Seamless Content Delivery over the Future Internet

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Abstract

The Future Internet of things and services is not envisaged to be simply a faster way to go online. What is expected to fundamentally change the way that people use the Internet is the ability to produce, and seamlessly deliver and share their own multimedia content. In this paper, we introduce and analyse innovative architecture components to offer media scalable content delivery, increasing the robustness, enriching the PQoS and protecting the content from unauthorized access over heterogeneous physical architecture and P2P logical overlay network topologies. Technology pillars in which the system is based are described: i.e. Multi-layered/Multi-viewed content coding, Multi-source/multi-network streaming & adaptation, content protection and lightweight asset management.

Keywords

Multi-layered/Multi-viewed content coding, SVC/MVC,Multi-source/multi-network streaming & adaptation, content protection, asset management

1. Introduction

Widespread and affordable broadband access opens up opportunities for delivery of new streaming services, making Information and Communications Technology (ICT) crucial to European growth and quality of life. The Future Internet of things and services is not envisaged to be simply a faster way to go online. What is expected to fundamentally change the way that people use the Internet is the ability to produce, and seamlessly deliver and share their own multimedia content. We expect that in a few years everyone will be multimedia content producer (by publishing digital pictures, video recordings, smart home surveillance, etc.), multimedia content mediator (by storing/forwarding streaming content) and multimedia content consumer (digital television, video on demand, mobile broadcasting and alike).

In this context, we consider the Future Internet of things and services as a dynamic and distributed environment, that enables new services and seamless, scalable and trusted multimedia content delivery, increasing the robustness and resiliency, enriching the PQoS both within the network and/or at the end-user terminal, while protecting the content from unauthorized access over heterogeneous physical architecture and overlay network topologies.

This concept is further elaborated in Figure 1. In case (a), we assume an integrated service/content provider's oriented business model, reflected to the network architecture. The service/content provider is located at the core network and offers streaming A/V services over broadcasting, interactive/on demand networks (including the Internet), and 2G+/3G/4G mobile networks. It is worth to note the great heterogeneity in the network segments characteristics of this approach. In this business model, we assume the capability to distribute resilient, scalable and personalised video streams. Moreover, in case of diverse network paths to a terminal (e.g. multi-access networks), the network may enrich the content either at the network and/or at the end-user terminal, by means of multiple description coding.

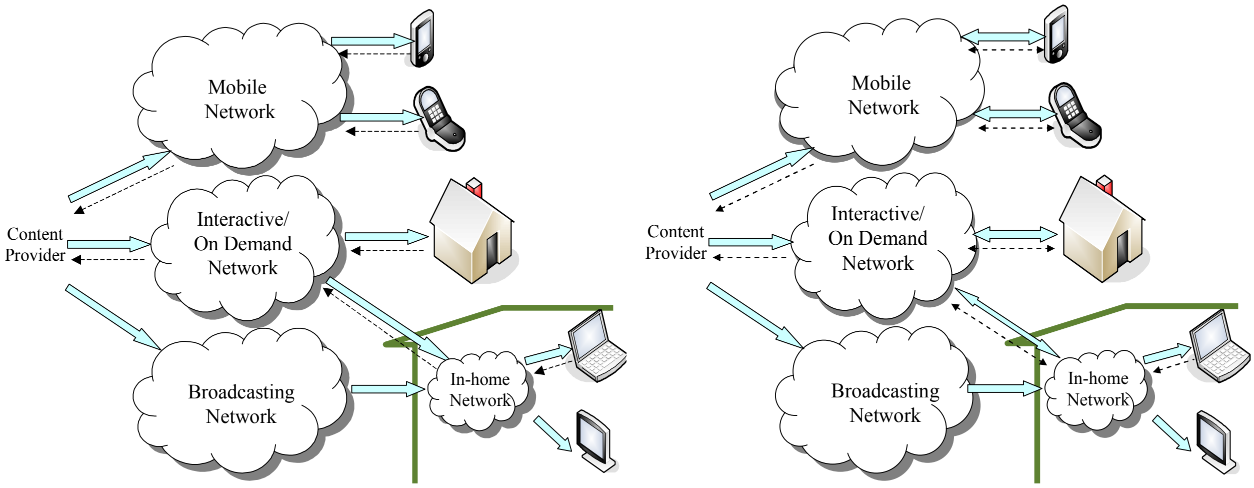

Figure 1: Logical Network Architecture a) Broadband donwlinks, b) Broadband bidirectional links

The next step to introduce seamless content distribution is to take advantage of the sufficient uplink capacity that most access technologies typically offer (Figure 1b). Individuals may operate as content creators and service providers by distributing their personal content including but not limited to video streams. Moreover, novel "follow me" like services may be introduced, where the home-based equipment may operate as service mediator and content forwarder and a subscriber may consume personalised streaming services, properly adapted to network characteristics/conditions and his mobile phone/PDA capabilities, while on the move.

However, the major envisaged potential of the Future Internet is shown in Figure 2 by introducing trusted Peer-to-Peer (P2P) overlay topologies in the broadband, heterogeneous architecture. This is also compatible with the increasing and expanding WiFi community networks architectures. In this case, services may be offered not only by centrally located media streaming servers, but by groups of end-user devices, acting as distributed content repositories. Given content protection and management is in place, network operators and service providers may offer value-added streaming services with remarkable PQoS, while avoiding the nightmare of network scaling and the expenses in network infrastructure upgrades, as the content (at least the most popular one) and the network resources (traffic load) may be distributed and thus balanced to a large number of peers. Moreover, individuals may produce their own (real-time) content and make it publicly available to a larger audience, without having to rely on a specific, expensive networking infrastructure. In this environment, video streaming scalability, resilience and PQoS may be exponentially increased, as not only multiple-networks, but also multiple-sources may stream video segments, enriching the content on-the-fly either at the network and/or at the end-user terminal.

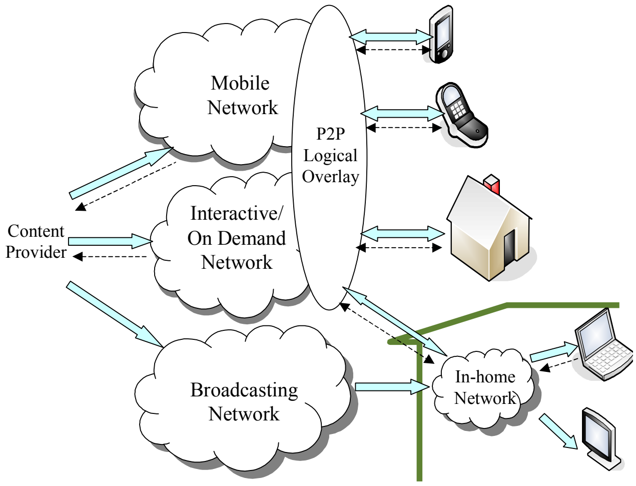

Figure 2: The proposed Future Internet logical network architecture

In order to realize the above service provisioning scenarios, a number of issues have to be considered and tackled. Advanced scalable and multiview video coding, knowledge of the network conditions, innovative cross layer optimization, real-time service adaptation, on-the fly PQoS enrichment, content protection are some of the issues that have to be solved (SEA, 2008). In this paper, we highlight and analyse the main pillars and introduce technologies and solutions that could be applied in the envisaged seamless content delivery in the Future Internet network evolution.

2. Proposed Network Architecture Innovations

Advanced coding schemes like Scalable Video Coding (SVC), Multi-View Coding (MVC), Multi-Description Coding (MDC) will facilitate video distribution with enriched QoS, especially in case of high-end multi-modal terminals able to receive and reconstruct multiple video streams segments (i.e. layers, views, descriptions). However, home terminals or low-cost mobile terminals may be only capable for decoding at a particular bit-rate or may be only feasible to correctly display up to a particular image resolution. Thus, in order to meet all proposed innovative features, the media delivery service architecture should be content aware and have knowledge of the access technologies as well as to the utilised end-user device capabilities and characteristics. The Future Internet network architecture has to provide the relative adaptation functionalities to seamlessly support the majority of terminals. It should be able to support terminal mobility, including service continuity, between different (radio) access technologies, or maintaining and supporting the same capabilities of access control (authentication, authorization), privacy and charging when moving between different (radio) access technologies. IP service continuity should be maintained, i.e. the network should hide the impact of mobility events to the end user and the IP application(s), i.e. the service can continue without user intervention or special application support to mask the effects of a mobility event.

In case of building a service architecture upon the described variety of access networks, it is desirable to have as much information and adaptation at the lower layers (up to the network layer) as possible, along with scalability functionality coming with the media codec. Certain functions such as content caching in the network, content adaptation and cross-layer optimization would certainly need knowledge of the network conditions/characteristics. In order to overcome this problem, wherever applicable in the proposed Future Internet architecture, we introduce intelligent media/ network aware nodes. A Media Aware Network Element (MANE) is defined as a network element, such as an application layer gateway that is capable of parsing certain aspects of the RTP payload headers or the RTP payload and reacting to the contents and modifiy session signaling (S. Wenger et.al. 2005) . In the foreseen network architecture, we propose two MANE types: a) seamless Home Media Gateway (sHMG), located at the edge of the extended home environment and b) seamless Network Media Gateway (sNMG) at the edge of the 3GPP Service Architecture Evolution (SAE) (Figure 3).

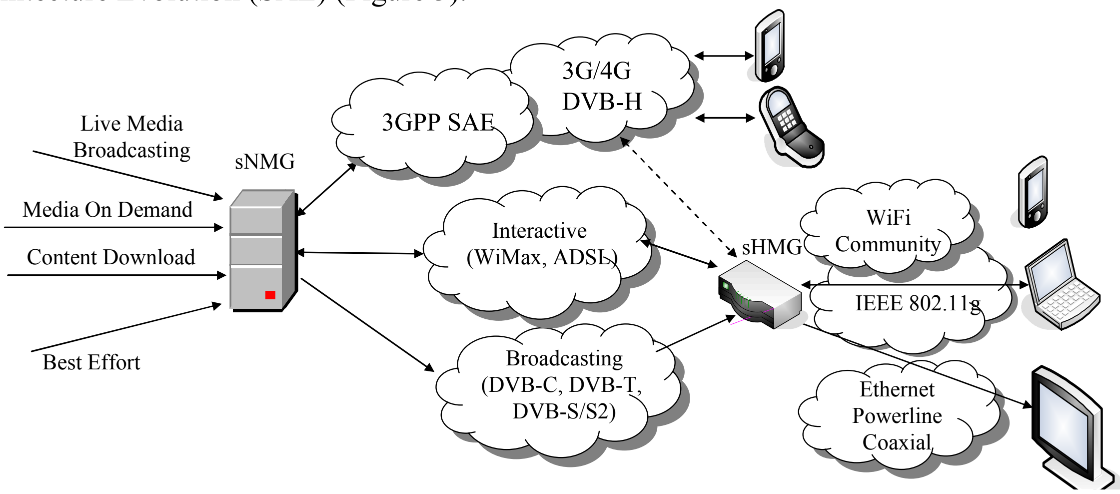

Figure 3: Proposed Content Delivery Network Architecture

The proposed MANE nodes will support the intelligent, seamless content distribution. They will offer functions like network and terminal awareness, content enrichment and content protection. In the longer term, they may be integrated on Internet Multimedia Systems (IMS) as define by ETSI TISPAN. They will offer multimedia storage, dynamic content adaptation and enriched PQoS by dynamically combining multiple multimedia content layers from various sources. Moreover, as they will have knowledge of the underlined networks, they will provide information on the network conditions/characteristics, which will be utilised by the Cross Layer Control (CLC) mechanism and adapt the multimedia streams to the next network in the delivery path. This will be extremely important in case of a low bandwidth, but guaranteed QoS mobile networks and in the broadband, but best effort P2P topologies.

3. Key Technology Pillars and Trends

For the introduction of novel services and new business models, including efficient, resilient, enriched Perceived QoS (PQoS) and seamless content delivery over the future Internet, apart from the network architecture, we expect that key-content pillars should be introduced including:

3.1 Multi-layered/Multi-view personalised content coding

In order to maximize video portability, scalability and error resilience across a number of heterogeneous terminals, we propose the H.264 Scalable Video Coding (SVC) as the major encoding standard (Schierl, 2006). The SVC intents to create a standard for efficient video compression that provides bit streams scalable in frame rate, resolution and SNR quality. The SVC extension is built on H.264 / MPEG-4 AVC and re-uses most of its innovative components. Initially, SVC generates a backwards-compatible H.264/MPEG-4 AVC compliant base layer and one or several enhancement layer(s). The base layer bit stream corresponds to a minimum quality, frame rate, and resolution (e.g., QCIF video), and the enhancement layer bit streams represent the additional information needed to improve the same video with gradually increasing quality and/or resolution (e.g., CIF) and/or frame rate.

The concept of Multi View Coding (MVC) is to allow for different views of video streaming without drastically increasing the data rate for the media delivery. For MVC, efficient coding is required, while new signalling mechanisms have to be developed and integrated into the service architecture. In the proposed architecture, we assume that efficient real time encoding/decoding for SVC/MVC coded H.264 streams is required for allowing MVC services initiated by the end-user. We will also focus on emerging solutions for MVC-like truly free viewpoint coding, adding selective depth information to a MVC coded sequence for true 3D display rendering.

3.2 Multiple Description Coding (MDC)

Future Internet should provide for inherited mechanisms for resilient content distribution. One method that could be applied is the Multi Desription Coding (MDC) approach. The MDC method generates two or more representations of the same data (images or video segments), which are transmitted over independent physical or logical paths; the PQoS depends on the number of received descriptions: a basic quality level is obtained when a single description is received, increased by subsequent received descriptions. However, traditional MDC schemes do not encompass simple tuning mechanisms, so as to adapt on varying network/user conditions. For the combination of MDC and SVC/MVC, a dynamic-adaptable MDC scheme compatible whould be implemented, allowing tuning of the redundancy according to the network conditions.

3.3 Multi-source/Multi-network streaming

In the Future Internet architecture, in order to increase the PQoS, a terminal may potentially receive different layer (SVC), views (MVC) or representation (MDC) of the same resource (video stream) transmitted from multiple sources. Moreover, multimodal terminals may enable not only selection of the best suitable network for a certain use case, but reception of different layers/views/representations of a stream via different networks and combine these to reach the best PQoS.

Different networks will provide different bandwidth, QoS, latency and error rates. In order to achieve multi-source /multi-network streaming, the Future Internet has to solve four significant problems: a) to enable fast/efficient discovery of compatible/complementary content segments (i.e. layers, view, representations) in alternative providers/peers, b) to achieve synchronization and lightweight content reconstruction mechanisms adapted to the user terminal and c) to introduce new network nodes or functional overload existing ones with QoS adaptation capabilities and d) to optimize radio access technology (RAT) resource usage and offer nodes.

3.4 P2P video streaming

Professional P2P streaming is a very challenging topic due to the content segments retrieval, setup, playback and channel change delays, and payback continuity issues. In most mesh-based P2P overlays, distribution graphs are implemented, where each node contacts a subset of peers to obtain a number of chunks. These schemes offer good resilience to node failures, but involve overheads, due to the exchange of buffer maps. On the negative side, they require large buffers to support parallel pulling and chunk store/forwarding.

The Future Internet should address P2P challenging topics including: a) peer retrieval optimization (possibly exploiting proper cross layer parameters), and b) application of proper coding techniques (e.g. to limit the traffic and delays due to buffer map exchange). Another important topic will be the distribution of multiple views over a P2P overlay and optimization of the visual quality and PQoS via exploitation of advanced source coding techniques (SVC, MVC, MDC) i.e. a basic, centric view will be distributed via overlay-multicast mechanisms to all participating nodes in the overlay, while a specific view requested only by some clients will be efficiently distributed within the overlay or from an alternative network.

3.5 Cross Layer Control (CLC) and Optimisation

Existing CLC provide significant improvements in the PQoS under specific networking and transmission conditions. However, none is directly applicable to the Future Internet concept, as the terminal will not necessarily know the actual physical layer infrastructure. Especially in the case of P2P topologies, the physical infrastructure may even be an arbitrary, timely varying combination of links belonging to different networks.

Moreover, no CLC scheme is able to advantage of the scalability (SVC), personalisation (MVC) and resiliency (MDC) features. The Future Internet should define a cross-layer scheme that will face the network and terminal heterogeneity and take advantage of the advanced coding and delivery schemes by proposing a network abstraction mechanism, able to model the underlined end-to-end path, describe the functional dependencies and determine the optimum adaptation of the multimedia resources.

3.6 Content Protection and lightweight asset management.

The Future Internet should provide new media protection paradigms for P2P networking, offering the necessary technology for content protection and rights protection, not only addressing professional content creators, but also user generated content to the users groups or individuals. One solution could be the tailoring of the MPEG21-IPMP and DMP concepts and standards, avoiding the use of legacy DRM schemes. Moreover IP P2P networks are lacking of media management solutions that can really improve the management of the digital items. Content needs to be managed to ensure that the network can handle user generated content and professional quality. For P2P networks, solutions will be developed using a lightweight asset management to ensure, along with the management of the content protection that the content arrives to the right user and the full chain is respecting the required features and quality.

4. Conclusions - The SEA Project

The Future Internet of things and services is not envisaged to be simply a faster way to go online. What is expected to fundamentally change the way that people use the Internet is the ability to produce, and seamlessly deliver and share their own multimedia content. In this paper, we have introduced and analysed innovative architecture components to offer media scalable content delivery, increasing the robustness, enriching the PQoS and protecting the content from unauthorized access. Moreover technology pillars are described e.g. Multi-layered/Multi-viewed content coding, Multi-source/multi-network streaming & adaptation, content protection and lightweight asset management.

Aiming to research the directions towards Future Internet and content delivery, the SEA (Seamless Content Delivery) project (ICT-214063), particaly funded by the European Commission was launched in January 2008. SEA is focused on seamless, personalised, trusted and PQoS-optimised multimedia content delivery, across broadband networks, varying from broadcasting to P2P topologies. SEA motivation is to implement a context-aware networking delivery platform, by focusing on four key principles:

- **Multi-layered/-viewed content coding,** considering the evolving H.264 SVC/MVC and their emerging successors, as the major foreseen delivery technologies over heterogeneous networks/terminals and large audiences.
- **Multi-source/-network content streaming** offering on-the fly content adaptation, increased scalability and enriched PQoS by dynamically combining content layers or representations of the same resource, transmitted from multiple sources and/or received over multiple networks.

- **Cross-network/-layer optimisation.** The network/terminal heterogeneity, also engaging P2P overlays and serving different quality and views will require cross-layer optimization, traffic adaptation and optimal use of the available network/terminal resources.
- **Content Protection.** A hybrid solution for personalised content protection by means of a combination of streaming encryption, content protection and rights management for new media, covering not only the legacy content creation chain, but also the private multimedia content.

SEA will test/validate the developed technologies over three interconnected tedbeds: a) a real-time emulated lab, b) a world-wide extended P2P testbed (PlanetLab) and c) a real 2G+/3G/4G/WLAN mobile trial. SEA aims to eventually provide citizens with the means to offer personalized A/V user-centric services, improving their quality of life, entertainment and safety.

5. Acknowledge

This publication presented the authors opinion. Yet, it is based on work performed in the framework of the Project SEA IST-214063, which is funded by the European Community. The authors would like to acknowledge the contributions to the SEA Project of colleagues from: STM, Synelixis, Thomson, Philips, Vodafone, Nomor, Fraunhofer HHI, Politechnico di Torino, Universidad Politécnica de Madrid, University of California, Los Angeles.

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