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Expand the internet access in an urban park using a Wi-Fi offloading technique

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ABSTRACT

Nowadays, smart devices have grown exponentially, so they have become a necessity rather than a luxury, therefore staying connected to the Internet has facilitated people to explore national and international news, make payments for services public, virtual shopping, scheduling medical appointments, among others. Now all this demand increases every day at excessive levels and adding the robust applications that are currently being developed and launched on the market.

Regarding this, it is known that currently, the internet service providers of the municipality of Soledad Atlántico do not have the physical infrastructure to maintain the availability of the service. This is where the project design of the Wi-Fi-Offloading solution to extend the coverage and the transmission of data from the cellular network, through the wireless network in the Muvdi park of the Municipality of Soledad Atlántico, is carried out with the aim of providing a solution and alternative so that the internet connection service remains available without import the data network to which you have access. The research methodology used for the development of the project is descriptive. The research design is qualitative, transactional, and non-experimental. At this moment, it is in a descriptive stage, carrying out tests, and then moving on to the applied stage.

1. Introduction

It is unmotivating, to move around each of the attractive places of the Muvdi park and notice that in the different areas or points you visit, the data network changes coverage (Edge, 3G, H +, LTE) and loses connection at wide intervals, that on different occasions only the terminal or Smartphone device (Tablet, Phone-Cell) is reset, to reconnect to the network that covers the current point. It is of common interest to make known the technologies, which make possible the exchange of data through the Internet. The majority of users with a smartphone already navigate from it, and in most cases, they do so through an internet data plan provided by their telephone service [1]. At this time the most widespread connection for our country is the 3G network, but this is changing little by little, and the 4G network is taking much more ground, thanks to the promise of offering higher speed, we can also find it with LTE. To identify which network is available, smartphones have an icon in the notification bar where you can see the different symbols as well as two arrows. Also, you can see the following letters H, G, E, H + or 3G and 4G or LTE.

It is necessary to point out another problem that undoubtedly affects the Muvdi Park. It is that the park only has a hotspot for access via Wi-Fi, making it difficult for users, visitors who are in the entertainment sites further away from the internet access point. To enjoy a service (Internet via Wi-Fi) stable, since the radius of coverage is insufficient to cover the entire area of the park, it is due to this that present problems and constant failures in the transmission of data to the Internet. Likewise, this problem generates a massive concentration in the place where the hotspot is located, saturating

the connections and providing a poor service, preventing a good experience for the user or visitor who decided to access the services provided by the park. In short, it has a Wi-Fi network, little available and stable to which even the most expert user is unlikely to access it thanks to the number of established connections that consume the resources of the Internet service provider via Wi-Fi. Therefore, to prevent all these failures and provide improvements in the link and traffic of the Internet network, it is required that there be at least three Internet providers devices via Wi-Fi (Hotspot) and be located and configured as such way that covers the entire area of the park and allows to maintain the availability and reliability of the service to the Internet network to avoid crowds of users at the same point and decrease the negative experience in terms of browsing the Internet of users and visitors from the park.

Wireless networks are very important nowadays because thanks to them it is possible to save, as much as space with cable spending, which uses radiofrequency technologies that allow mobility to the user without the need of a cable that connects it to the network [2]. Wireless networks facilitate operation in places where the computer cannot remain in one place, such as warehouses or offices that are located on several floors. Wireless networks are not expected to replace wired networks. It offers higher transmission speeds than those achieved with wireless technology. This situation entails that the data transmission of the users is carried out in a delayed manner, due to the saturation of the Wi-Fi communication device, product of the number of connections found by the user group at the same point they are looking for transmitting. Through the wireless network, this affectation would mean a decrease in the visitors for the poor service rendered to the citizen. However, the existing technology can provide solutions, which are already available in the local market in different brands and prices. To achieve this, it must have the priority of installing and configuring two new Wi-Fi access points to support all the connections of the wireless network, based on the installation and configuration of these devices. It is understood that a previous study of the network has been made where the statistics of daily connections and bandwidth available for the implementation of a solution design with regarding its introduction in the current topology of the wireless network of the Muvdi Park, the changes expected by the design of this solution are noted.

The objective of this research is to design a Wi-Fi Offloading solution to extend the coverage and data transmission of the cellular network through the wireless network in the Muvdi Park of the City of Soledad. In the planning of this research project, the authors rely on two types of study, because they are of high relevance for the realization of the proposed solution.

Descriptive research is applied in this solution design because it is necessary to describe the current status of the wireless coverage of the Muvdi Park of the Municipality of Soledad Atlántico, identify the point of most significant influx of users and visitors of the park and indicate the areas where the coverage of the cellular network changes bands, the sending, and reception of traffic being lower. Also, thanks to the use of observation, which approves the use of the senses, to obtain in a conscious and directed, data that provide elements for our research, allowing from it, to develop a hypothesis, and then reapplies observation, to verify if the hypothesis is met. The paper is organized in the following way: the initial conceptualizations are given in the introduction, then a fundamental review of the literature related to Wi-Fi Offloading is made. Continue with the explanation of the research methodology used. Subsequently, the results and discussions that have so far are shown, specifying what is expected to be developed in the following stages. Finally, the conclusions are defined.

2. Wi-Fi Offloading and Conceptualization

The significant increase in traffic in the cellular network has significantly surpassed the infrastructure of national IPS, leading to the saturation of these. It is for this reason that Wi-Fi Offloading is considered one of the most promising techniques to deal with the explosive increase of data in cellular networks due to its high speed of transmission of traffic and its low requirement of devices. Therefore, this technique will supply the current needs that affect not only the citizenship but also the companies that provide Internet service. Below are the documents that support the present investigation.

A previous research article entitled "Data Traffic Offload from Mobile to Wi-Fi Networks: Behavioral Patterns of Smartphone Users" presents a model for defining the behavior patterns of smartphone users when downloading data from mobile networks to networks Wi-Fi [3]. In other

publication entitled "Proposal for the design of a mobile data network with the Wi-Fi Offload solution complementary to the UMTS and LTE networks, which allows providing Internet service to mobile users through Wi-Fi access" explains the design of a mobile data network with the Wi-Fi Offload solution to be able to provide the mobile data service through a non-3GPP access network such as Wi-Fi as a technological alternative to improve the overall performance of the network, solve the problems indoor coverage problems and improve the user's browsing experience with speeds and quality of service that exceed 3G and equal and improve 4G at a lower price of Mbps [4]. In other project entitled "Design of Wi-Fi solution for download data from mobile networks 3g "explains how to build the best solution to optimize quality and service perception for congested mobile network zones [5]. In other research article entitled "Mobile data traffic offloading over Pass point hotspots" define mobile data traffic continues its tremendous growth. Road, with a growing number of smartphones, high-end phone tablets they require Internet access everywhere [6]. As a side effect of this explosion of mobile data, today, we face the challenge of managing traffic overloads in cellular networks.

The current cellular networks are experiencing explosive growth in data traffic, and this traffic generates a load on the network [7]. This growth is the result of smart devices, data-hungry mobile applications (for example, online social networks, Internet gaming, video streaming), according to Cisco's Global Visual. Network index (VNI), since 2007, global mobile data traffic is doubling every year. It is estimated that this growth rate will even increase more in the coming years. The realistic parameters of a saturated LTE cellular network, and see how it can be downloaded using data-offloading techniques as they are Small cells and Wi-Fi offload by using free software [8]. Due to the rapid growth of smartphones and tablets, data traffic in networks is increasing in the last years [9]. Until 2015, mobile connections are expected to reach 7.4 billion, surpassing the global population. As the popularity of extensive data, social media, video, and online game applications are growing rapidly; it will further boost data consumption and create tremendous network stress. The mobile data traffic grows at a compound annual growth rate (CAGR) of 131 percent between 2008 and 2013 and will exceed two Exabyte per month in 2013 [10]. At the same time, cellular operators in Europe are investing a large amount of money to drive machine-to-machine (M2M) communications for billions of machines and intelligent devices (e.g., cars and sensors), which will create additional mobile traffic. However, current cellular networks cannot adapt to an exponential growth of data of this type. Therefore, there is an urgency for the research community to look for new solutions. Fig. 1 shows a basic Wi-Fi Offloading network topology.

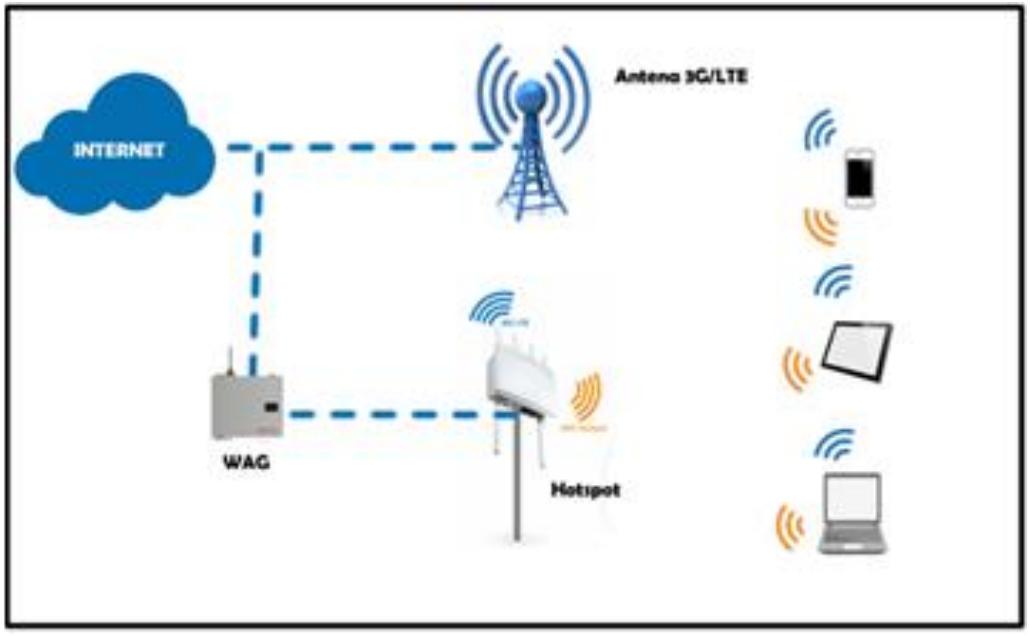

Fig. 1. Wi-Fi offloading network.

3. Method

The project is framed in the type of descriptive research [11]. Descriptive since all the documentation related to Wi-Fi Offloading have been reviewed. According to the research design, the project is Non-experimental, qualitative, and transactional. Non-experimental because it focuses on the study of the reality of network performance in an open area in its natural dynamics. The study does not create situations to observe what changes in the environment from a created situation but seek to describe, explain, and predict reality, from an approach. In later stages of the project, experiments will be carried out to analyze the impact of Wi-Fi Offloading and validate how it transforms the performance of the cellular network, modifying some variables that will be defined in later in the investigation.

Qualitative because it is based on a working hypothesis, defined as the saturation of the cellular network and the need to decongest it by expanding the capabilities (coverage, response times, D2D connectivity) of the wireless network. It is transactional because the measurements are taken in a single moment. It is expected in the future to perform a multivariate statistical analysis to compare the gap between the current values versus the new values of each metric reviewed in this study. Fig. 2 shows the stages of the project.

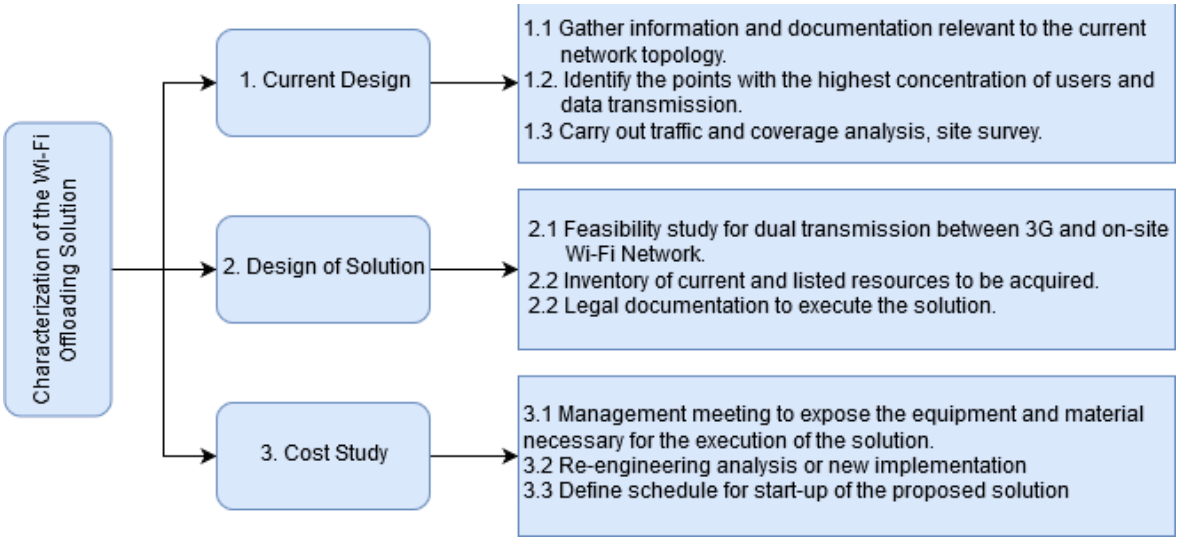

Fig. 2. Wi-Fi offloading solution characterization.

4. Results and Discussion

According to He et al., Wi-Fi Offloading is classified in five categories: 1) capacity; 2) cost; 3) energy; 4) rate; and 5) Continuity [12]. This classification obeys the interests of each operator in solving or developing products aimed at solving problems in the categories. Wi-Fi Offloading schemes are accommodated in some of the categories which are shown in Fig.3.

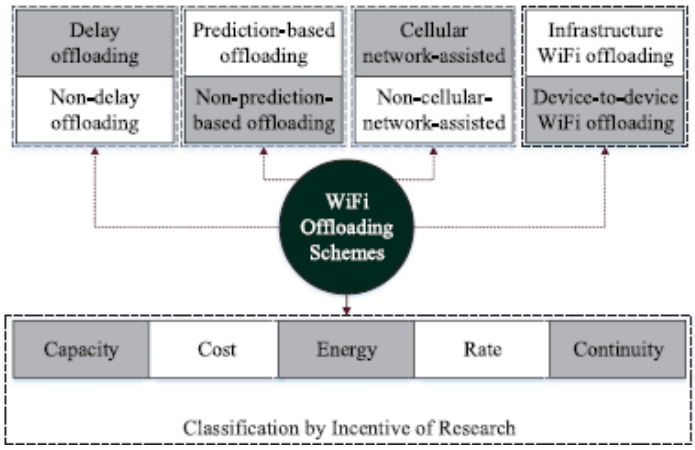

Fig. 3. Wi-Fi offloading schemes.

Considering delay technology, our proposal is based on Non-Delayed Offloading. The main reason is that for our environment it is the one that can provide the best results and it is relatively easy to start developing without incurring higher costs. This scheme is based on Wi-Fi first algorithm where users connect to a Wi-Fi access network whenever Wi-Fi coverage is available. Then UEs (user equipment) shift their data traffic to a Wi-Fi network. In other words, UEs offload their data traffic only if the received signal strength of Wi-Fi access is non-zero. Otherwise, they use cellular networks to transfer the data traffic, as Cheng et al. explain in their research [13].

In formulating the proposed Wi-Fi D2D-based offloading scheme, it is assumed that mobile nodes have both 3G/4G and Wi-Fi wireless network interfaces. Mobile nodes use the cellular network interface to transmit data in the general case but switch to the Wi-Fi network interface whenever Wi-Fi offloading is possible. The control flow chart of the proposed scheme is shown in Fig. 4.

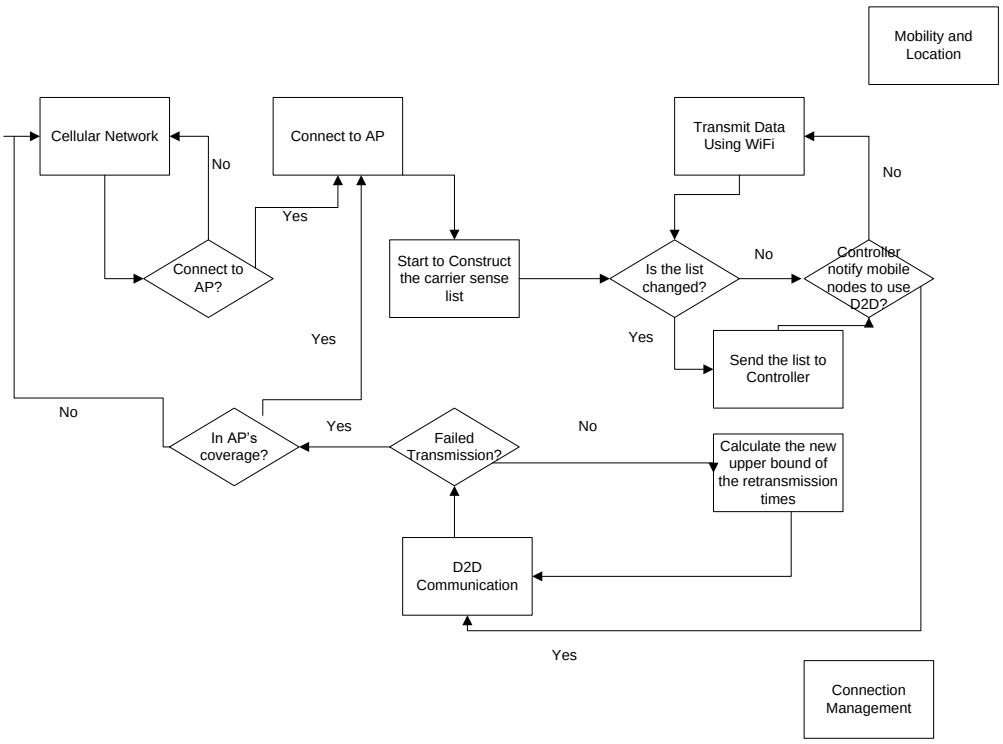

Fig. 4. Control flow chart of the proposed scheme.

To achieve the aforementioned D2D Wi-Fi offloading scenario, two critical issues must be resolved: (1) identifying whether or not the two peered mobile nodes that are communicating with each other are capable of performing Wi-Fi D2D communication; (2) deciding when the two peered mobile nodes should switch from Wi-Fi D2D communication back to infrastructure-based communication.

Table.1 Functions and Conditions of Algorithms

Algorithm	Function and Condition	Input Parameter	Variable Set
On the spot Offloading [20][53]	$Access_i \begin{cases} Wi-Fi & SNR_i^1 \geq 0 \\ LTE & otherwise \end{cases}$	SNR_i^1	0
Fixed SNR Threshold [21]	$Access_i \begin{cases} Wi-Fi & SNR_i^1 \geq SNR_{min}^1(load_i^1) \\ LTE & otherwise \end{cases}$	$SNR_i^1, load_i^1$	SNR_{min}^1
ANDSF Model based on Cell-ID [22]	$Access_i \begin{cases} Wi-Fi & SNR_i^1 \geq 0 \\ LTE & otherwise \end{cases}$	SNR_i^1	SNR_{min}^1
ANDSF Model base don Position [22]	$Access_i \begin{cases} Wi-Fi & Distance_i \geq D_{thr} \\ LTE & otherwise \end{cases}$	$Distance_i$	D_{thr}, SNR_{min}^1
Hybrid ANDSF Model [22]	$Access_i \begin{cases} Wi-Fi & \begin{cases} Distance_i < D_{thr} \\ SNR_i^1 > 0 \end{cases} \\ LTE & otherwise \end{cases}$	$Distance_i, SNR_i^1, load_i^1$	D_{thr}, SNR_{min}^1

There is a list of handover algorithms for the access network discovery and selection function to control the handover operations between 3G and non-3G networks. In the next stage of the project, we will decide which the most appropriated algorithm is. Table 1 shows several algorithms schemes based on different SNR thresholds.

Thanks to the research project developed in Muvdi Park, the necessary data and information were obtained to create the design of the proposed Wi-Fi Offloading solution. The present investigation will show the results obtained, considering the account that specific security measures in navigation govern the current Hotspot national parks, so the Ministry of Information Technologies and Communications (TICs) mentions some of the main characteristics and restrictions of the located Hotspot in each of the parks. Fig. 5 shows the main navigation restrictions for this kind of free connection.

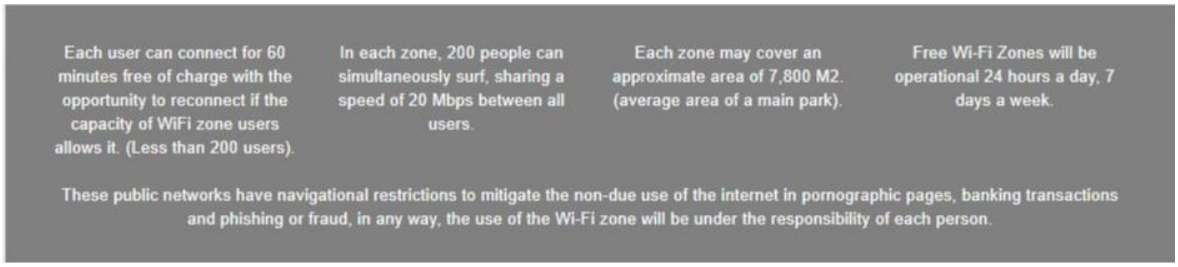

Fig. 5. Navigation restrictions.

Considering the previous provision demarcated by MINTIC and illustrated in Fig. 2. We proceeded to make the connection with the wireless internet access device. It was found that for the final devices you must log in from a captive portal which will ask the clients primary data to get personal information, contribute with the statistics required by the administration of the Wi-Fi zones for their control and accept all the conditions that imply connecting to the network.

Likewise, an analysis of the coverage range of the device was carried out, which showed that the range of coverage of the hotspot could cover an approximate area of 7,800 square meters according to ICT specifications. However, in the field, it can be seen in Fig. 6 that the distance is wider, but with inevitable delays and intermittency reaching approximately 18,000 square meters.

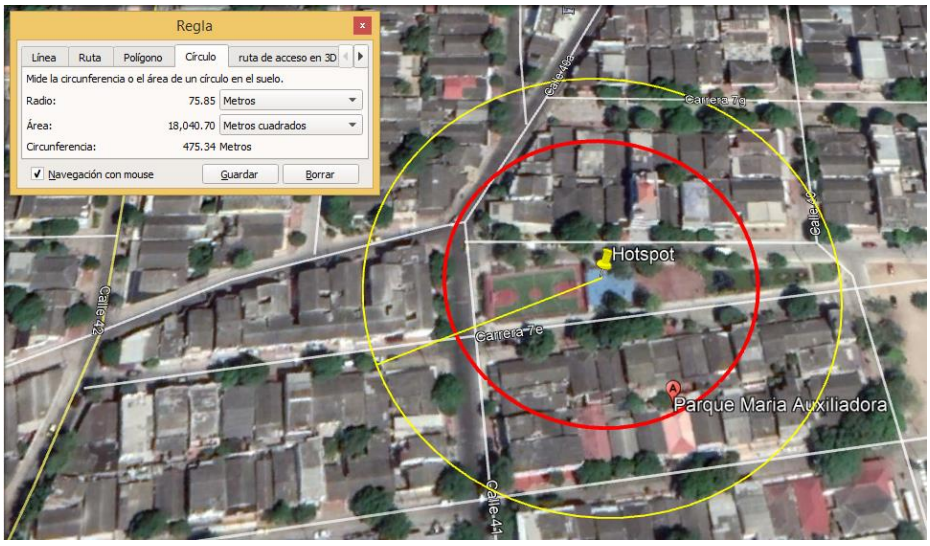

Fig. 6. Range of hotspot coverage

Similarly, the pertinent measurements were made on the bandwidth of the device (Hotspot) to know the variations between the data of loading and unloading of the information. Fig. 6 corroborates the bandwidth available for the wireless access device and details the number of successful pings for each of the tests, so it is detailed that the band is like the described by MINTIC in Fig. 7.

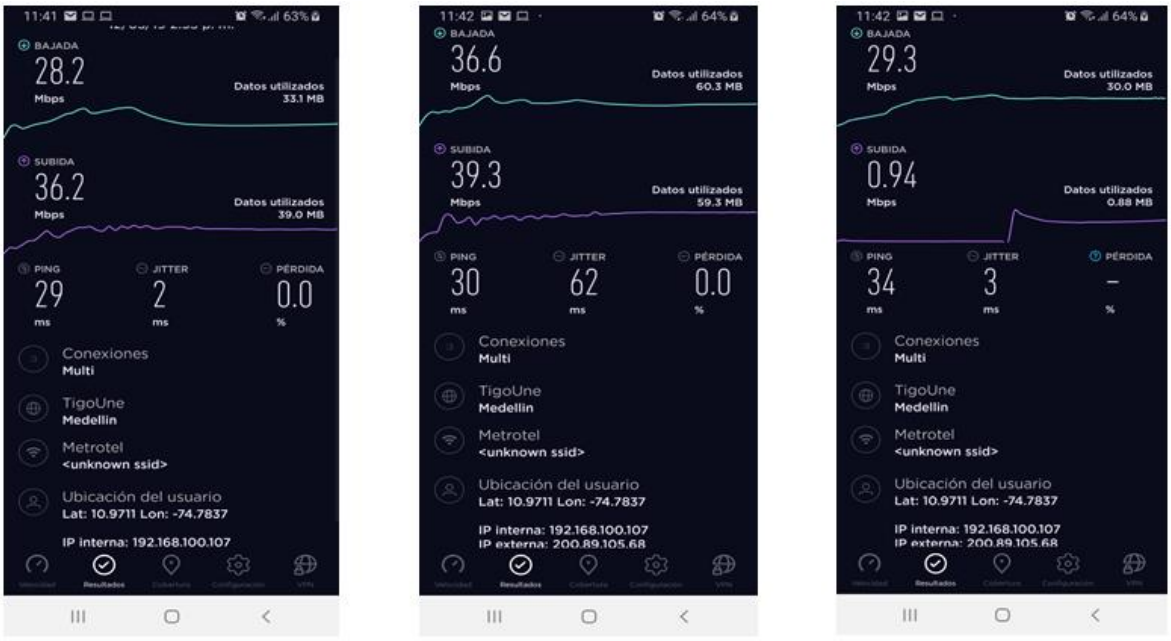

Fig. 7. Bandwidth test.

It is pertinent to mention that the infrastructure designed directly depends on the Colombian state, which provides the wireless access solutions to all the country's parks, as well as the participation of national and local cellular data service providers.

Consequently, the results of the authors of state-of-the-art documents who support the integrity of the present investigation will be cited.

The survey from 298 people consists of a data traffic generation request form, which is based on measurements made by the integrated application on their smartphones to complete an online study of user preferences [3]. Of this total, 221 (74.16%) were men, and 77 (25.84%) were women. According to the study, 98.9% of participants use Wi-Fi networks, and 74.16% reported using Wi-Fi networks almost often when accessing the Internet and uploading or downloading data. The majority of participants (77.85%) reported that they used only Wi-Fi networks when updating applications on their smartphones, while 14.43% reported using both mobile networks and Wi-Fi to do so.

Likewise, it exposes an example of the 28-day history of mobile data traffic and the Wi-Fi network for a single participant of the study, which is shown in Table 2. A significant difference can be seen in the traffic of data between mobile networks and Wi-Fi, as was the case of our study population in general.

Another research results show that is available to the mobile user to access both cellular and Wi-Fi technologies to unify security policies with EAP- AKA authentication process for all devices that use USIMs [4]. The method of authentication and encryption is the same for both a user accessing the mobile Internet services through a network of 3GPP or non-3GPP access. Also, step by step was detailed the whole process from a user turns on the mobile device to engage the network access 3GPP until it is enabled to interact with a public network either surfing the Internet or a private network with a connection intranet via mobile core. Similarly, clarifies that the proposed solution provides full integration with the mobile 3GPP network, allowing to give a mode convergent access handover without disconnection between access technologies such as (Cell access and vice versa) or between one network (Wi-Fi - Wi-Fi) while maintaining the same IP. Different suppliers worldwide include solutions Wi-Fi Offload own maximizing the benefits and operating costs. Finally, to meet the specific objectives the overall objective in proposing the design of a mobile data network with Wi-Fi complementary Offload solution to data networks UMTS and LTE that will allow decongesting the traffic generated by cell phone users is met redirecting mobile data downloading via a Wi-Fi network.

Table.2 Result of a Traffic Smartphone

ID	Mobile Networks			Wi-Fi Networks		
	Application	***Amount***		***Application***	***Amount***	
	Facebook	507	MB	Android OS	1.31	GB
	Opera	300	MB	Facebook	1.31	GB
	YouTube	29.8	MB	Google Play Store	569	MB
	Google Play Store	28.01	MB	YouTube	396	MB
	WhatsApp	27.45	MB	Messenger	245	MB
	Maps	12.41	MB	Opera	221	MB
	Vecernji list [Croatian national newspaper]	9.75	MB	WhatsApp	25.55	MB
1062014	Google Play Services	7.78	MB	Gmail	19.49	MB
	Messenger	5.56	MB	Vecernji list [Croatian national newspaper]	11.99	MB
	Android OS	5.06	MB	Google Play Services	6.41	MB
	Weather clock	1.76	MB	Video player	5.24	MB
	Skype	1.48	MB	Maps	2.6	MB
	Flipboard	1.44	MB	Google applications	2.3	MB
	Gmail	1.03	MB	Skype	1.02	MB
	Samsung Push Service	779	MB	Private Photo Vault	798	KB
28 days	0.92		GB	4.11		GB

A set of parameters used for typical bandwidths for LTE transmission on the downlink shown in Table 3, where the spacing of the subcarrier is Δ F = 15 kHz [6]. Where they selected 20 MHz transmission bandwidth, therefore the number of resource blocks per frame is equal to 100 RB, for example, allowing a maximum yield of 100.8 Mb / s for 64 QAM modulation. These parameters are used to calculate the demands of users in terms of RBs, knowing only the volume in bytes. Here they noted that the modulation used by each user depends on your level of signal to noise plus interference (SINR).

Table.3 Transmission parameters download

Parameters	Rate
Transmission bandwidth [Mhz]	20
Number of resource blocks	100
OFDMA symbols per 1 ms	14
Modulation symbol rate (Mb/s)	16.8
QPSK bit rate (Mb/s)	33.6
16QAM bit rate (Mb/s)	67.2
64QAM bit rate (Mb/s)	100.8

In other project, results of its degree a solution similar to the research project in progress, but implemented in a shopping mall, as item connection diagram of equipment where pose, the AP 7762-S (Indoor) will be pointed at an angle of 30° and 120° scanning or vice versa as appropriate and AP 7363 (Outdoor) will cover 360 omnidirectional configurations [5]. Table 4 and Table 5 shows design parameters and design results, respectively, arranged by the authors.

They add that for sizing the solution in shopping malls; the following basic data are:

- AP RuckusZoneFlex7363 estimated coverage: omnidirectional, from 30 to 50 meters radio coverage (as environmental conditions).
- Estimated coverage AP Ruckus ZoneFlex 7762-S: 30º and 120º targeted scanning or vice versa as appropriate with an average elevation of + - 20 meters target.
- The Maximum number of clients connected by AP 100 total users.
- The Maximum length of UTP cable to connect the AP with PoE 90 meters.
- Switch PoE feeding.

Table.4 Design Parameters and Results

Design Parameters	
UE/M^2	2
% operator users	30%
% simultaneous users	30%
# UE per AP	100

Table.5 Design Results

Design Results	
Average area of high traffic areas m^2	15000
Total Users/ m^2	30000
Average user x operator	9000
Beneficiary users	2700
Total AP to Install	**27**

The other results of scientific paper disclosed that an LTE network is congested and is expected to see a degradation of services, proportional to the number of users connected to the network will be simulated [8]. Several small cells to which users can connect then installed, and you will see how the system responds. Subsequently, it does the same with the Access Point Wi-Fi and finally shall together both small cells and Wi-Fi AP to evaluate the network. They assume that the reason why LTE and 802.11n be used, as can be seen in Table 6, it is because their parameters are very similar.

Table.6 Comparison of Certain Technical Aspects of LTE and WiFi 802.11n

Parameters	**LTE**	**802.11n**
BW (MHz)	20	20/40
MIMO	SI	SI
Modulation	64-QAM	64-QAM
Maximum Theoretical Download Speed (Mbps)	300	300/600

Another research made a comparison of MADNet's performance against 3G networks when users download and upload data [7]. They also show the results of the two cases separately, characterizing the system, considering the satisfaction of the users, the delays and the load of the network. Fig. 8 shows the main idea of MADNET network.

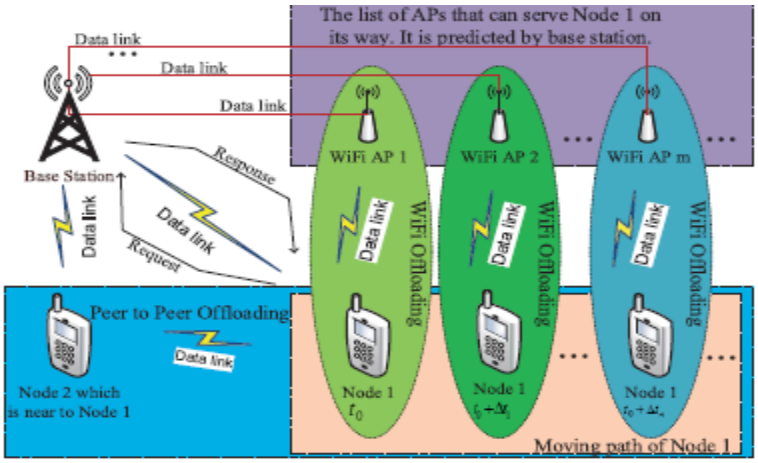

Fig. 8. The main idea of MADNET network.

User satisfaction: defined the satisfaction ratio (SR) to be Rs (t) R (t), where Rs (t) is the total number of satisfied requests (download or upload) at time t, and Ri (t) is the total number of requests made by users at time t. SR also evaluated over time in case of unloading (d0- D12). To improve readability, show only assessments for D0, D2, D8, D3, D9, D6, D12. As shown in Fig. 9, the SR remains stable in each simulation run after two days.

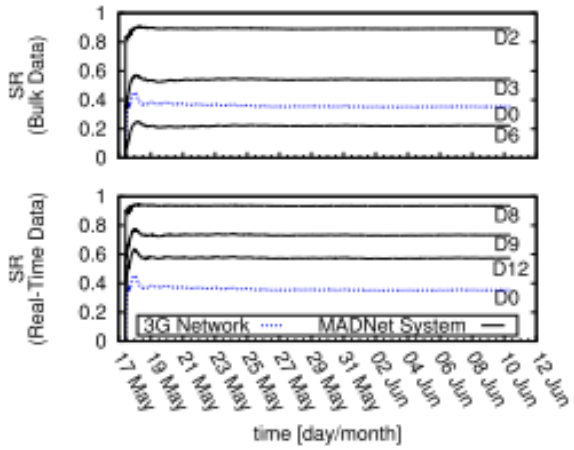

Fig. 9. Variation satisfaction index discharge over time with different configurations.

In the same way, they affirm that, in case of video transmission, the requests are always of greater satisfaction than within the 3G network. Therefore, the implementation of more access points increases the number of requests satisfied. However, such improvement is not directly proportional to the number of access points deployed. For example, the introduction of 41 APs in 3G networks (i.e., D12) increases the SR by 21.49%, while an improvement of 29.46% is obtained by aggregating 82 APs (i.e., D10) in the city. Besides, when implementing many APs (for example, D7), we get a high increase in the average RS of 60.92%, but more than 50% of the APs contribute more than half of the rise. Since the threshold also determines the centrality of the deployed PAs, they conclude that a more significant number of requests can be met through the strategic deployment of the PAs along the central streets of the PA urban area. Similar observations can be made for bulk data. However, in this case, if we implement very few APs (for example, D5 and D6), requests cannot be satisfied with the same proportion as in 3G networks. Despite this, we found that approximately the same satisfaction index of 3G networks can be obtained through 82 APs. Regarding the overall results, they observed that the decrease of the threshold keeps the SR at approximately the same value for both cases. In fact, for a given limit, the presence of cellular networks is the only difference between the two cases. Therefore, they conclude that the implementation of more APs (which are gradually placed in less central streets) makes the RS less influenced by cellular networks.

The entire importance of the Wi-Fi Offloading technique applied to the design proposed by the authors of this scientific article was evidenced in each of the results mentioned above, which will provide all the technical requirements to satisfy and correct the faults found in the network. Wireless and cellular data of the Muvdi Park of the Municipality of Soledad Atlántico.

5. Conclusion

The connections through the cellular data network are in constant growth; likewise, the robustness of the applications demand a higher consumption in the bandwidth. To all this, there is the inadequate infrastructure offered by the current Internet service providers in the country whose existing coverage solutions fluctuate when visiting different parts of the city as seen in the user equipment. Similarly, it occurs in the Muvdi Park, in which the coverage offered by the ISP, as well as the inadequate infrastructure of the current Wi-Fi-public zone, and changes in the quality of the cellular data network service that shelters the center recreational, impede efficient and stable Internet connectivity.

Given the above, a solution was designed using the Wi-Fi Offloading technique, which is adjusted to meet all the current needs faced by the park's internet service. It also allows all visitors to the recreational center not to agglomerate in a single point looking for a connection opportunity and get lost from the other entertainment offered. Thanks to the strategic distribution of access points proposed in the solution, which will provide coverage Total in the different areas facilitating a service availability with greater breadth and reliability that generates a pleasant browsing experience for all users and visitors. In the same way, traffic through the 3G and LTE networks will decrease, offering savings in the use of user data, which will also benefit the providers of the different cellular networks. As future work, it is expected to implement the complete solution in the park and replicate it in other cultural spaces of the city. Another alternative to investigate and enforce Wi-Fi offloading is through SDN, in which through software the handover can be performed between Wi-Fi APs and 3G/4G base stations, as Jang explains in his research [14]. This solution is called FMSDN (Flow Management and Mobile Data using SDN).

References

[1] Xataka Mexico, "H, H+, LTE... ¿Qué significan estos símbolos en la pantalla de mi teléfono?," *Movistar 4G LTE*, 2017. [Online]. Available: https://www.xataka.com.mx/movistar4glte/h-h-lte-que-significan-estos-simbolos-en-la-pantalla-de-mi-telefono. [Accessed: 14-Oct-2018].

[2] M. Wollschlaeger, T. Sauter, and J. Jasperneite, "The future of industrial communication: Automation networks in the era of the internet of things and industry 4.0," *IEEE Ind. Electron. Mag.*, vol. 11, no. 1, pp. 17–27, 2017.

[3] S. Husnjak, D. Peraković, and I. Forenbacher, "Data Traffic Offload from Mobile to Wi-Fi Networks: Behavioural Patterns of Smartphone Users," *Wirel. Commun. Mob. Comput.*, vol. 2018, no. 2608419, 2018.

[4] C. Ferigra, "Proposed design of a mobile data network with WiFi solution Offload complementary to UMTS and LTE networks, allowing to provide internet service to mobile users through a WiFi," Catholic University of Santiago de Guay, 2017.

[5] L. Acevedo, "Designing Wireless solution for downloading data from 3G mobile networks," Santo Tomas University, 2015.

[6] S. Hoteit, S. Secci, G. Pujolle, A. Wolisz, C. Ziemlicki, and Z. Smoreda, "Mobile data traffic offloading Passpoint over hotspots," *Comput. Networks*, vol. 84, pp. 76–93, 2015.

[7] A. R. Pawar, S. S. Bhardwaj, and S. N. Wandre, "Mobile data offloading techniques and related issues," *Int. J. Adv. Res. Comput. Eng. Tech.*, vol. 4, pp. 1367–1371, 2015.

[8] J. M. Koo, J. P. Espino, I. P. Armuelles, and B. Pérez, "Metodología para Evaluación de Técnicas de Data Offloading en una Red LTE," in *Twelfth LACCEI Latin American and Caribbean Conference for Engineering and Technology (LACCEI'2014)*, 2014.

[9] R. R. Pahlajani and G. R. Bamnote, "Mobile Data Offloading the Growing Need with Its Solutions and Challenges," *Int. J. Recent Innov. Trends Comput. Commun.*, vol. 2, no. 3, pp. 678–682, 2014.

[10] S. Dimatteo, P. Hui, B. Han, and V. O. K. Li, "Cellular Traffic Offloading through WiFi Networks," in *MASS '11 Proceedings of the 2011 IEEE Eighth International Conference on Mobile Ad-Hoc and Sensor Systems*, 2011, pp. 192–201.

[11] V. A. Lambert and C. E. Lambert, "Qualitative Descriptive Research: an Acceptable Design," *Pacific Rim Int. J. Nurs. Res.*, vol. 16, no. 4, pp. 255–256, 2012.

[12] Y. He, M. Chen, B. Ge, and M. Guizani, "On WiFi offloading in heterogeneous networks: Various incentives and trade-off strategies," *IEEE Commun. Surv. Tutorials*, vol. 18, no. 4, pp. 2345–2385, 2016.

[13] R. S. Cheng, C. M. Huang, and S. Y. Pan, "WiFi offloading using the device-to-device (D2D) communication paradigm based on the Software Defined Network (SDN) architecture," *J. Netw. Comput. Appl.*, vol. 112, pp. 18–28, 2018.

[14] H. C. Jang and C. H. Chang, "Context aware mobile data offload using SDN," in *2016 26th International Telecommunication Networks and Applications Conference*, 2016, pp. 185–190.