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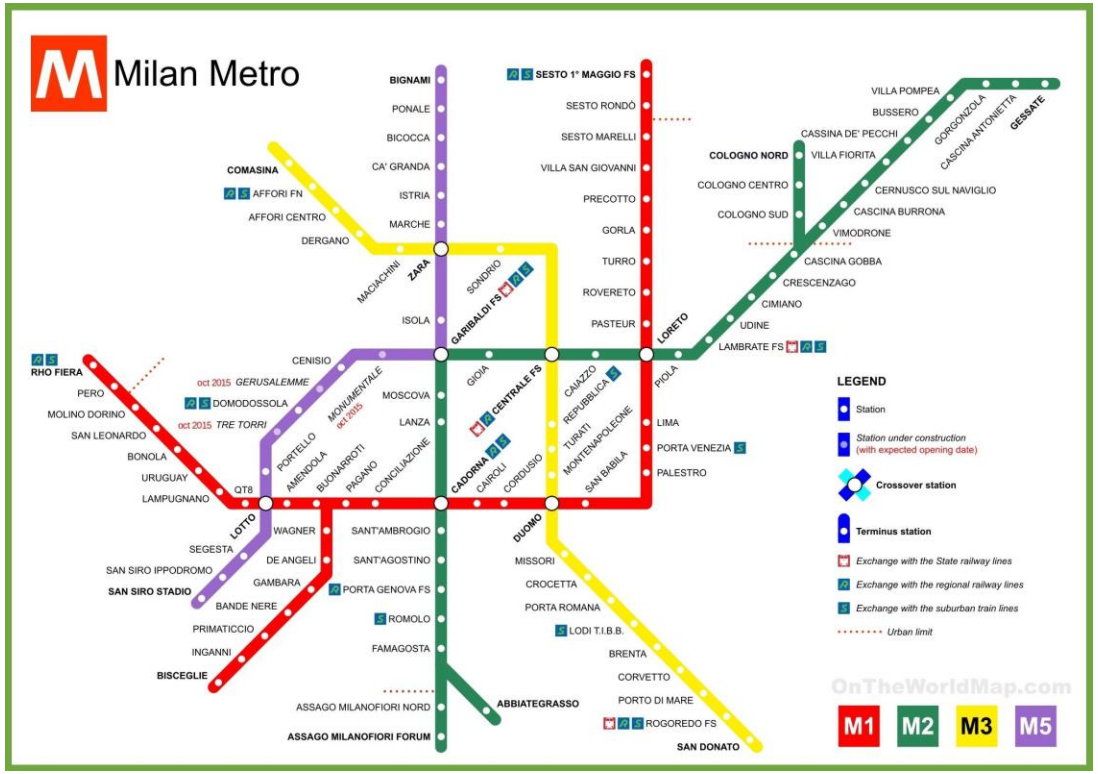
MILANO 1863

Exercise Lecture 2

"The purpose of abstraction is not to be vague, but to create a new semantic level in which one can be absolutely precise"

Edsger Dijkstra



System Description: ContainerOrchestrator (CO)

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- Consider a pre-existing container management system (CMS) managing software containers (e.g., Docker containers). CMS can be available in multiple instances, one per computing node. Each CMS instance provides operations to create, execute, stop, and destroy containers on the corresponding computing node. Moreover, it is able to return a list of the containers running on the node at a given time Containers are created from images, which are available on a catalogue known by each CMS instance. CMS instances are able to download and upload these images from the catalogue.
- Each computing node has a monitoring agent that gathers information regarding the status of the node (whether it is functioning or not, whether a CMS instance is running on it, etc.) and that can, in case, reboot the whole node restarting also the CMS.

System Description: ContainerOrchestrator (CO)

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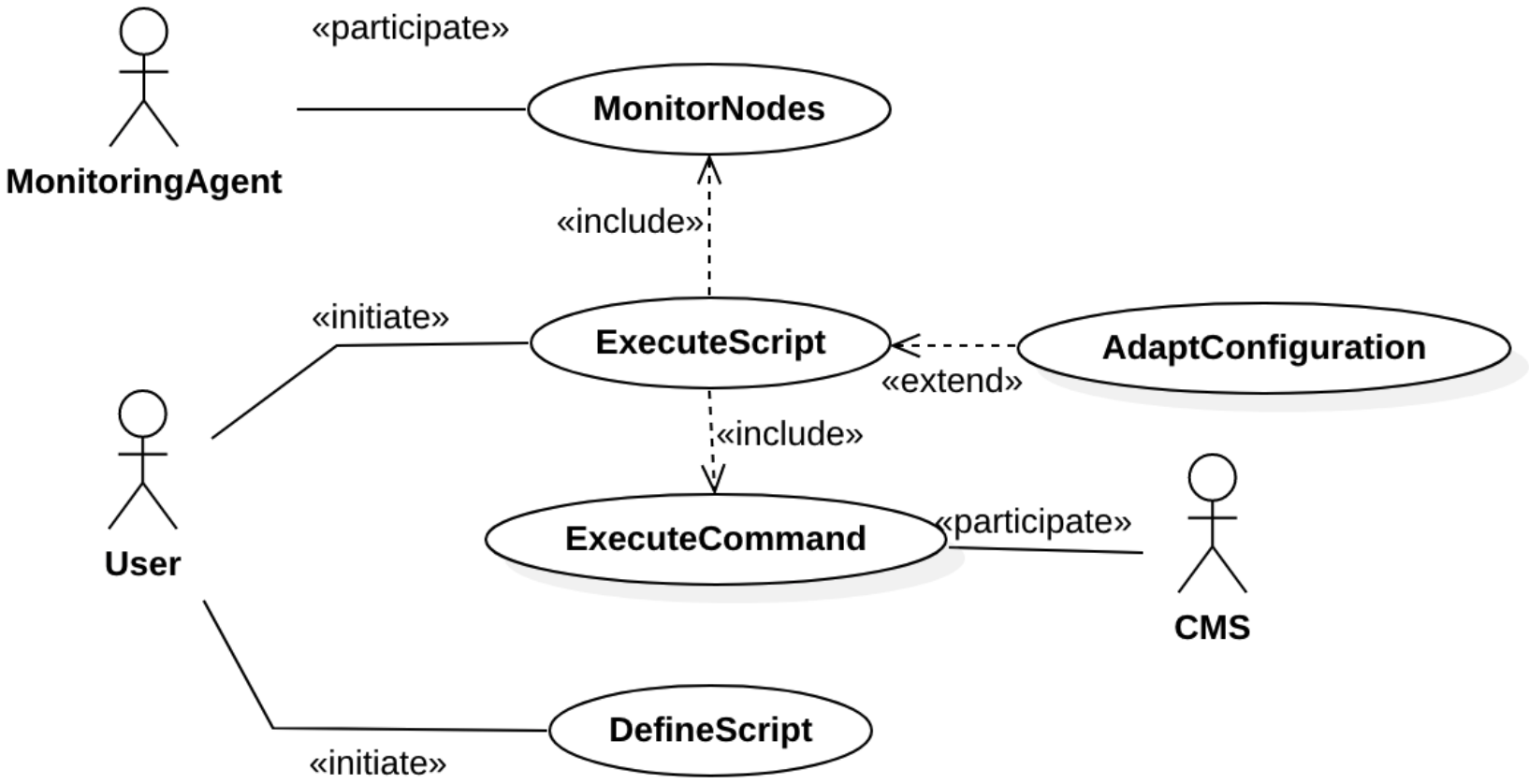
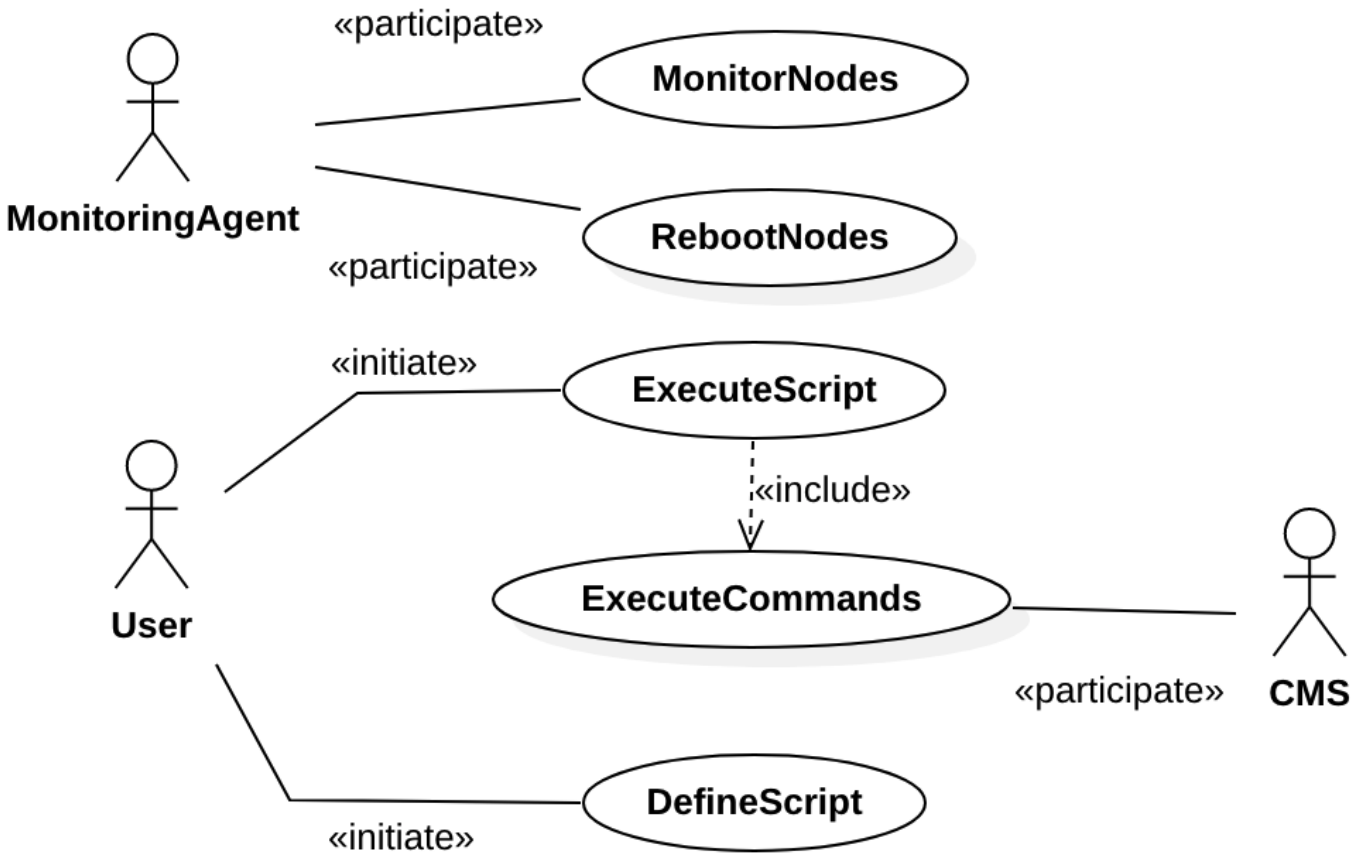
- We are tasked to develop a new system, ContainerOrchestrator (CO), that interfaces users with the CMS instances for the purpose of controlling the creation and management of containers on multiple nodes. Users of CO can write scripts that define plans of operations to be executed (e.g., start container x on node Y, stop container k on node J, migrate container w from node Y to node L if the CPU utilization on Y is over threshold h, create a new container from image I).
- CO can read and execute these scripts by sending the corresponding commands to the CMS instances. In addition, while a script is being executed, CO can exploit the monitoring agents to collect the status of each node – for instance, to assess the CPU utilization of a node or to check that a node is alive. Based on the information provided by monitoring agents, CO can perform the actions defined in the currently active script. For example, as soon as it sees that the CPU utilization of node Y is over the threshold h, CO can start the migration procedure by requesting the CMS instance of node L to run container w and then by requesting the CMS instance of node Y to stop w. Additionally, CO can ask the monitoring agent to reboot a CMS instance if needed.

Use a UML Use Case diagram to identify the actors relevant for the CO system and the corresponding use cases.
Provide a description of the actors and of the purposes of each use case.

Use Case Diagram: Option 1



Use Case Diagram: Option 2



- In the first approach monitoring is carried out during the execution of the scripts, in a “synchronous” manner (i.e., as part of the script execution).
- In the second approach, instead, monitoring occurs in an “asynchronous” manner; that is, it is performed independent of the scripts; when anomalies are detected, corrective reboot actions are taken.
- Note that, based on the request, the use case diagram must be defined from the perspective of the CO system. In this sense, those activities that involve the other actors but not CO are not part of this diagram.

Actors

- MonitoringAgent: it collects the status of each node and provides CO with this information. Based on this input, CO can perform the actions defined in the current script (e.g., migration procedures).
- User: a User actor writes scripts that define plans of operations (in the form of scripts) and then asks the system to execute such plans.
- CMS: a CMS instance provides operations to create, execute, stop, and destroy containers on the corresponding computing node.

Use cases for the first solution:

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- DefineScript: initiated by a user, who interacts with CO to define the plan of operations to be executed.
- ExecuteScript: initiated by a user, who asks the system to execute the plan of operations previously defined. The execution of the plan includes the monitoring of the status of the nodes; this information is used to decide about corrective actions, if they are necessary.
- ExecuteCommands: is included in ExecuteScripts. Its main purpose is to send the commands defined in the script to the CMS instances for execution.
- AdaptConfiguration: this use case is an extension of the ExecuteScript UC, in that it includes actions that, based on the information gathered from the MonitoringAgents, modify the configuration of the nodes (i.e., what containers are run on them) when necessary.
- MonitorNodes: this use case describes the collection of data regarding the operational status and performance metrics of nodes, which occurs while a script is executing.

Use cases for the second solution:

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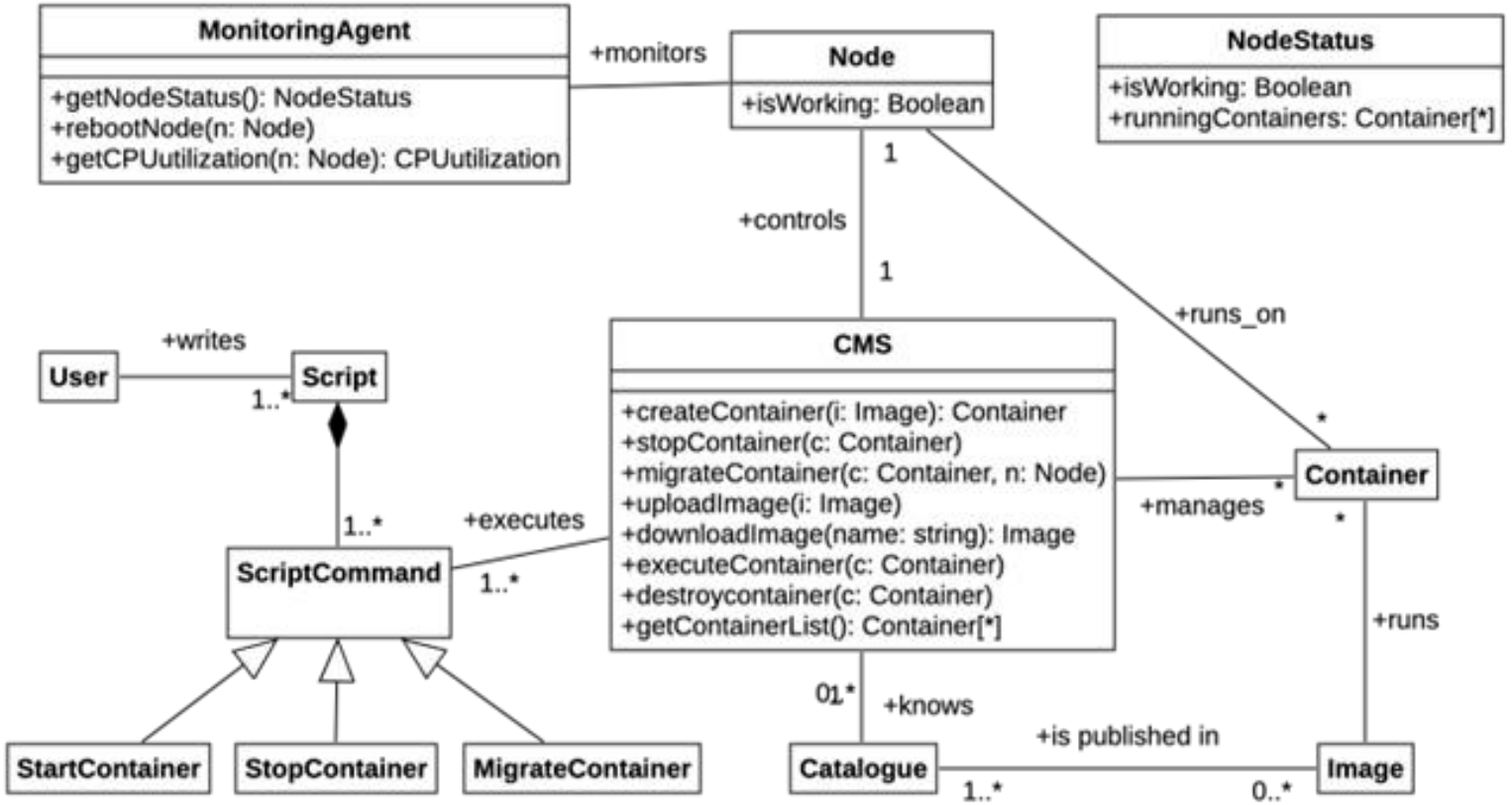
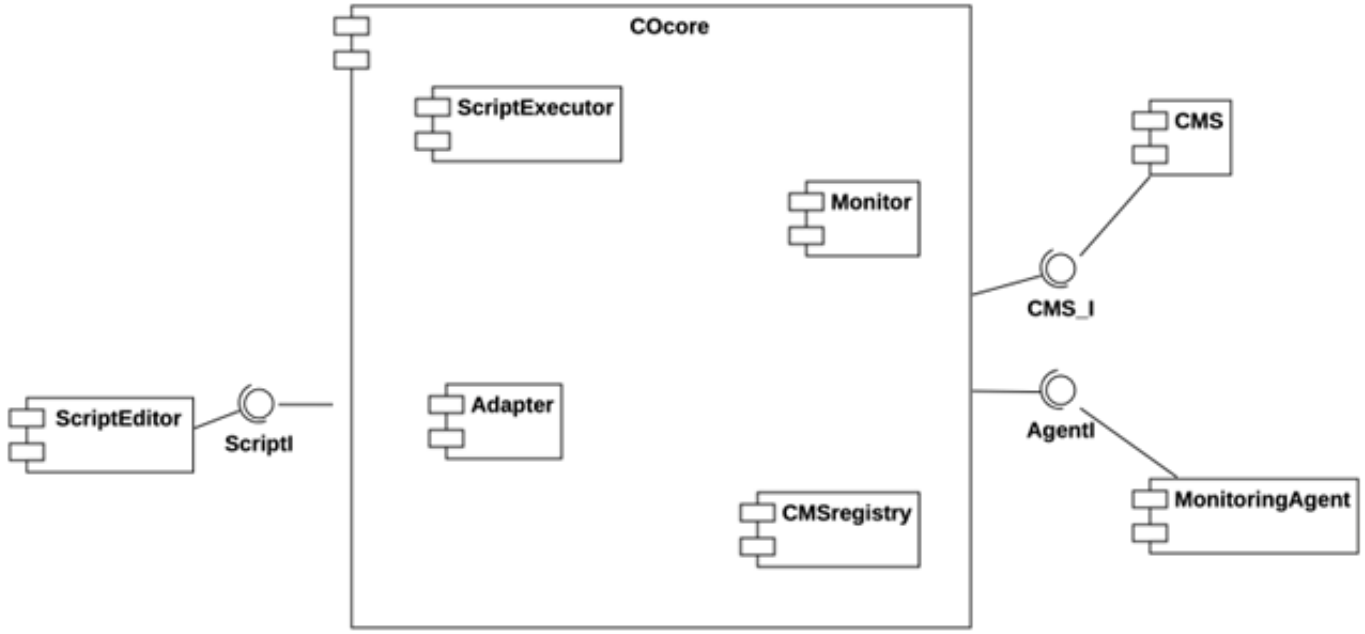
- DefineScript: same as the first solution.
- ExecuteScript: initiated by a user, who asks the system to execute the plan of operations previously defined.
- ExecuteCommands: same as the first solution.
- MonitorNodes: this use case describes systematic collection of data regarding the operational status and performance metrics of nodes, which occurs independently from the execution of scripts.
- RebootNode: this use case is triggered by the CO that asks the monitoring agent to reboot a CMS instance if needed based on the collected operational status of the corresponding node.

Use a UML Class Diagram to describe the domain of the CO system.

Class Diagram



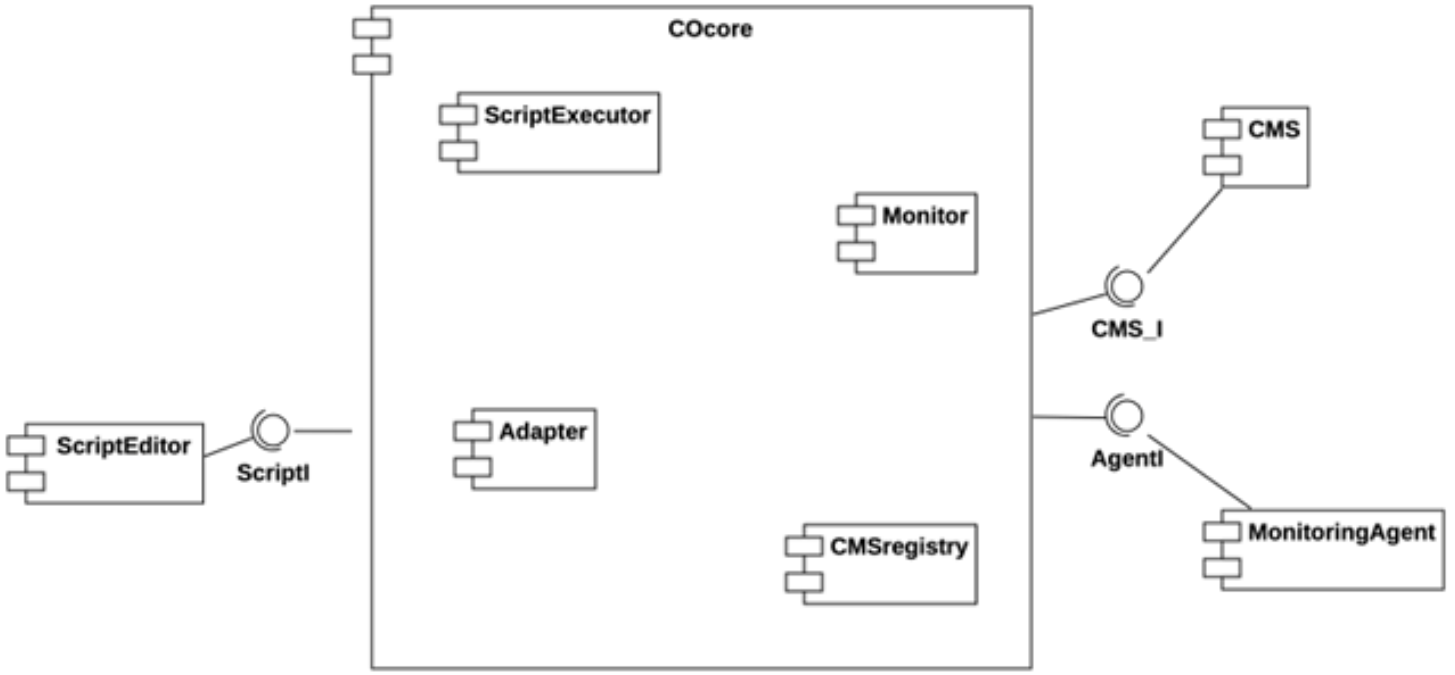
Consider the following UML Component Diagram:



The diagram depicts various components related to the CO system. Component ScriptEditor allows users to create scripts and send them for execution on the COcore. Component COcore is, as the name suggests, the core of the CO system. COcore has four subcomponents:

- ScriptExecutor is in charge of executing scripts created by users. In doing so, it sends the appropriate commands to the CMS instances and acquires monitoring information.
- Adapter is the component in charge of rebooting nodes, stopping and restarting CMS instances, requesting to CMS instances the restart of containers.

Consider the following UML Component Diagram:

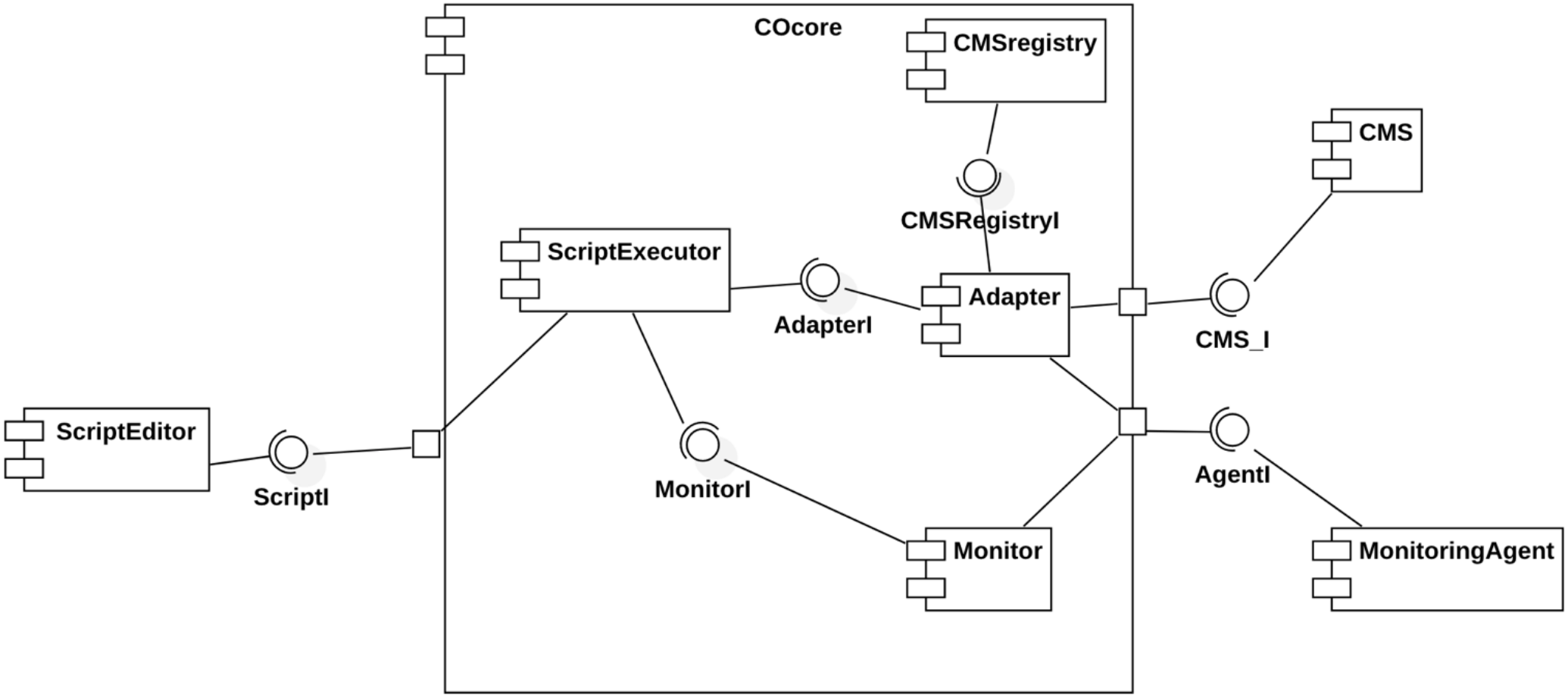


- Monitor checks the current situation of the nodes and provides this information to the components that need it.
- CMSRegistry is the component in charge of keeping track of the endpoints of each running CMS instance.

Components CMS and MonitoringAgent represent the elements mentioned in the system description above. As stated above, they can be available in multiple instances.

Complete the UML Component Diagram with the necessary connections and interfaces between the depicted components.

Component Diagram: Option 1



The key points of the architecture are the following:

- According to the text, ScriptExecutor sends appropriate commands to CMS instances and acquires monitoring information. To limit the number of COcore components using the external interfaces, the interaction with CMSs occurs always through the Adapter component and the interaction with monitoring agents to acquire monitoring information occurs always through Monitor.
- The Monitor component knows about MonitoringAgent endpoints. A different solution could consist in relying on the CMSregistry to this purpose. In this case, Monitor would use the interface offered by CMSregistry to retrieve the reference to the MonitoringAgents.

- As above, two solutions are proposed, which differ in the way they handle the interaction between the ScriptExecutor and the Monitor component (i.e., whether the monitoring occurs “synchronously” or “asynchronously” with respect to the execution of the scripts).

Solution 1:

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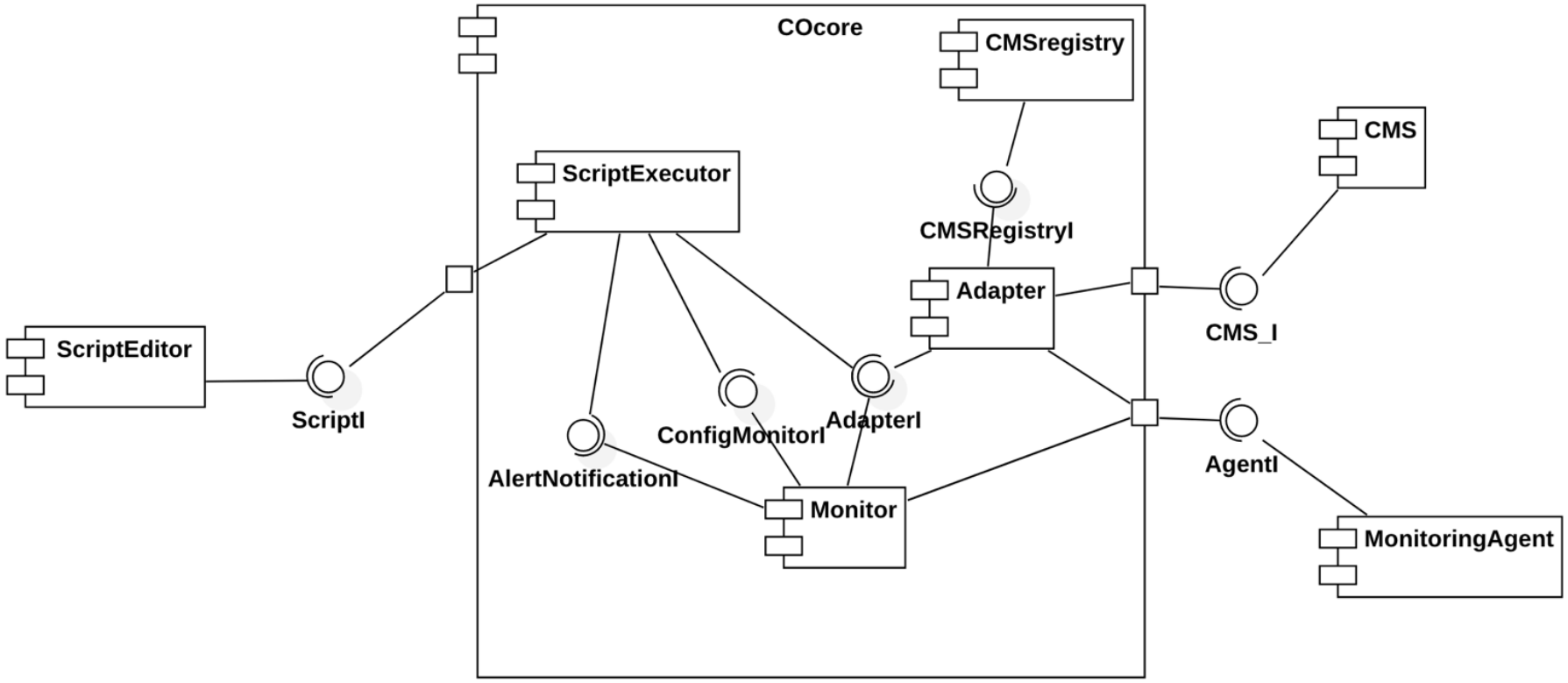
- ScriptExecutor offers the ScriptI interface exposed by COcore. Through this interface, ScriptExecutor receives the script to be executed. While executing a script, ScriptExecutor interacts with Adapter, through the AdapterI interface, to which it passes the commands that are to be executed, either by some MonitoringAgent, or by a CMS. To interact with these last ones, Adapter uses their interfaces CMS_I and AgentI. Moreover, it relies on the interface offered by CMSregistry (CMSRegistryI) to acquire information about the endpoints of the installed CMSs/Agents. For simplicity, we assume that CMSregistry is initialized at the system startup.
- If the currently active script includes conditional instructions that are executed if a certain condition to be monitored becomes true (e.g., CPU utilization about a certain threshold), then the ScriptExecutor will have to periodically contact Monitor to acquire the needed information and, possibly, execute the corresponding action. To this end, Monitor offers to ScriptExecutor the interface MonitorI, through which ScriptExecutor can retrieve monitoring information. Upon request, Monitor calls the MonitoringAgents through the AgentI interface and provides a response to ScriptExecutor.
- As a result, in this solution, the Monitor component is a passive element that is used by the ScriptExecutor as an intermediary with the MonitoringAgents.

Component Diagram: Option 2



Solution 2:

- In this case, the role of the Monitor component becomes more prominent and active. In fact, we want to avoid the need for ScriptExecutor to continuously poll Monitor to gather the information it is interested in. Moreover, we want to keep Monitor autonomous and able to control the status of CMSs independently of the commands received by ScriptExecutor, so to restart nodes/CMSs as needed by relying directly on the services offered by the Adapter and the MonitoringAgents.
- To achieve this behavior, Monitor will be active by itself and will continuously poll MonitoringAgents and send requests to them or to the Adapter to restart/stop/… nodes or containers. Moreover, Monitor offers the ConfigMonitorI interface to allow the ScriptExecutor to configure specific monitoring activities. For instance, through this interface, the ScriptExecutor is able to set an alert in case the CPU utilization overcomes its threshold, passing to the Monitor also the endpoint of its provided interface AlertNotificationI, through which the Monitor can send notifications to the ScriptExecutor.

For each interface identified in the UML Component Diagram (i.e., ScriptI, CMS_I and AgentI) define the operations they provide and provide a short description for each of them.

- CMS and MonitoringAgent are external actors, whose interfaces have been identified in the UML Class Diagram of question RASD_2.
- Interface CMS_I offers the following operations (from the UML class diagram):

  Container createContainer(Image i)

  void stopContainer(Container c)

  void migrateContainer(Container c, Node n)

  void executeContainer(Container c)

  void destroyContainer(Container c)

  Container [] getContainerList()
- Notice that the operations concerning the uploading and downloading of images are not used by COcore, so they are not part of this specific interface.

- Interface AgentI offers the following operations (from UML class diagram):

  NodeStatus getNodeStatus(Node n)

  void rebootNode(Node n)

  CPUutilization getCPUutilization(Node n)

- Interface ScriptI offers the operation:

  void executeScript(Script s)

that allows the script editor to execute a script.

- Interface AdapterI offers the following operation:

  void executeCommand(Command c).
- Command is a type including the following fields: commandName, parameterList, recipientGroup.
- commandName can correspond to an enumeration including all possible commands accepted by either CMS or MonitoringAgents.
- parameterList will be a list of key/value pairs representing the name and corresponding value of each of the parameters needed to run the specific command.
- Finally, we can make the hypothesis that recipientGroup can take as value a specific node, or Any in case the command can be executed on any CMS or MonitoringAgent chosen by the Adapter, or Broadcast in case the command is sent to all CMS or MonitoringAgents controlled by the CO.

- Interface CMSRegistryI offers the following operations:

  EndPoint getCMSEndPoint(Node n)

  EndPoint getAgentEndPoint(Node n)

  void addNode(Node n)

  void addCMS(CMS_EndPoint c, Node n)

  void addAgent(Agent_EndPoint a, Node n)

- Given a node controlled by CO, getCMSEndPoint and getAgentEndPoint return the endpoints of the CMS running on it or of the MonitoringAgent monitoring it, respectively. The add operations instead are executed when a new Node, CMS or MonitoringAgent is inserted in the system as a result of the execution of a script command.

- Interface MonitorI (interface defined in solution 1):
  NodeStatus getNodeStatus(Node n)
  void rebootNode(Node n)

- Interface ConfigMonitorI (interface defined in solution 2)
  void setMonitoringCondition(Condition c, AlertNotificationI handler)
  Condition is a type including the following elements:
  Metric: the metric to be monitored (e.g., CPU utilization or memory utilization)
  Threshold: a threshold value
  Operator: this can be lower, lowerEqual, greater, greaterEqual

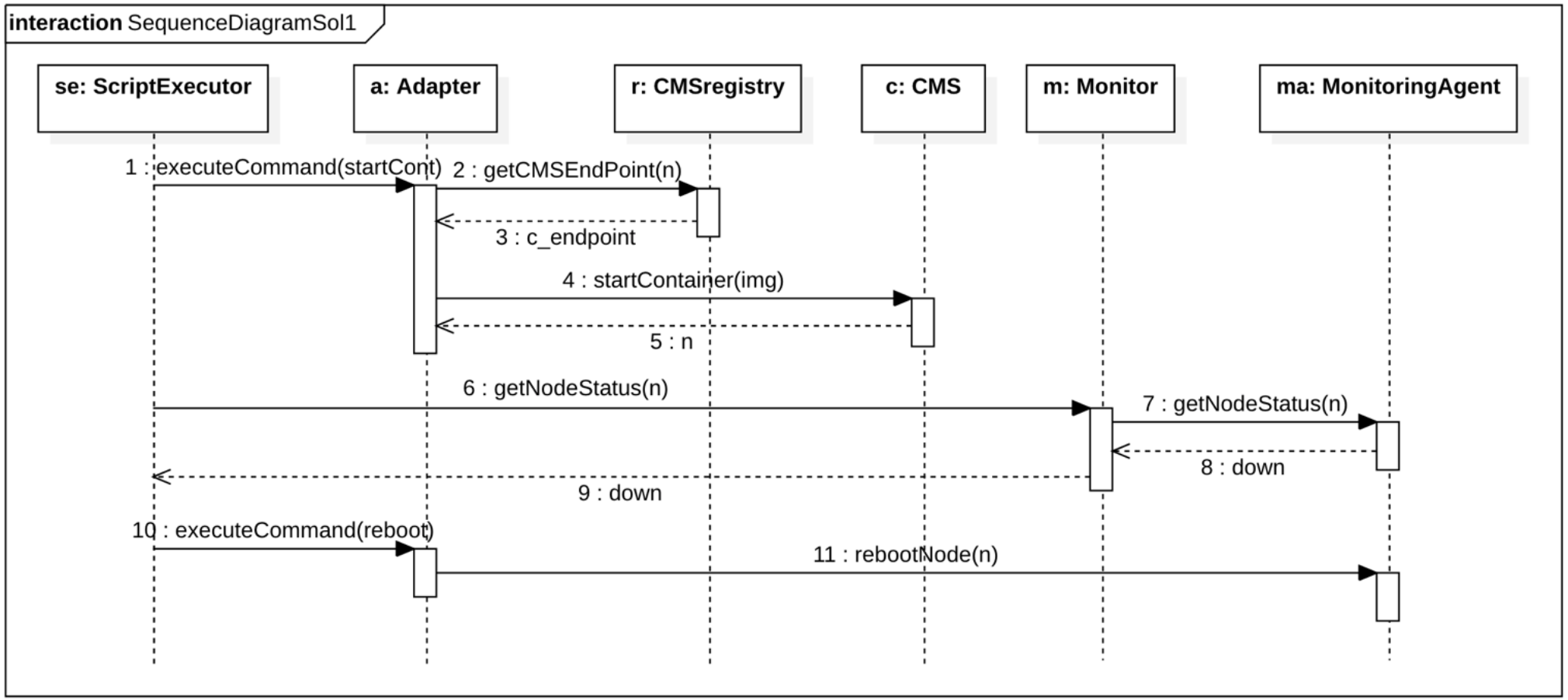
- Interface AlertNotificationI (interface defined in solution 2) allows the ScriptExecutor to be informed by the Monitor about relevant changes in some monitored metrics. It offers the following operation:

  void alert (Condition c)

where c is the condition that, according to the collected monitoring information, does not hold any more. This operation results in the execution of a thread internally to the ScriptExecutor that may trigger the execution of an interaction with the Adapter.

Define a UML Sequence Diagram that shows the interaction between the components of the architecture when the following scenario occurs: a new command requesting the creation of a container is read from the script and is executed. Then, a node fails and the system restarts it.

Sequence Diagram: Option 1

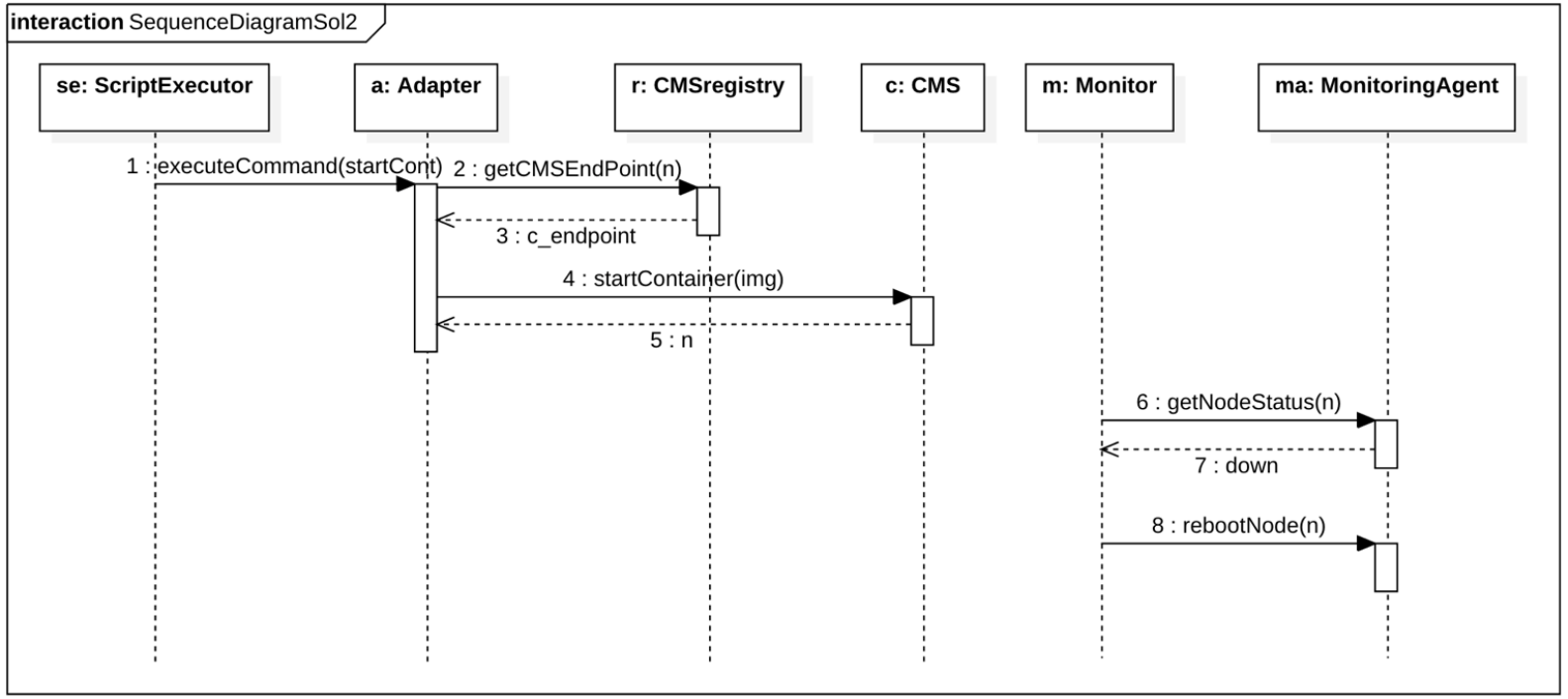


Sequence Diagram: Option 1

- For brevity, the diagram shows only the request from se to m that returns the information that the node is down. During the execution of the system, se will periodically poll m, which, in turn, will poll all agents to know about the status of nodes.

Sequence Diagram: Option 2

The following sequence diagram is associated with the architectural solution 2. As mentioned above, in this case Monitor is more autonomous and takes care of the so-called repair process independently from the other parts of CO.



SmartLightingKit

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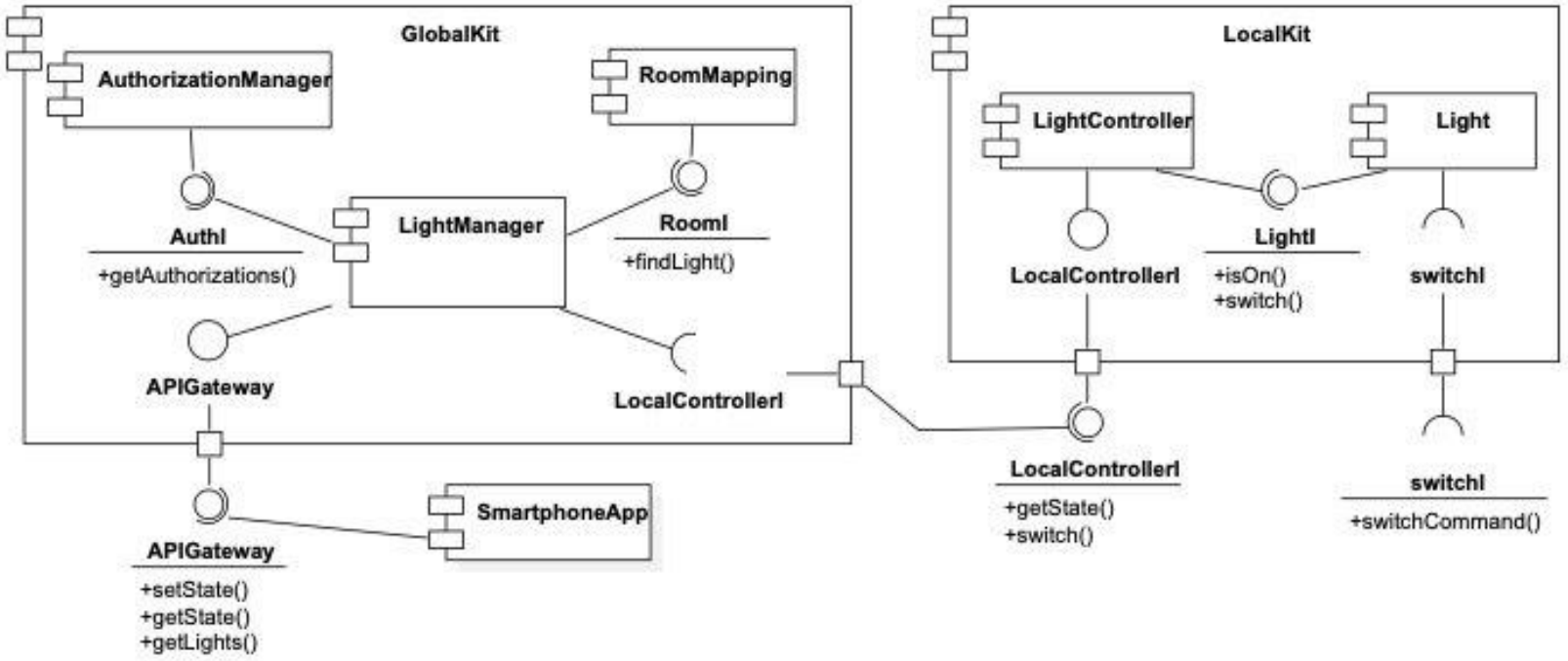
- SmartLightingKit is a system expected to manage the lights of a potentially big building composed of many rooms (e.g., an office space).
- Each room of the building, may have one or more lights.
- The system shall allow the lights to be controlled – either locally or remotely – by authorized users. Local control is achieved through terminals installed in the rooms (one terminal per room). Remote control is realized through a smartphone application, or through a central terminal installed in the control room of the building.
- While controlling the lights of a room, the user can execute one or more of the following actions: turn a light on/off at the current time, at a specified time, or when certain events happen (e.g., a person enters the building or a specific room). Moreover, users can create routines, that is, scripts containing a set of actions.
- SmartLightingKit manages remote control by adopting a fine-grained authorization mechanism. This means there are multiple levels of permissions that may even change dynamically.
- System administrators can control the lights of every room, install new lights, and remove existing ones. Administrators can also change the authorizations assigned to regular users. These last ones can control the lights of specific rooms. When an administrator installs a new light in a room, he/she triggers a pairing process between the light and the terminal located in that room. After pairing, the light can be managed by the system.

SmartLightingKit

• This diagram describes the portion of the SmartLightingKit system supporting lights turning on/off and lights status checking.



SmartLightingKit – part 2

- The diagram is complemented by the following description
  - `GlobalKit` is the component installed in the central terminal. It can be contacted through the `APIGateway` interface by the `SmartphoneApp` component representing the application used for remote control. `GlobalKit` includes:
    - `RoomMapping`, which keeps track, in a persistent way, of lights' locations within the building's rooms;
    - `AuthorizationManager`, which keeps track, in a persistent way, of the authorizations associated with each user (for simplicity, we assume that users exploiting the operations offered by the `APIGateway` are already authenticated through an external system and include in their operation calls a proper token that identifies them univocally); and
    - `LightManager`, which coordinates the interaction with all `LocalKit` components.
  - Each `LocalKit` component runs on top of a local terminal. Also, each `LocalKit` exposes the `LocalControllerI` interface that is implemented by its internal component `LightController`, which controls the lights in the room. Each light is represented in the system by a `Light` component which interacts with the external system operating the light through the `switchCommand` operation offered by the latter.

SmartLightingKit – part 2 (cont.)

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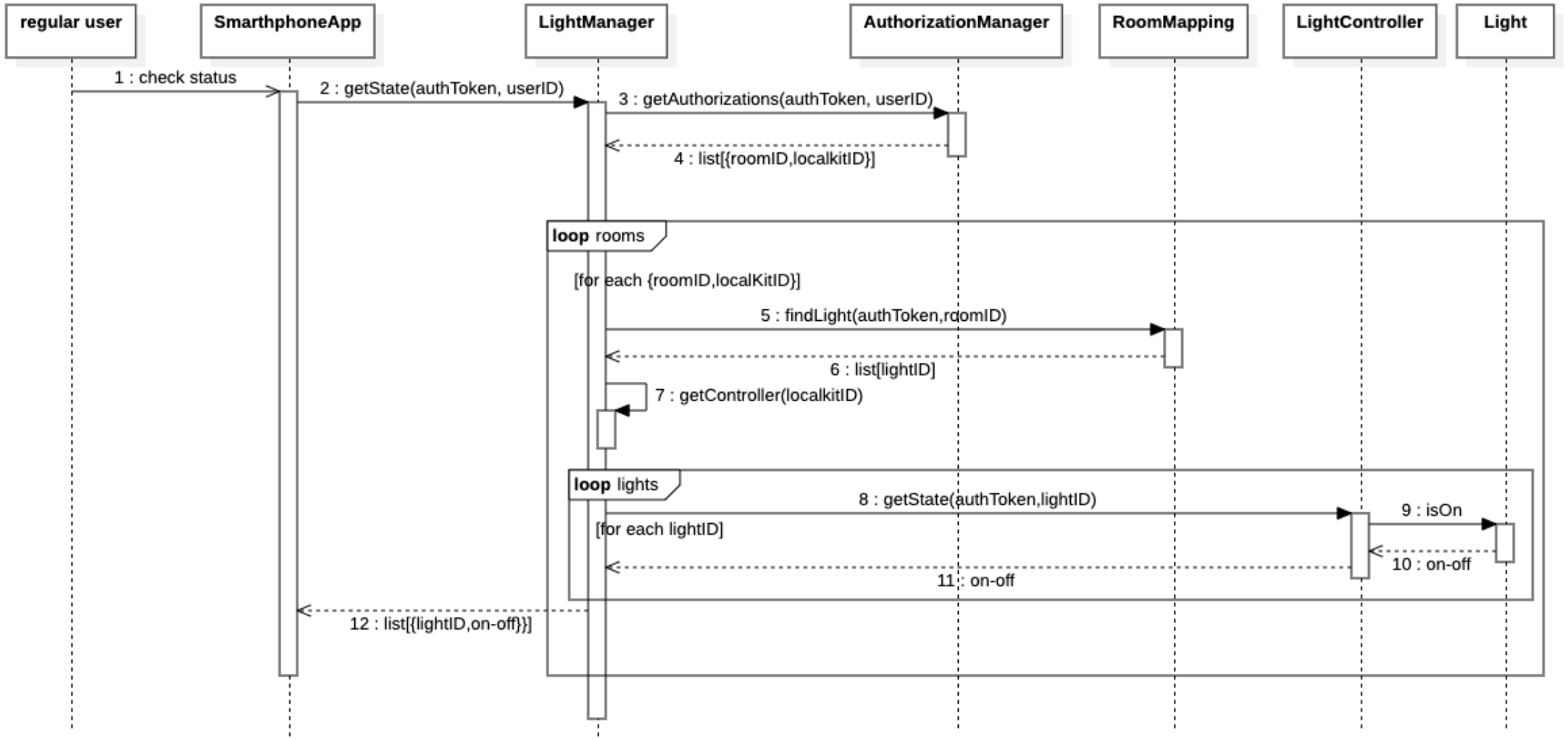
- Q1:
  Analyze the operations offered by the components shown in the diagram and identify proper input and output parameters for each of them.
- Q2:
  Write a UML Sequence Diagram illustrating the interaction between the software components when a regular user wants to use the smartphone application to check whether he/she left some lights on (among the lights he/she can control).

Operations

- **APIGateway**
- *getLights*: input = userID; output = list[lightID]
- *getState*: input = userID; output = list[(lightID, state)]
- *setState*: input = userID, lightID, state; output = none
- **AuthI**
- *getAuthorizations*: input = userID; output = list[(roomID, localKitID)]
- **RoomI**
- *findLight*: input = roomID; output = list[lightID]

- **LocalControllerI**
- *switch*: input = lightID; output = none
- *getState*: input = lightID; output = state
- **LightI**
- *isOn*: input = none, output = True/False
- *switch*: input = none, output = none
- **SwitchI**
- *switchCommand*: input = none; output = none
- **Note**
- State = On/Off;
- All the operations of `APIGateway`, `AuthI`, `RoomI`, `LocalKitI` receive as input also the authentication token.

Sequence diagram



SmartLightingKit – part 3

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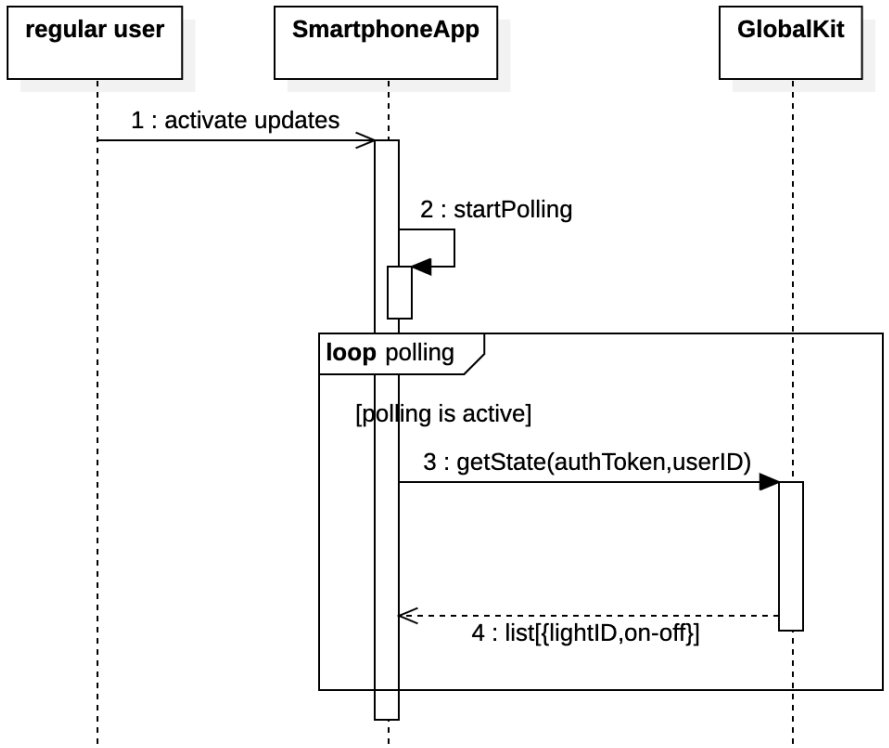
- Assume that, at a certain point, the following new requirement is defined:
  - **NewReq**: *"The smartphone application should allow users to activate/deactivate the receival of real-time updates about the state (on/off) of all the lights they can control."*
- Define a high-level UML Sequence Diagram to describe how the current architecture could accommodate this requirement.
- Highlight the main disadvantage emerging from the sequence diagram.

Realizing NewReq



- Problem: the current architecture does not support updates in push mode.
- The `SmartphoneApp` carries out a continuous polling process to retrieve the status of all the lights even in case it does not change.
- This propagates also internally to `GlobalKit` and the involved `LocalKits`, thus resulting in a potentially significant communication overhead.

What did we learn from this exercise?

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- From C&C structures we can:
  - Get an understanding of our system, infer which components are/can be replicated and how they could be allocated to execution environments
  - Identify and specify operations → essential to start development
  - Reason on the impact of changes
  - Identify new architectural options to address specific problems