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SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

Internet of things and smart cities and communities – Frameworks, architectures and protocols

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Reference architecture of spare computational capability exposure of IoT devices for smart home

Recommendation ITU-T Y.4469

ITU-T Y-SERIES RECOMMENDATIONS

GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

GLOBAL INFORMATION INFRASTRUCTURE	
General	Y.100–Y.199
Services, applications and middleware	Y.200–Y.299
Network aspects	Y.300–Y.399
Interfaces and protocols	Y.400–Y.499
Numbering, addressing and naming	Y.500–Y.599
Operation, administration and maintenance	Y.600–Y.699
Security	Y.700–Y.799
Performances	Y.800–Y.899
INTERNET PROTOCOL ASPECTS	
General	Y.1000–Y.1099
Services and applications	Y.1100–Y.1199
Architecture, access, network capabilities and resource management	Y.1200–Y.1299
Transport	Y.1300–Y.1399
Interworking	Y.1400–Y.1499
Quality of service and network performance	Y.1500–Y.1599
Signalling	Y.1600–Y.1699
Operation, administration and maintenance	Y.1700–Y.1799
Charging	Y.1800–Y.1899
IPTV over NGN	Y.1900–Y.1999
NEXT GENERATION NETWORKS	
Frameworks and functional architecture models	Y.2000–Y.2099
Quality of Service and performance	Y.2100–Y.2199
Service aspects: Service capabilities and service architecture	Y.2200–Y.2249
Service aspects: Interoperability of services and networks in NGN	Y.2250–Y.2299
Enhancements to NGN	Y.2300–Y.2399
Network management	Y.2400–Y.2499
Network control architectures and protocols	Y.2500–Y.2599
Packet-based Networks	Y.2600–Y.2699
Security	Y.2700–Y.2799
Generalized mobility	Y.2800–Y.2899
Carrier grade open environment	Y.2900–Y.2999
FUTURE NETWORKS	Y.3000–Y.3499
CLOUD COMPUTING	Y.3500–Y.3599
BIG DATA	Y.3600–Y.3799
QUANTUM KEY DISTRIBUTION NETWORKS	Y.3800–Y.3999
INTERNET OF THINGS AND SMART CITIES AND COMMUNITIES	
General	Y.4000–Y.4049
Definitions and terminologies	Y.4050–Y.4099
Requirements and use cases	Y.4100–Y.4249
Infrastructure, connectivity and networks	Y.4250–Y.4399
Frameworks, architectures and protocols	**Y.4400–Y.4549**
Services, applications, computation and data processing	Y.4550–Y.4699
Management, control and performance	Y.4700–Y.4799
Identification and security	Y.4800–Y.4899
Evaluation and assessment	Y.4900–Y.4999

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T Y.4469

Reference architecture of spare computational capability exposure of IoT devices for smart home

Summary

Recommendation ITU-T Y.4469 introduces spare computational capability exposure (SCCE) of Internet of things (IoT) devices for smart home and provides the characteristics and reference architecture of SCCE. In addition, it provides common procedures and several use cases to illustrate the concepts and the reference architecture of SCCE.

SCCE is a functional entity in the smart home that facilitates IoT applications to make full use of spare computational capabilities of IoT devices in smart home scenarios. SCCE collects the spare computational capabilities exposed by IoT devices and provides them to IoT applications. Using SCCE, the spare computational capabilities of IoT devices can be used by IoT applications instead of the cloud to reduce the requirements of cloud computing and network resources.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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Smart home, spare computational capability exposure.

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FOREWORD

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Table of Contents

Recommendation ITU-T Y.4469

Reference architecture of spare computational capability exposure of IoT devices for smart home

1 Scope

This Recommendation specifies characteristics and reference architecture of spare computational capability exposure (SCCE) of Internet of things (IoT) devices for smart home.

The scope of this Recommendation includes:

– overview of spare computational capability exposure of IoT devices;

– characteristics of spare computational capability exposure of IoT devices;

– reference architecture of spare computational capability exposure of IoT devices;

– common procedures of spare computational capability exposure of IoT devices.

In addition, relevant use cases of smart home are provided in Appendix I.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Y.4000] Recommendation ITU-T Y.4000/Y.2060 (2012), *Overview of the Internet of things.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 application [b-ITU-T Y.2091]: A structured set of capabilities, which provide value-added functionality supported by one or more services, which may be supported by an API interface.

3.1.2 capability [b-ITU-R M.1224-1]: The ability of an item to meet a service demand of given quantitative characteristics under given internal conditions.

3.1.3 device [ITU-T Y.4000]: With regard to the Internet of things, this is a piece of equipment with the mandatory capabilities of communication and the optional capabilities of sensing, actuation, data capture, data storage and data processing.

3.1.4 home device [b-ITU-T X.1111]: A home device is an entity (or a home appliance), such as PDA, PC, and TV/VCR, which controls or is controlled by another home device, or provides a service to home users. There are three types of home devices from the security point of view: type A, type B and type C. Type A home device, such as remote controller, PC or PDA, has a controlling capability of the type B home device or type C home device through the presentation page and rich display. Type B home device is a bridge that connects type C home devices with no communication interface to the home network; basically it communicates with the other devices in the home network on one end and uses some proprietary language on the other end (some examples include proprietary lighting control, etc.). Type C home device, such as security cameras, A/V devices, etc., only provides some sort of service to the rest of the home devices. Type A or type C home device is called a security console, if it has a security ownership of type B home device or type C home device. Any device in the home network can be classified into type A, type C or type A/type C according to the functionalities of a device.

3.1.5 Internet of things (IoT) [ITU-T Y.4000]: A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.

NOTE 1 – Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, whilst ensuring that security and privacy requirements are fulfilled.

NOTE 2 – From a broader perspective, the IoT can be perceived as a vision with technological and societal implications.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AI	Artificial Intelligence
CCP-FC	Computational Capability Publishing Functional Component
ES-FC	Exposure Support Functional Component
IoT	Internet of Things
PIR	Passive Infrared
RH-FC	Request Handling Functional Component
SCC	Spare Computational Capability
SCCE	Spare Computational Capability Exposure
SSAS	Service Support and Application Support
TS-FC	Task Scheduling Functional Component
TSP-FC	Task Support Functional Component

5 Conventions

The following conventions are used in this Recommendation:

– The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted, if conformance to this Recommendation is to be claimed.

– The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

6 Overview of SCCE of IoT devices for smart home

With the progress of IoT and artificial intelligence (AI) technologies, IoT applications for smart home have been growing more intelligent to provide increasing convenience. Computational modules are pieces of software that perform data processing for these applications (e.g., smart voice control). Running these modules typically requires sufficiently massive computational capabilities such that their resources are usually provided by cloud computing. That is, the computational modules run in the cloud to process the raw data produced by home devices. At the same time, there are some home devices that have excess computational capacity beyond what may be required for their own use, and can provide their spare computational capabilities. These home devices with spare computational capabilities may be used to run the computational modules locally instead of the cloud.

The spare computational capability exposure (SCCE) is a functional entity (see Figure 6-1) in smart home that facilitates enabling IoT applications to make full use of the spare computational capabilities of IoT devices within smart home scenarios. A spare computational capability (SCC) provider (e.g., P_1 to P_k in Figure 6-1) is a functional entity in a home device that can expose the dynamic spare computational capability of the home device to SCCE. Each SCC provider registers, unregisters and updates its own computational capability on the SCCE. The SCCE integrates these exposed computational capabilities according to access policies and publishes their information. SCC subscriber (e.g., S_1 to S_n in Figure 6-1) is a functional entity, usually in a resource-constrained home device, that can subscribe, unsubscribe and access the exposed computational capabilities on SCCE. When a home device encounters a situation where it has insufficient computational capability to process its own raw data, this home device can use its SCC subscriber to establish a connection with the SCCE, subscribe its needed computational capabilities and then send the identifiers of computational modules and the raw data to the SCCE. If the SCCE does not already have the computational modules, usually at the first time, it will get these modules from the computational module repository which stores and manages computational modules. The SCCE then distributes the computational modules and the raw data to SCC providers for processing after scheduling, gets back the processed data and returns the processed data to the SCC subscriber. After the unsubscription or disconnection of an SCC subscriber, the SCCE may withdraw the subscribed computational capabilities and delete the corresponding computational modules. As a result, through SCCE, IoT applications on home devices can take advantage of the spare computational capabilities exposed by SCC providers in smart home.

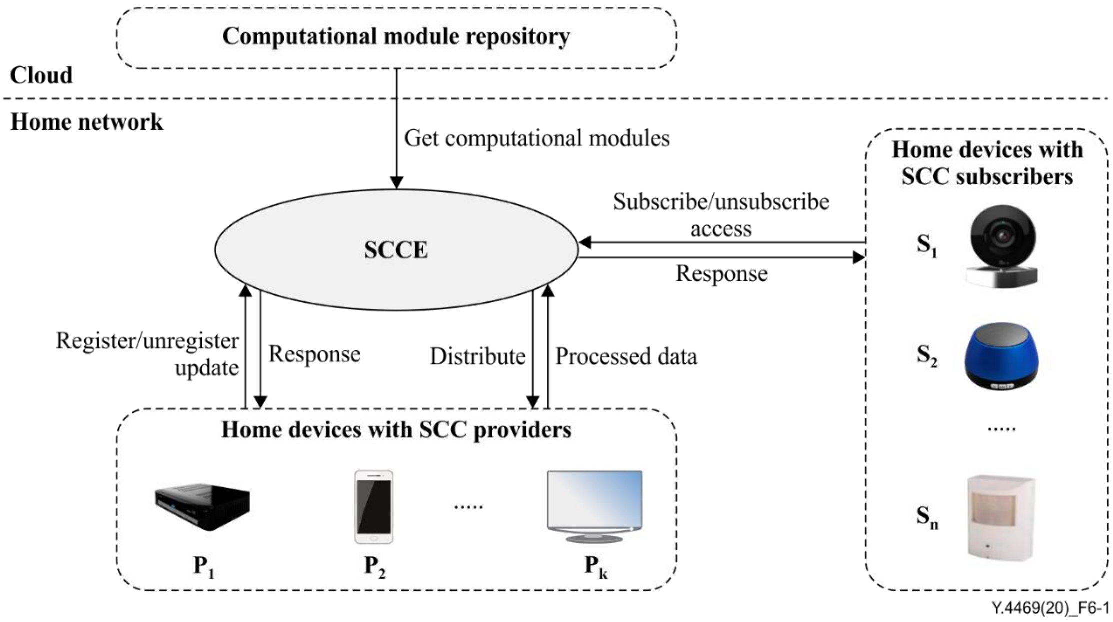

Figure 6-1 - Overview of SCCE

In practice, SCCE can be deployed on the home gateway, while the computational module repository is usually located in the cloud. The home devices with SCC providers that expose their spare computational capabilities to SCCE may be devices such as a set-top-box, smart phone, smart TV, etc.

From the perspective of IoT application providers, through SCCE, the spare computational capabilities of home devices can be used by IoT applications, as opposed to cloud-based computational capabilities, which reduces both the requirements for cloud computing and for network resources.

7 Characteristics of SCCE of IoT devices for smart home

7.1 Supporting heterogeneous home devices

SCCE supports a wide variety of home devices, allowing them to expose their computational capabilities or access the exposed computational capabilities. Heterogeneous home devices can be connected with SCCE to register part or all of their spare computational capabilities on the SCCE which may then be used by other resource-constrained home devices.

7.2 Management for exposed computational capabilities of home devices

SCCE exposes reference points for home devices, with which the home devices can expose part or all of their spare computational capabilities to the SCCE. In addition, SCCE supports access policies for these devices, integrates these exposed computational capabilities, publishes the information and manages the status of all the exposed computational capabilities of home devices.

On the other side, SCCE exposes reference points to SCC subscribers to support SCC subscribers to subscribe, unsubscribe and access the computational capabilities exposed by home devices.

7.3 Scheduling computational tasks

SCCE creates a computational task corresponding to an access to the exposed computational capabilities from SCC subscribers. SCCE manages the status of all the computational tasks and schedules these tasks, and makes these tasks run on SCC providers using their exposed spare computational capabilities. SCCE can also transfer a task from one SCC provider to another if the SCC provider cannot provide sufficient spare computational capability to continue running the task (e.g., the home device is powered off).

7.4 Management for computational modules

SCCE receives the identifiers of computational modules and the raw data from a SCC subscriber when the SCC subscriber requests access to computational capabilities. SCCE gets the computational modules from a computational module repository according to the identifiers if SCCE does not have them, usually at the first time. SCCE manages these modules and distributes them to SCC providers according to the computational tasks scheduling. These modules may be deleted by SCCE after the SCC subscriber unsubscribes its subscribed computational capabilities.

7.5 Connection status discovery

SCCE can discover automatically the connection and disconnection of home devices that choose to expose their computational capabilities to SCCE. On the other side, when a SCC subscriber is connected into the home network, it can establish the connection with SCCE to process the subscriptions. Also, the SCCE can discover the disconnection of a SCC subscriber and withdraw the computational capabilities allocated to the SCC subscriber.

7.6 Access control mechanism

SCCE provides access control mechanisms to ensure that only the authenticated SCC providers and SCC subscribers are allowed to establish connections with the SCCE and only the authenticated IoT applications are allowed to use the exposed computational capabilities.

8 Reference architecture of SCCE of IoT devices for smart home

8.1 General architecture

SCCE is a functional entity at the service support and application support (SSAS) layer of the IoT reference model defined in [ITU-T Y.4000], and facilitates IoT applications in home devices to use the spare computational capabilities of other home devices for data processing required by the IoT applications. Figure 8-1 shows the reference architecture of SCCE.

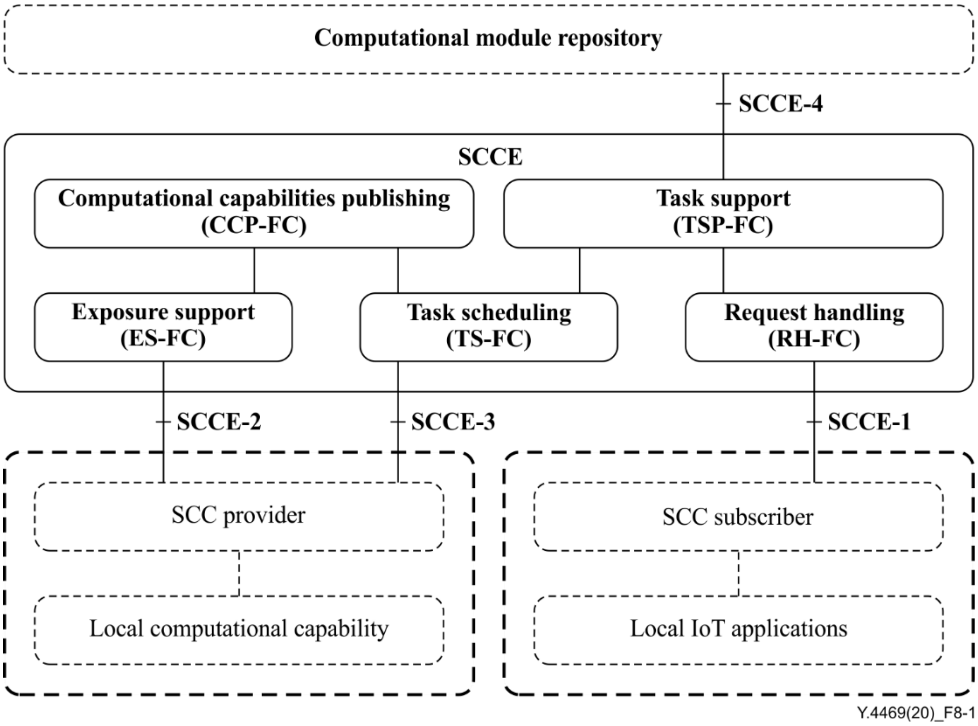

Figure 8-1 - Reference architecture of SCCE

SCCE includes five functional components, namely the exposure support functional component (ES-FC), the computational capability publishing functional component (CCP-FC), the request handling functional component (RH-FC), the task support functional component (TSP-FC) and the task scheduling functional component (TS-FC).

The SCCE exposes a group of reference points to interact with SCC providers and SCC subscribers in home devices and computational module repository, including:

– SCCE-1: for SCC subscribers to subscribe, unsubscribe and access the computational capabilities registered on SCCE;

– SCCE-2: for SCC providers to register, unregister and update their spare computational capabilities on SCCE;

– SCCE-3: for SCC providers to perform their exposed computational capabilities under the control of SCCE;

– SCCE-4: for SCCE to get computational modules from computational module repository.

NOTE – The functional components of SCCE interact with each other by internal interfaces. This Recommendation does not specify the internal interfaces.

The computational module repository stores and manages computational modules. SCCE gets these computational modules and makes them run on the home devices with spare computational capabilities to perform the data processing.

An SCC provider is a functional entity in a home device with spare computational capability and it registers, unregisters and updates the computational capability on SCCE. In addition, an SCC provider receives the computational modules and the raw data from SCCE, runs the modules to process the raw data and returns the processed data to the SCCE.

An SCC subscriber is a functional entity in a home device and the IoT applications in the home device use it to subscribe, unsubscribe and access the exposed computational capabilities on SCCE. In addition, when an IoT application in the home device needs to access other computational capabilities to process its raw data, this SCC subscriber will provide the identifiers of computational modules and the raw data to the SCCE for data processing and receive back the processed data.

8.2 Functional components

8.2.1 Exposure support functional component

The ES-FC exposes reference point SCCE-2 and provides access control mechanisms for SCC providers to expose their spare computational capabilities to SCCE. Through the ES-FC, SCC providers can establish connections with SCCE, and register, unregister and update the computational capabilities on the SCCE.

The ES-FC provides the following functionalities:

– discovering and managing the connection status of SCC providers;
– processing the registering and unregistering requests of the spare computational capabilities from SCC providers;
– monitoring the status of the exposed computational capabilities of SCC providers;
– sending the status of the dynamic exposed computational capabilities to CCP-FC (defined in clause 8.2.2);
– providing access policies and authentication for SCC providers.

8.2.2 Computational capability publishing functional component

The CCP-FC publishes the exposed computational capabilities on SCCE to support the scheduling in TS-FC (defined in clause 8.2.5). The CCP-FC gets the status of the dynamic exposed computational capabilities of SCC providers from ES-FC, stores the status and publishes them for other functional components.

The CCP-FC provides the following functionalities:

– recording and tracking the status of the dynamic exposed computational capabilities of SCC providers;
– predicting the future status of spare computational capabilities of SCC providers according to the analysis of previous status;
– publishing the status of exposed computational capabilities of SCC providers for other functional components of SCCE.

8.2.3 Request handling functional component

The RH-FC exposes reference point SCCE-1 and provides access control mechanisms for SCC subscribers to subscribe, unsubscribe and access the computational capabilities registered on SCCE. Through the RH-FC, SCC subscribers can establish connections with SCCE, subscribe the available computational capabilities, send its raw data to the SCCE for processing and receive the processed data.

The RH-FC provides the following functionalities:

– discovering and managing the connection status of SCC subscribers;
– interacting with TSP-FC (defined in clause 8.2.4) to process the subscription and unsubscription requests from SCC subscribers;
– receiving the identifiers of the computational modules and the raw data from SCC subscribers, and sending them to TSP-FC;
– notifying SCC subscribers of the status of their subscribed computational capabilities, if needed;

– providing access policies and authentication for SCC subscribers.

8.2.4 Task support functional component

The TSP-FC creates a computational task when it gets a computational access from SCC subscribers through RH-FC. The TSP-FC exposes reference point SCCE-4 to get computational modules from the computational module repository according to the identifiers of the modules provided by SCC subscribers.

The TSP-FC provides the following functionalities:

– creating computational tasks corresponding to the computational accesses from SCC subscribers;

– getting computational modules from computational module repository, if SCCE does not have the modules, usually at the first time;

– storing the computational modules and the raw data corresponding to every computational task and providing them to TS-FC;

– maintaining the status of computational tasks, including created, ready, pending, running, finished and cancelled.

8.2.5 Task scheduling functional component

The TS-FC schedules computational tasks based on the status of exposed computational capabilities from CCP-FC and computational tasks from TSP-FC, distributes the computational modules and the raw data to SCC providers and controls the running of the computational modules on SCC providers through the reference point SCCE-3 exposed by TS-FC.

The TS-FC provides the following functionalities:

– scheduling computational tasks and assigning the computational tasks to the selected SCC providers;

– sending the computational modules and the raw data of computational tasks to SCC providers;

– controlling the running of the computational modules on SCC providers;

– transferring a computational task from one SCC provider to another, due to the status changes of the spare computational capabilities of SCC providers.

8.3 Reference points

8.3.1 Reference point SCCE-1

The reference point SCCE-1 is exposed by the RH-FC to support the SCC subscribers to subscribe, unsubscribe and access the computational capabilities registered on SCCE.

The following interactions can be performed via the reference point SCCE-1:

– SCC subscribers establish and quit connections with SCCE;

– SCCE discovers the connection status of SCC subscribers;

– SCC subscribers subscribe, unsubscribe and access the registered computational capabilities on SCCE;

– SCCE notifies SCC subscribers of the dynamic status of the subscribed computational capabilities.

8.3.2 Reference point SCCE-2

The reference point SCCE-2 is exposed by the ES-FC to support SCC providers to expose their spare computational capabilities to SCCE.

The following interactions can be performed via the reference point SCCE-2:

– SCC providers establish and quit connections with SCCE;

– SCCE discovers the connection status of SCC providers;

– SCC providers register, unregister and update their exposed computational capabilities on SCCE.

8.3.3 Reference point SCCE-3

The reference point SCCE-3 is exposed by the TS-FC to support SCCE to control the running of the computational modules of the computational tasks on SCC providers.

The following interactions can be performed via the reference point SCCE-3:

– SCCE sends the computational modules and the raw data of computational tasks to SCC providers;

– SCC providers return the processed data to the SCCE after processing the raw data;

– SCCE controls the running of the computational modules on SCC providers, including start, pause and stop;

– SCC providers notify SCCE of the status of the computational modules.

8.3.4 Reference point SCCE-4

The reference point SCCE-4 is exposed by TSP-FC to support SCCE to get computational modules from computational module repository.

9 Common procedures of SCCE of IoT devices for smart home

9.1 Registering and updating computational capabilities

This procedure shows how a SCC provider registers and updates the spare computational capability of the device to SCCE (see Figure 9-1).

The main steps are outlined as follows:

1) the SCC provider registers the spare computational capability to SCCE through the reference point SCCE-2;

2) the ES-FC performs access control for the registration from the SCC provider;

3) the ES-FC returns the registration result to the SCC provider through the reference point SCCE-2;

4) after the successful registration, the SCC provider updates the status of the spare computational capability to SCCE when the status is changed.

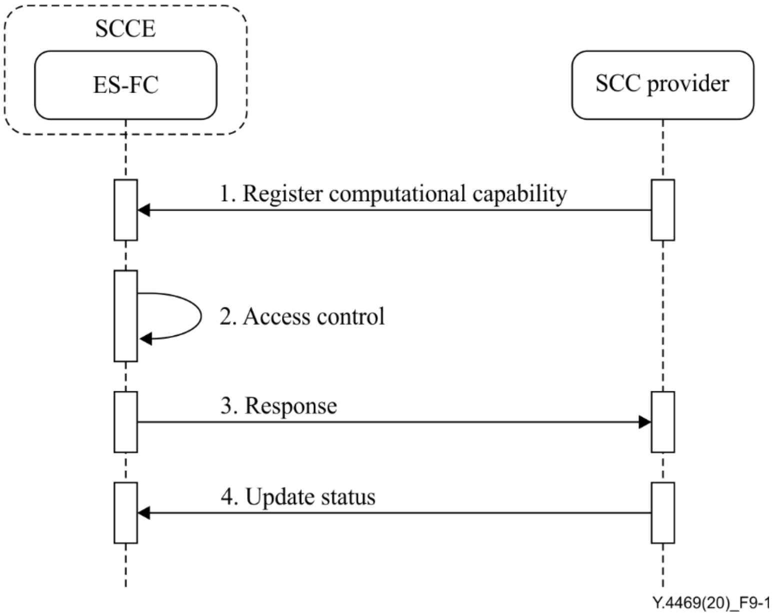

Figure 9-1 – Flow for registering and updating computational capabilities

9.2 Subscribing computational capabilities

This procedure shows how a SCC subscriber subscribes the exposed computational capabilities which have been published by SCCE (see Figure 9-2).

The main steps are outlined as follows:

1) the SCC subscriber subscribes the computational capabilities published by SCCE through the reference point SCCE-1;
2) the RH-FC performs access control for the subscription from the SCC subscriber;
3) the RH-FC sends the information of the required computational capabilities to the TSP-FC;
4) the TSP-FC checks the available computational capabilities for the subscription through TS-FC;
5) the TS-FC sends request to get the status of exposed computational capabilities from CCP-FC;
6) the CCP-FC sends back the status of exposed computational capabilities;
7) the TS-FC decides whether the subscription is accepted according to the status and sends the result to TSP-FC. If the available exposed computational capabilities can fulfil the subscription, the subscription will be accepted, or else it will be rejected;
8) the TSP-FC sends the response to the RH-FC;
9) the RH-FC returns the subscription result to the SCC subscriber through the reference point SCCE-1;
10) the CCP-FC updates the status of the exposed computational capabilities to TS-FC, and then the TS-FC updates the status of the subscribed computational capabilities to the SCC subscriber when the status is changed.

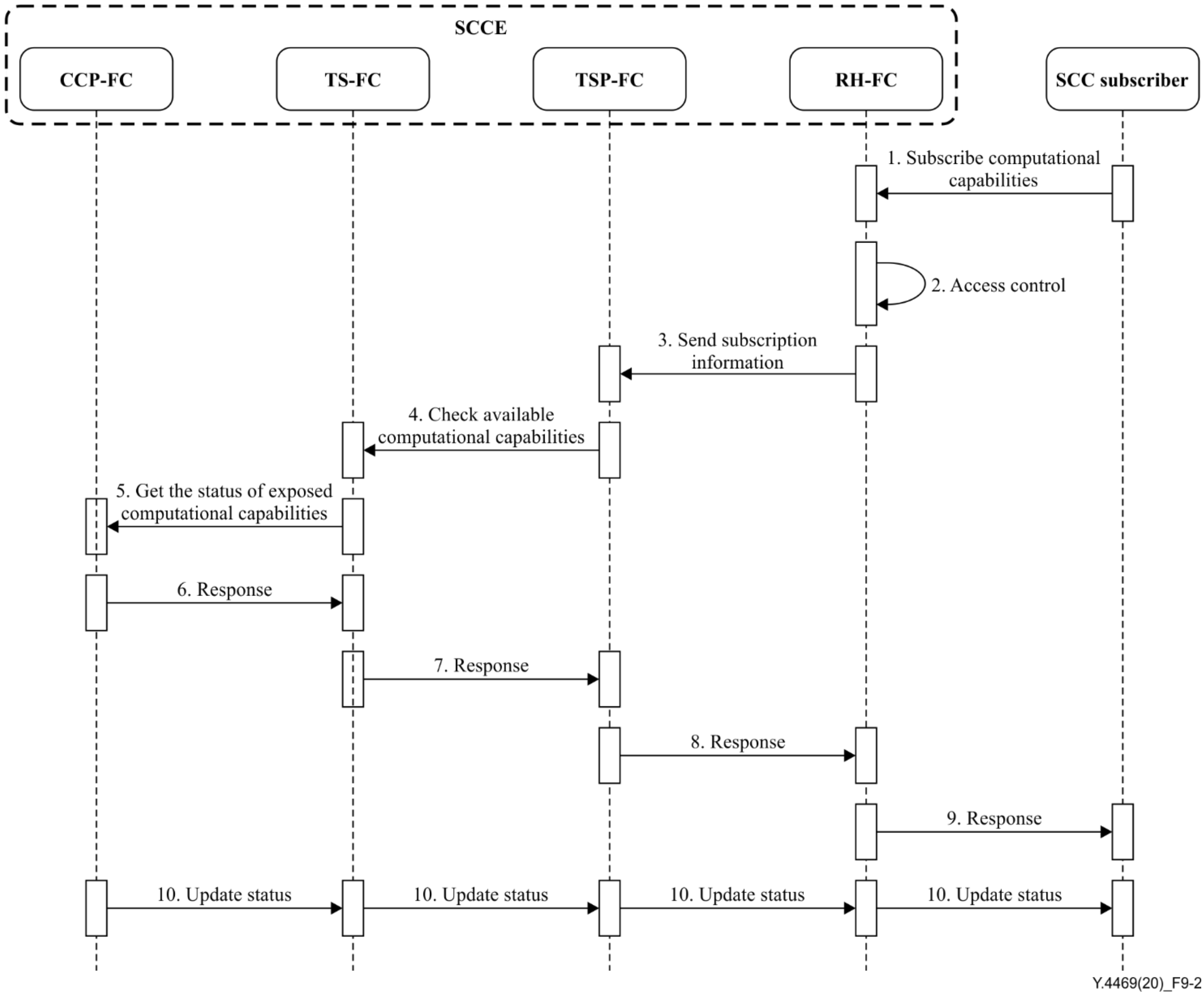

Figure 9-2 – Flow for subscribing computational capabilities

9.3 Accessing computational capabilities

This procedure shows how a SCC subscriber accesses the exposed computational capabilities which have been subscribed by the SCC subscriber (see Figure 9-3).

The main steps are outlined as follows:

1) The SCC subscriber sends an access request to its subscribed computational capabilities to the RH-FC through the reference point SCCE-1. The access information includes the identifiers of computational modules and the raw data which needs to be processed by the computational modules;

2) The RH-FC performs access control for the access request from the SCC subscriber;

3) the RH-FC sends the access information to the TSP-FC;

4) The TSP-FC creates a computational task corresponding to the access if the access request is accepted. It is assumed that the TSP-FC already has the computational modules, if not the TSP-FC needs to get the computational modules from the computational module repository according to the identifiers of these modules included in the access information, usually at the first time;

5) The TS-FC gets the computational task information from the TSP-FC. The information includes computational modules, raw data, and the status of the computational task;

6) The TS-FC schedules all the computational tasks and assigns the computational task of this access to the selected SCC providers;

7) The TS-FC sends the computational modules and the raw data to the selected SCC providers through the reference point SCCE-3. If a SCC provider already has a module, then the module will not be transmitted;

8) The SCC providers run these computational modules to process the raw data. One SCC provider may run one or more computational modules, depending on the exposed computational capability of the home device with this SCC provider;

9) The SCC providers send back processed data to the TS-FC after finishing the data processing through the reference point SCCE-3;

10) The TS-FC sends the processed data to the TSP-FC;

11) The TSP-FC updates the status of the computational task and sends the processed data to the RH-FC;

12) The RH-FC returns access response to the SCC subscriber through the reference point SCCE-1. The access response includes the access result and the processed data.

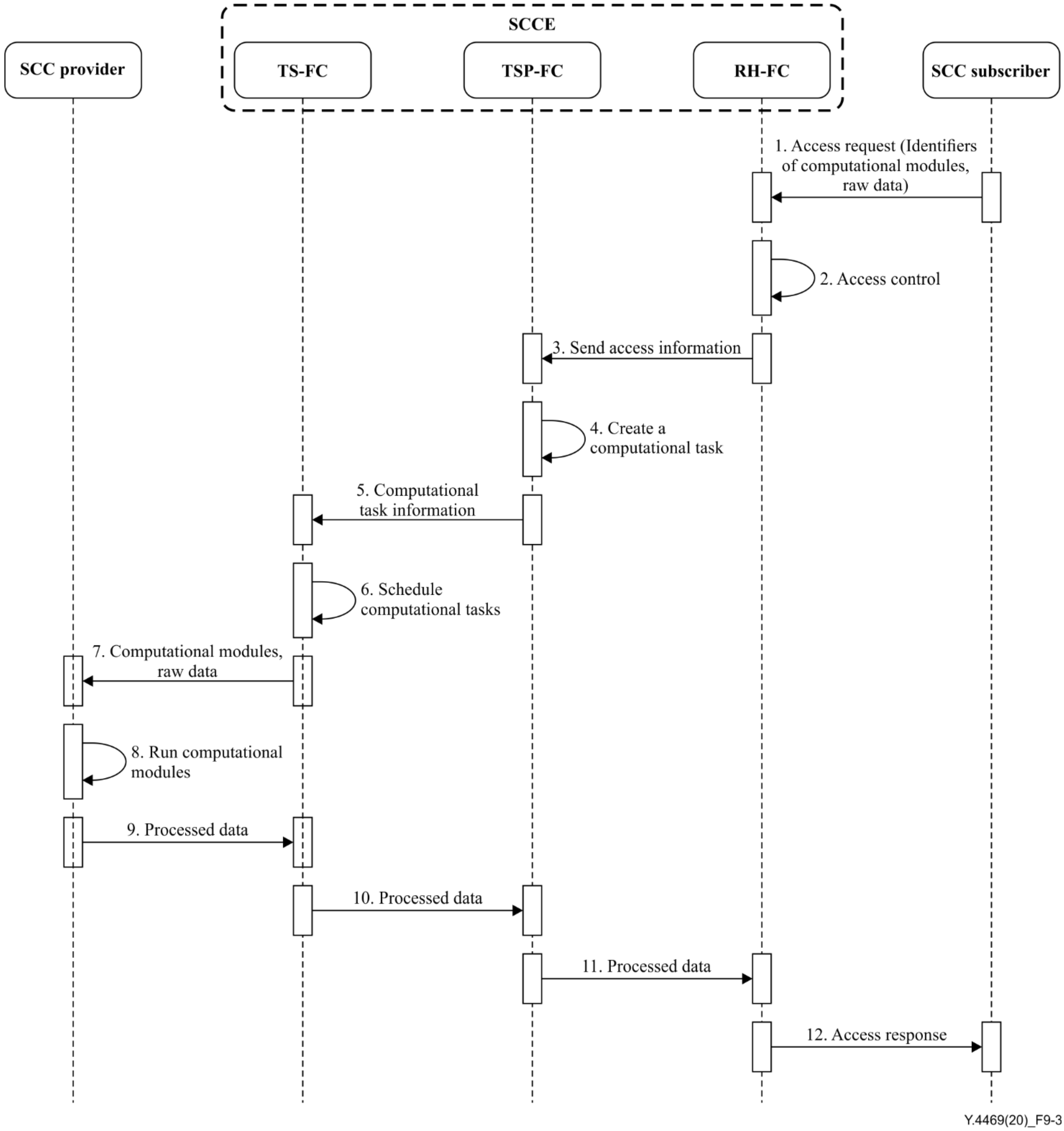

Figure 9-3 – Flow for accessing computational capabilities

10 Security considerations

SCCE is required to provide security mechanisms to authenticate and authorize SCC providers to expose their computational capabilities to SCCE, and for SCC subscribers to subscribe and access these computational capabilities. In addition, secure transmission is required when data are transported between SCCE and other functional entities.

Appendix I

Use cases of SCCE in smart home

(This appendix does not form an integral part of this Recommendation.)

This appendix provides use cases to illustrate the implementation of the SCCE.

I.1 Use case: SCCE promoting smart elderly care in smart home

Figure I.1 shows a use case where SCCE is applied for a smart elderly care application. Passive infrared (PIR) motion sensor can detect human motion based on the change of infrared radiation. The smart elderly care application uses a PIR motion sensor array deployed in a home environment to analyse user behaviours in order to detect anomalous events. This requires computational capabilities to process the PIR sensor data. As a PIR motion sensor array may have insufficient computational capability to support its full data processing needs, it will send its sensor data to the cloud for processing. Instead, SCCE can also provide these capabilities in another way.

In this case, SCCE works in the home gateway, and SCC providers work in common home devices such as set-top-box, smart phone and smart television. These devices may have spare computational capabilities and expose these capabilities to the SCCE. As a home device with SCC subscriber, the PIR motion sensor array subscribes and accesses the exposed computational capabilities. After the successful subscription, the sensor array will send sensor data and the identifier of a computational module to SCCE when accessing the exposed computational capabilities. The SCCE gets the computational module from the computational module repository in cloud according to the identifier, and distributes the module and the sensor data to one of the SCC providers (e.g., smart television) which is selected by TS-FC of SCCE. Then the SCCE gets back the processed data and returns these data to the PIR motion sensor array.

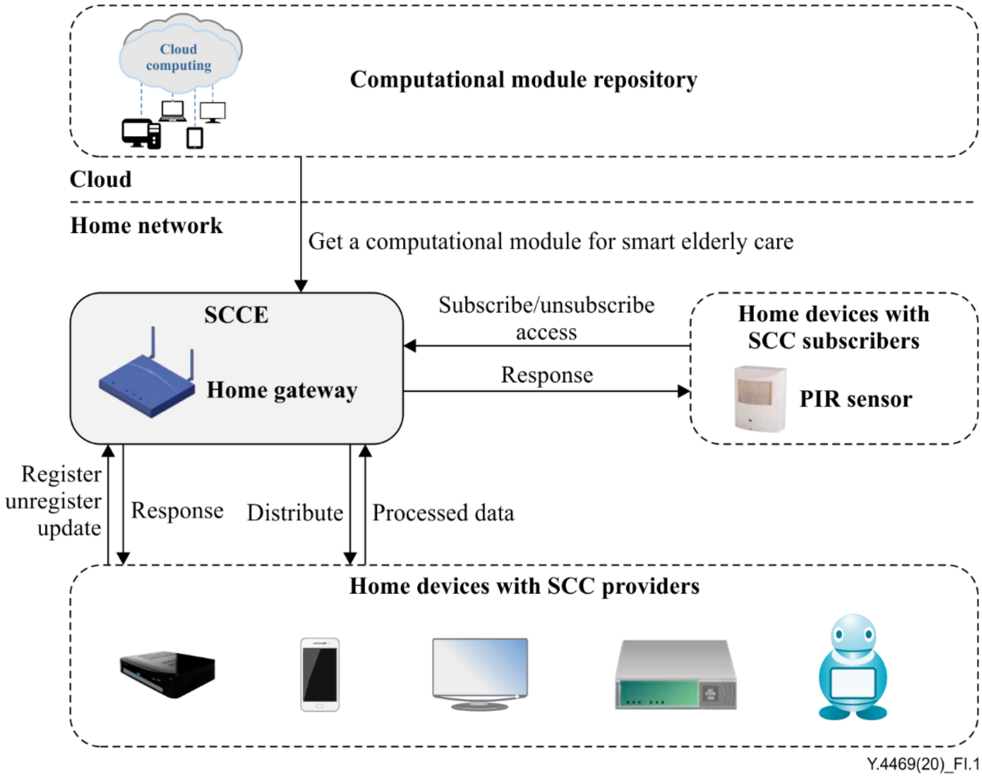

Figure I.1 – Use case: SCCE promoting smart elderly care in smart home

As a result, through the SCCE, the spare computational capabilities of home devices can be used to process the data produced by the PIR motion sensor array. One benefit of this is enabling the smart elderly care application to continue working during a time of network disconnection between the cloud and the home network. Additionally, another benefit is possibly the reduced requirement (and dependency) for cloud servers where that is important.

I.2 Use case: SCCE promoting smart voice control in smart home

Figure I.2 shows a use case where SCCE is applied for a smart voice control application. The smart voice control application enables users to control smart home devices by voice. Users can simply speak to a smart speaker in a natural way to control these devices such as air conditioner, water heaters, etc. Usually, processing voice data to understand user commands requires massive computational capabilities. Due to the constrained resources of the smart speaker, it will send the voice data to the cloud for processing. However, SCCE can also provide computational capabilities.

In this case, SCCE works in the set-top-box, and this set-top-box can provide spare computational capabilities as an SCC provider and expose its computational capabilities to the SCCE working in itself. The smart speaker is able to play sound and collect voice, but usually it may have insufficient computational capabilities to support processing all of its voice data. The smart speaker, as a home device with SCC subscriber, can subscribe and access the computational capabilities published by the SCCE. The smart speaker requires two computational modules to process its voice data, so it sends the identifiers of the two modules and the voice data to SCCE and the SCCE gets the modules from the computational module repository in cloud according to the identifiers. Because the set-top-box is the only home device with SCC provider in this case, the computational modules and the voice data can only be distributed to the set-top-box. The subscription and access will fail if the set-top-box does not have sufficient computational capabilities, and the smart speaker may get the needed computational capabilities from the cloud. Then the SCCE gets back the commands (output of the voice data processing) and returns the commands to the smart speaker.

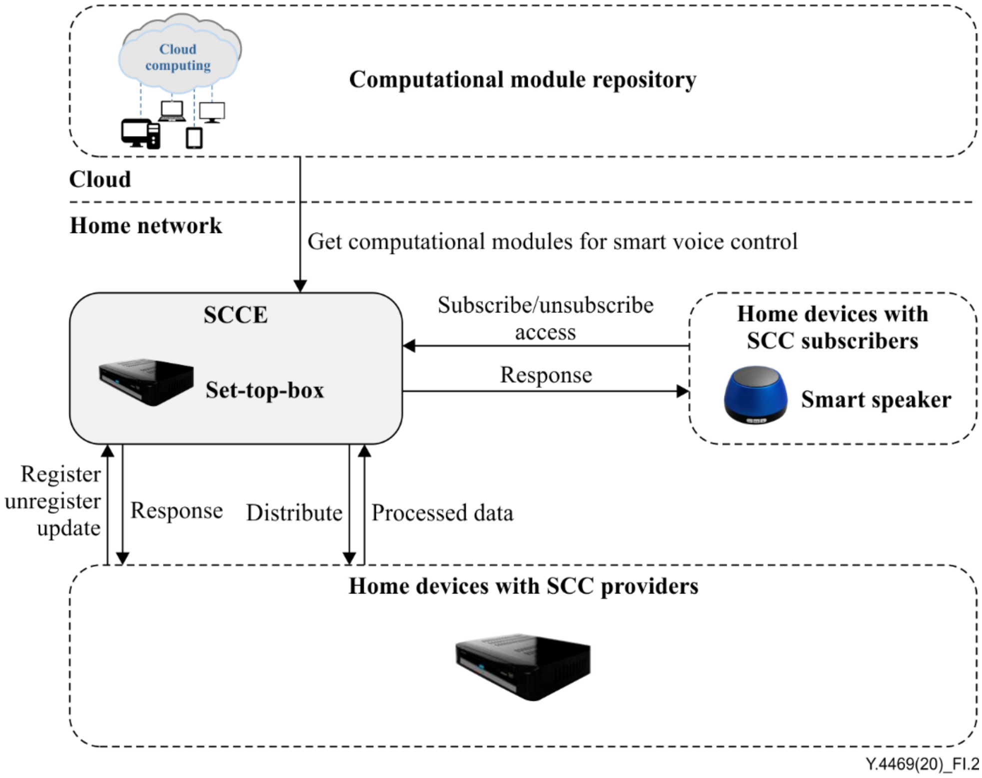

Figure I.2 – Use case: SCCE promoting smart voice control in smart home

As a result, through the SCCE, the smart voice control application can use the spare computational capability of the set-top-box to process voice data to understand commands. This allows the smart voice control application to continue working during times of network disconnection between the cloud and home network.

I.3 Use case: SCCE promoting smart video monitoring in smart home

Figure I.3 shows a use case where SCCE is applied for a smart video monitoring application. The smart video monitoring application can detect anomalous events (e.g., humans falling over) automatically and send anomalous event detection warnings. In contrast in traditional video monitoring applications, users are required to (manually/visually) review all the video to search for anomalous events. Usually, processing video data to detect anomalous events requires massive computational capabilities. Due to the constrained resources of the camera, it will send the video data to the cloud for processing. Instead, SCCE can also provide computational capabilities.

In this case, SCCE works in the home gateway, and SCC providers work in two smart phones which can expose their computational capabilities to the SCCE. The camera in the smart video monitoring application can only capture video and send out the video data over the network. The camera lacks sufficient computational capability to make further analysis on the video data and thus it may subscribe and access the exposed computational capabilities of the smart phones through the SCCE. After subscription, the camera will send video data and the identifier of a computational module to SCCE when accessing the exposed computational capabilities. The SCCE gets the computational module from the computational module repository in the cloud according to the identifier and distributes the module and the video data to one of the smart phones for data processing to detect anomalous events. When anomalous events are detected, SCCE gets these back and returns them to the camera.

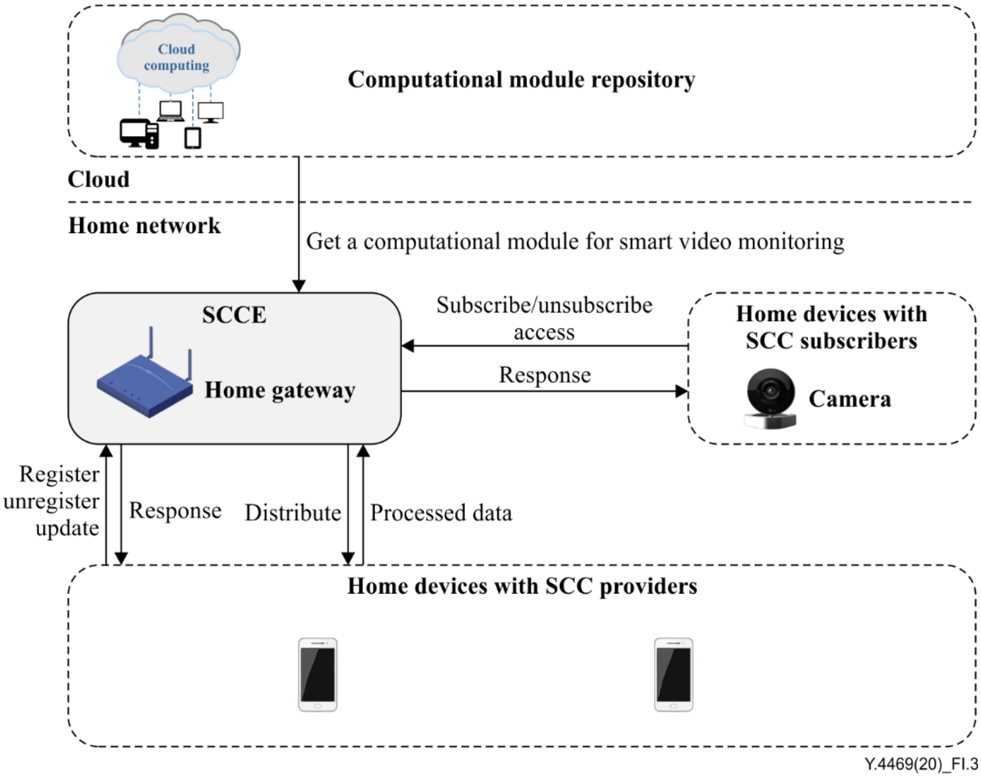

Figure I.3 – Use case: SCCE promoting smart video monitoring in smart home

As a result, through the SCCE, the smart video monitoring application can use the computational capabilities of smart phones to perform video abnormal event detection. The benefit is in reducing the requirements of cloud computing and network resources.

Bibliography

[b-ITU-T X.1111] Recommendation ITU-T X.1111 (2007), *Framework of security technologies for home network.*

[b-ITU-T Y.2091] Recommendation ITU-T Y.2091 (2011), *Terms and definitions for next generation networks*.

[b-ITU-R M.1224-1] Recommendation ITU-R M.1224-1 (2012), *Vocabulary of terms for international mobile telecommunications (IMT)*.

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