



Chapter 1 : Introduction to Internet of Things (IoT)		1-1 to 1-48
1.1	Internet of Things (IoT).....	1-1
1.1.1	Characteristics of IoT.....	1-2
1.2	IoT Vision.....	1-4
1.3	IoT and Digitisation.....	1-10
1.4	Economic Significance of IoT (Impact of IoT).....	1-11
1.5	Connected Roadways.....	1-13
1.6	Connected Factory.....	1-16
1.7	Smart Connected Buildings.....	1-18
1.8	Smart Creatures.....	1-21
1.9	Convergence of IT and OT.....	1-22
1.10	IoT Issues and Challenges.....	1-24
1.11	Technical Building Blocks (High-Level Architecture of IoT).....	1-25
1.12	IoT and M2M.....	1-27
1.12.1	Introduction to M2M.....	1-27
1.12.1(A)	Applications of M2M.....	1-27
1.12.1(B)	General High-Level Architecture of M2M (Defined by ETSI).....	1-28
1.12.1(C)	High-level Architecture of M2M for IoT.....	1-29
1.12.1(D)	Difference between IoT and M2M.....	1-30
1.13	The oneM2M IoT Standardised Architecture.....	1-30
1.13.1	The IoT World Forum (IoTWF) Standardised Architecture.....	1-32
1.13.2	Security in the IoT.....	1-37
1.14	A Simplified IoT Architecture (IoT Protocol Stack).....	1-37
1.14.1	The Core IoT Functional Stack.....	1-38
1.14.2	IoT Data Management and Compute Stack.....	1-40
1.14.2(A)	Why Sending All Data to The Cloud May Not Be The Obvious Choice? (Design Considerations and Data Related Problems).....	1-41
1.14.3	Fog Computing.....	1-41
1.14.3(A)	Fog Node.....	1-43
1.14.4	Edge Computing.....	1-45
1.14.4(A)	The Hierarchy of Edge, Fog and Cloud.....	1-45
1.14.5	Comparison between Edge, Fog, and Cloud Computing.....	1-45

Chapter 2 : Things in IoT		2-1 to 2-54
2.1	Things in IoT	2-1
2.2	Sensors, Actuators, and Smart Objects.....	2-3
2.2.1	Sensors.....	2-3
2.2.2	Types of Sensors.....	2-6
2.2.2(A)	Voltage Sensor.....	2-9
2.2.2(B)	Humidity Sensor.....	2-9
2.2.2(C)	Level Sensors	2-10
2.2.2(D)	USB Sensors.....	2-11
2.2.2(E)	Embedded Sensors.....	2-12
2.3	Wireless Sensor Networks	2-13
2.3.1	WSN Topologies	2-14
2.4	Actuators.....	2-16
2.4.1	Types of Actuators.....	2-16
2.5	Smart Objects.....	2-17
2.5.1	Common Smart Objects (IoT Devices).....	2-18
2.5.1(A)	Home Automation	2-18
2.5.1(B)	Industrial IoT	2-19
2.5.1(C)	Personal and Health Care	2-20
2.5.1(D)	Other Uses	2-21
2.6	IoT Enabling Technologies.....	2-22
2.6.1	Radio Frequency Identification (RFID) Technology.....	2-22
2.6.1(A)	How RFID Works?	2-23
2.6.1(B)	Application of RFID.....	2-24
2.6.2	RFID Protocol Standards.....	2-25
2.7	Micro-Electro-Mechanical Systems (MEMS)	2-27
2.8	Connecting Smart Objects.....	2-28
2.8.1	Communications Criteria	2-28
2.8.2	Comparison between Various Wireless Technologies based on Communication Criteria.....	2-34
2.9	IEEE 802.15.4	2-34
2.9.1	IEEE 802.15.4 - Device Types	2-34
2.9.2	IEEE 802.15.4 - Network Components.....	2-35
2.9.3	IEEE 802.15.4 - Network Topologies.....	2-35



2.9.4	IEEE 802.15.4 - High-level Architecture.....	2-36
2.9.5	IEEE 802.15.4 - Frame Structure.....	2-37
2.10	Bluetooth.....	2-38
2.11	ZigBee.....	2-40
2.11.1	Benefits of ZigBee.....	2-41
2.11.2	ZigBee Technical Specifications.....	2-41
2.11.3	ZigBee Architecture.....	2-41
2.11.4	ZigBee Devices.....	2-43
2.11.5	ZigBee Network Topology.....	2-43
2.11.6	ZigBee Application Profiles.....	2-44
2.12	NFC (Near Field Communication).....	2-44
2.12.1	How NFC Works?.....	2-45
2.12.2	NFC and other Contactless Protocols.....	2-46
2.12.3	Operation Modes of NFC Forum Devices.....	2-46
2.12.4	NFC Forum Tags.....	2-49
2.13	LTE-A (LTE Advanced).....	2-50
2.13.1	Comparison of LTE-A Against Other Technologies.....	2-52

Chapter 3 : The Core IoT Functional Stack
3-1 to 3-04

3.1	The Core IoT Functional Stack.....	3-1
3.2	Layer 1 - Things: Sensors and Actuators Layer.....	3-1
3.3	Layer 2 - Communications Network Layer.....	3-1
3.4	Layer 3 - Applications and Analytics Layer.....	3-1
3.4.1	Analytics Versus Control Applications.....	3-2
3.4.2	Data Versus Network Analytics.....	3-2
3.4.3	Data Analytics Versus Business Benefits.....	3-3
3.4.4	Smart Services.....	3-3

Chapter 4 : Application Protocols for IoT
4-1 to 4-20

4.1	IoT Application Transport Methods.....	4-1
4.2	IoT Protocols.....	4-3
4.2.1	Link Layer Protocols.....	4-5
4.2.2	Network Layer Protocols.....	4-6
4.2.3	Transport Layer Protocols.....	4-7
4.2.4	Application Layer Protocols.....	4-7
4.3	SCADA : (Supervisory Control and Data Acquisition).....	4-10



4.3.1	High-level Architecture of SCADA Systems.....	4-12
4.3.2	SCADA Protocol Standards.....	4-13
4.3.3	Background on SCADA.....	4-13
4.3.4	Adapting SCADA for IP.....	4-14
4.3.5	Distributed Network Protocol 3 (DNP3).....	4-14
4.3.6	Tunnelling Legacy SCADA over IP Networks.....	4-16
4.3.7	SCADA Protocol Translation.....	4-17
4.3.8	SCADA Transport over LLNs with MAP-T.....	4-18

Chapter 5 : Domain Specific IoTs**5-1 to 5-36**

5.1	Home Automation.....	5-2
5.1.1	Smart Lighting for Home.....	5-3
5.1.2	Smart Appliances.....	5-4
5.1.3	Intrusion Detection.....	5-5
5.1.4	Smoke / Gas Detector.....	5-5
5.2	Smart City.....	5-6
5.2.1	Layered Architecture.....	5-7
5.2.2	Smart Parking.....	5-7
5.2.3	Smart Lighting for Smart Cities.....	5-8
5.2.4	Smart Road.....	5-9
5.2.5	Structural Health Monitoring.....	5-10
5.2.6	Surveillance Applications.....	5-11
5.3	Health.....	5-12
5.3.1	Fitness and Health Monitoring.....	5-12
5.3.2	Wearable Electronics.....	5-13
5.4	Agriculture.....	5-15
5.4.1	Smart Irrigation.....	5-15
5.4.2	Greenhouse Control.....	5-15
5.5	Environment.....	5-16
5.5.1	Weather Monitoring.....	5-16
5.5.2	Air Pollution Monitoring System.....	5-17
5.5.3	Noise Pollution Monitoring.....	5-18
5.5.4	Forest Fire Detection.....	5-18
5.5.5	River Floods Detection.....	5-19
5.6	Logistics.....	5-20
5.6.1	Route Generation and Scheduling.....	5-20



5.6.2	Fleet Tracking.....	5-21
5.6.3	Shipment Monitoring.....	5-21
5.7	Retail Management.....	5-23
5.7.1	Inventory Management.....	5-25
5.7.2	Smart Payments.....	5-26
5.7.3	Smart Vending Machines.....	5-27
5.8	Industry Applications	5-28
5.8.1	Machine Diagnosis and Prognosis.....	5-29
5.8.2	Indoor Air Quality Monitoring.....	5-30
5.9	Energy	5-30
5.9.1	Smart Power Grid	5-30
5.9.1(A)	Characteristics of Smart Power Grid.....	5-31
5.9.1(B)	Applications of Smart Power Grid.....	5-31
5.9.2	Renewable Energy Systems.....	5-32
5.9.3	Prognostics.....	5-33

Chapter 6 : Create Your Own IoT**6-1 to 6-66**

6.1	System on a Chip (SoC)	6-1
6.1.1	Architecture of SoC	6-2
6.1.2	Applications of SoC	6-2
6.1.3	Comparison between SoC and a Traditional System.....	6-4
6.2	Single Board Computer (SBC).....	6-5
6.2.1	Block Diagram	6-6
6.3	Types, Specifications and Comparison of SBC Models	6-7
6.3.1	Raspberry Pi.....	6-7
6.3.1(A)	Features and Characteristics of Raspberry Pi	6-7
6.3.1(B)	Raspberry Pi Models.....	6-9
6.4	I/O and Network Access Devices	6-11
6.4.1	Raspberry Pi Interfaces	6-13
6.5	Introduction to Arduino	6-16
6.5.1	Interfacing of the Sensors and Actuators with Arduino	6-18
6.6	ESP32.....	6-19
6.7	littleBits (cloudBits)	6-20
6.8	Particle Photon.....	6-21
6.9	Beagle Board	6-23
6.10	IoT Software.....	6-25



6.11	Languages for Programming IoT Hardware.....	6-26
6.12	IoT Middleware Applications and API Development.....	6-28
6.12.1	Technology Functions and Services Provided by IoT Middleware	6-30
6.13	Amazon Web Services for IoT.....	6-30
6.13.1	Amazon EC2.....	6-30
6.13.2	Amazon S3.....	6-32
6.13.3	AWS Auto Scaling.....	6-33
6.13.4	Amazon Relational Database Service (RDS).....	6-34
6.13.5	Amazon DynamoDB.....	6-35
6.13.6	Amazon Kinesis.....	6-35
6.13.7	Amazon SQS.....	6-36
6.13.8	Amazon EMR.....	6-37
6.13.9	AWS IoT Greengrass.....	6-37
6.13.10	AWS IoT Core.....	6-38
6.13.11	AWS IoT Device Defender	6-39
6.13.12	AWS IoT Device Management.....	6-40
6.13.13	AWS IoT Analytics	6-41
6.13.14	AWS IoT SiteWise	6-43
6.13.15	AWS IoT Events	6-44
6.13.16	AWS IoT Things Graph.....	6-45
6.14	Making Front Ends.....	6-46
6.15	Logical Design of IoT.....	6-49
6.15.1	IoT Functional Blocks	6-49
6.16	IoT Communication Models.....	6-51
6.16.1	Comparison between IoT Communication Models	6-55
6.17	IoT Communication APIs.....	6-55
6.17.1	REST-based Communication APIs.....	6-55
6.17.1(A)	REST Architectural Constraints	6-57
6.17.1(B)	RESTful Web Service (or APIs)	6-58
6.17.2	WebSocket-based Communication APIs.....	6-58
6.17.3	Comparison between REST-based and WebSocket-based APIs.....	6-59
6.18	JSON-LD (JSON for Linking Data).....	6-60
6.18.1	Design Goals and Rationale	6-62
6.18.2	Syntax Tokens and Keywords.....	6-62
6.19	Board Comparisons	6-63