A Framework for Evaluating 5G Infrastructure Sharing with a Neutral Host

Vanessa Vasconcellos, Paulo H. Portela de Carvalho
Universidade de Brasília
Brasília, Brazil
Email: vanessa.vasconcellos@aluno.unb.br, paulo@ene.unb.br

***Abstract*—Infrastructure sharing has been a growing topic of interest in the context of the fifth generation of cellular technology (5G). With the expected Ultra-Dense Networks (UDN), which will lead to a relevant increase in the number of sites, concerns regarding the availability of space for new towers and masts in city centers arise. Also, the capacity of mobile network operators to handle the costs of these networks by themselves assuring the return of investment is put to the test. Neutral hosts appear as a promising solution to this challenge; however, it can be a complex business model. This paper proposes a mathematical model for calculating the benefits of infrastructure sharing, including the scenario with a neutral host, aiming at applying it to a tool-based framework which compares it to other sharing strategies, suggesting the best alternative from the financial perspective. Preliminary results show that sharing with a neutral host can increase savings in comparison to other passive sharing strategies; however, this advantage seems to hold only for a certain range of market share of the involved operators, being also affected by the amount of overlap of the desired infrastructures.**

I. Motivation

The new generation of cellular communications, 5G, is designed to respond to three different performance scenarios: enhanced mobile broadband (eMBB), ultra-reliable low latency communications (URLLC) and massive machine type communications (mMTC), according to The 5G Infrastructure Public Private Partnership (5GPP) [1]. Current networks are not ready to handle this traffic heterogeneity, the reason why new solutions must be proposed [2]. An approach for eMBB that has gained attention is network densification with the deployment of small cells [3], forming ultra-dense networks (UDNs).

Implementing 5G UDNs can be a very challenging task. This type of network is usually necessary to increase capacity in already crowded spaces as it is the case for dense city centers. In this context, mobile network operators (MNOs) probably deal with lack of space for the infrastructure, absence of electricity, and even fiber unavailability for back-hauling [4]. Also, with the decreasing tendency of revenues per bits of the later years [1], investing in network expansion to attend demand could be a burden to MNOs, especially to those with smaller portions of the market share (MS).

Infrastructure sharing appears as a solution for the lack of available resources (e.g. space and energy), and risks related to expansion costs. It consists of an agreement of two or more operators to mutually exploit existing or new network infrastructure, while fairly splitting deployment costs. Shared assets can be passive or active, depending on the resolved deal among involved partners.

A particularly interesting approach for sharing [4] for the special case of UDNs is sharing through a neutral host (NH). A neutral host is generally a third party, which offers its infrastructure for the benefit of multiple operators or any interested stakeholders. It shows to be promising in the context of dense networks especially because of the space-related issues, as it proposes a single network to attend the demand of multiple carriers.

In the context of 5G, more attention should be given to service differentiation and in [5], it is even possible to see a separation between the infrastructure and service provision on the services architecture imagined for the next generation. This raises the question as to whether an operator will continue to play both roles in the next few years.

Business models already including an NH appear in [4],[6], and given its rising importance, it will also be the topic of interest in this research. The framework idea that appears in [7] is used as the foundation of the study. The neutral host scenario is chosen as the infrastructure sharing strategy and compared to passive site sharing between, with varying combinations of MNOs. The addition of the neutral host model and the comparison of this type of infrastructure sharing to other passive sharing approaches is the main contribution of this work since the benefits of NH are rarely compared to other infrastructure sharing strategies in literature. Vila Olímpia region in São Paulo is chosen as a case of study to test our approach. As a business center of one of the biggest metropolis in the world, it is expected to develop multiple UDNs in a crowded scenario, where infrastructure resources are a scarce - a perfect fit for infrastructure sharing, especially with a neutral host.

The paper is structured as follows: Section II introduces the neutral host figure approach. Section III presents a complete framework used for evaluation of sharing through a neutral host business model and section IV shows the results of the analysis. Section V discusses preliminary results and suggests next steps.

II. Neutral Host

A neutral host is a business model (BM) that consists of a third party acting as owner, operator, and maintainer of a unique network infrastructure designed to attend the needs of

ISSN 2305-7254

multiple operators. This BM is generally adopted to resolve poor wireless coverage and capacity inside large venues or other busy locations, as it is the case for ultra-dense networks [3].

The greatest advantage of a neutral host is the fact that its main service is the infrastructure itself, which means that its only goal is to distribute the fixed costs of installations over as many operators as possible, in contrast to MNOs, which use them to seek competitive advantage among each other [10]. In addition, when only a single network is built, wastage of resources is avoided and space is used optimally, reasons why it is mostly used for UDNs.

Although very beneficial, neutral hosts business models can also be very challenging, especially when active resources of the network are also shared. In this case, spectrum concerns are raised and regulation might appear as an obstacle to allowing their implementation [3].

In this paper, our focus is given to passive infrastructure sharing only and the impacts of different operator market shares and area overlap are evaluated. The next section introduces the framework utilized for performing this study.

III. Solution Approach: A framework

This Section introduces our solution approach for evaluating the best fit for infrastructure sharing: a framework to dimension the network and to calculate resulting costs depending on the sharing approach. This framework idea appeared in [7], but now much detail was given to the Neutral Host model, neither, it is possible to test different combinations of partnerships among operators, varying the number of involved MNOs. Finally, the model did not took into consideration the market share of the MNOs to define the fair contribution of each to a sharing deal nor a very important technical condition for joint dimensioning, which is the overlap of the coverage area. The approach taken in this study fills these gaps and its structure is presented in Figure 1.

As Figure 1 shows, the first step of the framework is to dimension the required network - RND in the figure, meaning radio network dimensioning - to attend the coverage and capacity requirements. Those criteria are calculated operator-wise. To perform RND, we used the simulator found in [15] which gives the number of macrocells and microcells as an output for one MNO at a time, something we intend to modify in the future.

The next step is to calculate the possibilities for sharing considering deals among MNOs. The ”No sharing” block results are used as a baseline for calculating the savings, reason why those blocks are connected in the framework. Is is possible to see that multiple databases appear in Figure 1. They add to the framework the current situation of the infrastructure (if necessary), the expected demand, and finally the infrastructure costs found in [7]. Also, the path loss characteristics of section used for RND assume particular values in the context of 5G, the reason why the document ”5G specifications” [7] is highlighted.

Savings/km^2 obtained from sharing infrastructure are calculated. It is assumed that an operator shares with 1 to K operators (K being the total amount of MNOs in a giver region) and when all the operators agree on a single contract for sharing infrastructure, we consider this to be the scope of the neutral host.

The last block is exactly the update on savings where the costs model for sharing is replaced for the NH model. This step is necessary to assure that replacing a model of sharing among all MNOs by a neutral host is really safe; also, depending on the costs model presented by this third party offering infrastructure might be even more advantegous. The specifics of this block are under development at this moment, so we focus on modelling savings for the regular sharing approach.

For setting a sharing deal, some attributes must be considered. First it is necessary to understand whether an MNO will share macro or microcells. Macrocells are applied to attend coverage demands, being therefore related to the area where the MNO will install its infrastructure. Considering infrastructure sharing, two operators will only share macrocells when their areas of coverage overlap. So we define a coefficient λ to represent this amount, as in equation (1):

$$lambda_k = \frac{Area(C_{K,S})}{\sum_s Area(MNO_s)} \tag{1}$$

in which s represents the infrastructure sharing strategy index and k the MNO. Considering K MNOs involved in the deal, it can be assumed that $2^(K-1)$ different combinations from 1 to K sets of MNOs are available [17]. This combinations are represented by $C_{K,S}$ and the combined area of these MNOs appear on the numerator as $Area(C_{K,S})$. On the denominator, we find the sum of the areas of the MNO_k participating on the sharing deal. Finally, λ represents therefore overlapped area related to the total area of the MNOs involved on the agreement, considering that only that partial amount of the infrastructure should be shared.

For the case of microcells, they are usually applied to solve capacity issues [12]. being therefore related to the market share of an MNO in a given area. To decide the portion of these cells that should be shared, we define a coefficient γ, given by equation (2).

$$gamma_k = \frac{\mu_k Area(C_{K,S})}{\sum_s Area(\omega_s MNO_s)} \tag{2}$$

In equation , μ_k represents the market share of operator k. It calculates the number of users from operator k that area inside of the overlapped area and provides the fair portion of the costs that should be attributed to operator K in case of a sharing deal S. Given this equation and , we estimate the infrastructure costs as in (3):

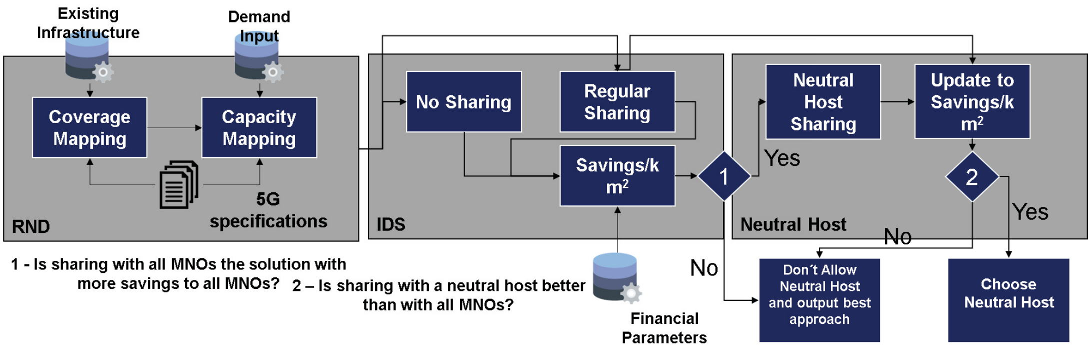

Fig. 1. Neutral Host Framework

$$Costs_{MNO_k} = \lambda_k * Unit_{Costs_{macrocells}} * Infra_{shared} + \gamma * UnitCosts_{microcells} * Infra_{shared} + UnitCosts_{macrocells} * Infra_{not_{shared}} + UnitCosts_{microcells} * Infra_{not_{shared}} \quad (3)$$

IV. Preliminary Results

A. Vila Olimpia Region

Vila Olimpia is a financial center in the city of São Paulo in Brazil. It is composed of a large business area but also of a residential quarter. It was chosen as a scenario for illustrating UDNs due to its characteristics of high population density and relevant economic development, matching the criteria for dense 5G networks.

The infrastructure required for this area is calculated by means of the simulator found in [15]. Users are considered to be uniformly distributed in the area. Table I shows the results:

TABLE I. Radio Network Dimensioning Results

Site	Amount	Site	Amount
Macrocell (3.5 GHz)	1	Microcell (26 GHz)	3

As seen in Fig. 1, some inputs are required to evaluate the capacity and coverage needs, they appear in the form of a document in this figure. Parameters used on the simulation are found in Table II.

TABLE II. Region and Network Features

Street width	10 m	Indoor users	70 %
Macro station height	30 m	Building heights	10 m
Area	2.1 km^2		

This information will serve as input for calculating the benefits of sharing strategies in the later Sections.

B. Results for Two Operators

In this section we present the results of applying the framework to a scenario of two MNOs considering the geographic data from Vila Olimpia as a base case to illustrate the costs behaviour with (a) market share and with (b) area overlap.

Fig. 2 show the results of varying market share, showing three scenarios: equal area overlap, greater portion of area of MNO A overlapped with area of MNO B, greater portion of area of MNO B overlapped with area of MNO A.

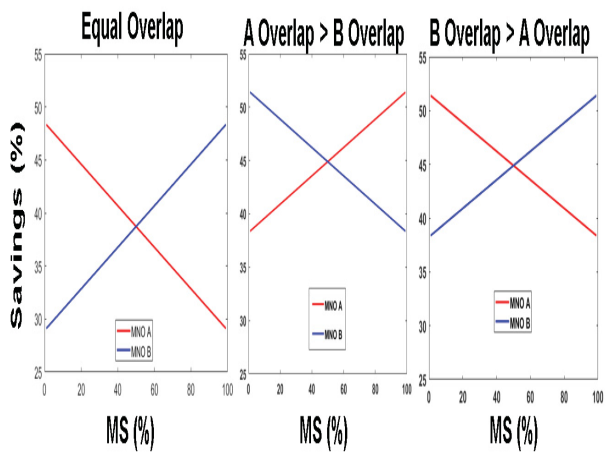

Fig. 2. Savings Behaviour with Market Share - From left to right: equal overlapped area, greater overlap in A, greater overlap in B

It is possible to observe that when both areas are equal, the savings range varies among a greater interval, if compared to the interval of variation for different areas. On the other hand, if areas differ, the common saving when market shares are equal is greater than for the symmetrical case.

Fig. 3 show the results of varying area, keeping the market share static.

When market share is kept static, for the same overlap there is obviously the same gain. When overlap increases, the MNO with lower market share is more benefited since it pays for a smaller portion both of the microcell and infrastructure.

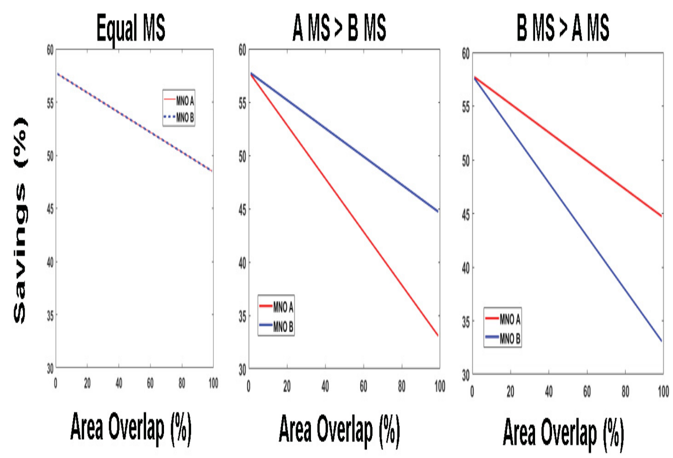

Fig. 3. Savings Behaviour with Overlap - From left to right: equal market share, greater A market share, greater B market share

The results in 2 are directly related to the microcells while the results in 2 are more related to macro cells. We see that the main cost component is the later, since sharing it can result in more savings than comparing to the microcells. This is because usually, this infrastructure is more costy [13].

Assuming that a deal with both MNOs would be suitable for a neutral host, we conclude that the deal can benefit one operator more than the other. However, it always brings savings, so the first insight would be that this deal will always be a good business model.

In the next section, we present the results for the study case in Vila Olimpia, checking whether this would be the same for a larger number of MNOs.

C. Results for Vila Olimpia Case of Study

The case of study in Vila Olimpia contemplates four MNOs sharing the greatest portion of the cellular communications market. They are referred to as operator A, B, C, and D. Their market share is shown in Table III for the city of São Paulo. These values were extracted from the brazilia regulatory body website.

TABLE III. MNOs Market Share in S ˜ao Paulo

Operator	Market Share
MNO A	42.7 %
MNO B	24.2 %
MNO C	22.5 %
MNO D	9.3 %

Applying equations 1-3 for calculating the costs and calculating the savings using the baseline as a reference, we get the results of IV.

Once again, the strategy that brought the highest benefit was the Neutral Host. On the other hand, the difference among other strategies is not expressive, and maybe if the areas

TABLE IV. Savings from Multiple Sharing Strategies

Share Strategy	2 MNOs	3 MNOs	4 MNOs (NH)
MNO A	48.62 %	53.69 %	56.21%
MNO B	44.47 %	49.10 %	51.42 %
MNO C	44.03 %	48.62 %	50.91 %
MNO D	40.11 %	44.28 %	46.37 %

overlap is changed for one or more MNOs and therefore the market share varied, different results are collected. Also, we see that the expected behaviour of benefits vs market share does not repeat what was seen for two MNOs in Figure 2, rather the opposite, since the MNO with the lowest market share is actually the one which collects least savings with sharing.

Considering these insights, one might find that the neutral host is not the stage of equilibrium for the sharing agreement, nor that the same behaviour always applies to market share vs savings and area overlap vs savings, it depends on both. In the continuity of this work, this topic will be further explored with more attention given to this issue, with the aid of game theory tools.

V. Conclusion

In this paper, a framework for calculating network costs with different approaches for network sharing deployment is shown, giving as output the resulting expenditures by MNO involved in the sharing agreements. A scenario of even distribution of users was chosen.

The study considered that a sharing agreement among all MNOs in a given region should be replaced by a neutral host and results suggests that this business model may not always be the best fit to all MNOs.

The analysis was focused on the financial aspects of passive infrastructure sharing; however, technical and regulatory perspectives of this strategy are also of main importance. Also, even distribution of users is not always the real case for sharing agreements. In addition, active infrastructure sharing is of great importance in the context of 5G. We suggest these topics should be included in future works.

References

[1] Colin and Forge, Simon, ”5G Deployment State of Play in Europe , USA and Asia”, p.7-26, 2019.

[2] Shafi et al, ”5G: A tutorial overview of standards, trials, challenges, deployment, and practice”, IEEE journal on selected areas in communications, v. 35, n. 6, p. 1201-1221, 2017.

[3] GSMA, ”Infrastructure Sharing: An Overview”, 2018. Accessed: Aug. 02, 2020. [Online]. Available: https://www.gsma.com/futurenetworks/wiki/infrastructure-sharing-an-overview

[4] Colman-Meixner, Carlos, et al. ”5G city: A novel 5G-enabled architecture for ultra-high definition and immersive media on city infrastructure.” 2018 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB). IEEE, 2018.

[5] Redana, Simone et al, 5G PPP Architecture Working Group: View on 5G Architecture, 2019.

[6] Ahokangas, Petri, et al. ”Business models for local 5G micro operators.” IEEE Transactions on Cognitive Communications and Networking 5.3 (2019): 730-740.

[7] Oughton, Edward J., et al. ”An open-source techno-economic assessment framework for 5G deployment.” IEEE Access 7 (2019): 155930-155940.
[8] Maternia, M., and S. E. El Ayoubi. ”5G PPP Use Cases and Performance Evaluation Models”, version 1, 2015.”
[9] CISCO, ”Cisco Annual Internet Report”, The Annual Internet Report, 2020.
[10] Frisanco T, et al, ”Infrastructure Sharing and Shared Operations for Mobile Network Operators”,2008
[11] El-Beaino, Wissam, Ahmad M. El-Hajj, and Zaher Dawy. ”On Radio network planning for next generation 5G networks: A case study.” 2015 International Conference on Communications, Signal Processing, and their Applications (ICCSPA'15). IEEE, 2015.
[12] ITU, ”ICT-Infrasctrucute tool kit”, 2018
[13] GSMA, ”Enabling Neutral Host”, 2018
[14] BEREC, ”Report on Infrastructure Sharing”, Report, 2018.
[15] E. J. Oughton. (Sep. 16, 2019). Python Simulator for Integrated Modelling of 5G (Pysim5g). Accessed: Aug. 12, 2020. [Online]. Available: https://github.com/edwardoughton/pysim5g
[16] Oughton, Edward J., and Zoraida Frias. ”The cost, coverage and rollout implications of 5G infrastructure in Britain.” Telecommunications Policy 42.8 (2018): 636-652.
[17] Cano, Lorena., et al. ”Cooperative Infrastructure and Spectrum Sharing in Heterogeneous Mobile Networks” IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, Vol 34, NO. 10, Oct 2016: 2617-2629.
[18] ANATEL. Operators Market Share in Vila Olimpia. Accessed: Oct. 10, 2020. [Online]. Available: https://https://www.anatel.gov.br/Portal/verificaDocumentos/documento.asp?numeroPublicacao..filtro=1documentoPath=275706.pdf