

# Choosing the best-fitting Wireless Sensor Network Technology

**How to choose the best fit for your application?**

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# Abstract

Next to the standard based technologies, vendors offer proprietary solutions, and additionally one could also choose to write everything from scratch to make sure it matches the application's needs 100%.

So which path to follow?

This presentation looks at many different aspects that have an influence on which RF technology/standard/protocol would be the best fit from a technology point of view; looking at topology, frequency, interoperability, etc.

# Quality of Service

First of all one must determine which Quality of Service the application requires before looking into detailed decision criteria

## Quality of Service (QoS)

- Reliability
- Battery life time
- Latency
- Co-existence



# Some decision criteria

- Radio frequency / Reliability / Co-existence
- Data rate
- Latency vs. Battery Life
- Interoperability / Standard / 3rd parties
- Feature set / Topology
- Commissioning / Security

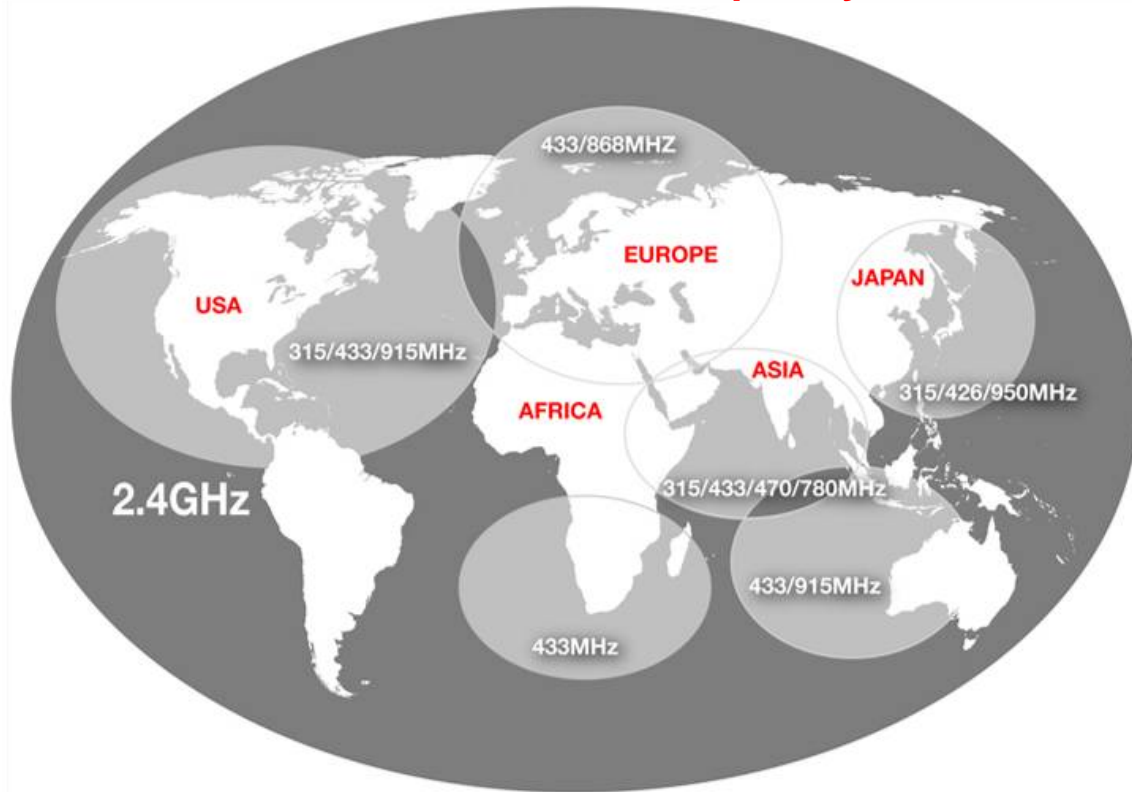


# Frequency

The choice of Frequency will influence

- RF range and maximum data rate
- Antenna design (size)
- Interference
- Regulations

## Unlicensed ISM/SRD Frequency Bands



# “World-wide” 2.4 GHz ISM Band

The 2400–2483.5 MHz band is available for license-free operation in most countries

## 2.4 GHz Pros

- Same solution for all markets without SW/HW alterations
- Large bandwidth available, allows many separate channels and high data rates
- 100% duty cycle is possible
- More compact antenna solution than sub-1 GHz

## 2.4 GHz Cons

- Shorter range than a sub 1 GHz solution (with the same current consumption)
  - Rule of Thumb: Double the frequency ~ half the range (e.g. 433 MHz longer range than 868 MHz)
- Many possible interferers are present in the band (WLAN, Bluetooth® technology, etc.)

# Sub 1GHz ISM Band

The ISM bands under 1 GHz are not world-wide and regulations vary a lot from region to region; however, in applications where range and robustness are critical parameters, sub GHz operation is an attractive choice.

## Sub 1GHz Pros

- Better range than 2.4 GHz with the same output power and current consumption
- Better penetration through buildings (concrete, wood etc) and “full house coverage” without extra power amplifier

## Sub 1GHz Cons

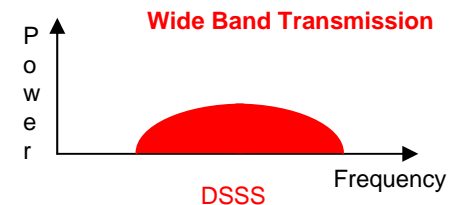
- Since different bands are used in different markets it can be difficult to find a design that can be used in all; however:
  - some can be combined (e.g. equal ref. design for 868 MHz and 915 MHz)
  - 433MHz can be used in USA, Europe, Africa and many parts of Asia (including China)
- More regulations regarding output power, data rate, bandwidth etc. than the 2.4 GHz
- Region specific regulations; e.g. duty cycle restrictions in Europe
- Lower frequency leads to bigger antennas

# Interference

Depending on the frequency chosen one has to cope with different types of interference.

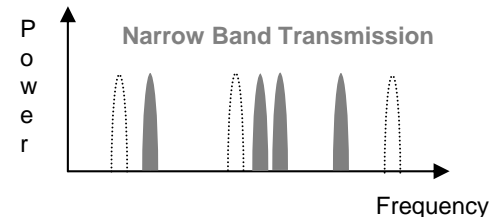
For wireless systems there are different methods to handle radio interference from WLAN, Bluetooth® devices, analog video, microwave ovens, other ISM systems, Cordless phones etc.:

- **DSSS** (Direct Sequence Spread Spectrum)
  - Increased robustness against multi-path fading
  - Increased sensitivity / robustness to narrow-band interference
  - Wider bandwidth required



- **Frequency agility**
  - Automatic or manual channel migration
  - The implementation has to account for sleeping devices as they might miss the control signal to switch channel while being asleep

- **Frequency hopping**
  - Synchronization required
  - The implementation has to assure that sleeping devices do not get out of sync



FHSS (Frequency Hopping Spread Spectrum)

# Regulations

## Unlicensed ISM/SRD bands

### USA/Canada:

260 – 470 MHz	(FCC Part 15.231; 15.205)
902 – 928 MHz	(FCC Part 15.247; 15.249)
2400 – 2483.5 MHz	(FCC Part 15.247; 15.249)

### Europe:

433.050 – 434.790 MHz	(ETSI EN 300 220)
863.0 – 870.0 MHz	(ETSI EN 300 220)
2400 – 2483.5 MHz	(ETSI EN 300 440 or ETSI EN 300 328)

### Japan:

315 MHz	(Ultra low power applications)
426-430, 449, 469, 955 MHz	(ARIB STD-T67/T9x)
2400 – 2483.5 MHz	(ARIB STD-T66)
2471 – 2497 MHz	(ARIB RCR STD-33)

**ISM** = Industrial, Scientific and Medical

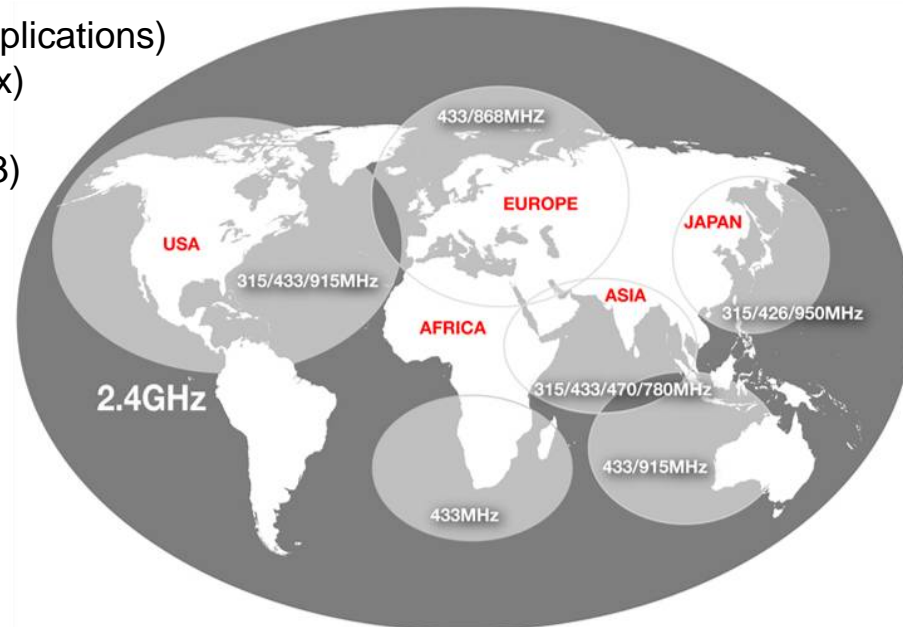
**SRD** = Short Range Devices

#### More info:

<http://www.fcc.gov>

<http://www.ero.dk>

<http://www.etsi.org>



# Standard vs. Proprietary

## Standards – pros

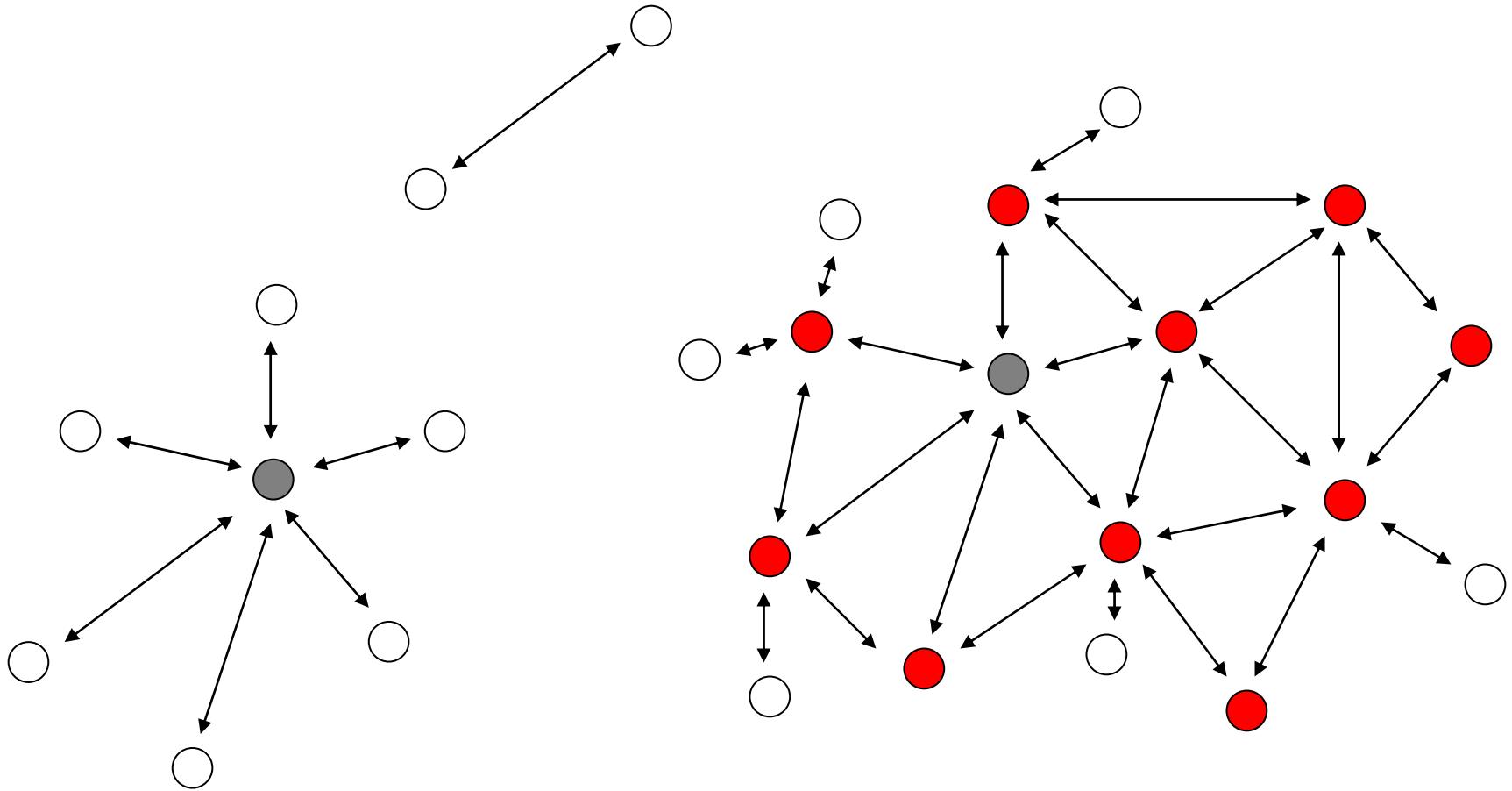
- Interoperability
- Easier to get started as features are already implemented  
e.g. the ZigBee standard provides routing algorithms that provide self-healing which you do not need to invent/implement yourself
- Mixed strategy: make and buy can be combined
- Multiple sources
- Economy of scales - competition
- Image/Marketing
- Products, modules and ICs with same technology

# Standard vs. Proprietary

## Standards – cons

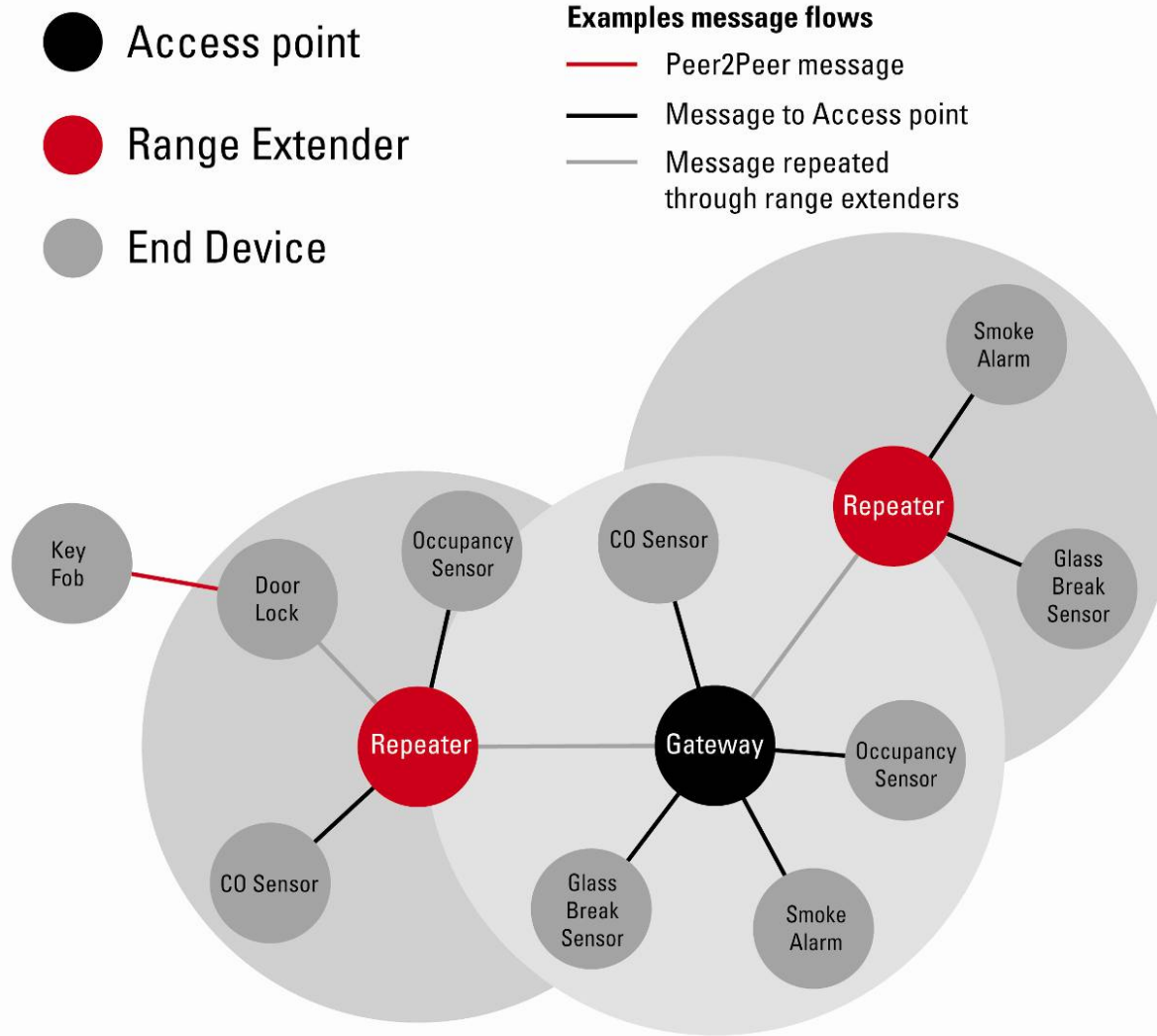
- Less design freedom
- Sometimes too many companies involved – many compromises
- Potentially (over) loaded with features
- Overhead
- Certification required to proof standard compliance

# Topology Peer2Peer? Star? Mesh?



# Topology

## Combining Star and Peer2Peer using repeaters?



# Topology

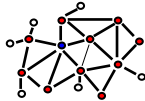
## What is the difference between Star and Mesh?

### Star network



- In a star network each node of the network is connected to a central node with a peer2peer connection.
- The data transmitted between two nodes travels through the central node unless the central node is the source/sink.
- In principle a protocol could also allow peer2peer communication without including the central node.

### Mesh network



- In Mesh networks some of the nodes of the network are connected to more than one other node in the network with a point-to-point link.
- Taking advantage of the resulting redundancy makes a mesh network more robust than a star network.
  - Data transmission between nodes will take the shortest route possible in the mesh and when a link breaks/fails and alternative route is found (if implemented by the protocol; e.g. self-healing feature in ZigBee).
- Supports bigger networks and covers a larger area (not restricted by RF range of a single node as messages can travel via several hubs).

# Feature set

**Next to the protocol specific features it is important to look at**

- Memory footprint and RAM usage
  - Depends mostly on number of protocol features
  - Is there enough code space and RAM available for the application?
- Effective data rate
  - Depends next to the chosen HW technology on protocol overhead
  - Keep in mind the difference between theoretical and practical data rates
- Power consumption (TX/RX)
  - Depends on the number of messages needed
- Extended features
  - Protocol specific (e.g. over-the-air-download)
  - Location
- API complexity
  - Is it easy to use? Can one use a reduced API set?



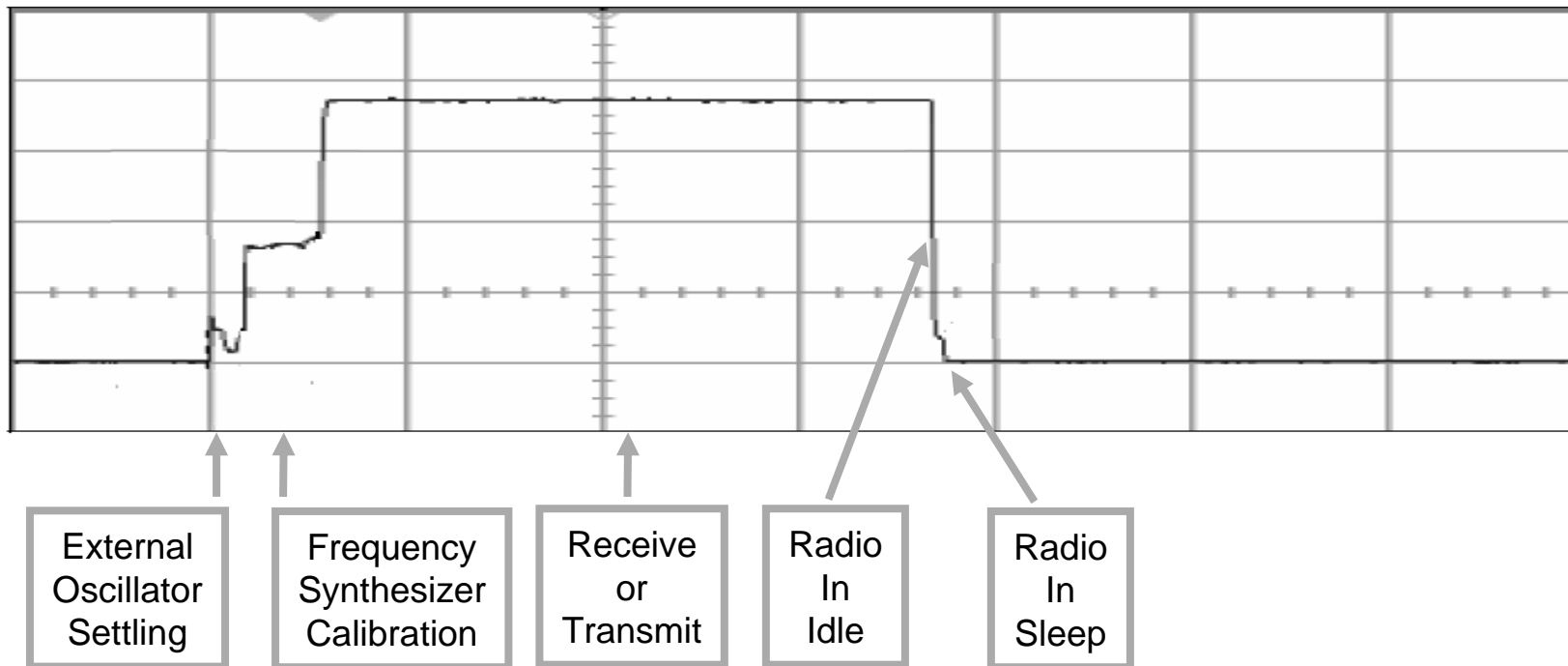
# RF performance / Range

- Antenna
  - Gain, sensitivity to body effects, etc.
- Channel Selectivity
  - Robustness regarding interference
- Sensitivity
  - Lowest input power with acceptable link quality (typically 1% PER)
- Output power
  - Possible (HW) vs. allowed (regulations) and useful (application)
- Environment
  - Line of sight, obstructions, reflections, multi-path fading, ...
- Range (link budget)
  - 120 dB link budget at 433 MHz gives approximately 2000 meters (TI rule of thumb)
  - Rule of Thumb:
    - 6 dB improvement ~ twice the distance
    - Double the frequency ~ half the range (433 MHz longer range than 868 MHz)

# Power consumption

- Sleep current / Start up times / Duty cycle
  - For a high duty cycle a low active current consumption is very important
  - For a low duty cycle the sleep current consumption is probably more relevant

**Typical Power Profile of a low power RF System**



# Available Expertise / Time to market / Tools

- What expertise do you have in-house?
  - Working with known technology (HW/SW) goes faster
  - Learning curve of new technology has influence on the product quality and time to market
- Design effort - How difficult is it to design the solution in? Is external help/expertise available?
  - Reference designs
  - 3rd parties (can provide development help or of the shelf modules/tools)
  - Modules
  - When using a standard you might/could buy certain parts of the shelf
- Tools (Compiler/Deployment/Commissioning/Monitoring)
  - Support
  - Availability
  - Quality



# Using external partners or modules

- Cost difference between module and self development covers:
  - Time to market - loss of sales
  - Certification (standard and regulatory)
  - Development risk
  - Capital binding
  - RF specialists required
  - Development administration overhead
- Additional benefits of using external partners/modules
  - Access to state-of-the art modules/expertise
  - Customer adaptations of "standard" modules

# Conclusion

The choice is not always that simple!

One has to look at the whole picture with regards to

- Time-to-market
- Required know-how
- Required resources
- Resulting costs
- Potential market
- ...

...combined with the application needs and targeted interoperability.

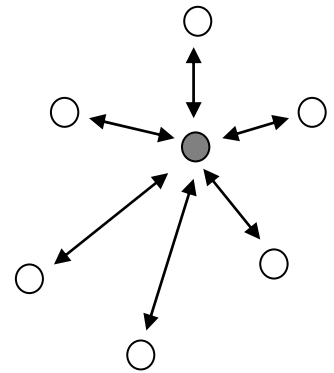
# Some examples for discussion

# Proprietary - Key features

- Full SW design freedom
  - You can implement exactly what you need/want
  - Optimal code size (as you do not have unused features implement)
  - You could e.g. only use the lower layer of SimpliciTI (MRFI layer)
- You can use any HW
- Only limitation given by regulations like FCC, ETSI, ...

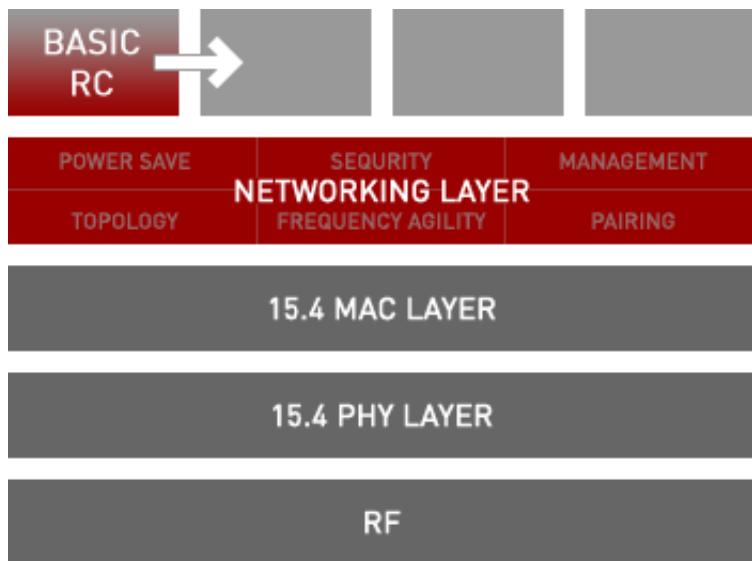
# IEEE 802.15.4 MAC

- Standardized HW & SW for battery-powered and/or mains powered nodes (IEEE 802.15.4 compliant)
  - DSSS included in the HW
  - Interoperability possible
- Beacon/Non-Beacon based star network
  - Allowing sleep mode in all nodes using Beacon-mode
- Suitable for applications with low data-rate requirements
- Code size (< 32 Kbyte)



- Standardized protocol
  - Interoperability possible (even up to the application layer using application profiles)
  - Off the shelf solutions/tools/modules
- Mesh networks (robustness/self healing)
- Long battery life
  - Router/Coordinator is not low power, but End device (e.g. light switch) is low power (many years on AA batteries)
- Supports large networks (hundreds of nodes)
- Intended for monitoring & control applications
- Easy to deploy (low installation cost)
- Code size (> 64 Kbyte; depends a lot on features & profiles used)
- Long feature list (Frequency agility, routing (self-healing), over the air download, binding, cluster library, security, m.m.)
- Based on all IEEE 802.15.4 compliant platforms

# ZigBee RF4CE

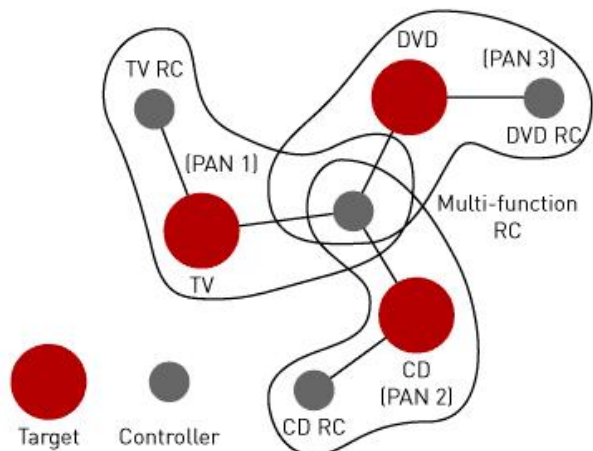


Based on IEEE 802.15.4

Includes a thin NWK layer

A single controller can control multiple targets (each link is point-to-point)

CERC interoperable profile



Thank you!

Questions?

Feel free to send me an email:

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