Drive Testing in 5G

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Abstract:- Cellular system propagation models are tailored for specific areas or terrains, but their effectiveness diminishes when applied to different environments. As a result, this reduced efficiency impacts the coverage, capacity, and quality of service in cellular networks. To evaluate the quality of service for 5G, drive testing is conducted, which involves measuring and assessing mobile network performance. Despite the increasing availability of performance data in mobile radio systems, there remains a necessity to assess network performance in real-world conditions. These assessments serve various purposes, such as deploying new network sites to meet coverage, capacity, and quality demands, optimizing the network, benchmarking performance, troubleshooting issues, and verifying performance after upgrades or reconfigurations. Drive tests and RF surveys are commonly used for these measurements, playing a crucial role in both the planning and optimization phases of network development. The primary focus of this paper is to explore the drive test process and RF planning in 5G mobile communications.

Keyword:*- Drive test, RF parameter.*

I. INTRODUCTION

To examine the radiation pattern and signal strength in a specific terrain, we need specific modeling techniques. These models help us forecast path loss between transmitter and receiver sites, enabling analysis of propagation characteristics. Efficiency is a crucial aspect of these models, which play a significant role in various areas. Changes in efficiency can impact the Quality of Service (QoS) in mobile networks. With the wireless industry experiencing rapid growth, 5G networks are being deployed and expanded quickly. This has led to intense competition among service providers. To gain a competitive edge, high-quality service is crucial. Network operators invest considerable effort in monitoring and maintaining the network's status to ensure its accuracy and comprehensiveness. This information, along with traffic data, is utilized to enhance network performance and operations. Drive tests are commonly employed by operators as a measurement tool to assess quality, identify issues, and address network problems.

Drive Testing is a technique used to measure and evaluate the coverage, capacity, and Quality of Service of a mobile radio network. This assessment involves checking the cell site's coverage criteria using an RF drive test tool. Data collected during the drive test, in the form of Log files, is then analyzed to assess various RF parameters of the 5G network. The method employs a motor vehicle equipped with mobile radio network air interface measurement equipment, capable of detecting and recording a wide range of physical and virtual parameters of mobile cellular service within a specific geographic area. Wireless carriers can enhance coverage and service for their customers by assessing the user experience in particular locations and implementing targeted network improvements based on the collected data. Drive test equipment gathers various data, including network-related information, details about services like voice and data, radio frequency scanner data, and GPS information to enable location logging. This data collection aids in assessing and optimizing network performance.

II. INFORMATION OBTAINED FROM A DRIVE TEST

The dataset gathered during drive testing field measurement may comprise details like**:**

- Signal Intensity
- Signal quality
- Interference
- Dropped calls
- Blocked calls
- Anomalous events
- Call Statistics
- Service Level statistics
- Handover information
- Neighbouring cell information

III. TYPES OF DRIVE TEST

Drive testing is divided into two main categories:

- **Pre Swap Drive Test**: This involves conducting drive tests on predetermined routes within specific cities using standard drive test tools at the network level. Before starting the project, the drive test routes and cities are agreed upon. The results obtained from the pre-swap drive testing serve as a reference for evaluating the radio network's performance after the swap is completed. The Pre Swap drive test report includes statistical data on parameters such as received downlink signal strength, Rx Quality, Call Setup Success Rate, Handover Success Rate, and Call Drop Rate. The outcomes of the Free Swap Drive Test are documented as the Network Quality Index (NQI).
- **Post Swap Drive Test**; The Post Swap Drive Test for Acceptance is conducted after the entire BSS Network has been swapped. Whenever feasible, the Post-swap drive testing is performed under similar traffic conditions as the pre-swap tests, using the same routes, weekdays, and time of the day. The same set of drive test routes used before the swap will be employed again. The Post Swap drive test report will contain the same reports as the Pre Swap Drive Test, and its results will be documented as well as digital maps are accessible, cartographic plots can be generated for the received downlink signal strength and R Quality. The network performance verification results are represented by the Network Quality Index (NQD), which serves as a benchmark for evaluating the network's performance. The

main aim of the radio network performance benchmarking process is to compare the performance objectives based on the NQI target from the Pre Swap Drive Test. The data from the Post Swap Drive Test is analyzed and presented in a separate test report, showing the NQI figures for each service area category. This presentation demonstrates whether the requirements outlined in the Pre Swap Drive Test NQI Target have been met. These are further classified as- Network Benchmarking, Optimization and Troubleshooting, Service Quality Monitoring. The resulting produced by drive testing for each of these purposes is different:

- **Network Benchmarking**: Sophisticated multi-channel tools are employed for network benchmarking, enabling the measurement of various network technologies and service types concurrently with high precision. This facilitates the acquisition of directly comparable information about competitive strengths and weaknesses. The results obtained from benchmarking activities, such as comparative coverage analysis or comparative data network speed analysis, are commonly utilized in marketing campaigns. Drive testing serves as the primary method for gathering networking benchmarking data, providing mobile network operators with accurate competitive insights into their own technical performance and quality levels, as well as those of their competitors.
- **Optimization and troubleshooting** data is primarily utilized to identify specific issues during the initial deployment of new networks or to investigate problems reported by consumers during the network's operational phase. Drive testing data plays a crucial role in diagnosing the root cause of particular network issues, often limited to specific areas, like dropped calls or missing neighbour cell assignments.
- **Service quality monitoring** usually includes placing test calls throughout the network to a stationary test unit, evaluating the relative quality of different services based on Mean Opinion Score (MOS). This monitoring process centres on the end user's experience of the service, enabling mobile network operators to investigate the technical cause of any perceived quality issues through time-correlated data collected during the drive test. Service quality monitoring is commonly automated to efficiently address subjective quality degradations.

IV. TOOLS AND DEVICES EMPLOYED DURING DRIVE TESTS

A typical drive-test system consists of a test mobile phone, software for controlling and recording data from the phone, and a Global Positioning System (GPS) receiver to obtain position information.

- TEMS Handset (complete with Charger, Headset, Data Cable) and USB Hub
- Laptop (installed TEMS Investigation) and Adapter
- GPS (Ext Antenna and Data Cable)
- Inverter and Terminal
- Scanner for GSM (Ext Antenna GPS and RF, Data Cable)
- Battery and Charger etc

V. REASON FOR CONDUCTING DRIVE TESTING

During drive testing of 5G, test teams travel along predetermined routes within the network region. During this process, they analyze calls and measure signal strength. Drive tests also involve evaluating unsuccessful handovers, audio quality, and call drop incidents, along with collecting test data. GPS is utilized to track and record the locations during these drive tests. The results are moved from the mobile station (MS) to a dedicated PC. In the drive test process, diverse data groups are analyzed to generate graphical and tabular data, which the test engineer interprets. The drive test includes testing both radial and azimuthal routes. In urban and suburban areas, the impact of street orientations is taken into account, while in rural areas, the effect of foliage patterns is considered. The drive test also accounts for both line of sight (LOS) and non-line of sight (NLOS) positions of the MS or receiver concerning the transmitter.

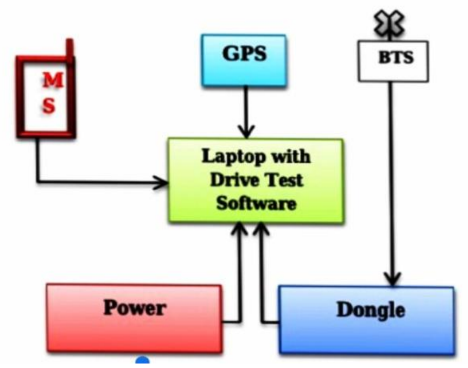

Fig. 1: Drive Testing System

Figure 1 illustrates the drive testing system comprising a GPS system, dongle, laptop with drive test software, mobile station, and power system. The GPS system, dongle, and mobile are connected to the laptop. The laptop hosts the installed drive testing software, acting as an interface between the dongle and laptop to facilitate the entire drive testing process. The power system plays a vital role in this setup. The GPS system is utilized for navigation, while the dongle receives signals transmitted by the BTS (Base Transceiver Station).

VI. SELECTION OF TEST SITE

During site selection, factors such as the maximum building height in urban and suburban areas, vegetation in rural areas, and the cluttering pattern of both buildings and vegetation are taken into account. The location and height of the base station antenna play a crucial role in the site selection process.

During the drive test, data is collected from all sectors of the transmitting antenna. The transmitter antenna's sectors are positioned at 120 degrees apart. The height of the base station antenna is 35m or higher above the ground, and it is located on masts or occasionally on rooftops. The transmitted signal's bandwidth is in the range of 806-960MHz (806-880MHz/880-960MHz).

VII. RF PARAMETERS FOR DRIVE TEST

Drive tests are analyzed using various parameters, which include the strength of the received signal, frame erasure rate, bit error rate, quality of speech, and carrier-to-interference ratio. These parameters help evaluate and assess the performance and quality of the network during the drive test.

- **Receiving Level (Rx Lev):** The receiving level refers to the signal strength measured at the receiver, expressed in decibels (dB) with a range from -30dB to -110dB.
- **Quality of voice(Rx Qual):** The quality of voice at the receiving level is assessed by the bit error rate (BER). The Rx Qual measurement ranges from 0 to 7.
- **Frame Ensure Rate(FER):** The Frame Erasure Rate (FER) indicates the proportion of frames discarded due to a significant number of non-corrected bit errors within the frame. FER serves as a quality indicator for the network.
- **BER Actual:** The Bit Error Rate (BER) is the ratio of the number of bit errors to the total number of bits transmitted within a specific time frame. It quantifies the voice quality within the network and depends on the Rx Qual value. The BER is meaningful and measurable up to 12.8%, which corresponds to the maximum Rx Qual value of 7.
- **SQI:** The Speech Quality Index (SQI) is the most suitable criterion for optimizing speech quality within the network. SQI is specifically designed to represent the speech quality rather than the radio environment conditions. It gets updated at intervals of 0.5 seconds and is calculated based on both Frame Erasure Rate (FER) and Bit Error Rate (BER). For EFR (Enhanced Full Rate) codec, the ideal SQI value is FR -21, and for HR (Half Rate) codec, it is -17.
- **Carrier-over- interference ratio(C/I);**The measurement compares the signal strength of the current serving cell to the signal strength of undesired signal components, and it needs to be higher than 9 for satisfactory performance.

VIII. RF SURVEY

The objective is to acquire fundamental understanding of the site, particularly in civil and other aspects. The initial RF survey of 5G is conducted with utmost care. Prior to the survey, RF Network Planning is carried out using sophisticated tools like ASSET 3G by AIRCOM. This planning tool generates a nominal network coverage plan considering capacity, equipment type, digital geographical map information, etc. The plan includes the optimal site locations, antenna height, antenna type, and ideal antennas to be used.

The subsequent phase involves performing an RF site survey, leading to the identification of several potential options for a single site, usually around three. Selecting the final site from these candidates involves the following procedures:

- Conducting a transmission feasibility study, considering Line-of-Sight for Microwave if required.
- Evaluating the structural stability of the site for implementation purposes.
- Engaging with a Real Estate Agency to negotiate a commercial deal with the site owner.

IX. TOOLS REQUIRED FOR RF SURVEY

- GPS
- Magnetic Compass
- Binocular
- Digital Camera
- Measuring Tape
- Stationary
- Safety kit

Fig. 2: Tools for RF Survey

X. MAJOR CONSIDERATIONS IN RF SITE SURVEY

During an RF site survey, several major considerations are taken into account to ensure optimal performance and coverage for the 5G wireless network. Some of the key considerations include:

- **Signal Strength:** Assessing the signal strength in different areas to determine potential coverage gaps or areas with interference.
- **Interference:** Identifying and mitigating sources of interference that could degrade the wireless signal.
- **Frequency Planning:** Planning the allocation of frequencies to avoid overcrowding and interference.
- **Line-of-Sight (LOS):** Checking for clear line-of-sight between transmitter and receiver for microwave links.
- **Building Structures:** Evaluating the structural integrity of buildings or towers for the installation of antennas and equipment.

- **Obstructions:** Identifying and addressing physical obstructions that could block or weaken the RF signal.
- **Antenna Placement:** Selecting suitable locations for antennas to optimize coverage and minimize signal loss.
- **Environmental Factors:** Considering environmental conditions such as weather, temperature, and vegetation that could impact signal propagation.
- **Power Requirements:** Ensuring adequate power supply for the equipment and antennas.
- **Safety:** Ensuring compliance with safety regulations and guidelines during the installation process.

By carefully considering these factors, an RF site survey helps in designing a robust and efficient wireless network that meets the required performance standards.

XI. DATA COLLECTION FOR RF SURVEY

During the Nominal Survey, the Survey Coordinator shares essential site data with the RF Engineer. This data helps the Engineer locate the site accurately. The information to be collected includes Latitude, Longitude, Tower Type, Number of Operators, Tower Height, Building + Tower Height Above Ground Level (AGL), Planned Antenna Height, Tilt (E/M), Orientation, Proposed Antenna Height, Tilt (E/M), Orientation, Layout Photos, Adjacent Building Details, and Adjacent Tower Details.

Fig. 3: Different sector photos

XII. PROCEDURE FOR RF SITE SURVEY

- **Step 1**: To begin with, ensure that you have all the necessary tools in your toolkit and have obtained all the data required for the RF Site Survey. It is essential for an RF Engineer to have a comprehensive understanding of how each tool functions. Next, head to the search area based on the predicted location coordinates using GPS and the location area map.
- **Step 2**: Utilizing a visual examination technique, verify the type of area (clutter), average building height, presence of buildings with and without basements, existence of high-tension wires/metro lines in the nearby vicinity, presence of other operators' sites within the search radius, and the potential for GBT, RTT, PST, or wall-mounted towers.
- **Step 3**: For the Nominal Site Survey, reach the designated location and, if necessary (in the case of RTT/PST/wall-mounted antennas), obtain permission from the building owner. Check the accessibility to the rooftop and evaluate all the conditions mentioned above in the rooftop section of the survey.
- **Step 4**: If the initial Nominal site fails to meet your selection criteria, search for a suitable building or existing tower within the designated search ring. Identify three potential locations that offer unobstructed views and better accessibility as close to the Nominal location as possible. Label the best option as candidate1, the next as candidate2, and the third as candidate3.
- **Step 5:**For each candidate location, proceed to the rooftop of the building or the top of the tower. Use GPS to record the latitude and longitude, determine the north direction with a magnetic compass, and calculate the proposed antenna orientation. Aim to achieve the planned antenna height and then calculate the Length of feeder cable, height of Pole/Tower, and antenna tilts required for optimal RF Coverage. Also, measure the distance and azimuth of each candidate site from the Nominal site.
- **Step 6**:In the case of a Blind Survey, utilize the Map source tool to mark the boundary of the area specified by the customer. Independently explore the entire area and select the nominal sites. The subsequent process remains the same as in the Nominal Survey.
- **Step 7**: Capture a series of 12 panoramic photographs at 30-degree intervals, beginning from the north direction, ensuring that they encompass 70% clutter and 30% sky. Also, take photographs in the direction of the proposed antenna azimuth to fulfill the coverage objective, considering a maximum of three sectors. Don't forget to take photographs of the tower foundation, building rooftop, entire building, latitude/longitude, nearby obstacles, and existing sites of other operators, among others.
- **Step 8**: Thoroughly complete the RF Survey form and checklist to ensure that no crucial aspect is overlooked during the survey process.

XIII. LOSS AND FADING FOR DRIVE TEST

Signal strength is a crucial aspect during drive tests, as it undergoes various fluctuations at the receiver site. These fluctuations are attributed to three different types of phenomena, which are analyzed to understand the variations in the received signal.

- **Propagation Loss:** Propagation losses are influenced by the site's environment, and alterations in the environment can impact the propagation loss. The variation in propagation loss typically ranges from 20 to 50 decibels per decade. Propagation loss can be attributed to various phenomena such as diffraction, scattering, or absorption when signals pass through terrain, foliage, or buildings.

  Propagation losses play a crucial role in mobile telephone communication, and several propagation models are built for different areas. Predicting propagation loss is essential in establishing communication between the transmitter and receiver.
- **Slow Fading:** Fading refers to the quick changes in the amplitude of a radio signal as it travels over a short distance within a brief time period. Slow fading occurs due to shadowing and is typically represented using a log-normal probability density function. The analysis of slow fading involves the use of a log-normal random process. Slow fading can be either time-dispersive or frequency-dispersive. The Doppler profile of the channel also significantly influences slow fading.
- **Fast Fading**: Fast fading occurs as a result of multipath effects in the received signal at the receiver site. To analyze fast fading, either Rayleigh or Ricean distribution is employed, describing the statistical time- varying characteristics of the received signal. Rayleigh distribution represents the signal envelope as a function of time. Fast fading is observed when the signal strength changes rapidly compared to the channel's rate of change.

XIV. STEPS INVOLVED IN CONDUCTING DRIVE TEST

During the drive test, the following steps are taken:

- Step1: Launch the investigation software such as TEMS (versions 8.1, 9.1, 10.1, and 13.1) on the laptop. When the system is opened, it typically displays the GSM window by default, presenting empty tables and charts intended for RF information.
- Step 2: The red colour symbol serves as an indication of the disconnection status for both the external device dongle and GPS. Once you click on 'connected ALL' in the connection toolbar, both devices are linked, and the red colour changes to green colour.

  In the subsequent step, the mobile device is connected in the 'idle mode'. The GSM window is initiated, revealing the latitude and longitude of the location, along with displaying real-time network data in the respective tables and charts**.**
- Step 3: Next, click on the 'record' toolbar to save the log file, and proceed by making an originating call from the current location.
- Step 4: Drive along the routes that cover the cell and its neighbouring cells.
- Step 5: The cell coverage, received signal strength, call connections, FR parameter, and various other factors are examined and recorded in the log file.
- Step 6: Eventually, the log file is created and can be exported to various formats to meet post-processing needs.

XV. TOOLS USED FOR DATA COLLECTION

During the drive test, data samples of the measured signal are collected using the TEMS Investigator dongle and software versions 8.1, 9.1, 10.1, and 13.1. The accuracy of this setup is +4dBm, with the calibrated power ranging from -100dBm to -40dBm. Additionally, a GPS receiver is utilized to collect location information of both the dongle and the drive test vehicle. The GPS accuracy has significantly improved to approximately 15 meters, surpassing the previous range of +200m to ‡300m, thanks to the recent deactivation of the selective variability.

TEMS Investigation serves as a comprehensive tool for troubleshooting, verification, optimization, and maintenance of wireless networks. With its capabilities for data collection, real-time analysis, and post-processing, TEMS Investigation combines multiple functions into a single equipment, eliminating the necessity for various tools and resulting in cost savings and time efficiency for operations staff. This versatile tool supports all major technologies, making it the perfect choice for deploying new networks and ensuring smooth integration with existing ones.

With TEMS Investigation, operators can enhance accessibility, retention, and service performance, benefiting from its support for various technologies such as LTE (FDD and TDD), GSM, GPRS, EDGE, WCDMA, HSPA, HSPA+, TD-SCDMA, CDMA (IS-95 to EV-DO Rev B), and WiMAX. Additionally, TEMS Investigation provides support for a diverse range of services.

The tool facilitates smooth integration between LTE, WCDMA/HSPA, and GSM/GPRS/EDGE networks, as well as LTE, CDMA EV-DO, CDMA2000, and IS95 networks.

XVI. CONCLUSION

Drive testing is a valuable method for measuring and evaluating the Quality of Service, coverage, and capacity of 5G mobile networks. TEMS Investigation serves as the primary tool for conducting drive tests, comprising both hardware and software components. The latest version of TEMS Investigation software is 13.1.

The hardware component of TEMS Investigation consists of a dongle. This tool provides support for a wide range of technologies, including LTE (FDD and TDD), GSM, GPRS, EDGE, WCDMA, HSPA, HSPA+, TD-SCDMA, CDMA (IS-95 to EV-DO Rev B), and WiMAX, as well as various services.

When selecting test sites for drive testing of 5G, factors like the height of the base station antenna, building height, and vegetation (in urban, suburban, and rural areas) are taken into consideration.

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