Politecnico di Milano
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CLup

Requirements Analysis and Specification Document

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1. Introduction

1.1 Purpose

During the ongoing COVID-19 pandemic, social distancing has proven to be a valuable tool to reduce the diffusion of the virus among the population. To enforce this kind of behaviour, governments around the world adopted strict lockdown policies, allowing people out of their homes only to carry out essential tasks. Grocery shopping has proven to be a challenging situation to regulate, due to the need for both restricting access to the shops and avoiding the formation of crowded queues outside of them.

To maximize the accesses to the store while preserving a safe environment and to ease visit planning, the store customer should be provided with a way to express preferences for a time slot and to indicate the approximate duration of his visit. Moreover, the accesses across different stores and day or time ranges should be balanced by proactively suggesting possible alternatives. Overall, each process should be easy to use to include all demographics.

The goal of the following document is to provide a comprehensive description of requirements and specification for the software-to-be under analysis. Relevant use cases and models will be addressed through the use of natural language, UML, and Alloy. Choices made regarding the interpretation, the problem under analysis and the related software-to-be will be clearly stated by the creators of this document, along with their rationale.

1.1.1 Goals

ID	Goal
G1	The number of people in the store should be compliant with the country's regulation.
G2	The distance between people in the store should be compliant with the country's regulation.
G3	Store managers should be able to regulate the influx of customers to the store.
G4	Every customer should be able to access a store.
G5	The distance between people in proximity to the store should be compliant with the country's regulation.
G6	Customers should be evenly distributed across the stores adopting the system.
G7	Customers should be evenly distributed across the available time slots.
G8	Customers should access a store in a time slot they deem acceptable.
G9	Customers should access a store at a location they deem acceptable.

1.2 Scope

1.2.1 Product

CLup is a system that allows to handle access to supermarkets when the flux of people is restricted. In particular, it allows customers to line-up remotely (i.e., without being physically in a line outside the supermarket) and suggests them the right time to go to the supermarket without having to form a queue outside.

CLup allows customers either to request access to the supermarket as soon as possible, or to book in advance an access to the supermarket at a given slot of date and time. In both cases, the system aims at preventing overcrowding in each area of the building. Access to the supermarket is granted only when using the system so that CLup can actively monitor the number of people inside the building.

Customers will be allowed to enter the store from the time they chose when requesting to line up, but no later than a centrally determined delay after the chosen time, after which their line up request will expire.

If many people are in a queue for the same access slot, CLup gives the customers possible alternatives about slots or supermarket that are less crowded. Moreover, upon customer request, it can proactively inform them if there are available slots in a given day or time range.

The main interface between CLup and the user is assumed to be an IT device with an Internet connection. However, since not all people may have access to such technologies, the system can be used, with limited functionalities, just through a standard telephone line or in presence.

The system is completed by an administrational dashboard that allows store managers to monitor the accesses to the supermarkets in real-time and to manage the queuing parameters, such as the maximum number of people allowed in the building at the same time.

1.2.2 World and Shared phenomena

1.2.2.1 World phenomena

ID	Phenomenon
WP1	The customer needs to go grocery shopping.
WP2	The customer arrives at the supermarket.
WP3	The customer asks to line up to a store assistant (fallback method).
WP4	The customer leaves the supermarket.
WP5	The local authority asks the store manager to report how many people are inside the building.
WP6	The local authority asks the store manager to increase or decrease the maximum number of people allowed inside the building.

1.2.2.2 Shared phenomena - controlled by the World

ID	Phenomenon
SP1	The customer asks the system to line up and enter the supermarket as soon as possible through an IT device.
SP2	The customer asks the system to book an entrance at the supermarket at a given date and time through an IT device.
SP3	The customer asks the system to line up and enter the supermarket as soon as possible through a standard telephone line.
SP4	The customer asks the system to book an entrance at the supermarket at a given date and time through a standard telephone line.
SP5	The store assistant asks the system to line up a customer, to let them enter the supermarket as soon as possible.
SP6	The customer asks the system to print the receipt of a request made by telephone with an on-site device.
SP7	The customer informs the system on the estimated duration of the visit to the supermarket.
SP8	The customer informs the system on the categories of products they intend to buy.
SP9	The customer scans the QR code receipt at the entrance of the supermarket.
SP10	The customer scans the QR code receipt at the exit of the supermarket.
SP11	The store manager queries the system for the number of people inside the building.
SP12	The store manager informs the system on the maximum number of people allowed inside the building.

1.2.2.3 Shared phenomena - controlled by the Machine

ID	Phenomenon
SP13	The system shows the user a QR code as a receipt of a request performed through an IT device.
SP14	The system prints through an on-site device a QR code as a receipt of a request performed through a standard telephone line.
SP15	The system prints through an on-site device a QR code as a receipt of a request performed through the on-site device itself.
SP16	The system informs the customer that it's time to go to the supermarket to take advantage of the requested slot.
SP17	The system allows a customer to enter the supermarket.
SP18	The system gives the customer suggestions on less crowded slots or supermarkets.
SP19	The system informs the customer that a specific time slot in a range they chose in advance is available

1.3 Definitions, acronyms, abbreviations

1.3.1 Definitions

Dashboard A panel usually containing instruments and controls.

Demographic The statistical characteristics of human populations (such as age or income) used especially to identify markets.

Fallback method A method used as reserve.

Lockdown policy A lockdown policy is a requirement for people to stay where they are, usually due to specific risks to themselves or to others if they can move freely.

Proxy Authority given to a person to act for someone else

Push notification A message that is "pushed" from the backend server or from the application to user interface, usually announced with sound and/or vibration of the device.

Receipt scanner In the context of the present system, a receipt scanner is an optical device that can read customers' line up receipts.

Social distancing In public health, social distancing, also called physical distancing, is a set of non-pharmaceutical interventions or measures intended to prevent the spread of a contagious disease by maintaining a physical distance between people and reducing the number of times people come into close contact with each other.

1.3.2 Acronyms

CE Conformité Européenne.

CLup Customers Line-up.

COVID-19 COronaVIrus Disease 2019.

DA Domain Assumption.

G Goal.

GDPR General Data Protection Regulation.

HTTPS HyperText Transfer Protocol Secure.

ISTAT Istituto nazionale di statistica.

IT device Information Technology device.

MTTF Mean Time To Failure.

MTTR Mean Time To Repair.

OTA Over The Air.

QR code Quick Response code.

R Requirement.

RASD Requirements Analysis and Specification Document.

SP Shared Phenomenon.

TLS Transport Layer Security.

UML Unified Modeling Language.

WP World Phenomenon.

1.3.3 Abbreviations

1.4 Revision history

Version	Date	Notes
V1.0	December 7, 2020	Initial release.

1.5 Reference documents

- **Alloy documentation**
- **R&DD Assignment AY 2020-2021**
- **The world and the machine** by M. Jackson
- **UML documentation**

1.6 Document structure

This document is structured in the following way:

1. The first chapter is an introduction and an overview of the project, setting the context leading to its development, the goals to be reached and providing a general description of its functionalities.
2. The second chapter is a formal description of the domain model and the project through the extensive use of class diagrams and state machine diagrams. Class diagrams provide a high level description of the domain entities and their relationships, while state machine diagrams focus on modeling the most important entities through their state transitions. Here are also presented all the functional requirements and domain assumptions required to achieve the previously stated goals.
3. In the third chapter non functional requirements are presented, and functional requirements are deepened thanks to the description of possible use cases through the use of natural language and thanks to sequence or activity diagrams, and the design constraints are stated.
4. The fourth and last chapter carries a formal analysis of the model through the use of the open source Alloy language and tool, including some configurations created by the tool.

2. Overall description

2.1 Product perspective

2.1.1 Class diagram

A UML class diagram describing the main entities involved in the system follows. Customers use the system to line up in the queue of a store and obtain a line up receipt, which will grant them a visit to the store. Each store belongs to a given chain of stores. Moreover, each store can be internally divided in departments, containing different categories of purchasable items. When the customers line up, they can specify the categories of items they intend to buy. Finally, the system knows the locations of the customers and of the stores.

The line up receipt is represented by a QR code for the customers that interact with the system with an IT device.

If the customers interact with the system using a standard telephone line, they are given a numeric code as a representation of the line up receipt, which they will be able to convert to a printed QR code line up receipt thanks to the store assistants outside of the store.

The customers who interact with the system in presence request the printed QR code line up receipt directly to the store assistants outside of the store.

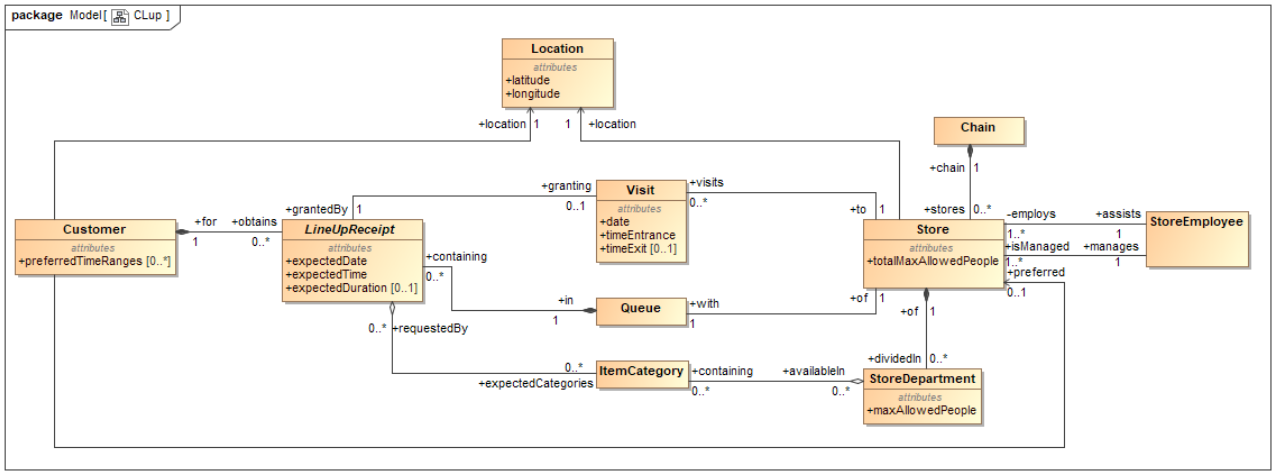


Figure 2.1: The class diagram of CLup's application domain.

2.1.2 State chart diagrams

The internal state of the main entities of the domain is better defined in the following UML state diagrams.

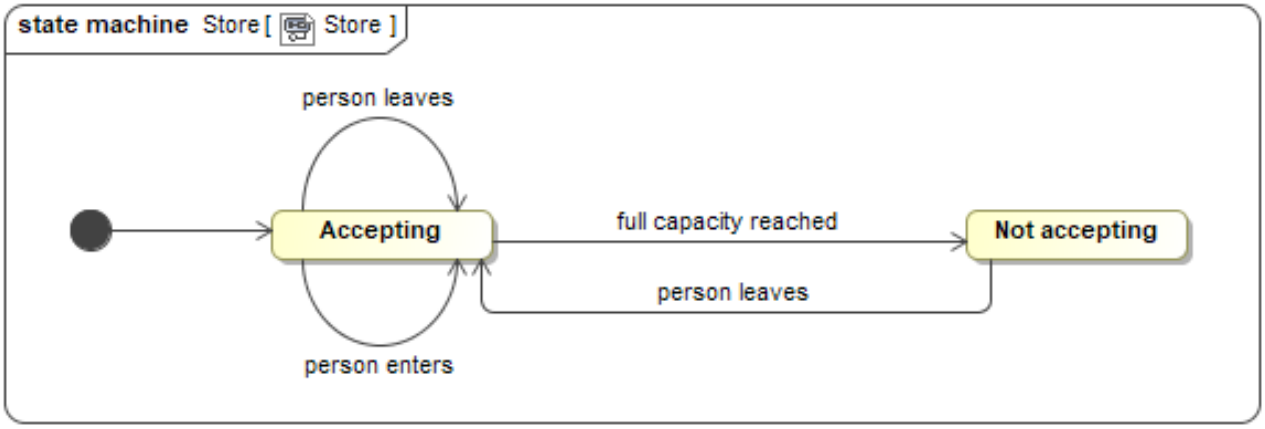


Figure 2.2: Statechart of a store in the application domain.

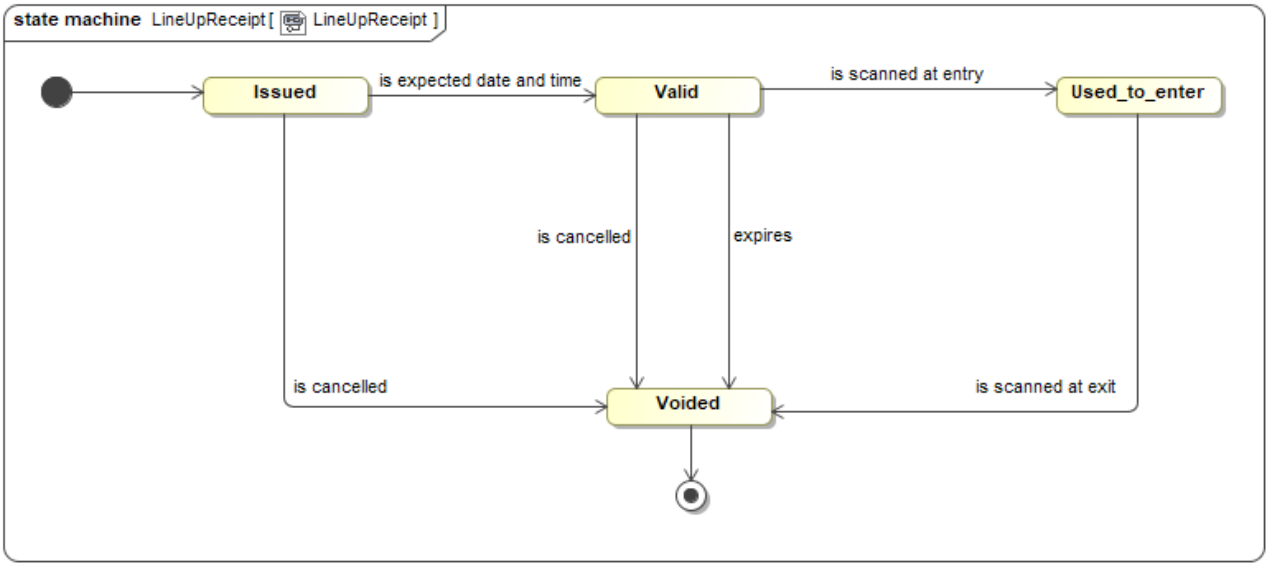


Figure 2.3: Statechart of a lineup receipt in the application domain.

2.1.3 Scenarios

2.1.3.1 Scenario 1

Luca lives in a country where lockdown policies are applied. The last time he shopped for groceries online, he forgot to add to the cart olive oil, and now he needs it. Waiting until the next delivery would take too much time, so Luca decides to line up for the nearest store. Luca opens CLup, looks for the nearest store and selects it. He then inserts the expected duration of his visit and the category of the item he wants to buy. Unfortunately, CLup estimates that the olive oil department will be busy for the next hours. CLup suggests an alternative store in proximity, where there is a free slot sooner. Luca accepts the suggestion and CLup queues Luca to access the store. Luca receives confirmation.

2.1.3.2 Scenario 2

Anna, a long time customer of the local store, wants to reserve a time slot to go grocery shopping the next week. Anna opens CLup and selects the desired store and the desired date and time slot. Not knowing yet which articles she might need, she does not fill the product categories section, and she does not provide any visit duration estimation. Once Anna confirms her intentions to CLup, the system predicts automatically the duration and the departments she is most likely to be in, based on the collected history of previous visits. CLup then checks if Anna's visit is compatible with the current schedule of the store, and, as the answer is positive, it shows a confirmation of the reservation to Anna.

2.1.3.3 Scenario 3

Maurizio reserved a slot in the queue to access the nearby store through CLup, but, due to an unforeseen commitment, he has to cancel the appointment. Maurizio opens CLup, selects the reservation and cancels it. The system removes Maurizio from the queue and sends a confirmation to the customer. Meanwhile, Patrizia wanted to access the store as soon as possible, but all the nearest time slots were busy, and the system delayed her reservation. CLup, aware of the recently freed time slot, sends a notification to Patrizia offering her to take it over. Patrizia opens CLup, accepts the offering and CLup queues her in the time slot.

2.1.3.4 Scenario 4

Alina is in line through CLup to access a store and her visit start time is near. CLup sends a notification to Alina to remind her of the visit. Alina departs from her home and approaches the store, showing the receipt on her IT device to the receipt scanner. CLup checks if the customer arrived either too early or too late with respect to the assigned time slot. Alina is perfectly in time and is allowed to enter the store. Finally, when the visit is coming to an end, Alina's receipt is shown once again at the store cashier, who scans it. CLup registers the end of the visit and sends a confirmation message to the cashier.

2.1.3.5 Scenario 5

Alessandro, a nurse, would like to stop at the store on the way home from work to do some urgent grocery shopping. Unfortunately, Alessandro's smartphone is out of charge, and he cannot use CLup. Alessandro stops at the store anyway, approaches the store assistant at the entrance, and asks for a receipt. The store assistant accesses CLup and requests to queue a visitor. The system adds the customer to the queue and sends the line up receipt as a confirmation. The store assistant prints the line up receipt and gives it to Alessandro, who waits his turn.

2.1.3.6 Scenario 6

Andrea does not own either a smartphone or a personal computer. Andrea would want to queue up immediately to go grocery shopping in a store adopting the CLup system, but, as he is missing any IT device, he can not access the system through the Internet. Andrea calls CLup's number, and the system guides him through the process: first of all, the synthesized voice asks Andrea if he would like to access the store as soon as possible or to reserve a time slot, and then the store he would like to visit. Once Andrea has answered the questions and confirmed his intentions, the system adds Andrea to the queue of the store. The system then dictates the numeric code to be used at the entrance of the store. Once Andrea confirms that he has understood the code, the interaction is closed.

2.1.3.7 Scenario 7

This time, Andrea would want to reserve a time slot to go grocery shopping next week. Andrea calls CLup's number and states, once asked, that he would like to use the reservation functionalities. CLup asks Andrea, in sequence, which store he would like to access, at what date, and at which time. The system repeats Andrea's choices and asks for confirmation. Once Andrea confirms, the system estimates the visit duration and checks if it is compatible with the current schedule. The system then dictates the numeric code to be used at the entrance of the store. Once Andrea confirms that he has understood the code, the interaction is closed.

The following week Andrea gets a call from CLup, as a notification for the incoming visit. As Andrea approaches the store, he goes to the store assistant, and shows her the numeric code for the visit. The store assistant accesses CLup, and provides the system the numeric code. The system gives a successful response to the store assistant, who then prints the ticket valid for the visit and hands it to Andrea. Now Andrea can access the store and do the shopping.

2.1.3.8 Scenario 8

Michael is a store manager at a famous supermarket chain, in a country in which COVID restrictions are in effects. One day, the country's government releases new safety standards for supermarkets safety, which includes the maximum amount of people per squared meter who can access the store. The next day, before the store opening, Michael needs to update its safety parameters with the newly defined ones. To do this, Michael accesses CLup system, and then requests to update the safety parameters. The system asks Michael for the confirmation and he confirms. The system now saves the new parameters, and puts them into effect, modifying the store queue availability.

2.1.3.9 Scenario 9

The same day Michael set the new safety parameters, the authorities come into his supermarket, asking for the supermarket's statistics about customers flux inside the supermarket. Michael accesses CLup system, and then requests to see the required statistics. The system provides the requested statistics, and Michael hands them to the authorities.

2.2 Product functions

The following functionalities must be provided by the system in order to satisfy the previously stated goals:

ID	Requirement
R1	The system must grant access to the store if and only if the desired safety standard are respected.
R2	The system must allow store managers to set the desired safety standards.
R3	The system must provide store managers with statistics about the accesses to the store.
R4	The system must allow every user to line up to access the store.
R5	The system must allow store assistants to act as proxies of multiple users.
R6	The system must provide the user with a valid receipt to enter the store at the assigned time.
R7	If a user owns an IT device or a telephone, the system must allow them to reserve a place in a queue in advance for a given day and time.
R8	The system must estimate the duration of a visit by a user who reserved a place, even if the user does not provide any indication on the visit duration.
R9	The system must estimate the departments visited by a user who reserved a place, even if the user does not provide any indication on the product category.
R10	In case of reservation, the system must grant access to the user before the ticket expires.
R11	If a user owns an IT device, the system must notify the user, based on their location, when it's time to leave to go to the store in time for the assigned entrance time.
R12	The system must not grant access to the user if their ticket is voided.
R13	If the number of people accessing the store in a given time and date is estimated to exceed to the desired security standard, the system must suggest alternative time slots and dates or an alternative stores to the user.
R14	The system must suggest a store reachable by the user.
R15	The system must suggest a time and date compatible with the user's schedule.
R16	If a time slot becomes free due to a cancellation, the system must offer users already in the queue the possibility to take over the time slot, and, if no users accepts, the system must mark the slot as available.

2.2.1 Mappings with goals

Goal ID	Requirement IDs
G1	R1, R2, R12, R13
G2	R1, R8, R9, R13
G3	R1, R2, R3, R8, R9, R12
G4	R4, R5, R6, R7, R10, R14, R15
G5	R7, R8, R10, R11, R16
G6	R13, R14, R15, R16
G7	R13, R14, R15, R16
G8	R7, R13, R15, R16
G9	R4, R13, R14, R16

2.3 User characteristics

The following users are addressed by the system:

- Store customers: people of any age, gender, nationality, and education interested in accessing the store. This includes people with physical or visual disabilities.
- Store managers: employees whose responsibility is to monitor and regulate the flow of people inside the supermarket.
- Store assistants: employees in charge of releasing the queue ticket to customers requesting them on-site.
- Store cashiers: employees in charge of scanning tickets at the time of checkout to register exits of the customers.

2.4 Assumptions, dependencies and constraints

2.4.1 Domain assumptions

ID	Domain assumption
DA1	The number of people who can access the store is either decided by the authorities, or by the manager, respecting the law.
DA2	Customers won't try to bypass the store access control measures.
DA3	The population is evenly distributed on the territory among store locations.
DA4	All customers who enter the supermarket check out with a human or automatic cashier.
DA5	All customers only visit the areas of the supermarket containing the item categories they declared when reserving their entrance through the system.
DA6	Customers will not form crowds outside of the store, if the queue is moderately long.
DA7	Few people do not have an IT device with support for Internet connectivity or a standard telephone line.

2.4.2 Constraints

In order to improve the ease of use of the system, customers will not authenticate to the system. For all the functionalities that require to know the identity of the customers, the system will use:

- when customers access the system with an IT device, a device identifier that the system generates and binds to the device itself
- when customers access the system with a standard telephone line, the caller identifier of the telephone line (telephone number)

For the authentication of store personnel (i.e., store assistants and store managers), instead, the system will integrate with the stores' identity systems.

3. Specific requirements

3.1 External interface requirements

3.1.1 User interfaces

3.1.1.1 User interfaces for the customers

User interfaces for the customers should be easy to use, thus taking into account the needs of people of all ages and possibly with disabilities.

All the customers need to interact with receipt scanners at the entrance of the stores to get access rights. Then, depending on the channel that customers want to use to obtain a line-up receipt, they may need to interact with additional user interfaces, as described in the following paragraphs.

User interfaces for the customers using IT devices The following mockups can be navigated with elementary interactivity at this link.

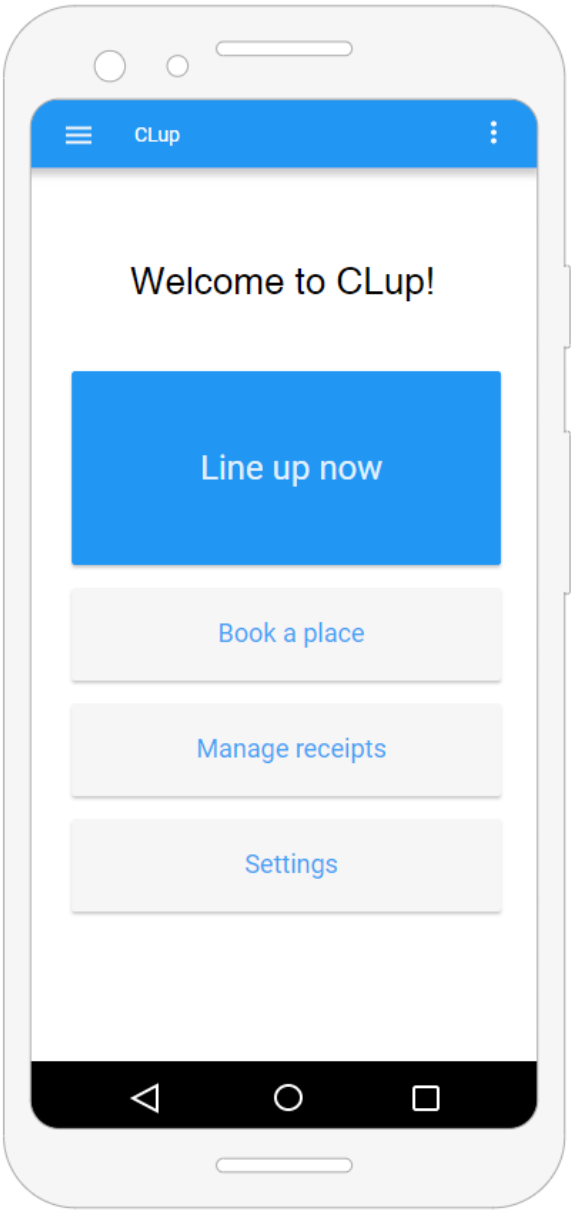


Figure 3.1: The welcome page.

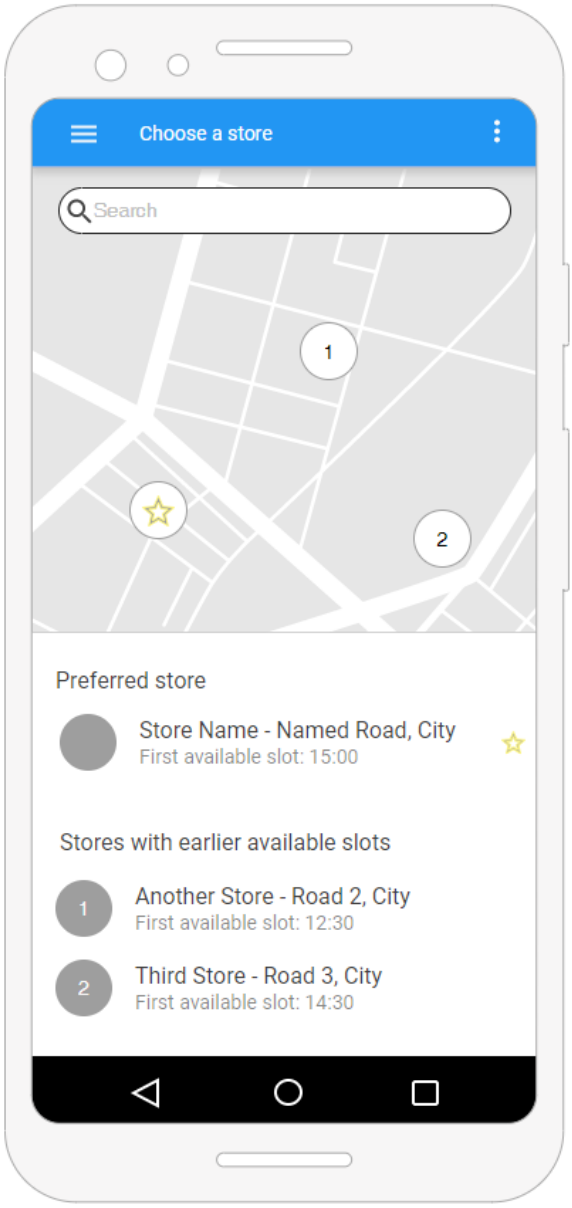


Figure 3.2: The stores map.

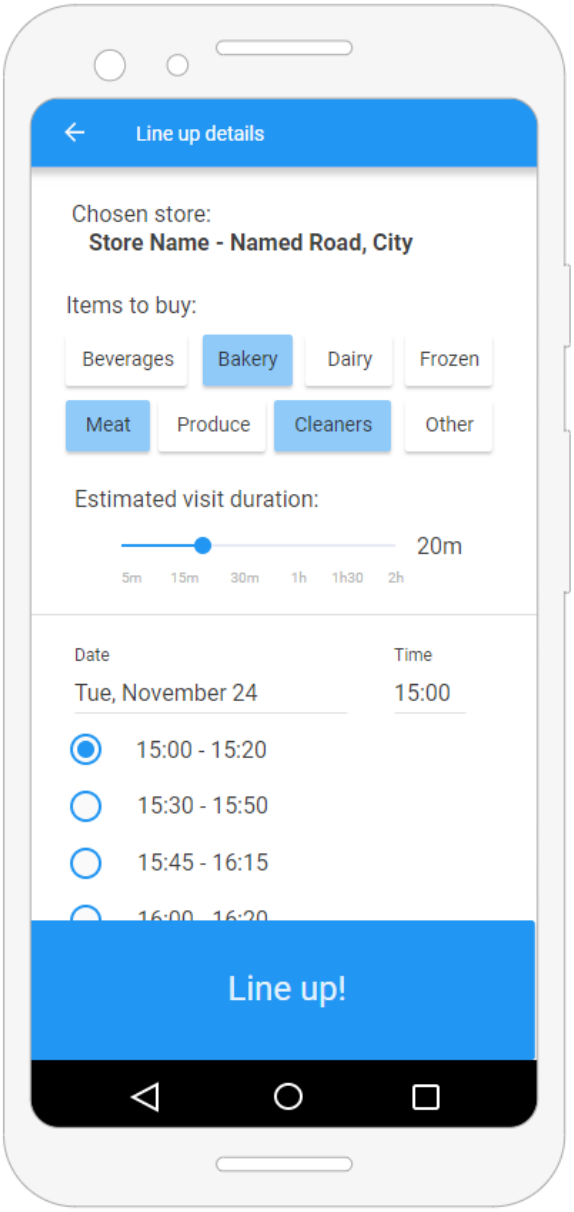


Figure 3.3: The booking function.

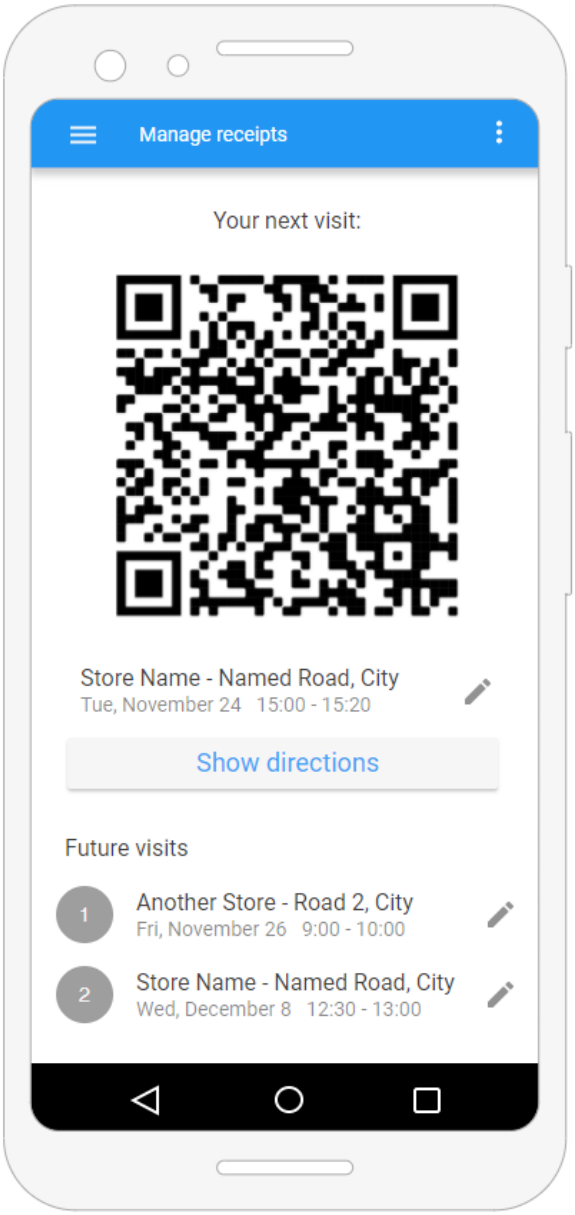


Figure 3.4: The line up receipt.

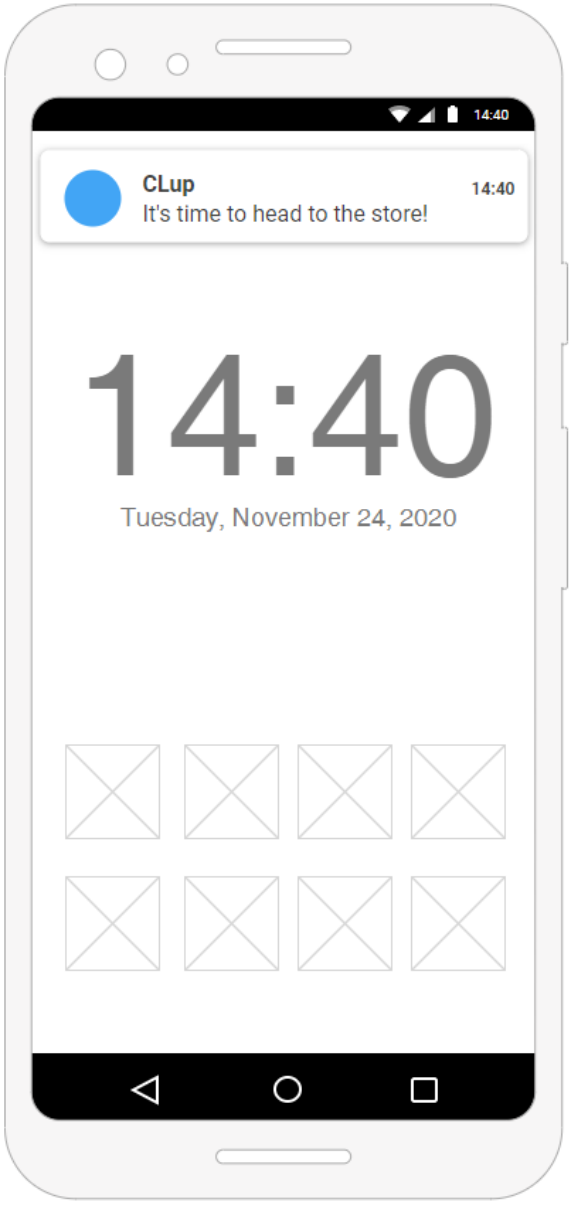


Figure 3.5: A push notification.

User interfaces for the customers using a standard telephone line Customers using a standard telephone line are allowed to use the system, although with limited functionality. Customers can interact with the system by calling a dedicated telephone number. An interactive system picks up the call, receives input from the customer through speech recognition and DTMF tones recognition, and replies to the customer through speech synthetization.

User interfaces for the customers using the system in presence (fallback method) Customers who cannot use one of the other methods described before can interact with the system, with limited functionality, thanks to store assistants outside of the stores. The assistants act as a proxy to the system for the customers, so no specific user interface is needed for these customers.

3.1.1.2 User interfaces for the store assistants

Store assistants can interact with the system to generate line up tickets for the customers.

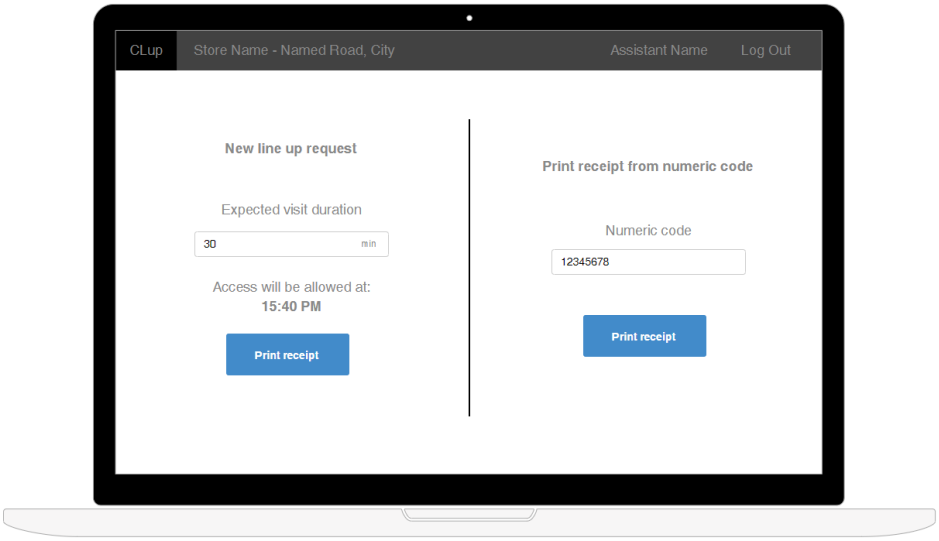


Figure 3.6: The interface for store assistants.

3.1.1.3 User interfaces for the store managers

Store managers can interact with the system to monitor the number of people inside the stores and to define limitations on the maximum number of people allowed in each department of the store.

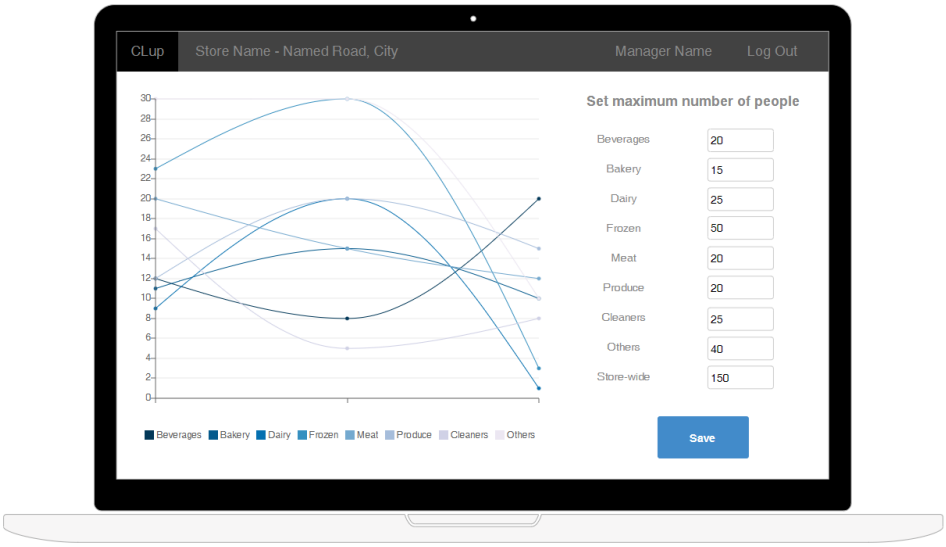


Figure 3.7: The interface for store managers.

3.1.2 Hardware interfaces

Customers who want to interact with the system with full functionality need to have an IT device with support for Internet connectivity (mandatory) and able to provide geolocation information (optional). Customers who do not satisfy this requirement but still want to interact with the system remotely need to have any kind of devices that is able to place phone calls to a standard telephone number.

Store assistants and store managers need to have an IT device with support for Internet connectivity. Store assistants systems need to interact with printers placed outside of the stores to print line up receipts for the customers that initially used a telephone line to interact with the system or for the ones who chose to use the system in presence, as a fallback.

Moreover, the system interacts with receipt scanners with support for Internet connectivity. Such devices will be placed at the entrance of the stores and they will unlock access control devices to let the customers enter.

Finally, the system interacts with receipt scanners with support for Internet connectivity placed at the cash counters (both automatic and human-managed) to register the end of a visit to the store.

3.1.3 Software interfaces

The IT device used by customers who want to interact with the system with full functionality, by store assistants and by store managers need to either have an Internet browser with HTML5 capabilities installed, or support the installation of native apps for the supported platforms (Android, iOS). Depending on the requirement which is satisfied, the system will use browser APIs or system APIs to interact with the user upon user request or with push notifications.

The system interacts with the software interfaces of the automatic phone call provider thanks to which customers can interact via a standard telephone line.

3.1.4 Communication interfaces

Customers who want to interact with the system with full functionality, store assistants, store managers and the devices that scan the customers' line up receipt use any kind of Internet connection to communicate with the system. Devices of customers who want to interact with the system with full functionality which are able to provide geolocation information use such system (GPS or equivalent) to retrieve the location. Customers who want to interact with the system remotely but do not have a suitable IT device use a standard telephone line to communicate with the system.

The system uses an Internet connection to communicate with the automatic phone call provider thanks to which customers can interact via a standard telephone line.

3.2 Functional requirements

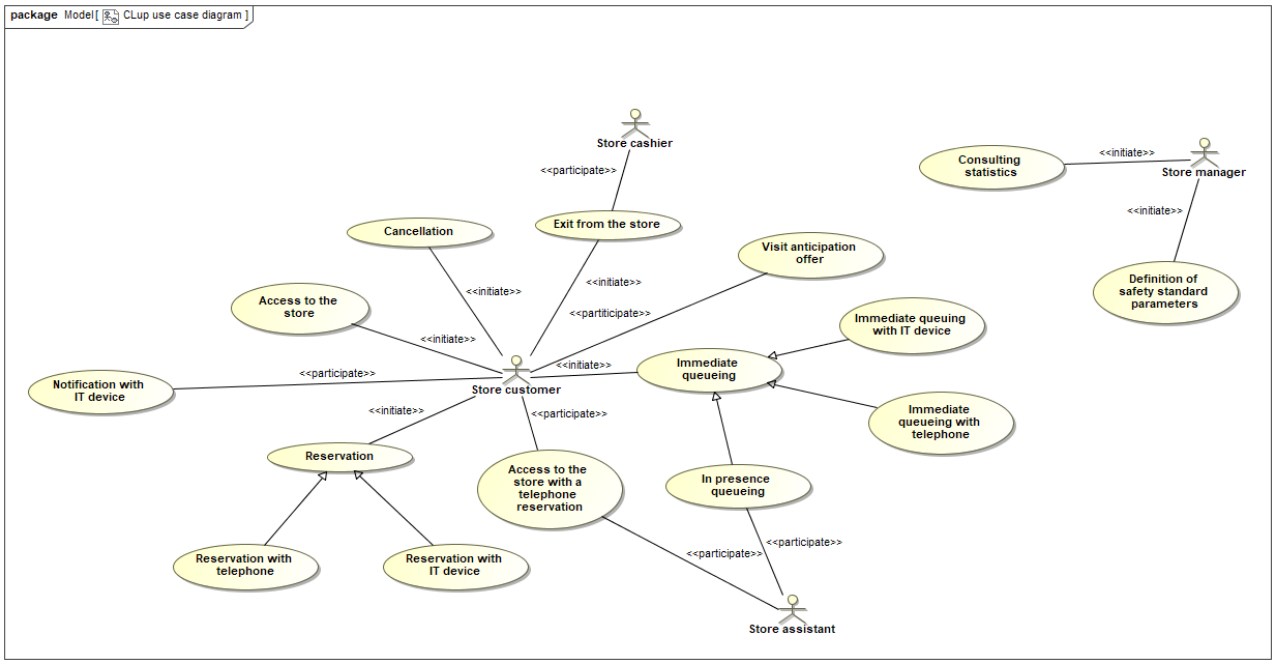


Figure 3.8: Use case diagram

3.2.1 Immediate queueing with IT device

Use Case	Immediate queueing with IT device
Actor	Store customer
Entry condition	The customer wants to access a store as soon as possible
Flow of events	• The customer selects the store they want to access • The customer inserts the expected duration of the visit • The customer inserts the categories of products they want to buy • The customer confirms their intention • The system estimates the expected duration of the visit and the visited departments • The system checks if the store has a free slot for the customer • The store has a free slot • The system queues the customer
Exit condition	The system shows a confirmation message to the user
Exceptions	If the store does not currently have a free time slot, the system will suggest an alternative store. If the customer still wants to queue for their store of choice, the system queues the user for the first available time slot.
Mapped requirements	R1, R6, R4, R8, R9, R13, R14, R15

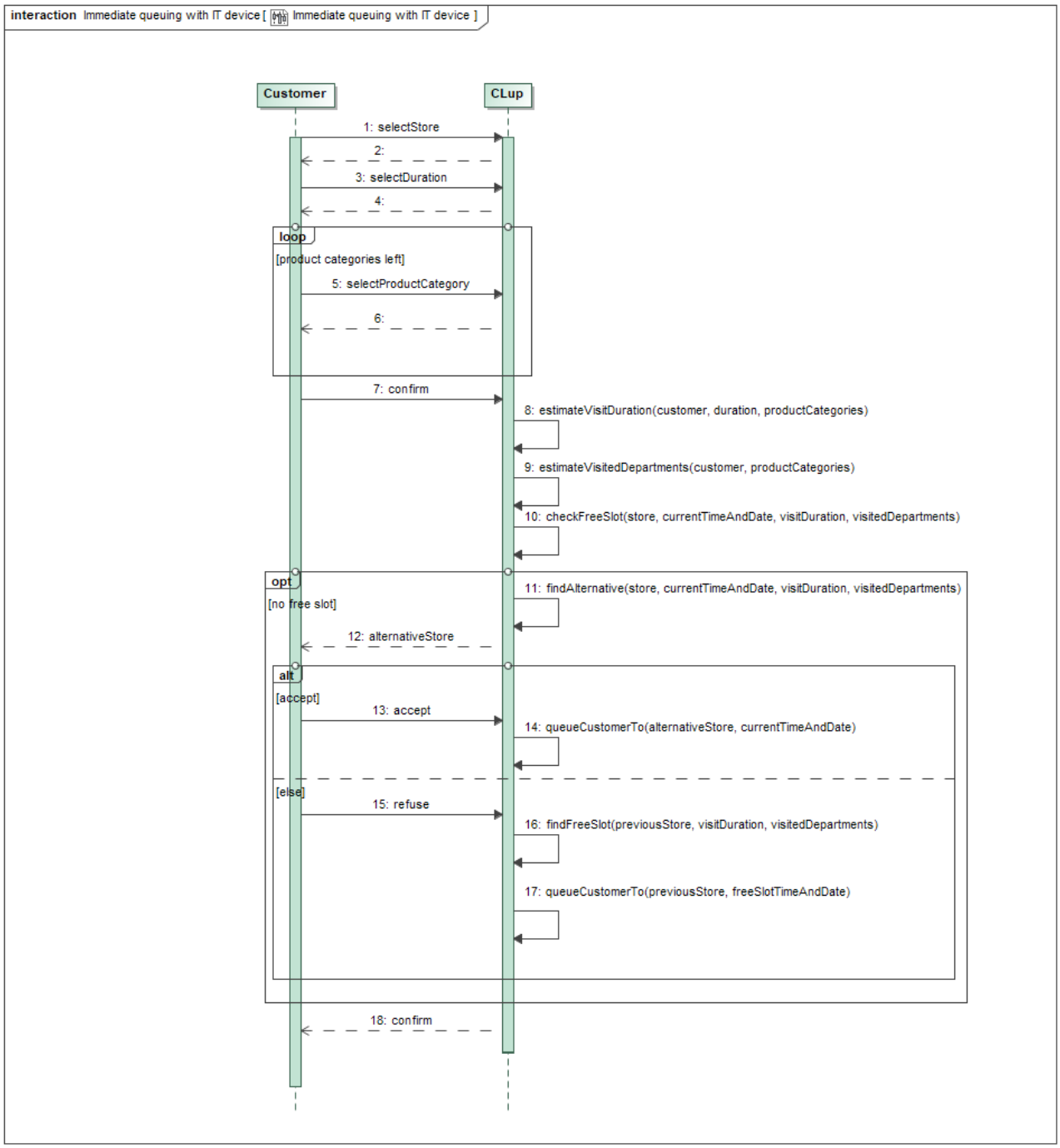


Figure 3.9: Immediate queuing with IT device sequence diagram

3.2.2 Reservation with IT device

Use Case	Reservation with IT device
Actor	Store customer
Entry condition	The customer wants to reserve a visit to the store
Flow of events	• The customer selects the store they want to access • The customer selects the time and date of the visit • The customer confirms their intention • The system estimates the expected duration of the visit and the visited departments • The system checks if the store has a free slot for the customer • The store has a free slot • The system queues the customer in the time slot
Exit condition	The system shows a confirmation message to the user
Exceptions	If the desired time slot and store are not compatible with the current scheduled queue, the system will suggest an alternative.
Mapped requirements	R1, R6, R7, R8, R9, R13, R14, R15

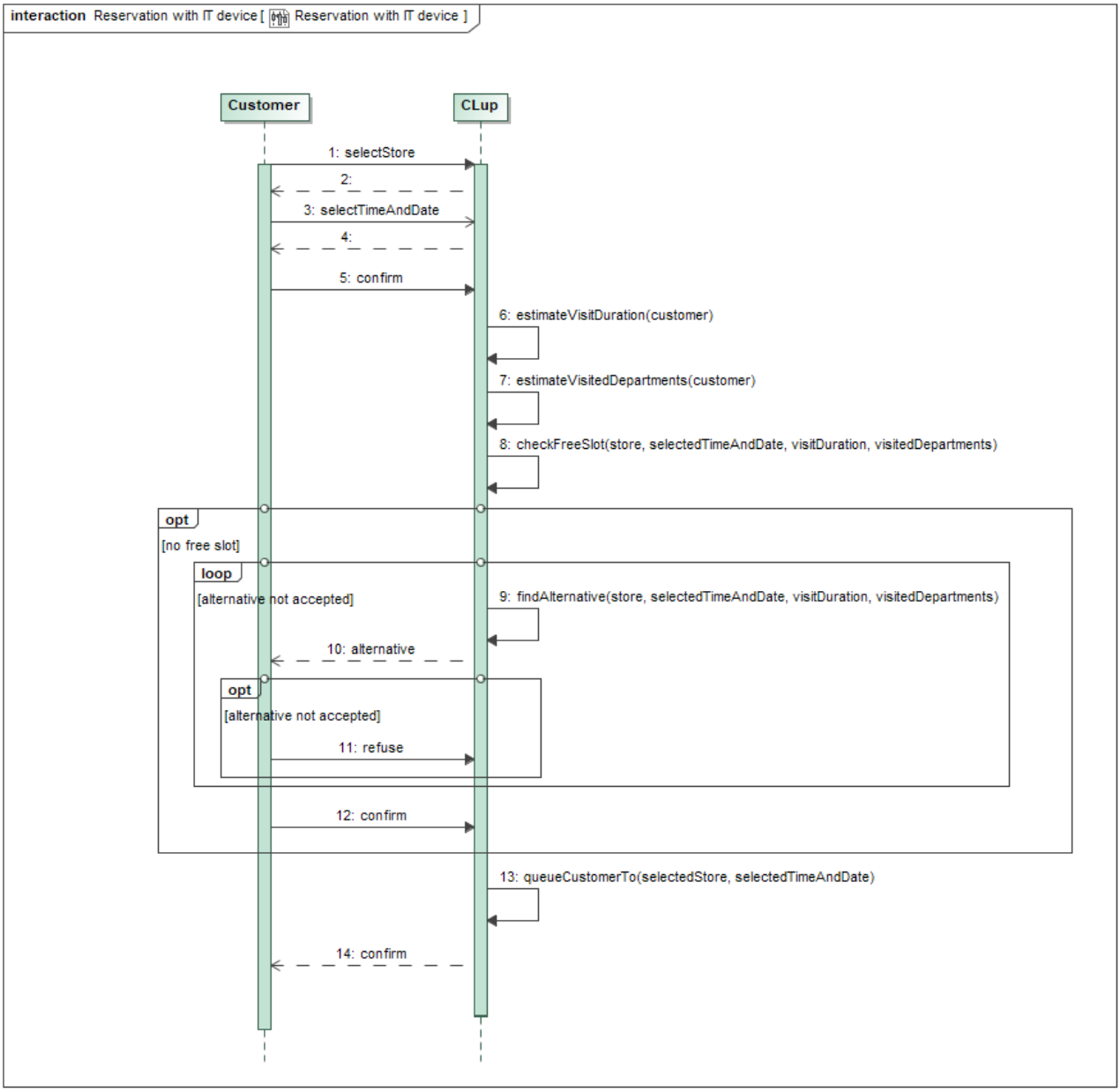


Figure 3.10: Reservation with IT device sequence diagram

3.2.3 Cancellation

Use Case	Cancellation
Actor	Store customer
Entry condition	A customer wants to cancel their reservation
Flow of events	• The customer select the cancellation option • CLup removes the customer from the queue
Exit condition	The system shows a confirmation message to the user
Exceptions	
Mapped requirements	R16

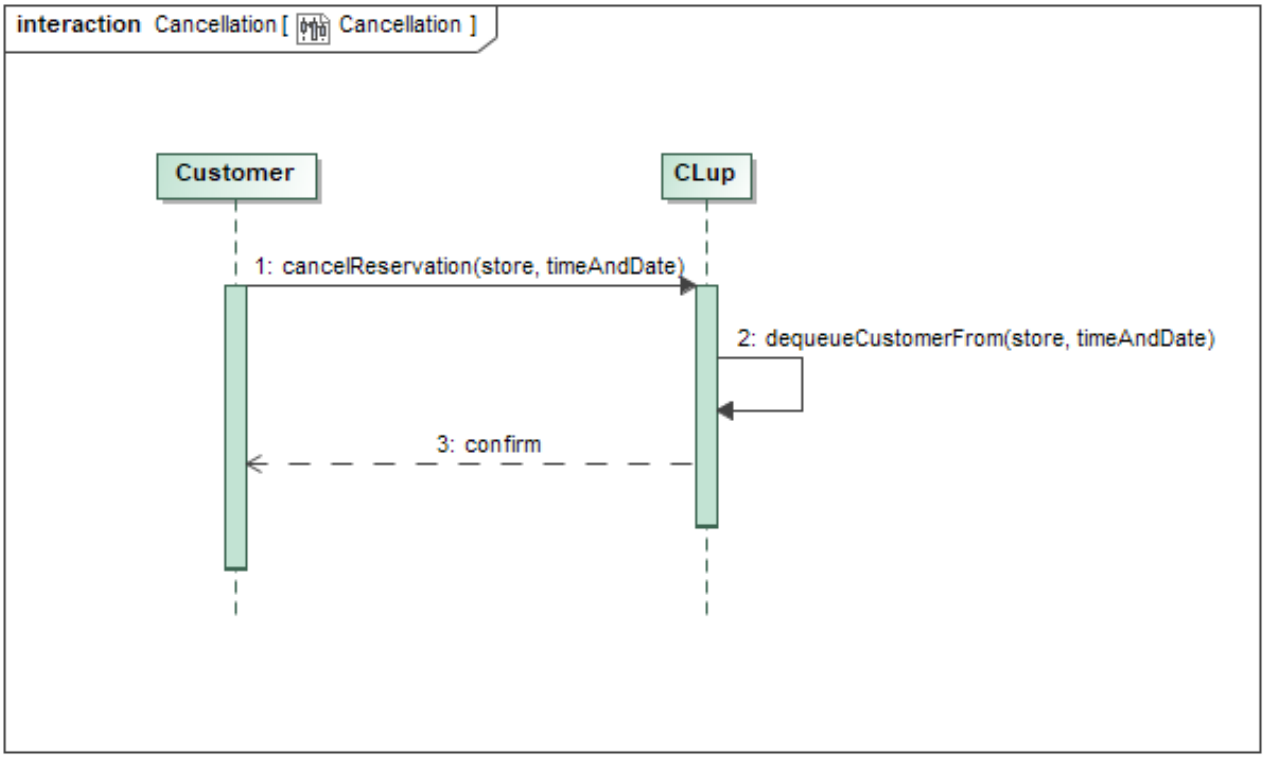


Figure 3.11: Cancellation sequence diagram

3.2.4 Visit anticipation offer

Use Case	Visit anticipation offer
Actor	Store customer
Entry condition	A customer cancels their reservation
Flow of events	• CLup checks if there is some user wanting to access the store as soon as possible and scheduled for a later visit • CLup sends a notification to the customer, offering to move up the visit • The customer accepts the offer • CLup queues the customer in the time slot
Exit condition	The system shows a confirmation message to the user
Exceptions	If no user accepts, the slot is kept free.
Mapped requirements	R14, R15, R16

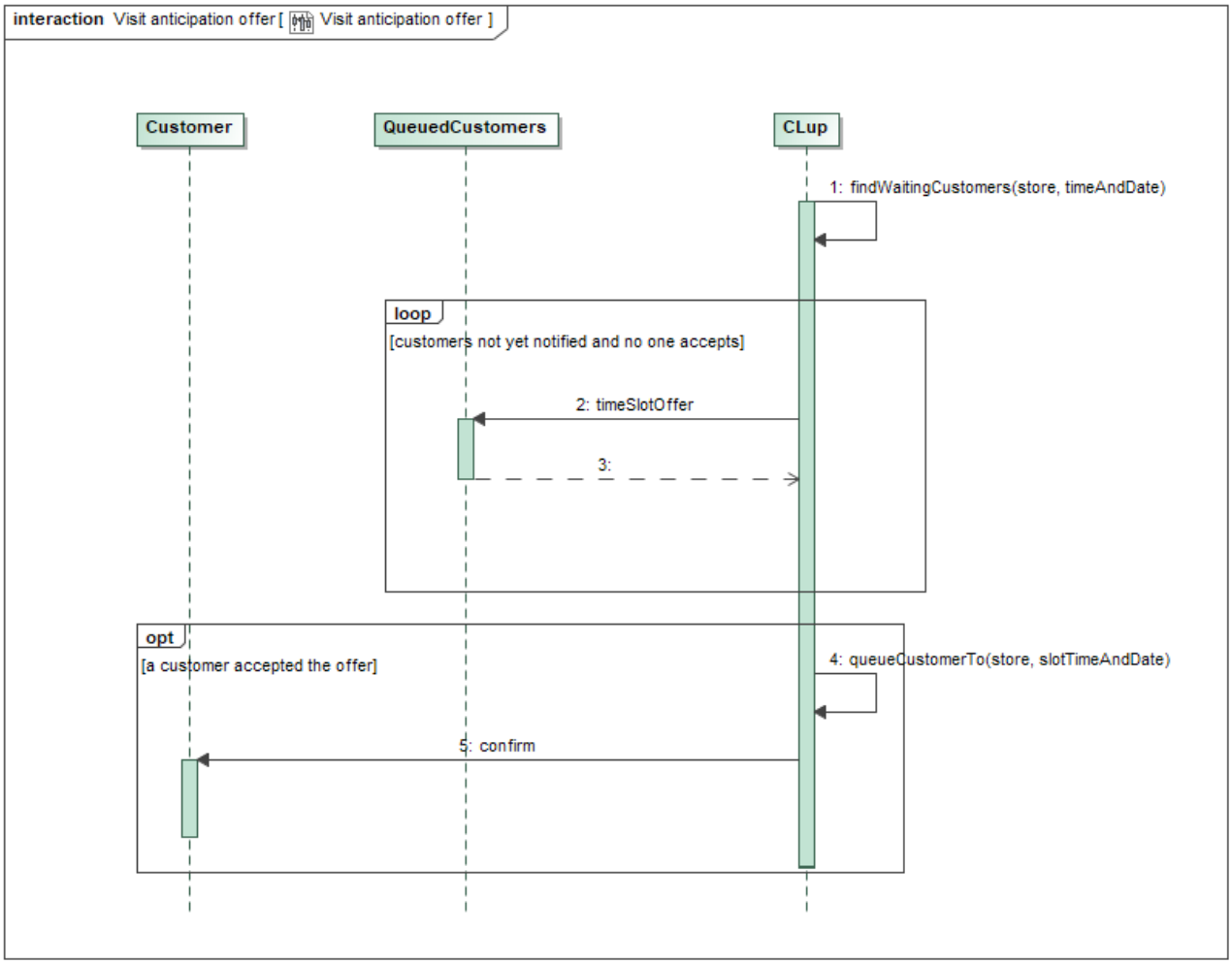


Figure 3.12: Visit anticipation offer sequence diagram

3.2.5 Notification with IT device

Use Case	Notification with IT device
Actor	Store customer
Entry condition	A customer's visit start time is near
Flow of events	• CLup sends the customer a notification to remind them of the visit
Exit condition	The customer approaches the store
Exceptions	
Mapped requirements	R10, R11

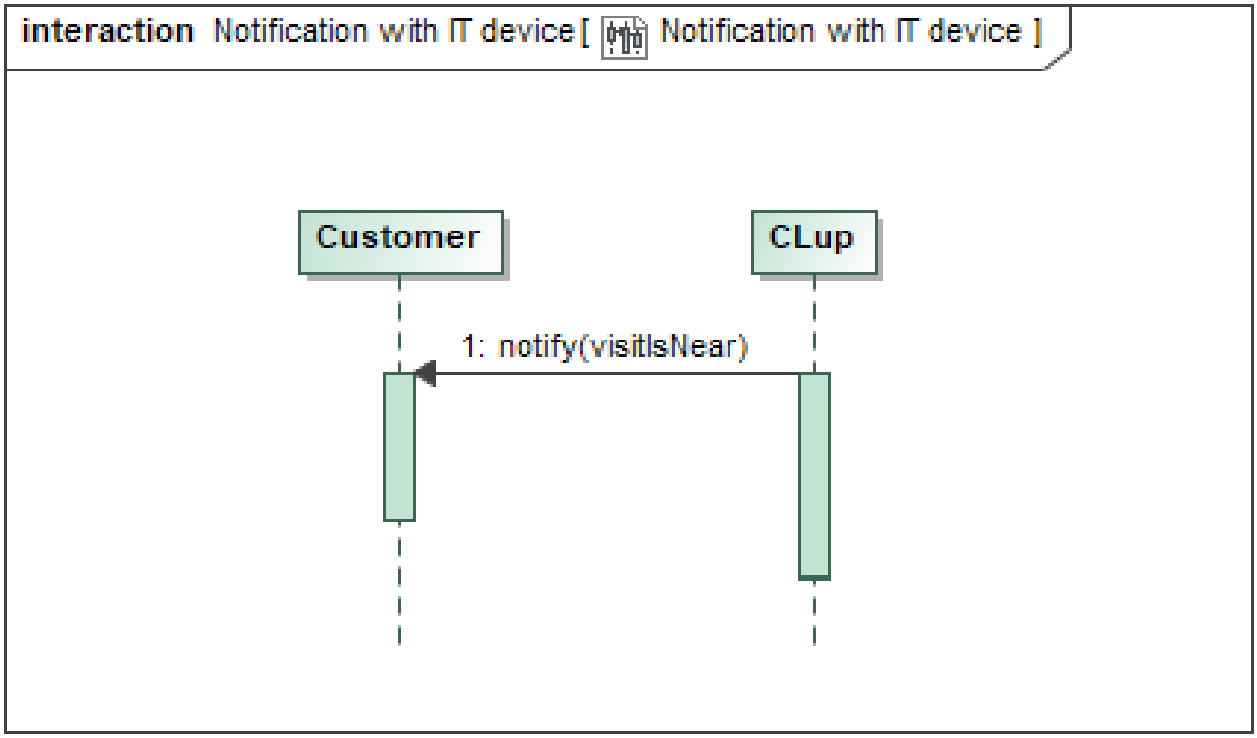


Figure 3.13: Notification with IT device sequence diagram

3.2.6 Access to the store

Use Case	Access to the store
Actor	Store customer
Entry condition	A customer approaches the store
Flow of events	• The customer scans their receipt at the store entrance • CLup checks if the current time is compatible with the receipt's start time slot
Exit condition	CLup allows the customer to enter the store
Exceptions	If the customer scans the receipt outside their time slot, they are not allowed to enter the store.
Mapped requirements	R10, R12

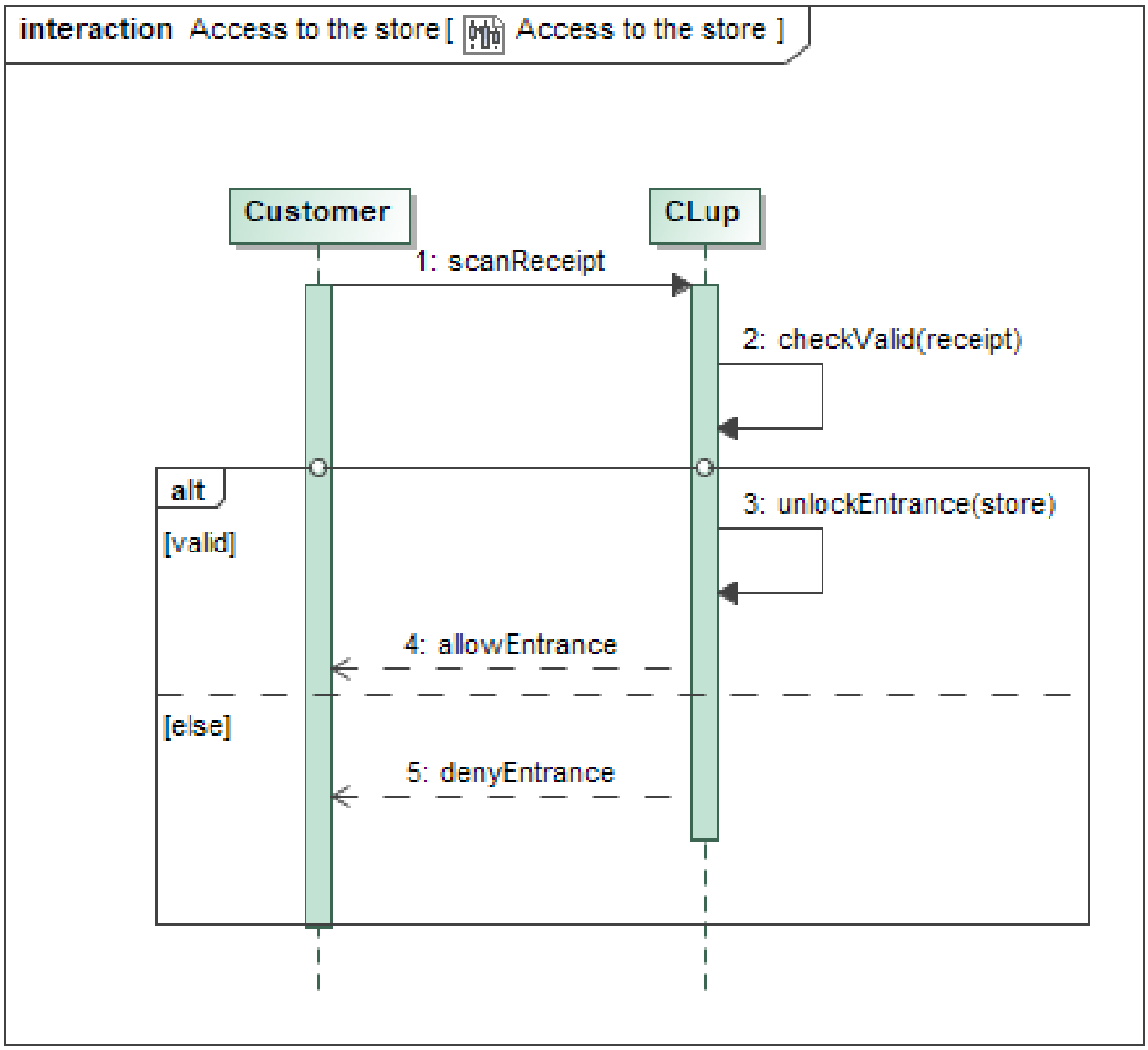


Figure 3.14: Access to the store sequence diagram

3.2.7 Exit from the store

Use Case	Exit from the store
Actor	Store customer, store's cashier
Entry condition	A customer has finished shopping
Flow of events	• The customer shows CLup's receipt to the store's cashier • The store's cashier scans the receipt • CLup registers the end of the visit
Exit condition	The system shows a confirmation message to the store's cashier
Exceptions	
Mapped requirements	R3, R12

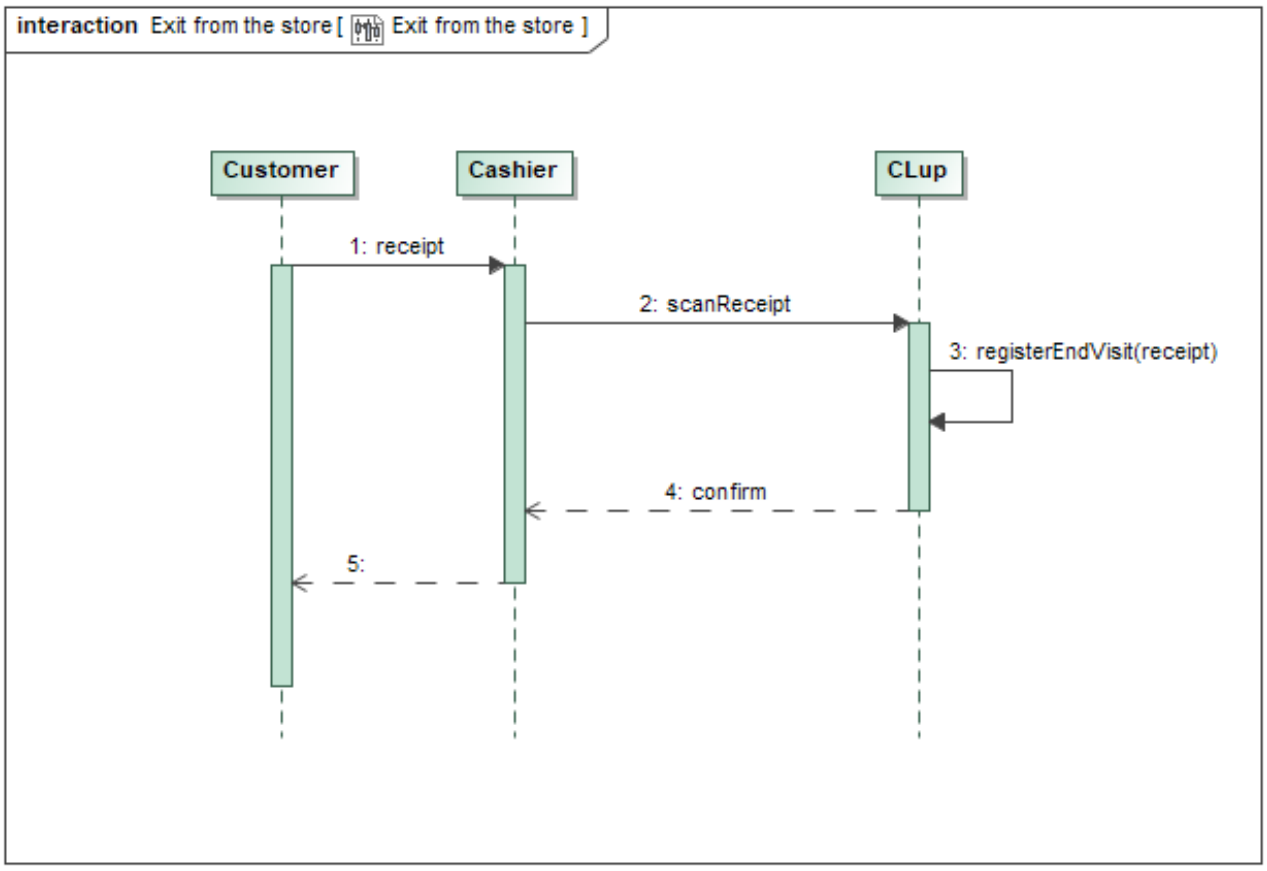


Figure 3.15: Exit from the store sequence diagram

3.2.8 In presence queueing

Use Case	In presence queueing
Actor	Store customer, store assistant
Entry condition	A customer asks a store assistant for a line up receipt
Flow of events	• The store assistant accesses CLup • The store assistant requests CLup to queue the customer • The system estimates the expected duration of the visit and the visited departments • The system finds the first available time slot in the assistant's store • CLup adds the customer to the queue in the first available time slot • CLup sends the line up receipt to the store assistant as a confirmation • The store assistant prints the line up receipt
Exit condition	The store assistant gives the printed line up receipt to the customer
Exceptions	
Mapped requirements	R1, R4, R5, R6, R8, R9

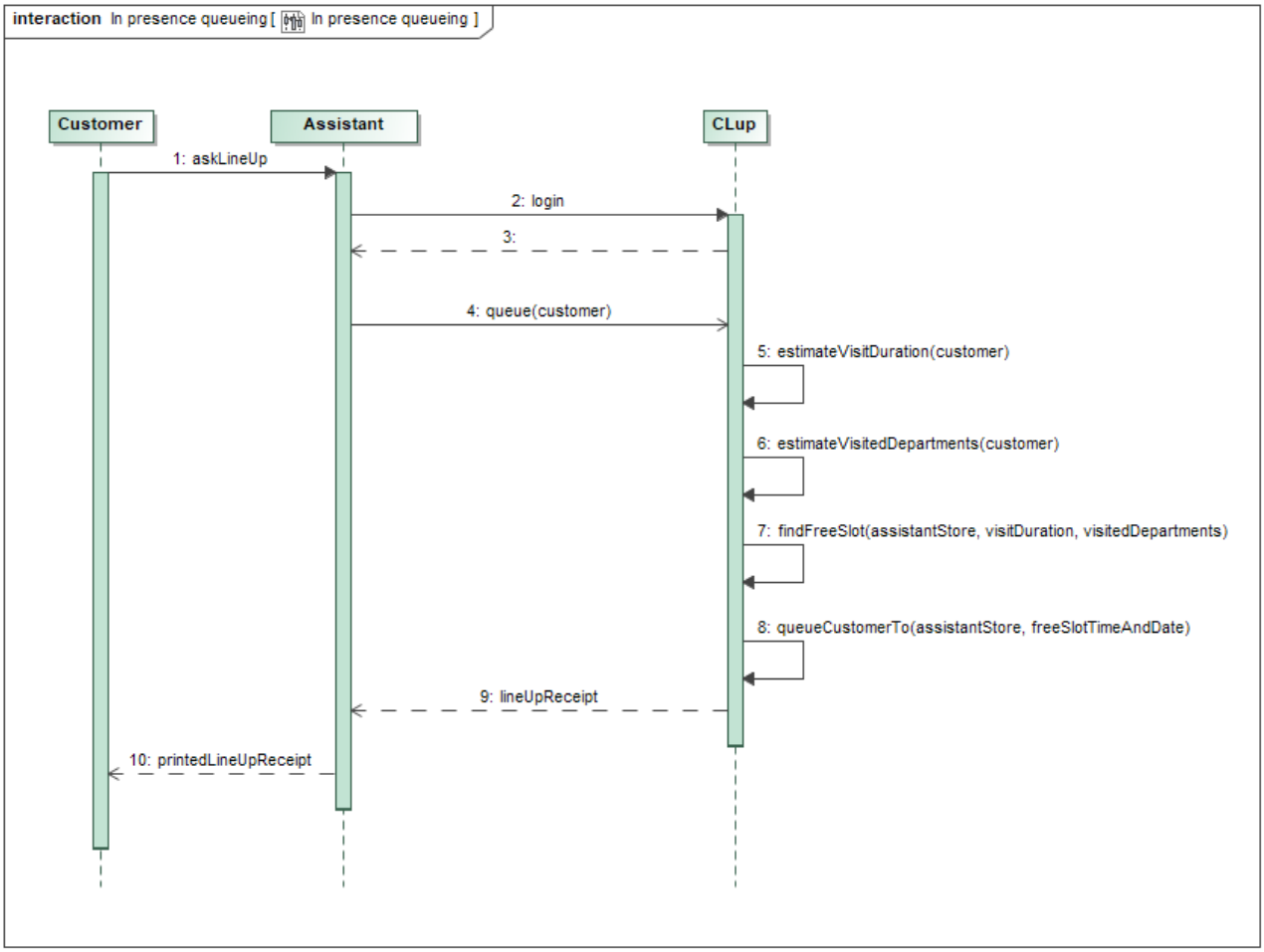


Figure 3.16: In presence queueing sequence diagram

3.2.9 Immediate queueing with telephone

Use Case	Queueing with telephone
Actor	Store customer
Entry condition	A customer calls CLup's telephone number
Flow of events	• CLup asks the customer if they would like to access the store as soon as possible or to reserve a time slot • The customer says they want to access the store as soon as possible • CLup asks which store the customer wants to access • The customer states the store they would like to access • CLup repeats the chosen options and asks for confirmation • The customer confirms their intentions • The system adds the customer to the queue to enter the store • CLup dictates the numeric code to use at the entrance to the customer • CLup asks for confirmation that the numeric code has been understood
Exit condition	The customer confirms
Exceptions	If the chosen store does not have any available slot, the system suggests an alternative. If the customer does not confirm their intentions, the system states again the available options. If the customer does not confirm the reception of the numeric code, the system repeats the numeric code.
Mapped requirements	R1, R4, R8, R9, R13, R14, R15

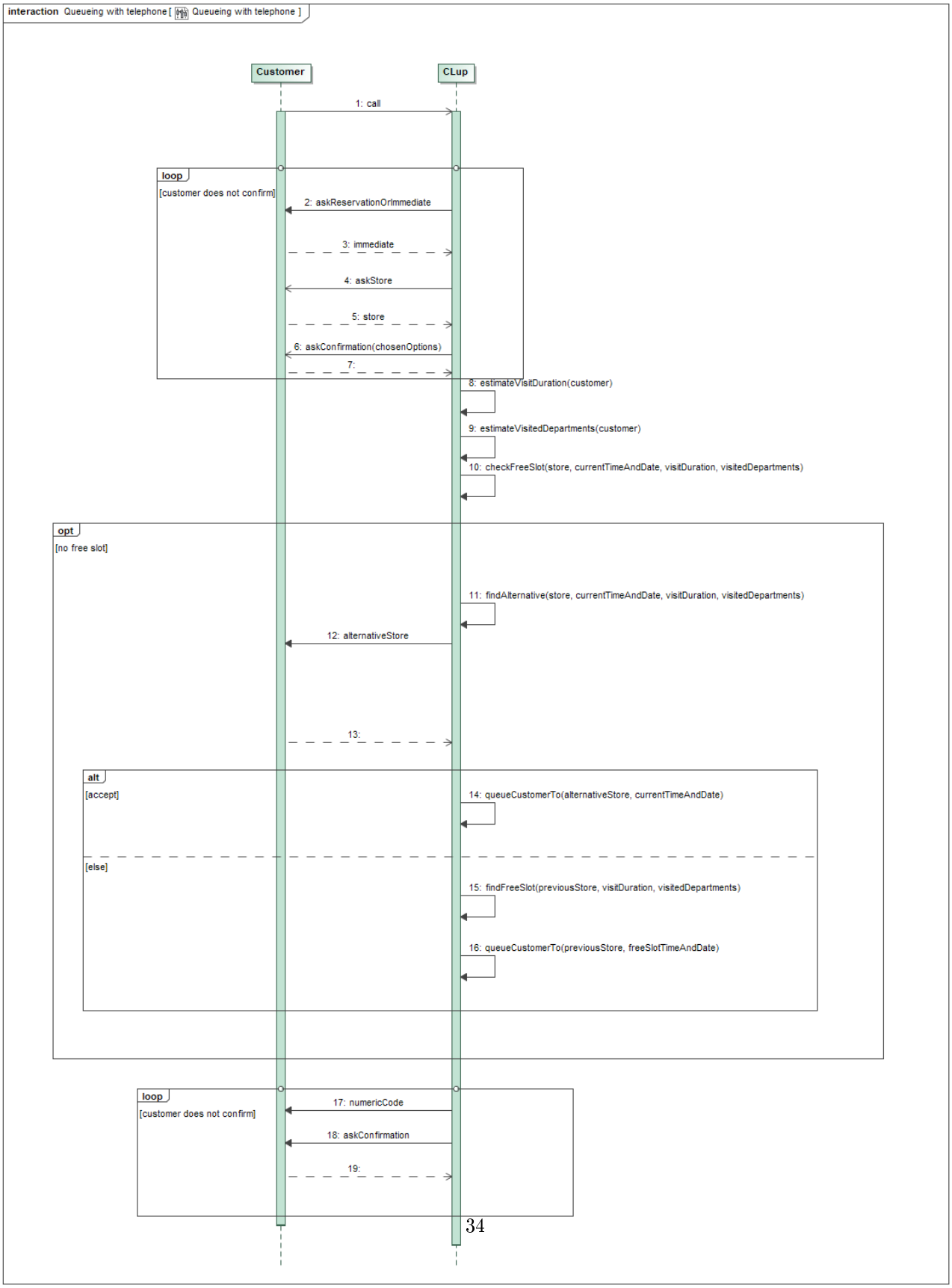
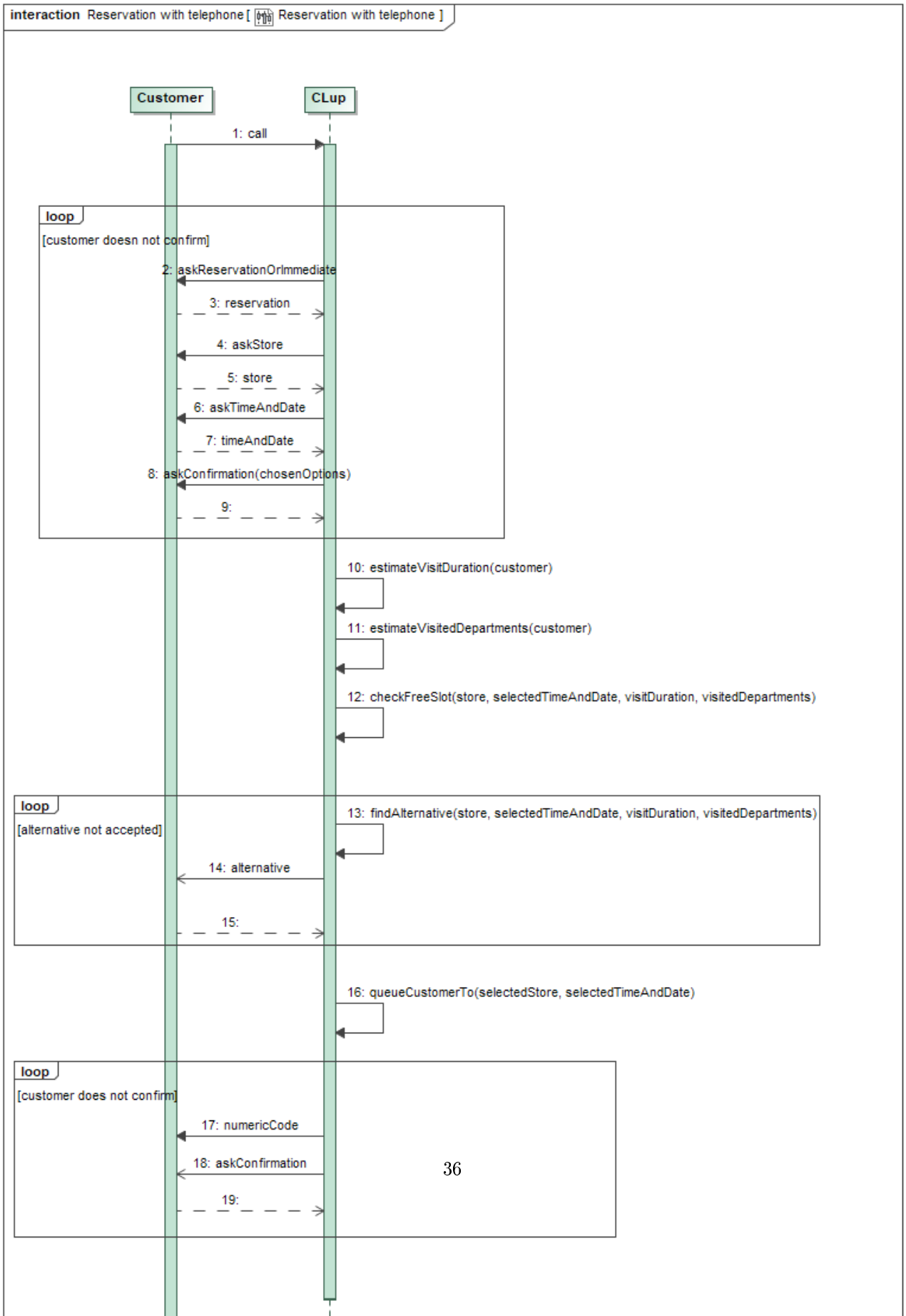


Figure 3.17: Queueing with telephone sequence diagram

3.2.10 Reservation with telephone

Use Case	Reservation with telephone
Actor	Store customer
Entry condition	A customer calls CLup's telephone number
Flow of events	• CLup asks the customer if they would like to access the store as soon as possible or to reserve a time slot • The customer says they want to reserve a time slot • CLup asks which store the customer wants to access • The customer states the store they would like to access • CLup asks in which date the customer would like to access the store • The customer states the desired date • CLup asks at which time the customer would like to access the store • The customer states the desired time • CLup repeats the chosen options and asks for confirmation • The customer confirms their intentions • CLup estimates the visit duration • CLup checks if the visit is compatible with the current schedule • The system adds the customer to the queue to enter the store • CLup dictates the numeric code to use at the entrance to the customer • CLup asks for confirmation that the numeric code has been understood
Exit condition	The customer confirms
Exceptions	If the reservation is not compatible with the current schedule, the system suggests an alternative. If the customer does not confirm their intentions, the system states again the available options. If the customer does not confirm the reception of the numeric code, the system repeats the numeric code.
Mapped requirements	R1, R7, R8, R9, R13, R14, R15


interaction Reservation with telephone [Reservation with telephone]
Customer
CLup
1: call
loop
[customer doesn not confirm]
2: askReservationOrImmediate
3: reservation
4: askStore
5: store
6: askTimeAndDate
7: timeAndDate
8: askConfirmation(chosenOptions)
9:
10: estimateVisitDuration(customer)
11: estimateVisitedDepartments(customer)
12: checkFreeSlot(store, selectedTimeAndDate, visitDuration, visitedDepartments)
loop
[alternative not accepted]
13: findAlternative(store, selectedTimeAndDate, visitDuration, visitedDepartments)
14: alternative
15:
16: queueCustomerTo(selectedStore, selectedTimeAndDate)
loop
[customer does not confirm]
17: numericCode
18: askConfirmation
19:

3.2.11 Access to the store with a telephone reservation

Use Case	Accessing the store with a telephone reservation
Actor	Store customer, store assistant
Entry condition	The visit start time of a customer who has reserved a place in the queue via telephone call is near
Flow of events	• CLup system calls the user, to remind them of the visit • The customer approaches the store • The customer goes to a store assistant, and shows them the numeric code • The store assistant accesses CLup system • The store assistant checks the numeric code
Exit condition	The store assistant prints the line up receipt
Exceptions	If the numeric code is invalid or expired, CLup returns an error to the store assistant.
Mapped requirements	R6, R10, R11

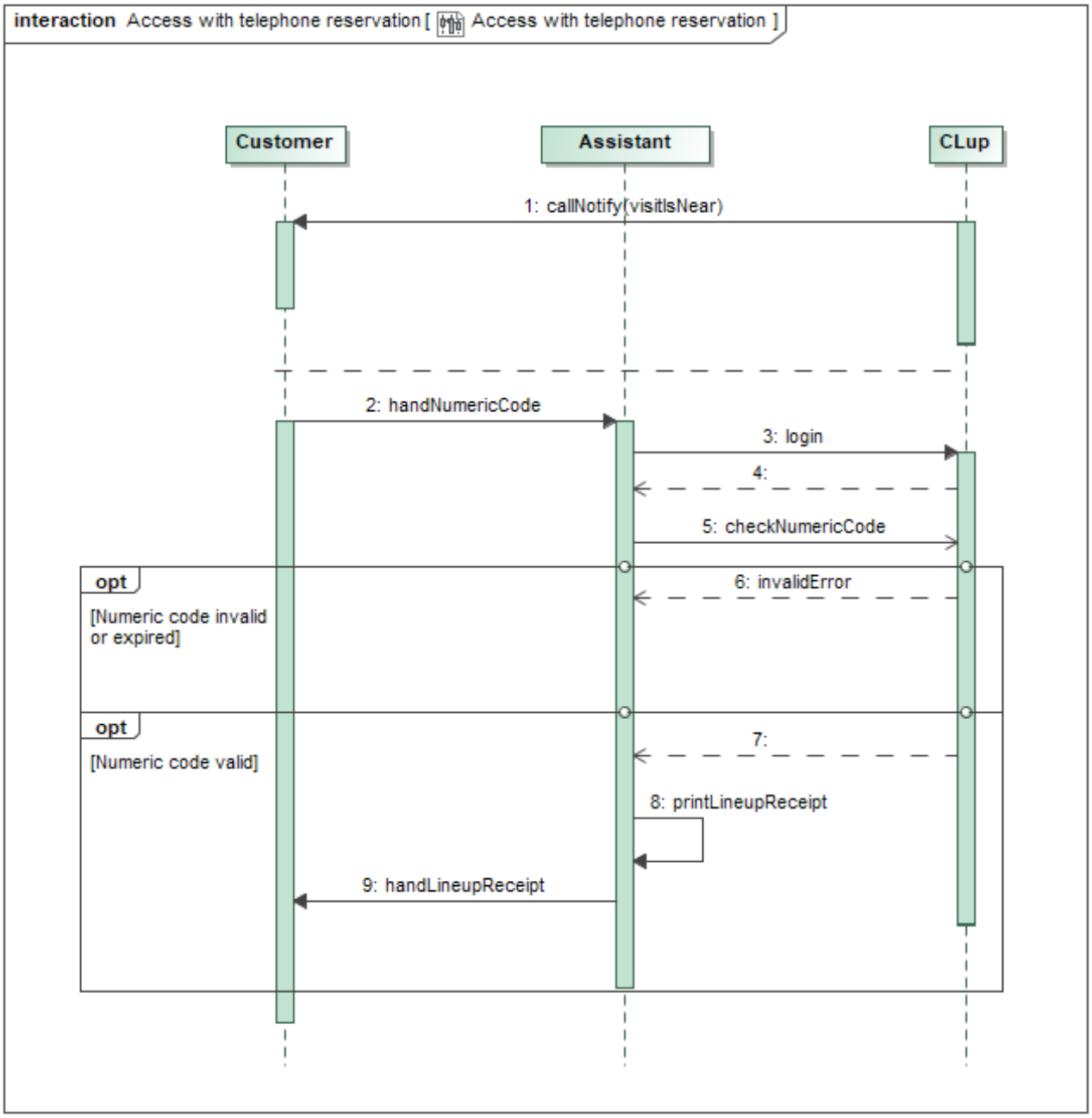


Figure 3.19: Access with telephone reservation sequence diagram

3.2.12 Consulting statistics

Use Case	Consulting statistics
Actor	Store manager
Entry condition	The store manager wants to consult current statistics
Flow of events	• The store manager accesses CLup • The store manager requests current statistics to CLup • CLup computes the requested statistics
Exit condition	CLup returns the requested statistics
Exceptions	
Mapped requirements	R3

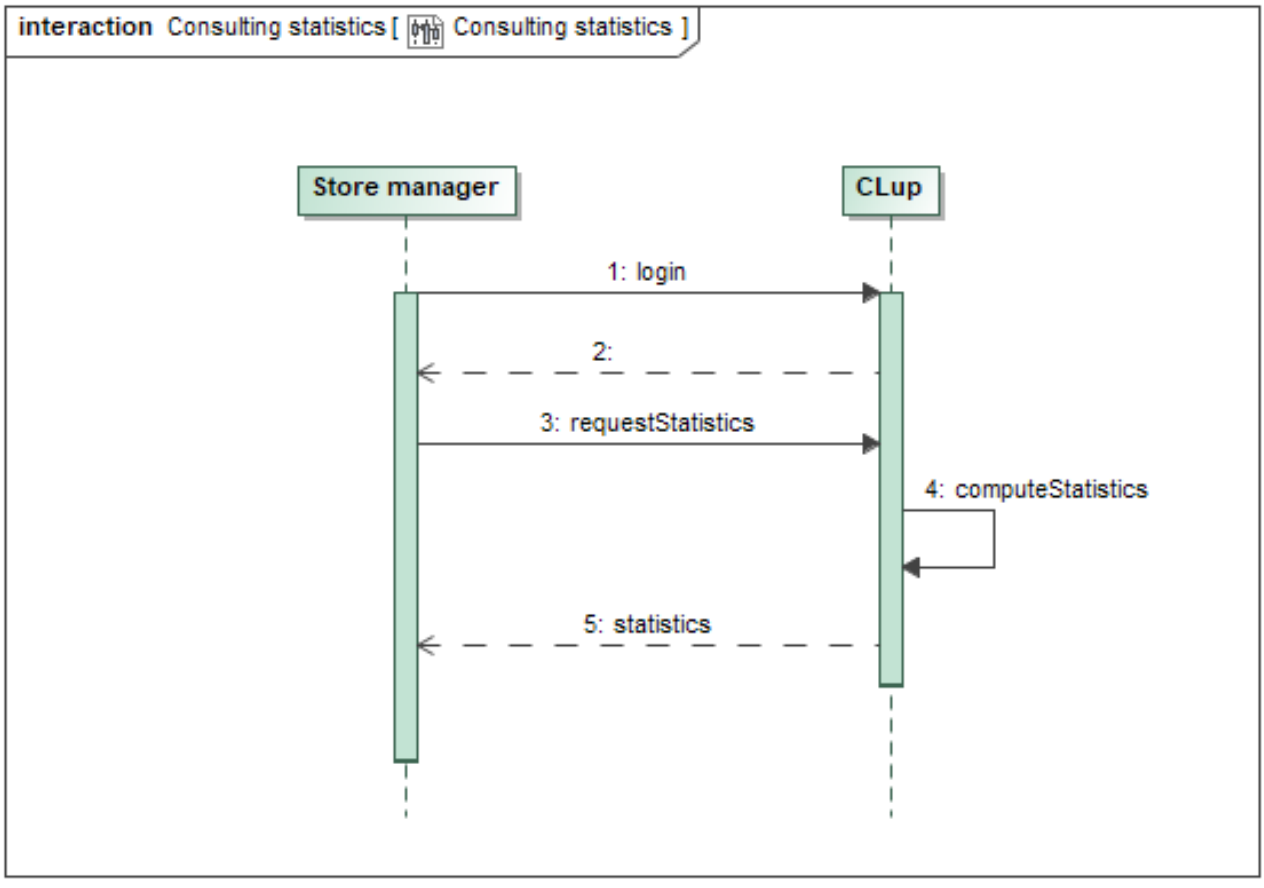


Figure 3.20: Consulting statistics sequence diagram

3.2.13 Definition of safety standard parameters

Use Case	Definition of safety standard parameters
Actor	Store manager
Entry condition	The store manager needs to define or update safety parameters
Flow of events	• The store manager accesses CLup • The store manager defines or updates the needed safety parameters • CLup asks for confirmation of the new safety parameters • The store manager confirms • CLup saves the new safety parameters • CLup updates the queue availability for the store according to the newly defined safety parameters
Exit condition	CLup confirms the succeeding of the operation
Exceptions	If the store manager does not confirm, nothing happens on CLup system, and the old safety parameters are kept.
Mapped requirements	R2

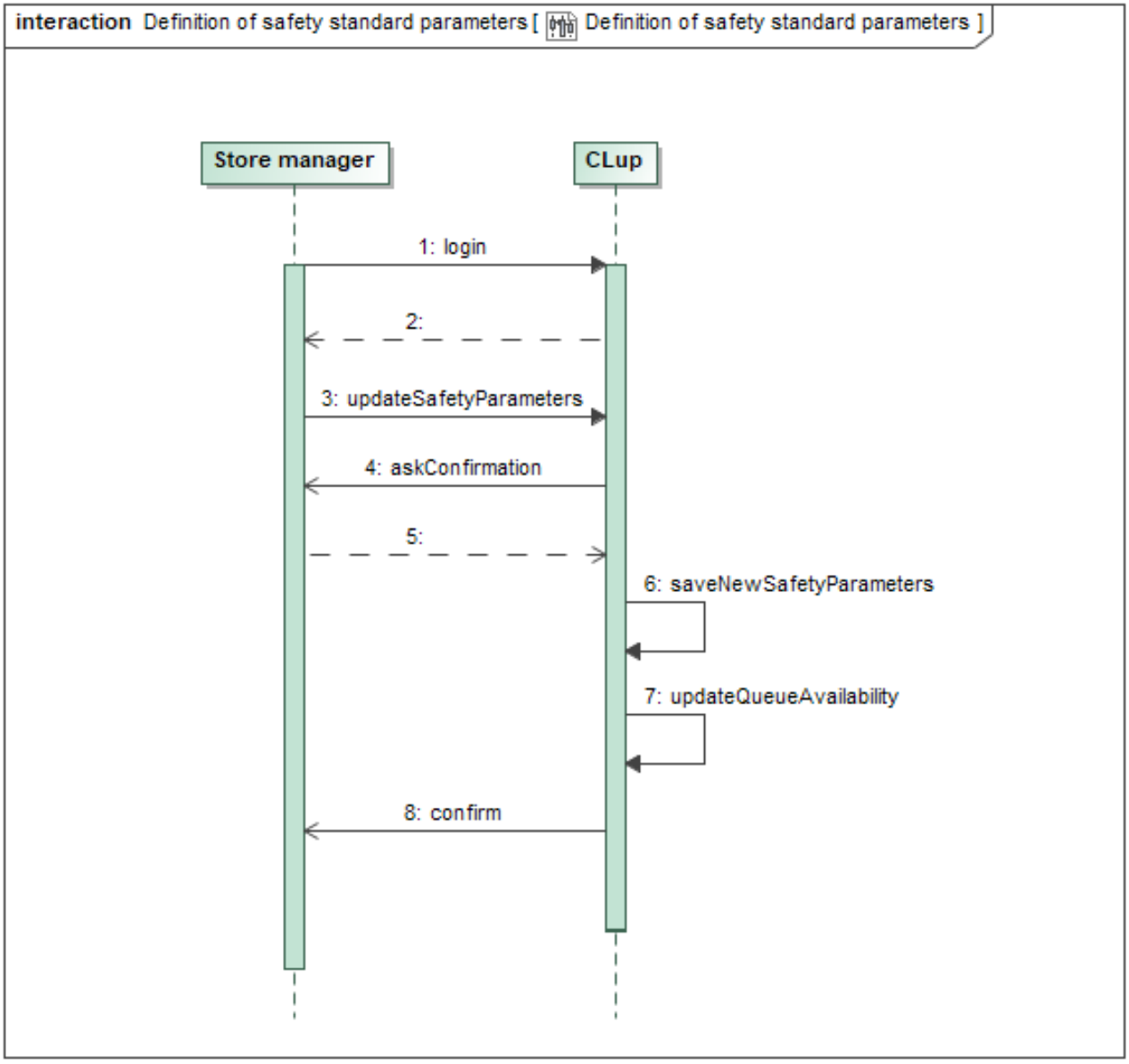


Figure 3.21: Definition of safety standard parameters sequence diagram

3.3 Performance requirements

The first country to adopt CLup will probably be Italy. According to ISTAT, in Italy, there are 16 648 813 family units and, according to FederDistribuzione, there are 25 534 grocery stores. Assuming a uniform geographical distribution of the family units and the grocery stores and that only one person per family unit does the grocery shopping for the whole family, the system should be able to support 700 users per store. Moreover, due to the critical function of CLup during the ongoing pandemic, the system is expected to be widely adopted across the country. Therefore, CLup should be able to scale quickly to provide nationwide support for around 17 000 000

users. CLup at launch will start with a limited number of stores, users and resources, and the scale-up costs and required resources should grow at most linearly with the growth of the user base. CLup should be able to maintain responsiveness even under the stated conditions of maximum capacity.

3.4 Design constraints

3.4.1 Standards compliance

As per privacy policies, CLup's user data must be treated respecting the law, depending on the country (i.e., the system should be GDPR compliant for all European countries).

All hardware interfaces present in supermarkets must comply the CE safety standard, in order to guarantee the maximum possible degree of safety and environmental protection.

3.4.2 Hardware limitations

Following are listed all the hardware requirements in order to use CLup with all its functionalities:

Smartphone

- GPS antenna
- Wi-Fi or mobile 3G/4G/5G connection

Personal Computer

- Wi-Fi or Ethernet connection

Ticket printers

- Wi-Fi, Ethernet or mobile 3G/4G/5G connection

Receipt scanners

- Image sensor
- Wi-Fi, Ethernet or mobile 3G/4G/5G connection

3.5 Software system attributes

3.5.1 Reliability

The modules of the system implementing functionalities needed to access the stores are of greatest importance, thus their supporting infrastructure should be characterized by the highest MTTF and lowest MTTR possible.

On the other side, all the reservation related functionalities, such as booking via IT device or telephone and notifications, are required to have good reliability, but can afford a slightly higher MTTR than the other system mentioned above. However, it is mandatory to ensure the lack of data losses during downtime.

3.5.2 Availability

All services are needed 24/7, so it is needed at least 99.99% availability, equivalent to an average of 1 minute of down-time per week. Both supermarkets and users need to be notified in case of any communication issues with CLup servers.

Stores should be able to communicate with CLup's servers during all their opening time span.

As shown in the following histogram, it is expected an high utilisation of all services during the day, and a low usage during night hours. This means that it is better to do all maintenance activities in the evening, during the night or in the early morning, in order to keep the availability of critical functionalities to its maximum, especially during busy hours.

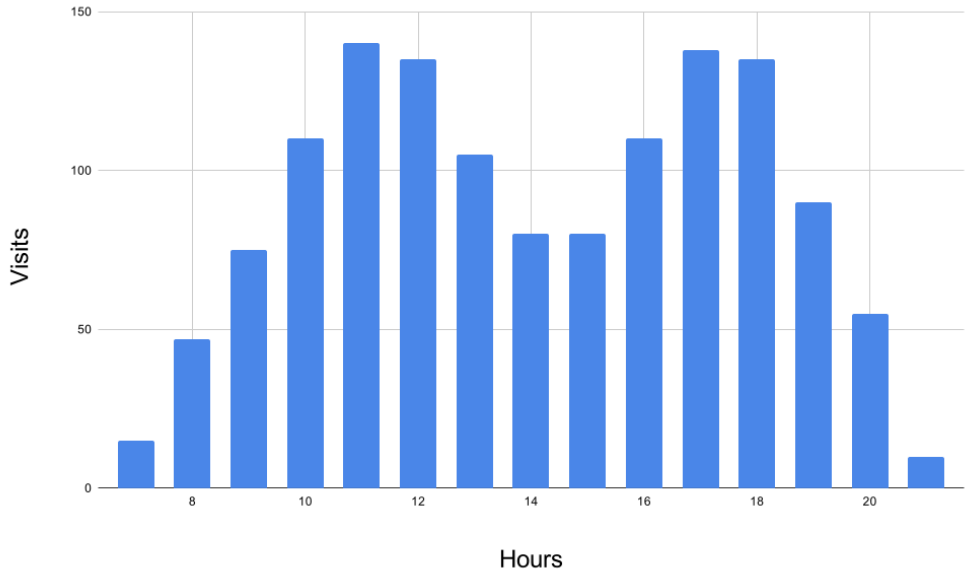


Figure 3.22: Average daily visits in the supermarket in Milan with the most affluence.
Credits: Google Popular Times (11/2020).

3.5.3 Security

All data inbound to CLup services must be treated as stated by GDPR regulations.

Store personnel (i.e., store managers and store assistants) will authenticate to the system using Single Sign On (SSO) integrations with the stores identity systems, using either OAuth or SAML. This will allow the system to delegate the user management to external identity systems, with the benefits of:

- not having to deal with sensitive information (e.g., passwords)
- inheriting the change of permissions of the users (e.g., a promotion from store assistant to store manager)
- providing the users with a unified and smooth log in experience (since they will use the same credentials they use to access all other stores' systems)

Additionally, to guarantee the protection of the customer's data in between servers and the user's device, all Internet traffic must be encrypted with a modern version of TLS, and sent via HTTPS protocol.

Finally, to guarantee data protection in the backend side, data at rest encryption needs to be used: this way the system should be protected from data breaches and thefts.

3.5.4 Maintainability

The back-end system must be designed for sustaining maintenance operations without having to shut down services, guaranteeing no down-time during these operations. For this reason, a dedicated staging environment must be put in place and used to test every new release of the software. The staging environment must be as similar as possible to the production environment, the only difference being the data that it works on: properly anonymized production data.

All devices inside the supermarkets, like ticket scanners and printers, must support OTA firmware updates. When necessary, these devices will have to be updated when the store is closed, to guarantee the maximum availability.

Customer's software on smartphones can be updated at any time.

3.5.5 Portability

CLup must be accessible for smartphones using Android (at least Android KitKat 4.4) and iOS (at least iOS 12.4) operating systems.

All customer side functions must also be provided on the Web platform, in order to be able to access CLup's services by Internet browsers, both from PC and smartphones.

The software for store managers and employees must be hosted on Web platform, with support for both PC and smartphone layouts.

4. Formal analysis

4.1 Overview

This section contains a formal model describing the core parts of the system. The model was defined using Alloy, an open source language and analyzer for software modelling. In particular, customers' line up, store access and store exit events are described.

The following additional assumptions have been added to the model for the sake of simplification, without significant loss of generality:

- Time is quantized in time slots; the duration of the time slots is unspecified, thus it would be possible to shrink indefinitely the length of time slots to achieve a very fine level of precision;
- Customers leave the store within the time slot limits they requested during the line up request; this is a strong assumption that, however, can be mitigated by the system using the statistical data of the past visits of a customer to provide accurate estimations of the leaving time. In particular, during a line up request, the system could lookup the mean amount of time the customer spent in the store more than they were allowed in the past visits, and add it to the following line up requests.

The formal model shows that the system described in the present document:

- is consistent with respect to the management of line up requests (i.e., it only accepts a line up request and emits the associated receipt if the requested store does not exceed the maximum number of customers allowed);
- is consistent with respect to the access to the store (i.e., it only allows a customer to enter the store if they have a valid line up receipt, they are using it for the first time to access the store and they are entering the store during the assigned time slot);
- is consistent with respect to the end of the visit to a store (i.e., it tracks the actual time slots the customer spent in the store);
- ensures that no more people than allowed are present inside each store.

4.2 Alloy model

4.2.1 Source code

```
// Signatures

sig Customer {
}
```

```
sig Receipt {
  receipt_customer: Customer,
  receipt_startSlot: TimeSlot,
  receipt_store: Store,
  receipt_timeSlots: some TimeSlot
} {
  receipt_startSlot in receipt_timeSlots
}

sig Store {
  store_maxCustomersPerSlot: one Int
} {
  store_maxCustomersPerSlot > 0
}

sig TimeSlot {
  timeSlot_previous: lone TimeSlot
}

one sig TIME_SLOT_ZERO extends TimeSlot {}
one sig TIME_SLOT_CURR extends TimeSlot {}
one sig TIME_SLOT_MAX extends TimeSlot {}

sig Visit {
  visit_endSlot: lone TimeSlot,
  visit_receipt: Receipt,
  visit_startSlot: TimeSlot,
  visit_store: Store,
  visit_timeSlots: some TimeSlot
} {
  visit_startSlot in visit_timeSlots and
  visit_endSlot in visit_timeSlots and
  visit_store = visit_receipt.receipt_store
}

// Utility functions

fun previousTimeSlots [t: TimeSlot] : set TimeSlot {
  t.timeSlot_previous.(*timeSlot_previous)
}

fun followingTimeSlots [t: TimeSlot] : set TimeSlot {
  timeSlot_previous.t.*(~timeSlot_previous)
}

fun receiptsForStoreContainingTimeSlot [s: Store, t: TimeSlot] : set Receipt {
  receipt_timeSlots.t <: receipt_store.s
}

fun visitsInStoreDuringTimeSlot [s: Store, t: TimeSlot] : set Visit {
  visit_timeSlots.t <: visit_store.s
}

// Constraints on signatures

// Time slots allowed in a receipt are contiguous, and all after the start time slot
fact {
  all r: Receipt, t: TimeSlot |
    t in r.receipt_timeSlots implies
      (t in r.receipt_startSlot or t.timeSlot_previous in r.receipt_timeSlots) and
      t not in r.receipt_startSlot.previousTimeSlots
}

// Time slots used for a visit are contiguous, and all after the start time slot and before the end time
    ↪ slot
fact {
  all v: Visit, t: TimeSlot |
    t in v.visit_timeSlots implies
      (t in v.visit_startSlot or t.timeSlot_previous in v.visit_timeSlots) and
      t not in v.visit_startSlot.previousTimeSlots and
      t not in v.visit_endSlot.followingTimeSlots
}

// Time slots are totally ordered
```

```
fact {
  all t: TimeSlot |
    (#timeSlot_previous.t = 1 iff t not in TIME_SLOT_MAX) and
    (#t.timeSlot_previous = 1 iff t not in TIME_SLOT_ZERO) and
    t->TIME_SLOT_ZERO in *timeSlot_previous
}

// No visit is being carried out in the future
fact {
  no visit_timeSlots.(TIME_SLOT_CURR.followingTimeSlots)
}

// All visits which have not ended are going on right now
fact {
  all v: Visit |
    no v.visit_endSlot implies
    TIME_SLOT_CURR in v.visit_timeSlots
}

// Constraints imposed by the system

// Each receipt can be used at most for one visit
fact {
  all disj v1, v2: Visit | v1.visit_receipt ≠ v2.visit_receipt
}

// Only allow to visit the store if the the entrance is during the assigned time slot
fact {
  all v: Visit | v.visit_startSlot = v.visit_receipt.receipt_startSlot
}

// Only emit receipts if the store has less customers than the maximum for all the requested slots
fact {
  all t: TimeSlot, s: Store |
    #receiptsForStoreContainingTimeSlot[s, t] ≤ s.store_maxCustomersPerSlot
}

// Assumptions

// All people leave the store within the time they are allowed
fact {
  all v: Visit | v.visit_timeSlots in v.visit_receipt.receipt_timeSlots
}

// Predicates

pred emitReceipt [c: Customer, s: Store, start: TimeSlot, slots: some TimeSlot, currentTime: TimeSlot, r'
    ↪ : Receipt] {
  // preconditions
  currentTime = TIME_SLOT_CURR
  start in slots
  all t: slots |
    #receiptsForStoreContainingTimeSlot[s, t] < s.store_maxCustomersPerSlot
  start in currentTime.followingTimeSlots
  all t: TimeSlot |
    t in slots implies
      (t in start or t.timeSlot_previous in slots) and
      t not in start.previousTimeSlots

  // postconditions
  r'.receipt_customer = c
  r'.receipt_store = s
  r'.receipt_startSlot = start
  r'.receipt_timeSlots = slots
}

pred enterStore [c: Customer, s: Store, r: Receipt, currentTime: TimeSlot, v': Visit] {
  // preconditions
  currentTime = TIME_SLOT_CURR
  r.receipt_customer = c
  r.receipt_startSlot = currentTime
  r.receipt_store = s

  // postconditions
```

```
  v'.visit_receipt = r
  v'.visit_startSlot = currentTime
  v'.visit_store = s
  currentTime in v'.visit_timeSlots
  no v'.visit_endSlot
}

pred exitStore [c: Customer, s: Store, r: Receipt, currentTime: TimeSlot, v: Visit] {
  // preconditions
  currentTime = TIME_SLOT_CURR
  r.receipt_customer = c
  v.visit_receipt = r
  v.visit_startSlot not in currentTime.followingTimeSlots
  v.visit_store = s

  // postconditions
  v.visit_endSlot = currentTime
}

// Assertions

assert noMoreCustomersThanAllowedInTheStores {
  all t: TimeSlot, s: Store |
    #visitsInStoreDuringTimeSlot[s, t] ≤ s.store_maxCustomersPerSlot
}

// Run

run emitReceipt for 10

run enterStore for 10

run exitStore for 10

check noMoreCustomersThanAllowedInTheStores for 5
```

4.2.2 Predicates execution and assertions checks

```
Executing "Run emitReceipt for 10"
   Solver=sat4j Bitwidth=4 MaxSeq=7 SkolemDepth=1 Symmetry=20
   41219 vars. 1267 primary vars. 108469 clauses. 140ms.
   Instance found. Predicate is consistent. 44lms.

Executing "Run enterStore for 10"
   Solver=sat4j Bitwidth=4 MaxSeq=7 SkolemDepth=1 Symmetry=20
   39786 vars. 1257 primary vars. 102022 clauses. 109ms.
   Instance found. Predicate is consistent. 66ms.

Executing "Run exitStore for 10"
   Solver=sat4j Bitwidth=4 MaxSeq=7 SkolemDepth=1 Symmetry=20
   39623 vars. 1257 primary vars. 101300 clauses. 82ms.
   Instance found. Predicate is consistent. 187ms.

Executing "Check noMoreCustomersThanAllowedInTheStores for 5"
   Solver=sat4j Bitwidth=4 MaxSeq=5 SkolemDepth=1 Symmetry=20
   7530 vars. 362 primary vars. 17322 clauses. 15ms.
   No counterexample found. Assertion may be valid. 2047ms.

4 commands were executed. The results are:
   #1: Instance found. emitReceipt is consistent.
   #2: Instance found. enterStore is consistent.
   #3: Instance found. exitStore is consistent.
   #4: No counterexample found. noMoreCustomersThanAllowedInTheStores may be valid.
```

Figure 4.1: Results of the execution of the Alloy predicates and assertions checks

4.2.3 Resulting worlds

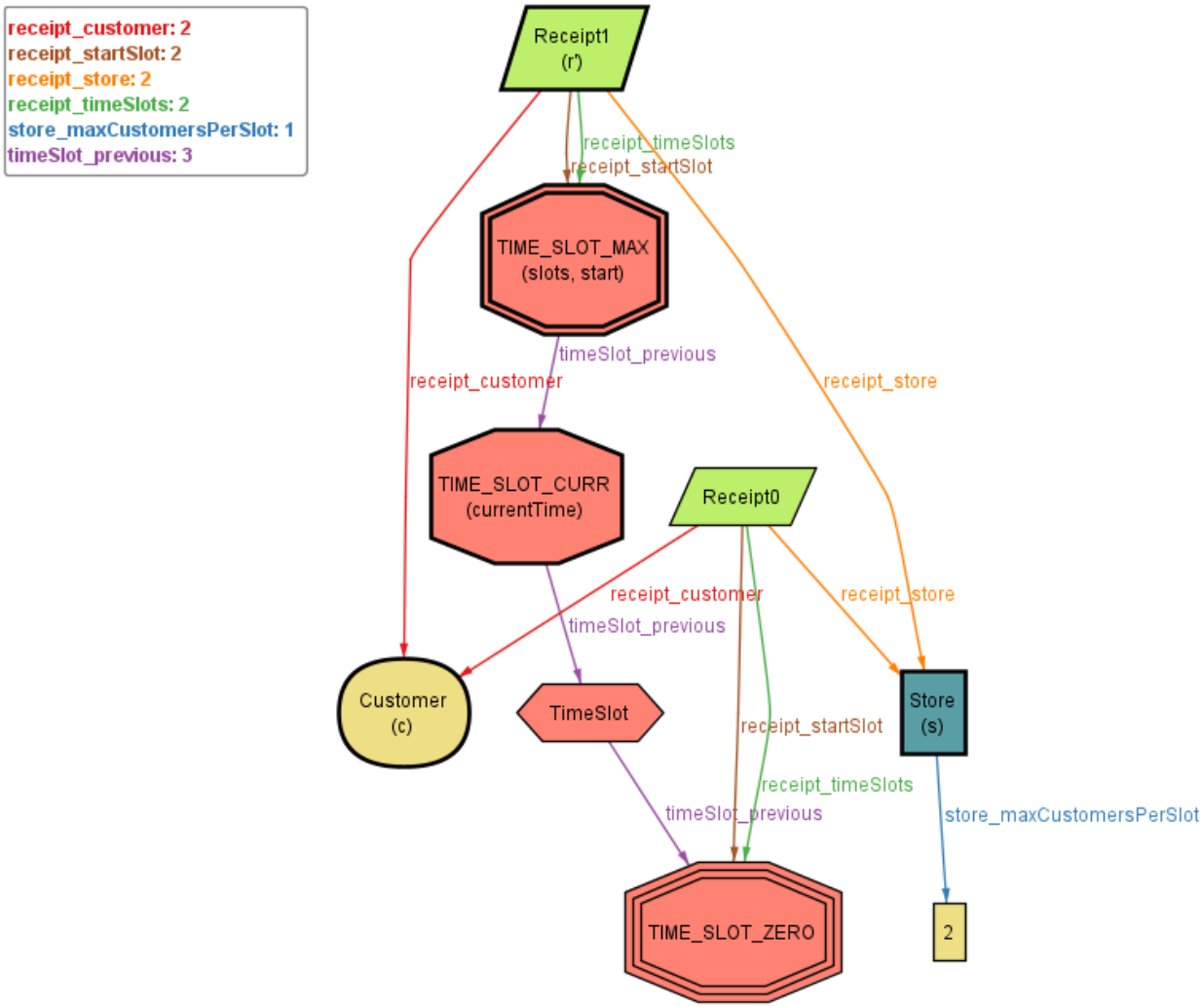


Figure 4.2: One of the worlds generated by the emitReceipt predicate

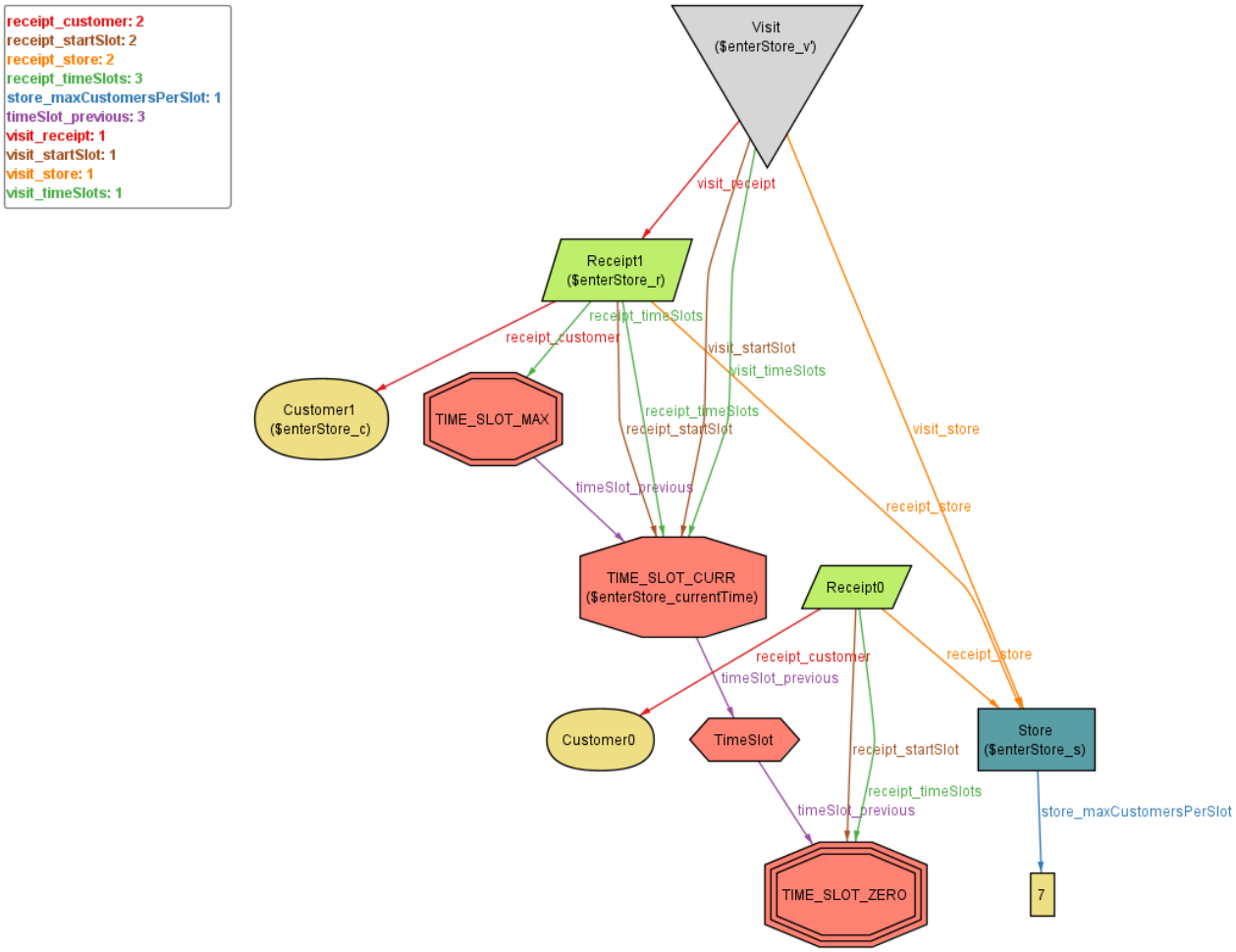


Figure 4.3: One of the worlds generated by the enterStore predicate

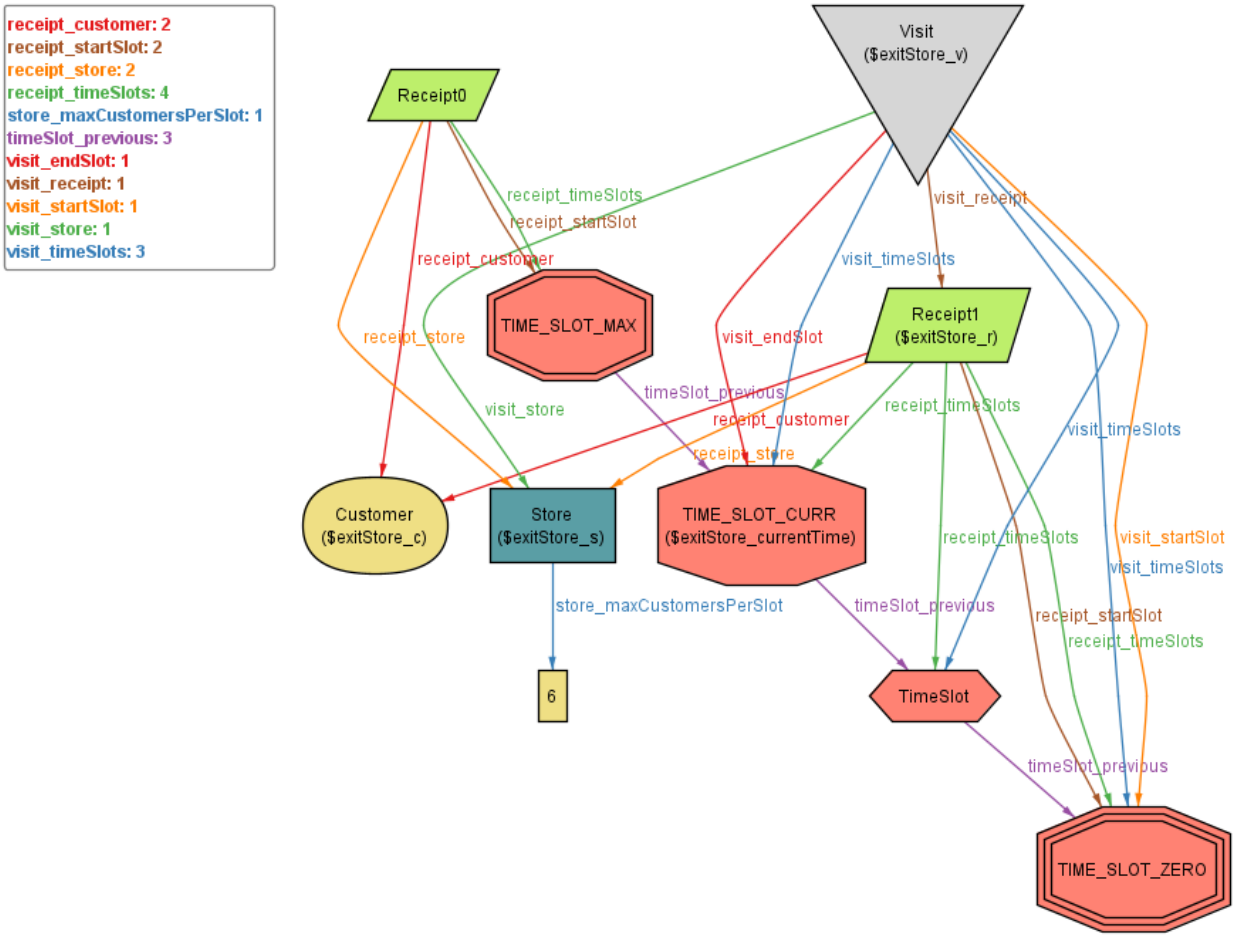


Figure 4.4: One of the worlds generated by the exitStore predicate

5. Effort spent

5.1 Andrea Riva

Date	Effort spent (h)	Notes
17/10/2020	0.5	Introduction briefing
09/11/2020	3.0	Scope
14/11/2020	1.0	Harmonization and task appointing meeting
14/11/2020	1.5	Initial version of class diagrams
18/11/2020	0.5	Reviews
18/11/2020	1.5	External interfaces
21/11/2020	1.0	Harmonization and task appointing meeting
21/11/2020	2.0	Mockups
22/11/2020	0.5	Fixes and general improvements
29/11/2020	4.0	Alloy model
29/11/2020	0.5	Improvements on constraints
04/12/2020	1.0	Mockups and general improvements
04/12/2020	2.5	Reviews
05/12/2020	1.0	Alignment meeting
05/12/2020	1.5	Alloy model and mockups improvements
07/12/2020	1.0	Alignment meeting
07/12/2020	1.5	Document refactoring and general improvements

5.2 Alessandro Sanvito

Date	Effort spent (h)	Notes
10/10/2020	1.0	Project set-up
17/10/2020	0.5	Introduction briefing
17/10/2020	0.5	Purpose description
10/11/2020	0.5	Scope review
11/11/2020	2.0	Purpose description
14/11/2020	1.0	Harmonization and task appointing meeting
16/11/2020	1.5	Introduction complete and store state machine
18/11/2020	0.5	Domain assumptions review
21/11/2020	1.0	Harmonization and task appointing meeting
22/11/2020	1.0	Product functions definition
22/11/2020	0.5	PR review and insertion of images in product perspective
23/11/2020	0.5	Insertion of images in external interfaces
27/11/2020	0.5	Requirements correction and general enhancement
28/11/2020	1.0	Use cases creation
29/11/2020	1.0	PR review
29/11/2020	1.0	Use cases creation
30/11/2020	3.0	Use cases creation
01/12/2020	1.0	Performance requirements identification
03/12/2020	2.0	Sequence diagrams creation and harmonization
04/12/2020	1.0	Sequence diagrams creation and harmonization
05/12/2020	1.0	Harmonization and task appointing meeting
05/12/2020	1.0	Use case diagram creation, refactoring, and document styling
06/12/2020	1.0	Use case to requirements and goal to requirements mapping

5.3 Luca Vecchio

Date	Effort spent (h)	Notes
17/10/2020	0.5	Introduction briefing
11/11/2020	0.5	PR review
11/11/2020	0.5	User characteristics
14/11/2020	1.0	Harmonization and task appointing meeting
14/11/2020	1.0	User characteristics
17/11/2020	0.5	PR review
21/11/2020	3.0	Assumptions, dependencies and constraints
21/11/2020	1.0	Harmonization and task appointing meeting
22/11/2020	0.5	PR review
25/11/2020	2.0	Design constraints
29/11/2020	3.0	Software system attributes
30/11/2020	2.0	PR review and fixes
3/12/2020	2.0	Functional requirements
4/12/2020	1.0	PR review
5/12/2020	1.5	Harmonization and task appointing meeting
5/12/2020	0.5	PR review and fixes
6/12/2020	0.5	Functional requirements
7/12/2020	1	Harmonization and task appointing meeting
7/12/2020	1	Sequence diagrams