The Lockdown Effect

Implications of the COVID-19 Pandemic on Internet Traffic

Oliver Gasser, Max Planck Institute for Informatics

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COVID-19 and the Internet

euronews.

Coronavirus: Half of humanity now on lockdown as 90 countries call for confinement

The New York Times

Working From Home: How Coronavirus Could Affect the Workplace

INSIDE HIGHER ED

Will Shift to Remote Teaching Be Boon or Bane for Online Learning?

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Under lockdown, Italy's social and family life goes virtual

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The Internet is essential in all these efforts, but how well does it cope?

Lots of data, lots of data crunchers

- Edge network: Large European ISP
- Core networks: 3 IXPs in Central Europe, Southern Europe, and US East Coast
- Academic network: REDIMadrid university network in Madrid

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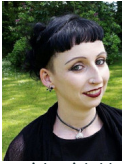

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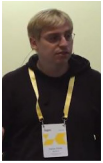

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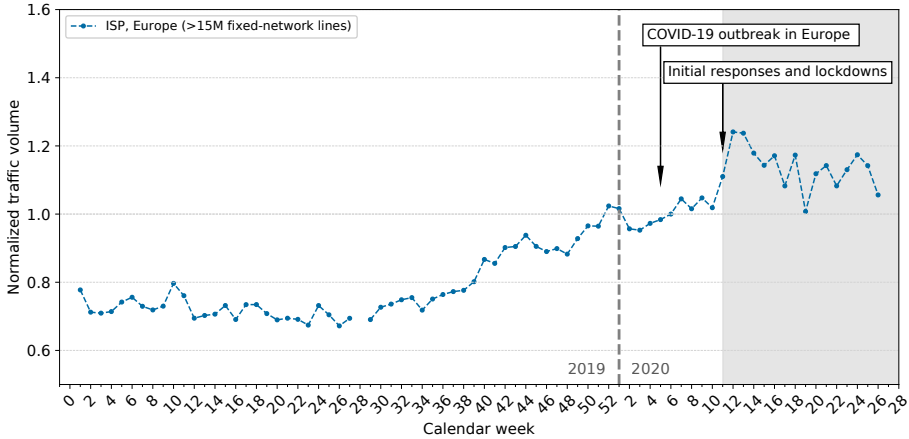
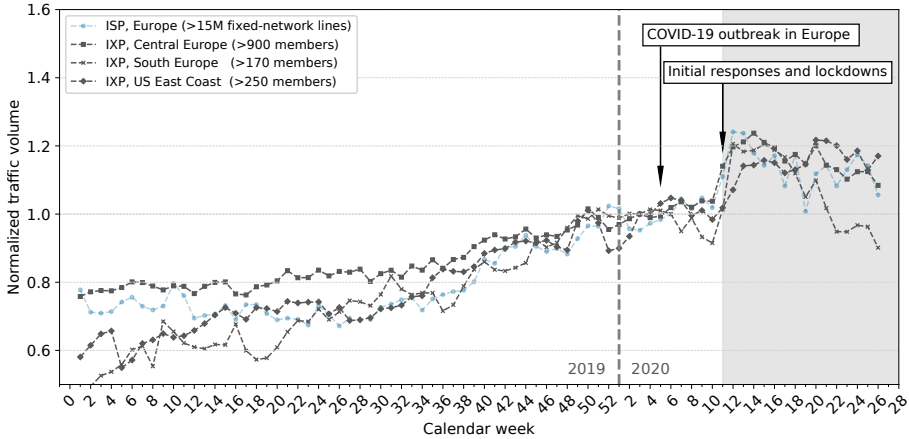
Traffic changes from January 2019 to June 2020



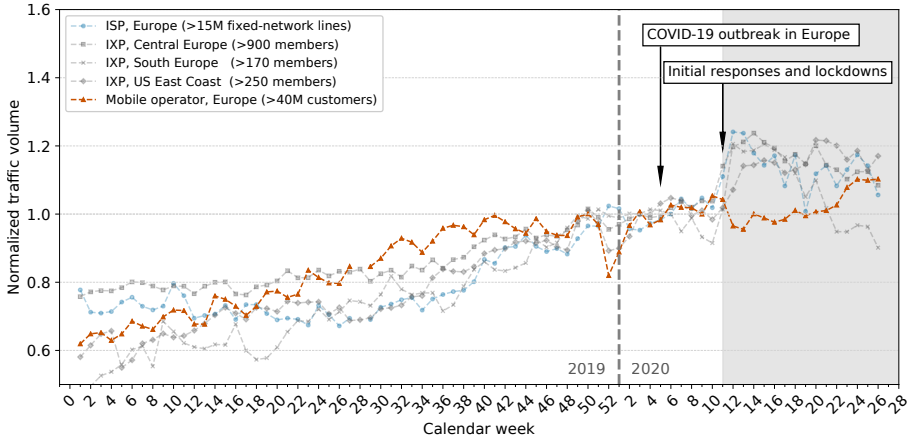
Once the lockdown started the ISP saw a +30% increase in traffic which normally spans over multiple months.

Traffic changes from January 2019 to June 2020



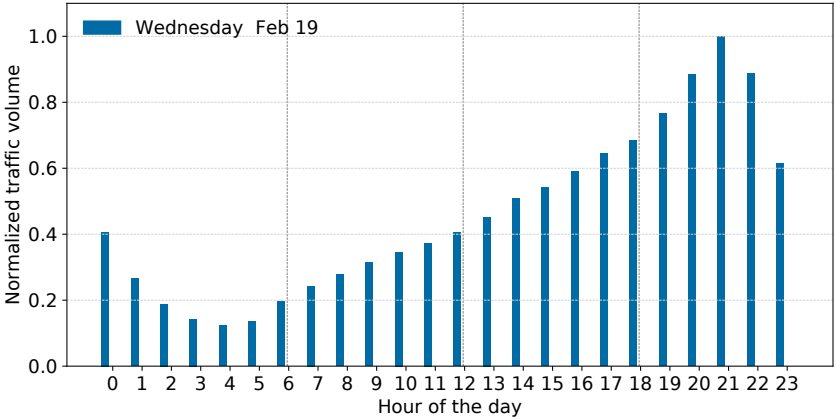
Similar behavior for the IXPs; for the IXP CE and IXP US the traffic levels remain elevated.

Traffic changes from January 2019 to June 2020



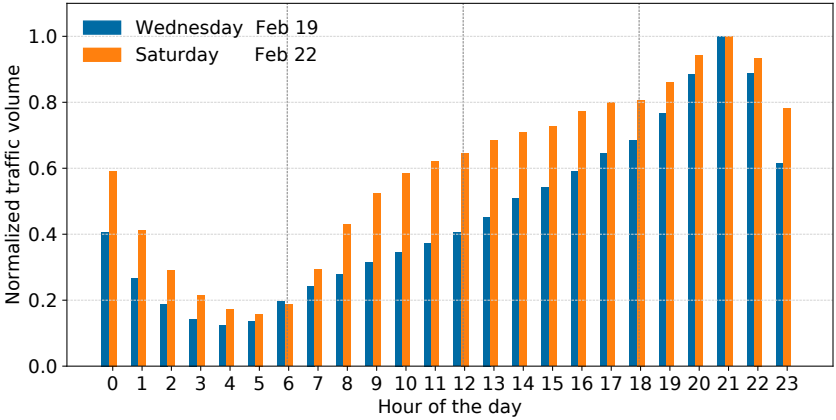
Once the lockdown started mobile traffic decreased measurably and increased again with the first relaxations in mid April.

Changes in workday vs. weekend patterns at the ISP



- Regular patterns
  - Workday: Strong increase in evening hours

Changes in workday vs. weekend patterns at the ISP



- Regular patterns
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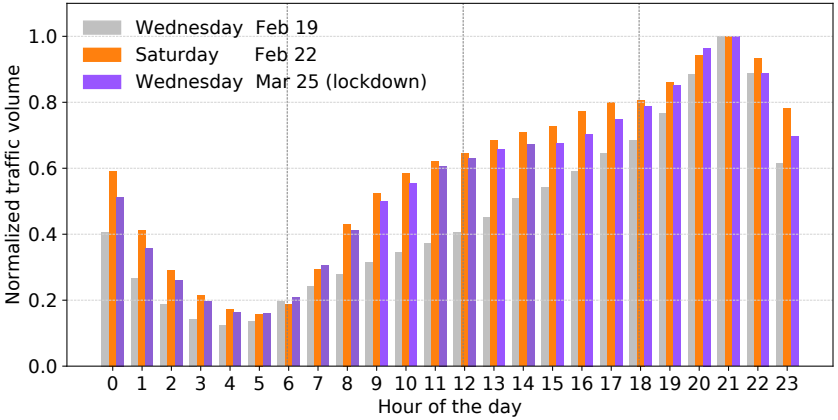
  - Weekend: More traffic during daytime

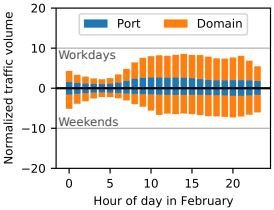
Changes in workday vs. weekend patterns at the ISP



- Regular patterns
  - Workday: Strong increase in evening hours
  - Weekend: More traffic during daytime
- **During lockdown: Workdays look more like weekends**

VPN identification

- Port-based: Well known port/proto combinations exclusively used by VPN services
- Domain-based: For TCP/443 traffic, IPs labeled `*vpn*`, but not `www.`



VPN traffic at the Central European IXP

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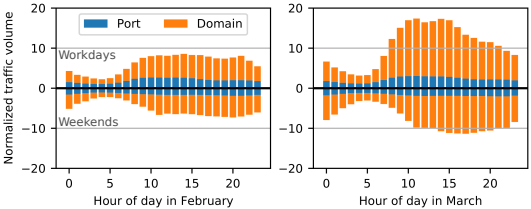

- 200% increase in VPN traffic in March during working hours

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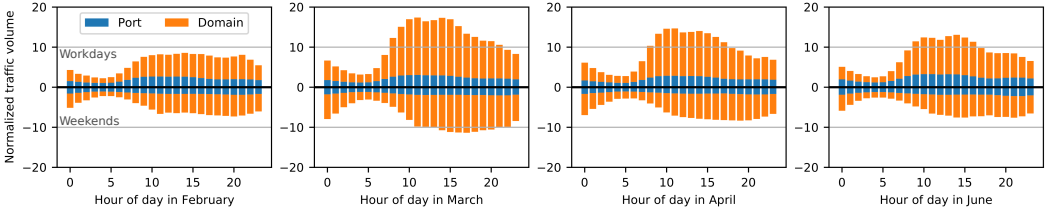

- **200% increase in VPN traffic in March during working hours**
- Slight decrease in April & June

People change $\rightarrow$ traffic changes

- Traffic increase of **15-30%** within a few **days**
- Difference between **workday and weekend** vanishes
- Applications for **remote work, education, VPN, and video conferencing** see significant increase in traffic

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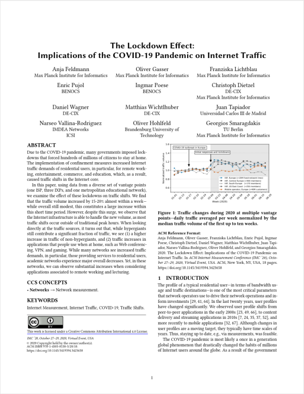
More in our *The Lockdown Effect* IMC 2020 paper

- Changes in transport ports
- Different traffic classes
- Educational network
- Hypergiants vs. non-hypergiants
- ...


The Lockdown Effect: Implications of the COVID-19 Pandemic on Internet Traffic

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ABSTRACT

Due to the COVID-19 pandemic, many governments imposed lockdowns that forced hundreds of millions of citizens to stay at home. The implementation of confinement measures increased Internet traffic demands of residential users, in particular, for remote working, entertainment, commerce, and education, which, as a result, caused traffic shifts in the Internet core.

In this paper, using data from a diverse set of vantage points (one ISP, three IXPs, and one metropolitan educational network), we examine the effect of these lockdowns on traffic shifts. We find that the traffic volume increased by 15-20% almost within a week—while overall still modest, this constitutes a large increase within this short time period. However, despite this surge, we observe that the Internet infrastructure is able to handle the new volume, as most traffic shifts occur outside of traditional peak hours. When looking directly at the traffic sources, it turns out that, while hypergiants still contribute a significant fraction of traffic, we see (1) a higher increase in traffic of non-hypergiants, and (2) traffic increases in applications that people use when at home, such as Web conferencing, VPN, and gaming. While many networks see increased traffic demands, in particular, those providing services to residential users, academic networks experience major overall decreases. Yet, in these networks, we can observe substantial increases when considering applications associated to remote working and lecturing.

CCS CONCEPTS

• **Networks** → Network measurement.

KEYWORDS

Internet Measurement, Internet Traffic, COVID-19, Traffic Shifts.

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Figure 1: Traffic changes during 2020 at multiple vantage points—daily traffic averaged per week normalized by the median traffic volume of the first up to ten weeks.

ACM Reference Format:
Anja Feldmann, Oliver Gasser, Franziska Lichtblau, Enric Pujol, Ingmar Poese, Christoph Dietzel, Daniel Wagner, Matthias Wichtlhuber, Juan Tapiador, Narseo Vallina-Rodriguez, Oliver Hohlfeld, and Georgios Smaragdakis. 2020. The Lockdown Effect: Implications of the COVID-19 Pandemic on Internet Traffic. In *ACM Internet Measurement Conference (IMC '20), October 27–29, 2020, Virtual Event, USA.* ACM, New York, NY, USA, 18 pages. https://doi.org/10.1145/3419394.3423658

1 INTRODUCTION

The profile of a typical residential user—in terms of bandwidth usage and traffic destinations—is one of the most critical parameters that network operators use to drive their network operations and inform investments [29, 41, 64]. In the last twenty years, user profiles have changed significantly. We observed user profile shifts from peer-to-peer applications in the early 2000s [23, 49, 66], to content delivery and streaming applications in 2010s [7, 24, 35, 37, 52], and more recently to mobile applications [32, 67]. Although changes in user profiles are a moving target, they typically have time scales of years. Thus, staying up to date, e.g., via measurements, was feasible.

The COVID-19 pandemic is most likely a once in a generation global phenomenon that drastically changed the habits of millions of Internet users around the globe. As a result of the government

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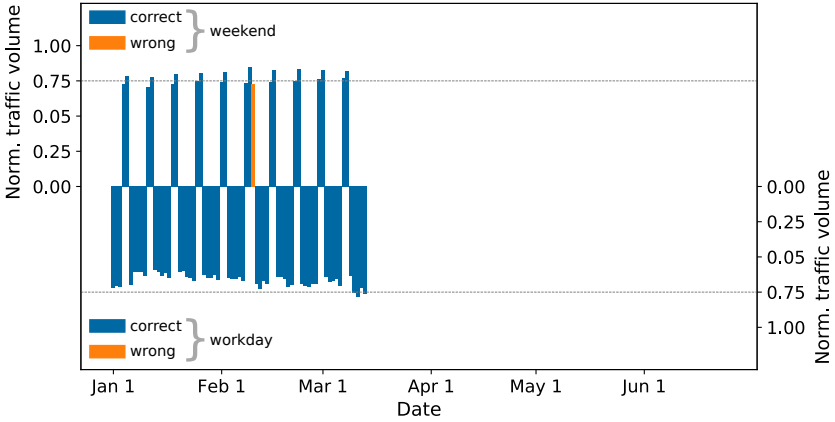
Backup

Changes in workday vs. weekend patterns at the ISP

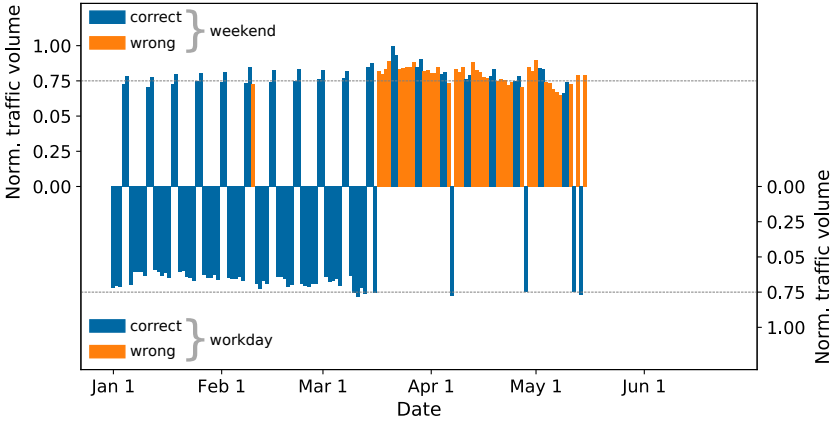
- Classify days into workdays or weekends using traffic patterns

Changes in workday vs. weekend patterns at the ISP



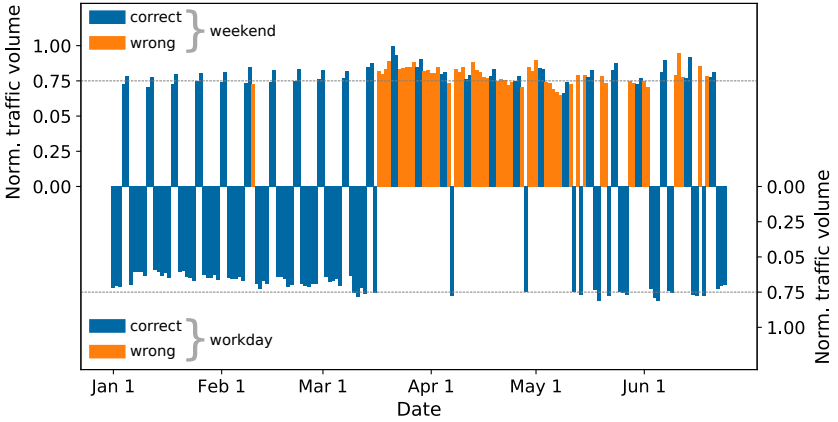
- Classify days into workdays or weekends using traffic patterns
- Pre-lockdown: Most days are classified correctly

Changes in workday vs. weekend patterns at the ISP



- Classify days into workdays or weekends using traffic patterns
- Pre-lockdown: Most days are classified correctly
- During lockdown: Workdays are classified as weekends

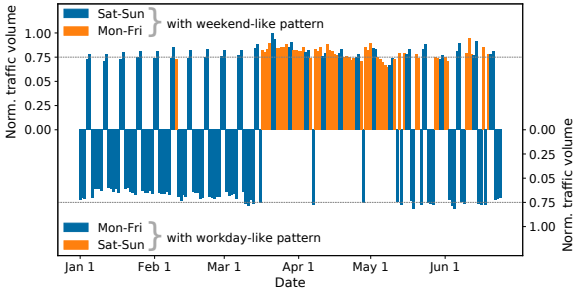
Changes in workday vs. weekend patterns at the ISP



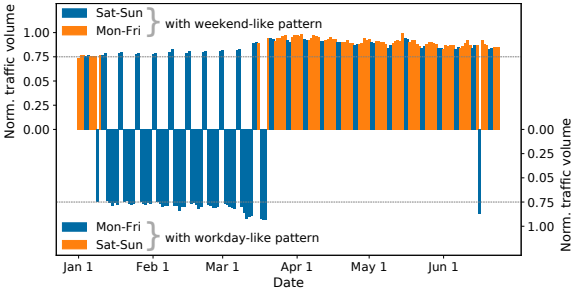
- Classify days into workdays or weekends using traffic patterns
- Pre-lockdown: Most days are classified correctly
- During lockdown: Workdays are classified as weekends; recovering after mid-May

Changes in workday vs. weekend patterns: ISP vs. IXP

ISP



IXP



Changes in workday vs. weekend patterns: ISP vs. IXP

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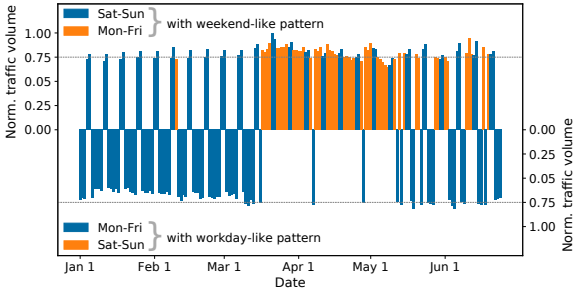

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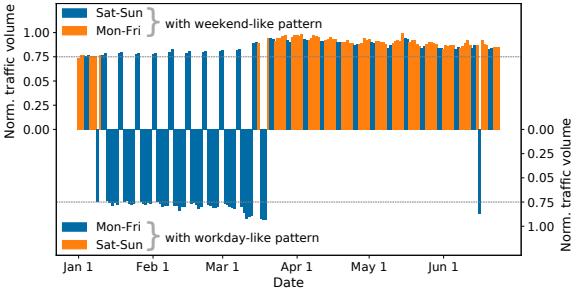

- At both vantage points workdays are mostly classified as weekends

Classify traffic by application class

- Classify based on transport ports and src/dst ASes

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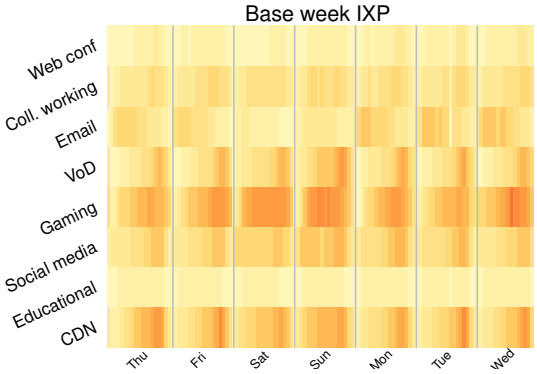

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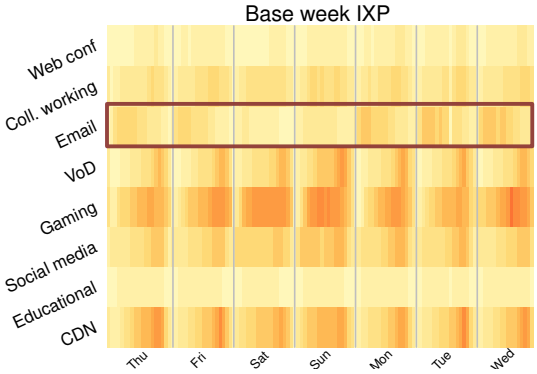

- Email during working hours

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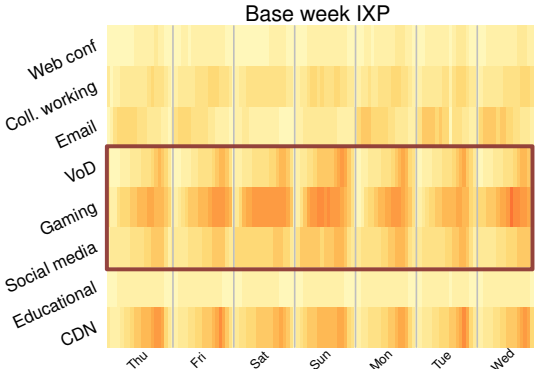

- Email during working hours
- Video, gaming, and social media during evening hours

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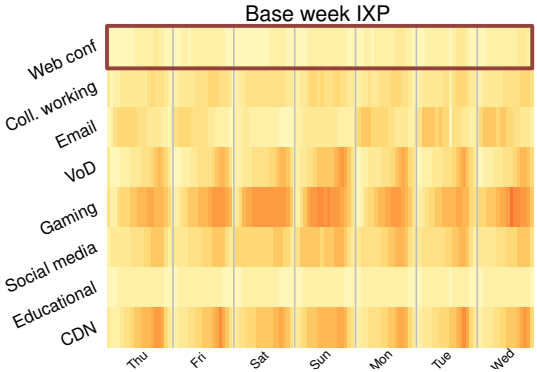
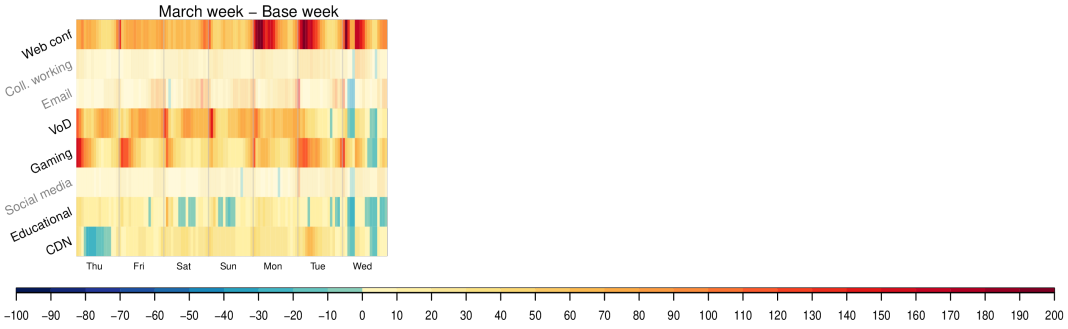


- Email during working hours
- Video, gaming, and social media during evening hours
- Hardly any web conferencing

Changes in application classes: Central European IXP



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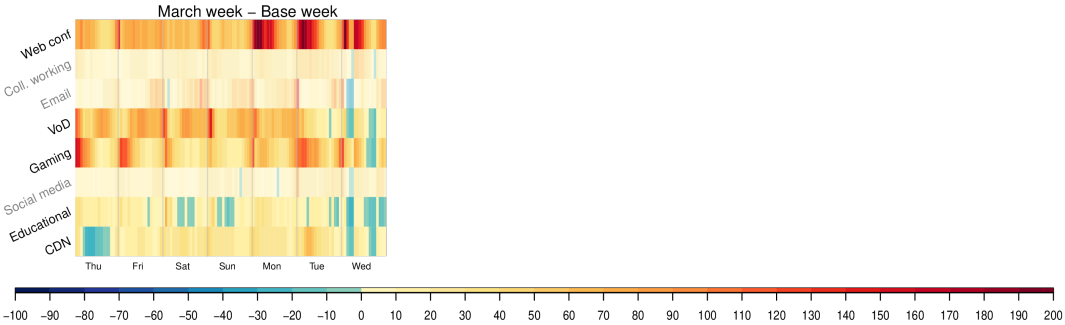

March:

- Increase in web conf., VoD, and gaming
- Partial decrease in CDN and educational traffic

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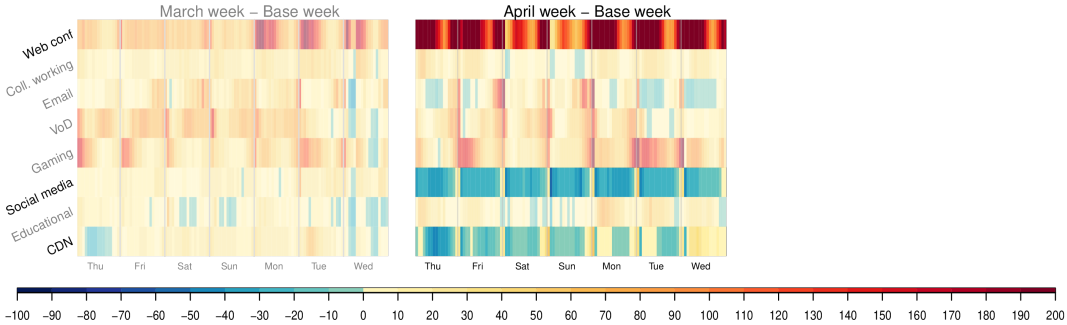

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April:

- Strong increase in web conf.
- Decrease in CDN and social media traffic

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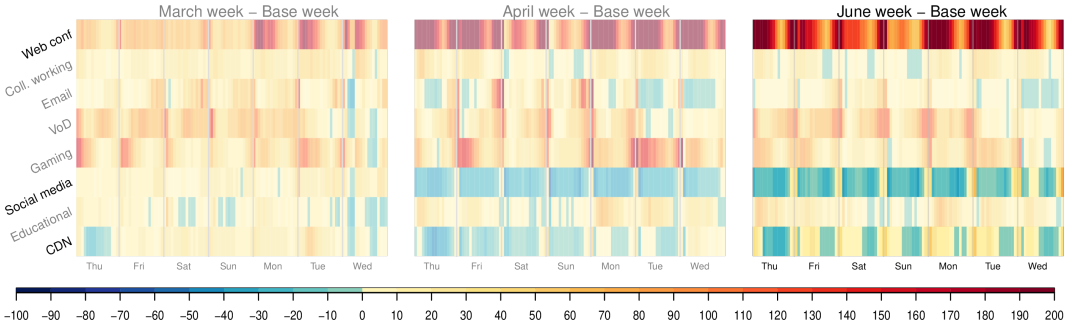

March:

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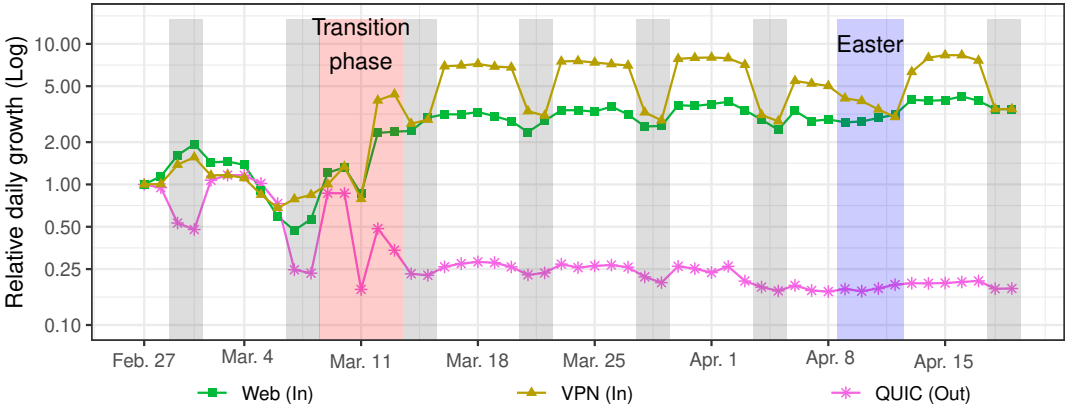
April & June:

- Strong increase in web conf.
- Decrease in CDN and social media traffic

Daily connections for different traffic classes at REDIMadrid



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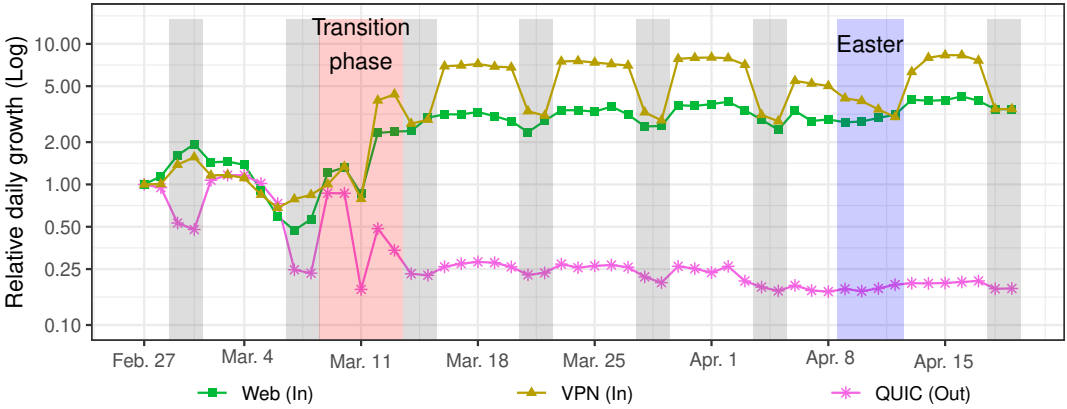


- Increase in incoming web and VPN traffic
- Decrease of outgoing QUIC traffic

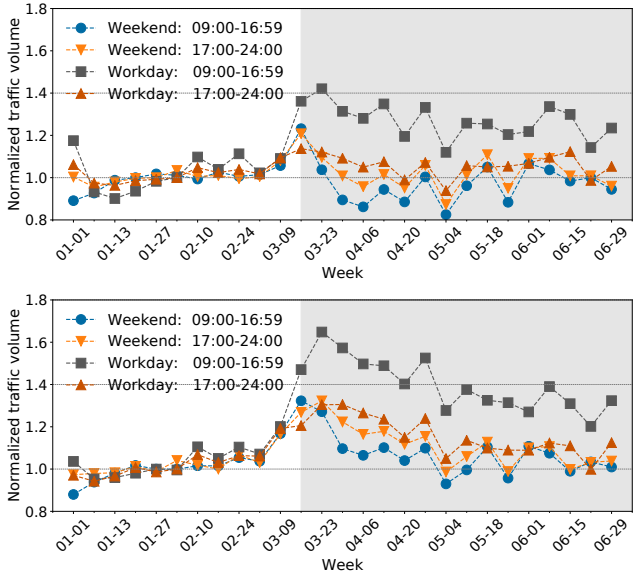
Analyzing the pandemic across time

- **base**: February before the lockdown
- **March**: During the lockdown
- **April**: First relaxation of restrictions
- **June**: Minimum restriction level

	ISP-CE	IXP-CE	IXP-SE	IXP-US	EDU
base	Feb 20–26	Feb 20–26	Feb 20–26	Feb 20–26	Feb 20–26
March	Mar 19–25	Mar 19–25	Mar 12–18	Mar 19–25	Mar 12–18
April	Apr 09–15	Apr 23–29	Apr 23–29	Apr 23–29	Apr 23–29
June	Jun 18–24	Jun 18–24	Jun 18–24	Jun 18–24	n/a

Our analysis is based on **four weeks** representing the course of the pandemic from **February 2020** to **June 2020**.

Hypergiants vs. non-hypergiants

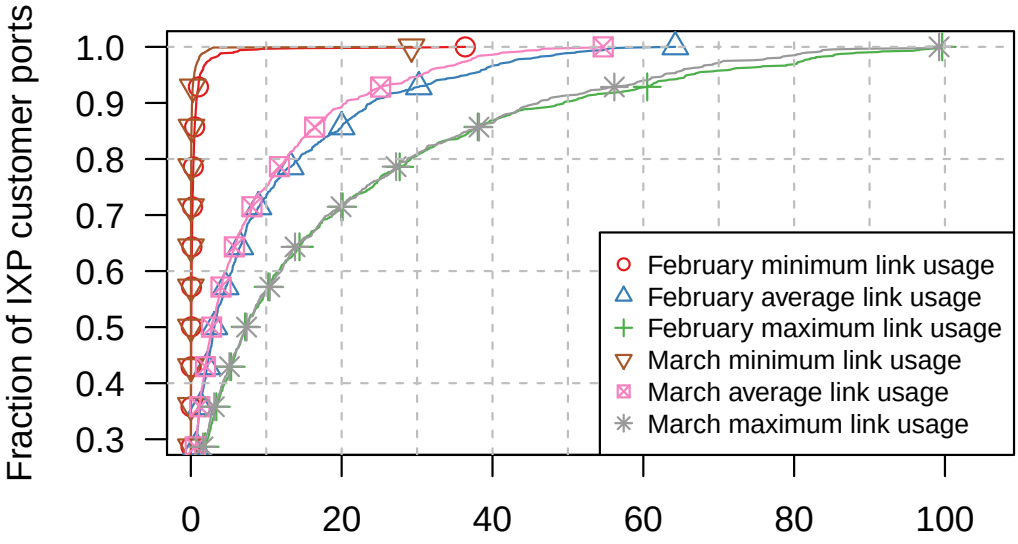


Hypergiant ASes

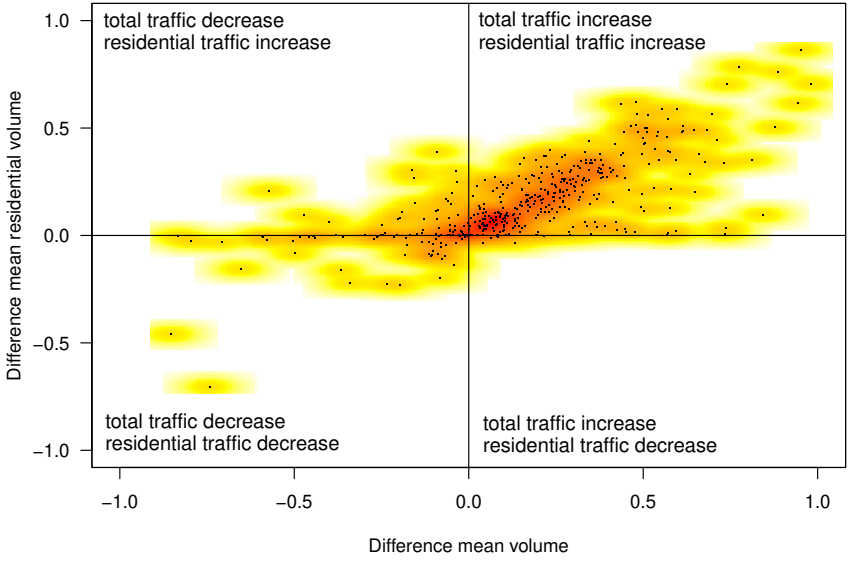
Org. Name	ASN
Apple Inc	714
Amazon.com	16509
Facebook	32934
Google Inc.	15169
Akamai Technologies	20940
Yahoo!	10310
Netflix	2906
Hurricane Electric	6939
OVH	16276
Limelight Networks Global	22822
Microsoft	8075
Twitter, Inc.	13414
Twitch	46489
Cloudflare	13335
Verizon Digital Media Services	15133

Table 1: List of Hypergiant ASes as defined by Böttger et al.

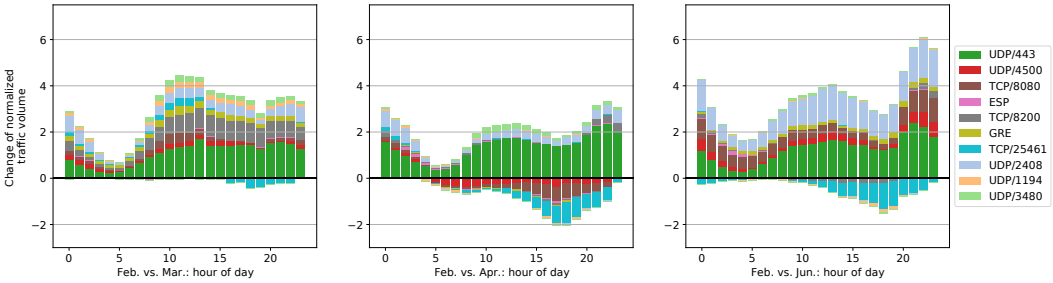
Link-utilization before and after the lockdown at the IXP-CE



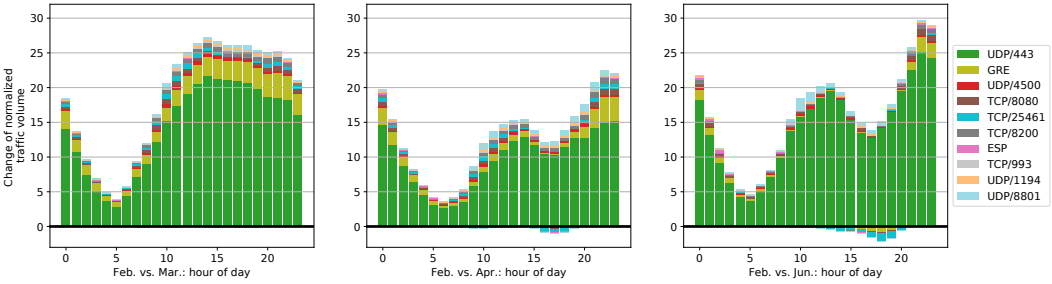
Heatmap of traffic shift vs. residential traffic shift (Feb. vs. Mar.)



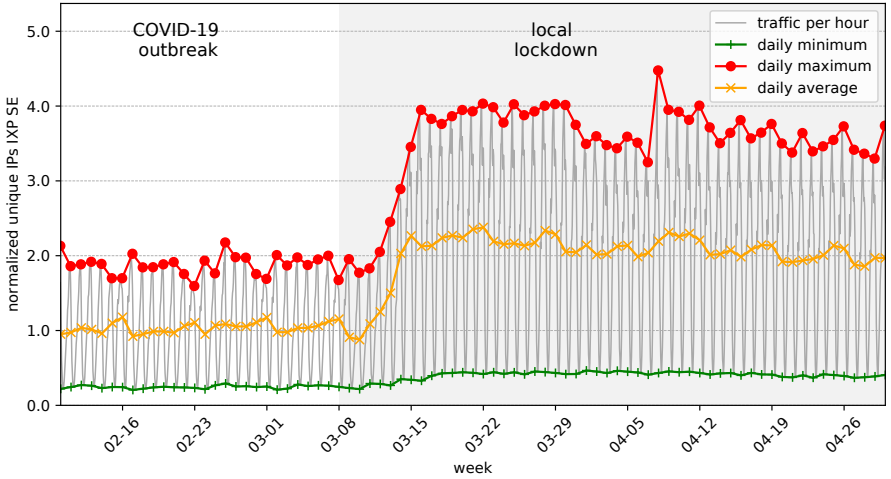
Traffic difference by top application ports at the IXP-CE



Traffic difference by top application ports at the ISP

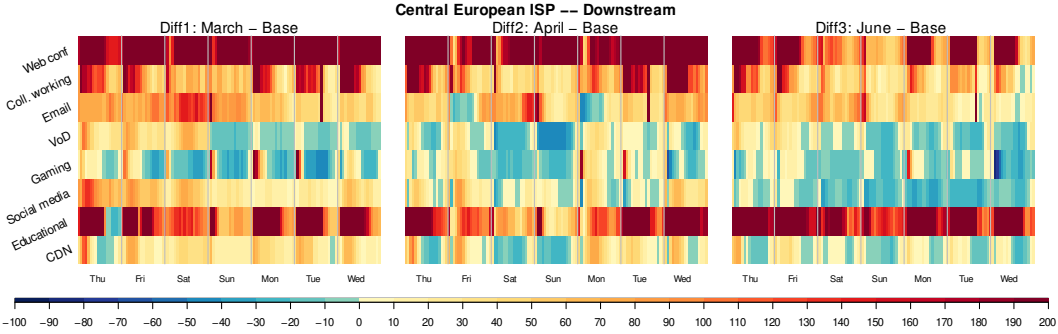


Gaming traffic: Southern European IXP



- Gaming: Large increase in number of active IP addresses and traffic volume

Changes in application classes: Central European ISP



March:

- Large increase in web conf., coll. working, edu traffic
- Partial decrease in VoD and gaming

April:

- Growth in Email less pronounced
- Decrease in social media

June:

- Web conf. still growing, more focused on working hours
- Moderate growth in coll. working
- Decrease of VoD, gaming and social media

Traffic changes $\rightarrow$ networks change

- Traffic increase of **15-30%** within a few **days**
  - Networks usually provision for $\approx$**30%** increase per **year**
- Impact on peak traffic is limited, but **valleys get filled**
- The Central European IXP reports capacity increase of around **1,500 Gbps**
- Networks could **react quickly** to the additional need for capacity

Networks can accommodate sudden changes in demand if they are planned with spare capacity and quick reaction times.