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全球科技產業併購決策之探索研究

An Exploratory Study on Global Technology Merger & Acquisition Decisions

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本論文係林敏慈君（R05749004）在國立臺灣大學企業管理碩士專班完成之碩士學位論文，於民國 107 年 06 月 14 日承下列考試委員審查通過及口試及格，特此證明

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Abstract

The explosive global population and the unprecedented growth of urbanization challenge cities' sustainability and efficiency. Technology is recognized as an essential element to resolve the issues for future inhabitation. While technology is highly leveraged to improve citizens' daily life, a city is transformed into a smart city. This digital transformation has been disrupting several related industries across the board and changing their competitive dynamics. This thesis is to discuss how the concept and vision of smart city drive major global players to aggressively reconfigure their business portfolios, especially through merging or acquiring target firms in the information and communications technology (ICT) sector. To facilitate research exploration, three cases (*Qualcomm-NXP* acquisition, *Broadcom-Qualcomm* proposal, and *SoftBank-ARM* acquisition) are purposely identified for detailed examination on the strategic motivations of engaging merger and acquisition (M&A) and the consequent influences on competitive landscape. After analyzing public information, this research discovers that the acquiring firms are faced with mature core businesses, so they are attracted by the target firms' growth potential for the emerging smart city market. In addition to growth, the acquiring firms also seek for value creation. By eliminating boundaries between firms and consolidating resources, the shared vision of

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smart city can be realized more efficiently. As for the influences on competitive landscape, these M&A measures disturb the original equilibrium of competition, more M&As might be induced until new equilibrium is achieved. Higher market power of the combined companies will cause redistribution of the profit pools and threaten operations of foundries and other IC design firms. To respond to the dramatic changes of competition, foundries have to search for breakthroughs on nanometer fabrication technologies. Other IC design firms should fortify intellectual property portfolios, deliver low-cost and low-power products, or reposition themselves as total solution integrators for the surging smart city industry.

Keywords: Smart City, Merger & Acquisition, Synergy, Competitive Landscape, Internet of Things, 5G

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Chapter 1

Introduction

1.1 Background

By 2030, the world's population is estimated to grow from current 7.6 billion to 8.6 billion. 60% of global people are projected to live in cities (United Nations, 2017). The number of megacities, cities with more than 10-million habitants, will increase from 31 to 41 (United Nations, 2016). Such a fast-growing trend of urbanization not only implies cities' dominance in economic development, but also indicates resource redistribution. As cities are accommodating more residents, concerns about sustainability, safety and efficiency of cities start to surface. Cities' infrastructures are concluded to be vulnerable to disasters and emergencies. In 2008, IBM (International Business Machines Corporation) unveiled the concept of "Smarter Planet" which lighted up feasibility of exploiting cutting-edge technologies to resolve challenges of future inhabitation. Since then, "Smart City" has gradually become a popular goal of cities' transformation.

Anticipating the potential demand pull of smart city, numerous industries and organizations are also challenged by the disruptive technology push. In a smart city, innovations from the technology industry will be highly integrated into people's daily life. Changes of consumers' behavioral patterns will significantly overturn companies'

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existing business models. Therefore, both the demand pull and the technology push trigger companies from the tech sector and non-tech sectors to strategically expand their business portfolios to obtain the essential technologies. Special expertise makes it difficult to cultivate the technologies internally. To overcome the formidable technology barriers and catch transient market opportunities, Merger and acquisition (M&A) is a must-have means for development.

1.2 Research Questions

During the past few years, the global M&A market has rejuvenated from the financial crisis in 2008. Technology constitutes a strong growing momentum of M&A activities. In 2016, deals for technology contributed to around 30% of the global M&A market and their values reached to $700 billion (Boston Consulting Group, 2017). Among these deals, a lot of acquiring companies originate from the non-tech sectors. They utilize M&A as an instrument to narrow technology gap, streamline operations, improve customer experiences, pursue growth, etc. The other acquiring companies are incumbents of the high-tech industry. Instead of organic growth, they implement M&A to become bigger and more comprehensive. This phenomenon contradicts to the practice greatly appreciated by investors in the past, especially for the high-tech

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industry—economy of specialization.

Based on these facts, this thesis will discuss how the vision of smart city drives global technology mergers and acquisitions. Besides, this thesis will focus on strategy analysis of recent technology M&A deals and further address the following two questions:

- **Research Question 1:**

  What is the strategic motivation that triggers recent M&As in the information and communications technology (ICT) industry?

- **Research Question 2:**

  How will the technology M&As affect competitive landscape of the information and communications technology industry?

1.3 Research Purpose

Smart city is an emerging market that progressively attracts attention from academia and from industries because of its potential to create gigantic economic values. As the world starts to experience the vast digital transformation toward smart city, this thesis intends to explore how firms' intellectual properties influence the global M&A

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market and identify the rationales for acquirers to seek M&A in the technology sector. In addition, this thesis attempts to derive causal relations between technical breakthroughs and companies' corporate strategies. After analyzing the competition and cooperation between companies, the thesis will summarize the key factors for IC design companies to succeed in the ambiguous smart city market. The discoveries are anticipated to be references for companies' corporate strategy development and an introductive literature for academic studies of smart city.

1.4 Research Methodology

The research started with analyzing information and communications technology architecture of a smart city and then focused on recent M&A activities of the industry. To analyze why M&A is chosen as the corporate strategy and how M&A will change the competitive dynamics, a qualitative research was conducted with the procedure as shown in Figure 1. To obtain more objective discoveries, the research adopted the qualitative, holistic and multiple-case designs described by Yin (2003) for case study to characterize three recent M&A activities of the semiconductor industry: the *Qualcomm-NXP acquisition*, the *Broadcom-Qualcomm proposal* and the *Softbank-ARM Holdings acquisition*. The three deals were selected because of their

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representative of technology and influence on industry structure. Data were collected from public sources like U.S. Securities and Exchange Commission, companies' websites, industry analyst reports, news, accounting and consulting firms' reports, etc. By analyzing each firm's status quo and comparing characteristics of the three cases, the research drew cross-case conclusions and finally provided suggestions to the research questions.

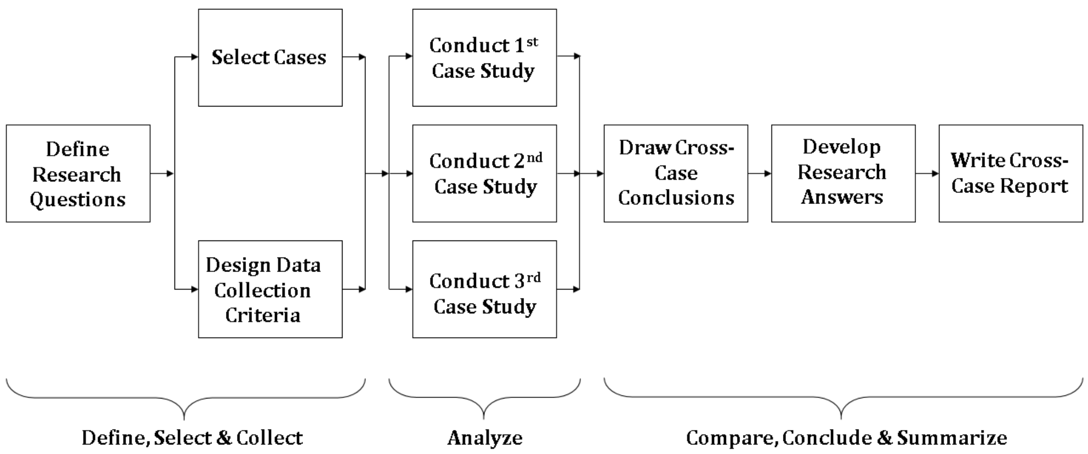

Figure 1: Multiple Case Study Procedure

1.5 Research Limitations

Analysis of this thesis is purely based on public information, so it might lack insiders' unique vision of evaluating strategic moves. Besides, the thesis focuses on case studies of three megadeals in the information and communications technology

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industry. This might constraints the findings on generalizability for small-sized companies. Conducting interviews and surveys on the involved management teams might be beneficial to realize companies' concerns and motivations in depth. Collecting and comparing more detailed data of various-sized deals would improve thoroughness of the discoveries.

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Chapter 2

Literature Review

2.1 Urbanization

Smith (1776) stated that the division of labor is not originally the effect of human wisdom, but the necessary consequence of human nature. Based on this proposition, O'Sullivan (2000) explained why a city exists from an economic point of view. Because an individual can't be self-sufficient, humans need to exchange their labor for the needs. When more and more people aggregate in physical proximity, opportunities to satisfy the needs and exchange labor become much more abundant. The proximity gradually evolves into a city. In addition, comparative advantages between different regions lead to the development of market cities. Internal scale economics triggers the formation of industrial cities. Agglomerative economics stimulates the growth of urbanization.

The National Research Council (2003) of the United States described the process of urbanization as a population shift from agriculture-centric settlements toward industry-and-service-centric settlements. Levels of urbanization are usually classified according to numbers of population, population density, percentage of urban to overall population, economic activities, etc. Intervals of levels are adjusted over time to reflect changing patterns of settlement. The World Bank (2009) analyzed the global urbanization trend from the 3-D aspects—density, distance and division. The United

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Nations (2015) indicated the global urban population exceeded the rural in 2007 for the first time in history and expected the trend to continue.

Coming with the unprecedented growth of global urbanization, demands from cities for natural resources and public services also increase dramatically. Cities are under substantial stress to search for the optimal balance between the economic and environmental trade-off. On one hand, cities are assumed to be the hubs boosting economic development by utilizing limited resources efficiently, so the residents can enjoy a prosperous life with great quality. On the other hand, while cities only occupy less than 5% of the global land, they constitute more than 66% of energy consumption and produce over 70% carbon emissions (Global Environment Facility, 2014). Cities are recognized to be responsible for pursuing sustainability, especially after the Paris Agreement ratified by 173 parties of the United Nations in 2016. How to achieve both the economic and environmental goals simultaneously under numerous constraints? Technology might be the key.

2.2 Smart City

Technology used to be viewed in several futuristic studies as the outcome of cities' civilization development that will eventually depress the growth of cities. Toffler (1980)

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predicted advanced telecommunications technologies will enable people to move back to the rural areas and work in electronic cottages instead of cities. People might migrate less because of business, but travel more for leisure. Gaspar & Glaeser (1998) disapproved this kind of opinions by investigating if improvement in information technology will decline face-to-face interactions and obsolete cities. Their study indicates telecommunications might be more a complement to rather than a strong substitute for face-to-face interactions and cities. Graham (1997) clarified transport and telecommunications flows incline to reinforce each other in reality. Telecommunications technology further creates the demand for physical co-presence from distant interactions. Actually, technology shapes cities to become more aggregate centers of human activities.

As the global urbanization trend becomes stronger, technology is considered as an essential element of cities' growth, especially to close the gap between economic development and environmental sustainability. Technological breakthroughs over periods turn imaginative ideas into "smarter" and feasible solutions. When technologies are highly correlated with and leveraged into citizens' daily life, cities' core operational systems can be advanced to provide customized services, reduce safety threats, eliminate traffic congestion, speed up communications connectivity, enhance business efficiency, lower water waste and smooth energy consumption (IBM, 2009). At this

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moment, a city transforms to a smart city.

The definition of smart city evolves rapidly. Albino et al. (2015) summarized various definitions of smart city and mentioned scopes of smart city have been extended from technology to including people and community needs. Ramaprasad et al. (2017) used an otology to characterize the logic of smart city's definitions. They revealed the social science field further exploits smart city to address social and human concerns and ecological issues. The United Nations adopts the following comprehensive definition established by The International Telecommunication Union to describe smart city (United Nations Human Settlements Programme, 2016):

"A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects".

Among various definitions, the consistency is that technology is a necessary component to construct a smart city. To create the values of smart city, technology is greatly utilized to overcome sociological, economical, psychological and ecological challenges resulting from urbanization.

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2.3 Strategy

As cities are transforming to be smarter, technology is changing people's behavioral patterns. Meanwhile, technology is disrupting industries and reshuffling business competition. To respond to the structural conversion, companies have to review market dynamics, scrutinize operations and redesign business models. Inevitably, companies must formulate new strategies.

Strategy analyses always start with understanding the external environment—the competitive landscape. Martin (2005) depicted history of the Structure-Conduct-Performance (S-C-P) Paradigm developed by industrial economists. The S-C-P framework argues that basic conditions of an industry affect industry structure, industry structure determines firms' behaviors, and firms' behaviors eventually determine profitability of the industry. The S-C-P approach provides companies a complicated tool to analyze imperfections of the market. Porter (1979) simplified the S-C-P Paradigm to his prestigious Five-Forces Framework. This new framework assists companies in systematically identifying the five major participants of business competition. Brandenburger & Nalebuff (1995) applied game theoretic concept to analyze dynamics of industries. They established the Value Net Framework and introduced complementors as a new player in business games. The Value Net Framework encourages companies to think about both cooperative and competitive

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approaches to change the games, not just to play the games.

After realizing external factors, strategy analyses continue with positioning and aligning activities. In the article "What is strategy?" Porter (1996) clarified the differences between operational effectiveness and strategic positioning. The former represents performing similar activities better than rivals do. The latter is performing similar activities in different approaches or even performing different activities. In short, strategy is about being different to deliver unique values. Besides, trade-offs are vital to strategy. Strategy is to make hard decisions on trade-offs, so companies can acquire sustainable advantages by creating consistent, reinforcing and optimizing fits among their activities.

Strategy formulation should correspond with companies' organizations. Vancil & Lorange (1975) decomposed strategy implementation for a diversified corporation into three levels—corporate strategy, business strategy and functional strategy. Planning processes of strategy in complex organizations require formal interactions across different levels of the organizational hierarchy. Salimian et al. (2012) summarized literature of the three strategy levels. Corporate strategy is designed for multi-business corporations to create values, configure organizations, coordinate businesses and allocate resources among different business units. Corporate strategy focuses on where to battle and involves decisions in diversification, merger and acquisition, divestiture

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and internationalization. Business strategy is also recognized as competitive strategy. It focuses on how to contest and relates to strategic positioning, competitive advantage and business model for competition. Functional strategy focuses on how to implement practices of each functional team like marketing, manufacturing, finance, supply chain, human resource, etc., so the overall activities are aligned to support business strategy. In other words, corporate strategy governs business strategy and the latter sequentially regulates functional strategy in diversified companies. Once the battlefields are locked down by corporate strategy, companies strive to win the competition via business strategy which is achieved by implementing functional strategy.

Porter (1987) illustrated corporate strategy is to make the value of a company as a whole greater than the sum of its business units. This indicates corporate strategy is to create synergy. Only when interrelationships between different businesses are meaningful for producing synergy, corporate strategy is successful in adding shareholders' values. Otherwise, corporate strategy might just purely perform as portfolio management that shareholders can also achieve by themselves through properly diversifying capital in an efficient financial market.

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2.4 Merger and Acquisition

Merger and acquisition is one of the tactics used by companies for corporate strategy. Gomez et al. (2011) explained the differences between merger and acquisition. Merger is that two companies combine into a single entity rather than remain owned separately and operate independently. The single entity comprises activities of the two combined firms. Acquisition is that one company takes over another company. By establishing the ownership, the acquiring company can control and dominate the acquired firm.

Gaughan (2007) elaborated some popular strategic motivations of companies to execute merger and acquisition. When timing is a very sensitive factor to achieve companies' strategic goals, M&A will be implemented instead of relying on organic growth. M&A is also a preferred choice for expansion into an unfamiliar geographic region, elevation in market share and enhancement of market power. M&A provides companies an opportunity to diversify into another fast-growing or more profitable business. M&A can be an instrument to secure key resources like raw materials, channels, patents, talents and research and development, so companies can gain long-term competitive advantages. Furthermore, M&A might increase shareholders' values by creating synergy. Synergy can be constituted from operations and corporate finance via M&A. By merging and acquiring another firm, a company might be able to increase

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revenue and reduce cost rather than two organizations operate irrelevantly. Besides, if cash flows of two companies are not perfectly correlated, M&A might benefit the combined entity with lower cost of capital because of reduced risks. Another financial synergy can be tax saving, though it's not a very popular motivation stimulating companies to employ M&A.

Gaughan also categorized M&A activities into three types based on their integrating direction on industry value chain. When two companies competing in the same business agree to combine together, this M&A is horizontal merger because it represents horizontal integration of the industry. When two companies with upstream-downstream relationship in an industry, their combination is vertical merger which results in vertical integration of the industry. If a company intends to combine another firm which is neither in competition nor in upstream-downstream relationship, it's practicing conglomerate merger via M&A. Under this scenario, the company is doing unrelated diversification from one industry to another different industry.

M&A for horizontal integration, vertical integration and unrelated diversification might correspond to stages of an industry life cycle. Carlton & Perloff (2005) illustrated how development of an industry can affect companies' decisions on vertical integration or specialization. Deans et al. (2002) depicted how industry concentration varies with stages of industry consolidation and predicted an industry will go through all four stages

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even quicker in the future. In summary, when a young industry is small, specializing in an activity does not pay for a firm, so all firms in the industry are vertically integrated to handle the entire production process. As an industry grows, firms are vertically disintegrated because transaction costs of each unit falls. Specialization in an activity starts to make business sense. If economy of scale significantly influences production costs, different firms will be more willing to combine together to obtain synergy in operational efficiency. M&A for horizontal integration might occur. As an industry matures or declines, its size shrinks. Firms will return back to be vertically integrated or look for opportunities of unrelated diversification to keep growth momentum.

Historically, M&As tend to occurs in cyclic waves. The Boston Consulting Group (2007) summarized six M&A waves from 1897 to 2006 and identified the major factors promoting each wave. The 6^{th} wave ended suddenly because of the global financial crisis in 2008. Harford (2005) identified economic, regulatory and technological shocks drive M&A waves when sufficient overall capital liquidity is available. However, if macro-level liquidity does not exist, these shocks won't cause M&A activities aggregate in time. Therefore, capital liquidity is the necessary component for economic, regulatory and technological shocks to drive M&A waves. Harford's research provides hints to explain why M&As rebounded in the past few years. As central banks keep quantitative easing measures to recover the global economy from the financial crisis,

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the 7th M&A wave starts. Meanwhile, technological breakthroughs disrupt various industries. Companies abruptly acknowledge they have been unconsciously losing their foundations. It's time to reconsider their corporate strategies. M&A seems to be a feasible and efficient shortcut for long-term value creation.

2.5 Moving Forward

While macroeconomic conditions spur the 7th wave, technology M&As flourish. Technology not only carries formidable threats but also highlights vast opportunities. Urbanization is enlarging cities. The demand for smart city is emerging. Technology building smart city is advancing. Corporate strategy is changing. Under this atmosphere, companies are eagerly participating in technology M&A, no matter they belong to the tech sector or the non-tech sectors.

In a young and small industry, firms are prone to be vertically integrated. To grasp opportunities of smart city, empirical cases of recent technology M&A activities show that except for vertical integration, companies are also aggressively handling horizontal integration and unrelated diversification. These M&As will eventually alter orders of industries and sway competitive landscapes. This thesis will focus on the information and communications technology industry and try to clarify strategic motivations and

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competitive consequences of the technology M&As for forming smart city.

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Chapter 3

Case Analysis

3.1 The Semiconductor Industry

Motivated by the vigorous demand of personal computers, the semiconductor industry burgeoned with a compound annual growth rate greater than 15% during the 1980s and 1990s (U.S. Department of Commerce, 2016). Popularity of communications devices and consumer electronics further stimulated the market expansion. However, based on the larger market foundation and restrained by the burst of Dot-com Bubble and the 2008 financial crisis, the industry's 5-year compound annual growth rates on average approached to 5% in the past two decades.

Roughly speaking, the global semiconductor revenues grew quite stably, from $45 billion in 1988 to $412 billion in 2017 as shown in Figure 2. However, if viewed with a finer scope, the industry's year-over-year growth rates fluctuate dramatically. The volatility gets amplified by the global economic booms and recessions. Severe cyclicality of revenues affects operating models chosen by semiconductor companies.

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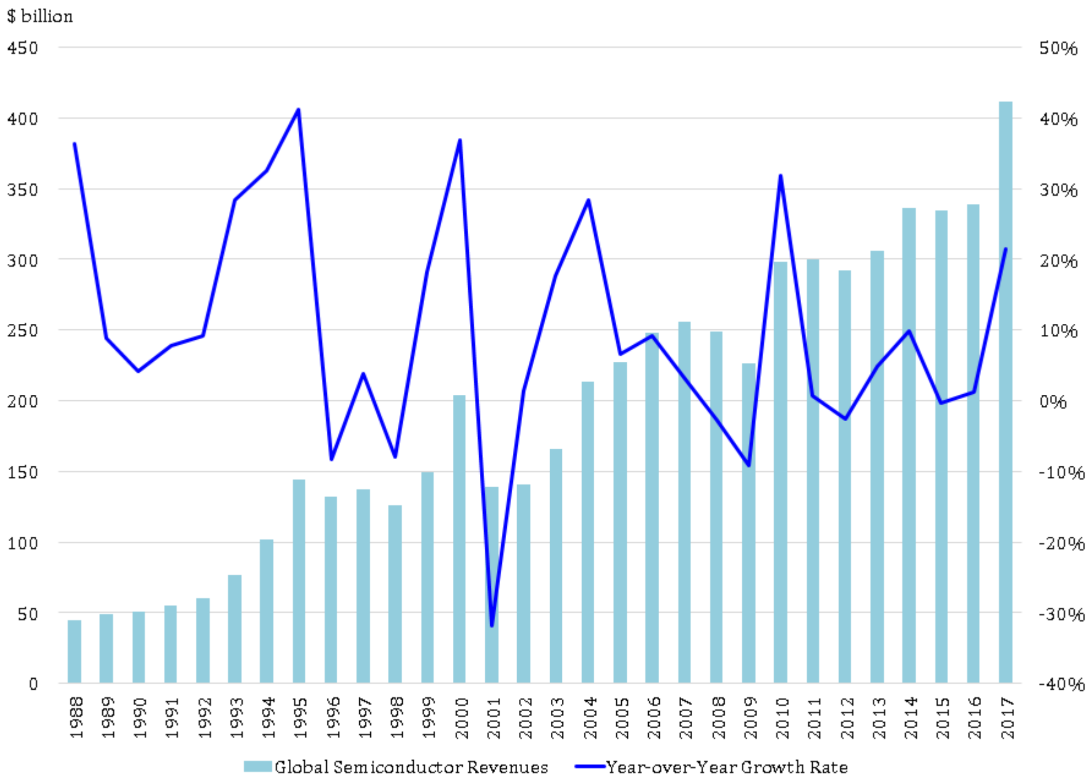

Figure 2: 1988-2017 Worldwide Semiconductor Revenues

Source: McKinsey & Company (2015[b]) and Semiconductor Industry Association (2016[a], 2018)

Integrated Circuits (ICs), the finished products of the semiconductor industry, can be categorized into two types: standard chips and specialized chips. Standard chips usually are common components used in various electrical systems, such as Dynamic Random Access Memory (DRAM) and Flash Memory. Different manufacturers can produce identical standard chips with almost no differentiation in functionality. Moreover, standard chips can be designed to be totally footprint-compatible, so they can be easily replaced by other brands without causing any issue of systems' operations. The homogeneous characteristic makes standard chips traded like commodities in the

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market. They are demanded in large volumes, but constitute lower profit margins due to the competition over price. Specialized chips are proprietary products of companies. Their performances, functionalities and footprints differ significantly. Once specialized chips are locked down by electrical system designers, signal routings of the whole circuitry on the Printed Circuit Boards (PCBs) are uniquely optimized to match characteristics of the selected chips. No identical substitution exists to make the same system work properly without any modification. Normally specialized chips require more research and development resources and they are what companies can differentiate themselves from others. Demands for specialized chips can be high or low in volumes, which is up to demands of the electrical systems. Specialized chips are usually purchased directly from IC suppliers via individual case-sensitive contracts.

ICs are non-perishable products with high ratios of economic value to weight. Transportation costs are relatively insignificant, so the semiconductor industry is a global market where companies located in diverse geographic zones compete or collaborate jointly. Companies in the industry require talented scientists and engineers to highly engage in research and development for patent creation, technology advancement, and product development. With appropriate designs, ICs are durable goods that can work reliably for years. However, rapid breakthroughs in technologies and expectation on improved customers' experiences result in frequent replacements of

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system devices, which in turn causes ICs being obsoleted much earlier than they start to malfunction. Therefore, prices of ICs decline quickly over time. Besides, severe cyclicality of demands promotes disequilibrium between demand and supply, which consequently leads to prominent fluctuations on IC's prices.

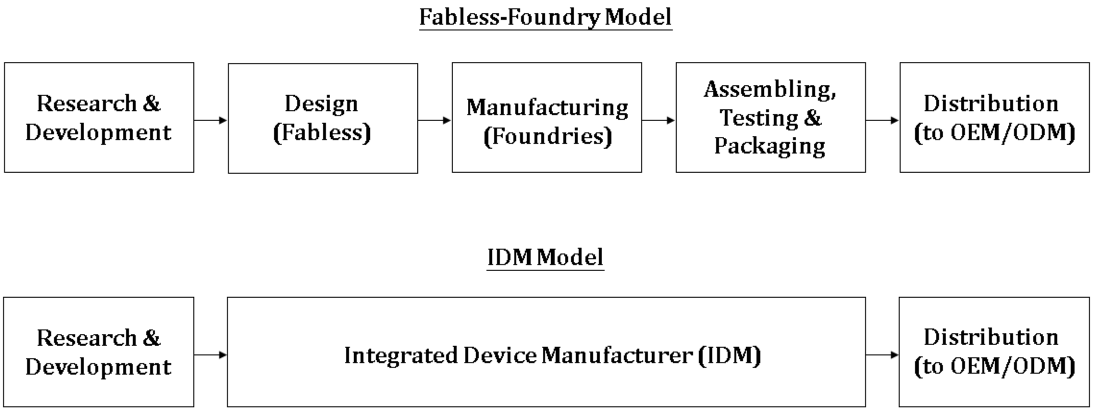

Figure 3: Value Chain and Operating Models of the Semiconductor Industry

Source: Semiconductor Industry Association (2016[b])

As Figure 3 indicates, value chain of the semiconductor industry can be briefly categorized into five activities: research & development, design, manufacturing, assembling, testing & packaging, and distribution. Advanced fundamental research & development studies are usually conducted by non-profit institutions, like CEA-Lti from France, IMEC from Belgium, ITRI from Taiwan, and two U.S.-based organizations, SEMATECH, and Semiconductor Research Corporation. Based on innovations discovered by the research and development institutions, ICs are designed

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to optimize cooperation of electronics components and routings of circuits, so the whole circuitries can perform desired functionalities. Manufacturing realizes circuit designs. This step creates circuit traces and sculptures electronics components on silicon wafers. After complex circuities are miniatured on chips, the integrated circuits are assembled, tested, and packaged to ensure performances meeting electrical, mechanical and thermal specifications. Finally, finished ICs are distributed to Original Equipment Manufacturers (OEMs) and Original Design Manufacturers (ODMs) to be integrated into electrical systems for miscellaneous applications.

Each activity of the value chain requests specialized skills and technologies. Besides, required capital investments differ significantly along the entire value chain. Fundamental research & development is usually supported by governments, academia and dominant companies due to uncertainties of commercializing pioneering innovations with decent returns. IC design requires talented engineers to create proprietary designs which outperform competitors'. IC design also highly relies on engineers to acquire patents for protecting and differentiating companies. As for manufacturing, it consumes tremendous financial resources for capital reinvestments to establish competitive advantages and prevent from potential entrants. Besides, engineers have to expertize in fine tuning all kinds of manufacturing parameters to boost yield rates and attain leadership of learning curves. The step of assembling,

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testing and packaging used to be a relatively labor-intensive activity. However, as packaging technologies improve, the task appears to be skill-intensive as well. Distribution of finished integrated circuits closely collaborates with supply chain procurement of OEMs and ODMs. Logistic efficiency, intelligence collection and demand forecasts are crucial for being responsive to market dynamics.

Differences in specialization and capital requirements impact companies' operational models under the cyclical characteristic of revenues. The fabless-foundry model represents vertical specialization. Companies focus on a particular activity of the semiconductor value chain. Fabless IC design houses recruit talented professionals to optimize circuitries and research technological breakthroughs. By outsourcing fabrication to foundries, IC design houses employ little capital investments and remain more operational flexibility. Because of lower entry barrier for capital, IC design easily attracts startups with innovative ideas to join the industry. By serving numerous fabless IC design houses, foundries can achieve higher capacity utilization rates, spread out formidable overheads, and obtain advancement on learning curves. The same operational logic also applies to companies devoting to assembling, testing and packaging. Focus strategy usually benefits managerial simplicity. Therefore, the fabless-foundry model is widely accepted by most companies of the industry. For example, Qualcomm, AMD and MediaTek are the representative fabless IC design

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companies; Taiwan Semiconductor Manufacturing Company (TSMC) is by far the largest foundry company of the world; Advanced Semiconductor Engineering (ASE), Amkor Technology and JCET are the major outsourced semiconductor assembly and test (OSAT) companies.

The other operational approach is the integrated device manufacturer (IDM) model. Companies operating at this model participate in all steps of IC design, fabrication, and assembling, testing & packaging. In other words, the IDM model exercises vertical integration of the value chain. Due to the high capital requirements of manufacturing, companies adopting the IDM model usually are worldwide major players of the industry, such as Intel, Samsung, Micron, Texas Instruments, Infineon and NXP. IDM companies contribute most of the industry revenues. However, they enjoy lower growth rates than fabless companies do. From 1998 to 2012, the compound annual growth rate for IDMs is 5% while it's 18% for fabless companies (Qualcomm, 2013). Even though vertical specialization seems to be a more reasonable measure for operational efficiency, some companies still remain vertical integration as IDMs to avoid transaction costs or pursue strategic effects. However, a trend that IDMs outsource partial of fabrication to foundry suppliers or OSAT companies emerges recently. The mixed operational model is referred as fab-lite. By operating at the fab-lite model, IDMs can avoid costly expenses to regularly upgrade facilities with cutting-edge equipment.

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In fact, at dawn of the semiconductor industry in 1950s, companies by nature had to be IDMs covering all activities of the value chain. Since 1985, the industry structure has gradually evolved from vertical integration to vertical specialization because the expanding market size is large enough to pay for specialized firms. Besides, technological innovations, patent licensing and intellectual property transfers between firms and across borders further facilitate the shift to specialization and globalization (Macher & Mowery, 2004). Nevertheless, as the industry's compound annual growth rate converges to 5%, people begin to wonder if the semiconductor industry reaches the maturity plateau of an industry life cycle. If the industry does mature, the decline phase might follow on the heels. Recent M&A activities of the industry seem to alter the trend of specialization. Are these M&As intended to preempt other players in a deteriorating game? Or, in contrast, they are aimed to ambitiously pioneer in another emerging growth potential—the era of smart city?

3.2 The Qualcomm-NXP Acquisition

On October 27, 2016, Qualcomm Incorporated (NASDAQ: QCOM) and NXP Semiconductors N.V. (NASDAQ: NXPI) announced Qualcomm will acquire NXP with cash on hand and new debt. The acquisition had been unanimously approved by both

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companies' boards of directors. The agreement was based on a tender offer provided by a subsidiary of Qualcomm to acquire all NXP's issued and outstanding shares for $110.00 per share in cash. This deal represented NXP's enterprise value was almost equivalent to $47 billion (Qualcomm, 2016[a]). After the announcement, the U.S. stock market encountered a strong bull year in 2017. NXP's stock price increased by 19.2%, from $98.21 to $117.09 per share, but Qualcomm's stock prices decreased slightly from $65.53 to $64.02 per share during the same period regardless of the exuberant atmosphere. In that year, NXP's non-GAAP operating income grew by 20%, compared with the results of 2016. Excellent earnings performances bolstered NXP's investors to argue that Qualcomm's original $110.00 per share offer was too low. To cease the objection, on February 20, 2018, Qualcomm announced an amended agreement to increase the acquisition price to $127.50 per share for nine NXP stockholders who collectively own more than 28% NXP's outstanding shares. The nine stockholders include hedge funds Elliott Advisors (UK) Limited and Soroban Capital Partners LP. Besides, the agreement also lowers the minimum tender condition of NXP's outstanding shares from 80% to 70% (Qualcomm, 2018).

Since the acquisition was announced, Qualcomm has been actively trying to obtain antitrust clearance from nine regulatory authorities across the globe. By the end of February 2018, Qualcomm has received approvals from eight of the authorities. The

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only pending clearance from the Ministry of Commerce (MOFCOM) in China is in final review stage, and Qualcomm is optimistic the transaction will be approved by MOFCOM pretty soon.

Qualcomm Incorporated

Qualcomm is a semiconductor company based in San Diego, California, U.S.A. The company was founded in 1985 to build “Quality Communications” for the world. Qualcomm concentrates on telecommunications products and is a pioneer in commercializing the Code Division Multiple Access (CDMA) technology for business applications. CDMA is a digital wireless communications technology previously used by the U.S. military. Messages that senders want to transmit are mixed with pseudo-random codes of higher frequency. Intended or unintended users may catch the transmitted signals over the air, but only users with the identical pseudo-random codes can recognize the messages. Comparing to other wireless technologies available in the market during 1980s and 1990s, CDMA is superior in providing secure communications, allowing more flexible use of bandwidth, and accommodating more users to communicate simultaneously. Except for the fundamental CDMA technology, Qualcomm develops several critical accompanying technologies to enhance performances of the CDMA communications systems. Qualcomm highly integrates all

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the technologies into single integrated circuits and builds up a comprehensive patent portfolio to firmly secure its CDMA dominance. Therefore, when CDMA becomes the basic standards of the 3rd Generation (3G) cellular communications systems, Qualcomm gains gigantic profits by monetizing the CDMA patents.

Technological evolution never stops, so does Qualcomm. To elevate data rates and spectral efficiency, the 4G mobile communications standards define Orthogonal Frequency Division Multiple Access (OFDMA) as the wireless transmission technology. The basic concept of OFDMA is to divide a whole available bandwidth into a large number of smaller bandwidths whose center frequencies are orthogonal to each other mathematically. A series of data packets are separated into different streams and then transmitted at the orthogonal center frequencies concurrently. Besides higher data rates, parallel processing and transmission of signals enable OFDMA to work together with the Multiple Input Multiple Output (MIMO) antenna technology to cancel out signal distortions occurred during wireless transmission. Experiences and leadership in the 3G systems nourish Qualcomm to stride early in the development of OFMDA wireless technologies. Just like what it does in the 3G CDMA systems, Qualcomm again pioneers in OFDMA-related patents and dominates the 4G mobile market. As for the 5G cellular mobile network to realize smart city, OFDMA is assumed to be the foundation of a unified air interface to support extreme variations of wireless

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connectivity services. Therefore, Qualcomm's heritage in the OFDMA technologies for 4G solidifies its current leadership in 5G technological development.

As for operational model, Qualcomm concentrates on fabless IC design and employs around 33,800 employees across the globe. It outsourced IC fabrication to TSMC, Samsung Electronics Co. Ltd., Global Foundries Inc., United Microelectronics Corporation, and Semiconductor Manufacturing International Corporation. IC assembling, testing and packaging activity has been assigned to suppliers like ASE, Amkor, Siliconware Precision Industries Co., Ltd. (SPIL) and STATS ChipPAC Ltd. (Qualcomm, 2017).

NXP Semiconductors N.V.

Because of the attempt to shift away from the cyclical semiconductor market and the intention to focus on healthcare and lifestyle products, Royal Philips Electronics sold its semiconductor business, Philips Semiconductors, to a consortium of private equity firms in 2006. The consortium includes Kohlberg Kravis Robert & Co. (KKR), Bain Capital, Silver Lake Partners, Apax Partners, and Alplnvest Partners. 80.1% of Philips Semiconductors' shares were acquired by the consortium and Royal Philips Electronics retained the remaining 19.9%. At the same time, the company's name was changed to NXP Semiconductors N.V., which represents "Next eXPerience". NXP

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keeps its Dutch nationality and headquarters in Eindhoven, Netherlands.

It seemed the independence from Royal Philips Electronics could allow the semiconductor business to realize its full potential for more opportunities. However, under Philips, the business mainly served internal customers from other divisions. The products were not developed to best match market opportunities. Privatization burdened NXP with $6 billion debts. What made situations even worse was the global financial crisis in 2008. The firm was on the brink of collapse due to cash shortage (Volberda et al., 2018). In 2008, NXP sold its Mobile and Personal business to get more than 1 billion euros to save the company. At the same time, NXP shrunk its size by reducing 32% of employees. Through a series of practices to decrease involvement in fundamental R&D, focus on applied engineering, avoid highly cyclical businesses dominated by very few global buyers, and target emerging niche markets, the company finally turned around and went public in 2010.

NXP announced its $40 billion merger with Freescale Semiconductor, Ltd. in 2015. NXP used to compete with U.S.-based Freescale in several businesses. Through this horizontal integration, NXP establishes itself as the top 1 leader in both the automotive semiconductor market and the general-purpose microcontroller products. Furthermore, the merged company becomes the powerhouse of High Performance Mixed Signal

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(HPMS) ICs and the 5th largest non-memory semiconductor in the world. A microcontroller (MCU) is a compact IC including processing units, memory, and input & output peripheral interfaces. Microcontrollers perform like small computers to automatically govern operations and storage of digital signals. Capabilities of implementing computations at low costs stimulate microcontrollers to be widely used in automobile electronics systems like Anti-lock Braking System. High Performance Mixed Signal ICs contain microcontrollers and circuitries handling analog signals from power units, radio waves, sensors, etc. By combining microcontrollers' digital processing capabilities with analog circuitries, High Performance Mixed Signal ICs can be designed as smart sensors for all kinds of data acquisition. Therefore, NXP's merger with Freescale greatly accelerates its strategy for smart city—to provide "Secure Connections for a Smarter World."

NXP hires around 31,000 employees in more than 33 countries. Except for IC design, NXP also participates in manufacturing activities and owns 5 wafer fabrication sites and 4 assembling & testing facilities. In other words, NXP is an integrated device manufacturer. Meanwhile, NXP also outsources some tasks to foundry suppliers and OSAT. Therefore, NXP operates at the mixture of fabless-foundry and IDM models.

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Operating Segments

Qualcomm has three operating segments: QCT (Qualcomm CDMA Technologies), QTL (Qualcomm Technology Licensing) and QSI (Qualcomm Strategic Initiatives). QCT is the IC chipset business which sells integrated circuit products of CDMA, OFDMA and other technologies. QCT also licenses system software to manufacturers who use Qualcomm's IC solutions in their system products. QTL basically is the licensing business which grants official rights to use portions of Qualcomm's intellectual property portfolio. Operating revenues of QTL include license fees and royalties. Unlike license fees to be paid in fixed amounts, royalties are generally charged as a percentage of the wholesale selling prices of manufacturers' finished products with deductible allowance for costs in transportation, insurance, packaging, and other Qualcomm-permitted items. QSI focuses on strategic investments for new market and technology opportunities. Most of QSI's investments are non-marketable equities and convertible debts of startup companies in digital media, e-commerce, healthcare and wearable devices.

Among the three operating segments, QCT and QTL conduct major operating activities of Qualcomm. QCT on average constitutes around two thirds of revenues and QTL brings in almost the remaining one third. QCT mainly serves markets for mobile

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computing, networking, automotive, healthcare, and Internet of Things. The IC chipset product portfolio includes mobile processors, cellular modems, server processors, platforms, embedded platforms, Bluetooth products, Wi-Fi products, and radio frequency products. Qualcomm's strengths in wireless communications make QCT's IC chipsets widely utilized as core components of smartphones, 3G and 4G cellular network systems and mobile personal computers. QCT competes aggressively with several international suppliers such as Broadcom Limited, Intel, Marvell Technology, Maxim Integrated Products, MediaTek, Nvidia, Realtek Semiconductor, Renesas Electronics Corporations, Samsung Electronics, etc. in several markets. For markets dominated by few large customers, like the smartphone market, QCT is also seriously challenged by customers' intentions to internally develop their own chipsets.

Qualcomm's comprehensive intellectual property portfolio in digital wireless communications technologies equips the QTL licensing business with incomparable market power. The monopoly status in CDMA-based and OFDMA-based patents even allows Qualcomm to request royalties from its competitors' customers. Therefore, even though QTL's operating revenues are relatively small in size comparing to QCT, the licensing business possess much higher profit margins than the IC chipset business. Around 80% of QTL's operating revenues remain as earnings before taxes, while the ratio is about 17% for QCT. Hence, QTL contributes more than 70% of the company's

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profits. In other words, the licensing business is the company's bonanza.

NXP used to be organized into two operating segments: Standard Products and High Performance Mixed Signals (HPMS). The Standard Products business sells standard chips that are demanded in large volumes. Due to the homogeneous characteristic of standard chips, the Standard Products business competes with others over prices and stringent levels of quality. The business accounted for 13% of NXP's revenues in 2016. On June 14, 2016, NXP announced the decision to divest the Standard Products business to a consortium of Chinese investors including Beijing Jianguang Asset Management Co., Ltd (JAC Capital) and Wise Road Capital LTD for $2.75 billion. The divestment was quickly completed on February 7, 2017. This transaction enables NXP to fully concentrate on the HPMS business which has growth outperforming the overall semiconductor market, high entry barriers, loyal customers, stable prices and lower long-term capital requirements.

In contrast to the Standard Products chipsets, NXP's HPMS products specialize in niche opportunities and are highly differentiated by application-specific features. The HPMS business serves more than 25,000 customers across the globe in fragmented markets of four scopes: automotive, secure identification solutions, secure connected devices and secure interfaces and infrastructure. For the automotive sector, the HPMS

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chipsets can support applications such as keyless car access, immobilizers, car infotainment, Advanced Driver Assistance System (ADAS), telematics, Anti-lock Braking System (ABS), transmission and throttle control, battery management, sensors, etc. The HPMS products are embedded in passports and banking cards for security and identification management. NXP's microcontrollers deliver secure features in connected devices like cellular phones, tablets, personal computers, televisions, and industrial equipment. Besides, the HPMS chipsets are integrated in infrastructures of wireless base stations and satellite & cable television networks for security control. NXP's HPMS business is actively engaged in the four diverse areas as the dominant leader. Especially in the automotive market which contributes to 41% of the company's revenues in the 4th quarter of 2017, NXP is the top one automotive semiconductor supplier in the world. Furthermore, the broad product portfolio of secure connected devices combining microcontrollers, short-range radio frequency technologies, security and sensors sets up NXP's solid foundation to expand into the emerging Internet of Things market.

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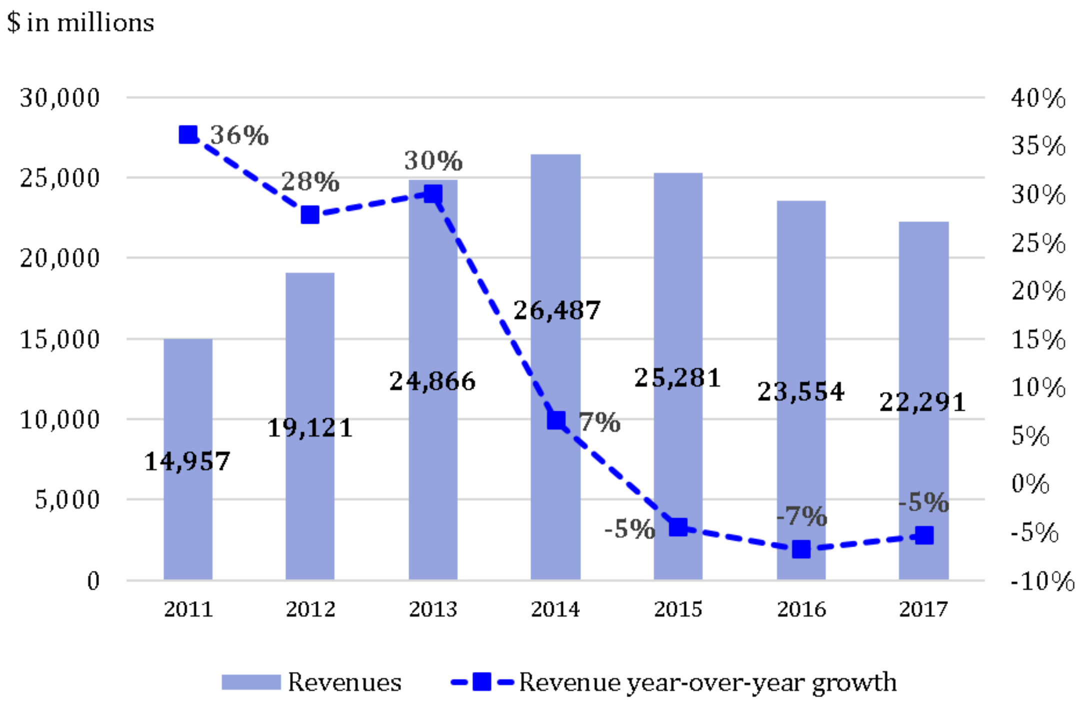

Figure 4: Qualcomm's 2011-2017 Revenues and Year-over-Year Growth Rates

Source: Qualcomm Incorporated Annual Reports Form 10-K

Figure 4 illustrates Qualcomm's sales during 2011 and 2017. After reaching the peak in 2014, Qualcomm's annual revenues have been declining for three straight years. Year-over-year growth rates plummet significantly. Qualcomm's businesses highly rely on a few big customers in the smartphone market. Apple Inc. and Samsung Electronics individually comprise more than 10% of the revenues. The two Chinese manufacturers, GuangDong OPPO Mobile Telecommunications Corp. Ltd. and vivo Communication Technology Co., Ltd., collectively comprise more than 10% of the

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revenues. These four customers compose 51% of revenues in 2017. Slowdown of the smartphone market suppresses QCT's IC sales. The volumes of shipped Mobile Station Modem (MSM) ICs, which perform voice and data communications, multimedia applications and global positioning functions for wireless devices, drop from 932 million for 2015 to 804 million for 2017. Following weak IC sales, the QTL's licensing business retrogrades accordingly. This further ceases the company's growth momentum and remarkably deteriorates the company's profitability.

Except for disappointing business performances, Qualcomm's monopoly power in the licensing business induced resistance around the world. In 2015, Qualcomm agreed to pay a $975 million fine imposed by the National Development and Reform Commission (NDRC) of China to end the 14-month government investigation into antitrust violations. In 2017, the Korea Fair Trade Commission (KFTC) decided to fine Qualcomm approximately $927 million. The Taiwan Fair Trade Commission (TFTC) also imposed a $778 million fine due to violation of the Taiwan Fair Trade Act. More than the regulatory issues, lawsuits with customers also happened. In 2017, Qualcomm awarded BlackBerry with $940 million in the arbitration for BlackBerry Limited's royalty overpayment. Apple Inc., one of Qualcomm's largest customers, filed a patent infringement dispute with Qualcomm and decided to underpay the requested royalties. This dispute also made Apple's suppliers, like Hon Hai Precision Industry Co.,

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Ltd./Foxconn, follow the same underpay actions against Qualcomm. These litigations further negatively impacted Qualcomm's financial results in 2017.

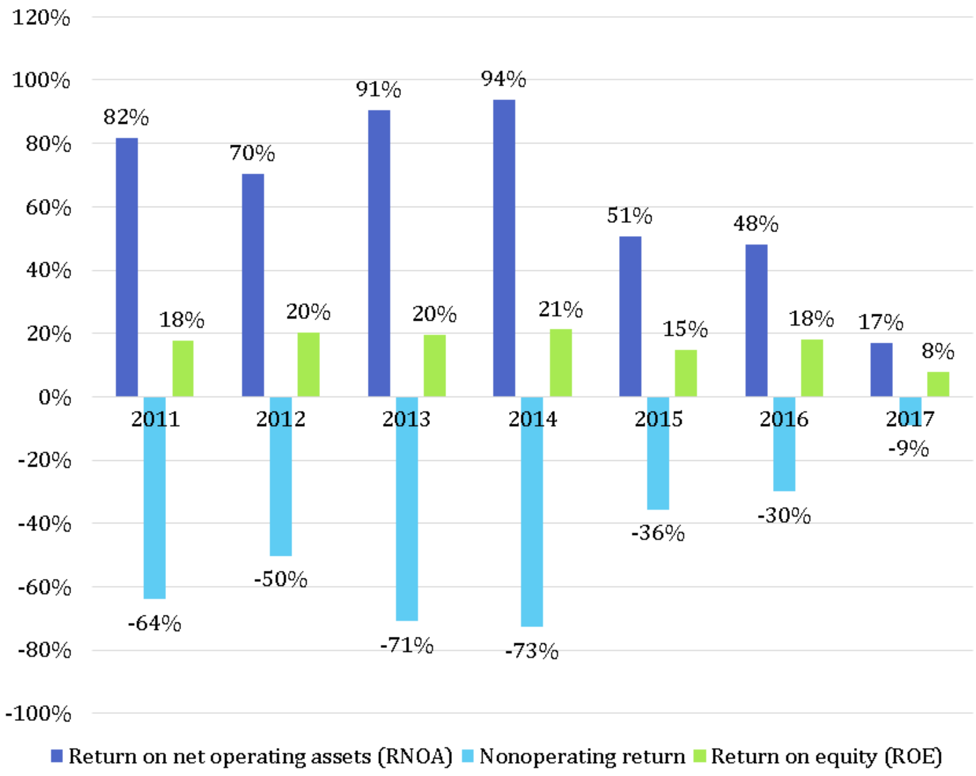

Figure 5: Qualcomm's 2011-2017 Profitability [1]

Source: Qualcomm Incorporated Annual Reports Form 10-K

Impotent sales and antitrust pressure trouble Qualcomm's financial performance. Return on equity (ROE) dramatically reduces to 8% in 2017 as shown in Figure 5. ROE

[1] In this thesis, calculations of RNOA, nonoperating return and ROE follow the definitions specified by Easton et al. (2017).

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can be decomposed into operating return and nonoperating return. Many high-tech companies prefer to hold large amounts of cash and marketable securities, so they can gain flexibility to promptly react to market opportunities and competitors' measures. Because of the excessive liquidity, high-tech companies usually maintain negative nonoperating returns that penalize ROE performance. Qualcomm adopts the same approach and keeps its nonoperating returns at the negative level from 2011 to 2017. However, starting from 2015, Qualcomm has been greatly increasing its financial leverage by incurring both short-term and long-term debts. This stimulates the nonoperating returns to increase from -36% to -9% in spite of Qualcomm's cash on hand approaching an extraordinary high level in 2017. The negative impacts on ROE from nonoperating returns have been limited to smaller scales. Therefore, the major factor for the shrinking ROE is not the growing nonoperating return, but the disappointing operating return in reality. Operating return is measured as return on net operating assets (RNOA). 2015 is the year that Qualcomm's RNOA plunged almost by one half of the previous year's level. The situation became even more serious in 2017. RNOA hit the record low 17%. The dissatisfactory operating results correspond to the sluggish smartphone market and the litigation issues.

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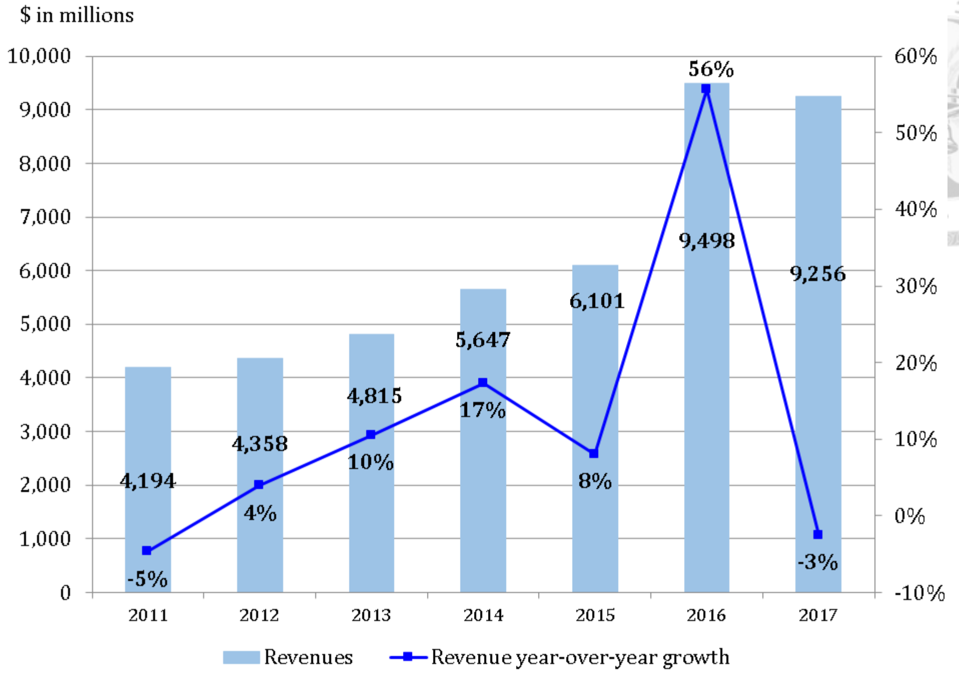

Figure 6: NXP's 2011-2017 Revenues and Year-over-Year Growth Rates

Source: NXP's Official Website for Investor Relations, NXP Historic Financial Model.

Figure 6 depicts NXP's sales during 2011 and 2017. NXP's revenues increased stably from 2011 to 2014. The robust growth was mainly driven by the HPMS business. In 2015, the HPMS growth was partially offset by decreases in the Standard Products business and manufacturing operations. Besides, the divestment of the RF Power business to Jianguang Asset Management Co. Ltd (JAC Capital) on December 7, 2015 also restrained overall revenue performance in the 2015 and 2016 fiscal years. The acquisition of Freescale greatly boosted NXP's growth in 2016, especially for the HPMS business, which enjoyed a 71% increase in operating revenues. The combined

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HPMS business from NXP and Freescale delivered an 8% revenue increase from the larger base in 2017. However, the divestment of the Standard Products business ended up the overall revenues with a decrease by 3%.

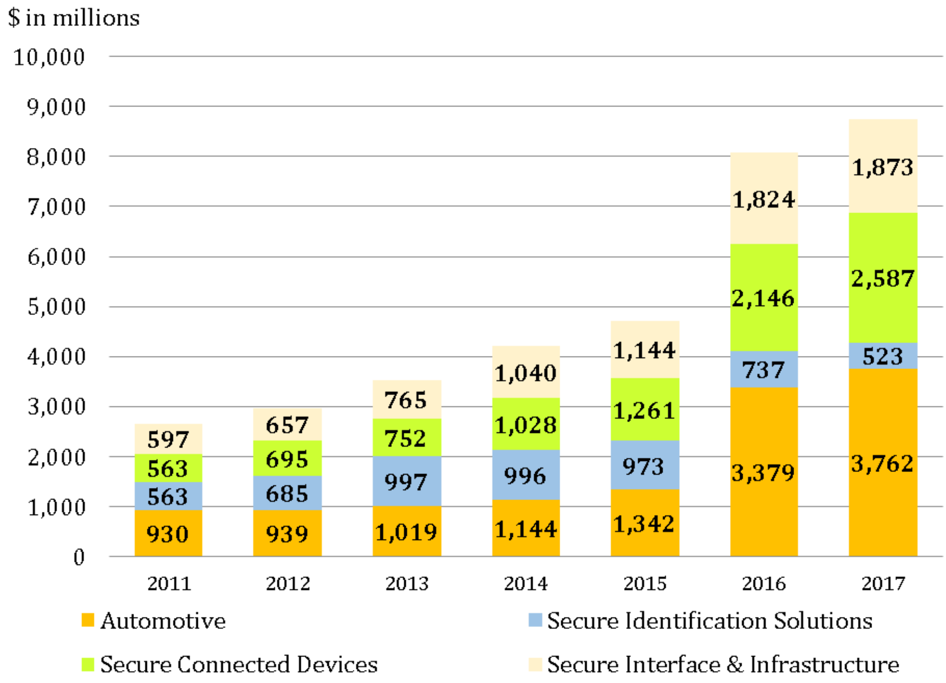

Figure 7: NXP's 2011-2017 HPMS Revenues

Source: NXP's Official Website for Investor Relations, NXP Historic Financial Model.

NXP's HPMS has been driving the company's growth momentum for years. Except for the secure identification solutions business line, all the other three business lines exhibit sturdy expansions as shown in Figure 7. In 2017, the automotive business line increased by 11%. The secure connected devices business line augmented by 21%.

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The secure interface & infrastructure business line grew by 3%.

3.3 The Broadcom-Qualcomm Takeover Attempt

On November 6, 2017, Broadcom Limited (NASDAQ: AVGO) unveiled a proposal to acquire Qualcomm for $103 billion, which was made up of $60 per share in cash and $10 per share in Broadcom stocks. If debts were included, Qualcomm's enterprise value approximately reached to $130 billion. The proposal was quickly rejected by Qualcomm because of its belief in that the enterprise value was underestimated. To resolve the impasse, on December 4, 2017, Broadcom and its supporting private equity firm, Silver Lake Partners, nominated 11 candidates to replace Qualcomm's board of directors and pursued Qualcomm shareholders' votes at Qualcomm's 2018 Annual Meeting of Stockholders. On February 5, 2018, Broadcom made a $121 billion "best and final" offer to Qualcomm. This updated offer was composed by $60 per share in cash and $22 per share in Broadcom stocks. The second offer was again dismissed by Qualcomm. On February 13, 2018, Broadcom conceded and proposed to reduce its slate of board nominees from 11 members to 6. On February 20, 2018, Qualcomm announced an amended agreement to increase the acquisition price for particular NXP stockholders. This decision disappointed Broadcom, and the

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acquirer responded with an offer reduced to $57 per share in cash and $22 per share in stocks. On February 27, 2018, Qualcomm changed its attitude and stated it would drop the objection if Broadcom's offer was above $90 per share. On March 4, 2018, two days before the scheduled Qualcomm's 2018 Annual Meeting of Stockholders, the Committee on Foreign Investment in the United States (CFIUS) responded to Qualcomm's secret and unilateral notice filed on January 29, 2018, which sought review of Broadcom's attempt. The CFIUS stated it has identified potential national security concerns and ordered Qualcomm to delay the meeting for at least 30 days. Broadcom tried to re-domicile back to the United States to address the concerns. On March 9, 2018, Qualcomm abruptly announced Paul E. Jacobs, the son of one Qualcomm's founder Irwin M. Jacobs, will no longer serve as Executive Chairman of Qualcomm's board of directors and will no longer serve in an executive management capacity. The board also eliminated the role of Executive Chairman established since 2014 and believed an independent Chairman is more suitable for Qualcomm's current situations. However, on March 12, 2018, President Trump signed an executive order to halt the proposed merger on the basis that the deal would threaten national security of the United States. Two days later, Broadcom announced it has terminated the offer to acquire Qualcomm and withdrawn its slate of independent director nominees for the election of Qualcomm's board.

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Broadcom Limited

Broadcom Limited is the successor to Avago Technologies Limited after the $37 billion merger between Avago and Broadcom Corporation, which was completed on February 1, 2016. Avago's history can be traced back to the semiconductor division of Hewlett Packard founded in 1961. In 1999, Hewlett Packard spun off all businesses not related to computers, storage, and imaging and these businesses became Agilent Technologies. In 2005, private equity firms Kohlberg Kravis Robert & Co. (KKR) and Silver Lake Partners acquired the semiconductor business of Agilent Technologies for $2.6 billion and named the new company as Avago Technologies. The company went public in 2009 and didn't stop its acquiring progress. In 2014, Avago acquired LSI Corporation whose history could be dated back to LSI Logic and AT&T Bell Laboratories. After the acquisition of Broadcom Corporation, Avago changed its name to Broadcom Limited. In 2017, Broadcom Limited again acquired Brocade Communications Systems. Therefore, the company has been gradually formed by a series of acquisitions. It's a lineage of several U.S.-based companies.

Inheriting technologies from its diverse origins, Broadcom Limited delivers discrete devices, IC chipsets, and firmware for various applications such as communications, storage, automation, display & lighting, capacitive sensors, etc. It is a leading company in the networking infrastructure market and provides solutions for

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both wired and wireless data communications. For wired data communications, Broadcom produces complex video processing ICs for cable, satellite, Internet Protocol, and terrestrial set-top boxes. Broadcom's broadband access products are widely used in modems, wireless local networks and residential gateways. Broadcom's Ethernet switching and routing technologies equip data centers and enterprises with networking capabilities, so digital data can be transmitted between numerous servers with low latency. As for wireless communications, Broadcom offers a broad variety of products covering radio frequency front end modules, power amplifiers, Wi-Fi controllers, Bluetooth, and global positioning system (GPS).

Broadcom Limited currently headquarters in Singapore and is planning to relocate its corporate back to the United States. The company hires around 14,000 employees across the globe (Broadcom, 2017). About 55% of the employees are located in North America, 38% in Asia, and 7% in Europe, the Middle East, and Africa. Broadcom outsources around three quarters of fabricating activities to Taiwan Semiconductor Manufacturing Company (TSMC) and the remaining one quarter to United Microelectronics Corporation, Semiconductor Manufacturing International Corporation, Global Foundries Inc., TowerJazz, and WIN Semiconductors Corporation. Broadcom contracts with Advanced Semiconductor Engineering (ASE), Amkor Technology, Inc., Siliconware Precision Industries Co., Ltd. (SPIL), Inari Technology

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SDN BHD, and Flextronics Telecom Systems, Ltd. for assembling and testing tasks. However, Broadcom also owns manufacturing facilities in the United States and Singapore. The internal manufacturing facilities are mainly utilized for products requiring proprietary processes. Therefore, Broadcom operates at the mixture of fabless-foundry and IDM models.

Operating Segments

Broadcom has four diversified operating segments: Wired Infrastructure, Wireless Communications, Enterprise Storage, and Industrial & Other. The Wired Infrastructure segment mainly serves the telecommunications service markets controlled by monopoly or oligopoly telecommunications companies for each geographic area. Its television set-top box product line provides platform solutions for service providers based on various transmission media to deliver video entertainments and networking capabilities in home environments. Besides, Broadcom's broadband access ICs and Ethernet switching products enable users to enjoy fast network connectivity via customer premises equipment (CPE). The Wired Infrastructure segment competes with several international semiconductor companies including Intel Corporation, NXP Semiconductors N.V., Quantenna Inc., STMicroelectronics N.V., MediaTek, Realtek Semiconductor, etc. Broadcom's broad product portfolio allows the Wired

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Infrastructure segment to differentiate itself by providing highly integrated and fully tested reference designs, so equipment manufacturers can efficiently shorten product development cycles and time to market.

The Wireless Communications segment supplies radio frequency devices and short to medium range wireless connectivity solutions for the mobile communications market which is mainly dominated by a few international manufacturers. For example, Broadcom's aggregate sales to Apple, Inc. alone accounts for more than 20% of total net revenue in the fiscal year 2017. Broadcom's Wi-Fi IC chipsets are also popularly employed to provide mobility for the customer premises equipment market, which is divided by the telecommunications service providers and several manufacturers targeting the retail sector. The Wireless Communications segment is gradually obsoleting standard discrete component products like diodes and transistors and focuses on products requiring advanced manufacturing processes or complex designs, so it can compete with other primary wireless solution providers like Qualcomm and Skyworks Solutions.

The Enterprise Storage segment produces stand-alone IC controllers and assembled printed circuit board (PCB) adaptors to transfer digital data between machines and storage devices with secure connections and high speed transmission. These solutions are provided for original equipment manufacturers (OEMs) to develop

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server and storage systems supporting mission critical storage traffic. Besides, the segment also assists hard disk drive (HDD) and solid state drive (SSD) OEMs in delivering greater density and capacity to meet the emerging demand for data storage. The Enterprise Storage segment originally competes with Marvell Technology, Microsemi Corporation, and Texas Instruments. After expanding the business scope by acquiring Brocade Communications Systems, the segment also starts to compete with Cisco Systems in the fiber channel switch market.

Optical isolators, or optocouplers, are the feature products of the Industrial & Other segment. Optocouplers can provide reliable isolation for signaling systems to be immune to electrical noise and interference. Optocouplers are required in wide variety of applications, such as automotive systems, factory automation and power generation & distribution systems. Except for optocouplers, the Industrial & Other segment also generates optical transceivers and motion encoders for factory automation. In addition, the segment offers light emitting diodes (LEDs) for lighting and display applications. The diversified product portfolio makes the Industrial & Other compete with companies of various backgrounds, such as Analog Devices, Cree, Inc., Hamamatsu Photonics, Heidenhain Corporation, Renesas Electronics, and Toshiba Corporation.

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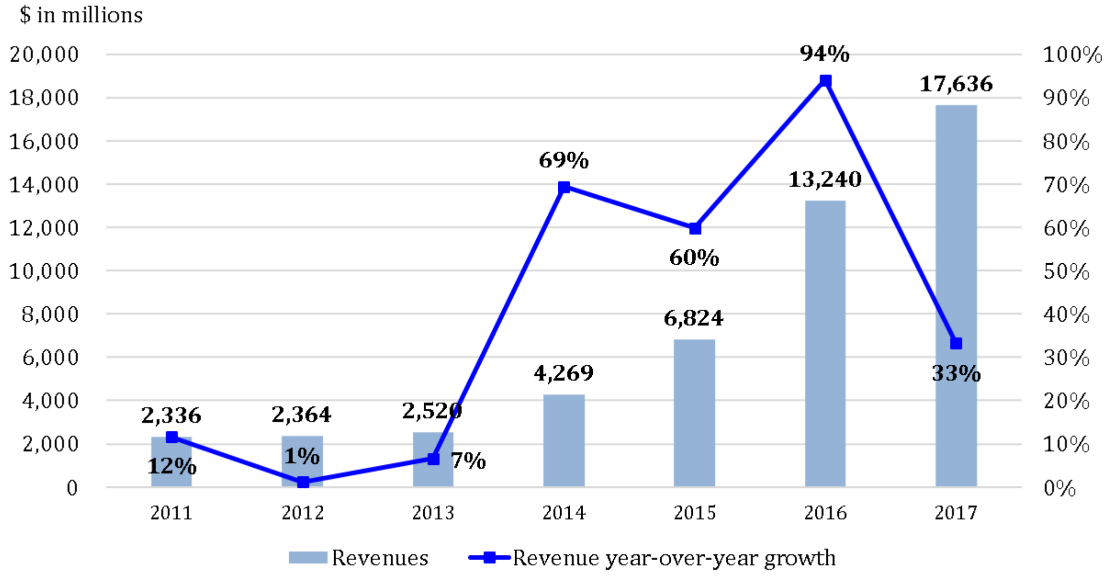

Figure 8: Broadcom's 2011-2017 Revenues and Year-over-Year Growth Rates

Source: Avago Technologies Limited and Broadcom Limited Annual Reports Form 10-K

Figure 8 shows Avago Technologies' and Broadcom Limited's revenue growth from 2011 to 2017. The company aggressively enlarges its size through M&A maneuvers. In 2014, revenues increased at an impressive rate of 69% mainly due to the acquisition of LSI Corporation and PLX Technology. Avago intensified its product portfolio from LSI with high-performance storage & networking chipsets and from PLX with interface connectivity solutions for semiconductor hardware and software. In 2015, the acquisition of Emulex Corporation, a provider of fiber channel host bus adaptors, further stimulated the growth of revenues. The acquisition of Broadcom Corporation dramatically boosted revenues for 2016 by 94% and for 2017 by 33%.

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Broadcom Limited's revenues are expected to keep growing significantly in the 2018 fiscal year because of the acquisition of Brocade Communications Systems in November 2017. By obtaining Brocade, Broadcom can enhance its leadership in fiber channel networking, internet protocol networking, and enterprise storage. In addition to rapid growth, Broadcom Limited also systematically transforms itself based on these M&A tactics. Figure 9 illustrates revenues of the four operating segments. The company puts more and more emphases on wired infrastructure and wireless communications. Besides, the company purposely enters the enterprise storage market. In other words, through these serial acquisitions, Broadcom Limited deepens its involvement in the data communications and data management markets, so it can greatly gain dominance in the foundations of smart city and quickly snap the related opportunities.

However, bold approaches also represent risks. M&A measures exactly nourish Broadcom rapid growth and access to long-term potential, but they also result in volatility of short-term profitability. Figure 10 shows Broadcom Limited's profitability from 2011 to 2017 fiscal years. The serial acquisitions since 2013 make ROE fluctuate dispersedly, with a range from 34% to -15%. The corresponding post-merger integration shrinks operating returns (i.e., RNOA). In addition, the company raised huge amounts of debts to fund the deals, so nonoperating returns are lifted significantly.

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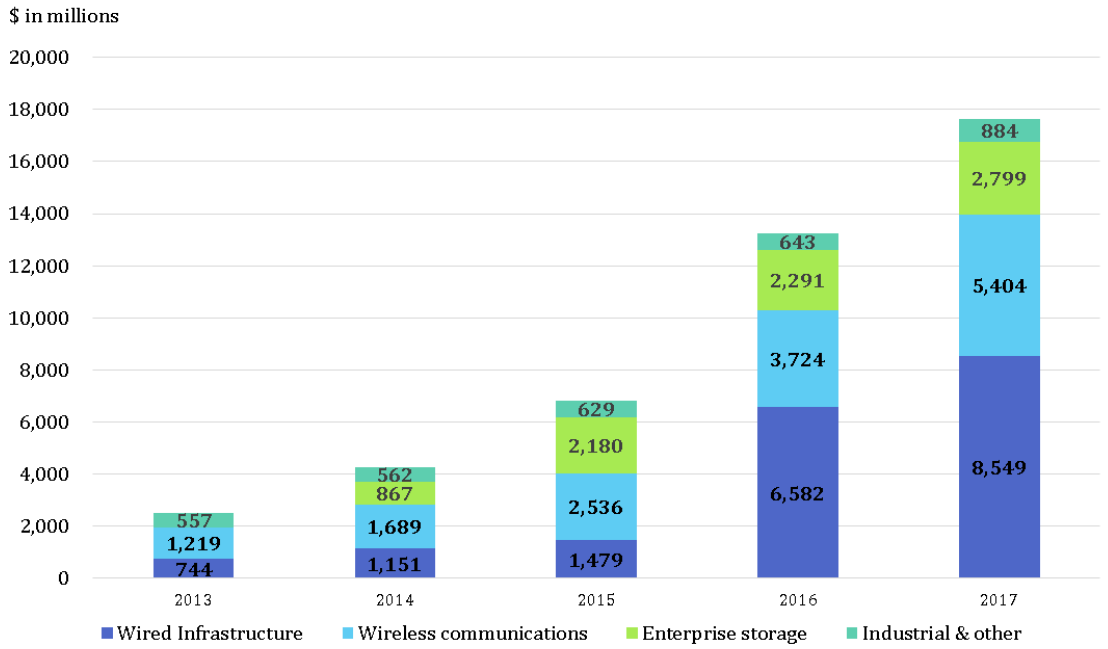

Figure 9: Broadcom Operating Segments' Revenues from 2013 to 2017

Source: Avago Technologies Limited and Broadcom Limited Annual Reports Form 10-K

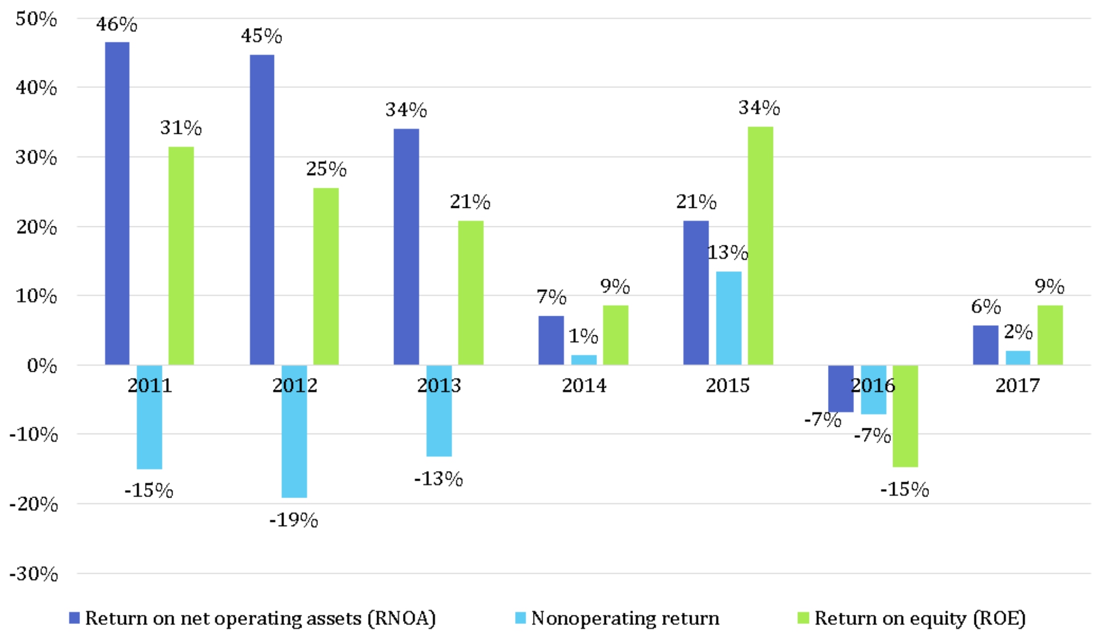

Figure 10: Broadcom Limited's 2011- 2017 Profitability

Source: Avago Technologies Limited and Broadcom Limited Annual Reports Form 10-K

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3.4 The Softbank-ARM Acquisition

On July 18, 2016, SoftBank Group Corp. and ARM Holdings plc announced the agreement of an all cash acquisition of ARM's 1,412 million shares with a total deal value around £24 billion British Pounds (GBP), which is about $31 billion U.S. dollars or ¥3.3 trillion Japanese Yens. This announcement surprised the world, especially because of the timing that 51.9% of the participating United Kingdom electorate just voted "Britain's Exit from the European Union" (Brexit) in the referendum on June 23, 2016. Masayoshi Son, the founder, Chairman, and CEO of SoftBank, publicly stated the acquisition will allow SoftBank to invest in ARM to fully release its potential. Remaining as an independent business within SoftBank, ARM will be supported to keep its management team, continue being headquartered in Cambridge, UK, and at least double the number of employees in the United Kingdom. Masayoshi Son claimed this acquisition represents the combined company is leading the Information Revolution to the "Next Paradigm Shift"—Internet of Things. This acquisition was efficiently approved by both jurisdictions of the UK and Japan and was completed on September 5, 2016. Starting from the next day, ARM ceased to be a listed company for the London Stock Exchange.

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SoftBank Group Corp.

SoftBank Group Corp. is a diversified holding company headquarters in Tokyo, Japan. Founded by Masayoshi Son under the name of SOFTBANK Corp. in 1981, the company originally operated as a distributor of packaged software and quickly diversified into the publishing business to introduce personal computers (PCs) and software by manufacturer. The company expanded its investment portfolio centered on the Internet and information technologies (IT) businesses around the world via maneuvers of venture capital, joint venture, and acquisitions. In 1996, the company and Yahoo! Inc. of the United States established Yahoo Japan Corporation and SoftBank became one of Yahoo! Inc.'s primary shareholders. SoftBank went public on the First Section of Tokyo Stock Exchange in 1998 and converted itself to a holding company next year. The company launched Yahoo! BB to provide broadband service via ADSL lines in 2001 and acquired JAPAN TELECOM to enter the fixed-line telecommunications business in 2004. In 2006, the company acquired Vodafone K.K. from the UK-based Vodafone Group and entered the mobile communications business. The mobile communications business was in alliance with Yahoo Japan Corporation to provide a wide variety of services and enabled SoftBank to become an integrated telecommunications service provider for both fixed-line and mobile communications. The company extended its telecommunications business scope to America by acquiring

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the U.S.-based Sprint Nextel Corporation in 2013. One month after SoftBank completed its acquisition of ARM, the company established a private SoftBank Vision Fund to invest in the global technology sector. Nowadays, the SoftBank Group is constituted by numerous subsidiaries operating in diverse fields, covering fixed-line communications, mobile communications, Internet, e-commerce, robots, semiconductor design, finance, sports, etc.

SoftBank's investment portfolio reflects Masayoshi Son's experiences as an entrepreneur and his idiosyncratic comprehension about how technologies are shaping the world. Masayoshi Son's has been recognized as a savvy venture capitalist with proven records. He started to invest in Yahoo! as early as 1995, the time when Yahoo! was just a very young startup firm. This investment was quickly rewarded with tremendous profits when Yahoo! went public next year. In 2000, Son invested $20 million in a Chinese e-commerce startup company and this investment was worth $58 billion 14 years later. This Chinese e-commerce company is Alibaba. In 2003, Son aided the Chinese online gaming developer, Shanda Interactive Entertainment, with $40 million when it encountered operational difficulties. After Shanda went public in 2004, SoftBank obtained $560 million profits by selling Shanda's shares. Son has been accumulating abundant wealth and admirable reputation from his successes. He is considered as the incomparable visionary who can accurately interpret consequences of

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the Information Revolution. Therefore, as he announced his gigantic plan for SoftBank Vision Fund to invest in the technology sector, the target $100 billion capital was quickly achieved by proactive and enthusiastic participants, including Saudi Arabia's sovereign wealth fund and worldwide technology companies like Qualcomm, Apple, Foxconn, and Sharp.

ARM Holdings plc

ARM is a semiconductor design holding company founded in Cambridge, UK in 1990 as a joint venture business between Acorn Computers and Apple. The company develops Advanced RISC Machine (originally named as Acorn RISC Machine and now simplified as ARM) architecture for processors and licenses the corresponding intellectual properties to IC design companies. In the computer engineering field, architecture represents the fundamental operational structure of a computer system whose processing follows a set of instructions. The instructions guide a processor to execute operations of arithmetic, logic, data, and control flow among relevant transistors. To support high-level programming language that is more convenient and friendly to software programmers to develop their codes, more complicated instructions have been gradually added. However, ease of software development is exchanged with higher hardware complexity and lower computing efficiency. To resolve the

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weaknesses, a simplified version of instruction sets was proposed later on. To distinguish the differences, architecture using complicated instruction sets is called as Complex Instruction Set Computer (CISC) architecture, and the other is called as Reduced Instruction Set Computer (RISC) architecture. RISC architecture only keeps basic instructions and simplifies operations of complicated instructions via basic ones. The simplicity reduces the number of required transistors and power consumption of processors. Fewer transistors result in lower fabrication costs and design costs. Therefore, RISC architecture is more cost efficient and energy efficient in contrast to CISC.

CISC architecture has been utilized by Intel and AMD for Central Processing Unit (CPU) of computers and servers for decades. Since these machines usually operate at locations with access to power sockets or high capacity batteries, there is no critical need to use RISC architecture, especially when both Intel and AMD have invested tremendous research & development resources in CISC architecture. ARM develops its proprietary architecture based on RISC, but can’t exhibit significant importance until the low costs and low power consumption features of ARM architecture are highly appreciated by the mobile device market. These two features enable mobile devices to perform miscellaneous applications with compact batteries. Due to the rapid growth of mobile devices, smartphones, and automotive electronics, ARM-based chip shipments

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experience exponential growth since 2000. In 2016, 17.7 billions of ARM-based chips were shipped worldwide and the accumulated amount as of the 3rd quarter of 2017 reached to 120 billion (ARM Holdings, 2018).

Unlike other fabless IC design companies or IDMs, ARM does not produce or sell any ICs. The company creates its unusual business model by licensing ARM architecture to more than 1,100 partners and assisting the partners in customizing their specialized IC products. In other words, ARM acts as an intellectual property and technical service provider in the semiconductor industry. This positioning strategy allows ARM to build up an ecosystem centering on ARM architecture and deliver its technologies to 80% of the global population.

Operating Segments

Before the acquisition of ARM, SoftBank Group operated with four major segments: Domestic Telecommunications, Sprint, Yahoo Japan, and Distribution. The Domestic Telecommunications segment is represented by the leading subsidiary, SoftBank Corp., which derives from the merger of four predecessors: SoftBank Mobile, SoftBank BB, SoftBank Telecom, and Ymobile in 2015. The segment focuses on the Japanese market for both retail and corporate customers to provide services of fixed-line communications, mobile communications, Internet, and mobile device sales. As

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Japanese telecommunications market is very matured, SoftBank stably ranks as the third largest oligopoly service providers for years with market share around 23.9%, following NTT DOCOMO’s 42.2% and KDDI’s 27.5% (SoftBank Group, 2015). In addition to the consolidated wired and wireless communications businesses, the Domestic Communications segment also includes subsidiaries working on settlement and card services.

The Sprint segment originates from the acquisition of Sprint Nextel Corporation in 2013. The maturity of Japanese telecommunications market stimulated SoftBank to search growth potential from a global scope. Sprint used to be the 3rd largest mobile carrier of the United States, but it got surpassed by T-Mobile which follows Verizon and AT&T. SoftBank tries to leverage its experiences in turning around Vodafone K.K. to improve the problematic Sprint business. Besides the mobile communications services, the Sprint segment also sells mobile devices and provides fixed-line telecommunications services in the United States.

The Yahoo Japan segment is represented by the leading subsidiary—Yahoo Japan Corporation. By operating Yahoo! JAPAN as the Internet portal, the segment is engaged in Internet advertising and e-commerce for the Japanese market. Yahoo! Japan used to be the most popular Internet portal in Japan for year, but its leadership has been challenged by Google through applications like Gmail, Google Maps, Chrome,

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and the Android platform. In addition to the Internet-based activities, the Yahoo Japan segment also contains mail-order businesses for stationery and office supplies.

The Distribution segment involves supply chain and channel activities of consumer electronics and software. For the overseas market, the segment is in charge of purchasing mobile devices from manufacturers as a wholesaler and then distributing the devices to telecommunications operators and retailers. As for the Japanese market, the segment sells PC hardware & software, peripherals, mobile devices, and accessories. Except for sales of devices, the segment also provides insurance plans for handsets and buy-back & trade-in services for used devices.

Right after SoftBank completed the acquisition of ARM, SoftBank Group added ARM's businesses as the 5th operating segment. In 2017, the six operating segment was created, which is SoftBank Vision Fund and Delta Fund. These two new segments display SoftBank Group Corp. enriches its business portfolio by diversifying into the semiconductor industry and further penetrating into the financial investment industry.

In contrast to the increasing number of SoftBank's operating segments, ARM Holdings reorganized its structure and aggregated all businesses into one operating segment—the IP Group (IPG). The only segment specialized in developing intellectual property for IC design and neutrally worked with its partners to create energy-efficient and sophisticated ICs based on ARM architecture. The RISC-based ARM architecture

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competes with Intel's CISC-based x86 architecture for processor IC design. Intel's x86 architecture is mainly used for personal computers and servers while ARM architecture is popularly employed for mobile devices because of its superiority in power consumption and costs. Unlike Intel developing x86 architecture for its own products, the IP Group segment implements the licensing business model to share intellectual property with other IC design firms like Qualcomm and NXP. The segment acquired upfront license fees by licensing its intellectual property to chip manufacturers and then charged for loyalty on a per chip basis. Moreover, the segment also gained income by providing software and technical services. The licensing mechanism promoted ARM architecture-based ICs to grow explosively and enabled the company to extensively enjoy benefits from its monopoly power in RISC architecture. The simple organizational structure of ARM reflected the company's high specialization of technology development and deep focus of business activities, even though the company essentially operated as a holding entity.

Financial Performance

Figure 11 shows SoftBank Group's revenue growth from 2010 to 2016 fiscal years. Before the acquisition of Sprint Nextel Corporation in 2013, the company's expansion was mainly driven by the mobile communications and the Internet businesses in the

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Japanese market. The addition of Sprint allowed SoftBank to geographically diversify its telecommunications business into the world's largest economy, almost double the company's net sales, and magnify its influences in the global mobile operator industry. The Sprint business by far became the largest revenue stream of the company and constituted more than 40% of net sales. In 2016, net sales of the Sprint segment increased in U.S. dollars; however, the stronger yens offset the improvement and partially caused the recession of revenues. Starting from 2016 fiscal year, ARM was included in SoftBank Group and the new business contributed around 1% of total revenues.

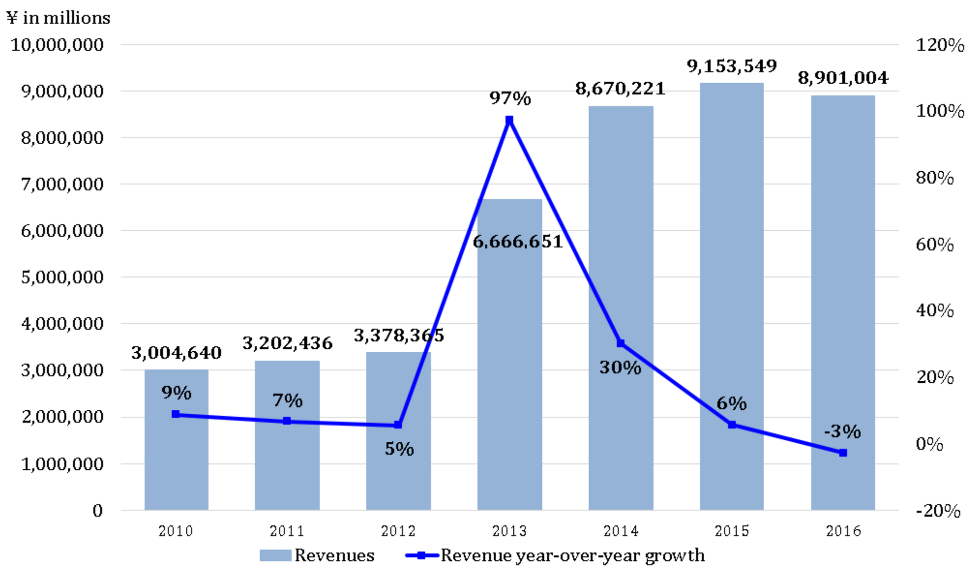

Figure 11: SoftBank Group's 2010- 2016 Revenues and Year-over-Year Growth Rates

Source: SoftBank Group Corp. Annual Reports[2]

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[2] The accounting standard has been changed from JGAAP to IFRS since 2012. Data for 2010 and 2011 might need to be adjusted to reflect changes of account definitions.

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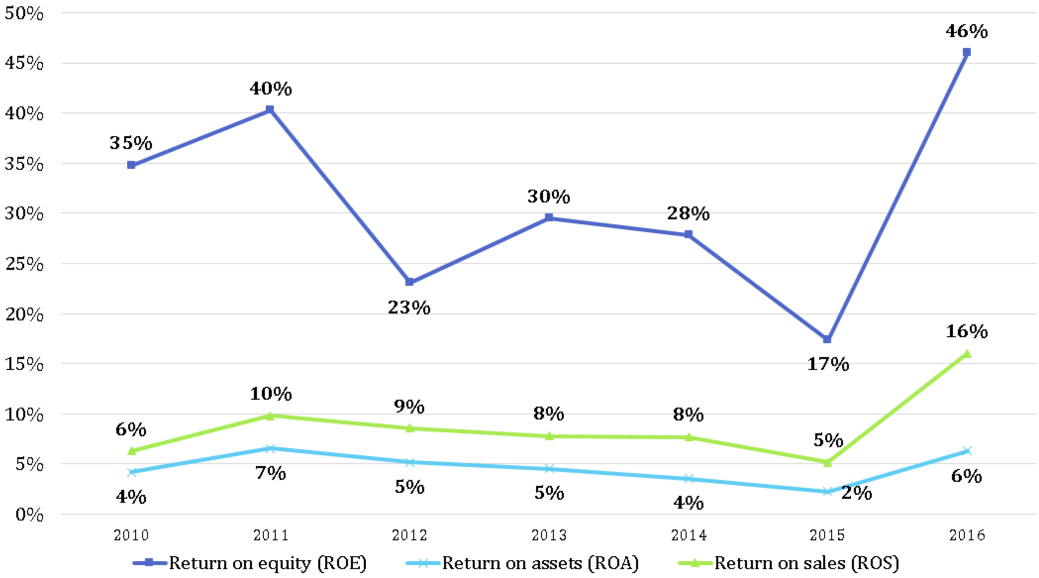

Figure 12: SoftBank Group's 2010- 2016 Profitability[3]

Source: SoftBank Group Corp. Annual Reports

Figure 12 summarizes profitability of SoftBank Corp. from 2010 to 2016. Historically, the company performed double-digit return on equity (ROE) for years by proficiently handling financial leverage. Besides, its ROE is also highly influenced by sales and purchases of venture capital investments. For example, the company sold its investment securities of Yahoo! Inc. with a ¥76,430 million gain in 2011. This resulted in simultaneous increases in ROE, return on assets (ROA), and return on sales (ROS). The company's activities in marketable securities also create dramatic fluctuations in

[3] Data for 2010 and 2011might need to be adjusted to match IFRS. 2016 data includes the new Arm segment. Due to the change of accounting standards in Japan and both the acquiring and the target firms are holding entities, profitability analysis of this case are conducted via the DuPont framework for simplicity.

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income taxes. ¥207,105 million of income taxes were credited in 2016 fiscal year because of the transfer of Alibaba shares between SoftBank Group and one of its subsidiaries, while ¥422,677 million were reported as an expense for income taxes in the previous year. Besides, the company also sold its shares of GungHo Online Entertainment, Inc., which partially contributed to the bounce of ROE, ROA, and ROS in 2016.

Since 2012, the company had been expanding its balance sheet by significantly incurring non-current liabilities to fund its acquiring activities. The company planned to develop its mobile Internet platform on a global scale by acquiring Sprint, so the company could achieve economies of scale in procurement of mobile devices and telecommunications equipment beyond diversification of business portfolio and elevation of global position. However, the post-merger integration for the Sprint business depressed the company's short-term profitability. Through measures of stabilizing operating revenues and reducing operating expenses, the Sprint business finally delivered positive operating income in 2015 fiscal year and exhibited very positive growth in 2016.

Figure 13 and Figure 14 illustrate revenue growth and profitability of ARM Holdings, respectively. ARM was a rapidly growing company with robust momentum. Unlike SoftBank's high utilization of financial leverage, ARM rarely operated the

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business with debt. Since ARM concentrated on intellectual property development and gained revenues via the licensing and loyalty business model, it performed relatively high-level of return on sales. To make this special mechanism work, ARM had to closely monitor its technical advancement. Except for developing technologies organically, the company also implemented M&As to obtain complementary technologies to enrich its intellectual property portfolio. In 2013, ARM acquired Finland-based Sensinode for its software technology for the Internet of Things. To extensively solidify its leadership in the Internet of Things development, ARM acquired Discretix, Inc. (trading as Sansa Security, Inc.) in 2015. This deal was beneficial to fill up the gap of providing security for smart connected devices in ARM's portfolio. Premiums paid for these M&A transactions were recorded as goodwill on ARM's balance sheet. That goodwill had been ranked as top one or two largest asset account for years somehow represented the necessity to own an abundant intellectual property portfolio for maintaining the licensing model.

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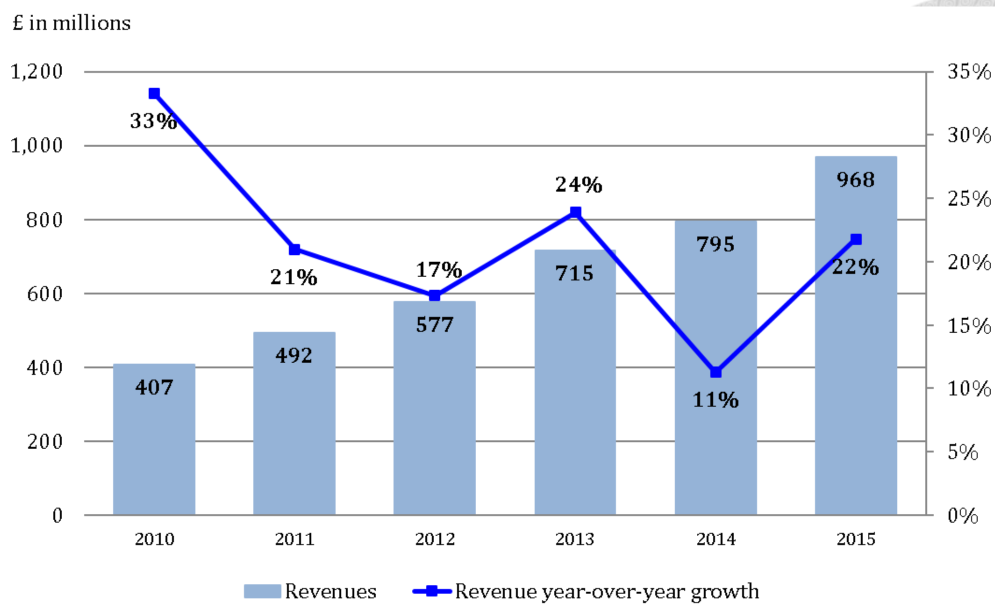

Figure 13: ARM Holdings' 2010- 2015 Revenues and Year-over-Year Growth Rates

Source: ARM Holdings Annual Reports

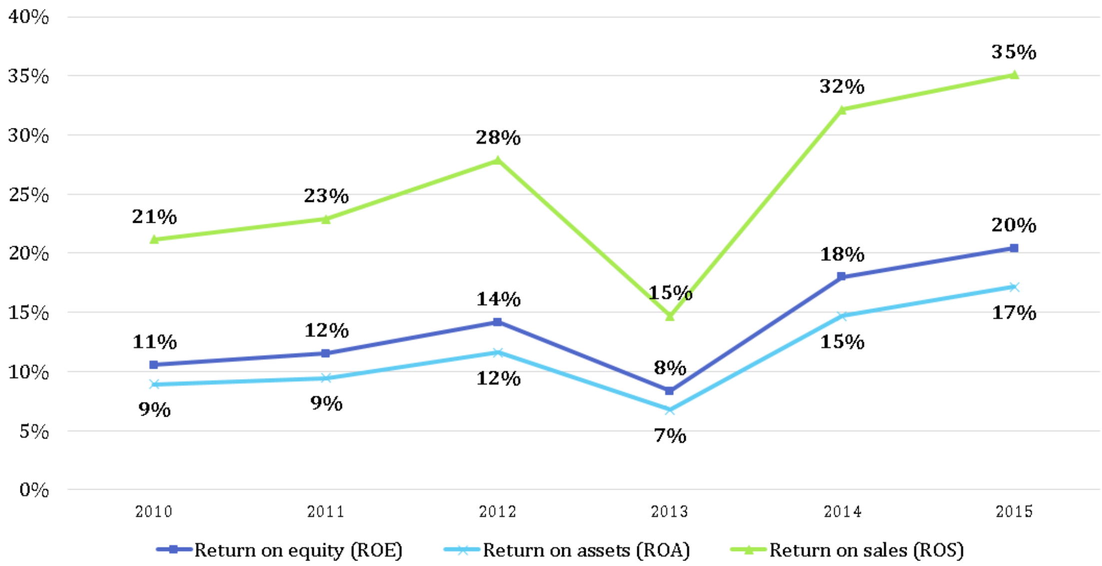

Figure 14: ARM Holdings' 2010- 2015 Profitability

Source: ARM Holdings Annual Reports

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Chapter 4

ICT Infrastructure of Smart City

4.1 Architecture

Block diagram is a graph used in electrical engineering to illustrate how a system transforms input into output. Principal functions of the system are represented by blocks. Arrows connecting blocks indicate relationships and operating flows between functions. If block diagram is applied to explain the system of smart city, the result should look like Figure 15.

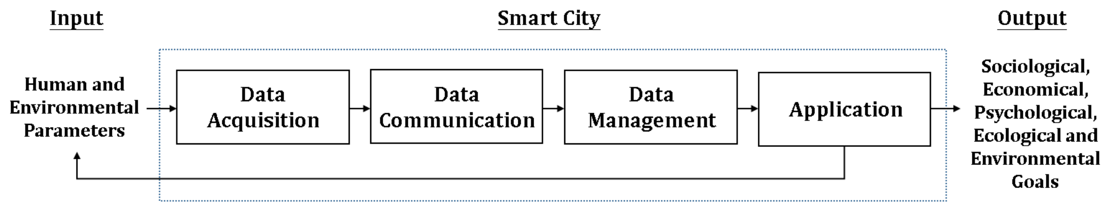

Figure 15: Block Diagram of Smart City

A smart city transforms the input parameters about human activities and living environments into goals that its residents would like to achieve. In other words, a smart city is a system that converts people's understanding about the current world into an improved world in the future. Malik & Shah (2017) proposed a four-layer model to implement a smart city via information and communications technologies (ICT). If the

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same concept is adopted, the system of smart city can be decomposed into four principal functions—data acquisition, data communication, data management and application.

4.2 Data Acquisition

Data acquisition can be categorized into three basic approaches: sensor-based, image-based and radio wave-based. Data acquisition function in a smart city's ICT architecture is usually referred as the sensor layer in technical discussions because sensors are widely used to capture all kinds of parameters about the world. Fraden (2004) described physical and electrical characteristics of various types of sensors and distinguished a sensor from a transducer. As Figure 16 shows, a transducer is a device that convers one type of energy into another. A sensor is a device that converts any type of energy into electrical signals. Sensors are a special type of transducers. If a sensor's output electrical signals can be transmitted accurately, people can remotely monitor environments and detect anomalies almost in real time.

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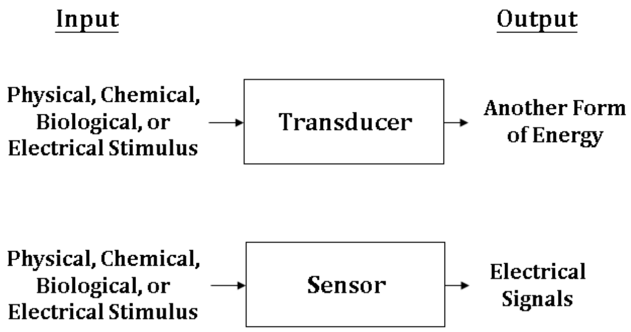

Figure 16: Block Diagrams of Transducer and Sensor

While technologies evolve rapidly, sensors are integrated with more intelligent features beyond the basic function of converting energy into electrical signals. Sensors nowadays can be complicated systems which contain transducers, analog to digital converters, microcontrollers, memories, power units, network interfaces, etc. Sensors of this kind are called smart sensors. Moreover, to enrich sensors with wireless connectivity for applications requiring mobility and flexibility, radio frequency (RF) transceivers are incorporated into sensors. Therefore, sensors can be communicated and controlled wirelessly.

Varieties in applications make sensors diversify in types and serve fragmented markets. To ensure interoperability of smart sensors produced by various manufacturers, the Institute of Electrical and Electronics Engineers (IEEE) established the IEEE 1451 family of standards for smart transducer interface. The IEEE 1451 standards define a transducer should be attached with a memory device storing identification, calibration,

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correction and manufacturing data (IEEE Std1451.0, 2017). The standards also describe specifications of the network interfaces to communicate with smart transducers. Standardization in electronic characteristics and network interfaces promote compatible operations, so sensors can work collectively no matter they origin from the same manufacturer or not.

With capability of sensing parameters, processing data and communicating with each other, wireless smart sensors aggregately form wireless sensor networks. Akyildiz et al. (2002) explained a sensor network is constituted by a large number of sensors whose positions do not have to be specified in advance. International Electrotechnical Commission (2014) illustrated operations of wireless sensor networks. Sensors first broadcast their status to the surroundings and receive status information from other sensors. Then sensors self-organize into a connected network according to some topologies. Sensors compute paths and establish links to transmit observed data from the source sensor to the destination. Since smart sensors can be located randomly and then work cooperatively, their networks can be utilized as a powerful tool to monitor a certain field suffering accidental disasters like floods. Furthermore, wireless sensor networks can also be employed in applications for agriculture, traffic control, health care, resource management, etc.

Following versatility in functionality, small physical size, low power consumption

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and low production costs are three critical features for smart sensors to exhibit economic values for smart city. With small size, smart sensors can be installed unobtrusively. This feature increases the acceptance by people. Very low power consumption can ensure sensors work properly for a relatively long time without any battery replacement. Low production costs light up the possibility of large-scaled deployment for smart sensors, so data about environments and human activities can be collected comprehensively. However, these three critical features are usually traded off with sensors' functional versatility under the same production technologies.

Breakthroughs of the Micro-Electro-Mechanical System (MEMS) technology introduce innovative solutions to resolve the trade-off. Developed based on integrated circuit (IC) fabrication technologies of the semiconductor industry, MEMS can miniaturize mechanical components to sizes of micrometer (μm) levels by selectively etching silicon wafers and adding structural layers. Meanwhile, MEMS technology integrates mechanical components with electronics devices, so complicated systems of smart sensors can be designed integrally on the common substrates to reduce power consumptions. Smaller sizes of smart sensor systems also significantly shrink production costs. McKinsey & Company (2015[a]) stated prices of MEMS sensors dropped by 30%-70% from 2010 to 2015. As semiconductor fabrication technologies advance from micrometer to nanometer ranges because of nanotechnology, miniature

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of smart sensors is moving forward to the Nano-Electro-Mechanical System (NEMS) technology, which is estimated to perform more superiority than MEMS in smaller size, higher precision and lower power consumption.

Except for sensors and transducers, image-based devices and systems are another important source to acquire data. Due to the development of Closed-Circuit Television (CCTV) for video surveillance, cameras have been widely deployed in cities as a critical safety infrastructure. Besides, the rapid growth of mobile devices in the past ten years makes smartphones and their standard parts like cameras deeply penetrate into people's daily life. The prevalence of cameras stimulates the volumes of videos and pictures created each day. Data in image formats increase dramatically. With improvements in image recognition technologies and big data analytics, valuable information can be efficiently extracted from piles of records.

Advancements of radio wave technologies also provide innovative means to gather data. Radio Frequency Identification (RFID) technologies are used to track inventories and logistics of products. By transmitting electronic identification information over radio waves within a certain range, RFID tags can be recognized by a reader immediately. Comparing to the barcode systems, RFID systems are superior in efficiency and convenience. Several RFID tags can be processed simultaneously, even though the tags are located inside objects and can't be observed from the appearance.

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Another common example of data acquisition via radio waves is Global Positioning System (GPS). The GPS system utilizes radio waves transmitted from 24 satellites located in six orbital planes to compute a device's exact location on the earth. While smartphones turn out to be people's necessary belongings, GPS, one of the standard features of smartphones, can gather data about flows of human movements. As navigation systems are popularly attached to vehicles, GPS can supply real-time information on traffic conditions.

While technologies keep evolving, data can be acquired from numerous sources in various formats than people previously would anticipate. Data acquisition is the foundation of a smart city's ICT infrastructure and the corresponding technologies enable people to know the world better and deeper from all kinds of angles.

4.3 Data Communication

The purpose of data communication is to transmit data from one location to another so information can be shared with people at a distance. Forouzan (2007) explained five components of data communication include sender, receiver, message, medium and protocol. A transmission medium is a physical path by which a message propagates from sender to receiver. A protocol is a set of rules specifying the formats

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of data communication between devices. Only when using the same protocol, a receiving device can recognize the same “language” and interpret the message provided by a sending device. Messages transmitted across media of different protocols require a gateway to act as a protocol translator to bridge the communications.

IEEE 1451 standards define the protocol for smart sensors to communicate with each other, so smart sensors can coordinate mutually and collectively constitute wireless sensor networks. If smart sensors are embedded into objects, the objects can communicate with each other via the established wireless sensor networks. In other words, the objects form Internet of Things (IoT).

The “Internet of Things” concept was firstly proposed by Kevin Ashton in 1999 to link the idea of RFID in Procter & Gamble’s supply chain management (Ashton, 2009). By empowering sensor technology, computers and the Internet don’t need to depend on human beings to manually capture and enter data. Human resources can be freed up and employed more productively. The definition of IoT varied with the improvements of technologies over the past two decades. Today, Internet of Things represents a world-wide communication network composed by interconnected objects with unique identities. The objects can be still or moving, such as buildings, home appliances, meters, physical devices, vehicles, trains, electrical devices, etc.

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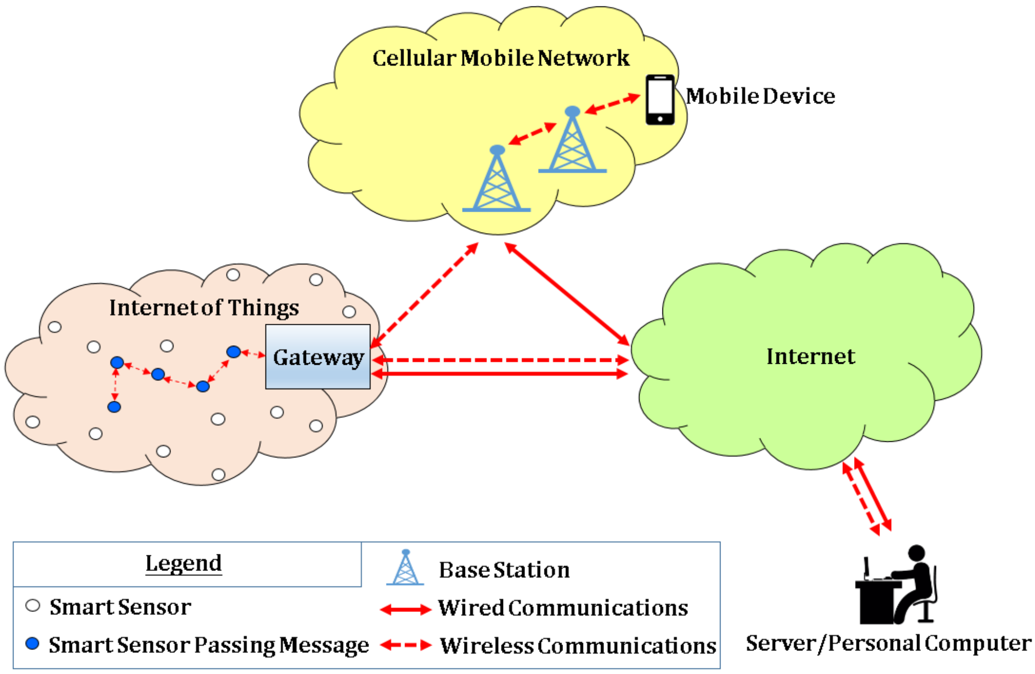

Figure 17: Data Communication between Internet of Things, Internet and Cellular Mobile Network

Figure 17 depicts data communications between Internet of Things, the Internet and cellular mobile network. Internet of Things connects objects. The Internet connects websites. Cellular mobile network connects people. Once parameters about the world are captured by smart sensors in a wireless sensor network, the acquired data can be forwarded within the network from the source sensor to the gateway. Then, the data are further transferred to the Internet via wired or wireless media. The wired transport network includes optical network, cable television (CATV) network, Ethernet network, etc. Wireless transmission can be implemented via various protocols. Medina et al. (2017) compared various wireless technologies according to range of available areas.

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Among all the wireless technologies, the most popular ones are Wi-Fi network and cellular mobile network. Wi-Fi networks specified in the IEEE 802.11 standards are existing wireless networks commonly installed in buildings and public areas for short to medium rage connectivity. Based on current deployment of Wi-Fi networks, the acquired data can be transferred from the gateway to the Internet without any significant extra infrastructure cost. As the acquired data are available on the Internet, people can access the data through servers or personal computers. In other words, people can remotely understand and monitor the parameters of a far field by establishing the link between Internet of Things and the Internet. If smart sensors are equipped with functions of accepting commands and activating objects to execute tasks, people can control operations of objects via the established link and expand scopes of their influences.

Instead of using servers or personal computers, mobile devices provide alternative terminals for human interactions. The prevalence of smartphones and tablets enables people to surf on the Internet with mobility and flexibility. Actually, smartphones play an increasingly important role in connecting people to the world. Thus, as long as the data acquired by smart sensors are accessible on the Internet, people can perceive the data via connected mobile devices wherever they go. Another route to obtain the acquired data from mobile devices is to bypass the Internet and interconnect Internet of

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Things and cellular mobile network directly. To achieve this, the gateway of a wireless sensor network needs to possess capabilities of interacting with a base station (BS) of cellular mobile networks. Besides, a base station will have to support enormous number of gateways if smart sensors are deployed extensively on billions of objects. However, this can't be fulfilled by the existing 4th Generation (4G) cellular mobile networks.

Mobile communications systems have been evolving tremendously from the 1st Generation to the 4th Generation since 1981. Each generation incorporates cutting-edge technological advancement for better user experiences. The 4G mobile networks can support downlink data rates up to 100 Mbps (megabit per second) for high mobility access and up to 1 Gbps (gigabit per second) for low mobility access. End-to-end latency is reduced to less than 100 millisecond (ms) (Abdullah et al., 2011). The 4G networks realize faster broadband internet access from mobile devices, which causes exponential growth of data traffic in mobile networks. The growth momentum is expected to continue stably. By 2020, mobile users on average will download 1 terabyte of data each year (Rappaport et al., 2014).

Faced with the steady demand for data traffic and preparing for the era of smart city, academia and the technology industry are aiming at the 5th Generation (5G) cellular mobile networks. Standards for the 5G communications are still under development and will not be completed before 2020. Wang et al. (2014) and Sasipriya

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& Vigneshram (2016) have identified that the 5G networks' performances should support 10,000 times data traffic, 10-100 times more devices, 10 Gbps peak data rate for low mobility access and 1 Gbps for high mobility access, less than 1 ms of latency and 10 years of machine-to-machine battery life.

To achieve the fabulous performances, architecture of cellular mobile network will be fundamentally redesigned. Agiwal et al. (2016) clarified the high frequency millimeter wave (mm-wave) bands, typically locate from 30 GHz to 300 GHz on the spectrum with wavelengths from 1 millimeter to 10 millimeters, will be exploited to accommodate vast data traffic. As wireless communications run at higher frequency bands, signals decay much more quickly during transmission. To adapt this physical characteristic and fulfill the less than 1 ms of latency requirement, mm-wave Base Stations will be densely deployed. Coverage areas, called as cells, will be much smaller for mm-wave Base Stations compared with 4G Base Stations. Large number of mm-wave Base Stations together with legacy 4G Base Stations will transform mobile networks from Base Station-centric architecture into User-centric architecture. Communications running at the mm-wave bands also shrink antennas' sizes. Smaller antennas will be extensively used to form large antenna arrays and cooperate with the massive Multiple Input Multiple Output (massive MIMO) technology to enhance spectral and energy efficiency.

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If the excellent performances of the 5G networks are achieved as expected, mobile network system will furnish people with seamless and ubiquitous wireless connectivity to anyone and anything at anytime and anywhere. At that moment, Internet of Things will be fully merged with the 5G cellular mobile network. The integration of Internet of Things, the Internet and the 5G cellular mobile network will greatly stimulate realization of smart city.

4.4 Data Management

Technically speaking, data only reflect pieces of raw reality. Without appropriate processing, data are not presentable and can't provide people with much information. The objective of data management is to convert data into information and knowledge for people to rationally explain phenomena and make insightful decisions.

Data management includes two parts—data analysis and data storage. Data analysis is the procedure of extracting useful information from raw data and modeling its statistical characteristics. Data storage infers technologies to retain digital assets in media efficiently and support lookup promptly. Organized collections of data constitute databases. Traditional data management focuses on creation, maintenance and manipulation of databases. However, in smart cities, heterogeneous data of formidable

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volume are instantly collected via smart sensors. The massive volume, extreme diversity and frequent updates overwhelm traditional data management techniques. To overcome the shortcomings, innovations of big data analytics, machine learning and cloud computing are utilized to implement data management of smart city.

Sagiroglu & Sinanc (2013) illustrated big data analytics means the process of revealing hidden patterns and secret correlations of large-sized complex data which people have difficulties in analyzing, storing and visualizing. Big data typically are described with three features: volume, variety and velocity. More frequent human activities in the digital world result in exploding volume of digital data created every day. Until 2003, the world had created 5 exabytes of data. 1 exabyte (EB) is equivalent to 10^{18} bytes. In 2016 alone, 16.1 zettabytes of data were generated and 1 zettabyte (ZB) is equal to 10^{21} bytes. Reinsel et al. (2017) indicated data is expected to grow at compound annual growth rate of 30% from 2015 to 2025 and reaches to 163 zettabytes per year. As for variety, the majority of digital data stored in databases used to be structured in a form like a table containing columns and rows, such as spreadsheets. Structured data can be easily searched from databases by simple and straightforward commands. Nowadays, unstructured data that are not organized in pre-defined manners, like text, pictures and videos, increase prominently and are considered to dominate in the future. When it comes to velocity of big data, Reinsel et al. (2017) also pointed out

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a digital interaction between a person and connected devices will on average occur for every 18 seconds by 2025. This means each person will originate 4,800 sets of data each day.

Volume, variety and velocity force people to deal with big data in different ways. To condense big data into knowledgeable information, big data analytics split raw data into independent blocks of data and then process the blocks in parallel with distributed computing resources. After removing redundancy, the processed data are combined together to form the compressed results. Splitting raw data into blocks shortens processing time and allows data processing to be implemented in scalable hardware resources available at that moment. Getting rid of redundancy can effectively reduce data size and decrease cost of data storage.

Machine learning is a technology to enrich computers with abilities to learn, so computers can assist people in analyzing huge data and distinguishing underlying patterns. Machine learning can be categorized into supervised learning and unsupervised learning according to if training data are used or not. An example of data and the corresponding desired results are provided for supervised learning to discover a pattern to best describe the correlations. The found pattern will be applied to handle new data later on. In contrast, unsupervised learning just directly figures out the pattern existing in data. With machine learning for data analysis, messy data can be classified,

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clustered and modeled quickly. Data analysis is not constrained by limited human resources any more.

Cloud computing enables users to ubiquitously access shared configurable software resources, hardware resources and data over the Internet from connected devices and computers. Applications of cloud computing have been emerging vigorously over the past few years because of reduced costs and operational flexibility for companies. Cloud computing applications basically can be separated into three types—Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). Companies rent Information Technology (IT) infrastructures, platforms and software from cloud computing service providers instead of purchasing and owning the equipment and software. Economy of scale for IT management can be achieved by aggregating service needs from several companies. Through the sharing mechanism of cloud computing, companies can minimize upfront capital expenditures and regular maintenance costs of IT infrastructures and concentrate on their core businesses. As for data storage, cloud computing systems are composed by largescale datacenters located globally. Digital assets from various parties can be allocated and deallocated in service providers' distributed systems across different regions. Comparing to centralized data storage, cloud computing is superior in convenient access, alleviated outage risks in a particular geographical region, and scalable usage

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for volatile demands.

Technologies of big data analytics, machine learning and cloud computing are integrated and coevolved together to settle data management of smart city. Only after immense amounts of raw data are transformed into informative knowledge, people can comprehend the world in depth and conduct more intelligent decisions in a data-centric smart city.

4.5 Application

Data fully exhibit their values when they promote actions to improve people's daily life. To implement improvements, practical applications are developed around cities. These applications incorporate results of data management with physical infrastructures and intangible services. A city is a complicated system. Each function of the complicated system interrelates with other functions and the system as a whole performs like a network. Positive network externality appears when one function meliorates. Positive externality intensifies exponentially while all functions progress together. As smart solutions occur across all sectors, a city is transformed into a smart city.

Deloitte (2015) detailed potential smart city applications for various functions,

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covering mobility, safety, energy, water & waste, buildings & homes, health, education, finance, tourism & leisure, retail & logistics, manufacturing & constructions, and government. Applications in mobility are designed to reduce traffic congestion by notifying people real-time parking availability and traffic conditions. Autonomous vehicles can be a novel method to fundamentally overturn commute experiences. Cities' safety can be better protected by smart solutions for risk assessments, crime prevention and emergency alerts. Energy can be consumed more economically with installations of smart meters and bi-directional grids. Water, a vital resource to lives, can be managed with applications of leakage detection, pollution detection and flood forecasts to secure cities' sustainability. Waste management can be adjusted with more flexibility. Applications to optimize energy and power consumptions can allow buildings and homes to be comfortable accommodations while remaining friendly to the environments. Health applications support doctors to diagnose diseases with the latest medical discoveries and assist people in preventive measures. Education can be customized to meet individuals' learning paces and needs. Financial transactions can be immediately executed with convenience and security. Applications in tourism & leisure aid cities to host special events and satisfy surging numbers of visitors. Activities of supply chain can be coordinated to meet dynamic market demands for retail & logistics. Repeating or dangerous tasks of manufacturing & constructions can

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be handled with applications of automation. With platform applications to openly communicate with residents, the public sector can streamline urban planning and policy making.

In the block diagram of smart city shown in Figure 16, a feedback arrow connects the application block and input parameters. It reflects outcomes of applications will eventually influence the environments and human activities. A smart city operates as a looped system. Changes thrive around the whole city system with applications taking place in each function of a city. Then, the city turns out to appear different characters. Smart applications adapt to the new characters and facilitate the city to continue evolving toward a better improved one in the future.

4.6 Technological Merger & Acquisition Deals

Smart city is a bold goal to resolve challenges of future inhabitation. Transforming a city into a smart city is an arduous task that requires efforts dedicated by various parties. Each function of smart city's ICT architecture requests specialized skills and proprietary technologies. Values of smart city can be demonstrated by integrating miscellaneous technologies and consolidating research and development resources of different firms. Therefore, smart city invokes merger & acquisition activities in the

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technology industry.

Verizon Communications, Inc., a U.S. based multinational telecommunications conglomerate, acquired Sensity Systems, Inc., a startup company located in Silicon Valley. Sensity capitalizes on sensors and networks controls of LED lighting systems. Sensity embeds sensor networks in 4 billion worldwide streetlights when replacing bulbs with energy-efficient LED luminaries. The sensor networks collect data for various smart city applications such as traffic management and air quality detection. Verizon sets up its toehold of Internet of Things via the acquisition of Sensity. Combining with its strength in wired and wireless communications, Verizon expands its business footprints into data acquisition and smart applications.

The network equipment and service giant, Cisco Systems, Inc. acquired Jasper Technologies for $1.4 billion in 2016. Jasper Technologies is a private company providing a cloud-based Internet of Things platform. The platform is designed for enterprises to manage connectivity for Internet of Things devices, phones & tablets, and connected car services over cellular networks. This M&A deal equips Cisco Systems with a more complete portfolio for data communication and data management, so the company can simplify the process of launching, managing and monetizing its Internet of Things services.

To better understand how the world moves, Google acquired Urban Engines which

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is a data analytics startup based in Silicon Valley. By using mobile technology, GPS and sensors, Urban Engines collects mobility data from billions of trips and the lives of millions of commuters. The startup exploits big data analytics to derive spatial and timing characteristics of moving things and moving people. After incorporating Urban Engines’ data management skills into Google Maps’ services, Google can help governments and organizations develop smart applications to relief stress on mobility and transportation.

To transform itself from a Personal Computer (PC) company to a powerhouse of numerous connected smart devices, Intel Corporation acquired Itseez, Inc. With technologies of computer vision and machine learning, Itseez can identify and track moving objects and detect human faces & actions from videos. Itseez also supports Advanced Driver Assistance System (ADAS) which recognizes traffic signs, warns lane departure, alerts collision, and detects pedestrians. Through this M&A transaction, Intel solidifies its dominance in Internet of Things and smart applications of autonomous driving, safety surveillance and industrial monitoring.

The above M&A deals are common in that acquirers are relatively much larger than targets. The acquirers take acquisitions measures to obtain specialized skills and proprietary technologies from the targets. M&A activities between two titans of the industry also prevail along with astonishing transaction values. For example,

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Qualcomm Incorporated acquired NXP Semiconductors, N.V. for $47 billion. Japan-based Softbank acquired ARM Holdings located in the United Kingdom for $31.6 billion. In November 2017, Broadcom Limited initiated a record-breaking $103 billion takeover bid for Qualcomm. This M&A attempt shocks the world and provokes turmoil in the semiconductor industry. Qualcomm believed its values were underestimated and rejected this proposal. Broadcom updated its offer with $121 billion in February 2018 and got turned down again because of the same reason. However, as Qualcomm claimed it's still open to more talks with Broadcom on this M&A proposal, the proposal abruptly got terminated because of political intervention.

Companies involving in the three M&A examples all have core businesses in communications products and services. Most of them are worldwide semiconductor giants. They are representative players of the industry and assumed to act as principal participants in smart city's data communication. They used to be either competitors or partners. Smart city brings abundant opportunities and threats follow if they remain still. Attracted by the growth potential and stressed by the lurking risks, the companies change corporate strategies. M&A measures alter their relationships and reorganize competitive landscapes. Ultimately, other companies in the industry are forced to contemplate new strategies. This thesis will concentrate on strategic analysis of the three M&A activities and discuss potential chain consequences for the semiconductor

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industry.

4.7 Strategic Fit

The Qualcomm-NXP Acquisition

Because of its advancement in OFDMA-based technologies, Qualcomm remains the leadership in the 5G technology development. However, the 5G standards will not be fully completed by 2020. It seems that commercialization and monetization of the 5G market can't be carried out in the near future. Besides, the smartphone market that Qualcomm highly depends on is so powerless. How to quickly lock down another promising growth momentum to aid the company during the gap between 2015 and the surge of the 5G market becomes very critical for Qualcomm. Is there an opportunity to immediately inject growth stimulus into the company and also simultaneously create more strengths for the 5G market in the long run? The acquisition of NXP can be a good resolution for this question.

According to IC Insights' forecast on the semiconductor industry, the automotive electronics sector is expected to demonstrate the strongest growth from 2015 to 2020 with a compound annual growth rate at 4.9% (McClean, 2016). One factor that constitutes the growth of automotive electronics is the steady expansion of the global

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automotive market. From 2005 to 2017, the volume of global new vehicle sales increased from 66 million to 97 million per year, which represents a 3% compound annual growth rate (Organisation Internationale des Constructeurs d'Automobiles, 2018). In addition to the primary demand for commutes and transportation, passengers consider safety, convenience, and infotainment systems are essential features of new cars. Besides, more and more automakers and high-tech companies are developing autonomous cars to overturn the experiences of mobility with a smarter way. All these premium features further raise semiconductor contents per car. Automotive electronics occupy increasing proportions of the total car costs, from a level of 2.5% in 1960s to 35% in 2010, and the percentage is expected to enlarge even more quickly with the popularity of electric vehicles (Nelson, 2010).

By acquiring Freescale Semiconductor, NXP leaps other competitors and ranks as the top one automotive electronics supplier in the world. In 2016, NXP led the market with a global market share of 13%, followed by Infineon Technologies' 8.9% and Renesas Electronics' 8.7% (台灣半導體產業協會, 2018). The top 7 suppliers collectively owned more than 52% of the global automotive electronics market, while Qualcomm, which ranked as the 21st supplier, only attained a market share of 1.2%. Therefore, the acquisition of NXP can remedy Qualcomm's sluggish performance in the smartphone market and compensate Qualcomm's weakness in the fast-growing

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automotive electronics market. The smartphone market and the automotive electronics market have distinct customer bases and requirements. The former is controlled by 4 major manufacturers (Apple, Samsung, OPPO and Vivo) and the latter is divided by numerous customers of diverse backgrounds, like Autoliv, Bosch, Continental, Delphi, Denso, Fujitsu Ten, Hyundai, TRW, Valeo, Visteon, etc. Comparing to the smartphone market, the automotive electronics market has extremely stringent requirements for reliability. Any minimal inaccuracy in design and manufacturing of vehicles can consequently result in serious injuries. Due to the safety and reliability concerns, it requires a lot of time and sales & engineering efforts to establish mutual confidence with customers in the fragmented automotive market. Therefore, except for the influx of stable growth, the acquisition of NXP also provides a complementary fit for Qualcomm to expand the automotive electronics market efficiently.

NXP's secure connected devices business line also provides another complementary fit for Qualcomm to construct its dominance for smart city. Qualcomm is proficient in cellular mobile network of smart city's data communication. NXP's expertise in microcontrollers and sensors can stretch out Qualcomm's reach to the data acquisition function. Furthermore, smart sensors constitute wireless sensor networks and form Internet of Things. The acquisition of NXP can promote Qualcomm to pioneer in the Internet of Things market and consolidate development of smart city's data

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communication.

More than complementary fits, the merger with NXP also furnishes Qualcomm with a supplementary fit to reinforce its development of the 5G market. Figure 18 is GSMA Intelligence's illustration of latency and bandwidth requirements for various applications. It represents economic values that can be realized via the 5G network. By achieving the requirement of less than 1 ms latency, the 5G network enables mission-critical services, such as autonomous driving. 5G's high bandwidth supports Internet of Things for billions of connected devices to communicate with each other. Popularity of autonomous cars and Internet of Things can further enhance people's utilization of the 5G network. As mission-critical services can also be executed and Internet of Things can be accessed via the 5G network, 5G cellular phones turn out to be the quick and convenient portal of the whole connected world. Eventually, Qualcomm can greatly benefit from the surging demand for 5G cellular phones, no matter through QCT's IC chipset sales or QTL's patent licensing. NXP's strengths in automotive electronics supply the essential elements of autonomous driving. Its expertise in microcontrollers and sensors is a necessary component for Internet of Things. By combining technologies of both companies, Qualcomm can simultaneously progress developments of the 5G, the autonomous driving, and the Internet of Things markets with highly integrated solutions. In other words, mission-critical services and Internet of Things are

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complementors of the 5G cellular mobile network. By taking the M&A tactic toward applications, data communications, and data acquisition, Qualcomm is shaping the game and changing the added values for smart city.

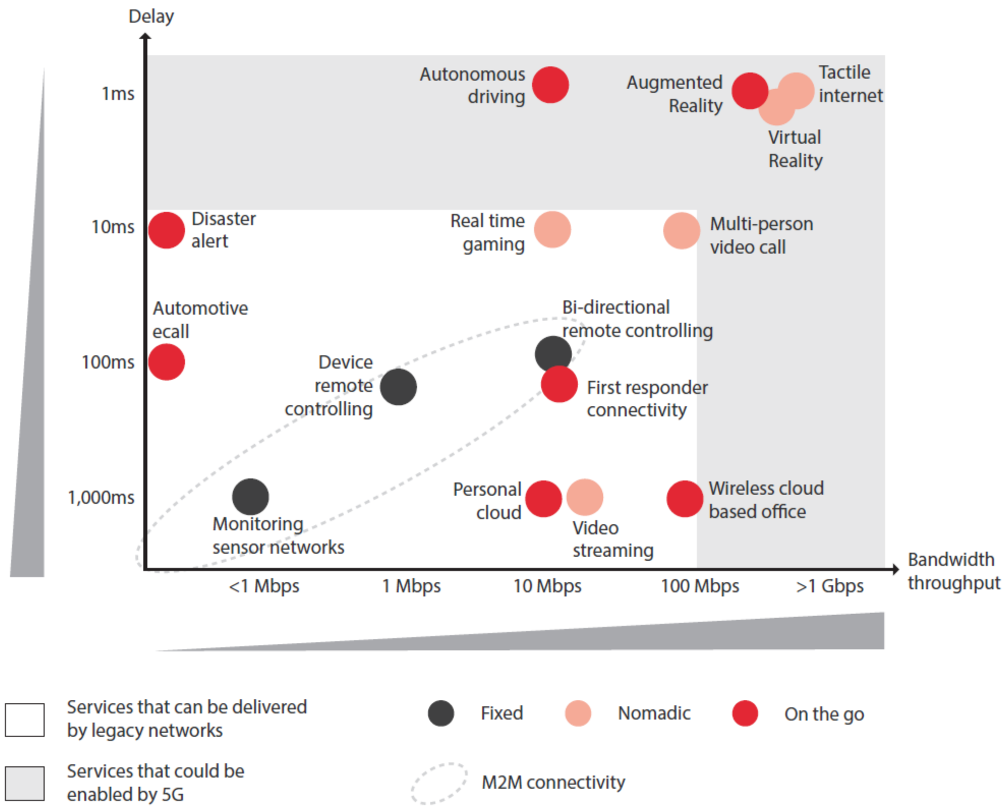

Figure 18: Bandwidth and Latency Requirements of Potential 5G Use Cases

Source: GSMA Intelligence (2014)

Except for diversifications in product lines and customer bases to enjoy operating synergies from economy of scope, Qualcomm expects the acquisition of NXP can

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create cost synergies of $1.9 billion (Qualcomm, 2016[a]). Out of the $1.9 billion, $1.4 billion comes from spending reduction under Qualcomm's Strategic Realignment Plan. $500 million originates from the targeted results of post-merger integration from NXP and Freescale. On July 22, 2015, to respond to the plummeting financial performance, Qualcomm announced the Strategic Realignment Plan to improve execution, enhance financial performance and drive profitable growth (Qualcomm, 2016[b]). A series of cost reduction actions related to research & development and selling, general and marketing expenses were implemented. Massive layoffs were launched. The number of employees decreased almost by 2,500 during the 2016 fiscal year. Particularly in the QCT business segment, jobs got cut the deepest. Besides elimination of positions, annual share-based compensation grants were reduced as well. Qualcomm claims the cost reduction initiatives were achieved by the end of 2016 fiscal year and other activities under the plan were completed by the end of 2017 fiscal year (Qualcomm, 2017). Qualcomm's statements on the $1.4 billion cost synergies and the completion of the cost reduction plan seem conflicting. Till the first quarter of 2018, Qualcomm and NXP still remain as stand-alone entities. Whether the cost reductions on Qualcomm itself can be recognized as the results of "synergies" might be questionable.

However, this doesn't imply there is no cost synergy in the Qualcomm-NXP acquisition. Qualcomm, NXP, and Freescale used to compete in several markets, so

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collectively speaking, duplicate resources do exist. Once Qualcomm acquires NXP, these duplicated resources are very likely to be eliminated. More layoffs might follow China's final approval on the deal. This could be a part of Qualcomm's Strategic Realignment Plan, but the actual effects derived from cost synergies might need to be reconsidered.

The Broadcom-Qualcomm Takeover Attempt

The Avago-Broadcom acquisition in 2015 shocked the semiconductor industry and provoked lots of confusion. Why would Broadcom Corporation agree to be acquired by Avago Technologies whose enterprise value was much smaller than Broadcom? Scott McGregor, Broadcom Corporation's CEO, explained the rationale during Broadcom Asia Media Summit in Beijing in July 2015 (林苑卿, 2015). As user devices are demanded to become more compact and lighter, ICs are requested to not only shrink sizes but also be capable of processing more complicated functionalities. To meet both features at the same time, the semiconductor industry has to rely on advanced manufacturing technologies. Moore (1965) stated "The complexity for minimum component costs has increased at a rate of roughly a factor of two years." The development of semiconductor chips used to follow Moore's Law for decades. The

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semiconductor fabrication becomes more cost efficient when manufacturing technologies reduce sizes of electronic devices to smaller scales. However, due to physical limitations, technical improvements in semiconductor manufacturing slow down as electronic devices have been shrunk to less than 28-nm scale. Manufacturing costs of ICs deviate from Moore's Law and increase prominently. At the same time, IC design costs augment because smaller electronic devices also cause higher degrees of design complexity. Increasing costs will heavily burden operations of small IC design companies. To control the growth of costs, improvements on IC design seem to be a more feasible approach. Broadcom Corporations considered only products providing more comprehensive features can satisfy the demands and eventually survive in the market. To create more powerful products, companies have to own a broad portfolio of intellectual property, which requests a lot of capital and resources to accomplish. Therefore, Broadcom Corporation estimated there will be a spiral effect on the semiconductor industry—the bigger will get bigger, and the smaller will be driven out of the market.

Holding this rationale, Broadcom Limited eagerly pursues a target to provide complementary fits for the coming era of smart city. Broadcom has secured its leadership in the wired sector of data communications. Broadcom also has Wi-Fi, Bluetooth, and GPS solutions for wireless connectivity. However, Broadcom's product

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portfolio still misses the most important core of smart city's data communications, which is the 5G cellular mobile network. By combining with Qualcomm, the leader of the 5G development, Broadcom can consolidate the resources of wired and wireless communications, produce complete end-to-end solutions, and amplify its influences in data communications of smart city. Ultimately, the combined company can dominate the standardization and commercialization of 5G.

Qualcomm's rich intellectual property portfolio will supply the most powerful weapon to compete and the most rigid shield to defend in the smart city market. By acquiring Qualcomm, Broadcom can integrate both companies' intellectual property to optimize IC designs and create products supporting broad features. This will greatly differentiate the merged entity from other IC design firms. Besides, if the two companies keep stand-alone, Broadcom will need to pay unavoidable licensing fees and loyalties to Qualcomm for utilizing the OFDMA-related technologies when it develops wired infrastructure to cooperate with the 5G systems. The acquisition of Qualcomm is beneficial to waive the licensing fees and loyalties, which become even more critical to companies' operations when the semiconductor industry is facing surging costs from both fabrications and designs. With the extensive intellectual property portfolio on hand, the merged entity can create extremely high entry barriers to intimidate other potential competitors.

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Except for consolidating resources of the wired and wireless communications for smart city's data communications, another complementary fit comes from integrating different functions of smart city's ICT architecture. Broadcom has the enterprise storage business for data management. The merger with NXP will extend Qualcomm's business reach to data acquisition and applications. Therefore, following the Qualcomm-NXP transaction, Broadcom's acquisition of Qualcomm will transform the whole combined entity into a total solution provider covering data acquisition, data communications, data management, and applications for smart city.

Once Qualcomm completes the acquisition of NXP, Qualcomm can also provide Broadcom with supplementary fits. NXP's secured connected devices business establishes a solid foundation in the Internet of Things market. Qualcomm dominates the cellular mobile network market. Broadcom has strength in wired infrastructure for the Internet. The sequential acquisitions can allow Broadcom to unite the three key elements of data communications. Emergence of the Internet of Things market and the 5G market will intensify exploitation of the Internet. Consequently, Broadcom's businesses in wired infrastructure and fiber channel will be further reinforced. Besides, Broadcom's enterprise storage business will greatly benefit from fluent end-to-end data transmission among the Internet, 5G, and Internet of Things.

If the two acquisitions are finished successfully, the combined new entity of

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Broadcom, Qualcomm, and NXP represents the convergence of data communications for smart city. In addition to the advantages from economies of scope, the new entity can also enjoy economies of scale to lower costs because of the formidable bargaining power to semiconductor fabrications, assembling, testing & packaging, and distribution. The new firm can also realize cost synergies by eliminating duplicate product lines & human resources and getting rid of the intermediate licensing fees and loyalties. By avoiding competition in the overlapped businesses such as Wi-Fi and Bluetooth, the new firm also enhances its bargaining power to customers and engineering professionals.

Broadcom is ambitious for “Connecting Everything” and is consistent with its rationale for getting bigger. In essence, Qualcomm does seem to be a good target for Broadcom to advance itself and make up the missing pieces for smart city. Because of the technical difficulties and capital intensity to integrate the Internet, the 5G cellular mobile network, and the Internet of Things, a strong player to converge the three networks should be able to remove intermediate transaction costs and speed up the realization of smart city. The strong player’s efforts in shaping the game will be rewarded with tremendous long-term profits. Broadcom tried to challenge for the role, but failed due to obstacles from politics, which were constituted by Qualcomm’s board of directors and the U.S. government.

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The SoftBank-ARM Acquisition

The SoftBank-ARM acquisition seems to be an unrelated diversification from the telecommunications service industry to the semiconductor industry. There are numerous concerns about if there is any value added or synergy created from this transaction, or essentially it's just a move to financially diversify SoftBank's investment portfolio. Faced with these inquiries, Masayoshi Son publicly explained, "I buy at the beginning of paradigm shifts. We are at that moment now with Internet of Things." (Millward, 2016). The company used to encounter several major shifts of the Information Revolution: from PC software distribution to the PC Internet and then to the Mobile Internet. SoftBank believes a world with billions of smart connected devices will be the next shift. That is the so called Internet of Things.

In other words, SoftBank is trying to inspire the realization of smart city. As a telecommunications service provider and an Internet portal operator, SoftBank has been actively involved in cellular mobile network and the Internet. Internet of Things will be the missing piece of smart city's data communications. ARM architecture has been flourishing in the mobile device market due to its strength in energy efficiency and low cost. The same features are extremely critical to smart sensors because of their limited batteries and tremendous volumes. Therefore, ARM architecture is expected to be the dominant architecture of IC design for both the 5G mobile network and Internet of

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Things. If the SoftBank-ARM acquisition is reviewed from the smart city concept, the deal will not be just an unrelated diversification any more. SoftBank bypasses several value chain activities of 5G and IoT devices and straightly implements backward integration. This movement empowers SoftBank to preempt its telecommunications competitors and mobile device suppliers by firmly securing the rare, valuable, and inimitable resource for building up smart city's data communications. Based on this rationale, ARM actually can aid SoftBank's businesses with a complementary fit. In addition, ARM's business also provides SoftBank with a supplementary fit. Once Internet of Things thrives, positive network externality among cellular mobile network, the Internet and Internet of Things will uplift demands for mobile communications and Internet contents. SoftBank's telecommunications and Internet businesses eventually will be greatly reinforced.

Except for considering fits for business portfolio, the acquisition of ARM also financially supplies SoftBank a complementary fit. SoftBank's core telecommunications business approaches to maturity and generates stable cash flows. The addition of ARM's business can enrich SoftBank's financial investment portfolio with potential for mighty growth and high profitability. As for ARM, SoftBank's stable cash flows can support it to expand the emerging Internet of Things market and develop advanced technologies for various smart city applications.

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By comparing the two companies' profitability performances as shown in Figure 12 and Figure 14, people can understand the two companies own very distinct managerial skills. SoftBank has expertise in applying finical leverage and demonstrates admirable achievement in spotting Information Revolution opportunities. In contrast, ARM possesses operations of high profit margin and minimally uses leverage. As end user devices become more sophisticated, circuitries supporting more functionalities will be highly integrated into single silicon chip. If ARM would like to maintain the licensing business model for the long run, the growth of its intellectual property portfolio will need to outpace the demand for complex solutions. No matter ARM chooses to obtain the required technologies via internal development or via M&A, the two approaches both request huge financial resources. Therefore, the merger with SoftBank can provide ARM a complementary fit for agile allocations of financial capital. By doing so, ARM can focus on research & development and intensify its intellectual property portfolio.

More than providing financial resources for long-term sustainability, SoftBank's telecommunications business in the U.S. and Japan also equips ARM with a perfect environment and platform to test and verify its applications for the 5G and Internet of Things. In other words, ARM gains the opportunities to utilize SoftBank's telecommunications networks to improve its proprietary technologies, so ARM can

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differentiate itself from other competitors. Therefore, the merger with SoftBank can expedite the realization of smart city with ARM-based technologies.

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Chapter 5

Conclusions

5.1 Strategic Motivation

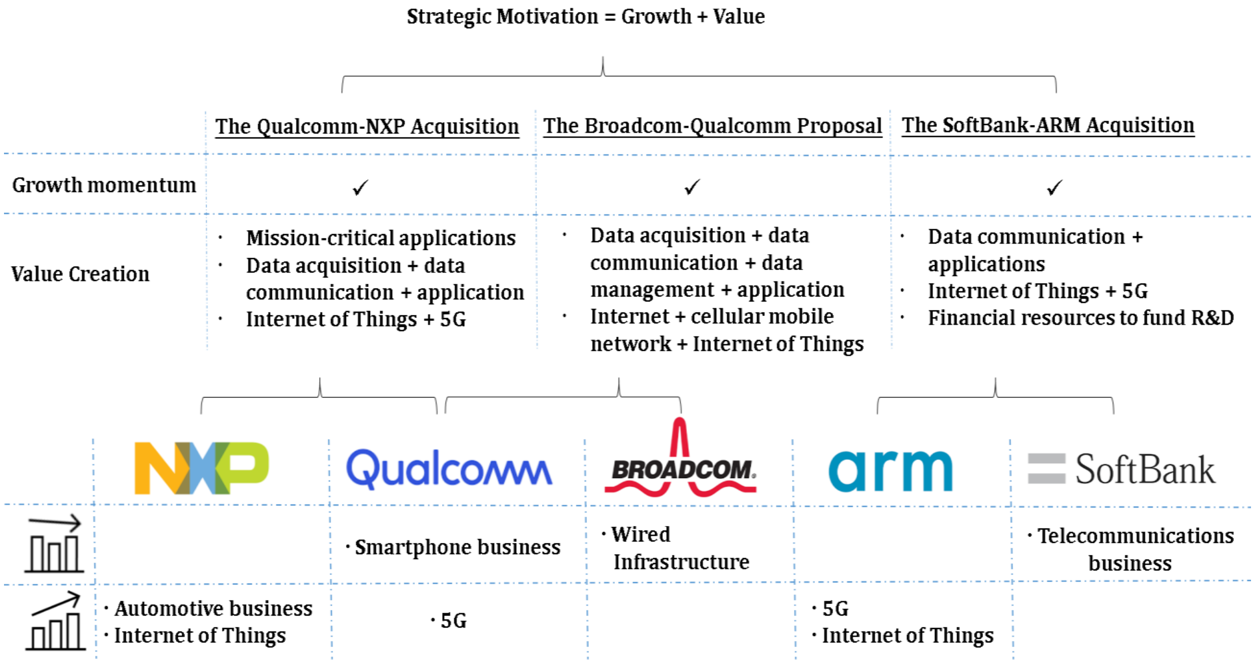

Figure 19: Strategic Motivation

Figure 19 briefly summarizes strategic motivation discovered via this research. In the three cases, all the acquiring firms are faced with potential problems due to its maturity of core businesses. The sluggish smartphone market annoys Qualcomm. High penetration of telecommunications markets caps Broadcom's infrastructure business and SoftBank's carrier services. This situation coincides with the decreasing compound annual growth rate of the semiconductor industry because telecommunications devices and equipment have replaced personal computers as the main driver of the industry's

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growth momentum. While the overall semiconductor industry seems to reach the maturity phase of low growth rate, some sectors start to appear a promising future to rejuvenate the industry. These sectors are all linked to the common theme—smart city.

The target firms of the three cases all possess unprecedented growth potential for data communications of smart city. NXP is a key player of Internet of Things. Qualcomm is leading the world to 5G. ARM will be a critical contributor to both 5G and Internet of Things. Therefore, these M&A activities present the acquiring firms are actively seeking growth opportunities, so they can prevent from involuntarily playing in a deteriorating game. Among the companies, Qualcomm happens to be an acquirer and a target at the same time. Since Qualcomm itself owns characteristics that Broadcom covets so eagerly, why would Qualcomm still pursue after NXP?

This question can be analyzed from two perspectives—growth and value. Qualcomm indeed can grasp the 5G opportunities; however, the 5G standards can’t be fully locked down until 2020. When the 5G network will be ready for extensive commercialization remains as big uncertainty. Qualcomm’s business highly depends on mobile communications and smartphone sales. Without 5G to trigger another massive wave of cell phone replacement, Qualcomm confronts the difficulty in keeping up competent growth for the short term. Therefore, Qualcomm needs NXP’s automotive business to resolve the distress.

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The second perspective is consistent with Broadcom's and ARM's rationale, which is value creation. From the supply side's point of view, the semiconductor industry has been structured in the form of vertical specialization for years. Especially for the IC design activity of the value chain, the whole market is segmented by numerous firms which can survive by just occupying a global niche. However, the bottleneck of semiconductor nanometer fabrication and the increasing complexity of IC design enlarge the costs of ICs. Higher costs challenge IC design companies' operations. IC manufacturers need to deliver more values, so they can uplift customers' willingness to pay. To create more added values, their products have to provide more impressive features. Therefore, some IC design companies are trying to consolidate research & development resources among firms. One way to achieve this outcome is to eliminate the boundaries between firms via M&A.

From the demand side's point of view to illustrate value creation, smart city is a formidable task to accomplish. As smart city is expected to resolve human beings' challenges by exploiting technologies to form total solutions, its implementation requires synchronized coordination between industries and high integration of companies' expertise. Comparing to the ultimate goal, what a niche-oriented specialized firm can achieve is relatively minimal. The organization of the semiconductor industry is too fragmented to efficiently take the responsibility.

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Inestimable transactions costs might be incurred when independent firms try to work together. Negotiations and lack of trust will slow down the progress. To avoid these uncertain factors, industry consolidation seems to be essential. Therefore, M&A maneuvers are launched.

Back to the Research Question 1 about strategic motivation of the M&As, for companies, vision and mission drive development of corporate strategy. In the three cases, the companies all have the vision for smart city. They all end up with implementing M&A as their corporate strategy. As their strength, weakness, and idiosyncratic situations differ, they set up different missions for themselves to accomplish. Qualcomm is "Leading the world to 5G". Broadcom aims to be the company "Connecting Everything". SoftBank is "Leading the Information Revolution to the Next Paradigm Shift". Besides, NXP positions itself to provide "Secure Connections for a Smarter World". ARM is "Architecting a Smarter World". The companies are looking for growth, and they are trying to create more added values as well. The M&A activities nourish them robust abilities to execute the missions and a shortcut to turn the shared vision of smart city into a reality.

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5.2 Influences on Competitive Landscape

Historically, elimination of duplicate resources often comes after horizontal integration. Most M&A transactions are involved with enormous deal values, so they are funded with additional debts. This causes combined companies are under great pressure to achieve cost synergy instantly. One way to eliminate duplication of resources is to discontinue the overlapped businesses. This approach typically will result in layoffs and reduction of competition. In other words, layoffs could happen to the Qualcomm-NXP acquisition and the Broadcom-Qualcomm case as well if the proposal did come true. IC design strongly relies on expert engineers to develop proprietary innovations and optimize chipset performance. Due to their leadership and scales in the IC design sector, Qualcomm, NXP and Broadcom have always been attracting superior engineers. Once the engineers are released from the overlapped businesses, other IC design companies, as buyers of the labor market, could benefit from the surging supply of high-quality human resources. It would be a great opportunity for other firms to enrich talent pools and enhance product performance.

Reduction of competition in IC design will generate direct impacts on downstream activities of the semiconductor value chain. As the IC design market gets concentrated via these M&As, the companies gain higher market power and locate in a superior position to dominate price of outsourced fabrications and testing processes. Profit

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margins of foundries, outsourced semiconductor assembly and test (OSAT) partners, distributors and OEM/ODM might thin due to their diminishing bargaining power. Especially for foundries, the bottleneck of nanometer technology elevates manufacturing costs, which in turn stimulates M&As of IC design firms. If the bottleneck can't be resolved efficiently as component devices keep shrinking, the IC design market could get even more concentrated via more M&As.

These M&As might also induce non-core businesses to be separated and divested, so the combined companies can focus on post-merger integration of more profitable core businesses. In addition, selling non-core businesses can bring in incomes to alleviate financial burdens of the additional debts. Even though the non-core businesses are not essential to the combined companies, they could possibly fit other firms' strategies for development. Therefore, other firms might also launch M&A activities to take over the non-core businesses. This could be one of the reasons why M&As tend to occur in cyclic waves. Once the original equilibrium of competition is disrupted by the first M&A measure, more M&As will be incurred until new equilibrium is achieved. In the Qualcomm-NXP case, Qualcomm operates as a fabless IC design firm, but NXP operates as an IDM. Once the acquisition is finished, NXP's fabrication facilities might be sold to specialized foundries, so the combined company can avoid capital-intensive in-house fabrication and concentrate on its core IC design businesses. This approach

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will disturb the existing balance of competition among foundry firms.

In addition, for IC design companies, M&As consolidate research & development resources and enrich intellectual property portfolios, so the combined companies can create high-end chipsets of more added values. This could raise customers' willingness to pay for system devices. Higher market power and more valuable products favor the combined companies to increase chipset prices. Therefore, end users of system devices might face price elevation once the combined IC design companies conduct the price increase approach.

The smart city-related industry is young and emerging, and the industry concentration is increasing. In previous academic literatures, some researchers explained specializing in an activity does not pay for a firm in a young industry because the industry size is too small. They concluded a new industry usually starts with the form of vertical integration. The semiconductor industry does start to shift toward integration because of smart city. However, unlike the previous experiences, the key factor causing this shift is not because the market size is too small, but because an individual's effort can hardly realize the arduous task.

Qualcomm's acquisition of NXP and Broadcom's takeover attempt for Qualcomm belong to horizontal integration of IC design in the semiconductor value chain. SoftBank's acquisition of ARM looks like an unrelated diversification from one

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industry to another. In other words, according to Porter's Five-Forces Framework, smart city stimulates companies to combine with their competitors and new entrants in the semiconductor industry, or substitutors, complementors, and customers if the analysis is conducted via the Value Net Framework. However, if the M&A activities are examined according to the ICT infrastructure of smart city, different understanding can be derived. By merging NXP, Qualcomm simultaneously performs horizontal integration for data communications and vertical integration toward data acquisition and application. Broadcom's intention to acquire Qualcomm originates from horizontal integration for data communications and comprehensive vertical integration of data acquisition, data communications, data management, and application, after Qualcomm completes the NXP deal. SoftBank's acquisition of NXP can be viewed as horizontal integration of data communications and vertical integration of data communications and application. The new understanding indicates one trend—smart city makes boundaries between firms and between industries become blurry, and decomposition of value chain activities needs to be reconsidered with new definitions.

Moreover, comprehensive intellectual property portfolios differentiate the combined companies with further technical advancement. Leadership of technologies promotes the combined companies to dominant specification developments of the smart city market. Therefore, via these M&As, the companies can instantly build up higher

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entry barriers and block others to share the economic pie. In other words, other IC design competitors are endangered with the preemptive M&As. If they remain still, they could encounter tougher competitions.

If other IC design companies would also like to pursue the high-end smart city market, they will inevitably need to extend their intellectual property portfolios. No matter this task is achieved by acquiring external efforts or growing internally, financial capital is required for realization. Therefore, funding will be the critical element for other firms to develop the high-end market. If the chance to enter the high-end market is minimal, there could be two alternative options for other IC design companies. The first one is to grow with the lower-end sectors. While billions of connected things are needed to realize smart city, companies can try to catch up with the unprecedented volumes of demand by providing chipsets of low power consumption and low costs. The other approach is to identify niche opportunities while the boundaries between industries and between value chain activities for smart city are still ambiguous. By repositioning themselves as total solution integrators, companies can also create unanticipated values. Implementation of this approach would start with redefinition of corporate strategies.

All of the three cases are cross-border M&As. This commonality corresponds to the fact that the semiconductor industry has been evolved to a global market during the

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past few decades. Because semiconductor companies usually can create significant streams to a country's gross domestic product (GDP) and contribute to high-income employment, companies with unique intellectual property of the industry are regarded as valuable assets of their home country. In contrast, they can also be viewed as dangerous threats in the eyes of competitors' home countries. Therefore, M&A activities in the semiconductor industry frequently raise governments' attention.

In the Qualcomm-NXP acquisition, the European Commission expressed concerns that the combined entity could bundle Qualcomm's baseband processor with NXP's near field communication (NFC) and security technologies to forbid rivals and increase royalty fees for mobile payment systems. To make the acquisition approved by the EU, Qualcomm had to commit to exclude certain NFC patents from the transaction. In contrast, the SoftBank-ARM acquisition was very welcomed by the United Kingdom because SoftBank promised to enhance its investment in the UK and doubled the number of employees locally. SoftBank's actions were beneficial for the government to gain investors' confidence, especially when the country's future looked gloomy because of Brexit. Broadcom's acquisition proposal for Qualcomm was blocked by the U.S. government due to impairment of national security. The U.S. government clearly stated that the U.S. position in the 5G market could be intentionally weaken by this deal. This will allow Huawei, a giant manufacturer of telecommunications equipment, to

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replace Qualcomm to dominate the standardization of 5G. The U.S. government's intervention exhibits its belief that Qualcomm's leadership in setting 5G standards is a special asset which should be cherished and well protected by the country. Furthermore, the emerging smart city market will be an important battlefield for future international competition.

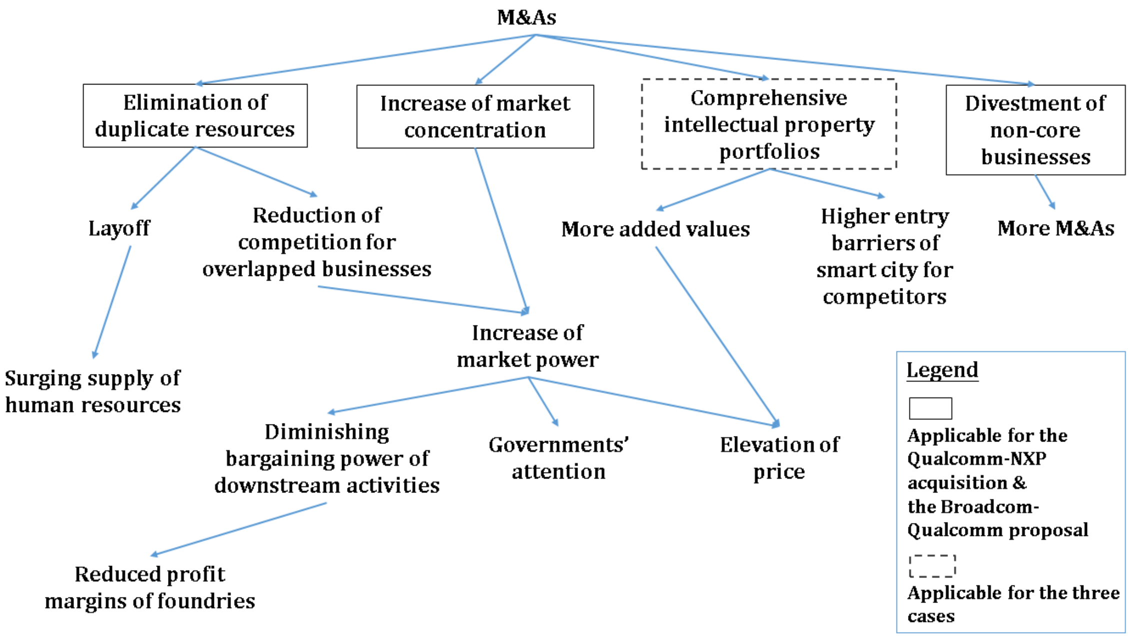

Figure 20: Influenced on Competitive Landscape

Figure 20 summarizes the causality to address the Research Question 2. As IC design of the semiconductor value chain is getting concentrated, the downstream activities of manufacturing, assembling, testing & packaging, and distribution will relatively locate in an inferior position for bargaining. Especially for semiconductor

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foundries, the bottleneck of nanometer fabrication technologies is one of the major factors provoking M&A activities of IC design companies. If fabrication costs can't be efficiently controlled, the industry consolidation might continue and profit margins of semiconductor fabrication can shrink unavoidably. As for other IC design companies, smart city will be a crucial trial for their intellectual property, financial capital, and abilities to integrate distinct skills into amazing total solutions. If intellectual property and financial capital are extremely challenging to get secured immediately, these companies might have to emphasize cost leadership or thoroughly search for any opportunity to become an excellent total solution integrator while industry boundaries are still ambiguous and have not been clearly reconfigured with new definitions.

5.3 The First Milestone

Since smart city is a strenuous task to conquer, where should the ICT industry start the first step? The three cases symbolize that the specialization boundaries among cellular mobile network, the Internet, and Internet of Things have been gradually erased because of the concept and vision of smart city. As the three networks get integrated, network externality originating from one of the networks will greatly spill over to the others. Therefore, securing leadership in Internet of Things and the 5G network

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represents dominance of smart city's data communications. Currently, the 5G mobile network is the most critical component to the realization of smart city. Once the 5G network performs as the world anticipated, the Internet of Things will be fully merged into and become a part of 5G. At that time, mission-critical services can be enabled and people can have ubiquitous connectivity to the whole smart world. Therefore, when the 5G network is available for massive commercialization, applications for smart city will sprout and countless economic values will be created accordingly.

The 5G network is so important to smart city and future economic growth, so the U.S. government intervened Broadcom's takeover proposal of Qualcomm. The 5G standards are currently under development by the 3rd Generation Partnership Project (3GPP). The 3GPP was founded in 1998 to collaborate regional telecommunications standard setting organizations from the United States, Europe, China, Japan, South Korea, and India. The 3GPP originally aimed to develop a globally applicable specification for the 3rd generation (3G) mobile communications systems. As time passes by, its scope has been extended to develop global technical specifications for 2G, 3G, 4G, and 5G. Therefore, if a company's outperforming technical features are adopted as the official specifications of the 3GPP, the company will quickly gain overwhelming competitive advantages in the global telecommunications market.

Qualcomm is the leading company of OFDMA technologies and aggressively

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works with the 3GPP to finalize technical specifications of 5G. To ensure its dominance in 5G's standardization, Qualcomm has to devote huge research & development efforts to technology advancement, so the engineering world can be convinced by feasibility of the technologies. Huawei and Samsung are also active participants of the 3GPP activities. That Huawei closely shadows Qualcomm in 5G technology development stimulates the U.S. government to take preventive measures in Broadcom's takeover proposal.

Therefore, the Broadcom-Qualcomm case reflects the world's proactive attitude toward smart city. Commercial deployment of the 5G network is the first milestone of building up smart city. To change the game of smart city, companies and countries are investing heavy resources in 5G technology breakthrough. That's because the control over the 5G development essentially signifies companies' and countries' leadership in the gigantic smart city market.

5.4 Future Research Suggestions

The unprecedented growth of global urbanization challenges the world's sustainability. Technology is recognized as the key to overcome the difficulty by transforming cities into smart cities. This digital transformation disrupts industries and

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inspires companies to take M&A measures as corporate strategies. This thesis ascertains strategic motivations of M&A activities in the information and communications technology industry and their impacts on competitive landscapes. After analyzing three megadeals (the *Qualcomm-NXP* acquisition, the *Broadcom-Qualcomm* proposal, and the *SoftBank-ARM* acquisition) in the semiconductor industry, the thesis discovers the acquirers are faced with mature core businesses, so they select the targets of strong growth potential in the emerging smart city market. Except for growth, the companies are also actively pursuing value creations. As costs of semiconductor fabrication can't be significantly reduced, IC design companies identify silicon chips have to perform more features to deliver more added values. Besides, highly integrated solutions are essential to efficiently realize smart city. Therefore, comprehensive intellectual property portfolio is getting more crucial to companies' competitive advantages. To enrich intellectual property portfolio, abundant financial capital is needed. Without powerful financial support, bidders of M&A transactions can easily turn out to be others' targets later on.

While IC design of the semiconductor value chain is getting consolidated, companies working on downstream activities are gradually losing bargaining power. Profit pools of the semiconductor industry will be redistributed because of the M&A activities. Especially for foundries, that the development of fabrication technologies

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deviates from Moore's Law might keep provoking the consolidation of IC design. Profit margins will be negatively affected because of the staggering progress of technical development. In addition, since the semiconductor industry has been global specialization for decades, M&A activities are very likely to happen across borders and seriously change global competition dynamics. Furthermore, smart city is expected to create tremendous economic values. Governments tend to be more sensitive to technology M&As to secure their shares in the growing economic pie. Among various technologies, the 5G mobile network is the first milestone toward the realization of smart city. Internet of Things will be merged as a portion of the 5G network once 5G systems are ready for commercialization. To succeed in the explosive 5G and Internet of Things markets, IC design companies have to invest in intellectual property, invent low-power & low-cost products or provide attractive total solutions.

This thesis tries to derive implications from three prominent M&A activities of the semiconductor industry. The implementation of smart city relies on high integration of various technologies. However, the ICT industry is segmented by players of different sizes and expertise. Therefore, more analyses for small-sized firms and for other sectors of the ICT industry would be beneficial to verify generalization of the discoveries. Furthermore, the discoveries are developed purely based on public information. Conducting interviews or surveys on the involved management teams should improve

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thoroughness and deepness of clarifying how the vision of smart city affects companies' M&A decisions.

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