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Evolution from 2G over 3G to 4G

In the past 20 years, fixed line and wireless telecommunication as well as the Internet have developed both very quickly and very slowly depending on how one looks at the domain. To set current and future developments into perspective, the first chapter of this book gives a short overview of major events that have shaped these three sectors in the previous two decades. While the majority of the developments described below took place in most high-tech countries, local factors, and national regulation delayed or accelerated events. Therefore, the time frame is split up into a number of periods and specific dates are only given for country-specific examples.

1.1 First Half of the 1990s — Voice-Centric Communication

Twenty years ago, in 1993, Internet access was not widespread and most users were either studying or working at universities or in a few select companies in the IT industry. At this time, whole universities were connected to the Internet with a data rate of 9.6 kbit/s. Users had computers at home but dial-up to the university network was not yet widely used. Distributed bulletin board networks such as the Fidonet [1] were in widespread use by the few people who were online then.

It can therefore be said that telecommunication 20 years ago was mainly voice-centric from a mass market point of view. An online telecom news magazine [2] gives a number of interesting figures on pricing around that time, when the telecom monopolies were still in place in most European countries. A 10-min "long-distance" call in Germany during office hours, for example, cost €3.25.

On the wireless side, first-generation analog networks had been in place for a number of years, but their use was even more expensive and mobile devices were bulky and unaffordable except for business users. In 1992, GSM networks had been launched in a number of European countries, but only few people noticed the launch of these networks.

1.2 Between 1995 and 2000: The Rise of Mobility and the Internet

Around 1998, telecom monopolies came to an end in many countries in Europe. At the time, many alternative operators were preparing themselves for the end of the monopoly and prices went down significantly in the first week and months after the new regulation

came into effect. As a result, the cost of the 10 min long-distance call quickly fell to only a fraction of the former price. This trend has continued to this day and the current price is in the range of a few cents. Also, European and even intercontinental phone calls to many countries, like the USA and other industrialized countries, can be made at a similar cost.

At around the same time, another important milestone was reached. About five years after the start of GSM mobile networks, tariffs for mobile phone calls and mobile phone prices had reached a level that stimulated mass market adoption. Although the use of a mobile phone was perceived as a luxury and mainly for business purposes in the first years of GSM, adoption quickly accelerated at the end of the decade and the mobile phone was quickly transformed from a high-price business device to an indispensable communication tool for most people.

Fixed line modem technology had also evolved somewhat during that time, and modems with speeds of 30−56 kbit/s were slowly being adopted by students and other computer users for Internet access either via the university or via private Internet dial-up service providers. Around this time, text-based communication also started to evolve and Web browsers appeared that could show Web pages with graphical content. Also, e-mail leapt beyond its educational origin. Content on the Internet at the time was mostly published by big news and IT organizations and was very much a top-down distribution model, with the user mainly being a consumer of information. Today, this model is known as Web 1.0.

While voice calls over mobile networks quickly became a success, mobile Internet access was still in its infancy. At the time, GSM networks allowed data rates of 9.6 and 14.4 kbit/s. over circuit-switched connections. Few people at the time made use of mobile data, however, mainly due to high costs and missing applications and devices. Nevertheless, the end of the decade saw the first mobile data applications such as Web browsers and mobile e-mail on devices such as Personal Digital Assistants (PDAs), which could communicate with mobile phones via an infrared port.

1.3   Between 2000 and 2005: Dot Com Burst, Web 2.0, Mobile Internet

Developments continued and even accelerated in all three sectors despite the dot com burst in 2001, which sent both the telecoms and the Internet industry into a downward spiral for several years. Despite this downturn, a number of new important developments took place during this period.

One of the major breakthroughs during this period was the rise of Internet access via Digital Subscriber Lines (DSL) and TV cable modems. These quickly replaced dial-up connections as they became affordable and offered speeds of 1 Mbit/s and higher. Compared with the 56 kbit/s analog modem connections, the download times for web pages with graphical content and larger files improved significantly. At the end of this period, the majority of people in many countries had access to broadband Internet that allowed them to view more and more complex Web pages. Also, new forms of communication like Blogs and Wikis appeared, which quickly revolutionized the creator−consumer imbalance.

Suddenly, users were no longer only consumers of content, but could also be creators for a worldwide audience. This is one of the main properties of what is popularly called Web 2.0 and will be further discussed later on in this book.

In the fixed line telephony world, prices for national and international calls continued to decline. Toward the end of this period, initial attempts were also made to use the Internet for transporting voice calls. Early adopters discovered the use of Internet telephony to make phone calls over the Internet via their DSL lines. Proprietary programs like Skype suddenly allowed users to call any Skype subscriber in the world for free, in many cases with superior voice quality. "Free" in this regard is a relative term, however, as both parties in the call have to pay for access to the Internet, telecom operators still benefit from such calls because of the monthly charge for DSL or cable connections. Additionally, many startup companies started to offer analog telephone to Internet Protocol (IP) telephone converters, which used the standardized SIP (Session Initiation Protocol) protocol to transport phone calls over the Internet. Gateways ensured that such subscribers could be reached via an ordinary fixed line telephone number and could call any legacy analog phone in the world. Alternative long-distance carriers also made active use of the Internet to tunnel phone calls between countries and thus offered cheaper rates.

Starting in 2001, the General Packet Radio Service (GPRS) was introduced in public GSM networks for the first time. When the first GPRS-capable mobile phones quickly followed, mobile Internet access became practically feasible for a wider audience. Until then, mobile Internet access had only been possible via circuit-switched data calls. However, the data rate, call establishment times and the necessity of maintaining the channel even during times of inactivity were not suitable for most Internet applications. These problems, along with the small and monochrome displays in mobile phones and mobile software being in its infancy, meant that the first wireless Internet services (WAP 1.0) never became popular. Toward 2005, devices matured, high-resolution color displays made it into the mid-range mobile phone segment and WAP 2.0 mobile Web browsers and easy-to-use mobile e-mail clients in combination with GPRS as a packet-switched transport layer finally allowed mobile Internet access to cross the threshold between niche and mass market. Despite these advances, pricing levels and the struggle between open and closed Internet gardens slowed down progress considerably.

At this point, it should be noted that throughout this book the terms "mobile access to the Internet" and "mobile Internet access" are used rather than "mobile Internet." This is done on purpose since the latter term implies that there might be a fracture between a "fixed line" and a "mobile" Internet. While it is true that some services are specifically tailored for use on mobile devices and even benefit and make use of the user's mobility, there is a clear trend for the same applications, services, and content to be offered and useful on both small mobile devices and bigger nomadic or stationary devices. This will be discussed further in Chapter 6.

Another important milestone for wireless Internet access during this time frame was 3G networks going online in many countries in 2004 and 2005. While GPRS came close to analog modem speeds, Universal Mobile Telecommunication System (UMTS) brought data rates of up to 384 kbit/s in practice, and the experience became similar to DSL.

1.4 Between 2005 and 2010: Global Coverage, Fixed Line VoIP, and Mobile Broadband

From 2005 to 2010, the percentage of people in industrialized countries accessing the Internet via broadband DSL or cable connections continued to rise. Additionally, many network operators started to roll out ADSL2+, and new modems enabled download speeds beyond 15 Mbit/s for users living close to a central exchange. VDSL and fiber to the curb/fiber to the home deployments offered even higher data rates. Another trend that accelerated since 2005 is Voice over Internet Protocol (VoIP) via a telephone port in the DSL or cable modem router. This effectively circumvents the traditional analog telephone network and traditional network fixed line telephony operators saw a steady decline in their customer base.

In this period, the number of mobile phone users had reached 3 billion. This means that almost every second person on Earth owned a mobile phone, a trend which only a few people foresaw only five years earlier. In 2007, network operators registered 1000 new users per minute [3]. Most of this growth has been driven by the rollout of second-generation GSM/GPRS networks in emerging markets. Owing to global competition between network vendors, network components reached a price that made it feasible to operate wireless networks in countries with very low revenue per user per month. Another important factor for this rapid growth was ultra-low-cost GSM mobile phones, which became available for less than $50. In only a few years, mobile networks have changed working patterns and access to information for small entrepreneurs like taxi drivers and tradesmen in emerging markets [4] as GSM networks were by that time available in most parts of the world. In industrialized countries, third-generation networks continued to evolve and 2006 saw the first upgrades of UMTS networks to High Speed Data Packet Access (HSDPA). In a first step, this allowed user data speeds between 1 and 3 Mbit/s which was particularly useful in combination with notebooks to give users broadband Internet almost anywhere.

While 3G networks had been available for some time, take-up was sluggish until around 2006/2007, when mobile network operators finally introduced attractive price plans. Prices fell below €40–50 for wireless broadband Internet access and monthly transfer volumes of around 5 Gbytes. This was more than enough for everything but file sharing and substantial video streaming. Operators also started to offer smaller packages in the range of €6–15 a month for occasional Internet access with notebooks. Packages in a similar price range were also offered for unlimited Web browsing and e-mail on mobile phones. Pricing and availability varied in different countries. In 2006, mobile data revenue in the USA alone reached a $15.7 billion, of which 50–60% was non-SMS (Short Message Service) revenue [5]. In some countries, mobile data revenues accounted for between 20% and 30% of the total operator revenue.

While wireless data roaming was still in its infancy, wireless Internet access via prepaid Subscriber Identity Module (SIM) cards was already offered in many countries at similar prices to those for customers with a monthly bill. This is another important step, as it opened the door to anytime and anywhere Internet access for creative people such as students, who favor prepaid SIMs to monthly bills. In addition, it made life much easier for travelers, who until then had no access to the Internet while traveling, except for

wireless hotspots at airports and hotels. An updated list of such offers is maintained by the Web community on the prepaid wireless Internet access Wiki [6].

1.5   2010 and Beyond

At the time of publication, the state of the mobile industry has once again changed significantly compared to the 2005–2010 area. In 2013, the number of mobile subscriptions is estimated to surpass 7 billion [7], up from 3 billion subscriptions only five years earlier. This means that the vast majority of the global population now owns a mobile device.

After Apple successfully entered the mobile domain with their iPhone in 2007 and Google following with their Android mobile operating system about a year later, innovation on mobile devices has decoupled from the telecoms industry and has moved toward IT-based software companies. It only took little time for this effect to become mainstream. In 2012, half the mobile phones sold in Germany, for example, were smartphones [8]. While smartphones for many years only covered the high end of mobile device sales, this has significantly changed in the meantime as well, with sophisticated Android devices now available for little more than €100.

While the growing number of voice minutes was previously the main driver for increasing network capacity, it is now the growing use of smartphones and Internet-based services on them that require constant investment on the network side to increase the capacity and reach. In the meantime, capabilities of UMTS networks increase further and data rates of up to 42 MBit/s can now be reached under ideal conditions. To further increase the capacity, Long Term Evolution (LTE) networks were launched in several countries early in this decade.

While the amount of data transferred in wireless networks is increasing year over year, this trend seems to be somewhat slowing. The German regulatory authority reported, for example, that year-over-year data growth in mobile networks has slowed to a factor of 0.5 in 2011, down from having doubled the year earlier and a three times increase in 2009 [9]. A 50% increase of the amount of data sent through mobile networks in one year is still impressive and requires network operators to spend a sizable amount of their revenue to increase the capacity of their networks.

Like with UMTS less than a decade earlier, early LTE networks were first used with data sticks. Mobile devices were only introduced in 2011 and like UMTS phones a decade earlier suffered from increased size, weight, heat generation, and higher power consumption, often leading to an inferior experience compared to high end High-speed Packet Access (HSPA+) devices. Unlike early UMTS devices, however, one significant difference is the absence of circuit-switched voice capabilities of LTE networks, which require LTE devices to use 2G or 3G networks for voice calls. Several VoIP over LTE solutions have been in the making for many years but no network operator has yet deployed a solution for the mass market. This is one of the biggest technical challenges ahead for the mobile industry in the years to come.

Another trend is the emergence of new mobile device types. Led by the success of netbooks and tablets that bridge the gap between smartphones with small screens and limited input functionalities on the one hand and notebooks with large screens and full keyboards

on the other leaves the industry experimenting of how to best unify the user experience across the different screen sizes and input capabilities. Already now it can be observed that websites previously designed for PCs and notebooks are modified for touch input, slightly smaller screen sizes, and less processing power. Graphical user interfaces for PCs are also undergoing change to adapt to non-keyboard based devices. Two examples are Windows 8 with its "Metro" tiles approach and Ubuntu with its "Unity" desktop environment.

1.6 All over IP in Mobile — The Biggest Challenge

A process now almost completed in fixed line networks is still in its infancy in mobile networks, moving the traditional telephony service to an IP-based infrastructure. This will be the most challenging task of mobile network operators in many years to come as they are on the one hand facing competition from Internet-based voice service providers and significant implementation challenges on the mobile network side on the other. Mobile network operators, however, have little choice but to face this challenge in one way or another, as 4G LTE radio and core networks are fully based on IP technology and do not support traditional mobile voice telephony. As this topic is of central importance and significant issues have to be overcome, a complete chapter in this book will describe this challenge in-depth.

1.7 Summary

This chapter presented how fixed and wireless networks evolved in the past 20 years from circuit-switched voice-centric systems to packet-switched Internet access systems. Due to the additional complexity of wireless systems, enhancements are usually introduced in fixed-line systems first and only some years later in wireless systems as well. To date, fixed-line networks offer data rates to the customer premises of tens to hundreds of megabits per second, in some cases already going beyond this. Wireless 3.5G networks are capable of data rates in the order of several megabits per second and 4G networks promise even higher data rates and much higher overall capacity. As current wireless systems will continue to play a major role in the evolution of mobile networks, this book therefore not only concentrates on 4G systems, but also discusses the evolution of 3G systems.

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