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Greening Video Distribution Networks

Energy-Efficient Internet Video Delivery

Springer

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ISSN 1617-7975 ISSN 2197-8433 (electronic)
Computer Communications and Networks
ISBN 978-3-319-71717-3 ISBN 978-3-319-71718-0 (eBook)
https://doi.org/10.1007/978-3-319-71718-0

Library of Congress Control Number: 2017961100

Printed on acid-free paper

This Springer imprint is published by the registered company Springer International Publishing AG part of Springer Nature
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword

The concept of the CONVINcE project grew out in 2013 of two observations: the Internet's carbon footprint was expected to exceed in 2020 that of air travel by a factor of two and the Internet traffic will be driven by video. Should people not be convinced of the necessity to reduce carbon dioxide emission, they will need to react to the economic aspect of the problem coming from the price of electricity, which will irremediably increase in the future.

Made up of 16 partners from four European countries, CONVINcE is a Celtic-Plus project addressing the challenge of reducing the power consumption in IP-based Video Distribution Networks (VDN). Partners followed an end-to-end approach, from the headend where contents are encoded and streamed to the terminals where they are consumed, embracing the Content Delivery Networks (CDN) and the core and access networks.

Partners' efforts concentrated on several topics. First on architectures, with a theoretical approach aiming at defining trade-offs between energy consumption and final user's Quality of Experience (QoE). Then, several concrete use cases were studied and some of them implemented. Particular focus was given to energy savings in mobile terminals, edge-cloud and green routing in the core network. Prefiguring tomorrow's networks, virtualization and Software Defined Networks (SDN) were not dismissed, and their influence on power consumption was assessed as well. In order to have accurate measurements of power consumption of devices, hardware and software measurement tools were developed. Industrial partners also conducted a techno-economic analysis with the objective to estimate potential energy savings brought by the project and subsequent gains for service and network operators. CONVINcE project contributed additionally to four different standardization forums: 3GPP, IEEE, IETF and MPEG. In these forums, the project contributed to six different working groups with 38 technical contributions.

An important conclusion of the project is that there is no 'magic solution' solving all consumption issues from the headend to the terminal. Optimization is the sum of several—even small—contributions properly implemented to save energy. Another important result of the project is that you must sometimes accept to consume more energy in one part of the system to save a lot in other parts. This is

typically the case where using a new encoding standard HEVC—in the headend increases significantly the energy consumption in this part, but divides by two the bitrate, leading to substantial savings in networks and terminals, with a high positive impact on the end-to-end consumption.

This book is a useful guide for those who want to reduce energy consumption in IP-based VDNs. Most of the chapters are direct results of the CONVINcE project, showing that use of new approaches and technologies can actually reduce the energy consumption in these networks, contributing so to reducing the carbon footprint of the Internet. I would like to thank the authors for their valuable contribution to this huge task.

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Preface

Introduction

Internet video delivery refers to Video Distribution Networks (VDNs). These are networks composed of several parts that together create a chain model from encoding and packaging the content, its transport and distribution to end users and to its consumption in terminals. The most important functionalities in these networks are video encoding/transcoding, adaptive bit streaming, core/metro networks, access networks, Content Delivery Networks (CDNs) and routing protocols.

Given the huge increase in video traffic expected in the next few years, this means one needs to solve associated problems like tempering the significant increase expected in energy consumption and to provide the expected end user Quality of Experience (QoE). For instance, it is mentioned that the European Council has set forth an important target in form of the so-called '20 20 by 2020' initiative, which means the goal is to reduce the greenhouse gases by 20% in European Union (EU) as well as to obtain a 20% share of renewable energies in EU. This further means there is a strong need to consider problems related to this, to study and to solve them.

Reducing energy consumption in VDNs also means addressing topics like software best practices and eco-design as well as power and Quality of Experience (QoE) based design.

Towards this goal, the Celtic-Plus project CONVINcE, financed 2014–2017, with participating industrial and academic partners from four European countries (France, Finland, Sweden and Turkey) brings in important contributions. This book reports an overview of the main research results obtained in CONVINcE.

Organization

The book is organized in a number of ten book chapters and a Foreword chapter that cover several of the most important elements of Video Distribution Networks. Nine book chapters have been written by people involved in the CONVINcE project, working with different elements and aspects of Video Distribution Networks. Furthermore, one more book chapter has been written by researchers at the University of Genoa, Italy and University of Malta. Particular focus has been given to elements like architectures, models, video encoding and decoding, mobile terminals, wireless sensor networking, Software Defined Networking (SDN) and techno-economic aspects.

Features

Based on the information regarding existing literature, one can state that today there is no other similar book. The uniqueness of the results reported in the book combined with the relevance and importance of the topic gives a unique position. Furthermore, it is expected that the experience obtained in the CONVINcE project will open up for other future relevant projects focused on the stringent problem of reducing the energy in Video Distribution Networks.

Target Audience

The book is addressed to several categories of readers: college students, engineers, researchers, networking scientists, computer scientists and industry people. The broad area of topics covered by the book combined with the practical insight creates good premises for opening the interest of many people involved in computer and telecommunication systems.

Karlskrona, Sweden Adrian Popescu

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Abbreviations

3GPP	3rd Generation Partnership Project
ACM	Association for Computing Machinery
API	Application Programming Interface
AVC	Advanced Video Coding
CAM	Video CAmera attached to a Computer
CCN	Content Centric Networking
CDN	Content Distribution Network
Cloud Computing	Internet-based computing
CONVINcE	Consumption OptimizatioN in VIdeo Networks
CPU	Central Processing Unit
DC	Data Center
DNS	Domain Name System
Edge Cloud	Optimizing cloud computing by performing data processing at the edge of the network
GPU	Graphics Processing Unit
GSM	Global System for Mobile Communication
H.323	Protocol for setup, management and termination of a media session
HEVC	High Efficiency Video Coding
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
HTTP-DASH	Dynamic Adaptive Streaming over HTTP
HW	Hardware
I/O	Input/Output
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IoT	Internet of Things
IP	Internet Protocol
IPTv	Internet Protocol Television

IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
ISO	International Standards Organization
ITU	International Telecommunications Union
LLN	Low-Layer Network
MPEG	Moving Picture Experts Group
MVC	Multi-View Coding
NFV	Network Function Virtualization
OTT	Over The Top
PSNR	Peak Signal-to-Noise Ratio
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RBG	Red/Blue/Green
SDN	Software-Defined Networking
SIP	Session Initiation Protocol
SLA	Service Level Agreement
SNMP	Simple Network Management Protocol
SVC	Scalable Video Coding
TCP	Transport Control Protocol
TV	Television
UHD	Ultra-High-Definition television
VDN	Video Distribution Network
VDS	Video Data Specification
VoD	Video on Demand
VoIP	Voice over IP
VPN	Virtual Private Network
VQM	Video Quality Model
WAN	Wide Area Network
Wi-Fi	Technology for Wireless Local Area Networking based on using IEEE 802.11 standards
WLAN	Wireless Local Area Network
WMSN	Wireless Multimedia Sensor Network
WPAN	Wireless Personal Area Network
WSN	Wireless Sensor Network