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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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Functional architecture for Internet of things services based on visible light communication

Recommendation ITU-T Y.4474

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Recommendation ITU-T Y.4474

Functional architecture for Internet of things services based on visible light communication

Summary

Recommendation ITU-T Y.4474 specifies the functional architecture for Internet of things (IoT) services based on visible light communication (VLC), which includes functional requirements, functional architecture, messages and information flows.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.4474	2020-08-29	20	11.1002/1000/14376

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Functional architecture, IoT services, visible light communication, VLC.

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Functional architecture for Internet of things services based on visible light communication

1 Scope

This Recommendation specifies the functional architecture for Internet of things (IoT) services based on visible light communication (VLC), which includes the following:

– functional requirements;

– functional architecture;

– messages and information flows based on the functional architecture.

The protocol stacks that can be considered in implementation are given in an appendix for three data types: light control data (LCD), device control data (DCD); and IoT service data (ISD).

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 Recommendation.

[ITU-T Y.4465] Recommendation ITU-T Y.4465 (2020), *Framework of Internet of things services based on visible light communications*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 channel [b-ITU-T G.9960]: A transmission path between nodes. One channel is considered to be one transmission path. Logically, a channel is an instance of a communication medium used for the purpose of passing data between two or more nodes.

3.1.2 data [b-ITU-T G.9960]: Bits or bytes transported over the medium or via a reference point that individually convey information. Data includes both user (application) data and any other auxiliary information (overhead, including control, management, etc.). Data does not include bits or bytes that, by themselves, do not convey any information, such as the preamble.

3.1.3 device [b-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 identifier [b-ITU-T Y.2091]: An identifier is a series of digits, characters and symbols or any other form of data used to identify subscriber(s), user(s), network element(s), function(s), network entity(ies) providing services/applications, or other entities (e.g., physical or logical objects). Identifiers can be used for registration or authorization. They can be either public to all networks, shared between a limited number of networks or private to a specific network (private IDs are normally not disclosed to third parties).

3.1.5 Internet of things (IoT) [b-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:

DCD Device Control Data

ID Identifier

IoT Internet of Things

IP Internet Protocol

IR Infrared

IS IoT Server

ISD IoT Service Data

LCD Light Control Data

LD Laser Diode

LED Light-Emitting Diode

MAC Medium Access Control

PD Photodiode

PHY Physical layer

RF Radio Frequency

UT User Terminal

UV Ultraviolet

VA VLC Agent

VL VLC Light

VLC Visible Light Communication

5 Conventions

In this Recommendation, the following conventions are used:

The keyword "**is required to**" indicates a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

The keyword "**is recommended**" indicates a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

The keywords "**R1**", "**R2**", "**R3**", "**R4**", "**R5**" and "**R6**" are used to indicate the reference points between two network elements in the functional architecture.

6 Overview

Visible light communication (VLC) [b-IEEE 802.15.7] is a wireless communication technology that uses visible light, as well as ultraviolet (UV) and infrared (IR) radiation, as a communication medium. Data is modulated and transmitted by a light-emitting diode (LED) or laser diode (LD). The modulated data is received by photodiode (PD) or image sensor. A device adapts to become either transmitting or receiving equipment. VLC can be used simultaneously with communication technologies based on radio frequency (RF).

[ITU-T Y.4465] specifies a framework that introduces the concept, high-level requirements and reference model for IoT services based on VLC. It also presents the network configuration that is depicted in Figure 1.

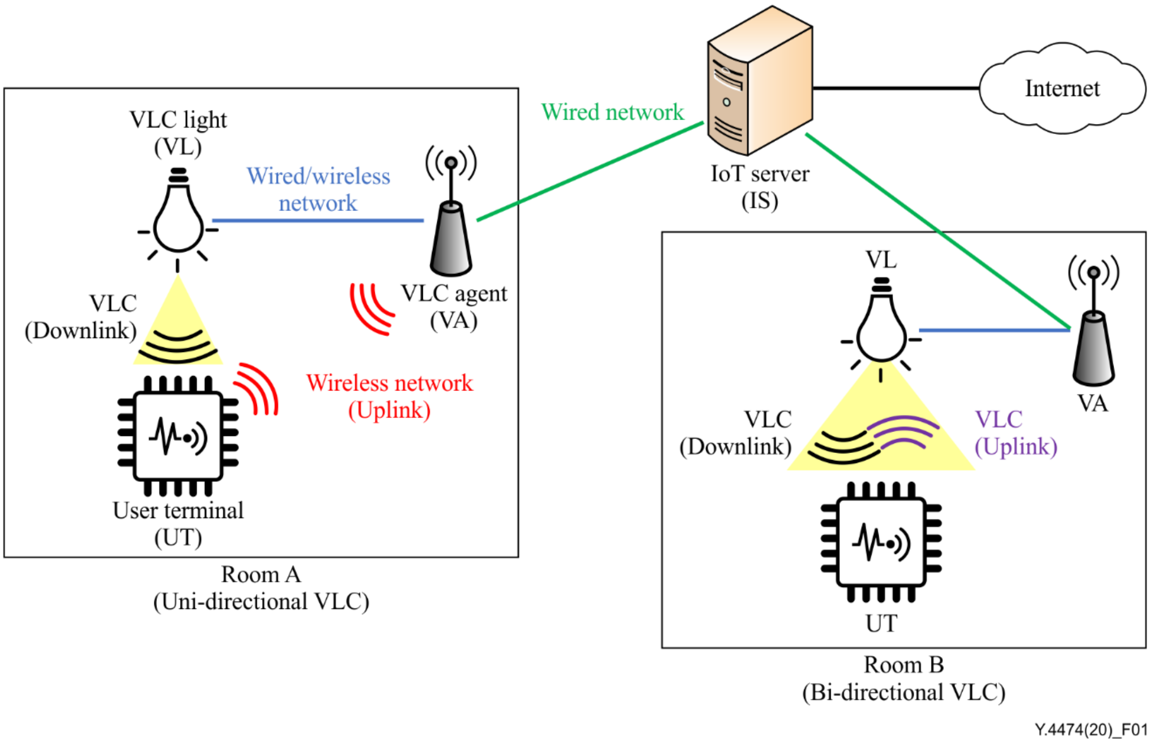

Figure 1 – Network configuration of IoT services based on VLC
(Figure 1 of [ITU-T Y.4465])

The framework for IoT service based on VLC comprises two parts: a) device management of IoT server (IS), VLC agent (VA), VLC light (VL) and user terminal (UT); b) supporting capabilities for IoT applications that run on UT.

This Recommendation firstly specifies the functional requirements for IoT services based on VLC in order to identify a set of functionalities for light control, data transfer, network management, mobility management, IoT service support and device management.

Based on the reference model of [ITU-T Y.4465], this Recommendation describes the functional architecture, which includes the specific functionalities based on the functional requirements and the reference points among network nodes in a VLC-based IoT service network.

Finally, the information flows are described with the associated messages for the following functionalities: device initialization, device monitoring in the active mode, device monitoring in the passive mode, service data transport, light control and device roaming.

7 Functional requirements

7.1 Light control

To manage the LED lights associated with VL in a VLC-based IoT service network, the following requirements need to be satisfied:

– it is **required** for IS to control the physical status of LED lights in the network;

– it is **required** for VL to configure the physical status of the associated LED lights.

7.2 Data transfer

To transfer ISD, DCD and LCD to a VLC-based IoT service network, the following requirements need to be satisfied:

– it is **required** for VA to forward ISD, DCD and LCD to its upstream and downstream devices;

– it is **required** for VL to forward ISD and DCD to its upstream and downstream devices;

– it is **required** for VA and VL to reference membership information when they forward data;

– it is **required** to perform the synchronous data transfer when UT uses bidirectional VLC;

– it is **required** to perform the asynchronous data transfer when UT uses unidirectional VLC.

NOTE – Examples of devices include IS, VA, VL and UT.

7.3 Network management

To manage the VLC channel and RF-based uplink channel in a VLC-based IoT service network, the following requirements need to be satisfied:

– it is **required** for VL to configure the parameters associated with the VLC channel;

– it is **required** for VL to include VLC channel information when VL advertises itself to downstream devices in the network;

– it is **required** for VA to manage the RF-based uplink channel for UT;

– it is **required** for VA and VL to include uplink channel information when they advertise themselves to downstream devices in the network.

NOTE 1 – The verb "to advertise" means to send messages to the network by using broadcasting or beaconing methods.

NOTE 2 – Examples of devices include IS, VA, VL and UT.

7.4 Mobility management

To manage the mobility of UT in a VLC-based IoT service network, the following requirements need to be satisfied:

– it is **required** for UT to manage light proximity information by receiving the device advertisement messages from its surrounding VLs periodically;

– it is **required** for UT to detect its movement event using light proximity information.

7.5 IoT service support

To support IoT services, the following requirements need to be satisfied:

– it is **required** for IoT services to be provisioned with a unique service identifier (ID);

– it is **required** for IS to periodically advertise information about IoT services to the network;

– it is **required** for UT to subscribe to relevant IoT services by using a service ID;

– it is **recommended** to include the service information when IS, VA and VL advertise themselves to the network;

– it is **recommended** for UT to include information related to its service subscription when the UT registers itself on an upstream device.

7.6 Device management

To manage devices (ISs, VAs, VLs and UTs) in a VLC-based IoT service network, the following requirements need to be satisfied:

– It is **required** for IS, VA, VL and UT to be discovered in the network;

– It is **required** for IS, VA, VL and UT to advertise themselves on the network periodically;

– It is **required** for VA, VL and UT to be registered on IS;

– It is **required** for IS, VA and VL to manage membership information.

8 Functional architecture

8.1 Architectural overview

From the functional requirements specified in clause 7 and the reference model in [ITU-T Y.4465], Figure 2 shows the functional architecture for IoT services based on VLC.

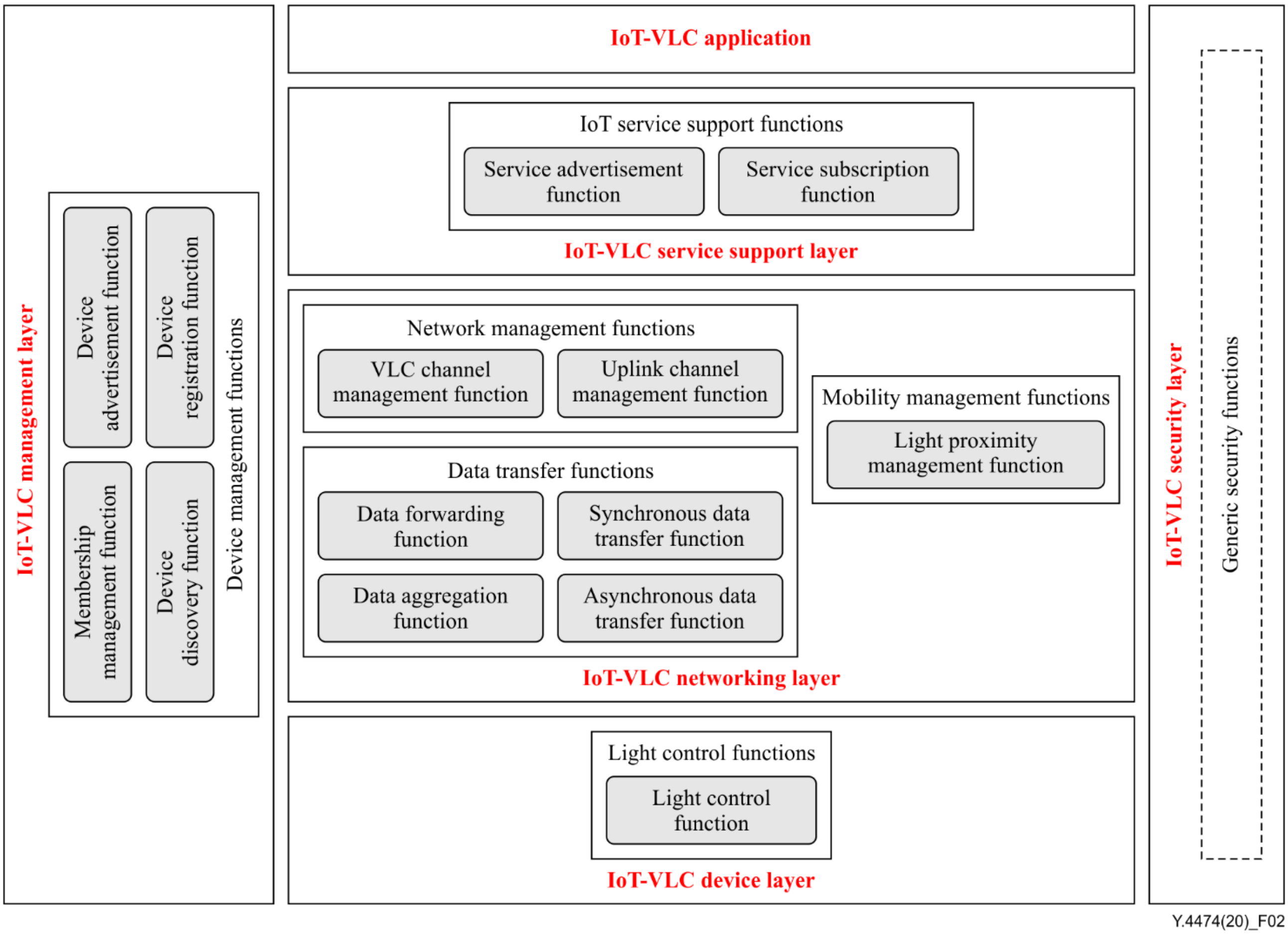

Figure 2 – Functional architecture for IoT services based on VLC

NOTE 1 – This Recommendation specifies the utilization of VLC technology to provide IoT services. Modification or enhancement of the VLC technology lies outside the scope of this Recommendation.

NOTE 2 – Examples of devices include IS, VA, VL and UT.

NOTE 3 – The IoT-VLC security layer may adopt generic security functionalities, which lie outside the scope of this Recommendation.

8.2 Light control function

This function manages the physical status of LED lights in the network.

A device having an LED light configures its physical status.

The managed physical status follows:

– the colour temperature of the LED;

– the brightness of the LED.

8.3 Data transfer functions

8.3.1 Data forwarding function

This function performs the data forwarding between the upstream device and the downstream device in a VLC-based IoT service network. When a device receives data, it decides to forward it by referencing membership information.

8.3.2 Data aggregation function

This function aggregates data to reduce the amount of traffic generated in the network.

This function uses the following information:

– device type of aggregator;

– device ID of aggregator;

– data type;

– aggregated data.

8.3.3 Synchronous data transfer function

This function transfers synchronous data for the device via the bidirectional network interface. When a device is equipped with a bidirectional network interface, it establishes a unified communication session between two endpoints (devices).

This function uses the following information:

– transport layer technology;

– endpoint information (port number and logical address).

8.3.4 Asynchronous data transfer function

This function transfers asynchronous data for the device via unidirectional network interfaces.

When a device is equipped with unidirectional network interfaces and needs to communicate with another device, it establishes a unidirectional communication session for each network interface between two endpoints (devices).

This function uses the following information:

– data direction (upstream or downstream);

– transport layer technology;

– endpoint information (port number and logical address).

8.4 Network management functions

8.4.1 VLC channel management function

This function manages the VLC channel.

For data communication using VLC, a VLC channel-providing device creates the VLC channel and advertises the VLC channel information to the network. A VLC channel-consuming device receives the VLC channel information from the network and connects to the channel. Both devices need to use the same VLC parameters. All VLC parameters are included in the VLC channel information.

When the VLC channel-providing device advertises itself to the network, it includes the VLC channel information.

8.4.2 Uplink channel management function

This function manages the RF-based uplink channel for a device equipping a unidirectional network interface. A channel-providing device creates the uplink channel and advertises the channel information to the network. A channel-consuming device receives the uplink channel information from the network and connects to the channel.

When the channel-providing device advertises itself to the network, it can also include the uplink channel information.

8.5 Mobility management functions

8.5.1 Light proximity management function

This function manages light proximity information for mobile devices. A mobile device periodically updates the light proximity information by listening to advertisements of its surrounding devices.

A mobile device judges its movement by utilizing light proximity information.

For each surrounding device, the light proximity information includes the following items:

– device type;

– device ID;

– VLC channel quality.

NOTE – The period of the timer for listening to a device advertisement depends on the implementation.

8.6 IoT service support functions

8.6.1 Service advertisement function

This function advertises the service on the network.

The service-providing device has a service list and periodically advertises it to the network using any beaconing or broadcasting methods.

For each IoT service, the service-providing device generates a unique service ID and creates data endpoints for transmitting service data. Then, the device adds the service to the list.

The data endpoints support both the synchronous data transfer and the asynchronous data transfer.

Each element in the service list has the following information:

– service id;

– data direction (upstream and downstream);

– transport layer technologies for each data direction;

– endpoint information (logical address and port number) for each data direction.

When a service-providing device advertises itself to the network, it can also include the service list.

NOTE 1 – A generation method for a service ID lies outside the scope of this Recommendation.

NOTE 2 – The period of the timer for advertising a service list depends on the implementation.

8.6.2 Service subscription function

This function prepares data communication for IoT services in the network.

A service-consuming device listens to the information about IoT services from the network and updates its service list. When the device needs an IoT service, it selects it from its service list and creates data endpoints for transmitting service data. The device then connects to the data endpoints of the IoT service provider and subscribes to the service by sending subscription information to the provider.

The consuming device chooses either synchronous or asynchronous data transfer.

This function uses the following information:

– device type of the service consumer;

– device ID of the service consumer;

– service ID;

– data direction (upstream or downstream) for data transmission;

– selected transport layer technology for data direction;

– endpoint information (logical address and port number) for the data direction.

When the consuming device registers with an upstream device, it can also include the information related to the service subscription.

8.7 Device management functions

8.7.1 Device discovery function

This function discovers devices in the network.

A device discovers another device by listening to its device advertisement from the network.

When a device needs to discover another device, it uses any broadcasting or beaconing methods in the network.

This function queries the network when a device finds no:

– device within the discovery timer;

– specific device, despite discovering a device.

Device discovery uses the device type to discover when a device queries the network.

NOTE – The period of the timer for listening to a device advertisement depends on the implementation.

8.7.2 Device advertisement function

This function makes a device discoverable on the network.

This function is performed when:

– a device receives a device discovery request from the network and the requested device type matches with it;

– the device registration succeeds;

– the advertisement timer expires.

A device periodically advertises itself to the network by utilizing any broadcasting or beaconing methods.

The device advertisement includes the following information:

– device type;
– device ID;
– the uplink channel information;
– the VLC channel information.

The device advertisement can also include information related to the IoT service advertisement.

NOTE – The period of the timer for device advertisement depends on the implementation.

8.7.3 Device registration function

This function registers the device with upstream devices.

When a device turns on, it finds an upstream device and initiates device registration with it. The upstream device then processes the registration and reports the registration result to the next upstream device until the result reaches the last upstream device in the network.

In processing the device registration, the upstream device can aggregate multiple registration results into one aggregated message.

The device registration includes the following information:

– device type;
– device ID.

The device registration can also include information related to the IoT service subscription.

NOTE – A generation method for a device ID lies outside the scope of this Recommendation.

8.7.4 Membership management function

This function manages the relationship among upstream and downstream devices, and utilizes the relationship to check the availability of downstream devices and packet forwarding.

The relationship is managed when:

– a downstream device registers with an upstream device;
– an upstream device finds a downstream device within the communication coverage;
– a downstream device is not in the communication coverage of the uplink device.

In the first case, the upstream device creates the membership information for the downstream device.

In the second case, the upstream device updates the membership information.

In the third case, the upstream device removes the membership information.

The membership information includes the following items:

– device type;
– device ID;
– logical address;
– physical address;
– registration time;
– last updated time.

8.8 Reference points

From the network configuration of [ITU-T Y.4465], Figure 3 shows the reference points among network elements for IoT services based on VLC.

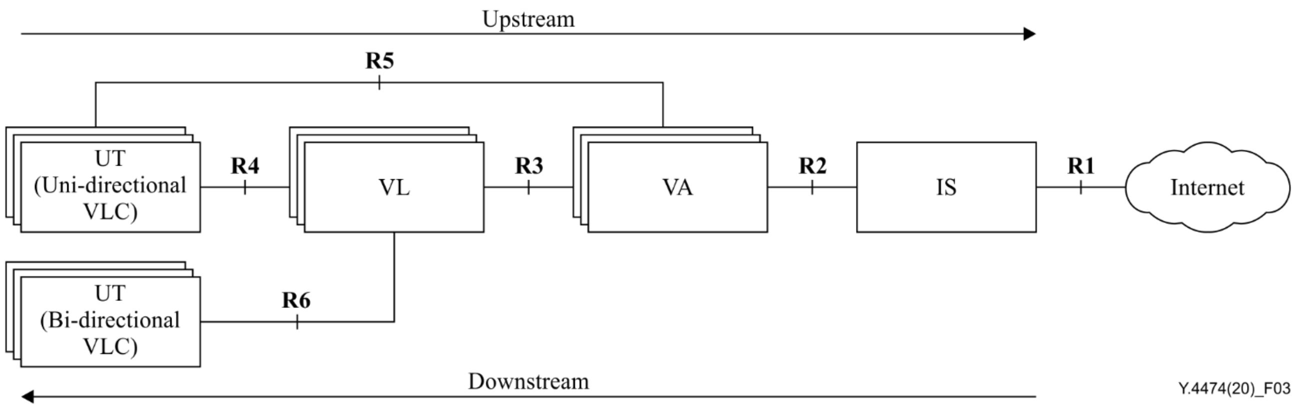

Figure 3 – Reference points among network elements for IoT services based on VLC

Each reference point is defined between two network elements, as follows:

– **R1**: Bidirectional reference point between IS and Internet;
– **R2**: Bidirectional reference point between IS and VA;
– **R3**: Bidirectional reference point between VA and VL;
– **R4**: Unidirectional reference point from VL to UT using unidirectional VLC;
– **R5**: Unidirectional reference point from UT to VA using the RF-based uplink channel of VA;
– **R6**: Bidirectional reference point between VL and UT with bidirectional VLC.

NOTE – Specification of reference point **R1** lies outside the scope of this Recommendation.

8.8.1 IS

IS manages all devices in the network and provides the IoT services based on VLC.

IS performs the following functions:

– synchronous data transfer;
– asynchronous data transfer;
– service advertisement;
– device discovery;
– device advertisement;
– membership management.

8.8.2 VA

VA manages its downstream VL and UT.

VA performs the following functions:

– data forwarding;
– data aggregation;
– uplink channel management;
– device discovery;
– device advertisement;
– device registration;
– membership management.

8.8.3 VL

VL is installed over its associated LED lights and transmits data using VLC.

VL performs the following functions:

- light control;
- data forwarding;
- data aggregation;
- vlc channel management;
- device discovery;
- device advertisement;
- device registration;
- membership management.

8.8.4 UT

UT represents a user device to utilize IoT services based on VLC.

UT performs the following functions:

- synchronous data transfer;
- asynchronous data transfer;
- light proximity management;
- service subscription;
- device discovery;
- device advertisement;
- device registration.

9 Messages and information flows

This clause presents the messages and information flows for IoT services based on VLC, which include device initialization, device monitoring, service data transport, light control and device roaming.

9.1 Device initialization

To provide IoT services based on VLC, all devices in the network need to be initialized.

Table 1 lists the messages and their information for the device initialization.

Table 1 – Messages used for the device initialization

Message name	Data type	Reference point	From	To	Information
IS advertisement	DCD	**R2**	IS	VA	– Device type (IS); – Device ID of IS.
VA registration	DCD	**R2**	VA	IS	– Device type (VA); – Device ID of VA.
VA advertisement	DCD	**R3**	VA	VL	– Device type (VA); – Device ID of VA; – Uplink channel information.
VL registration	DCD	**R3**	VL	VA	– Device type (VL); – Device ID of VL.

Table 1 – Messages used for the device initialization

Message name	Data type	Reference point	From	To	Information
VL registration report	DCD	**R2**	VA	IS	– Device type (VA); – Device ID of VA; – Registered device type (VL); – Registered device ID.
VL advertisement	DCD	**R4, R6**	VL	UT	– Device type (VL); – Device ID of VL; – Uplink channel information; – VLC channel information.
UT registration	DCD	**R6**	UT	VL	– Device type (UT); – Device ID of UT.
UT registration	DCD	**R3**	VL	VA	– Device type (VL); – Device ID of VL; – Device type (UT); – Device ID of UT.
UT registration	DCD	**R5**	UT	VA	– Device type (UT); – Device ID of UT.
UT registration report	DCD	**R2**	VA	IS	– Device type (VA); – Device ID of VA; – Registered device type (UT); – Registered device ID.

Figure 4 shows the information flows for the device initialization in bidirectional VLC.

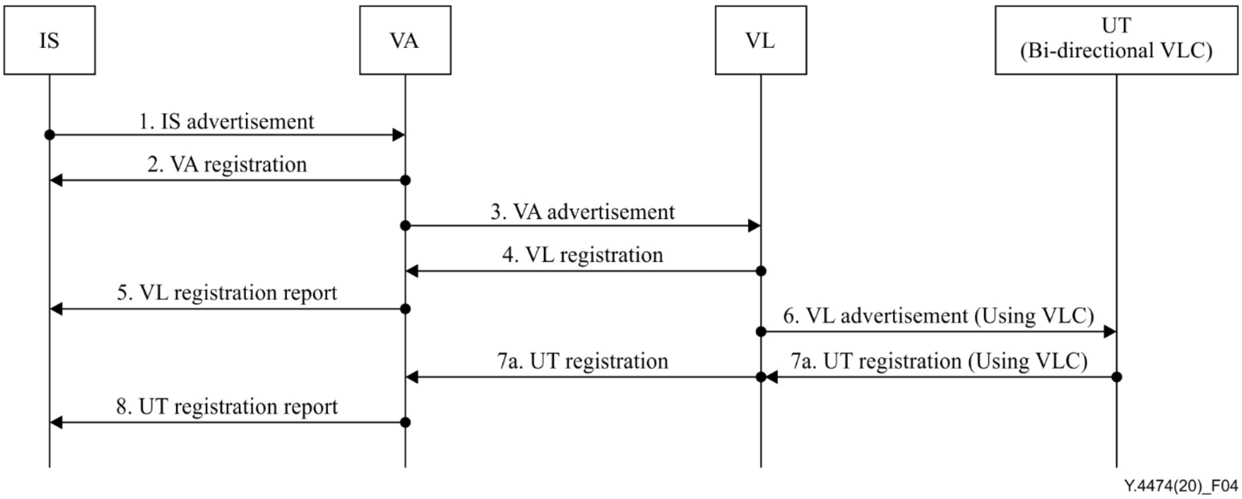

Figure 4 – Information flows for the device initialization in bidirectional VLC

Figure 5 shows the information flows for the device initialization in unidirectional VLC.

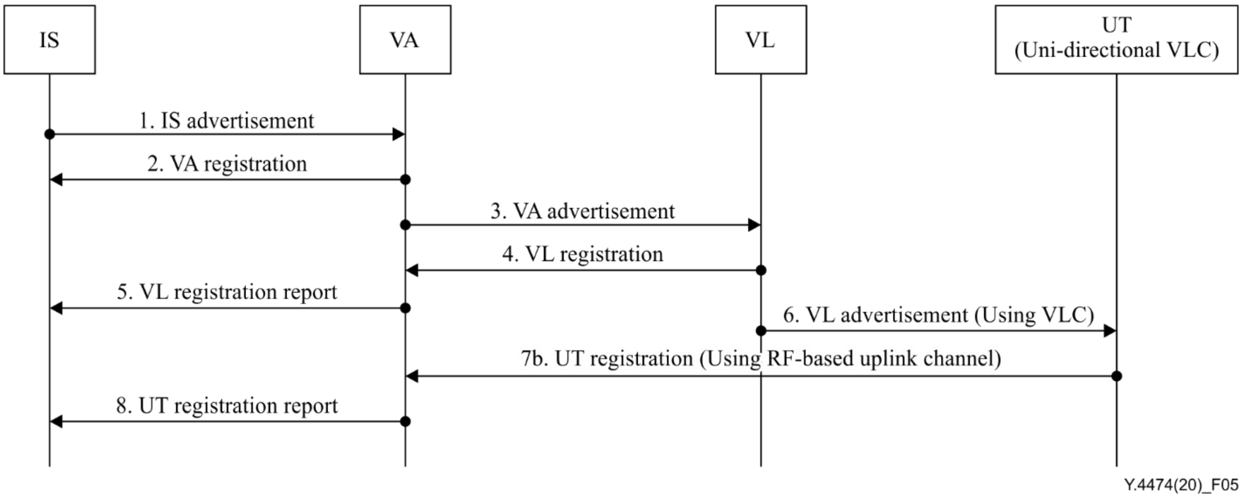

Figure 5 – Information flows for the device initialization in unidirectional VLC

The following describes the details of each operation in Figures 4 and 5:

1) by sending an IS advertisement message to the network, IS makes itself discoverable in the network;

2) when VA discovers an upstream device (IS), the VA updates its membership information and sends the VA registration message to IS – after IS receives the VA registration message, the IS updates its membership information;

3) after registering with IS, VA configures the RF-based uplink channel for the UT with unidirectional VLC and sends the VA advertisement message to the network – the uplink channel information is included in the VA advertisement message;

4) when VL discovers an upstream device (VA), the VL updates its membership information and sends a VL registration message to VA – the VL keeps the uplink channel information from the VA advertisement message;

5) when VA receives the VL registration message, the VA updates its membership information and sends a registration report to IS;

6) after registering with VA, VL configures the VLC channel and sends a VL advertisement message to the network using VLC – the message includes the uplink channel information and VLC channel information;

7) when UT discovers the VL, the UT updates its membership information and sends the UT registration message to the upstream device – in the phase of sending UT registration message, the UT performs as follows:

   a) the UT with bidirectional VLC sends a UT registration message to its upstream device (VL) using VLC – the VL then updates its membership information and sends a UT registration message to its upstream device (VA),

   b) the UT with unidirectional VLC sends a UT registration message to its upstream device (VA) using the RF-based uplink channel of VA;

8) when VA receives the UT registration message, the VA updates its membership information and sends the UT registration report message to IS – the IS then updates its membership information from the report message, and VA can aggregate the UT registration messages sent from multiple VLs and UTs.

9.2 Device monitoring (in the active mode)

In the active mode, IS initiates the device monitoring process to check the availability of registered devices (VAs, VLs and UTs).

Table 2 lists the messages and their information for device monitoring in the active mode.

Table 2 – Messages used for device monitoring (in the active mode)

Message name	Data type	Reference point	From	To	Information
Monitoring request	DCD	**R2**	IS	VA	– Device type to monitor (VA, VL and UT); – Device ID of IS.
Monitoring request	DCD	**R3**	VA	VL	– Device type to monitor (VL and UT); – Device ID of VA.
Monitoring request	DCD	**R4, R6**	VL	UT	– Device type to monitor (UT); – Device ID of VL.
Monitoring response	DCD	**R6**	UT	VL	– Device type (UT); – Device ID of UT.
Monitoring response	DCD	**R3**	VL	VA	– Device type (VL); – Device ID of VL; – Monitored device type (UT); – Monitored device ID.
Monitoring response	DCD	**R5**	UT	VA	– Device type (UT); – Device ID of UT.
Monitoring response (Aggregated)	DCD	**R2**	VA	IS	– Device type of aggregator (VA); – Device ID of aggregator (VA); Aggregated data: – Monitored device type (VL or UT); – Monitored device ID.

Figure 6 shows the information flows for the active mode of device monitoring in the bidirectional VLC.

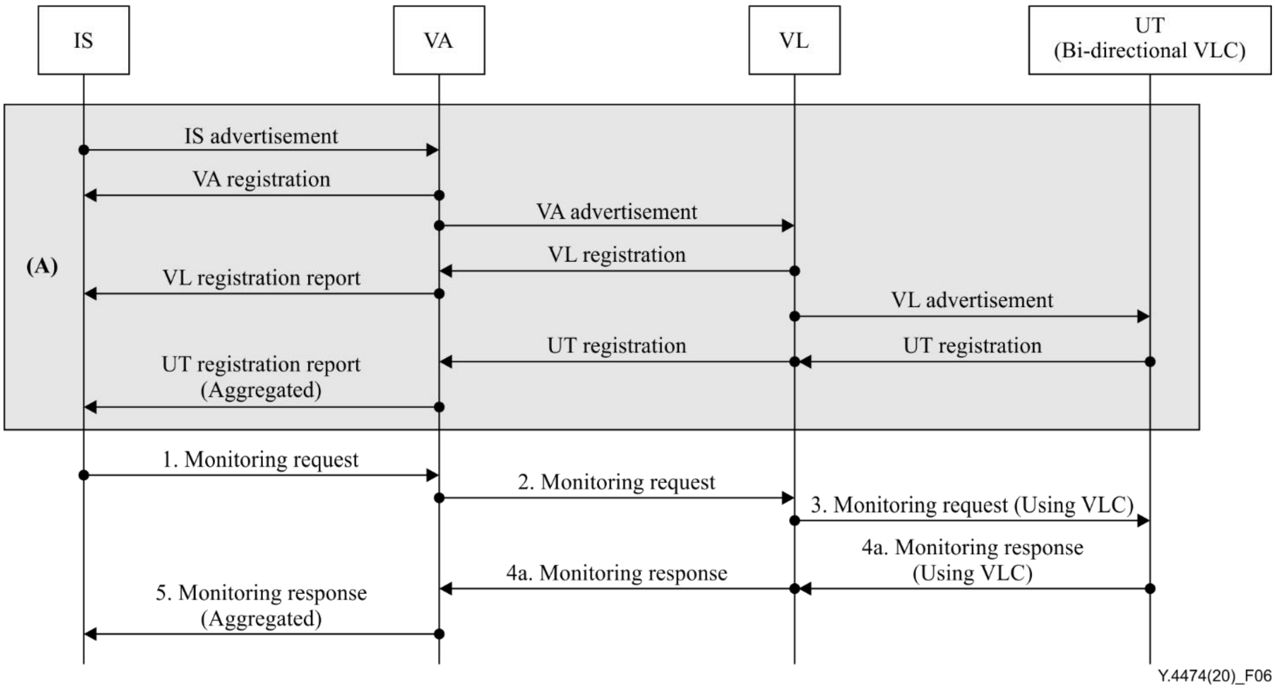

Figure 6 – Information flows for device monitoring (active mode) in the bidirectional VLC

Figure 7 shows the information flows for the active mode of device monitoring in unidirectional VLC.

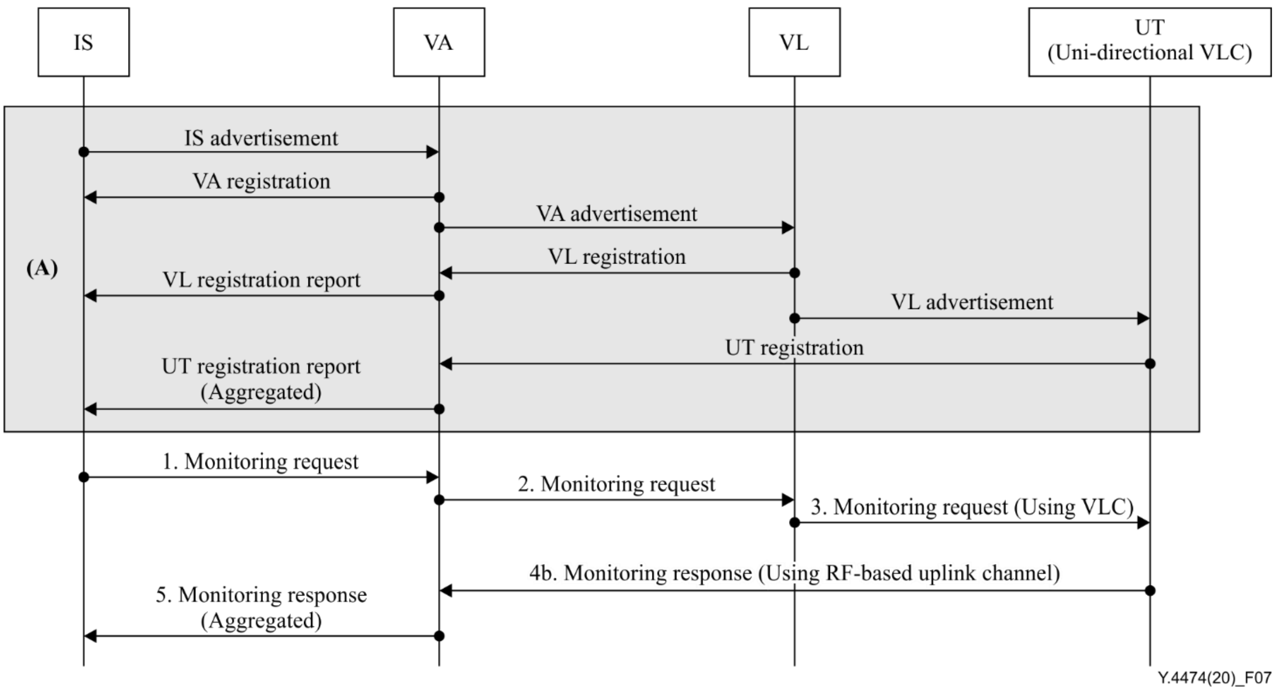

Figure 7 – Information flows for device monitoring (active mode) in unidirectional VLC

The following describes the details of each operation in Figures 6 and 7:

1) IS initiates the monitoring process by sending a device-monitoring request to the registered VA;

2) when VA receives the monitoring request, the VA analyses the monitoring request message, extracts the target devices and sends a monitoring request message to the corresponding devices;

3) when VL receives the monitoring request message, the VL analyses the message, extracts the target devices, and sends the monitoring request message to the corresponding devices using VLC;

4) when UT receives the monitoring request message, the UT performs as follows:

   a) the UT with bidirectional VLC sends a monitoring response message to its upstream device (VL) using VLC – the upstream device then updates its membership information and sends the monitoring response message to its upstream device (VA),

   b) the UT with unidirectional VLC sends a monitoring response message to its upstream device (VA) using the RF-based uplink channel of VA;

5) when VA receives the monitoring response message, the VA waits for monitoring response messages from multiple VLs and UTs, updates its membership information, aggregates the response messages and sends the aggregated response message to its upstream device (IS) – the IS then updates its membership information from the monitoring response message.

NOTE 1 – Flows in the shaded areas labelled (A) in Figures 6 and 7 relate to the device initialization. Detailed information flows are available in clause 9.1.

NOTE 2 – In step 5), the waiting period of the timer depends on the implementation.

9.3 Device monitoring (in the passive mode)

In the passive mode, registered devices report their availability to upstream devices periodically.

Table 3 lists the messages and their information for device monitoring in the passive mode.

Table 3 – Messages used for device monitoring (in the passive mode)

Message name	Data type	Reference point	From	To	Information
Live report	DCD	**R6**	UT	VL	– Device type (UT); – Device ID of UT.
Live report	DCD	**R3**	VL	VA	– Device type (VL); – Device ID of VL; – Monitored device type (UT); – Monitored device ID.
Live report	DCD	**R5**	UT	VA	– Device type (UT); – Device ID of UT.
Monitoring report	DCD	**R2**	VA	IS	– Device type (VA); – Device ID of VA; – Monitored device type (VL or UT); – Monitored device ID.

Figure 8 shows the information flows for the passive mode of device monitoring in bidirectional VLC.

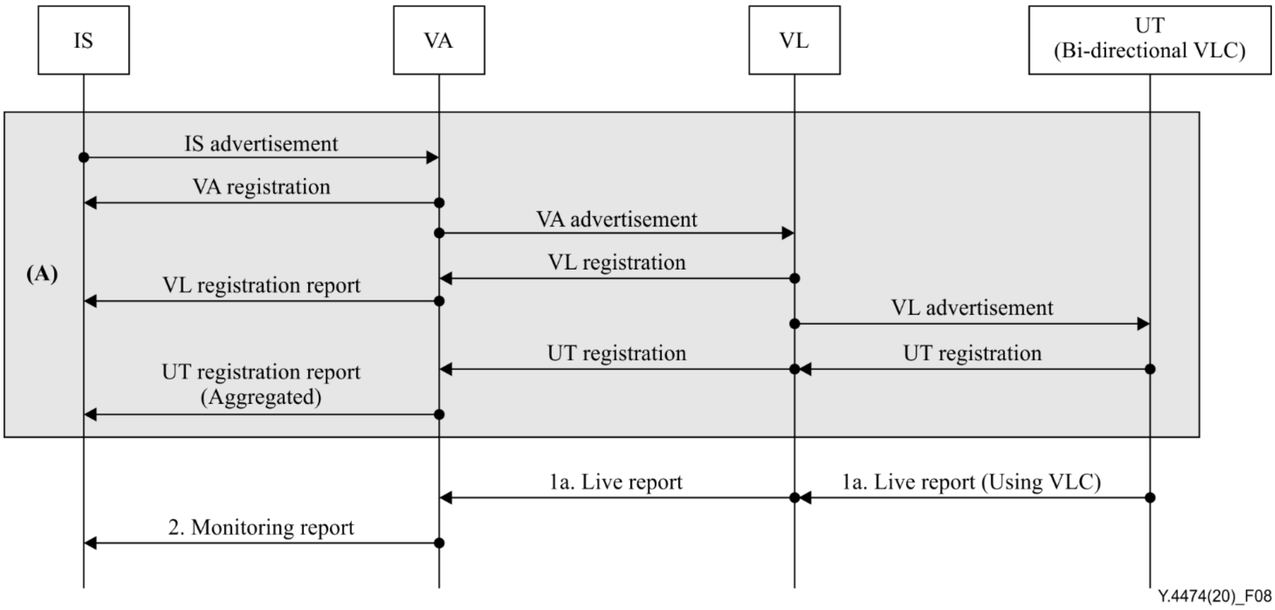

Figure 8 – Information flows for device monitoring (passive mode) in bidirectional VLC

Figure 9 shows the information flows for the passive mode of device monitoring in unidirectional VLC.

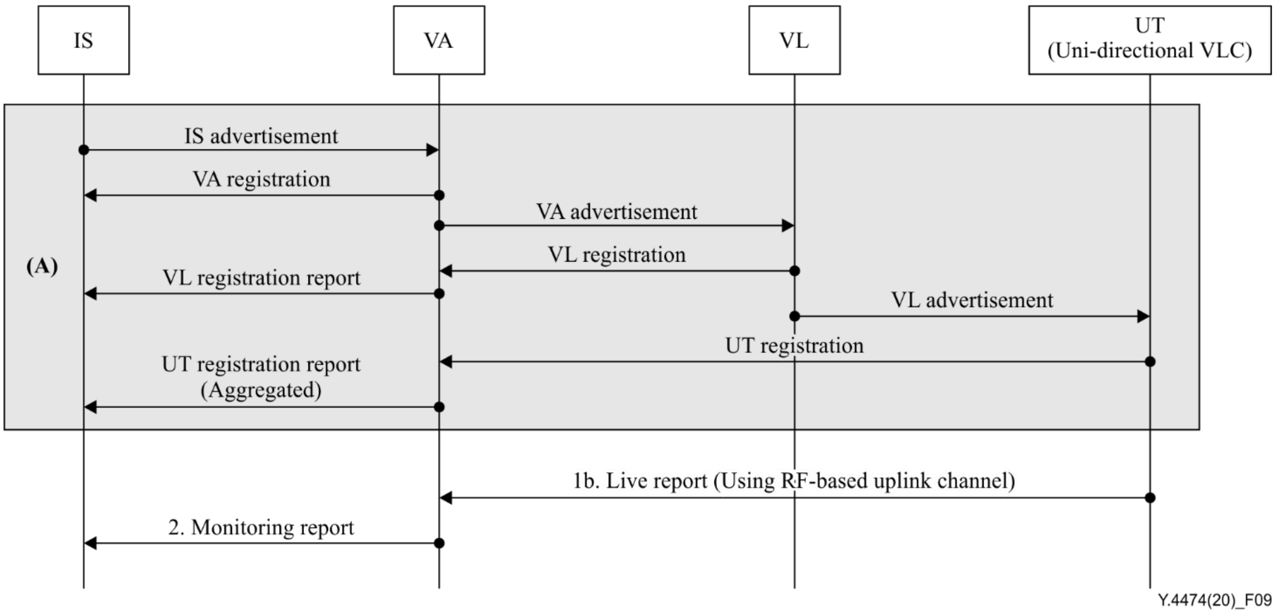

Figure 9 – Information flows for device monitoring (passive mode) in unidirectional VLC

The following describes the details of each operation in Figures 8 and 9:

1) the UT performs as follows:

   a) the UT with bidirectional VLC sends a live report message to its upstream device (VL) using VLC – the VL then updates its membership information and sends the live report message to its upstream device (VA),

   b) the UT with unidirectional VLC sends a live report message to its upstream device (VA) using the RF-based uplink channel of VA;

2) when VA receives the live report message, the VA updates its membership information and sends the monitoring report message to IS – the IS then updates its membership information

from the report message and VA can aggregate the live report messages sent from multiple VLs and UTs.

NOTE – Flows in the shaded areas labelled (A) in Figures 8 and 9 relate to the device initialization. Detailed information flows are available in clause 9.1.

9.4 Service data transport

In order to use an IoT service, both the IoT service-providing device (IS) and IoT service-consuming device (UT) need to know their endpoint information.

Table 4 lists the messages and their information for service data transport.

Table 4 – Messages used for service data transport

Message name	Data type	Reference point	From	To	Information
Service advertisement	ISD	**R2, R3, R4, R6**	IS	UT	Service list that has the following: – Service ID; – Supported transport layer technologies; – Service endpoint at IS.
Service subscription	ISD	**R2, R3, R6**	UT	IS	– Service ID; – Device type (UT); – Device ID of UT; – Selected transport layer technology; – Service endpoint at UT.
Service subscription	ISD	**R2, R5**	UT	IS	– Service ID; – Device type (UT); – Device ID of UT; – Selected transport layer technology; – Service endpoint at UT.
Service data (beacon data)	ISD	**R2, R3, R4, R6**	IS	UT	Service ID
Service data request	ISD	**R2, R3, R6**	UT	IS	Service ID
Service data request	ISD	**R2, R5**	UT	IS	Service ID
Service data response	ISD	**R2, R3, R4, R6**	IS	UT	Service ID

Figure 10 shows the information flows for service data transport in bidirectional VLC.

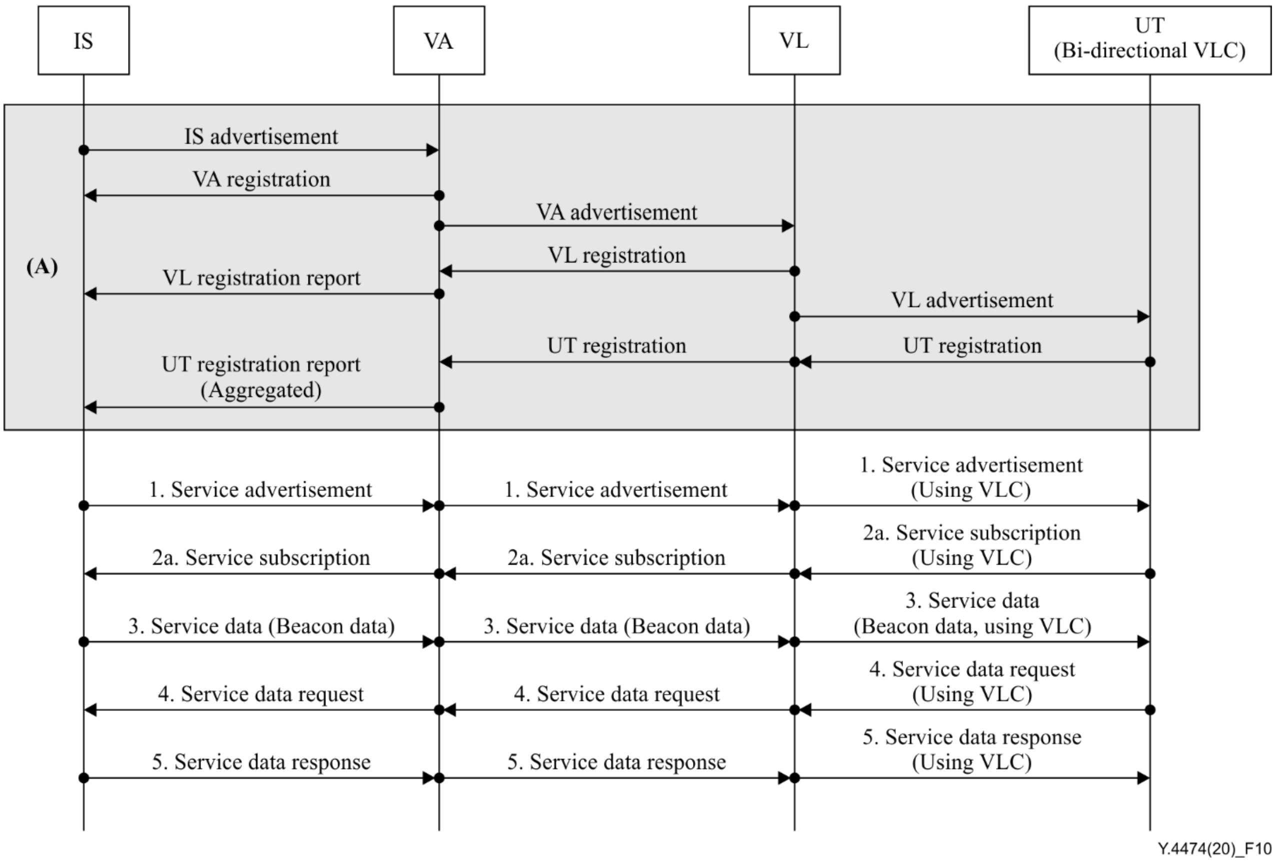

Figure 10 – Information flows for service data transport in bidirectional VLC

Figure 11 shows the information flows for service data transport in unidirectional VLC.

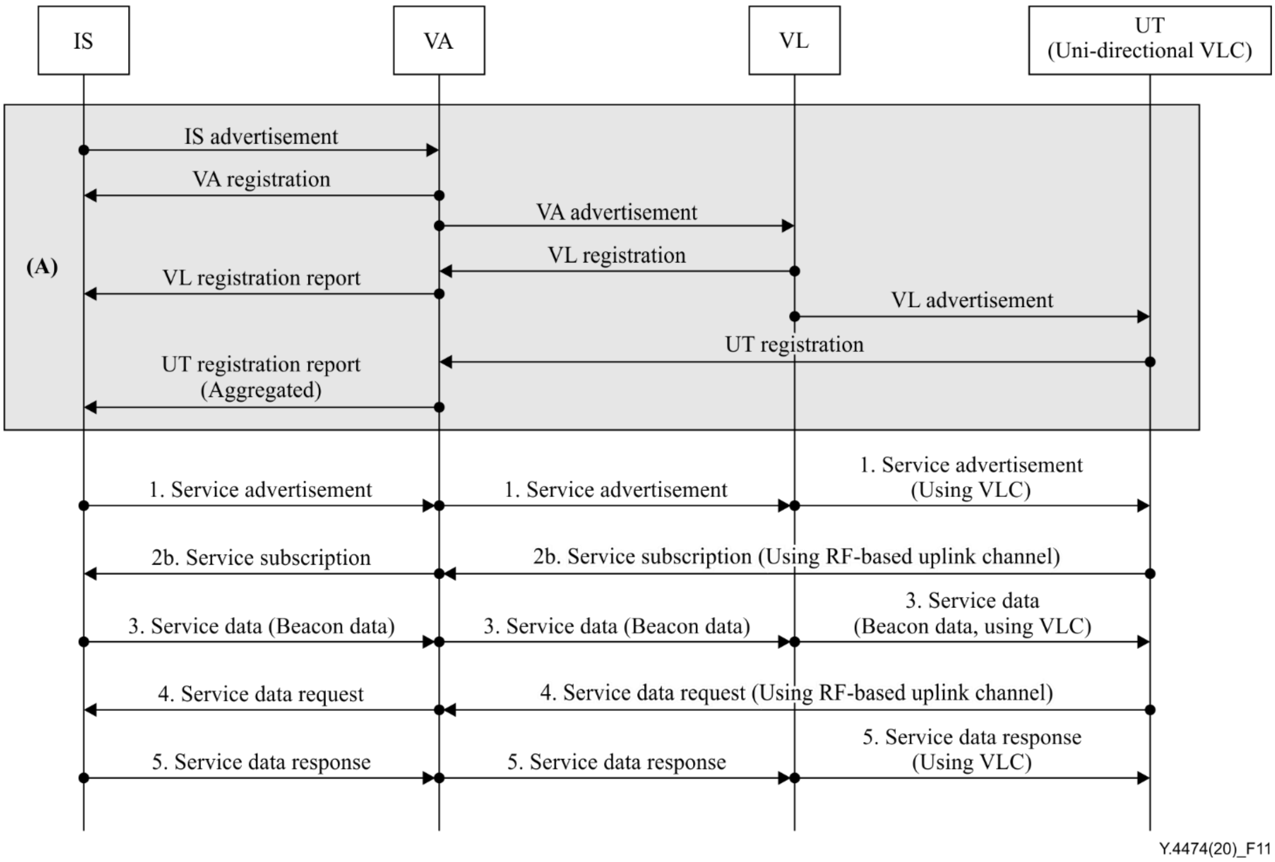

Figure 11 – Information flows for service data transport in unidirectional VLC

The following describes the details of each operation in Figures 10 and 11:

1) IS sends a service advertisement message to UT via VA and VL that contains information about IoT services;

2) when UT needs an IoT service, the UT makes the service endpoint, subscribes to the IoT service, and connects to the service endpoint at IS – while subscribing to the IoT service and connecting to the service endpoint, the UT performs as follows:

   a) the UT with bidirectional VLC sends a service subscription message to IS via VL (using VLC) and VA – the UT then connects to the service endpoint at the IS,

   b) the UT with unidirectional VLC sends a service subscription message to IS via VA (using the RF-based uplink channel of VA) – the UT then connects to the service endpoint at the IS;

3) when an IoT service has beacon data, IS sends the service data (beacon) to UT via the service endpoint between IS and UT;

4) when UT needs service data, it sends the service data request message to the IS via the service endpoint between IS and UT;

5) IS sends the requested service data to the UT via the service endpoint between IS and UT.

NOTE – Flows in the shaded areas labelled (A) in Figures 10 and 11 relate to the device initialization. Detailed information flows are available in clause 9.1.

9.5 Light control

Table 5 lists the messages and their information used for the light control.

Table 5 – Messages used for the light control

Message name	Data type	Reference point	From	To	Information
Light control	LCD	**R2**	IS	VA	Device list to control that has the following: – Device type (VL); – Device ID.
Light control request	LCD	**R3**	VA	VL	– Device type to control (VL); – Device ID to control.
Light control response	LCD	**R3**	VL	VA	– Device type (VL); – Device ID of VL.
Light control report	LCD	**R2**	VA	IS	– Device type (VL); – Device ID of VL.

Figure 12 shows the information flows for light control.

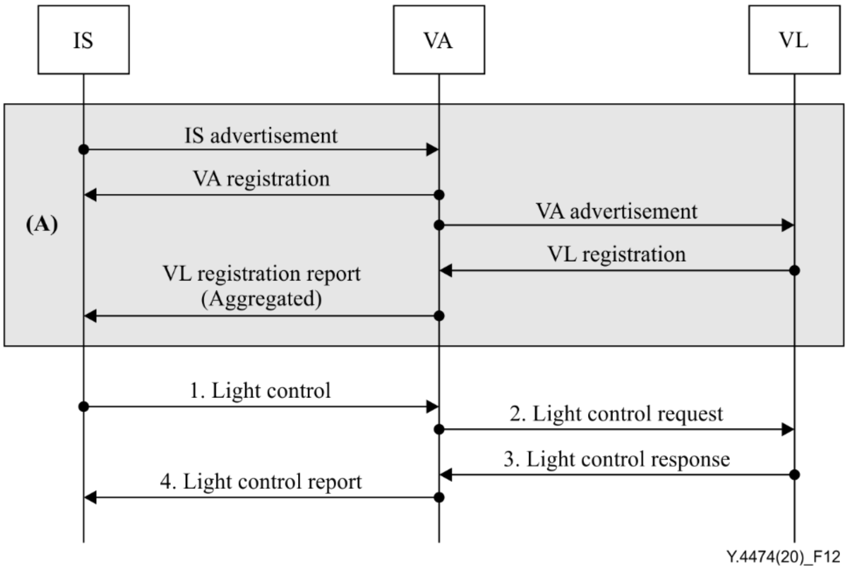

Figure 12 – Information flows for light control

The following describes the details of each operation:

1) IS initiates the light control process by sending a light control message to the corresponding VA, which has VL to control;

2) when VA receives the light control message, the VA analyses the message, extracts the target device, and sends the light control request message to the corresponding VL;

3) VL configures the associated LED light and sends the light control response to the VA;

4) when VA receives the light control response message, it reports the result of light control to the IS.

NOTE – Flows in the shaded areas labelled (A) in Figures 11 and 12 relate to the device initialization. Detailed information flows are available in clause 9.1.

9.6 Device roaming

When a mobile UT changes its location, it needs to register with the IS in order to use the network at the new location.

To support fast registration when a mobile UT changes its location, it initiates device roaming.

Table 6 lists the messages and their information used for the device roaming.

Table 6 – Messages used for device roaming

Message name	Data type	Reference point	From	To	Information
VL advertisement	DCD	**R4, R6**	VL1	UT	– Device type (VL); – Device ID of VL1.
VL advertisement	DCD	**R4, R6**	VL2	UT	– Device type (VL); – Device ID of VL2.
UT roaming report	DCD	**R6**	UT	VL	– Device type (UT); – Device ID of UT; – Past device type (VL); – Past device ID (VL1); – Current device type (VL); – Current device ID (VL2).
UT roaming report	DCD	**R3**	VL	VA	– Device type (UT); – Device ID of UT; – Past device type (VL); – Past device ID (VL1); – Current device type (VL); – Current device ID (VL2).
UT roaming report	DCD	**R5**	UT	VA	– Device type (UT); – Device ID of UT; – Past device type (VL); – Past device ID (VL1); – Current device type (VL); – Current device ID (VL2).
Roaming report	DCD	**R2**	VA	IS	– Device type (VA); – Device ID of VA; – Roamed device type (UT); – Roamed device ID.

Figure 13 shows the information flows for device roaming in bidirectional VLC.

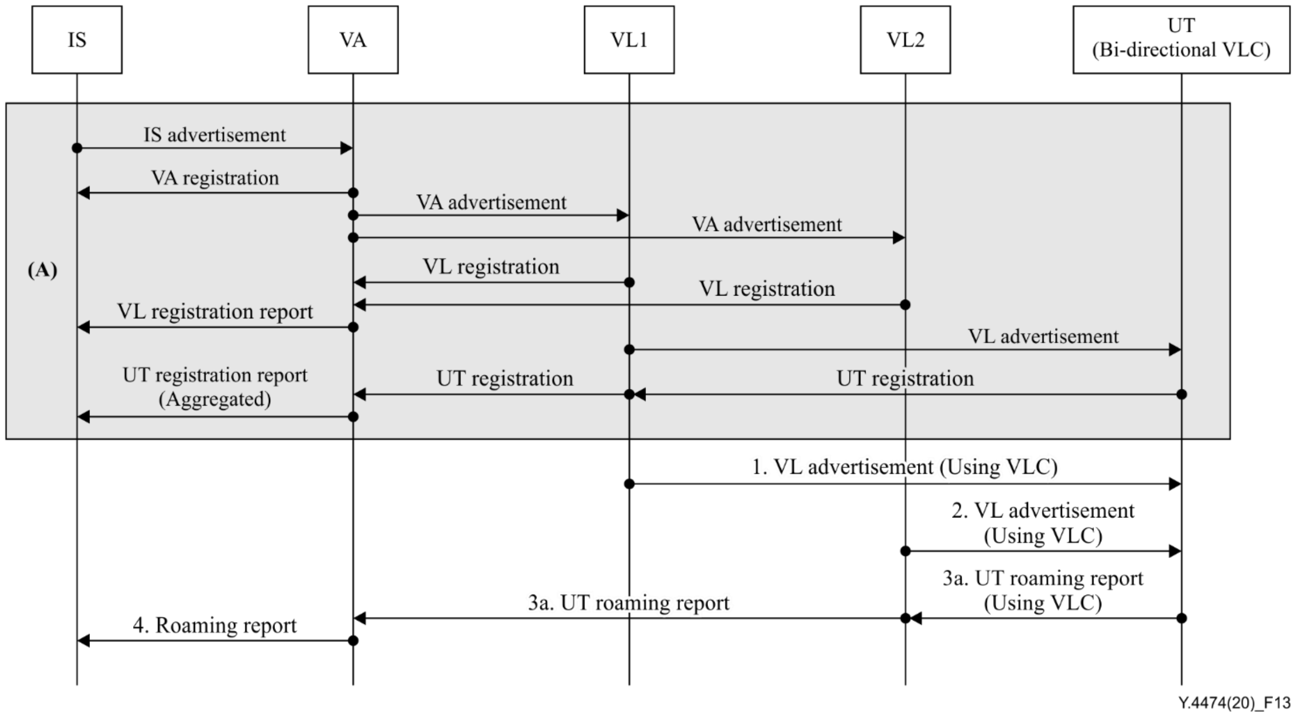

Figure 13 – Information flows for device roaming in bidirectional VLC

Figure 14 shows the information flows for device roaming in unidirectional VLC.

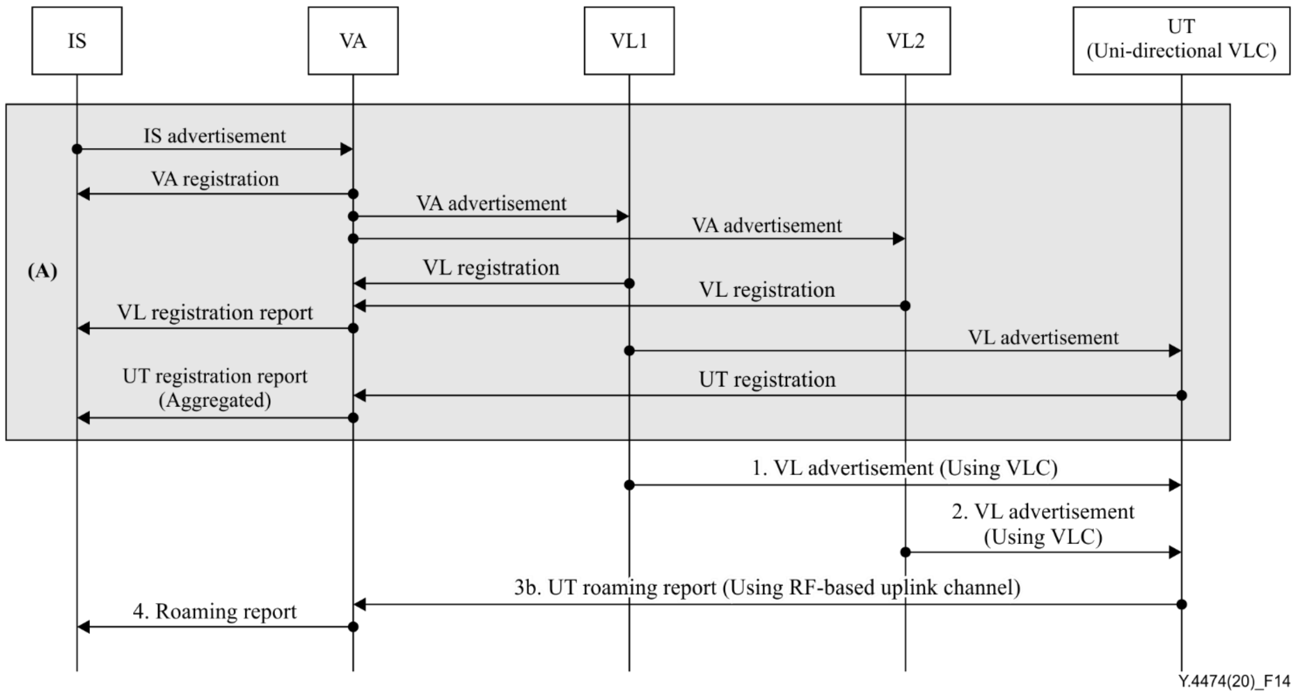

Figure 14 – Information flows for device roaming in unidirectional VLC

The following describes the details of each operation in Figures 13 and 14:

1) UT receives a VL advertisement message periodically and updates its light proximity information;

2) when UT moves to another place, it receives the VL advertisement messages within its proximity, updates its light proximity information, and detects the roaming event by referencing the light proximity information;

3) when UT detects the roaming event, it updates its membership information and sends the UT roaming report message to its upstream device – while sending UT roaming report message, the UT performs as follows:

   a) the UT with bidirectional VLC sends the UT roaming report to its upstream device (VL) using VLC – the VL then updates its membership information and sends the UT roaming report message to its upstream device (VA);

   b) the UT with unidirectional VLC sends the UT roaming report to its upstream device (VA) using the RF-based uplink channel of VA;

4) when VA receives the UT roaming report message, the VA updates its membership information and sends the roaming report message to IS – the IS then updates its membership information from the report message.

NOTE – Flows in the shaded areas labelled (A) in Figures 13 and 14 relate to the device initialization. Detailed information flows are available in clause 9.1.

Appendix I

Protocol stacks for the three data types

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

[ITU-T Y.4465] specifies three data types:

1) LCD;

2) DCD;

3) ISD.

Clauses I.1 to I.3 provide the protocol stacks for understanding of the bidirectional and unidirectional VLC network environment.

I.1 Light control data

Figure I.1 shows the protocol stack for LCD.

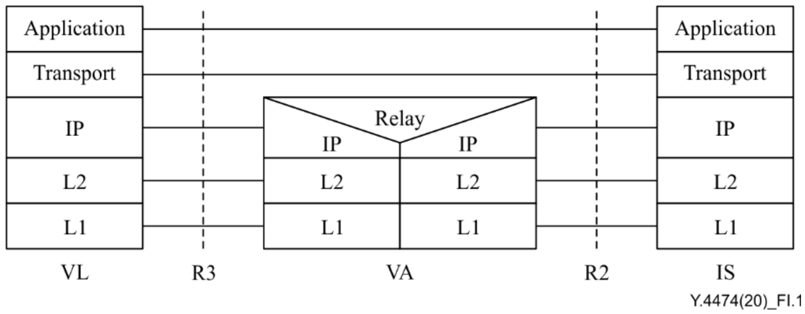

Figure I.1 – Protocol stack for LCD
IP: Internet protocol

I.2 Device control data

I.2.1 DCD in bidirectional VLC

Figure I.2 shows the protocol stack for DCD in the bidirectional VLC environment.

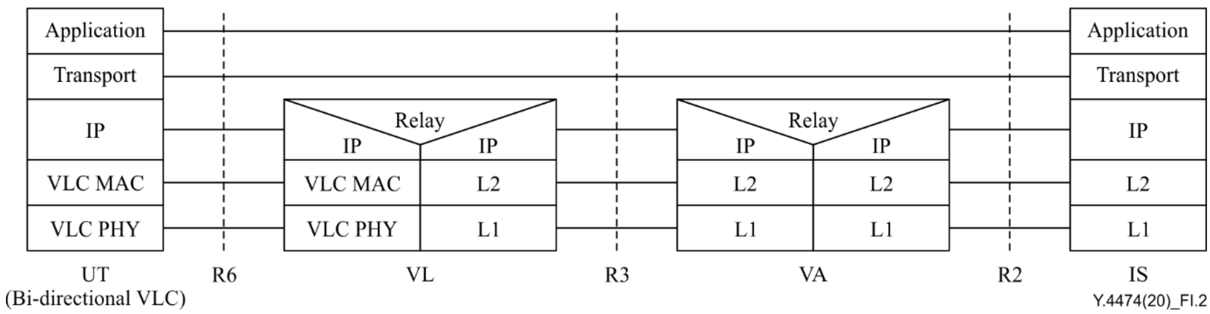

Figure I.2 – Protocol stack for DCD in the bidirectional VLC
MAC: medium access control; PHY: Physical layer

I.2.2 DCD in unidirectional VLC

Figure I.3 shows the protocol stack for DCD in the unidirectional VLC environment.

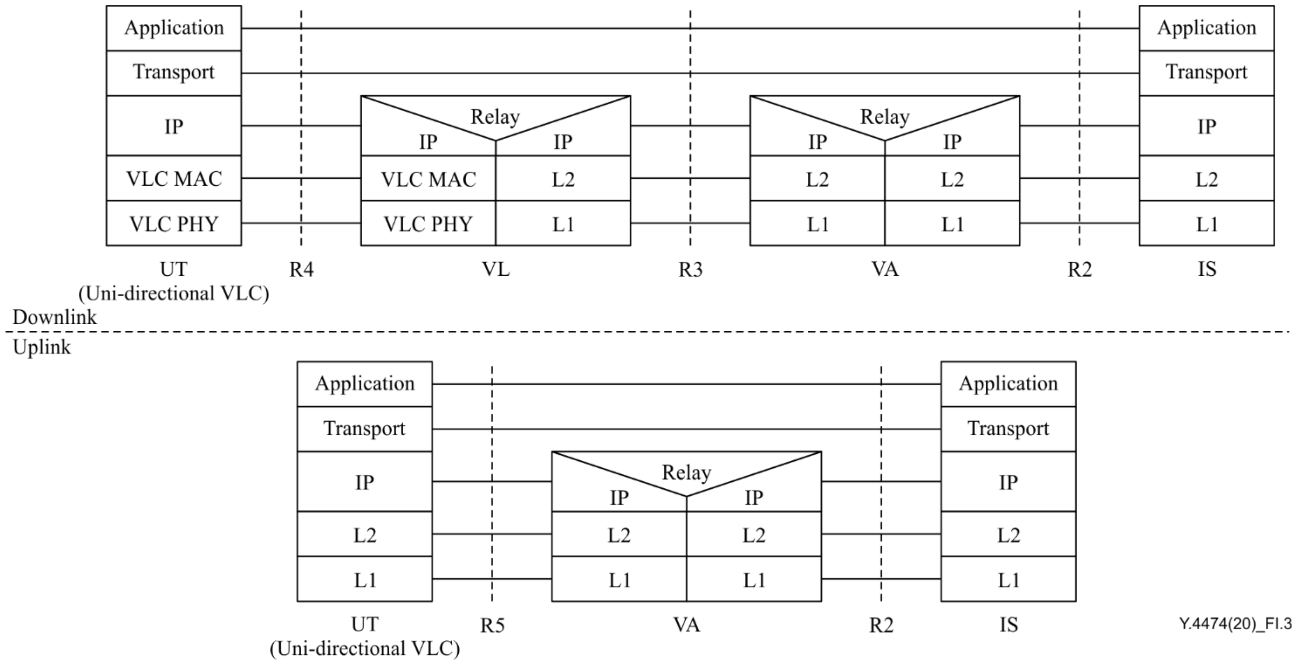

Figure I.3 – Protocol stack for DCD in the unidirectional VLC

I.3 IoT service data)

I.3.1 ISD in the bidirectional VLC

Figure I.4 shows the protocol stack for ISD in the bidirectional VLC environment.

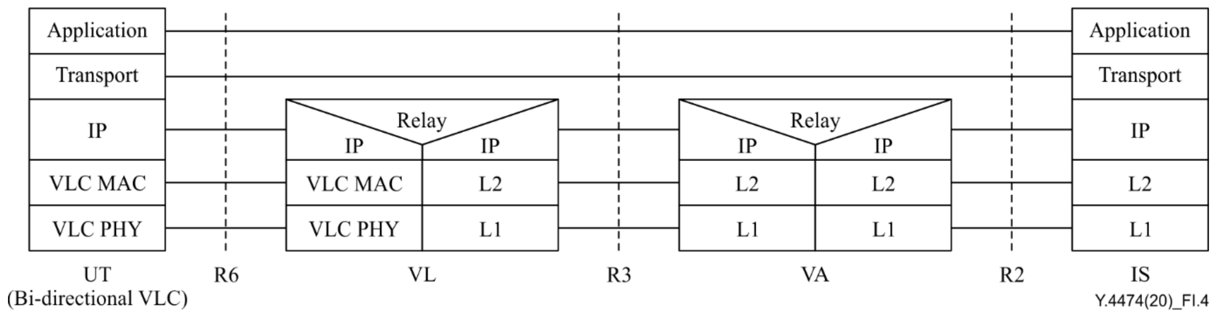

Figure I.4 – Protocol stack for ISD in the bidirectional VLC

I.3.2 ISD in the unidirectional VLC

Figure I.5 shows the protocol stack for ISD in the unidirectional VLC environment.

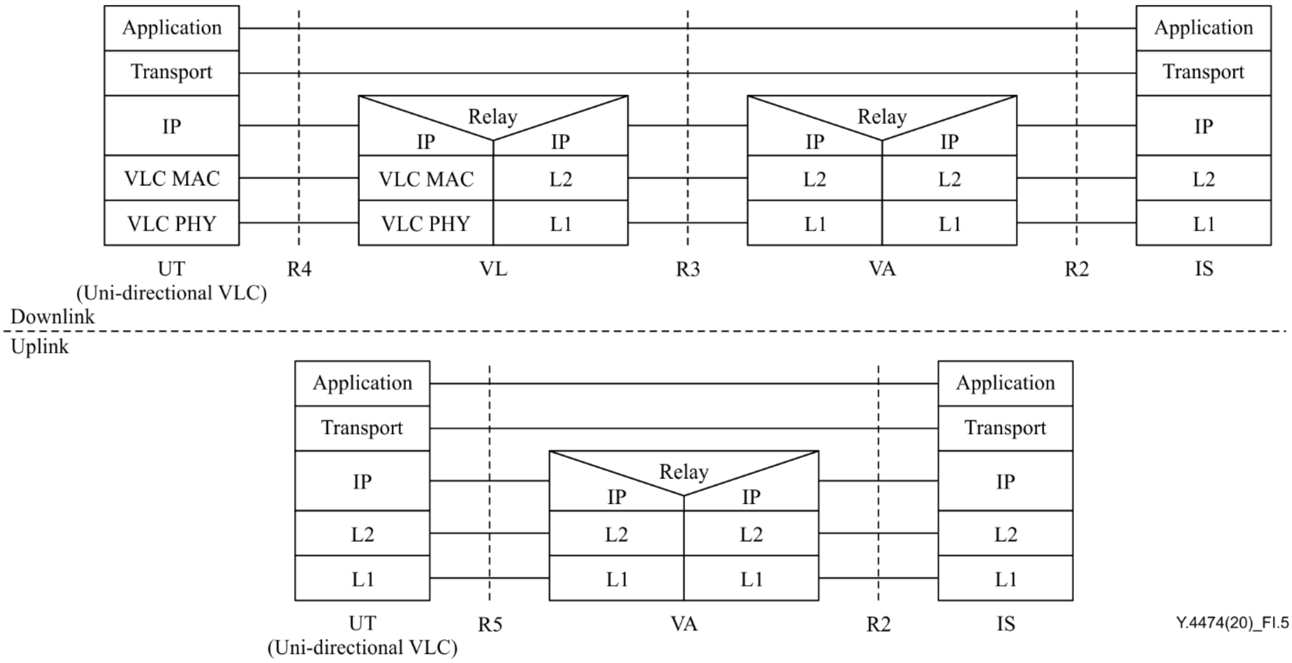

Figure I.5 – Protocol stack for ISD in the unidirectional VLC

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