Enhancing Mobile Video Delivery over an Heterogeneous Network Access with Information-Centric Networking

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ABSTRACT

Mobile video delivery drives Internet traffic evolution and puts colossal pressure on future 5G networks to support higher quality and lower latency requirements over an increasingly heterogeneous network access. Future Internet paradigms recentering communication around content, such as Information Centric Networks (ICN), appear as promising candidates to relieve the challenges of a mobility-robust, efficient and cost-effective video delivery, by integrating video-awareness at network layer. In this demo, we focus on ICN-enabled Dynamic Adaptive Streaming (DAS) over an heterogeneous wireless access. We integrate ICN capabilities in DAS clients requesting 4K video content to standard DAS servers. We deploy a virtualized ICN-enabled network slice using LXC containers to connect clients to servers through an heterogeneous wireless access (802.11n and LTE emulated radios) and a simplified backhaul.

The contribution of the demo is twofold. First it showcases what ICN can bring to DAS over a mobile heterogeneous access in virtue of its content-awareness at network layer. Second, it offers to the user a rich sandbox where several state-of-the-art DAS controllers are implemented and can be tested over ICN or standard TCP.

CCS CONCEPTS

• **Networks** → **Naming and addressing**; **Network experimentation**; **Logical / virtual topologies**;

KEYWORDS

Information-Centric Network; Video Delivery; Emulation

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1 INTRODUCTION

By 2020, video traffic will account for more than 80% of all the IP traffic and two-thirds of all Internet traffic will be generated by mobile and wireless devices [11]. Ever evolving video services (e.g. 4K-8K video, Virtual/Augmented Reality) drive future 5G networks design to match new mobile usages, very-high bandwidth requirements and ultra-low latency constraints. In last years, Dynamic Adaptive Streaming (DAS) has been introduced to accommodate video requirements by means of a flexible user-driven video rate adaptation. With DAS we refer to a variety of techniques, most of them relying on HTTP: some standardized like DASH, others proprietary solutions (Microsoft Smooth Streaming, Apple HLS to name a few). DAS interaction with the network is fundamental to achieve efficient mobile video delivery.

Information-Centric Networking (ICN) [10] defines a set of architectural designs (the most notable we refer to in terms of implementation are NDN and CCNx) providing content-awareness at network layer by using location independent names to drive forwarding, routing, transport and caching operations. It also presents numerous advantages for DAS in virtue of a connectionless consumer-driven transport which enables in-network loss and congestion control, multipath, multicast and edge-embedded caching. Thus, it appears as a natural candidate to enhance DAS [4] and overcome some of the known inefficiencies of connection-based transport (see [9] for an overview of video delivery over ICN). Hints on the benefits that ICN could bring to DAS (e.g. resulting from name-based forwarding or caching) are provided in [4, 12], where authors focus on ICN potential to assist DAS rate adaptation inside the network, rather than solely at the client side. Here, we take a step back and develop an experimental platform for DAS integrating latest state-of-the-art rate adaptation strategies and ICN mechanisms to efficiently support data delivery over mobile heterogeneous access, namely in-network loss control [3], optimal multipath transport and request forwarding [2, 5] and simple LRU in-network caching. Such reference platform, detailed in Sec.2 and publicly available in the open-source FD.io CICN project [1], is used in our demonstration to showcase ICN benefits over TCP/IP in terms of improved user experience, simplified management of mobility and reduced transport/control cost. A live monitoring of network status and of key video performance metrics is provided in the demo to quantify ICN advantages in terms of improved user experience and of transport cost reduction w.r.t. TCP-based solutions.

2 ICN-ENABLED VIDEO ARCHITECTURE

The mobile video architecture considered in the demo (Figure 1) consists of several DASH clients, both physical (tablets or desktop computers) and emulated (via Linux containers, LXC). Clients are connected using either WiFi 802.11n, LTE or Ethernet and request video encoded at qualities from LD to 4K to a DASH server.

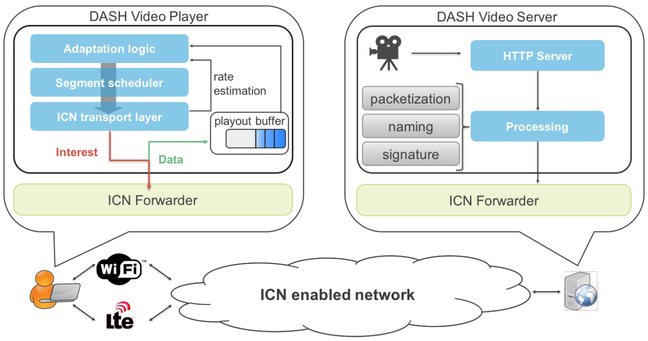

Figure 1: ICN-enabled video architecture

ICN-enabled Video Player. In order to support application-level selection of the network stack (ICN or TCP/IP), we have modified an existing video player[1], based on libdash, an open-source library that implements the MPEG-DASH standard. The player interacts with an ICN forwarder using an ICN transport layer and consumer/producer API [3, 5]. We have additionally implemented the following state-of-the-art bitrate adaptation logics: BBA [6], PANDA [8], BOLA [13], Adaptech [7], that, in ICN mode, are able to exploit the packet-level information coming from the ICN network and transport layer.

ICN-enabled Video Server. It consists of an HTTP server that can stream content over ICN or standard TCP/IP directly. Both TCP/IP and ICN stacks serve MPEG-DASH compliant 4K videos. In the ICN case, the server performs packetization and naming of DASH video segments to create ICN Data packets.

ICN-enabled Access/Backhaul Network. The network between the player and the server is ICN-enabled, but also supports standard TCP/IP. It consists of a series of LXC containers running the CICN forwarder. Different wireless accesses are emulated (WiFi 802.11n and LTE). We deploy the demo topology by means of an orchestrator that allows fast and automated ICN network deployment [1].

3 DEMONSTRATED ICN ENHANCEMENTS

DAS operates at the application layer, while ICN provides content awareness directly at the network/transport layer, enabling enhanced mobile video delivery by means of:

1) **Packet-level bandwidth estimation at client**
ICN enables fine-grained estimation of the available bandwidth leveraging packet arrivals at receiver, as opposed to the coarse application-layer estimation done at video-segment granularity with TCP. In this way, ICN is more reactive in taking rate selection decisions.

2) **Seamless mobility and in network loss control**
The connectionless and request-reply nature of ICN transport handles client mobility by design via receiver-driven request retransmissions and enables in-network loss detection and recovery [3]. Hence, it allows to overcome standard transport limitations amenable to inefficient video delivery: i.e. misinterpretation of channel losses as congestion signals by TCP and slow end-to-end loop control (at least one round trip time). ICN enables sub-round trip time loss control by delegation at key nodes (e.g. consumer/producer/access) of wireless, mobility, congestion events.

3) **Multi-path support and dynamic load-balancing**
ICN transport is connectionless and receiver-based, thus it natively supports packet-level load balancing over multiple and dynamically discovered network accesses (e.g. due to mobility during video streaming). This remains transparent to the application, with the controller still operating on the aggregate rate. Load-balancing decisions are dynamically taken by monitoring over time the residual latency behind each output interface, on a per-prefix basis.

The advantage over existing multi-path solutions is the finer packet granularity and the capability to exploit the aggregate bandwidth of all available accesses. Instead, the load-balancing of connection-based transport protocols requires the knowledge of all paths before connection instantiation and, if done at DASH segment-level like in TCP, it results in an oscillating selection of the paths over time, with a negative impact on the rate adaptation stability.

4) **In-network caching and unified unicast/multicast**
In-network caching is one of the basic features of ICN: content can be locally stored at every node and served in response to a request with no further propagation of the request. We show the benefits of in-network caching by simple video quality-aware caching and forwarding policies to reactively cache closer to the access the more popular qualities, based on the access-dependent request pattern (i.e. available per-user bandwidth, type of devices, etc). It results in a reduced transport cost (i.e. bandwidth savings or server load reduction) due to traffic localization at the edge and to multicast realized by aggregating requests or serving content from caches.

Overall, we observe benefits resulting from key features of ICN communication model, and additional opportunities may come from the design of video-specific enhancements of ICN (e.g. smart video-specific caching/ forwarding policies, network- assisted video delivery) to optimally support DAS.

We plan to leverage the demonstrated platform to continue the work in such direction. To summarize the ICN benefits for dynamic adaptive streaming, we show that ICN brings improved rate adaptation and dynamic load-balancing over multiple media leading to better user experience. In the network, video quality-aware forwarding/caching strategies can maximize traffic localization and bandwidth savings in backhaul/core via enhanced multicast and network-assisted rate adaptation.

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[1] https://github.com/bitmovin/libdash

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