Tackling User-Centric Media Demands through Adaptable Software Defined Infrastructures

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Abstract: **This paper proposes a conceptual approach to content delivery that addresses emerging media demand trends through cross-layer integration between Virtualised Service Networks (VSNs) and Information Centric Networking (ICN). The transformative effects of software-defined infrastructures are presented and how these technologies can support dynamics needed to deliver personalised, interactive, mobile, and localised media content to consumers.**

Keywords: software-defined infrastructures, layered modular architectures, media demand, personalisation, interactivity, mobility and localisation.

1 INTRODUCTION

Today's content delivery architectures (e.g. content delivery networks, distributed streaming and adaptive streaming) support on-demand access and adaptive quality levels whilst optimising network bandwidth and storage costs. In addition, advances in metadata management, broadband communications, device performance and versatile applications have helped drive the creation of content delivery platforms enabling the flow of petabytes of high-definition audio-visual content including stereo 3D content to millions of online viewers. These platforms support access to high-quality content anywhere and anytime, in a variety of formats with content tagged and enriched using well-structured metadata. While these Over-The-Top solutions provide some awareness of network performance (e.g. through client side monitoring and adaptation), they do not directly interact with underlying network management functions. This creates non-optimal resource allocations causing either overprovisioning costs for network operators or poor Quality of Experience for consumers.

In this paper we propose an approach to content delivery that addresses emerging media demand trends through cross-layer integration between Virtualised Service Networks (VSNs) and Information Centric Networking (ICN). We describe how unprecedented dynamics, fluidity and manageability can be offered by such software-defined technologies and how new adaptive content delivery architectures can be defined for efficient on-demand media whilst supporting the development and large-scale adoption of new forms of participatory interactive media. Our approach recognizes that adaptability and flexibility will be key to such future advances enabled by underlying network and service architecture [1][2][3] and we describe how cross-layer integration must address the need to optimise content delivery considering trade-offs between efficiency, performance, user experience and the expected demand patterns at different levels with future media architectures.

2 MEDIA DEMAND TRENDS

The digitisation of production processes is transforming the creative industries from supply chains based on the linear distribution of products to the mass audiences to adaptive production processes that incorporate participatory media from consumers and allows consumers to play an active role in story creation and storytelling. Digitisation firstly, increases digital connectivity (increasing speed and reach) to new types of links between previously unconnected physicalities, which in itself increases the distribution of control and resources. Secondly, digitisation fosters generativity through increasing digital convergence, increasing knowledge and resource heterogeneity allowing for changing the meaning of existing products and consumer experiences [4].

These shifts changes the way consumers' access and interact with media, with brands, and with each other and combined with ubiquitous Internet connectivity has created a massive structural transformation that has impacted business models, consumption patterns and content creation processes. Such demand is expected to be a user- and thing-centric [5] with a high degree of dynamicity driven by four main cross-cutting consumer demand trends: Personalisation, Interactivity, Mobility, and Localisation (PIML). Personalisation is concerned with tailoring content to the needs of individuals or groups, Interactivity allows individuals and groups to take an active role in the adaptation and production of content, Mobility provides access to content and interaction on the move, including scenarios of high mobility (transport) and at scale (large populations arriving and leaving a live

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event) whilst Localisation considers interaction between hyper local consumers, aggregators and broadcasters.

3 APPROACH

Our approach proposes to exploit the software-driven nature of compute, storage and communication infrastructures, particularly at the transport network level (See Figure 1). Layered modular architecture principles [6] are adopted at media and web resource level and extended through suitable layering to service routing and switching level, utilizing advances that exposes communication and routing resources through software, allowing for runtime operational and experimental manipulation. This includes the switching hardware deployed deep in the network and towards the edge of it, near end users and even on end user devices. At the compute and storage management level, a VSN defines a network of media services, utilising the infrastructure through Network Function Virtualization (NFV). The approach moves away from traditional data centre cloud resources to computing infrastructure that is distributed across service providers and network operators, possibly located in small location-based gateways or in common-of-the-shelf hardware that is collocated with network equipment close to users. This paradigm shift can currently be observed with industry efforts in the Mobile Edge Computing [7].

Services within the VSN are then orchestrated and managed through service endpoint management along a set of well-defined policies that govern execution to provide authoritative surrogate services. Surrogate service instances can then act under the fully qualified domain name of its origin, throughout the network with virtual machine management directly utilising the NFV-exposed resources. In addition, the flexible surrogate capability is enabled by a service routing layer that enables sub-1s switch-over times to surrogate resources for high availability, flexibility and resilience in situations where instances need to be instantiated, migrated, replicated and torn down according to demand. Such fast switch-over is enabled through interpreting HTTP-level traffic transfer as a routing problem rather than redirecting through DNS indirection as in today's CDN solutions [8]. The approach enables policy-compliant localisation of traffic, such as national regulation purposes or for achieving ultra-low latency in an advanced immersive interactive applications in order to achieve the goal of always having a service "one hop away". Another benefit of interpreting an HTTP-level service exchange as an exchange of information objects is that of enabling multicast delivery to the same HTTP requests within a certain time window; an important opportunity for personalized video streaming services where a statistical temporal correlation of viewers can be assumed (e.g. popular content at video platforms such as YouTube or NetFlix) or where the local experience might incur such correlation (e.g. an immersive stadium scenario where a certain number of viewers share the same viewing angle).

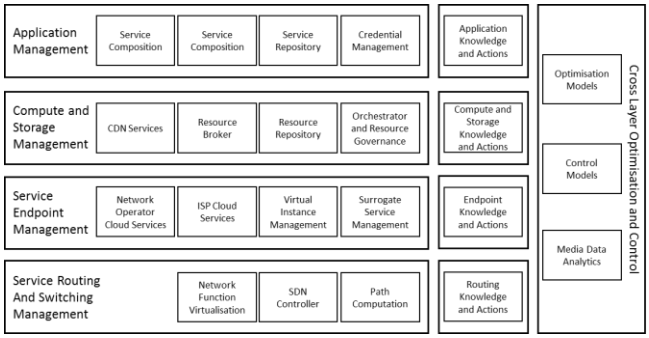

Figure 1: Cross layer content delivery over software-defined infrastructures

Cross-layer optimization and control (CLOC) allows decisions at the compute and storage layer to optimally exploit service endpoint management and service routing decisions. This is achieved through well-defined data and action points at each layer, consolidated in cross-layer knowledge and optimisation models that ultimately lead to holistic and coherent control decisions. The CLOC also addresses aspects of support multi-tenancy of services across heterogeneous network environments; a situation that is assumed a normality rather than an exception in future environments such as 5G. While the orchestration at the highest (cloud) level, together with the provided policy constraints, provide the initial framework for the CLOC, its runtime operation has to take into account the various services running over the overall platform while also reacting to changes in the operational environment (as well as to requirements) in a cognitive and reflective manner.

The proposed approach delivers significant benefits to content delivery systems aiming to offer services supporting PIML requirements. The linear increase of bandwidth costs in the case of *personalized* viewing services delivered via HTTP-based services can be stemmed by utilizing multicast delivery capabilities of information centric routing. The ability to provide flexible service endpoint management enables surrogate service endpoints provided near the end user, significantly improve *interactivity* by reducing service-level latency, while providing service synchronization among these distributed service endpoints as well as virtualized container migration, ultimately providing personalized services one hop away in infrastructures. Quality of Experience for *mobility* can be improved by three capabilities:

- Integration of viral content through service surrogating at the edge of the network and efficient multicast-enabled synchronization across surrogates with support for service placement based on flexible user/network constraints.
- Integration with NFV technologies for surrogate service provisioning allows for utilizing computing resources deep in the network and close to the edge and end user.

- Information centric routing provides direct path routing of content rather than triangular IP routing in today's solutions.

Finally, access to standard interfaces for software defined infrastructure covering communications, compute, and storage allows for flexible routing solutions for *localisation* of traffic through flexible service endpoint placement according to service-specific constraints, while providing an infrastructure with an edge/data centre capacity ratios that supports PIML-oriented workflows.

4 CONCLUSIONS

In this paper we have outlined a conceptual approach for how software defined infrastructures can support demand trends for PIML-oriented media consumption. Future work will now implement the conceptual model as part of the H2020 FLAME project to build evidence for effectiveness through an advanced digital innovation platform deployed for real-life smart city trials that engage ecosystems of creative industries (broadcast, gaming, etc.) and ICT industries (network operators, ISPs, service providers) responsible for online distribution, broadcast, communication, and distribution of digital content.

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