Internet of Things Protocols & Standards

The emerging "**Internet of Things**" covers a huge range of industries and scales of devices/applications. Below we take a look at a few of the protocols and standards that are helping to drive the topic forward.

Web Technologies:

REST (Representational state transfer) - RESTful HTTP
-Additional Resources in context of IoT

SOAP (Simple Object Access Protocol), JSON/XML, **WebHooks**, **Jelastic**, **MongoDB**

Websocket
The WebSocket specification—developed as part of the HTML5 initiative—introduced the WebSocket JavaScript interface, which defines a full-duplex single socket connection over which messages can be sent between client and server. The WebSocket standard simplifies much of the complexity around bi-directional web communication and connection management.

JavaScript / Node.js IoT projects

A list of IoT software projects like Contiki, Riot OS, etc can be found here.

IPv6
"IPv6, is an Internet Layer protocol for packet-switched internetworking and provides end-to-end datagram transmission across multiple IP networks."

6LoWPAN
"6LoWPAN is a acronym of IPv6 over Low power Wireless Personal Area Networks. It is an adaption layer for IPv6 over IEEE802.15.4 links. This protocol operates only in the 2.4 GHz frequency range with 250 kbps transfer rate."

UDP (User Datagram Protocol)
A simple OSI transport layer protocol for client/server network applications based on Internet Protocol (IP). UDP is the main alternative to TCP and one of the oldest network protocols in existence, introduced in 1980. UDP is often used in applications specially tuned for real-time performance.

uIP
The uIP is an open source TCP/IP stack capable of being used with tiny 8- and 16-bit microcontrollers. It was initially developed by Adam Dunkels of the "Networked Embedded Systems" group at the Swedish Institute of Computer Science, licensed under a BSD style license, and further developed by a wide group of developers.

DTLS (Datagram Transport Layer)
"The DTLS protocol provides communications privacy for datagram protocols. The protocol allows client/server applications to communicate in a way that is designed to prevent eavesdropping, tampering, or message forgery. The DTLS protocol is based on the Transport Layer Security (TLS) protocol and provides equivalent security guarantees."

MQTT (Message Queuing Telemetry Transport)
"The MQTT protocol enables a publish/subscribe messaging model in an extremely lightweight way. It is useful for connections with remote locations where a small code footprint is required and/or network bandwidth is at a premium."
-Additional resources

-**Mosquitto**: An Open Source MQTT v3.1 Broker
- **IBM MessageSight**

CoAP (Constrained Application Protocol)
"CoAP is an application layer protocol that is intended for use in resource-constrained internet devices, such as WSN nodes. CoAP is designed to easily translate to HTTP for simplified integration with the web, while also meeting specialized requirements such as multicast support, very low overhead, and simplicity. The CoRE group has proposed the following features for CoAP: RESTful protocol design minimizing the complexity of mapping with HTTP, Low header overhead and parsing complexity, URI and content-type support, Support for the discovery of resources provided by known CoAP services. Simple subscription for a resource, and resulting push notifications, Simple caching based on max-age."
-Additional resources

- **SMCP** — A C-based CoAP stack which is suitable for embedded environments. Features include: Support draft-ietf-core-coap-13, Fully asynchronous I/O, Supports both BSD sockets and UIP.

ROLL (IPv6 routing for low power/lossy networks)

XMPP (Extensible Messaging and Presence Protocol)
"An open technology for real-time communication, which powers a wide range of applications including instant messaging, presence, multi-party chat, voice and video calls, collaboration, lightweight middleware, content syndication, and generalized routing of XML data."
-Additional resources

- **XMPP-IoT**
"In the same manor as XMPP silently has created people to people communication interoperable. We are aiming to make communication machine to people and machine to machine interoperable."

Mihini/M3DA
"The Mihini agent is a software component that acts as a mediator between an M2M server and the applications running on an embedded gateway. M3DA is a protocol optimized for the transport of binary M2M data. It is made available in the Mihini project both for means of Device Management, by easing the manipulation and synchronization of a device's data model, and for means of Asset Management, by allowing user applications to exchange typed data/commands back and forth with an M2M server, in a way that optimizes the use of bandwidth"

AMQP (Advanced Message Queuing Protocol)
"An open standard application layer protocol for message-oriented middleware. The defining features of AMQP are message orientation, queuing, routing (including point-to-point and publish-and-subscribe), reliability and security."
- **Additional Resources**

DDS (Data-Distribution Service for Real-Time Systems)
"The first open international middleware standard directly addressing publish-subscribe communications for real-time and embedded systems."

LLAP (lightweight local automation protocol)
"LLAP is a simple short message that is sent between inteligent objects using normal text, it's not like TCP/IP, bluetooth, zigbee, 6lowpan, WiFi etc which achieve at a low level "how" to move data around. This means LLAP can run over any communication medium. The three strengths of LLAP are, it'll run on

anything now, anything in the future and it's easily understandable by humans."

LWM2M (Lightweight M2M)
"Lightweight M2M (LWM2M) is a system standard in the Open Mobile Alliance. It includes DTLS, CoAP, Block, Observe, SenML and Resource Directory and weaves them into a device-server interface along with an Object structure."

SSI (Simple Sensor Interface)
"a simple communications protocol designed for data transfer between computers or user terminals and smart sensors"

IOTDB
"JSON / Linked Data standards for describing the Internet of Things"

Reactive Streams
"A standard for asynchronous stream processing with non-blocking back pressure on the JVM."

SensorML
"SensorML provides standard models and an XML encoding for describing sensors and measurement processes."

Semantic Sensor Net Ontology - W3C
"This ontology describes sensors and observations, and related concepts. It does not describe domain concepts, time, locations, etc. these are intended to be included from other ontologies via OWL imports."

IPSO Application Framework (PDF)
"This design defines sets of REST interfaces that may be used by a smart object to represent its available resources, interact with other smart objects and backend services. This framework is designed to be complementary to existing Web profiles including SEP2 and oBIX."

OMA LightweightM2M v1.0
"The motivation of LightweightM2M is to develop a fast deployable client-server specification to provide machine to machine service.
LightweightM2M is principly a device management protocol, but it should be designed to be able to extend to meet the requirements of applications.
LightweightM2M is not restricted to device management, it should be able transfer service / application data."

Wolfram Language - Connected Devices:
"Well, within the Wolfram Language we've been building a powerful framework for this. From a user's point of view, there's a symbolic representation of each device. Then there are a standard set of Wolfram Language functions like DeviceRead, DeviceExecute, DeviceReadBuffer and DeviceReadTimeSeries that perform operations related to the device."

Content-Centric Networking (CCN) - **Technical Overview**
"Next-gen network architecture to solve challenges in content distribution scalability, mobility, and security.
CCN directly routes and delivers named pieces of content at the packet level of the network, enabling automatic and application-neutral caching in memory wherever it's located in the network. The result? Efficient and effective delivery of content wherever and whenever it is needed. Since the architecture enables these caching effects as an automatic side effect of packet delivery, memory can be used without building expensive application-level caching services."

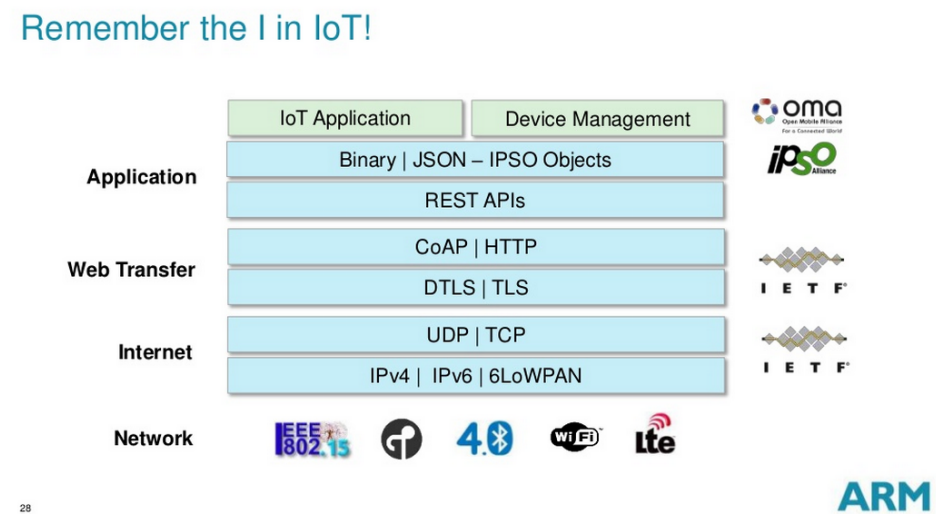
Telehash - JSON+UDP+DHT=Freedom
A secure wire protocol powering a decentralized overlay network for apps and devices

Time Synchronized Mesh Protocol (TSMP)
A communications protocol for self-organizing networks of wireless devices called motes. TSMP devices stay synchronized to each other and communicate in timeslots, similar to other TDM (time-division multiplexing) systems.

NanoIP
"NanoIP, which stands for the nano Internet Protocol, is a concept that was created to bring Internet-like networking services to embedded and sensor devices, without the overhead of TCP/IP. NanoIP was designed with minimal overheads, wireless networking, and local addressing in mind."

ONS 2.0

Graphic Overviews:



Credit: **Simon Ford - Director of IoT Platforms ARM**

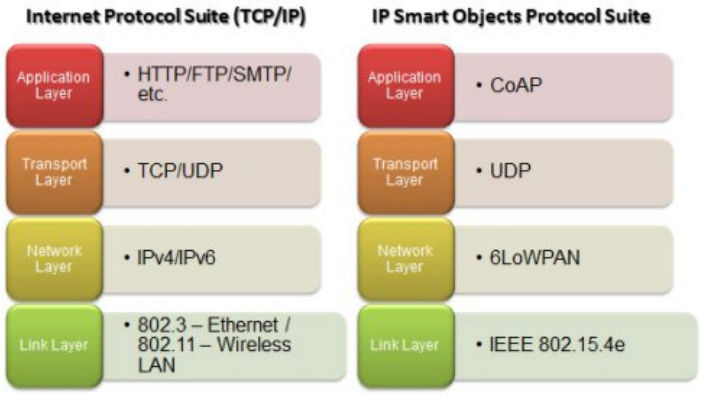


Figure 1 TCP/IP Stack and IP Smart Objects Protocol Stack

*Graphic via **Ronak Sutaria** and **Raghunath Govindachari** from **Mindtree Labs** in "**Making sense of interoperability:Protocols and Standardization initiatives in IOT**"*

IoT Communication stack from IoT-A Initiative

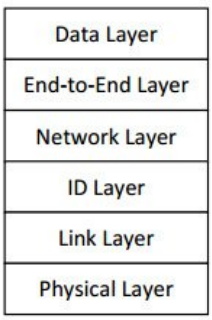
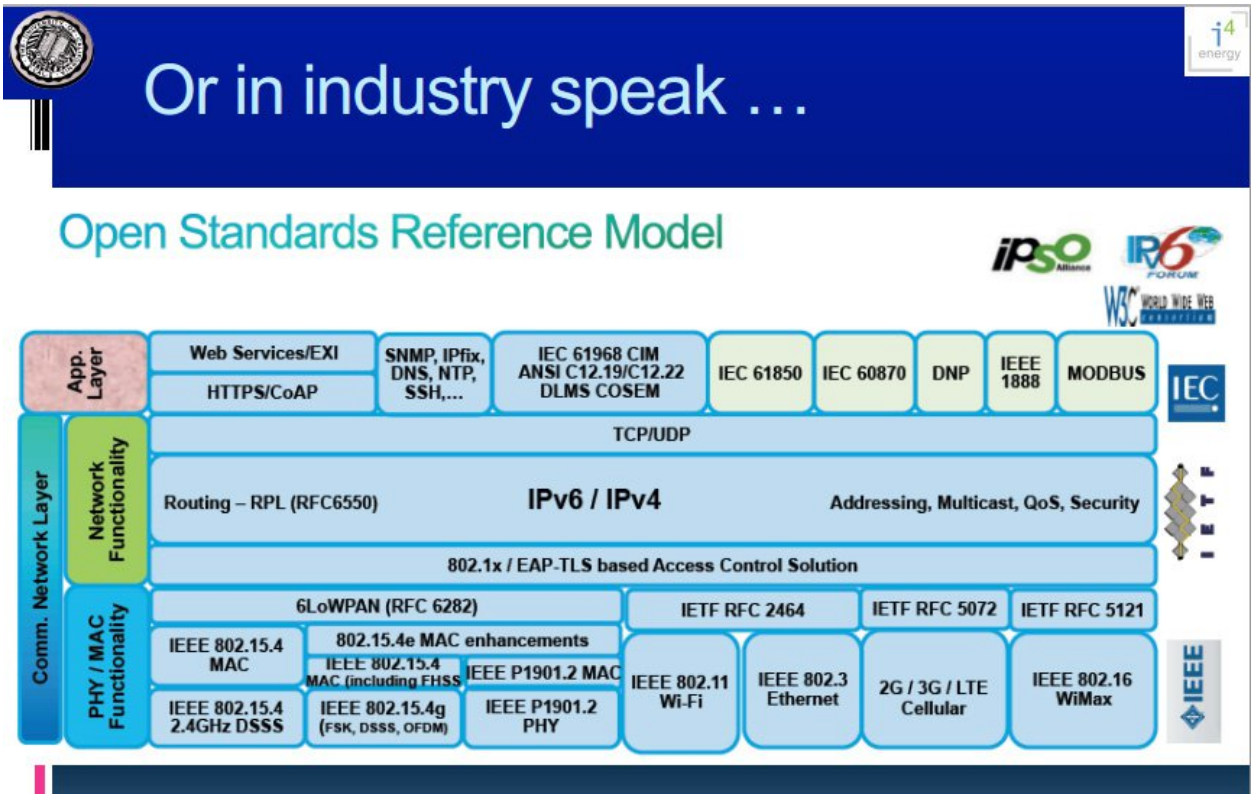


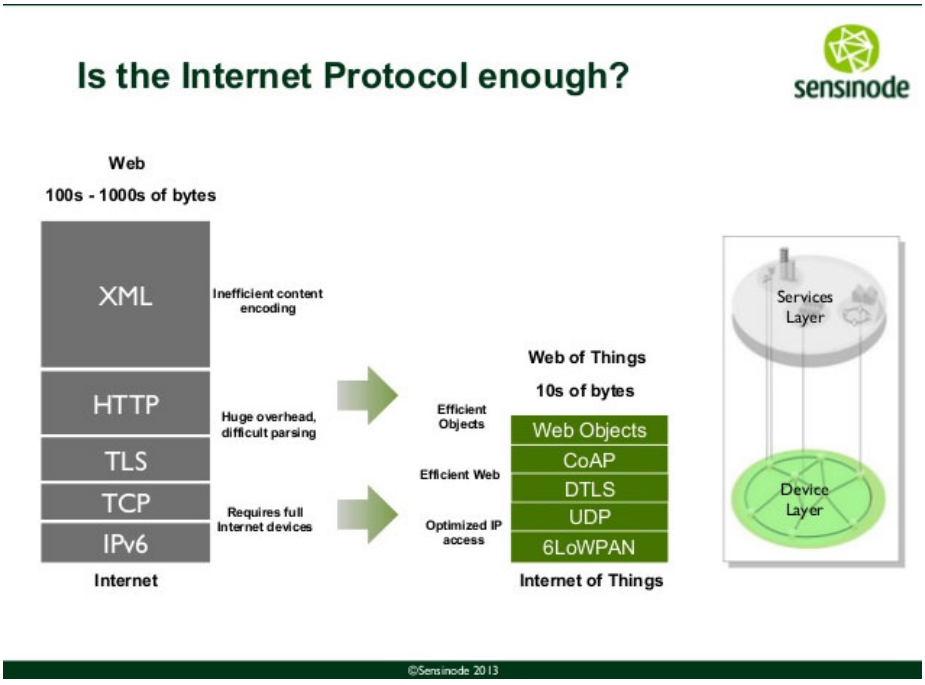
Figure 9 – IoT Communication stack

"The communication model aims at defining the main communication paradigms for connecting entities, as defined in the domain model. We provide a reference communication stack, together with insight about the main interactions among the actors in the domain model. We developed a communication stack similar to the ISO OSI 7-layer model for networks, mapping the needed features of the domain model unto communication paradigms. We also describe how communication schemes can be applied to different types of networks in IoT."

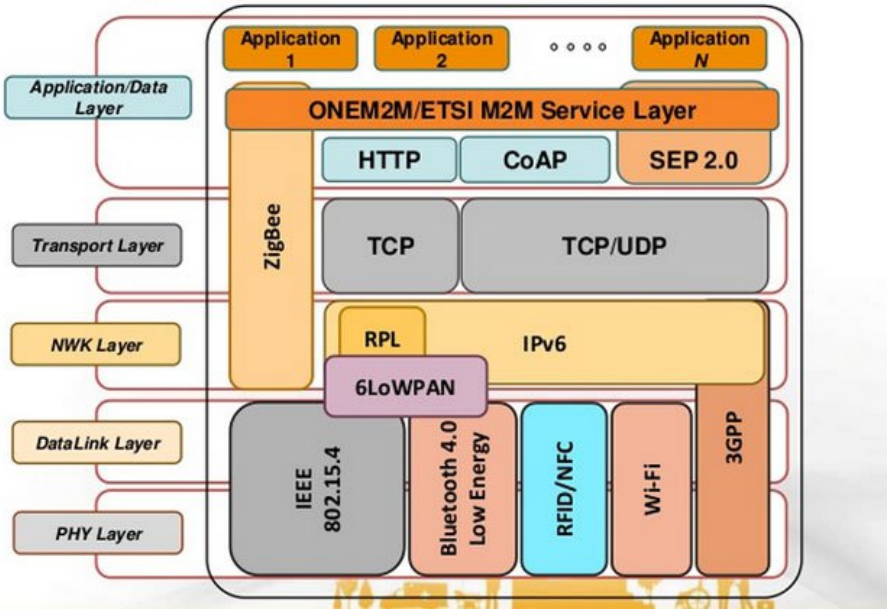
- The full reference model presentation can be found **here** (PDF).



Above Graphic: David E. Culler - The Internet of Every Thing - steps toward sustainability CWSN Keynote, Sept. 26, 2011 (Download PPT)



Graphic: Sensinode: - Zach Shelby: Is the Internet Protocol enough? (Full Presentation)



Graphic: EU Butler Project - Communication Issues

IEEE 1451:
The IEEE 1451, a family of Smart Transducer Interface Standards, describes a set of open, common, network-independent communication interfaces for connecting transducers (sensors or actuators) to microprocessors, instrumentation systems, and control/field networks.

IEEE 1888.3-2013 - "IEEE Standard for Ubiquitous Green Community Control Network: Security"
IEEE 1905.1-2013 - "IEEE Standard for a Convergent Digital Home Network for Heterogeneous Technologies"
IEEE 802.16p-2012 - "IEEE Standard for Air Interface for Broadband Wireless Access Systems"
IEEE 1377-2012 - "IEEE Standard for Utility Industry Metering Communication Protocol Application Layer"
IEEE P1828 - "Standard for Systems With Virtual Components"
IEEE P1856 - "Standard Framework for Prognostics and Health Management of Electronic Systems"

PHY / MAC Functionality:

Ethernet

WirelessHart
"WirelessHART technology provides a robust wireless protocol for the full range of process measurement, control, and asset management applications."

DigiMesh
"DigiMesh is a proprietary peer-to-peer networking topology for use in wireless end-point connectivity solutions."

ISA100.11a
"ISA100.11a is a wireless networking technology standard developed by the International Society of Automation (ISA). The official description is "Wireless Systems for Industrial Automation: Process Control and Related Application"

IEEE 802.15.4
IEEE 802.15.4 is a standard which specifies the physical layer and media access control for low-rate wireless personal area networks (LR-WPANs). It is maintained by the IEEE 802.15 working group. It is the basis for the ZigBee,ISA100.11a, WirelessHART, and MiWi specifications, each of which further extends the standard by developing the upper layers which are not defined in IEEE 802.15.4. Alternatively, it can be used with 6LoWPAN and standard Internet protocols to build a wireless embedded Internet.

NFC
Based on the standard ISO/IEC 18092:2004, using inductive coupled devices at a center frequency of13.56 MHz. The data rate is up to 424 kbps and the rangeis with a few meters short compared to the wireless sensornetworks.

ANT
ANT is a proprietary wireless sensor network technology featuring a wireless communications protocol stack that enables semiconductor radios operating in the 2.4 GHz Industrial, Scientific and Medical allocation of the RF spectrum ("ISM band") to communicate by establishing standard rules for co-existence, data representation, signalling, authentication and error detection.

Bluetooth
Bluetooth works in the 2.4 GHz ISM band and uses frequency hopping. With a data rate up to 3 Mbps and maximum range of 100m. Each application type which can use Bluetooth has its own profile.

ZigBee
The ZigBee protocol uses the 802.15.4 standard and operates in the 2.4 GHz frequency range with 250 kbps. The maximum number of nodes in the network is 1024 with a range up to 200 meter. ZigBee can use 128 bit AES encryption.

EnOcean
EnOcean is a an energy harvesting wireless technology which works in the frequencies of 868 MHz for europe and 315 MHz for North America. The transmit range goes up to 30 meter in buildings and up to 300 meter outdoor.

WiFi

Dash7
Based on the ISO 18000-7 Standard and uses a RF frequency of 433.92 MHz and a transfer rate up to 20kbps. The range can be adjusted from 100 to 10 kilometer with a dynamically adjustable datarate of 28 kbps to 200kbps. The ISO Standard is not available for free.

Thread
Built on open standards and IPv6 technology with 6LoWPAN as its foundation.

Weightless
Weightless is a proposed proprietary open wireless technology standard for exchanging data between a base station and thousands of machines around it (using wavelength radio transmissions in unoccupied TV transmission channels) with high levels of security.

WiMax
WiMax is based on the standard IEEE 802.16 and is intended for wireless metropolitan area networks. The range is different for fixed stations, where it can go up to 50 km and mobile devices with 5 to 15 km. WiMAx operates at frequencies between 2.5 GHz to 5.8 GHz with a transferrate of 40 Mbps.

Cellular:
GPRS/2G/3G/4G cellular

- View a more complete overview of IoT communication and technologies **here**.

Organizations:

- **ETSI** (European Telecommunications Standards Institute)
  - **Connecting Things Cluster**
- **IETF** (Internet Engineering Task Force)
  - **CoRE working group** (Constrained RESTful Environments)
  - **6lowpan working group** (IPv6 over Low power WPAN)
  - **ROLL working group** (Routing Over Low power and Lossy networks)
- **IEEE** (Institute of Electrical and Electronics Engineers)
  - **IoT "Innovation Space"**
- **OMG** (Object Management Group)
  - **Data Distribution Service Portal**
- **OASIS** (Organization for the Advancement of Structured Information Standards)
  - **MQTT Technical Committee**
- **OGC** (Open Geospatial Consortium)
  - **Sensor Web for IoT Standards Working Group**

- **IoT-A**
  "The European Lighthouse Integrated Project addressing the Internet-of-Things Architecture, proposes the creation of an architectural reference model together with the definition of an initial set of key building blocks."

- **OneM2M**
  "The purpose and goal of oneM2M is to develop technical specifications which address the need for a common M2M Service Layer that can be readily embedded within various hardware and software, and relied upon to connect the myriad of devices in the field with M2M application servers worldwide."
- **OSIOT**
  "An organization with the single focus to develop and promote royalty-free, open source standards for the emerging Internet of Things."
- **IoT-GSI** (Global Standards Initiative on Internet of Things)
- **ISA** International Society of Automation

- **W3C**
  - **Semantic Sensor Net Ontology**
  - **Web of Things Community Group**
- **EPC Global**
- **The IEC (International Electrotechnical Commission), and ISO (International Organization for Standardization), through the JTC (Joint Technical Committee)**. Committee **Page**
- **RRG** (Routing research group)
- **HIPRG** (Host identity protocol research group)

Eclipse Paho Project
"The scope of the Paho project is to provide open source implementations of open and standard messaging protocols that support current and emerging requirements of M2M integration with Web and Enterprise middleware and applications. It will include client implementations for use on embedded platforms along with corresponding server support as determined by the community."

OpenWSN
"Serves as a repository for open-source implementations of protocol stacks based on Internet of Things standards, using a variety of hardware and software platforms."

CASAGRAS
"We are a key group of international partners representing Europe, the USA, China, Japan and Korea who has joined a strategic EU funded 7th Framework initiative that will look at global standards, regulatory and other issues concerning RFID and its role in realising an "Internet of Things."

Alliances

AllSeen Alliance
"The AllSeen Alliance is a nonprofit consortium dedicated to enabling and driving the widespread adoption of products, systems and services that support the Internet of Everything with an open, universal development framework supported by a vibrant ecosystem and thriving technical community'

IPSO
"The Alliance is a global non-profit organization serving the various communities seeking to establish the Internet Protocol as the network for the connection of Smart Objects by providing coordinated marketing efforts available to the general public."

Wi-SUN Alliance
The Wi-SUN Alliance seeks to "advance seamless connectivity by promoting IEEE 802.15.4g standard based interoperability for global regional markets."

OMA (Open Mobile Alliance)
"OMA is the Leading Industry Forum for Developing Market Driven, Interoperable Mobile Service Enablers"
- **OMA LightweightM2M v1.0**

Industrial Internet Consortium
"Founded in 2014 to further development, adoption and wide-spread use of interconnected machines, intelligent analytics and people at work'

More organizations can be found in our IoT technical resources section.

Resources:

General:

- **"Making Sense of Interoperability: IoT Protocols and Standardization Initiatives"**, (2013) Sutaria. R. and Govindachari, R

"A number of different standardization bodies and groups are actively working on creating more inter-operable protocol stacks and open standards for the Internet of Things. As we move from the HTTP, TCP, IP stack to the IOT specific protocol stack we are suddenly confronted with an acronym soup of protocols- from the wireless protocols like ZigBee, RFID, Bluetooth and BACnet tonext generation protocol standards such as 802.15.4e, 6LoWPAN, RPL, CoAP etc. which attempt to unify the wireless sensor networks and the established internet."

- "**Architecture and protocols for the Internet of Things"**, (2010) A case study by A P Castellani, N Bui, P Casari, M Rossi, Z Shelby, M Zorzi
- "**Standardized Protocol Stack For The Internet Of (Important) Things**", (2012) Maria Rita Palattella, Nicola Accettura, Xavier Vilajosana, Thomas Watteyne, Luigi Alfredo Grieco, Gennaro Boggia and Mischa Dohler.
- "**Lightweight IPv6 Stacks for Smart Objects: the Experience of Three Independent and Interoperable Implementations**" Internet Protocol for Smart Objects (IPSO) ABy Julien Abeillé, Mathilde Durvy, Jonathan Hui, Stephen Dawson-Haggerty
- "**Smart Objects Demand a New Approach to Internet Engineering**" By Carolyn Duffy Marsan IETF Journal March 2012
- "**Beyond Interoperability – Pushing the Performance of Sensor Network IP Stacks**" By JeongGil Ko, Joakim Eriksson, Nicolas Tsiftes, Stephen Dawson-Haggerty, Jean-Philippe Vasseur, Mathilde Durvy, Andreas Terzis, Adam Dunkels and David Culle
- **Why IP for Smart Objects?** Jean-Philippe Vasseur & Adam Dunkels

- **Beyond MQTT: A Cisco View on IoT Protocols** - Cisco
- **Network Congestion & Lightweight Protocols** - Telit
- **The Choice Of Protocol For Iot And M2M Will Dictate The Emergence And Success Of The Market** - Michael Holdmann
- **Standards Drive the Internet of Things** - Zach Shelby
- **Understanding The Internet Of Things** - Ronak Sutaria & Raghunath Govindachari | Electronic Design
- **Understanding The Protocols Behind The Internet Of Things** (MQTT, XMPP, DDS, AMQP) - Electronic Design
- **Messaging Technologies: A Comparison Between DDS, AMQP, MQTT, JMS and REST** (PDF) PrismTech
- **MQTT and CoAP, IoT Protocols** - Toby Jaffey

MQTT:

- **MQTT and DDS for M2M: Disparate Approaches to the Internet of Things** - RTJ
- **Building the Internet of Things - DDS vs MQTT** Angelo Corsaro
- **MQTT Will Enable The Internet Of Things** - Andy Stanford-Clark in Electronic Design
- **Comparison of MQTT and DDS as M2M Protocols for the Internet of Things** - Real Time Innovations
- **QEST** is a stargate between the universe of devices which speak MQTT, and the universe of apps which speak HTTP and REST.
- **Using MQTT to connect Arduino to the Internet of Things** - Chris Larson
- **Introduction to MQTT** (PDF) - Dave Locke
- **MQTT and the language of the Internet of Things** - Housahedron
- **Exploring the Protocols of IoT** (MQTT & CoAP) - SparkFun

CoAP:

- **Introduction to CoAP the REST protocol for M2M** - By **Julien Vermillard**
- **CoAPing with the REST of the Internet of Things** - Embedded Software store
- **CoAP Tutorial** - Zach Shelby
- **Wireless Sensor Network Node with REST Advantages: CoAP Protocol** - WSN Magazine
- **CoAP Course for m2m and Internet of Things scenarios** - Carlos Ralli

XMPP:

- **Unify to bridge gaps: Bringing XMPP into the Internet of Things** (PDf)- Michael Kirsche, Ronny Klauck
- **XMPP Service Discovery extensions for M2M and IoT** - Servicelab
- **A Service Infrastructure for the Internet of Things based on XMPP** (PDF) - Sven Bendel, Thomas Springer, Daniel Schuster, Alexander Schill, Ralf Ackermann, Michael Ameling
- **Working In The Real World With IoT And XMPP**- Rdm For Hvac - Michael Holdmann

AMQP

- **Integrating the Internet of Things with AMQP** (PDF) - RedHat
- **AMQP and one possible future for messaging** - David Goehrig

RESTful HTTP:

- **RESTful HTTP in practice** - Infoq
- **Event Models for RESTful APIs** - **Michael Koster**
- **The Internet of Things for the REST of us** - Bosch
- **In Search of an Internet of Things Service Architecture:REST or WS-*? A Developers' Perspective** (PDF) - **Dominique Guinard**, **Iulia Ion**, and **Simon Mayer**

LwM2M

- **Manage all the things, small and big, with open source LwM2M implementations** - Benjamin Cabé

Additional Resources:

- **What a Mesh! Part 2-Networking Architectures and Protocols**

See Also: Internet of Things Software, Hardware, Platforms, Definitions