Paper

Integration of home digital network and Bluetooth wireless communication system

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Abstract — The paper presents new method of integration home digital network with Bluetooth wireless communication system. In this new application Bluetooth is used as one of the main ways of communication and information exchange between elements of the system for integrated, centralized control of the digital devices in the multimedia home platform. Bluetooth enables communication between multimedia gateway with the HTTP server inside and personal communication assistants (PCA), special kind of the remote control. The aim of the system is centralization of services in the multimedia gateway and integration of different services using only one control device.

Keywords — wireless communications, multimedia systems, multimedia services, multimedia home platform, digital network.

1. Introduction

With the very fast growth of the modern transmission techniques there are also quite different requests of the potential subscribers for the integration of the services from different media. Good example of this situation is our house's environment. Nowadays subscribers have a lot of services from different devices and it is very hard to control all of them using only one device. It is not good time for using varied control system for different devices. That is the reason why one of the main features of the future house will be complex system for the integrated control of the home digital network. After that, users receive a huge amount of data transmitted from the digital television operators to home set-top boxes (STB). So, it is necessary to prepare the real system for the integrated control of the home digital network devices.

In this paper authors would like to introduce a new system for integrated control of home digital network devices, which was prepared in the Institute of Radioelectronics, Warsaw University of Technology. One of the main purposes for this kind of system was to use efficient way of communication between user's control devices (PCA) and multimedia gateway. According to its obvious limitations it was impossible to use infrared communication protocol. Authors decided that the best solution would be using Bluetooth radio communication interface. The reasons for this decision and main features of Bluetooth communication interface will be described in the next sections. During creating the system authors had to create new language of the device's communication connected with the services and devices description. This special language will be described in the next sections.

System is divided into three parts. The central part of the system is the multimedia gateway with a HTTP server inside. Multimedia gateway receives requests and sends responses to the control devices. The second part of the system is Bluetooth/HTTP bridge. The bridge creates HTTP connection with multimedia gateway every time document arrives, sends and receives documents and searches the environment for new Bluetooth devices. The last part of the system is a specially designed PCA. In fact it is an advanced remote controller with the keyboard and graphics display.

2. Bluetooth radio interface

The first problem during creating system for integrated control of home digital network devices was choosing special protocol for communication between system elements. From the beginning of creating the system it was obvious, that for the communication between user's control devices and multimedia gateway should be used one of the wireless communication protocol. The protocol used in the system should be cheap, effective and secure solution. There were two choices – infrared protocol (IrDA) and Bluetooth communication interface.

Nowadays the most popular system is the infrared data communication protocol. It enables effective and secure data transfer with direct connection point – point [1]. Another features of the IrDA is low power consumption and simple cheap implementation. However, for this kind of system IrDA has some limitations and it was impossible to use this interface. First of all, IrDA enables only point – point communication, so with using IrDA there should be only one control device controlling each of home devices. This obvious limitation excludes utilization of this protocol in the system. Another disadvantage of the infrared communication protocol is line-of-sight feature and very narrow (30 degree) angle of proper functionality. One of the objectives of the system is the possibility of controlling all home devices from any place in the house and the features of infrared communication does not allow to this. Mentioned features caused that it was impossible to use IrDA in the system. In this case authors decided that better solution would be using Bluetooth wireless communication interface.

Initially Bluetooth wireless technology was created to solve a problem of replacing cables used for communication between such devices as: laptops, palmtops, personal digital assistant (PDA), cellular phones and other mobile devices [2]. Now Bluetooth enables users to connect to a wide range of computing and telecommunications devices without any need of connecting cables to the devices. Bluetooth is a radio frequency specification for short range, point-to-multipoint voice and data transfer. It operates in the 2.4 GHz ISM (Industrial-Scientific-Medical) band. This band is free for use, so it is not necessary to have special license for communicating in this frequency range. Of course this range is full of other signals from different devices, so it should have special methods of preventing interference with other signal. Bluetooth uses the frequency hopping (FH) technology and it avoids from the interference. It is also the reason, why Bluetooth is very secure protocol. Bluetooth is based on a low-cost, short-range radio link and enables communication via ad hoc networks. Main features of the Bluetooth communication protocol are [3]:

– nominal link range is 10 m, it can be extended to 100 m by increasing transmit power;

– connection is created every time, it is needed by using the ad hoc networks;

– basic unit in Bluetooth networks is a piconet, it supports up to 8 devices (1 master device and up to 7 slave devices);

– one Bluetooth device can be a part of different piconets, they can exist simultaneously;

– possible transmission through solid, non-metal objects;

– built-in methods of security and preventing interferences;

– Bluetooth allows easy integration of TCP/IP for networking;

– there are two types of possible transmission: synchronous and asynchronous.

Despite of the short range, Bluetooth protocol has also a lot of advantages that are very important in designed type of system [4]. These are:

– it is not necessary for the devices communicating using this protocol to directly see each other;

– very easy network creation and configuration (very efficient methods of looking for devices in the neighbourhood);

– possibilities of moving devices in the neighbourhood, not required line-of-sight.

All the presented features of Bluetooth wireless communication protocol and very rapid growth of the standard confirm, that Bluetooth is suitable solution for using in a system for integrated control of home digital network devices.

3. System architecture

As it was mentioned in an introduction, the whole system is divided into three main parts: PCA, Bluetooth/HTTP bridge and multimedia gateway. The general concept of the system architecture is presented in Fig. 1.

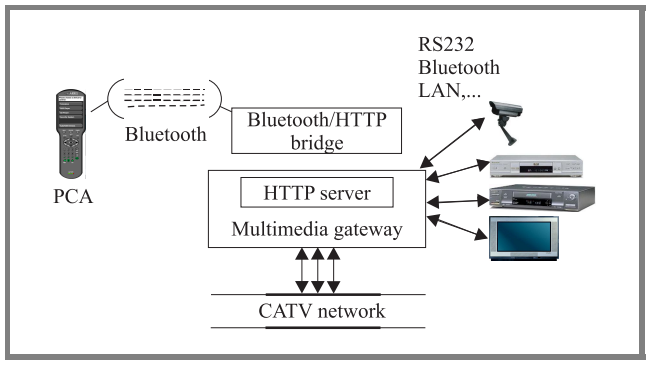

Fig. 1. General system architecture.

3.1. Personal communication assistant

The first part of the system is specially designed PCA. In fact it is an advanced remote controller with the keyboard and graphics display. One of the main objectives of the system is to enable the use of different services from the number of devices via the multimedia gateway and PCA from any place in the house, so for the communication between PCA and multimedia gateway, Bluetooth wireless protocol is used.

To extend the Java platform to consumer and embedded devices, Sun Microsystems developed special platform – J2ME (Java 2 Microedition). This platform is specially designed for programming such devices like: mobile phones, pagers, PDA, set-top boxes and others. This type of devices require special type of smaller Java virtual machine (VM), which is optimized for this environment. The core component of the J2ME platform is a special type of virtual machine called K-virtual machine (KVM). KVM is a Java virtual machine implementation designed specifically for small, resource-limited devices, it is based on the Spotless system developed originally at Sun Labs. KVM requires small computing resources (16-bits RISC or CISC processors) and small memory resources (160 – 512 kbit). There are two different configurations defined in the J2ME platform [5]:

– CLDC: designed for low-end consumer devices which have at least 160 kB available for the Java platform, processor speed starting from 16 MHz, limited power with usually battery operation and low-bandwidth connectivity and static size of the Java platform (VM + libraries);

– CDC: designed for high-end consumer devices with at least 2 MB available for the Java platform TCP/IP connectivity available.

Except these two different configurations there are different profiles in J2ME designed to accommodate the needs of a specific mobile consumer device market. Particularly, the mobile information device profile (MIDP) defines the architecture and API required to create applications for small, low-power mobile information devices like cell phones, pagers or PDA.

For the simulation of PCA authors used complete development environment which can help in creating and testing applications for mobile devices. Authors had at disposal also two Bluetooth communication modules with the programming interface and the programming simulation of the communication devices. The configuration of the modules was connected limited device configuration (CLDC) with the profile MIDP implemented. This configuration of the application platform enabled running applications with the KVM [6]. It was very good, because the PCA should be very cheap, effective solution with the minimum costs of production. Of course in these modules only basic Java classes from the main Java packages (java.lang, java.io, java.util) were implemented. There were also some classes for the creating user interfaces with the basic components for the small displays with limited number of buttons.

3.2. Bluetooth/HTTP bridge

Because Bluetooth modules were prepared to work with simulation environment in J2ME platform, it was not possible to use it in J2SE (Java 2 Standard Edition) platform. J2SE was necessary for using HTTP server in the main part of the system – multimedia gateway. That is the reason, why the third element of the system – Bluetooth/HTTP bridge was created. Bluetooth modules and API used in the system were not dedicated for Java 2 Standard Edition. They were designed for Java 2 Microedition, so it was necessary to create the bridge that would enable to convert the documents between Java 2 Microedition in PCA and Java 2 Standard Edition in multimedia gateway. Of course it is not the only objective of the bridge.

All the data exchange between PCA and multimedia gateway is done by using XML transaction documents. The first step of any action in the system is sending by the PCA transaction document with the service request. After finishing the action gateway sends to PCA transaction document with the service response. All ways of information exchange will be introduced in the next section. The main problem is that service request from the PCA is in a format not recognized by HTTP server. There has to be done conversion from Bluetooth data to HTTP request. Also in the return way, HTTP response document from server has to be converted to Bluetooth data message. All these conversions are done in the Bluetooth/HTTP bridge. After conversion the bridge sends request to multimedia gateway and response to PCA.

Every time transaction document from PCA arrives, the bridge creates the HTTP connection with multimedia gateway. There is no need of keeping this connection all the time, so it is created only if it is necessary. On the other hand, there is no constant connection between the bridge and PCA. One of the main features of Bluetooth protocol is that there is a possibility of creating ad hoc networks always, when Bluetooth device appears in the neighbourhood of other Bluetooth device. So, the bridge must search the neighbourhood and always when other Bluetooth device appears create the connection and assign them individual threads.

3.3. Multimedia gateway

The main part of the system is multimedia gateway, which is the communication node of the system. Multimedia gateway has a direct connection to all devices in home digital network. The gateway enables also the contact with the outside environment. The system of the integrated control of the home digital network (HDN) is based on the client – server architecture, where the clients are PCA and the server for the services concentrating is the multimedia gateway, which works as a HTTP server. There is also Java servlet technology in the gateway implemented.

According to the memory limitations of the PCA, it was necessary to treat PCA only as a navigation device, a kind of terminal for the multimedia gateway. In the multimedia gateway all services were centralized. Using HTTP server allows easier implementation of multi-access and multithread services. There is also the possibility to recall gateway using WWW, with very easy Internet based control. Multimedia gateway with the HTTP server can be used as a stand-alone device in the home neighbourhood. It can be also part of the advanced set-top box and can be at the subscriber's house or in the head-end as well.

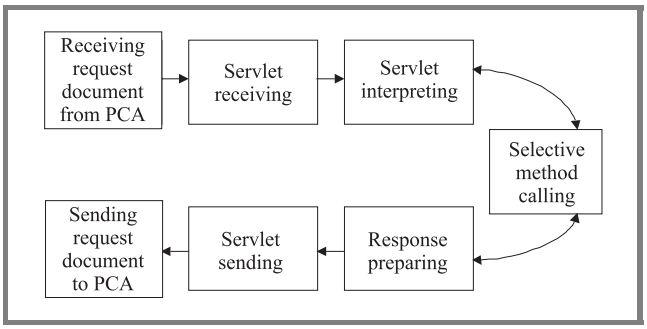

Fig. 2. Information flow at the multimedia gateway side diagram.

The protocol of the information between gateway and PCA is based on the exchange of the XML transaction documents. The diagram of the information flow in the system is presented in Fig. 2. The fundamental of any action in the system is sending by the PCA transaction document with the service request. This document is sent as a text stream to the Bluetooth/HTTP bridge, where it is changed

to the parameter of the servlet in the HTTP server. Multimedia gateway sends its response to the output stream of the HTTP server, then it is sending via the Bluetooth/HTTP bridge to the PCA.
First step of the session is a logging procedure – PCA sends to the gateway transaction document with user authentication information. As a response for correct logging procedure gateway sends to PCA main document with a set of services, ways of presentation services at the PCA's side and the action joined with the elements. Based on the main document PCA lists all available services on its screen. Choosing one of the menu element causes either execution of the action (sending proper transaction document) or entering to the next level of menu. After receiving request transaction document multimedia gateway executes actions and sends as fast as it is possible response document which is displayed on the PCA. After the user action PCA returns to the last menu, after executing all the needed services user do the logging out procedure and the session is closed.
Although to the most of the services this schema is good, there are a number of services with another way of the information flow. First of all these are notification services with the information about incoming new e-mail or caller identification of the new telephone call. It is well known, that in this case the initiative should not be from PCA but from the multimedia gateway.
Of course all data exchange between gateway and PCA is done with use of the Bluetooth/HTTP bridge. The bridge transforms Bluetooth data streams to HTTP requests and the other way round. Bridge is fully transparent for the documents.

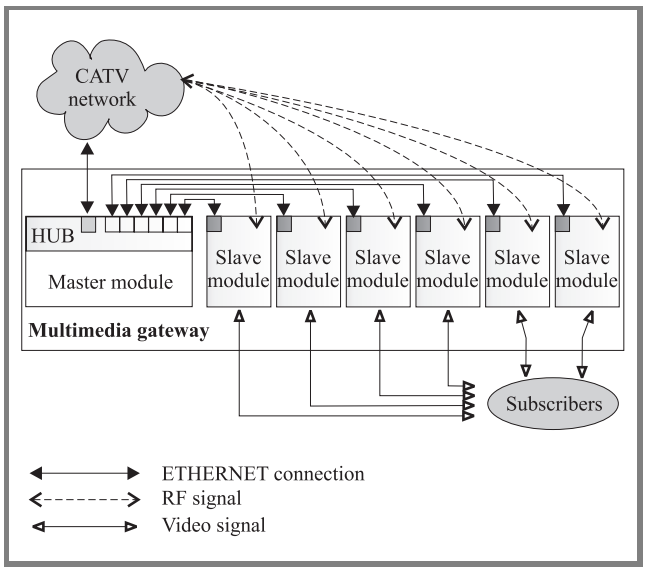

Fig. 3. The concept of multimedia gateway.

As it was mentioned before, using Bluetooth wireless communication protocol it is possible to use ad-hoc network, creating at the moment when it is necessary. Of course there is a possibility for multiple users to connecting to multimedia gateway simultaneously. If there are more than one PCA, Bluetooth master device can assign them individual threads and create special piconet. HTTP server inside multimedia gateway is also designed for multi-user operations. All this features make it possible to create one gateway designed for more than one user. This kind of multi-user multimedia gateway is presented in Fig. 3.
Designed multimedia gateway consists of one master module and number of slave modules. User's personal control devices communicate with master module via Bluetooth communication protocol. For connection between master and slave modules Ethernet cards are used. Multimedia gateway is connected to CATV network and have all possible input and output interfaces.

4. Types of transaction documents

There are three different types of XML transaction documents in the system: request document, response document and system main document. All of the types are described below.

4.1. Request document

Request document is sent by the PCA every time any service execution is needed. XML transaction request document contains all necessary information about desired service. In Fig. 4 is an example of request document.

```
<REQUEST>
    <CLIENT bda=„fff1" devicename=„PCA1"
        devicetype=„PCA"username=„Jerzy"/>
    <GATEWAY httphost=„localhost"
        servicename=„STBNavigator"
        serviceclass=„STBEngine"/>
    <PARAMname=„command" value=„channelup"/>
    <PARAMname=„execmode" value=„immediate"/>
</REQUEST>
```

Fig. 4. Example of request document.

Request document contains description of the client sending request, address of the target multimedia gateway, name of the required service, name of the class (driver) servicing the request and other parameters required to execute the service.

4.2. Response main document

There are two types of response documents: response main document and response simple document. Response main document is sent by the gateway to PCA as a response of logging procedure. In Fig. 5 is an example of this kind of document.
Response main document contains description of the menu tree, description of all user interface components and description of actions assigned to user interface components.

```
<RESPONSE type=„main”>
  <GATEWAY httphost=„localhost”
           servicename=„SystemLogin”
           serviceclass=„UserManager”/>
    <CLIENT bda=„fff1” devicename=„PCA1”
            devicetype=„PCA” username=„Jerzy”/>
    <CONTENT>
      <DISPLAY type=„menuset”>
        <MENUITEM caption=„ChannelDown”>
          <ACTION type=„GatewayRequest”>
            <GATEWAY httphost-„localhost”
                     servicename=„STBNavigator”
                     serviceclass=„STBEngine”/>
            <PARAM name=„command”
                   value=„channeldown”/>
            <PARAM name=„execmode”
                   value=„immediate”/>
          </ACTION>
        </MENUITEM>
      </DISPLAY>
    </CONTENT>
  </PARAM name=„execmode” value=„immediate”/>
</RESPONSE>
```

Fig. 5. Example of response main document.

4.3. Response simple document

Response simple document is sent by the gateway to PCA as a response for all client requests. In Fig. 6 is an example of this kind of document.

```
<RESPONSE type=„simple”>
    <GATEWAY httphost=„localhost”
             servicename=„STBNavigator”
             serviceclass=„STBEngine”/>
    <CLIENT bda=„fff1” devicename=„PCA1”
             devicetype=„PCA” username=„Jerzy”/
><CONTENT>
    <DISPLAY type=„none”/>
    <HIDDEN
      <DATAITEM name=„status” value=„ok.”/>
    </HIDDEN>
  </CONTENT></RESPONSE>
```

Fig. 6. Example of response simple document.

Response simple document contains description of the client sending the request, description of gateway from which response arrives and all the data as a result of command execution.

5. Conclusions

Authors proposed new architecture of the integration of home digital network with Bluetooth communication network. As an example of this application system for integrated control of home digital network devices was presented. Author's decision was to place central part of the system in the multimedia gateway and to use a HTTP server in the system. All services are centralized in multimedia gateway, user's control devices (PCA) are only terminals transmitting to gateway XML transactions documents.
Using all the features of Bluetooth communication interface it was possible to create efficient way of communication between devices, gateway and PCA. To enable this, authors have also created new language of the device's communication connected with the services and devices description. Using XML transaction documents made the system very flexible. Developing of the system and adding new services is also very easy – there is no need to modify the whole system but only one service module.
One of the other advantages of this system architecture is the fact, that the gateway need not be placed at the user's house – it can be placed at the cable television operator's side or completely different place in Internet.

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