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TRANSITION TO 5G STANDALONE (SA) MODE: CHALLENGES AND STRATEGIES

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Abstract

The benefits of 5G Standalone (SA) networks are extensive, with the most notable advantages categorized into ultra-low latency, advanced network slicing, massive machine-type communication (mMTC), and the fully independent architecture of SA networks. However, these advancements are not without challenges, including spectrum allocation, seamless core network migration, device interoperability, and the operational complexities involved. To overcome these hurdles, improvements must focus on enabling seamless interoperability between legacy systems and next-generation networks, driving greater alignment on standardization efforts across the industry, and incorporating automation technologies to streamline network operations. Introduced in 3GPP Release 15, 5G SA mode laid the foundation for 5G technology, emphasizing its transformative potential.

This paper explores several enhancements designed to facilitate a smooth transition to 5G SA, aiming to optimize integration, foster collaboration on standards, and leverage automation for efficient and scalable deployments.

Keywords: 5G, LTE, Network Slicing.

I. INTRODUCTION

With the growing demand for ultra-reliable low-latency communication (URLLC) and massive IoT connectivity, telecom operators are shifting from 4G LTE and 5G Non-Standalone (NSA) networks to 5G Standalone (SA) mode. While LTE and NSA modes leverage existing 4G infrastructure, 5G SA enables a fully independent 5G network core (5GC), opening new opportunities in network slicing and real-time applications. However, the transition is complex, requiring not only a shift in network architecture but also the adoption of new standards, devices, and operational frameworks.

This paper provides a technical overview of the 5G SA transition, focusing on direct evolution paths from LTE or 5G NSA, associated challenges, and potential improvements.

II. NETWORK ARCHITECTURE: LTE, 5G NSA, AND 5G SA COMPARISON

The network architecture of mobile communications has undergone significant changes with the introduction of 5G technologies. The core distinction is the architectures of LTE, 5G NSA, and 5G SA, each designed to meet varying operational demands and user expectations.

- LTE, characterized by its reliance on the Evolved Packet Core (EPC), provides a solid foundation for mobile broadband but is limited in its ability to support the expanding IoT landscape and advanced use cases.
- In contrast, 5G NSA leverages existing LTE infrastructure while integrating a 5G radio access network, allowing operators to enhance performance without overhauling core systems.
- In 5G SA design, we decouple the radio access and core networks, 5G SA enables advanced functionalities such as network slicing and ultra-low latency, paving the way for innovative applications and improved network efficiency.

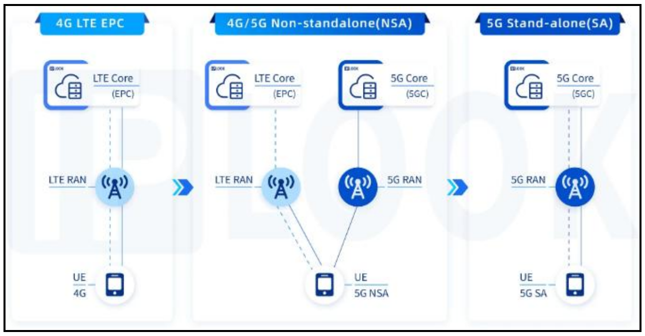

Figure 1: Comparison of LTE, 5G NSA and SA architecture

Feature	Architectures		
	LTE	*5G NSA*	*5G SA*
Core Network	EPC(LTE core)	EPC with 5G RAN integration	5GC(5G Standalone Core)
Latency	~20 ms	~15 ms	Sub-5ms (theoretical <1ms)
Spectrum	Sub-6 GHz	Sub-6 GHz + mmWave	Sub-6GHz, mmWave, unlicensed+ THz
Control Plane	LTE core	LTE core + 5G signalling	Native 5G signalling
Network Slicing	Limited or none	Limited slicing capability	Full slicing capability
Data Rate	Up to 1 Gbps	Up to 3 Gbps	Up to 10 Gbps and beyond
Mobility Mgmt	Handovers between LTE cells	Handovers between LTE cells – Dual Connectivity	Enhanced mobility management
Device Density	100,000 devices/km^2	1 million devices/km^2	1 million devices/km^2

Table1: features of lte, 5g nsa and 5g sa architectures [10]

III. ADVANTAGES OF 5G SA NETWORKS OVER 5G NSA/LTE

- **Ultra-Low Latency:** Achieves latencies as low as 1 ms, supporting real-time applications like augmented reality (AR), virtual reality (VR), and autonomous vehicles.
- **Enhanced Network Slicing and Flexibility:** Supports advanced network slicing capabilities, allowing operators to create tailored virtual networks for various applications, ensuring optimized performance.
- **Independent Core Network:** Operates on a dedicated 5G Core (5GC), eliminating reliance on legacy 4G infrastructure, which leads to improved efficiency and streamlined operations.
- **Higher Throughput and Efficiency:** Delivers greater data rates through technologies like Massive MIMO, while its cloud-native architecture enhances resource management and reduces operational costs.
- **Support for Emerging Use Cases:** Designed for ultra-reliable low-latency communication (URLLC) and massive machine-type communication (mMTC), catering to critical IoT applications.
- **Seamless Handover and Better Security:** Enables smoother connectivity between 5G services and includes enhanced security features, providing robust protection against cyber threats.
- **Optimized Resource Utilization:** Allows dynamic responses to changing traffic patterns, ensuring efficient utilization of network resources.

IV. TRANSITION PATHWAYS

Telecom operators may adopt one of two primary migration paths toward 5G SA:

4.1 Direct Transition from LTE to 5G SA: This path involves bypassing 5G NSA and directly upgrading both the core network and radio infrastructure to support 5G SA.

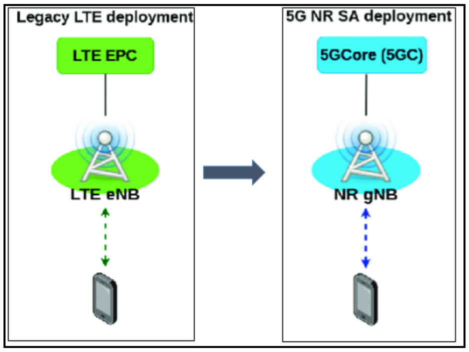

Figure 2 : Direct Transition from LTE to 5G SA

4.1.1 Advantages:

- **Immediate Access to Advanced Features:** Operators can implement advanced features such as network slicing and ultra-reliable low-latency communication (URLLC) right from the outset, enhancing service offerings.

- **Reduced Long-Term Complexity:** By establishing a 5G SA architecture early on, operators may simplify their network intricacy in the long run by eliminating the need to support legacy technologies like UMTS and GSM.

4.1.2 Challenges

- **Higher Risk of Implementation Failure: The** complexity of directly transitioning to a new architecture without the transitional phase may lead to higher risks associated with integration and network reliability.
- **Device Compatibility Issues:** There may be a limited number of devices initially available that fully support 5G SA features, potentially slow user adoption and service availability.

4.2 Gradual Migration from 5G NSA to 5G SA: In this approach, operators deploy NSA initially, leveraging 4G core (EPC), before migrating to SA mode by upgrading to a 5G Core (5GC).

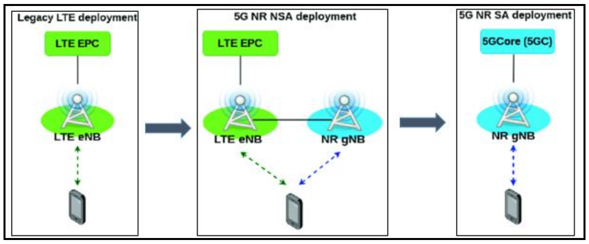

Figure 3: Gradual Migration from LTE to5G NSA to 5G SA

4.2.1 Advantages:

- **Lower Upfront Costs**: This approach allows operators to spread capital expenditures (CAPEX) over time as they upgrade their network incrementally, making it more financially adaptable.
- **Leverage Existing Infrastructure**: By utilizing existing LTE resources and equipment, operators can reduce the impact of the transition on their current operations and services.

4.2.2 Challenges:

- **Increased Operational Complexity**: Managing dual connectivity between LTE and 5G NSA can complicate network management, requiring additional training for resources.
- **Potential for Suboptimal Performance**: During the transitional phase, users may experience inconsistencies in service quality and performance as the network operates in a mixed-mode environment. Inability to handle the transition can cause degradation in user experience

V. KEY CHALLENGES IN TRANSITIONING TO 5G SA

5.1 Spectrum Allocation and Management

- **Dynamic Spectrum Sharing (DSS):** Implementing DSS can allow operators to optimize spectrum use across LTE and 5G, but it requires advance technology understanding and regulatory approval.

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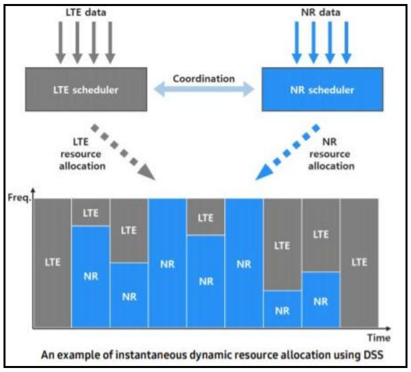

Figure 4 : Dynamic Spectrum Sharing [10]

- **Interference Management:** As new bands are introduced, managing interference becomes increasingly complex, necessitating innovative techniques to mitigate impacts on service quality.

5.2 5G Core (5GC) Implementation

- **Legacy System Integration:** Integrating the 5GC with existing legacy systems can pose challenges in terms of compatibility, requiring careful planning and execution.

5.3 Device Compatibility and User Equipment (UE)

- **Fragmentation of Device Ecosystem:** The varying capabilities of 5G devices in the market can lead to a fragmented ecosystem, complicating network management and service delivery.

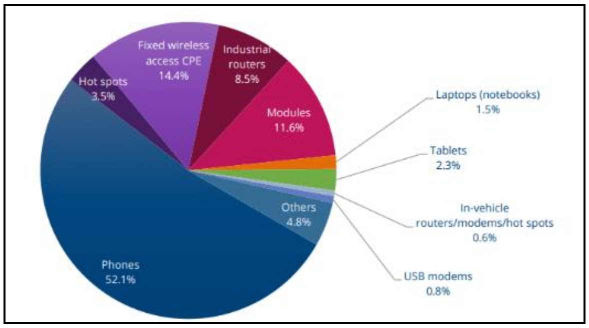

Figure 5: Types and their share of devices supporting 5G SA deployment

- **Consumer Awareness**: Users may not be aware of the differences between NSA and SA, leading to confusion and potential reluctance to adopt newer devices that support SA.4.4. Interoperability and Handover Complexity. Users will need to upgrade their devices to take advantage of 5G SA features which can lead to slower transition.

5.4 Interoperability and Handover Complexity

- **Quality of Service (QoS) Management:** Ensuring consistent QoS across LTE, NSA, and SA networks is challenging, especially for services requiring guaranteed performance metrics, like VoIP, IoT devices or real-time applications.
- **Handover Latency:** The handover process can introduce latency, especially when transitioning between different network types, impacting user experience and application performance.
- **End-to-End Testing:** Comprehensive testing across all network components and services is necessary to identify and resolve potential handover issues, which can be time-consuming and resource-intensive.

5.5 Operational and Cost Implications

- **Ongoing Maintenance Costs:** Beyond initial CAPEX, maintaining and operating dual networks (LTE and 5G) can lead to increased operational costs, necessitating effective resource management.
- **Skillset Gaps:** The transition to 5GC and SA may require upskilling existing staff or hiring new personnel with the necessary expertise, adding to operational (OPEX) challenges.
- **Vendor Management:** Collaborating with multiple vendors for equipment, software, and services can complicate operations and lead to potential integration issues, requiring effective vendor management.

VI. STRATEGIES FOR IMPROVING AND AFFECTING A FASTER 5G SA TRANSITION

6.1 Enhance Standardization and Vendor Interoperability

- Collaboration among OEMs and standards bodies (e.g., 3GPP) is essential to ensure seamless SA deployments with multi-vendor interoperability
- Establish standardized application programming interfaces (APIs) for faster easier integration of third-party applications and services.

6.2 Develop Efficient Handover Mechanisms

- Innovation into AI-driven handover algorithms can improve network performance, especially when switching between LTE, NSA, and SA modes.
- Predictive Handover Techniques: Implement predictive data analytics to anticipate user movement and optimize handover timing, minimizing service interruptions.

- Enhanced connectivity for autonomous vehicles, ensuring real-time handover switching without latency can be done using relative location of site and moving vehicle direction.

6.3 Spectrum Aggregation and Management Tools

- Operators need dynamic spectrum sharing (DSS) tools and policy frameworks to efficiently manage spectrum across multiple technologies.
- Real-Time Spectrum Monitoring: Develop tools for real-time monitoring and analytics of spectrum usage to optimize allocation and reduce interference. Check spectrum usage and efficiency in real time to adjust handover/switching parameters.

6.4 Leverage Automation and AI for Operations

- Network function virtualization (NFV) and automation frameworks can simplify core network management and enable zero-touch provisioning for new services.
- AI-Powered Predictive Maintenance: Use AI to predict network failures before they occur, enhancing reliability and reducing downtime.
- Potential Use Case: Automated network management for large-scale IoT deployments in industrial settings, facilitating real-time adjustments based on operational data.

6.5 Address Device Fragmentation

- Incentives for Manufacturers: Implement incentive programs for device manufacturers to prioritize the development of SA-ready devices and promote market awareness.
- Potential Use Case: Consumer electronics, such as smart home devices, that leverage 5G SA for enhanced connectivity, improved performance, and real-time responsiveness.

VII. CONCLUSION

Transitioning to 5G Standalone (SA) from LTE or Non-Standalone (NSA) networks is a necessity. Even though this transition involves significant technical challenges and operational complexities, it paves the way for advantages like ultra-low latency, network slicing, and efficient spectrum utilization. To ensure a successful shift, operators must tackle issues related to spectrum allocation, core network upgrades, and device compatibility. Additionally, advancements in interoperability, and policy frameworks will play a vital role in adoption of 5G SA and improving overall network performance.

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