Embedded systems engineering
Distributed real-time systems

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Moving on: data protocols

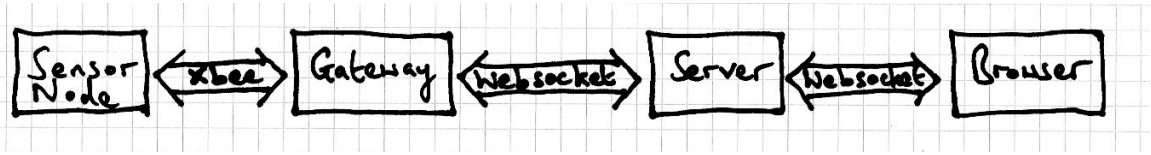
- MQTT
  - binary protocol for publish/subscribe architectures
  - lightweight, efficient, simple to implement, minimal packet overhead
  - developed by IBM and Arcom in 1999 for connecting oil pipelines over satellite links
  - Typically runs over TCP and TLS
  - OASIS standard (Banks and Gupta, 2014)
- CoAP – Constrained Application Protocol
  - specialized web transfer protocol for use with constrained nodes and constrained networks in the Internet of Things
  - based on the REST model: Servers make resources available under a URL, and clients access these resources using methods such as GET, PUT, POST, and DELETE.
  - Runs over UDP and DTLS
  - open standard RFC7252 (Shelby et al., 2014)

Moving on: naming

- The ‘strawman’ implementation has an entirely ad-hoc approach to naming, e.g.
  `http:hesabu.net/iot?id=SN01`
- Inter-operability requires a standard approach
- Enter **OMALWM2M**
  - Open Mobile Alliance LightWeight Machine-to-Machine protocol
  - Efficient Device <-> Server interface based on CoAP
  - Extensible object and resource model for application semantics
  - Public registry of objects from OMA etc.
  - Objects/Resources are accessed with simple URIs:
    `Object ID/Object Instance/Resource ID`, e.g.
    `4004/0/1`
  - A resource can be *read*, *written*, or *executed*

Moving on: security

Don't be the next Nissan Leaf (Hunt, 2016) !!!



- Sensor node to gateway (Xbee)
  - 128 bit AES encryption
  - Two security keys (network and link) that can be preconfigured or obtained during joining
  - Support for a trust centre (usually the coordinator)
  - Provision to ensure message integrity, authentication and confidentiality
- Gateway to server and server to browser (websocket)
  - Use the `wss://myserver.com` form of the protocol, which ensures that data is encrypted and sent using TLS.
  - Don't tunnel arbitrary TCP services over a websocket (vulnerable to cross-site scripting attack)
  - Validate client (browser) input, e.g. server may be vulnerable to SQL injection attack over websocket just as over TCP
  - Validate server data – treat as data, don't evaluate as code
  - Need client authentication/authorisation mechanism – 'ticket'-based protocol?

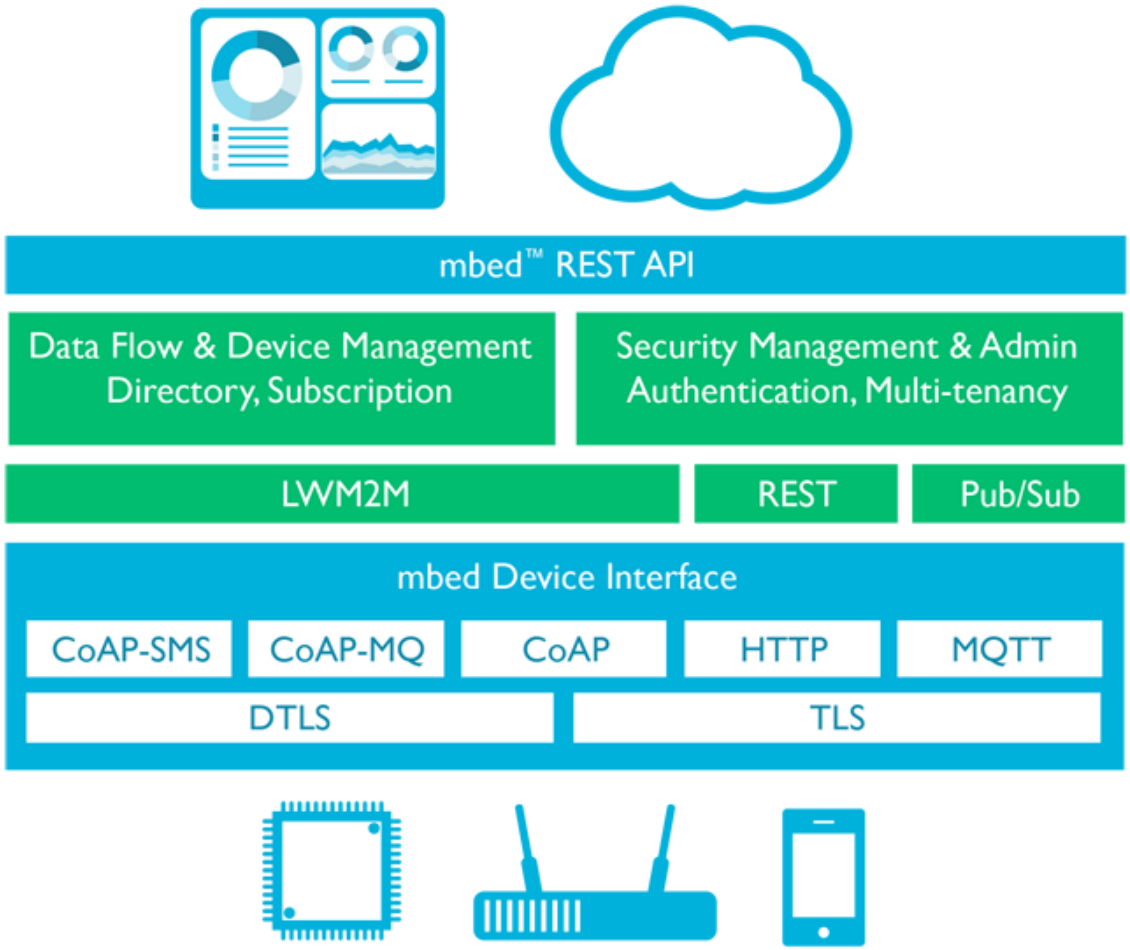
Design options I

- IP or not for communication at the sensor node (collapse the gateway into the node)?
  - 6LoWPAN – IPv6 over Low-power Wireless Personal Area Networks (802.15.4)
- What about the application and transport layers?
  - MQTT over TCP
  - CoAP over UDP
- What about the sensor node OS?
  - Lightweight threads, e.g. (Contiki, 2016) and (Riot, 2016)
    - ★ Both open-source and support protocols such as IPv6, 6LoWPAN and CoAP
  - Event-driven, asynchronous scheduler e.g. (mbed OS, 2016)

Design options II

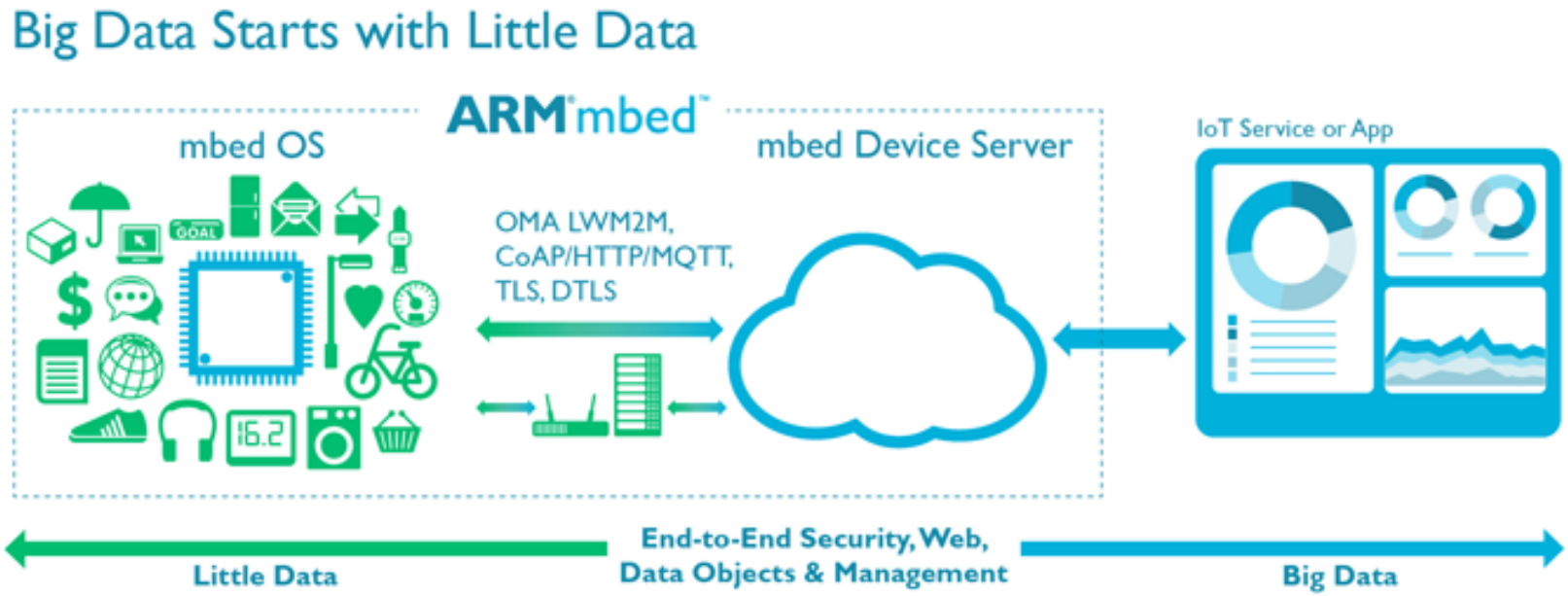
- What about the server?
  - Roll your own using `Node.js` instead of Python ?!
    - ★ Another event-driven, non-blocking I/O framework but for Javascript (in the server!)
  - Host an MQTT broker, e.g. Mosquitto (Eclipse, 2016a) and Mosca (Collina, 2016)
  - Use a cloud service, e.g.
    - ★ ARM device server (ARM Ltd., 2016d)
    - ★ IBM Watson Internet of Things (IBM, 2016)
    - ★ many others . . .
- and the clients?
  - Talking to the browser
    - ★ HTTP – REST
    - ★ Websocket – MQTT Javascript client, e.g. Eclipse Paho
  - Talking to the sensor nodes
    - ★ MQTT embedded client (supported by mbed), e.g. Eclipse Paho

ARM device server



(ARM Ltd., 2016d)

The ARM IoT Vision



(ARM Ltd., 2016c)

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