Packet Transfer of DLMS/COSEM Standards for Smart Grid

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***Abstract*— In this paper, we review packet transfer from DCU to meter by using DLMS/COSEM protocol. We descript the kind of book of DLMS/COSEM and explain the combination of DLMS/COSEM such as COSEM application process, COSEM application layer and connection manager. We show some example of packet transfer from application layer of DLMS/COSEM to data link layer and summary the size of packet of each command and response of DLSM/COSEM. Additionally, we will descript the ZigBee basic knowledge that used to physical layer of DLMS/COSEM protocol.**

Keywords—Smart grid; DCU, Smart meter, DLMS/COSEM, ZigBee

I. Introduction

Generally, the convention power transfer systems deliver power from central generators to customers. For smart grid (SG) system, it uses two-way communication for exchange information between smart sensors and distributed energy delivery networks. SG is the next-generation of electric power system since 2005. Therefore, SG becomes one of the fast growing research topics [1-4] because this system is a promising solution for energy crisis. In [1], J. Ekanayake, et al. present the six major advantages of SG. First, SG can open customer manage demand response and demand side through the integration of SG devices and SG can provide information related to energy consumption and usage price to customers. Second, SG systems combine renewable energy sources, distributed generation, residential micro-generation, and power storage for improving the performance of energy management. Third, SG has the optimization method for asset management to operate the power delivery system and pursuing efficient. Fourth, SG can self-recover when the power systems occur fault tolerant or the attraction form natural disaster. So, SG systems have a high reliability and the security of power. Fifth, SG can maintain the power quality of the electricity supply by providing the sensitive equipment for increasing the digital economy. Sixth, SG opens access to the markets through increased transmission paths, aggregated supply and demand response initiatives and ancillary service provisions. However, one of the important features of SG is the integration of secure, high-speed and reliable data communication networks for management the complex power systems intelligently and effectively. Thus, SG has complex environmental conditions, connectivity problems, dynamic topology changes, and interference and various fading during wireless communication.

The existing SG standardizations are the important topics that need to consideration too. W. Wang, et al. [2] and Z. Fan, et al. [3] present the communication network architecture of SG and discuss the communications standards and protocols in SG. Many standards have been proposed for using to develop the SG. Three famous SG standards include Distributed network protocol (DNP), Open smart grid protocol (OSGP) and DLMS/COSEM. First, DNP is first appeared in 1998 and DNP3 becomes the current version. At substations, it uses DNP3 protocol for control and equipment monitoring. The basic functions of an automated system of this protocol implements for communicating equipment states to the control station and deliver configuration commands to the electric equipments. However, DNP3 is not strictly guaranteed in the quality of communication. Second, OSGP [4] is proposed by the European Telecommunications Standards Institute (ETSI). This protocol is used in conjunction with the ISO/IEC 14908 control networking standard for smart grid applications. OSGP can optimize to provide reliability and efficiently of command and control information delivery for smart meters, solar panels, direct load control modules, gateways and other smart grid devices. However, OSGP is just open information at 2012. Hence, minimum works in literature are studied this standard. Third, the DLMS (Device Language Message Specification) User Association (UA) provides the DLMS/COSEM [5-7] that is the suite of standards. DLMS UA is considered by the IEC TC13 WG14 into the IEC 62056 series of standards. DLMS UA has been established for international standards to exchange data of a meter. Stated by DLMS UA, the meter must be embedded with the information including registration, maintenance and conformance testing services. COSEM (Companion Specification for Energy Metering) integrated set of the protocol layer (Transport Layer and Application Layer) to combine with DLMS protocol. The DLMS/COSEM Specification determines the protocol of an interface model and communication to exchange data of a meter equipment. The interface model provides a view of the functionality of the meter as it is available at its interfaces. This protocol is highly received interesting from many companies or research groups for using to SG devices including smart meters and DCU. Therefore, in this paper, we study and review the packet transfer of DLMS/COSEM.

On the other hand, the communication technology that connects between the DCU (Data concentrator unit) and AMI devices will have several options greatly [8]. ZigBee [9-12] is the one of the communication technologies that is highly received considered for using in smart grid. So, in this paper, we conclude the packet transfer and the size of data transfer of ZigBee too. The remainder of this paper is organized as follows. Section II gives the detail of smart grid. The detail of DLMS/COSEM protocol and its packet transfer are presented in Section III. The detail of basic knowledge of ZigBee is shown in Section IV. Finally, conclusions are presented in Section V.

II. SMART GRID SYSTEM

Smart grid [1-4] is to modify the old power grid to a powerful system reliable to achieve the control functions of the system to make the smart grid system effectively. A smart meter or AMI (Advanced Metering Infrastructure) is a keys device to implement smart grid. Smart meter is a two-way communication device that measures energy consumption from the appliances. The network size of smart grid can be classified into three areas including Wide area network (WAN), neighborhood area network (NAN) and home area network (HAN) or building area network (BAN). HAN or BAN has a small size of network area. It sends information and connects communication network from appliances to devices in a home or building. NAN has the network size bigger than HAN. This network collects data from multiple HANs and BANs and delivers the data to a data concentrator (DCU). DCU is a gateway for communication of data between the smart meter and the substation. Finally, WAN is the biggest network size. WAN carries information from DCU to control centers. Table I presents range, data rate requirement and the potential technologies of the different types of network.

A. DLMS/COSEM communication profile

The DLMS/COSEM is an interface model which is used to exchange the information of the meter. The interface model provides a view of the functionality of the meter as it is available at its interfaces. Communication protocols define how the information can access and transported. There are 4 standard document that identify the protocol for DLMS UA including Green Book, Yellow Book, Blue Book and White Book [5-7]. The COSEM meter object model and the object identification system are described by Blue book. Green book presents architecture and protocols of COSEM. The all questions concerning conformance testing are described by Yellow book. Term of glossary is presented by White book.

TABLE I: COMMUNICATION REQUIREMENT AND CAPABILITIES UNDER DIFFERENT TYPES OF NETWORKS

Types of Network	Range	Data Rate Requirements	Potential Technology
HAN or BAN	10m -100m	Application used low data rate device for communication	ZigBee , Wi-Fi, Ethernet, PLC
NAN	100m-10km	Depends on node density in the network	ZigBee , Wi-Fi, PLC, Cellular
WAN	<10km	High end device router/switch speed (100 Mbps to Gbps)	Fiber optic links, 3G/LTE, Ethernet, WiMAX,

III. DLMS/COSEM STANDARD

In this section, we review basic knowledge of DLMS/COSEM and present the data packet at data storage process.

Figure 1 shows DLMS/COSEM communication profiles that are classified by book color and OSI model. DLMS/COSEM communication profiles can be separated into two parts including application layer and other layer. The part that is upper the solid line is application layer. This part has three blocks that are COSEM application process, COSEM application layer and connection manager. The only COSEM application process is described in blue book. Other part is described in green book. The part that is lower the solid line can be separated into three ways following the communication types. For 3-layer CO HDLC, this way includes data link layer and physical layer. It not has transport layer. Data link layer includes two sublayers: LLD sublayer and HDLC sublayer. Next, TCP-UDP/IP has two layers: transport layer and data link layer. In transport layer, DLMS/COSEM adds wrapper sublayer before normal TCP and IPv4 sublayer. Finally, IEC 61334-5 S-FSK PLC profile is proposed for PLC communication. This way includes data link layer and physical layer like 3-layer CO HKLC.

In this paper, we interest to use ZigBee communication for physical layer. Therefore, we will descript only 3-layer CO HDLC because this way can apply to ZigBee communication.

A. Sequence of DLMS/COSEM

Data exchanges between DCU and smart meter are based on the client and server paradigm. DCU plays the rules of the client. For DLMS/COSEM, we can classify sequence of packet transfer between DCU and smart meter into three steps: set up data link, data transfer and disconnect data link as shown in figure 2.

1) Set up data link

At this step, DCU sends SNRM (Set Normal Response Mode) command to smart meter. When smart meter received this command and smart meter is ready to connect, smart meter will send acknowledgement that name is UA (Unnumbered Acknowledge) back to DCU.

2) Data trasfer

First, DCU will check the properties of smart meter before connection. DCU sends AARQ (A-Associate Request) to smart meter and the meter will send AARE (A-Associate Response) return to DCU. AARQ includes all properties that meter can do and AARE is the properties of each meter has. After checking the property, DCU and smart meter can send I-Frame for changing its information.

3) Disconnect data link

If DCU and smart meter finish transferring data, DCU will send the DISC (Disconnect) command for disconnect and smart meter send UA response for confirm.

B. Example of DLMS/COSEM packet transfer

1) COSEM application process

This process includes interface class and OBIS (Object Identification System) code. Each interface class has class_id (Class identification code). DLMS/COSEM provides many interface classes. The number of interface class depends on the type of process. For example, nine interface classes are used for data storage process as shown in figure 3.

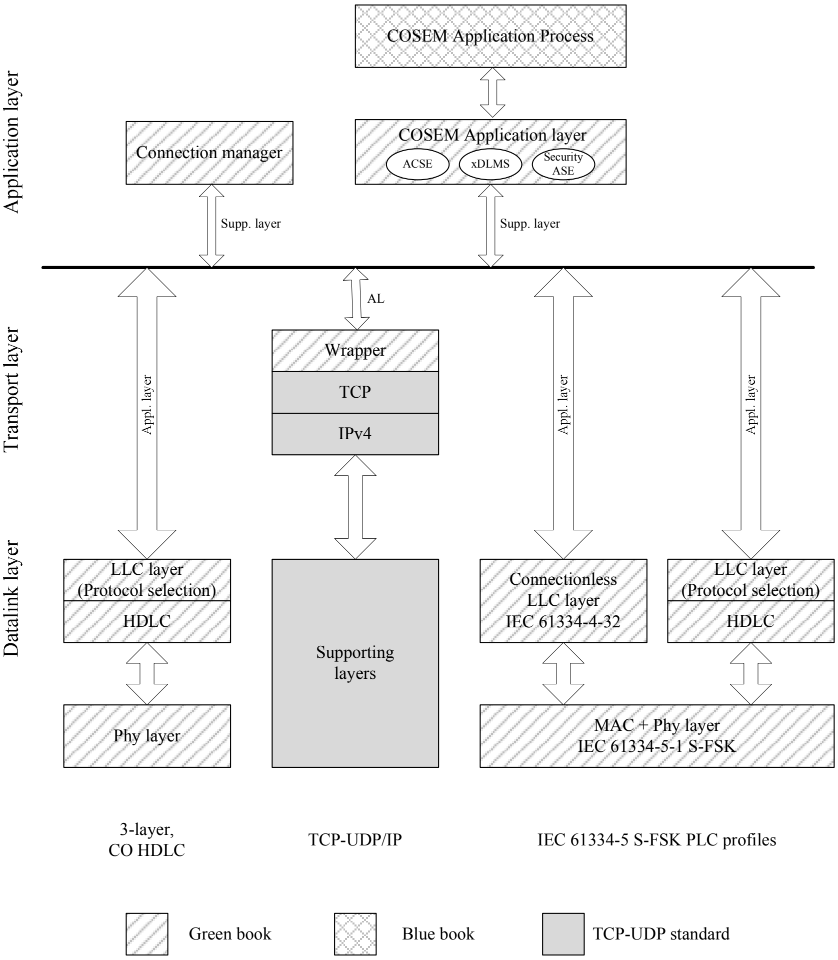

Fig 1. DLMS/COSEM communication profiles.

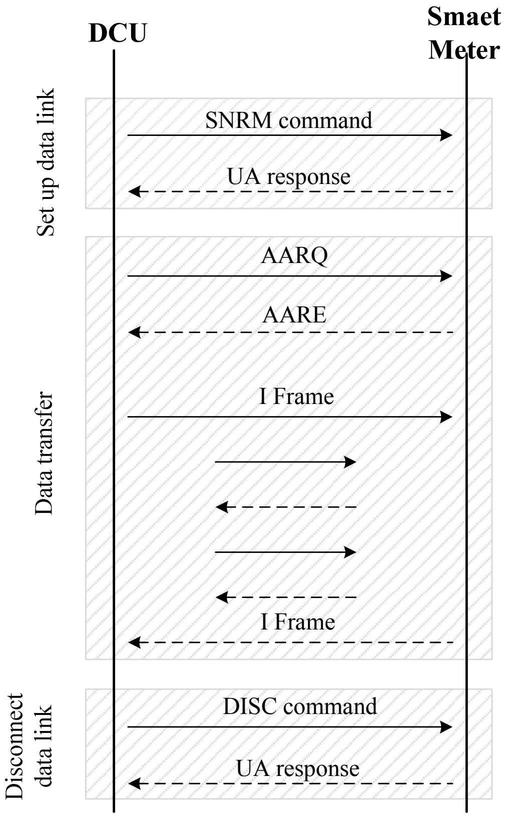

Fig 2. Sequence of packet transfer of DLMS/COSEM standard.

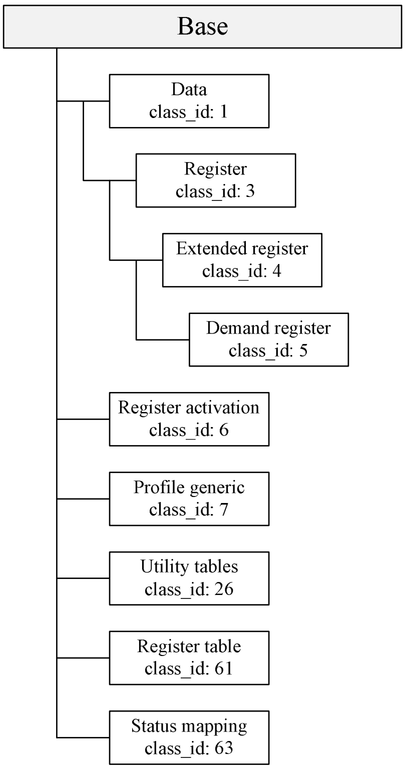

Fig 3. Example of Interface class for data storage.

For OBIS code, it likes a code for identified parameter that DCU needs to ask from smart meter.

A	B	C	D	E	F

Fig 4. OBIS code structure.

Figure 4 shows OBIS code including 6 value groups: A to F.

- Group A is referred to the information that we need to measure such as gas or electrical usage.
- Group B is identify the type of measuring channel number, such as HDLC, RS232 and TCP-UDP/IP.
- Group C is used to identify the parameter of the information source, including voltage, current, power, temperature and volume.
- Group D refers to measuring process of physical quantities related to parameter of group A, i.e., minimum electrical usage.
- Group E refers to further measuring information, such as electricity fee (tariff rates), identified by the parameter of group A.
- Group F is historical information in the meter related to parameter from groups A to E.

2) *COSEM application layer*

COSEM application layer combines three sections: ACSE, xDLMS and Security ASE (application service element). The xDLMS is language like html language but it is easy understand by human. Example of xDLMS is shown in figure 5.

```
<AssociationRequest>
  <ApplicationContextName Value="LN" />
  <InitiateRequest>
    <ProposedDlmsVersionNumber Value="06" />
     <ProposedConformance>
          <ConformanceBit Name="Action" />
          <ConformanceBit Name="EventNotification" />
          <ConformanceBit Name="SelectiveAccess" />
          <ConformanceBit Name="Set" />
          <ConformanceBit Name="Get" />
          <ConformanceBit Name="BlockTransferWithAction" />
          <ConformanceBit Name="BlockTransferWithSet" />
          <ConformanceBit Name="BlockTransferWithGet" />
          <ConformanceBit Name="Attribute0SupportedWithGet" />
          <ConformanceBit Name="PriorityMgmtSupported" />
          <ConformanceBit Name="Attribute0SupportedWithSet" />
          </ProposedConformance>
          <ProposedMaxPduSize Value="FFFF" />
          </InitiateRequest>
</AssociationRequest>
```

Fig 5. Example of xDLMS of AARQ from DCU to meter.

Next, COSEM application layer will transfer xDLMS code to APDU (Application Layer Protocol Data Unit) as shown in figure 6.

601DA10906076085740508010 1BE10040
E01000000065F1F040000FC1FFFFF

Fig 6. Example of APDU from xDLMS of AARQ.

The size of APDU varies following the length of xDLMS. Table II shows APDU size of command and response from DCU to smart meter.

Table II: Example frame and size of APDU.

Command	Frame	Size (Bytes)
SNRM	7EA00000020023219318717E	12
UA	7EA023210002002373F6C58180140502008006 02008007040000000010804000000001CE6A7E	33
AARQ	7EA02E0002002321107ECBE6E600601DA1090 60760857405080101BE10040E01000000065F1F 040000301DFFFFD4C57E	48
AARE	7EA03A2100020023309941E6E7006129A10906 0760857405080101A203020100A305A10302010 0BE10040E0800065F1F040000301D190000070 C527EE	60

COSEM application layer will send APDU to lower layer. In this paper, we will show only 3-layer CO-HDLC case. This case includes data link layer and physical layer. In data link layer, it has two sublayers including LLD and HDLC. LLC and HDLC sublayer have a frame structure as shown in figure 7 and figure 8, respectively.

After HDLC sublayer, all of frames will send to physical layer. In this paper, we use ZigBee communication that is physical layer. So, in next section, we will descript the basic packet transfer of ZigBee communication.

IV. ZIGBEE COMMUNICATION

ZigBee is known as low power wireless communication technology which is published by the ZigBee Alliance [9]. In IEEE 802.15.4 standard document [13], the ZigBee device operates in frequency the ISM band (915/868 MHz or 2.4 GHz). The advantages of ZigBee technology is that it can extend the transmission range of the network (mesh and multi-hop network) between meters or a meter and the DCU. ZigBee standards organization [14] cooperates with the Homeplug Alliance in order to further enhance utilizing the smart devices in HAN network. The meter obtains reading data, demand response, meter billing and etc., then sends these information to another clients using ZigBee device. Although, ZigBee is easy to utilize in practical network, there is not any standard that cooperates between ZigBee and DLMA/COSEM standard in smart grid network.

Considering the low power requirements, robustness, availability of ZigBee and the specific device for smart meter applications, ZigBee has a lot of potential in HAN network. This paper considers only 2.4 GHz. The 2.4 GHz band is used global and has 16 channels and a maximum over-the-air data rate of 250 Kbit/s. Table III shows the properties of the ZigBee communication.

Table III: ZigBee /802.15.4 detail of physical layer.

Frequency	Channels	Region	Data Rate	Baud Rate
868-868.6 MHz	0	Europe	20 kbit/s	20 kBaud
902-928 MHz	1-10	USA	40 kbit/s	40 kBaud
2400-2483.5 MHz	11-26	Global	250 kbit/s	62.5 kBaud

The IEEE 802.15.4 frame structures is designed to maintain the complexity in low level while making them sufficient and robust to transmit the data in a noisy channel. IEEE 802.15.4 frame adds to the structures with layer specific header and footer. The IEEE 802.15.4 MAC defines four frame structures:

- A coordinator uses the beacon frame to transmit beacons.
- To transmit the data, a ZigBee device sends the data through the data frame.
- An acknowledgment frame is used to confirm successful reception.
- A MAC command frame is used to handle all MAC control transfers.

The construction of data frame is illustrated in figure 9.

The IEEE 802.15.4 standard constrains the maximum packet size to 133 Byte. The physical protocol data unit (PPDU) is the total information that sends on the unlicensed band. The data frame of ZigBee has detail below:

Preamble Sequence	4 Bytes
Start of Frame Delimiter	1 Bytes
Frame Length	1 Bytes
The MAC adds the following overhead:	
Frame Control	2 Bytes
Data Sequence Number	1 Bytes
Address Information	4 – 20 Bytes
Frame Check Sequence	2 Bytes
n (Application data) length	≤ 102 Bytes

In summary, the total overhead for a single data packet is 15-31 bytes. The maximum frame size for putting the data information from application layer is not over 102 bytes (this number is not including any security overhead).

Destination LSAP	Source LSAP	LLC_Quality	Information
1 Byte	**1 Byte**	**1 Byte**	**n Byte**

Fig 7. LLD frame structure in DLMS/COSEM.

Flag	Frame format	Dest. address	Src. address	Control	HCS	Information	FCS	Flag
1 Byte	**2 Byte**	**1, 2, 4 Byte**	**1 Byte**	**1 Byte**	**1 Byte**	**n Byte**	**1 Byte**	**1 Byte**

Fig 8. HDLC frame structure in DLMS/COSEM.

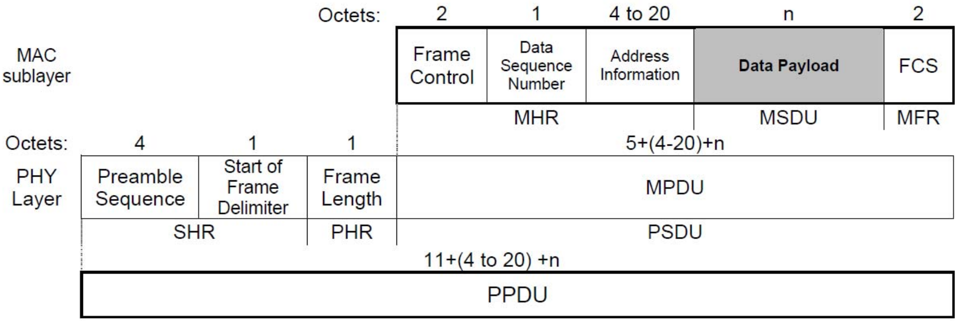

Fig 9. The construction of the data frame.

V. Conclusion

In this paper, we present the operation of the DLMS/COSEM protocol which is used to cooperate the operation between meter and DCU. The DLMS/COSEM communication profiles and sequence of packet transfer of DLMS/COSEM standard are described to overview the implementation of DLMS/COSEM standard. Moreover, we introduce a new perspective way to cooperate the device in the physical layer of the network by using low power consumption technology known as "ZigBee".

Acknowledgment

This work was partially supported by the Thailand Research Fund (TRF) under grant number: MRG5680101.

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