Problem Statement

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Subway station

This is the description of an Automated Fare Controller (AFC) system (Figure 1) and a Ticket Vending Machine (TVM) installed at each station of a subway line (Figure 2). Some actual examples of tickets can be found in the Figure 3.

Figure 1. Automated Fare Collection (AFC) system.

Figure 2. Ticket Vending Machine (TVM).

Figure 3. Actual examples of ticket images.

This line has two terminus stations, i.e. *Saint-Lazare* and *Olympiades* (Figure 4). For simplification, we assume that lines between stations are straight, and we can calculate directly on the distances between stations. For instance, the distance between the station *Madeleine* and the station *Gare de Lyon* can be calculated as the sum of the distance between *Madeleine* and *Pyramides* AND the distance between *Pyramides* and *Gare de Lyon*, or the difference of the distance between *Saint-Larare* and *Gare de Lyon* AND the distance between *Saint-Lazare* and *Madeleine*.

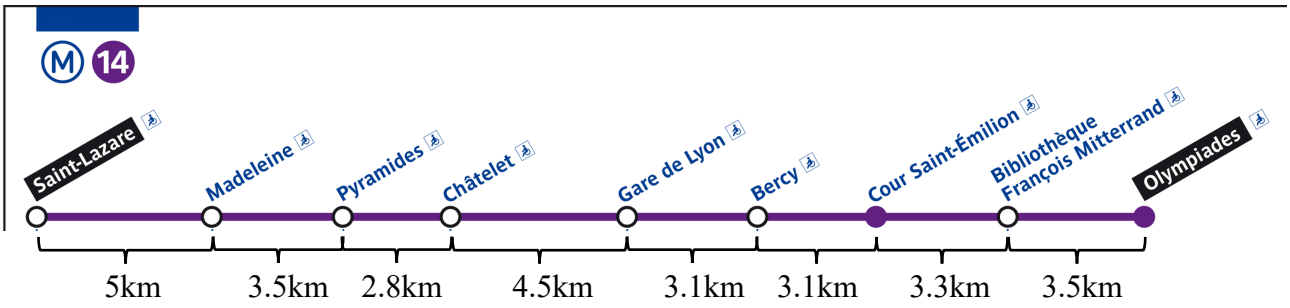

Figure 4. Subway map.

A. A fare of an itinerary is decided based on the distance between stations. The fare for up to 5 kilometers is 1.9 euros (this is called the base fare). An amount of 0.4 euro is added for each additional 2 kilometers. Any additional distance less than 2 kilometers is rounded up to 2 kilometers. For instance, for a distance of 7.3 kilometers, the fare is 2.7 euros.

B. In a ticket vending machine, passengers can choose to buy a type of traveling certificates in the menu: one-way ticket, twenty-four-hour ticket or prepaid card.
   - For a **one-way ticket**, passengers need to choose the two stations (embarkation) and the end station (disembarkation). Note that the end station cannot be the same as the start one. The system then calculates the fare and display to them.
   - For the **twenty-four-hour tickets**, the system displays the price of this type (i.e. 8.5 euros) to passengers.
   - **Prepaid cards** can be bought in the vending machine with a deposit of 16 euros. The default balance of 5 euros is then displayed in screen. Passengers can increase this balance for the prepaid card. The minimum balance is 2.5 euros. Hence you need at least 18.5 euros to buy a prepaid card, including 2.5 euros for its balance.

   Passengers can buy multiple tickets or cards in one order, but only one type in one order. The passengers can enter the number of tickets that they want to buy and confirm to buy in a confirmation screen with all necessary information about tickets, e.g. price, quantity, amount and total amount. After confirming the order, to pay the receipt, passengers insert a credit card to a slot of a credit card reader and follow the direction in the screen. The

machine has to connect to a card association[1] to process the transaction.
After the payment, the system prints tickets or issues prepaid cards. The ID of a ticket or traveling card is 14-character string, which can be automatically generated. The two first characters represent the type of the fare certificate (i.e. OW for one-way ticket, TF for 24h ticket, PC for prepaid card), the next eight numbers are the vending date (yyyymmdd, e.g. 20190930), the rest is auto-incremented from 0000 to 9999 for each type of traveling certificates in that day. Ticket images are generated based on the samples illustrated in the Figure 5, then sent to a specialized printer to print on a ticket paper with a pre-printed barcode. The printer or the card issuer then sent the barcode to the system for management. Passengers can return the prepaid card to get money (including the deposit and the remain balance in the card) back to their credit card in the vending machine.

Figure 5. Image samples of one-way tickets and 24h tickets.

C. The embarkation station and time are recorded when a passenger passes through the AFC system in that station to enter the platform area. A passenger can enter the platform area through the AFC system in any station, thus being able to embark, regardless of the station that issued the ticket. For instance, with a ticket issued at the Station *Madeleine*, a passenger can enter the platform area through the AFC system at the Station *Bercy*. Passengers put the ticket to a slot of a ticket recognizer in the AFC system to open that gate, then get it back on the other side of the gate. If they use a card, they need to put the card on a card scanner in the AFC system to open the gate. The ticket regconizer or the card scanner reads and convert the barcode of each ticket/card then return a corresponding ticket/card code (16-bit), which then can be mapped directly to the ticket/card ID (14-character string), to the AFC system for further processing. The gate will not be opened for passengers to enter if the ticket/card is already used to enter a station before.
D. Whenever passengers enter or exit the station, if the gate is opened, the system displays “Opening ticket/card…”, otherwise “Invalid ticket/card…” with a reason. In any case, the system then displays with some basic information of the ticket/card such as type, id, balance/valid until. The gate will not be opened if the ticket/card is not used to enter a station before.
E. Passengers can use one-way tickets only one time. Once a one-way ticket is used, it cannot be used to enter again. The passengers can only enter a station in between the two stations of the ticket and travel in any direction. For instances, with a one-way ticket of *Parymides* and *Gare de Lyon*, a passenger can only enter *Pyramides*, *Châteles* or *Gare de Lyon*. When they leave a station, the fare between the starting and the ending station is smaller than or equal to the ticket fare, the gate is opened. Otherwise, it is closed. For instance, with a one-way ticket of *Parymides* and *Gare de Lyon* (2.7 euros), if a passenger enter the *Châteles* station, he/she can exit either *Madeline*, *Pyramides*, *Châteles*, *Gare de Lyon* or *Bercy*; but neither *Saint-Lazare* nor *Cour Saint-Émilion*.
F. A twenty-four-hour ticket permits a passenger to freely embark or disembark multiple times at all stations within 24 hours from the time that the passenger uses it for the first time. After twenty-four hours from the first-time usage, the passenger can leave the

[1]The primary responsibilities of the Card Association are to govern the members (i.e. banks) of their associations, including interchange fees and qualification guidelines, act as the arbiter between issuing and acquiring banks, maintain and improve the card network and their brand, and, of course, make a profit.

platform area in any station but cannot enter any such area.

G. When a passenger enters a station with a prepaid card, if the balance on the card is less than the base fare, the gate is closed to prevent him/her from entering the platform area. When he/she leaves the platform area through the automated fare collection system in the station of disembarkation, the fare is calculated. If the balance is less than the amount of the fare, the gate is closed to prevent him/her from leaving the platform area. Otherwise, a balance adjustment is processed, i.e., the fare is subtracted from the balance on the card. The gate then is opened for the passenger to enter to the platform area.

H. If the gate is not opened, the passenger may charge more money to the card at a ticket vending machine to open the gate. To charge more money to the prepaid cards, the passenger can put a prepaid card on the screen so that the system can scan the card id for further processing. These tasks can be done at either TVMs inside the platform area or the ones outside the platform area (before entering a gate).

Please do the following tasks to have the expected outputs below.

1. Draw use case diagrams for the automated fare collection system and the selling ticket machine: at least one diagram for each system.
2. **You are asked to develop a program** which is limited to use cases described in the sections C to G of the AFC system. However, to test the program when a passenger moves from this station to another station, you have to provide command-line GUIs. To simulating user operations at stations, the program displays a list of stations to users for selection. The program reads from files (will be provided) and displays some existing tickets and cards with their types, status and necessary information. Users can choose to enter or exit a station with a ticket or a card by enter its pseudo bar code (8 uppercase letters for a card or 8 lowercase letters for a ticket). The program need to connect to the card scanner or the ticket recognizer to convert from the pseudo bar code to the corresponding card/ticket code (16 bits). This card/ticket code then can be mapped directly to the ticket/card ID (14-character string). You have to follow sample screens and flows of the program that can be found at the end of the problem statement (*).
   Assume that there is a specialized printer, a traveling card issuer, a traveling card scanner and a credit card reader that connect to each TVM; a ticket recognizer, a card scanner and a gate that connect to each AFC system. These devices are provided with SDKs for communication. The SDKs specification will be provided.

   Please develop the following items for all use cases from C to G:
   - Use case specifications
   - State machine diagrams for states of tickets/cards
   - Class diagram with full attributes and methods
   - Interaction diagrams (Sequence diagrams or Communication diagrams)
   - Source code (in Java or C++)

*** Sample screens of the program**