

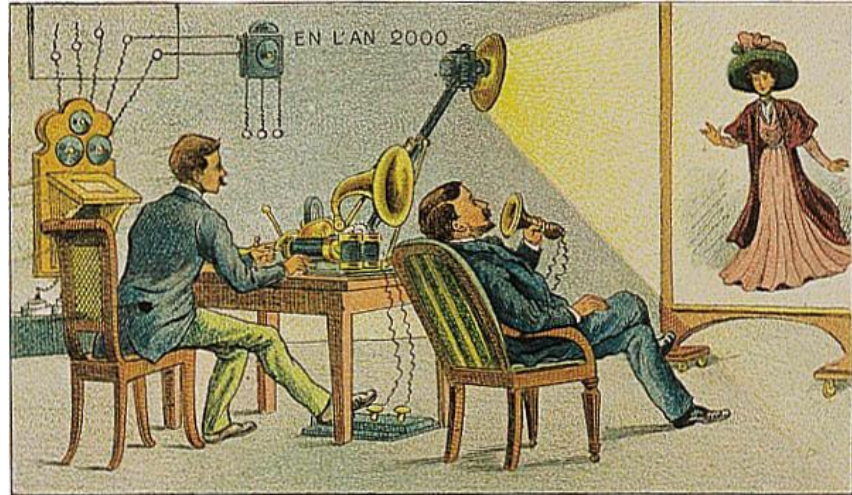


# The Rise of Video Communication and its Impact on Climate Change

Dr.-Ing. Christian J. Herglotz  
Chair of Multimedia Communications  
and Signal Processing

# From Fiction to Reality

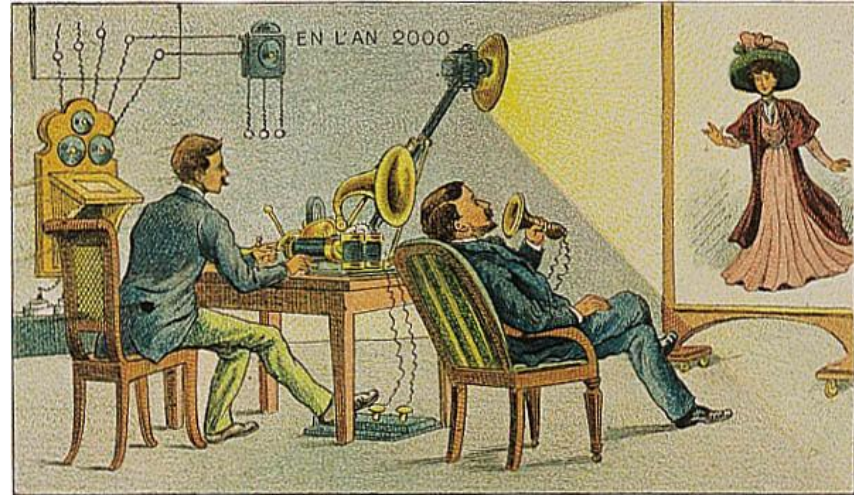
In the year 1910



By Villemard - [http://expositions.bnf.fr/utopie/grand/3\\_95b2.htm](http://expositions.bnf.fr/utopie/grand/3_95b2.htm) A reproduction of the early 20th century card / Репродукция, скан бумажной карточкиTransferred from en.wikipedia; transferred to Commons by User:Harryzilber using CommonsHelper., Public Domain, <https://commons.wikimedia.org/w/index.php?curid=7491953>

# From Fiction to Reality

In the year 1910



And today

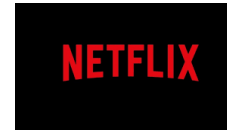
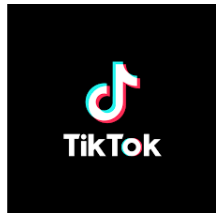


By Villemard - [http://expositions.bnf.fr/utopie/grand/3\\_95b2.htm](http://expositions.bnf.fr/utopie/grand/3_95b2.htm) A reproduction of the early 20th century card / Репродукция, скан бумажной карточки Transferred from en.wikipedia; transferred to Commons by User:Harryzilber using CommonsHelper., Public Domain, <https://commons.wikimedia.org/w/index.php?curid=7491953>



# Online Video Today

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[Pcgames.de](http://Pcgames.de), [amazon.de](http://amazon.de), [theverge.com](http://theverge.com), [internetmatters.com](http://internetmatters.com), [wikipedia.org](http://wikipedia.org), [tagesspiegel.de](http://tagesspiegel.de), [facebook.com](http://facebook.com), [tiktok.com](http://tiktok.com), [youtube.com](http://youtube.com), [Medienfachberatung.de](http://Medienfachberatung.de), [sky.de](http://sky.de)

# Online Video Today



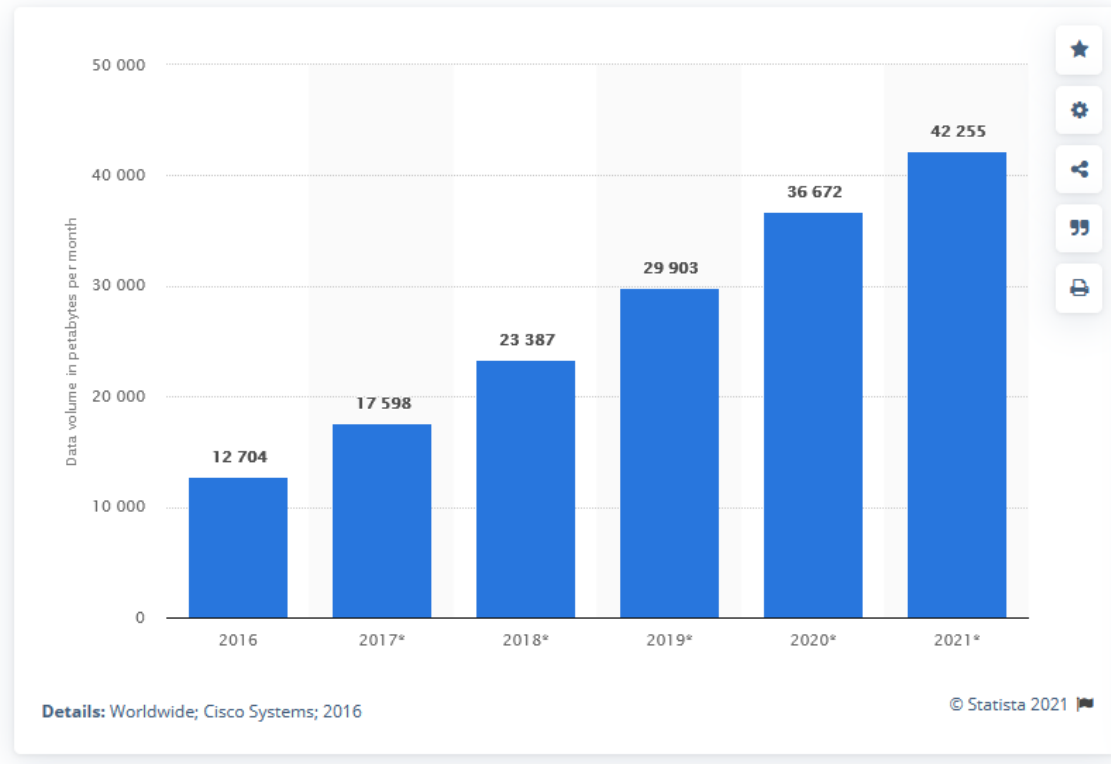
- Video Streaming
- Broadcasting
- Video Conferencing
- Social Networks
- Tubes
- Surveillance
- Automotive
- ...



Pcgames.de, amazon.de, theverge.com, internetmatters.com, wikipedia.org, tagesspiegel.de, facebook.com, tiktok.com, youtube.com. Medienfachberatung.de, sky.de

# Some Facts

**Data volume of global internet video to TV traffic from 2016 to 2021**  
*(in petabytes per month)*

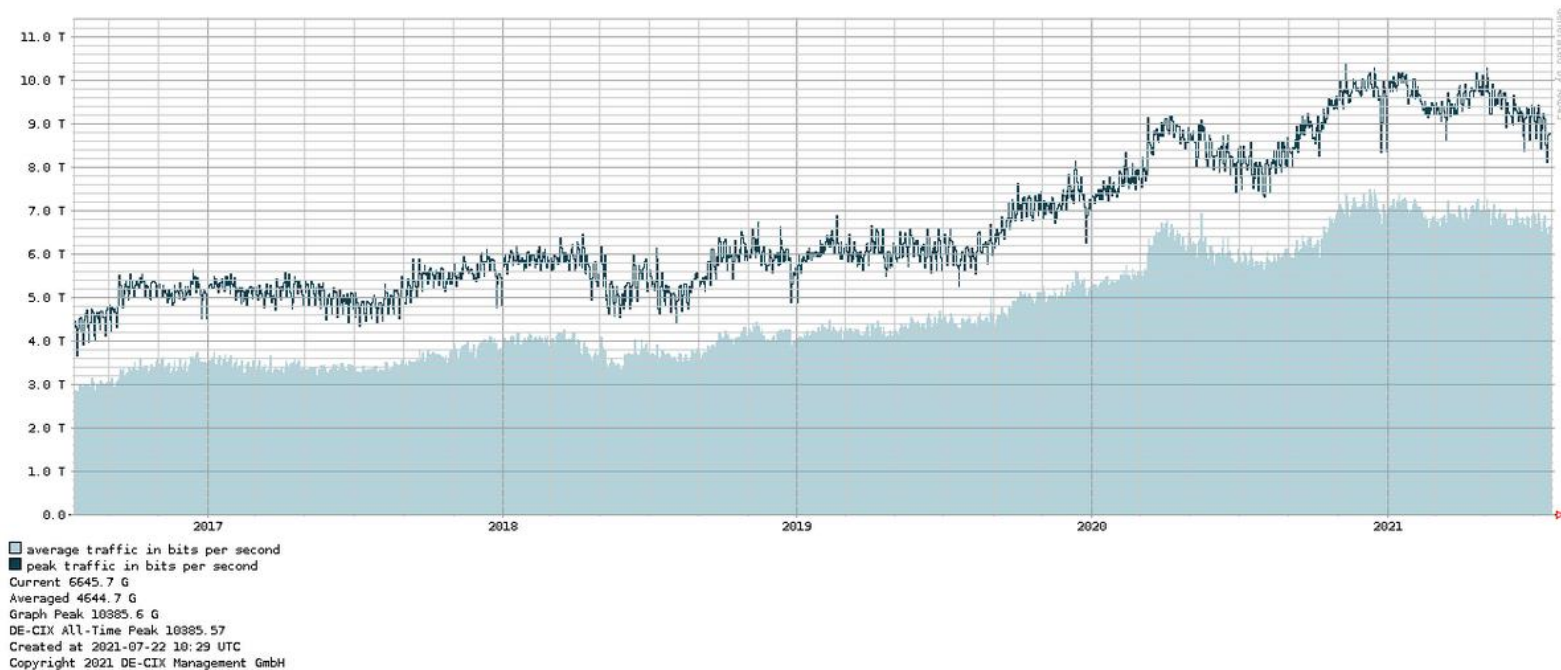


<https://www.statista.com/statistics/267222/global-data-volume-of-internet-video-to-tv-traffic/>

# Some Facts

## Internet Traffic at Europe's biggest Internet Exchange Point (DE-CIX Frankfurt)

### 5-year graph



<https://www.de-cix.net/en/locations/frankfurt/statistics>



[https://www.pngitem.com/middle/hwToi\\_28-collection-of-man-in-suit-clipart-png/](https://www.pngitem.com/middle/hwToi_28-collection-of-man-in-suit-clipart-png/)  
<https://clipartart.com/categories/power-plant-clipart.html>  
<http://clipart-library.com/plane-cliparts.html>  
<https://www.pinterest.com/pin/734438651707654395/>





<https://www.vecteezy.com/free-vector/mobile-man>

# The Shift project (July 2019) [1]:

In 2018, video communications  
caused 1% of  
greenhouse gas emissions.

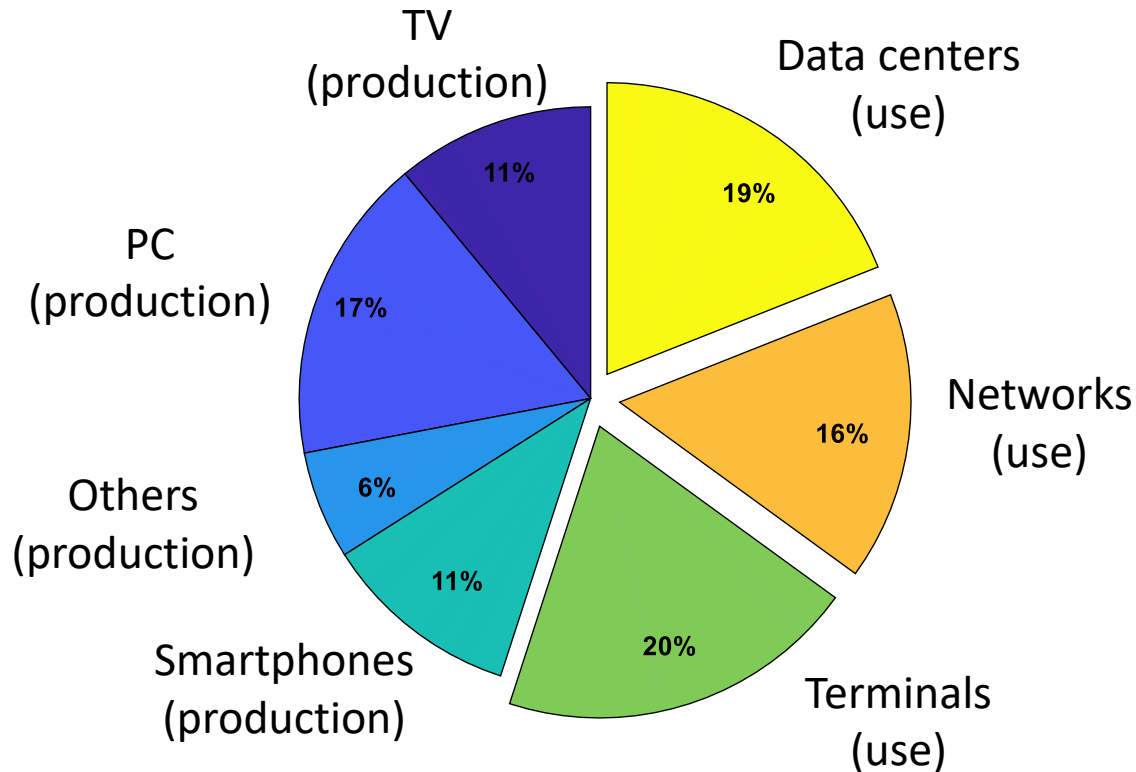
The annual growth in video data  
flow is larger than 25%.



[1] The Shift Project: CLIMATE CRISIS: THE UNSUSTAINABLE USE OF ONLINE VIDEO. Executive summary. July 2019. online available: [https://theshiftproject.org/wp-content/uploads/2019/07/Excutive-Summary\\_EN\\_The-unsustainable-use-of-online-video.pdf](https://theshiftproject.org/wp-content/uploads/2019/07/Excutive-Summary_EN_The-unsustainable-use-of-online-video.pdf)

# Energy Consumption in Online Video

## Energy Consumption in 2017



The Shift Project: „Lean ICT: Towards Digital Sobriety“, [https://theshiftproject.org/wp-content/uploads/2019/03/Lean-ICT-Report\\_The-Shift-Project\\_2019.pdf](https://theshiftproject.org/wp-content/uploads/2019/03/Lean-ICT-Report_The-Shift-Project_2019.pdf), March 2019.

# Outline

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- Hardware Setup for Online Video
- Power Consumption of Smartphones
- Energy Optimization for Decoding
- Outlook

# Outline

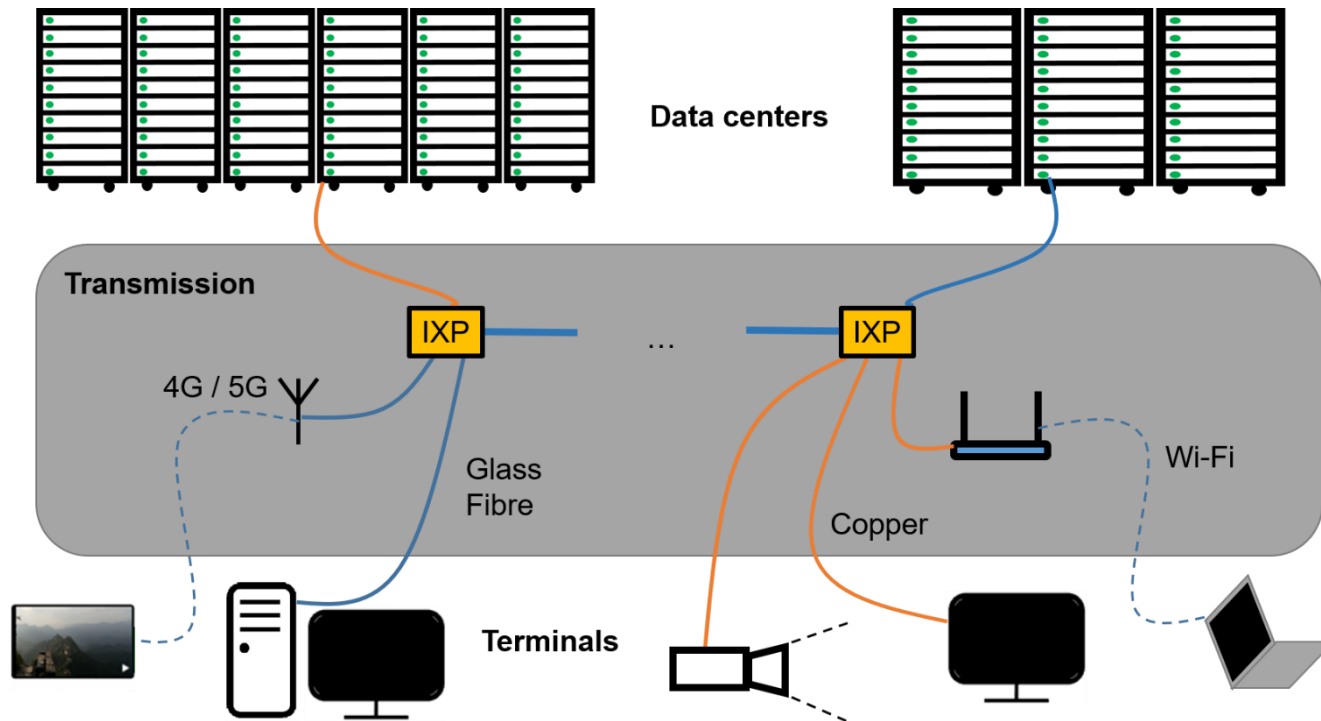
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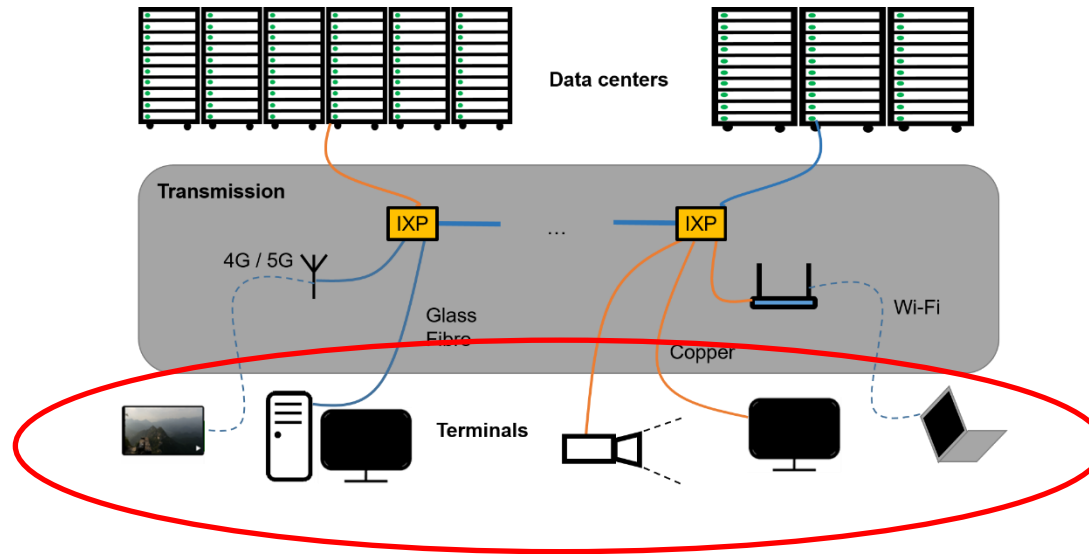
- **Hardware Setup for Online Video**
- Power Consumption of Smartphones
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- Outlook



# Hardware Setup for Online Video



# Tasks in Online Video



## Sender

- Capture
- Enhancement
- Encoding
- Storage
- Transmission

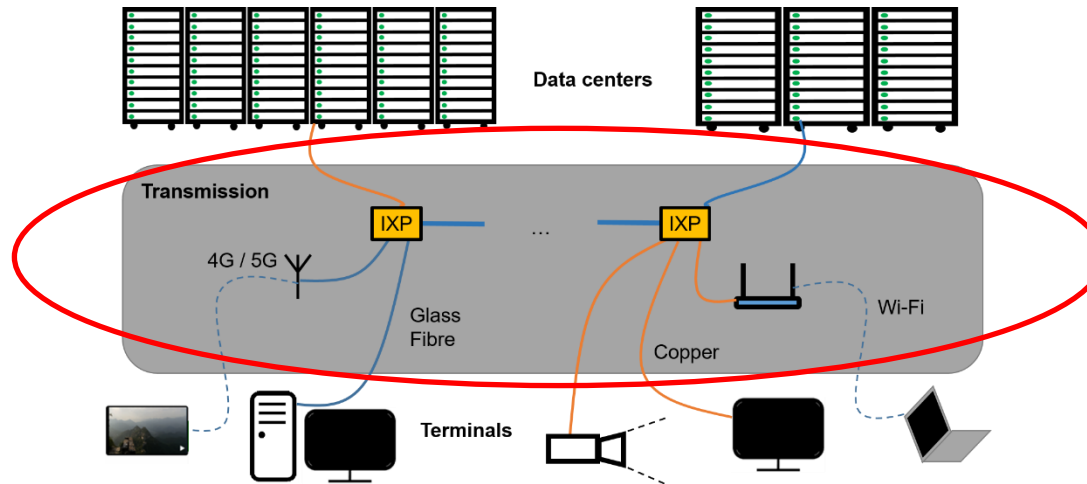
...

## Receiver

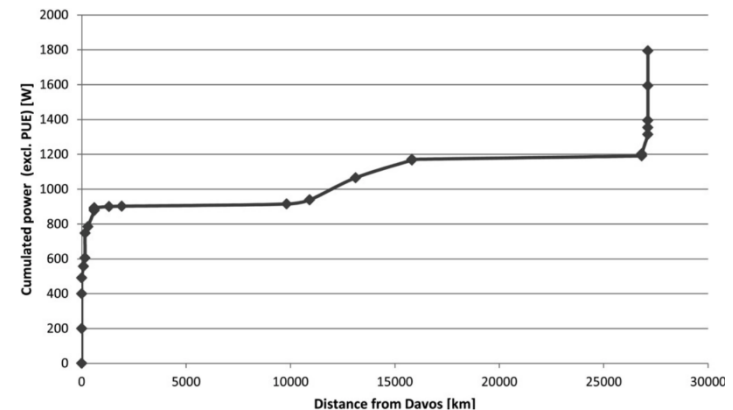
- Receive stream
- Decoding
- Error concealment
- Rendering
- Display

...

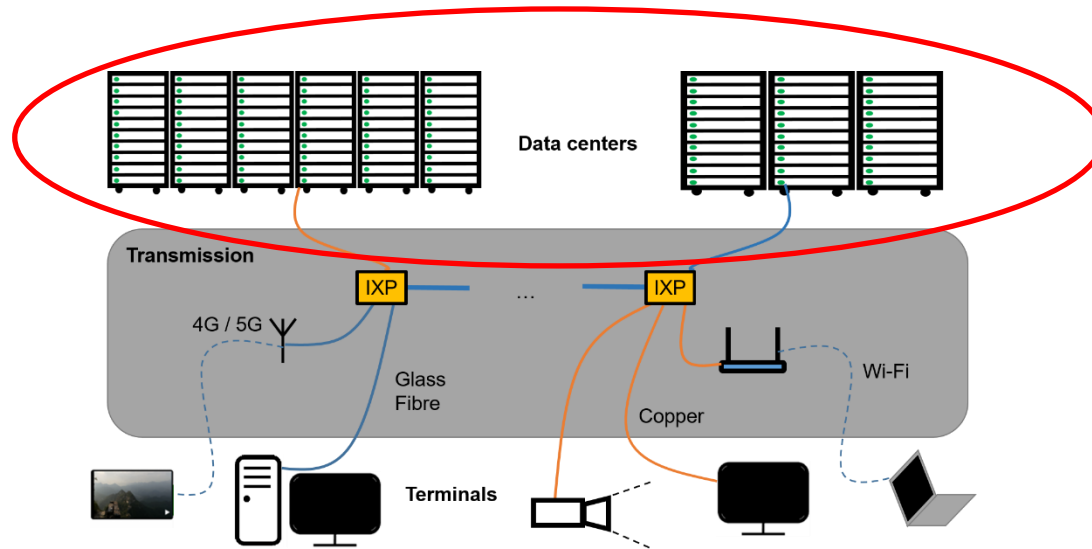
# Tasks in Online Video



- Routing
- Transmission
- Access networks: Fixed / mobile



# Tasks in Online Video



- Transmission
- React to requests
- Storage
- Encoding
- CDN maintenance
- ...

# Outline

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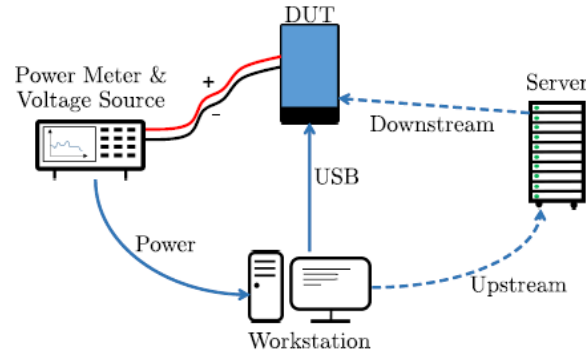


- Hardware Setup for Online Video
- **Power Consumption of Smartphones**
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# Mobile Devices

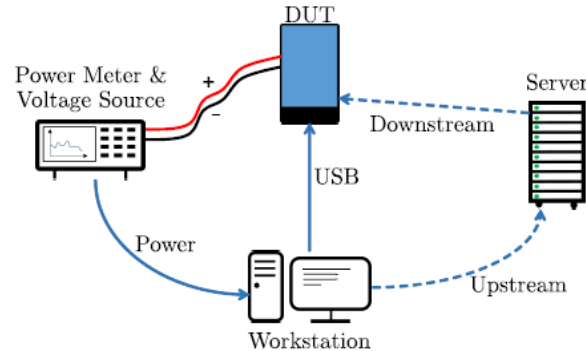
- Measurement Setup



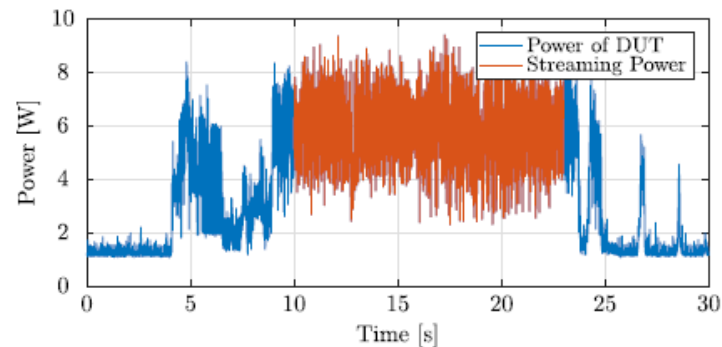
Herglotz, Christian, et al. "Power modeling for video streaming applications on mobile devices." *IEEE Access* 8 (2020): 70234-70244.

# Mobile Devices

- Measurement Setup



- Power consumption



## Extensive testing

- Bitrate, resolution, frame rate
- Local, WiFi, 3G
- Screen brightness
- HEVC / H.264
- Audio on / off...
- Different players
- ...

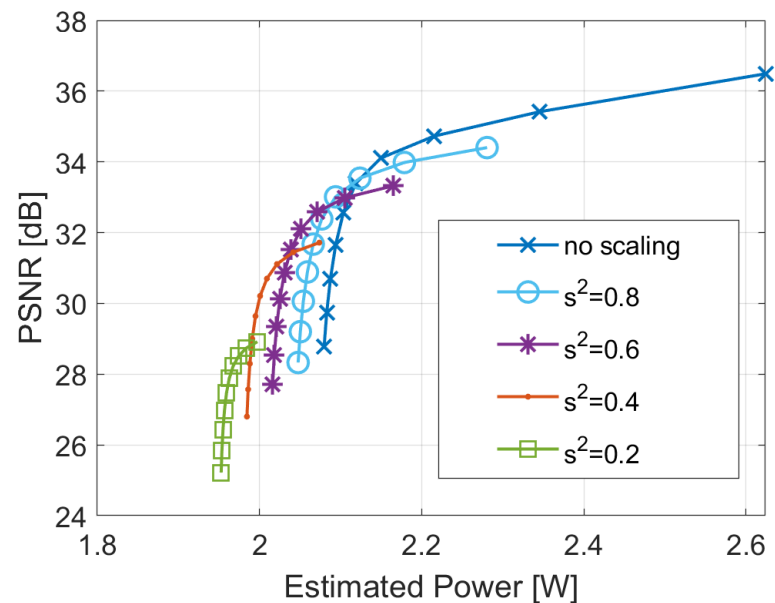


$k$	Variable	Description	Param. value ( $k = 11$ )
1	1	<b>Constant offset</b>	$\Pi_0 = 0.90$
2	$b_{\text{wifi}}$	<b>Bitrate (Wi-Fi)</b>	$\beta_{\text{wifi}} = 0.21$
3	$H$	<b>Lin. display brightness</b>	$\kappa = 0.79$
4	$f_v$	<b>Video frame rate</b>	$\epsilon_{\text{frame}} = 0.35$
5	$F_{3G}$	3G connection offset	$\Gamma_{3G} = 0.49$
6	$L$	Quadr. disp. brightness	$\lambda = 0.00$
7	$F_v$	Video decoding offset	$\Psi_0 = 0.00$
8	$b_v$	Video bitrate	$\epsilon_{\text{bit}} = 0.38$
9	$F_{\text{wifi}}$	Wi-Fi connection offset	$\Gamma_{\text{wifi}} = 0.17$
10	$F_a$	Audio decoding offset	$\Phi = 0.11$
11	$G$	Pixels per second	$\rho = 0.20$

## Most important components

# Optimal Spatial Scaling

## Power-distortion curves for spatial scaling



# Outline

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- Hardware Setup for Online Video
- Power Consumption of Smartphones
- **Energy Optimization for Decoding**
- Outlook



# Decoding-Energy Optimal Encoding

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## Exploit energy estimation in encoding

- Classic rate-distortion optimization (RDO)

$$\min J = \min D + \lambda \cdot R$$

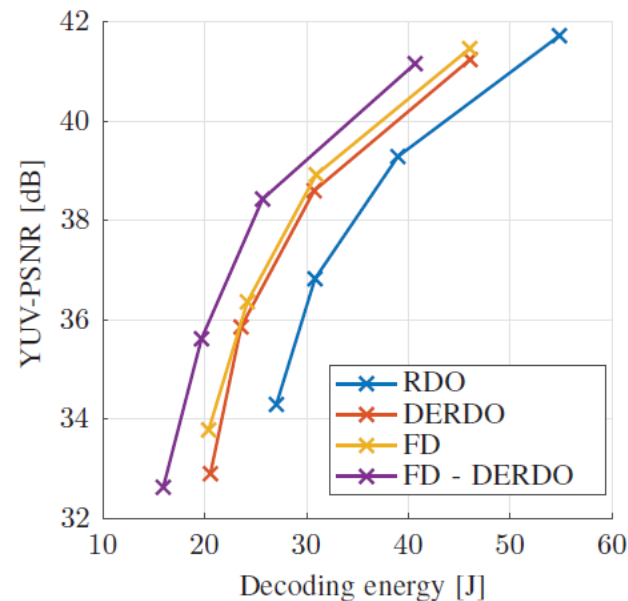
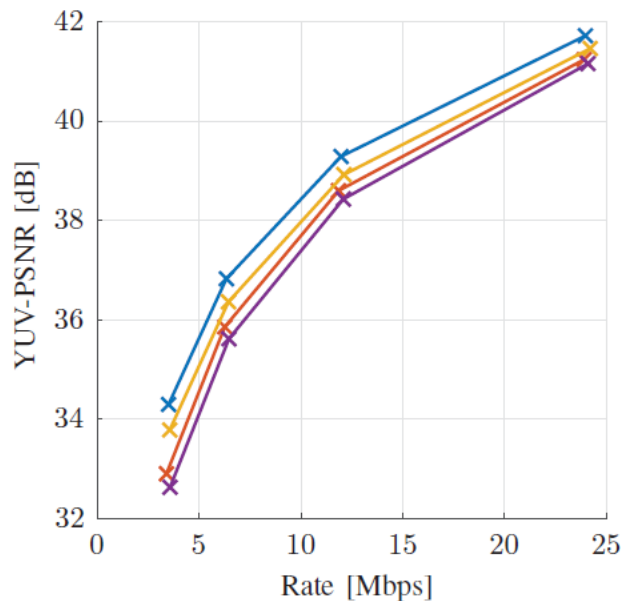
- Decoding-energy-rate-distortion optimization (DERDO)

$$\min J = \min D + \lambda \cdot R + \lambda_E \cdot E$$

# Decoding-Energy Optimal Encoding

## Implementation in x265-encoder

FD: fastdecode



Herglotz, Christian, et al. „Decoding Energy Optimal Encoding for x265." *accepted for International Workshop on Multimedia Signal Processing (MMSP), September 2020.*

# Outline

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- Hardware Setup for Online Video
- Power Consumption of Smartphones
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- **Outlook**

# Outlook

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- Energy optimizations in VVC
- Encoder-side energy analysis and optimization
- Global energy optimization



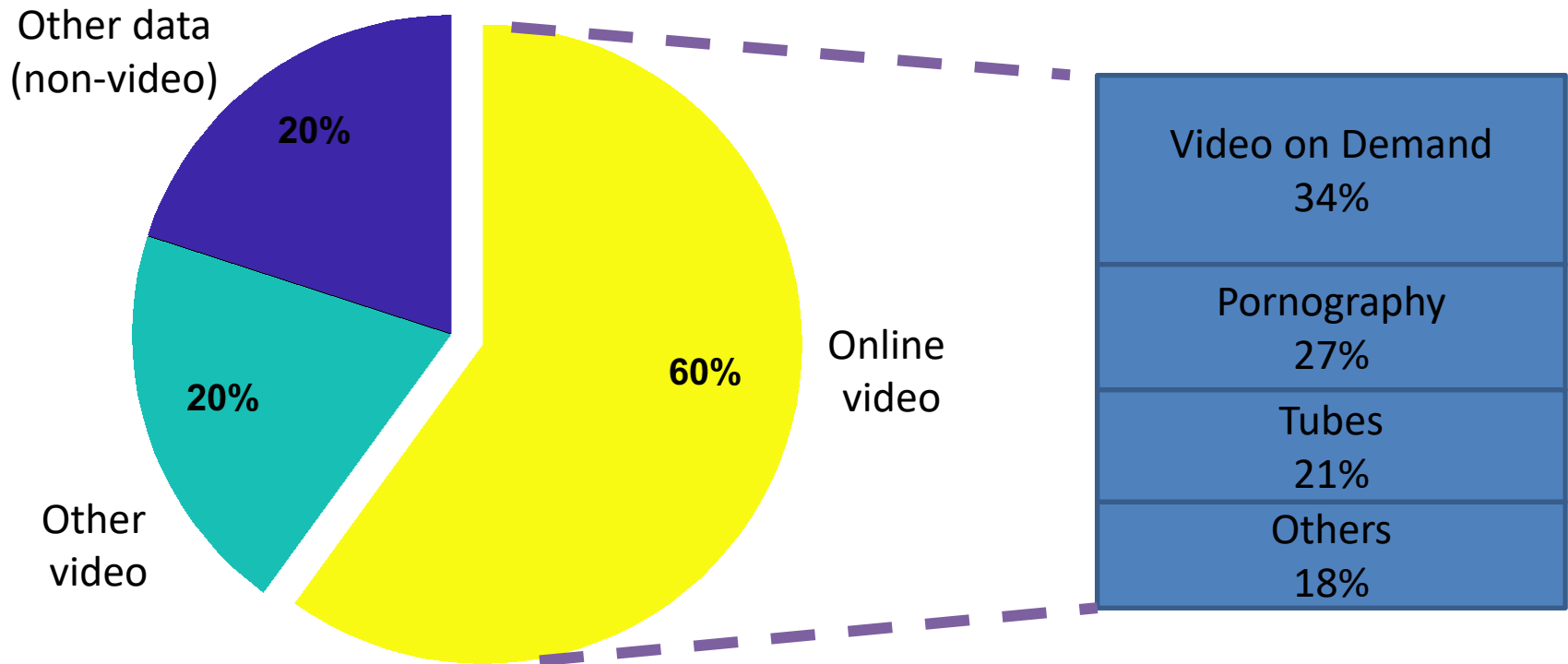
# Further Reading

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- The Shift Project: CLIMATE CRISIS: THE UNSUSTAINABLE USE OF ONLINE VIDEO. Executive summary. July 2019. online available: [https://theshiftproject.org/wp-content/uploads/2019/07/Excutive-Summary\\_EN\\_The-unsustainable-use-of-online-video.pdf](https://theshiftproject.org/wp-content/uploads/2019/07/Excutive-Summary_EN_The-unsustainable-use-of-online-video.pdf)
- Futuresource consulting: The Sustainable Future of Video Entertainment - From creation to consumption, August 2020, <https://www.interdigital.com/download/5fa0694a8934bdfd5f00596a>



## Online data flow per content [1]



# Decoding-Energy Optimal Encoding

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## Energy consumption of a software decoder

- Estimated energy

$$\hat{E} = \sum_{i=1}^N n_i \cdot e_i$$

$i$ : Feature index

$e_i$ : Specific energy coefficient

$n_i$ : Frequency of occurrences

# Decoding-Energy Optimal Encoding

## Energy consumption of a software decoder

- Estimated energy

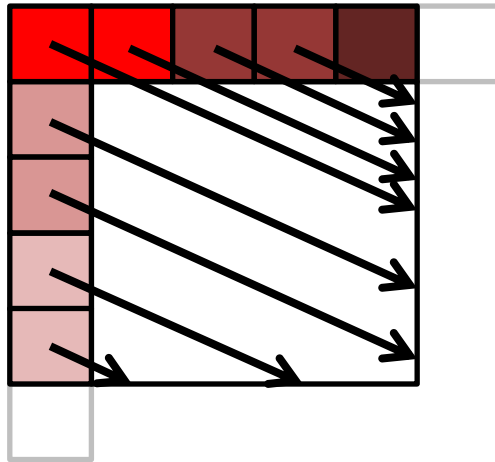
$$\hat{E} = \sum_{i=1}^N n_i \cdot e_i$$

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- Example 1: Decoding energy of one intra coded CU



PU size	Specific energy
32x32	273μJ
16x16	70μJ
8x8	25μJ
4x4	8μJ

# Decoding-Energy Optimal Encoding

## Energy consumption of a software decoder

- Estimated energy

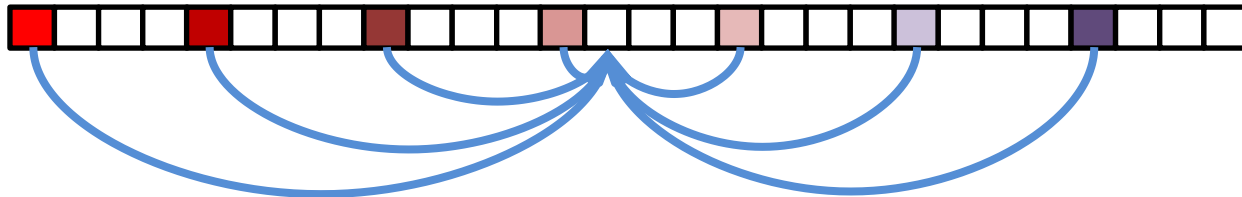
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- Example 2: Fractional pel filtering



# Decoding-Energy Optimal Encoding

## Energy consumption of a software decoder

- Estimated energy

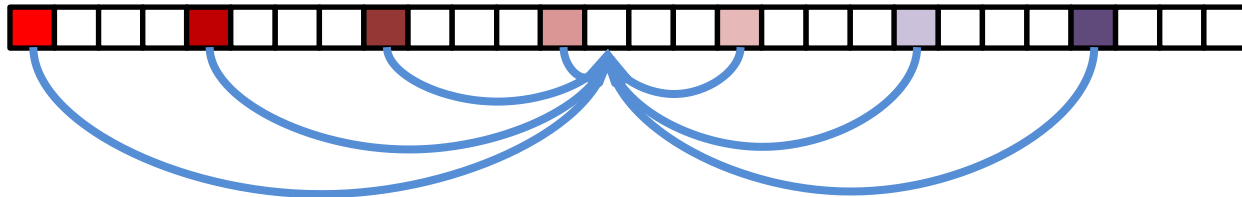
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- Example 2: Fractional pel filtering



- Ans many more...

# A Case-Study

## Energy Consumption for Online Lectures



The screenshot shows a video lecture interface. The main window displays a presentation slide titled 'Kapitel 2.a: Energiebedarf der Übertragung'. The slide content includes:

Studie aus dem Jahr 2015

- Intensität:  $0,06 \frac{kWh}{GB}$
- Der Wert halbiert sich ca. alle 2 Jahre  
→ wir rechnen mit  $0,02 \frac{kWh}{GB}$

Beispiel: Eine Folge „Game of Thrones“ in HD, 2 GB

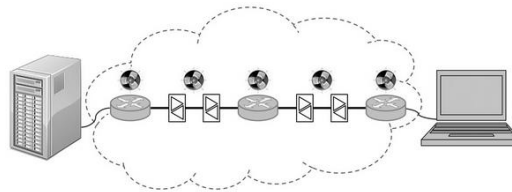
Art	CO <sub>2</sub>
100 km Autofahrt	16,6 kg
Einfamilienhaus pro Jahr (Erdgas)	2.828,0 kg
Passivhaus pro Jahr (Erdgas)	424,0 kg
Flug FRA-NY pro Person	1.000,0 kg
Aufwärmen Mittagessen	0,4 g
Eine Folge Game of Thrones	6,0 g $(150 \frac{CO_2}{kWh})$

The interface also shows a sidebar with navigation controls and a list of participants in the video call.

Ringvorlesung „FAUagainstCO2“, SS 2020

# A Case-Study

## Energy Consumption for Online Lectures



- 200 participants
- 2 GB of data
- 2 hours

1 Server:  
1 kWh

Transmission:  
 $201 \times 0,04 \text{ kWh}$   
 $= 8,04 \text{ kWh}$

Terminals:  
 $100 \text{ PCs} \times 150 \text{ W} \times 2 \text{ h}$   
 $+ 101 \text{ tablets} \times 40 \text{ W} \times 2 \text{ h}$   
 $= 38,08 \text{ kWh}$

# A Case-Study

## Energy Consumption for Online Lectures



### Overall CO<sub>2</sub>-Production:

Type	CO <sub>2</sub>
100 km car drive	20,0 kg
Small house per year	2.828,0 kg
Passive house per year	424,0 kg
Flight FRA-NY per person	1.000,0 kg
Train Erlangen – Munich	6,9 kg
Online lecture for 200 students	7,07 kg



# A Case-Study

## Energy Consumption for Online Lectures



### Overall CO2-Production:

Type	CO <sub>2</sub>
100 km car drive	20,0 kg
Small house per year	2.828,0 kg
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Flight FRA-NY per person	1.000,0 kg
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Online lecture for 200 students	7,07 kg

Per person:  
35 g