IOT & WIRELESS SENSOR NETWORKS(17EC752)

MODULE- 1

Overview of Internet of Things:

- **Syllabus:**

  IoT Conceptual Framework, IoT Architectural View, Technology Behind IoT, Sources of IoT,M2M communication, Examples of IoT. Modified OSI Model for the IoT/M2M Systems, data enrichment, data consolidation and device management at IoT/M2M Gateway, web communication protocols used by connected IoT/M2M devices, Message communication protocols (CoAP-SMS, CoAPMQ, MQTT,XMPP) for IoT/M2M devices.

- **Definition:**

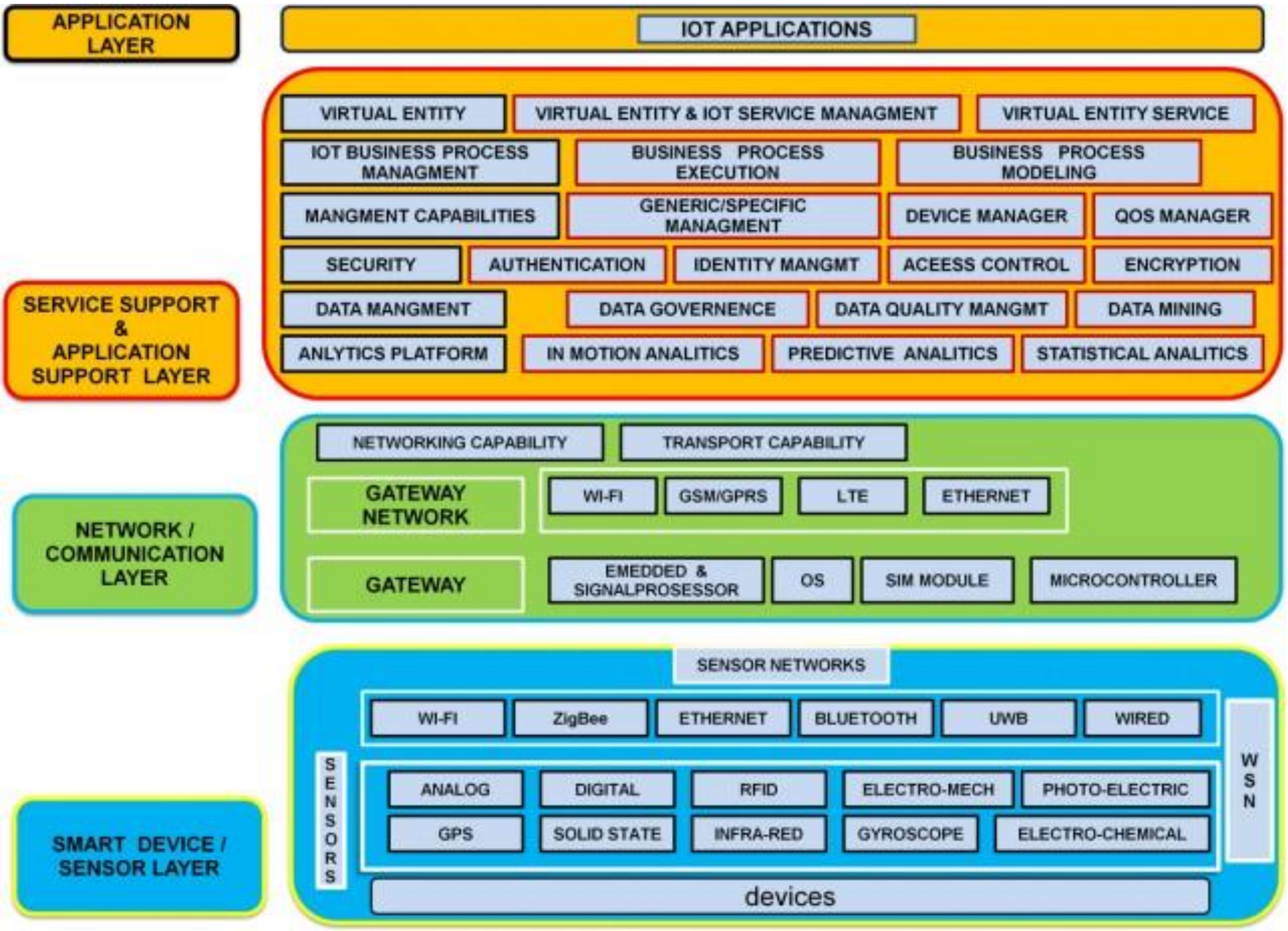
  The **Internet of Things (IoT)** is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.

- **ALTERNATIVE DEFNITION:**

The **Internet of things** refers to a type of network to connect anything with the Internet based on stipulated protocols through information sensing equipments to conduct information exchange and communications in order to achieve smart recognitions, positioning, tracing, monitoring, and administration.

- **Characteristics of IoT:**
- Interconnectivity
- Things-related services
- Heterogeneity
- Dynamic changes
- Enormous scale
- Safety
- Connectivity

Basic IoT Architectural View



APPLICATION LAYER

IOT APPLICATIONS

SERVICE SUPPORT & APPLICATION SUPPORT LAYER

VIRTUAL ENTITY | VIRTUAL ENTITY & IOT SERVICE MANAGMENT | VIRTUAL ENTITY SERVICE

IOT BUSINESS PROCESS MANAGMENT | BUSINESS PROCESS EXECUTION | BUSINESS PROCESS MODELING

MANGMENT CAPABILITIES | GENERIC/SPECIFIC MANAGMENT | DEVICE MANAGER | QOS MANAGER

SECURITY | AUTHENTICATION | IDENTITY MANGMT | ACEESS CONTROL | ENCRYPTION

DATA MANGMENT | DATA GOVERNENCE | DATA QUALITY MANGMT | DATA MINING

ANLYTICS PLATFORM | IN MOTION ANALITICS | PREDICTIVE ANALITICS | STATISTICAL ANALITICS

NETWORK / COMMUNICATION LAYER

NETWORKING CAPABILITY | TRANSPORT CAPABILITY

GATEWAY NETWORK | WI-FI | GSM/GPRS | LTE | ETHERNET

GATEWAY | EMEDDED & SIGNALPROSESSOR | OS | SIM MODULE | MICROCONTROLLER

SMART DEVICE / SENSOR LAYER

SENSOR NETWORKS

WI-FI | ZigBee | ETHERNET | BLUETOOTH | UWB | WIRED

SENSORS

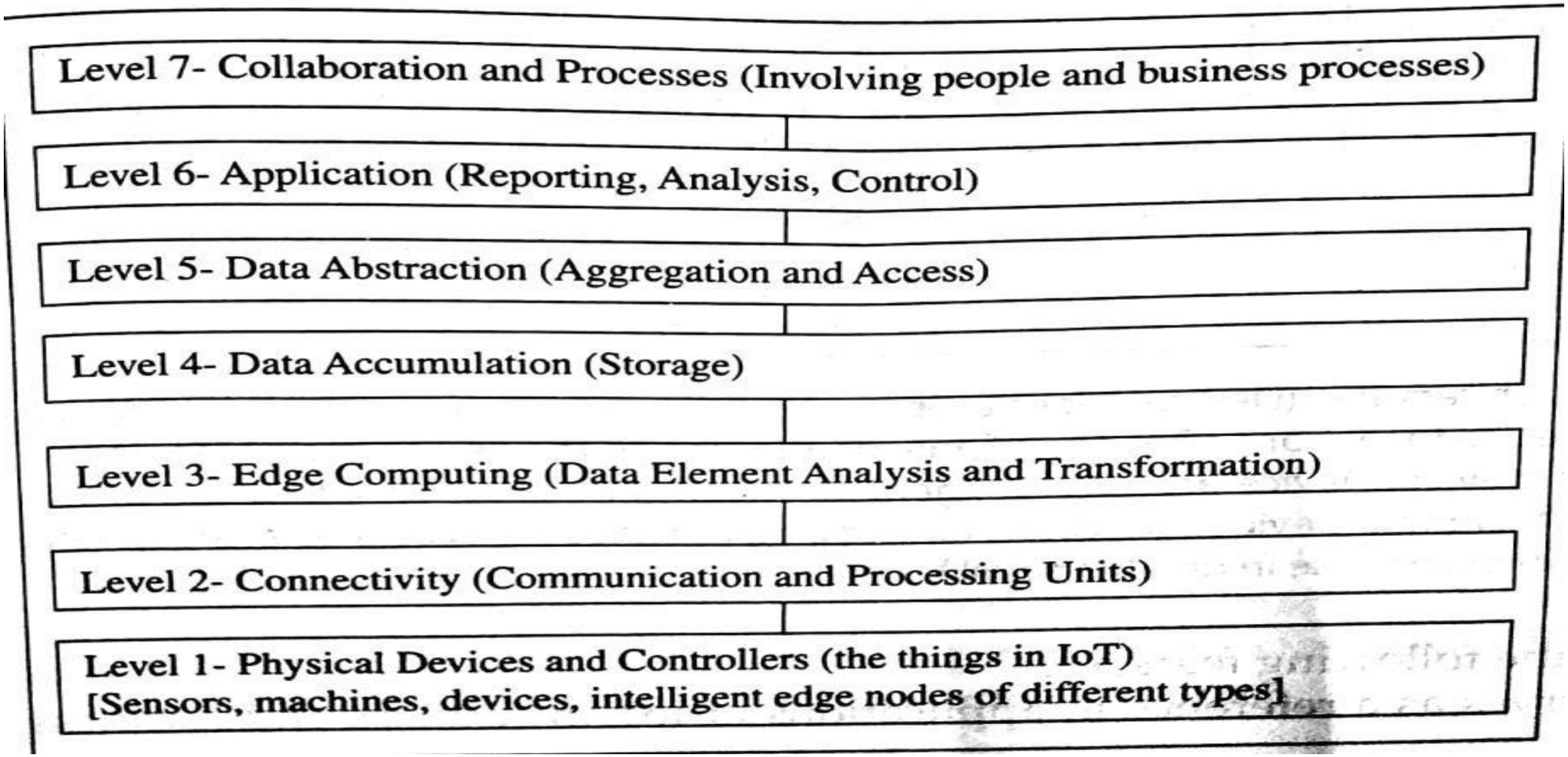
ANALOG | DIGITAL | RFID | ELECTRO-MECH | PHOTO-ELECTRIC

GPS | SOLID STATE | INFRA-RED | GYROSCOPE | ELECTRO-CHEMICAL

WSN

devices

IoT Architectural View



Level 7- Collaboration and Processes (Involving people and business processes)

Level 6- Application (Reporting, Analysis, Control)

Level 5- Data Abstraction (Aggregation and Access)

Level 4- Data Accumulation (Storage)

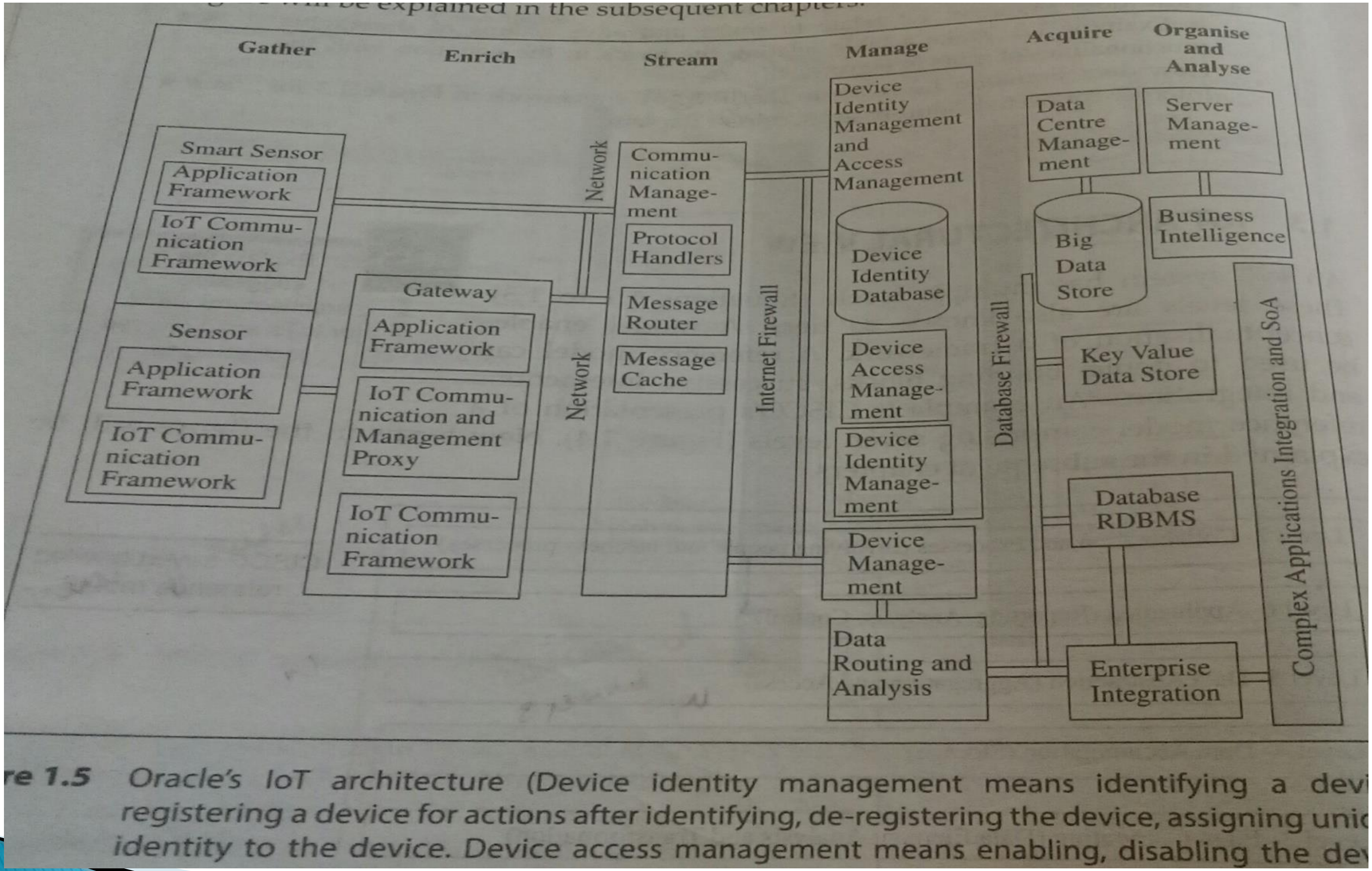
Level 3- Edge Computing (Data Element Analysis and Transformation)

Level 2- Connectivity (Communication and Processing Units)

Level 1- Physical Devices and Controllers (the things in IoT)
[Sensors, machines, devices, intelligent edge nodes of different types]

IEEE P2413

- Follows top- down approach.
- Does not define a new architecture but reinvent existing architectures congruent with it
- Gives a blue print for data abstraction.
- Specifies abstract IoT domain for various IoT domains.
- Recommends quality ‘**quadruple**’ trust that includes protection, security, privacy and safety.
- Addresses the documentation of data.
- Strives for mitigating architecture divergence



explained in the subsequent chapters.

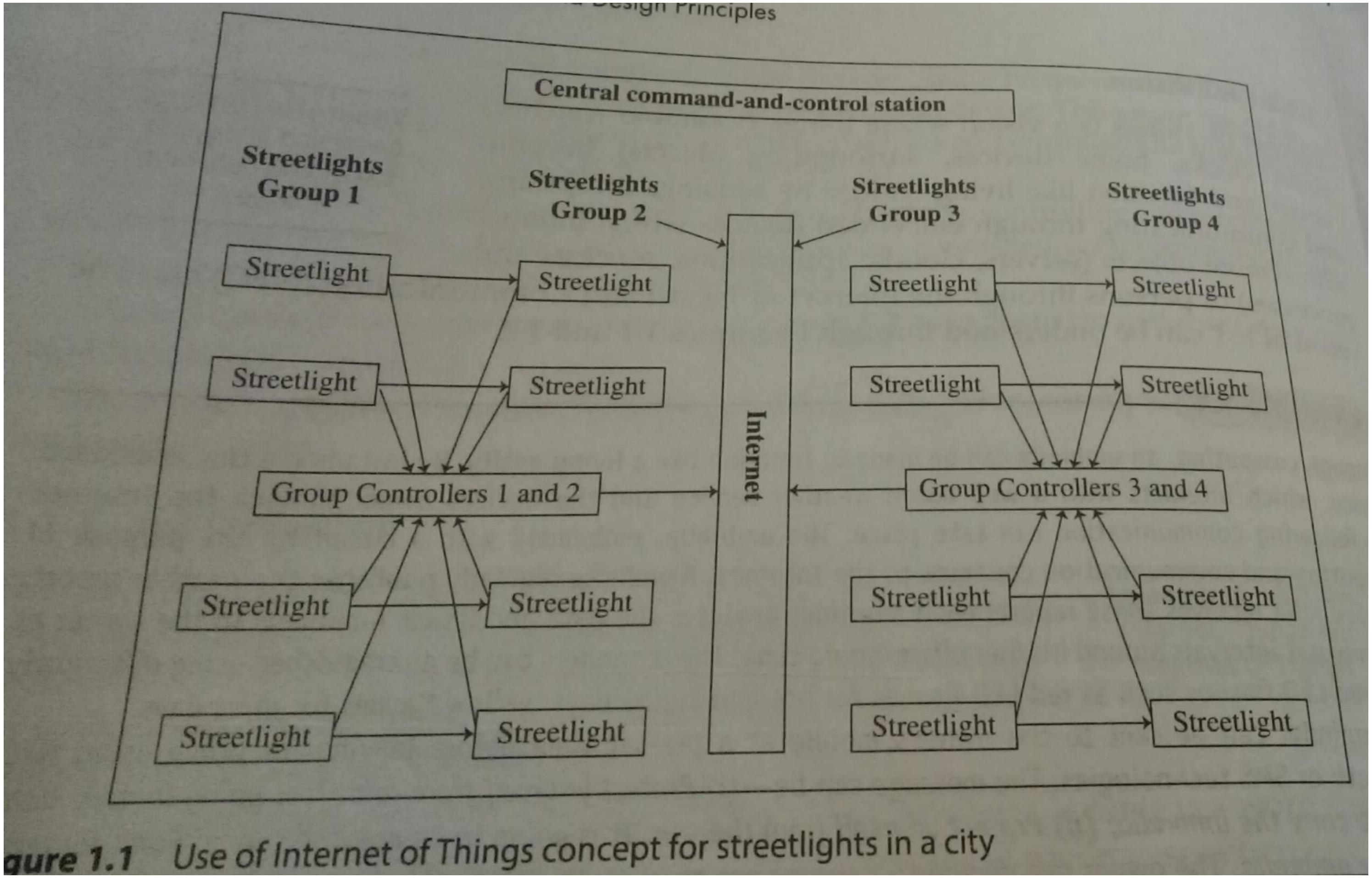
re 1.5 Oracle's IoT architecture (Device identity management means identifying a devi registering a device for actions after identifying, de-registering the device, assigning unic identity to the device. Device access management means enabling, disabling the dev

IoT Conceptual Frame Work:

- *Explain the concept of operation in an IoT System.*
- *Explain the Oracle Conceptual Frame work of IoT*
- *Explain the IBM Conceptual Frame work of IoT*

Physical Object+ Controller, Sensor & Actuators+ Internet= IoT................(1)

Example: street light controller



Central command-and-control station

Streetlights Group 1

Streetlights Group 2

Streetlights Group 3

Streetlights Group 4

Internet

Group Controllers 1 and 2

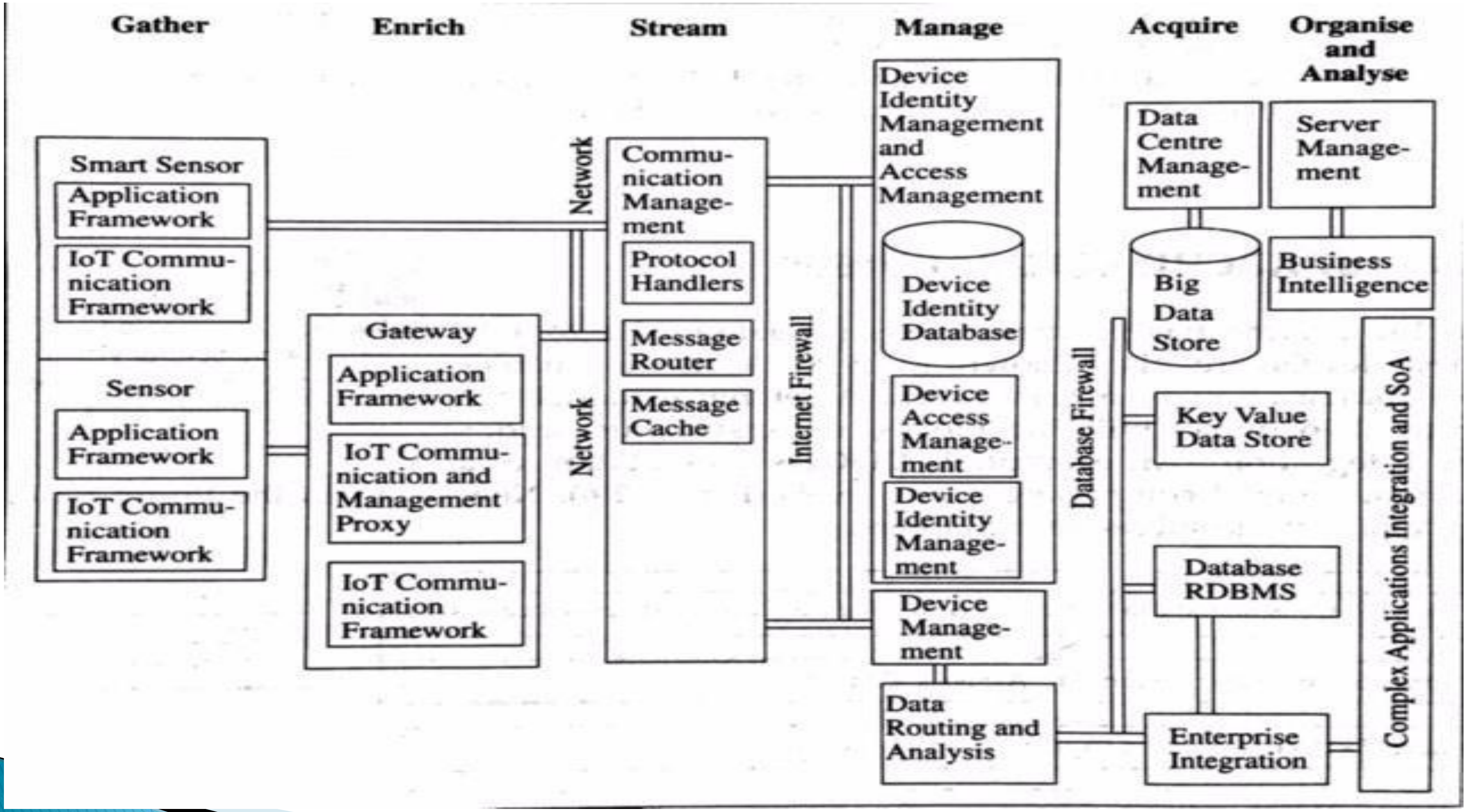
Group Controllers 3 and 4

Streetlight

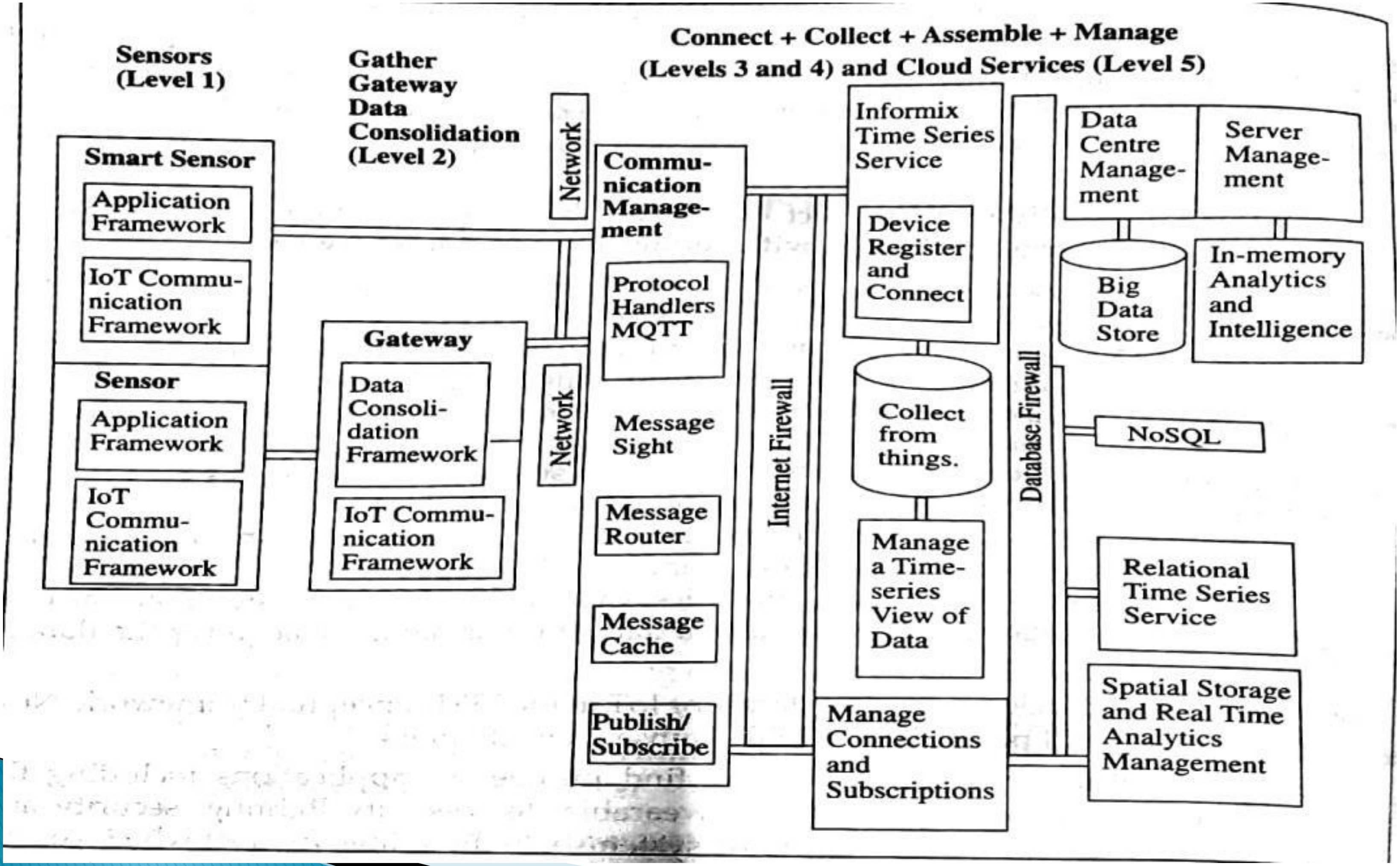
gure 1.1 Use of Internet of Things concept for streetlights in a city

- Gather + Enrich + Stream + Manage + Acquire + Organise& Analyse

=IoT with Connectivity to Data enter, Enterprise or Cloud……(ORACLE)



- Gather + Consolidate + Connect + Assemble + Manage& Analyse = IoT With Connectivity to Cloud Services……(IBM)


Sensors (Level 1)
Gather Gateway Data Consolidation (Level 2)
Connect + Collect + Assemble + Manage (Levels 3 and 4) and Cloud Services (Level 5)
Smart Sensor
Application Framework
IoT Communication Framework
Sensor
Application Framework
IoT Communication Framework
Gateway
Data Consolidation Framework
IoT Communication Framework
Network
Network
Communication Management
Protocol Handlers MQTT
Message Sight
Message Router
Message Cache
Publish/ Subscribe
Internet Firewall
Informix Time Series Service
Device Register and Connect
Collect from things.
Manage a Time-series View of Data
Manage Connections and Subscriptions
Database Firewall
Data Centre Management
Server Management
Big Data Store
In-memory Analytics and Intelligence
NoSQL
Relational Time Series Service
Spatial Storage and Real Time Analytics Management

Technology Behind IOT

- Hardware
- Integrated Development Environment (IDE)
- Protocols- HTTP,CoAP,MQTT,XMPP
- Communication-ZigBee,Bluetooth,WiFi, Ethernet, NFC,6LowPAN
- Network Backbone
- Software-RIOT OS, Eclipse IoT, Contiki OS
- Internetwork Cloud platforms/ Data Centre
- Machine Learning Algorithm and Software

Five Entities For Five Levels Behind an IOT System

- Device platform- hardware+software

  hardware- microcontroller, SOC

  software-API and web applications
- Connecting and Networking
- Server and web programming
- Cloud platform
- Online transactions processing, online analytics processing,data anaylitcs, predictive analytics and knowledge discovery for wider applications

Major Components of IoT System

- Physical Object
- Hardware
- Communication module
- Software

- Sensors and actuators
- Analog input to controller, example-thermistor, photoconductor, pressure guage and Hall sensor

- Digital input to cntroller,example-touch sensor, proximity sensor, metal sensor, traffic presence sensor

- Control units
- Microcontroller unit(MCU) or custom chip
- ATMega 328, ATMega 32u4, ARM Cortex and ARM LPC

MCU consists of

- Processor
- Internal RAM
- Internal Flash and Firmware
- Timers
- Programmable IO Ports
- General Purpose IO Ports
- Serial IO Ports
- PWM
- Analog to digital converter
- Communication network interface

- Communication Module:

–Protocol handlers, message queue and message cache.

- Software:
  - IoT device
  - IoT server
- Middleware:

–OpenIoT

–IoTSyS

–oBEX

- Operating System

–RIOT

–Raspbian

–Alloyn

–Spark

–Contiki OS

- Firmware

–Thingsquare Mist

- Development Tools and Open source framework for IoT implementation

–Eclipse IoT

–Arduino

–Kinoma Software platform

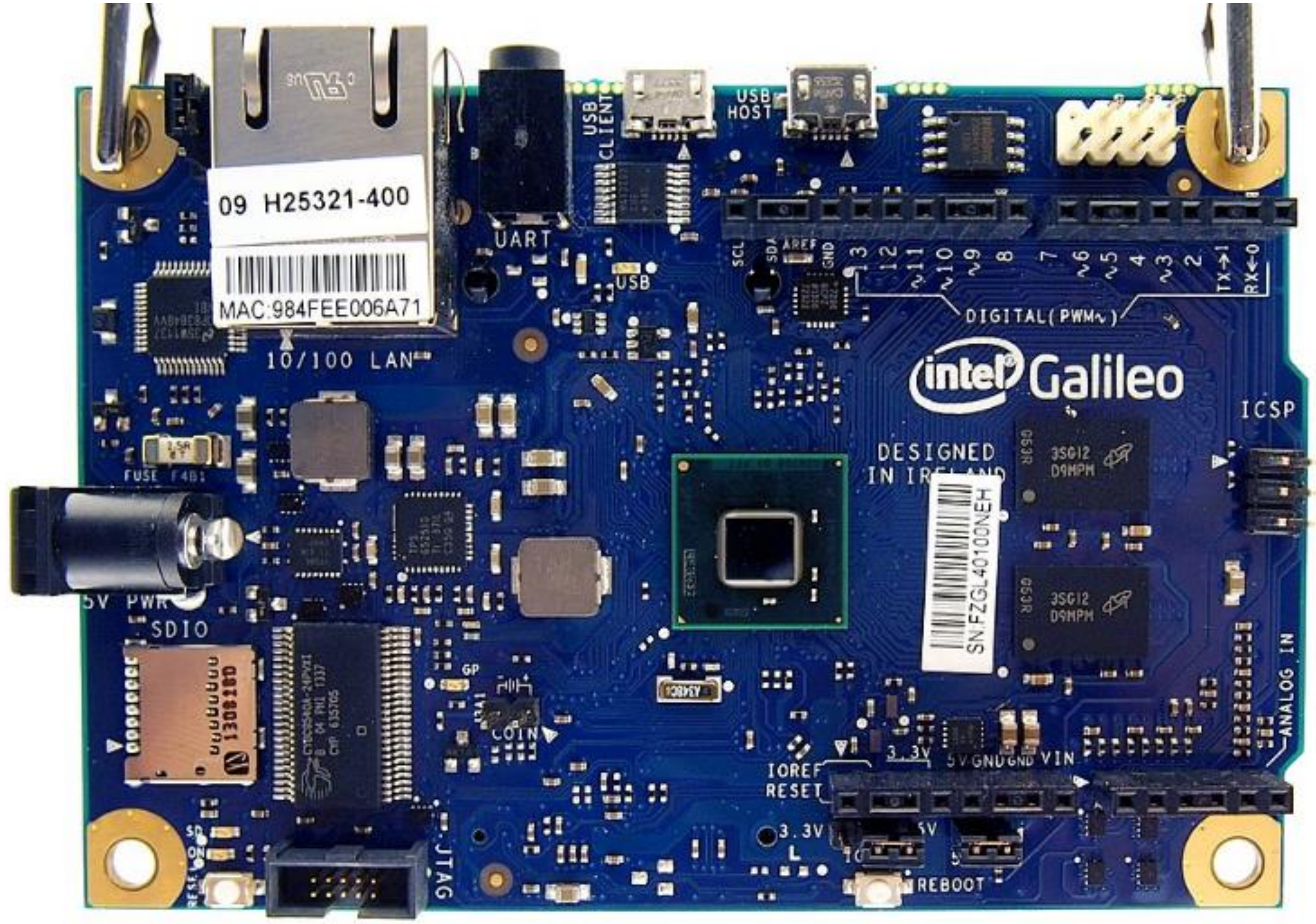
- APIs and device interfacing components

ARDUINO YUN

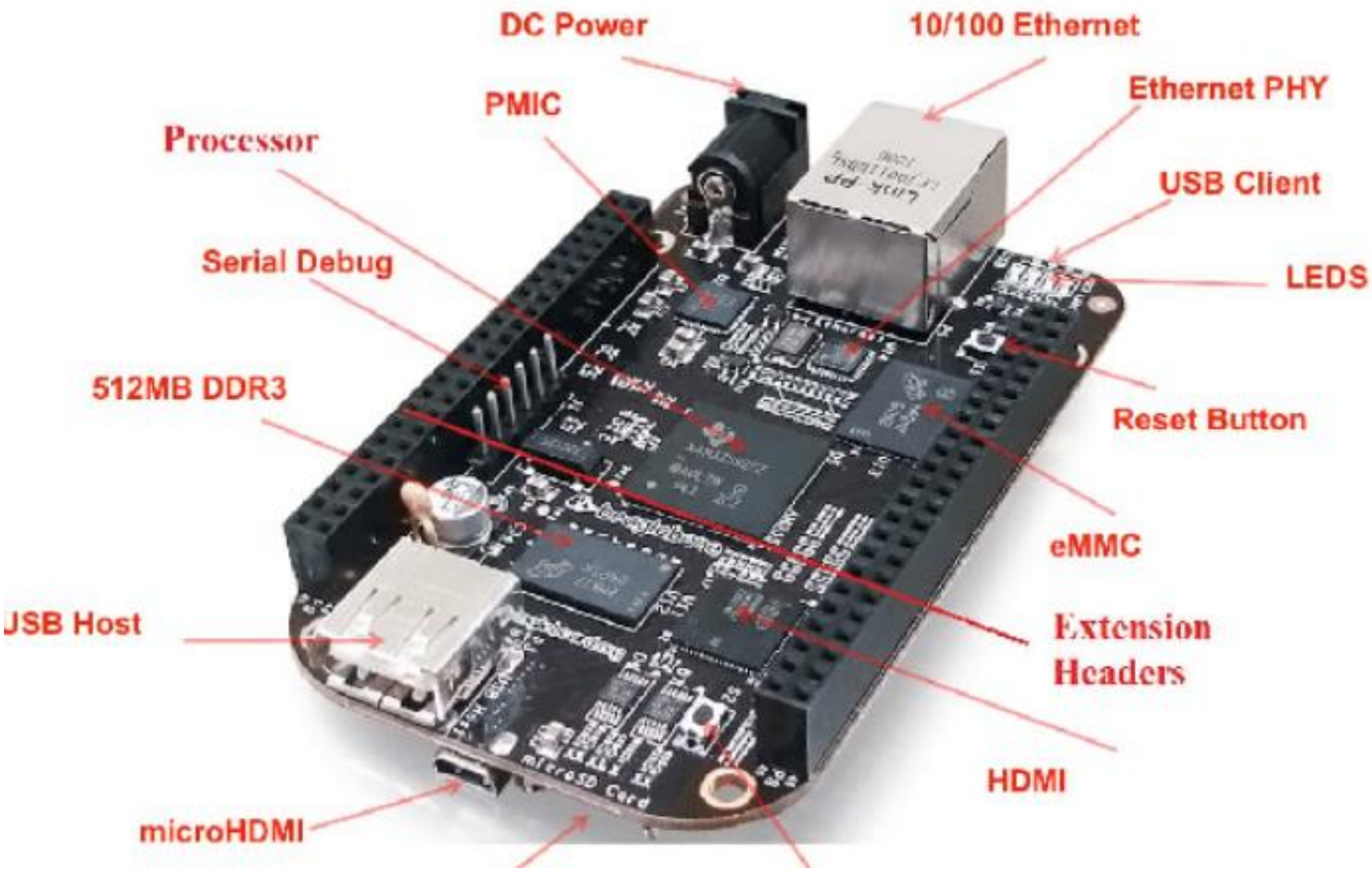
UNO
ARDUINO
DIGITAL (PWM~)
POWER
ANALOG IN
ARDUINO.CC
RESET
AREF
GND
TX
RX
ON
ICSP
IOREF
3.3V
5V
Vin
A0
A1
A2
A3
A4
A5

MICRODUINO

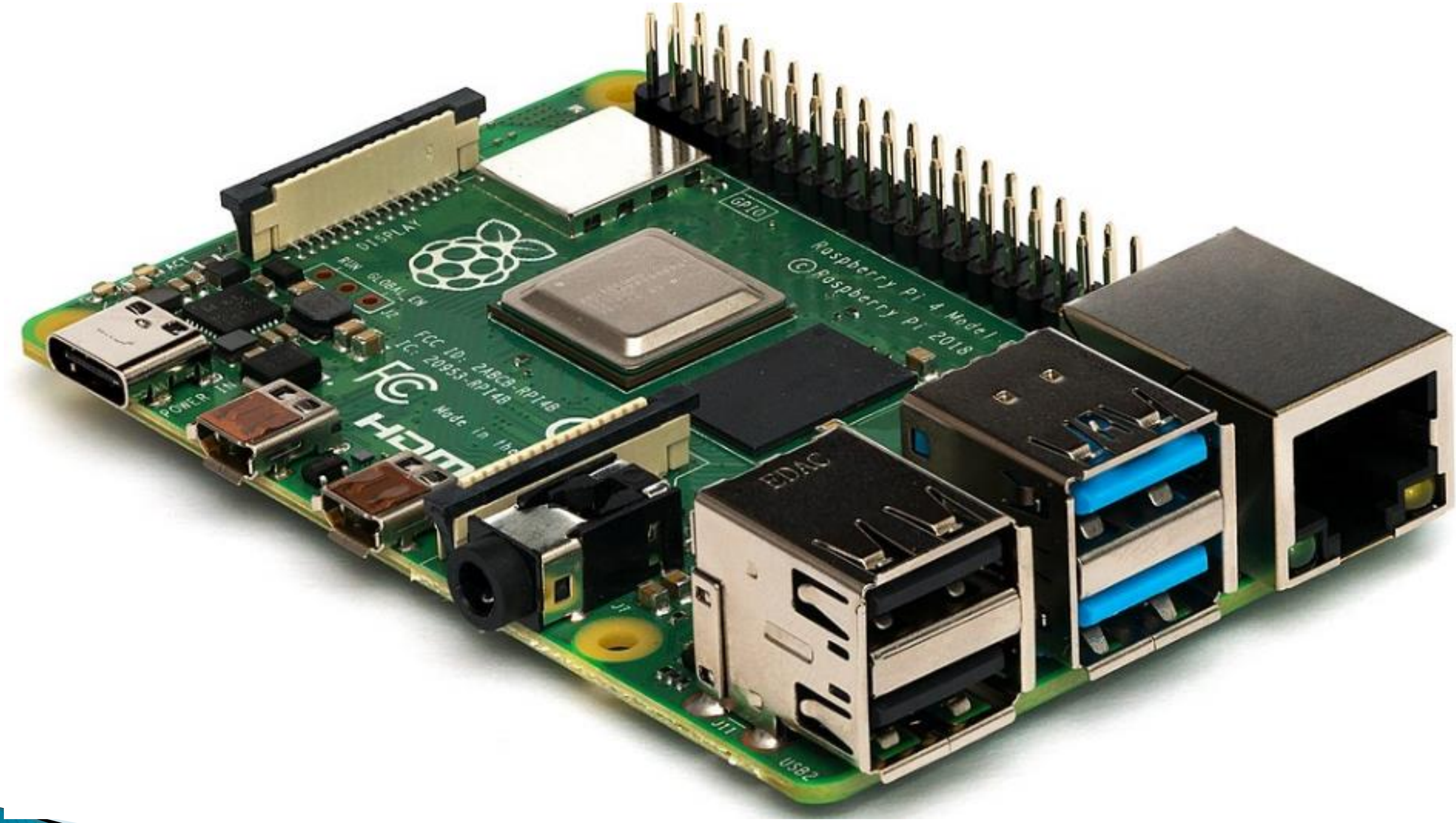
INTEL GALILEO



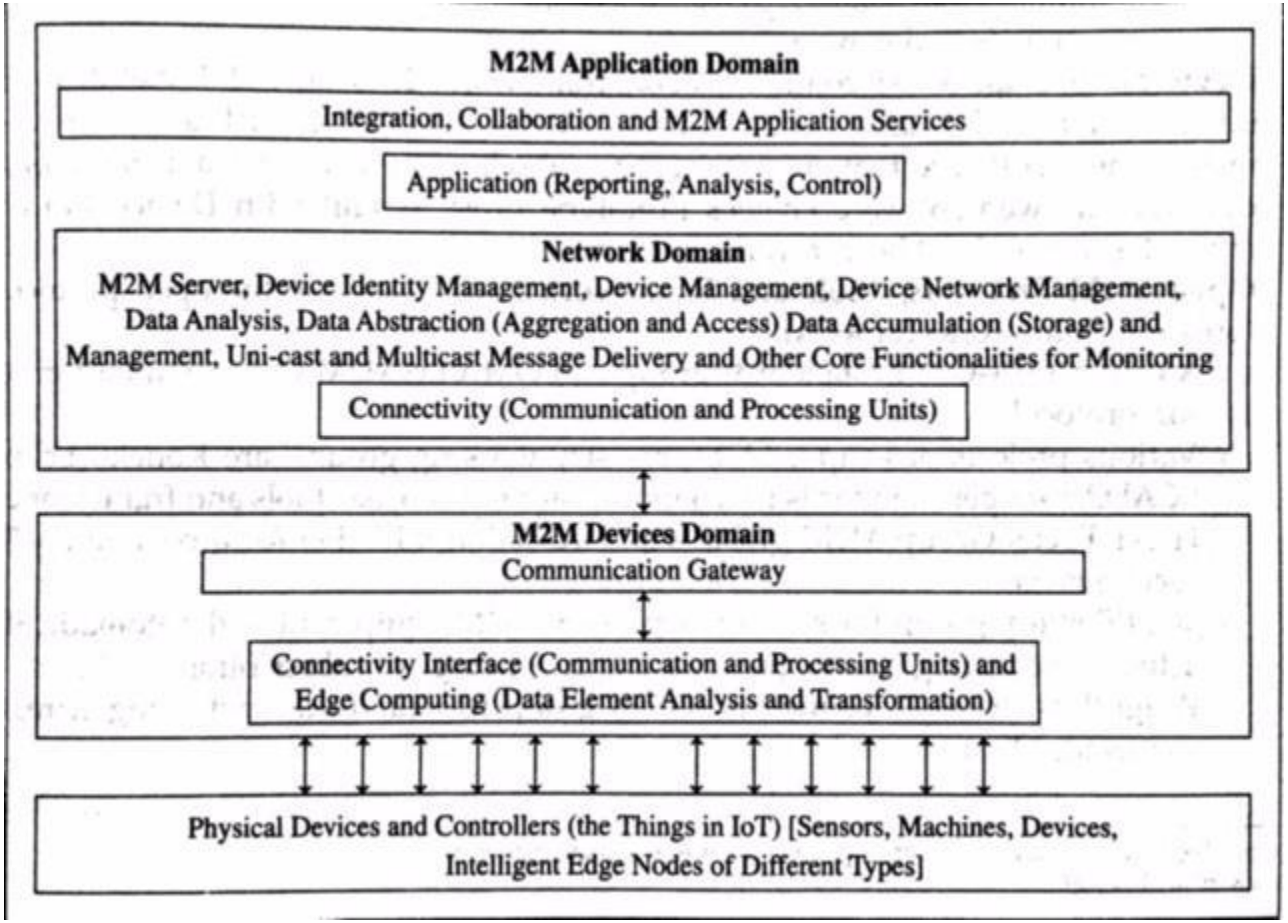
BEAGLE BOARD



RASPBERRY PI



M2M Communication –Architecture



M2M Application Domain

Integration, Collaboration and M2M Application Services

Application (Reporting, Analysis, Control)

Network Domain

M2M Server, Device Identity Management, Device Management, Device Network Management, Data Analysis, Data Abstraction (Aggregation and Access) Data Accumulation (Storage) and Management, Uni-cast and Multicast Message Delivery and Other Core Functionalities for Monitoring

Connectivity (Communication and Processing Units)

M2M Devices Domain

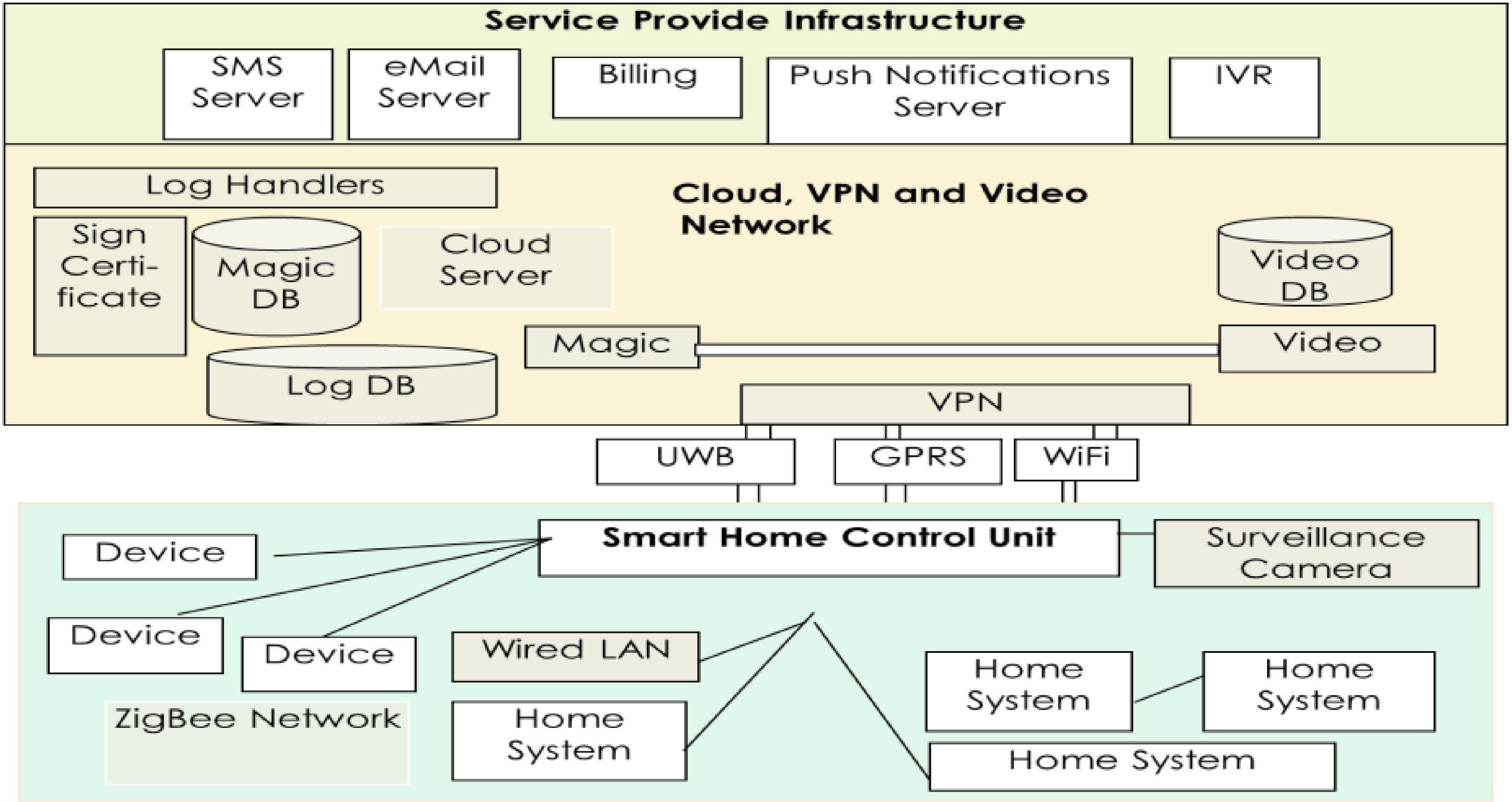
Communication Gateway

Connectivity Interface (Communication and Processing Units) and Edge Computing (Data Element Analysis and Transformation)

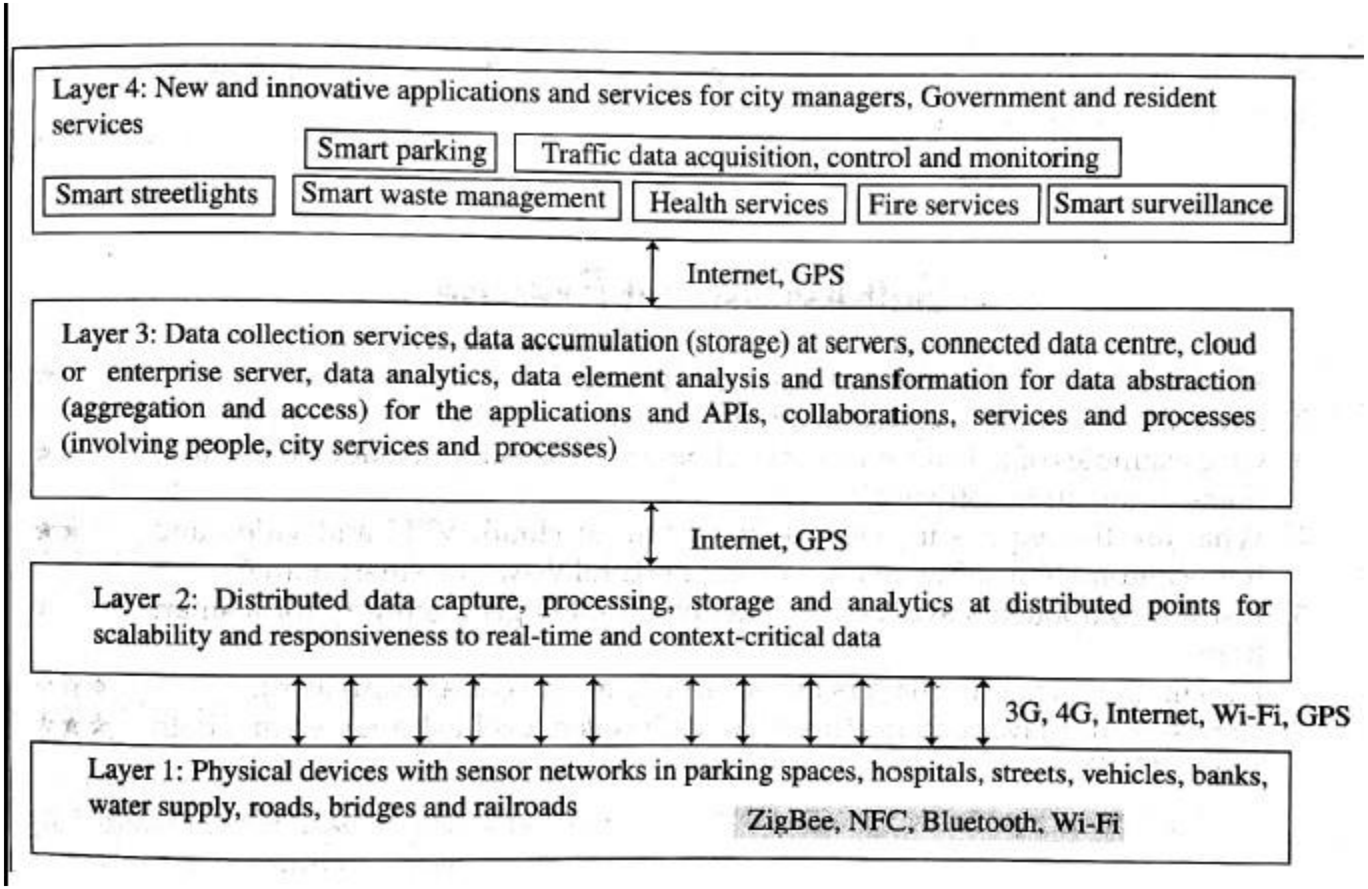
Physical Devices and Controllers (the Things in IoT) [Sensors, Machines, Devices, Intelligent Edge Nodes of Different Types]

- M2M Software and development tools
- Mango
- Mainspring
- Device Hive
- Open M2M protcol tools and framework
  Eclipse SCADA, Koneki, XMPP.

Smart home/Home Automation



Smart City



Layer 4: New and innovative applications and services for city managers, Government and resident services

Smart parking

Traffic data acquisition, control and monitoring

Smart streetlights

Smart waste management

Health services

Fire services

Smart surveillance

Internet, GPS

Layer 3: Data collection services, data accumulation (storage) at servers, connected data centre, cloud or enterprise server, data analytics, data element analysis and transformation for data abstraction (aggregation and access) for the applications and APIs, collaborations, services and processes (involving people, city services and processes)

Internet, GPS

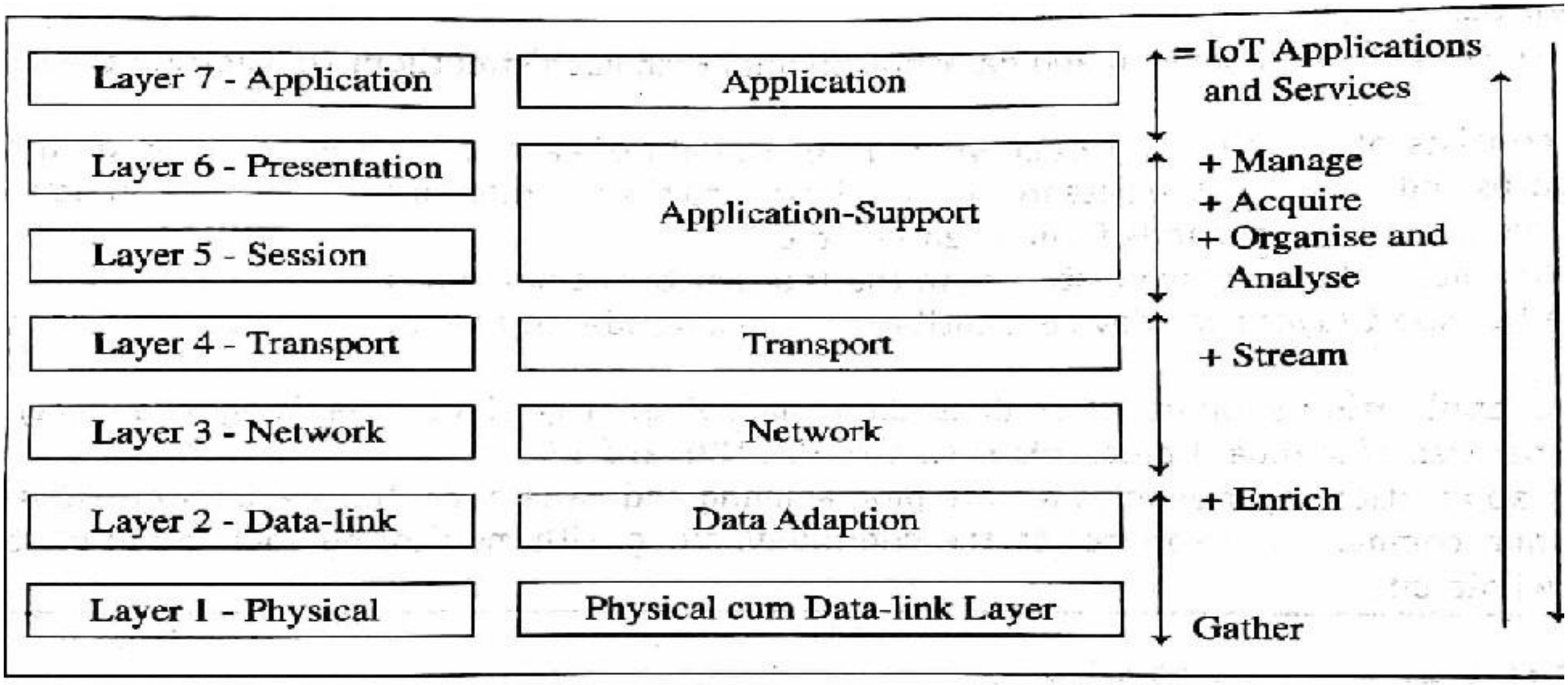
Layer 2: Distributed data capture, processing, storage and analytics at distributed points for scalability and responsiveness to real-time and context-critical data

3G, 4G, Internet, Wi-Fi, GPS

Layer 1: Physical devices with sensor networks in parking spaces, hospitals, streets, vehicles, banks, water supply, roads, bridges and railroads

ZigBee, NFC, Bluetooth, Wi-Fi

Modified OSI Model for the IoT/ M2M Systems



Layer 7 - Application	Application	= IoT Applications and Services
Layer 6 - Presentation	Application-Support	+ Manage + Acquire + Organise and Analyse
Layer 5 - Session		
Layer 4 - Transport	Transport	+ Stream
Layer 3 - Network	Network	
Layer 2 - Data-link	Data Adaption	+ Enrich
Layer 1 - Physical	Physical cum Data-link Layer	Gather

Data Enrichment, Data Consolidation and Device Management at Gateway:

- **Data Management and Consolidation Gateway:**

Gateway includes the following functions:

- Transcoding
- Privacy, Security

  -Devices and applications identity management

  -Authentication

  -Authorization

  -Trust

  -Reputation
- Integration
- Compaction and fusion

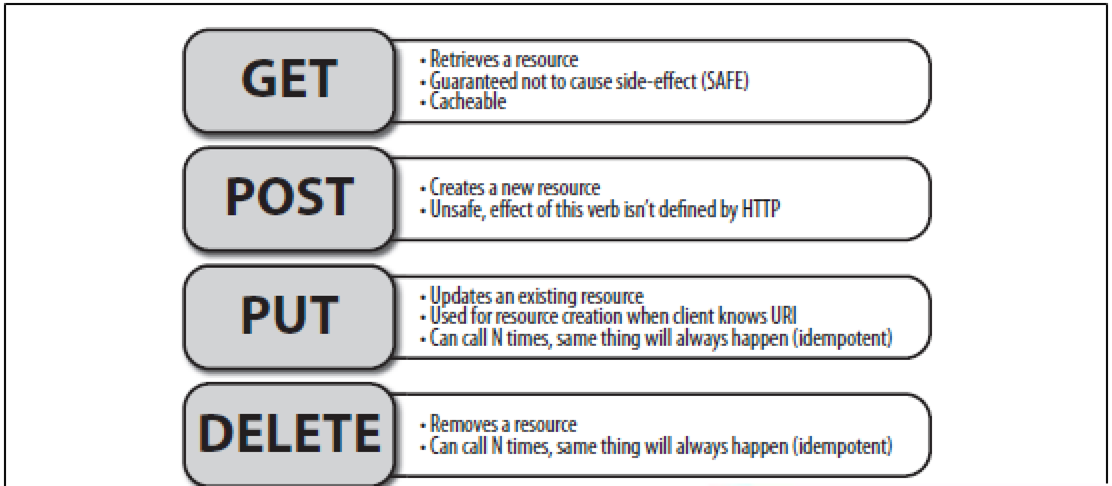
- **Data gathering and Enrichment**
- **Data gathering**
- Polling
- Event based
- Scheduled interval
- Continuous monitoring
- **Data Dissemination**
- Aggregation
- Compaction
- Fusion

- Data Source and Data Destination ID
- Address
- Data characteristics, formats and structures
- Device management at gateway
- Open mobile alliance(OMA)

Key Terms used in Communication

- **Application or APP**
- **Application Programming Interface(API):**
- **Web service**
- **Object**
- **Object Model**
- **Communication Gateway**
- **Class**
- **Client**
- **Server**
- **Representational State Transfer (REST):**
- **Broker**
- **Proxy**
- **Communication protocol:**
- **Web protocol**
- **Firewall:**
- **Universal Resource Locator**
- **Web Object**

Representational State Transfer (REST)

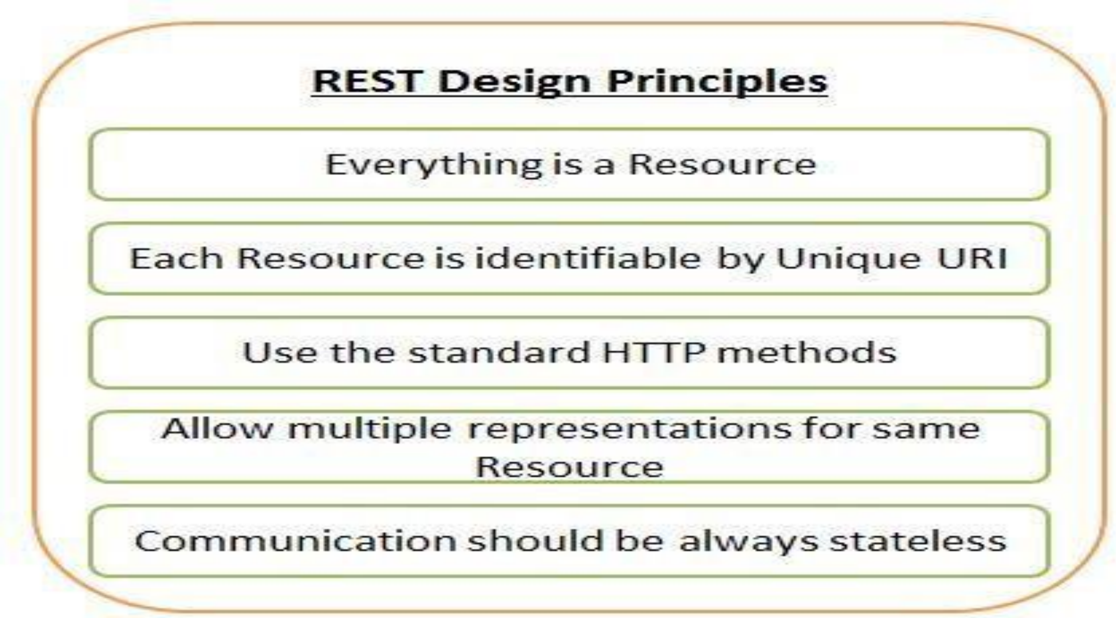


GET
- Retrieves a resource
- Guaranteed not to cause side-effect (SAFE)
- Cacheable

POST
- Creates a new resource
- Unsafe, effect of this verb isn't defined by HTTP

PUT
- Updates an existing resource
- Used for resource creation when client knows URI
- Can call N times, same thing will always happen (idempotent)

DELETE
- Removes a resource
- Can call N times, same thing will always happen (idempotent)



REST Design Principles

Everything is a Resource

Each Resource is identifiable by Unique URI

Use the standard HTTP methods

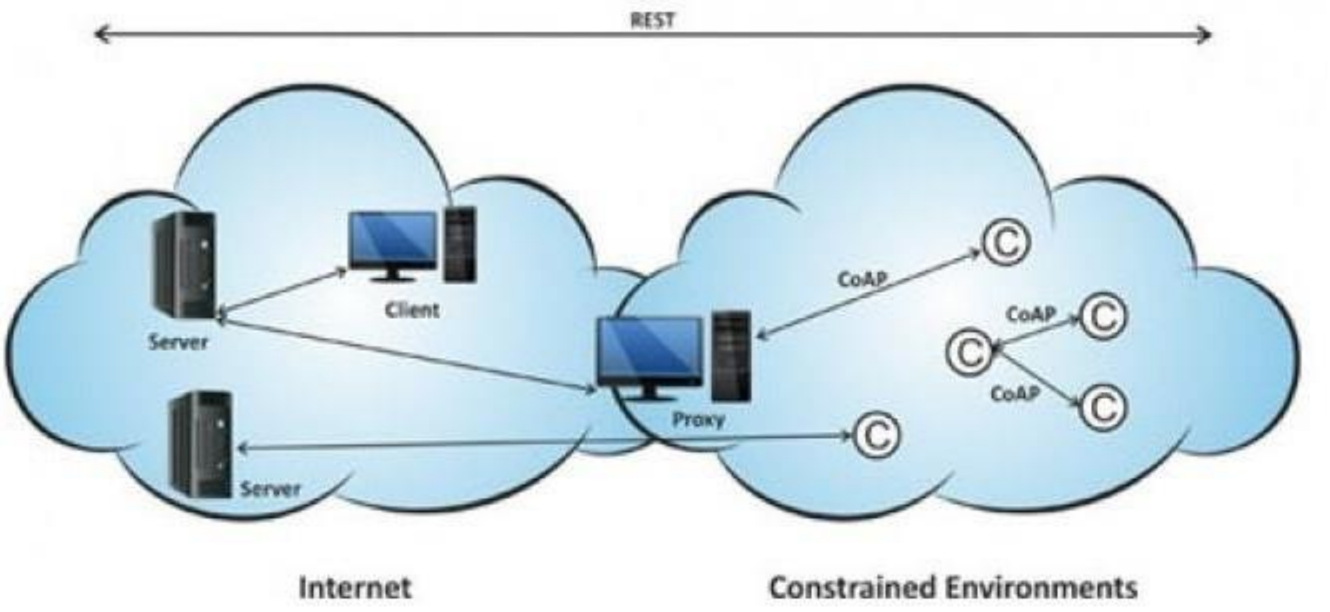
Allow multiple representations for same Resource

Communication should be always stateless

- **CoRE: Constrained RESTful Environment:**
- Data is limited in size
- Data routing-ROLL

- **Unconstrained Environment:**
- Web applications—HTTP & RESTful HTTP
- Routing over IP networks for internet

Constrained Application Protocol



CoAP protocol features

- It provides M2M communication in constrained environment.
- It provides security of data by datagram transportation layer security (DTLS).
- Asynchronous message exchange.
- Low header overhead and parsing complexity
- URI and content type support
- UDP binding with optional reliability supporting unicast and multicast requests.

CoAP Priority

- Quality of service with confirmable message
- When multicast support is needed
- Very low overhead and simplicity.
- CoAP follows a client-server communication model
- Client can GET, PUT, POST or DELETE the resources on network
- The CoAP defines a standard mechanism for resource discovery
- Servers provide a list of their resources, along with metadata about them, at /.well-known/core. For Quality of Service (QoS), Requests and response messages may be marked as confirmable or non-confirmable

- The CoAP defines a standard mechanism for resource discovery.
- Servers provide a list of their resources, along with metadata about them, at /.well-known/core. For Quality of Service (QoS), Requests and response messages may be marked as confirmable or non-confirmable.
- Confirmable messages must be acknowledged by the receiver. Non- confirmable messages are “fire and forget” type

CoAP Protocol Security

- Data Integrity
- Data Authentication
- Data Confidentiality
- It provides security over Datagram Transportation Layer Security in Application layer
- As CoAP runs over UDP protocol stack, there are chances of data loss or data disordering. But with DTLS security, these two problems can be solved

- **DTLS security adds three implementations to CoAP**

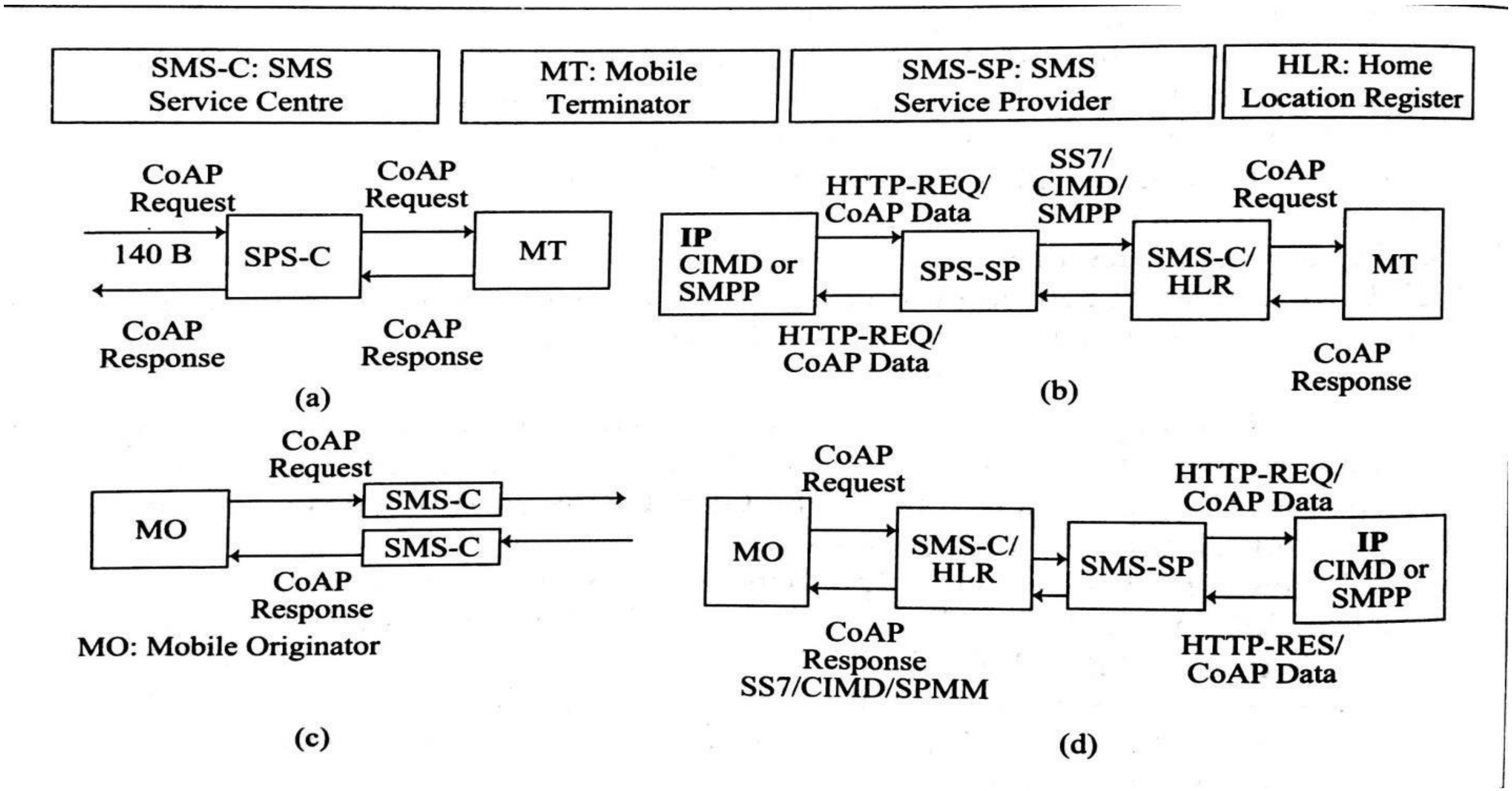
-Packet retransmission

-Assigning sequence number within handshake

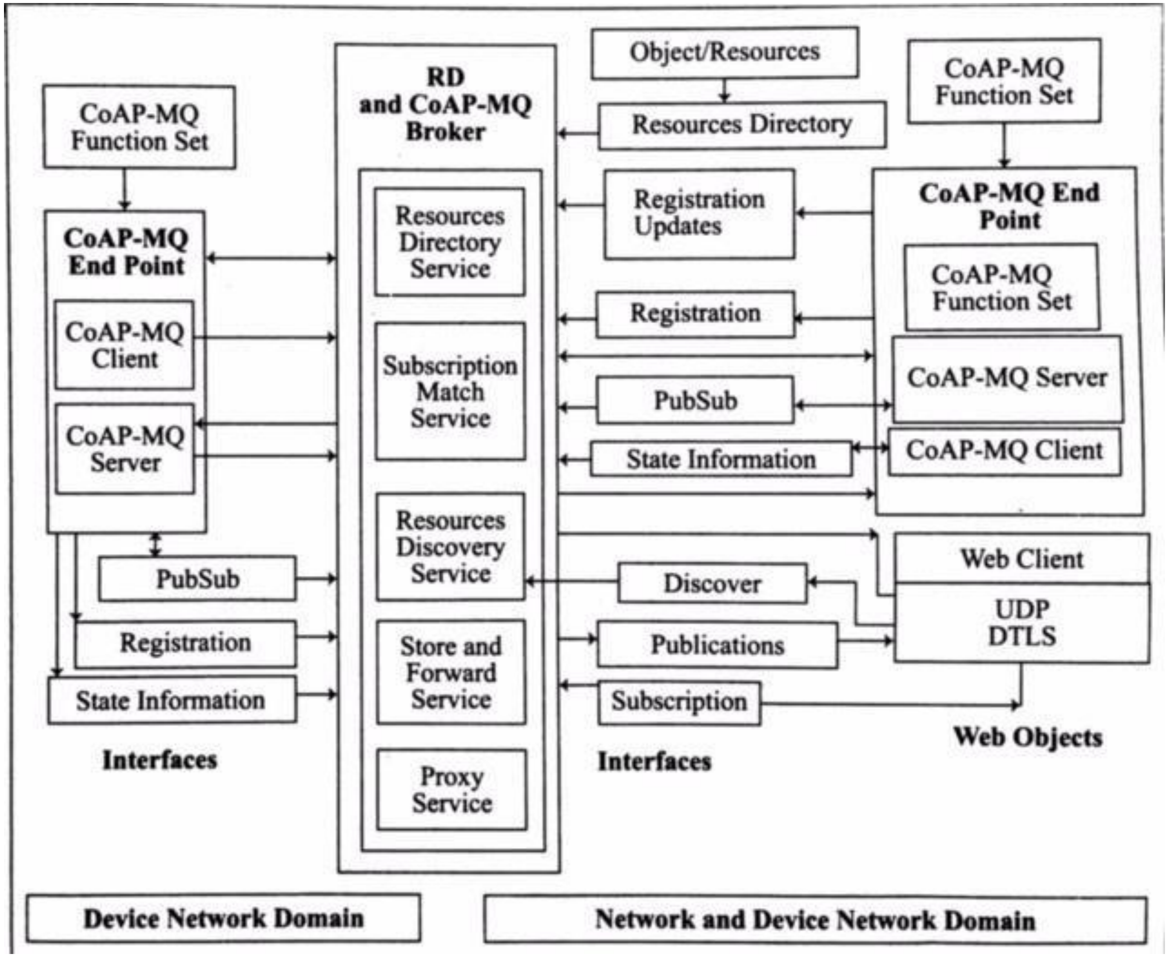
-Replay detection

- RESTful API design- model the system as a set of resources whose state can be retrieved and/or modified and where resources can be potentially also created and/or deleted.
- URI

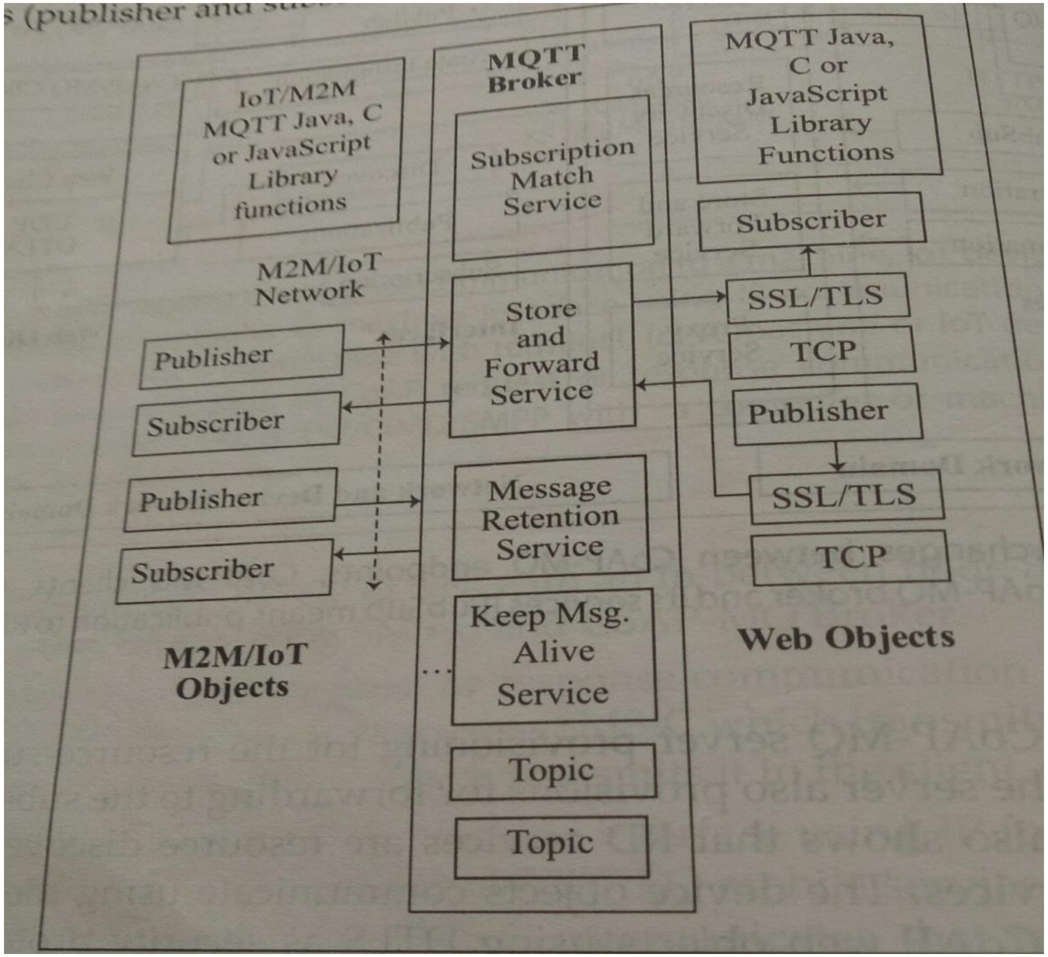
CoAP-SMS


SMS-C: SMS Service Centre
MT: Mobile Terminator
SMS-SP: SMS Service Provider
HLR: Home Location Register
CoAP Request
140 B
SPS-C
CoAP Request
MT
CoAP Response
CoAP Response
(a)
IP CIMD or SMPP
HTTP-REQ/ CoAP Data
SPS-SP
SS7/ CIMD/ SMPP
SMS-C/ HLR
CoAP Request
MT
HTTP-REQ/ CoAP Data
CoAP Response
(b)
CoAP Request
MO
SMS-C
SMS-C
CoAP Response
MO: Mobile Originator
(c)
CoAP Request
MO
SMS-C/ HLR
SMS-SP
HTTP-REQ/ CoAP Data
IP CIMD or SMPP
CoAP Response SS7/CIMD/SPMM
HTTP-RES/ CoAP Data
(d)

CoAP MQ


CoAP-MQ Function Set
CoAP-MQ End Point
CoAP-MQ Client
CoAP-MQ Server
PubSub
Registration
State Information
Interfaces
RD and CoAP-MQ Broker
Resources Directory Service
Subscription Match Service
Resources Discovery Service
Store and Forward Service
Proxy Service
Object/Resources
Resources Directory
Registration Updates
Registration
PubSub
State Information
Discover
Publications
Subscription
Interfaces
CoAP-MQ Function Set
CoAP-MQ End Point
CoAP-MQ Function Set
CoAP-MQ Server
CoAP-MQ Client
Web Client
UDP DTLS
Web Objects
Device Network Domain
Network and Device Network Domain

MQTT

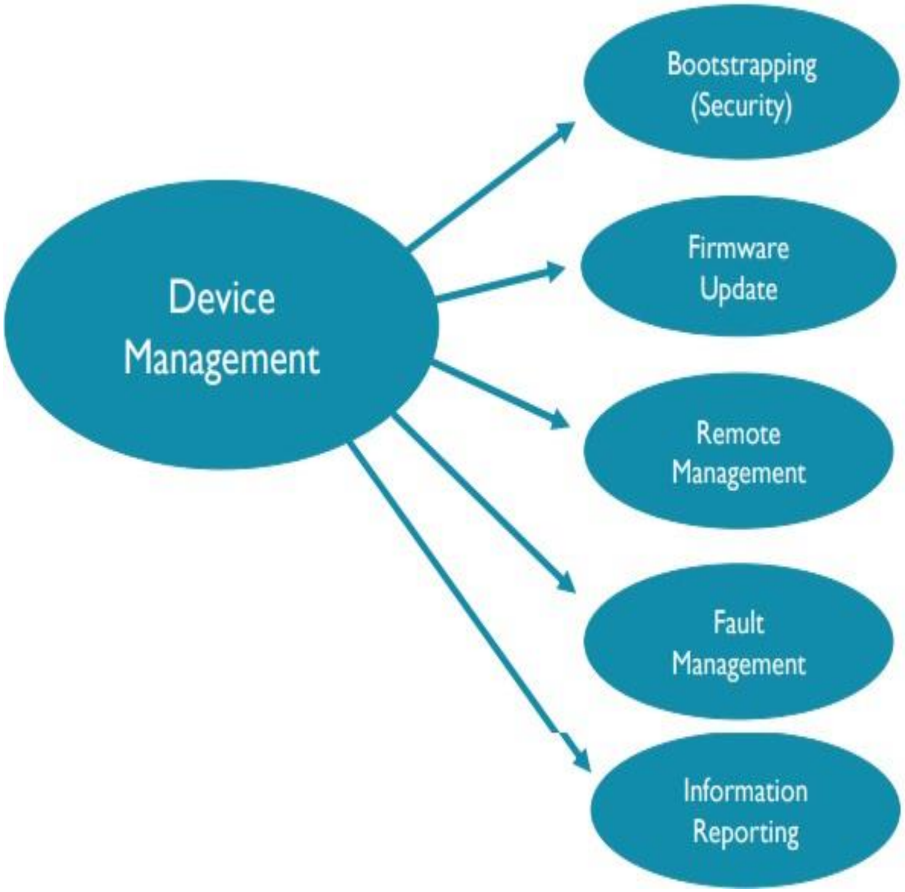

s (publisher and su
IoT/M2M MQTT Java, C or JavaScript Library functions
M2M/IoT Network
Publisher
Subscriber
Publisher
Subscriber
M2M/IoT Objects
MQTT Broker
Subscription Match Service
Store and Forward Service
Message Retention Service
...
Keep Msg. Alive Service
Topic
Topic
MQTT Java, C or JavaScript Library Functions
Subscriber
SSL/TLS
TCP
Publisher
SSL/TLS
TCP
Web Objects

XMPP (Extensible Messaging and Presence Protocol)

- Jabber open source community
- Advantages
- Open
- Standard
- Decentralised
- Secure
- Extensible
- Flexible
- Diverse

Lightweight Machine to machine Communication Protocol:

- Specified by OMA-Open Mobile Alliance for transfer of data/ message
- Light Weight Management
- An object or resource use CoAP, DTLS and UDP or SMS protocols for sending a request or response.
- Use of plain text for a resource or use of JSON during a single data transferor binary TLV format data transfer.
- An object or its resource access using an URI



Device Management

Bootstrapping (Security)

- Service provisioning
- Key management
- Provisioning of access control lists

Firmware Update

- Update application and system software
- Apply bug fixes and add new features

Remote Management

- Changes to settings
- Trigger actuators

Fault Management

- Report errors from devices
- Query status of devices

Information Reporting

- Notify changes in sensor values
- Retrieve configuration settings and device status