China – IoT Nation

AI and Big Data

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Dansk resume

Formålet med denne ICDK OUTLOOK er at belyse udviklingen af "Internet of things" (IoT) i Kina og inspirere virksomheder og universiteter til at se mod Kina for IoT partnerskaber og markedsmuligheder. Rapporten er en del af en todelt 'rapportserie' kaldet *China IoT Nation*. Denne rapport dækker Kinas politikker og brug af AI og Big Data i Kina og inkluderer input fra fem IoT-eksperter. Den anden rapport dækker emnet Smart Cities, og kan findes på ICDKs hjemmeside icdk.um.dk.

Politisk fokus

Over det sidste årti er der blevet implementeret en række politikker, der har påvirket udviklingen af Kinas IoT. "Den 12. femårsplan for IoT-udvikling", der blev udgivet i 2012, understregede den betragtelige kløft, der er mellem Danmark og Kina i udviklingen af IoT-teknologi. I "Special Action Plan for Internet of Things" fra 2013 blev 10 ministeriers IoT-indsatser koordineret. Planer som denne sigtede mod at introducere IoT i traditionelle industrier som detailhandel, produktion, og bankvæsen. I den nyere "Made in China 2025" strategi fra 2015 blev der afsat mere end 10 mia. RMB til udvikling af IoT-teknologi. Det nationale fokus på IoT har ligeledes affødt lokale initiativer.

Kina har siden 2015 haft en national strategi for Big Data, og i 2020 forventes AI-industrien at have en værdi på 150 mia. RMB. Kina har et nationalt mål om at være global leder inden for AI i 2030, og Big Data sikkerhed er højt på dagsordenen. Modsat Europa er fokus dog på at kontrollere data i stedet for at beskytte individers data.

Anvendelse af Big Data og AI

Brugen af Big Data og AI er drevet af hensyn til sikkerhed, profit, og livskvalitet, fra hhv. regering, industri og forbrugere.

Regeringens brug fokuserer primært på sikkerhed og overvågning. Industrien, motiveret af stigende arbejdsomkostninger, fokuserer øget effektivitet, kvalitet, og produktivitet. Forbrugerne fokuserer på øget livskvalitet og ønsker løsninger, der skaber nytte for dem. Da forbrugerefterspørgsel er en stor drivkraft bag IoT udviklingen i Kina, er mange kinesiske virksomheder aktive på business-to-consumer markedet (B2C).

AI bruges ved aktiviteter i forbindelse med infrastruktur såsom strømstyring, sensorteknologi, og kommunikation. I rapporten bliver 7 cases om AI og Big Data-løsninger fra både start-ups og tech giganter præsenteret sammen med en gennemgang af centrale kinesiske uddannelses- og forskningsinstitutioner, der arbejder med IoT, AI, og Big Data.

Executive summary

The purpose of this ICDK OUTLOOK report is to shed light on the development of the Internet of Things (IoT) in China and inspire corporates and universities to look to China for IoT partnerships and market opportunities. The report at hand is part of a two-part report series entitled *China IoT Nation*. It covers policies and use-cases related to AI and big data in China, and includes inputs from five IoT experts. The other report centres on the topic of Smart Cities and can be found on the ICDK Shanghai homepage: icdk.um.dk.

Relevant policies
Several policies affecting IoT development in China have been implemented over the last decade. For an overview of the most significant IoT policy developments in China from 2010-2018, see Figure 2.

The "12th Five Year Plan for IoT development", published in 2012, laid the groundwork for the Chinese government's focus on IoT. Consequently, in 2013 ten ministries started to coordinate policies and initiatives as stated in the "Special Project Action Plan for Internet of Things Development". These national plans, along with the 2015 "Internet Plus Action Plan", aim to introduce IoT into traditional industries such as retail, manufacturing and banking. The recent "Made in China 2025" set aside more than RMB 10 billion of funding for developing IoT initiatives. The national focus on IoT triggered local development plans. Guangdong, which provides subsidies for IoT applications in manufacturing, can be considered the province with the highest IoT ambitions.

China has had a national strategy for big data since 2015, and in 2020, AI is expected to be an industry worth RMB 150 billion. It is a national goal to make China a global leader in AI by 2030 and big data security is high on the agenda – however, unlike Europe, the focus is on ensuring control over the data, rather than protecting the data of individuals.

Big data and AI applications
Big data and AI deployment in IoT is driven by forces of security, profit and quality of life by government, industry, and consumers, respectively.

Government applications are mostly focused on security and surveillance while industry is focused on industry applications that increase efficiency, quality and productivity and is motivated by increasing labour costs. Consumers are concerned with increasing quality of life, and applications include solutions for creating more utility and better experiences for consumers. Business-to-consumer (B2C) is where Chinese companies are most active because consumer demand is the biggest driving force of Chinese IoT development and the area where most of the money is going.

AI is used in infrastructure-related activities, such as power management, sensor technology and communications. Seven cases of AI and big data solutions from both start-ups and tech giants are presented in this report along with a characterisation of academic institutions that are actively producing IoT, AI and big data publications.

Preface

According to the Chinese government, China missed out on the first three industrial revolutions, i.e. they were not front runners in inventing or introducing mechanisation, new energy sources, or electronics and computation on a mass scale in society. In the 21st century, the government is therefore fully committed to participating in, driving and benefitting from the fourth industrial revolution, i.e. smart automation.

Internet of Things (IoT) plays an important role in China's ambitions in the fourth industrial revolution. It provides the data that powers China's ambitions in artificial intelligence, it provides information for the systems that control China's increasingly smart cities and it monitors the health of individuals for the benefit of China's healthcare system. These are just a few areas where IoT is central to China's smart automation ambitions.

As is usually the case in China, the government has laid out its ambitions in numerous policies, which are important reference points and a good place to start if one wants to understand the direction of development within a certain field in China. As such, this report includes a section on China's national policies. However, the real impact is of course to be found in the implementation and, thus, we have made an effort to include several relevant use-cases as examples of China's endeavor to become an IoT Nation.

At the Innovation Centre in Shanghai, we have so far followed the development of China's IoT ambitions as part of our general surveying of the Chinese tech landscape. In some projects, for instance Nordic Sustainable Cities and various water-related projects, IoT is more prominent and we discuss new solutions with Chinese companies involved in these projects as well as exchange information about policy initiatives with government officials on different levels in the Chinese system.
The 'IoT Nation' reports, however, represent our first deep dive into the field of IoT. We have chosen to focus on two major IoT topics: big data and artificial intelligence in one report, and smart cities in the other.

We believe that both reports provide some valuable insights into these two important areas of IoT application. Furthermore, we hope they will inspire Danish stakeholders from corporates to start-ups, on the one hand, and universities to individual researches, on that other hand, to look towards China for inspiration, partnerships and market opportunities.

Innovation Centre Denmark in Shanghai is happy to support any China focused IoT initiatives that the two reports may inspire, and we are ourselves looking into ways of strengthening our capacity in this sector.
Enjoy the read!

Søren Boutrup, Executive Director
Martin Bech, Innovation Attaché

1. Introduction

This report examines the state of the *big data* and *artificial intelligence* (AI) stage of China's Internet of Things (IoT) value chain, from the perspectives of government policies, industry ecosystems, and academic research.

IoT describes the ability to connect any Internet Protocol-enabled device to the Internet. [i] There is an almost infinite number of applications for IoT, ranging from consumer wearables to robotic warehouses via facial recognition for surveillance. The market size for IoT in China has grown from RMB 170 billion in 2009 to more than RMB 1 trillion in 2017. It is expected to reach RMB 1.8 trillion by 2020. [ii]

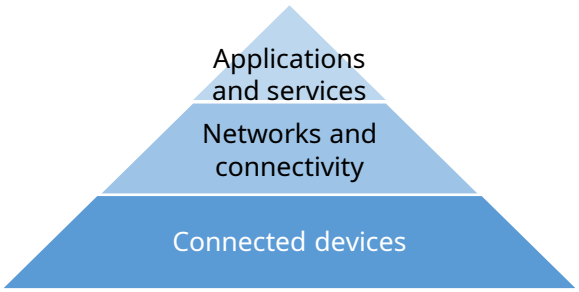


Figure 1. IoT and big data policies

The IoT value chain can be visualized as a pyramid. At the base are connected devices and sensors. On the consumer side, such devices include phones, fitness bands, connected cars, smart homes, and other devices. In industry, the base level of the pyramid includes sensors in anything from individual machines to entire connected factories, and from industrial drones to urban infrastructure. Yin Lu, Key Account Manager of TouchELX and one of five experts interviewed for this study, holds forth the distinction between devices that are built for interacting with humans (such as consumer-facing devices) and devices that either interact with each other (e.g. in robotic warehouses) or only feed sensor data to a computer cloud for analysis. [iii]

One step above this base level are *networks and connectivity*, both of which relate to how devices are connected and how they communicate. [iv] This level is also where service providers collect device and network data and upload it to a cloud. [v]

At the top of the pyramid are *applications and services*. These are closest to the eventual end users, whether they be enterprises or consumers.[vi] It is here that data are used as a resource for value adding in various forms. The IoT-enabled device becomes a platform for a host of applications and services. Consequently, physical products increasingly derive their value from the data generated or collected through their interaction with their surroundings rather than from the hardware itself. For example, some wearable devices collect data that is used

for personalized health advice; and sensors embedded in urban infrastructure can be used to optimize traffic flows.[1]

2. Government Policies

The Chinese government is an important driving force in the country's adoption of IoT. There are three interrelated sets of policies that pertain to the part of the IoT value chain where data is used to add value. The first are policies concerning overall IoT development, which in recent years have fused with policies emphasizing informatization and digital transformation. The second and third sets of policies relate to big data and AI, respectively. None of the three explicitly fall under the IoT policy umbrella, but they are nonetheless critical for IoT development because of their strong connection to numerous IoT applications, including autonomous driving, smart cities, consumer electronics, and smart manufacturing.

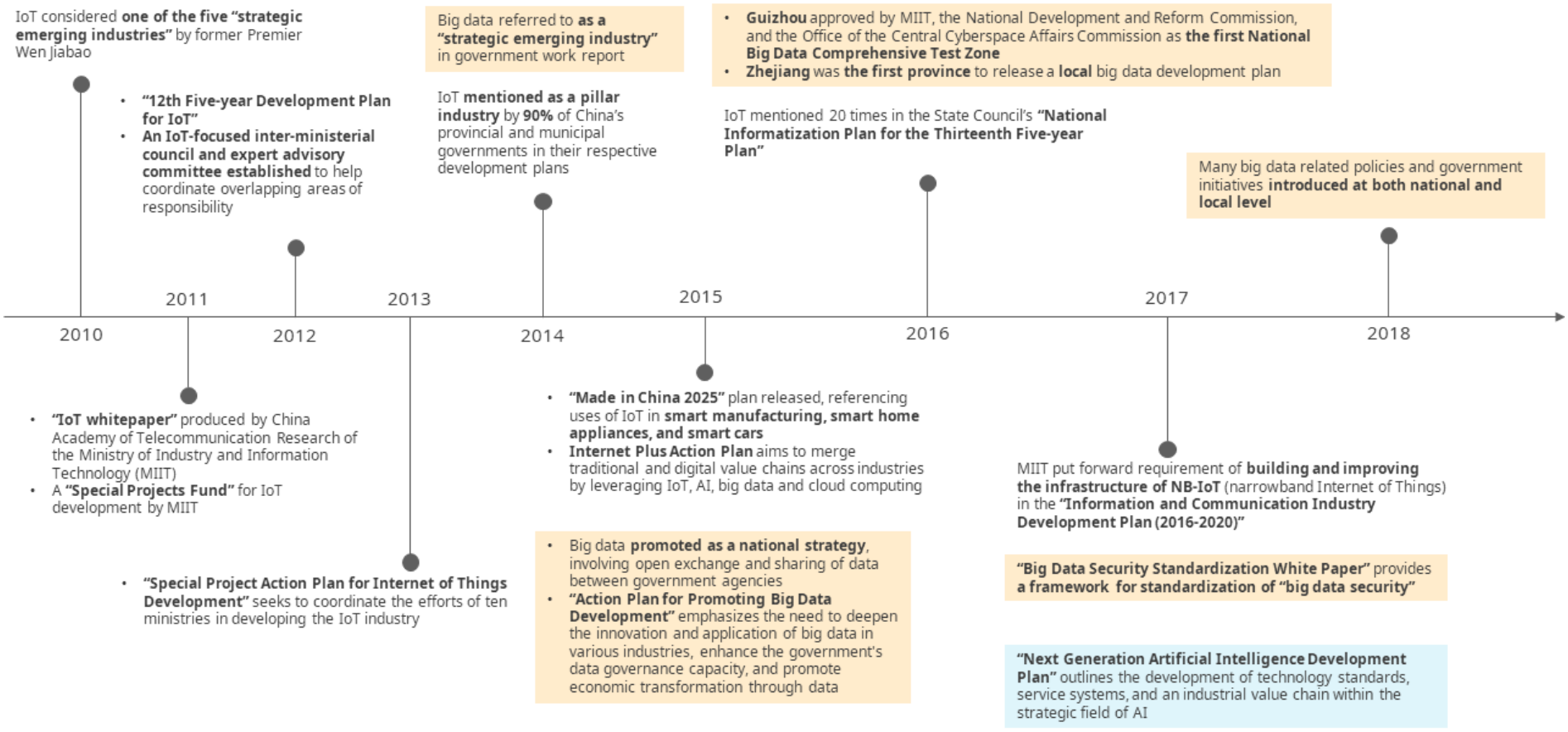
2.1 IoT policy development

The first indication of the Chinese government offering official support to IoT were remarks in former Premier Wen Jiabao's 2010 government work report, referring to IoT as a "strategic emerging industry".[vii] Over the next few years there was a string of work reports and policy documents that dealt with various aspects of IoT, particularly IoT infrastructure.

Ever since a 2011 "IoT whitepaper", the Ministry of Industry and Information Technology (MIIT) has been one of the government agencies most active in promoting IoT. In 2011, the ministry created a Special Projects Fund for IoT development.[viii] In 2012, it published the "12th Five Year Plan for IoT development." The report noted a big gap between China and other countries in core IoT technologies and high-end IoT products.[ix] The same year, China established an IoT-focused inter-ministerial council and expert advisory committee to help coordinate between overlapping areas of responsibility.[x]

In 2013, the "Special Project Action Plan for Internet of Things Development" sought to coordinate the efforts of ten ministries in developing the IoT industry.[xi] It identified goals, tasks, and responsible departments covering ten separate areas of IoT development policy: top-level design, standards formation, technology R&D, application and promotion, industrial support, business models, safety, government support, laws and regulations, and workforce training.

Figure 2. IoT and big data policies



These central government initiatives triggered local governments to create their own IoT development plans. By 2015, 90% of China's provincial and municipal governments mentioned IoT as a pillar industry in their respective development plans.[xii] IoT also made its way into the State Council's "Made in China 2025" plan, which includes references to smart manufacturing, smart home appliances, and smart cars. Under the plan, IoT and other technologies that boost manufacturing innovation will benefit from state funding in excess of RMB 10 billion.[xiii]
According to Nathan Lawes, Head of Ecosystem Development at IoT ONE, the significant amounts of public funding going into IoT development, and industrial IoT development in particular, is a clear illustration of the Chinese government's top-down approach. This approach sets China apart from the US, for example, where developments are bottom-up, driven by the research and development carried out by private companies.[xiv]

Also in 2015, the government launched the "Internet Plus Action Plan", which aims to merge traditional and digital value chains across industries. The plan aims to introduce IoT, big data, cloud computing, and mobile internet into manufacturing, retail, banking, and other traditional industries.[xv] Subsequently, the Chinese tech giants have moved to realize this vision under slogans such as *New Manufacturing* and *New Retail*.

In 2016, the focus on the information side of IoT became more explicit: IoT was mentioned 20 times in the State Council's "*13th Five-Year Plan for National Informatization Planning*". [xvi] The next year, the MIIT put forward the requirements of building and improving the infrastructure of *narrowband Internet of Things* (NB-IoT) in the "Information and Communication Industry Development Plan (2016-2020)". [xvii] Such networks make up the communications infrastructure for a wide range of connected devices and services.

2.2 Big data and AI policy development

Big data first appeared in a government work report in 2014, where it was referred to as a "strategic emerging industry."[xviii] In October 2015, it was promoted as a national strategy, which involved the open exchange and sharing of data between government agencies during the Fifth Plenary Session of the 18th Central Committee of the Communist Party of China.[xix] The same year, the State Council published the "Action Plan for Promoting Big Data Development".[xx] The document emphasized the need to deepen the innovation and application of big data in various industries, enhance the government's data governance capacity, and promote economic transformation through data.

A key national AI policy document is the "Next Generation Artificial Intelligence Development Plan" published in 2017. [xxi] The document outlines the development of technology standards, service systems, and an industrial value chain within the strategic field of AI. It calls for the cultivation of a number of the world's leading "AI backbone enterprises" by 2020. The same year, the core AI industry is to be worth RMB 150 billion, while related industries should reach a value of RMB 1 trillion. By 2030, China should be a global leader in AI

technologies and applications, making it the world's primary AI innovation center with a core AI industry exceeding a value of RMB 1 trillion.[xxii]

2017 also saw the publication of the "Big Data Security Standardization White Paper", co-edited by 25 organizations including China Electronics Standardization Institute, Tsinghua University, Sichuan University and Alibaba Cloud Computing Co., Ltd.[xxiii] It provided a framework for the standardization of "big data security" and suggested an agenda for the further development of big data security standards. This effort was one of many indications of the government's strong and growing data security focus.
Nathan Lawes argues, in relation to data security policy, that "China is just as strict as the EU when it comes to data management," but that its focus is different; the Chinese focus is not on protection of individuals' data, like in Europe, but on ensuring control over the data. Public-private partnerships are one way of building IoT-related control systems. The government's partnership with HikVision, which provides connected cameras with face recognition capabilities, is an example of this.[xxiv] According to Yin Lu of TouchELX, data protection is a growing concern related to national security and therefore of high priority to the Chinese government.[xxv]

2.3 Provincial policy development

At the province level, Nathan Lawes holds forth Guangdong as the province with the highest ambitions when it comes to government driving industrial IoT adoption, followed by Jiangsu, Zhejiang, Chongqing, and Shandong. In Guangdong, which is a center for manufacturing, the provincial government is subsidizing IoT applications in the manufacturing industry by up to 100% during the first year of adoption.[xxvi]
Many big data related policies and government initiatives were introduced in 2018 at both national and local levels. Of relevance to IoT is a cluster of policies aimed at regulating and promoting the use of big data in the industry. Two examples given below are the plan to promote the industrial IoT as in Guizhou Province, and connecting enterprises with clouds as in Zhejiang Province.

In 2016, Guizhou was approved as the first National Big Data Comprehensive Test Zone by MIIT, the National Development and Reform Commission, and the Office of the Central Cyberspace Affairs Commission.[xxvii] As a result and according to official statistics, more than 9,500 big data companies have established a base there.[xxviii] These include tech giants such as Alibaba, Huawei, Tencent, Baidu, and JD.com, as well as global companies such as Apple, Microsoft, and Oracle. The government is actively encouraging companies to adopt cloud computing solutions, many of which are hosted in Guizhou.

The same year, Zhejiang became the first province to release a big data development plan, closely following the State Council's "Action Outline for Promoting Big Data Development", published in 2015.[xxix] Aiming to become a leading "Data Power Province", the Zhejiang government established a big data management center with the aim of strengthening the top-level design of the big data industry construction. It also launched the first government data platform in China and approved the establishment of a big data trading and exchange platform to facilitate data integration across organizations.[xxx]

3. Industry Ecosystem

The deployments of big data and AI in the IoT value chain in China can be divided into three broad categories, described in this chapter. They are connected to the differing demands from different parts of society.

Professor Wang Haoyu of ShanghaiTech University describes how the deployments are pushed forward by three driving forces from government, industry, and consumer:

- The government is security-driven.
- The industry is profit-driven. IoT sensors facilitate cheaper quality control and higher yield.
- Consumers are life-quality-driven. They are looking for IoT devices which help improving the quality of life, such as wearable electronics for healthcare, smart IoT sensors for home appliances.[xxxi]

Business-to-government (B2G) applications, with a focus on security and surveillance applications. Unicorn start-ups, including HikVision, Sensetime, and Cloudwalk, are active in this space. Applications range from "emotion AI" to border control and public security solutions. The latter includes automated analytics of image data from networks of connected surveillance cameras, including facial and gait recognition.

Business-to-business (B2B) applications, where increased efficiency, quality, and productivity in various value chains are key objectives. Higher and more even quality levels are made possible by finer monitoring and control of production conditions using sensors, and for other optimizations in fields such as logistics and energy usage.

Increasing labor costs are mentioned by Nathan Lawes as a key motivation behind the use of industrial IoT, as many IoT applications can, to varying extents, substitute manual labor. Improvements in quality are possible through what Lawes describes as better visibility and accessibility, as connected sensors make more data available at every step in the production process. According to

Lawes, manufacturing is the single most important use case for IoT. Nonetheless, "it is surprising how low the adoption rate is right now. There is plenty of room for growth."[xxxii]

Some of the most interesting players in this space are attempting to build platforms that other companies can build solutions on top of. Two examples are Baidu's Apollo, which has the ambition of becoming an equivalent of Android for autonomous driving, and Horizon Robotics, which provides "autonomous driving on a chip".

Case: Clobotics

Clobotics, a Shanghai and Seattle based start-up, founded in 2016 by former Microsoft and Ehang executive George Yan. The company provides AIoT (Artificial Intelligence and IoT) solutions for wind power and retail industries. In both industries, the company has designed IoT solutions that collect image data, which is subsequently processed through AI image analysis algorithms, the results of which are used to improve productivity.

For the inspection of the condition of wind turbines, the company customizes drones, a process that includes equipping the drones with cameras, computing chips, and lidar systems. The result is a self-flying drone that autonomously takes aerial photos of wind turbines after calculating what the most relevant angles are based on an on-device analysis of the image and lidar data. 300,000–600,000 photos are taken by each drone; the photos are uploaded to a cloud and analyzed by the company's machine learning models to determine what condition the turbine is in and identify weakened components. George Yan holds forth that the company's solution radically reduces costs compared to traditional methods for wind turbine inspection, while simultaneously increasing the productivity of wind power operators.[xxxiii]

In retail, Clobotics provides an IoT device that is mounted in existing coolers in stores. Utilizing computer vision and deep learning technologies that run on edge and ultra-low-power communications, the solution facilitates accurate, real-time, and easy-to-scale in-store data collection. The device takes a photo every time a consumer opens and closes the door of a cooler to determine which specific product is being sold. The data that is collected about which products are sold, at what time they are sold, and how they are placed is uploaded to a cloud, currently through Wi-Fi and 4G connections. Customers include Coca Cola, Procter & Gamble, and Walmart, for whom optimal product placement is important. Store owners can follow the effects of different ways of placing products in real time through an app.[xxxiv]

Case: Baidu - building platforms for self-driving vehicles and voice devices

Baidu, the tech giant most widely known for its search engine, is increasingly shifting its focus to AI and big data in general, and to applications for connected self-driving vehicles in particular. On top of Baidu's open software platform Apollo[xxxv], more than 100 partners, ranging from car manufacturers such as Volkswagen, via universities including Tsinghua University, to software and hardware companies such as Intel, are building components and applications for self-driving vehicles.

DuerOS[xxxvi] is another Baidu initiative, through which the company is providing a platform for IoT devices with a voice interface, from in-vehicle navigation and infotainment to smart homes and wearables. Partners include high-profile consumer hardware companies such as Xiaomi and Lenovo. Baidu claims that there were more than 200 million devices using DuerOS as of January 2019.[xxxvii]

Case: Horizon Robotics: AI chips powering autonomous vehicles

Horizon Robotics, a start-up founded by a former head of AI at Baidu, is developing AI chips for use in IoT solutions in fields spanning autonomous driving, surveillance, and retail. After raising funds of US$ 600 million in February 2019, the company claims to have a value of at least US$ 3 billion.[xxxviii]

In the field of autonomous driving, Horizon Robotics' core product is an AI chip that processes the data collected by an autonomous vehicle's sensors, including but not limited to camera, radar, and lidar systems. Vice President Li Xingyu explains that in-vehicle AI is needed to make sense of the sensor data. The company is, for example, using supervised machine learning to train the system to distinguish roadway from sidewalks.[xxxix]

The autonomous driving that is under development in China is, however, not fully autonomous. Instead, the country is taking a big data approach by constructing a, to some degree, centralized system of what national policy documents call "intelligent connected vehicles" (ICV). One idea behind the ICV system is that it will be able to aggregate the data from sensors in vehicles with that generated by IoT devices in fixed road-side infrastructure. Aside from the autonomous driving AI chip, Horizon Robotics is also developing IoT cameras, for integration with the ICV system that can be mounted inside street lights. Li mentions that the ICV system will, for example, be aware of obstacles approaching around a street corner that the connected cameras will see, but that a fully autonomous car (that only relies on sensors on the vehicle itself) would not be able to detect. In line with how sensor data is used for decisions on what action to take in a factory, Li describes how a centralized ICV system might eventually, if all goes according to the plan, control all connected vehicles remotely.

Within the B2B space, Alibaba Cloud has partnered with Siemens on the launch of MindSphere, an Industrial IoT (IIoT) operating system. The technology incorporates sensors that create a digital "mirror" of companies' real life consumer products, capturing and broadcasting important information in order to increase efficiency.[xl]

Business-to-consumer (B2C) applications aiming to create more utility and better experiences for consumers. Consumer demand is, according to Professor Wang, the driving force behind IoT developments in China and the field into which most money is going.[xli] Consequently, B2C is where Chinese companies are most active. According to Yin Lu, consumer IoT devices are particularly easy to sell in China, since consumers are less concerned than consumers elsewhere about data privacy and what any personal data collected through IoT devices might be used for.[xlii]

Case: Voice-enabled consumer IoT for convenience, education, and security

The IoT applications that most people consciously interact with are found in the field of consumer electronics. An IoT application with which an increasing number of people are interacting, as part of their everyday lives, is that of "smart speakers" with integrated voice assistants. These devices are emerging following improvements in the AI algorithms for voice recognition and natural language processing, which have greatly facilitated voice interaction between humans and machines.

Chinese companies that have launched smart speakers during the last few years include tech giants Alibaba (calling its smart speaker *Tmall Genie*) and Baidu (*Xiaodu*), consumer electronics maker Xiaomi (*XiaoAI*), and online audio platform Ximalaya FM (*Xiaoya*).[xliii] Use cases are similar to those of Amazon's Alexa or the Google Assistant, including searching for information, online shopping, and controlling various home appliances.

Among the earliest Chinese smart speakers was DingDong[xliv], released in 2016 by LingLong, a company jointly owned by the e-commerce giant JD.com and the voice tech company iFlytek. The latter was in 2017 appointed the "national champion" of AI development for voice applications by the Ministry of Science and Technology.[xlv] Apart from the smart speaker, iFlytek is developing voice interfaces for a range of applications, including:

- Education: automated language-training tools with speech evaluation. The tool assists the teaching of spoken Chinese and English with features including evaluation of pronunciation and has been used by over 50 million students in primary and middle schools in China and Singapore, according to the company.[xlvi] English lessons were also available as a voice app in the DingDong speaker.
- Voice control of smartphones in collaboration with Huawei.[xlvii]
- Security: the company is developing "voice print" technology, which can identify individuals from their voices. The company mentions "intelligent access control" among the applications.[xlviii]

Amid the intense competition in the voice assistant market, one contender, Mobvoi, has pivoted toward enterprise solutions. By providing local, on-device AI they service niche segments such as banks, hospitals, airlines, and cars where the need for security or stability disqualifies cloud solutions.

3.1 Infrastructure, activities, and key players

Cutting across the three categories are infrastructure-related activities, such as sensors and perception, communications infrastructure, cloud solutions, and AI and machine learning solutions.

Sensors and perception: High-end sensors, particularly so-called perception technology which is used by IoT devices to sense their surroundings, have been described as a bottleneck that is restricting China's IoT development. Most of these sensors are being imported from abroad.[xlix] Yang Xueshan, former vice-minister of the Ministry of Industry and Information Technology and professor at Peking University, said at the China Internet of Things Industry Ecology Conference in 2018 that "What we lack most at present is perception [technologies]".[l]

Manufacturers of mid- and low-end sensors are, however, abundant in China. Kalewa, for example, is one of the leading companies in mainland China in RFID solutions for intelligent packaging, public transport, cold chain and logistics, intelligent warehouses, and many other applications.

Power management: Stable power supply remains a bottle-neck for data collection through IoT devices that cannot be connected to the power grid. A lot of research is therefore going into improving battery capacity and reducing the power demand of components used in IoT. Professor Wang at the ShanghaiTech University explains that there are also cases for which IoT devices are being built to generate their own power: for example, a device mounted next to a railway track might generate electricity from vibrations in the track caused by passing trains.A bottleneck for any IoT device that can, for some reason, not be connected to the power grid – for example a sensor at a remote location – is stable power supply. Power supply units for such applications is the research area of Professor Wang's research area., who He explains that the solution in many cases is to use batteries. Using a battery as the sole power source for a remote application does, however, entail significant costs when the battery is to be replaced. A lot of research is therefore going into both improving battery capacity and reducing the power demand of components used in IoT devices. In some situations, IoT devices can also be built to generate their own power. By way of example, Professor Wang mentions that a device mounted next to a railway track might generate electricity from vibrations in the track caused by passing trains.[li]

IoT communications infrastructure: Huawei, ZTE, and China Tower are all competing for market share on the communications side of IoT. China Tower was formed through the merger between the transmission operations of the three state-owned telecom operators, China Mobile, China Telecom, and China Unicom, and is the world's largest operator of mobile phone towers. Huawei and ZTE are involved in every part of the IoT value chain, from communications infrastructure to IoT devices and applications, in areas spanning smart cities, Industry 4.0, and consumer electronics. These companies are now at the center of the effort to commercialize the fifth generation mobile networks (5G), which

is expected to profoundly change entire industries as it will enable a 1,000-fold increase in Internet traffic over the next decade.[lii]

AI and machine learning solutions: Most of China's 14 AI unicorns (startups valued at US$ 1 billion or more) are present in the IoT value chain. The largest of them is DJI, a global leader in drone technology that uses a layer of AI and analytics for navigation, photography, and industrial applications for industries such as agriculture and forestry.[liii]

More than half of China's AI companies are financed by Baidu (48 companies), Tencent (37 companies), or Alibaba (31 companies). Among IoT related sectors, investments by the three tech giants are primarily in transportation (18 companies), home appliances (13 companies), and autonomous driving (8 companies). Other relevant sectors include chips (5 companies), retail (5 companies), machine vision (4 companies), and robotics (3 companies).[liv]

65% of China's AI start-ups focus on applications, which leaves only 35% to innovate in the technologies that underpin them. Among this minority of companies, about half is active in hardware, including the prominent AI chip maker Cambricon. The other half is active in algorithms, for example image recognition companies such as Face++ and Sensetime.

Case: Alibaba wants to dominate the IoT ecosystem

In 2018, Alibaba defined IoT as their new main track after e-commerce, finance, logistics and cloud computing. Apart from its plan to connect 10 billion devices within the next five years, Alibaba's initiative in IoT covers a large part of the value chain, from 5G network collaboration with China Tower, one of the world's largest telecommunications tower operators, to specific applications such as solutions for smart logistics and smart transportation.

Cooperating with China Tower in 5G and edge computing: In August 2018, Alibaba established a strategic partnership with China Tower to collaborate around cloud computing, edge (on-device) computing, big data, and 5G. China Tower will provide infrastructure for Alibaba's IoT projects through its 1.9 million telecommunications towers in the country, especially for their smart city and smart transportation projects.

AI chipmaking: In September 2018, Alibaba set up its own chipmaking subsidiary, Pingtouge Semiconductor Company, to make its own AI chips. Prior to this, Alibaba had spent several years investing in chipmakers. In April 2018, it wholly acquired Zhongtian Microsystems Co., Ltd., the only large company in mainland China with its own independent integrated CPU intellectual property cores (i.e. licensable chip layout designs that can be integrated into a larger software or hardware design). The new subsidiary, Pingtouge, is expected to combine the core technology of Zhongtian Microsystems and the chip research results of Damo Academy, Alibaba's research arm.

Alibaba hopes that Pingtouge will reduce its – and China's – reliance on foreign high-end chip technology and support the company's fast-growing cloud computing and IoT business. At the same time, Damo Academy is conducting R&D of superconducting quantum chips and quantum computing systems.

Collaboration with Rokid for smart logistics: In 2018, Cainiao Network, Alibaba's logistics platform operator, launched its latest solution, the logistics platform Cainiao Future Park. Leveraging IoT applications, big data, edge computing and AI, Cainiao Future Park is attempting to transform labor-intensive operations in industrial parks with sensors to monitor needs and report water, electricity, temperature and humidity conditions in real-time. Cainiao Future Park is present in Wuxi, Tianjin, Jiaxing, and Chongqing.

In May 2019, Cainiao Network announced a strategic partnership with Rokid, a Hangzhou-based start- up specializing in robotics, AI, and AR research and development. Rokid will use its technology to help Cainiao explore smart logistics and promote the construction of an open IoT logistics platform.

Case: AIoT: G7 forming the next generation of logistics infrastructure

The Chinese IoT start-up G7, a fleet management service provider, offers IoT and AI services to more than 60,000 customers and 800,000 commercial vehicles.

The Tencent-backed start-up completed a funding round of US$ 320 million in October 2018, setting a new record in the global IoT start-up space. Through subsequent funding rounds, the company increased its total investment amount to an estimated US$ 500 million, making it one of the most valuable IoT companies in the world.[lv]

Through its proprietary hardware devices, G7 collects and compiles data in real time on location, timing, fuel consumption, driving behavior and cargo status (temperature, humidity, etc.) for logistics companies and freight fleets.[lvi] The data is transmitted back to their management cloud platform in real time. Based on its proprietary artificial intelligence in IoT (AIoT) platform, G7 provides integrated fleet management solutions and services, which cover route optimization, safety, fuel, payments, financing, and Intelligent-Equipment-as-a-Service. It connects each truck, cargo owner, transportation agency, and driver with data collected through smart devices to improve the efficiency of logistics services.[lvii]

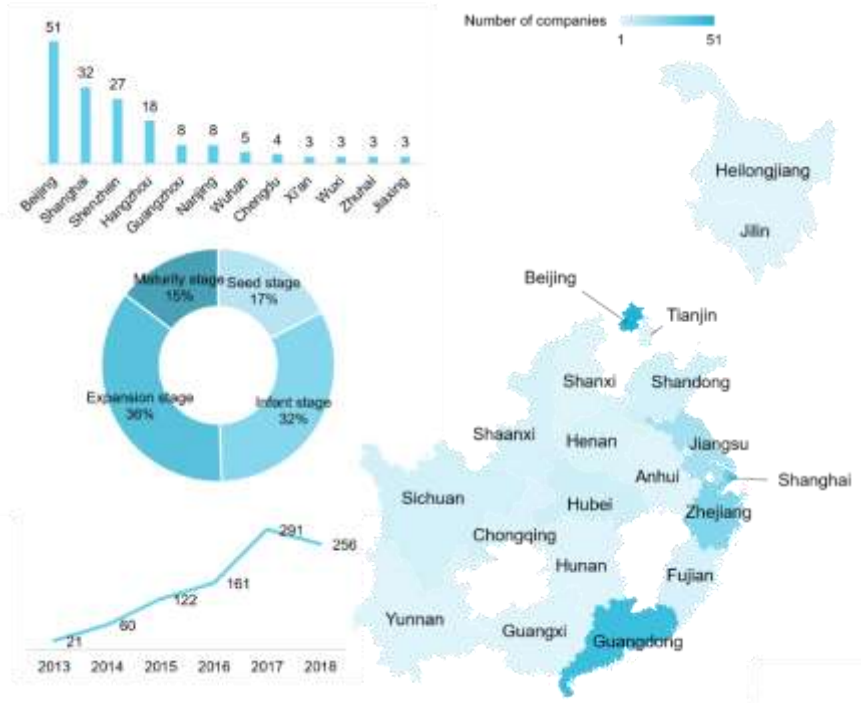


Figure 1. Distribution of Chinese companies mentioning both IoT and data analytics-related terms in their business scope that received investment capital during 2016-2019. *Map*: Number of companies per province. *Bar chart*: Chinese cities with the greatest number of companies. *Pie chart*: Shares of companies by investment stage. *Line chart*: Number of investment deals per year.

4. Academic research

Research into big data and AI related IoT research topics is taking place in academic institutions across China. The most active institutions, based on their number of academic publications in Chinese journals mentioning both IoT and data related keywords, are: Beijing University of Posts and Telecommunications; Chinese Academy of Sciences University; and Guangdong University of Technology. Table 1 below gives an overview over the ten post-prolific institutions, the research topics they are active in, and the authors of the related academic articles.

Table 1. China's 10 academic institutions with largest numbers of publications using a combination of keywords related to both IoT and data analytics.

INSTITUTION	CITY	TOPIC
Beijing University of Posts and Telecommunications	Beijing	Energy efficiency optimization, routing strategy, multi-dimensional data analytics, fiber sensing, industrial monitoring
Chinese Academy of Sciences University	Beijing	NB-IoT, Elasticsearch, data tampering detection, system monitoring, data fusion
Guangdong University of Technology	Guangzhou	Industrial IoT, product quality forecasting, massive real-time data streaming, system on chip, security chip, complex event detection, encryption
Nanjing University of Posts and Telecommunications	Nanjing	Machine-to-machine communication, equipment management, smart appliances, Raspberry Pi, Zigbee, performance analysis, data fusion, fuzzy theory
Inner Mongolia University	Hohhot	Geographic information system, water supply and drainage information system, smart water, smart home, environmental monitoring, wind power forecasting
Harbin University of Science and Technology	Harbin	Anomaly detection, data exchange model, intelligent manufacturing, TUN/TAP
Nanjing Posts and Telecommunications University	Nanjing	Wireless sensor network, optimization, real-time transmission
Jiangxi University of Finance and Economics	Nanchang	Cloud computing, AI, smart agriculture, e-government, government audit

INSTITUTION	CITY	TOPIC
Xidian University of Electronic Technology	Xi'an	Data security, smart transportation, license plate recognition, speed detection, behavioral semantic analysis
Hefei University of Technology	Hefei	Fault warning, digital twins, data collection, virtual monitoring, remote monitoring, multivariate visualization

However, much of the academic research into data analytics and machine learning solutions of relevance for IoT applications appear not to make use of IoT as a keyword in its publications. When looking at publications using keywords such as "data analytics", "data science", and "machine learning", without using IoT as a keyword, more of the top academic institutions in the country are represented. Figure 4 below shows the 10 institutions with largest numbers of publications:

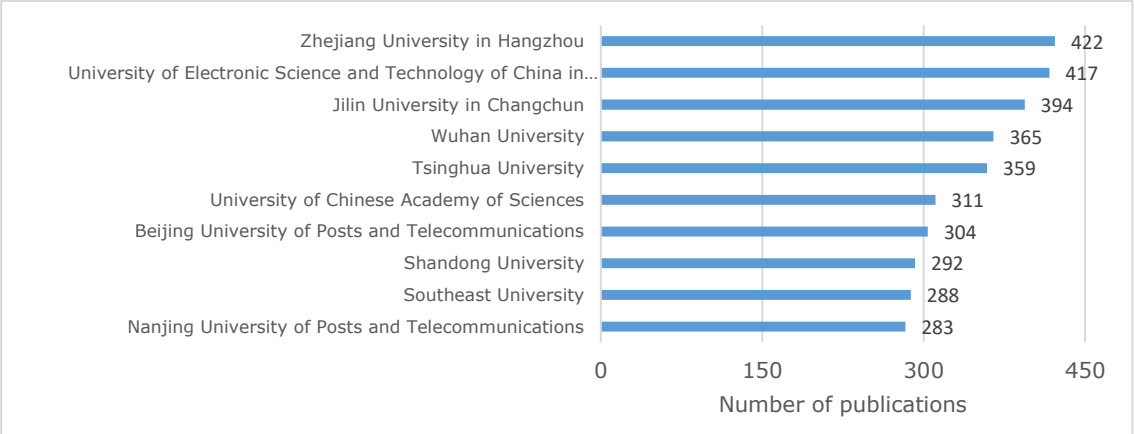


Figure 4. China's 10 academic institutions with largest numbers of publications using keywords related to data analytics and machine learning.

Case: Emotion-sensing connected cameras for spotting inattentive students

In March 2018, classrooms in Hangzhou No. 11 High School were equipped with cameras by HikVision that were connected to a system for emotion detection. The AI algorithms processing the image data collected through the cameras were able to determine whether students look sad, happy, disgusted, surprised, angry, or neutral – and their level of attention. The system was motivated as being a way to ensure that students are attentive and happy, learning quickly and, ultimately, scoring well on tests. As part of the system, a score could be generated for each student and made available for the teacher in real time, based on the student's level of attention.[lviii]

Emotion recognition is also an academic field; one example is the research being conducted at the National Engineering Laboratory for Speech and Language Information Processing at the University of Science and Technology of China on how algorithms for facial expression recognition through image analysis can be combined with sentiment detection through the analysis of human speech.[lix]

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