PROJECT 2 - Task Scheduling

EECE 7205 Fundamentals of Computer Engineering

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Problem Description

Implement and test the proposed algorithms in the “Task Scheduling” paper. You can use similar set up as in the paper. You can set up T_max in task migration around 1.5X of T_total of initial scheduling.

Requirements:

Except for input examples, other setups such as

T_send = 3,

T_cloud = 1,

T_receive = 1,

Number of local cores = 3, and their power consumption

P1 = 1

P2 = 2

P3 = 4

P4 = 0.5

can be kept the same

Requirements

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5 Examples:

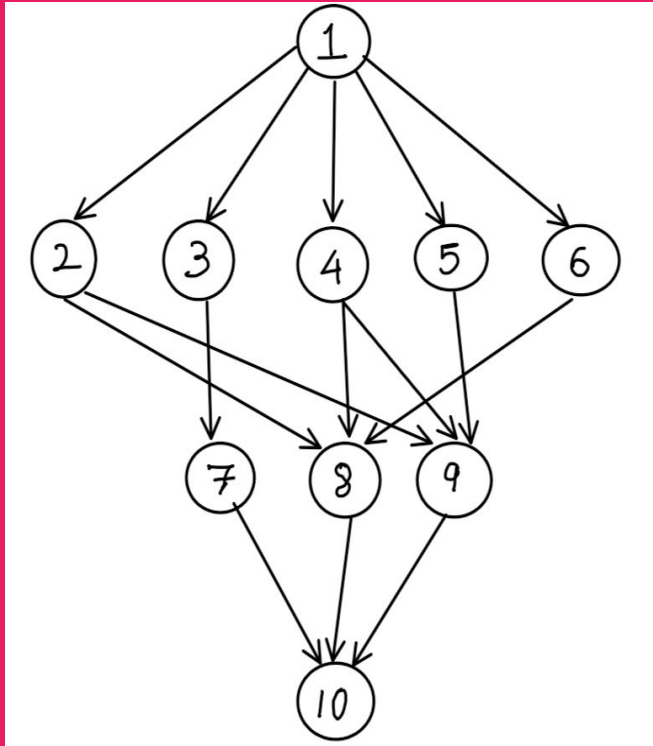
1. Exact same Figure 1 from paper.
2. From Figure 1, change only the connections.
3. From Figure 1, Increase task number to 20. (Core 1 slowed, core 3 fastest)
4. From example 3, have multiple entry tasks.
5. From example 3, have multiple entry tasks and exit tasks.

Results:

A. Figure of its task graph and its execution time table
B. Initial scheduling (Program output, visualized output, total energy from program and manually calculated total energy (with derivation)
C. Final scheduling (Program output, visualized output, total energy from program and manually calculated total energy (with derivation)
D. Summary of T_total and E_total of initial and final scheduling.

Example 1 - 10 tasks (Same from paper)

Graph:



Executable Time Table

Tasks	Core 1	Core 2	Core 3
1	9	7	5
2	8	6	5
3	6	5	4
4	7	5	3
5	5	4	2
6	7	6	4
7	8	5	3
8	6	4	2
9	5	3	2
10	7	4	2

Example 1: Initial Scheduling Table

Program output, visualized output

Program output

```
                                                Example 1: Initial Scheduling Table
TIME           : 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45
CORE 1         : -  -  -  -  -  4  4  4  4  4  4  4  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CORE 2         : -  -  -  -  -  6  6  6  6  6  6  -  8  8  8  8  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CORE 3         : 1  1  1  1  1  3  3  3  3  5  5  7  7  7  9  9 10 10  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Sending  : -  -  -  -  -  2  2  2  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Computing : -  -  -  -  -  -  -  -  2  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Receiving : -  -  -  -  -  -  -  -  -  2  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
```

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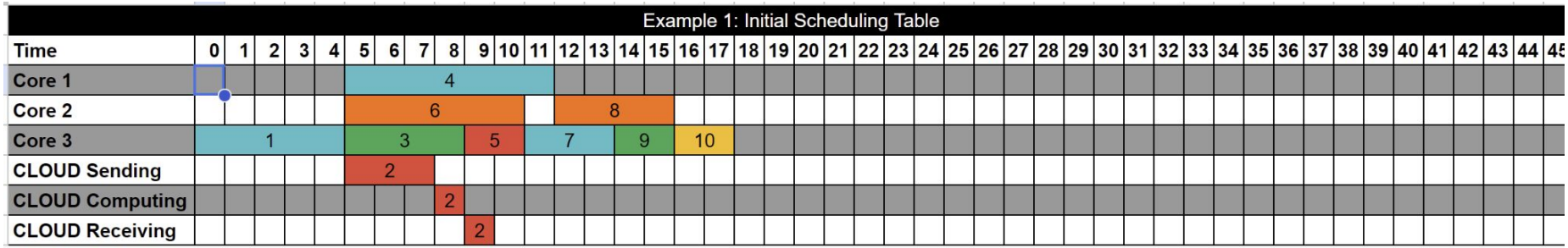
visualized output



Example 1: Initial Scheduling Table

Total energy from program and manually calculated

Total energy from program

```
Total Energy : 100.5
Total Time : 18
Initial Scheduling algorithm Execution Time: 1079 ms
```

Total energy manually calculated

Given, p1=1, p2=2, p3=4, p4=0.5 are the energy required for core 1,2,3 and cloud sending

E1= (7)*1 =7
E2= (6+4)*2 =20
E3= (5+4+2+3+2+2)*4 =72
E4= (3)*0.5 =1.5
E_Total= 100.5

Example 1: Final Scheduling Table

Program output, visualized output

Program output

```
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
                                                        Example 1: Final Scheduling Table
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
TIME            :  0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
CORE 1          :  -  -  -  -  -  5  5  5  5  5  -  -  -  -  8  8  8  8  8  8  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CORE 2          :  -  -  -  -  -  -  -  -  -  -  -  9  9  9  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CORE 3          :  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Sending   :  1  1  1  2  2  2  4  4  4  6  6  6  3  3  3  7  7  7  -  - 10 10 10  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Computing :  -  -  -  1  -  -  2  -  -  4  -  -  6  -  -  3  -  -  7  -  -  -  - 10  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Receiving :  -  -  -  -  1  -  -  2  -  -  4  -  -  6  -  -  3  -  -  7  -  -  -  -  10 -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
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```

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visualized output

Example 1: Final Scheduling Table

Time	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Core 1						5									8																															
Core 2												9																																		
Core 3																																														
CLOUD Sending	1			2			4			6			3			7					10																									
CLOUD Computing				1			2			4			6			3			7					10																						
CLOUD Receiving					1			2			4			6			3			7					10																					

Example 1: Final Scheduling Table

Total energy from program and manually calculated

Total energy from program

```
Total Energy : 27.5
Total Time : 25
Final Scheduling algorithm Execution Time: 733 ms
```

Total energy manually calculated

Given, p1=1, p2=2, p3=4, p4=0.5 are the energy required for core 1,2,3 and cloud sending

E1= (5+6)*1 =11
E2= (3)*2 =6
E3= (0)*4 =0
E4= (3+3+3+3+3+3+3)*0.5 =10.5
E_Total= 27.5

Summary

Initial Scheduling:
Total Energy: 100.5
Total Time: 18

Final Scheduling:
Total Energy: 27.5
Total Time: 25

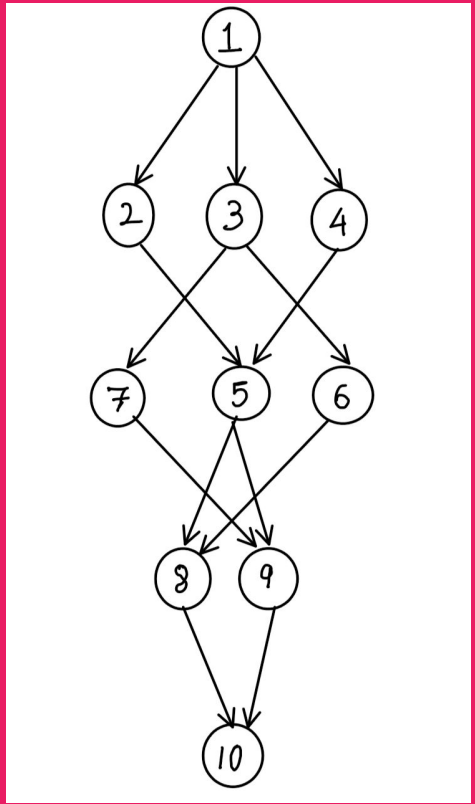
Total Energy Reduced : 72.64%
Time limit: 18*1.5 = 27 >= 27

Example 1: Summary Table

	Initial	Final
Total Energy	100.5	27.5
Total Time	18	25

Example 2 - 10 tasks (Same from paper) change only the connections

Graph:



Executable Time Table

Tasks	Core 1	Core 2	Core 3
1	9	7	5
2	8	6	5
3	6	5	4
4	7	5	3
5	5	4	2
6	7	6	4
7	8	5	3
8	6	4	2
9	5	3	2
10	7	4	2

Example 2: Initial Scheduling Table

Program output, visualized output

Program output

```
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                                                            Example 2: Initial Scheduling Table
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TIME            :  0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
CORE 1          :  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CORE 2          :  -  -  -  -  -  4  4  4  4  4  5  5  5  5  9  9  9  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CORE 3          :  1  1  1  1  1  3  3  3  3  6  6  6  6  -  8  8  - 10 10  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Sending   :  -  -  -  -  -  2  2  2  -  7  7  7  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Computing :  -  -  -  -  -  -  -  -  2  -  -  -  7  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Receiving :  -  -  -  -  -  -  -  -  -  2  -  -  -  7  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
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```

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visualized output

Example 2: Initial Scheduling Table

Time	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Core 1																																														
Core 2						4					5				9																															
Core 3	1					3				6					8			10																												
CLOUD Sending						2				7																																				
CLOUD Computing									2				7																																	
CLOUD Receiving										2				7																																

Example 2: Initial Scheduling Table

Total energy from program and manually calculated

Total energy from program

```
Total Energy : 95
Total Time : 19
Initial Scheduling algorithm Execution Time: 380 ms
```

Total energy manually calculated

Given, p1=1, p2=2, p3=4, p4=0.5 are the energy required for core 1,2,3 and cloud sending

E1= (0)*1 =0
E2= (5+4+3)*2 =24
E3= (5+4+4+2+2)*4 =68
E4= (3+3)*0.5 =3
E_Total= 95

Example 2: Final Scheduling Table

Program output, visualized output

Program output

```
                                                Example 2: Final Scheduling Table
TIME           :  0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45
CORE 1         :  -  -  -  -  -  -  -  -  -  -  -  5  5  5  5  5  -  9  9  9  9  9  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CORE 2         :  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CORE 3         :  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Sending  :  1  1  1  2  2  2  4  4  4  3  3  3  7  7  7  6  6  6  8  8  8  - 10 10 10  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Computing :  -  -  -  1  -  -  2  -  -  4  -  -  3  -  -  7  -  -  6  -  -  8  -  -  - 10  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Receiving :  -  -  -  -  1  -  -  2  -  -  4  -  -  3  -  -  7  -  -  6  -  -  8  -  -  - 10  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
```

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visualized output

Example 2: Final Scheduling Table

Time	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Core 1												5						9																												
Core 2																																														
Core 3																																													
CLOUD Sending	1			2			4			3			7			6			8				10																						
CLOUD Computing				1			2			4			3			7			6			8				10																		
CLOUD Receiving					1			2			4			3			7			6			8				10																		

Example 2: Final Scheduling Table

Total energy from program and manually calculated

Total energy from program

```
Total Energy : 22
Total Time : 27
Final Scheduling algorithm Execution Time: 380 ms
```

Total energy manually calculated

Given, p1=1, p2=2, p3=4, p4=0.5 are the energy required for core 1,2,3 and cloud sending

E1= (5+5)*1 =10
E2= (0)*2 =0
E3= (0)*4 =0
E4= (3+3+3+3+3+3+3+3)*0.5 =12
E_Total= 22

Summary

Initial Scheduling:
Total Energy: 95
Total Time: 19

Final Scheduling:
Total Energy: 22
Total Time: 27

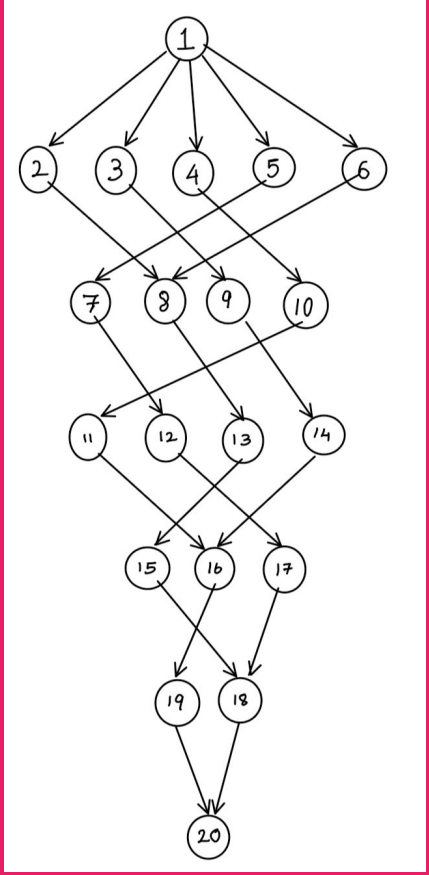
Total Energy Reduced: 76.84%
Time limit: 19*1.5 = 28.5 >= 27

Example 2: Summary Table

	Initial	Final
Total Energy	95	22
Total Time	19	27

Example 3 - 20 tasks (Core 1 is slowest, Core 3 fastest)

Graph:



Executable Time Table

Task	Core 1	Core 2	Core 3
1	9	7	5
2	8	6	5
3	6	5	4
4	7	5	3
5	5	4	2
6	7	6	4
7	8	5	3
8	6	4	2
9	5	3	2
10	7	4	2
11	4	3	2
12	5	2	1
13	6	3	2
14	7	3	2
15	5	3	2
16	7	2	1
17	7	5	4
18	8	6	3
19	5	4	3
20	4	3	2

Example 3: Initial Scheduling Table

Program output, visualized output

Program output

```
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                                                    Example 3: Initial Scheduling Table
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TIME            :  0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
CORE 1          :  -  -  -  -  -  3  3  3  3  3  3  9  9  9  9  9  - 11 11 11 11  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CORE 2          :  -  -  -  -  -  5  5  5  5  7  7  7  7  7 12 12 13 13 13  -  -  - 19 19 19 19  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CORE 3          :  1  1  1  1  1  2  2  2  2  2  4  4  4  8  8 10 10 14 14 15 15 16 18 18 18  - 20 20  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Sending   :  -  -  -  -  -  6  6  6  -  -  -  -  -  -  -  - 17 17 17  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Computing :  -  -  -  -  -  -  -  -  6  -  -  -  -  -  -  -  -  -  - 17  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Receiving :  -  -  -  -  -  -  -  -  -  6  -  -  -  -  -  -  -  -  -  - 17  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
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visualized output

<table>
<tr><th colspan="47">Example 3: Initial Scheduling Table</th></tr>
<tr><th>Time</th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th><th>21</th><th>22</th><th>23</th><th>24</th><th>25</th><th>26</th><th>27</th><th>28</th><th>29</th><th>30</th><th>31</th><th>32</th><th>33</th><th>34</th><th>35</th><th>36</th><th>37</th><th>38</th><th>39</th><th>40</th><th>41</th><th>42</th><th>43</th><th>44</th><th>45</th></tr>
<tr><td>Core 1</td><td></td><td></td><td></td><td></td><td></td><td colspan="6">3</td><td colspan="5">9</td><td></td><td colspan="4">11</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Core 2</td><td></td><td></td><td></td><td></td><td></td><td colspan="4">5</td><td colspan="5">7</td><td colspan="2">12</td><td colspan="3">13</td><td></td><td></td><td></td><td colspan="4">19</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Core 3</td><td colspan="5">1</td><td colspan="5">2</td><td colspan="3">4</td><td colspan="2">8</td><td colspan="2">10</td><td colspan="2">14</td><td colspan="2">15</td><td>16</td><td colspan="3">18</td><td></td><td colspan="2">20</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>CLOUD Sending</td><td></td><td></td><td></td><td></td><td></td><td colspan="3">6</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">17</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>CLOUD Computing</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>6</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>17</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>CLOUD Receiving</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>6</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>17</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Example 3: Initial Scheduling Table

Total energy from program and manually calculated

Total energy from program

```
Total Energy : 162
Total Time : 28
Initial Scheduling algorithm Execution Time: 585 ms
```

Total energy manually calculated

Given, p1=1, p2=2, p3=4, p4=0.5 are the energy required for core 1,2,3 and cloud sending

E1= (6+5+4)*1 =15
E2= (4+5+2+3+4)*2 =36
E3= (5+5+3+2+2+2+2+1+3+2)*4 =108
E4= (3+3)*0.5 =3
E_Total= 162

Example 3: Final Scheduling Table

Program output, visualized output

Program output

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                                                  Example 3: Final Scheduling Table
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
TIME            :  0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
CORE 1          :  -  -  -  -  -  4  4  4  4  4  4  4 10 10 10 10 10 10 10 11 11 11 11  - 19 19 19 19 19  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CORE 2          :  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  - 14 14 14  -  -  -  -  -  -  -  -  -  -  -  - 15 15 15  -  -  -  -  -  -  -  -  -  -  -
CORE 3          :  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  - 16  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  - 20 20  -  -  -  -
CLOUD Sending   :  1  1  1  6  6  6  3  3  3  5  5  5  9  9  9  2  2  2  7  7  7  8  8  8 12 12 12 13 13 13 17 17 17  -  - 18 18 18  -  -  -  -  -  -  -  -
CLOUD Computing :  -  -  -  1  -  -  6  -  -  3  -  -  5  -  -  9  -  -  2  -  -  7  -  -  8  -  - 12  -  - 13  -  - 17  -  -  -  - 18  -  -  -  -  -  -  -
CLOUD Receiving :  -  -  -  -  1  -  -  6  -  -  3  -  -  5  -  -  9  -  -  2  -  -  7  -  -  8  -  - 12  -  - 13  -  - 17  -  -  -  - 18  -  -  -  -  -  -
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

---

visualized output

Example 3: Final Scheduling Table

Time	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Core 1						4						10								11					19																					
Core 2																		14															15													
Core 3																								16																	20					
CLOUD Sending	1			6			3			5			9			2			7			8			12			13			17					18										
CLOUD Computing				1			6			3			5			9			2			7			8			12			13			17					18							
CLOUD Receiving					1			6			3			5			9			2			7			8			12			13			17					18						

Example 3: Final Scheduling Table

Total energy from program and manually calculated

Total energy from program

```
Total Energy : 65
Total Time : 42
Final Scheduling algorithm Execution Time: 585 ms
```

Total energy manually calculated

Given, p1=1, p2=2, p3=4, p4=0.5 are the energy required for core 1,2,3 and cloud sending

E1= (6+8+4+5)*1 =23
E2= (3+3)*2 =12
E3= (1+2)*4 =12
E4= (3+3+3+3+ 3+3+3+3+ 3+3+3+3)*0.5 =18
E_Total= 65

Summary

Initial Scheduling:
Total Energy: 162
Total Time: 28

Final Scheduling:
Total Energy: 65
Total Time: 42

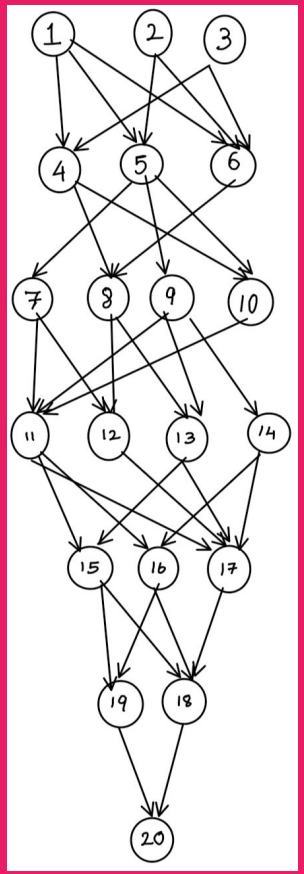
Total Energy Reduced: 59.88%
Time limit: 28*1.5 = 42 >= 42

Example 3: Summary Table

	Initial	Final
Total Energy	162	65
Total Time	28	42

Example 4 - 20 tasks (Same from Example 3, but have multiple entries)

Graph:



Executable Time Table

Task	Core 1	Core 2	Core 3
1	9	7	5
2	8	6	5
3	6	5	4
4	7	5	3
5	5	4	2
6	7	6	4
7	8	5	3
8	6	4	2
9	5	3	2
10	7	4	2
11	4	3	2
12	5	2	1
13	6	3	2
14	7	3	2
15	5	3	2
16	7	2	1
17	7	5	4
18	8	6	3
19	5	4	3
20	4	3	2

Example 4: Initial Scheduling Table

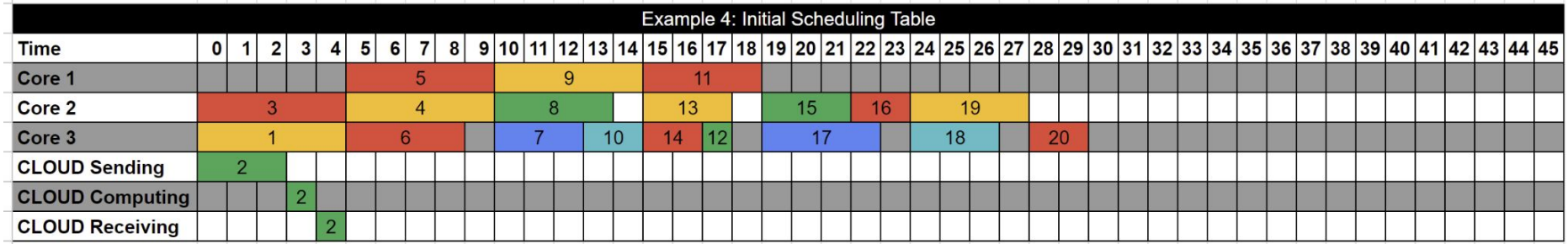
Program output, visualized output

Program output

```
                                                Example 4: Initial Scheduling Table
TIME           :  0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45
CORE 1         :  -  -  -  -  -  5  5  5  5  5  9  9  9  9  9 11 11 11 11  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CORE 2         :  3  3  3  3  3  4  4  4  4  4  8  8  8  8  - 13 13 13  - 15 15 15 16 16 19 19 19 19  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CORE 3         :  1  1  1  1  1  6  6  6  6  -  7  7  7 10 10 14 14 12  - 17 17 17 17  - 18 18 18  - 20 20  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Sending  :  2  2  2  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Computing :  -  -  -  2  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Receiving :  -  -  -  -  2  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
```

---

visualized output



Example 4: Initial Scheduling Table

Total energy from program and manually calculated

Total energy from program

```
Total Energy : 171.5
Total Time : 30
Initial Scheduling algorithm Execution Time: 475 ms
```

Total energy manually calculated

Given, p1=1, p2=2, p3=4, p4=0.5 are the energy required for core 1,2,3 and cloud sending

E1= (5+5+4)*1 =14
E2= (5+5+4+3+3+2+4)*2 =52
E3= (5+4+3+2+2+1+4+3+2)*4 =104
E4= (3)*0.5 =1.5
E_Total= 171.5

Example 4: Final Scheduling Table

Program output, visualized output

Program output

```
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
                                                        Example 4: Final Scheduling Table
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
TIME            :  0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
CORE 1          :  3  3  3  3  3  3  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  - 11 11 11 11  -  - 15 15 15 15 15 19 19 19 19 19  -  -  -  -
CORE 2          :  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  - 14 14 14  -  -  -  -  -  -  - 16 16  -  -  -  -  -  -  -  -  -  - 20 20 20  -
CORE 3          :  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Sending   :  1  1  1  2  2  2  4  4  4  5  5  5  6  6  6  9  9  9 10 10 10  7  7  7  8  8  8 13 13 13 12 12 12 17 17 17  - 18 18 18  -  -  -  -  -  -
CLOUD Computing :  -  -  -  1  -  -  2  -  -  4  -  -  5  -  -  6  -  -  9  -  - 10  -  -  7  -  -  8  -  - 13  -  - 12  -  - 17  -  -  - 18  -  -  -  -  -
CLOUD Receiving :  -  -  -  -  1  -  -  2  -  -  4  -  -  5  -  -  6  -  -  9  -  - 10  -  -  7  -  -  8  -  - 13  -  - 12  -  - 17  -  -  - 18  -  -  -  -
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

---

visualized output

<table>
<tr><th colspan="47">Example 4: Final Scheduling Table</th></tr>
<tr><th>Time</th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th><th>21</th><th>22</th><th>23</th><th>24</th><th>25</th><th>26</th><th>27</th><th>28</th><th>29</th><th>30</th><th>31</th><th>32</th><th>33</th><th>34</th><th>35</th><th>36</th><th>37</th><th>38</th><th>39</th><th>40</th><th>41</th><th>42</th><th>43</th><th>44</th><th>45</th></tr>
<tr><td>Core 1</td><td colspan="6">3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">11</td><td></td><td></td><td colspan="5">15</td><td colspan="5">19</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Core 2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">14</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">16</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">20</td><td></td></tr>
<tr><td>Core 3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>CLOUD Sending</td><td colspan="3">1</td><td colspan="3">2</td><td colspan="3">4</td><td colspan="3">5</td><td colspan="3">6</td><td colspan="3">9</td><td colspan="3">10</td><td colspan="3">7</td><td colspan="3">8</td><td colspan="3">13</td><td colspan="3">12</td><td colspan="3">17</td><td></td><td colspan="3">18</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>CLOUD Computing</td><td></td><td></td><td></td><td>1</td><td></td><td></td><td>2</td><td></td><td></td><td>4</td><td></td><td></td><td>5</td><td></td><td></td><td>6</td><td></td><td></td><td>9</td><td></td><td></td><td>10</td><td></td><td></td><td>7</td><td></td><td></td><td>8</td><td></td><td></td><td>13</td><td></td><td></td><td>12</td><td></td><td></td><td>17</td><td></td><td></td><td></td><td>18</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>CLOUD Receiving</td><td></td><td></td><td></td><td></td><td>1</td><td></td><td></td><td>2</td><td></td><td></td><td>4</td><td></td><td></td><td>5</td><td></td><td></td><td>6</td><td></td><td></td><td>9</td><td></td><td></td><td>10</td><td></td><td></td><td>7</td><td></td><td></td><td>8</td><td></td><td></td><td>13</td><td></td><td></td><td>12</td><td></td><td></td><td>17</td><td></td><td></td><td></td><td>18</td><td></td><td></td><td></td><td></td></tr>
</table>

Example 4: Final Scheduling Table

Total energy from program and manually calculated

Total energy from program

```
Total Energy : 55.5
Total Time : 45
Final Scheduling algorithm Execution Time: 533 ms
```

Total energy manually calculated

Given, p1=1, p2=2, p3=4, p4=0.5 are the energy required for core 1,2,3 and cloud sending

E1= (6+4+5+5)*1 =20
E2= (3+2+3)*2 =16
E3= (0)*4 =0
E4= (3+3+3+3+ 3+3+3+3+ 3+3+3+3 +3)*0.5 =19.5
E_Total= 55.5

Summary

Initial Scheduling:
Total Energy: 171.5
Total Time: 30

Final Scheduling:
Total Energy: 55.5
Total Time: 45

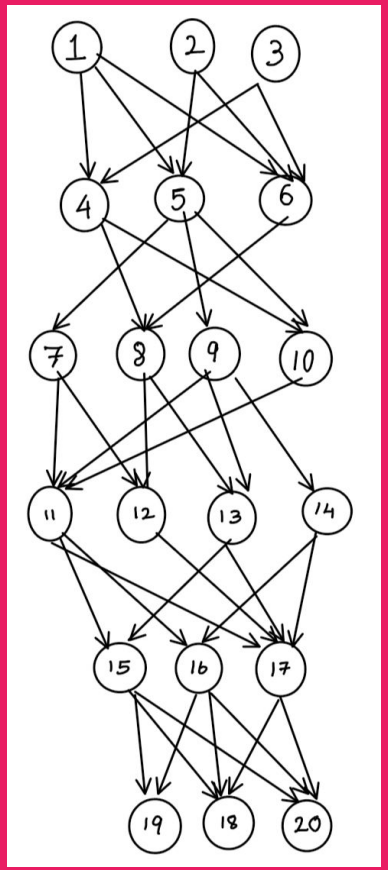
Total Energy Reduced: 67.6%
Time limit: 30*1.5 = 45 >= 45

Example 4: Summary Table

	Initial	Final
Total Energy	171.5	55.5
Total Time	30	45

Example 5 - 20 tasks (Same from Example 3, but have multiple entries and exits)

Graph:



Executable Time Table

Task	Core 1	Core 2	Core 3
1	9	7	5
2	8	6	5
3	6	5	4
4	7	5	3
5	5	4	2
6	7	6	4
7	8	5	3
8	6	4	2
9	5	3	2
10	7	4	2
11	4	3	2
12	5	2	1
13	6	3	2
14	7	3	2
15	5	3	2
16	7	2	1
17	7	5	4
18	8	6	3
19	5	4	3
20	4	3	2

Example 5: Initial Scheduling Table

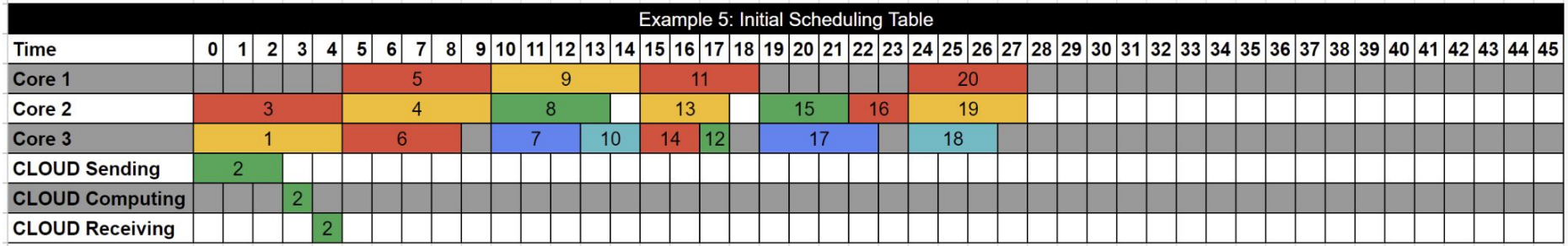
Program output, visualized output

Program output

```
                                                Example 5: Initial Scheduling Table
TIME           :  0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45
CORE 1         :  -  -  -  -  -  5  5  5  5  5  9  9  9  9  9 11 11 11 11  -  -  -  -  - 20 20 20 20  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CORE 2         :  3  3  3  3  3  4  4  4  4  4  8  8  8  8  - 13 13 13  - 15 15 15 16 16 19 19 19 19  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CORE 3         :  1  1  1  1  1  6  6  6  6  -  7  7  7 10 10 14 14 12  - 17 17 17 17  - 18 18 18  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Sending  :  2  2  2  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Computing :  -  -  -  2  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Receiving :  -  -  -  -  2  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
```

---

visualized output



Example 5: Initial Scheduling Table

Total energy from program and manually calculated

Total energy from program

```
Total Energy : 167.5
Total Time : 28
Initial Scheduling algorithm Execution Time: 520 ms
```

Total energy manually calculated

Given, p1=1, p2=2, p3=4, p4=0.5 are the energy required for core 1,2,3 and cloud sending

E1= (5+5+4+4)*1 =18
E2= (5+5+4+3+3+2+4)*2 =52
E3= (5+4+3+2+2+1+4+3)*4 =96
E4= (3)*0.5 =1.5
E_Total= 167.5

Example 5: Final Scheduling Table

Program output, visualized output

Program output

```
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
                                                   Example 5: Final Scheduling Table
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
TIME            :  0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
CORE 1          :  3  3  3  3  3  3  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  - 11 11 11 11  -  - 15 15 15 15 15  - 20 20 20 20  -  -  -  -
CORE 2          :  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  - 14 14 14  -  -  -  -  -  -  -  -  -  -  -  -  -  - 19 19 19 19  -  -  -  -  -
CORE 3          :  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  - 12  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
CLOUD Sending   :  1  1  1  2  2  2  4  4  4  5  5  5  6  6  6  9  9  9 10 10 10  7  7  7  8  8  8 13 13 13 16 16 16 17 17 17  - 18 18 18  -  -  -  -  -  -
CLOUD Computing :  -  -  -  1  -  -  2  -  -  4  -  -  5  -  -  6  -  -  9  -  - 10  -  -  7  -  -  8  -  - 13  -  - 16  -  - 17  -  -  - 18  -  -  -  -  -
CLOUD Receiving :  -  -  -  -  1  -  -  2  -  -  4  -  -  5  -  -  6  -  -  9  -  - 10  -  -  7  -  -  8  -  - 13  -  - 16  -  - 17  -  -  - 18  -  -  -  -
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
```

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visualized output

Example 5: Final Scheduling Table

Time	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Core 1	3																										11						15						20							
Core 2																					14																	19								
Core 3																														12																
CLOUD Sending	1			2			4			5			6			9			10			7			8			13			16			17				18								
CLOUD Computing				1			2			4			5			6			9			10			7			8			13			16			17				18					
CLOUD Receiving					1			2			4			5			6			9			10			7			8			13			16			17				18				

Example 5: Final Scheduling Table

Total energy from program and manually calculated

Total energy from program

```
Total Energy : 56.5
Total Time : 42
Final Scheduling algorithm Execution Time: 520 ms
```

Total energy manually calculated

Given, p1=1, p2=2, p3=4, p4=0.5 are the energy required for core 1,2,3 and cloud sending

E1= (6+4+5+4)*1 =19
E2= (3+4)*2 =14
E3= (1)*4 =4
E4= (3+3+3+3+ 3+3+3+3+ 3+3+3+3 +3)*0.5 =19.5
E_Total= 56.5

Summary

Initial Scheduling:
Total Energy: 167.5
Total Time: 28

Final Scheduling:
Total Energy: 56.5
Total Time: 42

Total Energy Reduced: 66.27%
Time limit: 28*1.5 = 42 >= 42

Example 5: Summary Table

	Initial	Final
Total Energy	167.5	56.5
Total Time	28	42