DSIoT Lecture 1 – Sensor to Cloud

Zürcher Hochschule
für Angewandte Wissenschaften
zhaw School of Engineering
InES Institute of
Embedded Systems

Introduction

Introduction
Session 1: oneM2M
- Investment Security
- Architecture and Model
- Services
- Resources and Communication

Session 2: LWM2M
- Purpose
- Object Model
- Device Management

Session 3: IPSO
- Sensor Objects and Resources

- Status: Communication
  - Two IoT protocols
  - Relationship to professional communication concepts
  - Automation communication systems
    - Various important concepts around low-level communication
    - Application management
    - Do not provide (standardised) device management
- Problem: How do IoT systems scale?
  - Need to manage devices, services ….
- oneM2M
  - Example of services required for large-scale application/system management
- LWM2M
  - Example of large scale device management
- IPSO
  - Example of application interface to device management

Sensors

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- Sensor – emits a signal due to a physical impulse
  - Communication
  - Sensors are typically
  - Relationship to professional communication concepts
  - Automation communication systems
    - Various important concepts around low-level communication
    - Application management
    - Do not provide (standardised) device management
- Problem: How do IoT systems scale?
  - Need to manage devices, services ….
- oneM2M
  - Example of services required for large-scale application/system management
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  - Example of application interface to device management

Targeted Results

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- Result 1:
  - oneM2M provides framework for common services in large-scale IoT systems
- Result 2:
  - Device management an integral function of large-scale IoT systems
  - LWM2M covers this functionality
- Result 3:
  - LWM2M offers dynamic resource/object handling for device management
  - It follows that this object creation/deletion can be used by the application layer as well
- Result 4:
  - IPSO uses resource/object function to abstract the physical into the cyber
    - A physical system is described by a set of resources
    - The application acts on these resources
  - Assumption is that the resources **adequately** capture the physical system
    - In practice this is not always the case -> Digital Twin

IoT Lecture 5

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Scaling IoT Systems

- IoT (academic model)
  - Includes device management and service management

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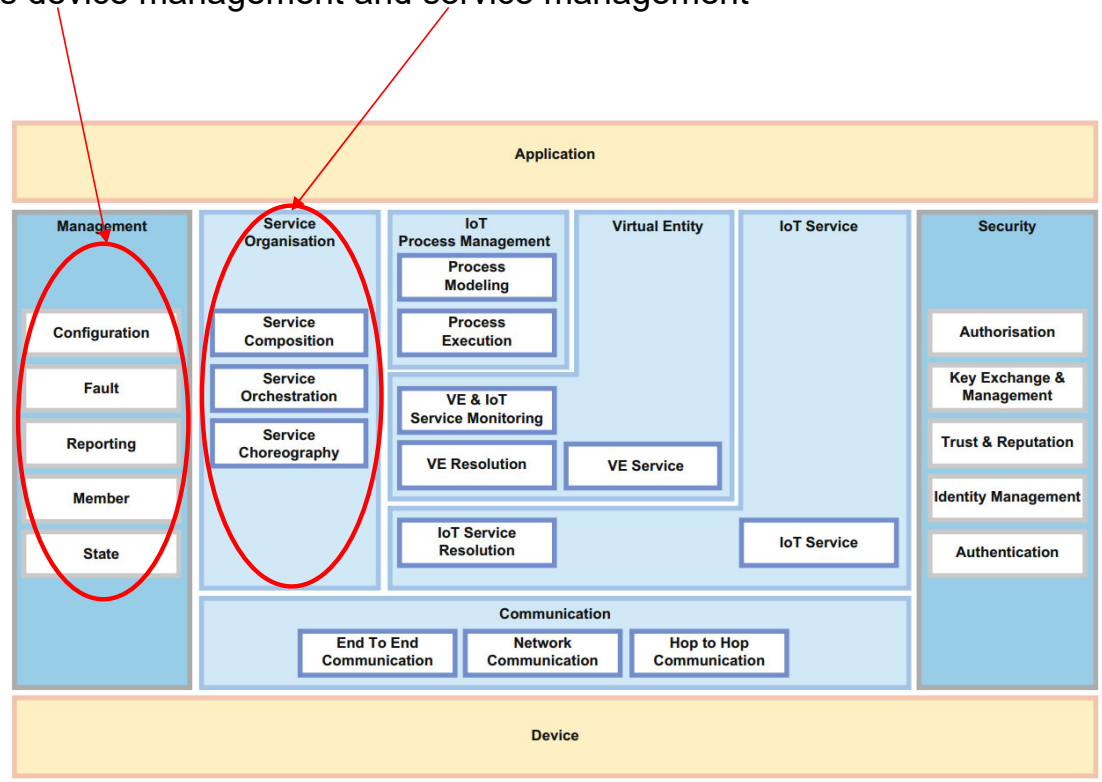

Utility investment costs (1)

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- Irish Water set up in 2013 as a new utility in Ireland. No previous history of usage based billing
- Supply and bill nearly 1.5 million households

- Systems based on the gas utility with ~440'000 customers
  - Customer Care / Billing
  - Work and Asset Management
  - Financial System
  - Procurement System
  - Capital Project Management

UISCE ÉIREANN : IRISH WATER

Bord Gáis Energy

Utility investment costs (2)

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- Four main consultants
  - IBM – €44.8 million
  - Accenture – €17.2 million €
  - Ernst & Young – €4.6 million €
  - KPMG – €2.2 million
- Average meter installation cost ~550 € - in addition to the fees mentioned above (2016)
- **Learning Aim 1a:** The students understand where the money is being spent in large-scale IoT systems
- **Learning Aim 1b:** The students understand the bottom-up approach to standardisation and open source software in the IoT sphere

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OneM2M: Investment Security

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- Many professional distributed systems can be made cheaper and more flexible using IoT architectures
- IoT will not catch on unless there is investment risk-reduction
- Risk reduction requires interoperability and standardisation
- oneM2M -> «unique gathering of 7 major standardisation organisations and tens of smaller consortium to achieve this standardisation»

http://www.onem2m.org/images/files/deliverables/TS-0001-Functional_Architecture-V1_6_1.pdf

January 2015

https://www.onem2m.org/using-onem2m/developers/basics#n1a

OneM2M: Architecture Model

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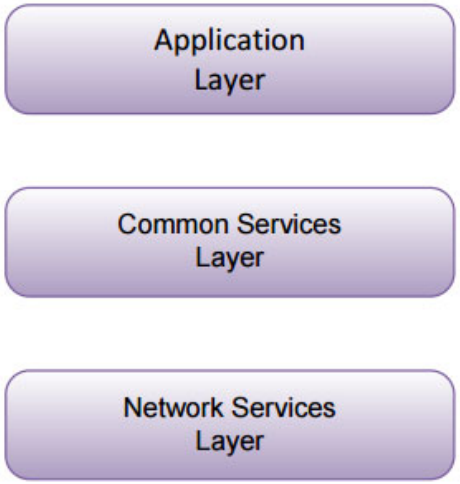
- One M2M offers a functional specification
- This defines the behaviour devices must have, not how they achieve it
- Therefore it defines interfaces, type, communication behaviour …
- It does this on the basis of an architecture model
- openM2M specifies the Common Services Layer



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OneM2M: Entities and Interfaces

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- AE – Application Entity,
  - The water-meter part of the smart-water-meter
  - This is application specific but the capabilities (f.i. precision) may be specified somewhere else
- CSE – Common Services Entity
  - Services that are common to all remote nodes
- NSE – Network Services Entity
  - Not the communication but the services on top of it
  - DNS or NTP

- **Learning Aim 2:** The students understand the rational behind the oneM2M functional architecture
- **Learning Aim 3:** The students will be able to explain the function of the NSE, CSE and AE

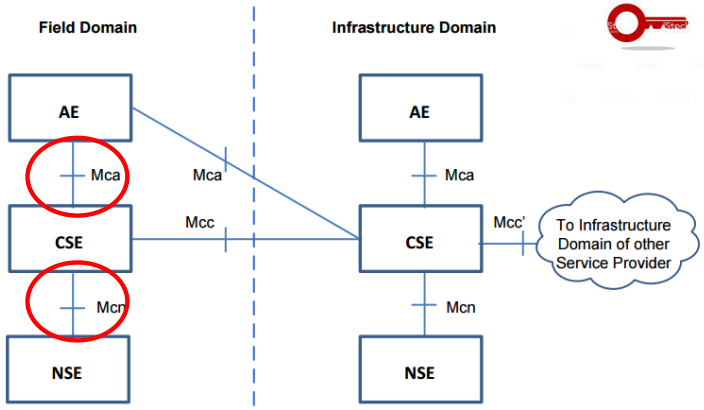

Figure 5.2.1-1: oneM2M Functional Architecture

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OneM2M: “Real-World” Application Example

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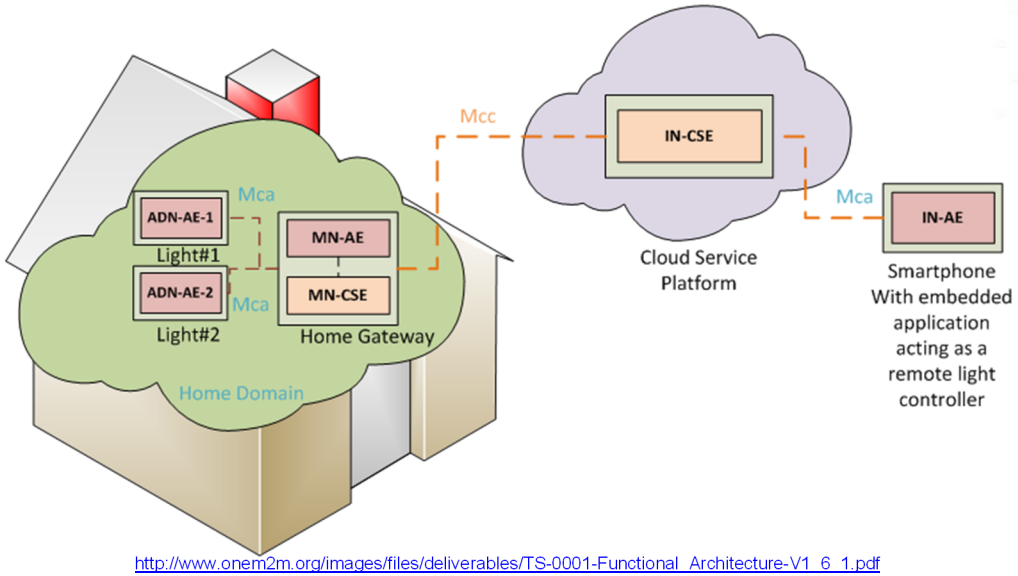
- This model allows the abstraction of the device application from the management and the actual hardware
  - This means that hardware can be made as cheap as possible rather than having to support management layers in software
  - Hardware does have to support some standardised communication



http://www.onem2m.org/images/files/deliverables/TS-0001-Functional_Architecture-V1_6_1.pdf
http://www.onem2m.org/application-developer-guide/architecture

OneM2M: Relationships between Entities

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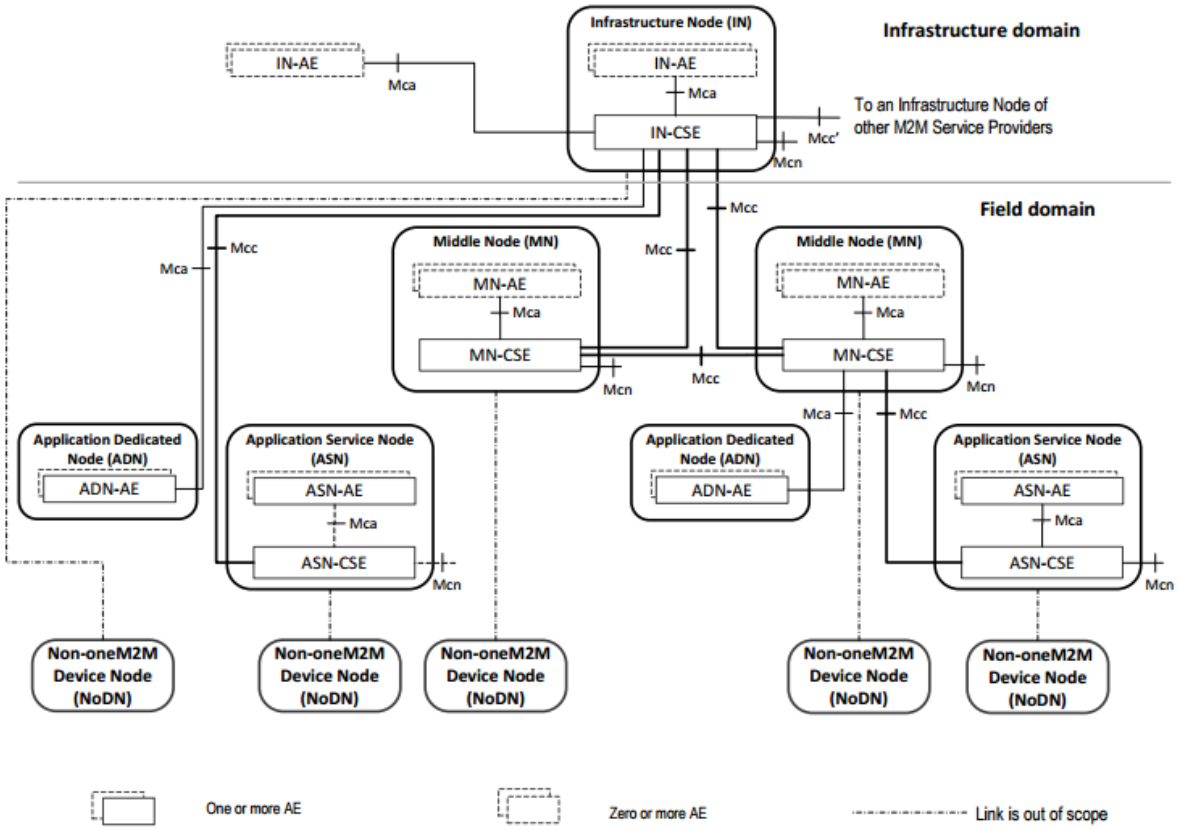

Figure 6.1-1: Configurations supported by oneM2M Architecture

- **LEARNING AIM 4:** The student will be able to explain how a non-oneM2M device is integrated in the framework

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OneM2M: Communication between Entities

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- Here the AE can communicate with the CSE via oneM2M communication mapped onto CoAP

- Whereas here the CSE may communicate via LWM2M over CoAP

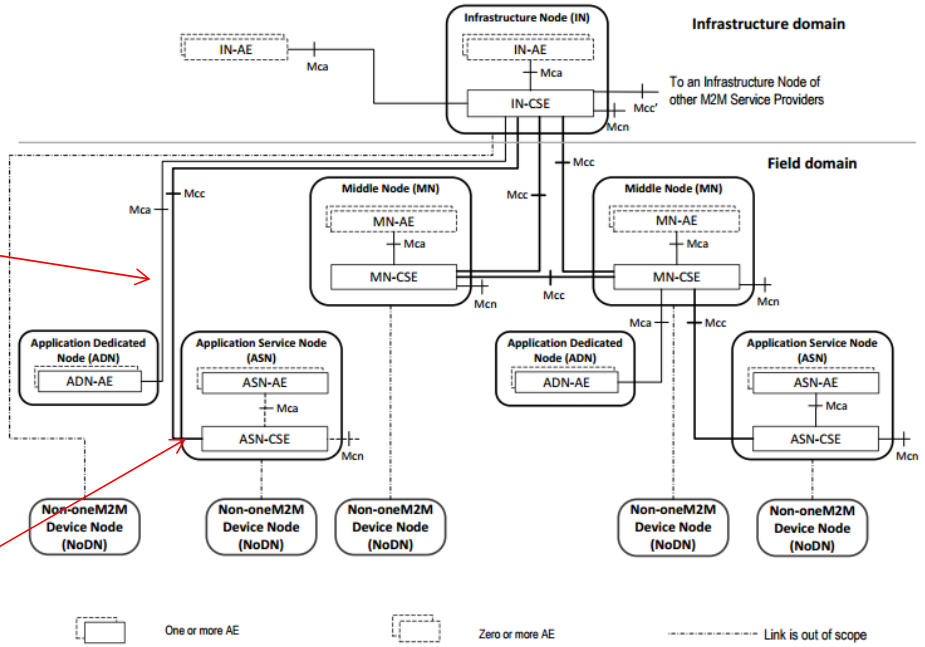

Figure 6.1-1: Configurations supported by oneM2M Architecture

Learning Aim 5: The students will be able to explain how CoAP and other communication protocols are mapped into the oneM2M functional model

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OneM2M: Common Services Entities (1)

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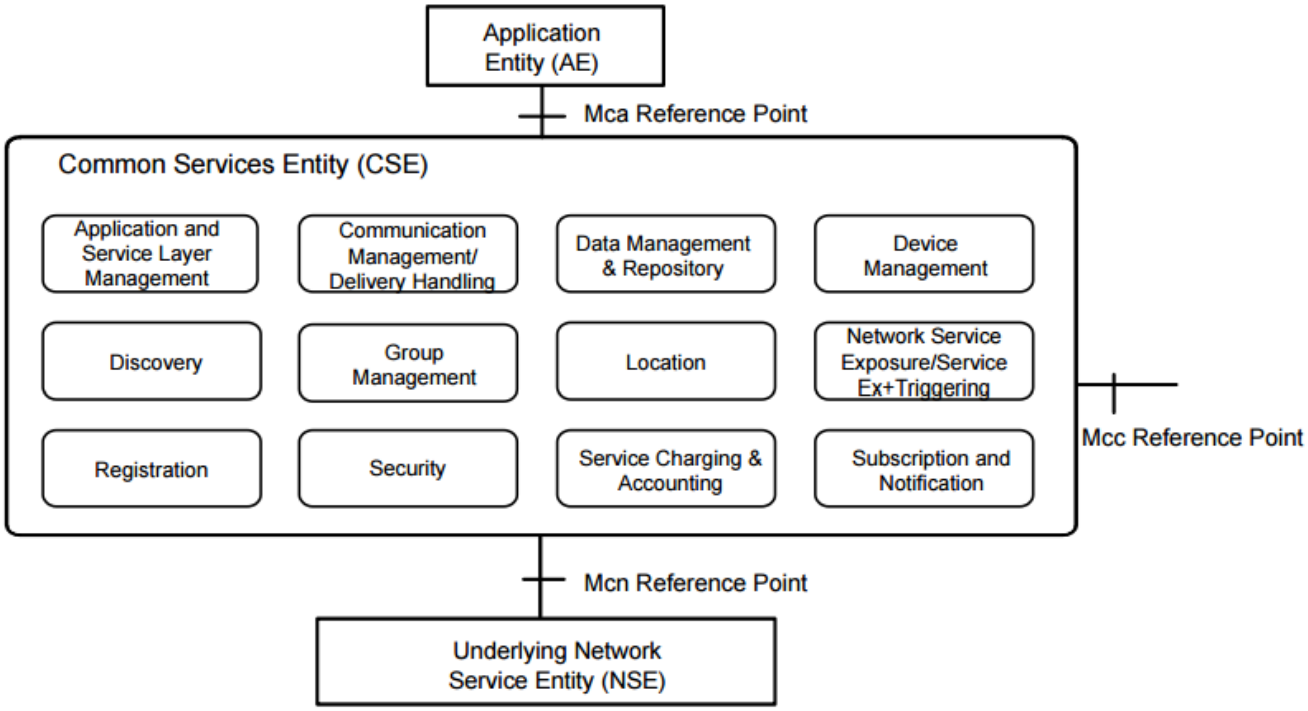

Figure 6.2-1: Common Services Functions

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OneM2M: Device Management & Data Management

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- Device Management
  - The Device Management (DMG) CSF provides management of device capabilities
  - Abstracts application from actual device
  - Covered by, f.i. LWM2M
  - Only management block with underlying specification (i.e LWM2M)
- Data Management & Repository
  - The Data Management and Repository … includes the capability of collecting data for the purpose of aggregating large amounts of data, converting this data into a specified format, and storing it for analytics and semantic processing

- **Learning Aim 4:** The students will be able to list and explain the various management services offered by the Common Services Entity

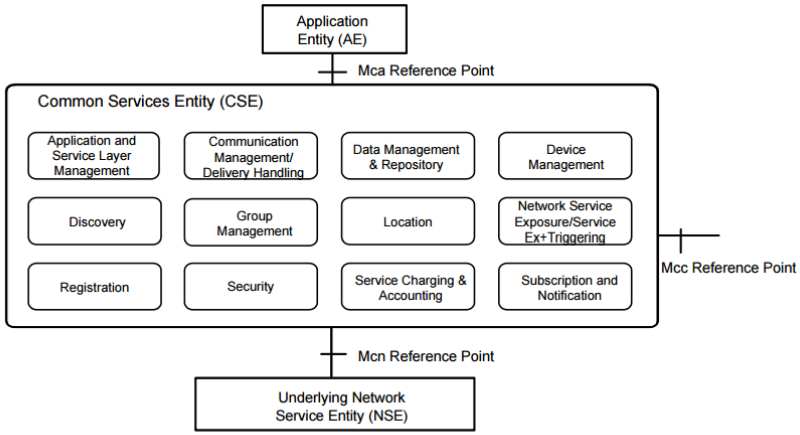

Figure 6.2-1: Common Services Functions

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OneM2M: Communication and Application Management

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- Communication Management
  - The CMDH CSF decides at what time to use which communication connection for delivering communications (e.g. CSE-to-CSE communications) and, when needed and allowed, to buffer communication requests so that they can be forwarded at a later time.

- Application and Service Layer Management
  - The Application and Service Layer Management provides management of the AEs and CSEs … This includes capabilities to configure, troubleshoot and upgrade the functions of the CSE, as well as to upgrade the AEs

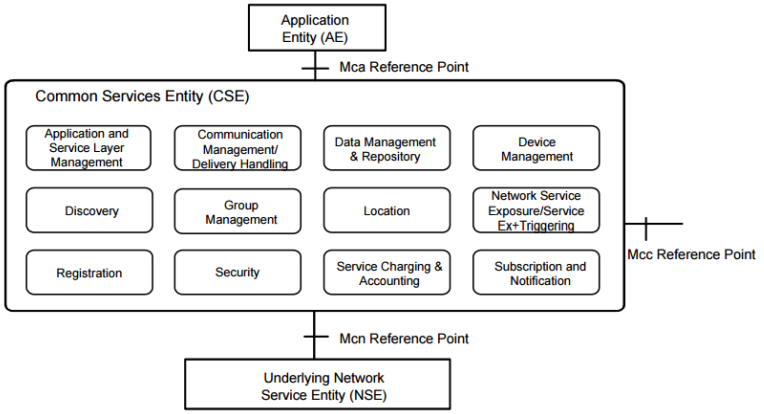

Figure 6.2-1: Common Services Functions

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OneM2M: Subscription Management

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- Subscription and Notification Management
  - The Subscription and Notification (SUB) CSF provides notifications pertaining to a subscription that tracks event changes on a resource (e.g. deletion of a resource). A subscription to a resource is initiated by an AE or a CSE and is granted by the Hosting CSE subject to access control policies. During an active resource subscription, the Hosting CSE sends a notification regarding a notification event to the address(es) where the resource subscriber wants to receive it.

- What the other management blocks do is deducible from the name

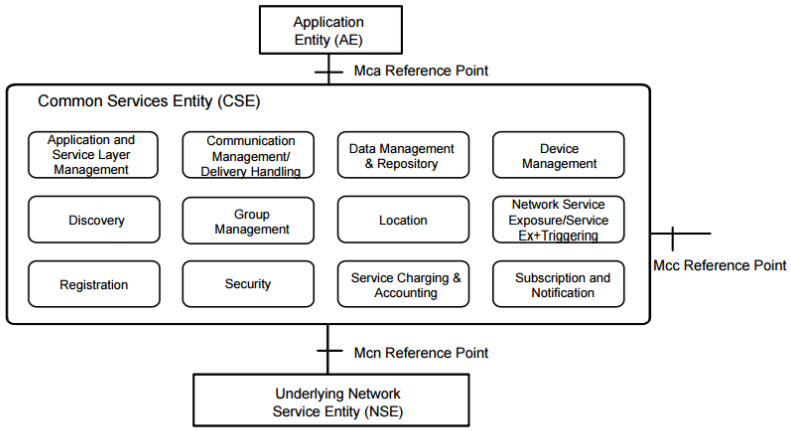

Figure 6.2-1: Common Services Functions

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OneM2M: Communication

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- oneM2M offers identifiers
  - Application Entity Identifier (AE-ID)
  - CSE Identifier (CSE-ID)
  - M2M node identifier
- M2M node identifier corresponds to the hardware
- oneM2M offers communication flow definitions on Mca and Mcc
- oneM2M offers definitions of operations
  - Create / Retrieve / Update / Delete / Notify

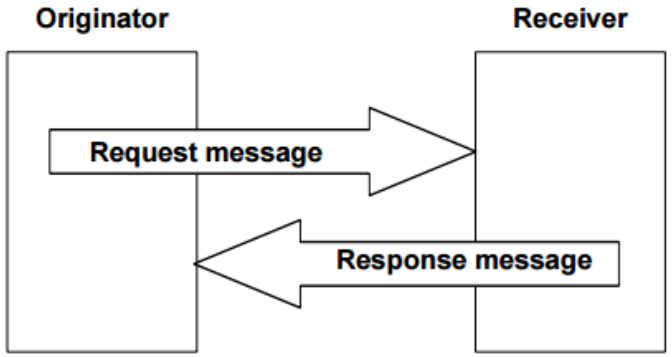

Figure 8.1.1-1: General Flow

http://www.onem2m.org/images/files/deliverables/TS-0001-Functional_Architecture-V1_6_1.pdf

OneM2M: Communication Behaviour

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- oneM2M offers communication behaviour definitions
  - blockingRequest
  - nonBlockingRequestAsync
  - nonBlockingRequestSynch
- These are mapped onto CoAP communication
- Bindings available for MQTT

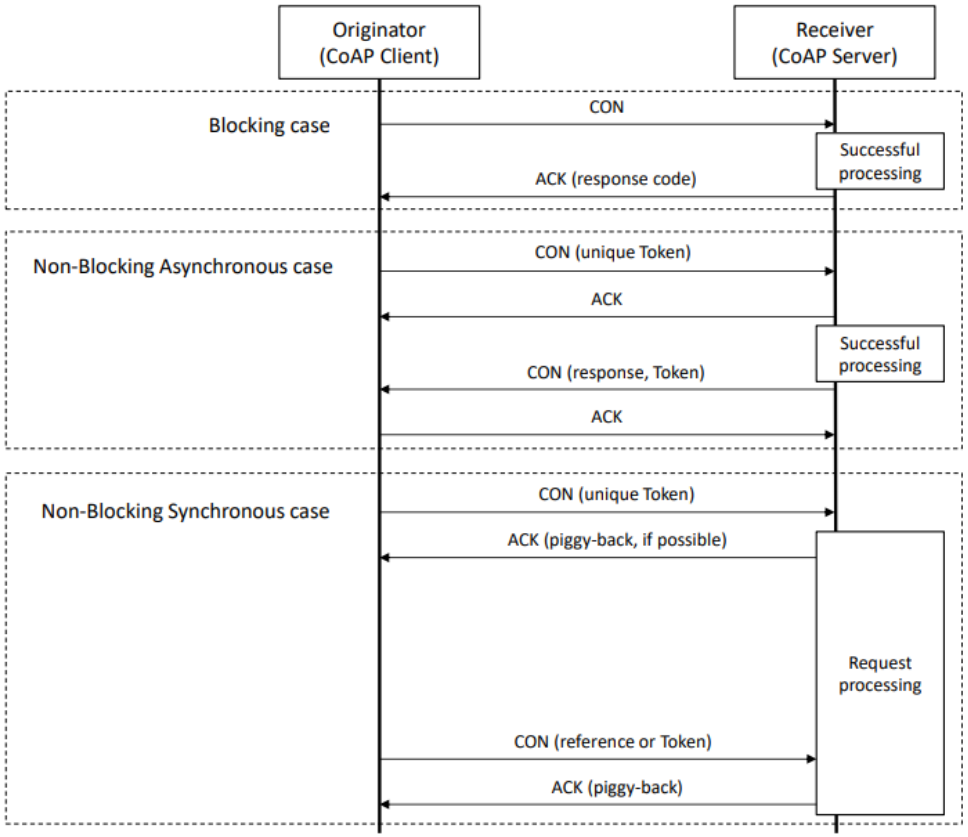

Figure 6.3.0-1: Accessing resource cases

http://www.ttc.or.jp/jp/document_list/pdf/j/TS/TS-M2M-0008v2.6.1.pdf

OneM2M: Resources

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- Operations return a mappable response code
- Resources are defined by structure and model

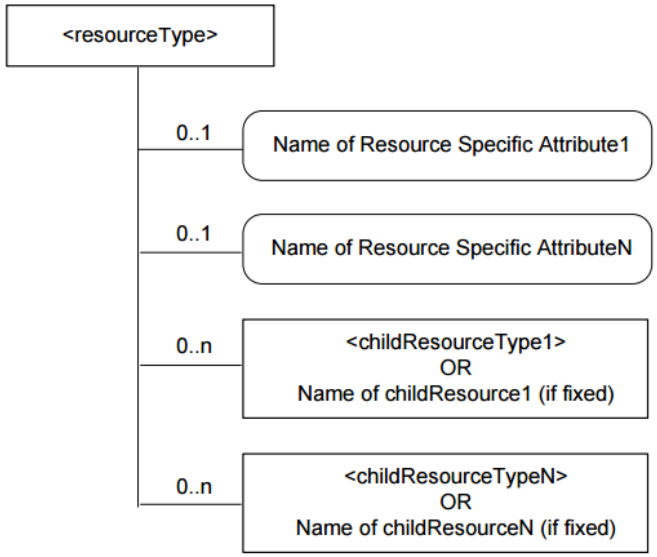

Figure 9.5-1: *<resourceType>* representation convention

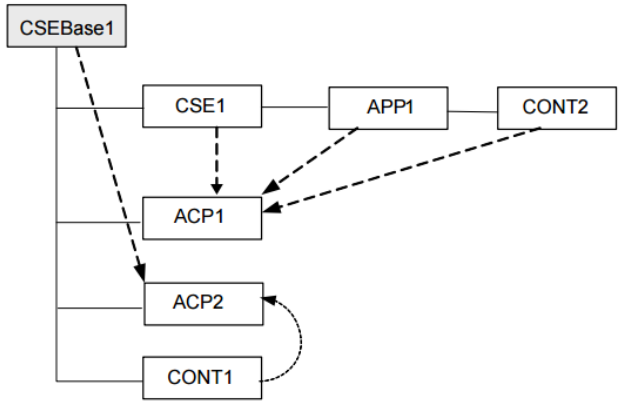

Figure 9.4.1-1: Resource Relationships Example in a CSE

Learning Aim 6: The students will be able to explain the object structure as defined by oneM2M

http://www.onem2m.org/images/files/deliverables/TS-0001-Functional_Architecture-V1_6_1.pdf

OneM2M: Resource Management Example

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- So this is mapped onto LWM2M like:

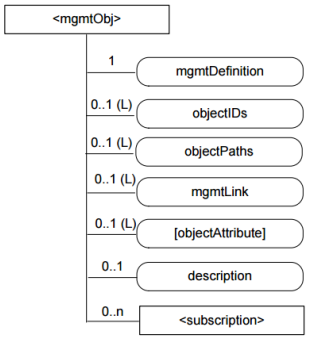
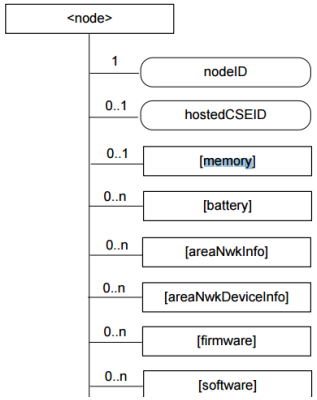


Figure 9.6.15-1: Structure of *<mgmtObj>* resource



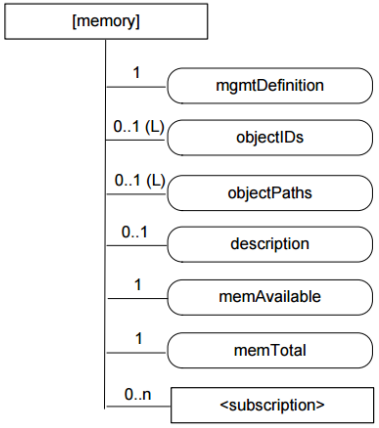


Figure D.4-1: Structure of *[memory]* resource

Table D.4-2: Attributes of *[memory]* resource

Attributes of *[memory]*	Multiplicity	RW/ RO/ WO	Description
resourceType	1	RO	See clause 9.6.1.3 where this common attribute is described.
resourceID	1	RO	See clause 9.6.1.3 where this common attribute is described.
resourceName	1	WO	See clause 9.6.1.3 where this common attribute is described.
parentID	1	RO	See clause 9.6.1.3 where this common attribute is described.
expirationTime	1	RW	See clause 9.6.1.3 where this common attribute is described.
accessControlPolicyIDs	0..1 (L)	RW	See clause 9.6.1.3 where this common attribute is described.
creationTime	1	RO	See clause 9.6.1.3 where this common attribute is described.
lastModifiedTime	1	RO	See clause 9.6.1.3 where this common attribute is described.
labels	0..1	RW	See clause 9.6.1.3 where this common attribute is described.
mgmtDefinition	1	WO	See clause 9.6.15. Has fixed value *"memory"* to indicate the resource is for memory management.
objectIDs	0..1 (L)	RW	See clause 9.6.15.
objectPaths	0..1 (L)	RW	See clause 9.6.15.
description	0..1	RW	See clause 9.6.15.
memAvailable	1	RW	The current available amount of memory. This attribute is a specialization of *[objectAttribute]* attribute.
memTotal	1	RW	The total amount of memory. This attribute is a specialization of *[objectAttribute]* attribute.

The Resource [memory] provides memory related information. For OMA LWM2M, this Resource shall be mapped to the unique Instance of LWM2M Device Object (LWM2M ObjectID: 3).

The context of this Resource is as follows.

Table 6.3.4-1 Context of resource [memory]

Context	Mapping
objectId	urn:oma:lwm2m:oma:3
objectPath	/3/0 (instance 0 of Object 3)

The attributes of this Resource shall be mapped to specific resources of the LWM2M Device Object Instance as follows:

Table 6.3.4-1 Attributes of resource [memory]

Attribute Name of [memory]	Mapping to resources in LWM2M Device Object Instance	
memAvailable	10	estimated current available amount of memory in KB
memTotal	21	total amount of storage space in KB in the LWM2M Device

http://www.onem2m.org/images/files/deliverables/TS-0008-CoAP_Protocol_Binding-V1_0_1.pdf

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OneM2M: Resource Management and Communication Mapping

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- UPDATEing a management object looks like:

Table 10.2.8.4-1: <*mgmtObj*> UPDATE

<*mgmtObj*> UPDATE	
Associated Reference Point	Mcc and Mca
Information in Request message	***From:*** Identifier of the AE or the CSE that initiates the Request ***To:*** The address of the <*mgmtObj*> resource ***Content:*** The representation of the <*mgmtObj*> resource for which the attributes are described in clause 9.6.15
Processing at Originator before sending Request	The Originator shall be an IN-AE, or a CSE which the on a managed entity is associated with
Processing at Receiver	For the UPDATE operation, the Receiver shall: • If the Originator is an IN-AE, identify the corresponding external management object on the managed entity according to the mapping relationship it maintains. Check if there is an existing management session between the management server and the managed entity. If not, request the management server to establish a management session towards the managed entity. Send the management request to update the corresponding external management object in the managed entity accordingly based on external management technology • Respond to the Originator with the appropriate response based on the response from the external management technology
Information in Response message	Error code if the external management object cannot be updated
Processing at Originator after receiving Response	None
Exceptions	• Corresponding entity (e.g. not

The Update primitive shall map to the LWM2M Write operation and shall return one of the codes described in table 6.4.31-1.

Table 6.4.3.1-1 : Update Returned Codes Mapping

oneM2M Primitive Status Code	Returned Codes	Description
success	2.04 Changed	"Update" operation is completed successfully
error - bad request	4.00 Bad Request,	The format of data to be updated is different
error - no privilege	4.01 Unauthorized	Access Right Permission Denied
error - not found	4.04 Not Found,	Target of "Update" operation is not found
error - not allowed	4.05 Method Not Allowed	Target is not allowed for "Update" operation

http://www.onem2m.org/images/files/deliverables/TS-0001-Functional_Architecture-V1_6_1.pdf

OneM2M: Communication Mapping

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Introduction
Session 1: oneM2M
- Investment Security
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- **Resources and Communication**

Session 2: LWM2M
- Purpose
- Object Model
- Device Management

Session 3: IPSO
- Sensor Objects and Resources

- If a AE has to communicate with a CSE over an external link then there is a CoAP mapping (and an MQTT mapping):

Table 6.2.1-1: oneM2M Operation Parameter Mapping

oneM2M Operation Parameter	CoAP Method
CREATE	POST
RETRIEVE	GET
UPDATE	PUT
DELETE	DELETE
NOTIFY	POST

Table 6.2.4-1 Mapping between oneM2M Response Status Code and CoAP Response Code

oneM2M Response Status Code	Description	Status Code of CoAP	Description
1000	ACCEPTED	None	Empty Acknowledgement Message shall be used.
2000	OK	2.05	Content
2001	CREATED	2.01	Created
2002	DELETED	2.02	Deleted
2004	CHANGED	2.04	Changed
4000	BAD_REQUEST	4.00	Bad Request
4004	NOT_FOUND	4.04	Not Found
4005	OPERATION_NOT_ALLOWED	4.05	Method Not Allowed
4008	REQUEST_TIMEOUT	4.04	Not Found
4101	SUBSCRIPTION_CREATOR_HAS_NO_PRIVILEGE	4.03	Forbidden
4102	CONTENTS_UNACCEPTABLE	4.00	Bad Request
4103	ACCESS_DENIED	4.03	Forbidden
4104	GROUP_REQUEST_IDENTIFIER_EXISTS	4.00	Bad Request
4105	CONFLICT	4.03	Forbidden
5000	INTERNAL_SERVER_ERROR	5.00	Internal Server Error
5001	NOT_IMPLEMENTED	5.01	Not Implemented
5103	TARGET_NOT_REACHABLE	4.04	Not Found
5105	NO_PRIVILEGE	4.03	Forbidden
5106	ALREADY_EXISTS	4.00	Bad Request
5203	TARGET_NOT_ SUBSCRIBABLE	4.03	Forbidden
5204	SUBSCRIPTION_VERIFICATION_INITIATION_FAILED	5.00	Internal Server Error
5205	SUBSCRIPTION_HOST_HAS_NO_PRIVILEGE	4.03	Forbidden
5206	NON_BLOCKING_REQUEST_NOT_SUPPORTED	5.00	Internal Server Error
6003	EXTERNAL_OBJECT_NOT_REACHABLE	4.04	Not Found

6.3.1 Blocking case

- If ***Response Type*** parameter is configured as "blockingRequest" (blocking case), the Originator (CoAP client) shall use the Confirmable Method for the resource to the Receiver (CoAP server).
- In case of successful processing of the request at the Receiver, the Receiver shall piggyback the response with an appropriate response code in the Acknowledgment message that acknowledges the Confirmable request.

http://www.onem2m.org/images/files/deliverables/TS-0008-CoAP_Protocol_Binding-V1_0_1.pdf

Summary

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- Large scale investment grade systems require risk reduction in terms of management and functionality management
- Also require interoperability between different manufacturers
- Interoperability can only be achieved by standardisation
  - Local standardisation – utility defines behaviour, but also has to pony up if it gets it wrong and changes required
  - Global standardisation
  - Using functional specification it is possible to define expected behaviour and let manufacturers work out the implementation details
  - Using functional specifications it is possible to map existing management and communication protocols into this functional description
    - Next session -> Lightweight Machine to Machine
- At the end of the day it makes it easier for implementers and makes the work re-usable if standards are adhered to
- oneM2M are working in the direction of a complete specification suite
- Still a long way to go …..

Results

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- Result 1:
  - oneM2M provides framework for common services for large-scale IoT systems
- Result 2:
  - Device management an integral function of large-scale IoT systems
  - LWM2M covers this functionality
- Result 3:
  - LWM2M offers dynamic resource/object handling for device management
  - It follows that this object creation/deletion can be used by the application layer as well
- Result 4:
  - IPSO uses resource/object function to abstract the physical into the cyber
    - A physical system is described by a set of resources
    - The application acts on these resources
  - Assumption is that the resources **adequately** capture the physical system
    - In practice this is not always the case -> Digital Twin

IoT Lecture 5

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Device Management OMA LWM2M

Introduction
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Session 3: IPSO
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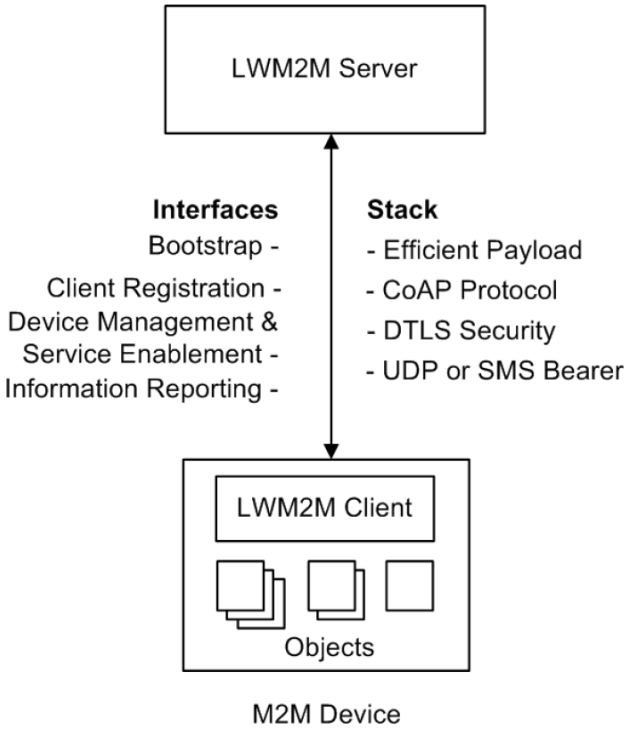
- Large scale device management an issue for 30 odd years
  - Mobile phones
  - (Telemetry systems)
- Open Mobile Alliance promulgated
  - Lightweight Machine to Machine Technical Specification
  - http://technical.openmobilealliance.org/Technical/technical-information/release-program/current-releases/oma-lightweightm2m-v1-0
  - This is a Device-Management Application Layer Communication protocol
  - Also provides service enablement
  - V1.2 11.2021



http://technical.openmobilealliance.org/Technical/technical-information/release-program/current-releases/oma-lightweightm2m-v1-0

Learning Aims

Introduction
Session 1: oneM2M
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Session 2: LWM2M
- **Purpose**
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- Device Management

Session 3: IPSO
- Sensor Objects and Resources

- **Learning Aim 1**: The students can explain the LWM2M object/resource model
  Learning Aim 2: The students understand the principle of dynamic resource and object instantiation
- **Learning Aim 3:** The students understand the principle of mapping LWM2M operations into CoAP frames
- **Learning Aim 4**: The students understand the principle as how the server and client communicate
- **Learning Aim 5**: The students understand the addressing principle of the objects/resources under LWM2M

Device Management OMA LWM2M

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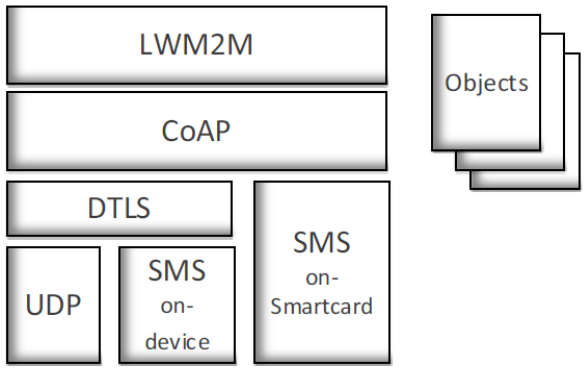
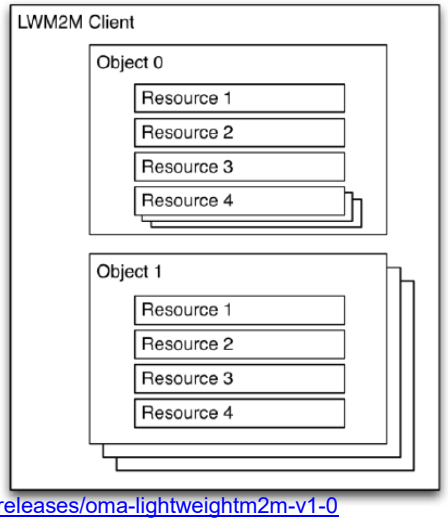
- Originally based on CoAP
- Adds an additional layer to standardise interface
- Uses simple object creation, update and deletion system.
- Relevant stuff is stored as a resource
- Resources are grouped into objects
- Standardises 8 different types of objects with single and multiple instances





Learning Aim 1: The students can explain the LWM2M object/resource model

http://technical.openmobilealliance.org/Technical/technical-information/release-program/current-releases/oma-lightweightm2m-v1-0

LWM2M Standard Objects

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Session 3: IPSO
- Sensor Objects and Resources

- LWM2M is a device management protocol based on objects holding resources
- Objects can be dynamically created and deleted
- LWM2M currently offers 8 standard objects
- LWM2M supports 4 interfaces
  - Bootstrap
  - Client Registration
  - Device Management
  - Information Reporting

Object	Object ID
LWM2M Security	0
LWM2M Server	1
Access Control	2
Device	3
Connectivity Monitoring	4
Firmware	5
Location	6
Connectivity Statistics	7

Learning Aim 2: The students know the standard LWM2M objects and can use them

http://technical.openmobilealliance.org/Technical/technical-information/release-program/current-releases/oma-lightweightm2m-v1-0

Device Management OMA LWM2M

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- Example of LWM2M Objects and Resources
  - What describes the device?
    - A Device Object

Learning Aim 3: The students understand the use of the standard LWM2M Device object

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Object definition

Name	Object ID	Instances	Mandatory	Object URN
Device	3	Single	Mandatory	TBD

Object	Object ID
LWM2M Security	0
LWM2M Server	1
Access Control	2
Device	3
Connectivity Monitoring	4
Firmware	5
Location	6
Connectivity Statistics	7

http://technical.openmobilealliance.org/Technical/technical-information/release-program/current-releases/oma-lightweightm2m-v1-0

Device Object (1)

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ID	Name	Operations	Instances	Mandatory	Type	Range or Enumeration	Units	Description
0	Manufacturer	R	Single	Optional	String			Human readable manufacturer name
17	Device Type	R	Single	Optional	String			Type of the device (manufacturer specified string : e.g. smart meters / dev Class…)
1	Model Number	R	Single	Optional	String			A model identifier (manufacturer specified string)
2	Serial Number	R	Single	Optional	String			Serial Number
18	Hardware Version	R	Single	Optional	String			Current hardware version of the device
3	Firmware Version	R	Single	Optional	String			Current firmware version of the device. The Firmware Management function could rely on this resource.
19	Software Version	R	Single	Optional	String			Current software version of the device. (manufacturer specified string). On elaborated LWM2M device, SW could be split in 2 parts : a firmware one and a higher level software on top. Both pieces ofSoftware are together managed by LWM2M Firmware Update Object (Object ID 5)

http://technical.openmobilealliance.org/Technical/technical-information/release-program/current-releases/oma-lightweightm2m-v1-0

Device Object (2)

Introduction
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Session 3: IPSO
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4	Reboot	E	Single	Mandatory				Reboot the LWM2M Device to restore the Device from unexpected firmware failure.
5	Factory Reset	E	Single	Optional				Perform factory reset of the LWM2M Device to make the LWM2M Device have the same configuration as at the initial deployment. When this Resource is executed, "De-register" operation MAY be sent to the LWM2M Server(s) before factory reset of the LWM2M Device.
6	Available Power Sources	R	Multiple	Optional	Integer	0-7		0 – DC power 1 – Internal Battery 2 – External Battery 4 – Power over Ethernet 5 – USB 6 – AC (Mains) power 7 – Solar
7	Power Source Voltage	R	Multiple	Optional	Integer		mV	Present voltage for each Available Power Sources Resource Instance. Each Resource Instance ID MUST map to the value of Available Power Sources Resource.
8	Power Source Current	R	Multiple	Optional	Integer		mA	Present current for each Available Power Source
9	Battery Level	R	Single	Optional	Integer	0-100	%	Contains the current battery level as a percentage (with a range from 0 to 100). This value is only valid when the value of Available Power Sources Resource is 1.

http://technical.openmobilealliance.org/Technical/technical-information/release-program/current-releases/oma-lightweightm2m-v1-0

Device Object (3)

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Session 3: IPSO
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20	Battery Status	R	Single	Optional	Integer	0-6		This value is only valid when the value of Available Power Sources Resource is 1.

Battery Status	Meaning	Description
0	Normal	The battery is operating normally and not on power.
1	Charging	The battery is currently charging.
2	Charge Complete	The battery is fully charged and still on power.
3	Damaged	The battery has some problem.
4	Low Battery	The battery is low on charge.
5	Not Installed	The battery is not installed.
6	Unknown	The battery information is not available.

10	Memory Free	R	Single	Optional	Integer		KB	Estimated current available amount of storage space which can store data and software in the LWM2M Device (expressed in kilobytes).
21	Memory Total	R	Single	Optional	Integer		KB	Total amount of storage space which can store data and software in the LWM2M Device (expressed in kilobytes).

http://technical.openmobilealliance.org/Technical/technical-information/release-program/current-releases/oma-lightweightm2m-v1-0

Device Object (4)

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11	Error Code	R	Multiple	Mandatory	Integer			0=No error 1=Low battery power 2=External power supply off 3=GPS module failure 4=Low received signal strength 5=Out of memory 6=SMS failure 7=IP connectivity failure 8=Peripheral malfunction When the single Device Object Instance is initiated, there is only one error code Resource Instance whose value is equal to 0 that means no error. When the first error happens, the LWM2M Client changes error code Resource Instance to any non-zero value to indicate the error type. When any other error happens, a new error code Resource Instance is created. This error code Resource MAY be observed by the LWM2M Server. How to deal with LWM2M Client's error report depends on the policy of the LWM2M Server.
12	Reset Error Code	E	Single	Optional				Delete all error code Resource Instances and create only one zero-value error code that implies no error.

13	Current Time	RW	Single	Optional	Time			Current UNIX time of the LWM2M Client. The LWM2M Client should be responsible to increase this time value as every second elapses. The LWM2M Server is able to write this Resource to make the LWM2M Client synchronized with the LWM2M Server.
14	UTC Offset	RW	Single	Optional	String			Indicates the UTC offset currently in effect for this LWM2M Device. UTC+X [ISO 8601].
15	Timezone	RW	Single	Optional	String			Indicates in which time zone the LWM2M Device is located, in IANA Timezone (TZ) database format.
16	Supported Binding and Modes	R	Single	Mandatory	String			Indicates which bindings and modes are supported in the LWM2M Client. The possible values of Resource are combination of "U" or "UQ" and "S" or "SQ".

http://technical.openmobilealliance.org/Technical/technical-information/release-program/current-releases/oma-lightweightm2m-v1-0

Device Object (5) – In real Life

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Resource Name	Resource ID	Resource Instance ID	Value	Notes
Manufacturer	0		Open Mobile Alliance	
Model Number	1		Lightweight M2M Client	
Serial Number	2		345000123	
Firmware version	3		1.0	
Available Power Sources	6	0	1	Internal Battery
Available Power Sources	6	1	5	USB
Power Source Voltage	7	0	3800	3.8V battery
Power Source Voltage	7	1	5000	USB VBUS
Power Source Current	8	0	125	125mA
Power Source Current	8	1	900	USB 900mA
Battery level	9		100	
Memory free	10		15	15 kB of free memory
Error code	11	0	0	No errors
Current Time	13		1367491215	May 2nd, 2013 at 11:42 AM
				GMT
UTC Offset	14		+02:00	UTC+2 (CET)
Supported Binding and Modes	15		U	UDP binding

Table 11: Device Object

One instance of this object **ONLY**

Device has battery and USB power -> two instances of this resource …

… ergo two instances of parameters …

… but one battery -> one battery level

Note: Only resources with Read-Attributes

http://technical.openmobilealliance.org/Technical/technical-information/release-program/current-releases/oma-lightweightm2m-v1-0

Device Management – Error Handling

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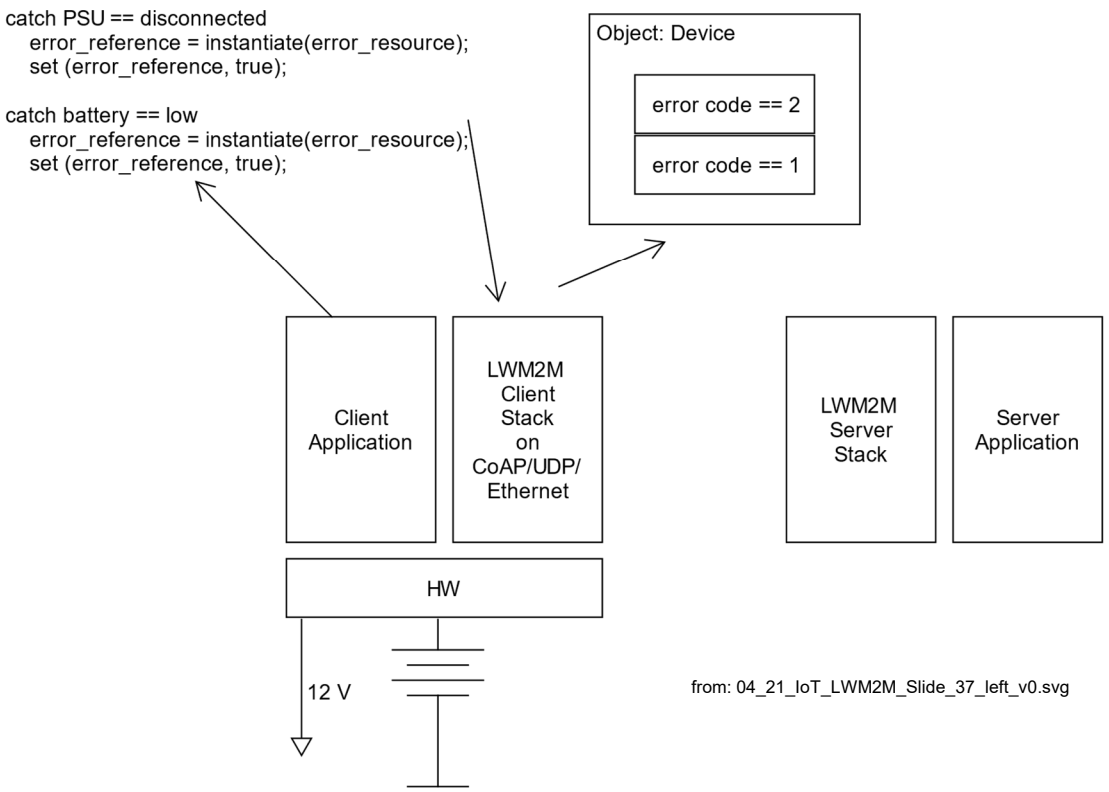

from: 04_21_IoT_LWM2M_Slide_37_left_v0.svg

Learning Aim 4: The students know and describe why dynamic object/resource creation is necessary

Learning Aim 5: The students recognise, understand and can use LWM2M addressing

Learning Aim 6: The students know the difference between a CoAP and LWM2M client/server

LWM2M Interfaces

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Session 3: IPSO
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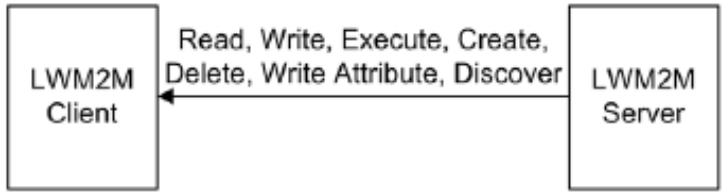
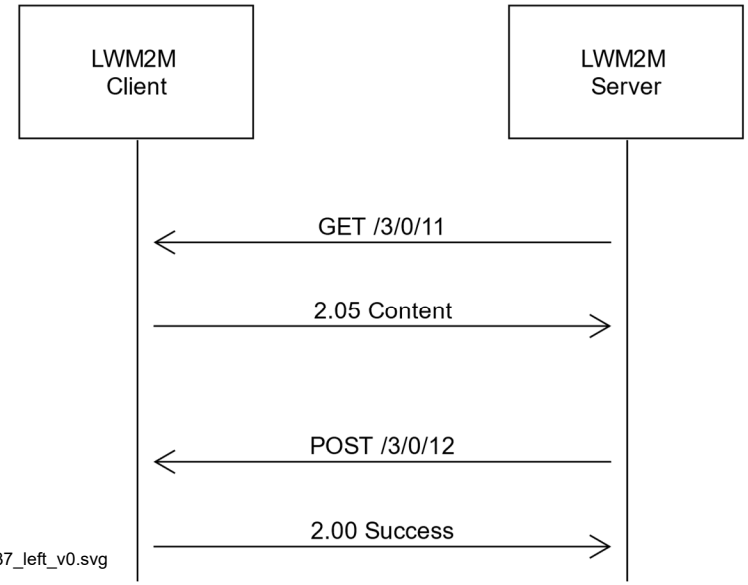
- So what does Device Management Require?

LWM2M Interface 1/4



- Exercise: what does this do?



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http://technical.openmobilealliance.org/Technical/technical-information/release-program/current-releases/oma-lightweightm2m-v1-0

Case Study LWM2M (1)

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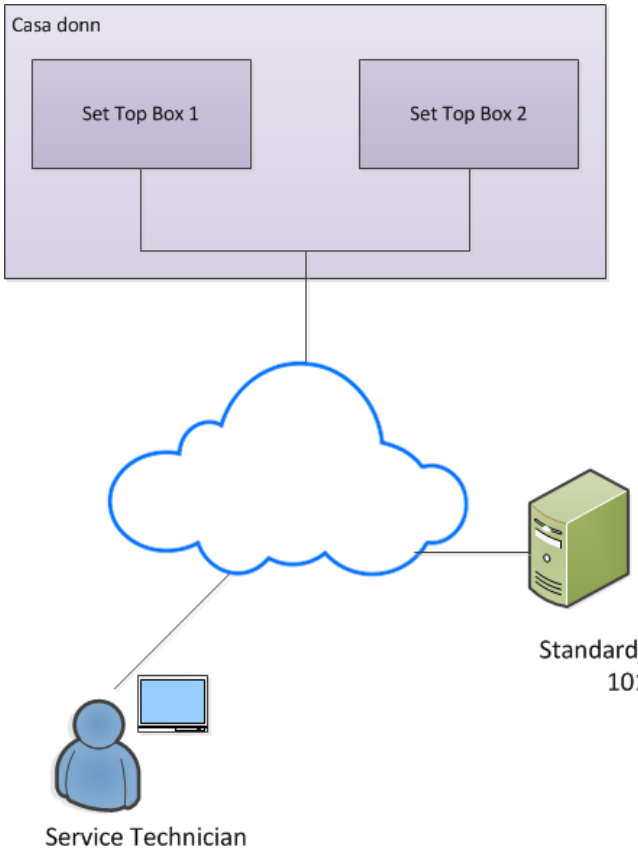
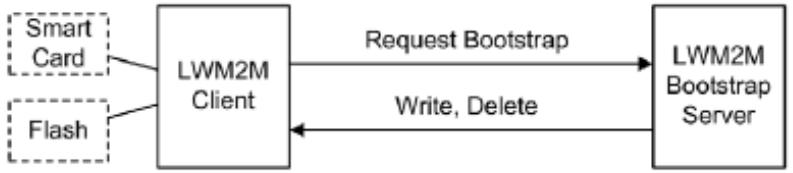


- donn rings customer service and complains about set top box 1 -> what happens?
- donn turns the STB off and on
- The device goes through the bootstrap process

Learning Aim 7: The students understand and can describe the LWM2M bootstrap process

LWM2M Interface 2/4



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Device Management OMA LWM2M

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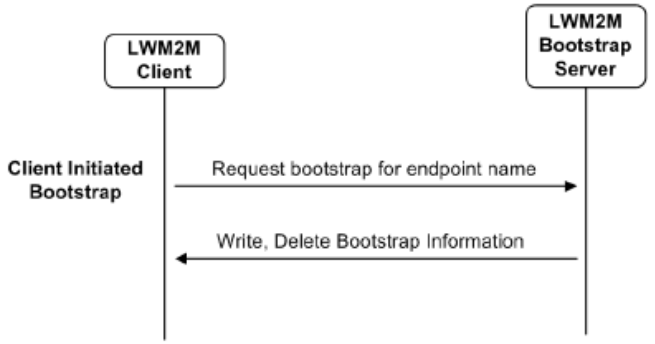
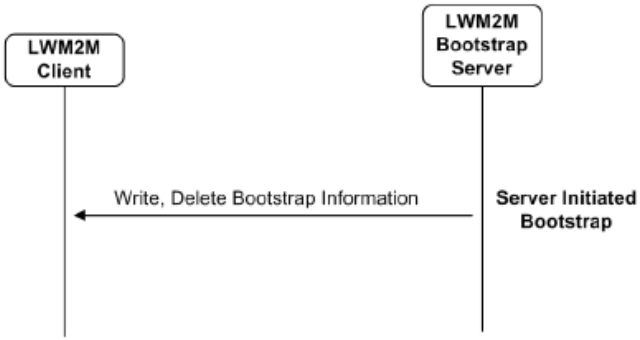
- There are four bootstrap modes supported:
  - Factory Bootstrap (Flash)
  - Bootstrap from SmartCard
  - Client Initiated Bootstrap
  - Server initiated Bootstrap
- Heavily implementation dependent





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Device Management OMA LWM2M

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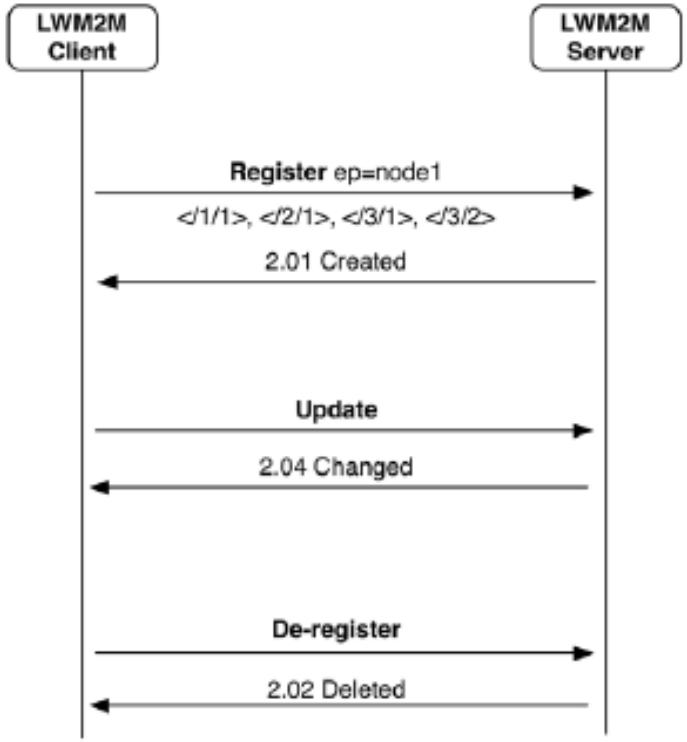
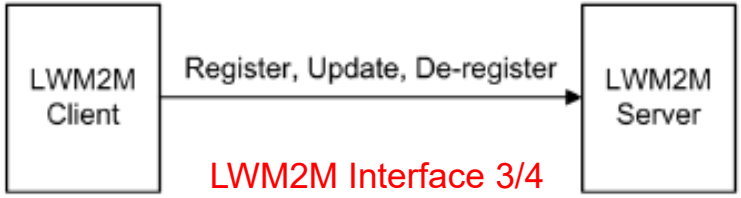


- After Bootstrap STB registers with server 101
- Customer service sends some message to Server 101

Learning Aim 8: The students understand and can describe the LWM2M registration process



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Device Management OMA LWM2M

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Session 3: IPSO
- Sensor Objects and Resources

- Server 101 creates a new Server Object and a new Access Control Object on Client
  - Server 202

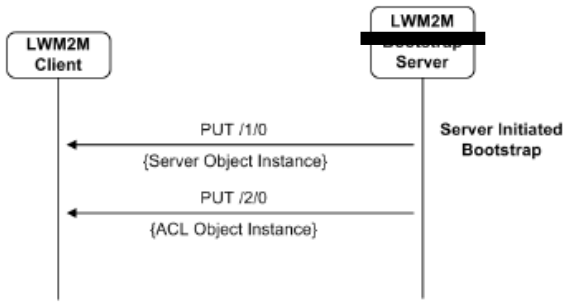
Object definition

Name	Object ID	Instances	Mandatory	Object URN
LWM2M Server	1	Multiple	Mandatory	TBD

Resource definitions

ID	Name	Operations	Instances	Mandatory	Type	Range or Enumeration	Units	Description
0	Short Server ID	R	Single	Mandatory	Integer	1-65535		Used as link to associate server Object Instance.
1	Lifetime	RW	Single	Mandatory	Integer		s	Specify the lifetime of the registration in seconds.
2	Default Minimum Period	RW	Single	Optional	Integer		s	The default value the LWM2M Client should use for the Minimum Period of an Observation in the absence of this parameter being included in an Observation. If this Resource doesn't exist, the default value is 1.
3	Default Maximum Period	RW	Single	Optional	Integer		s	The default value the LWM2M Client should use for the Maximum Period of an Observation in the absence of this parameter being included in an Observation.

Learning Aim 9: The students understand and can describe the use of the LWM2M Server and Access Control Objects



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Device Management OMA LWM2M

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- Server 202 performs debugging on STB
- - for instance by looking at Connectivity Monitoring Object …

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0	Network Bearer	R	Single	Mandatory	Integer			Indicates the network bearer used for the current LWM2M communication session from the below network bearer list. 0~20 are Cellular Bearers 0: GSM cellular network 1: TD-SCDMA cellular network 2: WCDMA cellular network 3: CDMA2000 cellular network 4: WiMAX cellular network 5: LTE-TDD cellular network 6: LTE-FDD cellular network 7~20: Reserved for other type cellular network 21~40 are Wireless Bearers 21: WLAN network 22: Bluetooth network 23: IEEE 802.15.4 network 24~40: Reserved for other type local wireless network 41~50 are Wireline Bearers 41: Ethernet 42: DSL 43: PLC 44~50: reserved for others type wireline networks.
1	Available Network Bearer	R	Multiple	Mandatory	Integer			Indicates list of current available network bearer. Each Resource Instance has a value from the network bearer list.
2	Radio Signal Strength	R	Single	Mandatory	Integer		dBm	This node contains the average value of the received signal strength indication used in the current network bearer in case Network Bearer Resource indicates a Cellular Network (RXLEV range 0…64) 0 is < 110dBm, 64 is >-48 dBm). Refer to [3GPP 44.018] for more details on Network Measurement Report encoding and [3GPP 45.008] or for Wireless Networks refer to the appropriate wireless standard.

3	Link Quality	R	Single	Optional	Integer			This contains received link quality e.g., LQI for IEEE 802.15.4, (Range (0..255)), RxQual Downlink (for GSM range is 0…7). Refer to [3GPP 44.018] for more details on Network Measurement Report encoding.
4	IP Addresses	R	Multiple	Mandatory	String			The IP addresses assigned to the connectivity interface. (e.g. IPv4, IPv6, etc.)
5	Router IP Addresse	R	Multiple	Optional	String			The IP address of the next-hop IP router. Note: This IP Address doesn't indicate the Server IP address.
6	Link Utilization	R	Single	Optional	Integer	0-100	%	The average utilization of the link to the next-hop IP router in %.
7	APN	R	Multiple	Optional	String			Access Point Name in case Network Bearer Resource is a Cellular Network.
8	Cell ID	R	Single	Optional	Integer			Serving Cell ID in case Network Bearer Resource is a Cellular Network. As specified in TS [3GPP 23.003] and in [3GPP. 24.008]. Range (0…65535) in GSM/EDGE UTRAN Cell ID has a length of 28 bits. Cell Identity in WCDMA/TD-SCDMA. Range: (0..268435455). LTE Cell ID has a length of 28 bits. Parameter definitions in [3GPP 25.331].
9	SMNC	R	Single	Optional	Integer		%	Serving Mobile Network Code. In case Network Bearer Resource has 0(cellular network). Range (0…999). As specified in TS [3GPP 23.003].
10	SMCC	R	Single	Optional	Integer			Serving Mobile Country Code. In case Network Bearer Resource has 0 (cellular network). Range (0…999). As specified in TS [3GPP 23.003].

http://technical.openmobilealliance.org/Technical/technical-information/release-program/current-releases/oma-lightweightm2m-v1-0

Device Management OMA LWM2M

Zürcher Hochschule für Angewandte Wissenschaften
School of Engineering
InES Institute of Embedded Systems

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… or by downloading new firmware

Name	Object ID	Instances	Mandatory	Object URN
Firmware Update	5	Single	Optional	urn:oma:lwm2m:oma:5

Resource definitions

ID	Name	Operations	Instances	Mandatory	Type	Range or Enumeration	Units	Description
0	Package	W	Single	Mandatory	Opaque			Firmware package
1	Package URI	W	Single	Mandatory	String	0-255 bytes		URI from where the device can download the firmware package by an alternative mechanism. As soon the device has received the Package URI it performs the download at the next practical opportunity.
2	Update	E	Single	Mandatory				Updates firmware by using the firmware package stored in Package, or, by using the firmware downloaded from the Package URI. This Resource is only executable when the value of the State Resource is Downloaded.
3	State	R	Single	Mandatory	Integer	1-3		Indicates current state with respect to this firmware update. This value is set by the LWM2M Client. 1: Idle (before downloading or after updating) 2: Downloading (The data sequence is on the way) 3: Downloaded If writing the firmware package to Package Resource is done, or, if the device has downloaded the firmware package from the Package URI the state changes to Downloaded. If writing an empty string to Package Resource is done or writing an empty string to Package URI is done, the state changes to Idle. If performing the Update Resource failed, the state remains at Downloaded. If performing the Update Resource was successful, the state changes from Downloaded to Idle.
4	Update Supported Objects	RW	Single	Optional	Boolean			If this value is true, the LWM2M Client MUST inform the registered LWM2M Servers of Objects and Object Instances parameter by sending an Update or Registration message after the firmware update operation at the next practical opportunity if supported Objects in the LWM2M Client have changed, in order for the LWM2M Servers to promptly manage newly installed Objects. If false, Objects and Object Instances parameter MUST be reported at the next periodic Update message. The default value is false.
5	Update Result	R	Single	Mandatory	Integer	0-6		Contains the result of downloading or updating the firmware 0: Default value. Once the updating process is initiated, this Resource SHOULD be reset to default value. 1: Firmware updated successfully, 2: Not enough storage for the new firmware package. 3. Out of memory during downloading process. 4: Connection lost during downloading process. 5: CRC check failure for new downloaded package. 6: Unsupported package type. 7: Invalid URI This Resource MAY be reported by sending Observe operation.
6	PkgName	R	Single	Optional	String	0-255 bytes		Name of the Firmware Package
7	PkgVersion	R	Single	Optional	String	0-255 bytes		Version of the Firmware package

http://technical.openmobilealliance.org/Technical/technical-information/release-program/current-releases/oma-lightweightm2m-v1-0

Case Study LWM2M (1)

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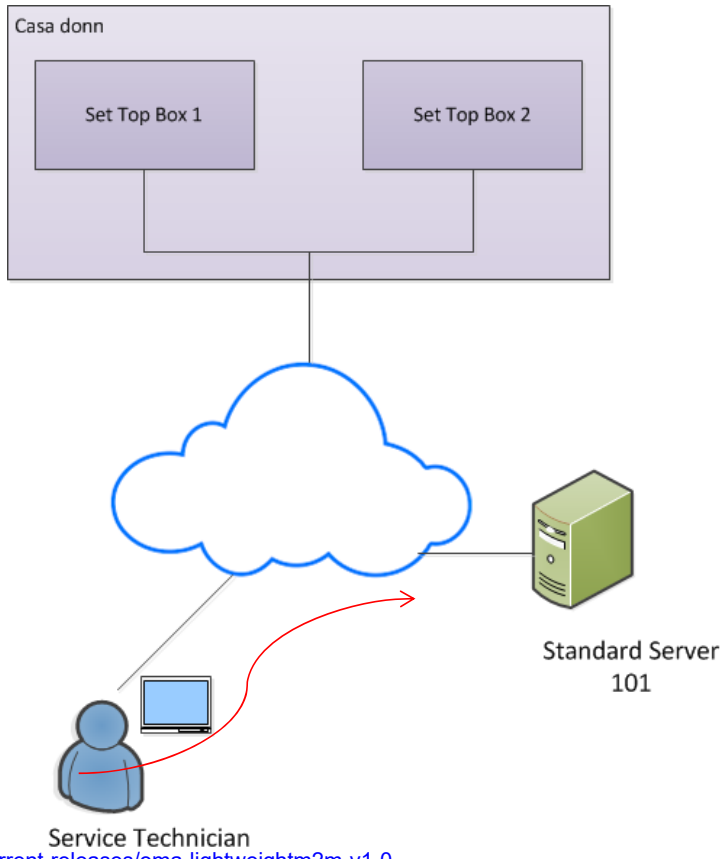
- When debugging finished Service Technician sends message to server 101
- Server 101 deletes access control (202) object
- Server 101 orders client to disconnect from server (LWM2M Server Object)
- Server 101 deletes server (202) object



http://technical.openmobilealliance.org/Technical/technical-information/release-program/current-releases/oma-lightweightm2m-v1-0

Summary

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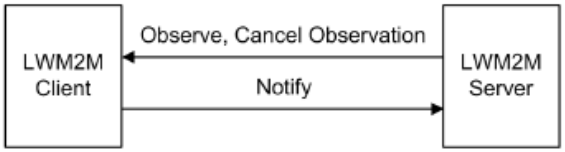
- LWM2M is a device management protocol based on objects holding resources
- The protocol is adapted to M2M devices running CoAP
- Each operation is mapped to a CoAP communication type
- It supports 4 interfaces
  - Bootstrap
  - Client Registration
  - Device Management
  - Information Reporting

- LWM2M currently offers 8 standard objects

Object	Object ID
LWM2M Security	0
LWM2M Server	1
Access Control	2
Device	3
Connectivity Monitoring	4
Firmware	5
Location	6
Connectivity Statistics	7



Learning Aim 10: The students understand and can describe the four LWM2M interfaces

LWM2M Interface 4/4

http://technical.openmobilealliance.org/Technical/technical-information/release-program/current-releases/oma-lightweightm2m-v1-0

Results

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- **Result 1:**
  - oneM2M provides framework for common services for large-scale IoT systems
- **Result 2:**
  - Device management an integral function of large-scale IoT systems
  - LWM2M covers this functionality
- **Result 3:**
  - LWM2M offers dynamic resource/object handling for device management
  - It follows that this object creation/deletion can be used by the application layer as well
- **Result 4:**
  - IPSO uses resource/object function to abstract the physical into the cyber
    - A physical system is described by a set of resources
    - The application acts on these resources
  - Assumption is that the resources **adequately** capture the physical system
    - In practice this is not always the case -> Digital Twin

IoT Lecture 5

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Standard Interfaces -> IPSO

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- **Sensor Objects and Resources**

- The idea of standard resource/object creation allows us to standardise access to sensors and actuators and their parameters

Learning Aim 1: The students know how an application benefits from LWM2M object/resource mechanisms.

Learning Aim 2: The students can describe a simple physical system using IPSO objects

- This is what IPSO does
  - SmartObject Guideline
  - September 2014

Object	Object ID	Multiple Instances?
IPSO Digital Input	3200	Yes
IPSO Digital Output	3201	Yes
IPSO Analogue Input	3202	Yes
IPSO Analogue Output	3203	Yes
IPSO Generic Sensor	3300	Yes
IPSO Illuminance Sensor	3301	Yes
IPSO Presence Sensor	3302	Yes
IPSO Temperature Sensor	3303	Yes
IPSO Humidity Sensor	3304	Yes
IPSO Power Measurement	3305	Yes
IPSO Actuation	3306	Yes
IPSO Set Point	3308	Yes
IPSO Load Control	3310	Yes
IPSO Light Control	3311	Yes
IPSO Power Control	3312	Yes
IPSO Accelerometer	3313	Yes
IPSO Magnetometer	3314	Yes
IPSO Barometer	3315	Yes

IPSO

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- We can communicate using well-understood frame types

Object Info:

Object	Object ID	Object URN	Multiple Instances?	Description
IPSO Analog Input	3202	urn:oma:lwm2m:ext:3202	Yes	Generic analog input for non-specific sensors

Resources:

Resource Name	Resource ID	Access Type	Multiple Instances?	Mandatory	Type	Range or Enumeration	Units	Description
Analog Input Current Value	5600	R	No	Mandatory	Float			The current value of the analog input.
Min Measured Value	5601	R	No	Optional	Float	Same as Measured Value	Same as Measured Value	The minimum value measured by the sensor since power ON or reset
Max Measured Value	5602	R	No	Optional	Float	Same as Measured Value	Same as Measured Value	The maximum value measured by the sensor since power ON or reset
Min Range Value	5603	R	No	Optional	Float	Same as Measured Value	Same as Measured Value	The minimum value that can be measured by the sensor

- Q – whats the path to the max range value of an analog input?
- Q – how do I know what resources are available?

Resource Name	Resource ID	Access Type	Multiple Instances?	Mandatory	Type	Range or Enumeration	Units	Descriptions
Max Range Value	5604	R	No	Optional	Float	Same as Measured Value	Same as Measured Value	The maximum value that can be measured by the sensor
Reset Min and Max Measured Values	5605	E	No	Optional	Opaque			Reset the Min and Max Measured Values to Current Value
Application Type	5750	R,W	No	Optional	String			The application type of the sensor or actuator as a string, for instance, "Air Pressure"
Sensor Type	5751	R	No	Optional	String			The type of the sensor, for instance PIR type

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