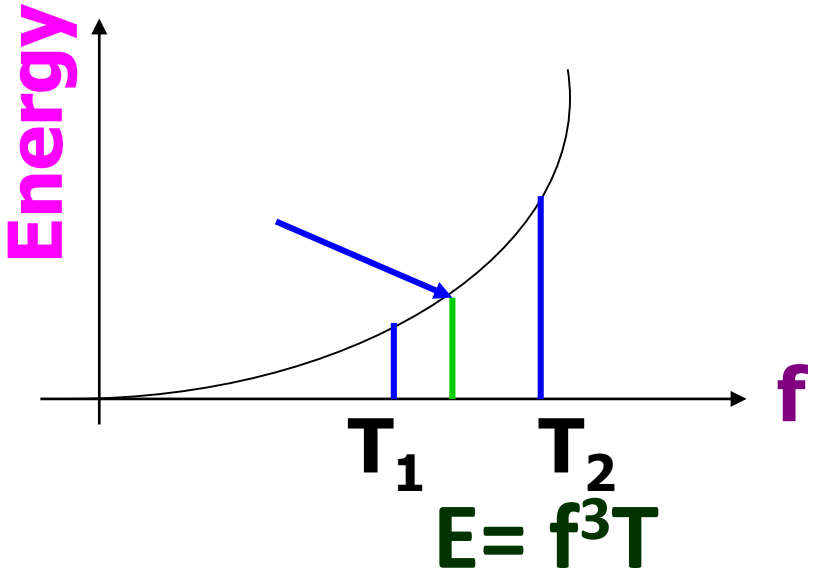
$$E = P.\ t \quad \alpha \quad f^3 t$$

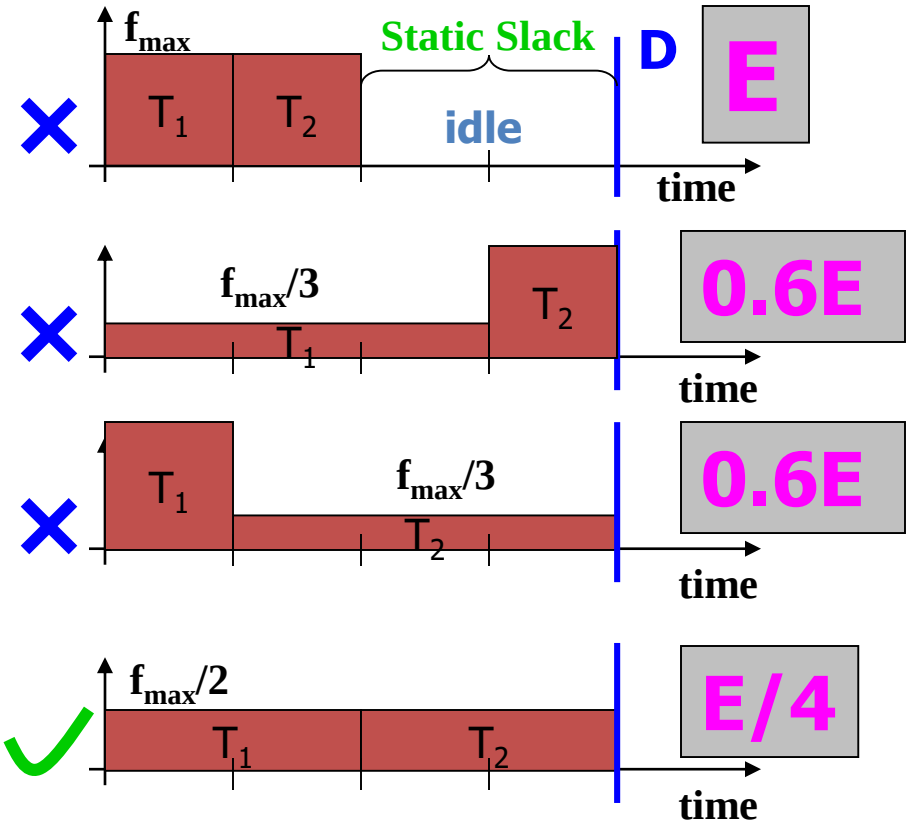
  - Execution time t is inverse to f, $t \ \alpha \ 1/f$

So $E \ \alpha \ f^2$

Power Aware Scheduling

Static slack: uniformly slow down all tasks





I. $f^3T+f^3T=2.f^3T=E$

II. $3(f/3)^3T+f^3T=0.57.E$

III. $f^3T+3(f/3)^3T=0.57.E$

IV. $2(f/2)^3T+ 2(f/2)^3T=E/4$

Energy Aware Scheduling

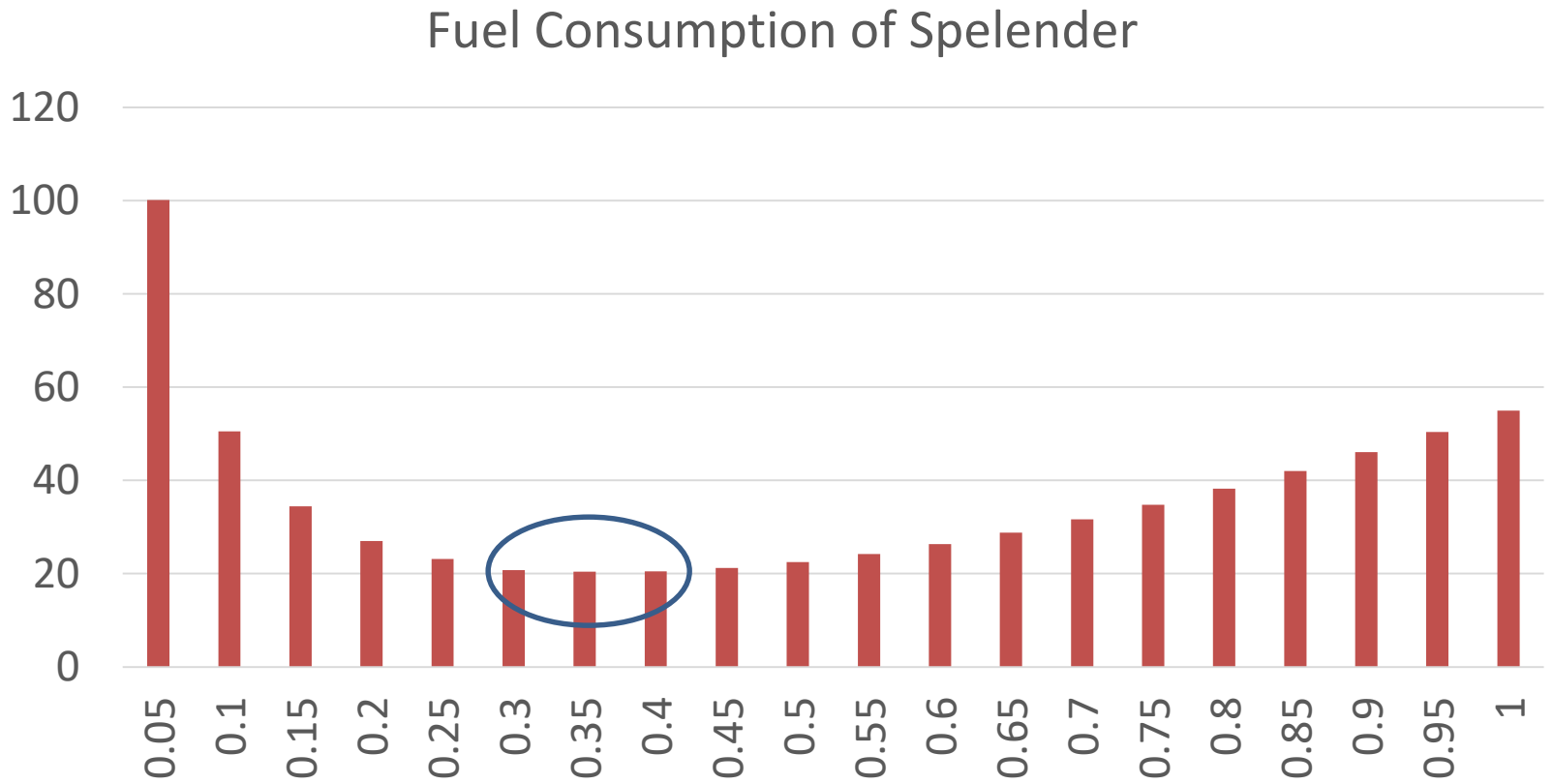
- E= P * T , More refined model P= Ps + k f^3
- Suppose f=[0:1].
- E= (Ps+kf^3)*T/f = T*[Ps/f + k.f^2]
- Min at dE/df=0, -Ps*1/(f^2)+2.k.f =0

➔ 2kf=Ps/(f^2) ➔ f^3 =Ps/2.k

➔ $f_c = \sqrt[3]{Ps/2.k}$

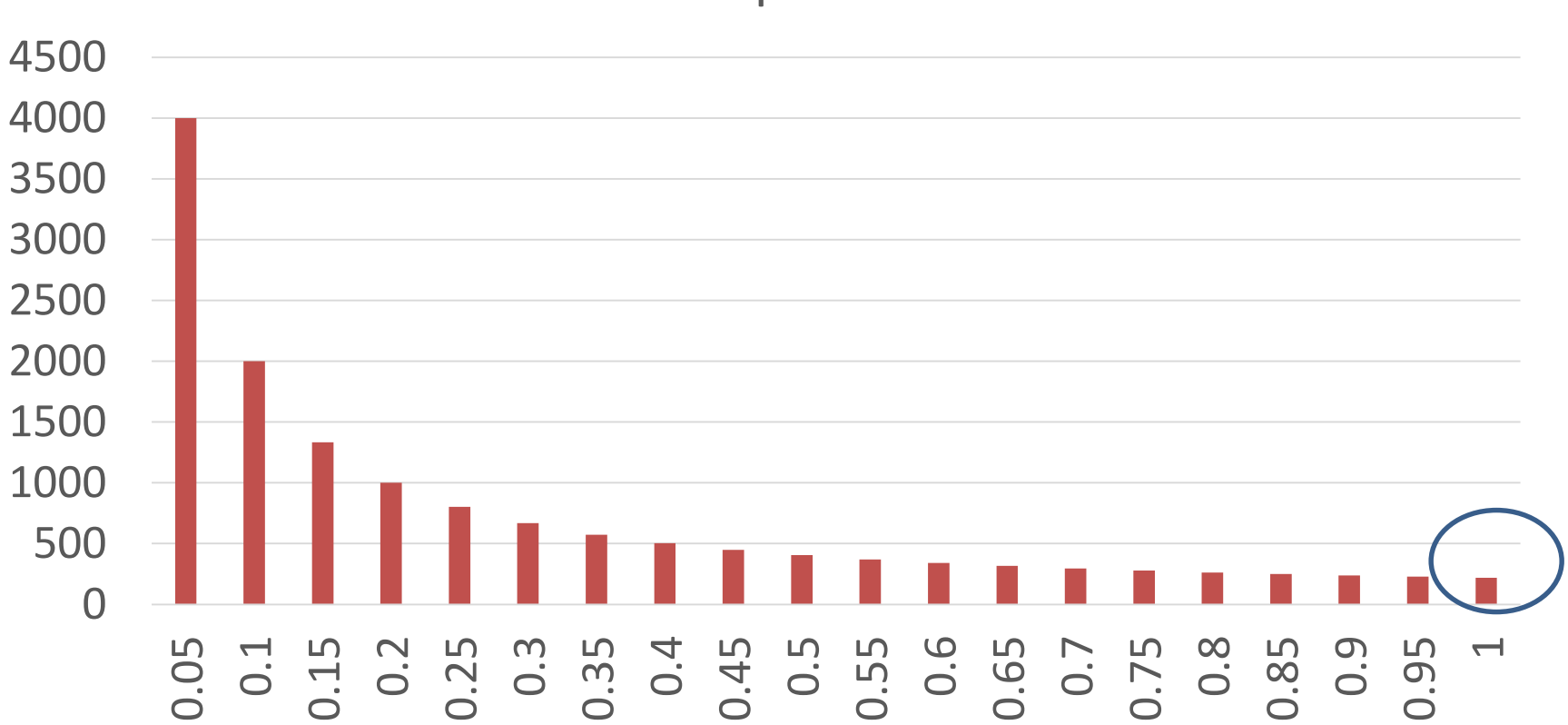
Full consumption of Splendor

- P= 5+50f^3
- Distance to travel 30km in 60 minutes deadline
  - Fc=0.368399



Full consumption of Bullet

- P= 200+20f^3
- Distance 30km in 60 minutes
  - Fc =1.709



Problems of Energy Efficiency

- Laptop Problem
  - Given the energy budget, maximize number of Job
  - Given the Budget money maximize your satisfaction
    - Go to Restaurant with Rs 100. Choose Items to fill you stomach with your budget.
  - Given Rs 20 for going from IITG to Airport
    - Go to Jhalukbari using IIT G bus freely, Take another public bus pay Rs 20 to reach Airport.
  - Given Rs 10 : not possible, you need to walk…:)
  - Given Rs 600 how to go : Hire Taxi
  - Given Rs 20000 how to go : Hire BMW/Mercedes along with many other cars for security personals

Problems of Energy Efficiency

- Server Problem
  - Budget is not constraints, minimize budget but do all the work (get all the items)
  - I want to Take all item of Thela/Bora..How much I need to pay? ---Bargaining

Server Problem Example : $P_\infty|p_j,d_j|\Sigma E_j$

- We have infinite processors
- Processor can be run at speed f=[0:1], PC=αf^3
- N Tasks with deadlines, Task arrived at time 0, preemption not allowed, p_j at f=1
- Execution time task t_j at freq f =$e_j(t_j,f)=p_j/f$;
- Energy consumption task t_j at freq f =E*time=PC(f)*$e_j(t_j,f)$= $\alpha f^3 p_j/f = \alpha f^2 p_j$
- **We want to execute all the tasks, and minimize the sum of EC of all the tasks**

Server Problem Example : $P_\infty|p_j,d_j|\Sigma E_j$

- We want to execute all the tasks, and minimize the sum of EC of all the tasks
- Solution
  - Select one processor for each of the tasks and total of N processors
  - Run the task at lowest feasible speed to meet the deadline $f_j=p_j/d_j$
- This gives (optimal) minimum ΣE_j
  - Total EC = $\Sigma E_j = \Sigma \alpha f_j^2 p_j$
  - As $(a+b)^2 > a^2+b^2$: running two task on one processor with higher speed consume higher energy

Laptop Problem Example : $P_\infty, E_b | p_j, d_j | \Sigma U_j$

- We have infinite processors
- Processor can be run at speed f=[0:1], PC=αf^3
- N Tasks with deadlines, Task arrived at time 0, preemption not allowed, p_j at f=1
- Execution time task t_j at freq f =$e_j(t_j,f)=p_j/f$;
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- **We want to execute maximum number of the tasks before deadline given the energy budget**

Laptop Problem Example : $P_\infty, E_b | p_j, d_j | \Sigma U_j$

- **We want to execute maximum number of the tasks before deadline given the energy budget**
- Solution:
  - Sort the tasks based on bare minimum energy requirement $E_j = \alpha f_j^2 p_j$
  - Select the maximum number of task from this set
- Given N item with weight w_1, w_2, ….w_N : the weight is critical/min energy required of the task
- Select Maximum number of item given the Budget of Knapsack. **0-1 Knapsack Problem**
- NPC and Pseudo polynomial time algorithm exist using Dynamic Programming.