INTRODUCTION

A mobile virtual reality service (VRS) will make the presence and presentation of the sounds and sights of an actual physical environment virtually available everywhere in real time through the use of mobile telecommunication devices and networks. Furthermore, the VRS is the conversion of a physical system into its digital representation in a three-dimension (3D) multimedia format. This paper addresses one aspect of the notion of bringing an actual multimedia environment to its virtual presence everywhere in real time. An international telecommunication union (ITU) recommendation document, containing ITU’s visions on mostly forward-looking and innovative services and network capabilities, addresses the capability needed in a telecommunication system to allow mobile access to real-time sights and sounds of an actual physical environment in the contest and forms of a VRS episode.

Presently, the availability of a VRS is limited to fixed-access phenomena in non-real time, for example, entertainment machines and various simulations equipment. There are also some limited fixed-access and real-time services that require low data transmission rates, such as net meetings. In the latter case, a user can experience a limited real-life environment as opposed to the former case of a non-real-life computer-generated environment. These existing virtual reality services do not allow user control in viewing 3D environments, and they are generally limited to viewing images on a monitor in two dimensions. The VRS-capable systems, however, will allow rather 3D...
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representations of remote real-life environments. For instance, a passenger in a
train or in a car could become a participant in a conference call in a 3D
environment or become virtually present among the audience in a concert hall or
sports stadium viewing a live concert or event.

There are a few obstacles and bottlenecks to the realization of such
VRS-capable systems. The development of real-time mobile 3D environments
requires:

• Super-high-speed data transmission rate capability for data streaming.
• Highly complex and sophisticated user equipment for user access, and
• An advanced signaling and controlling data network.

The advanced signaling and controlling data network is for initiating,
establishing, maintaining, and terminating VRS episodes. Exponential increases
in data transmission rates and innovative advances in development of terminal
equipment are paying the way for the provision of the VRS and the creation of
VRS episodes in the near future. Furthermore, the realization of the VRS
assumes that the high-tech industry will deliver super high data rate (SHDR)
transmission equipment offering a transmission speed of equal to or higher than
one gigabit per second to a single user or end point. The anticipated demand for
data transmission speed in 2005 will be higher than 20 M/s, upgraded from
today’s third-generation planned 2 Mb/s. The transmission speed requirements
for the so-called fourth generation systems in 2007 are expected to reach near
100 Mb/s. At these rates, telecommunication equipment should be able to
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transmit, transport, and receive sights and sounds of real-life environment for establishing a VRS episode.

The development of the core signaling and controlling network and its associated software platforms for VRS episode control and for terminal and end-user equipment mobility management is viewed as a major challenge in terms of its control logic and its application programming interfaces for provisioning of the VRS. This paper addresses the core network sub-system for VRS episode control. Several VRS use cases are presented first, and major issues for realization of the VRS are identified. The paper then proposes a solution scheme for the core network signaling and the VRS episode control. The final section of the paper describes an implementation scenario along with an example of signaling flows for establishing and controlling episodes.
PROBLEM STATEMENT

From a users perspective, the VRS is defined as the experience of viewing an object in its 3D environment and sensing its sound with its natural and real-world quality. By limiting the VRS to sight and sound, it is meant to disclaim creation of any other aspects of an actual physical environment, for example, smell of a flower or taste of a food. A few examples of the VRS is listed below:

- A virtual conference session depicting to every participant the presences of others in a virtual conference room with projector screen, drawing board, and so on.
- A virtual movie theaters where a user can view movies with the same feel as being in a movie theater.
- A virtual hospital operation room (OR) where a surgeon can remotely perform an actual operation and/or provide training to assistant surgeons and interns by showing and/or performing actual procedures.
- A virtual concert hall where a conductor can have the virtual presence of all, or a selective number of instruments players participating from all over the world for a rehearsal or actual performance.
- A virtual house, shop, or storage facility where a user can do a security check, identify product availability, or determine inventory levels of various items, respectively.
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- A virtual command center for navigating an aircraft, driving a train, or operating a motor vehicle where the virtual environment is created for the cockpit, the locomotive, or the driver’s seat respectively.

- From a network operator’s perspective, the provision of the VRS is the conversion of the sights and sound of an actual physical system into their virtual representation. For each required case and application, the development of the software platforms for the control and the management of the VRS and in terms of its control logic and application-programming interface is a major challenge. The VRS will include both terminal and personal mobility. It could be set up in a limousine, hotel, airport, home or office. Depending on the type and complexity of the actual system, the estimate for required data transmission rates varies from a minimum of tens of Megabits to a few Gigabits per user or user equipment.

Currently, the availability of the VRS is limited to fixed applications in non-real time, for example, entertainment machines and flight simulators. Some limited feature-fixed real-time services such as video-conferencing and net meetings, which require low data transmission rates, are also offered. However, the mobile, wireless, and real-time accessed sights and their virtual reality presence are still dreams. Major obstacles and bottlenecks to the achievement of such an ambitious goal include:

- Lack of VRS-capable user terminal equipment.
- Inadequate data transmission rates over the air, and
- Absence of efficient and suitable signaling and controlling network elements for initialing, establishing, maintaining and terminating mobile VRS episode.
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The section below addresses the signaling and controlling part of the solution, and proposes a VRS provisioning solution scheme by focusing on the core signaling and controlling network including a high level view of the signaling network architecture and its controlling functional entities. An underlying assumption for this proposed solution is that the high-tech industry will deliver the required SHDR radio transmission capability along with VRS-capable equipment.

Expectedly, the ongoing development activities on the optical capacity problems and the tripling antenna project will find their way into mobile telecommunication equipments in the near future and will alleviate some of the critical bandwidth problem. The requirements for mobile terminal equipment and the radio access network to meet the spectrum and data transmission speed requirements are beyond this section. Furthermore, this services capability may also be restricted in terms of mobility. In its early phases of development, the wireless SHDR transmission capability may be limited to slow-moving terminal equipment. Increases in the data rate in the post-IMT-2000 era could expectedly reach 100Mb/s for indoor access. The proposed solution describes a mobile VRS environment in general and its core network for signaling and controlling of a VRS episode in specific. It presents an overview of the VRS architecture and describes the various entities to perform the task of VRS provisioning. The VRS functional architecture is proposed in full harmony with preceding generations of all-IP multimedia core network functional architectures currently under study and development in the third-Generation partnership project.

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SOLUTIONS

The VRS realization scheme is built upon the development and availability of the following entities:

- Actual physical environment (APE)
- VRS user equipment (VUE)
- VRS access system (VAS) and
- VRS core system (VCS).

The figure presents a schematic view of these entities in a high-level illustration of the VRS functional architecture. In order to describe the VRS realization scheme, its functional architecture, and its components, definition of the following terms is needed.
Figure 1

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VRS EPISODES

A VRS episode is defined as the real-time establishment of sights and sounds streaming communication between one or more VRS users and sites. As a call is the establishment of communication between users in a voice network, and a session is a establishment of communication among severs and client in an IP multimedia network, a VRS episode is the establishment of a collection of calls and/or sessions in a multimedia super-high-capacity virtual reality environment.

ACTUAL PHYSICAL ENVIRONMENT

An actual physical environment (APE) is the real world environment of the subject to be presented (through sight and sound) to one or more VRS users or user equipment. Furthermore, it is the actual subject environment that is transmitted to and audio visually formed in a virtual environment.

VRS USER EQUIPMENT

VRS user terminal equipment (VUE) is the end-point device used by a user to transmit data on an APE and/or to receive data for establishing a VRS episode. The VUE can be in the shape and content of a toolkit such as a single handset, a headset, a helmet, a pair of gloves, a desk, a chair, a keyboard, a mouse, a screen, a video camera, or a recording device. It could also consist of any combination of these toolkits. The VUE is primarily a software-driven
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device and is controlled and/or manned by one or more users, network or both. An example of the VUE may be a setup similar to today’s T1 connection using two pairs of normal twisted wires, the same as one would find in a house or in a private booth. The use this VUE device is essential for both creation and provisioning of desired VRS episodes related to various applications. Another example of the VUE could be the equipment used by a head surgeon in his office environment to remotely guide a group of assistant surgeons performing a surgical procedure in a hospital.

VRS ACCESS SYSTEM

As shown in the figure 1, the VRS access system (VAS) is the intermediate VRS-capable system linking the VUE to the VRS core network system. It is a fix terrestrial or satellite radio access system that provides the mobile VUE with an access to the VRS.

VRS CORE SYSTEM

The VRS core system (VCS) is the controlling backbone network that, in conjunction with the VUE and VAS, manages the establishment of VRS episodes. Depending on the number of VUEs and APEs being used, there could be more than one VCS system involved in establishing a VRS episode. Building upon the session control schemes defined in 3GPP and 3GPP2 standards, the VCS supports many of the homeand-visited concepts that have already been environment in the third generation standards. A visited VCS (V-VCS) for a
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VUE is the core network system to which the VUE is attached. A VCS is labeled as the home VCS (H-VCS) to a VUE if the user has the subscription affiliation with the VCS. A VCS, either home or visited, that is in charge of establishing and managing a VRS episode is called a serving VCS (S-VCS). The two home and visited VCS types are shown in figure 1. A VCS system contains, in addition to other entities, three key VRS functional entities are described below. These functional entities are in addition to other entities and resource functions that may be present in a VRS for the purpose of establishing VRS episodes as well as supporting other services such as second generation calls, third-generation multimedia sessions, third-party value-added services providers.

VRS episode control entity. A VRS episode control entity (VECE) is a functional entity in charge of supporting and/or controlling a VRS episode. In a VRS episode there are two basic types of VECE for a VUE. They are the proxy VECE and the serving VECE. At the time of VUE’s registration with a visited VCS network, a VECE in the visited VC, labeled as a P-VECE is assigned to attend and monitor all requests coming from or going to the VUE. The S-VECE is a VECE in the serving network in charge of controlling the VRS episodes and keeping track of the VUE status. There is a 1-to-n correspondence between the VECE and VUE. During the time that a VRS episode is in progress, the P-VECE does not necessarily remain the same. Depending on the mobility range of the VUE, a handover of the VUE may be performed among several P-VECEs. However, the S-VECE for a VUE remains the same throughout a VRS episode.

In figure 1, the S-VECE represents the serving VECE that is located in the H_VCS is the S-VCS as well. This special handover feature is similar to the session mobility in third generation networks.

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VRS episodes management entity. For a VRS episode, there could be more than one VRS system. A VRS episode may involve a number of VUEs and APEs from a number of geographical positions and with a wide mobility range. Each VUE may be connected to a separate VCS through a separate P-VECE and served by an S_VECE and served by an S-VECE. Furthermore, for a VRS episode, there could be a number of S_VECEs to interact, synchronize, and coordinate. A VRS episode management entity (VEME) is a functional entity that manages a number of S_VECEs for a VRS episode. As such, it coordinates, synchronizes, and maintains all the communications between all S_VECEs for a VRS episode. In a physical implementation, a VEME may be defined as a multimedia management, control, and operations center interfacing with the S_VECE of each VUE participating in a VRS episode. FIGURE 2 shows an example of the VEME located in the H_VCS of the VUE. The VEME may be residing in a V_VCS or S-VCS and co-located with a VECE box or in a separate box. The VEME service may be offered by the third-party application server, which makes use of its underlying VCS capabilities. In such a case, the VEME could be an entity residing either in an independent external platform operated by the third-party service provider.
A schematic implementation of a VRS episode setup.
Figure 2.
GATEWAY ENTITY

The gateway entity (GWE) is a boundary functional entity with each VCS. It is the connecting point of all VECEs in a VCS network from one side and the GWE of another VCS from the other side. It is the point of entry and exit for all VRS episode control signaling message follows to and from a VCS, respectively. In addition, the GWE plays the role of a firewall, hides the structure of its underlying network, and facilities the flow and routing of the VRS signaling traffic. Figure 2 also shows the instance of two GWEs for a hypothetical VRS episode.

VRS IMPLEMENTATION SCENARIO

This section presents an example of the VRS architecture, a configuration scenario for a single VUE and multiple APEs participating in a VRS episode setup and the management of its signaling flows.
VRS SYSTEMS ARCHITECTURE AND CONFIGURATION

Figure 2 presents a schematic implementation of the VRS functional architecture with two primary VCS subsystems, home and visited, for one VUE and several secondary VCS subsystems, each serving one or more APEs. The example in Figure 2 shows only one VUE. However, it could be expanded to include multiple VUEs participating in a single VRS episode. The figure presents a configuration example for establishing a VRS episode. Each arrow in the figure corresponds to a signaling message exchange requesting an action or responding to a request. The VUE is the user equipment initiating a VRS episode setup. The VUE is visiting a network where the P-VECE is its first point of entry into the core network system, a visited V-VCS. For ease of illustration, in this example the H-VCS of the VUE is assumed and shown to be the same as the S-VCS. Therefore, the S-VECE is located in the VUE’s home network. In addition, in this configuration example the VRS episode management entity VEME is assumed to be located in the VCE’s home network.

The actual physical environment (APE) endpoints are shown as scattered globally across many VCS systems. Flows 5a through 5z in figure 2 represents the interactions between the VEME and the S-VECE of various endpoints. The access systems for these endpoints may include fixed and/or mobile systems.
Figure 3 presents the signaling information flows for the procedure to involve and setup a VRS episode based on the configuration shown in figure 2. To keep the figure form being cluttered, a sunny day scenario is assumed and no protocol response action is shown in this figure. Each double-headed arrow in figure 2 corresponds to two message flows or transaction, a request message and a response message. The response message could be simply a protocol response to a request message, acknowledging the request or sending an error message. A brief description of each signaling message flow is given below:

0. After the VUE’s attachment to, and registration with, the visited VCS(V-VCS), and at ground zero, a stimulus flow initiates the procedure for setting up a VRS episode. This is similar to today’s procedure for a 3G-user equipment (UE) procedure for registration with a 3G-multimedia mobile network. Furthermore, it is assumed that the VUE had already been registered with a visited VRS-capable VCS system. This flow is a request by a user to setup a VRS episode and it could be done via an automatic setup or a manually activated request. As a result of this registration procedure, a proxy VECE and a serving VECE are assigned to the registered VUE.
1. (1a and 1b) Initiating the request for establishing a VRS episode to the network via an intermediate access subsystem, the VRS user equipment (VUE) sends a VRS episode request to its service attendant, the P-VECE in the visited VCS network. Parallels may be drawn between these episode request messages and the session invite messages of the sip.

2. (2a, 2b, and 2c) Upon recognizing the request for establishing a VRS episode, the service attendant P-VECE, acting as a proxy VECE for the VUE, forwards the VRS episode setup request via the gateway entities (GWEs) in V-VCS and H-VCS to the S-VECE that is the serving service attendant in the VUE’s home network.

3. [Sub-routine]: The S-VECE sends n information query to the VUE’s service subscription database (SSdb) for the VRS service information, eg, service parameters, service authorization.

4. Recognizing the request for establishing a VRS episode, the S-VECE, after inquiring information on VUE’s subscription profile for service eligibility, sends a request for a VRS episode setup to the VEME. For ease of illustration, the S-VECE’s interaction with other entities in the network for verification of the VUE’s service eligibility, authentication, and service authorization are not shown here.
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5. [Sub-routine]: Using information on the VUE’s VRS subscription, the VEME identifies all end-points involved in the VRS, and dispatches notification requests for the VRS episode setup to various S-VECEs of the actual physical environment (APE) endpoints including those in the VUE’s home network (if any), e.g., APE. As shown by arrows 5a through 5z in figure 2, each S-VECE, acting on the request from the VECE, sends a request to the corresponding P-VECE each APE. In this example, one VUE and several APEs were assumed to be participating in the VRS episode setup as the episode endpoints, originating point and terminating points, respectively.

6. Once all would be participants in the VRS episode have been identified and/or alerted, and affirmative responses have been received by the VEME, the VEME responds positively to the VUE’s S-VECE.

7. (7a, 7b, and 7c) The S-VECE forwards the episode response message to the VUE’s E in the visited network, the V-VCS.

8. (8a and 8b) The P-VECE, in turn, forwards the response message to the VUE.

9. [Sub-routine]: At this point, all necessary protocol acknowledgment and notification have been received. The next move is to have all needed bearers for media transport established and to have the VRS episode setup for the specific VRS delivery.

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The proposed scheme in this paper is not restricted to the use of any specific standard protocol. A number of presently available protocols may be either readily, or with some enhancement, employable for the VRS episode initiation and setup.
CONCLUSION

This paper describes the concept of the VRS and the telecommunication environment for its realization. It identified major challenges for its realization. It calls for an SHDR transmission capability for the end-user equipment and networks. Assuming the availability of an SHDR transmission capability for the end-user equipment and networks, an example of the VRS system architecture was presented, and a systematic approach was proposed for a VRS implementation scenario. It illustrated a VRS control scheme and described the signaling information flows for setting up a VRS episode. This paper neither proposes the use of any specific transport or control protocols for implementation of the required tasks, nor does it restrict the use of any specific standard protocol. A number of presently available protocols may be revised and enhanced for initiating, establishing, and controlling VRS episode.
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APPENDIX

Panel 1. Abbreviations, Acronyms, and Terms

3D—three-dimension
3GPP—3rd Generation Partnership Project
3GPP2—3rd Generation Partnership Project 2
APE—actual physical environment
AS—applications server
GWE—gateway entity
H-VCS—home VCS
ITU—International Telecommunication Union
ITU-R—ITU—Radio communication Sector
ITU-T—Standardization Sector
P-VECE—proxy VECE
SHDR—super-high data rate
SIP—session initiation protocol
SSdb—service subscription database
S-VECE—serving VECE
Ti—digital carrier system for DSi signals
VAS—VRS access system
VCS—VRS core system
VECE—VRS episode control entity
VEM E—VRS episode management entity
VRS—virtual reality service
VUE—VRS user equipment
V-VCS—visited VCS
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ABSTRACT

This paper addresses the capability needed in telecommunication system to support mobile access to real-time sights and sounds of a complex environment defined as a virtual reality service (VRS) episode. The constant development of terminal and networking equipment are paving way for the provision of a VRS and the creation of VRS episodes. This paper describes a mobile VRS environment in general and the core architecture and describes the various entities employed to perform a VRS episode setup task. The proposed VRS architecture is in full harmony with the preceding generation of all-IP multimedia networks currently under study in the third generation partnership project.
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