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The history of mobile internet: the technology transformation that changed the lives of billions

Charting the future of innovation

The history of mobile internet: the technology transformation that changed the lives of billions

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Mobile broadband is the most popular means of internet access for billions of people worldwide. Its breakthrough is the result of several innovations: from the early development of mobile networks in the 1980s, the rapid uptake of internet in the 1990s, and the advances of devices in the 2000s. The move to mobile data and a new app economy secured the unprecedented rise of MBB services throughout the 2010s.

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Just over two decades ago, the first mobile broadband (MBB) services landed across consumer markets. For the first time, this made it possible to connect instantly to the internet from a mobile device almost anywhere in the world.

With this breakthrough, everything became possible. The blueprint for mobile communication was redrawn; the mobile phone was reinvented as a platform beyond voice and messaging, and the rules for communication, streaming, shopping, gaming, commuting and more were all rewritten.

Over the years, Ericsson Technology Review (ETR) [1] [2] has played a central role as a forum for sharing and spreading ideas and visions on many vital parts in this mobile miracle. Many innovations and trends that opened a pathway to MBB can be traced in ETR articles. While the forecasted evolution sometimes differed in detail, the overall direction of travel is clearly mapped.

In this article, we explore the technology story behind mobile internet and uncover how and why it came to be so deeply embedded across our societies and businesses.

1970s-2010s: paving the way to a mobile mass market

The advent of MBB is an innovation journey that stretches over many decades; from early mobile networks in the 1980s and the rapid uptake of the internet in the 1990s, to crucial device breakthroughs in the 2000s and the birth of the app economy in the 2010s.

1G: introduction of the first mobile systems

The foundation for MBB begins with the development of mobile telephony in the late 1970s and early 1980s. Advances in radio technology and the use of software-controlled switches enabled the initial development of mobile networks supporting voice and data services.

These developments were inherent in the first mobile communication systems, NMT (Nordic Mobile Telephony), AMPS (Advanced Mobile Phone System), and TACS (Total Access Communication System), which were based on the use of software switching and analog frequency division multiple access technology with limited capacity.

While the potential of mobile communication was not yet understood, it prompted a lot of learning around network and user devices [3]. Firstly, it quickly became evident that to encourage widespread uptake, user devices had to become more affordable, have good battery properties, and be compact and lightweight enough for mobile use. Secondly, the importance of good network coverage also became paramount, as users quickly expected to use the service everywhere.

Terms and abbreviations

3GPP – 3rd Generation Partnership Project | **CSP** – Communication Service Provider | **EDGE** – Enhanced Data Rates for GSM Evolution | **GPRS** – General Packet Radio Service | **GSM** – Global System for Mobile Communications | **HSDPA** – High-Speed Downlink Packet Access | **HSPA** – High-Speed Packet Access | **LTE** – Long Term Evolution | **MBB** – Mobile Broadband | **OTT** – Over-The-Top | **RAN** – Radio Access Network | **SMS** – Short Message Service | **TCP** – Transmission Control Protocol | **WCDMA** – Wideband Code Division Multiple Access

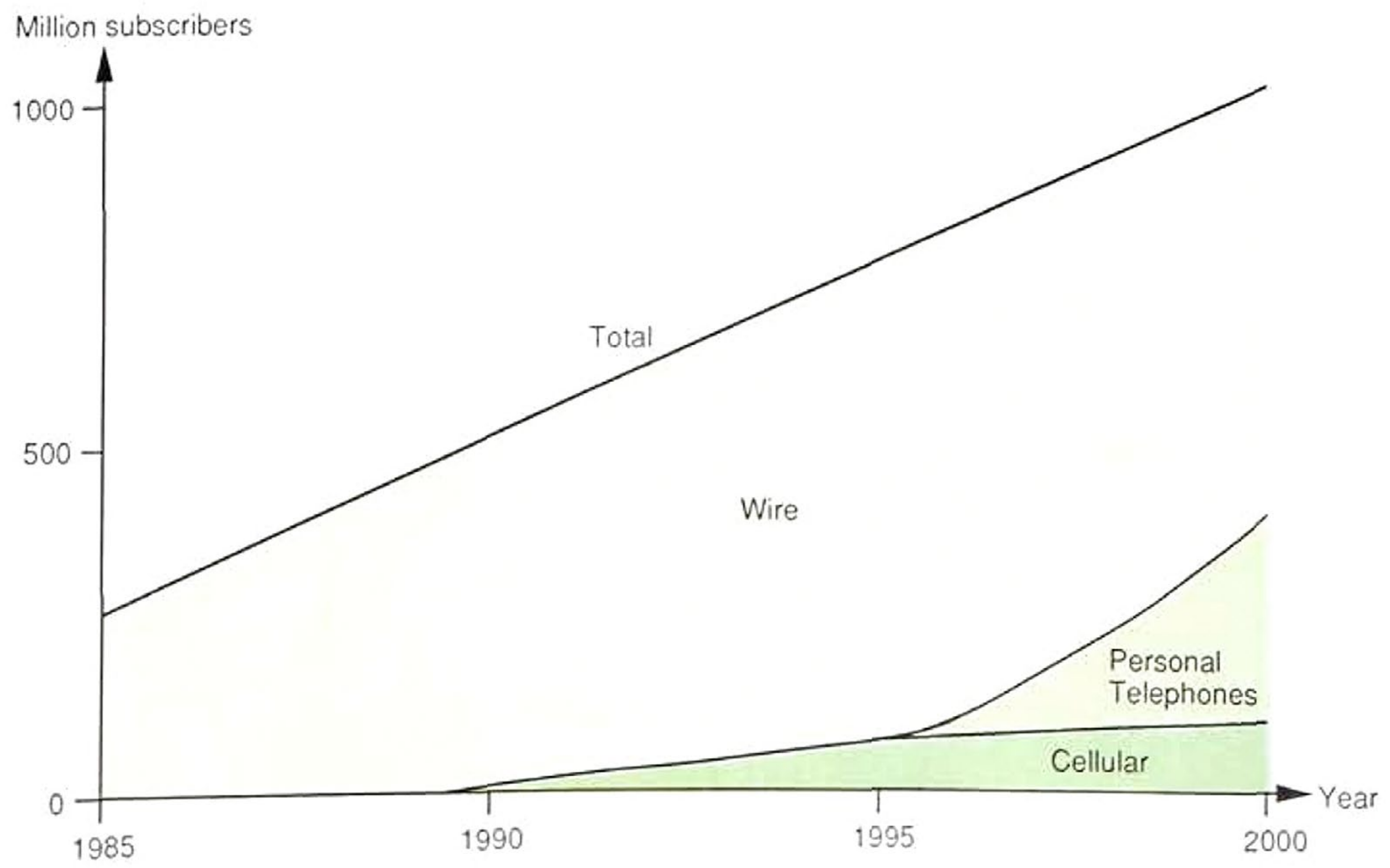


Figure 1: Prediction of subscriber growth in a 1990 ETR article [5]. The predicted success of mobile technology with 100 million mobile phone subscribers by 2000 was considered bullish. In retrospect, the growth was hugely underestimated and reflected the modest uptake of early mobile systems. The first one billion subscribers were reached in 2002, the second billion in 2005 and the growth rate increased even further after that [7].

While early mobile communication systems were well received on the market, high associated costs limited their appeal mainly to business users [4]. This resulted in projections for mobile markets being modest [5].

Even Ericsson underestimated the incredible growth-enabling force created by the availability of more advanced and affordable devices together with improved network capacity and coverage.

As shown in **Figure 1**, a 1990 ETR article [5] predicted 100 million mobile phone subscribers by the millennium; the actual number was more than seven times that amount [6] [7]. Improved device affordability and network performance drove a mass market that spurred even more investment in devices and networks.

Pioneering early pathways to mobile data
As mobile communication systems were being developed, the internet was emerging, together with a rapid uptake in the use of internet services accessed through fixed computers, as shown in **Figure 2**. The internet was built on the transition from circuit-switched to packet-switched data communication networks – a transition that spread across telecommunication domains and dissolved the borders between data and telecommunication. Leonard Kleinrock and Lawrence G Roberts received the L.M. Ericsson Prize in 1982 for their pioneering work in packet-switching theory and practical trials respectively, as elaborated on in their ETR articles [8] and [9].

Early mobile systems were seriously underestimated. By 2000, subscriber rates had outpaced early forecasts by more than 700 percent.

With the launch of Mobitex [11] in the same period came one of the first public mobile networks optimized for data and text communication, using digital packet-switching technology. It was a system separate from the mobile communication systems of the time and designed to replace the private mobile radio systems of taxi operators, blue light services, and haulage operators.

However, designs for application beyond this scope were already being considered, as the author of a 1989 ETR article [11] writes: "The introduction of public mobile data networks is expected to stimulate the development of new applications."

While Mobitex was without doubt a pioneering mobile data system and one of the first of its kind, it became redundant when efficient data communication capabilities were integrated into second generation (2G) systems.

2G: the arrival of SMS and limited data services
The launch of 2G systems like GSM (Global System for Mobile Communication), PDC (Personal Digital Cellular), D-AMPS (Digital Advanced Mobile Phone System) and cdmaOne in the early 1990s made data communication capabilities an integrated, albeit relatively limited part of mobile communication systems. Voice remained the primary service.

Mobile communications now began a very rapid growth period with technology and market maturing from earlier systems, first in Europe and other developed regions, and then spreading globally.

This growth period was propelled by mass production of network equipment and user devices, enabling strong economies of scale, which helped to gradually lower subscription and device prices for users. For the first time, this meant that users were not constrained by fixed telephony and could opt to go mobile.

While voice services remained dominant, the switch from analog to digital technology enabled support for SMS (Short Message Service) and 9.6 kbit/s circuit-switched data

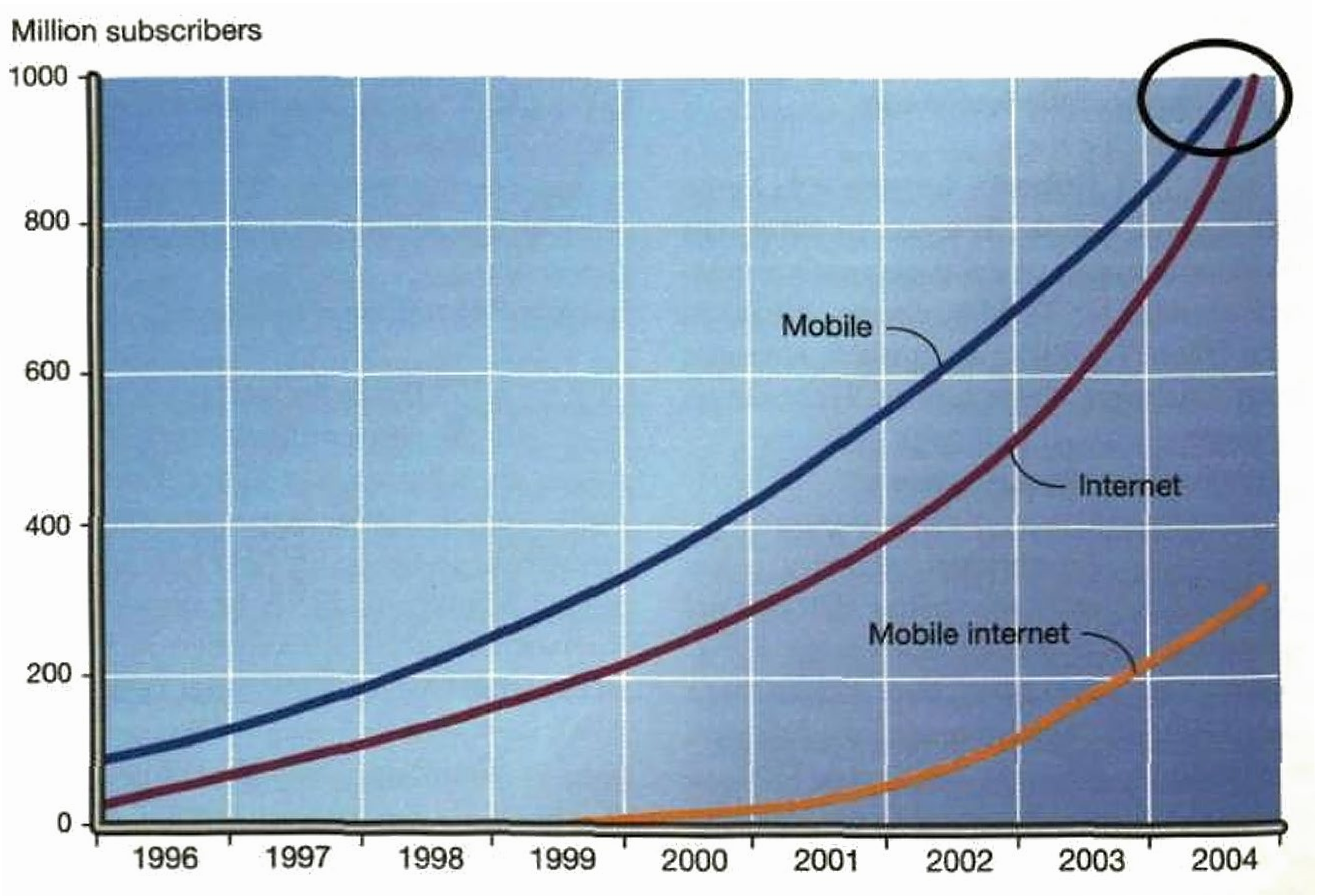


Figure 2: Forecast growth (subscribers) of fixed and mobile networks and the internet [10]. Even in the late 1990s, the number of mobile subscribers remained largely underestimated.

service. Although the data rate was limited, it was enough to enable a viable mobile internet connection for the first time on commercial mobile devices [12].

With GPRS (General Packet Radio Service) [13] came the introduction of packet-based services and network architecture in 2G systems. This evolution continued alongside the emergence of 3G, with the introduction of evolved GPRS and higher 2G data rates through EDGE (Enhanced Data Rates for GSM Evolution) [14].

3G: the concept of mobile internet is born

As 2G systems matured, the mobile industry realized a possible next step was to make the internet mobile. To prepare the groundwork for 3G, the European Commission and other administrative bodies began research projects to outline the technical and service criteria that 3G systems would require [15]. This drew the following conclusions: the peak rate of mobile networks must be comparable to fixed network connections; the mobile system must be capable of handling large amounts of data.

Both criteria were necessary to facilitate access to internet services available at that time and prepare the networks for a considerably richer service offering in the future.

The greatest need for development, and the industry's focus at that time, was to increase radio access network (RAN) capabilities. There were also important developments to the core network [13], user devices [16] [17] and business models.

In the 1990s, collective ambitions for a mobile internet prompted a step change in efforts to evolve mobile networks. Yet, these efforts were still largely guided and governed on a per-region basis, through many different and competing standardization bodies. The 3GPP (3rd Generation Partnership Project) was therefore formed to unify standards and facilitate a global, interoperable market with associated economies of scale benefits across both network and device domains. Through the 3GPP, most of Europe and Asia united around a commonly developed 3G standard [10] [18] [19].

The first release of the 3GPP's air interface standard, WCDMA (Wideband Code Division Multiple Access), enabled peak rates of 384kbps. This was, however, well below the 2Mbps target that the ITU (International Telecommunication Union) stipulated in the early 1990s, and efforts to improve this continued.

The first commercial 3G systems were launched in 2002 but the uptake of 3G users was initially slow. Peak rates of 384kbps improved on the speeds achieved by GSM and other 2G networks. The system was still based on circuit-switched technology inherited from the voice-based systems, making it difficult to reach high peak rates and high network capacity.

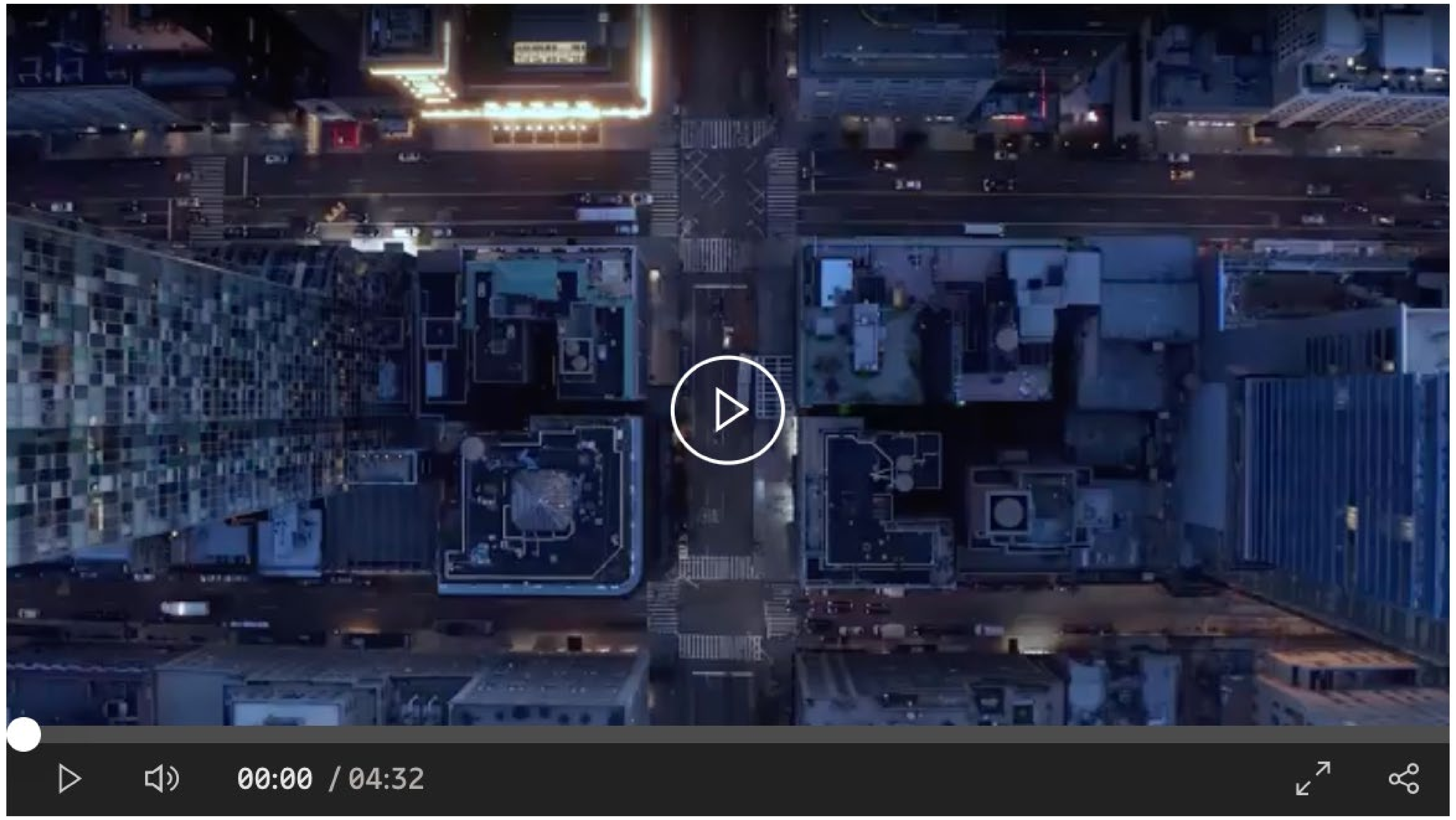
HSDPA (High-Speed Downlink Packet Access) [20] was introduced as the first step toward a true packet-based system, and it was soon able to increase peak rates and the network capacity by more than one order of magnitude, to several megabits per second in both the downlink and the uplink. It is worth noting that packet-based concepts had already been introduced in 2G systems in the late 1990s through GPRS, Enhanced GPRS and EDGE [13] [14].

In addition to higher peak rates, the performance characteristics of TCP/IP (Transmission Control Protocol/Internet Protocol) and the importance of low latency in the network were also identified as key areas of focus [20]. Specifically, these related to the handling of TCP slow start and its impacts on the service performance of the consumer. WCDMA using HSPA (High-Speed Packet Access) was now technically good enough to enable a revolution on the service side [21].

Lower price indexes led to a mobile boom in the 1990s. For the first time, mobile entered the mainstream.

Breakthrough of feature phones and early smartphones

Until the early 2000s, voice and messaging still dominated mobile communications. The evolution of mobile data was advancing steadily, spurred by pre-smartphone feature phones that enabled email access and media sharing.



Video: Erik Dahlman, Senior Expert Radio Access, rolls back the years on mobile evolution from 1G to 6G ↗

However, mobile data applications, consumer devices and the mobile data business model had not reached a satisfactory stage of maturity for widespread adoption. There was consensus in the industry that communication service providers (CSPs) should own such services.

Regarding devices, other challenges were emerging. In the early 2000s, mobile phones made rapid advances, now supporting other media beyond voice, such as photos, videos and music. Media communication was also enabled through evolved messaging services like MMS (Multimedia Messaging Service). However, this posed a challenge: network data support was not yet sufficiently omnipresent and affordable to allow for heavy data usage, such as that required to stream video or music.

Until that time came, most media were handled locally on the phone and then uploaded/downloaded to a PC through a wired connection or Bluetooth. As network data support improved in later years, the barriers for mobile media streaming were lowered, yet applications for managing the media were often brand specific, which in turn created walled gardens that did not bring mass scale.

The app model gains a foothold in the market

In this period, there were several attempts to create a business model with CSPs at the center of service offerings [22] [23] [24] [25] [26] [27]. A very early initiative, already introduced in 2G, was the specification of WAP (wireless application protocol) [22] [23]. While these solutions were able to penetrate the market, their success was limited. By late 1999, however, mobile internet adoption was gaining momentum, and the early shift into a new paradigm was taking place [18]. Early commercial success of solutions like i-mode in Japan were gaining traction, and expectations on the future success of mobile internet could be envisioned. This sentiment was echoed in the Ericsson Review in the same year: "The pieces of the puzzle are falling into place, opening the way for the mobile internet. Being 'always connected, always online,' users will, simply by clicking or tapping, be able to manage their business and private affairs at any time and from any place." [18]

During the transition to mobile data, many ideas were proposed and developed but did not materialize. The toughest challenge was to find a business model that could facilitate large scale growth of services.

The industry struggled to agree on a concept to facilitate scale and usability, while simultaneously giving CSPs a strong stake in the value chain. The possibility to provide services over-the-top (OTT) was explored, but not initially preferred. There was a strong belief that much business value would come in "owning" the subscriber, and the common mindset was to help the CSPs capture that ownership.

However, pivotal ideals such as simplicity and technical viability soon shifted the momentum in favor of the OTT solution. It may not have been the obvious solution initially, but the creation of the app concept comprised several aspects that proved vital for the success of mobile data [28]. Through apps, a plethora of services could be made available to the user, all delivered over an MBB connection.

The introduction of advanced email services in Blackberry and eventually the smartphone (e.g. iPhone) marked a sea change in commercial mobile devices, paving the way to new app-based business models through an attractive device interface. This helped spur the introduction of numerous creative third-party companies, which then set off an explosive evolution of lucrative mobile data services.

The "app model" allowed the global community of stakeholders and developers to access mobile communication. Through apps, each developer with their own interests and profit incentives could drive their own solution independently. Making the app concept device-centric enabled an economy of scale that would have been unlikely through CSP-centric models. The apps could be found in most cases through an intuitive, touch-based user interface that did not require manuals, reading or training on how to find, download or access relevant apps. This model then became attractive for all ages.

It is worth noting that the app model was developed as a mobile-first concept and became an indicative marker of a wider shift that was beginning across the industry, moving from wireless to fixed solutions.

4G LTE: completing the shift to global mobile internet services

WCDMA-based 3G carried many legacy features from earlier generations. This prompted the industry to develop a new truly packet-based system to support increasingly diverse and demanding MBB services [29]. Much of this work would form the backbone of the upcoming 4G Long Term Evolution (LTE) standard.

The packet bearer in LTE had many similarities with HSPA, albeit with one distinct and crucial difference: LTE was built only for packet data communication and could therefore enable far lower latency than its predecessor.

LTE became the first truly global standard, receiving widespread buy-in from North American stakeholders, further increasing the potential for economies of scale, particularly in innovation-rich US markets. The launch and evolution [30] of LTE firmly established the global success of MBB, and the paradigm shift that entailed. This evolution has continued into 5G and will most likely be a key aspect of all foreseeable future generations.

Summary: mobile broadband as a mobile evolution driver through the decades

Many defining technology developments and strategic decisions that drove mobile network evolution in previous decades occurred with the explicit goal of delivering MBB opportunities to the masses. These mainly comprised RAN developments, which had to solve numerous problems to increase capacity by several orders of magnitude per decade [31].

In this period, there were also significant developments towards an evolved packet core network [32]. Among the more fundamental steps, the transition from circuit-switched communication, which was initially used both for voice and data, to a packet-based solution, HSPA, ranks as one of the most pivotal breakthroughs to MBB. This same concept constituted the basis for LTE, which delivered a notable step change for MBB opportunities.

Today, the transition to MBB has proved to be a true paradigm shift.

- MBB has revolutionized how we communicate.
- MBB is available to a majority of people on the planet.
- MBB is the preferred internet access for most people and the only internet access for billions.
- MBB is the preferred means of providing private and public services and often the only way of accessing the service.
- Voice calls are no longer as common; other means of communication have reduced the need for voice, which is now also carried over other apps available on the internet.

The paradigm shift to mobile data has changed how we communicate in every country, social group and business. As many public and private services now assume the availability of smartphones, MBB is expected to be the dominant method for private communication, businesses, and service provisioning for a long time to come.

During this transition period, Ericsson has been a key contributor in shaping mobile internet and ETR has played an important role in sharing the development of technologies, services and business development [33]. A retrospective look back into the ETR archives reveals a fascinating journey of innovation leading up to the tremendous success of the mobile internet.

THE ERICSSON MOBILE PHONE STORY

Ericsson's mobile phone adventure started in Lund in 1983. Initially working from inside rented trailers, the company rode on the transition to digital standards [34] and became a household brand and global leader in the 1990s.

Ericsson ventured successfully into all mobile phone segments, from small [16] to rugged [17] as well as early smartphones [35]. The rapidly growing market for accessories such as earphones and in-car media also inspired the invention of Bluetooth [36]. Market consolidation, together with the prospect of a growing mobile phone market, drove the creation of the Sony Ericsson Mobile Communications (SEMC) joint venture, as well as the chipset company Ericsson Mobile Platforms (EMP), in 2001.

The following decade was one of success for both SEMC and EMP. SEMC utilized its holding companies' assets in mobile communications and entertainment to grow its product portfolio as well as pioneering the Symbian smartphone segment. EMP was equally successful as the world's largest supplier of chipsets for 3G phones in the mid-2000s [37].
In line with a strong market consolidation in mobile phone chipsets, Ericsson brought EMP into a joint venture with STMicroelectronics, ST-Ericsson, in 2009. In 2012, Sony acquired Ericsson's stake in Sony Ericsson, forming Sony Mobile Communications and only two years later, in late 2014, the majority of the former EMP engineers were transferred to Ericsson's Networks division, marking the end of Ericsson's 31-year history in mobile phones.

The authors

Joakim Bergström joined Ericsson in 1998 and is a senior expert in RAN standardization at Business Area Networks. He has more than 20 years' experience in RAN-related research and standardization work and has been deeply involved in the creation of 3G, 4G and 5G radio access technologies. With a focus on RAN, he has worked in the areas of operations and maintenance, transport, spectrum regulation and open source. Bergström holds an M.Sc. in electrical engineering from KTH Royal Institute of Technology in Stockholm, Sweden.

Peter von Butovitsch joined Ericsson in 1994 and has held various roles at Ericsson Research and in RAN system design during his time with the company. From 1999 to 2014, he worked for Ericsson in Japan and China. He is currently a technology manager at Systems & Technology. Butovitsch holds both an M.Sc. in engineering physics and a Ph.D. in signal processing from KTH Royal Institute of Technology. In 2016, he completed an MBA from the University of Leicester in the UK.

Björn Ekelund joined Ericsson in 1987 to architect Ericsson's first mobile phone for the GSM standard, and over the next three decades has held leading roles in Ericsson's mobile phone and chipset businesses. He now leads electronics, electromagnetics and robotics research at Ericsson Research. Ekelund holds an M.Sc. in electrical engineering and a Ph.L. in telecom microelectronics from Lund University in Sweden. He is a fellow of the Royal Swedish Academy of Engineering Sciences and a delegate of the Royal Swedish Academy of Sciences.

Kjell Gustafsson joined Ericsson in 1994 to build up a research group focusing on mobile phone technology. From research he transitioned into product development and system management and has held leading roles in these areas since then. He is currently Head of Standards & Technology at Ericsson in Lund. Gustafsson holds an M.Sc. in electrical engineering and a Ph.D. in automatic control from Lund University.

Johan Lundsjö joined Ericsson in 1996 where his initial focus was research, design and standardization of 3G radio interface protocols and network architectures. He has held various technical and people leader positions during the course of research and early development of 3G, 4G and 5G mobile systems, as well as in research on related network and cloud technologies. He is now Director of Communication at Ericsson Research, where current focus is on future 6G systems. Lundsjö holds an M.Sc. in electrical engineering from KTH Royal Institute of Technology.

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Further reading

- The evolution of mobile standards from 1G to 6G ↗
- Ericsson feature series, The rise of telephony ↗
- Ericsson research paper, Mobile broadband drives economic development ↗
- Ericsson Technology Review library, including early editions ↗

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