The impact of covid on network utilization: an analysis on domain popularity

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***Abstract*—The emergency related to the Coronavirus has impacted everyone's life. From the first weeks of 2020, in China, and for weeks later, in other countries of the world, isolation and social distancing measures have been adopted to avoid the spread of the virus, forcing people worldwide to isolate themselves in their homes. This represents a unique case of study to understand the impact of such measures on Internet utilization.**

In this paper, we provide insights on the use of different categories of Internet applications. We use two complementary sources of information: the lists from Alexa and Cisco Umbrella regarding the top 1 Million websites and domains used worldwide. Our results show that, during lockdowm time, the most used applications have been Youtube followed by Netflix, Facebook, Whatsapp and Skype. This shows how users have looked for consolation in entertainment apps such as youtube, Netflix, and in social media like Facebook. App of messaging services and collaboration, like WhatsApp and Skype, have been used to communicate with friends and families while also used for smart working. Contrasting the results from the two lists, we also uncover important difference in the usage from different kids of devices. We believe that the COVID-19 pandemic represents a very interesting situation from the network utilization point of view and we shed light on how such situation impacted the use of the Internet applications.

***Index Terms*—Covid-19, Application usage, Top 1M**

I. Introduction and motivation

The global emergency related to Coronavirus (COVID-19), spread in the last months, has changed the life of every person. Our life and our way of working have changed, and, with them, also the internet traffic has changed. Schools of all grades have adopted distance learning, and any kind of office has started the smart working. Lots of calls and remote connections to the office devices were held. Besides, the global pandemic and sequential lockdown have led to the high use of the Internet and the other online services also for leisure.

In this paper, we want to analyze the changes in Internet usage looking at the most searched domains and accessed websites. We have considered two datasets: the first one is provided by Cisco Umbrella [1]) and Alexa [2]. They provide every day a list of the top 1 million most popular domains and web sites according to their ranking. The two providers of the lists adopt different methods for such ranking: the Umbrella list contains the most queried domains based on passive DNS, the Alexa's list contains the most popular sites visited by people that use Alexa's browser extensions. We call the two lists simply Umbrella and Alexa in the following. We have analyzed the last two months of the year 2019 and the first four of 2020, looking at the trends of the most popular applications, divided by category, to spot changes of application usage during the lockdown. This analysis was born out to understand how users spent their time during a period when they were forced to spend their time at home. For example, videoconferencing and messaging applications have been widely used for both business and entertainment with friends and family. But also entertainment applications, included in the video and social media categories, have provided moments of lightness and entertainment. Thus, the categories we have considered are: video, social media, messaging, collaboration.

Our results confirm some results covered by the press in recent time, but also show interesting differences when contrasting Alexa and Umbrella. For example, we saw that: 1) in the video category, youtube.com always occupies position 2 in Alexa, higher than netflix.com, which, in turn, occupies a higher position that youtube.com in Umbrella; 2) in the social media category, the domain facebook.com occupies higher positions in the Alexa with respect to Umbrella, where the most popular domain is twitter.com; 3) in the messaging category, telegram.org presents an interesting change in Umbrella, where it scales different positions in the ranking. The domain whatsapp.com features an increase and a decrease respectively in Alexa and Umbrella; 4) in the collaboration tool category, skype.com has best performance in Umbrella, followed by zoom.us and webex.com. We believe these results and the analysis presented represent unique contributions that will be difficult in future time. At least we hope they will.

II. Related work

Scientific literature and several press and Internet companies have been focusing on the changes in Internet usage with the emergence of the world pandemic. There are works related to this topic, in different contexts, made with different datasets, and with different methodologies.

An interesting analysis was made by App Annie, an important analysis society, demonstrating how some conference applications, including Houseparty, Zoom, Hangouts Meet, and Microsoft Teams, recorded a high number of downloads

[1] https://umbrella.cisco.com/blog/2016/12/14/cisco-umbrella-1-million/
[2] https://toplists.net.in.tum.de/archive/alexa/

in the week 14-21 March 2020 worldwide, i.e. 62 million between IOS and Google Play [1]. The New York Times reported an analysis on the usage of different applications by American users. The analysis was conducted by SimilarWeb and Apptopia, two providers of online data. They showed that Facebook, Netflix, and Youtube were more used by websites than by phone apps. In fact, spending time at home mostly at laptop computers, Americans are beginning to appreciate large computer screens rather than small smartphone screens. SimilarWeb and Apptopia have also registered a visible increment on those applications, i.e. Google, Duo, and Houseparty video chat, which allows groups of friends to participate in a single video chat and play together. Increases were also recorded for videoconferencing applications such as Meets, Microsoft Teams and Zoom for smart working and virtual classrooms. One application not impacted by the crisis was Tiktok, which continued its rise even after the pandemic began [2]. Statista, web portal for statistics that collects a large amount of data on multiple topics, has shown the ranking of the most downloaded apps in the Google Play store after the coronavirus (Covid-19) outbreak in France as of April 3, 2020, by several downloads [3]. They have demonstrated that the five applications most downloaded in France during this period of lockdown were: Whatsapp, Zoom, TikTok, Houseparty, and Skype, in this order. The analysis of network traffic to know the needs of users in terms of application usage is a topic already frequently covered in the scientific literature. Martino et al. show a longitudinal view of the Internet traffic in five years, relying on data collected by a nation-wide Internet Service Provider (ISP) infrastructure. Through this data, they studied the evolution of the Internet in order to evaluate which services became popular and which get abandoned [4]. They demonstrated that video content drives the bandwidth demand and that users of social messaging applications, like Instagram, consume more and more traffic. In fact, the traffic of each Instagram user is already comparable to the traffic of video-on-demand users, such as Netflix or YouTube. Authors of [5] focused on the traffic of a year about three European countries through five vantage points with different access technologies. Their scope was to perform measurements of "What the user do with the Internet", for example they studied the popularity of the applications related to different categories (streaming Services over HTTP, File Hosting, Social Networking, Web and Peer-to-Peer). Favale et al. analyzed the impact of the quarantine period on the Politecnico di Torino campus network, focusing on collaboration and remote working platforms usage, remote teaching adoption, and look for changes in unsolicited/malicious traffic. They have demonstrated that in the Polito campus there are not big problems. They have encountered few cases of poor performance, probably related to people connected through 3G/4G operators [6].

III. Data and methodology

In this work, we rely on two popularity lists provided every day by Cisco Umbrella and Alexa: two different kinds of lists of the top 1 million most popular domains and web sites. The two lists differ in some aspects and they are created through two different processes, discussed in more detail in the section III-A. The **Cisco Umbrella Top 1M**, provided free of charge, is created through the DNS traffic to OpenDNS [3], its DNS resolver characterized by 100 billion daily requests from 65 million unique active users in more than 165 countries [7] [8]. The collection method of domains gathered by Cisco Umbrella consists of capturing not only browser-based traffic, such as Alexa, but also keeps track of internet activity on any port and not just port 80. The algorithm adopted to build the popularity list is relying on the unique number of IP clients visiting that domain compared to the sum of all requests to all domains [8]. **Alexa's top sites** is a list of websites ordered by Alexa Traffic Rank [9], generally provided for a fee. We have obtained these files through the project realized by Scheitle et al. [7], that they share the code, data, and additional insights into the following website https://toplists.github.io/.

The ranking provided by Alexa is generated by capturing data from Alexa's browser pluging on 25000 different browser extensions over a past three months from millions of users [10] [11]. "Alexa's Traffic Ranks are based on the traffic data provided by Alexa's global sample over a rolling 3 month period. Traffic Ranks are updated daily. A site's ranking is based on a combined measure of Unique Visitors and Pageviews. Unique Visitors are determined by the number of unique Alexa users who visit a site on a given day. Pageviews are the total number of Alexa user URL requests for a site. However, multiple requests for the same URL on the same day by the same user are counted as a single Pageview. The site with the highest combination of unique visitors and pageviews is ranked #1. Additionally, we employ data normalization to correct for biases that may occur in our data" [12].

A. Differences between the two lists

These top lists are created with different processes and data sources, generating different ranking. A first difference between the Top 1M's lists is that the Umbrella list contains subdomains (like hangouts.google.com) while the Alexa list includes only the top domains (like "google.com"). So, the Umbrella list holds practically less main domains than the million main domains of the Alexa list [13]. As mentioned in the section III, the two lists are produced with two different processes. Alexa receives web browsing data from users who have installed one of the many extensions of the Alexa browser. Cisco Umbrella, instead, builds these statistics from DNS queries sent via OpenDNS. Thus, Alexa analyzes data related to HTTP traffic from web browsers, while Umbrella takes a more global view by incorporating not only HTTP traffic from browsers. Besides, Umbrella's list contains several domains with non-authorized gTLDs (.mail) or test domains (www.example.com), not present in Alexa's list [13]. In the scientific literature, several works focus on the differences of the Top Internet lists, among which Cisco Umbrella and Alexa, helpful to understand the most used Internet domains.

[3]https://www.opendns.com/

Scheitle et al. studied the extent, nature and evolution of top lists used by research communities. They focused on three different popular top lists - Alexa, Cisco Umbrella and Majestic - and they evaluated their structure, stability, significance, the ranking mechanisms and the research result impact. In particular, related to the difference between Cisco Umbrella and Alexa lists, they specified that the clients using OpenDNS are not only PCs, but also mobile and IoT devices. Some clients that perform DNS queries to OpenDNS may be bogus, not existing, unlike Alexa that captures data related to websites visited by users. But, in general, Umbrella's list can be useful to analyze DNS traffic while Alexa's list can be interesting for a study focused on the human web [7]. Le Pochat et al. [11] detected a change in the way Alexa composes its lists: the data is averaged over a single day, causing half the list to change every day. Instead, for the Cisco Umbrella list, only 49% of domains respond with HTTP status code 200.

B. Our Approach

As mentioned in III, we have considered two different lists of popularity domains to observe the trend of the most used applications during the lockdown time. We have downloaded the .csv files, provided every day by Cisco Umbrella and Alexa, of two last months of 2019, November and December, and the first four months of 2020, i.e. January, February, March and the first thirteen days of April.

Our goal was to study the different trends of the traffic internet and, more specifically, of the use of the applications of different categories (sec IV) by the users before and after the spread of the COVID-19. We have analyzed only the first 10K domains of each .csv file, aiming to focus only on the most popular domains. As the beginning of the pandemic's spread in the world dates back to the first days of January [4], we have fixed the months of 2019 as the baseline. Then we have compared every week of the following months with the baseline to understand how the most popular domains have changed in every week of 2020 compared to the last months of 2019.

Algorithm 1 Create Result File

```
for i=0 to N do
    Y ← Domain_1 i
    SearchYinFile_2
    if YinFile_2 then
        Position ← Position_1 + Position_2
        POP(YinFile_2)
    else
        Position = Position_1 + 100K
    end if
end for
for j=0 to M do
    Y ← Domain_2 i
    Position = Position_2 + 100K
end for
```

The figure 1 summarizes the steps carried out to obtain our results; the component of the comparison, first and second,

[4]https://www.nytimes.com/article/coronavirus-timeline.html

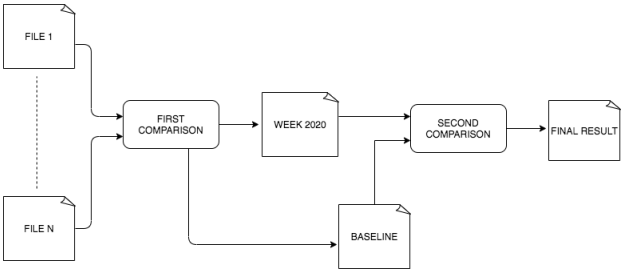


Fig. 1: Flow chart of our approach

is zoomed in the pseudo code reported in the figure 1. For each day of the weeks about months of 2020 and for those in the baseline (November and December), we calculated the average position of each domain and the variance to monitor the dispersion of data around the average position, following the scheme shown in the pseudo code 1. In particular, for each folder, corresponding to one week in 2020 or two months in 2019, we compare the first two files. The result of this comparison is compared with the third file and so on until we analyze all the files. The comparison between the two files, also reported by the pseudo code, is structured as follows: the domain is taken in the i-th position and searched in the second file. If it is present, then the position in the resulting file is given by the sum of the two positions, otherwise 100K is added to the position of the first file. If the domain is present in the second file, it is deleted so as to add to the resulting file, with a position equal to Position=Position_2+100K, all those domains that are present in the second file and not in the first one. We assign to the position a value equal to "100K" because, in this way, we mark that domain is not included in the first ten thousand domains on that date. Then, we have performed a comparison between the resulting file of each week and those of the baseline, also based on the pseudo code.

The final results are created in the following way:

- If a domain wais stored in both files, we recorded the average positions and variances for 2019 and 2020;
- if a domain wais presented in one file, we registered the average position and the variance of 2019 or 2020, based on which weeks or months contained this domain and 100K in the other two columns.

IV. A GLOBAL VIEW ON DOMAIN POPULARITY

Starting from the resulting files, obtained by applying the approach explained in III-B, we have analyzed several domains related to different categories of most used applications, both as web and mobile applications. We considered the following categories and related domains:

- **Social Media**: "facebook.com", "linkedin.com", "twitter.com", "snapchat.com","instagram.com", "tiktok.com";
- **Video**: "netflix.com", "youtube.com";
- **Messaging**: "whatsapp.net", "whatsapp.com", "telegram.org"
- **Collaboration Tool**: "zoom.us", "teams.microsoft.com", "skype.com", "webex.com", "hangouts.google.com".

We have chosen these categories to analyze the change in both entertainment and leisure applications (i.e. video, social media, and messaging) and collaboration applications, helpful for the distance learning and the smart working to which the whole world had to bend.

Label	Time Span
0	Nov - Dec 2019
1	1 Jan - 5 Jan 2020
2	6 Jan - 12 Jan 2020
3	13 Jan - 19 Jan 2020
4	20 Jan - 26 Jan 2020
5	27 Jan - 2 Feb 2020
6	3 Feb - 9 Feb 2020
7	10 Feb - 16 Feb 2020
8	17 Feb - 23 Feb 2020
9	24 Feb - 1 Mar 2020
10	2 Mar - 8 Mar 2020
11	9 Mar - 15 Mar 2020
12	16 Mar - 22 Mar 2020
13	23 Mar - 29 Mar 2020
14	30 Mar - 5 Apr 2020
15	6 Apr - 13 Apr 2020

TABLE I: Time Frames
:

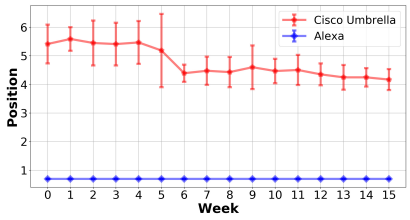
We will analyze each category in detail in the following subsections. For each domain, we have reported the error bar plot, where we plotted the average position and the variance for each week. In particular, the x-axis represents a specific time frame, whose order is listed in the table I, the y-axis shows the average position in the logarithmic scale.

A. Video

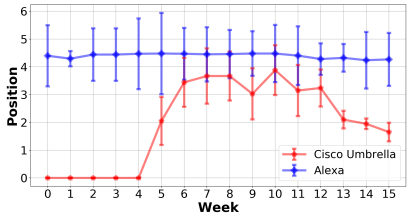
In the video section, we dwelt on Youtube and Netflix, both accessible by both browser and application. There are a lot of domains related to them, but we have considered "youtube.com" and "netflix.com". Figure 2a shows the trend of domain "youtube.com". In Alexa, this domain presents a regular trend; in particular, it has a constant average and zero variance. It always holds the second position in the list. Instead, in Cisco Umbrella, this domain always occupies the first position until the last week of January, then, later, lower positions in the ranking than the Alexa list with a dispersion of data around the average value. After the second month of February, this domain gains some positions. The "netflix.com" domain, 2b, occupies low positions in Alexa rather than Cisco Umbrella, where the trend is constantly in the two last months of 2019 and in every week of January 2020, and then there is an increase in the next weeks. Therefore, in the video category, the two domains analyzed have opposite behavior in the two datasets: for Alexa, the more popular domain is "youtube.com", for Umbrella, instead, is "netflix.com". The two domains, related to video streaming, were highly searched during the lockdown. In summary, "youtube.com" has been most searched by users via browsers and not by other types of applications such as (mobile phones, televisions and so on), in accordance with SimilarWeb and Apptopia [2]. We can observe the opposite behaviour in "netflix.com" domain.

B. SocialMedia

In the social media category, we have analyzed the six domains related to the most known applications: "facebook.com", "instagram.com", "tiktok.com", "snapchat.com",



(a) "youtube.com"



(b) "netflix.com"

Fig. 2: Video Category

"linkedin.com", "twitter.com". In the Top 1M files of Alexa, the domain "facebook.com" occupies high positions in the list, against to Cisco Umbrella dataset where the most popular domain, in this category, is "twitter.com". Besides, the domains "instagram.com", "linkedin.com", "twitter.com" and "tiktok.com" achieve better positions in Alexa's list and not in Cisco Umbrella's dataset. In contrast, "snapchat.com" occupies upper positions in Cisco Umbrella's list. Another significant aspect is related to the domain "facebook.com", that holds better positions in Alexa except for an overlap in the weeks of February and March. In all of the cases, there is an evident high value of standard deviation.

During this period of lockdown, the social media that has evolved the most has been "tiktok.com", with a decrease in the trend, and so rising in the ranking, from the first weeks of February. This decrease is more evident in Cisco Umbrella than in Alexa, probably because the greater use was due by application from a different type of devices and not by browser. In fact, different newspaper testify to the wide use of this application by users [14]. Another interesting trend to observe is "facebook.com", which shows how, during this lockdown period, this domain gained several positions in the Umbrella list between February and March. During the same weeks, in Alexa's list, this domain loses some positions in the ranking. We justify this behaviour with the same motivation as "tiktok.com", so more use by applications, through for example a mobile device, and not by browser, in contrast with the analysis reported by the New York Times [2].

C. Messaging

In the messaging category, we have analyzed three domains: "whatsapp.com", "telegram.org" and "whatsapp.net". The last domain is in the top 1 million of Cisco Umbrella and not in Alexa's list. Both for Umbrella and Alexa, the messaging domain most popular during this period of the pandemic

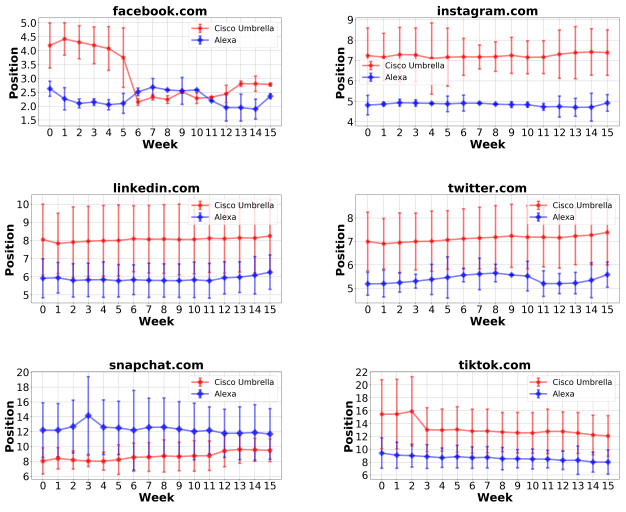
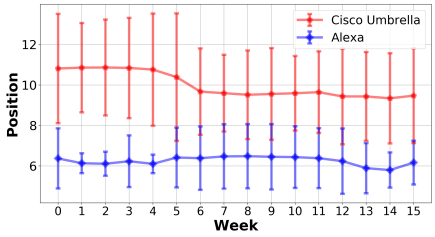


Fig. 3: Social Media Category

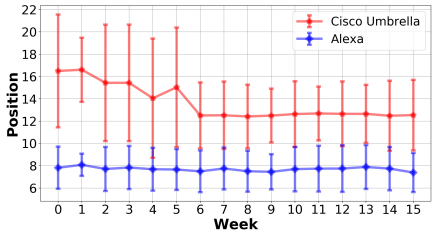
is "whatsapp.com", following by "telegram.org". More in detail, both "whatsapp.com" and "telegram.org", figure 4 (a) (b), take lower positions in the ranking in Alexa against Umbrella, probably for the same motivation of the video category IV-A. Therefore, for these two domains, the number of HTTP requests by the browser is greater than the number of queries to the OpenDNS server, that includes applications on different port numbers. The "whatsapp.net" domain, figure 7 (c), presents a high dispersion of data around the mean value, but the trend is fairly constant. During the lockdown period, we notice a significant change in telegram application usage, related to the "telegram.org" domain. This change is featured in the Umbrella dataset where this domain wins many positions in the rankings. Instead, for "whatsapp.com" domain, there is an increase and a decrease respectively in Alexa and Cisco Umbrella lists. The "whatsapp.net" domain, figure 7, has not undergone excessive variations during the quarantine.

D. Collaboration Tool

In the collaboration category, we have analyzed five domains related to the most popular platforms of collaboration: "skype.com", "zoom.us", "webex.com", "teams.microsoft.com", "hangouts.google.com". Among these domains, only three are included in both datasets: "zoom.us", "skype.com", "webex.com". The two remaining ones, i.e. "teams.microsoft.com" and "hangouts.google.com", are contained only in the Cisco Umbrella's list because in the files of the top 1 million of Alexa are not present subdomains III-A. The collaboration domain with the best performance, figure 5, is "skype.com" in the Umbrella's dataset, following by "zoom.us" and "webex.com" where there is an overlap between the two lists. In particular, we can notice a relevant aspect in the trend of zoom.us in correspondence of week 12: March 16th - March 22nd. In this interval, the domain acquired many positions in the rankings which may be justified considering that, during the first two weeks of



(a) "whatsapp.com"



(b) "telegram.org"

Fig. 4: Messaging Category - common domains

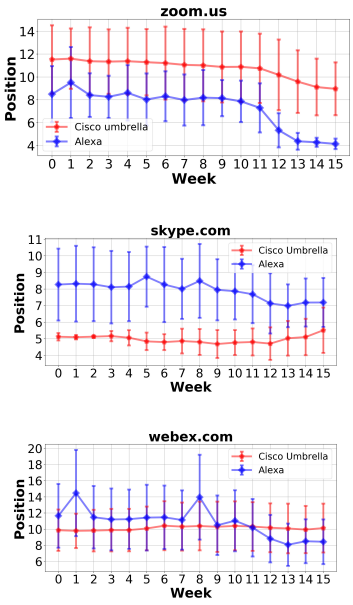
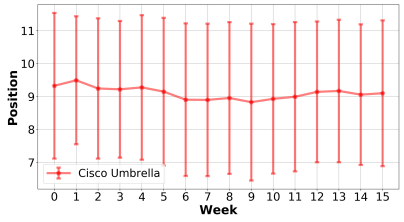


Fig. 5: Collaboration Tool Category - common domains

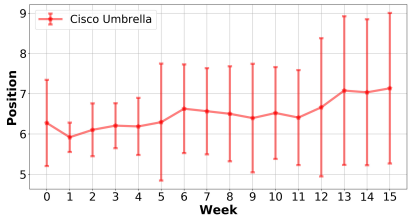
March, the beginning of the use of this tool by companies, universities, schools but also for entertainment was recorded. Instead, among the two domains contained only in Umbrella's list, the one with the highest position in the ranking is "teams.microsoft.com" (Fig. 6.

V. Discussion and Conclusion

Web and mobile applications played a significant role during the lockdown period, when the whole world was forced to hole up in their homes and go out only for basic needs.

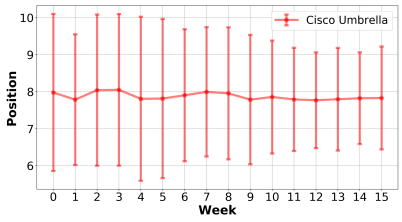


(a) "hangouts.google.com"



(b) "teams.microsoft.com"

Fig. 6: Collaboration Tool Category - Umbrella's domains



"whatsapp.net"

Fig. 7: Messaging Category - Umbrella's domain

Consequently, most employees were forced to adopt smart working, while schools and universities embraced distance learning, leading to the widespread use of video conferencing applications. Not only for work and distance learning, several applications have also been essential in your free time and to keep in touch with friends and relatives.

In this work, we have analyzed the trends of different applications, belonging to different categories, i.e. video, social media, messaging and collaboration tool. For this analysis, we have adopted two different, complementary data sources: the top 1 Millions lists provided every day by Cisco Umbrella and Alexa, containing the most popular domains and websites respectively. While confirming some results covered by the press, our results also show interesting difference noticed contrasting Alexa and Umbrella, e.g. youtube.com always occupies position 2 in Alexa', higher than netflix.com, which, in turn, occupies a higher position in Umbrella; facebook.com occupies higher positions in the Alexa with respect to Umbrella, where the most popular domain is twitter.com; whatsapp.com features an increase and a decrease respectively in Alexa and Umbrella; skype.com has best performance in Umbrella, followed by zoom.us and webex.com. These results are related to the use of different devices by the users, which are differently captured by the two lists. In our ongoing work we are looking at the possibility to dissect the analysis at Country level, as the lists used do not provide such information. Moreover, we are using a systematic approach [15] to understand the performance of the network during the lockdown. Preliminary results show that despite the major change in network access, use and operation conditions, no significant impact on the applications and network performance has been observed.

Acknowledgment

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