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Respecting and Protecting Intellectual Property: The Foundation of Innovation

Huawei White Paper on Innovation and Intellectual Property

(2020)

HUAWEI

Contents

Preface

The 2020 pandemic has had an unprecedented impact on the global economy, bringing lasting changes to the way we live, work, and learn. Fortunately, information and communications technology (ICT) is playing a vital role in our fight against the pandemic and in supporting new ways to do business.

For the past 30 years, Huawei has provided innovative products and solutions to ensure the secure and stable operations of our customers' networks no matter what comes their way, be it earthquakes, tsunamis, or even global conflict. In particular, throughout the 2020 pandemic, we have been helping telecom operators cope with surging network traffic while contributing to the fight against the coronavirus with ICT solutions like 5G, converged offices, teleconferencing, telemedicine, and remote education.

We are committed to providing our customers with innovative products and efficient services. This commitment is what helped us grow into what we are today. From early on, we began investing more than 10% of our annual revenue in R&D. Over the years, this commitment to nonstop, focused investment has helped us grow from a small unknown company into a leading global provider of ICT infrastructure, smart devices, and cloud service solutions.

Respecting and protecting intellectual property (IP) is the foundation of innovation. While promoting our own growth, we also license our patented technologies to other industry players to promote

shared success. Over the past 20 years, Huawei has conducted extensive cross-licensing negotiations with key patent holders in the ICT industry and has entered into more than 100 patent license agreements with major global ICT companies across Europe, the United States, Japan, and South Korea.

In 2019, we released our first IP white paper, which outlines our principles and practices in innovation and IP protection, as well as our contributions to the industry as a whole. This 2020 white paper focuses on Huawei's IP management prior to 2010, and uses historical data and key milestones to provide insight into Huawei's approach to R&D and innovation since the 1990s.

We believe that studying the past can better inform decisions for the future. Long-term investment in innovation, backed by the utmost respect for intellectual property, has been the driving force behind Huawei's business success, and also forms the cornerstone of our vision to build a fully connected, intelligent world.

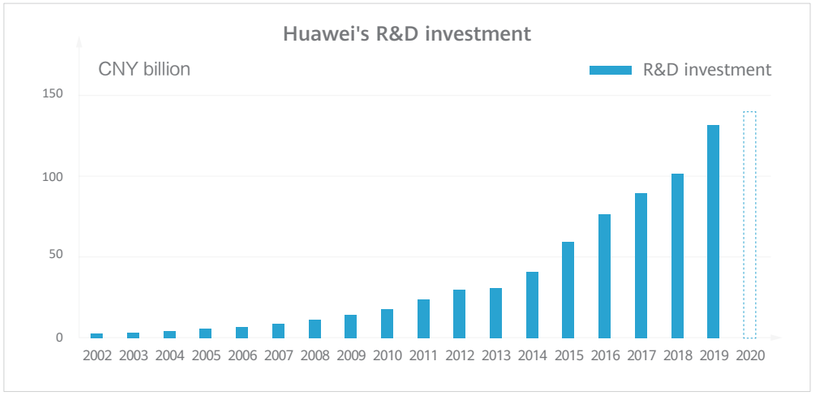
01 Innovation and intellectual property: Our values

- Huawei is committed to open research and innovation. We welcome integration with advanced technology across the global value chain, and we have the infrastructure in place to rapidly launch products and services with leading quality and performance to meet our customers' needs.
- Huawei actively protects its own intellectual property. Continuous R&D investments have made Huawei one of the world's largest patent holders. We are ready and willing to license our patents and technologies worldwide to drive progress in the industry.
- Huawei holds the intellectual property of others in the utmost regard. We comply with international rules and norms for intellectual property management and protection, and we endeavor to resolve IP disputes amicably through methods like cross-licensing and partnerships.

02 Investment and achievements

2.1 Long-term, focused investment

Long-term, focused investment in innovation is the cornerstone of Huawei's ongoing growth. The figure below shows the sustained increase in our R&D spend from 2002 to 2019.

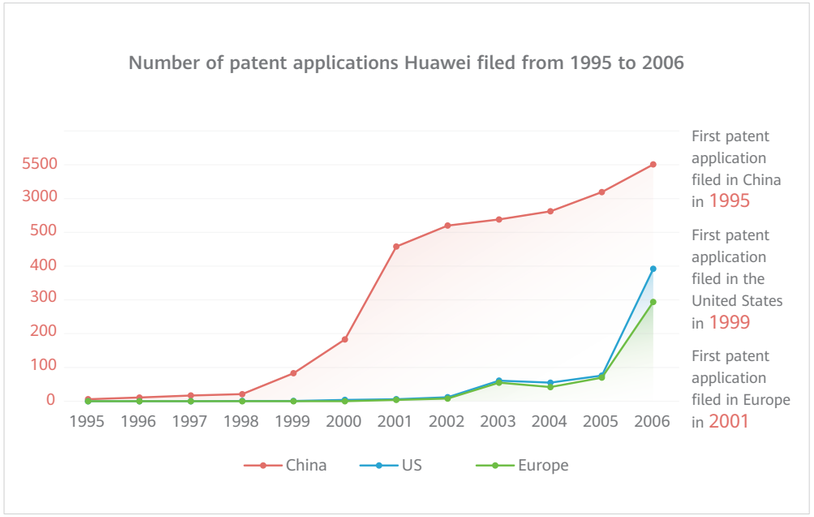


Note: As Huawei's 2020 annual report has not yet been released, the R&D investment for 2020 shown in this chart is a forecast.

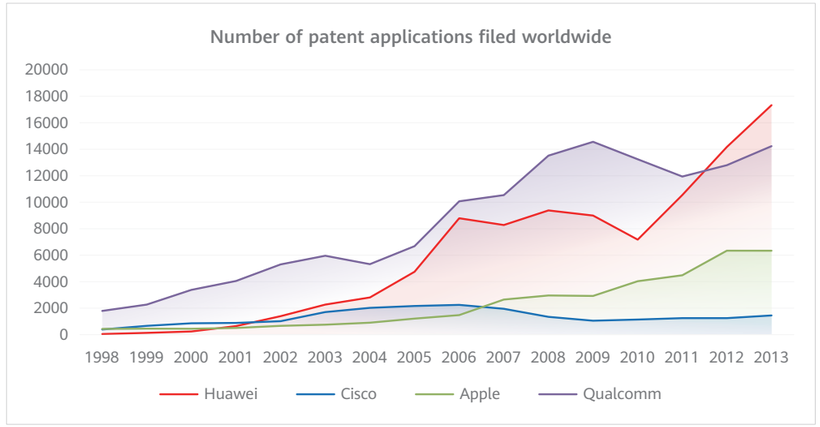
- As of the end of 2020, Huawei had 105,000 R&D employees, roughly 53.4% of our workforce. Our R&D investments totaled CNY131.7 billion in 2019, accounting for 15.3% of our annual revenue. From 2010 to 2019, Huawei's total R&D investment exceeded CNY600 billion (equivalent to about USD90 billion).
- Huawei ranked third on the 2020 EU Industrial R&D Investment Scoreboard.

2.2 A long history of patent management

Innovation relies on mutual respect for and protection of intellectual property. As such, we proactively manage our IP portfolio to ensure that our research and innovation fairly benefits both our organization and the industry at large. In 1995, we filed our first patent application in China and have since filed numerous applications in countries and regions around the globe, including both the United States and Europe. Below is a summary of the number of patent applications Huawei filed from 1995 to 2006.

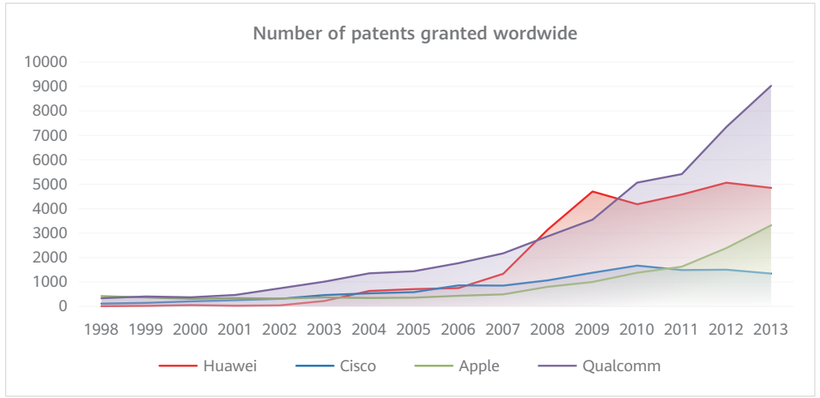


Starting in 2001, the number of patent applications we have filed worldwide has remained on par with industry leaders in the United States. The figure below shows the number of patent applications filed by Huawei from 1998 to 2013, side-by-side with our peers in the ICT industry.



Source: Orbit patent database (as of July 28, 2020)

Since 2004, the number of patents we have been granted has also remained on par with industry leaders in the United States. The figure below shows the number of patents granted to Huawei between 1998 and 2013, alongside the number of patents granted to our industry peers during the same period.



Source: Orbit patent database (as of July 28, 2020)

Sustained investment in innovation has made Huawei one of the world's largest patent holders. By the end of 2020, Huawei held more than 100,000 active patents in over 40,000 patent families worldwide.

Huawei is among the world's top companies by number of patent applications and number of patents granted in major countries and regions like China, the United States, and Europe. In recent years, we have ranked in the world's top 20 companies based on the annual number of patents granted by the United States. In 2019, Huawei had the second most patents granted by the European Patent Office. Huawei is also the largest patent holder in China.

03 Innovation and IP milestones

- In 1993, Huawei launched the C&C08, a large-scale digital exchange.
- In 1994, Huawei applied for its first trademark (" 華為 ").
- In 1995, Huawei filed its first patent application in China. That year, Huawei filed six patent applications in China for different technical fields.
- In 1995, Huawei established its Intellectual Property Department to improve its IP management and protection process and management system.
- In 1997, Huawei launched its wireless GSM solutions.
- In 1998, Huawei was granted its first patent in China.
- In 1999, Huawei submitted its first patent application in the United States, its first patent application outside China, which helped support the market expansion of its products worldwide.
- In 1999, Huawei launched the OptiX 2500+, the first multi-service transmission platform (MSTP) in the industry, leading the optical transport industry's evolution from synchronous digital hierarchy (SDH) to MSTP.
- In 2000, Huawei was granted its first US patent.
- In 2001, Huawei signed a patent license agreement with Qualcomm. Since then, Huawei has conducted extensive cross-

licensing negotiations with IP holders in the ICT industry and has entered into more than 100 patent license agreements with major global ICT companies across Europe, the United States, Japan, and South Korea.

- In 2001, Huawei sold Avansys Power, a subsidiary that specialized in power supply, to Emerson for USD750 million. This marked the first time Huawei monetized its R&D capabilities.
- In 2002, Huawei signed its first patent licensing agreement with Ericsson in the wireless field.
- In 2003, Huawei launched the MA5300, the industry's first digital subscriber line access multiplexer (DSLAM) built on Internet Protocol (IP) architecture.
- In 2003, Cisco and Huawei had an IP dispute. The following year, the two parties settled the dispute and filed a joint request to a United States court to terminate the lawsuit.
- In 2003, Huawei and 3Com established a joint venture. Huawei provided technology and R&D employees, and 3Com invested USD165 million. In 2006, Huawei sold its shares in the joint venture to 3Com for USD882 million.
- In 2004, Huawei launched the industry's first distributed base station and won a contract worth more than USD25 million from Telfort, a Dutch operator. This was Huawei's first major breakthrough in the European market.
- In 2004, Huawei launched the NE5000E core router that supports cluster networking based on a forward-looking architecture. This product has since set the gold standard for architecture in the industry and is still a star product today.

- In 2006, Huawei released the OptiX OSN 6800, the industry's first optical transport network (OTN) equipment, helping to drive transformation in the optical transport field.
- In 2006, Huawei launched the MA5600T, the industry's first platform to support both fiber access and copper access. Compared with its counterparts, this product used the least energy while delivering the same capacity, thus leading the industry's evolution into greener access networks.
- In 2007, Huawei and Symantec established a joint venture, Huawei Symantec, to develop storage products.
- In 2008, Huawei filed 1,737 patent applications under the Patent Cooperation Treaty (PCT), ranking first in the world for the first time.
- In 2009, Huawei was named as one of the World's 500 Most Influential Brands by World Brand Lab.
- In 2009, Huawei won the Corporate Award from the IEEE Standards Association.
- In 2009, Huawei, NTT DOCOMO, France Télécom (now Orange), the Electronics and Telecommunications Research Institute (ETRI), and VoiceAge jointly developed G.711.1, an extension to a widely used speech codec. As one of the core developers, Huawei established a patent pool.
- In 2010, Huawei filed a lawsuit against ZTE in Europe for patent and trademark infringement. In 2015, the European Court of Justice made a ruling that helped establish legal requirements for

the licensing negotiations of standard essential patents (SEPs).

- In 2011, Huawei established the 2012 Laboratories, a cradle for innovation where Huawei researchers explore platform technologies and other technologies of the future.
- In 2011, Huawei filed a lawsuit against Motorola in the United States after being involved in an IP dispute with the company. As part of the resolution of that lawsuit, Motorola paid Huawei a fee and obtained permission to transfer Huawei's confidential information to Nokia Siemens Networks as part of an existing M&A deal.
- In 2013, Huawei licensed its wireless standard essential patents to Teltronic, a European wireless equipment vendor.
- In 2014, Huawei launched its landmark smartphone, the Huawei Ascend Mate7.
- In 2015, Huawei signed a patent license agreement with Apple, to whom it licensed wireless standard essential patents.
- In 2016, Huawei and Samsung filed multiple patent infringement lawsuits against each other in China and the United States. In 2019, Samsung reached a settlement with Huawei and paid Huawei licensing fees.
- In 2016, Huawei launched the P9 smartphone, the first phone with a Leica dual-lens camera, allowing users to capture pictures in both color and black and white. The product set a new standard for smartphone photography.
- In 2017, Huawei was one of the top 3 Linux kernel contributors.

- In 2019, Huawei had the second most patents granted by the European Patent Office.
- In 2020, Huawei filed a patent infringement lawsuit against Verizon in the US, demanding compensation for patent infringement.
- In 2020, Huawei joined the Open Invention Network to support the development of the Linux community.
- In 2020, Huawei ranked third on the 2020 EU Industrial R&D Investment Scoreboard released by the European Commission.

04 A brief history of innovation at Huawei

Customer-centricity drives everything we do at Huawei. For the past 30 years, we have concentrated our R&D investment on building a portfolio of intellectual property that meets the practical needs of our customers. Throughout this process we have faced countless setbacks, but we have also experienced the joy of success that comes from meaningful breakthroughs in technology. The following are a collection of stories that highlight key moments in Huawei's history of innovation and IP development.

Boosting network capacity with new cluster routers

After the outbreak of COVID-19 in 2020, widespread social distancing and working from home led to a sudden surge in data traffic. To address this challenge, operators needed **cluster routers** – the top-layer "traffic hub" for Internet data scheduling and forwarding – **for their backbone networks.**

Despite a population of 1.4 billion, the backbone of China's Internet managed to effectively handle this deluge of new data throughout the pandemic, keeping families connected, kids in school, and companies in business. This would not have been possible without **Huawei's NetEngine5000E (NE5000E) cluster routers.**

But these cluster routers didn't suddenly appear overnight. They are the result of careful planning and concentrated investment in throughput, performance, and reliability.

Pushing the boundaries of router technology

Back in 1999, when the Internet was transitioning from 64 Kbit/s dial-up connections to 1 Mbit/s ADSL connections, the most advanced router in the industry was able to support a maximum bandwidth of 40 Gbit/s.

At the time, pretty much the entire industry felt that this was plenty for future network expansion. Huawei thought otherwise. We offered to develop a router with a capacity of 80 GB and a bandwidth of 160 Gbit/s, and proposed an architecture that would increase the router capacity linearly through stacking and cascading technologies.

By 2014, former giants in the cluster router domain had diminished due to a lack of forward-looking architecture. By contrast, Huawei's cluster routers supported the smooth expansion of network bandwidth and capacity for people the world over.

Owing to their advanced architecture, this new generation of routers have helped to address ongoing explosive growth in data traffic. The architecture we adopted for our cluster routers soon became mainstream in the industry, which has helped us achieve a roughly 40% share of the global router market.

First steps: supercharging circuit boards

In 1998, Huawei's engineers were in the process of researching and developing our mid-range **NE08 routers.** We were considering expanding the router's bandwidth by adding more slots. However, this particular router was only able to support a maximum of six slots, all of which would have to share a bandwidth of 1 Gbit/s. This was a serious bottleneck.

To solve this problem, Deng Chaojun, the project manager at that time, thought of **replacing the shared bus architecture with a**

switching fabric, which could increase the number of slots and linearly increase the router's overall bandwidth.

To make this a reality, Mr. Deng's team had to overcome two massive technical hurdles:

- **First, the team had to figure out how to transmit high-speed data signals on printed circuit boards (PCBs).**
- **Second, the team needed high-capacity chips that could support high-speed data switching.**

The R&D project, named "Project 1011", marked the beginning of Huawei's journey into developing core routers that would change the industry.

Before this, signals transmitted over shared bus architecture traveled slowly on PCBs, with speeds barely exceeding 33 Mbit/s. This was because existing routers employed single-ended signaling, a design whereby an electrical signal is sent serially over a single wire. While cheaper and easier to design, PCBs using single-ended signaling were subject to noise and interference, which limited the speeds at which data could be accurately transferred.

At the time, our R&D team wondered whether a PCB could carry differential signals (i.e., sending a single signal through a pair of wires) to speed things up, although no one in the industry had ever verified this concept before.

Our team was the first to do so, and the lab results were surprisingly good – the transmission rate reached 1.25 Gbit/s. This "dark horse" technology was first used in another one of Huawei's **switch products – the Radium 8750** – which would have otherwise failed owing to the same constraints created by the instability of traditional single-ended signal transmission.

The idea that emerged during research and development of the NE08 brought the Radium 8750 back to life. It later became the industry's first product developed with PCBs that could support lightning-fast data signal transmission.

Support for growing data traffic

By 2000, the development of data communications networks had entered a critical stage, and with an increasing number of Internet users, demands on traffic and bandwidth were growing exponentially.

Imagine half of China's 1.4 billion people suddenly going online. The demand on networks would be immense. Despite this growing understanding, no one in the industry would have thought that future routers would be able to support bandwidths of 100 gigabits, 400 gigabits, or even terabits per second.

At that time, one Cisco router on the market could support a maximum bandwidth of 40 Gbit/s, which was adequate for users at the time. Considering China's large population and broader industry trends, however, Huawei decided to go one step further by **developing a high-speed switching chip with a capacity of 80 GB and a bandwidth of 160 Gbit/s,** which had never been done before.

At the same time, we began researching a new router architecture that supported stacking and cascading to meet future demands for capacity expansion. Our management team told Project 1011 that it didn't matter whether or not the chip would ever see the light of day, they needed to start working on it.

After many twists and turns, our R&D team succeeded in developing a large-capacity and high-speed data switching chip in 2002, revolutionizing mainstream technology of the time and setting a new milestone in the development of Huawei's cluster routers.

First, the team established a new standard for high-capacity cluster routers – **multi-chassis cascading** – to overcome traditional constraints in bandwidth and capacity expansion. Our R&D team was acutely aware of what they had accomplished, and had the multi-chassis cascading technology for high-capacity cluster routers patented[1] in both China and the United States.

This technology was an industry first, and it laid a solid foundation for Huawei's core routers to support evolution toward greater bandwidth. As the industry continued to develop, core routers based on traditional single-chassis architecture gradually went by the wayside out of an inability to cope with surges in traffic and growing demands on bandwidth.

Second, Project 1011 established new hardware architecture for large-capacity core routers, replacing mainstream **asymmetric uplink-downlink architecture** for data flow processing with a higher-performing **symmetric uplink-downlink architecture.**

Symmetric architecture uses software to improve the quality of service (QoS) of data transmission, ultimately delivering better performance, lower power consumption, and greater scalability. With this innovation, Project 1011 had basically overcome all the major technical barriers to the development of next-generation core routers.

From ordinary to extraordinary

Huawei officially kicked off the development of our core routers in 2003. Three years later, we launched the industry's first **back-to-back core router – NE5000E 40G.** As an industry first, this solution allowed operators to more efficiently expand and upgrade their networks, and also double network capacity by directly connecting

[1] Examples of patents for Huawei's cluster router architecture:
CN1120599C: Data communication systems supporting smooth capacity expansion
US7936776B2: Smooth capacity expansion method and system for data communication products
US7602804B2: Smooth capacity expansion method and system for data communication products

two chassis with optical fiber.

In 2008, Huawei released the upgraded **2+8 (2 central chassis and 8 service chassis) core cluster router – the NE5000E 100G.** In this new generation of routers, each service chassis would be connected to the central chassis through more than 90 fiber optic cables, which meant there were almost 800 cables for eight service chassis. To reduce the number of cables, we simplified the optical fiber connections between multiple chassis, which sped up installation and maintenance and greatly enhanced system reliability.

Faced with the daunting challenge of connecting China's population and supporting explosive growth in data traffic, Huawei designed a forward-looking product architecture that would support effortless and expedient network evolution. In 2013, the NE5000E core cluster router continued pushing the boundaries of speed as it expanded from 100 Gbit/s to 400 Gbit/s, and then again to 800 Gbit/s and 1.6 Tbit/s in 2019.

In addition to advanced architecture and powerful data processing capabilities, cluster routers on core backbone networks require powerful error correction, fault tolerance, and self-healing capabilities to prevent network-wide service interruption. Huawei's core cluster routers have a built-in, high-reliability defense system that accounts for 80% of the entire system's code.

When China Telecom first explored the use of these cluster routers, it took an entire month just to test the equipment. Service continued flawlessly up until the last fiber optic cable and switching board were removed. In addition, there was not a single packet lost during a 72-hour full-traffic test. No matter how the test was performed, there were no issues with the equipment. Our cluster routers withstood the most stringent tests, surprising the customer with their exceptional stability.

A long road to the present

Huawei began researching core router technologies in 1998 and spent 15 years building our products into the de facto industry standard for performance and reliability. Committed to long-term R&D investment, we continue to pursue innovation in all aspects of router technology – including system architecture, chips, reliability, and integrated systems – and have created many industry firsts:

- First to apply high-speed switching fabric to router design in 1999
- First to launch a back-to-back cluster solution in 2006
- First to launch 400 Gbit/s (2013), 800 Gbit/s (2016), and 1.6 Tbit/s (2019) core cluster routers

It was an iterative, step-by-step process of breaking through one bottleneck after another to maximize the potential of communications networks.

Huawei and Motorola

Huawei and Motorola teamed up in 2000 and continued working closely together for a decade. In 2008, the companies ended up in court and later reached an agreement. Motorola ended up paying Huawei a fee for the right to transfer Huawei's trade secrets and confidential information.

A burgeoning partnership

Around 1999, Motorola was facing fierce competition from Ericsson and Nokia. It had missed out on several major market opportunities and gradually went into decline. To beef up its competitiveness and expand into the core network domain, Motorola pursued a partnership with Huawei.

Motorola brought Huawei onboard as an OEM partner, distributing our products under the Motorola brand. Specifically, Motorola relayed its customers' requirements (including carrier requirements) to Huawei, which was responsible for programming, product development, and resolving technical issues. Motorola was responsible for network installation, maintenance, and integration.

Throughout a decade of close partnership, Motorola and Huawei expanded the scope of our collaboration beyond core networks, including circuit-switched and packet-switched networks, to base stations and base station controllers. We also expanded the scope of our business from just a few countries to more than 40. Motorola purchased USD880 million worth of advanced core network and wireless access equipment from Huawei, and Huawei provided access to many trade secrets and technical information to thousands of Motorola employees worldwide.

The lawsuit

In 2008, Motorola filed a series of lawsuits for alleged trade-secret misappropriation against Lemko, a company founded by several former Motorola employees. Huawei was dragged into the lawsuits because Lemko had tried to sell its products to Huawei.

In June 2010, Motorola had been planning to sell its communications infrastructure business to Nokia Siemens Networks (NSN). As soon as an agreement with NSN was reached, Motorola added Huawei as a defendant in its lawsuits against Lemko on the grounds that a former Motorola employee had sent the specifications of a Motorola small-cell product to Huawei executives.

Huawei denied Motorola's allegations and provided substantial evidence in its defense, including millions of documents and nearly

100 million lines of source code for review by Motorola's lawyers and technical experts.

The evidence showed that Motorola provided the same small-cell product specifications to Huawei back in 2001, when the two companies were jointly bidding for a China Unicom project. The evidence also showed that the products in question were all independently developed by Huawei. Furthermore, it showed that the products that allegedly incorporated Motorola's trade secrets were actually products that Motorola was unable to develop on its own and had purchased from Huawei under the OEM agreement.

At the time, Motorola wanted Huawei to agree to transfer the OEM agreement – including all products, technologies, and commercial information that Huawei had provided to Motorola as part of their partnership – to Nokia Siemens Networks.

Motorola claimed that the OEM agreement was part of the infrastructure business it had planned to sell to NSN. Throughout our partnership, we had provided Motorola with a great volume of valuable and confidential technical information related to product design, operation, support, and interoperability, in addition to a large amount of commercial information used in sales. After Huawei objected, Motorola insisted on transferring our confidential information to close the deal with Nokia Siemens Networks.

Settlement

In January 2011, Huawei was left with no choice but to file a complaint against Motorola in the United States District Court for the Northern District of Illinois in Chicago, alleging that Motorola had violated the OEM agreement and used Huawei's trade secrets and copyrights without authorization. On that same day, the court issued a temporary restraining order at Huawei's request, and about

one month later, issued a preliminary injunction that enjoined Motorola from disclosing any of Huawei's confidential information to NSN without Huawei's consent. If Motorola could not obtain Huawei's consent to transfer its confidential information, the deal with NSN was likely to fall through.

In April 2011, Motorola agreed to pay a fee to Huawei in exchange for the permission to transfer Huawei's confidential information to NSN. Huawei and Motorola jointly announced that we had reached a settlement and all pending litigation would be dismissed.

This was the first time in Huawei's history that another company paid for the right to use our confidential information and technology. This occurred before we had established an intellectual property transfer and licensing program.

Huawei and Motorola's joint statement can be found at:
https://newsroom.motorolasolutions.com/news/motorola-solutions-and-huawei-issue-joint-statement.htm

Mergers and acquisitions

Over the past 30 years, Huawei has engaged in a number of major investments, joint ventures, and mergers and acquisitions. Each of these is a testament to our strengths in R&D as well as the value of our technological offerings and IP.

1. Selling Avansys Power to Emerson

When the IT bubble burst, the global communications industry went through a period of great difficulty. After carefully weighing the overall development strategy of our company, we decided to resharpen our focus on our core business: telecommunications. This necessitated the transfer or spin-off of some secondary businesses

such as the subsidiary Avansys Power.

Avansys Power was Huawei's largest subsidiary at the time. It specialized in the development, production, sales, and import/export of telecommunications power supplies and related products. Avansys Power held 48 patents, and brought in CNY2.6 billion in sales revenue and CNY500–600 million in profit in 2001, making it a leader in telecommunications power.

At the same time, the US energy company Emerson Electric was looking to enter the Chinese market. The best bet for Emerson was to acquire a Chinese business, so they offered to acquire Avansys Power.

Owing to the overall slump in the IT and communications industries – not to mention the global economy – the talks did not go well, and investors were not optimistic. At one point, negotiations were put on hold. But Emerson stayed the course because it saw the value of Avansys Power. Emerson believed that Huawei's technologies and products would help the company both pull through the economic downturn and continue to thrive in the long term.

After several rounds of negotiations, in March 2002 Emerson acquired Avansys Power's technologies, products, and teams for USD750 million, and established its Network Energy Power division built on Avansys Power's assets. Dr. Song Liuping, Huawei's Chief Legal Officer, recalled that the two parties spent a significant amount of time and effort making the deal, and had difficulty deciding whether to license or to transfer six of Huawei's patents. It took three days for them to finally reach an agreement, and the result greatly increased the technological value of the deal.

For more than a decade after the acquisition, Emerson Network

Power enjoyed rapid growth and sizeable market share, which brought considerable returns for its shareholders in the capital market.

2. Joint venture with 3Com

Around 2002, Huawei discussed potential cooperation on data communications products with 3Com, a US computer networking company. As part of the agreement, 3Com required that any product or technology provided by Huawei would be free from third-party intellectual property issues. We provided our router design and source code for 3Com's review, after which 3Com was reassured of Huawei's valid IPR and thus agreed to enter a partnership.

The following year, Huawei and 3Com set up a joint venture called H3C. Huawei provided technology and assets, taking a 51% stake in the venture. 3Com provided cash and its China business – worth USD165 million – and held the other 49%.

In collaboration with 3Com, we leveraged our strengths in technology, management, and product design to develop, produce, and sell a complete portfolio of cost-effective, enterprise-grade data communications products. The joint venture enabled 3Com to swiftly enter the lucrative Chinese market and accelerated Huawei's global business expansion. The arrangement was a cost-effective way for both companies to tap into new markets. Over the next three years, H3C's compound annual growth rate was more than 65%.

In November 2006, we sold our shares in H3C to 3Com for USD882 million. Over the four-year partnership, we earned USD1 billion from both the joint venture itself and the eventual selling of our equity.

In December 2009, 3Com was acquired by HP, which then

integrated H3C into HP Enterprise Business's network division. In 2010, H3C – along with its R&D team, products, and technologies, all from Huawei – overtook Cisco to become number one in the Chinese enterprise data communications market.

H3C was an exemplary model for joint ventures, with both sides leveraging their strengths to create a strong and competitive organization. H3C was extremely valuable to both parties, our customers, distributors, and other partners. And it still remains a positive example today for shared success in the data communications industry.

3. Combining strengths, promoting shared success

The model where Huawei provides technology and our partners provide capital has been consistently successful across all of our past mergers and acquisitions with US and European companies. This cooperative model has not only generated immense commercial value, bringing continuous returns to investors, it has also had a far-reaching impact on the industry by driving industry convergence.

A good example is a former joint venture between Huawei and Symantec, an international storage and security software manufacturer, that began in 2008. The joint venture ended up filing more than 300 patent applications, holding important roles in international and Chinese standards organizations, and becoming an industry leader in storage and security.

Another example is TD Tech, a joint venture between Huawei and Siemens established in 2004. TD Tech rapidly launched a commercial TD-SCDMA solution, becoming a leader in the field. This partnership also significantly reduced the costs that Huawei and Siemens would have otherwise needed to spend

on researching and developing TD-SCDMA products. TD Tech's products and solutions have been widely used in China Mobile's 3G and 4G networks, earning it the top spot in terms of market share.

Over the past 30 years of development, Huawei has encountered a variety of obstacles and opportunities. Our ability to navigate this challenging environment, earn industry recognition, and grow together with our partners is largely a result of providing unmatched R&D resources to fuel joint innovation and create unique business value for our customers.

3G, 4G, and then 5G

Huawei's current leadership in wireless technologies is the result of more than 20 years of focused investment in R&D, customer-centric innovation, and a commitment to creating real, practical value. It's the fruit of open collaboration with industry partners in international standards organizations, where we work as a team to share and apply the world's best innovations.

Necessity is the mother of invention

In the mid-90s, Huawei began researching second-generation (2G) mobile base stations in order to enter this hotly contended segment of telecom market.

In 1999, the Chinese government announced a major reshuffle of state-owned telecom operators. The newly established mobile operator, China Unicom, opened its first bid for network construction. This would have been a great opportunity, but Huawei missed its chance and ended up with what many would have considered low-value orders for deploying base stations in remote,

mountainous areas.

At that time, transporting tons of telecom equipment 1,000 meters up a mountain was enough of a challenge, let alone ensuring power supply and site security. If we had let these challenges get in the way, however, we would have lost the customer's trust and China Unicom would have shut the door on Huawei for good.

After multiple rounds of intense technical discussions, we came up with a revolutionary solution: splitting the integrated baseband unit (BBU) and remote radio unit (RRU) of a traditional base station into standalone units[2].

BBUs were larger and more complex. They consumed more energy and had more components, so they were deployed at the foot of the mountain. RRUs that were smaller in form factor and could withstand harsher conditions were installed on the top of the mountain, along with antennas, and they were connected to the BBUs at the foot of the mountain with optical fiber.

This solution greatly simplified deployment and improved the maintainability of our equipment. It connected remote communities and helped Huawei build a name for itself. Although the team that worked on the solution celebrated the success of the first base station with separated BBUs and RRUs, they were unaware of the impact this specially designed solution would have in helping Huawei make inroads into the global market.

Bringing distributed 3G base stations to Europe

By 2003, Huawei had yet to set foot in the European 3G market. After talking to a broad range of customers at length, we came

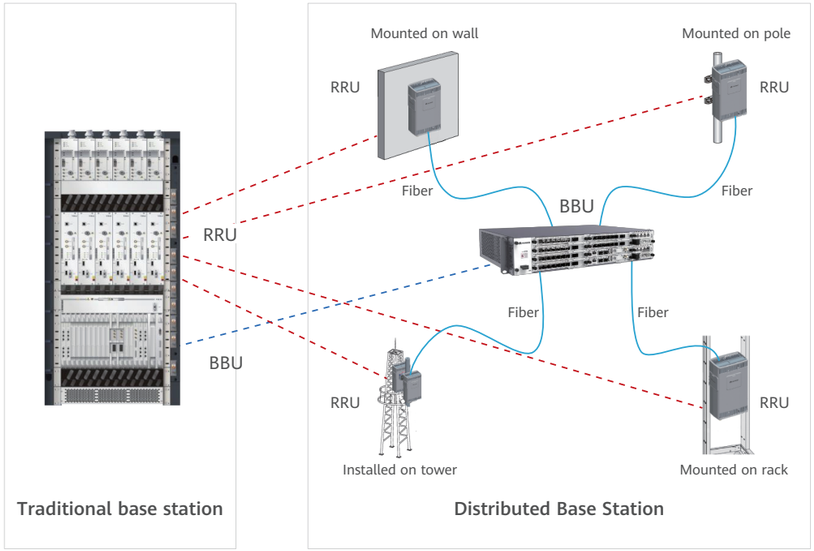
[2] Examples of Huawei distributed base station patents:
CN100382470C: Soft base station system based on fiber optic stretch
CN101166059B: An automatic time delay measurement method and system for optical fiber remote soft base station

to understand that it was increasingly difficult for operators to find equipment rooms in big European cities that could accommodate 3G base stations. On top of that, costs were getting higher by the day.

Installation was a nightmare. The cost of deploying 3G base stations was incredibly high because they were heavy and needed to be transported by trucks, and then by cranes, to equipment rooms on the roofs of buildings in narrow European neighborhoods. In addition, permission had to be obtained from the local authorities before a crane could be used, as roads would need to be blocked. Each installation cost USD8,000 to 18,000. The cost of renting space was also astronomical, so the best way to help our customers overcome these challenges was to design an easy-to-deploy base station that saved space.

After putting our heads together, we drew on the design of the solution we had used in the China Unicom project four years earlier, and came up with the Distributed Base Station (DBS) design.

Distributed base stations would employ a series of new technologies in addition to the separated BBU and RRU. The RRU could go anywhere – on rooftops, poles, or walls. The larger, traditional BBU was redesigned and broken down into smaller boxes that could be stacked or even stored in spare cabinet space inside the operators' existing 2G equipment rooms. The DBS was one-tenth the size and one-fifteenth the weight of traditional models, meaning an engineer could carry all units to the site by hand and install them with little effort.



This innovation changed the way that mobile networks were deployed and helped earn Huawei the recognition of leading operators in Europe. Distributed base stations were a new step forward for the mobile industry, and they became a de facto standard for all other telecoms equipment manufacturers to follow.

Up until this point, Huawei was an underdog, a follower. The distributed base station was our first major foray into industry leadership.

Simplifying 4G deployment with SingleRAN

When 4G came around, operators had to upgrade their equipment while ensuring the ongoing quality of 2G and 3G services. In 2007, right as operators were in the midst of this upgrade, they were drowning in capital and operating expenses.

Huawei responded to this dilemma with a new technology called SingleRAN that would allow operators to support 2G, 3G, and 4G on a single network. This would create an easy path for operators

to upgrade their networks without compromising profitability.

To make SingleRAN a reality, Huawei invested a significant amount of time and effort into resolving a great number of technical barriers, including those in mathematics, chip design, materials, and heat management. The resulting breakthroughs[3] made SingleRAN an instant success.

In December 2008, German operator O2 placed the world's first order for SingleRAN. This put them in a better position to deliver faster telecom services at much lower costs.

Other operators quickly followed suit. SingleRAN paved the way for European operators to painlessly upgrade to 4G, and it became highly acclaimed in global markets soon after its launch, later becoming the go-to global standard for mobile network architecture in the 4G era.

Going green with Blade Sites

In 2009, as demand for more green and sustainable technology was on the rise, operators were in the market for more energy-efficient equipment with a lower carbon footprint. Back then, telecoms sites consumed a massive amount of energy, and with all sorts of boxes, antennas, and complex cabling, they were also contributing to visual pollution in both rural and urban environments.

In response, Huawei leveraged decades of experience in network equipment design, as well as the design of PC blade servers, to launch a solution called Blade Site[4]. This new product adopted a unified modular design, with each of the major components shaped

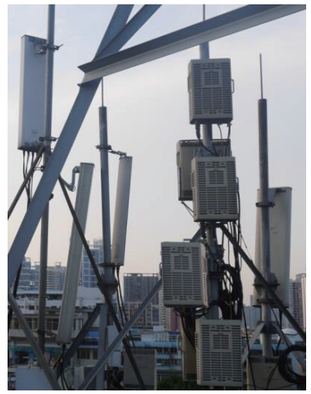
[3] Examples of Huawei SingleRAN patents:
CN101198150B: Method, device, and system for performing separate-way transmission in multimode wireless network

[4] Examples of Huawei Blade Site patents:
CN103596297B: Radio remote unit device and assembly thereof
EP3525354A1: Radio remote unit device and assembly thereof
US9642284B2: Radio remote unit device and assembly thereof
US9167712B2: Radio remote unit device and assembly thereof
EP2698922B1: Radio remote unit device and assembly thereof

like a thin, smooth blade, so that different modules could be seamlessly joined together like LEGOs.

Owing to their thin, streamlined shape, they were able to dissipate heat through natural thermal exchange with the surrounding environment, eliminating the need for air conditioning. This greatly lowered energy requirements and carbon emissions, making for much more eco-friendly connections. Furthermore, the unified appearance of Blade Sites reduced the physical footprint of the equipment, allowing them to blend into their environments better and reduce visual pollution.

Traditional distributed base station



Huawei's Blade Site

It took four years for Huawei to design Blade Site and put it into commercial use. The hard work of more than 3,600 engineers and billions of dollars of investment led to five core proprietary technologies.

At present, Blade Sites are being used in 310 networks across 170 countries, and more than 15 million blade RRUs are being used on live networks. Huawei's Blade Site is now seen as a de facto

industry standard, and other vendors have followed in Huawei's footsteps to launch their own blade site products.

Boosting 5G with Massive MIMO

Huawei began researching 5G back in 2009. After two years of in-depth research and analysis, we came to the conclusion that massive multi-antenna technology would become a new standard for future mobile networks. Despite industry concerns over the viability of Massive Multiple-Input Multiple-Output (Massive MIMO) technology, we decided to move forward with research that would ultimately result in multiple patented core technologies.[5]

Prior to Huawei's advancements in Massive MIMO, industry consensus was that its deployment faced two major barriers:

- At that time, it was only conceptual; there was no workable solution.
- The algorithms used to simultaneously manage so many antennas were exceptionally complicated.

Experts from the China Mobile Research Institute had been exploring multi-antenna technology for a long time, but feedback from equipment and chip vendors was disheartening: a Massive MIMO base station with 64 transmitters would weigh more than 100 kilograms and cost over ten times as much as a base station with eight transmitters. This meant a 64T Massive MIMO base station would simply not be commercially feasible.

[5] Examples of Huawei Massive MIMO patents:
CN110832949A: Data dimension reduction method, apparatus, and system, computer device, and storage medium
US20200162940A1: Data dimension reduction method, apparatus, and system, computer device, and storage medium
EP3641487A1: Data dimension reduction method, device and system, computer device, and storage medium
CN111108706A: Device and method for compressing and/or decompressing channel state information
US20200228232A1: Device and method for compressing and/or decompressing channel state information
EP3682568A1: Device and method for compressing and/or decompressing channel state information

In September 2014, Huawei's 128T Massive MIMO base station passed internal testing. When experts from the China Mobile Research Institute were invited to come see it, they were amazed to find that it performed three times better than existing products, yet weighed only 49 kilograms. Each unit had 128 radio frequency channels, two of which were only the size of a credit card. The technology had passed muster, and Huawei soon became recognized as a genuine frontrunner in Massive MIMO technology.

Fast forward to July 2018, and Huawei's 64T and 32T Dual-200 Massive MIMO products for 5G networks were first made available for commercial use, raising the bar for new networks in the 5G era.

Moving forward

Research and innovation are Huawei's bread and butter. Moving forward, we will shift from technology and engineering-oriented innovation to focus more on driving breakthroughs in basic research and inventing new fundamental technologies. Working closely together with academia and partners across all industries, we will create new value for customers and society.

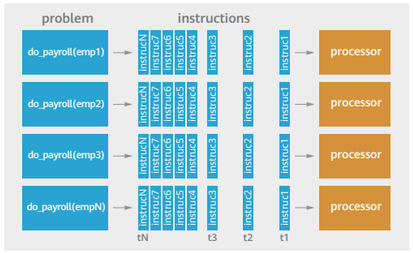
05 Breaking new ground

Starting in 2015, Huawei launched the Top Invention Awards program to recognize and reward Huawei employees who have made innovative discoveries that have the potential to fuel a new product series or become a key product feature with immense commercial value. This program builds a culture of innovation that inspires Huawei employees to keep pushing the boundaries of technology and making new breakthroughs.

The following are some of our top inventions over the past few years. Moving forward, more new products powered by these inventions will hit the shelves, and will extend the benefits of innovation to every person, home, and organization for a smarter and better world.

Top Invention: High-speed decoding of polar codes

- Patent family 1: Polar code decoding method and decoding apparatus CN105009461B/ CN107204779A/ EP3073642A1/ US9762352B2/ JP6184603B2/ KR101819015B1/ RU2649957C2/ ID2017/06416/ VN25371
- Patent family 2: Polar code decoding method and decoder CN104038234B/ US10270470B2/ EP2953307A1/ JP6075812B2/ IN329523A1/ KR10-1754912/ KR10-1814031



When information is sent through electrical signals, different aspects of the physical environment will interfere with its transmission, introducing errors. This interference is called noise. And the more information that is sent in a set period of time, the more noise there will be. This was a major barrier to the practical application of 5G.

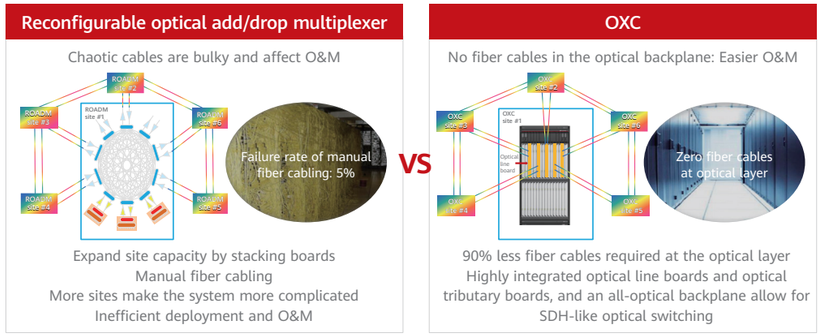
First introduced in 2009, polar codes demonstrated fantastic potential to correct these errors at the theoretical level. However, when it came to practical application, the high latency and slow speed of decoding them were major barriers to their development.

To solve these issues, Huawei created a high-speed parallel decoding algorithm that made decoding eight times faster. As a result, polar codes entered commercial use within 10 years of being invented. The algorithm is comprised of three key innovations: dividing polar codes into sub-codes, parallel computing, and multi-level breakdown and parallel maximum likelihood (ML) decoding.

Top Invention: Optical Cross Connect

> Patent family 1: Wavelength selective switch
CN104620155B/ US9762983B2/ EP3037865B1

> Patent family 2: Optical communications apparatus and method
CN105409140B/ US9641917B2/ EP3128682B1

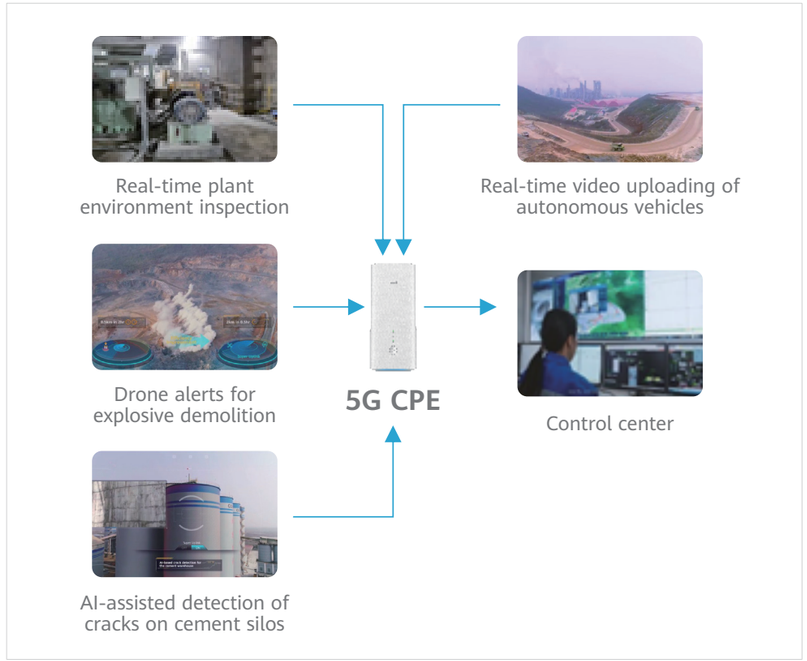


As a leader in optical networks, Huawei was the first company to use integrated interconnections to build an all-optical switching resource pool, thus achieving highly integrated, fiber patching-free, and all-optical cross-connections. This technology makes it more efficient than ever before to switch large-granularity services.

In 2019, Huawei launched the industry's first commercial Optical Cross Connect (OXC), which marked yet another milestone in the industry following the release of Huawei's Optical Transport Network (OTN).

Top Invention: Super Uplink for 5G

> Patent family 1: An uplink switch method, communication apparatus, and communication system
CN111200873A/ CN111200853A



With the growing adoption of 5G in B2B domains, networks need to offer faster uplink speeds and lower latency without compromising downlink speeds. Huawei has come up with a series of solutions to increase uplink coverage and bandwidth. Our two vital technologies – Uplink & Downlink Decoupling, and Super Uplink – have been accepted by 3GPP as part of the Release 15 and Release 16 specifications for global 5G networks, respectively.

- Uplink & Downlink Decoupling: Adds low frequency bands for uplink transmission in areas that lack uplink coverage in 3.5 GHz bands. Uses high frequency bands to carry 5G downlink services, and uses low frequency bands to carry 5G uplink services to increase 5G uplink coverage.
- Super Uplink: Features TDD/FDD coordination, high-band/low-band complementation, and time/frequency domain aggregation. It boosts uplink bandwidth and coverage and greatly reduces latency. As the industry's first time/frequency domain aggregation of TDD and FDD in the uplink frequency band, Super Uplink is a groundbreaking innovation in wireless communications. With its excellent speed and latency, Super Uplink is an optimal solution for both B2B and B2C markets.

Top Invention: Huawei OneHop for easy file transfer

- Patent family 1: A file transfer method and electronic device CN111492678A
- Patent family 2: A data transmission method and electronic device PCT/CN2018/110304

As we incorporate more and more devices into our daily lives, the ability to share files and photos between them has become overly complicated. Huawei OneHop resolves this problem by integrating device software and hardware capabilities to support instant file sharing across devices, whether they are smartphones, tablets, wearables, TVs, or car entertainment systems. There's no need to configure any aspect of the operating system; with OneHop, users can transfer a 10 MB file in milliseconds by simply tapping two devices together. The software development kit for Huawei OneHop is openly available to third parties via Huawei's OpenLab platform, which will help lay the groundwork for a more intelligent, interconnected ecosystem of devices.

Top Invention: Falcon Wing hinge for foldable screens

- Patent family 1: Rotating mechanism and folding terminal CN109936648B

> Patent family 2: Supporting component and smart device
CN110809073A/ CN209982521U

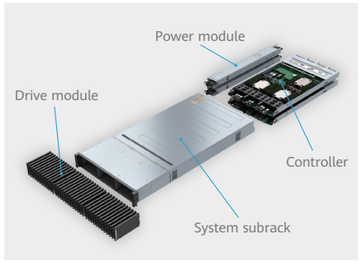
> Patent family 3: Support structure and foldable display device
CN110035140A/ CN210075297U

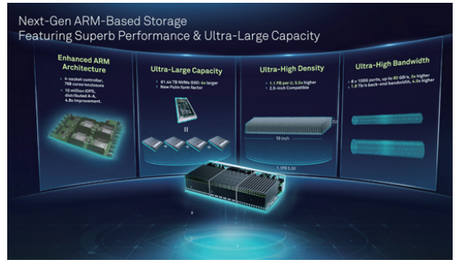
Huawei has been researching foldable phones for years, and one of our greatest achievements is the Falcon Wing hinge that allows the screen to fold and unfold smoothly. This tiny hinge is comprised of more than 100 precision-cut pieces, including a supporting mechanism, a rotation shaft, and a mechanism that guides movement.

The design of the hinge ensures that the flexible screen will not over-stretch while folding or bulge when unfolded. It is artistically crafted to dissolve into the device for a smooth and flat finish on both sides. The Huawei Mate X smartphone, which uses the Falcon Wing hinge, became an instant hit soon after it debuted in 2019.

Top Invention: Converged storage system

> Patent family 1: Electronic device, electronic system, and circuit board interconnection architecture thereof
CN103974538B/ EP2945470A1/ US8842441B2/ CN110998510A

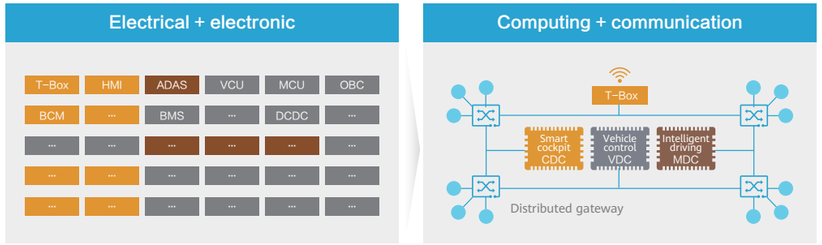




In February 2019, Huawei released a converged storage architecture that employs an orthogonal backplane as well as Palm/Half Palm solid-state drives to support both centralized and distributed storage, addressing user needs across a broad range of scenarios. In July 2019, Huawei launched the OceanStor Dorado product series built on this converged storage architecture. These products received wide acclaim for their massive boost in performance, capacity, and heat dissipation.

Top Invention: The Computing and Communication Architecture for vehicles

> Patent family 1: Vehicular electronic control system, method, and vehicle
CN201910865878.4/ CN201910867047.0



All vehicles of the future will be connected, autonomous, shared, and electric (CASE). Due to the limitations of existing electrical/electronic (E/E) architecture, in-car wiring is complicated, upgrading software is

difficult, and computing power is scattered across different vehicular modules. These barriers make it challenging to develop fully CASE vehicles.

In 2019, Huawei unveiled the Computing and Communication Architecture (CCA), which combines distributed networks and domain controllers in place of the bus network and distributed electric control units found in traditional E/E architecture. CCA makes it easier to upgrade software, replace hardware, and scale up the use of vehicle sensors.

Conclusion

Huawei's ability to grow and thrive lies in our substantial investment in R&D, focusing on innovation that meets our customers' practical needs. From early on, we have been investing more than 10% of our annual revenue back into R&D. More than three decades of intensive investment has led to many groundbreaking technologies and solutions across a broad range of information and communication technology fields.

Fostering the creation of cutting-edge technology requires arduous and consistent effort, and in pursuit of these advances, we are strong advocates for the respect and protection of intellectual property. To us, this is the foundation of our ability to keep innovating and bring the benefits of digital technology to every person, home and organization for a fully connected, intelligent world.