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# System-on-Chip Design: Examples

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## Outline

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- **Wireless Sensor Nodes**

  - IEEE 802.15.3

  - IEEE 802.15.4

- **WLAN Modems**

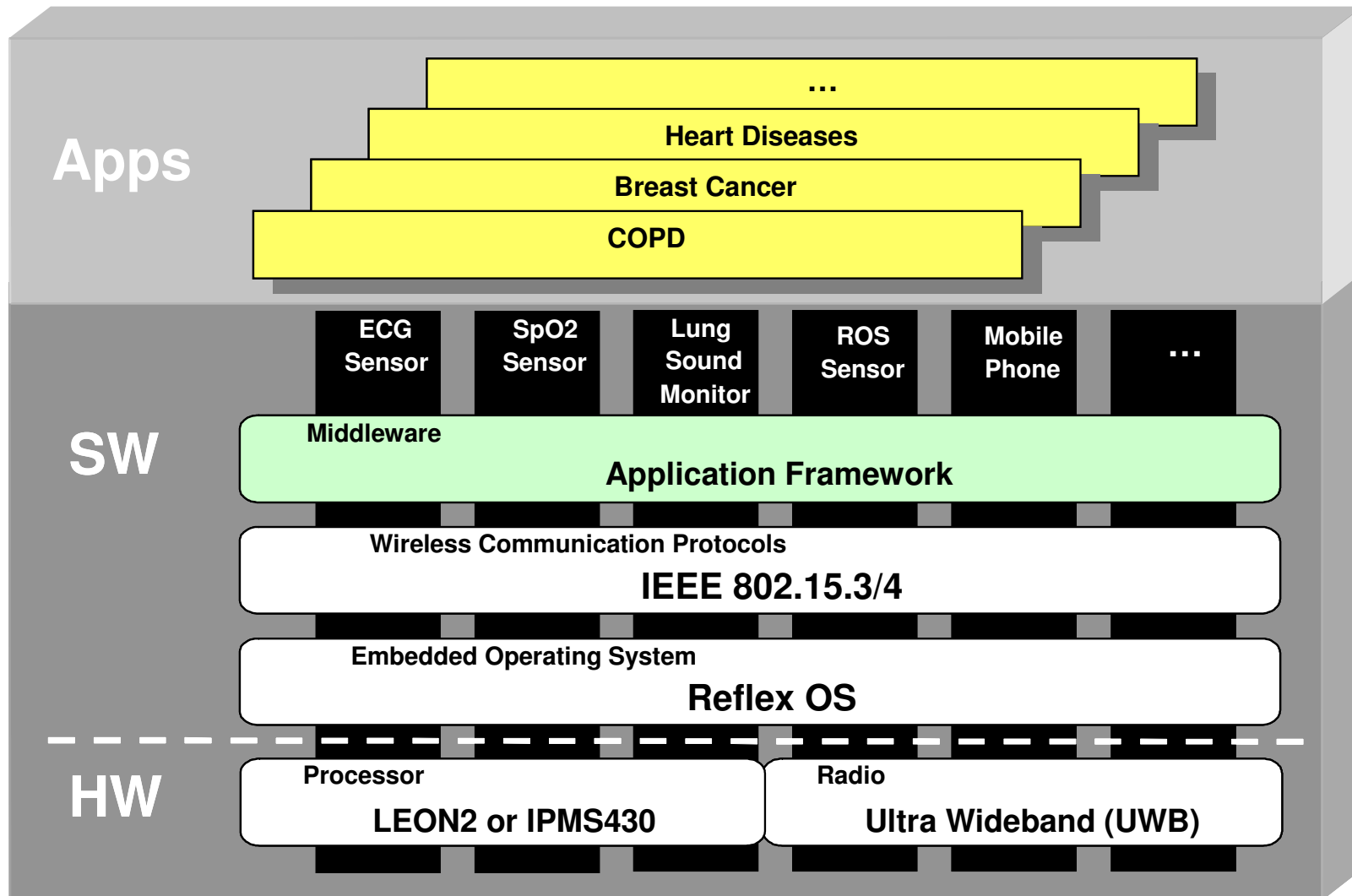
  - IEEE 802.11a

  - IEEE 802.11n

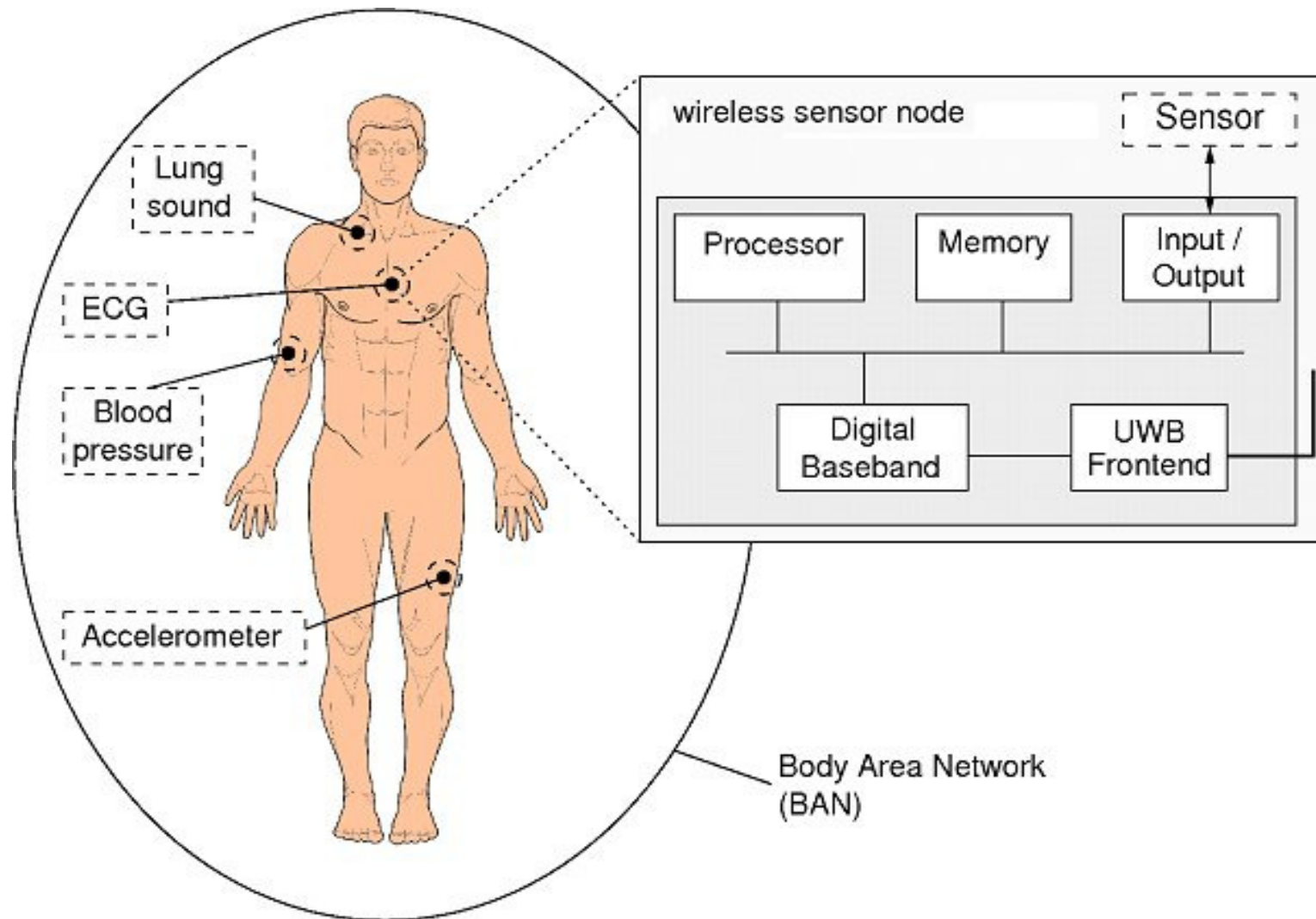
- **Fault-Tolerant SOCs**

  - LEON3-FT

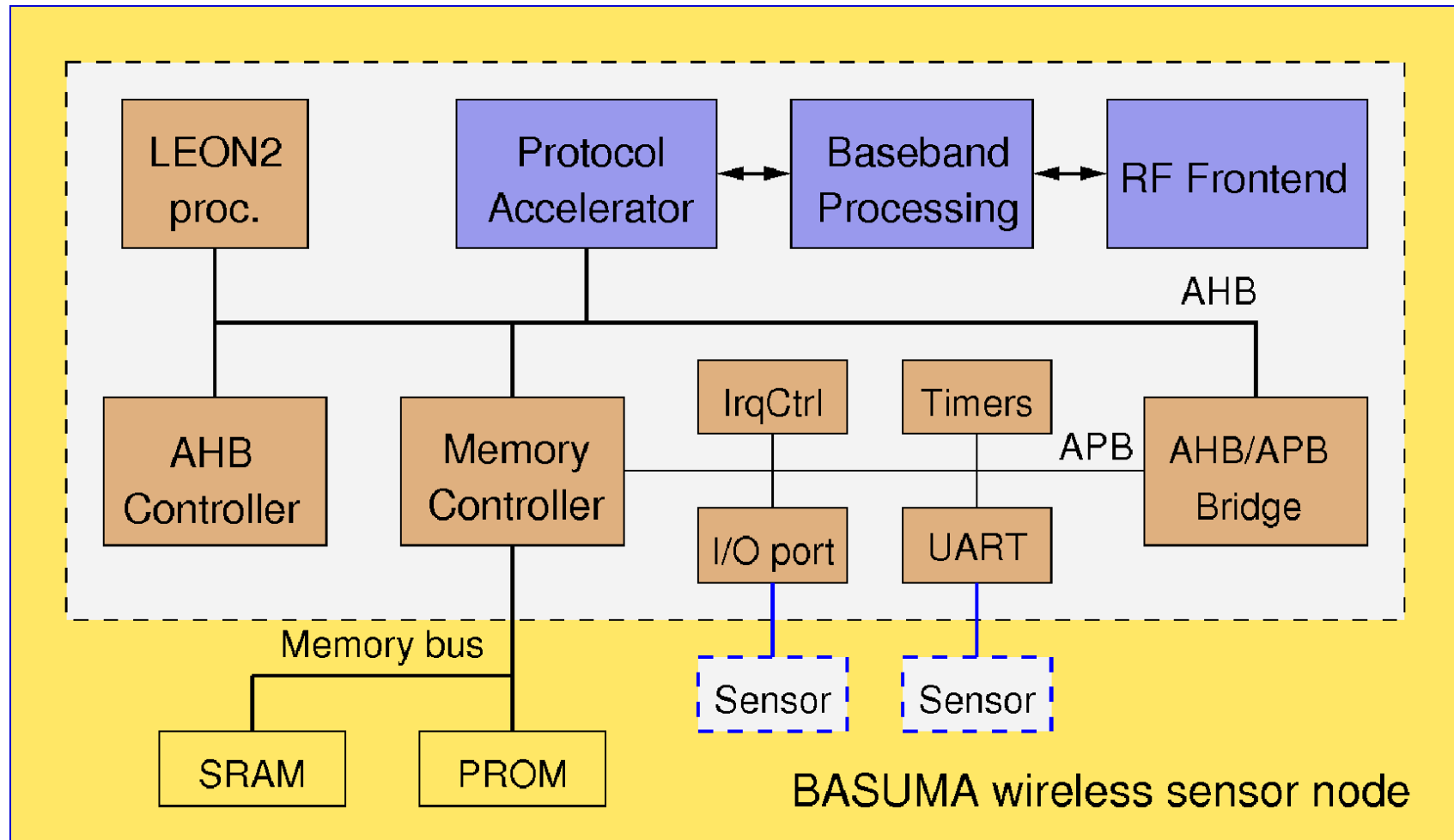
# Body Area System for Medical Applications



# Generic Wireless Communication Platform



# IEEE 802.15.3 Wireless Sensor Node (BASUMA)



## IEEE 802.15.3 MAC Protocol

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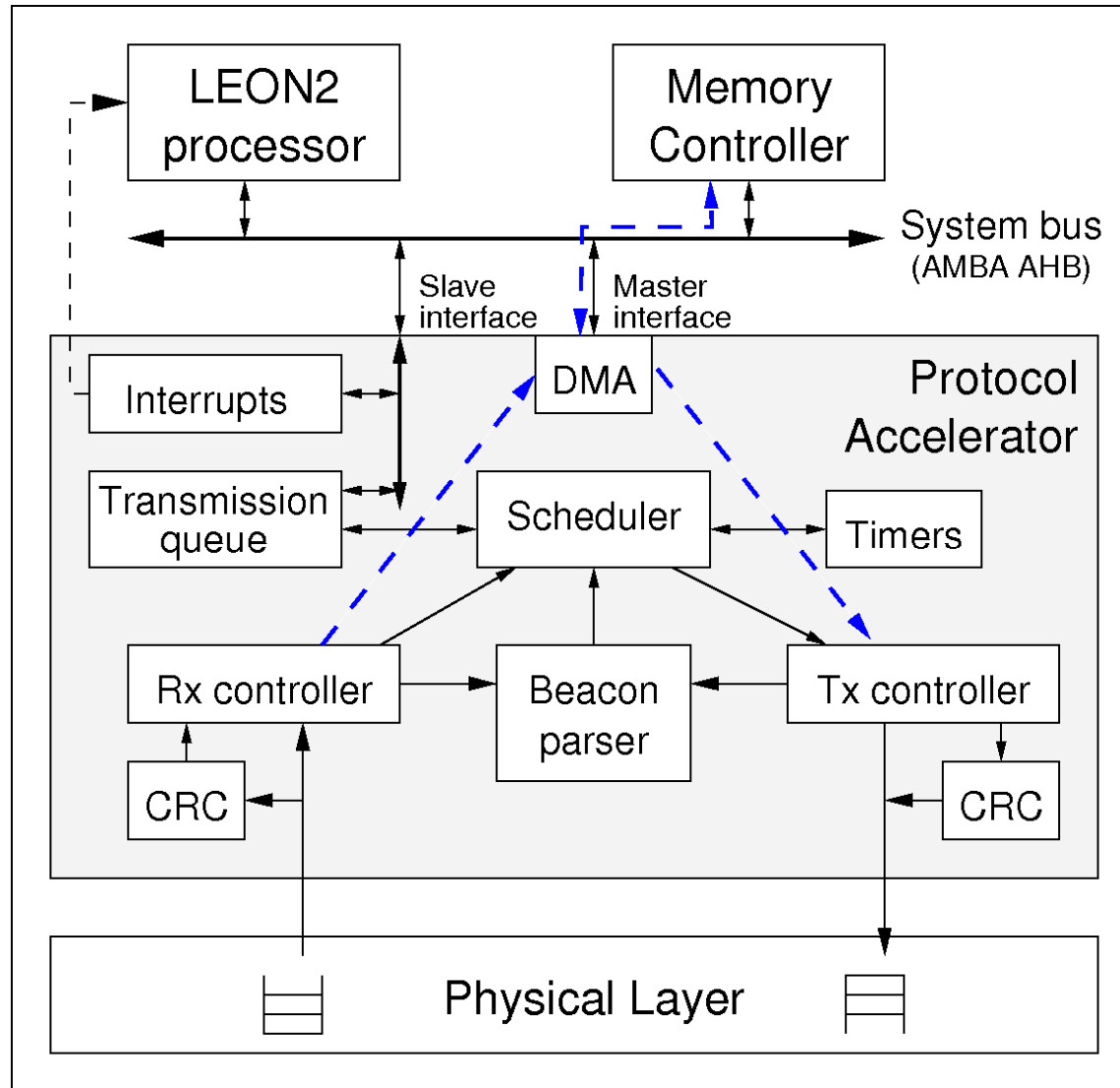
- **IEEE 802.15.3 standard provides**
  - Ad-hoc networking, quality of service and security
  - Various power management modes
  - Physical layer data rates from 11 to 55 Mbit/s
- **Medium Access Control (MAC) protocol functionality**
  - Data path**
    - Cyclic redundancy check (CRC) sum calculation
    - Encryption and decryption of the frame payload
    - Interfacing with the physical layer and frame buffering
  - Control path**
- **Profiling of the software using the processor IS simulator**
  - Time-critical protocol functions are iteratively removed from the software model and put into a hardware component

## Protocol Functions Designed in Hardware

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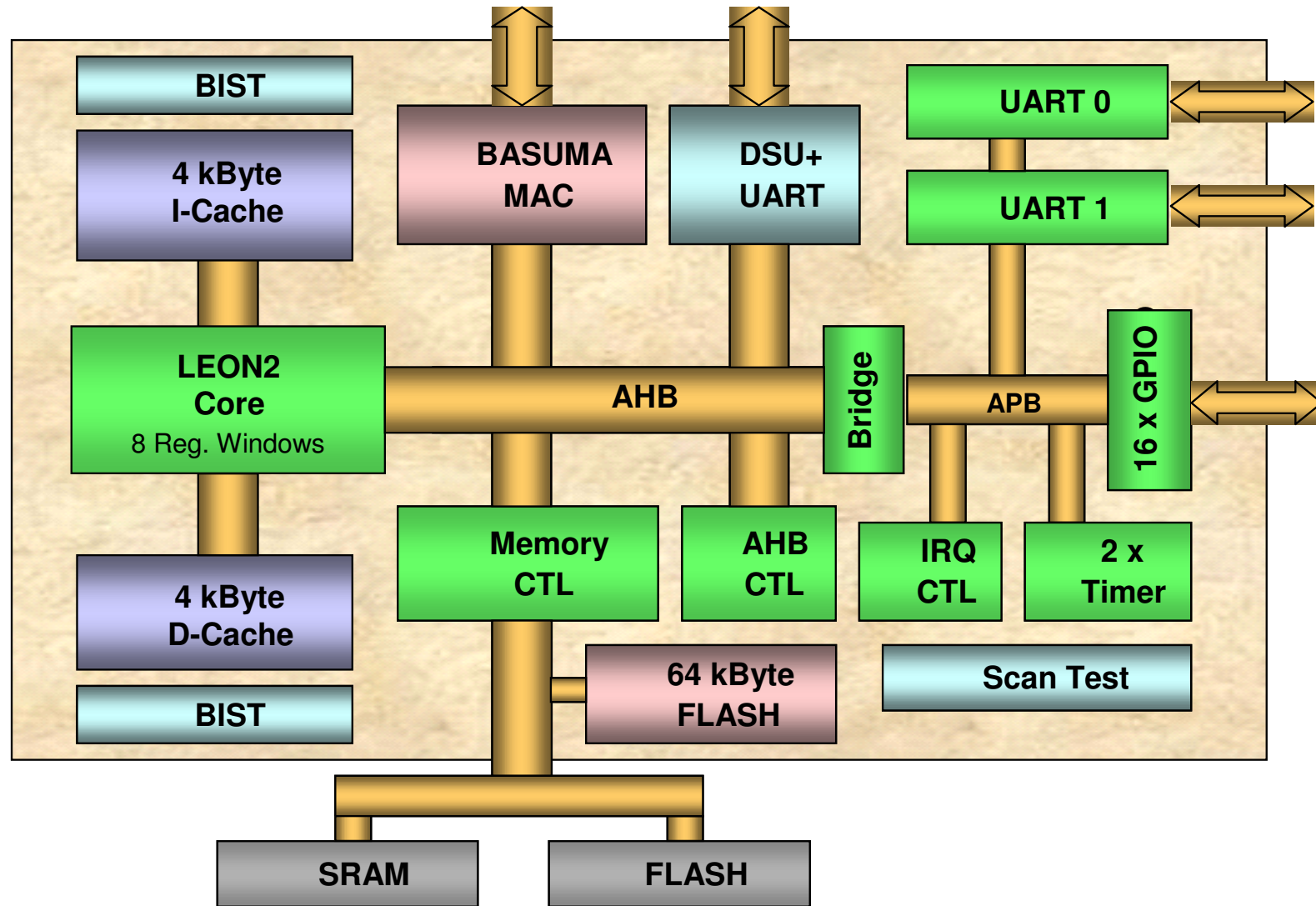
- To retrieve Rx frame data from the physical layer byte by byte, perform filtering and CRC check, and store the data by means of direct memory access
- To retrieve Tx frame data from a memory location, calculate and append the check sum, and push the data to the physical layer
- To signal a successful reception or transmission of a frame by an interrupt
- To analyze received and transmitted beacons and extract information on channel time allocations
- To manage a queue of frames and select an appropriate frame for transmission
  - **At the start of a time slot or following a frame transmission, to query a new frame from the queue and, in case that the frame must be acknowledged, wait for acknowledgment**
- To perform the backoff procedure in the contention access period
- To send an acknowledgment at the right time upon reception of a frame that needs to be acknowledged
- To calculate the actual duration of a frame transmission based on its payload length and data rate

# Architecture of MAC Protocol Accelerator

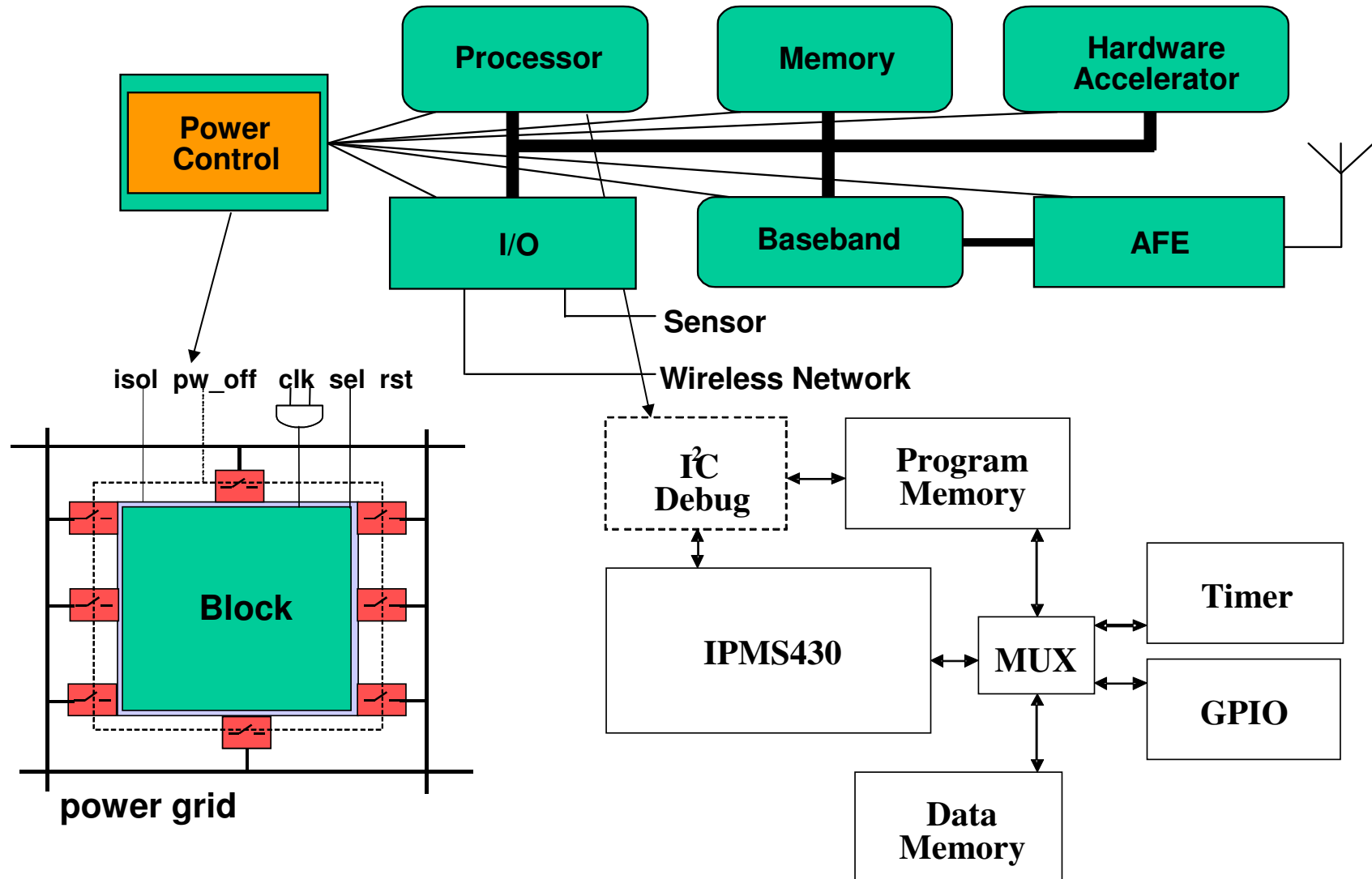




# BASUMA SOC Architecture

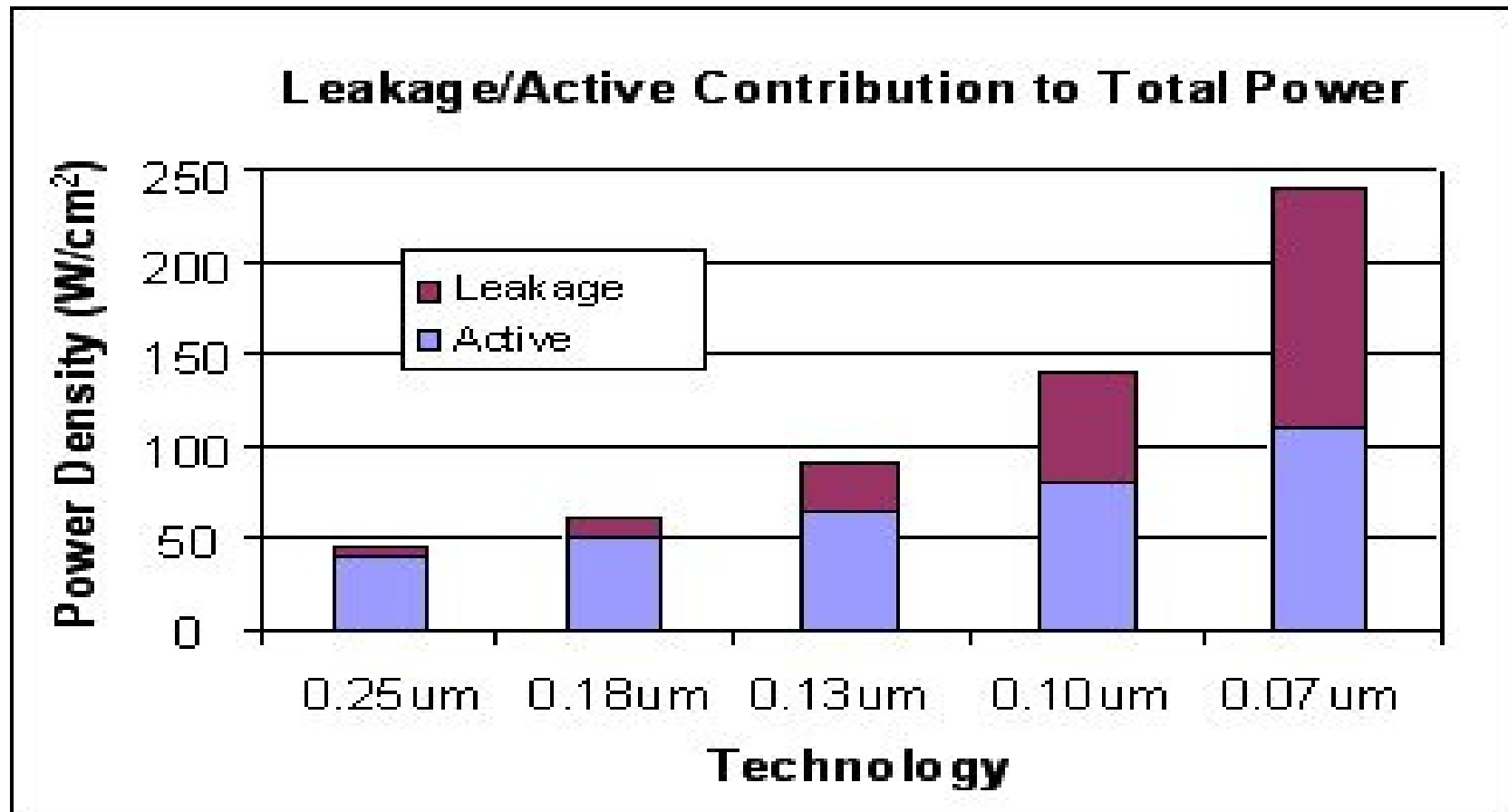


# IEEE 802.15.4 Wireless Sensor Node (TANDEM)

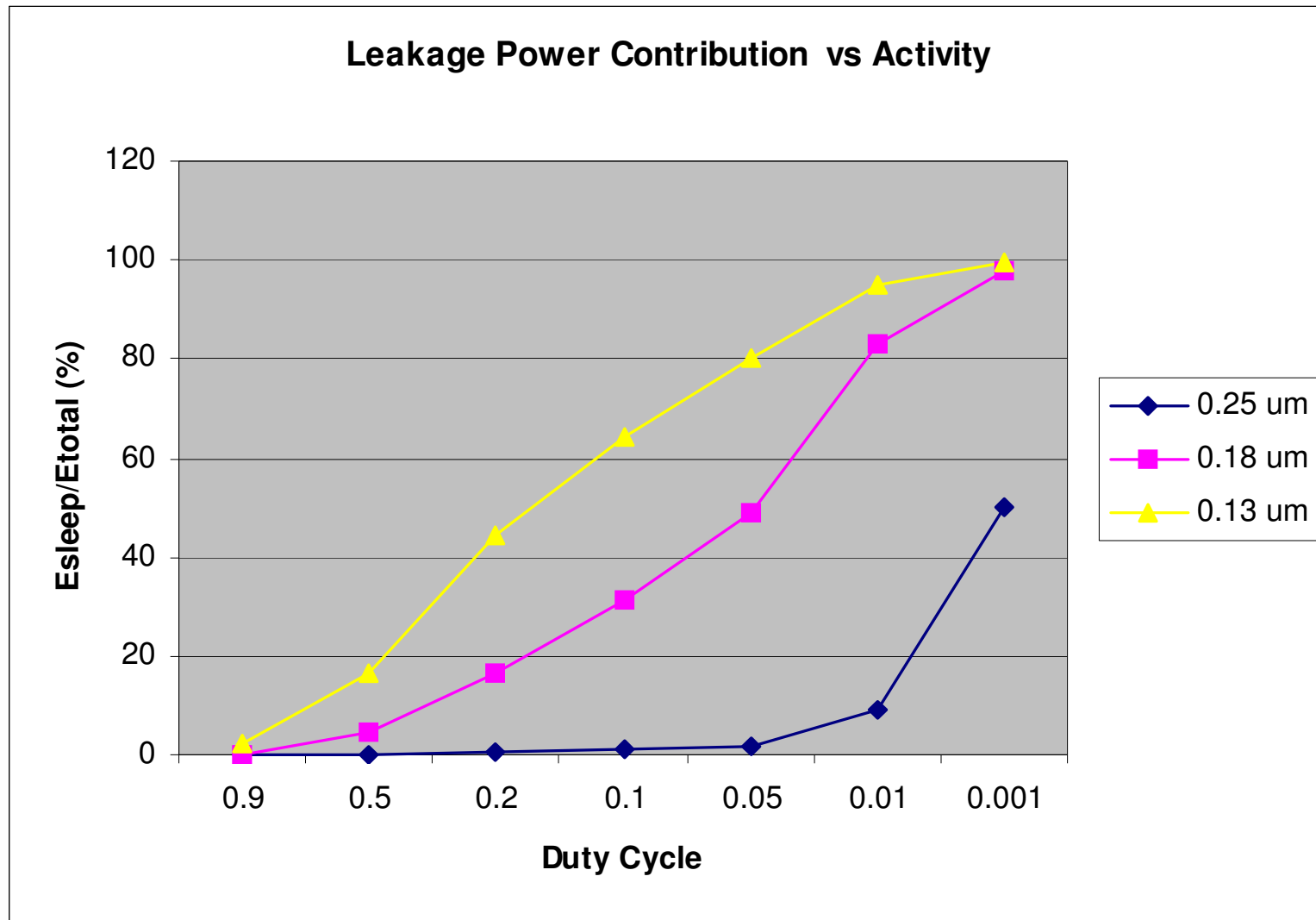


## Power Consumption in WSN

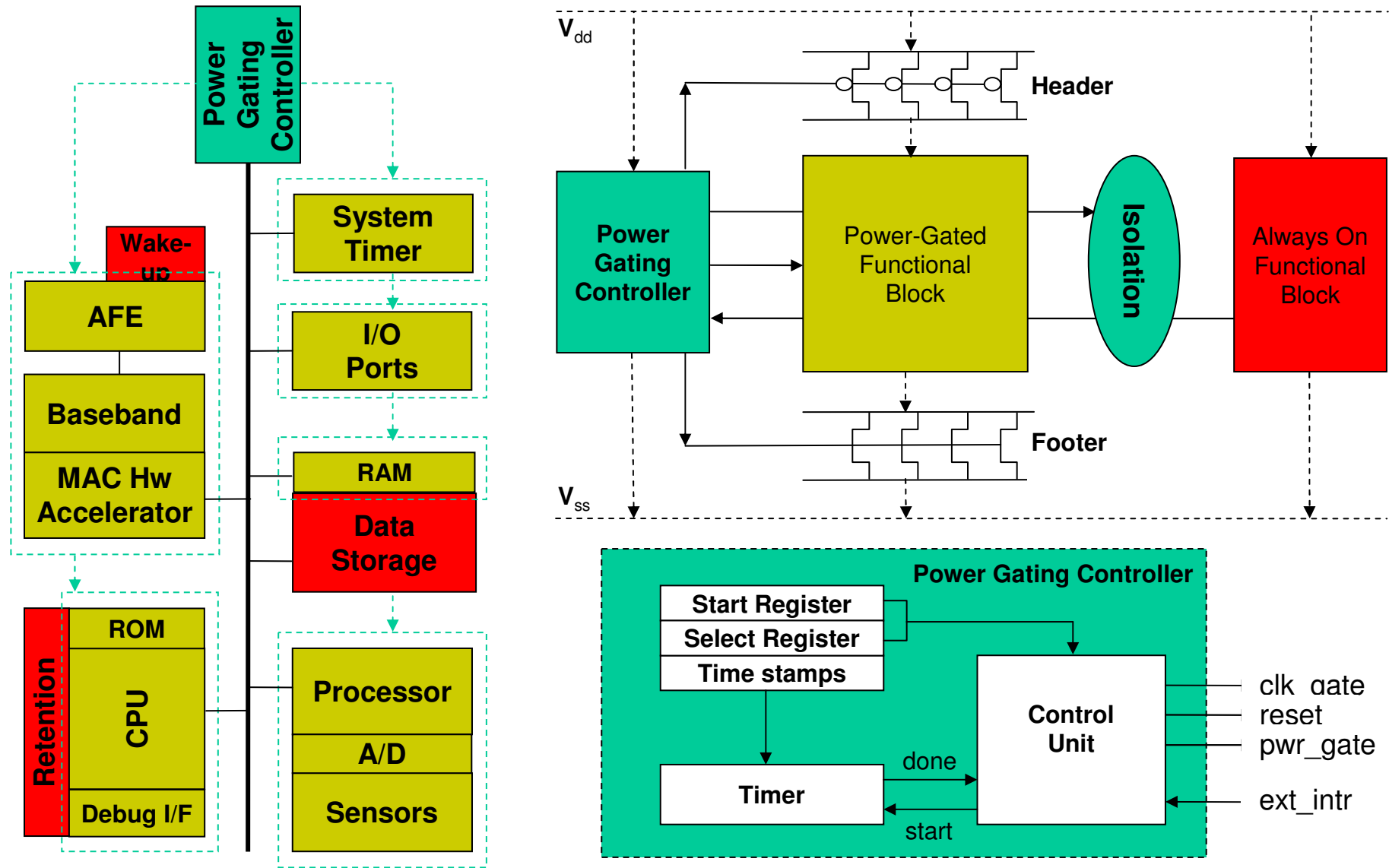
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# Leakage Power in WSN



# Power Gating in IEEE 802.15.4 WSN



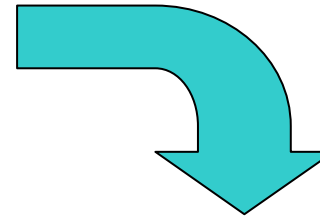
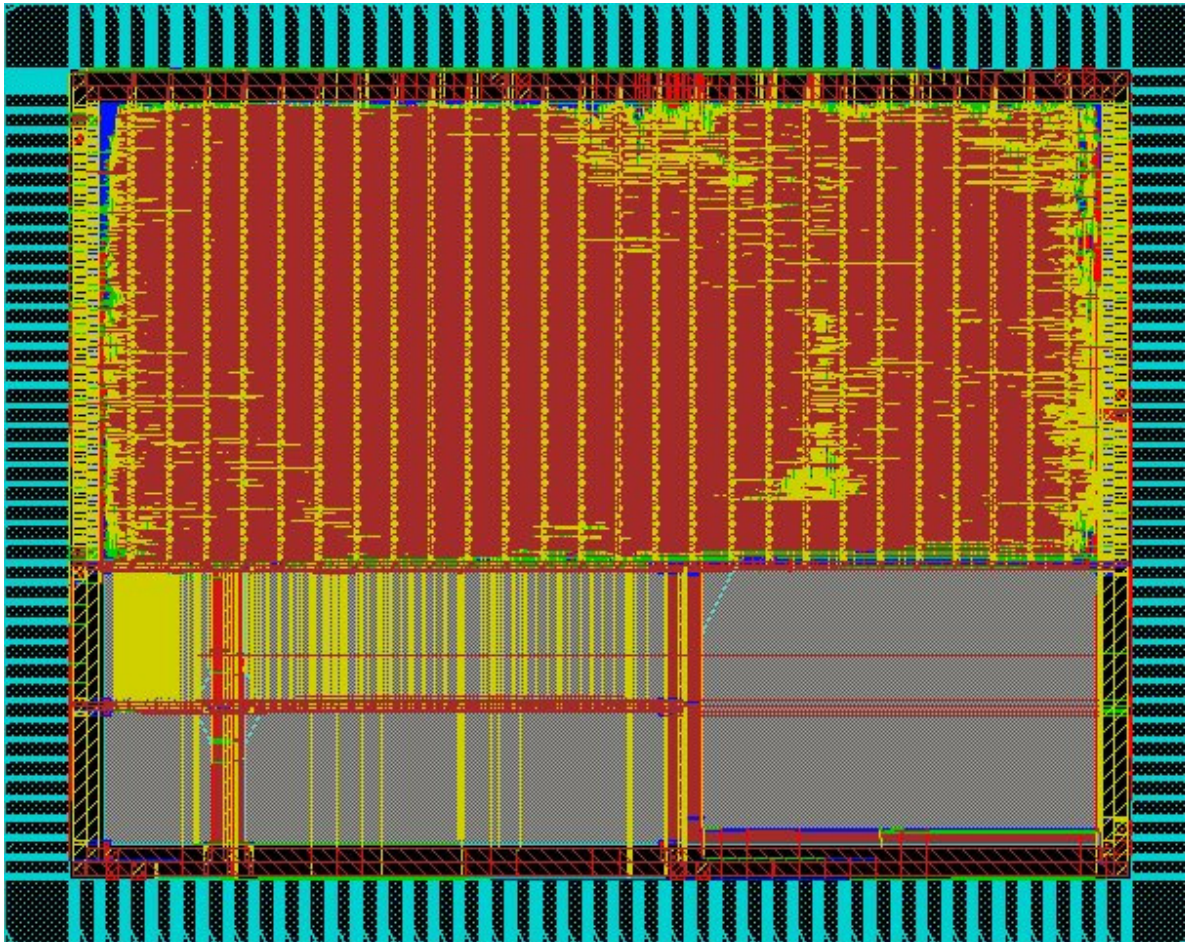
## **SOC Implementation Steps**

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- **Installation of the processor release**
- **Selection of the processor configuration and ASIC/FPGA library**
- **VHDL coding of MAC protocol accelerator**
- **Adaptation of system testbench**
- **Implementation of data and instruction caches including BIST**
- **Logic synthesis of the design**
- **Implementation of scan chain**
- **Generation and verification of the chip layout**
- **Simulation (functional, post-synthesis and post-layout net-list)**
- **Scan test vectors generation (ATPG)**
- **BIST and scan test simulation**
- **EVCD test vectors generation (with and without timing data)**

# BASUMA SOC Features

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Area (mm <sup>2</sup> )	31.9
Signal Ports	126
Power Ports	24
BIST Ports	12
Scan Ports	1(3)
Transistors (x10 <sup>6</sup> )	3.1
Scanable Flip-Flops (x10 <sup>3</sup> )	15
Cache Memories (kbytes)	9.5
Flash Memory (kbytes)	64
Power/Frequency (mW/MHz)	15
Maximum Frequency limited by Flash (MHz)	25