

Index

- 5G and 6G network, 42
- 5G connectivity, 148
- 5G networks, 67, 71
- 5G technology, 4, 5
- 6G, 122–124, 155, 189, 191, 193, 249
- 6G based IIoMT applications, 396–399
 - augmented reality (AR) and virtual reality (VR), 397
 - haptic internet, 397
 - holographic communication, 396–397
 - hospital to home services, 398
 - intelligent wearable devices, 398
 - sample reader sensors (SRS), 398
 - telesurgery, 399
- 6G capabilities
 - device explosion, 88
 - high data rates, 86–87
 - holographic communication, 98
 - network slicing, 92
 - quantum encryption, 98
 - ultra-low latency, 87–88
- 6G Internet of Things, 366–367, 382
- 6G networks, 67, 71, 72, 340–353, 358–359
- 6G technology, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 40, 41, 42, 43, 389, 392–394
 - communication standards, 393–394
 - comparison with 5G, 390
 - overview, 389, 392
- 6G terahertz communication, 285, 304–305
 - advantages in IIoT, 306–307
 - challenges and solutions, 307–309
 - framework for edge intelligence in IIoT, 305–306
 - implications in IIoT, 306–307
 - integration with edge computing, 305
 - introduction, 304
 - latency and bandwidth considerations, 307
 - security and privacy issues, 307–308
 - technological barriers, 308–309
- 6G transition, 85
- 6G use status matrix, 47
- 6G-powered factory, 48
- Access control, 275
- Adaptive computing acceleration engine (ACAE), 168
- Adaptive intelligence, 322
- Additive manufacturing, 6
- AI algorithms, 325–327
- AI paradigms, 326
- Anomaly detection, 30, 104, 224, 322, 327, 330
- AR (Augmented Reality), 233–235
- Architecture, 185, 186
- Architecture, edge computing, 324–325, 333–335

- Artificial Intelligence (AI), 3, 4, 6, 7, 8, 9, 11, 14, 16, 17, 51, 67, 71, 83, 151, 181, 182, 183, 184, 187, 189, 190, 191, 193, 268, 274, 289–290, 366
 - edge AI, 301, 315–316
- Attack, on Dyn company, 274
- Attack, Wanna Cry ransomware, 278
- Auction models, 72
- Augmented reality (AR), 6, 8, 9
- Augmented reality and virtual reality integration, 44
- Authentication, 11, 12, 76, 275, 277, 279
- Authentication mechanisms, 330–331, 334
- Authentication, peer, 279
- Automotive industry, 49, 278–280, 282
- Automotive industry, vulnerabilities, 278–279
- Autonomous robots, 8, 10
- Autonomous systems, 4, 5, 10, 16, 106–107, 245
 - adaptive navigation, 107–108
 - collaborative decision-making, 113
 - context-aware decision making, 107
- Autonomous vehicles, 253, 255, 263–264
- Availability (security principle), 273, 275, 277, 280
- Availability risks, 278, 280
- Availability risks, solutions, 282
- Bandwidth, 4, 5, 7, 9, 10, 13
- Bandwidth optimization, 126
- Base station (BS), 366, 370, 380–382
- Battery limitation, 365–366
- Beamforming, 5
- Behavioral analysis, 76–77
- Benchmark, 181, 191
- Blockchain, 18, 72, 73, 114, 222–238, 286, 312–314
 - benefits in IIoT, 314
- decentralized application (DApp), 313–314
 - for data security and integrity, 312
 - need for in IIoT, 313
 - overview of technology, 312
 - smart contract, 313–314
 - use cases, 313
- Byos secure gateway edge, 77, 78
- Carbon footprint, 7, 12
- Central processing units (CPUs), 181, 184, 185, 186, 194, 195
- Centralized network architecture, 5
- Challenges for 6G technology, 399–400
 - healthcare data analytics, 400
 - intelligent spectrum sharing, 400
 - location and precise positioning, 399–400
 - low power and communication, 399
 - security and privacy, 399
- Cloud, 181, 183, 184, 189, 190
- Cloud communication protocols, 331
- Cloud computing, 68–69, 82, 242–243, 285–286, 294–296
 - benefits and challenges of integration, 295–296
 - for industrial applications, 295
 - integration with edge, 286, 293, 296–299, 315–316
 - overview, 294–295
 - services, 295
- Cloud-based analytics, 145
- Cluster formation, 376
- Cluster-based communication, 366–367
- Cluster-head selection, 366, 371–376
- Clusters, 183, 184, 194
- Collaborative robotics (Cobots), 108
- Collaborative robots (COBOTS), 178
- Communication infrastructure, 222
- Computer-aided design (CAD), 323
- Computer-aided manufacturing (CAM), 323

- Computing, 181, 182, 184, 186, 187, 188, 189, 190, 193, 194
- Condition monitoring, 103, 332
- Confidentiality (security principle), 273, 275, 277, 280
- Confidentiality risks, 277, 280
- Confidentiality risks, solutions, 281
- Control latencies, 33
- Cores, 181, 183, 184, 185, 194
- Cryptographic mechanisms, 67
- Cryptographic tampering, 279
- C-V2X, 172
- CV2X communication, 278
- Cyber security enhancement, 148
- Cyberattacks, 11, 12
- Cyber-physical systems, 322–323
- Cybersecurity, 6, 12, 14, 85

- Data acquisition, 326, 333
- Data analytics (edge), 324–325, 334
- Data center, 181, 182, 183, 187
- Data centres, 125
- Data collection, 299–300
 - event-driven collection, 300
 - polling method, 299–300
 - real-time data streams, 300
- Data distribution, 27, 28, 31
- Data encryption, 76, 331, 334
- Data filtering, aggregation, and compression, 300–301
 - data aggregation, 300–301
 - data compression, 300
 - data filtering, 300
 - data sampling, 300
- Data fusion, 234–238
- Data integrity, 114, 274
- Data ownership and consent, 115
- Data processing (edge), 324, 334
- Data rates, 4, 5, 7, 11, 13
- Data security and integrity, 312–314
 - blockchain for, 312–314
- Data theft, 274
- Decentralized, 255
- Decentralized edge intelligence, 222–223
- Decision-making, real-time, 322, 324, 326
- Deep learning, 186, 327
- Device-to-Device (D2D) communication, 72
- DevOps methodologies, 35
- Differences between 5G and 6G, 43
- Digital health, 276
- Digital twin, 285–286, 309–311
 - framework in IIoT, 310–311
 - integration with IIoT, 309–310
 - introduction, 309
 - use cases, 309
- Digital twin technology, 148
- Digital twins, 9, 16
- Distributed AI, 26
- Distributed edge intelligence marketplaces, 239–241
- Distributed intelligence, 23, 26, 36
- Distributed network architecture, 5, 16
- DNN, 168
- Dominance of edge computing, 147
- Driver-less V2X, 172
- Drone communication, 29
- Drones, 10, 16
- Dynamic adaptability, 97

- Edge 5G NR, 129
- Edge AI, 149, 173, 182, 183, 187, 188, 222–238, 350, 354
- Edge computing, 5, 11, 13, 14, 16, 17, 51, 97–98, 100–101, 220–235, 285–286, 292–294, 296–299, 321–325, 361
 - architectures, 293
 - bandwidth optimization, 98
 - benefits, 292–293
 - clean edge, 293
 - conceptual framework with cloud, 296
 - edge-cloud synergy, 296–299

- integration with cloud, 286, 296–299
- need for IIoT applications, 292–293
- operational benefits, 293
- overview, 292
- performance, 296–297
- reduced latency, 97–98
- thick-edge connected to cloud, 293
- thin edge connected to cloud, 293
- Edge computing (EC), 69, 70, 124, 252
- Edge devices, 125, 220–222, 324, 333
- Edge intelligence, 166, 217–218, 222–241, 260, 301–302, 350–361
 - deep learning, 301–302
 - evolutionary algorithms, 302
 - federated learning, 302
 - machine learning algorithms, 301
 - reinforcement learning, 302
 - traditional ML algorithms, 301
- Edge intelligence (EI), 365–367
- Edge nodes, 125, 222
- Edge security, 330–331, 334
- Edge servers/gateways, 324–325, 333
- Edge-based data fusion, 234–238
- Edge-native optimization, 321–322, 329–330
- Edge-to-cloud, 263
- Edge-to-cloud connectivity, 302–303
 - cloud integration, 303
 - edge data processing, 303
 - edge device configuration, 303
 - hybrid architectures, 303
- Edge-to-cloud orchestration, 242–245
- eMBB, 130
- eMBB+ and URLLC+, 155
- Encryption, 7, 11, 12, 82, 275, 281
- Endpoint integrity, 279
- Energy efficiency, 5, 7, 11, 12, 13, 17, 256, 260, 365–366, 370, 380–382
- Energy management, 95
- Energy model, 370
- Energy-efficient edge computing, 229–232
- Environmental sustainability, 12, 13, 17
- Ethereum, 73
- Evolution of technology, 39, 40
- Extended reality (XR), 4, 5, 7, 8
- Fault detection, 94, 103–104, 332
- FDMA, 168
- Federated learning, 18, 27, 28, 35, 36, 37, 228–230, 257
- Fitness functions, 374–375
- Fitness tracker data API vulnerability, 276
- Fog computing (FC), 69, 70, 126, 229
- Fog nodes, 127
- Framework, 189, 191
- Future perspective of 6G technology, 400–401
 - case study (remote surgery), 401
- Gaussian process regression (GPR), 31
- GFLOPS, 185, 196
- Global system for mobile (GSM), 169
- GPRS, 169
- Graphics processing unit (GPU), 185, 186, 187, 191
- Hard-coded passwords, 276, 280
- Hash tree, 206
- Healthcare industry, 275–278, 280, 282
- Healthcare industry, vulnerabilities, 276–277
- High-performance computing (HPC), 195
- High-quality data collection, 157
- Holographic, 250
- Holographic communication, 5, 7, 98
- Homomorphic encryption, 206, 211
- Human-robot interaction (HRI), 31
- Hyper-connected world, 272–273
- IIoT, 201–203, 205, 209, 210, 214
- IIoT security, 74, 75, 78–80
- Immediate decision-making, 96–97
- Implantable defibrillator vulnerability, 276

- Industrial applications, 85
- Industrial automation, 144
- Industrial demands change, 147
- Industrial intelligence, 321–323
- Industrial Internet of Medical Things (IIoMT), 387, 394, 396
- Industrial Internet of Things (IIoT), 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 67, 69, 74, 220–222
- Industrial IoT (IIoT), 285–292, 295–296, 325–326
 - components of ecosystem, 288–290
 - data-driven decision making, 290–291
 - evolution, 288
 - foundations, 287
 - innovation and product development, 291
 - integration with blockchain, 313–314
 - integration with digital twin, 309–310
 - predictive maintenance, 291
 - process optimization, 291
 - quality control, 291
 - role in industrial transformation, 290–292
 - safety and compliance, 291
 - supply chain management, 291
- Industrial systems, 145–146
- Industry 4.0, 4, 6, 88, 152, 322–323
- Integration of 6G connectivity, AI, IoT, and edge computing, 51
- Integration of AR and VR, 233–235
- Integrity (security principle), 274, 275, 277, 280
- Integrity risks, 278, 280
- Integrity risks, solutions, 281
- Intelligent internet of everything, 171
- Intelligent reflective surfaces (IRS), 16
- Internet of Things (IoT), 51, 182, 184, 191, 219–220, 252, 254, 271–273, 325–326
- Internode, 181, 194
- Interoperability, 11, 12, 13, 14, 15, 16
- Intra-cluster distance, 374–375, 382
- Intra-node, 181
- Intrusion detection systems (IDS), 67, 76
- IoT devices, 45
- IoT revolution, 88
- IoT security, 78–80
- IoT security architecture, 271, 277
- IoT sensors, 326
- Large language models (LLMs), 321–322
- Latency, 3, 4, 5, 7, 8, 9, 10, 11, 13, 14, 16, 69, 251–254
- Lightweight machine learning, 329–330
- Liquid software, 168
- Long-term evolution (LTE), 170
- LoRa, 138
- LPWAN, 134–136
- Lyapunov stability, 32
- Machine learning (ML), 5, 7, 8, 9, 10, 17, 77, 83, 85, 224–230, 301–302
 - at the edge, 301–302
 - for edge intelligence, 301–302
 - IIoT analytics, 289–290
- Machine learning algorithms
 - reinforcement learning, 93
 - supervised learning, 92–93
 - unsupervised learning, 93
- Machine learning at edge, 327–330
- Machine-to-machine (M2M) communication, 271
- Maintenance, predictive, 322, 328–332, 336
- Malware, 274, 278
- Manufacturing technologies, 46, 48
- Marketplace, 239–241
- Massive IoT integration, 44
- Massive MIMO, 5, 15
- McAfee spectrum auction, 73
- Memory, 181, 184, 185, 186, 190, 194
- Merkle tree, 205–207, 210–212, 214

- Meta heuristic optimization, 366, 368
- MIMO, 129
- Mirai malware, 274
- Mixed reality (MR), 8, 233–234
- mMTC, 130
- Model compression, 329–330
- Multi-access edge computing (MEC), 70
- Multiprocessor, 184, 185

- Narrowband IoT, 139
- Network function virtualization (NFV), 69, 70
- Network lifetime, 365, 381–382
- Network security, 114
- Network segmentation, 275, 279
- Network slicing, 5, 8, 14, 92
- Next generation ultra-reliable low-latency communication (xURLLC), 30
- Node deployment, 369, 377

- Open RAN (O-RAN), 70, 71
- Operational resilience, 321–322
- Operational technologies (OT), 144
- Opportunities (edge computing), 328
- Optimization techniques, 329–330, 334
- Orchestration, 242–245
- Osprey optimization technique, 367–369, 371–376

- Parallel, 181, 184, 186, 194
- Patient controlled infusion system vulnerability, 276
- Pattern recognition, 30
- Performance, 181, 184, 185, 186, 187, 188, 194, 196
- Predictive analytics, 225, 322, 327–332
- Predictive maintenance, 6, 7, 8, 9, 16, 17, 94, 102–103, 224–226, 264, 328–332, 336
- Privacy, 12, 67, 72, 80, 259–260
- Privacy considerations, 114–115
 - anonymization techniques, 114–115
 - privacy impact assessments, 115–116
- Privacy protection, 334
- Privacy risks, 273
- Process optimization, 94, 151
- Processing, local/edge, 324–325
- Productivity, 85
- PROFINET, 14

- Quality control, 322, 332
- Quality of life (QOL), 387
- Quantum, 267–268
- Quantum communication, 4, 5, 8, 16
- Quantum computing, 8, 16
- Quantum encryption, 98

- Radio frequency identification (RFID), 271–272
- Real-time, 257
- Real-time analytics, 6, 8, 9, 10, 14, 18, 321–322, 324
- Real-time anomaly detection, 224
- Real-time data processing, 96–97
- Real-time decision-making, 304
- Real-time monitoring, 6, 8, 9, 10, 15, 82, 324, 332
- Real-time monitoring and control, 303–304
- Reconfigurable intelligent surfaces (RIS) technology, 32
- Reduced latency, 125, 128
- Redundancy, 77
- Reliability, 4, 6, 7, 10, 11, 15
- Remote maintenance, 6, 9
- Residual energy, 374–375, 380–382
- Resource allocation, 260–263
- Revolution, 40, 41, 42, 43, 44, 51, 54, 57, 63
- Robotics, 108
- Role of 6G in healthcare, 394–396

- Security and privacy, 342, 346,
347–350, 352, 353, 354, 355, 356,
357, 360
- Security attacks, 274
- Security audits, 77
- Security challenges, 113–114, 329–331,
334
 multi-layered security protocols, 115
 regular security audits and updates,
 115
- Security framework, 273–274
- Security of IIoT devices, 153–154
- Security patches, 275
- Security principles, 273–274, 277
- Sensors, 200, 203, 205, 208–210, 212,
214
- Sensors and actuators, 220
- Sensors, IoT, 326
- Service oriented architecture (SoA),
298–299
- Sigfox, 138
- Signification 6G technology, 43
- Simulation parameters, 380
- Sink distance, 374
- Smart buildings, 274–275, 280, 281
- Smart buildings, vulnerabilities,
274–275
- Smart cities, 4, 5, 221, 239, 243,
263–264, 269–270
- Smart city, 272
- Smart factories, 4, 6, 95, 323
- Smart grids, 15, 18
- Smart logistics and inventory
 management, 50
- Smart manufacturing, 3, 8, 9, 16, 40,
41, 42, 45
- Smart manufacturing and
 communication, 41
- Software defined networking (SDN),
69, 70
- Spectral efficiency, 24, 30
- Spectrum access, 71, 72
- Split learning (SL), 31
- Supply chain management, 333
- Supply chain optimization, 6, 10, 11,
95–96, 291, 306–307
- Supply chain visibility, 282
- Sustainability and energy efficiency,
156
- Sustainability focus, 148
- Swarm intelligence, 34, 35
- Swarm stability, 32
- Telecommunication, 361
- Terahertz (THz) frequencies, 4, 5, 7,
16, 73
- Third-party collaboration, 279
- Threat detection, 331
- Threat modeling, 275
- Threat protection, 82
- Time-sensitive networking (TSN), 14,
131–132
- Traditional manufacturing, 322–323
- Traffic flow prediction, 175
- Ultra-low latency, 23, 24, 36
- User interface, 219
- Virtual reality (VR), 7, 8, 233–235
- Vulnerabilities, causes, 280
- Wireless, 261, 267–269
- Wireless sensor networks (WSNs),
271–272, 366
- Workload, 181, 194, 195
- Zero trust security, 77