전력선 통신과 IEEE 802.15.4를 기반한 이종 홈네트워크를 위한 통합 부계층 구현

Implementation of Convergence sub-layer for a Heterogeneous Home Network based on Power Line Communication and IEEE 802.15.4

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Abstract - In this paper, a heterogeneous home network is designed and implemented based on the PLC (power line communications) and the IEEE 802.15.4. This paper presents the need of the heterogeneous home network and the convergence sub-layer. The convergence sub-layer is designed and implemented on the Xelline power line communication modem with IEEE 802.15.4 communication module.

Key Words : PLC, IEEE 802.15.4, Convergence sub-layer, Home Networks

1. Introduction

The home network has been famed as a promising technique. Every device using electrical power is a target of home networking. From bedrooms to a kitchen and a porch, from expensive A/V devices like a digital tv, a digital camcorder, and a DVD player to tiny monitoring sensor nodes, various devices in different conditions and purposes of users weight complexity of home networking. Generally, home appliances can be classified into three groups - multimedia, data, and control [1]- according to networking features. Networking technologies to bind these appliances are opened to all the media and protocols. The available home-networking technologies can be sorted as follows : the technologies that require new wires, reuse existing home wiring, and wireless networks[2]. Among various technologies that fall into the category requiring new structured wiring, Ethernet, Universal Serial Bus (USB), and IEEE 1394 deserve particular consideration. Even though they support user requirements, additional installation cost are not negligible. Most houses world-wide are equipped with structured wiring, at least for electricity and phone distribution. Reutilization of these networks for data distribution poses a very good opportunity for in-home networking, as it minimizes installation costs. As power lines, however, are not communication media primarily, high data quality is not guaranteed. Phone distribution and cabling for TV delivery are not enough. The 'no wires' RF technologies are considered to be the holy grail of the home network and are expected to play a key role in winning wide acceptance for the digital house. Though Bluetooth, IEEE 802.11b, and IEEE 802.15.4 are expected to capture the greatest share of the market for different applications, the frequency limitation, especially interference problems in 2.4GHz are the greatest wall for brisk activation of wireless devices[3].

In this paper, a wireless technology - IEEE 802.15.4 and a wired technology - PLC (power line communication) are comparatively studied. The main contributions of this paper are as follows. Firstly, a real-world implementation of a heterogeneous home networks based on the low rate wireless (IEEE 802.15.4) and PLC. Secondly, a network convergence is conducted to offer wide capacity for various controllable appliances. Addition of a wireless technology with PLC enlarges the network subjects to portable devices and appliances that require new wiring. Hereby, a new sub-layer protocol is proposed to utilize both PLC and wireless technologies at a low overhead, low cost, and low implementation complexities. A home network system is constructed with the proposed architecture using a table-driven network routing scheme to validate the architecture. This paper is organized as follows. Design of a heterogeneous home network is described in Section 2. The experimental results are given in Section 3. Then conclusion is given in Section 4.

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2. Design and implementation of heterogeneous network

The convergence sub-layer (Cslayer) locates between MAC sub-layer and network layer as shown in Fig.1. The main operations of Cslayer are frame management and medium selection. Cslayer manages the frames from network layer and various MAC layers. Cslayer selects suitable MAC layer to transmit data or control frames. To minimize the packet overhead and functional complexity is the key concept of the Cslayer design. For the low rate control network, not only small data packet size in data transmission, but small stack size in processing unit are required. Hereby Cslayer implements modules that manage each MAC interfaces with one byte header for MAC distinction. One byte header indicates which MAC interfaces have to be used for the data transmission. It is composed of 4-bits media indicator (MI) and 4-bits source media indicator (SMI). MI describes next node's media type and SMI source node's media type respectively. In this paper, media indicates MAC/PHY layer technique. Fig. 2 illustrates the frame architecture of Cslayer.

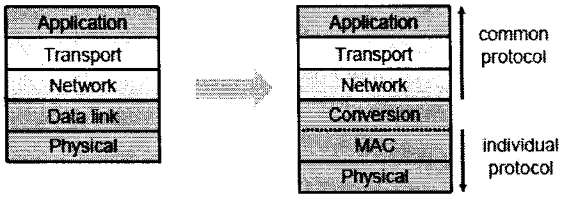

Fig 1. Position of Cslayer

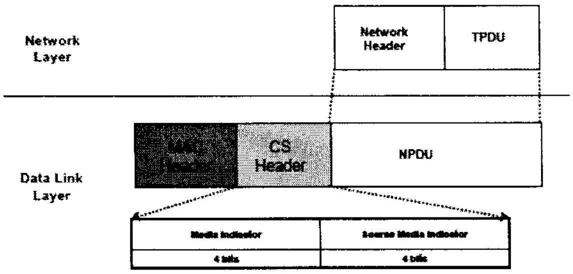

Fig 2. Frame architecture including Cslayer

To support heterogeneous transmission, nodes equipped with more than one network interfaces are required to take a role of a router. These nodes are called router functional nodes (RFN). Nodes only have a interface are called single interface nodes (SIN) with a prefix of interface. Network layer sends network protocol data unit (NPDU) with primitives to Cslayer for transmission. Primitives include source/destination address, media type, and parameters for MAC layer processing. To support Cslayer, a media indication field (MIF) is added to the routing table as shown in Fig. MIF manifests next hop node's media type. MIF displays its ability when the MAC level transmission occurs between two RFNs. As each media's network condition is different, adjacent nodes with one interface might not be neighbor with another interfaces. The operation of Cslayer is described in Fig. 3. The Fig 4 shows the change of routing tables from a general PLC network to a heterogeneous home network.

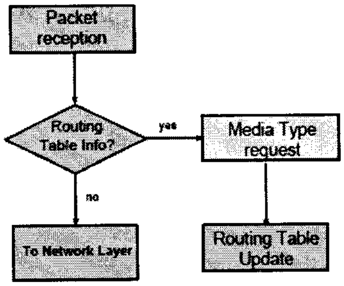

Fig 3. Flow chart of data processing in Cslayer

Node	Next Node	Distance
A	A	1
B	A	2
C	C	1

Node	Next Node	Distance	Media
A	A	1	PLC
B	A	2	PLC
C	C	1	802.15.4

Fig 4. Change of routing table

3. Experimental results

To implement the heterogeneous home network system using Cslayer, eX-tended Control Protocol (XCP) of Xelline company is used for upper layer transmission in this paper [4]. Because XCP uses table driven routing, MIF is managed with update of routing table. For low rate PLC technique, the XCP MAC/PHY technique is adopted. RadioPulse produces 2.4GHz chip and MAC stack conforming with IEEE 802.15.4. We implemented the system in our laboratory having 2 rooms. A test-bed for experiments isillustrated as Fig. 5 and 6. One PLC IEEE 802.15.4 RFNs, 2 PLC only SINs (p-SINs), and 2 IEEE 802.15.4 SINs (w-SINs), are used for experiments. For the data traffic generation, diverse applications are embedded with each nodes. w-SINs and r-SINs are with temperature, humidity and illuminance sensors. Analog input and digital input/output switches are loaded on p-SINs nodes.

Experiments are divided into two phases - a routing setup phase and a normal data transmission phase. During the routing setup phase, each node builds the routing table based on the proactive routing control packets. Using XCP network layer, an unestablished path causes control packet flooding. After the routing table becomes steady, the traffic induced by sensors and input switches flows on the network. Using a network analyzing tool - eXtended Network Analyzer (XNA) provided for the XCP network, network connectivity and paths are monitored as illustrated in Fig.7. Each group of SINs regard other SINs and RFNs as multi-hop nodes in the same network. Based on the test-bed illustrated in Fig. 6, a w-SIN node 3 has a routing table given like this at a point of time. Due to the wall between two rooms, w-SINs are not fully connected as a network. They have to use RFNs to relay the packets to the w-SINs in another room or the sink node. p-SINs are also operated in multi-hop environment, because of the insecure channel condition. We conducted a p-SINs only scenario, a w-SINs scenario, and a heterogeneous scenario. Experiments results are described in the Table.

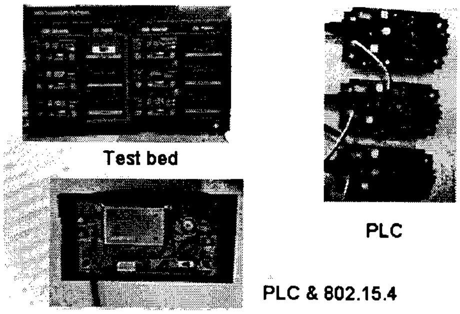

Fig 5. Test-bed for experiments

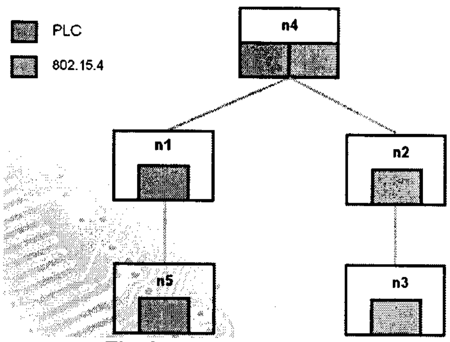

Fig 6. Topology of the Test-bed

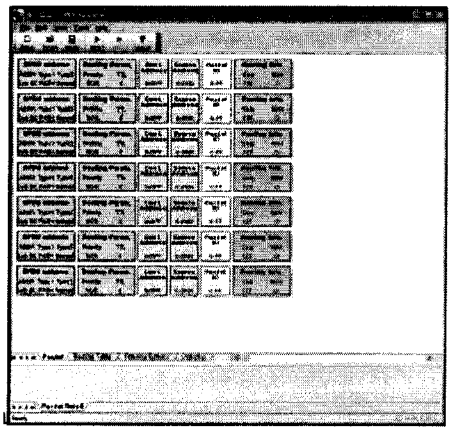

Fig 7. Packet monitoring of the eXtended Network Analyzer

4. Conclusion

In this paper, a heterogeneous home network is designed and implemented based on the PLC (power line communications) and the IEEE 802.15.4. This paper presents the need of the heterogeneous home network and the convergence sub-layer. The convergence sub-layer is designed and implemented on the Xelline power line communication modem with IEEE 802.15.4 communication module. We built a test-bed and conducted experiments.

As future work, we will build a large test-bed with tens of nodes in real home environments. The function to regulate the traffic due to the difference of data-rate of two different technology will be designed and implemented.

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