

Global Ranking of Heterogeneous Mobile Network Coverage

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Abstract: With mobile technologies and networks changing from homogeneous to heterogeneous architecture, the need to objectively evaluate quality of coverage and global ranking approaches is important. This paper proposes a new methodology for assessing global coverage of multi-technology mobile networks. The goal is to determine global degree of appreciation of the level of coverage of a given operator public network. The proposed approach examined existing methods, analysed their strength and limitations and compare against selected case studies (survey data). Three cases of radio coverage have been considered with appropriate formulas introduced. These are coverages of combined technologies over the same territory, combined technologies over same population, and combined technologies aggregating both territory and population. Mathematical model was used to calculate the combined coverage ratings. The result shows that the new proposed global assessment methodology is unified, objective and representative, and may serve as useful tool in decision making for both mobile operators and regulatory authorities.

Keywords: Assessment, Coverage, Mobile Network, QoS Ranking

I. INTRODUCTION

Over the years, multimedia mobile network technologies and services impact positively on businesses and the life of users globally. Research indicated that by 2020, mobile access networks will experience significant challenges, as traffic volumes are expected to increase 1000-fold, and the number of connected devices between 10-100 times higher than today's [1]. This means that the rapid changes in technologies and networks will certainly have impact on the engineering, operations and service quality of these networks. Today, anytime a new technology is being deployed another is announced. The challenge by all indications is how to reduce complexities in the provision of quality of service (QoS).

The evolution of mobile networks shows growing demand for new technologies and services. From first generation (1G) analogue system, through second generation (2G) digital system, to third (3G) and 4G generations high speed multi-media services [2]. These generations of technologies are each categorized based on transmissions signal, data rate, bandwidth and nature of the service provided.

With the diversity of services and methods; to changes in technology and tools, the need for a unified, objective, and reliable method to evaluate global coverage and ranking is necessary. In the proposed model, we consider three cases of coverage with appropriate formulas introduced.

These are cases of combined technologies over the same territory, combined technologies over same population, and combined technologies aggregating both territory and population. We analysed and evaluated the different methods and compare the results against selected case studies (Survey results).

The main objective of the paper is to develop a theoretical model to assess global coverage and ranking of multi-technology mobile network services. The rest of the paper is organized as follows: Section II contextualizes mobile radio network coverage assessment approaches. Section III explores global coverage ranking surveys of heterogeneous mobile network services. Section IV introduces the new global coverage and ranking methodology and Section V, concludes with evaluation of the new approach.

II. RADIO COVERAGE ASSESSMENT APPROACHES

Radio network coverage refers to measurement of systems with good signal level, signal availability and minimum threshold. It is also about the capability of service providers to ensure satisfactory service in terms of call set up (CSSR) or connection set up of data or multimedia applications. Coverage performance and evaluation are the most important steps for mobile operators because it is directly related to their revenue performance, quality, and customer satisfaction [3]. In this way, quality of service assessment helps operators identify their strengths and weaknesses, including options to maximize their revenue and business potential.

Techniques to monitor, measure QoS and assess network coverage of operators can help regulators overcome issues of compliance; protect customers and operators' interests [4]. [5] defined QoS as the collective effect of service performance which determines the degree of satisfaction of user of the service'. For end user, it is viewed as the combined effect of service expectations or experience of the user of the service.

From operator's perspective, a concept by which network parameters are defined, measured and controlled to achieve a level of service satisfaction. Quality of experience in contrast, is the "overall acceptability of delivered service as perceived subjectively by the end user" [6].

The two-main common Radio network coverage assessment approaches are objective and subjective methods; either of which may be measured by network operators themselves, independent parties or regulatory authorities.

The former evaluates coverage availability over network resources including specific radio channels, and relies on two investigation methods; drive tests (DT) and predictive radio planning tool (RDT) [7] – [16].

Drive test is important in any network quality performance measurement process because it helps Mobile operators' measure user experience efficiently in a given area; optimize their network to provide better coverage and quality of service to their customers. During drive test, field technicians collect data posing as users in investigating performance of the network at given locations and time. Different scenarios are used to test different aspects of the services such as in car, indoor and or outdoor etc.

Statistics collected during drive test and radio planning tool help figure out network anomalies from non-functioning sites, (transmission, frequency hopping, coverage overlaps, high interference spots, call setup failure, dropped call, equipment performance, capacity, handovers failure), accessibility and retainability [8]; It also provide useful recommendations to optimize radio network coverage. Drive test investigates not only coverage, but also connection establishment, quality of the communication (voice), and hand-over failures [9]. The goal is to measure key performance indicators (KPIs) through testing and rating of quality of mobile network performance.

A. Radio Planning Tools

Radio planning tools ensures data collected during drive test is reliable and objective. The Transmission Environmental Monitoring System (TEMS) Investigation tool for example, can be used for active end to end testing to troubleshoot, verify, and optimize network and to improve quality of experience of users. This specialized electronic equipment interfaces with the mobile handset and ensures that measurements taken are realistic and comparable to actual user experience. It combines both data collection, and analysis in real time as well as post processing functions.

Quality of Service measurement involves the following primary components: operability, accessibility and retainability and integrity constituting 90% of network related QoS criteria, while security and support 10% on non-network related QoS criteria. Measurement may be performed either objectively or subjectively. Objective measurements focus on network performance and other QoS parameters where these can be quantified. Measurements on call set-up time, call failures and interruptions criteria can easily be done via appropriate probes in appropriate locations. It may be made on real traffic or on artificially generated traffics on public or private networks.

The common coverage Key Performance Indicators (KPI) are as follows:

- RSRP (Reference Signal Received Power) for 3.9G (LTE) and 4G (LTE Advance)
- P-CCPCH RSCP (Primary Common Control Physical Channel RSCP) for 3G TDD (Time Division Duplex) network
- CPICH RSCP (Common Pilot Channel Received Signal Code Power) and Ec/No (energy per chip over noise ratio) for 3G FDD (Frequency Division Duplex) network and RxLev for 2G (GSM) network.

The coverage assessment in a mobile network based on drive test (DT) is given by the following formula:

$$N_{cov}^{DT}(\%) = \frac{N_{OK}}{N_f} \times 100 \quad (1)$$

Where:

- N_{OK} is the number of samples among the total number of filtered samples that satisfy the cell **accessibility** requirements for the mobile network technology.
- N_f is the total number of **filtered** samples collected during a drive test

Radio Drive Test (RDT) is most of the time used for planning purpose before network deployment. However, it may also be use after high precision calibration to get global radio coverage for each technology [10]. The coverage assessment in a mobile network based on RDT is given by the following formula:

$$N_{cov}^{RDT}(\%) = \frac{S_{OK}}{S_{total}} \times 100 \quad (2)$$

Where:

- S_{OK} is the surface area that satisfies the cell accessibility requirements for the mobile network technology
- S_{total} is the considered total area.

Radio coverage can sometimes be difficult to measure simply because parameters for assessment may be different. For instance, in a customer feed-back situation, or complaints, user's terminal behaviour, device condition, user location, environmental interference etc. [11]. By extension, individual opinions are often overestimated and that human judgment or misunderstanding may falsify results [12]. In this context, subjective (Qualitative) method of assessing radio network coverage can be expressed using human judgment and or opinion ratings. The perception of radio coverage of users evaluates the experience of the user about the actual coverage. In order to achieve subjective measures with objective coverage assessment, operators and regulators may apply different techniques or tools.

III. GLOBAL COVERAGE RANKING SURVEY OF HETEROGENEOUS MOBILE NETWORK

Mobile operator coverage measurement campaign gives better perspective of end-to-end QoE of users. This investigation involves gathering of reliable statistics on customer experience about a given service. Subjective measures with an objective assessment can help in the evaluation of coverage as perceived by the end user [13]. Survey campaign is therefore a quantitative and qualitative assessment of coverage as experienced by customers.

To appreciate results of objective measurements, land surveys are conducted, and views of users' quality of experience obtained. Different scenarios are employed such as circumstances in which mobiles are used; in car, building, streets, town, on Trains etc. and other ways mobiles are held by users [14].

Network quality performance assessment require specialized audit to monitor, measure, report and review against key performance targets using different approach. In this way regulators will have ability to protect quality of service interests of their customers.

Network coverage can be assessed using objective methods, drive test and radio planning (RP) tools [15]. How these tools have been utilized in two separate audits in countries Y and E have been evaluated as follows:

In the review of Case Study 1 (CS1) [16], we evaluated published survey data on multi-technology mobile network coverage in Country Y. Drive test (DT) has been used to investigate coverage observations. Measurements were conducted using three mobile phones 2G, 3G and 4G technologies; outdoor coverage measurements were performed on three operators represented as Mobile Network 1,2,3 (MN1, MN2 and MN3) using accessibility test. The test result shows the possibility that a service can be obtained within a given location when requested by users. CS1 survey requires the establishment for each operator direct correlation between the number of households covered and the percentage of the population in country Y. The following variables were used;

Variables OK and NOT-OK (NOK) was used to calculate the coverage rating. Where:

- OK is the number of successful measurements that satisfy the accessibility requirements.
- NOT-OK (NOK) the number of unsuccessful measurement lacking accessibility requirements.

Each technology's geographical coverage was computed using the number of successful measurements on technology used by the total number of measurements using formula:

$$N_{cov}(\%) = \frac{\sum OK}{\sum OK + NOK} \times 100 \quad (3)$$

Where N_{cov} is the total percentage of coverage

In the above expression, the global coverage rating equals total number of OKs divided by the total numbers of OKs plus total number of NOKs. The population coverage calculated by weighing the results with the population percentage.

In the review of Case Study 2 (CS2) [17], a second survey data in country E was evaluated. The survey measures outdoor coverage of operators (Q1 and V2); 2G and 3G technologies were used across country E. The coverage target obligations of the operators as set by the regulatory authority are the following:

- Geographical coverage- 100%
- Population coverage - 100%
- Q1 and V2 Operators - 2G (GSM and 2.5G (GPRS/EDGE) coverage - 100%
- V2 operator -3G (UMTS) and 3.5G (HSDPA) coverage – 90%

The minimum target set for the signal power level to qualify for coverage is (-85dBm at >-95%) of locations within any outdoor area of 100mx100m at a height of 1.5m. Using accessibility test, each operator is required to establish direct correlation between the number of households covered and the percentage of the population.

The coverage map of each operator was validated against outdoor coverage using drive tests. The tests were conducted at specific zones in country E. Calls placed via automatic test script driven by MobiTrace software that is mounted on a vehicle equipped with standard mobile phones.

Full radio trace has been recorded every second, showing signal power levels in 2G (RxLev) and 3G (RSCP in an idle measurement).

The coverage measurements were performed using set of tools in 2G and different set of tools in 3G. The coverage weighted by population percentage in each zone. Similarly, to calculate coverage rating, variables OK and NOT-OK (NOK) has been used; Where:

- OK is the number of successful measurements that satisfy the accessibility requirements.
- NOT-OK (NOK) number of unsuccessful measurement lacking accessibility requirements

Each technology's geographical coverage rate computed using formula.

$$N_{cov}(\%) = \frac{\sum OK}{\sum OK + NOK} \times 100 \quad (4)$$

The above formula explains the global coverage rating equals total number of network signal OKs divided by the total numbers of OKs plus total number of NOKs. The population coverage calculated by weighing the results with the population percentage in each zone using the most recent official statistics.

Our evaluation of case studies (CS1 and CS2) shows that methods used in the two coverage assessments have major limitations. The approaches used in the first place did not consider the combined coverage rating of the technologies across countries (Y and E). The two cases merely assessed separate coverage rating of each operator and technology. On the contrary, by considering all the technologies together (combined), it is possible to objectively rate globally the coverage of each operator.

IV. OBJECTIVE GLOBAL COVERAGE RATING

Coverage is one of the most important parameter of a network. It provides services where they are required by the user [18]. Coverage, capacity and quality requirements are basis for dimensioning quality of service for mobile networks. With no means of having access to a network, there will be no possibility to use services provided by the network [19].

A. Analysis of CS1 and CS2

As an investigation method, Operation and Maintenance Centre (OMC) counters have their strengths and weaknesses. From user perspective, analysis of CS1 shows that only drive test (DT) can provide performance measurement information. Measures used during drive test, and formula to calculate the results may not reflect the true state of network coverage. Secondly, outdoor DT measurement campaigns may not be difficult to perform but getting correct measurements inside solid structures like buildings can be challenging.

This is because when signal strikes the surface of a building it may be diffracted or absorbed; depending on the structure and the environment if absorbed the signal strength could be reduced [20]. In this context, CS1 coverage and QoS maps of the network may be incomplete. Another weakness is that mobile phones used to perform the test calls may have different quality/value and in different condition. In addition, KPIs used as representative of user experience may as well not show true reflection of the effective deployment of BTS antennas.

Radio Frequency (RF) interference, temporary breakdowns and congestion failures can result in measurement flaws. Besides, due to low customer count, relevant sample measurements in less accessible areas may be excluded from the drive test route. Nonetheless, it is important to appreciate that networks may not be designed with same priorities for coverage and potentially may be biased towards particular areas or type of user. The overall assessment of CS1 coverage survey suggests the approaches used falls short of objectivity.

In contrast, CS2 survey demonstrates similar coverage assessment approach, not only in terms of measurement method used but also the formula to calculate global coverage. While advantages of the different methods are noted, none of the two case studies (CS1 and CS2) provides unified, truly objective and representative global coverage and ranking methodology. To overcome limitations sighted, a new approach that may be acceptable to operators is proposed.

Base on the foregoing analysis, end user satisfaction and choice of KPIs will certainly depend on market players. By combining subjective and objective methods using mean opinion score (MOS) together with mathematical expressions, global coverage and ranking can be achieved; This may help ensure efficiency in global coverage and ranking assessment based on diversity of the methods, their strengths as well as weaknesses.

Accessing an operator network in a given area including the target mobile network requires that key performance indicator threshold level for coverage be guaranteed. For instance, a user who is able to access greater number of network is more covered than the one with lesser opportunities. Supposing:

- S1, is the total coverage area of combined 2G/3G/4G that enable a user access only one of these technologies. The probability of accessing the network in this part of the covered area is S1/S.
- S2, the total coverage area of combined 2G/3G/4G that enable a user access two of these technologies. The probability of accessing the network in this part of the covered area is S2/S.
- S3, the total coverage area of combined 2G/3G/4G that enable a user access any of these technologies. The probability of accessing the network in this part of the covered area is S3/S.
- S0 is the remaining area from the total.

It is possible to build a random variable with probability distribution as follows:

TABLE I
TERRITORIAL ACCESS PROBABILITY DISTRIBUTION

Data	Sub-area 0	Sub-area 1	Sub-area 2	Sub-area 3
X (3G-3G-4G)	0	1	2	3
Surface area	S ₀	S ₁	S ₂	S ₃

The variable X denotes the number of active technology 2G/3G/4G detected in the considered area which satisfies the coverage threshold. The combined coverage and ranking on territorial basis approximated by the mean access of a user to the considered operator network.

It is calculated as follows: where T_{cov} is the total territorial coverage rating and S is the total surface area.

$$T_{cov} = (S_1 + 2 \times S_2 + 3 \times S_3) / S \quad (5)$$

The percentage of population allocated to the different areas is calculated as follows: where P_{cov} is the total population coverage.

$$P_{cov} = p_1 + 2 \times p_2 + 3 \times p_3 \quad (6)$$

The global coverage rating of a mobile operator is expressed as:

Where α and β are ponderation coefficients. These may be set by mutual agreement between regulators and the actors, such as mobile operators, service providers and other user's Rights Protection Association.

V. PROPOSED GLOBAL APPROACH

$$Global_{cov} = \alpha \times T_{cov} + \beta \times P_{cov} \quad (7)$$

In the proposed approach using published survey data, we consider **Case Study 1(CS1)** and three network operators as Mobile Networks 1, 2, 3 (MN1, MN2, MN3) in country Y. We apply CS1 survey data to the proposed new methodology. We used a new formula to calculate the combined global coverage of all the three technologies in terms of network signal, territory as well as population.

In the new approach, we combined (2G-3G-4G) territorial mean coverage ranking in surface areas (S1, S2, S3) respectively and then the total territorial coverage. We then calculated the combined population coverage ranking based on percentage of the population (P0, P1, P2, and P3). With the results obtained, we calculated the combined population coverage. Assuming that the ponderation coefficients have been set at $\alpha = 0.5$ and $\beta = 0.5$ by mobile network actors, the Global coverage rating was calculated.

Table 2 below consider the case scenario of mobile Network operator 1 (MN1). We estimated that approximately half of the surface area $S = 780 \text{ Km}^2$, and covered by LTE. Then considering that in the same area, we also have 2G, 3G without LTE and 4G. Then according to our theory we get $S_3 = S/2$. Since approximately the second half of the area is not covered by 4G but is covered by 3GLTE and 3G without LTE, then $S_2 = S/4$ and $S_1 = S/4$. What is interesting in this case scenario is that a user gets at least one technology anywhere over the total area ($S_0=0$).

For network signal rate, we applied a published survey data to the new methodology and based our calculation on the power levels/threshold including the percentage (%) of surface covered by each operator network in a given area. From the results obtained, mathematical formulae was used to calculate territorial, population and global coverage of the combined (2G-3G-4G) technologies.

A. Results

TABLE II
SIGNAL COVERAGE OF OPERATOR MN1

Coefficient	Power Levels	Operator	Technology		
			2G	2G-3G	2G-3G-4G
1.0	Rx Lev >-85 dBm	MN1	99%	64%	39%
0.75	-95dBm<Rx Lev<-85dm	MN1	1%	22%	34%
0.5	-105dBm<Rx Lev<-95dBm	MN1	0%	11%	17%
0.25	Rx Lev<-105dBm	MN1	0%	3%	10%
Signal Coverage %			99.75 %	86.75%	75.5 %

TABLE III
SIGNAL COVERAGE OF OPERATOR MN2

Coefficient	Power levels/ Threshold	Operator	Technology		
			2G	2G-3G	2G-3G-4G
1.0	Rx Lev >-85 dBm	MN2	97%	87%	65%
0.75	95dBm<Rx Lev<-85dm	MN2	2%	11%	25%
0.5	105dBm<Rx Lev<-95dBm	MN2	0%	2%	9%
0.25	Rx Lev<-105dBm	MN2	0%	0%	1%
Signal Coverage %			98.5 %	96.25%	88.5%

TABLE IV
SIGNAL COVERAGE OF OPERATOR MN3

Coefficient	Threshold	Operator	Technology		
			2G	2G-3G	2G-3G-4G
1.0	Rx Lev >-85 dBm	MN3	97%	82%	52%
0.75	-95dBm<Rx Lev<-85dm	MN3	3%	14%	29%
0.5	-105dBm<Rx Lev<-95dBm	MN3	0%	3%	12%
0.25	Rx Lev<-105dBm	MN3	0%	3%	6%
Signal Coverage %			99.25%	94.75%	81.25%

TABLE V
COMBINED (2G-3G -4G) TERRITORIAL COVERAGE (Tcov)

DATA	Sub Area 0	Sub- Area S1 MN1	Sub- Area S2 MN2	Sub- Area S3 MN3
X (Tech)	0	2G	2G-3G	2G-3G-4G
Surface Area	S0	1443Km2	1505.4Km2	1384.5km2
Tcov coverage	%	95.8%	99.9%	91.9%

To calculate the combined territorial coverage access of the three technologies, we use the following expression.

$$T_{cov} = (S1 + 2 \times S2 + 3 \times S3) / S \quad (8)$$

$$= (95.8 + 2 \times 99.9 + 3 \times 91.9) / 1560$$

$$= 295.78\%$$

Since three technologies were tested across the different surface areas (S0, S1, S2, and S3), the combined (2G-3G-4G) global territorial coverage average of all the Operators was calculated as follows:

$$T_{cov} = 295.78\% / 3 \quad (9)$$

$$= 98.59\%$$

We divided the combined global territorial coverage rating by the number of technologies. The result showed the combined global territorial average coverage of the three technologies.

TABLE VI
COMBINED (2G-3G-4G) POPULATION COVERAGE (Pcov) RATING BASED ON PERCENTAGE OF THE POPULATION (P0, P1, P2, P3) ALLOCATED TO DIFFERENT AREASs (S0, S1, S2, S3)

DATA	Sub Area P0	Sub-Area P1 MN1	Sub-Area P2 MN2	Sub- Area P3 MN3
X (Tech)	0	2G	2G-3G	2G-3G-4G
Population coverage (Pcov)	P0	958050	959050	1106140
Coverage % (Pcov) of each Operator	%	77.26%	77.34%	89.20%

To calculate combined population coverage of the three technologies, we used following formulae:

$$P_{cov} = (P1 + 2 \times P2 + 3 \times P3) / S \quad (10)$$

$$= (77.26 + 2 \times 77.34 + 3) \times 89.20 / 124000$$

$$P_{cov} = 231.94\%$$

Since three technologies were tested across the different surface areas (S0, S1, S2, and S3), we calculated the combined (2G-3G-4G) average global population Coverage (Pcov) for all the operators as follows: We divided the combined global population coverage rating as above by the number of technologies. The result indicated the combined global population average coverage of the three technologies.

$$P_{cov} = 231.94\% / 3 \quad (11)$$

$$= 77.31\%$$

TABLE VII
COMBINED (2G-3G-4G) GLOBAL COVERAGE (Gcov) AND RANKING OF OPERATORS (MN1, MN2, MN3) BASED ON PERCENTAGE OF THE POPULATION AND SURFACE AREA.

CS1 Operator	MN1	MN2	MN3	Global Coverage Ranking		
Technology	2G-3G-4G	2G-3G-4G	2G-3G-4G	MN1	MN2	MN3
Gcov	83.33%	94.41%	91.75%	3	1	2
GTcov	95.80%	99.90%	91.90%	2	1	3
GPcov	77.26%	77.34%	89.20%	3	2	1

To calculate combined global Coverage rating for operators (MN1, MN2, and MN3) against target KPIs, we express as follows:

$$Global_{cov} = \alpha \times T_{cov} + \beta \times P_{cov} \quad (12)$$

$$= 0.5 \times 295.78\% + 0.5 \times 231.94\%$$

$$Gcov \% = 263.86\%$$

Since three technologies were tested across different surface areas (S0, S1, S2, S3), we calculated the combined technologies (2G-3G-4G) global average coverage of all the operators as follows: we divided the combined global coverage rating by the number of technologies and the result indicated the combined global average coverage of the technologies as shown below.

$$Gcov \% = 263.86\%$$

$$Global_{cov} \% = 263.86\% / 3 \quad (13)$$

$$= 87.95\%$$

TABLE VI
GLOBAL RANKING CRITERIA

Ranking	Coverage Appreciation
1	Better
2	Good
3	Poor

B. Analysis of the Results

Figures 1, 2, and 3 illustrate signal coverage of the combined (2G-3G-4G) technologies for each operator at different power levels. Comparing the coverage scores, Operator MN1 has better 2G signal coverage than MN2 and MN3. For combined 2G-3G signal coverage, operator MN2 has better coverage than MN1 and MN3. On combined 2G-3G-4G coverage, operator MN2 has better coverage performance. From a global point of view, operator MN2 has better *Signal and Territorial coverage* than operators MN1 and MN3. However, MN3 has better population coverage than MN2 and MN1. Operator MN1 has the least coverage performance in terms of *Signal, Territory and Population*.

Figure 4, 5, 6, 7, 8 indicate coverage plots of combined technologies (2G-3G-4G) of all the operators by territory, population, and globally. In Fig. 7, the ranking of coverage appreciation shows MN2 is better covered territorially than MN1 and MN3. However, by population, MN3 has better coverage than MN1 and MN2.

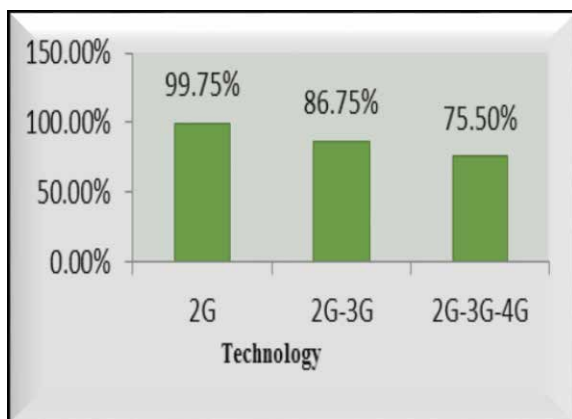


Figure 1. MN1 Combined Signal Coverage

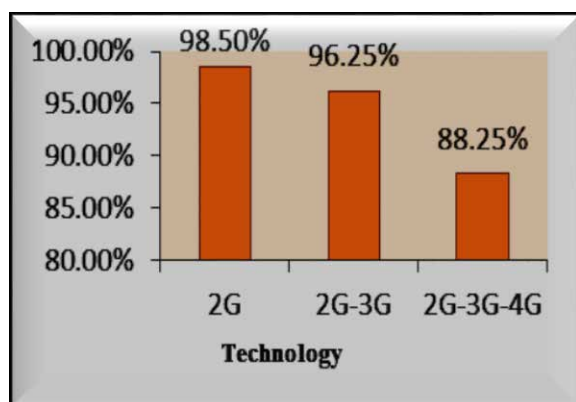


Fig.2. MN2 Combined Signal Coverage

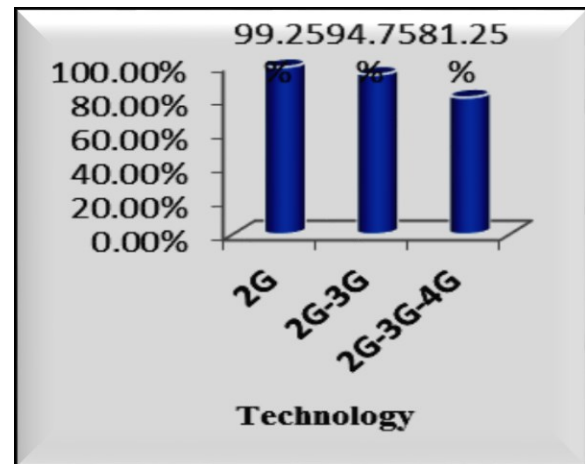


Fig.3. MN3 Combined Signal Coverage

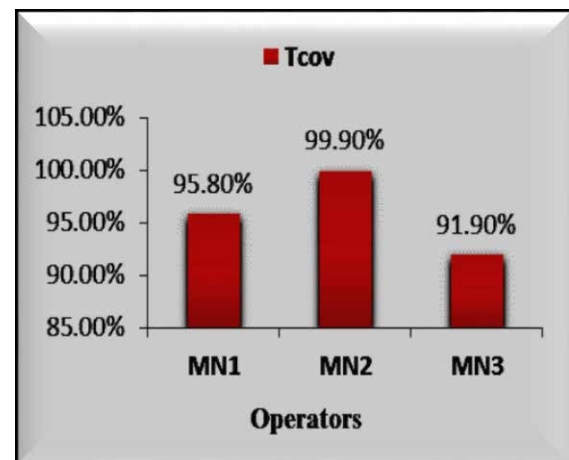


Figure 4. Combined Territorial Coverage Ranking

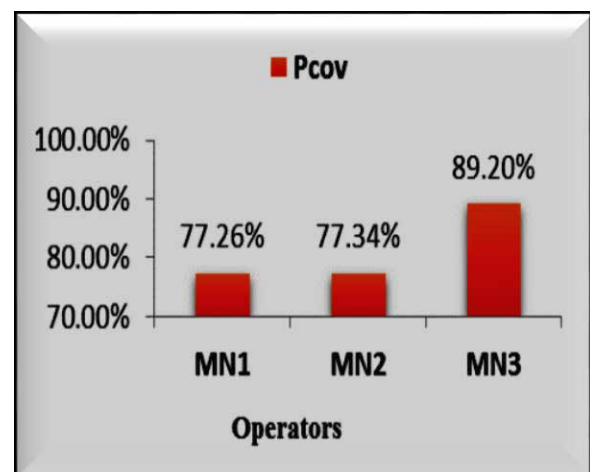


Fig.5. Combined Population Coverage Ranking

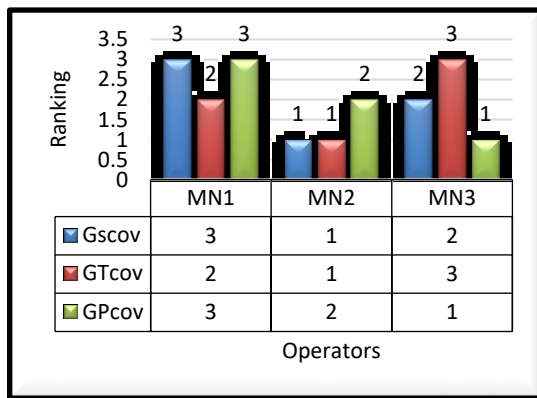


Fig 6. Global Coverage Ranking of Operators

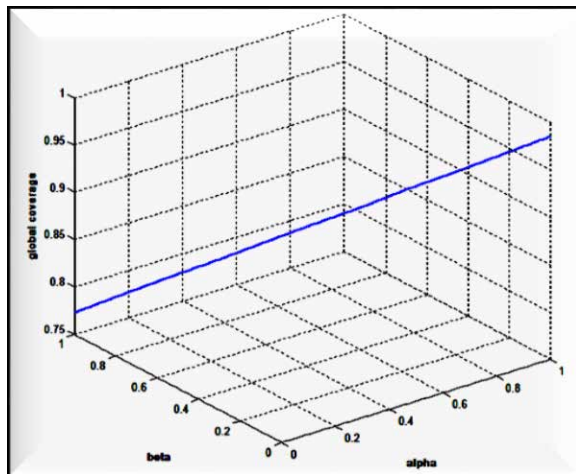


Fig. 7. Combined 3D Plot of Global Coverage Agregating Territory and Population

Fig.7 3D plot show that when alpha α equals 1, global coverage is the percentage of territory covered. Conversely, if beta β equals 0, the global coverage becomes percentage of population covered. When ponderation coefficient of alpha increases, then the percentage of global coverage will shift more towards the population. Similarly, if beta increases, the global coverage will shift towards the territorial surface. In this paper, we maintain the middle position with ponderation for alpha and beta set at 0.5.

VI. CONCLUSIONS

The new global coverage assessment approach of heterogeneous mobile networks was based on an objective strategy of considering all the potential territory to be covered in rural as well as density of population in urban areas. The assessment results indicate which operator had better coverage in a given area across the country. In this way, global ranking of operators in terms of signal, territorial and population coverage and the overall end user satisfaction assessment was achieved. Combining population and territory together in the global assessment approach fills the gap between actual and real coverage assessments. The major contribution of the new approach is the application of published survey data to the proposed methodology. Since our method outperforms limitations in existing ones, it can be considered objective, reliable, and representative. It may serve as a useful tool in decision making for both mobile operators and regulatory authorities.

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