Scheduling Strategies for minimizing response time on Heterogeneous Master-Slave Platforms

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Outline

- Master-Slave platform
  - Platform description
- Known Results
  - Throughput optimization
  - Bandwidth centric principle
- First Heuristic – Optimization of Bandwidth centric principle
- Second Heuristic – Analytical construction of periodic schedules
- Conclusions/Results

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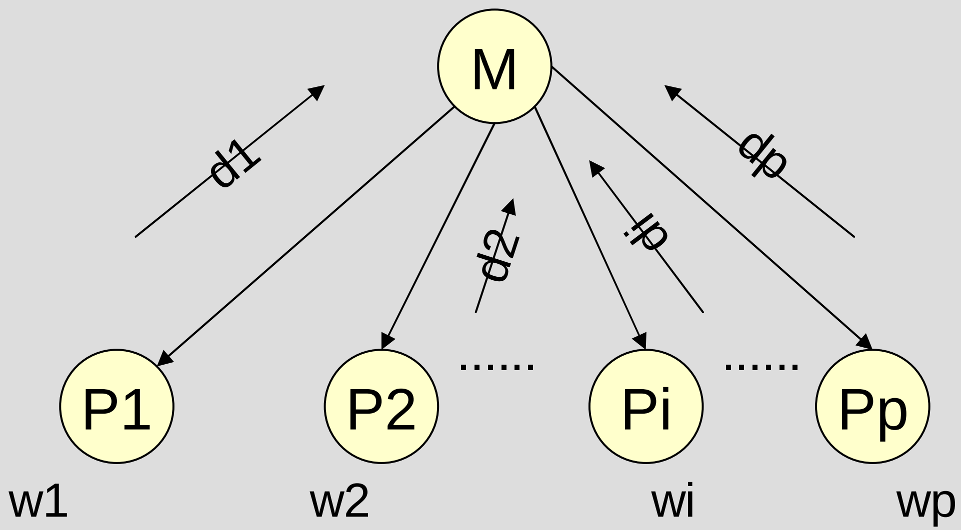
Master-Slave platform

-Platform description-

- Heterogeneous platform – computation time and communication times are different for each slave
- The tasks sent to the slaves are *independent* and *identical* -each represents the same amount of computation
- Tasks are sent regularly to the slaves every *R* units of time



Master-Slave platform

-Platform description-

- *wi* – time needed for slave Pi to compute a task
- *ci, di* – time needed to send/receive a task to/from slave Pi
- The communication model is *one-port* – a processor can send/receive only one task at a given time
- The communications and the computations are *overlapped*
- *Complexity*
  - the minimum time to process n tasks having p slaves is $O(n^2p^2)$ using *Greedy Algorithm*
  - the problem is *polynomial* for a linear chain or for a fork graph
  - *NP- complete* for tree-shaped platforms

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Known Results

-Throughput optimisation-

- Traditional objective of scheduling algorithms - *makespan minimisation*

 NP-hard in most practical situations, long and error-prone

- Instead of absolute minimisation of the execution time -> asymptotic optimality – optimal steady state algorithm
- Optimal steady state

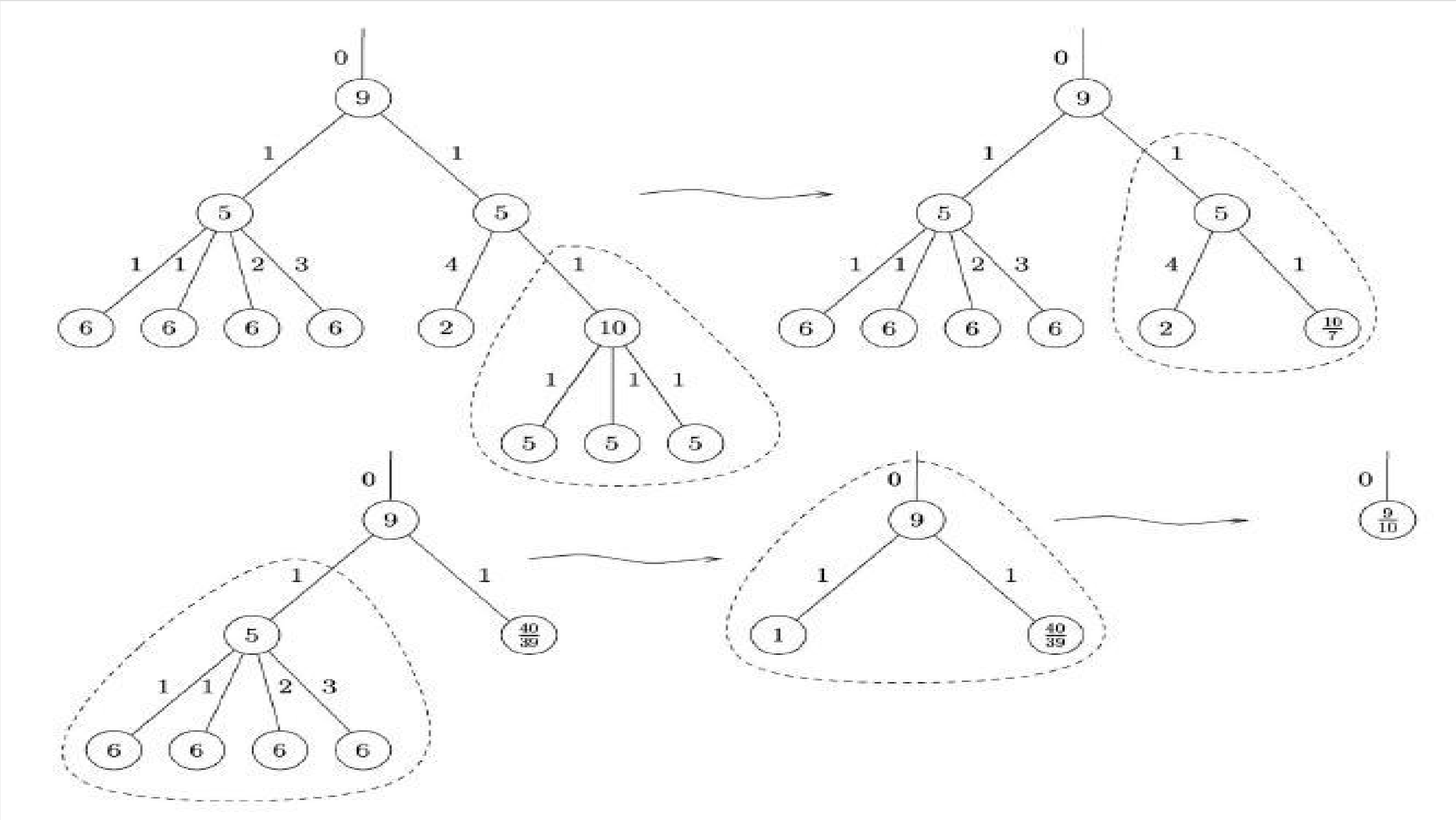
  – for each processor determine the fraction of time spent computing and the fraction of time spent sending or receiving

  - try to maximize the *throughput* (number of tasks processed per time-unit)

Known results
-Bandwidth-Centric principle-

- Used for tree-shaped platforms
- *Bandwidth* -the communication speed of the parent node
- If two children are in concurrence for obtaining a task ->task is given to the child with fastest communication time->optimize communication for parent
- Using a bottom-up transversal of the tree => obtain steady state throughput of the tree
  - leaves are reduced with the parent into a single node of equivalent computing power : $w = \frac{1}{n_{task}(F)}$

Example



Known results

-Bandwidth - Centric principle-

Algorithm

1) Sort the children by increasing communication times

c1≤c2≤...≤ck

2)Let p be the largest index so that $\sum_{i=1}^{p} \frac{ci}{wi} \leq 1$ .If p<k let

$\varepsilon = 1 - \sum_{i=1}^{p} \frac{ci}{wi}$; otherwise let $\varepsilon = 0$.

3)Then, $n_{task}(F) = \min\left(\frac{1}{c_0}, \frac{1}{w_0} + \sum_{i=1}^{p} \frac{1}{w_i} + \frac{\varepsilon}{c_{p+1}} \right)$

Known results

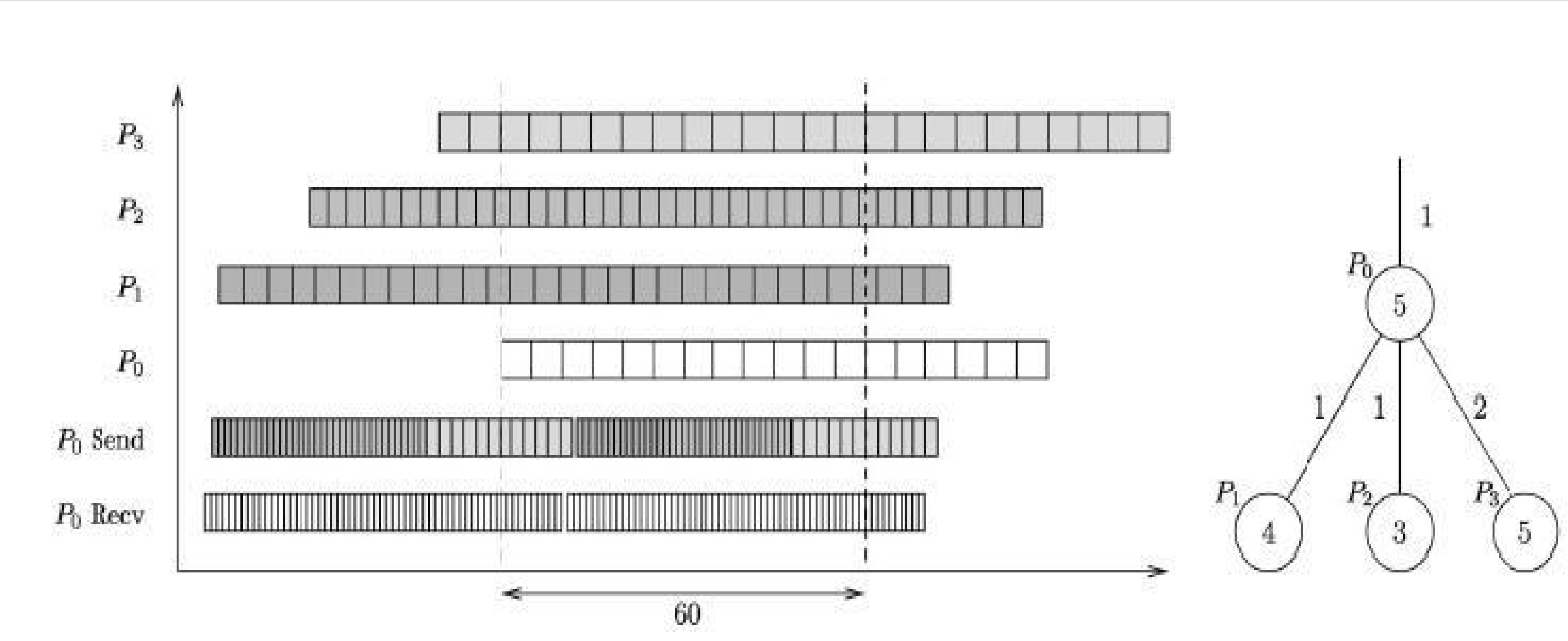
-Bandwidth - Centric principle-

- First term: $\frac{1}{c_0}$, the proc can not consume more tasks than sent by P_{-1}
- Second term:
  - ❖ if p=k then all the slaves are fed with tasks and they are computing steadily
  - ❖ if p<k some children will partially starve

- A slow processor with a fast communication link is preferred to a fast processor with a slow communication link !!!

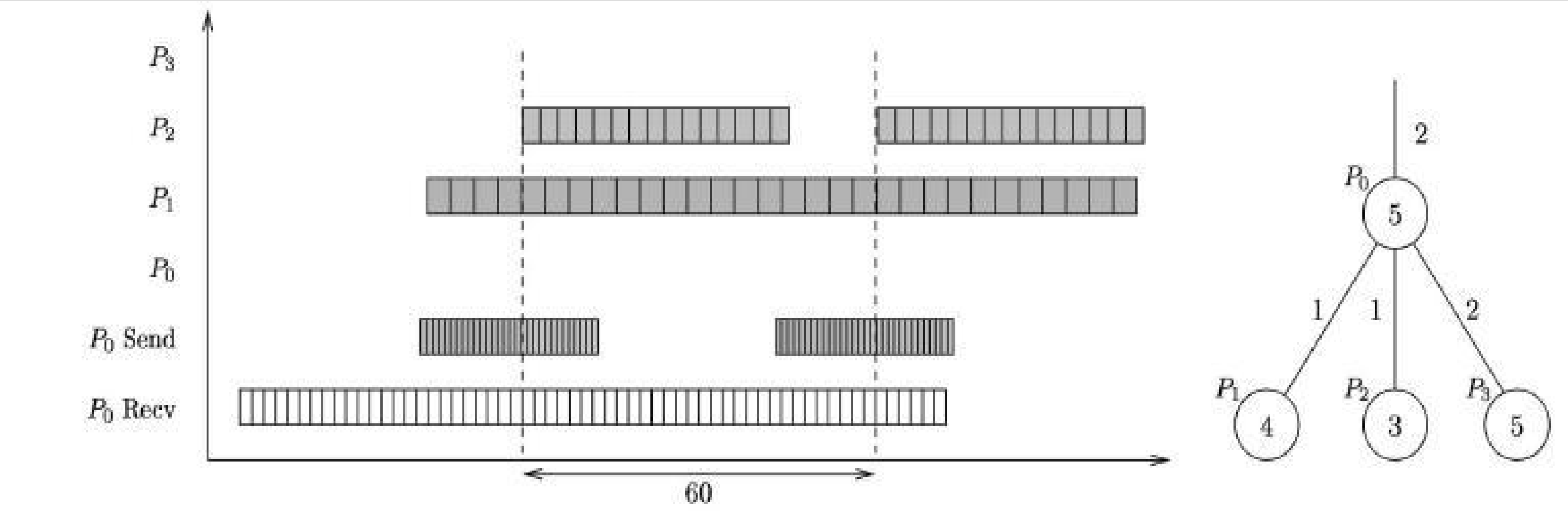
- After solving the linear program
  - ❖ characterize the schedule during one time-period
  - ❖ derive an actual schedule whose asymptotic efficiency will hopefully be optimal

Examples



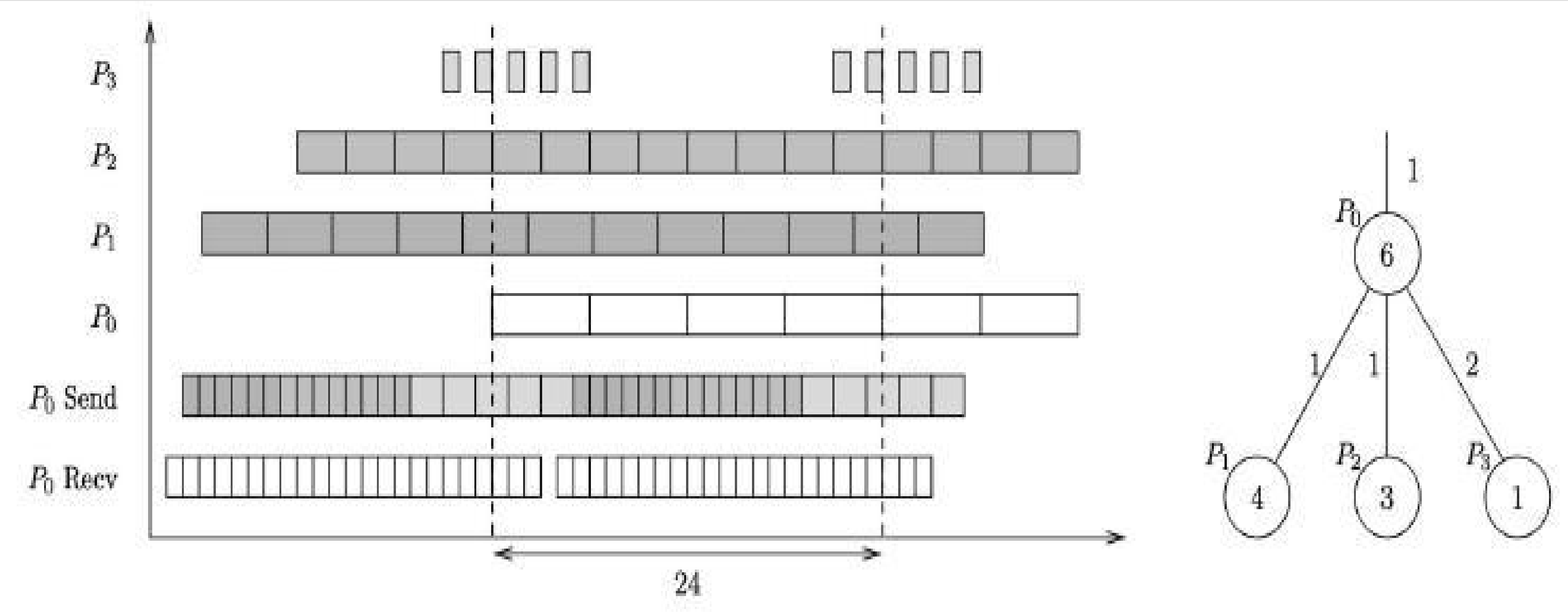
- Without saturation of the communication bandwidth all children can be kept *fully active*

Examples



- With saturation of the communication bandwidth some children are *partially idle* due to low bandwidth between Po and its parent.

Examples



- With saturation of the communication bandwidth- P**3** is *partially idle* because of its high computation speed

Known results

-Bandwidth - Centric principle-

- Periodic schedule – detailed list of actions of the processors during a time period
  - Starting at time-step t0 the whole pattern of computations and communications repeats every T time-units at time step t0+T, t0+2T and so on
  - Linear problem doesn't necessarily imply a polynomial T in the problem size
  - T might be exponential in the problem size

Drawback -the period can be very large

Solution: - restriction to fixed length periods

Known results

-Bandwidth - Centric principle-

- Because the period is too large the response time can be also very big
- Respose time – time passed since the task is realeased in the system till the master receives the result of the computation for that task
- Build the schedule considering the response time while enforcing a maximum throughput
- Goal – to obtain the maximum response time for a certain number of tasks as small as possible

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First Heuristic – Optimisation of Bandwidth centric principle

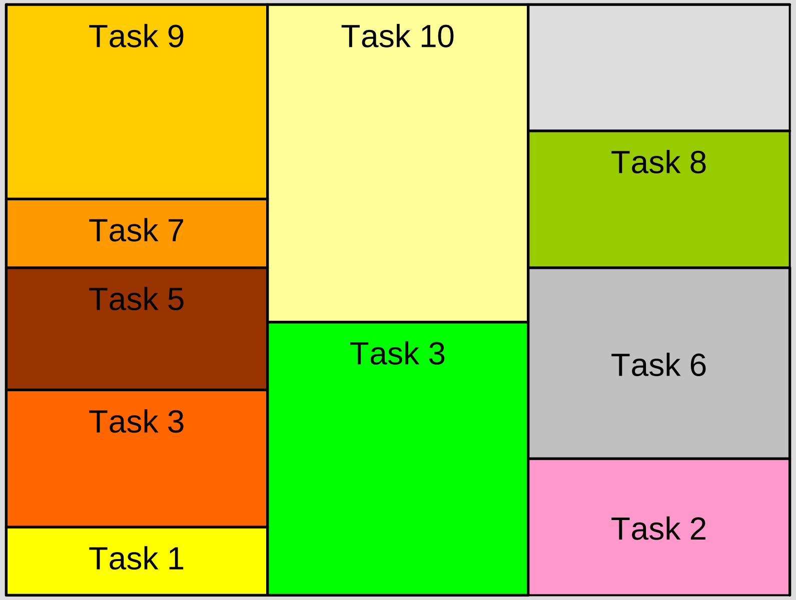
- The fork-graph platform is considered
- Having the maximum throughput $r_i \in Q$ for each node the periodic schedule is built :
  - ➢The rate R at which the tasks are arriving in the system is chosen as 2/(maximum throughput of the master)

    Heuristic will ensure 50% of optimal throughput
  - ➢Sending order of the tasks to slaves
    - for each slave build a heap
    - each time a task is sent increase the heap of the slave with the value of its maximum throughput
    - next task sent to the slave with the lowest heap value
  - ➢Receiving order:a slave sends the result to the master when it receives another task from the master

Example

- The slaves are ordered after the sending time *ci*
- 3 slaves with the next values of the throughput

$$r_1 = 0{,}5$$
$$r_2 = 0{,}2$$
$$r_3 = 0{,}3$$



$$\frac{1}{r_1} = 2 \qquad \frac{1}{r_2} = 5 \qquad \frac{1}{r_3} = 3{,}33$$

- The sending order will be : P1, P3, P1, P2, P1, P3, P1, P3, P1, P2

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Second Heuristic– Theoretically build of periodic schedules

- Period T will be fixed at the begining – multiple of the arrival rate R for the tasks
- R – computed like in the first period $R = \frac{2}{\max throughput}$
- ρ - the objective response time
- The schedule will be built by :
  - Ordering the slaves by increasing order of ***ci***, ***wi*** or ***ci+wi+di***
  - Find the ***maximum response time*** by building a schedule for the arrival rate **R** and a certain period **T**
  - Find the ***minimum response time-*** **min(ci+wi+di)**
  - **Binary search** between the minimum and the maximum value of the response time =>the **objective response time** ρ for which the schedule can be built

Building the schedule

- Apply the binary search for different values of the period **T** – T=5*R, T=10*R, T=20*R
- Consider the period for which the objective response time is minimum
- The number of tasks in one period is : tasksNo= $\frac{T}{R}$
- The total number of periods is $\frac{totalNumberOfTasks}{taskNo}$ where the

  total number of tasks for which the program is executed should be a multiple of ***tasksNo***

Building the schedule

- **About the period**
  - the period will be wrapped aroud
  - if a task can not finish its execution or its communication in one period it will be scheduled for the next period
  - each task will have an interval for sending, an interval for computing and one for receiving
  - each interval has an offset which shows if the interval belongs to the current period or to a period before it

Example for building the schedule

M	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
P1	0	-1		0		0	0			0	0		0	0				0			
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P2																					
P3																					

c[1]=1; w[1]=4; d[1]=1;

c[2]=2; w[2]=5; d[2]=1; R=3; T=7*R; tasksNo=7;

c[3]=3; w[3]=7; d[3]=1;

Example for building the schedule

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
M																					
P1	0	-1	-1	0		0	0	-1		0	0		0	0		0	0	0	0	0	
P2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P3	-1	-1	-1	-1	-1	-1												0	0	0	0

c[1]=1; w[1]=4; d[1]=1;

c[2]=2; w[2]=5; d[2]=1; R=3; T=7*R; tasksNo=7;

c[3]=3; w[3]=7; d[3]=1;

Second Heuristic

- The objective response time is also considered when sending a task to a processor
  - If end date – release date > objective response time for one task=> the next processor is tried
- If a task can not be sent to a certain slave because there is no more space or the response time is too big the cleanup has to be done
  - All the intervals used for sending, computing and receiving that task are deleted from the schedule