ISSN 2045-5119

TMCD Working Paper:

TMD-WP-66

The Catch up Pattern under a Window of Opportunity: the Experience of a Grassroots Company from a Developing Country

Yan Hui	Mammo Muchie	Maria Friis	Yin Xuefeng
Shanghai University	Tshwane University of Technology	Aalborg University Denmark	Tongji University

March 2015

The Catch up Pattern under a Window of Opportunity: the Experience of a Grassroots Company from a Developing Country

Yan Hui[1]
Mammo Muchie[2]
Maria Friis[3]
Yin Xuefeng[4]

Abstract
During the past 30 years China's economic development has made remarkable achievements. At the same time, the Chinese enterprises have also attempted to move from being labour intensive to high-tech intensive. The Chinese high-tech industry has made preliminary achievements in some aspects, particularly in telecommunications. Huawei has been regarded the most innovative company in China. Based on the case of the Chinese telecom industry and in relation with Korean case, the paper tries to understand what type of external environment provides a window of opportunity for industry catch up, and how does the external environment affect an enterprise's catch up pattern? This research further attempts to introduce catch up pattern joined together by external factors and internal factors. We particularly focus on deepening the understanding of low-end entry while integrating the theory of product life cycle to deduce a catch up innovation path, which can be helpful to refer by other grassroots companies in developing countries.

Key Words: high-tech, telecom, entrepreneurship, industrial catch-up,

Jel Code: L50, N45, O31, D02

1 Lecturer of School of Management, Shanghai University, PRC. dolphinsurfing@163.com

2 Professor of Tshwane University of Technology, South Africa; Visiting Scholar of Shanghai University sponsored by "Hi-end Foreign Expert Recruitment Program" by the State Administration of Foreign Experts Affairs of PRC

3 Staff of Civil Engineering Department, Aalborg University, Denmark

4 Associate Professor of School of Electronics and Information Engineering, Shanghai PRC

1. **Background**

Huawei was established in 1988, it has been among the top 500 companies globally and the world second largest telecom equipment provider. Another similar company, ZTE also achieved spectacular technology breakthrough and market development. Both Huawei and ZTE have developed from grassroots companies without any particular resource or support. What type of forces drive the grassroots latecomer to catch up in a high-tech industry so rapidly? More precisely, what characterise the external environment and internal qualities that spur this change? Successful change cannot occur without the interaction of external environment and internal factors. In the category of industry catch up, the external environment may provide a window of opportunity and the internal factors may be company strategy. Although technology and innovation are crucial to industry's catch up, a firm or an industry must be able to take advantage of that "window of opportunity" in the technology evolution trajectory when implementing social, industrial and technology policies for catch up; otherwise, they will stay behind (Perez and Soete, 1988; Freeman, 2002). The concept of window of opportunity was elaborated by Lee, Park and Krishnan (2014). They identified three windows of opportunity. One is the emergence of a new techno-economic paradigm (Perez and Soete, 1988), which place the incumbent and latecomer at the same starting line of the competition (Lee, Lim and Song, 2005). The second window of opportunity is business cycle, and the third is government regulations (Lee and Mathews, 2011, Mathews, 2005). Lee and Lim (2001) illustrated three patterns of catch up: path-following, stage-skipping and path-creating. Path-following refers to the catch up firms that follow the track of other innovative companies. Stage-skipping means that the catch up pattern skips some fixed stages of the track and it performs in a more effective way. Path-creating occurs when catch up firms abandon the existing technology trajectory and develop their own innovative technologies to narrow the gap between themselves and the leading companies.

The literature on catch up has focused mainly on the significance of the technology paradigm perspective, and the field grassroots catch up from developing countries is under-researched. Few papers have studied the Chinese telecom catch up in terms of path-following. Mu and Lee (2005) focused on the "trading market for technology" catch up strategy by analysing the knowledge diffusion from Shanghai Bell to other companies. They concluded that as a catch up condition, technological regime of telephone switches were featured by a more predictable technological trajectory and a lower cumulativeness. The condition helped the Chinese companies achieve a stage-skipping catch up. Liu (2007) reviewed the development of telecommunication equipment industry from fixed line to 3G, TD-SCDMA. Liu noted path-following by

concluding that the degree of matching between existing foreign products with the needs of the Chinese market was the primary incentive for Chinese companies to catch up. The possibility of redesigning foreign products to match the local market demands created the catch up space. In addition, Liu emphasised the important role of government in stage-skipping and path-creating models. In the most recent paper by Gao (2014), he reviewed the process of introducing the Chinese 3G standard TD-SCDMA and investigated how a latecomer could promote a technology standard, it in itself being the path-creating catch up model. Gao found that as a latecomer it was necessary to develop special capabilities to get support from the government and public stakeholders such as scholars, as for the latecomer, the development of innovation capabilities and new technologies are needed but far from sufficient. So the authors suggest that the experience could offer new insights for other latecomers from developing countries seeking their own standard-setting.

This research presents interesting insights and effectively constitutes the main clue to study the Chinese telecom industry's catch up. There are, however, a few points missing. 1) The above mentioned studies focused on the path-creating or stage-skipping models; path-following is under-researched. 2) The studies primarily analysed a catch up from the macro point of view to study the progress of the whole industry; it is also under-researched from a micro point of view, in that they failed to carefully observe one particular company's catch up. 3) Most of the research has focused on major state-owned Chinese telecom companies, while the in-depth research about grassroots telecom companies is almost non-existing. This paper aims to fill the gap by analyzing the case of Huawei, in relation with ZTE, a Korean TV industry and TD-SCDMA company.

The research will identify what type of external environment provides a window of opportunity for industry catch up, and how the external environment affects an enterprise's catch up pattern. Particularly, there will be focus on deepening the understanding of low-end entry by us integrating the theory of product life cycle to deduce a catch up path, which can be referred to by other grassroots companies in developing countries.

A choice is made to combine technology life cycle with low-end disruption theories, with analyses of the external and internal dimensions by focusing on the subject of industry catch up. More importantly, the paper shall through the case of Huawei integrate the two theories and observe, how the external and internal factors have a joint impact. Huawei has been selected as research case as it is a typical representation of a grassroots high-tech company in a developing country. The successful catch up of Huawei did not rely on any particular circumstance (as e.g. government subsidies). It all depended on the natural opportunity offered by market development and the company's successful implementation of its individual strategy. Today, Huawei represents the most successful catch up experience and the most innovative company in China. Therefore, Huawei's experience represents a strong

reference point to other grassroots companies. Since technology life cycle and low-end disruption are universal to any industry, the reference will be considered valuable for other industries as well.

The paper has five parts. The first part looks at the first window of opportunity, namely the angle of the techno-economics paradigm and starting to analyse the interaction mechanism between external environment and internal factors for the technology catch up. In this research, the window of opportunity occurs when a technological life cycle (Utterback, 1994) proceeds from one cycle to another, innovation is accelerated and the market is roiled because the incumbent and disruptor start from the same point at a rapid pace. Referring to internal factors, there will be a close look at low-end disruption strategy by analyzing the motivation and advantages integrating Christiansen's theory (Christiansen, 2003).Part two undertakes an in-depth analysis on how the grassroots company keeps low-end disruption and gradually achieves an incumbent position. The analysis shall continue to deepen the understanding about the low-end disruption, dominant technology and introduce the concept of aspiration level to guide further observation. It is believed that the observation will have significance for other similar enterprises, as many Chinese companies possess the same grassroots characteristics as Huawei. Part three introduces the cases of ZTE, Korean TV industry and TD-SCDMA, where it is found, that under such opportunity, there is another type of catch up model. Huawei and ZTE belong to path-following and the Korean TV industry and TD-SCDMA belong to path-creating model. The path-creating model is not the primary focus but a comparison shall be made in order to summarise more disciplines based on observation. In these two cases, the catch up skipped the original technology paradigm and radically designed a new industry standard. In the final part, the research questions shall be answered based on the above analyses.

The literature review covers mainly two parts: Christensen's technology disruptive (2003) and Dalum's technology life cycle (2002). Certain important concepts will also be introduced such as window of opportunity, dominant design, incremental/radical innovation and aspiration level. Literature has been selected from classical publications and papers, and discussions related to innovation or standardization in network economy shall be reviewed. The case of Huawei will be used to test the theories and deduce a more general pattern with the purpose of being relevant to other catch up companies and innovation researchers. .

Yin (1989) provided a comprehensive and systematic outline for a case study. For each interview was prepared a concise key research question. Centered on this key question other sub-questions were put forward one tier at a time. In each interview, the selection of theories (technology life cycle and technology disruptive) also guided every question raised to the interviewee. Detailed notes were made following all interviews. Due to the large quantity of information obtained from the interviews, the information was sorted by skipping non-relevant discussions and outlining answers to

the questions. For each interview the research question was referred back to and an answer to each question extracted based on the interview contents. The information of the interviews was integrated into different parts of the analysis. Through these interviews and seminars, first hand industry phenomena were observed and insights obtained. A future industry perspective was developed.

The contribution made by interviews with people involved in different areas of the telecom industry played a significant role in the overall study. It was essential to select appropriate interviewees and secure reliable sources. The interviews varied from one hour to three hours, in different locations including company offices or coffee bars. The interviews were carried out in a semi-organised way (Yin, 1989). Twenty one interviews were conducted with relevant personnel from the mobile industry. The selection criteria for the interviewees were as follows:

1) Relevant industry experience
2) Continual contribution to ongoing projects in their field
3) Ability to provide industry insights

The complete list is seen in Table 1: Basic data of interviewees

Company	*Name*	*Position*
Datang	Mr. Yang	Director
Datang	Mr. Li	Engineer
Eastcom	Mr. Zhao	Senior Manager
Huawei	Mr. Chu	VP
Huawei	Mrs. Xue	Manager
Huawei	Mr. Lu	R&D
Huawei	Mr. Zhong	R&D
Huawei	Mr. Zhang	R&D
Local S&T Bureau	Mr. Bo	Director
Motorola	Mrs. Ren	Manager
Motorola	Mr. Xu	Engineer
Motorola JV	Mr. Wang	General Manager
Nokia	Mr. Shen	Regional GM
TD-SCDMA Alliance	Mr. Yan	Staff
University	Dr. Yin	Professor
UTStarcom	Mr. Zhou	VP
UTStarcom	Mr. Liu	Manager
ZTE	Mr. Wang	Country GM
ZTE	Mrs. Ni	Assistant to VP
ZTE	Mr. Shu	Manager
Operator	Mr. Chen	Manager

(Source: adapted by the authors from this paper)

2. **Reviewing the Conceptual Frames for Technological Catch-up**

Technological regime is a popular dimension for understanding catch up. Among its

factors, technological opportunity is the most important one. According to Malerba (2005), technological opportunity reflects the likelihood of innovation for any given amount of money invested in search. According to Lee and Lim (2001), the cumulativeness of technical advance and the predictability of technological trajectory are the two important dimensions of the technological regimes. Regimes in which innovation is more predictable and frequent will improve latecomers' opportunity to catch up. The product life cycle provides the possibility to predict the evolution of technology. The product life cycle theory explains how a product develops through a number of different phases from introduction to growth, maturity and decline (Forrester, 1959; Brockhoff, 1967). The product life cycle concept has shown to be a powerful analytical tool to describe product development, to analyse an entire technology or a generation of a technology and technological innovations (cf. Bauer & Fischer 2000; Chase, Aquilano & Jacobs 2001).

According to Utterback (1994), in the beginning of the product life cycle, there is plenty of experimentation with different designs and technologies, which results in high innovation. In the early development stage, accelerated market dynamics and persistent uncertainty are observed. Companies are focusing on technological trajectories and importance of complementary assets. Along with the evolution of technology, the focus shifts slowly from product performance maximization to cost minimization, with market dynamics, standardization and incremental product and process innovations as well as a prominent role of complementary assets. In the mature phase, innovation rate fades, the products become standardised and the market is manipulated by oligopolies. It is also possible to see technology revitalization. Finally, in the decline stage, the market contracts and a given technology exits.

When a dominant design occurs, it is usually preceded by a disruptive technological change, followed by several rounds of incremental and sustaining changes to the original disruption before a true dominant product design can occur. The product, which is finally adopted by the industry as the 'standard' and therefore all firms must conform to, is the dominant design. Anderson and Tushman pointed out that each technology cycle starts with a technological discontinuity or a disruption (Anderson and Tushman 1990). Each technological discontinuity will have its own life cycle or technology cycle where the advent of the discontinuity will produce an era of ferment (ibid). At this point in the technology cycle, the industry is volatile and competition between firms is fierce. The era of ferment is characterised by continuous substitution as well as competition amongst the different designs that have been introduced by many firms. The design competition results in a dominant design (Utterback 1975). This dominant design is the culmination of many design phases and it is this dominant design that will become the accepted market standard.

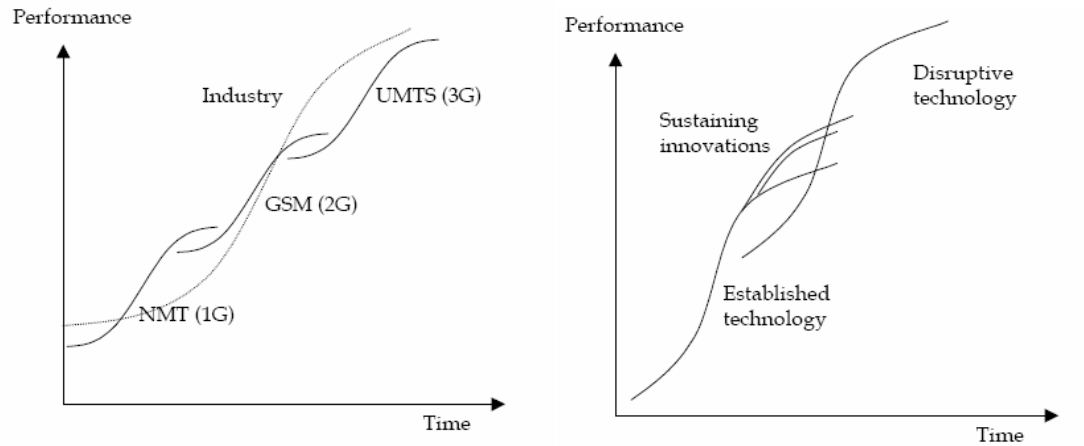
The technology life cycle theory closely connects the concepts including disruptive technology and radical innovation. In the beginning of the product life cycle companies experiment with different designs and technologies which result in a high

rate of innovation. It might be incremental or radical innovation. The one that successfully leads that trend and market may become a dominant design. Then technology life cycle progresses to the early development and the mature stage. Technology innovation also enters into a comparatively fallow period, when most companies focus on standardization of products and formalizing the processes. Not until the life cycle enters the decline stage and another new life cycle is looming technology innovation become active again. As it is introduced in Chapter 3 and 4, the ASIC from Huawei and PHS from ZTE are typical examples of incremental innovation. However the Korean TV industry and TD-SCDMA belong to radical innovation.

Technological life cycles in mobile communication

The concept of technological life cycles may be applied to the evolution of mobile communication technologies. The transformation from the first generation (1G) Nordic Mobile Telephony (NMT) technology to the second generation GSM constitutes a shift in technological life cycles. In addition, the coexistence and shifts of different technological life cycles is not an S-curve, which is full of disruption. The 1G mobile technology (Nordic NMT) commenced in 1981 and represented the first cycle. This technology achieved certain success within Europe. Then the digital technology GSM entered the market as a disruptive technology before NMT had entirely exited the market and it eventually developed into a dominant technology replacing the NMT and as well as fixed telephones. Along with the further development of mobile technology, 3G and the next generation technology are predicted according to the technology life cycle. However, it would not be straight forward and have to coexist with the GSM technology. Meanwhile, it would evolve alongside the evolution of other technologies (Dalum, 2002). The charts of S-curve technology life cycle and mobile technology life cycle are illustrated in Figure 2:

Figure 2:
General technology life cycle and telecommunications life cycle

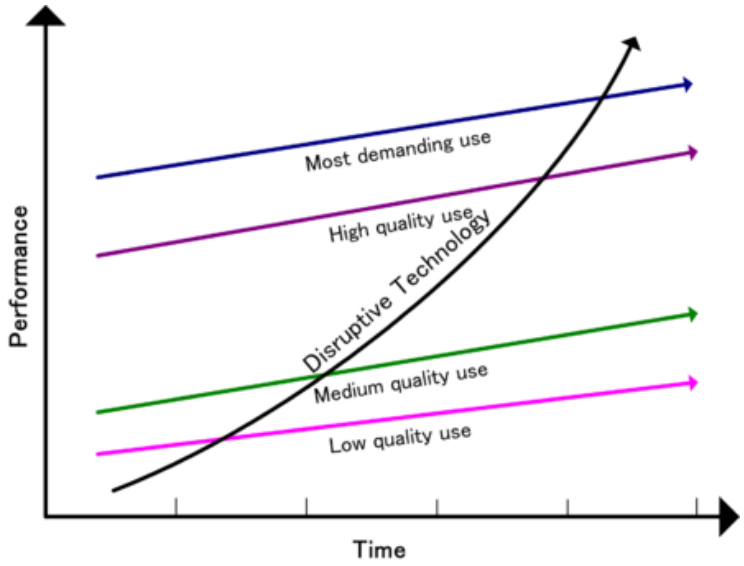


(Source: Dalum, 2002)

Technological disruption and market segments

Christensen (2003) distinguished between "low-end disruptions" which targets customers who do not need the full performance valued by customers at the high-end of the market and "new-market disruption" which targets customers who have needs that were previously un-served by the incumbents. Low-end disruptions target users have been overlooked by mainstream technologies, being considered too expensive or not sophisticated enough. This occurs when the rate at which a technology improves is higher than the rate at which customers are able to adapt to its new performance. This also means that the performance of the technology will exceed the needs of a particular market segment. When a disruptive technology enters the market at this point, it would cater to the particular segment of the market that has been overlooked or left behind by the mainstream technology. The disruptive technology may have lower performance than the mainstream technology but is adequate for the low-end market. In low-end disruption, the disruptor is initially focused on serving the least profitable customers, who are not willing to pay premium for enhancements in product functionality.

Figure 3:
Disruptive technology



(Source: Christensen, 2003)

However, once the disruptor has gained a foothold in the market, it will seek to improve its profit margin. The disruptor will have to enter the segment where the customer is willing to pay a little more for higher quality. In order to make this happen, the disruptor shall need innovation. On the other hand, the incumbent will not spend much to retain its share in a low-end and non-profitable segment, and will keep

focusing on profitable customers. After a number of such encounters, the incumbent will be squeezed into smaller markets than it was previously serving. Gradually, the disruptive technology will meet the demands of the most profitable segment and drives the established company out of the market. However, new market disruptions target new customer segments that were not previously served by the established product. It is when the technology is of poorer performance in almost all aspects and is only able to cater to a new or emerging market that was not served by the previous technology (Christensen, 2003). Please refer to Figure 3.

The main characteristics of an incumbent and a new market entrant are shown in the table below in Table 2. Both the incumbent company and the new market entrant serve the market based on their different missions. For the incumbent company, after having acquired product innovation or technology innovation, process innovation is essential to commence mass marketing. Process innovation will bring prices down and quality up. However this ambition also requires standards, procedures and administration, which inhibit further product innovation. The set up of process innovation will formalise a company's progress into an efficiency mode and larger profits, which results in more hesitation and concern over stepping into further innovation. By contrast, small, nimble, new companies move faster and are more willing to take risks, as they do not have any significant market assets. Even low profit innovation will attract them into moving into the market. Also, they are not tied down by any formalised processes (Tan, 2006).

Table 2:
Incumbent and a new market entrant

Incumbent company	*New market entrant*
Addresses old market	New and potential market
Large profits	Small profits
Existing processes	No existing processes
High marginal cost to move down market	Low or no marginal cost to move down market

(Source: adapted from Tan, 2006)

3. **Huawei's opportunity in the technology life cycle and low-end disruption**

Huawei Technologies is a private high-tech enterprise specialised in research and development (R&D), production and marketing of communications equipment and providing customised network solutions for telecom carriers. In addition to the 8 R&D centers in China, Huawei also established worldwide R&D centers in Stockholm, Sweden; Dallas and Silicon Valley, U.S.; Bangalore, India; Ferbane in Offaly, Ireland; Moscow, Russia; Jakarta, Indonesia and the Netherlands. Huawei Technologies Co. Ltd. is the second largest telecommunications equipment maker in

the world and has 140,000 employees (www.huawei.com.cn). Huawei commenced as a trading company for telecom equipment businesses. The strategy was to "introduce advanced products from foreign countries and promote them in the Chinese market". This was a "doing trade and manufacturing to support R&D" strategy. The strategy did lack ambition; it was a pragmatic position. The well-established MNCs including Ericsson, Nokia and Motorola fully dominated the Chinese market, which made it difficult for the newly-established Chinese telecom companies to survive in the market. Small companies as (at the time) Huawei had no choice but to take advantage of the short-term interest in front of them, by investing their efforts as an agent for foreign companies to sustain the running of the company.

Huawei also realised that they could no longer secure a long term survival in the market, if they were merely a go-between. The company decided to adjust its "trading business" and focus more on the "independent R&D, learning and absorbing, moving to high-end products". One interviewee told us: "Huawei worked as an agent only for a short time. We know little about it. The company soon changed the strategy to become a developer." Thus the company switched from an equipment importer to an independent developer for systems and technology. The decision was risky and the process to acquire independent research was difficult. Huawei invested considerable financial and human resources to support the independent research.

For nearly 20 years Huawei invested more than 10% of its sales revenue in R&D. Particularly, in 2005, Huawei spent 14% of its total revenue on R&D. Huawei's major expenditure on R&D is an unusual case among Chinese telecom firms. In 2002, average R&D expenditure in the top 100 Chinese telecom companies was only 3.8%, much lower than that of the global counterparts such as Cisco (25.3%), Intel (17.5 %), Microsoft (15.5%), and Nokia (10%) during the same year (Chen, 2006). As for human resource strategy, according to data collected in 2005, about 60% of Huawei's employees had gained Master or Ph.D. degrees and more than 25% bachelor degrees. Huawei made it compulsory for every employee to spend 7% of their time pursuing job-related training every year (He, 2005). From the 2008 data, Huawei had 97,500 employees, among whom 42.78% were R&D (37,432), 29.65% marketing (25,943), 6.88% management (6020) and 20.69% production (18104) (Huawei HR Annual Report, 2008). The interviewee in Huawei told us:" We are a typical a "dumbbell type enterprise. We have two focuses on R&D and sales but fewer employment in other departments. Every year we hire a lot of newly graduates for R&D and sales, and they have to come from the top universities."

Huawei commenced investing in 3G in 1995 and continued the ambition. During the next ten years Huawei invested up to RMB 5 billion in research and employed more than 6,000 researchers and engineers for research projects. The intensive R&D investment enabled Huawei to acquire 2,700 3G patents, of which 94% are invention patents. Until June 2006, Huawei had the Patent Cooperation Treaty PCT patented over 14,000 items, which was 2.4 times more than Cisco (Sun, 2008). In 2009 Huawei eventually ranked no. 1 in the world among all companies and individual applicants

for the PCT, according to statistics released from the World Intellectual Property Organization. Huawei had the highest number of patent filings with a total of 1,737 applications in 2008 (Du, 2009). With such a base of innovation, Huawei began to transfer its focus to USA and EU, aiming at supporting its international business expansion.

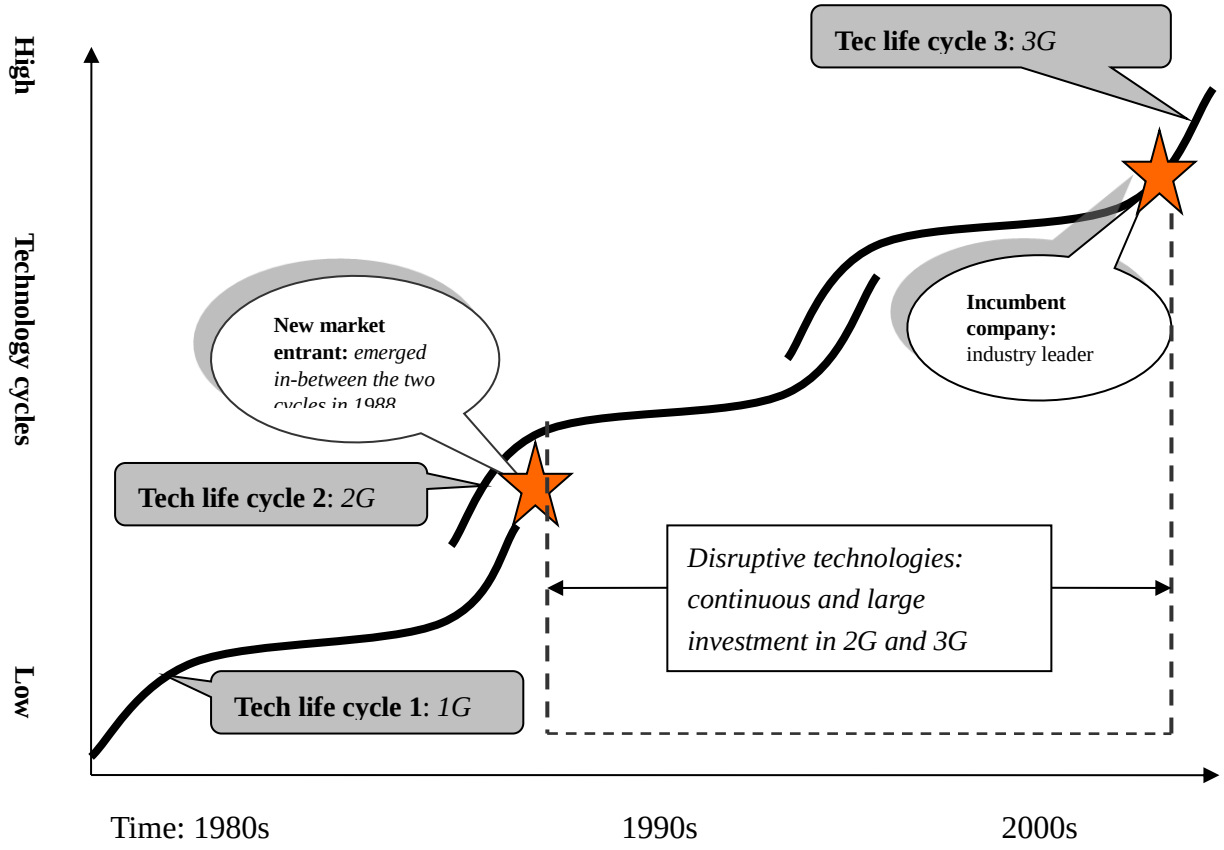
Huawei seeing the window of opportunity: from 2G to 3G

1G technology dominated the market in the 1980s, and gradually it was replaced by 2G (GSM) technology in the 1990s. Huawei was established late 1980, when 1G was at the end of its technology life cycle. Huawei began to focus on its own development beginning in the 1990s, when 2G was about to replace 1G technology. The company had a significant presence at the start of the 3G life cycle. During that time, there was increased experimenting with different designs and technologies, which resulted in high innovation. Accelerated market dynamics and persisting uncertainties in the new technology diagram of 3G provided opportunities for the new market entrant. Huawei emerged as one of the small companies competing with the incumbent companies. Although competition was keen, Huawei persisted in investing in developing its own technology, particularly in the less sophisticated technologies ignored by the MNCs. Large incumbent companies were occupied by "standardization of products and formalizing processes". This helped Huawei access the 2G industry in less profitable market segments. Gradually Huawei entered a higher-end market with more profit to follow. Huawei also commenced major investments in 3G development. In the early stage of 3G, the persisting uncertainty was obvious. Huawei insisted on developing 3G technologies in terms of capital, IPR (International Property Right) and human resources. Based on the market accumulation in the 2G technology, Huawei then provided the market with its 3G products when the technology was upgraded. Finally, after more than ten years of effort, Huawei became the provider for the mainstream operators in the high-end market replacing the incumbent companies as the market leader. In the context of the technology life cycle, the cycle offered Huawei unique opportunities for learning and catch up.

Huawei was born at a time between two product life cycles, i.e. when 1G was already mature and 2G was in a budding stage. Had Huawei been established during other stages, the company would have been another case. In the 1G's heydays, when incumbent companies had a firm grip on the technology resources, the industry tended to focus on technological trajectories and complementary assets. To a new market entrant with disruptive technology like Huawei, at this stage there was no competitive advantage. When 1G was developing and getting mature, the industry's resource allocations were centered on cost minimization and standardization and at this stage the market was controlled by oligopolies. Until the final stage of the life cycle the industry was basically controlled by standards and monopolies. Innovation development was in a state of suffocation, tending to fade. When 2G began to appear, the accelerated market dynamics and uncertainties provided an opportunity for the

development of disruptive technology. This market pattern is illustrated in Figure 4.

Figure 4:
Huawei's development and technology life cycle



(Source: adapted by the authors)

Huawei's low-end technology breakthrough: ASIC and board development

Huawei's research in its early stage reflected the mode of an active follower: imitate, improve and enrich. Ren Zhenfei, the founder of Huawei, used to admit that "Huawei indeed has no original invention until now. We improve ourselves based on the research product from Western countries, most of which can be represented in design, engineering realization and other technology adjustment" (Ren, 2000). The mobile R&D can be divided into three layers. The first is the core technology, which includes "exclusive technology" like Intel's CPU, Microsoft's operation systems, and Nokia's and Qualcomm's core chipsets. Huawei established its CMDA research in 1996 and soon realised that almost all core technologies in CDMA had been patented by Qualcomm. Therefore it was impossible for Huawei to avoid these patents. Huawei then decided to focus on the development of the next layer of mobile technology.

The second layer is non-core technology, namely ASIC. Such chips are characterised

by the large quantities and relatively smaller technological challenges. Most of Huawei's research efforts were focused on this layer. Huawei designed parts of the chips themselves and selected some to be processed further by foreign OEM manufacturers. This way Huawei replaced imported chips with self-designed ones. The savings were enormous: the cost for each chip designed by Huawei was at that time less than 15 USD, while it would cost more than 100 USD if it had been imported. The company saved many hundred millions USD by deploying self-designed chips. So Huawei continued to invest large sums in ASCI design. The ASIC chip design department employed more than three hundred engineers after 3 years' development. In 2004, a specialised chip design company, Hisilcon Design House, was set up. This company was managed separately from Huawei and provided professional design service for Huawei and other companies in the telecom industry (Cheng and Liu, 2003). The third layer of R&D is called "board development", which took advantage of the Chinese engineers to lower the production cost for circuit boards. For example, Huawei assigned engineers to investigate the possibility of reducing the cost for exchange customer boards - they attempted at replacing every unit in the board with new designs/solutions until they found solutions to improve results.

Huawei positioned itself advantageously in the second and third layer of technologies, particularly in the second layer. Although Huawei at that time did not have the capability to become involved in first layer R&D, the development in the application layers (the second and third layer) brought Huawei tremendous customer resources. Huawei invested more than 70% of its R&D funds aiming at meeting instant customer demands. The major investment in this field ensured that Huawei would always be part of the first camp in the development of NGN (Next Generation Network) ADSL, optical network and 3G. This is also one of the strategies Huawei used surviving in the sharp competition in the industry (ibid). As time went by and the learning increased, Huawei devoted more and more of its R&D to the core technologies. During one of the interviews, it was confirmed that Huawei were no longer only spending efforts on R&D for immediate use. One of the interviewees is from university professor who has long time cooperation with Huawei. He said that: "Huawei is also cooperating with universities researching for future applications that may come into uses after five to ten years or even further into the future. These research projects were getting closer and closer to the core part of telecom technologies. We believe we are on the track to the top of the world."

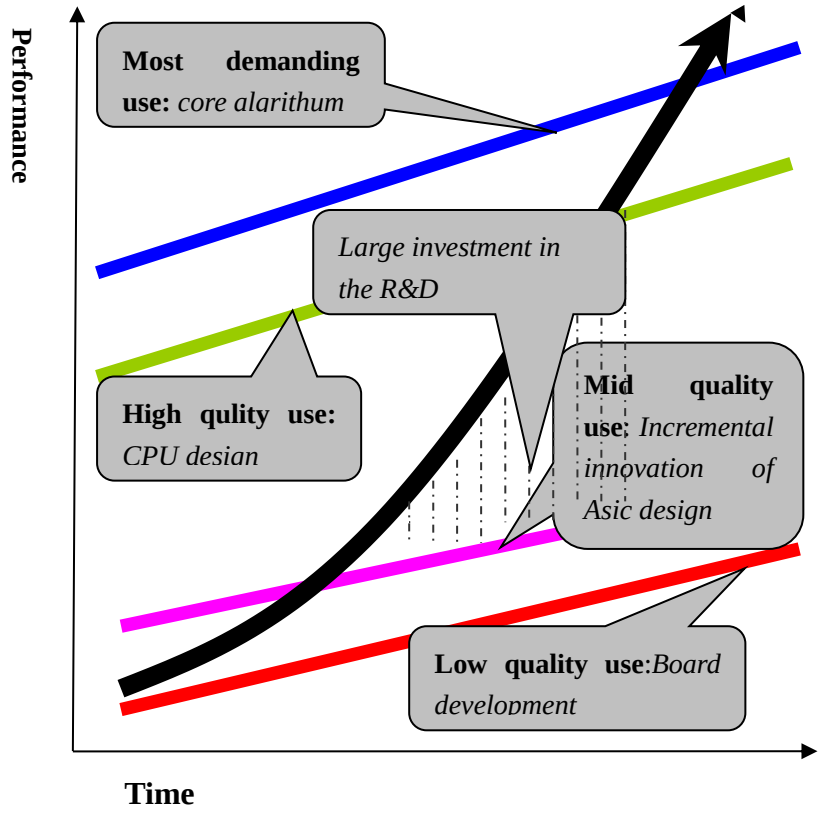
In the three-layer R&D strategy, Huawei chose the incremental innovation which was feasible compared to other sophisticated innovations, although compared to CPU, the ASIC was a small incremental technological improvement compared to the existing telecom products. It demanded less investments and effort, which was realistic and operable for Huawei at that time. With this strategy, Huawei focused on the second and third layer of technologies. It dedicated a large number of engineers to the development of the technologies. Huawei targeted ASIC and "board development"

which was overlooked by mainstream CPU providers, as these products were less profitable. The technology provided by Huawei could be of lower performance than the mainstream providers', but adequate for the low-end market. Due to the obvious price competitiveness and sufficient functions, the disruptive technology could exclude other powerful MNCs from the competition by firmly occupying a particular niche in the low-end of the market. This kind of innovative technology with strong regional character and timeliness is named "periodical dominant technology". The difference between the "periodical dominant design" and the "dominant design" as we usually know it, are the following: 1) "periodical dominant design" is not the summit in the similar technology, but it is certainly the most accepted and most popular in a particular market; 2) "periodical dominant design" tends to occur in the low-end of industrial chains and low-end markets; and 3) "periodical dominant technology" does not have the absolute technological advantage, so the disruptor needs to update the technology constantly according to market changes..

Huawei focused on serving the least profitable customers in order to establish its first foothold in the industry chain. The consumers in this market segment did not need full performance as the high-end customer needs and they were overlooked by mainstream technology companies, either because satisfying the needs were seen as less sophisticated or less profitable. Although the low-end customer segment was seen as a less attractive market segment, it provided Huawei with the chance of gaining a firm foothold in the industry chain. Huawei also used its advantages in cost and human resources by employing many engineers to focus on the development of the second and third layer technologies. This helped Huawei's technology to become more competitive, and enabled Huawei to gain a foothold in the chip design market as the "periodical dominant design" by focusing on incremental innovation of ASIC only within a particular market. First, the ASIC was applied by Huawei internally. Later, the ASIC technologies were provided to other companies. This way Huawei established its independent chip design company to provide services for other companies in the low-end market segment. The strategy helped them survive in the competition when they were small and young and accumulate experience, knowledge and capital for further ambitions. Currently, they moved more and more towards the first layer chip design. The interviewee from telecom operator recalled his experience with Huawei: "You can never imagine the way Huawei is doing sales. They were very humble, because they tried to promote good products with a low price. They were almost available for you at any time when you need help. The MNC in China cannot do like this. Finally I had to respect this company and I had no reason to ignore them."

For this part please see Figure 5.

Figure 5:
Breakthrough from ASIC and board development



(Source: adapted by the authors)

Going further to a higher-end technology: data communication and WCDMA

Although MNCs dominated the information industry, the ever-changing technology and market presented opportunities in the niche markets for small and nimble participants. Huawei was also aware of other opportunities in the telecom field than the digital exchange technology, seeking a breakthrough and avoiding being left behind. From 1993, Huawei began to explore data communications, mobile communications, optical transmission and other critical technologies in telecommunications. Huawei established the Shanghai and Beijing research centers in 1995 and invested in technologies such as basic and directional research. These research activities were not going to be profitable on a short-term basis. One example is Huawei's involvement in data communications. Since 1998 the telecommunications industry had undergone a major change. The internet was rapidly heating up and IP technology became an important direction of the future. Being fully aware of the trend, Huawei became an active player in data communications and also became the first domestic vendor in the field of mobile communications and other major equipment. This successful adaptation was made largely by Huawei's long-term accumulation of basic research in their research centers (Cheng and Liu, 2003). The interviewee told

us that Huawei set a particular department to follow the international technology trend in the world. But recently this department is involved more and more in global merging and investment focusing on small and innovative companies.

Another example is Huawei's WCDMA research case. After internal consideration and discussion Huawei gave up the development of the R99 version, which had become very mature in the overseas markets, although the company had spent some time on this product. Huawei terminated its development and redirected most of its resources to the development of the R4 version. Later the result showed that Huawei's decision had been correct. Huawei established its position in the WCDMA camp from a foothold, where they had few strong competitors. Today's Huawei is on par in many areas with other MNCs, including holding the leading position in a few areas (Cheng and Liu, 2003).

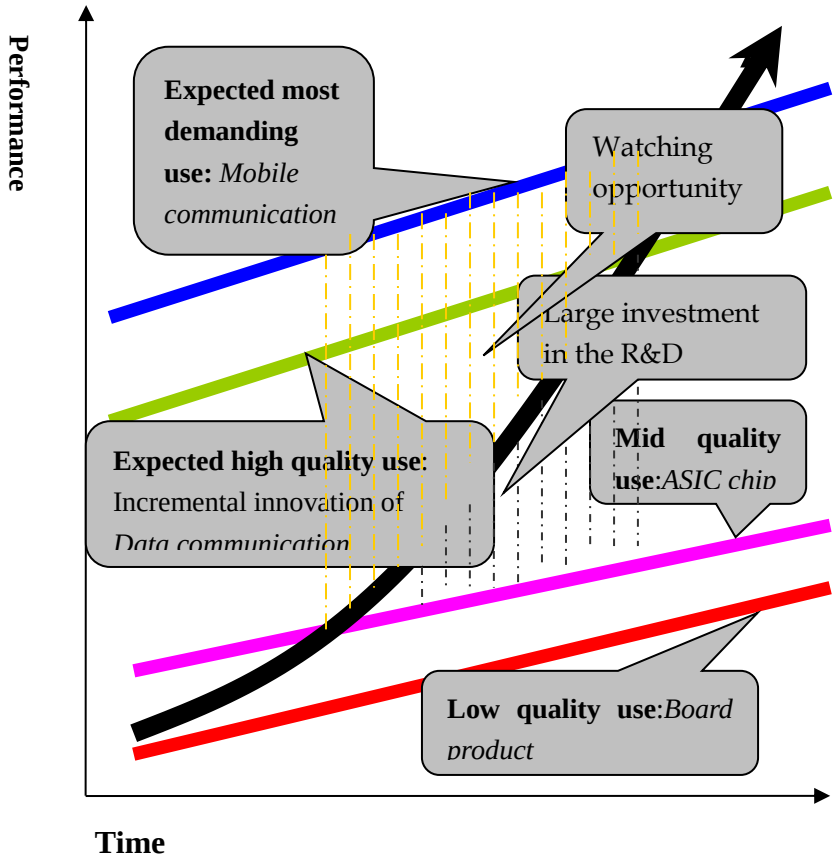
In the early days of Huawei, most of the technologies developed were imitations. After 1998 Huawei decided to put more effort into transforming from a technology follower or imitator to an innovator. Along with growing sales, Huawei perseveringly kept spending 10% of its annual revenue on R&D, reflecting a typical HR "smile curve": R&D 46%，marketing and sales 33% , administration 9%, production 12%. In 2005 Huawei's investment in 3G exceeded 4 billion RMB and obtained more than 600 patents. They reached the breakthrough by spending more resources in human, material and financial capital than their competitors. Internally in Huawei, it was called the "Intensity of Pressure Principle". It was a famous Huawei's principle in the industry, which also was one of Huawei's symbolic culture tabs (CEIBS Business Review, 2011). The company's research fully shifted to 3G (WCDMA/CDMA2000/TD-SCDMA), NGN, optical networks, xDSL and data communications. It was now a fully-fledged global high-tech company from China.

Huawei needed innovation in order to enter the segments where the customers were willing to pay a little more for higher quality products. Based on the achievements in ASIC and board development (low/mid quality use), Huawei also kept watching the opportunities in the fields of data communications, mobile communications, optical transmission (this was named "expected high quality use" in 2G technology) to seek a breakthrough and avoid falling behind, and even following WCDMA (this was named "expected most demanding use in 3G technology"). Now the target was no longer the low/mid quality technology; it was about driving the trend in a new technology. After Huawei decided where to focus, they spent major resources and efforts to make the technology competitive. Eventually, Huawei established its position in WCDMA camp from a wise foothold where they had few strong competitors. From this point Huawei was advancing from a low-end technology position to a higher-end technology position. Huawei made breakthroughs in the low-end market in 2G technology (for example, in ASIC development and board developing in chip design). They then went into data communications and WCDMA. The ASIC and board development were like seed of Huawei's own technology, although the performance

and added-value were not considerable as in other core technologies. The ASIC and board development however, provided the qualification for Huawei to survive in the telecom industry chain. Little by little the "technology seed" expanded and grew, eventually enabling them to move into a higher-end market and to manufacture products for higher quality use.

After Huawei had gained foothold in the market of ASIC and board development as a market disruptor, it sought to improve its profit margin by new innovations. Meanwhile, the incumbent kept focusing on the most profitable technology and customer. After several rounds of competition, the incumbent was pushed into a much smaller market than the one it had previously served. Gradually, Huawei's technology met the demand from higher and higher levels of markets and squeezed incumbent companies out of some of these markets. It is worth noting that in the process of Huawei's move from low-end to high-end, the so-called "high-end technology" was still relatively "high-end technology" in terms of Huawei's position. It was not the high-end of the entire industry. The innovation at this point was still incremental innovation.

Figure 6:
Breakthrough to a higher quality use/market



(Source: adapted by the authors)

The most high-end technology in the telecom industry are the core algorithms and CPU technology and the “high-end technology” that Huawei could break through at the time was only in digital communication and WCDMA. It still had quite some way to go to reach the real high-end technology. In the process of Huawei’s breakthrough advancing from low-end technology to high-end technology, the pattern (from low-end technology to high-end technology) was practiced again and again and the company gradually reached the real high-end technology of the industry over time. Huawei kept making breakthroughs from the relative low technology in high-end technology, and gradually moved closer to the core technology. The process is described in Figure 6.

1) The new disruptor applies disruptive technology to achieve technology breakthrough from the low-end part in which the new disruptor has the largest comparative advantages.

2) On the basis of this, the disruptor gradually will aim to improve the high quality use/market, but it is also a process of gradual ascension. In higher-end targets, there is also a relatively easy, simple and less competitive use/market. The disruptor constantly sets the targets as "expected higher quality use/market". This process will be repeated until the disruptor finally gets close to the top end of the market. Eventually, the disruptor replaces the incumbent.

3) If the disruptor rests on its laurels from the first round of breakthroughs instead of pursuing a higher level of breakthroughs, then the disruptor will always be a “disruptor” and never become an “incumbent”. There are many examples in China that after a disruptor completed the initial breakthrough with the first bucket of gold, they turned to other easier and more profitable businesses, running in the opposite direction of real R&D. The decisions of these different disruptors are driven by different aspirations. The aspiration level is crucial in decision making both as an individual and as a firm. According to Sidney (1957), aspiration levels are not fixed, but change along with the uniqueness of particular decision makers and the experience of those who are involved in processes of firm adaptation. Firms are able to motivate themselves towards particular aspirations by stressing the differences between the actual level of aspiration and the outcome achieved. In other words: decision making requires a longing towards that particular aspiration, though it may never be fully reached. Huawei maintained constantly strong levels of aspiration. The aspiration theory also indicates that the aspiration level changes according to the company’s experience. Successful experience will urge the company to go for a higher aspiration and frustrating experience will make the company consider shrinking. In the case of Huawei, the initial success prompted the company to a higher level of aspiration, and the higher aspiration level drives the company to aim at a higher quality

use/market. Only by maintaining a strong aspiration level, a company can make decisions to achieve the higher-end targets to ensure sustainable human and financial resources.

Breakthrough from a low-end market: necessary support for R&D

Huawei's focus on R&D was inseparable from the support by the "Chinese characteristic" business strategy. The company had to maintain good market performance and profits to sustain its R&D investments, thereby developing an advantageous cycle. As concluded by Ren, Chairman Mao and President Louis Gerstner (the former CEO of IBM) were the central figures that inspired Huawei's spirit of entrepreneurship (Cheng and Liu 2003). The principle "encirclement of the cities from the countryside" was widely applied by Huawei. Mao Zedong made a point of it. At a time when China was split into warlord domains, Mao led the people in the fight to establish revolutionary bases in areas where the enemy's control was weak, to encircle the cities from the countryside and ultimately to seize political power. They began in the rural areas and gradually encircled the cities. Huawei applied Mao's principles in its "battles" with MNCs: "occupying the countryside first in order to encircle the cities". Huawei targeted markets in small cities in remote and less developed provinces which were of no interest to or ignored by the MNCs. Then the move was made little by little from the low-end markets to the high-end markets.

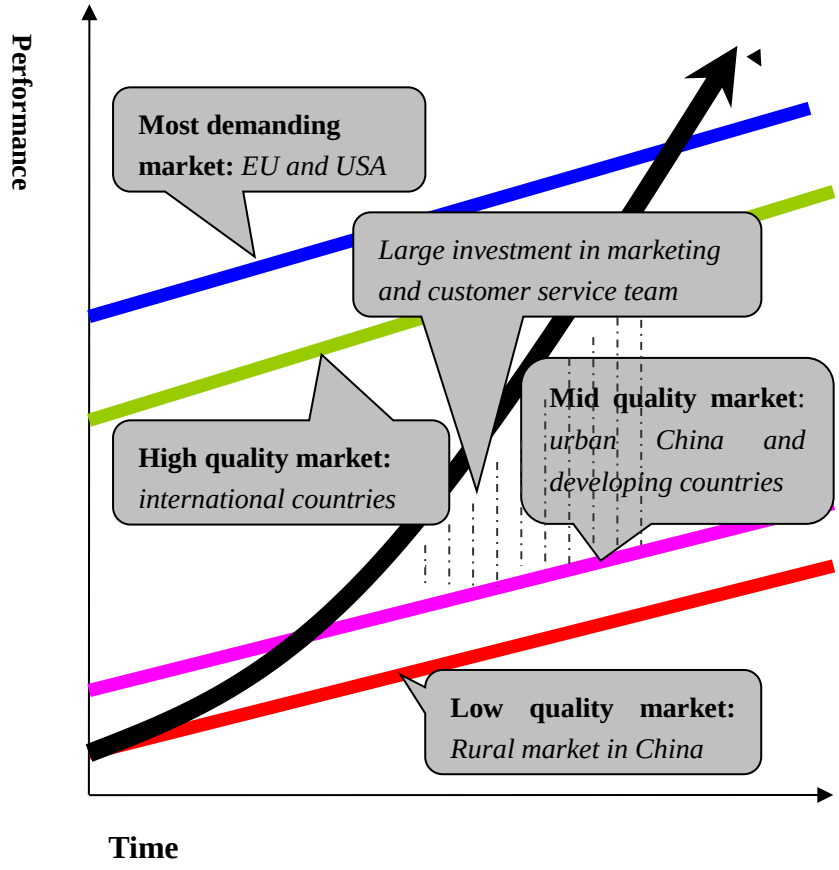
In 1998 Huawei regarded Shanghai Bell as their major competitor when they decided to promote the C & C08 switches. However, because of a few flaws of C & C08 and the established impregnable market position of exchange S1240 from Shanghai Bell, Huawei was at a disadvantage in confronting Shanghai Bell in the exchange market. Huawei adopted the strategy of breakthrough from the rural market in the northeast, northwest and southwest of China - the less developed provinces. In 1999 Shanghai Bell's market share was 90%. To make a breakthrough in this market, Huawei provided access network for the Sichuan provincial clients with very attractive prices, whereby they obtained a basic starting point in the Sichuan market. Step by step, Huawei won the newly added access network projects based on the tiny territory that was gained from the access networks market. As Huawei eventually acquired breakthrough in access networks (a less core part in a network), Huawei's business was naturally extended to exchange equipment. Finally Huawei emerged as the mainstream provider for exchange equipment (a core part of in a network) in Sichuan. After a couple of years, Huawei occupied a 70% share of the newly added market in Sichuan (Cheng and Liu, 2003).

Huawei's strategies for overseas expansion were similar to Huawei's aforementioned strategy for the domestic market: in the beginning a relatively "weak" target and then moving on to challenging a "strong" market. Huawei began its overseas expansion on the Russian market in 1995. The first contract that Huawei signed in Russia was worth a mere USD 38. 10 years later, in 2005, Huawei had total sales of USD 600

million in Russia (Ren, 2005). Consistent with the strategy, Huawei was also considering expanding business activities in other "less advanced" market, including South America, Africa, and the Middle East as target regions for its initial oversea expansion. Gradually, Huawei expanded its business operations to worldwide: in 2006, Huawei signed a number of major contracts, including one with Brazil's Vivo to build the largest GSM network in South America; an agreement with Britain's Vodafone to construct a WCDMA network in Spain; and a deal to build a 3G communications systems with Leap (USA), eMobile (Japan), and KPN (The Netherlands). Among the 12 contracts that Huawei signed during the first half of 2006, half of the contracts were on European market (The First Financial Daily, 2006). Huawei had now become one of the major telecom providers, also in developed countries. With a pioneering project, in 2009, Huawei won the first 4G project in the world; this was in Norway (Ward 2009).

Huawei's effort in marketing and sales were aimed at supporting and sustaining the major investments in R&D. The sales revenue was the source of R&D; also it was the ultimate goal of the R&D efforts. Huawei's sales strategy was the same as that for R&D: from rural market to cities, from developing countries to developed countries. That is from low-end market to a higher-end market. Firstly, Huawei targeted the rural markets and China and developing countries around the world (the low-end market). These markets did not need full performance value like other uses in high-end cities. The MNCs were occupied by the major markets, whereas rural markets and developing countries were overlooked by the MNCs. In addition, the profits from the rural markets/developing countries were much lower than that of the high-end markets. For these reasons, the MNCs were not interested in the low-end market. Huawei could therefore sell products in these markets with less competition by offering cheap but adequate products and good service. In this way, Huawei established its first customer base. Based on the first purchase, the clients tried more and more products from Huawei, and then finally the clients came to rely on Huawei's products. Of course, Huawei was also seeking the opportunity to move up to the markets where the clients could pay more with the opportunity of a higher profit margin. Huawei first entered the mid-quality markets in urban China, Russia, African and other developing countries by the least profitable products. After Huawei had gained a foothold in these markets, it moved to a higher profit margin and served the high-end market in USA as well as the European markets. After a long period of accumulation and learning, Huawei gradually met the demands of the most profitable segment and drove the established companies out of the market. Little by little, the incumbent companies (other MNCs) had smaller market shares than they were previously serving. After approximately twenty years of continuous efforts, Huawei finally became the provider on the most demanding markets in the Western European countries and USA. The success is built on extraordinary workload. The interviewee told us that: "We keep the tradition to have a sleeping bag in office, in case that if they need work overnight. Many of us work one day during the weekend." For this part please refer to Figure 7 and Table 3.

Figure 7:
Breakthrough from low-end market



(Source: adapted by the authors)

Table 3:
Incumbent and a new market entrant: MNC and Huawei

incumbent company: MNC	*New market entrant: Huawei*
Addresses old market: Europe and USA, major cities	New and potential market: rural market, African and other developing countries
Big profits: core parts of the products	Small profits: accessories
Existing process: big and well-established	No existing process: small and newly established
High marginal cost to move down market: slower to re-direct research in new technologies	Low or no marginal cost to move down market: fast to re-direct research in new technologies

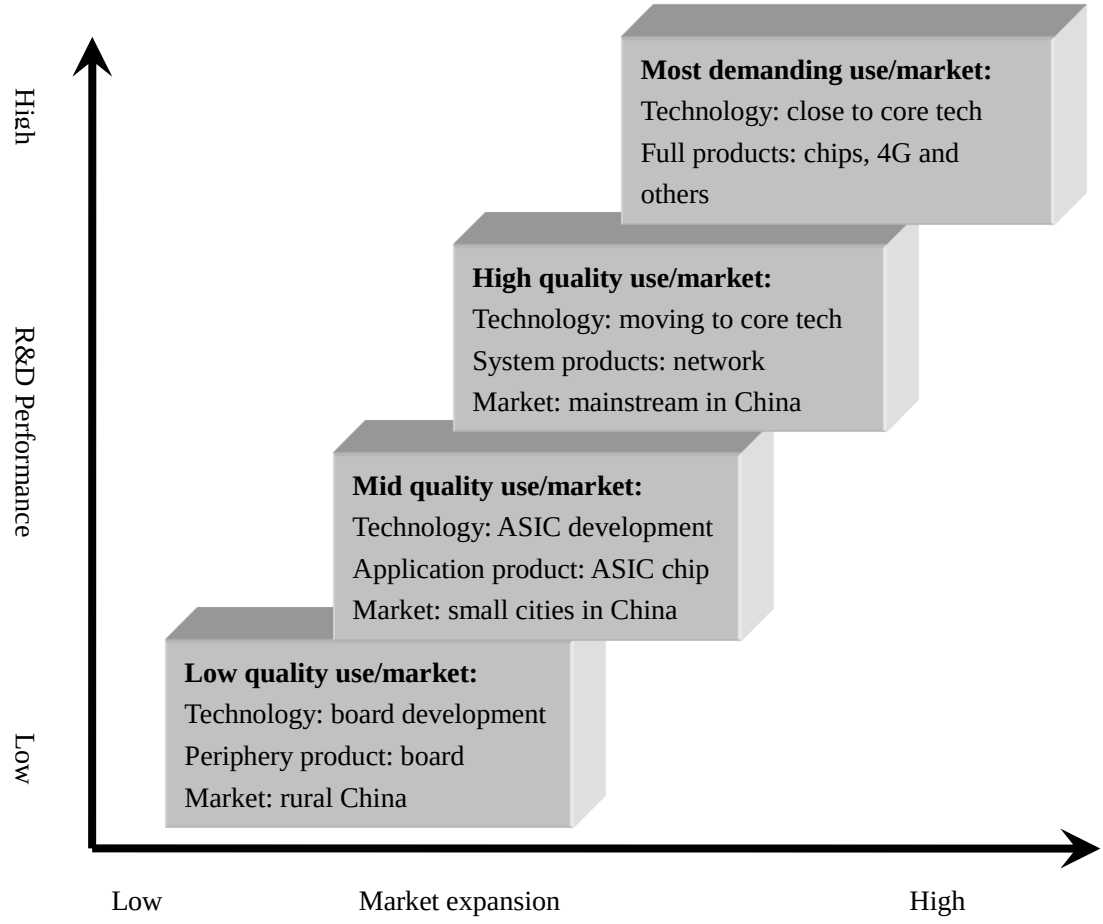
(Source: adapted by the authors)

The relationship between technology life cycle and breakthrough in technology/market

The technology life cycle provided opportunities both to technology catch up and

breakthrough from the low-end quality use/market. The relationship between the two was complementary to each other. During the transformation from 2G to 3G, external opportunities were present for all the newcomers in the telecom industry. At that time, the market surged by an undercurrent: on the surface, the matured incumbent technology controlled the market; essentially there was a strong demand from the market to develop new technology to improve or replace the incumbent technology. This was a universal opportunity, not just for Huawei, but for others as well. To break through from low-end in technology as well as market depended on the individual strategy of the company. Huawei chose the low-end market and simple technology to start in order to survive in the fierce competition. After more than 20 years of development, Huawei became the industry leader that it is today. Therefore, it is believed, that two conditions promoted Huawei to catch up and learn. These are two essential conditions: the former provides a macro environment for the growth of the company; the latter is the basic quality to guarantee a successful catch up. The relationship between technology life cycle and disruption is presented in Figure 8.

Figure 8:
The relationship between technology life cycle and breakthrough in technology/market



(Source: adapted by the authors)

4. **Huawei's catch up compared with other cases: ZTE, the Korean TV industry and TD-SCDMA**

Huawei in Relation with ZTE

ZTE was established in 1985. In the telecom industry it is by the time of writing ranked no. 2 in China and no. 4 in the world. Like Huawei, ZTE kept persistent investments in R&D, spending up to 10% of sales every year. 11 research centers were set up in China and four research institutes in USA, Korea and Sweden. In addition to soft exchange, CDMA, and WCDMA research, they also closely followed the pioneering technologies in the world. ZTE gradually moved from being a technology follower to becoming a leader, particularly in the areas of fixed line network and GSM. It is said that from 1980s to the early 1990s, the distance between ZTE and the then first class telecom companies from the developed countries was 10 years; in the last ten years of 1990s, the gap was reduced to 4-5 years. After the year 2000 until now, they have been more or less at the same level as other international players, particularly in the areas of 3G and Next Generation Networking (NGN) technologies (China Telecom Monthly，2004). The interviewee from ZTE said: "Both of us are the leading telecom providers in the world, we have some similarities. We are also proud of us. But for these years, it is we closely follow Huawei, not the opposite." ZTE shared a strategy similar to Huawei in terms of technology life cycle as well as low-end market accession:

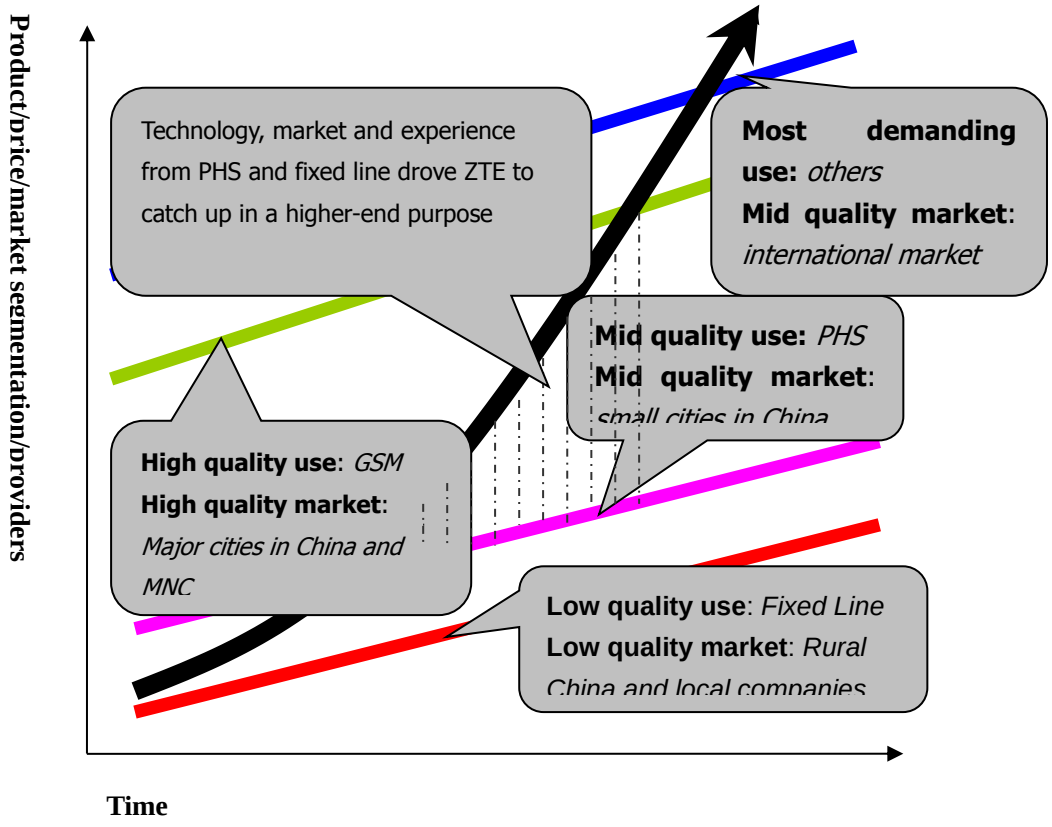
1）Fixed line in rural China (low quality use and low quality market): As a newcomer in the market, ZTE did not challenge the players with mainstream technology and high-end market. They entered the telecom market in the rural market by fixed line technology. After having gained experience, they focused on the small cities in China and initially skipping the most profitable market in the large cities.

2）PHS in 2G era (Mid-quality use and mid-quality market): During the years of 2G implementation, MNCs were occupied by the booming GSM business in big cities in China and were not interested in the less profitable markets in small cities and also did not consider the PHS technology (Personal Handy System, which was not advanced but cheap and practical) a challenge to GSM. ZTE chose the obsolete or less advanced technology and found a "blue ocean" with no strong competitors. PHS is also a typical "periodical dominant design" which helped ZTE survive in the competition with the MNCs and accumulated resources in terms of capital and technology. The accumulation made it possible for ZTE to catch up at a higher level, for example the 3G level.

3）Learning and catch up (High quality use and high quality market, and further): In this process, ZTE gained enough market success and accumulated considerable technology to support the company to seek further development in a higher-end

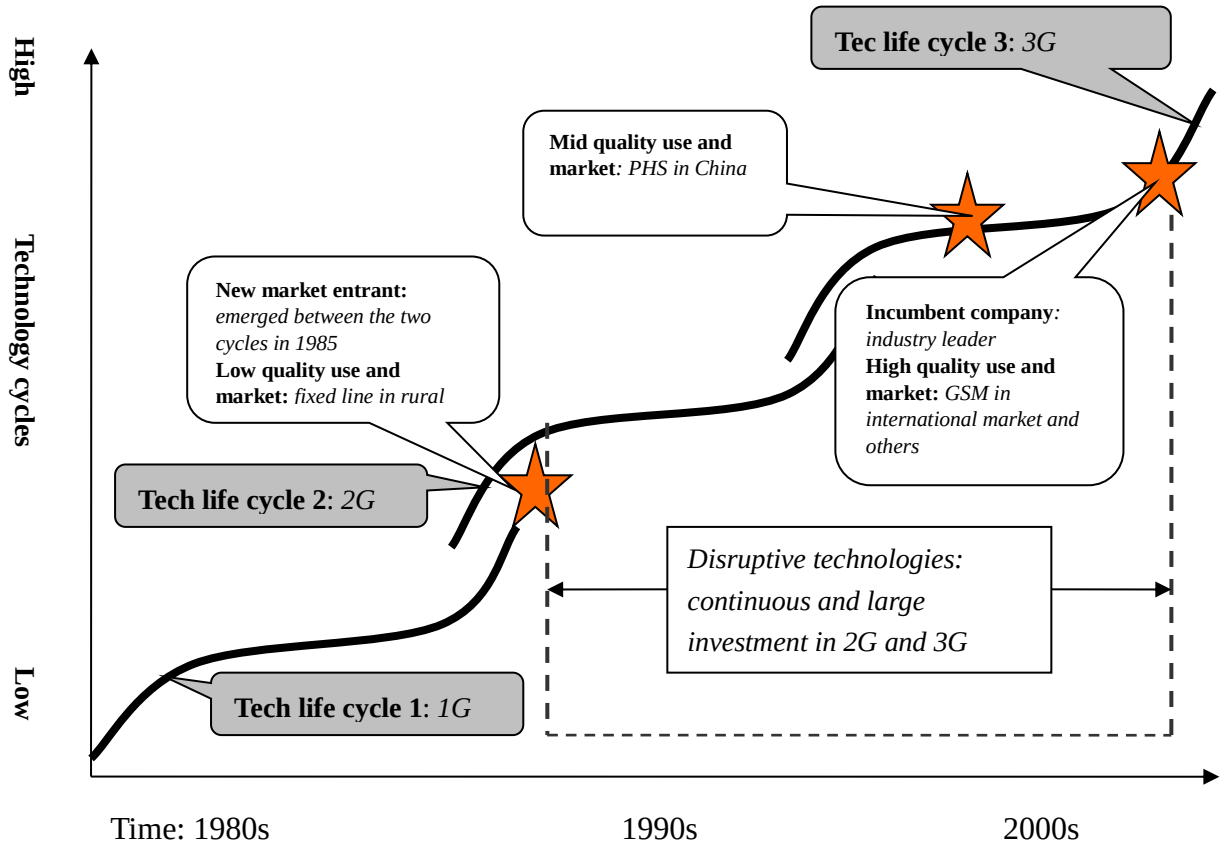
market/technology for a higher quality use, as in the market spaces of GSM and 3G. ZTE kept their eyes on the up-to-date technology and when they found one interesting, they directed all their resources towards the new technology, including the knowledge accumulated in previous stages. In this process, ZTE used experience and resources accumulated in PHS and other less sophisticated technologies to drive the R&D level to another height. Thereby the company gradually moved from a low-end technology to a high-end technology.

For the catch up process of ZTE, please refer to Figure 9 and Figure 10. For a comparison between Huawei and ZTE, please see Table 4.



(Source: adapted by the authors)

Figure 9:
Low-end disruption by ZTE



(Source: adapted by the authors)

Figure 10:
Technology breakthrough of ZTE

Table 4:
A comparison between Huawei and ZTE

	Huawei	*ZTE*	*Notes*
Established	1988	1985	Both established in window of opportunity
2013	No. 2 in the world, no. 1 in China	No. 4 in the world no. 2 in China	Leading companies
Low (example)	ASIC for internal use and domestic market	Fixed line in rural China	Both from low, mid to high levels
Mid (example)	Data communications	PHS in small cities	
High (example)	Mobile tech globally	GSM, 3G globally	

(Source: adapted by the authors)

Huawei in Relation with the Korean digital TV industry

Lee and Lim (2005) observed the Korean digital TV industry's catch up by using the window of opportunity when technology trajectory evolved from analog to digital. Japanese companies were the forerunners in analog TV. However, when the digital technology emerged in the early 1990s, Japan chose to insist on the analog technology due to the already expended costs. With the absence of Japanese companies on their home market, the Korean companies naturally were rid of the most powerful competitors. In addition, the Korean government was very optimistic about the digital technology and they firmly identified that the Korean companies should grasp the opportunity to catch up in digital technology. Despite the disadvantages implied by the technological regime and the risks facing early entrants in trajectory choice and initial market formation, the Korean firms had achieved a 'path-creating catch up' in digital TV. They closely watched the technological trends and the standard setting process to make sure that they were able to manage the risk in terms of choosing technological trajectory. The Korean firms developed the prototype digital TV and ASIC chips relying on the accumulated knowledge of the complementary assets (experience of producing analogue TV) and accession to the foreign knowledge (established overseas R&D posts and acquisition).The government played an important role through setting up a consortium composed of the major companies (Samsung and LG) together with universities and research institutes to tackle key problems and to jointly make the technological breakthroughs. As latecomer, the Korean digital TV industry achieved the catch up by the model of "path-creating", which abandoned the path of the old technology (the analogue technology) but directly accessed the path of future technology (the digital technology).

According to Perez and Soete (1988) and the authors' observation, the advantages of this window of opportunity may be summarised in the following three perspectives: A) Few competitors: since the MNCs tend to lock into the old technology due to the already-expended costs of their investments, they are reluctant to give up the investments, and their advantage in the old technologies turns into a burden in terms of following the technology trajectory. From this point of view, the catch up countries can be said to be at a rather advantageous position as they are not locked into old technologies. B) Less pressure: since the equipment to produce new industry goods has not yet been developed, volume production has not yet been formed. Therefore, the entry barrier associated with economies of scale does not exist. C) At the initial stage of a new technological paradigm, the performance of the technology is not stable, and the human resources with the prerequisite knowledge is easier to obtain than at later stages of technological evolution. This also presents less competition and pressure to the latecomer. Perez and Soete's paper (ibid.) strengthened the argument by showing how the emerging new technological paradigm could serve as a window of opportunity for the catch up firms. Also the study verified the findings by Lee and Lim (2001) that a path-creating catch up is likely to happen by public-private collaboration when the technological regime of the concerned industry features a fluid trajectory and high

risks.

4.3 Huawei in Relation with TD-SCDMA

In 1998, supported by the Chinese government, the Chinese company Datang submitted a 3G standard proposal. After fierce contest, ITU approved TD-SCDMA as one of the international standards in 2000. The 3G standardization system in China was featured as highly politicized in comparison with usual standard-settings elsewhere. In fact, the telecommunication industry was most likely to be determined by government committees due to government ownership of the communications infrastructure and frequencies in many countries. But this was not a unique state of affairs. For example, Japan used government consortia to drive standards development for new markets, as in the case of networked digital products (METI, 2004). In Europe, the efforts to create the very successful GSM standard in the 1980s were initially led by state-owned telecom operators and the European Commission.

The evolution from 2G to 3G provided the possibility for the Chinese enterprises in the view of the technology life cycle. According to the experience from 1G to 3G the technology life cycle of mobile communication was approximately 10 years for each cycle. 1G began to appear in the 1970s. 2G was developed in the late 1980s and 3G development began in the late 1990s. The best timing for an emerging company to raise a new standard is when an old technology matures, as the trend of technological development shall naturally need a new standard. The large domestic market in China offered the bargaining power for standard negotiation and the Chinese domestic industry's accumulation provided a key condition for this ambition. The Chinese enterprises for a very long period of time, could only stay in the low-end of industry chain with low profit margins to follow. At the same time, the Chinese enterprises paid substantial patent fees to the foreign companies. These factors restricted the development and learning of the Chinese enterprises. The comprehensive effect of the above factors forced the Chinese government to find a way to solve the industrial bottleneck. While the 3G opportunity enabled the Chinese government to see that mastering Chinese independent 3G standards might not only solve these problems, but also build a flagship for independent innovation strategies. This was just the starting point of a long march. The industrialization and commercialization that followed also needed large investments and efforts. The Chinese government spared no effort to support the entire process from industrialization to commercialization. This support came in the form of financial support, frequency reservation and timing arrangements.

The Chinese government support to TD-SCDMA development vigorously, arranging special funds as part of mobile projects and electronic development funds. They also coordinated the leading universities, research institutes and companies in the TD-SCDMA alliance to support TD research and to foster a new industry chain. The Chinese government also reserved valuable radio frequency particularly for TD and postponed the launching of 3G for a great length of time, waiting for the maturity of

TD. Without the support of the Chinese government, TD-SCDMA would not have developed into a practical and successful standard. Finally TD-SCDMA was launched during the 2008 Olympic Games in Beijing. For a comparison between the Korean TV industry and TD-SCDMA, please see Table 5.

Table 5:
A comparison between the Korean TV industry and TD-SCDMA

	Korean TV industry	*TD-SCDMA*	*Notes*
Time	In the mid-1990s,	1998-2000 submitted; 2008 commercialised	Window of opportunity
Result	Korean companies emerged as the world leader in several innovative digital products.	A new 3G standard TD-SCDMA	New standard
Process	The Korean government was very optimistic about the digital technology. It played an important role through setting up a consortium composed of the major companies, universities, and research institutes.	Government support: alliance, spectrum, time, budget and policy	Strong role of government

(Source: adapted by the authors)

Summing-up of the Relationships

From the discussion above it becomes clear that all the companies mentioned applied the window of opportunity coming from the technology life cycle. The differences between Huawei/ZTE and the Korean digital TV industry/TD-SCDMA may be found in these perspectives:

a) Different models of catch up: Although Huawei/ZTE had gained outstanding achievements both in 2G and 3G; Huawei/ZTE was still following other technology leaders' path in developing technologies and products. Huawei/ZTE had not created a nascent technology which took a different approach or built a new standard. Regardless of whether the path-following was market-driven or technology-driven, the catch up was not to create a brand new technology trajectory but to closely follow the most cutting-edge innovators and to develop the most competitive products along the trajectory set by others. The catch up by the Korean digital TV industry/TD-SCDMA was of the path-creating type. In the Korean case, the innovation discarded the original analog technology and invested

significant efforts in developing the new digital technology, which at the time was a newly emerged standard. This implied great risk and large investments for the Korean companies. Despite this, the development of digital TV technology achieved success due to the joint efforts led by the Korean government, companies, and universities. TD-SCDMA was a new 3G technology different from the standards proposed by other developed countries. The Chinese government gave up the two mainstream standards (WCDMA and CDMA2000) and allowed the TD-SCDMA to be established as a new standard challenging the incumbents.

b) Different initiatives: As Lee and Lim (2001) pointed out "a path-following catch up is likely to happen largely by private initiatives in industries where innovations are less frequent and the technological trajectory is less fluid, and thus the catch up target is more easily identified, whereas a path-creating catch up is more likely to happen by public-private collaboration where the involved technology is more fluid and the risk is high." As a typical grass-root company, Huawei/ZTE identified the innovation target through their own effort and exploration, and created their own development path along the innovation leader's track. They continuously identified new "expected high quality use" and accomplished "periodical dominant design" as an approach to achieving the higher technology. However, in the mode of path-creating, it is challenging for the individual company to create a new innovation target. For this reason, government participation and leadership are needed in the process to organise stakeholders to complete the sophisticated tasks. The Korean digital TV industry provides evidence for that: all along, the Korean government, companies and universities all joined the development of digital TV and they were assigned different tasks in the development groups. Eventually a new digital TV industry was established through the joint efforts by these stakeholders. In the TD case, the Chinese government was the general-in-coordinator that allocated the resources, including universities, companies and institutes, in the industry chain to ensure the success of the innovation. Please see Table 6 for the comparative roles of the companies.

The exploration of the relationship of the cases of Huawei, ZTE, Korean digital TV industry and TD-SCDMA shows the following:

1) The window of opportunity offered by the technology life cycle was important to the latecomers. All companies used the timing of technology life cycle as a window of opportunity to accomplish the catch up. Huawei and ZTE commenced the initial breakthrough when the technology was transferring from 1G to 2G. Huawei then realised catch up when the technology was upgraded from 2G to 3G based on the previous accumulation; TD-CDMA was prepared when the cycle switched from 2G to 3G. The Korean digital TV industry also took up the favorable opportunity when the technology was evolving from analogue mode to digital mode, and they successfully

withstood the tough competition from other MNCs and became leaders in the digital TV industry. To these latecomers, the external environment was similar: they were at the point when one technology was going to evolve to a higher level. Although Huawei and the Korean digital TV companies realised the breakthrough by different means, the windows of opportunity caused by the technology life cycle provided the natural driving force for the catch up. Huawei and ZTE were part of the path-following catch up, while the Korean digital industry and TD-SCDMA belonged to path-creating catch up. Although they were different in terms of innovation intensity, innovation quality and innovation approach, none of them would have realised catch up without the window of opportunity offered by the technology life cycle. Without the timing and the macro environmental condition, latecomers could not fundamentally reverse the original technological order established by the MNCs and eventually catch up the very same MNCs.

Table 6:
A comparison between grassroots and a public-private consortium

	Huawei/ZTE	*Korean digital TV industry/TD-SCDMA*
Leader	Grassroots: purely private	Public-private collaboration: government coordinated and company implemented
Model	Path-following	Path-creating
	Company identified target along the development of technology trajectory	Government lead consortium to target for new technology trajectory
Process	Low, mid to high quality use/market	Skipped low and go directly to high end
	Many periodical dominant designs	One dominant design to replace incumbent
	High aspiration level	---
	High R&D investment	Government budget, research funding and company investment
Result	Incremental innovation	One radical innovation

(Source: adapted by the authors)

2) With such opportunities, different models of catch up became possible. In the Huawei and ZTE cases, they followed the typical path-following model: companies identified their own catch up goal and track and invested in R&D focusing on the low-end market. After occupying the low-end market, the company enhanced its position on the track of path-following by accumulation in the low-end market and learning from the external knowledge base. With the right conditions, the latecomer

gradually replaced the incumbent company both in the market position and technology position. In the case of the Korean digital TV industry and TD-SCDMA, it was the joint efforts coordinated by the Korean/Chinese government and collaborations between the industry and universities. From the very beginning, this kind of path-creating catch up was looking to the high-end market. The R&D investment and technology learning were also favoured by the great support from the government. As a result, the industry realised a focused improvement of the leader of the new technology. A similar collaboration was also found in Japan. The government was able to set the direction of technological change and mobilise different resources to support national strategic goals in line with the technology trend. The government also worked with firms to forecast technology trends and facilitate the cooperation between companies and universities (Odagiri and Goto, 1993).

5. Conclusions:

From the case analysis of Huawei and in relation with the ZTE, the Korean digital TV industry and TD-SCDMA, it was concluded that the window of opportunity offered by the technology life cycle and the breakthrough from a low-end technology were the key contributors to Huawei's success in the early stages. This is inseparable from the support of the strong marketing capability. It was likewise concluded, that a successful catch up by a grassroots company cannot live without particular external factor and internal factors. Here we answer the research questions:

1) External factors: the evolution of technology life cycle provides a vibrant breathing space to the disruptor. During this period, the incumbent technology is moving from being stable to being in decline. New technology is still emerging and under exploration, which increases the possibility for the disruptor to survive the competition. The external factor is that the macro environment is optimistic and the market trend needs emerging technologies. Both Huawei and ZTE were emerging in this context, and they benefited from the window of opportunity.

2) Internal factors

A) Technology breakthrough: the disruptor chooses non-mainstream technology to realise a technology breakthrough, particularly focusing on those low-end technologies, which are supposed to meet low-end market and are ignored by the MNCs. Based on this, the disruptor gradually rises to a higher level of technology. That is to say, the grass-roots disruptor continuously launches incremental innovation approaching the core technology. For example, Huawei divided R&D into three levels. They deliberately avoided the core technology being the most difficult and challenging, and invested all their efforts and resources in the second and third layers. Although the benefits from these layers were relatively small compared to those of the core technology, this pragmatic approach allowed Huawei to firmly seize the second and third layer markets. Huawei then gradually

moved on to a higher level of technology. In the ZTE case, they first aimed at fixed lines, then PHS. These technologies were all neglected by the MNCs as they were considered to be low-end technology. Meanwhile, Huawei and ZTE constantly presented "periodical dominant design" to maintain leading positions in the non-mainstream technology area, the success of the "periodical dominant design" ensured the sustainable pursuit of technology catch up for these disruptors.

B) Market breakthrough: the typical method of a disruptor's market breakthrough is to "surround from countryside to city". Starting with the rural market and small cities, the disruptor provides the market by attractive price but sufficient-to-use products to meet the low-end market demands. By doing this, they gradually gain a firm foothold in the market. Huawei applied the strategy both in domestic and international markets. In China, they conquered the market from countryside to smaller cities; globally they began with developing countries, moving on to developed countries. In order to implement this strategy, Huawei invested large quantities of manpower in marketing development and it led the company staff to form the so-called smiling curve; that is to say a large number of investment in sales and R&D and a compression in the administrative sections. Due to the major investments in marketing development, Huawei could maintain sustainable success in the market and fulfilled the breakthrough from countryside to cities.

C) Technology breakthrough and market breakthrough are interdependent and inseparable. However, market dimension is an important part in technology innovation as innovation is a combination of technology with market (Liu, 2007). Lundvall (2006) also pointed out that interactions of producer and user(s) are extremely important for innovation. According to Liu (2007), in the case of China, the market is extremely important. The Chinese companies used their strong local market knowledge in competing with the MNCs to secure the first survival on the Chinese market. Usually, local market knowledge implies the capability to use existing technology in a new market. According to the present research, the company needs to select the niche market to avoid strong competitors in order to allow the R&D to get onto the right track. Only by doing so can the company meeting market demands. After being accepted by the market, the company must provide sufficient manpower and finance to support subsequent development. In order to realise fundamental technology innovation, strong market support is inseparable from technology innovation. The feedback from the market regarding demands and requirements provides further direction for research. The new research direction may not be the most cutting-edge technology, but the most desirable technology and products from the market's point of view. On one level, the market directs the future of research. This also follows Huawei's typical style: not focusing on the most cutting-edge technology, but focusing on the technology with the most practical significance; first to survive, then to develop. Both Huawei and ZTE were very strong in R&D and market development, and they also excelled in using the market resources to nourish and guide the future direction of R&D. In innovation

research, the value of marketing capability has not been given adequate attention. Many studies focus on the contribution from institution dynamics and the company's own technology learning capability. In this study, it is found that the market breakthrough capability for low-end technology is also part of an enterprise's catch up capability. It is one of the basic qualities that a catch up enterprise must possess. These two qualities (low-end technology and low-end market breakthrough) are indispensable for mutual support and jointly promoting a sustained technological catch up.

Following our research question, the authors identify that when an industry is experiencing a window of opportunity by the transformation of technology life cycle, different enterprises in the industry are facing the same opportunity. However, due to the different nature of the enterprises, the opportunity also indicates different paths for their catch up. The catch up pattern is concluded here:

Utterback (1994) named it "the era of ferment"; featuring as continuous substitution and competition amongst different designs that have been introduced by many firms. The cases in this paper, Huawei and ZTE, are examples of the many disruptors born into this background. Next, the disruptors generate many rounds of incremental and sustaining innovations to the original disruption before an outstanding disruptor survives and eventually successfully challenges the incumbent. With such forthcoming business environment and technology trend, disruptors diverge into two distinct paths:

1) Path-following: As explained, Huawei and ZTE implemented another type of technological catch up. It is a typical catch up model by a grassroots company during such a window of opportunity. The incumbent neglects the low-end market, while the disruptor devotes all resources to the low-end market. The disruptor may often launch very suitable products and technologies for the low-end market, it may even be better than that of the incumbents. The product or technology becomes "periodical dominant design" for the niche market. Relying on the "periodical dominant design", the disruptor is able to survive the competition and commence catch up.

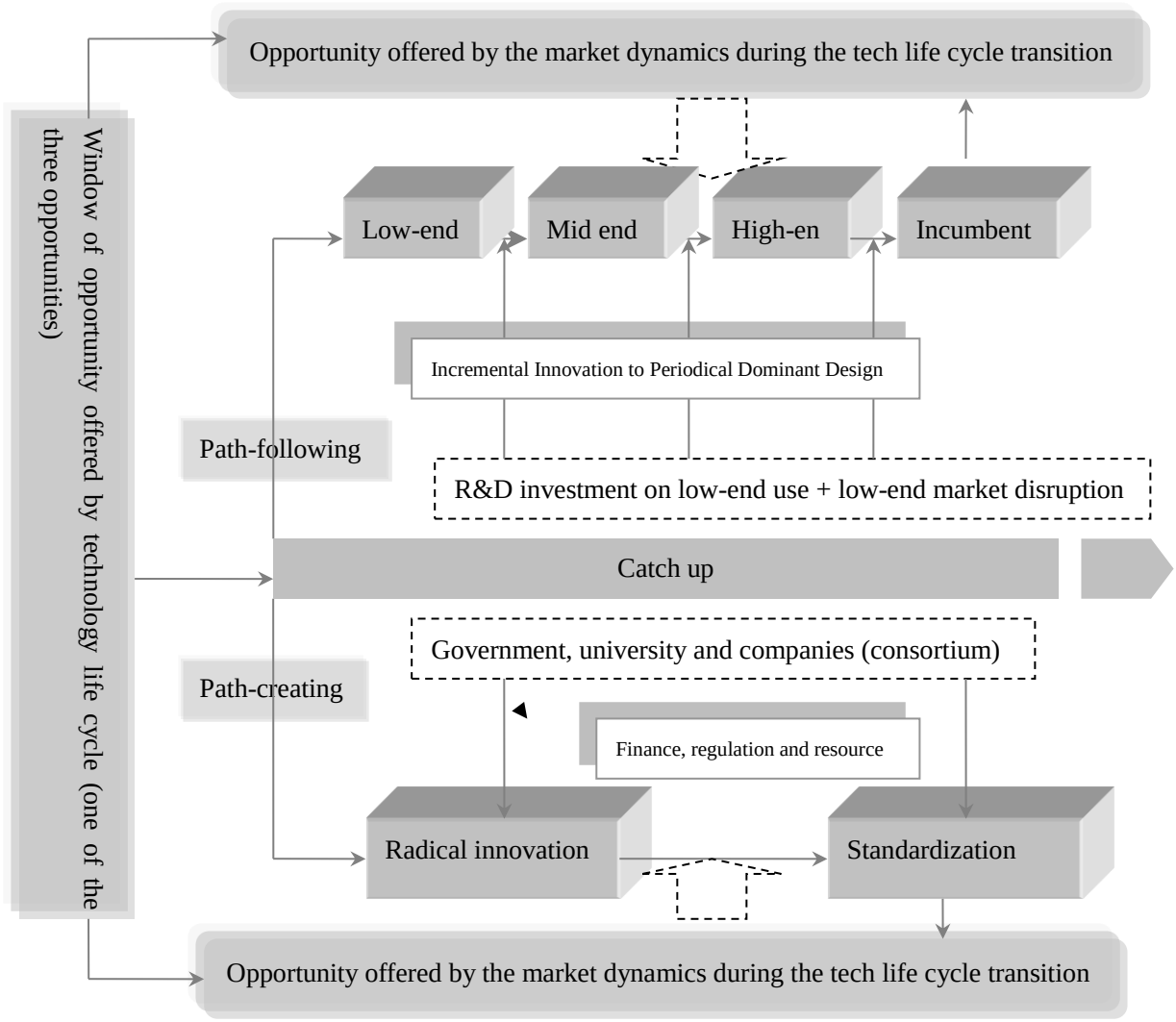
   In this process, with the constantly improved technology and the enriched market experience, the disruptor begins to develop more "expected high quality use", and introduce higher level of "periodical dominant design". At the same time, the disruptor's target customer is also moving towards the high-end market. However, these "expected high quality use", and "expected high quality market" are not the core technology and the high-end market from the point of view of the whole industry and the "periodical dominant design" is also subject to geographic restrictions. These technological achievements are insignificant compared to those of the incumbent, but for the disruptor it means, that they are on the right track learning to control and develop

the new technology and catch up. Through many cycles “expected high quality use" and continuous “periodical dominant design", the disruptor gradually encroaches on the higher-end market, and one of the outstanding disruptors will eventually come to replace the original incumbent to become leader of the industry.

Another point worth mentioning is that the significant difference between path-following and path-creating is a result of the different catch up models. Usually, path-following is for a single company to pursue technology innovation, but without the support from government and universities, it will be difficult for a single disruptor to breakthrough in core technology, not to mention breakthroughs in setting new technology standards. What has become apparent is that the disruptor is constantly seeking a higher level of technology and particularly in the direction of core technology; however it is difficult for the disruptor to replace the core technology with their innovation. In the path-creating model, being a strategic activity plotted by government, the innovation is geared toward creating a new technology from scratch. However, new standards may also be designed based on original technology, so that the underlying core technology might not be replaced entirely.

2) Path-creating: The Korean television industry and TD industry in China represent the catch up model of path-creating under the window of opportunity. It is not a model that can be accomplished by one enterprise alone. Discarding the current paradigm technology and setting up a new technological trajectory is very difficult even for an industry leader to achieve due to the large risks, pressure and investments required. Usually, there is a strong interest by the government and industry benefit behind the effort. The government expects to upgrade the technical level of the whole industry of the country through this model of catch up. Therefore, the government will choose an enterprise as a coordinator to implement technology innovation and to support the interests of the state. At the same time, the government uses its strong, synergetic power and resources to persuade related companies to support the technology innovation. Therefore, universities, research institutes and companies in the industry chain are included in the innovation activities. This way, the government provides support in the areas of finance, policy, regulations and human resources. Finally, with the support of the government, the radical innovation is achieved as a result of the collective efforts and the government will cooperate with the industry and the universities in setting new technical standards. Through such efforts, the disruptor replaces the original incumbent by one step-innovation. Please refer to Figure 11 for this part.

Figure 11:
Catch up pattern under a “window of opportunity”



(Source: adapted by the authors)

Through in-depth observation of the Huawei case, this study verifies the crucial role of low-end disruption for the catch up of grassroots companies. At the same time, the external factor of “window of opportunity” is an indispensable condition. The external environment provides a space for different companies to achieve different patterns of catch up. In low-end disruption, technology disruption and market disruption are synchronised. Innovation research usually does not pay attention to the importance of

market knowledge and market disruption. This study suggests that the low-end market disruption is part of innovation, as low-end technology disruption and market disruption are intertwined in promoting the catch up. The entire “incremental innovation track” is followed from low-end, mid-end and finally to high-end and a high aspiration level is regarded as critical in keeping the grassroots to continuously set the goal of “expected high-end use” and continuously promote “periodical dominant design”. Along this vein, the grassroots approaches the development of core technology one step after the other. In addition, Huawei is compared with ZTE, the Korean TV industry and TD-SCDMA. First, it is found that all catch up occurred during the transition phase of a technology lifecycle. That means the opening up of a window of opportunity is a prerequisite condition. But different companies have different patterns of catch up when given this opportunity. The grassroots companies, that lack governmental support, need to survive on the market based entirely on their own capabilities. This leads them to choose the conservation but moderate pattern of “path-following”. For the government-led consortium and state-owned companies supported by the government, the initiative usually carries the responsibility to drive the improvement of the whole industry, so they choose the risky and radical pattern of “path-creating”. This study concludes this to be a pattern of the two catch up patterns under the window of opportunity, which is illustrated in Figure 12.

Huawei’s success has its own special conditions of history and geography. Huawei faced the enormous Chinese market. The company would strive to tap their own resources on the domestic market, looking for the niche market which was ignored by MNCs. In many countries the domestic market is not large enough to support an innovative enterprise going from domestic to global and from low-end to high-end innovation. So while Huawei’s experience may be a reference for other developing countries and other innovative enterprises, they also need to adjust their specific strategy according to their own country/market circumstances. Another point worth noting is, that China is a large country with a large population; therefore, Huawei had the opportunity to gather a large body of inexpensive and excellent high-tech talents to compete with the MNCs during the early stage. Not many other countries would have been able tap into a similar source of manpower. In practice, this strategy is worth discussing. The path and strategies moving from low-end market to high-end market, from low-end to high-end technology may be put successful use in different enterprises in developing countries.

Reference:

Anderson, Philip, and Tushman, Michael L. (1990), "Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change". Administrative Science Quarterly 35: 604-633.

Bauer, H. H. and M. Fischer. (2000), "Product Life Cycle Patterns for Pharmaceuticals and their Impact on R&D Profitability of Late Mover Products". International Business Review Vol. 9 pp. 703-725.

Brockhoff, K. (1967), "A Test for the Product Life Cycle". Econometrica Vol. 35 3/4 pp. 472-484. Capitalist process, McGraw-Hill, New York.

CEIBS Business Review. The inspiration from Huawei's smile curve: what can other Chinese enterprises learn? Aug. 17th, 2011. (in Chinese)

Chase, R. B., N. J. Aquilano and F. R. Jacobs. (2001), "Operations Management for Competitive Advantage". McGraw Hill/Irvine, New York .

China Telecom Monthly (2004), "The emerging Chinese power --- ZTE's 20 years innovation". Dec., 12th, 2004. (in Chinese)

Chen Heli. (2006), "Domestic industries facing Innovation Revolution Opportunity in 3G times". Science and Technology Daily. March 9th. (in Chinese)

Cheng Dongshen and Liu Lili. (2003), "The Truth of Huawei". Modern China Publishing House. ISBN: 9787801702739. Dec of 2003. (in Chinese)

Christensen, Clayton M. (2003), "The innovator's dilemma: the revolutionary book that will change the way you do business". New York: HarperCollins. ISBN 0-06-052199-6.

Dalum, B., Pedersen, C. and Villumsen, G. (2002). "Technological Life Cycles: Regional Clusters Facing Disruption". DRUID Working Paper 2002-10.

Du Guodong. (2009), "Huawei patent filings rank first in the world". Chinaview. Feb., 3rd, 2009 (in Chinese)

Forrester, J. (1959), "Advertising, a problem in Industrial Dynamics". Harvard Business Review. 59 (March – April), pp100-110.

Freeman, C. (2002), "Continental, national and sub-national innovation System---complementarity and economic growth". Research Policy, Vol. 31, pp.191-211.

Gao, Xudong (2014), "A latecomer's strategy to promote a technology standard: The case of

Datang and TD-SCDMA". Research Policy, Vol.43, pp. 597 – 607.

He Zhimao (2005), "Decode Huawei's marketing strategy from 4P and 4C". New Marketing Magazine", the 26th of June (in Chinese)

Huawei HR Annual Report. Issued on the 18th of January, 2008
http://zhidao.baidu.com/question/90873949.html

Lee, Keun; Chaisung Lim and Wichin Song (2005), "Emerging Digital Technology as a Window of Opportunity and Technological Leapfrogging: Catch up in Digital TV by the Korean Firms". International Journal of Technology Management, 29, 40-63.

Lee, Keun and John A. Mathews (2011), "Upgrading in the Same Industry and Successive Entries in New Industries for Sustained Catch-up," E. Amann, J. Cantwell and M. Bell, Forthcoming in a Book on the Innovative Firms

Lee, Keun and Lim, C. (2001), "Technological regimes, catch up and leapfrogging: findings from the Korean industries". Research Policy, Vol. 30, pp.459–483.

Lee, Keun Tae Young Park and Rishikesha T. Krishanan (2014), " Catching-up or leapfrogging in Indian IT service sector: windows of opportunity, path-creating and moving up the value chain." Development Policy Review, July 2014.

Liu, Xielin (2007), "Path-following or Leapfrogging in Catch up: the Case of Chinese Telecommunication Equipment Industry", presented at CIRCLE seminar series 5th December 2006 Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE) Lund University.

Lundvall, Bengt-Åke (2006), "Innovation System Research and Policy: Where it came from and where it should go". For Kistep Forum on Innovation in Seoul, December 1st.

Malerba, F. (2005), "Sectoral Systems: How and Why Innovation Differs across Sectors". Oxford University Press, Oxford.

Mathews, John A. (2005), "Strategy and the Crystal Cycle." California Management Review, 47(2), 6-31.

Mu, Q., and K. Lee (2005), "Knowledge Diffusion and Technological Leapfrogging: the Case of Telecommunication Industry in China". Research Policy, Vol. 34, pp 759-783.

Odagiri, H., Goto, A. (1993), "The Japanese System of Innovation: Past, Present, and Future". In Nelson, R.R.(Ed.) 1993. National Innovation System: A comparative Analysis. Oxford University Press, Oxford. pp.76-114.

Ren, Leyi (2005), "Understanding Impaction to Operators and Manufacturers: 3G Frequency Allocation". Telecom World. Volume 23, 2005. (in Chinese).

Ren Zhengfei (2006), "Innovation is the unexhausted power for Huawei's development". People's Daily, July 10th, 2000. (in Chinese)

Perez, C., Soete, L. (1988), "Catching up in technology: entry barriers and windows of Opportunity". In Dosi, G., et al.(Eds.), Technical Change and Economic Theory. Pinter, New York, pp.458-479.

Sidney Siegel (1957), "Level of aspiration and decision making". Psychological Review, Vol. 64(4), Jul 1957, 253-262.

Sun Changxu (2008), "Twenty Years Review: the Chinese Telecom Enterprises from Small Workshops to World Giants". International Electronics Business. Sep., 11th, 2008. (in Chinese)

Tan, Su-en (2006), "Heterogeneous Networks and Services". PhD thesis, CICT, Danish University of technology.

The First Financial Daily (2006), "Huawei officially announced 2006 income as 65.6 billion". Feb., 18th (in Chinese)

Utterback, J. M. (1994), "Mastering the Dynamics of Innovation". Cambridge, MA: Harvard Business School Press.

Utterback, J.M (1975), "Successful industrial innovation: a multivariate analysis". Decision Sciences, 6: 65–77. doi: 10.1111/j.1540-5915.

Ward, Andrew (2009), "Huawei picked for Telenor 4G upgrade". Financial Times, Nov. 6th

Yin, R. K. (1989): Case Study Research: Design and Methods. Newbury Park, Sage Publications.

Acronyms:

- (1G) 1st Generation of mobile phone mobile communications standards
- (2G) 2nd Generation of mobile phone mobile communications standards
- (3G) 3rd Generation of mobile phone mobile communications standards
- (ADSL)Asymmetric Digital Subscriber Line
- (ASIC) Application Specific Integrated Circuit
- (CDMA2000) Code Division Synchronous Address
- (GSM) 2G standardization, Global System of Mobile
- (IPR) intellectual property right)

- (ITU) International Telecommunication Union
- (MNC) Multinational Corporation
- (NGN)Next Generations Networking
- (NMT)Nordic Mobile Telephony
- (OEM) Original Equipment Manufacturer
- (PHS) Personal Handy System
- (TDD)Time-Division Duplex
- (TD-SCDMA)Time Division Synchronous Address
- (WCDMA) Wideband Code Division Synchronous Address
- (WiMAX) Worldwide Interoperability for Microwave Access
- (xDSL) Digital Subscriber Line, including ADSL, RADSL,VDSL, SDSL,IDSL and HDSL
- 4G 4th Generation of mobile phone mobile communications standards

Names of organizations:

- (Datang) a telecommunication equipment vendor in the People's Republic of China
- (Eastcom) a Chinese state-owned telecom company
- (eMobile) a mobile phone brand in Japan marketed by eAccess
- (Huawei) a Chinese multinational networking and telecommunications equipment and services company
- (ITU) International Telecom Union
- (KPN) a Dutch landline and mobile telecommunications company
- (Leap) an American mobile operator
- (LG) a South Korean multinational conglomerate corporation.
- (Motorola) an American multinational telecommunications company
- (Nokia) a Finnish communications and information technology multinational corporation
- (Samsung) a South Korean multinational conglomerate company
- (TD alliance) The TD Industry Alliance（TDIA) was found in 2002. It is a social organization formed voluntarily by enterprises who actively commit themselves to the development of TDD mobile communication technology and engage in the R&D, production and service of TDD standard and products.
- (UTStarcom) an American company specializing in IP based Next Generation Network Solutions, Broadband Network Solutions and IPTV Solutions for Telecommunications companies and service providers.
- (ZTE) a Chinese multinational telecommunications equipment