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# 5G Network Slicing for Improved Meteorological Warning Dissemination

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## ABSTRACT

This study addresses challenges in meteorological warning dissemination by examining the limitations of traditional communication methods that have been used. Leveraging 5G technologies such as mobile communications, IoT, and advanced satellites, the research focuses on integrating 5G network slicing to enhance the transmission speed and accuracy of meteorological disaster warnings. The paper proposes a concise design reference scheme, defining key indices and requirements for 5G network slicing tailored to meteorological information transmission. The three-tiered end-to-end architecture of 5G network slicing, involving the management, control, and user planes, is outlined. Key components like CSMF, NSMF, and NSSMF contribute to the comprehensive life cycle management of end-to-end slicing. The study classifies Service Level Agreement (SLA) indicators for 5G network slicing, aligning them with industry standards, and establishes a foundational understanding for implementation. This framework aims to revolutionize information transmission, providing a scalable and adaptive solution for meteorological warning systems in dynamic environments.

***Keywords:*** network slicing , SLA , 5G, Weather warning information

## 1. INTRODUCTION

In the current landscape, the dissemination of meteorological disaster warning information in some countries heavily relies on conventional communication methods, presenting inherent challenges such as limited transmission speed due to the constraints of network capacity and bottlenecks. The intricacies involved in meeting the precise requirements for the accurate dispersion of early warning information in designated and remote areas further amplify these challenges. However, there is a promising avenue for overcoming these obstacles, driven by the continual evolution and development of emerging information and communication technologies [1]. Notably, countries worldwide are witnessing the continuous advancement of technologies like 5G mobile communications, mobile Internet, Internet of Things, , and satellite.

This confluence of cutting-edge technologies presents a transformative opportunity to address the existing limitations in meteorological disaster warning information dissemination. By synergizing these new information and communication technologies with strategic applications for early warning information dissemination, the potential to overcome the challenges becomes increasingly evident. A particularly promising solution lies in the utilization of 5G network slicing, a technology that empowers applications across diverse industries by providing assurances on critical network indicators such as bandwidth and latency [2]. This article delves into a comprehensive study of the definition and requirements of indices for 5G network slicing, specifically tailored to optimize the transmission of meteorological disaster warning information. Furthermore, the research aims to furnish practical and adaptable slice design reference solutions based on distinct application scenarios [3].

The foundational concept of network slicing involves operators strategically partitioning multiple end-to-end logical networks within the framework of traditional physical networks. This segmentation is intricately aligned with the diverse and dynamic needs of users across various industries, addressing critical indicators like latency, bandwidth, security, and reliability. These individualized logical networks encompass the access network, transmission network, and core network, each isolated from the others. Consequently, the application of network slicing technology emerges as a pivotal strategy capable of efficiently meeting the multifaceted requirements of different applications within the meteorological disaster warning information dissemination landscape.

## 2. 5G NETWORK SLICING TECHNOLOGY

The delineation of 5G network slicing is outlined in 3GPP TS 23.501, where the physical network undergoes subdivision into numerous logical networks. This modular approach allows a single network to serve multiple purposes, granting operators the flexibility to construct various dedicated, virtual, isolated, and versatile networks atop the physical infrastructure [4]. To cater to the diverse requirements of users across different industries, tailored logical networks are imperative, addressing specific network capabilities such as latency, bandwidth, and the number of connections.

Implementation of 5G network slicing is contingent upon SA network architecture. As per the 3GPP R15 protocol, slice identification and end-to-end (E2E) identification of user groups are established based on the 5G SA architecture, elucidating how slicing facilitates differentiation. Achieving differentiation for specific user groups typically necessitates intricate configurations in network and terminal settings. Notably, protocols like 2G/3G/4G/5G NSA lack the means to identify certain user groups in an end-to-end manner uniformly [5].

The architecture of 5G network slicing encompasses an end-to-end design comprising multiple subdomains and involving three distinct levels: the management plane, control plane, and user plane, as illustrated in Figure 1.

The overarching architecture for end-to-end slice management comprises crucial components as follows:

(1) The Communication Service Management Function (CSMF) serves as the entry point for slicing design. It transforms business system requirements into comprehensive end-to-end network slicing requirements, forwarding them to the Network Slice Management Function (NSMF) for network design. Typically, CSMF functionalities are derived from the transformation of the operator's Business Support System (BSS).

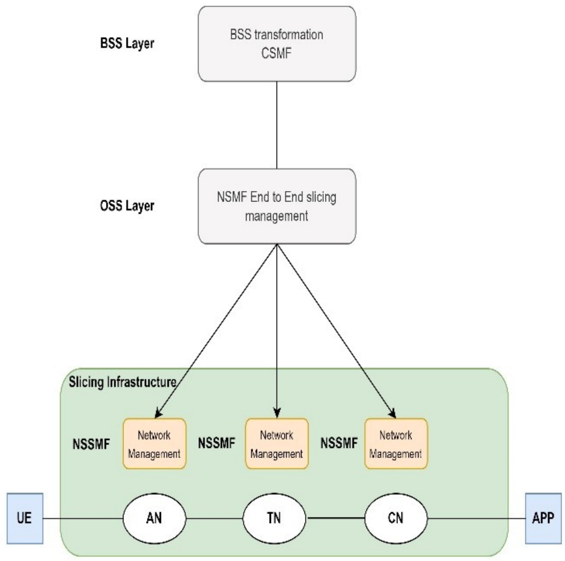


*Figure 1: Schematic diagram of 5G end-to-end slicing*

(2) The Network Slice Management Function (NSMF) assumes responsibility for end-to-end slice management and design. Upon obtaining the requisite end-to-end network slicing requirements, NSMF generates a slice instance. It further decomposes and consolidates the instance in alignment with the capabilities of each subdomain/subnet, transmitting deployment requisites to the Network Slice Subnet Management Function (NSSMF). NSMF functionalities are typically provided by cross-domain slicing managers.

(3) The Network Slice Subnet Management Function (NSSMF) takes charge of the slice management and design for subdomains/subnets, with distinct NSSMFs for the core network, transmission network, and wireless network [6].

NSSMF communicates subdomains/subnets capabilities to NSMF, facilitating autonomous deployment and enablement within the subdomain/subnet. Throughout the operational process, the subdomain/subnet undergoes slicing, accompanied by network management and monitoring. The collaboration of CSMF, NSMF, and NSSMF, through decomposition and coordination, culminates in the design and instantiation deployment of the end-to-end slicing network.

The complete life cycle management of end-to-end slicing encompasses activities such as slicing instance creation, monitoring, and release. This involves breaking down network requirements into individual domains like wireless network, bearer network, and core network, accomplishing slice end-to-end configuration. Information from each domain is collected and synthesized to generate slice-level statistical indicators, visually presented to integrate with the BSS system, supporting the design and launch of industry-specific slicing templates [7].

### *2.1 Network slicing SLA classification indicators*

Service Level Agreement (SLA): This constitutes a formal agreement, often referred to as a service level guarantee, that is negotiated between two parties—typically a service provider and a customer. Functioning as a contractual arrangement (or a segment thereof), its primary purpose is to establish a mutual understanding of services, priorities, responsibilities, and other relevant aspects.

Service Level Specification (SLS): Serving as the technical components and indicators of an SLA, the Service Level Specification defines parameters and associated threshold values for SLA indicators. It plays a crucial role in articulating the technical specifics of the agreed-upon service levels.

Currently, the industry has introduced several SLA-related standards. By amalgamating GSMA and 3GPP standards, the SLA indicators for 5G slicing encompass essential metrics such as user bandwidth, delay, packet reliability, throughput rate, positioning accuracy, isolation, among others. These indicators are precisely defined and detailed in Table 1, providing a comprehensive framework for evaluating and ensuring the performance of 5G slicing services.

**Table 1** Main indicators of 5G end-to-end slicing SLA

| SLA Indicator | definition |
|---|---|
| Network availability | The ability of a product to complete specified functions under specified conditions and within a specified time (Source: GJB451-90, IEC61907) |
| User rate (UL/DL) | Minimum data rate required to obtain adequate quality experience, except in the case of broadcast services (the value given is the maximum required) (Source: 3GPP TS 22.261/22.104) |
| Delay | End-to-end delay: The time it takes for transmission from the source to successful reception at the destination, measured at the communication interface (Source: 3GPP TS 22.261) |
| Reliable package | In the context of network layer packet transmission, the percentage value of the number of network layer packets successfully delivered to a given system entity within the time constraints required by the target service divided by the total number of network layer packets sent (Source : 3GPP TS 22.261) |
| Positioning accuracy | Positioning accuracy: describes how close the UE measured position is to the real position value (Source: TR 22.872) |
| Timing accuracy | This definition refers to the definition of Clock Synchronicity in 3GPP as follows: the maximum time deviation allowed in the synchronization domain between the master clock and any single UE clock (Source: 3GPP TS 22.104) |
| Cyber security | Ensure the confidentiality and integrity of information transmitted, exchanged and stored in the network from unauthorized tampering, leakage and destruction ; at the same time, ensure that the system operates continuously and reliably and provide continuous communication services without interruption |
| Isolation | Resource isolation requirements based on tenant business needs. "No sharing" means that the tenant requires complete isolation of slice resources, and the tenant's business and other businesses cannot share the same NSI. "Sharing" means that tenants have no mandatory requirements for resource isolation. |

## 3. SLICE DESIGN FOR WEATHER WARNING INFORMATION

### *3.1 Purpose and Characteristics of Meteorological Disaster Early Warning Efforts*

The objective of meteorological disaster early warning efforts is to anticipate and promptly address the impacts of meteorological natural disasters, aiming to minimize human and property losses.

The transmission and dissemination of meteorological disaster early warning information must adhere to specific standards. Once these predefined criteria are met, the responsible meteorological disaster early warning department should promptly issue relevant warnings. Subsequent to the warnings, each department is expected to implement corresponding precautionary measures swiftly to mitigate potential risks and reduce the impact on lives and property. Furthermore, the wide coverage of meteorological disaster early warning work is achieved by enhancing the monitoring and forecasting network. This enhancement serves to improve the accuracy, coverage, and speed of early warning information dissemination, eliminating any existing "blind spots" in the release of such information and enhancing overall dissemination efficiency.
The primary characteristics of meteorological disaster early warning efforts encompass:

(1) Timeliness: Given the rapid onset and high destructiveness of most meteorological natural disasters,

timely actions and measures by relevant agencies and departments are imperative.

(2) Accuracy: Involving the monitoring, transmission, and processing of substantial meteorological data, the accuracy of meteorological disaster early warning efforts is crucial. Decisions and actions must be based on precise and timely analysis to enhance the effectiveness of disaster response significantly.

(3) Openness: Following the analysis of meteorological monitoring information and the formulation of early warning information, relevant departments should promptly release it to the public. Delayed release or concealment of pertinent conclusions may result in adverse consequences.

(4) Multiple Levels: Recognizing the varying severity of meteorological disasters, the early warning mechanism should incorporate different levels, ranging from high to low. This tiered approach forms a systematic release and transmission mechanism for early warning information.

### *3.2 Analysis of Transmission Requirements for Meteorological Disaster Early Warning Information*

Meteorological disasters pose a significant threat to national development and the social economy, with a high incidence rate among natural disasters. Early warning signals for meteorological disasters directly impact public safety and property, necessitating the transmission of warning information to be effective, accurate, and widely covered. Given the urgency, early warning information must swiftly reach a large number of mobile phone users within the coverage of the 5G network, ensuring both promptness and precision. In designing a network-slicing solution for the transmission of meteorological disaster early warning information, the primary considerations should include real-time transmission, minimal delay, accuracy, low bit error rate, ample bandwidth, and the prevention of information/data backlog. The initial design of network slicing indicators aligns with weather warning information transmission requirements and network slicing classification standards with the following specifications:

(1) User bandwidth level B1 (1 ~ 10 Mbit/s): Considering that current early warning information transmission primarily involves text without pictures or videos, a smaller single user bandwidth (B1 level 1~10 Mbit/s) is deemed sufficient to meet the transmission needs of an individual user.

(2) Delay level T2 (20 ~ 50 ms): Given the imperative for rapid dissemination of early warning information to all users within a designated area in a short timeframe (1 min), a moderate delay level of T2 is chosen for a single user.

(3) Isolation level S1 (logical isolation): Recognizing that meteorological disaster warning information is public and non-sensitive, a recommended approach involves utilizing a resource preemption mechanism based on priority scheduling to achieve logical isolation.

(4) Management level M3 (operable): Due to its broad scope, meteorological disaster warning information typically requires customized user group management, new business online commissioning, independent troubleshooting, and control over access and permissions, making it suitable for M3 operability.

### *3.3 Design Principles*

In contrast to traditional Quality of Service (QoS) indicators, 3GPP has introduced new delay-based Guaranteed Bit Rate (GBR) types and designed the 5G QoS Index (5QI) to reflect service performance for 5G technologies and services. This new standard, 5QI, is defined based on service priorities and requirements for indicators such as delay and packet error rate, allowing base stations to select the appropriate resource scheduling scheme during the establishment of a Protocol Data Unit (PDU) session. Table 2 outlines the method for selecting resource scheduling schemes to meet the latency and reliability requirements of new business applications.

During the process of service scheduling, the delays and Quality of Service (QoS) of uplink and downlink data packets between the wireless air interface, wireless base station, and PDU Session Anchor (PSA) User Plane Function (UPF) can be monitored in both the terminal and the PSA UPF. Specifically, the delay in the wireless air interface can be provided by the 5G wireless access network (Next-Generation Radio Access Network, NG-RAN).

In contrast, the delay between the wireless base station and PSA UPF can be supplied by the GPRS Tunnelling Protocol User Plane (GTP-U) path level within the quality of service flow or at the user level. Based on the monitoring results of these delays, corresponding guarantee strategies can be implemented to address different needs [8].

**Table 2** Delay Critical GBR 5QI and QoS mapping

| 5QI value | Default priority | Packet delay/ms | Packet error rate | Default maximum data size/Byte | Default averaging time window/ms | Typical business |
|---|---|---|---|---|---|---|
| 82 | 19 | 10 | $10^{-4}$ | 255 | 2000 | Discrete Automation |
| 83 | 22 | 10 | $10^{-4}$ | 1354 | 2000 | Discrete Automation |
| 84 | 24 | 30 | $10^{-5}$ | 1354 | 2000 | smart transportati on system |
| 85 | 21 | 5 | $10^{-5}$ | 255 | 2000 | High voltage power distribution |

## *2.4 Design Plan*

When incorporating network slicing into the transmission of meteorological disaster early warning information, reference can be made to solutions applied in industries such as healthcare and electricity [9, 10,11]. A dedicated meteorological network can be established to facilitate the transmission of early warning information among monitoring stations, meteorological bureaus, and user terminals. The business aspects are categorized into intra-site, off-site, and inter-site and inter-user terminal scenarios, each with distinct workflow and slicing design variations.

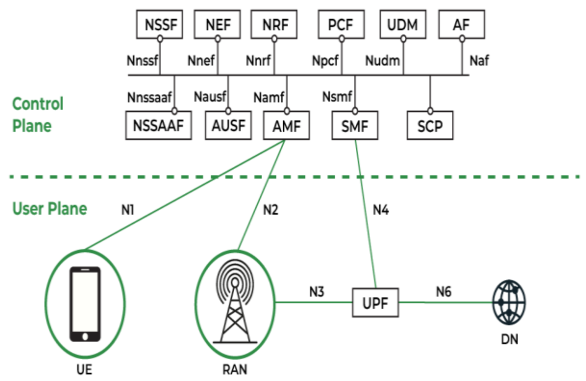


*Figure 2: 5G Architecture Diagram*

(1) Internal Transmission Networking

In the internal transmission networking segment, wireless indoor sub-stations using 5G-based wireless access equipment are employed for wireless access. These sub-stations then connect uniformly to the transmission slicing packet network (Slicing Packet Network) through a wireless centralized baseband unit (BBU) access ring. Within this network, the business originating from the detection station is conveyed to the 5G core network through the SPN access ring. The Multi-Access Edge Computing (MEC) can be deployed in the weather monitoring station or a data center between stations based on specific business needs. Non-mobile network requirements within the monitoring station can still be addressed using the existing wired office network, particularly for non-mobile network needs involving substantial equipment.

Most of the traffic within the monitoring station is routed into the 5G private network slicing through 5G wireless slicing, subsequently transmitted to the 5G core network meteorological private network slicing via the G.MTN/FlexE channel slicing of the SPN bearer network. In instances where the MEC is deployed in a data centre within a monitoring station or between monitoring stations, the business flow concludes nearby within the core network slice, connecting to the unified meteorological warning transmission platform or the data centre in the monitoring station through a dedicated wired line.

(2) Off-Site Networking

For network access beyond the monitoring station, the primary scenario involves using the downlink channel to transmit early warning information between the weather station and public mobile phone terminals. In this context, the 5G wireless access equipment in the Meteorological Bureau connects to the 5G public network, utilizing the G.MTN/FlexE channel established by the SPN network to transmit the prioritized early warning information to the 5G core network. Subsequently, the information is relayed to the user terminal.

(3) Inter-Site Networking

Network access between monitoring stations predominantly utilizes off-site networking, enabling remote connections from lower-level monitoring stations to higher-level stations/meteorological bureaus for data transmission. The business traffic from lower-level monitoring stations enters the 5G meteorological private network through 5G wireless slicing, proceeding to the upper-level site/meteorological bureau through the G.MTN/FlexE channel slicing of the SPN bearer network and the 5G core network meteorological slicing.

## 4. CONCLUSION

The freezing of the 3GPP 5G R17 version standard and the ongoing planning of R18 signify a progressive evolution in the capabilities of 5G network slicing and end-to-end network slicing. These advancements are poised to enhance the application of network slicing across diverse industries significantly. Concurrently, the operational deployment of 5G Standalone (SA) network lays the foundation for the widespread adoption of end-to-end network slicing technology. While the utilization of 5G network slicing in various industries is still in its early stages of exploration, this article addresses the specific requirements of weather warning information dissemination, presenting index reference values and solutions for 5G network slicing design. Looking ahead, continued refinement of design solutions is essential, aligning with relevant developments in 5G technology and pertinent research areas to further optimize the application of network slicing in the future.

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