Demo Abstract: Software Radio Implementation of Integrating Heterogeneous Wireless Networks

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Abstract—**Diverse types of networks function properly in our daily life nowadays. However, information transmitted in these networks has to follow different protocols with distinct devices. In this demo, we have implemented a heterogeneous wireless network testbed – *the Universal Sound* - to connect wireless sensor network, broadcast FM radio network and GSM network. Using USRP as a super and universal gateway, the action of the player can be sensed and sent by the sensors, while the piano sound representing different actions can be displayed by a personal computer, a radio set and a mobile phone.**

I. INTRODUCTION

We live in a world covered with ubiquitous wireless communication systems such as cellular networks, WLANs, FM radio network and so on. In addition, the wireless sensor network is also helping build a heterogeneous environment in terms of access technologies. To spread a message in all these wireless networks, we originally need different devices to connect with each type of network respectively. This induces non-negligible cost of system construction and brings obstacle for interconnection of different wireless networks. This has motivated us to integrate various wireless platforms using a universal device.

Integration of different technologies with different capabilities and functionalities could be an extremely complex task and involves issues at all layers of the protocol stack [1]. However, a software radio device can change modes by simply loading appropriate software into memory [2]. Using three USRP (Universal Software Radio Peripheral) [3] devices, we have envisioned an integration of three types of wireless networks. In our demo, when an event is triggered on the sensor nodes, a message will be sent through wireless sensor networks, broadcast FM radio networks and GSM networks. A piano sound representing different actions will spread over these networks as a sign of message reception. For a better description, we call this demo *the Universal Sound*.

II. DESIGN AND IMPLEMENTAITION

GNU Radio is a free software development toolkit [4]. In GNU Radio, the signal processing runtime and processing blocks are provided to implement software radios using readily-available, low-cost external RF hardware, such as Universal Software Radio Peripheral (USRP) and commodity processors. In *the Universal Sound*, we have integrated three types of wireless networks, as illustrated in Fig. 1. The realization of integration is mainly based on the USRP devices, which collect information from one type of network and retransmit it to others type of network. Since we have three types of wireless networks here, we use three USRP devices for the connection.

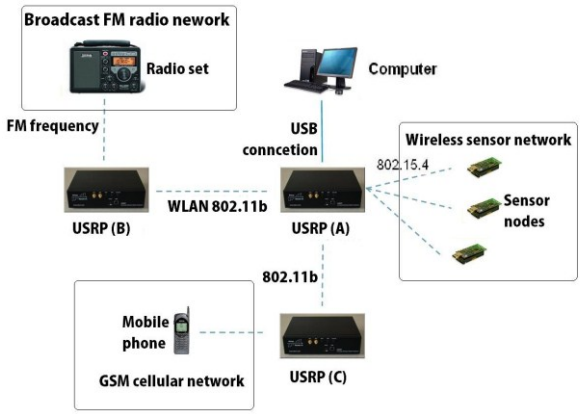

Figure 1. Architecture of the Universal Sound demo

A. Wireless Sensor Network

Between the TelosB sensor nodes and USRP (A) is the first integrated part, wireless sensor network. The USRP interoperates with the CC2420 radios found on TelosB motes [5]. For a better presentation effect, the sensor nodes are arranged linearly like keys in a piano keyboard. Light sensors in the nodes will trigger events when the "keys" are pressed. Message carrying the IDs of the nodes, i.e. the tones of the piano keys, will be sent by the nodes to the receiver end of USRP (A), and then reported to the PC (A) through the USB 2.0 connection. According to the ID received, PC (A) plays corresponding tones via virtual piano software. Because of the instant audio respond, when people press the sensor nodes, they feel like playing the piano.

B. Broadcast FM Radio Network

To send the sound information through broadcast FM radio at around 90MHz [4], another USRP device is needed. The USRP (B) receives message from USRP (A), and send out encoded sound signal at FM frequency band, say 89MHz. The receive-side RF front-end translates a range of frequencies appearing at its input to a lower range at its output [6]. One can hear the sound from a radio set if he/she turns the receiver frequency to 89MHz. Again, when the sensor node "keys" are

pressed, the radio set will play corresponding sound at the same time the computer plays sound by the sound card.

C. GSM Cellular Network

In this demonstration, the GSM system is implemented over an open-source project, OpenBTS [7]. The OpenBTS system uses the USRP and RFX 900 daughterboards to receive and transmit GSM signals. Similar to USRP (B), USRP (C) receives message from USRP (A), and give out calls at GSM-900 downlink band. A mobile phone user will be able to get a phone call from the computer and hear the piano sound in the call, as long as the information of his/her SIM card has been registered in the OpenBTS network.

The connection between each two USRPs is based on IEEE 802.11b protocol in WLAN. As it is the basic protocol used between USRPs, we don't regard it as another integrated type of wireless network.

III. DEMONSTRATION

In Section A above, we have already connected the sensor nodes with the computer. Although our main goal is to integrate three types of wireless networks, we also implement an Internet application for the *Universal Sound*. A webpage (http://gps.nju.edu.cn/tianyin) containing a virtual piano flash can be accessed from anywhere through the Internet, so that people can monitor the sensor piano keys on their own computer, and can even play the virtual piano collaboratively.

The objective of our demonstration is to show the integration of three types of wireless networks using software radio technology. Due to the hardware restriction that we have only two sets of USRP, we have to create two scenarios in the demonstration to show our idea in Figure.1.

1) Wireless sensor network + FM radio network: Two USRPs act as USRP (A) and USRP (B) respectively. In this part, we demonstrate the intergration of wireless sensor network and FM radio network, as showed in Fig. 2. We also present the Internet appliacation as an extention of *the Universal Sound*. When someone press the sensor node keyboard, sounds will come out from radio sets as well as from the computer sound card.

Figure 2. The Universal Sound Demonstration Part (1)

2) Wireless sensor network + GSM cellular network: In this part we make the two USRPs function as USRP (A) and USRP (C). We then demonstrate the intergration of wireless sensor network and GSM network, as showed in Fig. 3. For a better presentation, a phone call from the computer to a mobile phone with sound played in it should be put through before the keys are pressed down.

Figure 3. The Universal Sound Demonstration Part (2)

Notice that our demonstration follows either scenario but never both due to the restriction of hardware. It is necessary to change the daughterboard of USRP (B) to transfer it into USRP (C). USRP (A) remains the same in both two parts of demonstration. To build a full demonstration, a third USRP is needed.

Our demonstration implements the idea of using software radio to integrate different types of network. With wireless sensor network, FM radio network, GSM cellular network connected by USRP devices, and the extension of Internet application, an event triggered by a sensor will be noticed by people in every corner of the world. The piano form of presentation provides a better way of demonstrating. The effect that people hear sounds from radio sets, computers and mobile phones also matches the meaning of the demo's name, the universal sound.

IV. ACKNOWLEDGMENT

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