Transport Network Architecture Index in 5G and Cloud Era

IDC White Paper

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White Paper

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Sponsored by: Huawei Technologies

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EXECUTIVE SUMMARY

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

Over the next ten years, a combination of DX technologies (5G, IOT and AI) and Cloud are forecast to significantly impact all industries. 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.

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

Capable Transport networks enable next-generation service delivery

Existing transport networks have evolved gradually to handle the transition from 3G to 4G. This incremental approach leads to accumulating performance bottlenecks and risks in each layer of the network topology. These bottlenecks introduce challenges to realizing the promise of high-speed networks as offered by 5G.

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

KAI (Key Architecture Index) is an indexed transport model in 5G and Cloud era

In enabling an optimal transport network, IDC proposes a holistic index model measuring five dimensions of transport networks - **Congestion-free**, **Scalable**, **Simplified**, **Always on** and **Intelligent**. Each of these dimensions is evaluated across all layers of the transport network: physical optical cable layer, IP and DWDM layer, the manager/controller/analyzer layer.

The KAI model categorizes network factors as constants (difficult to change) which have long-term impact 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 & Cloud, assuring the network quality from early stage of design and planning while systematically reducing TCO.

Optimize network planning through KAIs

Throughout the network lifecycle, KAIs are used to accurately quantify, manage, and control key network factors. Operators examples from PLDT and Chinese operators illustrate best practices around the application of architecture indexes to the development of transport networks to support DX technologies.

TRANSPORT NETWORK CHALLENGES

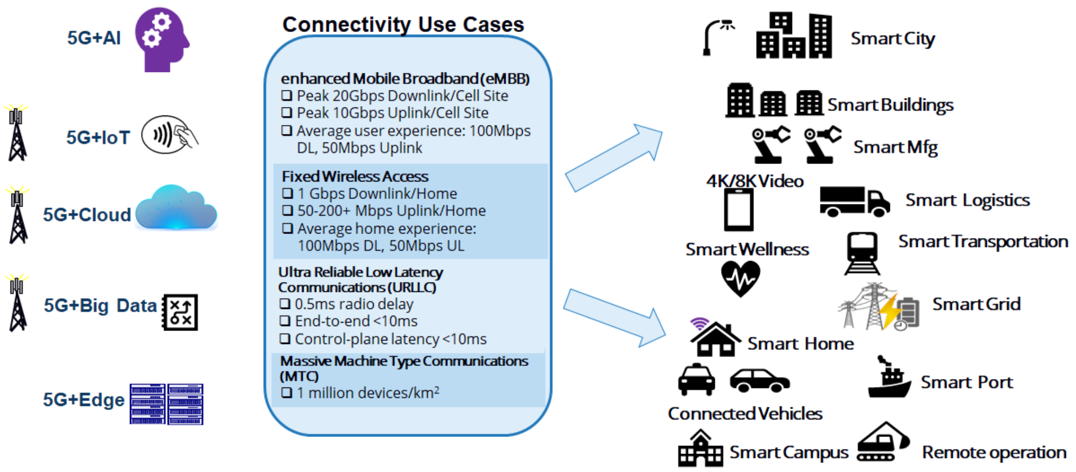
The top 4 for challenges for telecommunication operators are: surging traffic volume & the number of connections, flat revenue, rising OpEx and rising CapEx. IDC forecasts, for example, that IoT cellular connections will grow by 30% in APeJ (Asia Pacific excluding Japan) while cellular traffic will increase by 122% as HD/4K video IoT use cases evolve. Meanwhile cellular revenues will only grow by 2%.

New Services Bring Unprecedented Challenges and Business Opportunities

In the 5G and cloud era, Internet of Things, DX of all industries, and cloud migration of services will invariably generate hundreds of millions of new consumer and enterprise connections, driving more than 10 times bandwidth growth and highly stringent service assurance requirements. There will be tremendous business opportunities for telecom operators, but it is imperative that operators build transport networks that can support future service demands.

FIGURE 1

5G+cloud+AI+ecosystem accelerating the upgrade of a wide range of businesses and sectors



Source: IDC, 2020

5G User Experience and New Services Pose Higher Quality Requirements

Consumer mobile: The rise of 5G, Internet of Vehicles (IoV) and Industrial Internet

5G deployment began in some countries in 2019 and early data is indicating that over 20% traffic is due to low latency AR/VR services. 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 operators as they seek to maintain and enhance customer experience especially for low-latency use cases such as remote navigation control which requires a latency of less than 3ms.

Enterprise: 5G/Cloud services will be pervasive with stringent SLAs

'Cloud-first' strategy, IOT business and DX continues to drive the creation of innovative business models, giving momentum for the development of enterprise's data centers especially regional and edge DCs. The growth of east-west traffic between these DCs changes the legacy 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.

Home: A plethora of 12K VR/AR, 8K UHD video, and new smart home services

Home video streaming is evolving toward UHD, instantaneous experience, interactive feedback, real-time perception, and self-generated media content. From 2019-21, 8K VR videos have been put into large-scale commercial use in South Korea and Europe. In 3-7 years, Home VR will become the next-generation TV, covering VR live broadcast, IMAX cinemas, gaming, education, and shopping. Massive and high definition VR/AR (e.g.12K) services need to be carried by FTTH (Fiber-to-the-Home) at consumer-friendly service plans. The commercialization of WiFi6 will drive the push for both gigabit bandwidth and more home connections (smartphones, tablets, PCs, and home IoT devices).

Cloud: Edge computing enters the IaaS and PaaS foray

In the 5G and cloud era, cloud computing, big data, and AI will be integrated to implement intelligent upgrade of businesses and industries. 5G UPF (user plane function) and the cloud moves data processing from the central DCs to the edge to minimize latency, which is critical for industrial deployments with real-time processing and time-sensitive mission-critical decisions. IDC predicts that by 2024 over 75% of infrastructure in edge locations will be consumed/operated via an as-a-service model. Telecommunication operator's transport networks will be needed to ready for any new DCs set-up by providing DCI (Datacenter Interconnect).

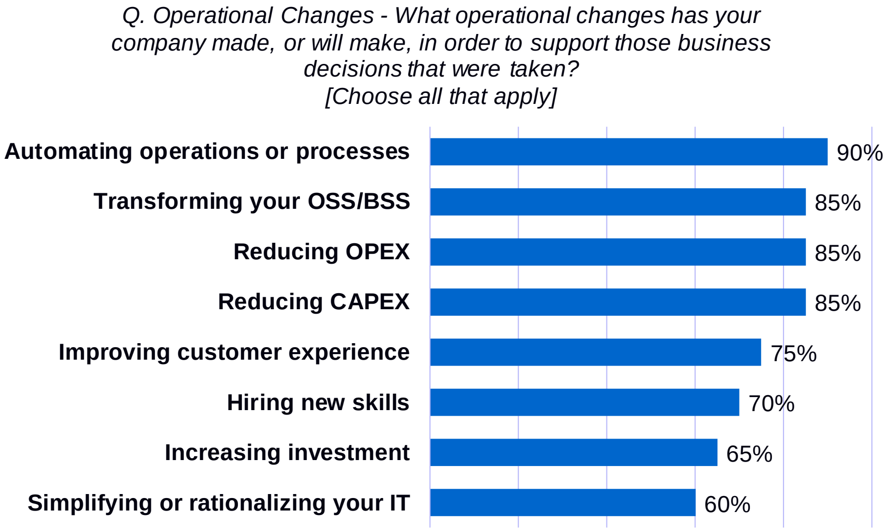
The number of NEs will grow rapidly causing more O&M complexity

5G access and broadband fixed access (10GPON) will drive the numbers of wireless base stations, core network NEs (Network Elements), and application connections increase significantly. Various use cases require differentiated SLAs. All those present new challenges to transport network O&M. According to statistics from operators, the average OpEx percentage of the telecom industry exceeds 70% annually from 2010 to 2019, posing a huge challenge to O&M costs.

The IDC 2019 Carrier Transformation Survey confirmed that Automation, OSS/BSS transformation, reducing OpEx, reducing CapEx, and improving customer experience are the top 5 priorities.

FIGURE 2

Operational challenges for telecommunication operators



Source: IDC 2019 APeJ Carrier Transformation Survey (N=200)

STRATEGIES FOR RE-ARCHITECTING THE TRANSPORT NETWORK FOR 5G/CLOUD

There is a technology gap between 4G and what 5G and Cloud require in terms of capacity, topology complexity, and fiber cable protection over the past decade due to patching and stacking of sites. Telecom operators need to adopt some proactive strategies for entire network life cycle including planning, construction, and maintaining with the objective to improve network quality of experience, scalability, resilience, simplifying the network and reducing O&M complexity.

Build congestion-free network

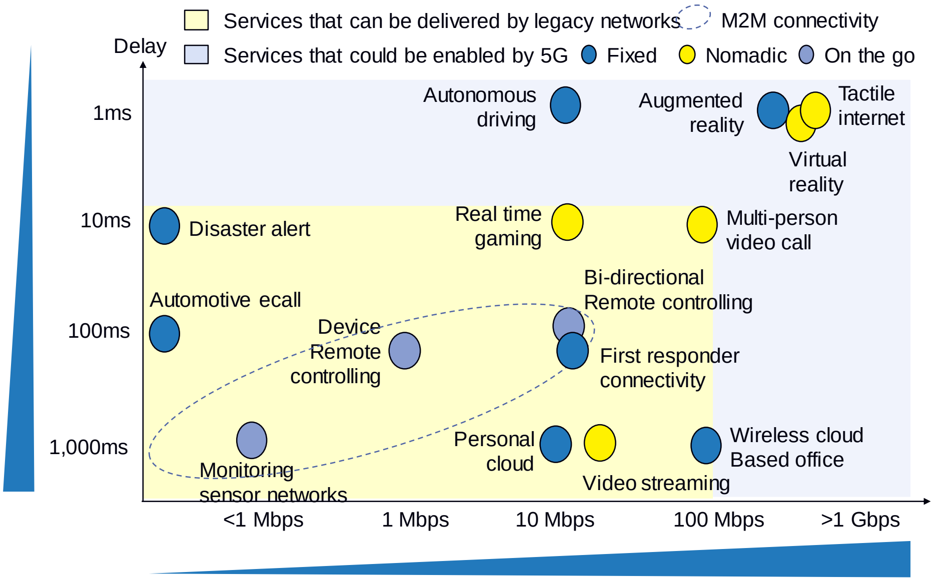
Congestion-free must be a key objective for the target transport network. The more congested the network is, the lower the quality of customer experience. As an example, latencies for Cloud VR video services will be adversely affected by increase of network traffic at different transmission rates. Operators need congestion-free to ensure high-reliability, low-latency, ubiquitous connectivity for new vertical industries. Congestion-free also becomes competitive differentiation when entering into SLAs with enterprises and industrial companies. In order to address congestion, it will be necessary to replace as many microwave links as possible with IP network and to optimize current IP traffic paths over fiber access.

Adopt scalable architecture

Global traffic growth could reach as high as 35+% with the proliferation of high-resolution self-generated media content, UHD video streaming, industry video use cases, and VR/AR by 2023. Therefore, to protect investment, the transport network must be able to seamlessly expand bandwidth with same platform while carrying increasingly heavy traffic. SLA requirements for new businesses and applications pose great challenges to transport flexibility.

FIGURE 3

Differentiated network requirements of new businesses



Source: GSMA Intelligence

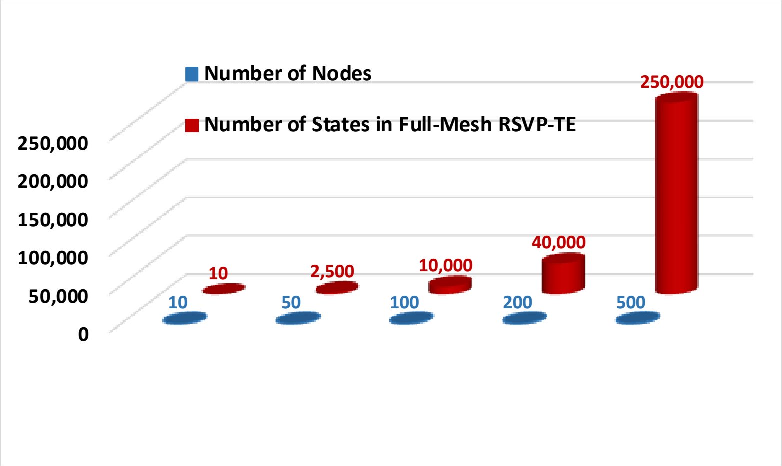
Simplify the IP protocol architecture

There are currently too many IP protocol types in today's IP/MPLS networks, the control plane path is complex, and the ability for the network to scale is limited. Moreover, bandwidth assurance and load balancing are not well supported due to the lack of central control which makes it virtually impossible to handle the increasing workloads and massive number of future connected devices. Segment Routing is a crucial technology to simplify routing protocols, router complexity and O&M challenges.

The low latency requirements demand accurate latency control in the routing protocol in addition to a flattened architecture. To support service innovation, the transport network also needs to support flexible service programming, network slicing, and cloud-centric network adjustment.

FIGURE 4

IP/MPLS labels per router increase as the square of the number of nodes



Source: IDC, 2020

Implement Always on (high resilience) to support cloud-centric applications/services

IDC predicts that by 2024, 50% of the Global 2000 organization surveyed have mastered "future of culture" needed to execute DX strategy, which drives society severe Internet dependency and higher network resilience. According to the 2019 Digital Trends Report released by the Alibaba Cloud Research Center, China's digitalization is expanding from the Internet to industries such as government, finance, retail, agriculture, industry, transportation, logistics, and healthcare. IDC predicts that by 2020, 50% of the world's top Global 2000 enterprises will have their key services digitalized.

Table 1

High Network Reliability Use Cases and Requirements

Industry Vertical	Use Case	E2E latency	Jitter	Reliability
Automotive	Coordinated control - platooning	<3 ms	1 ms	99.9999%
VR/AR	VR Critical Applications (remote motion control - surgery, drone)	10-20 ms	5 ms	99.9999%
Smart Grid	Transmission/grid backbone (Electricity distribution - high voltage)	<5 ms	1 ms	99.9999%
Factory	Process automation (chemicals, paper, gas and oil) - remote control	50 ms	20 ms	99.9999%
Health	Real-time command and control for remote surgery	10 ms	1 ms	99.9999%
Smart Cities	Remote drone operation (delivery surveillance)	10-30 ms	1 ms	99.9999%

Source: 3GPP, NGMN, 2019

Adopt Automated and Intelligent O&M operation to reduce complexity

In order to continuously deal with complexity challenges, network O&M needs to evolve towards platform-based, automated and proactive O&M with AI and Analytics. The SDN controller platform is introduced to automate and manage the lifecycle of the entire network across all layers and areas. On a typical large-scale telecom network, millions of fault-alarms are triggered every day. AI-based software can be used to reduce the number of alarms and faults on telecom networks by up to 90%. The effect is that troubleshooting becomes much more efficient and maintenance costs will decrease.

BUILDING THE TRANSPORT NETWORK ARCHITECTURE FOR 5G AND CLOUD ERA

Transport Network Architecture comprises 4 layers

Orchestration, fiber coverage, bandwidth availability and protection must be done holistically. The transport network for the next decade will need to adopt four layers as follows:

Centralized manager/Controller/Analyzer: SDN-based, complete life-cycle O&M and multi-layer synergy, AI.

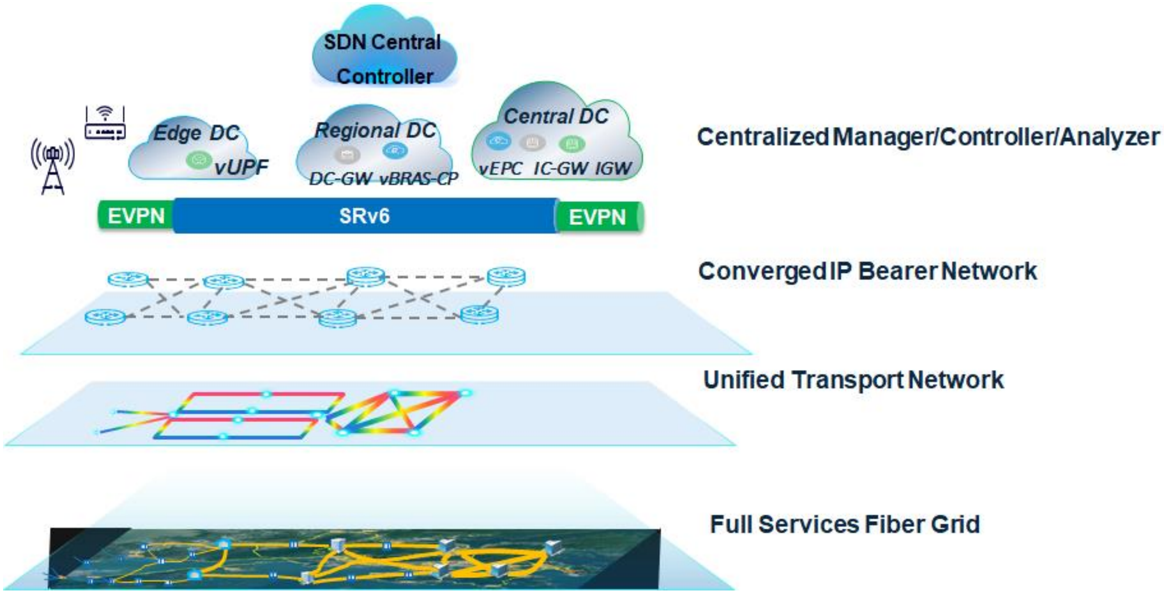
Converged IP network: Simplified IP enabled by E2E SRv6/Metro Spine-Leaf, Seamless WAN & Cloud.

Unified Optical Transport network: OTN network layer with ASON protection to optimize cost per bit.

Full-service fiber grid: Unified fiber grid network for all services, including FTTH/2B/4G/5G

FIGURE 5

The transport architecture encompasses four key layers



Source: IDC, 2020

KAI: Indexed Target Network Model

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 17 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.

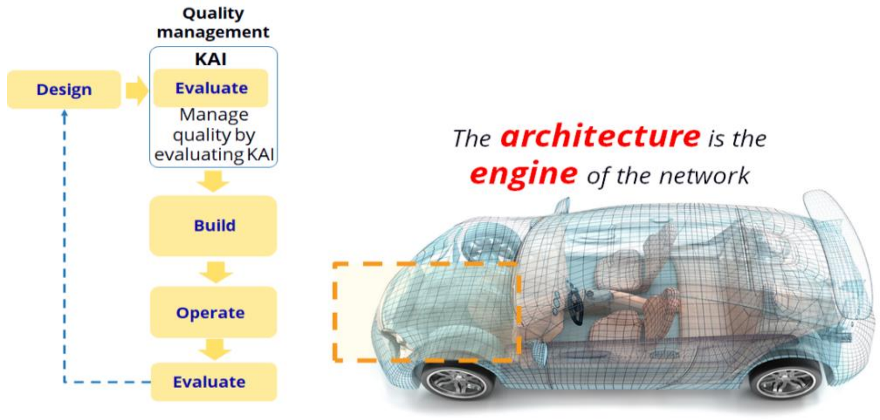
The KAI model determines the transport network quality and cost, facilitating network construction and management.

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. The successful practices of PLDT (Philippines) and operators in China show that the KAI model plays a significant role in guiding the construction of the future target transport network.

FIGURE 6

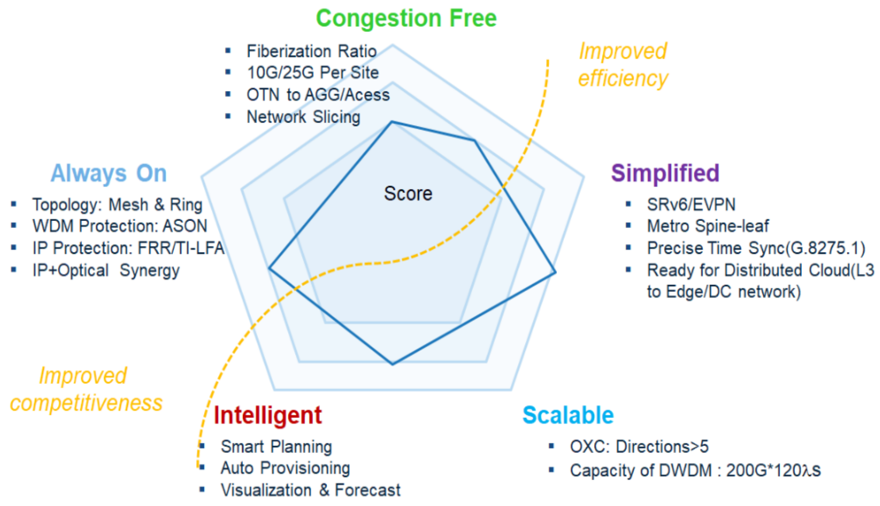
The architecture determines the ability



Source: IDC, 2020

FIGURE 7

KAI network model (5 dimensions with 17 indexes)



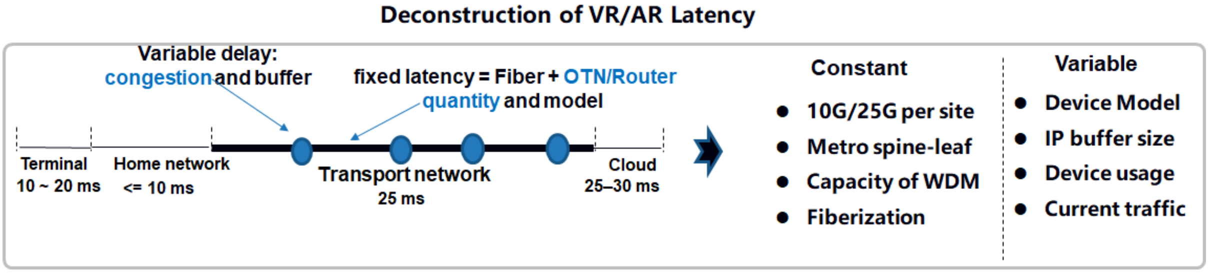
Source: IDC, 2020

Standardization: KAI is built by deconstructing KQIs (Operators' offering)

By deconstructing KPIs/KQIs from operators' 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 8

Example of deconstruction of Latency KQI into the relevant KAIs



Source: IDC, 2020

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.

Scoring & Weighting: setting criteria for overall capability evaluation

The index weights can be set based on the importance of indicators. Example: the most important is 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 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.

DETAILED INDEXES AND TECHNICAL IMPLICATIONS

Congestion-Free

Fiberization Ratio

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

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

The throughput of 5G NR base station is 3-15X higher than 4G LTE with more complex site location and optimization challenges. Moreover, Mutli-access Edge Computing (MEC), Industrial Internet of Things (IIoT), C-RAN and eCPRI necessarily need fiber access. eCPRI interfaces support bandwidth as high as 22 Gbps and require a latency ranging from 25 µs to 150 µs.

As of end of 2019, leading operators in Korea and Japan had a network fiberization ratio >90%.

10GE/25GE Per Site

The bandwidth of a wireless site is typically determined by its spectrum bandwidth and spectral efficiency. Also, depending on co-location of multiple base stations, enterprise data links and FTTH access sites. IDC believes that regardless of the scenario considered in the 2020-2023 timeframe, access sites will need at least 10GE/25GE ports per site and 50GE/100GE ring access points, and 400GE ports at aggregation/core layer. In addition, IP network traffic path planning needs to be optimized to eliminate unbalanced congestion.

TABLE 2

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
Peak value of a single cell	4 Gbps	12 Gbps
Average value of a single cell	0.78 Gbps	2.08 Gbps
Peak value of a single site	5.56 Gbps	16.16 Gbps
Average value of single site	2.34 Gbps	6.24 Gbps
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, 2019

OTN to Aggregation/Access

With the evolution to all-cloud converged networks, more and more new latency sensitive services such as manufacturer automation, and Cloud VR will come to market.

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

Site traffic will grow rapidly with 5G/10GPON deployments. OTN can be constructed to reduce cost per bit while catering to huge traffic volumes and reducing latency.

OTN delivers secure premium lease lines for VIP clients (Banks & Govt. etc).

OTN enables physical isolation between end users with no less than 99.99% link availability and OTN will deliver ultra-low end-to-end latency and low jitter.

OTN can save fiber resources.

Full services, 5G fronthaul, multiple wireless networks (2G/3G/4G), ring protection, and network flattening consume a large number of fiber cores which necessitate OTN to be deployed.

Network Slicing

Some uRLLC services may require guaranteed bandwidth even if the network is congested. For example, remote emergency service requires 50 Mbps to transmit video images of patients to the hospital. In a traditional network, bandwidth is usually shared and cannot be strictly guaranteed. Therefore, 3GPP proposes end-to-end slicing to divide a physical network into isolated slices. The transport network therefore must support dedicated bandwidth slicing. Granular slicing means that more industries applications can be supported.

FIGURE 9

Network resource sharing vs network slicing

Source: 3GPP, 2019

Scalable

The WDM network must ensure long-term stability, reduce the total cost of ownership (TCO) while at the same time supporting scalability, and the introduction of new and innovative services. A well implemented WDM network must be scalable in terms of bandwidth, site and optical degree, supporting diversified expansion scenarios.

Optical Cross-Connect (OXC): Directions > 5

Datacenter Interconnect (DCI) and 3D backbone require multiple fiber directions per site

In order to reduce the network latency, the transport network needs to be flattened by establishing direct fiber/wavelength connections between nonadjacent sites. In addition, WDM sites and new edge computing sites with high network workloads can be virtually connected via a new plane.

FIGURE 10

Flattened network between A-B   A new plane connecting A and B

Mesh
One-hop connection for high-quality services with new fiber directions

3D
Smooth reconstruction of existing networks, new 200G technologies, doubled bandwidth, and fast traffic grooming

Source: IDC, 2020

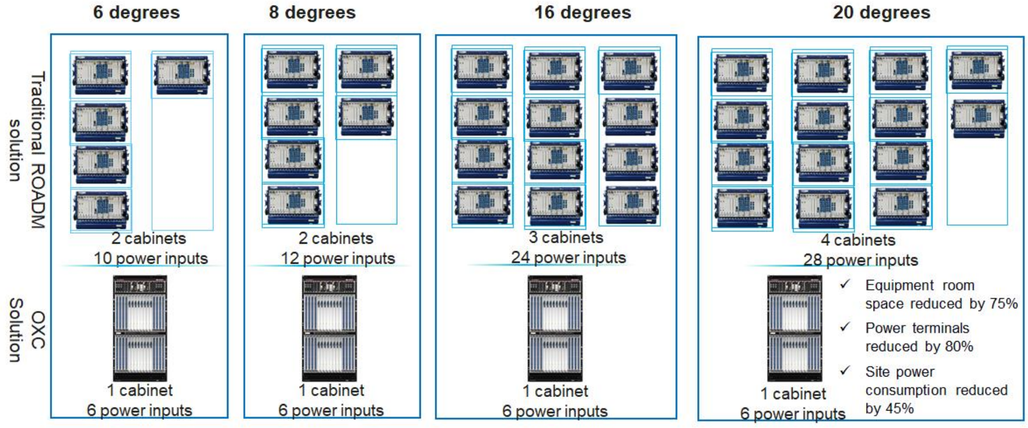
Highly integrated OXC reduces equipment room space, power consumption and the amount of engineering man-hours

Advanced OXC adopts a highly integrated all-optical backplane to save fiber jumper cables in sites with high degrees of directions. 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 current best practices suggest that OXC will be necessary for WDM sites to have >5 fiber directions, and that ROADM is suitable for less than 5 directions.

Note: the IP scalability includes metro Spine-Leaf topologies, segment routing (SR) protocol, and DC network's Scale-out is the Simplified part.

FIGURE 11

OXC solutions can lead to significant DC space savings



Source: IDC, 2020

*Capacity of DWDM: 200G*120λs*

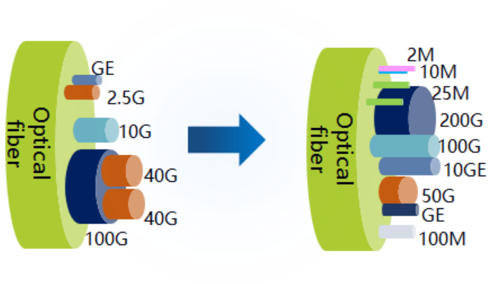
One of the best ways to contain CapEx in the transport network is to utilize solutions that maximize the Gbps/cable because physical fiber construction is costly. The cost of laying optical fibers (including trenching costs) can accounts for at least 50% of the total cost of a WDM network. the current best practice in the industry for increasing fiber capacity is to deploy 120 λs on a single fiber core with a capacity of 200 Gbps/ λ.

Deploy finer ODU granularity to improve bandwidth utilization

As premium private (MPLS, VPN) lines are gradually migrated to WDM network, traditional high capacity ODUk (ODU0/ODU1/ODU2/ODU4) have caused resources to often be wasted. For example, if a 150 Mbps private line uses traditional ODU0 (1.244 Gbps), the capacity utilization can be less than 15%. Therefore, OTN with flexible ODUk ranges from 2 Mbit/s to 200 Gbit/s, at increments of 2 Mbps, improving the wavelength utilization to nearly 100%.

FIGURE 12

Traditional WDM vs OTN with grooming



Source: IDC, 2020

Simplified

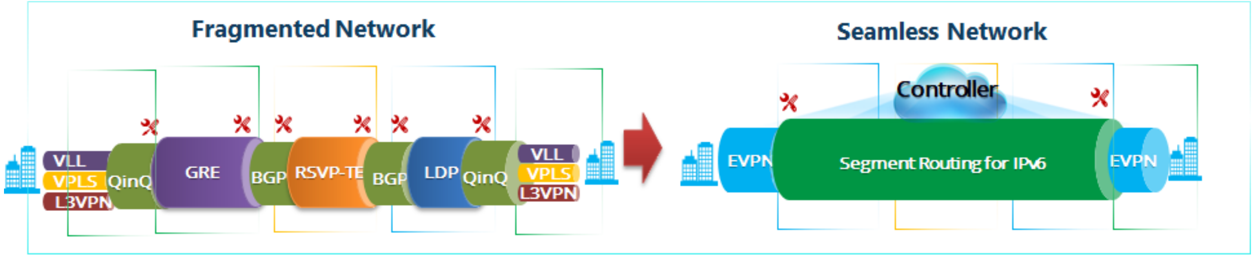
Segment Routing IPv6 (SRv6)/EVPN

SR replaces various IP/MPLS Protocols and facilitates service agility

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

FIGURE 13

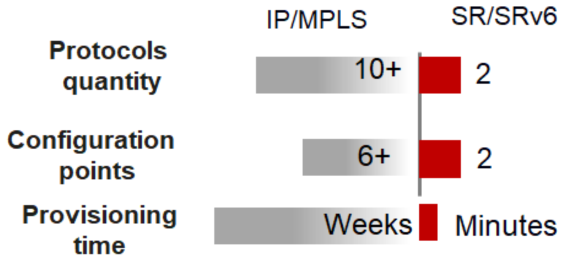
SRv6 with EVPN VS various protocols with fragmented VPN



Source: IDC, 2020

FIGURE 14

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



Source: IDC, 2020

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 with agility to support future 5G and IoT services. SRv6 enables application-oriented programming and supports E2E VPN deployment from the access site to datacenter IT backend and to external clouds.

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

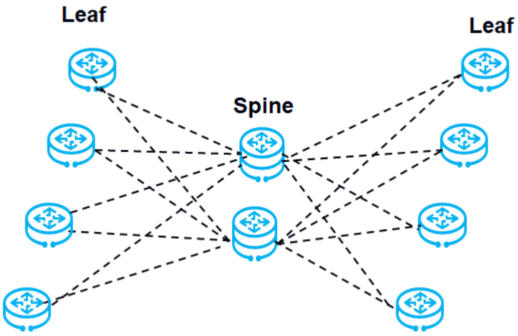
EVPN (Ethernet VPN) carries traditional E-Line, E-LAN, E-Tree, and L3VPN services in a unified manner and has the additional benefit of simplifying O&M.

Metro Spine-Leaf

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

FIGURE 15

Spine-Leaf Topology



Source: IDC, 2020

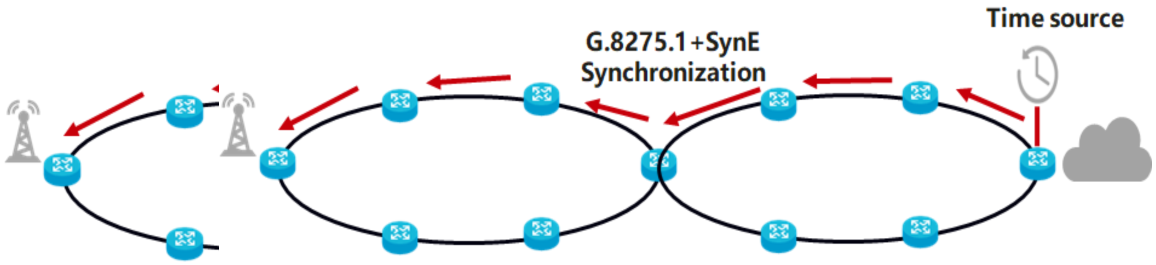
Spine-Leaf supports scaling with zero-impact. New nodes can be added, without affecting existing services. This prevents frequent physical architecture adjustment and supports long-term smooth network evolution.

Precise Time Synchronization (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 in basement, ITU-T G.8275.1 + SynE carried via fiber is regarded as a good option. The synchronization precision need to be less than 20 ns per hop, even less than 10 ns per hop in some scenarios like high-precision positioning. In order to improve time and clock synchronization O&M efficiency, automatic planning, provisioning, and fault locating are also critical.

FIGURE 16

Hop to Hop high-precision time synchronization



Source: IDC, 2020

Ready for Distributed Cloud - L3 to Edge/DC Network

A full-service offering (mobile, enterprise and home services) will necessarily include L2VPN, L3VPN links and multicast. When vertical industry applications are introduced, Edge DCs (including campus DCs) will be deployed for 5G core (UFC) and RAN (CU). For example, operators in Japan are dimensioning one edge DC for every ten 5G cell sites.

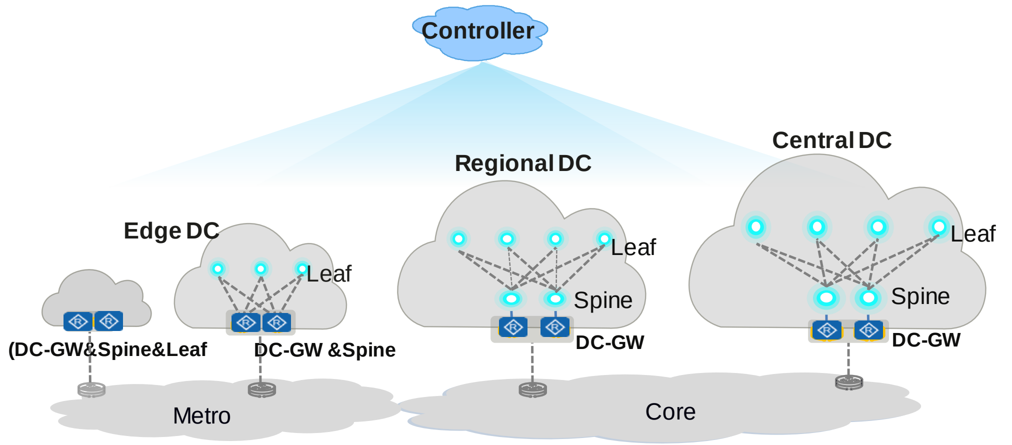
In 5G NSA networks, control signaling is forwarded by the 4G eNodeBs (as the anchor for control signaling), and data traffic is forwarded by the 5G NR gNodeBs. To reduce the delay and bypass traffic in 5G and cloud connectivity to support Any Place and Any Access Type, the transport network needs to provide the L3 feature in those radio sites.

The DC network can use Spine-Leaf architecture to facilitate non-blocking telecom cloud to support distributed computing and elastic scale-in/out, as well as to enable traffic to be forwarded along the optimal path. DC networks must be flexible. For example, the DC gateway-spine-leaf architecture (three-layer) is used for a central DC and regional DCs to meet the requirements of multiple service types and heavy traffic. But in edge DCs, three-layer, two-layer (DC gateway and spine node integrated), or one-layer (DC gateway deployed only) architecture is used according to available room space.

The DC network use routers as DC gateways with O&M demarcation for rapid deployment of new services and DCI (datacenter interconnect). DC networks have to be demarcated and isolated (in terms of O&M) from the external transport network to prevent resource conflicts. Routers that support SRv6 E2E network slicing, service provisioning automation are preferred here to facilitate DCI and on-boarding of new services.

FIGURE 17

DC networks for distributed DCs



Source: IDC, 2020

Always On

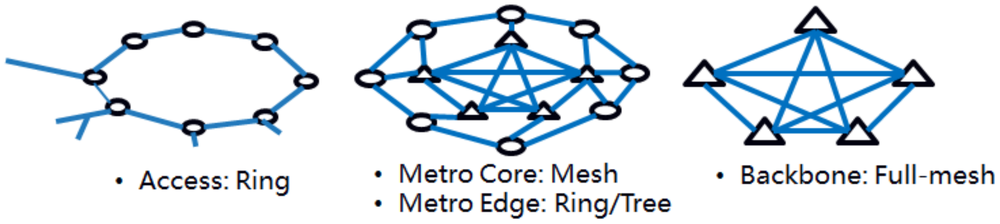
Always on transport networks need to deploy a number of protection mechanisms in in both Layer 1 and Layers 2-3. IDC analyzed a number of technologies and selected three indicators under the Always On dimension.

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. The WDM backbone and metro core layers require 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 18

High-reliability transport network topology



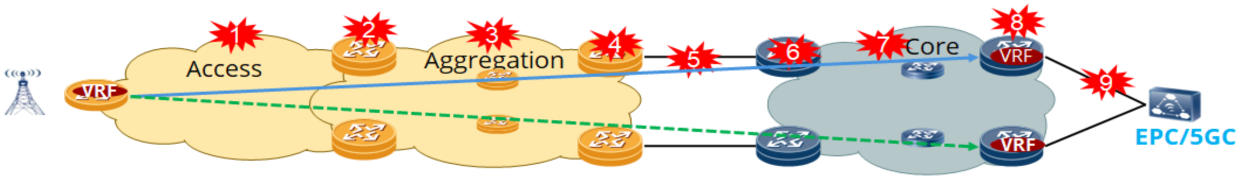
Source: IDC, 2020

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

IP-layer protection enables service-level and user-level protection. In the cloud era, IP protection is mandatory for network disaster management and high reliability service delivery. Protection technologies such as IP, MPLS, and SR 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 FRR (Fast Re-Route), IP networks must implement 50 ms fast protection failover, in order to protect ordinary voice and data sessions.

FIGURE 19

50 ms fast protection handover upon any node or link failure



Source: IDC, 2020

TI-LFA is independent of the topology and link quantities

As the number of IoT connections grows and consumer data demand continues to increase, telecom operators will need to embark on continuous expansion/construction of IP transport capacity, making network protection planning and deployment extremely complex. To address this issue, IP networks need to be implemented with fault detection and link failover protocols such as Topology Independent-Loop Free Alternative (TI-LFA) based on SRv6 which are straightforward to deploy and is independent of topologies and link quantities.

WDM Protection: ASON (Automatically Switched Optical Network)

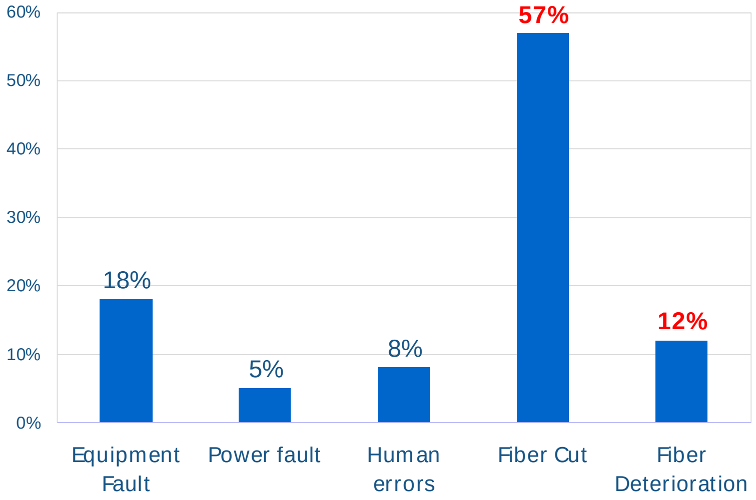
The optical fiber backbone network can be hundreds and thousands of kilometers long and vulnerable to natural disasters and roadside municipal construction works. In some Southeast Asian and South Asian countries, the number of fiber cuts per day exceeds 10, and the average fiber cut duration exceeds 8 hours. The availability of optical networks will fall to 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 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%, in order to prevent triggering IP network protection caused by fiber cuts which leads to IP frequent looping and rerouting.

FIGURE 20

70% of optical network faults are caused by fiber faults



Source: Real data for a South Pacific Operator

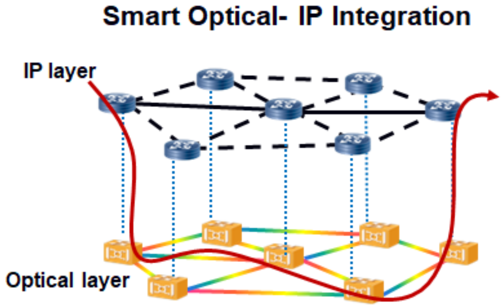
IP+Optical Synergy

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, WDM links are not load balanced. Combined IP and WDM synergistic O&M can be used to solve this problem and improve link utilization.

FIGURE 21

Large granularity traffic bypass IP network



Smart Optical- IP Integration

Fine granularity in the electrical layer and larger granularity in optical layer in order to enhance optical/ IP resource efficiency and reduce cost

Source: IDC, 2020

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 failure occurs IP & WDM allocate their own 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 combination.

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.

Intelligent

Smart Planning

Network construction in the past two decades has gradually evolved from deployments based on coverage requirements to deployments based on monetization optimization and customer experience. Network planning requires generous amounts of analysis of many different parameters, such as actual geographical population information, service development trend, and detailed resources on live networks. GIS-based, digital E2E planning tools can improve planning efficiencies with cloud computing and big data. The tools can also model service development trends, profiles of high-value areas based on historical data, as well as accurately evaluating network resources and enhancing ROI.

Auto Provisioning

Traditional service provisioning has always been a complex process in establishing configuration parameters on each NE according to specific service requirements (bandwidth, service type usually). With a centralized provisioning platform, configurable templates and new configuration protocols, the transport network can be made to be sense service intent (service requirements) and then, convert them into network configuration parameters and thereby automatically provision the service. Service intent can be used to detect required SLAs in real time in order to make suitable configuration changes.

The SDN controller can also perform auto provisioning across network layers and vendors, throughout the full O&M lifecycle, such as plug-and-play devices, plug-and-play networks, and self-service ordering.

Visualization & Forecast

The SDN Master Controller can be used to visualize service paths and service quality, and to predict traffic and network faults and carry out root cause analysis as well as to recommend troubleshooting policies. The in-flow detection directly marks packets and performs in a manner of flow-by-flow, hop-by-hop and real time for accuracy. Standardized telemetry protocols can be used to automatically and efficiently collect massive network data, implementing real-time network situational awareness. This approach is proactive because it aims for O&M system to resolve problems before customer complaints are received. The SDN Controller should have open sourced APIs to enable easy programming. During the evolution to future autonomous networks, the SDN controller will integrate with multiple vendor's network, OSS and Apps, and have northbound and southbound programming capabilities.

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 Network Planning & Engineering team at PLDT in the Philippines. PLDT, formerly known as Philippine Long Distance Telephone Company, is the oldest and largest Telecommunication 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 telecom operators, PLDT made a bold decision to build a totally new transport network next to the legacy network, instead of carrying out the typical piecemeal incremental upgrades. Below are the key objectives behind PLDT's visionary decision:

No risk or impact to existing services – being the largest provider of data communications service to enterprises in the Philippines, PLDT wanted to preserve SLAs for high-availability. 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 lead network outages and periodic downtimes. However, if PLDT chooses to build a whole new network, they can provision new services on this new network, and for existing services, PLDT would have ample time to schedule and migrate gradually, circuit by circuit, ensuring minimal impact to the service.

Unleash the full potential of SDN – If PLDT had selected to upgrade from the existing network, the entire process would have taken 3~5 years, and during that period a SDN-enabled network elements would have been installed but the legacy elements would not have been able to integrate into the SDN Controller system. This hybrid result would have prevented PLDT from reaping the economic and operational benefits of SDN. By building a new network instead, PLDT is able from the start to utilize the latest technologies and protocols such as Segment Routing, EVPN, TI-LFA, PCEP (Path Computation Element Protocol), to take full advantage of SDN orchestration and automation. PLDT can also extend network agility via automation and orchestration and offer a very competitive service with dynamic bandwidth provisioning.

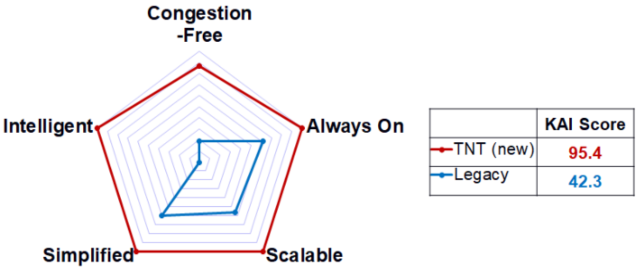
Cost per bit and TCO optimization – PLDT understands that negotiations and benchmarking with vendors during the procurement process can lead to some cost reduction, but the more impactful and longer-term cost reduction capabilities come from adopting an optimized, scalable architecture. For example, in the existing, legacy PLDT transport network there are sites with 3 separate and co-located routers: the first router is the NPE (Network Provider Edge) device interfacing to the fixed Carrier Ethernet Network (CEN), the second group acts as PE (Provider Edge) device for IP backbone/backhaul and the third group is an Aggregation Node for Mobile CEN device. By choosing to build a totally new network, PLDT was able to carry out planning in a more holistic manner and converge these groups of routers into a single group. That would be a direct reduction by 66% without factoring in other benefits such as SDN-based traffic engineering which could utilize the network resources in a much more efficient manner, would bring down the cost per bit as well.

PLDT is committed to delivering the best customer experience possible and has adopted an aggressive roll-out plan that started in in the early 2019 and completed the Phase 1 in December 2019. The new transport network is now declared Ready-For-Service.

IDC has interviewed the PLDT Transport Planning & Engineering team and apply the KAI model to evaluate this new transport network architecture and also the legacy network, and the result of the scoring is 95.4 and 42.3 respectively. This validates the correctness of technology selection that PLDT made.

FIGURE 22

KAI Scoring for PLDT Transport Network



Source: IDC, 2020

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+PR (Permanent Restoration) on the OTN layer, and TI-LFA (Topology Independent Loop-Free Alternate) technology on IP layer, which ensures the network 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.

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.

Intelligent. PLDT also scored a perfect 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.

Congestion-Free. PLDT scored a high score in this dimension. The new network consists of 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 transport network is congestion-free.

Scalable. PLDT 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 Philippines but also in the world.

CONCLUSION & ADVICE FOR TELECOM OPERATORS

New services driven by cloud, IoT and 5G, will bring new business opportunities, but at the same time will also challenge the existing IP transport (bearer) network infrastructure and increase TCO. CapEx & OpEx can be reduced starting with the design stage using established the KAI (Key Architecture Index) system as a reference standard for network evolution.

IDC believes that all operators should set targets for their transport networks using an index model similar to what we are proposing in this White Paper. IDC recognizes that operators are at different maturity stages in their DX journey, IDC recommends telecom operators 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.
- For operators 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.

GLOSSARY

Term/Acronym	Meaning
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
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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