MOBILE NETWORK OPTIMIZATION

A PRACTICAL GUIDE FROM BASICS TO OPERATIONAL EXCELLENCE

COMPLETE GUIDE FOR 2G, 3G, 4G, AND 5G, ERICSSON, NOKIA, AND HUAWEI

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Preface

Mobile network optimization is the art and science of extracting the maximum performance, capacity, and quality from a cellular network. In an increasingly connected world, where the user experience is paramount, the work of the network optimizer is crucial. This booklet was conceived as a practical and direct guide, leading the reader from fundamental concepts to advanced optimization techniques, with a specific focus on the three main infrastructure vendors: Ericsson, Nokia, and Huawei. Whether you are a junior engineer, an experienced technician, or a student, you will find here a valuable roadmap for your activities.

MASTER THE ART AND SCIENCE OF MOBILE NETWORK OPTIMIZATION

In an increasingly connected world, where mobile network quality has become a decisive factor for the success of operators and the satisfaction of millions of users, this book presents itself as the most complete and up-to-date reference on mobile network optimization.

WHAT YOU WILL FIND IN THIS WORK:

- **Proven Methodologies**: Step-by-step processes for systematic optimization and measurable results.
- **Multi-technology**: Detailed approaches for GSM, WCDMA, LTE, and 5G (NSA & SA).
- **Specialized Tools**: Advanced use of TEMS, Nemo, XCAL, Probe, and PHU.
- **Real Cases**: Detailed studies of complex problems and their solutions.
- **Vendor-Specific Optimization**: Specific configurations for Ericsson, Nokia, and Huawei.
- **Future Trends**: AI/ML, SON, Cloud, and Augmented Reality applied to optimization.

WHO THIS BOOK IS FOR:

- **RF and Optimization Engineers** seeking to deepen technical knowledge.

- **Mobile Network Managers** who need strategic vision and business metrics.
- **Telecommunications Students** looking for solid fundamentals and practical applications.
- **Operator Professionals** who desire operational excellence and competitive advantage.
- **Technical Consultants** who need a comprehensive and up-to-date reference.

WORK DIFFERENTIATORS:

- **Practical Approach**: Technical concepts explained through real-world applications.
- **Complete Update**: Coverage of the latest 5G SA and Massive MIMO technologies.
- **Multi-tool Integration**: Integration between different collection and analysis systems.
- **Strategic Vision**: Alignment between pure technique and business objectives.
- **Accessible Language**: Complex technical explanations presented clearly.

ABOUT THE APPROACH:

This book transcends the traditional technical manual, presenting optimization as a continuous and strategic process that connects the network infrastructure to the end-user

experience. Through field-validated methodologies and real success cases, the reader is guided from the fundamentals to the most advanced techniques, always focusing on operational excellence and value creation.

"It's not just about making the network work, but about making it excellent - every day, for every user, under all conditions."

TABLE OF CONTENTS

Chapter 7: Practical Optimization Cases

7.1 Case 1: Call Drop Resolution in Urban Area (Huawei)
7.2 Case 2: Throughput Improvement in Stadium (Ericsson)
7.3 Case 3: Handover Optimization on Highway (Nokia)

Chapter 8: Tools and Future Trends

8.1 Analysis Tools: TEMS, Nemo, Actix
8.2 Introduction to SON (Self-Organizing Networks)
8.3 Optimization for 5G Standalone (SA) and Massive MIMO
8.4 The Role of AI and ML in Optimization

Chapter 9: Collection and Analysis Tools - Specifications and Differentiators

9.1 Probe Systems - Passive Network Monitoring
9.2 TEMS Investigation - Real-Time Analysis
9.3 Nemo Outdoor - Large-Scale Collection
9.4 XCAL - Deep Protocol Analysis
9.5 PHU (Per-Hour Utilization) - Temporal Pattern Analysis

Chapter 10: Collection Methodologies by Technology

10.1 Configurations for GSM: Specific Parameters and Metrics
10.2 Configurations for WCDMA: Specific Parameters and Metrics
10.3 Configurations for LTE: Specific Parameters and Metrics
10.4 Configurations for 5G NR: Specific Parameters and Metrics
10.5 Multi-technology Collection: Challenges and Solutions

CHAPTER 1: INTRODUCTION TO MOBILE NETWORK OPTIMIZATION

1.1 What is Optimization and Why is it Important?

Mobile network optimization is a continuous and systematic technical process that aims to extract the maximum possible

performance from the existing network infrastructure. Imagine the mobile network as a complex road system: optimization would be the work of traffic engineers who adjust traffic lights, create exclusive lanes, improve signage, and optimize traffic flows to ensure traffic flows as smoothly as possible, avoiding congestion and ensuring everyone reaches their destination quickly and safely.

In concrete technical terms, optimization involves:

- **Fine-tuning of radio parameters**: Modifying antenna transmission power, adjusting tilt angles, optimizing handovers (transfers between cells), and calibrating hundreds of other parameters that control how radio signals behave in the environment.
- **Continuous performance analysis**: Constantly monitoring hundreds of technical indicators that show the "health" of the network, identifying problems before they become critical.
- **Correction of specific problems**: Resolving issues such as dropped calls in certain locations, slow internet at specific times, areas with inadequate coverage, or interference between neighboring cells.
- **Improvement of operational efficiency**: Ensuring that network resources (radio spectrum, processing capacity, energy) are used as efficiently as possible, allowing more users to be served with the same infrastructure.

The importance of optimization manifests at several levels:

- **End-User Experience**: When you make a call and it drops inexplicably, or when the internet becomes extremely slow in a certain location, or when videos constantly buffer - all these are problems that good optimization can solve. Satisfied users tend to stay with the operator and recommend its services.
- **Operational and Economic Efficiency**: Operators that optimize their networks well can serve more users with the same infrastructure, delaying investments in new antennas and equipment. A well-optimized network consumes less energy, requires less maintenance, and operates more predictably.
- **Competitive Advantage**: In saturated telecommunications markets, where all operators offer similar prices, network quality often becomes the decisive factor in consumer choice. A well-optimized network can be the difference between gaining or losing customers.
- **Preparation for Future Services**: Proper optimization creates the solid foundation needed to support emerging services such as Internet of Things (IoT), connected cars, augmented reality, and telemedicine, which require extremely reliable performance.

1.2 The Optimization Lifecycle: Drive Tests, KPIs, Adjustments, and Monitoring

The optimization process follows a continuous and iterative cycle, consisting of interconnected phases that constantly repeat. This cycle ensures that the network is continuously improved and adapted to changes in the environment and usage patterns.

Drive Tests are data collections performed by specially equipped vehicles that follow pre-defined routes. These vehicles function as mobile laboratories, carrying:

- **Professional scanners**: Specialized devices that measure all radio signals present in the area, regardless of whether they are connected to the operator's network or competitors'. They provide a complete view of the radio environment.
- **Test phones**: Devices that simulate the behavior of real users, making calls, sending messages, browsing the internet, and using applications, while collecting detailed data about the experience.
- **High-precision GPS systems**: Which correlate exactly each measurement with its geographical location, allowing the creation of precise coverage and quality maps.

- **Computers with specialized software**: That collect, process, and analyze data in real time, allowing engineers to identify problems during the test itself.

KPIs (Key Performance Indicators) are the "grades" or "thermometers" of the network. They objectively quantify performance in different aspects:

- **Drop Call Rate**: Percentage of calls that are involuntarily interrupted before their normal completion. In well-optimized networks, this value should be less than 1%.
- **Call Setup Success Rate**: Percentage of call attempts that are successfully completed. Values above 99% are considered excellent.
- **Accessibility**: The ability of users to connect to the network when needed, measured through indicators such as RRC Success Rate and E-RAB Success Rate.
- **Throughput**: Data transfer speed, both in download (direction from network to user) and upload (direction from user to network).
- **Latency**: The time it takes for a data packet to go from one point to another in the network. Crucial for real-time applications like online games and video conferences.

Adjustments are the technical interventions performed on the network to correct problems or improve performance:

- **RF (Radio Frequency) Adjustments**: Involve physical or configuration modifications to antennas - changing angles (tilt), direction (azimuth), height, or transmission power.
- **Parameter adjustments**: Modification of software settings that control the intelligent behavior of the network - criteria for handover, power control algorithms, admission control policies.
- **Coverage optimization**: Correction of areas with weak or non-existent signal through antenna reorientation, power adjustment, or installation of complementary equipment.

Monitoring is the continuous and systematic observation of network performance:

- **OSS (Operational Support Systems)**: Platforms that collect data from all network elements 24 hours a day, 7 days a week.
- **Advanced analysis tools**: That process the collected data, identify patterns, detect anomalies, and generate alerts when problems are detected or when performance falls below established limits.
- **Automatic reports**: That show trends over time, compare performance between different areas or periods, and provide insights for decision making.

1.3 Technology Overview: 4G (LTE) and 5G (NSA & SA)

Mobile networks have evolved through technological generations, each bringing significant advances in capacity, speed, and capabilities. Understanding these technologies is fundamental for effective optimization.

4G (LTE - Long Term Evolution) represents the fourth generation of mobile networks, bringing revolutionary advances:

- **Fully IP-based architecture**: Unlike previous generations that had separate infrastructures for voice and data, LTE uses only IP (Internet Protocol) networks for all services. This simplifies the architecture and reduces costs.
- **Significantly improved performance**: Offers latencies in the range of 20-40 milliseconds (compared to 100-200ms of 3G) and theoretical speeds of up to 300 Mbps download. In practice, users typically experience 10-50 Mbps.
- **Advanced radio access technologies**: Uses OFDMA (Orthogonal Frequency Division Multiple Access) for downlink, which is more efficient at handling multipath propagation (signal reflections), and SC-FDMA for uplink, which is more efficient in terms of device battery consumption.

- **MIMO (Multiple Input Multiple Output)**: Uses multiple antennas at both the base station and devices to improve capacity and reliability through spatial diversity.
- **Voice over LTE (VoLTE)**: Transmits voice calls as data packets over the 4G network, offering superior voice quality and faster call setup times.

5G (NSA & SA) represents the fifth generation, bringing not only incremental improvements but radically new capabilities:

- **NSA (Non-Standalone)**: A transition architecture that uses the existing 4G network as a base for control functions and adds 5G capabilities for increased data capacity. Imagine a car with a 4G engine that gets a 5G turbo - the base is old, but the performance is improved.
- **SA (Standalone)**: An independent and complete 5G architecture, with a dedicated core network and all functions implemented natively in 5G. It's like having a completely new car, designed from the start to be 5G.
- **Fundamental advantages of 5G**:
    - **Ultra-low latency**: Less than 10 milliseconds, enabling critical real-time applications like remote surgery and autonomous vehicle control.

- **Extreme bandwidth**: Up to 10 Gbps under ideal conditions, supporting 8K video streaming and virtual reality.
- **Massive IoT**: Support for up to 1 million devices per square kilometer, enabling smart cities with sensors everywhere.
- **Extreme reliability**: 99.999% availability for critical applications.

- **5G enabling technologies**:
  - **Massive MIMO**: Arrays with tens or hundreds of antenna elements that form precise directional beams.
  - **Beamforming**: Dynamic focusing of the signal directly to each user, improving efficiency.
  - **Network Slicing**: Creation of virtual networks dedicated to different types of services with specific requirements.
  - **Edge Computing**: Data processing closer to users, reducing latency.

Optimization in 5G introduces new challenges and opportunities, such as dynamic beam management, coordination between different frequency bands (sub-6 GHz and mmWave), and guaranteeing quality of service in network slices dedicated to specific applications.

CHAPTER 2: THE STEP-BY-STEP OPTIMIZATION PROCESS

2.1 Phase 1: Definition of Objectives and Goals (Key KPIs)

The first phase of the optimization process is crucial because it establishes what will be measured, how it will be measured, and what the desired results are. Without clear and measurable objectives, optimization becomes a random exercise without a defined direction.

Key KPIs (Key Performance Indicators) are quantifiable metrics that reflect critical aspects of network performance. They function like measurement instruments in a laboratory - each reveals something specific about the "health" of the network:

- **Accessibility**: Measures the ability of users to obtain service when needed. Includes:
    - **RRC Success Rate**: Success rate in establishing the initial connection between the device and the network. Values above 99.5% are considered excellent.
    - **E-RAB Success Rate**: Success rate in establishing the data bearers that carry the actual traffic. A typical target is above 99.0%.
- **Retention**: Evaluates the network's ability to maintain services once established. Comprises:

- **Drop Call Rate (DCR)**: Percentage of calls that are involuntarily interrupted after successful establishment. In optimized networks, it should be less than 1.0%.
- **E-RAB Drop Rate**: Drop rate of data connections. Values below 0.8% are considered good.

- **Mobility**: Measures the efficiency with which the network manages user movement between cells. Includes:
  - **Handover Success Rate (Intra-LTE)**: Success in transfers between cells of the same LTE technology. Should exceed 98%.
  - **Handover Success Rate (Inter-RAT)**: Success in transfers between different technologies (e.g., LTE to 3G). A typical target is above 96%.
- **Throughput and Quality of Service**:
  - **Downlink Average Throughput**: Average download speed experienced by users. Values above 25 Mbps are considered good.
  - **Uplink Average Throughput**: Average upload speed. A typical target is above 8 Mbps.
  - **Cell Edge Performance (5th Percentile)**: Performance of users in the worst coverage

situation (usually at the cell edge). Should be at least 2 Mbps download and 1 Mbps upload.

Establishment of SMART Goals:
Optimization goals should be Specific, Measurable, Achievable, Relevant, and Time-bound. For example: "Reduce the drop call rate in the central area from 2.5% to 1.0% within 4 weeks".

2.2 Phase 2: Data Collection (Drive Tests, Scanners, OSS Measurements)

Data collection is the "field investigation" phase where concrete facts about network performance are collected through multiple complementary methodologies.

Detailed Drive Tests involve vehicles equipped with specialized instrumentation that follow carefully planned routes:

- **Measurement equipment**: Includes professional scanners (like R&S TSME6), multiple test phones from different manufacturers, high-precision GPS, and computers with specialized software.
- **Collected metrics**:
    - **RF Parameters**: RSRP (Reference Signal Received Power), RSRQ (Reference Signal Received Quality), SINR (Signal to Interference plus Noise Ratio), PCI (Physical Cell ID), Timing Advance.