

Technical Analysis of Broadcasting and Television Converged Network Architecture Postprint

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Abstract

In the context of the new era, the continuous enrichment and improvement of new media service content has promoted massive user growth. However, the contradiction between user demands and the network service capabilities of new media services is becoming increasingly prominent, making the improvement of network service quality an urgent issue to be addressed. To meet this demand, network convergence is required. At present, an increasing number of experts and scholars are shifting their research focus to network convergence; however, most research remains at the basic application level of mutual service access, without deeply exploring deep-level systems such as the network layer and transport layer. Consequently, the network service bottleneck of new media services has not been fundamentally resolved. In practice, new media services often exhibit asymmetry between uplink and downlink, characterized by small uplink data volumes and large downlink data volumes, with concentrated features in key services and time periods during service delivery, creating pressure on network transmission. Network broadcasting possesses incomparable advantages in network transmission, featuring large capacity, wide coverage, strong reliability, and freedom from congestion. Therefore, the integration of communication networks and broadcasting networks has become the inevitable trend of network convergence. Based on this, this paper explores a broadcasting-television converged network architecture technology aimed at laying the foundation for improving new media service capabilities and providing users with high-quality experiences.

Full Text

Analysis of Broadcasting-Telecommunication Converged Network Architecture Technology

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Abstract: In the new era, the continuous enrichment and improvement of new media service content has driven substantial user growth. However, the contradiction between user demands and new media service network capabilities has become increasingly prominent, making network service quality improvement an urgent priority. Meeting this requirement necessitates network convergence. Currently, an increasing number of experts and scholars have shifted their research focus toward network convergence, but most studies remain at the basic application level of mutual service access without deep exploration of network and transport layers, leaving fundamental bottlenecks in new media service networks unresolved.

In practice, new media services typically exhibit asymmetric uplink/downlink patterns, with small uplink data volumes but large downlink volumes. Moreover, focus services and peak time periods demonstrate concentrated characteristics, creating pressure on network transmission. Broadcasting networks offer unparalleled advantages in network transmission: large capacity, wide coverage, high reliability, and freedom from congestion. Therefore, integrating communication networks with broadcast networks has become an inevitable trend in network convergence. This paper explores a suitable broadcasting-telecommunication converged network architecture technology, aiming to lay the foundation for improving new media service capabilities and thereby delivering quality user experiences.

Keywords: Broadcasting-telecommunication; mobile communication; convergence; network architecture; architecture technology; LLC frame

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In the design of broadcasting-telecommunication converged networks, it is essential to fully consider broadcasting characteristics and select converged networking technologies applicable to both unidirectional and bidirectional networks. This approach maximizes the utilization of effective network resources while minimizing protocol and equipment modifications, thereby achieving network convergence goals while reducing costs. Drawing on relevant research, two technical solutions can be adopted in broadcasting-telecommunication converged network design.

First, referencing 3GPP NSA network architecture technology, this architec-

ture can support 5G communication network technology and LTE technology. In this framework, 5G's LTE and NR serve only as information data transmission pathways. The control plane signaling bearer SRB can only be transmitted through the LTE air interface, while the data plane radio bearer DRB can be transmitted through either the NR or LTE air interface. When eNB and UE are at the PDCP sublayer, they can schedule the data plane radio bearer DRB to the NR air interface to achieve data transmission goals [2]. This represents the fundamental content of the 3GPP NSA network architecture. Based on this design concept, IP transport networks with different standards can be viewed as transparent transmission channels for PDCP sublayer frame streams, through which data plane radio bearers DRB are transmitted. This allows the use of different numbers of uplink and downlink data planes to uniformly carry full-IP broadcasting networks, LTE, and NR. This design approach for broadcasting-telecommunication converged networks is straightforward, enabling direct implementation through NSA core network expansion. Meanwhile, LTE can simultaneously transmit information data with WiFi networks. However, this architecture has a drawback: it cannot achieve the goal of one radio bearer supporting multiple transmission networks, cannot meet unified bearer requirements, and cannot dynamically schedule and allocate multiple network transmissions for a single radio bearer. Consequently, it cannot adapt to variations in link quality and load across multiple networks.

Second, using 5G, WiFi, 4G, and existing broadcasting transmission networks as IP service transmission channels to establish heterogeneous transmission channels and achieve network convergence transmission requirements through IP flows. This converged network architecture requires support from multiple devices, including multi-network distribution and aggregation server equipment and integrated terminal devices. Additionally, a virtual path must be established between servers and terminals, with a wireless resource management server and integrated IP protocol stack designed at the network layer [3]. In this architecture, the primary function of the resource management server is reasonable scheduling to achieve the goal of heterogeneous wireless network convergence. Furthermore, there are numerous physical transmission links between distribution and aggregation servers with integrated functionality. During service provision, these physical transmission links can ensure continuous transmission of application layer business data, preventing interruption even if a physical link fails. Meanwhile, data service flows generated during application transmission are scientifically scheduled by the resource management server, which selects one or multiple physical links for real-time transmission. In this process, even if a physical link disconnects due to various factors, the application layer data does not interrupt; the resource management server immediately selects alternative physical links to continue transmission. Additionally, during data encapsulation and decapsulation at the sender and receiver, analysis of the newly designed protocol is required to lay a solid foundation for flexible scheduling and scientific management by the resource management server.

To meet the requirements for cross-regional roaming and dynamic management

of multiple wireless resource management servers, IP protocols can be utilized. Specifically, IP protocols are used to achieve “homogenization” based on IP while shielding physical layer “heterogeneity,” during which the IP protocol stack plays its role in transformation and adaptation [4]. During network convergence, different network interfaces can be used to achieve multi-network access objectives, dispersing business data to different subflows for real-time transmission across different links. In downlink transmission, broadcast transmission links can be invoked for efficient data dissemination through multicast. This demonstrates that this converged network architecture can simultaneously satisfy aggregation of multiple link broadband capabilities, thereby improving overall transmission throughput performance. It is well known that broadcasting television signals have satellite, wireless, and cable network systems, resulting in relatively high signal coverage that facilitates full utilization of broadcasting-telecommunication converged network functions. Based on this, this paper constructs a broadcasting-telecommunication converged network architecture using terrestrial digital television as the foundation and leveraging broadcasting 5G networks, wireless local area networks, and telecommunications network resources to establish transmission links between network platforms and integrated terminals, fundamentally solving networking difficulties caused by different standards.

2. Multi-service Bearer Requirements Based on LLC Frames

If IP service flows are simultaneously carried and transmitted through multiple IP channels, the receiving party will inevitably encounter packet reordering issues [6]. To address this problem, it is necessary to solve the sequential delivery of IP service flows across multiple channels to ensure ordered arrival during bearer transmission. Currently, two methods can achieve sequential delivery: Multipath TCP protocol and LLC over tunnel technology. Through theoretical research and practical comparison, the latter offers greater advantages and is therefore selected for this broadcasting-telecommunication converged network architecture.

LLC over tunnel technology integrates LLC logical links with UDP tunnels, ensuring that corresponding UDP tunnels exist on all IP-packetized network links. When business IP shunting passes through LLC data encapsulation, it forms LLC frame streams, with each LLC frame stream divided into multiple LLC frames. Based on the link status of multiple different network accesses, multiple LLC frames can be sent to UDP tunnels corresponding to network links for transmission as UDP packets, thereby achieving data transmission goals for one IP service flow across multiple network links and obtaining aggregated transmission bandwidth [7]. After receiving the transmitted content, the receiving party accurately identifies LLC frames accepted by UDP tunnels as belonging to one logical connection based on numbering information in the LLC packet header. LLC frames from the same LLC logical link are submitted as needed using a

receiving window according to sequence number fields in the packet header, ensuring that IP service flows can meet parallel transmission requirements through LLC over tunnel technology with ordered transmission.

The above analysis demonstrates that LLC over tunnel technology offers incomparable advantages, specifically analyzed from the following points:

First, UDP tunnels are easier to implement than TCP tunnels, and distribution/aggregation servers can simultaneously serve multiple users.

Second, UDP tunnels facilitate unidirectional broadcast link transmission, benefiting network convergence between unidirectional links and full IP services.

Third, the same network link can simultaneously carry multiple LLC logical links, supporting multiple services while meeting broadcast, multicast, and unicast requirements.

Fourth, it achieves cross-transmission network business retransmission requirements while accepting link status reports and ARQ acknowledgment frames. ARQ acknowledgment frames and link status reports across transmission networks can achieve redundant transmission on different links, thereby reducing feedback information loss rates.

Fifth, it improves transmission network throughput without causing congestion like MPTCP, thus not affecting transmission rates. It can fully utilize useful bandwidth in transmission links to maximize aggregated transmission bandwidth.

3. IP Transmission Design Based on DTMB

DTMB is a terrestrial digital broadcasting television system with wide coverage. Therefore, in designing the broadcasting-telecommunication converged network architecture, this paper uses DTMB as the foundation for designing IP transmission channels to achieve IP coverage with natural multicast and large-scale coverage characteristics.

To meet this requirement, DTMB functions must first be expanded to enable broadcast links to carry unidirectional IP multicast packets and broadcast packets. Then, using LLC over tunnel technology and distribution/aggregation server equipment, a user plane system for IP full-service mobile access networks can be constructed. When multi-mode terminals need to use DTMB channels to transmit IP packet services, they must utilize IP signaling exchanged with operation and maintenance platforms to obtain channel signals. Multi-mode terminal devices can transmit signaling to distribution/aggregation server equipment through uplink transmission channels, which then forward it to the maintenance platform. At this point, multi-mode terminals can obtain IP signaling packets carried by LLC over tunnel technology in real-time through predefined DTMB channels, enabling them to receive downlink IP service packets through corresponding DTMB channels. In this process, DTMB channels serve only as one

network link for LLC over tunnel transmission.

To fully leverage the role and value of IP packet transmission, effectively improve IP packet transmission levels in DTMB channels, and meet IP full-service support requirements, three aspects must be addressed: First, ensure compatibility between standard TS packet formats and DTMB transmission standards. Second, ensure that the same DTMB channel can simultaneously carry downlink unicast packets and multicast packets for multiple terminals. Third, minimize TS packet padding overhead as much as possible [8].

To enable IP packets to be transmitted in DTMB standard TS packet formats and achieve unified multi-link transmission requirements, the PID field in TS packets must be redefined as a new PID type capable of carrying both unicast LLC frames and multicast LLC frames. Based on this, downlink unicast IP packets and IP packets can be transmitted. Additionally, PID-IP should be separately defined in reserved PIDs to meet the requirement of TS packets uniformly carrying IP service packets and signaling packets. The IP service packets involved include two types: IP multicast services and IP unicast services.

The design method for LLC frames carried over DTMB physical channels must address the following points: First, redefine a multicast service LLC frame type identifier using LLC frame type fields. Second, reasonably design the multicast service LLC format to simultaneously meet the requirements of carrying IP multicast service packet transmission and enable real-time transmission through IP tunnels on non-broadcast communication channels. Third, multicast service and unicast service LLC frames can undergo concatenation, segmentation, and other operations in TS packets to effectively reduce TS packet padding overhead. Fourth, since IP packets occupy significant transmission overhead in TS packets, header compression functionality can reduce overhead. Specifically, when distribution/aggregation servers provide support for a particular IP service flow, they can compress TCP and IP headers using mapping relationships between TCP headers, IP headers, and indexes, and transmit TCP headers, IP headers, and indexes through existing multi-links to multi-mode terminal devices. Only after terminal devices confirm the mapping relationship through uplink links can the goal of reducing IP header and TCP header overhead through Index be achieved.

In summary, traditional independent data and storage networks increase additional expenditures to a certain extent, highlighting unreasonable aspects of network architecture. Many experts and scholars have shifted their research focus toward integrating specialized PC storage networks into general-purpose networks. This is not only an effective measure for solving network service bottlenecks but also represents the inevitable trend of converged networks. Therefore, this paper proposes an integrated receiving terminal and a broadcasting-telecommunication converged network architecture supported by distribution/aggregation server equipment, aiming to lay the foundation for improving network service quality.

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