Application Telespazio VEGA Deutschland as "Junior Java Engineer"

Test assessment : WY Space exercise

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Source code: https://github.com/cguz/Interview_VEGA

1. Question to solve and Assumptions

The first step was to read the problem carefully to understand the problem and identify the question.

I describe the question to solve and establish some assumptions that I am going to follow during the development of the test.

1.1. Question to solve

The two question to solve are:

1. WY Space would like to take a text based schedule (detailed below) and use a program that can find the 30 minute period where the total downlink (all satellite passes) will be at its maximum.

2. Furthermore, they would like the program to determine if the ground station has the bandwidth to support this.

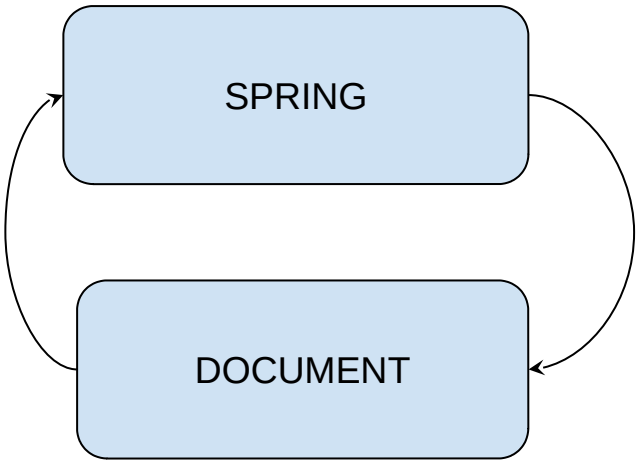
1.2. Assumptions

During the development of the test, I assume the following:

- All the pass schedules are related to the same day.
- Column **bandwidth per 30 minute period** in the pass schedule file means that, during the 30 minutes, the satellite consumes X bandwidth of the ground station from Earth.
- There can be more than one 30 minute period where the total downlink will be at its maximum, for instance, if they are equals.
- The time starts at 00:00, and it increases by 30 minutes. That is, the minutes in the start and end times can be only 00 or 30.

2. Methodology

I am going to follow the Agile development process. I will combine the development of the Spring and the writing of the present document.



I propose to develop the following Spring.

1. Spring 1 : Develop a prototype in OOP that solve the problem

3. Design and Development

3.1. Spring 1: Develop a prototype in OOP that solve the problem

Analysis of the problem

Figure 1 shows a sketch of the problem. In general, we have a ground station and several satellites. The satellites can communicate to the ground station. Each time the satellite sees the ground station, the satellite communicates the information, occupying the bandwidth of the ground station.

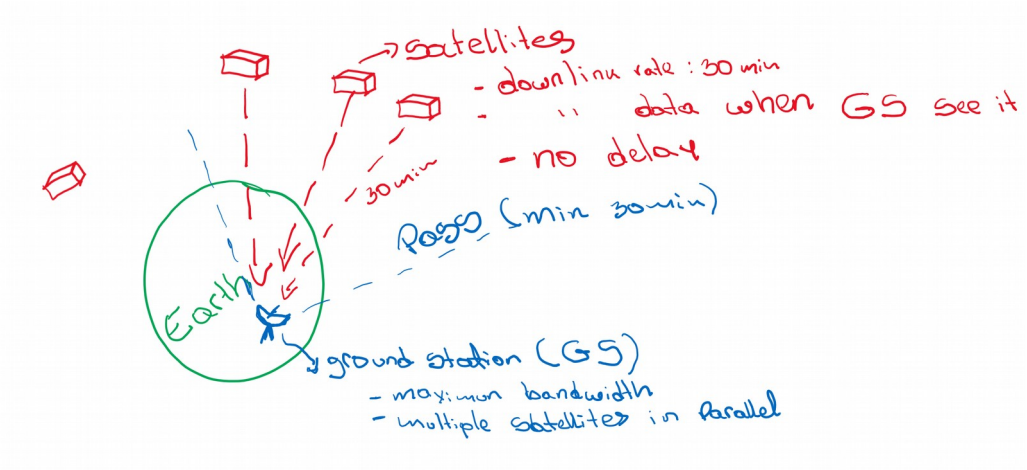


Figure 1. Sketch of the problem.

Satellite Name	bandwidth per 30 minute period	Start time	End time	Duration
RedDwarf	2	0:00	1:30	1:30
RedDwarf	2	2:30	4:00	1:30
RedDwarf	2	5:00	6:30	1:30
RedDwarf	2	7:30	9:00	1:30
RedDwarf	2	10:00	11:30	1:30
RedDwarf	2	12:30	14:00	1:30
RedDwarf	2	15:00	16:30	1:30
RedDwarf	2	17:30	19:00	1:30
RedDwarf	2	20:00	21:30	1:30
RedDwarf	2	22:30	0:00	1:30
Narcissus	5	0:30	3:30	3:00
Narcissus	5	5:30	8:30	3:00
Narcissus	5	10:30	13:30	3:00
Narcissus	5	15:30	18:30	3:00
Narcissus	5	20:30	23:30	3:00
Nostromo	3	0:00	0:00	0:00
Sulaco	10	3:00	3:30	0:30
Sulaco	10	15:00	15:30	0:30
Rocinante	30	12:00	16:30	4:30
Moya	10	0:00	3:00	3:00
Moya	10	8:30	11:30	3:00
Moya	10	17:00	20:00	3:00
Odyssey	15	2:00	8:00	6:00
Odyssey	15	16:30	22:30	6:00
Enterprise	30	9:00	10:30	1:30
Normandy	2	12:00	15:00	3:00

Table 1. pass schedule

Table 1 describes the pass schedule file. To try to understand this table, I draw the points in a chart. Figure 2 shows the chart of points of the pass schedule file.

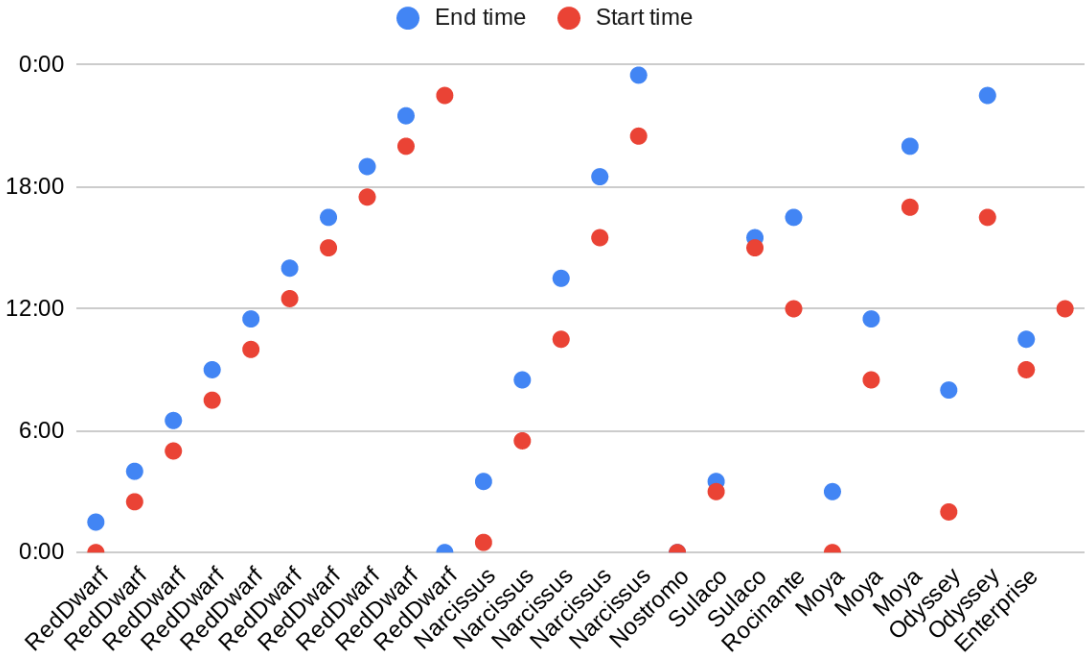


Figure 2. Chart of points of the pass schedule file

With the Figure, it is not easy to understand the problem. One approach to understanding better the problem is to draw the data in a timeline chart.

For this, I first sort the data by start time. See Table 2.

Satellite Name	bandwidth per 30 minute period	Start time	End time	Duration
RedDwarf	2	0:00	1:30	1:30
Nostromo	3	0:00	0:00	0:00
Moya	10	0:00	3:00	3:00
Narcissus	5	0:30	3:30	3:00
Odyssey	15	2:00	8:00	6:00
RedDwarf	2	2:30	4:00	1:30
Sulaco	10	3:00	3:30	0:30
RedDwarf	2	5:00	6:30	1:30
Narcissus	5	5:30	8:30	3:00
RedDwarf	2	7:30	9:00	1:30
Moya	10	8:30	11:30	3:00
Enterprise	30	9:00	10:30	1:30
RedDwarf	2	10:00	11:30	1:30
Narcissus	5	10:30	13:30	3:00
Rocinante	30	12:00	16:30	4:30

Normandy	2	12:00	15:00	3:00
RedDwarf	2	12:30	14:00	1:30
RedDwarf	2	15:00	16:30	1:30
Sulaco	10	15:00	15:30	0:30
Narcissus	5	15:30	18:30	3:00
Odyssey	15	16:30	22:30	6:00
Moya	10	17:00	20:00	3:00
RedDwarf	2	17:30	19:00	1:30
RedDwarf	2	20:00	21:30	1:30
Narcissus	5	20:30	23:30	3:00
RedDwarf	2	22:30	0:00	1:30

Table 2. pass schedule sorted by start time

With Table 2, I generated the timeline chart as follows.

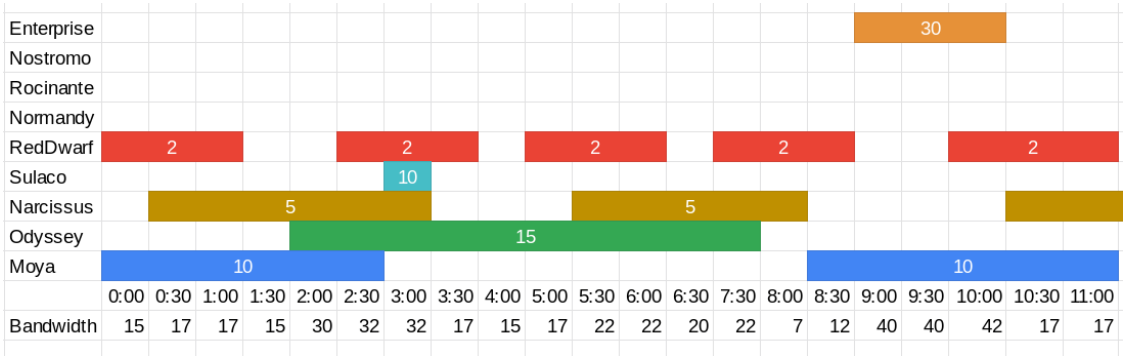


Figure 3. Timeline chart of the pass schedule

Now, it is clearer to calculate the total bandwidth consumed by the satellites during a given time.

Design of the solution

Approach 1:

In OOP, we can define the following class diagram (see Figure 4) to represent our problem.

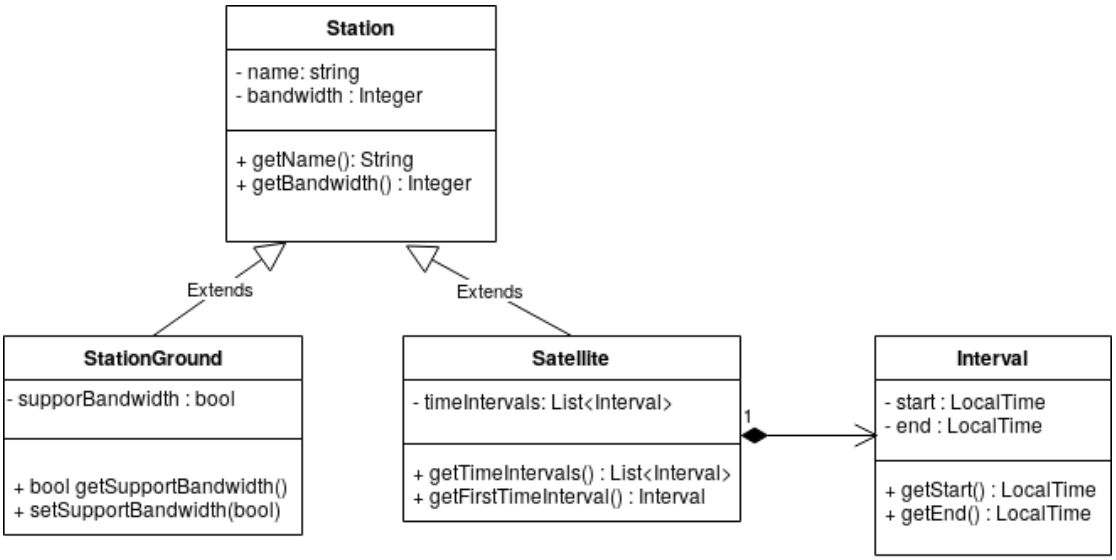


Figure 4. Class diagram of the problem WYSpace

The class **Satellite** extends the class **Station**, and it has a List of time intervals.

The class **StationGround** also extends the class **Station**. In this case, I consider the bandwidth attribute as the maximum bandwidth.

The trivial solution is to visit each time and check the satellites that intersect the given period within its interval of communication. This solution requires a time complexity of O(n*m), where n is the number of time intervals during a day, and m is the number of satellites.

A first prototype of the algorithm is as follow:

```
// declare a list of intervals as empty
periodTotalDownMax = {}

// maximum total bandwidth
maxTotalBandwidth = 0

// for each possible time in the interval
for time 00:00 to 00:00 (24:00) increased by 30:

        // calculate the total bandwidth occupied by the satellites in the given time
        totalBandwidth = 0
        for each satellite in pass schedule:
                if satellite.overlap(time) :
                        totalBandwidth+= satellite.getBandwidth()

        // whether the total bandwidth is higher than the bandwidth supports by the ground station
        if totalBandwidth <= stationGround.getBandwidth():

                // keep the maximum total bandwidth
                if totalBandwidth > maxTotalBandwidth :
                        periodTotalDownMax.clear()
                if totalBandwidth >= maxTotalBandwidth :
                        maxTotalBandwidth = totalBandwidth
                        periodTotalDownMax = {time}
```

else:
set support bandwidth to false in stationGround

Approach 2:

From this point on, I have a prototype that runs in linear time complexity. Note that sometimes its time complexity can be quadratic, e.g., when m >= n.

I think I can improve the solution with a better data structure. Thus, doing some research on the Internet I found the Interval Tree data structure [1], which is an extension of a red-black tree. The Interval Tree maintains a dynamic set of elements, with each element i containing an interval [i.start, i.end].

We say that intervals i and j overlap, if the intersection between i and j is different from null. That is, if i.start <= j.end and j.start <= i.end. Figure 5 shows all the cases where the two intervals satisfy the overlap.

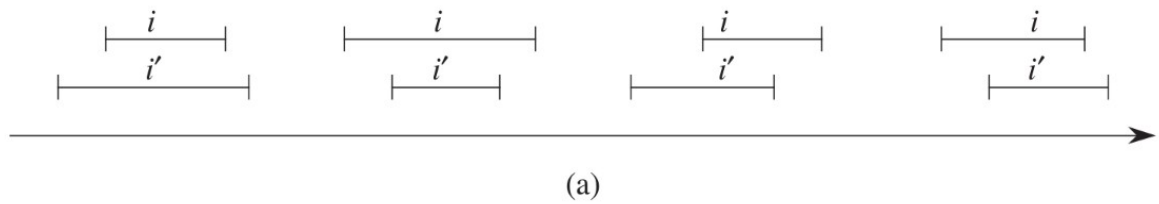


Figure 5. Cases where the two intervals overlap. Figure from [1].

With all this in mind, let's see the next proof of concept.

Let us assume the time intervals of the satellites ReDwarf, Sulaco, Narcissus, and Moya, shown in Figure 6.

RedDwarf	2				2		
Sulaco						10	
Narcissus			5				
Moya	10						
	0:00	0:30	1:30	2:00	2:30	3:00	3:30
Bandwidth	12	17	15	30	32	32	17

Figure 6. Time intervals proof of concept

A possible Interval tree is shown in Figure 7.

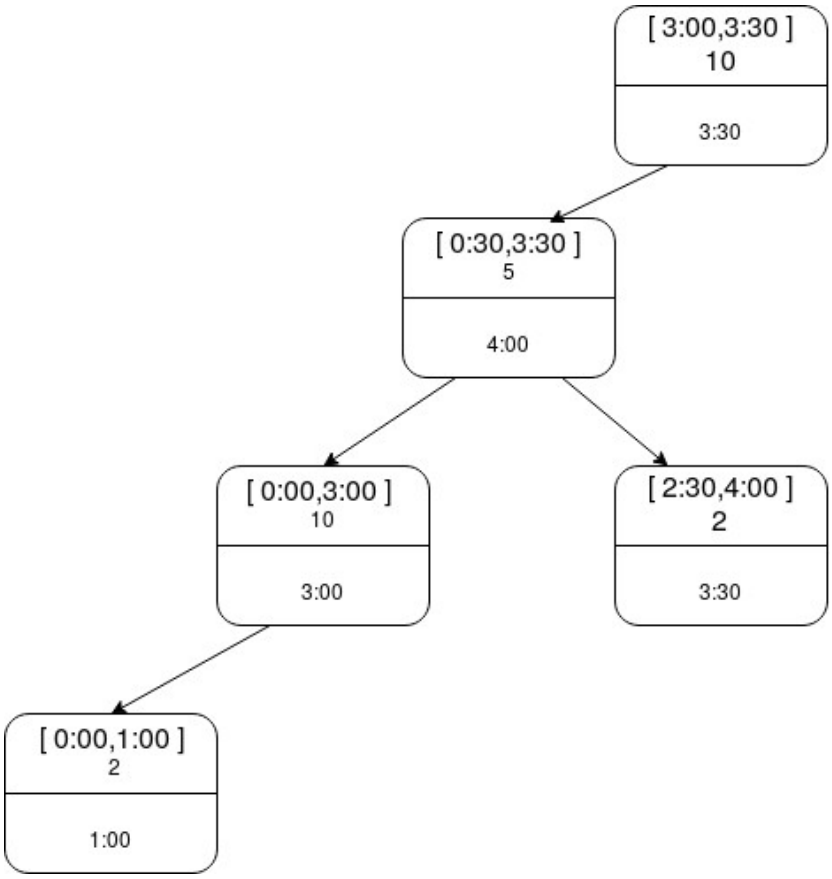
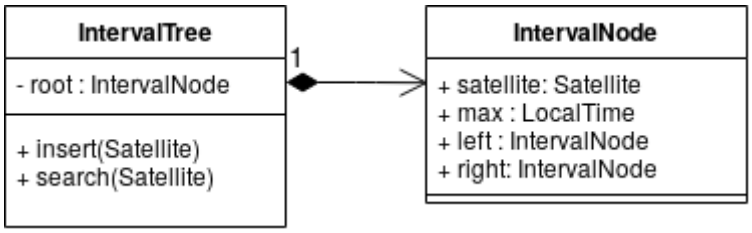


Figure 7. Interval Tree of the proof of concept

With this Interval tree, I calculate easily the total bandwidth occupied in a given time. For instance, given the time 0:30 and starting from the root of the node, we traverse the tree adding the bandwidth of any node which intervals fit 0:30. In this case, it would be : 5 + 10 + 2 = 17.

With this approach, I improve the time complexity to linear logarithm, O(n*log m).

In regards to the classes, I will need the following classes:



Development

25/09/2020 14:00

With all the design, I start to develop the prototype in Java. I will develop approaches 1 and 2 discussed in the previous section.

Approach 1

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During the development, I perform an improvement to the class diagram of Figure 4.

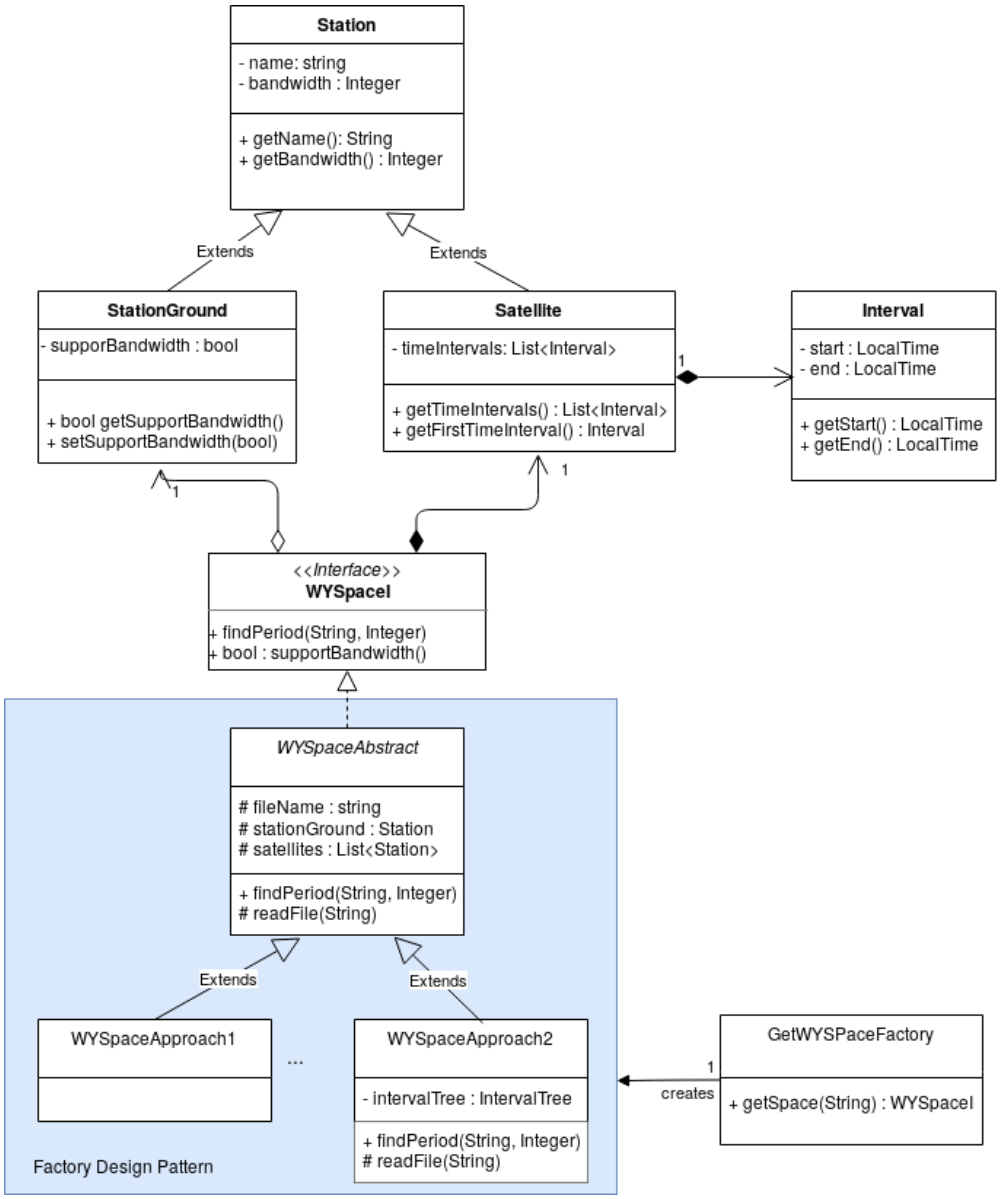

Figure 8. New Class Diagram of the proposed solution

Figure 8 shows the new class diagram. It has three new classes (WYSpaceApproach1, WYSpaceApproach2, GetIWYSpaceFactory), an Interface (WYSpaceI) and an Abstract class (WYSpaceAbstract). All of them developed with the Factory design pattern.

The main reason to use the factory design pattern is that I am going to implement two approaches to solve the problem. With this pattern, I can easily not only change between the two approaches but add a new one without affecting all the code. I only need to add the new class and insert the creation in the class GetWYSpaceFactory.

Approach 2

27/09/2020 11:00

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During the development of the second approach, I refactor the code and perform some updates to the class diagram.

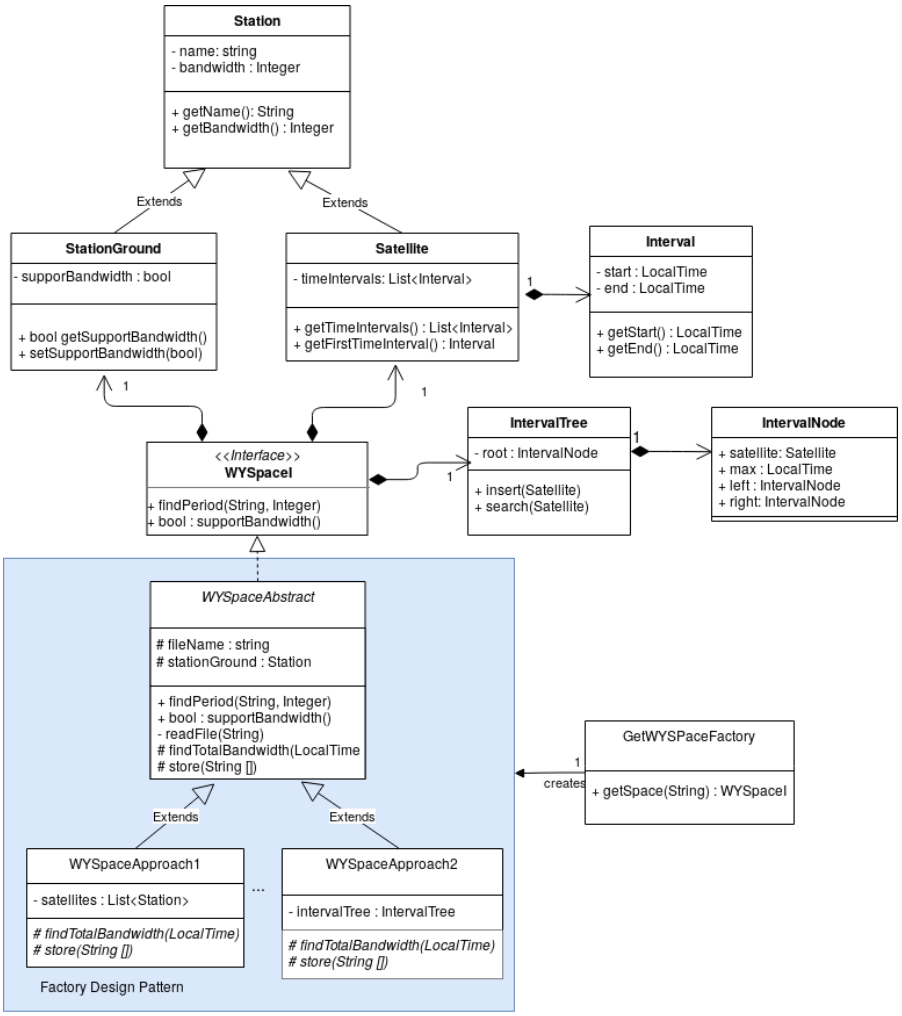

Figure 9. Final class diagram.

Figure 9 shows the final class diagram. The main changes were in the Factory Design Pattern to reuse as much as possible the code.

Note. I did not work on September 28 because it was my birthday.

Test

I tested the two solutions with the given input pass schedule file. It works fine for the two solutions.

A better solution is to implement Unit Tests with Junit.

29/09/2020 18:46

References

[1] Cormen, T. H., Leiserson, C. E., Rivest, R. L., & Stein, C. (2009). *Introduction to algorithms*. MIT press.