Technical Requirements of 5G Systems for Local Transport Networks: A Postprint Investigation

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Abstract

At present, fifth-generation mobile communication (5G) has become a global research hotspot. In the context of current network technologies, the application of 5G technology represents an imperative of the times, as it can effectively meet future demands for ultra-high traffic density, ultra-high connection density, and ultra-high mobility, thereby providing users with ultimate service experiences such as high-definition video, virtual reality, augmented reality, cloud desktop, and online gaming. 5G networks will also substantially improve the energy consumption and cost efficiency of network construction and operation, while enhancing service innovation capabilities. Furthermore, the application of 5G technology in the broadcasting and television industry can effectively elevate cloud-based production levels for broadcasting video services, increase video transmission density, and better satisfy diversified audience needs. Below, the author will conduct a detailed analysis of related issues based on personal understanding and insights.

Full Text

Technical Requirements of 5G Systems for Local Transport Networks

Abstract: Currently, fifth-generation mobile communications (5G) has become a global research hotspot. From the perspective of existing network technologies, the application of 5G technology is necessitated by the times, as it can effectively meet future demands for ultra-high traffic density, ultra-high connection density, and ultra-high mobility, thereby providing users with premium experiences for high-definition video, virtual reality, augmented reality, cloud desktops, online gaming, and other cutting-edge services. 5G networks will also substantially improve the energy consumption and cost efficiency of network construction and operation while enhancing service innovation capabilities. The application of 5G technology in the broadcasting and television industry can effectively

elevate the level of cloud-based video production, increase video transmission density, and better satisfy the diverse needs of audiences. This paper presents a detailed analysis of these relevant issues based on the author' s understanding and insights.

Keywords: 5G system; local transport network; technical requirements; interference; broadcasting and television industry
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1. Key Technical Characteristics of 5G Systems

The 5G network is primarily oriented toward mobile internet and Internet of Things (IoT) applications, encompassing multiple domains and featuring diverse application scenarios including continuous wide-area coverage, hotspot high-capacity, low-power massive connections, and low-latency high-reliability. The first two scenarios mainly target mobile internet applications, while the latter two focus on IoT and vertical industry applications. The 5G network architecture can be divided into three functional layers: the access plane, control plane, and forwarding plane. The control plane is responsible for generating global control strategies, while the access and forwarding planes execute these strategies. The application scenarios of 5G networks primarily include four aspects: continuous wide-area coverage, hotspot high-capacity coverage, low-power massive connections, and low-latency high-reliability scenarios. Each scenario faces different performance challenges, imposing varying requirements on user experience rate, connection density, end-to-end latency, mobility, traffic density, and user peak rate, which collectively present greater challenges for 5G system local transport technology.

Currently, the development of 5G technology has created a tremendous impact on existing transport networks. The primary reason is that operators have focused on constructing optical transport networks (OTN), Packet Transport Networks (PTN), and other technologies that still struggle to effectively meet 5G system transmission requirements. Presently, whether at the national backbone level, provincial backbone level, or local network transport equipment, the network architecture exhibits relatively dispersed distribution characteristics with multiple hierarchical layers, such as metropolitan backbone, aggregation, and access layers. To better meet equipment requirements, SDH technology emerged in local transport network technology, enabling the successful construction and continuous innovation of PTN networks. This technology demonstrates strong adaptability with numerous services and can provide economical and reliable bearer services for multiple applications, thereby satisfying operators' diversified operational needs. However, the technology also has inevitable drawbacks, such as difficulty meeting scalability and openness requirements, relatively high network construction and optimization costs, and consequently, it cannot effectively adapt to 5G network operational demands.

2. Functional Requirements of 5G Systems for Transport Networks

Based on the 5G network architecture, the optical transport network is positioned between the control plane and forwarding plane of 5G networks, serving as the fundamental bearer network. Faced with 5G networks, it must meet more stringent transmission performance and networking functional requirements compared to traditional 3G and 4G technologies. It needs to provide transport technology with superior performance, greater flexibility, and more intelligent operations. In practical applications, the primary technical requirements include the following aspects:

2.1 High Bandwidth and High Capacity

Since the beginning of the 21st century, mobile data traffic has experienced explosive growth. With the emergence of 4G technology, 5G technology has been put on the agenda. Research indicates that mobile data traffic will increase by nearly 20,000 times between 2010 and 2030. Compared with traditional 4G network technology, 5G networks offer superior bandwidth and capacity, providing users with experience rates exceeding 100 Mbps anytime and anywhere, with local hotspot areas requiring user experience rates of 1 Gbps, peak rates of 10 Gbps, and traffic density of 10 Tbps per square meter. During 5G system operation, massive data traffic requires transport network technology to provide broader bandwidth and higher-capacity fundamental bearer networks, specifically including fronthaul networks, backhaul networks, and core network transport networks, to satisfy the diversified usage requirements of 5G networks.

Based on the current development status of optical transport network technology, most regions in China have fully entered the 100 Gbps era for optical transport network backbones, which is gradually extending to metropolitan areas. Optical transport technologies exceeding 100 Gbps, particularly 400 Gbps, are also maturing through research and development in diverse technologies such as higher-order modulation, new ultra-low loss or large effective area fibers, flexible grids, and low-noise amplifiers, providing more diversified options for 5G system transport network technology.

2.2 Low Latency

In practical applications of 5G systems in internet and IoT domains, more demanding and stringent latency requirements are envisioned. Air interface latency should be less than 1 ms, with end-to-end latency at the millisecond level. The millisecond-level low-latency application scenarios require optical transport networks to provide not only extremely low transmission latency but also extremely low processing latency. Through end-to-end transmission verification of existing optical transport networks, the end-to-end latency of optical transport networks is primarily introduced by fiber transmission paths, with fiber transmission delay accounting for over 80% of the total end-to-end latency. Therefore, one important method for effectively reducing latency in optical transport networks is to adopt the shortest business transmission path for service path planning and provisioning, thereby satisfying more application scenarios.

2.3 High Reliability

Based on typical bearer requirements of mobile networks, transport networks primarily consist of fronthaul networks, backhaul networks, and core networks. 5G network service types will become more diverse, while multiple application scenarios demand improved service provisioning timeliness and flexible variable service bandwidth, all of which require optical transport networks to guarantee high transmission reliability. Currently, transport network technologies in many regions have implemented multi-level protection schemes including OLP OMSP, OCH, and ODUK SNCP. Meanwhile, most existing networks operate as ring networks, and the main path delay difference in optical transport network models is typically substantial, making them unsuitable for low-latency requirements of 5G networks and unable to adapt to high-reliability demands. Therefore, during transmission, further adjustments and optimizations of the transport network structure are needed, such as employing photoelectric hybrid cross-connection, network topology structure, and intelligent control functions to effectively improve the reliability and service robustness of optical transport networks, thereby better constructing low-latency and highly reliable transport networks.

2.4 Flexibility

5G network service types will inevitably become more abundant, with applications in multiple scenarios requiring continuously improving service provisioning timeliness and flexible variable service bandwidth. These requirements demand that transport networks possess dynamic assignment capabilities for flexible and variable bearer bandwidth. In recent years, to meet diversified service demands, optical transport networks have introduced various new technologies such as ODUflex and GMP, while also combining existing technologies including ROADM, flexible grids, variable transceivers, and electrical cross-connection. These technologies have effectively achieved flexible mapping and multiplexing, making bandwidth pipes more flexible.

2.5 Intelligence

The intelligent characteristics of 5G networks are undoubtedly more pronounced compared to traditional 4G and 3G networks. To meet these technical requirements, support for software-defined network control architecture is needed to achieve optimized and upgraded network capabilities. 5G networks will use SDN as the foundational technology to effectively separate the control plane from the forwarding plane, making the entire network more flexible, intelligent, efficient, and open. After introducing SDN functionality into optical transport networks, the main advantages of 5G networks include the following: First, the introduction of centralized control enhances the intelligent decision-making capability of the control plane, improving service deployment efficiency and network resource utilization. Second, through virtual network abstraction technology and resources, better decoupling of hardware and software can be achieved, and open interfaces can provide editable capacity optical transport network services, flexible bandwidth, and new customized services such as optical network VPNs to meet other diverse business requirements.

3. Challenges in the Development of Technical Requirements for Local Transport Networks in 5G Systems

In practical applications, as the bearer network, the transport network faces challenges in meeting 5G network requirements for high bandwidth, high capacity, low latency, high reliability, flexibility, and intelligence. Based on the current application status and development trends of transport network technology, future development of related systems may face challenges in the following aspects.

3.2 Selection and Implementation of Low-Latency and Flexible High-Performance Solutions

As mentioned above, end-to-end millisecond-level ultra-low latency is a typical performance requirement for 5G networks, and flexibility is one of the most prominent features of 5G networks compared to 3G and 4G networks—5G networks are more agile and adaptable. It has been previously mentioned that the main latency in long-distance optical transport networks is caused by physical fiber links. Apart from selecting more ideal physical fiber links, there are no other technologies to solve latency issues during system operation. Therefore, latency reduction technologies for optical transport networks primarily focus on node processing, with the most important being layer signal processing, such as currently widely applied FEC and DSP processing technologies. The processing latency of these technologies is inversely proportional to transmission performance. Under these constraints, how to further reduce processing latency while ensuring transmission performance has been an important topic explored by numerous experts and scholars. Furthermore, to better adapt to the flexibility of 5G network service applications, optical transport networks also need to provide flexible bearer bandwidth, requiring the adoption of multiple technologies for bandwidth adjustment. However, a major challenge that must be faced during bandwidth adjustment is the difficulty in achieving flexible coordination with the actual application of 5G services, which may affect the ultimate latency and flexibility performance.

3.3 Coordination and Interworking Between Transport Networks and Other Networks

5G systems involve multiple different types of technologies during application. In addition to traditional optical transport networks, 5G network bearer networks also include IP bearer networks and wireless bearer networks, with different bearer networks having varying functional roles and usage requirements. In practical 5G network bearer implementations, how to achieve rational allocation of networking functions among different bearer networks and realize seamless communication still faces multiple challenges and difficulties. In future applications of related technologies, it is necessary to clarify the roles of different bearer networks based on actual application requirements, ensure coordination and unification between the core bearer network required by 5G systems and other auxiliary bearer networks, thereby better leveraging the advantages of related technologies, reducing limitations imposed by transport networks on system applications, and promoting the development of related work in better directions.

4. Development Approaches for Technical Requirements of Local Transport Networks in 5G Systems

4.1 Further Optimization of Network Structure

Previous mobile communication networks were mostly based on hierarchical network structures with certain limitations, making it difficult to effectively meet the technical requirements of 5G systems for transport networks. Currently, network structures are trending toward flattening, which is basically consistent with the development trend of IP networks. Therefore, for 5G system transport network technology, it is necessary to fully consider how to adapt to the evolution of existing transport networks and upper-layer networks, thereby promoting better development and application of related technologies. Optimizing network structure and promoting flattening is extremely beneficial as it can effectively reduce various resource wastes and lower operational costs. Simultaneously, government departments need to provide guidance, collaborate with major enterprises to accelerate 5G deployment, reduce dependence on equipment manufacturers, and promote independent development of transport networks in the 5G era to better satisfy users' diversified needs and drive related work toward better development directions.

4.2 Flexible Application of PTN Network Technology

Currently, when implementing mobile communications, operators mostly use PTN technology to bear LTE networks. This technology offers strong data transmission performance and secure, reliable transmission. It can also exist independently of the customer and control layers, flexibly bearing multiple services. Therefore, to truly develop technical requirements for local transport networks in 5G, it is necessary to flexibly apply and research PTN network technology based on actual data transmission needs.

4.3 Effective Prevention of 5G Signal Interference to Broadcasting Networks

As a new system, 5G has multiple unstable factors during application and can easily cause interference to broadcasting signals. To address this issue, the author suggests that, on one hand, C-band filters resistant to 5G interference can be installed. When installing C-band filters is insufficient to counter 5G interference, the following solutions can be considered based on the interference situation: First, reduce 5G base station transmission power, adjust the maximum radiation direction or downtilt angle of the 5G system (which can increase isolation by 0-8 dB), or change 5G base station locations (requiring cooperation from relevant communication operators). Second, on the basis of installing C-band filters, replace with low-noise amplifiers (LNA/B) with filtering capabilities. Third, install shielding nets (which can increase isolation by 8-12 dB).

5. Impact of 5G on Video Production

5G is a general-purpose technology. Due to its characteristics of low latency, high bandwidth, and high scalability of cloud services, it will likely promote the explosion of 4K and bring rapid development to VR, enabling broader use of artificial intelligence technology in the broadcasting and media industry. The low latency, high bandwidth, and high scalability of cloud services in 5G networks make high-quality video transmission and sharing simple and feasible. Ultra-high-resolution video capture terminals do not require local processing but can directly upload through 5G networks, undergo cloud processing, and then be transmitted back through 5G networks.

Currently, many converged media centers or studios led by broadcasting organizations are expanding studio functions to enhance live interactive capabilities. Consequently, interactive immersive studios based on new-generation studio technologies such as virtual reality and augmented reality have emerged and can be widely applied in various scenarios including broadcasting studios, news reporting, sports event live broadcasting, and television variety shows.

The application of VR in the media industry may bring us a completely new narrative approach—not only can it display the entire environment where news events occur without omission, but its characteristics of "immersion" and "presence" can also allow audiences to experience situations firsthand and become true "eyewitnesses," examining and understanding news from a first-person perspective.

In summary, 5G systems impose multiple requirements on local transport network technology during application, including high bandwidth, high capacity, low latency, high reliability, flexible pipes, and intelligence. These pose higher challenges to traditional equipment. To better meet these transmission requirements and solve existing technical equipment problems, more capital and technical talent investment is needed. Only through such investment can we truly promote the development of China' s 5G system technology in better directions, satisfy the diversified application requirements of 5G technology, and drive continuous progress in related work. The application of 5G technology will bring new vitality to the broadcasting and television industry. Therefore, for the broadcasting and television industry, 5G represents a highway leading to an extremely valuable and promising future.

References

[1] Yao Yue. Prospects for Key Technologies of Fifth-Generation Mobile Communication Systems[J]. Telecommunications Technology, 2015(1): 18-21, 26.

[2] Chen Yong. Current Status and Development Prospects of Optical Transport Network Technology[J]. Guangdong Science and Technology, 2014(10): 227-228.

[3] Xu Qihua. Evolution of PON Technology[J]. Information & Communications, 2013(6): 235.

[4] Ma Jun. Challenges of 100Gbit/s Applications[J]. Telecommunications Technology, 2013(7).

[5] Liu Xiaoli, Men Shaojie. Research on Application and Development Trends of Transport Network Technology[J]. Telecommunications Technology, 2013(1): 22-25.

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Note: Figure translations are in progress. See original paper for figures.