||Jai Sri Gurudev||

B G S INSTITUTE OF TECHNOLOGY

BG Nagara-571448, Mandya

Department of Computer Science and Engineering

COURSE FILE

Course Coordinator	:	Swetha K R
Designation	:	Assistant Professor
Course Name	:	Internet of Things
Course Code	:	17CS81
Academic Year	:	2020-2021
For the period	:	19/04/2021 to 20/07/2021

Signature of Course Coordinator

Signature of HOD

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Karnataka (INDIA)

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BGS Institute of Technology

BG Nagara-571448, Mandya

VISION

BGSIT is committed to the cause of creating tomorrow's engineers by providing quality education inculcating ethical values

MISSION

- Imparting quality technical education by nurturing a conducive learning environment.
- Offering professional training to meet industry requirements.
- Providing education with a moral - cultural base and spiritual touch

DEPARTMENT

OF

COMPUTER SCIENCE AND ENGINEERING

VISION

To produce engineers by possessing good technical knowledge and ethics through quality education and research.

MISSION

M1: Achieve excellence by providing good infrastructure and competent faculty.

M2: Strengthening the technical, soft skills, leadership qualities and ethical values to meet the industry requirements.

M3: Facilitate experimental learning through research projects

Shailh

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PROGRAM OUTCOMES (POs)

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

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PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO 1: Graduates will be pursuing successful career and higher education.

PEO 2: Graduates will be able to apply the knowledge of programming skills to solve the real-world problems.

PEO 3: Graduates will display professional ethics to work in a team and lead the team by effectively communicating the ideas.

PEO 4: Graduates will practice lifelong learning.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO 1: Ability to apply Mathematical Methodologies, Management Principles and Ethics, Electronics and Embedded Systems and Programming Technologies to solve real time problems.

PSO 2: Ability to apply software design and development practices to develop software in emerging areas such as Internet of Things, Data Management, Social Networking and Security, Cloud and High-Performance Computing.

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Academic Calendar of EVEN semesters of UG Programmes for 2020-2021

Semesters / EVENTS	IV semester B.E./B.Tech.	IV semester B.Arch./ B.Plan.	VI semester B.E./B.Tech.	VI semester B.Plan./B.Arch	VIII semester B.E./B.Tech.	VII semester B.Plan./B.Arch.
Commencement of EVEN Semester	19.04.2021	19.04.2021	19.04.2021	19.04.2021	19.04.2021	19.04.2021
Last Working day of EVEN Semester	07.08.2021	07.08.2021	07.08.2021	07.08.2021	20.07.2021	20.07.2021
Practical Examinations	09.08.2021 To 19.08.2021	09.08.2021 To 19.08.2021	09.08.2021 To 19.08.2021	---	---	---
Theory Examinations	23.08.2021 To 09.09.2021	23.08.2021 To 09.09.2021	23.08.2021 To 09.09.2021	10.08.2021 To 31.08.2021	#22.07.2021 To 30.07.2021	#22.07.2021 To 30.07.2021
Internship	---	---	---	---	---	---
Internship Viva-Voce	---	---	---	---	02.08.2021 To 06.08.2021	---
Professional training / Organization study	---	---	---	---	---	---
Commencement of ODD Semester	13.09.2021	13.09.2021	13.09.2021	13.09.2021	---	09.08.2021 (IX sem Arch)

- The classroom sessions for even the semester should commence from the dates mentioned above. The classroom sessions for all the semesters would be in **Offline /Online/blended mode** until further orders.
- The Institute needs to function for **six days** a week with additional hours (**Saturday is a full working day**). #if required the college can plan to have extra classes even on **Sundays also**.
- If any of the above dates are declared to be a holiday then the corresponding event will come into effect on the next working day.
- Notification regarding the Calendar of Events relating to the conduct of **University Examinations** will be issued by the Registrar (Evaluation) from time to time.
- The faculty/staff shall be available to undertake any work assigned by the University.
- Academic Calendar may be modified based on guidelines/directions issued in the future by MHRD/UGC/AICTE/State Government.
- Revised Academic Calendar is also applicable for **Autonomous Colleges.** In case if any changes are to be affected by Autonomous Colleges in the academic terms and examination schedule, they could do so with the approval of the University.

6/4/2021

REGISTRAR

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B G Nagara, Nagamangala Taluk, Mandya District, Karnataka State, INDIA - 571448

CALENDAR OF EVENTS FOR B.E. VIII SEMESTER FOR THE ACADEMIC YEAR 2020-21

APRIL

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

Number of Working Days - 11

ACTIVITIES

19 - Registration & Commencement of 8th Semester Classes

MAY

Mon	Tue	Wed	Thu	Fri	Sat	Sun
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

Number of Working Days - 24

1 - May Day
14 - Ramzan
24-29 Technical Seminar Presentation

JUNE

Mon	Tue	Wed	Thu	Fri	Sat	Sun
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

Number of Working Days - 26

3, 4, 5 - Test 1
7-12 Internship Presentation
11 - Test 1 Progress Report Dispatch
12 - Class Teacher's Meeting
28, 29, 30 - Test 2

JULY

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

Number of Working Days - 17

2-Test 2 Progress Report Dispatch
3 - Class Teacher's Meeting
5-10 Final Project Presentation
15, 16, 17 - Test 3
19 - Submission of IA and Attendance
20 - Last Working Day
21 - Bakrid
21 - Bakrid

BGSIT IS COMMITTED TO THE CAUSE OF CREATING TOMORROW'S ENGINEERS BY PROVIDING QUALITY EDUCATION INCULCATING ETHICAL VALUES.

Theory Examinations	22-7-2021 to 30-7-2021
Internship / Project Viva-Voce	2-8-2021 to 6-8-2021
Commencement of ODD Semester	

Dr. B.K.Raghavendra
Academic Incharge

Dr. B.K.Narendra
Principal

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DEPARTMENT OF COMPUTER SCEINCE & ENGINEERING

INDIVIDUAL TIME TABLE

ACADEMIC YEAR : 2020-21	EVEN SEMESTER
Name of the Course Coordinator: Swetha K R	LECTURE HALL:
CLASS : VIII A & B	

DAY	9:00 am to 9:55 am	9:55 am to 10:50 am	10:50 am to 11:00 am	11:00 am to 11:55 am	11:55 am to 12:50 pm	12:50 pm to 01:45 pm	01:45 pm to 02:40 pm	02:40 pm to 03:35 pm	03:35 pm to 04:30 pm
MONDAY	IoT		TEA BREAK			LUNCH BREAK			
TUESDAY				IoT					
WEDNESDAY					IoT				
THURSDAY					IoT				
FRIDAY	IoT								
SATURDAY				IoT					

CODE	SUBJECT	STAFF
17CS81	Internet Of Things	Swetha K R

Swetha K R
Signature of Course Coordinator

B. K. Raghavendra
Signature of HoD

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INTERNET OF THINGS TECHNOLOGY [As per Choice Based Credit System (CBCS) scheme] (Effective from the academic year 2017 - 2018) SEMESTER – VIII			
Subject Code	17CS81	IA Marks	40
Number of Lecture Hours/Week	04	Exam Marks	60
Total Number of Lecture Hours	50	Exam Hours	03
CREDITS – 04			

Module – 1	**Teaching Hours**
What is IoT, Genesis of IoT, IoT and Digitization, IoT Impact, Convergence of IT and IoT, IoT Challenges, IoT Network Architecture and Design, Drivers Behind New Network Architectures, Comparing IoT Architectures, A Simplified IoT Architecture, The Core IoT Functional Stack, IoT Data Management and Compute Stack.	**10 Hours**
Module – 2	
Smart Objects: The "Things" in IoT, Sensors, Actuators, and Smart Objects, Sensor Networks, Connecting Smart Objects, Communications Criteria, IoT Access Technologies.	**10 Hours**
Module – 3	
IP as the IoT Network Layer, The Business Case for IP, The need for Optimization, Optimizing IP for IoT, Profiles and Compliances, Application Protocols for IoT, The Transport Layer, IoT Application Transport Methods.	**10 Hours**
Module – 4	
Data and Analytics for IoT, An Introduction to Data Analytics for IoT, Machine Learning, Big Data Analytics Tools and Technology, Edge Streaming Analytics, Network Analytics, Securing IoT, A Brief History of OT Security, Common Challenges in OT Security, How IT and OT Security Practices and Systems Vary, Formal Risk Analysis Structures: OCTAVE and FAIR, The Phased Application of Security in an Operational Environment	**10 Hours**
Module – 5	
IoT Physical Devices and Endpoints - Arduino UNO: Introduction to Arduino, Arduino UNO, Installing the Software, Fundamentals of Arduino Programming. IoT Physical Devices and Endpoints - RaspberryPi: Introduction to RaspberryPi, About the RaspberryPi Board: Hardware Layout, Operating Systems on RaspberryPi, Configuring RaspberryPi, Programming RaspberryPi with Python, Wireless Temperature Monitoring System Using Pi, DS18B20 Temperature Sensor, Connecting Raspberry Pi via SSH, Accessing Temperature from DS18B20 sensors, Remote access to RaspberryPi, Smart and Connected Cities, An IoT Strategy for Smarter Cities, Smart City IoT Architecture, Smart City Security Architecture, Smart City Use-Case Examples.	**10 Hours**

Course Outcomes: After studying this course, students will be able to

- Interpret the impact and challenges posed by IoT networks leading to new architectural models.
- Compare and contrast the deployment of smart objects and the technologies to connect them to network.

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• Appraise the role of IoT protocols for efficient network communication. • Elaborate the need for Data Analytics and Security in IoT. • Illustrate different sensor technologies for sensing real world entities and identify the applications of IoT in Industry.
Question paper pattern:
The question paper will have ten questions. There will be 2 questions from each module. Each question will have questions covering all the topics under a module. The students will have to answer 5 full questions, selecting one full question from each module.
Text Books:
1. David Hanes, Gonzalo Salgueiro, Patrick Grossetete, Robert Barton, Jerome Henry,"**IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things**", 1st Edition, Pearson Education (Cisco Press Indian Reprint). (**ISBN:** 978-9386873743) 2. Srinivasa K G, "**Internet of Things**",CENGAGE Leaning India, 2017
Reference Books:
1. Vijay Madisetti and ArshdeepBahga, "**Internet of Things (A Hands-on-Approach)**", 1st Edition, VPT, 2014. (**ISBN:** 978-8173719547) 2. Raj Kamal, "**Internet of Things: Architecture and Design Principles**", 1st Edition, McGraw Hill Education, 2017. (**ISBN:** 978-9352605224)

B. K. Raj

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BGS Institute of Technology

Mandya

COURSE BOOK

Period of the Semester : **From** 19 Apr 2021 **To** 20 Jul 2021

Dept-Sem-Sec: CS-8-A

Subject with Code: INTERNET OF THINGS TECHNOLOGY 17CS81

Time Slot

MON:	09:30 - 10:30	**TUE :**	11:00 - 12:00
WED:	12:30 - 13:30	**THU :**	12:30 - 13:30
FRI :	09:30 -10:30	**SAT :**	11:00 -12:00

Name of the Teacher : Ms Swetha K R

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BGSIT	Lesson Plan & Execution	
Name of the Faculty	*Ms Swetha K R*	
Dept-Sem-Sec:	*CS-8-A*	
Date of Commencement	*19 Apr 2021*	
Last working day of Semester	*20 Jul 2021*	
Source Material List		
1	Vijay Madisetti and ArshdeepBahga, "Internet of Things (A Hands-on-Approach)", 1 stEdition, VPT, 2014. (ISBN: 978-8173719547) Kamal, "Internet of Things: Architecture and Design Principles", 1st Edition, McGraw Hill Education, 2017. (ISBN:978-9352605224)	
Course Outcome List		
1	Understand The Impact And Challenges Thrown By The IoT Networks And Smart Objects.	
2	Apply Diverse Methods Of Deploying Smart Objects And Connect Them To Network And Illustrate Different Sensor Technologies For Sensing Real World Entities.	
3	Analyse The Network Model And Optimize Them For IoT	
4	Analyze The Protocols Of Different Layers Of Network Model And Optimise Them For IoT.	
5	Understand The Role Of Data Analytics And Use Of Data Analysis Tools For Securing IoT.	
Subject Name	INTERNET OF THINGS TECHNOLOGY	

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Period	Date	Topic	Date	Topic
			Execution	
		Module 1		
1	19 Apr 2021	What is IoT, Genesis of IoT	19 Apr 2021	What is IoT, Genesis of IoT
5	20 Apr 2021	IoT and Digitization, IoT Impact	20 Apr 2021	IoT and Digitization, IoT Impact
7	21 Apr 2021	Convergence of IT and IoT	21 Apr 2021	Convergence of IT andIoT
8	22 Apr 2021	IoT Challenges	22 Apr 2021	IoT Challenges
9	23 Apr 2021	IoT Network Architecture and Design	23 Apr 2021	IoT Network Architecture and Design
10	24 Apr 2021	Drivers Behind New Network Architectures	24 Apr 2021	Drivers Behind NewNetwork Architectures
11	26 Apr 2021	Comparing IoT Architectures	26 Apr 2021	Comparing IoT Architectures
12	27 Apr 2021	A Simplified IoT Architecture	27 Apr 2021	A Simplified IoT Architecture
13	28 Apr 2021	The Core IoT Functional Stack	28 Apr 2021	The Core IoT Functional Stack
14	29 Apr 2021	IoT Data Management and Compute Stack	29 Apr 2021	IoT Data Management and Compute Stack
		Module 2		
15	6 May 2021	Smart Objects: The “Things ” inIoT	6 May 2021	Smart Objects: The “Things ” inIoT
16	7 May 2021	Smart Objects: The “Things ” inIoT	7 May 2021	Smart Objects: The “Things ” inIoT
17	8 May 2021	Sensors	8 May 2021	Sensors
18	10 May 2021	Sensors	10 May 2021	Sensors
19	11 May 2021	Actuators	11 May 2021	Actuators
20	12 May 2021	and Smart Objects	12 May 2021	and Smart Objects
21	13 May 2021	Sensor Networks	13 May 2021	SensorNetworks
22	14 May 2021	Connecting Smart Objects	14 May 2021	Connecting Smart Objects

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Period	Execution			
	Date	Topic	Date	Topic
43	26 Jun 2021	Formal Risk Analysis Structures: OCTAVE and FAIR	26 Jun 2021	Formal RiskAnalysis Structures: OCTAVE and FAIR
44	28 Jun 2021	The Phased Application of Security in an Operational Environment	28 Jun 2021	The Phased Application of Security in anOperational Environment
Module 5				
45	3 Jul 2021	IoT Physical Devices and Endpoints - Arduino UNO: Introduction to Arduino, Arduino UNO	3 Jul 2021	IoT Physical Devices and Endpoints - Arduino UNO: Introduction to Arduino, ArduinoUNO
46	5 Jul 2021	Installing the Software, Fundamentals of Arduino Programming	5 Jul 2021	Installing the Software, Fundamentals of Arduino Programming
47	6 Jul 2021	IoT Physical Devices and Endpoints , RaspberryPi: Introduction to RaspberryPi	6 Jul 2021	IoTPhysical Devices and Endpoints, RaspberryPi: Introduction to RaspberryPi
48	7 Jul 2021	About the RaspberryPi Board: Hardware Layout, Operating Systems on RaspberryPi	7 Jul 2021	About theRaspberryPi Board: Hardware Layout, Operating Systems on RaspberryPi
49	8 Jul 2021	Configuring RaspberryPi, Programming RaspberryPi with Python	8 Jul 2021	ConfiguringRaspberryPi, Programming RaspberryPi with Python
50	9 Jul 2021	Wireless Temperature Monitoring System Using Pi, DS18B20 Temperature Sensor	9 Jul 2021	Wireless Temperature MonitoringSystem Using Pi, DS18B20 Temperature Sensor
51	10 Jul 2021	Connecting Raspberry Pi via SSH, Accessing Temperature from DS18B20 sensors	10 Jul 2021	Connecting Raspberry Pi via SSH, Accessing Temperature from DS18B20 sensors
52	12 Jul 2021	Remote access to RaspberryPi, Smart and Connected Cities	12 Jul 2021	Remote access to RaspberryPi, Smartand Connected Cities
53	13 Jul 2021	An IoT Strategy for Smarter Cities, Smart City IoT Architecture	13 Jul 2021	An IoT Strategy for Smarter Cities, Smart City IoT Architecture

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Period		Execution		
	Date	Topic	Date	Topic
54	14 Jul 2021	Smart City Security Architecture, Smart City Use-Case Examples.	14 Jul 2021	Smart City Security Architecture, Smart City Use-Case Examples.

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DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

COURSE OUTCOMES AND CO-PO MAPPING WITH JUSTIFICATION

COURSE CORDINATORS: Niveditha N M / Swetha K R
SEM: VIII
COURSE CODE: 17CS81
COURSE NAME: INTERNET OF THINGS TECHNOLOGY

CO1	Understand The Impact And Challenges Thrown By The IoT Networks And Smart Objects.
CO2	Apply Diverse Methods Of Deploying Smart Objects And Connect Them To Network And Illustrate Different Sensor Technologies For Sensing Real World Entities.
CO3	Analyse The Network Model And Optimize Them For IoT
CO4	Analyze The Protocols Of Different Layers Of Network Model And Optimise Them For IoT.
CO5	Understand The Role Of Data Analytics And Use Of Data Analysis Tools For Securing IoT.

PSO1	Ability to apply Mathematical Methodologies, Management Principles and Ethics, Electronics and Embedded Systems and Programming Technologies to solve real time problems.
PSO2	Ability to apply software design and development practices to develop software in emerging areas such as Internet of Things, Data Management, Social Networking and Security, Cloud and High-Performance Computing.

COs	POs												PSOs	
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	-	-	2	-	-	-	-	-	-	-	-	-	2
CO2	2	2	1	-	-	1	-	-	-	-	-	-	-	2
CO3	1	2	-	2	-	-	-	-	-	-	-	-	-	2
CO4	1	2	-	-	-	-	-	-	-	-	-	-	-	2
CO5	1	3	-	2	-	-	-	-	-	-	-	-	-	-
AVG	1.4	2.25	1	2	-	1	-	-	-	-	-	-	-	2

COs	Levels	Justification
CO1.PO1	2	Will understand the basics of IOT, how the technology emerged
CO1.PO4	2	Will be able to understand the challenges of IOT & smart objects and analysethem
CO1.PSO2	2	Will be able to know all the basic knowledge and smart objects
CO2.PO1	2	Will be able to understand the fundamentals of deploying behind smart objects
CO2.PO2	2	Will be able to analyse the different network model used for deploying for smart objects.
CO2.PO3	1	Will be able to illustrate different technologies behind sensors for solving real world problems.
CO2.PO6	1	Will be able to understand the basic measures like safety, social etc for deploying for smart objects
CO2.PSO2	2	Will be able to analyse the ability to deploy the smart objects and their networks
CO3.PO1	1	Will be able to understand the basic network model.
CO3.PO2	2	Will be able to analyse the network Drivers Behind New Network

		Architectures,
CO3.PO4	2	Will be able to analyse the IoT Application Transport Methods, IoT Access Technologies
CO3.PSO2	2	Will be able to analyse the network model with respect to IOT network.
CO4.PO1	1	Will be able to understand the need of optimisation of network
CO4.PO2	2	Will be able to identify and analyse the profile and compliance.
CO4.PO4	2	Will be able to analyse the behaviour of application & transport layer of the network layers.
CO4.PSO2	2	Will be able to understand the nature of work of different layers of network.
CO5.PO1	1	Will be able to understand the basic principles of data analytics.
CO5.PO2	2	Will be able to analyse the working of data analytics and machine learning environments of IOT
CO5.PO4	2	Will be able to conduct investigation on Formal Risk Analysis Structures.
CO5.PSO2	2	Will be able to understand the environment of data analytics of tools used for it.

1. Niveditha N M

Swethakr

2. Swetha K R

Signature of Staff Coordinator

Swethakr

Signature of Reviewer

B. K. Raghu

Signature of HOD

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GBCS SCHEME

USN

15CS81

Eighth Semester B.E. Degree Examination, Dec.2019/Jan.2020
Internet of Things Technology

Time: 3 hrs. Max. Marks: 80

Note: *Answer any FIVE full questions, choosing ONE full question from each module.*

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. What is IOT? Explain evolutionary phases of the internet. (06 Marks)
b. Explain Access Network sublayer with a neat diagram. (06 Marks)
c. What are the elements of one M2M IOT architecture? Explain. (04 Marks)

OR

2 a. Explain the functionality of IOT network management sub layer. (05 Marks)
b. Describe IOT World Forum (IOTWF) Standardized architecture. (07 Marks)
c. Compare and contrast IT and OT. (04 Marks)

Module-2

3 a. With a neat diagram, explain how actuators and sensors interact with physical world. Classify actuators based on energy type. (08 Marks)
b. List out the limitations of the smart objects in WSNs and explain the data aggregation in WSN with a neat diagram. (08 Marks)

OR

4 a. What is Zigbee? Explain 802.15.4 physical layer, MAC layer, and security. (08 Marks)
b. Explain LoRaWAN standard and alliance MAC layer and security. (08 Marks)

Module-3

5 a. With a neat diagram, explain 6LOWPAN protocol header comparison and fragmentation. (08 Marks)
b. List and explain the key advantages of internet protocol. (04 Marks)
c. Explain RPL encryption and authentication on constraint nodes. (04 Marks)

OR

6 a. Explain tunneling legacy SCADA over IP networks ad SCADA protocol translation with a neat diagram. (08 Marks)
b. Describe MQTT framework and message format in detail. (08 Marks)

Module-4

7 a. Explain the elements of Hadoop with a neat diagram. (07 Marks)
b. Explain neural network in machine learning with a detailed example. (05 Marks)
c. Describe the components of FNF. (04 Marks)

OR

8 a. Explain Formal Risk Analysis Structures. (08 Marks)
b. Explain the Purdue model for control hierarchy and OT network characteristics. (08 Marks)

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Module-5

9 a. Explain the following with respect to Arduino programming.
   i) Structure
   ii) Functions
   iii) Variables
   iv) Flow control statements
   v) Data type
   vi) Constants. (08 Marks)
 b. Explain Raspberry Pi learning board. (08 Marks)

OR

10 a. Write a python program on Raspberry Pi to blink an LED. (06 Marks)
 b. Explain Smart city security architecture. (06 Marks)
 c. Write a short note on :
   i) IOT challenges
   ii) Backhaul Technologies. (04 Marks)

*****

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Internet of Things (IoT) Question Bank

1. What is Internet of Things (IoT). What are components required to design IoT Device and which device we called IoT device explain with example.
2. Explain Internet of Things (IoT) with example.
3. Give brief overview of IoT.
4. What is vision of IoT?
5. Explain four Pillars of IoT and how they are inter-connected with each other?
6. What are different challenges of IoT?
7. What are different components required for IoT device?
8. What is Machine to Machine communication (M2M)?
9. Explain different Characteristics of IoT.
10. What effect will the internet of things (IoT) have on our daily lives? Explain with any one example of smart device.
11. Explain Challenges and requirements of IoT device.
12. Explain vision of IoT?
13. Explain an emerging industrial structure for IoT.
14. What are different business and research opportunities for IoT?
15. Explain layered architecture of IoT.
16. Explain building block of IoT.
17. Explain different networking and communication model in IoT.
18. What are different wired and wireless connectivity we can used in IoT explain with example.
19. Explain wireless sensor network?
20. What is relation between WSN and IoT. Explain with example.
21. Write note on : RFID, NFC, ZigBee.
22. What effect will the internet of things (IoT) have in healthcare? Explain with any one example of smart device.
23. What is ZigBee?
24. Explain IoT protocol stack.
25. Explain in details IoT Architecture layers.
26. Explain Near Field Communication (NFC) and RFID.
27. Explain TCP/IP vs IoT protocol sack.

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28. What is requirement of IoT Protocol Standardization?
29. Explain with example MQTT Protocol. What is role of MQTT protocol in IoT?
30. Write a note on : CoAP, REST, XMPP.
31. What are different IoT protocols?
32. What is role of Cloud Computing and Big Data in Internet of Things?
33. What is IoT Analytics?
34. Explain Data visualization and its importance in IoT.
35. Explain what are the components and Communication media required for making smart building.
36. Difference between Web of Things versus Internet of Things.
37. Explain WoT with example.
38. Explain Two Pillars of the Web.
39. What are different Platform Middleware for WoT?
40. What is WoT Portals and Business Intelligence?
41. Explain Cloud of Things.
42. Why we need of IoT Security.
43. Explain issues in IoT security.
44. Write a note on: 1) Trust for IoT 2) Security and Privacy for IoT 3) Physical IoT Security.
45. Explain on Devices Security and Privacy of IoT cloud.
46. What is Role of the Internet of Things for Increased Autonomy and Agility in Collaborative Production Environments?
47. Explain IoT Application and Deployment Scenarios in different domains.
48. Explain IoT Smart X Applications?
49. Write note on: Wearable - Smart Cities- Smart Home – Smart HealthCare- Agriculture - Smart Grid.
50. Explain with example: Wearable - Smart Cities- Smart Home – Smart HealthCare- Agriculture - Smart Grid.

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BGSIT BG Nagara	Doc. Title: Internal Test Question Paper		Doc. No.:06#Form#02b
	Page 1 of 1	Date: 01.04.2018	Rev. No. 00

Internal Test Question Paper Format – CBCS Scheme(VTU)

Name of the Faculty/s:
Swetha K R
Date: 03-06-2021

Signature: Swetha K R

Reviewer's Signature:	B. K. Raj

BGS Institute of Technology

Department: CSE

Test: I

USN:

Semester: VIII **Section:** A & B

Subject Name & Code: Internet of Things (15CS81)

Date: 03-06-2021
Time: 9:30 AM to 10:30 AM

Duration:1 Hr
Max. Marks: 30

Note: Select one question from each part

Q. No	Questions	Marks	CO	Levels
	Part A			
1	a) What is IOT? Explain in detail on Genisis of IOT	7.5	CO1	L1
	b) Discuss IOT challenges.	7.5	CO1	L2
	OR			
2	a) Explain The IoT World Forum (IoTWF) Standardized Architecture	7.5	CO1	L2
	b) Write and explain modified OSI model for the IOT/M2M systems	7.5	CO1	L2
	Part B			
3	a) Explain Design Constraints for Wireless Smart objects	7.5	CO2	L2
	b) list and explain different types of sensors.	7.5	CO2	L1
	OR			
4	a) Briefly explain IEEE 802.15.4 MAC format	7.5	CO2	L2
	b) Write a short note on Frame Format with the Auxiliary Security Header Field for 802.15.4-2006 and later versions	7.5	CO2	L2

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CBCS Scheme

DEPARTMENT: COMPUTER SCIENCE & ENGINEERING

Scheme & Solution – TEST – 1 Date: 03-06-2021

Semester: VIII Subject Title: Internet of things Subject Code: 17CS81

<table>
<tr><th>Question Number</th><th>Solution</th><th>Marks Allocated</th></tr>
<tr><td>1 a)</td><td>IoT is a technology transition in which devices will allow us to sense and control the physical world by making objects smarter and connecting them through an intelligent network.</td><td>1</td></tr>
<tr><td></td><td>GENESIS OF IOT
The person credited with the creation of the term "Internet of Things" is Kevin Ashton. While working for Procter & Gamble in 1999, Kevin used this phrase to explain a new idea related to linking the company's supply chain to the Internet.the evolution of the Internet can be categorized into four phases. Each of these phases has had a profound impact on our society and our lives.</td><td>3</td></tr>
<tr><td></td><td>
These four phases are further defined in Table below.</td><td>2</td></tr>
<tr><td></td><td>
<table>
<tr><th>Internet Phase</th><th>Definition</th></tr>
<tr><td>Connectivity (Digitize access)</td><td>This phase connected people to email, web services, and search so that information is easily accessed.</td></tr>
<tr><td>Networked Economy (Digitize business)</td><td>This phase enabled e-commerce and supply chain enhancements along with collaborative engagement to drive increased efficiency in business processes.</td></tr>
<tr><td>Immersive Experiences (Digitize interactions)</td><td>This phase extended the Internet experience to encompass widespread video and social media while always being connected through mobility. More and more applications are moved into the cloud.</td></tr>
<tr><td>Internet of Things (Digitize the world)</td><td>This phase is adding connectivity to objects and machines in the world around us to enable new services and experiences. It is connecting the unconnected.</td></tr>
</table>
</td><td>1.5</td></tr>
</table>

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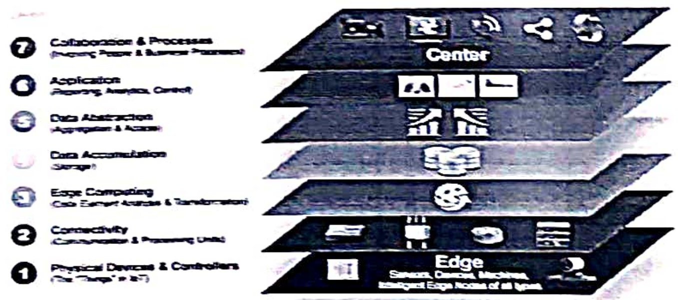
Question Number	Solution	Marks Allocated
1 b)	(table below)	7.5

Challenge	Description
Scale	While the scale of IT networks can be large, the scale of OT can be several orders of magnitude larger. For example, one large electrical utility in Asia recently began deploying IPv6-based smart meters on its electrical grid. While this utility company has tens of thousands of employees (which can be considered IP nodes in the network), the number of meters in the service area is tens of millions. This means the scale of the network the utility is managing has increased by more than 1000-fold! Chapter 5, "IP as the IoT Network Layer," explores how new design approaches are being developed to scale IPv6 networks into the millions of devices.
Security	With more "things" becoming connected with other "things" and people, security is an increasingly complex issue for IoT. Your threat surface is now greatly expanded, and if a device gets hacked, its connectivity is a major concern. A compromised device can serve as a launching point to attack other devices and systems. IoT security is also pervasive across just about every facet of IoT. For more information on IoT security, see Chapter 8, "Securing IoT."
Privacy	As sensors become more prolific in our everyday lives, much of the data they gather will be specific to individuals and their activities. This data can range from health information to shopping patterns and transactions at a retail establishment. For businesses, this data has monetary value. Organizations are now discussing who owns this data and how individuals can control whether it is shared and with whom.
Big data and data analytics	IoT and its large number of sensors is going to trigger a deluge of data that must be handled. This data will provide critical information and insights if it can be processed in an efficient manner. The challenge, however, is evaluating massive amounts of data arriving from different sources in various forms and doing so in a timely manner.
Interoperability	As with any other nascent technology, various protocols and architectures are jockeying for market share and standardization within IoT. Some of these protocols and architectures are based on proprietary elements, and others are open. Recent IoT standards are helping minimize this problem, but there are often various protocols and implementations available for IoT networks. The prominent protocols and architectures—especially open, standards-based implementations—are the subject of this book.

2 a)

- While various IoT reference models exist, the one put forth by the IoT World Forum offers a clean, simplified perspective on IoT and includes edge computing, data storage, and access. It provides a succinct way of visualizing IoT from a technical perspective. Each of the seven layers is broken down into specific functions, and security encompasses the entire model. 1



2.5

Explanation:- Each layer explanation

4

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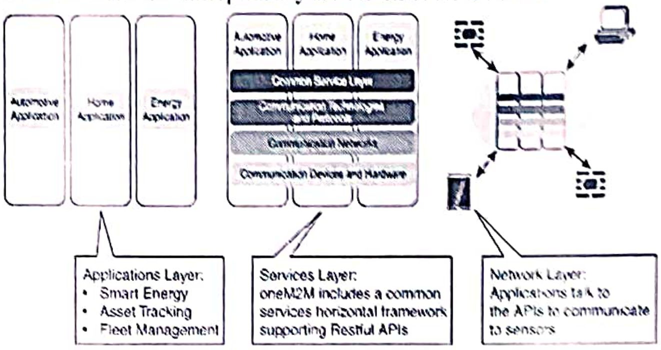
Question Number	Solution	Marks Allocated

The oneM2M IoT Standardized Architecture

b) In an effort to standardize the rapidly growing field of machine-to-machine (M2M) communications, the European Telecommunications Standards Institute (ETSI) created the M2M Technical Committee in 2008. The goal of this committee was to create a common architecture that would help accelerate the adoption of M2M applications and devices. Over time, the scope has expanded to include the Internet of Things. — 2

One of the greatest challenges in designing an IoT architecture is dealing with the heterogeneity of devices, software, and access methods. By developing a horizontal platform architecture, oneM2M is developing standards that allow interoperability at all levels of the IoT stack



2.5

3

Explanation:

3

3 a)

Class	Definition
Class 0	This class of nodes is severely constrained, with less than 10 KB of memory and less than 100 KB of Flash processing and storage capability. These nodes are typically battery powered. They do not have the resources required to directly implement an IP stack and associated security mechanisms. An example of a Class 0 node is a push button that sends 1 byte of information when changing its status. This class is particularly well suited to leveraging new unlicensed LPWA wireless technology.
Class 1	While greater than Class 0, the processing and code space characteristics (approximately 10 KB RAM and approximately 100 KB Flash) of Class 1 are still lower than expected for a complete IP stack implementation. They cannot easily communicate with nodes employing a full IP stack. However, these nodes can implement an optimized stack specifically designed for constrained nodes, such as Constrained Application Protocol (CoAP). This allows Class 1 nodes to engage in meaningful conversations with the network without the help of a gateway, and provides support for the necessary security functions. Environmental sensors are an example of Class 1 nodes.
Class 2	Class 2 nodes are characterized by running full implementations of an IP stack on embedded devices. They contain more than 50 KB of memory and 250 KB of Flash, so they can be fully integrated in IP networks. A smart power meter is an example of a Class 2 node.

3.5

Wireless sensor networks are made up of wirelessly connected smart objects, which are sometimes referred to as *motes*.The following are some of the most significant limitations of the smart objects in WSNs:

- Limited processing power
- Limited memory
- Lossy communication
- Limited transmission speeds
- Limited power

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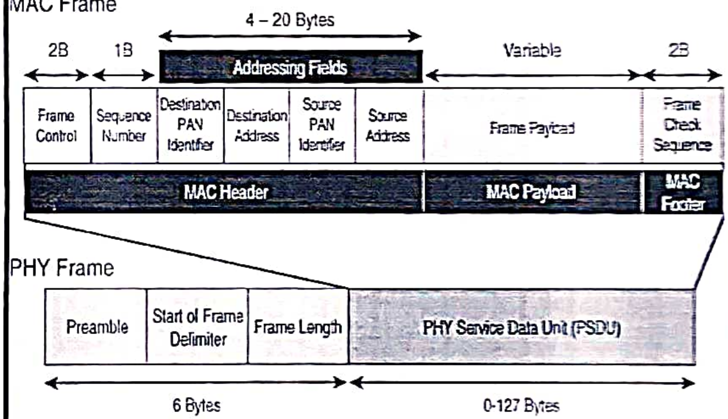
Question Number	Solution	Marks Allocated
b)	(sensor table below)	7.5

Sensor Types	Description	Examples
Position	A position sensor measures the position of an object; the position measurement can be either in absolute terms (absolute position sensor) or in relative terms (displacement sensor). Position sensors can be linear, angular, or multi-axis.	Potentiometer, inclinometer, proximity sensor
Occupancy and motion	Occupancy sensors detect the presence of people and animals in a surveillance area, while motion sensors detect movement of people and objects. The difference between the two is that occupancy sensors generate a signal even when a person is stationary, whereas motion sensors do not.	Electric eye, radar
Velocity and acceleration	Velocity (speed of motion) sensors may be linear or angular, indicating how fast an object moves along a straight line or how fast it rotates. Acceleration sensors measure changes in velocity.	Accelerometer, gyroscope
Force	Force sensors detect whether a physical force is applied and whether the magnitude of force is beyond a threshold.	Force gauge, viscometer, tactile sensor (touch sensor)
Pressure	Pressure sensors are related to force sensors, measuring force applied by liquids or gases. Pressure is measured in terms of force per unit area.	Barometer, Bourdon gauge, piezometer
Flow	Flow sensors detect the rate of fluid flow. They measure the volume (mass flow) or rate (flow velocity) of fluid that has passed through a system in a given period of time.	Anemometer, mass flow sensor, water meter

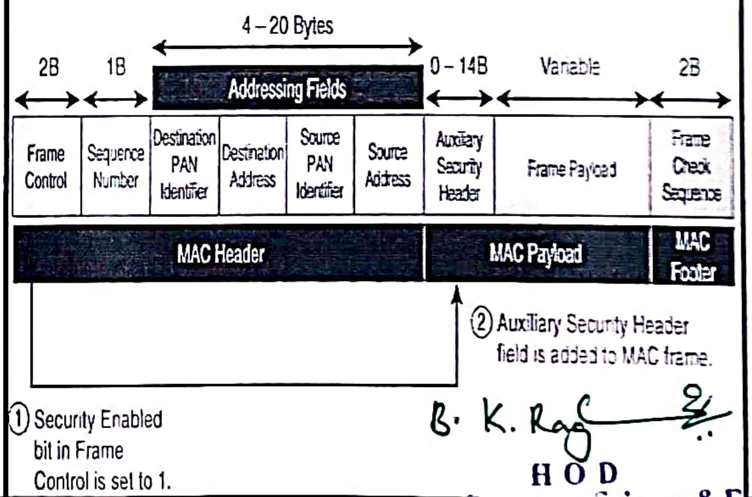
4 a) Explanation: — 5

MAC Frame



2.5

b) Explanation: — 5



2.5

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BGSIT BG Nagara	Doc. Title: Internal Test Question Paper		Doc. No.:06#Form#02b
	Page 1 of 1	Date: 01.04.2018	Rev. No. 00

Internal Test Question Paper Format – CBCS Scheme(VTU)

Name of the Faculty/s:
Swetha K R
Date: 28-06-2021

Signature: Swetha K R

Reviewer's Signature:	Shashikala

BGS Institute of Technology

Department: CSE & ISE

Test: II

USN:

Semester: VIII **Section:** A & B

Subject Name & Code: Internet of Things (15CS81)

Date: 28-06-2021
Time: 9:30 AM to 10:30 AM

Duration:1 Hr
Max. Marks: 30

Note: Select one question from each part

Q. No	Questions	Marks	CO	Levels
	Part A			
1	a) Explain working of IP as the IOT Network layer	7.5	CO3	L2
	b) Describe the application protocols for IOT	7.5	CO3	L2
	OR			
2	a) Discuss the various methods used in IOT application protocol	7.5	CO3	L2
	b) Discuss OCTAVE and FAIR formal risk analysis	7.5	C04	L2
	Part B			
3	a) Explain in detail how IT and OT security practices and systems vary in real time	7.5	CO4	L2
	b) What do you mean by data and analytics for IOT? Explain.	7.5	CO4	L1
	OR			
4	a) Discuss the various methods used in IOT application transport	7.5	CO4	L2
	b) with a case study relate the concept of IOT.	7.5	CO4	L2

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BGS Institute of Technology
Department: CSE & ISE
Test: II

Semester: VIII **Section:** A & B

USN:

Subject Name & Code: Internet of Things (15CS81)

Date: 28-06-2021
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Note: Select one question from each part

Q. No	Questions	Marks	CO	Levels
	Part A			
1	a) Explain working of IP as the IOT Network layer	7.5	CO3	L2
	b) Describe the application protocols for IOT	7.5	CO3	L2
	OR			
2	c) Discuss the various methods used in IOT application protocol	7.5	CO3	L2
	d) Discuss OCTAVE and FAIR formal risk analysis	7.5	C04	L2
	Part B			
3	b) Explain in detail how IT and OT security practices and systems vary in real time	7.5	CO4	L2
	b) What do you mean by data and analytics for IOT? Explain.	7.5	CO4	L1
	OR			
4	b) Discuss the various methods used in IOT application transport	7.5	CO4	L2
	b) with a case study relate the concept of IOT.	7.5	CO4	L2

Seethala
Signature of staff

Shalini
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CBCS Scheme

DEPARTMENT: COMPUTER SCIENCE & ENGINEERING

Scheme & Solution – TEST – II Date: 16-06-2021

Semester: VIII Subject Title: Internet of things Subject Code: 15CS81

Question Number	Solution	Marks Allocated
1 a)	➢ The Business Case for IP: This section discusses the advantages of IP from an IoT perspective and introduces the concepts of adoption and adaptation. ➢ The Need for Optimization: This section dives into the challenges of constrained nodes and devices when deploying IP. This section also looks at the migration from IPv4 to IPv6 and how it affects IoT networks. ➢ Optimizing IP for IoT: This section explores the common protocols and technologies in IoT networks utilizing IP, including 6LoWPAN, 6TiSCH, and RPL. Profiles and Compliances: This section provides a summary of some of the most significant organizations and standards bodies involved with IP connectivity and IoT. ➢ Data flowing from or to "things" is consumed, controlled, or monitored by data center servers either in the cloud or in locations that may be distributed or centralized. ➢ Dedicated applications are then run over virtualized or traditional operating systems or on network edge platforms (for example, fog computing). ➢ lightweight applications communicate with the data center servers. ➢ the system solutions combining various physical and data link layers call for an architectural approach with a common layer(s) independent from the lower (connectivity) and/or upper (application) layers.	7.5
b)	With the TCP/IP protocol, two main protocols are specified for the transport layer: Transmission Control Protocol (TCP): ➢ This connection-oriented protocol requires a session to get established between the source and destination before exchanging data. ➢ we can view it as an equivalent to a traditional telephone conversation, in which two phones must be connected and the communication link established before the parties can talk. User Datagram Protocol (UDP): ➢ With this connectionless protocol, data can be quickly sent between source and destination—but with no guarantee of delivery. ➢ This is analogous to the traditional mail delivery system, in which a letter is mailed to a destination. ➢ Confirmation of the reception of this letter does not happen until another letter is sent in response. ➢ TCP is the main protocol used at the transport layer.	7.5

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Question Number	Solution	Marks Allocated
	➢ This is largely due to its inherent characteristics, such as its ability to transport large volumes of data into smaller sets of packets. ➢ In addition, it ensures reassembly in a correct sequence, flow control and window adjustment, and retransmission of lost packets. ➢ These benefits occur with the cost of overhead per packet and per session, potentially impacting overall packet per second performances and latency. ➢ In contrast, UDP is most often used in the context of network services, such as Domain Name System (DNS), Network Time Protocol (NTP), Simple Network Management Protocol (SNMP), and Dynamic Host Control Protocol (DHCP), or for real-time data traffic, including voice and video over IP. ➢ In these cases, performance and latency are more important than packet retransmissions because re-sending a lost voice or video packet does not add value. ➢ When the reception of packets must be guaranteed error free, the application layer protocol takes care of that function. ➢ When using TCP, each packet needs to add a minimum of 20 bytes of TCP overhead, while UDP adds only 8 bytes. ➢ TCP also requires the establishment and potential maintenance of an open logical channel. ➢ IoT nodes may also be limited by the intrinsic characteristics of the data link layers. ➢ For example, low-power and lossy networks (LLNs), may not cope well with supporting large numbers of TCP sessions.	7.5
2 a)	With the TCP/IP protocol, two main protocols are specified for the transport layer. Transmission Control Protocol (TCP): ➢ This connection-oriented protocol requires a session to get established between the source and destination before exchanging data. ➢ we can view it as an equivalent to a traditional telephone conversation, in which two phones must be connected and the communication link established before the parties can talk. User Datagram Protocol (UDP): ➢ With this connectionless protocol, data can be quickly sent between source and destination—but with no guarantee of delivery. ➢ This is analogous to the traditional mail delivery system, in which a letter is mailed to a destination. ➢ Confirmation of the reception of this letter does not happen until another letter is sent in response. ➢ TCP is the main protocol used at the transport layer. ➢ In addition, it ensures reassembly in a correct sequence, flow control and window adjustment, and retransmission of lost packets. ➢ These benefits occur with the cost of overhead per packet and per session, potentially impacting overall packet per second performances and latency. ➢ In contrast, UDP is most often used in the context of network services, such as Domain Name System (DNS), Network Time Protocol (NTP), Simple Network Management Protocol (SNMP), and Dynamic Host Control Protocol (DHCP), or for real-time data traffic, including voice and video over IP	7.5

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Question Number	Solution	Marks Allocated

b)

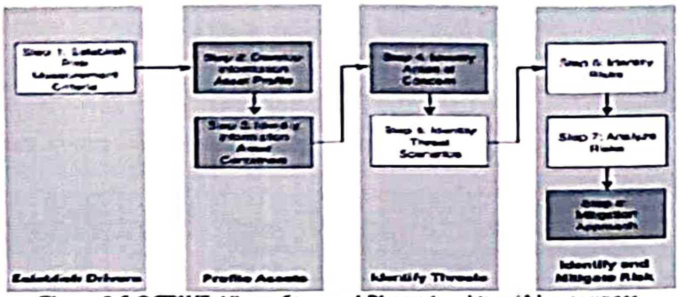

Figure 8-5 OCTAVE Allegro Steps and Phases (see https://blog.compass-security.com/2013/04/lean-risk-assessment-based-on-octave-allegro/).

Marks: 2

Explanation:

Marks: 5.5

3 a)

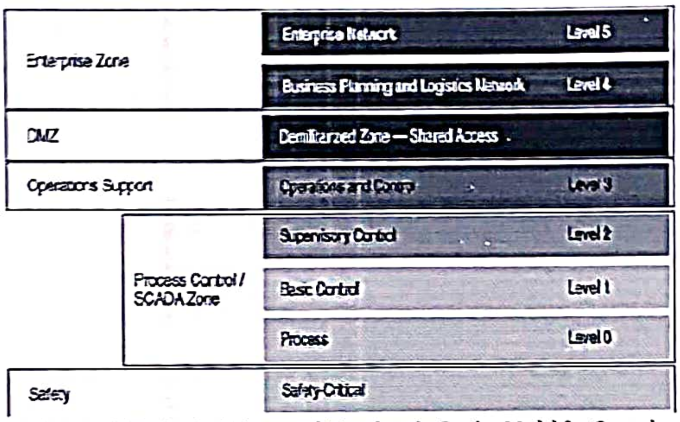

Figure 8-3 *The Logical Framework Based on the Purdue Model for Control Hierarchy*

Marks: 2

Explanation:

Marks: 5.5

b)

In the world of IoT, the creation of massive amounts of data from sensors is common and one of the biggest challenges—not only from a transport perspective but also from a data management standpoint.

- A great example of the deluge of data that can be generated by IoT is found in the commercial aviation industry and the sensors that are deployed throughout an aircraft.
- Modern jet engines are fitted with thousands of sensors that generate a whopping 10GB of data per second.
- modern jet engines, may be equipped with around 5000 sensors.
- A twin engine commercial aircraft with these engines operating on average 8 hours a
- day will generate over 500 TB of data daily, and this is just the data from the engines!
- Aircraft today have thousands of other sensors connected to the airframe and other systems. A single wing of a modern jumbo jet is equipped with 10,000 sensors.

Marks: 7.5

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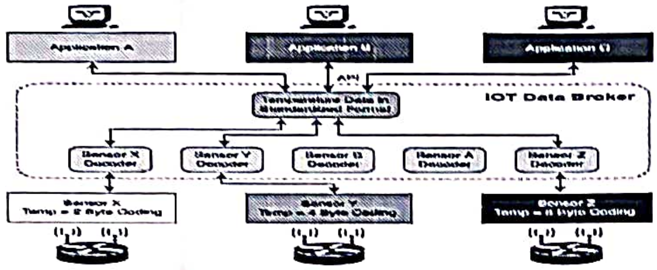
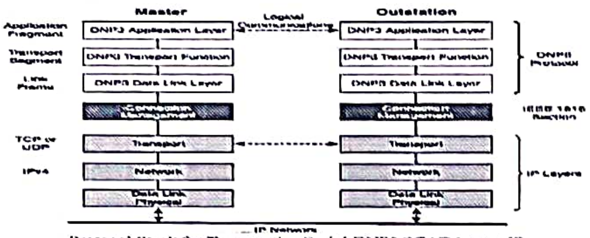
Question Number	Solution	Marks Allocated
4 a)	A. IoT Application Transport Methods: The following categories of IoT application protocols and their transport methods are explored in the following sections: 	2
	1. Application layer protocol not present: In this case, the data payload is directly transported on top of the lower layers. No application layer protocol is used. Protocol Stack for Transporting Serial DNP3 SCADA over IP	2
	2. Supervisory control and data acquisition (SCADA): SCADA are one of the most common industrial protocols in the world, but it was developed long before the days of IP, and it has been adapted for IP networks. 3. Generic web-based protocols: 1. Generic protocols, such as Ethernet, Wi-Fi, and 4G/LTE, are found on many consumer- and enterprise-class IoT devices that communicate over non-constrained networks. 4. IoT application layer protocols: 1. IoT application layer protocols are devised to run on constrained nodes with a small compute footprint and are well adapted to the network bandwidth constraints on cellular or satellite links or constrained 6LoWPAN networks. 2. Message Queuing Telemetry Transport (MQTT)and Constrained Application Protocol	3.5
b)	A Brief History of OT Security: ➢ One example of a reported incident where physical damage was caused by a cybersecurity attack is the Stuxnet malware that damaged uranium enrichment systems in Iran. ➢ In both incidents, multiple steps led to the undesirable outcomes. ➢ Historically, attackers were skilled individuals with deep knowledge of technology and the systems they were attacking. ➢ However, as technology has advanced, tools have been created to make attacks much easier to carry out. ➢ To further complicate matters, these tools have become more broadly available and more easily obtainable.	7.5

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BGS Institute of Technology
Department: CSE & ISE
Test: III

USN:

Semester: VIII Section: A & B
Subject Name & Code: Internet of Things (15CS81)

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Q. No	Questions	Marks	CO	Levels
	Part A			
1	a) Explain benefits of flow analytics in addition to other network management services.	7.5	CO4	L2
	b) Give a brief note on Arduino UNO.	7.5	CO5	L2
	OR			
2	a) Explain edge analytics core functions.	7.5	CO4	L2
	b) With a neat diagram, explain wireless temperature monitoring system using Raspberry Pi.	7.5	CO5	L2
	Part B			
3	a) With a neat diagram explain lambda architecture.	7.5	CO4	L2
	b) Explain in detail smart city IOT architecture.	7.5	CO5	L1
	OR			
4	a)With a neat diagram explain Apache Kafka cluster.	7.5	CO4	L2
	b) With a neat diagram, explain Raspberry Pi board.	7.5	CO5	L2

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CBCS Scheme

DEPARTMENT: COMPUTER SCIENCE & ENGINEERING

Scheme & Solution –TEST–III **Date: 16-07-2021**

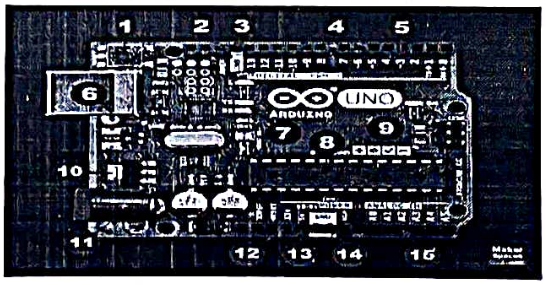
Semester: VIII **Subject Title:** Internet of things **Subject Code:** 17CS81

Question Number	Solution	Marks Allocated

1 a)

1. Network traffic monitoring and profiling:
   - Flow collection from the network layer provides global and distributed near-real-time monitoring capabilities.
   - IPv4 and IPv6 network wide traffic volume and pattern analysis helps administrators proactively detect problems and quickly troubleshoot and resolve problems when they occur. **2**
2. Application traffic monitoring and profiling:
   - Monitoring and profiling can be used to gain a detailed time-based view of IoT access services, such as the application-layer protocols, including MQTT, CoAP, and DNP3 as well as the associated applications that are being used over the network.
3. Capacity planning:
   - Flow analytics can be used to track and anticipate IoT traffic growth and help in the planning of upgrades when deploying new locations or services by analyzing captured data over a long period of time.
   - This analysis affords the opportunity to track and anticipate IoT network growth on a continual basis. **5.5**
4. Security analysis:
   - Because most IoT devices typically generate a low volume of traffic and always send their data to the same server(s), any change in network traffic behavior may indicate a cyber security event, such as a denial of service (DoS) attack.
   - Security can be enforced by ensuring that no traffic is sent outside the scope of the IoT domain.
   - For example, with a LoRaWAN gateway, there should be no reason to see traffic sent or received outside the LoRaWAN network server and network management system.
5. Accounting:
   - In field area networks, routers or gateways are often physically isolated and leverage public cellular services and VPNs for backhaul.
   - Deployments may have thousands of gateways connecting the last-mile IoT infrastructure over a cellular network.
   - Flow monitoring can thus be leveraged to analyze and optimize the billing, in complement with other dedicated applications, such as Cisco Jasper, with a broader scope than just monitoring data flow. .
6. Data warehousing and data mining::
   - Flow data (or derived information) can be warehoused for later retrieval and analysis in support of proactive analysis of multiservice IoT infrastructures and applications.

b)



2

- Arduino Uno is a microcontroller board based on the ATmega328P.
- It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button.
- "Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer release

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Question Number	Solution	Marks Allocated

1. Reset Button – This will restart any code that is loaded to the Arduino board
2. 2. AREF – Stands for "Analog Reference" and is used to set an external reference voltage
3. Ground Pin – There are a few ground pins on the Arduino and they all work the same
4. Digital Input/Output – Pins 0-13 can be used for digital input
5. PWM – The pins marked with the (~) symbol can simulate analog output
6. 6. USB Connection – Used for powering up your Arduino and uploading sketches
7. TX/RX – Transmit and receive data indication LEDs
8. ATmega Microcontroller – This is the brains and is where the programs are stored
9. Power LED Indicator – This LED lights up anytime the board is plugged in a power source
10. Voltage Regulator – This controls the amount of voltage going into the Arduino board
11. DC Power Barrel Jack – This is used for powering your Arduino with a power supply
12. 3.3V Pin – This pin supplies 3.3 volts of power to your projects output.
13. 5V Pin – This pin supplies 5 volts of power to your projects
14. Ground Pins – There are a few ground pins on the Arduino and they all work the same
15. Analog Pins – These pins can read the signal from an analog sensor and convert it to digital.

5.5

2 a)

1. Filter:

➢ The streaming data generated by IoT endpoints is likely to be very large, and mos of it is irrelevant. For example, a sensor may simply poll on a regular basis tc confirm that it is still reachable.

➢ The filtering function identifies the information that is considered important.

2. Transform:

➢ In the data warehousing world, Extract, Transform, and Load (ETL) operations are used to manipulate the data structure into a form that can be used for other purposes.

➢ Analogous to data warehouse ETL operations, in streaming analytics, once the data is filtered, it needs to be formatted for processing.

3. Time:

➢ As the real-time streaming data flows, a timing context needs to be established. This could be to correlated average temperature readings from sensors on a minute-by- minute basis.

➢ For example, Figure shows an APU that takes input data from multiple sensors reporting temperature fluctuations. In this case, the APU is programmed to report the average temperature every minute from the sensors, based on an average of the past two minutes.

4. Correlate:

➢ Streaming data analytics becomes most useful when multiple data streams are combined from different types of sensors.

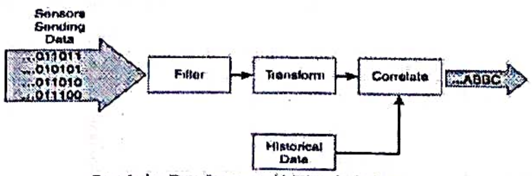
➢ For example, in a hospital, several vital signs are measured for patients, including body temperature, blood pressure, heart rate, and respiratory rate.

➢ These different types of data come from different instruments, but when this data iscombined and analyzed, it provides an invaluable picture of the health of the patient at any given time

➢ For example, historical data may include the patient's past medical history, such as blood test results.

➢ Combining historical data gives the live streaming data apowerful context and promotes more insights into the current condition of the patient (see Figure).

5.5



Correlating Data Streams with Historical Data

2

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Question Number	Solution	Marks Allocated

5. Match patterns:

- Once the data streams are properly cleaned, transformed, and correlated with othe live streams as well as historical data sets, pattern matching operations are used tc gain deeper insights to the data.
- For example, say that the APU has been collecting the patient's vitals for some tim and has gained an understanding of the expected patterns for each variable bein monitored.
- If an unexpected event arises, such as a sudden change in heart rate or respiration the pattern matching operator recognizes this as out of the ordinary and can tak certain actions, such as generating an alarm to the nursing staff.
- The patterns can be simple relationships, or they may be complex, based on th criteria defined by the application.

6. Improve business intelligence:

- Ultimately, the value of edge analytics is in the improvements to business intelligence that were not previously available.
- For example, conducting edge analytics on patients in a hospital allows staff tc respond more quickly to the patient's changing needs and also reduces the volum of unstructured (and not always useful) data sent to the cloud.

5.5

b)

Raspberry Pi which having inbuilt wi-fi, which makes Raspberry Pi to suitable for IoT applications, so that by using IoT technology this monitoring system works by uploadin the temperature value to the Thingspeak cloud by this project you can able to learn to how to handle cloud-based application using API keys. In this monitoring system, we used Thingspeak cloud, the cloud which is suitable to view the sensor logs in the form of grap plots. Here we created one field to monitor the temperature value, that can b reconfigurable to monitor a number of sensor values in various fields. This basic wil teach you to how to work with a cloud by using LM35 as a temperature sensor, to detec the temperature and to upload those values into the cloud.

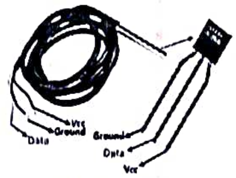


Fig:DS18B20 Temperature Sensor Pinout

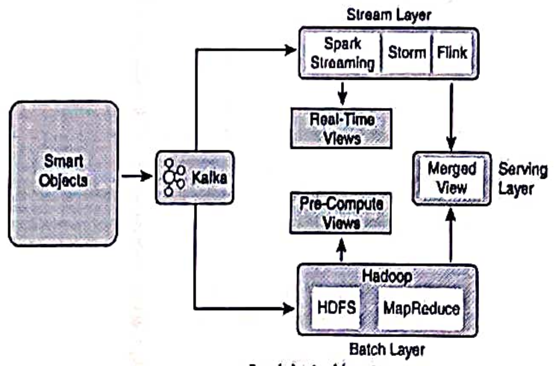
Fig: DS18B20 Temperature Sensor

2

Explanation:

5.5

3 a)



Lambda Architecture

2

Explanation:

5.5

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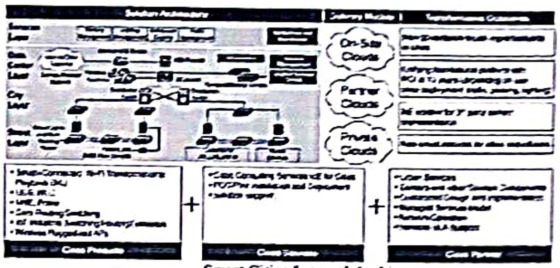
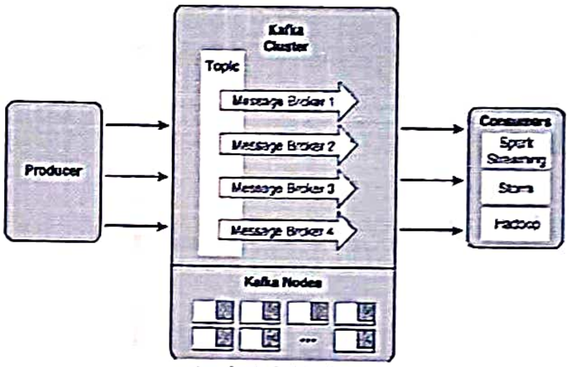
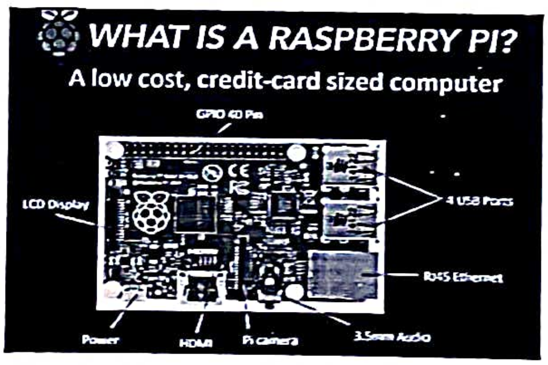
Question Number	Solution	Marks Allocated
b)	Explanation:  Smart Cities Layered Architecture	5.5 2
4 a)	Explanation:  Apache Kafka Data Flow	5.5 2
b)	 Raspberry Pi is the name of a series of single-board computers made by the Raspberry Pi Foundation, a UK charity that aims to educate people in computing and create easier access to computing education. The Raspberry Pi launched in 2012, and there have been several iterations and variations released since then. The original Pi had a single-core 700MHz CPU and just 256MB RAM, and the latest model has a quad-core 1.4GHz CPU with 1GB RAM. The main price point for Raspberry Pi has always been $35 and all models have been $35 or less, including the Pi Zero, which costs just $5.	2 5.5

USN : ____________________

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DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

I - OTHER ASSESSMENT (ASSIGNMENT)

Semester: 8-CBCS 2017

Subject: INTERNET OF THINGS TECHNOLOGY (17CS81)

Faculty: Ms Swetha K R

Max Marks: 10

Instructions to Students:

Answer all Questions

Answer all questions

Marks CO BT/CL

1. List and explain the requirements driving specific architectural Changes for IoT.

[3.0] 1 [1]

2. With a neat block diagram illustrate The IoT World Forum (IoTWF) Standardized Architecture. (explain every layer)

[3.0] 1 [1]

3. Explain Design Constraints for Wireless Smart Objects

[4.0] 1 [3]

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BGS Institute of Technology
DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
II - OTHER ASSESSMENT (ASSIGNMENT)

Semester: 8-CBCS 2017
Subject: INTERNET OF THINGS TECHNOLOGY (17CS81)
Faculty: Ms Swetha K R Max Marks: 10

Instructions to Students:

Answer all the Questions

Answer all questions

Question	Marks	CO	BT/CL
1. What is IOT ? Explain in detail on Genesis of IOT? Discuss IOT Challenges?	[3.0]	1	[1]
2. Write and explain modified OSI Model for the IOT/M2M system ?	[3.0]	1	[3]
3. Briefly Explain IEEE 802.154 MAC format	[4.0]	1	[3]

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DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

III - OTHER ASSESSMENT (ASSIGNMENT)

Semester: 8-CBCS 2017

Subject: INTERNET OF THINGS TECHNOLOGY (17CS81)

Faculty: Ms Swetha K R　　　　Max Marks: 10

Instructions to Students:

Answer all questions

<u>Answer all questions</u>

Question	Marks	CO	BT/CL
1. With a neat diagram explain wireless temperature monitoring system using raspberry pi	[3.0]	1	[3]
2. Explain in detail Smart city IOT architecture	[4.0]	1	[2]
3. With a neat diagram explain rasberry board	[3.0]	1	[3]

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BGS INSTITUTE OF TECHNOLOGY

Department of Computer Science & Engineering

VIII CS "A & B" Student List - Academic Year 2020-2021

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2	4BW17CS002	AISHWARYA D	28	4BW17CS035	MAANYA K V	55	4BW17CS064	SIDDARTH SINGH
3	4BW17CS003	AISHWARYA G P	29	4BW17CS036	MANJUSHREE C S	56	4BW17CS065	SINCHANA B R
4	4BW17CS004	AISHWARYA K.P	30	4BW17CS037	MANOJ S B	57	4BW17CS066	SMITHA B U
5	4BW17CS005	AJAY S	31	4BW17CS038	MEGHANA K	58	4BW17CS067	SMITHA M
6	4BW17CS006	AKANKASHA K P	32	4BW17CS039	MEGHANA M V	59	4BW17CS068	SNEHA N J
7	4BW17CS009	ANUPAMA A M	33	4BW17CS040	NAVYASHREE H D	60	4BW17CS069	SOWNDARYA L T
8	4BW17CS010	ATHFIA FARHEEN N	34	4BW17CS041	NIKITH G S	61	4BW17CS070	SPOORTHI H
9	4BW17CS012	BHAVAN A J	35	4BW17CS042	NOOR AYESHA S	62	4BW17CS071	SPOORTHI R
10	4BW17CS013	BHAVANI N D	36	4BW17CS043	POOJA D R	63	4BW17CS072	SPOORTHI C
11	4BW17CS014	BHUMIKA M R	37	4BW17CS044	POOJA K S	64	4BW17CS074	SWATHI D
12	4BW17CS015	BINDU H	38	4BW17CS045	POOJASHREE G	65	4BW17CS075	TASMIYA
13	4BW17CS016	BRUNDA D	39	4BW17CS046	PRIYADARSHINI P	66	4BW17CS076	TEJAS RAHUL R
14	4BW17CS017	CHAITHRA R	40	4BW17CS048	PRIYANKA V L	67	4BW17CS077	THEJAS G C
15	4BW17CS018	CHAITHRA JAIN H P	41	4BW17CS050	PUNEETH RAJ B S	68	4BW17CS078	VARALAKSHMI C K
16	4BW17CS020	DEEKSHITHA C	42	4BW17CS051	RAHUL B	69	4BW17CS081	YASHASHWINI H M
17	4BW17CS021	DEEPIKA A N	43	4BW17CS052	RAKESH C S	70	4BW17CS082	YOGASHREE C R
18	4BW17CS022	DIVYA KHYANI	44	4BW17CS053	RAKSHITHA N	71	4BW17CS083	YOGESH G L
19	4BW17CS023	DIVYASHREE K H	45	4BW17CS054	RAMYA K L	72	4BW17CS084	NAMRATHA
20	4BW17CS024	HARISH GOWDA	46	4BW17CS055	RANJITHA B S	73	4BW17CS085	NAYANA
21	4BW17CS025	HARSHITHA Y	47	4BW17CS056	RITESH KUMAR CHANDA	74	4BW17CS086	SOWMYA JAKKULA
22	4BW17CS026	HEMA D	48	4BW17CS057	ROHIT KUMAR JHA	75	4BW18CS400	ANUSHA K J
23	4BW17CS027	INDU SHREE G J	49	4BW17CS058	SAHANA L M	76	4BW18CS401	BHAVYA J K
24	4BW17CS028	ISHWARAPPA HAVIN	50	4BW17CS059	SANJANA GOWDA N C	77	4BW18CS402	BINDHUSHREE A C
24	4BW17CS029	JEEVAN R	51	4BW17CS060	SANJAY KUMAR C G	78	4BW18CS403	DHANANJAYA
25	4BW17CS031	JINASHREE P	52	4BW17CS061	SHANKREPPA HANDARGAL	79		
26	4BW17CS032	KARTHIK K P	53	4BW17CS062	SHIFAALI	80		

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20	18ISE039	SANJANA D R	sanjanasanjana5010@gmail.com	9535614304	H raju	7996661834	doddabyadarahally, pandavapura(t), mandya(d)
21	18ISE044	VANDANA	nanduv975@gmail.com	6360990491	Adinarayan	7483529087	near bypass road gauribidanur (t),chikkaballapur(d)
22	18ISE045	VINITH S	vishwavinith15@gmail.com	9611260561	N suresh	9900608149	ashoknagar 5th cross mandya
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25	18ISE048	YOUNUS ZAIN	yunuszain83@gmail.com	7259480083	naushad pasha	9380404636	shanti nagar 3rd cross ,bagur road channarayapatna
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28	19ISE401	KARTHIK	kartikhonwadkar236@gmail.com	8618032424	Chandrashekar	9742472389	gadag
29	18ISE040	SHASHANK GOWDA	shashankgowdagn20040@gmail.com	9008997604	Hema JM	9611864480	makhan ambikanagara channarayapatana
30	18ISE041	SONASHREE	sonukanthraj104@gmail.com	9845929778	kanthraj	9972965770	javaregowda road ,kuvempu nagar ,channarayapatana
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DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

RESULT OF VIII- CS A 2020-2021 (EVEN SEM)

Sl. No.	Subject	Total	Pass	Fail	AB	%age	Staff
1	INTERNET OF THINGS AND APPLICATIONS	72	71	1	nil	98	Swetha K R
2	BIG DATA ANALYTICS	72	72	nil	nil	100	Divya B M
3	NETWORK MANAGEMENT	72	71	1	nil	98	Kavyashree N
4	INTERNSHIP-PROFESSIONAL PRACTICE	72	72	nil	nil	100	Uma H R
5	PROJECT WORK PHASE - II	72	72	nil	nil	100	Swetha K R
6	SEMINAR	72	72	nil	nil	100	Divya B M

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BGS INSTITUTE OF TECHNOLOGY
DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
CO PO Attainment

Course Coordinator: Swetha K R
Subject Name: Internet of Things
Sub code: 17CS81

														IA	ASST	CIE=0.9*IA+0.1*ASST				
CO1	252	251	2	2												507	170	2.98	3.00	2.98
	84	84	1	1												170				
CO2	61	63	183	182												489	166	2.95	3.00	2.95
	22	22	61	61												166				
CO3	244	244	6	238												732	247	2.96	3.00	2.97
	82	82	2	81												247				
CO4	6	9	12	238	71	180	156	95								767	257	2.98	3.00	2.99
	2	3	4	80	24	60	52	32								257				
CO5	71	179	156	96												502	168	2.99	3.00	2.99
	24	60	52	32												168				

	0.6	0.3	0.1	
	CIE	SEE	CES	TOTAL
CO1	2.98	1.28	2.52	2.43
CO2	2.95	1.28	2.58	2.41
CO3	2.97	1.28	2.58	2.42
CO4	2.99	1.28	2.58	2.43
CO5	2.99	1.28	2.58	2.44

CO-PO/PSO Mapping Table

PO/PSO		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2.43	2			2										2
CO2	2.41	2	2	1			1								2
CO3	2.42	1	2		2										2
CO4	2.43	1	2												2
CO5	2.44	1	3		2										
Sum		7	9	1	6										8
Weighted Sum		16.97	21.9	2.41	14.57		2.41								19.40
Target		1.4	2.25	1	2		1								2
PO Attainment		1.13	1.8	0.80	1.62		0.80								1.62

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MODULE 1

What Is IoT?

IoT is a technology transition in which devices will allow us to sense and control the physical world by making objects smarter and connecting them through an intelligent network.

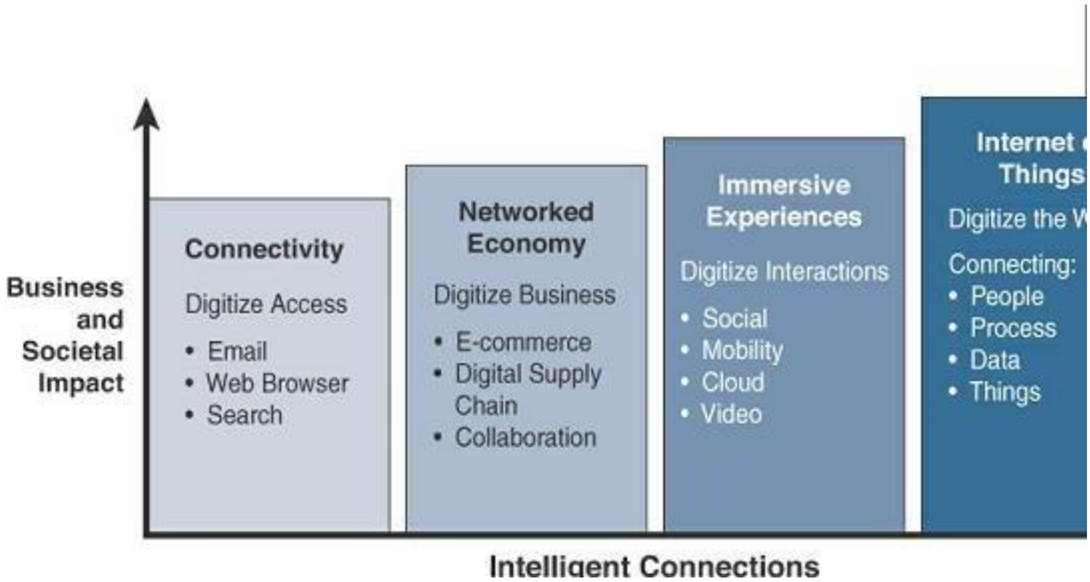
GOAL: The basic premise and goal of IoT is to "connect the unconnected." This means that objects that are not currently joined to a computer network, namely the Internet, will be conn ected so that they can communicate and interact with people and other objects.

When objects and machines can be sensed and controlled remotely across a network, a tighter integration between the physical world and computers is enabled.

This allows for improvements in the areas of efficiency, accuracy, automation, and the enable ment of advanced applications.

GENESIS OF IOT

The person credited with the creation of the term "Internet of Things" is Kevin Ashton. While working for Procter & Gamble in 1999, Kevin used this phrase to explain a new idea related to linking the company's supply chain to the Internet.



the evolution of the Internet can be categorized into four phases. Each of these phases has had a profound impact on our society and our lives. These four phases are further defined in Table below.

Internet Phase	Definition
Connectivity (Digitize access)	This phase connected people to email, web services, and search so that information is easily accessed.
Networked Economy (Digitize business)	This phase enabled e-commerce and supply chain enhancements along with collaborative engagement to drive increased efficiency in business processes.
Immersive Experiences (Digitize interactions)	This phase extended the Internet experience to encompass widespread video and social media while always being connected through mobility. More and more applications are moved into the cloud.
Internet of Things (Digitize the world)	This phase is adding connectivity to objects and machines in the world around us to enable new services and experiences. It is connecting the unconnected.

IOT AND DIGITIZATION

IoT and *digitization* are terms that are often used interchangeably. In most contexts, this duality is fine, but there are key differences to be aware of.

At a high level, IoT focuses on connecting “things,” such as objects and machines, to a computer network, such as the Internet. IoT is a well-understood term used across the industry as a whole. On the other hand, digitization can mean different things to different people but generally encompasses the connection of “things” with the data they generate and the business insights that result.

Digitization, as defined in its simplest form, is the conversion of information into a digital format. Digitization has been happening in one form or another for several decades. For example, the whole photography industry has been digitized. Pretty much everyone has digital cameras these days, either standalone devices or built into their mobile phones. Almost no one buys film and takes it to a retailer to get it developed. The digitization of photography has completely changed our experience when it comes to capturing images.

CONVERGENCE OF IT AND OT

Until recently, information technology (IT) and operational technology (OT) have for the most part lived in separate worlds. IT supports connections to the Internet along with related data and technology systems and is focused on the secure flow of data across an organization. OT monitors and controls devices and processes on physical operational systems. These systems include assembly lines, utility distribution networks, production facilities, roadway systems, and many more. Typically, IT did not get involved with the production and logistics of OT environments.

Management of OT is tied to the lifeblood of a company. For example, if the network connecting the machines in a factory fails, the machines cannot function, and production may come to a standstill, negatively impacting business on the order of millions of dollars. On the other hand, if the email server (run by the IT department) fails for a few hours, it may irritate people, but it is unlikely to impact business at anywhere near the same level. **Table below highlights some of the differences between IT and OT networks and their various challenges**.

Criterion	Industrial OT Network	Enterprise IT Network
Operational focus	Keep the business operating 24x7	Manage the computers, data, and employee communication system in a secure way
Priorities	1. Availability 2. Integrity 3. Security	1. Security 2. Integrity 3. Availability
Types of data	Monitoring, control, and supervisory data	Voice, video, transactional, and bulk data
Security	Controlled physical access to devices	Devices and users authenticated to the network
Implication of failure	OT network disruption directly impacts business	Can be business impacting, depending on industry, but workarounds may be possible
Network upgrades (software or hardware)	Only during operational maintenance windows	Often requires an outage window when workers are not onsite; impact can be mitigated
Security vulnerability	Low: OT networks are isolated and often use proprietary protocols	High: continual patching of hosts is required, and the network is connected to Internet and requires vigilant protection

Source: Maciej Kranz, *IT Is from Venus, OT Is from Mars*, blogs.cisco.com/digital/it-is-from-venus-ot-is-from-mars, July 14, 2015.

IOT CHALLENGES

The most significant challenges and problems that IoT is currently facing are

Challenge	Description
Scale	While the scale of IT networks can be large, the scale of OT can be several orders of magnitude larger. For example, one large electrical utility in Asia recently began deploying IPv6-based smart meters on its electrical grid. While this utility company has tens of thousands of employees (which can be considered IP nodes in the network), the number of meters in the service area is tens of millions. This means the scale of the network the utility is managing has increased by more than 1,000-fold! Chapter 5, "IP as the IoT Network Layer," explores how new design approaches are being developed to scale IPv6 networks into the millions of devices.
Security	With more "things" becoming connected with other "things" and people, security is an increasingly complex issue for IoT. Your threat surface is now greatly expanded, and if a device gets hacked, its connectivity is a major concern. A compromised device can serve as a launching point to attack other devices and systems. IoT security is also pervasive across just about every facet of IoT. For more information on IoT security, see Chapter 8, "Securing IoT."

Privacy	As sensors become more prolific in our everyday lives, much of the data they gather will be specific to individuals and their activities. This data can range from health information to shopping patterns and transactions at a retail establishment. For businesses, this data has monetary value. Organizations are now discussing who owns this data and how individuals can control whether it is shared and with whom.
Big data and data analytics	IoT and its large number of sensors is going to trigger a deluge of data that must be handled. This data will provide critical information and insights if it can be processed in an efficient manner. The challenge, however, is evaluating massive amounts of data arriving from different sources in various forms and doing so in a timely manner.
Interoperability	As with any other nascent technology, various protocols and architectures are jockeying for market share and standardization within IoT. Some of these protocols and architectures are based on proprietary elements, and others are open. Recent IoT standards are helping minimize this problem, but there are often various protocols and implementations available for IoT networks. The prominent protocols and architectures—especially open, standards-based implementations—are the subject of this book.

IoT Network Architecture and Design

The unique challenges posed by IoT networks and how these challenges have driven new architectural models.

- Drivers Behind New Network Architectures
- Comparing IoT Architectures.
- A Simplified IoT Architecture
- The Core IoT Functional Stack
- IoT Data Management and Compute Stack

DRIVERS BEHIND NEW NETWORK ARCHITECTURES

This begins by comparing how using an architectural blueprint to construct a house is similar to the approach we take when designing a network. Take a closer look at some of the differences between IT and IoT networks, with a focus on the IoT requirements that are driving new network architectures, and considers what adjustments are needed.

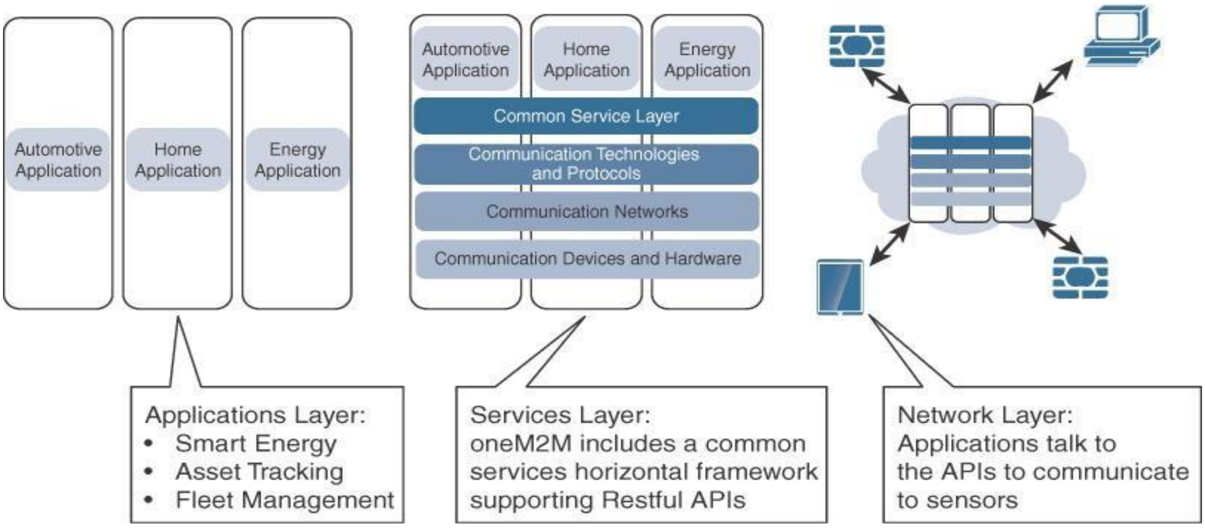
Challenge	Description	IoT Architectural Change Required
Scale	The massive scale of IoT end-points (sensors) is far beyond that of typical IT networks.	The IPv4 address space has reached exhaustion and is unable to meet IoT's scalability requirements. Scale can be met only by using IPv6. IT networks continue to use IPv4 through features like Network Address Translation (NAT).
Security	IoT devices, especially those on wireless sensor networks (WSNs), are often physically exposed to the world.	Security is required at every level of the IoT network. Every IoT endpoint node on the network must be part of the overall security strategy and must support device-level authentication and link encryption. It must also be easy to deploy with some type of a zero-touch deployment model.
Devices and networks constrained by power, CPU, memory, and link speed	Due to the massive scale and longer distances, the networks are often constrained, lossy, and capable of supporting only minimal data rates (tens of bps to hundreds of Kbps).	New last-mile wireless technologies are needed to support constrained IoT devices over long distances. The network is also constrained, meaning modifications need to be made to traditional network-layer transport mechanisms.
The massive volume of data generated	The sensors generate a massive amount of data on a daily basis, causing network bottlenecks and slow analytics in the cloud.	Data analytics capabilities need to be distributed throughout the IoT network, from the edge to the cloud. In traditional IT networks, analytics and applications typically run only in the cloud.
Support for legacy devices	An IoT network often comprises a collection of modern, IP-capable endpoints as well as legacy, non-IP devices that rely on serial or proprietary protocols.	Digital transformation is a long process that may take many years, and IoT networks need to support protocol translation and/or tunneling mechanisms to support legacy protocols over standards-based protocols, such as Ethernet and IP.
The need for data to be analyzed in real time	Whereas traditional IT networks perform scheduled batch processing of data, IoT data needs to be analyzed and responded to in real-time.	Analytics software needs to be positioned closer to the edge and should support real-time streaming analytics. Traditional IT analytics software (such as relational databases or even Hadoop), are better suited to batch-level analytics that occur after the fact.

COMPARING IOT ARCHITECTURES

The oneM2M IoT Standardized Architecture

In an effort to standardize the rapidly growing field of machine-to-machine (M2M) communications, the European Telecommunications Standards Institute (ETSI) created the M2M Technical Committee in 2008. The goal of this committee was to create a common architecture that would help accelerate the adoption of M2M applications and devices. Over time, the scope has expanded to include the Internet of Things.

One of the greatest challenges in designing an IoT architecture is dealing with the heterogeneity of devices, software, and access methods. By developing a horizontal platform architecture, oneM2M is developing standards that allow interoperability at all levels of the IoT stack



The Main Elements of the oneM2M IoT Architecture

The oneM2M architecture divides IoT functions into three major domains: the application layer, the services layer, and the network layer

- **Applications layer:** The oneM2M architecture gives major attention to connectivity between devices and their applications. This domain includes the application-layer protocols and attempts to standardize northbound API definitions for interaction with business intelligence (BI) systems. Applications tend to be industry-specific and have their own sets of data models, and thus they are shown as vertical entities.

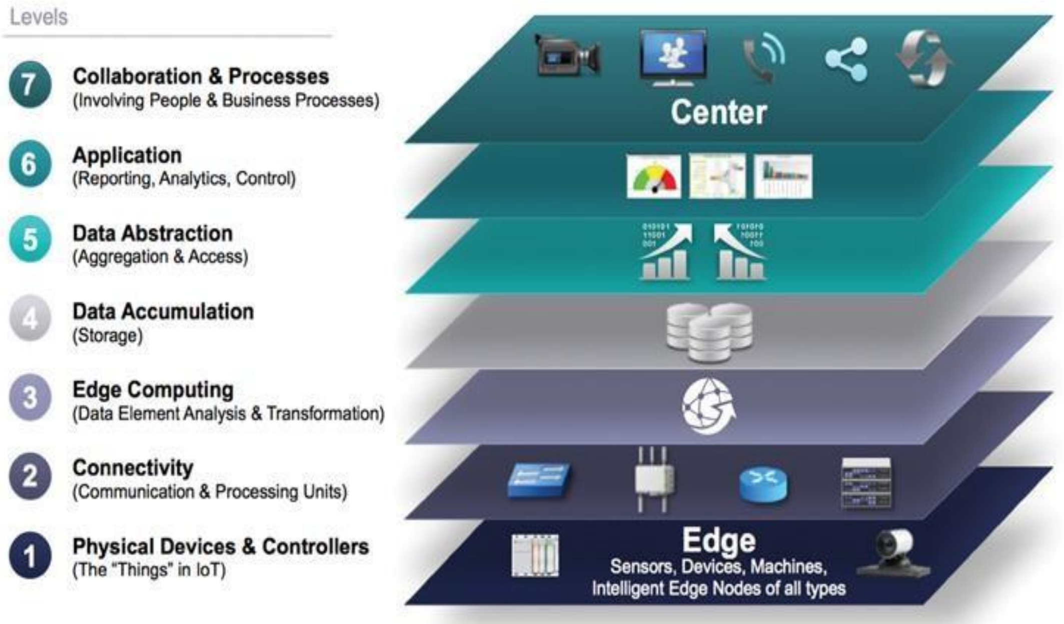
- **Services layer:** This layer is shown as a horizontal framework across the vertical industry applications. At this layer, horizontal modules include the physical network that the IoT applications run on, the underlying management protocols, and the hardware. Examples include backhaul communications via cellular, MPLS networks, VPNs, and so on. Riding on top is the common services layer.

- **Network layer:** This is the communication domain for the IoT devices and endpoints. It includes the devices themselves and the communications network that links them. Embodiments of this communications infrastructure include wireless mesh technologies, such as IEEE 802.15.4, and wireless point-to-multipoint systems, such as IEEE 801.11ah.

The IoT World Forum (IoTWF) Standardized Architecture

This publish a seven-layer IoT architectural reference model.

- While various IoT reference models exist, the one put forth by the IoT World Forum offers a clean, simplified perspective on IoT and includes edge computing, data storage, and access. It provides a succinct way of visualizing IoT from a technical perspective. Each of the seven layers is broken down into specific functions, and security encompasses the entire model.



Using this reference model, we are able to achieve the following:

1. Decompose the IoT problem into smaller parts
2. Identify different technologies at each layer and how they relate to one another
3. Define a system in which different parts can be provided by different vendors
4. Have a process of defining interfaces that leads to interoperability
5. Define a tiered security model that is enforced at the transition points between levels

Layer 1: Physical Devices and Controllers Layer

The first layer of the IoT Reference Model is the physical devices and controllers layer. This layer is home to the "things" in the Internet of Things, including the various endpoint devices and sensors that send and receive information. The size of these "things" can range from almost microscopic sensors to giant machines in a factory. Their primary function is generating data and being capable of being queried and/or controlled over a network.

Layer 2: Connectivity Layer

In the second layer of the IoT Reference Model, the focus is on connectivity. The most important function of this IoT layer is the reliable and timely transmission of data. More specifically, this includes transmissions between Layer 1 devices and the network and between the network and information processing that occurs at Layer 3 (the edge computing layer).

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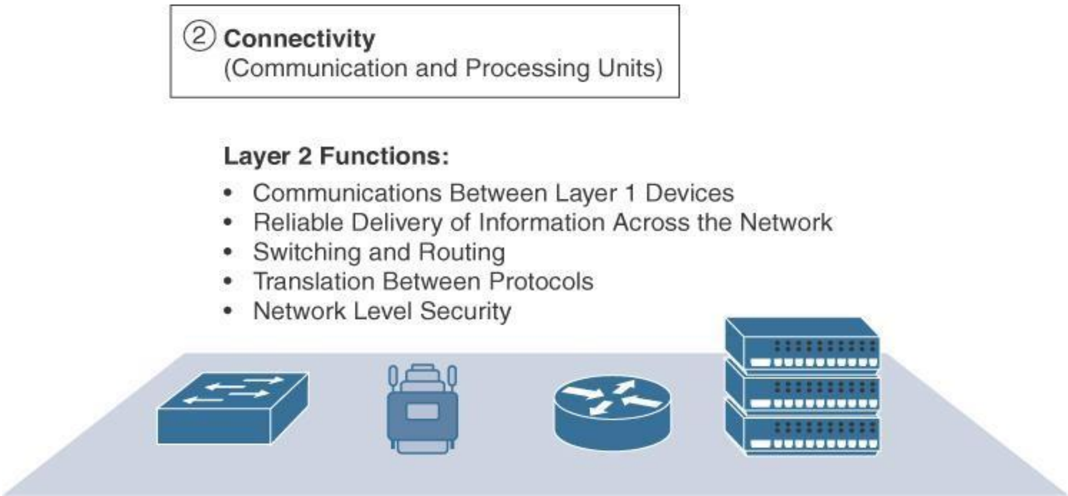
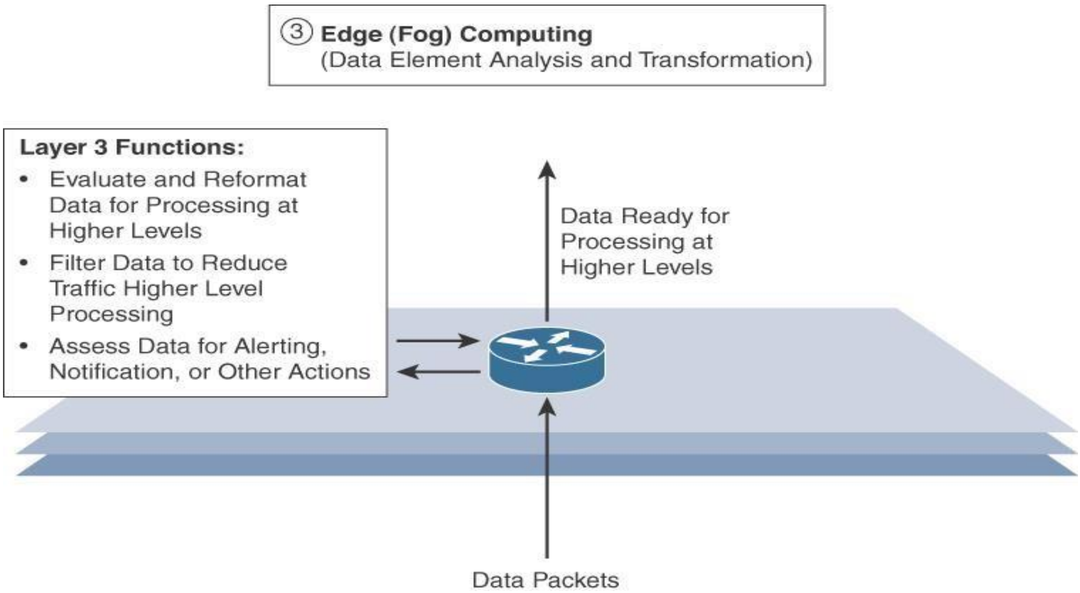


IoT Reference Model Connectivity Layer Functions

Layer 3: Edge Computing Layer

Edge computing is the role of Layer 3. Edge computing is often referred to as the "fog" layer and is discussed in the section "Fog Computing," later in this chapter. At this layer, the emphasis is on data reduction and converting network data flows into information that is ready for storage and processing by higher layers. One of the basic principles of this reference model is that information processing is initiated as early and as close to the edge of the network as possible



IoT Reference Model Layer 3 Functions

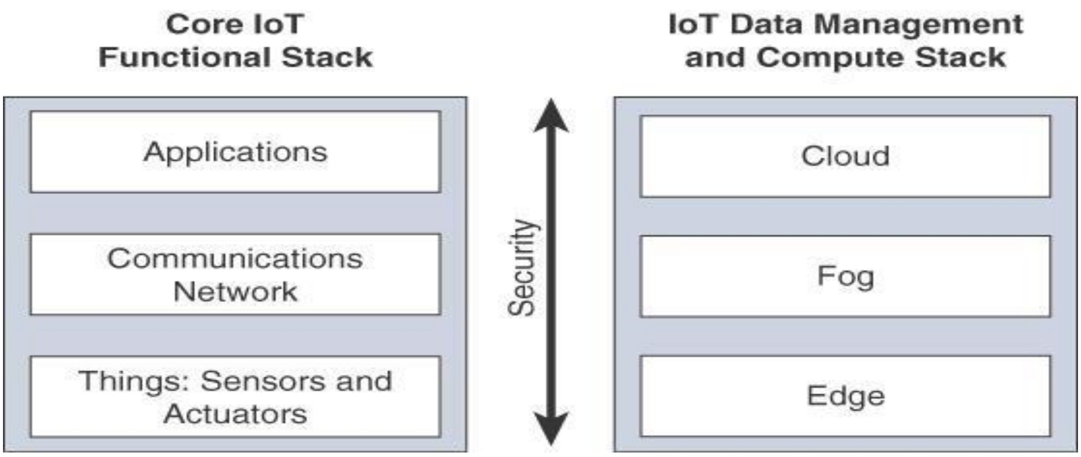
Another important function that occurs at Layer 3 is the evaluation of data to see if it can be filtered or aggregated before being sent to a higher layer. This also allows for data to be reformatted or decoded, making additional processing by other systems easier. Thus, a critical function is assessing the data to see if predefined thresholds are crossed and any action or alerts need to be sent.

Upper Layers: Layers 4–7

The upper layers deal with handling and processing the IoT data generated by the bottom layer. For the sake of completeness, Layers 4–7 of the IoT Reference Model are summarized in Table .

IoT Reference Model Layer	Functions
Layer 4: Data accumulation layer	Captures data and stores it so it is usable by applications when necessary. Converts event-based data to query-based processing.
Layer 5: Data abstraction layer	Reconciles multiple data formats and ensures consistent semantics from various sources. Confirms that the data set is complete and consolidates data into one place or multiple data stores using virtualization.
Layer 6: Applications layer	Interprets data using software applications. Applications may monitor, control, and provide reports based on the analysis of the data.
Layer 7: Collaboration and processes layer	Consumes and shares the application information. Collaborating on and communicating IoT information often requires multiple steps, and it is what makes IoT useful. This layer can change business processes and delivers the benefits of IoT.

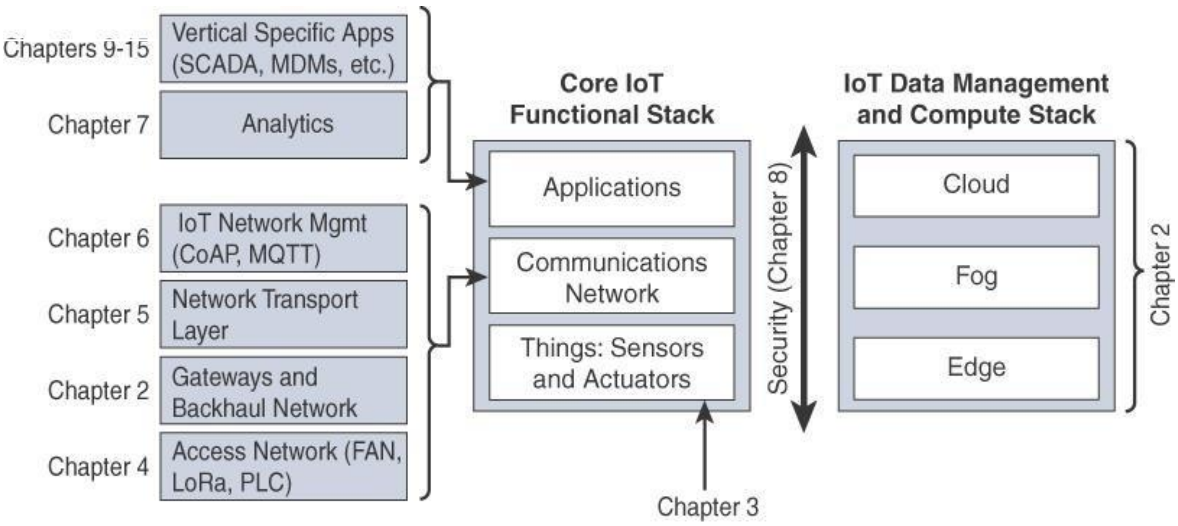
A SIMPLIFIED IOT ARCHITECTURE



Simplified IoT Architecture

The presentation of the Core IoT Functional Stack in three layers is meant to simplify your understanding of the IoT architecture into its most foundational building blocks. The network communications layer of the IoT stack itself involves a significant amount of detail and incorporates a vast array of technologies.

Data management is aligned with each of the three layers of the Core IoT Functional Stack. The three data management layers are the edge layer (data management within the sensors themselves), the fog layer (data management in the gateways and transit network), and the cloud layer (data management in the cloud or central data center). An expanded view of the IoT architecture presented as below:



Expanded View of the Simplified IoT Architecture

The Core IoT Functional Stack can be expanded into sublayers containing greater detail and specific network functions. For example, the communications layer is broken down into four separate sublayers: the access network, gateways and backhaul, IP transport, and operations and management sublayers.

The applications layer of IoT networks is quite different from the application layer of a typical enterprise network. Instead of simply using business applications, IoT often involves a strong big data analytics component. One message that is stressed throughout this book is that IoT is not just about the control of IoT devices but, rather, the useful insights gained from the data generated by those devices. Thus, the applications layer typically has both analytics and industry-specific IoT control system components.

presented in Part II, and it gives you the tools you need to understand how these technologies are applied in key industries in Part III.

THE CORE IOT FUNCTIONAL STACK

IoT networks are built around the concept of "things," or smart objects performing functions and delivering new connected services. These objects are "smart" because they use a combination of contextual information and configured goals to perform actions.

From an architectural standpoint, several components have to work together for an IoT network to be operational:

- "Things" layer:
- Communications network layer
- Access network sublayer
- Gateways and backhaul network sublayer
- Network transport sublayer
- IoT network management sublayer
- Application and analytics layer

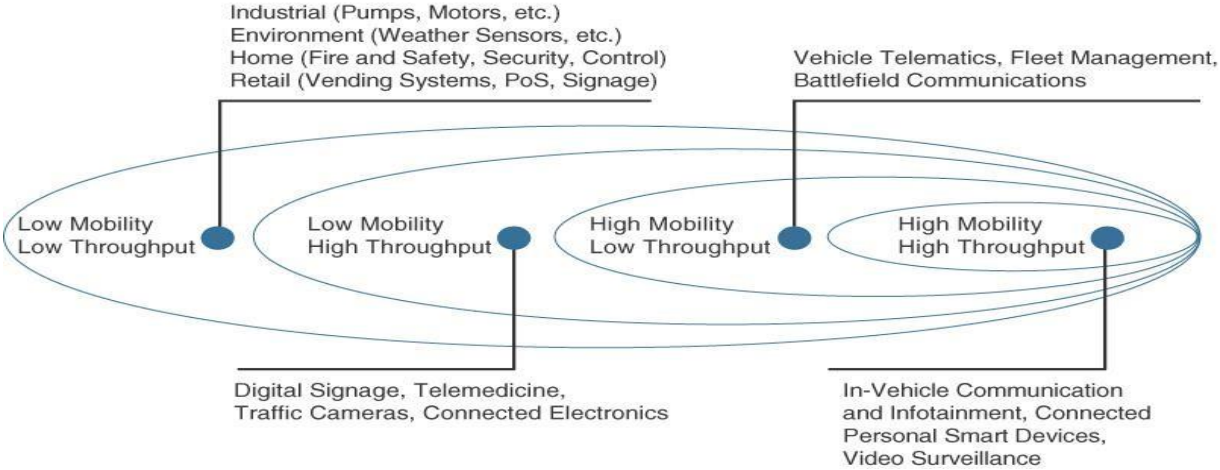
The following sections examine these elements and help you architect your IoT communication network.

Layer 1: Things: Sensors and Actuators Layer

"Smart Objects: The 'Things' in IoT," provides more in-depth information about smart objects. From an architectural standpoint, the variety of smart object types, shapes, and needs drive the variety of IoT protocols and architectures. One architectural classification could be:

- **Battery-powered or power-connected:** This classification is based on whether the object carries its own energy supply or receives continuous power from an external power source.
- **Mobile or static:** This classification is based on whether the "thing" should move or always stay at the same location. A sensor may be mobile because it is moved from one object to another or because it is attached to a movin
- **Low or high reporting frequency:** This classification is based on how often the object should report monitored parameters. A rust sensor may report values once a month. A motion sensor may report acceleration several hundred times per second.
- **Simple or rich data:** This classification is based on the quantity of data exchanged at each report cycle
- **Report range:** This classification is based on the distance at which the gateway is located. For example, for your fitness band to communicate with your phone, it needs to be located a few meters away at most.
- **Object density per cell:** This classification is based on the number of smart objects (with a similar need to communicate) over a given area, connected to the same gateway.

Below figure provides some examples of applications matching the combination of mobility and throughput requirements.



Example of Sensor Applications Based on Mobility and Throughput

Layer 2: Communications Network Layer

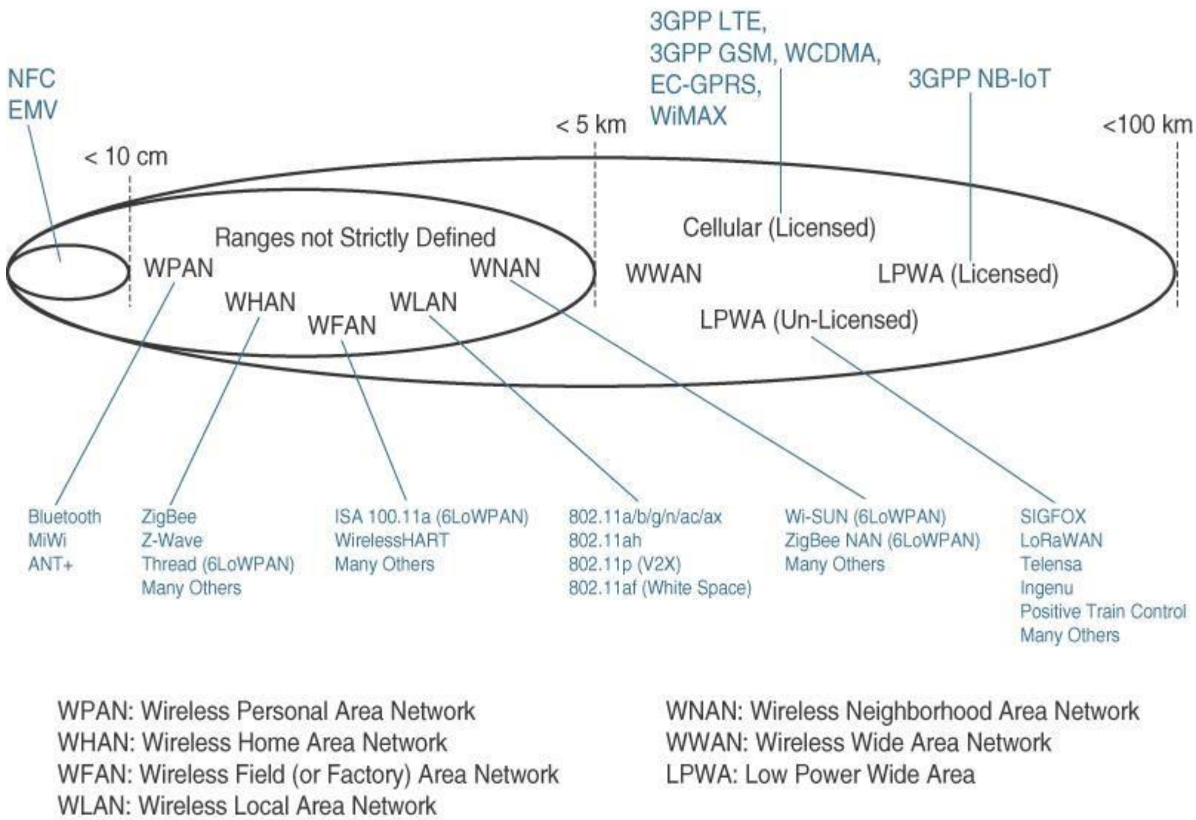
Once you have determined the influence of the smart object form factor over its transmission capabilities (transmission range, data volume and frequency, sensor density and mobility), you are ready to connect the object and communicate.

Compute and network assets used in IoT can be very different from those in IT environments. The difference in the physical form factors between devices used by IT and OT is obvious even to the most casual of observers. What typically drives this is the physical environment in which the devices are deployed. What may not be as inherently obvious, however, is their operational differences. The operational differences must be understood in order to apply the correct handling to secure the target assets.

Access Network Sublayer

There is a direct relationship between the IoT network technology you choose and the type of connectivity topology this technology allows. Each technology was designed with a certain number of use cases in mind (what to connect, where to connect, how much data to transport at what interval and over what distance). These use cases determined the frequency band that was expected to be most suitable, the frame structure matching the expected data pattern (packet size and communication intervals), and the possible topologies that these use cases illustrate.

One key parameter determining the choice of access technology is the range between the smart object and the information collector. Figure 2-9 lists some access technologies you may encounter in the IoT world and the expected transmission distances.

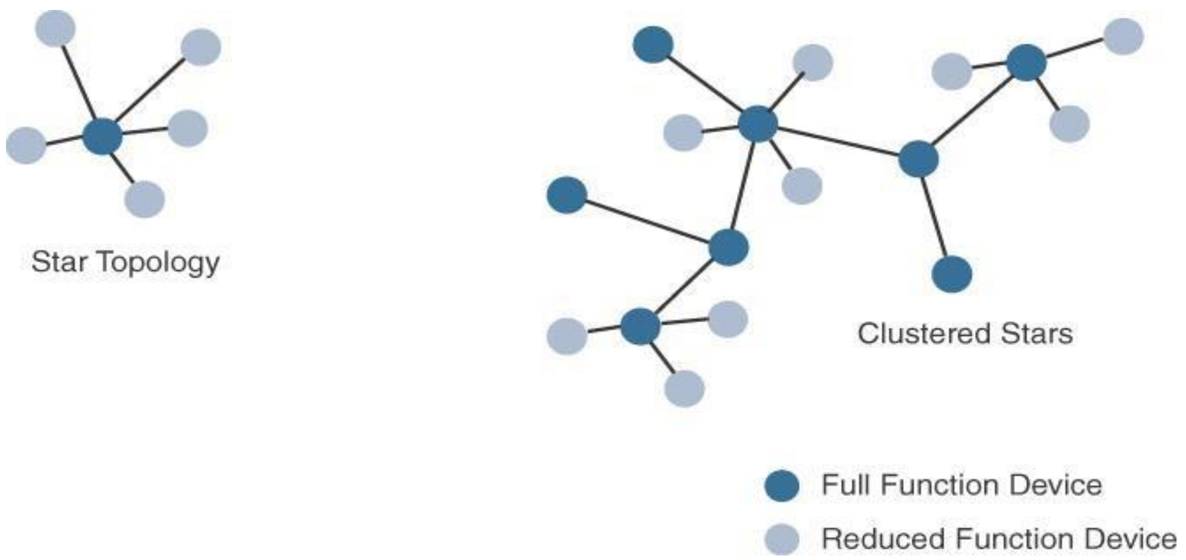


Access Technologies and Distances

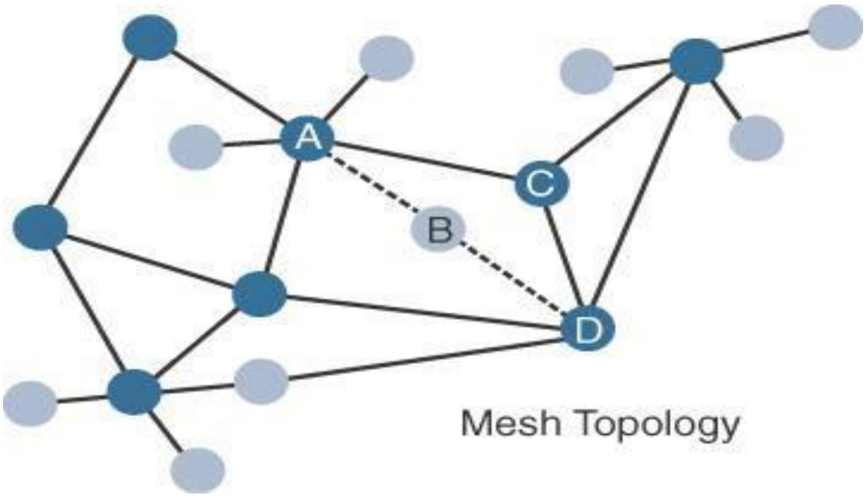
- ✓ Range estimates are grouped by category names that illustrate the environment or the vertical where data collection over that range is expected. Common groups are as follows:

- **PAN (personal area network):** Scale of a few meters. This is the personal space around a person. A common wireless technology for this scale is Bluetooth.
- **HAN (home area network):** Scale of a few tens of meters. At this scale, common wireless technologies for IoT include ZigBee and Bluetooth Low Energy (BLE).
- **NAN (neighborhood area network):** Scale of a few hundreds of meters. The term NAN is often used to refer to a group of house units from which data is collected.
- **FAN (field area network):** Scale of several tens of meters to several hundred meters. FAN typically refers to an outdoor area larger than a single group of house units. The FAN is often seen as "open space" (and therefore not secured and not controlled).
- **LAN (local area network):** Scale of up to 100 m. This term is very common in networking, and it is therefore also commonly used in the IoT space when standard networking technologies (such as Ethernet or IEEE 802.11) are used.

- ✓ Similar ranges also do not mean similar topologies. Some technologies offer flexible connectivity structure to extend communication possibilities:
  - **Point-to-point topologies**
  - **Point-to-multipoint**



Star and Clustered Star Topologies



Comparison of the main solutions from an architectural angle.

Technology	Type and Range	Architectural Characteristics
Ethernet	Wired, 100 m max	Requires a cable per sensor/sensor group; adapted to static sensor position in a stable environment; range is limited; link is very reliable
Wi-Fi (2.4 GHz, 5 GHz)	Wireless, 100 m (multipoint) to a few kilometers (P2P)	Can connect multiple clients (typically fewer than 200) to a single AP; range is limited; adapted to cases where client power is not an issue (continuous power or client battery recharged easily); large bandwidth available, but interference from other systems likely; AP needs a cable
802.11ah (HaloW, Wi-Fi in sub-1 GHz)	Wireless, 1.5 km (multipoint), 10 km (P2P)	Can connect a large number of clients (up to 6000 per AP); longer range than traditional Wi-Fi; power efficient; limited bandwidth; low adoption; and cost may be an issue
WiMAX (802.16)	Wireless, several kilometers (last mile), up to 50 km (backhaul)	Can connect a large number of clients; large bandwidth available in licensed spectrum (fee-based); reduced bandwidth in license-free spectrum (interferences from other systems likely); adoption varies on location
Cellular (for example, LTE)	Wireless, several kilometers	Can connect a large number of clients; large bandwidth available; licensed spectrum (interference-free; license-based)

Architectural Considerations for WiMAX and Cellular Technologies

Layer 3: Applications and Analytics Layer

Once connected to a network, your smart objects exchange information with other systems. As soon as your IoT network spans more than a few sensors, the power of the Internet of Things appears in the applications that make use of the information exchanged with the smart objects.

Analytics Versus Control Applications

Multiple applications can help increase the efficiency of an IoT network. Each application collects data and provides a range of functions based on analyzing the collected data. It can be difficult to compare the features offered. From an architectural standpoint, one basic classification can be as follows:

- **Analytics application:** This type of application collects data from multiple smart objects, processes the collected data, and displays information resulting from the data that was processed. The display can be about any aspect of the IoT network, from historical reports, statistics, or trends to individual system states. The important aspect is that the application processes the data to convey a view of the network that cannot be obtained from solely looking at the information displayed by a single smart object.

- **Control application:** This type of application controls the behavior of the smart object or the behavior of an object related to the smart object. For example, a pressure sensor may be connected to a pump. A control application increases the pump speed when the connected sensor detects a drop in pressure. Control applications are very useful for controlling complex aspects of an IoT network with a logic that cannot be programmed inside a single IoT object, either because the configured changes are too complex to fit into the local system or because the configured changes rely on parameters that include elements outside the IoT object.

Data Versus Network Analytics

Analytics is a general term that describes processing information to make sense of collected data. In the world of IoT, a possible classification of the analytics function is as follows:

- **Data analytics:** This type of analytics processes the data collected by smart objects and combines it to provide an intelligent view related to the IoT system. At a very basic level, a dashboard can display an alarm when a weight sensor detects that a shelf is empty in a store. In a more complex case, temperature, pressure, wind, humidity, and light levels collected from thousands of sensors may be combined and then processed to determine the likelihood of a storm and its possible path .

- **Network analytics:** Most IoT systems are built around smart objects connected to the network. A loss or degradation in connectivity is likely to affect the efficiency of the system. Such a loss can have dramatic effects. For example, open mines use wireless networks to automatically pilot dump trucks. A lasting loss of connectivity may result in an accident or degradation of operations efficiency (automated dump trucks typically stop upon connectivity loss). On a more minor scale, loss of connectivity means that data stops being fed to your data analytics platform, and the system stops making intelligent analyses of the IoT system.

Data Analytics Versus Business Benefits

Data analytics is undoubtedly a field where the value of IoT is booming. Almost any object can be connected, and multiple types of sensors can be installed on a given object. Collecting and interpreting the data generated by these devices is where the value of IoT is realized.

Smart Services

- The ability to use IoT to improve operations is often termed “smart services.” This term is generic, and in many cases the term is used but its meaning is often stretched to include one form of service or another where an additional level of intelligence is provided.

- Smart services can also be used to measure the efficiency of machines by detecting machine output, speed, or other forms of usage evaluation.

- Smart services can be integrated into an IoT system. For example, sensors can be integrated in a light bulb. A sensor can turn a light on or off based on the presence of a human in the room.

IOT DATA MANAGEMENT AND COMPUTE STACK

This model also has limitations. As data volume, the variety of objects connecting to the network, and the need for more efficiency increase, new requirements appear, and those requirements tend to bring the need for data analysis closer to the IoT system. These new requirements include the following:

■ **Minimizing latency:** Milliseconds matter for many types of industrial systems, such as when you are trying to prevent manufacturing line shutdowns or restore electrical service. Analyzing data close to the device that collected the data can make a difference between averting disaster and a cascading system failure.

■ **Conserving network bandwidth:** Offshore oil rigs generate 500 GB of data weekly. Commercial jets generate 10 TB for every 30 minutes of flight. It is not practical to transport vast amounts of data from thousands or hundreds of thousands of edge devices to the cloud. Nor is it necessary because many critical analyses do not require cloud-scale processing and storage.

■ **Increasing local efficiency:** Collecting and securing data across a wide geographic area with different environmental conditions may not be useful. The environmental conditions in one area will trigger a local response independent from the conditions of another site hundreds of miles away. Analyzing both areas in the same cloud system may not be necessary for immediate efficiency.

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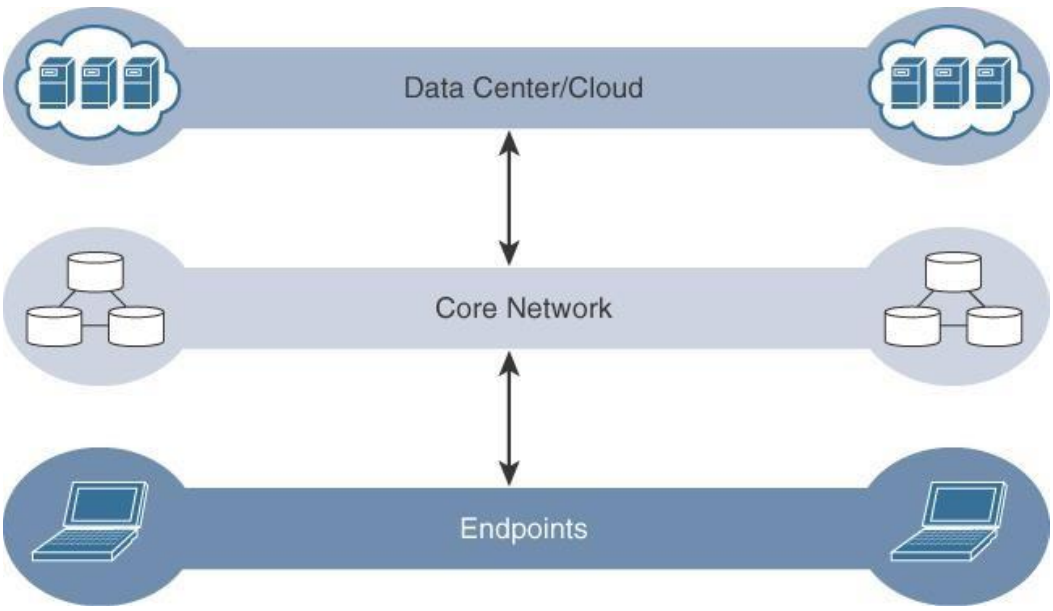


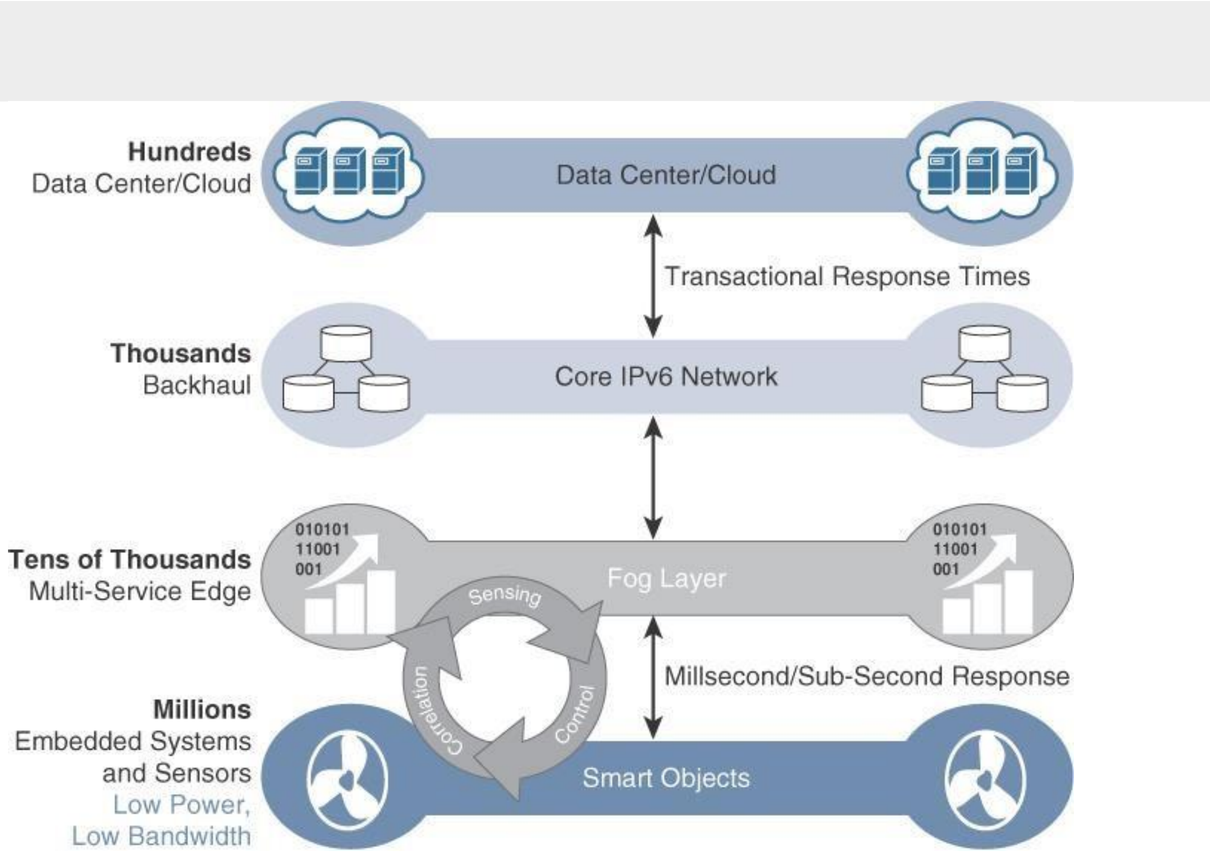
The Traditional IT Cloud Computing Model

IoT systems function differently. Several data-related problems need to be addressed:

- Bandwidth in last-mile IoT networks is very limited. When dealing with thousands/millions of devices, available bandwidth may be on order of tens of Kbps per device or even less.
- Latency can be very high. Instead of dealing with latency in the milliseconds range, large IoT networks often introduce latency of hundreds to thousands of milliseconds.
- Network backhaul from the gateway can be unreliable and often depends on 3G/LTE or even satellite links. Backhaul links can also be expensive if a per-byte data usage model is necessary.
- The volume of data transmitted over the backhaul can be high, and much of the data may not really be that interesting (such as simple polling messages).
- Big data is getting bigger. The concept of storing and analyzing all sensor data in the cloud is impractical. The sheer volume of data generated makes real-time analysis and response to the data almost impossible.

Fog Computing

The solution to the challenges mentioned in the previous section is to distribute data management throughout the IoT system, as close to the edge of the IP network as possible. The best-known embodiment of edge services in IoT is fog computing. Any device with computing, storage, and network connectivity can be a fog node. Examples include industrial controllers, switches, routers, embedded servers, and IoT gateways. Analyzing IoT data close to where it is collected minimizes latency, offloads gigabytes of network traffic from the core network, and keeps sensitive data inside the local network.



The IoT Data Management and Compute Stack with Fog Computing

Fog services are typically accomplished very close to the edge device, sitting as close to the IoT endpoints as possible. One significant advantage of this is that the fog node has contextual awareness of the sensors it is managing because of its geographic proximity to those sensors. For example, there might be a fog router on an oil derrick that is monitoring all the sensor activity at that location. Because the fog node is able to analyze information from all the sensors on that derrick, it can provide contextual analysis of the messages it is receiving and may decide to send back only the relevant information over the backhaul network to the cloud. In this way, it is performing distributed analytics such that the volume of data sent upstream is greatly reduced and is much more useful to application and analytics servers residing in the cloud.

Fog applications are as diverse as the Internet of Things itself. What they have in common is data reduction—monitoring or analyzing real-time data from network-connected things and then initiating an action, such as locking a door, changing equipment settings, applying the brakes on a train, zooming a video camera, opening a valve in response to a pressure reading, creating a bar chart, or sending an alert to a technician to make a preventive repair.

The defining characteristic of fog computing are as follows:

- **Contextual location awareness and low latency:** The fog node sits as close to the IoT endpoint as possible to deliver distributed computing.
- **Geographic distribution:** In sharp contrast to the more centralized cloud, the services and applications targeted by the fog nodes demand widely distributed deployments.
- **Deployment near IoT endpoints:** Fog nodes are typically deployed in the presence of a large number of IoT endpoints. For example, typical metering deployments often see 3000 to 4000 nodes per gateway router, which also functions as the fog computing node.
- **Wireless communication between the fog and the IoT endpoint:** Although it is possible to connect wired nodes, the advantages of fog are greatest when dealing with a large number of endpoints, and wireless access is the easiest way to achieve such scale.
- **Use for real-time interactions:** Important fog applications involve real-time interactions rather than batch processing. Preprocessing of data in the fog nodes allows upper-layer applications to perform batch processing on a subset of the data.

Edge Computing

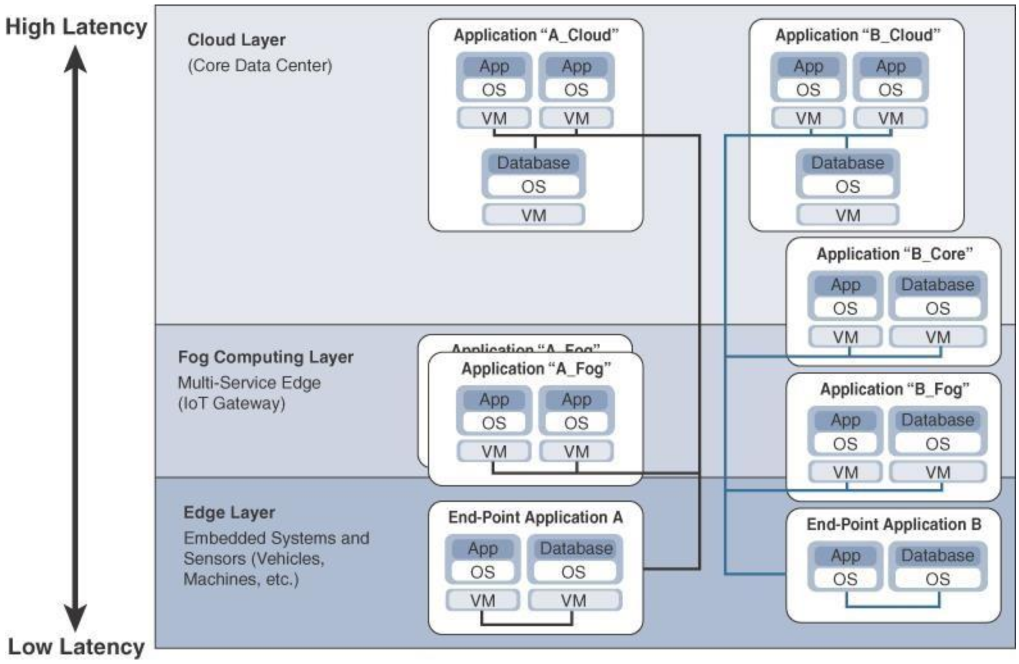
Fog computing solutions are being adopted by many industries, and efforts to develop distributed applications and analytics tools are being introduced at an accelerating pace. The natural place for a fog node is in the network device that sits closest to the IoT endpoints, and these nodes are typically spread throughout an IoT network

Note

Edge computing is also sometimes called “mist” computing. If clouds exist in the sky, and fog sits near the ground, then mist is what actually sits on the ground. Thus, the concept of mist is to extend fog to the furthest point possible, right into the IoT endpoint device itself.

The Hierarchy of Edge, Fog, and Cloud

It is important to stress that edge or fog computing in no way replaces the cloud. Rather, they complement each other, and many use cases actually require strong cooperation between layers. In the same way that lower courts do not replace the supreme court of a country, edge and fog computing layers simply act as a first line of defense for filtering, analyzing, and otherwise managing data endpoints. This saves the cloud from being queried by each and every node for each event.



Distributed Compute and Data Management Across an IoT System

From an architectural standpoint, fog nodes closest to the network edge receive the data from IoT devices. The fog IoT application then directs different types of data to the optimal place for analysis:

- The most time-sensitive data is analyzed on the edge or fog node closest to the things generating the data.
- Data that can wait seconds or minutes for action is passed along to an aggregation node for analysis and action.
- Data that is less time sensitive is sent to the cloud for historical analysis, big data analytics, and long-term storage. For example, each of thousands or hundreds of thousands of fog nodes might send periodic summaries of data to the cloud for historical analysis and storage.

In summary, when architecting an IoT network, you should consider the amount of data to be analyzed and the time sensitivity of this data. Understanding these factors will help you decide whether cloud computing is enough or whether edge or fog computing would improve your system efficiency. Fog computing accelerates awareness and response to events by eliminating a round trip to the cloud for analysis. It avoids the need for costly bandwidth additions by offloading gigabytes of network traffic from the core network. It also protects sensitive IoT data by analyzing it inside company walls.

INTERNET OF THINGS TECHNOLOGY

Course Coordinator: Swetha K R

Course Name: Internet of things

Course Code: 17cs81

Module – 1

Chapter1: What Is IoT?

Chapter 2: IoT network architecture and design

Module 1 - Syllabus

- What is IoT?
  - Genesis of IoT
  - IoT and Digitization
  - IoT Impact
  - Convergence of IT and IoT
  - IoT Challenges
- IoT Network Architecture and Design
  - Drivers Behind New Network Architectures
  - Comparing IoT Architectures
  - A Simplified IoT Architecture
  - The Core IoT Functional Stack
  - IoT Data Management and Compute Stack

Text book

David Hanes, Gonzalo Salgueiro, Patrick Grossetete, Robert Barton, Jerome Henry, **"IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things"**, 1st Edition, Pearson Education (Cisco Press Indian Reprint)

Chapter 1 & 2

IoT Fundamentals

Networking Technologies, Protocols, and Use Cases for the Internet of Things

David Hanes • Gonzalo Salgueiro
Patrick Grossetete • Rob Barton • Jerome Henry

ciscopress.com

Foreword by **Rowan Trollope**

What Is IoT?

- The basic premise and goal of IoT is to “connect the unconnected.”
- This means that objects that are not currently joined to a computer network, namely the Internet, will be connected so that they can communicate and interact with people and other objects.
- IoT is a technology transition in which devices will allow us to sense and control the physical world by making objects smarter and connecting them through an intelligent network

Contd..

- When objects and machines can be sensed and controlled remotely across a network, a tighter integration between the physical world and computers is enabled.
- This allows for improvements in the areas of efficiency, accuracy, automation, and the enablement of advanced applications.
- Instead of viewing IoT as a single technology domain, it is good to view it as an umbrella of various concepts, protocols, and technologies

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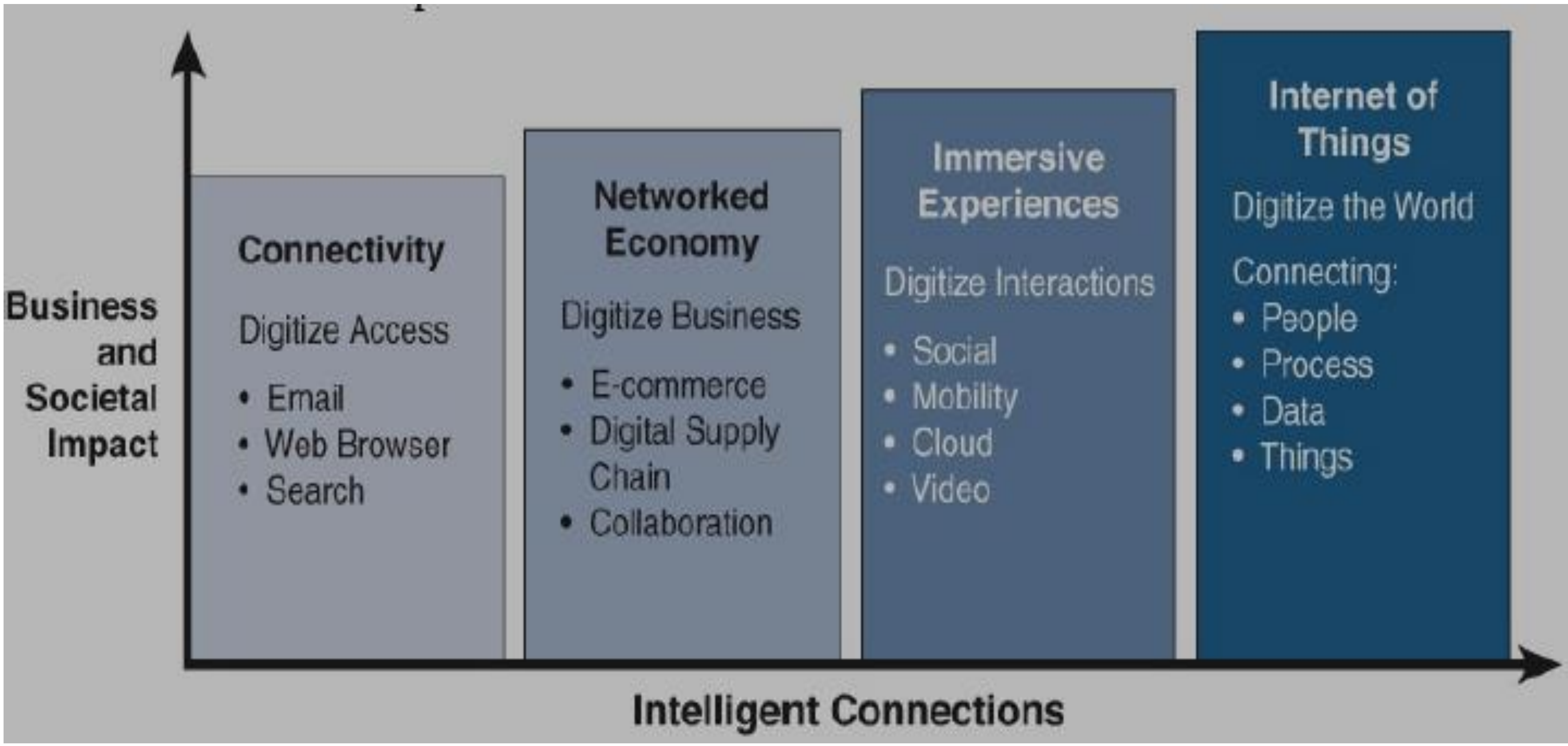
- The wide array of IoT elements is designed to create numerous benefits in the areas of productivity and automation, at the same time it introduces new challenges, such as scaling the vast numbers of devices and amounts of data that need to be processed.

Genesis of IoT

- The age of IoT is often said to have started between the years 2008 and 2009.
- During this period, the number of devices connected to the Internet eclipsed the world’s population.
- With more “things” connected to the Internet than people in the world, the Internet of Things was born.
- The person credited with the creation of the term “Internet of Things” is **Kevin Ashton**.
- His quote says “In the twentieth century, computers were brains without senses—they only knew what we told them.”
- IoT is changing this paradigm; in the twenty-first century, computers are sensing things for themselves

The evolution of the Internet



The evolutionary phases of the Internet

Internet Phase	Definition
Connectivity (Digitize access)	This phase connected people to email, web services, and search so that information is easily accessed.
Networked Economy (Digitize business)	This phase enabled e-commerce and supply chain enhancements along with collaborative engagement to drive increased efficiency in business processes.
Immersive Experiences (Digitize interactions)	This phase extended the Internet experience to encompass widespread video and social media while always being connected through mobility. More and more applications are moved into the cloud.
Internet of Things (Digitize the world)	This phase is adding connectivity to objects and machines in the world around us to enable new services and experiences. It is connecting the unconnected.

IoT and Digitization

- *IoT* and *digitization* are terms that are often used interchangeably.
- In most contexts, this duality is fine, but there are key differences
- Difference: IoT focuses on connecting “things,” such as objects and machines, to a computer network, such as the Internet.
- IoT is a well-understood term used across the industry as a whole.
- Digitization generally encompasses the connection of “things” with the data they generate and the business insights that result.

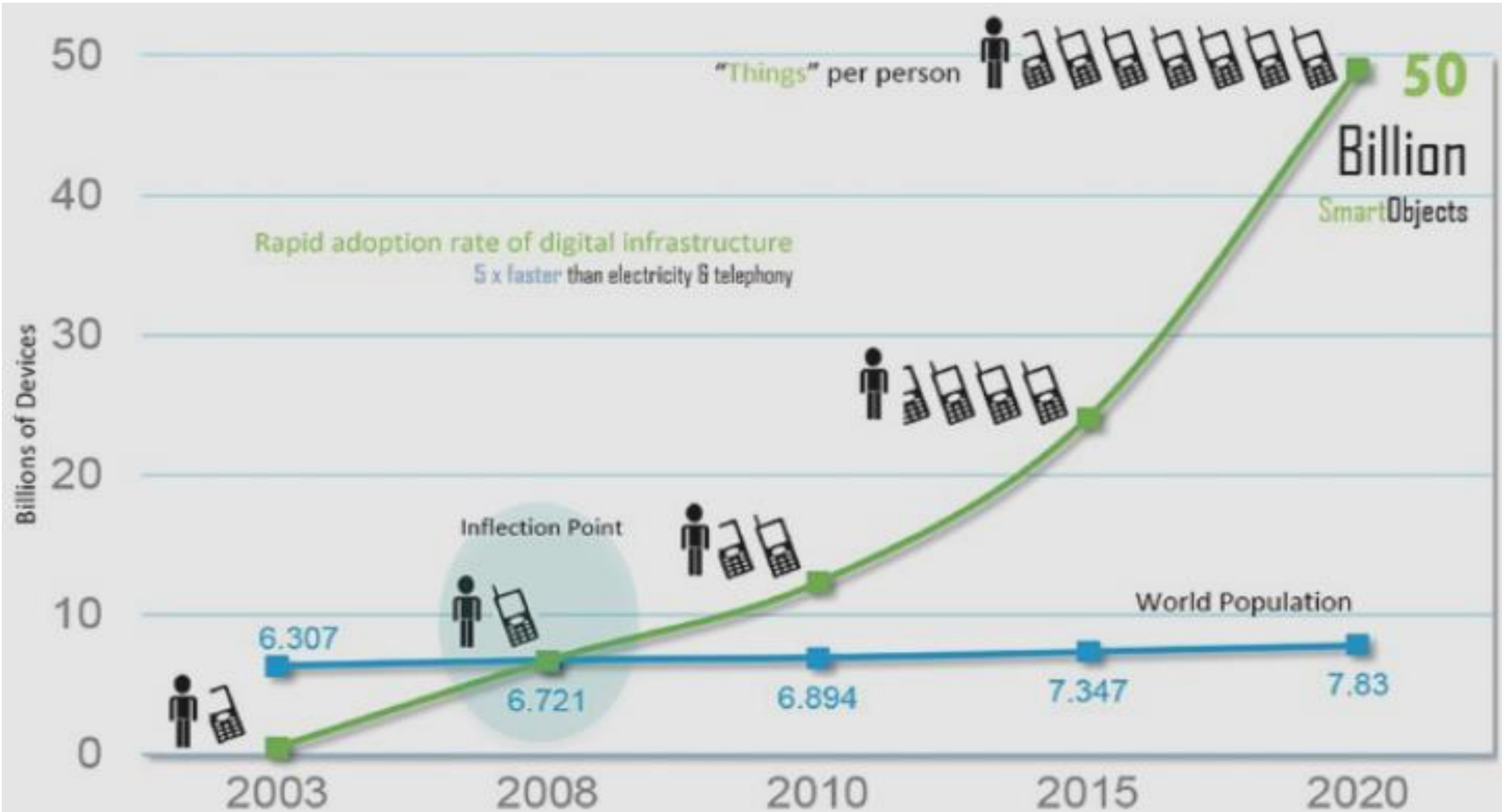
Contd …

- For example, in a shopping mall where Wi-Fi location tracking has been deployed, the “things” are the Wi-Fi devices.
- Digitization, as defined in its simplest form, is the conversion of information into a digital format.
- In the context of IoT, digitization brings together things, data, and business process to make networked connections more relevant and valuable.
- Example: Many people can relate to is in the area of home automation with popular products

IoT Impact

- Projections on the potential impact of IoT are impressive.
- About 14 billion, or just 0.06%, of “things” are connected to the Internet today.
- Cisco Systems predicts that by 2020, this number will reach 50 billion
- These new connections will lead to $19 trillion in profits and cost savings
- IoT will fundamentally shift the way people and businesses interact with their surroundings.
- Managing and monitoring smart objects using real-time connectivity enables a whole new level of data-driven decision making.

The Rapid Growth in the Number of Devices Connected to the Internet



Connected Roadways

- People have been fantasizing about the self-driving car, or autonomous vehicle.
- While this fantasy is now becoming a reality with well-known projects like Google’s self-driving car
- IoT is also a necessary component for implementing a fully connected transportation infrastructure.
- IoT is going to allow self-driving vehicles to better interact with the transportation system around them through bidirectional data exchanges while also providing important data to the riders.
- Self-driving vehicles need always-on, reliable communications and data from other transportation-related sensors to reach their full potential.

Contd …

- *"Connected roadways"* is the term associated with both the driver and driverless cars fully integrating with the surrounding transportation infr

Google's Self-Driving Car

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- Basic sensors reside in cars already.
- They monitor oil pressure, tire pressure, temperature, and other operating conditions, and provide data around the core car functions.
- From behind the steering wheel, the driver can access this data while also controlling the car using equipment such as a steering wheel, pedals, and so on.
- The need for all this sensory information and control is obvious.
- The driver must be able to understand, handle, and make critical decisions while concentrating on driving safely.
- The Internet of Things is replicating this concept on a much larger scale.

Contd …

- As automobile manufacturers strive to reinvent the driving experience, these sensors are becoming IP-enabled to allow easy communication with other systems both inside and outside the car.
- In addition, new sensors and communication technologies are being developed to allow vehicles to “talk” to other vehicles, traffic signals, school zones, and other elements of the transportation infrastructure.

Today’s transportation challenges

Challenge	Supporting Data
Safety	According to the US Department of Transportation, 5.6 million crashes were reported in 2012 alone, resulting in more than 33,000 fatalities. IoT and the enablement of connected vehicle technologies will empower drivers with the tools they need to anticipate potential crashes and significantly reduce the number of lives lost each year.
Mobility	More than a billion cars are on the roads worldwide. Connected vehicle mobility applications can enable system operators and drivers to make more informed decisions, which can, in turn, reduce travel delays. Congestion causes 5.5 billion hours of travel delay per year, and reducing travel delays is more critical than ever before. In addition, communication between mass transit, emergency response vehicles, and traffic management infrastructures help optimize the routing of vehicles, further reducing potential delays.
Environment	According to the American Public Transportation Association, each year transit systems can collectively reduce carbon dioxide (CO_2) emissions by 16.2 million metric tons by reducing private vehicle miles. Connected vehicle environmental applications will give all travelers the real-time information they need to make “green” transportation choices.

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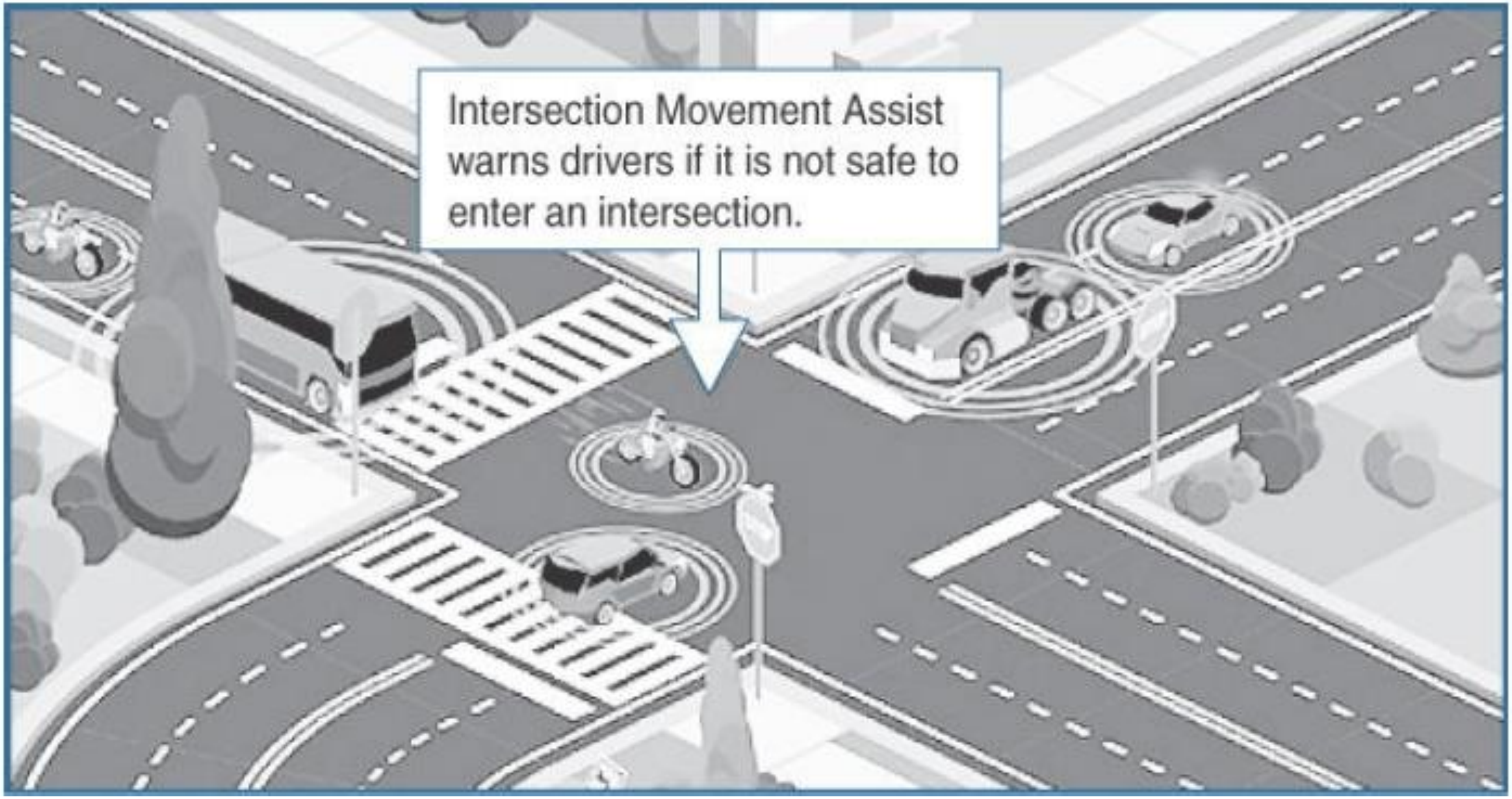
- By addressing the challenges, connected roadways will bring many benefits to society.
- These benefits include:
  - reduced traffic jams and urban congestion,
  - decreased casualties and fatalities,
  - increased response time for emergency vehicles, and
  - reduced vehicle emissions.
- EX: with IoT-connected roadways, a concept known as Intersection Movement Assist (IMA) is possible.
- This application warns a driver when it is not safe to enter an intersection due to a high probability of a collision—perhaps because another car has run a stop sign or strayed into the wrong lane.

Application of Intersection Movement Assist



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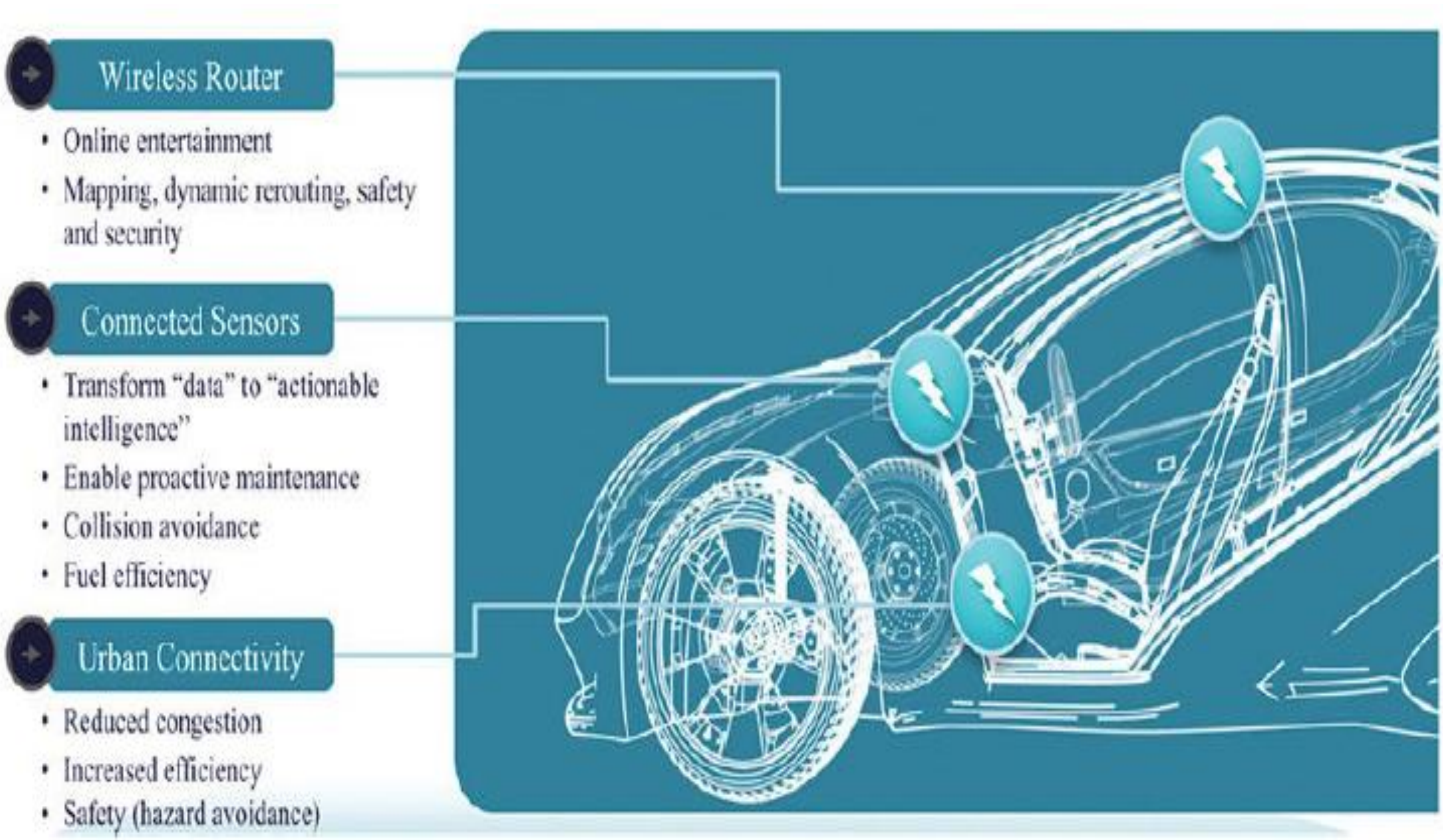
- IMA is one of many possible roadway solutions that emerge when we start to integrate IoT with both traditional and self-driving vehicles.
- Other solutions include:
  - Automated vehicle tracking
  - Cargo management, and
  - Road weather communications.
- With automated vehicle tracking, a vehicle’s location is used for notification of arrival times, theft prevention, or highway assistance.

Contd …

- Today's typical road car utilizes more than a million lines of code.
- As cars continue to become more connected and capable of generating continuous data streams related to location, performance, driver behavior, and much more, the data generation potential of a single car is amazing.
  - It is estimated that a fully connected car will generate more than 25 gigabytes of data per hour

The Connected Car



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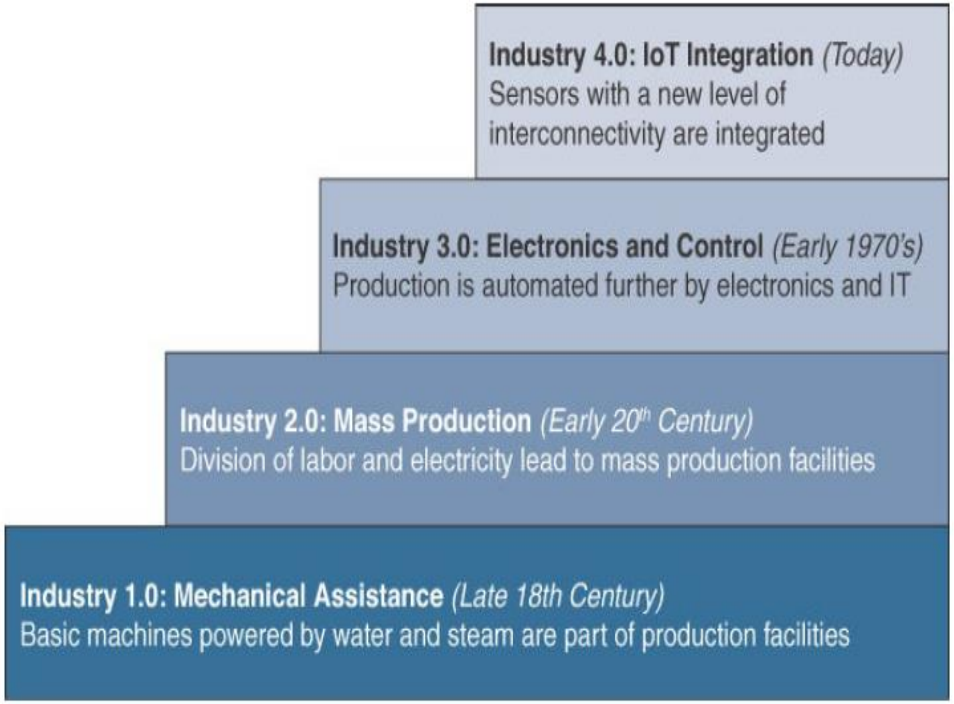
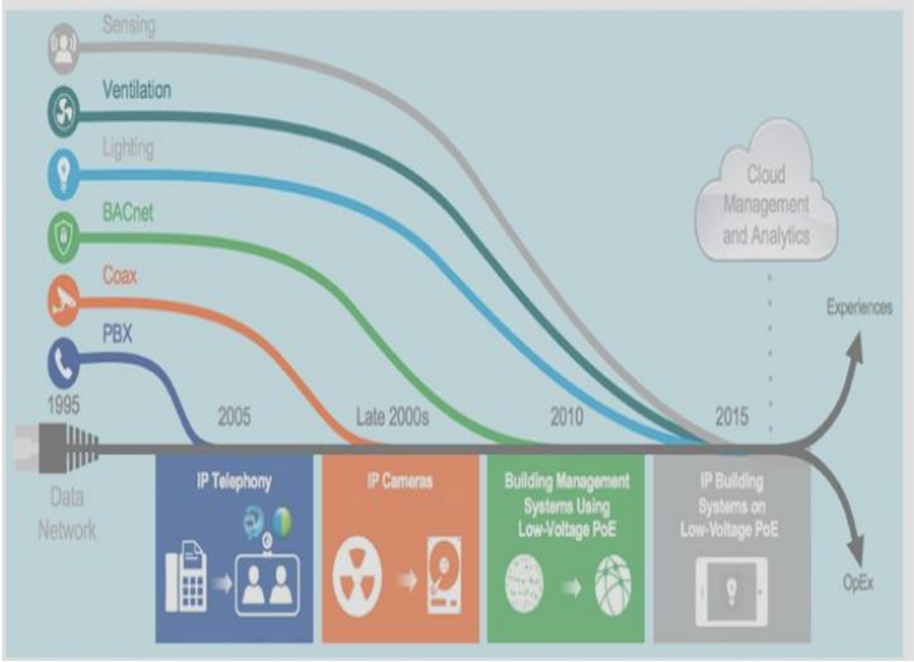
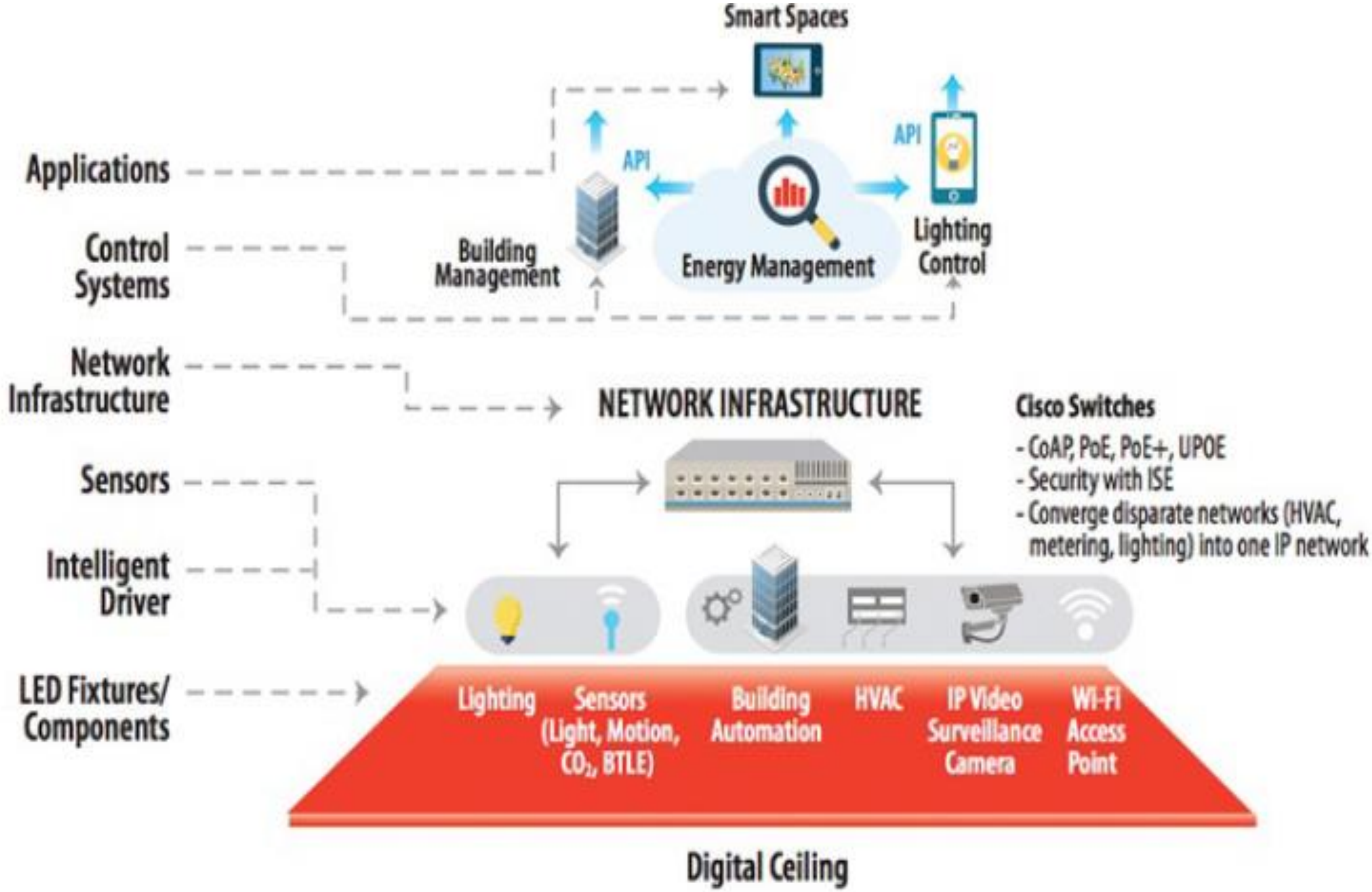
- In the future, car sensors will be able to interact with third-party applications, such as GPS/maps, to enable dynamic rerouting to avoid traffic, accidents, and other hazards.
- Similarly, Internet-based entertainment, including music, movies, and other streaming or downloads, can be personalized and customized to optimize a road trip.
- All these data opportunities bring into play a new technology: the **IoT data broker**

Other applications

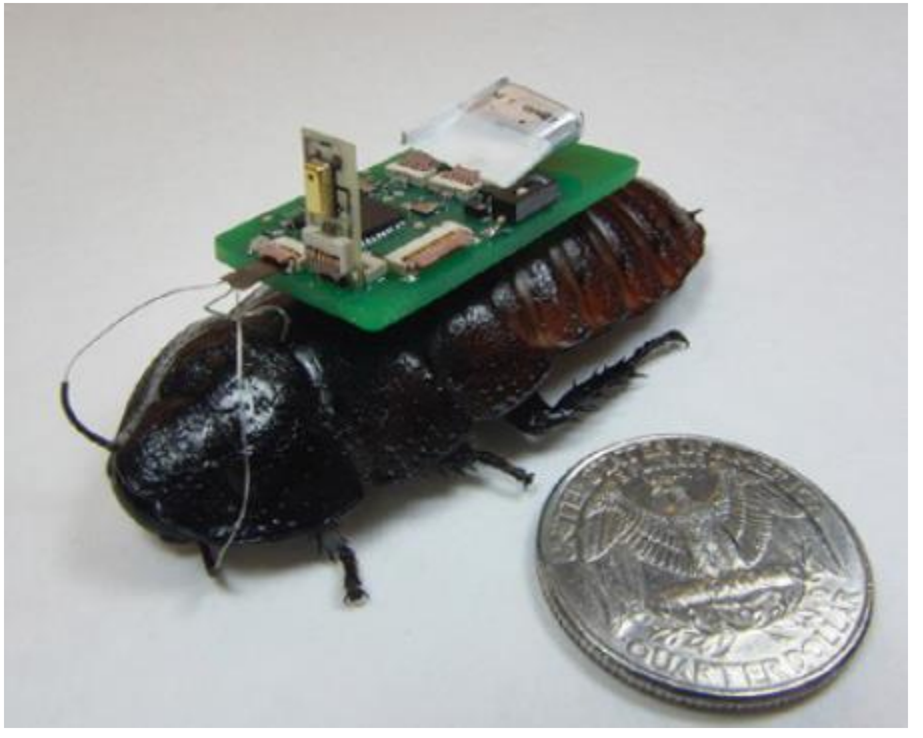
- **Connected Factory**
- **Smart Connected Buildings**






Smart Spaces
Applications
API
API
Building Management
Energy Management
Lighting Control
Control Systems
Network Infrastructure
NETWORK INFRASTRUCTURE
Cisco Switches
- CoAP, PoE, PoE+, UPOE
- Security with ISE
- Converge disparate networks (HVAC, metering, lighting) into one IP network
Sensors
Intelligent Driver
LED Fixtures/ Components
Lighting
Sensors (Light, Motion, CO2, BTLE)
Building Automation
HVAC
IP Video Surveillance Camera
Wi-Fi Access Point
Digital Ceiling

Smart Creatures



IoT-Enabled Roach Can Assist in Finding Survivors After a Disaster

Convergence of IT and OT

- Information technology (IT) and operational technology (OT) have for the most part lived in separate worlds.
- **IT** supports connections to the Internet along with related data and technology systems and is focused on the secure flow of data across an organization.
- **OT** monitors and controls devices and processes on physical operational systems.
  - These systems include assembly lines, utility distribution networks, production facilities, roadway systems, and many more.
- Typically, IT did not get involved with the production and logistics of OT environments.

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- The IT organization is responsible for the information systems of a business, such as email, file and print services, databases, and so on.
- The OT is responsible for the devices and processes acting on industrial equipment, such as factory machines, meters, actuators, electrical distribution automation devices
  - OT has used dedicated networks with specialized communications protocols to connect these devices, and these networks have run completely separately from the IT networks

Comparing Operational Technology (OT) and Information Technology (IT)

Criterion	Industrial OT Network	Enterprise IT Network
Operational focus	Keep the business operating 24x7	Manage the computers, data, and employee communication system in a secure way
Priorities	1. Availability 2. Integrity 3. Security	1. Security 2. Integrity 3. Availability
Types of data	Monitoring, control, and supervisory data	Voice, video, transactional, and bulk data
Security	Controlled physical access to devices	Devices and users authenticated to the network
Implication of failure	OT network disruption directly impacts business	Can be business impacting, depending on industry, but workarounds may be possible
Network upgrades (software or hardware)	Only during operational maintenance windows	Often requires an outage window when workers are not onsite; impact can be mitigated
Security vulnerability	Low: OT networks are isolated and often use proprietary protocols	High: continual patching of hosts is required, and the network is connected to Internet and requires vigilant protection

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- With the rise of IoT and standards-based protocols, such as IPv6, the IT and OT worlds are converging or, more accurately, OT is beginning to adopt the network protocols, technology, transport, and methods of the IT organization, and the IT organization is beginning to support the operational requirements used by OT.
- When IT and OT begin using the same networks, protocols, and processes, there are clear economies of scale.

Challenges

- There are fundamental cultural and priority differences between these two organizations.
- IoT is forcing these groups to work together, when in the past they have operated rather autonomously.
- Ex:
  - The OT organization is puzzled when IT schedules a weekend shutdown to update software without regard to production requirements.
  - On the other hand, the IT group does not understand the prevalence of proprietary or specialized systems and solutions deployed by OT.

Contd …

- The overall benefit of IT and OT working together is a more efficient and profitable business due to:
  - reduced downtime, lower costs through economy of scale, reduced inventory, and improved delivery times.
- When IT/OT convergence is managed correctly, IoT becomes fully supported by both groups.
- This provides a “best of both worlds” scenario, where solid industrial control systems reside on an open, integrated, and secure technology foundation

IoT Challenges

- Many parts of IoT have become reality, but certain obstacles need to be overcome for IoT to become ubiquitous throughout industry and our everyday life.

Challenge	Description
Scale	While the scale of IT networks can be large, the scale of OT can be several orders of magnitude larger. For example, one large electrical utility in Asia recently began deploying IPv6-based smart meters on its electrical grid. While this utility company has tens of thousands of employees (which can be considered IP nodes in the network), the number of meters in the service area is tens of millions. This means the scale of the network the utility is managing has increased by more than 1,000-fold! Chapter 5, "IP as the IoT Network Layer," explores how new design approaches are being developed to scale IPv6 networks into the millions of devices.
Security	With more "things" becoming connected with other "things" and people, security is an increasingly complex issue for IoT. Your threat surface is now greatly expanded, and if a device gets hacked, its connectivity is a major concern. A compromised device can serve as a launching point to attack other devices and systems. IoT security is also pervasive across just about every facet of IoT. For more information on IoT security, see Chapter 8, "Securing IoT."

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Privacy	As sensors become more prolific in our everyday lives, much of the data they gather will be specific to individuals and their activities. This data can range from health information to shopping patterns and transactions at a retail establishment. For businesses, this data has monetary value. Organizations are now discussing who owns this data and how individuals can control whether it is shared and with whom.
Big data and data analytics	IoT and its large number of sensors is going to trigger a deluge of data that must be handled. This data will provide critical information and insights if it can be processed in an efficient manner. The challenge, however, is evaluating massive amounts of data arriving from different sources in various forms and doing so in a timely manner. See Chapter 7 for more information on IoT and the challenges it faces from a big data perspective.
Interoperability	As with any other nascent technology, various protocols and architectures are jockeying for market share and standardization within IoT. Some of these protocols and architectures are based on proprietary elements, and others are open. Recent IoT standards are helping minimize this problem, but there are often various protocols and implementations available for IoT networks. The prominent protocols and architectures—especially open, standards-based implementations—are the subject of this book. For more information on IoT architectures, see Chapter 2, "IoT Network Architecture and Design," Chapter 4, "Connecting Smart Objects," Chapter 5, "IP as the IoT Network Layer," and Chapter 6, "Application Protocols for IoT," take a more in-depth look at the protocols that make up IoT.

Chapter 2

IoT Network Architecture and Design

Index

- Drivers Behind New Network Architectures
- Constrained Devices and Networks
- Comparing IoT Architectures
- A Simplified IoT Architecture
- The Core IoT Functional Stack
- IoT Data Management and Compute Stack

Drivers Behind New Network Architectures

- traditional network architectures for IT have served us well for many years, they are not well suited to the complex requirements of IoT
- The key difference between IT and IoT is the data.
  - While IT systems are mostly concerned with reliable and continuous support of business applications such as email, web, databases, CRM systems, and so on, IoT is all about the data generated by sensors and how that data is used.
- The essence of IoT architectures thus involves how the data is transported, collected, analyzed, and ultimately acted upon.

Challenge	Description	IoT Architectural Change Required
Scale	The massive scale of IoT end-points (sensors) is far beyond that of typical IT networks.	The IPv4 address space has reached exhaustion and is unable to meet IoT's scalability requirements. Scale can be met only by using IPv6. IT networks continue to use IPv4 through features like Network Address Translation (NAT).
Security	IoT devices, especially those on wireless sensor networks (WSNs), are often physically exposed to the world.	Security is required at every level of the IoT network. Every IoT endpoint node on the network must be part of the overall security strategy and must support device-level authentication and link encryption. It must also be easy to deploy with some type of a zero-touch deployment model.
Devices and networks constrained by power, CPU, mem-ory, and link speed	Due to the massive scale and longer distances, the networks are often constrained, lossy, and capable of supporting only minimal data rates (tens of bps to hundreds of Kbps).	New last-mile wireless technologies are needed to support constrained IoT devices over long distances. The network is also constrained, meaning modifications need to be made to traditional network-layer transport mechanisms.

The massive volume of data generated	The sensors generate a massive amount of data on a daily basis, causing network bottlenecks and slow analytics in the cloud.	Data analytics capabilities need to be distributed throughout the IoT network, from the edge to the cloud. In traditional IT networks, analytics and applications typically run only in the cloud.
Support for legacy devices	An IoT network often comprises a collection of modern, IP-capable endpoints as well as legacy, non-IP devices that rely on serial or proprietary protocols.	Digital transformation is a long process that may take many years, and IoT networks need to support protocol translation and/or tunneling mechanisms to support legacy protocols over standards-based protocols, such as Ethernet and IP.
The need for data to be analyzed in real time	Whereas traditional IT networks perform scheduled batch processing of data, IoT data needs to be analyzed and responded to in real-time.	Analytics software needs to be positioned closer to the edge and should support real-time streaming analytics. Traditional IT analytics software (such as relational databases or even Hadoop), are better suited to batch-level analytics that occur after the fact.

Scale

- The scale of a typical IT network is on the order of several thousand devices—typically printers, mobile wireless devices, laptops, servers, and so on.
- The traditional three-layer campus networking model, supporting access, distribution, and core.
  - What happens when the scale of a network goes from a few thousand endpoints to a few million.
  - How many IT engineers have ever designed a network that is intended to support millions of routable IP endpoints?
- This kind of scale has only previously been seen by the Tier 1 service providers.
- IoT introduces a model where an average-sized utility, factory, transportation system, or city could easily be asked to support a network of this scale.
- Based on scale requirements of this order, IPv6 is the natural foundation for the IoT network layer.

Security

- Evidence of targeted malicious attacks using vulnerabilities in networked machines
- The frequency and impact of cyber attacks in recent years has increased dramatically.
- Protecting corporate data from intrusion and theft is one of the main functions of the IT department.
  - IT departments go to great lengths to protect servers, applications, and the network, setting up defense-in-depth models with layers of security designed for protection
- Despite all the efforts mustered to protect networks and
- data, hackers still find ways to penetrate trusted networks.
  - The first line of defense is the perimeter firewall.

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- However, IoT endpoints are often located in wireless sensor networks that use unlicensed spectrum and are not only visible to the world through a spectrum analyzer but often physically accessible.
- As more OT systems become connected to IP networks, their capabilities increase, but so does their potential vulnerability
- Traditional models of IT security are simply not designed for the new attack vectors introduced by IoT systems.
- IoT systems require consistent mechanisms of authentication, encryption, and intrusion prevention techniques that understand the behavior of industrial protocols and can respond to attacks on critical infrastructure.

For optimum security, IoT systems must:

- Be able to identify and authenticate all entities involved in the IoT service (that is, gateways, endpoint devices, home networks, roaming networks, service platforms)
- Ensure that all user data shared between the endpoint device and back-end applications is encrypted
- Comply with local data protection legislation so that all data is protected and stored correctly
- Utilize an IoT connectivity management platform and establish rules based security policies so immediate action can be taken if anomalous behavior is detected from connected devices
- Take a holistic, network-level approach to security

Constrained Devices and Networks

- Most IoT sensors are designed for a single job, and they are typically small and inexpensive.
  - They often have limited power, CPU, and memory, and they transmit only when there is something important.
  - The networks that provide connectivity also tend to be very lossy and support very low data rates.
- This is a completely different situation from IT networks, which enjoy multi-gigabit connection speeds and endpoints with powerful CPUs.
- If an IT network has performance constraints: Upgrade to a faster network.
- If too many devices are on one VLAN and are impacting performance, carve out a new VLAN and continue to scale as much as need.
  - However, this approach cannot meet the constrained nature of IoT systems.
- IoT requires a new breed of connectivity technologies that meet both the scale and constraint limitations.

Data

- IoT devices generate a mountain of data.
- In general, most IT shops don't really care much about the unstructured data generated by devices on the network.
  - However, in IoT the data is precious, as it is what enables businesses to deliver new IoT services.
- Although most IoT-generated data is unstructured, the insights it provides through analytics can revolutionize processes and create new business models.
  - Ex: a smart city with a few hundred thousand smart streetlights, all connected through an IoT network

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- The insights that can help predict when lights need to be replaced or whether they can be turned on or off at certain times, thus saving operational expense.
- However, when all this data is combined, it can become difficult to manage and analyze effectively.
- Therefore, unlike IT networks, IoT systems are designed to stagger data consumption throughout the architecture, both to filter and reduce unnecessary data going upstream and to provide the fastest possible response to devices.

Legacy Device Support

- Supporting legacy devices in an IT organization is not usually a big problem.
- If someone’s computer or operating system is outdated, simply upgrade it.
- If someone is using a mobile device with an outdated Wi-Fi standard, such as 802.11b or 802.11g, simply deny them the access to the wireless network, and they will be forced to upgrade.
- In OT systems, end devices are likely to be on the network for a very long time—sometimes decades.
- As IoT networks are deployed, they need to support the older devices already present on the network, as well as devices with new capabilities.

Contd …

- Legacy devices are so old that they don't even support IP.
  - For example, a factory may replace machines only once every 20 years. It does not want to upgrade multi-million-dollar machines just so it can connect them to a network for better visibility and control.
- Many of these legacy machines might support older protocols, such as serial interfaces, and use RS-232.
- In this case, the IoT network must either be capable of some type of protocol translation or use a gateway device to connect these legacy endpoints to the IoT network.

Comparing IoT Architectures

- In the past several years, architectural standards and frameworks have emerged to address the challenge of designing massive-scale IoT networks.
- The foundational concept in all these architectures is supporting data, process, and the functions that endpoint devices perform.
- Two of the best-known architectures are those supported by oneM2M and the IoT World Forum (IoTWF)

The oneM2M IoT Standardized Architecture

- In an effort to standardize the rapidly growing field of machine-to-machine (M2M) communications, the European Telecommunications Standards Institute (ETSI) created the M2M Technical Committee in 2008.
- The goal of this committee was to create a common architecture that would help accelerate the adoption of M2M applications and devices.
- Over time, the scope has expanded to include the IoT.
- In 2012 ETSI and 13 other founding members launched oneM2M as a global initiative designed to promote efficient M2M communication systems and IoT.

Contd …

- The goal
- of oneM2M is to create a common services layer, which can be readily
- embedded in field devices to allow communication with application servers.1
- oneM2M’s framework focuses on IoT services, applications, and platforms.
- These include smart metering applications, smart grid, smart city automation, ehealth,
- and connected vehicles.

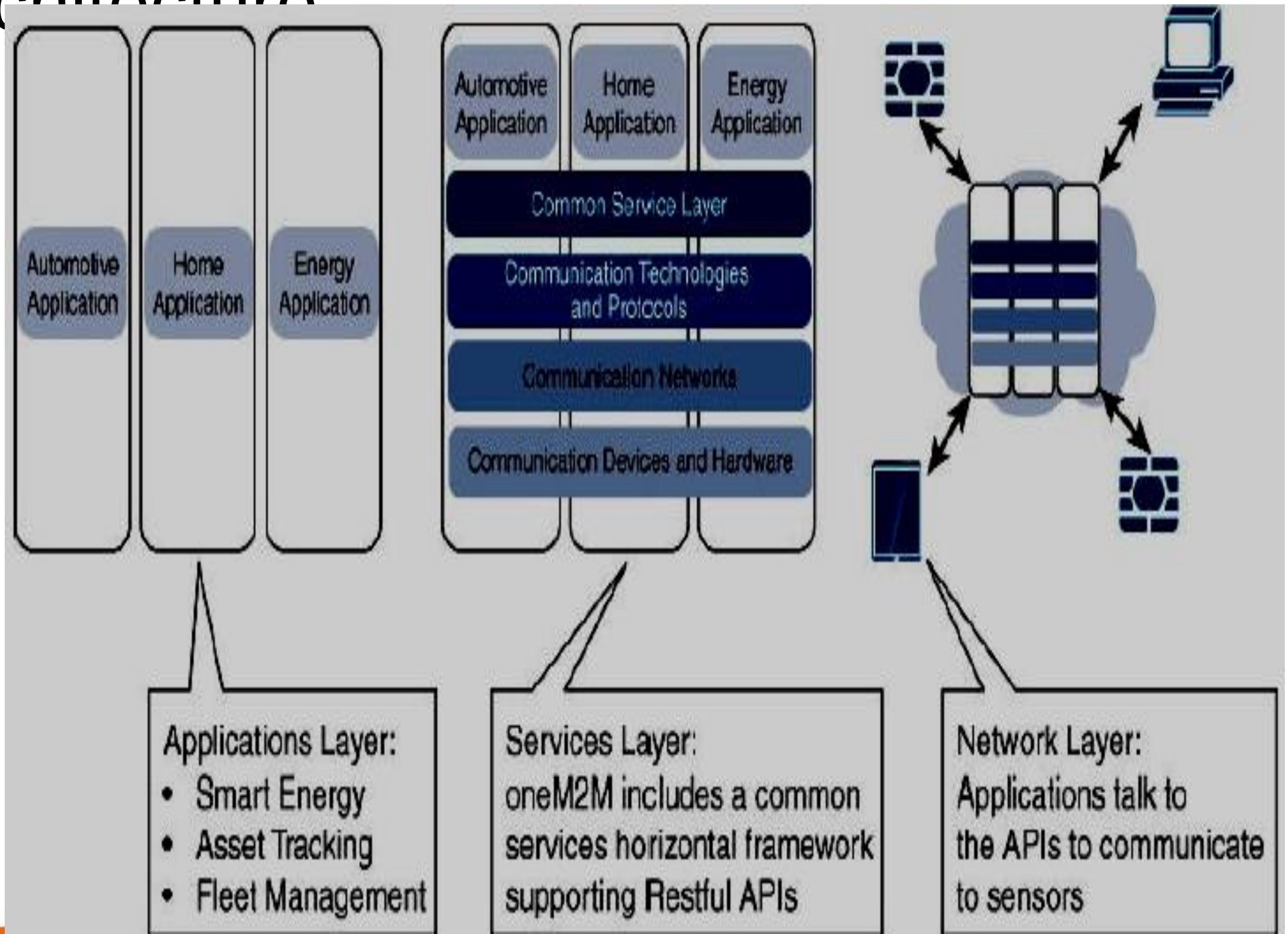
Contd …

- One of the greatest challenges in designing an IoT architecture is dealing with the heterogeneity of devices, software, and access methods.
- By developing a horizontal platform architecture, oneM2M is developing standards that allow interoperability at all levels of the IoT stack.
- Example: you might want to automate your HVAC system by connecting it with wireless temperature sensors spread throughout your office.

Contd …

- You decide to deploy sensors that use LoRaWAN technology.
- The problem is that the LoRaWAN network and the BACnet system that your HVAC and BMS run on are completely different systems and have no natural connection point.
- This is where the oneM2M common services architecture comes in.
- The oneM2M architecture divides IoT functions into three major domains:
  - the application layer, the services layer, and the network layer.

The Main Elements of the oneM2M IoT Architecture



Applications layer:

- The oneM2M architecture gives major attention to connectivity between devices and their applications.
- This domain includes the application-layer protocols and attempts to standardize northbound API definitions for interaction with business intelligence (BI) systems.
- Applications tend to be industry-specific and have their own sets of data models, and thus they are shown as vertical entities.

Services layer:

- This layer is shown as a horizontal framework across the vertical industry applications.
- At this layer, horizontal modules include the physical network that the IoT applications run on, the underlying management protocols, and the hardware.
  - Example: backhaul communications via cellular, MPLS networks, VPNs, and so on.
- Riding on top is the common services layer.
- This conceptual layer adds APIs and middleware supporting third-party services and applications.

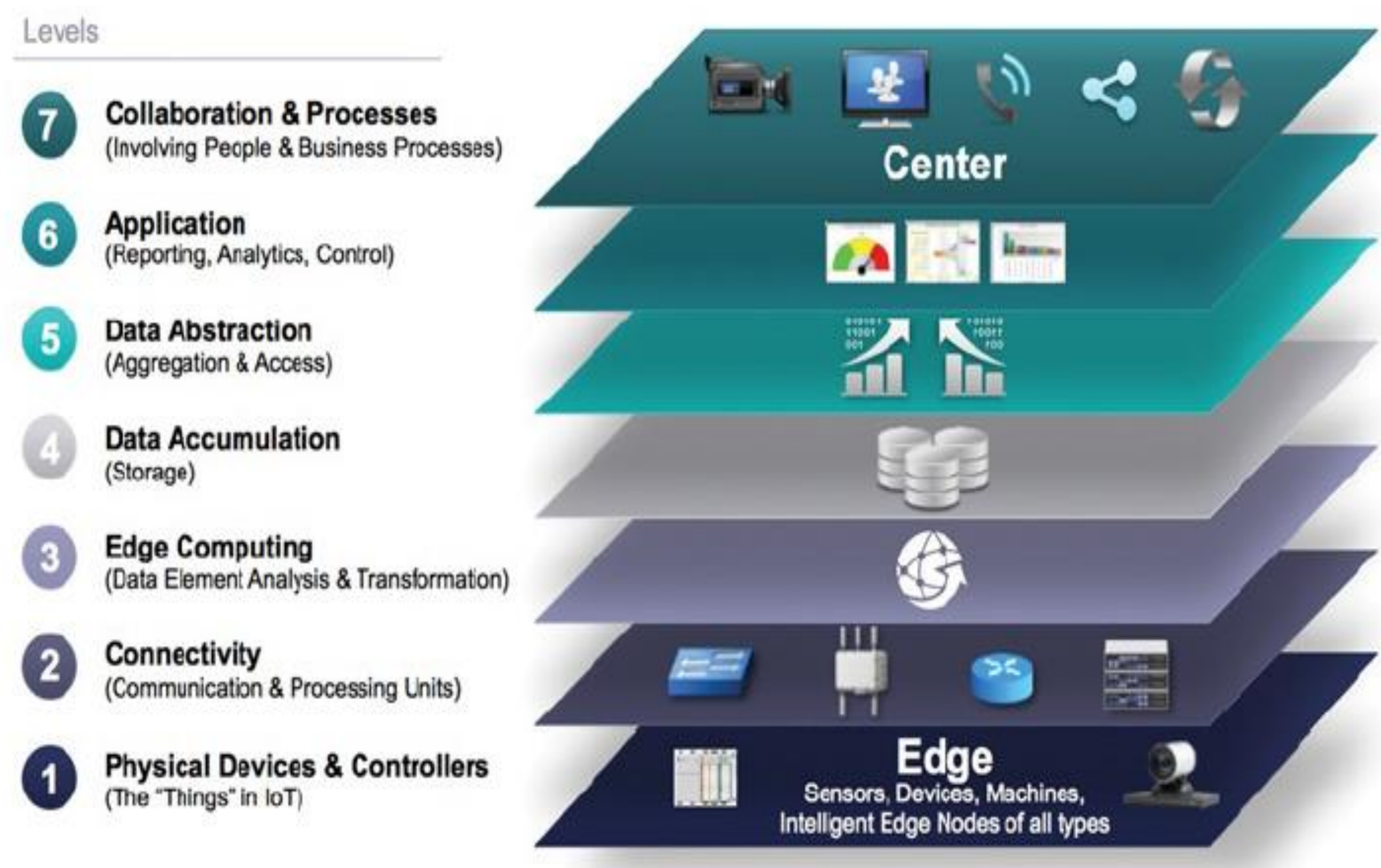
Network layer:

- This is the communication domain for the IoT devices and endpoints.
- It includes the devices themselves and the communications network that links them.
- Embodiments of this communications infrastructure include wireless mesh technologies, such as IEEE 802.15.4, and wireless point-to-multipoint systems, such as IEEE 801.11ah.
- Also included are wired device connections, such as IEEE 1901 power line communications.

The IoT World Forum (IoTWF) Standardized Architecture

- In 2014 the IoTWF architectural committee published a seven-layer IoT architectural reference model.
- While various IoT reference models exist, the one put forth by the IoT World Forum offers a clean, simplified perspective on IoT and includes edge computing, data storage, and access.
- It provides a brief way of visualizing IoT from a technical perspective.
- Each of the seven layers is broken down into specific functions, and security encompasses the entire model.

IoT Reference Model Published by the IoT World Forum



contd ...

- The IoT Reference Model defines a set of levels with control flowing from the center, to the edge, which includes sensors, devices, machines, and other types of intelligent end nodes.
- Data travels up the stack, originating from the edge, and goes to the center. Using this reference model, we are able to achieve the following:
  – Decompose the IoT problem into smaller parts
  – Identify different technologies at each layer and how they relate to one another
  – Define a system in which different parts can be provided by different vendors
  – Have a process of defining interfaces that leads to interoperability

contd ...

- Define a tiered security model that is enforced at the transition points between levels
- The following sections look more closely at each of the seven layers of the IoT Reference Model.

Layer 1: Physical Devices and Controllers Layer

- The first layer of the IoT Reference Model is the physical devices and controllers layer.
- This layer is home to the “things” in the Internet of Things, including the various endpoint devices and sensors that send and receive information.
- The size of these “things” can range from almost microscopic sensors to giant machines in a factory.
- Their primary function is generating data and being capable of being queried and/or controlled over a network.

Layer 2: Connectivity Layer

- In the second layer of the IoT Reference Model, the focus is on connectivity.
- The most important function of this IoT layer is the reliable and timely transmission of data.
- This includes transmissions between Layer 1 devices and the network and between the network and information processing that occurs at Layer 3 (the edge computing layer).
- The connectivity layer encompasses all networking elements of IoT and doesn't really distinguish between the last-mile network (the network between the sensor/ endpoint and the IoT gateway), gateway, and backhaul networks.

IoT Reference Model Connectivity Layer Functions

② **Connectivity**
(Communication and Processing Units)

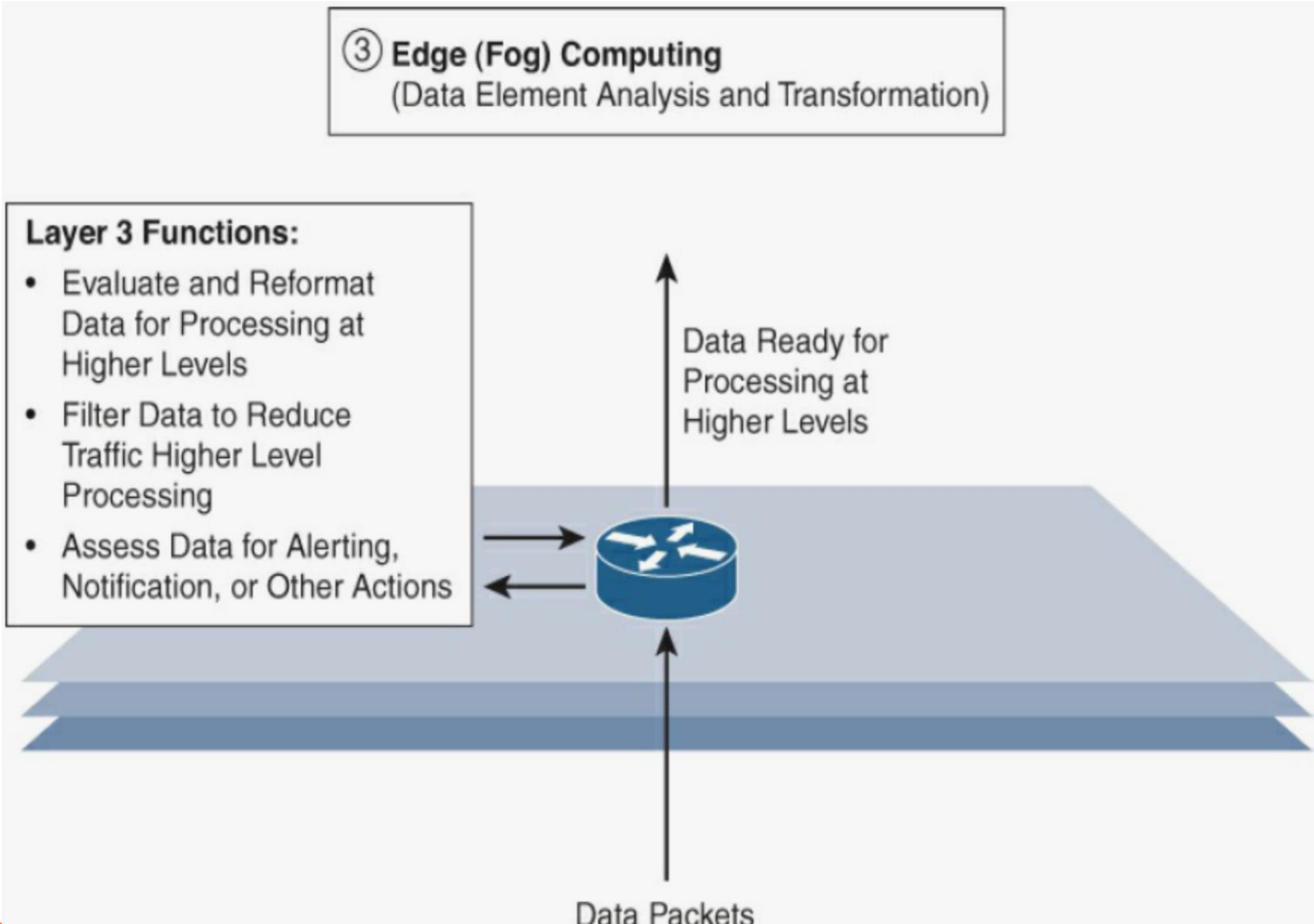
Layer 2 Functions:

- Communications Between Layer 1 Devices
- Reliable Delivery of Information Across the Network
- Switching and Routing
- Translation Between Protocols
- Network Level Security

Layer 3: Edge Computing Layer

- Edge computing is the role of Layer 3.
- Edge computing is often referred to as the “fog” layer
- At this layer, the emphasis is on data reduction and converting network data flows into information that is ready for storage and processing by higher layers.
- One of the basic principles of this reference model is that information processing is initiated as early and as close to the edge of the network as possible

IoT Reference Model Layer 3 Functions



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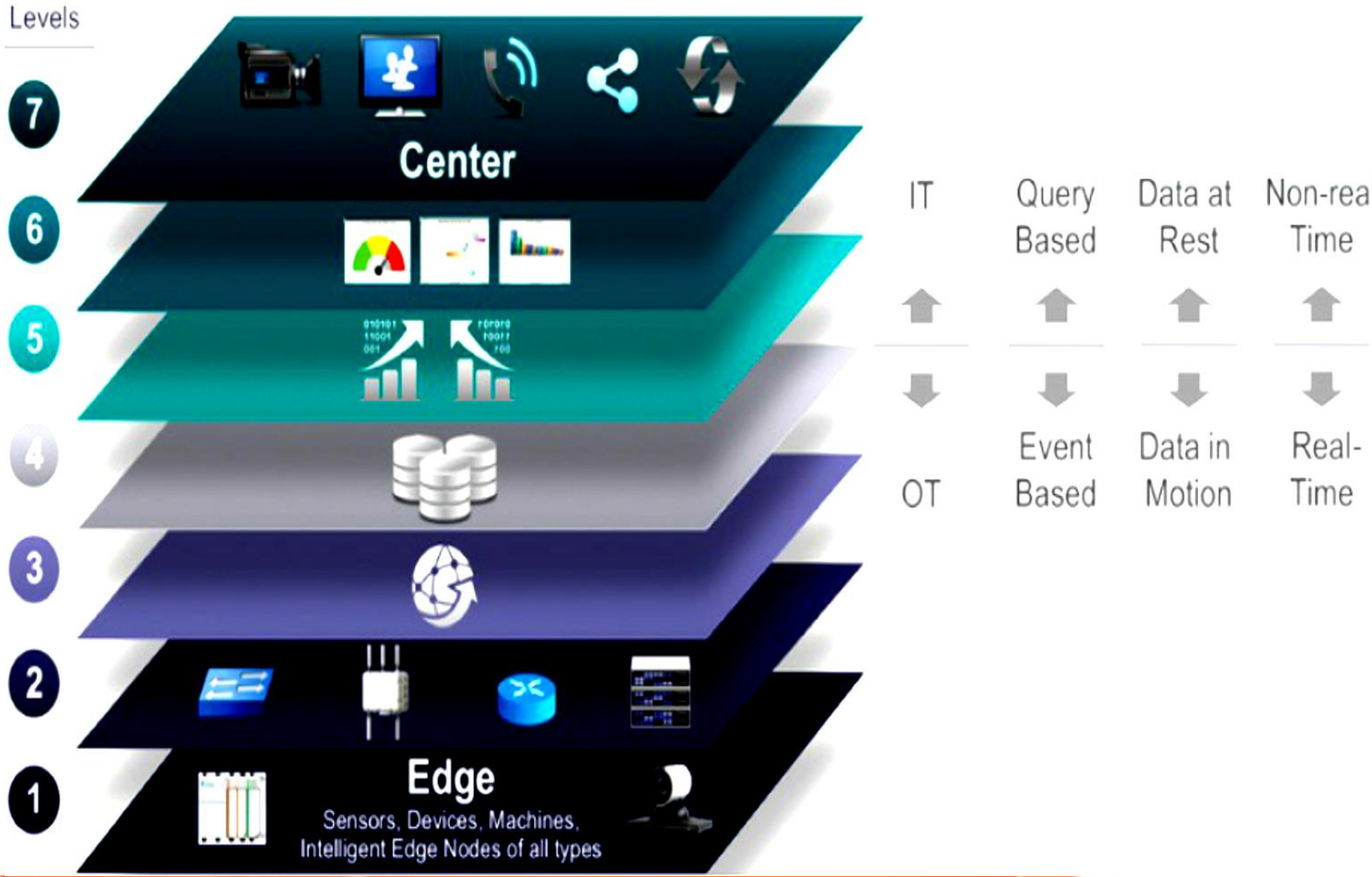
- Another important function that occurs at Layer 3 is the evaluation of data to see if it can be filtered or aggregated before being sent to a higher layer.
- This also allows for data to be reformatted or decoded, making additional processing by other systems easier.
- Thus, a critical function is assessing the data to see if predefined thresholds are crossed and any action or alerts need to be sent.

Upper Layers: Layers 4–7

- The upper layers deal with handling and processing the IoT data generated by the bottom layer.

IoT Reference Model Layer	Functions
Layer 4: Data accumulation layer	Captures data and stores it so it is usable by applications when necessary. Converts event-based data to query-based processing.
Layer 5: Data abstraction layer	Reconciles multiple data formats and ensures consistent semantics from various sources. Confirms that the data set is complete and consolidates data into one place or multiple data stores using virtualization.
Layer 6: Applications layer	Interprets data using software applications. Applications may monitor, control, and provide reports based on the analysis of the data.
Layer 7: Collaboration and processes layer	Consumes and shares the application information. Collaborating on and communicating IoT information often requires multiple steps, and it is what makes IoT useful. This layer can change business processes and delivers the benefits of IoT.

IT and OT Responsibilities in the IoT Reference Model



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- An interesting aspect of visualizing an IoT architecture this way is that you can start to organize responsibilities along IT and OT lines.
- IoT systems have to cross several boundaries beyond just the functional layers.
- The bottom of the stack is generally in the domain of OT.
  - For an industry like oil and gas, this includes sensors and devices connected to pipelines, oil rigs, refinery machinery, and so on.
- The top of the stack is in the IT area and includes things like the servers, databases, and applications, all of which run on a part of the network controlled by IT.
- In the past, OT and IT have generally been very independent and had little need to even talk to each other.
- IoT is changing that paradigm.

Contd ...

- At the bottom, in the OT layers, the devices generate real-time data at their own rate
- Not only does this result in a huge amount of data transiting the IoT network, but the top layer will be able to consume that much data at the rate required.
- To meet this requirement, data has to be buffered or stored at certain points within the IoT stack.
- Layering data management in this way throughout the stack helps the top four layers handle data at their own speed.
- As a result, the real-time “data in motion” close to the edge has to be organized and stored so that it becomes “data at rest” for the applications in the IT tiers.
- The IT and OT organizations need to work together for overall data management.

Additional IoT Reference Models

IoT Reference Model	Description
Purdue Model for Control Hierarchy	The Purdue Model for Control Hierarchy (see www.cisco.com/c/en/us/td/docs/solutions/Verticals/EttF/EttFDIG/ch2_EttF.pdf) is a common and well-understood model that segments devices and equipment into hierarchical levels and functions. It is used as the basis for ISA-95 for control hierarchy, and in turn for the IEC-62443 (formerly ISA-99) cyber security standard. It has been used as a base for many IoT-related models and standards across industry. The Purdue Model's application to IoT is discussed in detail in Chapter 9, "Manufacturing," and in Chapter 10, "Oil & Gas."

Contd ...

Industrial Internet Reference Architecture (IIRA) by Industrial Internet Consortium (IIC)	The IIRA is a standards-based open architecture for Industrial Internet Systems (IISs). To maximize its value, the IIRA has broad industry applicability to drive interoperability, to map applicable technologies, and to guide technology and standard development. The description and representation of the architecture are generic and at a high level of abstraction to support the requisite broad industry applicability. The IIRA distills and abstracts common characteristics, features and patterns from use cases well understood at this time, predominantly those that have been defined in the IIC.

Contd ...

Internet of Things–Architecture (IoT-A)	IoT-A created an IoT architectural reference model and defined an initial set of key building blocks that are foundational in fostering the emerging Internet of Things. Using an experimental paradigm, IoT-A combined top-down reasoning about architectural principles and design guidelines with simulation and prototyping in exploring the technical consequences of architectural design choices.

BGS Institute of Technology

Department of Computer science & Engineering

INTERNAL AUDITING

DATE: 23/07/2021

Name of the Faculty:	Swetha C.R
Designation:	Assistant professor
Subject Name with Code	Internet of things 17CS81

SL. No.	Contents	EVEN (2020-21) Theory	Lab
1	Faculty Profile	✓	[illegible]
2	Vision and Mission of the Institute	✓	
3	Vision and Mission of the Department	✓	
4	Department PEO's and PSOs,	✓	
5	Course Outcome	✓	
6	Mapping of COs and POs, PEOs, PSOs	✓	
7	Assessment Tools and Procedure for Assessment of Cos (IA Test, Quiz, Surprise test, Assignment, University Examination)	✗ ✓	
8	Previous University Question Papers	✓	
9	COE of Institute and COE of the Department (COE= Calendar of Events)	✓	
10	Time Table (Class and Individual)	✓	
11	Course Plan (Syllabus Copy along with CO and hours)	✗	
12	List of Text and Reference Books	✓	
13	Lesson Plan	✓	
14	Batch wise Assignments	✓	
15	Students Roll Call with phone numbers (Procter Details batch wise)	✓	
16	Report of Guest Lectures	✓	
17	Notes	✓	
18	Question Bank	✓	
19	FEED Back Report (Mid of the semester & End of the Semester)	✓	
20	Communications with Faculty and Students	✓	
21	Academic Diary	✓	
22	Course end survey		

Satisfactory.

Signature Of External Auditor   Signature Of Academic Incharge   Signature Of HoD   Signature Of principal

Dept. of Computer Science & Engg. B.G.S. [illegible] B.G. Nagar [illegible] Nagamangala Tq. [illegible]

Principal B.G.S.I.T.

||Jai Sri Gurudev||

BGS Institute of Technology

Department of Computer Science and Engineering

Academic year 2020-21	(ODD / EVEN)
Name of the Faculty with Designation	Swetha K.R, Assistant professor.
Course Name with code	Internet of things, 17CS81.

Feed Back Report

No. of Students participated	50/72	Overall Feedback	69.4%

Course End Survey

CO's	CO.1	CO.2	CO.3	CO.4	CO.5	CO.6
Av. Rating	2.52	2.58	2.58	2.58	2.58	

CO Attainment

CO's	CO.1	CO.2	CO.3	CO.4	CO.5	CO.6
Attainment	2.43	2.41	2.42	2.43	2.44	

PO / PSO Attainment

PO/PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
Attainment	1.13	1.8	0.80	1.62		0.80								1.62

Analysis of CO, PO/PSO Attainment [Review of attainment (course attainment)]

Suggest to increase attainment target value & to arrange guest lecturer/ workshop.

Shashi

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Karnataka (INDIA)

||Jai Sri Gurudev||

BGS Institute of Technology

Department of Computer Science and Engineering

Result Analysis CIE				
	Test-1	Test-2	Test-3	IA Final
22 (≥76%)	72	72	72	72
12-22 (≥41% ≤75%)				
12 (≤40%)				
Total No of Students	72	72	72	72

Action taken for Slow learners:

Test-1

Test-2

Result Analysis SEE					
Course name with Code	Total Appeared	FCD	FC	Pass %	Failed
Internet of things 17CS443	72	25	20	98%	01

Remarks: Satisfactory, Suggest to have one out of syllabus program! Shalini!

Seetha K.R.
Faculty

Shalini
HOD