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SERIES F: NON-TELEPHONE TELECOMMUNICATION SERVICES

Audiovisual services

Requirements for low-latency interactive multimedia streaming

Recommendation ITU-T F.746.1

International Telecommunication Union

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Recommendation ITU-T F.746.1

Requirements for low-latency interactive multimedia streaming

Summary

Recommendation ITU-T F.746.1 describes the major functions and their interactions for low-latency interactive multimedia streaming (LIMS). The scenarios and requirements are also identified in this Recommendation.

Desktop and client-server applications can be provided to users through LIMS. The desktop application software and client software of client-server applications are deployed in the LIMS platform (server) and the outputs of the applications are delivered back to users as media streams.

In such a way, the traditional data storing, computing and graphic processing tasks are offloaded from user devices to LIMS servers. Provided the interaction delay is kept low, LIMS can provide the same experience to end users with less powerful devices.

The output of one instance of the application can be encoded into different audio and video formats, which can be sent to one or more user devices simultaneously. That means the application can be used continuously when the user switches from a powerful device such as a high-end computer to a less powerful device such as a mobile phone or vice versa.

Since the software is no longer installed in the user device, easier deployment, maintenance and upgrade of the software is possible in the centrally-managed LIMS servers are much easier than before. If needed, it is easy to provide centralized management capability to fulfil the requirements of enterprises, such as single sign-on and access control.

It is very difficult to hack an application provided through LIMS. Furthermore, software reverse engineering is no longer possible, which is useful for the protection of intellectual property rights.

Since the delay of interaction with the application has a major impact on the user experience, it is critical for LIMS to keep the interaction delay in a range that the end user is willing to tolerate.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T F.746.1	2014-10-14	16	11.1002/1000/12225

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Interactive multimedia streaming, low-latency, service provider.

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FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

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In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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1 Scope

This Recommendation identifies the functions, scenarios and requirements for low-latency interactive multimedia streaming (LIMS).

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T H.263] Recommendation ITU-T H.263 (2005), *Video coding for low bit rate communication.*

[ITU-T H.264] Recommendation ITU-T H.264 (2013), *Advanced video coding for generic audiovisual services.*

[ITU-T H.265] Recommendation ITU-T H.265 (2013), *High efficiency video coding.*

[ITU-T T.81] Recommendation ITU-T T.81 (1992), *Information technology – Digital compression and coding of continuous-tone still images – Requirements and guidelines.*

[ITU-T T.87] Recommendation ITU-T T.87 (1998), *Information technology – Lossless and near-lossless compression of continuous-tone still images – Baseline.*

[ITU-T T.800] Recommendation ITU-T T.800 (2002) | ISO/IEC 15444-1:2004, *Information technology – JPEG 2000 image coding system: core coding system.*

[ISO/IEC 14496-3] ISO/IEC 14496-3 (2009), *Information technology – Coding of audio-visual objects – Part 3: Audio*.

3 Definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 application server: A device composed of the server software of a client-server application as well as the hardware and software environment to support it.

3.2.2 low-latency interactive multimedia streaming (LIMS): A service used to provide the applications to users as interactive media streams.

3.2.3 low-latency interactive multimedia streaming (LIMS) client: A device used to collect the user commands and send them to the LIMS server as well as display the media stream from the LIMS server.

3.2.4 low-latency interactive multimedia streaming (LIMS) platform communication module: A module used to receive user commands from the LIMS client and send them to the LIMS proxy service module as the input of application logic.

3.2.5 low-latency interactive multimedia streaming (LIMS) proxy service module: A module used to provide the software environment for desktop application software or the client software of client-server application. It is also responsible for forwarding the user commands from the LIMS platform communication module to the application, and sending the output of the application to the LIMS visualization and compression module.

3.2.6 low-latency interactive multimedia streaming (LIMS) server: A device composed of the LIMS platform communication module (LPC), LIMS proxy service module (LPS), LIMS visualization and compression module (LVC) and LIMS stream service module (LSS).

3.2.7 low-latency interactive multimedia streaming (LIMS) stream service module: A module used to receive audio and video streams from the LIMS visualization and compression module and stream the mixed media stream back to the LIMS client.

3.2.8 low-latency interactive multimedia streaming (LIMS) visualization and compression module: A module used to convert the output of application into images and audio data and encode them into video streams and audio streams.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AAC	Advanced Audio Coding
ALS	Audio Lossless Coding
CPU	Central Processing Unit
DDoS	Distributed Denial of Service
GPU	Graphical Processing Unit
HID	Human Interface Device
LIMS	Low-latency Interactive Multimedia Streaming
LPC	LIMS Platform Communication
LPS	LIMS Proxy Service
LSS	LIMS Streaming Service
LVC	LIMS Visualization and Compression
MPEG	Motion Picture Experts Group
PC	Personal Computer
TV	Television
USB	Universal Serial Bus
VoD	Video on Demand

5 Conventions

In this Recommendation the following conventions are used:

– "Shall" indicates a mandatory requirement.

– "Should" indicates a suggested but optional course of action.

– "May" indicates an optional course of action rather than a recommendation that something take place.

6 Introduction

In a low-latency interactive multimedia streaming (LIMS) system, a user's experience of one application is the display of an interactive media stream customized for him/her.

The various functions and modules required by a LIMS system are shown in Figure 6-1.

The LIMS client collects the user inputs from devices such as a keyboard, pointing device or any other input device and transfers them to the LIMS server as user commands.

The LIMS platform communication (LPC) module of the LIMS server relays the user commands to LIMS proxy service (LPS), which are used as the input of the application software. Besides providing the input and output channels, the LPS is also responsible for providing all the necessary software environment and resources for the application software, which might be the software of desktop applications or the client software of client-server applications.

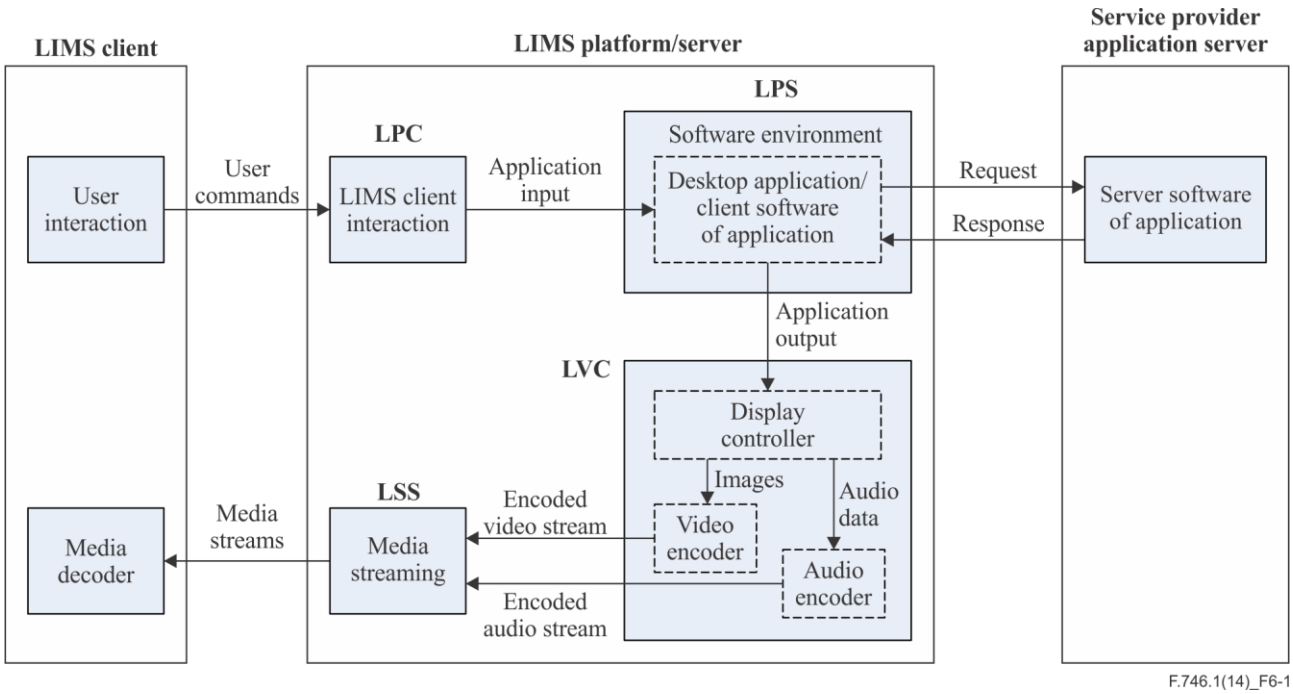

Figure 6-1 – Framework of a LIMS system

The commands are then processed by the application logic, which is part of the standalone desktop program or the server software of a client-server application.

The output is then processed by the display controller. Usually a graphical processing unit (GPU), of LIMS visualization and compression (LVC) module shall convert the visual information into images and an audio driver shall convert the audio information into audio data. The images and audio data shall be compressed by the video encoder and audio encoder respectively. The resulted audio stream and video stream shall be sent to LIMS streaming service (LSS), which delivers the mixed media stream back to the LIMS client. Finally, the LIMS client decodes the media stream and displays the audio and video contents to the user.

The software including a standalone program of a desktop application and the client part of a client-server application is not installed in the user devices as before. That means a user device will not execute the application logic as well as most of the graphic processing tasks. The tasks left to the user device are collecting the user inputs/commands from the keyboard, mouse as well as other input

devices and forwarding them to the LIMS server, and displaying the media streams which is the output of the application sent back from the LIMS server.

The software is deployed in the LIMS servers and the output of application logic is sent to the display controller for further processing, in which case GPU rendering and audio processing might be involved. The output images from display controller might be encoded or compressed into different formats, such as lossy and lossless JPEG formats [ITU-T T.81], [ITU-T T.87] or JPEG 2000 format [ITU-T T.800]. The output images are further encoded into video sequences. Many video codec standards are available, such as [ITU-T H.263], [ITU-T H.264], [ITU-T H.265]. Both lossy digital audio compression and lossless audio compression codec standards are available, such as advanced audio coding (AAC) and MPEG-4 audio lossless coding (ALS) [ISO/IEC 14496-3].

There are several protocol stacks can be used to provide media content streaming service, such as the RTSP/RTP/RTCP [b-IETF RFC 2326], [b-IETF RFC 3550] stack.

The audio and video codecs, as well as the streaming service, should be chosen according to the processing power of the LIMS server, the bandwidth of network as well as the processing resources of the LIMS client.

Since computing and graphic processing tasks are offloaded from user devices to the LIMS server, the LIMS client could be much less powerful than an off-the-shelf PC with a multiple-core CPU, multiple-gigabytes memory and multiple-gigabytes storage. Even with a less powerful CPU and lower memory frequency, the LIMS client still could have the similar experience if the interaction delay is low or is tolerable for the user experience.

Since all the graphic processing and video encoding tasks are fulfilled in the LIMS servers, the application output could be encoded into multiple audio and video streams with different formats and sent to different LIMS clients (user devices) simultaneously. It is easy to support multi-cast applications such as videoconferencing and multi-player games.

Besides the benefits brought to end users, service providers could also benefit from LIMS. First of all, rather than being deployed on all kinds of user devices, software programs can now be deployed in the centrally managed LIMS servers. It is much easier to deploy new software or upgrade and maintain the installed software.

In LIMS, all the applications are provided by the LIMS server. If needed, it is easy to provide a centralized management capability to fulfil the requirements of the enterprise, such as single sign-on and access control. A user is allowed to log in to the LIMS platform once and be authenticated to access to all the applications and resources without being prompted to log in again at each of them, i.e., the using of applications and resources does not require further authentication processes. Furthermore, all the data and transaction logs are commonly saved in the LIMS platform. This builds a centralized data backup, which can be shared among the enterprise under a particular security policy.

The LIMS platform provides enhanced security protection for the applications. When trying to hack an application delivered by LIMS, a hacker has to analyse the media stream. Most information about the application is unrecoverable based on the LIMS media stream. Hacking of the application is extremely difficult, if not impossible. Even if some sensitive information, such as usernames, might be recoverable, all the information sent from the LIMS platform is encoded by the video and audio codec. Since it is very hard to analyse such media streams, it will be extremely difficult to hack a password by a brute force attack. Compared with protecting many personal computers against distributed denial of service (DDoS) attacks, the deployment of DDoS protection on the LIMS platform is much easier and more effective. As the user receives only a media stream, it is relatively easy to keep sensitive information readable and keep it from being copied. Furthermore, software reverse engineering is no longer possible which is useful for the protection of intellectual property rights.

A LIMS system shall collect the user inputs, forward them to the LIMS server, execute the application logic, accomplish audio and graphic processing, encode the audio and video streams and stream the mixed audio/video media stream back to the user. To ensure a good user experience, the sequential execution of these operations, one after another, should be completed very quickly. The interaction delay shall be low enough so that it is tolerable. Different applications have different thresholds for maximum tolerable delay. Appendix I shows experimental results of the tolerable delay for average users of several applications. Further experimental results may be available in the future.

7 Scenarios for LIMS

7.1 LIMS for enterprise application delivery

An enterprise can provide all of its business applications to its employees or customers via LIMS, no matter what kind of application they are.

By doing so, the following LIMS characterized use cases can be provided.

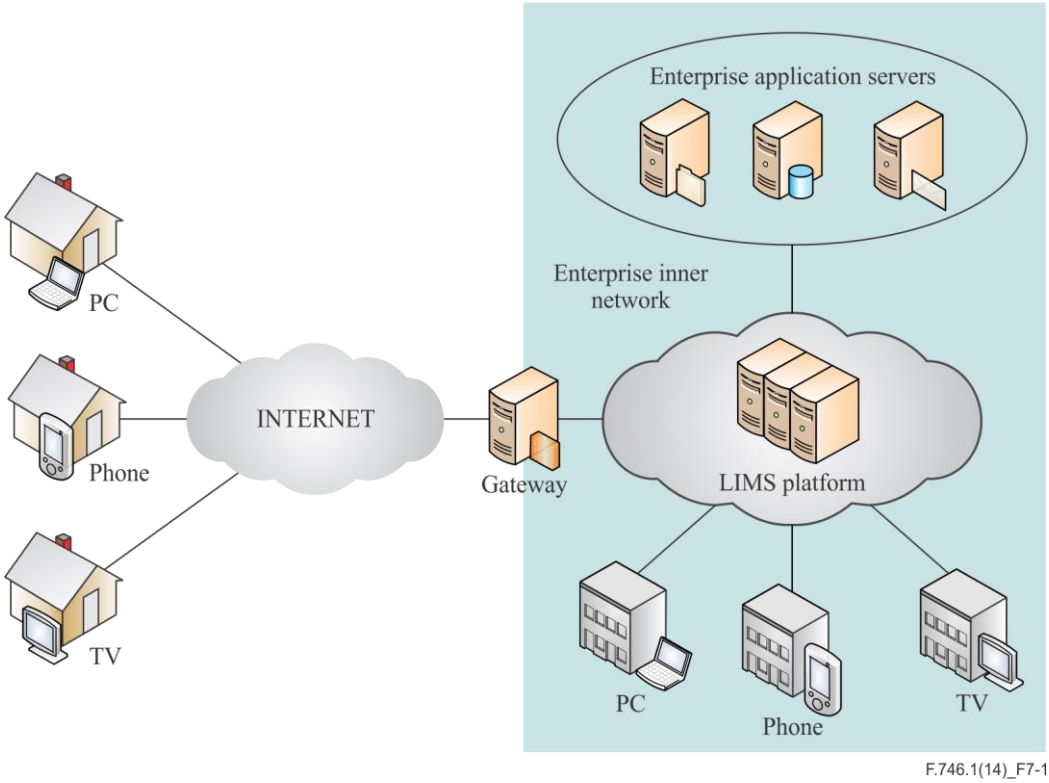

Figure 7-1 – Scenario of LIMS for enterprise application delivery

7.1.1 One platform to deliver all applications

The LIMS platform can support the delivery of any application.

When the enterprise deploys a new application, it just needs to deploy it to the application server(s), connect the new servers to the LIMS platform, and create the appropriate configuration and test the application on the LIMS platform before release.

7.1.2 Multiple terminal supporting for an application

For applications allowing simultaneous access to multiple users, each user accessing the service may use a different kind of terminal.

When developing an application, the developer does not need to consider the adaptation of different terminals. The terminal adaptation problem can be solved by the LIMS platform. Once the application is deployed on the platform, it can be used seamlessly across multiple devices, such as personal

computers (PCs), phones and television (TV) sets. The usage of any application is not limited by the computing or storage resource on the terminal, except that all LIMS-enabled terminals shall support media stream playback.

If a user suspends an application on a terminal, e.g., a notebook, the application can be resumed from any terminal, starting right from the stop point.

7.1.3 Customizable unified client

A unified client is provided to the users, either employees or customers. With this client, a personal portal that can be customized by the user is provided. This portal provides users with consistent service experience. In other words, no matter what kind of terminal is used, the service remains unchanged from the view point of the users.

Through this portal, the user can access all the applications and resources provided by the enterprise. The addition of new applications, the removal of old applications or the software upgrade of existing applications requires no modification to the unified client.

7.2 LIMS for application delivery service

By deploying the LIMS platform in the Internet, commercial LIMS application delivery service can be provided. Besides the use cases listed in clause 7.1, in this scenario, the use cases listed in the following subclause can be supported.

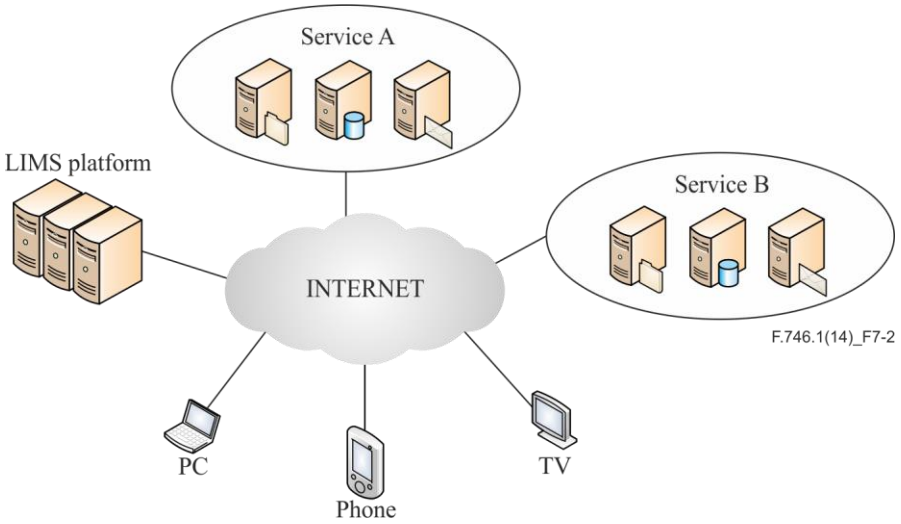

Figure 7-2 – Scenario of LIMS for application delivery service

7.2.1 Trial service

As the application delivered by the LIMS platform can be used without download and installation process, it is convenient for an application to be released for trial. At the beginning, a user can, for example, use a free 30-day trial of this application. At the conclusion of the trial period, the user is then required to pay for further usage. As there is no need to download and install software, such trial service is more convenient for end users.

7.3 LIMS for family application delivery

A service provider for family entertainments can provide video interaction applications to its clients based on LIMS, as shown in Figure 7-3.

By doing so, besides the use cases listed in the previous clauses, the following LIMS characterized use cases can be provided.

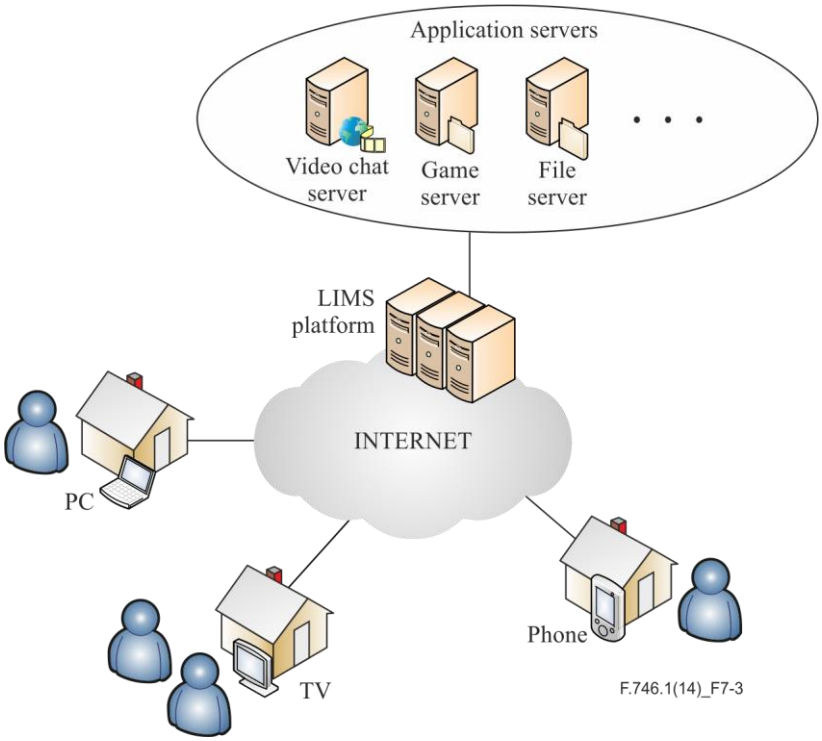

Figure 7-3 – Scenario of LIMS for family application delivery

7.3.1 Family entertainment service

The LIMS platform provides entertainment applications for family users, for example the online game service. Individual users in a family can play any game application deployed in the LIMS platform. Multiple users either within the same house or staying in a different location can play the same game with different terminals simultaneously. When a user plays the game, the game audio and video can be recorded and transformed to media streaming for video on demand (VoD), to be watched by other people.

7.3.2 Family multimedia communication service

LIMS enables novel multimedia communication for its users:

– On the one hand, users can transmit their portraits, along with their voices and text messages, to a chat application server deployed in the LIMS platform. All audio, video and text are combined to create media streams that are then distributed to all users;

– On the other hand, users can simultaneously run more than one application deployed in LIMS, i.e., game and drawing applications, where the views from the applications can also be mixed with the user videos and text messages.

8 Requirements for LIMS

This clause addresses the requirements for LIMS services. The description of the following requirements takes the framework shown in Figure 1 as a reference.

8.1 General requirements

GEN-01: A LIMS system shall have one or multiple LIMS clients and one LIMS platform. It may have a set of interfaces to the service provider/application server.

GEN-02: A LIMS system should provide applications to its users transparently. That is, the adoption of the LIMS technique should introduce no change to the user experience of an application, such as its user interface and process.

GEN-03: Messages for management shall be exchanged between the LIMS client and the LIMS platform for supporting LIMS client registration, end user registration, application discovery, end user authorization as well codec selection.

GEN-04: There shall be enough bandwidth between one LIMS client and the LIMS platform to satisfy the requirements of the media stream being sent from LIMS platform to the LIMS client. The interaction delay shall be sufficiently low to guarantee a similar user experience no matter what kind of terminal or network is used.

GEN-05: A LIMS system may adopt either a centralized or a distributed architecture. For example, a local company may deploy LIMS centralized, and a multinational company may need distributed LIMS deployment.

8.2 Client-side requirements

CLI-01: A LIMS client shall decode the mixed audio/video streams sent from the LIMS platform.

CLI-02: A LIMS client shall collect the user inputs and transfer them to the LIMS platform.

CLI-03: A LIMS client shall register itself to the LIMS platform.

CLI-04: A LIMS client shall register the end user which is the owner of the client to the LIMS platform.

CLI-05: A LIMS client shall have the capability of discovering the applications installed in the LIMS platform.

CLI-06: A LIMS client shall have the capability of choosing the audio and video codecs.

8.3 Platform-side requirements

PLT-01: A LIMS platform shall provide the software environment required by application software. The software environment for a particular application may include the operating system, the database system, specific development tools or compiler. The installation, uninstallation and upgrade of application software shall be supported.

PLT-02: A LIMS platform shall relay the user commands from the LIMS client to the application logic.

PLT-03: A LIMS platform shall process the output of the application logic and encode the resulting images and audio data into video and audio streams according to the codec requirements of the LIMS client and the available bandwidth between them.

PLT-04: A LIMS platform shall deliver a mixed media stream to the LIMS client.

PLT-05: A LIMS platform should support the registration of the LIMS client.

PLT-06: A LIMS platform should support the registration of the end user.

PLT-07: A LIMS platform should provide the information of the applications to the LIMS clients.

PLT-08: A LIMS platform should authorize or reject the requests for using applications from LIMS clients.

PLT-09: A LIMS platform should provide the capability of logging all the instructions issued by a user as well as the output of the application logic.

PLT-10: A LIMS platform may support single-sign-on. After login to the LIMS platform, the access to every application should not require further login.

PLT-11: A LIMS platform should support application management. It should allow the loading, updating, suspending and removing of an application. It should support collecting the usage statistics for an application.

PLT-12: A LIMS platform should support multiple service providers concurrently. It shall support the communication between service providers and the client parts of client-server applications installed in the platform.

8.4 Requirements for the service provider side

SP-01: LIMS should support applications from different service providers (application server). No extra development of the server software of client-server applications should be required.

SP-02: Service providers may require the LIMS system to provide usage information about their applications, such as the number of online users and their usage, etc.

8.5 Codec requirements

COD-01: The LIMS implementation shall encode both audio and video streams in a very short time. Several issues affect the encoding delay limitation, such as the applications supported, the service coverage of the system and the underlying bandwidth conditions, etc. The time limitation varies among different use cases. The experimental results of the tolerable delay for average users of several kinds of applications are shown in Appendix I, which may be used as a reference to set the time limitation of the audio and video codecs used.

COD-02: To avoid unpredictable congestion caused by instantaneous high traffic load, the LIMS implementation should choose the codecs which generate stable bitrate traffic load.

COD-03: To adapt to the changing network conditions, the codec system shall generate streams with different rates. Each quality class of the mixed audio/video stream is optimized for a specified range of available network bandwidth. The LIMS implementation changes the audio/video rate (quality) according to the available network bandwidth and the requirement of the LIMS client.

COD-04: To guarantee low latency required by interactive applications, the codec system may adjust the number of data buffered. Generally, the more data are buffered, the more the delay introduced by a codec is.

COD-05: The LIMS platform shall support multiple users simultaneously. Interference between different streams is strictly prohibited.

8.6 Security requirements

SEC-01: A LIMS system shall protect its users' privacy. As all information of a user is being stored on the platform, appropriate methods shall be deployed on the platform to protect users' privacy. At the same time, some authentication and confidentiality methods should be deployed between a LIMS client and the platform.

SEC-02: Appropriate authorization methods should be deployed to prevent unauthorized access to user data and multimedia streams.

SEC-03: Appropriate data recovery methods should be deployed to prevent a LIMS system from data loss caused by unpredictable environmental disaster. For the multimedia streams generated by the LIMS platform, an appropriate backup and recovery scheme should also be adopted.

SEC-04: Appropriate methods should be deployed to prevent attacks targeted at the LIMS platform.

SEC-05: Appropriate high availability architecture may be adopted to provide reliable service to the users.

Appendix I

An experiment for measuring the delay tolerance level of various applications

(This appendix does not form an integral part of this Recommendation.)

Subjective evaluations were carried out to evaluate how users felt about multiple applications under different delay conditions. A standardized opinion questionnaire was used throughout the evaluation.

I.1 Testing environment

Server (APP-HOST): One PC with Windows XP was used as server, with universal serial bus (USB) driver and human interface device (HID) server. Multiple applications were running on the server. One delay toolset was installed to introduce extra delay to the running applications.

Client: One PC, with USB client delay toolset, mouse and keyboard installed, was used for the Client.

Connectivity: Two computers were connected using a crossover cable.

Interactions: The motion of the mouse of the client was sent to the server and translated into the motion of a pointer on the display of the server, and other operations of the mouse, such as clicking or hovering were then used as the input of the running application. The input of the keyboard of the client was also sent to the server and used as the input to the running application.

Aim: Before being sent to the application on the server, the input message of the mouse and keyboard from the client was delayed according to pre-set parameters. Users evaluated the experience of multiple applications under different added delays.

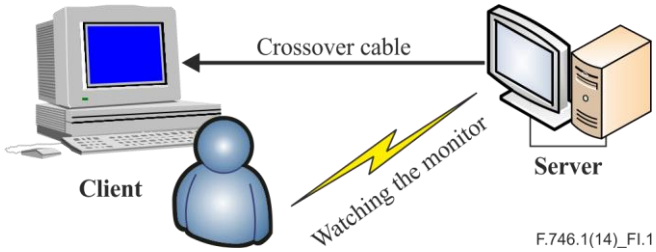

Figure I.1 – Test environment

I.2 Extra delay imposed and applications tested

I.2.1 Extra delay imposed

The extra delay added in test was in the range of 0 ms to 320 ms.

The maximum step size of the added delay was 40 ms.

I.2.2 Applications tested

To be impartial to all applications, the actual names of the tested applications were removed:

1) Casual games: CG1, CG2;
2) Word processing: WP1, WP2;
3) Video-on-demand: VoD1, VoD2, VoD3;
4) Web browsing: WB1, WB2, WB3;
5) Real-time strategy games: RTS1, RTS2, RTS3;
6) Role-Playing game: RPG1, RGP2;
7) Racing game: RG1, RG2;

8) Fighting game: FG1.

I.3 Test solutions

Fifty users who attended the test were given standardized questionnaires to fill their subjective evaluation for each application under different added delay conditions. There were three options in the questionnaire: significant delay (unacceptable), delayed but acceptable, timely (satisfactory). The operational procedures for different applications are given as follows.

1. Casual games: CG1, CG2
   - Log in CG1 or CG2 with your own account and password.
   - Play your favourite game.
2. Word processing: WP1, WP2
   - Create a new file.
   - Input a paragraph of 100 or more words.
   - Edit the paragraph.
3. Video-on-demand: VoD1, VoD2, VoD3
   - Click the shortcut to the program.
   - Search for your favourite movies.
   - Watch one movie for at least 5 minutes.
4. Web browsing: WB1, WB2, WB3
   - Click the shortcut to the web browser.
   - Input a URL in the address bar.
   - Browse the opened website for at least 5 minutes.
5. Real-time strategy games: RTS1, RTS2, RTS3
   - Play the game for at least 10 minutes.
6. Role-playing game: RPG1, RPG2
   - Play the game for at least 10 minutes.
7. Racing game: RG1, RG2
   - Play the game for at least 10 minutes.
8. Fighting game: FG1
   - Play the game for at least 10 minutes.

Table I.1 – Extra delays imposed in the group of tests

# of Test	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Extra delay added (ms)	0	40	80	120	160	200	240	280	320

NOTE – When the extra delay is set to zero, the original delay of the input message, i.e., from the time of clicking of the mouse to the time of clicking message arriving at the application, was about 30 to 40 ms.

I.4 Test results

In the following tables, for a given extra delay, the number in the second row represents the number of users who chose *significant delay (unacceptable)* in the questionnaire of the corresponding test, the number in the third row represents the number of users who chose *delayed but acceptable*, and the number in the fourth row represents the number of users who chose *timely (satisfactory)*.

Table I.2 – Test results for casual games (CG1 and CG2)

Extra delay added (ms)	0	40	80	120	160	200	240	280	320
Significant delay (unacceptable)	0	0	0	0	9	35	50	50	50
Delayed but acceptable	0	17	38	48	41	15	0	0	0
Timely (satisfactory)	50	33	12	2	0	0	0	0	0

Table I.3 – Test results for word processing (WP1 and WP2)

Extra delay added (ms)	0	40	80	120	160	200	240	280	320
Significant delay (unacceptable)	0	0	0	0	3	32	39	42	49
Delayed but acceptable	0	0	19	37	46	18	11	8	1
Timely (satisfactory)	50	50	31	13	1	0	0	0	0

Table I.4 – Test results for video on demand (VoD1, VoD2 and VoD3)

Extra delay added (ms)	0	40	80	120	160	200	240	280	320
Significant delay (unacceptable)	0	0	0	0	7	32	39	47	50
Delayed but acceptable	0	2	7	37	39	18	11	3	0
Timely (satisfactory)	50	48	43	13	4	0	0	0	0

Table I.5 – Test results for web browsing (WB1, WB2 and WB3)

Extra delay added (ms)	0	40	80	120	160	200	240	280	320
Significant delay (unacceptable)	0	0	3	4	8	36	45	49	50
Delayed but acceptable	0	2	5	37	40	14	5	1	0
Timely (satisfactory)	50	48	42	9	2	0	0	0	0

Table I.6 – Test results for RTS1, a real-time strategy game

Extra delay added (ms)	0	40	80	120	160	200	240	280	320
Significant delay (unacceptable)	0	0	0	10	13	46	50	50	50
Delayed but acceptable	0	0	34	38	37	4	0	0	0
Timely (satisfactory)	50	50	16	2	0	0	0	0	0

Table I.7 – Test results for RTS2, a real-time strategy game

Extra delay added (ms)	0	40	80	120	160	200	240	280	320
Significant delay (unacceptable)	0	0	0	10	15	8	49	50	50
Delayed but acceptable	0	0	30	36	34	42	1	0	0
Timely (satisfactory)	50	50	20	4	1	0	0	0	0

Table I.8 – Test results for RTS3, a real-time strategy game

Extra delay added (ms)	0	40	80	120	160	200	240	280	320
Significant delay (unacceptable)	0	0	0	4	4	25	37	45	49
Delayed but acceptable	0	6	10	21	37	23	13	5	1
Timely (satisfactory)	50	44	40	25	9	2	0	0	0

Table I.9 – Test results for RPG1, a role-playing game

Extra delay added (ms)	0	40	80	120	160	200	240	280	320
Significant delay (unacceptable)	0	0	0	0	0	0	0	0	0
Delayed but acceptable	0	0	0	0	2	5	6	5	30
Timely (satisfactory)	50	50	50	50	48	45	44	35	20

Table I.10 – Test results for RPG2, a role-playing game

Extra delay added (ms)	0	40	80	120	160	200	240	280	320
Significant delay (unacceptable)	0	0	0	0	3	5	22	40	50
Delayed but acceptable	0	0	2	39	38	42	28	10	0
Timely (satisfactory)	50	50	48	11	9	3	0	0	0

Table I.11 – Test results for RG1, a racing game

Extra delay added (ms)	0	40	80	120	160	200	240	280	320
Significant delay (unacceptable)	0	0	0	0	4	5	12	25	38
Delayed but acceptable	0	1	5	6	19	33	30	23	12
Timely (satisfactory)	50	49	45	44	27	12	8	2	0

Table I.12 – Test results for RG2, a racing game

Extra delay added (ms)	0	40	80	120	160	200	240	280	320
Significant delay (unacceptable)	0	0	0	0	0	0	0	0	0
Delayed but acceptable	0	0	0	0	0	4	5	15	26
Timely (satisfactory)	50	50	50	50	50	46	45	35	24

Table I.13 – Test results for FG1, a fighting game

Extra delay added (ms)	0	40	80	120	160	200	240	280	320
Significant delay (unacceptable)	0	0	0	0	0	0	0	2	28
Delayed but acceptable	0	0	0	0	0	7	17	33	18
Timely (satisfactory)	50	50	50	50	50	43	33	15	4

Bibliography

[b-IETF RFC 2326] IETF RFC 2326 (1998), *Real Time Streaming Protocol* (*RTSP*).

[b-IETF RFC 3550] IETF RFC 3550 (2003), *RTP*: *A Transport Protocol for Real-Time Applications*.

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