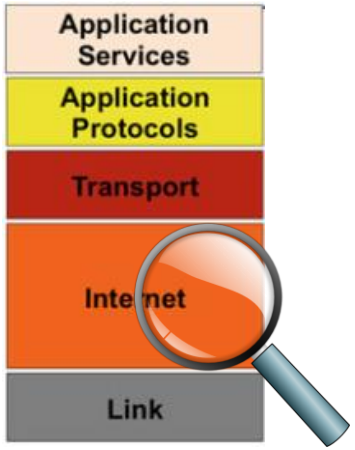
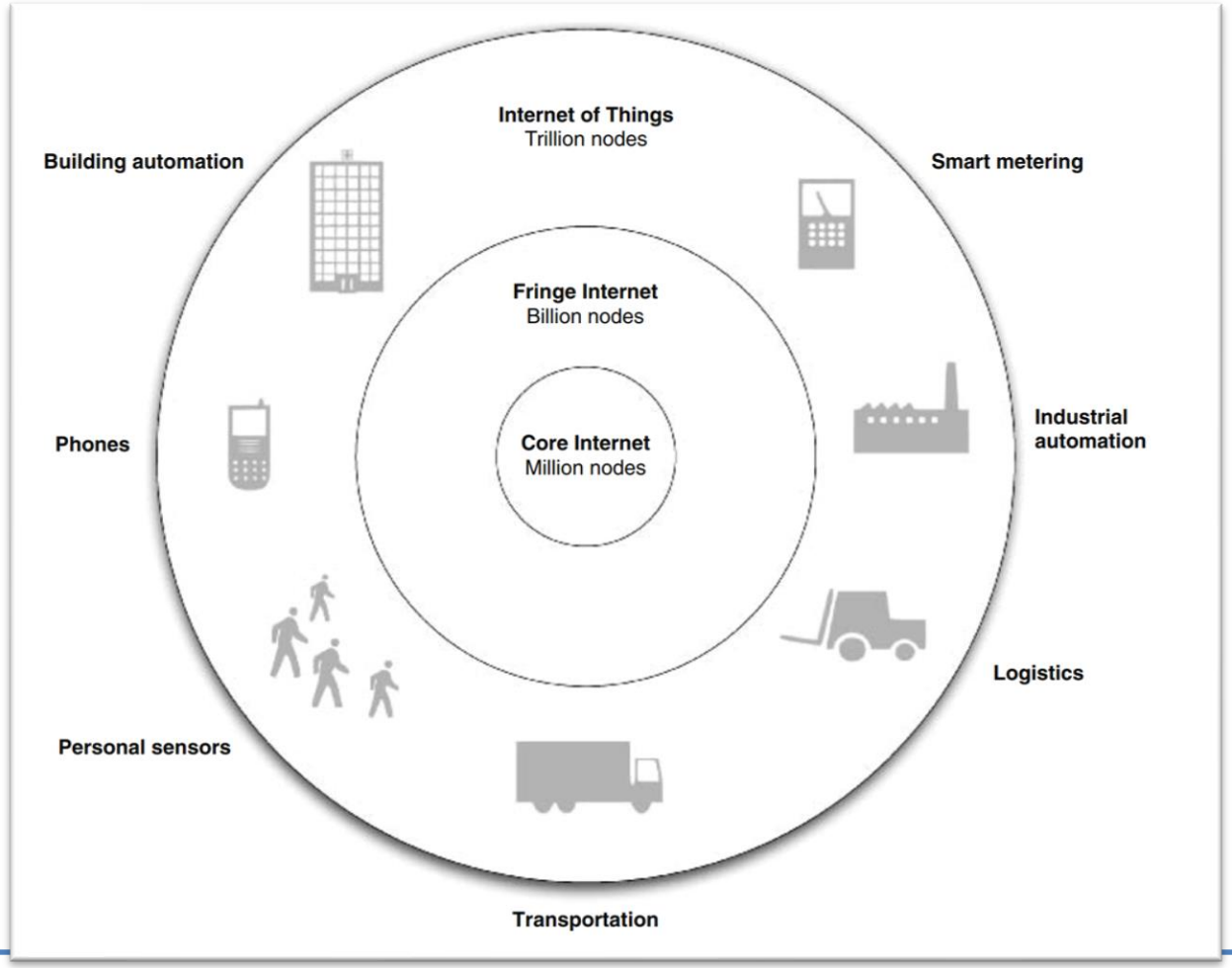
Ch. 12 - IoT Internet Layer
Challenges and Protocols

COMPSCI 147
Internet-of-Things; Software and Systems



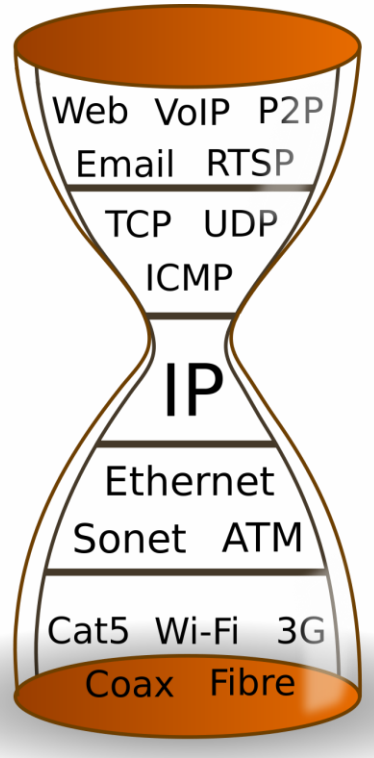


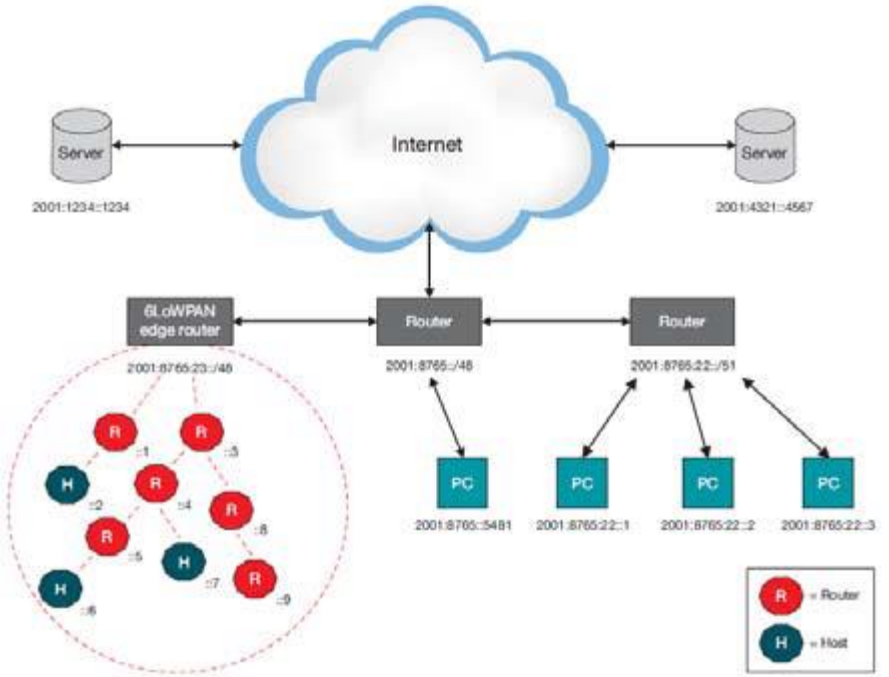
The Internet of Things vision

INTERNET LAYER : PROTOCOLS FOR IOT

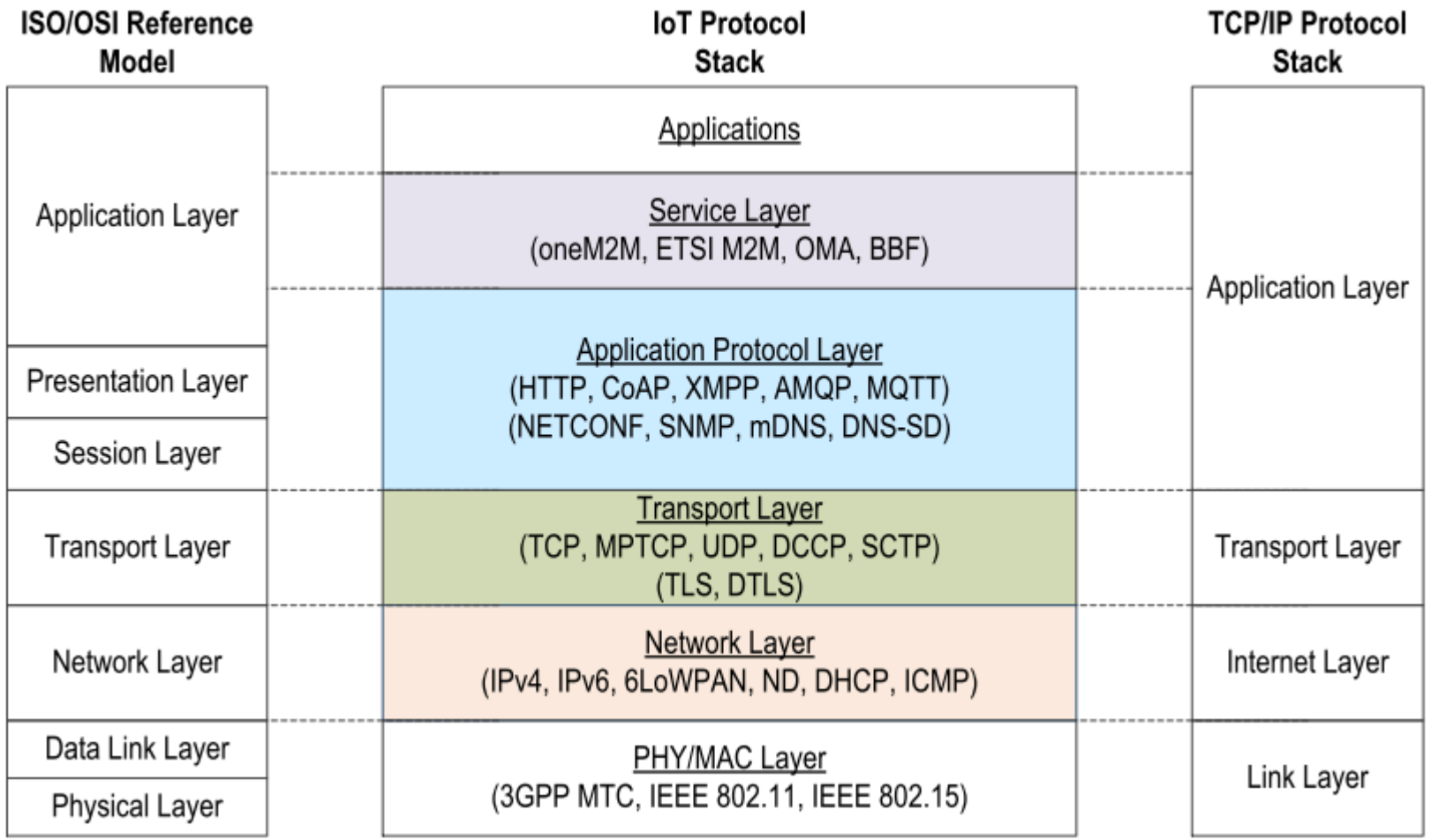
Why move away from proprietary technologies and move towards IP based connectivity:

- Open, long-lived, reliable **standards**
- **Easy** learning-curve
- Transparent **Internet** integration
- Network **maintainability**
- Global **scalability**
- **End-to-end** data flows





THE INTERNET LAYER IN THE IOT PROTOCOL STACK



THE INTERNET LAYER IN THE IOT PROTOCOL STACK

- Recall:
  The network layer is responsible for the **delivery** of individual **packets** from the **source** host to the **destination** host.

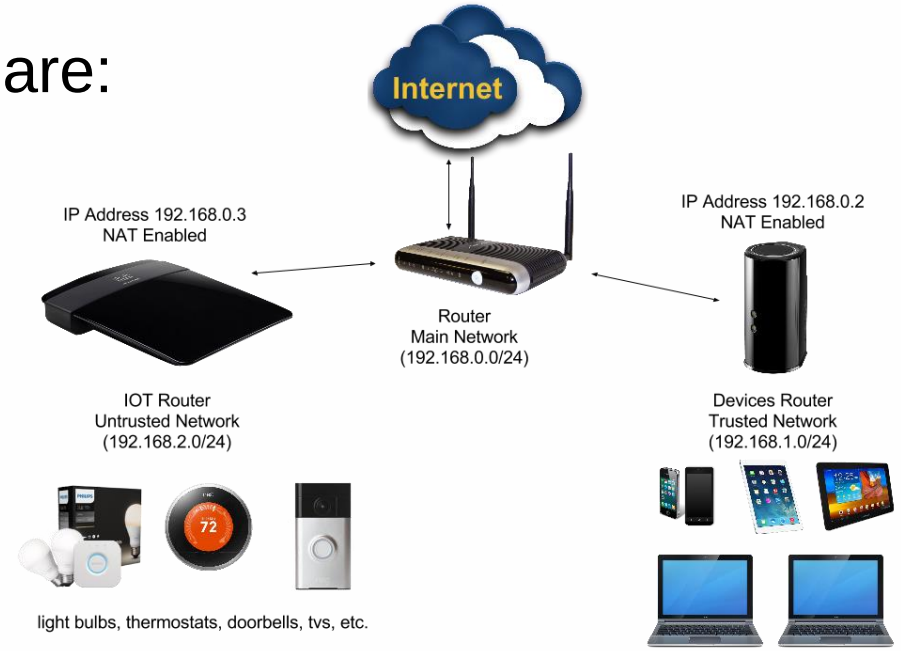
  – Logical addressing
    - Header is added to assist in routing

  – Main device is router:
    - Forwarding. When a packet arrives at a router's input link, the router must move the packet to the appropriate output link (in a single router).

    - Routing: Path taken by packets as they flow from a sender to a receiver.

THE INTERNET LAYER IN THE IOT PROTOCOL STACK

- Examples of Network layer Routed protocols are:
  - IP, IPX, AppleTalkRouting protocols are used to create routing table
  - Routing tables are used to determine the best path / route.
- Routing protocols provide periodic communication between routers in an inter-network to maintain information on network links in a routing table.
- Examples of Network layer Routing protocols are:
  - OSPF, IGRP/EIGRP, RIP, BGP.
- Transmits Packets.



INTERNET LAYER – GENERAL CHALLENGES OF IOT DEPLOYMENTS

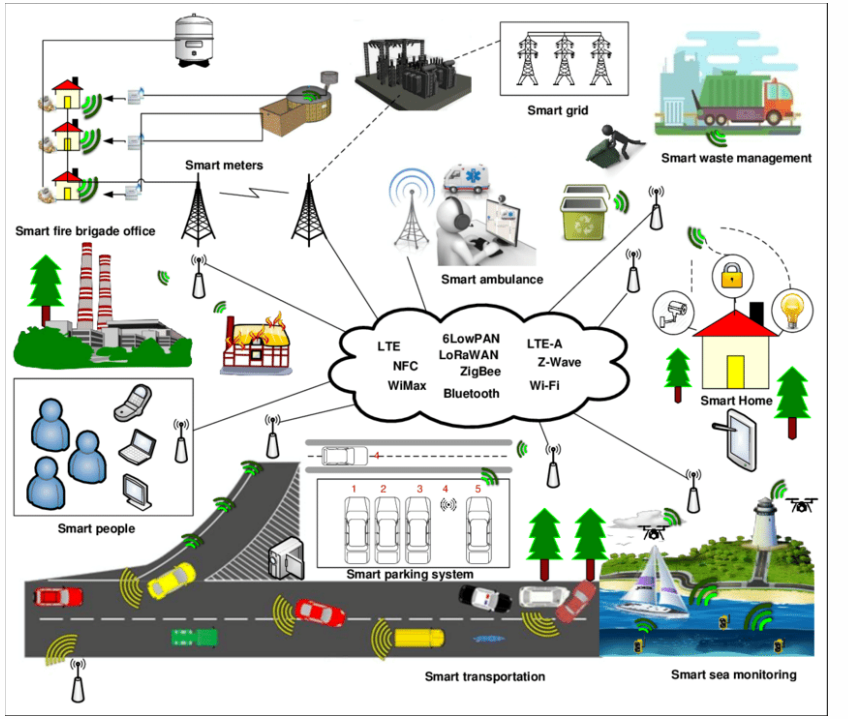
- IoT deployments constrains **=>**
  often **Low-power and Lossy Networks** (LLNs)
  - Lossy = The packet drop rate is high
  - LLN = **large** number (thousands) of constrained embedded devices with **limited power**, **memory**, and **processing resources.**

- Interconnected using a variety of **link layer** technologies
  - ZigBee, BLT, Wi-Fi, etc.

INTERNET LAYER – GENERAL CHALLENGES

- Use cases for LLNs
  - Building automation (HVAC, lighting, access control, fire), connected homes, health care, environmental monitoring, urban sensor networks (e.g., Smart Grid)

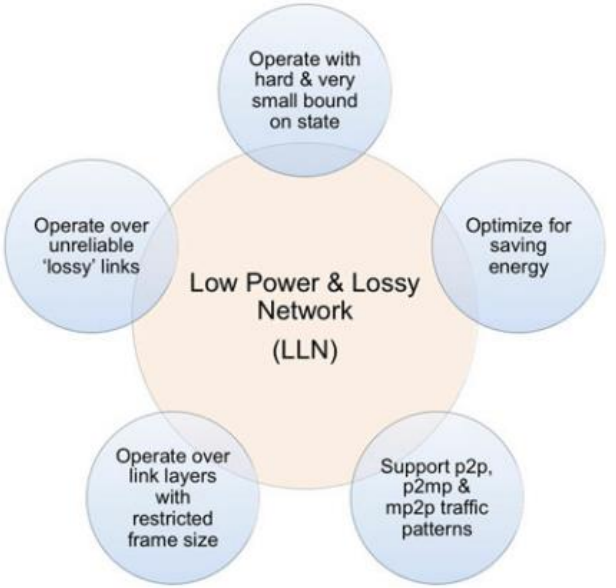
Source: Efficient Fire and Security Solutions Private Limited

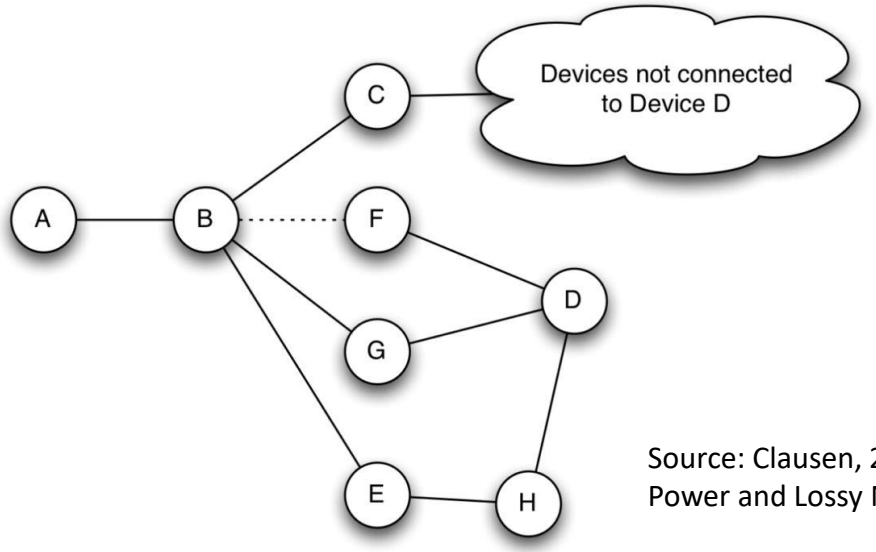


Source: Yaqoob et al., 2017. Enabling Communication Technologies for Smart Cities.

INTERNET LAYER – SPECIFIC CHALLENGES

- LLNs present **5** challenges to the Internet layer (IL):
  1. LLNs operate with a **hard, very small** bound on **state**
     - IL protocols need to **minimize** the amount of **state** that needs to be kept per node for **routing** or **topology maintenance** functions.
  2. LLNs are optimized for saving energy
     - Employing extended **sleep cycles**
     - Routing protocols need to operate under **constant topological changes** due to sleep/wake cycles



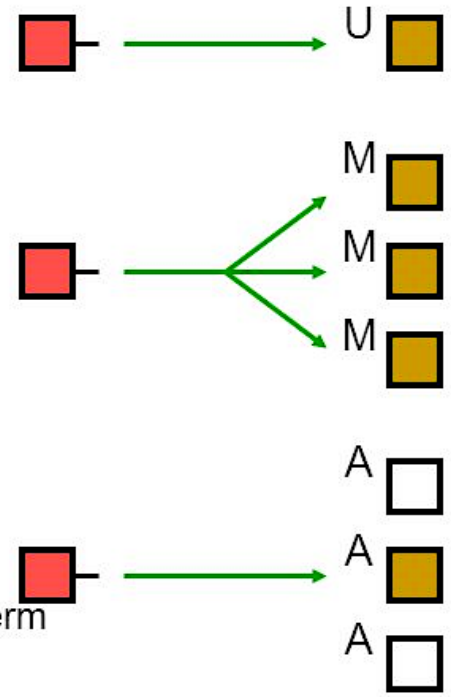


Source: Clausen, 2018. Depth First Forwarding for Low Power and Lossy Networks: Application and Extension

INTERNET LAYER – SPECIFIC CHALLENGES

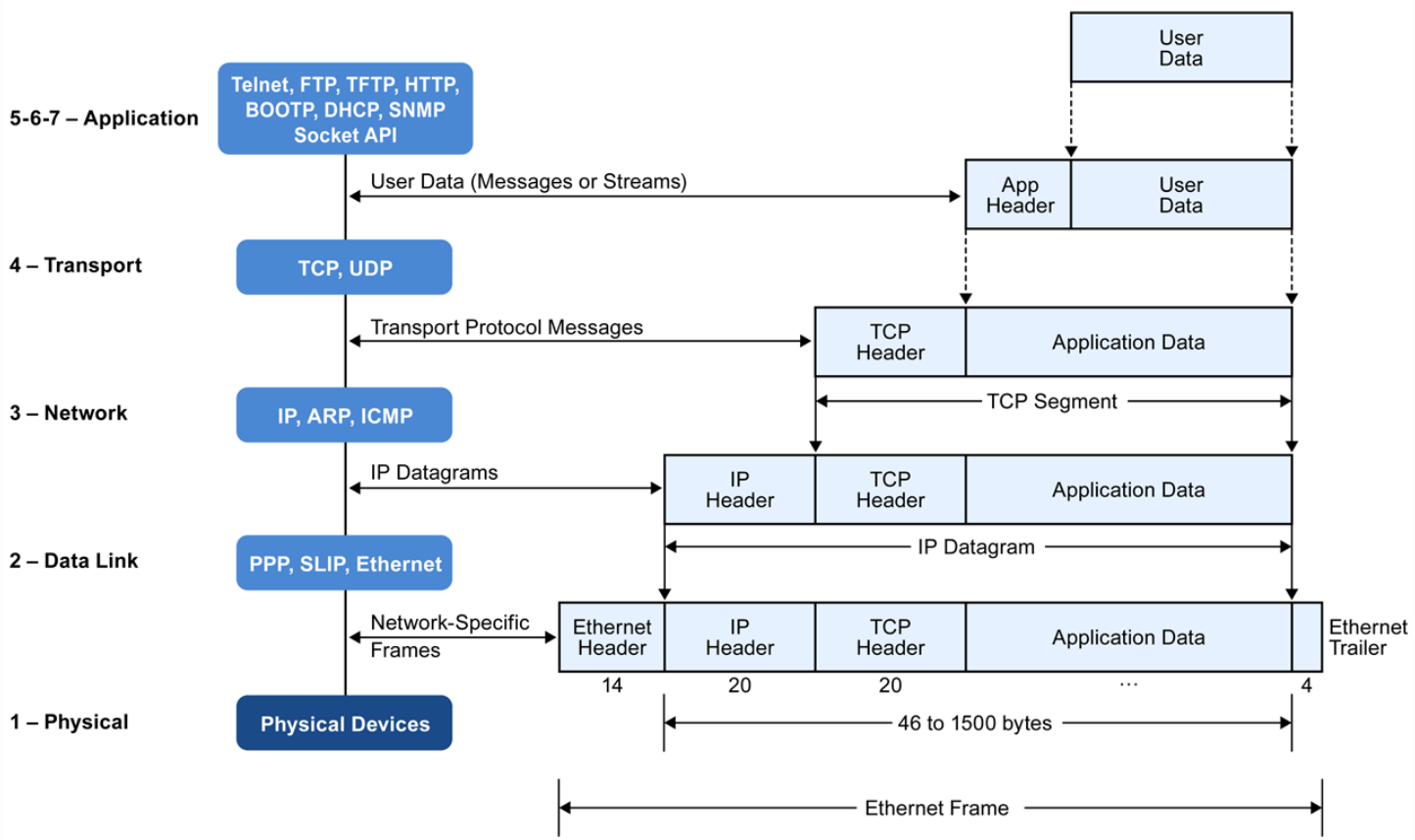
3. Traffic patterns within LLNs include
   - Flows can be: Point-to-point // Point-to-multipoint // Multipoint-to-point
   - **Unicast** and **multicast** should be considered.

- Unicast
  - Address of a single interface
  - Delivery to single interface
  - for one-to-one communication
- Multicast
  - Address of a set of interfaces
  - Delivery to all interfaces in the set
  - for one-to-many communication
- Anycast
  - Address of a set of interfaces
  - Delivery to a single interface in the set
  - for one-to-nearest communication
  - Nearest is defined as being closest in term of routing distance
- No Broadcast



INTERNET LAYER – SPECIFIC CHALLENGES

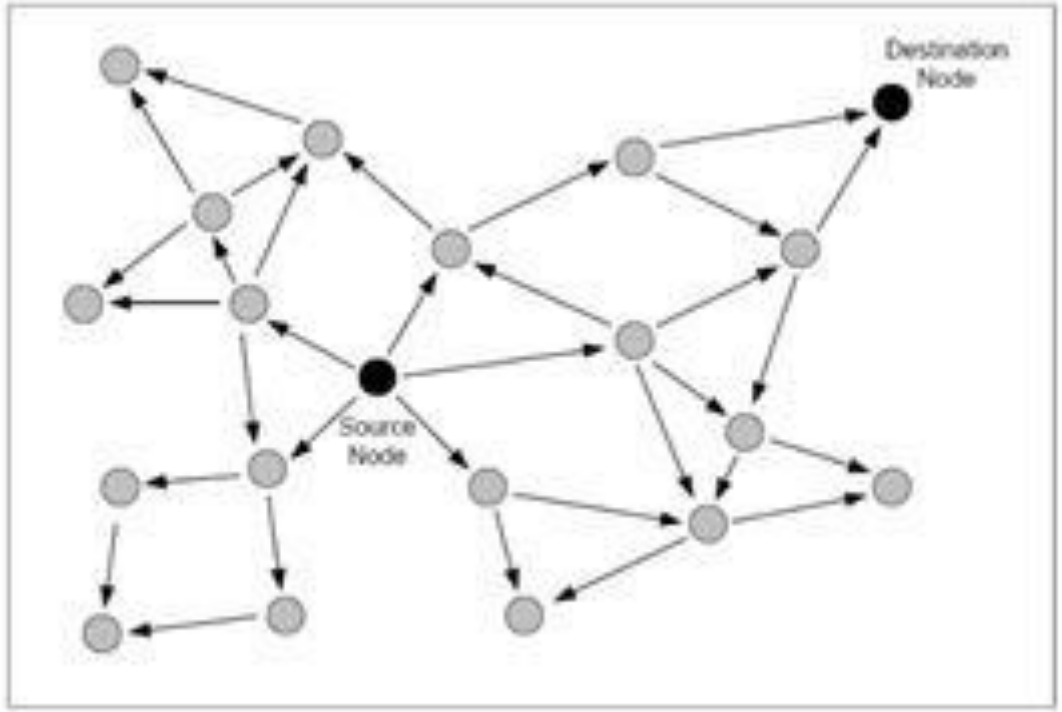
4. LLNs are typically employed over link layer **technologies** with **restricted frame-sizes**
   - Routing protocols should be adapted for technologies in the link layers



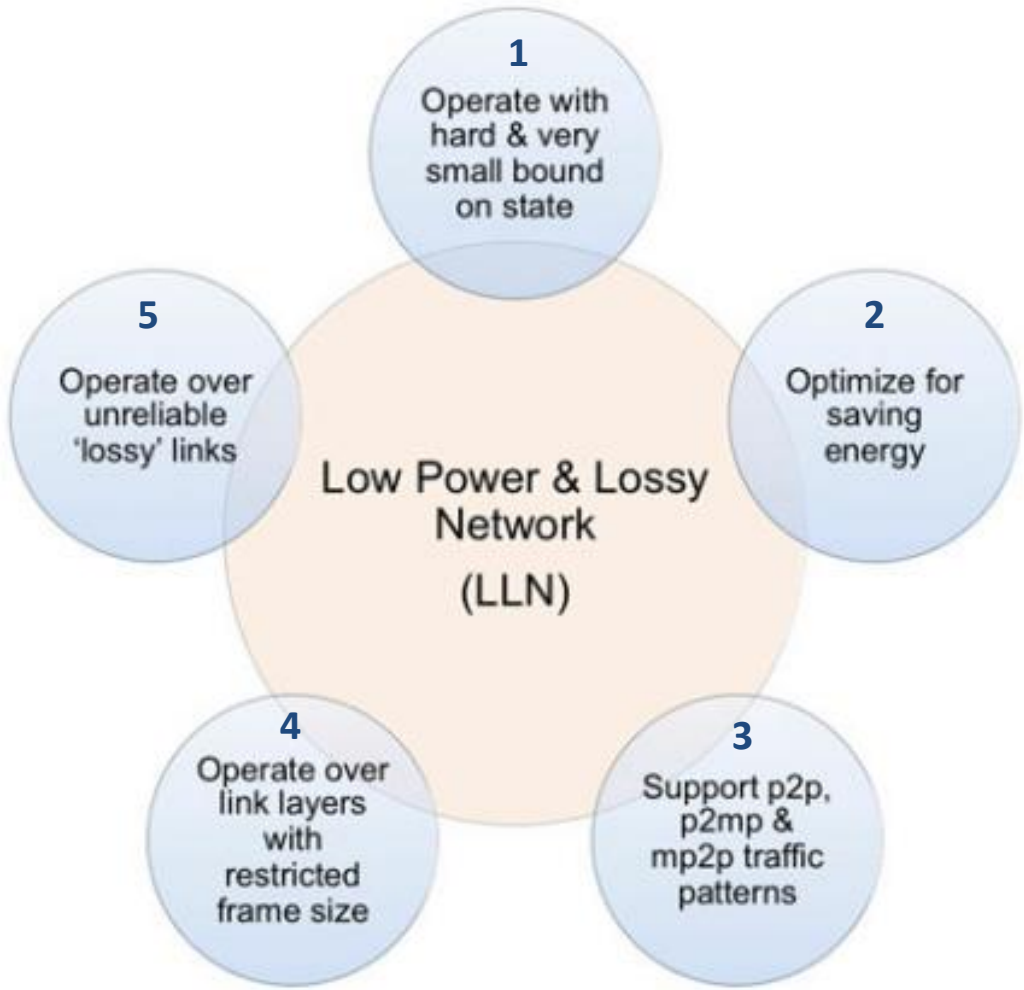
INTERNET LAYER – SPECIFIC CHALLENGES

5. Links within LLNs may be inherently **unreliable** with **time varying loss characteristics**

- IL protocols need to offer **high reliability** under those characteristics



DESIGN FACTORS IN INTERNET LAYER PROTOCOLS FOR IOT



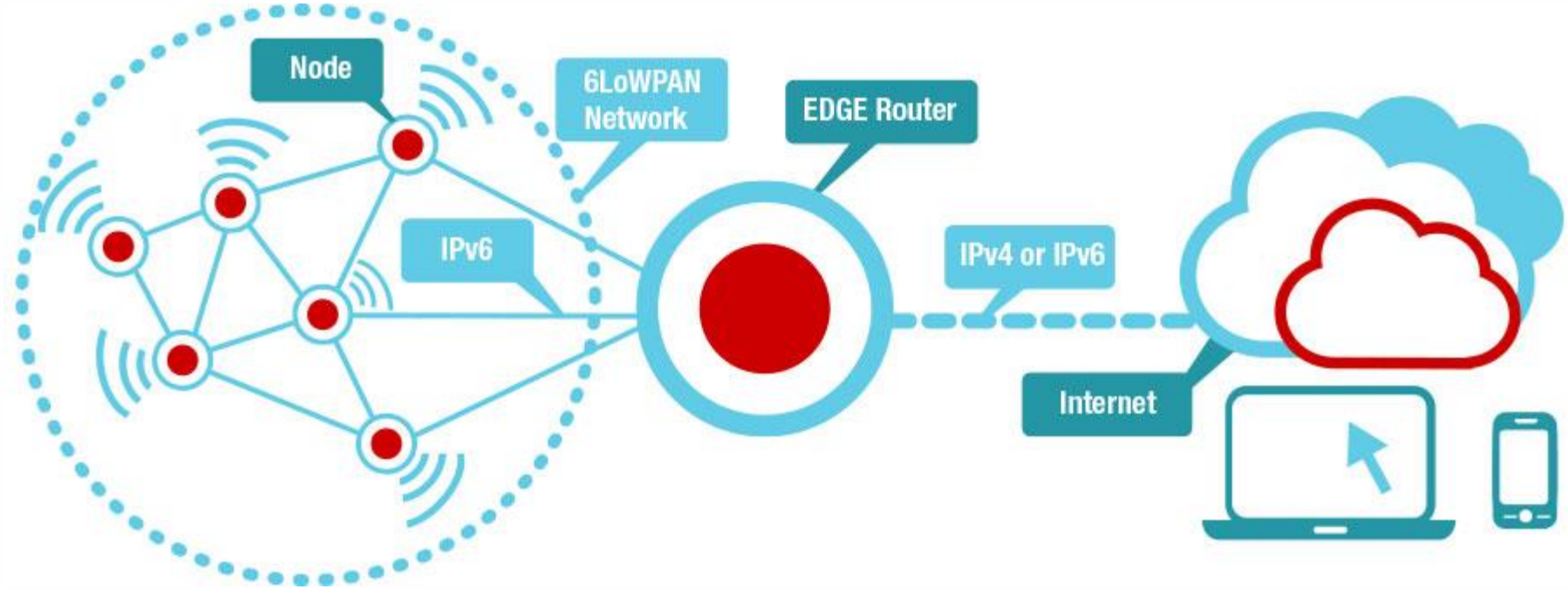
INTERNET LAYER - INDUSTRY OPEN STANDARDS

1. 6LoWPAN
   - IPv6 over Low Power Wireless Personal Area Network
   - Adapting IPv6 to the IEEE 802.15.4 (ZigBee) link layer.

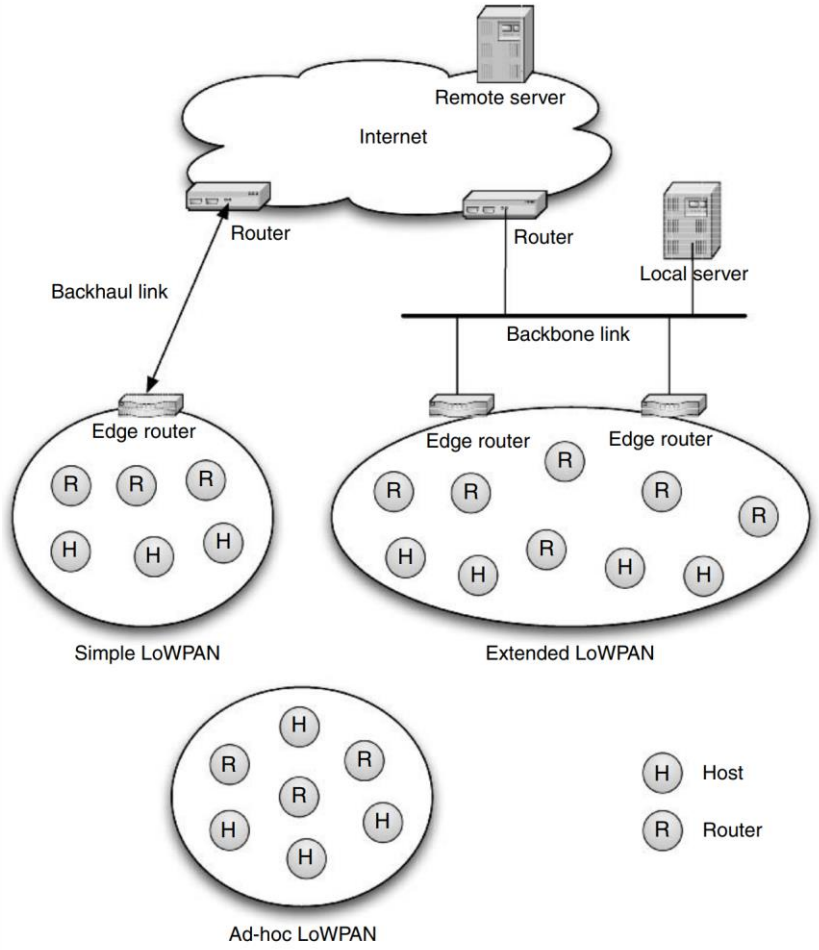
2. RPL : Routing Protocol over Low-power
   - Link independent IPv6 Routing Protocol for Low-Power and Lossy Networks

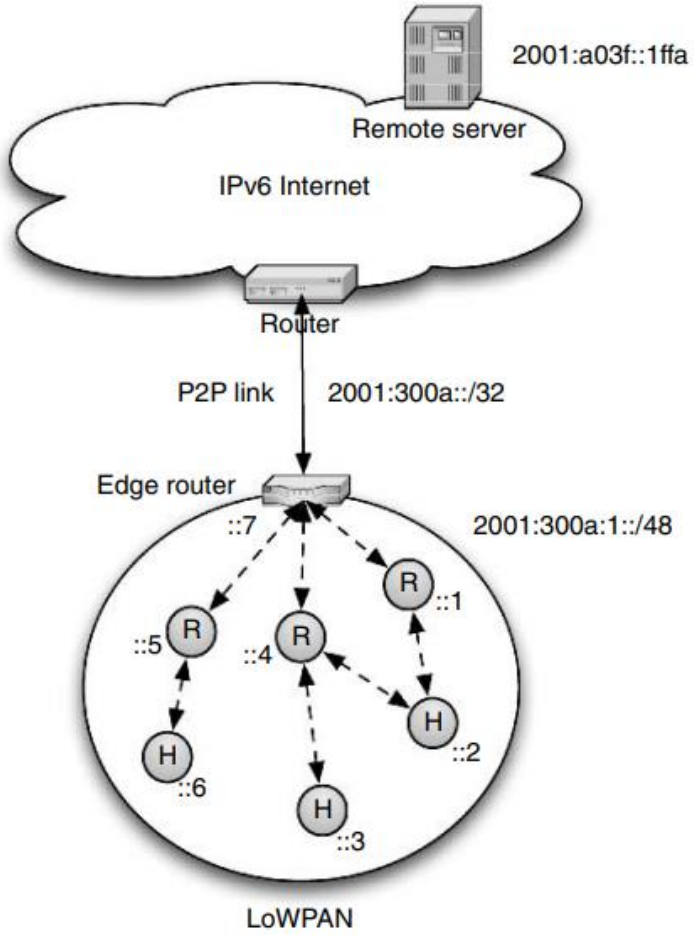
INTERNET LAYER - INDUSTRY OPEN STANDARDS - 6LOWPAN

A 6LoWPAN system is a low-power wireless mesh network where every node has it's own IPv6 address allowing it to connect directly to the Internet



INTERNET LAYER - 6LOWPAN ARCHITECTURE

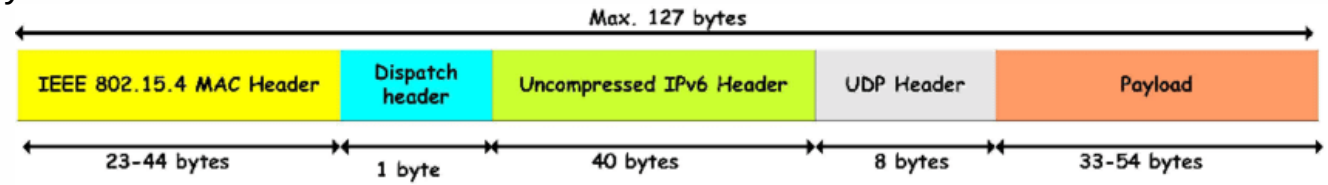




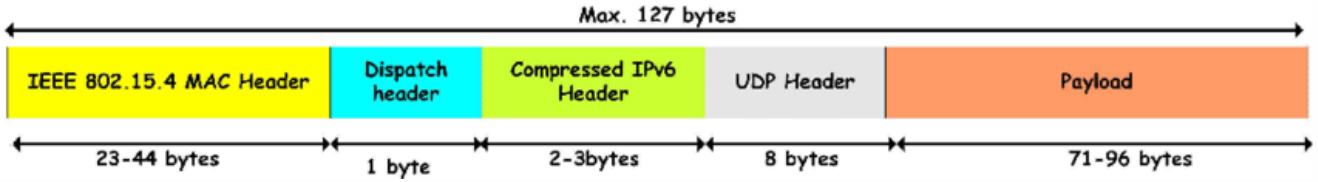
INTERNET LAYER - INDUSTRY OPEN STANDARDS - 6LOWPAN

6LoWPAN: Adapting IPv6 to the IEEE 802.15.4 link layer.

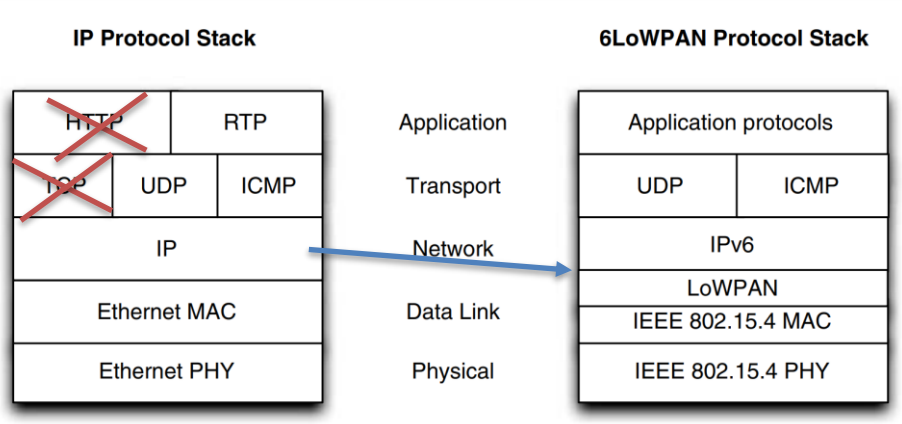
– Designed to work with restricted frame size
  - The base maximum frame size for 802.15.4 is 127 bytes
  - 25 bytes reserved for the frame header
  - 21 bytes for link layer security.
  - IPv6 packet header, on its own, is 40 bytes



– 6LoWPAN provides three main functions:
  - IPv6 header compression,
  - IPv6 packet segmentation and reassembly
  - Forwarding (also referred to as mesh addressing).



– 6LoWPAN compress the IPv6 header into 2 bytes



INTERNET LAYER – MOBILITY

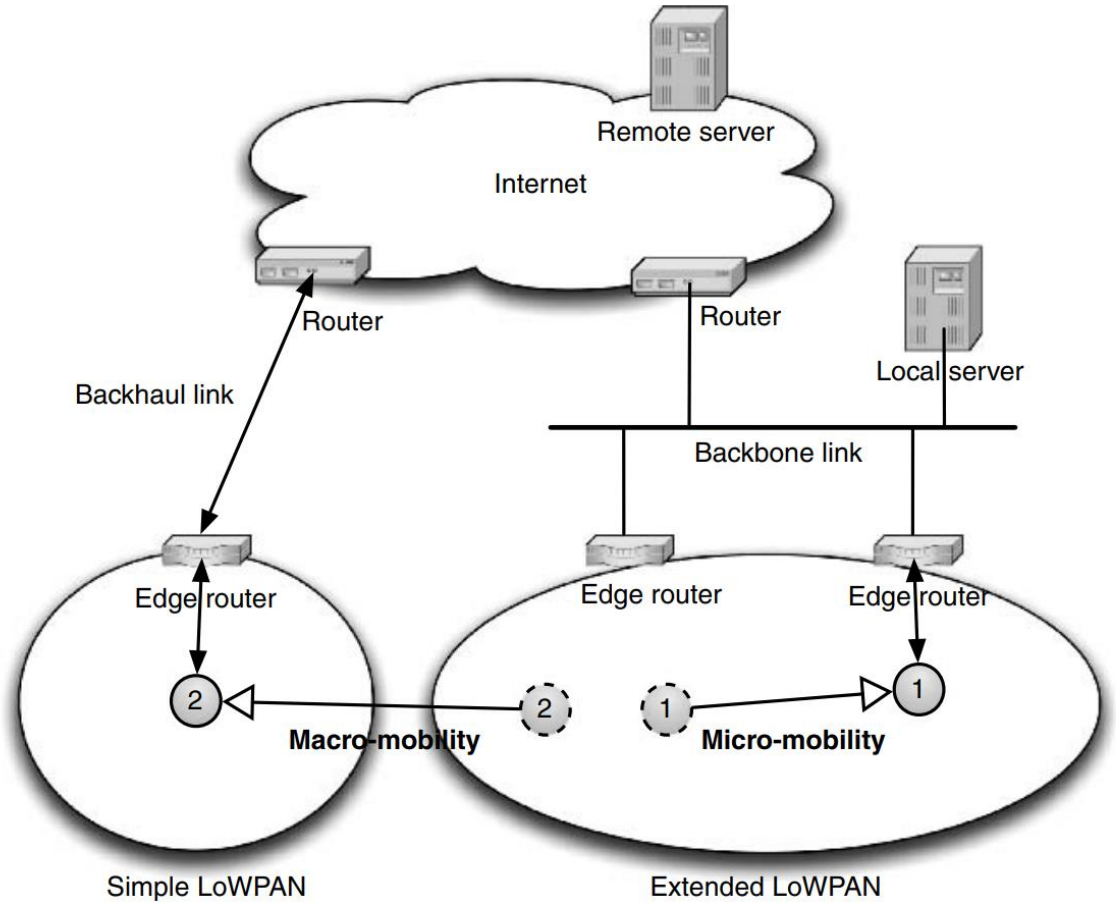
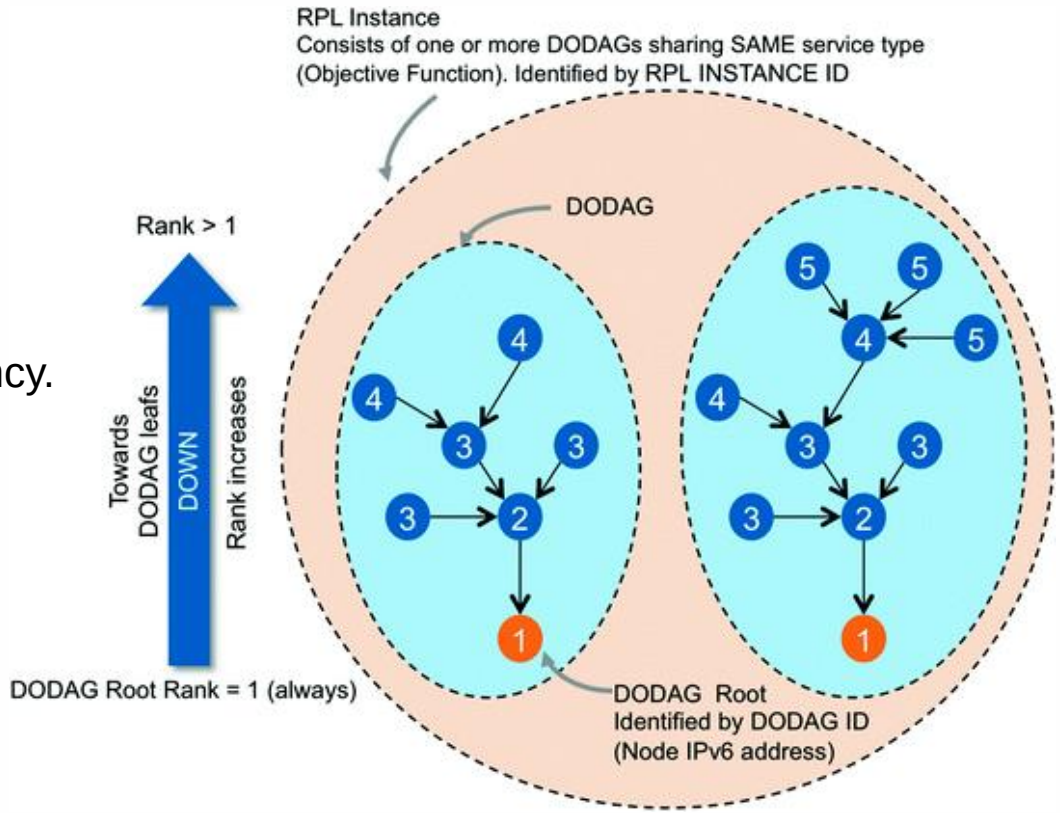


Figure 4.2 The difference between micro-mobility and macro-mobility.

INTERNET LAYER - INDUSTRY OPEN STANDARDS - RPL

RPL : IPv6 Routing Protocol for LLNs

- RPL is a distance-vector routing protocol (opposed to a link-state paradigm)
  - Link-state routing protocols build and maintain a database of the entire network on every node
- RPL computes a Destination Oriented Directed Acyclic Graph (DODAG)
  - minimizing the latency of communication
  - maximizing the probability of message delivery.
  - Includes a shortest-path selection algorithm based on Link latency. reliability, or node energy level.



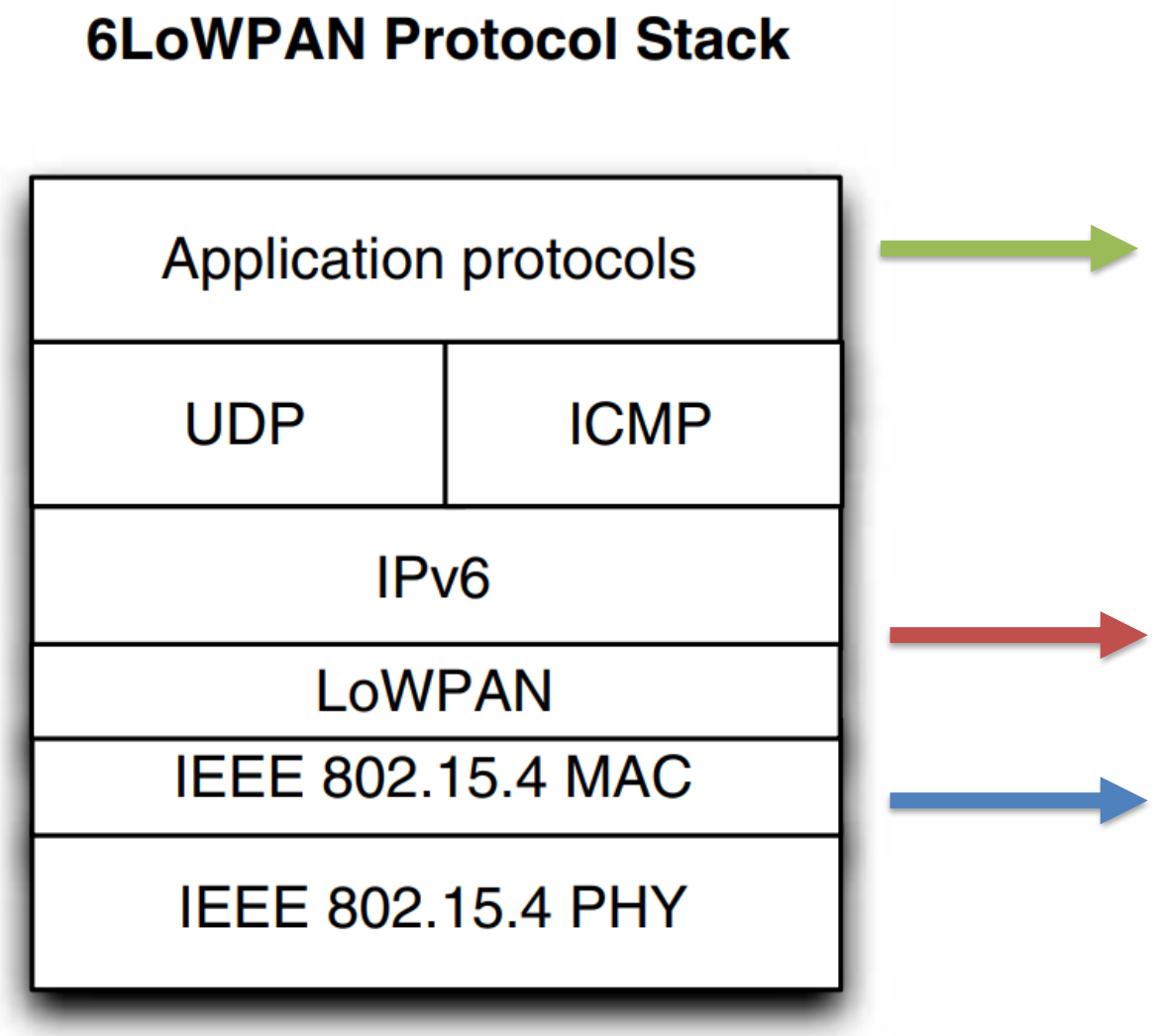
INTERNET LAYER - INDUSTRY OPEN STANDARDS - RPL

RPL Main Advantages:

- RPL is a proactive protocol
  - It can calculate alternate paths as part of the topology setup,
  - It does not rely on determine backup paths after a failure occurs

- RPL is under-reactive
  - Failures are handled by locally choosing an alternate path, which makes the protocol well suited for operation over lossy links.

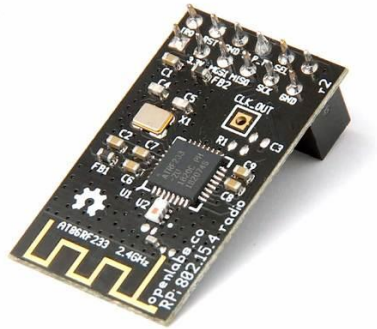
INTERNET LAYER – WHAT ABOUT SECURITY



How to use 6LoWPAN in your own project

- Unfortunately, current ESP32s do not support 802.15.4 link layer and hence we cannot use the radio for 6LoWPAN.

- But we can get 6LoWPAN over 802.15.4 modules:



ADDITIONAL RESOURCES

- IPv6 over Low-Power Wireless Personal Area Networks (**6LoWPAN**)
  - Texas Instruments
    - https://youtu.be/zzoZNG_NB_c
  - Zach Shelby
    - https://www.youtube.com/watch?v=4baf7N2N_Wo
- IPv6 Routing Protocol for LLN (**RPL**)
  - Akif Mufti
    - https://youtu.be/6AP7p0sbBro
- An open-access book
  - 6LoWPAN: The Wireless Embedded Internet, by Z. Shelby, C. Bormann, 2009.