COL733 Minor Exam

Viraj Agashe

TOTAL POINTS

48 / 50

QUESTION 1

Question 1 15 pts

1.1 1.1 2 / 3

+ 0 pts Incorrect.

✓ **+ 1 pts** *Model on GPU*

✓ **+ 1 pts** *printing on CPU*

+ 1 pts Add send/recv nodes on CPU-GPU boundaries

+ 0 pts Reference edges cannot cross device boundaries.

+ 0 pts Same var must be on the same device.

+ 0 pts Placement does not logically modify the original graph. Still has two var(stats) etc.

1.2 1.2 3 / 3

✓ **+ 1 pts** *(a) True*

✓ **+ 1 pts** *(b) False*

✓ **+ 1 pts** *(c) True*

+ 0 pts Incorrect

1.3 1.3 3 / 3

+ 0 pts Incorrect

+ 0.5 pts 3 var(stats*) -> Read -> F

✓ **+ 0.5 pts** *Some filter/router after ML model*

✓ **+ 1 pts** *Router routes output to AssignAdd of stats1/stats2.*

+ 1 pts Router routes output to AssignAdd of stats unconditionally.

✓ **+ 1.5 pts** *Does not maintain Stats variable. But logically correct.*

+ 3 pts Does not maintain separate Stats1/Stats2 variables. Logically correct

1.4 1.4 2 / 3

- 3 pts Same variable and its read, AssignAdd ops should be on the same device

- 3 pts Reference edges cannot cross device boundaries

- 3 pts Incorrect/vague

✓ **- 0 pts** *OK*

- 1 pts print on GPU

- 1 pts ML model on CPU

✓ **- 1 pts** *Missing send/recv nodes*

1.5 1.5 3 / 3

+ 0 pts Incorrect

✓ **+ 1 pts** *Stats1 was checkpointed at 155 frames.*

✓ **+ 1 pts** *Worker crashed after printing 194 frames.*

✓ **+ 1 pts** *Another worker recovered from checkpoint and continued execution*

QUESTION 2

CIEL and Scalability 20 pts

2.1 2.1 2 / 2

✓ **- 0 pts** *Correct*

- **- 1 pts** Missing diagonal edge
- **- 0.5 pts** Missing up edge
- **- 0.5 pts** Missing left edge
- **- 2 pts** Incorrect/vague

2.2 2.2 **3 / 3**

- **+ 0 pts** Incorrect
- ✓ **+ 1 pts** *Ts=0.9*
- ✓ **+ 1 pts** *S=9/13*
- ✓ **+ 1 pts** *E=9/26*

2.3 2.3 **3 / 3**

- **+ 0 pts** incorrect
- ✓ **+ 1 pts** *compute time = 25ms*
- ✓ **+ 1 pts** *download time = 20ms*
- ✓ **+ 1 pts** *Master schedules 1 task at 1 worker at a time*

2.4 2.4 **2 / 2**

- **+ 0 pts** Incorrect
- ✓ **+ 1 pts** *S=225/210*
- ✓ **+ 1 pts** *E=225/420*

2.5 2.5 **1 / 1**

- **+ 0 pts** Incorrect
- ✓ **+ 1 pts** *2 microseconds*

2.6 2.6 **3 / 3**

- **+ 0 pts** Incorrect
- ✓ **+ 1 pts** *Back to back task assignment*
- ✓ **+ 1 pts** *Task assignment respects dependencies*
- ✓ **+ 1 pts** *Optimal placement with Tp=150ms*

2.7 2.7 **2 / 2**

- **+ 0 pts** Incorrect
- ✓ **+ 1 pts** *S=225/150=3/2*
- ✓ **+ 1 pts** *E=225/300=3/4*

2.8 2.8 **2 / 2**

- **+ 0 pts** Incorrect
- ✓ **+ 1 pts** *Finishes in 7 CPU blocks total*
- ✓ **+ 1 pts** *Tasks are scheduled back to back*

2.9 2.9 **2 / 2**

- **+ 0 pts** Incorrect
- ✓ **+ 1 pts** *S=12/7*
- ✓ **+ 1 pts** *E=6/7*

QUESTION 3

True/False 9 pts

3.1 3.1 **1 / 1**

- **+ 0 pts** False
- ✓ **+ 1 pts** *True*

3.2 3.2 **1 / 1**

- ✓ **- 0 pts** *Correct*
- **- 1 pts** Incorrect

3.3 3.3 **1 / 1**

- ✓ **- 0 pts** *Correct*
- **- 1 pts** Incorrect

3.4 3.4 **1 / 1**

- ✓ **- 0 pts** *Correct*
- **- 1 pts** Incorrect

3.5 3.5 **1 / 1**

- ✓ **- 0 pts** *Correct*
- **- 1 pts** Incorrect

3.6 3.6 **1 / 1**

✓ **- 0 pts** *Correct*

- 1 pts Incorrect

3.7 3.7 **1 / 1**

✓ **- 0 pts** *Correct*

- 1 pts Incorrect

3.8 3.8 **1 / 1**

✓ **- 0 pts** *Correct*

- 1 pts Incorrect

3.9 3.9 **1 / 1**

✓ **- 0 pts** *Correct*

- 1 pts Incorrect

QUESTION 4

Network Time Protocol 3 pts

4.1 4.1 **1 / 1**

✓ **- 0 pts** *65 ms*

- 1 pts Incorrect

4.2 4.2 **2 / 2**

✓ **- 0 pts** *128.5*

- 2 pts Incorrect

QUESTION 5

5 Map Reduce **3 / 3**

+ 0 pts Incorrect

✓ **+ 1.5 pts** *Worse performance due to cluster writes by mappers*

✓ **+ 1.5 pts** *Better FT. Need not rerun completed map tasks*

Name: Viraj Agashe Entry number: 2020CS10567

***Q1 [15 marks]* TensorFlow**

Let us say that you want to count the number of four wheelers and two wheelers from two cameras in IIT Delhi during Rendezvous 2024. The Rendezvous organizers have heard a lot about TensorFlow and insist that you use it for this project.

Since your team knows about the operational semantics of TensorFlow, you came up with the following program. You plan to directly use the TensorFlow graph API.

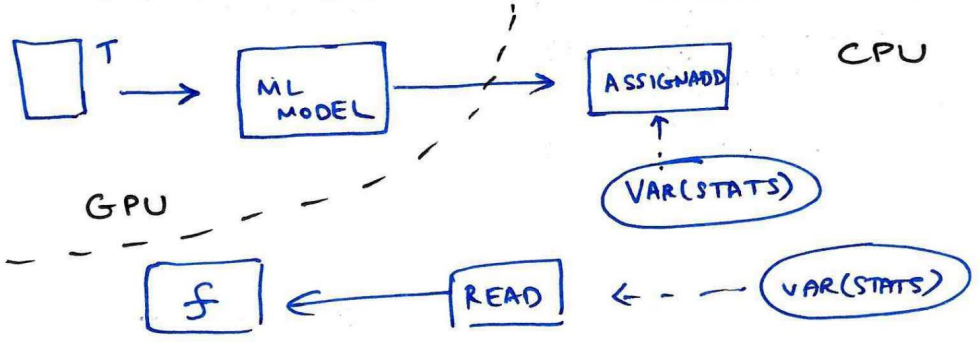
*generated using DALL-E

The graph above feeds the camera frames as tensors to a vehicle counting ML model. When a frame is input, the model generates a 3x1 tensor representing the number of four wheelers, two wheelers, and 1 respectively. For the example image above, the model outputs (1, 1, 1). This tensor is added to the Stats variable which is initialized to (0,0,0).

Stats variable is also read and sent to a function `f`. This function does not produce any output tensors but just logs its input tensor to a fault tolerant storage. For instance, it might print "`After 1 frames, two wheelers=1, four wheelers=1`".

For the questions below, please assume that this graph is connected to two traffic cameras that feed it input frames.

Q1.1 [3 mark] Let us say that this graph is running on a single machine with a CPU and a GPU. How might you place this graph? Use the CPU and the GPU.



Name: Viraj Agashe Entry number: 2020CS10567

Q1.2 [3 marks] (True/False) Can the graph print the following? **Assume that the machine never crashes for Q1.2.**

(a) *[1 marks]*

```
After 1 frames, two wheelers=1, four wheelers=1
After 1 frames, two wheelers=1, four wheelers=1
After 2 frames, two wheelers=2, four wheelers=3
```

TRUE

(b) *[1 marks]*

```
After 3 frames, two wheelers=3, four wheelers=3
After 1 frames, two wheelers=1, four wheelers=1
After 2 frames, two wheelers=2, four wheelers=3
```

FALSE

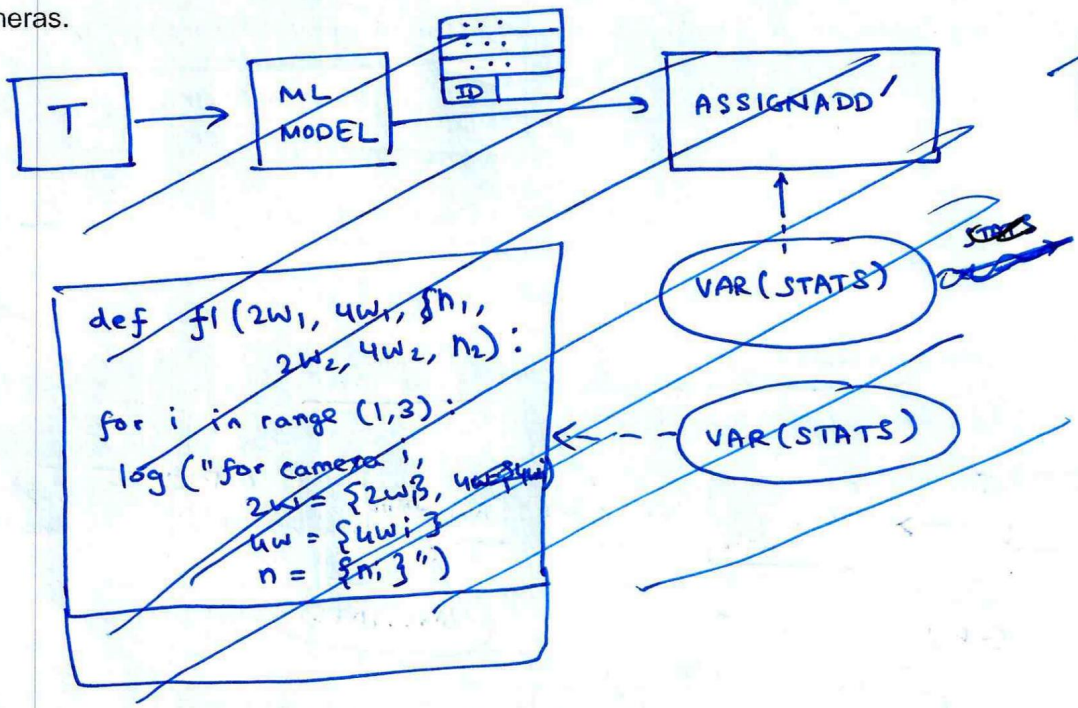
(c) *[1 marks]*

```
After 1 frames, two wheelers=1, four wheelers=1
After 3 frames, two wheelers=3, four wheelers=3
```

TRUE

chk

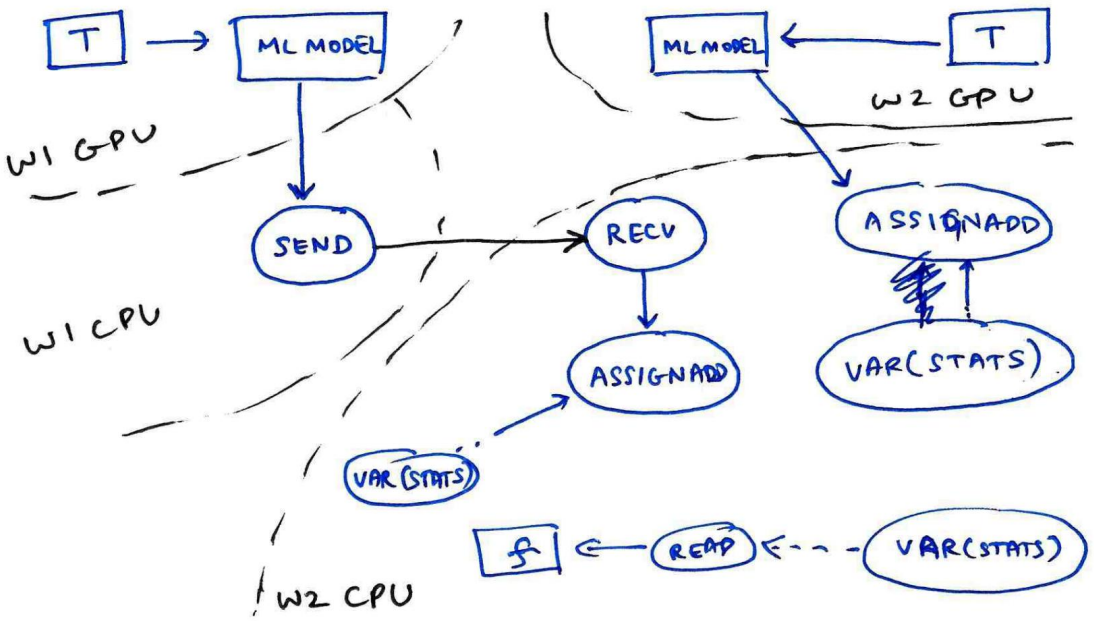
Q1.3 [3 marks] Let us say now we want to get separate stats from the two traffic cameras. For this, let us say that the vehicle counting ML model produces a 4x1 tensor for each input image, i.e, it also produces a camera ID 1 or 2 to identify between the two cameras. Please modify the graph to calculate and print `Stats1` for the traffic camera with ID 1, `Stats2` for the traffic camera with ID 2, and `Stats` for the total of both the traffic cameras.



NOTE: Please see last page ~~for reference~~.

Name: Viraj Agashe Entry number: 2020CS10567

Q1.4 [3 marks] Let us say that this graph is running on two machines each with a CPU and a GPU. How might you place this graph? Use both the CPUs and GPUs.
Hint: Remember that parts of the graph can be duplicated to do "concurrent execution".



Q1.5 [3 marks] Upon running your graph above, we observe the following log statements for the log file of traffic camera 1 stats:

```
...
After 193 frames, two wheelers=311, four wheelers=772
After 194 frames, two wheelers=312, four wheelers=775
After 156 frames, two wheelers=276, four wheelers=657
After 157 frames, two wheelers=279, four wheelers=659
...
```

Explain how one might see this log file.

Suppose above, the W2, on which the stats are stored, crashes, and now W1 tries to recover from the crash. Suppose W2 stored its stats periodically at some remote storage. In tensorflow, checkpointing is typically asychronous since we are usually okay with working with stale weights (in ML). So, we recover from an old state (not fresh). Therefore we see that there is a big drop in the values of frames, 2W, 4W etc.)

(P.S. this problem does not seem like a good application of TF — only ML model should be in TF, the outputs etc. can be stored & handled with something like Spark).

Name: Viraj Agashe Entry number: 2020CS10567

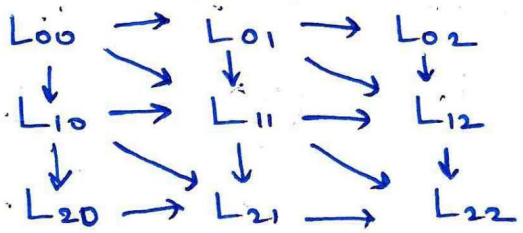
Q2. [20 marks] CIEL and scalability

We looked at the following program to compute the longest common subsequence.

```
import ray
ray.init()

@ray.remote
def lcs(X, Y, bleft, bup, bsize, Lleft, Lup, Ldiag):
  # declaring the array for storing the dp values
  L = [[None] * bsize for i in range(bsize)]

  def l(i, j):
    if i >= 0 and j >= 0:
      return L[i][j]
    if i < 0 and j < 0:
      return Ldiag[bsize+i][bsize+j] if Ldiag is not None else 0
    if i < 0:
      return Lleft[bsize+i][j] if Lleft is not None else 0
    return Lup[i][bsize+j] if Lup is not None else 0

  # Note: L[i][j] contains length of LCS of X[0..i-1] and Y[0..j-1]
  for i in range(bsize):
    for j in range(bsize):
      left = bleft*bsize + i
      up = bup*bsize + j
      if left == 0 or up == 0:
        L[i][j] = 0
      if X[left-1] == Y[up-1]:
        L[i][j] = l(i-1, j-1) + 1
      else:
        L[i][j] = max(l(i-1, j), l(i, j-1))
  return L

# Driver code
if __name__ == '__main__':
  S1 = # input string 1 with length=30,000
  S2 = # input string 2 with length=30,000

  m, n, bsize = 30000, 30000, 10000
  X, Y = ray.put(S1), ray.put(S2)
  f = [[None] * (n//bsize + 1) for i in range(m//bsize + 1)]

  for bleft in range(0, m//bsize):
    for bup in range(0, n//bsize):
      fleft = f[bleft-1][bup] if bleft > 0 else None
      fup = f[bleft][bup-1] if bup > 0 else None
      fdiag = f[bleft-1][bup-1] if bleft > 0 and bup > 0 else None
      f[bleft][bup] = lcs.remote(X, Y, bleft, bup, bsize,
                                 fleft, fup, fdiag)

  L = ray.get(f[m//bsize-1][n//bsize-1])
  print(f"Length of LCS is {L[bsize-1][bsize-1]}")
```

Name: Viraj Agashe Entry number: 2020CS10387

Q2.1 [2 marks] Draw the task DAG for the above program.
Hint: Notice that the program computes 9 2D array objects each of size 10,000 x 10,000. You can refer to these 9 array objects as $L_{0,0}$, $L_{0,1}$, … $L_{2,2}$ respectively.



TASK DAG.

We will make simplifying assumptions and do "back of the envelope calculations" in the following problems. Let us say that our setup contains 2 workers and a master. Workers are connected with one another over a 2GBps link. It takes 1ns to compute one entry in the 2D array object. We assume that the workers have RDMA-enabled NICs where RDMA stands for "remote direct memory access", i.e, the workers' network interface cards (NIC) can directly download objects from another worker's memory without interrupting the CPU of either worker. We ignore the effects of memory hierarchy, locality, and caching. We ignore the round trip latency to/from master.

Therefore, computing a 2D array object of size 10,000 x 10,000 takes 10,000 * 10,000 * 1ns = 100ms. We assume that each entry in the array is an integer of 4 bytes. So downloading one 2D array object from one worker to another on the 2GBps link takes 10,000*10,000*4/(2*1000,000,000) s = 200ms.

The following shows an execution timeline. Blocks on the CPU timeline show the time taken to calculate a 2D array. Blocks on the NIC timeline show the time to download the object from the other worker.

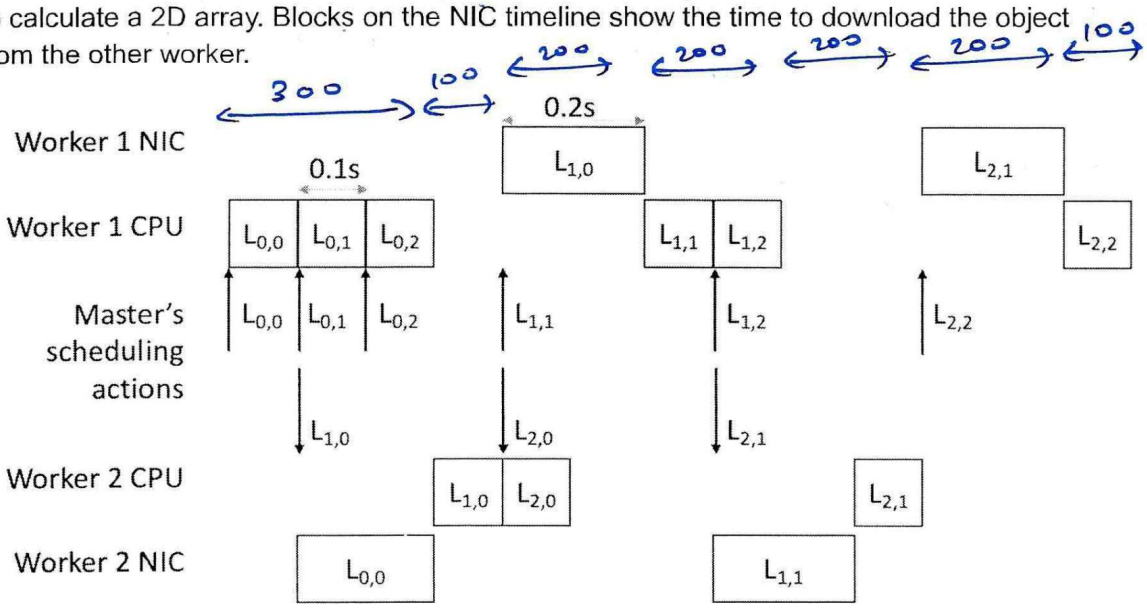


Figure 2A: Execution timeline with a 1ns compute time and a 2GBps link.

Name: Viraj Agashe Entry number: 2020CS10562

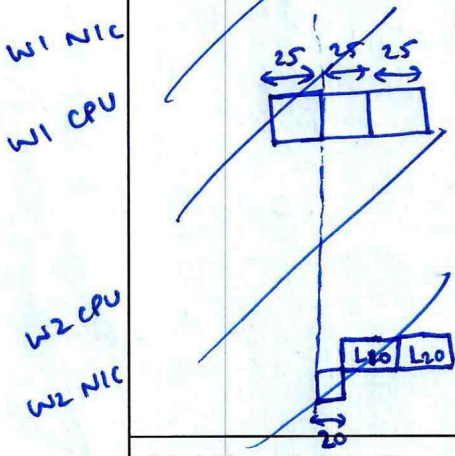
Q2.2 *[3 marks]* For the execution timeline in Figure 2A, what is the speedup and efficiency? Assume p=2 for two workers, i.e, do not count master in your calculation.

Speedup = $\frac{T_s}{T_p} = \frac{9 \times 100}{1300} = \frac{9}{13}$

Efficiency = $\frac{T_s}{PT_p} = \frac{9}{2 \times 13} = \frac{9}{26}$ (very poor)

Q2.3 *[3 marks]* Let us say that we upgrade the CPU of workers such that they can now support vectorized instructions. Effectively, each array entry can now be computed 4x faster: in 0.025ns. We further make the network link between workers 10x faster: i.e, 20GBps instead of 2GBps. Redraw Figure 2A for this setup.

Network time = 20 ms, compute time = 25 ms.



(Drawn on last page)

Please check.

Q2.4 *[2 marks]* For the execution timeline that you drew in Q2.3, what is the speedup and efficiency? Again assume p=2.

Speedup = $\frac{T_s}{T_p} = \frac{9 \times \frac{100}{4}}{210} = \frac{225}{210} = \frac{15}{14}$

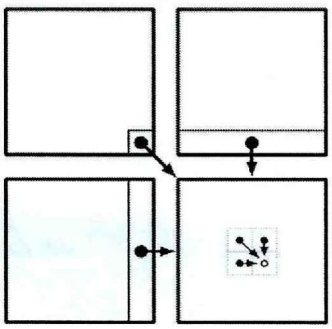
$= 1.07\times$

See last page

Efficiency = $\frac{T_s}{PT_p} = \frac{1.07}{2} = 0.535$

1.07
14 | 15
14
100

We realize that downloading entire 2D arrays from one worker to another is actually quite wasteful. As shown in the right side figure, to compute one 2D array object, the algorithm only requires the bottom-most row from the 2D array above, the right-most row from the 2D array to the left, and just one value from the diagonal 2D array.



So, let us say that the programmer downloads only the required portion of the 2D array objects.

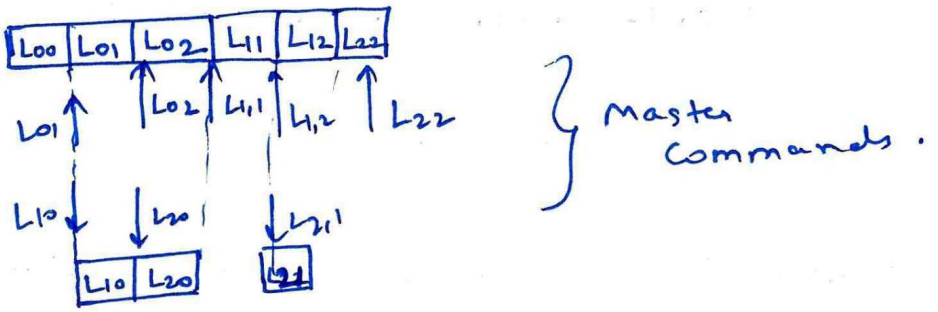
Name: Viraj Agashe Entry number: 2020CS10587

Q2.5 *[1 marks]* How long does it take to download a row from the 2D array object of 10,000 x 10,000 integer entries on a 20GBps link?

$= 10000 \times 4 / 20 \times 10^9 = 0.2 \times 10^{-5} = 2 \times 10^{-6}$ s

$= 2 \times 10^{-3}$ ms

Q2.6 *[3 marks]* Notice that the download time in Q2.5 is much smaller than the computation time. We can now assume download times to be zero in our calculations. Redraw the execution timeline from Q2.4. Create optimal placement of tasks, i.e, put tasks on workers such that we have minimum total execution time.

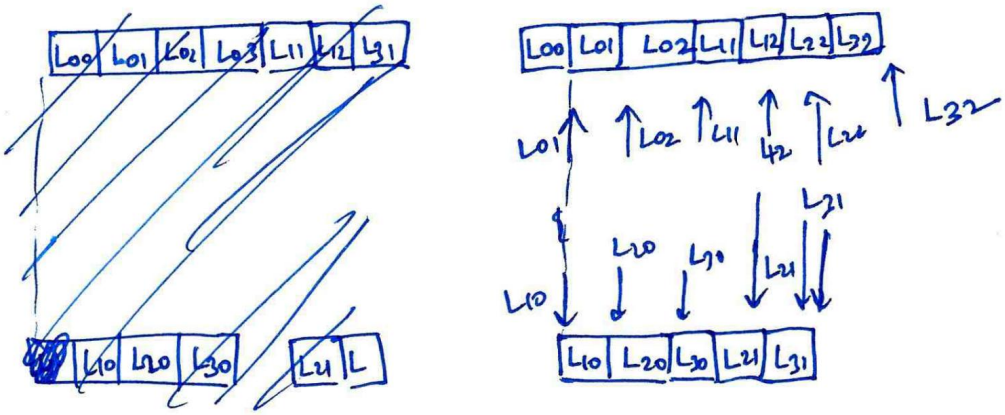


Q2.7 *[2 marks]* What is the speedup and efficiency for the timeline in Q2.6.

$\text{Speedup} = \frac{T_S}{T_P} = \frac{9 \times T_{BLOCK}}{6 \times T_{BLOCK}} = \frac{9}{6} = 1.5\times$

$\text{Efficiency} = \frac{T_S}{pT_P} = \frac{9}{12} = 0.75$

Q2.8 *[2 marks]* Redraw the timeline for Q2.6 assuming that we create 12 2D array objects each of size 7500 * 10000.



Q2.9 *[2 marks]* What is the speedup and efficiency for the timeline in Q2.8?

$\text{Speedup} = \frac{T_S}{T_P} = \frac{12 \times T_{BLOCK}}{7 \times T_{BLOCK}} = \frac{12}{7} = 1.7\times$

$\text{Efficiency} = \frac{T_S}{pT_P} = \frac{1}{2} \times \frac{12}{7} = \frac{6}{7} = 0.85$

Name: Viraj Agashe Entry number: 2020CS10582

Q3 [9 marks] True/False questions. If you are unsure about your answer, you may also provide a justification.

Q3.1 [1 mark] Spark's resilient distributed datasets are immutable.

True

Q3.2 [1 mark] Spark guarantees correctness under faults even when the tasks are non-deterministic.

False (eg. consider a transformation which multiplies all entries in RDD with the current time)

Q3.3 [1 mark] Checkpoints produced by Flink contain the "state" of all the nodes. It is guaranteed that all the nodes were simultaneously in the checkpointed state during the execution.

False. (Checkpoint gives a consistent state, but not guarantee of all having been in the state)

Q3.4 [1 mark] Session windows are all of the same length.

False.

Q3.5 [1 mark] Sliding windows do not overlap with one another.

False.

Q3.6 [1 mark] False sharing in page-based DSM implementation improves system performance.

False.

Q3.7 [1 mark] Reducing page size reduces false sharing in page-based DSM.

True.

Q3.8 [1 mark] Assuming no failures and no stragglers, records would typically see lower latency in Flink than in Spark's micro-batch based streaming.

True.

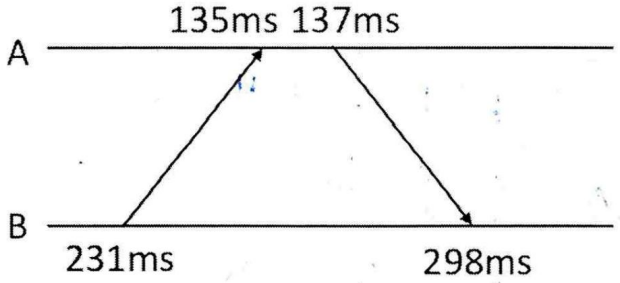
Q3.9 [1 mark] While recovering from a worker failure, records would typically see lower latency in Flink than in Spark's micro-batch based streaming.

False.

Name: Viraj Agashe Entry number: 2020CS10367

Q4 [3 marks] Network time protocol

Nodes A and B do the exchange as shown. The figure also shows the local clock time of A and B at send and receive events. Assume that the network time taken from A to B is the same as in B to A.



$\frac{rtt}{2} = t_1 - t_0 - \theta$

$= 135 + 128.5 - 231$

1
135
128.5
2635
231
325

Q4.1 [1 mark] What is the round trip time between A and B?

65 ms

$\frac{rtt}{2} = 32.5 \Rightarrow rtt = 65$ ms

Q4.2 [2 marks] By how many milliseconds is A's clock behind B's clock?

128.5 ms

$\theta = \frac{(t_1 + t_2) - (t_0 + t_3)}{2}$

$= \frac{135 + 137 - (231 + 298)}{2} =$

1
137
135
272

4 1
8 29
− 272
2517
2

= 128.5

Q5 [3 marks] MapReduce

In MapReduce, map tasks write to local disk and reduce tasks write to cluster file system. Let's say we modify this behavior so that the map tasks also write to the cluster file system. What will be the impact of this decision on performance and fault tolerance? Justify your answer.

I believe this will lead to reduced performance of MapReduce. This is because, after the map phase, the reducers need to get the (K,V) pairs remotely from the mappers — remote reads.

If we additionally enforce needing to write to cluster fs ⇒ lot of remote writes as well, without any performance benefit (still need remote reads to get data for reducers).

Fault Tolerance might become more efficient — if mapper crashes, after mapping (during reduce phase), its computations are already stored in cluster fs so we don't need to do the mapping again (which we need to do with local storage after maps)

$t_3 - t_2 + \theta$

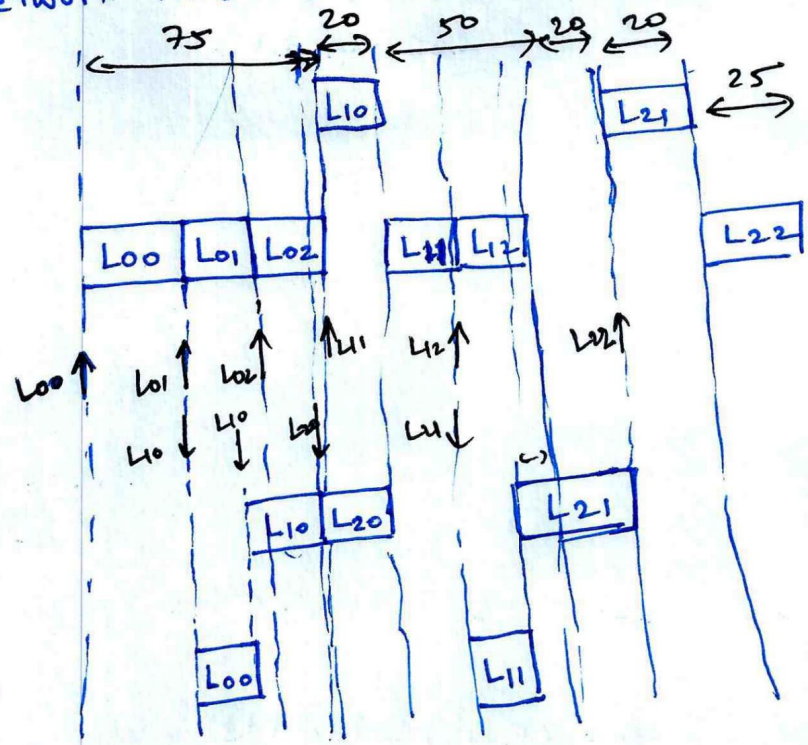
$= 298 - t_3$

$298 - 137 - 128.5$

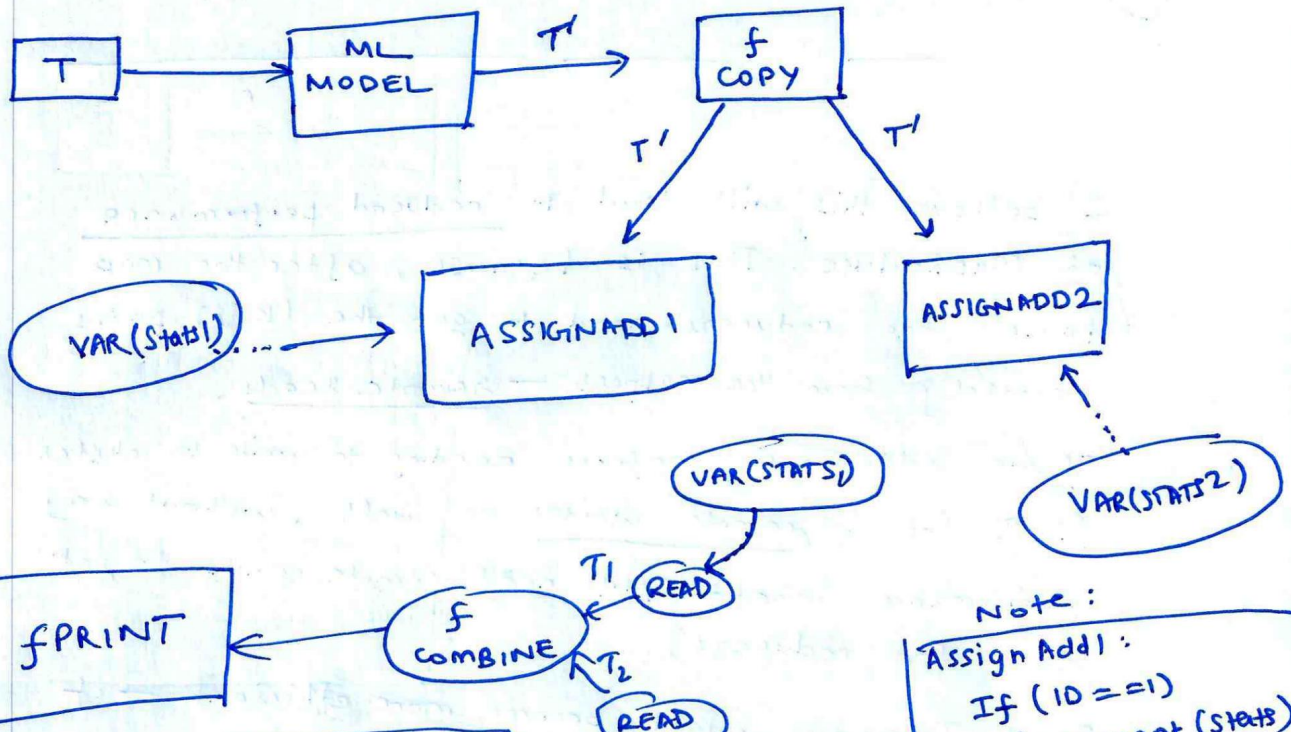
137
128
265

298
265
33

Q2.3. Network Time = 20 ms, Compute Time = 25 ms



Q1.3.




```
def fprint(4w1, 2w1, n1,
           4w2, 2w2, n2):
print("After {n1} frames for CAM1,
       two wheelers = {2w1}
       four wheelers = {4w1}")
print("After {n2} frames for CAM2,
       two wheelers = {2w2}
       four wheelers = {4w2}")
print("After {n1+n2} frames.
       two wheelers = {2w2}
       four wheelers = {4w2}
```