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Smart Multimedia Routing and Adaptation using Service Specific Overlay Networks in the Ambient Networks Framework

Frank Hartung, Stephen Herborn, Markus Kampmann, Stefan Schmid

***Abstract*—We outline initial results of recent work in defining an architecture for Smart Multimedia Routing and Transport (SMART) within the Ambient Networks Integrated Project. In which we introduce the concept of service provisioning with Service Specific Overlay Networks. We provide a high-level description of the required overlay network components and elaborate on our SMART design concepts.**

***Index Terms*—media routing, overlay networks, media adaptation, ambient networks**

Introduction

THIS paper describes early results of ongoing work on advanced multimedia routing and adaptation in the context of the Ambient Networks Integrated Project [1]. The overall goal of the Ambient Network Project is to develop a vision for future wireless and mobile networks, by creating an innovative, industrially exploitable new internetworking framework based on the dynamic composition of networks. A key aspect is the establishment of a common control layer for various network types, which will provide end users with seamless multi-access connectivity to enable selection of the best available network. For an operator, the AN concept should allow flexible and dynamic network configuration and management. The aim of the work presented here is to define and develop a novel architecture for Smart Multimedia Routing and Transport (SMART) for the next generation mobile and wireless networks. SMART deals with the optimization of media delivery services by taking advantage of network-side media processing capabilities that are built into Ambient Networks. In contrast to today's application layer-based end-to-end media services, SMART adopts a decentralized approach, and moves the control and resource allocation for such services into the network, offering novel types of media delivery capabilities beyond those known from today's best effort networks. The SMART framework supports different content distribution paradigms, namely content distribution networks (CDNs), peer to peer distribution, unicast distribution, and multicast/broadcast distribution.

Goals of this Work

The goal of this work within the Ambient Networks project is to define a routing transport framework that provides the following:

- Provisioning of a scalable and adaptive multimedia delivery network (for the huge number of media services on the world-wide inter-network).
- Support for advanced multimedia routing, caching and adaptation through network-side processing of multimedia data.

- Extending the existing caching strategies known from the proxy concepts to enable the network to maximize the throughput and the user convenience as well as to minimize connection delays.
- Enabling the delivery of media data to user groups ranging from single users to millions of simultaneous users. This includes support for multicast and broadcast services.
- Support of different kinds of mobility services.

Thus, the ambition is to design a network architecture and mechanisms that ease the installation and deployment of mobile networks, and are inherently self-configuring and scalable. This will ease the deployment of services significantly, ranging from messaging and peer-to-peer services to large-scale multi-user services with millions of simultaneous users.

Smart Multimedia Routing Architecture using Overlays

A basic assumption of this work is that the underlying legacy routing infrastructure is based on best effort datagram routing, i.e., IP, and does not provide QoS or packet prioritization mechanisms on this level.

An important contribution of the SMART architecture so far is the concept of service-specific overlay networks, or SSONs [3], that work on top of the IP infrastructure. The central idea is that different 'virtual networks' [4] are deployed for every media delivery service (or group of services) in order to tailor the network to the distinct requirements (such as QoS requirements, media formats, responsiveness, cost, security, distribution topology) of the service.

Through the initial stages of this work area we have defined the following components of the SMART architecture (Fig. 1):

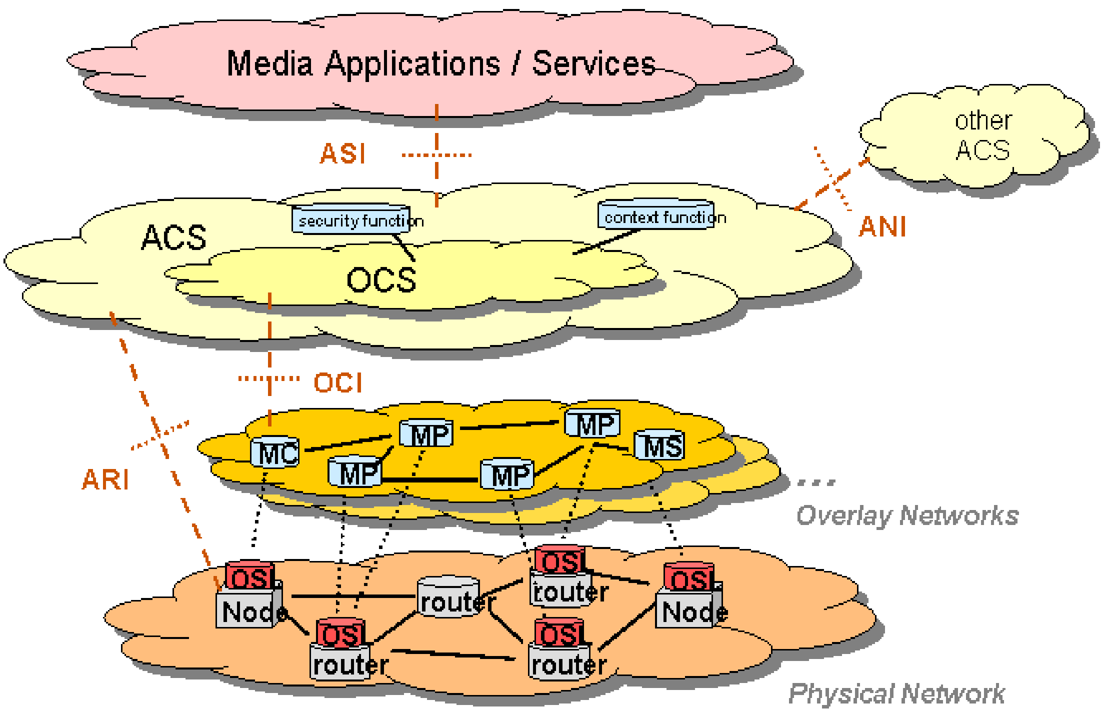

Fig. 1. The Smart Multimedia Routing and Transport (SMART) Architecture

- Overlay Control Space (OCS) – The control-plane functions of the SMART architecture.
- Overlay Support Layer (OSL) – The necessary platform support to control and manage the virtual networks across highly heterogeneous access networks and technologies. In other words, the OSL links the control plane to the real-world underlying routing infrastructure,.
- Overlay Nodes (ONodes) – The network elements that constitute a service-specific overlay.

Overlay nodes can take on the roles of MediaClients (MC), MediaServers (MS), and MediaPorts (MP) – or any combination of those. These entities are controlled by the OCS to form a suitable network for the particular media service. The MediaPorts, as special network-side nodes, have the role of providing value-added functionality, such as caching or adaptation facilities, flow synchronization or special types of routing capabilities, inside the network, where most appropriate for the media service. Fig. 2 shows the structure of an Ambient Networks Overlay Node (ONode). Shown on the right-hand side is the control plane. The OCS controls the media routing and adaptation capabilities of the SSONs, and thus of the overall network. It is part of the overall control space, the ACS (Ambient Control Space). The left-hand side depicts the user plane, which transports the actual data. An ONode can contain MC, MS or MP functionality. The OSL connects the higher-level functionality to the underlying basic routing functionality.

In order to convey media flows to the end-user in the best way and according to the end-user and service provider preferences, the infrastructural components of the SMART architecture are provided with context information from other functional Ambient Network elements. This includes e.g. node and link status in the underlying low-level network, mobility, context, composition and security information.

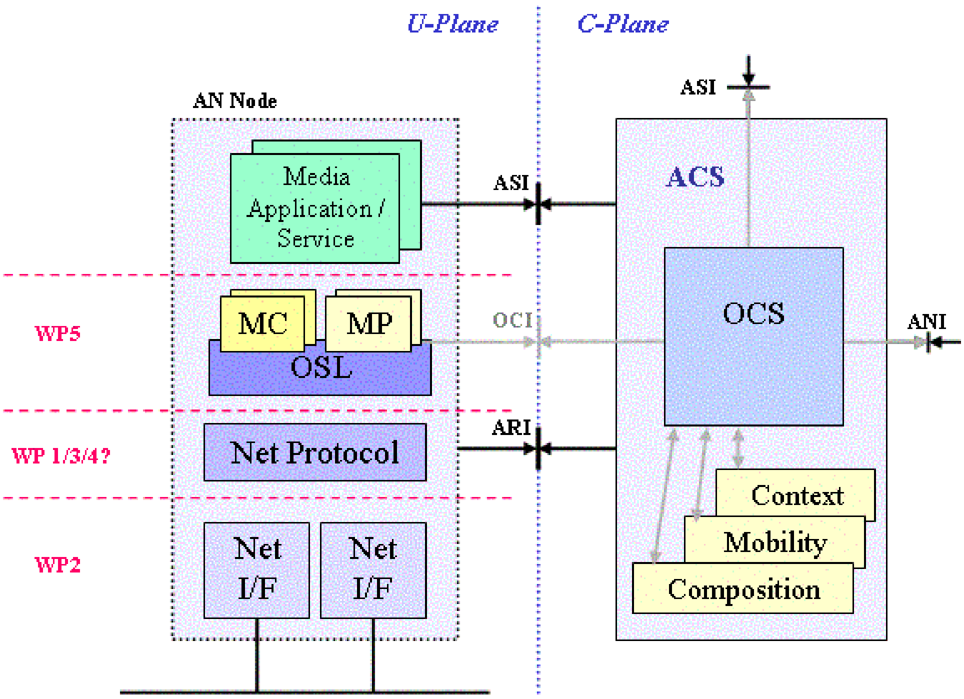

Fig. 2. Structure of an ONode

Concepts of SMART Architecture

The basic concepts that guide the design and realization of the SMART architecture are the following:

A. SSONs are deployed to allow the transparent inclusion of network-side MediaPorts into the end-to-end communication path(s) from the MediaServer(s) to the MediaClient(s). MediaPorts can have different functionalities, specifically routing and overlay routing functionality, but also media storage/caching functionality, and media adaptation (e.g., transcoding) functionality. This concept implies the choice of appropriate paths in the underlying network, depending on the characteristics and requirements of the multimedia service or other factors like user preferences, connectivity and mobility constraints, etc. Examples of services are peer-to-peer communications, messaging or multicast streaming.

B. Service-specific overlay networks should adapt as a result of overlay nodes joining/leaving the virtual network or nodes changing their properties, e.g. moving in the underlying network topology (for example, it might be advantageous to re-configure the overlay in order to include new/other MediaPorts to better support node mobility). This introduces the notion of 'adaptive overlays' that dynamically re-configure themselves in order to optimize the media delivery path. Dynamic adaptation of an overlay should also take place in response to changes in the underlying network (for example, changing QoS characteristics or new network resources becoming available). Note however that overlay adaptation is not expected to take place in a highly dynamic or fast manner. Rather, it is expected to take place in the background in a way that is transparent to end-users.

C. Highly dynamic or fast alterations in the delivery of media flows on the overlay should be addressed by means of overlay-level routing capabilities. Note that we expect overlay-level routing to be highly dynamic (since it is very lightweight - based only on a local alteration of the routing table) and scalable (as it is specific to the particular overlay network).

D. The routing logic of an overlay network and, more specifically, of its MediaPorts, enables the dynamic provision of media content on a per service basis, and makes use of all available context information to update its routing decisions. For example, context changes such as changes of 'virtual link' QoS, user preferences or service requirements can trigger dynamic changes of the routing behavior on the overlay network [5]. Through the OSL, these changes are conveyed to, and implemented in, the MediaPorts constituting the SSON, and thus in the underlying IP routing infrastructure,.

Conclusion

We have presented early results and elaborated on the main concepts of our work on advanced media routing and adaptation. In order to develop future networks that allow easy deployment of media services, a self-configuring overlay network approach using service specific overlay networks is used. The SSONs are initiated and initialized on a per-service basis, and are adaptive with respect to topology changes or changes in the properties of involved nodes and links. Further work in the development of the SMART architecture will include detailed system design and media routing logic specification, as well as an implementation of a proof of concept demonstrator system.

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Frank Hartung studied electrical engineering at RWTH Aachen, Germany, and NTNU Trondheim, Norway. He received a Dipl.-Ing. from RWTH Aachen in 1992 and a Dr.-Ing. from University of Erlangen, Germany, in 1999. He has been with Ericsson Research since 1999. His main interests are in the areas of mobile multimedia services, media transport, mobile broadcast services, and multimedia content protection.

Stephen Herborn is a research student with the School of Electrical and Telecommunications Engineering, University of New South Wales, Sydney. He has been attached to National ICT Australia (NICTA) since 2003.

Markus Kampmann studied electrical engineering at University of Bochum, Germany. He received a Dipl.-Ing. from University of Bochum in 1993 and a Dr.-Ing. from University of Hannover, Germany, in 2002. He has been with Ericsson Research since 2001. His main interests are in the areas of mobile multimedia, media delivery and transport, video streaming and video coding.

Stefan Schmid received a M.Sc. in Computer Science (Diplom Informatik) from the University of Ulm ,Germany, in 1999 and a Ph.D. in Computer Science from Lancaster University (U.K.) in 2002. He has been with Next Generation Internet group of NEC Europe Ltd in Heidelberg, Germany, since 2004. His main interests are in the areas of multimedia services, overlay delivery networks, active and programmable networks and Mobile IPv6.