A verification plan to assess the quality of mobile telephony in Brazil

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Introduction

Brazil has more mobile chips than its inhabitants. There are 242 million smartphones in use in Brazil and 217 million inhabitants [1]. 75% of Brazilian production is transported by road [2]. And less than 10% of federal and state highways have a cellular signal. The country records more than 18,000 cases of cargo theft on highways per year [3]. With the start of operations in the 5G frequency in 2022, the expectation is that the 4G signal will cover 100% of the highways only in 2029 [1].

Main Idea

With 90% of the population having internet access [4], it is essential to know the quality of this access. For this, we created a verification plan with the following cases:

1. What is the disconnection rate within closed environments, such as shopping malls?
2. On the journey by car, what is the condition of the signal?
3. Within schools, what is the quality of the signal?
4. What is the interference rate on dates with a large flow of people and vehicles, such as national holidays or New Year's Eve?
5. What happens if: Your car has an electrical fault in the middle of the road at night or you need to change a tire?

We evaluated the transit route between the City of São José do Campestre and Natal (fig.1) over a year, which allowed us to raise hypotheses and test scenarios. The São José do Campestre and Nova Cruz route (fig. 2).

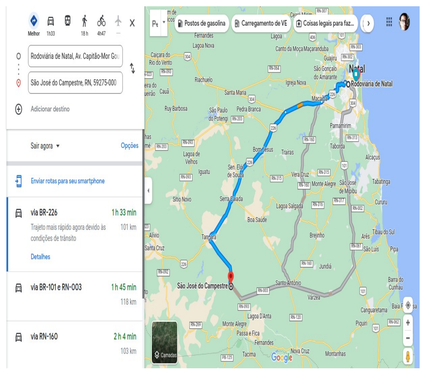

Fig. 1: It shows the distance between cities and the average time spent under perfect conditions.

Among the cities shown in Figure 1, we have more than one million inhabitants. Near the center of the image is a large road crossing, where heavy vehicle traffic. Where there is more traffic, there is no signal. In March of this year, 48 municipalities were targets of attacks, with invasions and explosions of cars and buildings.

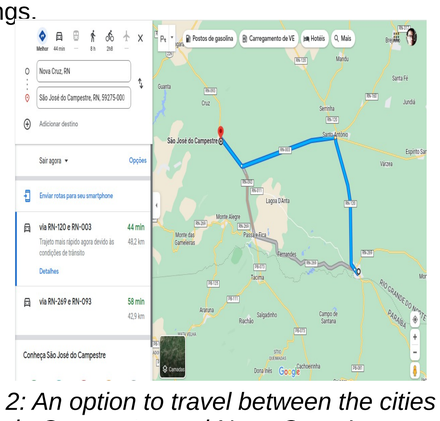

Fig. 2: An option to travel between the cities of São José do Campestre and Nova Cruz. In gray, we have the route made by bus.

Test Methodology

When a problem affects a person, we can consider it as a case. When it involves two people, we have a recurrence. When millions are impacted, there are several ways to quantify that impact. One is looking at consumer defense portals, as shown in Figure 3. We can see that among the primary sources of complaints in Brazil, four of the top five positions are occupied by mobile phone companies.

The reason behind these numbers is the object of study of this paper. There is in Brazil a regulatory agency for telecommunications, ANATEL. One of the obligations of companies is to show the coverage of their signal. The companies in the table shown in Figure 3, in positions: 1,2,3, and 5, are the largest telecommunications companies in Brazil, both in cable and mobile internet [5]. They claim that they serve 97% of the population of Brazil [6], but how is this possible if: less than 10% of the roads are covered by the 4G signal and within covered cities, there are uncovered spots, which we call blind spots?

01	Oi Fixo/Celular	49.404
02	Claro / Embratel / Net / Nextel	43.373
03	VIVO/ TELEFONICA /GVT	40.842
04	BRADESCO	32.106
05	Tim / Intelig	31.476
06	BANCO PAN	27.775
07	ITAÚ	27.328
08	BMG	18.077
09	Banco Santander	17.482
10	Caixa Econômica Federal	17.234

Fig. 3: We present the ranking of companies with the most complaints in Brazil. Next to the average rate of complaints per month in Brazil. Positions 1,2,3, and 5 belong to telecommunications companies [5].

Having known the problems closely and following the statistics, the first hypothesis was: to find a test to evaluate the quality of the service, but we didn't find one. Then came our first test using UVM[7]. The verification plan was created so that it would be possible to evaluate contexts and usage scenarios, UVM was chosen because it easily allows functions made in C/C++ to be easily connected with SystemVerilog (figure 4), and thus we would have the possibility to test hardware and software, in different levels of abstractions, including the use of PSS.

```
129     virtual function void pack_ptp_header_with_options(uvm_packer packer,
130             bit local_pack_transport_specific,
131             bit local_pack_message_type,
132             bit local_pack_ptp_reserved_1,
133             bit local_pack_version,
134             bit local_pack_message_length,
135             bit local_pack_domain_number,
136             bit local_pack_ptp_reserved_2,
137             bit local_pack_flags,
138             bit local_pack_correction_field,
139             bit local_pack_ptp_reserved_3,
140             bit local_pack_source_port_identity,
141             bit local_pack_sequence_id,
142             bit local_pack_control_field,
143             bit local_pack_log_message);
144
145         if (local_pack_transport_specific) begin
146             `uvm_pack_enum(transport_specific);
147         end
148
149         if (local_pack_message_type) begin
150             `uvm_pack_enum(message_type);
151         end
152
153         if (local_pack_ptp_reserved_1) begin
154             `uvm_pack_array(ptp_reserved_1);
155         end
```

Fig. 4: UVM Packet (adaptation).

The first test tested the mobile phone signal oscillation in a building with 60 rooms divided into six corridors; the rooms in the third and fourth corridors would have the same connectivity as the first and last broker, more external, and with access to the street. UVM allows the models used to be tested with different frequencies. Our model used frequencies compatible with 4G in Brazil, and the results were: the middle rooms had the worst performance; on average, the connectivity rate dropped by 17%, and among the corridors, the third and fourth corridors had a difference in level, they were four meters below the story of the first corridor. From the fourth to the first runner, the difference reached, in the worst case, 76% in the tests. The building in question is a technical school where no one understood why cell phones oscillated and with high frequencies were out of range in the rooms on the fourth corridor. The building's own Wi-Fi was poor at this point.

As it is a technical school, it was proposed that students investigate the case. To confirm that the test was efficient in its calculations. Figure 5 shows 4G coverage in the city marked as the starting point in Figure 1. The colors indicate 100% coverage in the town, but this is false [6].

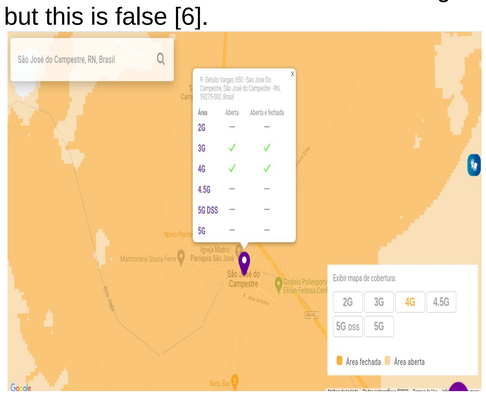

Fig. 5 According to VIVO's coverage page, the city is covered by 4G throughout, as shown by the orange tone [6].

If the city is covered in its entirety, why is the downtown hospital is there no connectivity within the wards or corridors? Because the signal is terrible in schools, or does it not work in some spaces? Because even the houses are closer to the city center, the tower is in the upper part, and the center is in the lower part of the city. Why is the signal not 4G inside the houses? Tests created in UVM using DVT[8] indicated that the signal frequency was lower than promised. The average download speed found was below 2Mbps, different from the rates that operators legally deliver. The download rate that operators claim to enter is seen in Figure 6 [9].

Claro	70,1%	18,3 Mbps
Vivo	**64,6%**	**14,2 Mbps**
TIM	60,3%	12,7 Mbps
Oi	43,3%	8,8 Mbps

Fig. 6 The download rate promised by the largest telephone companies in Brazil is associated with the percentage of signal quality.

The slightest difference between the test download rate and the rate promised by the operators was 4x, and the highest rate was 9x higher [9]. We try to broaden the view of the range of the signal. Figure 6 shows the exact route shown in Figure 1. However, you can see the 4G sign on the way, and what we saw is that the dark blue part indicates connectivity, and the white amount has no signal [10].

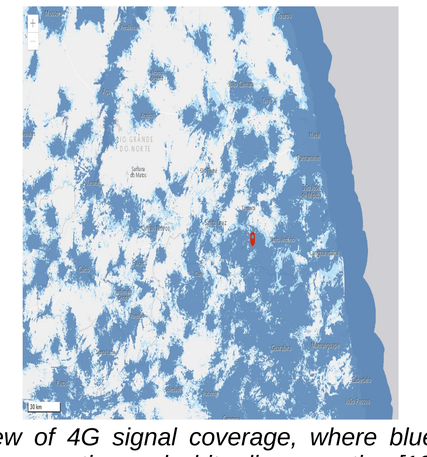

Fig 7 View of 4G signal coverage, where blue color indicates connection and white disconnection [10].

How can it reach 97% coverage of the population without having the same percentage of the range of the territory? Analyzing Figure 7, this inconsistency can be seen.

Results

The software results indicated that it would not be possible to watch the video in the room in the center of the building. The disconnection rate on the route between the cities shown in Figures 1 and 2 was estimated at 84% of the way. And Uber would only be triggered moving away from the crowd. With these results, we tried reproducing the tests using smartphones and just running the tasks. And we confirm the tests [11].

Taking the route inside a bus between the points indicated in Figures 1 and 2 and trying to send instant messages through tools such as WhatsApp, there was no signal for 84% of the trip. The roads cut through cities and grew along the edges of these roads, yet part of the distance is entirely white, as shown in Figure 7. This means that 84% of the route does not have a sign. With the negative results [12], we sought justifications from the operators, and their responses can be summarized in one sentence: “areas of low population density are discovered, so on intercity trips, it is common that there is no connection. At the end of the year, we expanded our operations, but we could not meet the abnormal demand”.This justification cannot be accepted, as the airport serves more than 2 million passengers and is in a region with no signal or poor signal.

Conclusions

The use of UVM proved to be a powerful tool for tests involving frequency and download rates. With the collected results, we propose test models, naming them rupture and shock tests or even explosion tests by profoundly altering ideal conditions by addressing worst-case and best-case possibilities. In the group of these tests is the rupture test, which analyzes the impact of the delay found in transmitting messages with the found signal frequencies. It is considering two-factor authentication tools. First in its expiring code model and second in its expiring token model. The second was a proposal for future work. Our tests are advancing in analyzing the functioning of two-factor authentication [13] applications on smartphones connected to 4G and 5G. And at a lower stage of analysis, the difficulties that evaluate the generation of tokens as validation of authenticity, a method used by finance companies and health plans. In preliminary tests, the failure rate was nine for every ten tickets generated in closed environments such as hospitals. Creating an alert, as this type of tool, is used to authorize medical procedures, including urgent ones. We are working on developing these tests.

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