Index

a
accelerometers, 451, 595, 598, 599, 604
accident and emergency (A&E)
  personnel, 475, 477
accuracy, 13, 104, 121, 162, 278, 397,
  403, 447, 469, 470, 487, 515,
  516, 545, 558
active devices, 83
active power control (APC), 398
actuators, 7, 8, 13, 14, 24, 30, 65, 72, 84,
  102, 173, 226, 321, 331, 367,
  369, 388, 394, 536, 570, 593
Adafruit, 154, 170, 172
Adafruit Feather Bluefruit, 154
adaptable self-organizing systems,
  70–72
adaptations, 31, 87, 199, 231, 417,
  483–485
adaptor
  A-adaptor and Tadaptor, 485, 490
  application binding, 484
  transmission binding, 484
advanced distribution network
  architectures, 387, 391
Advanced Encryption Standard
  (AES), 231
Advanced Message Queuing Protocol
  (AMQP), 97, 130, 305
advanced metering infrastructure
  (AMI), 297, 335, 400
Advanced Traffic Management Systems
  (ATMSs), 303
agriculture, internet of things, 510
  application
    in crop disease/pest
      management, 518–519
    crop water stress index, 513–514
    data acquisition, 514–515
    fertilization, 516–518
    irrigation, 512
    irrigation system, 515–516
    in PA, 511–512
    precision livestock farming
      (PLF), 519–522
  architecture, 512
  data collection, 510–511
  fertilizing, 516
  history of, 507
  IoT-backboned PA, 510
  seamless integration, 509
  site-specific operation, 511
  water consumption, 513
  world population, 508
AIOTI. see Alliance for Internet of
  Things Innovation (AIOTI)
Airbnb, 62
Akamai’s Edge Computing, 122
alert care givers, 84
Alexanderson, Ernst, 135
allergy, 478
Alliance for Internet of Things
  Innovation (AIOTI), 11, 196,
  198, 211, 309
alliances, 11, 205, 296, 309
alliances (continued)
Industrial Internet Consortium, 309–311
Platform Industrie 4.0, 311–314
American Department of Defense (DoD), 547
analog-to-digital converter (ADC), 497
anticipatory standards, 193
anticounterfeiting measures, 35
antitheft protection, 35
Apple HomeKit, 377
application domains and related applications, 34
Application Entities (AEs), 305
application layer, 15, 80, 93, 95, 100
collaborative aware services, 101
identity-related services, 100–101
information aggregation services, 101
ubiquitous services, 101
architecture, 14, 80–81
agriculture IoT, 512
blockchain-based, 266, 267
centralized client–server, 256
cloud-based, 9
evolved packet core (EPC), 346
generic, of smart connected home, 368
generic three-tier IoT, 196
hierarchical cloud, 482–485
modern Microservices-based, 307
OPC Unified, 18
overall system, 572
and reference models, 14–16
architecture for IoT, 12
revised fog-enabled, 123
for RFID-tagged items, 140
Smart ambulance, 477
three-layered, 117, 311
typical control, for distributed smart grid, 392
usable multiservice, 322
Arduino, 8, 154–157, 159, 170–174, 177, 198, 576, 580, 600, 601
Arduino boards, 154, 155–162, 172, 577, 579
Arduino/Genuino 101, 157, 158, 159, 161
Arduino/Genuino MKR1000, 155, 157, 159
data capturing, 579
Due, 158
Mega 2560, 155, 158
selected, 156
Uno, 155, 159, 161
Yún, 156
Arduino hardware development
platforms, 155
boards (see Arduino boards)
connectivity and flexibility/
cost, 157–159
onboard sensors and hardware security features, 161–162
operating systems and programming languages for, 159–160
power consumption, 157–159
processing and memory/storage capacity, 155–157
processing and storage capacity of Arduino Boards, 157
size, 157–159
Arduino Language (AL), 160
Arduino MEGA 2560, 600
Arduino project for IoT application, 173
Arduino IDE
and downloading libraries, 174–175
accessing manage libraries functionality, 175
choosing board on tools menu, 174
choosing serial port, 175
and Mosquitto software, 173
and testing application, 177–180
Mosquitto broker running on a Linux computer, 179
Mosquitto subscriber running on a Linux computer, 179
project source code, 176–177
Arduino code, 177
wiring diagram, 176
Arduino temperature logger project
using the Fritzing software, breadboard diagram, 178
Arrowhead Framework, 80
artificial intelligence (AI), 36, 70, 472, 546
Artificial Pancreas Systems, 457
ASHRAE Standard 90.1-2010 Modeling of energy opportunities, 411
Ashton, Kevin, 3
Asset Administration Shell (AAS), 312
asthma COPD overlap syndrome (ACOS), 478
atmospheric conditions, 56
ATMs as smart objects online, 3
audit procedures, 275, 279, 280
points to consider before, 283
risk identification and assessment, 282
strategy, 283–285
ASSET management, 285
CHANGE management, 285
health and safety, 284
monitoring, 284–285
resilience, 284
security, 284
use cases of, 286
bring your own devices, 286
electronic utility meter readers, 286
smart parking meter interfaces, 286–287
autism spectrum disorder (ASD), 565
behavioral data analysis
sensing the emotion, 570–571
China, technology-based intervention, 567
challenges of, 567–568
emotion recognition, 568
broadcasting through affective object, 583–585
emotional facial action coding system (EMFACS), 580–582
by neuro-typical individuals, 569
preliminary testing results, 582–583
through Microsoft kinect, 580
emotion recognition, environment, 571
naturalistic play, 573–574
system background/architecture, 572–573
individuals, emotion expressiveness of, 568–569
IoT-based natural play
environment, 566
monitoring and tracking individuals, 571
naturalistic settings, 569–570
neurotypical (NT), 565, 566
sensors/sensor fusion, 574
hardware design, on emotion/actuation, 574–577
indoor temperature/humidity detection, data management, 579–580
pressure sensors, 577–579
ubiquitous affective objects, 569–570
Autoconfiguration, 79, 85, 94, 230
Auto-ID. see automatic identification (Auto-ID)
automatic generation control (AGC) regulation, 398
automatic identification (Auto-ID), 13, 25, 83, 136, 138, 146
Auto-ID Centre, 137
automatic transfer switch (ATS), 334
automobiles, 8
insurance, 40
autonomous driving system, 517
autoregressive integrated moving average (ARIMA), 494
Autosar, 203, 204
autoscaling, 104
Auxiliary Security Header (ASH), 231
Avatar, 312
avian influenza evaluation, 520
awareness, 31, 40, 534, 535, 569, 571
b
backscatter RFID systems, 136
BACnet, 407
bandwidth, 19, 24, 54, 57, 84, 89, 114, 121, 124, 126, 171, 303, 321, 337, 339, 340, 343, 348, 438, 501, 515, 607
BANs. see Body Area Networks (BANs)
battery capacities, 24
Bayesian network model, 496, 497
BeagleBone Black, 8, 154
behavioral imaging, 570
behavioral measurement, 573
BeiDou (China), 28, 517
BID. see binding identifier (BID)
Big Data, 43, 51, 65, 74, 81, 288, 331, 543
analytics, 103, 104
based business models, 38
models for data correlation, 415
streaming processing
technologies, 104
comparison, 104
big events IoT, applications of, 556
binding controller (BC), 483
binding identifier (BID), 484
Bio-Sense, 476
biosensors
designed to withstand harsh operating
environment, 481
heat sensing, 482
molar heat output of enzyme-catalyzed
reactions, 482
network, 482
reliability, 481
biosignal processing, 486
Bitcoin blockchain, 260, 261
Bitcoin cryptocurrency, 259
black box, 40
BLE. see Bluetooth Low Energy (BLE)
blind SQL injection attacks, 279
blockchain-based security solutions, 262
architecture for IoT devices in smart
homes, 266–268
Blockchain 2.0, 261
challenges, 270
and future research, 270
handling access transaction, 269
handling store transaction, 269
improved reliability of medical IoT
devices, 269–270
IoT device identity validation, 265
and IoT systems, 261–262
secure data store system for access
control information, 266
secure firmware updates in IoT
devices, 263–264
secure management of IoT
devices, 262–263
structure, 260
technology, 259–261
Trusted Computing Base
(TCB), 264–265
Bluetooth, 16, 18, 84, 477, 485
based systems, 282
Bluetooth 4.1, 167
Bluetooth 4.2, 232, 233
Bluetooth Low Energy (BLE), 130, 224,
231
BMSs. see building management systems
(BMSs)
Body Area Networks (BANs), 120
body language, 569, 570
Bonferroni, 496
Brillo operating system, 16, 360, 373
Brillouin Optical Time-Domain
Reflectometry method, 593
Building Energy Data Exchange
Specification (BEDES), 439
building management systems
(BMSs), 333, 398
business layer technologies, 101
big data analytics, 103
Apache Apex, 103
Apache Flink, 103
Apache Kafka, 104
Apache Spark, 103
semantics, 101–102
IoT Database (IOTDB), 102
Media Types for Sensor Markup
Language (SenML), 102
RESTful API Modeling Language
(RAML), 102
Sensor Model Language
(SensorML), 102
Wolfram Data Drop, 102
business model innovation, 37–38
computerization, 37
pricing, 37
web interface, 37
BYOD infrastructure, 290
calibration errors, 488
calibration regression analysis, 488
California Earthquake Authority (CEA), 485
Calm Computing, 7
cameras, 8, 66, 67, 73, 365, 530, 542
digital, 18, 409
fixed, 556, 557
surveillance, 265, 550, 551
video, 366
capacitive sensors, 575, 576, 578
Carbon emissions, 436
Car Connectivity Consortium (CCC), 202
cause–effect dependencies, 69
C-based IoT operating systems, 105
CBM. see condition-based monitoring (CBM)
CBOR Object Signing and Encryption (COSE), 222, 224
CCL. see cloud control layer (CCL)
cellular-based networking standards, 19
cellular phones, 58
networks, 480
CEO drives, 287
China
Academy of Telecommunications Research, 347
Autism Spectrum Disorder, 567
BeIDou, 517
Internet of Things Union Sensing China, 12
localization, 28
set IoT on strategic agenda, 11
smart manufacturing, 210
chip cards, 58
chronic obstructive pulmonary disease (COPD), 477
Cisco’s Internet of Things Reference Model, 80
Cisco’s IOx, 122
Cisco’s reference model, 81
Cisco Systems, 4
class-based low latency queue (CB-LLQ), 490
clean energy environments, 441
cloud-based Hadoop cluster, 121
cloud computing, 29–30, 113, 114, 116–118, 534
advantages of using, 118
fast time to market, 119
fast ubiquitous access, 118
flexibility, 118
reliability, 118
common cloud-based IoT architecture, 117
examples of cloud-based IoT, 119
health/well-being, 120–121
industrial, 119
smart cities, 119–120
functions, 511
key challenges, 121
high/unpredictable latency, 121
high uplink bandwidth requirements, 121
no in-network filtering or aggregation, 121
privacy and security concerns, 122
uninterrupted internet connection required, 121
scale and latency in cloud-based IoT systems, 118
service models, 116
cloud control layer (CCL), 483
cloud datacenters, 114
cloud-like services, 122
cloud network controller (CNC), 483
cloud optimization controller (COC), 483
cloud service controller (CSC), 483
cloud storage, 120, 262, 267, 268, 404, 511, 595
Cluster of European Research Projects on the Internet of Things (CERP-IoT), 5
CNC. see cloud network controller (CNC)
CoAP. see Constrained Application Protocol (CoAP)
COBOL, 54
COC. see cloud optimization controller (COC)
codifying information, 402
CO₂ emissions, 303, 364
cognitive impairment, 464
collisions, 57, 244, 246
repetitive, 544
commercial off-the-shelf (COTS), 60
common factory, 10
communication, 58, 80, 304, 416
devices, 57
infrastructure, 192
medical device, 57
technologies, 4, 6, 86
ANT+, 87
Bluetooth Low Energy (BLE), 87
Cellular Networks, 88
comparison of, 90–91
DASH7 Alliance Protocol (D7A), 88
5G, 89
IEEE 802.15.4, 87
Light Fidelity (Li-Fi), 89
Long-Range Wide-Area Network (LoRaWAN), 88
near-field communication (NFC), 86
power-line communication (PLC), 86
SigFox, 88
Software Defined Network (SDN), 89
and standards for IoT, 20–21
ultra-wide bandwidth (UWB), 86–87
Weightless, 88
Wi-Fi, 87
X10, 86
Z-Wave, 88
community-based disease transmission simulation models, 493
compatible devices, 18, 57
competing on analytics, 38
compound annual growth rate (CAGR), 295
computation, 98
cloud, 100
fog, 100
local, 98, 100
Computer-Aided Design (CAD) software, 172
computer revolution, 53
computer scientists, 192
concealable devices, 53
Concise Binary Object Representation (CBOR), 224
condition-based monitoring (CBM), 482
Connected Cows, 521
Connecting Things program, 11
connectivity, 13, 16, 18–19, 84, 106, 114, 126, 154, 161, 167, 304
bidirectional, 142
high-bandwidth, 303
in-campus, 334
internet, 434
inter-UAV, 540
IPv6, 230
layer, 14, 15, 114
M connectivity, 343
onboard, 168
Constrained Application Protocol (CoAP), 18, 96, 130, 223, 225–228, 305
Denial-of-Service against, 235–237
attack against a server IoT device, 236
Message Authentication Code, 237
Object Security for, 228–229
security modes, 225–226
system, 108
content-based networking, 416
Content-Centric Networking (CCN), 416
content delivery networks (CDNs), 122
context
awareness, 31
based information, 36
based services, 35, 37
Context-adaptive Binary Arithmetic Coding (CABAC), 339, 340
continuous wave (CW) radio generation, 136
controlled selfassessment (CSA), 282
cooperating systems, 51, 64
coordination mechanisms, 201
COPD diagnosis, 494
corrosion, 56
CO₂ sensing, 389
cost advantages, 39
cost-saving advantages, 275
COTS. see commercial off-the-shelf (COTS)
CPSs. see cyber-physical systems (CPSs)
critical peak pricing (CPP), 403
CRM. see customer relationship management (CRM)
crop canopies, 514, 515
crop’s water demand, 514
crop water stress index (CWSI)-based irrigation management, 513
crop–water stress signals, 514
crowd sensing, 331
crowdsensing leverages, 332
CRUD (Create, Read, Update, or Delete) operation, 261
cryptography, 58
cryptosecurity protocols, lightweight formats for, 224–225
CSC. see cloud service controller (CSC)
customer relationship management (CRM), 311
CUSUM chart, 494
CWSI models, 516
irrigation management, 514
cyberattack, 63, 68, 280
cyber–physical–social systems, 54–56
cyber-physical systems (CPSs), 193, 300
cybersecurity, 51, 67, 194, 320
indirect attack, 68
Data-Centric Publish-Subscribe (DCPS), 97
data-centric storages, 29
data collection system, 69
data, context and interaction (DCI), 307
data distribution service (DDS), 12, 97, 113, 306
data exchange, 95–96, 304
Advanced Message Queuing Protocol (AMQP), 97
CoAP, 96
Data Distribution Service (DDS), 97–98
Extensible Messaging and Presence Protocol (XMPP), 96
Message Queue Telemetry Transport (MQTT), 96–97
on OSI layer stack, 306
data formats, 18
Data from the latest Commercial Buildings Energy Consumption Survey (CBECS), 389
data-generating devices, 8
Datagram Transport Layer Security (DTLS) protocol, 162, 223, 241
based group communication, 240–241
Denial-of-Service, 238–239
amplification effect, 238
attack targeting a DTLS server, 238
ClientHello messages, 238, 239
message exchange, 227
poorly scalable storage of preshared keys on server, 239
scalability issues, 238–239
security modes, 225–226
data in motion (DMo) framework, 128
data-oriented networking, 416
data packet, 417
data quality, 32
data content, 32
dimensions of, 32
effects of increased, 33
object granularity and type, 32
reach, 33
time granularity, 32
data security, 387
data
DallasTemperature, 175
DApp (Decentralized App), 261
data acquisition, 36
for the IoT through RFID, 138
data analysis/extracting knowledge, 70
data archiving, 29
data capturing, 6, 579
data centricity, 38
Datagram Transport Layer Security (DTLS) protocol, 162, 223, 241
based group communication, 240–241
Denial-of-Service, 238–239
amplification effect, 238
attack targeting a DTLS server, 238
ClientHello messages, 238, 239
message exchange, 227
poorly scalable storage of preshared keys on server, 239
scalability issues, 238–239
security modes, 225–226
data in motion (DMo) framework, 128
data-oriented networking, 416
data packet, 417
data quality, 32
data content, 32
dimensions of, 32
effects of increased, 33
object granularity and type, 32
reach, 33
time granularity, 32
data security, 387
DallasTemperature, 175
DApp (Decentralized App), 261
data acquisition, 36
for the IoT through RFID, 138
data analysis/extracting knowledge, 70
data archiving, 29
data capturing, 6, 579
data centricity, 38

Index 651
data storage system, 7
data transmission, 408
    JSON format, 579
    network management architecture, 579
daunting task, 64
DDS. see Data Distribution Service (DDS)
DDS Interoperability Real-time Publish-Subscribe Wire Protocol (DDSI-RTPS), 306
decarbonization, 388
DEEJAM networks, 245
demand response (DR), 297, 333, 338, 387, 440
    principles, 402
Demand Response Management System (DRMS), 394
    using IoT principles, 396
Demand side management (DSM), 298
demography, 63
denial-of-service (DoS), 221
Destination-Oriented Directed Acyclic Graph (DODAG), 93
developer (inventor), 35, 63–64
device compatibility, 18
Devices Profile for Web Services (DPWS), 18
device-to cloud model, 374
device-to-device model, 374
device-to-gateway model, 374
digital cameras, 409
digital elevation models (DEM), 593
    implementation, 594
digital health, 447
digital meter, 334
digital shadow, 300
digital signature, 417
digital subscriber line (DSL) 3G/4G, 117
digital transformation, 303
Digital Twin, 312
directive on security of network, and information systems, 258–259
disruptive events, 58
Distributed Denial of Service (DDoS) attack, 67
distributed energy resources (DERs), 425
    resources, 388
distributing (electrical) energy, 387
Distribution Grid Management (DGM), 297
DNS. see Domain Name System (DNS)
do-it-yourself (DIY)
    home, 362
    security systems, 100
Domain Name System (DNS), 28
Domoticz, 373
DPWS. see Devices Profile for Web Services (DPWS)
driverless cars, 67
driverless vehicles, 330–331
    levels of vehicle automation based on, 330–331
drones, 530
drone-strikes, 529
DTLS protocol. see Datagram Transport Layer Security (DTLS) protocol
dynamic generalized linear model (DGLM), 496, 497
Dynamic Host Configuration Protocol (DHCP) server, 85
eEAN International, 137
EARS monitor bioterrorism, 476
economy, 38, 42, 58, 59, 61, 442
    benefits, 13
ecosystem of evolved power grid, 387
efficiency, 3, 13, 35, 104, 333, 520
    emergency support system, 481
    energy, 128, 233, 301, 364, 388, 400, 412
    farm, 509
    High Efficiency Video Coding (HEVC) algorithm, 338
    improvements, 39, 385
    life-activity, 320
    trade power, 146
    water use, 513
efficient and scalable group key management, 241–243
Efficient XML Interchange (EXI), 18, 102
e-health, 197, 347
EIoT. see Energy Internet of Things (EIoT)
EIoT deployment
  EIoT devices, to enable integration of renewable energy generation, 432
  EIoT elements, 434
    goals of EIoT energy management, 434
  EIoT to manage and incorporate renewables into energy grids, 432
EIoT web diagram, 438
  energy IoT device datasets, 435
  energy management, 433
  network functionality, 435–439
    central control, 436–437
    gateway, 438
    smart controls and customer usage, 436
  Web of EIoT, 437–438
    nondispatchability, 433–434
    unpredictability, 433
  electrical energy, 387
  electrical engineers, 192
  electrical power, 53
  electric currents in the brain (EEG), 451
  electric meters, 321
  electric power, 69, 386
  electroencephalogram (EEG), 120
  electromagnetic compatibility (EMC), 475
  electromechanical switches, 60
  electronic article surveillance (EAS) systems, 136
  electronic barcodes, 26
  electronic components, 53
  electronic credentials, 62
  electronic patient records (EPR), 475
  electronic payment systems, 58, 59
  Electronic Product Code (EPC), 27, 28, 85, 137
    update, 477
eLORAN, 57
embedding, 13, 14, 19, 27, 135, 141, 520, 572
emergency medicine
  binding meta-objects, 490
  biosensing network, 481–482
  case study
    ambient environment, 497–498
    chronic obstructive pulmonary disease, 492–493
    data acquisition/data analytics, 494–495
    decision/selection process, 495–497
    on-scene diagnosis and prognosis, 493–494
    compatibility, 486–492
    control system, 483
    electronic patient record retrieval, in multihop communication, 491–492
  hierarchical cloud architecture, 482–485
  integration, 486–492
  IoT-based local area weather observation, 486
  operational consistency, 487–491
  point-of-care environment, 478–481
  reliability assurance, 487–491
  service binding, 484
  smart ambulance architecture, 477
  weather observation, for remote rescue, 485–486
Emoncms, 579
  user interface, 581
Emotional Facial Action Coding System (EMFACS), 580
  emotion recognition, 568, 570
  emotion-related physiological data, 572, 573
  emotion-sensitive environmental data, 572
  emotion visualization and broadcast module, 584, 585
Encapsulated Security Protocol (ESP), 230
Encryption, 222
energy-consuming devices, 435
energy efficiency building upgrade process, 412
Energy Information Administration (EIA), 385
Energy Internet of Things (EIoT), 386
applications, 388
challenges, 415–417
electricity consumption, 390
and intensities, 390
energy-efficiency resources, 387
energy element (EE), 386
traditional power grid interconnect, 386
energy IoT device datasets, 435
energy optimization studies, typical process used in, 413–414
future directions, 415–417
total U.S. electricity consumption and intensities, 2012, 390
traditional power grid that interconnects EEs, 386
energy metering, 408
energy-supporting elements, 425
energy use intensity (EUI), 410
English Channel, 57
enhanced mobile broadband (eMBB), 343
enterprise resource planning (ERP), 311
entity, boundary, interactor (EBI), 307
environment, 56
physical, 56–57
environmental device controller (ECC), 483
EPC. see Electronic Product Code (EPC)
EPCglobal Tag Data Standard, 28, 137
erosion, 61, 511
ESSENCE system, 476
Ethereum, 261
Ethernet, 27, 89, 158, 160, 161, 167, 168, 173, 176, 177, 180, 279, 370, 407
Ethernet interface (eth0), 184
e-tickets, 4
ETSI Technical Committees (TCs), 194
European Article Number (EAN) International, 137
European Commission 7th Framework program, 11
European Environment Agency (EEA), 385
European Research Cluster on the Internet of Things (IREC), 80
European RPAS Steering Group (ERSG), 547
European Telecommunications Standards Institute (ETSI), 306
European Telecommunications Standards Institute Technical Committee (ETSI TC), 80
EU’s Unify-IoT project, 18
evolved packet core (EPC) architecture, 347
e-wallet, 137
EWMA charts, 494
exhaust gases, 58
exploitation, 6, 35, 363
eXtensible Markup Language (XML), 33
messages, 96, 307
parsing, 102
Extensible Messaging and Presence Protocol (XMPP), 130, 171
f
FAA-controlled airspace, 547
Facebook, 41
face capture capabilities, 580
face tracking, 580
testing, 582, 583
Facial Action Coding System (FACS), 580
algorithm, 580
facial expressions, 568
analysis, 571
false discovery rate (FDR), 496
FANET/WFANET flying, 554
FDA regulatory requirements, 499
Federal Aviation Administration (FAA), 547
Federal Trade Commission (FTC), 287
Firewalls, 246–247
first input, first output (FIFO), 490
flying ad hoc networks, 530–533
flying, internet of things, 530, 533
applications
commercial package delivery, 539
in emergency situations, 537–538
government official
missions, 539–540
novel applications, 540–542
smart cities, 538–539
smart farms, 539
surveillance, 538
traffic monitoring, 538
car traffic management, 538
case studies, 549
remote/ peripheral areas as fog enabler, 552–555
targeted services delivery on big events, 555–557
WFANETs, for surveillance tasks in smart farms, 549–550
challenges, 542
general issues, 542–543
safety issues, 547–549
security issues, 543–547
characteristics of, 536–537
cooperation/collaboration, 536
emergency situations
first aid and supplies, 538
search and rescue, 537
flying ad hoc networks, 530–533
fog/cloud computing, 534–535
multiple connections, 533
unmanned aerial vehicles (UAVs), 530, 533
unmanned aircraft systems, 529, 537
Flying Thing, 533
flying vehicles, 548
fog computing, 29–30, 114, 122, 534
advantages of using, 124–125
addressing privacy concerns, 125
conserving bandwidth, 125
improving reliability, 125
minimizing latency, 124
examples of fog-based IoT, 128
health/well-being, 129
industrial domain, 128
smart cities, 128–129
key challenges, 130
programmability, 130
reliability, 131
resilience, 131
scalability, 130–131
semantic interoperability, 130
technological interoperability, 130
potential future fog use cases, 125
connected vehicles, 126
education, 126
health care, 126–127
smart buildings, 127
smart grid, 125
surveillance, 127
virtual reality, 128
wearables, 127–128
fog nodes, 123
footprint, 29
FORTRAN, 54
fossil energy, 210
Fourth Industrial Revolution, 10
framework, 12–14
Frequency-Hopping Spread Spectrum (FHSS), 244
Fritzing software, 182
g
Galileo (EU), 28, 517
galvanic skin response (GSR), 451
gateway devices suitable for local computation, processing, and storage, 124
gateway hardware, 124
5G broadband, 607
General Data Protection Regulation (GDPR), 257–259, 262
to achieve compliance, 258
define data, 257
legislation, 258
General Purpose I/O (GPIO) pins, 161
3rd Generation Partnership Project (3GPP), 304
Generic Header Compression, 230
Genesis Block, 259
geographic information system (GIS), 510, 511
geo mapping tools, 518
3G/4G/5G networks, 442, 546
GHG emissions, 301
Ginger.io, 461–462
global energy data, 385
Global Information Grid (GIG) project, 306
global positioning system (GPS), 28, 84, 517
devices, 510
enabled device, 492
GPS receiver modules, and Internet connection (GPRS/HSDPA) modules., 172
GPS SafeSole, 464
high accuracy, 517
location, 541
navigation, 57
navigation, applications rely on, 57
signal, 57
spoofing, 542
technology, 545
global standards collaboration (GSC), 201
Global System for Mobile (GSM) module, 18, 20, 192, 595, 596, 598, 601, 602, 604
EC-GSM-IoT for licensed bands, 304
mobile communications platform standards, 192
shields., 160
SIM900A GSM module, 601, 602
GLONASS (Russian), 28, 517
4G LTE mobile communication network, 515
Google, 16
Google Cardboard, 128
Google Cloud Messaging, 120
GoogleMaps, 41
government official missions, 539–540
border surveillance, 539
forest fire detection and illegal logging, 540
GPS. see global positioning system (GPS)
Great Hunger, 518
grid-related sensors, 389
grid stability, 436
grid-wide energy, 386
gross domestic product (GDP), 191, 298
ground control station (GCS), 530, 531
Group REkeying Protocol, 242
GSM module. see Global System for Mobile (GSM) module
G20 Summit, 56
2G telephony, 607
Guaranteed Time Slot (GTS) mode, 245
5G wireless technologies, 398
GY-61 accelerometer, 601
sensor, 599
gyroscopes, 451
h
hardware, 114
embedded security, 154
stack, 16
Header, Dictionary, Triples (HDT), 309
health care
dimensions of internet of things applications in, 453–455
degree of action provided by application, 453
goal of application, 453
locus of health care issue, 453
primary user of application, 453
source of data, 453
time dimension, 453
type of health care issue, 453
market, 299
professionals, 447
providers, 450
systems, 448
Health Fog, 129
heterogeneous, 533
application services, 18
applications, 113
system, 64
High Efficiency Video Coding (HEVC) algorithm, 338
higher node mobility, 532
Index 657

high-level view of an IoT architecture, 15
Highly Scalable Scheme (HISS), 242
Holt–Winter exponential smoothing methods, 494
home appliances, 8
home area networks (HANs), 400
home automation, 388
Home Gateway Initiative (HGI) standardization organization, 370
home intelligence, 387
hospital acquired infection (HAI) risk of, 479
HTC Vive, 128
HTTP. see Hyper Text Transfer Protocol (HTTP)
human behaviors, 54
human-driven applications, 123
human machine interfaces (HMIs), 312
H2020 UNIFY-IoT project, 34
Hypercat Alliance, 28
Hyper Text Transfer Protocol (HTTP), 225, 305

i
IBM 360 mainframe, 54
ICT. see information and communication technology (ICT)
identification, 25, 84
addressing schemes
based on IPv6 and electronic product code, 27–28
radio frequency, 25–26
IEEE 802.15.4, 18
standard, 223, 231
ZigBee, 485
IETF Constrained Application Protocol (CoAP)/REST engine, 18
IFML. see Interaction Flow Modeling Language (IFML)
implications and challenges, 38
changed value creation, 39–40
increased awareness for information spaces, 40–41
new markets, 38–39
social, ethical, legal, and risk aspects, 41–44
In-Circuit Serial Programming (ICSP) header, 161
in-cloud central control system, 520
in-cloud intelligent management system, 521
Independent system operators (ISOs), 396, 437
Indian Standard (IS) procedures, 597
Industrial Internet, 10
Industrial Internet Consortium (IIC), 12, 195, 204, 207, 309, 312, 314
functional domains of IIRA based on, 310
Industrial Internet of Things (IIoT), 4, 10, 81, 119, 295, 296, 298, 300, 302, 304, 305, 307, 309, 314
Industrial Internet Reference Architecture (IIRA), 17, 80, 81, 309, 310, 312, 313
industrial revolution, 53
Industry 4.0, 9, 10, 54, 312
c conceptualization, 24
vision, 10
Industry standards for EIoT, 439
Building Energy Data Exchange Specification (BEDES), 439, 440
Institute of Electrical and Electronics Engineers (IEEE), 441
open automated demand response, 440
influenza-like illness (ILI), 476
Information and Communication Technology (ICT), 296, 320, 426
infrastructure, 14
modern, derived qualities of, 31–32
systems, 191
information-centric networking, 416
information modeling, 307
Information Technology (IT) auditing, 275, 279
use cases of, 286–287
systems, 221
infrared (IR) readers, 83
Infrastructure as a Service (IaaS), 100, 116
innovation
  categories, 35
  process, 36–37
  product, 35–36
  technology-driven, 35
Institute of Electrical and Electronics Engineers (IEEE), 6, 162, 167, 193, 194, 195, 204, 223, 224, 229, 441
802.3af (2003) standard, 408
48-bit Extended Unique Identifier, 340
802.3bt, Type 3 standard, 408
802.3 standard, 407
802.15.4 standard, 231, 304
2030™ standard, 441
802.15.4 ZigBee or Bluetooth, 485
insurance premiums, 40
integrated circuit, 136
integration of renewable sources, 387
Intel Edison Open, 8
intelligent algorithms, 71, 520, 522
intelligent autonomous system, 522
Intelligent Electronic Devices (IEDs), 302
intelligent transport systems (ITSs), 302, 331
Intel’s Intelligent Edge, 122
interaction capabilities, 8
Interaction Flow Modeling Language (IFML), 12
interface, 8, 184, 222, 344, 451
  adaptive smart home interfaces, 380
  Application Programming Interface (API), 371
Camera Serial Interface (CSI), 168
circuitry, 141
DDS Application Programming Interface (API), 306
Display Serial Interface (DSI), 168
High-Definition Multimedia Interface (HDMI), 165
intelligent, 6
interactive, 388
levels, 97
PMIPv6-based interfaces, 346
reference, 346
Serial–parallel interface, 486
Smart Parking Meter, 286
Two Wire Interface (I2C/TWI) communication, 161
Universal Serial Bus (USB) port, 161
user, 63, 499
web-based, 603
without any coding, 106
Inter-Integrated Circuit/Two Wire Interface (I2C/TWI) communication, 161
internal audits, 281
internal machine communications (IMC), 530
International Air Transport Association (IATA) resolutions, 140
International Electrotechnical Commission (IEC), 312
International Electrotechnical Committee, 193
International Energy Agency (IEA), 298, 385
International Organization for Standardization (ISO), 193
International Standards Organization (ISO), 470
International Telecommunication Union (ITU), 193
International Telecommunication Union - Telecommunication Standardization (ITU-T), 80, 302
Internet, 4, 67, 73, 113, 124, 129, 137, 211, 436
  access, 53
  of computers, 135
  connected appliances, 432
  connectivity, 84
Internet and Communication Technologies (ICTs), 275
Internet Engineering Task Force (IETF), 11, 27, 192, 226
Internet Key Exchange version 2 (IKEv2) protocol, 223
Index

Internet of Cows, 521
Internet of Flying Things (IoFT), 533–548, 534, 550, 552–557
networks, 557
Internet of Goats, 522
Internet of Medical Things (IoMT), 81, 108
Internet of Pigs, 522
Internet of Things. see IoT
Internet of Things — Architecture (IoT-A), 80
Internet of Things Architecture (IoT-A) project, 11
Internet of Things European Research Cluster (IERC), 11
Internet of Things-Initiative (IoT-i), 11
Internet of Things Reference Architecture (IoT RA), 80
Internet of Vehicles (IoV), 81
Internet Protocol (IP)
address, 28, 79
based networking infrastructure, 5
camera, 566, 574, 575
layer, 81
protocol, 388
Internet Protocol for Smart Objects (IPSO) Alliance, 11
Internet Protocol Security (IPsec), 162
IPsec Authentication Header (AH), 162
enabled shoe-mounted sensor platform, 144
interoperability, 14, 16, 18, 80
degradation, 59
and technologies, 303
communication, 305–306
connectivity, 304–305
data exchange, 306–309
intrusion detection systems (IDS), 235, 246
anomaly-based, 246
cluster-based, 246
signature or rule-based, 246
watchdog-based, 246
intuitive interaction, 33
IoT aquaculture, 520
IoT-based applications, 197
disciplines involved in, 199
(emerging) application areas, 198
IoT-based multimedia (IoTMM) applications, 321
IoT communication infrastructure, 518
IoT data exchange protocols, comparison, 99
IoT design and prototyping using Arduino Boards, 169–171
using Raspberry Pi platforms, 172–173
IoT ecosystem, 321
IoT environment generalized smart ambulance, 495
IoT five-layer architectural model, 82
IoT hardware development platforms, features, 154
IoT irrigation system diagram, 515
IoT platforms and operating systems, 105
C-based IoT operating systems, 105
Contiki, 105
RIOT, 105
comparison of IoT platforms, 107
of operating systems, 106
embedded operating systems/RTOS, 105
platforms, 105
AWS IoT, 106
Bosch IoT Suite, 106
EVRYTHNG, 106
IBM Watson, 106
Kaa, 107
ThingWorx, 106
Xively, 106
IoT–PoC environment, 478
IoT-related health care applications and their dimensions, examples of activity tracker, 467
automated medical dispenser, 464–465
CoaguChek®, 465–466
continuous glucose monitoring system, 468
EpiWatch represented in the snowflake model, 459
Ginger.io application, 461, 462, 463
GPS SmartSole, 462
Owlet Smart Sock 2, 460
Philips Automated Medication Dispenser service, 464
Propeller, 460
Smart Sock 2, 460–461
SmartSole, 463–464
IoT sensing networks, 481
IoT standardization, 194, 426
generic three-tier IoT architecture, 196
IoT system requirements, 114
data confidentiality and security, 115
data distribution, 115
flexible self-organization, 115
processing services, 115
reliability, 115
scalability, 115
scalable storage, 115
iPhone, 53
IPsec Authentication Header (AH), 230
IPsec, compressed, 222, 229–231
IPv6 over Low-power Wireless Personal Area Network (6LoWPAN), 18, 20, 27, 85, 87, 144, 195, 222, 224, 229–233, 246, 247, 341, 342, 373
devices, 246
6LoWPAN Border Router (6BR), 246
6LoWPAN Mapper (6Mapper), 247
networks, 229, 230, 240, 246
protocol, 144

j
JAMMY device, 246
Jari Arkko, 192
Java, 64
JavaScript Object Notation (JSON)-based hypermedia catalog format, 94
JavaScript Object Signing and Encryption (JOSE), 225
Jini platform, 376

k
Karimi, K., 571
key performance indicators (KPIs), 312
Kinect HD facial capture moment, 583
Kinect™ sensor, 566, 574, 582
Kinect V2 API, 580

l
Last-Value Queues (LVQs), 97
latency-sensitive applications, 114
layer technologies, application, 100
collaborative Aware Services, 101
identity-related services, 100–101
information aggregation services, 101
ubiquitous services, 101
learning disabilities, 570
learning machines, 54
LED-based luminaries, 406
LED stripe play-table embedded, 584
life saving devices, 51
lightweight communication protocols, 16
Linux-based OSes support, 166
International Data Corporation (IDC), 5
Worldwide Internet of Things Forecast, 5
localization, 28–29
location-based services, 37
logical key hierarchy (LKH), 242
long network lifetime, 80
long-term operation, 60
life cycles, 60
LoRa Alliance, 19, 88, 91, 304
LORAN-C, 57
LoRaWAN, 20, 88, 130, 327, 373
LoS links, 540
low-cost IoT framework, 593
background, 594–595
components selection, 599
accelerometer, 599
GSM module, 601–602
microcontroller, 600–601
moisture sensor, 599–600
components used in, 606
results, 603–605
system design/implementation, 595
alert-generating unit, 596
data logging/thresholding unit, 596
sensing unit, 595–596
testing, 596
data logging/alerts, 602
experimental procedure, 602–603
lab-scale ramp setup, 598–599
soil characteristics, 597–598
traditional landslide monitoring technologies, 595
low earth orbit (LEO) satellites, 338
6LoWPAN. see IPv6 over Low-power Wireless Personal Area Network (6LoWPAN)
Low-Power Wide-Area Networks (LPWANs), 19, 304
LPWAN. see Low-Power Wide-Area Networks (LPWANs)
LVQs. see Last-Value Queues (LVQs)

m
MAC addresses, 27
machine-to-machine (M2M) communications, 8–10, 84, 123, 201, 305, 338, 531, 546 standards, 16 environments, 321
gateway, 487
Malacca Strait, 57
management software, 16
MANET (Mobile Ad hoc NETwork), 532
man–machine symbiosis, 54
manufacturers, 66
Manufacturers Alliance for Productivity and Innovation (MAPI), 12
manufacturing execution system (MES), 311
market integration, storage, 387
market overview, 296
energy, 296–297
health care, 297–298
manufacturing, 299–301
smart cities, 301–302
transportation, 302–303
Mauritius Declaration on the Internet of Things, 43
mDNS. see multicast Domain Name System (mDNS)
Media Access Control (MAC) layer, 231
medical device, 8, 67, 69
Medical IoT, 480
Medicine and Health Care Products Regulatory Agency (MHRA), 470
mediocrity, 51
memory, 14
MEMS. see microelectromechanical system (MEMS)
mentality mismatch, 65
Message Authentication Codes (MACs), 225
Message Queuing Telemetry Transport (MQTT), 12, 18, 305
communications, 162
components, 171
protocol, 128
microcontroller, 600
board, 601
microelectromechanical system (MEMS), 481
based sensors, 594, 595
MicroGrid Control (MGC), 394
MicroGrids, 388, 389, 425
micro Secure Digital (SD) card reader, 157
Microsoft, 16, 123
Microwave Institute Foundation, 136
middleware technologies, 93–94
miniaturization, 4
Mirai botnet, 67
missing data, 63
mobile ad hoc networks (MANETs), 491, 532
mobile communications, 19, 37
mobile crowdsensing (MCS), 332
mobile device-based videoconferencing, 447
Mobile IPv6 (MIPv6)
  mobility management techniques, 332
  protocols, 321
mobile messaging, 54
mobile phones, 7, 54, 114
mobility (AIM) technologies, 25
Modbus, 407
Modbus fieldbus systems, 304
Model View Controller (MVC), 307
Moderate Resolution Imaging Spectroradiometer (MODIS) system, 514
Moore’s law, 53
moral decision-making abilities, 73
Morley, Dick, 312
motivation, 417
MQTT. see Message Queuing Telemetry Transport (MQTT)
multicast Domain Name System (mDNS), 28
multihop cellular networks, 491, 532
multihop communication, 491
environment, 491
multilevel neural network, 71
multimedia capabilities in IOT, 338–340
multimedia streaming capabilities, 19

n
Named Data Networking (NDN), 416, 417
NASA moon flight program, 61
NAT. see network address translation (NAT)
natural gas, 389
navigable ship, 58
navigation systems, 37
NDN. see Named Data Networking (NDN)
NDVI. see Normalized Difference Vegetation Index (NDVI)
near-field communication (NFC), 20, 84, 86, 90, 141, 278, 282, 304, 373, 452
neo-pixel stripe-embedded play table, 585
Net of Everything, 4
network address translation (NAT), 79, 230, 340
networked system, 68
network hardware, 114
networking layer, 18
network layer technologies, 84
network reliability, 480
network service entities (NSEs), 305
network technologies, 16–19
Neul, 304
neurotypical (NT), 565
temporal facial data, 569
New Out Of Box Software (NOOBS), 167
NINJA-IDE, 172
NIS directive, 258–259
  ensuring IT security, 259
  handling incidents, 259
  preventing risks, 259
nonvolatile storage, 113
Normalized Difference Vegetation Index (NDVI), 516, 517
North Korean jamming, 57
N-Wave, 19, 304, 373

O
OAuth 2.0 authorization framework, 222, 223, 234
OAUTH-based authorization, 233–235
OAuth messages, 223
Object Management Group (OMG), 97, 306
Object Security of CoAP (OSCOAP), 228
object security of content (OSCON), 229
obstacles, 533
Oculus Rift, 128
on-chip two-electrode ECG, 571
OneWire, 175
on-scene treatment, 480
OPC UA (OPC Unified Architecture), 18
OpenAutomatedDemandResponse
(OpenADR), 439
systems, 440
OpenAutomotiveAlliance(OAA), 202
OpenFieldMessageBusProtocol
(OpenFMB), 373, 416
OpenFogConsortium, 30
OpenMotics, 373
OpenPlatformCommunicationsUnified
Architecture(OPCUA), 306
OpenSSL, 174
OpenStack, 129
OpenSystemsInterconnectionmodel
(OSI model), 16, 81, 304, 545, 546
application layer, 546
data security and unlawful
attacks, 546
flying thing memory, 547
OSI layer stack, connectivity on, 304
perception layer, 545
phishing access attacks, 546
semantic web layer cake on top
of, 308
transportation layer, 546
operational technology (OT), 295, 296, 386
operations support systems
(OSS), 386–387
optimal enablement of video, 338–340
Oracle, 26
Organization for Economic Co-operation
and Development (OECD), 298
OSI model. see OpenSystems
Interconnectionmodel(OSI
model)
over-the-counter (OTC), 497
OWL. see WebOntologyLanguage
(OWL)

ParticlePhoton, 154
particle size distribution, 597
passive devices, 82
PassiveRadioFrequencyIdentification
(RFID) Tags, 83
patient context controller (PCC), 483
patient monitoring, 480
PCC. see point of common coupling
(PCC)
peer-to-peer (P2P) mode, 491
perception layer technologies, 81–82
personal area networks (PANs), 16, 87
personal customer data, 38
PersonalDigitalAssistants(PDAs), 119
personally identifiable information
(PII), 470
personal monitoring systems, 457
pervasive health monitoring, 84
Petya worm, 68
Photovoltaic (PV), 298
physical object, 7
physical security/surveillance, 408
physiological measurement, 573
plant diseases
pest management system, 519
potato blight, 518
Platform as a Service (PaaS), 116
PlattformIndustrie4.0, 312
plumbing, 9
PMIPv6, 347
3GPP/ETSI protocol stack
specification of, 344
usage in 3GPP context, 345
PoC. see Point-of-Care (PoC)
Point-of-Care (PoC), 478
environment assessment, 497
high-tier architecture, 498
integrated IoT sensing, 479
real-time monitoring, 497
sensing system, 497
point of common coupling (PCC), 389
pollution, 58
trend, 69
pop-up satellite archival tag (PSAT), 522
position identification, 492

P
PANs. see personal area networks
(PANs)
paramedics, 478
particle concentration, 69
active RFID tags, 83
connecting sensors to
Internet, 142–144
Ecosystem, 138
historical perspective, 135–137
CW radio wave transmission, 136
development of standards to ensure
interoperability, 137
in electronic article surveillance
(EAS) systems, 136
for livestock tracking/business and
industrial applications, 136
in transportation management,
inventory management
and, 136–137
and Internet of Things (IoT), 137–138
in the IoT, specific role of, 137–138
low cost of RFID sensor-tag
implementation, 145
network topologies for linking RFID
sensors to the Internet,
143
object identification using, 139–140
passive, advantage, 146
reader, 26
RFID–WSN IoT realizations, 144
security features, 145
semipassive tags, 83
sensor localization, 141–142
sensors, 140–141, 146
surface acoustic wave (SAW)-based
RFID tag, 141
tagged or barcoded items, 3, 13, 26,
522, 553
UHF-RFID readers based on, 146
universal RFID system, 137
WSN implementations, 145
WSN sensors as data routers for RFID
tags, 144
radio waves, 29
RAMI 4.0, 81
ramp
sensors on pipe, 605
value of accelerations/soil
moisture, 604
Raspberry Pi Foundation, 172
Raspberry Pi hardware platforms, major
features of, 8, 154, 163
connectivity and flexibility/
customizability, 167–168
cost, 165–166
hardware security features, 168–169
vcgen<code style='color: #0050b3; font-family: monospace;'>gencmd measure_volts</code>
command, 169
onboard sensors, 168–169
operating systems/programming
languages, 166–167
power consumption, 165–166
processing and memory/storage
capacity, 163
processing speed and memory/storage
capacity, 164
selected Raspberry Pi models, 164
size, 165–166
Raspberry Pi project for IoT
application, 180
constructing and testing
circuit, 182–183
development and testing of a Python
web application, 183–184
Python code, 184
downloading and installing required
packages, 180–184
installing operating system, 180
Raspberry Pi web-controlled LED project
using Fritzing software, breadboard
diagram, 182
real-life power management optimization
approaches, 410–414
Real-Time Clock (RTC), 157
Real Time Kinematic (RTK), 517
real-time locating systems (RTLS), 83,
84
real-time management mechanisms, 388
real-time operating systems (RTOSs), 98,
159
real-time performance, 548
real-time sensor values, 603
real-time visualizations, 8
realworld programming, 64
recovery point objective (RPO), 284
recovery time objective (RTO), 284
Index

recruitment system, 60
Red Cross blood indicators, 489
Reference Architecture Model Industrie 4.0 (RAMI 4.0), 80, 312
reference architectures, 17
reference models, 14
Regional Transmission Operator (RTO), 437
regulators, 66–67
requirements, 256
reliability centered maintenance (RCM) analysis, 488
Remote Procedure Calls (RPCs), 305
remote terminal units (RTUs), 312
renewable energy resources, 387
renewable resources, 425
Representational State Transfer (REST), 102
concepts, 305
Request for Comments (RFC), 307
resource-constrained IoT network, 224
resource-constrained IPv6-connected IoT network, 222
Resource Description Format, 94
Resource Description Framework (RDF), 308
Resource Description Framework Schema (RDFS), 308
Resource owner, 234
Resource server (RS), 234
return on investment (ROI), 386
revised fog-enabled architecture combining fog and cloud-based IoT, 123
RFID. see radio frequency identification (RFID)
RFID Sensor Network (RSN), 545
risks associated with IoT, 276
availability, 278
cloud infrastructure attacks, 279
confidentiality, 278
identity management, 278–279
integrity, 278
malware attacks, 279
physical attacks, 279
privacy, 277–278
robotics, 24
RRobust Header Compression (ROHC), 230
routing, 92–93
Routing Protocol for Low Power and Lossy Networks (RPL), 18, 92, 108, 224, 246, 247
topology, 93
RPL. see Routing Protocol for Low Power and Lossy Networks (RPL)
RTCA/DO-178C for UAV software, 548
s
sadness, 582
safety measures, 72
safety zone, 57
SBC. see single board computers (SBC)
scalability, 79, 221
Schrödinger’s equation, 71
Secure Sockets Layer/Transport Layer Security (SSL/TLS), 162
security, 14, 92, 197, 199. see also specific entries starting as security
cameras, 409
Datagram TLS (DTLS), 92
IEEE 1888, 92
Internet Protocol Security (IPsec), 92
in IoT protocols and technologies, 222–224
management, 65
threats, 529
Transport Layer Security (TLS), 92
"security by design" approach, 281
security considerations in EIoT, 441
cyber intrusions, 441
external dependencies, 442
operational complexities, 442
protocol flaws, 442
software malfunctions, 441
unintended consequences, 442
security issues, flying
data link layer, 544
desynchronization attack, 545
HELLO flood attack, 544
hijack flying things, 545
man-in-the-middle attacks, 545
network layer, 544
physical layer, 543
sinkhole attack, 544
transport layer, 545
wormhole, 544
seismic activity, 56
selective jamming, 244
in wireless networks, 244–246
self-organizing network (SON)
approach, 343
semantic Web standards, 33
semipassive devices, 83
sensors, 4, 7, 8, 14, 22–24, 40, 53, 320, 406
data, 113
embedded sensors, 84
environmental, 54
hardware, common usage of, 113
Kinect V2 sensor, 582
list of, 576
nodes, 113
rich environments, 408
stationary, 332
surfaces, 56
Separation of Concerns (SoC), 307
service discovery, 94
DNS Service Discovery (DNS-SD), 94
HyperCat, 94
Multicast DNS (mDNS), 94
Physical Web, 95
Universal Plug and Play (UPnP), 95
sexual orientation, 73
SG. see smart grid (SG)
Shewhart, 494
Shodan, 42
short message service (SMS), 54
Sigbox, 19
Sigfox, 130, 304, 373
signal-to-noise ratio (SNR), 492
silos, 18
SIM900A GSM module, 601, 602
Simple Object Access Protocol (SOAP), 305
single board computers (SBC), 8, 154
site-specific agriculture (SA), 508
skills emotion recognition, 565
smart actuators, 84
smart ambulance
architecture, 477
challenges, 498
reliability, 498–499
security/privacy, 500
staff training/operating procedures, 499–500
standards, 499
smart appliances, 387
SmartBox, 571
smart buildings, 320, 332–334, 388
and architecture, 11
smart campuses, 334, 388
smart car, 62
smart chicken farm, 520, 521
smart cities, 11, 54, 72, 320, 387, 388
challenges and future research, 349–350
initiatives, global distribution, 326, 330
IoFT, applications of, 554
IoT applications, 321–330
graphical examples, 325
IoT ecosystem applicable to, 321
key underlying technologies IOT applications, 340–348
specific applications, 330
crowd sensing, 331–332
driverless vehicles, 330–331
smart buildings, 332–334
smart campuses, 334–337
smart grid, 337–338
smart connected home architectures, 375
centralized, 375–376
distributed, 376
challenges and research directions, 376
interoperability, 377
privacy, 377–378
reliability, 378–380
security, 377–378
usability, 380–381
concept, 360
domain, 360
smart connected home (continued)
generic architecture, 368
integration between smart home devices
and third-party service, 372
malicious threat agents targeting, 379
sensor types, and corresponding data captured by, 369
stakeholders, 362–363
systems, 364
energy systems, 364–365
entertainment, 365
health care service, 365–366
security, 366–367
technologies, 367
actuators, 367
cloud services, 372–373
communication protocols/models, 373–374
end user client devices, 372
gateways, 369–372
functions, 370–372
integration platforms, 373
sensors, 367
types of, 361
smart controls, and customer usage, 436
smart cow farm, 520, 521
Smart Cows, 521
smart dust, 57
smart energy, 11
Smart Energy Profile (SEP), 374, 407
smart environments, 8
smart farms
applications, 539
identification of fire, 539
service integration, 539
surveillance, 539
of crop fields, 552
WFANET application
surveillance situations, 551
control architecture, 392
EIoT-based, 444
elements, 400
evolved, 387
interoperability, 441
programs, 12
Smart Grid 1.0, 2.0 and 3.0, 388
typical control architecture for, 392
smart health care applications, dimensions of
health care provider–individual dimension, 458
internal–external measures dimension, 457–458
monitor–manage dimension, 456–457
physical–mental dimension, 455–456
prevent–cure dimension, 456
well-being—illness dimension, 455
smart health care ecosystem, 448–453
applications and interfaces, 451–452
challenges, 469
changing health care provider–patient roles, 471
data issues, 470–471
lack of standards, 469–470
connecting components, 452
devices and sensors, 451
health care providers, 450
patient at the center, 449–450
stakeholders, social support, 452
smart home, 38. see also smart connected home
smart home energy management systems (SHEMSs), 417
smart metering, 12, 387
smart mobility, 11
smart object, 3, 7, 8
Smart Oyster Farm, 522
smartphones, 16, 64, 84, 113, 321
devices, burning, 24
SmartSantander, 120
smart services, 320
smart transportation, 302
smartwatch, 84, 566
smart water management, 11
SMS alert, 603, 605
SoC. see Separation of Concerns (SoC)
social interaction, 54, 568
social interactive behaviors quality of, 570
social media, 58
social structures, 54
socioeconomic networks, 40
sociometers, 573
software agents, 37
Software as a Service (SaaS), 116
cloud-provided service, 333
software components, 16
software-defined radios (SDR) approach, 343
software engineers, 193
software stack, 16
soil moisture, 597
soil movement, 597
soil sample, physical characteristics, 597
solar systems, 388
spatiotemporal surveillance, disease modeling, 495
specific hardware, 14
SQL command injection, 67
Stack4Things, 128
standardization environment, 199–201
European Standards Organizations (ESOs), 199
National Standards Organizations (NSOs), 199
standardization, in selected application areas, 201
intelligent transport systems (ITS), 201–204
entities and links between, 203–204
time line, 204
smart cities (SC), 201, 208–210
entities and links between, 209
model, 208
time line, 210
smart grid (SG), 201, 205–208
links between SSOs in, 207, 208
smart manufacturing (SM), 201, 205
links between SSOs in, 206
speculation, 210–213
time line, 211–212
IoT standardization entities, 212
wireless communication, 211
standard operating procedures (SOP), 480
standards, 14. see also entries starting as standardization
Standards Developing Organizations (SDOs), 296
Standards Setting Organizations (SSOs), 193, 194
cross-SSOs coordination entity, 213
developing dedicated IoT-specific standards, 195–196
relevant, web of, 200
specialized standardization entities, 213
State Energy Efficiency Resource Standards, 389
state of health (SoH), 499
statistical process control (SPC), 495
ST elevation myocardial infarction (STEMI), 479
stereoscopic aerial photographs technique, 593
stress, 59, 165, 238, 302, 451, 455, 458, 461, 462, 481, 482, 569
Stuxnet worm, 68
Sula A., 572
Supervisory Control And Data Acquisition (SCADA) systems, 285, 338
components, 392
supply–demand imbalance, 398
surveillance system implementations, 476
Susceptible–Exposed–Infected–Removed (SEIR) model, 498
sustainable energy, managing impact of, 426–432
demand curve, 429
distributed renewable generation sources, 427
EIoT dynamic reduction simulation, 431
energy storage technologies, 429
household demand curve, 428
load shift simulation, 431
sustainable energy, managing impact of
(continued)
net load, 2, 429
net load curve, 428
solar output, 427
curve, 428
storage simulation, 430
supply curve, 429
Swiss server, 67
Synchronous DynamicRAM
(SDRAM), 157
syndromic surveillance algorithms, 493
Syntax-based Context-adaptive Binary
Arithmetic Coder (SBAC), 340
system-object identifier (SID), 484
system on a chip (SoC), 98, 157, 158,
163, 307, 485
systems Integration (SI) program, 397

t
technical challenges, 303
technical revolutions, 52
characteristic properties, 52
technological development, 388
technology-based intervention (TI), 567
technology-driven innovations, 35
telecommunication engineers, 192
telemedicine, 477
teletype, 64
Tesla, Nikola, 3
thermal camera, 515
things/device layer, 15
Time Division Multiple Access (TDMA)
wireless networks, 245
slots, 244
superframes, 244
timeless perspective, 58
Time Slotted Channel Hopping
(TSCH), 232
timing of Ramadan, 59
TM-Coin protocol, 264, 265
total energy consumption, 389
toy-like systems, 64
track and publish national, 385
trade-off, 51
transaction costs, 201
transferring adaptable objects, 62
transforming data, 38
transmission and distribution
systems, 387
Transmission Control Protocol
(TCP), 171, 305
layer, 81
transmission error, 548
transportation, 58, 275
systems, 42
Transport Layer Security (TLS), 226
trauma entails image processing
gines, 479
traumatizing violation, 277
Trusted Computing Base (TCB), 264
Trusted Execution Environment
(TEE), 265
TTL pins, 602
two-factor authentication (2FA), 279
two-way vehicular communications, 477

u
UAVs. see unmanned aerial vehicles
(UAVs)
Ubiquitous Code (uCode), 85
UbiquitousComputing, 5
UIPEthernet, 175
ultrahigh frequency (UHF)
spectrum, 136
Uniform Resource Identifier (URI), 28,
85
Uniform Resource Locators (URLs), 95
unique identification number (ID), 139
United States Army (US Army), 547
Universal Asynchronous Receiver/
Transmitter (UART)
communication, 161
module, 486
Universal Plug and Play (UPnP), 18
Universal Serial Bus (USB) port, 161
unmanned aerial vehicles (UAVs), 510,
511, 530, 531
based remote sensing, 593
remote areas applications, 535
remotely piloted aircraft, 531
unmanned aircraft system (UAS), 530
unmanned vehicles (UV), 515
urban automated meter readers (AMRs), 338
urban challenges, and IoT-supported solutions, 323
URI. see Uniform Resource Identifiers (URI)
usage-based cost model, 114
US-based Uniform Code Council (UCC), 137
user control layer (UCL), 483
user interface (UI), 484, 499
user network controller (UNC), 483
users’ physiological data, 574
user’s stress level, measurement, 569

value-added services, 113, 122
value-creation activities, 38
variable rate technology (VRT), 518
automatic VRT chemigation, 519
variable renewable energy sources (VRES), 394
vehicle crashes, LED cabin lighting systems, 499
vehicle-specific applications, 532
vehicle-to-vehicle (V2V) communication, 491
very low node density, 533
video analytics (VSaas), 127
video-oriented applications, 321
video streaming, 123
virtual information, 14
visible light communication (VLC), 89
Visual Basic 4, 60
Voice Over IP (VoIP), 408

WBAN. see wireless body area networks (WBAN)
wearable biosensors, 482
wearables, 11
web browsing, 123
WebIDE, 172
Web of EIoT, 437
Web Ontology Language (OWL), 308
Web Services, 33
WebSockets, 305
WFANET application, 550
surveillance situations, 551
WFANETs. see Wide FANETs (WFANETs)
WFANETs application, 549
wide area network (WAN), 334
Wide FANETs (WFANETs), 540, 541, 550
Wi-Fi, 16, 18, 27, 84, 546, 596
Alliance, 18, 87
enabled energy, 435
Williams, M.A., 574
wind energy, 298
Win32DiskImager, 180
Windows, 16
wireless biosensing system, 481
wireless body area networks (WBAN), 550
wireless communication, 135, 338
systems, 193
wireless connectivity, 154
WirelessHART, 231
wireless local area network (WLAN), 480
devices, 16, 29, 477
wireless personal area network (WPAN), 144
wireless sensor network (WSN), 22, 79, 113, 222, 485, 497, 515, 533, 594
hierarchical deployment, 23
large-scale distributed, 522
protocols, 85
sensors, 24
WLAN. see wireless local area network (WLAN)
Wolfram Cloud, 103
Working Group for IoT Standardization (WG3), 309
world energy consumption, 385
World Health Organization (WHO), 298
World Radio Conference of 2012 (WRC‘12), 347
World Wide Web, 3, 332
WPAN. see wireless personal area network (WPAN)
<table>
<thead>
<tr>
<th>Letter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>WSN. see wireless sensor network (WSN)</td>
<td>y YL-69 soil moisture sensor, 600, 601</td>
</tr>
<tr>
<td>x X.509 certificate, 226</td>
<td>z ZigBee, 16, 97, 231, 373, 407, 442, 452, 477 stack, 408 Zipcar, 37 Z-Wave, 373 devices, 88</td>
</tr>
<tr>
<td>Xerox Palo Alto Research Center, 5</td>
<td>XML. see eXtensible Markup Language (XML)</td>
</tr>
</tbody>
</table>