Assessing Quality of Experience while comparing competing mobile broadband services from the user perspective

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Abstract. The growth of mobile traffic is exploding globally, and users can already choose their best smartphone or tablet options from a handful of manufacturers based on specific criteria such as price and usability. It is much less clear when the user needs to pick from various mobile broadband service providers when choices are available. After all, how does one know what is the best provider for a given usage profile? This work uses drive tests to investigate the variation of radio frequency conditions and relate them to the quality of experience from the viewpoint of the user.

1. Introduction

Everything is going mobile. This evolution is driven by video, cloud-based services, the internet and machine-to-machine (M2M) connectivity. Access to the internet is a prerequisite and will drive further build-out of mobile networks. By 2017, an astonishing 85 percent of the world’s population will be covered by 3G networks while 4G ramps up its global deployment [1].

This work focuses on studying different sources of information to develop objective tools users could leverage to find out about the mobile broadband service offered by different providers in a given geographical area. Therefore, it looks for relevant information made available by modems, tablets and smartphones with the purpose of letting users make a more educated guess of what operators could better provide service in the areas where people live, work or just entertain themselves.

2. Relevant technology components

When planning a new one or optimizing a network already in production, mobile broadband providers have to rely on a small set of radio frequency parameters to establish whether a given geographical region meets the target service level. And it is common practice to rely on parameters that measure signal strength, interference and link quality [3][4].

The first one is signal transmit power, which establishes how far out any information coming from the radio station will propagate. The second is signal interference, which depending on the cellular technology considered may be caused by the other cell phones and modems in the service area.

When considering HSDPA, other parameters like channel quality may be of importance. HSDPA requires user equipment to compute a metric known as Channel Quality Indicator (CQI), which represents the status of the radio frequency conditions in a given moment. It is important to note that
The CQI is a metric computed at the user equipment and sent in the uplink to the radio station and user for the optimization of the packet scheduling policy chosen by the operator. As opposed to RSCP and Ec/Io, which are metrics associated with the entire cell, the CQI is a representation of the unique view from the perspective of the user. This indicator is also a parameter computed by user equipment and used also in LTE networks as an input for packet scheduling [2].

![Multiple cellular radio stations](image)

**Figure 1.** Multiple cellular radio stations

The diagram in Figure 1 shows a simplified example of a WCDMA/ HSDPA network with 3 distinct cells A, B and C, with an overlapping area Z. This diagram can be seen as a snapshot reflecting mobility and radio frequency conditions in a given moment in time.

All things being equal, and if the backhaul linking all three base stations to the core of the service provider have equivalent capacity, the best broadband experience tends to be the one for the user equipment in cell B. For this particular case, the Received Signal Code Power (RSCP), the usual signal strength metric for WCDMA-based networks, is expected to be ideal given the close range to the base station antenna.

Furthermore, this same user equipment is located into a cell with very few other devices: in this particular scenario, there is only the device in area Z. This device is thus less prone to suffer phone-based interference, which is a fact peculiar to WCDMA or any other technology where mobile phones and modems use the same frequency to communicate simultaneously. In WCDMA terminology, the status of signal and interference is frequently measured by the ratio of the received signal code power (RSCP) divided by the total received power (RSSI) in the channel bandwidth (Ec/Io) [3].

As mentioned above, HSDPA requires user equipment to compute a metric known as Channel Quality Indicator (CQI) which is a measurement of the state of radio frequency conditions on the downlink channel (from base station to user equipment) in a given moment. In a scale that ranges from zero to 30 (zero being the worst possible condition), the device computes this indicator based on the probability to transmit successfully with a high throughput to the base station it is associated with in a particular instant. After receiving this information, this measurement is used by the base station to...
make proper scheduling arrangements, assigning more resources to the devices with a better detected radio frequency condition.

3. Related Work
In the United Kingdom, the Office of Communications (Ofcom), the national regulatory agency, has been working with broadband service assessment for some time. As for mobility, a detailed study of nationwide mobile broadband service has been done by the agency, combining the subjective perception of service by the users with the objective evaluation of periodic automated tests [6].

These objective tests included software-based probes, static hardware probes and vehicle-based tests with smartphones collecting measurement data while moving in a geographical area. Ofcom has recently issued a request for input to its efforts on assessing the quality of mobile broadband, indicating it considers important to take the initial study further [6]. In the United States, the Federal Commission of Communications (FCC) is also observing closely how the industry evolves, with a focus on the state of market competition, as part of its annual reports to the American congress [7].

In Brazil, Anatel, the national telecommunications regulatory agency, and Inmetro, a government agency for standards and technology, teamed up with CGI.br, the Brazilian Internet governance body, to assess fixed broadband service [8]. This initial effort on assessing broadband at a national level has provided the necessary feedback for Anatel to issue new regulation with regard to managing quality in mobile broadband [9]. This regulation requires operators to constantly monitor download speeds, which must not be on average less than 60% of the advertised speed. Unfortunately, the rules do not require operators to make public the state of radio frequency parameters during drive tests, so that academic research could help users understand better in what conditions data was collected.

Figure 2. An application performance valley
4. Methodology
With the purpose to study how radio frequency parameters affect application level performance, all application measurement sessions were processed as to find a sequence of performance valleys. In this context, a valley of interest "v" is composed of a limited length sequence of samples, marked by the starting and ending sample, respectively denoted by the "s" and "e" in Figure 2.

A valley considered of interest has a maximum time window from the start to the end sample, lasting usually a few seconds. It is composed of two sections: a) the initial section where the application level metric decreases from the starting sample "s" all the way to the sample with the lowest performance value, denoted by "v" and b) the section with a gradual increase from sample "v" to sample "e". Also, a valley will only be accepted if the application performance at sample "s" differs from "v" at least by a given percentage (Δ1).

Furthermore, it is only accepted as a valid valley if performance at "e" is better than "v" by a given minimum percentage (Δ2).

5. Description of the Experiment
Located between the mountains and the sea, Rio de Janeiro is a challenging urban area to plan wireless services for. Specifically two areas in town were chosen due to its peculiarities. The first is the surrounding area of a lake in the southern section of Rio de Janeiro, known as "Lagoa."

The second area used for drive tests was the route that links two of the largest sports arenas in the city of Rio de Janeiro. In a stretch of an approximate 15-mile (22 km) round trip drive, this particular road crosses a residential area of middle class inhabitants that starts at the Maracanã stadium and ends at the Engenhão stadium. These are two of the most important venues of the upcoming sports events to be held in Rio de Janeiro, most importantly the Summer Olympics 2016.

The equipment used for the drive test data collection process was a SwissQual Diversity Benchmark, with a 3G spectrum analyzer [5] operating in the frequencies of 850 Mhz and 2.1 Ghz. The particular model used is equipped with 4 independent Intel Core 2 Duo 2 Ghz units with 2 Gb of RAM each, running Windows 7 Professional. Each unit is capable of starting and managing tests for one individual 3G service provider, for a total of four simultaneous possible tests. Each test unit is connected to a WCDMA/HSPA+ 850/2100 Mhz Sierra Wireless AirCard USB 308 modem. This particular model is of Category 14, and its maximum throughput is 21 Mbps.

FTP download was the application used as a reference for user experience of the perceived quality of service. The dedicated FTP server acting as the repository for file downloads is located in a datacenter. It is in a controlled environment with a 10 Gbps Internet link and dedicated computational resources enough to hold hundreds of simultaneous FTP sessions.

6. Results
The analysis of data collected during drive tests was broken down into a sequence of valleys of interest as defined above. By observing the defined reference values for RSCP, Ec/Io and CQI, it was possible to match cases where the performance drop coincided with a turn to the worse on any one of these RF parameters alone or in combination.

The reference values are set so that any occurrence of signal strength (RSCP) below -100 dBm is considered to be a possible cause for performance drops on FTP downloads, given a weak signal scenario.

Any occurrence of Ec/Io of -12 dB or smaller is considered an obstacle to good performance due to higher interference. And finally any occurrence of CQI equal to 14 or less is considered as a possible reason for the performance decrease.

Figure 6 shows a breakdown of possible causes for performance valleys for the drive tests we have done for each of the four major mobile broadband service providers. It holds an interesting finding that is associated with all four service providers studied in the drive tests. As shown by the dark blue bar in the graphs, a significant proportion of the throughput drops is not associated with any of the three radio frequency parameters considered.
In the cases where none of the radio frequency parameters could be seen as possible causes for the speed decrease events, an excessive load on either end of the FTP test sessions could be a possible cause. But since all caution was used at the communication endpoints, either the backhaul connecting the radio station to the core network of the service provider cannot handle the aggregate traffic of all radio stations in the geographical area, or the core itself needs to adjust better to the traffic coming from the mobile broadband users.
7. Conclusion
In this work we have presented components of mobile broadband technology and introduced the radio frequency parameters that best measure parameters with important impact on user experience, that is, signal strength, interference and channel quality.

In this particular set of drive tests, all mobile service providers have shown application performance problems even when all radio frequency parameters are at adequate levels. This implies that even when service coverage is adequate, there is no UMTS cell oversubscribing and the user acknowledges a crystal clear wireless channel, our FTP download speeds suffered in performance at least 30% of the cases. This observation suggests limitation in the backhaul or in the network’s infrastructure in the areas where the drive tests occurred.

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