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Development of IT Industry in China in the New Age

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Abstract: The article explains the role and future trend of IT industry, and states that information technology represented by the Internet and computers has brought about the third industrial revolution in history. An important impetus for economic growth in modern times, the IT industry has greatly promoted sustainable development and is profoundly changing mankind's way of life and production. In discussing the development trend of world IT industry, the article suggests that with potential new breakthroughs in information technology, the trend of agglomeration and integration of industries has become increasingly obvious, competition of intellectual properties and standards is intensifying and ubiquitous network is taking shape. It points out that China should bring into better play the role of IT industry as an "amplifier" in economic growth, a "transformer" in development mode and a "propeller" in industrial upgrading. It is important to follow a policy that emphasizes independent innovation, market-driven approach, open and compatible technologies, integrated and comprehensive applications, and serving both military and civil purposes, so that a quantum leap of IT industry will be achieved. China should advance industrialization with information technologies and promote the IT industry in the course of industrialization in an effort to build an IT industry with Chinese characteristics. Greater efforts should be made to develop such core sectors as microelectronics, computer, software, key components and materials, as well as sectors with international competitiveness, including broadband mobile communication, next-generation network and information services. Continued improvement should be made in policies guiding the development of IT industry with a view to making China a country with a strong IT industry by 2020.
Key words: IT industry, industrial development, development strategy, new age, China
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Introduction

In the world today, the rapid development of hi-tech industries, represented by the IT industry, is promoting the structural transformation, optimization and upgrading of the global industry. It brings about profound changes to the life style and production mode of human society. Since the beginning of the 21st century, the IT industry is changing with each passing day, and its popularity and application have increasingly significant impact on economic, political, social, cultural and military development in the world. The IT industry has become an important measure of the power, international competitiveness, and degree of modernization of a country or region. How to fully understand the development trend of the modern IT industry and map out our strategy concerning the development and policy orientation of the contemporary IT industry is a critical issue deserving our careful study.

1 Position and Role of the IT Industry

In the mid 18th century, the first industrial revolution symbolized by the steam engine ushered in the age of mass machine production. From the late 19th to the mid 20th century the second industrial revolution symbolized by electrical machines brought human beings to an Electrical Age. In the second half of the 20th century, the third industrial revolution represented by the computer and the Internet swept the world, causing the production pattern of the human society to change from industry-domination to integration between information and industry. Labor productivity has been remarkably increased, and the productivity of the overall society as well as the progress of human civilization has reached an unprecedented level. The world has entered an information age (see Fig. 1).

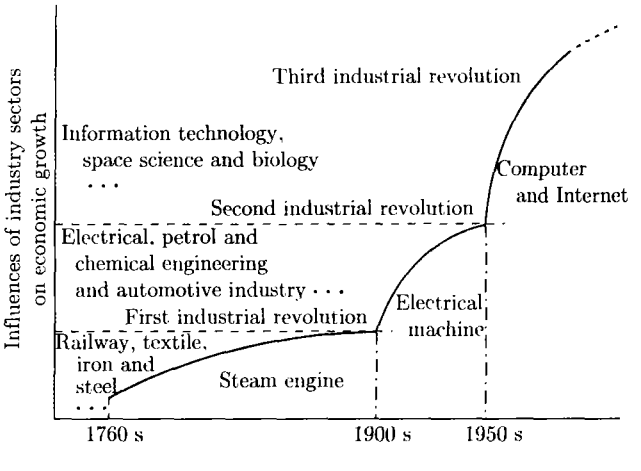

Fig. 1 Three industrial revolutions

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1.1 The Frontier of Scientific and Technological Innovation

Information technology is one of the fastest developing, most widely used, and most pervasive forms of high technology. An advanced level of information technology is a manifestation of the innovative capabilities of a country. The development history of science and technology shows that in the past, it would take a long time to put scientific discovery and technological innovation to industrial use. Today, in contrast, the innovation of contemporary information technology is applied more quickly. New technologies are emerging one after another in the fields of computers, microelectronics, software, communication and the Internet. In particular, the key technologies, processes and performance of integrated circuits are updated more rapidly (see Table 1①). In 1965, Moore[1] made a prediction about how the integration degree of IC would double. From 1960 to 1975, the number of transistors in an IC doubled annually on the average. From 1970 to 2004, the number of transistors in a dynamic memory doubled every 18 months on the average, and the number of microprocessors doubled approximately every 24 months. From 1971 to 2006, the cost of a single transistor in a CPU dropped approximately by a digit every 7 years. The performance/price ratio of integrated circuits was obviously raised (see Fig. 2).

Table 1 Milestones of IC technology development

Components and their performances	1st generation	2nd generation	3rd generation
	1975—1985	1985—1995	1995—2005
Characteristic dimension/μm (got smaller every generation)	$\geqslant 1.00$	1.00—0.35	0.35—0.09
Wafer diameter/cm	10.16—15.24	15.24—20.32	20.32—30.48
(Wafer diameter/in.)	(4—6)	(6—8)	(8—12)
Mainframe DRAM Bit/Mb	$\geqslant 1$	4—16	64—256
Number of transistors in a CPU	10^4—10^5	10^6—10^7	10^8—10^9
Wavelength of light source for lithography/nm	436	365	248

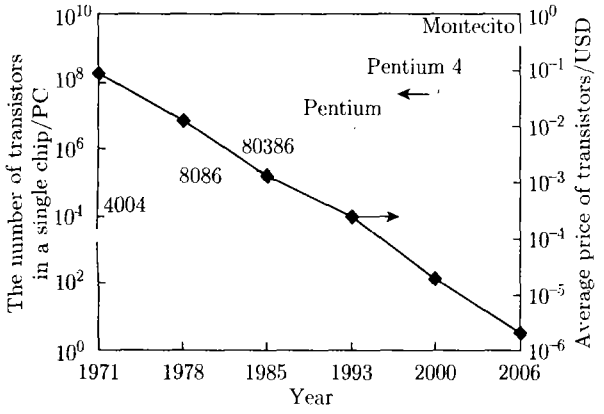

Fig. 2 Integration of CPU and corresponding price per transistor

The invention, creation and widespread application of information technology effectively promotes the integration of hardware manufacturing and software development, the combination of goods production and service management, and the combination of a real economy and virtual economy, thus forming a powerful drive for socioeconomic development. Having pervaded every discipline and field, information technology forcefully stimulates the development of physical science, life science, new energy, new materials, aviation, space technology and other engineering technologies. It boosts intersection and integration between different disciplines and enormously improves man's ability to understand, protect, adapt to and change nature. Particularly, the wide use of the Internet gives rise to faster accumulation and dissemination of knowledge and creates opportunities for all-round breakthroughs of science and technology.

1.2 A Leading Industry of the National Economy

Information technology is a typical general-purpose technology (GPT)[2]②. Compared with specialized technologies, information technology, in combination with traditional technologies, can generate more associated and driving effects in every field of national economy. Information technology revolutionizes the production patterns and organizational forms of traditional, agricultural and tertiary industries, constantly creates new economic growth points and new derivative industrial sectors, and effectively improves the quality and benefit of economic growth. The IT industry is characterized by rapid growth rate, fast technological advancement, good economic profit and close association

①Source: Research Report on the Development Trend of Information Technology by Ministry of Information Industry, 2007

②Normally, a general purpose technology should meet the following conditions: great potentials for technical innovation, plenty of uses, applicable in most economic fields, and mutually complementary with other technologies

with other industries, which are the basic features of a leading industry. The IT industry has become an important engine of economic growth in the new age (see Table 2③).

Table 2 Contribution of IT sector to global GDP growth in 2007

Department	Contribution to global GDP /%
Communication service	2.7
Communication equipment	0.6
Software and computer service	1.7
Computer hardware	0.8
TV	0.7
Consumer electronics	0.7
Total	7.2

Since the second half of the last century, the growth of the global IT industry has obviously accelerated, with its annual average growth rate higher than that of the petroleum and mining industry, chemical engineering industry, food, beverages and tobacco industry, and transportation industry④. The ever expanding scale of the IT industry causes it to play an increasingly important role in the national economy. In 1978, the global IT industry accounted for 1.5% of the GDP in the world. This figure rose to 3.4% in 2000 and reached 4.3% in 2006. From the 1970s to the beginning of the 21st century, the percentage of the IT industry in the GDP of the United States almost doubled. From 1990s onward, this percentage has also increased remarkably in EU, Japan and Korea (see Fig. 3[3]).

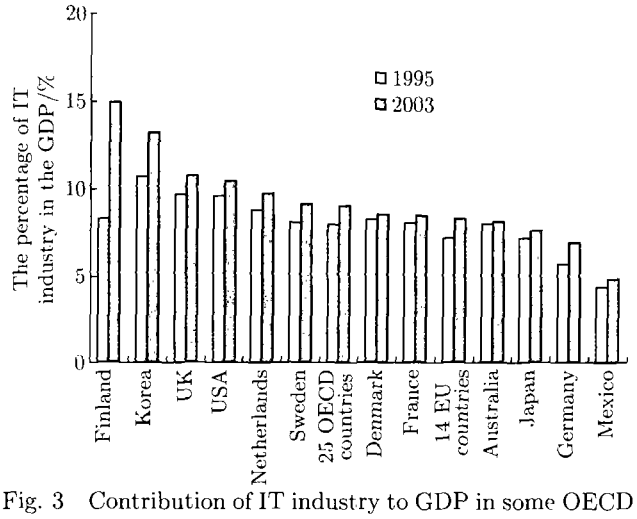

Fig. 3 Contribution of IT industry to GDP in some OECD countries and regions

③Source: DigiWorld (2007: 24)

④Source: Cit. IC Insights, ST

1.3 A Major Force that Promotes Sustainable Development

In modern society, the factors contributing to economic growth have expanded from capital, land and labor to technology, knowledge and information. As a production factor available for infinite use, information can produce incremental benefits, expand the drive of growth, and promote sustainable economic growth[4]. Development and use of information allow technology, knowledge, and other new production elements to be fully explored in economic growth, and make an increasingly greater contribution to the economic growth. In developed countries, the contribution made by technological advances based on information use accounts for 70% of general economic growth[5,6].

According to statistics, the energy consumption per unit increment of the IT industry is much lower than the average level of other industries. For example, the energy consumption per unit increment of electronic industry in China is merely 7.7% of the average level of other industries in total (see Table 3⑤). The rapid growth of the IT industry is beneficial to natural resource conservation and environmental protection. Using information technology to reform conventional industries may realize accurate control of time, space, quantity and quality during the course of production, reduce resource consumption, space occupation and pollutant discharge, and increase productivity. Taking advantage of such IT means as modern logistics networks, E-commerce and enterprise resource planning (ERP), firms may effectively keep down stock, reduce consumption, and improve efficiency, which in turn leads to full utilization of various resources. Wide use of geographical information technology like aerial

Table 3 Energy consumption of industrial growth per RMB 10000 in different sectors in 2007 in China

Sector	Energy consumption of industrial growth per RMB 10000/TCE
All industries sectors	1.9594
Electric power	7.3673
Metallurgy	4.2155
Building materials	3.8234
Chemical engineering	3.3967
Coal	2.7113
Petroleum and chemical engineering	1.5968
Non-ferrous metals	1.5067
Textile	0.9186
Light industry	0.7425
Pharmacy	0.6274
Machinery	0.2995
Electronics	0.1502

⑤Source: National Bureau of Statistics of China

survey, remote sensing and global positioning in geological, oceanic, hydrological and meteorological fields improves our ability to observe and predict ecological changes, adapt to and protect the natural environment, and respond to and cope with major incidents. Therefore, the IT industry and its application have become an indispensable element of the harmonious relationship between man and nature.

1.4 Profound Changes in People's Lifestyle and Production Mode Brought about by Information Technology

Every major technological revolution has had a profound impact on the production capabilities and lifestyle of mankind. Application of information technology enables human activities to overcome past reliance on conventional means of transportation and communication, and expand the scope of development and interaction. The advance of information technology facilitates flexible arrangement and organic combination between laborers, tools and objects of labor, and optimizes the mode of production. The revolutionary change in labor tools and application of intelligent equipment in the production process greatly improve conventional mechanization and automation, thus further liberating people from heavy manual labor to do more complex mental work. The rigid production mode is converting to a flexible production mode, and the monotonous centralized mass-production is changing into a modular combination production on a proper scale. As a result, firms can better adapt to changes in the marketplace.

The development of information technology improves people's living standards. Online shopping, telemedical care, video on demand, videophone and email provide great variety and convenience to people's lives, expand the scope of social contacts and information exchange, and increase disposable time. More importantly, due to breakthroughs achieved in such technologies as super-large capacity storage and information search, the ability to obtain, transmit and utilize knowledge has been improved to unprecedented levels. E-learning and distant education have changed the traditional mode of learning, offered richer learning resources, improved learning efficiency and promoted life-long learning, which speeds up the accumulation of human capital and creates a better climate for the full development of human beings (see Table 4).

Table 4 Statistics of global Internet users⑥, cell phone users⑦, email accounts, e-services⑧ and e-commerce⑨

	Year						
	2001	2002	2003	2004	2005	2006	2007
Number of the Internet users/$\times 10^8$ person	4.91	6.18	7.17	8.54	10.21	10.96	13.20
Number of cell phone users/$\times 10^8$ person	9.64	11.67	14.12	17.58	21.62	26.59	33.00
Number of email accounts/$\times 10^8$ person	6.7	8.0	9.5	10.8	13.0	15.2	19.9
Export of e-services/$\times 10^8$ USD	15 057	16 240	18 654	21 924	22 627	—	-
Revenue of e-commerce in USA /$\times 10^8$ USD	10 800	15 100	17 060	20 510	25 790	29 370	

1.5 A Core Driving Force of New Military Reform

New military changes in the contemporary era affect the whole world and involve all military sectors. Mushrooming advanced technologies symbolized by information technology offer technical conditions for new military changes, the core of which is informatization. Warfare is transforming from machine-based forms to information-based forms. The role of information combat is getting more and more conspicuous in actual fights and deterrence. Separate units of electronic warfare equipment are becoming linked via networks. The connection between information systems and weapons is becoming ever more integrated. New information-based battle means are increasingly sophisticated. The information-based campaign will become a highly-controllable form of campaign with high effect to cost ratio. With the support of IT equipment, information acquisition and processing capability, weapon precision and battlefield transparency are improved to unprecedented levels, and features of modern warfare such as suddenness, three-dimensionality, maneuverability, speediness and in-depth strike are very prominent. The party with the hi-tech advantage has better battle effectiveness and dominates the war. IT-based arms constitute an important part of the combat abilities of a military form. Significant changes have taken place in battle patterns, battle theories and force structure. Many countries are adjusting their military strategies to adapt to the new world situations and military conflict development. It has become a main objective of contemporary military reform throughout the world to win a war in an IT-based environment.

⑥Source: Internet World Stats, Internet Telecommunication Union

⑦Source: Internet Telecommunication Union

⑧Source: UN Commodity Trade Statistics Database

⑨Source: U.S. Census Bureau

1.6 A Strategic Commanding Height

As a major support of informatization and economic growth as well as a strong foundation of modernized national defense, the IT industry has become the focus of global economic, political, cultural, social, and particularly scientific and technological as well as military competitions. International competition in the IT industry is becoming increasingly complex, and the competitive pressure in this field is intensifying. The United States, Japan, European countries and other developed countries have launched national strategies to boost the development of their IT industries. Some major developed countries have taken domination over core technologies and online information resources. With their advantage in information technology and information resources, they are exerting more influence on developing countries. Every military power in the world attaches great importance to the development of military information technology and equipment. Multinational companies aim to strengthen their position in global competition by means of controlling the core technologies and essential standards. Adopting catch-up or overtaking strategies, many developing countries are striving to improve the environment for investment, absorb advanced technologies from other countries, promote industrial transformation and upgrading, and propel the growth of the IT industry. At present, the competition of comprehensive national power, which centers round the control of information technology and information resources, is represented by the IT capabilities of the country.

2 Development Trend of the Global IT Industry

Matter, energy and information are the three essential elements of the objective world. In the mid and late stages of industrialization, information technology has become an advanced intelligent tool; information resources have become important strategic resources; IT innovation has become a mainstream development course of advanced productivity. From the 1990s on, the development of information technology has been oriented towards high performance, wide scope and multi-directional purpose. The digital, integrated, intelligent and network-based tendency is continuing. The ability to process mass and complex information has been remarkably improved. Resources are utilized and allocated at a much higher level and efficiency. New materials and processes are in wide use, and bottlenecks restraining industrial development are mitigated. Division of labor is finer. New business forms are emerging. Competition in intellectual property and standards is becoming more and more intense. New changes appear in the competition between firms. Ubiquitous network environment, digitalized production and service, and information based weapons are the frontiers for the application of cutting-edge technologies. In the future, the IT industry shows new trends of further development.

2.1 Prospective Major Breakthroughs of Information Technology

In the world today, the fast pace of IT development has never abated, heralding an array of major technological breakthroughs in quick succession. Along with the upgrading of semiconductor materials and optoelectronic materials and the advance of technological equipment and processes, integrated circuit technology has entered a Nano Age. In the near future, the chip integration level and processing ability will continue to increase exponentially[10], and round wafers will become larger with an ever-increasing integration rate and ever-decreasing characteristic dimensions (see Fig. 4[11]). System on chip (SoC) will become the future development trend with much lowered level of energy consumption and cost.

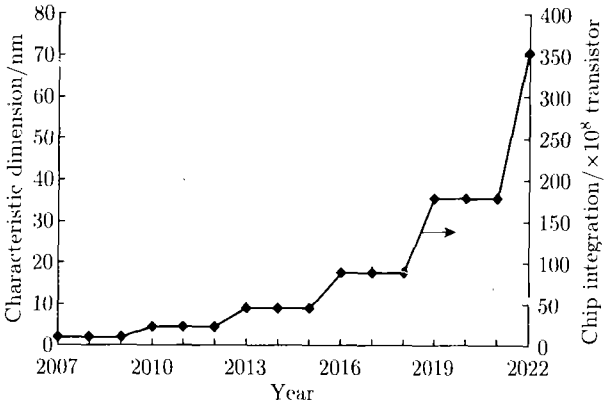

Fig. 4 Characteristic dimension and chip integration

Network technology is developing towards broadband, wireless and intelligent network. The widening of bandwidth for mobile communication and the mobilizing of fixed communication is increasingly integrated. Various access technologies are emerging, and the application of RFID[12] has a bright prospect. The optical communication technology featuring mass storage, super speed and super-long distance is in wider use, and the Internet protocol (IP) based communication network is speeding up (see Fig. 5). The integration of telecommunication networks, computer networks, and radio/cable TV network is more evident and will form a powerful multi-channel and multimedia information

[10] Source: International Semiconductor Roadmap 2007 issued by International Roadmap Committee predicts that, compared with 2007, the characteristic dimensions in 2022 will be 5.2 times smaller, the integration level will be 31 times larger, and the clock frequency will be 2.05 timer higher

[11] Source: International Semiconductor Roadmap 2007, http://www.itrs.net/

[12] Radio Frequency Identification, also known as electronic label

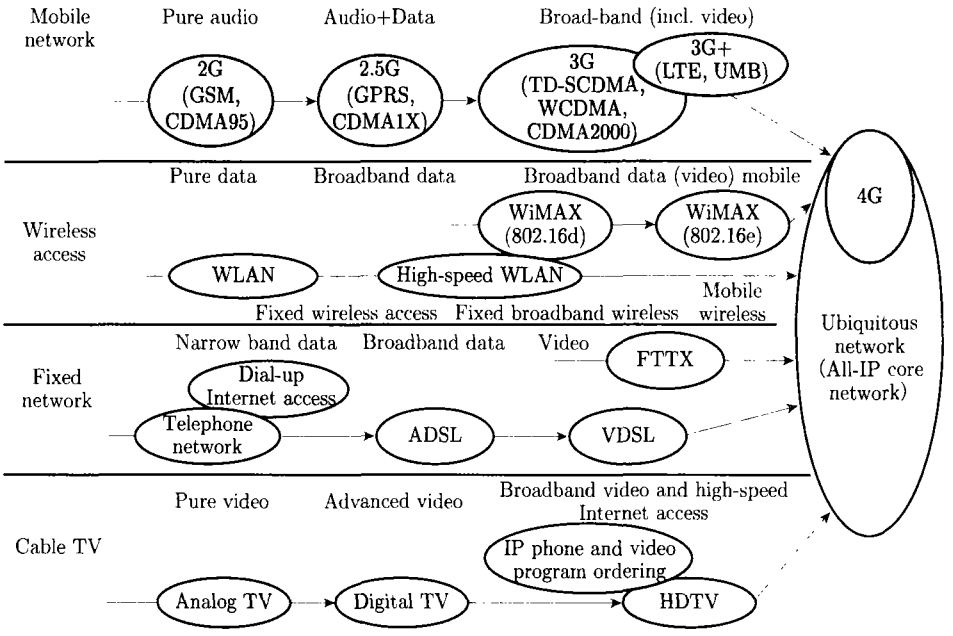

Fig. 5 The trend of information network technology development

platform. Information networks will cover all sorts of terminals.

The development of high-performance computing is oriented toward computation-intensiveness and data-intensiveness, driving the improvement of capability computing and capacity computing synchronously, which will gradually meet the needs to solve large scientific and engineering computations and complex problems. High-performance computers and servers, along the route of multi-core CPU[13] and multistage parallel structure, are developing towards the speed of trillions of times or even faster, and transforming from a focus on peak performance of computing speed to the pursuit of comprehensive information processing performance. At present, the emerging "cloud computing" may simulate various resources in the network into computing resources provided by a virtual computer system for users. Meanwhile, new breakthroughs are expected in such fields as quantum computing, photon computing, biological computing and artificial intelligence. Computing technology and computer architecture are facing thorough-going changes.

Software systems are quickly developing toward a network-based, intelligent and highly-reliable stage. The tendency toward open source codes is intensifying, and the operating system, database and middleware are integrating into a uniform system software platform. In the open and dynamic environment of the Internet application, "software as a service" (SaaS) has become a major direction of software development.

2.2 The IT Industry Approaching Continuous Steady Growth

In the 1990s, the world IT industry experienced a period of unusual growth and then returned to rational growth after the network bubble burst at the start of the 21st century. In recent years, the growth of the IT industry is becoming more stable, with longer cycles and smaller amplitudes (see Fig. 6[14]). In a future period, the mushrooming of new products and services in the IT industry will create a large number of derivative needs. Fast and extensive applications and use of information technology will expand the market for industrial development. The information network infrastructure will shift to a network of the next generation where the

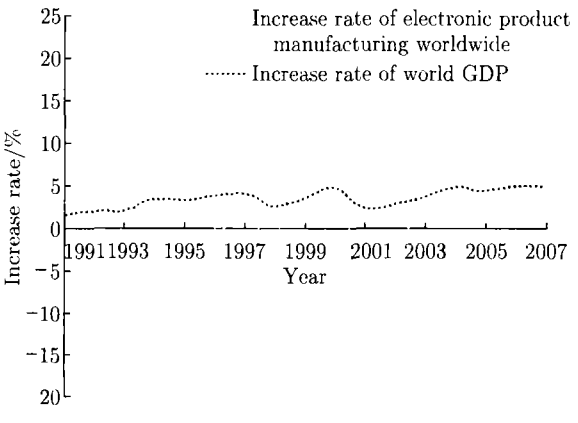

Fig. 6 Increase rate of world GDP and electronic product manufacturing from 1991 to 2007

[13] Multi-core CPU, short for multi-core central processing unit, means a micro processing unit integrating two or more cores in order to improve computing ability

[14] Data of world electronic manufacturing industry are from Yearbooks of World Electronics Data; data of world GDP are cited from IMF Data Mapper

information service and application will have a grander prospect. Governments of different countries are supporting the development of IT industries in their countries by putting in place sound and favorable policies and regulations. These factors will help improve the climate for the development of the IT industry, promoting the continuous and steady development of the industry.

Needless to say, the uncertainty of world economy will affect the development of the IT industry in the short term. Nevertheless, the development of the IT industry is unlikely to fluctuate radically in the long run. It is forecast that upgrading of IT products will accelerate the needs for information service which will have greater impact and make greater contributions to global economic growth (see Fig. 7[15]).

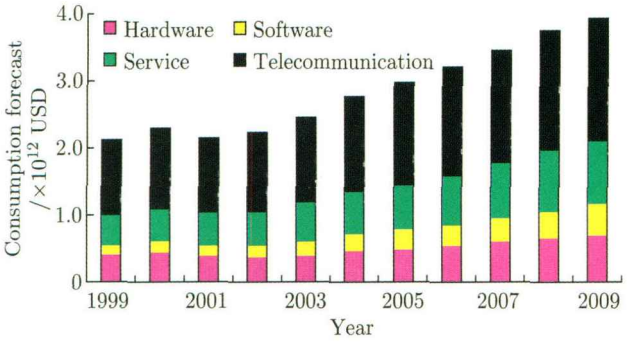

Fig. 7 The trend of IT product consumption in the world

2.3 Industrial Agglomeration and Convergence Increasingly Evident

Under the influence of global economic structural adjustment, the IT industry is transferring at a faster pace, thus forming a batch of highly concentrated industrial bases leading the tide of the global IT industry. The agglomeration effect is closely associated with the short life cycle of IT products and fine division of labor. IT product users raise very demanding requirements about time, quality, cost and service (TQCS), which necessitate the geographical concentration of related firms. Firms need to focus on their own specialized production process and collaborate closely with other firms and industries in the same or closest localities. Industrial agglomeration helps reduce production and transaction costs and results in improved economies of scale and integrated collaborative ability. From a developmental perspective, the geographical agglomeration effect will influence the layout of the world IT industry for a long time.

With information technology advancing and new IT products and services constantly emerging, the agglomeration in the IT industry will further increase. This agglomeration will be mainly embodied by the functional integration of terminal products, that is, integration of personal computing, telecommunication, and consuming electronics, by service integration of operating platforms (i.e., the integration of telecommunication service, contents services, and computing services); and by the integration of telecommunication network, computer network, radio and cable TV network. Application service based on information technology and the Internet will inevitably promote the expansion of the traditional service industry, boost the development of the modern service industry, and significantly raise service efficiency. Meanwhile, information technology is rapidly permeating other industries, upgrading and reforming traditional industries as well as forming novel technological fields, management style and industrial structure, with greater and greater impact on the entire national economy.

2.4 Intellectual Property and Standards the Core of Competition

Patents, intellectual property and standards are not only important incentives and safeguards of innovation but also critical factors to the success and development of companies. According to the data issued by World Intellectual Property Organization, the number of patent applications in the field of semiconductors in 2006 was 67.1% over that of 2002 (see Table 5[16]). In order to obtain IT intellectual property, different countries and firms increase investment, and introduce and implement intellectual property strategies. The number of patent applications has become a critical indicator of a country's competitive power and development level in the field of information technology (see Table 6[17]). While expanding their own patents, some large multinational companies buy up small enterprises owning patent technologies to maintain their competitive edge. Some have even formed intellectual property and patent exchange alliances with a view to leading the industry development trend.

Using technical standards to achieve maximum interest in intellectual property has become a representative means of competition in the IT industry. Internationally, the formulation of technical standards should be open, universal and convenient to facilitate technological diffusion and intellectual property share. However, some intellectual property holders transform sole ownership of intellectual property into exclusive standards in order to harvest more profits and long-term benefits. More and more enterprises come to realize

[15] World Information Technology and Service Alliance Public Policy Report, 2007 (figures in 2008 and 2009 are estimates)

[16] WIPO Patent Report 2007. PCT refers to Patent Cooperation Treaty

[17] Data from 2000 to 2004 are cited from OECD Work on Patents; data from 2005 to 2006 are provided by Electronic Intellectual Property Center of Ministry of Information, People's Republic of China

Table 5 PCT patent applications in the IT field

No.	Field	Year of public release					Annual growth rate from 2002 to 2006/%
		2002	2003	2004	2005	2006	
1	Movie and TV (audio)	5 391	6 057	6 075	6 718	7 322	35.8
2	Telecommunication	11 167	10 821	10 441	11 674	13 478	20.7
3	Computer	11 096	9 916	9 535	11 026	13 428	21.0
4	Semiconductor	3 612	4 051	4 109	4 727	6 034	67.1
	Total	31 266	30 845	30 160	34 145	40 262	28.8

Table 6 Comparison of IT PCT patent applications in China, US, Japan and EU

	Year						
	2000	2001	2002	2003	2004	2005	2006
US	17 246	15 721	14 395	14 953	14 525	14 077	16 427
EU	11 927	12 508	12 082	12 207	12 016	12 845	12 549
Japan	4 525	4 994	5 934	7 288	8 658	11 031	11 250
China	221	303	478	723	1 078	1 075	1 853

that they will not enjoy a competitive edge unless they do well in acquiring IT intellectual property or standards. This has become an important aspect of competition, cooperation and development in the IT industry.

2.5 Widespread Existence of Information Network

In the 21st century, driven by such novel technologies as wireless access, RFID, network application, and man-machine interaction, the "ubiquitous network[18]" (see Fig. 8), a brand-new network which may realize

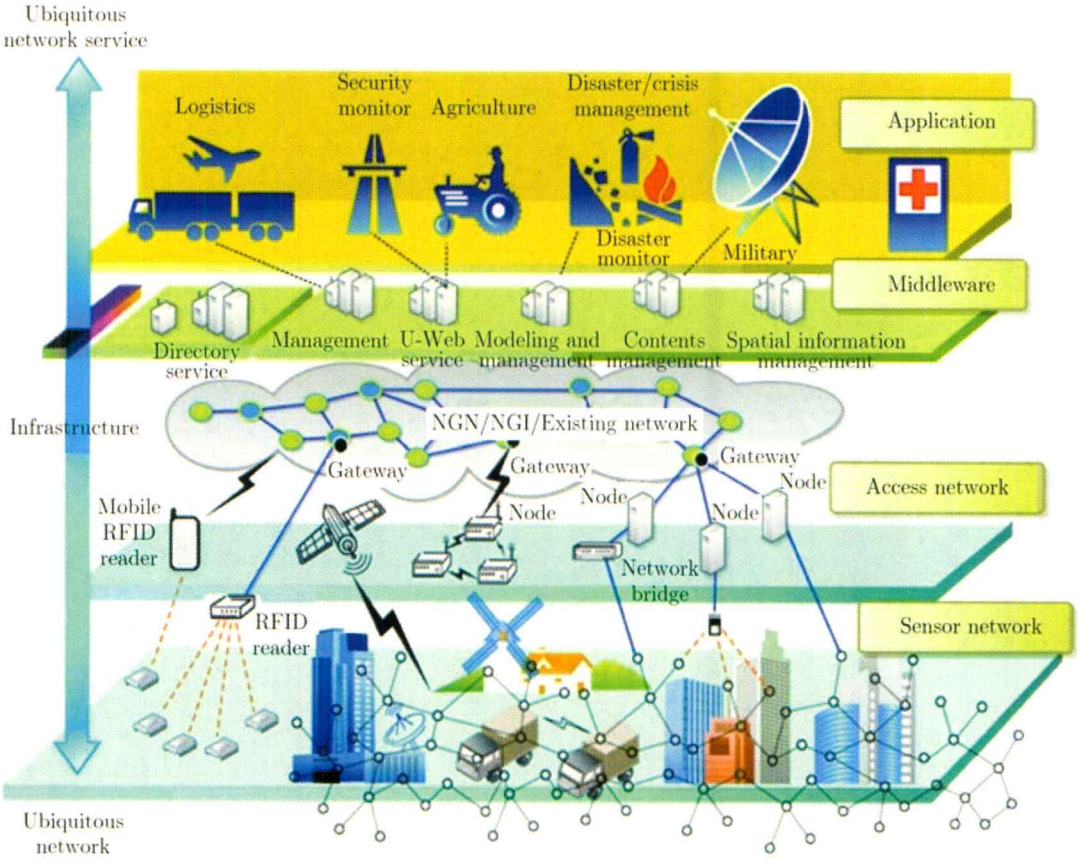

Fig. 8 Ubiquitous network

person-to-person, person-to-object, and object-to-object communication, and "ubiquitous computing" are becoming a reality and gradually put to use. The person-to-object and object-to-object communication is regarded as the most striking characteristic of the ubiquitous network. The rapid development of wireless,

[18] Ubiquitous, originating from Latin, means be everywhere at the same time

broadband and Internet technologies takes the use of the ubiquitous network to a higher level. The integration of different networks, access and applied technologies will realize a seamless information link between production, transportation, exchange and consumption of goods. Popular application of network will bring about a change of the organizational decision-making process from a hierarchical structure to a flat structure, a change of the organizational structure from a vertical chain to a horizontal network, a change of the organizational pattern from a series of departments to incorporated collaboration, a change of the organizational behavior from low efficiency to fast response, and a change of decision-making mechanism from highly centralized decision-making to close-to-site decision-making.

The ubiquitous network fortifies the application services of existing networks and brings along a series of new service fields. It will satisfy people's greater demands for public service, commercial service, medical care, education, entertainment, environmental control, and domestic work, substantially improving living conditions and opening up a broader realm for digitized life. Moreover, it will enable people to effectively predict, warn against and cope with natural disasters and unexpected incidents, bettering our ability to respond to and deal with emergencies. The ubiquitous network will increase integration between hardware and software, system and terminal, contents and application, significantly joining together and extending the original industrial value chain, forming more value-added applications, and powerfully pushing the IT industry forward. It may be prophesied that the ubiquitous network will become a general infrastructure, just like power grids and pipelines, merged into the daily life and work of people, and become an important platform of economic, political cultural and various other social activities.

While seeing the positive role of information technology and the IT industry, we should be aware of the problems arising along with their development, such as scientific and technological ethics, the digital divide, information security and Internet governance. We should take advantage of the merits and avoid the deficiencies so that information technology and the IT industry can benefit the people more effectively.

3 Features of IT Industry Development in China

Since the reform and opening-up of China in the late 1970s, the IT industry of China has seen rapid growth. Particularly in the recent two decades, with enormous advances in IT technologies and optimization of the industrial structure, a course of development featuring government guidance, market orientation, and open development has greatly promoted socioeconomic development and to a large extent met people's ever-increasing demand for IT products and services (see Fig. 9[19]).

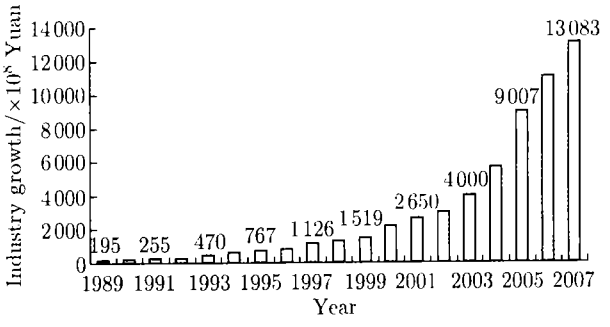

Fig. 9 Growth of IT industry from 1989 to 2007 in China

3.1 National Strategic Decision Guiding Industrial Development

China attaches great importance to the development of the IT industry as well as research into the situation and trend of the world IT industry. Fully understanding of the rule of IT development, based on the needs of national economic development, China lost no time in formulating a development strategy and plan, defining the course and objective of development, and launching many incentive policies and measures guiding and promoting the sound development of the IT industry.

In 1983, the Chinese government decided to speed up the development of the electronic industry and set a target that the gross product of the electronic industry should octuple from 1980 to 2000 and the electronic industry's contribution to the GDP should increase from 1.4% to 3%. In 1984, the Chinese government launched a development guideline "to build foundations, raise levels, improve quality, pursue profits, octuple the gross product and overpass by ten years"[20]. The Chinese government designated consumer electronic products as a key sector, and implemented the completely localized production project of color TV sets. By 1990, the output of consumer electronic products had accounted for 50% of the total output value of the electronic industry. Meanwhile, effective measures were taken to support the growth of fundamental and investment products such as integrated circuits, computers and programmable exchange. The gross product of the elec-

[19] Source: Ministry of Information Industry, People's Republic of China

[20] "Octuple the gross product and overpass by ten years" means the gross product of the electronic industry is to be octupled from 1980 to 2000, and the major products and production technologies are to reach the level of developed industrial countries in late 1980s and early 1990s, with certain technologies on a par with the level of developed industrial countries. This objective is 10 years more ambitious than the objective stipulated by the government for an average industry

tronic industry in 1990 was almost 8 times that in 1980.

In the 1990s, the Chinese government defined the electronic industry as a pillar industry of the national economy and launched the strategic plan of promoting informatization in the national economy. It launched a series of industrial policies to promote the development of mobile communication, software and integrated circuits and started up many special programs such as the localization of digital programmable exchange. and "908" and "909" projects dedicated to integrated circuits. Driven by market demands, the sectors of microelectronics, computers, telecommunication, software, and information services developed speedily and the internal adjustment of the industrial structure accelerated. By 2000, the weight of investment products representing technological level and higher added value had approached 40%. In fact it shows that national strategic decisions forcefully propelled industrial development. By 2000, the electronic industry had grown to a scale much greater than planned in 1984 and had become an import pillar industry indeed.

At the beginning of the 21st century, the Chinese government put forward a development strategy of accelerating industrialization through informatization, and promoting informatization through industrialization, and following a development course of new-type of industrialization. Moreover, the government puts the development of the IT industry on its priority list, and stresses the wide application of information technology in economic and social fields. At present, China ranks number one in the output of electronic and IT products (see Table 7[21]), with the average annual growth rate from 2001 to 2007 approximating 30%[22], and the output of many IT products ranking number one in the world[23].

3.2 Market-oriented Reform Upgrading Micromechanism

The electronic industry is one of the first sectors to go through market-oriented reform. From the founding of the People's Republic of China in 1949 to the mid-1980s, most of the national electronic firms were operated under the planned economy system. In 1986, the electronic industry took the lead in the reform of the planned management system. Boundaries were removed; government functions were separated from enterprise management; enterprises previously managed by the central government became the responsibility of the local government. Enterprises' rights to independent management were expanded. Those measures greatly increased the vigor and vitality of the enterprises. In 1992, the government set the objectives for the system reform towards a socialist market economy. After that, the market-oriented reform of the electronic industry picked up speed and gradually changed the industry from a hierarchical system to a self-managed system supervised by industry associations. By introducing a shareholding system, establishing a modern corporate system and improving the environment for development, state-owned, private and foreign-funded enterprises flourished in competition, and a number of large local enterprises with good comprehensive strengths and some small and medium-sized enterprises with special advantages thrived rapidly. In 2007, the number one enterprise of the top 100 IT enterprises in China reported an annual revenue of more than RMB 140 billion, which was 160 times more than the revenue of the number one enterprise in 1987. The sales revenue of each of the top three companies exceeded RMB 100 billion[24].

The establishment of enterprises' central role in the market and the gradual maturity of the market system has led to an effective microeconomic development mechanism, directed the optimal allocation of industrial resources, speeded up the process of elimination, merger and restructuring of the underperformed enterprises, and raised industrial concentration. Before, 57 color TV manufacturers were listed as under the national planned economic management, but none of them reached reasonable economies of scale. At present, the combined sales revenue of the top 5 color TV manufacturers accounts for 70% of the total sales revenue of color TV sets in the country. Both China's

Table 7 Top ten electronic and information product manufacturing countries/regions in 2007

Country or region	Output/$\times 10^8$ USD	Annual growth rate/%
China	3594.27	19.00
USA	2833.55	2.11
Japan	1875.62	0.62
Korea	1120.10	5.24
Germany	744.33	1.94
Malaysia	586.09	6.28
Singapore	542.26	2.28
Chinese Taiwan	472.12	7.34
Mexico	454.21	13.75
Britain	364.82	0.05

[21] Source: The Yearbook of World Electronics Data 2007

[22] Source: Ministry of Information Industry, People's Republic of China

[23] The output of more than 10 kinds of complete products including mobile phones, notebook computers. color TV sets, digital programmable exchanges and digital cameras, and components and materials such as color kinescopes, capacitors, resistors, micro motors, loudspeakers, magnetic materials, printed circuit boards and network cables rank number one in the world

[24] Source: Ministry of Information Industry, People's Republic of China

output and export of color TV sets rank number one in the world. Chinese enterprises specializing in communication equipment manufacturing, personal computers, electronic terminals and peripheral equipment are rapidly rising up, with their shares in the international market increasing steadily. As microeconomic vitality grows, a batch of enterprises enjoying their own advantages have developed by leaps and bounds, thus attracting a wealth of capital and talents and boosting industrial cluster and development. The cluster effect is apparent in the Pearl River Delta, the Yangtze River Delta, the area surrounding the Bohai Sea, and other areas, with such indicators as industrial growth, sales revenue, profits and number of employees of those areas accounting for more than 80% of the nation's total[7]3. Some new industrial clusters are beginning to take shape.

3.3 Adoption of the Open-up Policy Promoting Global-oriented Economic Reform

The electronic industry is one of the first sectors to use foreign capital. The economic reforms of the late 1970s and early 1980s accelerated the adaptation of China's electronic industry to the international system of labor division. By the end of 2007, the accumulated utilization of foreign capital by China's IT industry exceeded USD 160 billion, and all the multinational IT firms listed in Fortune's Top 500 had come to invest in China[7]5.

The IT industry is a capital-technology-knowledge-intensive industry. Accelerating opening up to the world is a necessary step to make up the domestic shortage of funds and improve technological capabilities. The opening up in the IT industry started from the introduction of advanced technologies, processing trade in the form of processing materials supplied by clients, processing raw materials on clients' demands, assembling parts for the clients, and compensation trade. With the augmentation of foreign capital and better industrial supporting capabilities year by year, the export of IT products continues to increase (see Fig. 10). The contribution of IT exports to total sales increased from 23% in 1989 to nearly 60% in 2007.

After China's entry into the WTO, Chinese IT firms go abroad at a faster pace. The ability of major communication equipment manufacturers, PC manufacturers, and telecommunication service providers to run their business and to operate their capital on a multinational basis has improved remarkably. A batch of small and medium-size enterprises, which are highly dynamic and full of growth potential, achieved noted success in trailblazing financing channels, innovating business models, and developing novel operations. China's IT industry has become an important part of the global IT industry.

3.4 Technology Further Upgraded

For a long time, China mainly adopted a catch up strategy due to the restraints of economic conditions and technological level. In order to catch up with the advanced technologies in the world, the Chinese government paid special attention to the introduction, digestion and absorption of advanced information technology, and subsequent innovation. The investment in research and development has been increasing year by year, and the range of invested entities have extended from scientific research institutes to innovative firms. As a result, the innovative and technological abilities of Chinese IT firms continue to grow. After years of efforts, considerable breakthroughs have been made in fields such as communications, integrated circuits, high-performance computing and software. China's technology in digital programmable exchange, mobile communication, digital mobile trunked communication and optical communication is on a par with leading countries in this field. Specifically, TD-SCDMA[25], for which China holds the core intellectual property rights, has become one of the international standards of third-generation mobile communication. China-made Tera-scale large computer systems, high-performance computers and servers are among the best in the world. General-purpose CPUs and other middle-end and upper-end chips have been successfully developed and put into production. China is able to design integrated circuits of less than 90 nm with an integration rate exceeding 30 million gates, greatly narrowing the gap with the leading technologies in the world. China has successfully developed digital TV terrestrial transmission technology[26] and digital audio-video coding and decoding technology[27], which supports the de-

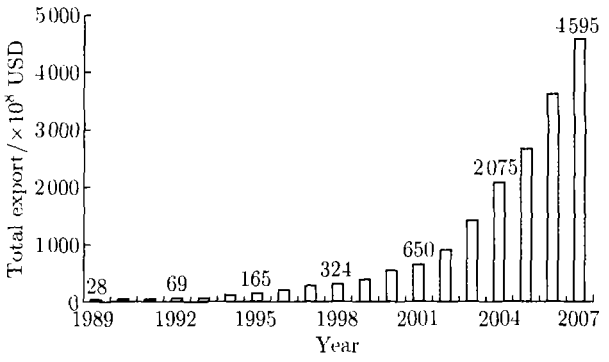

Fig. 10 Export of IT products from China from 1989 to 2007

[25]Time division-synchronous code division multiple access, proposed by China, has become an interfacing technology officially published by ITU for the third-generation mobile communication

[26]Digital TV terrestrial transmission technology means digital TV transmission technology by sending TV programs from the transmitter to user's receiver terrestrially

[27]Digital audio-video coding and decoding technology means the technology that codes digital audio-video signals to reduce its rate and meet the requirements for storage and transmission with the existing technology

velopment of digital TV business. Home-made middleware, financial and enterprises management software, and anti-virus software are strong competitors of foreign products.

3.5 The IT Industry Further Developed in Both Military and Civil Applications

Shortly after the founding of the People's Republic of China, the electronic industry turned out a batch of communication, computer, radar, surveillance, electronic warfare and other electronic equipment for military use. Thorough large-scale construction from the "First Five-Year Plan" to the "Fifth Five-Year Plan", the electronic industry had formed a fairly complete mix of sectors, and had reached a considerable scale, and a certain level of technological sophistication. After economic reforms of the late 1970s and early 1980s, the Chinese electronic industry was rapidly oriented towards civil applications. A batch of firms began to produce TV sets, video tape-recorders, hi-fi equipment and other consumer electronic products. Production for military applications was gradually replaced by production for civil applications, which formed the technical and physical foundation for the all-round development of China's IT industry.

In the 1990s, in line with the new trend of world military development, the Chinese government made a series of timely, major strategic decisions concerning the development of national defense and military modernization, bringing about new opportunities for the development of the IT industry, especially the military electronic industry. By implementing major special projects, the military electronic industry has been succeeded in the research and development of an array of urgent key IT equipment, achieved breakthroughs in some critical technologies, and formed the research and development system for military IT equipment. More and more military components and software are put to use in the civil field, and a number of civil IT firms have begun to undertake military IT research and development, promoting the joint development of military and civil IT research and production.

3.6 Production and Application Combined to Expand the Scope of Development

As a strategic pillar industry of the national economy, the IT industry makes continuous contributions to improve the quality benefit of economic development and meet the ever-increasing demand of the people. Meanwhile, wide use of information technology also drives the rapid development of IT industry. In the past decade, the huge demand in the telecommunication market fostered the rapid development of IT infrastructure and telecommunication equipment manufacturing, and facilitated breakthroughs in wireless, fixed, exchange and transmission fields. After making quantum leaps, the performance of the IT network infrastructure has been upgraded on a full scale, with the network scale and the number of telephone and Internet users ranking the first in the world (see Fig. 11). The IT development and IT-based reform of conventional industries opens up greater potential for the future growth of IT industry. "Golden Card", "Golden Customs", "Golden Tax" and other "golden" projects centering round the application of information technology in banking and taxation have been launched one after another, and a batch of important business application systems have been put to use in government departments. All these are examples of direct and wide applications of information technologies. In 1993, the "Golden Card" project was implemented. After an over ten-year effort, 1.6 billion UnionPay cards had been issued nationwide, and the intelligent IC cards issued in all the industrial sectors had reached 4 billion by the end of 2007. E-commerce and E-administration provide a vast market for home-made network exchange and core routing equipment. The need for complex computation in geology, exploitation of natural resources and meteorology stimulates domestic research and development on high-performance computers. The upgrading of petrochemical, metallurgical, equipment manufacturing and electric power industries gives rise to the integration and application of automatic control, computer simulation and artificial intelligence.

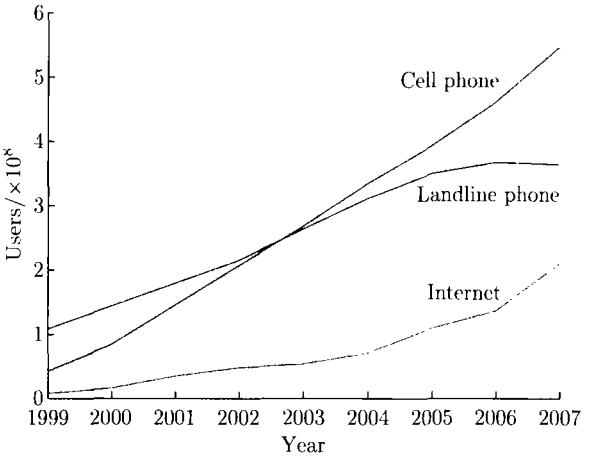

Fig. 11 Users of fixed line, cell phone, and Internet in China from 1999 to 2007

Although substantial development has been achieved in China's IT industry, a gap exists between it and the advanced level of the world. There remain some challenges and problems in the following aspects:

(1) Core technology is dominated by other countries. The majority of intellectual properties and technical standards are controlled by foreign enterprises in such fields as upper-end chips, core software, critical components and special equipment. China relies on import for certain core technologies, products and equipment, which restrains the independent growth of China's IT industry.

(2) Industrial structure is in dire need of optimization. In the international industrial division of labor, most Chinese IT firms belong to the downstream of the industrial chain and the lower end of the value chain, with a large proportion of processing and assembling and low profit. Chinese IT firms are poor in independent development, and few of them are internationally competitive.

(3) The application of information technology is still at an early stage. In every sector of the national economy, the application of information technology is in its infancy. The absence of an overall strategy with regard to the use of information technology to improve competitiveness and the failure to realize in-depth application in areas like process reengineering, market response, and decision-making analysis in certain sectors and departments limit the overall upgrading of IT application. Generally inclined to introduce foreign equipment and service, users focus more on hardware and construction rather than on software and maintenance and fail to combine application with production. The domestic market has not formed a powerful pull to the domestic industrial development. Meanwhile, the domestic industrial technology is yet to be improved to meet the needs for various applications.

(4) The industrial system needs to be improved. A system of venture capital has not been fully established. Enterprises have not accumulated a substantial amount of capital. Production, education and research remain unlinked. The system for industrial application of innovations has not been fully developed. The technological innovation system for enterprises remains to be improved. The system barriers of industrial monopoly, sector isolation and segmentation restrain the positive interaction between network, industry and application. Government agencies need to further improve their macroeconomic guidance, market oversight and public services, and develop proactive overall strategic research.

4 IT Industry Development Strategy in the New Age

At present and for a long time into the future, China is blessed with huge opportunities for strategic development. Accelerating the development of IT industry is the destined pathway and a prerequisite as we forge ahead towards the modernization, industrialization and building up of military strength of our country. Large in scale as it is, China's IT industry has to conquer a multitude of structural problems before it can be further strengthened or expanded. Though China enjoys great capacity for innovation in some areas, the developed world will continue to enjoy the overall competitive edge for a long time, leaving China no choice but to keep investing in innovation and improving the process of transforming research achievements into economic leverage. Enterprises, whose overall competitiveness is expected to develop further to face up to high-end competition and requirements from the global division of labor, are now a decisive force in the market; IT application has been primarily successful, however we have observed a noticeable imbalance of IT application and we expect the continuous merging of informatization into industrialization. The country has been quite successful in its efforts to support and guide the development of the IT industry while the obstacles hindering the development of the industry still exist. The reform and opening up of China is in dire need of new breakthroughs, which requires us to be farsighted and adopt a global mindset in our strategic decision and planning based on the reality of China, to position the industrial development in line with the newly proposed development strategies so that the IT industry can become an "amplifier" for economy growth, a "transformer" of development model and a "propeller" for industrial upgrading, which may bring about new leaps for the IT sector. This serves as the strategic basis for China's IT development in the new age.

4.1 Strategies

Working towards the goal of building a moderately prosperous society in an all-round way and making China a powerful country in terms of IT capacity around 2020 through a new industrialization pathway, it is important to follow the state policy that emphasizes independent and manageable development, open and compatible technologies, integrated and comprehensive applications, military-civil interaction and market-driven approach for quantum leap development, so as to effect transformation of the IT industry from the past scale-velocity model to the new innovation-benefit model, allowing the IT sector to play an active role in facilitating strategic and structural adjustment in national economy and promote overall economic and social development. Informatization shall lead industrialization, which may in turn facilitate the process of informatization. Such combined and coordinated efforts are beneficial as we explore the pathway for IT development with Chinese characteristics.

4.1.1 *Taking Aim at Forefront Technology and Proprietary IPR*

To acquire proprietary IPR and lead information technology development is essential and indispensable for the development of the IT industry in China. We must be able to independently develop and master information technologies related to national security; we must be self-reliant and make endeavors to develop and improve core technologies which cannot be otherwise purchased or exchanged for. The field of information technology offers spacious room for innovation and therefore it is proper to prioritize research efforts and render support for the most promising fields

that may lead to breakthroughs and technological revolution while staying focused on innovation in fundamental areas; it is important to seize opportunities for the fusion of different information technologies and encourage interdisciplinary development and integrated innovation. Meanwhile, international resources must be drawn upon so that we can learn from the cream of the crop of the world in a consistent and sustained manner, assimilating state-of-the-art technologies for re-innovation. Through the partnership of industry, academia, research and application, a complete innovation chain will take shape, addressing a full spectrum of issues from R&D all the way to production and application so as to bring about breakthroughs in key areas of information technology. We expect the enterprises to assume a major role in innovation and improve their capacity for research and development so that the industry's core competitiveness can be enhanced through ownership of more extensive intellectual property right.

4.1.2 *Leveraging on Domestic Market Advantages and Driving Industrial Development by Application*

Endowed with a huge market, China is in a favorable position to leverage on its market advantages in developing its IT industry with Chinese characteristics. At present, China enjoys steady and moderately fast economic growth. The consumption pattern is gradually being transformed and upgraded as we step up our efforts for industrialization, informatization, urbanization and further development of our market and globalization strategies. We must continue to promote the informatization of national economy and society, speed up information technology renovation of the machinery, metallurgy, transportation, light and textile industries, boost modern service industry development such as finance, business and trade, logistics and e-commerce sectors, start up e-governance and improve the public information systems for education, scientific research, public health, etc. Other approaches such as widespread information service, extensive application of computer and network technologies and opening up a niche market for the rural population and low-income groups may help create broader market and greater demand for the IT industry. It is of paramount importance to seize every market opportunity, make accurate forecast of market trend and explore market potentials in order to develop the IT industry; emphasis must also be placed on improving product and service quality and after-sales service quality, on developing famous brands and on building highly competitive business conglomerates to win the trust of the consumers. In the meantime, market oversight effectiveness and service quality must be enhanced in an effort to encourage and regulate market competition, bring down the level of government interference and create a favorable market environment for IT industry development.

4.1.3 *Seeking Development through Opening-up to Elevate the Role of China in International Division of Labor*

The opening-up policy is a vivid example of the success of China's rapid development, a policy which China will continue to uphold for the long-term benefits of the development of its IT industry with Chinese characteristics. The accelerated flow of production factors and relocation of industries in the course of globalization makes it imperative for us to take initiative to not only become a constituent part of the international division of labor by industries but also occupy the high-end position in the industrial chain and expand market share, so as to fully participate in the international division of labor and cooperation in areas of production, service and scientific research for achieving a mutually beneficial situation. Meanwhile, we must further strengthen our strategic partnership with large MNCs with global operational strength and attract more of the world's leading high-end information product manufacturers and information service providers to do business in China in addition to attracting more FDI to build up global or regional R&D centers and operation centers, moving towards a higher level of localization and integration of R&D, production and services. We must be actively involved in information technology outsourcing (ITO), business process outsourcing (BPO), and improving the product mix of imported and exported IT products. It is important to bring change to the trade model, expand the service trade market, explore a new model of international investment and technical cooperation, participate in the work of the international technology and industry alliances and eventually elevate the overall strength of our "Go Abroad" strategy.

4.1.4 *Focusing on Government and Market Coordination, Pooling Strength for Great Undertakings*

The combination of government guidance and market mechanism is an inherent requirement for developing an IT industry with Chinese characteristics. As we improve the system of socialist market economy, a bigger role must be given to the basic function of the market in resource allocation. The market must be assigned all tasks within its capacity to enable economic entities of different ownership to give full play to their respective strengths in market competition for mutual promotion and common development. On the other hand, the development of IT industry requires government support and guidance. The government must map out scientific development plan and make decision on relevant policies in accordance with the special features of different development phases, areas and locations and take measures to deal with market dysfunction and defects. The solution to the bottleneck issues of the IT industry also entails the implementation of large-scale projects and special scientific research projects, more intensive

military-civil interaction, bidirectional transformation, and a better presentation of government policy that encourages and prioritizes the use of innovation achievements to spur domestic industry development. Meanwhile, we must forge ahead in our reform to solve the problems in the existing systems that constrain the development of China's IT industry.

4.2 Strategic Focuses

The information industry covers extensive areas and different categories. Therefore, it is unwise and impossible to speed up development of all areas at the same time. Priorities must be given to the development of core industries such as microelectronics, computers, software, key component parts and raw materials as well as industries in which China enjoys an international competitive edge such as broadband and mobile communications, next generation network, information services, etc. Though endowed with great market prospects, fast technological progress and cross-industry synergy, these industries are facing intense international competition and are likely to be overtaken by other countries if we fail to make continuous progress. We must aim at a leadership position in industrial development to safeguard the core interest of our national industries, and we must gather all resources available to apply to key areas for major breakthroughs.

4.2.1 *Microelectronics*

Microelectronics serves as the foundation of the IT industry. Microelectronic technologies are advancing rapidly and there is huge demand from the market which involves enormous amount of investment. A few countries enjoy monopoly power in some key technological processing equipment, which is an important part of the technology embargo imposed by certain countries. The characteristic dimensions of microelectronic technology are now measured by nanometers, which will inevitably lead to major revolutions of new material, new structure, processing techniques, interconnection techniques and design techniques. It is generally believed that the key to integrated circuit technology is the development beyond the 90 nm point, especially at the 45/32 nm point, which is expected to bring about revolutionary changes (see Fig. 12). Therefore, it is important to be proactive in drafting the blueprint for original innovative research and development work for futuristic technologies and be focused on the design technologies, key processing techniques, specialized equipment and key materials in order to construct a new system of independent innovation. Emphasis must also be placed on nurturing a group of IC design and manufacturing enterprises with international competitiveness, improving the overall technological competence of the microelectronic industry and building up one of the most important microelectronic industry bases in the world.

(1) High-end design technologies. IC design plays a vital role in the growth of the microelectronics industry. However. it is also one of the weakest links of the industry chain that hinder industrial development. SoC is an important direction of IC development. Compact in size, SoC guarantees high performance and relatively low cost, thus having great potential for future development. Tremendous efforts are required for different areas of design research such as system and architecture design, algorithm, coordination of software and hardware (see Fig. 13). We must make breakthroughs in the design, verification and testing technologies for high-end embedded chips, RF circuits as well as digital/analog mixed circuits; we must continue to develop advanced and ready-to-use design-aided tools, explore and develop the terahertz high-speed integrated circuit and develop SoCs with proprietary IPR in areas with

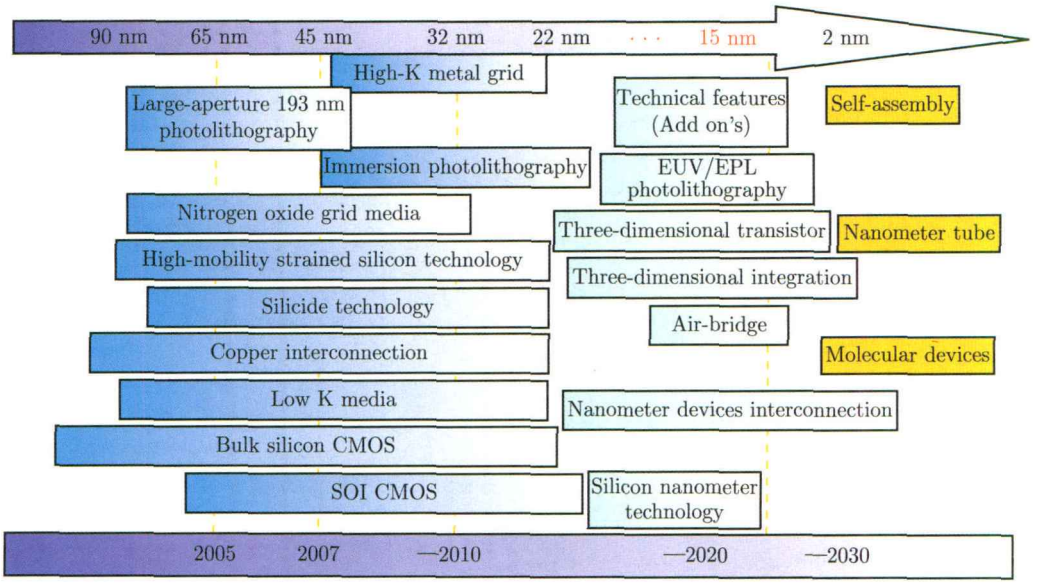

Fig. 12 The trend of key technology of microelectronics beyond 90 nm

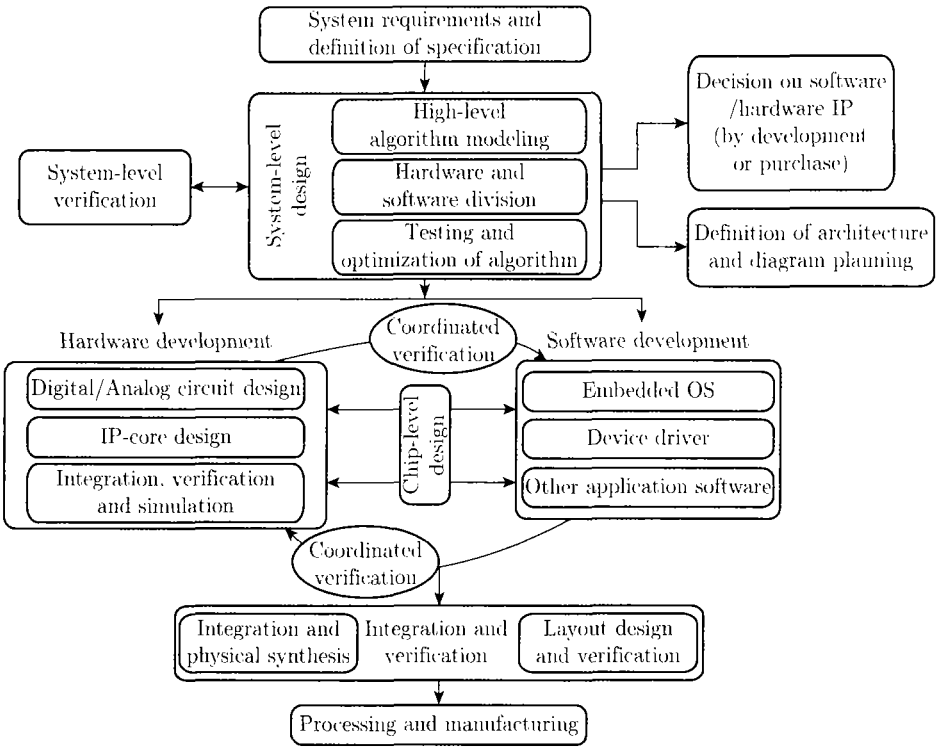

Fig. 13 Simplified design flowchart of SoC

huge market demand such as mobile communications, digital TV, smart card, network terminals and information securities, etc., so that the independently designed mainstream products can reach the forefront of international standards.

(2) Key manufacturing equipment and measuring instruments. This area constitutes a precondition for the development of the microelectronics industry as well as the bottleneck of the industry yet to be tackled. Photo lithography machines, etching machines and ion implanters are key manufacturing equipment for chip manufacturing, for which mass-production and wide application must be realized on the basis of prototype development. Next generation lithography (NGL)[28] will be one of the most important components of our research and development agenda. NGL development helps bring China's nanometer IC industry to a new height. The EUVL technology, which is currently under development, makes it possible to reduce the size of image by way of adjusting the wavelength of light and through multiple-lens reflection (see Fig. 14). Since equipment is the physical realization of technique, special attention should also be paid to the trend of physical realization of manufacturing technologies and techniques with great efforts being made in developing state-of-the-art automatic manufacturing equipment such as high-density packaging equipment as well as key processing modules, measuring instruments, tools and auxiliaries.

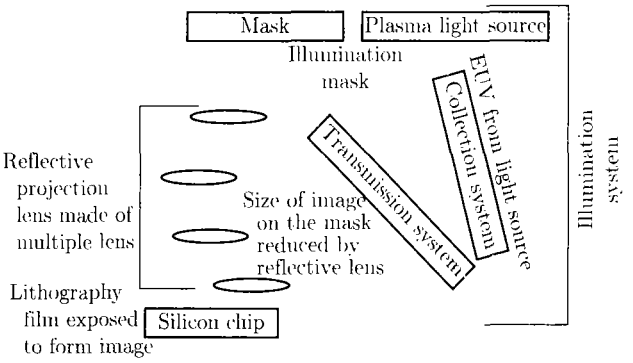

Fig. 14 Schematic diagram of EUVL

Electronic measuring instruments are essential for testing the performance and quality of electronic raw materials, products, devices and systems and are especially important for applications such as SoC measurement systems, parameter measurement for new component parts of display, digital audio and video product development, production and checking, online testing for chip-components, consistency tests for mobile communications terminals, etc. Meanwhile, electronic measuring instruments and meters are finding extensive applications in different sectors of the national economy and the development of electronic measuring instruments is also an indispensable condition for the spread of information technology. High-performance measur-

[28]NGL (next generation lithography) is an area which is currently being explored, including EUVL, EPL, XRL, EBDW, etc., while EUVL and EPL are generally considered the most promising research areas

ing instruments for general purposes serve an important basis for ensuring high-level IT applications, system performance and security and therefore merit our close attention.

(3) New materials. Breakthroughs in IC raw materials may lead to drastic change in the microelectronics industry. An important item on the microelectronics industry development agenda should be the accelerated industrialization of silicon wafer materials, microprocessing materials, polishing and grinding materials and packaging materials with focus on the forefront core processing techniques of ULSI based on the latest progress and achievements worldwide in the area of microelectronic materials. We must actively explore potential materials for silicon-based photoelectric integrated chips and silicon-based mixed integrated chips and non-silicon materials, which are believed to have great application potentials, so as to create technological leverage for breakthroughs in power consumption and line width[29].

4.2.2 *High-performance Computing*

Computing technology stays at the heart of the IT industry. Developing high-performance computing technologies is one of the strategic options for strengthening the IT industry of China. We may take high-performance CPU, GPU, high-performance super computer and network computing technologies as priorities to enable the parallel development of both capability computing and capacity computing, increase overall information processing efficiency by a substantial margin and endeavor to achieve an advanced level of high-performance computing even by international standards.

(1) High-performance CPUs and GPUs. The performance of a computer system is decided by its CPU. To meet the current needs for independent development of the computer industry in China, we must pool efforts and resources for successful development of high-performance CPU Chips, especially high-performance multi-core and many-core CPUs, which is an observable trend of CPU development, while the high-performance embedded CPU is also one of the directions. We aim at winning ourselves a desirable position internationally in the area of independently developed high-performance CPU chips. The GPU is mainly used for graphic processing. The powerful floating point computing performance of the GPU has drawn wide attention, and we must step up our R&D efforts for GPU development.

(2) High-performance super computers. The super computer is an indispensable technological means for complex large-scale computing tasks with a significant role to play in the national economy and cutting-edge scientific areas. We must independently develop super computers with higher overall efficiency and performance, acquire ownership of high-performance computing, mass storage and low power consumption technologies, etc., and develop large-scale application systems that work with such technologies. More powerful high-performance super computers must be developed in a timely manner to meet the needs of national economic development and national defense for high-speed computing. We should endeavor to make China one of the top players in the world in terms of its high performance computing capability (see Fig. 15[30]).

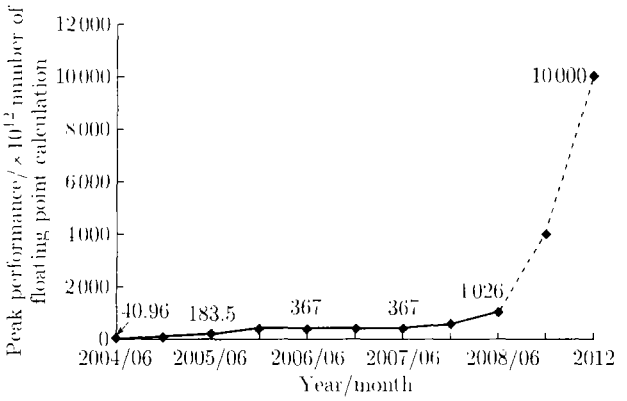

Fig. 15 The peak value of high performance computer in the world

(3) Network computing technologies. Taking advantage of the fast-growing and widespread networks is a new way to improve computing capability and mass information processing capacity at relatively low cost with high efficiency and pervasive existence of application. This is an area of huge potential for development. By improving the key technologies for high-performance scheduling, network resource management and secured resource sharing and, through research and development efforts in network-integrated computing systems based on heterogeneously distributed computing and storage for enhancing resource sharing and coordination in network environments, it is possible to create a virtual computing environment that better utilizes massive online information resources.

(4) Non-traditional computing technologies. A revolution of computing technologies and computer architecture in general may come, which will bring about huge development opportunities. Once a technological breakthrough is achieved in the current work in search of new algorithms from a bionic perspective

[29]Silicon-based new materials mainly include silicon-on-insulator, strained silicon, BiCMOS, etc., while non-silicon based new materials mainly include GaAs, InP and GaN, etc

[30]The data for the period 2004—2008 are from http://www.top500.org, an authoritative international high-performance computer rating organization; the data for the period 2009—2012 are based on the estimates of planned research projects publicized by relevant international companies

based on the intelligent system of the human brain, it may greatly enhance computer capabilities such as super large-scale parallel computing, hyper-powerful error tolerance and associative thinking, high level of self-adaptation and self-organization that are hardly imaginable with traditional computers, leading to unforeseeable revolutions of information technology. Inside an optical computer, an optical beam takes the place of current in the course of calculation and storage. With different wavelengths representing different data, highly complicated computing tasks can be completed at great speed. The technology may help escalate both information processing speed and capability. Quantum computing makes use of qubits[31] and quantum status[32] and their conversion to speed up data search and big integer decomposition and thus achieves super-high performance for information processing. Efforts must be made in forefront technological areas of biological computing, photon computing, quantum computing and artificial intelligence to promote the interconnection and convergence of various disciplines such as informatics, physics, biology and cognitive science towards achievements and original innovation in key technological fields like multi-band computing, semantic analysis, human brain structure simulation, machine learning, etc.

4.2.3 *Software*

A knowledge-production-oriented strategic industry featuring zero pollution, low power consumption and high employment rate, software is the soul of the IT industry, bearing both technical and cultural properties. In order to drive development of China's software industry either in terms of scale or technological competence, it is imperative to make full use of our advantages in Chinese language processing and human resources, keep in line with the international trend of open source code, boost the industry through application, give equal attention to both the internal and the external and cultivate dynamic comparative advantage in international division of labor.

(1) System software. As the foundation for application software, system software is the cornerstone of software systems. Multi-core CPU and high-performance computers all need the support from operating systems, a situation that heralds precious opportunities for OS development taking advantage of the current level of technological achievements. Highly trustable server OS for multi-core CPUs, secure and user-friendly desktop OS, large general-purpose database management systems that are highly reliable, secure, and high-performing as well as the middle-ware that supports network services can all be taken as focuses for development. The combination of system software such as operating systems and CPU design is conducive to the coordinated development of the software industry.

(2) Embedded software. An important trend featuring hardware and software integration and the embedding of software into hardware has been observed. China's huge manufacturing industry offers favorable market conditions for developing embedded software. A focus on the integration of hardware and software technologies, the improvement of the chain of coordination and emphasis on the development of embedded basic software and application software will help us achieve differentiating product series with practical value and high cost-performance ratio and create a new growth point for the software industry as a whole.

(3) Software and information services. "Software as a Service" brings to us a precious opportunity for the software industry to transform itself. China's software and information service sectors have much to gain if we are successful in building upon our national culture and applying the outstanding achievements of the world's civilizations. Information services such as the digitalization of cultural products and digital content development will make new growth points for the software industry. In the face of the needs of various industries in the national economy, we must provide comprehensive IT solutions and carry out business process restructuring, reengineering and optimization to address the problems troubling different industries, industrial sectors in various development stages. The development and thriving of new Internet-based businesses such as e-commerce, e-finance, online education, value-added wireless Internet services and the application of a greater number of differentiating and highly competitive service technologies and business models will be a great force behind the prosperity of the Internet industry and the momentous growth of a network economy.

4.2.4 *Network*

The network is a key infrastructure that facilitates the construction of an information society. An advanced network industry bears special significance for enhancing the capability for innovation, safeguarding national information security and driving IT industry transformation. Converging the three networks (e.g. the telecommunication, computer and cable TV) is an important strategic option to be adopted for a major transformation of the network industry. It is imperative, therefore, in the course of economic and social informatization, to speed up the development and deployment of a ubiquitous network and build a comprehensive national network infrastructure. This also serves as an important means to address unexpected events such as extreme weather conditions, earthquakes, geol-

[31] Qubit is a basic information unit of a quantum computer, in which the basic particles, such as electrons, photons and ions, are referred to as qubits

[32] Quantum status refers to the status of atoms, neutrons, protons and other particles, representing the energy, rotation, movement, magnetic field, and other physical properties of the particles

ogical disasters as well as severe epidemics. We must continue our efforts to develop the next generation network technologies and wireless broadband technologies, formulate relevant standards, focus on the study of terahertz technology and strive for competitive edges in technology, intellectual property rights, standards formulation and market and further enhance the core competitiveness of Chinese enterprises.

(1) Broadband mobile wireless communications. Broadband mobile wireless communication is one of the major means of offering large capacity multimedia information communication access to anyone at any time and place. We expect breakthroughs in key technologies such as the new generation wireless transmission and networking technologies while the utilization efficiency of the spectrum and transmission efficiency will be improved and the seamless interconnection between heterogeneously structured networks will be realized by means of IP technology. The independently developed 3G technology (TD-SCDMA) has already been commercialized. Following technological evolution closely is necessary to be in a position to develop the next generation broadband wireless network technologies. We must further intensify our research efforts for future systems (see Fig. 16) such as TD-LTE[33] and actively work out cooperation models for the parallel development of the overall supply system on the industry chain and operation so as to provide more new and innovative technologies for next generation standards of mobile communications and to achieve competitive edge both in terms of technology and market. Meanwhile, we must pay special attention to low cost, low power consumption and environmental friendliness, as we develop key chips, core component parts and multi-frequency, multi-model and multi-media terminals, among other products, to meet the developmental needs.

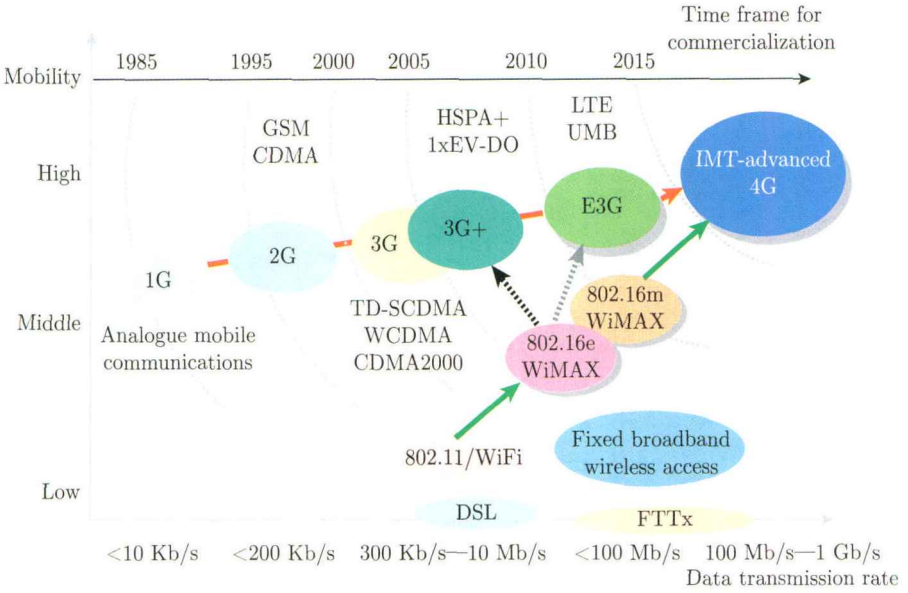

Fig. 16 Evolution of mobile wireless technologies

(2) Next generation network. The next generation network, which supports multiple businesses and improves communication performance by a substantial margin, is the direction into which the national information infrastructure must evolve. Since we have observed the trend of more diversified access technologies, integration of core architecture and enriched and more extensive application services, it is necessary to study the structure of the next generation network and key technologies of networking and network convergence, develop key devices such as the high-capacity and scalable router and signaling gateway, and build a secure and reliable carrier network. In the meantime, equal attention should be paid to sensor network technology and its application. We must intensify our research efforts for the study of a ubiquitous heterogeneous network, build various stub networks according to a unified network protocol and speed up the construction of cross-networks, seamless connection and a ubiquitous network.

(3) Network and information security. Network and information security are important components of national security. Security issues must be considered, and proactive measures must be taken when a network is being designed or software is being developed in order to form a security architecture that offers effective protection. Emphasis must be placed on the research and development of network and information security technologies and functions such as network reliability, network security protection, content security, encryption and encrypting keys, etc. Network and information security systems should be further improved, and network credibility systems and Internet event analysis

[33] TD-SCDMA Long Term Evolution

systems should be built. We must also enhance specialized network and information security services and better screen and filter the large-scale spread of hazardous and junk information over the Internet for more effective management and healthier development of the Internet.

4.2.5 *Key Component Parts and Materials*

Key component parts are a basic element of the IT industry. High-performance and highly reliable microelectronic components, photo-electronic components and vacuum electronic components, among others, are the basis for information acquisition, transmission, processing, storage, display and utilization. Key component parts occupy the front end of the industry chain of information product manufacturing and therefore decide the performance of entire devices. The sustained development of China's IT industry should be led by the demand for entire devices and we must focus on making breakthroughs for the key component parts that constrain industrial development and upgrading the industrial structure and technological capability of China's electronic component part industry in a comprehensive manner by developing new and high-end component parts so as to form an industrial system for component parts which features a complete spectrum of parts supply, mutual support and capacity for large-scale manufacturing.

(1) New types of component parts and electronic materials. More and more, electronic component parts come in the form of modules that operate with greater precision, multiple functions and lower power consumption as they are continuously miniaturized. The technological capability of the new type of component parts industry can be improved by adopting advanced design and manufacturing technologies such as functional integration, micro-manufacturing, three-dimensional packaging and comprehensive system testing, leading to breakthroughs for key technologies of sensitive component parts and sensors and developing component parts for high-frequency surface acoustic wave and high-frequency microwave medium. Electronic materials are used to produce the component parts, serving as a medium for the realization of functions of the component parts. Development of new materials may lead to great innovation for component parts. Functional and structural electronic materials including semiconductors such as mono-crystalline silicon and polycrystalline silicon, green cell materials, advanced electronic ceramic materials, liquid crystal materials and flat panel conductive glass should be actively developed, and the exploration of theories for as well as the development of new material must be given priority in order to realize innovation and development.

(2) High-end special-purpose component parts. High performance, reliability and long lifecycle are the basic requirements for high-end special-purpose component parts. Efforts must be made to establish an industrial system for astronautic-grade special-purpose component parts and make major technological breakthroughs in microwave power components such as special traveling wave tubes, GaN and SiC, signal processors such as ADC and DSP as well as high-precision detecting devices such as IRFPA. It is also important to develop new electric and electronic components such as VD-MOS, IGBT, CCD and FPGA in an effort to realize self-reliance and meet the needs of national development strategies.

(3) Display and photovoltaic component parts. Display components are an integral part of the photo-electronic industry serving as indispensable information display devices for televisions, computers and mobile handsets. Digitalization, flat panel, higher definition, enhanced brightness, lower power consumption are the features of display components evolution. In order to speed up the transformation of China's display component industry, we are in dire need of effective solutions to key technologies and equipment for new display components and we need to integrate and promote the development of TFT-LCD and PDP industries in terms of scale and technological capacity. The present task is to initiate research projects on new display technologies that best represent the future of the industry, such as OLED (see Fig. 17) and laser 3D stereoscopic imaging (see Fig. 18), etc. so as to narrow the gap between the domestic industry and the more advanced international technological expertise.

In Fig. 17, OLED is the charge carrier double injection type of light-emitting component. The working principle of OLED is: driven by external voltage, the electrons and the hole injected at the electrodes compound with each other in the organic material and generate energy. The energy is then transmitted to the molecules of the organic light-emitting substance which turns from the ground state to the excited state. The excited molecules emit light when returning from the excited state to the ground state through the process of radioactive transition.[34]

Figure 18(a) shows how the moving screen in the three-dimensional space intercepts and captures the 2D image cast by the high-speed projector in different positions along the z-axis to from a true 3D image. Figure 18(b) illustrates how the red, green and blue laser combine into one beam shot onto the spinning screen to

[34] At present, the world's display component parts industry has completed the digitalization and transformation to flat panel and high definition. Mainstream flat panel display technologies include PDP, TFT-LCD and OLED, of which the PDP and TFT-LCD are more mature technologies. Costs are driven downwards rapidly due to mass-production of PDP and TFT-LCD display components, which are gradually replacing the traditional CRT display component to become the mainstream technologies worldwide

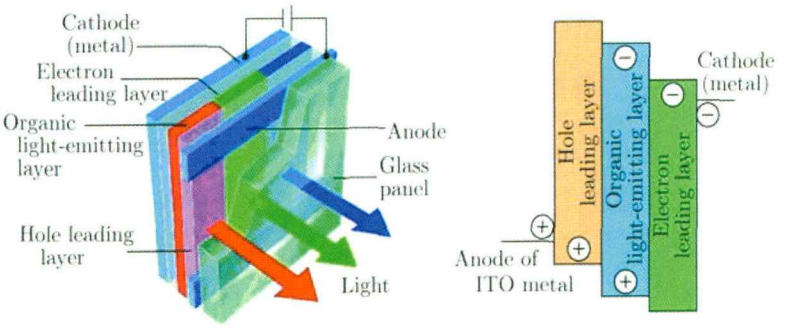

Fig. 17 Schematic diagram of OLED

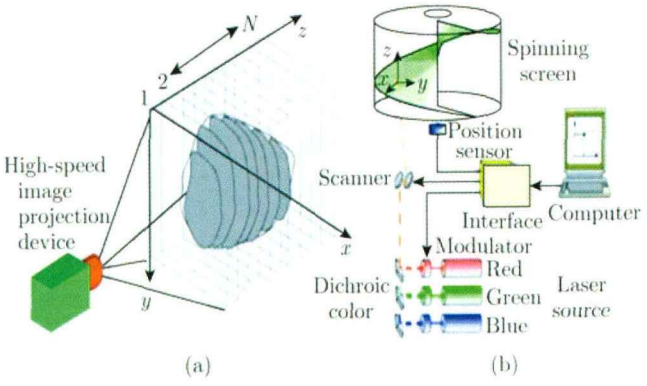

Fig. 18 Laser 3D stereoscopic imaging

form a highlighted colorful spot, and when the screen spins fast enough, it turns transparent and the colorful spot seems to be floating in the air and becomes a 3D pixel. A number of such 3D pixels can form a 3D object.

Photovoltaic component parts are the most basic components for photoelectric conversion. The solar energy photovoltaic industry turns out to be a highly promising direction for the development of clean energy. The expansion and upgrading of the solar energy photovoltaic industry mainly involve finding solutions to the problems of basic material and whole-set device, mastering material purification techniques and developing processing techniques and key equipment such as cell modules and relevant instruments and meters. Meanwhile, the exploration for new material must be continued in order to further improve the efficiency of photoelectric conversion of the cells for better utilization of solar energy. The newly developed film solar cell (see Fig. 19) is a highly efficient energy product and a new member to the construction material family. The technology helps reduce cost substantially and is therefore suitable for large-scale application, leading a new trend and becoming a hot topic widely discussed in the international photovoltaic industry. China should focus on the development of highly efficient and less costly film solar cell technologies that are suitable for mass-production and large scale deployment.

In Fig. 19, the Cu (In, Ga)Se_2 thin film solar cell (CIGS for short) is composed of three parts, i.e. the bottom-contact electrode, P-N junction CIGS/CdS and top-contact electrode; the sunlight goes through the transparent and conductive ZnO:Al layer and CdS layer onto the CIGS on the light absorption layer to generate extra electron-hole pairs; in the electric field of the P-N junction, the extra electron moves to the external circuit through the top-contact ZnO:Al layer and the hole moves to the external circuit through the bottom-contact Mo, which completes the process of photoelectric conversion.

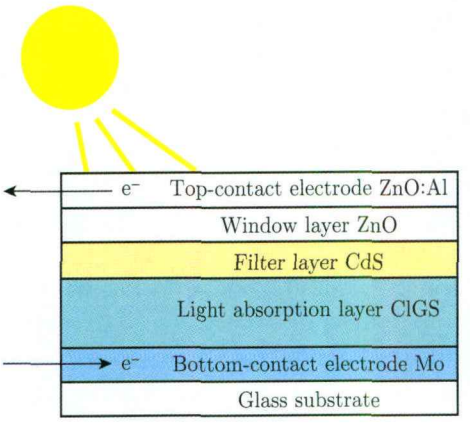

Fig. 19 CIGS thin film solar cell

5 Policies and Measures for IT Industry Development

Policy improvements for the IT industry are a strategic move to face up to international competition, speed up industrial development and drive the lofty course of modernization in the new age. We should give priority to the development of policies for the IT industry in the overall economic policy system based on the real current situation of China and in line with the great trend of global development. Emphasis should be placed on the role of the government in providing effective guidance, formulating strategies and developing rules for the marketplace. We must continue to improve the systems and mechanisms, building up a sound legal system so

as to create a favorable environment for industrial development.

5.1 Making Core Technological Breakthroughs in Key National Projects

There are already success stories of core technological breakthroughs achieved in key national projects and special science and technology projects. The project implementation should be focused on key development areas of the IT industry. We should make best use of the limited resources and motivate all stakeholders in order to make technological breakthroughs and transfer research achievement into productive force. Science and technological advances must be closely combined with economic development. The government should assume an important role in this process to organize, coordinate and guide industrial development, formulate plans, gather necessary resources, proceed with well-conceived deployment, nurture innovative groups and actively explore new models for carrying out key projects and special science and technology projects under the socialist market economy system. We must make strenuous endeavors to acquire core information technologies of paramount importance to the strategic interests of the country, develop key information products with proprietary IPR and key information devices that demonstrate the technological capabilities of the industry. We should also push for the implementation of key projects and special science and technology projects that are already scheduled in order to win ourselves a vantage point for future competition.

5.2 Encouraging the Use of Domestically Produced First-of-its-kind Products

Domestically produced first-of-its-kind IT products are facing tremendous barriers to enter the market, which discourages independent innovation of the IT industry. The situation must be looked into and addressed in the shortest possible time, for which it is necessary to revise relevant provisions of laws and regulations on tendering and bidding processes and develop tendering and bidding procedures that support first-of-its-kind products. We should improve the policies for IT application, encourage innovation through government procurement initiatives, offer "preferred-product" status to the products of independent innovation in public spending and give priority to innovative products and technologies. Special subsidies, tax credit, credit facility or guarantee against risks may be granted to the buyers of domestically produced first-of-its-kind products as a way of encouragement. High-quality products and services should be supplied to rural areas and the middle and western parts of China at lower prices. The research, development and application of domestically produced IT products must be accelerated to facilitate information technology reconstruction for industries as well as the informatization of the national economy and society.

5.3 Forging Ahead Towards "Triple Play"

"Triple Play" is the future of the telecommunication, cable TV and computer networks. The technological trend of "Triple Play" reflects the objective needs for a higher level of interconnectivity, resource-sharing and eliminating redundant infrastructure construction. Proper overall planning is the basis for promoting the integration of businesses, networks and terminals. We should also formulate policies with respect to business license, interconnectivity and cross-network settlement, etc. and allow bidirectional entry into both the telecom network and cable network. We should try out new mechanisms for network-building and information resource-sharing, promote business model innovation and strengthen cooperation among different processes such as network operation, equipment manufacturing, application services and system integration. More extensive and profound reform of telecommunication management systems and operational mechanisms of the cable TV network is required, and an industry regulatory system featuring the separation of administration from supervision, lifting of government control on business operation and division of government functions and public functions must be established in an effort to standardize the regulatory contents, improve supervision measures, emphasize oversight responsibilities and establish a scientific and reasonable oversight system.

5.4 Building International IT Industry Bases

The IT industry is highly internationalized. In order to enhance the international competitiveness of China's IT industry, we should pay attention to both the domestic and foreign markets and participate in high-profile international exchanges and cooperation more extensively, allocate and utilize resources across the world in a reasonable manner, and strengthen international economic and technological exchanges and cooperation in an all-round manner so as to form an openly constructed industrial system. Keeping in line with the trend of globalization, we should draw upon China's comparative advantages to combine commodity trade with service trade, further internationalize our information service industry and build industry bases that boast unique features and enjoy international leadership in areas of microelectronics, computer, component parts, software and service outsourcing, etc. We should fulfill our obligations and responsibilities as a member of the WTO, step up efforts for inter-government coordination and establish collaboration and problem-solving mechanisms to resolve in an appropriate manner the international disputes of the IT industry with respect to trade, investment and IPR.

5.5 Implementing Fiscal and Taxation Policies Supporting Industrial Development

The fiscal and taxation policies exert a huge influence on industrial development. More fiscal and taxation support is required for the development of the

IT industry. Fiscal expenditures should be applied to key research areas for development of core technologies and improvement of innovative capabilities. Fiscal expenditures should serve an important role to guide private and institutional investments in proper areas. Preferential policies such as tax credits and grants of interest free loans may motivate big enterprises to innovate and help SMEs strengthen their capacity for innovation. Supporting measures such as VAT transformation, accelerated depreciation, and differentiated export tax rebates can adopted for strategic development areas such as microelectronics, software and key component parts. For enterprises involved in transnational merger and acquisition or asset reorganization, efforts must be made to prevent double taxation, help reduce investment risks faced by the enterprises, implement the policy of deducting R&D investment from the taxable amount and encourage IT enterprises to develop new products, processing techniques and technologies.

5.6 Establishing Venture Capital Mechanism for Innovation and Development

The IT industry carries the distinct features of high investment, high risk and high returns and its development requires a relaxed financial environment. Rendering support for entrepreneurship and innovation through venture capital investment and striving for a sound cycle of industrial development are important approaches adopted by the developed countries to develop their IT industry. The key to the establishment and improvement of China's venture capital investment mechanism is to vitalize the capital market, improve the investment entry and exit mechanism, accelerate the construction of a stock market sector for entrepreneurship and provide support for qualified enterprises to go public as well as more flexible financing channels for IT businesses, especially the SMEs. Meanwhile, we should actively set up venture capital funds and industry investment funds and encourage participation in investment in the form of scientific research achievements as a production factor so that a market-operation-based venture capital investment system which relies mainly on social capital and which enjoys policy support can take shape.

5.7 Assurance and Support from IPR and Relevant Standards

Intellectual property rights are the lifeline of the IT industry. Without IPR, an industry is deprived of the right of speech in the international community. The protection of IPR should be considered an integral part throughout the process of IT industry development, and we must cultivate an ethos of respect for IPR and the awareness of the importance of IPR protection. As we try to protect our own IPR, we should also show respect for others' IPR, settle IPR disputes in a proper way, strengthen the protection of patents, trademarks, copyrights and commercial secrets and guard against the abuse of intellectual property rights. The efforts to protect IPR should be intensified, and IPR infringements and instances of piracy should be severely punished by law. We should make faster move to build special IPR censorship mechanisms for transactions under M&A and technical transfers in order to prevent the loss of IPR. In the course of IT product development and production, due attention must be paid to the products' compatibility with existing international standards. We should make greater endeavors to study and formulate our own technological standards and spare no efforts to promote relevant technologies so that they become international standards whereby China has a louder voice in the formulation of international standards. In areas related to national security, compulsory national standards must be developed and enforced. Enterprises should be given a major role in the application of IPR and in the development of standards so that the enterprises are motivated to be in possession of more patents and proprietary IPR.

5.8 Developing the Talented as Industrial Leaders and High-end Technological Leaders

The competition of the IT industry is fundamentally the competition of technologies, the success of which is eventually decided by the talent pool of human resources. The focal point of such competition is the competition for talented people as highly competent industry leaders and high-end technological leaders. In order to develop industry leadership, we should establish and fortify the concept of talent as the most important resource as we push forward the reform of the talent development system to adopt an employment mechanism featuring openness, mobility and the best utilization of talents and create an environment where talented people can stand out from their peers. Young talents should become the major force to drive development and, in seeking talents for theoretical innovation and more versatile talents with multiple qualifications and technical skill sets, we need to think out-of-the-box to identify talents and assign them with proper tasks so that a group of talented industry leaders can be developed through practice. It is advisable to explore and try out incentive mechanisms such as well-disciplined application of stock and option incentives so as to work out favorable distribution policies that help attract, retain and make the best use of talents. Enterprises, higher education institutions and research institutions should be encouraged to make concerted efforts for developing high-end talents. We should be actively engaged in the international competition for high-end talents to attract more high-level talents to come and work in China and encourage the students studying overseas to return to the motherland and contribute to the development and prosperity of the country.

5.9 Improving the Legal System for IT Industry Development

Either from a historical perspective or based on present reality, the upgrading of effective policies and measures of the IT sector into laws and regulations through legislative procedures is conducive to industrial development and technological advances. For forefront fields in need of more mature practices, it is necessary to take into consideration the actual conditions and draw upon good experience from foreign countries to fortify the scientific nature and enhance the predictability of legislative procedures. Focusing on the industrial development strategies and key areas, we must take quicker steps to formulate laws and regulations on telecommunication, integrated circuit and software sectors as well as IT application, and revise and improve laws and regulations on IPR and relevant standards when appropriate. We must take quick action to organize study and formulate laws and regulations on online government administration, e-commerce, information security, personal information protection and online behavior protection for minors in order to address the issues of information security, Internet crime and Internet governance, etc. We should intensify our effort for law enforcement, adopt stricter standards for judicial procedures so that all laws and regulations are strictly followed and all violations punished, thus creating a sound legal environment for the development of the IT industry.

6 Conclusion

The ultimate task of China's IT industry development is to make breakthroughs in core technologies and elevate innovation capacity. Under most circumstances, it is not a lack of potential for progress but a lack of ambition and acumen for innovation that stands in our way. In most scenarios, it is not a lack of potential for breakthroughs but a lack of confidence in victory that prevents us from achieving success. From an objective observation of the development history of China's IT industry, we can see the buildup of energy, and we have every reason to expect the realization of breakthroughs that are currently being envisioned. China will undoubtedly become a world leader in terms of IT development so long as we persevere in the development pathway for our IT industry with Chinese characteristics.

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References

[1] MOORE G E. Cramming more components onto integrated circuits [J]. *Electronics*, 1965, **38**(8): 114-117.

[2] BRESNAHAN T F, TRAJTENBERG M. General purpose technologies: Engines of growth [J]. *Journal of Econometrics*, 1995, **65**(1): 83-108.

[3] OECD. OECD information technology outlook [R]. OECD Publishing, 03-10-2006.

[4] ROMER P M. Increasing return and long-run growth [J]. *Journal of Political Economy*, 1986, **64**(5): 1002-1037.

[5] ABRAMOVITZ M. Resource and output trends in the United States since 1870 [J]. *American Economic Review, Papers and Proceedings*, 1956, **46**(2): 5-23.

[6] DENISON E F. Why growth rates differ: Postwar experience in Nine Western Countries [M]. Washington DC: The Brookings Institution, 1967.

[7] Ministry of Information Industries (MII). Review on the 10th five-year development of information industries (telecom volume) [M]. Beijing: Posts & Telecom Press, 2006 (in Chinese).