CONVINcE

D1.1.5

Forecast Models

Editor: Adrian Popescu (BTH)

Reviewer: Miika Komu (Ericsson)

Authors: Yong Yao (BTH)
Patrik Arlos (BTH)
Rickard Ljung (Sony)
Erkki Harjula (UO)
Yannick Carlinet (Orange)
Björn Landfeldt (LU)
Saeed Bastani (LU)
Raoul Monnier (Harmonic)
Praboda Rajapaksha (IMT)
Reza Farahbakhsh (IMT)
Noel Crespi (IMT)

Executive Summary

Objective

Deliverable D1.1.5 “Forecast Models” is the fifth document provided in WP1 – Task 1.1 The objectives of this document are to go one step forward and to provide forecast models expected in networking scenarios considered in CONVINcE. Basically, this document further develops on the models considered in the four previous Deliverables D1.1.1 to D1.1.4 and focuses on data forecast for video streaming in relevant networking environments. It is reminded that the focus in CONVINcE is on minimum e2e power consumption for video streaming and best end-user Quality of Experience (QoE) obtained at the terminal, for relevant networking scenarios.

The focus of this deliverable on rechhcFust models expected to be met in the ture, when the live reaming video is expected to increhhcFuse the overhhcFull shhhcFure of strehhcFuming in the Internet trhhcFuff the most importhhdbn dbt mb 3SECSQUcFtdcccFadsconsidered in this document8dsccdsccSKoSShsS:Gbsce “s

Table of Contents

Table of Figures

Table of Tables

1 Document history and abbreviations

1.1 Document history

Version	Date	Description of the modifications
	14.11.2016	Draft of ToC (BTH)
0.1	20.12.2016	First version
0.2	01.02.2017	Second version
1.0	15.02.2017	Final version

1.2 Abbreviations

ASF	Advanced Streaming Format
ARPU	Average Revenue Per User
BS	Base Station
CRAC	Computer Room Air Conditioning
CBSN	Camera-Based Sensor Network
CDN	Content Distribution Network
CG	Cloud Gaming
CPU	Central Processing Unit
CU	Common Unit
CRN	Cognitive Radio Network
DASH	Dynamic Adaptive Streaming over HTTP
DC	Data Center
DE	Deployment efficiency
e2e	end-to-end
EE	Energy Efficiency
ESB	Enterprise Service Bus
FLV	Flash Video
FIFO	First-Input-First-Output
GR	Goodput Ratio
HD	High Definition
HE	Head End
HFC	Hybrid Fiber-Coaxial
HPC	Hardware Performance Counter
IaaS	Infrastructure as a Service
IP	Internet Protocol
IPTV	Internet Protocol TV
ISMA	Internet Streaming Media Alliance
LVS	Live Video Streaming
LLN	Low-Layer Network
MOOP	Multiple Objective Optimization Problem
NFV	Network Function Virtualization
MOS	Mean Opinion Score
MRN	Mobile Radio Network
NVE	Network Virtualization Environment
ODVS	On-Demand Video Streaming
OPEX	Operating Expenditures

OTT	Over the Top
PaaS	Platform as a Service
PCA	Principal Component Analysis
PDU	Power Distribution Unit
PDH	Provisioning Delivery Hysteresis
PMC	Performance Monitoring Counter
QoE	Quality of Experience
QoEW	Quality of Experience Watt
QoS	Quality of Service
RAN	Radio Access Network
RBS	Radio Base Station
RTP	Real-Time Transport Protocol
RTT	Round Trip Time
SaaS	Software as a Service
SD	Standard Definition
SE	Spectrum Efficiency
SLA	Service Level Agreement
SDN	Software Defined Network
SOTA	State of the Art
UDP	User Datagram Protocol
UPS	Uninterruptible Power Supply
VDN	Video Distribution Network
VM	Virtual Machine
WAN	Wide Area Network

1 INTRODUCTION

The goal of the CONVINcE project is to develop new technological solutions to reduce the energy consumption in IP-based video networks with an end-to-end perspective, from the Head End through the network and finally to terminals. Four Deliverables have accordingly been written D1.1.1, D1.1.2, D1.1.3 and D1.1.4. These documents are dedicated to different important aspects, i.e., Deliverables D1.1.1 “Application Scenarios”, D1.1.2 “System Requirements”, D1.1.3 “High-Level Architecture Design” and D1.1.4 “Theoretical Models”. With reference to these deliverables, the focus of Deliverable D1.1.5 “Forecast Models” is laid on the forecast models expected to be met in the future, when live streaming video is expected to increase the overall share of the Internet traffic.
Three categories of network architectural solutions are considered in CONVINcE. Furthermore, on top of the network architecture, Content Distribution Network (CDN) and Video Distribution Network (VDN) are considered.
A set of adequate system requirements has accordingly been defined for CONVINcE. These are requirements that refer to functional aspects, non-functional aspects as well as users and system interfaces. Based on this, the document CONVINcE D1.1.3 defines the high-level architecture and, related to this, the service models for CONVINcE as well as some implementation details and the associated performance optimization are defined in the document CONVINcE D1.1.4.

1.1 Scope

The goal of the CONVINcE research project is to develop new solutions for reducing the end-to-end power consumption in IP-based video networks, beginning with the Head End (HE) and ending to terminals, also including the core and the access networks. As mentioned above, the focus of this document is laid on some forecast models expected to be met in the future, when live streaming video is expected to increase the overall share of the Internet traffic. Among others, the customers are expected to move beyond on-demand video to live streaming vieweing behaviour. According to CISCO’s June 2016 Report on Visual Networking Index, this share is expected to jump to 82% by 2020! Also, it is expected that live streaming will show a sharp rise especially in social media.
Today, live streaming is still in its early stages, and large efforts to develop the standards and technology as well as to monetize the live videos are emerging, with special focus on Over-The-Top (OTT) solutions.
In the end, this is also expected to change social media algorithms that affect the video content. It is also important to mention that live streaming has now emerged as the preferred way not only for person-to-person sharing but also for business-to-customer and business-to-business communication. Among others, live streaming is significantly used by social platforms like Facebook (Facebook Live), YouTube, Snapchat and Twitter, where all of them have significantly enhanced their live streaming platforms and user experience (the so-called high-definition video experience). It is also important to mention that advertisers are expected to heavily invest in online video, especially in live streaming. The conclusion is that live streaming is expected to be a sustainable business as well.
The purpose of this document is to report on data forecast expected to be met in relevant networking areas, i.e., video streaming in Radio Access Networks (RAN), in Wide Area Networks (WAN), in Access Networks (AN) as well as in Content Distribution Networks (CDN).
These networking technologies are expected to be very much influenced by the extreme development expected in video streaming.
The results of this document will be used as input to the document Milestone M1.1.3 as well as future activities in using the project results.

1.2 Document Structure

The document structure is as follows:

- Section 2 presents the data forecast for video streaming in RAN
- Section 3 presents the data forecast for video streaming in WAN
- Section 4 presents the data forecast for video streaming in AN
- Section 5 presents the data forecast for video streaming in CDN
- Section 6 summarizes the document

2 DATA FORECAST FOR VIDEO STREAMING IN RAN (SONY)

The radio access network (RAN) traffic is growing significantly each year, and estimations from the industry indicate that the traffic in RAN network will continue to grow at a rapid pace, due to the evolution of services applied to the mobile communication systems. Video streaming is the main driver for increased data traffic, and video streaming services are already today consuming majority of all data in mobile networks.

The Ericsson consumer report (Ericsson n.d.) is a global study of data communication statistics, and the study includes analysis of both regional mobile data growth and application specific data. The 2016 report outlines that the total mobile data traffic in RAN is expected to rise at a compound annual growth rate (CAGR) of around 45 percent. Between 2016 and 2022, smartphone traffic is expected to increase by 10 times.

Specifically, for video streaming in RAN the Ericsson consumer report estimates that mobile video traffic is forecasted to grow by around 50 percent annually through 2022. In 2022, video will account for around 75% of all mobile data traffic. In data, the global mobile video traffic is expected to grow from ~4ExaBytes to over 50ExaBytes to year 2022. This is illustrated in the figure 1 below.

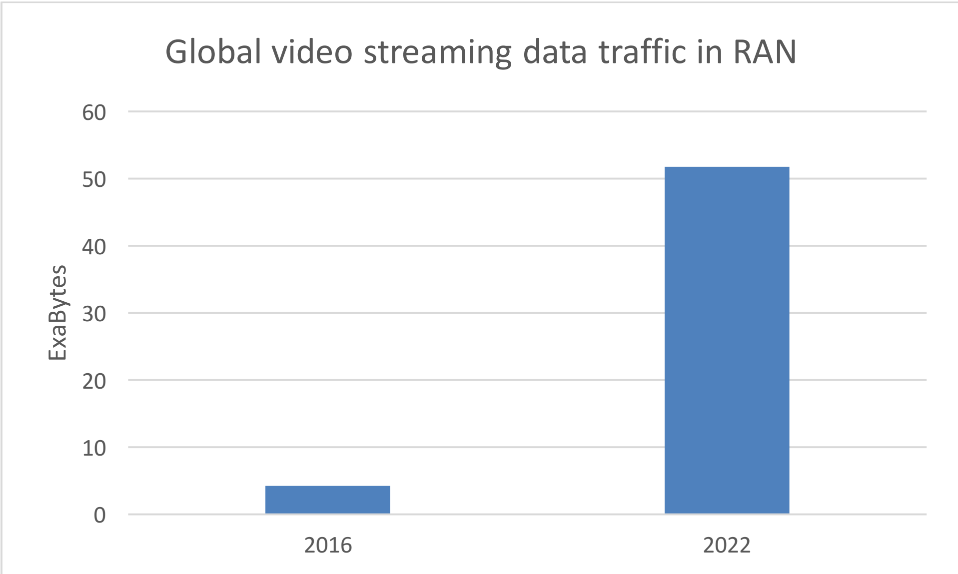


Figure 1: Global video streaming data traffic in RAN growth prediction, Ericsson mobility report

The data forecast for video streaming in RAN per device is per Ericsson mobility report expected to grow in a similar pattern. In particularly the Western Europe, where the CONVINcE project consortium also resides, the average mobile video traffic per device is expected to reach 15 Gigabyte per month in 2022. This is 13 times increase within the predicted time frame. The average mobile video streaming data traffic in RAN per device per month predictions for different regions is illustrated in the figure below.

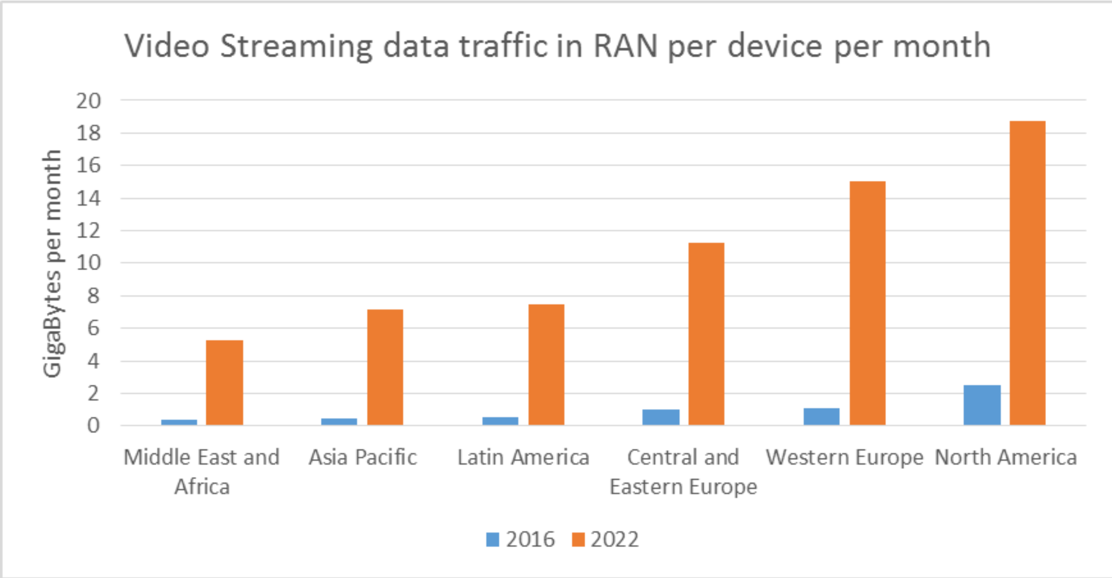
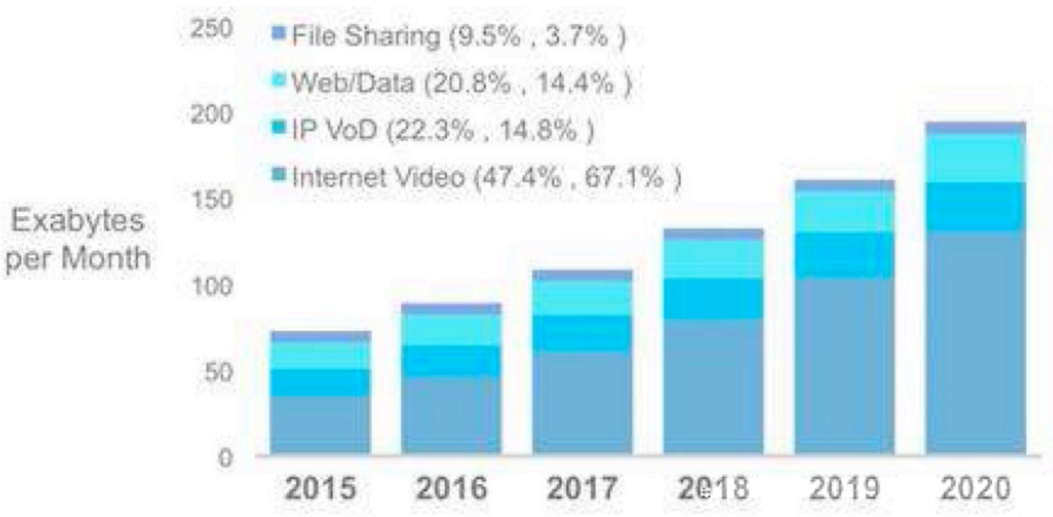


Figure 2: Global video streaming data traffic in RAN growth prediction, Ericsson mobility report

To increase the confidence in the estimations, the same level of video streaming data traffic growth in RAN is predicted by another key industry player. In early 2016 Cisco presented their "visual networking index" (Cisco n.d.), where they predict that mobile video will increase 11-fold between 2015 and 2020, accounting for 75 percent of total mobile data traffic by the end of the forecast period.
Further, to support the predictions of the large annual growth in video streaming traffic over RAN, the evolution of data traffic capacity in the RAN technical standard is continuing. In the 2020-time frame, a new generation radio access system, developed by 3GPP, is estimated to reach the mobile communication market. The new radio access system is in first phase targeted the higher system capacity and higher data rate use cases such as ultra-high resolution video streaming. Hence, it can be expected that the video streaming forecast will continue its rapid growth also beyond 2020.

3 DATA FORECAST FOR VIDEO STREAMING IN WAN (ORANGE)

Since almost all application traffic goes through the WAN, we here focus on the global IP video traffic. Per Cisco Visual Networking Index (VNI), an ongoing initiative to forecast the impact of visual networking applications, the proportion of IP video traffic will amount to 82 percent of the global IP traffic by 2020 (it was 70 percent in 2015). This is illustrated in the figure below that indicates that file sharing and web/data traffic volume does not increase as sharply as IP video traffic:



Figures (n) refer to 2015, 2020 traffic shares.

Source: Cisco VNI Global IP Traffic Forecast, 2015–2020

Figure 3: Data forecast (1)

The IP video traffic consists mainly of

- video surveillance traffic
- Internet video to TV traffic
- Virtual reality traffic
- Video-on-Demand (VOD) traffic

And we will now see how each type of traffic will evolve from now up to 2020.
Video surveillance traffic is expected to be multiplied by a factor 10. In fact, it has already doubled from 2014 to 2015. Eventually this traffic will make for around 4 percent of the global IP traffic.
Internet video to TV will be 26 percent of the global IP traffic in 2020. It will increase by 26 percent each year.
Virtual reality traffic already quadrupled from 2014 to 2015, and it is expected to be multiplied by a factor 61 between 2015 and 2020.
VoD traffic will double from 2015 to 2020, amounting to the equivalent of 7.2 billion DVDs per month.

The figure below shows the growth year-by-year of online video, digital TV and mobile video. It is interesting to note that the mobile video market will grow the fastest.

Source: Cisco VNI Global IP Traffic Forecast, 2015–2020

Figure 4: Data forecast (2)

In conclusion, the IP video traffic will reach in 2020 an amount of 1.88 ZB (zettabytes, i.e. 1.88e21 bytes). It represents 160 EB per months, or 160e19 bytes per month.

4 ENERGY CONSUMPTION FORECAST MODEL FOR STREAMING IN ACCESS NETWORKS (UO)

4.1 Introduction

Battery duration is undoubtedly one of the most essential factors affecting the feasibility of mobile Internet communication. For long, one of the main challenges of mobile networking has been the fact that the battery technology does not improve at the same pace as the power requirements (Ravi et al. 2008). Thus, energy-efficient solutions are essential for keeping battery life on an acceptable level. With mobile devices, the network interface accounts for a major component of the total power consumption (Pering et al. 2006), emphasizing the importance of energy-efficient networking.

In general, Internet traffic can be categorized into two basic types: signaling and media transfers. Signaling includes network transactions consisting of separately sent and received small messages, transmitted in single packets, such as maintenance messaging, instant messaging, and service lookups. Media transfers include network transactions consisting of series of packets, such as file transfers and media streaming. These traffic types have radically different energy consumption characteristics in wireless networks. Whereas the energy consumption of media transfers in wireless networks can be estimated quite accurately using the amount of transmitted data, frequent signaling consumes significant amounts of energy regardless of the relatively small amount of transferred data (Eronen 2008).

4.1.1 Cellular networks

In cellular networks, low latency, high throughput and support for high mobility are important design features, aiming to achieve high-quality user experience. The cellular energy saving mechanisms have been optimized for minimizing the energy consumption during long idle periods and ensuring low latency and high throughput during intensive network usage.

The energy consumption of the 3G radio interface is mostly influenced by the radio resource management performed at the network operator side by the Radio Network Controller (RNC) (Vergara & Tehrani 2013, Vergara et al. 2014, Perälä et al. 2009, Haverinen et al. 2007). The RNC uses the Radio Resource Control (RRC) and the Radio Link Control (RLC) protocols. RRC includes three states: IDLE, PCH (paging channel, alternative to IDLE), DCH (dedicated channel), and FACH (forward access channel). IDLE and PCH states provide low energy consumption for idle periods, but the latency is relatively high in this state. DCH state gives maximum throughput with minimum delay at the cost of high energy consumption. In FACH, the energy consumption is reduced at the cost of lower throughput, when compared to DCH. Changing from the idle state to either of the data transfer states requires a setup time. The additional energy consumed during the setup time is called ramp energy (Balasubramanian et al. 2009). After the completion of a data transfer, the radio link remains in a data transfer state for a while waiting for further data transfers, before moving to idle state. The additional energy consumed during this time is called tail energy (Balasubramanian et al. 2009). The transitions between states are controlled using inactivity timers and RLC data buffer thresholds set by mobile operators.

The 4G technology (also known as 3G LTE) is an evolution of the 3G technology. In 4G, the power saving mechanism is more sophisticated (Bontu & Illidge 2009, Koskela & Vatjus-Anttila 2015, Hoque et al. 2015). In 4G, RRC provides three main states: IDLE, CONNECTED (or ACTIVE) and DORMANT. In IDLE state, the radio is in a low-power state, only listening to control traffic. CONNECTED state is used to transmit data or to listen for incoming data, and network resources are allocated for the device to give maximum throughput with minimum delay at the cost of high energy consumption. DORMANT state has the following sub-states: Short discontinuous reception (DRX) and Long DRX. In DORMANT state, no specific network resources are allocated for the device. Wireless radio remains most of the time switched off to save energy and is periodically turned on to check for new incoming traffic. With short DRX, the period is shorter, providing faster response time, and with Long DRX, the period is longer, providing lower energy consumption. The transition from CONNECTED to IDLE state occurs through Short DRX and Long DRX states. The typical transition time from the CONNECTED state to IDLE is only a few seconds. This significantly improves the energy-efficiency of 4G as compared to 3G. In addition, 4G provides better energy per bit ratio despite the higher energy consumption in CONNECTED state (Huang et al. 2013).

4.1.2 WiFi networks

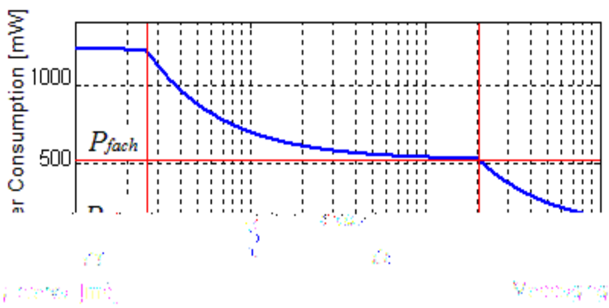
In IEEE 802.11 WLAN networks, the energy saving mechanisms have been optimized for minimizing energy consumption in active network usage. The main principle is to avoid negative effects on performance, particularly the long response times that are present in older cellular network technologies. The transmission energy consumption for WLAN is mostly influenced at the driver level in the WLAN client (Vergara & Tehrani 2013, Vergara et al. 2014). In constantly awake mode (CAM), the power-saving features are disabled to achieve maximum performance. The power save mode (PSM) allows clients to switch to low power mode for predefined periods when not transferring any data, similarly to DRX states in 4G. In this mode, the access point buffers downlink frames for the clients and clients wake up periodically to receive buffered frames from the access point using Power Save Poll (PS-Poll) message. Idle listening is the dominant source of energy consumption in WLAN Zhang & Shin (2012). The PSM mode reduces the energy consumed by idle listening by sleep scheduling. However, through a real-world traffic analysis. Adaptive PSM is a common mechanism to overcome the overhead and latency drawback of using PS-Poll mechanism (Krashinsky & Balakrishnan 2002, Pyles et al. 2012). In adaptive PSM, the state transitions between CAM and PSM are based on heuristics considering, e.g., the traffic profile or device display mode (on/off).
To sum up, the traditional energy consumption estimation models, based solely on the amount of transferred data, are obsolete for today's mobile networking. This section introduces an energy consumption model for estimating the energy consumption of mobile wireless connections.

4.1 The model

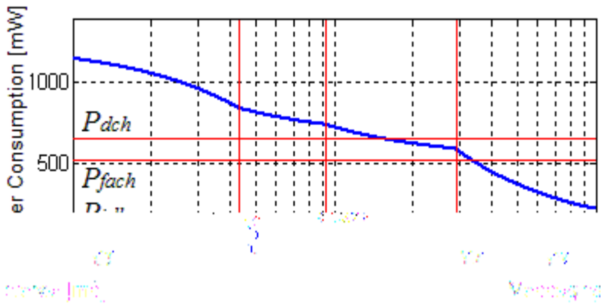
In Harjula et al. (2014), we introduced the *e-Aware* model for estimating how application layer properties affect the energy consumption of mobile devices operating in mobile networks. The model estimates the energy consumption originating from network operations based on two energy consumption elements, *signaling* and *media* transfers. The distinction between signalling and media transfers is made due to their different energy consumption characteristics that were studied in (O et al. 2009; Z et al. 2010; E, T, and M 2011). The model takes as parameters the transmission interval and packet size for transferred data chunks smaller than 1500 bytes and the amount of moved data for data chunks greater than 1500 bytes. Power and energy consumption estimates are produced as output for a given scenario. The model calculates the total energy consumption estimation as a sum of energy consumption originating from signalling (data chunks under 1500 bytes) and from media transfers (data chunks over 1500 bytes) (Eq. 1). The details of the model are presented in Harjula et al. (2014).

$$\mathrm{P(t)} = \max\left[P_{sig}(t), P_{med}(t)\right] \quad (1)$$

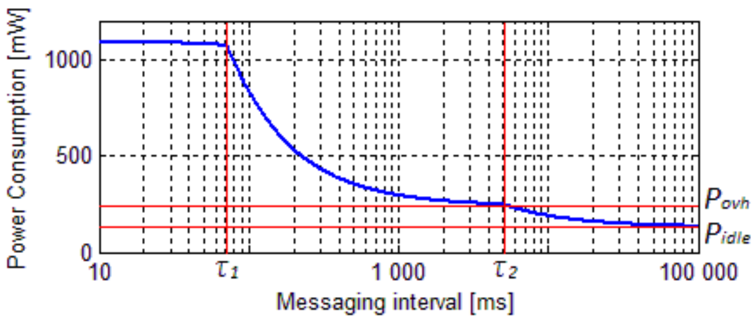
For signalling, the model simulates the power consumption of a mobile device with different network interfaces using a set of equations based on the state machines of the wireless protocols and the empirical power consumption measurement data gathered by (O et al. 2009; Z et al. 2010). In addition to the traffic parameters, the algorithm uses network-specific parameters, such as timeout intervals, packet size thresholds and practical upload/download transfer rates. Fig. 5 (a) shows a typical power consumption curve with 3G radio interface for packets sized below 250 Bytes, and Fig. 5 (b) shows the curve for packets above 250 Bytes in 3G. Fig. 5 (c) shows the similar curve for WLAN networks with all packet sizes.



(a) 3G <250B packet



(b) 3G >250 B packet



(c) WLAN

Figure 5: Estimated power consumption for signalling in 3G and WLAN networks (Harjula et al. 2014)

For full data-rate transfers, the model first calculates the data transfer time (t_{tra}), including the setup time, by using the size of the moved data object and the practical upload/download data transfer rates given as parameters. During t_{tra}, the power consumption is averagely P_{ul} for uploads or P_{dl} for downloads, after which the power consumption returns to P_{idle} through intermediate power states. P_{ul}, P_{dl} and P_{idle} are defined based on the measurements of (O et al. 2009; Z et al. 2010).
According to obtained results, the accuracy of the e-Aware model is high in application scenarios where the traffic consists of frequently sent packets with low variance in packet sizes (3-6% estimation error) and full-bandwidth data transfers (< 1% estimation error). When the packet sizes vary significantly, the accuracy was found lower, but still acceptable (14–21% estimation error). The e-Aware model was found to have strong potential to facilitate the development of energy-efficient networking solutions by reducing the need for time-consuming iterations between system development and evaluations with real-life networks and devices.

4.2 Applicability to CONVINcE project

The e-Aware model is applicable for CONVINcE project with some additions and modifications, described below.
The previous model, described in Section 5.1 was based on measurements that were made with a smartphone more than six years ago. Thus, the energy profiles need to be updated to comply with today's devices and networks. The WiFi and 3G measurements need to be rerun and 4G measurements need to be added. This work is currently ongoing and expected to be finished during the first quarter of 2017.
Furthermore, the original model does not consider streaming. However, since streaming can be considered as a series of downloads/uploads combined with some control messaging, the model can be used to estimate the power consumption of streaming as well. For this, the input parameters for streaming need to be added and the program logic need to be updated. This work is also ongoing and expected to be finished during the first quarter of 2017.
It should also be noticed that the model estimates only the power consumption of networking and network-related computing. The effect of video processing, displaying and UI tasks are excluded from the estimation.

5 DATA FORECAST FOR VIDEO STREAMING IN CDN (IMT AND UNIV LUND)

A recent study shows by the end of the year 2016, 47% of the world population is using the Internet which is almost a penetration rate of 50%. On the other hand, the total international bandwidth had reached to 185,000 Gbit/s (ITU n.d.). An important reason that leads to this considerable increment is new type of services and content (e.g. video and multimedia content).
According to data forecast of the visual Networking Index (VNI) by provided by CISCO (Cisco2 n.d.), by 2020 global IP traffic will reach 2.3 ZB per year and that of by the end of 2016 is 1.1 ZB. Interestingly, smartphone traffic will exceed traffic originating from PCs traffic after 4 years, where in 2015, PCs accounted 7 times more total IP traffic than smarthones. In 2015, 70 % of the total global IP traffic is video traffic and by 2020 video will be 82% off all traffic, and video-on-demand (VoD) traffic will nearly be doubled by 2020. More detail on this estimation can be find in Table 1.

Consumer Internet Traffic, 2015–2020							
	2015	**2016**	**2017**	**2018**	**2019**	**2020**	**CAGR 2015–2020**
By Network (PB per Month)							
Fixed	39,345	48,223	59,294	72,442	88,399	107,375	22%
Mobile	3,027	5,127	8,326	12,609	18,436	26,080	54%
By Subsegment (PB per Month)							
Internet video	28,768	38,116	50,512	66,263	86,708	109,907	31%
Web, email, and data	7,558	9,170	11,061	12,752	14,060	17,006	18%
File sharing	5,965	5,938	5,858	5,742	5,645	5,974	0%
Online gaming	82	126	189	294	421	568	47%

Table 1: Cisco VNI forecast and methodology, 2015-2020 (Cisco2 n.d.)

Due to these trends in video consumption, many researchers have investigated several aspects of Internet video including network protocols and hardware components. Up to 45% of the Internet traffic is carried by CDNs in 2015, which shows video content distribution in CDNs plays a major role. Based on the data forecasting of the VNI, CDNs will carry nearly two-thirds of the overall Internet traffic by 2020 combining live broadcasting, video telephony, teleconferences, Internet gaming traffic, Internet video surveillance traffic etc. Table 2 includes detail on global content delivery network internet traffic in coming years (Cisco2 n.d.).

CDN Traffic, 2015–2020							
	2015	2016	2017	2018	2019	2020	CAGR 2015–2020
By Geography (PB per Month)							
North America	11,080	15,094	20,113	26,382	33,829	41,292	30%
Asia Pacific	5,590	7,807	10,924	15,115	20,711	27,628	38%
Western Europe	5,025	6,798	9,096	11,903	15,744	19,817	32%
Central and Eastern Europe	1,086	1,649	2,473	3,656	5,429	7,648	48%
Latin America	853	1,207	1,662	2,210	2,890	3,877	35%
Middle East and Africa	285	478	797	1,286	2,066	3,734	67%
Total (PB per Month)							
CDN Internet traffic	23,919	33,033	45,065	60,553	80,670	103,996	34%

Table 2: Global content delivery network internet traffic, 2015-2020 (Cisco2 n.d.)

CDNs consist of hierarchical storage systems including rich content caching mechanisms to achieve fast content access providing better QoE to end users. Delivering high quality videos such as live videos and Video-on-demand (VOD) through very large bandwidth networks to large amount of end users is the main focus of the CDN providers. Developing a CDN solution for a large set of clients is expensive. Therefore, there are several CDN providers, and they perform online/offline video streaming via CDN, that are integrated with P2P networks as a hybrid CDN-P2P solution. For example, LiveSky (Yin and et al 2009) is one of the largest hybrid streaming systems available at present. The servers in CDN are organized in a tree structure whereas hybrid architectures form a tree-mesh overlay. There are two main P2P media streaming mechanisms that are integrated with CDN for utilizing upload bandwidth of the clients: namely, mesh-based pull system (Li and et al 2005) (peers share the information about their media repository) and tree-based push system (Castro and et al 2003) (each client can become a server to some other clients). Tree-based push systems are the widely-used extension of the CDNs.
Video streaming in CDN and more generally in Internet can be classified into two main categories: video on demand (VoD) and live streaming. Even-though many live streaming protocols can be utilized in VoD, there are key differences among these two techniques. Live streaming uses synchronous transmission using a broadcast server and VoD utilizes asynchronous transmission allowing a user to watch whenever necessary and therefore these videos are cached in a nearby serves for later requests. Compared to live streaming, VoD uses more user interactions (fast forward, fast rewind, and pause). Hence, VoD systems use start-up latencies and prefetch data at few anchor points allowing user to jump into another view point in the video timeline (Huang and et al 2008).
Presently, VoD industry is one of the profitable markets with different service providers such as YouTube, Netflix, and Amazon earning billions of revenues annually. Other than this, most of the TV broadcast networks (for instance BBC) offer VoD services. Additionally, much of the user generated video content are shared and distributed to very large number of users in social networks. For example, Facebook, Instagram, and Snapchat are a few of them. The VoD industry is led by YouTube connecting almost one third of all people on the Internet and, every day, it generates billions of views from the users who watch hundreds of millions of hours of YouTube videos (YouTube n.d.). The next most widely used VoD service provider is Netflix. Statistics of Netflix in 2015 shows that about 70 million subscribers worldwide were willing to pay for their services. By 2020, Netflix penetration rate forecast to be about 35% in many countries other than USA (Statista n.d.).
More recent research has focused on streaming videos over the Internet directly via Web using Dynamic Adaptive Streaming over HTTP protocol (HABS) (Müller, Lederer, and Timmerer 2012). HABS

considers a media file to be a collection of several components: audio, video, and subtitles that are stored separately on the HABS server. These components are delivered to the user separately and combined at the user's device. Adaptive streaming is a hybrid approach of progressive download and streaming acting as a pull-based mechanism combined with HTTP protocol. The same video can be provided under different bitrates, suitable for device's corresponding resolutions and quality levels allowing the client to switch between different bitrates at each request. Since adaptive streaming uses HTTP protocol, it eases traversing through NATs and firewalls, and keeps fewer information on the server side which allows HTTP servers to be more scalable. Using HTTP as a media protocol overcomes several disadvantages compared with RTP or RSTP protocols. Therefore, HTTP adaptive streaming enables CDNs to enhance the scalability of their content distribution (Begen, Akgul, and Baugher 2011).

6 CONCLUSIONS

The goal of the document D1.1.5 “Forecast Models” is to present data forecast information expected in relevant networking areas, i.e., for video streaming in Radio Access Networks (RAN), in Wide Area Networks (WAN), in Access Networks (AN) as well as in Content Distribution Networks (CDN).
These are networking technologies expected to be heavily influenced by the strong development foreseen in video streaming technology.
The results of this document indicate, among others, that the amount video traffic is raising, also including the OTT traffic generated by different video providers. Connected with this, description of different CDNs has been done. A model to estimate energy consumption in wireless traffic has been developed as well.
Future work is to continue this and to use the information presented in this document to plan and to prepare to improve video streaming technology as indicated in the document.

7 BIBLIOGRAPHY

Begen, A., Akgul, T., & Baugher, M. (2011). Watching video over the web: Part 1: Streaming protocols. *IEEE Internet Computing*.

Castro, M., & et al. (2003). SplitStream: high-bandwidth multicast in cooperative environments. *ACM SIGOPS Operating Systems Review, 37*(5).

Cisco. (kein Datum). Von http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.html abgerufen

Cisco2. (kein Datum). Von http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/vni-hyperconnectivity-wp.html abgerufen

E, H., O, K., & M, Y. (2012). Energy Consumption Model for Mobile Devices in 3G and WLAN Networks. *9th IEEE Int. Conference on Consumer Communications and Networking*, S. 532–537.

E, H., T, K., & M, Y. (2011). Comparing the Performance and Efficiency of Two Popular DHTs in Interpersonal Communication. *IEEE Wireless Communications and Networking Conference*, S. 2173–2178.

Ericsson. https://www.ericsson.com/assets/local/mobility-report/documents/2016/ericsson-mobility-report-november-2016.pdf abgerufen

Eronen , P. (2008). TCP Wake-Up: Reducing Keep-Alive Traffic in Mobile IPv4 and IPsec NAT Traversal. *Rep. NRC-TR-2008-002*.

Huang, Y., & et al. (2008). Challenges, design and analysis of a large-scale p2p-vod system. *ACM SIGCOMM computer communication review, 38*(4), S. 375-388.

ITU. (kein Datum). Von http://www.itu.int/en/ITU-D/Statistics/Pages/facts/default.aspx abgerufen

Li, B., & et al. (2005). Coolstreaming: a data-driven overlay network for efficient live media streaming. *IEEE INFOCOM*.

Müller, C., Lederer, S., & Timmerer, C. (2012). An evaluation of dynamic adaptive streaming over HTTP in vehicular environments 2012. *4th Workshop on Mobile Video*.

O, K., E, H., J, K., & M , Y. (2009). Battery Life of Mobile Peers with UMTS and WLAN in a Kademlia-based P2P Overlay. *20th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications*, S. 662–665.

Popescu A., e. a. (2015). *CONVINcE D1.1.1 Application Scenarios.*

Popescu A., e. a. (2015). *CONVINcE D1.1.2 System Requirements.*

Popescu A., e. a. (2016), *CONVINcE D1.1.3 High-Level Architecture Design*.

Popescu A., e. a. (2016), *CONVINcE D1.1.4 Theoretical Models*.

Statista. (kein Datum). Von https://www.statista.com/topics/842/netflix/ abgerufen

Yin, H., & et al. (2009). Design and deployment of a hybrid CDN-P2P system for live video streaming - experiences with LiveSky. *17th ACM international conference on Multimedia*.

YouTube. (kein Datum). Von https://www.youtube.com/yt/press/en-GB/statistics.html abgerufen

Z, O., E, H., O, K., & M , Y. (2010). Performance Evaluation of a Kademlia-based Communication-oriented P2P System under Churn. *Computer Networks, 54*(5), 689–705.