White Paper

Transport Network Architecture Index in 5G and Cloud Era

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1.0 EXECUTIVE SUMMARY

KAI (Key Architecture Index) has been further enhanced

In the quest for delivery of optimal transport networks in 2020 IDC proposed a holistic five dimensional index model for transport networks – **Congestion free**, **Scalable**, **Simplified**, **Always on** and **Intelligent (CASSI)**. Each of these dimensions is evaluated across all layers of the transport network: physical optical fiber resource, DWDM, IP and intelligent O&M layer. Enhancements have been made to the Key Architecture Index (KAI) to better reflect changes in home office traffic, the proliferation of Giga broadband and the increased emphasis on edge computing and cloud connectivity.

The KAI model categorizes network factors as constants (or difficult to change) which have long-term impact on network quality and performance, while filtering short-term device configuration-related factors (as network variables) for routine optimization. In this way, KAI creates a holistic, quantitative and systematic transport network model for 5G, Giga to home, enterprise connectivity & Cloud. The model takes into account assurance of network quality from early stage of design and planning while systematically reducing TCO.

Combined DX (Digital Transformation) & Cloud create unprecedented business opportunities

The combination of DX technologies (5G, IOT and AI) and Cloud are forecast to significantly impact all industries in the coming years. According to IDC's global Future of Connectedness (FOC) 2021, “by 2022, 60% of all network resources will be deployed at remote edge or service provider locations, allowing business leaders to leverage the agility of their network resources, up from 20% in 2020”.   DX technologies enable use cases including expanded use of robotics, remote control of equipment, the expression of supply and distribution chains and the experience of retailing and entertainment. Analytics, led by machine learning and AI, will drive real time business outcomes led by the exponential expansion of data sets. IDC also forecast that “by 2023, 60% of enterprises will deploy AI-enabled tools and functions to manage network performance issues proactively to deliver improved performance of applications by as much as 35%.”

All these changes will depend fundamentally on the capabilities offered by the underlying transport network.

Capable Transport networks enable next-generation service delivery

The rapid development of cloud AR, cloud VR, live broadcast, cloud gaming, online education, and online ultra-high definition video is an important opportunity for Comms SPs to grow in the future. On the other hand, Enterprise migration of their production and office systems to the cloud continues unabated.

A holistic transport network architecture must deliver high capacity, high availability, low latency and highly scalable designs. Delivery of this goal requires minimizing OpEx and CapEx, maximizing automation and self-healing whilst enabling optimal operational efficiency.

Use KAI as a reference model to plan, build and optimize transport network

The KAI model described in this paper was developed and updated with support from major COmms SPs including PLDT and MTN. These Comms SPs have contributed transport network case studies to this whitepaper to illustrate the application of the KAI model over time.

PLDT is the largest Comms SP in Philippines. The KAI model was used to evaluate the architectural effectiveness of the Comms SP's recently completed construction of a countrywide, converged transport network to support both mobile and fixed line connectivity use cases. MTN is the largest Comms SP in the African continent with 278 million subscribers and a wide range of network maturity across 21 OpCos.

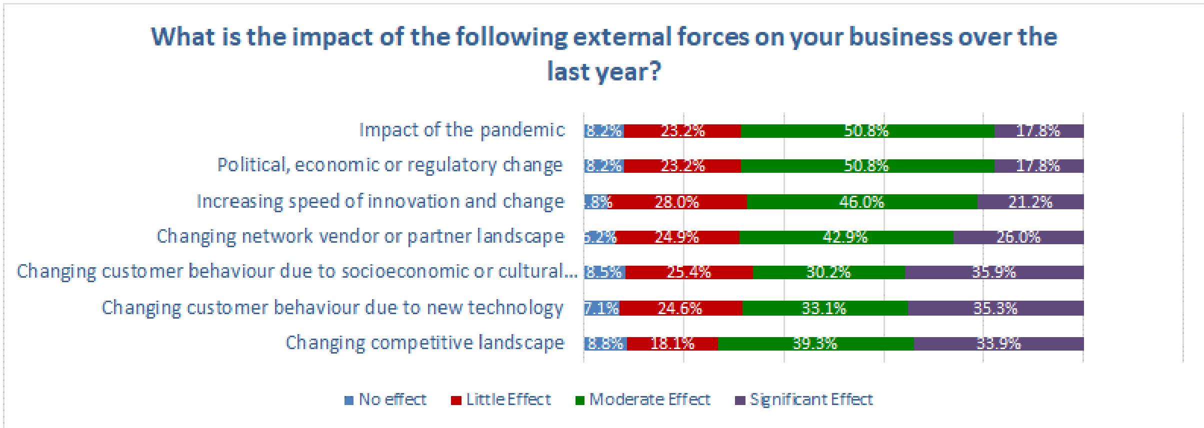
The service providers studied in the White Paper shared their thoughts, strategies and challenges in their journey of transport network transformation. We believe these insights can act as a good reference for other Comms SPs.

2.0 KEY TRENDS IMPACTING NETWORK ARCHITECTURE

Through 2025, service providers will look to transform business and operations to align with the digital economy's continuously evolving requirements. Comms SPs form the essential link in digital value creation chains. Simultaneously, competition with digital-native and over-the-top (OTT) providers, such as Facebook, Amazon, Netflix, WeChat, and Google, for the hearts, minds, and eyeballs of consumers and business alike, leads to a landscape in which thrivers are defined by their agility, speed, and time to market.

FIGURE 1

External forces impacting enterprises



Source: IDC AP Carrier Transformation Survey 2021,n=280

Several major changes in the market have occurred since the publication of the initial version of the transport model. Changes in both business and consumer connectivity environments plus the ongoing impact of the global pandemic are accelerating digital transformation initiatives, impacting the definition of work, the relationships between business and their customers and the role of the home in enabling entertainment, work life and learning. Though factors at the time, they have emerged as key drivers which fundamentally transform the role of the connectivity layer. We'll discuss some of the key trends below:

1. Business Driven and Customer Requirements Driven:

In today's service provider industry, where aggressive competition is driving flexible subscription models with a wide variety of service options and commodity pricing, customer service has become a key differentiator for all CSPs.

Unhappy customers have access to choose connectivity solutions and are quick to change. That churn can seriously impact revenues and profit margin. Hence, the traditional ‘break/fix’ approach to providing network QoS is no longer adequate. End customers, in both consumer and enterprise space, are completely dependent on always-on connectivity in their homes, offices and on-the-go. Moreover, even short service outages or interruptions, or even poor network experience, can have long term impact on the reputation of Comms SP services.

This has resulted in Comms SPs taking a more proactive approach to their network architectures and focusing on Cloudification, Convergence, and accelerating their 5G implementations.

Virtualization, Cloudification and Software Defined Infrastructure

For enterprises, 'Cloud-first' strategies, IoT use case implementation and digital transformation initiatives continue to drive the creation of innovative business models while putting pressure on the scale and capability of digital infrastructure. The growth of east-west traffic between these enterprise, colocation and public cloud data centers (DCs) changes the underlying traffic model (volume and directions) of the transport network. The integration and convergence between DCs and transport networks drive the capability, openness and intelligence of the transport network. Enterprises require higher SLAs for reliable and secure private lines to connect branches or clients and interact with DC for acknowledging applications requirements. Moreover, the trend of "enterprise to cloud" is a critical and growing development, as more and more applications migrate to cloud and from private cloud to multi-cloud.. Thus, Comms SPs need to build transport networks to multiple clouds, especially public clouds. Examples include Singtel's Liquid X infrastructure manager, DT's "Cloud Broker" strategy and Telstra's Telstra Program Network (TPN) which allows customers to construct networks from buildings blocks such as hyperscaler cloud connect, various VNFs and virtual routers.

Software Defined Infrastructure is changing the way that the network is architected and is impacting all major domains – RAN, optical transport, packet core and IT Systems. The network transformation will utilize cloud-native technologies such as containers, Network Function Virtualization (NFV) Virtual Network Functions (VNFs) and Cloud-native Network Functions (CNFs). Legacy systems are now challenged to be more real time and to repeatedly synchronize with multiple business processes as 5G/MEC infrastructure is deployed. Backend IT systems such as OSS/BSS, application platforms must adapt to this new model when provisioning and monetizing solutions. Network slicing — the virtual segment of the network designed to address specific network performance conditions — will drive strong real-time operational needs to the provisioning, inventory, assurance, and monetization functions.

Convergence

Convergence is occurring at several levels at the Comms SPs: (1) convergence of fixed and mobile network access and transport, (2) convergence or bundling of fixed and mobile services where regulation allows it, (3) convergence of the mobile and fixed business entities and/or divisions (e.g. NTT DoCoMo and NTT Communications Japan). One of the key trend aroundnetwork convergence is that incumbent mobile network operators (MNOs) are now building and offering FTTX services for both residential and enterprise customers. MNOs are looking at fiber infrastructure as part of a long- term strategy to stabilize revenue and profits. The challenge of reducing overall network TCO revolve around building the fiber network according to a holistic and systematic methodology.

MNOs and integratedComms SPs are exploring constructing "converged" transport networks for all services including Giga home/industries/SMEs/5G. In this model, each service can run on its own "logical" network which can guarantee the experience. Some new concepts need to be introduced like "network slicing" in the fixed broadband network, similar to the 5G network slice.

Fixed Wireless Access (FWA) is another byproduct of the general converged network trend. IDC estimates that over 65-70% of Comms SPs globally are pursuing LTE/5G FWA in an effort to increase wallet share and flexibility for consumer and enterprise customers. 5G FWA is being considered as a substitute or complement to FTTX, reducing CAPEX, and speeding time to market for services increasing Comms SPs' total addressable market.

For example, in Japan, NTT DoCoMo has started to offer 5G FWA for consumers that use a Customer Premise Equipment (CPE) with built-in antenna for indoor reception. Besides what the Comms SPs in the U.S. such as Verizon are doing with 5G FWA, in Asia Pacific, IDC expects that leading Comms SPs will offer FWA such as in Australia (Optus, TPG, and NBN), PRC (China Telecom), Philippines (Globe telecom and PLDT/Smart), Malaysia (Maxis, Axiata, and Celcom), Japan (Rakuten, NTT DoCoMo, KDDI, Softbank) and South Korea (KT and LGU+).

5G and Edge computing

5G deployment began in some countries in 2019 and early data is indicating that over 20% of 5G traffic is due to low latency services like AR/VR. By 2023, IDC forecasts that 5G will command over 1 billion global connections and bandwidth demand will grow at a CAGR of 25-31%. APeJ will see 9.3 billion IoT connections, a CAGR of 21.1%, generating 5-10% of total network traffic as 4k video surveillance and intelligent image recognition evolve. The migration from 4G to 5G will be a significant challenge for Comms SPs as they seek to maintain and enhance customer experience. This is especially true for low-latency use cases such as remote navigation control which requires a latency of less than 3ms.

In the 5G and cloud era, cloud computing, big data, and AI will be integrated to implement intelligent upgrade of businesses and industries. The 5G UPF (user plane function) and the cloud moves data processing from the central DCs to the edge to minimize latency. IDC predicts that by 2024 over 75% of infrastructure in edge locations will be consumed/operated via an as-a-service model. Comms SP's transport networks will be needed to ready for any new DCs set-up by providing DCI (Datacenter Interconnect). Many of the use cases that are envisioned for industry and enterprises will require low-latency compute resources and these will increasingly be hosted not on the cloud but on an edge cloud. As a result, leading hyperscale companies such as Microsoft Azure, AWS, and Google are partnering with CSPs to deliver cloud platforms optimized for the edge.

Private Networking

Private Networking has been utilized in industries such as mining, ship building, and railways. 5G and edge computing will enable a wide range of industry use cases including smart manufacturing, public transport networks, autonomous and advanced driver assisted systems (ADAS), construction, retail banking, healthcare, smart cities (airports, ports), and sports and music venues/stadiums. Private Networking will utilize both sub-7 GHz and mmWave 5G bands to deliver up to 10 Gbps per access point. For CSPs, this is an essentially new opportunity enabled by 5G, cloud and the edge. Campus networks present an opportunity for both fixed broadband access and Wi-Fi and 4G/5G access and moreover, edge compute resources can also be incorporated to support AR/VR-based learning. Many Comms SPs are reporting substantial interest from their enterprise customers in delivery of private networks. Fixed broadband access networks such as GPON can be extended private network scenarios. These fixed broadband networks can be designed for and brought straight into campus, industrial park complexes (servicing multiple clients), smart ports and ship building yards.

2. Policy Driven

Sustainability: Network GHG Emissions and Energy Efficiency Challenges

Worldwide initiatives at a regulatory and national level are addressing specific areas oriented toward a greener, more digital, and more resilient society. With greater awareness among consumers around matters such as the environment, telecom service providers are looking to prove their commitment, expertise, and action in such areas stand a greater chance of attracting and retaining customers – both enterprise and consumers.

One of the key areas within the Comms SP environment when it comes to sustainability is its network operations. The proliferation of 4G and 5G base stations, gigabit home connectivity, and cloud-based applications means that CSPs must now start to address Green House Gas (GHG) and electric power consumption and carbon neutral goals. As the industry starts to study options for 6G the role of sustainability will become critical. 5G-based systems will need to deliver the highest possible efficiencies in order to address the exponential demand for data usage. A simplified network architecture is crucial for the improvement of the network energy efficiency.

3. Work from Home (WFH)

The COVID-19 pandemic has led to

(1) Sudden and urgent demand for bandwidth upgrade as people stayed home and

(2) Enhancement to the customer experience relating to bandwidth and access to cloud hosted applications.

In emerging markets where the FTTX penetration was low, IDC has witnessed a rapid deployment of FTTH as xDSL and LTE FWA were not able to cope with YoY home data usage growth of 50-65% or higher.

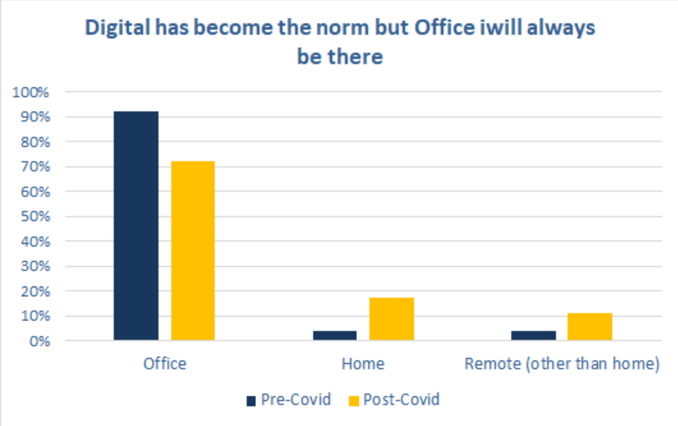
Working from home means the home is becoming a multi-functional center. Not only for entertainment, but also for work like video conference/remote access office ERP requiring more stringent network requirement such as home Wi-Fi coverage. WiFi 6 and even fiber to the Room (for large houses) may also be necessary.

We expect the bandwidth demand to continue with respondents highlighting that on an average they still plan to spend about 28 percent of time working from locations other than the office, once the pandemic restrictions are eased.

There were several other consequences of WFH: even as households in emerging markets households sought to get FTTH service, MNOs saw data traffic in 2020 increase by as much as 65% YoY in some markets. Bandwidth competition between on-line schooling and business video conference calls presented an opportunity for CSPs and vendors to offer SD-WAN solutions that enable households to manage and prioritize bandwidth usage. CSPs in merging market stepped up their FWA and FTTH marketing and investment.

FIGURE 2

Demand for bandwidth as a consequence of the pandemic



Source: IDC Asia/Pacific Next-Gen Networking and Comms Survey 2021, n=1400

4. Competition Driven

Customer Experience and Cost Optimization

In the consumer connectivity market, customer experience was already an important criteria. However, the COVID-19 pandemic has accentuated the importance of consistent and reliable connectivity and capacity. In the enterprise market, cost optimization is being realized through enhanced cloud connectivity, the introduction of edge computing, Software Defined architecture and cloud-native orchestration and automation.

As a result of the drivers noted above, 69% of Comms SPs have indicated that the rapidly evolving customer landscape is one of the biggest threats to their business and are beginning to treat their networks as a competitive advantage, rather than as a commodity – and leveraging network-based intelligence to differentiate themselves in a crowded telecom marketplace.

3.0 ENTERPRISE AND CONSUMER REQUIREMENTS

3.1 Enterprise to Cloud

3.1.1 BUILDING THE NETWORK ARCHITECTURE FOR Enterprise Digitalization

Scenario 1. Comms SPs providing connectivity to Cloud Service Providers: Cloud service providers continue to expand cloud data center offerings domestically and regionally. Cloud providers typically utilize dark fibers for that purpose.

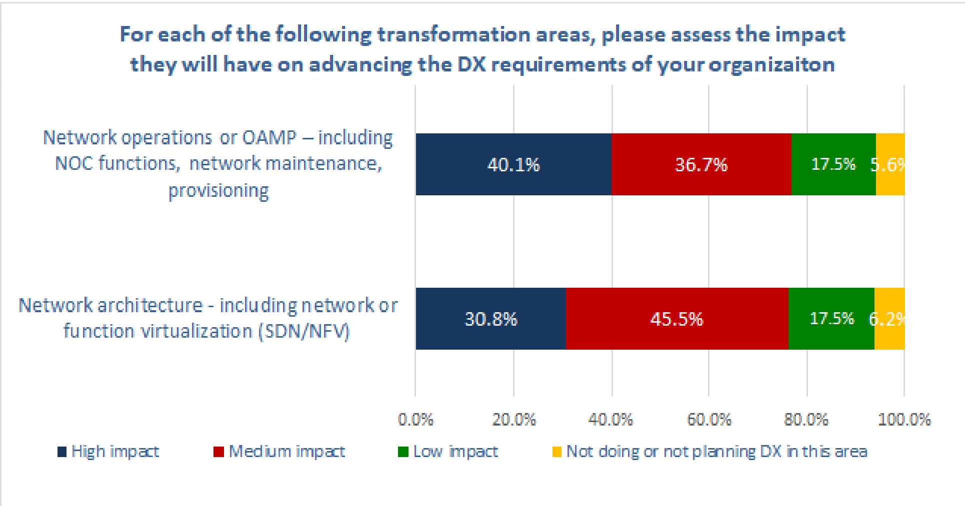
- **Requirement 1:** Fiber/OTN to multiple data centers, and dedicated physical connection resources between cloud pools. High availability and resilient connectivity between multiple data center environments operating as cloud resource pools. In Europe, for example, some OTTs are requiring Comms SPs to provide deeper optical OTN network into the metros as well as for DCI. In Asia/Pacific for example, OTTs and CDNs have established large wholesale agreements with major Comms SPs. OTTs are requiring mainly 100G ports and are sending out RFIs for 1 Tbps ports for the 2022-2023 timeframe. CDNs often use 2 x 10 G but on the same cable system while OTTs prefer to have 4 x 100G spread across 4 different cable systems, which means that typically the OTTs need to partner with more than one Comms SP in that region to get access to four different cable systems

- **Requirement 2:** On-demand access to network connectivity to cloud resource pools
- **Requirement 3:** interconnect with cloud service provider's cloud management platform to realize "Network as a Service": Agile connection based on multi-cloud requirements, automatic deployment, visualized, manageable, and predictable connection SLAs, and SLA-based self-optimization.

Comms SPs are actively working to address these requirements and have highlighted that they expect network architecture transformation as well as taking an AI-led approach to network operations to have a significant impact on their business.

FIGURE 3

Factors impacting Comms SP DX initiatives



Source: IDC AP Carrier Transformation Survey 2021, n=280

Scenario 2. Accelerating Large Enterprise DX:

- **Requirement 1:** Industry 4.0 and other DX initiatives such as in transportation, utilities, and smart cities will require deeper reach of the OTN and they will typically be multi-cloud implementations. 5G Network slicing across different domains to support enterprise requirements will need E2E optical fiber network and high-availability service with adequate SLA (Service Level Agreements). 49% of organizations highlighted network slicing as one of the top expected benefits of 5G networks. Edge computing nodes will require low-latency fiber access in order to support many types of time-sensitive use cases. For example, early tests around the globe with Cellular Vehicle to Everything (C-V2X) have highlighted the need for E2E low latency from vehicle to edge/cloud and back to the vehicle using the Vehicle-to-Network (V2N) cellular (e.g. LTE/5G) access. Network slicing will be utilized in the C-V2X use cases in order to assure adequate bandwidth and edge resources (connected by fiber) since safety is greatly impacted by the performance of the E2E connection.
- **Requirement 2: Differentiated Cloud-network Service.** Enterprises and organizations have started adopting software-defined network architectures, but the fundamental driver is the migration to public cloud, together with DX campaigns, which made cloud connectivity central to the business strategy to enable analytics, storage, and artificial intelligence (AI)/machine learning (ML). The leading Comms SPs are providing one-stop routing/transport connectivity to multi-cloud scenario with guaranteed SLA, self-

optimization capabilities. Facing competition from OTT, Comms SPs are considering introducing SD-WAN services as a new option to strengthen their competitive positioning.

- **Requirement 3:** Orchestration with Cloud Dashboard, Network Dashboard. Automatic deployment, visualized, manageable, and predictable connection SLAs, and SLA-based self-optimization. IDC's Asia/Pacific Next-Gen Networking and Communications survey highlights that organization discussions around cloud have moved on from whether or not cloud, to how many clouds. As a result, they're expecting their Comms SPs to provide them with a broad cloud portfolio helping them address the challenges of migrating to, and manage a multi-cloud ecosystem. When asked about their cloud investment plans, 64% of organizations (up from 46% today) highlighted adopting Cloud interconnect solutions, 54% highlighted adopting Cloud Orchestration platforms (up from 35% today), and 50% highlighted adopting Cloud lifecycle services (up from 31% today), over the next 12-18 months.

Scenario 3. Supporting SME: SMEs are moving more and more of their core business applications to the cloud to enhance the productivity and production efficiency of enterprise core business, and how the Comms SP's network architecture to match

- **Requirement 1:** Service experience assurance for high-value applications for commercial broadband users (OLT access)
- **Requirement 2:** E2E network management and control capability for intelligent service acceleration (Identifies valuable applications on the home network and bearer network, manages bearer network slices, and identifies VAP users.)

3.1.2 MTN Case Study: 2B Transport Network transformation across the Group

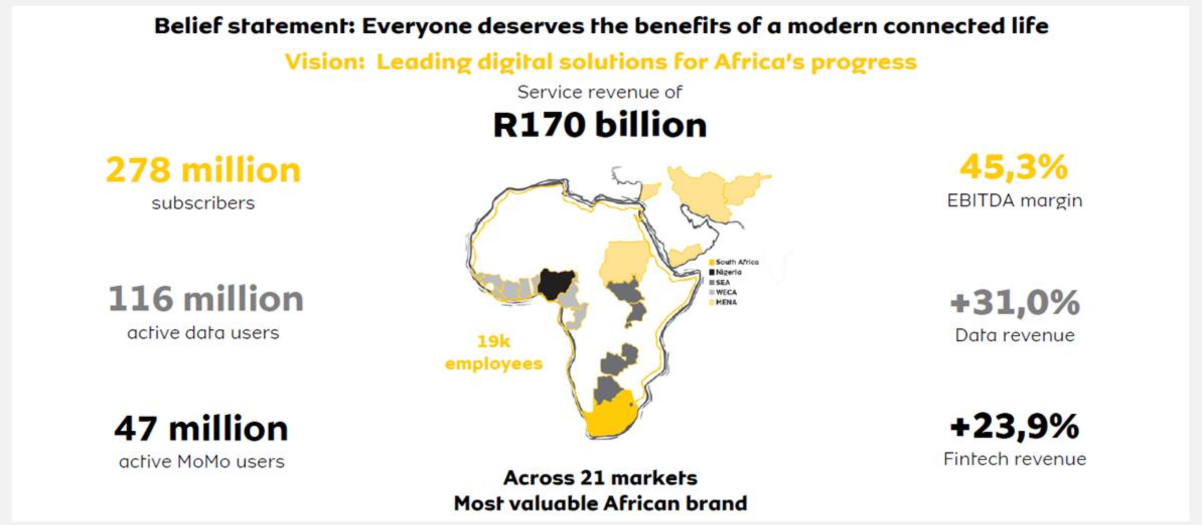
The MTN Group is headquartered in Johannesburg and operates in 20 countries in Africa and the Middle East, has over 278 million subscribers and is the largest telecom network in Africa. After South Africa, the second largest revenue contributor is MTN Nigeria. Since its inception as M-Cell in 1994 when the operator was established with assistance from the South African government, MTN has grown organically and through acquisitions and mergers. In terms of subscribers, the largest top seven OpCos are in order Nigeria, Iran, South Africa, Ghana, Uganda, Ivory Coast and Cameroon.

MTN Group has embarked on its "Ambition2025 Strategy" which seeks to develop 5 growth platforms: (1) Fintech solutions, (2) Digital services, (3) Enterprise services, Network-as-a-Service (NaaS), and API marketplace. In April 2021, MTN started its initiative to improve its Transport network's CASSI (Congestion Free, Always on, Simplified, Scalable, and Intelligent) KAI indices by end of October 2021. Being a diverse group of OpCos, MTN Group needed to develop a Transport architecture that enabled Tier 1 OpCos to reach their growth potential as well as Tier 2/3 OpCos. In the markets where 5G has been launched first such as South Africa, the operator aims to achieve latency reduction (35 ms in LTE) to 10 ms (5G NR) and bandwidths of 45 Mbps (LTE) with 500 Mbps (5G NR).

MTN has laid out a detailed strategy to transform and upgrade its Transport network across the Group using timelines that are realistic and tailored to the maturity of the network in the local OpCo markets.

FIGURE 4

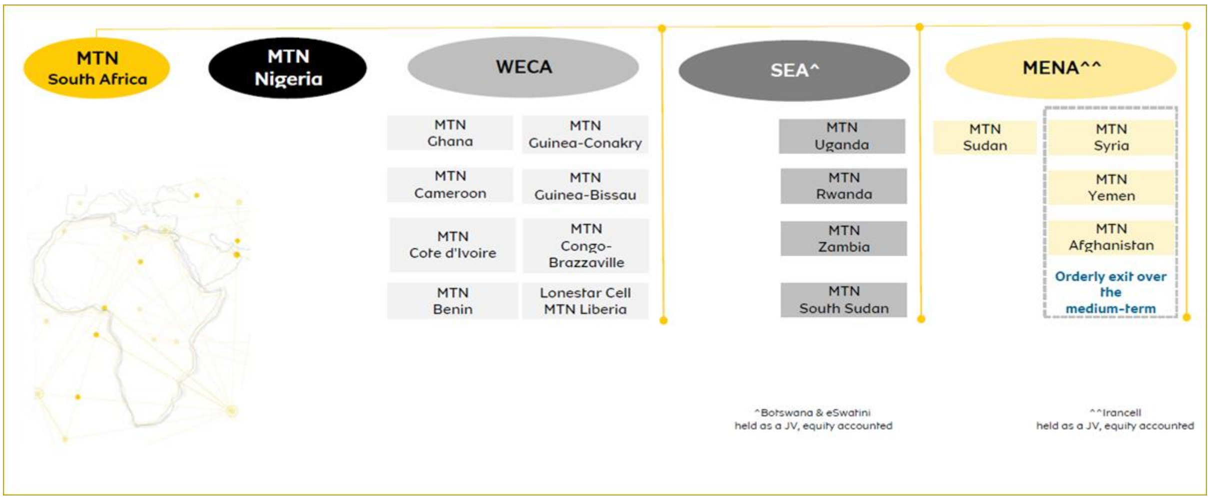
MTN is the leading Comms SP on the African continent



Source: MTN, 2021

FIGURE 5

MTN Group Transport Network Transformation Plan



Source: MTN, 2021

In Figure 6, we provide the overall 2B scoring for the MTN Group noting that this is across the entire group of OpCos. If only the top 5-7 OpCos were evaluated the overall scoring would be higher.

Congestion Free. MTN Group received modest scores in this category due to the variation of Fiber-to-the-sites across the group. For example, in South Africa in the larger cities, the FTTS rate is about 65%, and for enterprise customers mainly located in the big cities, the fiberization is 30%

above the average.   In Nigeria for example, only 30% of the aggregation sites have OTN. In some OpCos, slicing technology has been introduced for new routing platforms.

Always On. Using Nigeria as an example roughly 38% sites had >= 3D degrees on the WDM. Overall we rated MTN with a better than a good score to reflect the progress made in its WDM topologies. Also in Nigeria, MTN enabled roughly 1/3 of its WDM sites with ASON protection. In some OpCos, Ti-LFA has been deployed to provide ms-level switchover to assure the private line availability.

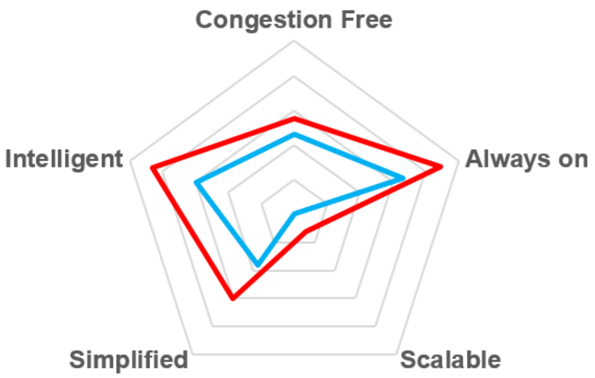
Simplified. The converged network supports multi-services. For example, in South Africa the converged network supports mobile, home broadband, and enterprise services in some OpCos, SRv6 (Uganda) has been enabled to provide fast TTM and SLA assured connections.

Scalable. In order to enhance multi-cloud connectivity and provide on-stop cloud-network services, the South African OpCo is integrating with public clouds.

Intelligent. Overall we rated a moderately good score for the MTN group with respect to 2B. In some OpCos, Based on open API, SDN controller has been deployed to provide automatic service provisioning, predictive maintenance (SLA visibility and fault awareness) and intelligent optimization to achieve high efficient O&M.

FIGURE 6

KAI Scoring for MTN Transport Network



	KAI Score
Current	75.7
Legacy	52

Source: IDC, 2021

3.2 Giga Home Broadband

3.2.1 BUILDING THE NETWORK ARCHITECTURE FOR Giga Home Broadband

Scenario 1. Broadband service convergence: As an increasingly large number of people work from home, MNOs are actively offering FTTx and FWA. MNOs are looking to achieve large-scale network construction with the optimized TCO, quick provisioning to deliver enhanced customer experiences.

- **Requirement 1:** Comms SPs need to consider the total TCO of the whole network and not just specific network domains. When MNOs, for example, decide to build a converged network and enter the fixed broadband access business they can encounter both TCO challenges and opportunities based on their experience and lack of experience in certain network domains. The same would apply to fixed Comms SPs when planning the physical layer including power, and sites for private networking and FWA. The IP layer also needs to be converged and will impact TCO.
- **Requirement 2**: Comms SPs need to implement rapid deployment and this is particularly important currently as fixed fiber broadband access is in high demand due to COVID-19.

Scenario 2. Fixed incumbents maintaining their competitiveness: MNOs are presenting a significant challenge off the growth of smartphones andfixed incumbents need to offer competitive plans and high-quality user experience while optimizing their cost structures. Comms SPs are beginning to address how to enhance the home Giga experience. For example, Singtel launched Gamer Pro Fiber bundle which included dedicated 1 Gbps for the family in addition to 1Gbps for gaming purposes. This was based on Singtel's WTFast GPON, and also included ASUS RT-AX86U WiFi 6 Gaming Router - to help customers create a fast and stable gaming network.

- **Requirement 1**: Converged access and aggregation, outdoor, FMC site, and adequate fiber capacity to Central Offices.
- **Requirement 2: Customer e**xperience and customer assurance (especially the home office during the pandemic).

3.2.2 Case Study: EMEA Operator

In the ToH market, the traditional copper/cable access mode is rapidly evolving to FTTH optical access. On the other hand, driven by services and competition, users have higher bandwidth and Customer Experience requirements for home broadband. Giga-to-home and Giga-to-room are being recognized by high-value customers and will be gradually promoted.

We investigated the ToH business strategy of an EMEA operator (anonymity on request). 85% of the subscribers of this operator have more than 3 rooms. Customer Experience issues caused by poor indoor Wi-Fi coverage led to many customer complaints.

In order to improve user experience and customer loyalty, the EMEA operator initiated a Giga to room strategy as follows:

1. **Home access:** 1 Gbps super bandwidth access through Fiber to the Room and Wi-Fi 6 are deployed with seamless roaming are achieved without service interruption.

2. **Home Network Issue Insight:** The EMEA operator introduced big data collection and evaluation to identify home issues proactively and resolve remotely, which can help to bring down user complains by 30%, and home technician visits by 40%, which greatly improved the fault locating, rectification efficiency, reduces customer complaints and home visits.

3. **Transport Target Network:** Besides the access network, the transport network planning is very important for the end-to-end experience assurance. The EMEA operator is now planning the target network considering to be more simplified in its architecture and layers, thereby improving the latency and forwarding efficiency. On the other hand, to improve the O&M efficiency and TTM, the EMEA operator is validating new solutions like SRv6 and SDN to cater the new requirement of network intelligence and automation.

3.3 5G Transport Network

3.3.1 BUILDING THE TRANSPORT NETWORK ARCHITECTURE FOR 5G AND CLOUD ERA

2B and 2H will require different enhancements to be made to the transport network. For example, 2B will be an early user of network slicing as well as OTN to Aggregation/Access. 2H will need converged network in the access and aggregation layer. For Comms SPs that also have a mobile service, the fiberization ratio of 4G/5G sites will become a critical parameter that also will impact the dimensioning of the access and aggregation layer.

Each Comms SP is at a different stage in the upgrade and modernization of their transport network. Some Comms SPs such as HKT (Hong Kong) and SKT (Korea) built G-PON networks as part of their fixed broadband network and then extended them to provide access for 4G and 5G base stations. In the case of SKT, the operator developed what it calls "5G-PON" for remote site access (fronthaul) with 50 ms ring switching protection. HKT has deployed its converged 10G-PON network and C-RAN (Cloud-RAN) which has enough capacity to offer wholesale bandwidth to competitors. This configuration is less prevalent in the market and the more common configuration.

Other Comms SPs in the region that are building and upgrading their optical transport into converged architecture are KT, Rakuten, Bharti Airtel and Reliance Jio. In all of those cases the comm SP needed to enhance the fronthaul, the backhaul and the Data Center Interconnect (DCI) to support both fixed broadband expansion and mobile data explosion. The anticipated role of edge computing in future 5G networks will also provide a strong incentive to build converge network and scalable capacity because both consumer and enterprise use cases will require in the future tremendous amounts of edge compute resources. mmWave 5G with site capacity >10-14 Gbps will also impose considerable bandwidth requirements indoor settings and selected outdoor hotspot zones.

3.3.2 PLDT CASE STUDY: BUILDING AN ENTIRELY NEW STATE-OF-THE-ART SDN-ENABLED TRANSPORT NETWORK

In order to develop the KAI model against a real network, IDC interviewed the Transport Transformation CFT (Cross functional Team) in 2020 and Technology Strategy and Transformation PLDT team in 2021 in the Philippines. In IDC's 2020 assessment of PLDT's transport network transformation we focused on ToC but in the ensuing 18 months PLDT has made significant progress in the ToH and ToB areas. PLDT, formerly known as Philippine Long Distance Telephone Company, is the oldest and largest Comms Service Provider in the Philippines in terms of assets and revenues, which operates mobile and fixed services, serving both consumer and enterprise. As part of its transport network modernization, unlike many other Comms SPs, PLDT made a bold decision to build a totally new transport network, the first phase of which to be completed by February 2020, next to the legacy network, PLDT opted for this total revamp instead of carrying out the typical piecemeal incremental upgrades. The timing was impeccable because the lockdowns due to the COVID-19 pandemic because soon after the first phase of the transformation had already been completed. Below are the key objectives behind PLDT's visionary decision and an update on where the Comms SP is today.

Aggressive FTTH expansion prevented negative impact to existing enterprise or residential services during the pandemic- prior to 2020, PLDT had already begun going back to 2018 to increase its FTTH service reach to homes. In 2020 PLDT added 1.8 million homes passed with its fixed broadband network rollout. In 2020 the number of FTTH ports increased by 560K and in first half of 2021, PLDT reported another 478k new installs and migration; compared to 2019, the number of FTTH ports at the end of 2020 were 23% higher. The financial results in both 2020 and 1H21 supported the massive investment in the fiber network infrastructure: in 1H21 the company reported an increase in home broadband revenues of 32% and an increase in fixed 265k broadband subscribers to reach 3.451 million subscribers. PLDT has ramped up its efforts in the migration from copper-based (ADSL, VDSL and VVDSL) to FTTH with priority in ADSL. PLDT is aiming to achieve 70% FTTH coverage of the cities and municipalities by the end of 2021.

If PLDT had chosen instead to carry out incremental upgrades to the existing network such as upgrading hardware and software, changing the configuration (from LDP to Segment Routing, changing from VPLS to EVPN and so on), these projects would invariably have led to network outages and periodic downtimes and would not have prepared PLDT for the huge network traffic increases that ensured as a result of the lockdowns. By building a whole new transport optical network PLDT is able to provision new services on the network, and for existing services, PLDT thus had ample time to schedule and migrate gradually, circuit by circuit, ensuring minimal impact to the service. We also note that during the actual lockdowns the PLDT engineers were able to continue their installations and network capacity upgrades because it a Comms SP is treated as a essential service. . With the first phase of new transport network completed, PLDT was able to carry out massive capacity expansion of its Domestic and International capacity in a very short period of time during the lockdown period.

Enhanced the submarine cable capacity, data center connectivity and introduced SD-WAN. PLDT reported that its 1H21 data center revenues increased by 22% YoY. This was the direct results of several important steps that PLDT took starting in 2020: (1) PLDT increased the submarine cable capacity substantially to support the hyperscalers, CDNs and enterprises. PLDT has had a number of co-location arrangements with the hyper scalers which also has proved highly beneficial to the hyperscalers and to PLDT's enterprise and consumer customers (2) By introducing 200G lambdas on the backbone network, PLDT was able to increase the DCI bandwidth in order to support the overall huge increases in internet traffic from both enterprises, on-line education and work from home. SD-WAN services grew by 110% YTD vs. the same period last year.

Enhanced Customer Experience. PLDT has been very committed to delivering the best customer experience possible and has adopted an aggressive roll-out plan that started in the early 2019 with the first completing in February 2020 at which time the new transport network was declared Ready-For-Service. The pandemic heightened the need for excellent home broadband performance and in both the FTTH and Fixed Wireless (TE) Access services customers were able to conduct their work and on-line education without any serious disruption.

SDN for the Transport Network. In the process of building a new transport network instead, PLDT designed in automation and orchestration for the optical network taking advantage of new technologies and protocols including Segment Routing, EVPN, TI-LFA, PCEP (Path Computation Element Protocol), to take full advantage of SDN orchestration and automation.

IDC applied the KAI model to evaluate the new transport network and legacy transport network architecture based on our understanding of PLDT's network from the interviews. The results of the scoring are 95.4 and 42.3, respectively, which reflects the technology choices and the exquisite timing of implementation made by PLDT which positioned it for the perfect IP traffic storm as a result of the pandemic.

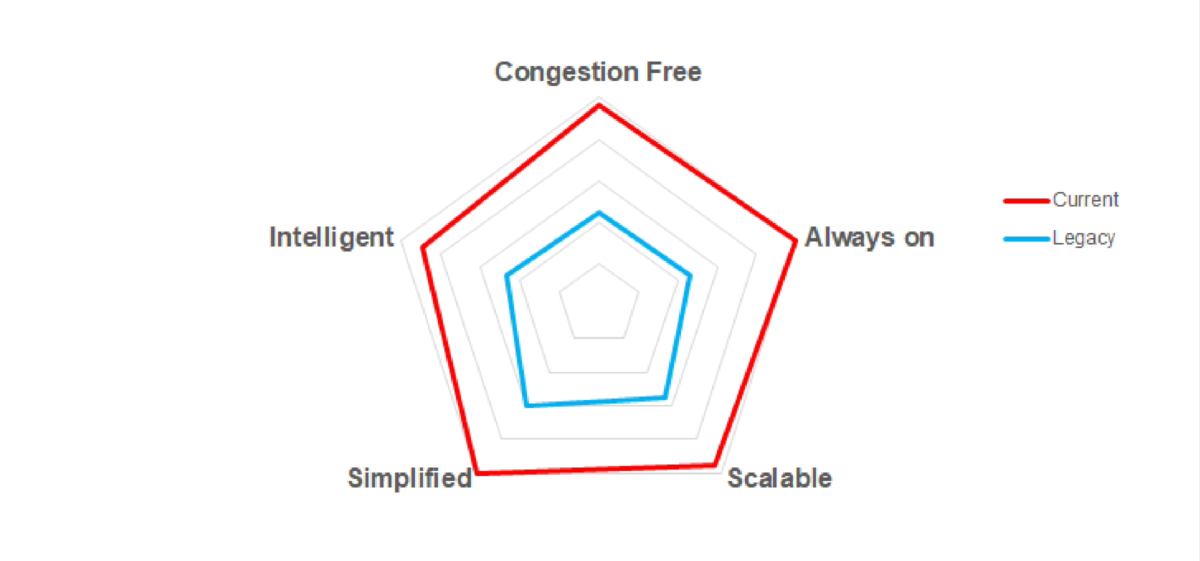
Congestion Free. PLDT scored a high score in this dimension. The new network consists of a pure 100GE interface and the equipment is capable of 4Tbps/slot. Compared with the legacy network which uses mainly 10GE for the trunk lines and has a maximum capacity of 200Gbps/slot only, there is a 20x improvement in capacity. The ultra-large bandwidth and capacity ensures the transport network is congestion free. In 2020 PLDT expanded its total international and local internet capacity by more than double. PLDT expanded its Caching capacity by 92%. International traffic has grown 165% and the Caching traffic has grown by 82% in 2021 YTD. PLDT operates a network via ePLDT of 10 major data centers across the nation in Luzon, Visayas and Mindanao which is further augmented by capacity expansions on sea landing sites. On the fixed enterprise side of the business PLDT like other Comms SPs has operated enterprise IP VPN and MPLS services. PLDT's core network can support Network-as–Service (NaaS) for mobile, enterprise and Home FTTH business. The use of Layer 2 and Layer 3 VPN with different levels of QoS effectively delivers a fixed network slicing capability.

Always On. PLDT's transport network was given a perfect score in the Always On KAI dimension which is due to the fact that PLDT deployed ASON 1+1+R (Restoration) on the OTN layer, and TI-LFA (Topology Independent Loop-Free Alternate) technology on the IP layer, which together ensures the network is able to sustain multiple fiber cut and each switchover is within sub-50ms. Network resilience is especially crucial in the Philippines due to its frequent natural disasters such as typhoon, flooding and earthquakes, and Philippines is also one of the fastest-growing economies in Asia with a lot of constructions ongoing. Cuts in terrestrial fibers and sub-sea cable occur on a regular basis. In terms of the Broadband Remote Access Servers (BRAS) PLDT is implementing dual hot-standby (aka load sharing mode). The BRAS handle the FTTH and xDSL traffic from fixed broadband homes.

Simplified. PLDT scored a perfect mark in "Simplified" KAI. This is due to the fact that PLDT implemented the latest Segment Routing and EVPN protocols, which gives the operator traffic engineering capabilities and enhanced protection. PLDT has also adopted Spine-Leaf topology in its Metro Network. Spine-Leaf topology is the superior topology in terms of scalability and availability. PLDT also incorporated L3 forwarding to the edge, which makes it ready for Distributed Cloud Core. Moreover, the converged network supports multi-services.

FIGURE 7

KAI Scoring for PLDT Transport Network



Source: IDC, 2021

Scalable. PLDT scored a highscore in this category as it has deployed a state-of-the-art system: 200Gbps*96 λs optical system at its backbone network making it one of the most advanced optical transport systems not only in the Philippines but also in the world to date.

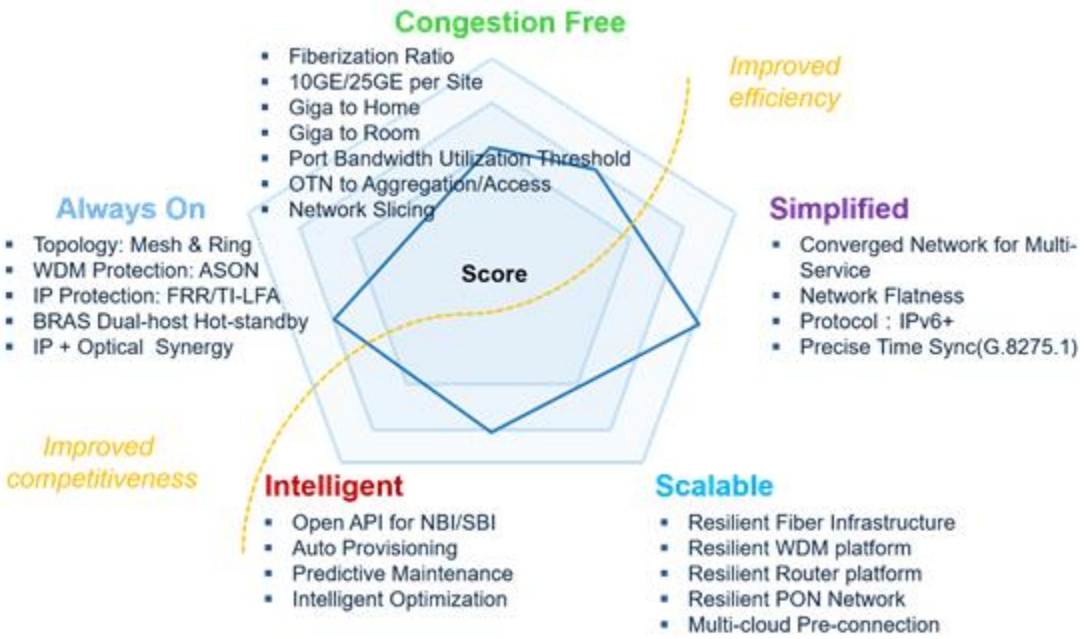
Intelligent. PLDT also scored a high mark in the “Intelligent” KAI owing to the fact that the new network incorporates an SDN layer with a hierarchical architecture: a single Master Controller and multiple Domain Controllers. Full-service life-cycle automation functions are also enabled, such as service provisioning, planning, visualization, simulation and forecast. In 2021 PLDT is in the process of migrating enterprise customers to the new highly scalable network coupled with SDN orchestration for resiliency and dynamic bandwidth allocation. IMS based voice transformation has been completed and currently PLDT is progressing towards virtualization of the core. PLDT furthermore is also in the process and implementing an automated services provisioning and after sales customer management, for enterprise, through an establishment of an e2e Service Orchestration. In the 2H services, PLDT is able to collect, analyze and optimize poor QoE through a range of operating parameters such as sync rates and jitter measurements.

4.0 KEY ARCHITECTURE INDEXES

In order to develop a quantifiable Key Architecture Model for assessing a target network architecture, IDC proposes a holistic index model including 5 dimensions with 25 indexes: **Congestion free**, **Scalable, Simplified**, **Always on** and **Intelligent**, which encompass all layers of the transport network: physical optical cable layer, IP and DWDM layer, and the management/controller/analyzer layer. The model identifies fundamental network factors as constants (hard-to-change) which long-term impact network quality and performance, while filtering short-term device configuration-related factors (as network variables) for routine optimization.

FIGURE 8

KAI network model (5 dimensions with 25 indexes)



Source: IDC, 2021

4.1 The KAI model determines the transport network quality and cost, facilitating network construction and management.

A perfect network architecture can assure service quality quantitative targets and deliver adequate capacity but remain scalable for the next 3 to 7 years, ultimately reducing TCO. Currently, the key quality/performance indicators (KQIs/KPIs) such as bandwidth, latency, and jitter, do not provide insights into underlying factors driving those KQIs, like fiber infrastructure, topology, and technology and operation capability. KQI/KPIs are really a micro index at the link level but they do not give deep insights into the entire transport network. KAI is deconstructed from KQI/KPI into a quantitative methodology to assess high service quality, reliability, and self-healing capabilities for transport networks.

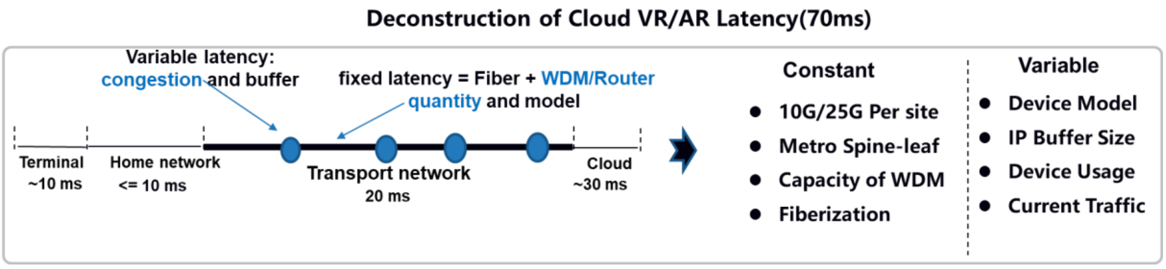
KAI can be used to accurately quantify, manage, and control in all network development cycle of planning, design, construction and operation.

4.2 Standardization: KAI is built by deconstructing KQIs (Comms SPs' offering)

By deconstructing KPIs/KQIs from Comms SPs' offered services, normalizing factors, discarding easy-to alter factors, we can filter out the relatively fixed and fundamental/underlying factors (network constants) that determine the network quality level into 5 dimensions. The five dimensions are further decomposed into 17 constituent, measurable Indexes.

FIGURE 9

Example of deconstruction of Latency KQI into the relevant KAIs



Source: IDC, 2020

4.3 Digitalization: quantifying KAIs as indicators for full life-cycle evaluation

Each index is further broken out into constituent, measurable indicators (for example: Fiberization ratio into fiber access ratio of radio sites), so that the index can be quantified in an objective and original way.

4.4 Scoring & Weighting: setting criteria for overall capability evaluation

The index weights can be set based on the importance of indicators. For example: the most important is the user experience which means more weight for congestion-free dimension, then future development (simplified, scalable, protection) and convenience for internal O&M (intelligence). The scoring of each index is based on the transport network's target value assigned based on its service requirements and leading practices. Finally, a total score for the transport network can be developed. The higher the score, the more capable and efficient for 5G and Cloud network requirements.

Table 1 shows the updated indexes used in KAI and the impact on three key scenarios: 5G services (consumer and enterprise),ToBusiness (ToB) and ToH (To Home). The "Common" column refers to parameters that impact all three scenarios.

TABLE 1

Key Architecture Indexes for Enterprise to Cloud

Category	Parameter	Service Strategy Relevance			
		Common	5G	ToB	Giga to Home
Congestion Free	Fiberization Ratio	***			
	10GE/25GE per Site		***		
	Giga to Home				***
	Giga to Room				***
	Port Bandwidth Utilization Threshold	***			
	OTN to Aggregation/Access			***	
	Network Slicing			***	
Always On	Topology: Mesh & Ring	***			
	WDM Protection: ASON	***			
	IP Protection: FRR/TI-LFA	***			
	BRAS Dual-Host Hot standby				***
	IP+Optical Synergy	***			
Scalable	Resilient Fiber Infrastructure	***			
	Resilient WDM Platform	***			
	Resilient Router Platform	***			
	Resilient PON Network				***
	Multi-cloud Pre-connection			***	
Simplified	Converged Network for Multi-service	***			
	Network Flatness	***			
	Protocol:IPv6+	***			
	Precise Time Sync(G.8275.1)		***		
Intelligent	Open API for NBI/SBI	***			
	Auto Provisioning	***			
	Predictive Maintenance	***			
	Intelligent Optimization	***			

Source: IDC, 2021

5.0 CONCLUSION AND ADVICE FOR COMMS SERVICE PROVIDERS

New services driven by Giga home and enterprise to cloud will bring new business opportunities, but at the same time will also challenge the existing IP transport (bearer) network infrastructure and increase TCO.The advent of 5G mobile and FWA services will put further stress on legacy transport architectures but with the careful methodology and architectural reference system that KEI provides it can be possible to reduce CapEx & OpEx. In this White Paper we have presented several examples of leading Moss SPs that took proactive steps to redesign and rebuild their transport networks to enable new services and scaling.

IDC believes that all Comms SPs should set targets for their transport networks using an index model similar to our KAI system. IDC recognizes that Comms SPs are at different maturity stages in their DX journey, IDC recommends Comms SPs to adopt systematic, network-wide, global vision and methods to design, manage, and control the quality, and ultimately improve the competitiveness and efficiency, and embrace the future by:

- Applying KAI model to network planning, construction, and intelligent O&M.
- Designing for 5G average and peak bandwidths that will be on the order of 3-10X what LTE is consuming today
- Enhancing the data center and DCI and international bandwidth where relevant to enhance the OTT traffic flows
- For Comms SPs with OpCos in multiple countries, adjusting the target goals for indicators such as fiberization taking into account the maturity of each market in terms of their own infrastructure.
- Using digital IT planning and measurement tools to improve the efficiency of network planning, construction and O&M.

APPENDIX A. KAI 2.0 INDEXES

In this Appendix, we provide a technical description of the IDC Key Architecture Indexes version 2.0. Table A1 shows a summary of the five KAI 2.0 categories and their underlying parameters which are used for scoring the architecture index. KAI can be used to accurately quantify, manage, and control in all network development cycles of planning, design, construction and operation.

TABLE A1

Key Architecture Indexes Description and Scoring

Category	Parameter	Description
1.0 Congestion Free	1.1 Fiberization Ratio	Fiber ratio to the mobile sites or FBB users to evaluate the fiber coverage capability
	1.2 10GE/25GE per Site	10GE/25GE to Site to evaluate 5G readiness of the bearer network
	1.3 Giga to Home	FBB high bandwidth to the home
	1.4 Giga to Room	FBB high bandwidth to every room in a home
	1.5 OTN to Aggregation/Access	OTN metro site coverage to enable high metro capacity and flexible networking
	1.6 Port bandwidth Utilization Threshold	Threshold once exceeded requires capacity expansion
	1.7 Network Slicing	The IP network supports slicing to enable differentiated SLA services
2.0 Always on	2.1 Topology: Mesh & Ring	Evaluation of WDM directions and IP ring formation rate to improve redundant protection capability
	2.2 WDM Protection: ASON	WDM technologies such as ASON to improve availability and protect against multiple fiber cuts.
	2.3 IP Protection: FRR/TI-LFA	IP technologies such as TI-LFA to enable millisecond-level protection

TABLE A1

Key Architecture Indexes Description and Scoring

Category	Parameter	Description
	2.4 BRAS Dual-host Hot-standby	BRAS dual host protection, once one fails, another one will take over smoothly
	2.5 IP + Optical Synergy	Synergy between IP layer & WDM layer in visualization, protection & provisioning, troubleshooting, etc.
3.0 Scalable	3.1 Resilient Fiber Infrastructure	Fiber access capability for all services, which is the most valuable resource for Comms SPs to provide fast TTM & high SLA services.
	3.2 Resilient WDM Platform	The evaluation of wavelength occupation & per-channel bandwidth to reflect the scalability of the WDM platform
	3.3 Resilient IP Platform	The evaluation of slot/port usage to reflect the scalability of the IP platform
	3.4 Resilient PON Network	FTTH access with resilient scalability like split-ratio adjusting
	3.5 Multi-cloud Pre-connection	Setting up pre-connection cooperation with Public clouds to offer fast TTM service to 2B enterprises
4.0 Simplified	4.1 Converged Network for Multi-service	Converged network platform for all services other than siloed networks with high TCO.
	4.2 Network Flatness	Based on the ratio of pass-through traffic to local traffic, quantitatively analyzes the flatness of the metro network.
	4.3 Protocol: IPv6+	IP network SRV6 ready, to enable one-click deployment and one-hop cloud access
	4.4 Precise Time Sync(G.8275.1)	Precise Time Sync. Can provide high synchronization to improve wireless network efficiency and experience
5.0 Intelligent	5.1 Open API for NBI/SBI	Standardized NBI for easy platform interconnection
		Open South Bound Interface to 3rd party
		IP Service programmable
		Interface orchestration & programmable
	5.2 Auto Provisioning	Automatic deployment and commissioning, 1-time site visit, and fast TTM
		Network slicing automation
		Bandwidth on-demand-adjustment
		Auto ODN registration & topology display
	5.3 Predictive Maintenance	Network & Service Visibility
		Service health check based on alarms & KPI
		AI-Based Fault root cause analysis
		Fiber health check based on Low light detection
	5.4 Intelligent Optimization	Intelligent Optimization for IP & WDM path
		Home wifi poor-QoE client analysis and optimization

Source: IDC, 2021

A1.Congestion-Free

A1.1 Fiberization Ratio

Fiber infrastructure has become a key part of national economic development as Gigabit access to the home (on-line schooling), gigabit access to the enterprises (and schools) and Gigabit access for consumers will help bridge the digital divide and enable a Digital Economy to flourish. The EU, for example, recently released Connectivity for a Competitive Digital Single Market-Towards a European Gigabit Society highlighting the strategic importance of fiber infrastructure.

Comms SP's full-service offerings (5G, Cloud and FTTH) need fiber for access and backhauling

At the beginning of 5G construction, network planners focused on the peak rate of the 5G base station because the throughput of the 5G NR base station is 3-15X higher than 4G LTE. But the enhanced bandwidth does come with more complex site location and optimization challenges. As 5G deployments get underway, customers and MNOs now are looking at the SLAs and QoS parameters for 5G, such as latency, jitter, packet loss, etc., Fiber is the ideal transport medium to provide stable bandwidth and ultra-high bandwidth but depending on the maturity and geography of the coverage area other technologies such as E-Band microwave and satellite VSAT are also used in remote areas.

Moreover, Multi-access Edge Computing (MEC), Industrial Internet of Things (IIoT), C-RAN and eCPRI necessarily need to be connected with fiber optic cable. The fronthaul can utilize eCPRI interfaces to support bandwidth as high as 22 Gbps and latencies on the order of 25 µs to 150 µs.

As of the end of 2020, leading comms SPs in China had a 100% network fiberization, while Korea and Japan had a network fiberization ratio >90%. Latin America had a 50% network fiberization, while the Middle East and North Africa were on the order of 20% network fiberization.

A1.2 10GE/25GE per Site

The bandwidth of a wireless site is typically determined by its spectrum bandwidth and spectral efficiency. Also, depending on the co-location of multiple base stations, enterprise data links and FTTH access sites. IDC believes that regardless of the scenario considered in the 2020-2025 timeframe, access sites will need at least 10GE/25GE ports per site and 50GE/100GE ring access points, and 400GE ports at the aggregation/core layer. In addition, IP network traffic path planning needs to be optimized to eliminate unbalanced congestion.

Table A2

5G Cell Site Requirements for transport bandwidth

Parameter	5G Mid-band (C-Band)	5G High-Band (mmWave)
Spectrum resources	3.4GHz-3.5GHz,100MHz bandwidth	28 GHz or higher spectrum, 400/800 MHz bandwidth
Base station Configuration	3 Sectors, 64T64R	3 Cell, 4T4R
The peak value of a single cell	4 Gbps	12 Gbps
The average value of a single cell	0.78 Gbps	2.08 Gbps
The peak value of a single site	5.56 Gbps	16.16 Gbps
The average value of a single site	2.34 Gbps	6.24 Gbps

Table A2

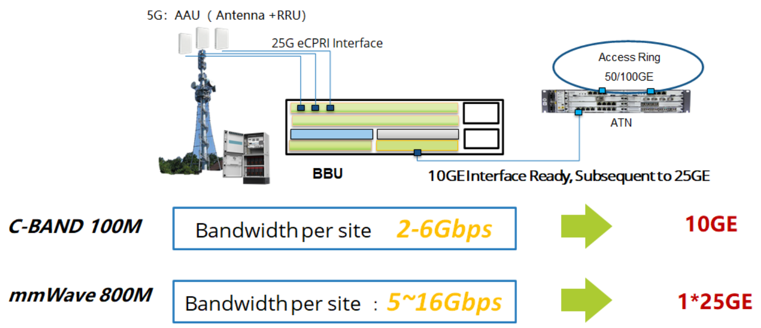
5G Cell Site Requirements for transport bandwidth

Parameter	5G Mid-band (C-Band)	5G High-Band (mmWave)
The peak value of an access ring (8 C-band + 4 mmWave sites per ring)	21.94 Gbps	56.82 Gbps
Peak value of aggregation ring	131.64 Gbps	340.92 Gbps

Source: IDC, 2021

FIGURE A1

Fronthaul and aggregation site bandwidth requirements



10GE per site is a basic requirement; 10GE/25GE per site meets long-term demand

Source: IDC, 2021

A1.3 Giga to Home

Cloud services, ultra-HD video content (4K/8K, 360-degree panoramic view) are becoming mainstream in home broadband. For example, live shopping, VR house viewing, online education and home office are becoming more prevalent in people's lives due to the epidemic.

Video services are typically characterized by ultra-high speed and low latency. For example, the average bitrate of 8K videos is 120 Mbps and the average bitrate of cloud games require 30 ~ 50 Mbps. normally, the traffic burst is 3~5 times the service's bitrate, PON network capacity should be large enough to contain the traffic burst. Therefore, 500 Mbps to 1000 Mbps is a good ballpark bandwidth for the best home user experience when delivering these high-quality services.

Moreover, the OLT platform should be capable of evolving to next-generation technologies, providing Giga home broadband service in high-value/fiercely competitive areas, and providing 500Mbps or 300Mbps home broadband service in suburban/rural areas. The bandwidth planning for OLT uplink must be considered to ensure a good user experience in the busy hour. Each market will see the local Comms SPs offering different data rate packages that might offer 100 Mbps, 300 Mbps, 500 Mbps, and 1000 Mbps.

As the research showing that a leading Comms SP in Asia, 66% of home broadband subscribers were on Gbps plans; in china, the number of Giga home broadband users reached 15 million in June 2021 with a penetration rate of 3% and the penetration rate is planned to reach 30% in 2025.

A1.4 Giga to Room

It is no longer enough to simply offer Gbps services to homes. Coverage of the Wi-Fi signal inside the home is an important factor affecting the home user's experience. According to Comms SPs' statistics, 60% of home broadband service tickets are caused by poor Wi-Fi experience (poor coverage, poor signal, etc.).

- **Comms SPs must improve home Wi-Fi quality.** Comms SPs can adopt Wi-Fi 6 ONTs with 160 MHz bandwidth for small-sized households to meet burst requirements of higher than 2 Gbit/s rates.
- **The Mesh WIFI.** The ONT Mesh Wi-Fi network provides 100 Mbit/s continuous coverage and seamless inter-room roaming for multiple rooms in a home.
- **Indoor optical fiber.** In addition to using Wi-Fi 6 ONTs, mid-range and high-end home broadband users can deploy optical fibers indoors to implement gigabit transmission between multiple APs in a home, preventing the home Wi-Fi network from becoming congested and providing seamless inter-room roaming as well. This solution has been put into large-scale commercial use in China and is called Fiber to The Room (FTTR).

  Wi-Fi6/FTTR is deployed to be deployed in markets around the globe. FTTR pilots have been completed in 30 provinces and cities in China, and FTTRs have been put into commercial use in 10 provinces and cities. It is estimated that 40% of home users will undergo Giga-to-Room reconstruction in the next five years. (With +1 Room, with +2 Rooms or more)

A1.5 OTN to Aggregation/Access

The proliferation and deployment of full-service converged networks will enable more and more new latency-sensitive, high-bandwidth services such as DC interconnection, premium private lines, manufacturing automation, cloud VR, cloud gaming, and 4K\8K HD video services.

OTN will play a central role in reducing the cost of delivery $/Gbps

Site traffic will grow rapidly with Giga home broadband services, 5G deployment, and ToB services. 5G fronthaul, ring protection, and network flattening consume a large number of fiber cores.

To meet the requirements of high bandwidth and massive fiber connection, OTN can save fiber resource and reduce cost per bit while catering to huge traffic volumes, reducing latency.

OTN delivers secure premium lease lines for VIP clients.

In the headquarter-branch interconnection and cloud-connect scenario, E2E OTN (OTN CPE to enterprise) enables physical isolation between end-users with no less than 99.99% link availability. OTN will be used to deliver ultra-low end-to-end latency and low jitter.

OTN can take over the High-value enterprise customers who still use SDH

The core requirements of existing enterprise customers on SDH live networks for private lines are hard isolation, high reliability, and low latency. However, SDH equipment is coming to the end of its life cycle, occupying a large amount of equipment room space and high single-bit power consumption, reducing the competitiveness of carriers' SDH leased line services. SDH networks will evolve to OTN networks, increasing network capacity by at least 100 times, providing millisecond-level ultra-low latency and no less than 99.99% ultra-high reliability.

A1.6 Port Bandwidth Utilization Threshold

Traffic bursts occur on the bearer network. Reducing network utilization can effectively prevent traffic bursts from affecting user experience. According to the IDC's survey, the bandwidth usage of the access/aggregation/core layer is not higher than 50%, so that the network has sufficient bandwidth resources to absorb traffic bursts to avoid affecting user experience.

A1.7 Network Slicing

The networks are evolving to a multi-service integrated bearer.

uRLLC services require guaranteed latency even if the network is congested. For example, a remote emergency service might require 50 Mbps to transmit video images of patients to the hospital. In a traditional network, bandwidth is usually shared and cannot be strictly guaranteed.

Vertical industry customers' operational technology systems are gradually migrating to the cloud but as they do migrate there will be a stringent requirement for deterministic SLAs, high availability, and secure cloud connection service. For example, special applications in industrial control, intelligent manufacturing, Internet of Vehicles (IoV), intelligent transportation and logistics, and other vertical industries require networks to provide an enterprise-to-cloud connection with stable millisecond-level latency and nearly 100% service availability. Traditional IP network is best-effort service forwarding, which cannot meet the new SLA requirements of enterprise core service systems.

3GPP proposes end-to-end slicing to divide a physical network into isolated slices. Therefore the transport network must support dedicated bandwidth slicing so effectively the physical network is divided into multiple slicing private networks. Resources of the slicing private networks are isolated from each other, preventing poor service experience caused by microburst interference between different service flows. Based on the network slicing technology, carriers can provide rich and differentiated SLA connection services for the digital transformation of vertical industries. For example, different slicing networks can provide customized network topologies and differentiated SLA connection services for different industries, such as finance, government, and healthcare, enabling enterprise digitalization, improving enterprise production.

Granular slicing means over time that more industries applications will be supported.

FIGURE A2

Network resource sharing vs network slicing

Source: 3GPP, 2019

A2. Always On

Always on transport networks need to deploy a number of protection mechanisms in both Layer 1 and Layers 2-3. IDC analyzed a number of technologies and selected three indicators under the Always On dimension.

A2.1 Topology: Mesh & Ring

Site and fiber path redundancy are fundamental factors influencing reliability. Core sites need optical cable redundancy to maintain high-reliability service and to avoid single points of failure.

However, network reliability comes at a cost. When the number of network nodes is the same, mesh networking has the highest reliability but the highest cost. Ring networking has high reliability and moderate costs. The smaller the number of nodes on the ring, the fewer services affected by a single node fault, and the higher the network reliability. The chain topology has the lowest reliability. In terms of reliability, mesh networking is superior to small rings, small rings are superior to large rings, and large rings are superior to chains.

Considering reliability and cost, the core layer of the IP network features a few nodes and abundant optical fiber resources. Therefore, one can use mesh networking and spine-and-leaf networking at the aggregation layer. The access layer has many nodes and the optical fiber deployment is challenging with high deployment costs. Therefore, ring networking is generally recommended.

The WDM backbone and metro core layers require a mesh networking with three or more optical cable routes to prevent two or more simultaneous faults as well as to achieve one-hop connections between DCs. The WDM aggregation and access layers need to use ring networking to implement 1+1 protection for all nodes and to add direct links between important nodes on demand.

FIGURE A3

High-reliability transport network topology

Source: IDC, 2021

A2.2 WDM Protection: ASON (Automatically Switched Optical Network)

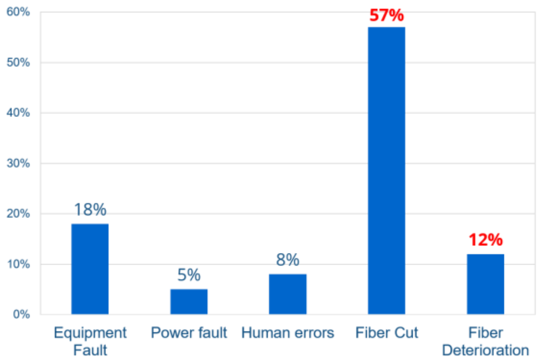
The optical fiber backbone network can be hundreds and thousands of kilometres long and will be vulnerable to natural disasters and roadside municipal construction works. In some Southeast Asian and South Asian countries, the number of fiber cuts per day exceeds 10, and the average fiber cut duration exceeds 8 hours. The availability of optical networks will fall too much lower than 99% in these countries.

ASON protects against multiple fiber cuts, achieving 99.999% WDM availability

5G high-value sites, core backbone sites, and premium private lines for banks, governments, and VIP enterprises require extremely high availability. ASON deploys multiple protection levels (Gold, Silver, and Copper) according to the WDM site's role (type of network layer, region location, and industry use case), to ensure that services are not interrupted when more than two or three fiber cuts occur simultaneously. In this way, the availability can be increased to 99.99% or 99.999%, to prevent triggering IP network protection caused by fiber cuts which leads to IP frequent looping and rerouting.

FIGURE A4

The main cause of optical network faults



Source: Real data for South Pacific Comms SP

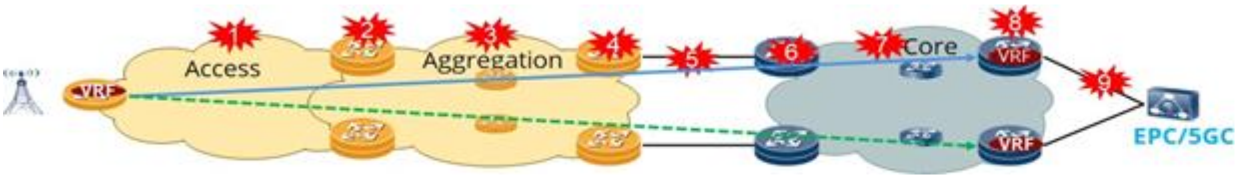
A2.3 IP Protection: FRR/TI-LFA (FRR/Topology Independent Loop Free Alternative)

In cloud implementations, a high-reliability IP network is mandatory for network disaster management and high-available service delivery.

When a network fault occurs, services are quickly switched to the normal path to minimize the impact on services. This is an important indicator of network reliability. At the IP layer, common fault scenarios such as link faults, intermediate node faults, and ingress and tail nodes (dual nodes) need to be considered. In addition, path protection must be topology independent (inter-board) to avoid micro-loops during path switching. Corresponding Protection technologies such as FRR, TI-LFA, etc. can be deployed to implement link-level backup, fault detection, and fast recovery. With pre-set paths redundancy, including the primary service path, backup path, and best-effort path, and the fast fault detection like BFD, IP networks must implement 50ms fast protection failover, to protect ordinary voice and data sessions.

FIGURE A5

20-50 ms fast protection handover upon any node or link failure



Source: IDC, 2021

TI-LFA is a topology-independent and loop-free path switching algorithm that can effectively handle link faults and intermediate-node faults.

A2.4 BRAS Dual-host Hot-standby

The BRAS is an important service gateway node for home broadband services. It is a bridge between the fixed access network and the backbone network. It manages access users, implements value-added services, forwards routes, and aggregates ports. The BRAS functions like the MME/S-GW in the LTE network.

The fault of BRAS will affect a large number of users. One way to improve BRAS reliability is to deploy two BRASs in mutual backup mode:

1, **BRAS cold-backup**: When no-fault occurs, the two BRASs work in load balancing mode. If a BRAS fails, the other BRAS takes over services from the faulty BRAS to minimize the impact on services. Users need to redial and reconnect to the Internet.

2, BRAS Dual-host hot-standby: To further reduce the service interruption time, two BRASs that back up each other can use a dedicated data synchronization mechanism to synchronize and back up their user access information before a fault occurs, the users are not aware of the interruption and still keep online.

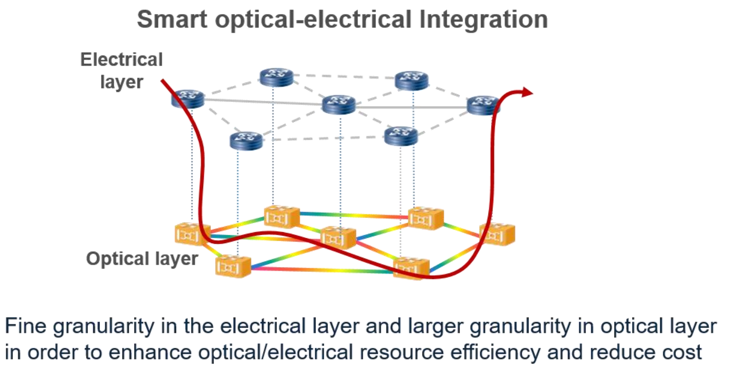
A2.5 IP+Optical Synergy

Integrated planning of IP and WDM and real-time traffic scheduling improve network resource utilization.

In the past, IP and WDM networks were independently planned and maintained at different layers, making it difficult to quickly schedule links based on actual traffic. As a result, the load of WDM links are not balanced. Combined IP and WDM synergistic O&M can be used to solve this problem and improve link utilization.

FIGURE A6

High granularity traffic bypasses the IP network



Source: IDC, 2021

Integrated protection for IP and WDM networks improves service availability

Without integrated protection, the IP and WDM networks are not aware of each other's service priorities. If/when a failure occurs IP & WDM allocate their spare resources separately for recovery, which may result in high-priority services failing. IP+optical synergy uses multi-layer integrated recovery to dynamically plan and protect E2E services. In some scenarios, it can reduce protection costs through flexible combinations.

The IP and WDM multilayer integrated solutions use a unified controller to enable multi-layer link visualization and unified management, and to realize automated service provisioning (the service provisioning period is shortened from weeks to hours), fault diagnosis, fault simulation and risk analysis, simplifying O&M.

A3. Scalable

For future services, whether it be 5G, gigabit home broadband, or cloud-enabled industry networks, carrier networks must be able to support flexible service development.

We need to consider five aspects to build a flexible and scalable network:

1. Fiber infrastructure
2. All-optical as basis
3. Converged IP bearer
4. Optical access network
5. Multi-cloud pre-connection

From the perspective of long-term service development, the network should provide more agile and cost-optimal basic capabilities to help carriers take advantage of service development opportunities in uncertain future environments.

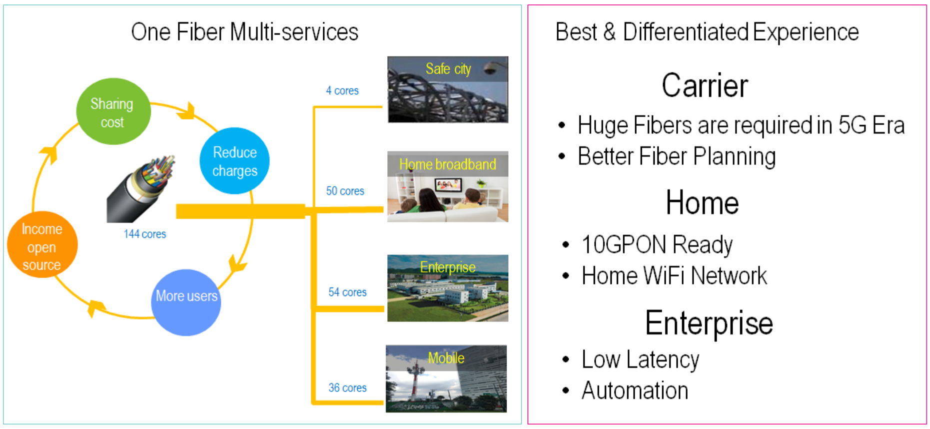
A3.1 Resilient Fiber Infrastructure

Optical fiber is the foundational infrastructure of the entire network. And just as in highway planning, the traffic and congestion on the fiber infrastructure must be optimized and used efficiently.

For full-service access, we need to consider home broadband, enterprise, and mobile services together. The distribution of traffic among high-value users is an important consideration during optical fiber planning.

FIGURE A7

Building the fiber infrastructure



Source: IDC, 2021

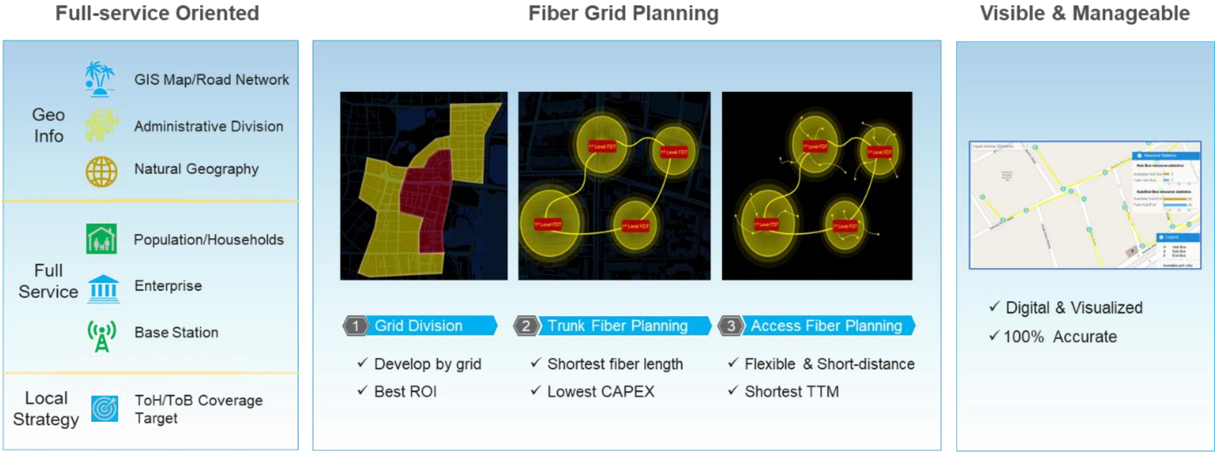
First, we need to divide grids based on the density and number of high-value users. Regions are developed grid by grid from high-priority to low-priority. In this way, network planning, construction, marketing, installation, and maintenance can be centralized within a period to quickly deploy services, achieving optimal ROI.

Then, to plan trunk fiber paths based on the distribution of high-value users in the grid. The shortest trunk fiber covers the most high-value users, minimizing the CAPEX with short construction period.

Finally, to plan fiber access points based on the user heat map, covering more target users with the shortest distance, allowing high-value users to easily access the network, with the shortest TTM.

FIGURE A8

Fiber grid planning for a 20-year life cycle



Source: IDC, 2021

The leading full-service Comms SPs have completed the construction of a unified full-service optical cable network based on the integrated service area. For example, based on the density and distribution of base stations, enterprises, and households in Asia, the coverage area of the integrated service area, the number of optical intersections per grid, and the coverage radius of optical intersections are listed in the table below.

TABLE A3

Fiber Grid Metrics by Comms SP C

Scenario	Grid Coverage Area (km2)	FDT Density (Qty/km2)	FDT Coverage Radius (m)
Dense Urban	< 2	15-Oct	100 - 200
Urban	2~5	10-Jul	150 - 400
Rural & Town	5~10	7-Apr	200 - 500

Source: Real Comms SP C

Fiber Grid Planning can meet the requirements for full-service development in the next 10-20 years with an optimal cost.

In addition, no fiber splicing solution need to be considered. The fiber splicing technology used in the traditional fiber network deployment has disadvantages, such as high skill requirements for construction engineers, no guarantee of splicing quality, long fiber splicing time, and so on. More advanced technologies, such as pre-connection, need to be considered for optical networks.

A3.2 Resilient WDM Platform

DWDM networks are gradually evolving from basic networks to production networks. For example, DWDM networks provide ultra-low latency OTN dedicated networks for industries such as finance, media, and manufacturing. New services, both as a basic network and a production network, have higher requirements on the flexible and on-demand smooth evolution of the DWDM network.

On the other hand, the network traffic increases rapidly but unevenly, It caused partial congestion.

Operators may need to add more channels or build a new DWDM network to address all of the challenges and requirements.

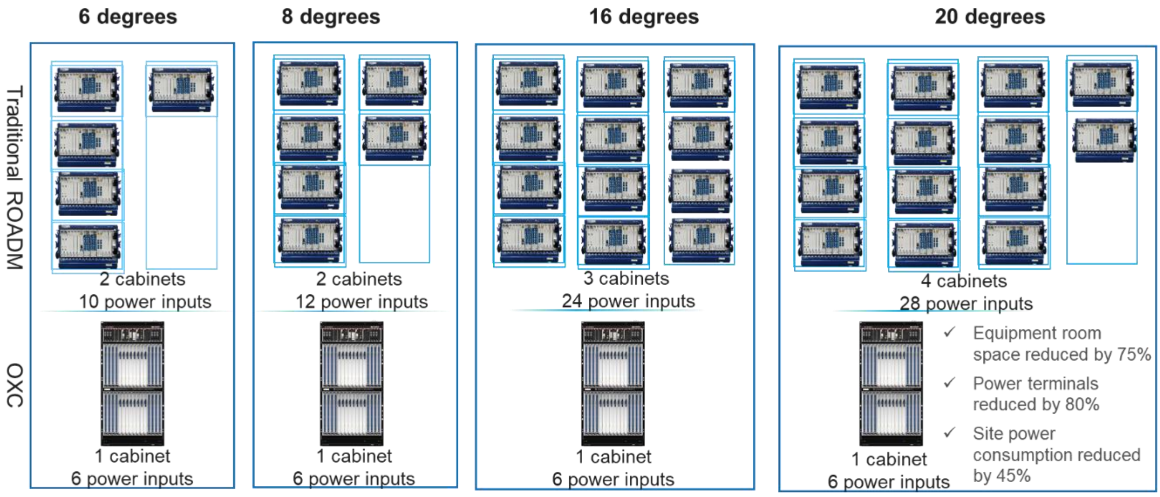
To ensure long-term stability and reduce the total cost of ownership (TCO) while at the same time supporting scalability and the introduction of new and innovative services. IDC notes that an implemented DWDM network with a scalable multi-optical degree and 200G/400G per channel platform should be considered.

Highly integrated OXC reduces equipment room space, power consumption and the number of engineering man-hours.

Advanced OXC adopts a highly integrated all-optical backplane to save fiber jumper cables in sites with high degrees of direction. Compared with traditional ROADM, OXC reduces the equipment footprint by up to 75%, the number of power terminals by 80%, and power consumption by 45%. Moreover, new fiber expansion engineering work can be shortened from weeks to hours. The industry practices show that OXC is necessary for the WDM sites with more than 5 fiber directions and ROADM is suitable for less than 5 fiber directions.

FIGURE A10

OXC can lead to significant DC space savings



Source: IDC, 2021

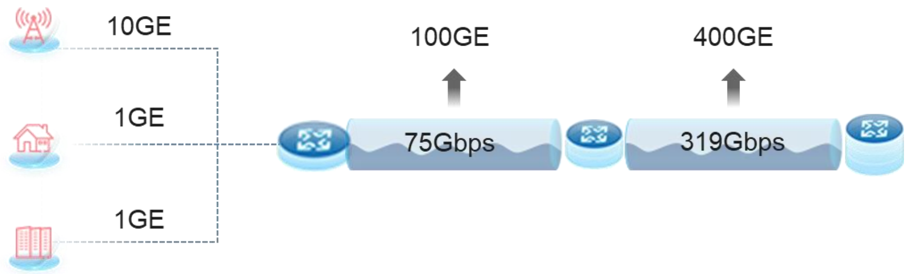
A3.3 Resilient Router Platform

The FMC services require high-bandwidth and low-latency IP network. The network architecture should be scalable both on the capacity and architecture.

The router platform should offer scalability of 10GE/50GE/100GE up to 400GE and consider integrated multi-service capability of SR, BRAS, NAT, IPSec, etc., which can fully meet flexible connection requirements brought by 5G service, home broadband, and cloudification services.

FIGURE A11

Aggregation and backhaul bandwidths



* **Service model of traffic prediction:** 624 base stations + 56K home broadband + 1.3K enterprise@181km^2

Source: IDC, 2021

A3.4 Resilient PON Network

When implementing large-scale FTTH construction, Comms SPs need to consider factors such as user development plan and traffic forecast brought by service development in the next 3 years and plan PON networks based on optimal costs and flexible capacity expansion.

Optimal cost-effective network construction. Based on the number of users covered by each access site and the difficulty in obtaining site resources (backhaul optical fibers and power supply), the CO and the outdoor site is flexibly adopted. In this approach, Comms SPs can maximize base station resource reuse and quickly deploy services for wireless Comms SPs to build fixed networks. For fixed network Comms SPs, when the user density is lower than 1K, the base station site can be used to install PON devices to avoid excessive costs and slow TTM caused by new equipment rooms.

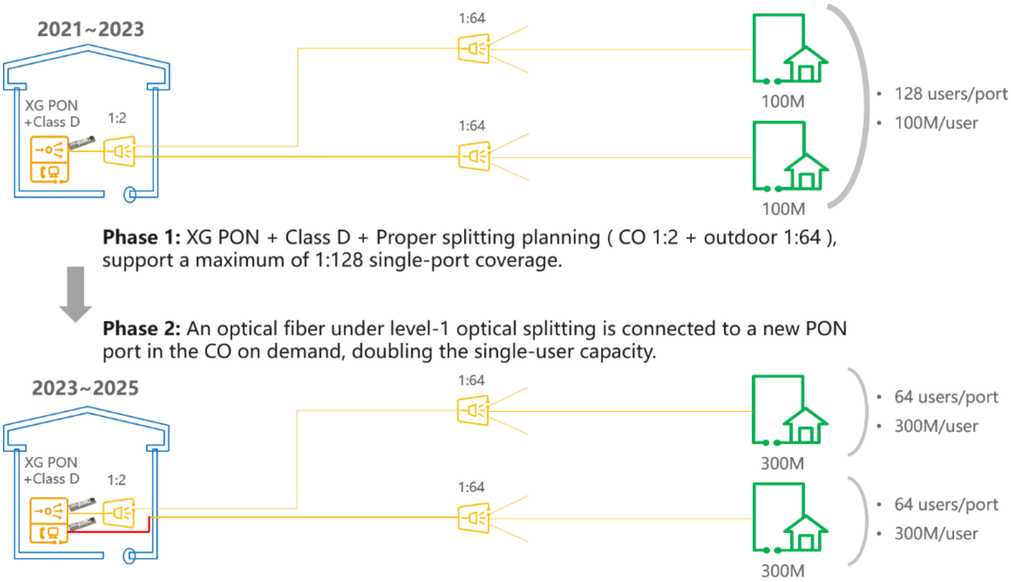
Flexible and elastic capacity expansion. In traditional PON network planning, two-level splitting and 1:64 splitting ratios are used because of the limited optical power attenuation caused by multi-level splitting and large splitting ratios. Compared with the advanced Class D optical module, the large split ratio of 1:128 brings more flexibility to PON network planning.

High-density areas. In densely populated high-value urban areas competition and user demand are driving the requirement for 1:64 optical splitting in the newer networks, and GPON or 10G PON platforms provide flexibility to realize high-bandwidth connectivity.

Medium-density zones. Medium- and lower-value new deployment scenarios are usually located in suburban and rural areas. Users are widely distributed, the density is relatively low, and the traffic requirements are low in the initial stage. Therefore, it is recommended that the 1:128 split ratio based on the ClassD optical module be planned (1:2 for the equipment room and 1:64 for the outdoor). The coverage area can thus be enhanced, the user access capability is improved, and the initial investment is reduced. After the traffic increases, the split ratio is 1:64 as required.

FIGURE A12

XG PON



Source: IDC, 2021

A3.5 Multi-cloud Pre-connection

The emergence of multi-cloud applications in the enterprise space will drive cloud computing into the multi-cloud era. Influenced by multiple factors, such as enterprise digital transformation, cloud services, and national strategies, more and more enterprises, industries, and government agencies are migrating their services to the cloud. As key information technology systems and core production systems are migrated to the cloud, enterprises can deploy multi-cloud disaster recovery and multi-active deployment to improve service reliability and availability.

- Organization cloud strategies continue to evolve, with more workloads being deployed in multi-cloud/hybrid environments, including both public and dedicated infrastructures, as enterprises focus on modernizing applications as well as infrastructures. These hybrid/multi-cloud environments now provide major cloud challenges and opportunities for service providers. The cloud connectivity market grew 33.2% in 2020 and will continue to grow at a CAGR of over 17% to 1.4 billion USD in Asia/Pacific, over the next 5 years. **Different cloud service providers provide different cloud services.** Different systems of enterprises will be deployed on different clouds. Enterprises need agile, on-demand, and one-node access to multiple clouds. The disaster recovery and multi-active deployment of enterprise key information systems and core production systems require agile, ultra-broadband, and elastic multi-cloud connection services to improve the reliability and availability of enterprise core systems.
- **Comms SPs use the cloud backbone network to implement multi-cloud and multi-network pre-connection.** Cloud pools are agilely connected to the cloud backbone network, providing high-reliability connection services for enterprises that can access multi-cloud upon network access. In addition, the TTM can be shortened from months to days.

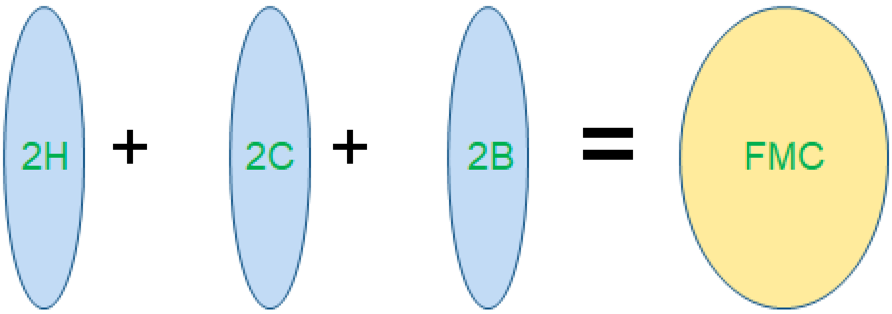
A4. Simplified

A4.1 Converged network for Multi-service

To achieve a higher service and TCO competitive edge, most Comms SPs tend to introduce and offer multi-services to users, as a result, a unified target bearer network to transport mobile, fixed and private line traffic has been well acknowledged. For example, Telefonica has released Fusion strategies to simplify networks and reduce costs in all OpCos.

FIGURE A13

Converged Network



Source: IDC, 2021

The key value propositions of network convergence are as below:

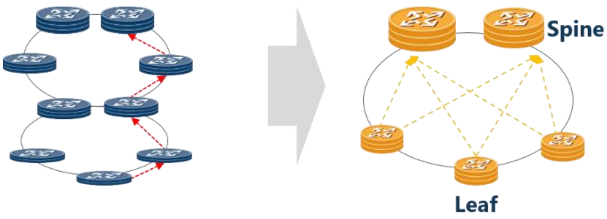
1. One converged target network for all services, instead of several siloed networks.
2. One IP+Optical target network to replace legacy SDH, ATM, L2 LAN switch types.
3. One access network (e.g. GPON) for integrated 2H & 2B access.
4. Simplified technologies, O&M, and staff Competencies.
5. Greener with higher power efficiency.

A4.2 Network Flatness

The traditional ring-based aggregation layer topology is not suitable for heavy-traffic, low-latency services and edge computing. The two-layer Spine-and-Leaf topology reduces network problems caused by bandwidth bottlenecks, load imbalances, packet loss, and high latency due to multi-layer traffic aggregation. Moreover, the complex requirements can be reduced of some spine nodes (leaf nodes are still needed to support FMC (fixed-mobile convergence) and cloud service access.

FIGURE A14

Spine-and-Leaf Topology



Source: IDC, 2021

Spine-and-Leaf supports scaling with zero impact. New nodes can be added, without affecting existing services. This prevents frequent physical architecture adjustment and supports long-term smooth network evolution.

Network flatness evolution from the existing ring/chain topology to the spine-and-leaf topology will take time to implement. Normally, node traffic volume, fiber/WDM resource, and evolution TCO should be considered. Those nodes or rings which have high traffic, especially high bypass traffic, should be chosen as the highest priority ones.

A4.3 Protocol： IPv6+

The IPv6+ technology system is a next-generation intelligent IP technology system oriented to cloud applications and industry interconnection, following the Internet-oriented IPv4 technology system and connection-oriented MPLS technology system.

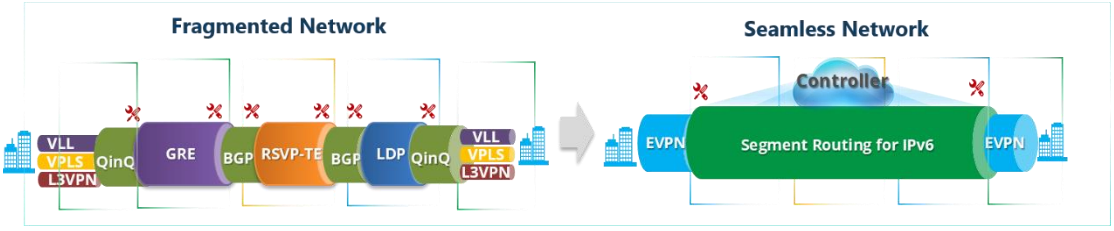
The IPv6+ system has rich technical connotations. SRv6, on-demand detection, new multicast, and APN6 are all components of the IPv6+ architecture. As both the Linux kernel and the network already support SRv6, which greatly facilitates the creation of end-to-end connections between servers. SRv6 can seamlessly connect the cloud and network, providing unlimited possibilities for cloud-network synergy. Therefore, SRv6 is an enabling protocol for cloud-network synergy.

SRv6 replaces various IP/MPLS Protocols and facilitates service agility

SRv6 can reduce the number of protocols running on IP/MPLS networks, simplifying O&M complexity. With SDN controller, SRv6 can support optimal paths, fast re-routing, global resource predictability, traffic path optimization in large-scale networks, and in addition, SRv6 simplifies the control plane, lowers requirements on routers, decoupling VPN and tunnels to facilitate flexible IP network extension.

FIGURE A15

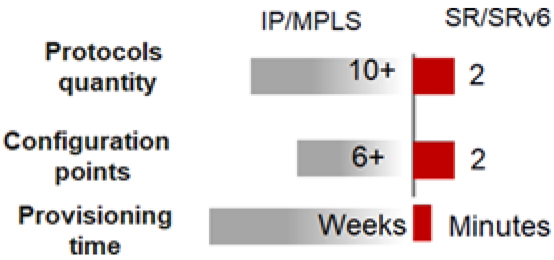
SRv6 with EVPN vs various protocols with fragmented VPN



Source: IDC, 2021

FIGURE A16

Comparison of service provisioning time needed for IP/MPLS vs SR



Source: IDC, 2021

SRv6 is well suited for large-scale and cloud deployments

As long as the intermediate network is IPv6-ready, large scale VPN services can be rapidly deployed seamlessly and with agility to support 5G and IoT services. SRv6 enables application-oriented programming and supports E2E VPN deployment from the access site to the data center IT backend and to external clouds.

EVPN unifies transport of different L2VPN and L3VPN Services and simplifies O&M

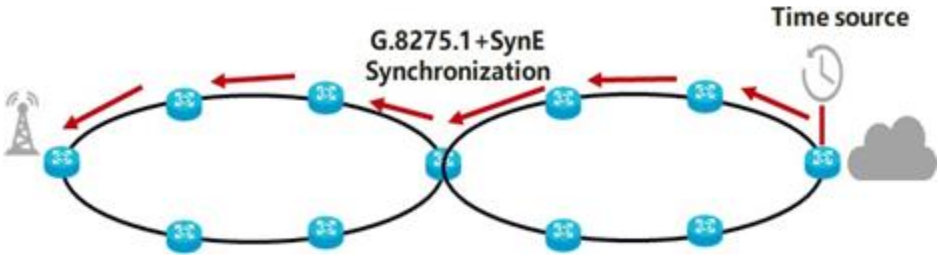
EVPN (Ethernet VPN) carries traditional E-Line, E-LAN, E-Tree, and L3VPN services in a unified manner and has the additional benefit of simplifying O&M.

A4.4 Precise Time Sync(G.8275.1)

The synchronization precision between 5G TDD NR gNodeBs must be less than 3 us. Since GPS signal acquisition is difficult in some locations such as deep indoor or basement, ITU-T G.8275.1 + SynE carried via fiber is regarded as a good option. The synchronization precision needs to be less than 20 ns per hop, even less than 10 ns per hop in some scenarios like high-precision positioning. To improve time and clock synchronization O&M efficiency, automatic planning, provisioning, and fault locating is also critical.

FIGURE A17

Hop-to-hop high-precision time synchronization



Source: IDC, 2021

A5. Intelligent

A5.1 Open API for NBI/SBI

Network Openness is an important trend in the telecom industry. The core requirement is an open architecture that requires northbound OSS interconnection and southbound multi-vendor IP network management.

Firstly, the NBI programmability could be used to orchestrate atomic APIs into scenario APIs, simplify interface parameters, reduce OSS development workload, and reduce overall system integration time and cost. Secondly, the driver adaptation of third-party devices is developed through southbound interfaces to implement unified management of multi-vendor and segmented devices. By defining service scenarios, the E2E automatic configuration and management of services could be implemented.

Comms SPs have begun to improve network automation and intelligence through open APIs. Swisscom home broadband services are upgraded from existing copper lines to FTTH networks, and northbound APIs are used to adapt to existing OSS. The integration time is reduced from 9 months to 3 months. Austria H3A developed multi-vendor device drivers to combine two IP networks, manage multi-vendor devices in a unified manner, and implement end-to-end provisioning across vendors.

A5.2 Auto Provisioning

Automatic deployment is to streamline IT systems such as BSS, OSS, and EMS, orchestrate access-side device provisioning and service provisioning processes and implement site automation and service provisioning automation. It is often used for 5G bearer CSG rollout, fast private line service provisioning, and on-demand agile bandwidth adjustment to achieve fast TTM.

1) **CSGs/CPEs automatic online**: Planning network parameters in advance, CSGs/CPEs are automatically detected and managed based on the preset configuration process. In this way, CSGs/CPEs can be deployed within minutes or hours after only a one-time site visit.

2) **Automatic service provisioning**: After streamlined the provisioning process from the unified portal to the EMS, the SLA-based routing provisioning could be implemented. For example, in a cloud-network scenario, the multi-cloud pre-connection-based IT system can implement automatic resource check, multiple SLA-constraint paths calculation, and automatic service provisioning and acceptance, etc.

3) **BOD**: Through Open APIs, devices and parameters could be applied to customers' self-service APPs, to implement network visualization, self-service fault reporting, and on-demand bandwidth adjustment.

4) **Network slicing**: Based on one physical network, network slices could be created within minutes via one-click automatic planning and deployment. In addition, visualized O&M, differentiated network planes and deterministic SLA capabilities are implemented for industry users.

In the large-scale deployment scenarios of 5G bearing and OTN private lines, such as in China Mobile, the automatic deployment capability has been put into commercial use.

Auto ODN registration & topology display

FTTH construction and fiber-based reconstruction of existing copper lines have led to the construction of a large number of ODN networks. The requirements for reducing E2E costs, rapidly constructing networks to seize the market, and reducing OPEX are strong.

Fiber pre-linking (fiber splicing-free) and app scanning for digital bar codes of ODN components and pigtails enable fast ODN network construction, automatic and accurate resource recording, and fast FTTH service provisioning.

ODN Sense (such as optical iris) accurately restores the ODN topology and displays the ODN topology in real time on the cloud management platform, making resources visible and manageable. When an ODN fault occurs, the fault can be demarcated within minutes and the fault can be located within meters.

In the Latin America broadband fiber construction market, the digital ODN provisioning technology effectively reduced ODN construction and O&M costs and achieved large-scale application.

A5.3 Predictive Maintenance

In the past, most maintenance methods are passive responses. When a fault occurs, the response process is driven by the NMS fault alarms or the customer complaints. In addition, there is no effective method to demarcate and locate faults. The fault usually takes hours or even days due to the experience of O&M engineer.

Now, differentiated network KPIs (bandwidth, latency, etc.) have become the new network monetization methods. Comms SPs need a proactive approach to be aware of network KPIs in real-time and predict network faults that may arise. In this approach, Comms SPs can resolve problems before customer complaints are received.

Implementing real-time network KPIs awareness and efficient collection.

The in-flow, high accuracy, real-time and E2E/Hop-by-hop O&M technologies are preferred to detect the network KPI data in seconds-level accuracy. The standardized telemetry protocols can be used to automatically and efficiently collect massive network KPI data at a minutes-level and send it to an analysis system to demarcate and locate network KPI problems at the minutes-level.

Predict network faults.

AI and big data technologies are used in networks to analyze abnormalities of massive network indicators, accurately detect potential network risks, and automatically recommend high-risk levels for handling. E.g. the fault Root Cause Analysis technology can intelligently aggregate massive alarms to reduce invalid work orders.

Predictive maintenance of fiber network.

Optical parameter modelling and analysis of OTN and PON devices are used to establish a fiber deterioration feature database to identify optical line deterioration, repair optical lines in advance, and eliminate service security risks.

A5.4 Intelligent optimization

In a private line scenario, Comms SPs may face complaints and fines due to SLA deterioration. Manual post-event adjustments often take hours or days. Intelligent optimization can detect service SLA deterioration in real-time and trigger network resource re-optimization when the threshold is exceeded to ensure service SLA.

An Comms SP in the EMEA implemented the intelligent optimization function to optimize the traffic path, SLAs of base station and private line services in the integrated bearer network automatically.

Wi-Fi experience is mainly affected by interference, roaming & configuration issues. A common method for handling these issues is door-to-door service, but this is inefficient and costly.

Home Wi-Fi parameter optimization can be used to reduce unnecessary door-to-door visits. When a home terminal roams in different rooms or multiple APs interfere with each other, the multi-beam antenna of a Wi-Fi6 home terminal can be used to move with the user. The cloud Wi-Fi management platform can automatically optimize home Wi-Fi interference, roaming, and configuration problems.

A Comms SP in the EMEA used a SaaS-based home Wi-Fi management platform to optimize their home Wi-Fi experience.

GLOSSARY

Term/Acronym	Meaning
KAI	Key Architecture Index
5G NR	5G New Radio
ASON	Automatically Switched Optical Network
BSS	Business Support System
DWDM	Dense Wave Division Multiplex
DU	Distributed Unit
CU	Centralized Unit
EPC	Evolved Packet Core
EVPN	Ethernet VPN
FRR	Fast Re-Route
ITU-T	International Telecommunication Union-Telecommunication Standardization
mMIMO	Massive MIMO
MIMO	Multiple Input Multiple Output
mmWave	24-100 GHz millimeter wavelength
MTC	Machine Type Communications
NFV	Network Function Virtualization

Term/Acronym	Meaning
NSA	Non-Standalone
OSS	Operational Support System
OTN	Optical Transport Network
OXC	Optical Cross Connect
PCEP	Path Computation Element Protocol
ROADM	Re-configurable Add Drop Multiplexer
RSVP-TE	Resource Reservation Protocol – Traffic Engineering
SDN	Software Defined Networking
SR	Segment Routing
TI-LFA	Topology Independent Loop Free Alternative
URLLC	Ultra-Reliable Low Latency Communications
WDM	Wave Division Multiple Access

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