

CELLULAR NETWORK DEPLOYMENT

Complete Deployment Manual

Technologies from 2G to 5G
From planning to operation



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PREFACE

The Mobile Communication Journey: From Past to Future

Mobile telephony represents one of the most extraordinary technological journeys of humanity. What began as a basic voice service for a restricted elite has transformed into a critical infrastructure connecting billions of people, driving economies, and redefining how we live, work, and relate.

This manual was born from the need to document and preserve the knowledge accumulated over more than four decades of mobile network evolution. From the first analog 1G systems, which allowed voice communication with poor quality and non-existent security, to today's 5G networks that offer multi-gigabit speeds, ultra-low latency, and support for critical applications, we have witnessed an unprecedented technological revolution.

Approach and Methodology

The development of this work followed a systemic and multidisciplinary approach, recognizing that the successful deployment of mobile networks requires the harmonious integration of technical knowledge, project management, regulatory compliance, and market understanding. Each chapter was structured to provide:

- **Solid Theoretical Foundations:** Detailed explanations of the physical and mathematical principles governing mobile telecommunications
- **Proven Practical Methodologies:** Step-by-step processes validated in real deployments
- **Detailed Technical Specifications:** Specific parameters and configurations for each technology
- **Lessons Learned:** Field experiences highlighting common pitfalls and best practices
- **Future Vision:** Emerging trends and technologies that will shape the next chapter of telecommunications

Target Audience and Applicability

This manual was developed to serve a broad spectrum of professionals:

Engineers and Technicians will find detailed specifications, installation procedures, and essential configuration parameters for their daily work.

Managers and Leaders will have access to planning methodologies, feasibility analysis, and management tools that support strategic decision-making.

Academics and Researchers will have a solid base of established knowledge and future directions for investigation.

Students and Professionals in Training will find a structured learning path from fundamental concepts to the most advanced implementations.

Structure and Organization

The content organization follows a logical progression that accompanies the complete lifecycle of a mobile network deployment project:

Part I - Fundamentals and Planning (Chapters 1-3) establishes the conceptual basis, feasibility analysis, and regulatory aspects.

Part II - Design and Dimensioning (Chapters 4-6) addresses detailed planning, network architecture, and physical infrastructure.

Part III - Implementation and Integration (Chapters 7-9) covers installation, configuration, and integration of all systems.

Part IV - Testing and Optimization (Chapters 10-11) details validation, acceptance, and performance improvement procedures.

Part V - Operation and Maintenance (Chapters 12-13) deals with continuous operation, security, and compliance.

Part VI - Sustainability and Innovation (Chapters 14-15) explores environmental, social aspects and future trends.

Supplementary Chapters include practical cases, lessons learned, and a detailed compendium of equipment.

Historical Context and Sector Importance

Mobile telephony has transformed from a luxury service to an essential utility. In developing countries, mobile networks often represent the first and only form of internet access for large portions of the population. In developed countries, they are the backbone of digital transformation, enabling everything from smart cities to autonomous vehicles.

The mobile telecommunications sector has generated an economic ecosystem that includes equipment manufacturers, application developers, content providers, and a myriad of value-added services. It is estimated that for every direct job in the sector, another 3-5 indirect jobs are created in the economy as a whole.

Challenges and Opportunities

Current challenges include:

- The need for massive investments to support exponential growth in data traffic
- The increasing complexity of operating multi-technology, multi-vendor, and multi-layer networks

- Demands for greater energy efficiency and environmental sustainability
- The urgency to ensure cybersecurity in an increasingly connected world

Opportunities are equally significant:

- The digital transformation of entire industries through 5G and IoT
- The digital inclusion of historically disconnected populations
- Innovation in services and applications we cannot yet imagine
- Contribution to achieving the UN Sustainable Development Goals

Acknowledgments

This work is the result of the contribution of hundreds of professionals who generously shared their knowledge and experiences. Field engineers who faced adverse conditions to install sites in remote locations, network operators who maintained critical services 24x7, regulators who balance innovation and consumer protection, and academics who expand the frontiers of knowledge - all have left their mark on this manual.

Invitation to the Reader

We invite you, the reader, not only to consume this content but to contribute to its continuous evolution. Mobile telecommunications is a dynamic field where today's state-of-the-art becomes tomorrow's legacy technology. Your experiences, insights, and criticisms are valuable to keep this manual relevant and useful for the next generations of professionals.

May this work serve as a reliable compass on your journey through the fascinating world of mobile telecommunications and inspire innovations that continue to connect people and transform societies.

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CHAPTER 1: INTRODUCTION TO MOBILE TELEPHONY

1.1 FUNDAMENTAL CONCEPTS AND DEFINITIONS

1.1.1 Comprehensive Definition of Mobile Telephony

Mobile telephony represents a sophisticated telecommunications system that allows bidirectional voice and data communication through the use of electromagnetic waves. This system connects portable devices to a fixed network of base stations, characterized by user mobility and the capacity for automatic handover between coverage cells.

Structural Components of the System:

Mobile Device (User Equipment - UE):

Comprises cell phones, smartphones, USB modems, and other terminal equipment. Each device contains an identification module (SIM/USIM) that authenticates the user on the network. These devices have specific radio interfaces for each technological generation and function as the direct point of contact with the end user.

Base Radio Station (BTS/NodeB/eNodeB/gNB):

Fixed equipment strategically positioned that establishes direct communication with mobile devices. Located at the geometric center of each coverage cell and responsible for controlling and managing the radiofrequency resources assigned to that specific cell.

Radio Access Network (RAN):

Integrated set of base stations and their associated controllers. This network dynamically manages radio resources, controls user mobility between cells, and serves as the physical interface between mobile users and the core network.

Core Network:

Considered the brain of the system, the core network is responsible for subscriber management, service provisioning, billing systems, and interconnection with other telecommunications networks.

1.1.2 Detailed Operating Principle**Complete Sequence of a Mobile Call:****Phase 1 - Call Initiation:**

The user initiates the call through their mobile device, which transmits a request signal to the

nearest base station. This signal contains subscriber identification information and details of the requested service.

Phase 2 - Routing to the Core Network:

The base station receives the signal and forwards it through the access network to the appropriate controller (BSC, RNC, or directly to the core network, depending on the technology). The controller manages multiple base stations and optimizes radio resource usage.

Phase 3 - Central Processing:

The signal arrives at the switching center (MSC/MME), which identifies the subscriber by querying the subscriber database (HLR/HSS). The center verifies the subscriber's validity, their contracted services, and resource availability.

Phase 4 - Connection Establishment:

The switching center establishes the connection with the destination, which can be another mobile subscriber, fixed network, or data service. The entire communication path is configured, and resources are allocated in all network segments.

Phase 5 - Bidirectional Communication:

Once the complete path is established,

bidirectional voice or data communication occurs. The network continuously monitors connection quality and manages possible transfers between cells during user mobility.

Handover Mechanism (Transfer Between Cells):

Trigger Conditions for Handover:

- Signal strength of the current cell below the established minimum threshold
- Signal strength of a neighboring cell consistently stronger
- Neighboring cell with available capacity to accept a new user
- Detected user movement between coverage areas of different cells

Sequential Handover Procedure:

1. The mobile device continuously reports signal strength measurements to the current base station
2. The base station analyzes these measurements and decides when to initiate the handover procedure

3. The new destination base station is contacted, and resources are pre-allocated
4. The mobile device receives instructions to tune to the new frequency/cell
5. Communication is transferred seamlessly to the new cell without perceptible interruption
6. Resources in the original cell are released after transfer confirmation

1.2 HISTORICAL AND TECHNOLOGICAL EVOLUTION

1.2.1 First Generation - Analog Systems (1G)

Historical Context and Development:

The first generation of mobile telephony emerged in the early 1980s as an evolution of previous mobile radio systems. The fundamental innovation was the implementation of the cellular concept, allowing frequency reuse and significantly increasing system capacity.

Main Implemented 1G Systems:

AMPS System (Advanced Mobile Phone System):

Developed collaboratively by Bell Labs and Motorola, AMPS represented the first

commercially successful cellular system. Its initial deployment occurred in Chicago in 1983, using the 800 MHz band with specific division: 824-849 MHz for uplink (device to base) and 869-894 MHz for downlink (base to device). Each channel occupied 30 kHz of spectrum using FM modulation for voice with ± 12 kHz deviation. The system supported approximately 60 channels per cell and did not incorporate any security or encryption mechanisms.

NMT System (Nordic Mobile Telephone):

Developed in cooperation by Sweden, Norway, Denmark, and Finland, NMT was initially launched in the 450 MHz band (NMT-450) in 1981, later evolving to the 900 MHz band (NMT-900). It was characterized by excellent coverage in rural areas due to the low frequencies used and introduced the pioneering concept of international roaming between countries.

TACS System (Total Access Communication System):

Derived from AMPS but adapted for the European market, TACS operated in the 900 MHz band with 25 kHz channels. It was mainly implemented in the

UK and Italy, with its ETACS variant expanding capacity through additional channels.

Fundamental Limitations of 1G Systems:

- Extremely limited capacity due to inefficient spectrum use
- Inconsistent voice quality affected by noise and interference
- Complete absence of security - conversations could be intercepted by common scanners
- Incompatibility between different national systems
- Excessive battery consumption in mobile equipment
- Large-sized and heavy devices, inadequate for manual transport

1.2.2 Second Generation - Digital Revolution (2G)

Transition to Digital Technology:

The second generation marked the complete transition from analog to digital systems, initiated in the early 1990s. The fundamental milestone was the development of the GSM standard (Global

System for Mobile Communications), which became the most widely adopted mobile telephony system globally.

Detailed 2G Implementation Chronology:

- 1991: First commercial GSM network in Finland by operator Radiolinja
- 1992: First GSM networks implemented in other European countries
- 1993: First CDMA network (IS-95) deployed in the United States
- 1995: Complete D-AMPS (digital TDMA) specifications published
- 1997: Introduction of GPRS (2.5G) for packet data transmission
- 1999: EDGE standardized as the final evolution of GSM (2.75G)

Technical Architecture of the GSM System:

Base Station Subsystem (BSS):

Comprises the Base Transceiver Stations (BTS) and their controllers (BSC). Each BTS contains 1 to 12 transceiver units (TRX), each operating on a different frequency pair. Each TRX supports 8

TDMA timeslots, allowing up to 96 simultaneous calls per BTS in maximum configuration. The BSC typically manages up to 100 BTS, being responsible for handovers, channel allocation, power control, and radio resource management.

Network Switching Subsystem (NSS):

Includes the Mobile Switching Center (MSC), which processes voice and data calls, manages subscriber location, supplementary services, and interconnection with other networks. A typical MSC processes up to 300,000 subscribers and 2,000 simultaneous calls. The Home Location Register (HLR) stores permanent information of all subscribers, while the Visitor Location Register (VLR) maintains temporary data of subscribers currently located in the geographic area under the responsibility of the associated MSC.

Operation Support Subsystem (OSS):

Operations and maintenance center (OMC) that monitors and controls the entire GSM network, collecting performance statistics, generating alarms, and allowing remote configuration. The Network Management Center (NMC) manages multiple OMCs at the national or regional level.