Examining 5G Adoption: Effects on Network Traffic and Mobile Service Usage

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***Abstract*—With the launch of 5G and tremendous advancements in the traffic monitoring infrastructure of the modern telecom industry, we have an unprecedented opportunity to characterize the impact of this new wireless technology on end users. In this work, we conduct a first-of-its-kind analysis of 5G adoption over both space and time by leveraging massive measurement data at a national scale. We reveal the state of 5G incidence on total mobile traffic, its adoption across various services and devices, its temporal fluctuations, and the causes associated with the observed phenomena.**

I. INTRODUCTION

With the advancement in the deployment of 5G across the world, it is critical to understand the evolution, performance, and impact of this new cellular technology on users. However, due to intense competition in this market, operators tend to disclose minimal information about 5G deployment.

The latest Ericsson mobility report [1] stipulates that 5G has already passed 1.7 billion subscriptions worldwide by the end of the first quarter of 2024. They also specify that 160 million subscriptions occurred in the last quarter of 2024. They reported statistics on Western Europe, which is the focus of this study, indicating that 5G subscribers rose from 72 million in 2022 to 143 million at the end of 2023.

These figures offer only a high-level view of 5G technology. Many questions remain, such as 5G's spread over space and time, the difference in usage patterns from that of 4G, and, its utilization of specific mobile applications.

To the best of our knowledge, only the work of Parastar *et al.* [2] has tried to answer these questions using network operator data to understand the temporal evolution and characteristics of local deployment, the diversity of the 5G-enabled device ecosystem and overall network performance. Nevertheless, our work aims to fill a gap in characterizing 5G adoption over space and time, with a strong emphasis on the consumption of individual services. Out key insights are as follows.

- In 2023, the advancement of 5G deployment and adoption is at a relatively early stage in a developed country like France, as it is strongly focused on metropolitan areas with a slow growth rate.
- Different services and devices (*e.g.*, iOS versus Android) are affected by high-speed 5G in heterogeneous ways.
- 5G's temporal behavior differs from 4G, showing a circadian rhythm with strong overnight peaks, mainly due to download-heavy apps in specific urban neighborhoods.
- The aforementioned overnight peaks of 5G appear in areas with lower education and income, indicating that the local population may be using 5G *dongles* as a replacement for expensive fiber Internet access at home.

II. DATA AND METHODS

Our study builds upon hourly mobile data traffic collected at NSA, which offers the coexistence of both 4G and 5G, for the year 2023 from March 1st to June 1st. We employ the geographical coordinates of the NSA to draw a Voronoi tessellation of the French territory and distribute the traffic uniformly corresponding to the NSA station over its Voronoi cell. Then, weighted spatial interpolation is leveraged to map the mobile traffic recorded in Voronoi cells to each IRIS (a statistical boundary that encompasses a population of 2,000 per unit). We restrict the analysis to those IRIS which have almost full coverage of 5G. As we are interested in understanding the incidence of 5G with respect to total mobile traffic, we employ the 5G ratio measured at a given IRIS zone ℓ and over a time period t is defined as

$$R^{\ell}_{5G}(t) = \frac{v^{\ell}_{5G}(t)}{v^{\ell}_{4G}(t) + v^{\ell}_{5G}(t)}, \tag{1}$$

where $v^{\ell}_{\star}(t)$ is the volume of data traffic generated by technology $\star$. Based on (1), $R^{\ell}_{5G}(t) = 0$ if 5G demands are absent and the mobile traffic is only generated by 4G devices, whereas $R^{\ell}_{5G}(t) = 1$ if 5G has already seized the whole user demand. All these steps adhere to the policies of the General Data Protection Regulation (GDPR) in force in Europe.

III. RESULTS

Highlights of nationwide 5G adoption: We begin our analysis on 5G adoption in France by exploring the fraction of the total traffic contributed by 5G connections. Therefore, in Figure 1, we show the incidence of the hourly $R_{5G}(t)$ at the national scale over the full data collection period. We can observe that $R_{5G}(t)$ ranges typically between 0.10 and 0.18, *i.e.*, 5G users are responsible for 10% to 18% of the overall mobile data traffic across France. Interestingly, the average nationwide 5G adoption is not constant in time: it increases from 12.7% on March 1 to 13.3% on May 31, shown by the red dashed line.

5G adoption across mobile services: To understand the 5G adoption across different services, we ranked the first 100

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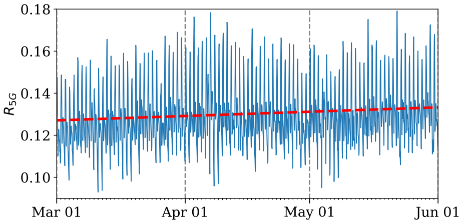

Fig. 1: Nationwide 5G ratio, R_{5G}, computed on a hourly basis during the three-month observation period. Linear trend in red.

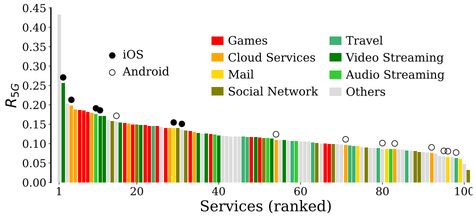

Fig. 2: Ranking of mobile applications based on their 5G ratio.

mobile services based on their R_{5G}. Figure 2 proves that different mobile services adopted 5G with diverse intensity irrespective of their popularity. However, a clear pattern for Operating System specific applications can be observed: iOS-specific applications consistently appear at the top of the ranking (with an average $R_{5G} = 0.18$). In contrast, Android-based ones are gathered at the bottom (with an average $R_{5G} = 0.09$). This suggests that iOS users are well ahead in the 5G adoption when compared to Android users.

5G temporal dynamics: We plotted the median week of R_{5G} to understand how the temporal dynamics of 5G adoption evolve. Figure 3 shows consistent overnight (22:00-7:00) peaks. To understand the cause of these peaks, we clustered the service-level median weeks to identify the applications responsible for this phenomenon, resulting in two clusters, as described in Figure 4. Although the dynamics of the two clusters do not show significant differences during active hours (7:00–22:00), the pattern of Cluster A clearly correlates with the overnight peaks observed in Figure 3. Cluster A applications are download-heavy, like social media and video streaming, indicating higher 5G usage than Cluster B.

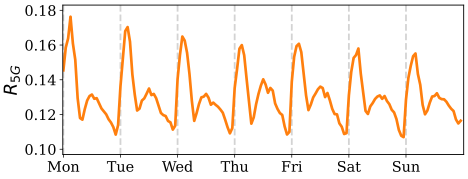

Fig. 3: Median week of 5G ratio in total traffic.

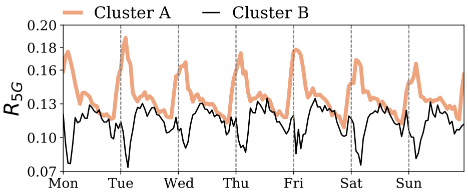

Fig. 4: Median 5G ratio by service class of Clusters A and B.

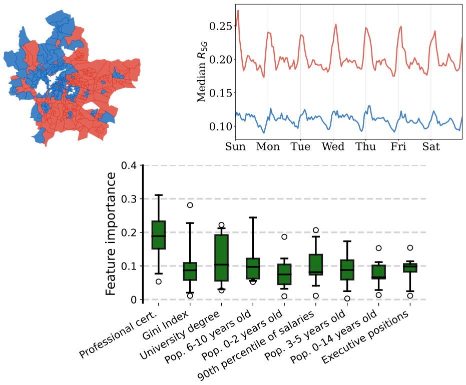

Fig. 5: Map of blue and red clusters from $R^{\ell}_{5G}(t)$ clustering across city locations (left) and average median weeks (right).

Spatial component to service-level 5G usage: We analyze Cluster A applications to study 5G's geographical impact in cities. Within each city, we then clustered these median weeks across locations ℓ, employing an agglomerative hierarchical clustering algorithm on pairwise distances between the median weeks of $R^{\ell}_{5G}(t)$ for all locations ℓ in the same city. In all cities, we again identified two clusters, identified as red and blue clusters. Figure 5 shows an example of a city where we can observe the average median weeks of $R^{\ell}_{5G}(t)$ for the blue and red clusters. In the blue cluster, we have zones with low 5G adoption for services in Cluster A. Quite surprisingly, these zones do not show the typical nighttime peaks in the 5G ratio that were a distinctive feature of Cluster A in the temporal analysis. In contrast, zones in the red cluster show a significantly higher 5G incidence for Cluster A applications and are marked by the typical strong overnight peak. We further explored the red cluster by correlating these areas with socioeconomic status indicators as shown in Figure 5. As a result, we observed that the overnight peaks (red cluster) were more prominent in lower education and income parts of the cities. This led to the speculation that people living in these areas use 5G dongles as a proxy for high-cost fiber internet.

IV. CONCLUSIONS

We carried out a first-of-its-kind analysis of 5G adoption, revealing several interesting and partially unexpected patterns in 5G demand. The main limitation is that the study focuses on one mobile operator and a specific country. While not globally generalizable, we expect the results to apply to much of Europe.

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