Assignment 1: A connected fleet backend

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MPMOB

a. The deployment of an international fleet of e-scooters

1. How many 10GbE network interfaces is required for the fleet without the camera added?

To solve this problem, I use UTC time as the standard (consider UTC as 0) and transfer different countries' time to UTC pre location. I take DST (*Daylight Saving Time*) into account here, so I determine the time difference from UTC time based on the website [*https://time.is*](https://time.is).

Countries	Time Zone
UTC	0
Stockholm	2
London	1
New York	-4
Sapporo	9
Johannesburg	2
Sydne	10
Salé	1

Table 1.1 Different countries time zone

Next, we need to convert the utilization of e-scooter in different countries to the same time zone and calculate the number of e-scooter usage in the UTC standard.

Utilization/Time	00-01	01-02	02-03	03-04	~~~~	20-21	21-22	22-23	23-24
UTC	0.04	0.03	0.03	0.03	~~~~	0.38	0.23	0.15	0.05
Stockholm	0.03	0.03	0.05	0.28	~~~~	0.15	0.05	0.04	0.03
London	0.03	0.03	0.03	0.05	~~~~	0.23	0.15	0.05	0.04
New York	0.38	0.23	0.15	0.05	~~~~	0.56	0.67	0.71	0.54
Sapporo	0.68	0.6	0.65	0.64	~~~~	0.28	0.53	0.72	0.69
Johannesburg	0.03	0.03	0.05	0.28	~~~~	0.15	0.05	0.04	0.03
Sydney	0.6	0.65	0.64	0.6	~~~~	0.53	0.72	0.69	0.68
Salé	0.04	0.03	0.03	0.03	~~~~	0.38	0.23	0.15	0.05

Table 1.2 Different countries utilization of e-scooter

By the ***Fleet size*** table, we can get each countries number of vehicles, so we can calculate the number of e-scooters in use during each time period.

Time	e-scooter numbers
00-01	9562.56
01-02	8123.02
02-03	7785.06
03-04	8323.08
04-05	11151.84
05-06	14613.62
06-07	16779.02
07-08	17824.68
08-09	18006.8
09-10	19044.1
10-11	19598.98
11-12	19606.4

12-13	17648.62
13-14	16107.52
14-15	14780.48
15-16	15934.18
16-17	16970.36
17-18	16278.74
18-19	13857.4
19-20	12050.24
20-21	12297.78
21-22	13463.86
22-23	13483.22
23-24	11387.88

Table 1.3 Different time period e-scooter numbers

This will satisfy the conditions of our fleet when we satisfy the data flow at the maximum number of vehicles. From the table 1.3, we can get that the maximum number of e-scooter is **19606.4.**

Then, we need to calculate the data volume in each e-scooter. The data types and notations are as following table.

Data type	Byte
int8	1
int64	8
int16	2
int32	4
unit32	4
float	4
double	8

Table 1.4 Different data types

According to the general equation:

$$Data\ Volume = Frequency\ (HZ) \times (Timestamp\ + Data\ type\ \times byte) \qquad (1-1)$$

Timestamp: Data type is int64

We can get the following results

Signal	Data	Frequency (Hz)	byte
battery0_temp0	float	10	120
battery0_temp1	float	10	120
battery0_charge	int16	10	100
battery0_voltage	int16	10	100
battery0_amp	int16	10	100
battery0_serial	int64	1	16
motor_rpm	int32	10	120
ecu0_temp	float	10	120
ecu0_load	int16	10	100
ecu0_mem	int32	10	120
gnss0	double x 2	10	240
gnss0_satellites	int16	10	100
gnss0_state	int8	10	90
imu0	float x 9	100	4400
state_operation	int16	1	10
state_alarm	int8	1	9
user_id_app	uint32	1	12
user_id_phone	uint32	1	12
user_weight	float	1	12

headlight_status	int8	10	90
wheel_speed0	float	100	1200
wheel_speed1	float	100	1200
steering_angle	float	10	120
brake_pos	int16	10	100
Sum			8611

Table 1.5 e-scooter data volume

From Table 1.4 we can know that each e-scooter data volume is **8611 bytes.**

So,

$$Max\ MB/s = \frac{8611\ bytes\ \times\ 19606.4}{1024\ \times\ 1024} = 161\ MB/s \qquad (1-2)$$

A typical 10 GbE connection can handle 1250 MB/s, so we need $\frac{161}{1250} = \mathbf{0.1288}$ 10 GbE.

So, we need 1 10 GbE.

2. Is it possible to upload the video feed from the entire the fleet and, if so, what resolution and frequency could we support if we want to maximize resolution?

From the slide we can know that in most populated areas in Sweden 4G can be used, realistically giving **10 Mbit/s = 1.25 MB/s.** Each e-scooter is equipped with a 4G link, and we require to not use more than 80% of the link, which allow for data buffering. So, the transfer speed is **1 MB/s.**

Since RGB images take up more volume, I use h.264 to compress the images. We want to maximize resolution and we choose **2592x1944**, and the output frequency: 1, 4, 10, 15. (The final results include signal and video data)

Motion rank 2

When frequency = 15,

$$Transfer\ speed = \frac{15 \times (8 + 2592 \times 1944 * 2 \times (0.07/8))}{1024 \times 1024} = 1.26\,MB/s > 1\ MB/s \quad (2-1)$$

Which Does not meet the requirements.

When frequency = 10,

$$Transfer\ speed = \frac{10 \times (8 + 2592 \times 1944 * 2 \times (0.07/8))}{1024 \times 1024} + 0.008 = 0.849\,MB/s < 1\ MB/s \quad (2-2)$$

At this frequency the requirements are fulfilled.

Motion rank 4

When frequency = 10,

$$Transfer\ speed = \frac{10 \times (8 + 2592 \times 1944 * 4 \times (0.07/8))}{1024 \times 1024} = 1.68\,MB/s > 1\ MB/s \quad (2-3)$$

Which Does not meet the requirements.

When frequency = 4,

$$Transfer\ speed = \frac{4 \times (8 + 2592 \times 1944 * 4 \times (0.07/8))}{1024 \times 1024} + 0.008 = 0.67\,MB/s < 1\ MB/s \quad (2-4)$$

At this frequency the requirements are fulfilled.

In conclusion, when **motion rank is 2**, we are supposed to **choose the resolution is 2592×1944 and frequency is 10Hz**, which data transfer speed is 0.849 MB/s. When **motion rank is 4**, we are supposed to **choose the resolution is 2592×1944 and frequency is 4Hz**, which data transfer speed is 0.67 MB/s.

3. How many 10GbE network interfaces do we need to use in our server backend to support the incoming data volume from the entire fleet (i.e. do not worry about storage)?

In question 2, we calculate each vehicle data volume in different motion rank. So in this section, we need to meet the requirement that we can transfer this data when the vehicle is at its maximum.

Motion rank 2

$$Data\ volume = \frac{0.849 \times 19606.4}{1250} = 13.32\ 10GbE$$

So, we need 14 10GbE network interfaces.

Motion rank 2

$$Data\ volume = \frac{0.67 \times 19606.4}{1250} = 10.68\ 10GbE$$

So, we need 11 10GbE network interfaces.

In conclusion, when **motion rank is 2**, we need **14 10GbE network interfaces** and when **motion rank is 4**, we need **11 10GbE network interfaces**.

b. Keeping the flow.

In order to solve this problem, I made the following assumptions:

1. As the drive buffer is used for larger data processing or copying operations, reading, and writing at the same time may reduce the overall performance of the drive. Therefore, I assume that the buffer stores data while the vehicle is in motion and sends information when the vehicle is still.
2. When choosing video quality, we need to ensure that it does not overflow during vehicle operation and that the buffer is emptied within 1 hour after the vehicle stops.
3. I assume that the e-scooter can work for two hours at 15km/h, and it needs to transfer data from the buffer to the cloud during the period when there is power.
4. I assume that the utilization rate per hour is the amount of time each vehicle is used in that time period and empty the buffer within that hour.
5. I assume that e-scooter will replace the battery in a timely manner and clear the hard drive buffer every hour.

It is known that the transmission rate of 4G is 1MB/s

Then this problem is simplified, I need to calculate the time period of the longest usage time, the stored data cannot overflow, and the data can be transferred out through 4G in time during the remaining time period.

In Table 1.2, we know that during 7:00 ~ 8:00, the usage of vehicle is at peak, which is 72%. According to the calculation, the vehicle usage time was 43.2 minutes and the time to transfer data was 16.8 minutes. So, the amount of data transferred is $Data\ volume = 60\ \times 60\ \times 1 = 3600\ MB$, and hard drive buffer has 4096 MB. Therefore, we have $3600 \times 0.72 + 4096 = 6688\ MB$ amount of storage space during the time the vehicle is in use. We want to ***maximize resolution,*** so we start with the highest quality image to calculate.

Motion rank 2

Resolution 2592×1944 Frequency 15

$$Transfer\ speed = \left(\frac{15 \times \left(8 + 2592 \times 1944 * 2 \times \left(\frac{0.07}{8} \right) \right)}{1024 \times 1024} + 0.08 \right) \times 60 \times 60 \times 0.72 = 3477MB < 4096MB$$

This meets our assumption, but the refresh rate is low. When the refresh rate of the camera is higher, more and more adequate image information is returned.

I try other resolution as follows.

Resolution 1920×1080 Frequency 15

$$Transfer\ speed = \left(\frac{15 \times \left(8 + 1920 \times 1080 * 2 \times \left(\frac{0.07}{8} \right) \right)}{1024 \times 1024} + 0.008 \right) \times 60 \times 60 \times 0.72 = 1366MB < 4096MB$$

So, the final answer is **Resolution 2592×1944 Frequency 15**

Similarly, we can obtain motion rank 4

Motion rank 4

Resolution 2592×1944 Frequency 10

$$Transfer\ speed = \left(\frac{10 \times \left(8 + 2592 \times 1944 * 4 \times \left(\frac{0.07}{8} \right) \right)}{1024 \times 1024} + 0.008 \right) \times 60 \times 60 \times 0.72 = 4373MB < 6688MB$$

So, when motion rank is 4, the final answer is **Resolution 2592×1944 Frequency 10**

In conclusion, we found a significant improvement in the quality of the uploaded images after setting the hard drive buffer.