Mobile IPTV

Approaches, Challenges, Standards, and QoS Support

IPTV is defined as multimedia services, such as TV, video, audio, text, graphics, and data, delivered over IP-based networks managed to support quality of service (QoS), quality of experience, security, interactivity, and reliability. Mobile IPTV extends those services to mobile networks. The authors discuss mobile IPTV standardization's status, related approaches in the field, and technical challenges to enhancing mobile IPTV services. Given the critical role of QoS in the technology's widespread adoption, the authors also propose an efficient signaling scheme to support QoS for seamless mobile IPTV services.

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Mobile IPTV lets mobile users transmit and receive multimedia traffic, such as TV signals, video, audio, text, and graphics, through IP-based networks with the support of quality of service (QoS) and quality of experience (QoE), security, mobility, and interactivity. In short, mobile IPTV extends many IPTV services to mobile users.

To coordinate and promote development of global IPTV standards, the ITU-T in 2006 formed a focus group called FG IPTV, which took into account the existing work of ITU-T study groups and other standards development organizations. Then, in January 2008, the IPTV Global Standards Initiative (IPTV-GSI) took over the IPTV standardization role.

In this article, we describe the current status of mobile IPTV standardization as well as mobile IPTV approaches and technical challenges. Additionally, we propose an efficient signaling scheme to support QoS for seamless mobile IPTV services. QoS support is critical for video delivery systems, especially in the mobile environment, and a requirement for viewer satisfaction.

Architectures and Approaches

ITU-T defines the IPTV architecture[1] and further classifies it into next-generation-network (NGN)-based and non-NGN-based architectures. In this article, we address non-NGN-based architectures for mobile IPTV services. In future work, we'll incorporate the NGN-

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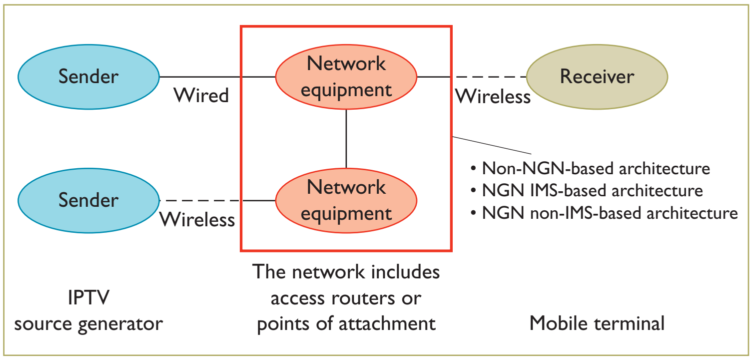

Figure 1. Mobile IPTV architecture. In the first stage, a wireless interface enables communication between the access network and the receiver. In the second stage, the wireless section extends to the sender, giving the sender's and receiver's devices mobility. (NGN: next-generation network; IMS: IP-based Multimedia Subsystem)

based mobile IPTV approach, which considers the IP-based Multimedia Subsystem (IMS).

Figure 1 shows an overall mobile IPTV architecture. In the first stage, a wireless interface enables communication between the access network and the receiver (mobile IPTV terminal). Because IPTV is access agnostic according to ITU-T's definition, various wireless access networks, such as wireless LAN (WLAN),[2] WiMAX,[3] and cellular networks,[4] can exist. Each wireless technology has its own characteristics, which service providers should carefully consider when deploying mobile IPTV.

In the second stage, the wireless section extends to the sender so that both the sender's and receiver's devices can be mobile. Moreover, user-created content is becoming more popular in the Internet community; any mobile user can create IPTV content and provide it to other mobile IPTV users.

Some of the approaches for mobile IPTV services we'll discuss in this section are already in use. From the users' perspective, no big functionality differences exist among the approaches, but the detailed technologies differ.

Mobile TV Plus IP

Using traditional digital broadcast networks, mobile TV plus IP delivers IP-based audio, video, graphics, and other broadband data to mobile users.[5] This approach aims to build an environment in which stable broadcasting facilities and content combine with diverse Internet-based services. Additionally, mobile TV plus IP uses wide area wireless networks, such as cellular networks, to support interactivity.

Digital Video Broadcasting's Convergence of Broadcast and Mobile Services (DVB-CBMS; www.dvb.org/groups_modules/technical_module/tmcbms), DVB IP Infrastructure (DVB-IPI; www.dvb.org/groups_modules/technical_module/tmipi), and the World Digital Multimedia Broadcasting (WorldDMB) Forum (www.worlddab.org) are key standards groups in this area. DVB-CBMS is developing protocol specifications for bidirectional, IP-based broadcasting over DVB-H, the specification for bringing broadcast services to battery-powered handheld receivers (www.dvb.org/groups_modules/technical_module/tmh). DVB-IPI specifies technologies on the interface between an IP network and retail receivers, enabling the end user to receive DVB services over IP-based networks. The WorldDMB Forum is enhancing and extending Eureka 147, originally developed for digital radio applications, to support IP-based and video services.

Although this mobile TV plus IP approach is classified as mobile IPTV, the use of broadcasting networks might cause loss of IP individuality, such as point-to-point interactive communication and personalized services.

IPTV Plus Mobile

Is networked TV the future of television? A lot of services similar to IPTV are already on the market, and more are in progress. Telco giants say IPTV is the new source of revenue. IPTV services originally targeted fixed terminals such as set-top boxes, but mobility possibilities have grown out of the fixed mobile convergence trend.

The Alliance for Telecommunications Industry Solutions (ATIS) in the US and ITU-T IPTV-GSI internationally are primary standards organizations in the IPTV plus mobile field.

Mobile IPTV specifications development is a relatively new effort. ITU-T FG IPTV has collected requirements for IPTV, including mobile IPTV. ATIS, however, has yet to show interest in mobility support. The main problem of this approach is slow development, even for fixed wireless IPTV only.

Cellular

The Open Mobile Alliance's Broadcasting Working Group (OMA BCAST) is working on technologies for providing IP-based broadcast services in the mobile environment. The technique's main goals are to define an end-to-end framework for mobile broadcast and compile the set of necessary enablers. A key feature of the cellular approach is the bearer agnostic, which means it can adopt any broadcast-distribution network as its transport means.

OMA BCAST currently applies only to mobile terminals, but its specification might expand to cover fixed terminals.

Internet

A product of the entertainment business, Internet or Web TV comprises numerous Internet video services worldwide. With the Internet approach, the model form depends on the business types and infrastructures it will support.

Anyone can use this approach to play a role in the value chain; the user can be a content provider, service provider, or consumer. This flexibility enables a universe of highly diversified and dynamically independent production, as well as a global reach.

However, QoS isn't guaranteed because the approach is based on the best-effort service model. Nevertheless, through its rapid adaptation to customer needs, the Internet approach might become dominant in the near future.

Technical Challenges

Mobile IPTV services must overcome several obstacles to a successful launch and wide use. Because of a lack of consensus, we don't present detailed solutions to each technical issue in this section.

Mobile IPTV implies at least one wireless link between the source, such as a streaming server, and the destination, such as a mobile terminal. Therefore, most of the technical challenges are related to the wireless link.

Terminal Capabilities

Moving IPTV content from a standard home display to a mobile terminal with a small screen raises various concerns. Compared to fixed terminals, mobile terminals have limited capabilities. This trait primarily affects portability, which leads to a small video display, low-power processor (because of a small battery), limited storage, and so on. Being lightweight is also an important feature of a mobile terminal.

These capability limitations mean that only a restricted set of technologies is possible through mobile IPTV solutions. For example, the content-providing server should consider the mobile terminal's screen size when sending a video stream.

Bandwidth

Although the wireless link's effective bandwidth is growing rapidly, it won't be sufficient for mobile IPTV until the 4G wireless network's full deployment. Only then will the wireless link bandwidth become broad enough to accommodate high-definition video services. Even when the 4G wireless network is available, the bandwidth might not be sufficient if bandwidth-greedy services such as ultra-definition (UD) video emerge and the number of users increases rapidly. The wireless link will always have less bandwidth than the wired link, and the number of high-bandwidth applications will continue to increase. Therefore, bandwidth-aware solutions are always desirable for mobile IPTV services in the wireless environment.

Wireless Link

The wireless link is vulnerable to physical factors. When the mobile IPTV terminal moves around, packets can suffer quality degradation from such factors as shadowing and fading as they travel through wireless channels. Even when mobile IPTV terminals are stationary, temporal reflectors and obstacles in the wireless environment can affect the received signal quality and cause burst packet losses. Such quality degradation is intrinsic in the wireless link. So, the mobile IPTV servers and terminals should react adaptively to the wireless link's varying conditions.

Service Coverage

The purpose of mobile IPTV devices is to provide anytime, anywhere access to IPTV services. However, it's virtually impossible to deploy a wireless network that covers all geographical areas with no dead spots. Enabling *vertical handover* between heterogeneous wireless networks — for example, WiMAX, WLAN, and 4G networks — can resolve service-coverage limitations. Vertical handover occurs when a network node changes the type of connectivity it uses, usually to support node mobility. But, the technical challenges of seamless handover remain, such as how to sustain mobile IPTV services while moving across different wireless networks without any significant performance degradation and how to select the best network among them for mobile IPTV.

Dynamic Environment

Unlike the wired channel's more static properties, the wireless channel's characteristics vary because of the effects of fading, shadowing, reflection, refraction, scattering, diffraction, and interference. Vertical handover, which changes the media access control and physical layers (MAC/PHY), available bandwidth, and, possibly, IP address, might also greatly affect mobile IPTV service quality. Therefore, because most of the wired network solutions won't work properly, mobile IPTV should employ wireless-specific and mobility-aware technologies.

Scalable Video Coding

The scalable video coding (SVC) technology lets the system consider the network's terminal types and available bandwidth. Although SVC enables scalable representation of video content with high coding efficiency, it's difficult to perform real-time encoding because of the SVC encoders' complexity. Additionally, further study is needed on how to best control the SVC rate according to network resource availability.

QoS and QoE

For high-quality mobile IPTV services, supporting key QoS factors, such as packet loss, bandwidth, delay and jitter, and packet-error ratio, is important. Mobile IPTV delivery systems must be able to handle such factors through careful system design (for example, over-provisioning or use of NGNs), careful traffic control in the network (such as traffic engineering and service differentiation), and optimized buffering and error-correction at the receiver. In particular, reacting quickly to varying conditions in the wireless link is critical.

Supporting user-perceived QoE by providing a resource-aware mobile IPTV service is also important — for instance, increasing or decreasing the transmission rate according to the user's expectation.

Business Issues

The major business concern regarding mobile IPTV is the possibility of low consumer demand for mobile IPTV viewing on tiny screens. Wide adoption requires a business model for making mobile IPTV services attractive to users.

User interface is another obstacle to a successful mobile IPTV business. The small mobile device form hinders development of a fancy user interface. Mobile IPTV growth will require a highly creative and innovative human-machine interface suitable for the mobile device.

Watching live TV while mobile is one of mobile IPTV's most attractive features. So, access to popular real-time TV programs and rich content should be provided. Content tailored for mobile environments, such as small screen size and random and short watching time, is key.

Standardization Status

The standards groups in mobile IPTV-related standardization include DVB-CBMS, OMA-BCAST, Third Generation Partnership Project Multimedia Broadcast Multicast Service, and WiMAX-Multicast Broadcast Service. For unified mobile IPTV services, these organizations should harmonize their efforts.

Currently, ITU-T is trying to coordinate IPTV-related standardization activities to develop global IPTV standards for the market. Table 1 shows the ITU-T FG IPTV requirements directly related to mobile IPTV.[6] After FG IPTV activities closed, IPTV-GSI formed to promote greater efficiency in producing IPTV recommendations.

QoS Support

QoS support is crucial for successful mobile IPTV business. In the mobile environment, mobile IPTV services can frequently suffer from an unreliable network connection and insufficient bandwidth. Thus, service continuity requires an awareness of varying wireless-link conditions, such as shadowing and fading.

We propose an efficient signaling scheme to support QoS for seamless mobile IPTV service. The scheme defines a new option in high-layer protocols for carrying link characteristics information (LCI). Ji Zhang and colleagues used the LCI as an extension of TCP Quick-Start to let end nodes quickly adjust their sending rate for ongoing connections according to the link condition.[7]

For high-layer protocols for mobile IPTV services, we selected the Datagram Congestion Control Protocol (DCCP) and Real-Time Transport Protocol/Real-Time Transport Control Protocol (RTP/RTCP). We extended these protocols to provide a reliable means for deliv-

Table 1. Mobile IPTV requirements.

Feature	Optional
Content management	Support bandwidth request and congestion control capabilities.
IPTV terminal device	Have the capability to provide information regarding its bandwidth availability.
IPTV architecture	Support signaling capabilities for transmitting bandwidth-related information.
IPTV architecture	Use bandwidth-related information to determine the appropriate content coding means to deliver the content.
Feature	**Recommended**
IPTV content	Deliver content in several optional versions to be selected according to the capabilities (such as access rate, resolution, and supported formats) of the IPTV terminal receiving the content.
IPTV architecture	Allow delivery of IPTV services over different access networks, such as cable, optical, xDSL, and wireless.
IPTV architecture	Allow delivery of IPTV services to any IPTV terminal device, such as a mobile phone, PDA, or set-top box.
IPTV architecture	Adapt dynamically to change in wireless networks characteristics, such as bandwidth and packet-loss ratio, when the system delivers the service over a mobile network.
IPTV architecture	Support capabilities for the interoperability and user mobility between IPTV networks, allowing customer access to IPTV services whether or not the customer is mobile.
IPTV architecture	Allow service continuity over heterogeneous networks.
IPTV architecture	Support an IPTV terminal with the capability to choose the desired content format if multiple formats are available.
IPTV architecture	Support the ability to identify wireless-network characteristics information that the IPTV terminal sends.

ering the LCI information from a mobile IPTV terminal to an IPTV content provider. The IPTV content provider can quickly adjust its sending rate for the ongoing session according to the bandwidth information contained in the LCI option, as Figure 2 illustrates. Our scheme can apply to both horizontal and vertical handovers.

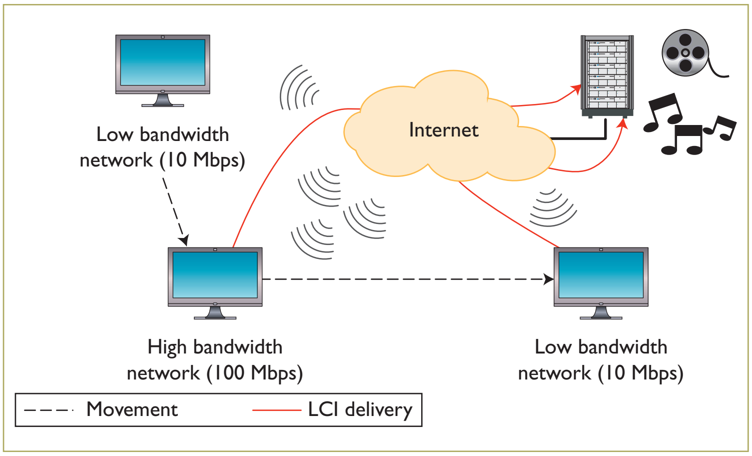

Figure 2. Link characteristics information (LCI) delivery. The LCI delivery mechanism for mobile IPTV during a vertical handover. When the mobile IPTV terminal senses a significant change in the wireless-channel capacity, the higher-layer protocol message carries the LCI.

Using a DCCP LCI Extension

Figure 3 illustrates the procedure for DCCP mobility support for QoS-enabled mobile IPTV.[8] After handover, the mobile IPTV terminal sends a DCCP-Request message with an Attach-Gencon (generalized connection) option to the IPTV content server. The system uses the Gencon to implement the subprotocols that create and update generalized connections.[9]

For LCI delivery, we define a new DCCP LCI option included in the option field of the DCCP-Request and other related messages. This option can include parameters such as network type, interface type, and bandwidth.

The system uses the DCCP LCI option in the DCCP-Request message with the Initiate-Gencon option for opening an early session, and also in the DCCP-Request message with the Attach-Gencon option for handover. The system can also use it in the DCCP-Data message when the wireless-link status changes abruptly.

Detailed signaling procedure. The signaling procedure for message exchange after handover begins with the mobile IPTV terminal collecting information on the new wireless link's characteristics and including it in the LCI option. Then, the system includes the LCI option in the DCCP-Request with the Attach-Gencon option and sends it to the IPTV content server.

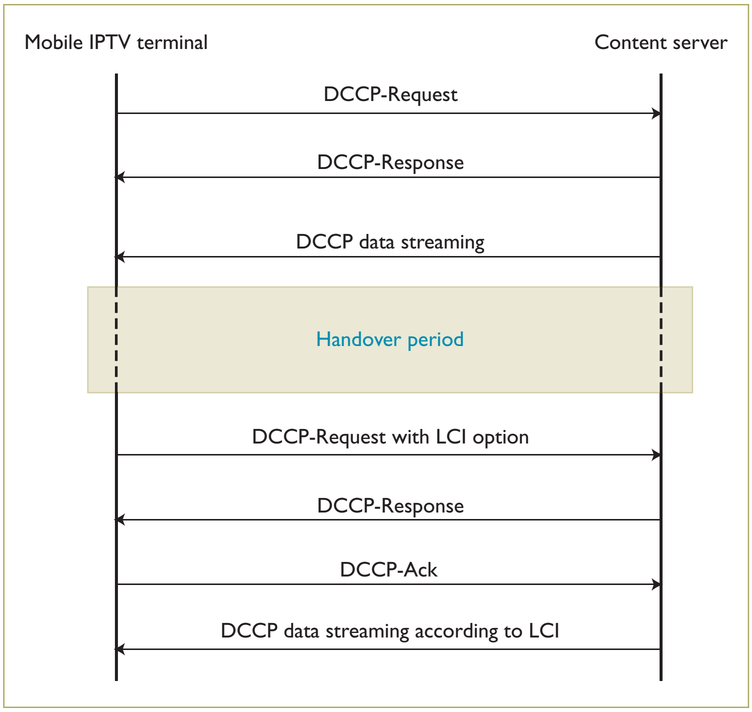

Figure 3. Signaling process for link characteristics information (LCI) delivery using the Datagram Congestion Control Protocol. Using the information, the IPTV content server can adjust the sending rate according to the network condition (for example, handover).

Upon receiving the DCCP-Request message, the IPTV content server extracts the Gencon-ID included in the message and prepares for data communication with the mobile IPTV terminal. During this time, the IPTV content server analyzes the mobile IPTV terminal's network information contained in the LCI option.

Based on the LCI option's content, the IPTV content server can determine the congestion-window size that early data communication used since the handover by comparing it with the standard congestion-window size. After data communication begins, the congestion-window size increases continuously until it reaches the optimal size.

Using the result from the LCI analysis, the application adjusts the sending rate. For example, the application increases the sending rate if the new network's link status is better than the previous one, which results in increased throughput. The application decreases the sending rate if the new network's link status is worse than the previous one, which results in reduced packet loss.

Performance evaluation and comparison. We evaluated QoS performance in two cases: before and after employing the LCI option. The Linux kernel (version 2.6.16) embodies DCCP, which uses congestion control identifiers (CCIDs) 2[10] and 3.[11] We used CCID 2 and detailed scenarios for performance evaluation and comparison.

After a mobile IPTV terminal establishes a communication channel with the IPTV content server using the DCCP protocol, the IPTV content server sends data to the mobile IPTV terminal. After some time, the mobile IPTV device performs the handover to move to a new access network. The types of movement include WLAN-to-LAN (the low- and high-bandwidth networks in Figure 2, respectively) and LAN-to-WLAN. We measured the performance in all cases.

Figure 4a shows data throughput from a case in which the mobile IPTV terminal moves from a high-bandwidth network to a low-bandwidth network. Data throughput equals the amount of data received for stabilization time divided by stabilization time. As the figure shows, the data throughput measured without using the LCI option is about 1.87 megabits per second, and the data throughput measured using the LCI option is about 6.64 Mbps. Using the LCI, the stabilization time decreases, and the data throughput increases more than three times, as Figure 4 shows.

Using an RTP/RTCP LCI Extension

To provide the mobile IPTV user with seamless services, this approach newly defines the transmission of RTP/RTCP feedback (FB) messages, including the network-link characteristics. We provide QoS support at the application level using the RTCP FB message, which is designed to transport application-defined information (see Figure 5).

The mobile IPTV terminal notifies the server of its network-link characteristics via the RTCP FB message if either the network-link characteristic is changed without handover or handover occurs to another network (either vertical or horizontal). The mobile IPTV server should adapt the transmission behavior according to the current link condition.

Detailed signaling procedure. The LCI includes the link characteristics of the current network, where the mobile IPTV terminal is attached, or the new network, where the mobile IPTV terminal will move. The RTCP FB message carries the LCI.

LCI transmission involves four general steps.

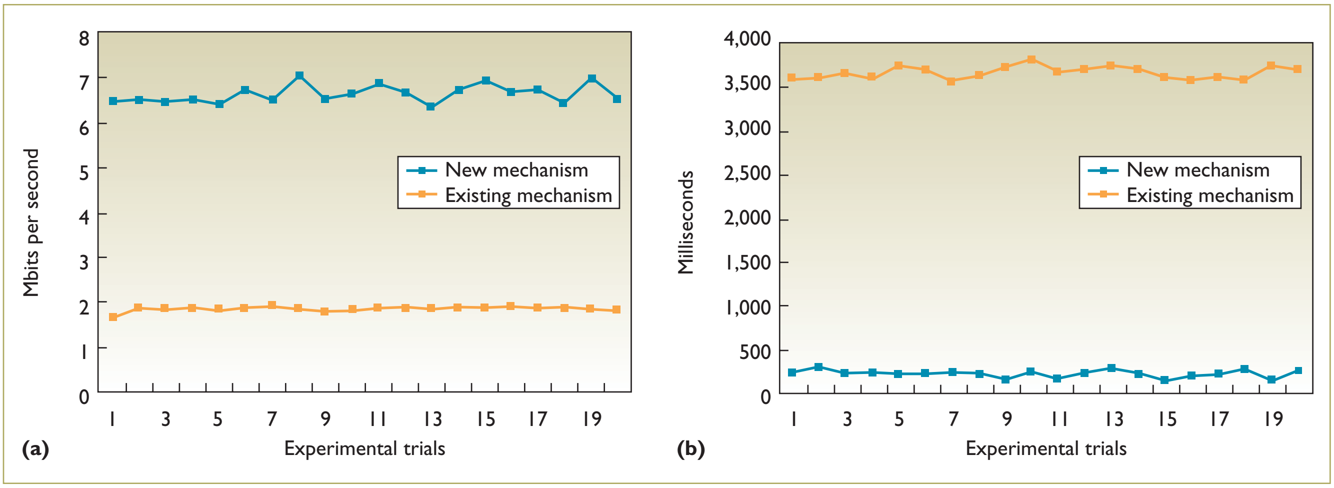

Figure 4. Comparing data throughput and stabilization time using the Datagram Congestion Control Protocol. (a) Data throughput increases and (b) stabilization time decreases.

First, using a low-layer (layer 2) triggering event, the mobile IPTV terminal detects the link status on the basis of the number of users in the link and handover occurrence. For instance, the increased number of users might cause increased traffic and therefore reduce the available network bandwidth. Handover to another network might also cause a change in the link characteristics. The system detects these link characteristics at the low layer (layer 2) and delivers the information to the high layer, RTCP, as an event.

Next, upon receiving the event, RTCP sends the RTCP FB message containing the LCI to the IPTV content server. In case of handover, the information will be the new network's link characteristics. Then, upon receiving the RTCP FB message, the IPTV content server prepares to adjust its transmission behavior according to the link characteristics of the network where the mobile IPTV terminal is attached and sends a response to indicate that the preparation is complete.

Finally, for the sake of reliable QoS, especially in case of handover, the mobile IPTV terminal moves to another network after receiving a response from the IPTV content server. This can reduce the signaling and data transmission delay because the content server can adjust the sending rate in advance of handover. If the response is delayed, the mobile IPTV terminal performs handover first and then retransmits the RTCP FB message.

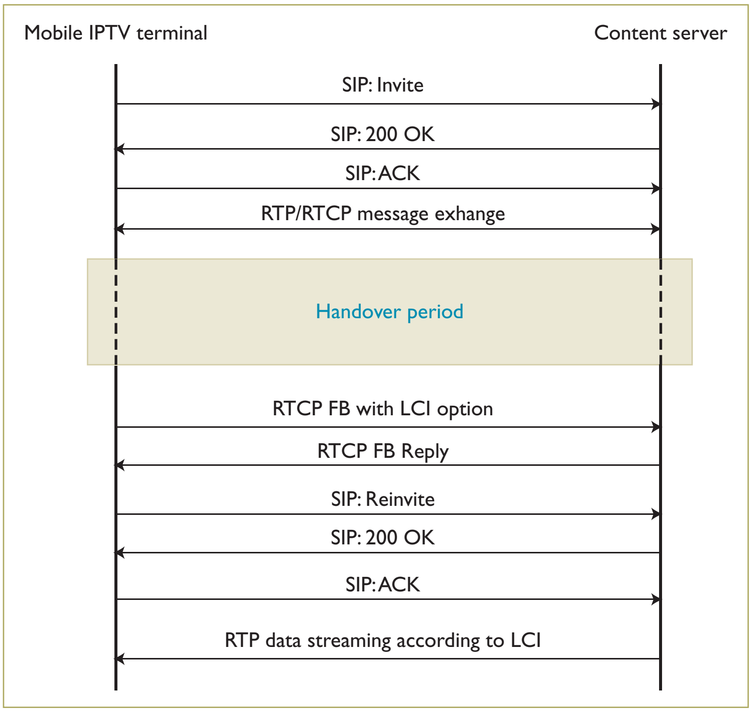

Figure 5. Signaling process for link characteristics information (LCI) delivery using Real-Time Transport Protocol/Real-Time Transport Control Protocol. Using the information, the IPTV content server can adjust the sending rate according to the network condition (for example, handover).

Performance evaluation and comparison. In our implementation, the mobile IPTV terminal and the IPTV content server establish a session using the Session Initiation Protocol (SIP). The IPTV content server's initial transmission rate is unchanged until the mobile IPTV terminal notifies the server of its changed link status. To verify LCI delivery's usefulness, we measured the following two parameters:

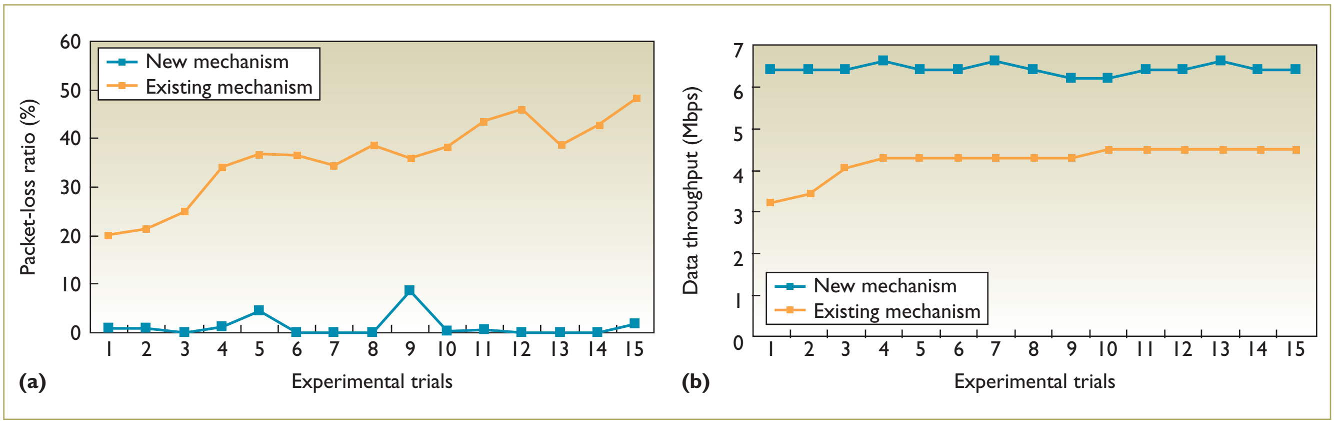

Figure 6. Link characteristics information (LCI) delivery's value. We measured (a) packet-loss ratio using the Real-Time Transport Protocol (RTP) and (b) data throughput using RTP with and without LCI notification.

- Packet-loss ratio (%) = (the number of packets the sender transmits – the number of packets the receiver receives) / the number of packets the sender transmits) × 100.
- Data throughput (bits per second) = (the number of packets the receiver receives × the number of bits per packet) / the measurement time in seconds).

We measured the packet-loss ratio when the receiver (mobile IPTV terminal) moved from LAN to WLAN, and the data throughput when the receiver moved in the reverse direction — that is, during handover from WLAN to LAN. Because measuring handover performance isn't this experiment's focus, we ignored packets lost during handover. We measured the packet-loss ratio and data-throughput parameters 15 times in two cases: handover without notification of LCI and handover after transmitting LCI. Figure 6 shows the measurement results.

For RTP/RTCP implementation, we used Vovida SIP-1.5.0, which comprises SIP and RTP/RTCP. In this implementation, the session is established between the sender (IPTV content server) and the receiver (mobile IPTV terminal) through SIP. We added the mobility support function to the existing implementation.

With the existing mechanism in which the mobile IPTV terminal doesn't send its LCI, the packet loss is approximately 40 percent when the terminal moves to WLAN from the higher-speed LAN. When the mobile IPTV terminal moves to the higher-speed LAN from WLAN, data throughput is about 4.22 Mbps, which is lower than the available capacity. Our proposed mechanism resolves the problems of high packet loss and low data throughput. As Figure 6 shows, the packet-loss ratio drops to 1.23 percent in WLAN, and the data throughput increases to 6.43 Mbps in LAN.

Technical issues and work items remain for mobile IPTV standardization. First, although our proposed mechanism, based on DCCP and RTP/RTCP options, works well in the mobile environment, it's not currently interoperable with systems that implemented the DCCP and RTP/RTCP specifications. Wider use of the LCI option will require its standardization, particularly for DCCP and RTP/RTCP. Second, as mobile IPTV standardization accelerates, the requirements might change.

Other more general suggestions for future work include defining a common framework for obtaining the dynamic network link characteristics information from various mobile IPTV devices. Also, further experiments should compare vertical handover scenarios, such as WiMAX and WLAN, WLAN and cellular, and WiMAX and cellular.

Given the link information in the LCI option, the mobile IPTV content server must use a scalable media format, such as H.264 Scalable Extension or MPEG Scalable Video Coding. We used our own scalable solution based on MPEG-4, which is composed of frames. Finally, our experiments focused on measuring packet loss and throughput performance. Future studies should consider other performance aspects, such as latency. Moreover, there should be a way to provide protection from misbehaving users reporting unnecessary network information to the mobile IPTV content server.

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