Video Streaming in FiWi Access Networks

Navid Ghazisaidi, Arizona State University, Tempe, AZ, USA
navid@asu.edu
Martin Maier, Optical Zeitgeist Laboratory, INRS, Montreal, QC, CANADA
maier@emt.inrs.ca
Martin Reisslein, Arizona State University, Tempe, AZ, USA
reisslein@asu.edu

1. Emergence of FiWi networks

Bimodal fiber-wireless (FiWi) networks may be considered the endgame of broadband access. FiWi access networks aim at seamlessly converging the latest optical and wireless broadband technologies, capitalizing on the capacity of optical networks and the ubiquity and mobility of wireless networks. FiWi networks involve the deployment of both radio-over-fiber (RoF) and radio-and-fiber (R&F) technologies [1]. Significant progress has been made at the physical layer toward the commercial realization of RoF networks. In a recently reported RoF field trial, the Georgia Institute of Technology successfully demonstrated the delivery of 270 Mb/s standard definition (SD) and 1.485 Gb/s high definition (HD) real-time video streams using 2.4 and 60 GHz millimeter-wave transmissions over standard single-mode fiber [2].

RoF networks are well suited for medium access control (MAC) protocols that deploy centralized polling and scheduling, e.g., cellular and WiMAX networks. However, for distributed MAC protocols, such as the widely deployed DCF in IEEE 802.11 WLANs, the additional fiber propagation delay may exceed certain MAC protocol timeouts, e.g., ACK timeout. As a consequence, optical fiber can be deployed in WLAN-based RoF networks only up to 1948 meters. R&F networks can avoid these limitations by means of protocol translation at the optical-wireless interface and controlling access to the optical and wireless media separately from each other [3].

1.1 Video delivery over FiWi Networks

Recently, the University of California Davis developed an R&F prototype by integrating Ethernet passive optical networks (EPONs) with an IEEE 802.11g WLAN-based wireless mesh network (WMN) [4]. The reported results show that the quality of video transmissions sharply deteriorates for an increasing number of wireless hops. In fact, the video client shows a blank screen after four wireless hops. These experimental results clearly show that a more involved study of integrated EPON/WLAN-based WMN networks are needed to support video traffic, especially given the fact that the sum of all forms of video (TV, video on demand, Internet, and P2P) is expected to account for over 91% of global consumer traffic by 2014, whereby Internet video alone will account for 57% and 3D/HD Internet video will comprise 46% of all consumer Internet video traffic by 2014, respectively [5].

A key requirement for providing video services over FiWi access networks is to deliver the video frames in a timely manner so that the receiver can continuously play back the video. This timely video frame delivery is made challenging by the highly varying (bursty) video traffic bit rates produced by the efficient video coding standards, especially the H.264 Scalable Video Coding (SVC) standard.

2. Video MAC Protocol (VMP)

In the recent paper [6], we have taken first steps toward the development and evaluation of a suite of advanced MAC protocols, for future EPON-based R&F FiWi networks delivering streaming video. In [6] we focus on a video MAC protocol (VMP) for streaming pre-recorded video in the downstream direction. The goal of VMP is to seamlessly integrate MAC mechanisms in the optical and wireless network segments for improved performance. In our VMP protocol, we introduce three main MAC enhancement techniques to improve the quality of received video streams at the end-users, namely: (i) We examine MAC frame fragmentation in conjunction with two-level (hierarchical) frame aggregation. (ii) We introduce hybrid wireless channel access control consisting of reservation-based periods, non-polling contention-based periods, and polling contention-free periods. We achieve polling contention-free channel access through multi-polling medium access control over the integrated FiWi network segments. (iii)

We introduce prefetching of video frames in conjunction with a hybrid reservation/contention-based MAC protocol over the integrated fiber-wireless network segments, whereas existing state-of-the-art MAC mechanisms consider video delivery over an isolated wireless network segment with hybrid reservation/contention-based MAC without prefetching [7].

3. Overview of Results

We found that prefetching mechanisms [8] benefit significantly from hybrid reservation/contention-based MAC protocols in FiWi networks. In particular, without reservations all video packets have to content for wireless channel access leading to a high proportion of collisions and relatively inefficient packet transport. At the other extreme, when dividing up the bottleneck bandwidth equally among the nodes receiving video streams there is no bandwidth left for contention. That is, there is effectively one "circuit" of fixed bandwidth to each receiving node and no more (global) statistical bandwidth sharing. This lack of global bandwidth sharing leads to relatively high starvation probabilities for the streaming of bursty video traffic.

The lowest playback starvation probabilities are achieved for moderate levels of reservation such that a basic level of the variable bit rate video traffic benefits from the efficient contention-free fixed-bandwidth "circuit" to each receiver. The traffic exceeding the reserved bandwidth for a node contends for the globally shared remaining bandwidth pool. Overall, our results indicate that video prefetching with channel probing reduces the video starvation probability by over an order of magnitude compared to reservation/contention MAC.

4. Summary and Outlook

We have briefly reviewed the emerging area of video streaming over Fiber-Wireless (FiWi) access networks as well as a first study of efficient integrated medium access control (MAC) mechanisms for FiWi networks with streaming prerecorded video traffic in the downstream direction. We have found that hybrid reservation/contention-based medium access control benefits significantly from prefetching of video frames with channel probing. For a wide range of reserved bandwidth levels, prefetching with channel probing robustly reduces playback starvation probabilities by over an order of magnitude.

An important direction for future work is to examine the internetworking of the FiWi network MAC protocols with metropolitan area networks, such as ring and star-based optical metro networks. Another important direction for future work is to examine efficient mechanisms for upstream (from the individual wireless stations to the Optical Line Terminal) transport of streaming video.

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Navid Ghazisaidi is with Ericsson Inc., San Jose, CA. He received his MSc degree in

Electrical Engineering with specialization in Telecommunications (with distinction) from the Blekinge Institute of Technology (BTH), Karlskrona, Sweden in 2006, and his PhD degree in Telecommunications from the University of Quebec, INRS, Montréal, Canada, in 2010. Dr. Ghazisaidi was a Research Associate at the School of Electrical, Computer, and Energy Engineering, Arizona State University (ASU), Tempe, AZ, USA, from September 2010 through November 2010. He was a Visiting Researcher at the Deutsche Telekom Laboratories (T-Labs), Berlin, Germany, and participated in the prestigious European research project ACCORDANCE (A Converged Copper-Optical-Radio OFDMA-based Access Network with high Capacity and flExibility), January 2010 through April 2010. He was a Researcher in the Computer Network (CN) group at the University of Basel, Basel, Switzerland, and participated in the the prestigious European research project BIONETS (BIOlogically-inspired autonomic NETworks and Services), September 2006 through January 2007. His research interests are in the area of MAC protocol design for Fiber-Wireless (FiWi) networks.

Martin Maier (maier@ieee.org) is an associate professor at the Institut National de la Recherche Scientifique (INRS), Montreal, Canada. He was educated at the Technical University of Berlin, Germany, and received MSc and PhD degrees (both with distinctions) in 1998 and 2003, respectively. In the summer of 2003, he was a postdoc fellow at the Massachusetts Institute of Technology (MIT), Cambridge. He was a visiting professor at Stanford University, Stanford, October 2006 through March 2007. Dr. Maier is a co-recipient of the 2009 IEEE Communications Society Best Tutorial Paper Award. His research activities aim at rethinking the role of optical networks and exploring novel applications of optical networking concepts and technologies across multidisciplinary domains, with a particular focus on communications, energy, and transport for emerging smart grid applications and bimodal fiber-wireless (FiWi) networks for broadband access. He is the founder and creative director of the Optical Zeitgeist Laboratory (www.zeitgeistlab.ca) and author of the book Optical Switching Networks (Cambridge University Press, 2008), which was translated into Japanese in 2009.

Martin Reisslein is an Associate Professor in the School of Electrical, Computer, and Energy Engineering at Arizona State University (ASU), Tempe. He received the Dipl.-Ing. (FH) degree from the Fachhochschule Dieburg, Germany, in 1994, and the M.S.E. degree from the University of Pennsylvania, Philadelphia, in 1996. Both in electrical engineering. He received his Ph.D. in systems engineering from the University of Pennsylvania in 1998. During the academic year 1994—1995 he visited the University of Pennsylvania as a Fulbright scholar. From July 1998 through October 2000 he was a scientist with the German National Research Center for Information Technology (GMD FOKUS), Berlin and lecturer at the Technical University Berlin. He currently serves as Associate Editor for the IEEE/ACM Transactions on Networking and for Computer Networks. He maintains an extensive library of video traces for network performance evaluation, including frame size traces of MPEG-4 and H.264 encoded video, at http://trace.eas.asu.edu. His research interests are in the areas of multimedia networking, optical access networks, and engineering education.