IoT Device Standards

bill.curtis@arm.com – IoT Strategy

IoT is not a new idea

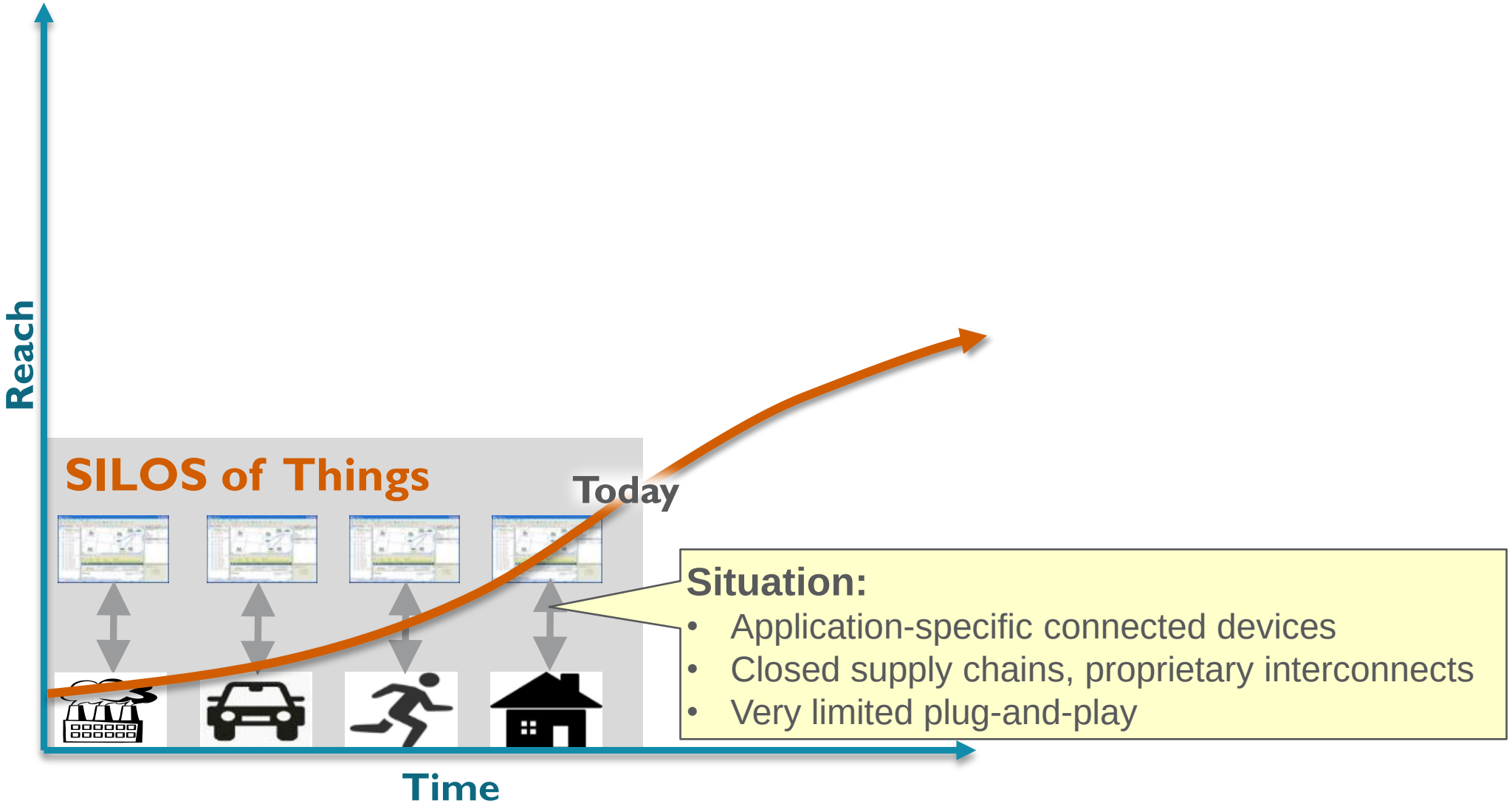
THINGS around us become smart and connected

- This is not a new idea .. it's been going on for >20 years[1]
- 2010: Connected things > world population (6.8B)

[1] Weiser, Mark (1991) "the Computer for the 21st Century"
Ubiquitous computing: "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."

Motorola pager watch – 17 years ago

Accelerating IoT

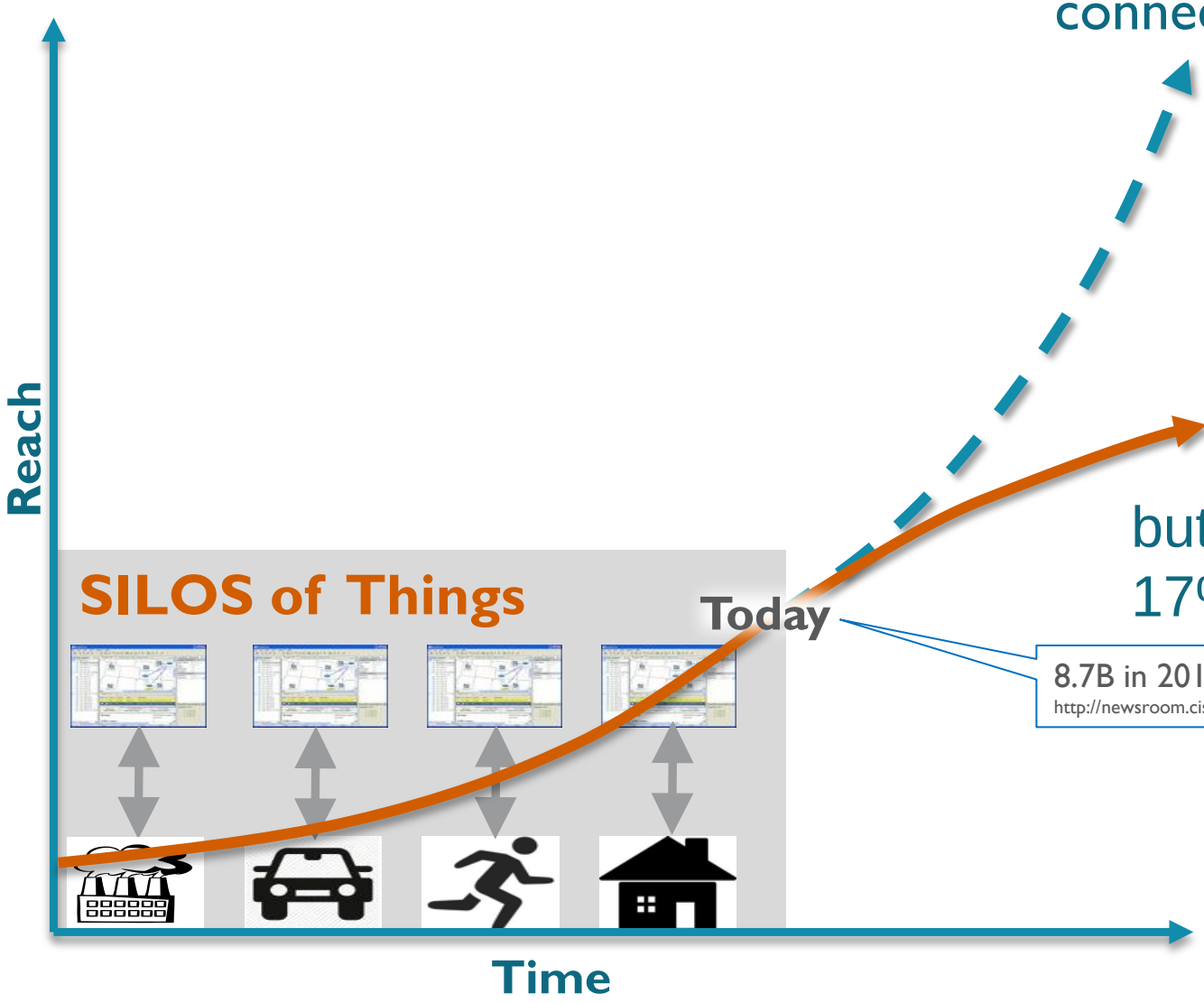


Accelerating IoT

INTERNET of Things

Analysts predictions for connected devices (2020):

- 30 billion?
- 50 billion?
- *75* billion?

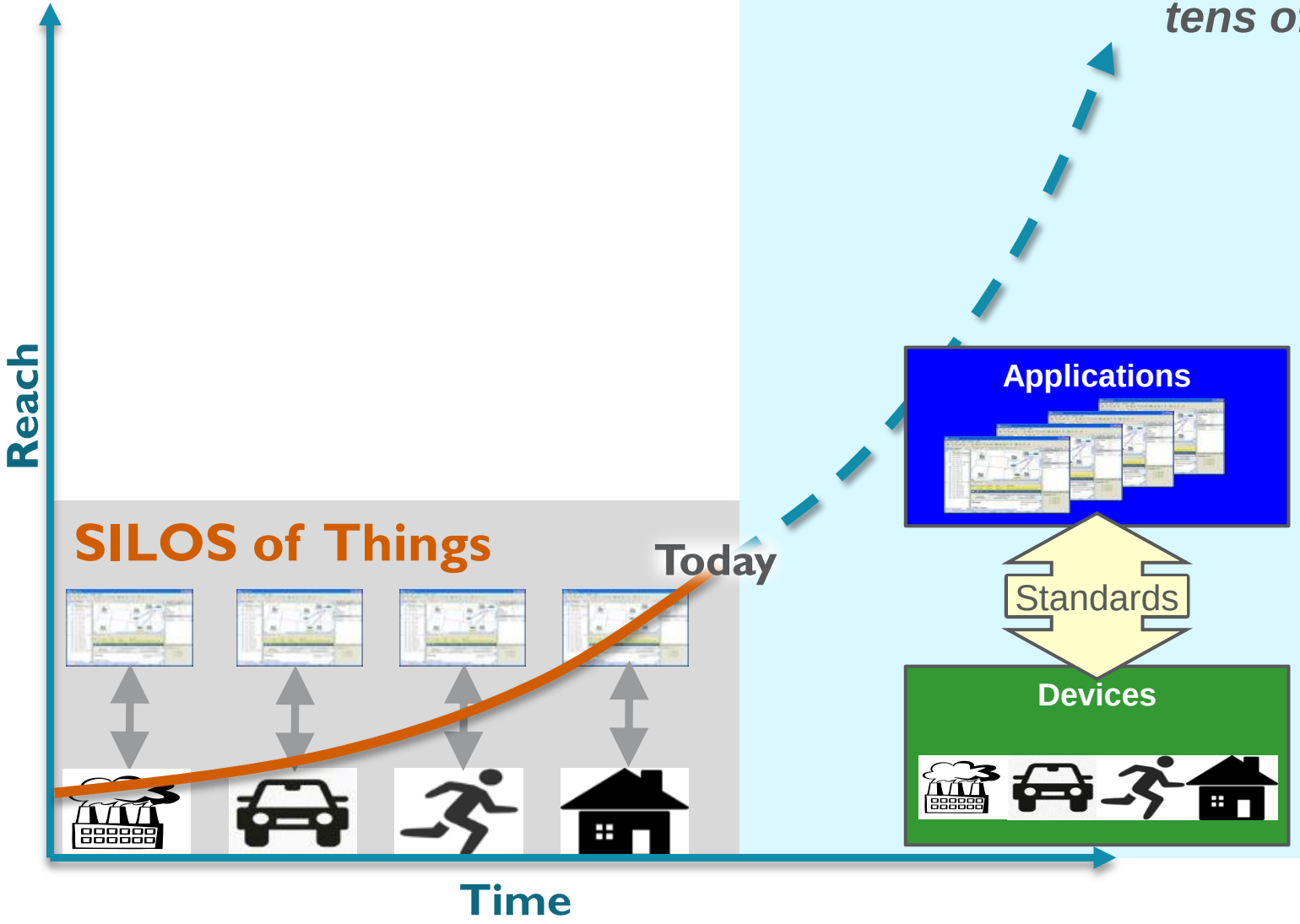


Current trends show strong growth

but analysts are more optimistic:
17% .. 31% CAGR, 2012-2020

8.7B in 2012 (Cisco)
http://newsroom.cisco.com/feature-content?articleId=1208342

Accelerating IoT



INTERNET of Things

What will drive demand for many tens of billions more devices?

Better IoT Platforms

… that can "weave themselves into the fabric of everyday life"

- Integrated wireless
- Right-size processors, memory
- Low cost, low power
- Secure, trustworthy
- Easy software development
- Easy integration into "things"

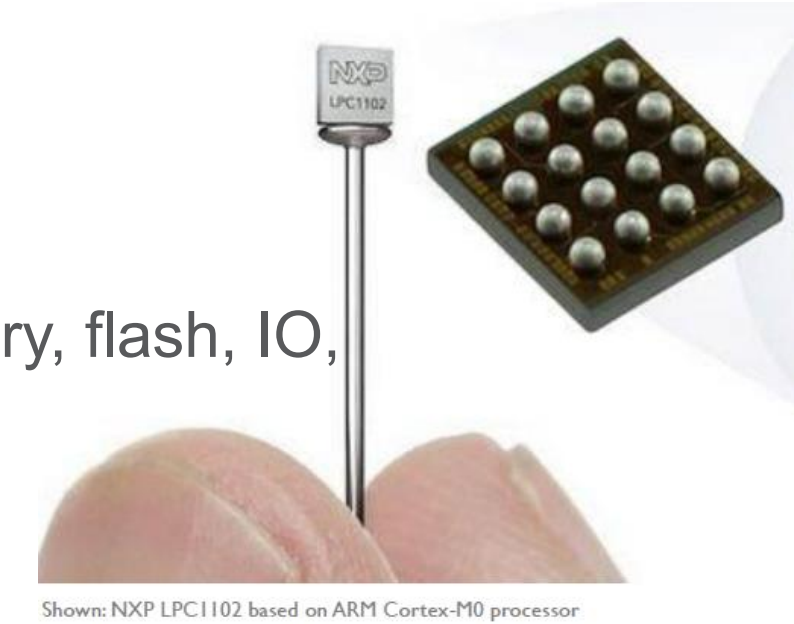
Internet-scale IoT ecosystems

Bust the silos

- Standards-based connectivity
- Standards-based provisioning
- Open markets for devices, apps
- End-to-end security

IoT **SoC platform** evolution

- **Wireless** On-chip radios
  Optimized for IoT bandwidth, power
- **Right size** 32 bit processor with “the right” memory, flash, IO,
- **Low cost** Embeddable, often disposable
- **Low power** No visible power source
  Power managed (off or asleep much of the time)
- **Secure** Trustworthy … *by design*
- **Easy dev’t** Stacks, tools, software
- **Easy integration** into real-world “things”



Shown: NXP LPC1102 based on ARM Cortex-M0 processor

Industry challenge

IoT **ecosystem** evolution

- The problem that we need to solve: Bust the silos!
  - 40 years ago: Internet technologies displaced proprietary interconnects
  - 25 years ago: Web applications – “100% reach”
  - 7 years ago: Mobile revolution: Internet and web in your hand
- Obvious IoT strategy: *Follow the Internet model*
  - Open standards enable independent development of solution components
- However, IoT platforms are *constrained*
  - Internet / Web standards can’t be used as-is
- “INTERNET” of things is not a new idea
  - >7 years of standards development

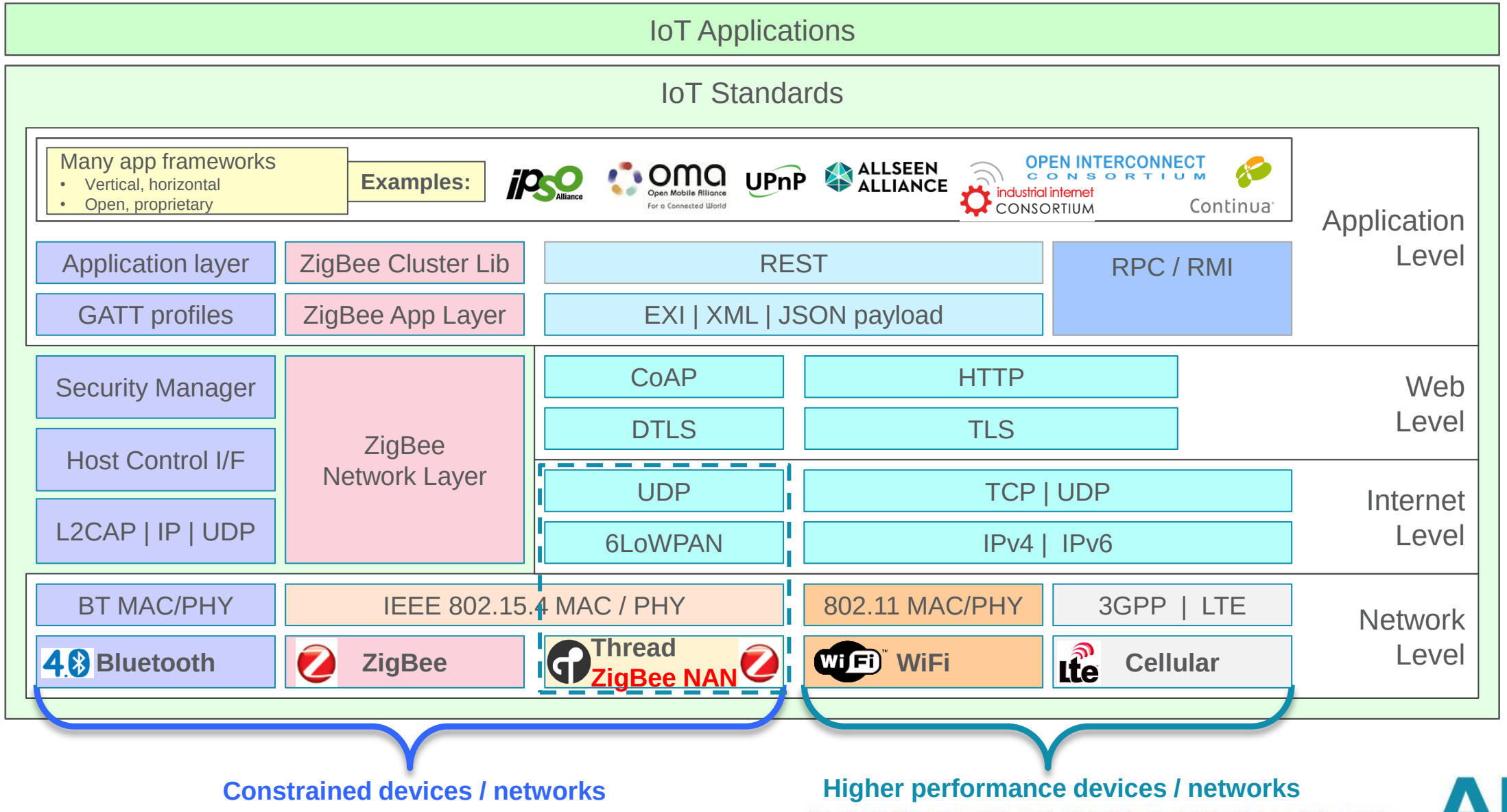
- Low power platforms
- Limited memory, flash
- Limited computation
- Low power wireless
- Low bandwidth
- Small packets
- Sleepy
- No UI

Plenty of IoT / M2M standards to choose from

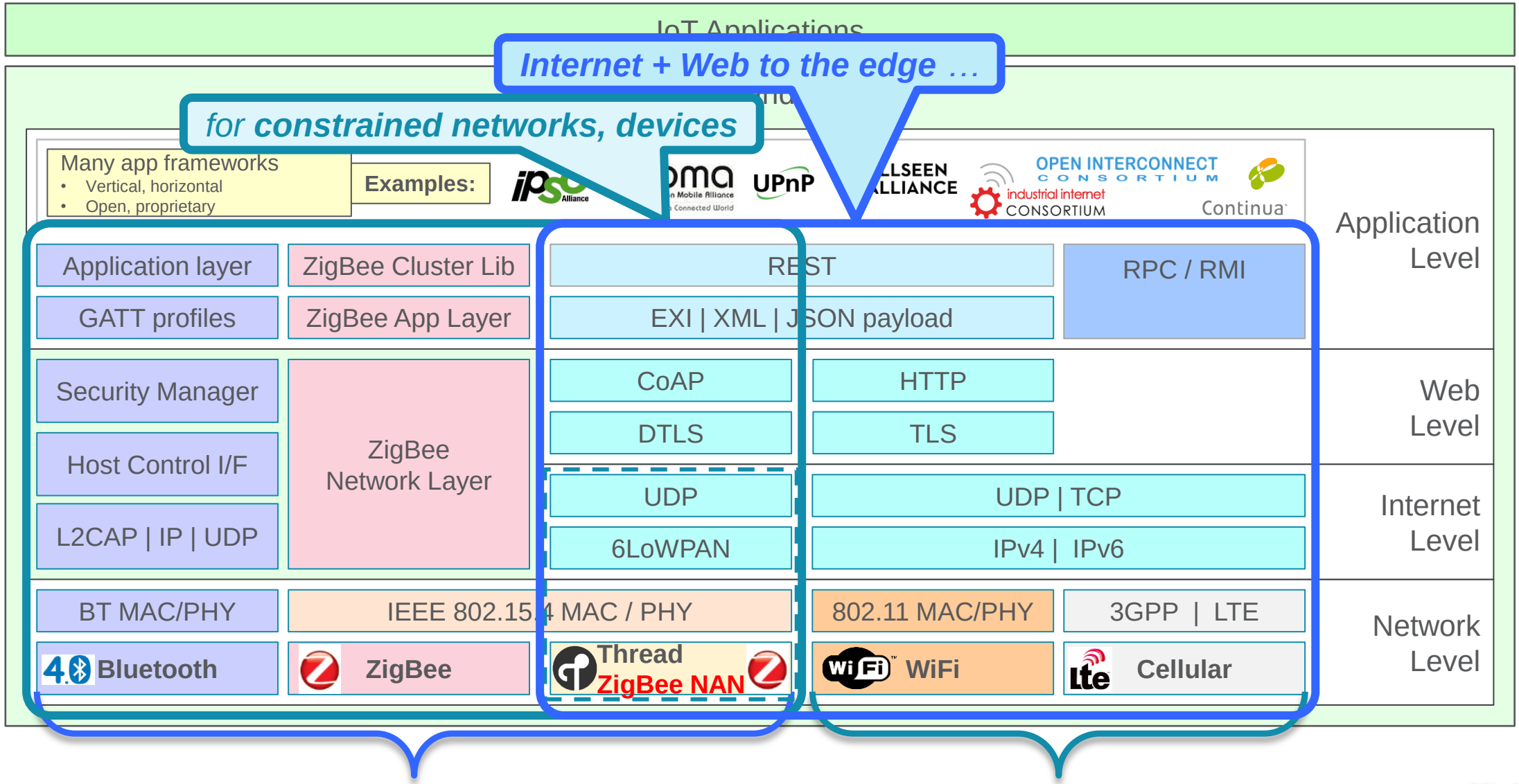
>120 standards relevant to IoT

- **Horizontal**
  - 3GPP, 3GPP2, ACM, AHCIET, AIM, AllSeen Alliance, ANCE, Bluetooth SIG, CINTEL, CITEL, Hart Communication Foundation, IETF, IPSO Alliance, MIG, MQTT.org, NFC Forum, ngConnect, NYCE, OASIS, ODVA, OGC, ONVIF, Open Interconnect Consortium, OSGi, PUCC, SD Card, SIM Alliance, TCG, Thread, W3C, WAVE2M, ZigBee Alliance
- **Automotive**
  - AEC-Q100, AUTOSAR, CAR2CAR, CE4A, ERTICO, Global Platform, Icar Support, ITSA, ITS Info-Comms Forum, JASPAR, Mobey Forum, MOST Cooperation, OSPT Alliance, PATA, SAE International, UIC, ATMIA, ISIS, ISO, NACHA, NAMA, SPA
- **Healthcare**
  - AAMI, AdvaMed, American Telemecine Ass'n, ASME, ASTM Int'l, Canadian Telehealth Forum, CDISC, CEN/TC 251, CLSI, Continua Alliance, EHTEL, European Mhealth Alliance, GE1 Healthcare, HIMSS, HITSP, HL7, IHT2, ISO/IEEE 11073, ISO TC215, Joint Commission (JCAHO), mHealth Alliance, MITA, MITA DICOM
- **Home Automation**
  - ASIS Int'l, Aureside, BACnet, Broadband Forum, CABA, EnOcean Alliance, HGI, Home Grid Forum, Home Plug Alliance, KNX, OBIX, PSIA, SIA (security), Z-Wave Alliance
- **Industrial**
  - AIA, Automation Federation, CiA, Industrial Internet Consortium, ISA, M-Bus, Modbus, OCARI Alliance, OMAC, OPC, SMLC
- **Utilities, Smart Grid**
  - AAPA, CIGRE, DLMS, DRSG Coalition, EDSO, EEI, ENTSOE, ESMKIG, Eurelectric, EUTC, Gridwise Alliance, Gridwise Architecture Council, JSCA, NEMA, NIST, T&D Europe, TIA TR-51, UCA, UTC Smart Network Council, UTC
- **Supply Chain**
  - AIM, APICS, CSCMP, GS1, ISM, SCM, XBRL Int'l
- **ITU GSC (Global Standards Collaboration) members**
  - ITU-T, ARIB, ATIS, CCSA, ETSI, ISACC, TIA, TTA, TTC
- **ITU GSC observers**
  - 4G America, AICTO, CDG, GISFI, GSMA, IEC, IEEE, ISO / IEC JCT, OMA, SCTE

Navigating IoT Standards

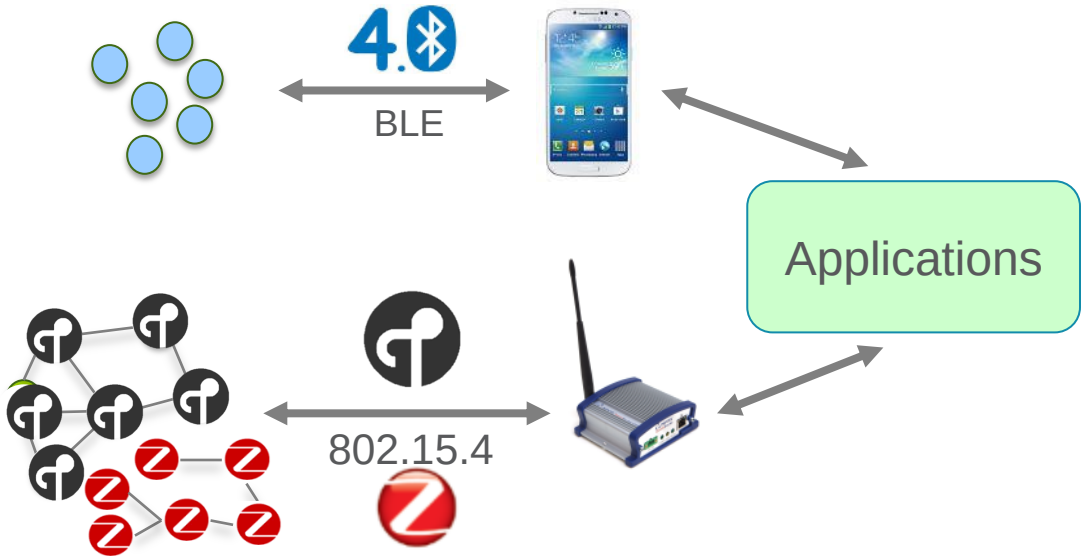


Navigating IoT Standards



Constrained networks for IoT

- Bluetooth Low Energy (BLE) PAN – hub/spoke topology
  - Widely deployed in phones, tablets
  - Becoming ubiquitous for low-power PAN
  - Smart phone is a “natural” proxy / access point
- 802.15.4 – mesh topology
  - Consumer
    - Thread (2015)
    - ZigBee Pro
  - Industrial
    - ZigBee SE (Smart Energy)
    - ZigBee NAN (neighborhood area)
- Challenges for constrained networks
  - Slow – low data rate “tens to hundreds of k-bits” typical
  - Sleepy – aggressive power management
  - No delivery or in-order guarantee – dropped packets simply drop!
  - Multicast



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Thread: Low-bandwidth mesh network for consumers

- Why mesh for consumer / residential?
  - Whole-home coverage
  - Enable very low power radios
  - Coverage increases as devices are added

- Options today
  - WiFi
  - ZigBee Pro
  - Z-Wave
  - Insteon
  - Bluetooth / BLE variants
  - (others)

- None provide all of these features
  - Efficient mesh
  - Open protocol
  - IP based (IPv6)
  - Low power (sub-10 mW roadmap)
  - Resilient – No single point of failure
  - Multi-vendor silicon
  - Multi-vendor interoperability
  - Secure, consumer-friendly, easy to install

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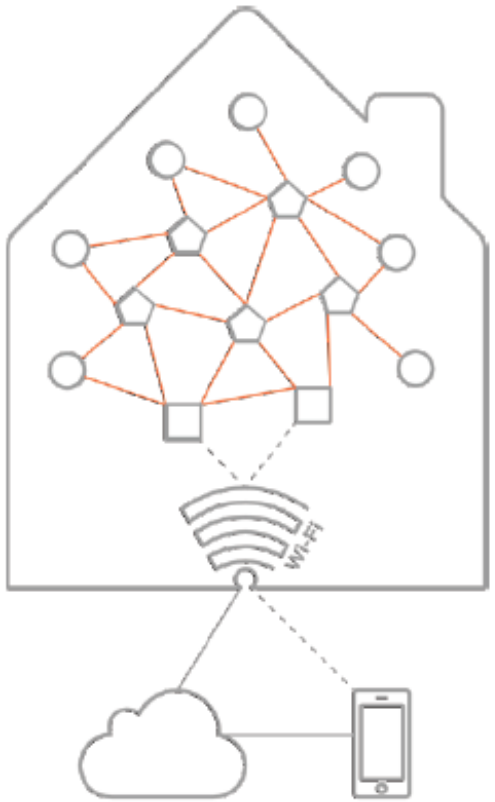
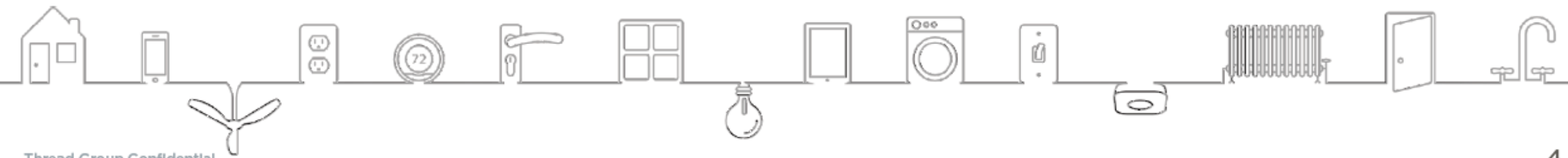
THREAD Target applications

Thread is designed for all sorts of products in the home

- Appliances
- Access control
- Climate control
- Energy management
- Lighting
- Safety
- Security



Devices working together to form a cohesive mesh network



THREAD What it delivers

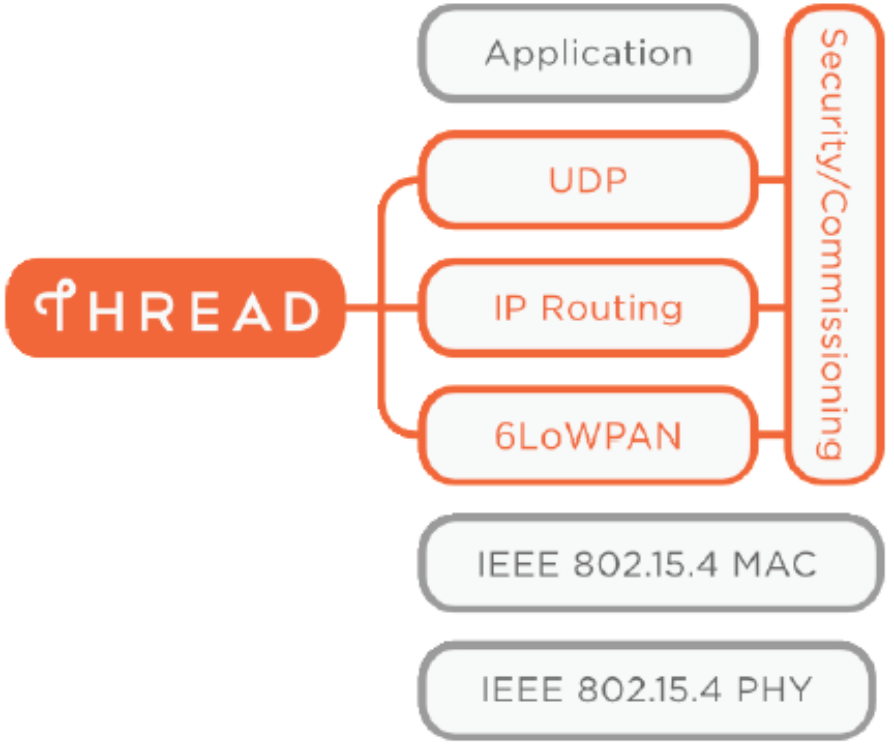
www.threadgroup.org

A secure wireless mesh network for your home and its connected products

- Built on well-proven, existing technologies
- Uses 6LoWPAN and carries IPv6 natively
- Runs on existing 802.15.4 silicon - product development can start today
- Designed with a new security architecture to make it simple and secure to add and remove products
- Supports 250+ products per network
- Designed for very low power operation
- Legacy-free design

Status: Under development. Certified products in 2015

Thread can support many popular application layer protocols and platforms



A software upgrade can add Thread to currently shipping 802.15.4 products

Why Internet + Web to the network edge for IoT?

- **"Web scale" growth for IoT** – including constrained networks, devices

- **Give every device a unique address**
  - "IPv6 is The most suitable framework for IoT"*
  - IPv6 is IoT-friendly by design
  - Mobile, secure, open, global
  - Legacy IPv4 via tunneling

- **Enable Web-scale software development**
  - Client / server computing with 100% reach
  - Use Web-scale standards, design patterns, tools
  - RESTful, application-independent, hypermedia
  - Device and resource discovery; automated provisioning

* The Internet of Everything through IPv6: An Analysis of Challenges, Solutions and Opportunities
Antonio J. Jara, Latif Ladid, Antonio Skarmeta - http://ipv6forum.com/iot/images/jowua-v4n3-6.pdf

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Key Internet / web protocols

Can Internet / Web protocols scale down to constrained IoT networks?

- **Addressing** **IPv6**
  - Uniform, unique addressing
- **Transport** **TCP**
  - Guaranteed in-order packet delivery
- **Application** **HTTP**
  - Any type of message can be exchanged between any nodes
- **Security** **TLS**
  - Secure messaging using standards-based protocols

- **Inefficient over constrained networks**
  - 40 byte IPv6 header is ~1/3 of an 802.15.4 packet

- **Impractical with unreliable networks**
- **Fails on sleepy platforms**

- **Requires reliable, in-order transport (TCP)**

- **Requires reliable, in-order transport (TCP)**

Internet / Web protocols for constrained IoT networks

Application
1000s of bytes

Web Object

HTTP

TLS
(TCP)

IPv6

IPv6 ➔ **6LoWPAN**
- Header compression on sensor networks

TCP ➔ **UDP**
- No guarantee of packet delivery or order

HTTP ➔ **CoAP**
- HTTP-like (REST) protocol for constrained devices

TLS ➔ **DTLS ➔ eDTLS**
- TLS over UDP – stateless – one packet at a time

Proxy

IoT Backhaul
100s of bytes

Binary Web Object

CoAP

DTLS (UDP)

IPv6

Router

IoT Sensor Network
10s of bytes

Binary Web Object

CoAP

DTLS (UDP)

6LoWPAN

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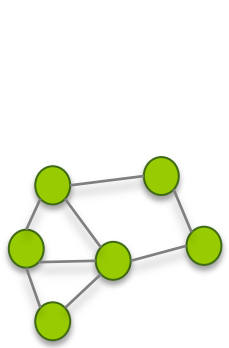
Little data to big data:
Deploying constrained Internet / Web protocols



Proxy
Router
Access Point

Applications

IoT apps

Big data

CoAP | MQTT-SN	HTTP | MQTT
UDP	TCP
DTLS	TLS
6LoWPAN	IPv6

Constrained Internet / Web

Internet / Web

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6LoWPAN

IPv**6** **Lo**w power **W**ireless **P**ersonal **A**rea **N**etworking

Improve efficiency of IPv6 addressing constrained links

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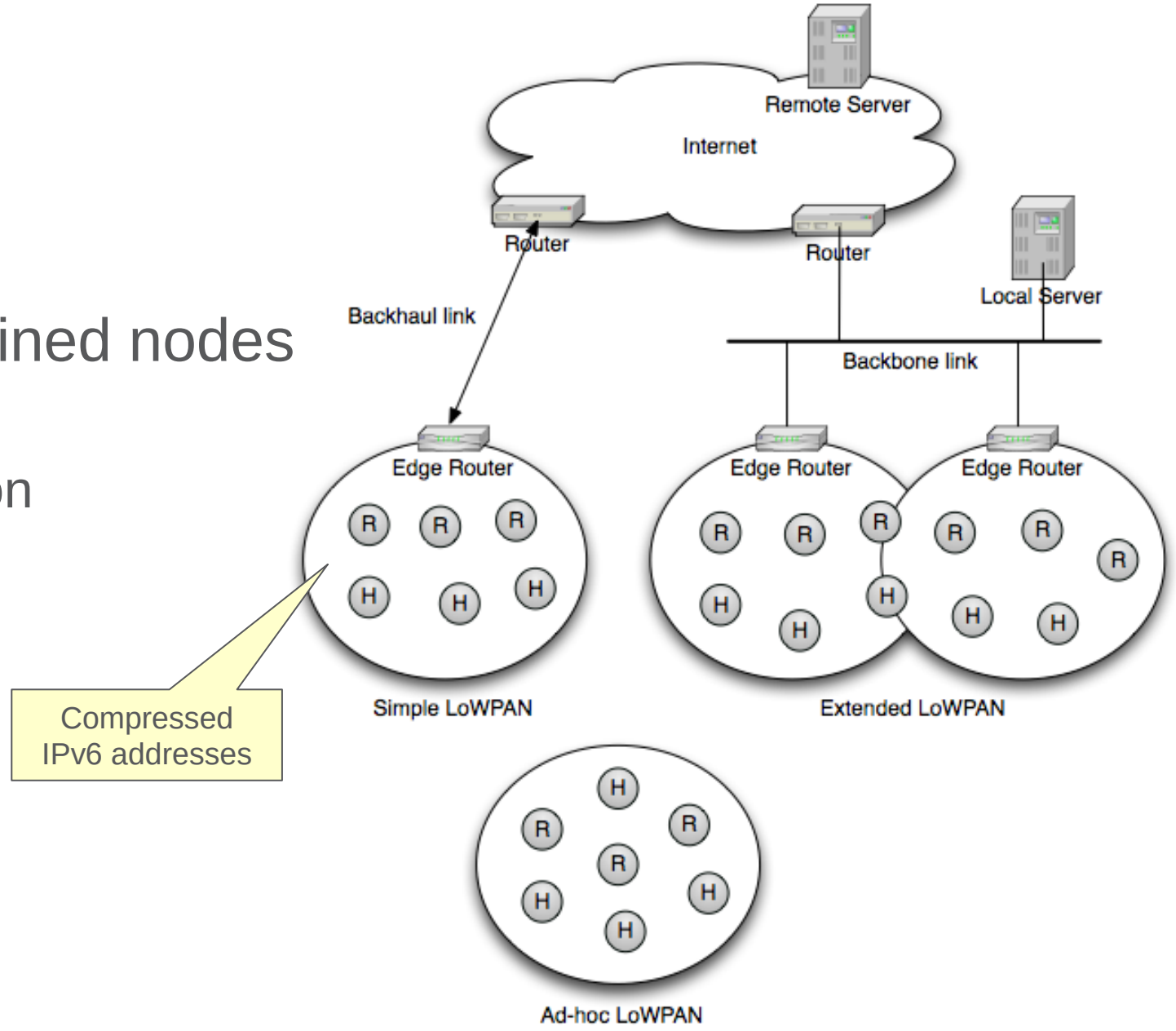
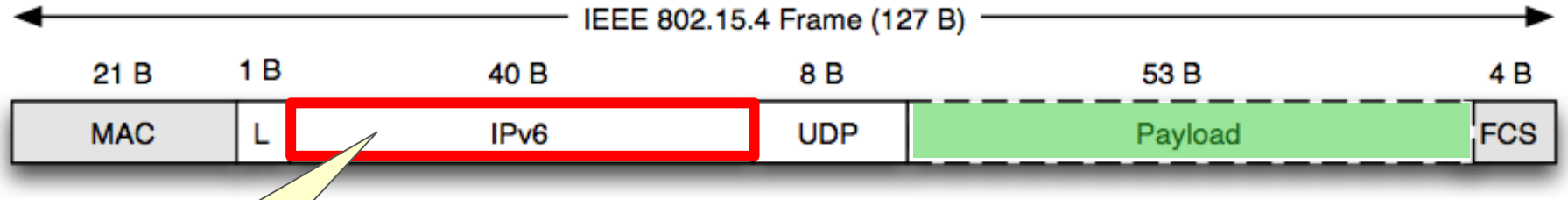
6LoWPAN Topology

- Hierarchical
- Uses IPv6 addressing
- Enables low power constrained nodes
- Edge routers
  - Perform header compression
  - Hide node constraints
  - Discover low power nodes
- Node types
  - Host (endpoint)
  - Router (forms a mesh)
- IPv4 support?
  - Yes, via tunneling

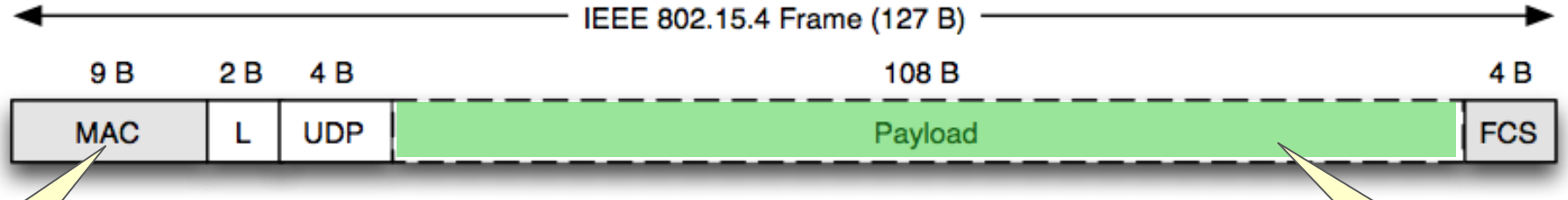


6LoWPAN “compression”



Full UDP/IPv6 (64-bit addressing)

Remove 40 byte IPv6 address and other redundant info



Minimal UDP/6LoWPAN (16-bit addressing)

MAC address is proxy for IPv6 - unique on WPAN

Larger payload! ~2X in some cases

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Security

DTLS: TLS for constrained devices

“The value of BIG DATA depends on trust in LITTLE DATA”

TLS, DTLS

- TLS – Transport Layer Security
  - The most widely deployed protocol for securing network traffic
  - Uses TCP
  - Requires reliable, in-order packet delivery
- DTLS – Datagram Transport Layer Security
  - Designed for UDP
  - Works over constrained platforms and networks
  - Works with unreliable, out-of-order packet delivery
  - No multi-record stream cyphers
- eDTLS on small embedded platforms
  - Goal: Reduce state-machine code size
  - Compress handshake protocol messages, reduce application data overhead
  - Keying flexibility: Pre-shared, raw public/private, X.509 certificate

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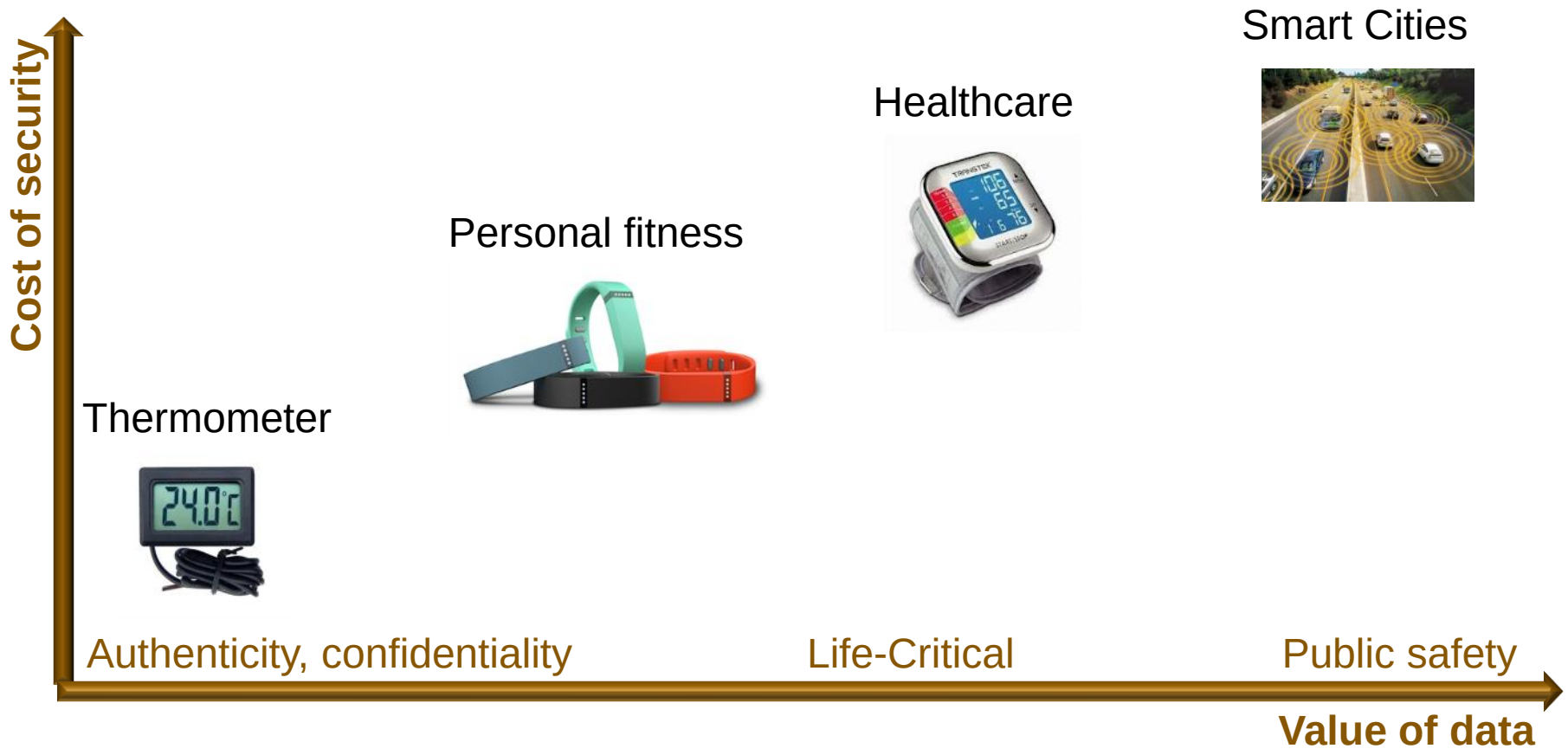
Device security: How much is enough?



- DTLS is the easy part. IoT security provisioning and management is more difficult.
- Goal: MUTUAL TRUST between devices and applications
- *Higher security means higher cost, complexity, power*

CoAP

Constrained Application Protocol

Improve efficiency of payloads for constrained networks while maintaining Internet / Web design patterns

CoAP summary

- Apply REST principles to constrained devices
  - Web apps see a RESTful API (HTML, JSON, XML, …)
- CoAP is optimized for constrained IoT networks
  - CoAP handles the nasty details of transient, slow, unreliable connections

	CoAP	**HTTP**
Transport	UDP	TCP
Message confirmation	Optional – confirmable, non-confirmable	All messages acknowledged
Message order	Not ordered	Ordered
Requests/responses	Asynchronous	Uses established connection
Encoding	Can be binary	Plain text (usually)

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REST: Representational State Transfer

- It's the HTTP client-server programming style
  - W3C Technical Architecture Group – *it's how the Web works*
  - Roy Fielding's dissertation – *2000, UC Irvine*
  - *Simple methods: Get, Put, Post, Delete (and a few others)*

- Central concepts
  - Resources – anything that can be named
    - Transparent connections – applications just need URI (uniform resource identifier)
  - Interfaces – simple, basic client/server communication
    - Nothing app-specific – it's just GET, PUT, POST, DELETE
  - Representations – current or intended state of a resource
    - Standard formats: HTML, JSON, EXI (Efficient XML Interchange), XML, …
  - Hypermedia-driven applications
    - REST applications can **discover** how to interact with resources

REST for IoT: CoAP

- CoAP – Constrained Application Protocol
- REST for IoT
  - **Implementation** ~~HTTP~~ **CoAP**
  - **Resources** Uniform identifiers (anything with a name)
  - **Interfaces** GET, PUT, POST, DELETE (not app-specific)
  - **Representations** ~~Page description~~ **Binary objects**

- CoAP key features
  - RESTful HTTP-like response/request
  - Easy to interface with RESTful web applications
  - UDP based (asynchronous messaging)
  - Compensates for transient / unreliable characteristics of IoT networks
  - Resource discovery and linking (RFC6690)
  - Simple web-compatible proxy and cache options

Moving up the stack:
IoT Objects

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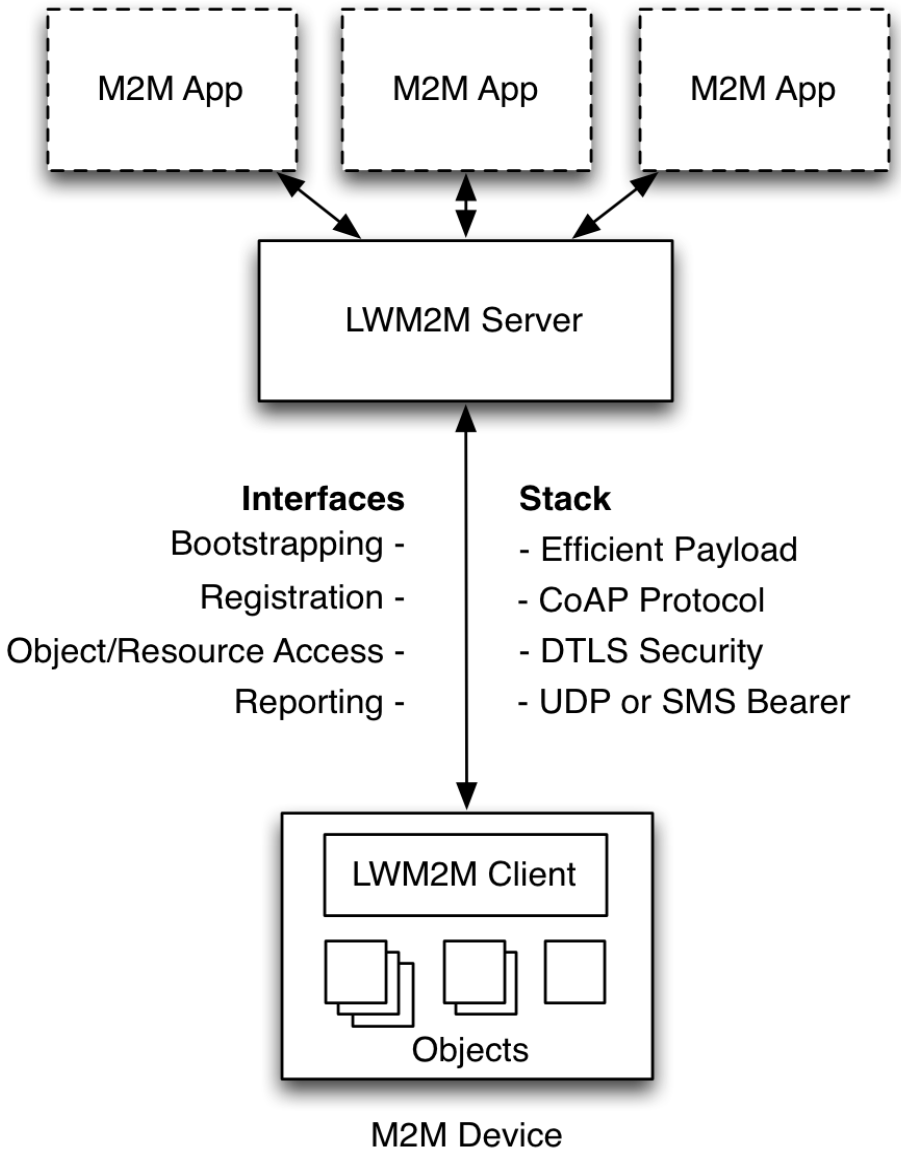
CoAP ➔ OMA LWM2M ➔ IPSO

IPSO – smart objects built on top of LWM2M
- Application objects using LWM2M object model
- Composable – complex objects can be built up from simple ones
- Extensible – easy to add new resources and object types

LWM2M – built on top of CoAP
- Server profile for IoT middleware
- Simple, re-usable object model
- Device management objects
- API for onboarding, management

CoAP
- Device abstraction API and data compatibility layer
- Designed for constrained networks and devices
- HTTP proxy through standard web APIs
- Resource directory for scalable discovery and linking

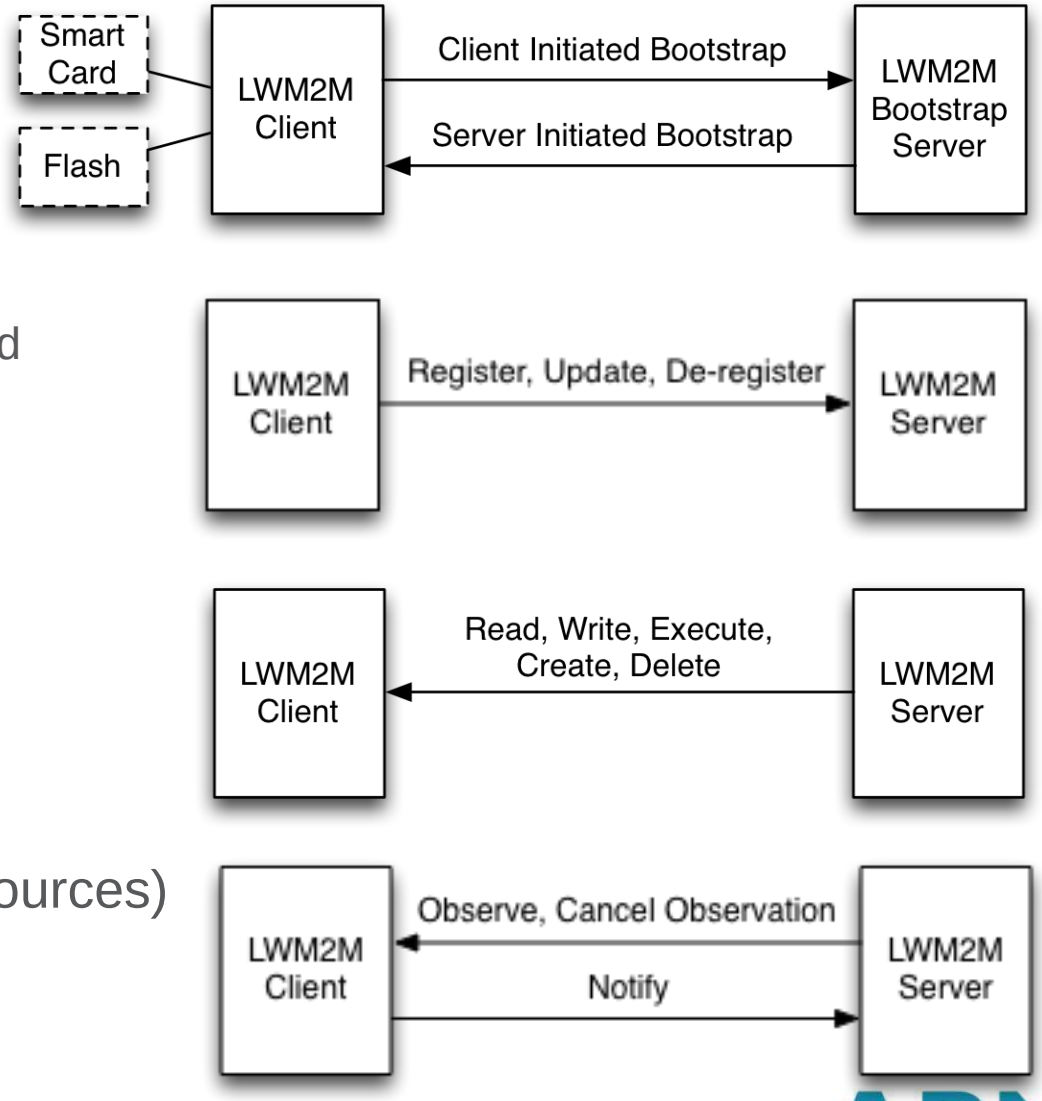
OMA LWM2M Reference Architecture



- Web Applications
  - Application abstraction via HTTP/REST API
  - Resource discovery and linking
- LWM2M Server
  - CoAP – HTTP Caching Proxy
  - Resource Directory
  - Gateway and Cloud deployable
- LWM2M Clients
  - Device abstraction through CoAP
  - LWM2M Objects
  - Any IP network connection

LWM2M Interfaces

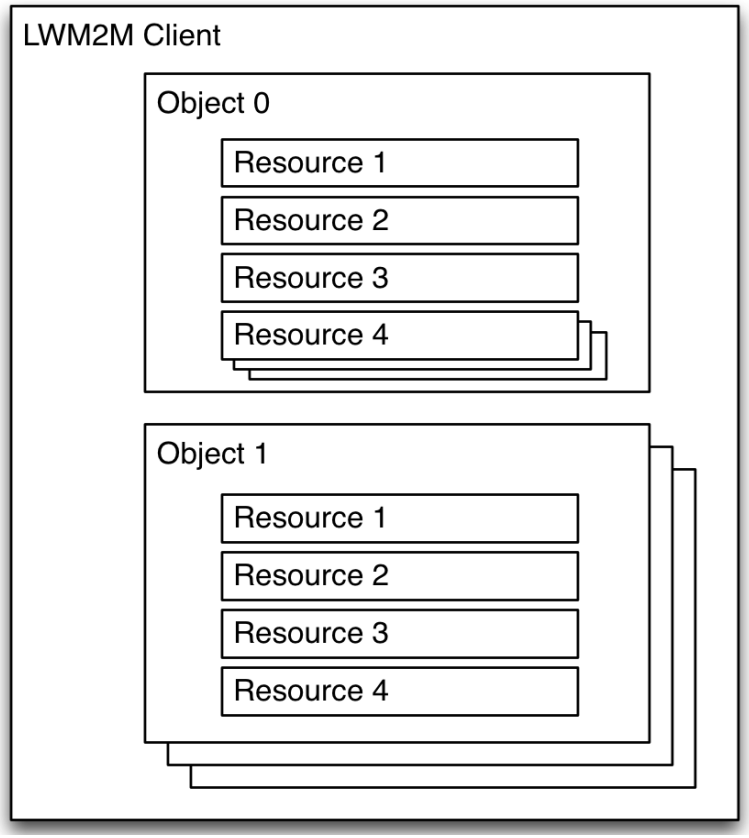
- Bootstrap Interface
  - Configure servers, keys
  - Bootstrap
    - Pre-configured, smart card, client initiated, server initiated
- Registration Interface
  - Resource directory (RFC6690 based)
- Management Interface
  - Object instances and resources
- Reporting Interface
  - Observe / subscribe (to object instances and resources)
  - Asynchronous notification

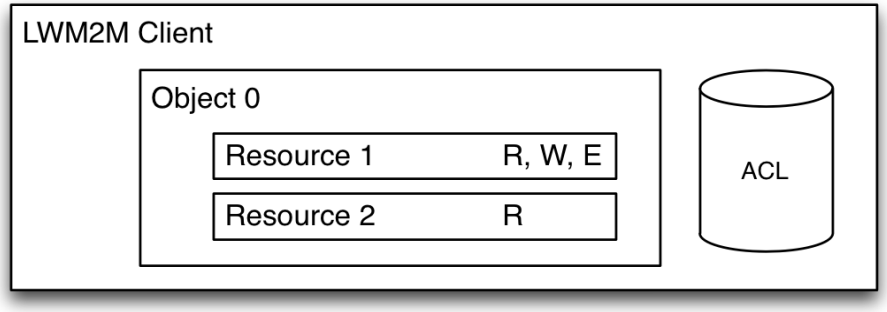


OMA LWM2M Object Model

- Client: has one or more Object Instances
- Object: is a collection of Resources
- Resource: is an atomic piece of information
  - Read, write, execute
  - Can have multiple instances
- Objects and Resources:
  - 16-bit integer IDs
  - 8-bit integer instances
- Accessed with simple URIs:

```
/{Object ID}/{Object Instance}/{Resource ID}
e.g.
/3/0/1
```





Summary

Summary

- Standards-based ecosystems will accelerate IoT growth
- Constrained IoT devices will account for a large part of the projected 17..31% IoT industry CAGR
- “Web to the edge” based on industry standards is practical today for constrained IoT devices
  - Protocols: IPSO → OMA Lightweight → CoAP → 6LoWPAN
  - Networks: WiFi, Thread, ZigBee NAN



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Thanks!

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