A Statistical Framework to Monitor the Quality of Service in Mobile Networks

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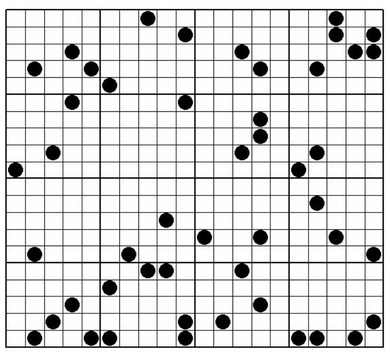
1. Background

- Foster competition in telecom through regulation → minimum standards for QoS
- There are not yet normalized technical specifications or recommendations targeted for regulators
- Res. 95 (Hammamet) ITU → references to create national measurement frameworks, strategies & testing methodologies to monitor QoS → guidance to regulators
- Representative samples are needed to produce QoS monitoring results at a national level

2. Statistical modeling approach

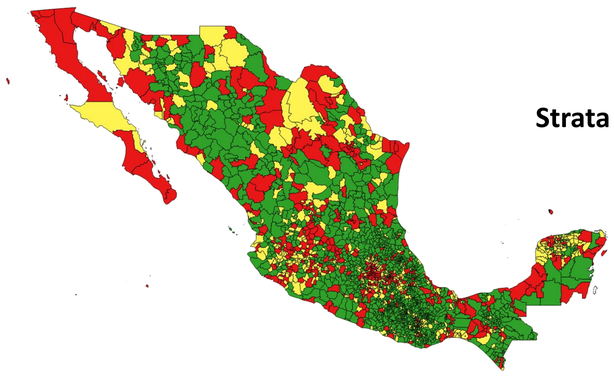
- Two-steps model:
- First step:
  - Stratified Random Sampling
  - Select the geographical locations to be measured in the country

- Second step:
  - Simple Random Sampling
  - Determine sample size for each of the geographical regions



3. Stratification

- Construct the strata by selecting non-overlapping groups from the geographical regions in the country
- Stratification is used to produce a smaller bound on the error of estimation than would be produced by a simple random sample of the same size alone



Strata : Municipalities { **Urban**, **Suburban**, **Rural** }

- Mexico is divided into smaller geographical regions called municipalities which are classified into the strata according to the population:

Urban ≥ 15 000
2 500 ≤ Suburban < 15 000 inhabitants
Rural < 2 500

- Determine the number of municipalities to be measured every year:

$$n = \frac{\left(\sum_{i=1}^{L} N_i \sigma_i\right)^2}{N^2 D + \sum_{i=1}^{L} N_i \sigma_i^2}$$

$$n_i = n\left(\frac{N_i \sigma_i}{\sum_{i=1}^{L} N_i \sigma_i}\right)$$

$$i = 1,2,3$$

Where:

L = Total number of strata (L = 3);
σ_i= expected standard deviation for stratum i;
N_i = number of municipalities en each stratum;
N = total number of municipalities;
$D = \frac{B^2}{4}$, where B is the bound on the error of estimation;
n_i= total number of municipalities in stratum i, and
n = number of municipalities to be measured

4. Simple random sampling

- Used to define the number of events needed to measure certain KPI with a defined confidence level and error of estimation
- Sample size:

$$m_i = \frac{z_{1-\alpha/2}^2}{a^2} \cdot \left(\frac{\sigma_i}{\bar{\bar{x}}_i}\right)^2$$

$$\bar{x}_i = \frac{\sum_{k=1}^{m_i} x_k}{m_i}$$

Where:

m_i = simple size for stratum i;
$z_{1-\alpha/2}$= percentil $1-\alpha/2$ of a standard normal distribution;
$1-\alpha$= confindence level;
a = bound on the error of estimation;
$\bar{x}_i$= mean value for the parameter under observation in stratum i, and
σ_i y $\bar{x}_i$ are calculated from previos measuring campaigns.

5. Obtaining national level results

- A weight is defined based on the population on each stratum N_i with respect to the total population N

$$w_i = N_i/N$$

- Weighted values for mean and standard deviation for the KPI based on the mean values for each stratum i:

$$\bar{x} = \sum_{i=1}^{L} w_i \bar{x}_i \qquad \sigma^2 = \sum_{i=1}^{L} w_i^2 \sigma_{\bar{x}_i}^2 \qquad \sigma_{\bar{x}_i}^2 = \frac{\sigma_i^2}{m_i}$$

- **Hypothesis testing** to determine if the operator achieves the threshold established by the regulator (statistical inference):

$$x_{st} = \frac{\bar{x} - \mu}{\sigma}$$

$Z_{1-\alpha}$ = 1.64 for a standard normal distribution with a significance level of 5%

If the test satistic (x_{st}) is greather than or equal to a critical value $z_{1-\alpha}$, then, statistically, there is not sufficient information to reject the null hypothesis with a significance level of α; *otherwise*, the null hypothesis is rejected and the alternative hypothesis is accepted;

6. Recommendations for regulators

- To achieve national level metrics, different variables have to be taken into account:
  - Geographic extension to cover
  - Characteristics of geographical regions
  - Cost
  - Resources (time, equipment, human resources)
- Representative samples can be achieved through stratification and simple random sampling
- It is important to "calibrate" the formulas with results obtained from each measurement campaign
- A methodology should define the duration of each event (for example, duration of the test, guard time intervals, setup time, time between events)
- With the KPI definition and the testing methodology, it is possible to obtain the number of working days needed to perform a measurement campaign

Cost-benefit analysis

7. Ongoing work

- Contribute to the Study Group 12 of the ITU to issue recommendations for regulators
- Study measuring methodologies for the telecommunication services in Mexico
- Propose a national statistical framework to achieve representative results as part of the enforcement strategies of the regulation in Mexico

8. References

[1] Scheaffer, Mendenhall, Ott, Gerow, "Elementary Survey Sampling", 7th edition, Brooks/Cole 2012, USA.

[2] International Telecommunication Union, Telecommunication Standardization Sector, "Resolution 95 - Initiatives to raise awareness on best practices and policies related to service quality", 2016, Hammamet, Tunisia.

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