ETH zürich

The Direct Energy Consumption of ICT

Digitalization and the Rebound Effect - Seminar HS2019

Zuowen Wang

institute for pervasive computing

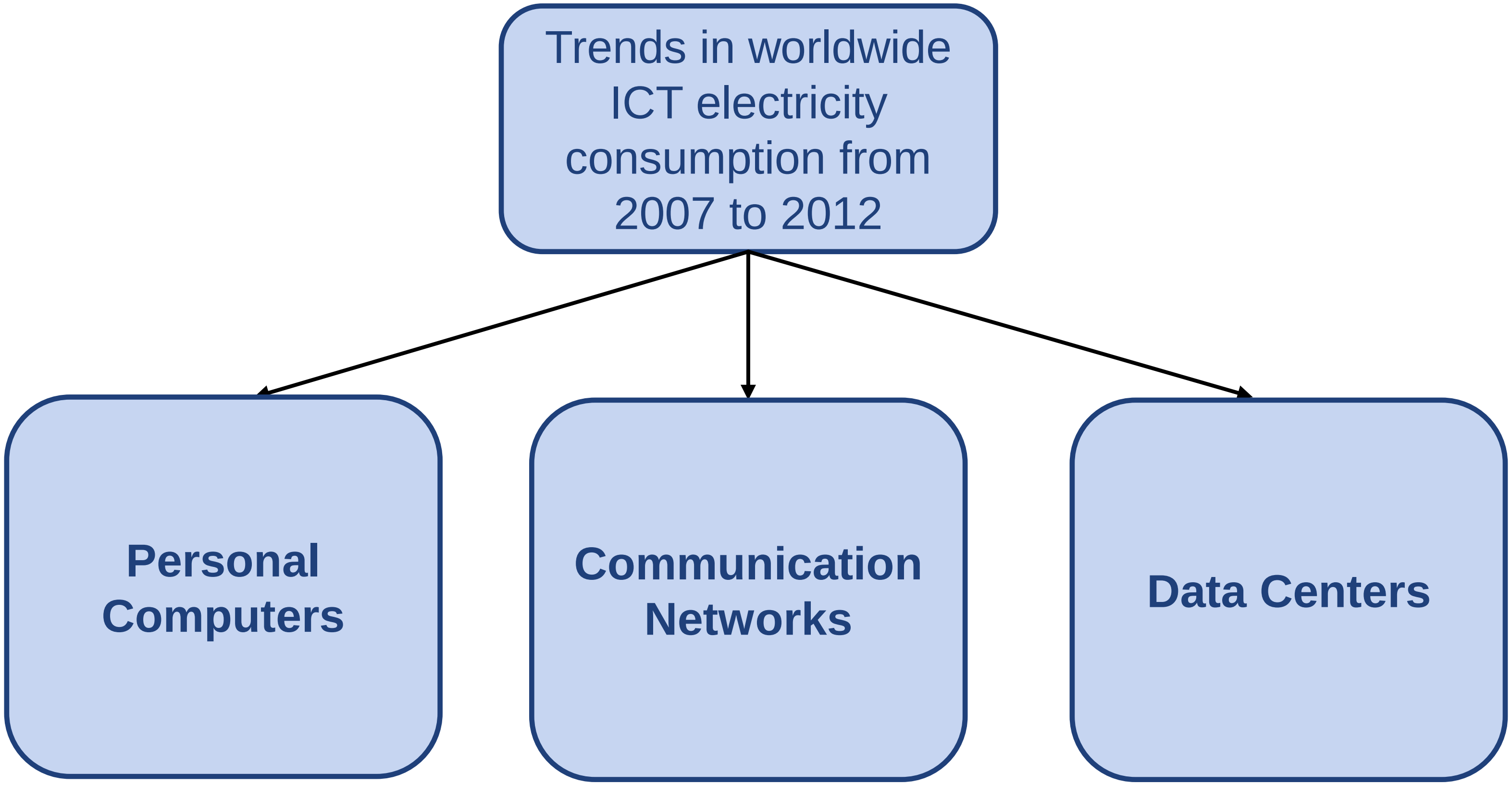
Road Map

1. Three major domains
   a. Personal Computers
   b. Communication Networks
   c. Data Centers

2. Methodologies/Approaches

3. Outlook：5G Base Stations

Three Domains



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Personal Computers

- Laptops
- Desktops

- LCD Monitors
- CRT Monitors

No smartphone/ tablet/ PDA etc.

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No smartphone/ tablet/ PDA etc.

PC: Laptops, Desktops & Household, Office

Approach:

Annual Sales Data & lifetime distribution & energy/device

PC: Laptops, Desktops & Household, Office

Goal: **Estimate** #Laptops and #Desktops

1. sales data 1991-2010 **(available)**

exponential
extrapolation

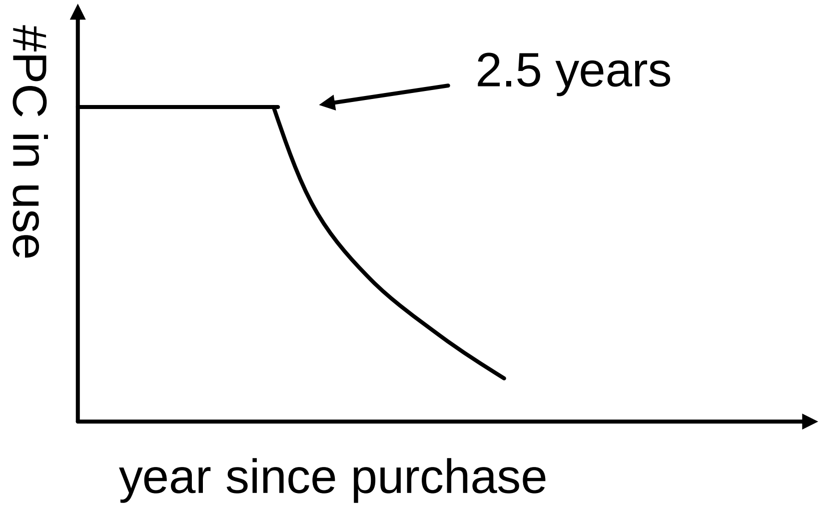
future sales data 2011-2012

PC: Laptops, Desktops & Household, Office

Goal: **Estimate** #Laptops and #Desktops

2. #PC 2000-2006 (available) & #sales 1991-2006 (available)

Lifetime distribution of PCs



[1] UN, World population prospects: the 2010 revision, UN population Division, 2011
[2] UN, Millennium development goals indicators, UN Statistics Division, 2010.

PC: Laptops, Desktops & Household, Office

	Energy/device (kWh/y)	
	2007	2012
Office desktops	149	137
Household deskt.	231	213
Office laptops	46	39
Household lapt.	70	59
Total computers		

[3]A brief history of personal computer vendors. Asymco
[4]KPCB top mobile internet trends. M.Murphy
[5]Energy consumption of consumer electronics in US homes in 2010. B. Urban

PC: Laptops, Desktops & Household, Office

	Energy/device (kWh/y)		Worldwide energy use (TWh)	
	2007	2012	2007	2012
Office desktops	149	137	51.4	46.2
Household deskt.	231	213	91.2	105.9
Office laptops	46	39	4.1	8.3
Household lapt.	70	59	17.7	45.2
Total computers			164.4	205.6

[3]A brief history of personal computer vendors. Asymco
[4]KPCB top mobile internet trends. M.Murphy
[5]Energy consumption of consumer electronics in US homes in 2010. B. Urban

External Monitors

	Energy/device (kWh/y)		Worldwide energy use (TWh)	
	2007	2012	2007	2012
CRT monitors	175	175	46.6	31.9
LCD monitors	70	70	27.9	69.6
Total monitors			74.5	101.5

[6]Trends in worldwide ICT electricity consumption from 2007 to 2012. W.V. Heddeghem et al.

In Total

	Worldwide energy use (TWh)	
	2007	2012
Office desktops	51.4	46.2
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Total computers	164.4	205.6
CRT monitors	46.6	31.9
LCD monitors	27.9	69.6
Total monitors	74.5	101.5
Total	238.9	307.1

[6]Trends in worldwide ICT electricity consumption from 2007 to 2012. W.V. Heddeghem et al.

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Total monitors	74.5	101.5
Total	238.9	307.1

1.3% **1.6%**

[6]Trends in worldwide ICT electricity consumption from 2007 to 2012. W.V. Heddeghem et al.

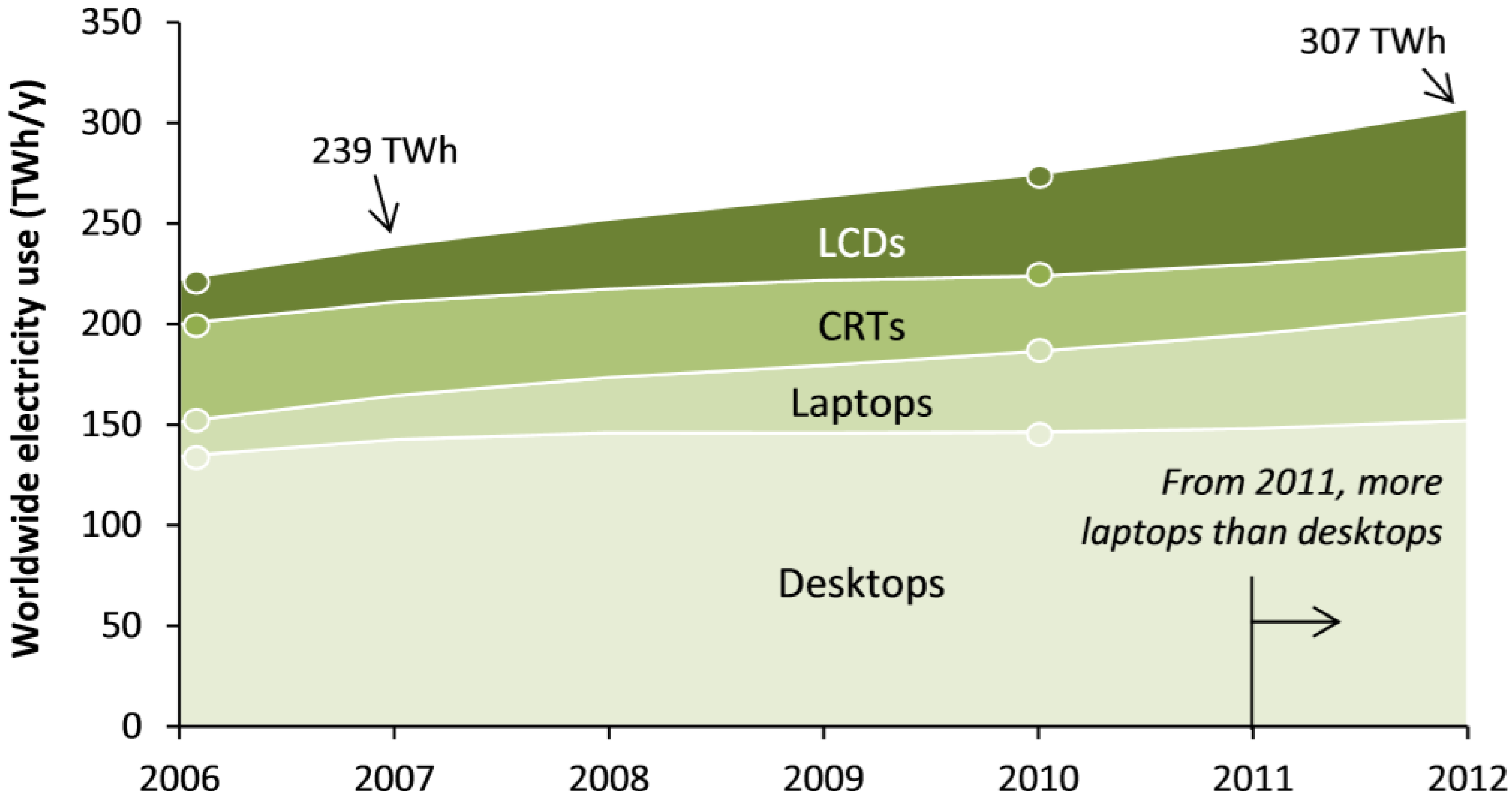
Presence and Future?

- LCD Monitors — "LED" is a type of LCD monitor:

  20%-30% of power saving,
  can be used typically 5-10 years

- ~~CRT Monitors~~ — Future: maybe OLED monitor

Presence and Future?



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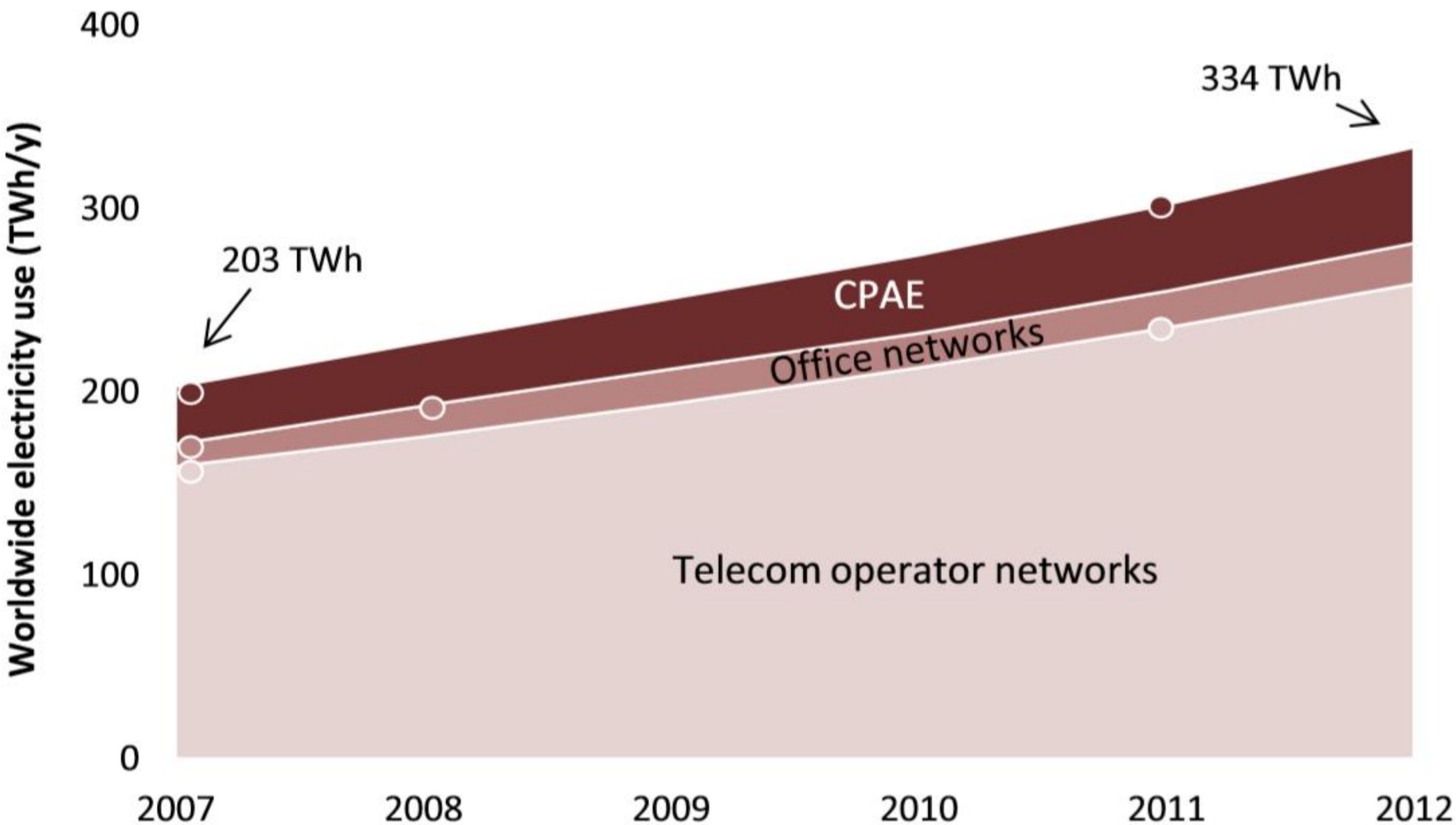
Communication Networks

Customer Premises Access Equipment (CPAE)

Office Networks

Telecom Operator Networks

Communication Networks



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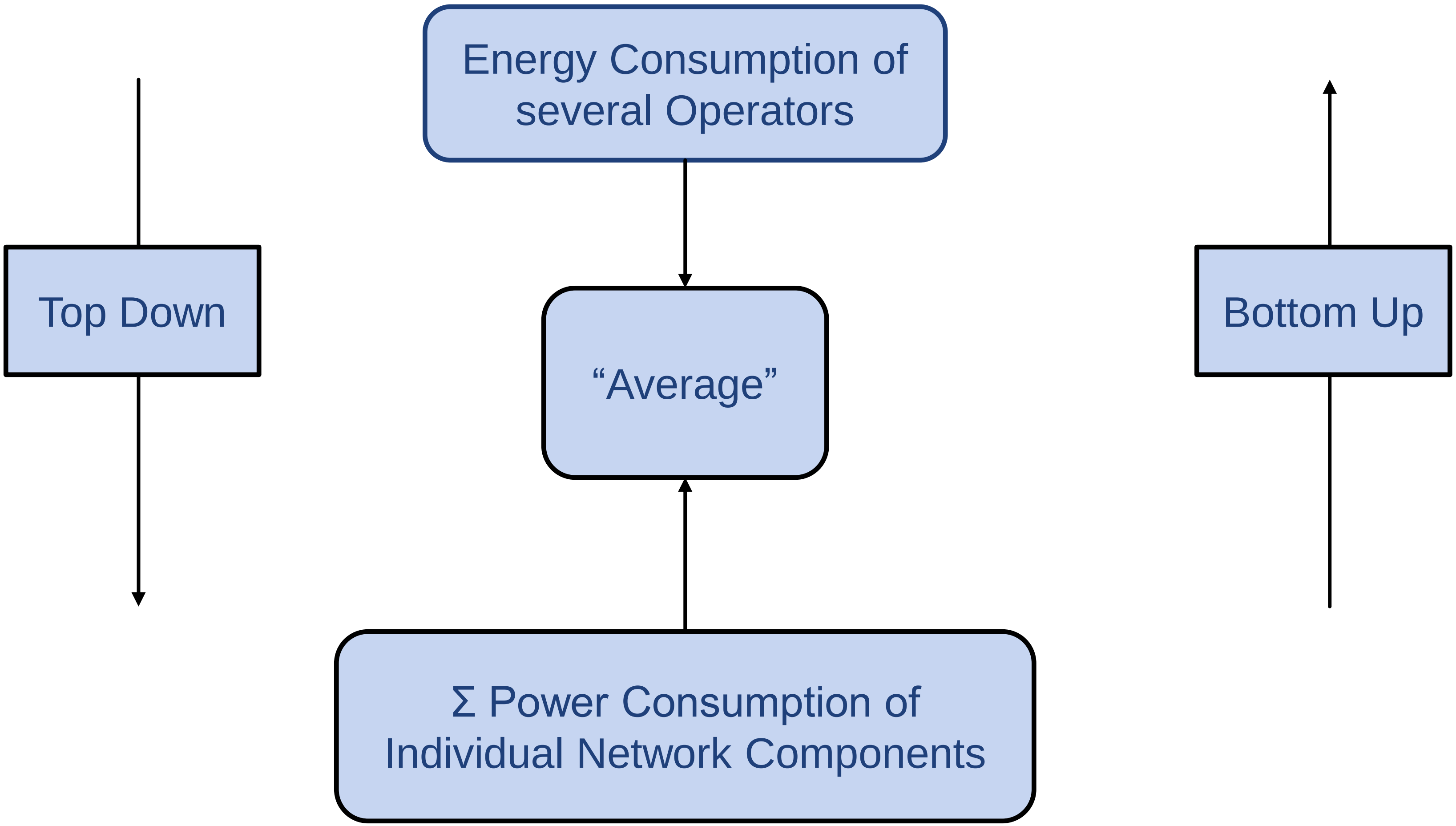
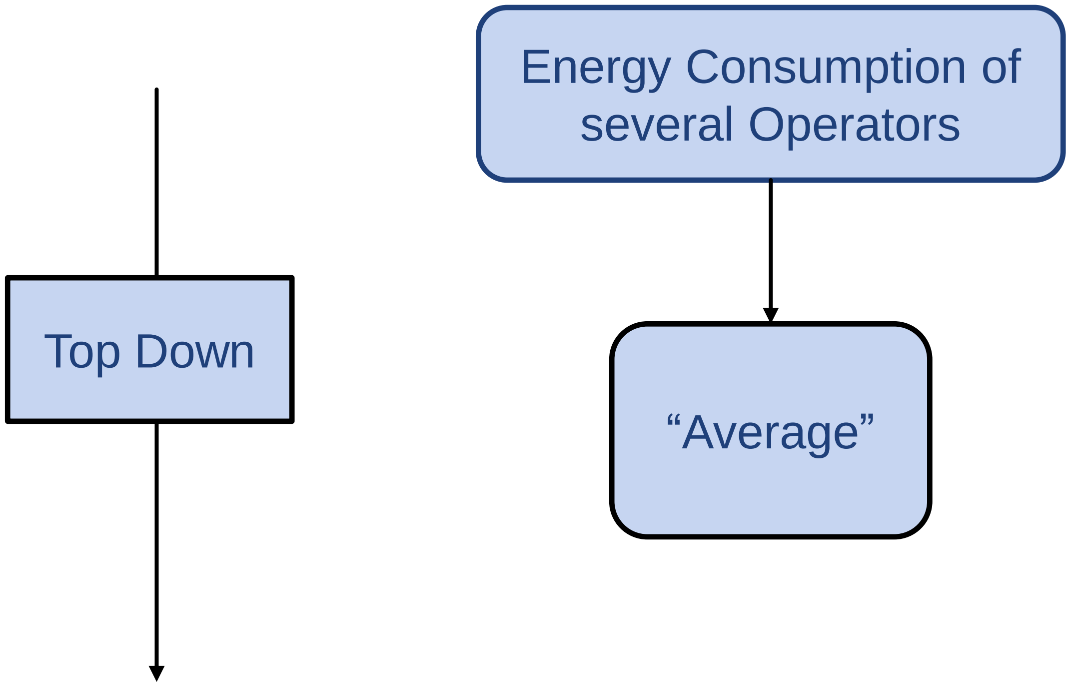
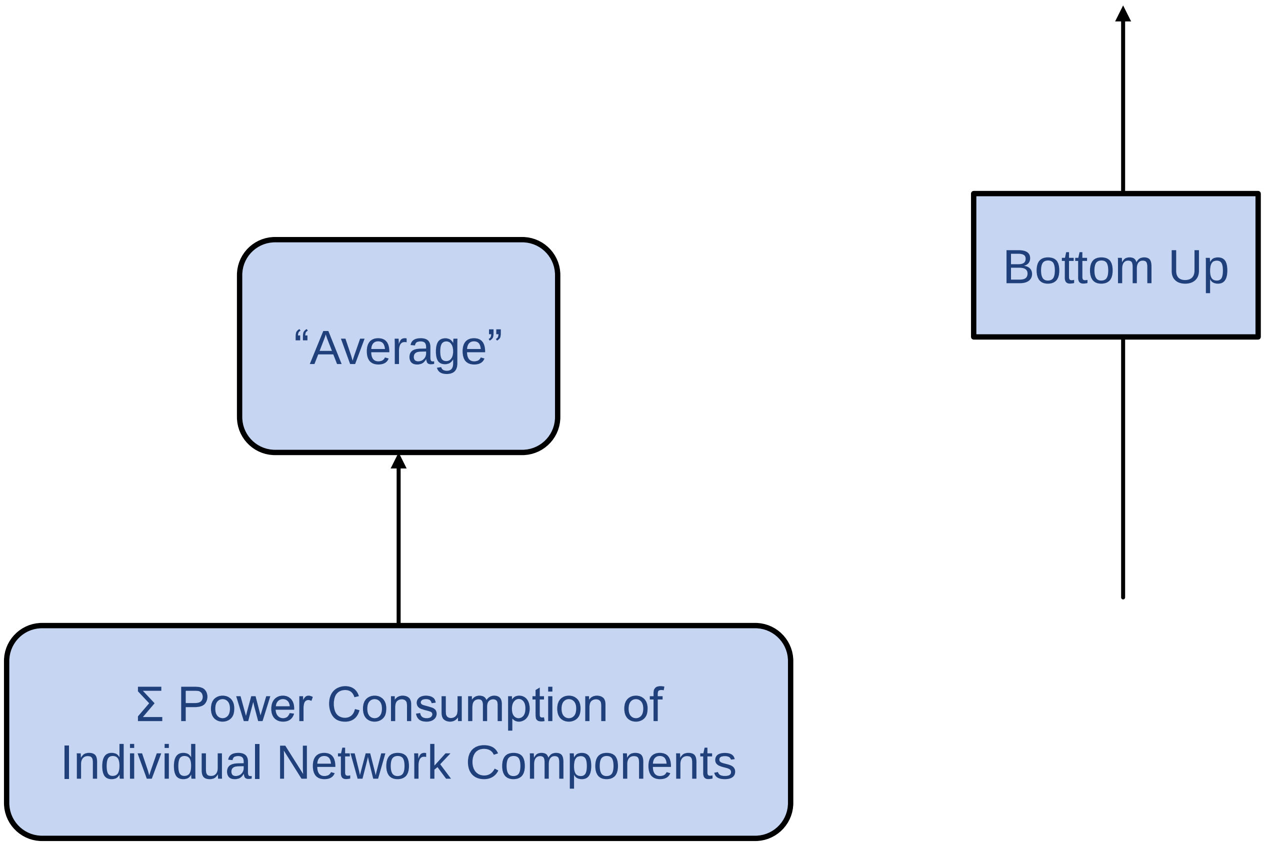
Telecom Operator Networks



Telecom Operator Networks



Telecom Operator Networks



Communication Networks

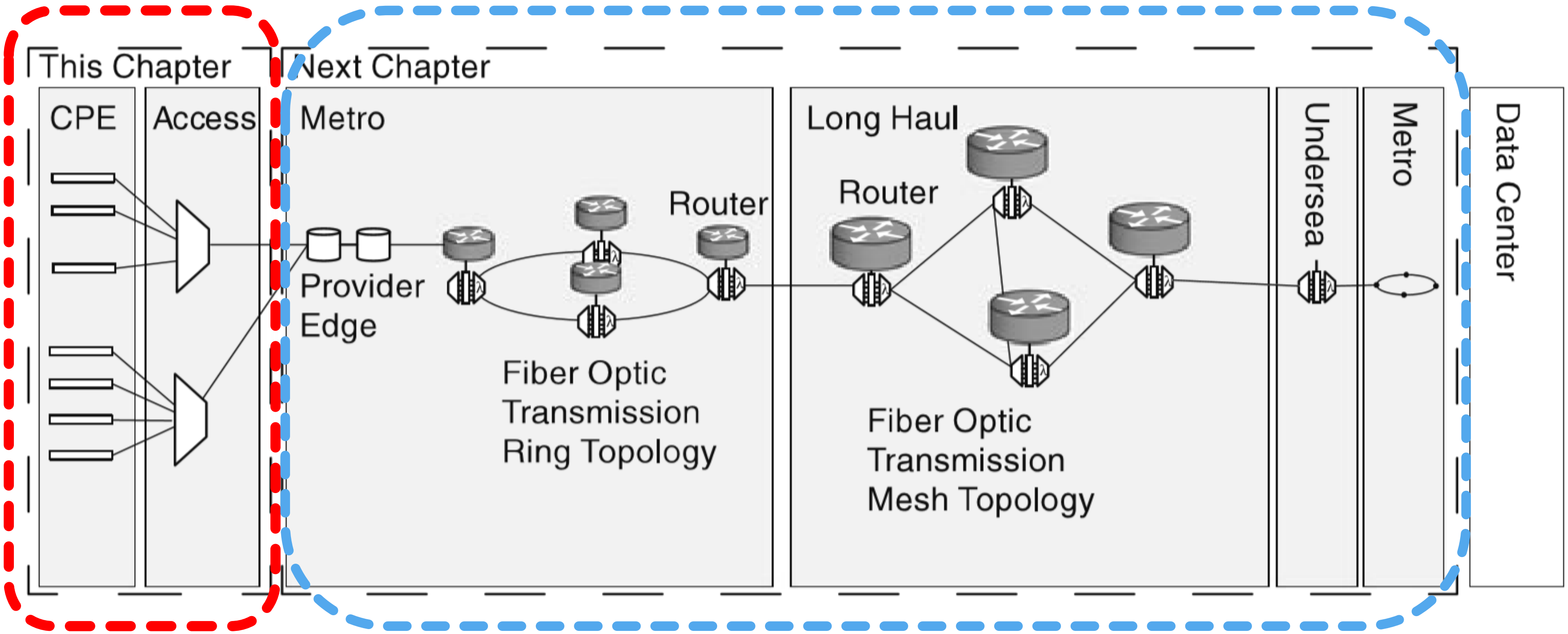


Fig. 1 Model of the Internet structure

CPAE **Telecom Operator Networks**

[7]The Energy Intensity of the Internet: Home and Access Networks. V.C. Coroama et al.

Question

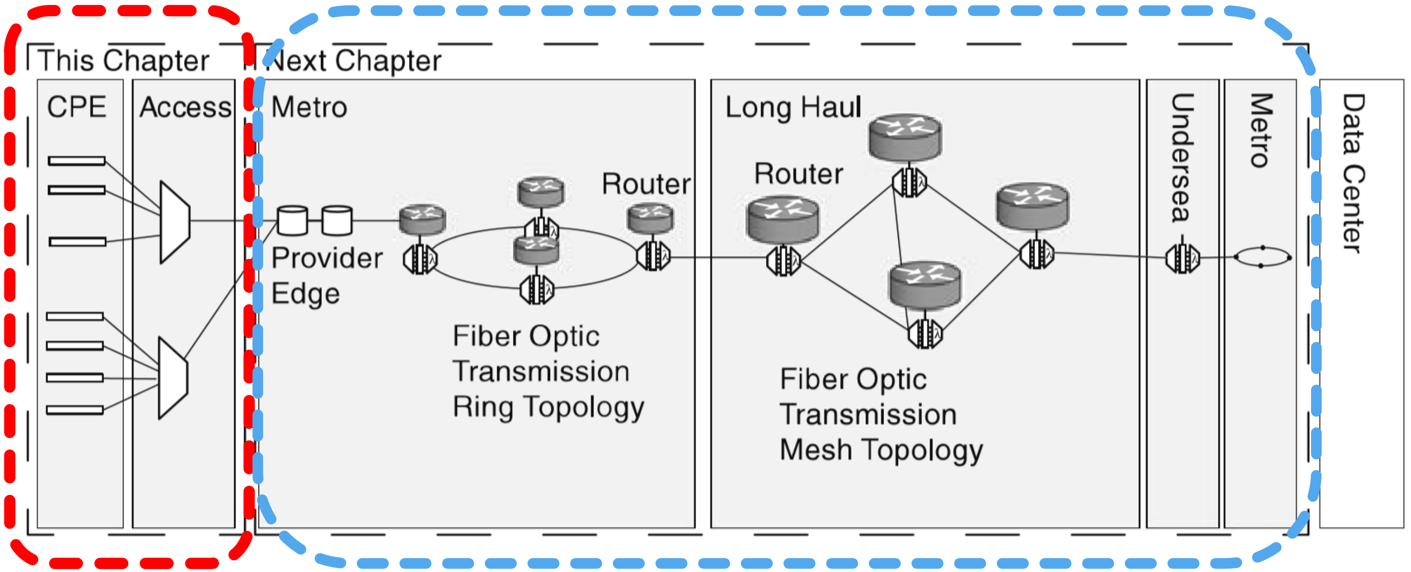


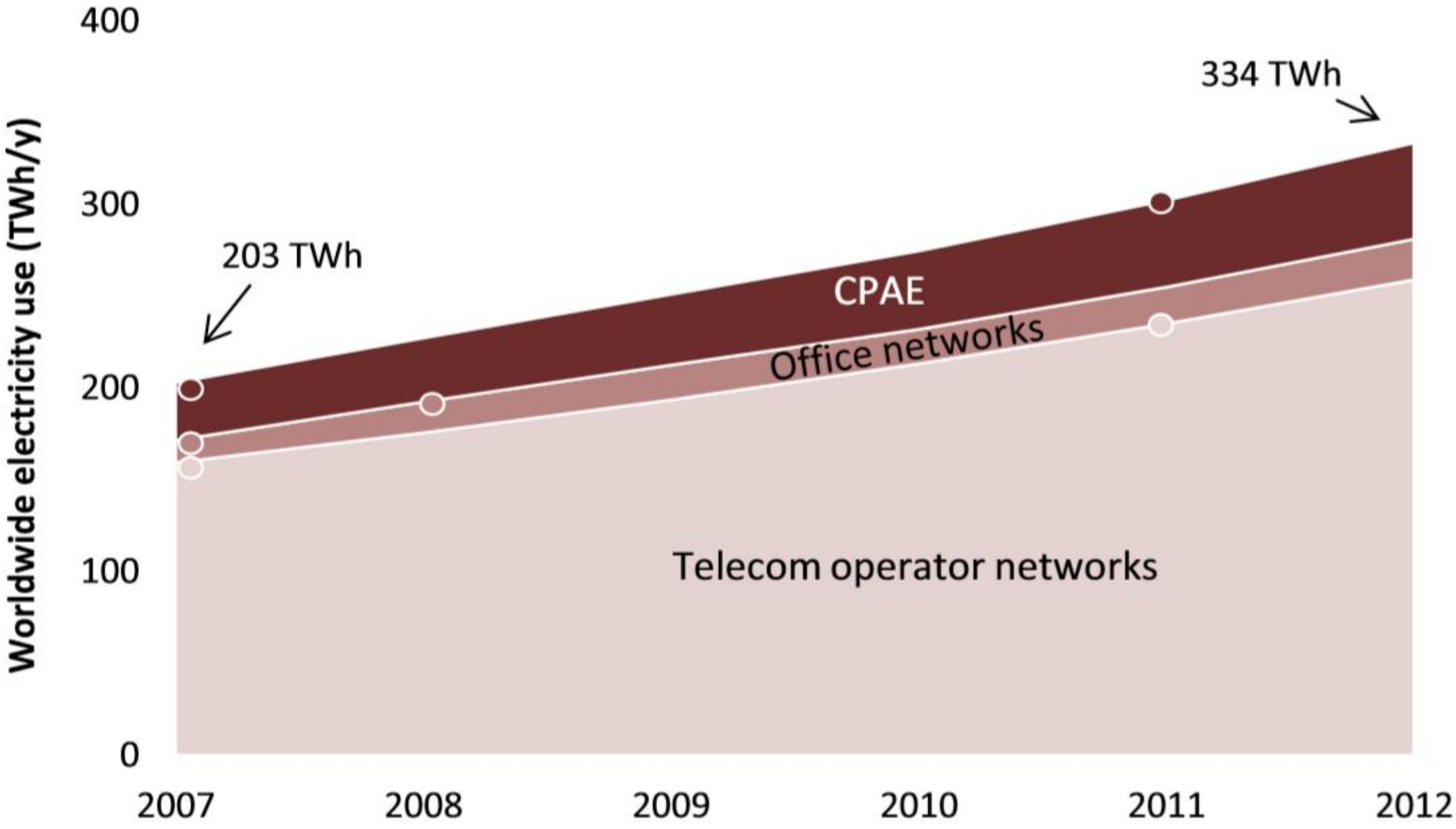
Fig. 1 Model of the Internet structure

CPAE

Telecom Operator Networks

[7]The Energy Intensity of the Internet: Home and Access Networks. V.C. Coroama et al.

Communication Networks



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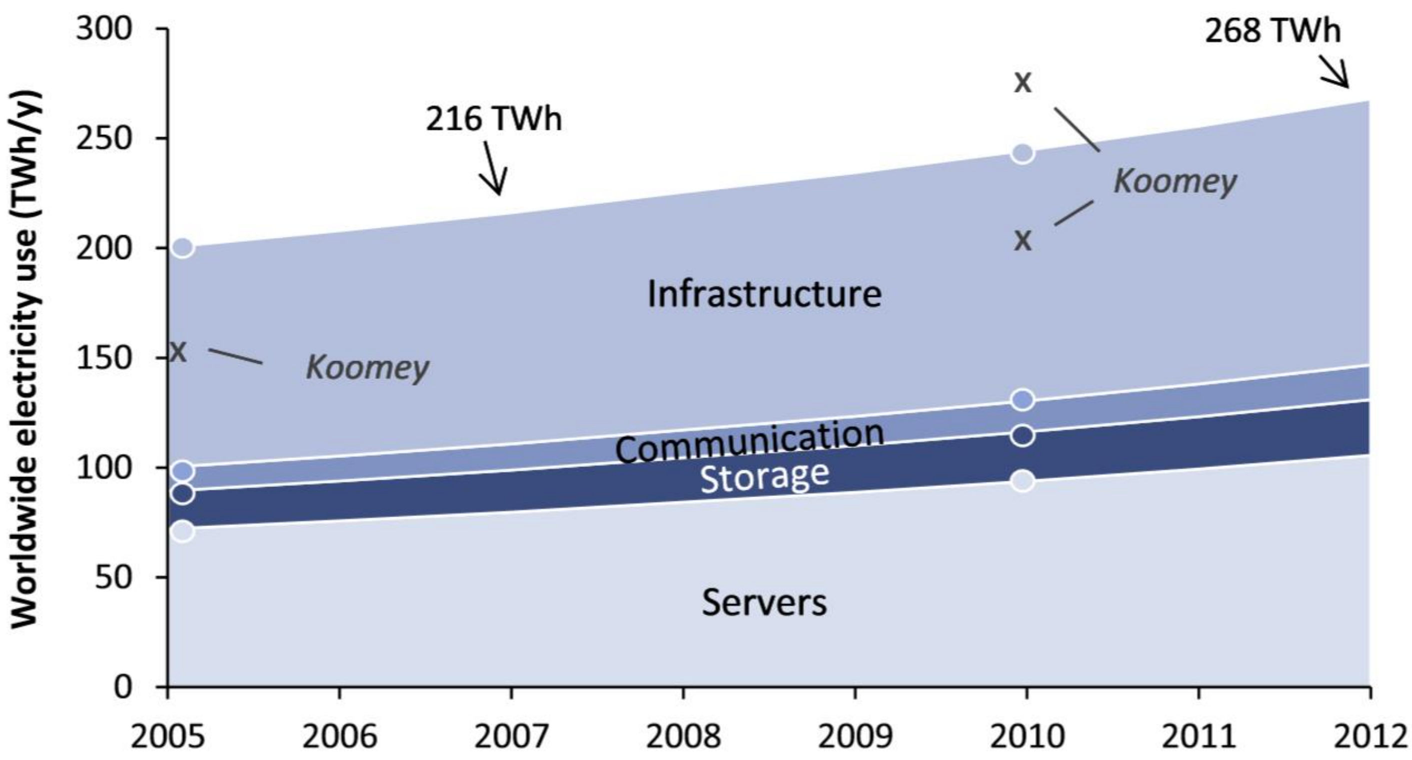
Data Centers

- Servers
- Communication Equipment (intra data center networks)
- Storage
- Infrastructure Overhead (cooling, UPS, lighting etc.)

Data Centers



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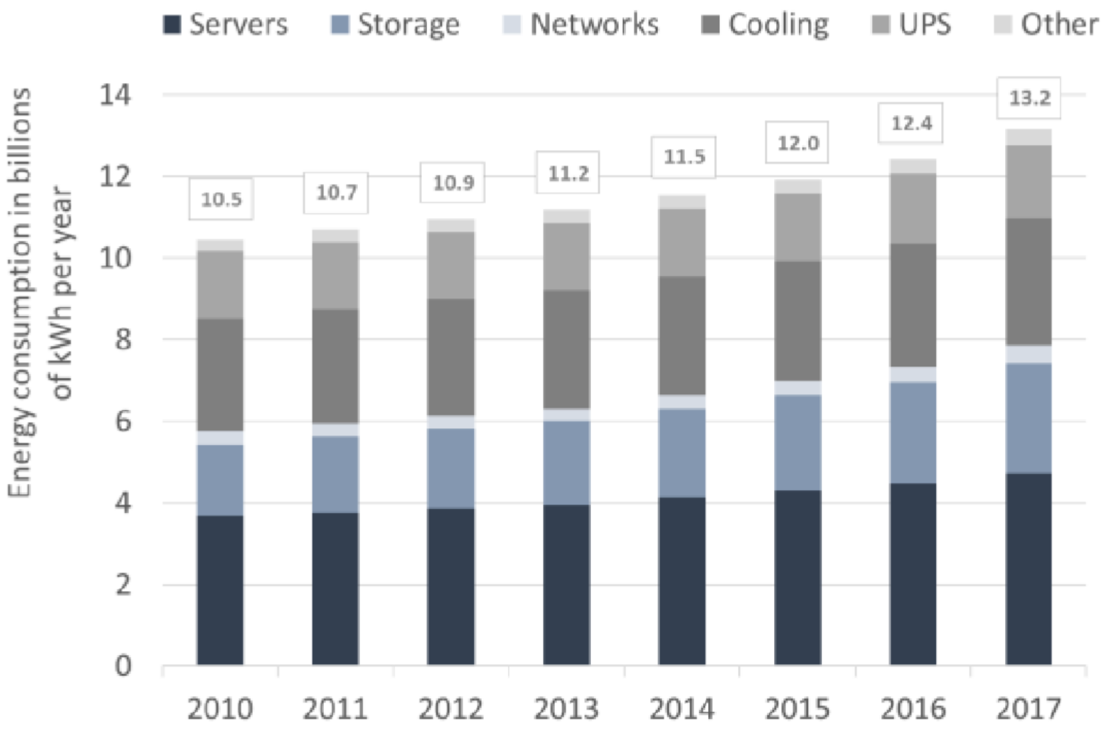
Data Centers in Germany



Energy consumption of servers and data centers in Germany in the year 2010 to 2017 (Source: Borderstep)

[8] Energy consumption of data centers worldwide. R. Hintemann et al.

Data Centers in Germany

- IT components: **5.8** billion kWh (2010) to **7.9** billion kWh (2017)
    - 36%
- Infrastructure: **4.7** billion kWh (2010) to **5.3** billion kWh (2017)
    - 12%
- PUE: **1.98** (2010) to **1.75** (2017)
    - Newly built ones: 1.3 and lower

the Power Usage Effectiveness: total / IT

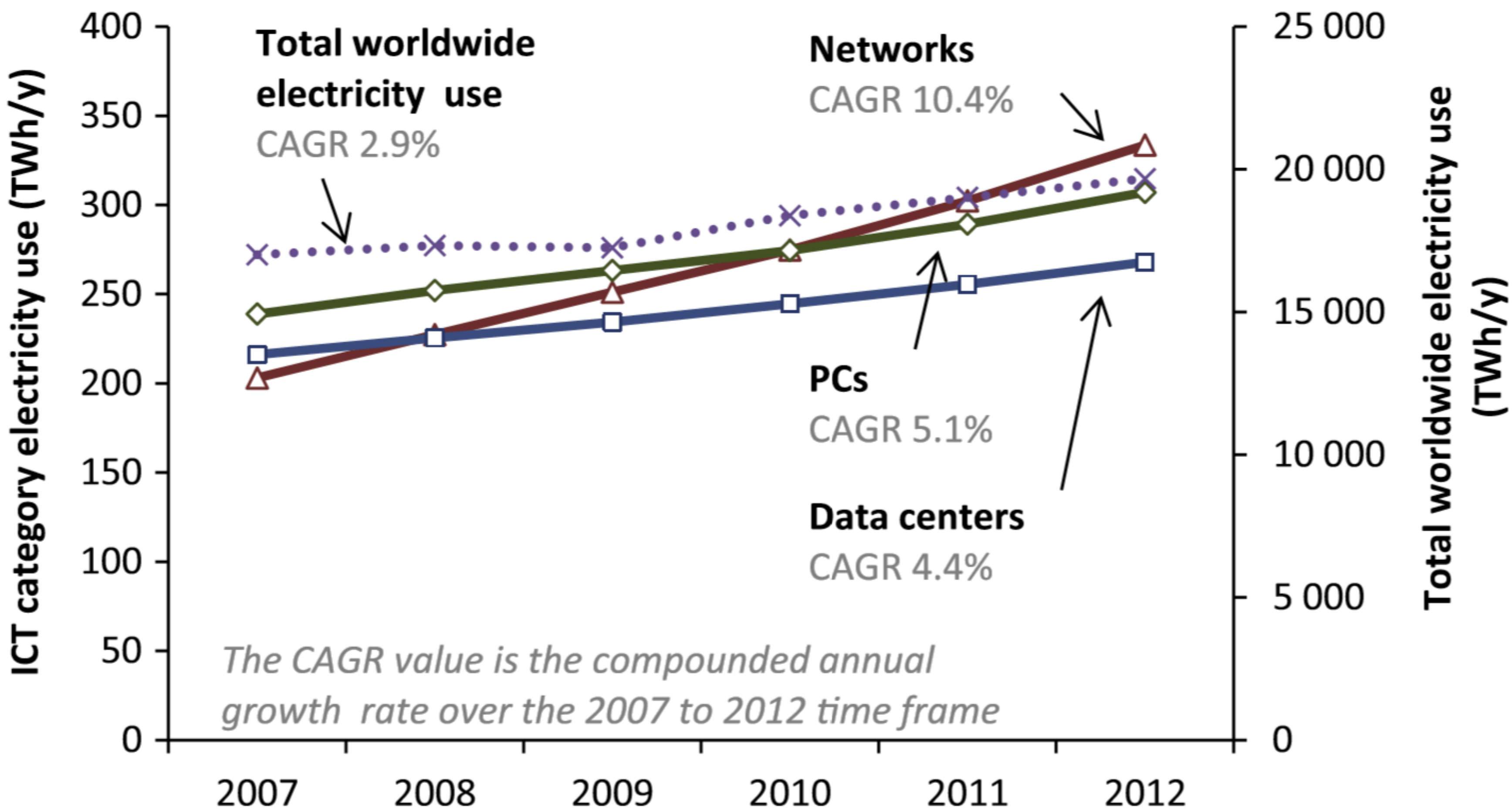
[8] Energy consumption of data centers worldwide. R. Hintemann et al.

iCloud

Alibaba Cloud

HUAWEI

Three major domains - Conclusion



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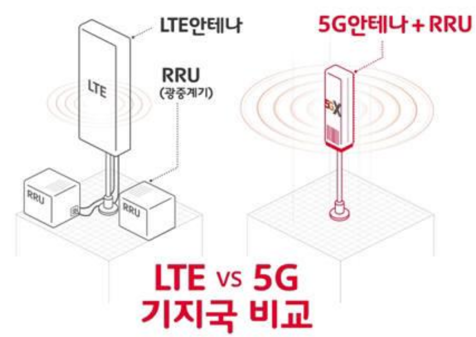
5G Base Station

BBU

RRU

Antenna

AAU



5G Base Station

设备分类	业务负荷	中兴		华为	
		AAU/RRU平均功耗(W)	BBU平均功耗(W)	AAU/RRU平均功耗(W)	BBU平均功耗(W)
5G	100%	1127.28	293.012	1175.4	325.8
	50%	892.32	293.012	956.8	325.8
	30%	762.43	292.537	856.9	319
	20%	733.92	293.233	797.5	319
	10%	699.36	293.416	738.6	319
	空载	633	293.568	663.0	330
4G	100%	289.68	175.68		
	50%	273.58	174.32		
	30%	259.1	171.92		
	空载	222.59	169.44	236.7	286.26

5G Base Station

Type	Load	ZTE		Huawei	
		AAU/RUU avg. (W)	BBU avg (W)	AAU/RUU avg. (W)	BBU avg. (W)
5G	100%	1127.28	293.012	1175.4	325.8
	50%	892.32	293.012	956.8	328.5
	30%	762.43	292.537	856.9	319
	20%	733.92	292.233	797.5	319
	10%	699.36	293.416	738.6	319
	0%	633	293.568	663.0	330
4G	100%	289.68	175.68		
	50%	273.58	174.32		
	30%	259.1	171.92		
	0%	222.59	169.44	236.7	286.26

5G Base Station

5G Base Station

	BBU(W)	AAU(W)	per Node(W)
Huawei	500	1000	3500
ZTE	315	980	3255
Datang	800	1380	4940
Nokia-Bell	Commercial product not yet finalized		
Ericsson			
4G baseline	250	350	1300

bit efficiency?

Energy Efficiency Challenges of 5G Small Cell Networks

Xiaohu Ge [Senior Member, IEEE], **Jing Yang**, **Hamid Gharavi [Fellow, IEEE]**, and **Yang Sun**

Abstract

The deployment of a large number of small cells poses new challenges to energy efficiency, which has often been ignored in fifth generation (5G) cellular networks. While massive multiple-input multiple outputs (MIMO) will reduce the transmission power at the expense of higher computational cost, the question remains as to which computation or transmission power is more important in the energy efficiency of 5G small cell networks. Thus, the main objective in this paper is to investigate the computation power based on the Landauer principle. Simulation results reveal that more than 50% of the energy is consumed by the computation power at 5G small cell base stations (BSs). Moreover, the computation power of 5G small cell BS can approach 800 watt when the massive MIMO (e.g., 128 antennas) is deployed to transmit high volume traffic. This clearly indicates that computation power optimization can play a major role in the energy efficiency of small cell networks.

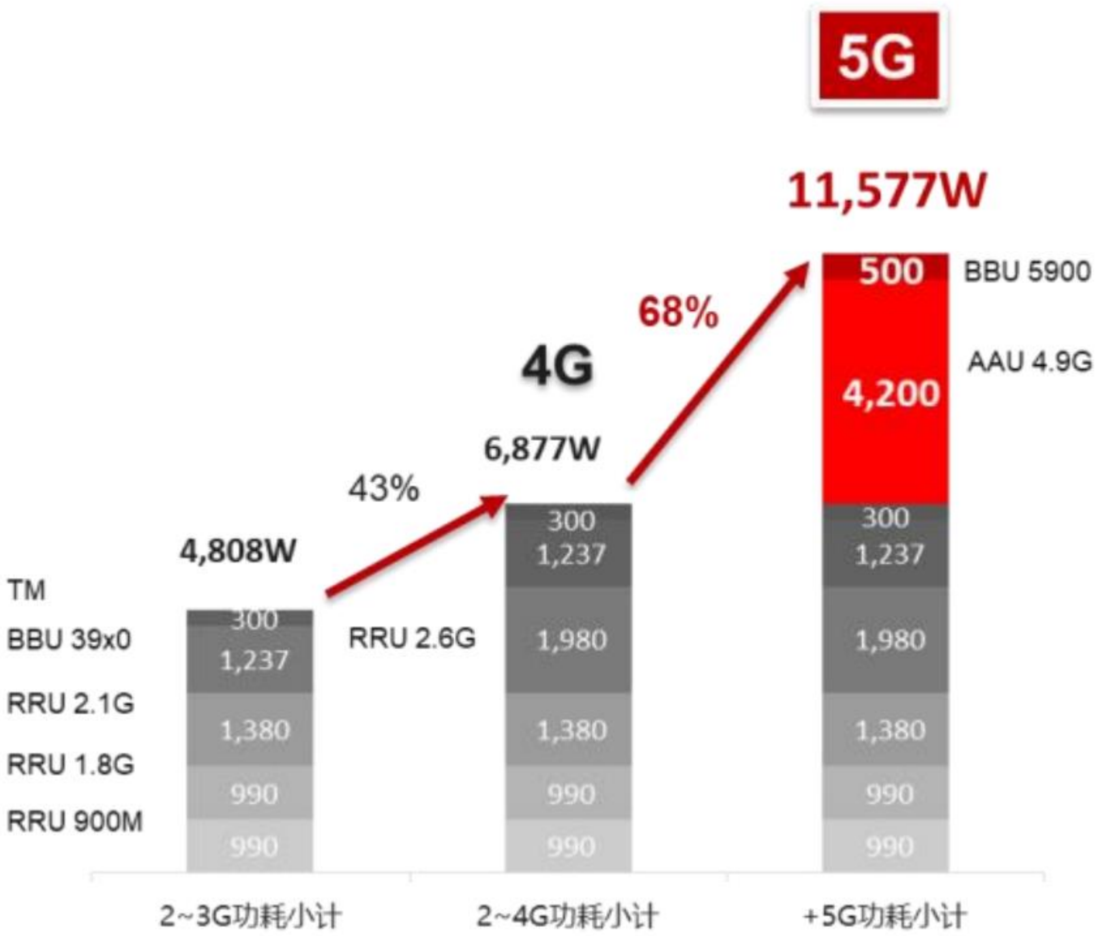


图1：5G单站典型最大功耗

Source: Huawei 5G power whitebook. 2019

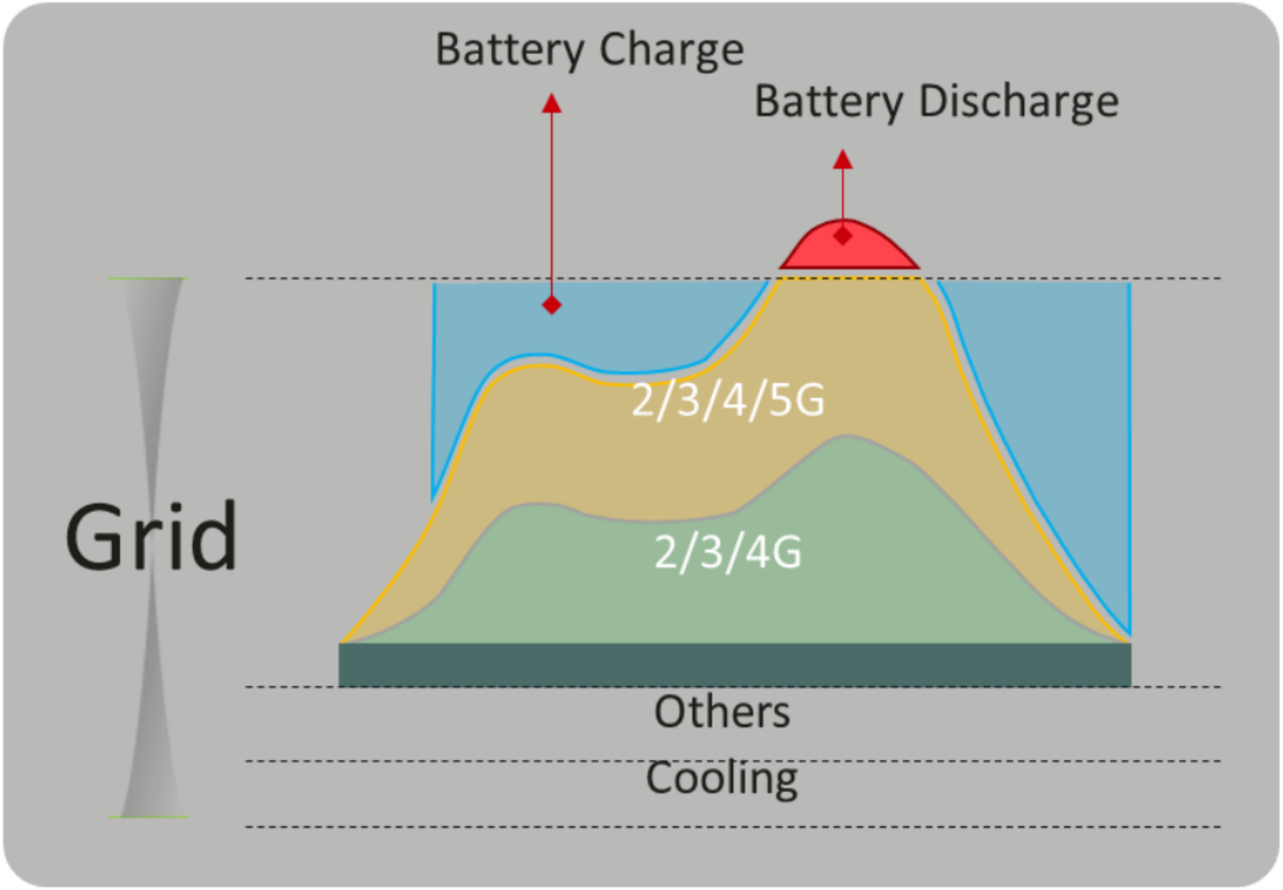


图14：5G电源实现智能削峰

Source: Huawei 5G power whitebook. 2019

References

- [1] UN, World population prospects: the 2010 revision, UN population Division, 2011
- [2] UN, Millennium development goals indicators, UN Statistics Division, 2010.
- [3]A brief history of personal computer vendors. Asymco
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- [8] Energy consumption of data centers worldwide. R. Hintemann et al.
- [9] Energy Efficiency Challenges of 5G Small Cell Networks. 2017. X.H. Ge. Et al.
- [10] Source: Huawei 5G power whitebook. 2019

- Thanks for listening!
- Comments ? Questions?