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From Net Neutrality to ICT Neutrality

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Preface

ICT (for *Information and Communication Technology*) is omnipresent in our modern society, and the economy has gone beyond the industrial economy to the Internet and ICT economy. Thanks to hyper-connectivity, there are now lots of opportunities for innovation. As of January 2022, the top 3 most valuable companies worldwide are all ICT companies (Apple Inc., Microsoft, Alphabet Inc.), and three other ICT companies (Amazon Inc., Facebook, Tencent) appear in the top 10.[1] Internet Service Providers (ISPs), Content Delivery Networks (CDNs) and cloud providers, and social network actors, all services and content providers are among actors researching a business model as profitable as possible.

But the success of ICT is often coined to be linked to the open and free Internet, fostering participation and innovation. With numerous actors willing to design and implement business models to increase their revenue, the impact on the whole network outcome can be significant. That issue has been highlighted when ISPs started claiming that some big content providers, representing an important part of the traffic flowing through their network, should participate to the network infrastructure upgrading costs, with the threat of being blocked or slowed down in case of refusal. This launched the *network neutrality debate*. Basically, net neutrality means that Internet providers should treat all Internet packets the same way, regardless of their type, content, origin, or destination. Network (non-)neutrality has become a very hot topic in the past few years, at the same time from political, economic, and daily life points of view, because it may refashion the Internet business model and in general the telecommunications vision and future. Our purpose is to review the debate and discuss arguments and regulation passed worldwide. We also aim at providing a balance between mathematical theory and practical discussion.

Another issue is that while the network neutrality issue has been the polarizing on ISPs' role, the Internet has changed from the simple content-ISP-users delivery chain to a more complicated ecosystem with numerous intermediaries between content and users and players affecting the online experience. The book aims at

[1] https://fxssi.com/top-10-most-valuable-companies-in-the-world.

highlighting the role of those other actors (CDNs, search engines, "structuring platforms," social networks, etc.) and the impact of their possibly non-neutral behavior, which can bypass the general neutrality principles without violating the (packet-based) rules currently evoked in the debate. A typical example is the ranking algorithms of search engines being suspected of voluntarily putting in a higher position their own businesses or their "relations" and lowering the position of competitors, leading to the so-called *search neutrality debate*. One of our goals is open the reader to the complications of limiting the neutrality debate to ISPs, potentially requiring to extend the neutrality framework to a general definition encompassing all actors and clarifying the rules. That issue leads to a debate on the transparency of algorithms, expected by regulatory bodies, that we hint in the last chapters.

We hope that the text will open the readers' mind to the issues of fairness, freedom, and economic efficiency, among others, and illustrate the complexity of confronting those high-level considerations with the constantly evolving ICT technical realities.

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About the Authors

Patrick Maillé graduated from Ecole Polytechnique and Telecom Paris, France, in 2000 and 2002, respectively. He has been with IMT Atlantique (formerly Telecom Bretagne) since 2002, where he obtained his PhD in applied mathematics in 2005 and his habilitation (Rennes 1 university) in 2015. He has held visiting scholar appointments at Columbia University (June–December 2006) and UC Berkeley (academic year 2014–2015). His research interests are in all economic aspects of telecommunication networks, from pricing schemes at the user level to auctions for spectrum and regulatory issues. He currently serves as an Associate Editor for *Electronic Commerce Research and Applications* (Elsevier) and *IEEE Open Journal of the Communications Society*. He has authored or co-authored more than 150 papers on those topics and is along with Bruno Tuffin the author of *Telecommunication Network Economics: From Theory to Applications* published by Cambridge University Press in 2014.

Bruno Tuffin received his PhD degree in applied mathematics from the University of Rennes 1 (France) in 1997. Since then, he has been with Inria in Rennes and has been the leader of the team called ERMINE since January 2022. He spent 8 months as a postdoc at Duke University in 1999. His research interests include developing Monte Carlo and quasi-Monte Carlo simulation techniques for the performance evaluation of telecommunication systems and developing new Internet-pricing schemes and telecommunication-related economic models. He has published close to 200 papers on those issues. He has also led or participated into several French and European projects and co-organized several conferences. He is currently Area Editor for *INFORMS Journal on Computing* and Associate Editor for *ACM Transactions on Modeling and Computer Simulation* and *Queuing Systems: Theory and Applications* and was formerly Associate Editor for *Mathematical Methods of Operations Research* and *INFORMS Journal on Computing*. He has

written or co-written three books: *Rare Event Simulation Using Monte Carlo Methods* published by John Wiley & Sons in 2009, *La simulation de Monte Carlo* (in French) published by Hermes Editions in 2010, and *Telecommunication Network Economics: From Theory to Applications* published by Cambridge University Press in 2014, also co-authored with Patrick Maillé.

Acronyms

ADSL	Asymmetric Digital Subscriber Line
AI	Artificial intelligence
API	Application Programming Interface
ARCEP	Autorité de régulation des communications électroniques, des postes et de la distribution de la presse
ARPA	Advanced Research Projects Agency
BEREC	Body of European Regulators for Electronic Communications
BT	British Telecommunications
CDN	Content delivery network
CERN	European Organization for Nuclear Research
CP	Content provider
CRTC	Canadian Radio-television and Telecommunications Commission
CTR	Click-through rate
DNS	Denial of service
DPI	Deep packet inspection
DSL	Digital subscriber line
EU	European Union
FCC	Federal Communications Commission
FTC	Federal Trade Commission
FTTH	Fiber to the home
GAFAM	Google, Apple, Facebook, Amazon, and Microsoft
ICT	Information and Communication Technology
IoT	Internet of Things
IP	Internet Protocol
ISP	Internet service provider
NIST	National Institute of Standards and Technology
NPT	Norwegian Post and Telecommunications Authority
OECD	Organisation for Economic Co-operation and Development
OS	Operating system
OSI	Open System Interconnection
P2P	Peer to peer

QoE	Quality of experience
QoS	Quality of service
RFC	Request for Comments
SE	Search engine
TCP	Transmission Control Protocol
TRAI	Telecom Regulatory Authority of India
UDP	User Datagram Protocol
VoIP	Voice over Internet Protocol

Chapter 1
Introduction: A Bit of History

1.1 The Advent of the Digital Economy and the Need for Regulation

ICT (for *Information and Communication Technology*) is an acronym that designates the field integrating all technologies dealing with communications, computing, and information processing. ICT is the extension of IT, for *Information Technology*, which was coined for the first time around the Second World War (particularly in Los Alamos for nuclear research) for the development of computers. The extension to ICT was to encompass electronic communications. ICT concerns the design, development, and analysis of hardware and software in computer and information systems, including networking, data management, etc. It has become omnipresent in our daily life and changed the way we live and work. ICT tools assist us at each step of our activities: we use computers and smartphones to communicate, even with people far way, through voice calls, emails, videoconferences, and social networks; we can access any information and buy everything online; ICT enables new education means, including virtual reality, interactive multimedia, and distance courses; it simplifies entertainment, thanks to online and on-demand television and video gaming; it simplifies healthcare with tele-health and distant monitoring; it also helps companies in their activities; it is key in the development of robots to perform many tasks, etc.

The impact and weight of ICT in the worldwide economy keeps increasing. Many types of figures can be given, and the reader is advised to look for example at the Web page maintained by OECD (Organisation for Economic Co-operation and Development) with some key ICT indicators http://www.oecd.org/internet/broadband/oecdkeyictindicators.htm, or at [79]. To illustrate the increasing impact of ICT in our lives, let us focus on e-commerce (i.e., buying things online). Updating data published in [104], e-commerce sale have increased from US$1.34 in 2014 to US$3.53 trillion in 2019 and $4.9 trillion in 2021 (an average 20% growth, almost unaffected by the COVID-19 crisis); they are projected to reach US$6.4

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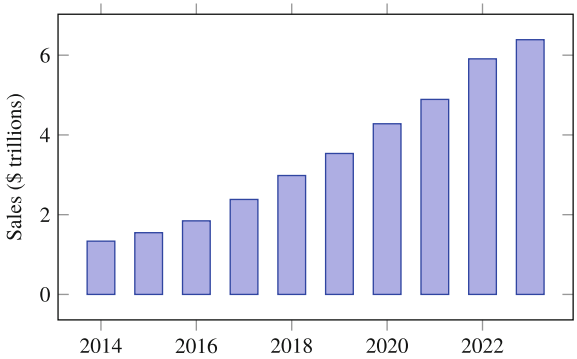

Fig. 1.1 Evolution of e-commerce sales (Statista data). Values from 2014 to 2020 are real data, 2021 and later projected values

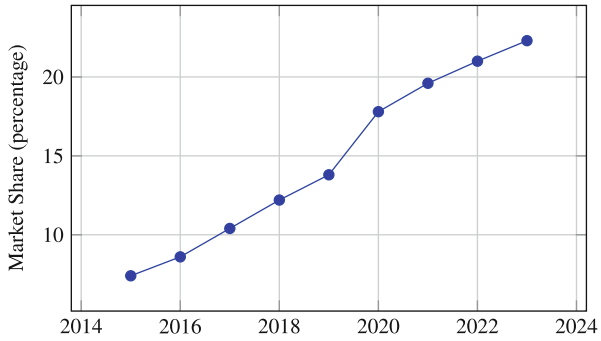

Fig. 1.2 Evolution of e-commerce market share. Values from 2015 to 2020 are real data, 2021 and later projected values

trillion in 2023. Figure 1.1 details this evolution of worldwide sales with values per year. Not only sales value increases: the e-commerce share of total global retail industry also keeps increasing, and that trend is expected to continue as shown in Fig. 1.2.[1] Another notable indicator of ICT predominance can be found on the businesses' side: as of January 2022, the top three most valuable companies worldwide are all ICT companies (Apple Inc., Microsoft, Alphabet Inc.), and three other ICT companies (Amazon Inc., Facebook, Tencent) appear in the top ten.[2] Finally, Fig. 1.3 plots the volume of Internet traffic year by year from 1990 to 2017, with predictions at the time we got figures for 2018 and later. It illustrates the growth and increasing importance of Internet traffic in our modern society and the associated technological challenges we are facing if we want to ensure a sufficient

[1] For data, see https://www.shopify.com/enterprise/the-future-of-ecommerce or https://www.emarketer.com/content/global-ecommerce-2020.

[2] https://fxssi.com/top-10-most-valuable-companies-in-the-world

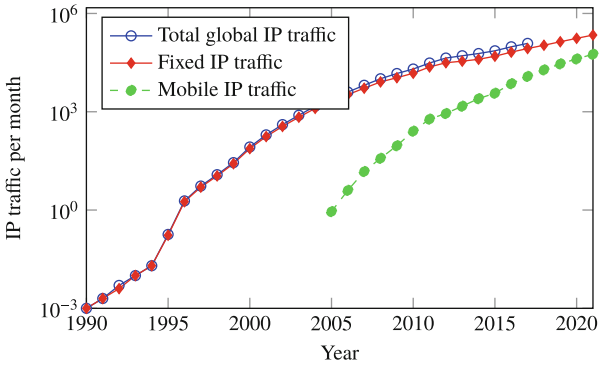

Fig. 1.3 IP traffic evolution in petabytes per month, logarithmic scale (Cisco data)

quality of service to all users: new technological concepts need to be created to ease the load on the network, wired (e.g., with caching), and/or wireless (with the evolution from 3G to 4G and now the advent of 5G).

But all the advances to ease our life and business are also accompanied with many fears and threats. First, it is often argued that ICT impacts physical activity[3] and therefore impacts health, due to the increasing time spent in front of screens and the less physically demanding tasks we tend to do. Another complaint is that ICT reduces physical social interactions and therefore somewhat counterintuitively favors isolation. A third raised concerns the easiness of disseminating fake news enabled by ICT, which has become a major concern for public education: the news were before managed by professionals (journalists) checking facts in most cases; now any individual can propagate false information without control. Moreover, all those new ICT activities have also brought a new type of criminality, named cybercriminality. The new types of offenses include[4] (i) phishing, using fake email messages to get personal information (email account, data, bank account, credit card number), (ii) hacking a network or a Web site, and (iii) distributing hate or pornography. Consequences include identity theft, cyber-extorsion (e.g., ransomware), cryptojacking, or cyberespionage. Finally, there is an increasing concern about the environmental impact of ICT, in terms of greenhouse gas emissions and power consumption (it is expected that billions of IT Internet-connected devices will produce 14% of global emissions by 2040, and the communications industry could use 20% of all the world's electricity by 2025[5]).

In summary, ICT brings a lot of positive externalities to society, eases life, and offers opportunities and new interactions but naturally comes with some issues

[3] https://medicalnewsbulletin.com/technology-physical-activity-levels-students/

[4] See among others https://www.government.nl/topics/cybercrime/forms-of-cybercrime.

[5] https://www.climatechangenews.com/2017/12/11/tsunami-data-consume-one-fifth-global-electricity-2025/

and worries. ICT keeps evolving, and as it involves several types of interacting commercial actors, behaving in most cases selfishly to maximize their profits, it seems important that society checks the impact of those behaviors on social welfare to prevent a potential harm. This is typically why regulatory bodies have been introduced: to ensure a fair use of ICT.

One of the most vivid debates in ICT about potential behaviors harming welfare regards what occurs in the Internet "pipes": that is the so-called Net neutrality debate, which we detail, develop, and extend in this book. The next section recalls some historical events and explains why the debate has become a major issue. We will next discuss how and why it can be extended to all domains of ICT.

1.2 The Internet: Worries About the Lack of Neutrality

The central element of the ICT economy is probably the Internet network. The principle of the Internet started in the early 1960s (even by Feb. 7 of 1958, when the Advanced Research Projects Agency (ARPA) was launched in the USA, starting research on the topic). The basic idea was to be able to connect computers in order to share information and resources for research, but also in order to provide a robust network to the US military during the Cold War. At that time, the USA was worried about the scientific advances from the Soviet Union, in particular their success with the Sputnik satellite in 1957, igniting fears about the impact it could have on the US long-distance communication network. The project, led by J.C.R. Licklider, was the inception of what we now know as the Internet. The concept was (and still is) to transmit data by cutting information into so-called *packets* sent independently one after the other and re-ordered at the received end. In contrast to the traditional telephone network transmission method, called *circuit-switching* because a *circuit* (a set of resources necessary for the communication along the whole path) is built and reserved for the communication, there is no need to reserve resources here: packets can be sent one after the other and re-sent in case of any problem, making the communication more robust. A packet is easily built and is made of two parts: the *payload* containing the slice of data to be sent and the *header* containing information such as source, destination, and any other useful detail used for routing among other things [84, 174]. The first connection between two computers was effective in 1965, between the Massachusetts Institute of Technology and California, followed by the "ARPAnet" network and connecting universities and research organizations in contract with the US Defense Department. That network was implementing applications, routing, and addressing protocols still in use nowadays. Many other networks of universities were then created using the same protocols and were therefore able to interoperate with ARPAnet. The Internet was officially created in 1983, when ARPAnet was separated from the military network, connecting universities across the USA. The transmission control protocol (TCP) was adopted, facilitating transmissions between computers and boosting the network development. Internet communications knew major progresses with the