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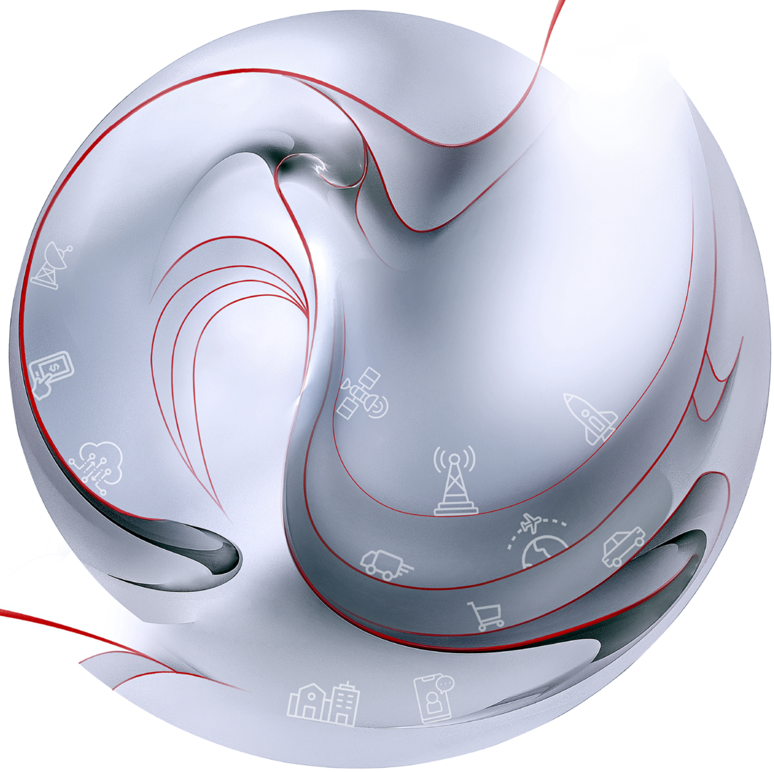
Striding towards the Intelligent World 2030

Ten Trends Shaping the Future of Connectivity

The Road to 2030 in the Age of Intelligence

Data-driven Solutions for Driving Away Algae



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Imagination Sees the Future, Technology Builds It

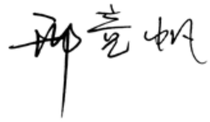
Today, digital technologies are emerging and iterating faster than at any time in history.

Information flows created by technologies, such as 5G, cloud, video, IoT, and AI, are defining the trends that are reshaping the world. What will the future world look like? Popular sci-fi, like *The Three-Body Problem*, *The Matrix*, *Ready Player One*, and *Upload* represent imagined futures. "With imagination, we can see the future. But with technology, we can get there," said William Xu, Director and President of the Institute of Strategic Research of Huawei, at Huawei Global Analyst Summit 2021.

For example, to transcend physical limitations and improve our sensory abilities, we need to make more powerful cameras. To augment biological intelligence, we must develop new types of computing. To overcome the obstacles of physical space, we need to develop faster and lower-latency networks for real-life holographic communications. To expand the limits of cognition, we must develop more advanced mesoscopic devices. And so on.

In the next ten years, there will be hundreds of billions of connections, broadband speeds will reach 10 Gbps per person, computing power and storage capacity will both see a 100-fold increase, and more than 50% of all the energy we use will come from renewable sources. Technology needs to evolve around the generation, transmission, processing, and use of information and energy. Breakthroughs in connectivity are a defining feature of every era. By supporting hundreds of billions of diverse connections and the exponential growth in fiber capacity, we will lay the groundwork for the applications of the future. As a result of the digitalization of industries during this time, the industrial Internet will drive the emergence of new IP protocols.

Huawei's vision and mission is to bring digital to every person, home and organization for a fully connected, intelligent world. We're excited to work with more enterprises and organizations to realize the digital transformation, deployment of intelligence in industries, and exploration of cutting-edge science and technology. We fully believe in the role of technology in driving society forward and that's why we continue to innovate – to build a better, shared future for mankind.



Xing Jingfan

Contents

Industry Trends

04
Striding towards the Intelligent World 2030

12
Ten Trends Shaping the Future of Connectivity

Expert Voices

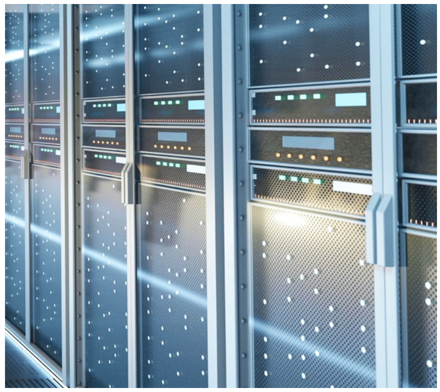
18
The Road to 2030 in the Age of Intelligence

25
Stronger and Smarter 5G, Optical & IP Networks by 2030

30
Dell'Oro Group on Campus Network Trends in the Post-pandemic Era

Developers

46
From Cloud-Network To Computing-Network Convergence

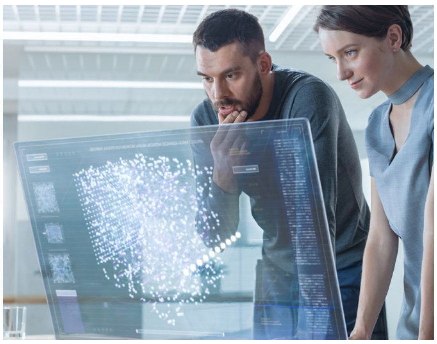


New Solutions

34
Data-driven Solutions for Driving Away Algae

39
Embarking on a Customer-centric Digital Transformation Journey

43
Strengthening the Internet with Enhanced IP Capabilities



Striding towards the Intelligent World 2030

Nine tech challenges and research directions

At Huawei Global Analyst Summit 2021, Director of the Board and President of Huawei's Institute of Strategic Research, William Xu, shared the company's vision for an intelligent world in 2030, highlighting the nine technological challenges and research directions that will help bring it to fruition. Key to this vision is greater collaboration between industries, academia, and research institutions, alongside an open, inclusive, and collaborative approach to innovation that unleashes the full potential of human creativity to address the challenges we all face.

By William Xu, Director of the Board & President of Institute of Strategic Research, Huawei

We have all had a difficult year, with many new challenges brought about by the pandemic and anti-globalization. Today, we're looking at the beginning of a decade that will bring many new uncertainties and opportunities. The ICT industry will also face new challenges and need to make breakthroughs.

Population and energy underpin the well-being of society

A UN report shows that by 2030, the global population will reach 8.6 billion, with over 12% being 65 or older, while the percentage of people aged 25 years or younger is decreasing. This ageing population and the resulting labor shortages are hindering social progress. There is an increasing need for solutions that not only prolong life, but also improve quality-of-life and ensure dignity during end-of-life care.

Global energy consumption is growing at an annual rate of 1.7%, and energy consumption has increased by 22 times since the 18th century. Currently, 85% of energy comes from fossil fuels. Energy sustainability is a daunting challenge that faces us all.

The path to sustainability: Low-carbon, electric, and intelligent

By 2030, we forecast that more than 50% of all energy will come from renewable sources, more than 50% of cars sold will be electric, and more than 18% of homes will have smart robots. By empowering a wide range of industries, ICT has the potential to reduce global carbon emissions by 20% over the next decade.

Transcend limits and embrace the future

We have many expectations for the future that will require us to transcend our limits.

We hope to exceed the biological limits of perception. Current phone cameras have achieved 100x zoom, but a huge gap still exists between camera capabilities and what we see animals achieving in the natural world. For example, spiders are excellent at detecting the outlines of objects and motion, and we may learn from them to develop cameras that meet the requirements of autonomous driving.

We hope to go beyond biological intelligence as we develop new computing technologies. Although we now have many AI applications, deep neural networks are hard to train and consume large amounts of energy. They cannot fulfill functions as efficiently as the brains of ants. An ant's brain only consumes 0.2 mW of power, but can process many activities, like nesting, socializing, fighting, and feeding aphids. I think we can learn from such creatures during AI development by starting with building intelligence in simple scenarios.

We hope to transcend physical limits and enjoy a truly immersive experience. Existing 5G networks are far from being able to offer such experiences. Therefore, we must offer faster network speeds and lower latency for life-size holographic communication.

By 2030, we forecast that more than 50% of all energy will come from renewable sources, more than 50% of cars sold will be electric, and more than 18% of homes will have smart robots.

1. Defining 5.5G to support hundreds of billions of diverse connections
2. Nanoscale optics for an exponential increase in fiber capacity
3. Optimizing network protocols to connect all things
4. Advanced computing power strong enough for the intelligent world
5. Extracting knowledge from massive multi-modal data for breakthroughs in industrial AI
6. Going beyond von Neumann architecture for 100x denser storage systems
7. Combining computing and sensing for a hyper-reality, multi-modal experience
8. Enabling continuous self-monitoring for more proactive health management
9. An intelligent Internet of Energy for the generation, storage, and consumption of greener electricity

The nine challenges and research directions

We also hope to extend our horizons by developing mesoscopic devices. Scientists use computing to realize molecule- and atom-level design and assembly to greatly improve the performance of chips and components.

Pillars of the future: Challenges and research directions

Our world is built upon three pillars – matter, energy, and information. Together, they determine how the world works. From them, we can determine what future challenges we will face. Matter is the origin of existence; energy drives motion; and information determines connections.

By 2030, there will be hundreds of billions of connections around the world. Broadband speeds of 10 Gbps on average will be available to every user. We will see a 100-fold increase in computing power and storage capacity, and more than 50% of all energy will come from renewable sources. This means that the technologies that power the generation, transmission, processing, and use of information and energy will need to evolve.

Based on these predictions, I would like to talk about the challenges we will need to address and development directions over the next decade.

Challenge 1: Defining 5.5G to support hundreds of billions of diverse connections

Our first challenge will be connecting all things. In addition to connecting people, we must also connect massive numbers of things. The demands for those connections will be very diverse.

The three use cases defined by 5G cannot support some of the more diverse IoT scenarios. For example, industrial IoT

applications require both massive numbers of connections and large uplink bandwidth. So they need Uplink Centric Broadband Communication (UCBC) – a scenario that falls between eMBB and mMTC. There are also applications that need ultra-broadband, low latency, and high reliability. These require Real-Time Broadband Communication (RTBC), which is a scenario that falls between eMBB and URLLC. Vehicle-road collaboration in connected vehicles requires both communication and sensing capabilities. So we need another new scenario, Harmonized Communication and Sensing (HCS).

5.5G must cover these three new scenarios – UCBC, RTBC, and HCS – in addition to the current three 5G scenarios, namely eMBB, mMTC, and URLLC. Together, they will take us beyond the connectivity of everything and enable the intelligent connectivity of everything.

Challenge 2: Nanoscale optics for an exponential increase in fiber capacity

The key hindrance for 5G connectivity will lie in the quantity of connections, while the key hindrance for fiber connectivity will lie in fiber capacity.

Today, a single fiber can simultaneously support 1 million 4K video streams. In 2030, it will need to be able to support 1 million people interacting in mixed reality. This means that the capacity of a single fiber will need to expand by 10-fold and exceed 100 Tbps.

First, we will have to work on optical transceiver lasers and use high-modulation components to double or triple baud rates. In addition, new modulation coding and algorithms will be required to multiply capacity. Thin-film, high-bandwidth modulators will be the way forward.

Today, our primary networks can support tens of billions of consumer connections. By 2030, they will need to support hundreds of billions of industry connections.

Second, we must develop new, broad-frequency, and low-noise optical amplifiers that support manual control for reliable, ultra-long haul transmissions. The key technology will be optical amplification that will bring us close to the quantum limit.

Third, we will need to study dynamic controls for optical networks and transform the WDM network into a synchronous system. This will allow us to improve anti-interference features and efficiently use optical resources through computing. The key technology here will be micro-cavity optical frequency combs.

Longer term, we will also need to research new fiber and optical systems, like Space Division Multiplexing (SDM), to increase the capacity of a single fiber by 100-fold.

Challenge 3: Optimizing network protocols to connect all things

Today, our primary networks can support tens of billions of consumer connections. By 2030, they will need to support hundreds of billions of industry connections. This will present three major obstacles for network protocols.

The first will be related to achieving deterministic networks. These networks need guaranteed deterministic latency. We must use new network calculus theories and protocols to transform the best-effort network latency we have today into a deterministic latency that can be calculated in advance.

The second obstacle will be in security. When all things are connected, security systems will face serious challenges. Large numbers of devices like drones, cameras, edge computing devices, and sensors will all present new security risks. The time is ripe to develop intrinsic, end-to-end security frameworks and protocols.

The third obstacle we will face is in flexibility. As the variety of industry requirements increases, some will require longer IP addresses, while others will require shorter. To overcome the related challenges, we will need to expand IP addresses with fixed lengths and develop new Internet protocols that feature sematic and syntax flexibility.

Challenge 4: Advanced computing power strong enough for the intelligent world

If connectivity determines the breadth of the intelligent world, computing will determine its depth.

In 2030, the demand for computing power will see a 100-fold jump. In the past, we would see single-core CPU performance increase about 50% every year. But now, that rate has dropped to around 10%. We're also finding that general-purpose computing is very inefficient in some domains. Providing sufficiently advanced computing power will be a huge challenge.

First, we must move digital computing from general-purpose computing to special-purpose computing, and then to heterogeneous computing that allows for the coexistence of multiple computing architectures like CPUs, GPUs, and xPUs.

Second, we will need to leverage the benefits of analog computing in special-purpose domains. Photonic computing will be used in domains like signal processing, combinatorial optimization, and machine learning. In particular, photonic computing has huge application potential in Massive MIMO and optical communication.

Challenge 5: Extracting knowledge from massive multi-modal data for breakthroughs in industrial AI

The intelligent world would be impossible without AI, so the next challenge is about the fragmentation of AI applications and AI trustworthiness.

We believe the key to addressing the issue of fragmentation will be to develop general-purpose AI models. General-purpose AI systems can be achieved by using large amounts of unlabeled data and larger models, and shifting from supervised to self-supervised learning. Making breakthroughs in these areas will be critical.

In addition, we should bring AI and scientific computing together. This will also help address the fragmentation of AI applications. AI will bring new approaches, methods, and tools for scientific computing, while a rigorous scientific computing system will help make AI more explainable.

AI trustworthiness is our long-term goal. This trustworthiness is particularly important in key domains that can involve matters of life and death, such as autonomous driving, where we must address challenges from relevance to causality.

Challenge 6: Going beyond von Neumann architecture for 100x denser storage systems

Storage capacity and performance will be two issues that need to be addressed for future storage systems.

First, we need much higher storage capacity. Capacity density will need to be 100 times higher than what we currently have. However, existing storage media cannot achieve this level of capacity density due to process and power consumption restrictions. To overcome this capacity hurdle, we will need breakthroughs in new technologies, including high-capacity and low-latency memory technologies, ultra-large capacity media technologies such as DNA storage and high-dimensional optical storage, and ultra-large storage space model and coding technologies.

Second, we will also require significantly improved storage performance. As the data access bandwidth of storage systems increases from TBs to PBs, and access latency drops from milliseconds to microseconds, we will need performance density to increase 100 times beyond what's currently available. Under the von Neumann architecture, data needs to be transmitted between CPUs, memory, and storage media. The PCIe and DDR bandwidths we currently have will be unable to keep up with network performance growth. To break through this performance wall, we will need to move past the von Neumann architecture and shift away from CPU-centric storage and towards memory- and data-centric storage. We will also need to focus more on computing migration rather than data migration.

AI trustworthiness is our long-term goal. This trustworthiness is particularly important in key domains that can involve matters of life and death, such as autonomous driving.

Challenge 7: Combining computing and sensing for a hyper-reality, multi-modal experience

Challenge number seven will be creating an inspired user experience that can be an integral part of the intelligent world. This kind of hyper-reality will become true reality by 2030.

Hyper-reality experiences can be achieved when the virtual world is seamlessly integrated with the physical world, and when the virtual world can accurately perceive and render the physical world while understanding user intent in mixed reality. Hearing, vision, touch, and smell must all be integrated to enable multi-modal interactions between individuals and hundreds of edge devices. To achieve this goal, the integrated user environment must work like a super computer. Multi-modal sensors are needed to collect and transmit language, touch, light perception, neural activity, and other types of information, as well as to perceive user intent. Technologies like naked-eye 3D, holographic projection, AR contact lenses, digital smell, and digital touch will all be necessary in order to display the information to users.

With the support of brain-computer interfaces, sEMG interfaces, and wearable robots, we can enable the elderly to proactively manage their own health.

Challenge 8: Enabling continuous self-monitoring for more proactive health management

Ageing populations will lead to increases in chronic illness. 85% of deaths are currently attributed to chronic illness. Effectively treating chronic illness requires real-time monitoring. This, in turn, requires medical-grade wearables to achieve non-invasive blood glucose monitoring, and continuous blood pressure and ECG monitoring. For example, fiber-optic sensors can provide more accurate pulse waves than PPG sensors. They can also offer higher-quality data for blood pressure modeling and algorithms.

We should look into building a complete big data platform for personal health based on cloud services and AI technologies to enable proactive health management. With the support of brain-computer interfaces, sEMG interfaces, and wearable robots, we can enable the elderly to proactively manage their own health.

Challenge 9: An intelligent Internet of Energy for the generation, storage, and consumption of greener electricity

New carbon neutrality and emissions peak targets have accelerated global transformation towards new energy. But this transformation also brings new challenges to the fields of electricity generation, energy storage, and electricity consumption.

Electricity generation systems have moved closer and closer to individual users as centralized generation has evolved into distributed generation. In the past, consumption happened only on the user-level. In the future, electricity generation will also happen on-site. However, before this is a reality, there will need to be more bidirectional energy codes and the electrical grid will need to become more like the Internet. Electricity generated from new energy sources is more volatile and also intermittent, and often needs to take advantage of the complementary nature of multi-energy systems. Therefore, huge challenges must be resolved before new energy becomes a primary energy source.

While we previously only had to worry about generation and consumption, new energy makes energy storage buffer systems equally critical. We will no longer just instantaneously generate the amount of electricity needed to simply meet user demand. This will make our energy grids far more complex. We must determine how to store large amounts of energy at low cost, with zero carbon emissions, and how to maximize the use of green electricity through intelligent scheduling.

In terms of energy consumption, we must promote integrated smart energy to build energy management systems for households, buildings, and factories, and create zero-carbon communities, campuses, and cities.

An intelligent Internet of Energy must be developed to achieve greener electricity generation, storage, and consumption. This will require advancements in several key technologies.

(1) Management technologies: Digital technologies, such as big data, AI, and cloud, must be integrated with the Internet of Energy to achieve bit-based watt management through an energy cloud and energy network.

(2) Control technologies: Power electronics-based energy routers can be used to build intelligent energy network controllers that realize bidirectional energy flows and intelligent energy distribution.

(3) Storage technologies: New energy storage technologies, including new electrochemical and hydrogen storage mediums, need to be developed for multiple scenarios to meet growing storage requirements.

(4) Power electronic technologies: Wide-bandgap semiconductors, including SiC and diamond for medium- and high-voltage applications and GaN for medium- and low-voltage applications, will be vital for more efficient and compact energy components.

These are the nine technological challenges and directions for further research that we believe will be crucial, based on our experience in the ICT industry. These also represent what we believe is needed to achieve an intelligent world by 2030: Stronger connectivity, faster computing, and greener energy.

Overcoming challenges through an open, inclusive, and collaborative approach to innovation

We need to pool the wisdom and innovation capabilities of everyone to continue driving human development and tackle the massive challenges facing us all. We must overcome challenges by taking an open, inclusive, and collaborative approach to innovation. Industry players must collaborate closely with universities and research institutions, and inform and guide scientific research by defining universal and industrial challenges.

People have always imagined what the future will be like. But technology actually takes us there. We must integrate industrial challenges and academic insights, then adopt a venture capital mindset to innovate together and build the Intelligent World of 2030.

We must integrate industrial challenges and academic insights, then adopt a venture capital mindset to innovate together and build the Intelligent World of 2030.

Ten Trends Shaping the Future of Connectivity

To move beyond connecting individuals and organizations to connecting societies, the connectivity industry needs to keep innovating to adapt to rapid changes in service diversity and volume.

By Du Wei, Chief Connectivity and Network Strategic Planning Expert, Huawei

From 2G and NGN in the voice era to 3G, 4G, and multi-play in the video era to 5G, SDN, and NFV in the cloud era, we're moving into the digital and intelligent age with a wave of new development trends. Through integrated innovation, the industry will improve network value and deliver differentiated service experience to support the fully connected, intelligent world.

Five years ago, carriers began to plan for next-gen network transformation under Network 2020, with a focus on network cloudification. Then as 2020 came around, mobile access evolved from 4G to 5G and fixed access shifted from GPON to F5G. Carriers could gradually build ubiquitous gigabit access networks for individuals, homes, and enterprises. The three major carriers in China and mainstream international Internet Exchange Providers (IXPs) have built ultra-broadband cloud interconnections (data center interconnect/DCI) backbone networks.

Network 2020 architecture enabled networks to support the work and life of hundreds of millions of home users, and the Internet became more than just a tool of consumer video entertainment, evolving into a tool of the home office.

In the next five years, the connectivity industry will see 10 new trends.

Trend 1: Networks will become a value center as they shift from cloud-network synergy to computing-network integration

Over the past five years, cloud-network synergy has been achieved between cloud and devices to connect the two, so that rich content on the cloud can be smoothly displayed on various smart devices. At that time, cloud-network synergy meant that networks can provide content services for devices through cloud-device interconnection focusing on downlink traffic.

In the future, with the emergence of a large number of real-time services like cloud VR, machine vision, and autonomous driving, devices will generate a huge amount of data that needs to be uploaded to the edge and cloud computing nodes for processing. The processed data will then be sent back to the devices in real time. This means networks will need to support interconnection between the device, edge, and cloud with a focus on uplink traffic to provide intelligent services for devices.

Edge computing has eliminated the independence of traditional clouds and networks. As computing becomes a part of networks, the efficiency and reliability of edge computing is deeply intertwined with network bandwidth, latency, security, and isolation. Services can only be delivered efficiently when computing and networks are integrated.

In the cloud-network synergy era, networks were cloud-centric. The cloud required network connectivity and openness, and best-effort service quality. Networks were the cost center.

In the computing-network integration era, networks will be user-centric. Users will require lower latency, higher security, and higher reliability from their networks, as well as deterministic service quality. Networks will be transformed into a value center.

Trend 2: D/O/I/CT technologies will converge to build new communications capabilities

Over the past 10 years, the connectivity industry has undergone an IP transformation, two rounds of cloudification, and a convergence of information technology (IT) and communications technology (CT). This created converged products such as IP base stations, IP-DSLAMs, IP microwave, IPRAN/SPN, Cloud EPC, Cloud IMS, and Cloud BRAS, improving network flexibility, agility, and openness.

In the next five years, more technologies will continue to converge. Digital technology (DT), primarily AI, will converge with CT to incubate products and solutions like autonomous driving networks, intelligent connectivity, cognitive radio networks, and cognitive optical systems, and continuously improve network intelligence levels. As industry digitalization advances, operational technology (OT), characterized by real-time performance and high reliability, will be integrated with CT to drive the maturity of converged solutions such as TSN and 5G URLLC, and make networks more deterministic.

Only new agile, intelligent, real-time, and open communications networks that combine DT, OT, and IT technologies will be well-positioned to build next-generation infrastructure for the intelligent world.

Trend 3: Post-classical network architectures will support sustainable network development

Over the past 70 years, Moore's law and the Shannon limit have been considered classical theories of the connectivity industry. However, they're beginning to fail as we

Only new agile, intelligent, real-time, and open communications networks that combine DT, OT, and IT technologies will be well-positioned to build next-generation infrastructure for the intelligent world.

Innovation in post-Moore and post-Shannon architectures can continuously grow network capacity to meet the requirements of massive data transmission in the intelligent world.

observe new types of development in the new network era.

As we move towards 7-nm semiconductors, communications network chips can no longer both reduce power consumption and improve capacity. Therefore, network nodes need to shift from centralized to distributed, which requires architectural innovation to address the challenges of network traffic growth. This will take data communications networks to a post-Moore architecture era. At the same time, the coding efficiency of wireless and optical systems is also hitting a ceiling.

New spectrum can increase network capacity, while advances like semantic communications and knowledge-aided signal processing in communications equipment can boost transmission efficiency, taking wireless and optical networks are entering the post-Shannon architecture era.

Innovation in post-Moore and post-Shannon architectures can continuously grow network capacity to meet the requirements of massive data transmission in the intelligent world.

Trend 4: Optical and electronic technologies will converge to enable many industries

Wireless, optical, and data communications technologies are relatively independent of each other. However, as high-speed, high-frequency, and cost-effective networks emerge, traditional electronic technologies will encounter barriers to sustainable development such as distance and power consumption.

In the next five years, the integration of optical and electronic technologies will enable the high-speed processing of electronic components and reduce power consumption, bringing new products such as optical input/output chipsets and opto-electronic co-packaging. New optical technologies will extend the transmission distance of high-speed ports on data communications equipment. New types of antennas that directly connect to optical fiber will reduce the weight and power consumption of base stations, and lasers will replace microwave to achieve 100-Gbps high-speed data transmission between low-earth orbit satellites. Wireless coverage will be replaced by visible light with higher penetration capability to meet the communications requirements of underwater mobile devices, and far infrared light technology will achieve higher transmittance to accurately detect brain waves.

Optics will become a fundamental technology within the communications industry and it will support the connectivity of industries.

Trend 5: Internet protocol with enhanced awareness enables unified bearing of multiple planes on the same network

IPv6 not only features a larger address space than IPv4, but it also supports the flexible definition of services with locators and IDs separated. Different ID attributes can be defined to enable service awareness, thus enabling better services based on a better understanding of service requirements.

To simplify cloud-network collaboration, SRv6 can be defined to support both MPLS WAN private line and VXLAN private line services. To improve network computing efficiency, Compute First Networking (CFN) can be defined to identify service requirements for both computing and connectivity resources, and allocate the most appropriate computing resources for processing data traffic. In the future, new ID attributes can be defined for different industry requirements to continuously improve the service awareness capability of IP networks and supporting the interconnection of a given service with any other.

Using flexible IPv6 addresses, a new type of IP network with port-level, tenant-level, and service-level planes can be built in one system. This network is compatible with traditional networks and it can identify multiple service requirements and coordinate optical and wireless network resources, among others, enabling the unified bearing of multiple planes on the same network.

Trend 6: Wireless networks progress toward full connectivity, full coverage, and full spectrum

Connecting the unconnected will continue to be the direction of wireless network development. Wireless networks are expanding from connecting consumers to connecting industries. In the next five years, wireless networks will evolve from 5G to 5.5G, which will bring real-time communication, super uplink, and converged sensing in addition to 5G's high bandwidth, massive connections, and ultra-reliability.

In the next 10 years, wireless network coverage will expand from urban and rural areas to mines, oceans, and aircraft, creating an integrated network system covering the space, sky, and ground. In the future, wireless networks' use of spectrum resources will also expand beyond the current sub-6 GHz frequencies to include millimeter wave, terahertz, and visible light. This will bring a 100-fold increase in network capacity and satisfy the long-term needs of the intelligent world.

Trend 7: New security architecture integrates cloud, networks, and chips

The trends of cloudification, mobility, and convergence of 2B and 2C services are blurring the traditional boundaries of security. In the future, enterprises will no longer be able to ensure security through the defensive denial of access to the core. Cybersecurity should be extended to the edge, devices, and chips. In addition, attackers are now using AI to boost attacks, requiring defense systems to be more intelligent and make more accurate assessments by dynamically analyzing attacker behavior.

The trends of cloudification, mobility, and convergence of 2B and 2C services are blurring the traditional boundaries of security.

As attacks are increasingly borderless and intelligent, we must combine the computing capability and flexibility of cloud, the physical security of chips, and the isolation and real-time collaboration of networks to build a new security architecture that features full trust and cloud-network-chip integration to avoid security vulnerabilities in networks.

Trend 8: Network administration shifts from software-defined to digital twins

In recent years, as software-defined networking (SDN) and telemetry technologies advance, the capability of software to abstract away physical devices is improving.

In the next five years, AI will be introduced to existing cloud-based network management platforms to learn from training data and perform the closed-loop simulation of action to be taken. Instructions and operations are first executed in a simulation, after which they're sent to the SDN controller for real execution on the network. This simulation process improves system robustness and predictability.

In the next 10 years, as sub-second/millisecond-level hard real-time network data collection, modeling, simulation, prediction, and control capabilities become mature, and with the adoption of the new computing-network integrated architecture, an always-on digital twin network system will be built for physical networks. This will accelerate innovation in network software functions.

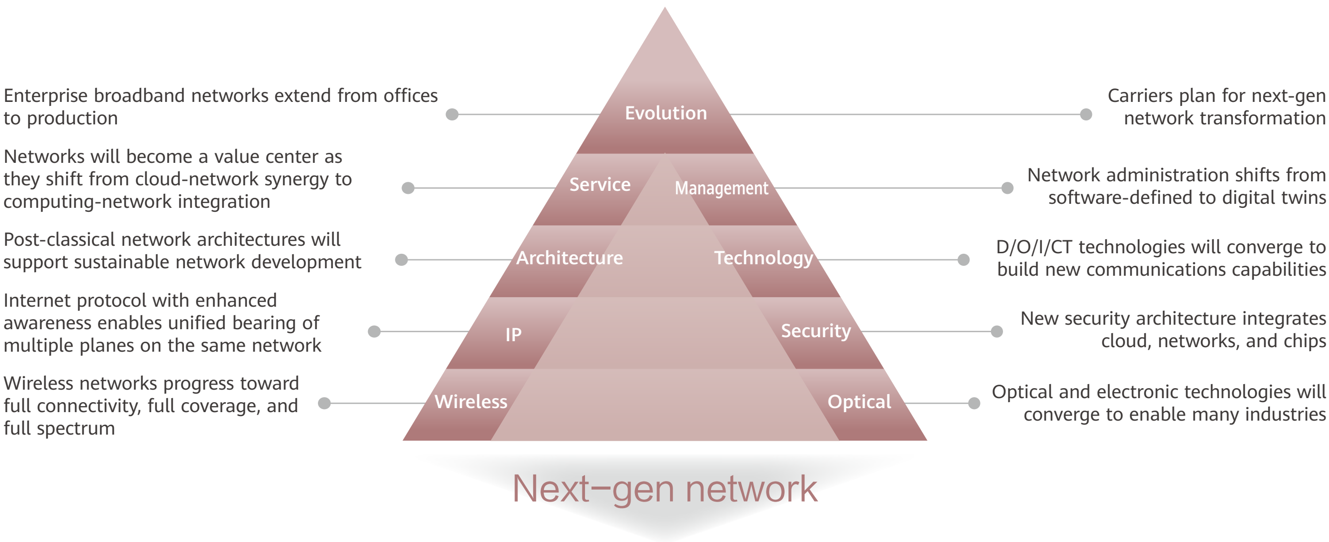
Trend 9: Carriers plan for next-gen network transformation

In recent years, with the communications industry paying more attention to new connectivity technologies such as CFN, intelligent connectivity, 5.5G/6G, F5G, and IPv6+, major carriers have begun to look ahead and plan next-generation networks for the next five to ten years.

The traffic volume of 5G will be close to that of fixed broadband, and wireless networks (RAN) and fiber networks (FAN) will come to equal broadband access networks in scale.

As industry digitalization progresses, current data center Internet (DCI) networks will be extended to MANs and the edge, resulting in the formation of industry-oriented backbone networks (IBNs) that are as important as consumer-oriented backbone networks (CBNs).

Based on the computing-network integrated architecture, new network intelligence (ADN)



Ten technology trends that will influence the next-gen network

and edge computing (MEC) capabilities will be built at the network edge. The network edge will evolve from pipe-based transparent transmission of traffic to an intelligent edge with integrated sensing capabilities.

Carriers are now poised to transform toward intelligent, simplified next-generation networks to achieve balanced development.

Trend 10: Enterprise broadband networks extend from offices to production

As industry digitalization from IT to OT enters its most difficult phase, new applications such as remote control, machine vision, man-machine collaboration, and edge computing require a new enterprise broadband network that can provide high bandwidth and meet real-time communication requirements.

Next-generation enterprise networks will eliminate the boundary between IT and OT networks and enable the converged bearing of IT and OT through deterministic broadband networks such as 5G and time-sensitive networking (TSN) as well as network slicing technology. This will allow enterprises to upgrade from the traditional human-centric, pyramid-shaped operation architecture to an intelligence-centric, flattened operation architecture. This satisfies the requirements of any-workforce connectivity.

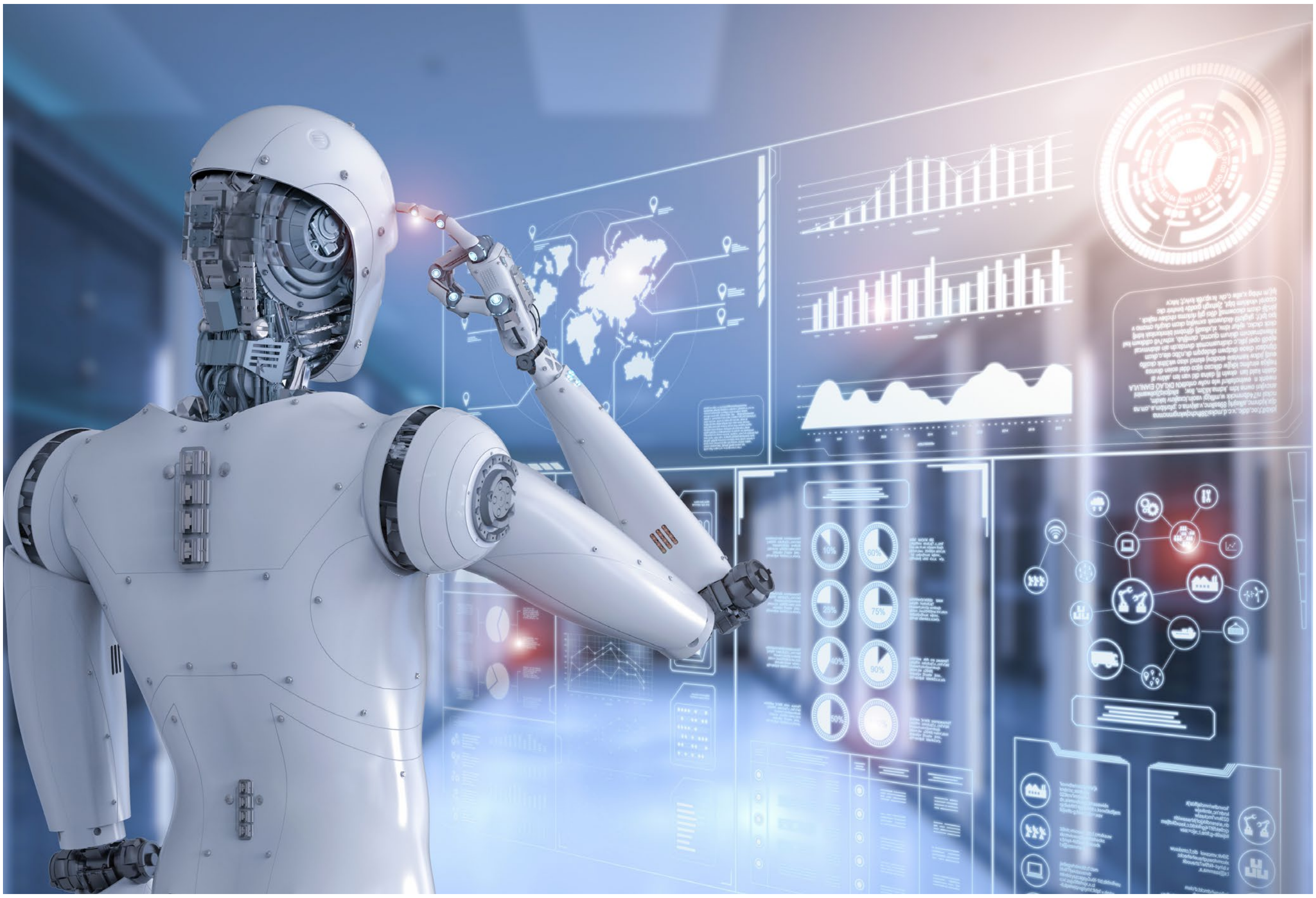
Next-generation enterprise networks will also decouple data from the transport layer. That means, based on a universal transport layer, devices from different vendors will be able to flexibly share data and work seamlessly together, satisfying the requirements of any-workload connectivity.

Next-generation enterprise networks will be more intelligent. They will meet the requirements of borderless and mobile working, and support intent-driven, automated network management and AI-based proactive security. This satisfies the requirements for any-workplace connectivity.

The Road to 2030 in the Age of Intelligence

As the cornerstone of the intelligent era, the ICT industry is facing huge development opportunities and challenges. The key to development in the intelligent era lies in technological innovation, mutual trust, and cooperation.

By 36Kr



On May 11, 1997, IBM's supercomputer Deep Blue caused a sensation throughout the world when it defeated the then world chess champion, Garry Kasparov. It was hard to imagine that Deep Blue was a giant that weighed 1,270 kilograms, had 32 brains (microprocessors), and could perform 200 million calculations per second, with a computing power of 11.38 GFLOPS.

On March 15, 2016, AlphaGo, Google's Go-playing AI, won the final match in a five-part man-machine series of matches against then world Go champion Lee Sedol, beating Sedol four matches to one. According to Sogou CEO Wang Xiaochuan, AlphaGo's computing power is 30,000 times that of IBM's Deep Blue. Today's most powerful modern supercomputers boast hundreds of thousands of times more computing power than Deep Blue. In fact, any laptop has more computing power than Deep Blue, showing how quickly computing power has progressed over the past 20 years.

Kai-Fu Lee said that chess is considered as a standard for testing the level of an AI. Go has 300 more times the possible plays than chess, so if AI can defeat the best human Go players, that indicates that the development of AI has entered a new stage. To many observers, AlphaGo's victory over Lee Sedol heralded the dawn of the AI era. Google's former CEO Eric Schmidt said that no matter who wins the game, it is actually a victory for humans.

The future is here

Today, AI technology is being widely applied. In the stock market, AI is better at adapting to changes and predicting results than people are. In the news media industry, AI writes faster and makes fewer errors than human writers. In smart manufacturing, more robots are being equipped with sensors and AI capabilities to work with people.

In the healthcare domain, AI-enabled medical equipment has greatly changed the way medical services are delivered and received, improving the well-being of patients at lower cost.

In the logistics domain, intelligent robotic warehousing systems use AI capabilities provided by micro data center facilities both on the cloud and on site to communicate with each other and handle tasks, shortening the time required for order picking to minutes.

Intelligent transportation systems use big data and cloud technology to improve transportation efficiency and reduce environmental pollution by easing traffic congestion and cutting energy consumption.

When COVID-19 broke out, intelligent technology played an active role in pandemic prevention and control, drug development, disease diagnosis and treatment, and more. Intelligent technology gave birth to new ways of working and living, such as cloud conferencing and cloud classrooms, and contributed greatly to resuming production.

Israel, for example, has a very small land area, less than half of the Pearl River Delta in China and 45% of the land is desert.

When COVID-19 broke out, intelligent technology played an active role in pandemic prevention and control, drug development, disease diagnosis and treatment, and more.

Intelligent technology will become a new driver of economic growth, a new blue ocean for industry development, and a new engine for the high-quality development of the digital world.

Arable land accounts for only one-fifth of Israel's land area — the country is pretty barren. Israel gets only two-thirds as much annual precipitation as China's rainless central and western regions. However, by using big data and AI, Israel has turned itself into a major agricultural exporter. The annual yield of cotton is 7,500 kg per hectare, and the annual yield of citrus fruits can be up to 4.5 tons per hectare.

This is the magic of intelligent technology. The core technologies of the first Industrial Revolution, second Industrial Revolution, and Information Revolution were steam engines, electricity, and computers/semiconductor chips, respectively. Each technological revolution reshaped the industrial landscape and created new industries that characterized the era.

We are now witnessing the Intelligent Revolution led by 5G, IoT, and AI. Intelligent technology will become a new driver of economic growth, a new blue ocean for industry development, and a new engine for the high-quality development of the digital world.

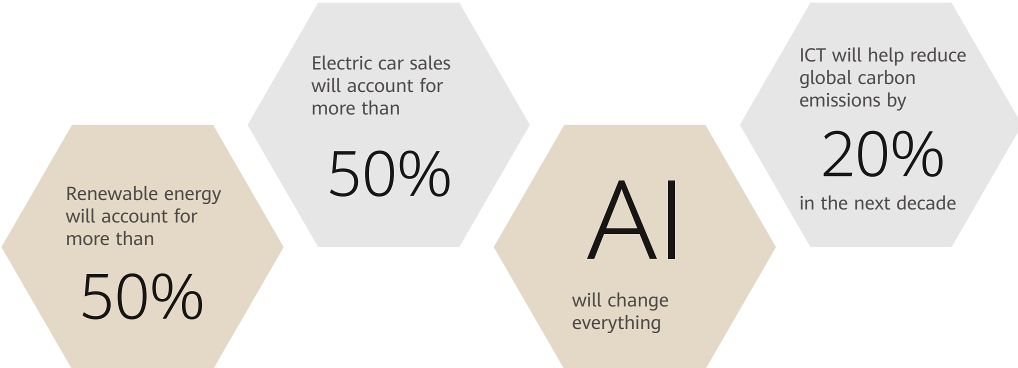
New challenges of the intelligent world

Bill Gates once said that we always overestimate the change that will occur in the next two years and underestimate the change that will occur in the next ten. This is exactly the mistake that many people are making with the Intelligent Revolution. We have overestimated the development speed of intelligent technology in the next two years. However, although 5G cannot meet the requirements of diverse IoT scenarios today, we've perhaps underestimated the changes it will bring in the next decade.

The Intelligent Revolution will bring us both unprecedented opportunities and challenges. We envision that a fully connected, intelligent world is just around the corner. However, the reality is that most current technologies are still far from mature and reliable.

Humanity and the capabilities that we've acquired through the use of current technology does not always mean we can outperform other animals in the natural world. For example, phone cameras have achieved 100x zoom, but there's still a huge gap between camera capabilities and a spider's eyes in terms of detecting the outlines of objects and motion. Therefore, we may learn from spiders to develop cameras that meet the requirements of autonomous driving. An ant's brain only consumes 0.2 mW of power, but can process many activities, like nesting, socializing, fighting, and feeding aphids. Today's deep neural network training in the AI domain is nowhere near as efficient as an ant's brain. If we can learn more about how the ant brain works, the industry may find new types of computing with lower power consumption and higher efficiency.

From a long-term perspective, the ICT industry is facing new challenges in the next 10 or even 20 years, and urgently needs a new round of breakthroughs. "The continuous development of IoT services such as autonomous driving requires ultra-broadband, low latency, and highly



What does Huawei predict 2030 will look like?

reliable computing power," said William Xu, Huawei's Director of the Board and President of the Institute of Strategic Research, at the Huawei Global Analyst Summit 2021. "However, 5G is currently not mature enough to support these diverse IoT scenarios."

Huawei believes that by the next decade, there will be hundreds of billions of connections around the world. Broadband speeds of 10 Gbps will be available for every user. We will see a 100-fold increase in computing power and storage capacity. More than 50% of energy will come from renewable sources. The technologies that power the generation, transmission, processing, and use of information and energy will need to evolve.

Based on these predictions and assumptions, Huawei presented, for the first time, the challenges and research directions it foresees in the next decade.

- Defining 5.5G to support hundreds of billions of diverse connections
- Nanoscale optics for an exponential increase in fiber capacity
- Optimizing network protocols to connect all things
- Computing power strong enough for the intelligent world
- Extracting knowledge from massive data for breakthroughs in industrial AI
- Going beyond von Neumann architecture for 100x denser storage systems
- Combining computing and sensing for a hyper-reality, multi-modal experience
- Enabling continuous self-monitoring for more proactive health management
- An intelligent Internet of Energy for the generation, storage, and consumption of greener electricity

These nine challenges and research directions are linked to each other. When we try to understand them based on the three pillars of our world – matter, energy, and information, the logical relationship among these challenges and research directions will become clearer to us.

Let’s consider the challenges of aging

populations and accelerating energy consumption. Data shows that global energy consumption is growing at an annual rate of 1.7%. According to report statistics, the pace of energy consumption has increased by 22 times since the 18th century. Currently 85% of the energy comes from non-renewable fossil fuels, while other emerging energy sources are not ready yet to play a major role. Therefore, low-carbon energy, broader electrification of industries, and intelligence are the path to sustainability.

Huawei estimates that by 2030, more than 50% of all energy will come from renewable sources, and more than 50% of cars sold will be electric. By empowering a wide range of industries, ICT has the potential to reduce global carbon emissions by 20% over the next decade. To build an intelligent Internet of Energy to achieve green electricity generation, storage, and consumption, advancements in the following key technologies are required.

First, management technologies. Digital technologies, such as big data, AI, and cloud, need to be integrated with the Internet of Energy to achieve bit-based watt management through an energy cloud and energy network.

Second, control technologies. Power electronics-based energy routers can be used to build intelligent energy network controllers that realize bidirectional energy flow and intelligent energy distribution.

Third, energy storage technologies. New energy storage technologies, including new electrochemical and hydrogen storage mediums, need to be developed for multiple scenarios to meet these growing storage requirements.

Fourth, power electronic technologies. Wide-bandgap semiconductors, including SiC and diamond for medium- and high-voltage applications, and GaN for medium- and low-voltage applications will be needed to make energy components more efficient and compact.

The intelligent era is still in its infancy, but the next ten years promises to bring changes that are more revolutionary than ever imagined. To advance toward the intelligent world of 2030, we need to address a range of challenges, involving connectivity, capacity, protocols, and computing power.

According to William Xu, the nine technological challenges and directions for further research represent what Huawei believes is needed to achieve an intelligent world by 2030: stronger connectivity, faster computing, and greener energy.

Embracing the next decade

With imagination, we can see the future, but with technology, we can get there. In his book The Inevitable, Kevin Kelly argues that there has never been a better day in the whole history of the world to invent something.

At the beginning of the third decade of the 21st century, we can see that the ICT industry is facing tremendous development opportunities and that the world is moving towards digitalization and intelligence. What will the world look like in 2030?

Many of the new technologies we know will reach the tipping point of revolution and penetrate further into every aspect of our lives. The creation and practices of entrepreneurs have shown people what the future can look like. In the future, technologies such as autonomous driving, robotics, IoT, 3D printing, blockchain, and hyper-reality, multi-modal experience will mature and be applied.

Yuval Noah Harari, author of the best-seller Sapiens: A Brief History of Humanity, once predicted that future machines would know you better than you know yourself, because artificial intelligence programs would be learning about you every day, beginning at birth, reading your every email and listening to every beat of your heart. Ultimately, it would be able to help you make better choices about anything, including life-changing decisions like who to marry and when. Heavy manual labor will increasingly be handled by robots, allowing humans to spend more time thinking and with family and friends.

What can we do today to advance toward the intelligent world of 2030? The answer lies in two key concepts — technological innovation and trust-based cooperation.

Huai Jinpeng, an academician of the Chinese Academy of Sciences, once argued that choice of a direction and path has become an ability and wisdom. In his view, cooperation and communication are the best choice when facing challenges and confusion in the intelligent era. The right

To advance toward the intelligent world of 2030, we need to address a range of challenges, involving connectivity, capacity, protocols, and computing power.

path to intelligent development is to ensure that we are moving in the right direction without being concerned about immediate benefits.

To meet the needs of human development and solve the problems we face, we need to bring together the wisdom and creativity of all mankind.

This is in line with Huawei's belief that to meet the needs of human development and solve the problems we face, we need to bring together the wisdom and creativity of all mankind. We must overcome challenges through an open, inclusive, collaborative, and innovative mechanism. We also need to combine industry, academia, research, and applications to address challenges and embrace opportunities with technological innovation.

Examples in this regard include:

- Supported by governments and the coordination of industry organizations, we can work together with industry players in industry alliances to create a development environment that encourages unity and cooperation for shared success.
- Leveraging industry and enterprise resources, we can set up innovation laboratories in universities to develop high-quality basic research talent and industry talent to meet society's need for diverse intelligent development.
- Allowing industry challenges and the world's most pressing problems to determine the direction of scientific research, leveraging the sturdy platforms and resources of enterprises, driven by high-quality research projects, and with the leadership of scientists, academicians, and experts, we can support promising young and mid-career scientists in conducting exploratory and original basic research. This will expand China's room for maneuver and influence worldwide in basic technology research and innovation.
- We can also identify and develop market demands, and set up R&D and application pilots for typical industry use cases based on leading enterprises to create a virtuous cycle of application, demand, and supply.

Undoubtedly, in terms of the prospect of creating a fully intelligent world by the next decade, the ability to unite the entire industry for collaborative innovation in certain areas of focus will really make a difference. Restoring the normal business order of the semiconductor industry requires rebuilding global trust and collaboration in the global value chain. As William Xu said, we need to integrate industrial challenges and academic insight, then adopt a venture capital mindset to innovate together and build the intelligent world of 2030.

In the current environment, this trust and cooperation will not be easy to restore, but with the powerful vision of an intelligent world to guide us, we believe that humanity is bound to reach a consensus.

In his book Intelligent Age, Wu Jun said that in past technological revolutions, a person, an enterprise, or even a country had only two options: join the wave and become one of the top 2%, or wait and hesitate, and then be eliminated. How can we become one of the 2% today? The simple answer is that we must ride the waves of the Intelligent Revolution.

Stronger and Smarter 5G, Optical & IP networks by 2030

Innovation in basic technologies and stronger 5G, optical, and IP networks are key to meeting the needs of more complex scenarios in the next decade. We need to integrate industrial challenges and research insights; adopt a venture-capitalist mindset; and innovate under a framework of open, inclusive, and collaboration between the industry, universities, and research institutes.

By Huang Haifeng, tech journalist

What will the world demand of the ICT industry in 2030? How much innovation will it take to get there? How do we develop a new mechanism for collaborative innovation between the industry, universities, and research institutes? At Huawei's Global Analyst Summit 2021, the company's Director of the Board and the President of the Institute of Strategic Research William Xu explained the nine challenges that we need to address and the research directions that will allow us to meet those challenges, including the development of connection technologies and innovation in basic technologies.

The role of connection technologies in the next decade

Stronger 5G

William Xu believes that one of the challenges is to define 5.5G so as to support hundreds of billions of connections and a very diverse range of IoT scenarios. Although the 5G-defined use cases of eMBB, uRLLC, and mMTC have generated more than 1,000 commercial contracts and revenues of US$1.2 billion for industries like energy, healthcare, and transportation, they still cannot accommodate certain IoT scenarios.

Huang Yuhong, Deputy General Manager of China Mobile Research Institute, pointed out that, "UHD and immersive services will become more popular in consumer markets, and enterprise markets will have more differentiated requirements for 5G. We've witnessed the deep integration of 5G into industries, giving rise to new requirements. Sustained growth of those industries will require continual evolution and innovation in 5G."

We've proposed that within this decade, 5.5G must cover three new scenarios that aren't yet covered by 5G: Uplink-Centric Broadband Communication (UCBC), Real-Time Broadband Communication (RTBC), and Harmonized Communication and Sensing (HCS). Together they will take us beyond the connection of everything, enabling the intelligent connection of everything.

Wang Zhiqin, Vice President of the China Academy of Information and Communications Technology, spoke on the topic of Beyond 5G (B5G), mentioning the potential of technologies such as ultra-large-scale antennas, terahertz communication, integrated AI communication, Computing First Networks, and deterministic networks – all technologies that have the potential to address the scenarios Xu described in his recent speech.

By 2030, our primary networks will need to support trillions of industry connections.

To promote the evolution of 5G, China Mobile (Shanghai) Industrial Research Institute and Huawei have jointly published the *5G Positioning Open API Industry White Paper* and defined 5G location architecture and open APIs for providing 5G location services, laying a solid foundation for upgrading to 5.5G capabilities.

Stronger optical networks

To deliver larger capacity, higher speed, and lower latency, optical networks that simply serve as underlying bearer networks today must be transformed into networks that provide services. Therefore, the second challenge William Xu highlighted is developing nanoscale optics for an exponential increase in fiber capacity.

As the capacity of reconfigurable optical add/drop multiplexer (ROADM) or optical cross-connect (OXC) continues to evolve, existing technologies are enough to meet the capacity requirements of evolving optical nodes over the next three years. Although it's still unknown which technologies will be used to meet the capacity requirements thereafter, it's likely that future traffic demand will drive trends toward ultra-large capacity, ultra-high-speed, and ultra-long-haul transmission.

At the Huawei Global Analyst Summit, William Xu laid out the path forward as he sees it. First of all, we will have to work on optical transceiver lasers and use high-modulation components to double or triple baud rates. New modulation coding and algorithms are required to multiply the capacity. And thin-film high-bandwidth modulators can greatly improve performance and be used in photoelectric devices on a wide scale.

Second, we must develop new, broad-frequency, and low-noise optical amplifiers that support manual control for reliable, ultra-long-haul transmissions. The key technology that brings us close to the quantum limit will be optical amplification.

Third, we will need to study dynamic controls for optical networks and transform the WDM network into a synchronous system to improve anti-interference features and efficiently use optical resources through computing. The key technology will be micro-cavity optical frequency combs.

In the longer term, we will also need to research new fiber and optical systems like

Space Division Multiplexing (SDM), which has the potential to increase the capacity of a single fiber by 100-fold and improve data link utilization.

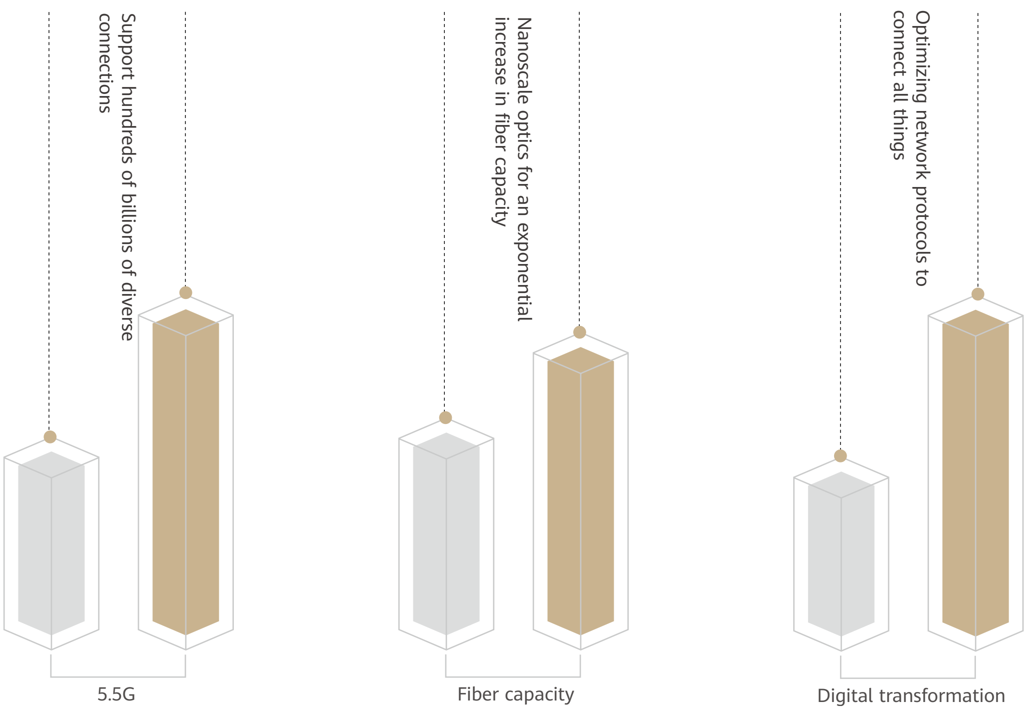
Stronger IP networks

By 2030, our primary networks will need to support trillions of industry connections. Xu believes that another challenge facing us is optimizing network protocols to connect all things. The digital transformation of governments, finance, healthcare, education, and SMEs will bring three major challenges to network protocols:

The first challenge will be achieving deterministic networks. In the past, network speeds were uncertain, sometimes fast and sometimes slow. But today, stable and deterministic network capabilities are a common requirement of industry customers. Deterministic networks and differentiated service capabilities are required to move the core production system of an enterprise from an on-premise cloud to an off-premise cloud.

To achieve deterministic networks, industry experts suggest that multi-purpose fiber should be used to build private networks for industry customers. Product functions should be iteratively enhanced from four perspectives: full cloudification, full convergence, full automation, and full services. In addition, operators must select industries and scenarios in which to make breakthroughs based on their own network planning pace.

Security: When all things are connected, security systems will face serious challenges, as large numbers of devices like drones, cameras, edge computing devices, and sensors will all present new security risks.



The time is ripe for intrinsic, end-to-end security frameworks and protocols. As a new foundation for network construction, the Industrial Internet requires more advanced endogenous network security technologies than previous networks.

"Endogenous network security" refers to security functions or attributes built on endogenous factors such as system architectures, mechanisms, scenarios, and rules. It involves capabilities such as self-discovery, self-repair, and self-balancing against general cyber attacks, as well as automatic predictions, automatic alarms, and emergency response in the face of large-scale cyber attacks.

Huawei has been exploring endogenous security for a long time. We haven't just embedded endogenous security into ICT infrastructure, we also provide external security solutions that complement each other to make networks stronger and better ensure security.

Flexibility: "As the variety of industry requirements increases, some will require longer IP addresses, while others will require shorter. To resolve this issue, we will need to expand IP addresses with fixed lengths and develop new Internet protocols that feature semantic and syntax flexibility," said William Xu. The industry is focusing on technologies such as IPv6+ and SRv6 to make IP networks more flexible.

As the latest technology evolved from IPv6, IPv6+ has attracted much attention due to its potential to improve network flexibility. Wu Hequan, an academician at the Chinese Academy of Engineering, believes that because IPv6+ meets the requirements of cloud-network synergy by allowing flexible networking, it's well placed to become the intelligent IP network protocol of the cloud-network era.

IPv6-based SRv6 has been rolled out in a number of carriers' live networks. In November 2020, China Telecom initiated the centralized procurement of devices integrated with SRv6 for CN2-DCI. China Mobile and Huawei have successfully completed the pilot deployment of the G-SRv6 header compression solution on the live network of China Mobile Guangdong. There's also strong support for SRv6 in the financial industry. Both China Construction Bank and the Agricultural Bank of China have started to deploy SRv6, aiming to make future cloud backbone networks more intelligent, agile, and ubiquitous.

However, the flexibility of IP networks cannot be achieved overnight. Related industries must work hand in hand on standards, ecosystem development, and deployment to accelerate the creation and application of new technologies over the next ten years.

Open and inclusive collaboration

To build an intelligent world by 2030, industries, universities, and research institutes should pool humanity's collective wisdom and innovation capabilities through an open, inclusive mechanism for collaborative innovation, to meet our development requirements and resolve problems.

Zhu Jinkang, a professor from the University of Science and Technology of China, stated, "Basic theories and innovation approaches about complex networks are two major factors that restrict 5G evolution. The industry, universities, and research institutions must work together to tackle the basic technical problems in 5G evolution."

As a major promoter of industry-university-research collaboration, Huawei has always attached great importance to technical innovation collaboration with universities. Huawei CEO Ren Zhengfei once said: "Universities should focus more on scientific theories and discoveries, whereas enterprises should focus more on technology, engineering, and inventions. When the results of the two sides are combined, greater energy will be generated."

In 2016, Huawei's proposal for polar codes for 5G was accepted by 3GPP, which greatly improved Huawei's stature in international standards organizations. The implementation of polar codes was the culmination of billions of dollars of investment by Huawei, R&D by thousands of our wireless experts, and theoretical research by Professor Erdal Alican from Turkey, who discovered polar codes. This is an example of how in-depth collaboration between academia and the ICT industry can crack difficult problems and further the development of the industry.

In addition to close collaboration with universities, Huawei has heavily invested in growing its R&D teams in basic research. In 2020, Huawei invested more than 140 billion Chinese yuan (US$21.6 billion) in R&D, ranking third among enterprises globally. Huawei employs thousands of the world's top mathematicians and physicists, and we've long been committed to investing 20% to 30% of our annual R&D budget into basic research.

In the next decade, close collaboration between the industry, universities, and research institutes will empower universities to make more breakthroughs and innovations in basic theories. These innovations may boost the development of the ICT industry in the next decade, and its effects may still be felt even further into the future. We believe that collaborative innovation will drive social, economic, and human progress, and ultimately lead to an intelligent world by 2030.

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Dell'Oro Group on Campus Network Trends in the Post-pandemic Era

Dell'Oro Group Founder & CEO Tam Dell'Oro and Huawei's Jason Ding discusse the new era of digitalization and networking trends that is unfolding.

The pandemic-driven increase in enterprise digitalization and more widespread use of technologies like cloud, IoT, and AI has had a far-reaching impact on campus networks. Dell'Oro Group Founder and CEO Tam Dell'Oro sat down with Jason Ding, Marketing Director of Huawei's Campus Network Domain, to talk about the current campus network trends and technologies of future campus networks. They also covered the change in enterprise office, production, and infrastructure that we're seeing in the post-pandemic era, and new ways to accelerate enterprise digital transformation.

Dell'Oro Group is a leading market analysis and research firm covering the areas of telecommunications, enterprise networks, data center IT infrastructure, servers, and storage systems. Dell'Oro Group also provides detailed analyses on data center cloud providers. The company's founder and CEO Tam Dell'Oro has been the lead analyst on the Wireless LAN research program since January 2017.

The future of work

Jason Ding: Some enterprises are choosing to have their employees work from home permanently, some want them to return to the office, while others prefer a mix of the two. Are you seeing these trends happening globally and how will it change campus infrastructure?

Tam Dell'Oro: Yes, we're definitely seeing change in the works. Many systems integrators and some IT managers I've interviewed have indicated that they're looking to downsize their office space, as more employees are working remotely at least part of the time.

What may unfold after the pandemic is a higher percentage of people who will be working remotely a couple of days a week.

People still need to come together for innovation and collaboration. What this means is that the office network will likely be less wired with assigned workstations, and more wireless where there'll be a docking station and an electric charger for a cell phone, and transient people coming through using the same desk. What that also means is conference rooms having video conferencing capabilities and more sensors signaling when heating or lighting is needed — essentially buildings will become more intelligent. We expect real estate agencies to use technology to increase the attractiveness of their buildings, because more commercial real estate may become available. There will be more applications where people can reserve rooms remotely, and see what services are available in the vicinity and how to locate them, for example, getting meals or cleaning clothes. So, we'll see quite a significant change unfolding with the buildings and the workplace.

Ding: Yes, exactly. That's exactly the transformation we're seeing in different types of campuses or different types of the buildings. It's not just wired to connect people and connect devices, but also wireless as the first strategy to enable all digital services and build smart buildings.

The future of infrastructure

Ding: Wi-Fi 6 is the latest Wi-Fi standard and it brings better bandwidth, a better experience for roaming and latency, and better interference suppression. When we need to build a smart building or smart infrastructures, what are the procurement factors for Wi-Fi infrastructure itself? And what are the other procurement factors that enterprises need to consider as they build fully wireless connectivity for a better user experience across their campus and across their infrastructures. Finally, what are some of the technologies that customers need to think about when they're constructing or planning new infrastructures in 2021?

Dell'Oro: What we're seeing is predictive analytics. We're seeing a higher demand for applications that are going to run over these Wi-Fi networks that previously weren't a consideration — like remote troubleshooting, sensing who the users are that are coming into rooms, and dealing with multiple different applications that those users might need, like dealing with issues like healthcare, distancing, and perhaps temperature gauging. And like

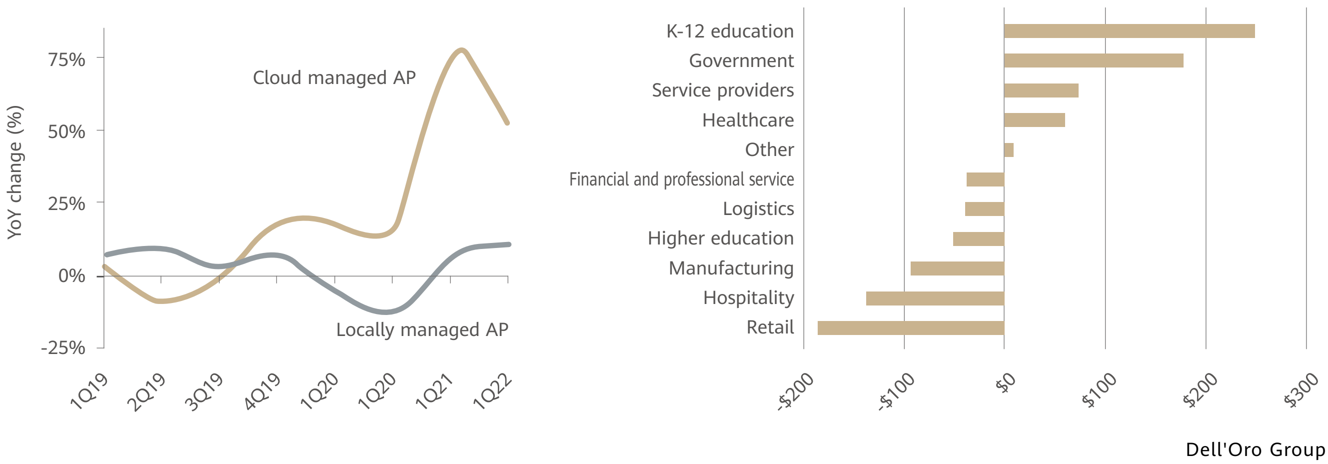


Figure 1: Enterprise wireless AP shipment YoY

location tracing — if someone has been sick, who else have they been in contact with? So, it's not just bandwidth; it's a step-up in the intelligence of the network.

We also saw that cloud-managed wireless LAN sales shot up in the second quarter and third quarter of 2020. Demand leveled off a little in the fourth quarter, but there's always seasonality. People definitely want to deploy technologies where they can do more network management remotely and troubleshooting remotely. There is definitely more demand for remote capabilities.

Ding: The infrastructures that enterprises own today are global. You may have your factory in Shanghai. You may have your R&D center in Hong Kong or in Singapore. You have to manage your global infrastructures in a single place to help easily and quickly deploy your digital services. So, there's another trend where applications are going to cloud. We're seeing more enterprises using cloud-based SaaS applications for their office work, for their marketing, for their sales, and even for their production operations. With greater cloudification, do you see the increased adoption of SD-WAN technology within campus networks? What do you predict for 2021?

Dell'Oro: We've definitely seen an uptake of SD-WAN and cloud management. SD-WAN has incorporated much more security, with more business-critical applications and people remotely trying to connect. The importance of security has shot up.

Ding: Yeah, when we have critical meetings with different locations globally, everyone within the campus and customers or partners must all have the same experience, for example, zero jitter and no interruptions. People may not be able to travel today, but they want to have the same experience virtually as they do with in-person meetings. That's the requirement for SD-WAN and also for the Wi-Fi network. Within the campus, we need Wi-Fi to enable or assure experience. Outside the campus, we need to have SD-WAN at the other end of the infrastructure to enable experience for cloud and public cloud services.

The future of production

Ding: We talked a lot about the office environment and about how infrastructure enables smart work. What about production? We're seeing that IP technology, the wireless LAN, the SD-WAN, and also SDN and AI technology, is starting to be used in various industries, like healthcare, manufacturing, retail, and education. Do you see any use cases in any of these sectors? How are they using the latest technology to enable digital applications or digital services?

Dell'Oro: Absolutely. The pandemic has been a trigger. And the pandemic has escalated the awareness of the governments of many different countries that businesses, schools, and cities need to advance and enable their people, their residents, and their constituents. We've seen a remarkable increase in Wi-Fi in the second half of 2020, particularly from the education sector, mostly lower education kindergarten through 12th grade, followed by the government sector. The next thing we see advancing is the manufacturing sector. These vertical industries have embraced Wi-Fi technology the fastest. Note that the service provider sector has grown in strength from the increase of work-from-home managed services.

Significant funding has flowed into schools, into city townships, just to enable communications. Local politicians have been getting involved with network deployment, both long-haul and Local Area Networks, to enable Internet connectivity to the home for both education and work performance. That means they're setting up Wi-Fi in buildings, in libraries, or in parking lots. Some governments have been advancing manufacturing to attract business globally, using sensors to read license plates or bar codes so that trucks or machines can be directed without a human. Other governments have been advancing technology at universities to attract students and be ranked among the world's leading universities in research and technology.

Ding: Yes, within education, teachers are teaching in front of the camera and students are staying in their dorms. There is demand in our buildings and dormitories for better Wi-Fi connectivity to enable a better bandwidth and allow multiple users to connect to the infrastructure simultaneously and stably, thereby delivering better education experiences.

In agriculture, we're seeing that digital technologies like Wi-Fi and IoT are used to monitor pigs, and make rearing pigs smarter, for example, so we can know their temperature, the food they eat, monitor when they walk, and make sure they aren't sick. Those are the examples of Wi-Fi, IoT, and campus technologies that not only exist in office environments, but are also starting to emerge in various sectors. The post-pandemic era is activating those new use cases and new applications in those spaces.

It is foreseeable that we will have better network and service experiences not only in offices, but also in homes, public spaces, and in production spaces. Governments will provide better and more convenient public services, enterprise employees will work anytime, anywhere, and students will learn and communicate at any time, in any location. One of key enablers for this better world will be the future-proof campus network.

The service provider sector has grown in strength from the increase of work-from-home managed services.

Data-driven Solutions for Driving Away Algae

Cyanobacteria, or blue-green algae, is a major headache for urban water management. It's a danger to fish, contaminates drinking water, and ruins the visual appeal of the area it affects. The traditional approach to algae management focuses on prevention and treatment and is far from adequate – until now. Advances in AI, big data, and 5G can automate the whole process, from identification and monitoring to harvesting, without increasing labor.

By Pan Wei, Solution Architecture & Design, Enterprise BG, Huawei

Many cities in the southern reaches of the Yangtze River are home to vast water networks dotted with scenic lakes and tourist-targeted lakeside restaurants and entertainment. The boost to city incomes is accompanied by blooms of blue-green algae in spring, summer, and fall, which degrade aquatic ecology and deter tourists with the unpleasant look and smell.

In the past, algae management relied on manual observation, manually operated unmanned aerial vehicle (UAV) inspections, and aquatic weed harvesters. However, as algae floats with the wind, these method aren't sufficient.

The digital foundation of Huawei's smart city approach can be applied to local ecology through AI-enhanced UAVs. Invoking and orchestrating UAV fleet management and route planning capabilities makes regular, task-driven algae inspections possible.

Visible light imaging

Examining the difference between the optical properties of a blue-green algal bloom and unaffected water shows that the refraction of algae improves significantly in infrared and near-infrared bands, but remote sensing reflectance (Rrs) is higher in the green band, as algae contains chlorophyll-a. The most common way to tell algae and normal water apart is to reconstruct simple features, such as band variances, based on the data of different bands and multispectral

Figure 1: Algae floating on a lake surface (simple identification)

Figure 2: Algae floating on a narrow waterway surface (more complex identification)

Figure 3: Shoreline algae

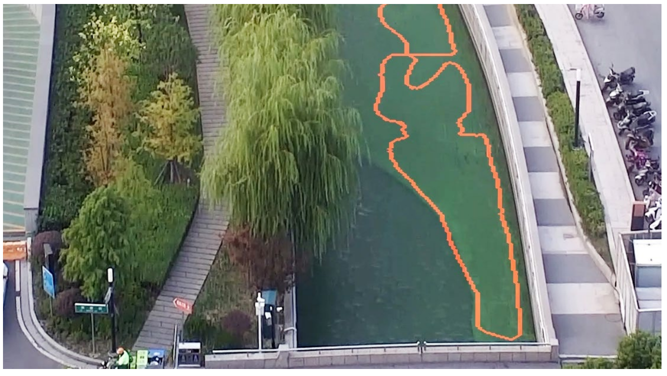
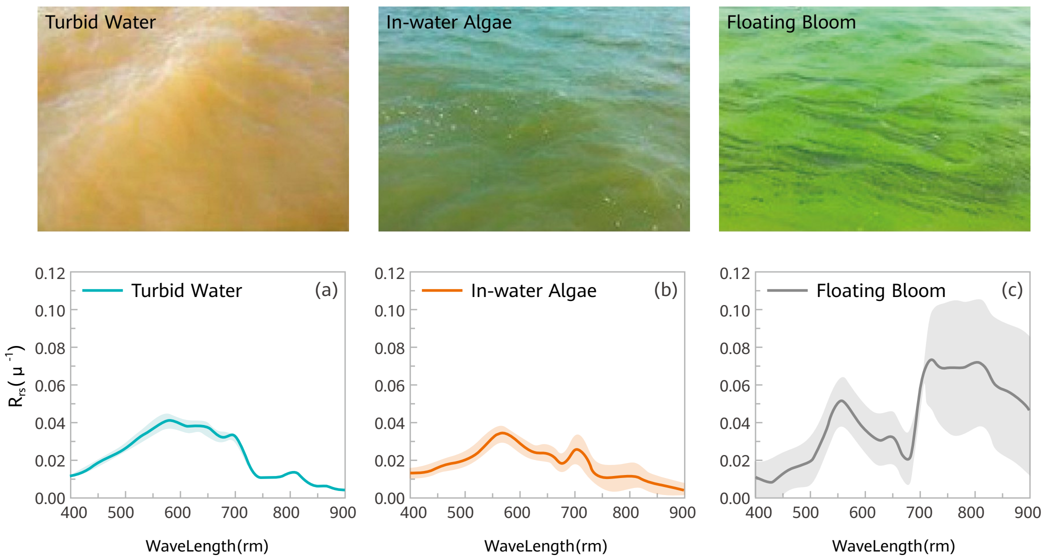


Figure 4: Algae on a neighborhood river surface identified by AI-powered UAVs



Source: The Assessment of Landsat-8 OLI Atmospheric Correction Algorithms for Inland Waters, MDPI, 2018

Figure 5: Variations in bio-optical properties (Rrs) of turbid water, in-water algae, and floating bloom

imaging. Differences can be identified using classical imaging segmentation methods or classification methods, such as support vector machine (SVM), for machine learning.

UAV-mounted cameras normally use visible-light images, which requires machine vision. Unlike multispectral images, visible-light images don't cover infrared bands and the green band is basically indistinguishable, making it difficult to accurately identify blue-green algae. As UAVs are deployed outdoors, their detection functionality is also affected by factors like shooting angle, distance, and lighting conditions. The color of some algal blooms can appear almost identical to the surrounding water due to strong light reflection, so sample images don't accurately show color variance. City managers must frequently change the cameras in the UAVs or mount multiple cameras on a single UAV, which boosts identification efficacy but reduces efficiency and is limited by the battery life of UAVs.

To address this problem, we must identify the optimal technical path for visible-light-based visual recognition. Huawei's Intelligent Operation Center (IOC) features big data and AI capabilities that use a deep neural network algorithm and multi-scale fusion network to extract datasets of algal images from various types of terrain, ranging from simple water-surface and shoreline to more complex water flows through median strips or shoreline neighborhoods. Complex models plus constant learning and training allow Huawei's IOC to more accurately and efficiently detect algae.

Powered by IOC for algae prevention

The IOC enables municipal authorities to deploy large-scale intelligent services. Its AI platform can centrally develop algorithm models and provide full-lifecycle management services. The IOC integrates machine vision identification capabilities into various APIs that can be orchestrated and coordinated for the reuse, combination, and large-scale development of user applications. The solution minimizes manual intervention and O&M costs, and supports integrated operations.

Key technologies

Video data collection: The video cloud supports H.264 and H.265 video coding formats, receives and stores real-time video streams from UAVs over the Internet, and exposes video capture and retrieval services to the AI platform through APIs.

5G connection: Powered by 5G's low latency and high bandwidth, UAVs support 4K ultra-HD image transmission and AI-enabled real-time identification and alerts.

AI algorithm scheduling: The AI platform can invoke the video stream data sent from the UAVs to calculate the longitude, latitude, severity, and distribution of algal blooms based on video timestamps and flight data. It calculates the accumulated algae area discovered by the UAVs, captures algae images and video clips, and sends different levels of alarms to the work order preprocessing and distribution system.

Application integration and message integration: The API gateway acts as the service platform that receives algae identification data sent from the AI platform. It packages other service logic data, such as real-time UAV location, and uses the messaging middleware service to place the data in message queues. It then sends the message queues to visualized user interfaces or other service systems that subscribe to the message service.

Big data analytics and processing: The deep learning module underpins algae identification algorithms. Based on data governance, it packs algae data into different subjects and defines data dimension structures based on different service requirements to provide customized content.

UAV fleet management capability: The UAV hangar and management software provided by Huawei's partners enables fully autonomous UAV scheduling and driving. The hangar supports automatic take-off, landing, and charging. Flight packets can be sent back to the IOC in real time to open up the scheduling capability.

Optimized flight: The IOC controls the hangar and sets fleet flight routes and mission plans based on factors such as key areas, time, and tasks. The UAVs take off automatically and the AI algorithm automatically calculates the area and location of algae and algal protein concentration. Automated incident reports and work orders enable prompt, accurate, and efficient harvesting. The IOC normalizes the process of sending information such as algae alarms and work order closure statistics to different users in the form of SMS messages or printed reports.

One city in Jiangsu deployed an IOC in 2020. It covers 19 square kilometers of water in the city with two UAVs, averaging 12 flights per

The IOC controls the hangar and sets fleet flight routes and mission plans based on factors such as key areas, time, and tasks.

Data can train and optimize an AI algae visual identification model, and identify enterprises that discharge wastewater, components in wastewater, discharge locations, and the raw materials and processes they use.

day. Without increasing staffing or vessels, 36,000 tons of blue-green algae have been harvested since the system was deployed and 15.1 tons of algae sludge were divided, boosting efficiency by more than 45%.

Stopping water pollution at the source

Seasonal changes and local weather patterns can affect blue-green algae growth, but it's the industrial wastewater and domestic sewage that cause the major spikes. Wastewater, for example, can lead to excessive nutrients such as nitrogen and phosphorus, encouraging year-round blooms in river basins with concentrations of businesses and restaurants. Harvesting teams could clear the areas daily, but the blooms would return the next day. So, the solution is to control the sources of pollution.

To get the most out of technology, water needs to be able to purify itself through restored aquatic food chains. We must control industrial wastewater and domestic sewage discharge, and treat wastewater to remove nutrients that cause blue-green algae spikes. The IOC's big data platform performs vertical and horizontal data mining, with blue-green algae alarms and clean-up tasks generated based on wastewater discharge standards and data for sewer monitoring and enterprise violators that's provided by various authorities. The IOC can profile enterprises located along riverways to enable wastewater governance from the source.

For data quantification and modeling, water pollution models can be created based on the data, such as algal protein density, pH, electrolyte, chlorophyll, and turbidity, obtained by IoT sensors on unmanned surface vessels (USVs) during river cruises. This data can train and optimize an AI algae visual identification model, and identify enterprises that discharge wastewater, components in wastewater, discharge locations, and the raw materials and processes they use. The data can be used to study how these factors relate to the distribution, area, and concentration of seasonal algae outbreaks and the number of harvesting operations, and can help identify illegal discharge through concealed pipes or leaks. The process requires the traversal of various combinations of possibilities, simulation-based inference, and decision-making.

USVs can send up-close monitoring data back to the IOC through the 5G network. UAVs can automatically respond to the requests of USVs and follow their tracks in the sky. In-depth detection and wide-area monitoring by both UAVs and USVs can make water management more time-efficient and intelligent.

Thermal mapping services provided through high-altitude remote sensing satellites can be used to periodically analyze the distribution of algae on the surface of large bodies of water. Along with weather data, this enables targeted trend analyses, mission planning and route design for cruise flights, and harvesting operations, which minimize the time and labor required for these operations. This space-sky-surface collaboration not only applies to blue-green algae identification, but also to urban water resource management, ecological restoration, environmental protection, disaster prevention, and more.

Embarking on a Customer-centric Digital Transformation Journey

With 5G, customers demand more diverse telecom services. For carriers, this is both a blessing and a curse, as it creates business opportunities but poses new challenges for network O&M. Huawei's SmartCare enables open, automated, and intelligent digital capabilities, enabling carriers to maximize the value of their data, improve customer experience, and boost operational efficiency.

By Liang Shiming, General Manager, SmartCare Domain, Global Technical Service Department, Huawei

The mobile Internet is growing at lightning speed and has become the enabler of digital lifestyles. Digital technology is reshaping the way we live: A few taps on a smartphone app and we can do pretty much anything nowadays – it's our personal assistant that makes everyday life easier and more enjoyable.

Digital technology now plays a critical role in every link of the food delivery process, including the automated recommendation of restaurants by distance, online category selection supported by real-time inventory data synchronization, SLA management (such as courier and delivery status), and cost management based on customer satisfaction. Thanks to digital technology, the whole process can be finished in less than an hour. Digital technology has not just changed how consumers order food delivery, it has pushed the catering industry as a whole towards Internet-based business models.

A similar trend is seen in the telecom industry, where OTT players are eating into carriers' markets. In response, carriers need to be more proactive and reinvent themselves to create new sources of growth.

Customer experience: The heart of digital transformation

Digital transformation is a massive undertaking that involves all aspects of a business. TM Forum's anatomy of a digital native depicts the essential components of digital transformation. Customer centricity – or more specifically customer experience – is at the heart of this journey, enabled by a unified digital platform, automation, cloud,

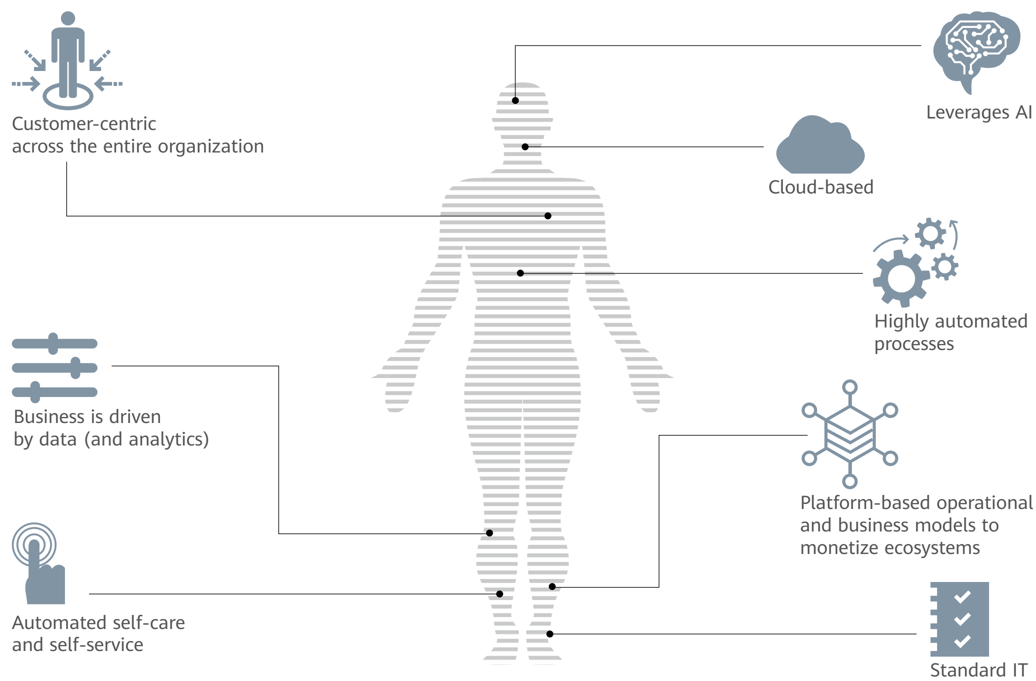


Figure 1: TM Forum's anatomy of a digital native

and AI. Clearly, it's vital for an established business to choose the right path to digital transformation because this will entail new systems in addition to changes to the corporate culture and corporate functions.

MIT has identified four path to digital transformation (see Figure 2) that reflect the characteristics and stages of different industries.

- Highly industrialized companies, such as manufacturing companies, may prefer the first path, in which they make their platforms more standards-compliant for greater operational efficiency.
- Some companies whose business is under threat because of market disruptors are more suited to the second path in which they pursue customer-experience-centric transformation. Companies in service sectors like catering and finance are examples of companies in this category.
- Some asset-heavy companies directly deliver services to end users and share some similarities with companies that follow the first and second pathways. Companies in this category best suit the third path in which they pursue digital transformation by focusing on both customer experience and operational efficiency. Telecom carriers are a good example of companies in this category.
- Asset-light companies, such as Internet companies, often abandon legacy architecture and build cloud-native operations systems by moving along the fourth path.

Convergence platforms boost openness, intelligence, and efficiency

Huawei's SmartCare helps carriers build

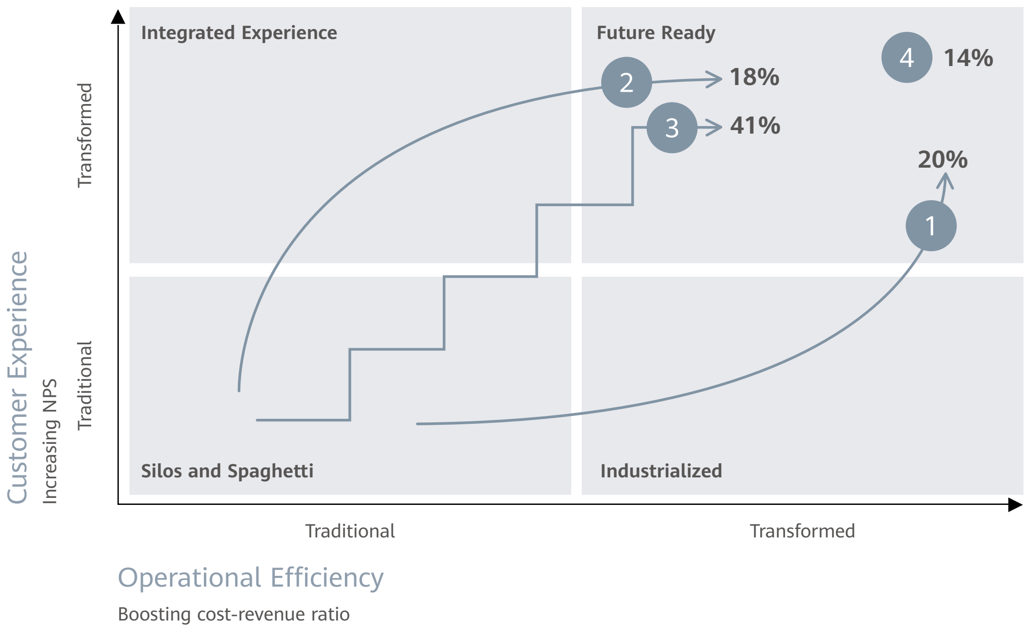


Figure 2: Four pathways to digital transformation; the MIT Center for Information Systems Research (CISR)

a unified digital foundation for a better customer experience and higher operational efficiency. SmartCare is powered by Huawei's General Digital Engine (GDE), which includes leading technologies for data sharing, intelligent operation processes, capability sharing, and integrated low-code application development. SmartCare is a convergence platform that enables greater openness, intelligence, and efficiency, and the ability to deliver a rich set of scenario-specific applications alongside ecosystem partners.

Traditional data mining uses sandboxes for raw data processing. The computing and storage resources needed to execute this approach are extremely difficult to predict. In addition, this approach requires high levels of expertise from developers, and makes it difficult to amass and share models and assets.

This is where Huawei's GDE can help. Its big data processing platform DataCube packages data into separate subject area models to enable no-code or low-code development. This lowers the barriers to entry for application development and cuts the time needed to develop an analytics application down to 7–15 days, as opposed to the 45 days it normally takes. This open platform gives developers the capabilities they need, and paves the way for transforming towards integrated research and operations.

The AI engines inside SmartCare automate repetitive tasks and use AI to handle more complex tasks, drastically improving the accuracy of tasks like data traffic forecasting, complaint forecasting and prevention, automated sensing and assessment of wireless network performance, and identification of potential 5G customers.

SmartCare is a comprehensive solution for data collection, computing, and analytics, and leads the industry with its ability to collect data from over 20 5G interfaces. Its core algorithms – including those for intelligent traffic-based scheduling, and the intelligent identification and storage of hot and cold data – bring system energy efficiency to an unprecedented level, reducing energy consumption by at least 20%.

With SmartCare, all of a carrier's departments – from network deployment, network optimization, and O&M, to customer service, marketing, and sales – can integrate their data and obtain the scenario-specific applications they need to meet customer demand for all types of services on all types of networks. For example, SmartCare can provide 5G use cases covering the entire customer journey and the carrier's operating process. Such use cases include value-driven network construction; a 5G service provisioning map; service assurance for high-value customers; and service experience management for Cloud X, ToB private lines, and HD video uploading. SmartCare works in close collaboration with carriers' operating processes to maximize the value of their data.

Over the past decade, Huawei has worked closely with industry organizations to develop SmartCare, contributing to telecom network experience standards and processes. By the end of 2020, SmartCare had already helped 110 carriers operate 180 networks in more than 70 countries, boosting networks' operational efficiency and customer experience. Huawei has built two global SmartCare showcases, one with China Mobile Zhejiang and another with Hong Kong Telecommunications. The company has also established a customer experience research center called eLab. Moving forward, Huawei will keep working on customer experience management.

Future generations of Huawei's SmartCare convergence platform will provide more open capabilities to empower more developers. Huawei will continue to contribute to experience standards, and, through partnerships and joint innovation with carriers, facilitate carriers' experience-centric digital transformation in O&M and operations. Ultimately, Huawei is dedicated to helping carriers maximize network value and make an intelligent experience available for all.

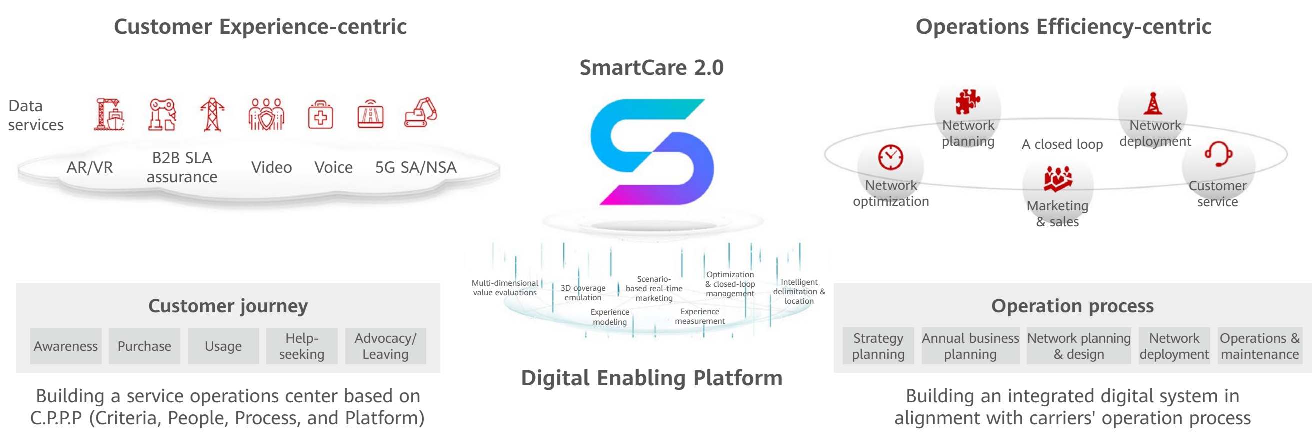


Figure 3: A digital transformation solution that focuses on customer experience and operational efficiency

Strengthening the Internet with Enhanced IP Capabilities

The limited domains that enable some IP network capabilities to be enhanced provide a new way for IP networks to benefit from cloud and AI, as they navigate industry digitalization through scenario-based innovation.

By Tang Xinbing, CTO of Huawei Data Communication Product Line

Brian Carpenter, author of "Architectural Principles of the Internet (RFC 8799)", recently published a new article titled "Limited Domains and Internet Protocols (RFC 8799)". The article has made limited domains a new trend that's gaining traction in the Internet technology community.

In the article, Carpenter said that, "There is a tendency when new protocols and protocol extensions are proposed to always ask the question 'How will this work across the open Internet?'"

According to Carpenter, this is not always the right question, "There are protocols

Over the course of industry digitalization, we have noticed that the idea of limited domains can be used to enhance some IP network capabilities.

and extensions that are not intended to work across the open Internet." On the contrary, their requirements and semantics are specifically limited, as there are tens of billions of nodes that connect directly and indirectly to the Internet. While it's clearly desirable to use common solutions wherever possible, it's increasingly difficult to do so to satisfy widely varying requirements. For example, the supervisory control and data acquisition (SCADA) networks used in connected vehicle and industrial control domains and the enterprise networks used for cross-regional and multi-campus interconnection have their own specific requirements. The solutions, technologies, and protocols used to satisfy these requirements only need to work within specific limited domains.

The Internet Engineering Task Force (IETF) requires that protocol innovation is deployed across the whole Internet on a global scale. However, this requirement is so high that it may restrain some scenario-based innovation that enhances partial capabilities.

Over the course of industry digitalization, we have noticed that the idea of limited domains can be used to enhance some IP network capabilities. That means providing enhanced IP capabilities in limited domains to turn non-IP devices into IP devices. This provides a new way for the scenario-based innovation of IP network technology. With the wide application of new technologies, such as 5G, cloud, big data, artificial intelligence, and machine vision, IP WANs open the door for industries to benefit from cloud and AI technologies. Industry digitalization scenarios require real-time data collection, aggregation, and accurate analysis, based on which enterprises can adjust production and transactions.

For example, although industrial cameras can greatly boost the quality inspection efficiency of production lines, they must be deployed on the production line. Therefore, industrial cameras can only rely on industrial buses to collect and analyze data and deliver braking instructions over the LAN. This makes it difficult to implement remote control and use cloud technology to improve computing efficiency.

In another example, Industry 4.0 proposes separating the logic control, program storage, and I/O modules of programmable logic controllers (PLCs). It instead recommends optimizing PLCs' logic control programs by using data analytics on the cloud and adjusting the actions of I/O modules in real time to improve industrial production efficiency and manufacturing flexibility. This requires latency levels normally achieved with an industrial bus from the IP WAN, not just LAN. Conventional IP networks cannot meet this latency requirement, and it's only possible with enhanced IP capabilities such as deterministic IP WAN.

However, deploying this level of enhanced IP capability across the open Internet is neither necessary nor possible. If we provide specific enhanced IP capability sets in limited domains for specific scenarios to meet scenario-specific requirements, then the originally non-IP-based devices can become IP-based and serve as connected nodes on

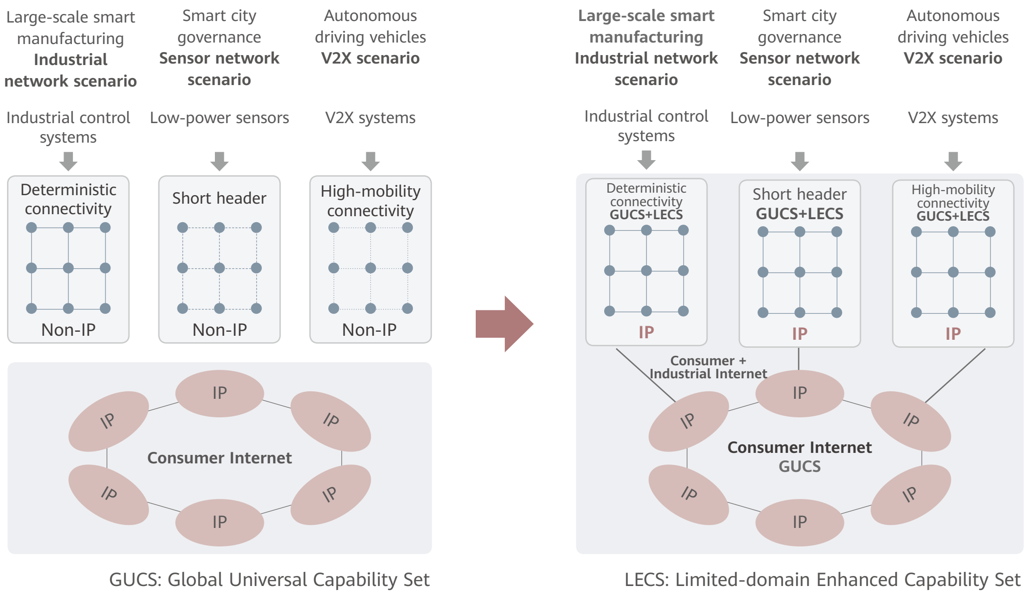


Figure 1: Providing enhanced IP capability sets in limited domains, and using universal capability sets beyond limited domains

the IP WAN to benefit from cloud and AI technologies.

However, there are concerns that deploying an enhanced capability set in limited domains could lead to a split Internet. However, there's growing evidence that these concerns may be unfounded. Limited-domain networks also support global universal capability sets, so the limited domains remain part of the open Internet and are globally accessible like other network domains.

Networks beyond these limited domains lack enhanced capability sets, but can still use the original global capability sets. For example, although high-speed trains run at a much higher speed on high-speed rails than regular trains, they can still run on regular rails at reduced speeds because high-speed trains also use standard wheels and rails, and the high-speed railway network is part of the entire railway network. In fact, the enhanced IP capability sets in limited domains make originally non-IP-based devices IP-based, turning them into new connected nodes on the open Internet. This objectively expands the scope of the Internet, strengthening the Internet, rather than splitting it.

Advancing IP technologies are breaking the bottleneck in consumer Internet growth and are being applied in more challenging vertical-industry scenarios to help real-economy industries, such as transportation, energy, and manufacturing, embrace the benefits of cloud and AI. This means we must keep up with the evolving requirements of vertical industries and open up new frontiers of all-IP networks through scenario-based innovation.

From Cloud-Network Convergence to Computing-Network Convergence

As the Industrial Internet and AI mature, computing resources are everywhere and Compute First Networking (CFN) has become the new focus of ICT network development. By providing users with integrated services such as diversified computing power and cloud service applications, China Unicom is transforming itself from a traditional pipe operator into an integrated information service provider.

By Tang Xiongyan, Chief Scientist, China Unicom Research Institute

Enterprise digitalization is accelerating and the large corresponding number of enterprise cloud applications make computing power an imperative. The demands that cloud places on network performance today go beyond just bandwidth and latency; they prompt a new focus on more flexibly providing computing power configurations. As more enterprises migrate to cloud, the more demands that cloud places on network architecture.

CUBE-NET 2.0 advances cloud-network convergence

In 2015, China Unicom realized the significance of cloud to the development of networks. Therefore, we published the *New-Generation Network CUBE-Net 2.0 White Paper*. The paper presents our vision of a decoupled, intensive network architecture oriented toward both cloud and devices that can build elastic ultra-broadband networks based on SDN/NFV. With these networks, China Unicom can provide cloud-network converged services for users and develop an open industry ecosystem. CUBE-Net 2.0 is our top-level design for network transformation, and has evolved our transformation to become based on SDN, NFV, cloud, and intelligence.

Over the past few years, guided by CUBE-Net 2.0, China Unicom carried out a number of practical implementations of cloud-network convergence. The most important work was done in 2016, when we upgraded our IP networks for government and enterprise customers into SDN-based CloudBond networks, and called it China Unicom Industrial Internet (CUII). China Unicom also promoted the use of SDN in the metropolitan domain to build intelligent MANs. The intelligent MAN is a next-gen metro IP network infrastructure developed using SDN and Segment Routing (SR) technologies. With the wide-area CloudBond network and intelligent MAN, we can provide users with end-to-end integrated cloud and network services, offering them easy access to cloud, cloud-to-cloud interconnection, and scalable cloud-network services.

Currently, China Unicom's CloudBond network covers over 300 cities in China, and we now own over 200 four- and five-star data centers. The CloudBond network serves both China Unicom's own cloud and also 50 Chinese and international cloud service providers, including the top 10 providers. That means users of China Unicom's CloudBond network service can freely choose other cloud service providers they want.

Carriers need to provide more intelligent and converged services for computing to take place on devices, at the edge, or in the cloud.

Ubiquitous computing drives the deeper integration of computing and networks

The Internet has also been growing and evolving from consumer-oriented to industry-oriented. In the era of the consumer-oriented Internet, carriers mainly provided the basic pipe-based connectivity and data services that support content services between cloud and devices. Today, as we enter the era of the industry-oriented Internet and witness the development of AI, computing resources are now everywhere. Carriers need to provide more intelligent

Carriers can play an important role in delivering diversified computing power to users and applications.

and converged services for computing to take place on devices, at the edge, or in the cloud. This is the beginning of an evolution from central-cloud-based cloud computing to ubiquitous computing.

China is advancing its New Infrastructure initiative, which is the new engine that will boost the digital economy. New Infrastructure includes three areas: information-based infrastructure, converged infrastructure, and innovative infrastructure. Carriers are most concerned with information-based infrastructure, which consists of communication network infrastructure, computing infrastructure, and new technology infrastructure.

As the focus of cloud computing moves toward edge computing, the computing power of the cloud, edge, and devices will be further synergized. We're entering a time of ubiquitous computing, in which computing and networks will be deeply integrated. A major advantage of ubiquitous computing is the reduction in both latency and cost. Latency is reduced because users and applications can obtain the computing services they need nearby and some applications can utilize computing power on the device or edge, rather than in a central cloud. The shortening of the physical transmission distance also reduces transmission costs. China Unicom can assign different computing resources for different applications, so that computing power is better utilized, which lowers computing power costs. Ubiquitous computing services require Compute First Networking (CFN) to realize intelligent computing power scheduling and efficient computing power transmission. Therefore, CFN has become one of the new focuses of ICT network development.

There are various computing resources out there with technologies including CPUs, GPUs, and ASICs. Computing power is distributed among central clouds, the edge, and devices. Two major technical service forms are cloud computing and supercomputing. Carriers can play an important role in delivering diversified computing power to users and applications. Various application service providers may require different computing resources, and carriers can serve as the intermediary for computing power and applications to provide these resources to users. They can integrate different services to provide integrated computing power and applications for users. In this way, carriers can transform themselves from traditional pipe operators into integrated information service providers.

Networking is the underlying technology of computing services, so carriers need to enhance their network capabilities to achieve sensing-based computing power scheduling and deterministic connections. To roll out a CFN, the network must be able to sense applications and computing power. Specifically, carriers can use the IPv6 extension header to transfer the application information prompt requirement to the network, and deploy services and adjust resources to meet the SLA requirements of applications. To establish deterministic connections, carriers can develop deterministic networks that ensure end-to-end transmission quality by avoiding

congestion and redundant transmission, specifying data transmission paths, and controlling end-to-end latency. It is crucial that the network can sense computing resources to realize flexible allocation and dynamic scheduling, so it can route tasks to the correct target compute nodes.

Developing CFN technology

To realize the intelligent scheduling of computing power and provide deterministic services, CFN must be enabled by three elements: the networking element and the cloudification element, which we are already familiar with, and the compute element, which is new.

First, networking technology needs to be further developed. In the past, our networks mainly focused on the end-to-end bandwidth of connectivity. Today, we need to pay more attention to end-to-end determinism to enable lossless network transmission. In terms of network

At the end of 2020, China Unicom took the lead in establishing the CFN Industry Alliance to further drive the development of CFN technologies.

cloudification, we used to develop SDN and NFV. Today, we need to integrate SDN and NFV more closely. In particular, intelligent technologies need to be introduced to develop network AI. We should also use SR technology to support more flexible and centralized network control and scheduling. We also need to add new computing elements. That is to say, we need to enable the transaction and routing of computer power. Ultimately, we must realize two key features: sensing-based computing power scheduling and deterministic connections.

China Unicom has attached great importance to the development of CFN in recent years, actively promoting the R&D of CFN technologies. In 2019, we published the first CFN white paper in China. In 2020, we published the White Paper on CFN Architecture and Key Technologies. These white papers systematically describe the current status and prospects of CFN architecture, its technical standards, and ecosystem collaboration. At the end of 2020, China Unicom took the lead in establishing the CFN Industry Alliance to further drive the development of CFN technologies.

Moving toward cloud-network convergence 2.0

Cloud-network convergence is still in its initial phase, the phase that China Unicom's CloudBond is also in. In this phase, although cloud computing and network services are provided in an integrated way network services are mainly used for the central cloud, and the cloud and network are relatively independent. China Unicom believes that the second phase of cloud-network convergence will be computing-network integration. With the development of edge computing and AI, computing power is everywhere. Networks need to provide more intelligent services for the efficient collaboration of cloud, edge, and device computing. There will be deeper integration of computing and networks. In this computing-network-integration phase, we need to achieve sensing-based computing power scheduling and deterministic connectivity.

To facilitate the development of networks, China Unicom plans to introduce a number of network innovations in 2021, mainly in three aspects: The first is realizing computing-network integration through CFN. The second is using deterministic networks to provide customized services with deterministic experience for vertical industry applications and video services. The third is building an all-optical base to provide the optimal network infrastructure for cloud-network services.

To facilitate the evolution of the entire network, China Unicom will upgrade its CUBE-Net 2.0 to CUBE-Net 3.0. CUBE-Net 2.0 was a network based on SDN/NFV, and CUBE-Net 3.0 is defined as the next-generation digital infrastructure which features computing-network integration. We would like to work with industry partners on CUBE-Net 3.0 to build a future-oriented next-generation digital infrastructure to better serve the digital economy and boost China's cyber development strategy.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