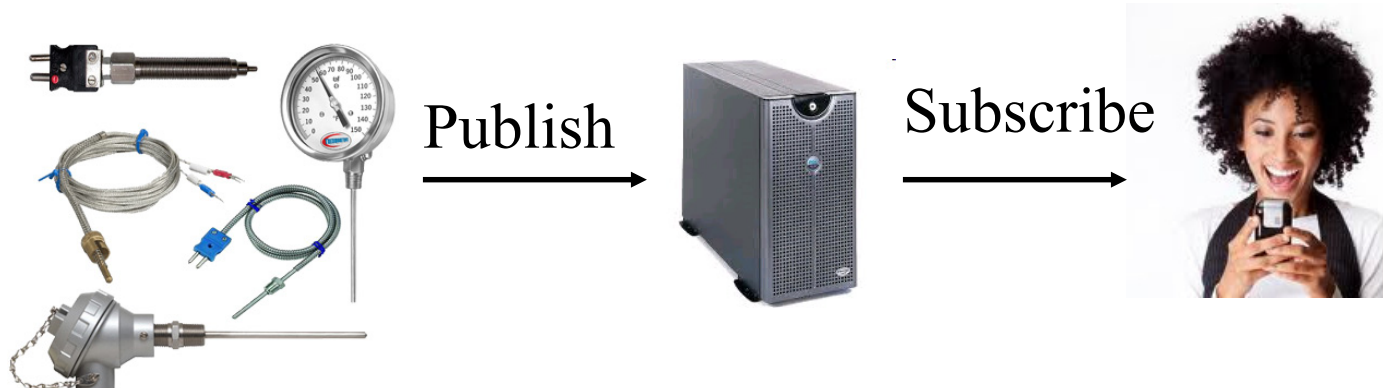# Messaging Protocols for Internet of Things: MQTT

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These slides and audio/video recordings of this class lecture are at:
http://www.cse.wustl.edu/~jain/cse570-15/

Overview

❑ MQ Telemetry Transport (MQTT)

➢ MQTT Concepts

➢ MQTT Application 2

➢ MQTT vs. HTTP

❑ Single-Board Microcontrollers

❑ Note: This is a part of a series of lectures on Internet of Things.
Please see the URL on the first slide and every slide for other lectures of this series.

IoT Ecosystem

		Security	Management
Applications	Smart Health, Smart Home, Smart Grid Smart Transport, Smart Workspaces, …	TCG, Oath 2.0, SMACK, SASL, ISASecure, ace, CoAP, DTLS, Dice	IEEE 1905, IEEE 1451, …
Session	**MQTT**, CoRE, DDS, AMQP , …		
Routing	**6LowPAN**, **RPL**, 6Lo, 6tsch, Thread, 6-to-nonIP , …		
Datalink	WiFi, Bluetooth Smart, ZigBee Smart, Z-Wave, DECT/ULE, 3G/LTE, NFC, Weightless, **HomePlug GP**, 802.11ah, **802.15.4**, G.9959, WirelessHART, DASH7, ANT+ , LoRaWAN, …		
Software	Mbed, Homekit, AllSeen, IoTvity, ThingWorks, EVRYTHNG , …		
Operating Systems	Linux, Android, Contiki-OS, TinyOS, …		
Hardware	ARM, **Arduino**, Raspberry Pi, ARC-EM4, Mote, Smart Dust, Tmote Sky, …		

MQ Telemetry Transport (MQTT)

❏ Lightweight messaging protocol for M2M communication

❏ Telemetry = Tele-Metering = Remote measurements

❏ Invented and sponsored by IBM.
Now Open source. Open Source libraries available.

❏ MQ originated from "message queueing (MQ)" architecture used by IBM for service oriented networks. There is **no** queueing in MQTT.

❏ Telemetry data goes from devices to a server or broker.
Uses a publish/subscribe mechanism.
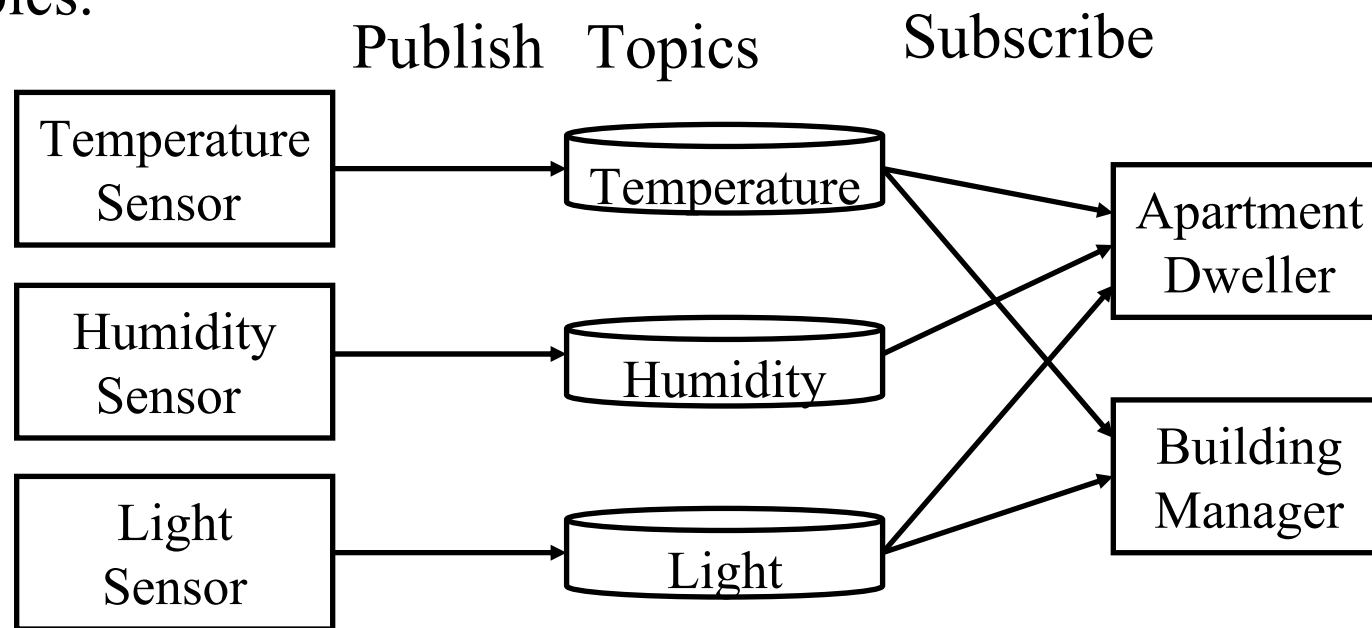
❏ Lightweight = Low network bandwidth and small code footprint

MQTT (Cont)

❑ Facebook messenger uses MQTT to minimize battery usage. Several other applications in medical, environmental applications

❑ Many open source implementations of clients and brokers are available

➢ Really small message broker (RSMB): C

➢ Mosquitto

➢ Micro broker: Java based for PDAs, notebooks

MQTT Concepts

❑ **Topics/Subscriptions**: Messages are published to topics. Clients can subscribe to a topic or a set of related topics

❑ **Publish/Subscribe**: Clients can subscribe to topics or publish to topics.

Publish   Topics   Subscribe

Temperature Sensor	→	Temperature	⟶	Apartment Dweller
Humidity Sensor	→	Humidity		Building Manager
Light Sensor	→	Light		

Ref: V. Lampkin, et al., "Building Smarter Planet Solutions with MQTT and IBM WebSphere MQ Telemetry," IBM Redbooks, SEP-2012, ISBN: 0738437085, 268 pp., (Safari Book), http://www.redbooks.ibm.com/redbooks/pdfs/sg248054.pdf
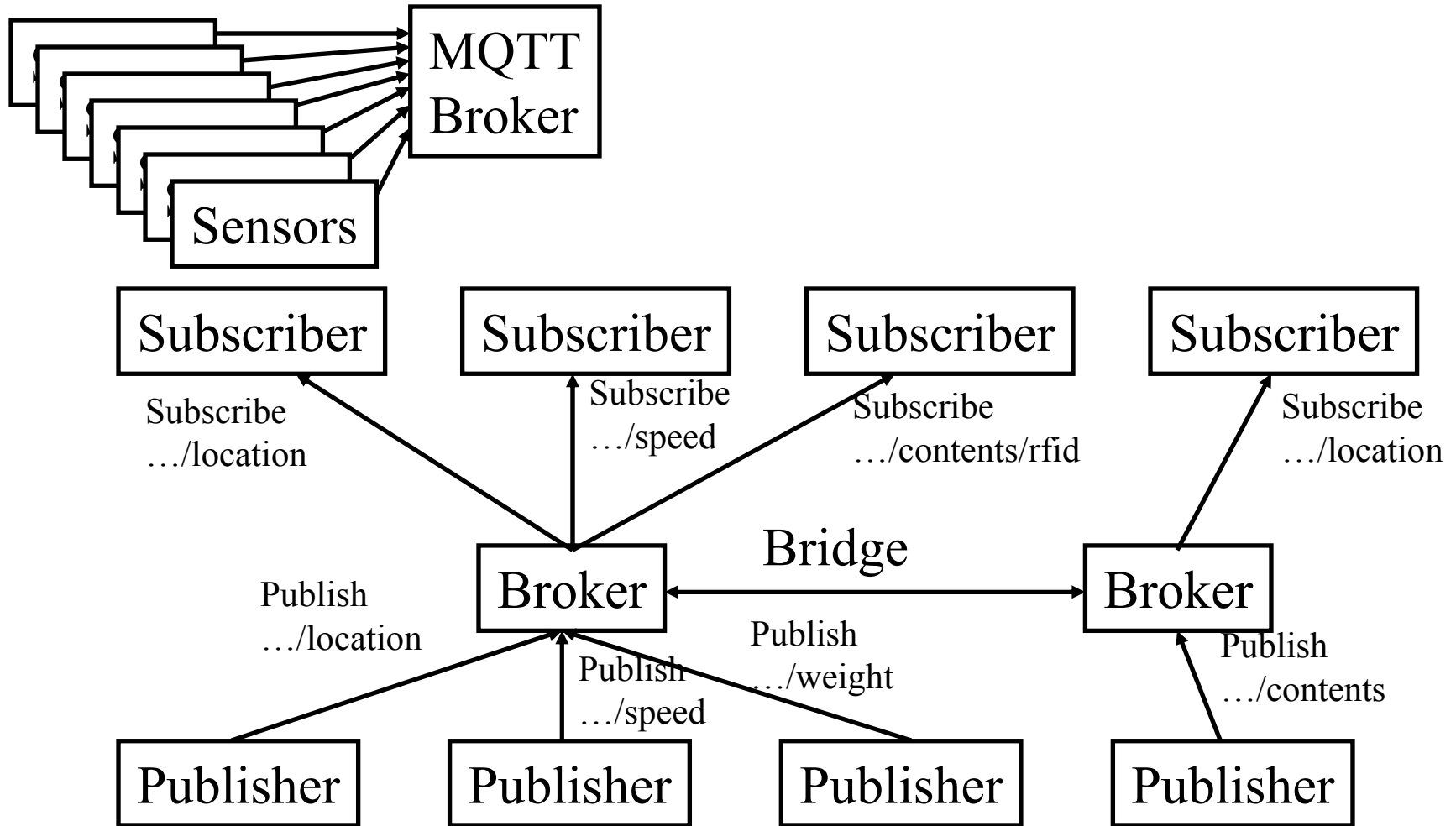
MQTT Concepts (Cont)

❑ **Quality of Service Levels**: Three levels:
0 = At most once (Best effort, No Ack),
1 = At least once (Acked, retransmitted if ack not received),
2 = Exactly once [Request to send (Publish), Clear-to-send (Pubrec), message (Pubrel), ack (Pubcomp)]

❑ **Retained Messages**: Server keeps messages even after sending it to all subscribers. New subscribers get the retained messages

MQTT Concepts (Cont)

- **Clean Sessions** and **Durable Connections**: At connection set up: Clean session flag $\Rightarrow$ all subscriptions are removed on disconnect Otherwise subscriptions remain in effect after disconnection $\Rightarrow$ Subsequent messages with high QoS are stored for delivery after reconnection

- **Wills**: At connection a client can inform that it has a will or a message that should be published if unexpected disconnection $\Rightarrow$ Alarm if the client looses connection

- Periodic **keep alive** messages $\Rightarrow$ If a client is still alive

- **Topic Trees**: Topics are organized as trees using / character /# matches all sublevels /+ matches only one sublevel

MQTT Example

MQTT Broker

Sensors

Subscriber

Subscriber

Subscriber

Subscriber

Subscribe …/location

Subscribe …/speed

Subscribe …/contents/rfid

Subscribe …/location

Bridge

Publish …/location

Broker

Broker

Publish …/speed

Publish …/weight

Publish …/contents

Publisher

Publisher

Publisher

Publisher

MQTT Application Examples

❑ Home pacemaker monitoring solution

➢ Sensors on patient

➢ Collected by a monitoring equipment in home (broker) using MQTT

➢ Subscribed by a computer in the hospital

➢ Alerts the doctor if anything is out-of-order
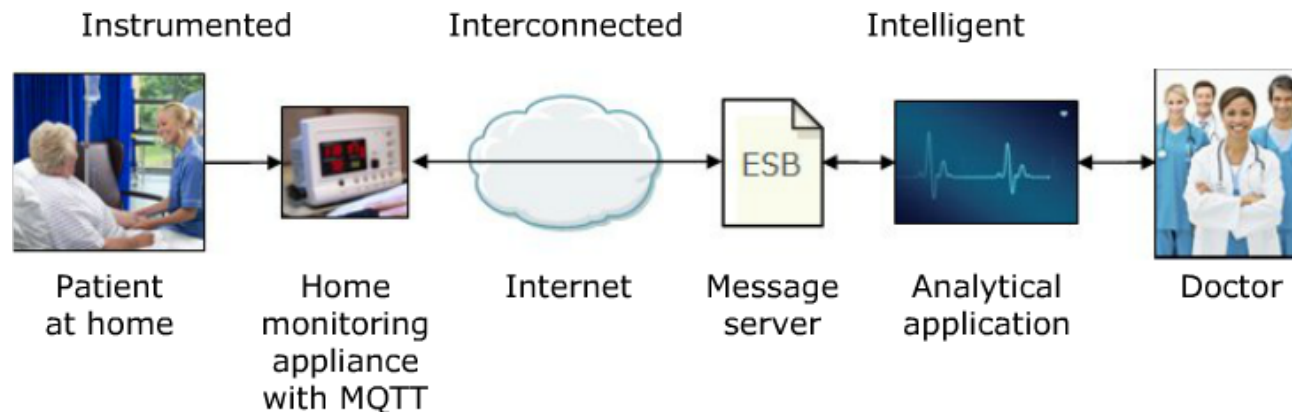
Source: Lampkin 2012

MQTT vs. HTTP

	MQTT	HTTP
Design	Data centric	Document centric
Pattern	Publish/Subscribe	Request /Response
Complexity	Simple	More Complex
Message Size	Small. Binary with 2B header	Large. ASCII
Service Levels	Three	One
Libraries	30kB C and 100 kB Java	Large
Data Distribution	1 to zero, one, or n	1 to 1 only

❑ Open source, http://www.eclipse.org/paho/

❑ Clients available in .NET, Perl, Python, REXX, Rube,

❑ Also for Arduino, Mbed, Nanode, Netduino

Single-Board Microcontrollers

❑ Open-source hardware designs

❑ **Arduino**: 8-bit Atmel AVR or 32-bit Atmel ARM
Comes with a compiler and a boot loader
Currently $20. Arduino Nano, $9

  ➢ Bare Bones Board kit (Boarduino): $18

  ➢ Shields: Expansion boards for motors,
    Ethernet, GPS, Display, …

  ➢ Arduino IDE in Java w programming in C or C++

  ➢ Applications: Oscilloscope, Drone, Phone, …

❑ **Netduino**: 32-bit ARM using .NET
Pin compatible with Arduino shields

❑ **Mbed**: 32-bit ARM Corex-M microcontroller

❑ 126 microcontrollers listed in Wikipedia

Ref: http://en.wikipedia.org/wiki/Arduino, http://en.wikipedia.org/wiki/Netduino, http://en.wikipedia.org/wiki/Mbed,
http://en.wikipedia.org/wiki/Category:Microcontrollers

Summary

- ❑ MQTT is a protocol used to publish and subscribe sensor information
- ❑ Lightweight, low code size, open source

Reading List

❑ V. Lampkin, et al., "Building Smarter Planet Solutions with MQTT and IBM WebSphere MQ Telemetry," IBM Redbooks, SEP-2012, ISBN: 0738437085, 268 pp., (Safari Book), http://www.redbooks.ibm.com/redbooks/pdfs/sg248054.pdf
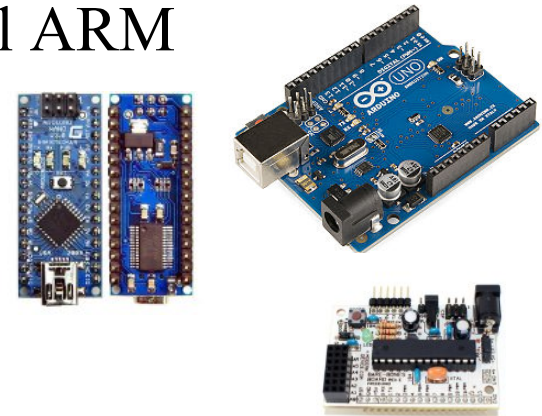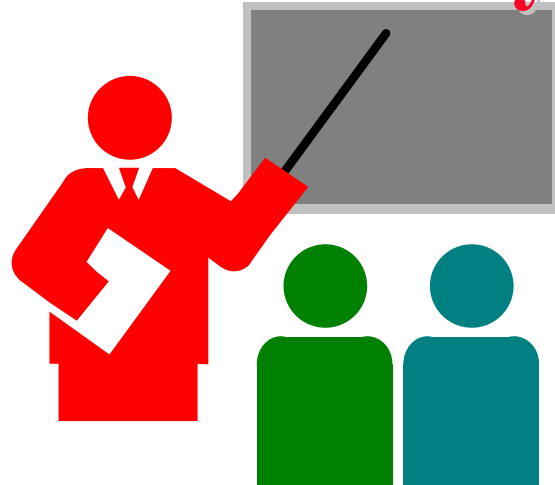
❑ http://en.wikipedia.org/wiki/MQ_Telemetry_Transport

❑ http://en.wikipedia.org/wiki/Category:Microcontrollers

Acronyms

- .NET   Microsoft's software framework
- 3G   Third Generation
- AMQP   Advanced Queueing Message Protocol
- ARC-EM4   Name of a Product
- ARM   Acorn RISC Machine
- ASCII   American Standard Code for Information Exchange
- AVR   Name of Atmel 8-bit RISC processor
- CoAP   Constrained Application Protocol
- DDS   Data Distribution Service
- DECT   Digital Enhanced Cordless Telecommunication
- DTLS   Datagram Transport Level Security
- GP   Green Physical Layer
- GPS   Global Positioning System
- HTTP   Hypertext Transfer Protocol
- IDE   Integrated Development Environment
- IEEE   Institution of Electrical and Electronics Engineers

Acronyms (Cont)

- IoT   Internet of Things
- IP   Internet Protocol
- ISASecure   Security Certification by ISCI
- ISCI   ISA Security Compliance Institute
- kB   Kilo Byte
- LoRaWAN   Long-Range Wide Area Network
- LTE   Long-Term Evolution
- MQ   Message Queueing
- MQTT   MQ Telemetry Transport
- NFC   Near Field Communication
- PDA   Personal Digital Assistant
- QoS   Quality of Service
- REXX   REstructed eXtended eXecutor (an interpreted programming language)
- RPL   Routing over Low-Power and Lossy
- RSMB   Really small message broker

Acronyms (Cont)

- SASL   Simple Authentication and Security Layer
- SMACK   Simplified Mandatory Access Control Kernel
- TCG   Trusted Control Group
- TinyOS   Tiny Operating System
- ULE   Ultra-Low Energy
- URL   Uniform Resource Locator
- WiFi   Wireless Fidelity
- WirelessHART Wireless Highway Addressable Remote Transducer Protocol