A Common Signaling Mechanism for Coexistence between High-speed Power Line Communication

Hui-Myoung Oh†, Sungsoo Choi*, Jimyung Kang* and Won-Tae Lee*

Abstract – In the field of high-speed power line communications, there are three major standards; ISO/IEC 12139-1, IEEE 1901-2010, and ITU-T G.99xx. However, they are not interoperable because of having their own physical and MAC layer specification. Actually, they cannot even avoid interfering with each other because they are using the same frequency band of 1 ~ 30 MHz. In this paper, a common signaling mechanism is suggested which uses multi-carrier partitioning and carrier sensing, so that all standards can be coexisted by sharing time resource. The suggested mechanism has been compared with the ISP protocol which is included in IEEE and ITU-T standard for coexistence.

Keywords: Power line communications, Standard, Coexistence, Signaling mechanism

1. Introduction

In the last 10 years, high-speed power line communications (PLC) technology has been developed with the development of information and communication technology. High-speed PLC uses the frequency band of about 1 ~ 50 MHz and has the data rate of more than 10 Mbps.

Currently in the field of high-speed PLC, there are three major standards; ISO/IEC 12139-1 [1], IEEE 1901-2010 [2], and ITU-T G.99xx [3]. However, they are not interoperable with each other because they have their own specification of physical and medium access control (MAC) layer. Actually, even one of them cannot even avoid interference from others because they are using the same frequency band of 1 ~ 30 MHz. In fact, three standards all could have a problem of coexistence.

Recognizing the issue of coexistence, IEEE had suggested the inter-system protocol (ISP) that is a coexistence mechanism between the heterogeneous systems [2]. However, the ISP currently covers only two standards of IEEE and ITU-T [3]. Consequently, it needs to be modified to include ISO/IEC standard. In this paper, regarding to modification of the ISP, a new common signaling mechanism is suggested which is based on multi-carrier partitioning and carrier sensing. The results of comparing between the mechanisms are also presented.

2. Overview of IEEE’s ISP

The ISP allows for power line communications channel resources to be shared in the time domain (TDM) and the frequency domain (FDM) among systems that comply with IEEE and ITU-T standards. The basic mechanism of the ISP is based on the network status which is determined in accordance with the information on coexisting system presence, resource requirements, and resynchronization request. Each system uses the common signaling mechanism to exchange the network status [2].

Fig. 1 shows the ISP common signal format. One ISP signal consists of 16 orthogonal frequency division multiplexing (OFDM) symbols, and its first and last 2 symbols are multiplied by a window function. $T_w$, $T_s$, and $T_{total}$ are 512, 1024, and 8192 samples, respectively. The duration of one sample is 0.01 usec (100 MHz sampling).

Fig. 1. The ISP common signal format [2].

The ISP assigns five different phases to the common signal using the start numbers as shown in Table 1. Each phase is selected as its usage. ACC means an access system, and IH-W, -O, and -G means an in-home system complying
with IEEE Wavelet PHY, IEEE OFDM PHY, and ITU-T G.99xx, respectively. Actually, IEEE standard has two heterogeneous physical layer specifications.

### Table 1. Phase vector start numbers [2]

<table>
<thead>
<tr>
<th>Phase No.</th>
<th>Start No.</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1</td>
<td>1</td>
<td>ACC</td>
</tr>
<tr>
<td>Phase 2</td>
<td>2</td>
<td>IH-W, resync</td>
</tr>
<tr>
<td>Phase 3</td>
<td>14</td>
<td>II-O, resync</td>
</tr>
<tr>
<td>Phase 4</td>
<td>42</td>
<td>ACC FDM interference</td>
</tr>
<tr>
<td>Phase 5</td>
<td>58</td>
<td>IH-G, resync</td>
</tr>
</tbody>
</table>

The ISP also assigns time durations (called by ISP windows) synchronized with AC cycles to coexisting systems as shown in Fig. 2. However, the system complying with ISO/IEC standard cannot participate in coexistence because these ISP windows are fixed and there is no room for a new system.

**Fig. 2.** Periodic allocation of ISP window [2].

**Fig. 3.** General TDMA structure of the ISP [2].

For the proper operation of the ISP, a coexisting system must monitor ISP windows of other systems and periodically transmit its own ISP signal. It needs to know IPS window timing through the synchronization and resynchronization mechanism between coexisting systems.

### 3. New Common Signaling Mechanism

Adopting the similar TDM mechanism with the ISP, we suggest more simple mechanism based on multi-carrier partitioning and carrier.

At first, we use a new common signal set which is partitioned as shown in Fig. 5 with Table 2. Of course, this mechanism includes ISO/IEC standard (II-I). Even though this signal set is also based on the OFDM symbol specified by the same numerical parameters (such as frequency bandwidth, FFT size, sampling rate, signal length, and so on) as used in the ISP protocol, it can be differently used, that is, it allows each coexisting system to recognize the current network status through just sensing carriers of this signal set in the frequency domain.
Another important fact is that each coexisting system can simultaneously transmit its own signal in an ISP window because all coexisting systems use different sub-carrriers which are determined and fixed in advance. The sub-carrriers do not interfere with each other because they are originally orthogonal. Consequently, they can quickly update the network status with a period of one TISP. It is 4 times (if the ISP were covering ISO/IEC standard, then it was 5 times) faster than the original ISP. Fig. 6 shows an example of the network status monitoring.

**Fig. 6. Example of carrier sensing by IH-I.**

Fig. 7 shows the modified TDMS allocation including three standards. As a result, the modified ISP can allow up to 1 access and 5 in-home systems to be coexisted. When resource allocation mechanism is considered, fairness is very important. Coexisting systems want to fairly share the given resource according to the network status. Another one of the important factors is the cost of complexity. This is related to system reliability. The modified TDMS allocation table has been designed so that coexisting system can occupy more than one TDMS slot (marked with W, O, G, I, and A) and maintain the occupancy as possible.

An example of coexistence situation according to the modified ISP is shown in Fig. 8. Assuming the proper operation, a system which wants to participate in coexistence should first monitor the current network status, and then it may transmit its own signal in the next ISP window, and it can finally be allowed to allocate some time slots. The existing system should continuously monitor the network status and accordingly change the TDMS allocation index. This process may take the multiple of TISP.

**Fig. 7. Modified TDMS allocation.**

**Fig. 8. Example of Coexistence.**
A Common Signaling Mechanism for Coexistence between High-speed Power Line Communication

The results of the comparison of the ISP and the modified ISP can be summarized as Table 3. Even though the fairness of the modified ISP is not good on the case of index 45 in Fig. 7, it is probably not a problem because the worst case that 5 systems (ACC, IH-W, IH-O, IH-G, and IH-I) are applied at the same time would be rare. The unfairness could be improved in such a way increasing the number of TDMS slots and adjusting the allocation pattern.

Table 3. Summary of results of comparison

<table>
<thead>
<tr>
<th></th>
<th>ISP</th>
<th>Modified ISP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covering standards</td>
<td>IEEE, ITU-T</td>
<td>IEEE, ITU-T, ISO/IEC</td>
</tr>
<tr>
<td>Common signal multiplexing</td>
<td>Based on phase vectors</td>
<td>Based on subcarrier partitioning</td>
</tr>
<tr>
<td>System recognition method</td>
<td>Based on phase detection</td>
<td>Based on carrier sensing</td>
</tr>
<tr>
<td>Minimum duration of network status updating</td>
<td>$4^*T_{ISP}$</td>
<td>$T_{ISP}$</td>
</tr>
<tr>
<td>TDMS allocation fairness</td>
<td>Good</td>
<td>Not bad</td>
</tr>
<tr>
<td>Resource occupancy</td>
<td>Good</td>
<td>Good</td>
</tr>
</tbody>
</table>

4. Conclusions

In this paper, after reviewing of IEEE’s ISP, the new common signaling mechanism has been suggested, and the modified ISP with which has also been suggested. The modified ISP could cover all of three high-speed PLC standards and be simple and faster than the ISP. However, the problem of fairness and complexity is still a subject to be further studied.

References


Hui-Myoung Oh received B.S., M.S., and Ph.D. degree in electrical and electronic engineering from Yonsei University. His research interests are information and communication technology, smart grid, power-line communications, and signal processing.

Sungsoo Choi received Ph.D. degree in information and communications engineering from Gwangju Institute of Science and Technology. His research interests are power-line communications, high availability communications, and their design and implementation for a System-On-a-Chip.

Jimyung Kang received B.S. and M.S. degree in computer science engineering from Seoul National University. His research interests are communication and machine learning in electricity.

Won-Tae Lee received B.S. and M.S. degree in electrical engineering from Yonsei University, and Ph.D. degree in electronic engineering from Kyungnam University. His research interests are smart grid ICT and power-line communications.