Wi-Fi performance analysis in the city center of Zagreb

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***Abstract*—In this study, we analyze Wi-Fi(802.11) occupation around the City Center of Zagreb and make frequent speed measurements between an Access Point and a Device in many crowded and uncrowded Wi-Fi areas. This enables us to see what impact Wi-Fi traffic has on other Wi-Fi traffic, and what kind of configurations (Wi-Fi version, security configurations, etc. . .) have the most impact on network quality for neighboring devices**

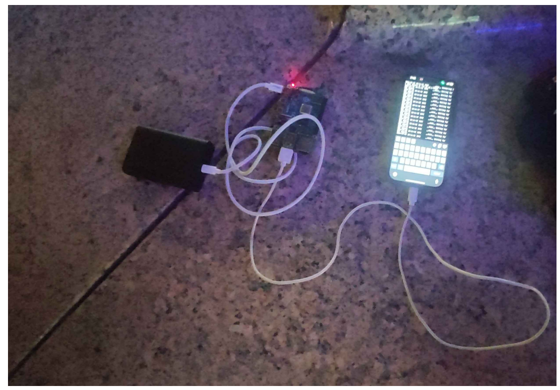
I. Introduction

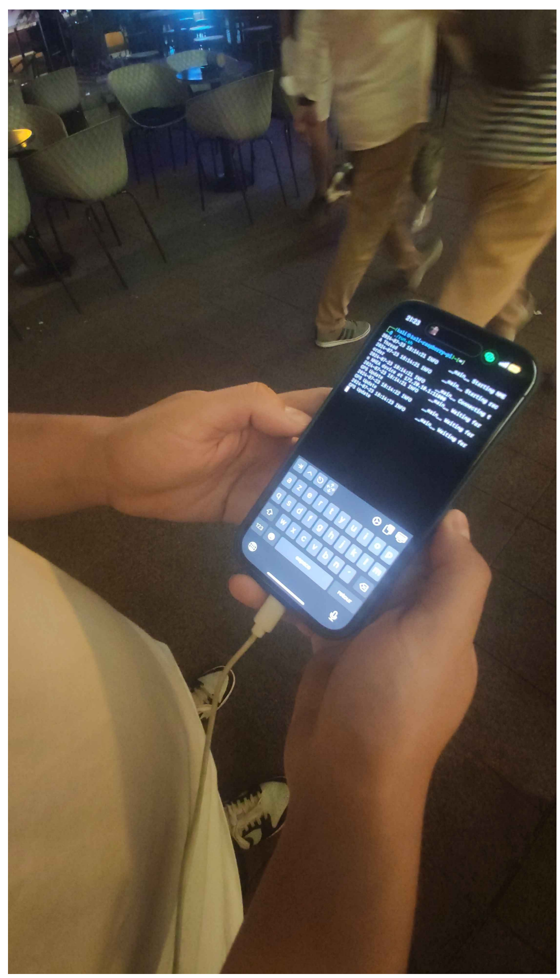
This paper gives an overview of the different deployment of the Wi-Fi around Zagreb. The Wi-Fi is a technology widely used nowadays, both in the industry and in personal use. The objective of this paper is to analyze and illustrate how the Wi-Fi deployment is done through the city center of Zagreb and to make claims based on the data we gathered about speed and response times in differing network environments

II. Measurements methodology

To realize that, we went through a tour in Zagreb using the following peripherals

1) A Raspberry Pi 4B, that periodically records all information about nearby Wi-Fi devices, including signal strength, frequency, security settings and SSIDs. The Raspberry Pi also connects to a specified hotspot after each measure and does ping tests and IPerf2 measurements to the hotspot.
2) An Android device, always placed at 15m from the Raspberry Pi, running a hotspot. The device is also running an IPerf2 server using the “Iperf2 for Android” application.
3) An IPhone, connected via USB Tethering to the Pi and connected to it via SSH using this local network. This IPhone is running the “NMEAGPS” application, that allows it to send its GPS coordinates via the NMEA protocol to the Raspberry Pi which records it for each measure, and the iSH app, that provides a working Linux environment that is used for the SSH connection to the Raspberry Pi





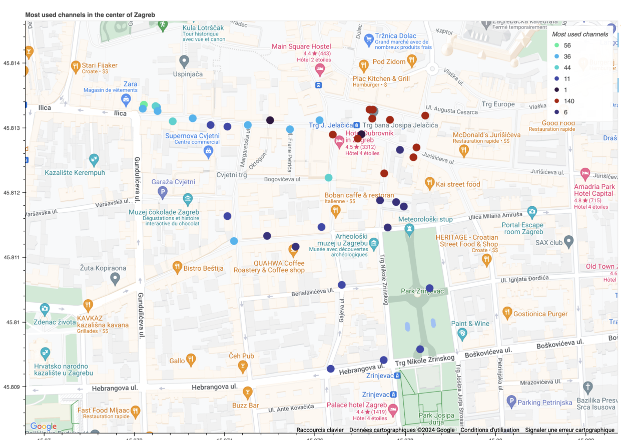
III. Interference and Quality

In our analysis, we observed significant variability in Wi-Fi interference across different locations in the city center of Zagreb. Wi-Fi interference was assessed by examining two main factors: the number of Wi-Fi hotspots and their respective signal strengths.

Interference levels were primarily gauged using the Received Signal Strength Indicator (RSSI) values. High levels of interference are typically indicated by strong RSSI values from multiple nearby networks, especially when these networks are operating on the same or nearby channels. This type of interference can lead to increased packet loss, higher latency, and reduced throughput, adversely affecting the overall quality of service.

Our findings indicate that areas with the highest Wi-Fi interference corresponded to those with the highest density of Wi-Fi hotspots. Specifically, the vicinity of Trg bana Josipa Jelačića showed substantial interference due to the high concentration of access points. In these high-density areas, we observed strong RSSI values from numerous access points, which exacerbated the interference.

To better illustrate the interference landscape, we conducted a detailed analysis of the signal strengths and channel usage across different locations. The results, depicted in the following graph, highlight the distribution of signal strengths and the number of hotspots in various parts of the city center.



Key observations from our analysis include:

- Signal Strength: High RSSI values from multiple sources often indicate areas of high interference. These areas experienced degraded performance due to the increased noise floor, which affects the signal-to-noise ratio (SNR) and subsequently the quality of the Wi-Fi connections.
- Channel Congestion: Heavy utilization of specific channels can lead to congestion. In our study, we identified that certain channels were more frequently used in high-density areas, contributing to higher interference levels and reduced network performance.
- Spatial Distribution: The spatial distribution of hotspots also played a crucial role in interference patterns. Areas with closely spaced access points exhibited higher interference compared to those with more distributed setups.

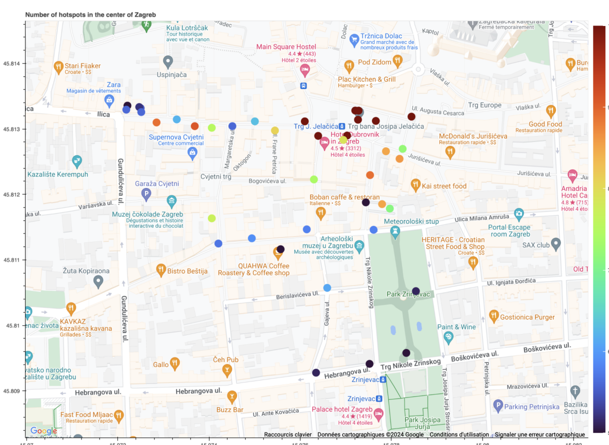
To mitigate these issues, it is essential to adopt strategies such as careful channel planning, the use of dynamic frequency selection (DFS), and the deployment of advanced Wi-Fi technologies that can adapt to changing interference patterns. By understanding the interference landscape, network administrators can make informed decisions to enhance the performance and reliability of Wi-Fi networks in urban environments.

IV. Performance

The performance of Wi-Fi networks in the city center was evaluated based on four criteria: the number of hotspots, the most used channels, the speed of the connections and the latency of the connections.

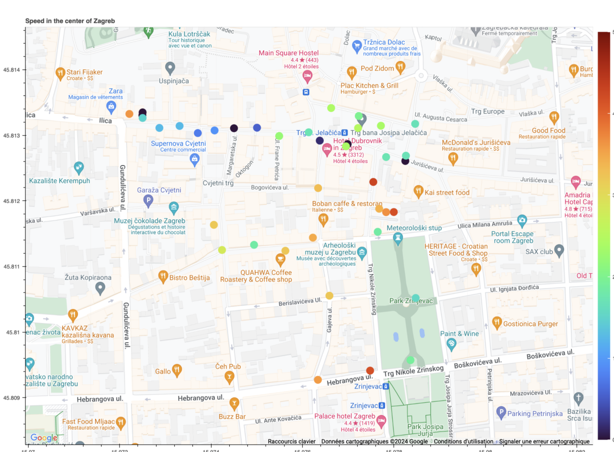
A. Number of Hotspots in the Center of Zagreb

The density of Wi-Fi hotspots is a critical factor influencing network performance. The higher the number of hotspots in a given area, the more potential for interference and reduced performance due to signal overlap.



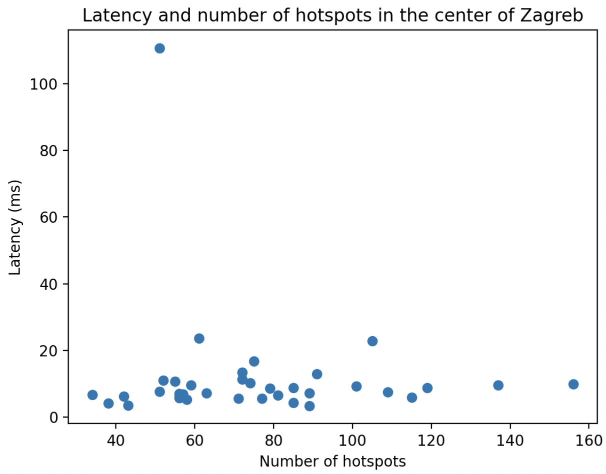
B. Speed in the Center of Zagreb

Speed tests conducted across different locations provided insights into the actual performance experienced by users. The speed varied significantly depending on the local density of Wi-Fi networks and the channels they operated on.



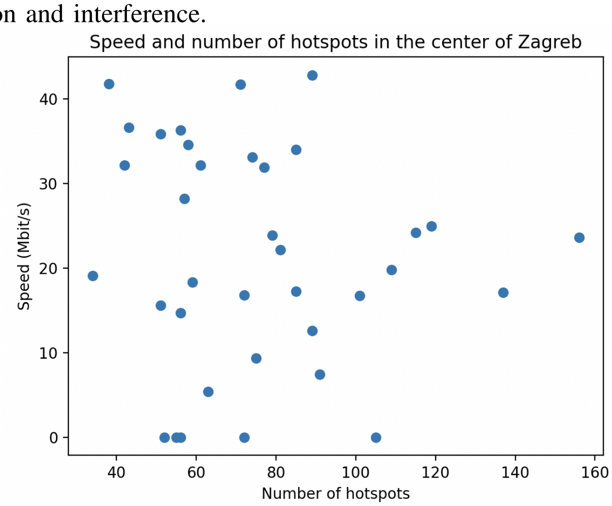
C. Latency in the Center of Zagreb

The latency of Wi-Fi connections in relation to the number of hotspots is illustrated in the graph below. Higher latency is observed in areas with more hotspots, although some locations with fewer hotspots also show high latency, possibly due to other environmental factors.



D. Speed and number of hotspots in the center of Zagreb

The relationship between the number of hotspots and the speed of the Wi-Fi connection is depicted in the following graph. It shows that areas with a higher number of hotspots tend to have variable speeds, indicating the impact of congestion and interference.



V. Conclusion

Based on our data, we can conclude that Wi-Fi performance in the city center of Zagreb is highly variable and depends on several factors, including the density of hotspots, channel usage, and the level of interference. High hotspot density areas, such as around Trg bana Josipa Jelačića, exhibited significant signal interference, leading to reduced performance. Conversely, areas with fewer hotspots had better performance metrics.

To improve Wi-Fi performance in densely populated areas, several measures can be implemented:

- Optimized Channel Selection: Encouraging the use of less congested channels can reduce interference and improve overall network performance.
- Dynamic Channel Allocation: Implementing dynamic channel allocation systems that can automatically switch to less crowded channels in real-time can help manage interference.
- Upgrading to Newer Wi-Fi Standards: Adoption of newer Wi-Fi standards (such as Wi-Fi 6) that offer better performance and efficiency in high-density environments.
- Better Access Point Placement: Strategically placing access points to minimize overlap and interference, potentially using directional antennas to limit signal spread.
- Regulating Transmit Power: Adjusting the transmit power of access points to appropriate levels can help in reducing unnecessary interference.

Future work could involve more granular measurements, such as assessing the impact of different types of building materials on Wi-Fi performance, and exploring advanced techniques like beamforming and mesh networking to enhance overall network quality. Additionally, integrating user feedback and real-world usage patterns could provide a more comprehensive understanding of Wi-Fi performance in urban environments.

The results also show that while high hotspot density generally correlates with reduced speed and increased latency, the relationship is not strictly linear. Other factors such as the physical environment, types of Wi-Fi devices, and network configurations play significant roles. Hence, a multifaceted approach is essential for optimizing urban Wi-Fi networks.

References

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