P2P Streaming Linked with Home Networks

We implemented a prototype application that allows listening to and viewing multimedia content recorded with a video recorder using a mobile terminal, as part of our efforts toward realizing services linked with home networks and mobile networks. This prototype achieved streaming content distribution over two different networks by making use of remote control of information appliances and P2P streaming technologies in connection with existing home network technologies. This research was conducted jointly with the Mino laboratory (Professor Michihiko Mino), the Academic Center for Computing and Media Studies, Kyoto University, and the Nakamura laboratory (Professor Yukihiro Nakamura), Graduate School of Informatics, Kyoto University.

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1. Introduction

Now that PCs and mobile terminals have practically completed the process of becoming fully connected to networks, various other types of devices (audiovisual devices, white goods, digital cameras etc.) are rapidly becoming networked as well. These devices are connected to various types of networks such as the Internet, mobile networks and home networks. Since each network has unique characteristics in terms of, for example, protocols and bandwidth, it has so far been difficult to achieve seamless communication among these heterogeneous networks. Lately, however, the demands for environments that allow these fundamentally different networks to communicate with each other are gaining momentum.

Home networks are one of the network types that are currently attracting attention of many people. In a typical home, there is a wide variety of information appliances, and many of these are becoming equipped with functions to connect to networks. A home network is configured using the network functions available in these heterogeneous information appliances, and the means of connection are diverse as well. Specifically, in addition to common means such as wireless LAN, infrared communication and Bluetooth™*1, the Institute of Electrical and Electronics Engineers' (IEEE) standard IEEE1394*2 is often used for communication of wide-band multimedia data, for example between audiovisual devices. The IEEE1394 transmission standard is widely known as FireWire*3 or i.LINK*4.

In order to achieve services linking such home networks and mobile networks, it is necessary to develop bidirectional communication capabilities between the information appliances and mobile terminals. As specific examples, we consider information appliance operation services that allow a user to turn on the air conditioning system and lighting at home using a mobile terminal before going home, services that notify about visits by guests to the user's mobile terminal when the user is not at home, services that allow playing video-recorded TV programs using a mobile terminal when the user is out. **Figure 1** shows some examples of services that can be linked to a home network.

This article introduces Peer-to-Peer (P2P) streaming technologies that allow direct data communication between information appliances and mobile terminals without going through a server. It also presents a prototype of a information appliance linking application that allows distributing multimedia content from home video recorders to mobile terminals etc., along with evaluation test results.

2. Services Linking Home Networks and Mobile Networks

Among the services described in Chapter 1, this chapter focuses on technologies for implementing services that allow

*1 Bluetooth™: A registered trademark of Bluetooth SIG, Inc. in the United States.
*2 IEEE1394: High-speed serial bus standard standardized by IEEE in 1995.
*3 FireWire: IEEE1394 is a communication standard originally developed by Apple Computer, Inc. and FireWire was its development code name. It is currently used as the nickname of IEEE1394.
*4 i.LINK: An alias for IEEE1394 used by Sony Corp. for its products.

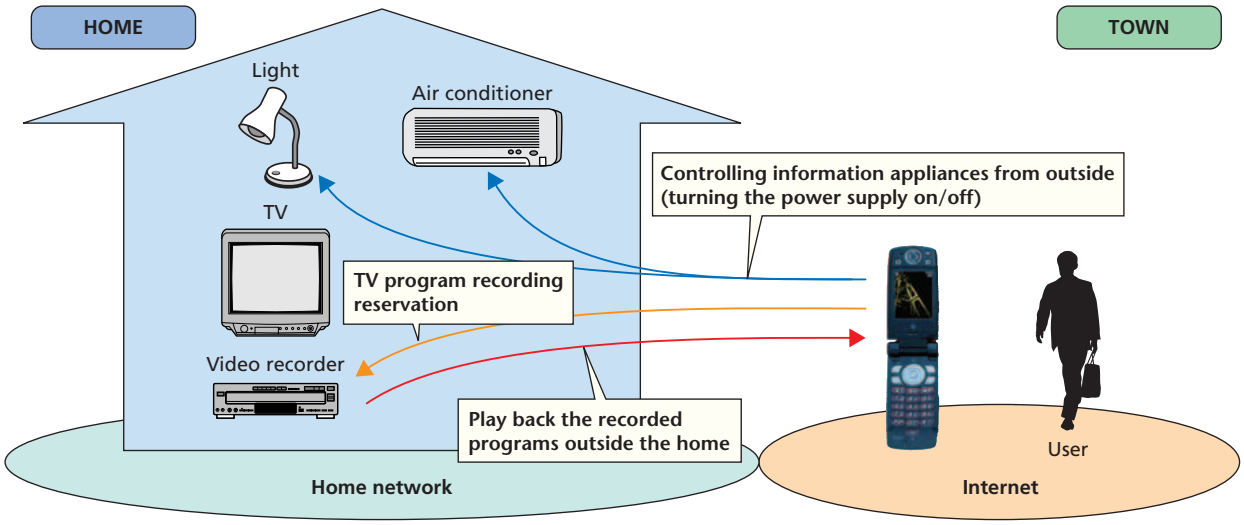


Figure 1 Services made available by linking a mobile network to a home network

remote control of a video recorder from a mobile terminal, and services that allow playing video-recorded programs using the mobile terminal. In order to implement these services, the following three technologies are required.

1) Technology for remote control of the video recorder from the mobile terminal via a mobile network and/or the Internet
2) Technology for bidirectional communication between the mobile terminal and the video recorder
3) Streaming technology for distributing content from the video recorder to the mobile terminal

Technology 1) requires linking with existing home network technologies. Since the majority of audiovisual devices, including video recorders, must be able to handle large volumes of data, they tend to adopt IEEE1394-compliant networks that allow high-speed wide-band communications. IEEE1394 specifies two types of communication methods: asynchronous communication[*5] and isochronous communication[*6]. For instance, the Audio/Visual Control digital interface command set (AV/C) is an application protocol that conforms to the asynchronous communication specification of IEEE1394. AV/C is a command set developed for the purpose of controlling audiovisual devices connected to IEEE1394 networks. It is thus possible to achieve remote control of the video recorder by transmitting this command set to the video recorder via the Internet.

Technology 2) makes use of a P2P technology that allows communication over heterogeneous networks. We have carried forward R&D of a P2P platform [1] that allows connecting devices (PCs, information appliances, mobile terminals etc.) distributed in heterogeneous network environments (environments where devices communicating via Internet Protocol, IEEE1394, Bluetooth™ co-exist) in a seamless manner and executing various applications. The P2P platform is an overlay network that constructs a network on the application layer. By using the communication functions provided by the P2P platform, seamless connection between the mobile terminal and video recorder becomes possible. In order to make communication functions conforming to IEEE1394 available on the P2P network, we designed an audiovisual application protocol with functions similar to IEEE1394 AV/C as an application protocol for the P2P platform.

Technology 3) makes use of the streaming technology on the P2P platform. Chapter 3 presents an overview of the P2P streaming technology implemented in this work.

3. P2P Streaming Technology

The P2P streaming technology refers to a mechanism to transfer streaming data on a P2P network. Each node on a P2P network is able to distribute, relay and receive data. In addition to the implementation-related advantages of the technology, such as the fact that a large-scale server is not required as each node is able to act as a relay, there is also the advantage that streaming can be achieved independently of the underlying net-

*5 Asynchronous communication method: A method guaranteeing secure packet transmission, used to communicate messages of control systems.
*6 Isochronous communication method: A method that does not guarantee secure packet transmission but guarantee Quality of Service (QoS), such as bandwidth and delay time, used mainly for communication of streaming data.

works because the network is controlled on the application layer. It is thus possible to distribute streaming content in a communication environment where heterogeneous networks coexist, which is assumed in ubiquitous environments.

In general, streaming is configured with a function that manages the routing of the streaming data and a function that transfers streaming data along the established routes. Two approaches to implementation of these functions can be considered—either using the same protocol or using two separate protocols for the two functions. The latter method is adopted in the P2P streaming technology we propose here; the control messages for managing the routing are transferred by the P2P protocol and the streaming data is transferred using an existing multimedia communication protocol. This method was adopted for the following reasons.

- If control messages and streaming data are transferred using the P2P protocol only, it becomes necessary to encode the streaming data using eXtensible Markup Language (XML) because the P2P protocol is defined using XML; this would generate a large overhead.
- If the streaming data is transferred using the P2P protocol, the opportunity to utilize existing multimedia communication protocols, such as the Real-time Transport Protocol (RTP) and IEEE1394 isochronous communication systems which are optimized specifically for each network, cannot be exploited.

As the protocol for routing management of streaming data on the P2P platform, we defined a new P2P streaming control protocol, which provides functions for setting, maintaining and releasing routing. **Figure 2** shows the P2P streaming protocol stack. The P2P streaming control protocol is used to manage the routing between the video recorder and the mobile terminal.

4. Prototype of Moving Image Distribution Application and Performance Evaluation

In order to confirm the effectiveness of the proposed system, we developed a prototype application that achieves distribution of moving images between a video recorder on the IEEE1394 network and a mobile terminal on the Internet. This application is comprised of a video recorder, a proxy, a home gateway and a mobile terminal, as shown in **Figure 3**. The mobile terminal and home gateway are connected via the Internet, while the home gateway and video recorder are connected via the IEEE1394 network. The two different networks are connected seamlessly using the P2P communication technology.

The home gateway restricts access to audiovisual devices such as the video recorder existing on the home network from the Internet to improve the security and provides a well-defined interface hiding the differences among the networks. Moreover, since current video recorders do not support the P2P protocol, a proxy model was adopted in this application. The proxy provides functions for protocol conversion between P2P messages

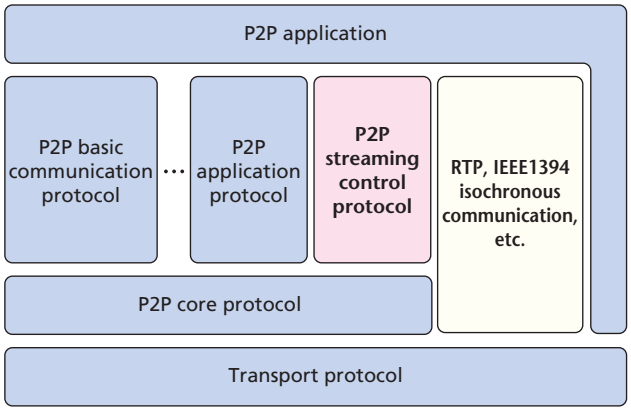
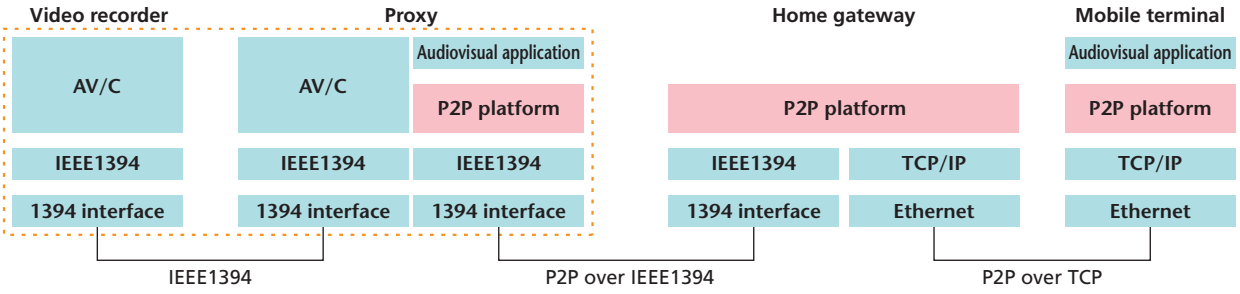


Figure 2 P2P streaming protocol stack



TCP/IP: Transmission Control Protocol/Internet Protocol

Figure 3 Moving image distribution application

and IEEE1394 AV/C messages as well as for distributing video and audio data received from the video recorder via the IEEE1394 network after converting into formats suitable for Internet communication bandwidth and playback environment on the mobile terminal.

Figure 4 shows the message sequence of this application. First, the mobile terminal uses the P2P protocol to detect the video recorder on the home network, and then sends a playback command to the video recorder. Upon receiving the playback command, the proxy converts the playback command of the audiovisual application protocol into the equivalent playback command of IEEE1394 AV/C and sends it to the video recorder. Moreover, in response to the playing request, it sets up a streaming route to the mobile terminal. After setting the route, the proxy converts video data encoded using Moving Picture Experts Group (MPEG) 2-Transport Stream (TS) format received from the video recorder into MPEG4 format. Lastly, the converted MPEG4 data is transmitted to the mobile terminal via the home gateway. Windows Media Player, which is widely used now, was used to playback the MPEG4 stream on the mobile terminal.

We also evaluated the performance of the prototype application. First, we tested distribution of moving images between the video recorder and mobile terminal, and confirmed that the moving images were distributed without problems. The delay time, from the time the video recorder started transmission of the streaming data until the time the mobile terminal began to receive it, was approximately 20 s. We investigated the reason why this delay occurred and found that caching of the transcoder (ffmpeg) adopted in this prototype for conversion from MPEG2 to MPEG4 took almost the same time. This delay can thus be expected to be improved by changing the transcoder. Next, we measured the network delay from the mobile terminal to the proxy and found it to be 5 ms or less; the network delay is thus ignorable. We finally measured the time required for routing in this environment without network delay and found that the time required for the mobile terminal to set the route to the proxy via the home gateway was 1266 ms (average time of five trials). From this measurement result, we confirmed that the application achieved a level of performance that poses no problems in practical distribution of streaming content.

5. Conclusion

This article explained the P2P streaming technology that we have developed to establish a seamless connection and support streaming content distribution between a home network and a mobile network. We also developed a prototype application that uses the P2P streaming technology to link a home network and a mobile network and remotely control a video recorder connected to the home network from the mobile terminal, and demonstrated the effectiveness of the proposed method.

In the future, we will examine QoS-related control, such as measuring the available bandwidth between the mobile terminal and the proxy, and dynamically adjusting the transfer bandwidth by means of transcoder setting accordingly.

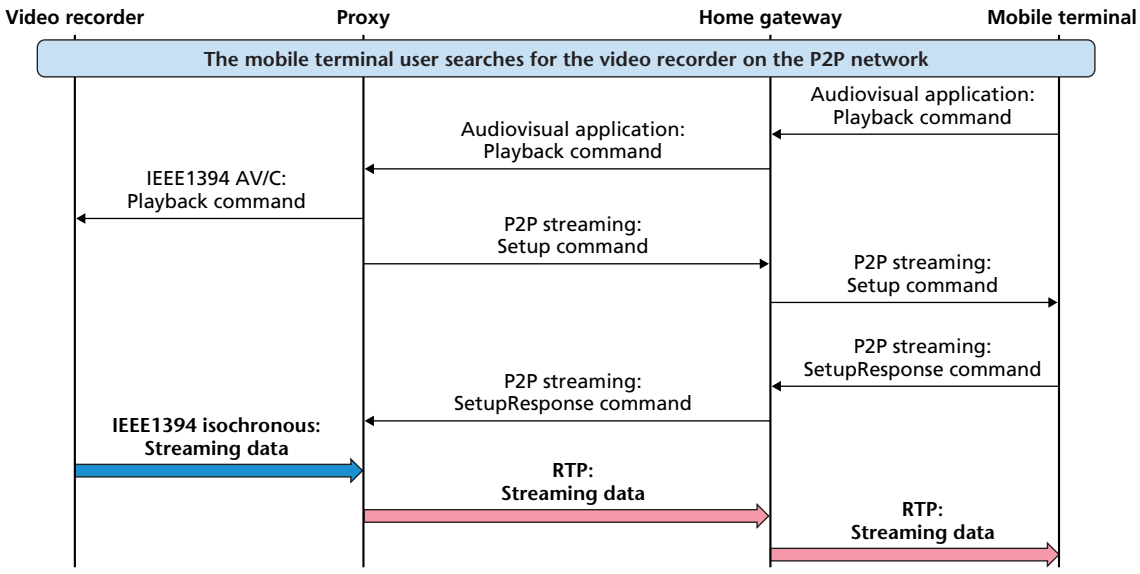


Figure 4 Message sequence

REFERENCES

[1] N. Ishikawa, T. Kato, H. Sumino, J. Hjelm, K. Miyatsu and S. Murakami: "Jupiter: Peer-to-Peer Networking Platform over Heterogeneous Networks," The 3rd International Conference on Computing, Communications and Control Technologies (CCCT' 05), 2005.

ABBREVIATIONS

AV/C: Audio/Visual Control digital interface command set
IEEE: Institute of Electrical and Electronics Engineers
MPEG: Moving Picture Experts Group
P2P: Peer-to-Peer
QoS: Quality of Service
RTP: Real-time Transport Protocol
TCP/IP: Transmission Control Protocol/Internet Protocol
TS: Transport Stream
XML: eXtensible Markup Language