Design Principles for Connected Devices

IoT or M2M device data refers to the data meant for communication to an application, service or process. Data also refers to data received by a device for its monitoring or for actions at actuator in it. Data stack denotes the data received after the actions at various in-between layers (or levels or domains). Actions at the data-adaptation or other layers can be related to data privacy, data security, data consolidation, aggregation, compaction and fusion. An action can be a gateway action—using one protocol for reception and another one for transmission.

There are the key terms which need to be understood to learn the design principles of connected devices for IoTs:

Layer refers to a stage during a set of actions at which the action is taken as per a specific protocol or method, and then the result passes to the next layer until the set of actions complete. A layer may consist of various sub layers.

Physical layer refers to a layer at transmitting-node or at the receiving node for the data bits. The transfer uses physical systems and refers to wireless or wired transmission. This layer is the lowest layer.

Application layer refers to a layer for transmitting or receiving the data bits of an application. Data bits route across the network and transfer takes place as follows: application data from the application layer transfers after passing through several in-between layers to the physical layer, and from there it transmits to the receiving-end physical layer. Then, the data at the receiving node transfers from the physical layer to the application layer after passing through several in-between layers.

Level refers to a stage from the lowest to the highest. For example, acquiring device data and actions that may be considered at the lowest level and actions in business processes at the highest level. **Domain** refers to a set of software, layers or levels having specific applications and capabilities. For example, CoRE network, access network, service capabilities and applications can be considered as one domain, say, network domain. A domain generally has limited interactions with other domains or outside the domain.

Gateway refers to software for connecting two application layers, one at the sender and the other at the receiver [application layer gateway (ALG)]. A gateway may be of different types. A communication gateway at device and gateway domain has capabilities as protocol-conversion during communication between two ends when each end uses distinct protocols. An Internet gateway may have capabilities besides protocol conversion, transcoding data, device management and data-enrichment before the data communicate over the Internet. Dictionary meaning of gateway is a place you go through because it leads to a much larger place.

IP stands for Internet Protocol version 6 (IPv6) or Internet Protocol version 4 (IPv4) for the network layer (v6 means version 6, v4 version 4). **Header** means a set of octets containing information about the data being sent. Header packs the data of a layer before transmission to the next layer during communication between two end-points. The size of a header and its fields are according to the protocol used for creating data stack at a layer. For example, IPv4 header has fields as per IP network layer, Universal Datagram Protocol (UDP) header as per UDP at the transport layer and so on. Each header field has distinct meanings. The field size can be between 1 and 32-bit in a packet. A field helps in processing the packet when transferring it from one layer to the next one.

Packet means packaged data-stack which routes over the network. Packet size limit is according to the protocol. For example, IPv4 packet size limit is 216 B (214 words with 1 word = 4 octet). Protocol Data Unit (PDU) is a unit of data which is specified in a protocol of a given layer which transfers from one layer to another. For example, PDU is bit which transfers from physical layer; frame from data-link layer; packet from network layer; segment from transport layer and text (plain, encrypted or compressed) from application and other layers.

Maximum Transmission Unit (MTU) is the largest size frame or packet or segment specified in octets (1 octet = 1 byte = 8 bits) that can be sent in a packet or frame-based network such as the Internet. For example, consider transfers of a segment from the transport layer using the Transmission Control Protocol (TCP) to the network layer. The MTU determines the maximum size of each data stack in any transfer to the network layer. The network layer determines the maximum size of each frame in any transfer to the data-link layer and then uses MTU of the data-link layer.

Star network denotes the number of nodes interacting with a coordinator or master node. Mesh network denotes the number of nodes that may interconnect with each other. End-point device or node denotes the one that provides connectivity to a coordinator or router. Coordinator denotes the one that connects to a number of end-points as well as routers in a star topology and forwards the data stack from one attached end point/router to another.

Master refers to the one who initiates the pairing with the devices in a star topology network. Slave means one that pairs with a master, uses the clock signals from master for synchronization and uses address assigned by the master at the beginning. Router refers to a device or node capable of storing paths to each destination to which it has logical links. The router sends the data stack according to the available path or paths at a receiving instance.

ISM band means Industrial, Scientific and Medical (ISM) radio frequency (RF) bands. 2.4 GHz and the frequencies are 915 MHz for North America, 868 MHz for Europe and 433 MHz band for Asia in ISM bands. Application means software for specific tasks, such as streetlight monitoring or control. Service means service software, for example, report generation or chart visualization service.

Process means a software component, which processes the input and generates the output; for example after analyzing the data or acquiring the data. An operating system controls a process, memory for the process and other parameters of the process.

Suggested models, conceptual frameworks, reference models and architectures for the IoT/M2M suggest the following:

- Need of designing a communication framework for connecting devices, for their local area networking and provisions for data gathering.
- Need of designing a data enrichment, data consolidation and data transformation framework.
- Need of designing gateway components for connecting the device’s network with the web/Internet.
- Need of application and applications-support frameworks for services, applications and processes.

A number of international organisations have taken action for IoT design standardisation. Following are the examples:

Internet Engineering Task Force (IETF), an international body initiated actions for addressing and working on the recommendations for the engineering specifications for the Internet of Things. IETF suggests the specifications for the layers, and the engineering aspects for the IoT communication, networks and applications.

International Telecommunication Union for Telecommunication (ITU-T) suggested a reference model for IoT domain, network and transport capabilities for the IoT services and the applications at the application and application-support layers.

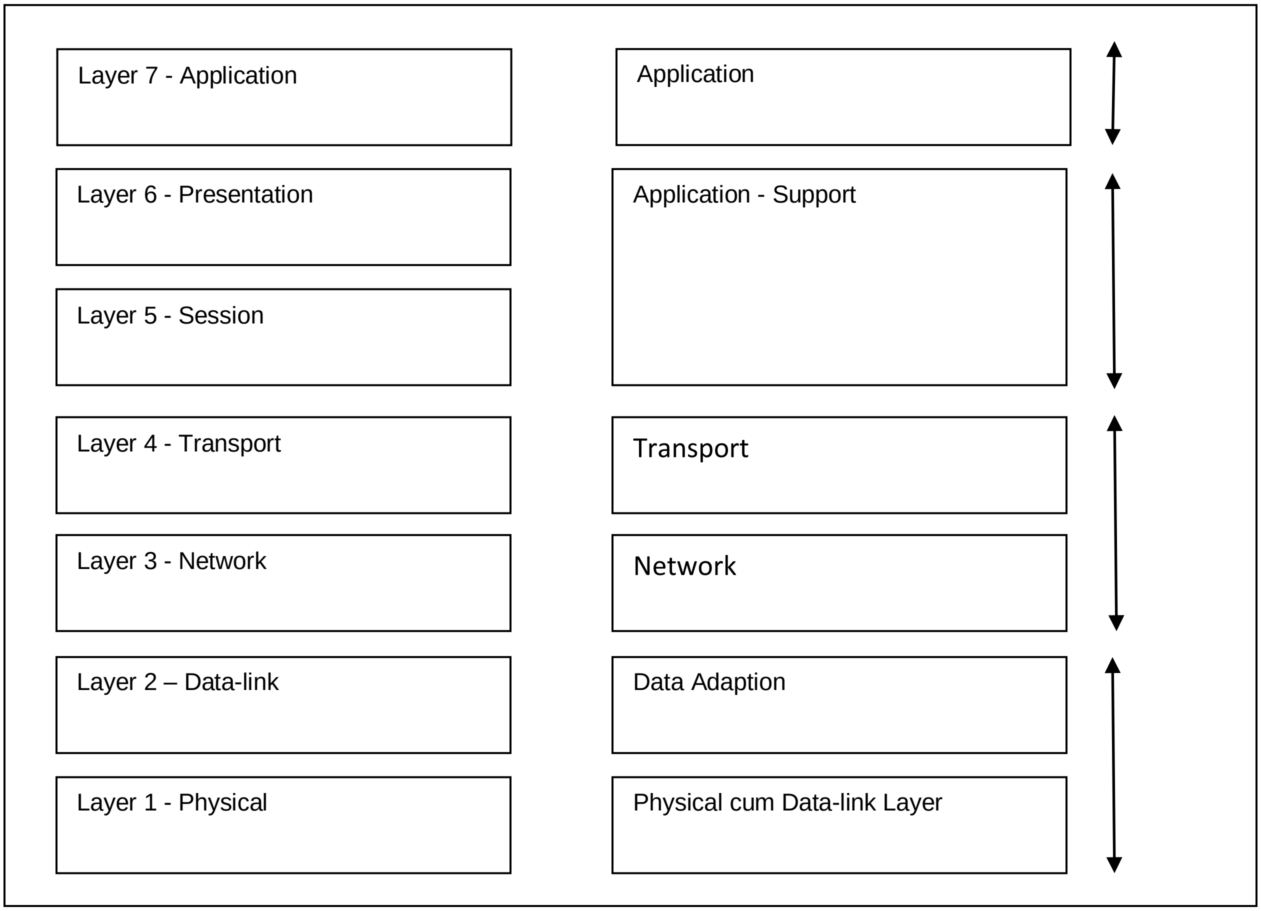
European Telecommunication Standards Institute (ETSI) initiated the development of a set of standards for the network, and devices and gateway domains for the communication between machines (M2M). ETSI proposed high-level architecture for applications and service capabilities.

Open Geospatial Consortium (OGC), an International Industry Consortium, has also suggested open standards for sensors' discovery, capabilities, quality and other aspects with support to geographical information web support.

Modified OSI Model for the IoT/M2M Systems

OSI protocols mean a family of information exchange standards developed jointly by the ISO and the ITU-T. The seven-layer OSI model is a standard model. It gives the basic outline for designing a communication network. Various models for data interchanges consider the layers specified by the OSI model, and modify it for simplicity according to the requirement. Similarly, IETF suggests modifications in the OSI model for the IoT/M2M.

A classical seven-layer OSI model (on the left) and the modifications in that model proposed by IETF (in the middle). Data communicates from device end to application end. Each layer processes the received data and creates a new data stack which transfers it to the next layer. The processing takes place at the in-between layers, i.e. between the bottom functional-layer to the top layer. Device end also receives data from an application/service after processing at the in-between layers.


Layer 7 - Application
Layer 6 - Presentation
Layer 5 - Session
Layer 4 - Transport
Layer 3 - Network
Layer 2 – Data-link
Layer 1 - Physical
Application
Application - Support
Transport
Network
Data Adaption
Physical cum Data-link Layer

Lowest layer, L1, is the device layer and has device and gateway capabilities.

- Next layer, L2, has transport and network capabilities.
- Next layer, L3, is the services and application-support layer. The support layer has two types of capabilities—generic and specific service or application-support capabilities.
- Top layer, L4, is for applications and services.

ITU-T recommends four layers, each with different capabilities. A comparison of ITU-T RM1 with the six-layer OSI model can be made as follows:

- RM1 device layer capabilities are similar to data-adaptation and physical cum datalink layers.
- RM1 network layer capabilities are similar to transport and network layers.
- RM1 upper two layer capabilities are similar to top two layers.

A comparison with the CISCO IoT reference model (RM2) can be made as follows:

- RM1 L4 capabilities are similar to RM2 collaborations and processes, and application top two levels.
- RM1 L3 capabilities are similar to RM2 three middle-level functions of data abstraction, accumulation, analysis and transformation.
- RM1 L2 layer capabilities are similar to RM2 functions at connectivity level.
- RM1 L1 device layer capabilities are similar to RM2 functions at physical devices level.