

ZTE



5G CDN White Paper



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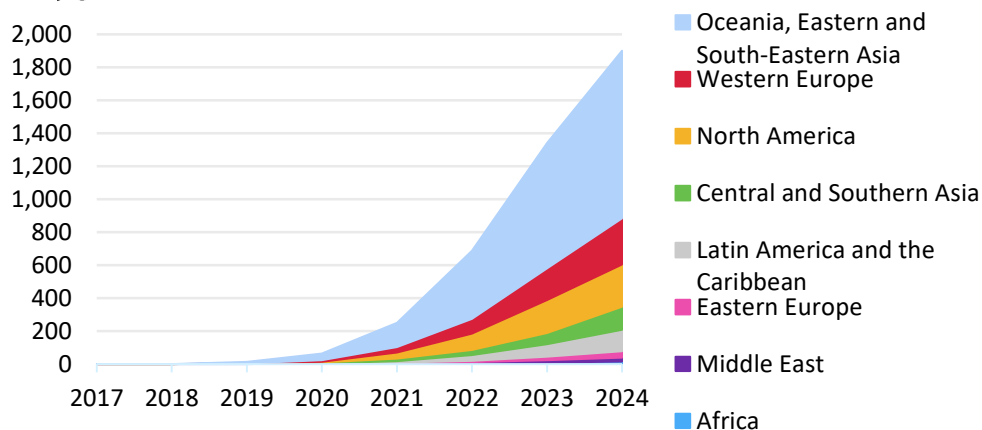
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1. Opportunities and challenges in the 5G era

As 5G goes mainstream, a world where everything is connected is becoming a reality. With 5G's super-fast speed and massive bandwidth, video is expected to thrive in the 5G era. Video, moving beyond its traditional role in entertainment, has become the most important form of media and information carrier.

When it comes to making short-term gains from using 5G connectivity and equipment, video can provide operators with the clearest proof. Many operators has bundled video services with innovative video forms like VR. Omdia expects global 5G mobile subscriptions to surpass 1 billion by 2023.

Global 5G mobile subscriptions will surpass 1 billion by 2023, driven by growth in China (millions)



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5G features high bandwidth, low latency, massive connectivity, and so is well placed to eliminate the bottlenecks currently experienced by video transmission in terms of traffic, rate, and cost. In the coming years, video is expected to become the main driver of 5G traffic and promote continuous growth in 5G network investment, with short video among the earliest applications to benefit from 5G.

A dramatic increase in 5G connectivity and traffic, however, presents the following challenges to operators:

- As short video and We Media like TikTok and WeChat prevail across the world, and people's social needs keep growing in the post-pandemic era, interactive live broadcasting, online education and cloud gaming have become part of people's life.
- As enterprise applications develop rapidly, video conferencing, video

surveillance, live broadcasting at public venues like stadiums/arenas, remote healthcare, and live broadcasting of entertainment and cultural events are increasingly being adopted. In addition, places like subway stations, railway stations, airports, and other densely populated areas produce highly concentrated traffic, requiring timely video distribution and video service with low latency, wide coverage, and content distribution to the edge. Meanwhile, large surges in traffic show obvious tidal effects.

- To meet today's growing demands for new videos and immersive experience, HD channels, VR/AR and 8K+ ultra high definition (UHD) services begin to grow at an explosive rate, posing higher requirements for traffic and bandwidth, and placing bearer network under increasing pressure.

2. Evolving towards virtualization: 5G CDN helps building flexible and smart content distribution network

The traditional CDN provides video streaming service for users with a hierarchical architecture, including content center, regional center and edge nodes. Pushing content in such a cascading way poses a number of problems, for example, slow speed, high back-to-source traffic, long construction period, low utilization during idle hours, and backbone traffic overload during peak hours. Such architecture can no longer meet the traffic and user requirements of 5G networks.

As operators are pushing ahead with cloud-network integration and cloud-edge collaboration strategies, edge nodes become the focus of the cloud-network architecture. Both operators and internet cloud service providers have been aggressively deploying edge nodes, taking CDN as the network infrastructure.

ZTE's 5G CDN is a new CDN software product developed based on the traditional CDN. By upgrading the existing CDN edge nodes, the lightweight service loading of virtual CDN (vCDN) can be achieved, enabling nearby access, auto scaling, fast deployment, and experience upgrade. It can also share resources, reduce traffic of the backbone network, and save investment.

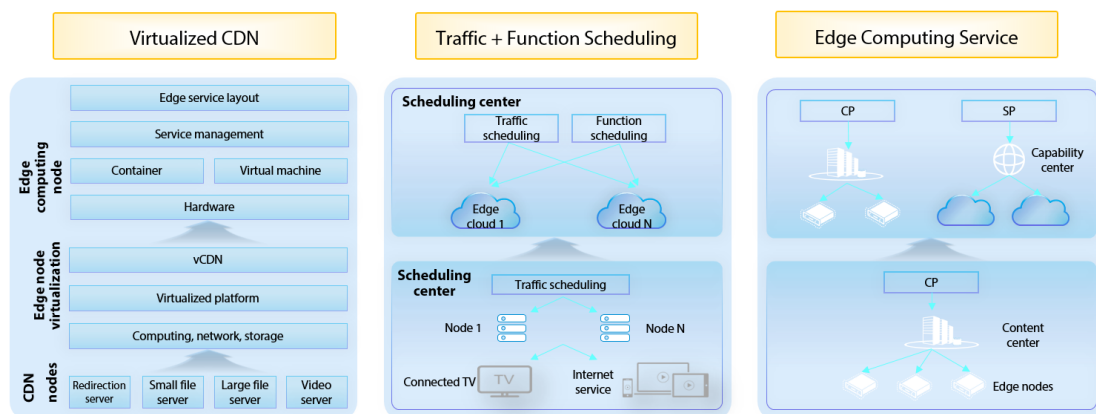
2.1 Cloud-edge collaboration: Evolution from CDN to virtualized CDN architecture

As a development direction and trend, virtualized CDN can meet today's various

demands, including sharing resources among nodes or different platforms, dealing with flash crowds in traffic during holidays or special events, and edge computing's special requirements for containers and virtual machines.

The traditional CDN is now evolving into the virtualized architecture. The virtualized CDN facilitates flexible allocation of resources and achieves on-demand adjustment of CDN resources based on the capacity scaling capability of cloud platform. For example, vCDN nodes can be fast deployed and configured for rapid launch and deployment of CDN capabilities during traffic spikes of CDN service. The CDN nodes can be released when CDN service enters an idle state, so that edge computing service can use the idle resources to offer service capabilities. The evolution from the traditional CDN to vCDN is reflected in the following three aspects:

- ✧ CDN nodes are gradually virtualized.
- ✧ CDN traffic scheduling is upgraded to the traffic and function scheduling of edge computing.
- ✧ CDN media content distribution is upgraded to edge computing service.

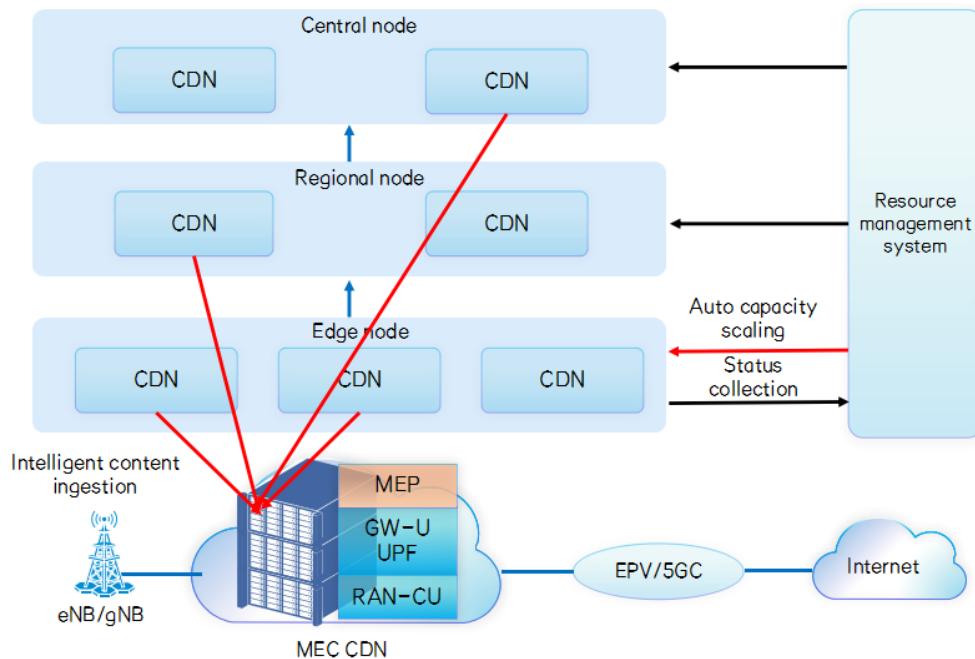


Based on the previous CDN research achievements of edge cloud collaboration, ZTE and China Mobile have been working together to deploy edge cloud and CDN resources in phases. They will gradually virtualize CDNs and put them on existing edge clouds.

5G CDN supports the containerized deployment of CDN nodes, and forms unified resource allocation and management of vCDN after integrating with the cloud management platform (CMP).

2.2 Popular content replication: The popular content can be effectively shared, thus greatly balancing the load on the entire network.

5G CDN can predict flash crowds intelligently. When a traffic storm is about to occur, lightweight vCDNs are rapidly deployed by using the auto scaling technology. 5G CDN adopts its exclusive multi-layer distribution technology to obtain popular content from CDN nodes at different network layers and then put them into work within a short time, effectively fixing the tidal effects.



For popular content, 5G CDN introduces AI technologies to its smart scheduling for decision-making on popular content and load scheduling mechanism. It collects users' service data in real time, and quickly replicates the popular content to different nodes and different devices in the nodes, making sure load is balanced across all these nodes and devices. 5G CDN guarantees balanced traffic, makes full use of the network resources for vCDN nodes, and avoids poor user experience caused by tidal effects.

2.3 UHD experience: Speedy distribution and service for massive UHD 8K/VR content with high bitrate

In the 5G era, improved user experience is the key to retaining customers and attracting new customers. As content bitrates keep improving and immersive video services like HD channels, VR/AR and Free-Viewpoint Video (FVV) emerge, increasing demands have been made for better user experience. To offer ultimate user

experience, moving nodes downward to the edge is the key.

5G CDN, based on the traditional CDN video service, has fully supported the latest technologies and services in the industry. It adopts P2P solution for speedy content distribution, which greatly shortens the time for delivering massive HD content. Taking a 2-hour 4K movie as an example, it only takes one tenth of the time or even less to push the content to the edge node. In addition, the edge node fully supports AVS3 and other new codec protocols, realizing full compatibility with the UHD content service.

3. Evolving towards edge cloud: 5G CDN integrates with edge computing for secure capability exposure and sharing

Edge computing includes three elements: network, computing (edge cloud), and application. It shares resources and moves capabilities downward to the edge by deploying capabilities like computing and storage on the network edge closer to users to provide the IT environment for applications. Edge cloud, as one of the service forms for edge computing, will become the best choice to bear edge computing in the future.

Aside from improving user experience and cutting investment in backbone networks, the virtualized CDN also makes full use of its technical expertise to achieve resource sharing and capability exposure.

Relying on the cloud platform and video processing capabilities, 5G CDN realizes functions of the cloud transcoding platform, including video encoding and decoding, 2D-to-3D video conversion, image quality enhancement, image rendering, image frame extraction, and multiprotocol conversion. These functions are independent, small and lightweight micro-service modules. The loose coupling between modules and systems and among modules meets the design requirements of K8S and Docker. These micro-service modules gradually accumulate to enrich the PaaS capability components while offering edge service capabilities, enabling the development and sharing of platform capabilities and enhancing the core competence of edge computing.

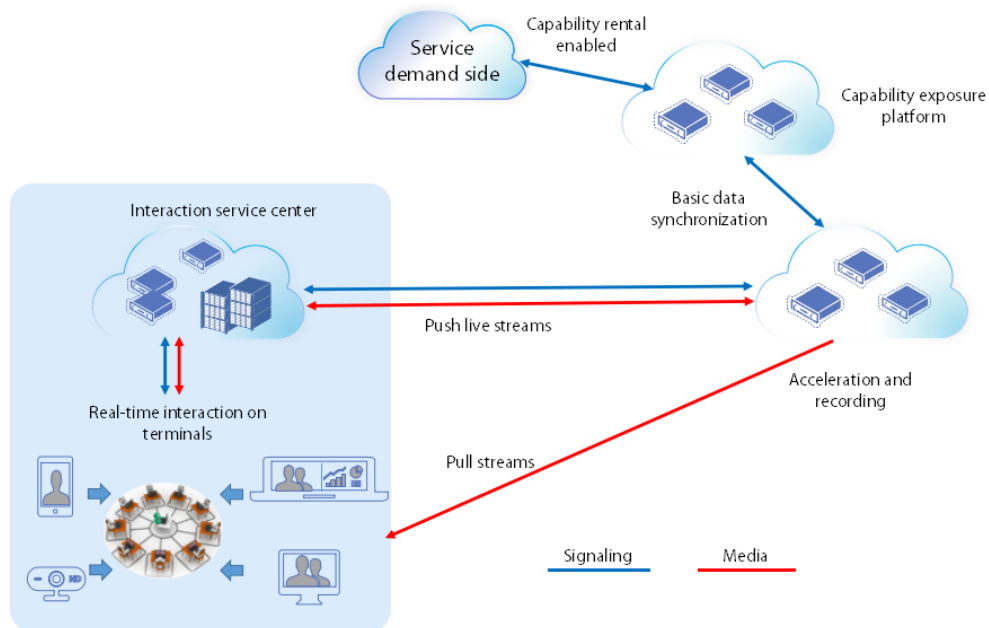
3.1 Capability exposure, realizing network-wide distribution of live videos streamed by users

5G CDN adopts the new Mesh CDN architecture to expose the live broadcasting capability on the basis of the edge cloud. Users can freely set the live broadcasting time and region, code stream bandwidth, and other personalized requirements. Users can also purchase services and push live streams with one click to realize network-wide distribution.

Relying on over a decade of experience in video processing, media conversion and storage performance, 5G CDN supports the protocol conversion function to meet today's mainstream media ingestion, conversion and service requirements of the internet.

Incoming protocol	Video coding	Audio coding	Outgoing protocol
TS over UDP	H264/H265	AAC/MP3/MP2/AC-3/E-AC-3	HLS
TS over UDP	H264/H265	AAC/MP3/MP2/AC-3/E-AC-3/OPUS	DASH
TS over UDP	H264/H265	AAC/MP3/MP2/AC-3/E-AC-3	HLS
HLS	H264/H265	AAC/MP3/MP2/AC-3/E-AC-3	HLS
RTMP PULL	H264/H265	AAC	TS over UDP
RTMP PUSH	H264/H265	AAC	TS over UDP
RTMP PUSH	H264/H265	AAC	RTMP PULL
RTMP PUSH	H264/H265	AAC	HTTP FLV
HTTP FLV	H264/H265	AAC	TS over UDP
HTTP FLV	H264/H265	AAC	HLD
HTTP PUT	H264/H265	AAC	FILE
RTMP PUSH	H264/H265	AAC	OMAF
MP4文件	H264/H265	AAC	OMAF
RTP	H264/H265	AAC	RTMP PULL/HLS/HTTP FLV
TS	H264/H265/AVS2/AVS+	AAC	HLS
RTSP	H264/H265/AVS2/AVS3	AAC	HLS

Based on this, operators can enable industrial applications for scenarios including live sports streaming in arenas and stadiums, live camera broadcasting for cultural tourism, live conferencing, and online interactive education, greatly expanding the business range of edge cloud.



3.2 Cloud transcoding, delivering brand-new immersive video experience

5G CDN deploys the cloud transcoding system on the edge cloud to provide a wide variety of functions and service, including video stitching, video decoding, video tile, image frame extraction, game rendering, various types of encoding, and multi-protocol packaging. Given the strengths of vCDN, the transcoded video media can be directly ingested into vCDN for accelerated distribution on the entire network, bringing users the best immersive experience.

3.2.1 8K VR FOV

5G CDN fully supports the VR FOV technology and provides three technical models.

- **Pyramid model:** Prepare panoramic code stream with uneven quality for each viewpoint during content preparation. The high-quality field of view is at the bottom of the model. As the pyramid height rises, the resolution of other regions is reduced through sub-sampling. Based on the user's current viewpoint, gesture and location, the terminal requests the corresponding viewpoint files from the server.
- **Tile-based transmission solution:** When preparing content, divide the VR image into several tiles, and each region corresponds to one code stream that can be decoded independently. Meanwhile, prepare one low-quality panoramic VR

code stream. The tile-based FOV transmission overlaps a low quality background stream with a high-quality FOV stream. This solution can effectively solve three major problems in the VR application, including the high-resolution panoramic video transmission bandwidth, decoding capability and rendering output.

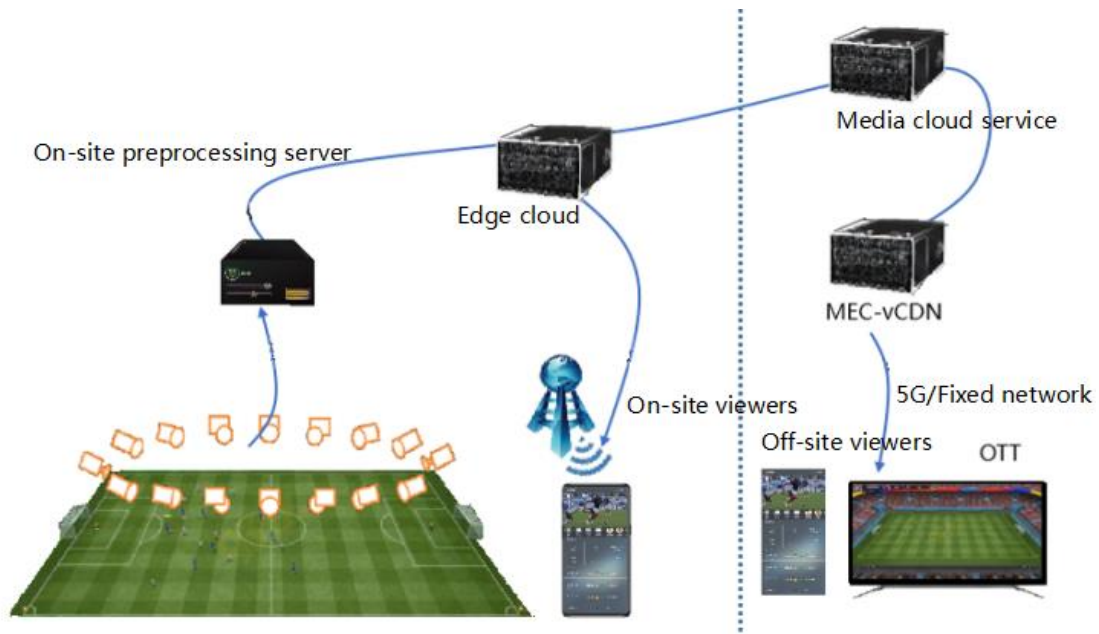
- **FOV+ solution:** The FOV+ technology transmits images with a slightly larger FOV to cope with network and process latency. If a user rotates head at a speed of 120 degree per second, the transmission of an additional 6 degrees of image in all directions can compensate for 50 ms RTT latency, thus relaxing the interactive experience requirement for an MTP latency of less than 20 ms.

Powered by the 8K VR FOV technology, it is able to overlap and render three different media streams, including the high-definition FOV stream, standard-definition background stream and fast-sent I frame stream, which means 70% of bandwidth for 8K VR can be saved. A good VR experience can be guaranteed while the turning latency is less than 160 ms, enabling fast startup of less than 1 second, crisper videos, and smooth rotation.

3.2.2 Free-Viewpoint Video (FVV)

The FVV system arranges dozens or even hundreds of cameras at several locations to capture videos, so that users can watch personalized and bullet-time videos.

FVV adopts many advanced technologies to deliver an immersive user experience with high-quality videos. The frame synchronization technology ensures consistency of images from multi-channel videos. The AI-enabled real-time video stabilization algorithm keeps the multi-channel videos stable. The multi-channel 4K real-time coding technology, CDN distribution with ultra large capacity and low latency, edge computing technology, and 5G networks realize 4K FVV live broadcasting with ultra low latency. Multi-terminal adaptation brings the same immersive user experience with a unified style across different terminals.

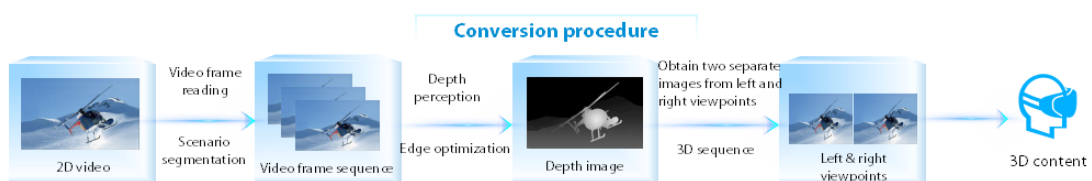


3.2.3 2D-to-3D video conversion

This technology creates videos with 3D effects from ordinary 2D video files by using cloud transcoding, enabling a wide variety of VR content.

By virtue of the depth image based rendering (DIBR) algorithm, the introduced deep learning, and the strong computing capability of 5G CDN, this technology achieves fully automated 3D conversion and a dramatic rise in conversion efficiency compared to the traditional conversion mode that combines with a later manual repair. Users can enjoy immersive 3D videos by simply wearing 3D shutter glasses or VR headsets. In terms of image tuning, the parallax tuning technology can maximize the visual space and expressiveness of videos.

The 2D-to-3D video conversion technology combines 360-degree 3D videos with spacial sound to create an amazing sense of real-life presence. Fully automated 3D reconstruction, especially real-time 2D-to-3D video conversion are the core competence to attract users and improve viewing experience.



3.2.4 VR social experience

5G CDN launches a brand-new VR social service based on live VR broadcasting. It allows up to eight viewers to interact with each other on social media while watching programs like sports games, concerts or games at the same time.

Adopting technologies like frame synchronization, it allows multiple viewers to watch synchronized videos and choose desired camera angles, meeting the entertainment and social needs of users from different areas in the post-pandemic era.

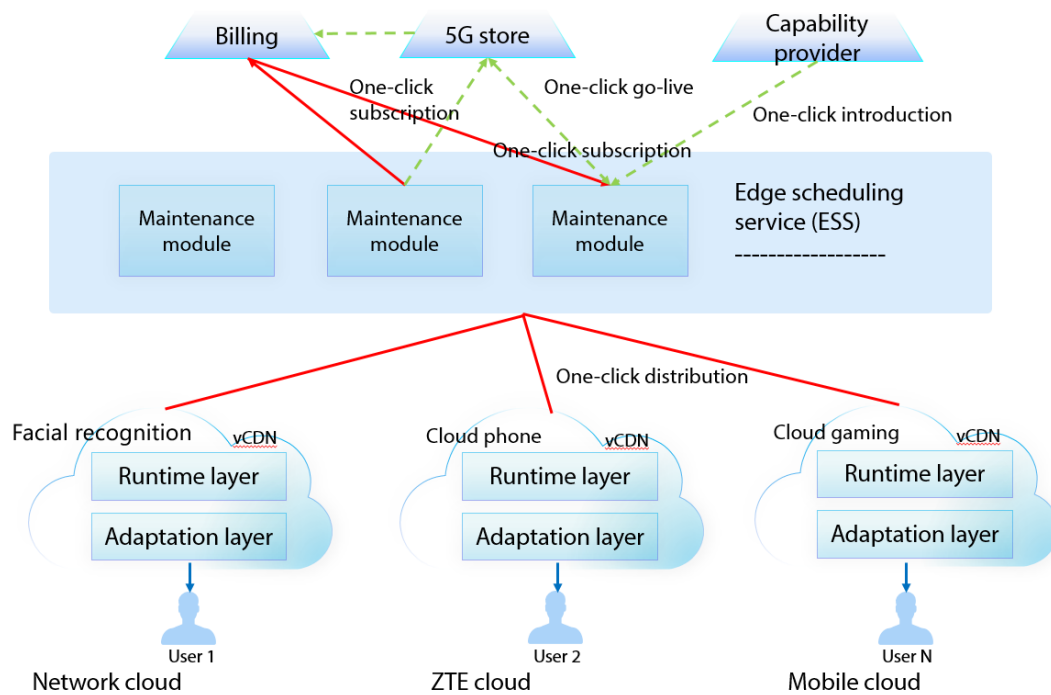
3.3 Edge scheduling, realizing flexible scheduling and agile maintenance of third-party apps on the cloud platform

5G CDN's edge computing creates an intelligent vCDN edge network with the "3+4+N" means. The number 3 indicates three layers of the network, including the scheduling layer, operation layer, and adaptation layer. This architecture realizes the unified scheduling, distribution and deployment of capabilities. The number 4 indicates four capabilities of the edge scheduling service (ESS). And the letter N indicates N apps that ESS can rapidly introduce in the edge cloud.

The operation layer provides a standard runtime environment so that capabilities like vCDN can be rapidly deployed across different clouds. The adaptation layer provides the standard API for the same type of capabilities, enabling fast interconnection and easing the workload of re-interconnection caused by switching between similar capabilities.

5G CDN introduces ESS to enable fast deployment of various capabilities across different clouds and flexible scheduling of third-party apps on the cloud platform. It plays to its strengths with edge computing and achieves resource sharing.

By virtue of ESS, content ingestion, go-live, subscription and distribution can be implemented through one click respectively, which enables B2B capability exposure, rapid ingestion, and enrichment of edge computing services.



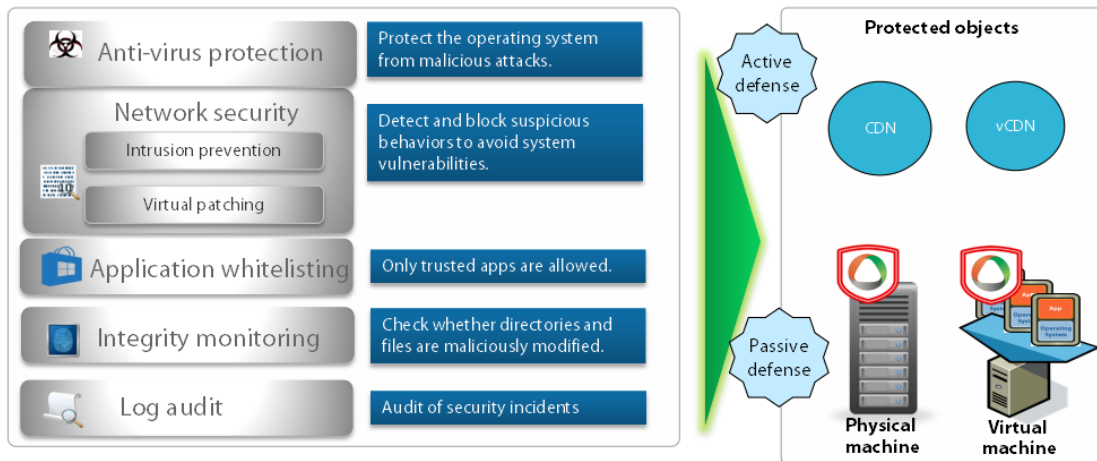
4. 5G CDN, creating a perfectly secure edge cloud platform for users and data

The widely spread CDN equipment stores and manages massive video content, uses the operators' core resources, and serves hundreds of millions of users. Therefore, the security of CDN systems and platforms is crucial to all the users and operators.

To guarantee highly efficient and secure CDN operation, 5G CDN designs a dynamic security protection system, focusing on the security of infrastructure, content, service and data.

4.1 Infrastructure security: Make sure CDN infrastructure runs properly through dynamic security defense.

5G CDN protects the infrastructure from two aspects: active vulnerability scanning and dynamic security defense, guaranteeing secure operation of the physical and virtual machines.



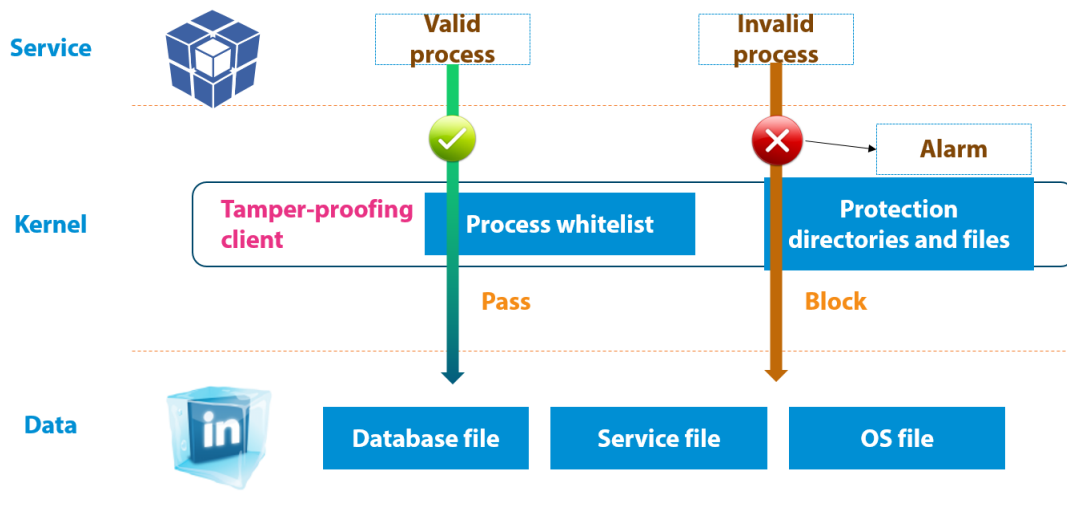
The active scanning can find and fix vulnerabilities on the host and virtual machine, prevent malicious attacks, and supervise the integrity of operating system (OS) directories.

The dynamic security defense guarantees system security of the entire platform. It detects the operating system and middleware software to prevent hacking. It deploys high-performance firewall, hardens the OS, and implements preventive maintenance to protect the system. It also audits each access to the infrastructure and identifies the cause of each security incident, guaranteeing system security of the entire platform.

4.2 Content security: Content tamper-proofing keeps the local cache of 5G CDN under control in real time

CDN stores massive videos, images, texts, and other key assets which are crucial to content providers (CP), users and operators. Therefore, the top priority is to protect the security of its content.

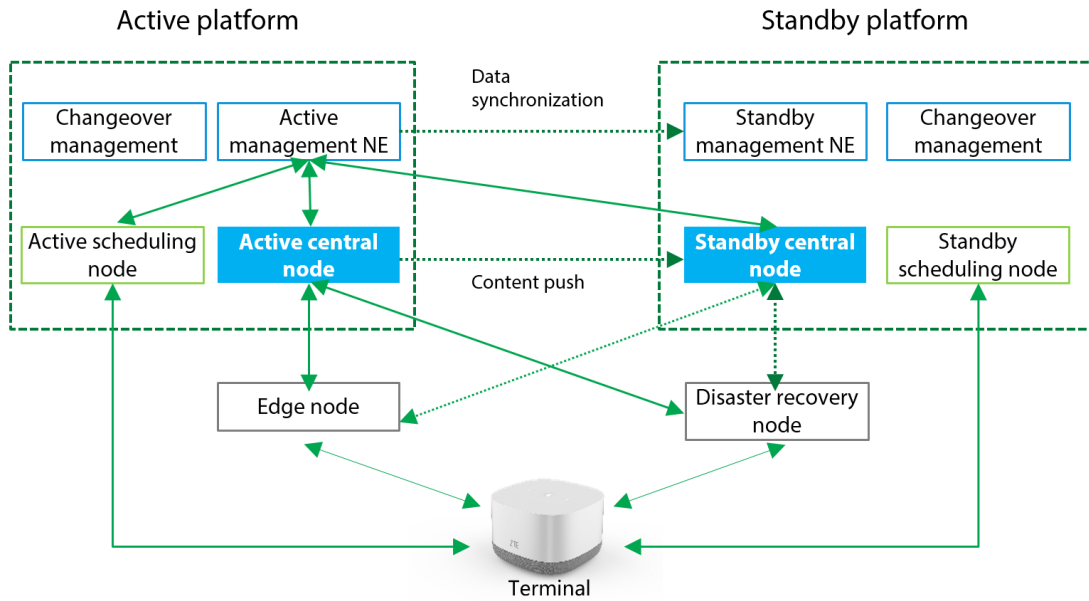
Based on the OS kernel, 5G CDN’s content tamper-proofing protects the above-mentioned content by censoring files. Such kernel-level protection is regarded as the highest level of protection. By monitoring the protected content in the CDN system in real time, 5G CDN can instantly detect hacking and content tampering, trigger alarms and block invalid processes, guaranteeing data security and users’ core interests.



4.3 Service security: Remote disaster recovery guarantees network-wide service reliability for 5G CDN

CDN serves billions of users on the entire network. Once power interruption, network failure or other forces beyond control occur, damage to some nodes will affect the service for thousands of users, and damage to the management platform will cause a serious network-wide breakdown involving millions or even tens of millions of users.

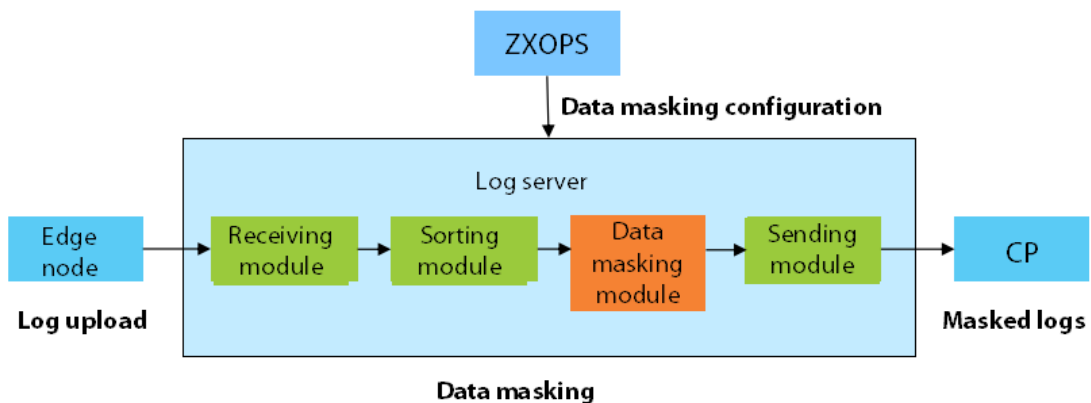
To deal with these potential threats, 5G CDN forms a complete set of disaster recovery mechanism based on severity and fault level. It guarantees remote disaster recovery backup in terms of data, management, scheduling, content center, and edge nodes. For core network elements (NE) and database at the management side, it adopts dual-center code standby disaster recovery. For central nodes and scheduling center, it supports active-active hot standby disaster recovery. Edge nodes use the dual-node hot standby disaster recovery. Therefore, in case of an emergency, CDN service security and network-wide service reliability can be guaranteed by fast changeover.



4.4 Data security: Data leakage prevention enables data masking for 5G CDN

The General Data Protection Regulation (GDPR) in the EU and Implementation Rules for Broadcasting Security Management in China both impose strict requirements for security of personal data. It is required to follow information security rules and protect the privacy of personal data during runtime of the CDN system.

5G CDN has integrated a wide variety of data security encryption and data masking rules that comply with data security regulations around the world. Users can flexibly configure and select encryption and data masking strategies and encryption algorithms in a visual manner. Sensitive data, including user name, account, user data, password, IP, email address, and operation data, can be replaced by functional fictitious data with only one click, making sure user data and privacy are well protected.



5. AI-enabled solution creates new service model for 5G CDN

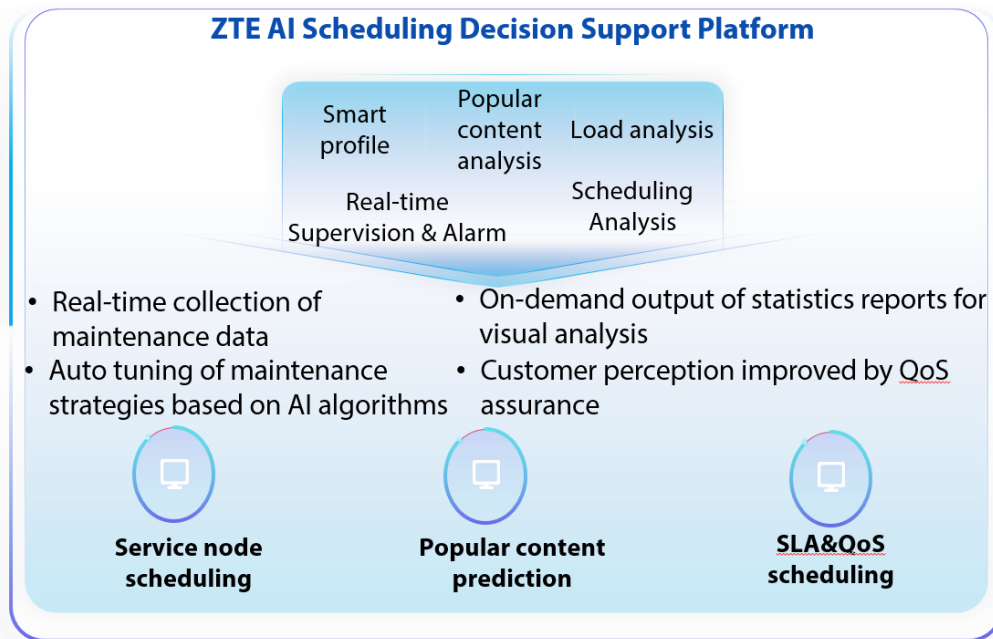
In the future, to give full play to the advantages of CDN, a new-generation intelligent CDN which is integrated and open should be built based on technological accumulation and the strengths of network and cloud platforms. It should enhance flexible scheduling of computing, storage and network resources and maximize resource utilization, thus governing key factors for multiple applications, including storage resources, scheduling modes, network resources, and service quality levels.

The AI-enabled CDN provides high-speed, secure and stable service over the entire network. It achieves network-wide service through one-time access, and enhances operators' operating and control capabilities, thus making full use of the system resources and maximizing revenue. The AI-enabled CDN has two key technologies.

5.1 Intelligent routing

The intelligent routing technology consists of the smart scheduling decision support system (DSS) and global scheduling system. The smart scheduling DSS introduces AI technologies to support decisions on popular content and schedule loads by collecting relevant indicators. It can solve the key scheduling and routing problems arising from the scheduling service.

- Relying on big data analysis, the smart analysis system can predict traffic spikes and popular content (VOD and live TV), prepare popular content in advance and then push it to edge nodes on demand, which greatly reduces the pressure on networks from data transmission. By enabling load balancing between nodes and devices, as well as among nodes, cities/regions, and users, it protects the service from quality problems like stuttering caused by intense pressure on single node or device.
- Relying on service level agreement (SLA), high-level users are loaded to the optimal node, realizing different service levels for different users.



The intelligent routing technology enables visual analysis of multidimensional real-time data like network traffic, user behavior and service quality, and adopts the AI algorithm to tune the maintenance strategies, effectively balancing the bearer network resources and improving users' access quality.

To meet personalized service needs, 5G CDN will keep exploring relationships between content, between content and people, and between people, providing users with personalized service based on the analysis from the big data platform. The future 5G CDN will collaborate with specific service models to offer a more personalized service experience and more intelligent user experience.

5.2 Intelligent slicing

The future CDN can have slicing-based resource and quality assurance by virtue of the interaction between the CDN service maintenance management system and the 5G core network slicing management system. The combination of 5G CDN and 5G network slicing mainly has the following technical evolution paths.

- In the future, 5G CDN system is expected to be able to identify different slicing users and provide unified service capabilities according to users' requirements.
- By supporting slicing recognition and providing service binding functions, 5G CDN can provide different slicing customers with exclusive service. When CDN capabilities are bound to a certain slicing resource, all the users from this

network slice can enjoy exclusive service.

- 5G CDN is expected to provide different service for different tenants of the same network slice. Since various tenants have different requirements for bandwidth and storage resource, in addition to the network slice, 5G CDN management system also needs to perceive various demand from different users of this network slice and allocate different resources from the CDN resource pool.

With the customized network resources offered by 5G network slicing, CDN can further improve its content distribution service capabilities. It should be capable of supporting VR, AR, MR, XR and other new multimedia services that require high bandwidth, low latency and strong interaction in the future 5G scenarios. It should also provide customized capability service and quality assurance for different business clients.

6. Create a win-win partnership ecosystem together with operators

Relying on the 5G CDN platform, ZTE works with operators to explore scenarios such as audio-visual entertainment, online education, smart cultural tourism, and intelligent content services for public venues like stadiums/arenas, keeping empowering industrial application by virtue of capability aggregation, technical evolution and model innovation. ZTE has already helped operators complete 5G application deployment in several vertical industries, including entertainment, culture, education, games, and sports.

- **Audiovisual entertainment:** The Audiovisual Technology Center explores and nurtures new technologies, new applications, new products, new models, new ecosystems, and new consumption in terms of 4K/8K UHD video, interactive video, XR, and other high-tech video services, delivering a brand-new immersive audiovisual experience together with 5G technologies.
- **Cloud gaming:** As 5G technologies become widely adopted, cloud gaming is booming. The emergence of cloud gaming removes the constraints on game release models and gives assurance in terms of fighting against the underground industry chain and enhancing big data statistics and analysis. 5G CDN guarantees highly efficient and secure transmission for the cloud gaming service.

- Interactive online education: Integrating video platform capabilities such as interactive live broadcasting and service management, ZTE offers the interactive online education service through its terminals, including the Wi-Fi 6 router, AI education STB, AI touchscreen speaker, and 5G mobile phone, creating the online education SaaS featuring multiple teaching scenarios, multiple terminal types and multiple network conditions.
- Smart cultural tourism: Backed up with ZTE's CDN cloud transcoding platform, live broadcast of the beautiful scenery is realized by using the set-top box, smart phone and standalone VR headset, enabling fascinating virtual sightseeing tours. With 5G CDN's powerful media processing capability, people can enjoy HD live broadcast of spectacular scenery online.
- Intelligent venue solution: ZTE's 5G Live TV solution provides customers with innovative live broadcast features like multi-viewpoint video (MVV), UHD free-viewpoint video (FVV) and panoramic VR. At a speed skating test event in early April 2021, an actual end-to-end latency as low as 0.3 seconds was achieved for 4K FVV live service, setting a new industry record for low latency and delivering an ultimate game-watching experience.