FUNDAMENTALS OF COMPUTER ENGINEERING

PROJECT 2

Task Scheduling

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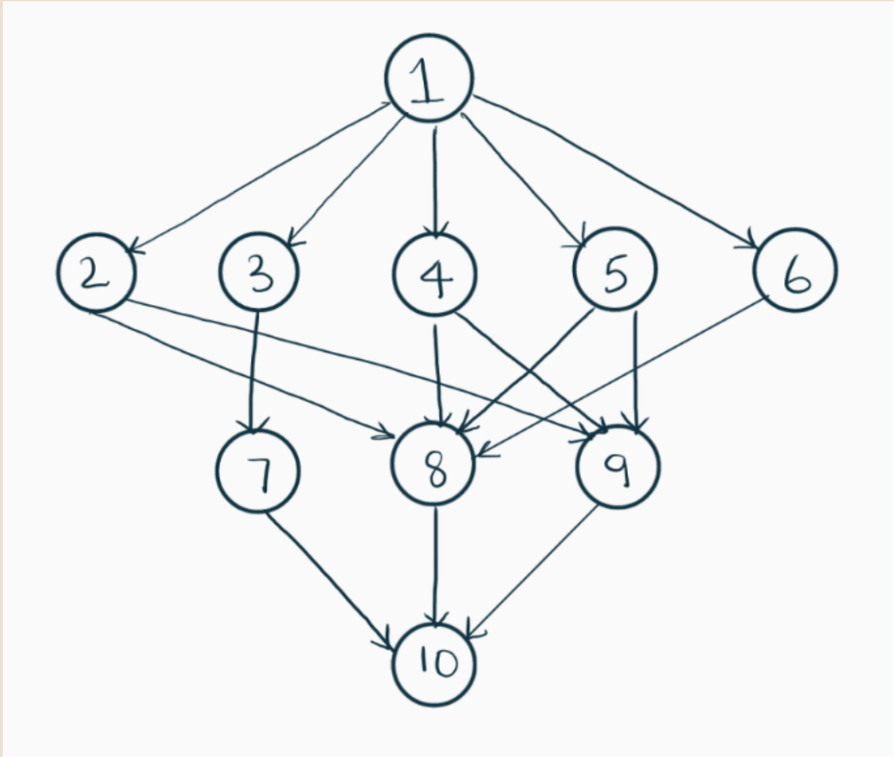
Northeastern University | 2024

INPUT 1



Task Graph 1 consists of 10 tasks with one entry task and one exit task.

Execution Time for Task Graph 1

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

INITIAL SCHEDULING FOR TASK GRAPH 1

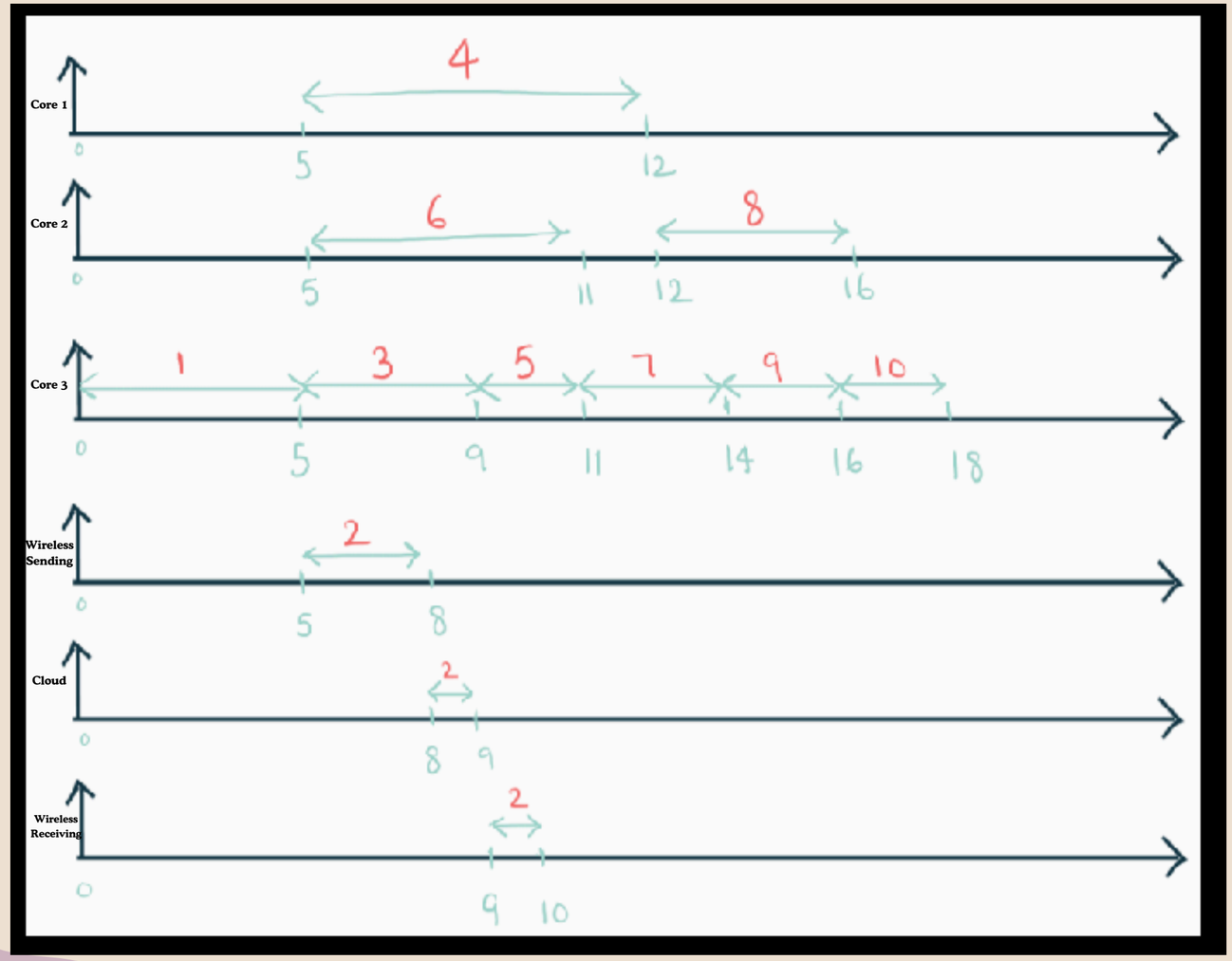
```
Initial scheduling:
Task 1 runs on local core3; start time: 0, finish time: 5
Task 3 runs on local core3; start time: 5, finish time: 9
Task 2 runs on the cloud; start time: 5, finish time: 10
Task 6 runs on local core2; start time: 5, finish time: 11
Task 4 runs on local core1; start time: 5, finish time: 12
Task 5 runs on local core3; start time: 9, finish time: 11
Task 7 runs on local core3; start time: 11, finish time: 14
Task 8 runs on local core2; start time: 12, finish time: 16
Task 9 runs on local core3; start time: 14, finish time: 16
Task 10 runs on local core3; start time: 16, finish time: 18
Total energy is: 100.5
Completion time is: 18
Initial scheduling took 0.022 ms to execute
```

Total completion time for scheduling is 18.

Total Energy Consumed is 100.5.

Running time of initial scheduling program is 0.025 ms

INITIAL SCHEDULING TASK GRAPH 1



Manual Calculation of Energy Consumption

E1=(7*1)=7;

E2=(6+4)*2=20;

E3=(5+4+2+3+2+2)*4=72;

Es=(3*0.5)=1.5;

E_Total=7+20+72+1.5=100.5

Task Priority Order: 1,3,2,6,4,5,7,8,9,10

FINAL SCHEDULING FOR TASK GRAPH 1

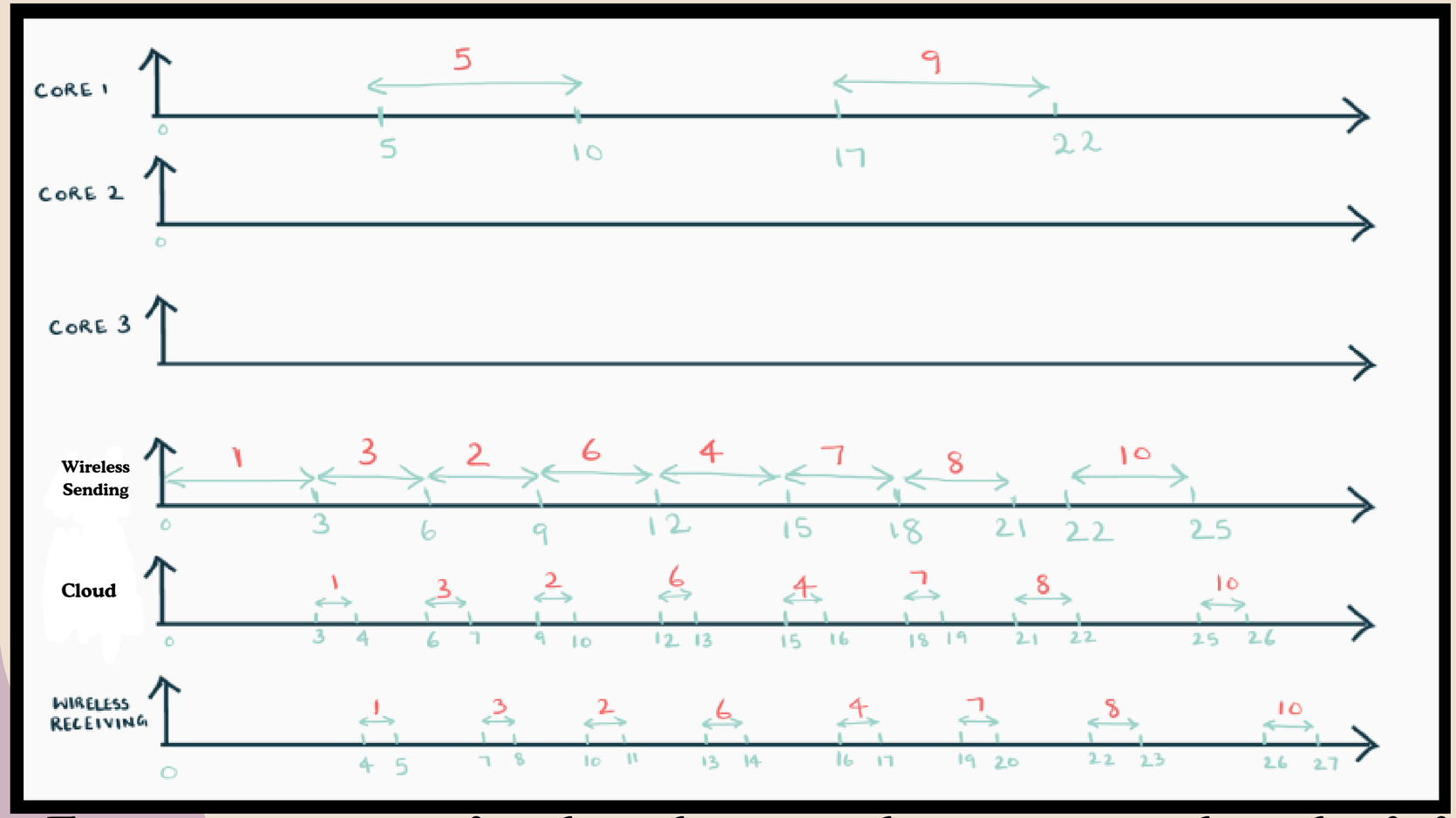
```
Post Task Migration:
Task 1 runs on the cloud; start time: 0, finish time: 5
Task 3 runs on the cloud; start time: 3, finish time: 8
Task 2 runs on the cloud; start time: 6, finish time: 11
Task 6 runs on the cloud; start time: 9, finish time: 14
Task 4 runs on the cloud; start time: 12, finish time: 17
Task 5 runs on local core1; start time: 5, finish time: 10
Task 7 runs on the cloud; start time: 15, finish time: 20
Task 8 runs on the cloud; start time: 18, finish time: 23
Task 9 runs on local core1; start time: 17, finish time: 22
Task 10 runs on the cloud; start time: 22, finish time: 27
Total energy is: 22
Completion time is: 27
Task migration took 1.493 ms to execute
```

Total completion time for scheduling is 22 .

Total Energy Consumed is 27.

Running time of initial scheduling program is 0.025 ms

FINAL SCHEDULING TASK GRAPH 1



Manual Calculation of Energy Consumption

E1=(5+5)*1=10;

E2=0;

E3=0;

Es=(3*8*0.5)=12;

E_Total=10+12=22

Energy consumption has decreased as compared to the initial scheduling, while total time taken is lesser than T_max derived

CONCLUSION

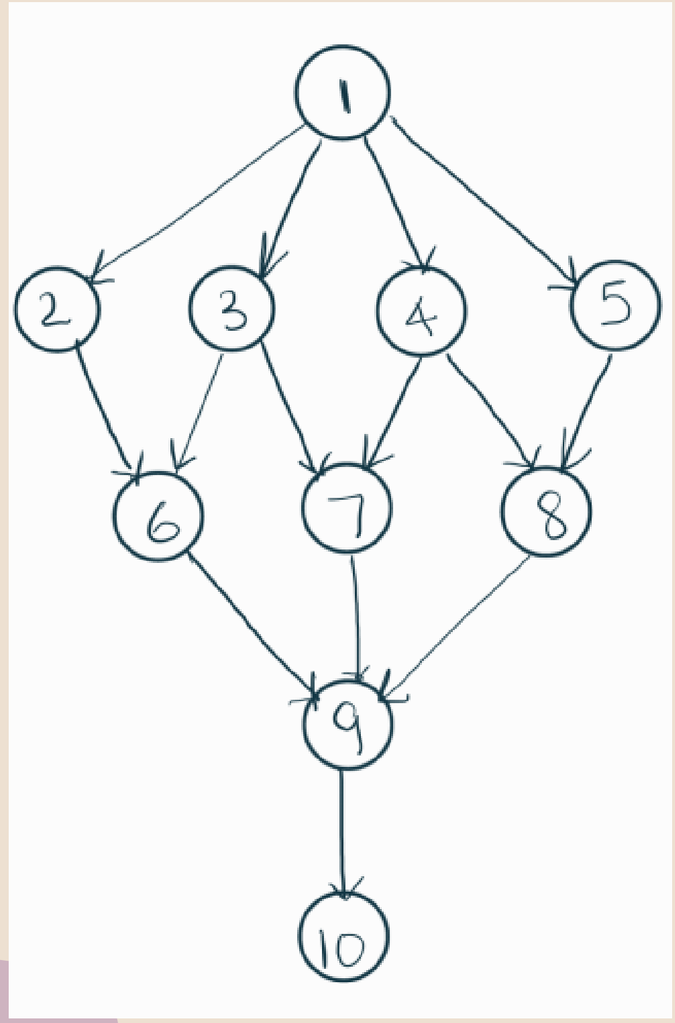
The results obtained in Initial and Final Scheduling was an exact match with the one in the paper.

Total Time Taken for Initial Scheduling: 18
Total Time Taken for Final Scheduling: 27

While the final scheduling increased the total time of operations, it significantly reduced the total energy consumption compared to the initial scheduling.

	Value
T_Total (Initial)	18
T_Total (Final)	27
E_Total (Initial)	100.5
E_Total (Final)	22

INPUT 2



Task Graph 2 consists of 10 tasks.
There is one entry task and one exit task.

Execution Time for Task Graph 2

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

INITIAL SCHEDULING FOR TASK GRAPH 2

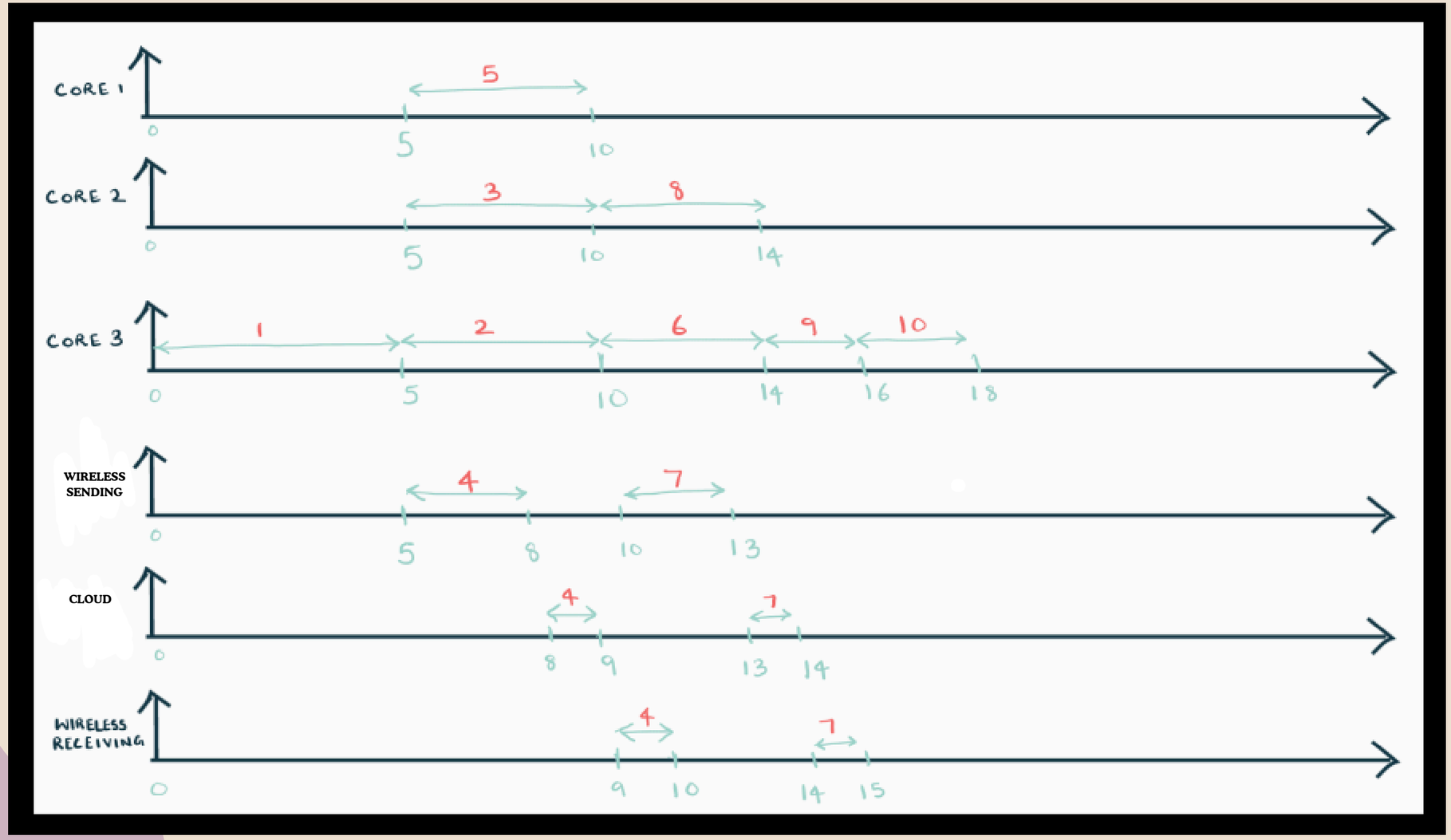
```
Initial scheduling:
Task 1 runs on local core3; start time: 0, finish time: 5
Task 2 runs on local core3; start time: 5, finish time: 10
Task 3 runs on local core2; start time: 5, finish time: 10
Task 4 runs on the cloud; start time: 5, finish time: 10
Task 5 runs on local core1; start time: 5, finish time: 10
Task 6 runs on local core3; start time: 10, finish time: 14
Task 8 runs on local core2; start time: 10, finish time: 14
Task 9 runs on local core3; start time: 14, finish time: 16
Task 7 runs on the cloud; start time: 10, finish time: 15
Task 10 runs on local core3; start time: 16, finish time: 18
Total energy is: 98
Completion time is: 18
Initial scheduling took 0.028 ms to execute
```

Total completion time for scheduling is 18.

Total Energy Consumed is 98.

Running time of initial scheduling program is 0.028 ms

INITIAL SCHEDULING TASK GRAPH 2



INITIAL SCHEDULING TASK GRAPH 2

Manual Calculation of Energy Consumption

$$E1=(5*1)=5;$$
$$E2=(5+4)*2=18;$$
$$E3=(5+5+4+2+2)*4=72;$$
$$Es=(3+3)*0.5=3;$$
$$E\_Total=5+18+72+3=98$$

FINAL SCHEDULING FOR TASK GRAPH 2

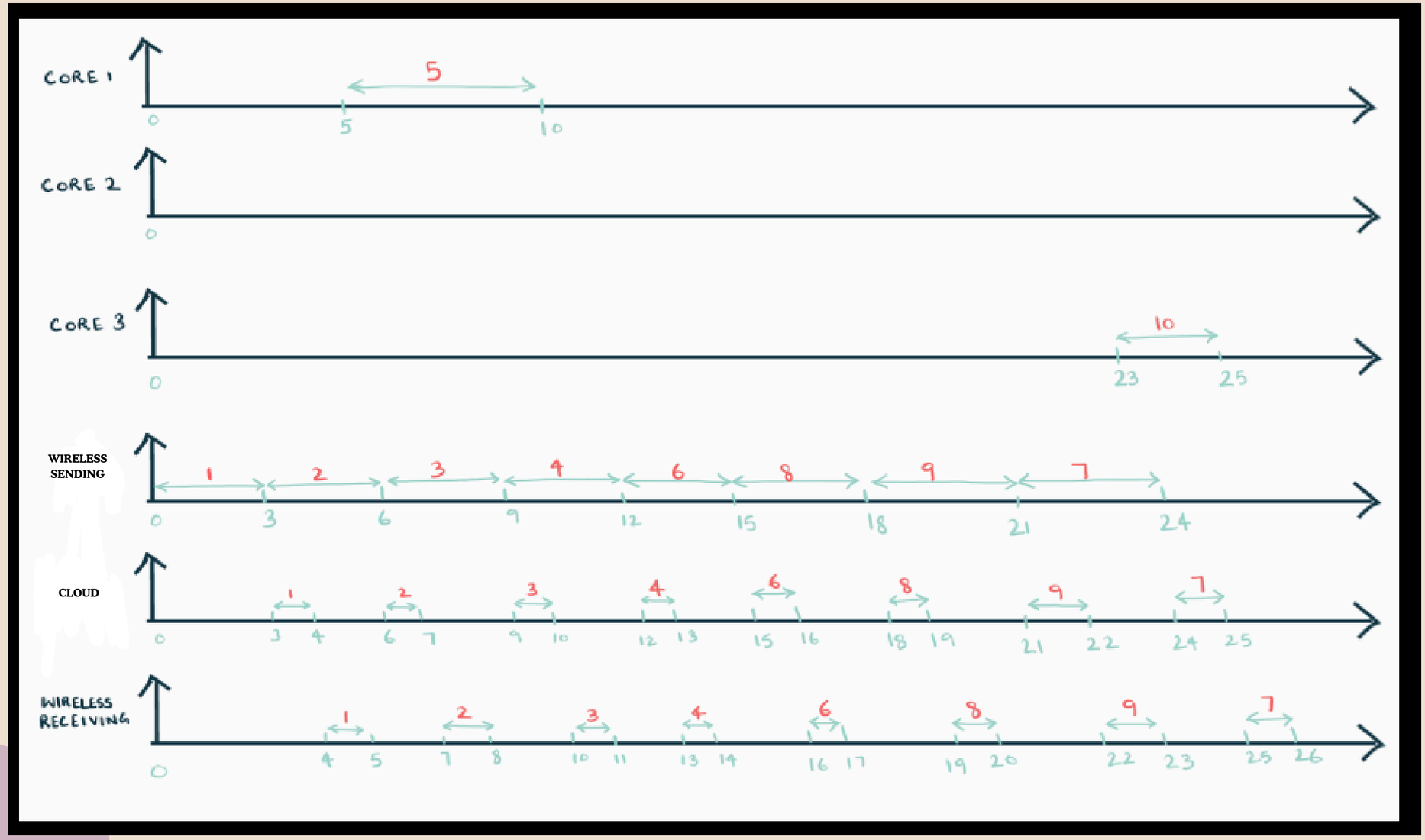
```
Post Task Migration:
Task 1 runs on the cloud; start time: 0, finish time: 5
Task 2 runs on the cloud; start time: 3, finish time: 8
Task 3 runs on the cloud; start time: 6, finish time: 11
Task 4 runs on the cloud; start time: 9, finish time: 14
Task 5 runs on local core1; start time: 5, finish time: 10
Task 6 runs on the cloud; start time: 12, finish time: 17
Task 8 runs on the cloud; start time: 15, finish time: 20
Task 9 runs on the cloud; start time: 18, finish time: 23
Task 7 runs on the cloud; start time: 21, finish time: 26
Task 10 runs on local core3; start time: 23, finish time: 25
Total energy is: 25
Completion time is: 26
Task migration took 1.382 ms to execute
```

Total completion time for scheduling is 26 .

Total Energy Consumed is 25.

Running time of initial scheduling program is 1.382 ms

FINAL SCHEDULING TASK GRAPH 2



FINAL SCHEDULING TASK GRAPH 2

Manual Calculation of Energy Consumption

$$E1=5*1=5;$$

$$E2=0;$$

$$E3=2*4=8;$$

$$Es=(3*8*0.5)=12;$$

$$E\_Total=5+8+12=25$$

CONCLUSION

Total Time Taken for Initial Scheduling: 18
Total Time Taken for Final Scheduling: 26

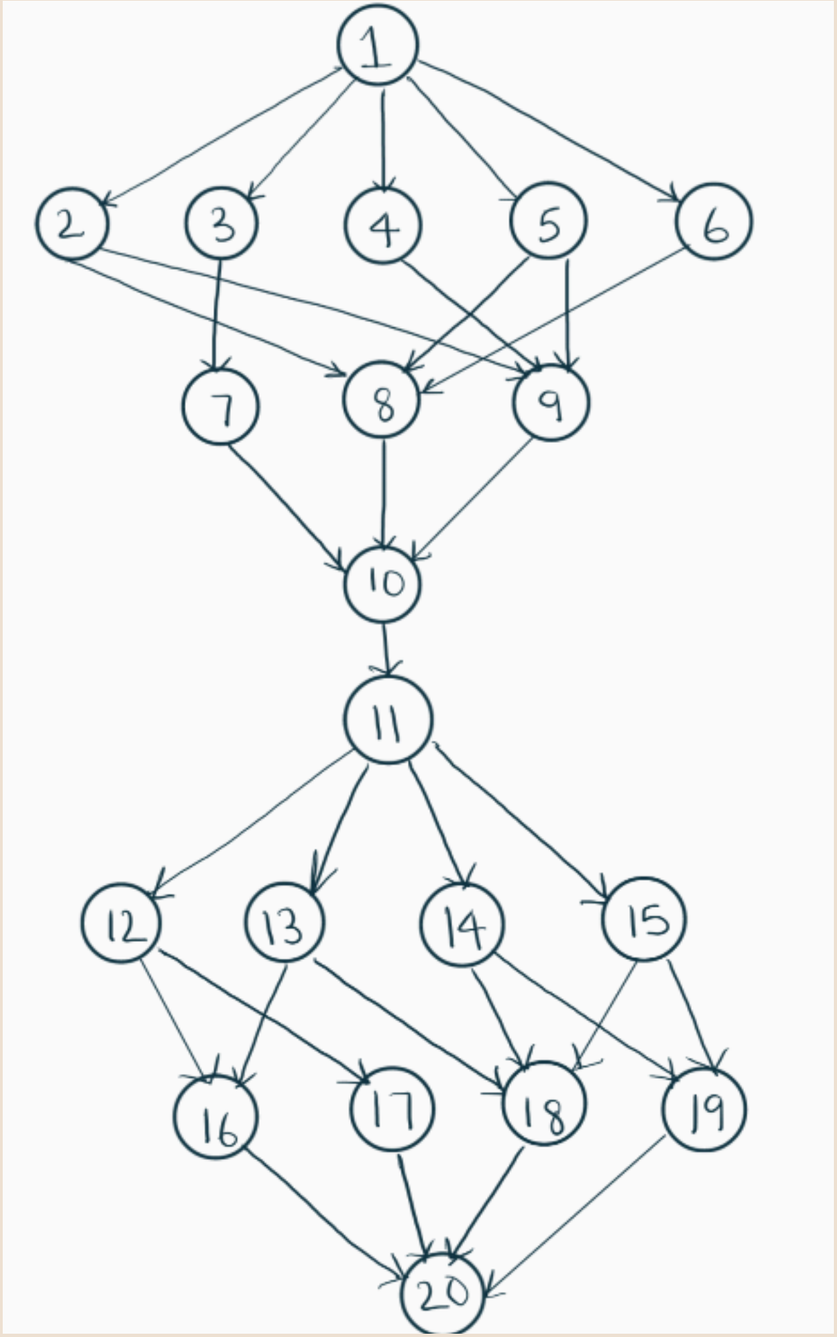
While the final scheduling increased the total time of operations, it significantly reduced the total energy consumption compared to the initial scheduling.

By transferring tasks that occur on local cores to the cloud, we achieve an energy saving of about 73% while only extending the process by 8 units of time

	Value
T_Total (Initial)	18
T_Total (Final)	26
E_Total (Initial)	98
E_Total (Final)	25

INPUT 3

Task Graph 3 consists of 20 tasks.
There is one entry task and one exit task.



Execution Time for Task Graph 3

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

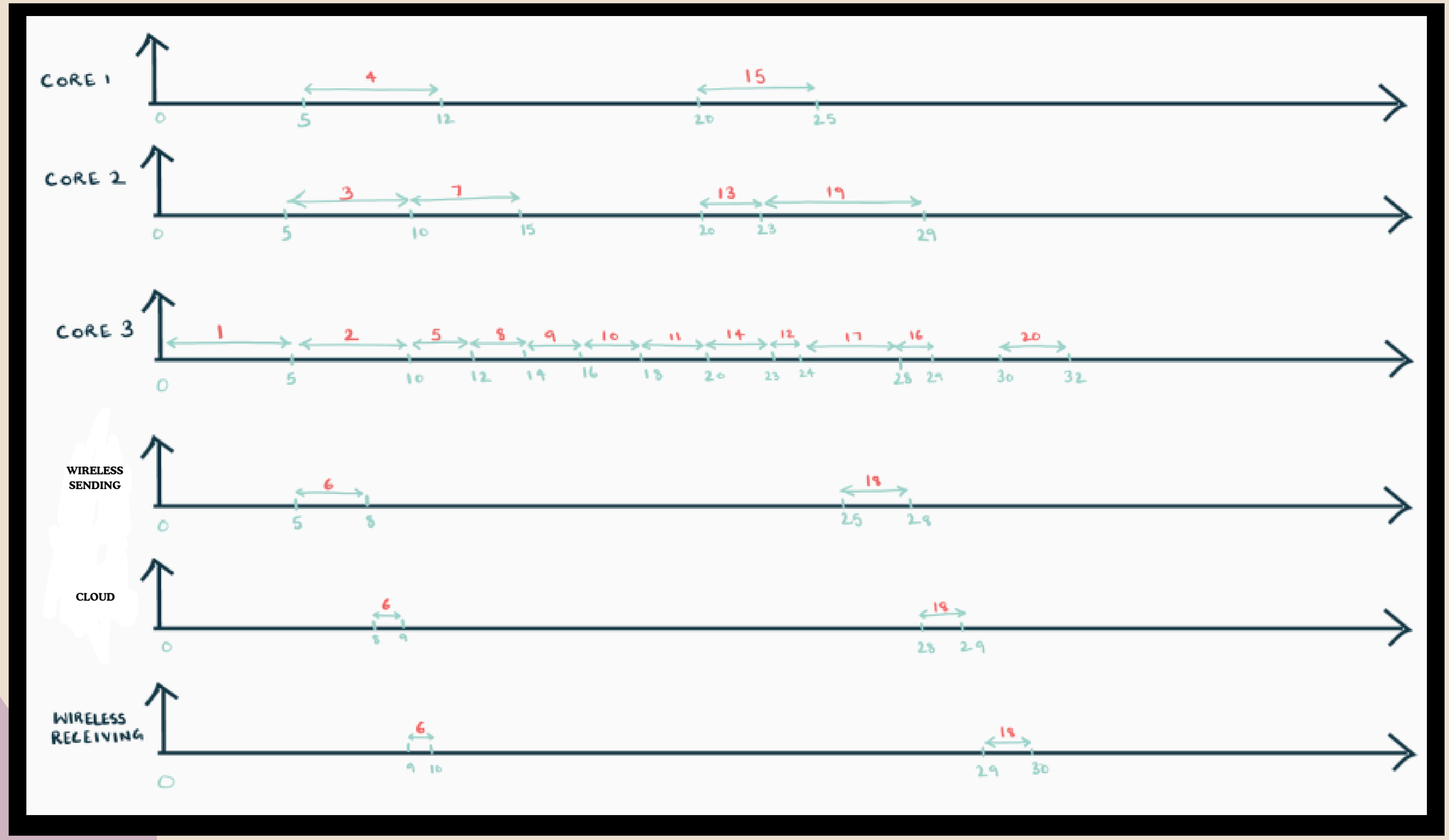
Task	Core 1	Core 2	Core 3
11	4	3	2
12	5	2	1
13	6	3	2
14	8	5	3
15	5	3	2
16	7	2	1
17	9	5	4
18	8	7	3
19	7	6	1
20	4	3	2

INITIAL SCHEDULING FOR TASK GRAPH 3

```
Initial scheduling:
Task 1 runs on local core3; start time: 0, finish time: 5
Task 2 runs on local core3; start time: 5, finish time: 10
Task 3 runs on local core2; start time: 5, finish time: 10
Task 6 runs on the cloud; start time: 5, finish time: 10
Task 4 runs on local core1; start time: 5, finish time: 12
Task 5 runs on local core3; start time: 10, finish time: 12
Task 7 runs on local core2; start time: 10, finish time: 15
Task 8 runs on local core3; start time: 12, finish time: 14
Task 9 runs on local core3; start time: 14, finish time: 16
Task 10 runs on local core3; start time: 16, finish time: 18
Task 11 runs on local core3; start time: 18, finish time: 20
Task 14 runs on local core3; start time: 20, finish time: 23
Task 13 runs on local core2; start time: 20, finish time: 23
Task 15 runs on local core1; start time: 20, finish time: 25
Task 12 runs on local core3; start time: 23, finish time: 24
Task 17 runs on local core3; start time: 24, finish time: 28
Task 18 runs on the cloud; start time: 25, finish time: 30
Task 19 runs on local core2; start time: 23, finish time: 29
Task 16 runs on local core3; start time: 28, finish time: 29
Task 20 runs on local core3; start time: 30, finish time: 32
Total energy is: 177
Completion time is: 32
Initial scheduling took 0.071 ms to execute
```

Total completion time for scheduling is 32.
Total Energy Consumed is 177.
Running time of initial scheduling program is 0.071 ms

INITIAL SCHEDULING TASK GRAPH 3



INITIAL SCHEDULING TASK GRAPH 3

Manual Calculation of Energy Consumption

$$E1=(7+5)*1=12;$$

$$E2=(5+5+3+6)*2=38;$$

$$E3=(5+5+2+2+2+2+2+3+1+4+1+2)*4=124;$$

$$Es=(3+3)*0.5=3;$$

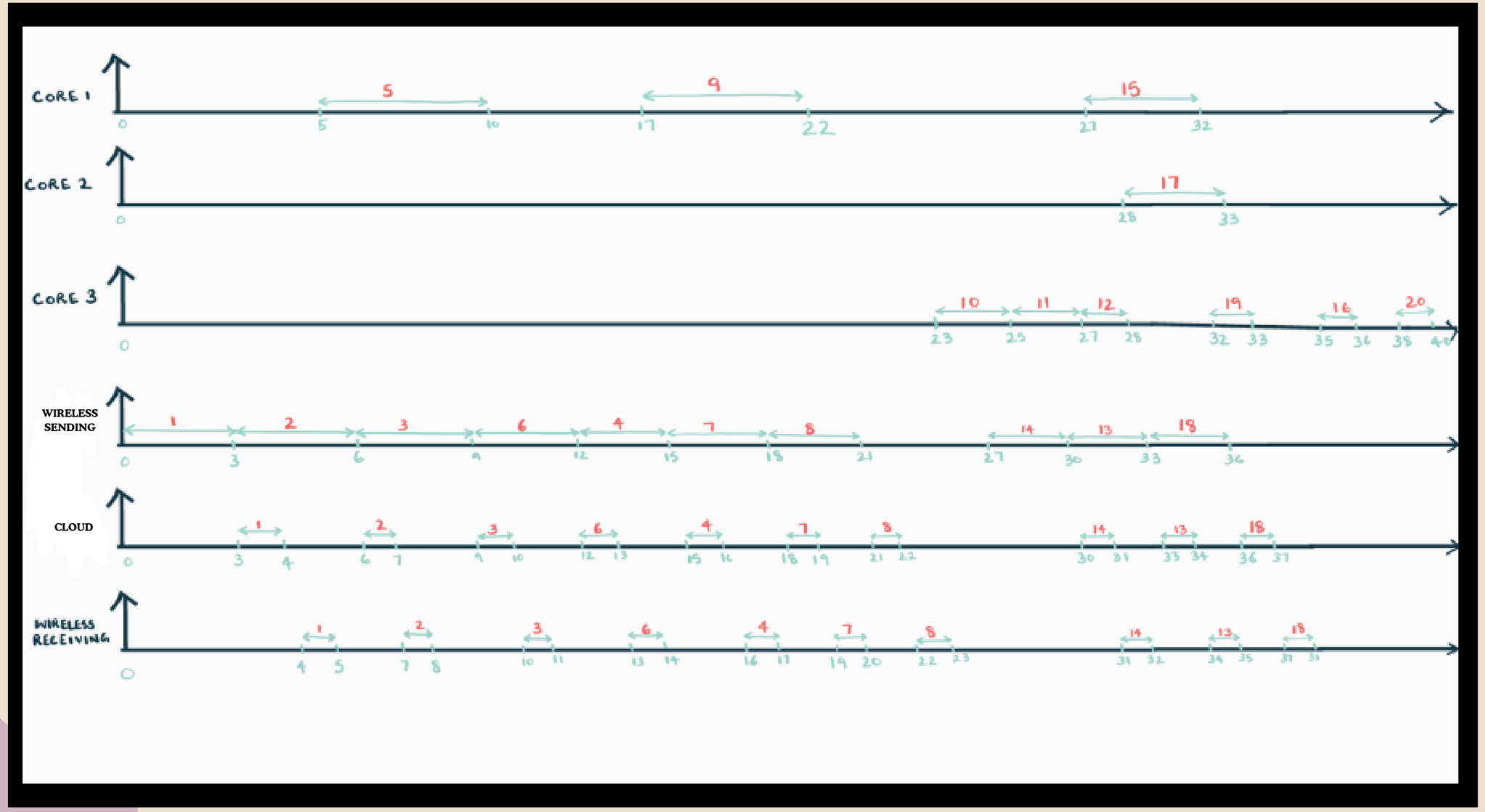
$$E\_Total=12+38+124+3=177$$

FINAL SCHEDULING FOR TASK GRAPH 3

```
Post Task Migration:
Task 1 runs on the cloud; start time: 0, finish time: 5
Task 2 runs on the cloud; start time: 3, finish time: 8
Task 3 runs on the cloud; start time: 6, finish time: 11
Task 6 runs on the cloud; start time: 9, finish time: 14
Task 4 runs on the cloud; start time: 12, finish time: 17
Task 5 runs on local core1; start time: 5, finish time: 10
Task 7 runs on the cloud; start time: 15, finish time: 20
Task 8 runs on the cloud; start time: 18, finish time: 23
Task 9 runs on local core1; start time: 17, finish time: 22
Task 10 runs on local core3; start time: 23, finish time: 25
Task 11 runs on local core3; start time: 25, finish time: 27
Task 14 runs on the cloud; start time: 27, finish time: 32
Task 13 runs on the cloud; start time: 30, finish time: 35
Task 15 runs on local core1; start time: 27, finish time: 32
Task 12 runs on local core3; start time: 27, finish time: 28
Task 17 runs on local core2; start time: 28, finish time: 33
Task 18 runs on the cloud; start time: 33, finish time: 38
Task 19 runs on local core3; start time: 32, finish time: 33
Task 16 runs on local core3; start time: 35, finish time: 36
Task 20 runs on local core3; start time: 38, finish time: 40
Total energy is: 76
Completion time is: 40
Task migration took 21.028 ms to execute
```

Total completion time for scheduling is 40.
Total Energy Consumed is 76.
Running time of initial scheduling program is 21.028 ms

FINAL SCHEDULING TASK GRAPH 3



FINAL SCHEDULING TASK GRAPH 3

Manual Calculation of Energy Consumption

$$E1=(5+5+5)*1=15;$$
$$E2=(5)*2=10;$$
$$E3=(2+2+1+1+1+2)*4=36;$$
$$Es=(10*3*0.5)=15;$$
$$E\_Total=15+10+36+15=76$$

CONCLUSION

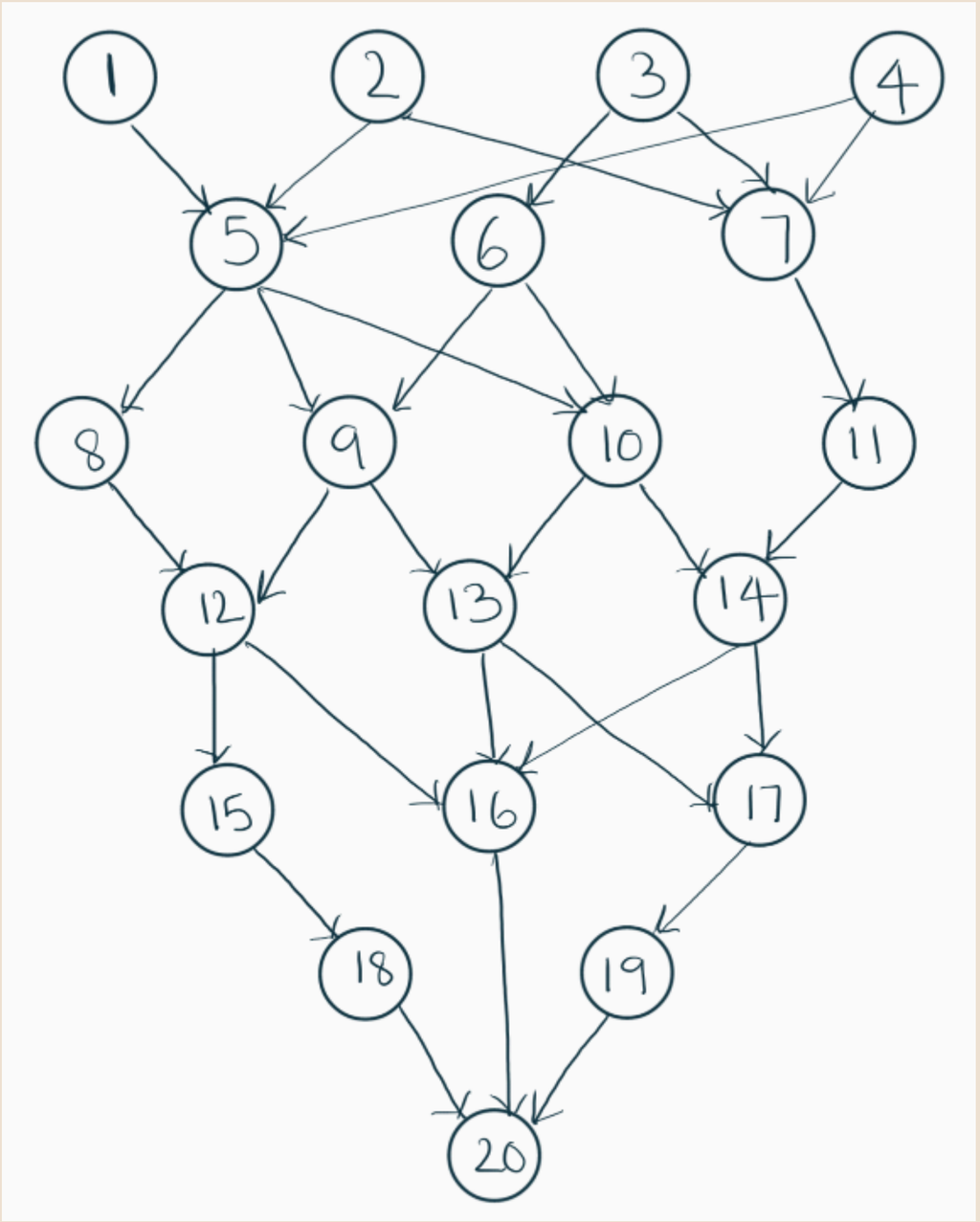
Total Time Taken for Initial Scheduling: 32
Total Time Taken for Final Scheduling: 40

While the final scheduling increased the total time of operations, it significantly reduced the total energy consumption compared to the initial scheduling.

By transferring tasks that occur on local cores to the cloud, we achieve an energy saving of about 60% while only extending the process by 8 units of time

	Value
T_Total (Initial)	32
T_Total (Final)	40
E_Total (Initial)	177
E_Total (Final)	76

INPUT 4



Task Graph 4 consists of 20 tasks.
There are multiple entry tasks and one exit task.

Execution Time for Task Graph 4

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

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

INITIAL SCHEDULING FOR TASK GRAPH 4

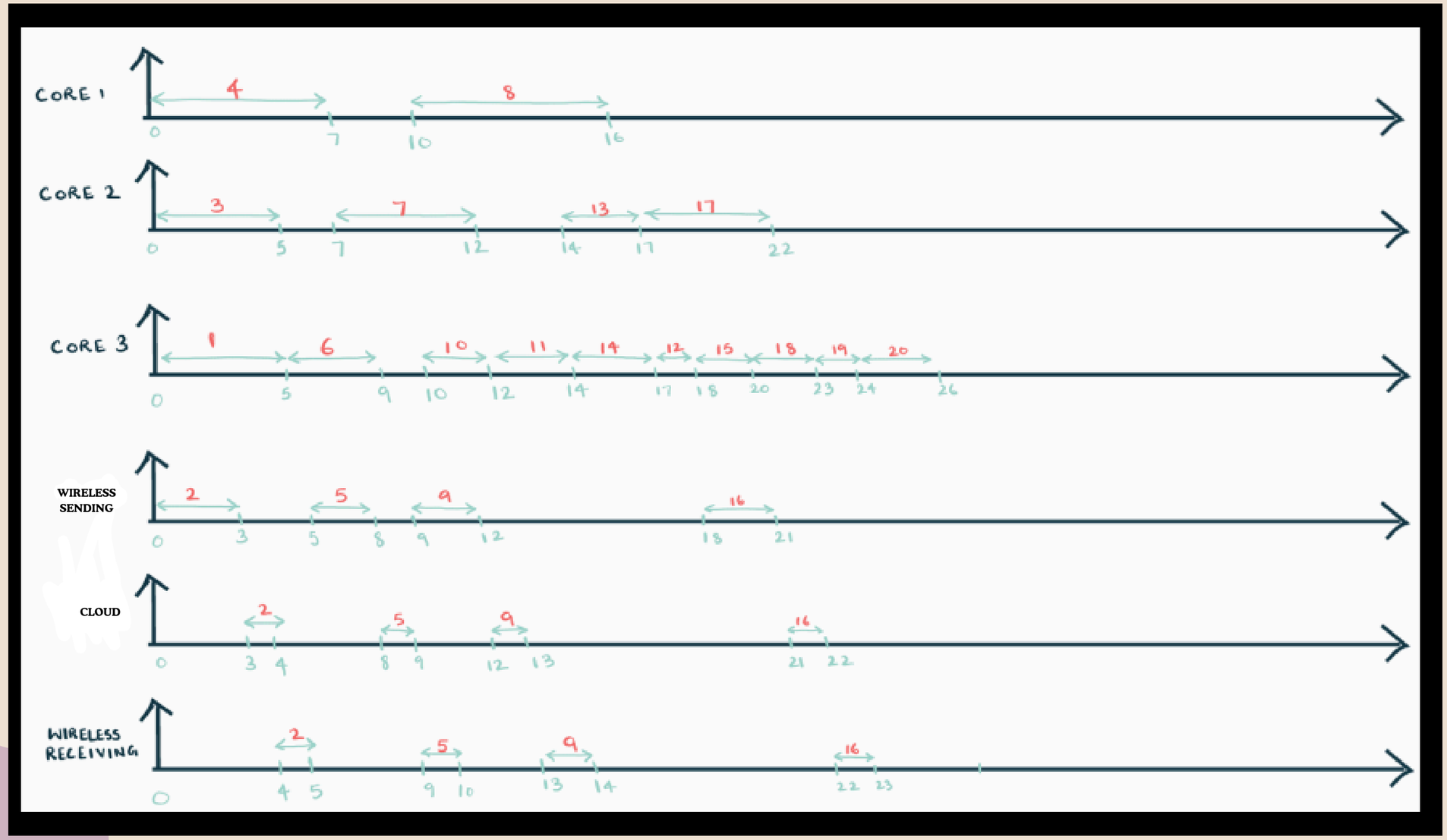
```
Initial scheduling:
Task 1 runs on local core3; start time: 0, finish time: 5
Task 3 runs on local core2; start time: 0, finish time: 5
Task 2 runs on the cloud; start time: 0, finish time: 5
Task 4 runs on local core1; start time: 0, finish time: 7
Task 6 runs on local core3; start time: 5, finish time: 9
Task 7 runs on local core2; start time: 7, finish time: 12
Task 5 runs on the cloud; start time: 5, finish time: 10
Task 10 runs on local core3; start time: 10, finish time: 12
Task 11 runs on local core3; start time: 12, finish time: 14
Task 9 runs on the cloud; start time: 9, finish time: 14
Task 8 runs on local core1; start time: 10, finish time: 16
Task 14 runs on local core3; start time: 14, finish time: 17
Task 13 runs on local core2; start time: 14, finish time: 17
Task 12 runs on local core3; start time: 17, finish time: 18
Task 17 runs on local core2; start time: 17, finish time: 22
Task 15 runs on local core3; start time: 18, finish time: 20
Task 18 runs on local core3; start time: 20, finish time: 23
Task 19 runs on local core3; start time: 23, finish time: 24
Task 16 runs on the cloud; start time: 18, finish time: 23
Task 20 runs on local core3; start time: 24, finish time: 26
Total energy is: 155
Completion time is: 26
Initial scheduling took 0.068 ms to execute
```

Total completion time for scheduling is 26.

Total Energy Consumed is 155.

Running time of initial scheduling program is 0.068 ms

INITIAL SCHEDULING TASK GRAPH 4



INITIAL SCHEDULING TASK GRAPH 4

Manual Calculation of Energy Consumption

$$E1=(7+6)*1=13;$$

$$E2=(5+5+3+5)*2=36;$$

$$E3=(5+4+2+2+3+1+2+3+1+2)*4=100;$$

$$Es=(4*3*0.5)=6;$$

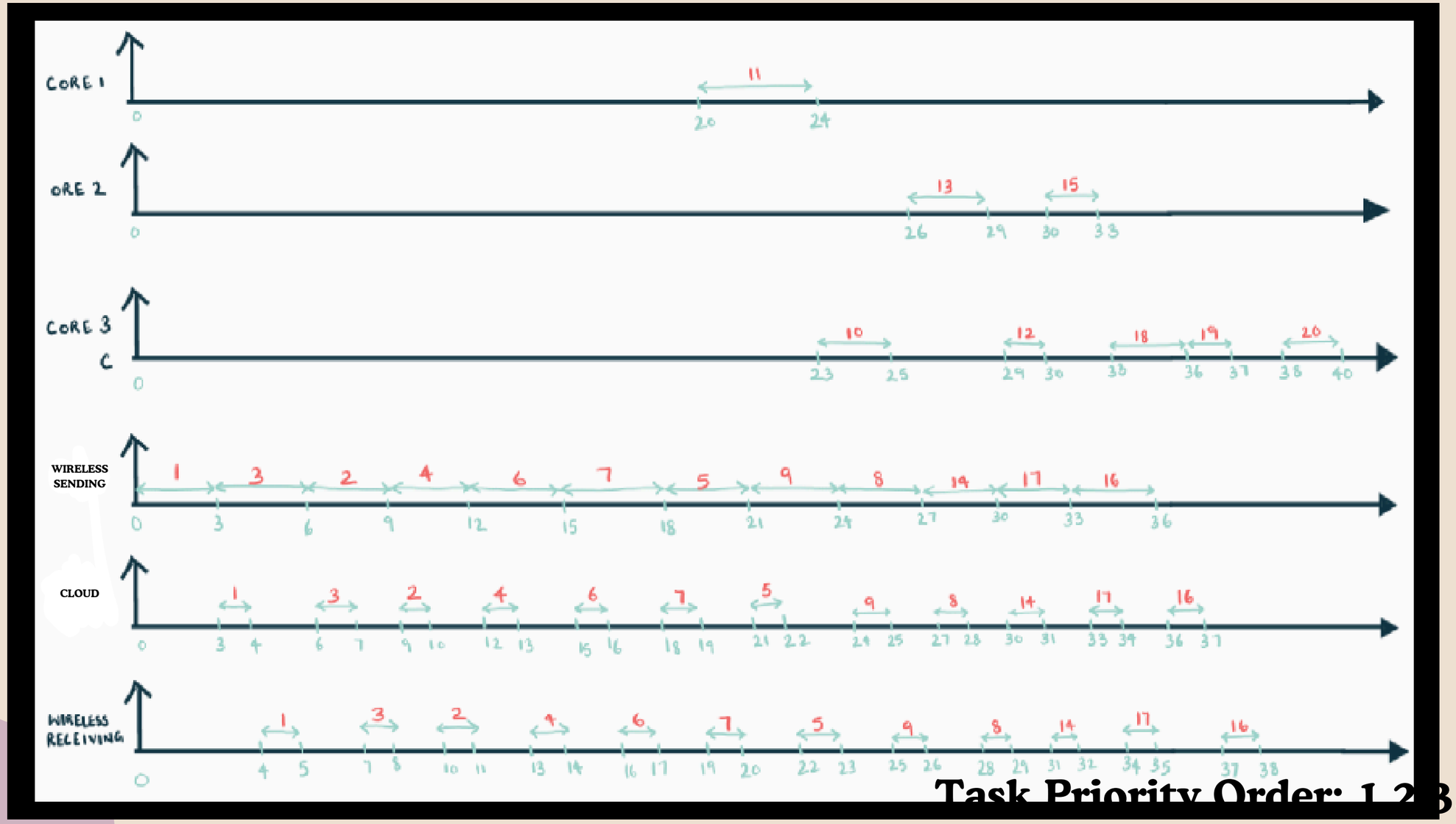
$$E\_Total=13+36+100+6=155$$

FINAL SCHEDULING FOR TASK GRAPH 4

```
Post Task Migration:
Task 1 runs on the cloud; start time: 0, finish time: 5
Task 3 runs on the cloud; start time: 3, finish time: 8
Task 2 runs on the cloud; start time: 6, finish time: 11
Task 4 runs on the cloud; start time: 9, finish time: 14
Task 6 runs on the cloud; start time: 12, finish time: 17
Task 7 runs on the cloud; start time: 15, finish time: 20
Task 5 runs on the cloud; start time: 18, finish time: 23
Task 10 runs on local core3; start time: 23, finish time: 25
Task 11 runs on local core1; start time: 20, finish time: 24
Task 9 runs on the cloud; start time: 21, finish time: 26
Task 8 runs on the cloud; start time: 24, finish time: 29
Task 14 runs on the cloud; start time: 27, finish time: 32
Task 13 runs on local core2; start time: 26, finish time: 29
Task 12 runs on local core3; start time: 29, finish time: 30
Task 17 runs on the cloud; start time: 30, finish time: 35
Task 15 runs on local core2; start time: 30, finish time: 33
Task 18 runs on local core3; start time: 33, finish time: 36
Task 19 runs on local core3; start time: 36, finish time: 37
Task 16 runs on the cloud; start time: 33, finish time: 38
Task 20 runs on local core3; start time: 38, finish time: 40
Total energy is: 70
Completion time is: 40
Task migration took 19.096 ms to execute
```

Total completion time for scheduling is 40.
Total Energy Consumed is 70.
Running time of initial scheduling program is 19.096 ms

FINAL SCHEDULING TASK GRAPH 4



Task Priority Order: 1,2,3,6,4,5,7,8,9,10

FINAL SCHEDULING TASK GRAPH 4

Manual Calculation of Energy Consumption

E1=(4*1)=4;

E2=(3+3)*2=12;

E3=(2+1+3+1+2)*4=36;

Es=(12*3*0.5)=18;

E_Total=70

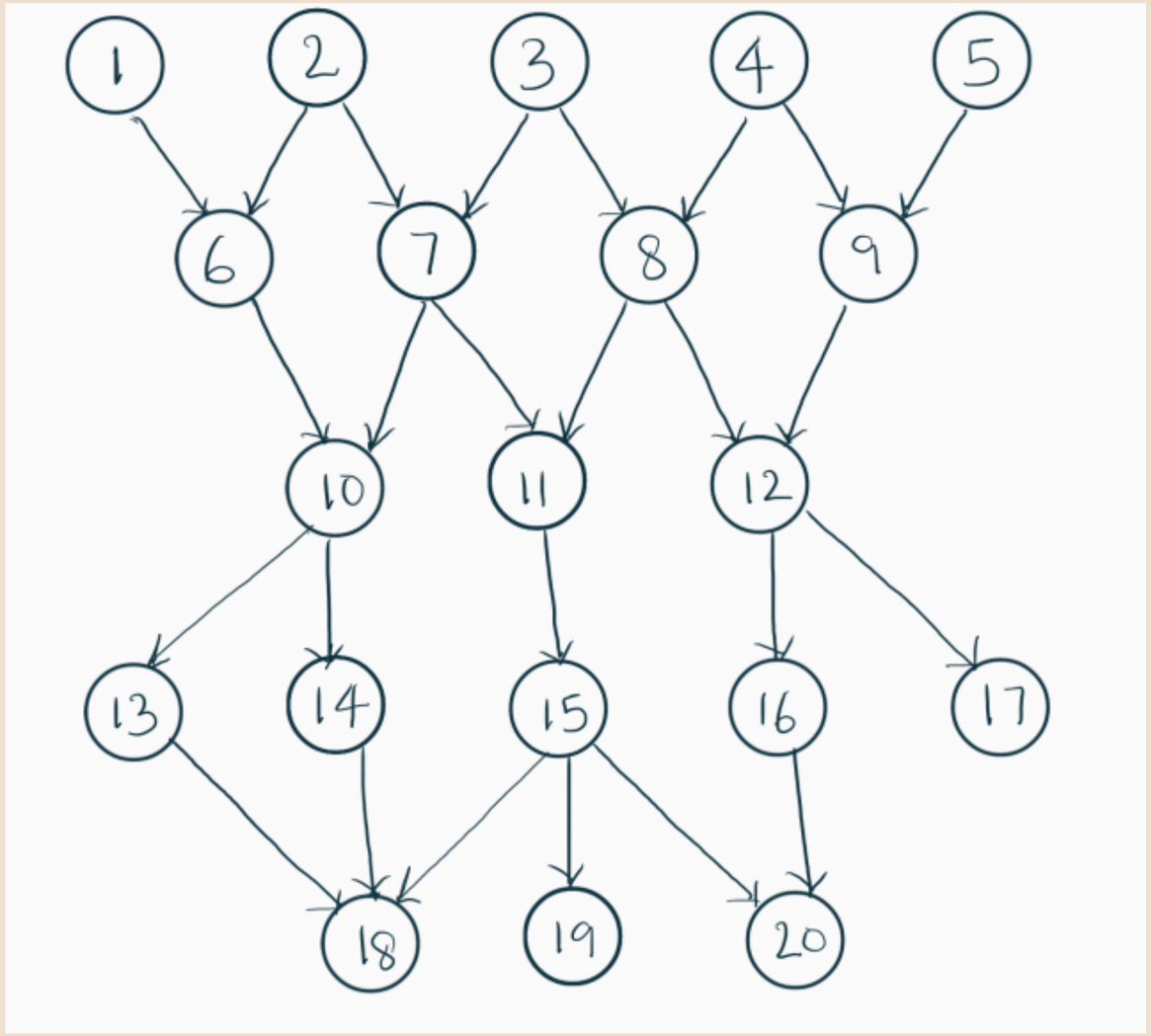
CONCLUSION

Total Time Taken for Initial Scheduling: 26
Total Time Taken for Final Scheduling: 40

While the final scheduling increased the total time of operations, it significantly reduced the total energy consumption compared to the initial scheduling.

	Value
T_Total (Initial)	26
T_Total (Final)	40
E_Total (Initial)	155
E_Total (Final)	70

INPUT 5



Task Graph 5 consists of 20 tasks.
There are multiple entry tasks and multiple exit tasks

Execution Time for Task Graph 5

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

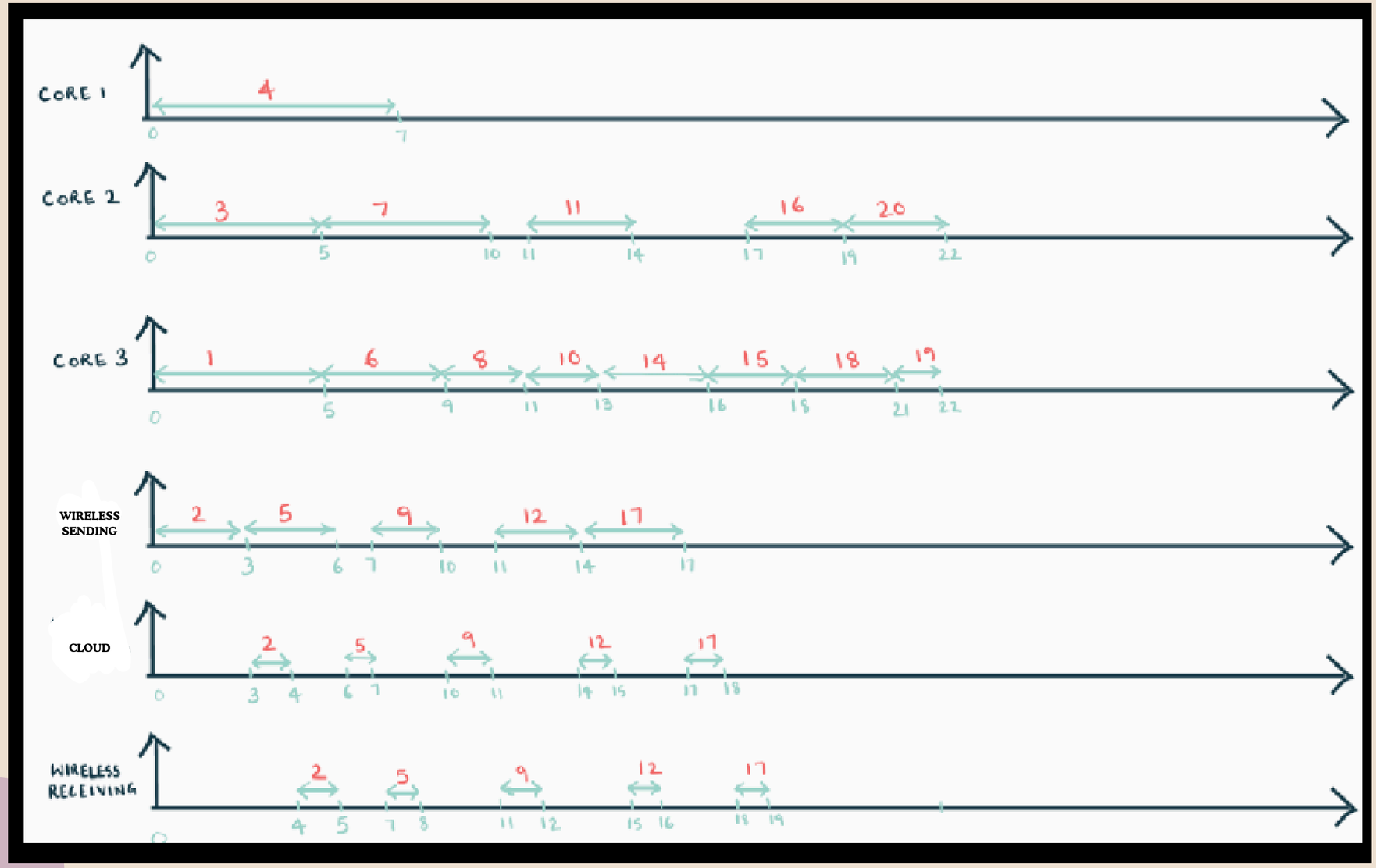
Task	Core 1	Core 2	Core 3
11	4	3	2
12	5	2	1
13	6	3	2
14	8	5	3
15	5	3	2
16	7	2	1
17	9	5	4
18	8	7	3
19	7	6	1
20	4	3	2

INITIAL SCHEDULING FOR TASK GRAPH 5

```
Initial scheduling:
Task 1 runs on local core3; start time: 0, finish time: 5
Task 2 runs on the cloud; start time: 0, finish time: 5
Task 3 runs on local core2; start time: 0, finish time: 5
Task 4 runs on local core1; start time: 0, finish time: 7
Task 6 runs on local core3; start time: 5, finish time: 9
Task 7 runs on local core2; start time: 5, finish time: 10
Task 8 runs on local core3; start time: 9, finish time: 11
Task 5 runs on the cloud; start time: 3, finish time: 8
Task 10 runs on local core3; start time: 11, finish time: 13
Task 9 runs on the cloud; start time: 7, finish time: 12
Task 11 runs on local core2; start time: 11, finish time: 14
Task 14 runs on local core3; start time: 13, finish time: 16
Task 13 runs on local core2; start time: 14, finish time: 17
Task 15 runs on local core3; start time: 16, finish time: 18
Task 12 runs on the cloud; start time: 11, finish time: 16
Task 16 runs on local core2; start time: 17, finish time: 19
Task 17 runs on the cloud; start time: 14, finish time: 19
Task 18 runs on local core3; start time: 18, finish time: 21
Task 19 runs on local core3; start time: 21, finish time: 22
Task 20 runs on local core2; start time: 19, finish time: 22
Total energy is: 144.5
Completion time is: 22
Initial scheduling took 0.069 ms to execute
```

Total completion time for scheduling is 22.
Total Energy Consumed is 144.5
Running time of initial scheduling program is 0.069 ms

INITIAL SCHEDULING TASK GRAPH 5



INITIAL SCHEDULING TASK GRAPH 5

Manual Calculation of Energy Consumption

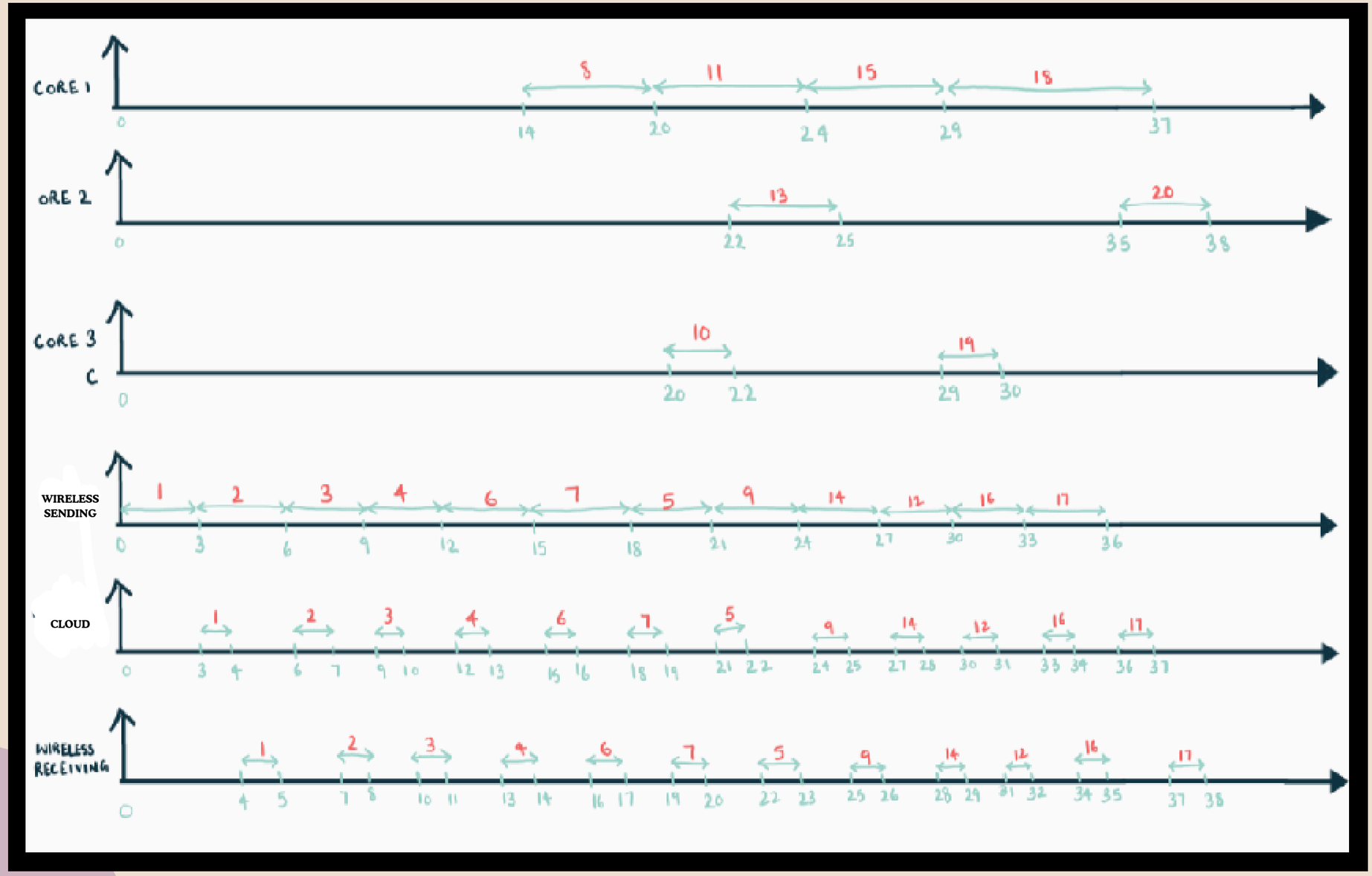
$$E1=(7*1)=7;$$
$$E2=(5+5+3+2+3)*2=36;$$
$$E3=(5+4+2+2+3+2+3+1)*4=88;$$
$$Es=(5*3*0.5)=7.5;$$
$$E\_Total=7+36+88+7.5=144.5$$

FINAL SCHEDULING FOR TASK GRAPH 5

```
Post Task Migration:
Task 1 runs on the cloud; start time: 0, finish time: 5
Task 2 runs on the cloud; start time: 3, finish time: 8
Task 3 runs on the cloud; start time: 6, finish time: 11
Task 4 runs on the cloud; start time: 9, finish time: 14
Task 6 runs on the cloud; start time: 12, finish time: 17
Task 7 runs on the cloud; start time: 15, finish time: 20
Task 8 runs on local core1; start time: 14, finish time: 20
Task 5 runs on the cloud; start time: 18, finish time: 23
Task 10 runs on local core3; start time: 20, finish time: 22
Task 9 runs on the cloud; start time: 21, finish time: 26
Task 11 runs on local core1; start time: 20, finish time: 24
Task 14 runs on the cloud; start time: 24, finish time: 29
Task 13 runs on local core2; start time: 22, finish time: 25
Task 15 runs on local core1; start time: 24, finish time: 29
Task 12 runs on the cloud; start time: 27, finish time: 32
Task 16 runs on the cloud; start time: 30, finish time: 35
Task 17 runs on the cloud; start time: 33, finish time: 38
Task 18 runs on local core1; start time: 29, finish time: 37
Task 19 runs on local core3; start time: 29, finish time: 30
Task 20 runs on local core2; start time: 35, finish time: 38
Total energy is: 65
Completion time is: 38
Task migration took 22.852 ms to execute
```

Total completion time for scheduling is 38.
Total Energy Consumed is 65.
Running time of initial scheduling program is 22.852 ms

FINAL SCHEDULING TASK GRAPH 5



FINAL SCHEDULING TASK GRAPH 5

Manual Calculation of Energy Consumption

$$E1=(6+4+5+8)*1=23;$$
$$E2=(3+3)*2=12;$$
$$E3=(2+1)*4=12;$$
$$Es=(12*3*0.5)=18;$$
$$E\_Total=23+12+12+18=65$$

CONCLUSION

Total Time Taken for Initial Scheduling: 22
Total Time Taken for Final Scheduling: 38

While the final scheduling increased the total time of operations, it significantly reduced the total energy consumption compared to the initial scheduling.

	Value
T_Total (Initial)	22
T_Total (Final)	38
E_Total (Initial)	144.5
E_Total (Final)	65

THANK YOU