A Year in Lockdown:
How the Waves of COVID-19 Impact Internet Traffic

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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?

REUTERS

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

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

Goals

- Understand the impact of the COVID-19 pandemic on the Internet by analyzing more than **two years** of Internet traffic data from a diverse set of vantage points
- Characterize traffic shifts due to changes in user demands and see how the Internet reacted
- Trying to understand if there is a “new normal” in Internet traffic

Lots of data, lots of data crunchers

Anja Feldmann
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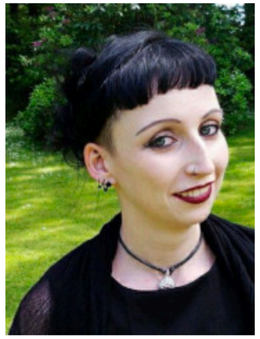

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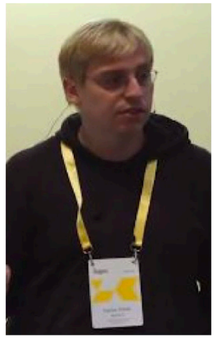

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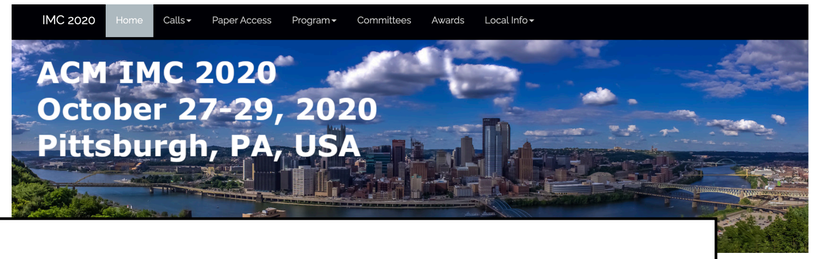
One study, two papers



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.

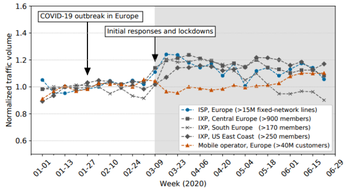

Figure 1: Traffic changes during 2020 at multiple vantage points—daily traffic averaged per week normalized by the median traffic volume of the first up to ten weeks.

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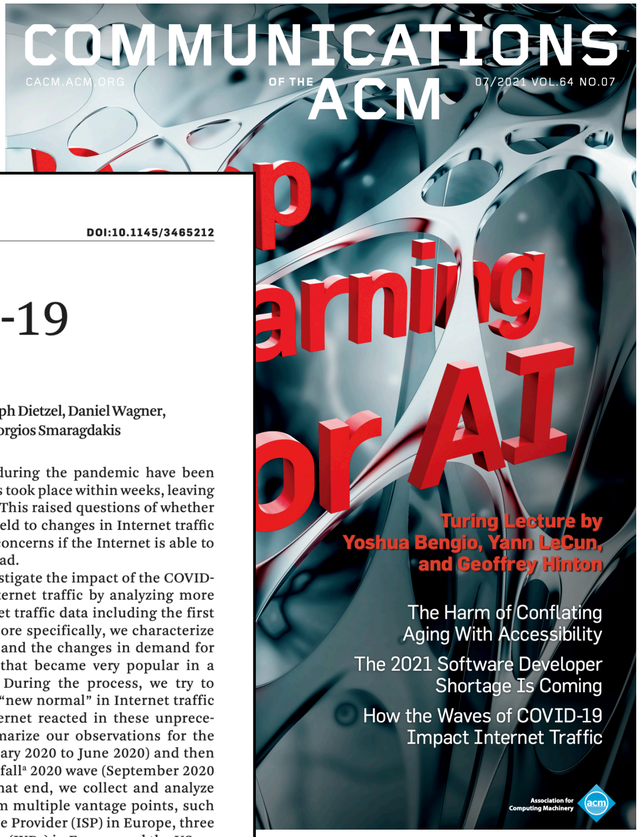
1 INTRODUCTION

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



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A Year in Lockdown: How the Waves of COVID-19 Impact Internet Traffic

By 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

Abstract

In March 2020, the World Health Organization declared the Corona Virus 2019 (COVID-19) outbreak a global pandemic. As a result, billions of people were either encouraged or forced by their governments to stay home to reduce the spread of the virus. This caused many to turn to the Internet for work, education, social interaction, and entertainment. With the Internet demand rising at an unprecedented rate, the question of whether the Internet could sustain this additional load emerged. To answer this question, this paper will review the impact of the first year of the COVID-19 pandemic on Internet traffic in order to analyze its performance. In order to keep our study broad, we collect and analyze Internet traffic data from multiple locations at the core and edge of the Internet. From this, we characterize how traffic and application demands change, to describe the "new normal," and explain how the Internet reacted during these unprecedented times.

1. INTRODUCTION

The worldwide pandemic caused by the Corona Virus 2019 (COVID-19) is a once-in-a-generation global phenomenon that changed the lives of billions of people and destabilized the interconnected world economy. What started as a local health emergency in Asia at the end of 2019, turned into a global event at the beginning of 2020 when the first cases appeared on other continents. By March 2020, the World Health Organization (WHO) declared COVID-19 as a pandemic, causing many governments around the globe to impose strict lockdowns of economic and social activities to reduce the spread of COVID-19. These measures changed the habits of a large fraction of the global population, who now depend on residential Internet connectivity for work, education, social interaction, and entertainment.

Changes in Internet user behavior are common, but they normally occur gradually and over long periods of time. Notable examples of such changes are the increase in demand for peer-to-peer applications that happened in the early 2000s; the increase of traffic served by content delivery networks—such as an increase in streaming—

Internet user behavior during the pandemic have been unique because the shifts took place within weeks, leaving hardly any time to react. This raised questions of whether user behavior changes yield to changes in Internet traffic and, more importantly, concerns if the Internet is able to sustain this additional load.

In this paper, we investigate the impact of the COVID-19 pandemic on the Internet traffic by analyzing more than two years of Internet traffic data including the first year of the pandemic. More specifically, we characterize the overall traffic shifts and the changes in demand for particular applications that became very popular in a short amount of time. During the process, we try to understand if there is a "new normal" in Internet traffic and to see how the Internet reacted in these unprecedented times. We summarize our observations for the spring 2020 wave (February 2020 to June 2020) and then extend our study for the fall[a] 2020 wave (September 2020 to February 2021). To that end, we collect and analyze network traffic data from multiple vantage points, such as a large Internet Service Provider (ISP) in Europe, three Internet Exchange Points (IXPs) in Europe and the US, as well as a mobile operator and a metropolitan academic network in Europe (REDIMadrid).

Our main observations can be summarized as follows:

- Changes in traffic volume follow demand changes, causing a traffic surge of 15–20% during the fall 2020 lockdown for the ISP/IXPs in our study. In summer 2020, after the reopening of the economy, an increase of about 20% at one IXP, but only 6% at the Tier-1 ISP, is still visible. The fall 2020 wave also had an impact, with the annual traffic increase in 2020 being higher than in a typical year.
- The observed traffic increase mostly takes place during nontraditional peak hours. Daily traffic patterns are moving to weekend-like patterns, especially during the spring 2020 lockdown.

a We use "spring" and "fall" from the viewpoint of the Northern hemisphere, where our vantage points are located. Exchange both terms for the Southern hemisphere.

Vantage points

3 IXPs

IXP Central Europe
IXP Southern Europe
IXP US East Coast

Interconnecting networks

Central Europe: 900+ members, 8+ Tbps peak traffic
Southern Europe: 170+ members, 500+ Gbps peak traffic
US East Coast: 250+ members, 600+ Gbps peak traffic

IPFIX flows collected at the public peering platforms
Data has been analyzed strictly on premise and results are aggregated

3 IXPs

IXP Central Europe
IXP Southern Europe
IXP US East Coast

Interconnecting networks

ISP

Central Europe

Residential customers working from home

Services ~15M fixed line subscribers + Tier 1 transit network
No hosted CDN caches, but a diverse peering infrastructure

Subscriber view: Netflow captured at the Border Network Gateways (BNGs)
AS level view: Netflow collected at the border routers

Data has been analyzed strictly on premise and results are aggregated

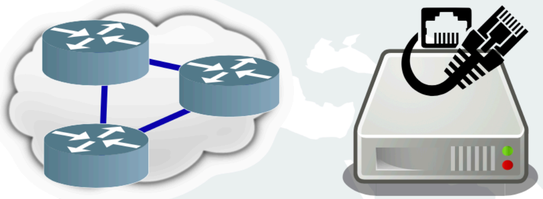
3 IXPs

IXP Central Europe

IXP Southern Europe

IXP US East Coast

Interconnecting networks



ISP

Central Europe

Residential customers working from home

EDU

Madrid region

Service network interconnecting universities and research institutions

Academic network interconnecting 16 universities and research centers (Madrid region)
Serves ~290K users (including WiFi access, student halls, etc)

Anonymized NetFlow data captured at the border routers

MOBILE

3 IXPs

IXP Central Europe

IXP Southern Europe

IXP US East Coast

Interconnecting networks

ISP

Central Europe

Residential customers working from home

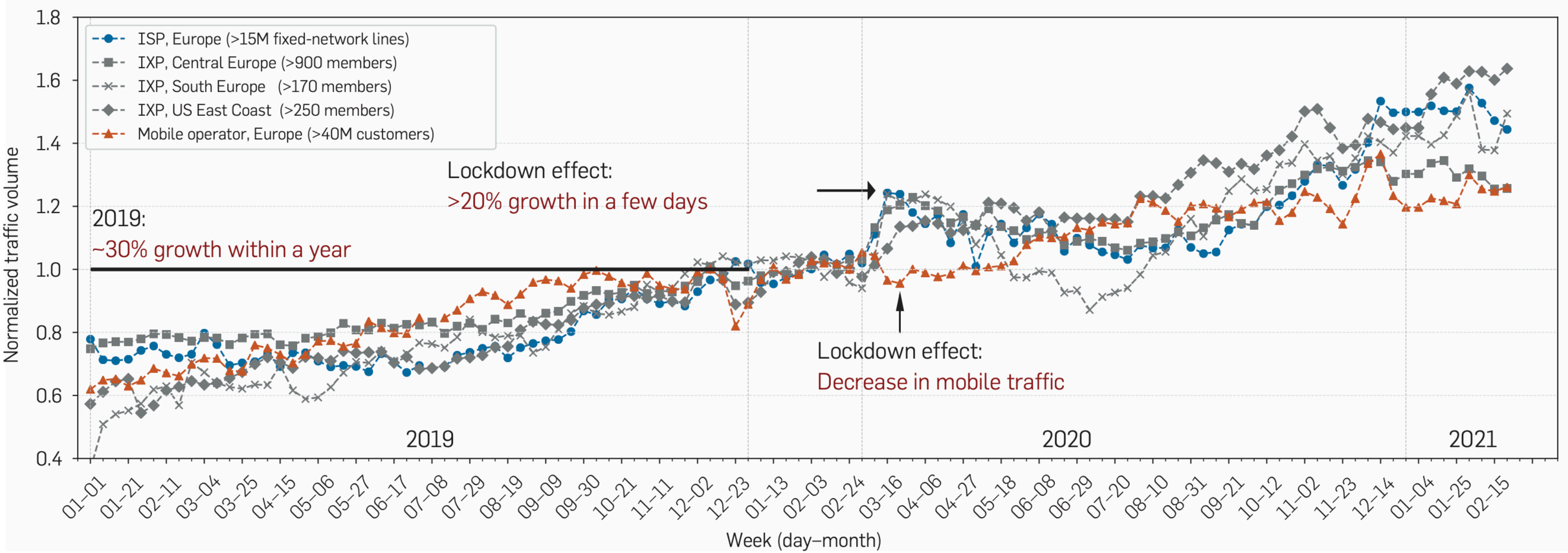
EDU

Madrid region

Service network interconnecting universities and research institutions

European mobile provider with 40M+ customers

Analyzing the pandemic across 2 years



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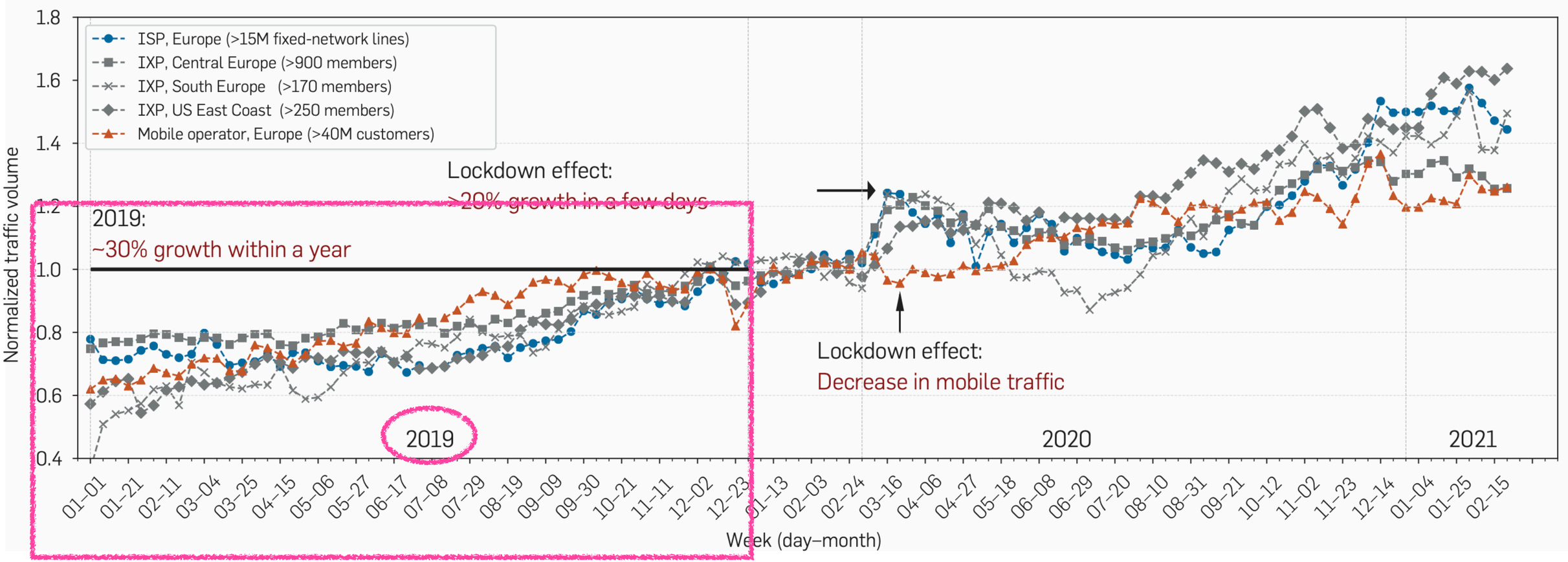

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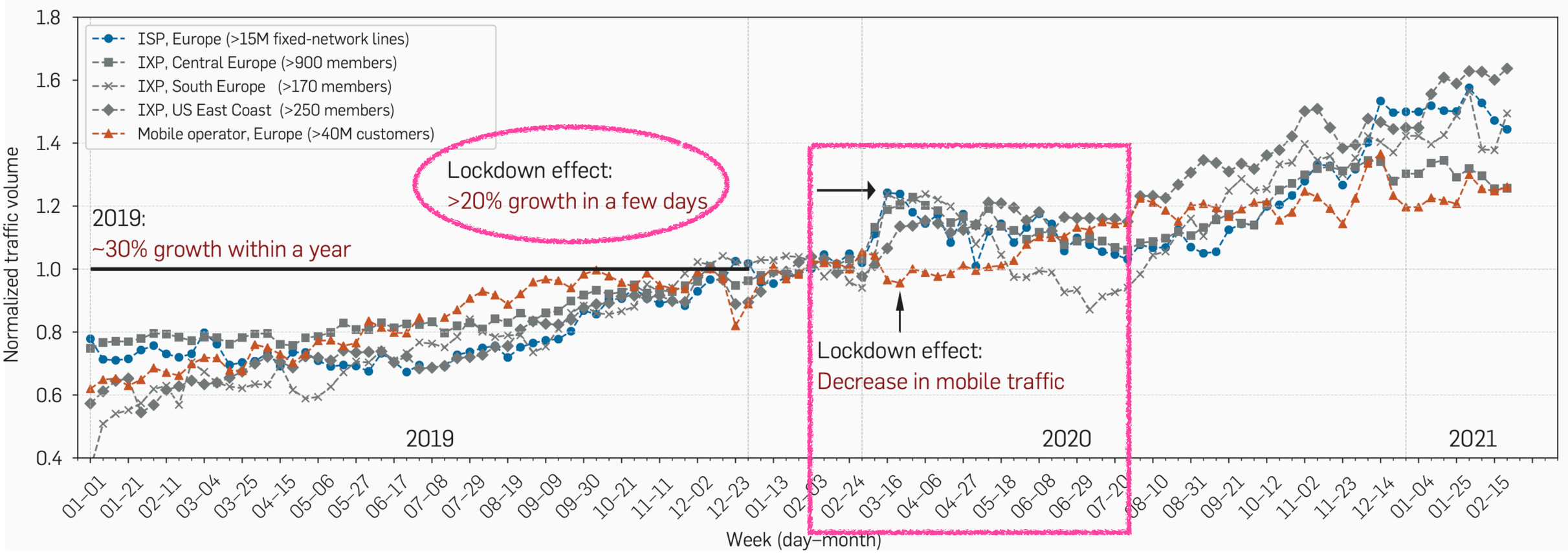

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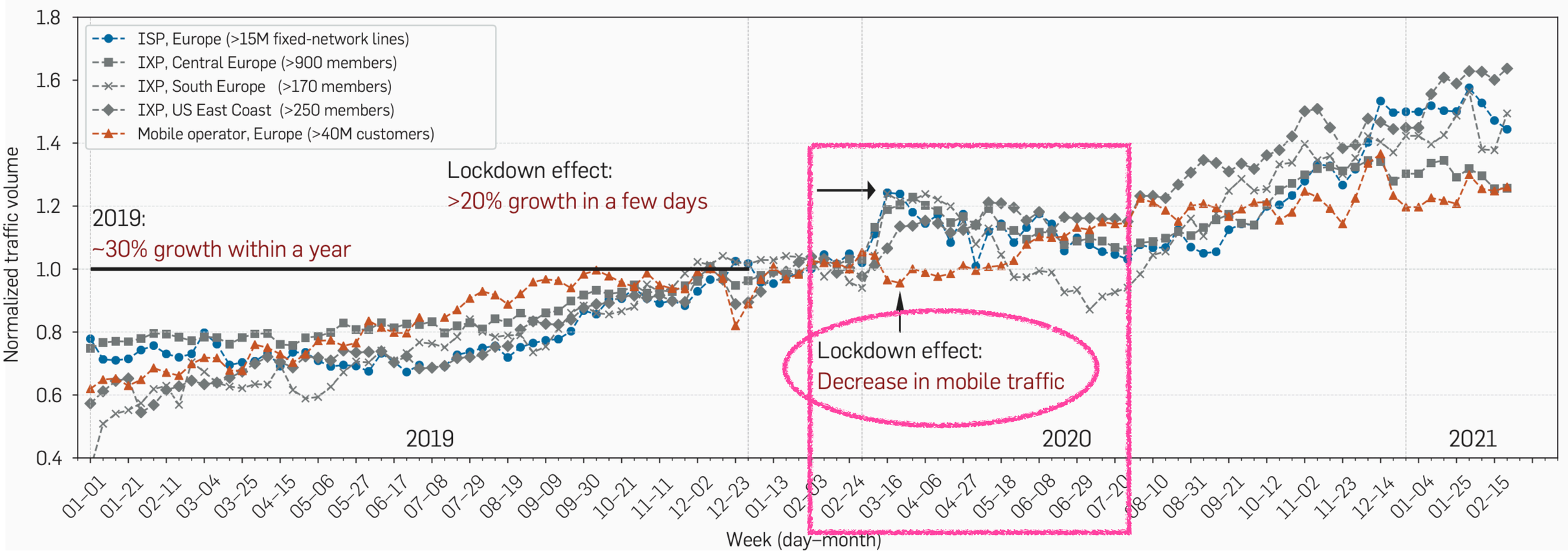

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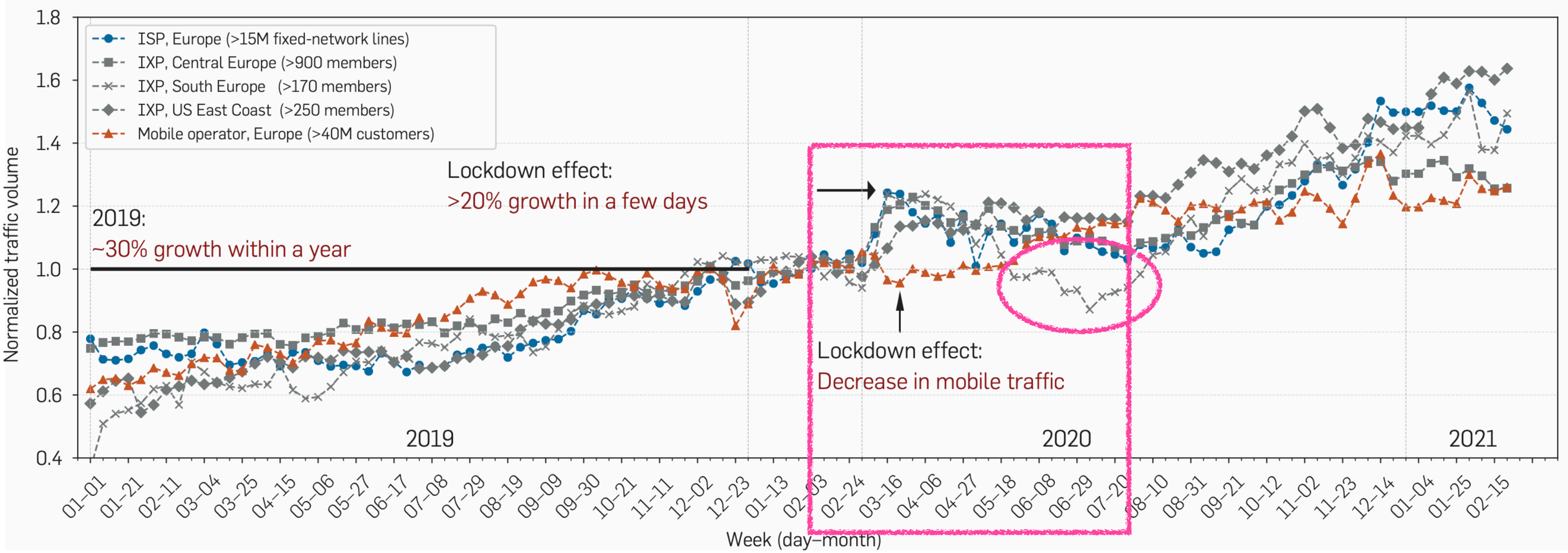

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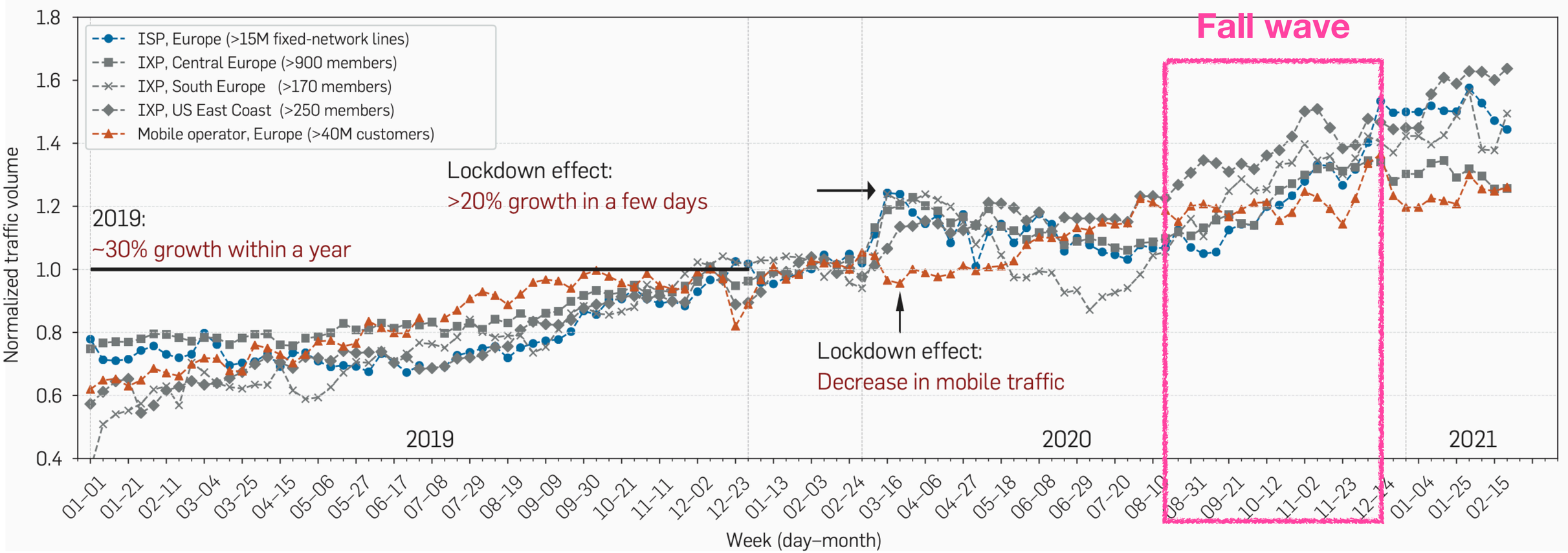
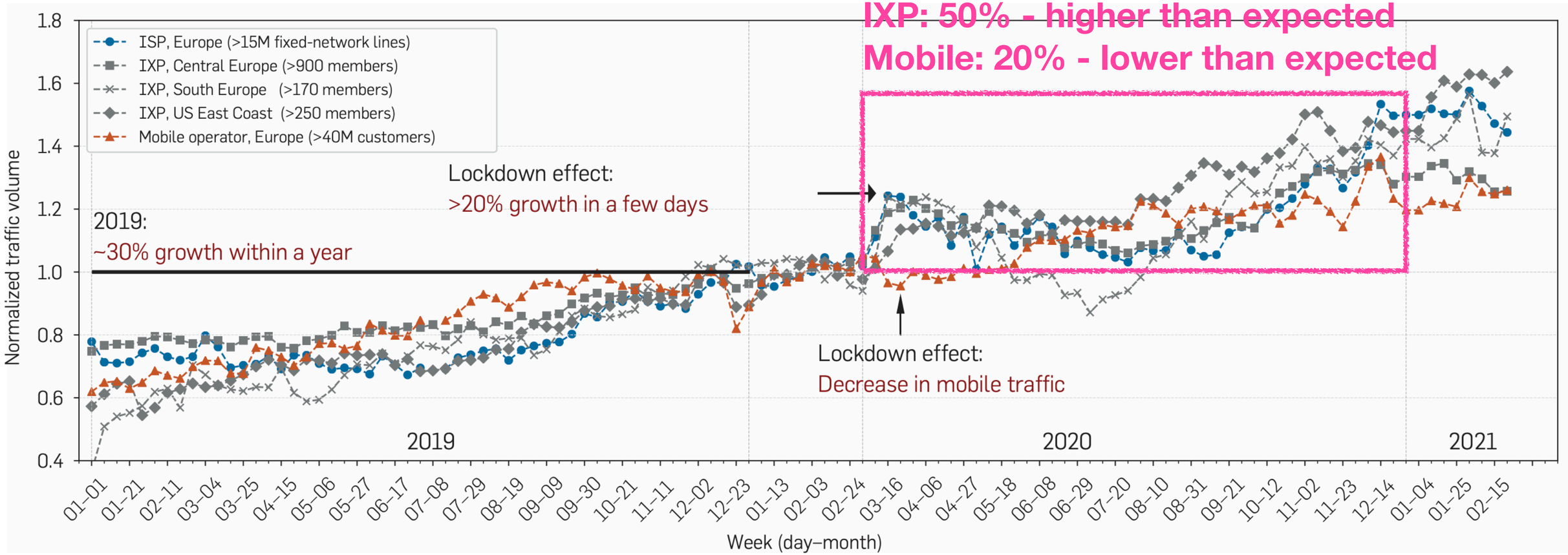


Analyzing the pandemic across 2 years

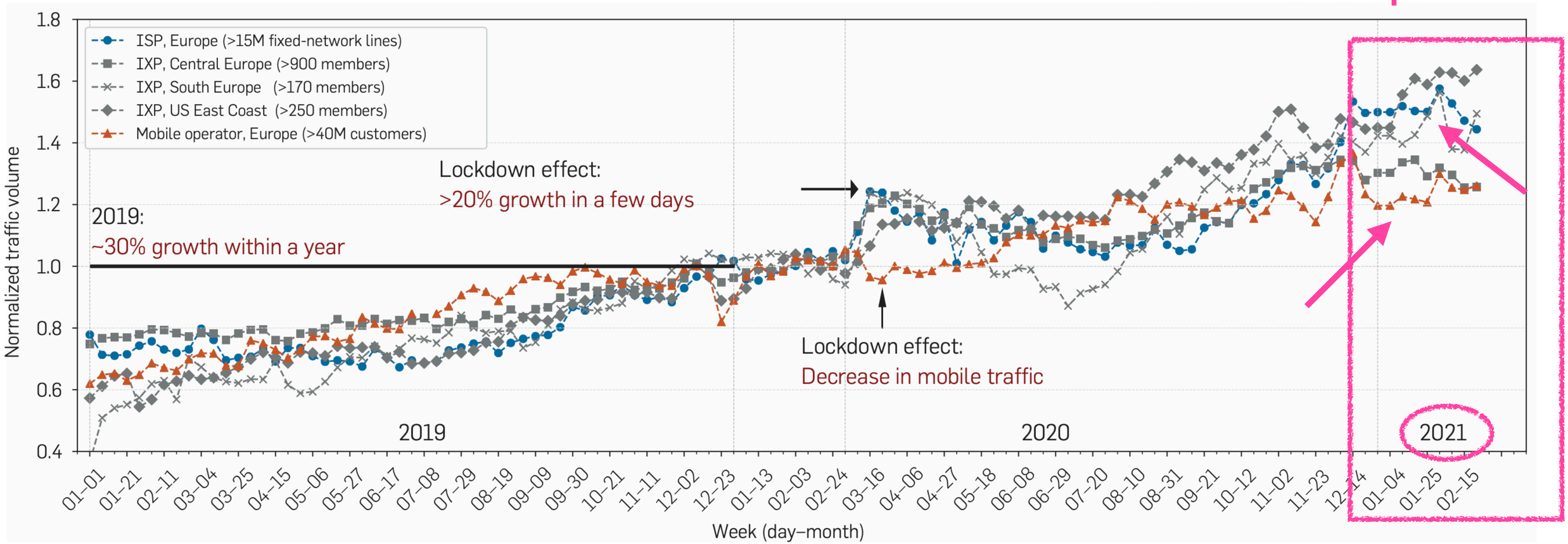
2020 annual increase

ISP: 35% - higher than expected
IXP: 50% - higher than expected
Mobile: 20% - lower than expected

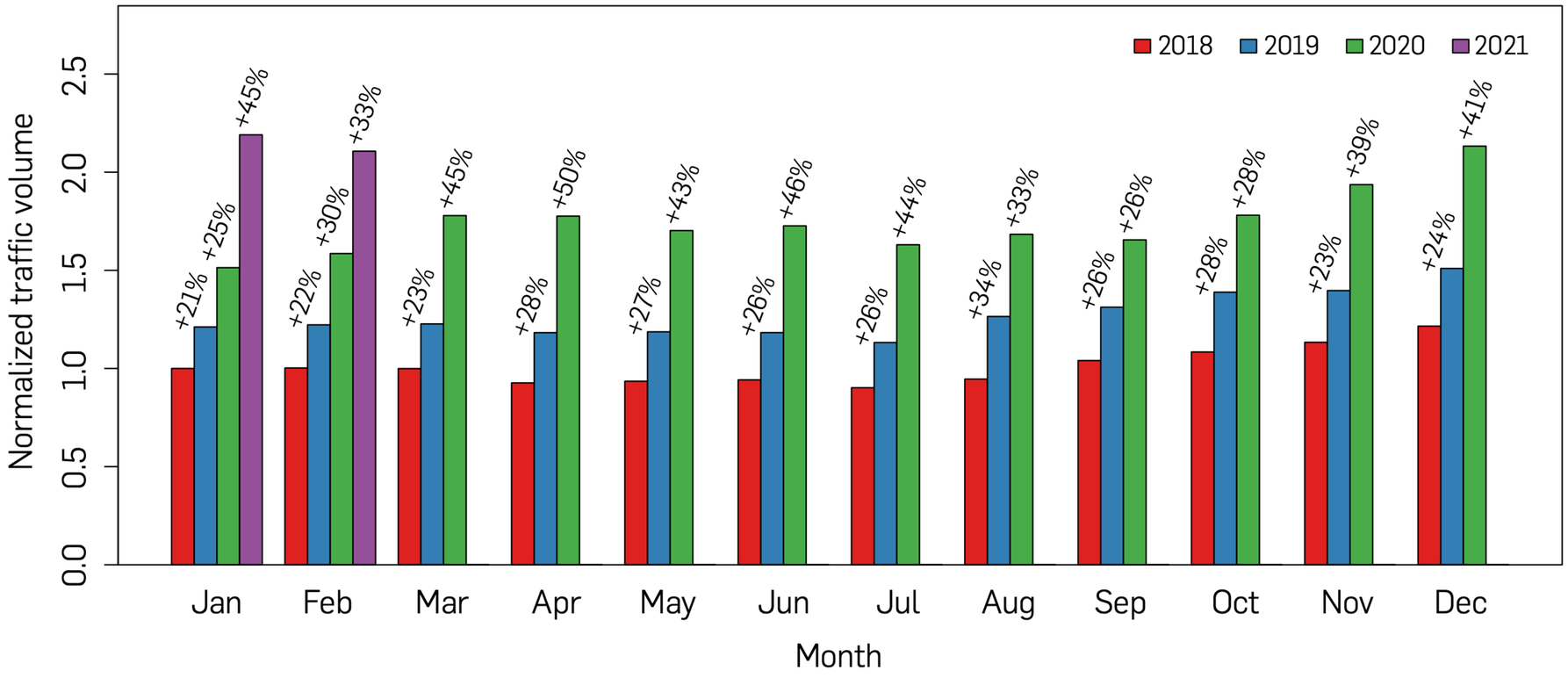


Analyzing the pandemic across 2 years

Superposition of waves
Snow in S Europe



A view from the ISP: downstream traffic changes



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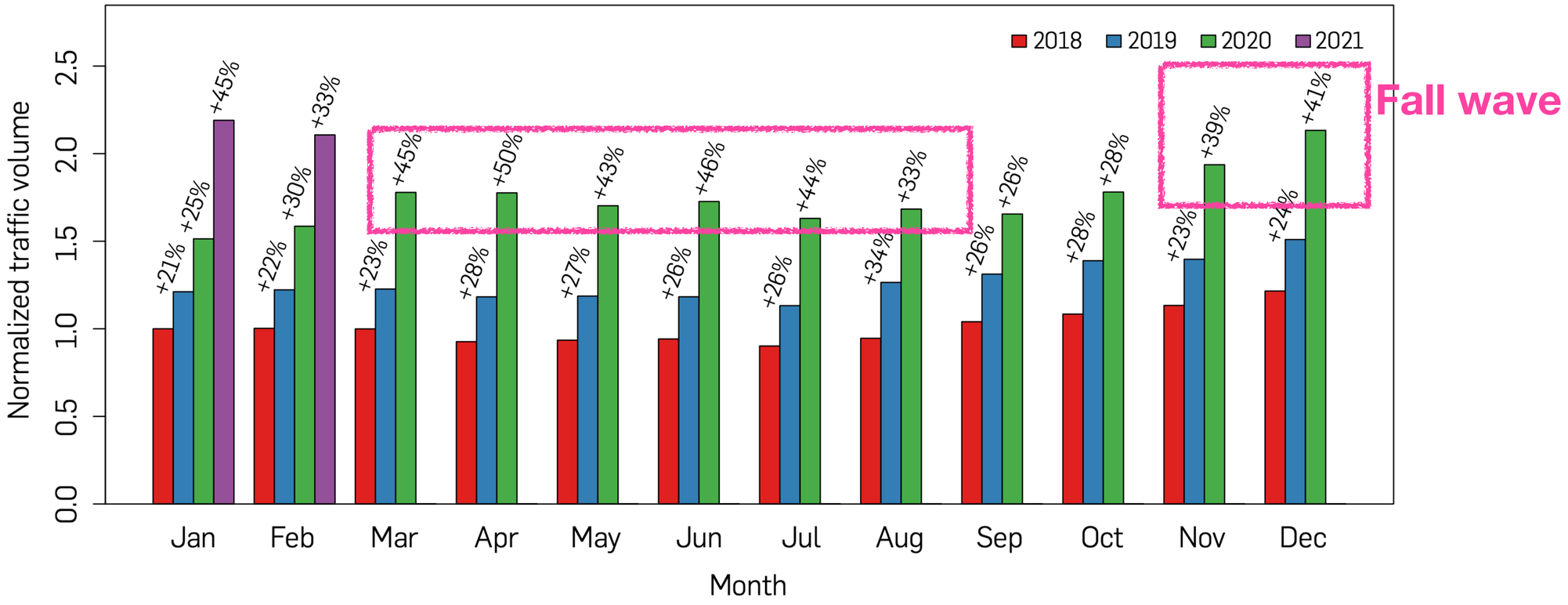

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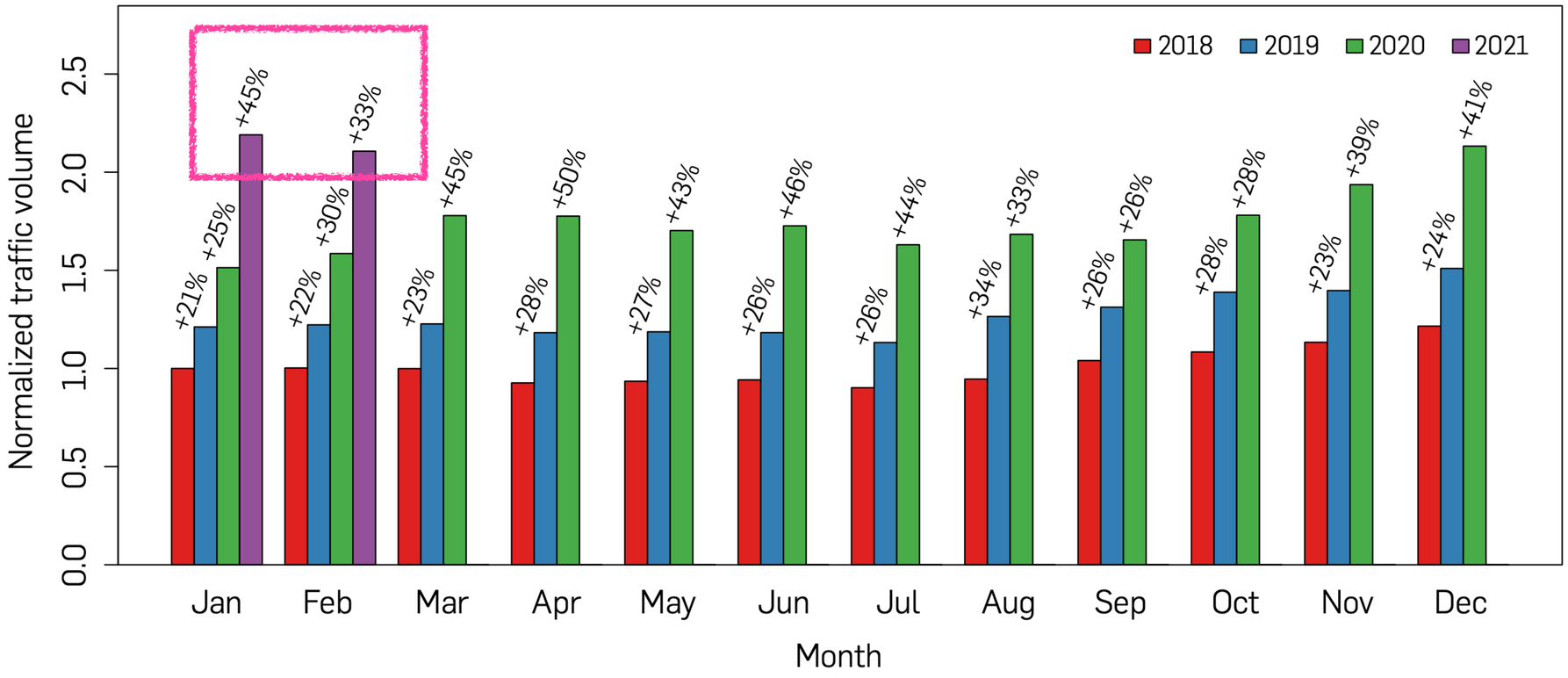


Did these networks cope well with the traffic volume shifts?

- In general, yes.
- We observed capacity increases of 1,500 Gbps (3%) across many IXP members, and also new interconnections.
- Networks ranging from very large to moderate size, with ample experience in provisioning and planning, spare capacities and fast enough reaction times. Reports in less-developed regions suggest serious performance degradation

Shifts in Internet usage patterns: A view from the ISP

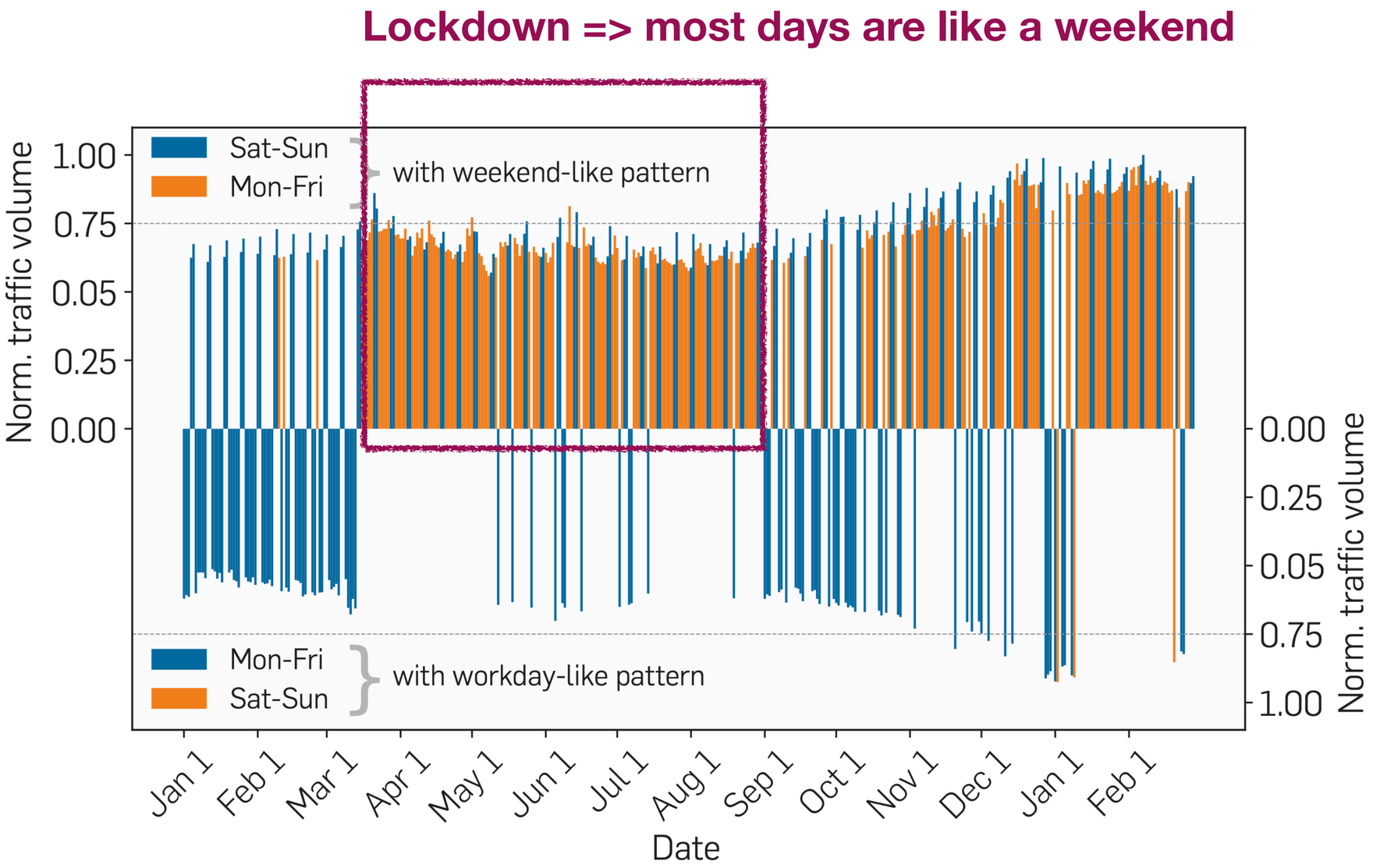
Shifts in Internet usage patterns: A view from the ISP

regular workday traffic patterns are significantly different from weekend patterns

On workdays, traffic peaks are concentrated in the evening, typically between 18:00 and midnight, also referred to as “peak hours.”

During the weekend, the activity is more distributed also in the nonpeak hours as more people are at home and using the Internet

Shifts in Internet usage patterns: A view from the ISP



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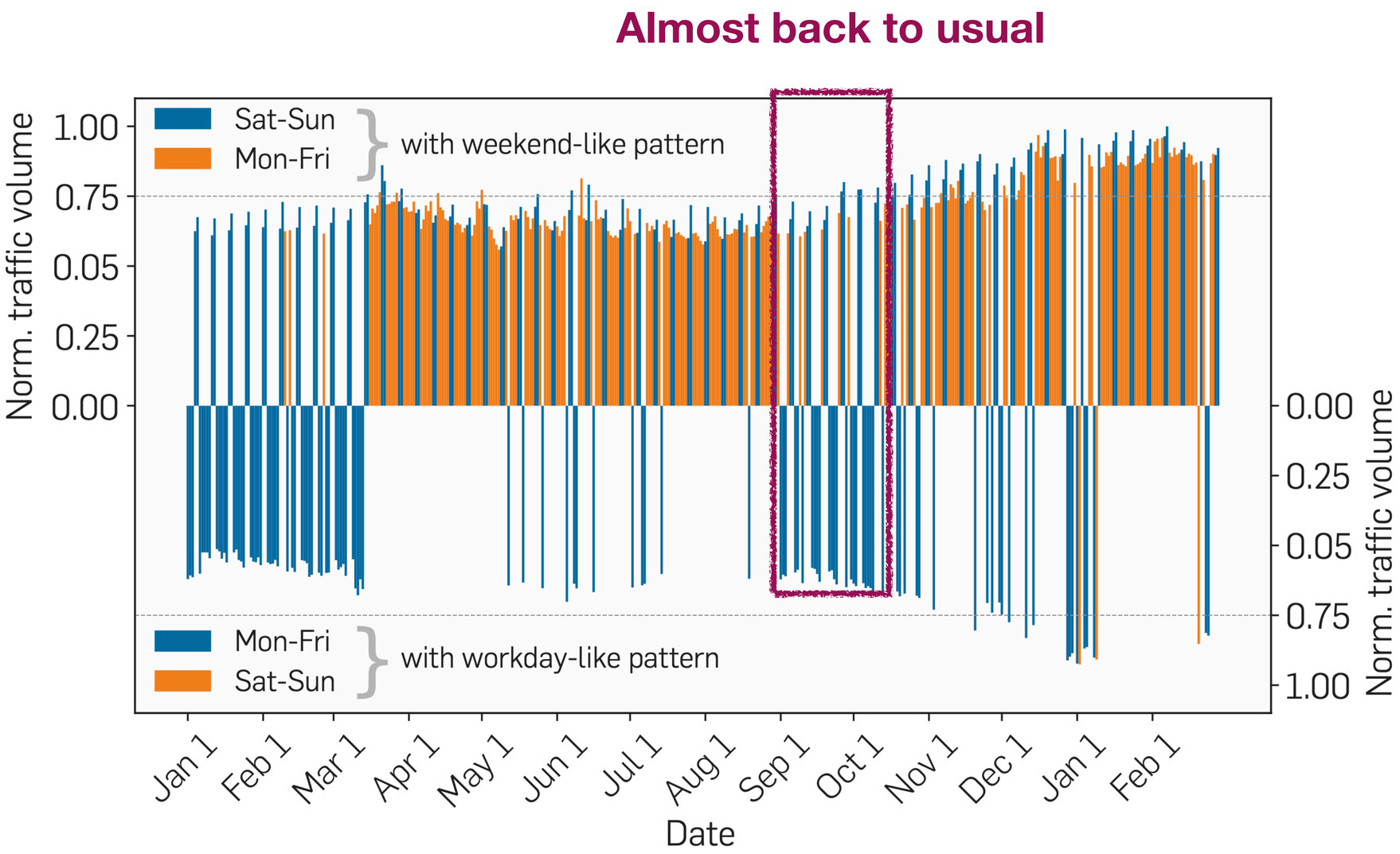

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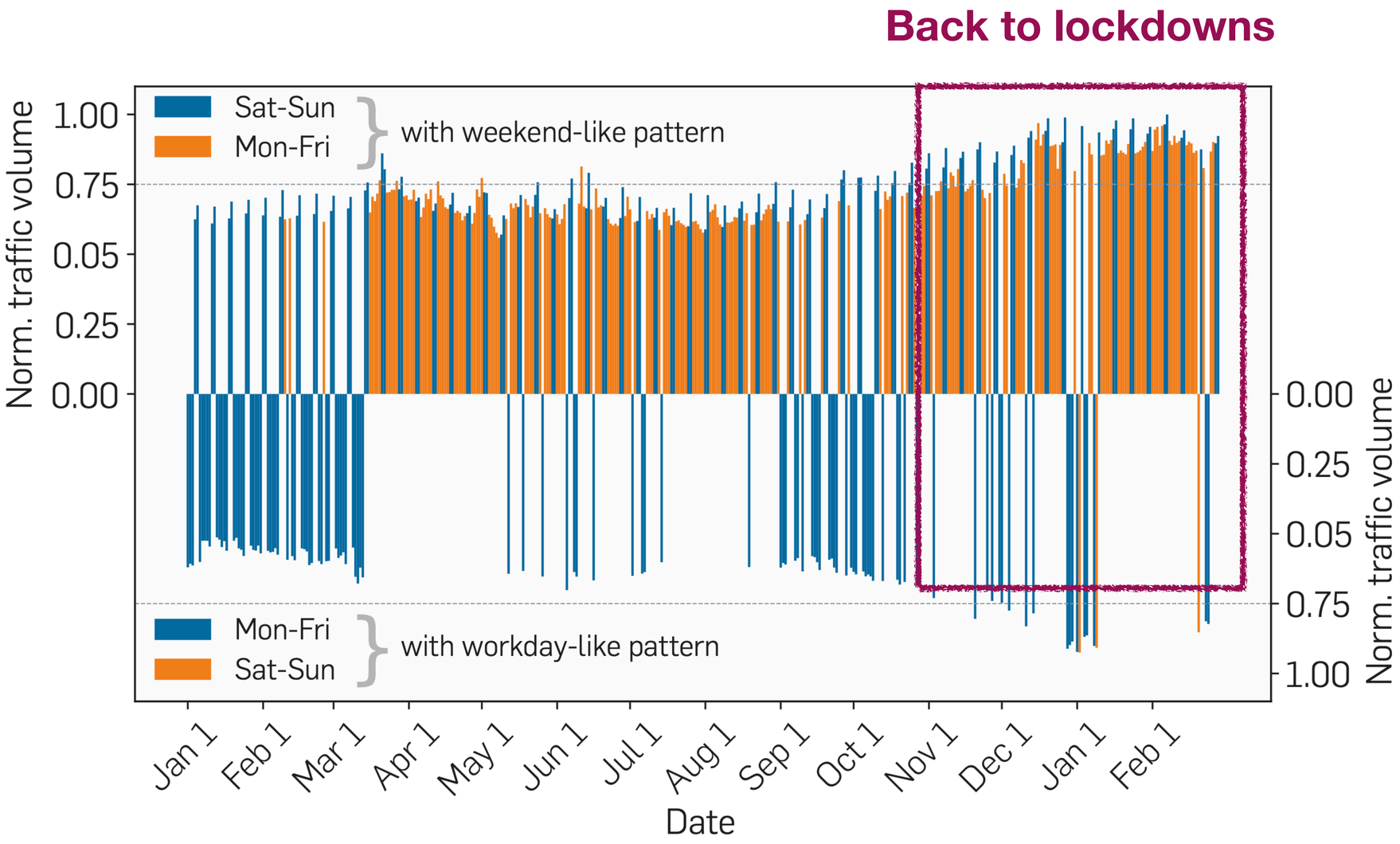
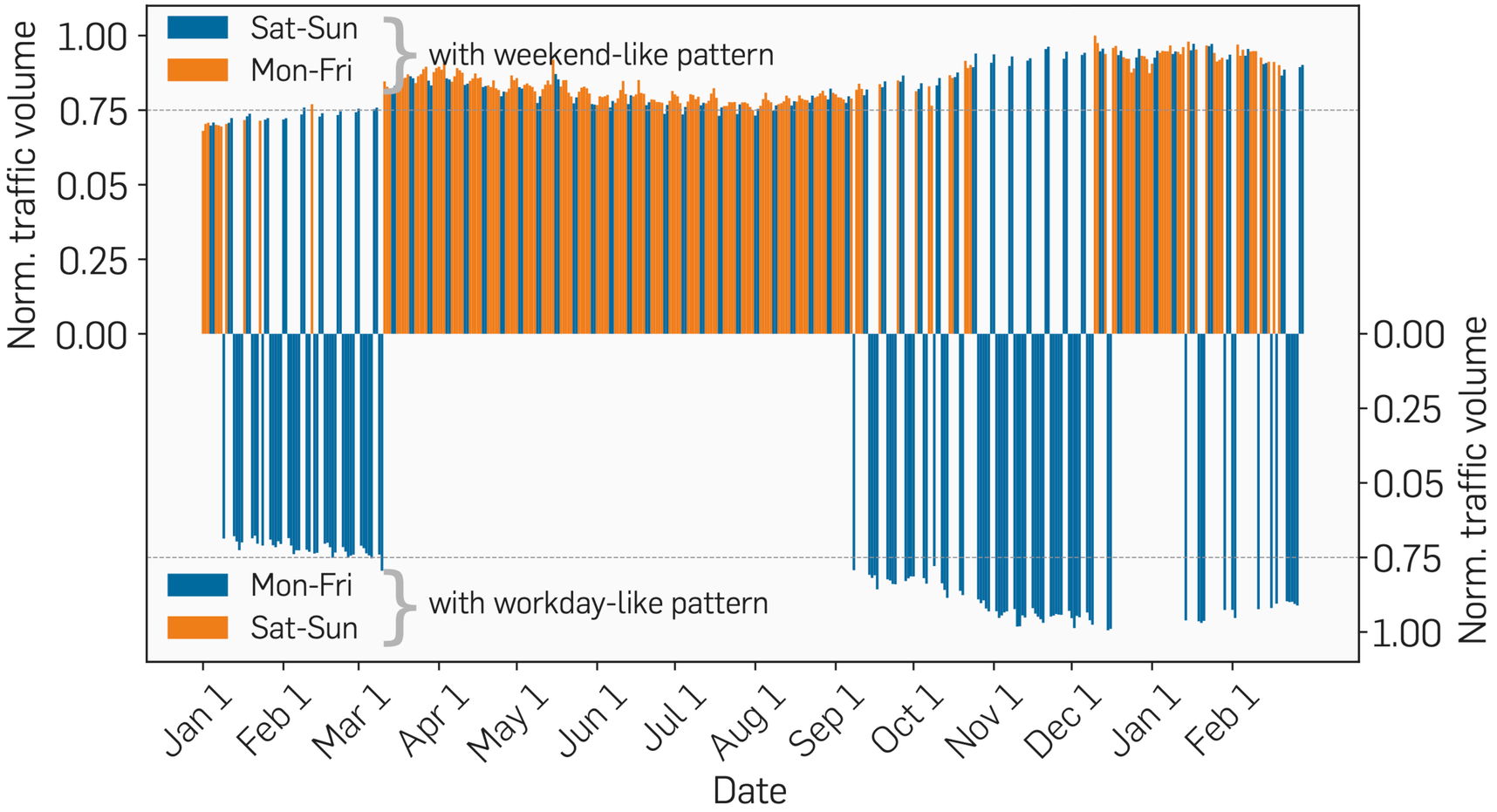
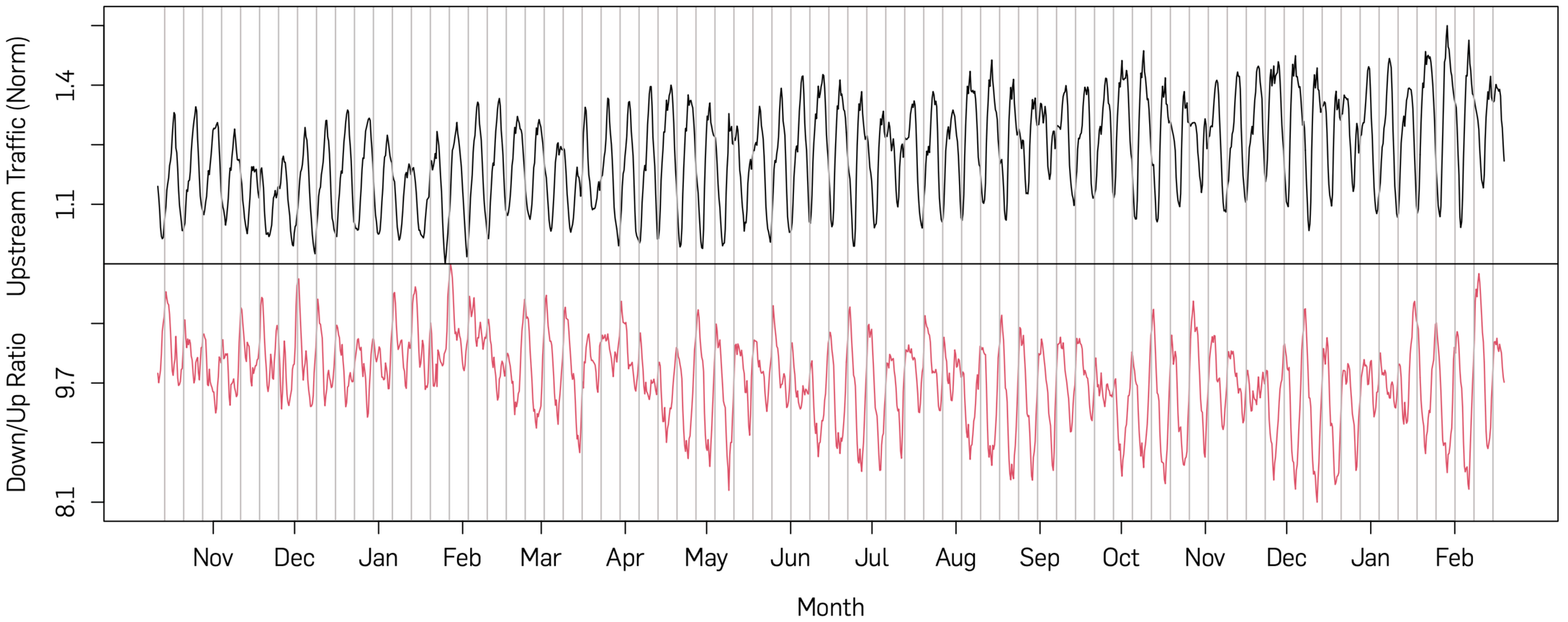


Shifts in Internet usage patterns: A view from the IXP-CE

Behavior more clearly noticeable at the IXP



Effects on traffic asymmetry at the ISP



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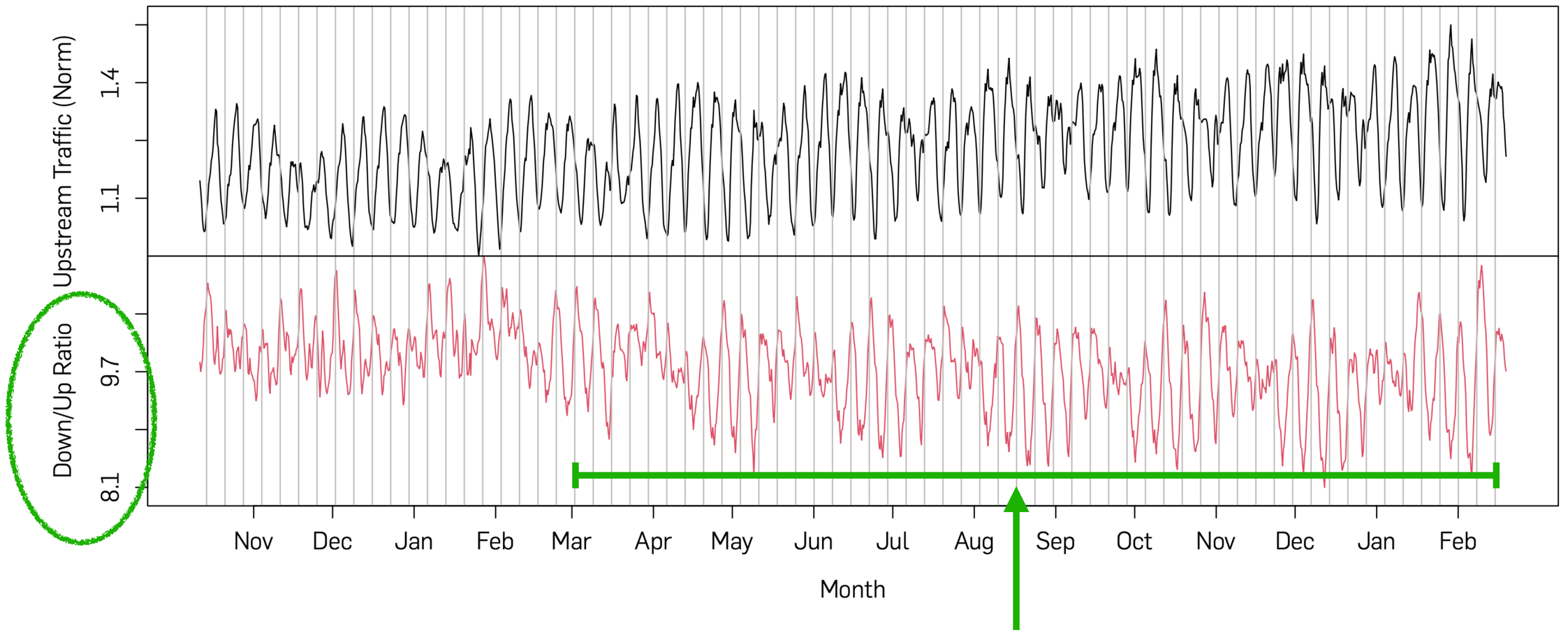
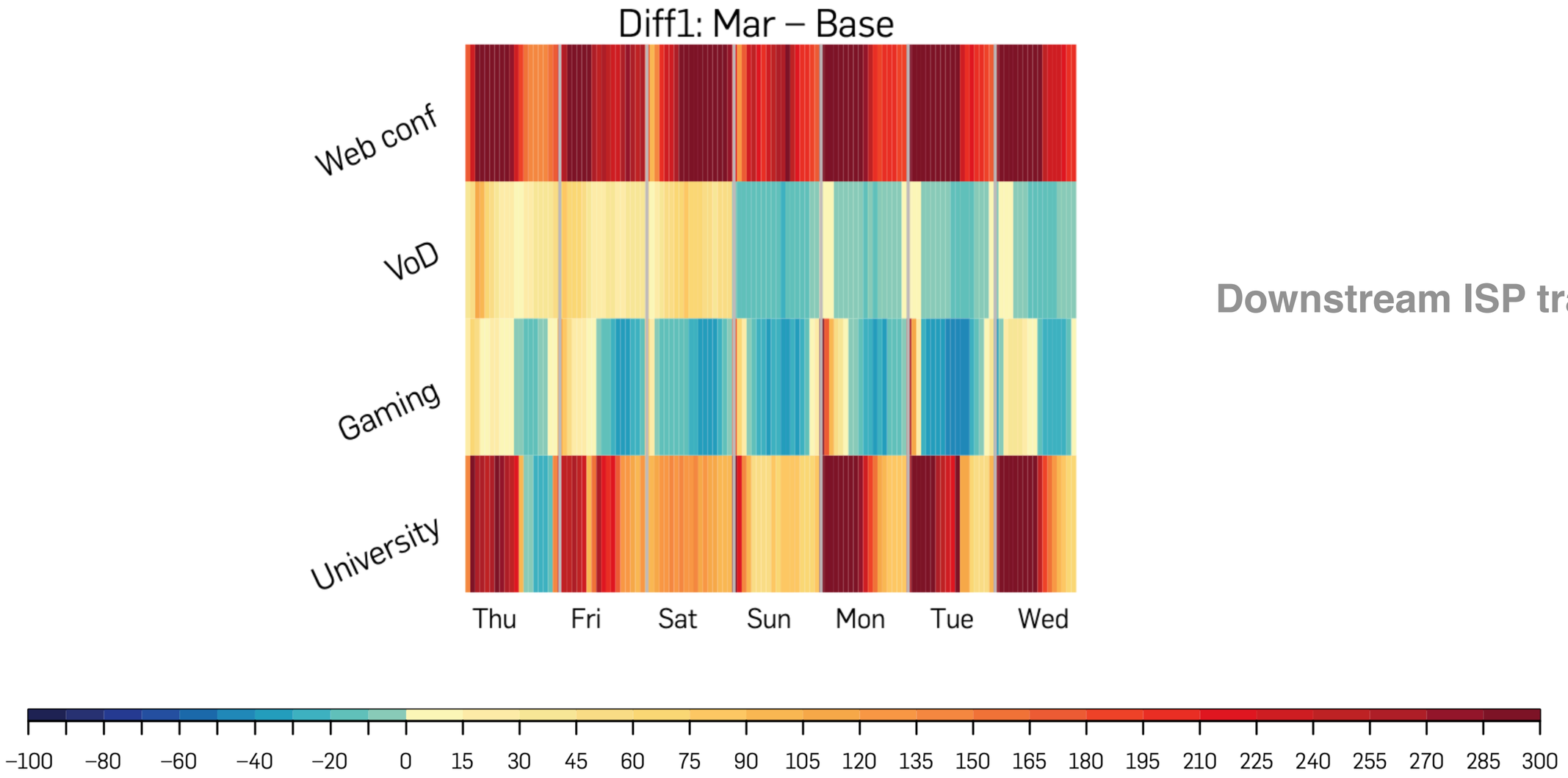


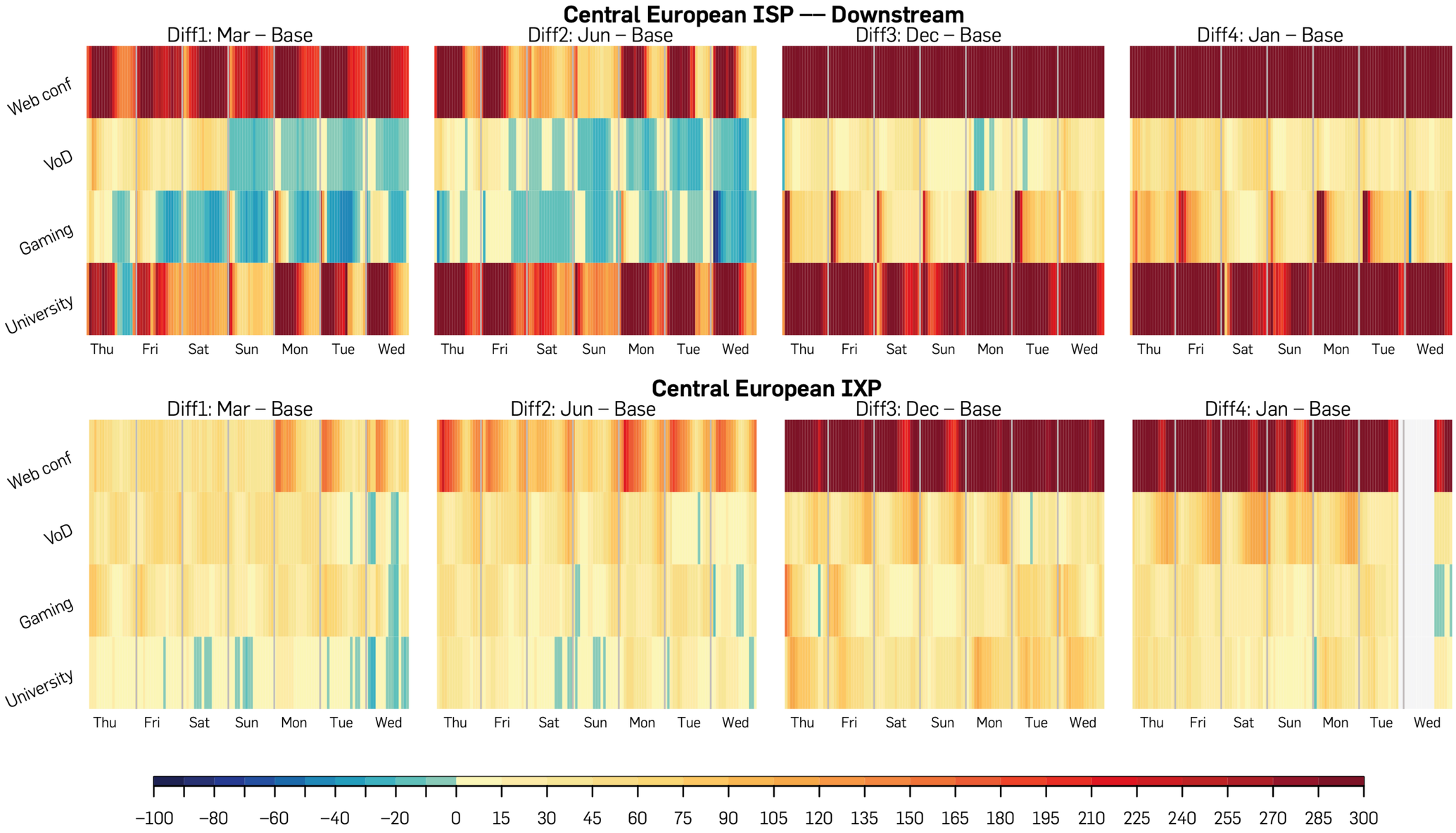
increase in remote working and teleconferencing applications that utilize user upstream bandwidth much more than other popular user applications (e.g., video streaming and browsing)

Application traffic shifts

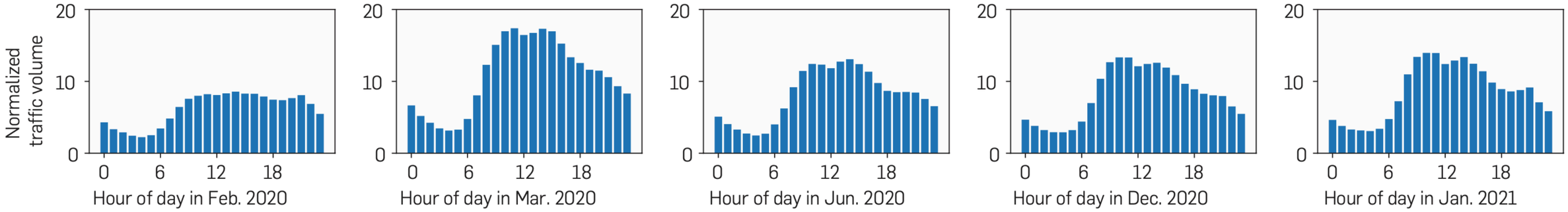


Downstream ISP traffic

Application traffic shifts



VPN traffic evolution

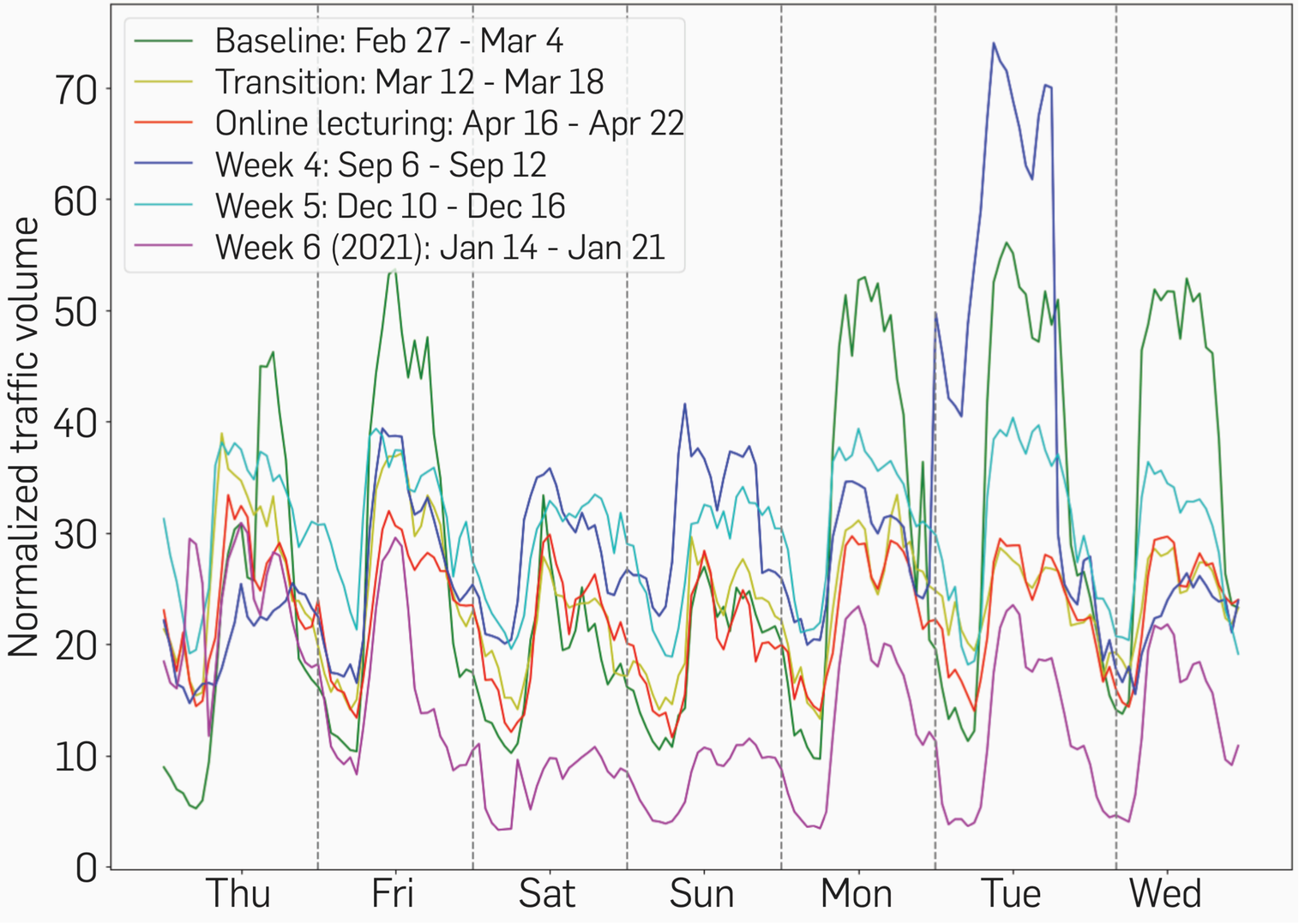


Large increase of VPN traffic in March 2020

Partial recession in June 2020

Lockdown measures are back => increase, though not as much as in March 2020

A view from REDIMadrid: Traffic volume



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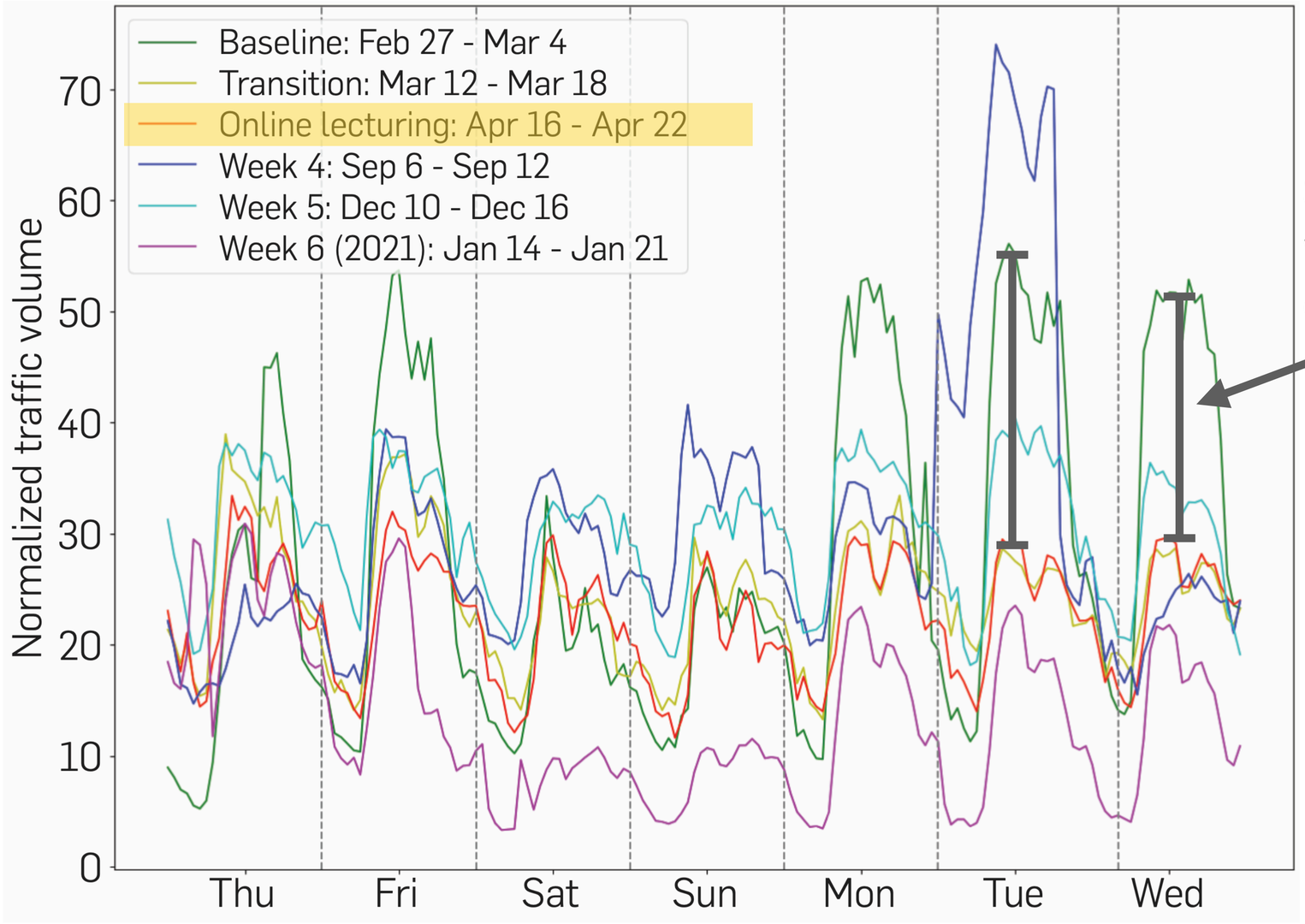
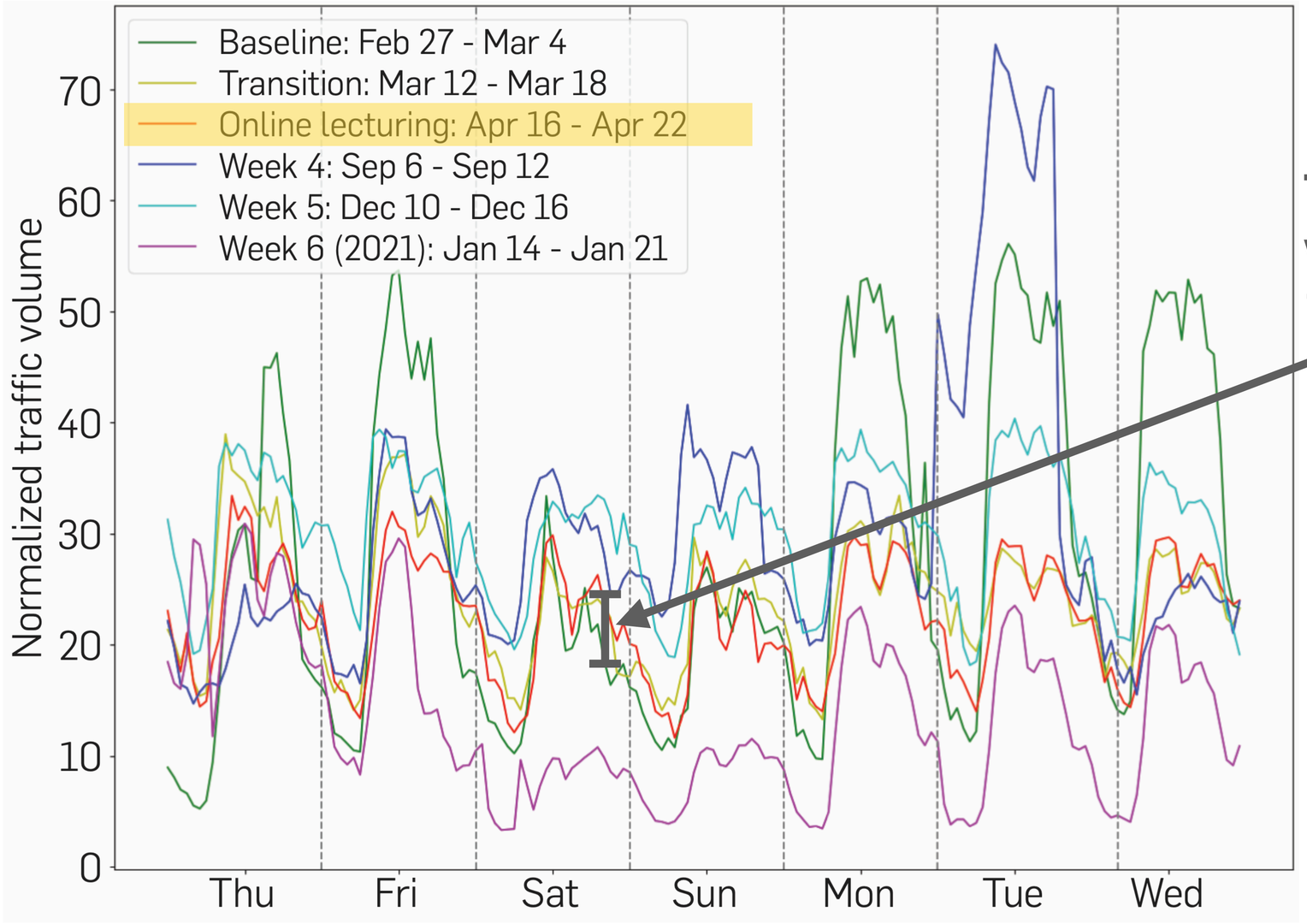


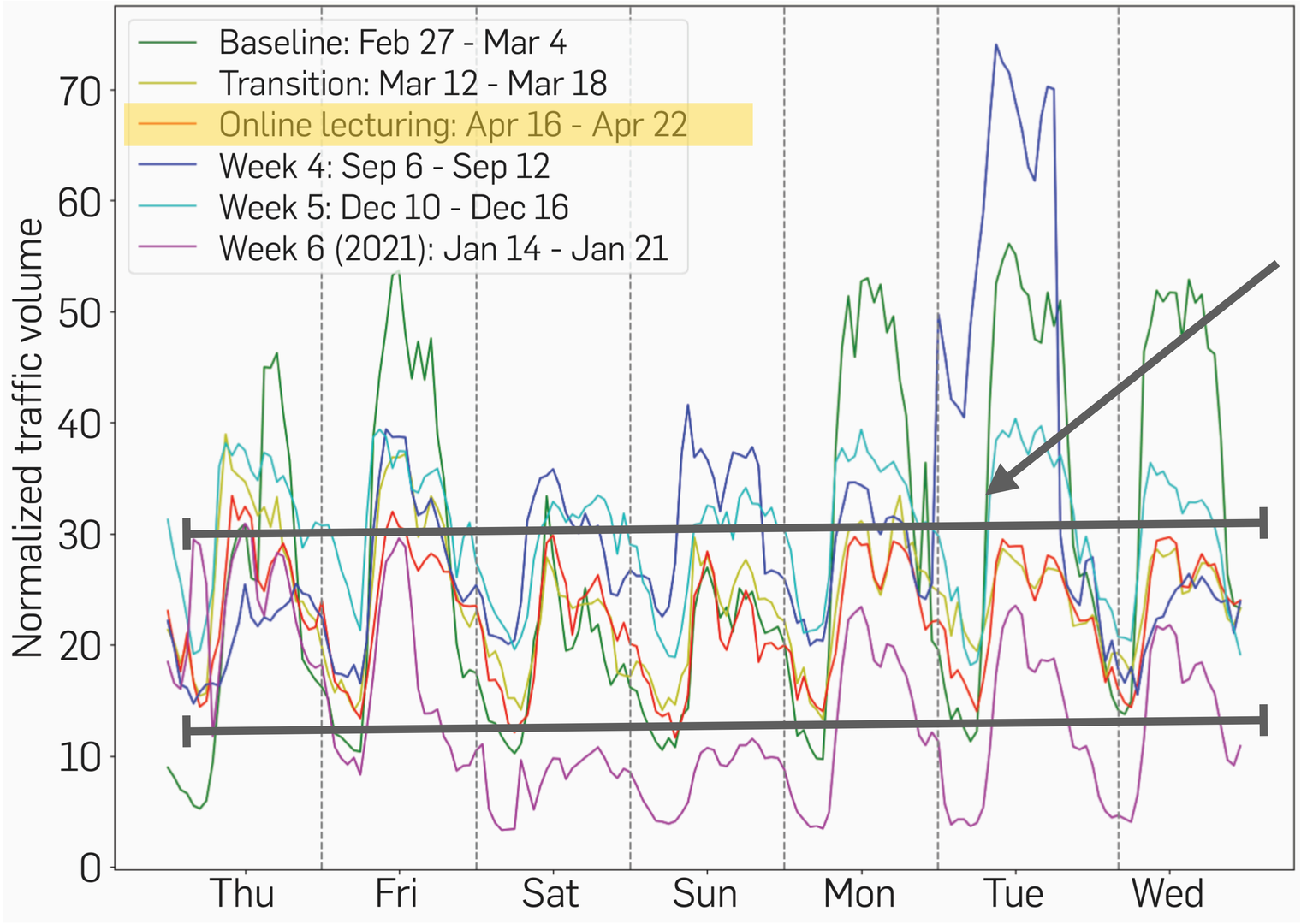
Significant drop, with a max. of 55% during Tue and Wed

A view from REDIMadrid: Traffic volume



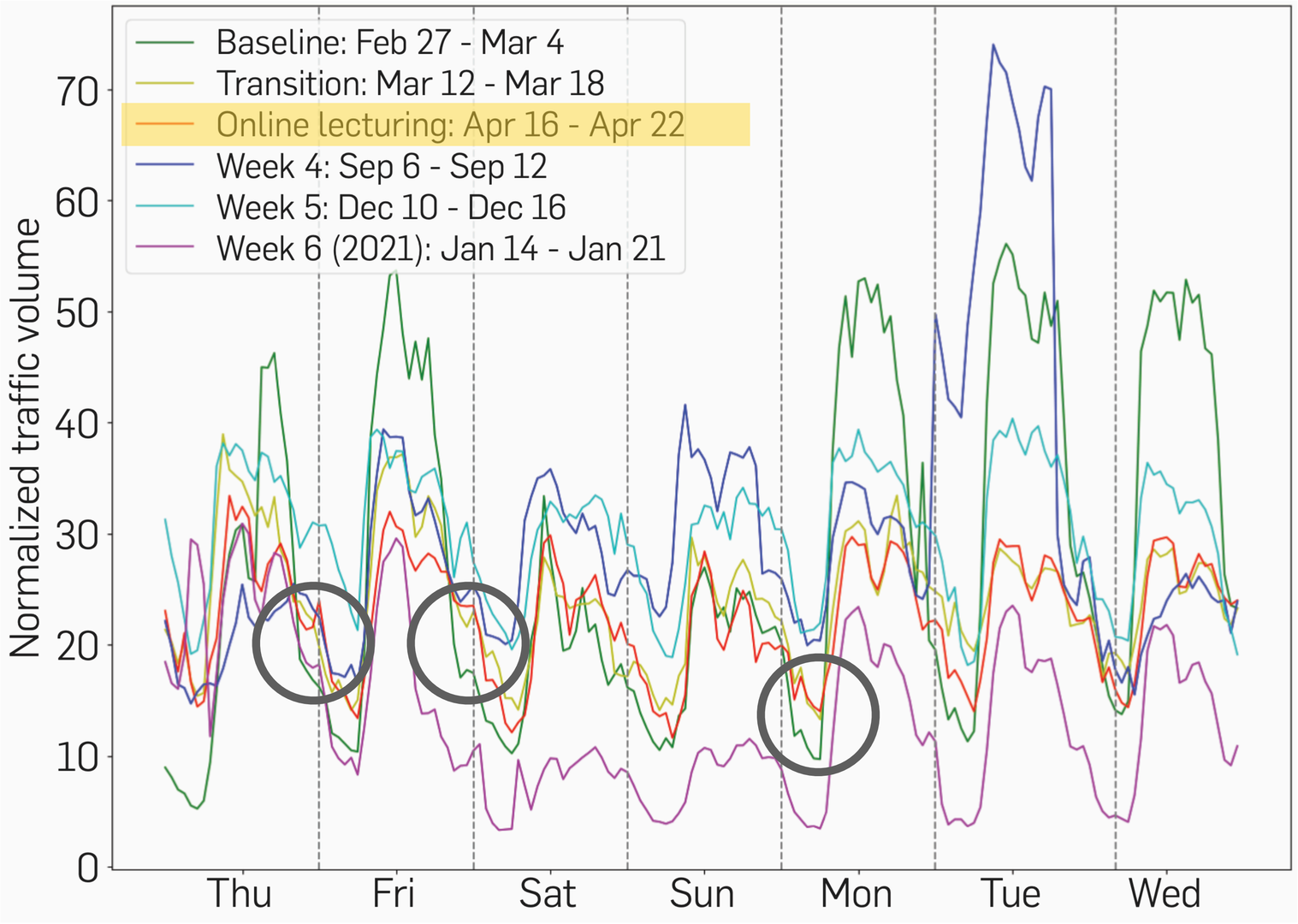
Traffic increases on weekends — up to 14% on Saturdays

A view from REDIMadrid: Traffic volume



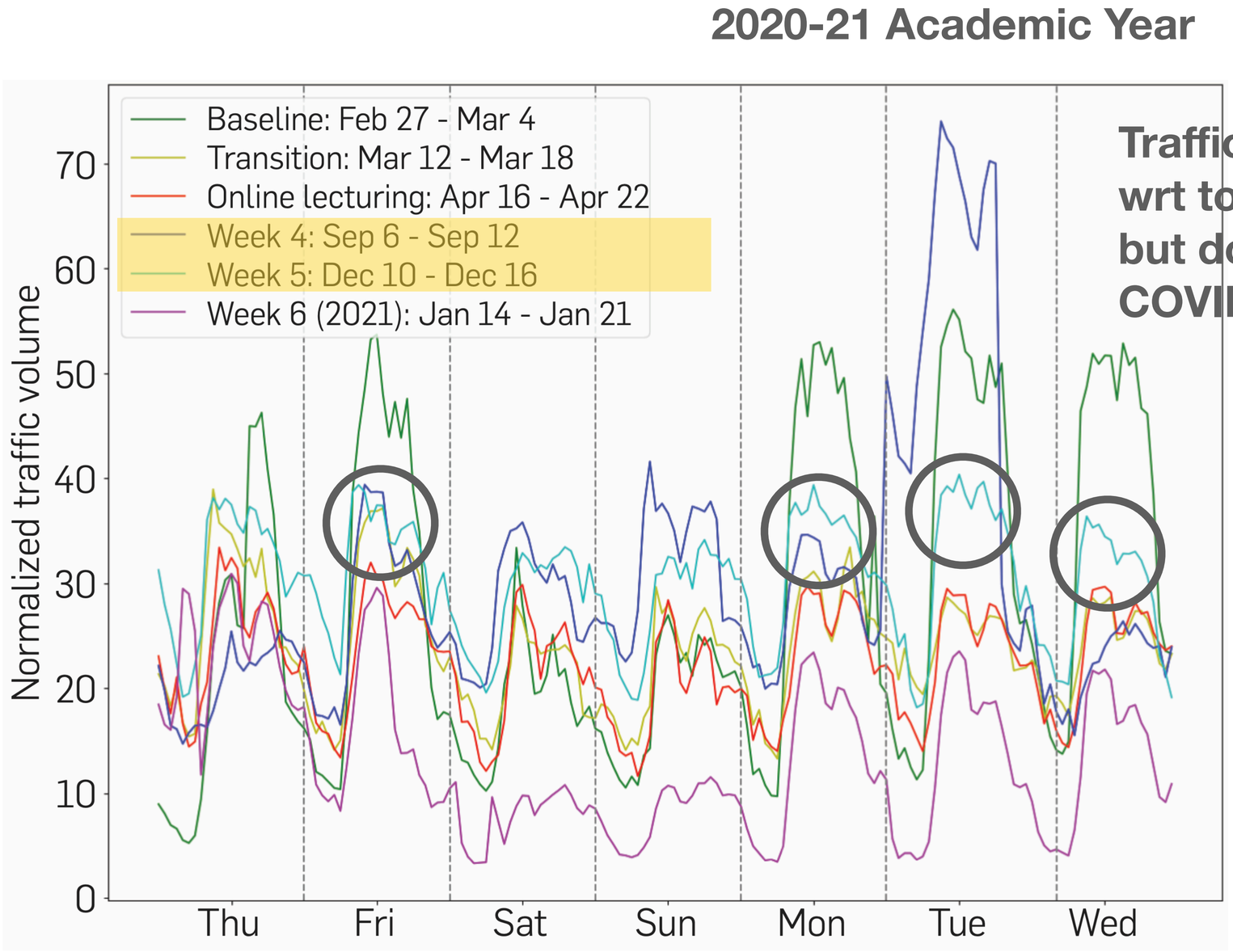
Every day is a weekend day

A view from REDIMadrid: Traffic volume



Night traffic much higher than pre-COVID

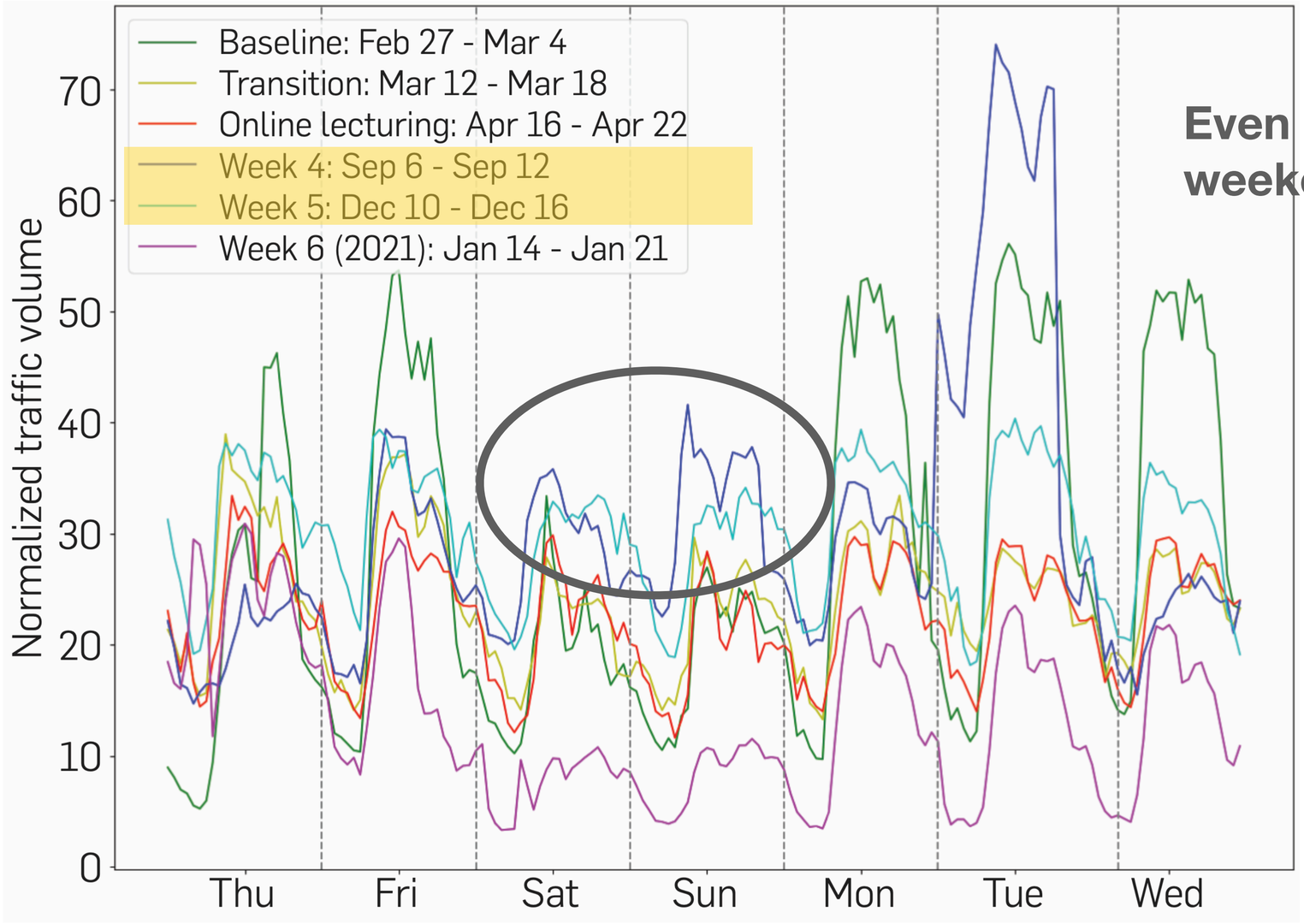
A view from REDIMadrid: Traffic volume



Traffic volume increases wrt to the Spring regime but doesn't reach pre-COVID levels

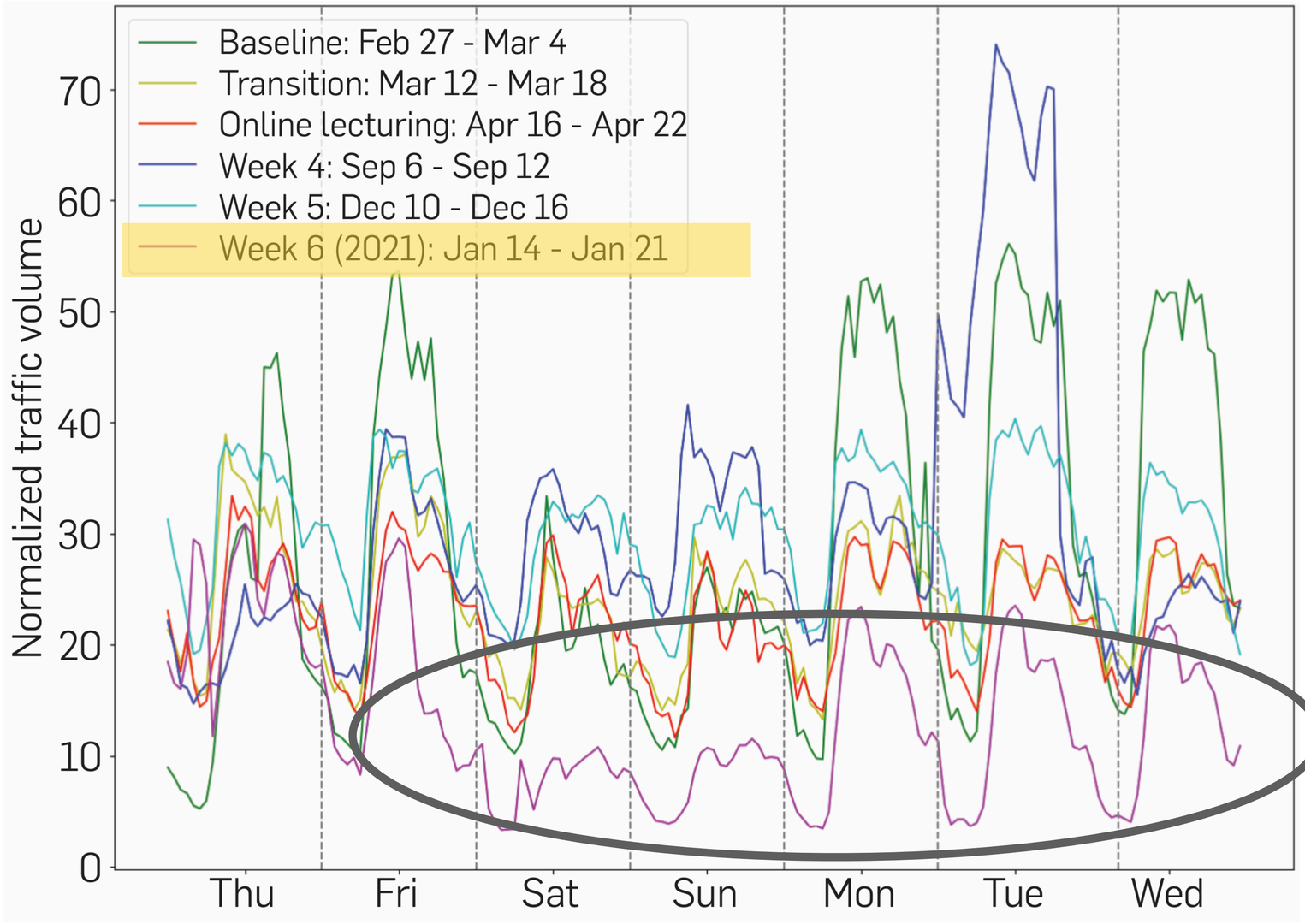
A view from REDIMadrid: Traffic volume

2020-21 Academic Year



Even more traffic on weekends

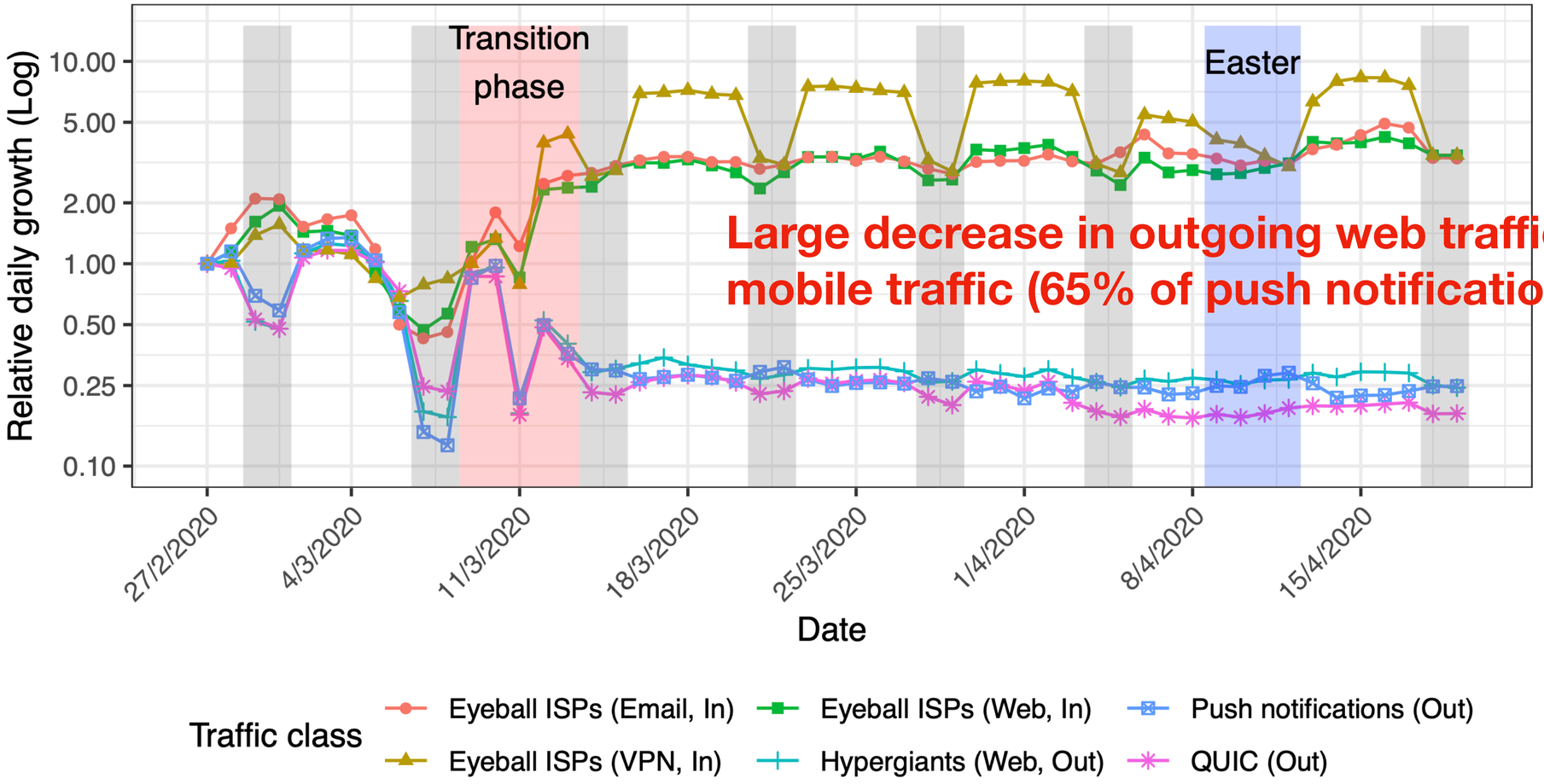
A view from REDIMadrid: Traffic volume



Filomena

A view from REDIMadrid: Protocol changes

Large increase in incoming web (1.7x), email (1.8x), VPN (4.8x), remote desktop (5.9x), and SSH (9.1x) traffic.



Large decrease in outgoing web traffic (50%) and mobile traffic (65% of push notifications)

People change => traffic changes

- Changes in people’s lives lead to **new traffic patterns**
- Difference between **workday and weekend** vanishes
- Applications for **remote work, education, VPN, and video conferencing** see significant increase in traffic
- **Absence of users** can lead to decrease in traffic for certain applications
- Many of the relevant applications are not served by hypergiants => **sole focus on hypergiants is not sufficient**

Traffic changes => networks change

- Traffic increase of **15-30%** within a few days
- Networks usually provision for **~30% increase per year**
- Impact on peak traffic is limited, but **valleys get filled**
- Networks could **react quickly** to the additional need for capacity
- Overall a success story

Thank you!

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