The Lockdown Effect

Implications of the COVID-19 Pandemic on Internet Traffic

Oliver Gasser, Max Planck Institute for Informatics

Sixth RSNOG Conference · November 26, 2020

COVID-19 and the Internet

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?

REUTERS

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

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?

REUTERS

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

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

Lots of data

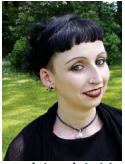
- Edge network: Large European ISP
- Core networks: 3 IXPs in Central Europe, Southern Europe, and US East Coast
- Academic network: REDIMadrid university network in Madrid

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

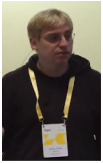
Anja Feldmann
MPII

Oliver Gasser
MPII



Franziska Lichtblau
MPII

Enric Pujol
BENOCS



Ingmar Poese
BENOCS

Christoph Dietzel
DE-CIX

Daniel Wagner
DE-CIX

Matthias Wichtlhuber
DE-CIX

Juan Tapiador
Universidad Carlos III de Madrid

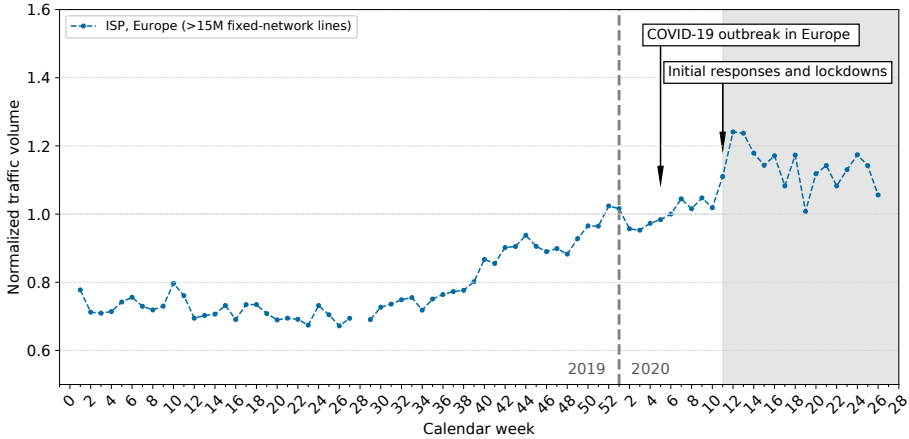
Narseo Vallina Rodriguez
IMDEA, ICSI

Oliver Hohlfeld
Brandenburg University of Technology

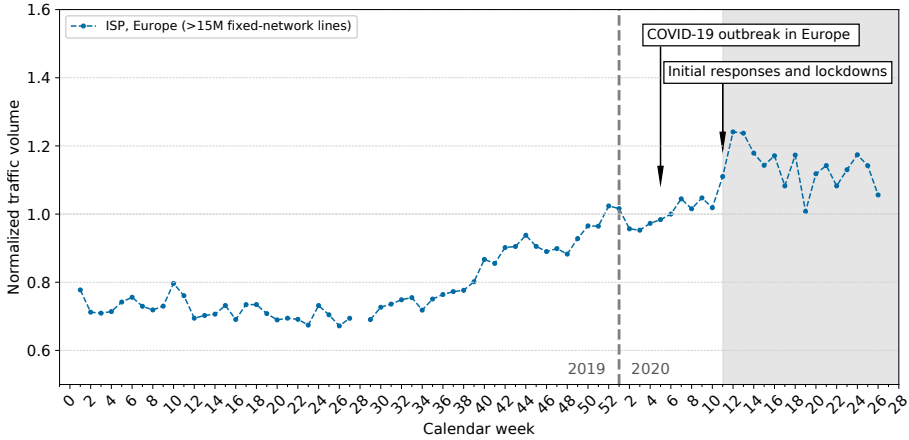
Georgios Smaragdakis
TU Berlin, MPII

Traffic changes in different networks

Traffic changes from January 2019 to June 2020

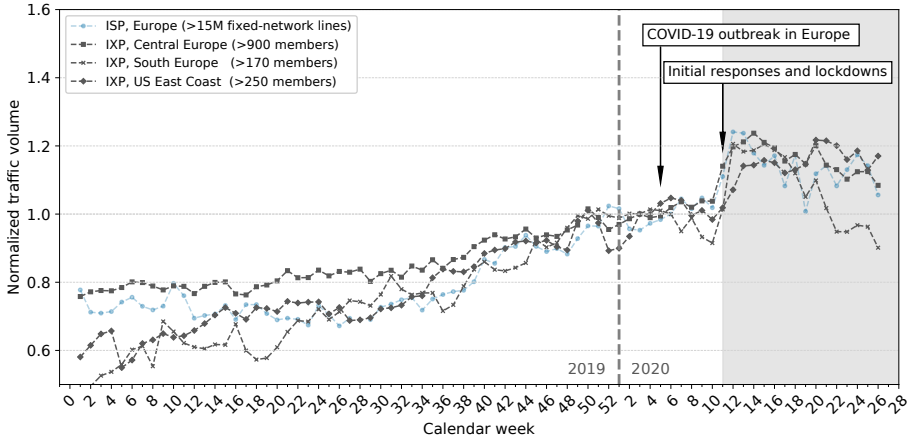


Traffic changes from January 2019 to June 2020



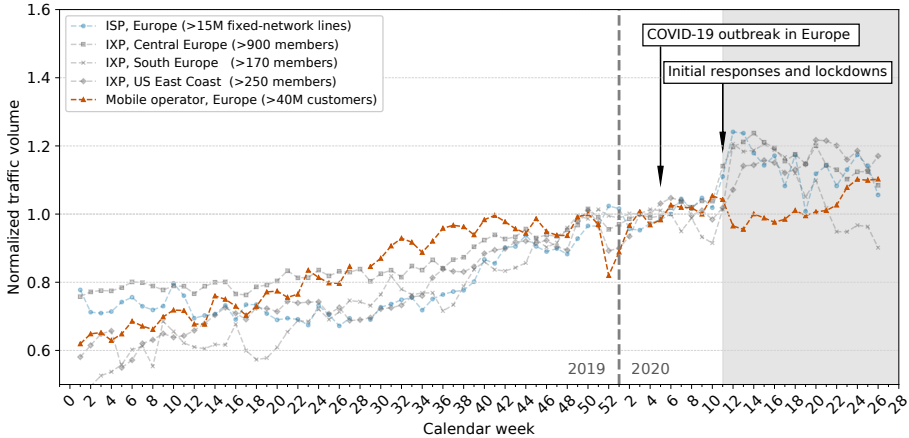
Once the lockdown started the ISP saw a +30% increase in traffic which normally spans over multiple months.

Traffic changes from January 2019 to June 2020



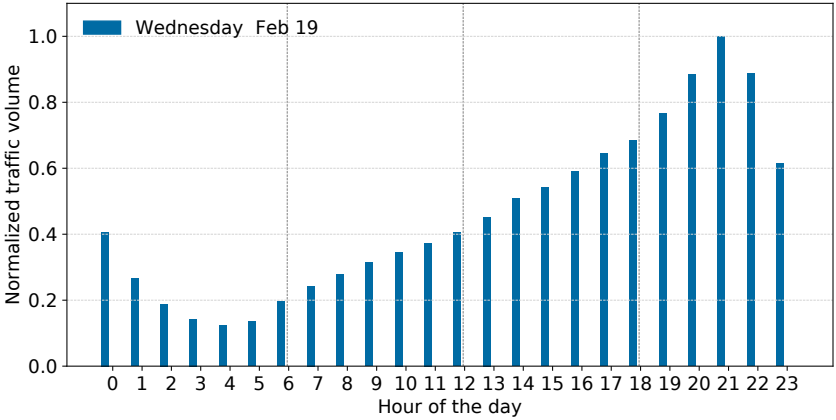
Similar behavior for the IXPs; for the IXP CE and IXP US the traffic levels remain elevated.

Traffic changes from January 2019 to June 2020



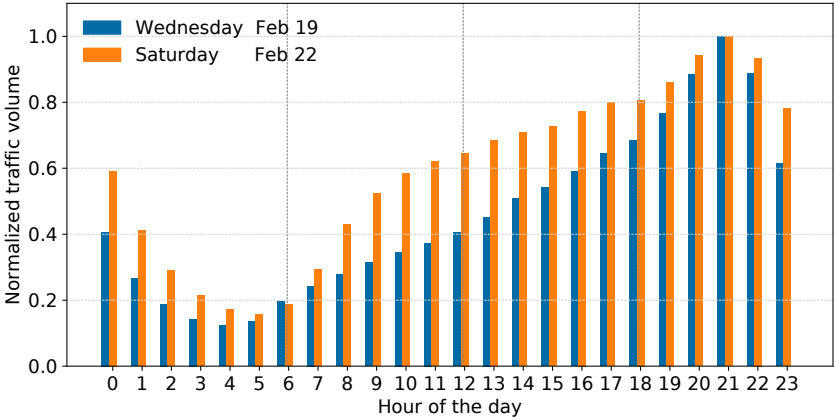
Once the lockdown started mobile traffic decreased measurably and increased again with the first relaxations in mid-April.

Changes in workday vs. weekend patterns at the ISP



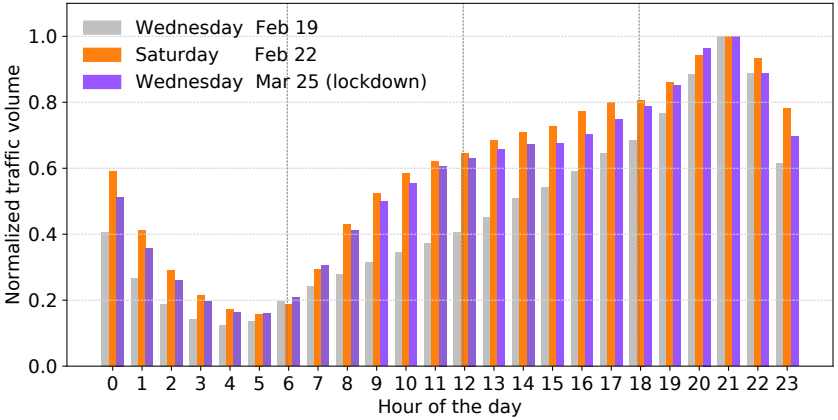
- Regular patterns
  - Workday: Strong increase in evening hours

Changes in workday vs. weekend patterns at the ISP



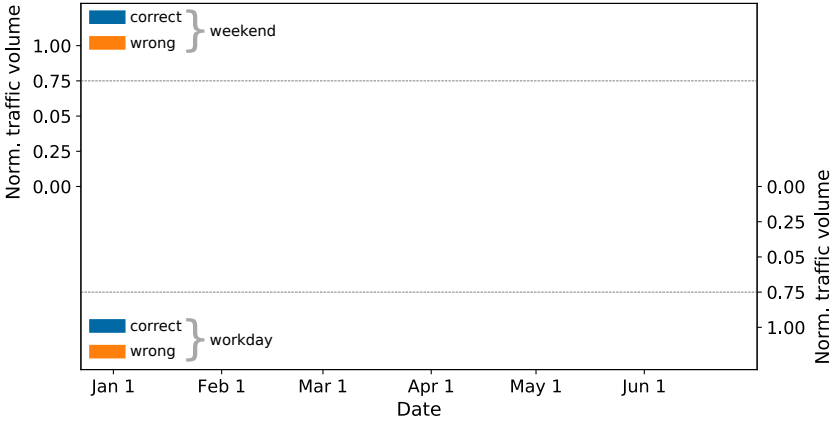
- Regular patterns
  - Workday: Strong increase in evening hours
  - Weekend: More traffic during daytime

Changes in workday vs. weekend patterns at the ISP



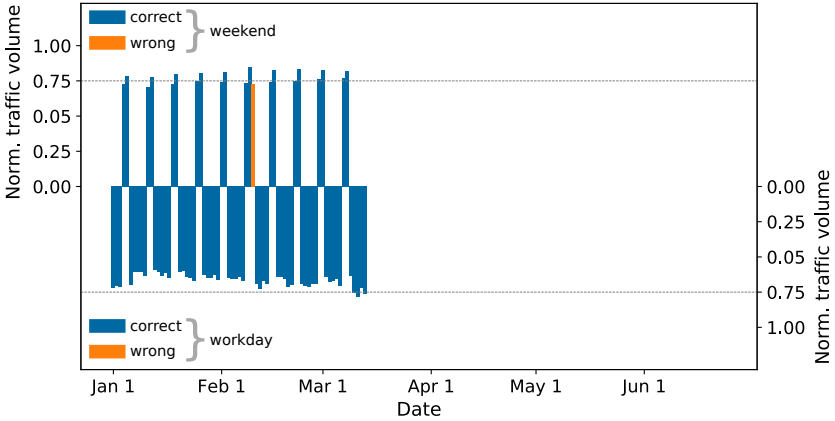
- Regular patterns
  - Workday: Strong increase in evening hours
  - Weekend: More traffic during daytime
- **During lockdown: Workdays look more like weekends**

Changes in workday vs. weekend patterns at the ISP



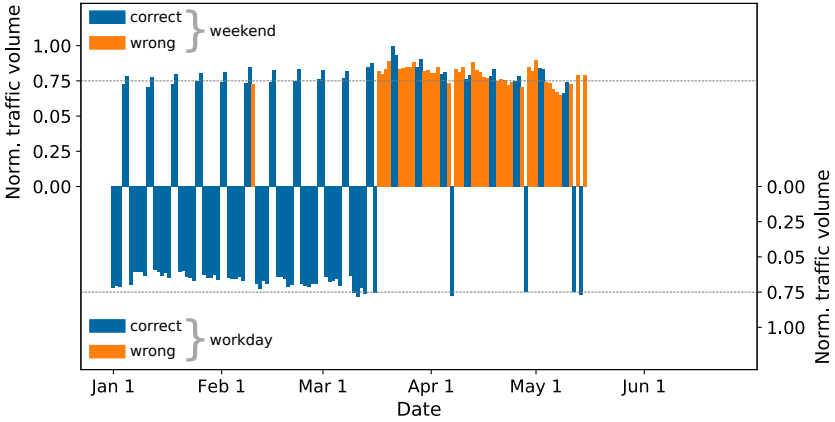
- Classify days into workdays or weekends using traffic patterns

Changes in workday vs. weekend patterns at the ISP



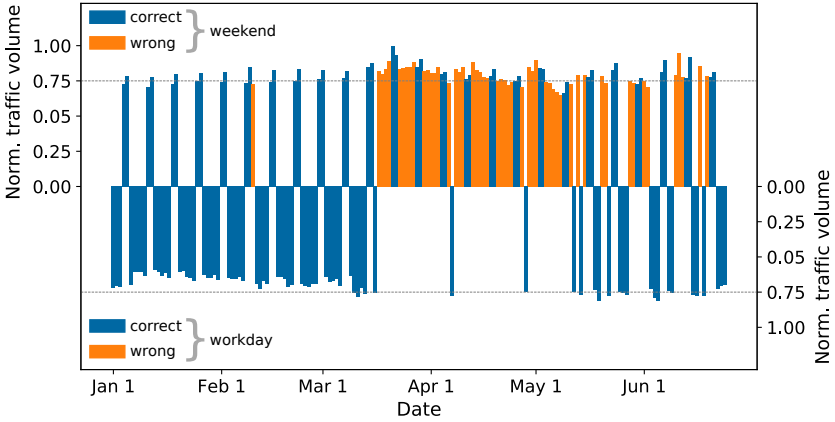
- Classify days into workdays or weekends using traffic patterns
- Pre-lockdown: Most days are classified correctly

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 mid-May**

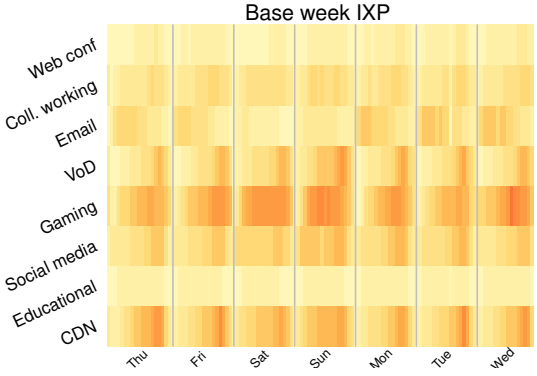
Application-level traffic changes

Classify traffic by application class

- Classify based on transport ports and src/dst ASes

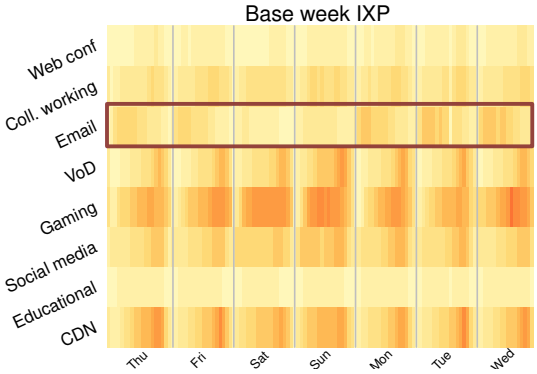
Classify traffic by application class

- Classify based on transport ports and src/dst ASes



Classify traffic by application class

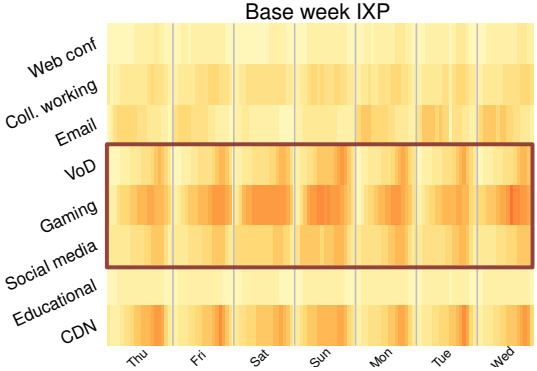
- Classify based on transport ports and src/dst ASes



- Email during working hours

Classify traffic by application class

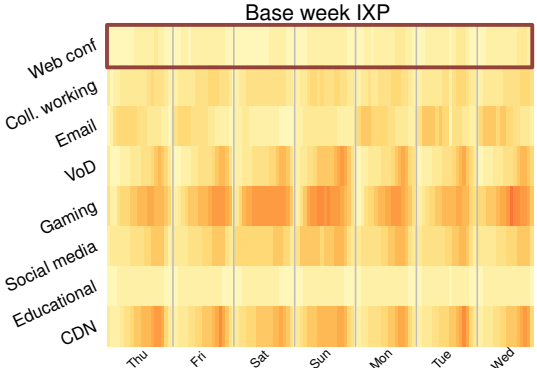
- Classify based on transport ports and src/dst ASes



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

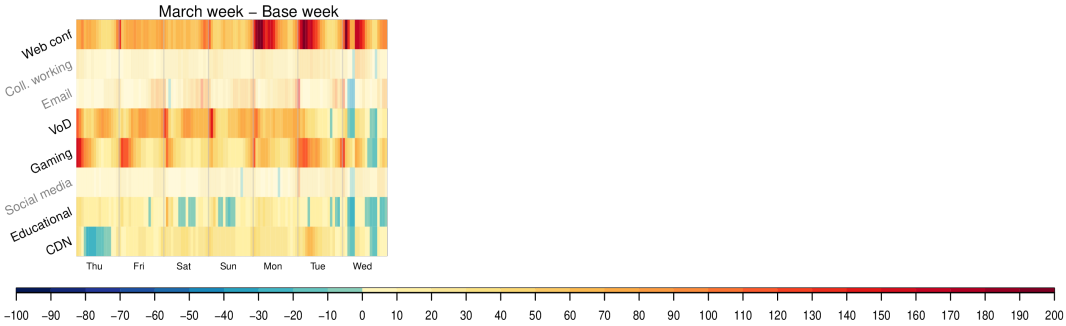
Classify traffic by application class

- Classify based on transport ports and src/dst ASes

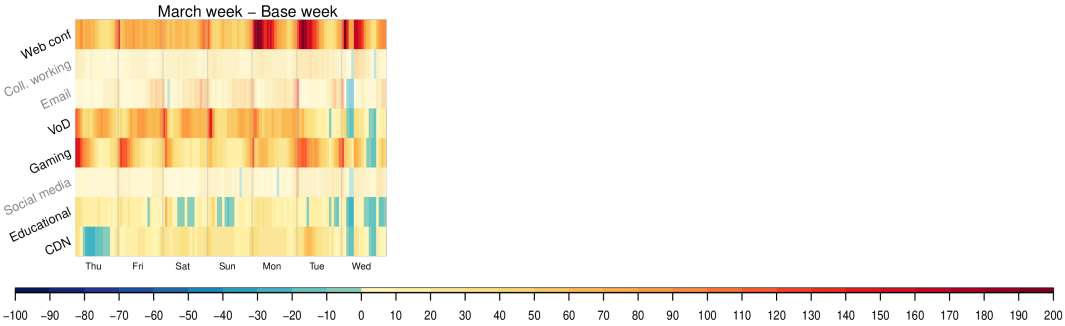


- Email during working hours
- Video, gaming, and social media during evening hours
- Hardly any web conferencing

Changes in application classes: Central European IXP



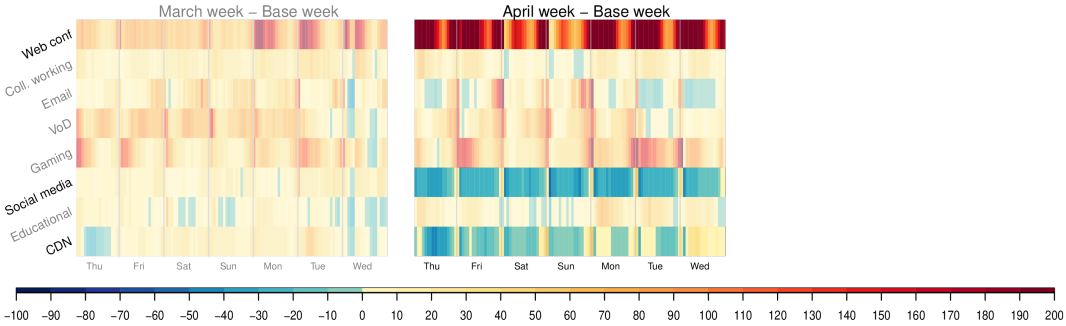
Changes in application classes: Central European IXP



March:

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

Changes in application classes: Central European IXP



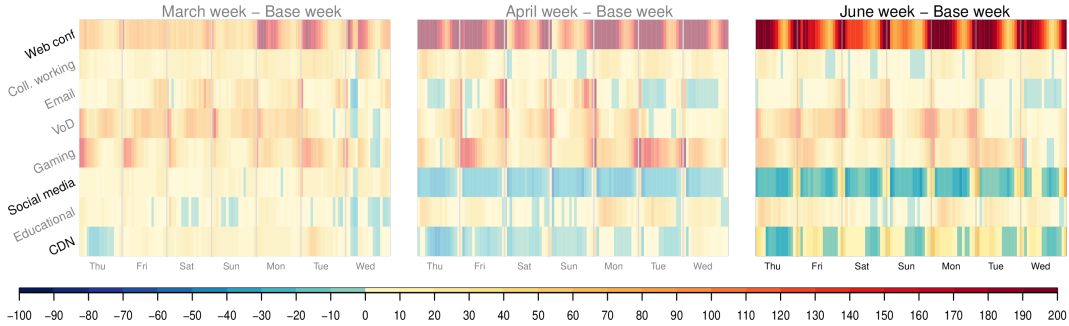
March:

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

April:

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

Changes in application classes: Central European IXP



March:

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

April & June:

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

VPN traffic: Central European IXP

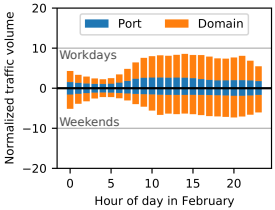
VPN identification

- 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: Central European IXP

VPN identification

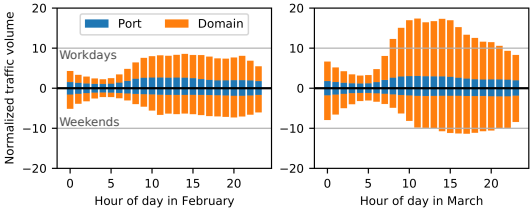
- Port-based: Well known port/proto combinations exclusively used by VPN services
- Domain-based: For TCP/443 traffic, IPs labeled `*vpn*`, but not `www.`



VPN traffic: Central European IXP

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.`

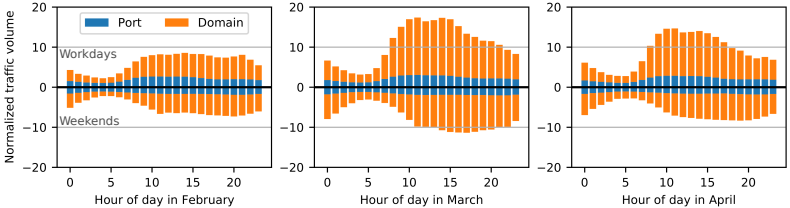


- 200% increase in VPN traffic in March during working hours

VPN traffic: Central European IXP

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.`

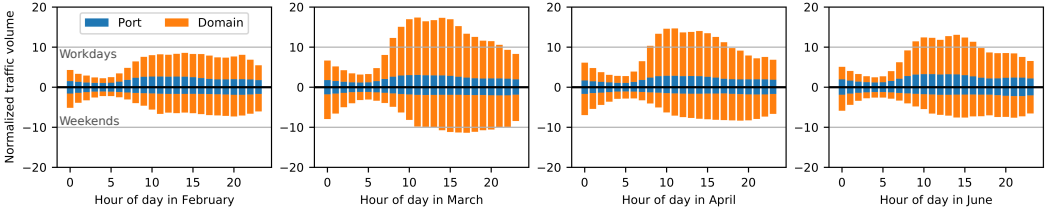


- **200% increase in VPN traffic in March during working hours**
- Slight decrease in April

VPN traffic: Central European IXP

VPN identification

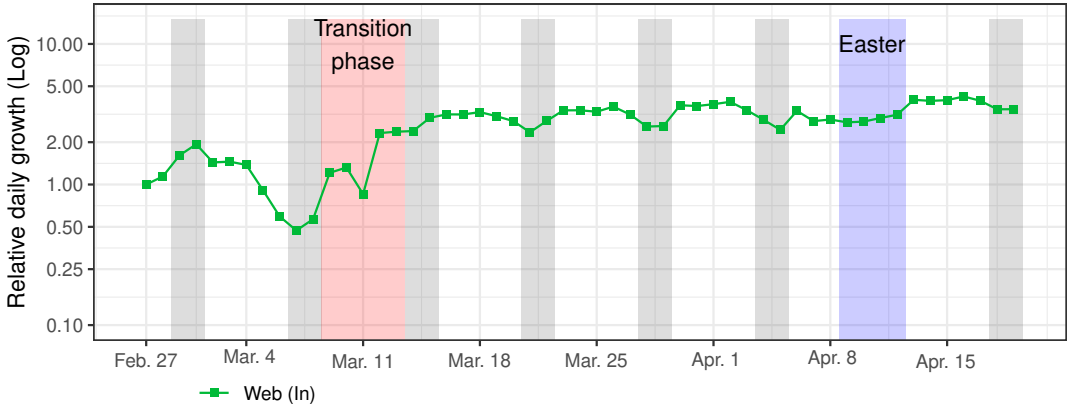
- Port-based: Well known port/proto combinations exclusively used by VPN services
- Domain-based: For TCP/443 traffic, IPs labeled `*vpn*`, but not `www.`



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

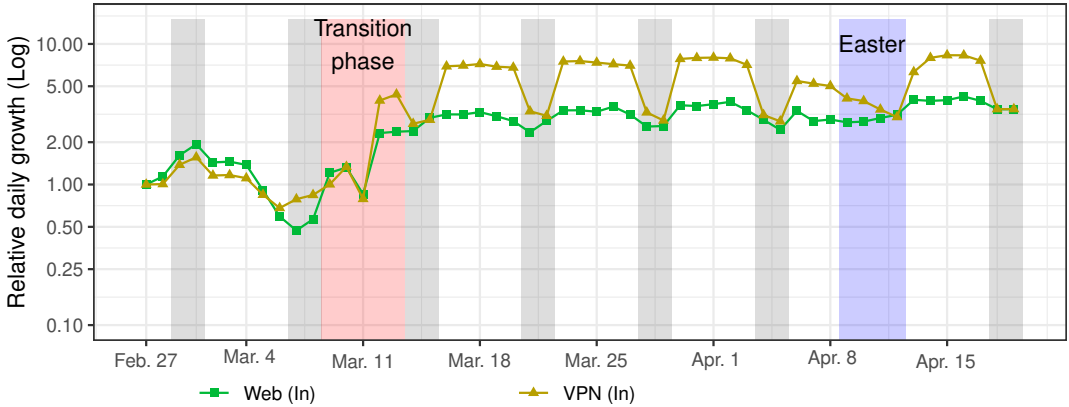
How did educational traffic change?

Daily connections for different traffic classes at REDIMadrid



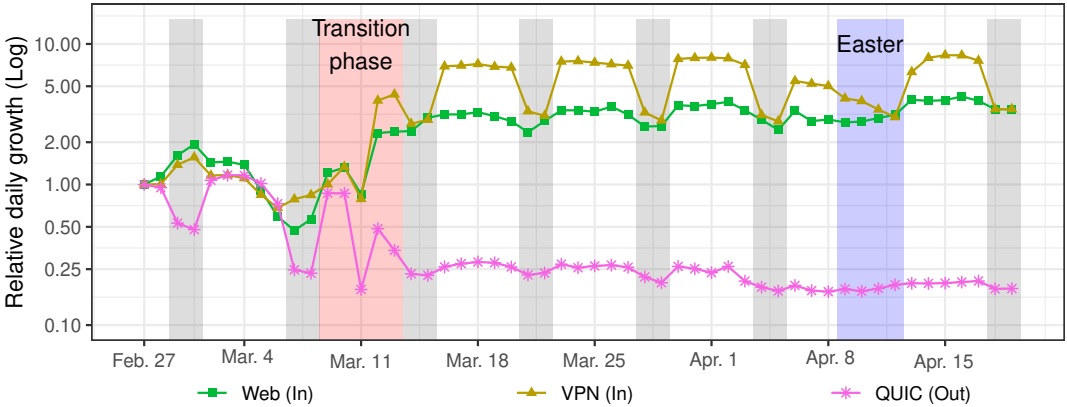
- Increase in incoming web traffic

Daily connections for different traffic classes at REDIMadrid



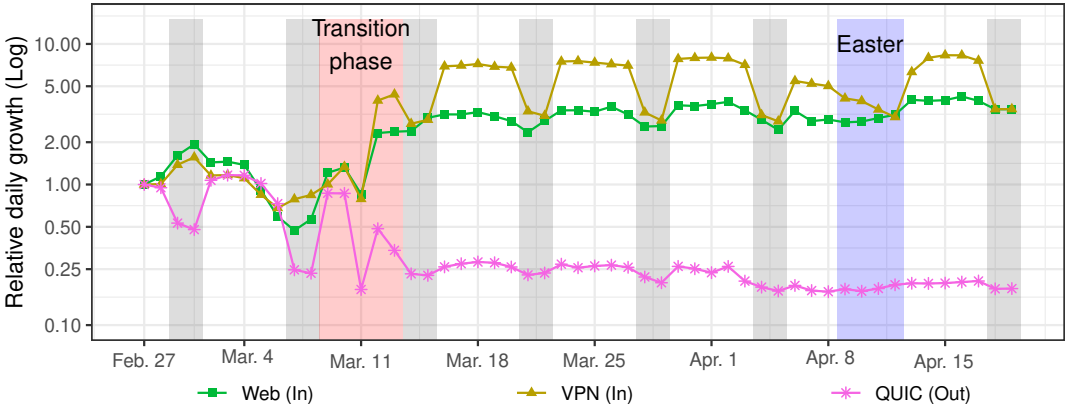
- Increase in incoming web and VPN traffic

Daily connections for different traffic classes at REDIMadrid



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

Daily connections for different traffic classes at REDIMadrid

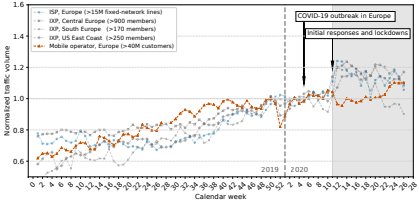


- Increase in incoming web and VPN traffic
- Decrease of outgoing QUIC traffic
- Absence of users leads to traffic decrease

What we found

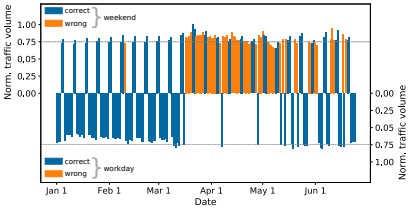
People change → traffic changes

- Traffic increase of **15-30%** within a few **days**



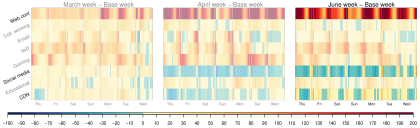
People change → traffic changes

- Traffic increase of **15-30%** within a few **days**
- **Workdays** start to look like **weekends**



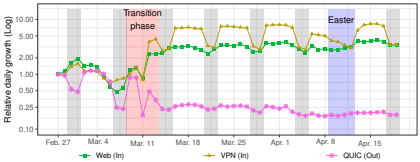
People change $\rightarrow$ traffic changes

- Traffic increase of **15-30%** within a few **days**
- **Workdays** start to look like **weekends**
- Increase in **remote work, education, VPN, and video conferencing** traffic



People change → traffic changes

- Traffic increase of **15-30%** within a few **days**
- **Workdays** start to look like **weekends**
- Increase in **remote work, education, VPN, and video conferencing** traffic
- **Absence of users** leads to traffic decrease

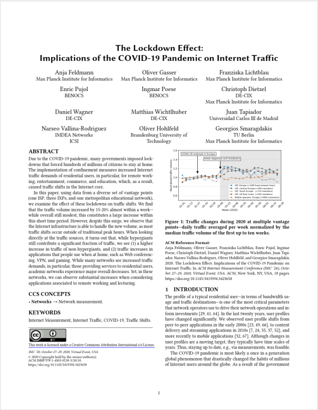


People change → traffic changes

- Traffic increase of **15-30%** within a few **days**
- **Workdays** start to look like **weekends**
- Increase in **remote work, education, VPN, and video conferencing** traffic
- **Absence of users** leads to traffic decrease

More in our *The Lockdown Effect* IMC 2020 paper

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



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

Anja Feldmann, Max Planck Institute for Informatics
Oliver Gasser, Max Planck Institute for Informatics
Franziska Lichtblau, Max Planck Institute for Informatics
Enric Pujol, BENOCS
Ingmar Poese, BENOCS
Christoph Dietzel, DE-CIX, Max Planck Institute for Informatics
Daniel Wagner, DE-CIX
Matthias Wichtlhuber, DE-CIX
Juan Tapiador, Universidad Carlos III de Madrid
Narseo Vallina-Rodriguez, IMDEA Networks, ICSI
Oliver Hohlfeld, Brandenburg University of Technology
Georgios Smaragdakis, TU Berlin, Max Planck Institute for Informatics

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.

IMC '20, October 27–29, 2020, Virtual Event, USA

ACM ISBN 978-1-4503-8138-3/20/10.
https://doi.org/10.1145/3419394.3423658

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

1

oliver.gasser@mpi-inf.mpg.de

dl.acm.org/doi/10.1145/3419394.3423658