1

Introduction

Preview Questions

- How do technology, business and policy considerations matter to the telecommunications industry?
- How does the telecommunications industry feature in the global economy?
- In recent years, which industry segment has filed the largest number of patents?
- What are the reasons for the phenomenal growth in the number of broadband subscribers in recent years?
- How may a broadband content/service provision functions and structure be characterised?

Learning Objectives

- An historical overview of the telecommunications industry
- An overview of the current state of the telecommunications industry
- An introduction to the technology–business–policy framework
- An introduction to the content/service, retail, infrastructure model for analysing broadband telecommunications businesses
- An introduction to telecommunications management and information and information technology management fields

Broadband Telecommunications Technologies and Management, First Edition. Riaz Esmailzadeh.

Companion Website: www.wiley.com/go/BTTM

Historical Note

An early example of a *telecommunications system* is the Royal Mail of the Persian Empire circa 500 BC. The Empire ruled over the region between the Indus River (present day India/Pakistan) and Thrace in the present day European Turkey. It also extended as far as Libya in North Africa. The Empire was divided into different 'Satraps' or provinces, which were ruled by governors appointed by the central government. To rule effectively, fast and reliable messaging between Susa the capital and provincial centres was necessary. However, the distances were prohibitively long, and the means of travel were slow. For example, the distance between Susa and Sardis, a major Empire centre in Lydia, was some 2700 km. Travelling this distance on foot would take 90 days. A faster way of travelling was by horse but the animal and the rider needed food, water and rest. A messenger travelling by horse could expect to cover perhaps 100 or so kilometres per day, which would have been a great improvement but this still required 27 days of travelling. The Empire needed to respond to emergencies, whether local unrest or natural disasters, and clearly such long delays were not acceptable as they would greatly reduce the chances of a successful response.

The Persians had constructed a network of roads and relay stations to improve travelling time. At these relay stations fresh horses and couriers were ready to receive a message and take it to the next station, thereby removing the need to rest riders and horses. The ancient Greek historian Herodotus (484–425 BC) wrote of these Persian mounted postal carriers: 'Neither snow nor rain nor heat nor gloom of night stays these couriers from the swift completion of their appointed rounds'. Interestingly, this is the unofficial motto of the US Postal Service [1].

The main Royal Highway that connected Susa and Lydia comprised of 111 'relay' stations, as recounted below by Herodotus describing the road, the courier resting places and the horse exchange system as a marvel of its time. This relay system enabled the Royal Mail mounted couriers to travel the distance of 2700 km in 7 days. This was the fastest method of 'telecommunications' for its time and was an important tool in the governance and security of the Empire [2] (Figure 1.1).

> Now the true account of the road in question is the following: Royal stations exist along its whole length, and excellent caravanserais; and throughout, it traverses an inhabited tract, and is free from danger. In Lydia and Phrygia there are twenty stations within a distance of 94½ parasangs.[1] On leaving Phrygia the Halys has to be crossed; and here are gates through which you must needs pass ere you can traverse the stream. A strong force guards this post. When you have made the passage, and are come into Cappadocia, 28 stations and 104 parasangs bring you to the borders of Cilicia, where the road passes through two sets of gates, at each of which there is a guard posted. Leaving these behind, you go on through Cilicia, where you find three stations in a distance of 15½ parasangs. The boundary between Cilicia and Armenia is the river Euphrates, which it is necessary to cross in boats. In Armenia the resting-places are 15 in number, and the distance is 56½ parasangs. There is one place where a guard is posted. Four large streams intersect this district, all of which have to be crossed by means of boats. The first of these is the Tigris; the second and the third have both of them the same name, though they are not only different rivers, but do not even run from the same place. For the one which I have called the first of the two has its source in Armenia, while the other flows afterwards out of the country of the Matienians. The fourth of

[1] A parasang is a measure of distance and equals approximately 6 km.

Figure 1.1 Persian Empire circa 500 BC, and the Royal Mail route. Reproduced with permission of the University of Texas [3]

> the streams is called the Gyndes, and this is the river which Cyrus dispersed by digging for it three hundred and sixty channels. Leaving Armenia and entering the Matienian country, you have four stations; these passed you find yourself in Cissia, where eleven stations and 42½ parasangs bring you to another navigable stream, the Choaspes, on the banks of which the city of Susa is built. Thus the entire number of the stations is raised to one hundred and eleven; and so many are in fact the resting-places that one finds between Sardis and Susa [4].

Development and operation of the Royal Highway and Royal Mail depended on a number of technological advances. These included better tools for building roads; better methods for horse breeding; training programmes for horse riding couriers and so on. Technological development for other applications contributed as well. For example, the development of papyrus as a medium for writing contributed to the operational simplicity as paper was lighter to carry than baked clay and less susceptible to breakage. The location of relay stations was likely determined based partly on a number of these technological parameters. For instance, the inter-station distance would have been a factor of the terrain, as well as the fastest speed a horse could typically travel.

Of similar importance were business and operational issues including the costs of operation and maintenance of stations, the number of couriers and their rotation, the security of the stations and so on. These issues and associated costs would have been weighed against the value of telecommunications speed: how important was a 7-day end-to-end travel compared with an 8-day or 6-day travel? In modern days a cost–benefit analysis (CBA) or a cost–effectiveness analysis (CEA) is usually undertaken to arrive at an optimal solution. While it is not known whether the Persians ever undertook such a formal analysis, experience from other courier systems should have given them a guideline for ‘good’ – if not the ‘best’ – practice. As the cost of operation was borne by the Empire, it is difficult to determine how much each individual message transfer cost. Private usage of the courier system, perhaps for trade purposes, is not recorded. The cost of sending such a private message could have given insight into the overall cost of the operation.

The Royal Highway and the Royal Mail clearly had a great strategic and security importance for the Persian Empire. Business considerations would have included the high cost of constructing, securing and operating the stations, and of maintaining the roads but this must have been justified by the strategic benefits that the system provided. The Empire's policy in funding, building and maintaining the road was also important in the continued operation of the system.

★ ★ ★ ★ ★

Communication has always been a basic human need. We primarily used it for security: to protect ourselves and our kin. As we evolved, we have used it to learn about others and convey information about ourselves such as what we do and will, how we wish to do business, what our interests are, and so on. Development of speech (our primary communication method), and as we evolved, writing at the dawn of civilization, were major advances which have laid the foundation of an ever advancing civilization in which we live today. Such information may be communicated in person, or through means and devices that carry information to remote locations. We define this transfer of information across time and place as telecommunications, and consider that it has been with us from the very beginning of civilisation, as illustrated in the Royal Mail example.

'Telecommunications' is a recent term (first used in a book in 1904 [5]) and generally means the science and technology of communicating over a distance. An alternative definition may focus on the *utility* of telecommunications, which is communication of *information* over a distance. The terminology may only be a century old, however the need for communicating and conveying information to remote locations (both physically and temporally) predates civilization and has existed since the dawn of humankind. An in-depth discussion and analysis of telecommunication methods of early societies is outside the scope of this text. The brief history below is intended to establish a context within which we may analyse present day broadband telecommunication systems.

A major reason for the development of telecommunications in early human history was security. Smoke signalling or sound signalling would have alerted a friend to the approach of a foe. The means by which information was conveyed, the 'technology' in the above example, were fire and associated smoke or sound. These techniques were still in use by many indigenous societies when they came into contact with explorers from the 'old' world. These techniques are obviously limited by the extent of human hearing and sight, but relay techniques could be used to extend the telecommunications range. The extent of these beacons and their reliability was a function of terrain and weather, and therefore their utility was limited.

As human societies evolved there was another important application for telecommunications. As humans transitioned from a hunter–gatherer existence into complex farming communities, early forms of trade appeared. There was a need to convey messages between trading partners residing in remote places. Initially the messages were carried orally. Soon however, letters were being exchanged: a letter written on clay dates back to 7000 years ago [6]. As societies became more complex, the sending of messages between centres of governance and trade became more frequent and the speed of transmission more important. As a result, conveying of messages in written form using couriers became common. The Royal Mail of the Persian Empire was an advanced form of such a telecommunications system.

Security and trade have continued to remain a major reason for the development and maintenance of telecommunications infrastructure. Increasingly trade, for example across the Silk

Road, required a reliable messaging system. In contrast with the internal security-focused telecommunications systems, such as that of the Royal Mail, many of these trade-focused communications were across 'national' boundaries. It should be noted that the benefits of this telecommunications system were experienced by all and not just the senders and receivers. The society at large benefits from improved security, enhanced efficiency of trade and so on.

Very few telecommunications technology advances are recorded until the late 18th century and the development of Visual Telegraphy by Claude Chappe in 1794 (see Historical Note in Chapter 2). This development owed its existence to a number of advances including architecture and building construction technologies and the invention of optical telescopes. It also depended on social/policy developments such as re-emergence of strong central governance or 'empire' which could build and benefit from a telecommunications infrastructure. The discoveries of electricity and electromagnetic field in the 19th century were further theoretical foundations which led to the invention of electrical telegraphy and telephony and the modern systems we use today.

Some 2500 years after the Royal Mail was constructed and operated by the Persian Empire, many governments around the world are making decisions on how to build, and to what extent fund, their national telecommunications infrastructure. Again, construction and operating costs of a telecommunications system are weighed against business and strategic benefits of a national robust infrastructure which benefits most if not all of society. From a government policy point of view, telecommunications is a public need as well as a tool for state security. Broadband telecommunications has been called the infrastructure of the 21st century, and is considered as important as electricity, water, roads and other national infrastructure. Many of our needs are delivered over this infrastructure such as education, health, information, entertainment, security, social connectivity and so on. Efficient development, management and operation of broadband telecommunications are high on the agenda of governments of developed and developing countries.

Most national governments generally have aimed to ensure access to high quality telecommunications services are provided to the society on an equitable basis. An infrastructure to 'connect people' and facilitate fast and reliable messaging continues to be a multifaceted strategic asset.

This book focuses on broadband telecommunications as an ecosystem designed not only to connect people to each other, but also as a means to connect people to content and services such as information, entertainment, work, trade, goods, and so on. It is more than just an infrastructure: it also contains means of customer service, data collection and content delivery. An end-user connects to a broadband telecommunications infrastructure managed by a business entity that ensures high quality information transfer. The subscriber connectivity needs are managed by a service provision retailer who not only connects the users to others, but also delivers content from countless sources worldwide. This industry ecosystem can be drawn as a three-layer diagram as shown in Figure 1.2. We will demonstrate the complexity of the underlying technologies, business structure, and policy requirement of constructing and operating this ecosystem, and describe models which can be used for its analysis.

For this ecosystem to operate efficiently several factors need to be considered. Each layer uses a range of different technologies, each of which contributes to system efficiency. Moreover, diverse business models and industry alliances may exist at and across layers. From a public policy point of view, broadband telecommunications is vital to a national

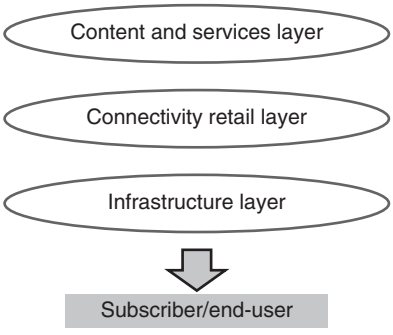

Figure 1.2 Broadband telecommunications industry ecosystem

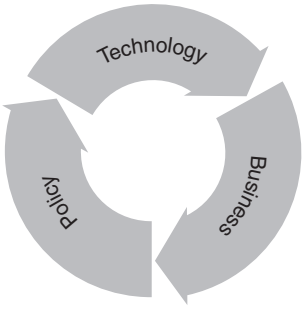

Figure 1.3 Technology–business–policy framework

economy. Furthermore, there are monopoly considerations, as well as privacy and confidentiality issues which require government attention and often regulation. Analysing a broadband telecommunications business is complex; it requires examination of technology, business and policy issues.

The Royal Mail *telecommunications system* is a good example of the analysis model we use extensively in this book. In this model three important elements contribute to the success of a product: technology, business and policy [7]. As illustrated in Figure 1.3, the three elements influence each other: the technology value proposition provides business advantage, which exists within a policy milieu, which may be subject to adjustment and government intervention. Policy direction may in turn influence the technology selection process, thereby closing the loop. We demonstrate that an overall evaluation of all three elements is necessary in analysing a telecommunications technology product. Clearly different products depend to a different degree on each aspect, but nevertheless all three will impact on a product's success.

The technology–business–policy framework is valuable to telecom analysts as it enables them to first examine whether a telecommunications technology is reliable and efficient. Next it requires them to consider costs of development of the product, provision of service,

maintenance and so on, and determines whether a product can be sold to a customer for a price to produce a profit. It then needs to review the national and global policy issues that govern product development and service delivery, and determines product compliance; or, if necessary, what policy modification is needed.

Why Broadband Telecommunications?

The second half of the 20th century witnessed the evolution of the information communication technology (ICT) industry. The industry grew from serving niche applications to becoming a vital tool in helping to improve and even facilitate government and business operations and processes.

Early ICT systems were standalone computers which were mainly used in process automation and number-crunching applications. ICT systems have since evolved to facilitate not only automation, but also facilitate connectivity between suppliers and customers in business value chains. Information gathering from customers and suppliers is possible on an unprecedented scale. Furthermore, information gathering from ubiquitous sensor networks is forecast to become a major source of data collection in the future. Information so gathered is being used to obtain business intelligence to further enhance operational efficiency and to control business functions. Because of these developments, the ICT industry is now one of the most important sectors of the world economy, and employs an increasingly large number of technology and managerial ICT professionals. Figure 1.4 shows the employment trends in the ICT industry for 1995 and 2010 and how the share of ICT jobs in the economies of Canada, USA, Australia and the EU has grown. Note that this is a narrow definition which only considers ICT specialists as those, 'who have the capabilities to develop, operate and maintain ICT systems. ICT

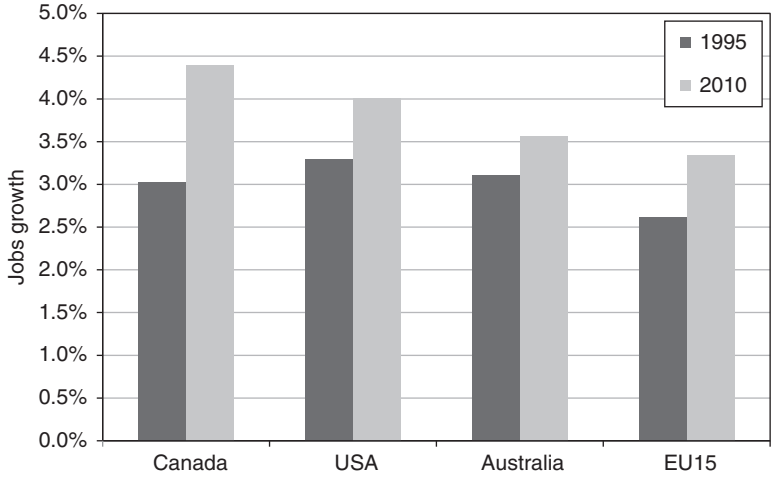

Figure 1.4 Sample job number growth within the ICT industry. Reproduced with permission of Organisation for Economic Co-operation and Development (OCED)

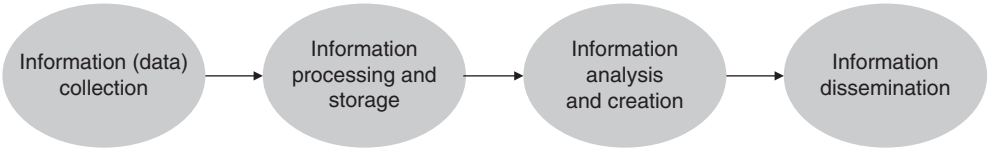

Figure 1.5 Information flow model

constitutes the main part of their job'. It does not include workers who use ICT products in their everyday jobs [8].

'Information' is at the centre of ICT industry activities, whose processes deal with how this 'information' is gathered, stored, analysed and disseminated. This information flow, as illustrated in Figure 1.5, is one way to analyse how effectively an organisation manages and uses the information it has. Among these processes, telecommunications can be defined as the technology and business processes associated with gathering and disseminating information.

'Modern' telecommunications, defined by its use of mechanical and electrical equipment and provision of a much faster transmission of messages, is a relatively recent development and its history can be traced to the late 18th century. Developments of visual and electrical telegraphy and telephony have significantly transformed how we *tele*-communicate. Modern telecommunications has been instrumental in the coming of a new age of global cooperation (and at times conflict) across national boundaries, leading to our present-day world order. In particular, the digital communications revolution of the last two decades of the 20th century has been the platform on which the ICT industry has been built.

Telecommunications has been the subject of research in multinational companies as well as major universities and government-funded institutions for more than two centuries. According to the World Intellectual Property Organisation (WIPO) 6.8% of all patents filed under the Patent Cooperation Treaty (PCT) in 2013 were in the telecommunications field. Indeed electrical machinery, apparatus, energy (14 897 filings), computer technology (14 684 filings), and digital communication (14 059 filings) were the top three areas of patent filings [9]. Moreover, the top four and all of the top 15 patent applicants were either purely telecommunications companies or had telecommunications units (Figure 1.6).

Telecommunications is also a major industry segment in its own right with many companies including operators, manufacturers and service providers among the world's most valuable. In addition, telecommunications has traditionally been one of the most regulated industries both nationally and internationally: indeed, the incumbent monopoly telephone operator was government owned until recent years. Although the industry has been deregulated, still the telecommunications portfolio is usually represented by a senior government minister, and one or more departments who regulate and monitor telecommunications service provision. At the international level, telecommunications technologies were one of the earliest to be standardised across national boundaries as interoperability was necessary for international trade. Nowadays, the development and ratification of international standards is generally accepted as a prerequisite for the success of a new telecommunications system. Such standardisation is done under the auspices of the International Telecommunications Union (ITU).

Modern telecommunications, if marked by the inventions of telegraphy and telephony, date back to the mid-to-late 19th century. Despite this, usage of telecommunication services was

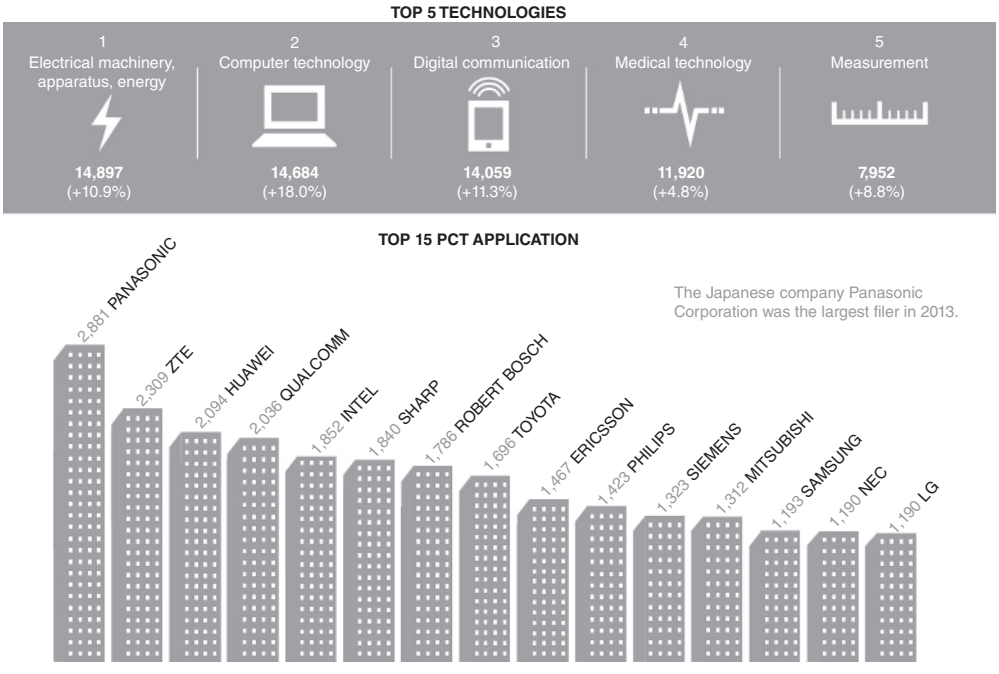

Figure 1.6 Patent application filed under the PCT in 2013. Reproduced with permission of World Intellectual Property Organization [9]

quite limited until very recently. Access to these services became widespread in developed countries by the second half of the 20th century. However, the vast majority of the population in developing countries had little or no access to telephony services, nor much use for telegraphy. Universal access to voice and message transmission only became possible with the introduction of inexpensive mobile telephony and internet systems and services. Figure 1.7 shows the growth in the number of mobile phone subscribers in developed and developing countries. The number of subscribers grew by a factor of 7.5 over a period of 12 years, reaching a global 100% penetration rate in 2013, a compound annual growth rate (CAGR) of 18.3%. The growth rate and rapid adoption in developing countries for these services is indicative of the basic need for telecommunications services. If prices are affordable, everyone will want to have access. This rapid adoption also demonstrates the effectiveness of national and international policies in standardisations, allocation of resources such as frequency spectrum, and deregulation of the telecommunications industry [10].

The technological and business transformations noted above have led to the rise of broadband telecommunications. Broadband telecommunications may be defined as information transmission at 'very high' rates. This 'very high' has been changing over the years: while a 256 kilobits per second (kbps) link was considered broadband in 2000; broadband today (2014) refers to several tens of megabits per second (Mbps). Some analysts even define broadband telecommunications systems as those capable of supporting transmission rates of 100 Mbps to 1 gigabit per second (Gbps) and more.

In contrast to telephony, the history of data communication and subsequently broadband telecommunications is very recent and began only in the late 1980s. Technologies to enable

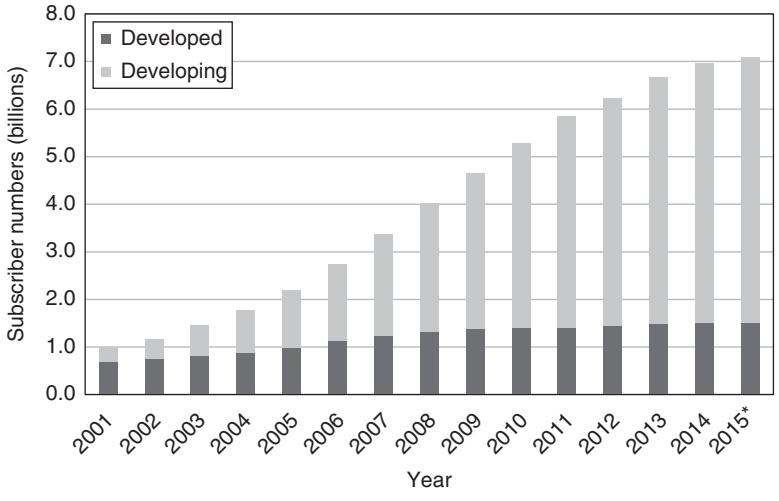

Figure 1.7 Growth of mobile telephone subscriber numbers in developed and developing countries during 2001–2015. 2013–*2015 figures are estimates. Reproduced with permission of Organisation for Economic Co-operation and Development (OCED)

computer-to-computer data communications emerged in the second half of the 20th century. Initially such services were provided to large companies, governments and universities using dedicated links such as coaxial and optical fibre cables. Data communications from subscriber premises also became possible at very low transmission rates using telephone lines and dial-up modems.

Large scale broadband telecommunications service delivery to subscriber premises only gained popularity with services such as email and the World Wide Web. Higher transmission rates became possible as technologies such as digital subscriber line (DSL), and optical fibre based systems such as Fibre-to-the-Home (FttH) and hybrid fibre-cable (HFC) were developed in the late 1990s. The introduction of wireless broadband technologies within the 3G standards in the early 2000s made it possible for nearly a third of the world's population to access the data communications network from individual subscriber premises. In most OECD countries the total fixed and wireless broadband subscription numbers are at near saturation levels (Figure 1.8). The main reason for such growth is the economic benefits of broadband connectivity. Efficient provision of broadband telecommunications services is an important business and policy issue in virtually every country around the world.

The growth of broadband telecommunications services has profoundly impacted many facets of our lives. It has significantly changed the way we study, work, play, entertain, take care of our health, share knowledge, socialise, and even wage war. The way we do business has changed to an extent that a whole new field of business – electronic commerce – enabled by the advancements in the telecommunications technology has emerged, and given rise to many successful new companies over the past two decades. The impact of the telecommunications industry may be measured by the fact that while the costs of making long distance phone calls has fallen to nearly zero, investment in infrastructure equipment as a share of global Gross Domestic Product (GDP) has risen significantly. The OECD reports a CAGR of 5.7% over the 2000–2009 decade in the ICT industry. As a share of GDP, the ICT industry has been growing as shown in Figure 1.9. It is expected to grow further over the coming decade as our life and work changes more as a result of information and communications technology development [11].

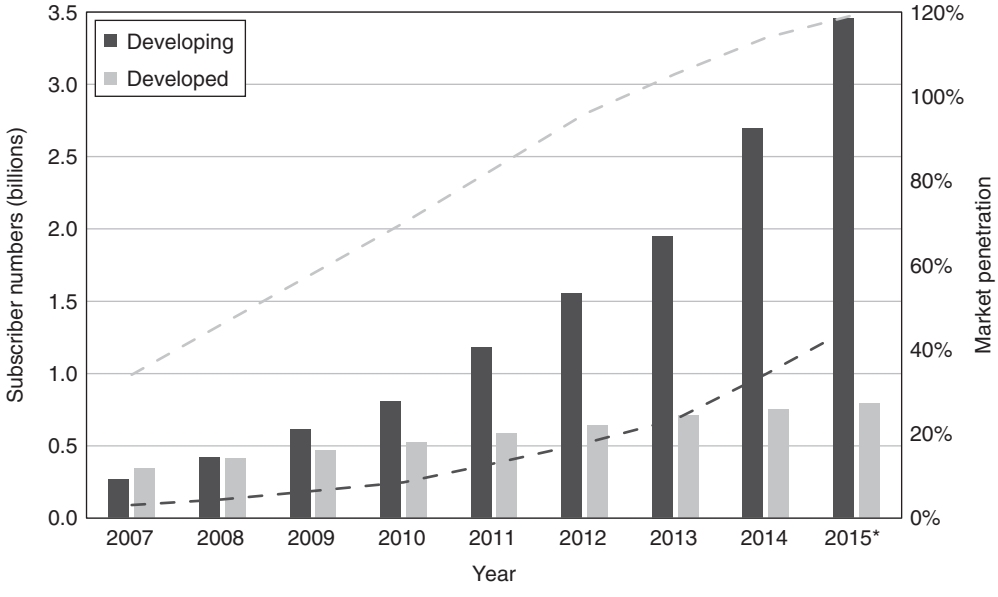

Figure 1.8 Fixed and wireless broadband subscriber numbers (columns, left-hand vertical axis) and the total penetration ratio (dotted line, right-hand vertical axis) in developed and developing countries. ITU data [10] and author analysis. 2013–*2015 figures are estimates. Source: Informa Telecoms and Media, July 2011. Reproduced with permission of Organisation for Economic Co-operation and Development (OCED)

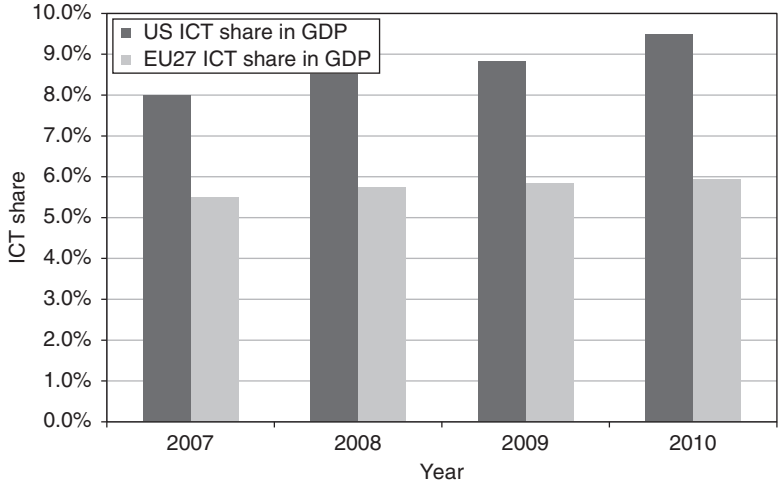

Figure 1.9 ICT share of GDP in the US and EU. Source: http://www.oecd.org/sti/broadband/oecdkeyictindicators.htm, from 'Share of ICT-related occupations in the total economy in selected countries, narrow definition', accessed 4 February 2014. Reproduced with permission of Organisation for Economic Co-operation and Development (OECD)

Further demonstrating the importance of telecommunications is the significant share of ICT expenditure and revenue in national GDPs. In the OECD alone the total telecom sector revenue stood at some $1.36 trillion. It has been growing steadily at a CAGR of nearly 7% over the past three decades [12, 13].

A large number of services depend on broadband telecommunications. These include telemedicine, remote manufacturing, tele-education, and telepresence conferencing. Broadband telecommunications has facilitated a global infrastructure that supports hitherto unforeseen services and business activities. The coming decades are expected to witness the roll-out of a network of sensors which collect information on our environment and surroundings, our health, our work and many other aspects of our lives and share it across a network referred to as the Internet of Things (IoT). These systems are expected to connect over a ubiquitous telecommunications network, development and roll-out of which is forecast to be a major economic activity in both the developed and developing countries of the world in the near to medium future. Broadband telecommunications will remain a significant part of our lives.

Review Questions

1. Why did the Persians build the Royal Highway?
2. The cost of building the Royal Highway must have been quite high. Why do you see the trade-off considerations for the Persian Empire vis-à-vis this cost at the design stage?
3. What technological, business and policy issues had to be addressed in building the Royal Mail system?
4. How can the technology, business and policy framework be useful in analysing telecommunications systems?
5. What are the three layers in a broadband content/service provision system? How do these relate to each other?
6. Although telecommunications comprises only 3–4% of global GDP, the share of global patent applications in 2013 was nearly 7%. Explain two reasons why this is the case.
7. What are the drivers behind the phenomenal growth of mobile and broadband subscriber numbers around the world?
8. Why is the mobile subscriber number growth in the developing countries larger than that of the developed countries?
9. What do you see as the reasons for the growth of ICT jobs around the world?
10. Why do you see the importance of studying telecommunications management? How does this relate to the broader topic of information and information technology management?

References

[1] http://www.postalmuseum.si.edu/museum/1e_faqs.html#history10, accessed 4 February 2014.
[2] Graf, D.F. (1994) *The Persian Royal Road System*, cited in http://en.wikipedia.org/wiki/Royal_Road, accessed 20 August 2015.
[3] http://www.lib.utexas.edu/maps/historical/shepherd/persian_empire.jpg, accessed 20 August 2015.
[4] http://www.thelatinlibrary.com/historians/herod/herodotus7.html, accessed 20 August 2015.
[5] Estuanie, E. (1904) *Traite Pratique de Telecommunications Electrique*, cited in Huurdeman, A.A. (2003) The Worldwide History of Telecommunications, Wiley Interscience.

[6] Anonymous (1928) World's Oldest Letter, The Canberra Times (31 May), p. 4.
[7] Krishnan, R. (2007) Lecture slides on E-Commerce course, Heinz College, Carnegie Mellon University.
[8] http://www.oecd.org/sti/broadband/oecdkeyictindicators.htm, accessed 20 August 2015.
[9] http://www.wipo.int/export/sites/www/ipstats/en/docs/infographics_patents_2013.pdf, accessed 20 August 2015.
[10] http://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx, accessed 20 August 2015.
[11] ICT R&D, Innovation and Growth. http://ec.europa.eu/digital-agenda/sites/digital-agenda/files/KKAH12001ENN-chap4-PDFWEB-4_0.pdf, accessed 20 August 2015.
[12] www.oecd.org/sti/ieconomy/46471775.xls, accessed 20 August 2015.
[13] OECD. OECD Communications Outlook 2013. http://www.oecd.org/sti/broadband/oecd-communications-outlook-19991460.htm