

(51) International Patent Classification:
H04B 10/10 (2006.01)(21) International Application Number:
PCT/EP2012/054671(22) International Filing Date:
16 March 2012 (16.03.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
11158494.2 16 March 2011 (16.03.2011) EP(71) Applicant (for all designated States except US):
SIEMENS AKTIENGESSELLSCHAFT [DE/DE]; Wiltelsbacherplatz 2, 80333 München (DE).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **WALEWSKI, Joachim** [DE/DE]; Hofmarkweg 3, 82008 Unterhaching (DE). **BAHR, Michael** [DE/DE]; Mona-Lisa-Straße 4, 81827 München (DE).(74) Common Representative: **SIEMENS AKTIENGESSELLSCHAFT**; Postfach 22 16 34, 80506 München (DE).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: A METHOD AND DEVICE FOR NOTIFICATION IN A SYSTEM FOR VISIBLE-LIGHT COMMUNICATION

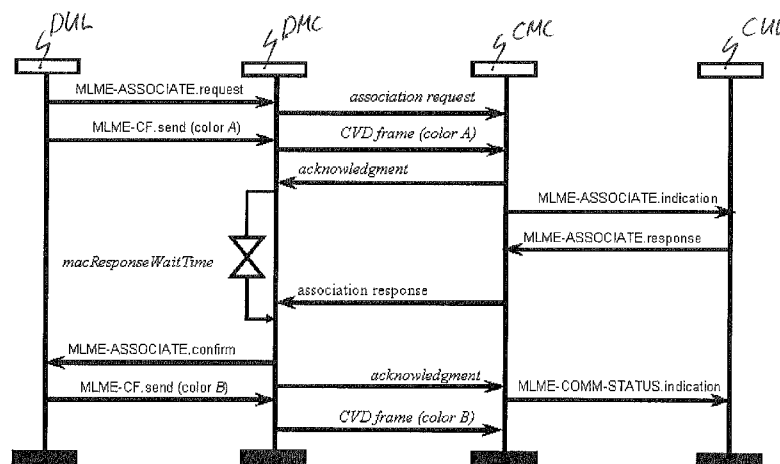


FIG 1

(57) Abstract: The present invention proposes means for providing visible notification by a device in a visible-light-communication system based on the specifications of IEEE 802.15.7. The invention allows higher levels to invoke through one standardized interface the medium-access-control (MAC) sub-layer for the purpose of color-function support. The present invention enables invocation of a transmission of color, visibility, and dimming (CVD) frames by a higher layer, creating a unified interface between the MAC sub-layer and the higher layers. The method is providing a primitive for requesting, by the at least one upper layer to the at least one interface of the medium-access-control entity (MAC) layer, a transmission of at least one visibility frame.

Description

A Method and Device for Notification in a System for Visible-Light Communication

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The invention relates to a method and device for communicating by a visible-light transmission of data. Specifically, the invention relates to a method and device providing visible notifications in a system for visible-light communication based on the specifications of IEEE 802.15.7.

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In the field of indoor wireless networks, visible-light communications (VLC) is garnering increasing attention. One of the type of emitters used in this technology are light-emitting diodes, which can synergistically provide both illumination and data transmission.

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One possible transmission mode for VLC is known as color-shift keying (CSK). CSK supports visible-light communications using multi-color light sources and photodetectors. CSK is a modulation scheme for visible-light communication involving multiple light sources. CSK keeps the average emitted optical color and the total optical power constant during communication by taking advantage of the persistence of the human eye. According to a draft standard D6 of IEEE 802.15.7, a CSK signal is generated by using three color light sources. Hereinafter, said draft standard D6 of IEEE 802.15.7 is simply referred to as »draft standard«.

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In CSK, the transmission of data is provided by applying a modulation of the three colors which is not detectable by a human eye in normal operation modes, since the human's eye persistence of vision is not able to follow the modulation frequency. There are scenarios, however, in which a visible modulation of the colors is desirable in contrast to synergistically provide illumination by a VLC system. These scenarios are reflected in chapter 5.1.12 of the draft standard.

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According to the draft standard, a color-function support is defined, in which various colors can be used to indicate various statuses of a device to a human recipient, for instance the human user of a VLC transceiver. Such an indication is also referred to as color notification.

Alternatively, or as a complement, notifications are indicated by an intermittence of the illumination. This kind of notification is also referred as blinking notification which is reflected by chapter 5.3.9 of the draft standard.

The color-function support aims at an intuitive visualization of state changes of devices involved in the visible light communication to a user, e.g. for the purpose of indicating connected devices, a good link, a broken link, a status in which a file transfer is almost completed etc.

For a specific notification, a specific color or, alternatively, a variety of at least two alternating colors of light, emitted by the optical source, can be used. According to the draft standard, the colors chosen for different statuses are left to the discretion of an implementer.

Currently, the color-function support defined by the draft standard is solely implemented in a MAC (medium-access control) sub-layer of the protocol used in visible-light communications.

The color function is requested by a color visibility dimming (CVD) frame issued within the MAC sub-layer. Such color visibility dimming frames are generally used for color, visibility and dimming support. The payload of the frame consists of visibility patterns of appropriate intensity and color.

Due to the implementation in the MAC sub-layer, which is relatively close to the physical or hardware layer, it is currently not possible for higher levels, namely, the application level, to directly invoke color-function support. This

drawback, however, inadequately limits the essence of such notification, since it is rather in the discretion of an application layer to handle a notification than the MAC sub-layer. Within the MAC sub-layer, in turn, the scope of instructions is limited to a hardware-based view.

Accordingly it is an object of the present invention to provide means allowing higher levels to invoke one standardized interface to the MAC sub-layer for the purpose of color-function support.

It is a further object of the present invention to enable invocation of a transmission of CVD frames by a higher layer and to create a unified interface between the MAC sub-layer and a higher layer.

According to a preferred embodiment of the invention, a method for enabling a visible notification by a device in a system for visible-light communication is provided, the communication system being based on the specifications of IEEE 802.15.7.

The device is including a medium-access-control entity (MAC) interfacing in between a physical layer (PHY) and at least one upper layer, the at least one upper layer being hierarchically arranged above the medium-access-control entity (MAC). The medium-access-control entity (MAC) is including at least one interface (MLME-SAP, MCPS-SAP) to said upper layer, said method including the step of:
providing a primitive for requesting, by the at least one upper layer to the at least one interface (MLME-SAP, MCPS-SAP) of the medium-access-control entity (MAC), a transmission of at least one visibility frame.

The invention provides a primitive for requesting a transmission of CVD frames by a higher layer, e.g. through an MLME interface.

The objects as well as further advantages of the present invention will become more apparent and readily appreciated from the following description of the preferred embodiments, taken in conjunction with the accompanying drawing of which:

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Fig. 1 depicts a timing diagram showing the exchange of messages between different layers of a device and a coordinator in a visible-light communication system, the messages supporting a color-function notification for an association according to an embodiment of the invention;

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Fig. 2 depicts a timing diagram showing the exchange of messages between different layers of an originator and a recipient in a visible-light communication system, the messages supporting an acknowledgement indication accompanying a data transfer according to an alternative embodiment of the invention;

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Fig. 3 depicts a timing diagram showing the exchange of messages between different layers of a recipient and an originator in a visible-light communication system, the messages supporting a channel-quality indication according to an alternative embodiment of the invention;

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Fig. 4 depicts a timing diagram showing the exchange of messages between different layers of a recipient and an originator in a visible-light communication system, the messages supporting an indication of a file-transfer status according to an alternative embodiment of the invention;

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Fig. 5 depicts an architecture of a device in a visible-light communication system in accordance with the state of the art ;

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Fig. 6 depicts a timing diagram showing the exchange of messages between MAC sub-layers of a device and a coordinator in a visible-light communication system, the messages supporting an association in accordance with the state of the art;

Fig. 7 depicts a timing diagram showing the exchange of messages between MAC sub-layers of a device and a coordinator in a visible-light communication system, the messages supporting an acknowledgment indication in accordance with the state of the art;

Fig. 8 depicts a timing diagram showing the exchange of messages between MAC sub-layers of an originator and a recipient in a visible-light communication system, the messages supporting a file transfer status indication in accordance with the state of the art;

Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawing.

Referring to Fig. 5, an architecture of a device in a visible-light communication system in accordance with the state of the art is illustrated.

The architecture of a visible-light communication system is generally defined in terms of a number of layers and sub-layers. Each layer is responsible for one part of the draft standard and offers services to the higher layers. The interface between the layers serves to define the logical links that are described in the draft standard.

More specifically, figure 5 shows an architecture of a VPAN device (visible-light communication personal area network) according to chapter 4.4 of the draft standard.

A VPAN device comprises of a physical layer PHY, which contains a light transceiver along with its low-level control mechanism which are generally directed to an optical layer OPT including the actual optical devices, including light emitting diodes and/or photodetectors.

Further on, a medium-access control layer MAC is providing access to a physical layer PHY for all types of transfers. Figure 5 shows these layers in a graphical representation, which are described in more detail in chapters 4.4.1 and 4.4.2 of the draft standard.

The upper layers UL, shown in Figure 5, consist of a - not shown - network layer, which provides network configuration, manipulation, a - not shown - message routing entity and a - not shown - application layer, which provides the intended function of the device.

A logical link control layer LLC accesses the medium-access control layer MAC through the service-specific convergence sub-layer SSCS. Both, logical link control layer LLC and service-specific convergence sub-layer SSCS are hereinafter assumed to be likewise included in the upper layer.

Interfaces, also referred to as SAP or »service access points« by the draft standard, are used to access certain attributes from another layer. The medium-access control layer MAC provides two service access points.

MAC data is accessed by a first access point MCPS-SAP (»MAC common part sub-layer SAP«) while MAC management is accessed by a second access point MLME-SAP (»MAC sub-layer management entity SAP«). Both access points are regarded as interface to an upper layer in the generality of the foregoing.

A device-management entity DME is supported in the architecture. The DME interfaces the MAC. The physical layer PHY interfaces with the MAC, The DME can access the PHY through

the MAC sub-layer for the purpose of, e.g., dimming an illumination of the visible-light communication system. In Figure 5, three boxes without reference signs on the right side of the device-management entity DME are characterizing the multi-purpose interfacing of the device-management entity DME by various applications including, but not limited to an entity for dimming the illumination of the visible-light communication system.

10 The device-management entity DME is hereinafter assumed to be likewise included in the upper layer.

The DME can access certain attributes from respective service access points. These service access points include the access point MLME-SAP mentioned above and a PLME-SAP («physical-layer management entity») for interfacing the physical layer PHY. The MLME-SAP is currently used in order to provide dimming information from the device-management entity DME to the medium-access control layer MAC. The device-management entity DME can also control the physical layer PHY by the service access point PLME-SAP for a selection of optical sources and photodetectors. The device-management entity DME is not the only entity that is able to access the access point MLME-SAP. Referring to fig. 5, any higher layer, including the service-specific convergence sub-layer SSCS, can access the access point MLME-SAP.

In the following section, three use cases according to the state of the art are described in Figure 6, Figure 7, and Figure 8.

Fig. 6 depicts a timing diagram showing the exchange of messages between MAC sub-layers of a device and a coordinator in a visible-light communication system, the messages supporting a visual notification of an association in accordance with the state of the art. Fig. 6 shown here is substantially identical to a figure 35 in chapter 5.1.12.1 the draft standard.

Specifically, figure 6 shows an exchange of messages between a MAC sub-layer entity DMC of the device and a MAC sub-layer entity CMC of the coordinator. The exchange of messages is serving the purpose of associating the device with a designated coordinator, whereby the association is to be notified by a color-function support using CVD frames according to the draft standard. The CVD frames are used between state changes to provide visual information to the user regarding the communication status, here an association of the device to the coordinator.

At the beginning, the MAC sub-layer entity DMC of the device sends a message captioned »association request« to the MAC sub-layer entity CMC of the coordinator. This association request is communicated using the MLME-ASSOCIATE.request primitive as described in chapter 6.3.1.1 of the draft standard. The process of association is generally described in chapter 5.1.4.1 of the draft standard.

In order to notify the user, a frame captioned »CVD (using color 'B')« is sent by the MAC sub-layer entity DMC of the device to the MAC sub-layer entity CMC of the coordinator using a chosen color, which is exemplarily set to »color 'B'«.

Said frame captioned »CVD (using color 'B')« is a color visibility dimming (CVD) frame serving the purpose of visual notification.

As shown, the frame can be sent repeatedly in order to repeat the visual notification.

Finally, after the association is completed, the MAC sub-layer entity CMC of the coordinator sends a message captioned »association response« to the MAC sub-layer entity DMC of the device in order to inform the device of a successful or failed association.

In Figure 7, an exchange of messages between a MAC sub-layer entity OMC of an originator and a MAC sub-layer entity RMC of a recipient is depicted, the messages supporting an acknowledgement indication accompanying a data transfer according to the state of the art as described in the draft standard.

The procedure starts by sending a data message, which is sent by the originator's MAC sub-layer entity OMC.

10 The successful reception of the data frame is communicated by the recipient's MAC sub-layer entity RMC to the originator's MAC sub-layer entity OMC by sending a message captioned »acknowledgement«.

15 In order to notify this successful data transfer, the recipient's MAC sub-layer entity RMC sends a corresponding frame captioned »CVD frame(using color 'B')« to the MAC sub-layer entity OMC of the originator. Said frame captioned »CVD (using color 'B')« is a color visibility dimming (CVD) frame
20 serving the purpose of visual notification.

In the lower half of fig. 7, a similar message exchange is depicted with the difference that the acknowledgment is not arriving which is leading to the assumption of the originator
25 that the data transfer was not successfully completed and that the transfer is to be indicated by a visible color C, e.g. red.

In order to notify this data transfer failure, the recipient's MAC sub-layer entity RMC sends a corresponding frame captioned »CVD frame(using color 'C')« to the MAC sub-layer entity OMC of the originator. Said frame captioned »CVD (using color 'C')« is a color visibility dimming (CVD) frame
30 serving the purpose of visual notification.

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In Figure 8, an exchange of messages between a MAC sub-layer entity OMC of an originator and a MAC sub-layer entity RMC of a recipient is depicted, the messages supporting a file-

transfer status indication accompanying a data transfer according to the state of the art, as described in chapter 5.1.12.4 of the draft standard.

- 5 The purpose of a color-supported notification is to allow a user to infer the remaining or transferred file size through the color of the CVD frame.

As shown in the example of Figure 8, the originator transfers
10 data frames to the device, which are numbered by a certain value K,M,N according to a respective data size measured in bytes. Different stages of the file transfer process can be represented with different choices of colors. For example, in order to use this indication the recipient needs to know the
15 total file size to be transmitted.

The remaining file size can be obtained by subtracting the transferred file size from the total file size. A MAC PIB attribute is used for the color assignment of the CVD frame
20 when the CVD frame is sent to indicate the application-dependent information, such as the file-transfer status.

The procedure starts by sending data frames captioned »data (#K+2)«, »data (#K+1)«, »data (#K)« from the originator's MAC
25 sub-layer entity OMC to the recipient's MAC sub-layer entity RMC.

As long as the remaining or transferred file size is above a value of L bytes, the recipient's MAC sub-layer entity RMC
30 sends a frame captioned »CVD (using color 'A')« to the MAC sub-layer entity OMC of the originator. Said frame captioned »CVD (using color 'A')« is a color visibility dimming (CVD) frame serving the purpose of visual notification. For instance, a color A like orange can be displayed to the user,
35 indicating, that a current data transfer will be still consuming a considerable amount of time to be completed.

After the transmitted data frames have reached a limit of M by sending data frames captioned »data (#M+2)«, »data (#M+1)«, »data (#M)«, which, in turn leads to a remaining file size of less than N bytes, the recipient's MAC sub-layer entity RMC sends a frame captioned »CVD frame(using color 'B')« to the MAC sub-layer entity OMC of the originator. For instance, a color B like yellow can be displayed to the user, indicating, that a current data transfer will be soon completed.

Hereinafter, an exemplary implementation according to an embodiment of the invention will be described. In accordance with the invention, a primitive for requesting a transmission of at least one visibility frame is to be implemented, whereby the request is directed from the upper layer to the interface of the medium-access-control entity. For interfacing either the medium-access-control link-management entity service access point (MLME-SAP) or the medium-access-control common-part sub-layer service access point (MCPS-SAP) according to the system architecture of the draft standard shown in figure 5 can be chosen. Choosing the first mentioned interface medium-access-control link-management entity service access point (MLME-SAP) has some advantages over the latter mentioned interface, which will be explained further down in the description. Therefore, the implementation according to this embodiment will be described with respect to the interface MLME-SAP, without limiting the generality of the invention.

An exemplary primitive for requesting a transmission of at least one visibility frame, or CVD frame, according to this embodiment is defined as a message MLME-CF.send(...). This message includes three parameters, namely CVDRetentions, CVDCColor, CVDDuration and CVDCycleLength. The message MLME-CF.send(CVDRetentions,CVDCColor,CVDDuration,CVDCycleLength) is issued by an upper layer to the medium-access-control entity.

If the arguments of the message MLME-CF.send() are empty or not present, default and/or current settings of attributes are used within the MAC sub-layer. The attributes are also referred to as PIB attributes (physical-layer personal-area-
5 network information base) according to the draft standard.

Default PIB attributes can be inquired with a message MLME-GET and can be changed with a message MLME-SET. Said messages are known primitives for reading PIB attributes, which are
10 described in the draft standard in chapter 6.3.4 and 6.3.10, accordingly.

Naturally the caption of messages, parameters, attributes etc. used in this description is not decisive. In other
15 words, the implementation of this embodiment can be realized with any other alternative captions.

The parameters of this message are explained below.

20 The »CVDRepetitions« parameter states the number of times a CVD frame is repeatedly sent. Its data type is an integer having a valid range from zero to 255.

The »CVDColor« parameter defines a color of the CVD frame
25 during a pertinent repetition. Its data type is a column vector of n_1 integers. The values of each respective element of the column vector can range from 0 to 255. Each element is a pointer to the look-up table captioned »phyColorFunction«.
Said look-up table is organized in three columns per row,
30 whereby a first row is an index, a second and a third column define the color. The »phyColorFunction« look-up table is defined in table 99 of the draft standard.

The »CVDDuration« parameter is a column vector of n_2 integers.
35 The values of each respective element of the column vector can range from 1 to 10,000. Each respective element of the column vector defines the duration of the CVD frame in increments of 10 ms during a pertinent repetition.

The »CVDCycleLength« parameter is a column vector of n_3 integers. The values of each respective element of the column vector can range from 1 to 65,536. Each respective element of the column vector defines the time between a beginning of a transmission of two adjacent CVD frames during the pertinent repetition by an incremental factor of 10 ms.

An exemplary primitive for confirming a transmission of at least one visibility frame, or CVD frame, according to this embodiment is defined as a message MLME-CF.confirm(...). This message includes one parameter, namely Status. The message MLME-CF.send(Status) is issued by the medium-access-control entity to the upper layer after an execution of an action instructed by the message MLME-CF.send (...). It is sent by the medium-access-control entity to the upper layer.

The »Status« parameter defines the status of attempting to invoke color-function support. Its data type is an enumeration consisting of the fields TRANSMISSION_SUCCESS, FAILURE, CVD_FRAME_NOT_SUPPORTED, CURRENTLY_NOT_POSSIBLE and INVALID_PARAMETERS.

Hereinafter, MAC-PIB attributes (physical-layer personal-area-network information base) are defined. These attributes are used within the MAC sub-layer. Each attribute is providing data reflecting a setting, which was previously set by a message. The data will be saved until it is changed by another message.

The MAC-PIB attribute »macCVDRepetitions defines the number of times CVD frames are sent. Its data type is an integer having a valid range from zero to 255. The factory default for this MAC-PIB attribute can be optionally set to a value of zero.

The MAC-PIB attribute »CVDColor« defines a color of the CVD frame during a pertinent repetition. Its data type is a col-

umn vector of n_1 integers. The values of each respective element of the column vector can range from 0 to 255. Each element is a pointer to the look-up table captioned »phyColor-Function«, which is described above. The factory default for this MAC-PIB attribute can be optionally set to a vectorial value of zero.

The MAC-PIB attribute »macCVDDuration« is a column vector of n_2 integers. The values of each respective element of the column vector can range from 1 to 10,000. Each respective element of the column vector defines the duration of the CVD frame in increments of 10 ms during a pertinent repetition. The factory default for this MAC-PIB attribute can be optionally set to a vectorial value of 50.

The MAC-PIB attribute »macCVDCycleLength« is a column vector of n_3 integers. The values of each respective element of the column vector can range from 1 to 65,536. Each respective element of the column vector defines the time between a beginning of a transmission of two adjacent CVD frames during the pertinent repetition by an incremental factor of 10 ms. The factory default for this MAC-PIB attribute can be optionally set to a vectorial value of 100.

According to an alternative embodiment, an interface with less functionality may be defined. If, e.g., a default duty cycle ($\text{CVDDuration}/\text{CVDCycleLength} = 0.5$) is chosen, either CVDCycleLength or CVDDuration can be discarded.

Reference will now be made to Figure 1 showing a timing diagram showing the exchange of messages between different layers of a device and a coordinator in a visible-light communication system, the messages supporting a color-function notification for an association according to an embodiment of the invention.

In Figure 1, an exchange of messages between an upper layer entity DUL of a device, a MAC sub-layer entity DMC of the de-

vice, a MAC sub-layer entity CMC of a coordinator and an upper layer entity CUL of the coordinator is depicted.

Generally, an upper layer entity is assumed to be an entity which is hierarchically and/or logically positioned in a layer above the MAC sub-layer. An upper layer entity includes an entity being part or assigned »upper layers« in the sense of the architectural description outlined above, including the link control layer LLC and/or service-specific convergence sub-layer SSCS and/or to the device-management entity DME along with the respective interfaces also referred to as service access points. Examples for an upper layer include an application such as a web browser, FTP (file transfer protocol), a VoIP (voice over internet protocol) phone, etc.

The device's MAC sub-layer entity DMC is interfaced by one of the MAC service access units MLME-SAP, MCPS-SAP (not shown in Fig. 1). Hereinafter it will be assumed that the medium-access-control link-management entity service access point MLME-SAP will be used in this embodiment without limiting the generality of the invention.

The procedure starts by sending a known MLME-ASSOCIATE.request message which is sent by an upper layer, here a device upper layer entity DUL to a device's MAC sub-layer entity DMC, the message being a primitive allowing the device to request an association with the coordinator. The MLME-ASSOCIATE.request message is described in chapter 6.3.1.1 of the draft standard.

On receipt of the MLME-ASSOCIATE.request primitive by the device's MAC sub-layer entity DMC, the device's MAC sub-layer entity DMC sends a message captioned »association request« to the MAC sub-layer entity CMC of the coordinator, as shown in Fig. 1.

In a next step, according to a preferred embodiment of the invention, a primitive for requesting a transmission of at

least one visibility frame is transmitted. Specifically, a request message MLME-CF.send(color A), which is sent by the at least one upper layer, here a device's upper layer entity DUL to a device's MAC sub-layer entity DMC, the message MLME-CF.send(color A) requesting a transmission of at least one
5 visibility frame having a color »A«.

For exemplary purposes it is assumed that the argument »color A« of the message MLME-CF.send(color A) is specifically including the following parameters in its argument:
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CVDR repetitions = 1;  
CVDColor = 10;  
CVDDuration = 50; and;  
15 CVDCycleLength = 100.
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Hence the message MLME-CF.send(color A) is specifically of the form MLME-CF.send(1,10,50,100).

20 The frame MLME-CF.send(color A) is used to effect a visual notification that an attempt to associate the device has been started. This may be exemplarily indicated by assigning a yellow color for color A.

25 After reception of the message MLME-CF.send(color A) by the device's MAC sub-layer entity DMC, the device's MAC sub-layer entity DMC sends a corresponding frame captioned »CVD frame(using color 'A')« to the MAC sub-layer entity CMC of the coordinator using a chosen color, which is exemplarily
30 set to »color 'A'«. Said frame captioned »CVD (using color 'A')« is a color visibility dimming (CVD) frame serving the purpose of visual notification.

The reception of the association request is confirmed by a
35 message captioned »acknowledgement« which is sent from the coordinator's MAC sub-layer entity CMC to the device's MAC sub-layer entity DMC.

In a further step, the reception of an association request is indicated by the coordinator's MAC sub-layer entity CMC to the coordinator's upper layer entity CUL by sending a message entitled »MLME-ASSOCIATE.indication« according to chapter 6.3.1.2 of the draft standard.

Upon reception of the MLME-ASSOCIATE.indication primitive, the coordinator's upper layer entity CUL determines whether to accept or reject the still unassociated device. The coordinator's upper layer entity CUL then issues a message captioned »MLME-ASSOCIATE.response« according to chapter 6.3.1.3 of the draft standard to the coordinator's MAC sub-layer entity CMC.

Finally, after the association is completed, the MAC sub-layer entity CMC of the coordinator sends a message captioned »as-sociation response« to the MAC sub-layer entity DMC of the device in order to inform the device of a successful or failed association.

The association decision and the response have to become available at the device within a time captioned »macResponse-WaitTime«. After this time, the device requesting association attempts to extract the association response command frame from the coordinator, in order to determine whether the association was successful.

After reception of the message captioned »association response« at the MAC sub-layer entity DMC of the device, a message captioned »MLME-ASSOCIATE.confirm« according to chapter 6.3.1.4 of the draft standard is sent to the device's upper layer entity DUL in order to inform the upper layer of the initiating device whether its request to associate was successful or not.

The successful reception of the message captioned »MLME-ASSOCIATE.confirm« is finally communicated by the device's MAC sub-layer entity DMC to the coordinator's MAC sub-layer

entity CMC by sending a message captioned »acknowledgement«. Upon reception of said acknowledgement, the coordinator's MAC sub-layer entity CMC issues a message captioned » MLME-COMM-STATUS.indication« to the coordinator's upper layer entity
5 CUL.

After reception of the message »MLME-ASSOCIATE.confirm« at the device's upper layer entity DUL a visual notification of the association status is desirable and supported by means of
10 this embodiment of the invention. The device's upper layer entity DUL issues a message MLME-CF.send(color B) to the device's MAC sub-layer entity DMC which sends a corresponding frame captioned »CVD frame(using color 'B')« to the MAC sub-layer entity CMC of the coordinator using a chosen color,
15 which is exemplarily set to »color 'B'«. The message MLME-CF.send(color B) is used to effect a visual notification that the association of the device has been completed. This may be exemplarily indicated by a assigning a green color for color B.

20

In the following, the implications on the physical layer after the reception of the message MLME-CF.send(color A) are described. These implications are not shown in Figure 1.

25 After the reception of the message MLME-CF.send(color A) at the device's MAC sub-layer entity DMC, the device's MAC sub-layer entity DMC invokes a - not shown - message captioned »PD-DATA.request« as specified in chapter 9.3.1 of the draft standard, the PD-DATA including parameters received by the
30 MLME-CF.send(color A) request.

In the - not shown - physical layer a data packet of a color »10« according to the phyColorFunction table is composed, at least one data packet having a total duration of 50*10 ms.
35 Instead of using a single packet, a sequence of a plurality of packets can be used. The total duration of the sequence has to be equal to the duration in a case using a single frame. The next transmission of a color-function color visi-

bility dimming (CVD) frame is scheduled after a time period of 50 ms, according to the arguments calculated as $(100 \times 10 - 50 \times 10)$. This data packet is »tunneled« through the physical layer PHY, and at least one optical transmitter is emitting
5 the corresponding light with the color A.

After the physical layer PHY has reported a successful transmission to the device's MAC sub-layer entity DMC by aid of a - not shown - PD-DATA primitive, the device's MAC sub-layer
10 entity DMC in turn reports the successful execution with the MLME-CF primitive »MLME-CF.confirm« to the device upper layer entity DUL. For the sake of improved clarity, this message is not shown in Figure 1.

15 In figure 2, an exchange of messages between an upper layer entity OUL of an originator, a MAC sub-layer entity OMC of the originator, a MAC sub-layer entity RMC of a recipient and an upper layer entity RUL of the recipient is depicted.

20 Specifically, figure 2 depicts a timing diagram showing the exchange of messages between different layers of an originator and a recipient in a visible-light communication system, the messages supporting an acknowledgement indication accompanying a data transfer according to an alternative embodiment of the invention.
25

The originator's MAC sub-layer entity OMC is interfaced by one of the MAC service access units MLME-SAP, MCPS-SAP (not shown in Fig. 2). Hereinafter it will be assumed that the medium-access-control link-management entity service access
30 point MLME-SAP will be used in this embodiment without limiting the generality of the invention.

The procedure starts by sending a known MCPS-DATA.request
35 message which is sent by an upper layer, here an originator upper layer entity OUL to a originator's MAC sub-layer entity OMC, the message being a primitive allowing the originator to request a data transfer to the recipient. The MLME- MCPS-

DATA.request message is described in chapter 6.2.1 of the draft standard.

On receipt of the MCPS-DATA.request primitive by the originator's MAC sub-layer entity OMC, the originator's MAC sub-layer entity OMC sends a message captioned »data frame« to the MAC sub-layer entity RMC of the recipient, as shown in Fig. 2. The data frame message readily includes the payload of data which has to be sent to the recipient.

The successful reception of the data frame is communicated by the recipient's MAC sub-layer entity RMC to the originator's MAC sub-layer entity OMC by sending a message captioned »acknowledgement (requested)«. In parallel, the recipient's MAC sub-layer entity RMC issues a message captioned »MCPS-DATA.indication« to its upper layer entity RUL.

The device that sends the data frame shall wait a time captioned »macAckWaitDuration« for a corresponding acknowledgement frame to be received. After reception of a message captioned »acknowledgement (requested)« at the MAC sub-layer entity OMC of the originator within the time period captioned »macAckWaitDuration« a message captioned »MCPS-DATA.confirm« according to chapter 6.2.2 of the draft standard is sent to the originator's upper layer entity OUL in order to inform the upper layer of the initiating originator whether the data transfer was successfully completed or not. It is assumed that the data transfer was successfully completed for the first data frame and that the successful completion is to be indicated by a visible color B, e.g. green.

In order to notify this successful data transfer a primitive for requesting a transmission of at least one visibility frame is transmitted according to a preferred embodiment of the invention. Specifically, a request message MLME-CF.send(color B), which is sent by originator's upper layer entity OUL to the originator's MAC sub-layer entity OMC, the message MLME-

CF.send(color B) requesting a transmission of at least one visibility frame having a color »B«.

After reception of the message MLME-CF.send(color B) by the
5 originator's MAC sub-layer entity OMC, the originator's MAC sub-layer entity OMC sends a corresponding frame captioned »CVD frame(using color B)« to the MAC sub-layer entity RMC of the recipient.

10 In the lower half of fig. 2, a similar message exchange is depicted with the difference that the acknowledgment is not arriving within the time period »macAckWaitDuration« and a number of retries captioned »x macMaxFrameRetries« was not able to alter this situation. It is finally assumed that the
15 data transfer was not successfully completed for this data frame and that the transfer is to be indicated by a visible color C, e.g. red.

In order to notify this data transfer failure the primitive
20 for requesting a transmission of at least one visibility frame is transmitted according to a preferred embodiment of the invention. Specifically, a request message MLME-CF.send(color C), which is sent by originator's upper layer entity OUL to the originator's MAC sub-layer entity OMC, the message MLME-
25 CF.send(color C) requesting a transmission of at least one visibility frame having a color »C«.

Figure 4 depicts a timing diagram showing the exchange of messages between different layers of a recipient and an ori-
30 ginator in a visible-light communication system, the messages supporting an indication of a file-transfer status according to an alternative embodiment of the invention;

Specifically, an exchange of messages between an application
35 layer entity OAP of an originator, an upper layer entity OUL of the originator, a MAC sub-layer entity OMC of the originator and a MAC sub-layer entity RMC of a recipient is depicted.

For the sake of clarity, the application layer entity OAP is described separately from the upper layer entity OUL of the originator. However, the application layer entity OAP is considered being part of the upper layer entity OUL, too.

According to Figure 4, the application layer entity OAP of the originator sends a message captioned »transfer data« to the upper layer entity OUL of the originator. The message captioned »transfer data« includes the payload of data which has to be sent to the recipient.

The upper layer entity OUL substantially conducts the transmission by sending a known MCPS-DATA.request message to the originator's MAC sub-layer entity OMC.

On receipt of the MCPS-DATA.request primitive by the originator's MAC sub-layer entity OMC, the originator's MAC sub-layer entity OMC sends a message captioned »data frame« to the MAC sub-layer entity RMC of the recipient. The data frame message accordingly includes the payload of data which has to be sent to the recipient.

The successful reception of the data frame is communicated by the recipient's MAC sub-layer entity RMC to the originator's MAC sub-layer entity OMC by sending a message captioned »acknowledgement«.

For the sake of clarity, other confirmation and/or acknowledgment messages, e.g. sent to the upper layer entity OUL of the originator, to the application layer entity OAP of the originator are not shown in Figure 4. Also not shown are messages exchanged by recipient's MAC sub-layer entity RMC to its upper layers.

The application layer entity OAP of the originator is calculating the remaining file size while the data transfer is in progress. As long as the remaining file size is exceeding a

value of L bytes, see figure 4, a visual notification remains unchanged. At the time the remaining file size is not any longer exceeding a value of L bytes, a message MLME-CF.send(color D) is used to effect a visual notification that the data transfer has been almost completed. This may be exemplarily indicated by assigning a yellow color for color D.

In fact, the application is the most suitable entity for calculating the remaining file size. The major drawback of the state of the art, outlined in the description of Figure 7, whereby on the level of the MAC sub-layer such calculations are hardly feasible, is hereby rectified using the inventive principle of placing the discretion of requesting a notification in the upper layers, here, in the application level.

Figure 3 depicts a timing diagram showing the exchange of messages between different layers of a recipient and an originator in a visible-light communication system, the messages supporting a channel-quality indication according to an alternative embodiment of the invention.

Specifically, an exchange of messages between an upper layer entity RUL of a recipient, a MAC sub-layer entity RMC of the recipient and a MAC sub-layer entity OMC of an originator is depicted.

It is assumed that the originator's MAC sub-layer entity OMC sends a message captioned »data frame« to the MAC sub-layer entity RMC of the recipient. The data frame message readily includes payload of data which has to be sent to the recipient.

The successful reception of the data frame is communicated by the recipient's MAC sub-layer entity RMC to the originator's MAC sub-layer entity OMC by sending a message captioned »acknowledgement (requested)«. In parallel, the recipient's MAC

sub-layer entity RMC issues a message captioned »MCPS-DATA.indication« to its upper layer entity RUL.

In the upper layer entity RUL, the communication quality is
5 calculated. The communication quality may be obtained by various metrics. For example, FER or frame error rate statistics can be averaged over multiple frames in order to choose the color of the CVD frame.

10 For example, a parameter »ppduLinkQuality« according to chapter of 9.3.3 of the draft standard can be used for this purpose. Based on this parameter, a frame error rate or FER is calculated. It, according to Fig. 3, is lower than a threshold of FER #1, a request message MLME-CF.send(color B) is
15 sent by the recipient's upper layer entity RUL to the recipient's MAC sub-layer entity RMC, the message MLME-CF.send(color B) requesting a transmission of at least one visibility frame; having a color »B«.

20 The visual notification can help providing misalignment indication to the user in a line-of-sight link. Different colors can be used to indicate different states of misalignment. For example, green, blue, and red CVD frames can be used to visualize high, middle and low data rates respectively. The
25 choice of the colors and the data rate range is, again, left to the implementer.

A major advantage of the proposed notification according to the invention is that a blinking notification, which is
30 specified in a separate chapter of the draft standard, can readily be facilitated by the invention.

If color of CVD frames is chosen differently from that of data transmission, MLME-CF.send can be used for blinking by
35 setting CVDR repetitions, CVDDuration, and CVDCycleLength accordingly. Even multi-color blinking is feasible by means of the invention. One can even achieve same color blinking by adjusting the duty cycle.

In order to accommodate 1 Hz blinking one has to set CVDCycleLength = (100) and for 2 Hz blinking CVDCycleLength = (200).

5

If one chooses a 50% duty cycle for the blinking, the corresponding lengths of the CVD frames are CVDDuration = (50) and (100), respectively.

10 Further more, dimming and MLME-CF.send can be used in combination. If, e.g., transmitter is currently set at 90% dimming, the dimming primitive can be used to increase radiant power of transmitter during emission of CVD frames.

15 This would be implemented as follows:

- Change dimmer setting with MLME-SET primitive (set the MAC-PIB attribute macDim to the intended level)
- Invoke submission of one CVD frame with MLME-CF.send (CVDR repetitions = 1; it is advantageous to set CVDCycleLength = CVDDuration).
- 20 - After completion of the CVD transmission, as, for instance, indicated by MLME-CF.confirm, set back the dimming level to the initial level by use of the the MLME-SET primitive (see above).
- 25 - After a preset duration, e.g. macCVDCycleLength, start this process

According to figure 5, not only access to the MAC sub-layer through next higher layers but also device-management entity
30 DME is possible, which itself has access to the MLME interface (MLME-SAP). Thus not only higher/upper-layer applications can invoke color-function and blinking-notification support from standard-conform VLC devices.

35 The invention opens standard-conform VLC devices up to novel applications:

- A facility-management system of a building is interfacing to VLC-enabled lamps via the DME interface. In cases of

alerts, the MLME-CF interface is used to make all the lamps blink, e.g. with red repetitive color bursts. This can automatically be adapted to the lamp color. If a lamp usually emits »reddish« light, it chooses a different color for the alert, for instance blue.

- The facility-management system uses this functionality to both warn and guide people during an emergency. For instance, it invokes the lamps illuminating escape routes with a different color or a different repetition frequency or duty cycle.
- The facility-management of a multiple-user building, e.g. a library, informs the visitors of the impending closure of the building at the end of the day via repetitious changes of the color and/or intensity) of the emitted light.
- Another option is to address the lamps through a remote lamp-control system, e.g. Digital Addressable Lighting Interface, DALI.
- The facility-management system (which includes the lamps) of a private home is coupled to the TIVO, set-top box, or the like. When an important event occurs, e.g. the second half of a football game starts, it changes the color of the emitted light to alert the household of this fact. Here, the set-top box forwards an alert to the facility-management system, which in turn invokes color-function support of all lamps via the DME interface.
- In a similar scenario the household is informed of the end of a commercial break by aid of color-function support.
- A battery-driven VLC emitter is informing human users of a low battery by invoking the color-function support. This can also be done in combination with the dimming functionality using a blinking notification.
- A computer that is connected to the DME of a lamp via, for instance power-line communication, uses color-function support, optionally in combination with the dimming functionality, to inform the user that an email has arrived.
- »Down stream« from a traffic accident, the color and/or intensity of the light emitted by street lamps is changed

by aid of color-function support and/or the dimming functionality. Here, the color and/or frequency of this change are adapted to the position of the street lamp. For instance, lamps that are closer to the accident are invoked with shorter CVD cycle lengths than those further away.

- All lamps controlled by a municipality are color and/or intensity modulated with a known pattern when a major catastrophe is occurring and the people in the municipality are asked to consult the public information services in order to inform themselves about the catastrophe and recommended actions.

In summary, embodiments of the invention are aiming a development of a unified solution with the following directives:

- Only uses one set of MAC-PIB parameters for all embodiments;
- Defines a unified, slim interface between upper layers and the device-management entity (DME) that also allows changing the above MAC-PIB parameters;
- Enables non-application-layer specific use cases via the device-management entity (DME);
- Support a straight-forward implementation of the blinking-notification functionality.

In summary, embodiments of the invention have the following advantages:

- Minimal implementation overhead in the MAC;
- Can be accessed by higher communication layers and also the device-management entity (DME);
- Fits within a large number of use cases and applications;

Embodiments of the invention can be implemented in computing hardware (computing apparatus) and/or software, including but not limited to any computer that can store, retrieve, process and/or output data and/or communicate with other computers.

The processes can also be distributed via, for example, downloading over a network such as the Internet. A pro-

gram/software implementing the embodiments may be recorded on computer-readable media comprising computer-readable recording media. The program/software implementing the embodiments may also be transmitted over a transmission communication media such as a carrier wave. Examples of the computer-readable recording media include a magnetic recording apparatus, an optical disk, a magneto-optical disk, and/or a semiconductor memory (for example, RAM, ROM, etc.). Examples of the magnetic recording apparatus include a hard disk device (HDD), a flexible disk (FD), and a magnetic tape (MT). Examples of the optical disk include a DVD (Digital Versatile Disc), a DVD-RAM, a CD-ROM (Compact Disc - Read Only Memory), and a CD-R (Recordable)/RW.

15 The invention has been described in detail with particular reference to preferred embodiments thereof and examples, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention covered by the claims.

What is claimed is:

1. A method for providing visible notification by a device in a system for visible-light communication based on the specifications of IEEE 802.15.7,
5 the device including a medium-access-control entity (MAC) interfacing in between a physical layer (PHY) and at least one upper layer, the at least one upper layer being hierarchically arranged above the medium-access-control entity (MAC),
10 the medium-access-control entity (MAC) including at least one interface (MLME-SAP, MCPS-SAP) to said upper layer, said method including the step of:
providing a primitive for requesting, by the at least one upper layer to the at least one interface (MLME-SAP, MCPS-SAP)
15 of the medium-access-control entity (MAC), a transmission of at least one visibility frame.
2. Method according to claim 1, including the step of providing a primitive for confirming, by the at least one interface (MLME-SAP, MCPS-SAP) of the medium-access-control entity (MAC) to the at least one upper layer, a transmission of
20 at least one visibility frame.
3. Method according to one of the aforementioned claims, said
25 primitive for requesting including:
 - a parameter defining a number of times a CVD frame is repeatedly sent and/or;
 - a parameter defining a color of the CVD frame during a pertinent repetition and/or;
 - 30 - a parameter defining a duration of the CVD frame and/or;
 - a parameter defining a time between a beginning of a transmission of two adjacent CVD frames during the pertinent repetition.
- 35 4. Method according to one of the aforementioned claims, said primitive used for requesting a blinking notification.

5. A device for providing visible notification in a system for visible-light communication based on the specifications of IEEE 802.15.7,

the device including a medium-access-control entity (MAC) interfacing in between a physical layer (PHY) and at least one upper layer, the at least one upper layer being hierarchically arranged above the medium-access-control entity (MAC), the medium-access-control entity (MAC) including at least one interface (MLME-SAP, MCPS-SAP) to said upper layer,

the at least one upper layer entity providing a primitive for requesting a transmission of at least one visibility frame by at least one interface (MLME-SAP, MCPS-SAP) of the medium-access-control entity (MAC).

6. Device according to claim 5,

said at least one interface (MLME-SAP, MCPS-SAP) of said medium-access-control entity (MAC) providing a primitive for confirming a transmission of at least one visibility frame to the at least one upper layer.

7. Device according to one of the aforementioned claims 5 and 6,

the upper layer including a device-management entity (DME) and/or a logical link control layer (LLC) and/or a service-specific convergence sub-layer (SSCS).

8. Device according to one of the aforementioned claims 5 to 7, said primitive for requesting including:

- a parameter defining a number of times a CVD frame is repeatedly sent and/or;
- a parameter defining a color of the CVD frame during a pertinent repetition and/or;
- a parameter defining a duration of the CVD frame and/or;
- a parameter defining a time between a beginning of a transmission of two adjacent CVD frames during the pertinent repetition.

9. A computer program product, the computer program product containing a program code stored on a computer-readable medium and which, when executed on a computer, carries out a method according to one of the aforementioned claims 5 to 8.

5

10. A data storage carrier that stores a computer program to cause a computer to perform a method according to claim 9.

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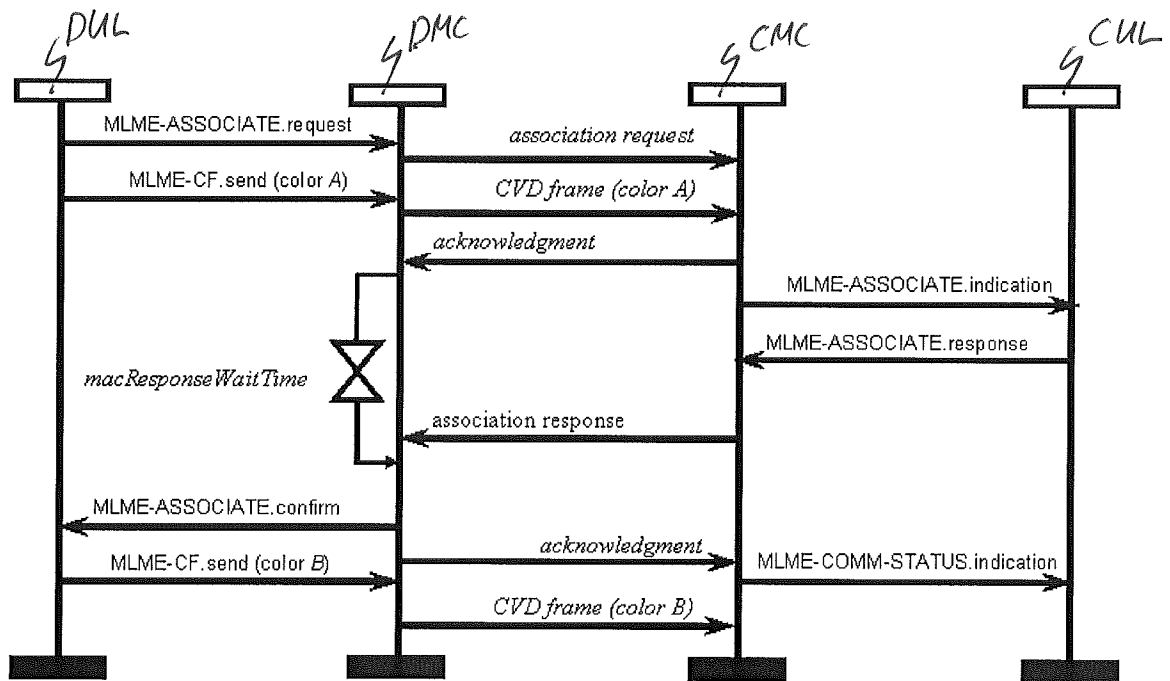


FIG 1

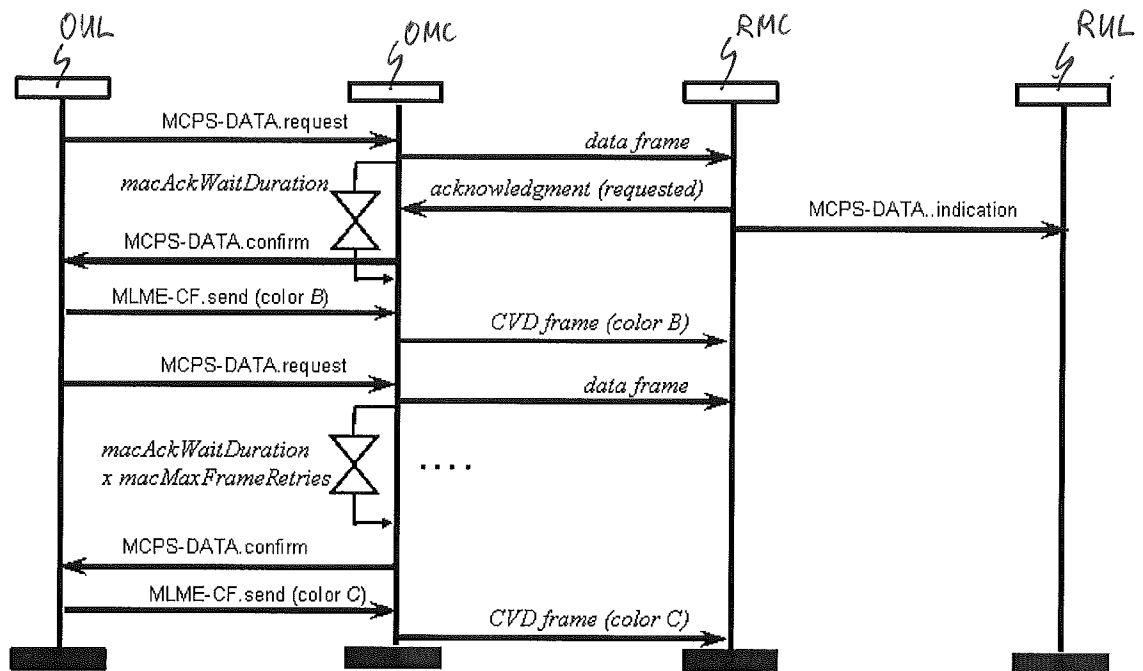


FIG 2

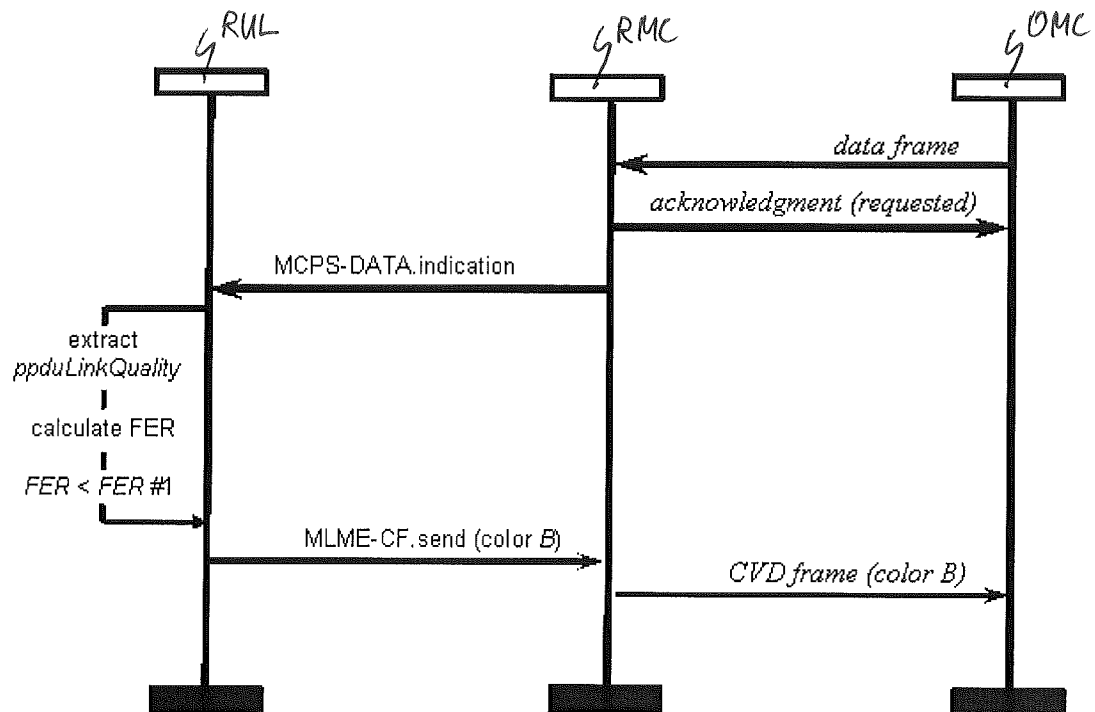


FIG 3

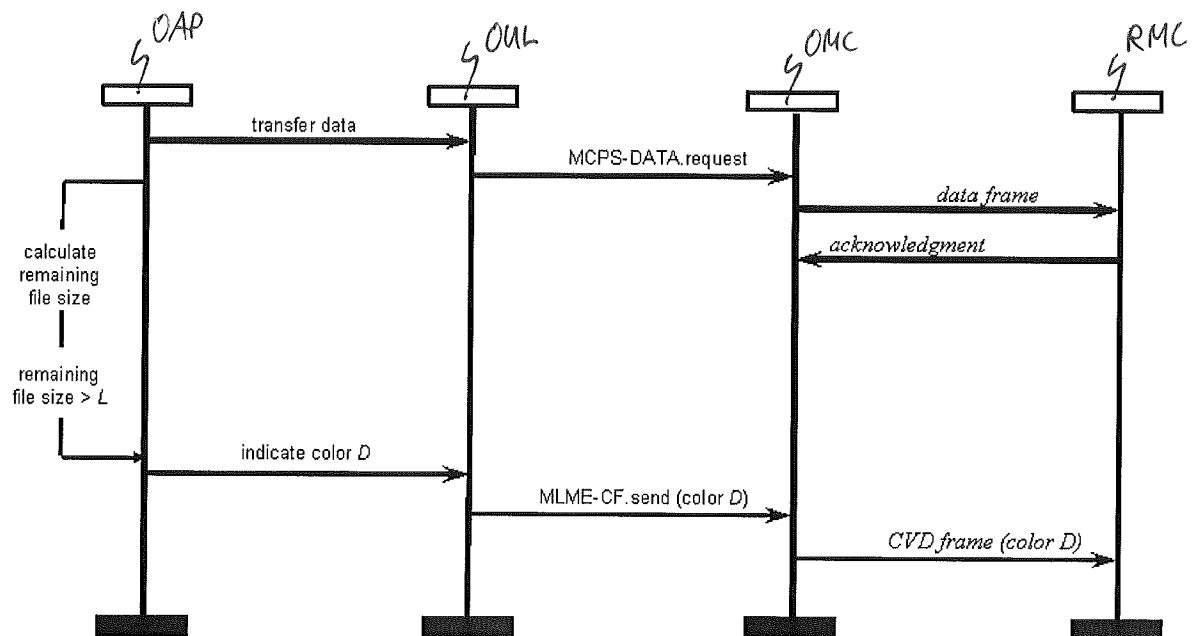
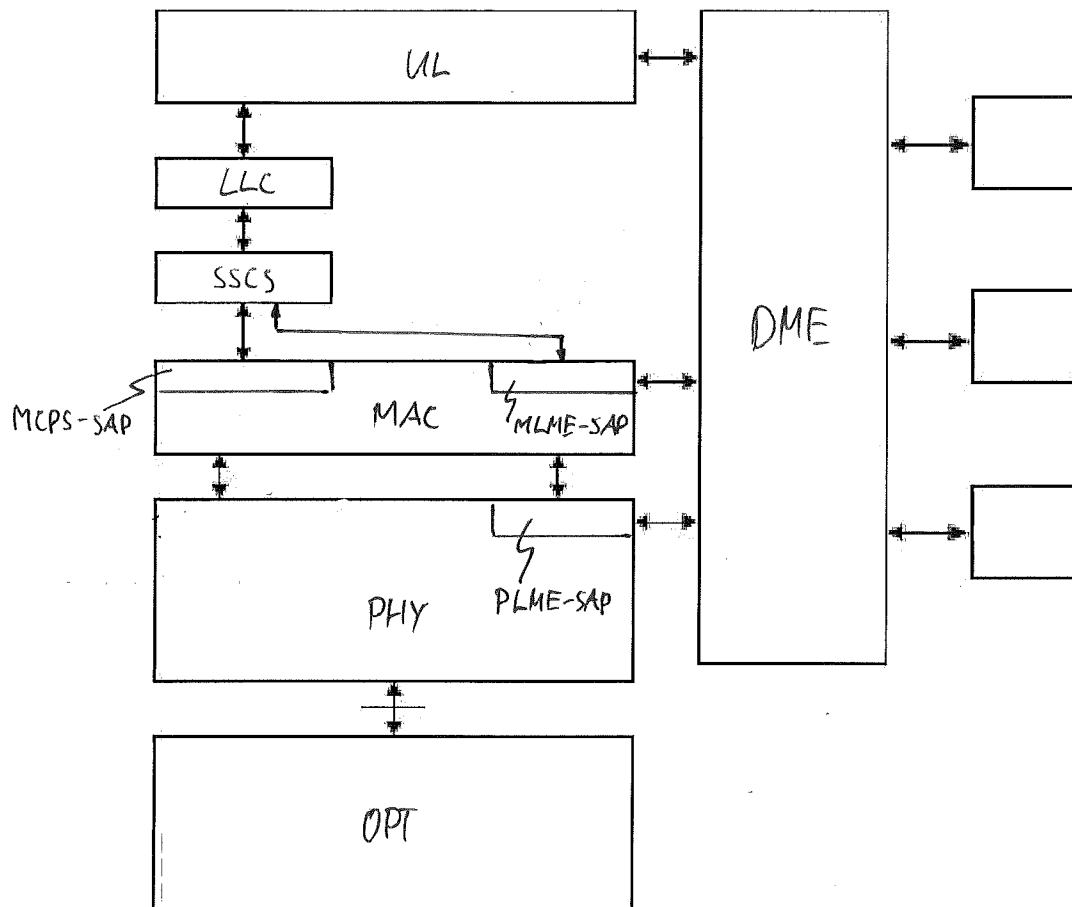


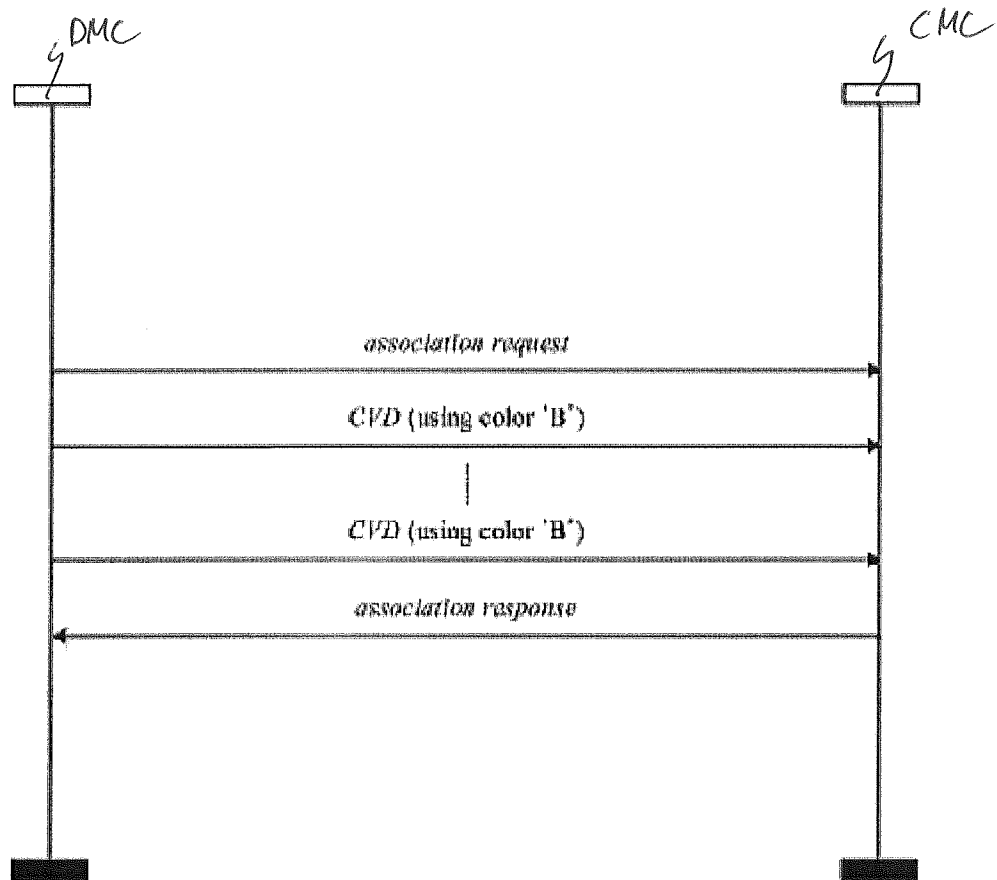
FIG 4



STATE OF THE ART

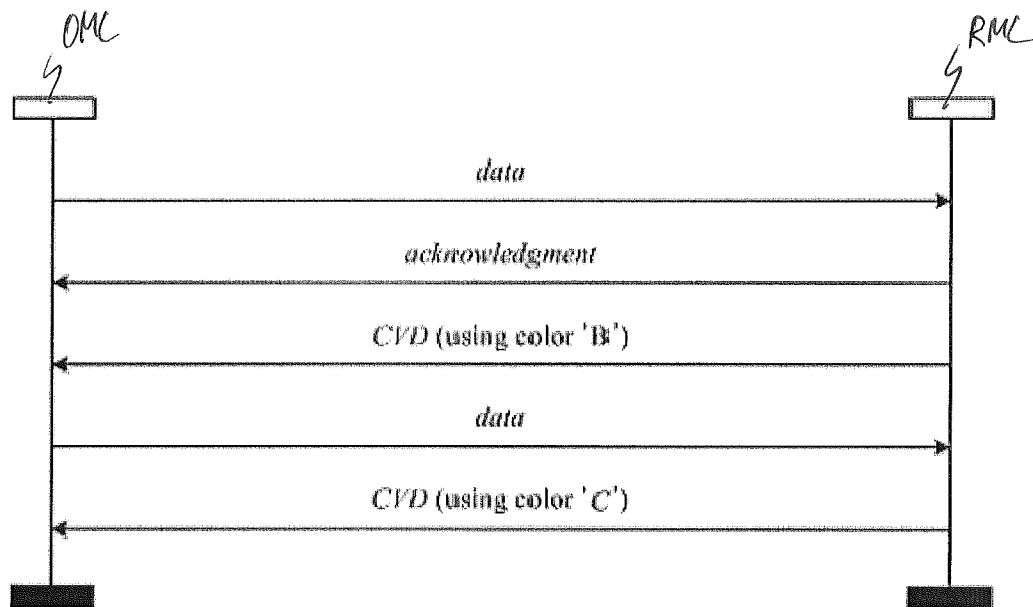
FIG 5

6/8



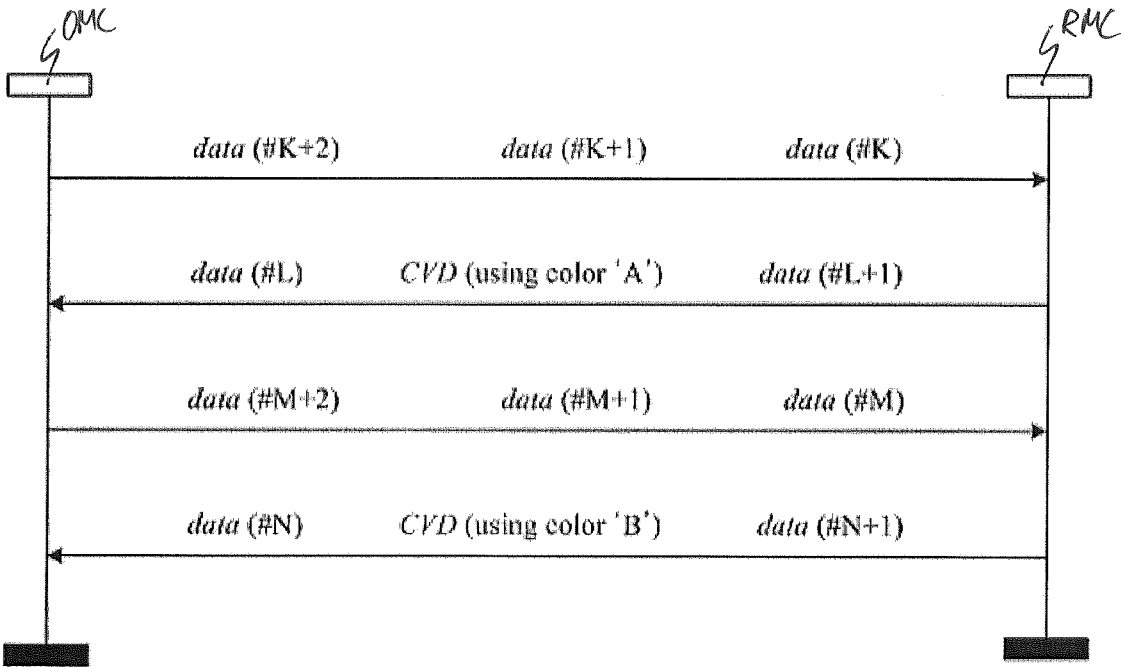
STATE OF THE ART

FIG 6



STATE OF THE ART

FIG 7



STATE OF THE ART

FIG 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/054671

A. CLASSIFICATION OF SUBJECT MATTER INV. H04B10/10 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) H04B		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, INSPEC, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	"d4P802-15-7 Draft Standard ; d4P802-15-7 Draft Standard", IEEE DRAFT; D4P802-15-7 DRAFT STANDARD, IEEE-SA, PISCATAWAY, NJ USA, vol. 802.15.7, 14 November 2010 (2010-11-14), pages 1-296, XP017637045, [retrieved on 2010-11-14] the whole document -----	1-10
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents :		
"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search	Date of mailing of the international search report	
11 May 2012	18/05/2012	
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Petitit, Nicolas	