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6LoWPANs: An Overview

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LLNs[1]

What Are They?

Low-power and lossy networks (LLNs) are networks made of highly constrained nodes:

- Limited CPU
- Limited Memory
- Limited Power

interconnected by a variety of "lossy" links:

- Low-power Radio Links
- Power-line Communication (PLC)

Some Characteristics:

- Low Speed
- Low Performance
- Low Cost
- Unstable Connectivity

LoWPANs and IEEE 802.15.4

An Instance of LLNs

IEEE 802.15.4[2] defines standards for low-rate wireless networks for the physical layer and MAC sublayer.

Characteristics of a Low-power Wireless Personal Area Network (LoWPAN)[1]:

- Limited Processing Capability
  - 8, 16, 32-bit Processors
  - Clock Rate in Order of Tens of MHz
- Small Memory Capacity
  - Only a Few Kilobytes of RAM
  - A Few Dozen of Kilobytes or Megabytes of ROM

Figure: IMote2: wireless sensor network node[3] with 256kB RAM, 32MB Flash

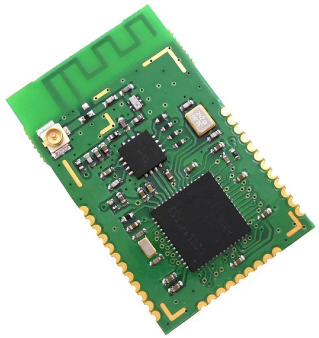

Figure: CC2538: wireless microcontroller System-on-Chip (SoC) with 32kB RAM, 512kB Flash[4]

Characteristics of LoWPANs[1]

- Low Power
  - Radio Frequency Transceivers' Currents Between 10 to 30 mA
- Short Range
  - 10 Meters defined by IEEE 802.15.4
  - Tens of Meters
  - Over 100 Meters in line-of-sight situations
- Low Bit Rate
  - 250 kbit/s defined by IEEE 802.15.4 in the 2.4-GHz band
  - 20, 40, 100 kbit/s

About 6LoWPAN

The IETF

The Internet Engineering Task Force (IETF), which is responsible for the technical standards of many Internet protocols such as HTTP, TCP, UDP, etc., has defined IPv6 over Low-power Wireless Personal Area Network (6LoWPAN) in RFC 4919[5].

Figure: The IETF Logo[6]

About 6LoWPAN

Why?

The application of IP technology is assumed to provide the following benefits[5]:

1. Existing Infrastructure
2. Already Working Technology
3. Open and Freely Available
4. Tools for Diagnostics, Management, and Commissioning
5. Connectable to Other IP-based Networks

Figure: 6LoWPAN Logo

Use Cases

The Internet of Things

6LoWPANs have changed IoT radically. Before, a complex application layer gateway was needed to make devices such as ZigBee, Bluetooth and proprietary systems connect to the Internet.[7]

Figure: LIFX LED Bulbs[8]

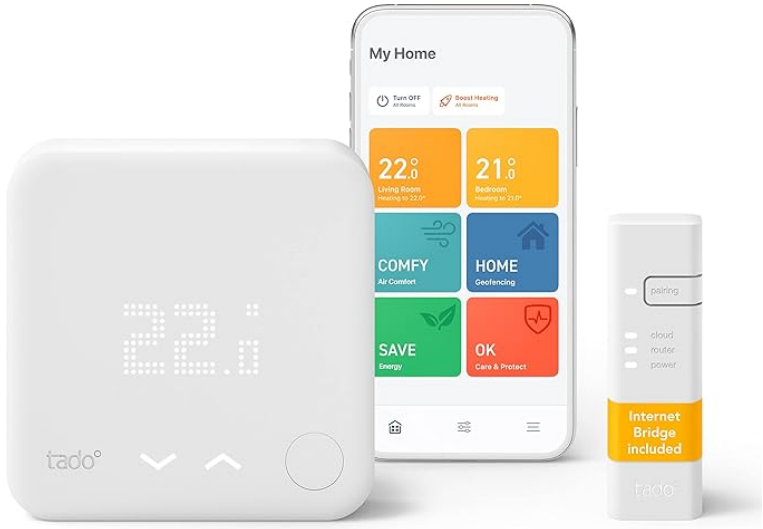

Figure: Tado Smart Thermostat[9]

Network Architecture

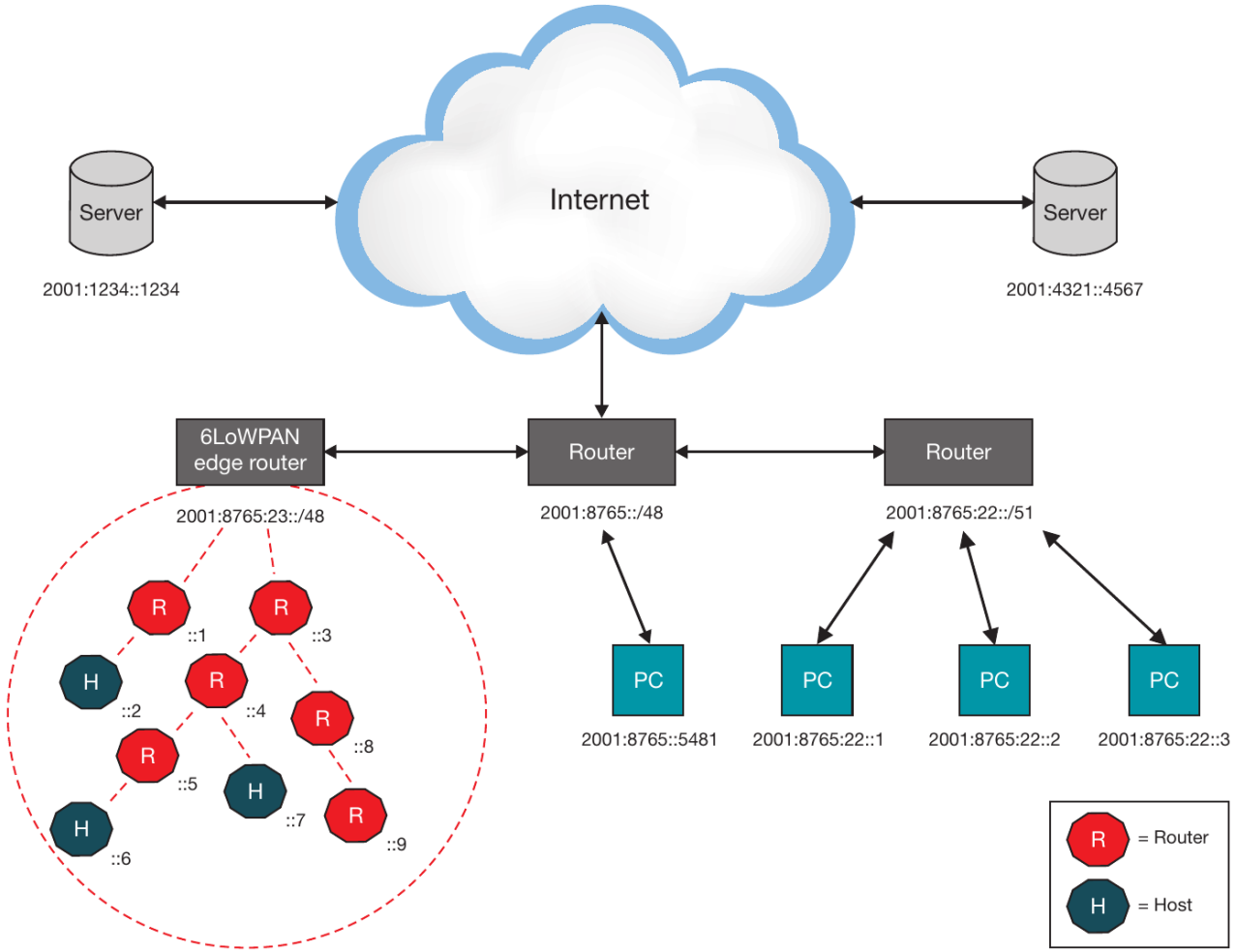

Figure: An example of an IPv6 network with a 6LoWPAN mesh network[7]

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A number of challenges are faced for applying IP on LoWPANs[5]:

1. IP Connectivity
   - Auto Configuration
   - Large Address Space
     - IPv6 has $3.4 * 10^{38}$ unique addresses
   - Limited Packet Size
   - Simple Interconnectivity to Other IP Networks like the Internet
2. Topologies
   - Mesh and Star Topologies
   - Requirements for The Routing Protocol:
     - Low (or no) Overhead On Data Packets
     - Low Chattiness
     - Computation And Memory Requirements
     - Appropriate Routing In The Presence of Sleeping Nodes
3. Service Discovery
4. Security

Maximum Transmission Unit (MTU)

The MTU size for IPv6 packets over IEEE 802.15.4 is 1280 octets. However, a full IPv6 packet does not fit in an IEEE 802.15.4 frame[5] because the maximum packet size in IEEE 802.15.4 is 127 bytes.

Some solutions have been applied in 6LoWPANs adaptation layer:

- Data Fragmentation and Reassembly
- Header Compression

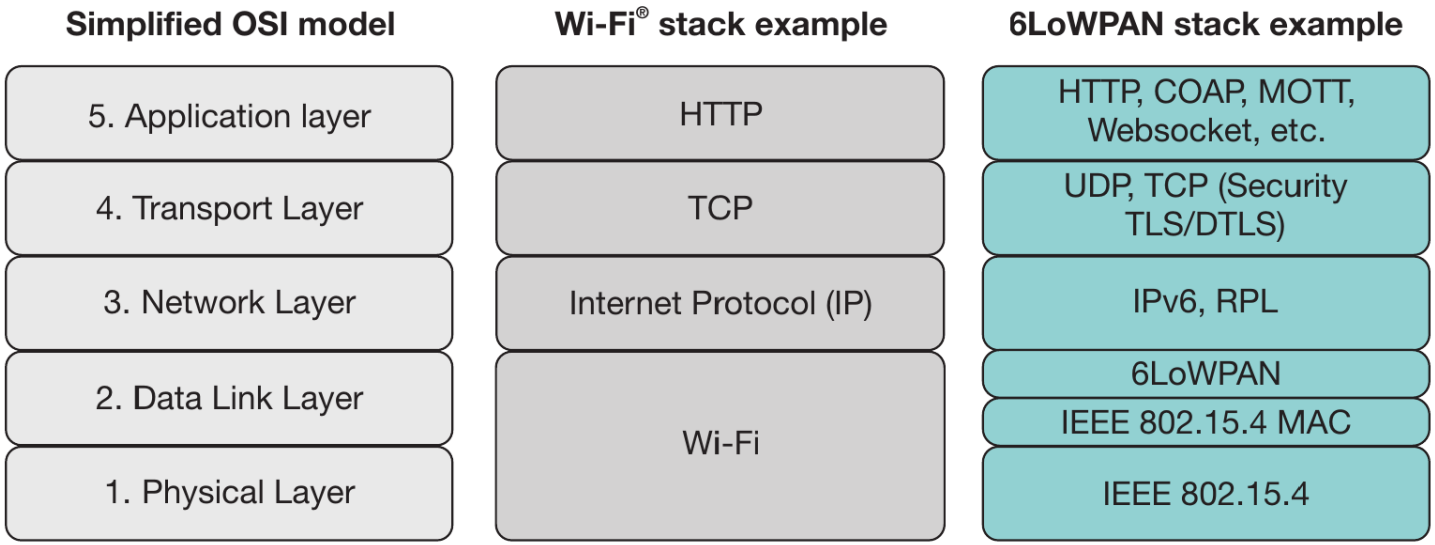

Figure: The OSI model, a Wi-Fi stack example and the 6LoWPAN stack[7]

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Route-over (layer three) Forwarding

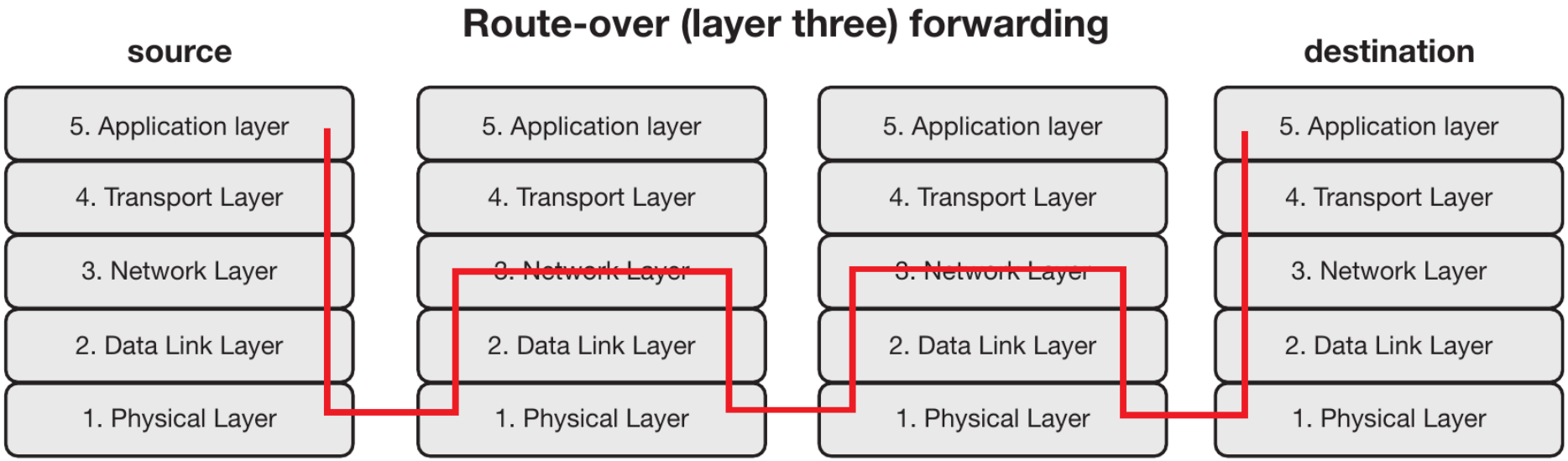

Figure: Route-over Forwarding in The Network Layer[7]

- Each hop represent an IP router.[7]
- The most widely used routing protocol for route-over 6LoWPAN networks today is routing protocol for low-power and lossy networks (RPL) as defined by IETF in RFC 6550.[7]

Mesh-under (layer two) Forwarding

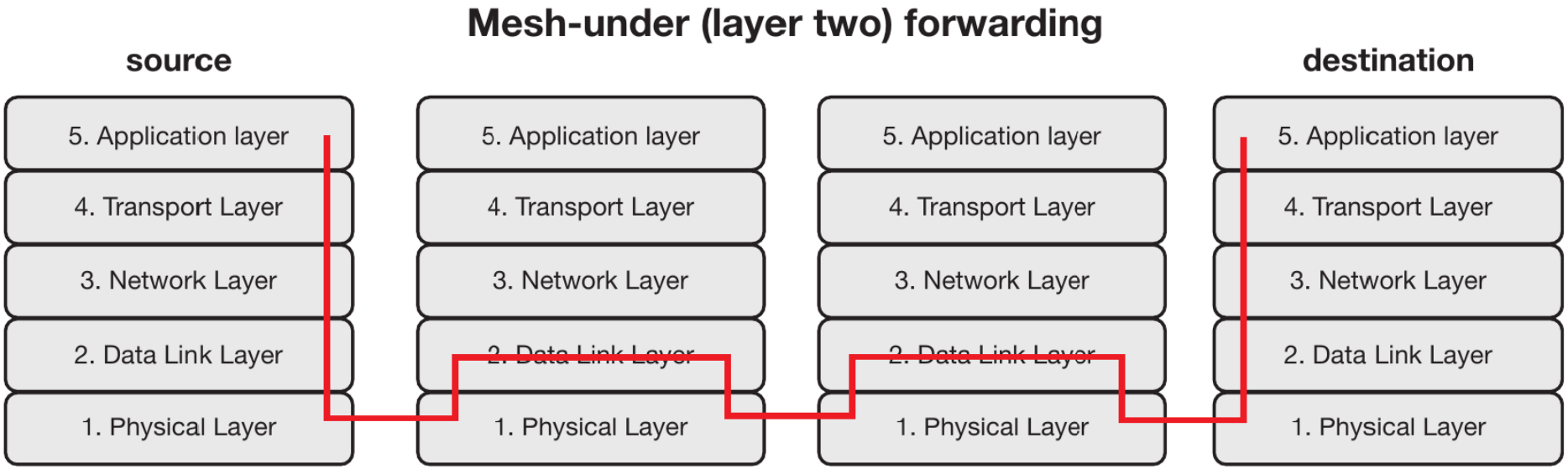

Figure: Mesh-under Forwarding in The Data Link Layer[7]

- Mesh-under networks are considered to be one IP subnet.[7]
- The only IP router in such a system is the edge router.[7]
- Mesh-under networks are best suited for smaller and local networks.[7]

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The possible dimensions for scenario categorization[1]:

- Deployment
- Network Size
- Power Source
- Connectivity
- Multi-Hop Communication
  - The number of hops needed to reach the destination or the edge of the network.
  - A single hop for simple star topology.
  - Multi-hop communication for more elaborate topologies: meshes or trees.
- Traffic Pattern
  - Point-to-Multipoint (P2MP)
  - Multipoint-to-Point (MP2P)
  - Point-to-Point (P2P)
- Security Level
- Mobility
- Quality of Service(QoS)
  - Parameters for QoS should consider collective data for latency, packet loss, data throughput, etc.

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A Use Case and Its Requirements

Example: Healthcare at Home by Tele-Assistance

A senior citizen who lives alone wears one to several wearable LoWPAN nodes to measure heartbeat, pulse rate, etc.[1]

Figure: Dangers of Seniors Living Alone.[10]

Proposed Method and Things to Consider[1]

Proposed Method:

- Densely installed nodes for movement detection
- A LoWPAN border router (LBR) at home for sending information
- LCDs to check the data at home

Things to Consider:

- Node Management
  - Different Duty Cycles
- Multipath Interference
  - Walls and Obstacles
  - Change of Body Position During Sleep
- Data Gathering.
  - Periodic
  - Event-driven: Very Time-critical
- Privacy
  - Secret Keys Between Sensor Nodes
  - Role-based Access Control

Parameters

Dominant parameters in healthcare applications[1]:

1. Deployment: Pre-planned.
2. Network Size: Small, high node density.
3. Power Source: Hybrid.
4. Connectivity: Always on.
5. Multi-Hop Communication: Multi-hop for home-care devices; patient's body network is star topology. Multipath interference due to walls and obstacles at home must be considered.
6. Traffic Pattern: MP2P/P2MP (data collection), P2P (local diagnostic).
7. Security Level: Data privacy and security must be provided. Encryption is required. It is required that role-based access control be supported by a lightweight authentication mechanism.
8. Mobility: Moderate (patient's mobility).
9. QoS: High level of reliability support (life-or-death implication), role-based.

6LoWPAN Applicability

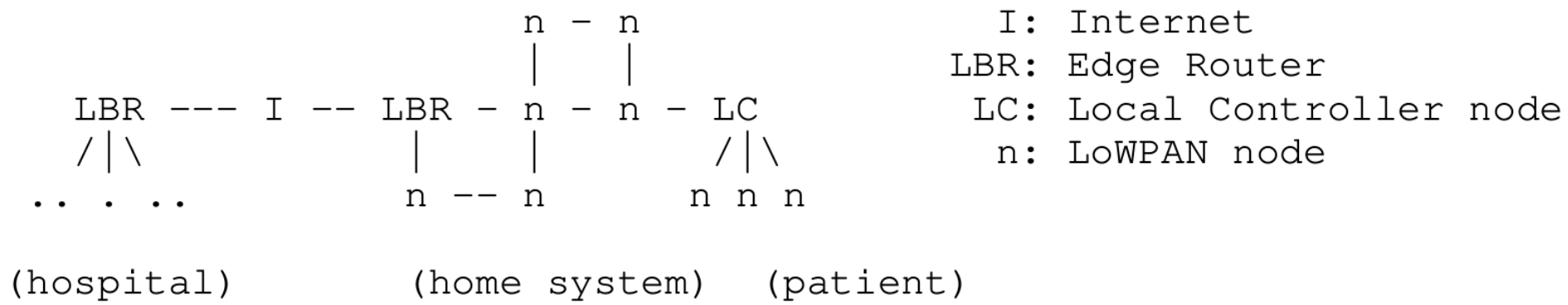

Figure: A Mobile Healthcare Scenario[1]

The patient's body network can be simply configured as a star topology with a LC dealing with data aggregation and dynamic network attachment when the patient moves around at home.[1]


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