

Communication and Networking in the IoT

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System Energy Efficiency Lab

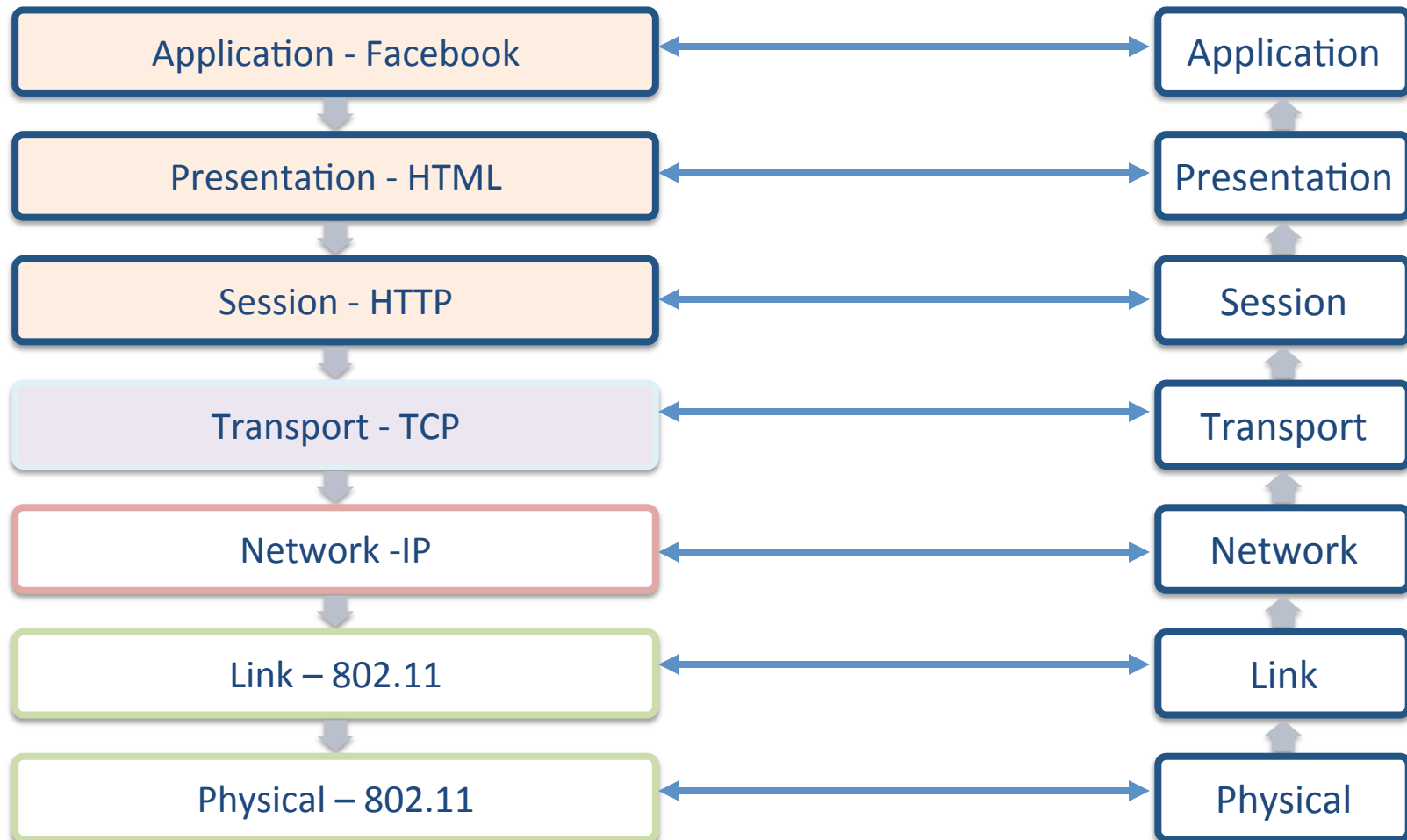


Internet of Things

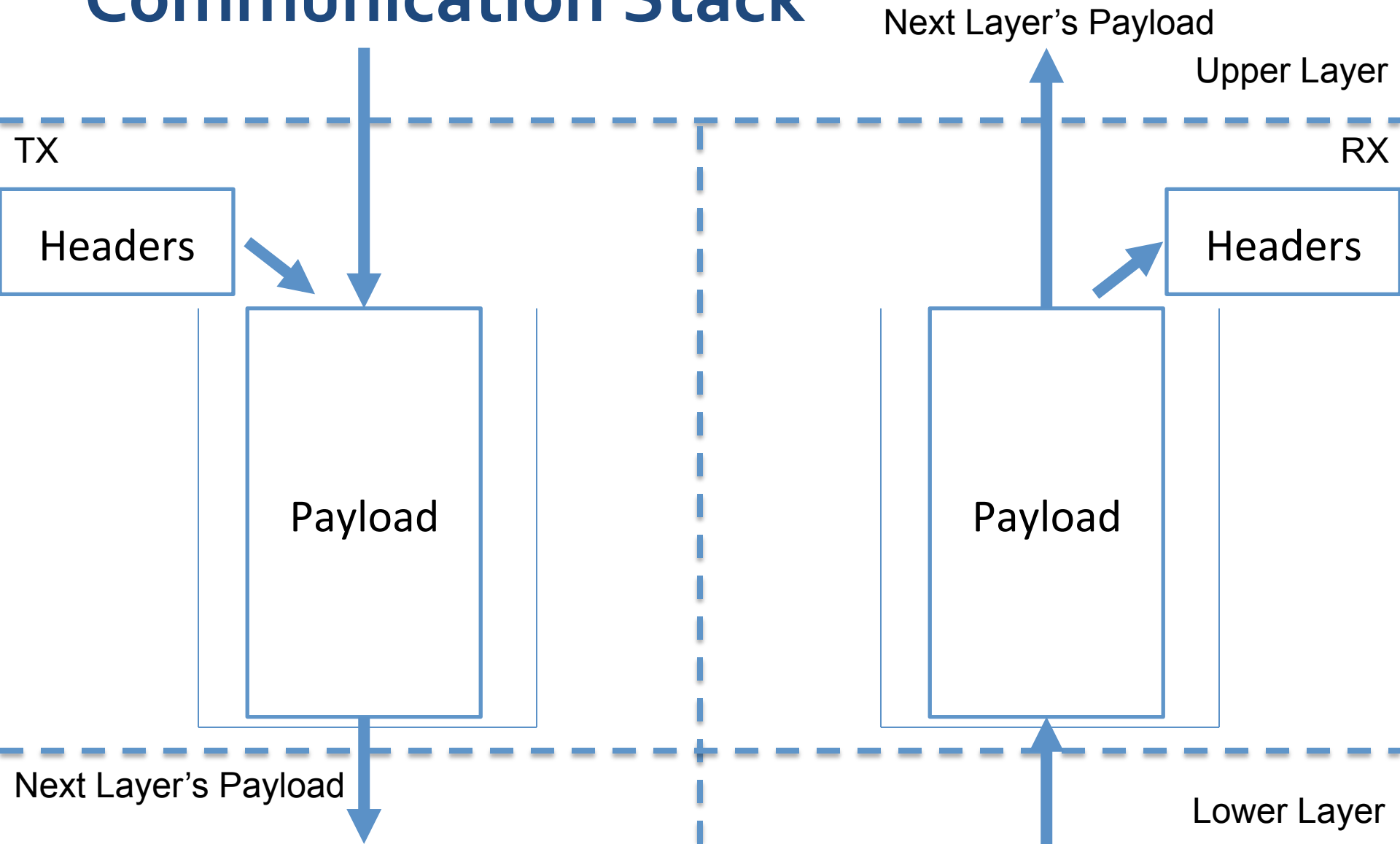
- **Networking**
 - link (machines, especially computers) to operate interactively
- **Communication**
 - the imparting or exchanging of information or news



OSI Layers



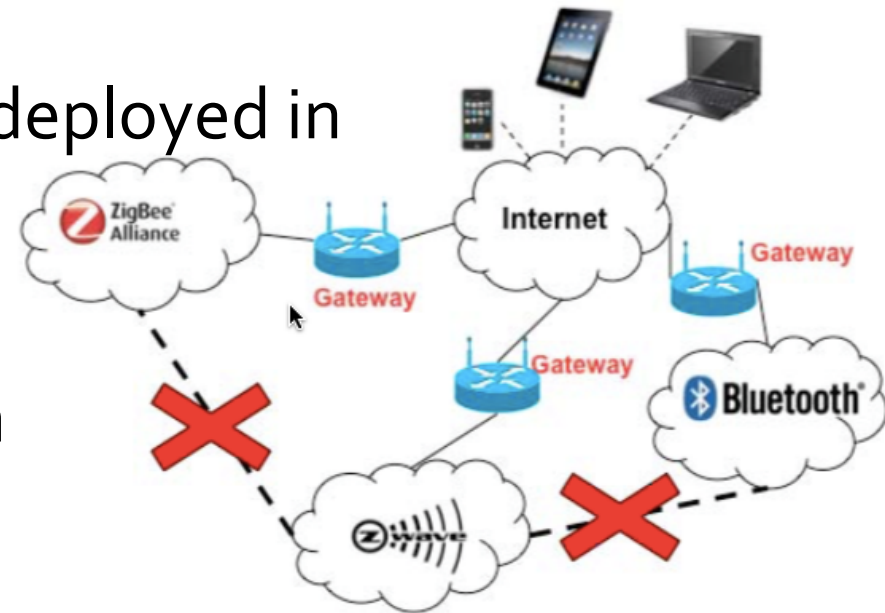
Communication Stack



The connection problem in IoT

Many different protocols are deployed in WSNs

They cannot understand each other

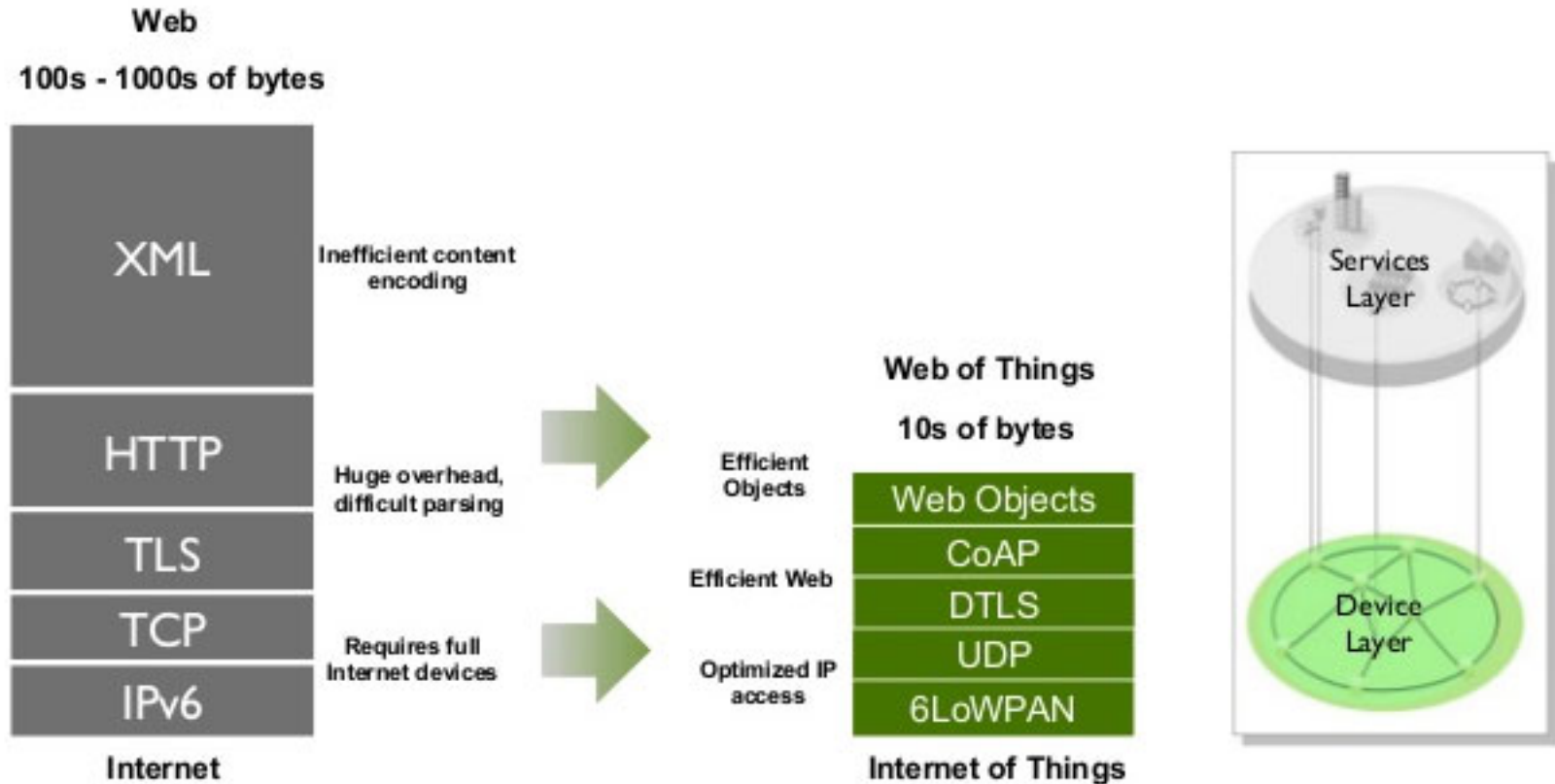


and this is **NOT** a software related issue!

Common solution:

gateways connecting WSNs to internet

Current internet is not enough

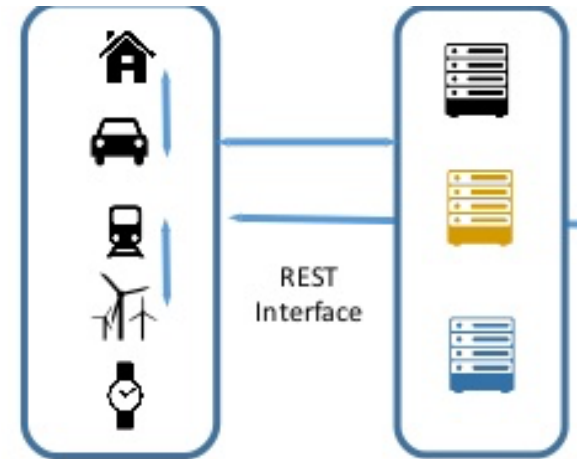


Application Layer

- Commonly designed with Presentation and Session
- Common data representation and data retrieval
- Lighting automation, home automation, distributed control, Skype, Facebook, Hangouts
- Mostly unaware of underlying infrastructure

Application Layer in IoT

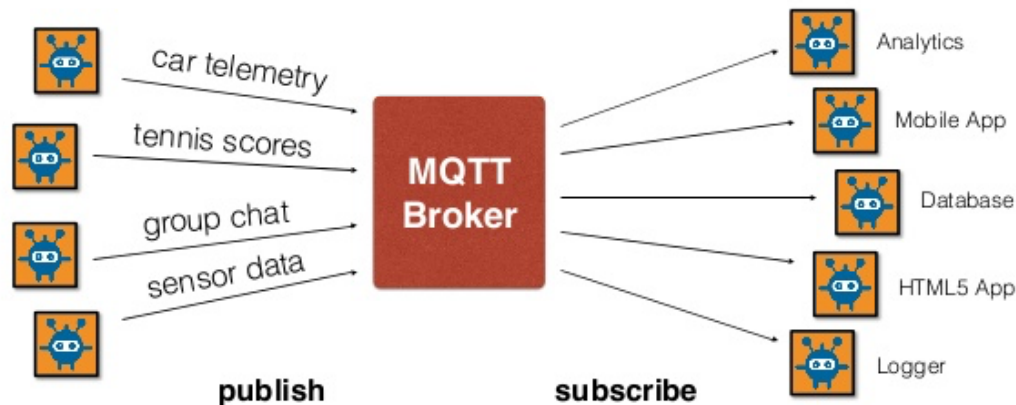
- WSNs with embedded devices are memory, CPU, energy constrained
- CoAP: Constrained Application Protocol
 - Easily convertible to HTTP
 - Supports multicast
 - Very low overhead (4-byte header + TLVs)
 - Data needs to be polled (Put/Get)



Application Layer in IoT

- MQTT
 - Publisher – Subscriber model
 - Light weight, minimizes code on remote end
 - Data is published once available
 - Good for M2M Networks, distributed control apps

MQTT pub/sub decouples **senders** from **receivers**



Open Problems

- Unification/Standardization:
 - Unified data representation
 - Unified and seamless data translation
- Very small code space and memory requirements
 - Where to store/cache data

Transport Layer

- Segmentation and reassembly
- End-to-end communication reliability
- Congestion control
- Reordering
- Security is added through Transport Layer Security

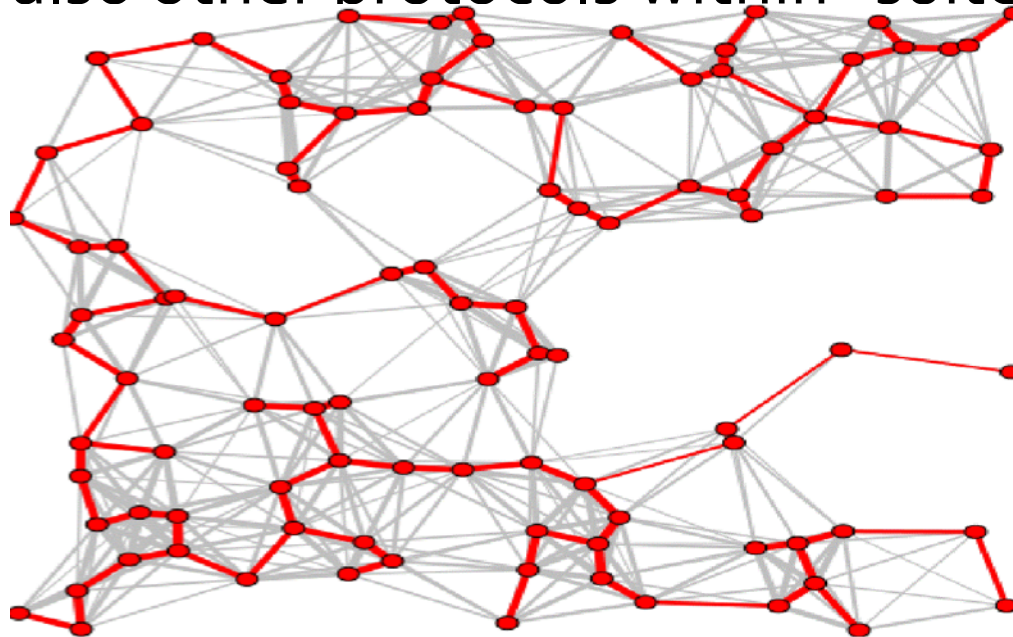
	Seg. & Reass.	End2End Reliability	Cong. Control	Reordering
TCP	YES	YES	YES	YES
UDP	NO	NO	NO	NO
DCCP	NO	NO	YES	NO
SCTP	NO	YES	YES	YES (opt)

Open Problems

- TCP is \$\$\$\$\$:
 - High memory usage
 - End to end communication resource usage
 - High loss links
- UDP is:
 - Not reliable
 - Assumes ordered delivery

Network Layer

- Management of multiple nodes
- Addressing & Routing & Security (IPSec)
- Internet Protocol (IP) is the dominant solution
- There are also other protocols within “suite” solutions

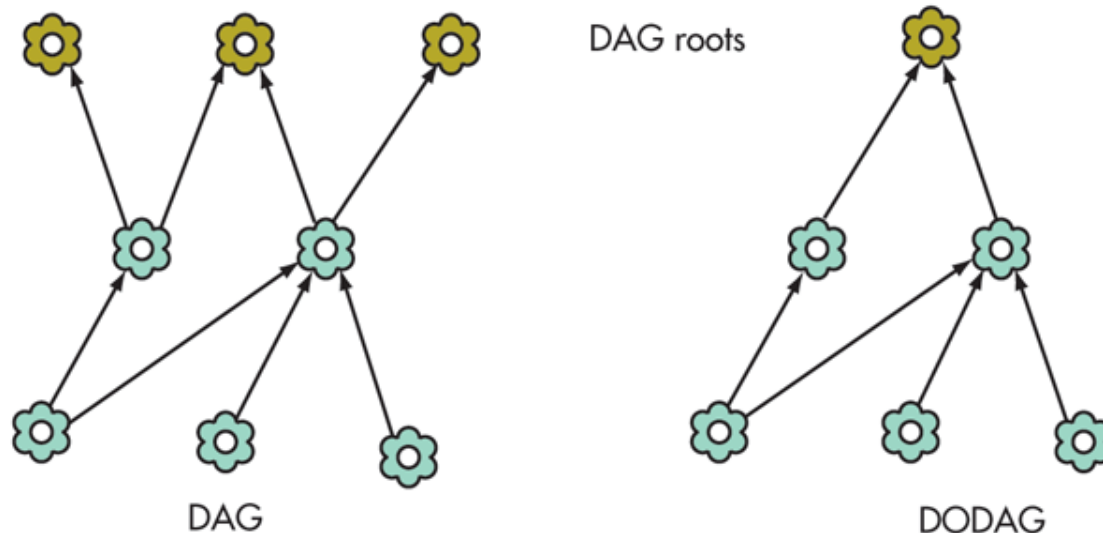


Network Layer in IoT

- Routing Protocol for Low-Power and Lossy Networks (RPL):
 - Dominant routing protocol for IPv6 on WSNs
 - Creates directed trees
 - Flexible architecture for energy, delay, link quality based routing selections
- IP is very inefficient by itself
 - 6LowPAN is used for improvement (cross-layer compressing)

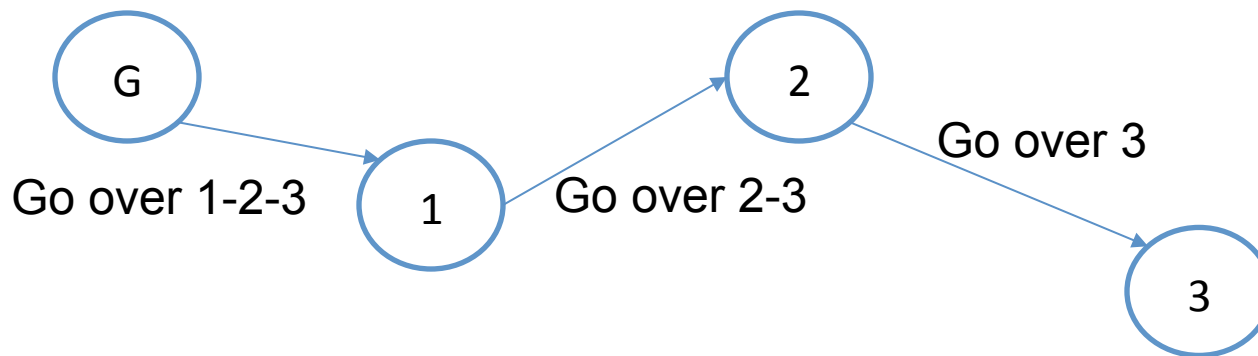
RPL

- Creates destination oriented directed acyclic graphs
- Optimized for upward (sink destined) traffic
- Supports mobility (treated as lossy link)
- Supports multiple DODAGs (sinks)
- Supports different routing modes (non/storing mode)



RPL + Memory Problem = Nonstoring Mode

- A routing table entity contains Node ID + Next Hop = 32 bytes per destination
- RAM is a luxury in small devices
- Nonstoring mode solves the memory problem by storing the routing table only at the gateway



Link Layer

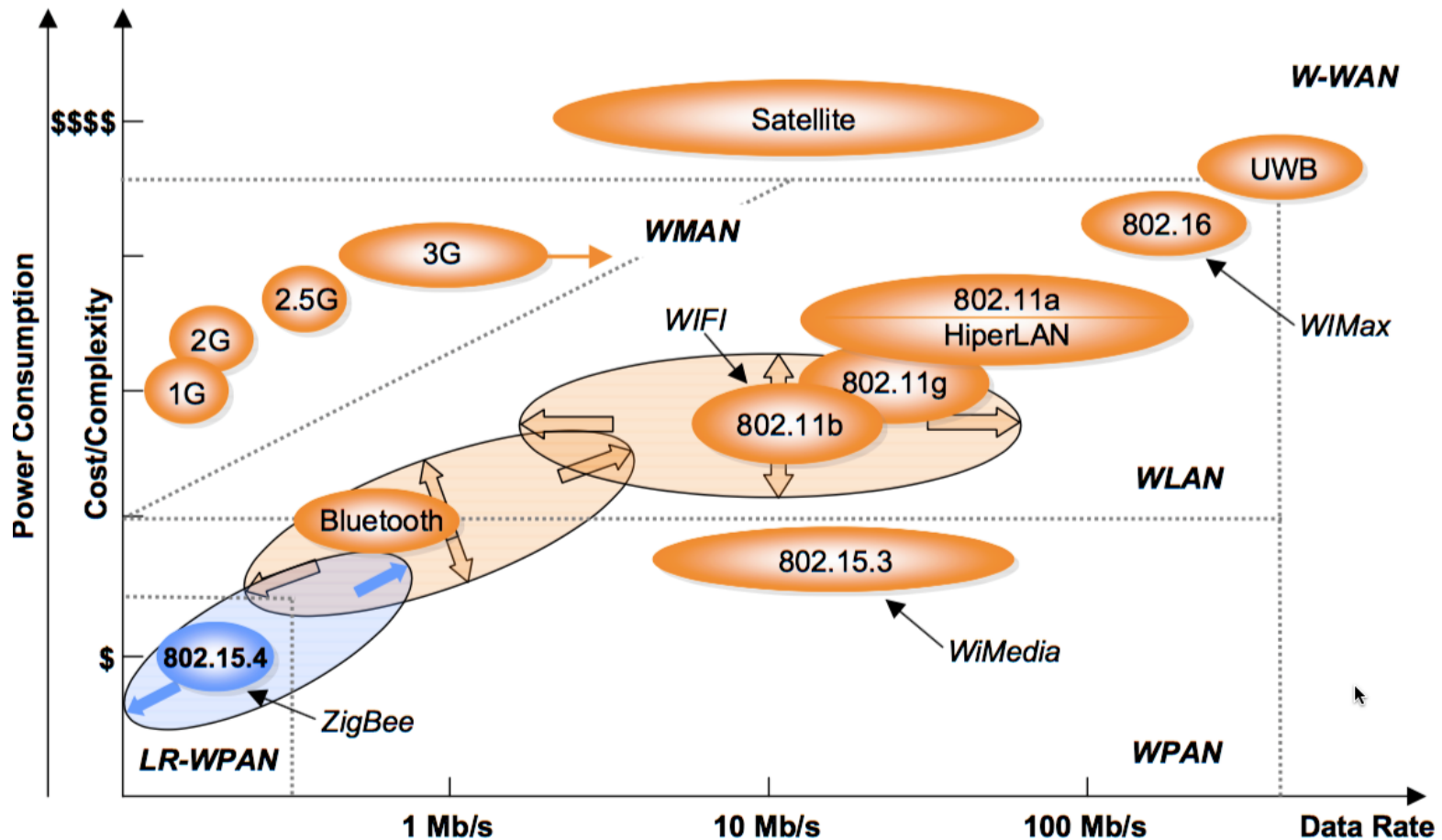
- Reliable communication within a single transmission range
- Contains the Media Access Control (MAC) sublayer
- Solves the interference problem
- Mostly contains Automatic Repeat Request (ARQ) mechanisms
- Mostly coupled with the Physical Layer

Link Layer in IoT

- Bluetooth:
 - Popular, low energy, low cost, two different types for speed and energy (~2Mbps)
- WiFi (IEEE 802.11):
 - Most popular option, high speed (>Gbps), high cost
- X10 (Power Line):
 - Very slow (~kbps), low cost, already deployed infrastructure
- IEEE 802.15.4:
 - Emerging choice for WSNs, low cost, low speed (<1Mbps)



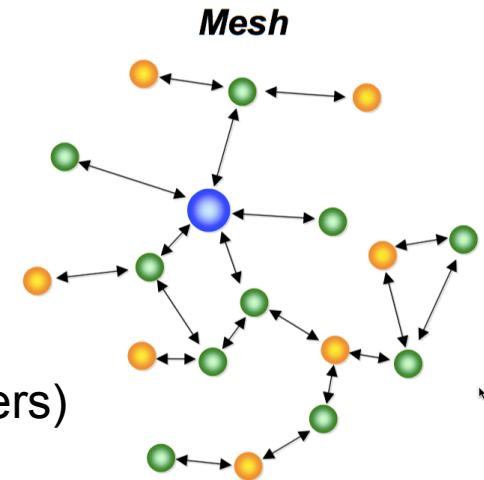
Link Layer in IoT



IEEE 802.15.4

Beacon 1	Slot 1	...	Slot n	Beacon 2
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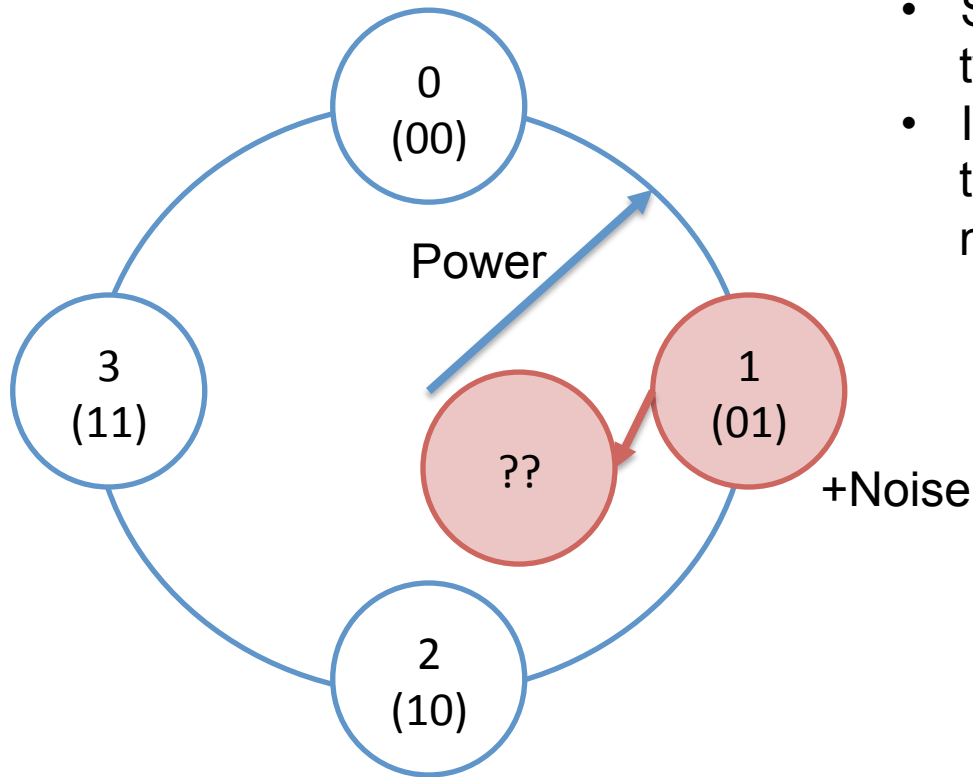
- Time Division is the best way to conserve energy
 - Sleep until next action
 - Conserve energy
- Beacon frequency is adjustable
 - Ability to change duty cycle
 - Conserve energy
- Operates on 2.4GHz (along with WiFi, BT, many others)
 - Interference
 - Uses frequency hopping
- Supports multi-hop, requires hand-shaking
- *How the slots are distributed is NOT defined (open to implementation, no standard yet, open research question)*



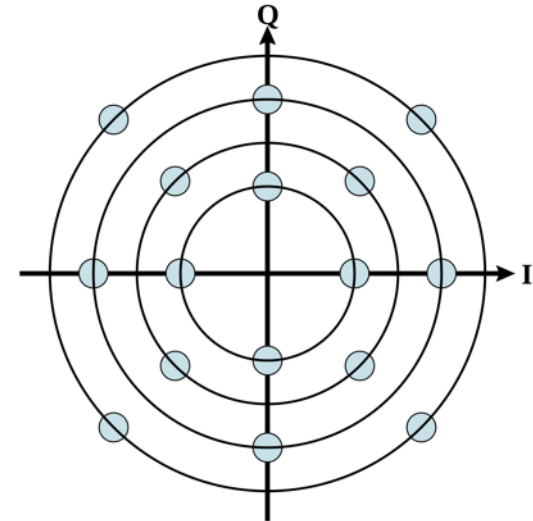
Physical Layer

- Actual communication over a physical medium
- Requires hardware implementation (DSP)
- Once selected, (almost) impossible to change (Software defined radios excluded)
- Common properties:
 - Operating Frequency + Bandwidth
 - Constellation Mapping + Encoding
 - Forward Error Correction Encoding
 - Signal Shaping
 - Signal Timing + Synchronization

Physical Layer



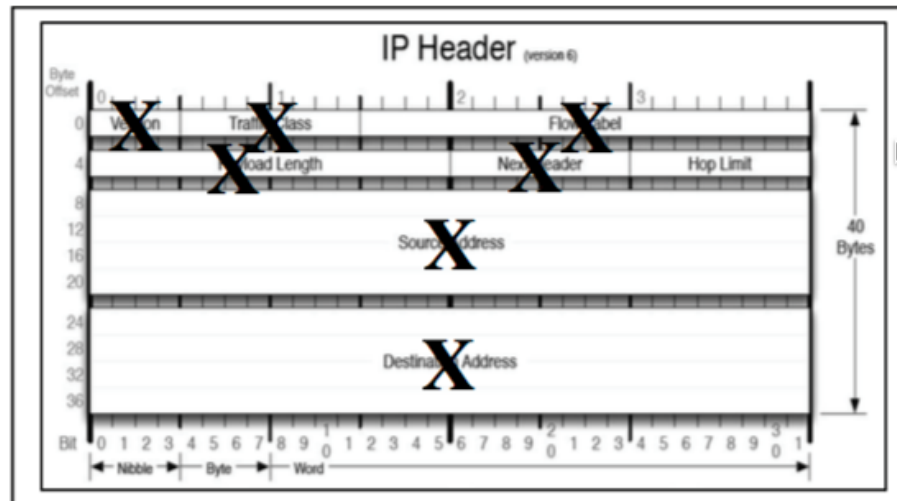
- Shortest distance between two points is: $\text{Power} \times \sqrt{2}$
- If noise is big enough to shift this distance, the receiver makes an error



	Range	Error	# of Symbols	Speed	Cost
More Power:	MORE	LESS	MORE	MORE	MORE

6LowPAN

- IPV6 has 128 bit address, but 802.15.4 has 2^{16} address space. These addresses are PAN only.
- Most IPV6 traffic is static (same IP, same ports)
- 6LowPAN compresses the header from 40 bytes to 2 bytes (without state information)
- **IP on WSNs is now possible**



Suite Solutions - ZigBee

- 802.15.4 as PHY and MAC
- Own Network Layer & Routing (not IP)
- New version with IP as Network layer is also out using 6LowPAN
- Maintained by ZigBee Alliance



Suite Solutions: ZWave

- Smart Home communication solution
- All layers are defined and not standard
- Uses <GHz frequencies for lower interference
- Source routing & master-slave coordination

Suite Solutions: INSTEON

- Uses both Power Line and RF
- Extension of X10
- Used for Home Automation devices



RF-ID

- Only Physical and Link layer is defined
- Currently used to receive 128 bit ID codes
- Link Layer is a Slotted Aloha





Questions?

THANKS