Layering, Stacks, Protocols

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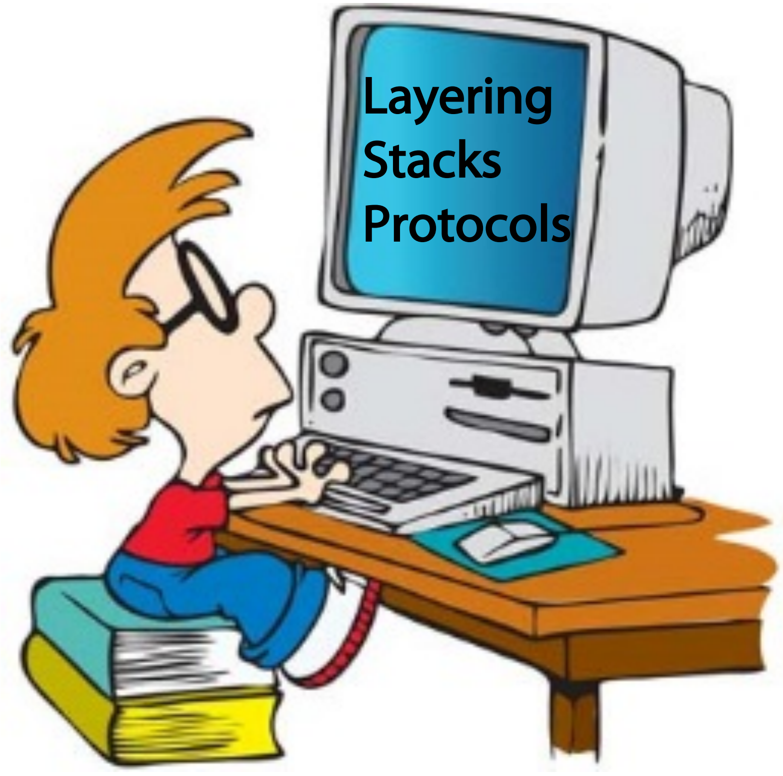


Introduction

Internet Of Things

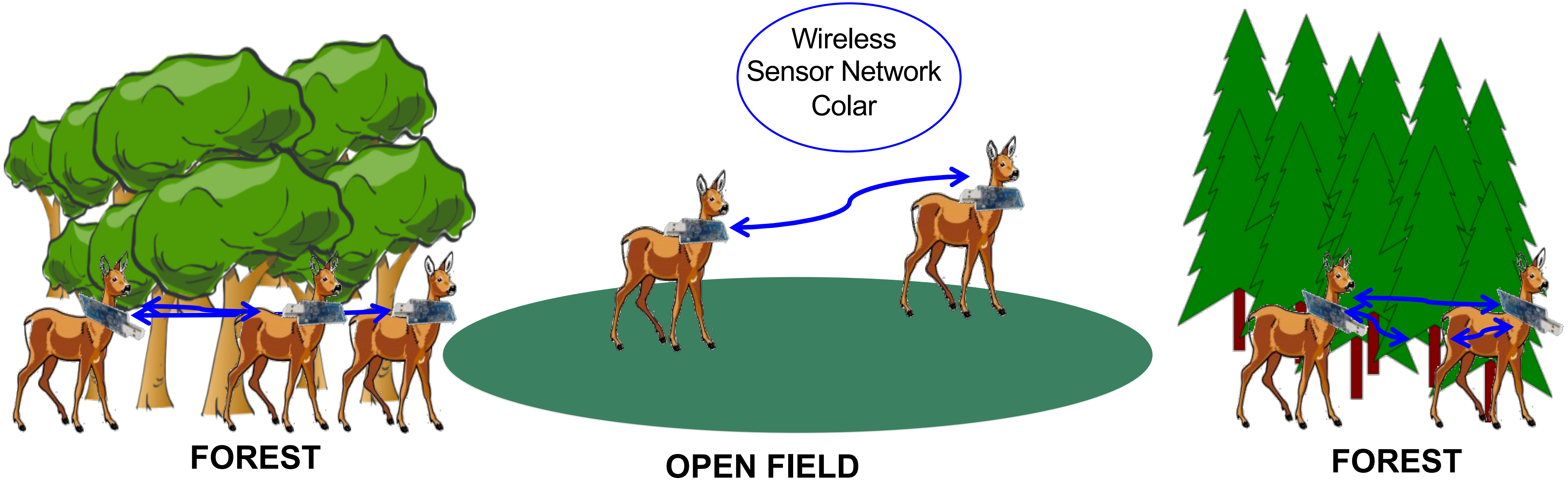
- A set of interconnected computing devices
  - Autonomously coordinate
  - Acquire data (sensors) and operate (actuators) in the physical world
  - Are seamlessly integrated with
    - information systems
    - Internet

How to connect Things

- How can they talk to each other? (interconnecting)
- How they can be part of the WWW?

How to connect Things?

Biologist



Detour…

Layering

- Fundamental abstraction of systems, models, communication networks

Separation of Concerns (SoC)

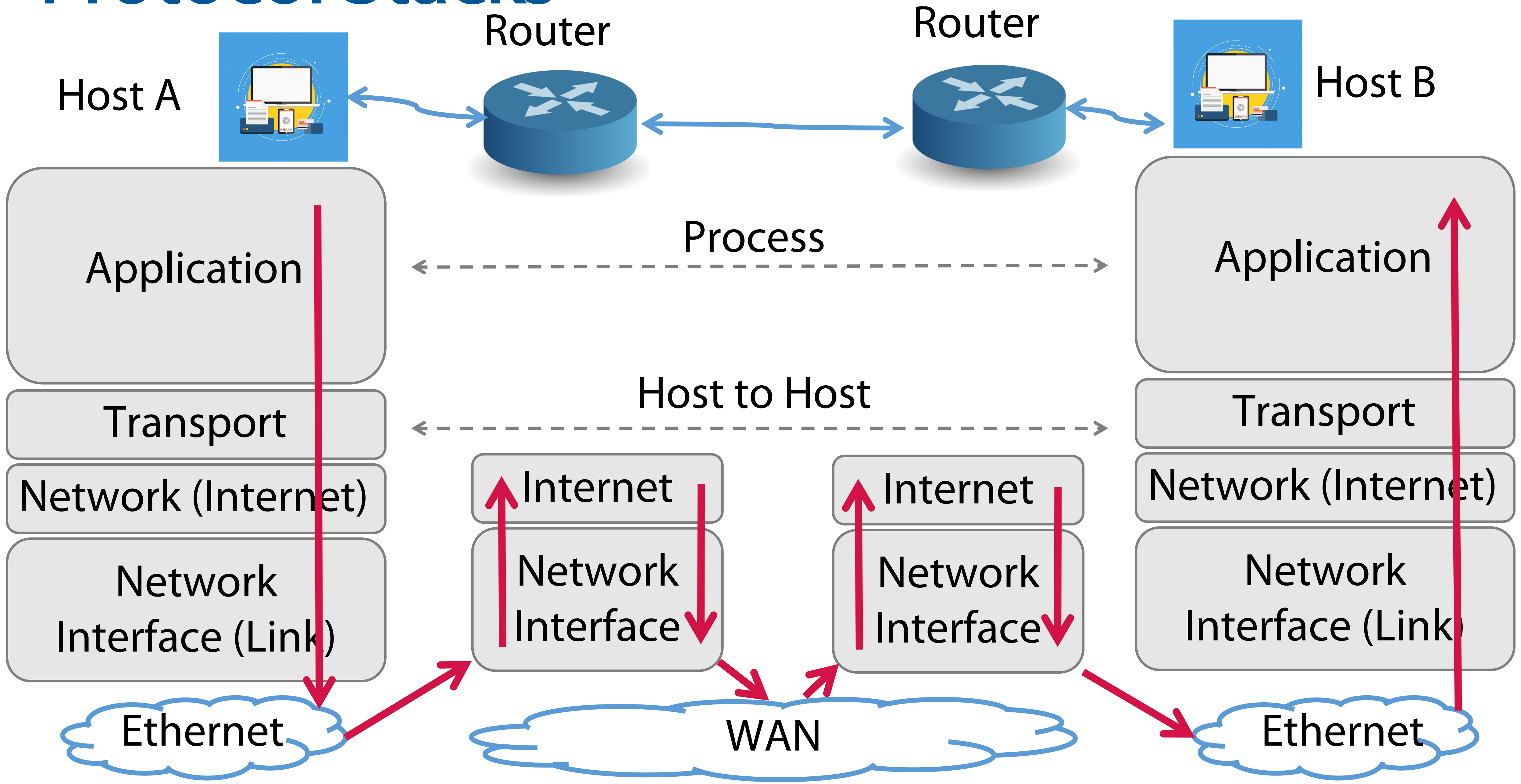
- Solving different issues separately is a *Good Idea*
- Complex solutions need a structured approach for solving them
  - Solutions become easier to create
  - Parts of solutions may become reusable
  - Parts of solutions may become replaceable
- Is a good idea but not without costs
  - “vertical integration” allows optimizations not possible in structured design
  - “design depends largely on constraints” (Charles and Ray Eames)

https://dret.net/lectures/iot-spring15/layering

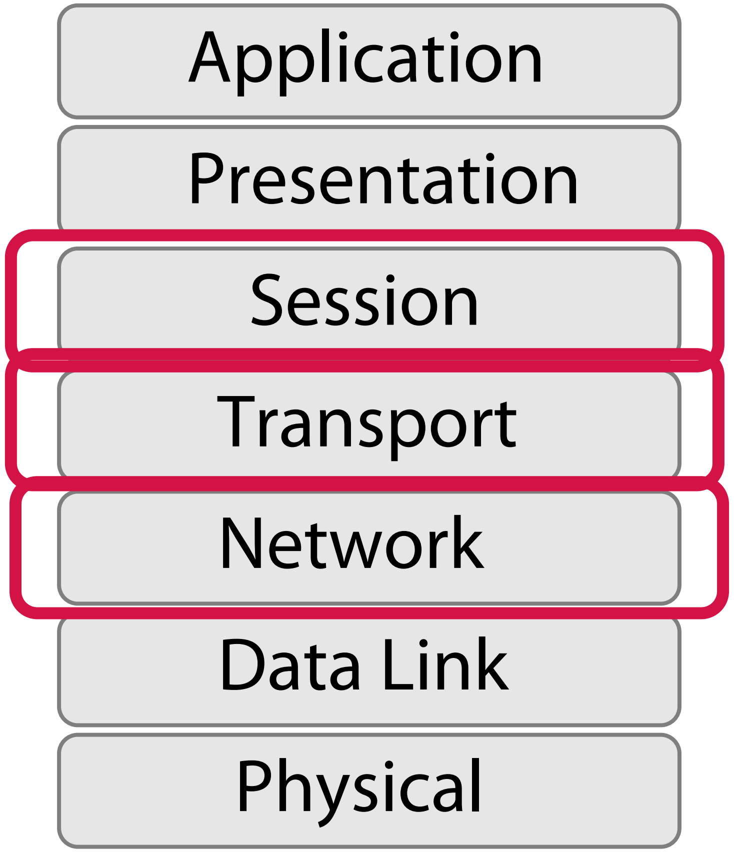
Protocol Stacks

OSI Model	Protocols & Services	TCP/IP Model
Application	HTTP, FTP Telnet, NTP DHCP	Application
Presentation		
Session		
Transport	TCP, UDP	Transport
Network	IP	Network (Internet)
Data Link	Ethernet Wi-Fi	Network Interface (Link)
Physical		

Protocol Stacks



Protocol Stacks



Network

- Allows addressing
- TCP/IP stack: IP addressing

Transport

- Process to process connectivity
- TCP/IP stack: host to host connectivity

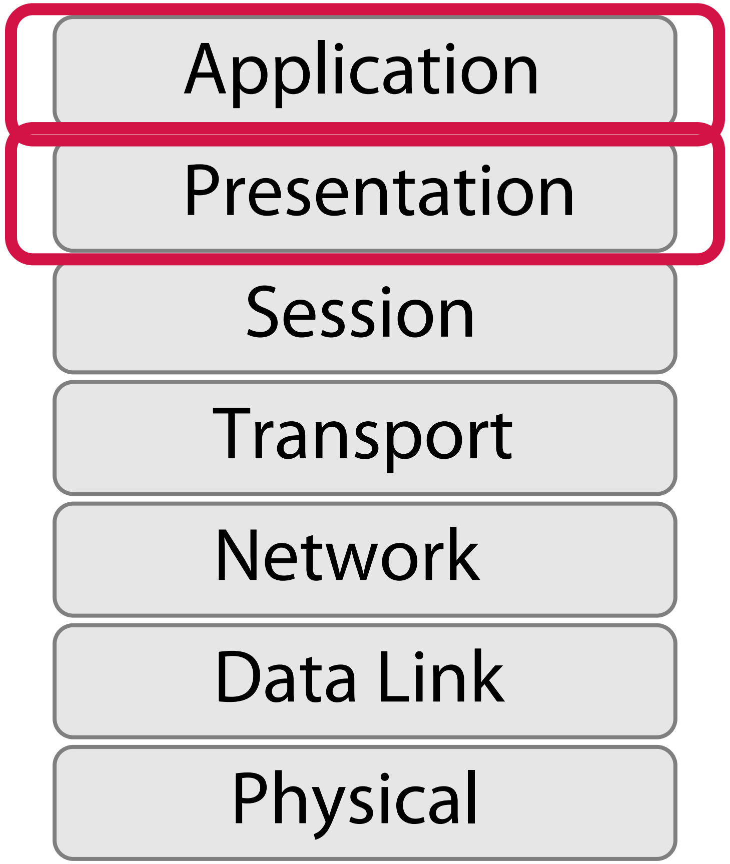
Session

- Apps should be able to start/pause/restart and end sessions
- Can be terrible for scalability: creating tight coupling between two processes
- REST tries really hard to build a session-free web (“stateless interactions”)

Protocol Stacks

Presentation

- Internet has media types & same "generic" data representation languages (e.g., XML, JSON, RDF)



Application

- Anything that is built on top of the network stack
- Can select (some of the) aspects of the stack
  - TCP: reliable and flow-controlled
  - UDP: both for real-time & loss tolerant data
- Lower layers are completely invisible to applications
- Complete abstraction is a dream, complete control is a nightmare
  - Or is it the other way around? It all depends on the scenarios
  - Internet and apps evolve, protocols evolve and features evolve

So/Too Many Protocols

Protocols/standards necessarily a tradeoff

- Dedicated solutions can be more specialized/optimized
- Generalized solutions have advantages of reuse/interoperability

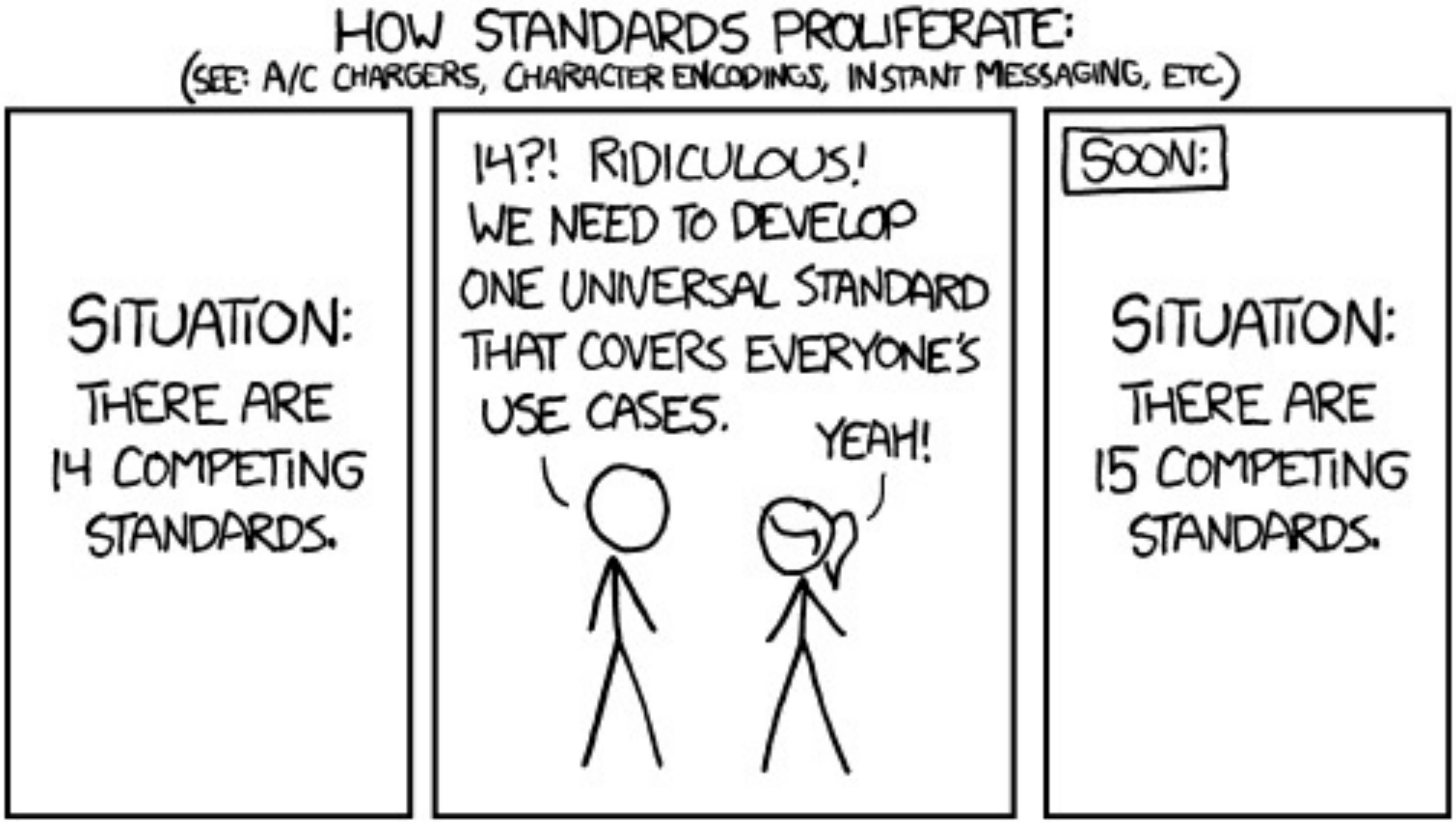
Even “the Internet” was the only solution initially

- OSI was developed as an alternative
- TCP/IP won ad today is **the only** connectivity layer in most scenarios

As new scenarios emerge, the landscape evolves

- Eventually, very few proven solutions become (de-facto) standards

Creating the Silver Unicorn Hammer



https://xkcd.com/927/

Why is the IoT Different?

- Low-cost tiny devices
- Limited resources (computing, memory, storage)
- Energy constraints

Device level

- Large scale networks
- Individual addressing of the nodes
- Amount of generated data
- Lossy environments

Network level

- Diverse requirements/technologies
- Maintenance
- Evolvability, extensability

Non-technical challenges

Why is the IoT Different?

- Spectrum availability & interference
  - Limited unlicensed spectrum
  - Shared medium
- Wireless devices co-existance problems
  - Wi-Fi, wireless sensor networks
- Power and energy management
  - Low power wireless, energy harvesting
- Addressing
- Data rates & volumes
  - Devices with different data rates
  - Where to store and process (in-network, edge, cloud?)

Why is the IoT Different?

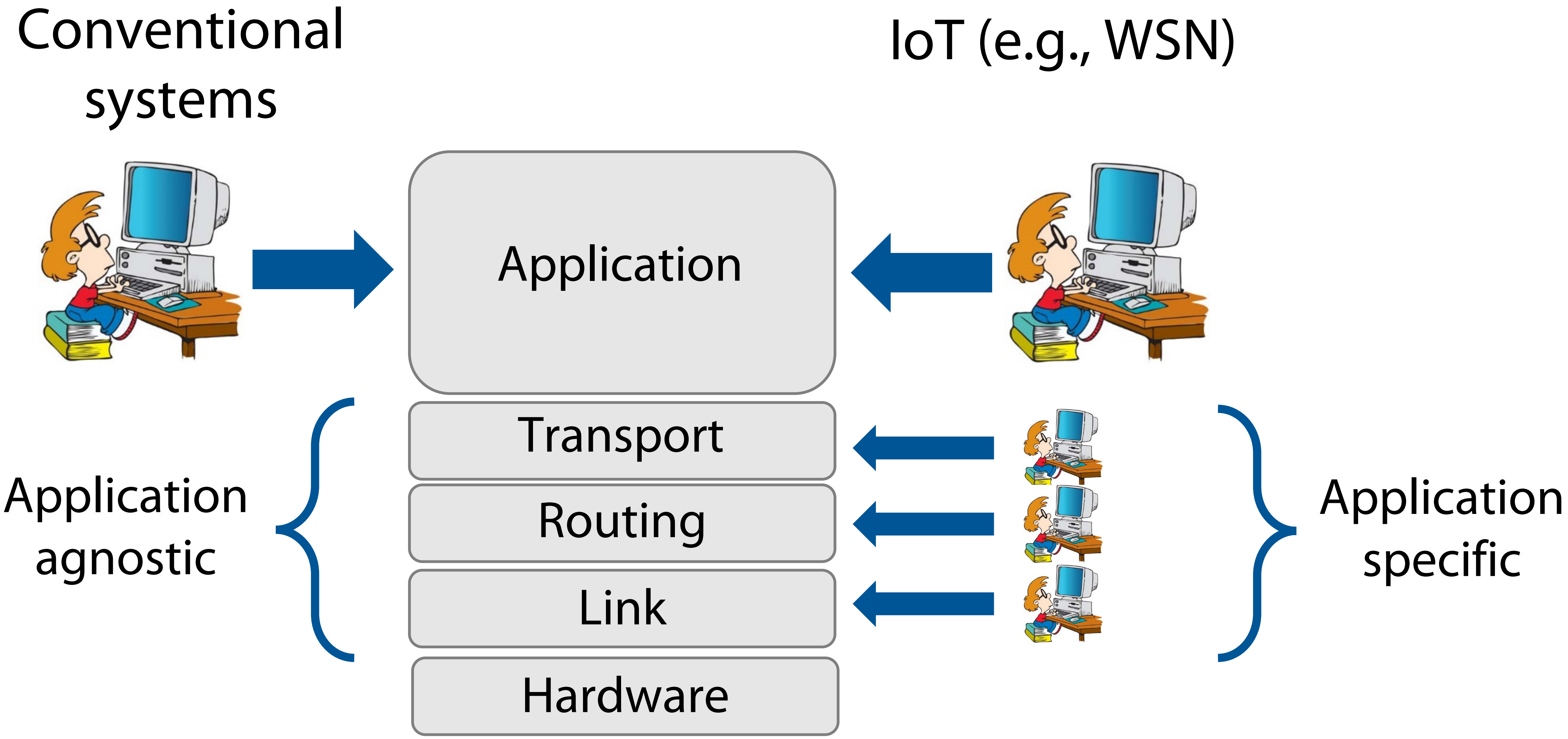
- Privacy and security
- Dense networks
  - Excessive collisions => delays/data loss
  - Challenges: protocol design

Infrastructure is different with different constraints!!!

Towards the Real IoT

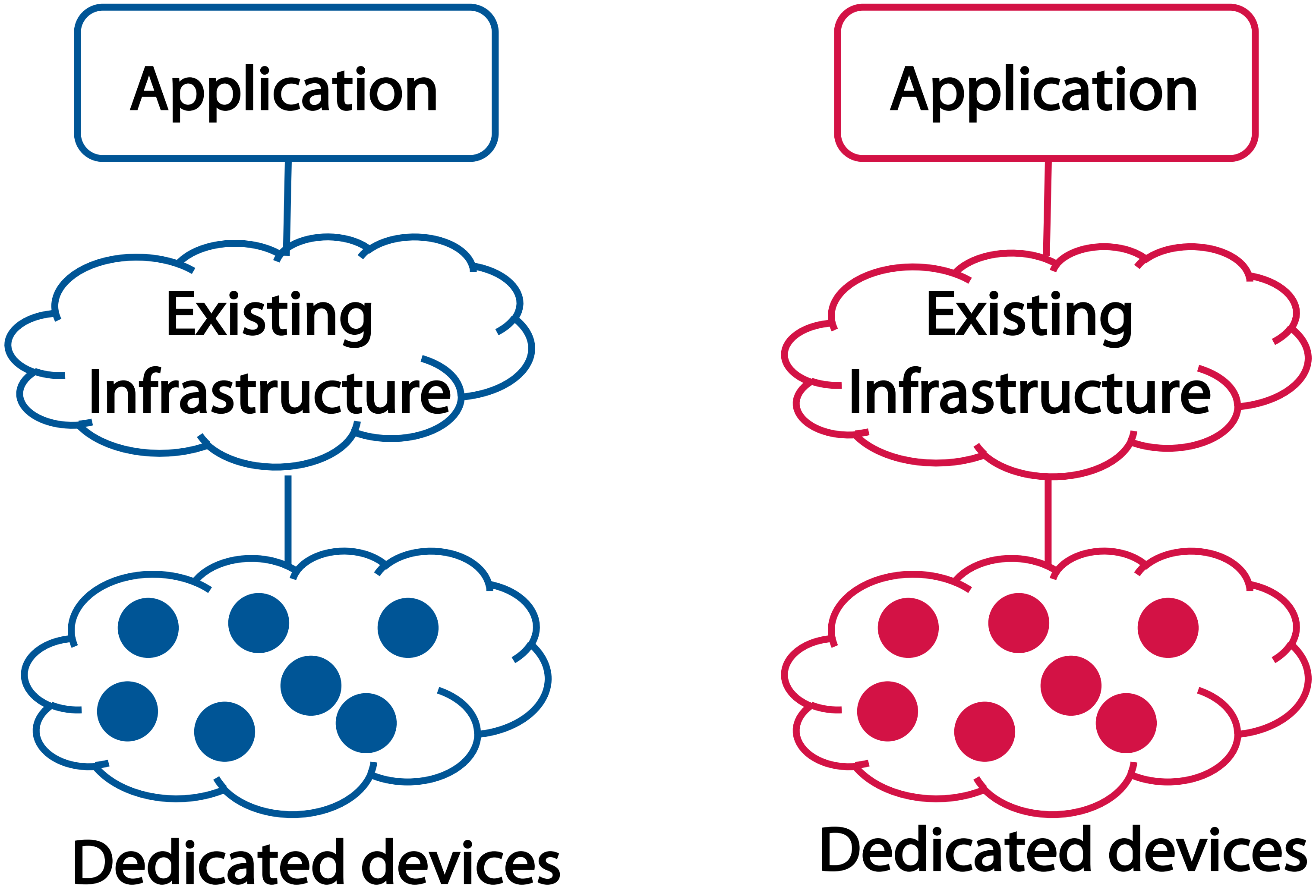
- Writing IoT applications requires understanding the **constraints**
- Above all, the **network** effect is what matters
- Design of new protocols required
  - Unique characteristics
  - Different requirements

Towards the Real IoT



Towards the Real IoT

Many “vertical “ solutions: interaction with devices via proprietary systems

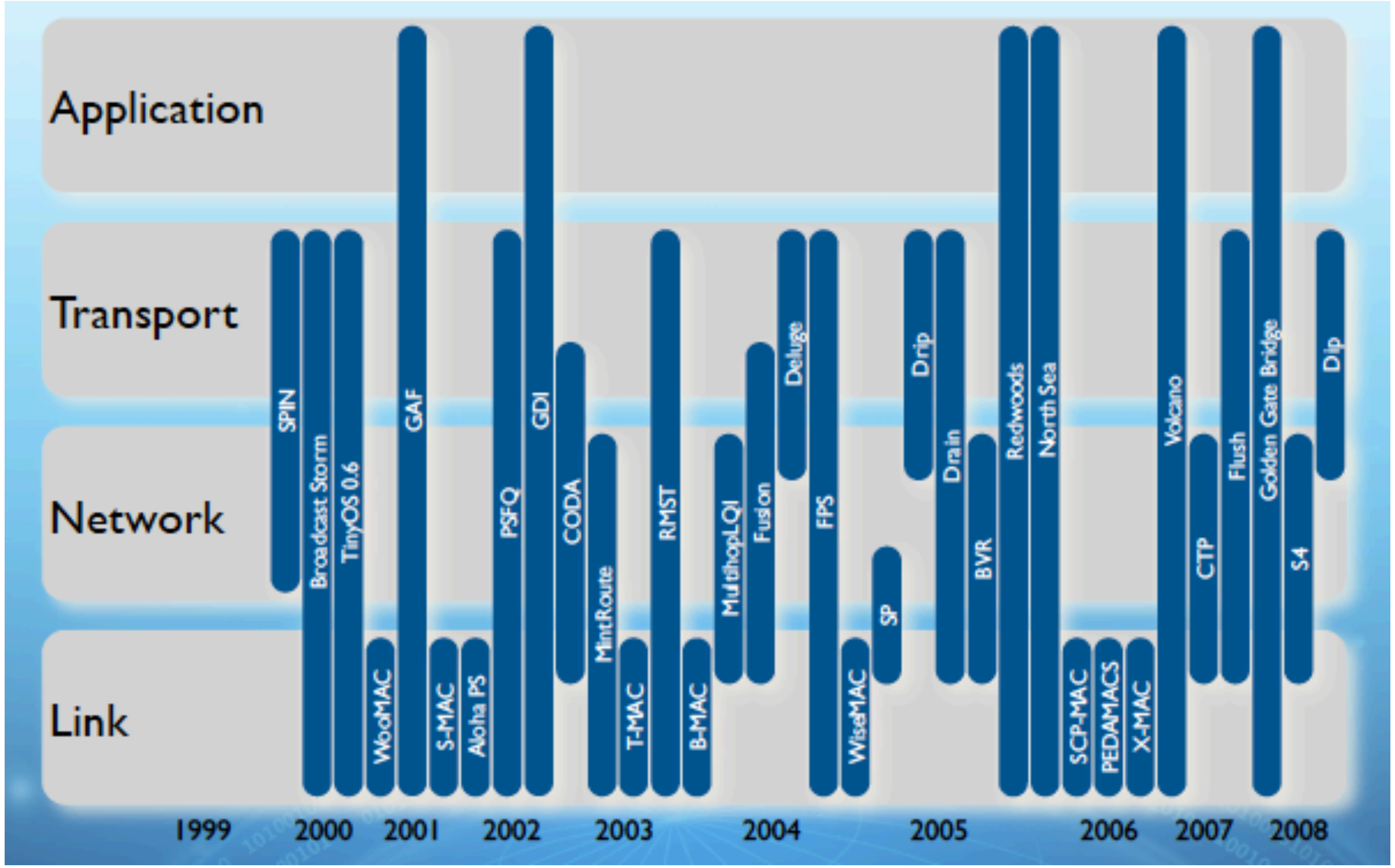


- Highly optimized!
- Operate in isolation
- Inefficient
- Do not scale well

Towards the Real IoT

Initially, the community rejected the IP architecture

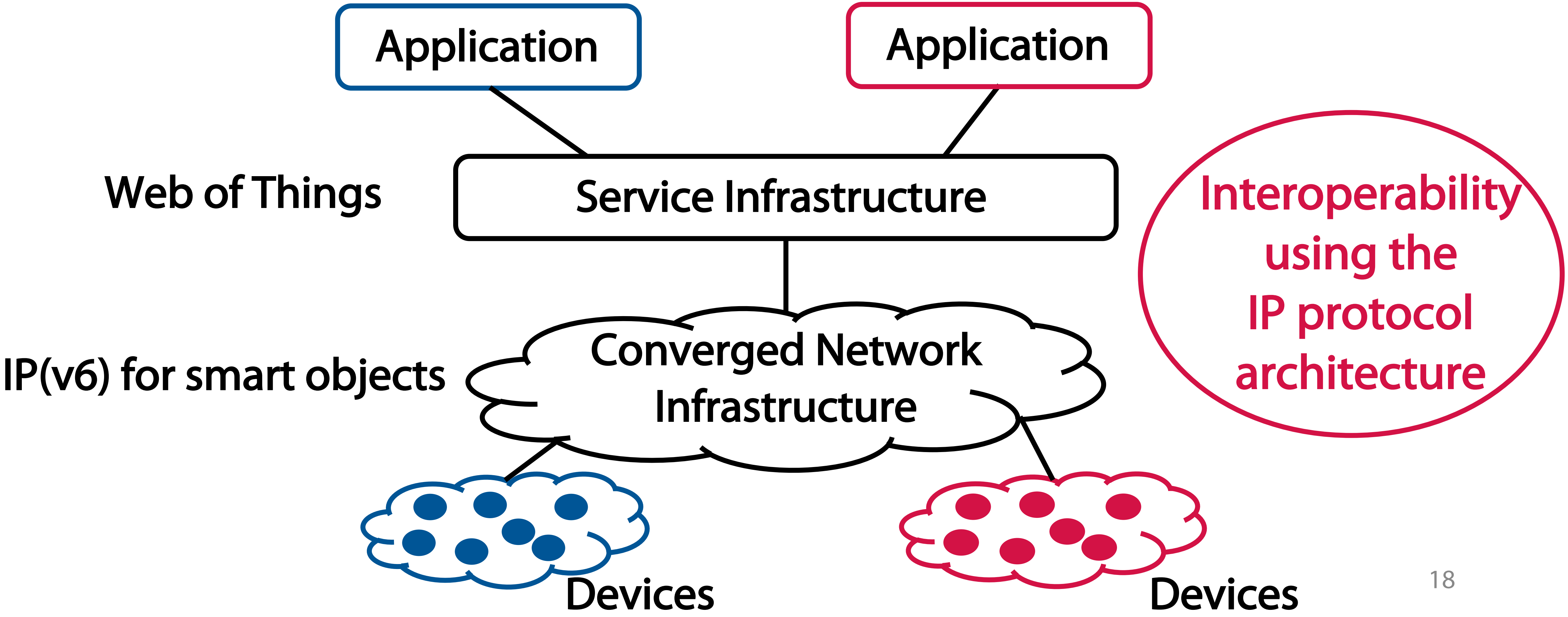
- “Resource constraints may cause us to give up the layered architecture”
- “It is reasonable to assume that networks can be tailored to the applications at hand”



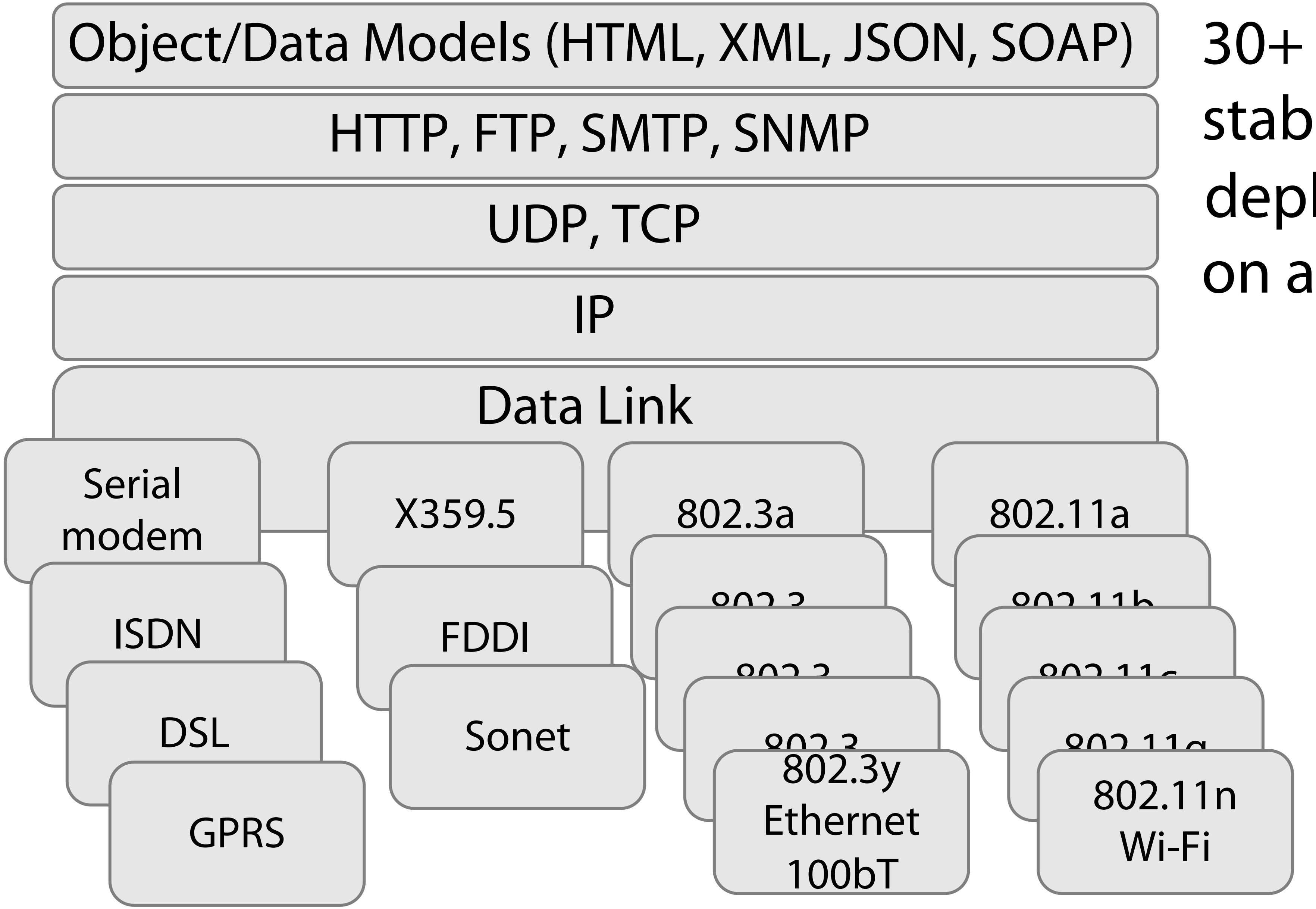
https://people.eecs.berkeley.edu/~culler/talks/Culler-21stCCC.pdf

Towards the Real IoT

Community converging to distributed intelligence & actions across standardized networks and interfaces



Converging to the IP Architecture



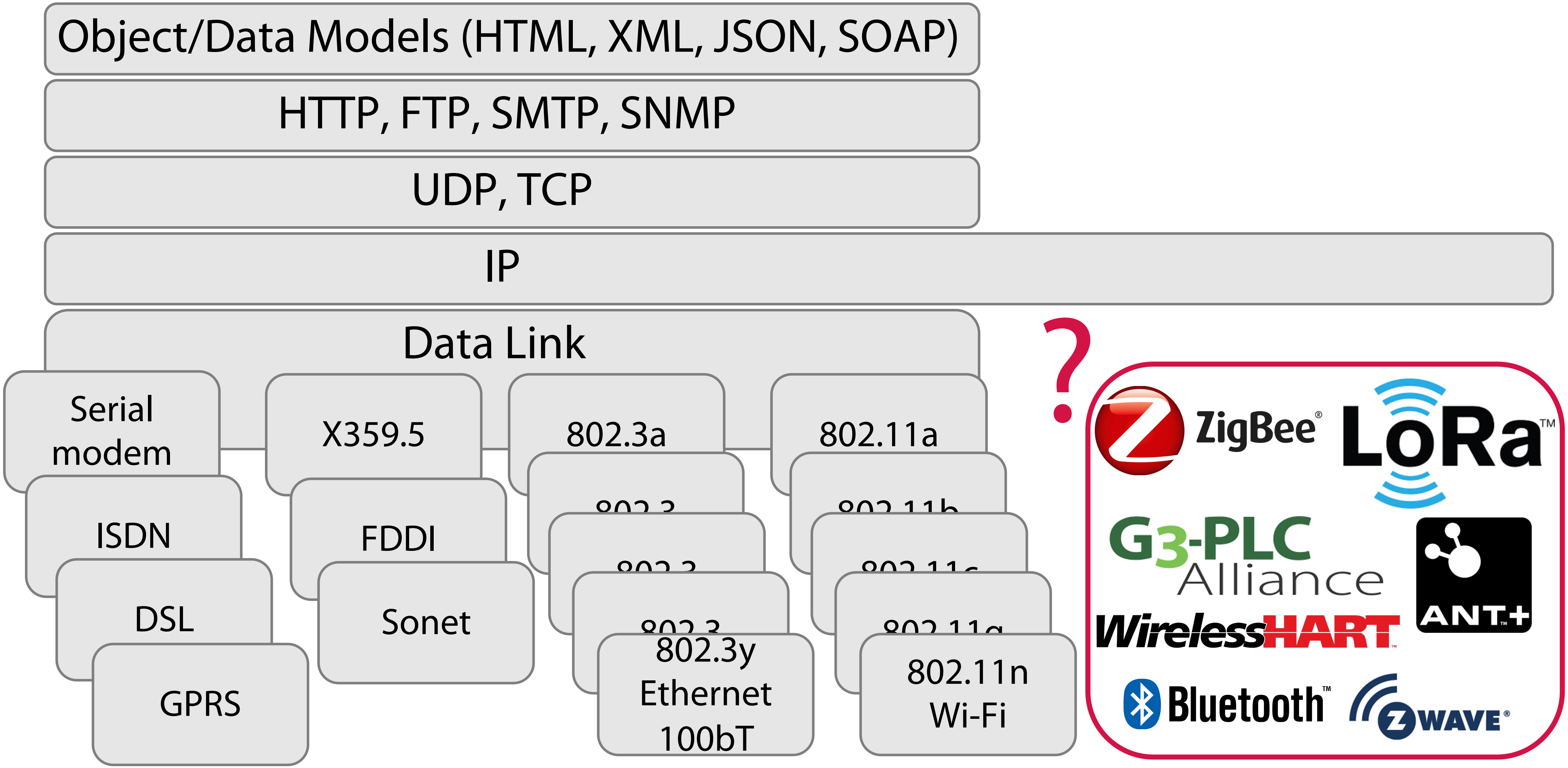
30+ years experience: stable architecture deployed and working on a large scale

Converging to the IP Architecture

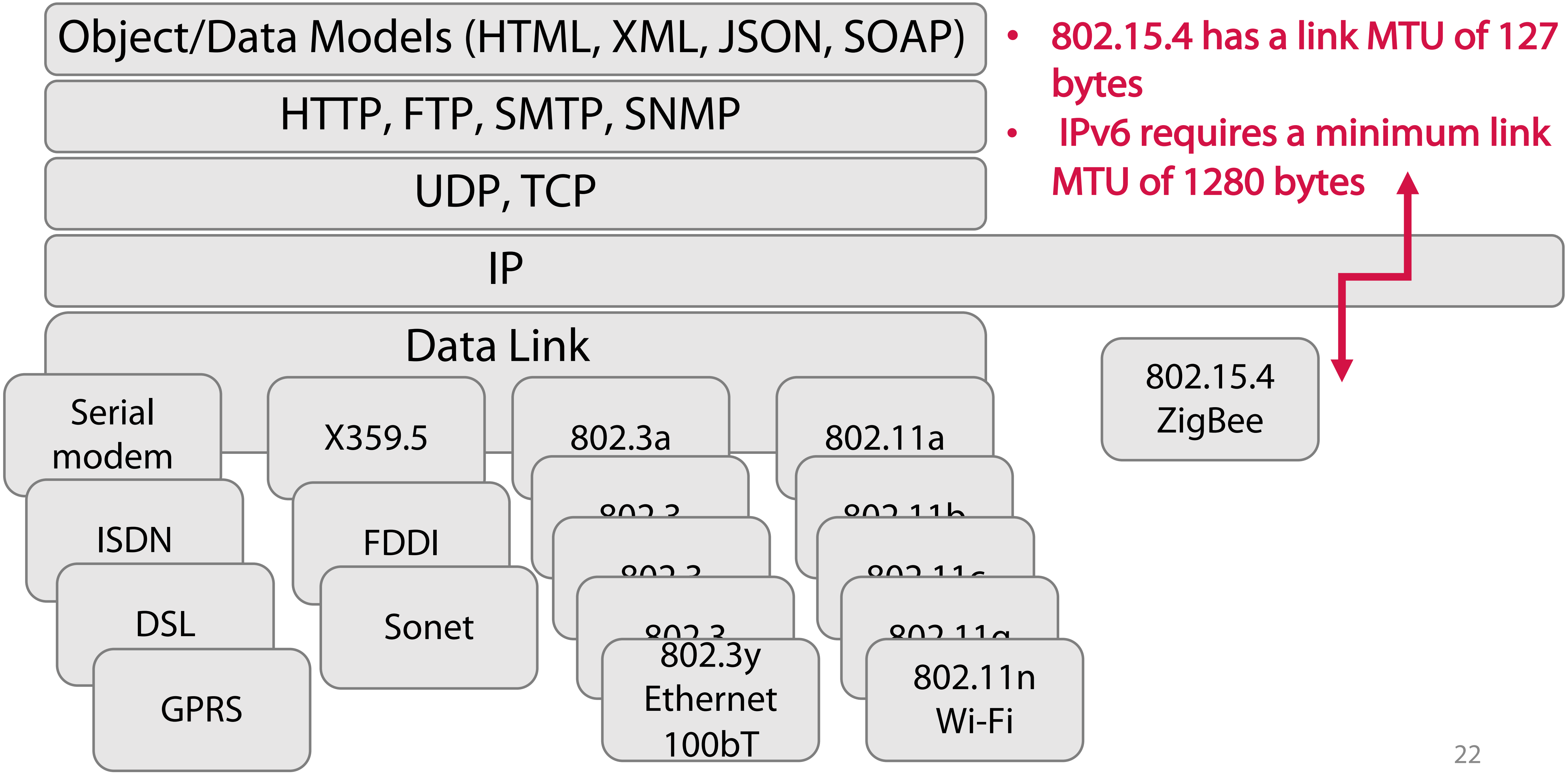
Link layer technologies for IoT: tens of different technologies

One common denominator: low-power, limited data rate

Converging to the IP Architecture

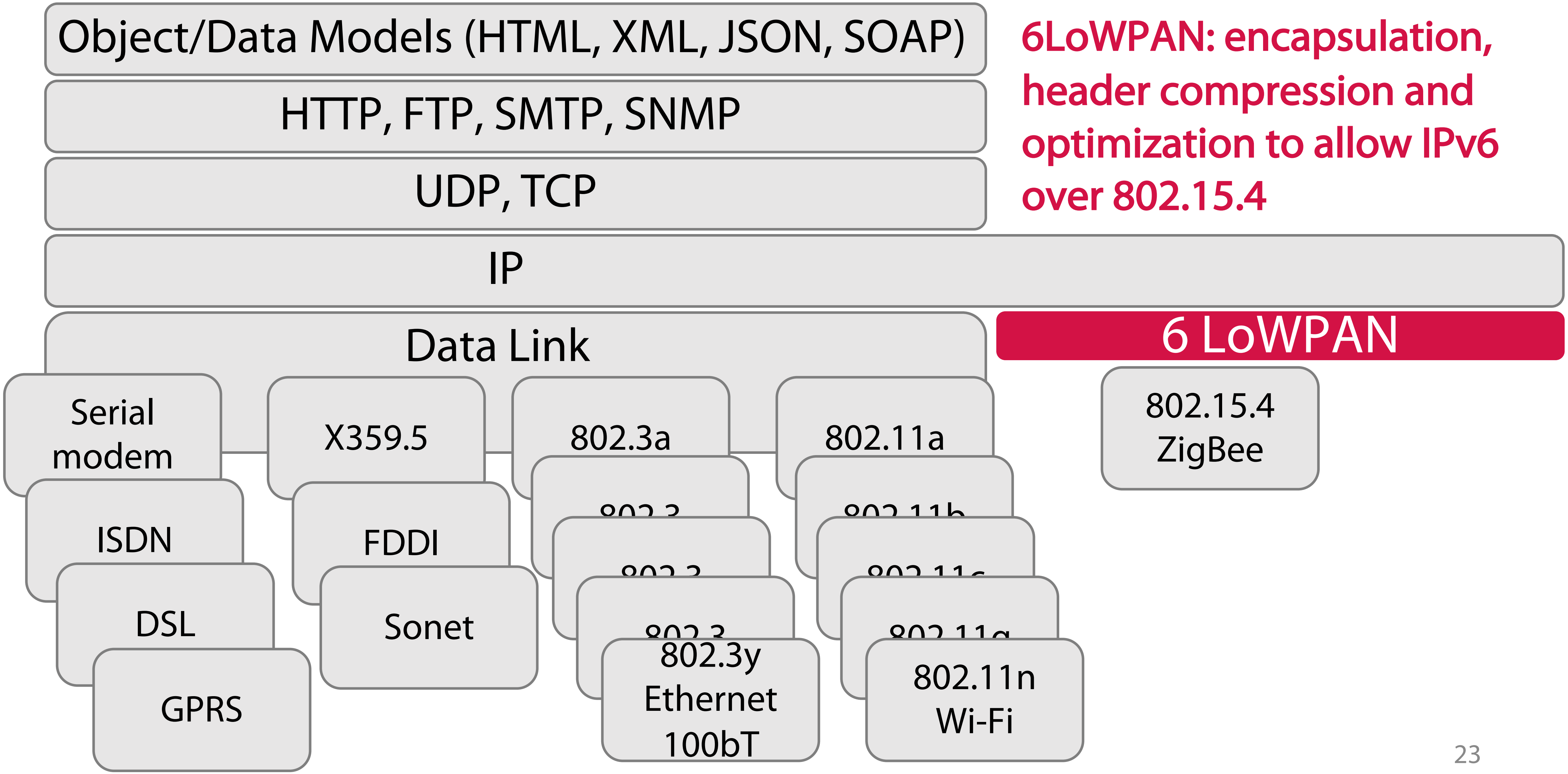


Converging to the IP Architecture



- 802.15.4 has a link MTU of 127 bytes
- IPv6 requires a minimum link MTU of 1280 bytes

Converging to the IP Architecture



6LoWPAN: encapsulation, header compression and optimization to allow IPv6 over 802.15.4

Converging to the IP Architecture

Object/Data Models (HTML, XML, JSON, SOAP)

HTTP, FTP, SMTP, SNMP

UDP, TCP

IP

Data Link

- Serial modem
- ISDN
- DSL
- GPRS
- X359.5
- FDDI
- Sonet
- 802.3a
- 802.3y Ethernet 100bT
- 802.11a
- 802.11n Wi-Fi

6lo: IP over networks of resource-constrained nodes
https://tools.ietf.org/wg/6lo/

6 lo

- ZigBee
- LoRa
- G3-PLC Alliance
- ANT+
- WirelessHART
- Bluetooth
- ZWAVE

Converging to the IP Architecture

IETF Datatracker | Groups | Documents | Meetings | Other | User | Document search

User
- Sign in
- Password reset
- New account
- Preferences

Groups
- Active WGs
- Active RGs
- Other

By area/parent
- Applications and Real-Time
- General
- Internet
- Ops & Mgmt
- Routing
- Security
- Transport
- IRTF

New work
- Chartering groups
- BOFs

Other groups
- Concluded groups
- Non-WG lists

Documents

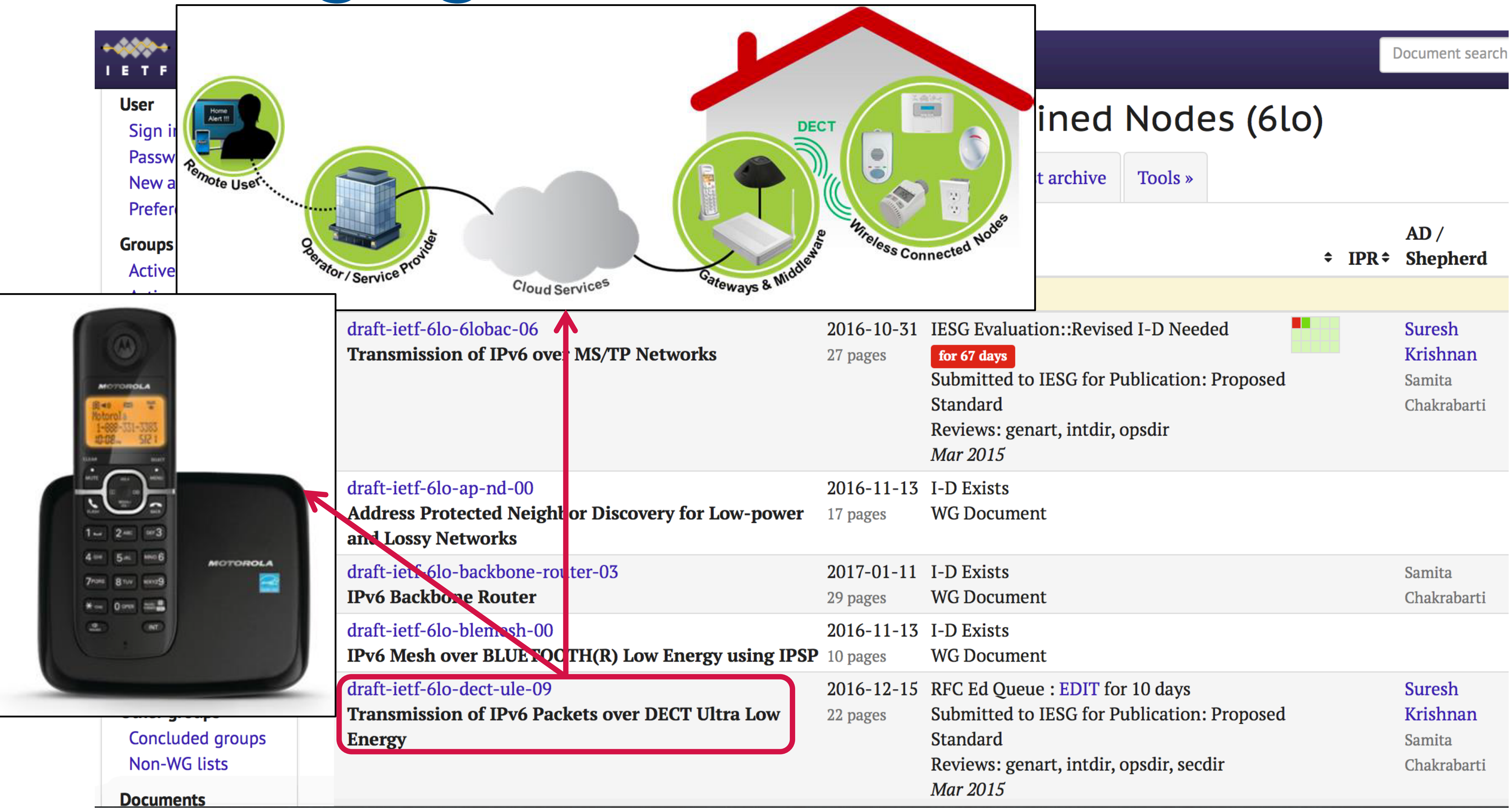
IPv6 over Networks of Resource-constrained Nodes (6lo)

Documents | Charter | Meetings | History | Photos | Email expansions | List archive | Tools »

Document	Date	Status	IPR	AD / Shepherd
Active Internet-Drafts				
draft-ietf-6lo-6lobac-06 **Transmission of IPv6 over MS/TP Networks**	2016-10-31 27 pages	IESG Evaluation::Revised I-D Needed for 67 days Submitted to IESG for Publication: Proposed Standard Reviews: genart, intdir, opsdir *Mar 2015*		Suresh Krishnan Samita Chakrabarti
draft-ietf-6lo-ap-nd-00 **Address Protected Neighbor Discovery for Low-power and Lossy Networks**	2016-11-13 17 pages	I-D Exists WG Document		
draft-ietf-6lo-backbone-router-03 **IPv6 Backbone Router**	2017-01-11 29 pages	I-D Exists WG Document		Samita Chakrabarti
draft-ietf-6lo-blemesh-00 **IPv6 Mesh over BLUETOOTH(R) Low Energy using IPSP**	2016-11-13 10 pages	I-D Exists WG Document		
draft-ietf-6lo-dect-ule-09 **Transmission of IPv6 Packets over DECT Ultra Low Energy**	2016-12-15 22 pages	RFC Ed Queue : EDIT for 10 days Submitted to IESG for Publication: Proposed Standard Reviews: genart, intdir, opsdir, secdir *Mar 2015*		Suresh Krishnan Samita Chakrabarti

https://datatracker.ietf.org/wg/6lo/documents

Converging to the IP Architecture



Converging to the IP Architecture

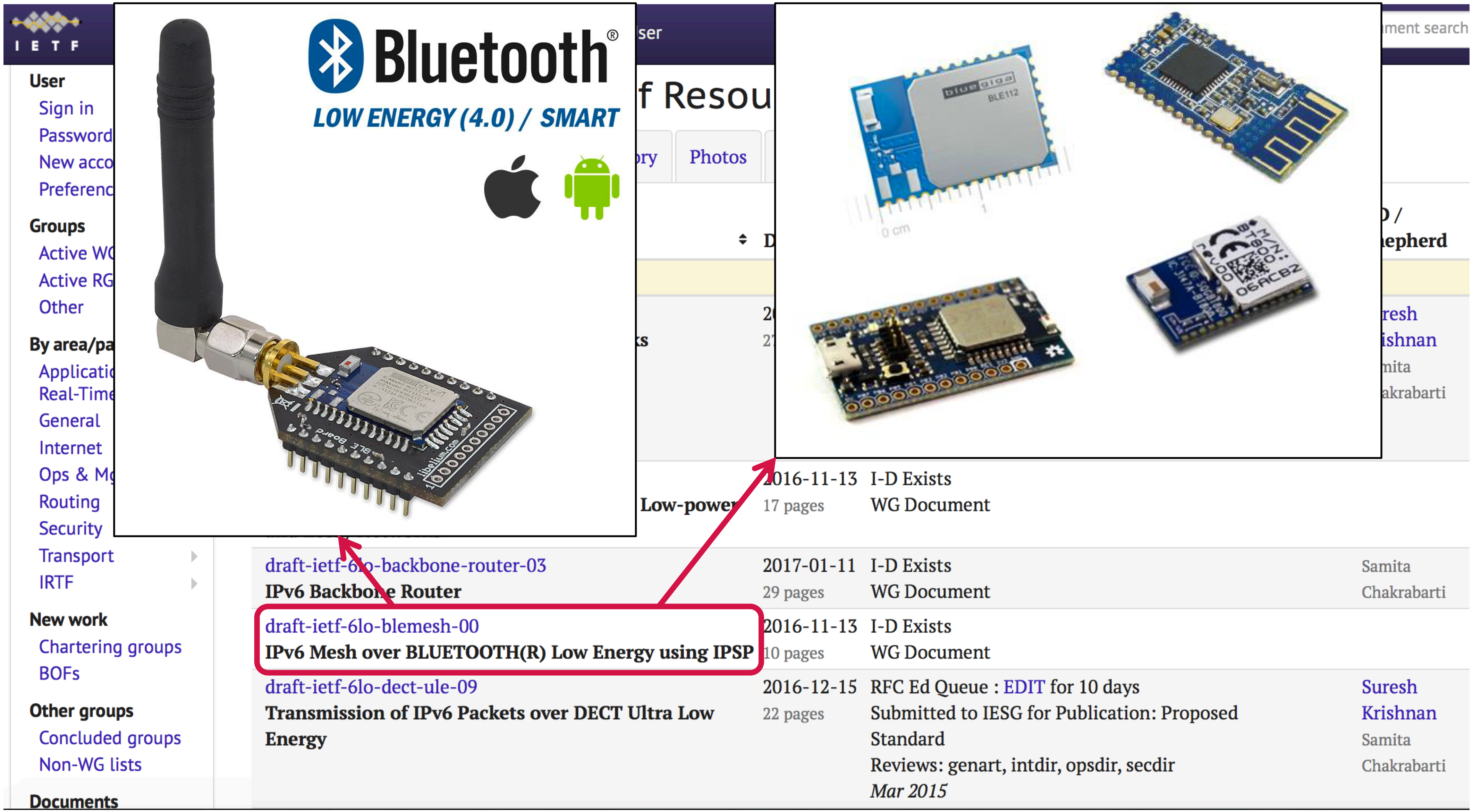
IETF Datatracker | Groups | Documents | Meetings | Other | User | Document search

Statistics
Tutorials
Report a bug

RFC 7400 *(was draft-ietf-6lo-ghc)* **6LoWPAN-GHC: Generic Header Compression for IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs)**	2014-11 24 pages	Brian Haberman Ulrich Herberg
RFC 7428 *(was draft-ietf-6lo-lowpanz)* **Transmission of IPv6 Packets over ITU-T G.9959 Networks**	2015-02 21 pages	Brian Haberman Samita Chakrabarti
RFC 7668 *(was draft-ietf-6lo-btle)* **IPv6 over BLUETOOTH(R) Low Energy**		Brian Haberman Gabriel Montenegro
…t-ietf-6lo-ethertype-request) **… Ethertype for IPv6 with Low-Power … Area Network (LoWPAN)**		Suresh Krishnan Samita Chakrabarti
…t-ietf-6lo-paging-dispatch) **IPv6 over Low-Power Wireless Personal Area Networ… (6LoWPAN) Paging Dispatch**		Suresh Krishnan james woodyatt

ZWAVE®

Converging to the IP Architecture



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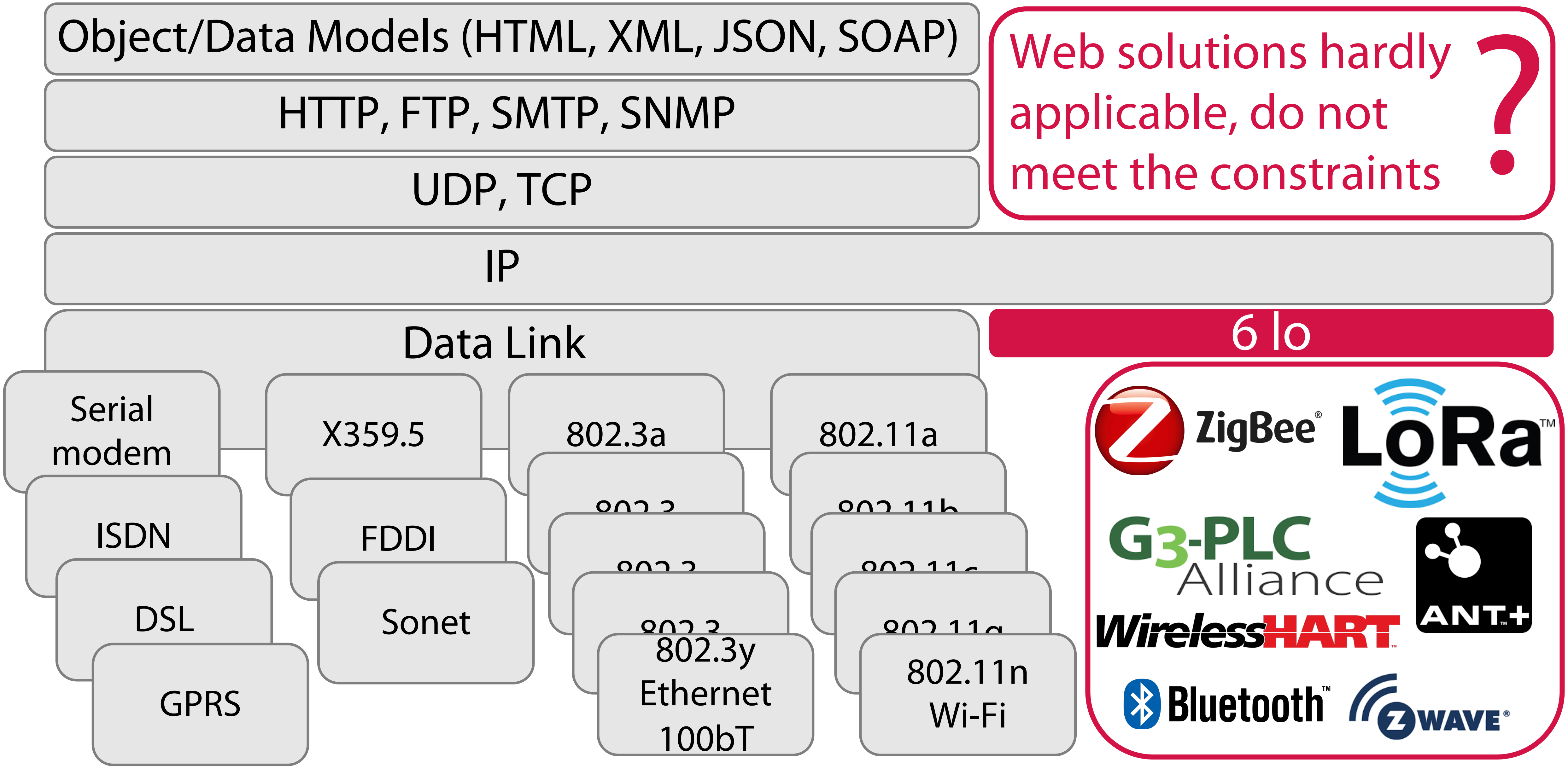

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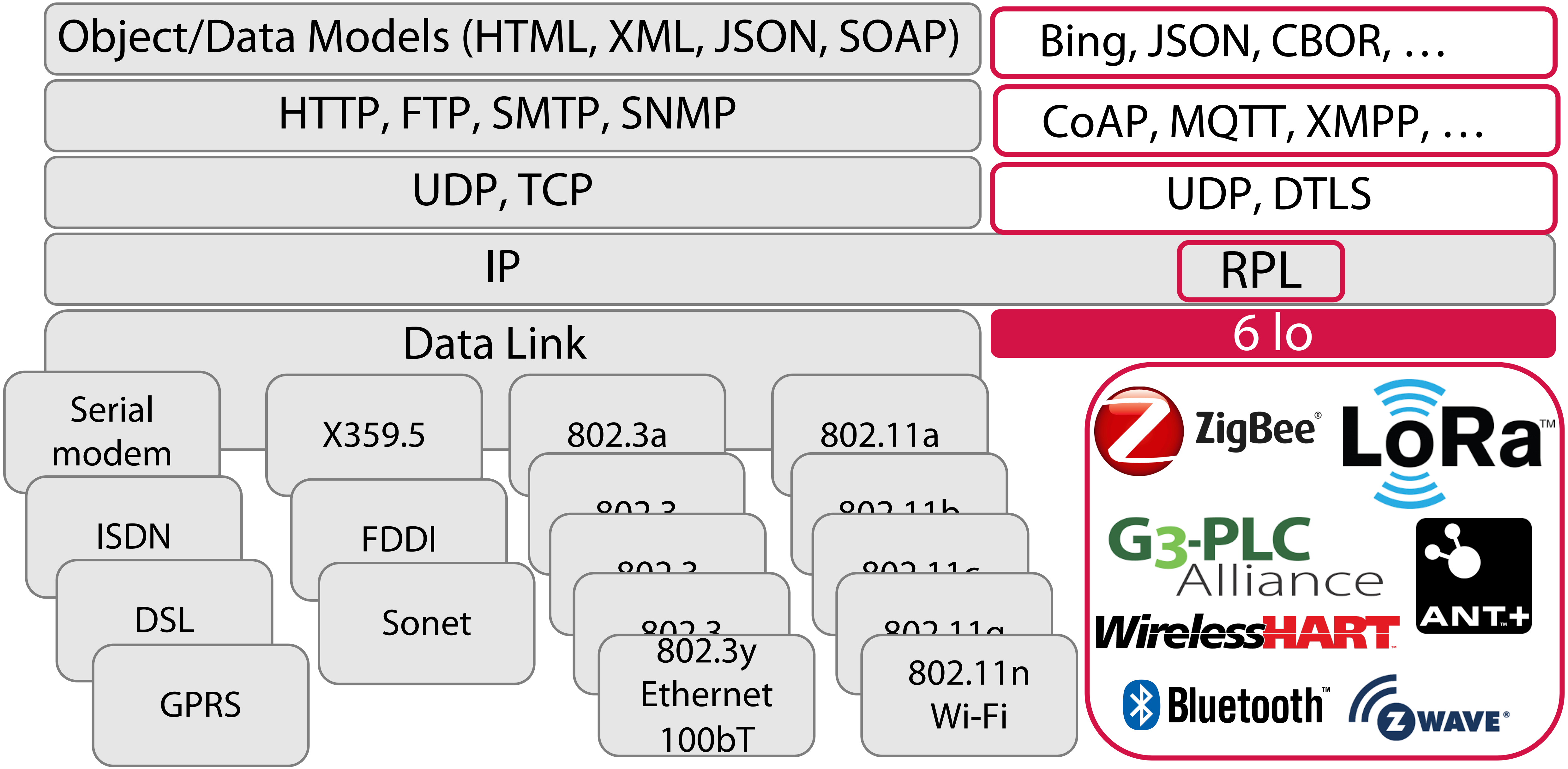

Instead of Conclusions