

---

## Contents

---

|  |      |
|--|------|
| <b>Foreword</b> . . . . .  | xi   |
| <b>Preface</b> . . . . .   | xiii |
| <b>Acknowledgements</b> . . . . .                                  | xv   |
| <b>Preamble</b> . . . . .  | xvii |
| <b>Part 1. Introduction – The Buzz about IoT and IoE</b> . . . . . | 1    |
| <b>Chapter 1. Introduction</b> . . . . .                           | 3    |
| 1.1. Definition of communicating- or connected Things . . . . .    | 3    |
| 1.1.1. Connected Things – Communicating Things . . . . .           | 3    |
| 1.1.2. Definition of the IoT . . . . .                             | 4    |
| 1.1.3. Internet of x . . . . .                                     | 5    |
| <b>Chapter 2. The (Overly) Vast World of IoT</b> . . . . .         | 9    |
| 2.1. 2011–2016: the craze for the term “Connected Thing” . . . . . | 9    |
| 2.1.1. The catch-all . . . . .                                     | 9    |
| 2.1.2. Fashion, buzz and “bubble” . . . . .                        | 10   |
| 2.1.3. “Hype” cycle for innovations . . . . .                      | 11   |
| 2.2. The true goal of this book . . . . .                          | 14   |
| <b>Chapter 3. Why a Connectable Thing?</b> . . . . .               | 15   |
| 3.1. Examples of connectable things . . . . .                      | 15   |
| 3.1.1. Home care for the elderly . . . . .                         | 16   |
| 3.1.2. In the automotive industry . . . . .                        | 19   |

|  |    |
|--|----|
| <b>Part 2. Constraints Surrounding an IoT Project . . . . .</b>                    | 21 |
| <b>Chapter 4. Aspects to be Taken into Consideration . . . . .</b>                 | 23 |
| 4.1. Aspects pertaining to the concrete realization of Connected Things . . . . .  | 23 |
| 4.1.1. Financial and marketing aspects . . . . .                                   | 24 |
| 4.1.2. Technical and industrial aspects . . . . .                                  | 24 |
| 4.1.3. Regulatory and normative aspects . . . . .                                  | 24 |
| 4.1.4. Security aspects . . . . .  | 24 |
| 4.1.5. Cost aspects . . . . .  | 24 |
| <b>Chapter 5. Financial and Marketing Aspects . . . . .</b>                        | 27 |
| 5.1. Economic aspects . . . . .  | 27 |
| 5.1.1. Saleable / buyable . . . . .  | 27 |
| 5.2. Ergonomic aspects . . . . .   | 29 |
| 5.2.1. Mechanical form and design vs ergonomics . . . . .                          | 29 |
| <b>Chapter 6. Technical and Industrial Aspects . . . . .</b>                       | 31 |
| 6.1. Technical aspects . . . . .   | 31 |
| 6.1.1. Life cycle of a new product . . . . .                                       | 31 |
| 6.1.2. Techno-economic feasibility . . . . .                                       | 32 |
| 6.1.3. Design . . . . .  | 32 |
| 6.1.4. Industrialization, manufacturing process<br>and quality assurance . . . . . | 32 |
| 6.2. Energy aspects . . . . .  | 32 |
| 6.2.1. Power supply to the Thing . . . . .   | 33 |
| 6.3. Industrial aspects . . . . .  | 39 |
| <b>Chapter 7. Regulatory and Normative Aspects . . . . .</b>                       | 41 |
| 7.1. Regulatory aspects and recommendations . . . . .                              | 41 |
| 7.1.1. Radiofrequency regulations . . . . .  | 42 |
| 7.2. Health-related recommendations . . . . .                                      | 43 |
| 7.2.1. Exposure of the human body to electromagnetic fields . . . . .              | 44 |
| 7.2.2. Specific Absorption Rate (SAR) . . . . .                                    | 44 |
| 7.3. Societal regulations and individual freedoms (privacy) . . . . .              | 45 |
| 7.3.1. The various data needing to be protected . . . . .                          | 45 |
| 7.3.2. Loi Informatique et Libertés . . . . .                                      | 45 |
| 7.3.3. Mandate 436, PIA and RFID and IoT applications . . . . .                    | 46 |
| 7.3.4. GDPR – General Data Protection Regulation . . . . .                         | 49 |
| 7.3.5. Privacy by design . . . . .   | 51 |
| 7.4. Environmental regulations and recycling . . . . .                             | 53 |
| 7.4.1. Electronic waste treatment . . . . .  | 53 |

|  |            |
|--|------------|
| 7.4.2. Regulation and organization of the chain . . . . .          | 54         |
| 7.4.3. Labeling of electrical and electronic equipment . . . . .   | 54         |
| 7.5. Normative aspects . . . . .                                   | 55         |
| 7.5.1. ISO/AFNOR . . . . .   | 55         |
| 7.5.2. IEEE . . . . .  | 56         |
| 7.5.3. ETSI . . . . .  | 56         |
| <b>Chapter 8. Security Aspects . . . . .</b>                       | <b>59</b>  |
| 8.1. Security aspects . . . . .                                    | 59         |
| 8.1.1. The weak links . . . . .                                    | 60         |
| 8.1.2. Possible solutions . . . . .                                | 62         |
| 8.1.3. Definition and choice of security target . . . . .          | 63         |
| 8.1.4. Concepts of security levels applied in IoT . . . . .        | 64         |
| 8.1.5. True security – the “Secure Element” . . . . .              | 67         |
| 8.1.6. Cryptography . . . . .                                      | 70         |
| 8.1.7. Symmetric and asymmetric encryption . . . . .               | 71         |
| 8.1.8. Consumer Things, IoT, security... and the Cloud . . . . .   | 75         |
| 8.2. Judging the quality of security . . . . .                     | 80         |
| 8.3. Some thoughts about security, privacy and IoT . . . . .       | 81         |
| 8.4. Vulnerabilities and attacks in the IoT chain . . . . .        | 82         |
| 8.4.1. Attacks on the software layer . . . . .                     | 83         |
| 8.4.2. Attacks on the board or Thing . . . . .                     | 84         |
| 8.4.3. Attacks on the integrated circuits . . . . .                | 84         |
| 8.4.4. Security standards . . . . .                                | 85         |
| <b>Part 3. Overall Architecture of the IoT Chain . . . . .</b>     | <b>87</b>  |
| <b>Chapter 9. Communication Models in IoT . . . . .</b>            | <b>89</b>  |
| 9.1. Communication models in IoT . . . . .                         | 89         |
| 9.1.1. OSI model . . . . .   | 89         |
| 9.1.2. TCP/IP model . . . . .                                      | 92         |
| 9.1.3. By way of conclusion . . . . .                              | 98         |
| <b>Chapter 10. Overall Architecture of an IoT System . . . . .</b> | <b>101</b> |
| 10.1. Overall architecture of a CT and IoT solution . . . . .      | 101        |
| 10.1.1. Description of the complete chain . . . . .                | 102        |
| 10.2. From a more technological point of view . . . . .            | 102        |
| 10.2.1. Architecture and overview of an IoT chain . . . . .        | 102        |
| 10.2.2. The “base station/gateway” . . . . .                       | 106        |
| 10.2.3. The “Cloud” zone . . . . .                                 | 109        |
| 10.2.4. The “User” zone . . . . .                                  | 110        |
| 10.3. The very numerous protocols involved . . . . .               | 113        |

|  |     |
|--|-----|
| <b>Part 4. Detailed Description of the IoT Chain . . . . .</b>               | 117 |
| <b>Part 4A. From the User (The Outside World) to the Thing . . . . .</b>     | 119 |
| <b>Chapter 11. From the Outside World to the Thing . . . . .</b>             | 121 |
| 11.1. Connection of the Thing to the outside world . . . . .                 | 121 |
| 11.1.1. Using sensors . . . . .  | 121 |
| 11.1.2. Using wired connections . . . . .                                    | 122 |
| 11.1.3. Using RF links . . . . .   | 122 |
| 11.1.4. Very Short Range (<10 cm) . . . . .                                  | 122 |
| 11.1.5. Short range SR Wide band (tens of meters) . . . . .                  | 124 |
| <b>Chapter 12. The Secure Connected Thing . . . . .</b>                      | 127 |
| 12.1. Physical constitution of the Thing . . . . .                           | 127 |
| 12.1.1. Sensors . . . . .  | 127 |
| 12.1.2. Local intelligence – microcontroller . . . . .                       | 128 |
| 12.1.3. Security (SE) . . . . .  | 128 |
| <b>Part 4B. From the Thing to the Base Station . . . . .</b>                 | 131 |
| <b>Chapter 13. Means of Communication to Access a Base Station . . . . .</b> | 133 |
| 13.1. Possible network connectivity technologies . . . . .                   | 133 |
| 13.1.1. Local or ultra-local non-operated RF networks . . . . .              | 135 |
| 13.1.2. Extended-deployment operated RF networks . . . . .                   | 136 |
| 13.1.3. Is there space for all these technologies? . . . . .                 | 136 |
| 13.2. Medium-range MR Wide-band (hundreds of meters) . . . . .               | 136 |
| 13.2.1. Wi-Fi . . . . .  | 137 |
| 13.3. Long-range (LR – tens of kilometers) . . . . .                         | 138 |
| 13.3.1. NB, UNB, WB, UWB, FHSS, DSSS and RF regulations . . . . .            | 138 |
| 13.3.2. Regulators and regulations . . . . .                                 | 140 |
| 13.3.3. RF bases . . . . .   | 146 |
| 13.4. LTN – Low-Throughput Network . . . . .                                 | 152 |
| 13.4.1. Long Range LR - LTN . . . . .  | 153 |
| 13.4.2. LR LTN in (U)NB – SIGFOX . . . . .                                   | 156 |
| 13.4.3. LR LTN in DSSS (spectrum spreading) – LoRa, from Semtech . . . . .   | 167 |
| 13.4.4. A discussion of spectrum spreading – SS . . . . .                    | 169 |
| 13.4.5. LR WB . . . . .  | 192 |
| 13.4.6. Operated LR WB networks . . . . .                                    | 196 |

---

|   |     |
|---|-----|
| <b>Part 4C. From the Base Station to the Server . . . . .</b>               | 203 |
| <b>Chapter 14. Network Access Layer – IP . . . . .</b>                      | 205 |
| 14.1. IPv4 . . . . .  | 205 |
| 14.1.1. Operation . . . . .   | 206 |
| 14.1.2. Services provided . . . . .   | 206 |
| 14.1.3. Reliability . . . . .   | 206 |
| 14.2. IPv6 . . . . .  | 207 |
| 14.2.1. Differences between IPv6 and IPv4 . . . . .                         | 207 |
| 14.2.2. Problems of privacy and/or anonymity? . . . . .                     | 209 |
| 14.3. 6LoWPAN . . . . .   | 209 |
| 14.3.1. Description of the technology . . . . .                             | 210 |
| 14.3.2. Integration of an IPv6 packet into an IEEE 802.15.4 frame . . . . . | 210 |
| 14.3.3. Autoconfiguration of an IP address . . . . .                        | 211 |
| 14.3.4. Network supervision and management . . . . .                        | 211 |
| 14.3.5. Constraints on “upper-layer” applications . . . . .                 | 211 |
| 14.3.6. Security . . . . .  | 212 |
| 14.3.7. Routing . . . . .   | 212 |
| <b>Chapter 15. The Server . . . . .</b>                                     | 215 |
| 15.1. Conventional functions of a server in IoT . . . . .                   | 216 |
| <b>Chapter 16. Transport and Messaging Protocols . . . . .</b>              | 219 |
| 16.1. Transport . . . . .   | 219 |
| 16.1.1. Operation . . . . .   | 220 |
| 16.1.2. Structure of a TCP segment . . . . .                                | 220 |
| 16.2. “IoT messaging” technologies . . . . .                                | 221 |
| 16.2.1. Main protocol parameters . . . . .                                  | 221 |
| 16.3. Protocols . . . . .   | 225 |
| 16.4. HTTP – HyperText Transfer Protocol . . . . .                          | 226 |
| 16.5. HTTP/2 . . . . .  | 227 |
| 16.6. MQTT – Message Queuing Telemetry Transport . . . . .                  | 227 |
| 16.6.1. Security in MQTT . . . . .  | 229 |
| 16.7. CoAP – Constrained Application Protocol . . . . .                     | 229 |
| 16.8. XMPP . . . . .  | 230 |
| 16.9. DDS – Data Distribution Service . . . . .                             | 231 |
| 16.10. AMQP – Advanced Message Queuing Protocol . . . . .                   | 232 |
| 16.11. SMQ . . . . .  | 233 |
| 16.12. JMS – Java Messaging Service . . . . .                               | 233 |
| 16.13. Other protocols . . . . .  | 234 |

|   |            |
|---|------------|
| 16.14. The broker . . . . .   | 234        |
| 16.14.1 Examples of possibilities . . . . .   | 235        |
| 16.15. Programming languages . . . . .  | 236        |
| 16.16. Operating systems . . . . .  | 236        |
| <b>Part 4D. From the Cloud Server to the Various Users . . . . .</b>                  | <b>237</b> |
| <b>Chapter 17. Cloud and Fog Computing . . . . .</b>                                  | <b>239</b> |
| 17.1. Cloud computing? . . . . .  | 239        |
| 17.1.1. What is its mode of operation? . . . . .                                      | 240        |
| 17.1.2. Advantages and benefits in IoT applications . . . . .                         | 240        |
| 17.1.3. Types of Cloud computing . . . . .  | 241        |
| 17.1.4. Cloud products and services . . . . .   | 241        |
| 17.2. Example: the PaaS platform AWS IoT . . . . .                                    | 242        |
| 17.3. How security is managed . . . . .   | 244        |
| 17.4. Fog computing? . . . . .  | 245        |
| 17.5. Big data . . . . .  | 246        |
| 17.6. Natural interfaces . . . . .  | 247        |
| <b>Part 5. Concrete Realization of an IoT Solution Examples and Costs . . . . .</b>   | <b>249</b> |
| <b>Chapter 18. Examples of the Concrete Realization of Connected Things . . . . .</b> | <b>251</b> |
| 18.1. Subject/application taken as an example . . . . .                               | 251        |
| 18.1.1. Architecture of the product: a communicating physical Thing . . . . .         | 253        |
| 18.1.2. Mandatory steps in creating the Thing . . . . .                               | 255        |
| <b>Chapter 19. Cost Aspects . . . . .</b>   | <b>261</b> |
| 19.1. CAPEX and OPEX are in the same boat . . . . .                                   | 261        |
| 19.1.1. CAPEX . . . . .   | 262        |
| 19.1.2. OPEX . . . . .  | 273        |
| 19.1.3. Conclusions . . . . .   | 275        |
| 19.1.4. Very important conclusions . . . . .  | 276        |
| <b>Conclusion . . . . .</b>   | <b>279</b> |
| <b>Bibliography . . . . .</b>   | <b>281</b> |
| <b>Index . . . . .</b>  | <b>285</b> |