EGRBAC AND PDR-EGRBAC POLICIES FOR A SMART HOME

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The purpose of this use case is to provide a depiction of a smart home environment where users are allowed access to specific device roles, or subsets of the device’s functionalities.

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ROLES:

Parent: someone who can access all the devices in the smart house. The role parent can be associated with the homeowner to whom all functionalities of smart home devices are available.

Kid: someone who has access to only a subset of the devices’ capabilities. Parents want children to have access only to the kids-friendly content on entertainment devices (TV, DVD, and PlayStation). Children shouldn't be able to use some device features that are meant to be properly managed by an adult, like turning the oven on and off.

Adult: has access to the adult controlled devices such as turning on/off the oven, unlocking the door, and using the thermostat.

Babysitter: has scheduled access to subset of functionalities of the smart house. We want the babysitter to access the required adult-controlled functionalities, such as turning the oven/thermostat on/off and lock/unlock the front door. However, we don't want to provide the babysitter extra access, like changing the thermostat schedule. If a delivery person rings the doorbell while the babysitter is at home, the babysitter should be allowed to handle the event. We also want him/her to be able to control children’s devices.

Guest: can be a friend, a relative, or a visitor to whom we want to give limited access to the devices in the house. He can control the lights or the entertainment devices.

Neighbor: someone trustworthy who can help the family watch their home when they are on vacation. While the family is away, in case of an emergency, the neighbor can use his smartphone to view who is at the door.

Maid: responsible for cleaning; they must complete tasks like vacuuming, sweeping, emptying trash cans, dusting shelves, cleaning windows, and mopping floors. Some housekeepers change linens, wash dishes, and do light ironing and laundry. They have access to the cleaning devices.

Teenager: (presented as 16 years old) they are familiar with all the smart devices in the home and know how to use them very well. As a young adult, he can be trusted to use capabilities responsibly.

Authorities: to handle emergency situations; this role allows the police, firefighters, or doctors to use devices like door lock, windows, and surveillance cameras only when an emergency arises.

Chef: has access to all kitchen appliances (oven, fridge, cooktop, food processor, coffee machine).

Manager: the super user, the system administrator. It can also be covered by the homeowner.

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EGRBAC policy

Users (U), Roles (R) are well-known sets in RBAC systems. A user is a person who is authorized to interact with smart home devices. In context of smart homes, a role includes parents, kids, neighbors, and such representing the relationship between the user and the family. UA is a many-to-many relation that assigns users to roles.

**U** = {angela, giuseppe, alessio, gianluigi, jonathan, gaia, daria, catia, mario, roberta, anna, bob}

**R** = {kid, parent, babysitter, guest, neighbor, maid, teenager, authorities, adult, manager, chef}

**UA** = {(jonathan, kid), (angela, parent), (giuseppe, parent), (gaia, babysitter), (daria, guest), (gianluigi, neighbour), (catia, maid), (alessio, teenager), (mario, authorities), (roberta, adult), (anna, manager), (bob, chef)}

Smart home appliances like a smart TV are considered devices (D).

Operations (OP) are actions performed on devices in accordance with manufacturer specifications. A permission is a device, operation pair that allows you to perform an operation on one device. The set of permissions P is a subset of D×OP.

**D** = {DoorLock, TV, DVD, PlayStation, Oven, Fridge, DishWasher, Washer, SmartToy, Windows, BurglarAlarm, Thermostat, Alexa, Lights, SurveillanceCameras, SmokeAlarm, Safe, Computer, SmartClock, TempoStudio (fitness device), BluetoothSpeaker, GarageDoor, SmartRobot Vacuum Cleaner, SmartCoffee Machine, Smartwatch, SmartCookware&Cooktop, Kitchen FoodProcessor, IceMaker}

**OP** = {Lock, Unlock, On, Off, PG, R, OnOven, OffOven, OnFridge, OffFridge, DisplayFood,

SetTemperature, OnDishwasher, OffDishwasher, OnWasher, OffWasher, RecordVoice, PlaySound, OnW, OffW, Activate, Deactivate, OnThermostat, OffThermostat, SheduleThermostat, ActivateAlexa, OnLight, OffLight, StartRecording, StopRecording, DeactivateSmokeAlarm, OpenSafe, CloseSafe, Onc, Offc, Connect, VolumeUp, VolumeDown, DisplayTime, MicrophoneMuteSwitch, OnTempoStudio, OffTempoStudio, OnBS, OffBS, ManageAudio, OnGarage, OffGarage, OnRobot, OffRobot, Setting, BrewCoffee, MonitorHeartRate, OnCooktop, OffCooktop, Pulse, Off, High, Low, Clean, Power}

Device Roles (DR) are used to categorize the permissions of different devices. The many-to-many PDRA relation specifies this assignment.

**DR** = {Entertainment\_Devices, Adult\_Controlled, Owner\_Controlled, Kids\_Friendly\_Content, Lighting\_Devices, Cleaning\_Devices, Teenager\_Controlled, Door\_Device, Thermostat\_Device, Fridge\_Device, Oven\_Device, PlayStation\_Device, Safe\_Device, Computer\_Device, Clock\_Device, Fitness\_Devices, Windows\_Devices, Garage\_Device, Kitchen\_Devices}

**P1** = {TV, DVD} × {On, Off, PG}

**P2**= {TV, DVD, PlayStation} × {On, Off, PG}

**P3**= {Oven} × {OnOven, OffOven}

**P4** = {Fridge} × {OnFridge, OffFridge,DisplayFood, SetTemperature}

**P5**= {DoorLock} × {Lock, Unlock}

**P6**= {DishWasher, CleaningMachine} × {Onwasher, OffWasher, OnDishwasher, OffDishwasher}

**P7** = {Light} × {OnLight, OffLight}

**P8**= {SurveillanceCameras} × {StartRecording, StopRecording}

**P9** = {Thermostat} × {OnThermostat, OffThermostat, ScheduleThermostat}

**P10** = {Thermostat} × {OnThermostat, OffThermostat}

**P11** = {SmokeAlarm} × {DeactiveSmokeAlarm}

**P12** = {BurglarAlarm} × {Activate, Deactivate}

**P13**= {Alexa} x {ActivateAlexa}

**P14**= {Safe} x {OpenSafe, CloseSafe}

**P15** = {Computer} x {Onc, Offc}

**P16** = {PlayStation} x {R}

**P17** = {SmartClock} x {Connect, VolumeUp, VolumeDown, DisplayTime,

MicrophoneMuteSwitch}

**P18** = {TempoStudio} x {OnTempoStudio, OffTempoStudio}

**P19** = {BluetoothSpeaker}x {OnBS, OffBS, ManageAudio}

**P20** = {Windows} x {OnW, OffW}

**P21** = {GarageDoor} x {OnGarage, OffGarage}

**P22** ={SmartToy}x{RecordVoice, PlaySound}

**P23** ={SmartRobot Vacuum Cleaner}x{OnRobot, OffRobot, Setting}

**P24** ={SmartCoffee Machine}x{BrewCoffee}

**P25** ={Smartwatch}x{MonitorHeartRate}

**P26** ={SmartCookware&Cooktop}x{OnCooktop, OffCooktop}

**P27** ={Kitchen FoodProcessor}x{Start, Off}

**P28** ={IceMaker}x{Clean, Power}

**P29** ={SmartRobot Vacuum Cleaner}x{OnRobot, OffRobot}

P =

**PDRA** = {{P1 U P16} × Entertainment\_Devices} U {P16 × PlayStation\_Device}

U {{P2 U P22} × Kids\_Friendly\_Content} U {{P3 U P4 U P5 U P10 U P11 UP20} × Adult\_Controlled} U {{P8 U P9 U P12 U P14 U P23 U P25} × Owner\_Controlled} U

{P7 × Lighting\_Devices} U {{P6 UP29}× Cleaning\_Devices} U {P13 U P19 × Teenager\_Controlled} U {P5 × Door\_Device} U {P3 × Oven\_Device} U {P4 × Fridge\_Device} U {P9 × Thermostat\_Device} U {P14 × Safe\_Device} U {P15 × Computer\_Device} U {P17 × Clock\_Device} U {{P18 U P25} × Fitness\_Devices} U {P20 × Windows\_Devices} U {P21 x Garage\_Device} U {{P3 U P4 U P24 U P26 U P27 U P28} × Kitchen\_Devices}

Environment Roles (ER) represent environmental contexts, such as daytime/nighttime, and winter/summer. Environment roles are triggered by Environment Conditions (EC) such as daylight, or weather. EA maps each environment role to a subset of EC.

**EC** = {weekends, evenings, vacation, TRUE, emergency, certain day, at\_home}

**ER** = {Entertainment\_Time, Not\_At\_Home, Any\_Time, At\_Home, Emergency\_Time, Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday}

**EA** = {({weekends, evenings}, Entertainment\_Time), ({vacation}, Not\_At\_Home), ({TRUE}, Any\_Time), ({emergency}, Emergency\_Time), ({at home}, At\_Home),

({certain day}, Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday)}

As an example to clarify how environmental roles work, assume we have two different babysitters, one who comes on Friday and one who comes on Wednesday. Their permissions are distinguished based on the environment role.

Each role pair is a combination of a role and currently active environment roles. A role pair rp has a role part rp.r that is the single role associated with rp, and an environment role part rp.ER.

**RP** = {(kid,{Entertainment\_Time}), (kid,{At\_Home}), (parent,{Any\_Time}), (parent,{Not\_At\_Home}), (chef,{At\_Home}), (babySitter,{Wednesday}), (babySitter,{Friday}), (maid,{At\_Home}), (neighbor,{At\_Home}), (guest,{At\_Home}), (manager,{Any\_Time}), (adult,{Any\_Time}), (teenager,{Any\_Time}), (teenager,{Entertainment\_Time}), (authorities,{Emergency\_Time})}

NOTE: the roles (*role*,{AtHome}) will be active only when connected to wifi.

RPDRA, combining all of these elements together, assigns device roles to role pairs.

**RPDRA** = {((parent,{Any\_Time}),Adult\_Controlled), ((parent,{Any\_Time}),Owner\_Controlled), ((parent,{Any\_Time}),Entertainment\_Devices), ((parent,{Any\_Time}),Cleaning\_Devices), ((parent,{Any\_Time}),Lighting\_Devices), ((parent,{Any\_Time}),Door\_Device), ((parent,{Any\_Time}),Fridge\_Device), ((parent,{Any\_Time}),Oven\_Device), ((parent,{Any\_Time}),Thermostat\_Device),

((parent,{Any\_Time}),Kids\_Friendly\_Content), ((parent,{Any\_Time}),PlayStation\_Device), ((parent,{Any\_Time}),Safe\_Device), ((parent,{Any\_Time}),Computer\_Device), ((parent,{Any\_Time}),Clock\_Device) , ((parent,{Any\_Time}),Fitness\_Device), ((parent,{Any\_Time}),Windows\_Devices), ((parent,{Any\_Time}),Garage\_Device), ((babysitter,{Friday}),Door\_Device),

((babysitter,{Wednesday}),Door\_Device), ((kid,{At\_Home}),Lighting\_Devices),

((kid,{Entertainment\_Time}),Kids\_Friendly\_Content), ((maid,{At\_Home}),Door\_Device), ((teenager,{Any\_Time}),Lighting\_Devices), ((maid,{At\_Home}),Cleaning\_Devices), ((teenager,{Any\_Time}),Teenager\_Controlled), ((teenager,{Entertainment\_Time}),Entertainment\_Devices)}

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PDR-AEGRBAC policy

Administrator Users (AUser) are a subset of regular users, with administrative authorizations. Administrator users would be recognized by their assignment to Administrative Roles (AR).

**AUser** = {anna, angela, giuseppe, alessio, roberta, catia, bob}

**AR** = {Manager, Home\_Owner, Teenager\_Devices\_Manager, Adult\_Manager,

Entertainment\_Manager, Cleaning\_Manager, Kitchen\_Manager, Kids\_Manager}

**AUA** = {(angela, Home\_Owner), (giuseppe, Home\_Owner), (roberta, Adult\_Manager),

(angela, Adult\_Manager), (giuseppe, Entertainment\_Manager), (anna, Manager), (catia, Cleaning\_Manager), (alessio, Teenager\_Devices\_Manager), (bob, Kitchen\_Manager), (gaia, Kids\_Manager)}

Administrative User Assignment (AUA) assigns administrator users to administrative roles. "Administrative Unit" (AU) refers to an abstraction for a unit of administration that includes the range of management for its enclosed AR. Each Administrative Unit (AU) is made up of two parts: an AR that is specifically associated with each AU, and a subset of authorized tasks, specifically Administrative Tasks (AT). Any possible authorization assignment included in an AU's corresponding AT can be managed by any AR included in the AU.

**AU** = {Admin\_Control, Ownership\_Control, Teenager\_Devices\_Control, Adult\_Management, Entertainment\_Management, Cleaning\_Management, Kitchen\_Management, Kids\_Control}

Prohibited assignments indicate access denial instead of granting it.

For instance, a babysitter shouldn't be allowed access to the owner's devices and neither does she need it.

**ProhibitedAssignment** = {((kid,{Entertainment\_Time}), Entertainment\_Devices),

((babySitter,{Friday}), Cleaning\_Devices), ((guest,{At\_Home}), Owner\_Controlled), ((babySitter,{Wednedsay}), Safe\_Device),

((maid,{At\_Home}), Owner\_Controlled), (babySitter,{Wednesday}), Owner\_Controlled), (babySitter,{Friday}), Owner\_Controlled),

((babySitter,{Friday}), Safe\_Device), (guest,{At\_Home}),Safe\_Device),

((kid,{At\_Home}), Adult\_Controlled), ((kid,{At\_Home}), Cleaning\_Devices), ((kid,{At\_Home}), Owner\_Controlled), ((chef,{At\_Home}), Owner\_Controlled), ((adult,{At\_Home}), Owner\_Controlled), ((neighbor,{At\_Home}), Owner\_Controlled), (neighbor,{At\_Home}), Safe\_Device), (chef,{At\_Home}), Safe\_Device), (adult,{At\_Home}), Safe\_Device), (maid,{At\_Home}), Safe\_Device)}}

**AT** = {at0, at1, at2, at3, at4, at5, at6, at7}

**at0** = {(kid,{Entertainment\_Time}), (kid,{At\_Home}), (parent,{Any\_Time}), (guest,{At\_Home}), (parent,{Not\_At\_Home}), (chef,{At\_Home}), (babysitter,{Friday}), (babySitter,{Wednesday}), (maid,{At\_Home}), (neighbor,{At\_Home}), (adult,{Any\_Time}), (teenager,{Any\_Time}), (teenager,{Entertainment\_Time}), (authorities,{Emergency\_Time})} x {Entertainment\_Devices, Adult\_Controlled, Owner\_Controlled, Kids\_Friendly\_Content, Lightning\_Devices, Cleaning\_Devices,

Teenager\_Controlled, Door\_Device, Thermostat\_Device, Fridge\_Device, Oven\_Device, PlayStation\_Device, Safe\_Device, Computer\_Device, Clock\_Device, Fitness\_Devices, Windows\_Devices, Garage\_Device, Kitchen\_Devices} \ {ProhibitedAssignment}

**at1** = {(parent,{Any\_Time}), (guest,{At\_Home}), (babysitter,{Friday}), (babysitter,{Wednesday}), (kid,{Entertainment\_Time}), (adult,{Any\_Time}), (teenager,{Entertainment\_Time})} x {Entertainment\_Devices, Kids\_Friendly\_Content­, PlayStation\_Device} \ {ProhibitedAssignment}

**at2** = {(parent,{Any\_Time}), (authorities,{Emergency\_Time})} x {Owner\_Controlled, Safe\_Device} \ {ProhibitedAssignment}

**at3** = {(parent,{Any\_Time}), (guest,{At\_Home}), (maid,{At\_Home}), (kid,{At\_Home}),

(babySitter,{Friday}), (babySitter,{Wednesday}), (neighbor{At\_Home}), (authorities,{Emergency\_Time})} x {Adult\_Controlled, Lighting\_Devices, Cleaning\_Devices, Oven\_Device, Fridge\_Device, Thermostat\_Device, Door\_Device, Computer\_Device, Clock\_Device, Fitness\_Devices, Windows\_Devices, Garage\_Device} \ {ProhibitedAssignment}

**at4** = {(teenager,{Any\_Time}), (guest,{At\_Home})} x {Teenager\_Controlled, PlayStation\_Device} \{ProhibitedAssignment}

**at5** = {(maid,{At\_Home})} x {Garage\_Device, Cleaning\_Devices, Lighting\_Devices, Windows\_Devices} \ {ProhibitedAssignment}

**at6** = {(chef,{At\_Home})} x {Kitchen\_Devices, Lighting\_Devices} \ {ProhibitedAssignment}

**at7** = {(babysitter,{Wednesday}), (babysitter,{Friday}} x {Kids\_Friendly\_Content} \ {ProhibitedAssignment}

ARATA is a one-to-one relation which is Administrative Role to Administrative Task assignment. It means only one AR could be authorized to activate authorizations included in the corresponding AT.

ARAUA is a one-to-one relation, which is Administrative Role to Administrative Unit Assignment. It means no more than one AR can be assigned to an AU.

**ARATA** = {(Admin,at0), (Entertainment\_Manager,at1), (Home\_Owner,at2), (Adult\_Manager,at3), (Teenager\_Devices\_Manager,at4), (Cleaning\_Manager,at5), (Kitchen\_Manager,at6), (Kids\_Manager,at7)}

**ARAUA** = {(Home\_owner, Ownership\_Control), (Adult\_Manager, Adult\_Management),

(Entertainment\_Manager, Entertainment\_Management), (Admin, Admin\_Control), (Cleaning\_Manager, Cleaning\_Management), (Kitchen\_Manager, Kitchen\_Management),

(Teenager\_Devices\_Manager, Teenager\_Devices\_Control), (Kids\_Control, Kids\_Manager)}

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Function assignRPDR(𝑎𝑢𝑠𝑒𝑟 ∈ 𝐴𝑈𝑠𝑒𝑟,𝑎𝑟 ∈ 𝐴𝑅,𝑟𝑝 ∈ 𝑅𝑃,𝑑𝑟 ∈ 𝐷𝑅) allows a user 𝑎𝑢𝑠𝑒𝑟 with 𝑎𝑟 role to add the (𝑟𝑝,𝑑𝑟) to the set of RPDRA of operational model. As a result, the device role dr would be assigned to the role pair rp, adding a new rule to the EGRBAC set of policies.

PDR-EGRBAC POLICY: assignRPDR

In this set of assignment functions, a manager gives parents permission to control all devices in the house.

assignRPDR(anna,Manager,({(parent,{Any\_Time}),Adult\_Controlled}))

assignRPDR(anna,Manager,({(parent,{Any\_Time}),Owner\_Controlled}))

assignRPDR(anna,Manager,({(parent,{Not\_At\_Home}),Owner\_Controlled}))

assignRPDR(anna,Manager,({(parent,{Any\_Time}),Door\_Device}))

assignRPDR(anna,Manager,({(parent,{Any\_Time}),Frigde\_Device}))

assignRPDR(anna,Manager,({(parent,{Any\_Time}),Oven\_Device}))

assignRPDR(anna,Manager,({(parent,{Any\_Time}),Entertainment\_Devices}))

assignRPDR(anna,Manager,({(parent,{Any\_Time}),Windows\_Devices}))

assignRPDR(anna,Manager,({(parent,{Any\_Time}),Safe\_Device}))

assignRPDR(anna,Manager,({(parent,{Any\_Time}),Kids\_Friendly\_Content}))

assignRPDR(anna,Manager,({(parent,{Any\_Time}),Lighting\_Devices}))

assignRPDR(anna,Manager,({(parent,{Any\_Time}),Cleaning\_Devices}))

assignRPDR(anna,Manager,({(parent,{Any\_Time}),PlayStation\_Device}))

assignRPDR(anna,Manager,({(parent,{Any\_Time}),Fitness\_Devices}))

assignRPDR(anna,Manager,({(parent,{Any\_Time}),Thermostat\_Device}))

assignRPDR(anna,Manager,({(parent,{Any\_Time}),Computer\_Device}))

assignRPDR(anna,Manager,({(parent,{Any\_Time}),Clock\_Device}))

A teenager can control the entertainment devices during their entertainment time, and he must be able to control the lights and fitness devices. We also take into consideration the possibility of assigning adult devices to him.

assignRPDR(anna,Manager,({(teenager,{Entertainment\_Time}),Entertainment\_Devices}))

assignRPDR(anna,Manager,({(teenager,{Entertainment\_Time}),PlayStation\_Device}))

assignRPDR(anna,Manager,({(teenager,{Any\_Time}),Teenager\_Controlled}))

assignRPDR(anna,Manager,({(teenager,{Any\_Time}),Adult\_Controlled}))

assignRPDR(anna,Manager,({(teenager,{Any\_Time}),Lighting\_Devices }))

assignRPDR(anna,Manager,({(teenager,{Any\_Time}),Fitness\_Devices }))

A manager allows an adult to control the adult devices: assignRPDR(anna,Manager,({(adult,{Any\_Time}),Adult\_Controlled}))

A manager allows the chef to use kitchen devices and lighting devices after gaining access to the door:

assignRPDR(anna,Manager,({(chef,{At\_Home}),Door\_Device,Kitchen\_Devices}))

assignRPDR(anna,Manager,({(chef,{At\_Home}),Door\_Device}))

assignRPDR(anna,Manager,({(chef,{At\_Home}),Door\_Device,Lighting\_Devices}))

A child can control the lights and only the devices with content suitable for him. Here we have the actions performed by a manager:

assignRPDR(anna,Manager,({(kid,{Entertainment\_Time}),¬Entertainment\_Devices, Kids\_Friendly\_Content }))

assignRPDR(anna,Manager,({(kid,{At\_Home}),Lighting\_Devices }))

A Manager can assign the babysitter, who comes on Friday or Wednesday, access to the door lock, windows, and lighting devices. She must be able to control children's devices to better interact with them.

assignRPDR(anna,Manager,({(babysitter,{Friday}),¬Adult\_Controlled,Door\_Device}))

assignRPDR(anna,Manager,({(babysitter,{Friday}),Door\_Device,Lighting\_Devices }))

assignRPDR(anna,Manager,({(babysitter,{Friday}),Lighting\_Devices,¬Adult\_Controlled,Windows\_Devices}))

assignRPDR(anna,Manager,({(babysitter,{Friday}),Lighting\_Devices,¬Adult\_Controlled,Thermostat\_Device}))

assignRPDR(anna,Manager,({(babysitter,{Friday}),Door\_Device∧Windows\_Devices∧Thermostat\_Device,Adult\_Controlled }))

assignRPDR(anna,Manager,({(babysitter,{Friday}),Lighting\_Devices,Kids\_Friendly\_Content}))

assignRPDR(anna,Manager,({(babysitter,{Wednesday}),¬Adult\_Controlled,Door\_Device }))

assignRPDR(anna,Manager,({(babysitter,{Wednesday}),Door\_Device,Lighting\_Devices}))

assignRPDR(anna,Manager,({(babysitter,{Wednesday}),Lighting\_Devices,¬Adult\_Controlled,Windows\_Devices}))

assignRPDR(anna,Manager,({(babysitter,{Wednesday}),Lighting\_Devices,¬Adult\_Controlled,Thermostat\_Device}))

assignRPDR(anna,Manager,({(babysitter,{Wednesday}),Lighting\_Devices,

Kids\_Friendly\_Content}))

A manager gives the maid permission to control the cleaning devices in the house after gaining access to the door. We can give her access to the fridge or the garage if there is a need to clean them.

assignRPDR(anna,Manager,({(maid,{At\_Home}),Door\_Device}))

assignRPDR(anna,Manager,({(maid,{At\_Home}),Windows\_Devices}))

assignRPDR(anna,Manager,({(maid,{At\_Home}),Door\_Device,Lighting\_Devices}))

assignRPDR(anna,Manager,({(maid,{At\_Home}),Door\_Device∧Lighting\_Devices,Cleaning\_Devices}))

assignRPDR(anna,Manager,({(maid,{At\_Home}),Cleaning\_Devices,Fridge\_Device}))

assignRPDR(anna,Manager,({(maid,{At\_Home}),Door\_Device∧Lighting\_Devices,Thermostat\_Device}))

assignRPDR(anna,Manager,({(maid,{At\_Home}),Cleaning\_Devices,Garage\_Device}))

A guest can also be a friend, so we consider the possibility of assigning him permission to control the lights and the entertainment devices.

assignRPDR(anna,Manager,({guest,{At\_Home}),Door\_Device}))

assignRPDR(anna,Manager,({(guest,{At\_Home}),Door\_Device,Lighting\_Devices}))

assignRPDR(anna,Manager,({(guest,{At\_Home}),Lighting\_Devices,Entertainment\_Devices}))

assignRPDR(anna,Manager,({(guest,{At\_Home}),Door\_Device,PlayStation\_Device}))

A manager gives the neighbor permission to control lights when at home.

assignRPDR(anna,Manager,({(neighbor,{At\_Home}),Door\_Device}))

assignRPDR(anna,Manager,({(neighbor,{At\_Home}∧ Door\_Device,Lighting\_Devices}))

As we mentioned before, authorities must be able to access the doors and windows during an emergency. It is the manager who assigns those permissions to them.

assignRPDR(anna,Manager,({(authorities{Emergency\_Time}),Door\_Device}))

assignRPDR(anna,Manager,({(authorities{Emergency\_Time}),Windows\_Devices}))

assignRPDR(anna,Manager,({(authorities{Emergency\_Time}),Door\_Device∧Windows\_Devices,Owner\_Controlled}))

The homeowner gives parents control of devices, such as the safe, even when they are not at home; in this case study, the homeowner is also the parent role.

assignRPDR(giusppe,Home\_Owner,({(parent,{Any\_Time}),Owner\_Controlled}))

assignRPDR(giusppe,Home\_Owner,({(parent,{Not\_At\_Home}),Owner\_Controlled}))

assignRPDR(giusppe,Home\_Owner,({(parent,{Any\_Time}),Safe\_Device}))

The adult manager allows parents to control all the devices that fall within his administrative unit. These assignRPDR functions are like the ones above, but the action is performed by the Adult Manager.

assignRPDR(angela,Adult\_Manager,({(parent,{Any\_Time}),Adult\_Controlled}))

assignRPDR(angela,Adult\_Manager,({(parent,{Any\_Time}),Door\_Device}))

assignRPDR(angela,Adult\_Manager,({(parent,{Any\_Time}),Fridge\_Device}))

assignRPDR(angela,Adult\_Manager,({(parent,{Any\_Time}),Oven\_Device}))

assignRPDR(roberta,Adult\_Manager,({(parent,{Any\_Time}),Windows\_Devices}))

assignRPDR(angela,Adult\_Manager,({(parent,{Any\_Time}),Lighting\_Devices }))

assignRPDR(angela,Adult\_Manager,({(parent,{Any\_Time}),Cleaning\_Devices }))

assignRPDR(roberta,Adult\_Manager,({(parent,{Any\_Time}),Fitness\_Devices}))

assignRPDR(roberta,Adult\_Manager,({(parent,{Any\_Time}),Thermostat\_Device}))

assignRPDR(roberta,Adult\_Manager,({(parent,{Any\_Time}),Computer\_Device}))

assignRPDR(roberta,Adult\_Manager,({(parent,{Any\_Time}),Clock\_Device}))

An adult manager allows the chef to use lighting devices after gaining access to the door.

assignRPDR(roberta,Adult\_Manager,({(chef,{At\_Home}),Door\_Device}))

assignRPDR(roberta,Adult\_Manager,({(chef,{At\_Home}),Door\_Device,Lighting\_Devices }))

An adult manager allows the kid to use lighting devices.

assignRPDR(roberta,Adult\_Manager,({(kid,{At\_Home}),Lighting\_Devices}))

Here we have the same permissions assigned to the babysitter as described before, but the action is performed by an adult manager.

assignRPDR(angela,Adult\_Manager,({(babysitter,{Friday}),¬Adult\_Controlled,Door\_Device}))

assignRPDR(angela,Adult\_Manager,({(babysitter,{Friday}),Door\_Device,Lighting\_Devices}))

assignRPDR(angela,Adult\_Manager,({(babysitter,{Wednesday}),¬Adult\_Controlled, Door\_Device}))

assignRPDR(roberta,Adult\_Manager,({(babysitter,{Wednesday}),Door\_Device, Lighting\_Devices}))

assignRPDR(roberta,Adult\_Manager({(babysitter,{Friday}),Lighting\_Devices ∧ ¬Adult\_Controlled,Windows\_Devices}))

assignRPDR(roberta,Adult\_Manager,({(babysitter,{Wednesday}),Lighting\_Devices ∧ ¬Adult\_Controlled,Windows\_Devices}))

assignRPDR(roberta,Adult\_Manager,({(babysitter,{Friday}),Lighting\_Devices ∧ ¬Adult\_Controlled,Thermostat\_Device}))

assignRPDR(roberta,Adult\_Manager,({(babysitter,{Wednesday}),Lighting\_Devices ∧ ¬Adult\_Controlled,Thermostat\_Device}))

assignRPDR(roberta,Adult\_Manager,({(babysitter,{Friday}),Door\_Device ∧ Windows\_Devices ∧ Thermostat\_Device,Adult\_Controlled}))

An adult manager gives the maid permission to control the cleaning devices in the house after gaining access to the door. We can give her access to the fridge or the garage if there is a need to clean them.

assignRPDR(angela,Adult\_Manager,({(maid,{At\_Home}),Door\_Device}))

assignRPDR(angela,Adult\_Manager,({(maid,{At\_Home}),Windows\_Devices}))

assignRPDR(angela,Adult\_Manager,({(maid,{At\_Home}),Door\_Device,Lighting\_Devices}))

assignRPDR(angela,Adult\_Manager,({(maid,{At\_Home}),Door\_Device ∧ Lighting\_Devices, Cleaning\_Devices}))

assignRPDR(angela,Adult\_Manager,({(maid,{At\_Home}),Cleaning\_Devices,Fridge\_Device}))

assignRPDR(roberta,Adult\_Manager,({(maid,{At\_Home}),Door\_Device ∧ Lighting\_Devices, Thermostat\_Device}))

assignRPDR(roberta,Adult\_Manager,({(maid,{At\_Home}),Cleaning\_Devices,Garage\_Device}))

An adult manager gives the guest permission to control lights when at home.

assignRPDR(angela,Adult\_Manager,({guest,{At\_Home}),Door\_Device}))

assignRPDR(angela,Adult\_Manager,({(guest,{At\_Home}),Door\_Device,Lighting\_Devices}))

An adult manager gives the neighbor permission to control lights when at home.

assignRPDR(angela,Adult\_Manager,({(neighbor,{At\_Home}),Door\_Device}))

assignRPDR(angela,Adult\_Manager,({(neighbor,{At\_Home})∧ Door\_Device, Lighting\_Devices}))

Here we have a set of rules defined as above, but they can also be performed by an adult manager.

assignRPDR(angela,Adult\_Manager,({(teenager,{Any\_Time}),Adult\_Controlled}))

assignRPDR(roberta,Adult\_Manager,({(teenager,{Any\_Time}),Lighting\_Devices }))

assignRPDR(roberta,Adult\_Manager,({(teenager,{Any\_Time}),Fitness\_Devices }))

assignRPDR(angela,Adult\_Manager,({(authorities{Emergency\_Time}),Door\_Device}))

assignRPDR(angela,Adult\_Manager,({(authorities{Emergency\_Time}),Windows\_Devices}))

assignRPDR(angela,Adult\_Manager,({(authorities{Emergency\_Time}),Door\_Device ∧ Windows\_Devices,Owner\_Controlled}))

An entertainment manager gives parents access to entertainment devices.

assignRPDR(giuseppe,Entertainment\_Manager,({(parent,{Any\_Time}),Entertainment\_Devices}))

assignRPDR(giuseppe,Entertainment\_Manager,({(parent,{Any\_Time}),Kids\_Friendly\_Content}))

assignRPDR(giuseppe,Entertainment\_Manager,({(parent,{Any\_Time}),PlayStation\_Device}))

We don’t want kids to have access to entertainment devices during their entertainment time, but only to the content suitable for them (defined in the Kids Friendly Content device role).

assignRPDR(giuseppe,Entertainment\_Manager,({(kid,{Entertainment\_Time}),¬Entertainment\_Devices,Kids\_Friendly\_Content}))

The babysitter could use the entertainment devices after putting the baby to bed, so we gave her this permission.

assignRPDR(giuseppe,Entertainment\_Manager,({(babysitter,{Friday}),Lighting\_Devices,Entertainment\_Devices}))

assignRPDR(giuseppe,Entertainment\_Manager,({(babysitter,{Wednesday}),Lighting\_Devices,Entertainment\_Devices}))

A teenager can control the entertainment devices during their entertainment time.

A guest can be a friend of the teenager, so we give him access to entertainment devices too.

assignRPDR(giuseppe,Entertainment\_Manager,({(guest,{At\_Home}),Lighting\_Devices,

Entertainment\_Devices}))

assignRPDR(giuseppe,Entertainment\_Manager,({(teenager,{Entertainment\_Time}),Entertainment\_Devices}))

assignRPDR(giuseppe,Entertainment\_Manager,({(teenager,{EntertainmentTime}),PlayStation\_Device}))

A teenager can also be the manager of an administrative unit and control his own devices. He can also allow a guest to control the PlayStation.

assignRPDR(alessio,Teenager\_Devices\_Manager,({(teenager,{Any\_Time}),Teenager\_Controlled}))

assignRPDR(alessio,Teenager\_Devices\_Manager,({(teenager,{Entertainment\_Time}),

PlayStation\_Device}))

assignRPDR(alessio,Teenager\_Devices\_Manager,({(guest,{At\_Home}),Door\_Device,

PlayStation\_Device}))

We consider an administrative unit managed by the maid so that, when needed, she can give herself control of the garage or windows to clean them.

assignRPDR(catia,Cleaning\_Manager,({(maid,{At\_Home}),Door\_Device ∧ Lighting\_Devices,Cleaning\_Devices }))

assignRPDR(catia,Cleaning\_Manager,({(maid,{At\_Home}),Cleaning\_Devices,Garage\_Device}))

assignRPDR(catia,Cleaning\_Manager,({(maid,{At\_Home}),Cleaning\_Devices,Windows\_Devices}))

A chef can be in charge of an administrative unit and can manage access to appliances in the kitchen and lights.

assignRPDR(bob,Kitchen\_Manager,({(chef,{At\_Home}),Door\_Device,Kitchen\_Devices}))

assignRPDR(bob,Kitchen\_Manager,({(chef,{At\_Home}),Lighting\_Devices}))

The Kids Manager gives babysitters permission to control kids-friendly content devices.

assignRPDR(gaia,Kids\_Manager,({(babysitter,{Friday}),Lighting\_Devices,

Kids\_Friendly\_Content}))

assignRPDR(gaia,Kids\_Manager,({(babysitter,{Wednesday}),Lighting\_Devices,

Kids\_Friendly\_Content}))

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PDR-EGRBAC POLICY: revokeRPDR

Function revokeRPDR(𝑎𝑢𝑠𝑒𝑟 ∈ 𝐴𝑈𝑠𝑒𝑟,𝑎𝑟 ∈ 𝐴𝑅,𝑟𝑝 ∈ 𝑅𝑃,𝑑𝑟 ∈ 𝐷𝑅) would allow an administrator user 𝑎𝑢𝑠𝑒𝑟 with 𝑎𝑟 role to revoke a device role from a role pair.

For each rule assignRPDR, there is a corresponding rule revokeRPDR, so we won’t provide a further explanation.

revokeRPDR(anna, Manager, ({(parent,{Any\_Time}),Adult\_Controlled}))

revokeRPDR(anna, Manager, ({(parent,{Any\_Time}),Owner\_Controlled}))

revokeRPDR(anna, Manager, ({(parent,{Not\_At\_Home}),Owner\_Controlled}))

revokeRPDR(anna, Manager, ({(parent,{Any\_Time}),Door\_Device}))

revokePDR(anna, Manager, ({(parent,{Any\_Time}),Frigde\_Device}))

revokeRPDR(anna, Manager, ({(parent,{Any\_Time}),Oven\_Device}))

revokeRPDR(anna,Manager, ({(parent,{Any\_Time}),Entertainment\_Devices}))

revokeRPDR(anna, Manager, ({(parent,{Any\_Time}),Windows\_Devices}))

revokeRPDR(anna, Manager, ({(parent,{Any\_Time}),Safe\_Device}))

revokeRPDR(anna, Manager, ({(parent,{Any\_Time}),Kids\_Friendly\_Content}))

revokeRPDR(anna, Manager, ({(parent,{Any\_Time}),Lighting\_Devices}))

revokeRPDR(anna, Manager, ({(parent,{Any\_Time}),Cleaning\_Devices}))

revokeRPDR(anna, Manager, ({(parent,{Any\_Time}),PlayStation\_Device}))

revokeRPDR(anna, Manager, ({(parent,{Any\_Time}),Fitness\_Devices}))

revokeRPDR(anna, Manager, ({(parent,{Any\_Time}),Thermostat\_Device}))

revokeRPDR(anna, Manager, ({(parent,{Any\_Time}),Computer\_Device}))

revokeRPDR(anna, Manager, ({(parent,{Any\_Time}),Clock\_Device}))

revokeRPDR(anna, Manager, ({(teenager,{Any\_Time}),Teenager\_Controlled}))

revokeRPDR(anna, Manager, ({(teenager,{Entertainment\_Time}),

Entertainment\_Devices}))

revokeRPDR(anna,Manager, ({(teenager,{Entertainment\_Time}), PlayStation\_Device}))

revokeRPDR(anna,Manager, ({(teenager,{Any\_Time}),Adult\_Controlled}))

revokeRPDR(anna,Manager, ({(teenager,{Any\_Time}),Lighting\_Devices }))

revokeRPDR(anna, Manager, ({(teenager,{Any\_Time}),Fitness\_Devices }))

revokeRPDR(anna, Manager, ({(adult,{Any\_Time}),Adult\_Controlled}))

revokeRPDR(anna, Manager, ({(chef,{At\_Home}),Kitchen\_Devices}))

revokeRPDR(anna, Manager, ({(chef,{At\_Home}),Door\_Device }))

revokeRPDR(anna, Manager, ({(chef,{At\_Home}),Lighting\_Devices }))

revokeRPDR(anna,Manager, ({(kid,{Entertainment\_Time}), Kids\_Friendly\_Content }))

revokeRPDR(anna, Manager, ({(kid,{At\_Home}),Lighting\_Devices }))

revokeRPDR(anna, Manager, ({(babysitter,{Friday}),Door\_Device }))

revokeRPDR(anna, Manager, ({(babysitter,{Friday}),Lighting\_Devices }))

revokeRPDR(anna, Manager, ({(babysitter,{Friday}), Windows\_Devices }))

revokeRPDR(anna, Manager, ({(babysitter,{Friday}), Thermostat\_Device }))

revokeRPDR(anna, Manager, ({(babysitter,{Friday}),Adult\_Controlled }))

revokeRPDR(anna, Manager, ({(babysitter,{Friday}), Kids\_Friendly\_Content }))

revokeRPDR(anna, Manager, ({(babysitter,{Wednesday}), Thermostat\_Device }))

revokeRPDR(anna, Manager, ({(babysitter,{Wednesday}), Kids\_Friendly\_Content }))

revokeRPDR(anna,Manager, ({(babysitter,{Wednesday}),Door\_Device }))

revokeRPDR(anna, Manager, ({(babysitter,{Wednesday}), Lighting\_Devices}))

revokeRPDR(anna, Manager, ({(babysitter,{Wednesday}),Windows\_Devices }))

revokeRPDR(anna,Manager, ({(maid,{At\_Home}),Door\_Device}))

revokeRPDR(anna,Manager, ({(maid,{At\_Home}),Windows\_Devices}))

revokeRPDR(anna,Manager, ({(maid,{At\_Home}),Lighting\_Devices}))

revokeRPDR(anna,Manager, ({(maid,{At\_Home}),Cleaning\_Devices}))

revokeRPDR(anna,Manager, ({(maid,{At\_Home}),Fridge\_Device}))

revokeRPDR(anna,Manager, ({(maid,{At\_Home}),Thermostat\_Device}))

revokeRPDR(anna,Manager, ({(maid, {At\_Home}),Garage\_Device}))

revokeRPDR(anna,Manager, ({guest,{At\_Home}),Door\_Device}))

revokeRPDR(anna,Manager, ({(guest,{At\_Home}),Lighting\_Devices}))

revokeRPDR(anna,Manager, ({(guest,{At\_Home}), Entertainment\_Devices}))

revokeRPDR(anna, Manager, ({(guest,{At\_Home}),PlayStation\_Device}))

revokeRPDR(anna,Manager, ({(neighbor,{At\_Home}),Door\_Device}))

revokeRPDR(anna,Manager, ({(neighbor,{At\_Home},Lighting\_Devices}))

revokeRPDR(anna,Manager, ({(authorities{Emergency\_Time}),Door\_Device}))

revokeRPDR(anna,Manager, ({(authorities{Emergency\_Time}),Windows\_Devices}))

revokeRPDR(anna,Manager, ({(authorities{Emergency\_Time}),Owner\_Controlled}))

revokeRPDR(giusppe, Home\_Owner, ({(parent,{Any\_Time}),Owner\_Controlled}))

revokeRPDR(giusppe, Home\_Owner, ({(parent,{Not\_At\_Home}),Owner\_Controlled}))

revokeRPDR(giusppe, Home\_Owner, ({(parent,{Any\_Time}),Safe\_Device}))

revokeRPDR(angela, Adult\_Manager, ({(parent,{Any\_Time}),Adult\_Controlled}))

revokeRPDR(angela,Adult\_Manager, ({(parent,{Any\_Time}),Door\_Device}))

revokeRPDR(angela,Adult\_Manager, ({(parent,{Any\_Time}),Fridge\_Device}))

revokeRPDR(angela, Adult\_Manager, ({(parent,{Any\_Time}),Oven\_Device }))

revokeRPDR(roberta, Adult\_Manager, ({(parent,{Any\_Time}),Windows\_Devices }))

revokeRPDR(angela, Adult\_Manager, ({(parent,{Any\_Time}),Lighting\_Devices }))

revokeRPDR(angela, Adult\_Manager, ({(parent,{Any\_Time}),Cleaning\_Devices }))

revokeRPDR(roberta, Adult\_Manager, ({(parent,{Any\_Time}),Fitness\_Devices }))

revokeRPDR(roberta, Adult\_Manager, ({(parent,{Any\_Time}),Thermostat\_Device }))

revokeRPDR(roberta, Adult\_Manager, ({(parent,{Any\_Time}), Computer\_Device }))

revokeRPDR(roberta, Adult\_Manager, ({(parent,{Any\_Time}),Clock\_Device }))

revokeRPDR(roberta, Adult\_Manager, ({(chef,{At\_Home}),Door\_Device }))

revokeRPDR(roberta, Adult\_Manager, ({(chef,{At\_Home}),Lighting\_Devices }))

revokeRPDR(roberta, Adult\_Manager, ({(kid,{At\_Home}),Lighting\_Devices }))

revokeRPDR(angela, Adult\_Manager, ({(babysitter,{Friday}),Door\_Device }))

revokeRPDR(angela, Adult\_Manager, ({(babysitter,{Friday}),Lighting\_Devices }))

revokeRPDR(angela, Adult\_Manager, ({(babysitter,{Wednesday}),Door\_Device }))

revokeRPDR(roberta, Adult\_Manager,({(babysitter,{Wednesday}),Lighting\_Devices}))

revokeRPDR(roberta, Adult\_Manager, ({(babysitter,{Friday}),Windows\_Devices }))

revokeRPDR(roberta, Adult\_Manager,({(babysitter,{Wednesday}),Windows\_Devices }))

revokeRPDR(roberta, Adult\_Manager,({(babysitter,{Friday}), Thermostat\_Device }))

revokeRPDR(roberta,Adult\_Manager,({(babysitter,{Wednesday}),Thermostat\_Device}))

revokeRPDR(roberta, Adult\_Manager, ({(babysitter,{Friday}), Adult\_Controlled }))

revokeRPDR(angela,Adult\_Manager, ({(maid,{At\_Home}),Door\_Device}))

revokeRPDR(angela,Adult\_Manager, ({(maid,{At\_Home}),Windows\_Devices}))

revokeRPDR(angela,Adult\_Manager, ({(maid,{At\_Home}),Lighting\_Devices}))

revokeRPDR(angela,Adult\_Manager, ({(maid,{At\_Home}), Cleaning\_Devices}))

revokeRPDR(angela,Adult\_Manager, ({(maid,{At\_Home}),Fridge\_Device}))

revokeRPDR(roberta,Adult\_Manager, ({(maid,{At\_Home}),Thermostat\_Device}))

revokeRPDR(angela,Adult\_Manager, ({(maid,{At\_Home}),Garage\_Device}))

revokeRPDR(angela,Adult\_Manager, ({guest,{At\_Home}),Door\_Device}))

revokeRPDR(angela,Adult\_Manager, ({(guest,{At\_Home}),Lighting\_Devices}))

revokeRPDR(angela,Adult\_Manager, ({(neighbor,{At\_Home}),Door\_Device}))

revokeRPDR(angela,Adult\_Manager, ({(neighbor,{At\_Home}),Lighting\_Devices}))

revokeRPDR(angela,Adult\_Manager, ({(teenager,{Any\_Time}),Adult\_Controlled}))

revokeRPDR(roberta, Adult\_Manager, ({(teenager,{Any\_Time}),Lighting\_Devices }))

revokeRPDR(roberta, Adult\_Manager, ({(teenager,{Any\_Time}),Fitness\_Devices }))

revokeRPDR(angela,Adult\_Manager, ({(authorities{Emergency\_Time}),Door\_Device}))

revokeRPDR(angela,Adult\_Manager,({(authorities{Emergency\_Time}),Windows\_Devices}))

revokeRPDR(angela,Adult\_Manager,({(authorities{Emergency\_Time}),Owner\_Controlled}))

revokeRPDR(giuseppe,Entertainment\_Manager,({(parent,{Any\_Time}),Entertainment\_Devices }))

revokeRPDR(giuseppe,Entertainment\_Manager,({(parent,{Any\_Time}), Kids\_Friendly\_Content }))

revokeRPDR(giuseppe,Entertainment\_Manager,({(parent,{Any\_Time}),PlayStation\_Device}))

revokeRPDR(giuseppe, Entertainment\_Manager, ({(kid,{Entertainment\_Time}),

Kids\_Friendly\_Content }))

revokeRPDR(giuseppe, Entertainment\_Manager, ({(babysitter,{Friday}), Entertainment\_Devices }))

revokeRPDR(giuseppe,Entertainment\_Manager,({(babysitter,{Wednesday}),Entertainment\_Devices }))

revokeRPDR(giuseppe,Entertainment\_Manager,({(guest,{At\_Home}),

Entertainment\_Devices}))

revokeRPDR(giuseppe,Entertainment\_Manager,({(teenager,{Entertainment\_Time}),Entertainment\_Devices}))

revokeRPDR(giuseppe,Entertainment\_Manager,({(teenager,{EntertainmentTime}),PlayStation\_Device}))

revokeRPDR(alessio,Teenager\_Devices\_Manager,({(teenager,{Any\_Time}),Teenager\_Controlled}))

revokeRPDR(alessio, Teenager\_Devices\_Manager, ({(teenager,{Entertainment\_Time}),

PlayStation\_Device}))

revokeRPDR(alessio,Teenager\_Devices\_Manager,({(guest,{At\_Home}), PlayStation\_Device}))

revokeRPDR(catia, Cleaning\_Manager, ({(maid, {At\_Home}), Cleaning\_Devices }))

revokeRPDR(catia, Cleaning\_Manager, ({(maid, {At\_Home}), Garage\_Device}))

revokeRPDR(catia, Cleaning\_Manager, ({(maid, {At\_Home}), Windows\_Devices }))

revokeRPDR(bob, Kitchen\_Manager, ({(chef,{At\_Home}),Kitchen\_Devices}))

revokeRPDR(bob, Kitchen\_Manager, ({(chef,{At\_Home}),Lighting\_Devices}))

revokeRPDR(gaia,Kids\_Manager,({(babysitter,{Friday}), Kids\_Friendly\_Content }))

revokeRPDR(gaia, Kids\_Manager,({(babysitter,{Wednesday}),Kids\_Friendly\_Content }))

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SAMPLE ANALYSIS QUESTIONS

1. (reachability) Can a kid control the adult devices?

No, the analysis took longer but always within seconds.

1. (escalation of privileges) Can a guest get the same privileges as the homeowner and control Owner Controlled devices?

According to the policy rules, a guest does not have access to the owner's devices.

1. (reachability) Can the babysitter who comes on Wednesday control the clock device?

It is important to check this eventuality because she could change the date and get the same privileges as the babysitter who comes on Friday.

However, according to the rules of the policy, the babysitter does not have access to the clock.

1. (availability) Can a maid clean a room and use the cleaning devices if she doesn’t have access to the room she has to clean?

If there are rules for assigning lights and doors, the maid can have access to the cleaning devices. No otherwise.

1. (reachability) Can a user control the smart toy?

This is problematic because he could spy on or interact with the child playing with the toy.

Except for family members, only the babysitter can control children's devices, while a guest is denied access based on the rules of the policy.