

The Common-Interface-Based Residential Gateway (GIB-RG)

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Abstract

Homes contain a number of home appliances and electrical subsystems manufactured by different companies. Especially, a home gateway is at the heart of the smart home platform. Because current home gateways have been developed without the standard and consisted of only a built-in system with fixed interfaces, users hardly add interfaces and remove unnecessary ones. To overcome these troubles, a standardized Residential Gateway (RG) has emerged.

For a standardized Residential Gateway(RG) platform, this paper proposes the open hardware architecture, the common transfer protocols and the common middleware. The open hardware architecture is a system with the thin and lightweight PCMCIA interfaces. The TCP/IP and the ethernet are adopted as the common transfer protocols due to their wide deployment. We also choose the embedded linux and the simple UPnP as the common middleware.

The set of the Common-Interface-Based Residential Gateway (CIB-RG) which consists of a Gateway Internal Protocol (GIP) processing system, a WLAN LGI, a LonWorks LGI and a ADSL WGI, are developed and also demonstrated.

Keywords: Residential Gateway (RG), Home Gateway, LAN Gateway Interface (LGI), WAN Gateway Interface (WGI), Universal Plug and Play (UPnP), PCMCIA, Gateway Internal Protocol (GIP), Common Interface (CI)

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Homes contain a number of home appliances and electrical subsystems manufactured by different companies. Especially, a home gateway is at the heart of the smart home platform. Because current home gateways have been developed without the standard and consisted of only a built-in system with fixed interfaces, users hardly add interfaces and remove unnecessary ones. To overcome these troubles, a standardized Residential Gateway (RG) has emerged.

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Introduction

- ☀ The Residential Gateway(RG) is at the heart of Home-area Networking Solution
- ☀ Current Industry Status
 - Closed and Fixed architecture
 - Support only a few interfaces
 - Zero-Compatibility and Hard Expandability due to Non-standardization.
- ☀ Standards for Residential Gateway
 - TIA's TR-41.5 committee has attempted
 - ISO/IEC JTC 1/SC 25 developed the first specification of HomeGate in October 1998
- ☀ Benefits of RG's Standardization
 - Reduced development and maintenance costs by using open architecture
 - Unlimited support of a lot of interfaces

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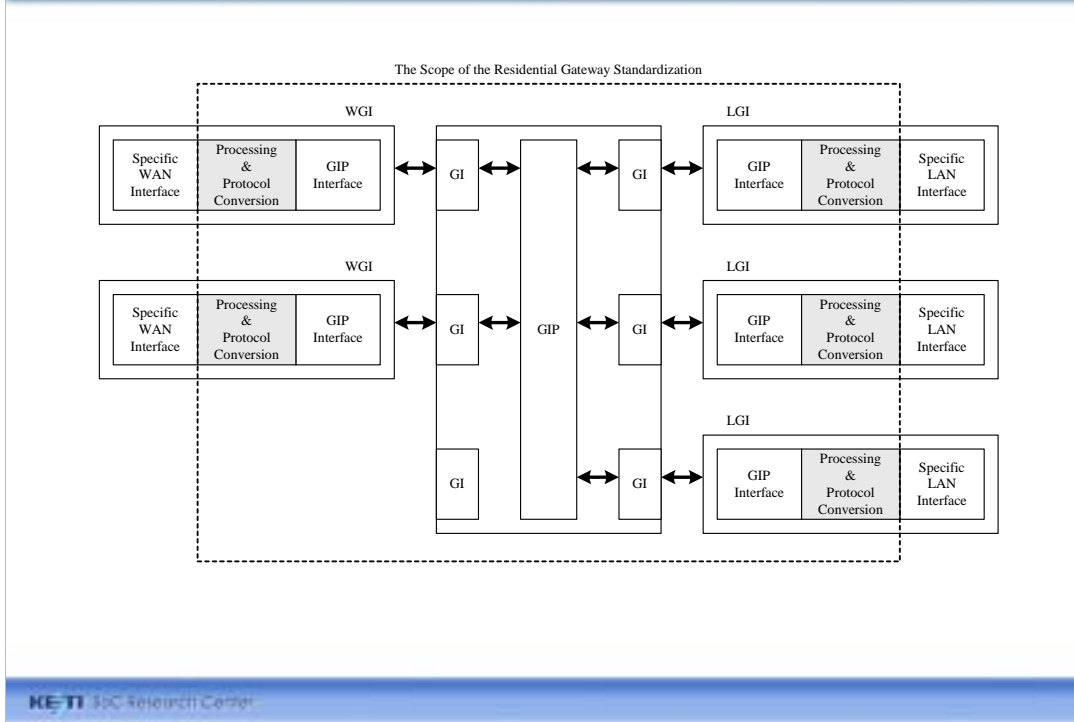
1. Introduction

At the heart of home-area networking solution is a forthcoming new home appliance, called a residential gateway. Recent products are typically incommutable, their connecting method and operation middleware are different each other. In other words, they are not standardized. Thus, current products are hardly compatible and expanded.

TIA's TR-41.5 committee has attempted creating specifications for a centralized gateway device. Working Group 1 of ISO/IEC JTC 1/SC 25 developed the first specification of HomeGate in October 1998. In an area of middleware, OSGi was born for open service architecture. The standardized RG can take an advantage of good compatibility, reduced development period, easy maintenance, low cost, etc. It is also able to support diverse interfaces and plentiful services without any limitation.

However, the development of the RG standard is inactive and many companies have developed their own RG products, so they are limited to a particular category such as broadband internet access, telephony over IP, and home automation. Flexibility and compatibility are almost impossible.

HomeGate of ISO/IEC JTC 1/SC 25 WG1



1.1 Overview of a standardized RG

The HomeGate specified by ISO/IEC JTC 1/SC 25 WG1, consists of three modules, LAN Gateway Interface (LGI), WAN Gateway Interface (WGI) and Gateway Internal Protocol (GIP).

A WGI functions a specific WAN interface, a GIP interface and a protocol conversion. A specific WAN interface can be a modem for xDSL, DOCSIS or PSTN and supply a fundamental internet connection. A WGI also supports the protocol conversion between the GIP and the WAN specific protocol for example, Network Address Translation (NAT) and Virtual Private Network (VPN) and so on.

A LGI provides the LAN specific interface such as the Ethernet, the Bluetooth, the wireless LAN, the IEEE1394 and the LonWorks. The protocol conversion between the LAN specific interface and the GIP is also supplied.

For support of plentiful services and various interfaces, RG standardization must be active and thus we have focused on the first standardized specification of ISO/IEC JTC 1/SC 25 WG1 and in this paper, the RG architecture is proposed based on it in detail.

Choice of Common Interfaces

- ☀ Physical layer
 - PCMCIA interface
 - Thin, Small, Lightweight
 - A Neat Appearance without a Projection after card insertion
- ☀ Network & Transfer layer
 - Ethernet & TCP/IP protocol suite
 - The best popular protocol deployed widely
 - Easy Implementation and Maintenance
 - Seamless Convergence with the broadband internet
- ☀ Middleware
 - Embedded Linux
 - Universal Plug and Play
 - Simple, Easy implementation
 - Supporting the Bridge for a difference middleware

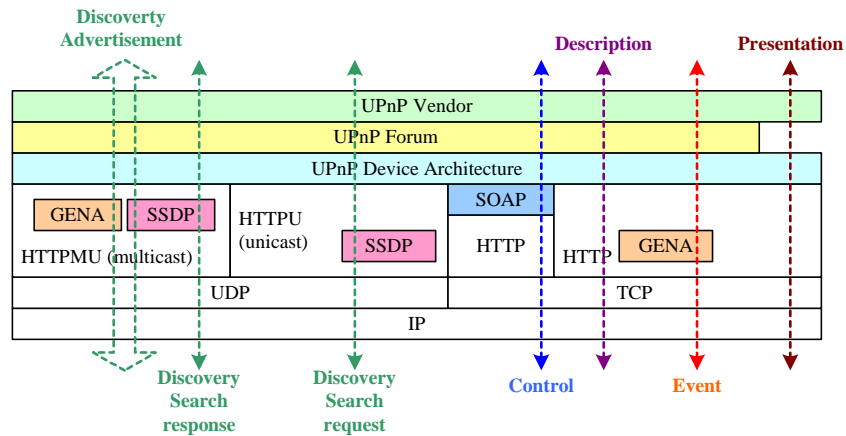
2. Common-Interface-Based Residential Gateway (CIB-RG)

For the CIB-RG, a choice of the GIP is necessary. The GIP can include the specification for the hardware interconnecting method between a LGI or a WGI and a GIP system. The network protocol, transfer protocol, middleware and application also need to be specified as the GIP.

We adopted the PCMCIA-based hardware architecture as a common hardware interface. The Ethernet and the TCP/IP protocol suite is applied to common transfer protocols. We made also a choice of the Universal Plug and Play (UPnP) as a common middleware.

A PCMCIA interface is compact, thin, small and lightweight and supports a neat appearance due to hiding in a gateway box. The TCP/IP and the Ethernet are the most popular internet/LAN protocols. Due to wide deployment, system development with the TCP/IP and the Ethernet is not difficult. Because broadband internet typically constitutes the TCP/IP protocol suite, seamless internet connection can be provided. The UPnP, which provides discovery, access of services and eventing, has been emerging since home appliance market boomed. The UPnP framework is simpler than the OSGi and the UPnP Forum is active to improve the UPnP protocols.

The Common Middleware, UPnP



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2.1 The Common Middleware, UPnP

First of all, we propose the common middleware. In order to provide a reasonable level of computational and communications capability and be interoperable with other devices in their environment, the standard-based connectivity and communications protocols is needed.

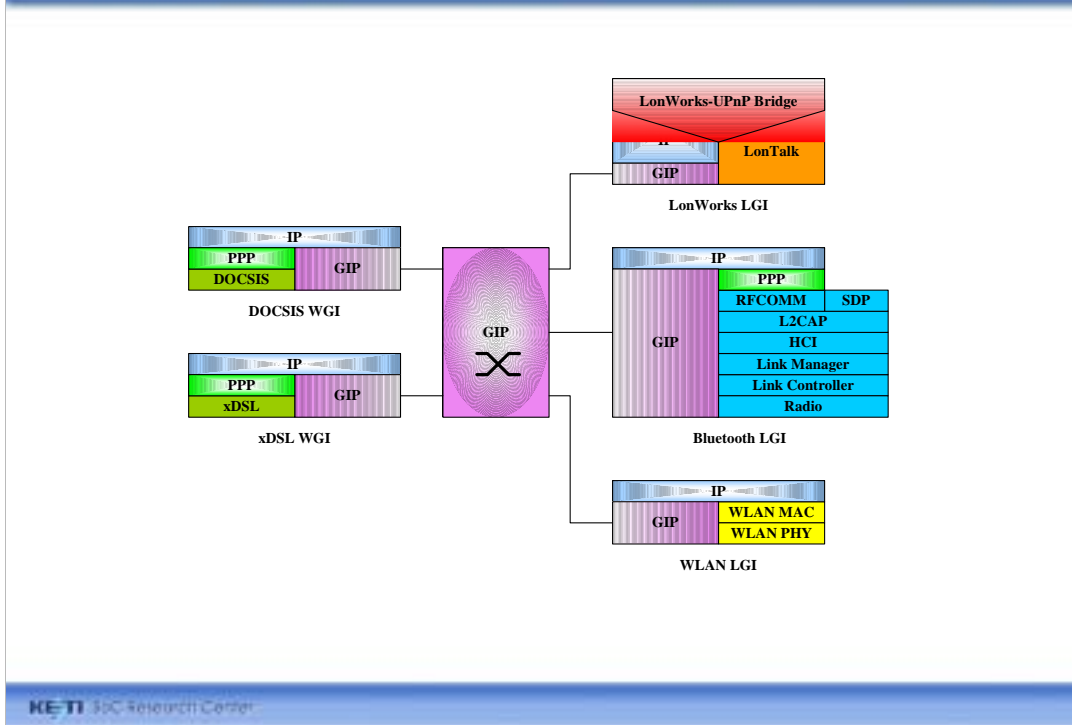
Various middlewares such as UPnP, JINI, OSGi¹⁾ and HAVi²⁾ are emerging. The UPnP is one of these middleware led by Microsoft. HAVi has the troubles of the connectivity limitation and high cost due to IEEE1394. The JINI needs the JAVA virtual machine, which is heavy for the tiny device. The OSGi has plentiful capability but is too fat to its commercialization.

The UPnP consists of XML, HTTP, GENA³⁾, SSDP⁴⁾, SOAP⁵⁾ and the TCP/IP. The UPnP is easier to its implementation than the JINI and the OSGi due to its simple architecture and character-based property.

In this paper, the UPnP is adopted as the common middleware. Therefore, services for residential applications must be generated by the UPnP. The uncommon services must be also converted into the UPnP.

- 1) OSGi: The Open Services Gateway Initiative
- 2) HAVi: Home Audio Video Interoperability
- 3) GENA: Generic Event Notification Architecture
- 4) SSDP: Simple Service Discovery Protocol
- 5) SOAP: Simple Object Access Protocol

The Common Protocol Stack



2.2 The Common Transfer Protocol

Second, we propose the common transfer protocol. The new protocol is not suitable for the common transfer protocol. However the new protocol may take much labor, the import of legacy transfer protocols can lessen an effort. Thus, we choose the Ethernet and the TCP/IP protocol suite among the legacy transfer protocols due to their popularity and wide deployment.

All packets run through a GIP system in the Ethernet or the IP form. If the LAN specific interface in the LGI or the WAN specific interface in the WGI includes the ethernet or the IP stack, minimum conversion is required. Otherwise for example the LonWorks with the LonTalk protocol, the protocol conversion is a considerable part for a LGI or a WGI.

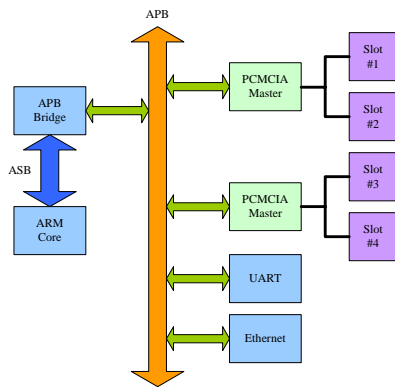
It is possible that a bluetooth mobile terminal accomplishes its own purpose for example, working as a remote controller, or a voice terminal. Fortunately the LAN access protocol (LAP) is one of the bluetooth service profiles. The LAP of the bluetooth helps the bluetooth LGI to require minimum protocol conversion, that is, The mobile bluetooth terminal with the LAP can be provided with the LAN service easily with the only bluetooth access point.

Unfortunately, a LonWorks device is unable to use the TCP/IP and the UPnP but a LonTalk. To access LonWorks devices with our common transfer protocols and middleware, the LonWorks-UPnP bridge is necessary in the LonWorks LGI.

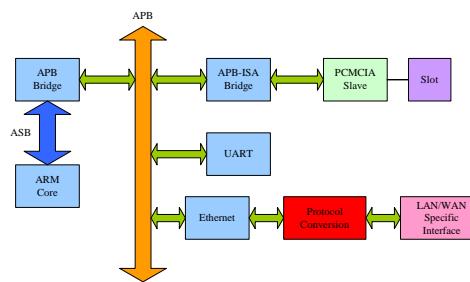
A WGI serves the function of the Internet Gateway Device(IGD). The WGI also supplies a internet sharing, a NAT, a PPP, a firewall and etc.

The Open Hardware Architecture

Blockdiagram of a GIP Processing Box



Blockdiagram of a LGI/WGI



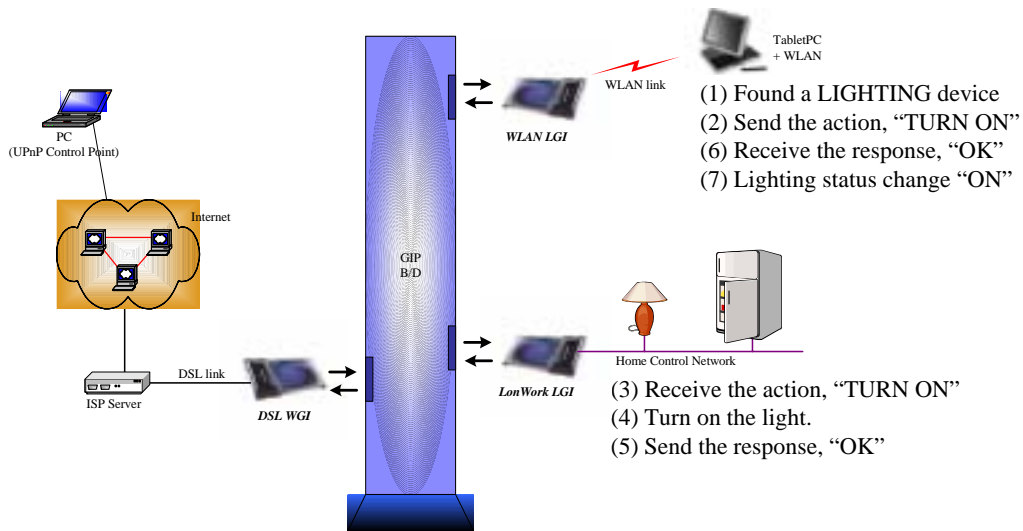
2.3 The Open Hardware Architecture

Finally, We propose the open hardware architecture in detail. The PCMCIA interface is adopted for the interconnection method. So, a GIP processing system includes PCMCIA master controllers and a PCMCIA slave controller is necessary for a WGI and a LGI.

The GIP processing system implemented in this paper consists of a CPU, two PCMCIA master controllers, four PCMCIA slots, etc. The WGI also is organized with a CPU, a PCMCIA slave controller, a PCMCIA slot, a WAN specific interface, a protocol conversion and etc. The LGI is same as the WGI except the protocol conversion and the specific LAN interface. Especially, an ARM7TDMI core is used as a CPU and the UPnP-LonWorks bridge is implemented as a protocol converter for the LonWorks LGI.

Local Operation

(0) All LGIs and a WGI advertise themselves as soon as "Power On".



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3.1 Local Area Operation

It is the example that the WLAN TabletPC accesses the light capable of the LonWorks. A user turns on a residential gateway, a GIP system and the LonWorks LGI are pulled in the GIP system. The LGI also begins to run.

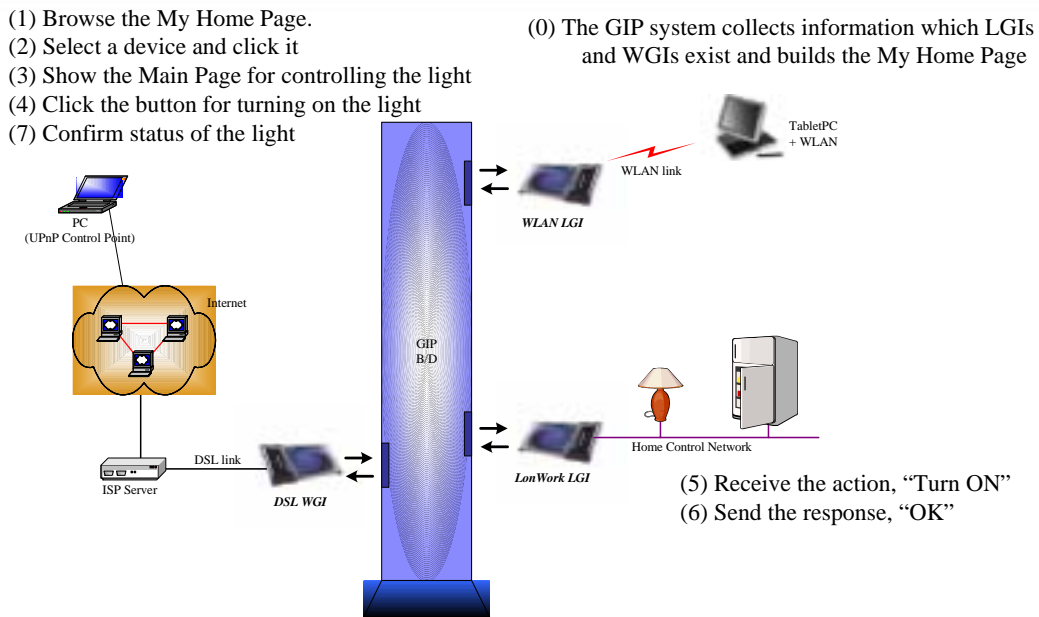
As soon as LGIs turn on, they broadcast the advertisement message. Thus, a control point (called as a client in the UPnP lingo) in the TabletPC can obtain the information of devices. It is a matter of course that a control point in the TabletPC can search devices.

Users choose the LonWorks light device out of the list of the GIP system, fetches the presentation HTML file and clicks "Turn On" button. This action message is transferred to the destination in the UPnP form through the LGIs and the GIP system.

After the LonWorks-UPnP bridge in the LonWorks LGI receives the action message, the bridge tries to turn on the light and send the response message. If turning on the light is successful, the user will receive the positive response and show the status of the light with turning on.

Because the LonWorks light cannot communicate with the UPnP and the TCP/IP, the LonWorks light has to communicate the LonWorks-UPnP bridge in the LonWorks LGI and the control point has to exchange the UPnP message for the LonWorks-UPnP bridge. The bridge controls the light actually.

Broadband Operation



3.2 Wide Area Operation

It is the example that the terminal outside a home accesses the LonWorks light in a home. A GIP system starts, the WLAN LGI, the LonWorks LGI and the ADSL WGI are also pulled in the GIP system. A WGI and LGIs begin too. The GIP system collects the information of LGIs or a WGI running in the GIP system.

A outdoor user can browse his or her home page in a residential gateway. There is the list of devices installed in a home in this home page. A user chooses the LonWorks light device out of the list, downloads the presentation HTML page and clicks "Turn On" button. This action message destined for the light is conveyed in the UPnP form from a remote user's terminal through the internet and the GIP system into the LonWorks LGI.

After the LGI receives the action message, the bridge in the LGI tries to turn on the light and send the response message. If turning on the light is successful, the user must receive the positive response and show the status of the light with turning on.

Because multicast packets for the UPnP discovery cannot be transmitted to the outdoor user, remote users outside the home cannot receive the UPnP advertisement message and the response of the UPnP search. So, they must fetch their home page first.

Demonstration

Left: LonWorks HomeAutomation Testbed
Right: The set of the CIB-RG.



TabletPC with WLAN
(running UPnP Control Point,
Connecting the WLAN LGI)

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4. Demonstration

We implemented the residential gateway consisting of a GIP system, a WLAN LGI, a LonWorks LGI and a ADSL WGI.

The WLAN LGI connects the GIP system with a PCMCIA interface. The LonWorks LGI board also connects both the GIP system with a PCMCIA interface and the LonWorks-UPnP bridge with a Ethernet interface.

The TabletPC with Windows XP TabletPC edition connects the access point in the WLAN LGI and controls the LonWorks devices through the LonWorks-UPnP bridge located in the LonWorks LGI.

Conclusion

- ☀ Current closed RG platform has a lot of problems, hard upgrade, poor compatibility and so on
- ☀ RG's standardization activity is in progress but not active
- ☀ We proposed the Common-Interface-Based Residential Gateway (GIB-RG) which defines the open hardware architecture, the common transfer protocols and middlewares
- ☀ We demonstrated the CIB-RG system with WLAN LGI, LonWorks LGI and ADSL WGI
- ☀ The common RG architecture has an advantage of easy implementation, maintenance and good compatibility.

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Conclusion

For standardized residential infrastructure, this paper proposes the open hardware architecture, the common transfer protocol and the easy middleware. The prototype of the CIB-RG was implemented based on the ARM platform and demonstrated with the LonWorks home automation testbed.

The CIB-RG is able to take advantage of diverse interfaces, remove unnecessary ones or add necessities easily. It is also convenient for upgrades of the qualities of a system, and provides various services at low cost.

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