Ubiquitous Interface Technologies

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Abstract

This article introduces a mobile adaptive terminal architecture as an interface for flexible use of various network resources, such as devices and wireless access measures in ubiquitous environments, without troublesome settings or operations by users or applications. It aims to provide seamless services that adapt autonomously to the user's movements and changes in the state of resources.

1. What are ubiquitous interface technologies?

The processing ability of handsets and their input/output quality (e.g., their screen/camera resolution) are much more restricted than those of home appliances and personal computers. However, it might be possible to provide high-quality mobile multimedia services by supplementing handsets with other devices such as TVs and video cameras and high-speed wireless access. A ubiquitous interface lets a mobile user utilize user-oriented network resources by dynamically discovering devices and wireless access points in his/her vicinity and autonomously switching between them according to his/her preferences and needs and those of the applications being used.

2. Ubiquitous environment

Ubiquitous access environments are being created as third-generation (3G) cellular services and wireless local area network (wireless LAN) services are spreading. The development of multimedia appliances, home networks, and sensor networks has been progressing toward ubiquitous environments. Mobile terminals such as handsets and PDAs are surrounded by ubiquitous network resources although they are severely constrained in computing (CPU speed, memory capacity, battery power, etc.) and input/output resources (screen size, speaker quality, etc.) due to size and cost requirements. They can utilize devices like TVs and surround-sound speakers to provide rich services such as video conference and music on demand. In an environment where networked devices are embedded all over the place, people may be able to make voice calls by such ubiquitous devices while moving around without holding their mobile phones.

3. Scenario

To illustrate how a ubiquitous interface might be used, Fig. 1 shows the scenario of a seamless video conference that is implemented using locally situated devices and wireless access points. First, User 1 starts up a video conferencing application on a mobile handset (MH1) and calls the mobile handset (MH2) of another user (User 2). In a corridor, MH1 detects that a wireless LAN is available and establishes a session with video and voice input/output with MH2 via the wireless LAN.

When User 1 moves into a meeting room, MH1 discovers an Internet-connected external display and external speakers and a Bluetooth camera. Based on the user's preferences, the video input/output and voice input/output are switched from the built-in devices of the mobile handset to the external camera, display, and speaker. This is done by routing the video and voice signals from MH2 directly to the external display and speaker. On the other hand, the Bluetooth camera is not connected directly to the Internet, but can be used to input video signals via a

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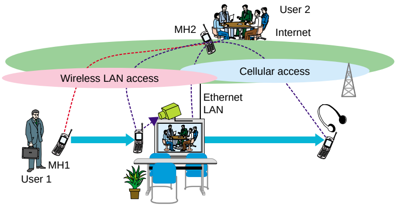


	Corridor	Meeting room	Outdoors
Network interface	Wireless LAN	Wireless LAN (camera and Bluetooth connection)	Cellular network (headset and Bluetooth connection)
Video output	Built-in display	External display	Built-in display
Video input	Built-in camera	Bluetooth camera	Built-in camera
Voice output	Built-in speaker	External speaker	Bluetooth headset
Voice input	Built-in microphone	Built-in microphone	Bluetooth headset

Fig. 1. Seamless video conferencing.

Bluetooth interface to MH1, which relays them to MH2 via the wireless LAN.

Finally, when User 1 leaves the meeting room, MH1 detects that it has left the accessible area of the external devices and wireless LAN and switches the video input/output and voice input/output session to its built-in devices via the cellular network.

4. Research issues

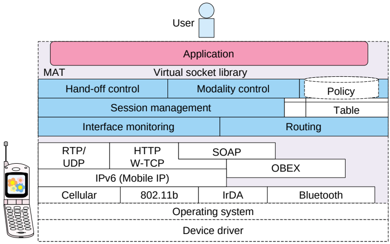
Devices and wireless access are diverse network resources which have different attributes in functionality and capability, although they have limited geographical service areas. Since the availability of resources changes when a user migrates, a system needs to monitor the availability of resources in use and switch (hand off) from obsolete resources to newly available ones to provide a continuous service. Customized resource discovery and selection mechanisms are also needed because each application requires different types of resources and a user usually has preferences and a policy for the choice of access networks and devices. The hand–off process requires complex session management involving multiple devices including internal/external devices and corresponding hosts, and multiple network interfaces, e.g., 3G cellular, 802.11b, and Bluetooth. Furthermore, with regard to how these devices are connected, it is necessary to consider not only "global" devices that have global IP addresses accessible to a host on an external network, but also "local" devices that cannot be accessed in this way. This is because a home network or intranet is likely to contain many devices with private IP addresses and non-IP devices, such as Bluetooth headsets.

5. Mobile adaptive terminal architecture

We propose the mobile adaptive terminal (MAT) architecture shown in Fig. 2. Each module of the MAT is described below according to the hand-off procedure shown in Fig. 3.

5.1 Interface monitoring

This module monitors the network interface and uses various service/device discovery protocols such as SLP (service location protocol, RFC2608), Jini (www.jini.org), and UPnP (universal plug and play, www.upnp.org) to discover available resources and monitor their status. The availability of wireless access points is generally judged from the received signal strength or frame error rate, while the availability of devices is judged from the positional relationship or distance between the user and the device. Here, it is assumed that the terminals can acquire information about the user's position from a GPS (global positioning system) sensor or a sensor network.



RTP: real-time transport protocol, UDP: user datagram protocol, HTTP: hypertext transfer protocol, W-TCP: wireless transmission control protocol, SOAP: simple object access protocol, OBEX: object exchange protocol, IP: Internet protocol, IrDA: infrared data association

Fig. 2. Mobile adaptive terminal architecture.

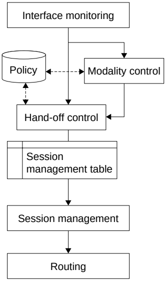


Fig. 3. Hand-off procedure.

It is also assumed that for each device, the IP address and port number used for media input/output, the transfer/control protocol, and the service area (e.g., the name of a place or its latitude and longitude) are registered in a service directory.

5.2 Hand-off control

This module judges whether or not to switch resources according to the policy based on information about the resources currently available at the current location. When it decides to perform a switch, it updates the corresponding location in the session management table to the contents of the resource to be switched in. For example, when a user with a priority-based policy enters a room where there are multiple cameras, the camera with the highest priority is selected. It is also possible to consider rules based on attributes such as display size, surround-sound functions, transfer speed, and cost.

5.3 Modality control

If a sensor network can be used to obtain information about a user's circumstances—e.g., whether the user is walking or sitting down or is close to someone else—then it may be possible to optimize the device selection and input/output means (modality). For example, a policy could be established whereby when the user is using nearby devices to display a received text message, the entire message is displayed on an external display if the user remains in one place, but is played back as speech via an external speaker if the user is walking, and is summarized on a built-in display if there is someone else nearby. This module selects devices and media types according to this sort of policy.

5.4 Session management and routing

Figures 4 and 5 illustrate the session management sequence used when switching the output interface. In the case of a global device (Fig. 4), once the device has been set up, MH1 informs MH2 of the device's IP address and port number. Upon receiving this notification, MH2 updates its own table and forwards the media stream directly to the external device, bypassing MH1. But at the same time, to switch the output smoothly, the routing module in MH2 forwards the media stream to both MH1 and the global device. This soft hand-off protocol eliminates any gap in the media stream output that might be experienced by the user when devices are switched.

When a local device is involved (Fig. 5), the session management module in MH1 updates its own table, and relays the media stream from MH2 to the device. Here, according to the policy, the setup is performed preemptively at the same time as the device discovery. This allows the hand-off to be performed straight away as soon as the decision to do so has been made. On the other hand, when a network interface is switched, signaling is only performed by MH1 and MH2. When MH1 informs MH2 of the IP address of the new network interface (a cellular network in this case), MH2 updates the table and routes the media stream to the IP address of the cellular interface.

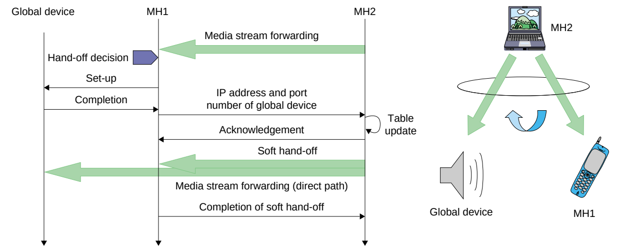


Fig. 4. Session management sequence (global device).

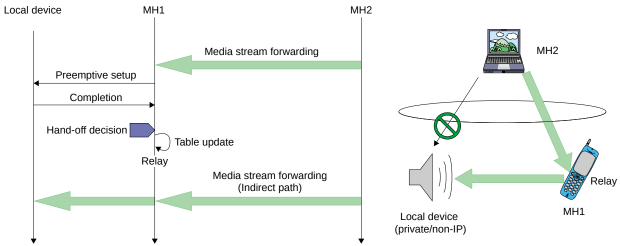


Fig. 5. Session management sequence (local device).

6. Implementation

Based on the proposed architecture, we built a testbed in an experimental house and implemented a follow-me music service as a test application (Fig. 6). A mobile laptop computer equipped with cellular and Wi-Fi interfaces executes an application program that functions as an MP3 player, which receives and plays back RTP (real-time transport protocol) packets from the MP3 streaming server. The user of the mobile terminal moves around in the experimental house carrying an RFID tag specifying this user's ID. RFID readers are situated at the entrances of the house and rooms, and when the tag is read, the user's position is reported to a location server.

In the living room of the experimental house, we installed speaker devices (global and local) equipped with MP3 audio output interfaces and a wireless LAN access point. The service area of the devices covers the living room, and the area of the wireless LAN was registered in the service directory as covering the living room and the adjoining entrance hall. As the user policy, more priority was given to wireless LAN than to the cellular network, and more priority was given to external devices than to built-in devices. Furthermore, the policy was set so as to preemptively set up the resources of adjoining blocks.

Trials performed with this testbed confirmed that the music autonomously tracked the user's position: the audio playback was automatically switching to an external speaker when the user entered the living room and returned to the built-in speaker when the user left the living room. The soft hand-off mechanism made it possible to achieve seamless device hand-offs with no breaks in the music.

When the user moved from the living room to the

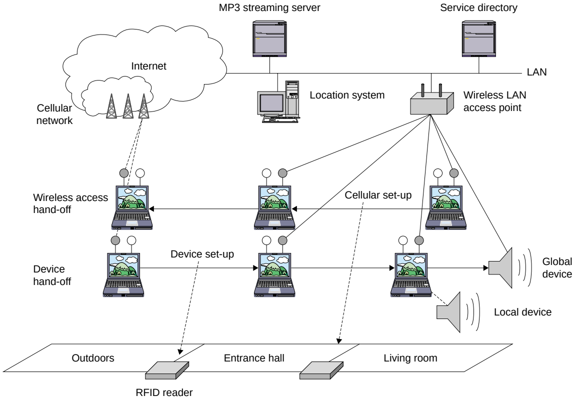


Fig. 6. Testbed.

entrance hall and then went outdoors, the hand-off from the wireless LAN to the cellular network took place automatically without any breaks in the music. In this experimental environment, the setup of cellular connection was started up preemptively when the user entered the entrance hall, allowing the setup to be completed before the wireless LAN link quality decreased. In a conventional protocol based on the received signal strength, the cellular connection is not started until a reduction in wireless LAN quality is detected after the user goes outside. Since this results in lower throughput during the time taken to establish a connection (about 10 seconds on average), preemptive connection is useful.

7. Comparison with conventional protocols

By introducing a session management module, the proposed adaptive terminal architecture provides an application-layer protocol that gives integrated support for wireless access and device hand-offs. Conventional protocols have implemented the switching of either wireless access measures or devices, but not both. Most wireless access hand-off protocols are network-layer protocols based on Mobile IP [1], but since device hand-off involves multiple terminals, it cannot be dealt with at the network layer. Also, since the proposed protocol is based on an end-to-end approach [2] in which the mobile terminals manage the session, there is no need to deploy network nodes such as home agents. It also reduces the functional load due to session management on devices. Furthermore, the soft hand-off protocol can handle the switching of media that are sensitive to interruption, such as music and phone conversations.

8. Conclusion

We presented the mobile adaptive terminal architecture as a ubiquitous interface technology for diverse surrounding network resources. To create new services that exceed the limited computing power of cellular phones, we plan to extend our architecture to cooperate with a huge amount of computing and storage resources on a grid computing infrastructure*1.

*1 a grid computing infrastructure: A collection of resources such as CPUs, networks, storage, and instruments owned by multiple organizations that is coordinated to allow them to solve a common problem.

References

[1] M. Stemm and R. H. Katz, "Vertical handoffs in wireless overlay networks," Mobile Networks and Applications, Vol. 3, No. 4, pp. 335-350, 1998.

[2] A. C. Snoeren and H. Balakrishnan, "An end-to-end approach to host mobility," Proceedings of the sixth annual international conference on mobile computing and networking, Boston, MA, U.S.A., pp. 155-166, Aug. 2000.

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