ISIGrowth

INNOVATION-FUELLED, SUSTAINABLE, INCLUSIVE GROWTH

Working Paper

The Dynamics of Innovation in the Wireless Telecom Industry during two Eras of Technological Convergence, 1995-2015

Henrik Glimstedt
Stockholm School of Economics

09/2017 May

This project has received funding from the European Union Horizon 2020 Research and Innovation action under grant agreement No 649186

THE DYNAMICS OF INNOVATION IN THE WIRELESS TELECOM INDUSTRY DURING TWO ERAS OF TECHNOLOGICAL CONVERGENCE, 1995-2015

Henrik Glimstedt

Stockholm School of Economics

May 22, 2017

This project has received funding from the European Union Horizon 2020 Research and Innovation action under grant agreement No 649186

ABSTRACT

This paper traces the changing dynamics and strategies of innovation in wireless infrastructure industry, covering three major phases: (1) massive adaptation of wireless services in the 1990s and the Internet Cries, (2) the smartphone revolution and the trends to commoditization of wireless systems and (3) search for new profitable growth in services, cloud and Internet-of-Things. It analyses the development of the specific industry character: role of open industry standards as pathways for innovation, the continuous leadership of vertically integrated incumbent system integrating vendors, the regionalization of communication markets, and the development of telecom regulations. It shows how the equipment industry's continuous massive R&D efforts (i.e. 3G, HSPA, HSPA+ and 4G wireless systems) enabled the smartphone revolution, whilst the intensive competition among wireless operators trickled down to the incumbent equipment vendors in terms of a lethal mix of requirements for high-performing equipment and very competitive pricing, a combination which undermined vendor's margins. In the process, industry incumbents shared new generations of technologies with new innovative Asian entrants through the open standards regime, leading to more global and heated competition. As the competition developed from "regionalized and moderate" to "globalized and intensive", both European incumbents and Asian entrants explored services and software as new areas of profitable growth. In particular, the paper analyses how the industry players, in stiff competition with the 'IT giants' and platform leaders of the Internet economy, are seeking leadership in cloud and Internet-of-Things through the launch of the 5th Generation wireless services, to be standardized in 2020. To explain the competitive outcomes in the different periods outlined above we need to link two levels of the analysis:

- *Firm Level Sources of Competitiveness*
    - *Strategic commitments and business models*

    - *Governance of internal resource allocation and the social organizational integration of knowledge, capabilities and resources within the company, as well as with external suppliers and partners*
    - *Financial resource commitments*
- *Standards and the Industry Architecture*
    - *Governance of wireless standard setting processes, regional and global*
    - *Governance of and business models for knowledge integration of evolving technologies within generations of standards*
    - *Short-term and long-term impact of industry architecture on firm-level performance*

Introduction

On February 22nd 2016, Hans Vestberg, then the CEO of Ericsson entered the stage at the annual World Mobile Congress in Barcelona. In his keynote address, "Partnership for Innovation", Vestberg focused on how collaboration and new ways of working spurs innovation and creates new solutions, especially partnerships between Ericsson and the two tech giants Cisco and Amazon should foster innovation-based growth. In his presentation, Vestberg stressed that the partnership would add further muscularity to Ericsson's far-reaching ambitions to become a leader not only in the 5th Generation. In turn, this would strengthen Ericsson in its role as integrator of other rapidly advancing IT-technologies, such as cloud computing and sensors, into what the industry calls the Internet-of-Things (IoT from hereon).[1] Few could question Ericsson's role as one of the long-term sponsors of the visions of the *connected society*. It was one three leading competitors, sponsoring the long-term evolution of mobile broadband technology, Under the bold heading of *50 Billion Connected Devices,* the company have persistently advocated a strategy for connecting machines into wireless networks.

The hype around IoT at did not surprise the people that continuously watch and discuss the evolution of the mobile telecom business. The buzz surrounding IoT connects to a bigger drama that now impact and shape the wireless telecom sector globally. To get a glimpse of these current affairs, we need to appreciate the real impact of the smartphone revolution on today's telecommunications sector. Whilst the vision of digital wireless services included the notion of wireless data and internet access from the mid-1990s, it was the introduction of smartphone that unlocked promise of 3G mobile networks. According to research by the international wireless industry association, the average adoption rate for developed markets of 84% is approaching saturation whereas the number of

[1] As the CEO one of the three undisputed world leaders in mobile communications systems, this was far from Vestberg's first address at the WMC. His presentation would however become his last one in this capacity as the CEO of Ericsson. About nine months later, he was asked by Ericsson's chairman of the board of directors to step down. There were issues regarding Vestberg's generous compensation package, the lackluster performance of the stock and the company's future competitive position against its competitors. Whilst the disappointing trends in revenues and profit margins in the current 4G markets clearly undermined Vestberg, the board was also concerned about his ability to chart a course and drive execution for revitalization of Ericsson in the next generation of communication technologies.

users still are growing at higher pace in Asia, Latin America and Africa (GSMA 2017, 12). Smartphone adoption is accelerating across the developing world; there were 3.8 billion smartphone connections at the end of 2016, accounting for more than half of total connections (excluding M2M) worldwide. Adoption rates have reached 65% of the connected base in developed markets. Smartphone connections in the developing world reached 47% of the total connections base by the end of 2016, largely due to growth in Asia Pacific and Latin America (GSMA 2017, 12). In Sub-Saharan Africa, the take-off is imminent. Market research for Nigeria, for example, indicates that over 80% of all internet users rely on smartphones as their sole on-ramp for access to the Internet (Ericsson 2015b, 7). The growing number of smartphones and other advanced devices drive the increasing the use of 'data intensive' applications, particularly video streaming, on mobile networks. This has amounted to an explosion of data traffic. The growing number of smartphones and other advanced devices (e.g. tablets) are increasing the use of data-intensive applications, such as video streaming, on mobile networks. Cisco (2017) estimates that smartphones generate massive amount of data traffic compared to feature phones[2]. The increasing use of mobile broadband-enabled smartphones will generate an explosion of data traffic, with volumes forecast to grow at a CAGR of 57% to 2019, an almost tenfold increase, with volumes to grow at a rate of ca 50% over the next five years – a more than seven-fold increase – approaching 40 EB per month by 2020. This is equivalent to a global average of 7 GB per subscriber per month (GSMA 2015, 14f)

One the smartphone technology diffused, mobile network operators invested continuously in infrastructure to update their network and deploy new technologies. To meet demand for mobile data, furthermore, operators stepped up their investment plans, particularly by adding more capacity to the mobile networks. The mobile CAPEX is a good indicator of the level of investment performed by mobile operators. One the one hand, operators have rolled out more 3G/HSPA equipment as a short term solution. By doing so, their networks can accommodate more data traffic without reducing the cost efficiency of the

[2] In 2016, the typical smartphone generated 48 times more mobile data traffic (1,614 MB per month) than the typical basic-feature cell phone (which generated only 33 MB per month of mobile data traffic. (Cisco 2017)

networks. Operators have also moved onto the next technological stage by rolling out cost-effective network equipment. New network technology generations such as HSPA+ or LTE, that is 3.5G and 4G, more than halve the cost per gigabyte with their increased capacity per site, still relieving network capacity constraints.[3] According to a report by IDATE, the consultancy, there has been a pattern of uneven development. Generally, the most recent technologies were deployed most broadly in the North American, Japan and South Korean markets. In those markets, LTE deployment reached between 70 and 95%. In the large European markets, i.e. UK, Germany, Italy and France, CAPEX investments have, however, been almost flat over the past few years in Europe. One direct consequence of the lack of investment has delayed the LTE take-off (IDATE 2015, 7).[4]

As the smartphone became widely used across large parts of the populations throughout the world, the sheer growth of demand for wireless services has been stunning, However, the financial well-being of mobile operators are suffering from the widening disconnect between the demand-side developments, that is the market penetration of data intensive smartphones, and the revenues that operators can command on the supply-side. While most operators are managing to grow their top line with mobile data, there is a treacherous undercurrent. The usual economies of scale, it seems, malfunctions in the following way: mobile data ARPUs are not delivering the same financial margins as voice (which relies on quality service [*latency]* rather than high *bandwidth* as for data transfer). A significant share of smartphone customers became unprofitable because mobile data offers are mainly structured around bundled, flat-fee plans. Operators were lacking, under the current bundled business model, capabilities to transform increasing demand into revenues and profits. The increasing data traffic per user

[3] HSPA+ and LTE are expected to support three to five times as much traffic as HSPA (7.2 MBit/s) with the same spectrum, reducing cost per gigabyte by 40 to 70 percent compared with the currently implemented network (Grijpink et al, 2016, 23).

[4] As also noted by IDATE Consulting (2016), the contrast between EU5 and other regions is even more striking when taking into account the respective size of the markets. CAPEX per population (pop) ratios display the amount of money spent per inhabitant (EUR/inhabitant). CAPEX per pop ratios are much higher in Asian countries and in the USA than in EU5. It is the highest in Japan with more than 100€ per pop per year, whereas the USA and South Korea are respectively at EUR 80 and EUR 60 per pop per year. Europe again falls behind with a widening gap towards the USA during the 2008-2014 period of time at less than EUR 40 per pop in 2014.

has not matched the ARPU, the average revenue per user. Since 2010, this disconnect has developed into global problem, although it is most pronounced in the European market: "Although the emerging mobile data arena will prove to be a sizeable growth engine for most telecom operators…", McKinsey reported, "… preserving its long-run profitability could become a significant challenge and priority for operators." (McKinsey 2012, 3)"

For the period between 2006 and 2014, research by Research Center on Regulations in Europe shows, the average price tariffs in the OECD countries steadily declined with around 50% for the period, or almost 2.2% per quarter (Genakos, Valletti, and Verboven 2015, 14). Operators in countries with a low degree of market concentrations reduced tariff prices at a somewhat higher pace than in in countries typified by competition between many smaller operators (Genakos, Valletti, and Verboven 2015, 16) . Adding to this toxic situation, top-line growth slowed down around in 2014. Western Europe, according to Ovum, an London-based market intelligence group, expects see very limited revenue growth in the period between 2016 and 2018. By 2019, Western Europe will experience revenue decline also in real terms. For all other regions, revenue CARGs will be modest, or around 2%. Central and Southern Asia and Africa is predicted to grow faster than average, at of 5.1%, 4.5%, and 3.6%, respectively, through 2019 (Ovum 2015, 11). At the heart of this un-development is the increasing cut-throat competition on data plans for smartphones, which on average is 50% lower in Europe compared to other developed markets .

With shrinking market cap and average return on capital employed for major European operators, such as Vodafone (UK), Organge (Fr) and Telefonica (Sp), telecom CEOs began to look consolidation through M&A. In 2012 and 2013, European authorities gave the green light to minor attempts to consolidate in smaller regional markets but also a more significant merger, i.e. Telefónica's 2014 takeover of E-Plus in Germany, which stimulated a slew of merger proposals. European competition authorities however struggles to strike a balance between protecting the regional operator's business while also protecting their customers. In 2016, Brussels for example decided to block the much-anticipated merger of O2 and the UK branch of Hutchison's Three. As

emphasized of independent industry analysts, FT reports, the collapse of the deal leaves both operators in a precarious situation (Financial Times, May 11, 2016). This is an unsustainable situation that threatens both the long-term health of the telecoms industry.

Trickling down of cost-pressure to wireless infrastructure equipment vendors

No other group of actors in the mobile communication industry, most observers agree, feels the operator's dire situation more deeply and profoundly than the four leading full-service manufacturers of mobile systems – Huawei, Ericsson, NSN, ZTE and Samsung. To meet operator's seemingly endless demand for capacity Since the coming the second generation digital services 1990s, equipment vendors have engaged in continuous innovation in new generations of radio access technology and core system products to meet the operator's seemingly endless needs for high capacity at constantly lower costs. Yet, the development of operating margins in key product areas, such as radio base stations, suggests that wireless connectivity has been put on a trajectory towards commoditization in a maturing market.

Network capacity expanded primarily through innovation. Between 2006 and 2015, the R&D investments by Huawei, Ericsson, Qualcomm and their peers in evolved and new generations of wireless infrastructure technologies resulted in major increases in network efficiencies. Especially new network and spectrum technologies such as 3G HSPA+ and 4G LTE technologies opened up large amounts of capacity to the operators. The equipment vendor' brought those innovative were brought to the market at high cost. Ericsson, which is most heavily specialized in wireless equipment, is a case in point. With 1/3 of the workforce (or 21,400 employees) in research, Ericsson's R&D spending 2012 at 32.8 billion kronor ($4.9 billion), and accounted for 14.4 percent of the Stockholm-based supplier's sales. On average, Ericsson R&D/sales ratio amounted to 15% of its revenues on R&D between 2006 and 2015. In real terms, R&D expenses have increased from 27bn in 2007 to 36bn SEK in 2015 (Ericsson 2015a). Huawei has consistently increased the proportion of funds invested in R&D relative to turnover. R&D/Sales ratio for Huawei --where almost half of its workforce is in

R&D-- was 13.7 percent in 2012. Since 2013, the Chinese vendor reports that R&D spending growth at a higher pace than its revenues. These levels are typical to the industry. On average, the industry leaders --Huawei, NSN Networks (Nokia-Siemens-Alcatel-Lucent) and Ericsson-- allocated on average 14,6% of their annual incomes to R&D between 2011 and 2014. The average combined R&D-spending by the leading equipment vendors 2011-2014 reached $57,7bn in total. In broad strokes, the equipment vendors have to different degrees focused their R&D-efforts in four areas:

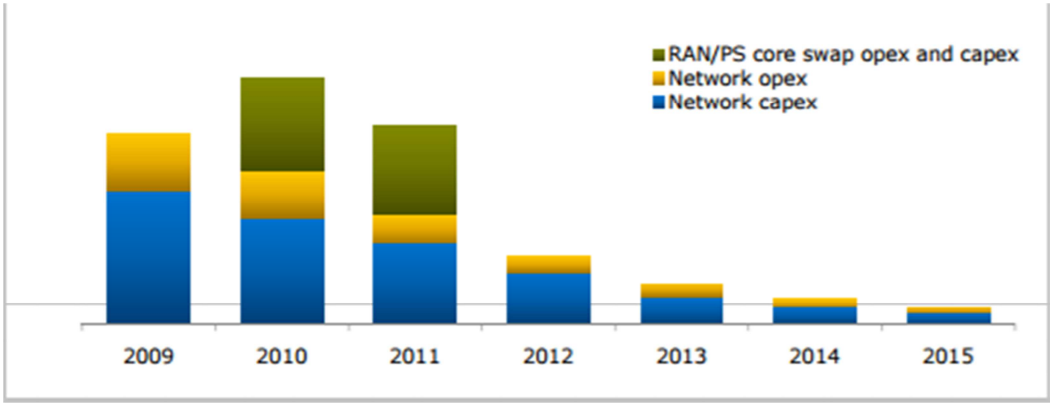
- spectrum efficiency and radio access/antenna technologies,
- IP systems (i.e. core/edge routers and Ethernet switches),
- network virtualization, data center technology and software defined architecture (i.e. decoupling of network hardware, functions and control
- signal processing technologies (i.e. software algorithms and ASIC architecture).

Despite the R&D intensiveness, the equipment vendors increasingly experienced a profit squeeze. Particularly in the European wireless markets, operators began to take full advantage of the rivalry between incumbent equipment vendors and low-cost entrants (i.e. Huawei). The unusual combination of high R&D-cost and falling revenues naturally undermined the financial results of the equipment vendors. Huawei, the tremendously successful company that gobbled up markets shares with promptness for the decade in all parts of the global market except in the US between 2006 and 2016, experienced the benefits of double-digit growth. Still, the operating margin has remained below 15% between 2012 and 2015. In the same period, Ericsson posted operating margins between 6 and 8%, with a jump up to 12% in 2016 due to aggressive cost-cutting (through implementation of the Profit Plus initiative). For the sector, the combined operating margin averaged at 7,3% between 2009 and 2015 (Xerfi Global 2016, 58).

What thus typifies the vendor sector is commoditization of wireless connectivity *and* the high pressure on R&D to deliver spectacular technological advances. Without these cost-saving innovations, the demand from today's data hungry end-consumers would not have been possible to meet neither

economically nor in technical terms. Research by independent analysts, such as Analysys Mason (2013) and Booze Allen (2013), shows that, for investments in latest LTE equipment, the ToC per unit of network capacity has decreased with no less than 95% compared to investments in 2.5 or early 3G technologies. Published reports by Telenor points in the same direction: the operators are increasingly getting a 'bigger bang for the buck'.

Diagram 1: Figure 1: Development of Network Spending per Gigabyte, 2009-2015



Adopted from: (Spilling 2016)[5]

Peter Laurin, senior vice president and head of Ericsson's global sales to Vodafone, confirmed in an interview with the author that network cost efficiency have increased between one hundred and two hundred times between 2006 and 2016, depending on site utilization (Larurin 2016). Even if being great news for the customer, who enjoys the benefit of dirt-cheap data plans, it is however a far more troublesome development for the equipment vendors. For each invested Euro in R&D –it seems-- the financial returns to innovation shrinks even further.

Internet-of-Things: the Light in the Tunnel

So, here we are at a juncture in the evolution of the mobile communication business where means and ends do not quite match -- at least not for equipment manufacturers. No wonder that Ericsson and its peers spent so much time on IoT at the MWC. As the stakes got higher, the participants of the MWC were not only looking for answers concerning how big the pie will be, but also what companies

[5] Telenor presentation by Rolv Olof Spilling, CTO, https://www.telenor.com/wp-content/uploads/2012/03/cmd10-02-2-rolv-erik-spilling-modernisation-of-the-mobile-network.pdf

will lead the way into the profitable business models. While previous generations of mobility solutions were put to the market by a closely knit group of incumbent players – wireless system vendors, phone manufacturers and the mobile operators – IoT involved a much broader range of software and hardware companies from all corners of the world of information and communication technologies. To the companies that dominated wireless connectivity industry (e.g. Vodafone, Ericsson and Huawei) the prospect of IoT meant that their incumbent positions were challenged by all types of companies that lead in the now converging sectors (e.g. IBM, General Electrics, Accenture, Amazon, Cisco, Google, Oracle or Apple to round up some of the usual suspects). They were all asking the same questions: which position in the IoT value chain will capture most of the value; who will lead and become the incumbent dominator of the IoT? Therefore, many executives that addressed the 2016 WMC put heavy emphasis on new partnerships just like Vestberg did. Executives were trying to draw the attention to the emergence of new technologically capable combinations of companies (under their direction) that together would provide 'industry leadership' into the technological convergence that now was called IoT. In other words: the new visions technological convergence have triggered a tendency towards attempts to create partnerships for market domination.

Convergence -- a *deja-vu*

For people with long experience of the communication technology and services sector, there is something peculiar about current events. Particularly term *convergence* has a familiar ring. In the 1990's and in the years around the new Millennium, operators and vendors alike used the term to flag for a series of technological shifts, or 'generations of technologies' in the wireless communication business that would integrate voice, data and entertainment services.

Table 1: Mobile Services: 1G-5G

Generation	Target Customer	Primary Service	Differentiation	Weakness
1G	Wealthy people and corporate	Voice	Mobility	Poor spectral efficiency; major security issues
2G	B2C; broader consumer segments	Voice + SMS	Secure mass-adoption	Data limited to SMS
2.5	See above	Voice + SMS + WAP	First attempt at data	Very limited data rates
3G	See above	Limited broadband	Better Internet experience	Performance failure, too much hype
3G HPDA	See above	Wireless Broadband	True Internet browsing	Still too tied to legacy architecture and protocols, but
4G	See above	All-IP	Fast broadband, cost-reduction	
5G	B2B services; IoT	All-IP	Fast, low latency	

Source: GSMA, 2016

Few, if any, industries has so systematically linked the concept of *generations* of innovative technologies in the marketing of equipment and services as the wireless telecom operators and the wireless equipment vendors.

The transition from 3G to 4G services has offered users access to considerably faster data speeds and lower latency rates, and therefore the way that people access and use the internet on mobile devices continues to change dramatically. Across the world operators are typically reporting that 4G customers consume around double the monthly amount of data of non-4G users, and in some cases three times as much. An increased level of video streaming by customers on 4G networks is often cited by operators as a major contributing factor to this. The Internet of Things (IoT) has also been discussed as a key differentiator for 4G, but in reality the challenge of providing low power, low frequency networks to meet the demand for widespread M2M deployment is not specific to 4G or indeed 5G.

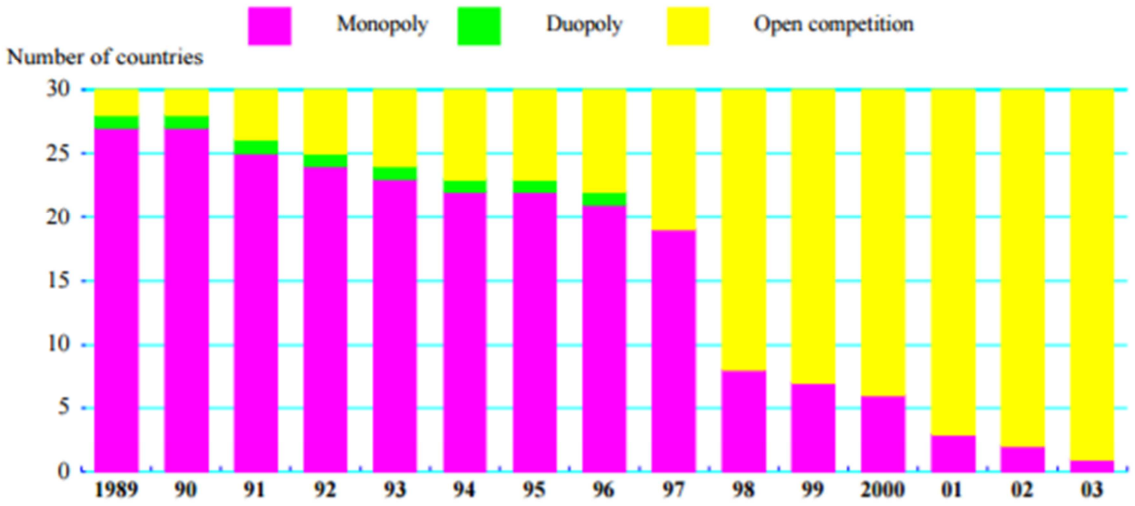
Re-regulations and privatizations: paving the way for new generations

Throughout the European Union countries, the regulatory framework of the telecommunications industry changed radically during the 1980s and l990. In particular, the vision of a common integrated wireless telecommunications market was at the center of these developments. Already in the 1980s, the process of privatization and re-regulations world transformed the emerging

wireless sector. While national telecom authorities and their international organization a major part, the Commission of the European Communities believed that the implementation of a pan-European wireless service was essential to the more general aspirations for the integrated European market (Garrard, 129-130.). In particular, the Commission of the European Community developed a series of policy documents – so called White Paper and Green Books – from 1984 and the mid-1990s, broadly defining a path forward towards a deregulated, internally harmonized, competitive and fully integrated European market for telecommunication services[6]. Starting in 1988, through a step by step approach, the EU liberalised all segments of the telecoms market: terminal equipment, value-added services, satellite equipment and services, cable TV networks and mobiles communications. This process culminated in 1998 with the liberalisation of voice telephony and infrastructures. To create a unified EU-wide telecoms market, common rules were needed for the purpose of continuous technological integration and harmonization. This was done by the establishment of the so-called Open Network Provision – or ONP Framework. The purpose was to set the rules for open access to the networks of the old monopolies so that the new entrants could offer services in competition - on equal terms - with the ex-monopolies. Under the new set of rules, national regulators were required offer spectrum licenses to at least three new entrants that were encouraged to compete with the ex-monopolist operator in the provision of mobile services.

[6] There is an excellent literature on the development of European telecommunications policy and its impact on the evolution of the wireless sector. This section draws in particular on (Garrard 1998, Glimstedt 2001, Lazer and Mayer-Schonberger 2001, Lembke 2002, Pelkmans 2001, Zysman and Schwartz 1998)

Diagram 2: Market liberalization, OECD area, 1989-2003



Adopted from: (OECD. 2004)

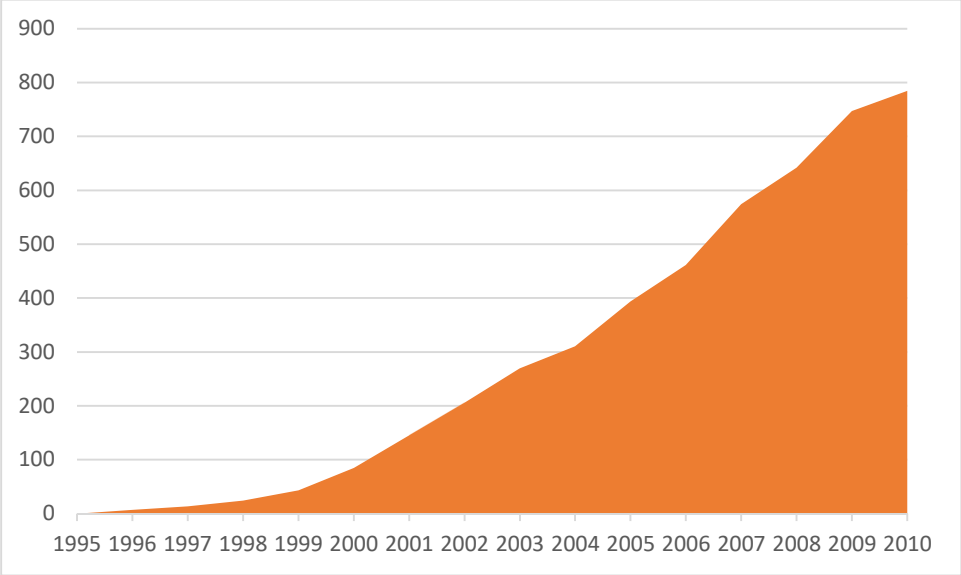
In parallel, European policymakers influenced the wireless market by pressing hard for a set of common wireless standards –GSM and UMTS—in order to stimulate innovation as well as economies of scale in the wireless communication sector. Harmonization of spectrum represented a necessary condition for market integration across the different member states. New standardization agencies were established with a mandate to open markets to competition, prevent incumbents from abusing their position and avoid collusion between national operators. Other actions were undertaken to liberalize the industry, including number portability and carrier selection. In addition, progress was made towards the privatization of state-owned operators.

Almost a full decade ahead of Europe, the de-regulation cycle in the United States was in full swing by the mid-1980. The break-up of AT&T monopoly paved the way for wireless operators. By the middle of the 1980s, FCC began to issue wireless phone licenses for dedicated rural and metropolitan areas, and by the first generations wireless operators began to deploy analog cellular wireless systems in the United States, i.e. United/Sprint, Bell Atlantic, GTE, AirTouch/Verizon) and Cingular/AT&T VoiceStream/T-Mobile. Beginning with Vodafone (1986) and SFR (1989), British and French regulators issued wireless to private wireless operators in Europe.

Demand and Growth

Even if there were tendencies to a growing demand for cellular services in the 1980s – we all recall the mobile phones in the size of a regular brick as a symbol for success in movies in the 80s – the inclination of people to embrace the mobile services came as a surprise also to the most enthusiastic tech evangelists. From the mid-1990s, demand for wireless cellular services grew also in developing world. In China alone, the number of subscribers increased from 3.63 million in 1994 to nearly 200 million by 2002. A few years later, China Mobile surpassed Vodafone in terms of number of subscribers.

Diagram 3: China's subscriber base, in millions



Source: ITU Database

With more than 4,7 billion unique subscribers in 2016 globally, mobile market penetration reached 63% of the global population. In one or another way, more than two thirds of the global population has access to mobile services (GSMA 2016).

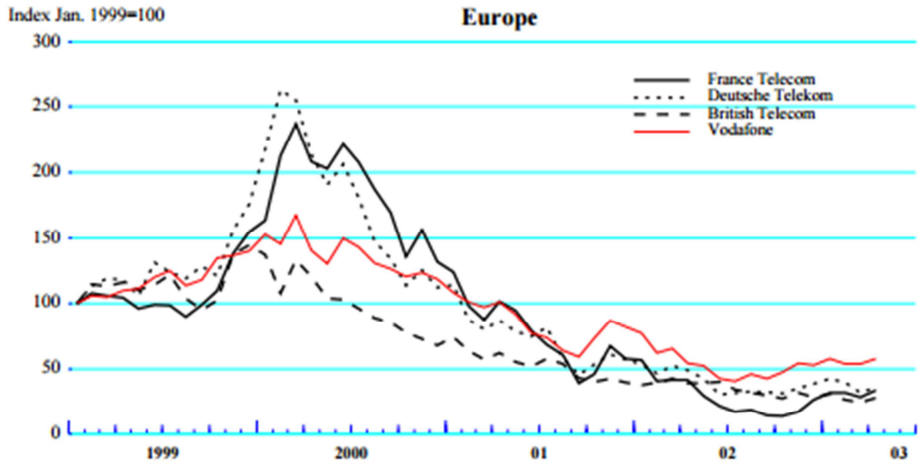
From 'New Economy' to 'Internet Crises'

In 1980s and 1990s, telecom operator executives began to worry about tendencies in the ITC sector. One thing seemed almost certain: a technological cocktail consisting of three ingredients --Moore's Law, optical networking and TCP/IP—

would sooner or later disrupt the incumbent operator's fixed telecommunications business. If a phone call could be routed over the Internet instead of switched through the operator's networks, it would be impossible for operators to defend the pricing. Therefore, there was a widespread agreement that "voice over IP" would destroy the 'closed circuit business model'. In that scenario of disruptive innovation, wireless as added value services fitted in perfectly as a substitute for the shrinking fixed line business.

The arrival of wireless services was timely. Customers did not just increase in numbers; the amount of average revenue per user increased was pushed upwards as customers both made more calls and adopted more innovative services, e.g. SMS and pre-paid. With dramatically better growth and EBITDA-margins around 40% for wireless operators (as in the case of Vodafone in 1999), the business case seemed clear -- technology would pay-off sooner than later. Financial investors flocked around the opportunity of providing wireless telecommunication as a relatively expensive service in rapidly growing markets.

Diagram 4: Value of European Telecom Operators 1999-2003



Adopted from (Lenain and Paltridge 2003).

When the wireless industry began to push for the notion of convergence between IP and voice services through the concept of "wireless internet" in the late 1990s, the financial market's expectations on the arrival of a so called *new economy* triggered a financial boom telecommunications companies. Valuations of wireless

operators increased beyond all expectations. Both financial markets and public policy were eager to profit. When the government issued bidding for 3G-licenses to mobile operators, the financial markets did not flinch. They were more than eager to as they proved to be willing to pull together financial backing for the operators multi-billion bids in the 3G-spectrum auctions between 2000 and 2002 (Binmore and Klemperer 2002, Van Damme 2002). The financial market's eagerness to risk big money in telecom peaked at the Millennium. In an action the ran in March 2001, the British government raised 24 billion £ (or 34 billion $) in what was frequently called the "biggest auction ever" (Binmore and Klemperer 2002). The 3G-auctions fetched no less than 45,9bn$ in Germany and 10,1bn$ in Italy. Smaller countries, as Norway, offered 3G licenses for between 200 and 500 million USD. Only months after the British auction, the telecom operators would be drawn into a sharp industry recession. For more than three years, 'the internet crises' offered but long shadows over the telecommunications industry in the period between summer of 2001 and early spring 2004. British Telecom (BT) was a case in point: In the period of deregulation in the 1990s, BT transformed itself from a British operator to world telecommunications provider, collaborating in joint venture named Concert with AT&T and investing in Asia-Pacific region to provide global reach. The Internet Crises saw a complete reversal. Concert was dissolved, BT divested across Asia, and mobile operations in Europe were sold-off. BT's chairman and CEO have both resigned following the 3G disaster. As Sir Peter Bonfield, BT's CEO frankly admitted to the Sunday Times, London, 18 February 2001, 'We spent £10 billion too much'.

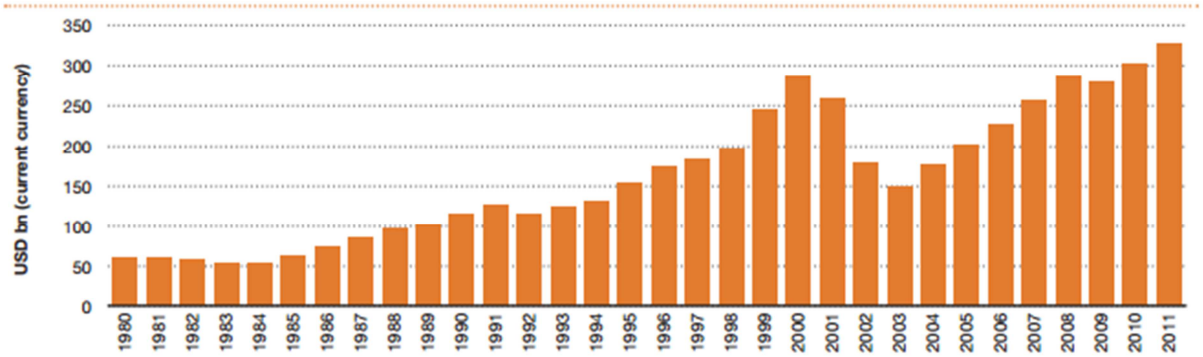
Having rushed into financial traps laid by government in the 3G auctions, Sir Bonfield was the only one among his peers that lost his bearings. Similar series of events shaped the misfortunes of France Telecom, Deutsche Telecom, Vodafone, KPN and Telefonica, which all, by 2001, carried outstanding debt. Typically, the levels varied between $62bn (France Telecom) and $31bn (KPN). According to the *Financial Times*, stock market valuations of telecommunication companies had fallen by an average of 60 per cent by September 2001 from their high point in year 2000. Taking into account the write-offs, bankruptcies and

closures worldwide, "probably $1000 billion gone up in smoke" (FT, 5 September 2001).

Implications for equipment vendors in the 1990s

In optimistic 1990s, however, the financial craze proved to be 'manna from heaven' for wireless equipment vendors, at least in the shorter term. With the financial markets were eager to channel vast sums into the wireless sector and the end-users willingness to sign up with operators at high prices per minutes, the wireless operators were heavily induced to invest in network capacity. In 1990, operators invested CAPEX around 50 bn$ per year in network equipment. A decade later, their combined CAPEX soared to 250 bn$ on the yearly basis.

Diagram 5: Global CAPEX in the Telecommunications sector, 1990-2011



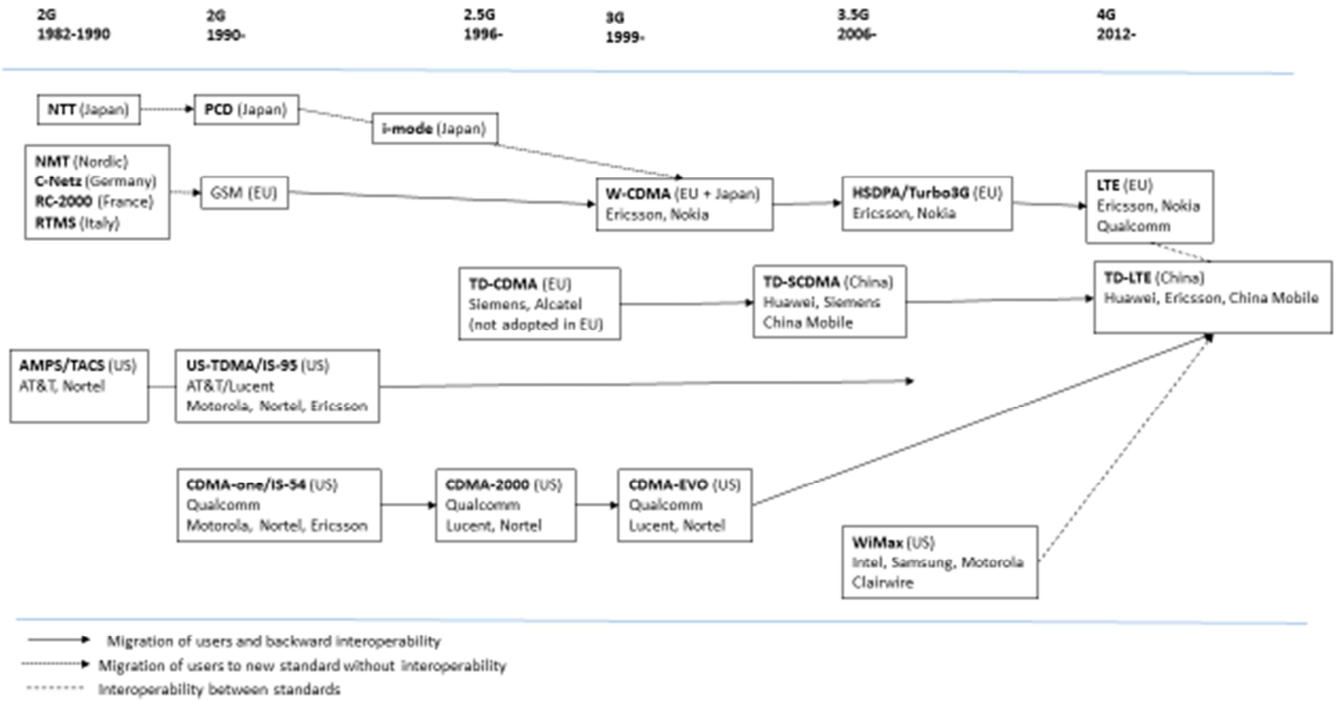
Sources (Reynolds 2009)

According Reynolds, around 60% of those investments were directly linked to increased wireless networking capacity. Accumulated capital investment by telecommunication operator Verizon between 2004 and 2007 was larger than the capital investment of major industrial companies, including GE, IBM, mega-sized retailers like Wal-Mart, leading energy companies such as Exxon Mobile or Conoco Phillips, automobile manufacturers such as GM and Ford and consumer product companies such as Johnson and Johnson, in the same period (Reynolds 2009, 15).

Standards – pathways to innovations

Due to the need for interconnectivity in communication systems, innovation in wireless technologies is closely linked to standards and standardization processes. The general development forward from 1G to 4G wireless broadband services followed distinct technological paths with clear trajectories, which defined wireless standards. For the different generations of wireless services, European, North American and Asian standards development organizations (SDOs) sponsored different wireless standards, which in turn were building on different technologies and system architectures.

Figure 1: Evolution of Standards by area of origins and major sponsors



Source: Author's analysis

When 1G analog wireless cellular emerged in Europe and Japan, it did so under the auspices of national monopolist operators. Hence, the technological coordination and standardization was led by the national operators, often with assistance of their national suppliers. The objective was to serve a small niche of the national telecom markets. In the United States, FCC commissioned to AT&T

to draft the standard that FVCC defined as AMPS, which was published as an open standards and adopted also in the UK (as TACS). The Nordic operators a similar 'open' approach to standardization through the joint standardization of the NMT-system. Although critical, the market impact of analog systems were limited: By 1990, only a handful European countries had reached above one percent market penetration: the Nordics (between 5% and 7%), Switzerland (2,6%), United Kingdom (2%). European policy makers, who were now about to pave the ways for the European Single Market, pushed hard for de-regulation of the communication sector, including a common European wireless standard (GSM), which would enable Europe-wide wireless services. In a not always so light-handed manner, the Commission of the European Community pulled strings and pushed national regulators, operators and telecom equipment manufacturers into the GSM standard in order to generate major economies scale, lower prices and future-oriented notion of innovative wireless data services. If pan-European powers were instrumental in shaping the politics of the first common European wireless system, the technologies upon which the standard was building were drawn from many different sources. GSM developed technologically as a bottom-up process in which competing wireless vendors contributed different technological solutions to the standard. GSM evolved as *intra-standard competition* (competition within the standard), meaning that the companies that originally designed the standard thereafter competed against each other by offering GSM-systems (as opposed to offering systems of a different standards as in the pre-GSM era).

In the US, the FCC favored the idea that each vendor should develop its own standard. I would then be up to the 'market', that is, to operators and individual subscribers to choose between existing standards, according to the principle of *inter-standard competition* (competition between standards). This became evident when FCC supported the standardization of IS-54 developed by Qualcomm in parallel with D-AMPS (IS-95), which had roots in the collaboration between AT&T and Motorola. Qualcomm also worked closely with Asian operators, particularly with South Korea's telecom operator and Korean hand-set manufacturers, to expand the basis for ISA-54 into Asia.

Table 2: Overview of Wireless Standardization Regimes in Europe and United States

	CEPT (-1988	ETSI 1988-1994	ETSI/3GPP (1994-	United States
Market scope	National	European	Global	Global
Role of operators	Major; direct	Declining; in-direct; also through MoU	Limited; direct	Limited, indirect
Role of equipment vendors	Limited; indirect	Growing; direct	Growing; direct	Major; direct
Role of national governments	Major, indirect through nat operators	Limited; indirect	None	Limited
Role of EU	None	Active; indirectly supporting EU-based vendors and operators	Active; indirectly supporting EU-based vendors and operators	--
Basic principle	Formal standard (by committee)	Hybrid: Competition within standard	Hybrid: Competition within standard	Market: Competition between standards
Implication	Government (through the monopoly operator) decide over standards and its technical underpinning in national markets	EU politics decide on a framework for a common standard; equipment vendors and operators agree on technical underpinnings	EU politics decide on a framework for a common standard; equipment vendors and operators agree on technical underpinnings	Regulator neutral. Any actor can develop and submit a standard. The market (operators) are free to choose from competing standards
Outcome	Fragmentation between countries	Common standard (GSM)	Common standard (UMTS, LTE)	Competition between standards and fragmentation within the US market
Architecture	Closed	Open	Open	Closed

Sources: (Bekkers 2001, Cowhey, Aronson, and Richards 2008, Funk 1998, Funk and Methe 2001, Garrard 1998, Glimstedt 2001, Lindmark 2002, Palmberg, Bohlin, Iversen, et al. 2006, Palmberg, Bohlin, Saugstrup, et al. 2006, Pelkmans 2001)

With the policies that promoted integration and competition in the European market, the battle over markets shares resulted in quality of services, technological innovation as well as in reduced prices.

From Standard to Product Innovation

There has been a widespread celebration of the wireless equipment vendor's commitment to innovation in wireless broadband. While the generations of

wireless technologies often has been referring to the evolution of wireless air interface technologies, that path to wireless broadband has been building on the (far less discussed) process of integration of thousands of discrete product developments into a new complex system of wireless technologies. Intensive long-term research efforts and innovative productive development in areas transport optical technologies, transport protocols, package switching, routers, ASIC-design, software-based features from the 1980 and onwards thus provided the basis for the different generations of mobile broadband services. Although patents cannot be regarded seen as a particularly good indicator of research intensity, it is worth noting that the number of essential patents tripled between the second and third generation and quadrupled between the second and fourth generation.

Table 3: Major innovations in radio base station technologies by generations

	Analog 1G	Digital 2G	Digital 2.5G	Digital 3G	Digital 3.5G	Digital 4G	Digital 5G
Interface Technology	FDMA	TDMA	GPRS EDGE CDMA	WCDMA	HSPA HSPA+	OFDMA	
Bandwidth	2kb	64kb	144kb	2mb	4mb	1gb	10-100gb
Switching	Circuit	Circuit	Packet	PacketATM	PacketATM PacketIP	All- IP	All-IP
RBS volume (in liters per voice channel)		14 l/channel	8 l/channel	4/channel	2 l/channel	0,l/channel	
RBS mode	Single mode	Single mode	Multi-mode	Multi-mode	Multi-mode	Multi-mode	Multi-mode
Signal processing		1M	5M	20M	20M	50M	
ASIC tech			0,25um	0,13um	90-65nm	32nm	
Essential patents (claimed)		13 853		43.658		61.833	

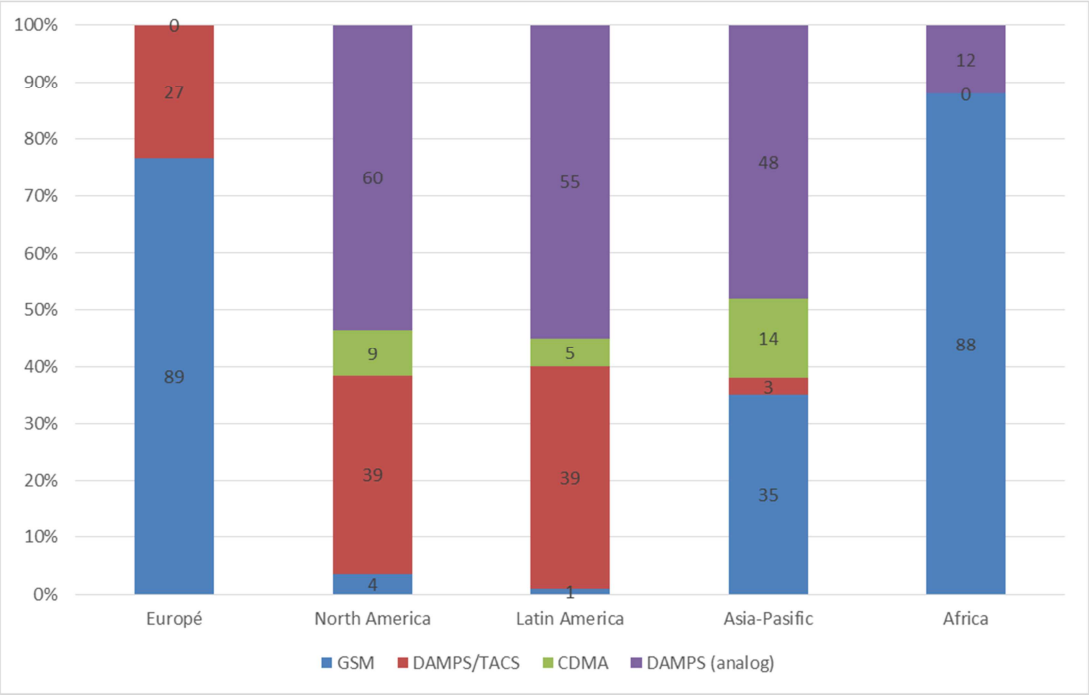
Source: author's analysis of Ericsson (Macro) RBS 200, RBS 3000 and RBS 6000 series

Regionalization of competition

GSM became a European success story in the 1990s, as European wireless operator converged in their decisions to move into the digital services through the GSM system. GSM marked the end of the fragmentation of wireless services. The

second generation was just a few years into deployment when its main backers in Europe looked for a way to build on momentum created by GSM.

Diagram 6: Wireless Standard's Market Share by Region, 1999



Source: ITU

The plan was to make Europe a powerful center of 3G, a process which would integrate wireless voice services with more expanded "Internet-like" services. However, the GSM-technologies were not enough scalable to support wireless broadband services. In the mid-1990s, there were considerable efforts on upgraded GSM services (i.e. GSM 2.5, supported by EDGE and GPRS). But most actors within the industry would soon come to the conclusion that, if wireless broadband should become a technological reality, they would need to shift to a new technology. One feasible alternative technology --all parties now agreed by the mid-1990s -- was a technology called 'spread spectrum' (or CDMA), which had been developed and deployed in 2G-mode in the United States (and Korea) by Qualcomm as IS-54. In the 1980s, CDMA spread spectrum technology was generally held to be a superior wireless technology, but only so in theory and in experimental sites. For real market applications, it was considered to be too complex. Qualcomm, a San Diego-based company, however proved the sceptics wrong by developing a set of patented technologies that solved the major issues.

Within Europe, the European Commission funded large-scale research programs on different wireless broadband technologies. One group, including Siemens and Nokia, tried to extend GSM technology by adding elements of CDMA. The other group, led by Ericsson, focused on a 'wideband' version of spread spectrum technology, later called W-CDMA.

EU thus deployed its supra-national policies to pull together Europe's universities, equipment vendors and other relevant actors into a coordinated European plan for 3G. According to the European principle of competition between of different pre-standards, a range of technology consortia were therefore invited into the standardization process to challenge the two main candidates. At the end of the selection process, Europe would stand united behind one 3G-technology to be called UMTS just like it rallied around the GSM standards for second generation in the late 1980s. After a period of trials negotiations and a voting process between 1997 and 1999, ETSI announced its winner: UMTS was to be based on the concept of W-CDMA pioneered by the consortium led by Ericsson.

Equipment vendors quickly dedicated resources to the development of third generation already when the second generation systems won market traction. Most operators agreed with the vendors that the future wireless services would involve some kind of extended added value 'Internet-like' services. Therefore, equipment vendors competed to establish a third generation so that operators would be locked-into a secure path of technological up-grades. If operators would opt for UMTS as its third generation technology, the operator would be locked into GSM for the second generation to secure full back-wards compatibility between generations. In other words: establishing UMTS was a way of selling second generation GSM-equipment.

The notion of the UMTS as a 'launch pads' for European wireless operators and equipment vendors created debate in the United States. Particularly Qualcomm argued that the European standardization process excluded non-European firms from contributing to the European standardization process whilst Europe, furthermore, infringed on Qualcomm's vast portfolio of patents. In 1998 and 1999, this matter was bought up for negotiations between the US and

European Commission through an intervention by the US secretary of State. Much like the prelude to the GSM standard, also the third generation of wireless services attracted interest at the highest political levels involving the US secretary of state, and high-ranking EU officials (Glimstedt, 2001).

Table 4: Inter-Standards Competitive Groupings by Wireless Standards: vendors, operators and countries

	GSM W-CDMA, LTE	CDMA, CDMA2000	TD-SCDMA	WiMax
Leading Vendors (in 1999)	Ericsson, Alcatel, Nokia	Qualcomm, Nortel, Lucent	Siemens, Huawei, ZTE	Motorola, Intel, Samsung
Flagship Operators	Vodafone, AT&T, China Unicom	Sprint, Verizon	China Mobile	Clairwire, Sprint
Geopolitical	Europe, Japan	USA, South Korea	China	Silicon Valley

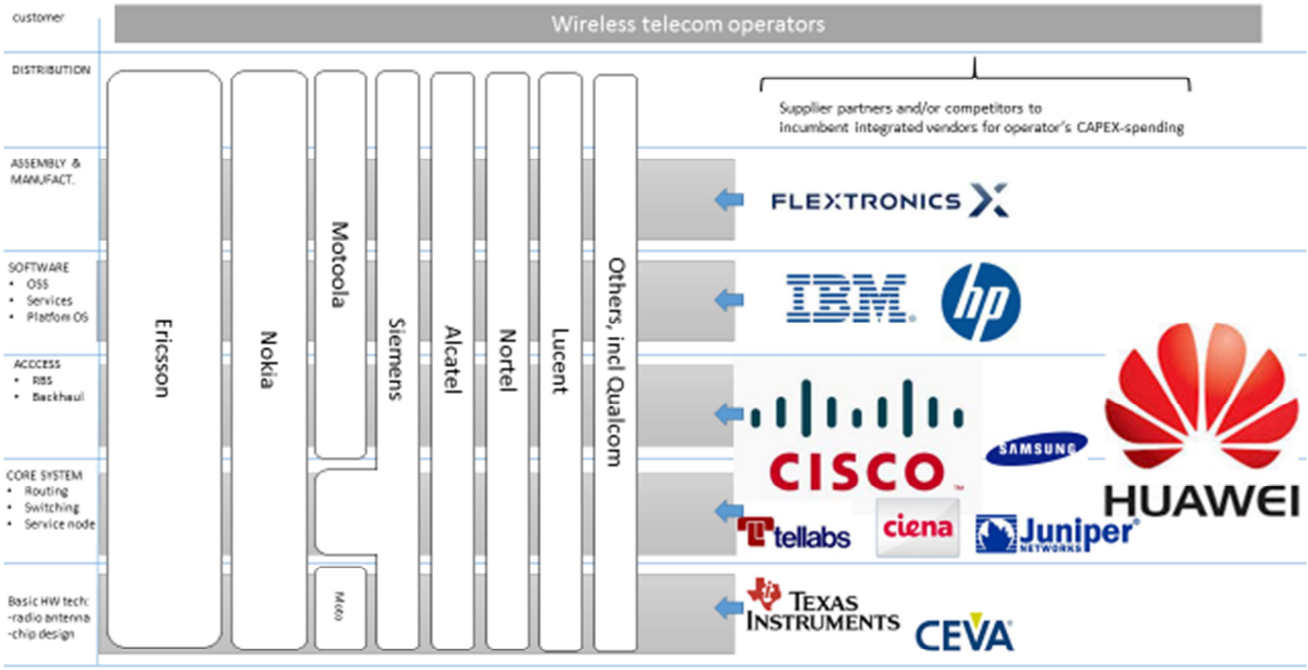
Source: the author's analysis

China also entered into the game. Already before China's entry into GATT, the Chinese government began to plan for expanding wireless services in China's gigantic market. One of the issues discussed among China's leaders was the dependence on foreign standards and the cost of foreign patent royalties. Thus China began to review its options, as they saw a 'battle-of-systems' in wireless technologies with two opposing main camps -- Qualcomm of the United States joined by the South Korean handset manufacturers *versus* Europe's UMTS with its allied partners, including Ericsson and Nokia. The Chinese government played two cards simultaneously: It wanted to to kick-start 2G wireless services through making deals with both the European camp and the camp led by Qualcomm. In addition, the government initiated research collaboration around a new 3G-standard (TD-SCDMA) sponsored by China to be deployed by the leading domestic operator, China Mobile, in order to reduce the dependence of technology.

Incumbent and entrant firms under uncertainty

Broadly speaking, by the late 1990s there were two basic types of innovating equipment vendors in the wireless industry. On the one hand, incumbent telecom system vendors (such as AT&T/Lucent, Nortel, Ericsson, Siemens, Alcatel and Nokia) were the early system integrators in 1G and 2G technologies. These firms made the heaviest investments in R&D, spending 15-20% of the revenues on research and product development, they developed and agreed on standards, that is the basic system architecture design, and they captured the position of incumbent providers of wireless telecom system to the wireless telecom operators across the world. In essence, they mastered the art of designing and building complex wireless systems consisting of infrastructure as well as mobile phones and integrating the systems into the operators already existing 'legacy' circuit switched voice-systems. With the introduction of NTT's wireless network, also Japanese competitors entered the wireless systems business.

Figure 2: Figure: Incumbent OEM in the late 1990s (by revenues and business model) and new entrants (by value chain segments)



A second category of firms entered the wireless industry with the increasing importance of data services and package switching from the late 1990s and

onwards as the community of incumbents prepared the way forward towards 3G systems. 'Red hot' new economy companies, like Cisco, Juniper; Ciena, Redback and Tellabs, responded to the new opportunity by entering the wireless core network market with their powerful IP router technologies. Among the entrants, particularly Cisco were successfully responding the operator's demand for large-scale core- and edge network routers. At the Millennium, Cisco's line of service provider routers (i.e. Series 7500 and Series 12000 introduced in 1995 and 1996) captured no less than 50% of that market. Other IT actors, like HP, Accenture and IBM, were making inroads into the telecom operator market. *Business Week* (Nov 4, 2002):

> "The situation facing telecom today is eerily like that which confronted the info-tech business a decade ago. Proprietary products are being superseded by cheaper open systems built from off-the-shelf parts. Vertically integrated giants such as Ericsson, Lucent, and Nortel Networks are being undercut by newcomers such as Cisco Systems…just as IBM and Digital Equipment were battered by low-cost *PCs* from Dell Computer."

Being strengthened by its staggering success in network routers, Cisco pushed boldly into new markets and was believed to be the future 'king of the hill' in the competition for the operator's infrastructure investments. Nowhere was Cisco's swagger about its disruptive capabilities more apparent than in the company's unflinching attempt move into the telecommunications-equipment market, and thus into the market domain which was controlled by powerhouses as Nortel, Lucent, Siemens, Alcatel, and Ericsson. After her interview with John Chambers, Cisco's [former] CEO, on Cisco's attempt at disrupting the telecom equipment vendors, journalist Stephanie N. Mehta writing for Fortune, the business journal, offered the following thoughts:

> "With his patient speaking style and West Virginia drawl, he made Internet Protocol, or IP, seem somehow less intimidating. When he called rival telecom-gear makers 'old world' companies, his tone was

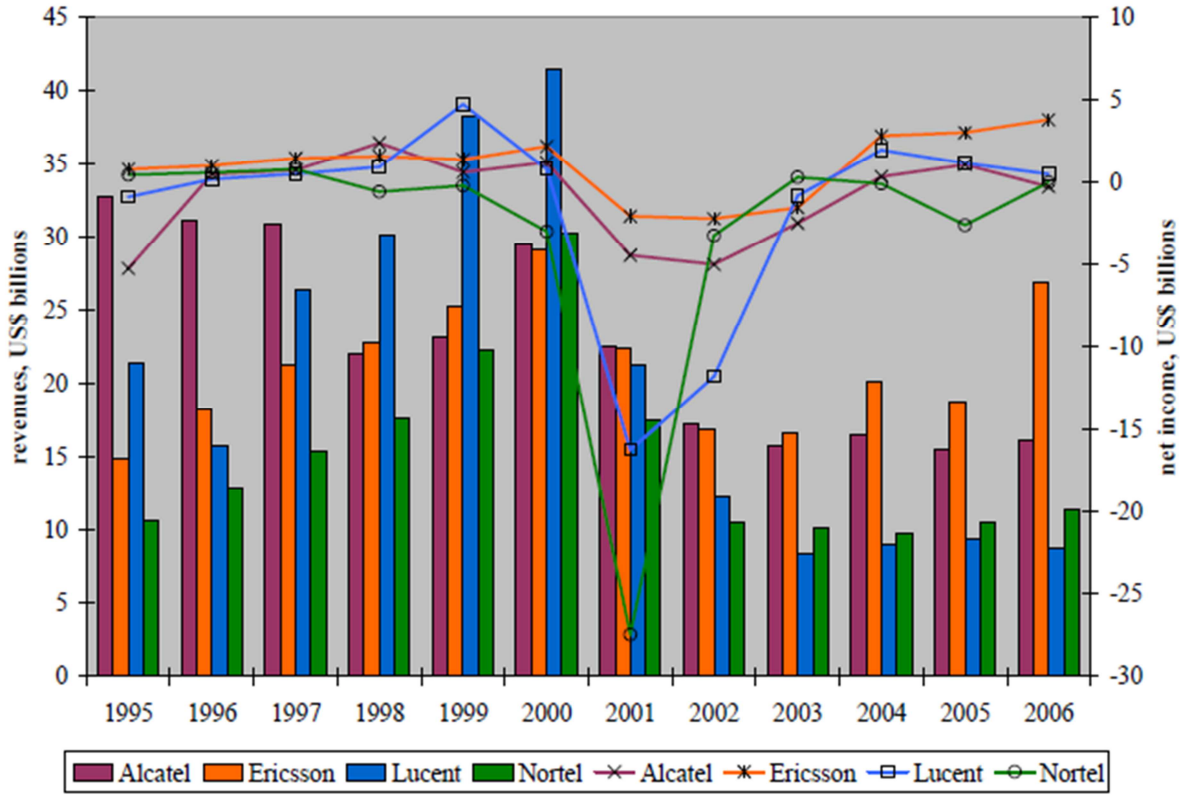
never mean-spirited. Rather, it was almost as if he felt sorry for them" (*Fortune*, May 14, 2001)

In Asia, China's domestic telecom market grew very fast during the 1990s. Among the Chinese vendors serving the developing Chinese market, Huawei transformed itself from being a distributor of PBX-switches (private office telecom switches) into a highly capable provider of digital fixed line switches. Drawing on an alliance with Bell Shanghai, the former distributer designed its own digital switch (C&C08), which no Chinese competitor could rival in terms of price and performance. Huawei owed its success to the ability to integrate externally sourced know-how with its massive internal R&D-investments. With the same speed and precision Huawei absorbed GSM radio base station technologies, which was followed by the company's own full-line offering of wireless system products. Due to its unique grip on Chinas systems, Huawei's engineers were in an advantageous position when it came to develop and implement wireless 'added value' components (e.g. pre-paid and text messaging) in the Chinese telecom infrastructure. With original design of innovative low-cost line of GSM products, Huawei began hence to have impact also outside China in the late 1990s.

Before these questions would find their answers, the communications industry went from boom to bust in the Internet Crises that begun as a reaction in the US stock market when the high level of financial leverage proved unsustainable. Stock prices like stone to the bottom of the ocean with the same as velocity as Internet companies went bankrupt. For the equipment vendors, the real issue was whether or not this was the beginning of a new industry trajectory; was this the moment in the history when century-old industry incumbents would finally be pushed aside by radical innovators, like Cisco?

All vendors faced a sharp decline in orders for telecom equipment, causing companies to downsize dramatically in order to avoid going bankrupt. Ericsson saw no other way than radically reducing employees from around 120.000 people to just below 50.000 through three consecutive cost-cutting programs. Lucent and Nortel slashed jobs and divested assets even more brutally, leaving to companies with just around 25% of the workforce employed at the peak in year 2000.

Diagram 7: Major Incumbent's Revenues and Net Income 1095-2006



Source: Lazonick and March, 2011

The outcome of the crises was complex. Both Germany's Siemens and Lucent of the United States found it difficult to restore growth after the demand for wireless equipment began to recover in 2004. Siemen's merged with Nokia, forming NSN in 2006. At the same point in time, the Lucent's operations were combined with Alcatel as the two companies were joined together into the second big merger in the wake of the crises. By then Motorola's radio base station business gained little traction with the major operators, making the American tech giant dependent on its mobile phone arm. Because the Motorola's big gamble in satellite mobile systems – Iridium – failed as a business, the once market leading tech firm began to slide out of the market. Motorola had a brief moment of success with the Razor, the successful 'flip phone'. Despite stellar global sales in 2002-2004, Motorola was not able transform revenues from the world wide success with Razor into follow-ups. Apple offered Motorola the opportunity to design a mobile phone around the iTunes service, but Motorola fumbled that windfall by launching the awkward Motorola Rokr E1. Steve Jobs proudly

presented it in September 2005 as "the iTunes phone", but he also saw its obvious design flaws. At this point, Jobs broke off from the collaboration with Motorola to set a new course for Apple together with AT&T, the only GSM operator in the US market.

Figure 3: Industry Consolidation: the major mergers and acquisitions, 1990-2016

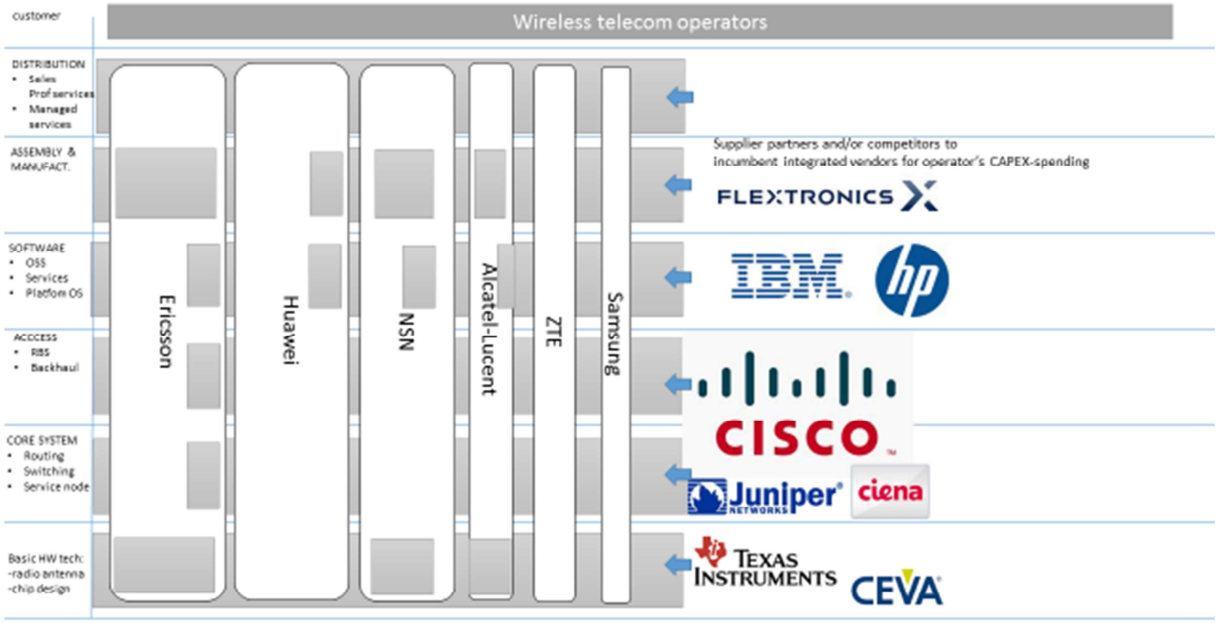
Nortel Networks, another North American tech giant, also crumbled in the first decade after the Millennium. In 2009, Nortel's owners agreed to split Nortel in parts that were sold-off to the highest bidders; Ericsson got the network division (with its business with leading US operators) and Google got the patent portfolio.

Apart from reshaping the landscape of integrated vendor, the Internet Crises put an end to the major niche-players attempt to expand into radio-base stations and thereby threaten the incumbent position of the integrated vendors through radical disruptive technological innovations.

If the North American incumbent's ability to compete in the post-crises markets were limited, European incumbents fared better by comparison. When the market recovered in winter 2004/2005, Ericsson responded with surprising ease. After three years of frozen investment programs, the operators needed to add capacity to the wireless networks, which created the mini-boom in 2005. Ericsson's readiness to ship radio base stations helped the Swedish company restored its pre-crises command of market. In response to Ericsson's quick build-up of capacity to meet customer demand in volume markets (GSM) as well as high-margin products (3G), the remaining competitors tried to counter Ericsson

by orchestrating two the major mergers between Alcatel-Lucent and Nokia-Siemens in a search for volumes. Whereas NSN built a stronger position in wireless networks markets, Alcatel-Lucent became the less successful of the two companies. By 2010, the revenues of the French company were down to ca 50% of the earnings of NSN in the same year.

Figure 4: Incumbent OEM's business model and entrant challengers by value chain segments, 2014.

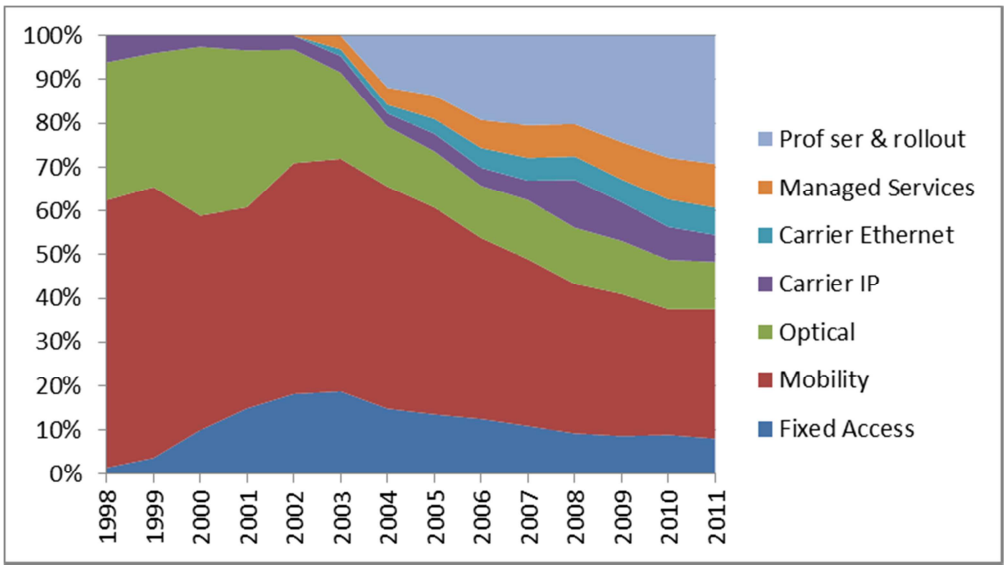


Huawei moved forcefully into the global markets with is low-cost offer. A CTO of a French optical networks operator was quoted in the Economist: "when we first saw Huawei's equipment, we could not believe a Chinese company could match a Western one – and we were proved wrong" (Economist, Jan 8, 2005). That was not an isolated observation. In 2009, Huawei rivaled Ericsson's leading position in the GSM market (primarily in Asia), and was beginning to win a strong position in more advanced 3G equipment. Whilst becoming an increasingly innovative vendor, Huawei still priced its equipment very aggressively, pushing depressing average margins from levels around 20% to 10%, or even less.

Diversification into 'Managed Services'

In the short run, the Internet Crises forced vendors to take a new stance on costs. All vendors slashed costs aggressively. Across the leading corporations, more than 200.000 employees were laid off in a gruesome downsizing process. Typically, the downsized organizations were down to less than 50% in terms of employment. Outsourcing and off-shoring hence became a common practice. The degree of outsourcing increased from the late 1980s and onwards. Ericsson led the way by forming an alliance with Flextronics, the electronic device manufacturer, for a large chunk of its manufacturing. By 2002, all incumbents followed the cue, initiating a process towards outsourcing a substantial part of its manufacturing operations to EDM-partners. It was however Huawei's entry through aggressively priced quality products that face of the wireless equipment market in a more permanent way. Particularly Huawei's European competitors responded by focusing on services, offering 'managed services' to operators that were eager to reduce operational costs (in response to high debt and soaring capex spending).

Diagram 8: Operator's global CAPEX by type



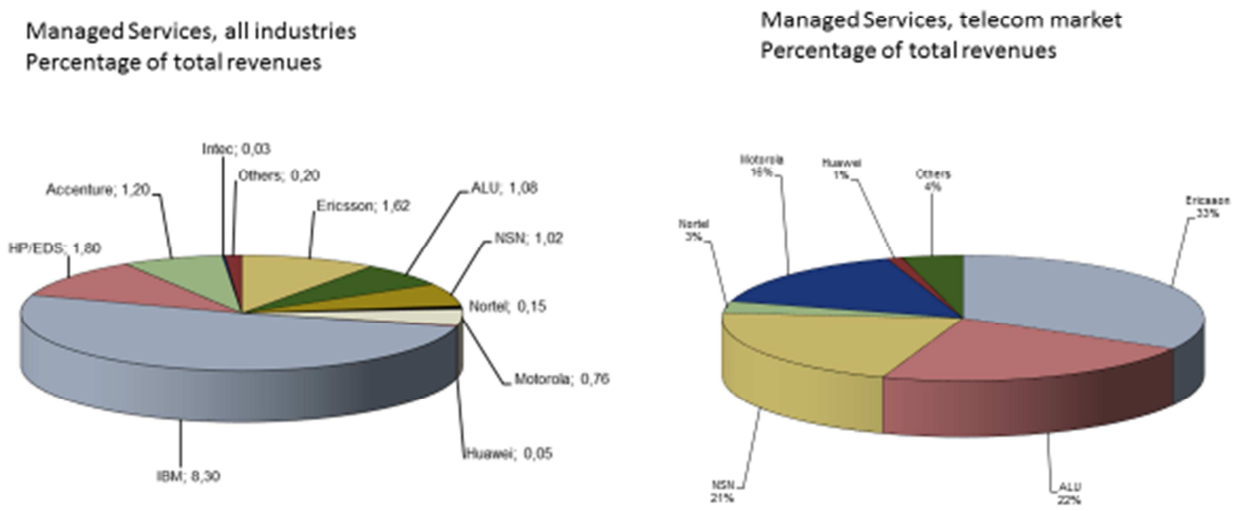
Source: Dell'Oro, several years.

By the late 90s, the operators spent ca 60% of the capex on wireless infrastructure equipment (mobility). In the same period, there was a boom for

optical networking and Carrier IP due to investments Internet services. Increasingly, wireless 3G services also required increasing spending on IP and Ethernet routers. Manages services grew slowly, but the revenues were concentrated to a few vendors, i.e. Ericsson, Alcatel-Lucent and Nokia. Among those competitors, Ericsson took the lead with the aim set at getting to 30% share of the total revenues.

Vodafone and Ericsson were the first put their signatures on agreements concerning the Britain-based operator's networks in Italy in 2004. The two parties shortly thereafter signed as second and much more encompassing agreement concerning Vodafone's network in the UK.

Diagram 9: Managed Serices in 2013



Source: Del'Oro (2013)

Thereafter, managed services market expanded quickly. Nokia Siemens Networks and Alcatel-Lucent followed in Ericsson's footsteps and benefitted from a trend where a large number of operators, many of them from developing regions, outsourced their day-to-day network management and operations in return for a considerable cost savings. Just as in wireless equipment, the old

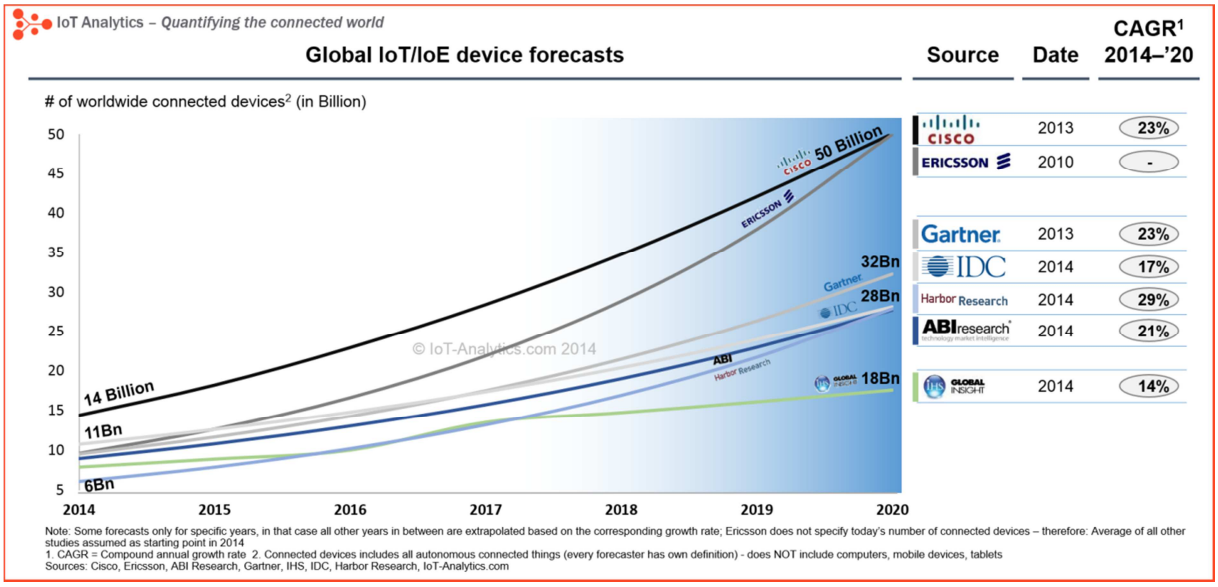
vendors dominated carrier market in managed services. It was conclusion was not forgone outcome, as the operators were taking the decisions to outsource operations of their networks. For the managed services market in general, excluding telecom, it was the large IT-companies, e.g. IBM, HP and Accenture, that dominated.

From Managed Services to IoT Verticals

From a certain distance, it would look as the equipment vendors already by, say, 2006 were comfortably in the process of moving away from their original core business (i.e. network equipment) into the novel area of services and software. From the end of the crises around 2004, the short-term quest for top-line growth – revenues – primarily motivated the diversification by Ericsson and its followers onto the managed services market. Ericsson, for example, developed strategic plans with two faces, including continued leadership in wireless connectivity combined with certain areas of targeted growth, particularly relating to services, IP-networking, TV/Media and support software. The formula was simple enough: as the cost and price of radio connectivity drops radically, everything that can be connected into a wireless network will be connected wirelessly. By Ericsson's strategists, this was seen the precondition of the C*onnected Society*. By 2010, Ericsson laid out its approach to service-driven growth more carefully. Ericsson's strategists suggested a specific relationship between network equipment sales and services-based revenues. Equipment provided the basis for the future services contracts; *"…winning large [network equipment] projects are…"* the argument run, *"…a necessary first step to secure future software and services business when upgrades and/or expansions of the networks take place."*

A few years later, the industry's vision for services matured into a more coherent understanding of services and software as targeted growth areas of the equipment vendors. Across the industry, equipment vendors, as well as some leading operators, began to include novel concepts of cloud computing, smart cities, M2M, internet-of-things and vertical (industry specific solutions) in an extended concept of services and software, linking it to a 5th Generation of wireless services. Among the equipment vendors, Ericsson emerged as a

champion of that extended view of services when the company promoted the view of the *connected society* (or the *50bn connected devices strategy*). There was no lack of supporters of the notion of a connected society in the making:



Source: IoT Analytics, 2015

Major influential advisory firms began to promote the view of cloud and IoT as the rising growth opportunity also for the incumbent actors within the world of wireless telecommunications; cloud and IoT markets was slanted for fast paced advance: watchers of industrial trends, such as Gartner and McKinsey Global Institute, began to prophecy of IoT as a major growth pool, expanding at 20-30% CAGR to reach revenues between three and six trillion USD in 2025. *"Who will …"* McKinsey probed *"… capture this investment opportunity?"*

There have been numerous predictions about the size of the IoT today as well as in the near future. The most widely cited is that of Ericsson. Prior to Ericsson's report, Intel estimated in 2009 that there were already five billion devices connected to the internet. Even if these high numbers seems high, which perhaps could be expected, estimated by less biased organizations, such as the OECD (2012; 2015) are not suggesting that they are widely off the mark. A few years later, Gartner and other industry advisory groups published more conservative estimates. Even if less aggressive, these later calculations point nominate IoT as a critical high-growth opportunity.

IoT epitomizes the 'third wave' in the development of the Internet. While the www of the 1990s connected one billion users via PCs, and the mobile internet of the 2000s connected two billion users via smartphones -- now approaching six billion), the IoT is projected to connect between 20 and 50 billion "things" to the internet by 2020, ranging from wearable devices to automobiles, appliances, and industrial equipment. Just as the Internet, IoT is not a unified 'technology'. Rather, it is the service [outcome] of a combination of advances within a number of interrelated technological areas of innovation:

Table 5: Internet-of-Things by Area of Innovation

AREA of INNOVATION	TECHNOLOGY	SERVICE	DISTINCTIVE FEATURES
Sensors and modem			
IT System	Virtualization	Cloud	
Connectivity platforms			
Wireless connectivity	LPWA, low-latency TDD/FDD design	M2M	Cost, low energy, low latency; massive connectivity (50k/cell)
Wireless connectivity	Optimized OFDM	LTE 5G	1GB bandwidth at 10% of today's cost per MB
Analytics	--	Big Data	
IT and telecom system control	SDN and NFV	Slicing;	
Antenna technologies	MIMO		

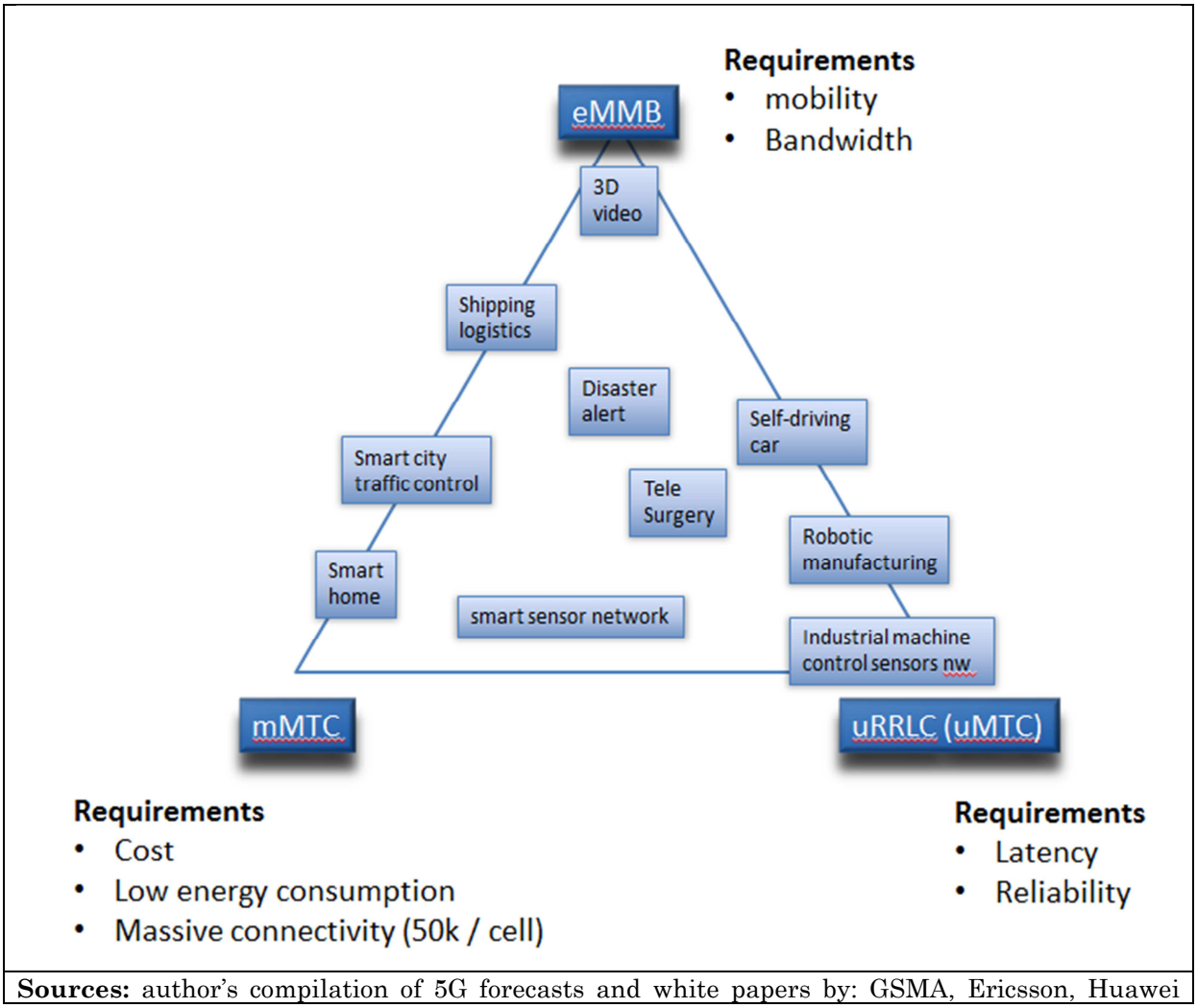
Source: Author's analysis

More or less simultaneous advances in these areas of innovation, as well as the general diffusion of new business models in scalable cloud services, i.e. pay-as-you-go, allowed pointed towards 'use cases' within IoT. Improved wireless connectivity technologies allow objects to be controlled remotely across IoT services. Therefore, wireless equipment vendors, industry associations and various consultancies and analysts advocate that the transition from 4G to 5G will be pivotal to the development of IoT.

On the one hand, 5G continues the path set by previous generations of standards towards low-cost mobile broadband. Compared to the progress between the third and fourth generations, which took wireless broadband from 10 mbps to 100 or 150 mbps, 5G takes another a huge leap forward towards 1 to 10 gbps

throughput. IoT devices are going to have varying capabilities and data demands and the 5G network needs to support them all. With IoT, users (private or corporate sector) individuals we are going to see services that only need a tiny amount of data and a long battery life as well devices that require fast speeds and reliable connectivity. To work well, a fully realized internet of things ecosystem must have a 5G network that connects all of these devices and takes into consideration the use of power, data demand, and spectrum. Therefore, 5G is not one technology (just supporting higher bandwidth) but a platform bundling together different wireless connectivity technologies with very different characteristics. Critically,5G thus involves low-power and low-bandwidth technologies that improve other dimensions, such as latency and reliability (uRRLc) or cost, size and power-consumption of connected devices (mMTC).

Figure 5: Internet-of-Things: use cases by type of wireless technologies and business requirements



Sources: author's compilation of 5G forecasts and white papers by: GSMA, Ericsson, Huawei

Nokia, and Qualcomm.

There is a widespread agreement concerning the impact of IoT on various settings and industries. Whilst the notion of 'smart homes' has attracted considerable attention since the 1990s, most predictions points to IoT and 5G as business-to-business solutions. In particular, the 'usual suspects' among the industry analysts points to four sectors, or 'verticals', where the impact of IoT will figure most prominently:

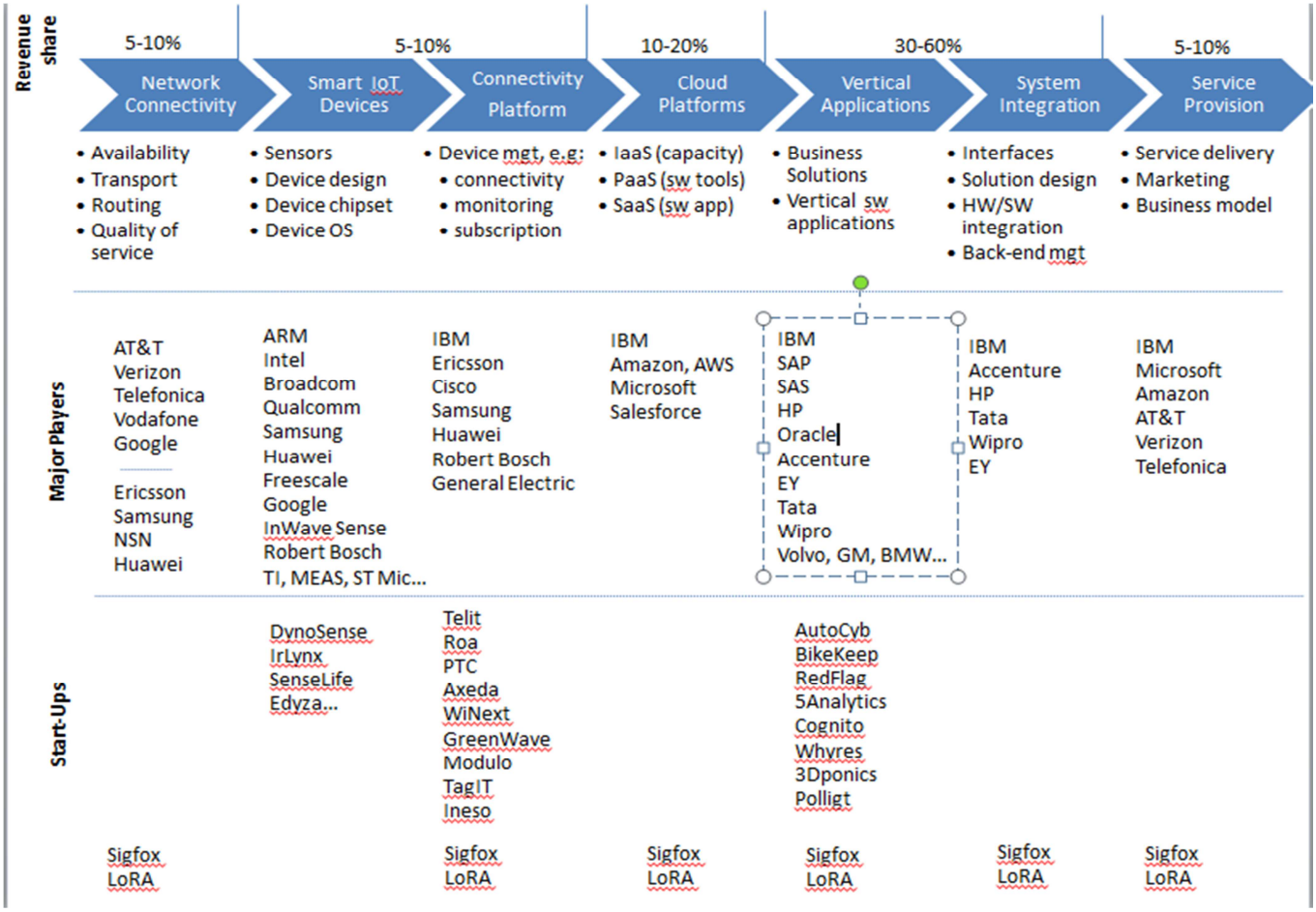
- the automotive industry, e.g. the connected self-driving car,
- the utilities sector, e.g. smart electrical grids,
- high-tech manufacturing, e.g. remote process control and machinery management
- the logistics and retailing sectors e.g. tracking of objects
- medical services, e.g. telemedicine and patient monitoring

Concerning the revenues from providing IoT-services to the actors within the different verticals, there is much speculation on how much there is to be gained from providing IoT services to the different verticals. Estimates of revenues by industry (vertical) vary a lot, just as the estimates of the number of connected devices also are varying. For example, estimates for the automotive sector build on approximations of the impact of IoT on the 'connected' and autonomously driving car. In general, analysts propose that revenues from the sectors that will experience fast and deep up-take of IoT services (above) will each become 0,5 to 2 billion USD markets for providers of IoT services. The questions, then, become twofold: who will capture these opportunities and how will they be captured?

In sharp contrast to the value chain of mobile equipment and services, which is typified by mature market consolidation, the IoT industry is still in the making. The charting of the actors by the value chain (below) builds on the author's scan of company web pages and start-up listings by IEEE (http://iot.ieee.org/startups.html). It shows how incumbent IT companies with decades of experience as providers of ITC solutions are flocking around the IoT-

opportunity, but there is still, apart from IBM, very little vertical integration. The wireless operators are holing a particular positon as the providers of licensed wireless spectrum in the value chain, which is reserved to operators that have that scare resource.

Figure 6: Major and minor actors by the IoT value chain 2016



Source: company web sites 2015-2016; IEEA 2016

IoT attracts a fair amount of VC funding[7] and start-up activity. The listing above of start-ups only reports a fraction of the +100 new start-ups that entered the market in 2016. Leading IT research firm Gartner has revealed that it is tracking some 200+ IoT platforms, Forbes reports (Forbes, Oct 4, 2016). As the major IoT

[7] Funding to IoT companies has more than quadrupled over the past five years, with year-over-year growth in every year except 2013. This past year saw 83 percent growth over 2014's funding tally, making 2015 a boom year overall for the IIoT, which has driven a cumulative $7.4 billion in venture investment over the past six years (KPMG 2016; CB Insights 2016)

companies try to strengthen their IoT offering horizontally and vertically, they target the more advanced start-ups. According to a study from Strategy Analytics (2016), there were almost two dozen major IoT-related M&A during the first quarter of 2016. Their findings indicated that the most desirable acquisition targets had developed core competencies around analytics, security, connectivity platform capabilities and services. Highlighting the state of play, tech giants such as Cisco, Intel and Microsoft, spent out on acquisitions to enhance their IoT portfolios. Microsoft acquired Italian-based IoT service Solair, which specializes in verticals such as hospitality, manufacturing, retail and transportation. Cypress Semiconductor revealed that it intended to acquire Broadcom's wireless IoT business and related assets in a $550m deal. Cisco Systems paid $1.4bn for Jasper Technologies, the developer of IoT platforms for major operators such as AT&T. Also notable is the increase in the worth of the companies being acquired. While vendors are still acquiring companies for $50, $100 and $200 million USD dollars, billion dollar acquisitions, such as Cisco's $1.4 billion purchase of Jasper Technologies, became more common in 2015 and 2016 (Strategy Analytics 2016; EY 2016).

The Paradoxes of IoT for the Wireless Equipment Vendors

Evidently, the development within the IoT industry presents the wireless equipment manufacturers with an unpresented opportunity. If the analysts are correct in their predictions that IoT will be the big next phase in the evolution of the ITC industries, there will be an increasing demand for wireless connectivity. Simply put: if IoT takes off at a large scale, the traffic in the wireless networks will increase and there will be additional demand to up-grade the existing wireless broadband networks as well as building new narrowband M2M networks. For the wireless operators and the vendors of wireless equipment, there are a series of interrelated headaches. The wireless operators, as spectrum licensees, enjoy the privileged position of having a legally regulated monopoly on wireless radio transmission. Yet, the competition between wireless operators is fierce and, as we already have discussed, the commoditization of connectivity is currently progressing at high pace. So, what does the IoT business case really

look like for the operators? The simple truth for operators, it seems, boils down to a increased focus on providing IoT services, as opposed to providing raw connectivity to a IoT provider like IBM. Numerous international telecom operators such as Verizon (via nPhase, a joint venture with Qualcomm), Telefonica and Deutsche Telekom are starting to position themselves as service enablers. AT&T provides cellular connections to over a million vehicles including Tesla, Audi and GM. This year, an analyst predicts that AT&T's revenue from the Internet of things will exceed $1 billion, most of which is from connected cars[8]. First, operators have built 'core competence' to run and manage applications over the network with differentiated quality-of-service levels. Therefore, wireless operators, like AT&T, have successfully implemented IoT platforms, supporting IoT-services to industrial users in various segments. In this way, AT&T is moving beyond just selling consumers and business connectivity access. It is now pushing into consulting services and integrating technology by dedicating vast resources to the growing field of software and services, offering industry specific cloud-based solutions and pre-packaged vertical software for transportation and logistics services, connected cars, insurance, medical services, etc.

The IoT scenario for wireless operators trickles down to the wireless equipment vendors. Just remaining in the position a provider of wireless equipment will hardly make for good strategy for the same reasons as drives the wireless operators to make the strategic move towards software and services.

Summary

Concerning technological innovations, the evolution of wireless services has been characterized by three phases: voice calls, wireless broadband connectivity enabled the smartphone and internet and the emerging M2M-scenario with applications such as smart cities and self-driving cars. The business cycle was shaped by a business boom in the era of voice (1990s), which came to an abrupt halt with the Internet Crisis (2001-2003). Recovery began in the late 2003 and

[8] http://www.zdnet.com/article/connected-cars-expected-to-be-a-1b-business-for-at-t-in-2015/

continued with sustained growth for almost a decade by the smartphone revolution.

Table 6: General trends in the wireless industry from late 1990s to 2016: technologies, services, standards, markets and the intensiveness of competition :

	Late 1990s	2001-2003	2004-2014	2014-
Technology	2G Narrow-band. First steps of radical innovation in 3G broadband tech	3G transition to broadband	Incremental path to 3G+ and 4G broadband	Transition to 5G and the IoT scenario
Service	Voice w sms	Voice, photo, music, limited internet.	Smartphone with full internet, app markets. Vendors also diversify into managed services	M2M/IoT aims at the growth of 5G in B2B (verticals)
Standards	Regionalization of standards in EU, US and Asia.	Intense inter-standard competition between EU, US and China	Trend towards convergence on LTE 'family of standards'	LTE dominates; wireless now only a part of a much larger eco-system of industry standards (e.g cloud standards)
Markets	Regionalized	Regionalized	Trends to globalization	Emergence of regional vertical B2B markets?
Intra-standards competition	Rapid growth and strong profitability. High margins and weak competition within the regional standards.	From boom to bust	Recovery and growth, but weaker profitability due to intense competition	Fierce competition with commoditiza-tion of connectivity, or return to profi-table growth? Wireless vendors need to compete with IT-companies in IoT

In the 1990s, there was a trend to regionalization as Europe supported GSM and it's broadband off-springs (i.e. UMTS, HSPA, LTE). US and South Korean actors pushed the San Diego-based Qualcomm's CDMA-technologies as the basis for wireless broadband. The battle was not only for the domestic/regional markets but, in particular, for the growing Asian markets. China entered the standards competition through establishing an initiative around it's TD-SCDMA-standard. By the end of the first decade of the new Millennium, China as well as Qualcomm gradually began to align with the LTE-initiative, contributing to a trend towards

technological globalization. Whilst, competition between standards decreased, the competition between the vendors within the LTE "family of standards" increased. Even if the demand for wireless equipment and capacity grew with the smartphone revolution, the competition became vendors became intense, with Huawei's entry and considerable concentration of capital through horizontal and vertical mergers. By 2015, there were many voices echoing the view that commoditization, thin margins and relentless competition shaped the vendor industry. At that point, the novel sequence of radical innovation linked to 5G, cloud and IoT —many argued— would re-install the foundations for to high-margin growth once again. The question was, of course, if wireless equipment vendors were in position to compete for the high-margin parts of the IoT-business?

REFERENCES

Analysys Mason. 2013. Bringing down the cost of mobile data traffic: investing in new technologies and more spectrum: Wireless network traffic worldwide: forecasts and analysis 2013–2018.

Bekkers, Rudi. 2001. *Mobile Telecommunications Standards: Gsm, Umts, Tetra, and Ermes*: Artech House.

Binmore, Ken, and Paul Klemperer. 2002. "The biggest auction ever: the sale of the British 3G telecom licences." *The Economic Journal* 112 (478).

Cisco. 2017. "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016–2021.". http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.html.

Cowhey, Peter F, Jonathan D Aronson, and John E Richards. 2008. "The Peculiar Evolution of 3G Wireless Networks: Institutional Logic, Politics, and Property Rights." *Governing Global Electronic Networks*:149.

Ericsson. 2015a. Annual Report 2015.

Ericsson. 2015b. Internet Goes Mobile: Country Report Nigeria.

. In *Ericsson Consumer Insight Report*. Stockholm: Ericsson.

Funk, Jeffrey L, and David T Methe. 2001. "Market-and committee-based mechanisms in the creation and diffusion of global industry standards: the case of mobile communication." *Research Policy* 30 (4):589-610.

Funk, Jefrey L. 1998. "Competition between regional standards and the success and failure of firms in the world-wide mobile communication market." *Telecommunications policy* 22 (4-5):419-441.

Garrard, Garry A. 1998. *Cellular communications : worldwide market development*, *The Artech House mobile communications series*. Boston, MA: Artech House.

Genakos, Christos, Tommaso Valletti, and Frank Verboven. 2015. Evaluating market consolidation in mobile communications. Brussels: Centre on Regulation in Europe, CERRE.

Glimstedt, Henrik. 2001. "Competitive dynamics of technological standardization: The case of third generation cellular communications." *Industry and Innovation* 8 (1):49-78.

GSMA. 2015. "The Mobile Economy 2015." GSM Association (GSMA). http://www.gsma.com/mobileeconomy/global/2015/GSMA_Global_Mobile_Economy_Report_2015.pdf.

GSMA. 2016. The Mobile Economy 2016. GSM Association (GSMA).

GSMA. 2017. The Mobile Economy 2017. In *URL: https://www.gsmaintelligence.com/research/?file=9e927fd6896724e7b26f33f61db5b9d5&download:* GSM Association (GSMA).

IDATE. 2015. Mobile operators' investments: Europe needs a pro-investment mobile regulatory framework.

Larurin, Peter. 2016. Senior Vice President. edited by Henrik Glimstedt.

Lazer, David, and Viktor Mayer-Schonberger. 2001. "Governing networks: telecommunication deregulation in Europe and the United States." *Brook. J. Int'l L.* 27:819.

Lembke, Johan. 2002. "EU regulatory strategy for mobile Internet." *Journal of European Public Policy* 9 (2):273-291.

Lenain, Patrick, and Sam Paltridge. 2003. "After the telecommunications bubble."

Lindmark, Sven. 2002. *Evolution of Techno-Economic Systems-An Investigation of the History of Mobile Communications*: Chalmers University of Technology.

McKinsey. 2012. 0.1 cent per MB: Ensuring future data profitability in emerging markets.

OECD. 2004. *OECD Communications Outlook 2003*: OECD Publishing.

Ovum. 2015. Telecoms, Media and Entertainment Outlook 2015.

Palmberg, Christopher, Erik Bohlin, Eric J Iversen, and Richard Tee. 2006. "Standards dynamics and industrial organization in the mobile telecom sector." *info* 8 (4):33-48.

Palmberg, Christopher, Erik Bohlin, Dan Saugstrup, and Anders Henten. 2006. "3G Standards: the battle between WCDMA and CDMA2000." *info* 8 (4):10-20.

Pelkmans, Jacques. 2001. "The GSM standard: explaining a success story." *Journal of European Public Policy* 8 (3):432-453.

Reynolds, T. 2009. "The Role of Communication Infrastructure Investment in Economic Recovery." *OECD Digital Economy Papers* No 154

Spilling, Rolv-Olov. 2016. Network Modernization.

Van Damme, Eric. 2002. "The European UMTS-auctions." *European Economic Review* 46 (4):846-858.

Xerfi Global. 2016. Telecom Equipment Groups: World market Analysis 2016-2020.

Zysman, John, and Andrew Schwartz. 1998. *Enlarging Europe : the industrial foundations of a new political reality*, *Research series*. Berkeley, CA: International and Area Studies, University of California at Berkley.