ARM IoT Tutorial

CoAP: The Web of Things Protocol

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The Architecture for the Digital World®

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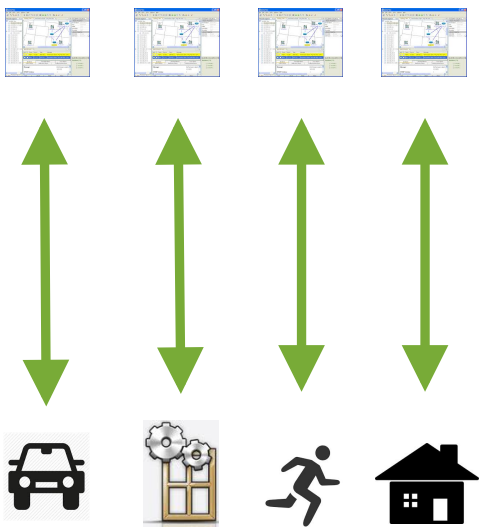
Introduction

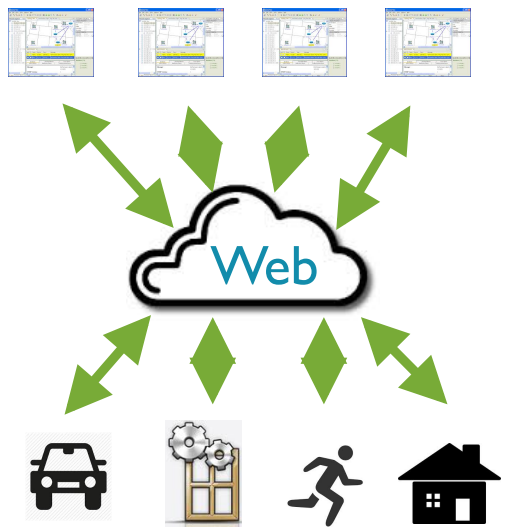
Evolution from M2M to IoT

M2M



Big Data

Internet of Things



Little Data

Services

The Web

Things

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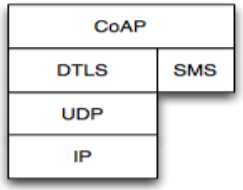
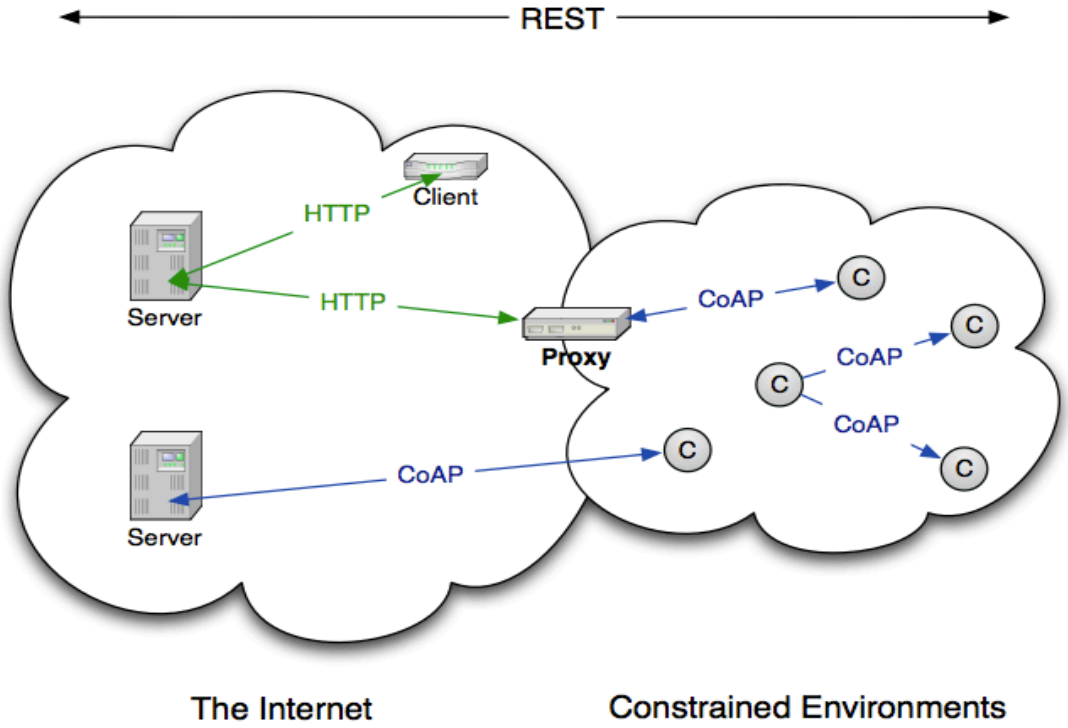
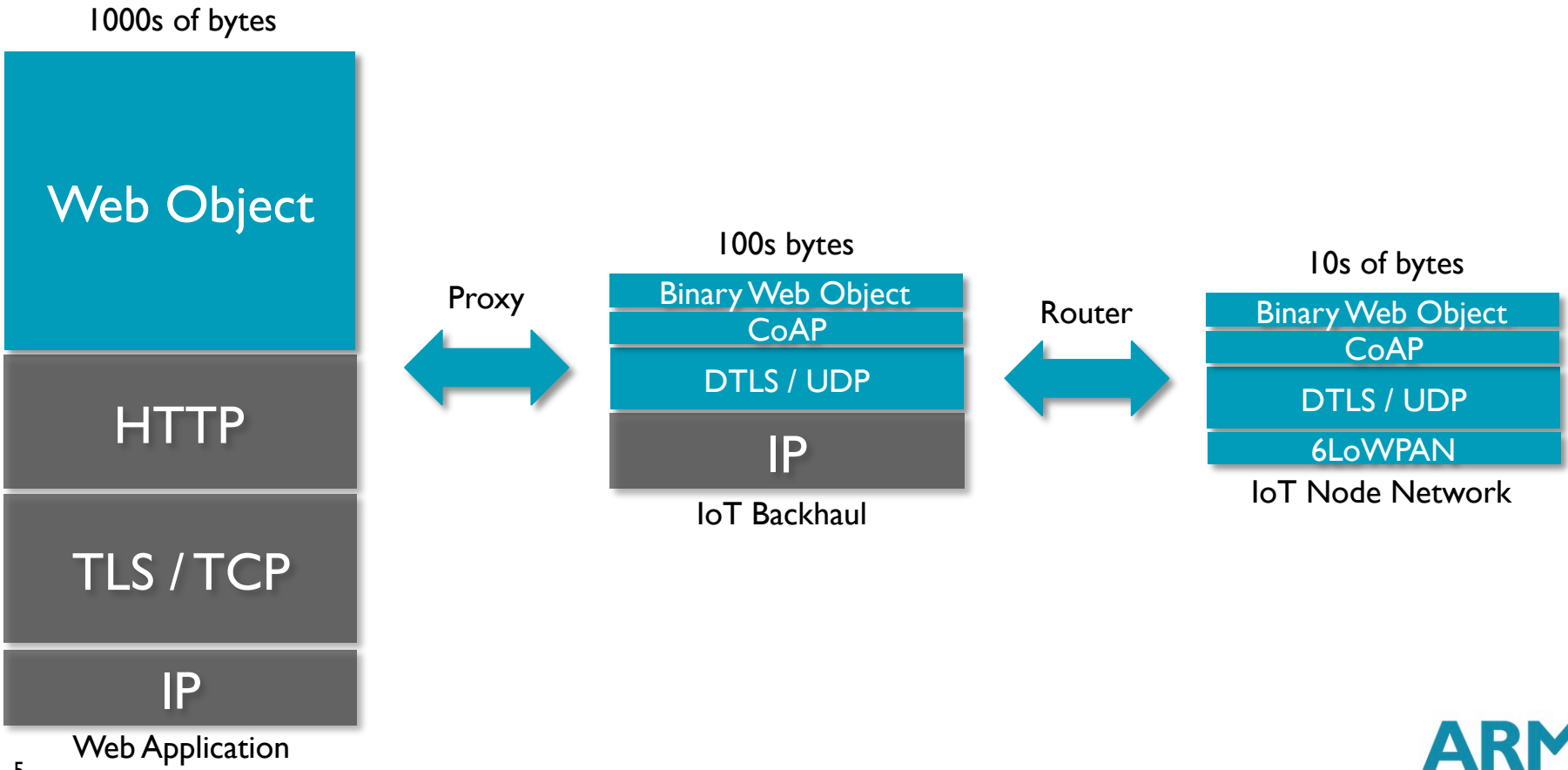
CoAP: The Web of Things Protocol

- Open IETF Standard
- Compact 4-byte Header
- UDP, SMS, (TCP) Support
- Strong DTLS Security
- Asynchronous Subscription
- Built-in Discovery





From Web Applications to IoT Nodes



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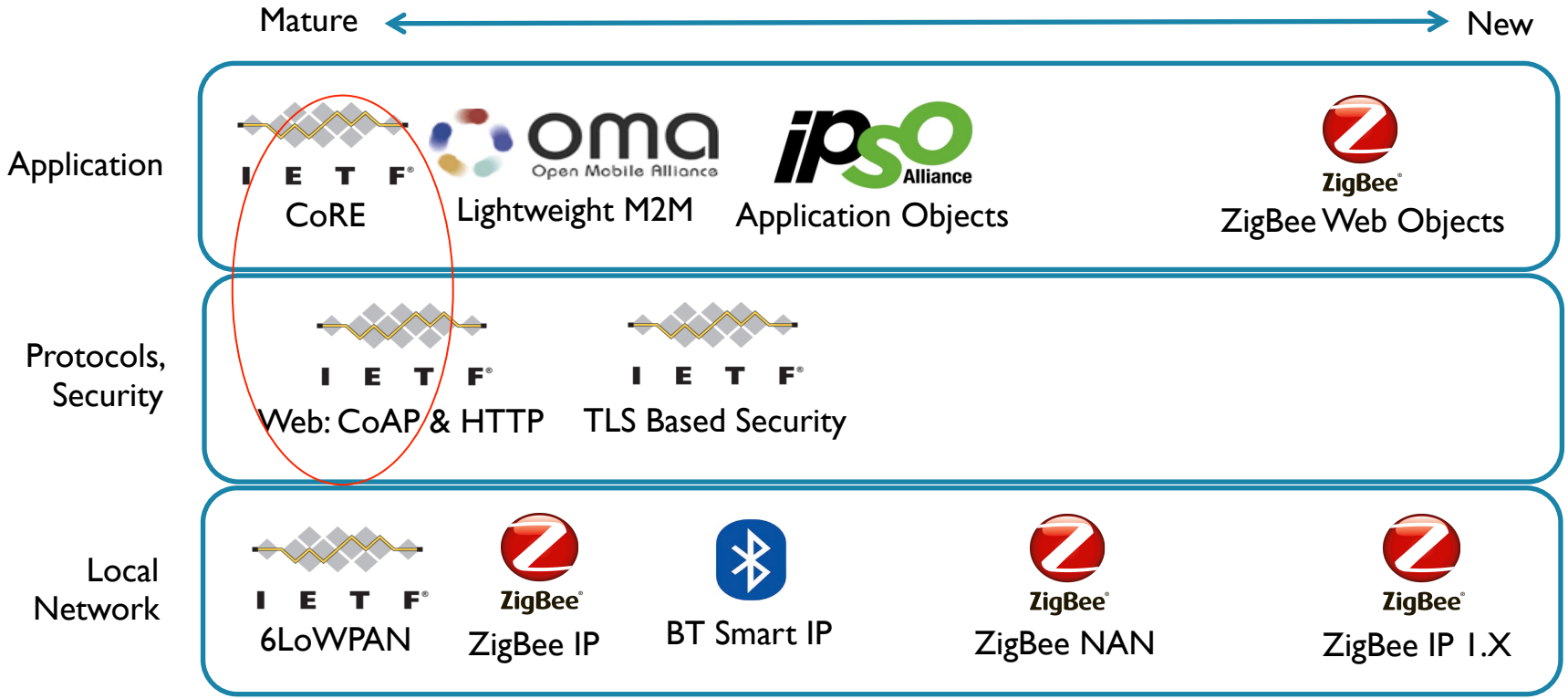
CoAP is One Key IoT Standard



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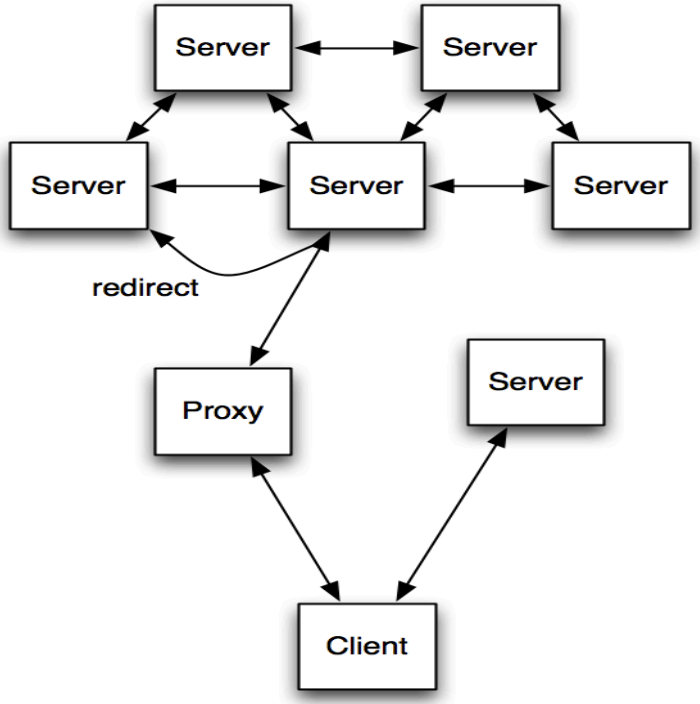
The Web and REST

The Web Architecture



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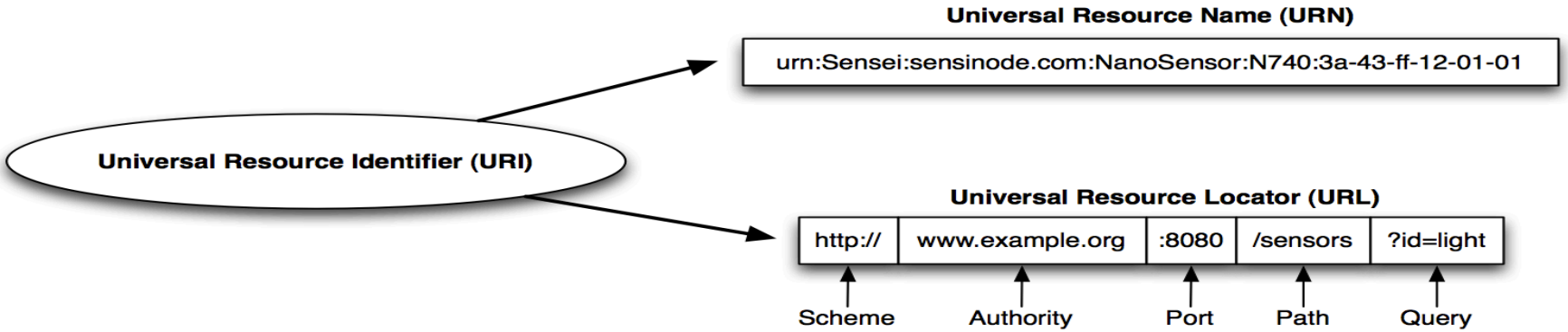
Web Naming



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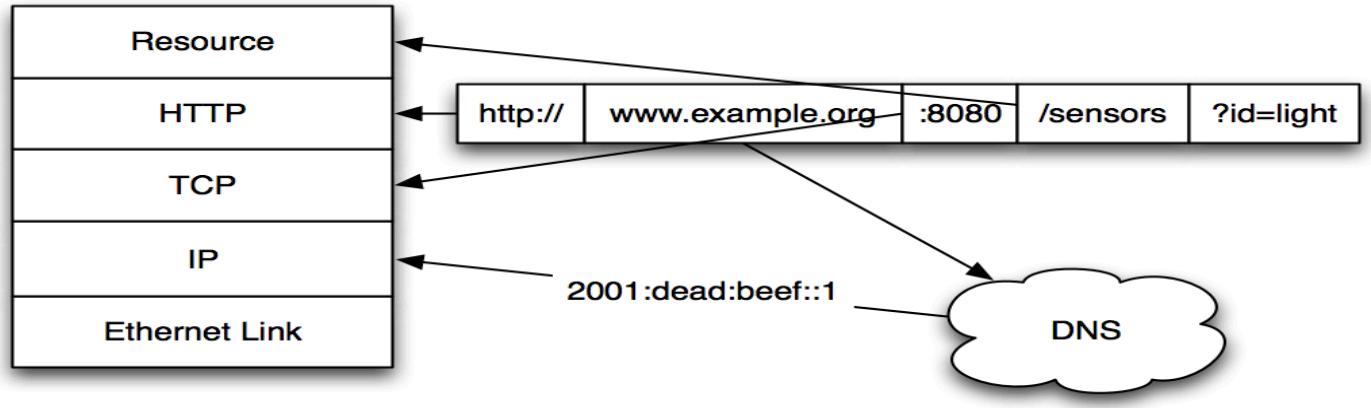
URL Resolution



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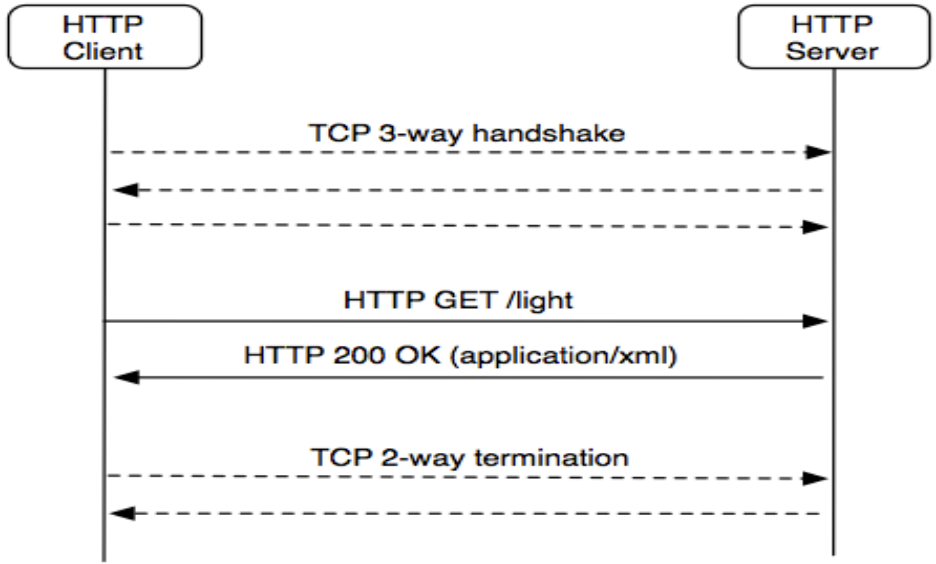
An HTTP Request



See RFC2616 - Hypertext Transfer Protocol v1.1

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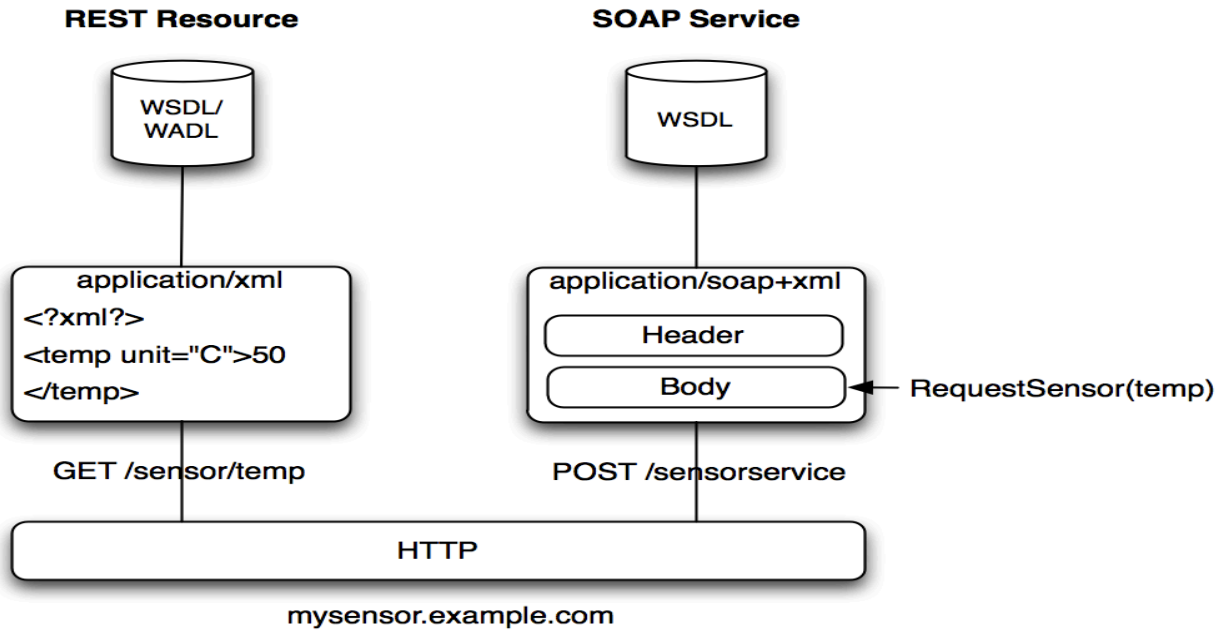
Web Paradigms



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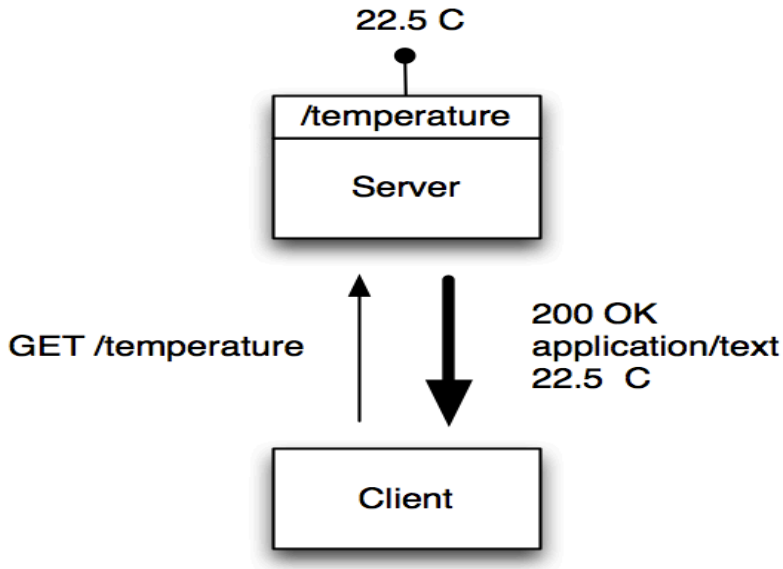
A REST Request



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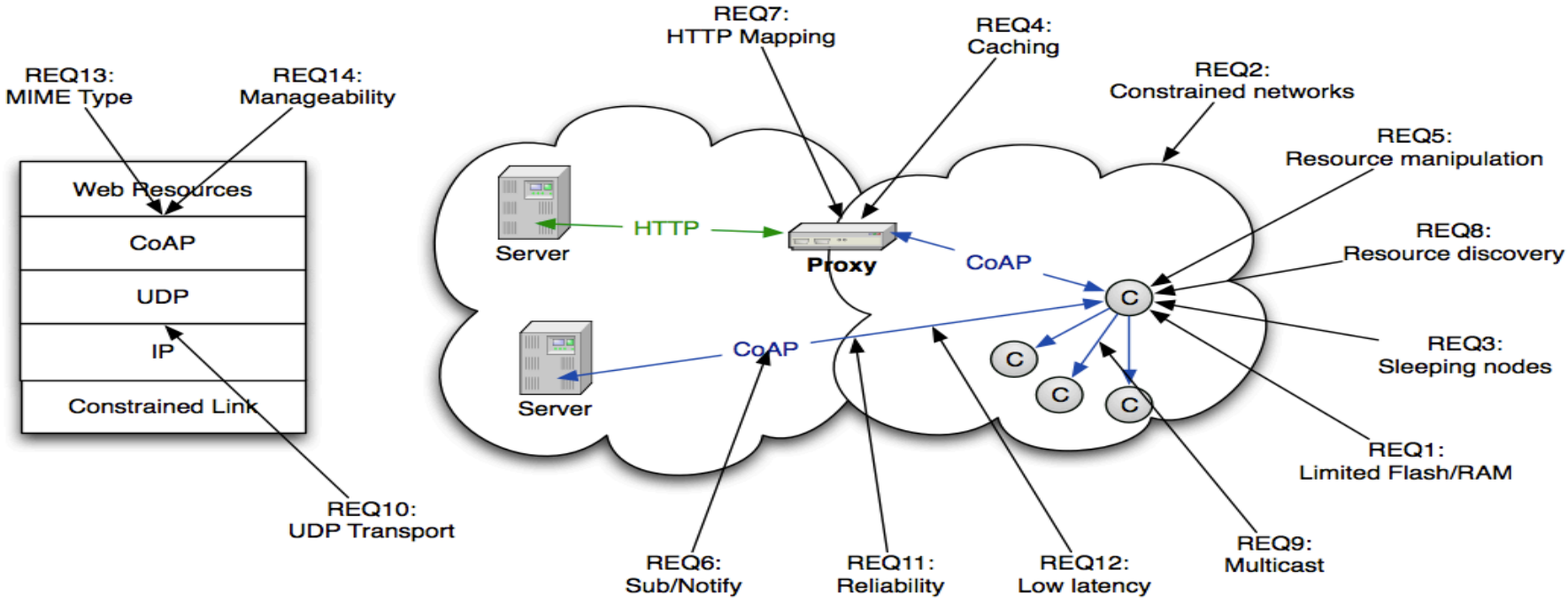
CoAP: Constrained Application Protocol

CoAP Design Requirements



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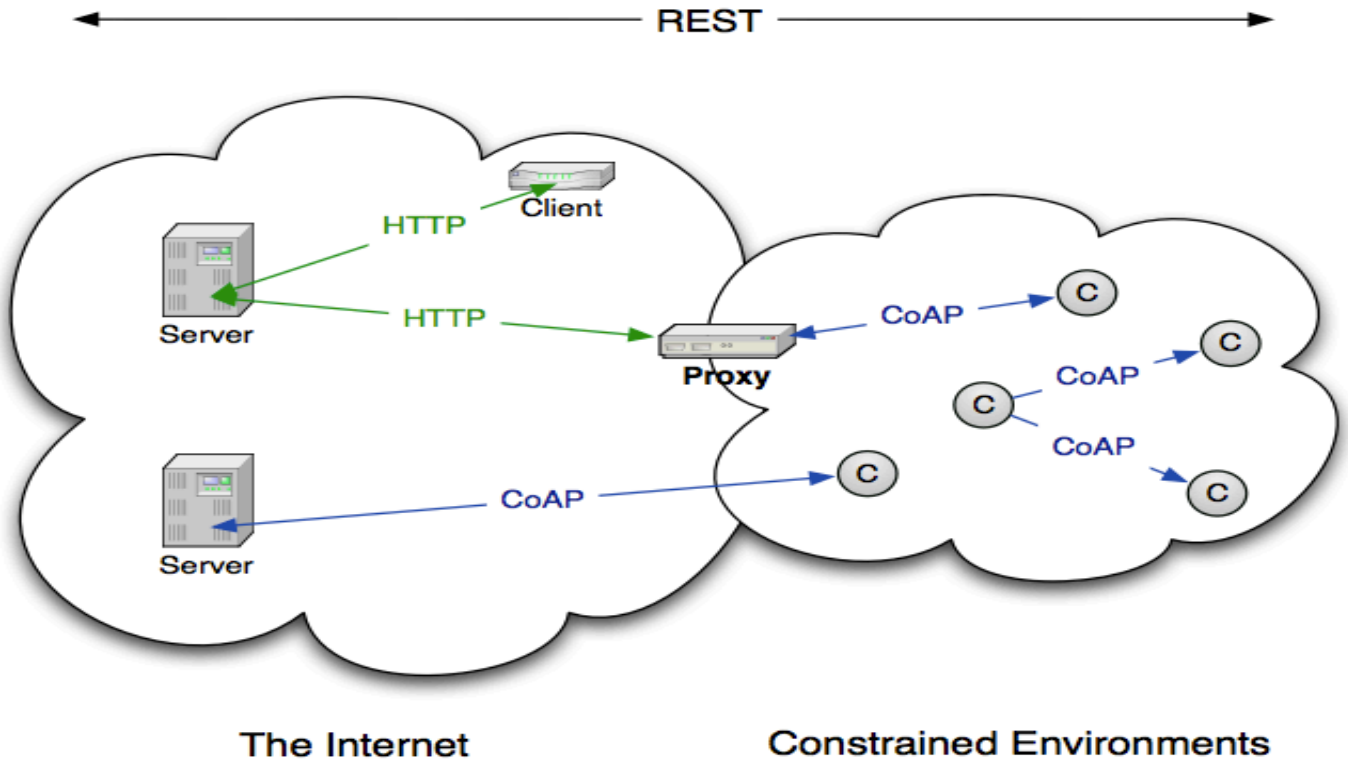
The CoAP Architecture



What CoAP is (and is not)

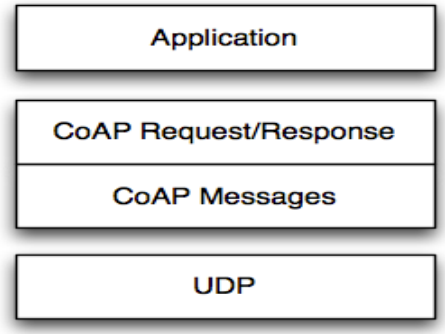
- Sure, CoAP is
  - A very efficient RESTful protocol
  - Ideal for constrained devices and networks
  - Specialized for M2M applications
  - Easy to proxy to/from HTTP

- But hey, CoAP is not
  - A general replacement for HTTP
  - HTTP compression
  - Restricted to isolated “automation” networks

CoAP Features

- Embedded web transfer protocol (coap://)
- Asynchronous transaction model
- UDP binding with reliability and multicast support
- GET, POST, PUT, DELETE methods
- URI support
- Small, simple 4 byte header
- DTLS based PSK, RPK and Certificate security
- Subset of MIME types and HTTP response codes
- Built-in discovery
- Optional observation and block transfer

Transaction Model



- Transport
  - CoAP currently defines:
  - UDP binding with DTLS security
  - CoAP over SMS or TCP possible
- Base Messaging
  - Simple message exchange between endpoints
  - Confirmable or Non-Confirmable Message answered by Acknowledgement or Reset Message
- REST Semantics
  - REST Request/Response piggybacked on CoAP Messages
  - Method, Response Code and Options (URI, content-type etc.)

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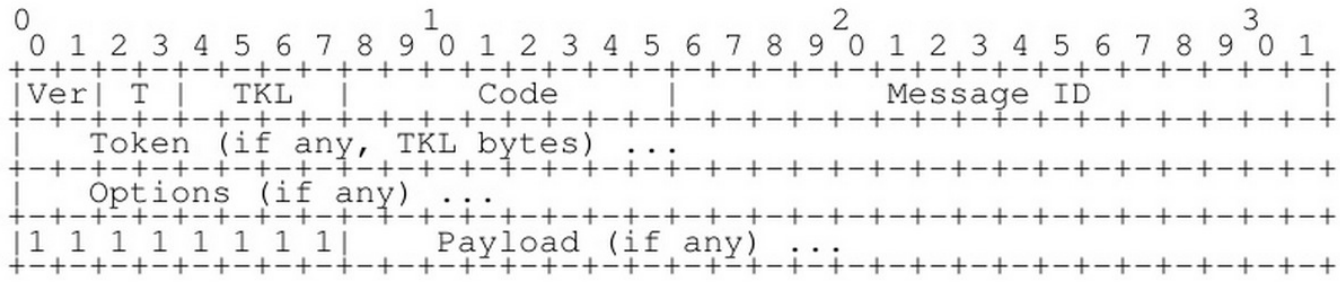
Message Header (4 bytes)



Ver - Version (1)

T - Message Type (Confirmable, Non-Confirmable, Acknowledgement, Reset)

TKL- Token Length, if any, the number of Token bytes after this header

Code - Request Method (1-10) or Response Code (40-255)

Message ID - 16-bit identifier for matching responses

Token - Optional response matching token

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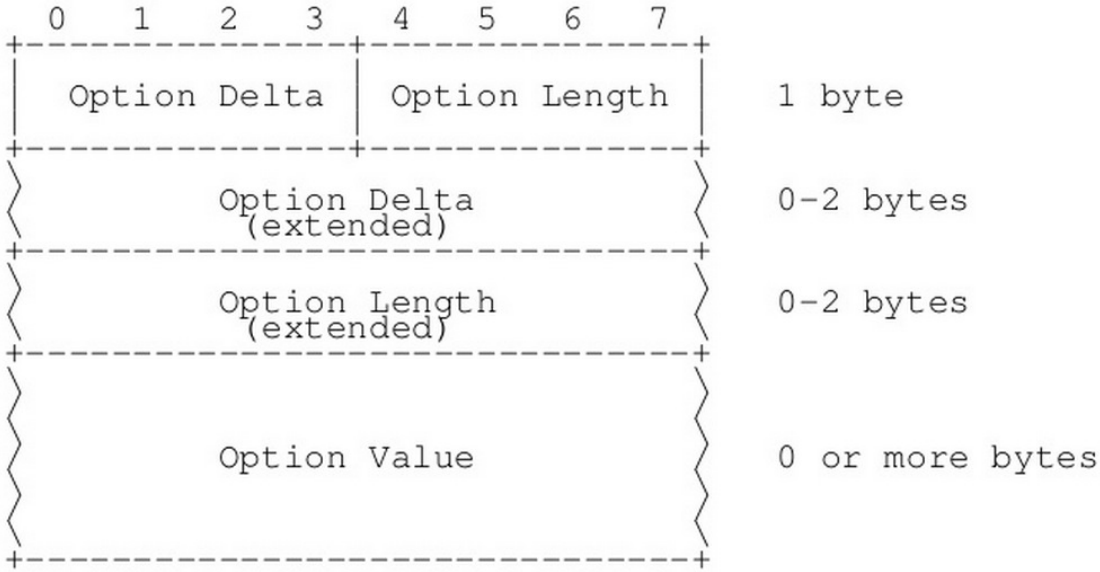
Option Format



Option Delta - Difference between this option type and the previous

Length - Length of the option value

Value - The value of Length bytes immediately follows Length

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Base Specification Options

No.	C	U	N	R	Name	Format	Length	Default
1	x			x	If-Match	opaque	0-8	(none)
3	x	x	-		Uri-Host	string	1-255	(see below)
4				x	ETag	opaque	1-8	(none)
5	x				If-None-Match	empty	0	(none)
7	x	x	-		Uri-Port	uint	0-2	(see below)
8				x	Location-Path	string	0-255	(none)
11	x	x	-	x	Uri-Path	string	0-255	(none)
12					Content-Format	uint	0-2	(none)
14		x	-		Max-Age	uint	0-4	60
15	x	x	-	x	Uri-Query	string	0-255	(none)
16					Accept	uint	0-2	(none)
20				x	Location-Query	string	0-255	(none)
35	x	x	-		Proxy-Uri	string	1-1034	(none)
39	x	x	-		Proxy-Scheme	string	1-255	(none)

C=Critical, U=Unsafe, N=NoCacheKey, R=Repeatable

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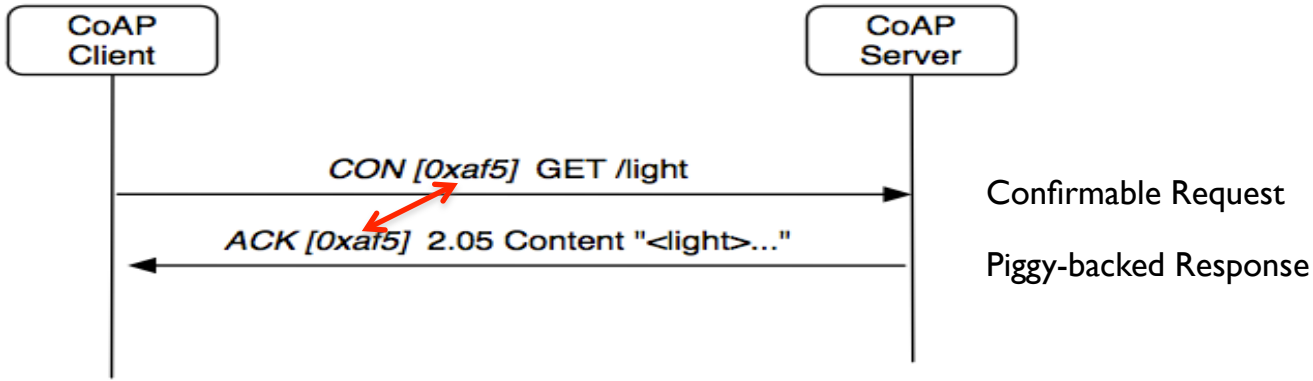
Request Example



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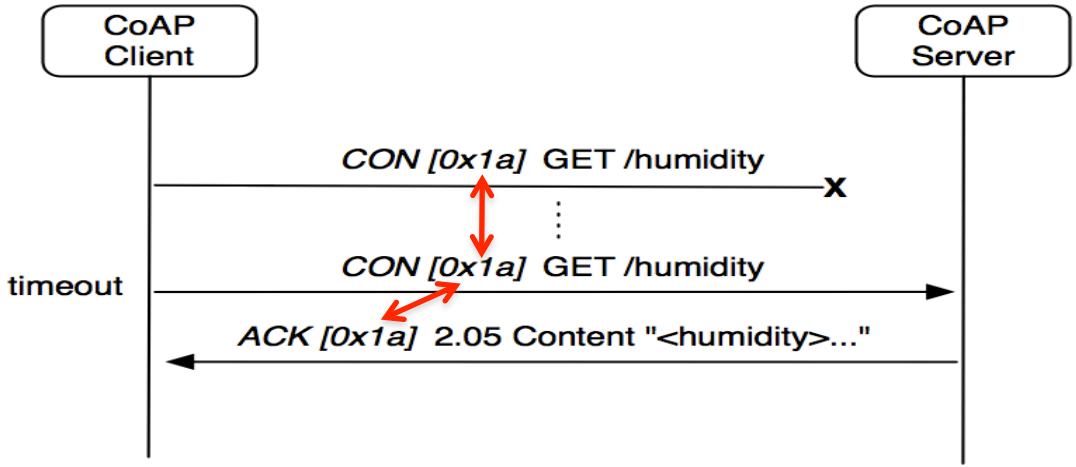
Dealing with Packet Loss



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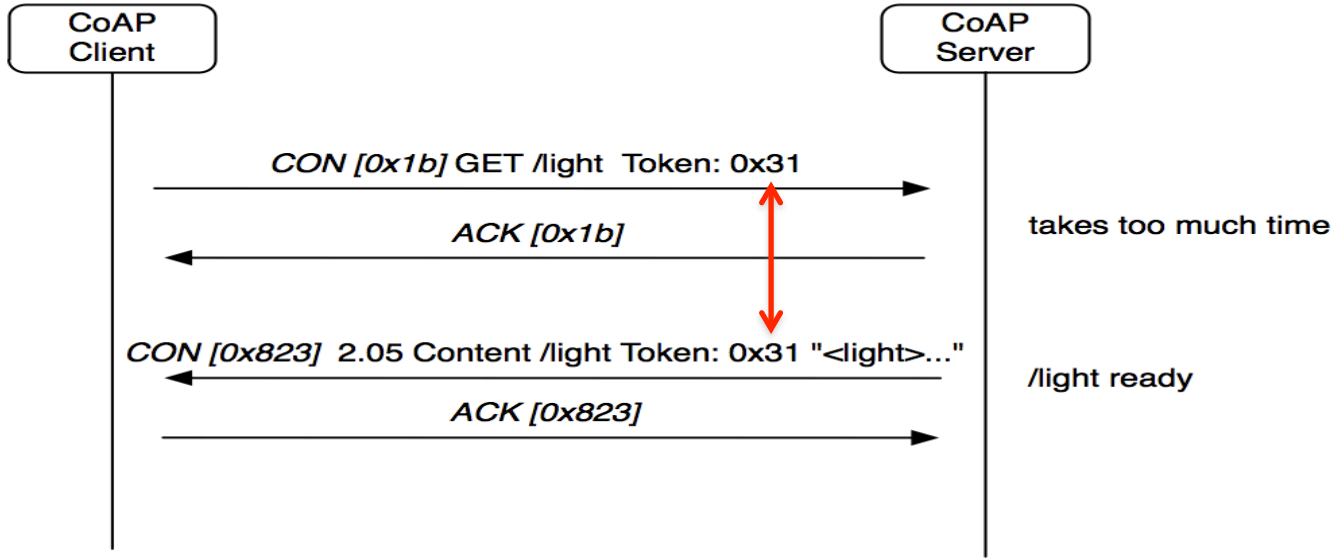
Separate Response



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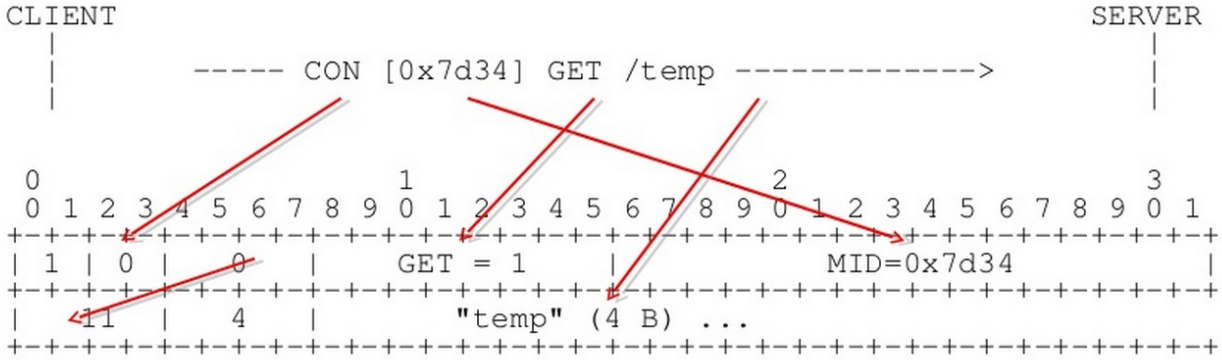
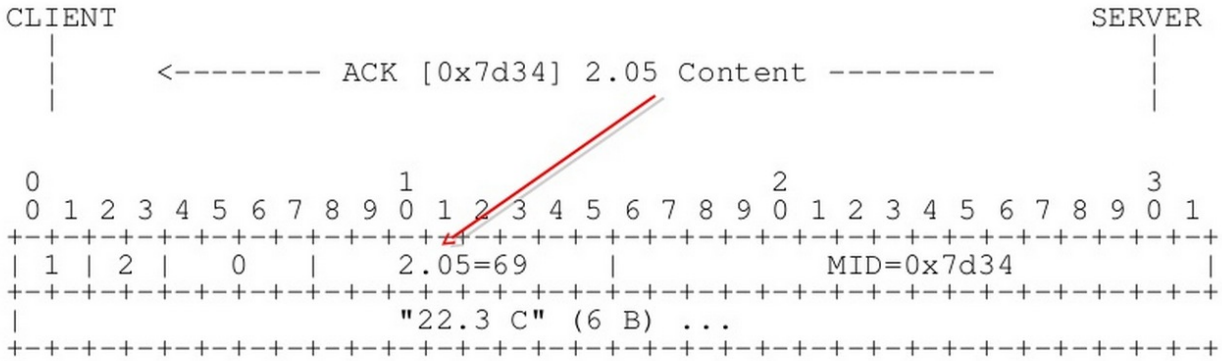
Bits and bytes...





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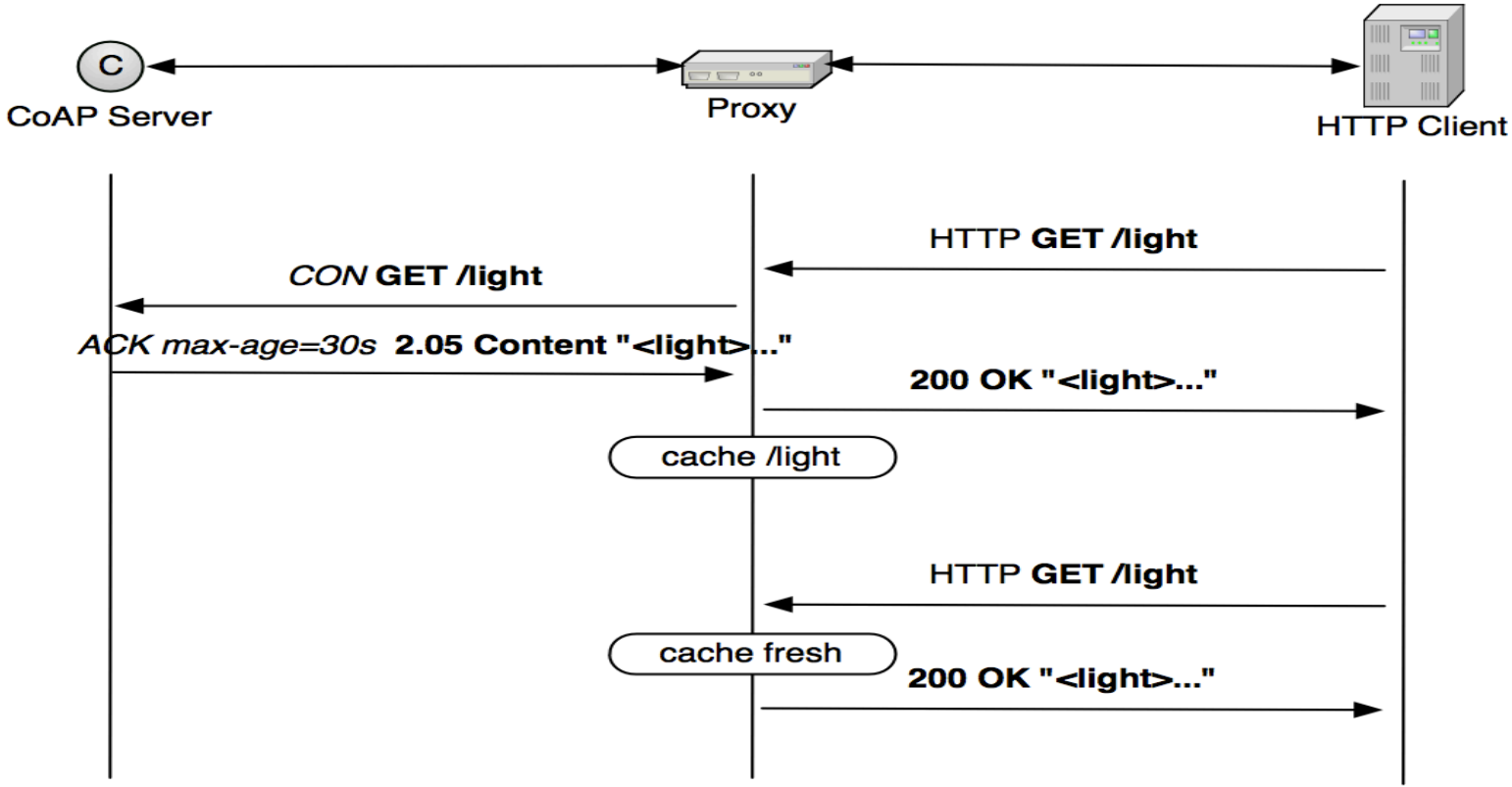
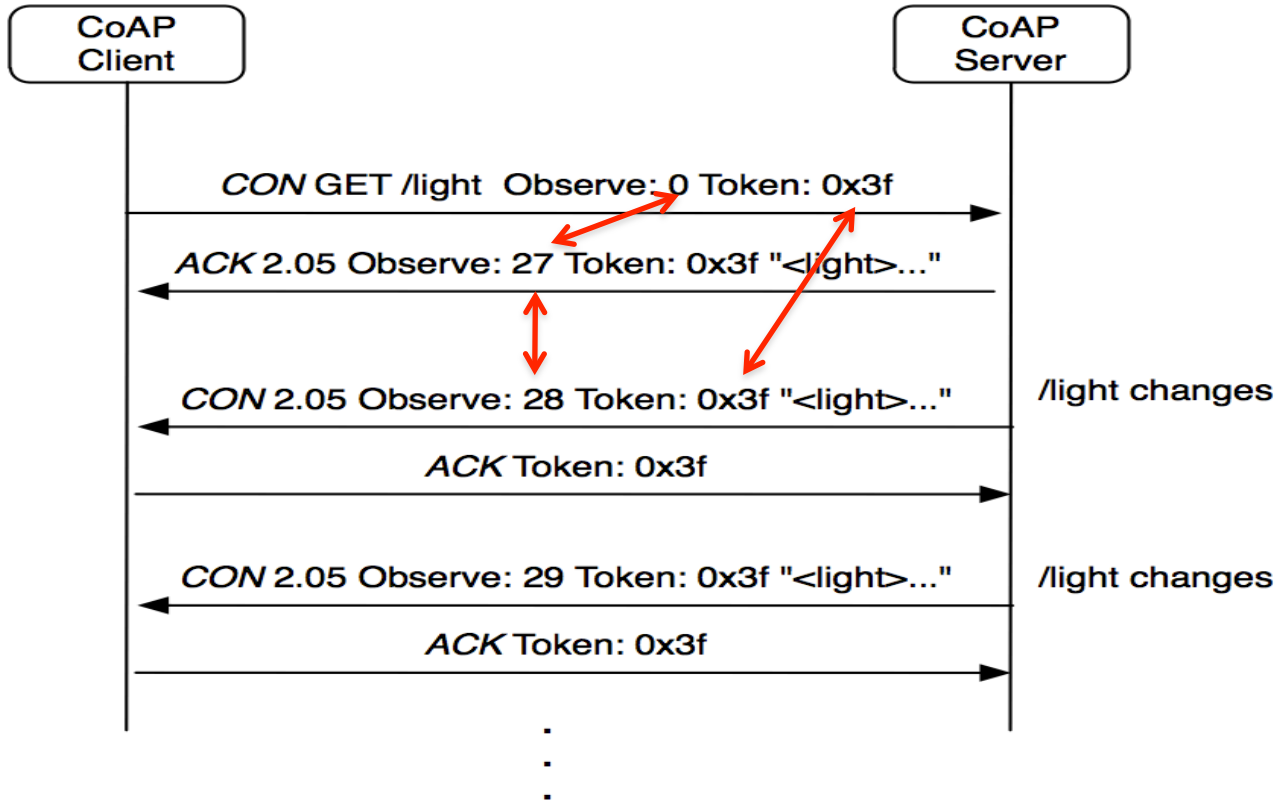
Caching

- CoAP includes a simple caching model
  - Cacheability determined by response code
  - An option number mask determines if it is a cache key
- Freshness model
  - Max-Age option indicates cache lifetime
- Validation model
  - Validity checked using the Etag Option
- A proxy often supports caching
  - Usually on behalf of a constrained node,
  - a sleeping node,
  - or to reduce network load

Proxying and caching



Observation



See draft-ietf-core-observe

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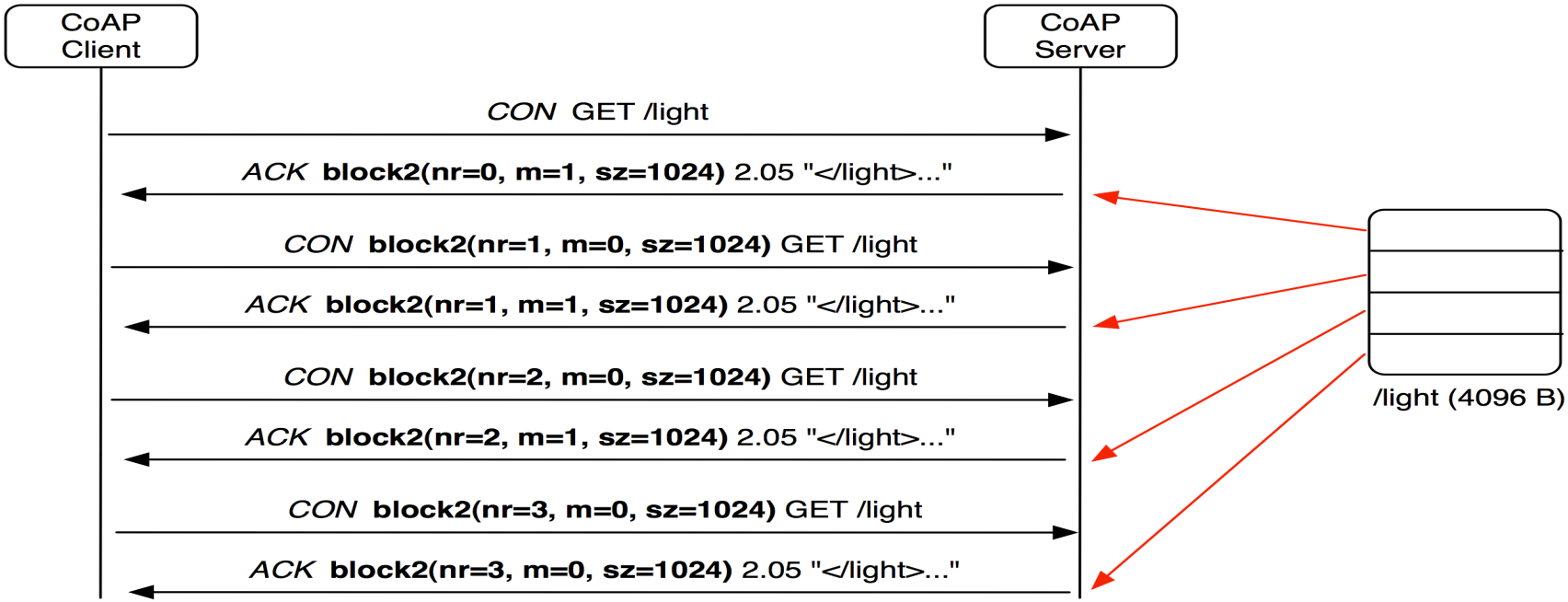
Block transfer



See draft-ietf-core-block

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Getting Started with CoAP

- There are many open source implementations available
  - mbed includes CoAP support
  - Java CoAP Library Californium
  - C CoAP Library Erbium
  - libCoAP C Library
  - jCoAP Java Library
  - OpenCoAP C Library
  - TinyOS and Contiki include CoAP support
- CoAP is already part of many commercial products/systems
  - ARM Sensinode NanoService
  - RTX 4100 WiFi Module
- Firefox has a CoAP plugin called Copper
- Wireshark has CoAP dissector support
- Implement CoAP yourself, it is not that hard!

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Discovery & Semantics

What is Web Linking?

- Links have been around a long time
- Web Linking formalizes links with defined relations, **typed links**
  - HTML and Atom have allow links
- RFC5988 defines a framework for Web Linking
  - Combines and expands the Atom and HTML relation types
  - Defines a unified typed link concept
- A link can be serialized in any number of formats
  - RFC5988 revives the HTTP Link Header and defines its format
  - Atom and HTML are equivalent serializations

What is Web Linking?

- A type link consists of:
  - Context URI – What the link is from
  - Relation Type – Indicates the semantics of the link
  - Target URI – What the link is too
  - Attributes – Key value pairs describing the link or its target
- Relations include e.g. copyright, author, chapter, service etc.
- Attributes include e.g. language, media type, title etc.
- Example in HTTP Link Header format:

```
Link: <http://example.com/TheBook/chapter2>; rel="previous"; title="previous
  chapter"
```

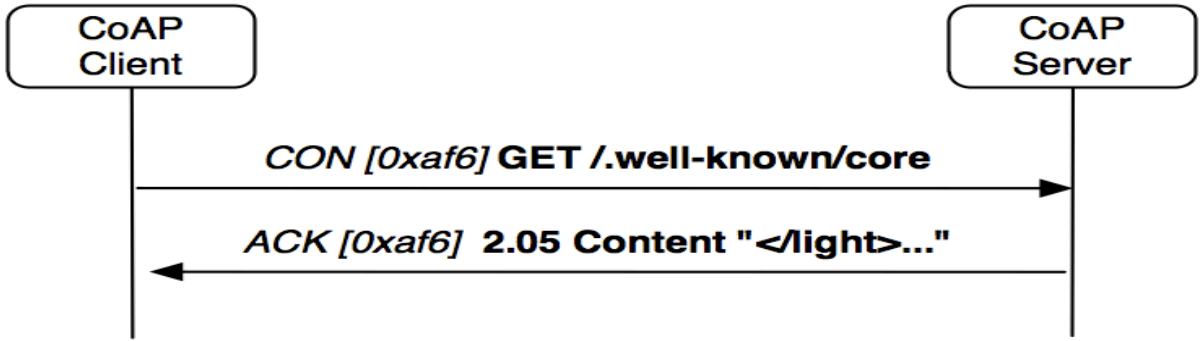
Resource Discovery

- Service Discovery
  - What services are available in the first place?
  - Goal of finding the IP address, port and protocol
  - Usually performed by e.g. DNS-SD when DNS is available
- Resource Discovery
  - What are the Web resources I am interested in?
  - Goal of finding URIs
  - Performed using Web Linking or some REST interface
  - CoRE Link Format is designed to enable resource discovery

CoRE Link Format

- RFC6690 is aimed at Resource Discovery for M2M
  - Defines a link serialization suitable for M2M
  - Defines a well-known resource where links are stored
  - Enables query string parameters for filtered GETs
  - Can be used with unicast or multicast (CoAP)
- Resource Discovery with RFC6690
  - Discovering the links hosted by CoAP (or HTTP) servers
  - GET /.well-known/core?optional_query_string
  - Returns a link-header style format
  - URL, relation, type, interface, content-type etc.

CoRE Resource Discovery




```
</dev/bat>;obs;rt="ipso:dev-bat";ct="0",
</dev/mdl>;rt="ipso:dev-mdl";ct="0",
</dev/mfg>;rt="ipso:dev-mfg";ct="0”,
</pwr/0/rel>;obs;rt="ipso:pwr-rel";ct="0",
</pwr/0/w>;obs;rt="ipso:pwr-w";ct="0",
</sen/temp>;obs;rt="ucum:Cel";ct="0"
```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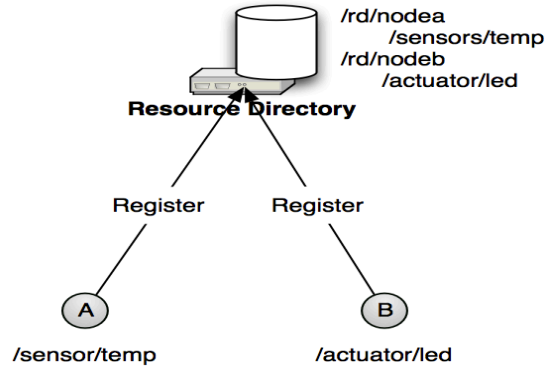
Resource Directory

- CoRE Link Format only defines
  - The link format
  - Peer-to-peer discovery
- A directory approach is also useful
  - Supports sleeping nodes
  - No multicast traffic, longer battery life
  - Remote lookup, hierarchical and federated distribution
- The CoRE Link Format can be used to build Resource Directories
  - Nodes POST (register) their link-format to an RD
  - Nodes PUT (refresh) to the RD periodically
  - Nodes may DELETE (remove) their RD entry
  - Nodes may GET (lookup) the RD or resource of other nodes



See draft-ietf-core-resource-directory

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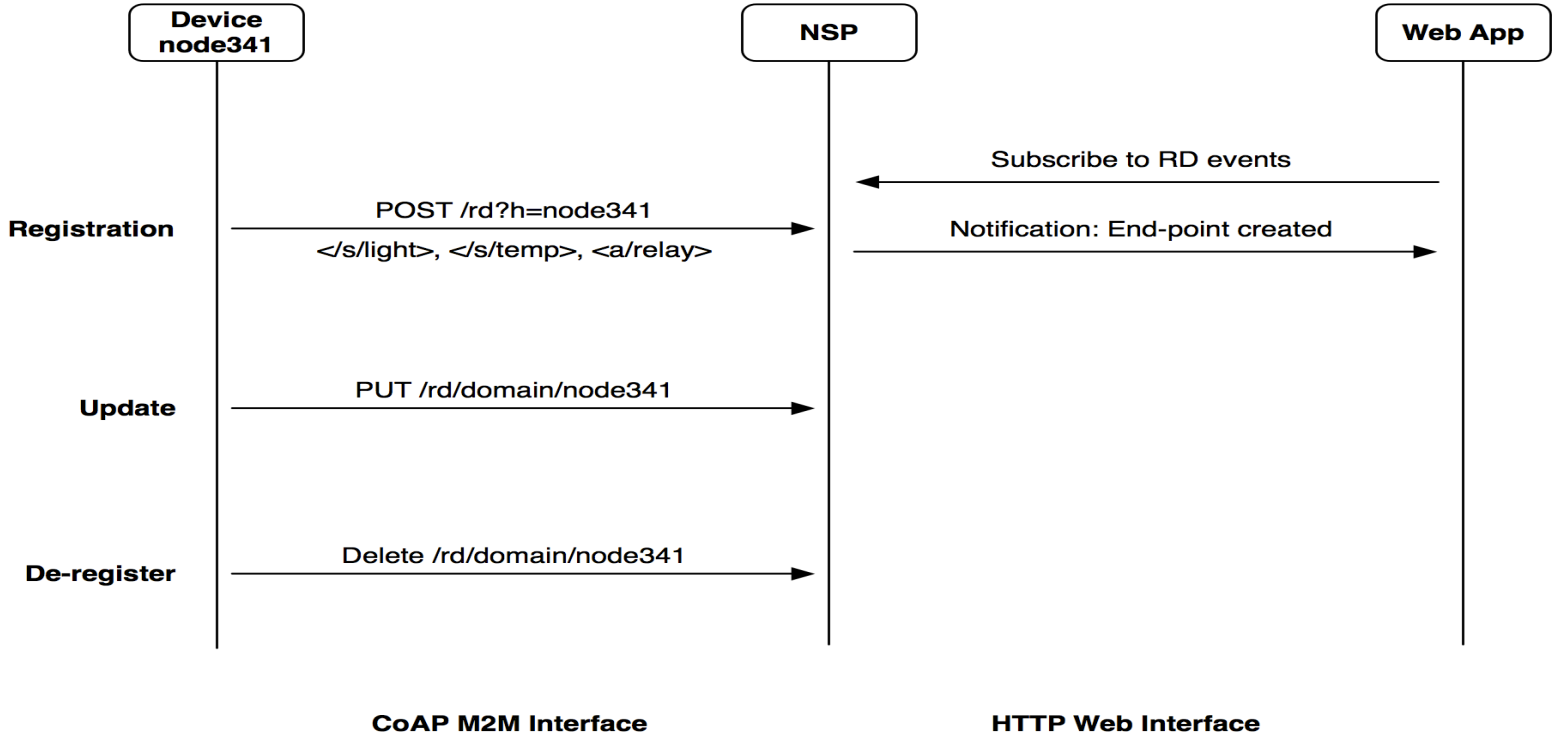
Resource Directory



See draft-ietf-core-resource-directory

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How to get Semantic?

- So how to use CoRE in real applications?
- Resources need meaningful naming (rt=)
- A resource needs an interface (if=)
  - See [draft-vial-core-link-format-wadl] on using WADL for this
- A payload needs a format (EXI, JSON etc.)
  - Deployment or industry specific today
  - oBIX, SensorML, EEML, sMAP etc.
  - SenML is a promising format [draft-jennings-senml]
  - CBOR is a standard for binary JSON [RFC7049]
- Promising data semantics for use with CoAP
  - OMA Lightweight M2M [http://j.mp/lwm2m]
  - IPSO Objects [http://www.ipso-alliance.org/smart-object-committee-charter]
  - CoRE Interfaces [draft-ietf-core-interfaces]

CoRE Link Format Semantics

- RFC6690 = Simple semantics for machines
  - IANA registry for rt= and if= parameters
- Resource Type (rt=)
  - What is this resource and what is it for?
  - e.g. Device Model could be rt="ipso.dev.mdl"
- Interface Description (if=)
  - How do I access this resource?
  - e.g. Sensor resource accessible with GET if="core.s"
- Content Type (ct=)
  - What is the data format of the resource payloads?
  - e.g. text/plain (0)

CoRE Interfaces

- CoRE Interfaces [draft-ietf-core-interfaces]
  - A paradigm for REST profiles made up of function sets
  - Simple interface types

Interface	if=	Methods
Link List	core.ll	GET
Batch	core.b	GET, PUT, POST (where applicable)
Linked Batch	core.lb	GET, PUT, POST, DELETE (where applicable)
Sensor	core.s	GET
Parameter	core.p	GET, PUT
Read-only Parameter	core.rp	GET
Actuator	core.a	GET, PUT, POST
Binding	core.bnd	GET, POST, DELETE

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