Low-Power RF Protocol Overview

How to choose the best fit for your application?

June 2009 – Version 1.7 TFL

When customers want to design a product using an RF solution they are often wondering which of the many available RF protocols to use.

Marketing material often only focuses on one protocol at a time or only compares one protocol with others where it is stronger.

This presentation aims at helping with the decision process with respect to which of the protocols to choose that TI offers/supports.

Definition of "protocol": In the field of telecommunications, a communications protocol is the set of standard rules for data representation, signaling, authentication and error detection required to send information over a communications channel

Note: It is up to the presenter and the time slot available to choose whether all material (especially both use cases) should be covered.

The material is modular and allows the presenter to take out certain detail slides if needed.

The case study slides are quite packed and the presenter might consider to use animation to have the different section appear slowly or split the single slides up into 2 or 3 slides (Pro/Cons/Conclusion)

Abstract

Texas Instruments Low Power RF (TI LPRF) offers RF solutions (Transceivers and SoCs) that target many different RF frequencies and standards.

For some of them TI provides the HW (sub1GHz and 2.4 GHz) and SW (proprietary: SimpliciTI™; standards: MAC 802.15.4, RemoTI™ and Z-Stack™ for the ZigBee® standard) and for others it provides the HW only and cooperates with partners to provide the SW (Wireless M-Bus, 6LoWPAN, SP100, WHART).

This training helps the attendee to better understand which questions to ask when taking the decision on which SW (RF protocol) to use. Although the main topic is SW also HW related questions like "Which frequency is targeted?" are discussed as they have an influence on which SW protocols one can chose from.

Then the advantages and disadvantages of the different protocols are discussed in more detail by looking at two different use cases

(1) Point-to-point connection for a remote control

(2) Multi node network to control the temperature in a house

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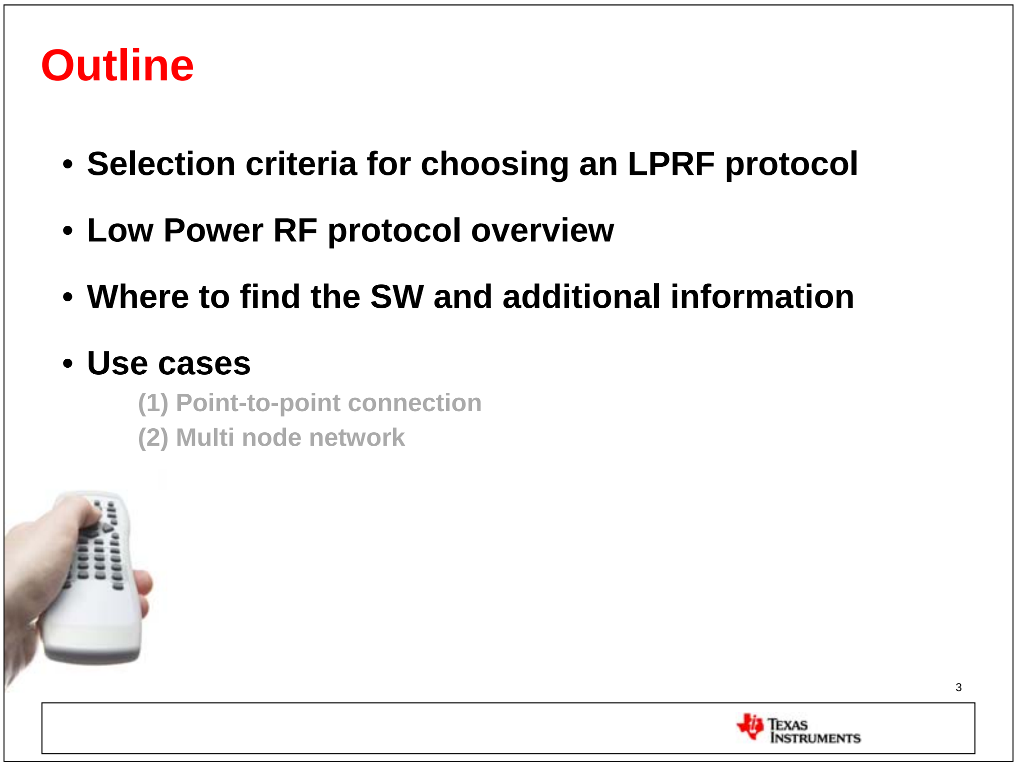
Abstract:

The decision of which RF protocol fits best for a certain application is not always easy; hence, the following slides will give some idea of what decision criteria and which aspects to look at.

Many companies have only 1 or two RF protocols to offer; hence, they do their best to convince the customer that their solution is the best for each application.

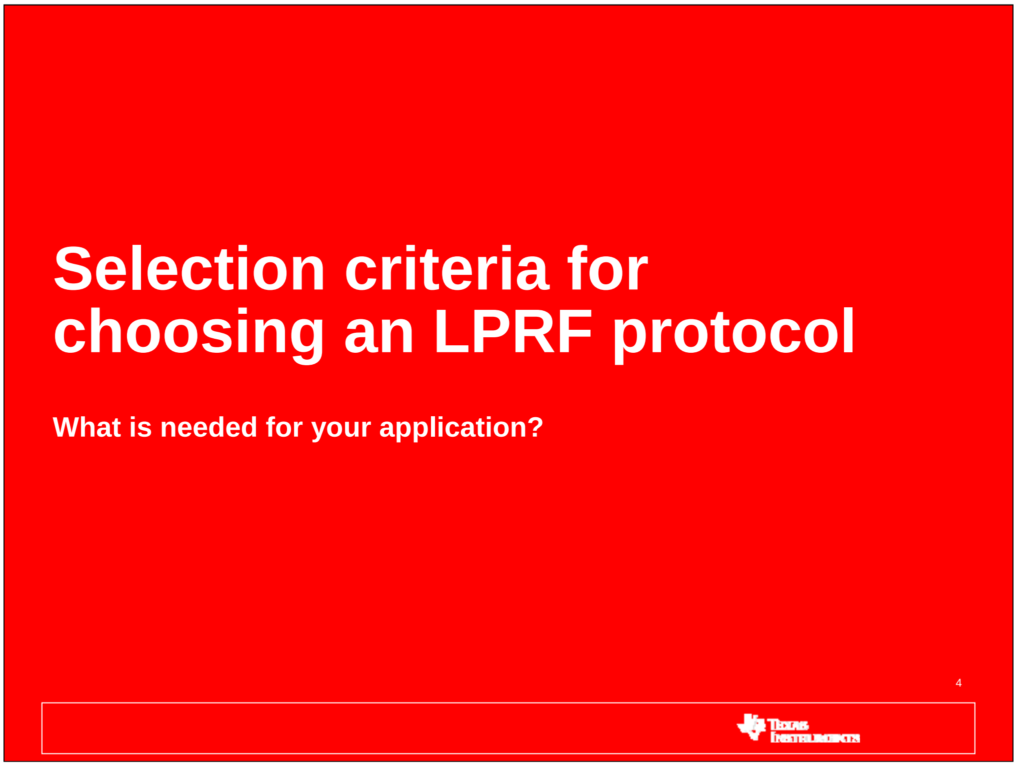
However, if you have a *hammer* it is not smart to see a *nail* in every application; especially not if you also have other *tools* in your pocket, because in case it is a *screw* it is better to use your *screw driver*.



Outline:

The presentation covers the following sections:

1) Decision criteria to consider – What to think of and look at before taking the decision.
2) Overview of what protocols and HW TI offers – Looking at the SW solution offered by TI LPRF
3) Where to find more info – providing links to useful information (SW, Community, 3rd party development network)
4) APPENDIX: Two example use cases – Looking at two completely different scenarios and showing how the different protocols fit in



When looking at which protocol to use it is important to know what is required from the targeted application's point-of-view.

In this section different questions/thoughts are considered that, depending on how they are answered for a particular application, will guide you to a good protocol fit.

Some users tend to look at the feature set of the protocols and then think the more the better or they do not see the differences between them as both might use the same wording but actually mean different things. Others think the smaller the code size the better, and so on… There are many different/individual views out there.

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

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Quality of Service is a known term in many Wireless technology areas (e.g. mobile phones)

When defining an application one often has already quite a clear picture of what kind of Quality of Service is expected:

-**Reliability**: Can one live with broken links, dead nodes (e.g. out of range), missed packets?

-**Battery life time**: How long should the battery powered devices last before they require battery change? Retransmissions increase power consumption. This parameter depends on how well HW and SW are set together to a low power system. It does not help to have a low power consumption HW wise if the protocol SW requires long active periods due to a lot of signaling (an vice versa).

-**Latency**: How fast must a message travel between A and B; can there be retransmissions? Depending on the effective/resulting data rate several transmissions might be needed to get big messages across which increases latency.

-**Co-existence**: What about systems in the near proximity (neighborhood) of the application? Can it cope with parallel/interfering systems? Other radio technologies?.

Some of the above QoS parameters are connected; e.g. to save power to reach a long battery life it is good to have devices going into sleep mode, but as they cannot receive any data in sleep mode latency increases.

The QoS needed is a good guide to find the right protocol fit. In some cases it might even help you to see that a wired solution might be needed, but those cases are rare.

An example could be that one wants ultra-low power in all nodes, but at the same

Some decision criteria

- Frequency
- Interoperability / Standard
- Topology
- SW feature set
- HW feature set
- Available Expertise
- Time to market
- Tools

…Conclusion

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This slide is an overview of the decision criteria discussed in the next sub sections!

This list is not complete but contains the decision criteria that are believed to be the most important to consider when looking at which protocol to use.

Of course one should first have a clear picture of which application one needs and which features the final product must provide.

The following is also listed on the following subsection intro slides:

Frequency: The Frequency determines which HW can be used, but it also has an influence on the protocol as TI-MAC, RemoTI and Z-Stack target the 2.4GHz space. Frequency is also relevant with respect to targeted market due to RF regulations (2.4GHz only global frequency band). More details in the following slides.
Interoperability: This is important in case that the product should be capable to interact with products from other vendors. RemoTI and Z-Stack (ZigBee) are the only solutions offering/enabling 100% interoperability. The TI-MAC can interoperate with other vendor solutions if the others are IEEE 802.15.4 compliant and both parts have agreed on the Higher Layer and Application protocol. SimpliciTI can provide it as well if the parties agree on how to use the SimpliciTI protocol. The latter of course also counts for pure proprietary solutions.
Topology: Does one need only point to point, or is a mesh NWK preferred/needed? A mesh could provide more range without using a high radio range (less interference).
SW feature set: The SW feature set is addressed in more detail in the key feature list for the different protocols later on, but this section mentions some important ones to consider when choosing a protocol.
HW feature set: Does the hardware provide what is needed? Does the performance match the application needs?
Available expertise: Depending on the know-how and experience available one might prefer a certain protocol. If one has none one could hire a 3rd party. It is important to have both RF and SW protocol expertise.

Time to market: Depending on the application it might often be easier to go with a protocol that offers the features needed (ZigBee, TI-MAC, SimpliciTI) than implementing them from scratch. However, it is important to check what is needed and what is offered. Also the learning curve with the protocol (due to its complexity) has an influence on the time to market.

Tools: It is also important to be aware of the tools needed to work efficiently with a protocol (in general one would always need a compile to build/debug the code and a packet sniffer to monitor the air traffic for debugging/monitoring).

Conclusion: One really has to look at the full picture!

Frequency: (5 slides)

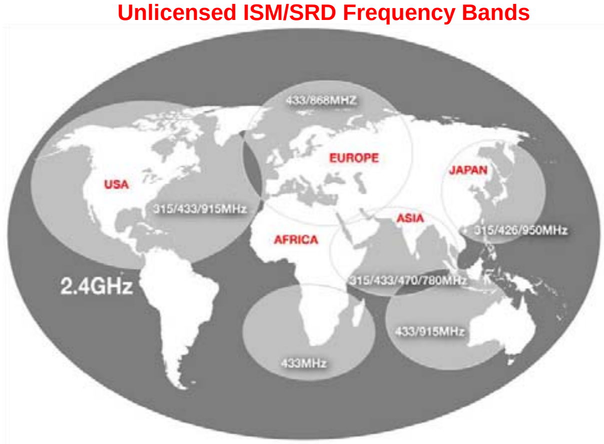
Frequency: The Frequency determines which HW can be used, but it also has an influence on the protocol as TI-MAC, RemoTI and Z-Stack target the 2.4GHz space. Frequency is also relevant with respect to targeted market due to RF regulations (2.4GHz only global frequency band).

Frequency

The choice of Frequency will influence

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

Unlicensed ISM/SRD Frequency Bands



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Frequency (slide 1 of 5) Little overview/intro - More details on following slides

Rules of Thumb

6 dB increase of output power or improve sensitivity by 6db the range is doubled.

Doubling the RF frequency reduces the range by a factor of 2.

“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.)

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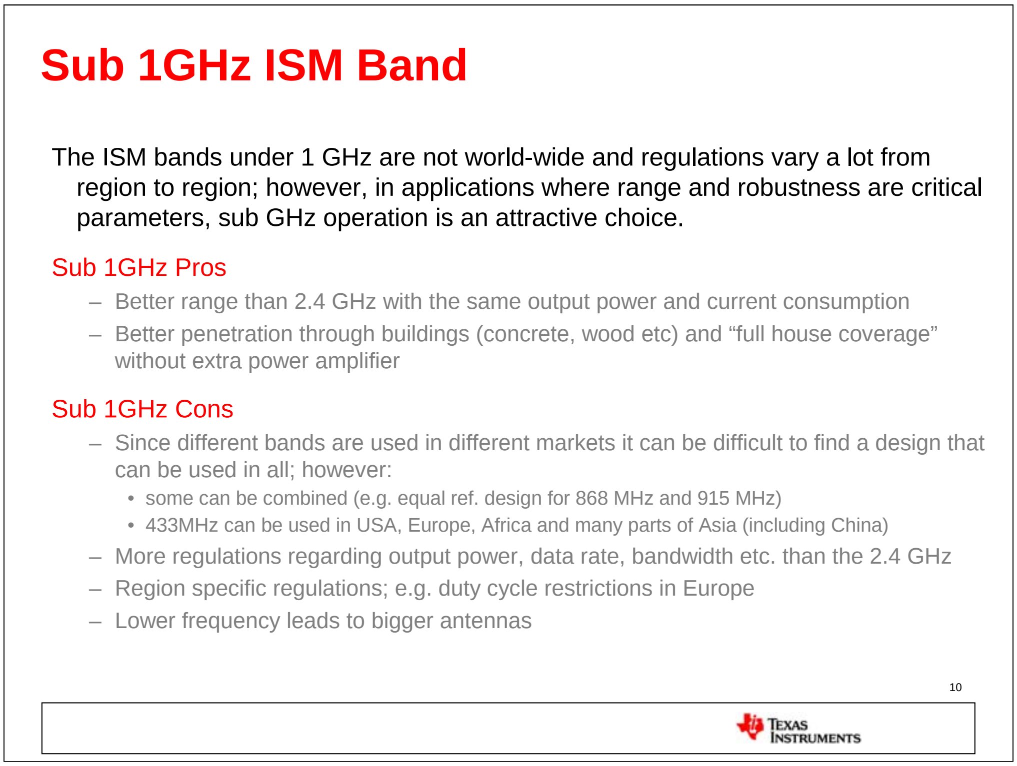
Frequency (slide 2 of 5) Pros and cons of using 2.4GHz

Rules of Thumb

6 dB increase of output power or improve sensitivity by 6db the range is doubled.

Doubling the RF frequency reduces the range by a factor of 2.



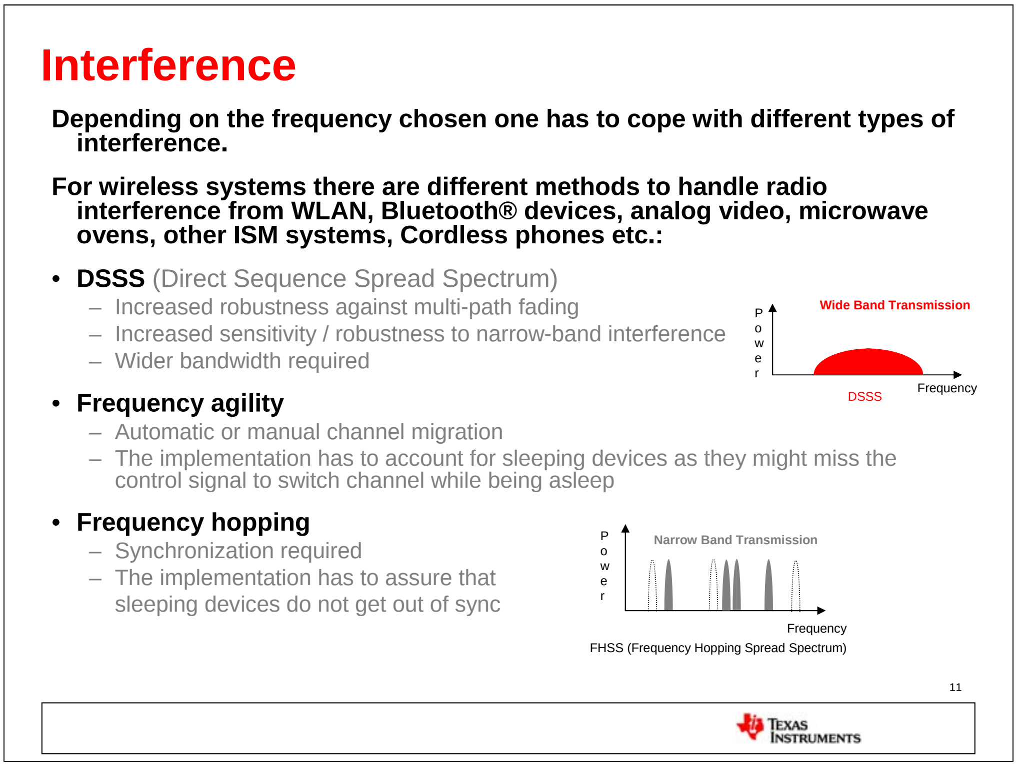
Frequency (slide 3 of 5) Pros and cons of using sub 1GHz

Sub GHz frequency bands are in general more regulated than the 2.4GHz band. Restrictions are put on e.g. output power, duty cycle and bandwidth usage. Although this generally requires more attention in the design cycle, it gives the benefit of more reliable links due to less interference (less “crowded” bands than 2.4GHz). In applications where range and robustness are critical parameters, sub GHz operation is the obvious choice.

The regulations for the sub 1GHz are a bit messy (as illustrated on Frequency slide 5 of 5) as each country has its own regulations for it and they often look at different aspects (amplitude, duty cycle, etc.)

Rules of Thumb

> 6 dB increase of output power or improve sensitivity by 6db the range is doubled.
>
> Doubling the RF frequency reduces the range by a factor of 2.



Frequency (slide 4 of 5) Interference

Frequency bands, and especially the 2.4 GHz band, can be crowded with lots of devices like WLAN, Cordless Phones, Bluetooth devices as well as other proprietary systems. For stationary systems operating on a single channel this can be a problem if the channel is jammed by other devices. A robust system should have some kind of channel migration scheme in place.

To understand interference one has to look both in the frequency and time domain as different standards and protocols are occupying the band differently. Although a system might occupy a wide part of the band, it might not be transmitting at all times and the time between can be utilized. Some systems are hopping at a deterministic frequency pattern (802.11) while others might hop at a pseudo-random frequency (Bluetooth technology) and this knowing the environment and possible interferences can be an advantage.

How one handles interference and how serious one takes this depends on the application and how important it is that communication is robust. Some applications might accept a few packages lost every now and then while others can't live with package losses at all. Few can tolerate being fully jammed for a period of time.

DSSS is a modulation scheme where the data signal is combined with a higher data rate sequence (chips) that is thereby spreading the energy of the original signal into a much wider band. Since the chips are a redundant bit pattern for each bit that is transmitted, one can still recover the original data if one or more bits in the transmitted pattern are lost due to interference.

Frequency Agility (FA) is a scheme where the system will move away from a noisy channel. This requires that some sort of synchronization in the system so that all devices move at the same time or one have to implement a scheme which allows for devices (especially sleeping devices) to find each other if one changes the frequency without all devices knowing.

Frequency Hopping (FH) is a scheme where each transmission is on a new channel/carrier either at a fixed or pseudo-random sequence. A variant, called Adaptive Frequency Hopping (**AFH**), improves resistance to interference by avoiding using crowded frequencies in the hopping sequence. Sleeping devices could require special attention if the FH is based on a specific timing and timers are turned off or less precise in low power mode.

FH also has the benefits that in some bands, systems with FH are allowed to transmit with <u>a higher output power</u> than non FH systems, thus have a higher range.

Regulations **Unlicensed ISM/SRD bands**

USA/Canada:

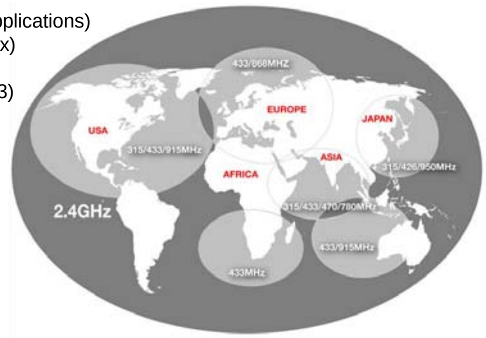
260 – 470 MHz	(FCC Part 15.231; 15.205)
902 – 928 MHz	(FCC Part 15.247; 15.249)
2400 – 2483.5 MHz	(FCC Part 15.247; 15.249)

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
http://focus.ti.com/lit/an/swra090/swra090.pdf (AN001)
http://focus.ti.com/lit/an/swra060/swra060.pdf (AN032)
http://focus.ti.com/lit/an/swra048/swra048.pdf

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Frequency (slide 5 of 5) Regulations to follow

The regulations for the sub 1GHz are a bit messy as each country has its own regulations for it and they often look at different aspects (amplitude, duty cycle, etc.)

More info can be found here:

http://www.fcc.gov

http://www.ero.dk

http://www.etsi.org

http://www.arib.or.jp/english/index.html

http://focus.ti.com/lit/an/swra090/swra090.pdf (AN001)

http://focus.ti.com/lit/an/swra060/swra060.pdf (AN032)

http://focus.ti.com/lit/an/swra048/swra048.pdf

Interoperability / Standard (2 slides)

Interoperability: This is important in case that the product should be capable to interact with products from other vendors. The ZigBee standards offers the possibility of 100% interoperability by defining application profiles to unify the communication between devices. The TI-MAC can interoperate with other vendor solutions if the others are IEEE 802.15.4 compliant and both parts have agreed on the Higher Layer and Application protocol. SimpliciTI can provide it as well if the parties agree on how to use the SimpliciTI protocol. The latter of course also counts for pure proprietary solutions.

Standard vs. Proprietary

ZigBee Alliance

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

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Interoperability / standard (slide 1 of 2) Looking into the pros of using a standard.

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

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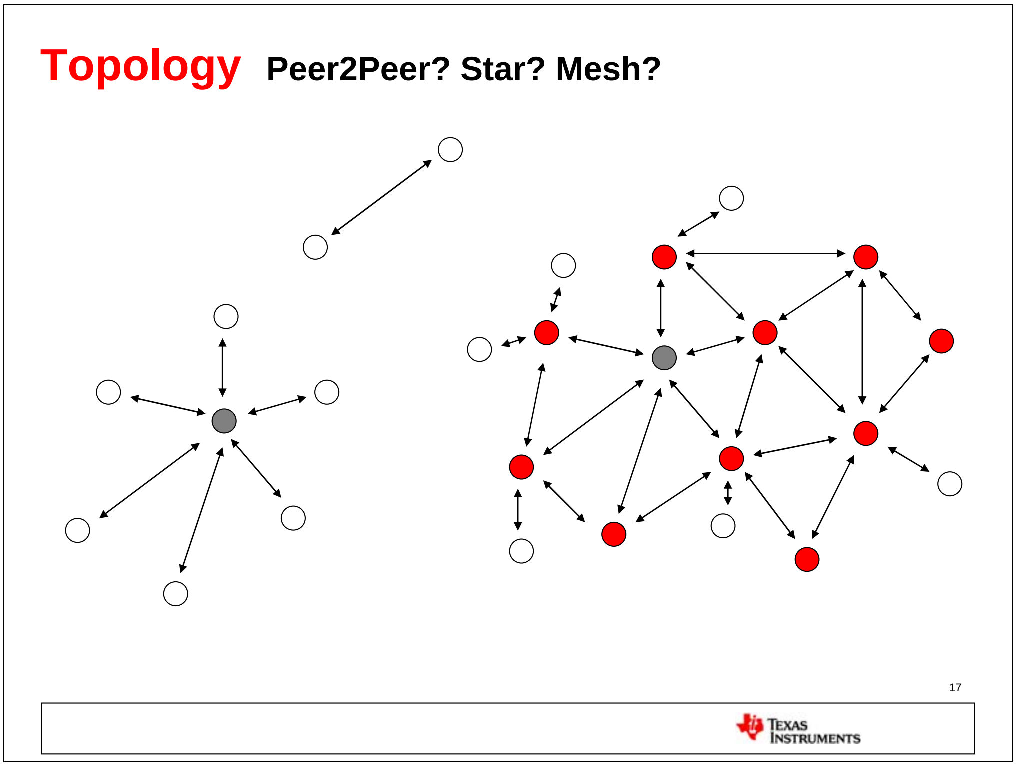
Interoperability / standard (slide 2 of 2) Looking into the cons of using a standard.

Topology (4 slides)

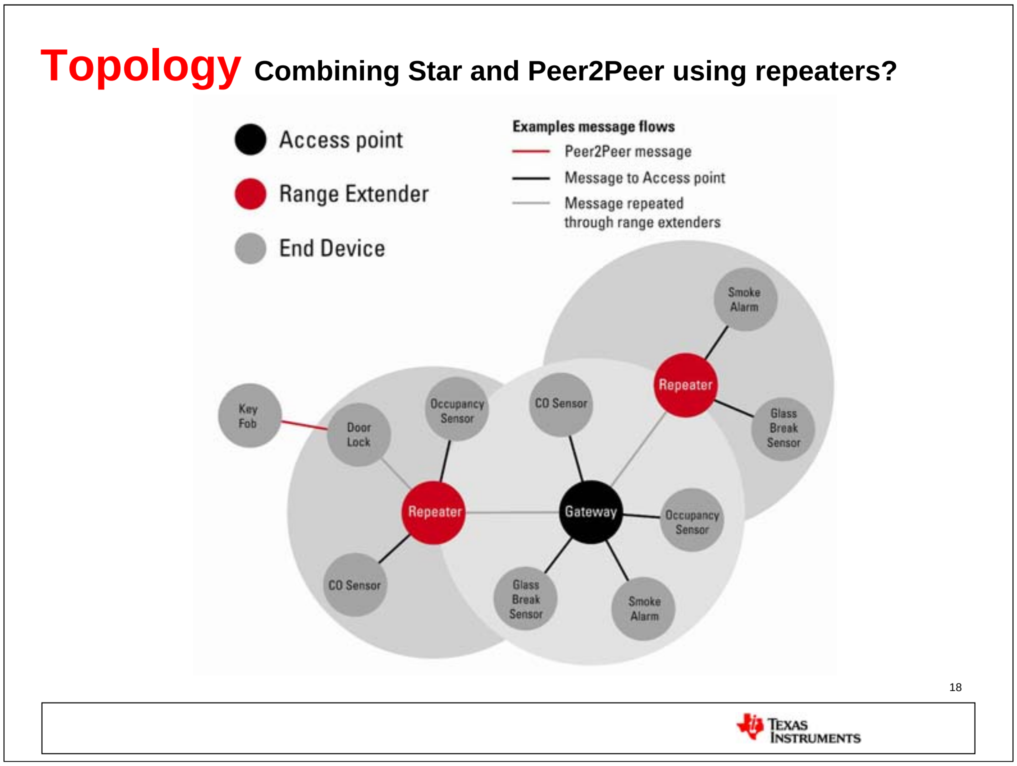
Topology: Does one need only point to point, or is a mesh NWK preferred/needed? A mesh could provide more range without using a high radio range (less interference).



Topology (slide 1 of 4)

There are far more topologies than the three illustrated; however, these are some of the most referenced ones.

As shown on the following slides there are possibilities to combine them or define special versions using additional protocol features.

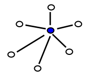


Topology (slide 2 of 4)

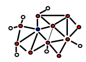
The above shown topology is an example of what one can achieve using SimpliciTI.

Note: A range extender is just that; i.e. it is not a router but just a pass through device that simply repeats the signal it received.

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).

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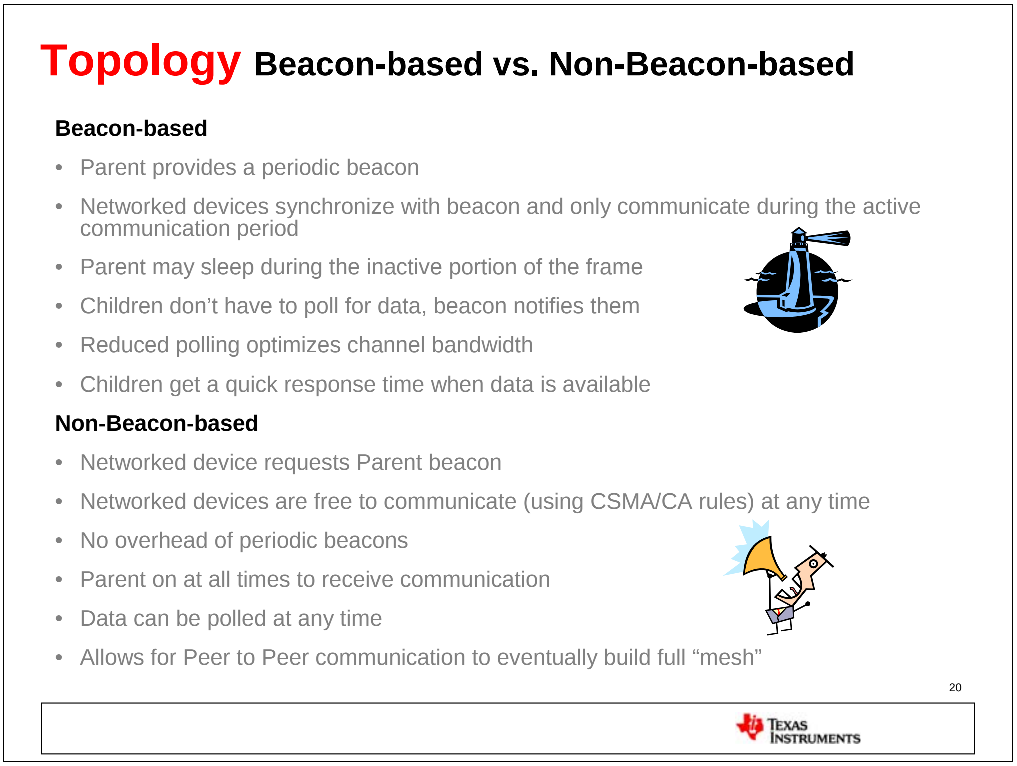
Topology (slide 3 of 4)

When comparing a star network with a mesh network it is best to take a closer look at what they provide.

A mesh network is basically a set of connected star networks which compared to the star network provides the following main advantages:

-Redundancy as there are often several alternative routes from A to B.

-Longer radio range as messages can travel using several hops.



Topology (slide 4 of 4)

When looking at LPRF protocols it is worth mentioning that TI-MAC also enables the so-called beacon mode which allows all devices to use sleep mode; hence they could potentially all be battery powered. Beacon mode was also originally considered for ZigBee but it got removed from the ZigBee stack profiles as it is not feasible in larger networks and it does not support Mesh networking.

However, when looking at a smaller network topology based on a star the beacon mode of the TI-MAC is an attractive feature.

In the beacon and non-beacon based solutions an end devices <u>wakes up</u> regularly:

Either as it knows there is a periodic beacon of the parent it has to listen to (beacon-based)

or because it wants to poll its parent (non-beacon based; here it does not have to be periodic, but often it is implemented using a polling rate).

The difference is that in beacon-based the parent determines with its beacon when to wake up while in the non-beacon based solution the end-device decides itself.

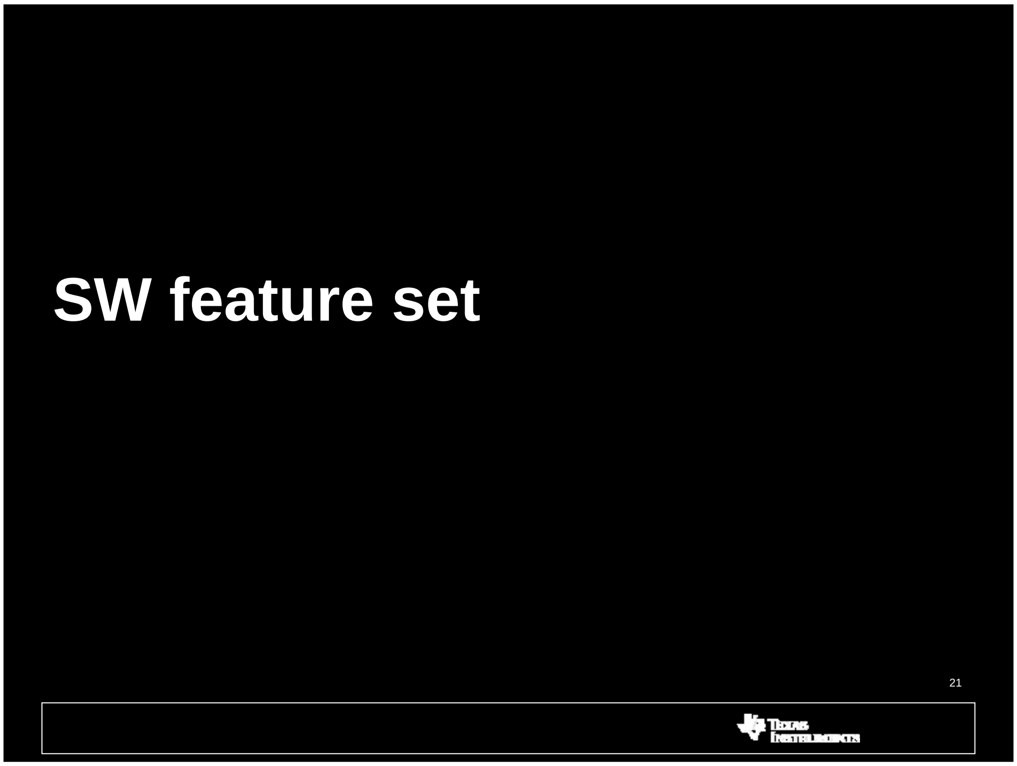
Then it checks for data to receive:

In the beacon based mode it simply listens to its parent after it received the beacon.

In the non-beacon based mode it actively sends out a data request and waits for the reply of the parent.

If it wants to send data:

It waits until a specified moment in time (beacon order set by the NWK parameters) after its parents beacon before transmitting its own data.



SW feature set (1 slide)

SW feature set: The SW feature set is addressed in more detail in the key feature list for the different protocols later on, but this section mentions some important ones to consider when choosing a protocol.

SW 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?

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SW feature set (slide 1 of 1)

Does the protocol provide what is needed?

Is there enough memory for the code and operation? (flash & RAM)

Is the effective data rate (that can be achieved for the targeted traffic model) sufficient?

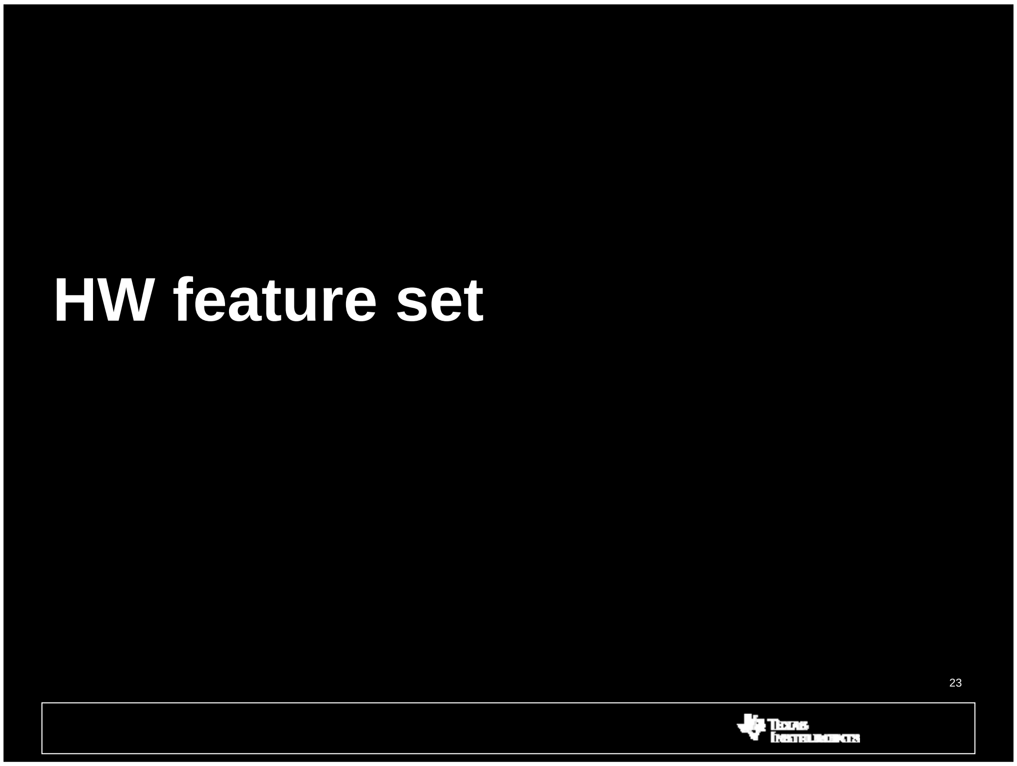
Is the SW supporting the targeted power consumption?

-Number of messages

-Number of retransmissions etc.

Are there extended features that should be used; e.g. over the air download of new firmware? Location?

Is the API of the SW easy to use? Is the SW in total easy to use and understand?



HW feature set (3 slides)

HW feature set: Does the hardware provide what is needed? Does the performance match the application needs?

-Is the RF performance good enough? (Sensitivity, max TX power, Selectivity)

-How does the power consumption look like and is it easily controlled by the SW?

-Does the HW provide the peripherals needed (timers, interfaces, etc.)?

-Is it difficult to design the final layout? Are there reference designs?

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)

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HW feature set (slide 1 of 3)

Is the RF performance good enough? (Sensitivity, max TX power, Selectivity, Range)

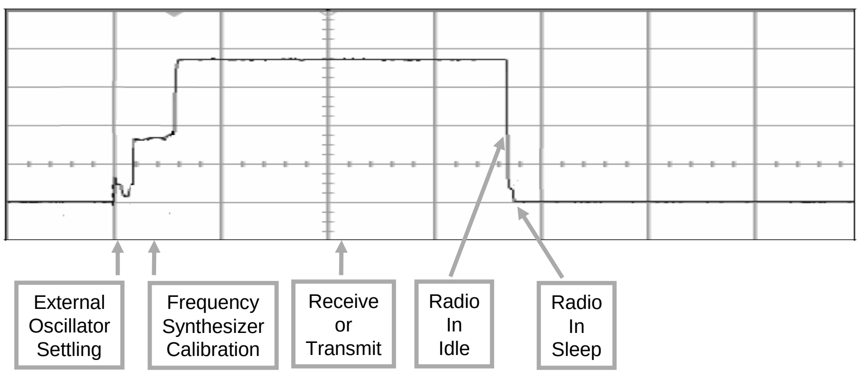
All the listed points have an influence on the RF performance hence also range; hence, depending on the application needs they can have significant impact on the protocol choice.

For example certain protocols as Z-Stack, TI-MAC, and RemoTI only support 2.4 GHz solutions.

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 LPRF System



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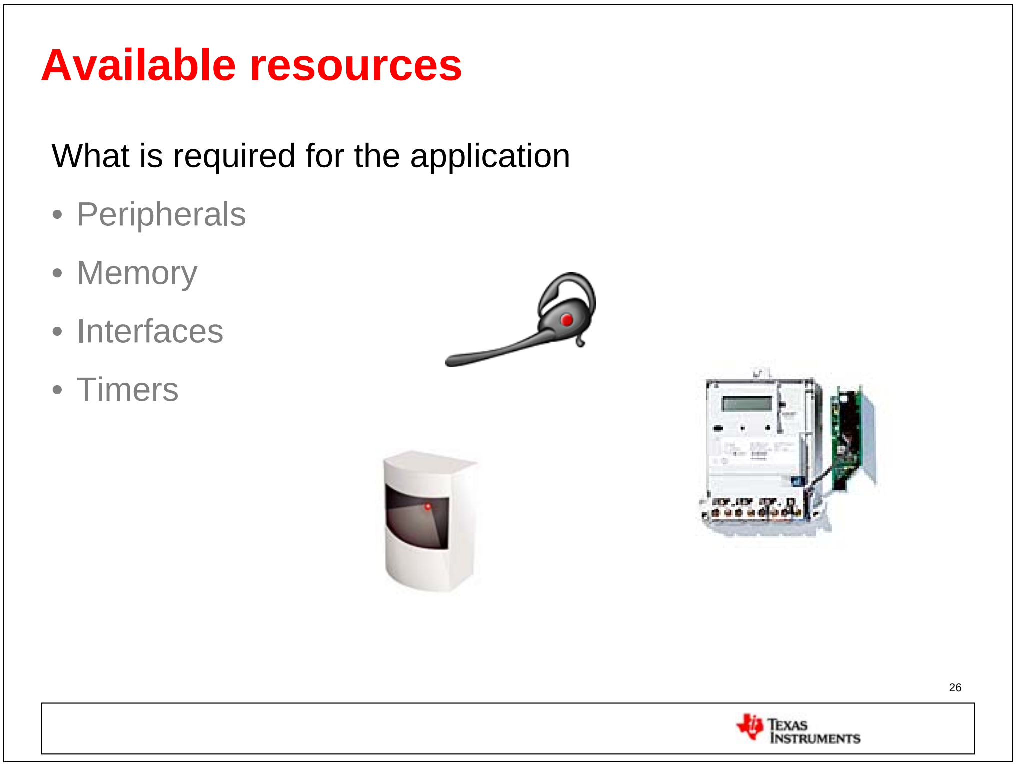
HW feature set (slide 2 of 3)

Power consumption is a key decision criteria when choosing low power RF solutions; as a result, one has to be very careful when evaluating it.

The protocol comes with a certain activity profile for each node regarding duty cycle, number of messages to send, stand by mode, etc.

Hence, it is not enough to simply look at the HW performance numbers alone (power consumption numbers for RX/TX and stand-by, start-up times, time needed to switch mode, …);

one has to look at the total picture (SW & HW).



HW feature set (slide 3 of 3)

Does the hardware provide what is needed with regards to resources (Peripherals, flash, RAM, timers, interfaces, etc.)?

Subsection (2 slides)

Available expertise: Depending on the know-how and experience available one might prefer a certain protocol. If one has none one could hire a 3rd party. It is important to have both HW/RF and SW/protocol expertise.

Time to market: Depending on the application it might often be easier to go with a protocol that offers the features needed (ZigBee, TI-MAC, SimpliciTI) than implementing them from scratch. However, it is important to check what is needed and what is offered. Also the learning curve with the protocol (due to its complexity) has an influence on the time to market.

Tools: It is also important to be aware of the tools needed to work efficiently with a protocol (in general one would always need a compiler to build/debug the code and a packet sniffer to monitor the air traffic for debugging/monitoring).

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

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(slide 1 of 2)

When looking at the development of a new product one also has to look at aspects like:

Know-how:

Which expertise do you have in house to do so? Does it make sense to train your own staff? Is it better to hire a 3rd party (see also next slide)?

Is the chosen technology easy to deploy/design-in?

Modules:

Modules are a good proof of concept start to the project; once you are satisfied with initial results you can go over to reference design if you are concerned about costs above 50k units per year.

Tools:

Are additional tools needed for deployment/commissioning?

Do you know the supported compilers? Are they powerful enough to support your needs (e.g. debugging support)?

Additional tools might add additional cost, but if the quality is high they often save more money than they cost (compared to freely available tools).

Who writes the better compiler? An IC/stack/application vendor or a compiler company?

Who writes the better packet sniffer? An IC/stack/application vendor or a specialized company?

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

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(slide 2 of 2)

It makes sense to consider the use of modules and/or external design/development help provided by 3rd parties.

Conclusion (1 slide)

As illustrated on the next slide: One really has to look at the full picture!

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.

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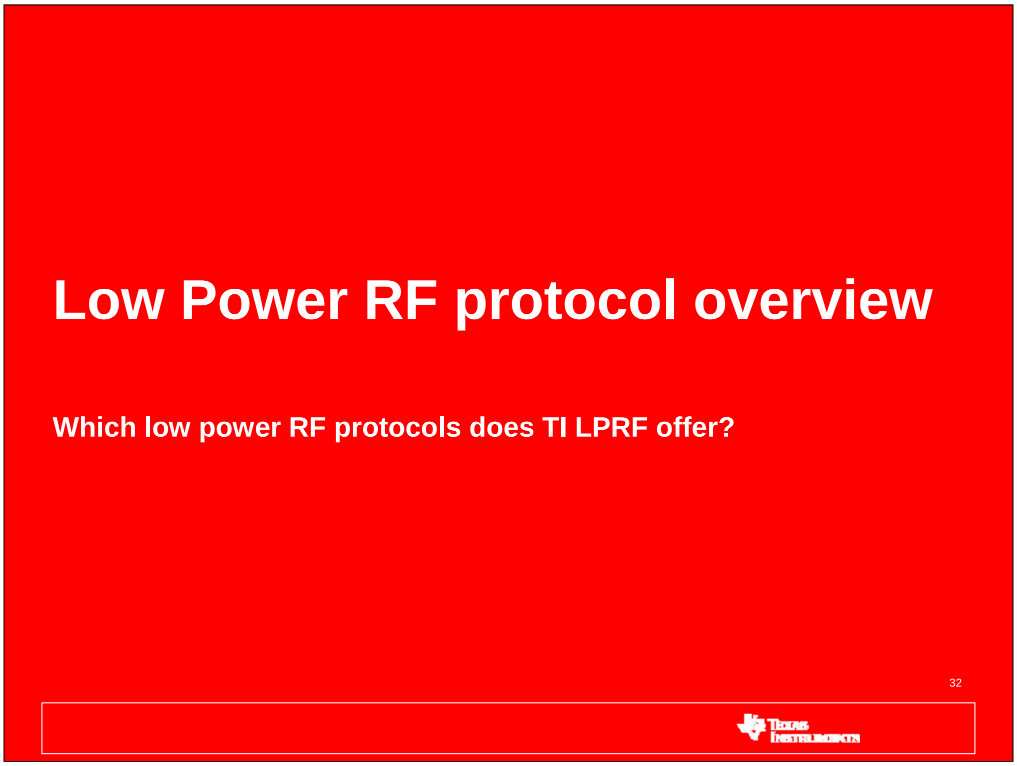
Conclusion (slide 1 of 1)

There is of course no simple conclusion as it really depends on so many factors which solution to choose (hence also no simple decision tree provided).

The main point to mention here is that one has to take the whole picture into account instead of looking at single features/topics/preferences only; e.g. One might be happy with the choice regarding all the discussed topics, but if it hits the potential market too late or with the wrong price it does not really matter that it is technically the perfect solution. On the other side if the focus is too much time line and cost perspective the solution might not be as good as needed to satisfy the end customer.



This section provides an overview of TI LPRF SW and HW offerings.

Low Power RF protocol overview

Layer \ Solution	Proprietary	SimpliciTI™	TI-MAC	RemoTI™	Z-Stack™
Application	Design freedom	Design freedom	Design freedom	Design freedom*	Design freedom*
Higher Layer Protocol	Design freedom	Design freedom	Design freedom	RF4CE	ZigBee
Lower Layer Protocol	Design freedom	SimpliciTI	IEEE 802.15.4	IEEE 802.15.4	IEEE 802.15.4
Physical Layer	TI HW	TI HW	IEEE 802.15.4	IEEE 802.15.4	IEEE 802.15.4
Frequency	Sub 1 GHz 2.4 GHz	Sub 1 GHz 2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz

Increasing interoperability

* RF4CE® and ZigBee® (HA, CBA, SE) standard define application user profiles that the user might use

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This slide is a simplification and does not contain all details, because if it did, it would be far too complex.

The main idea is to show that the different offerings have significant differences regarding which parts they offer and which parts the user can/must design himself.

The layered architecture is related to the OSI Model (Open Systems Interconnection Reference Model).

In the following some info is given on how to read the scheme followed by some additional comments.

The 1st column explains the 4 different layers and shows which frequencies are supported:

-**The physical layer; i.e. the HW/chip used.**

-Where TI HW stands for all TI RF chips (including the IEEE 802.15.4 chips)

-Where IEEE 802.15.4 in principle stands for all IEEE 802.15.4 compliant platforms, but in this case it mainly addresses TI's IEEE 802.15.4 HW (CC2420, CC2430/2431, CC2520, CC2480, CC2530 …)

-**The lower layer**; i.e. the SW driving the radio

-In some cases known as HAL (TI-MAC, RemoTI, and Z-Stack) or MRFI (SimpliciTI)

-**The higher layer protocol**; i.e. special network protocol functionality

-Here it is important to mention that SimpliciTI and TI-MAC might also offer some Higher Layer Protocol functionality but as they do not provide a full Higher Layer Protocol it is not marked as such.

-In RF4CE and ZigBee these are given by the standard (NWK layer etc.)

-**Application layer**

-For all protocols the user can freely write the application; however, for RF4CE and ZigBee the standards offers so-called application user profiles that standardize the communication in order to guarantee real 100% interoperability; hence, the footnote.

-**General comments:**

-Obviously the interoperability increases from the left to the right as more details are defined/standardized.

-The blocks are equally wide, however, the different protocols do not have the same "size"; the different solutions differ in feature set, code size, etc. (For more details about this the reader is referred to the overview slide providing links to additional information for each protocol)

Low Power RF protocol - HW overview

Platform	Proprietary	SimpliciTI	TI-MAC	RemoTI	Z-Stack
CC111x	supported	supported	Not feasible	Not feasible	Not feasible
CC251x	supported	supported	Not feasible	Not feasible	Not feasible
MSP430+CC1101	supported	supported	Not feasible	Not feasible	Not feasible
MSP430+CC2500	supported	supported	Not feasible	Not feasible	Not feasible
MSP430+CC2520	supported	supported	supported	Not supported	supported
CC2430/2431	supported	supported	supported	Not supported	supported
CC2480	Not supported	Not supported	Not supported	Not supported	supported
CC2530	supported	supported	supported	supported	supported

Additionally one can use the RF front end (PA/LNA) devices CC2590 & CC2591 for any 2.4 GHz based LP RF solution

Low-Power RF
Low-Power RF ICs
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This slide gives an overview regarding which HW and SW combinations are possible (e.g. ZigBee solution can only be based on IEEE 802.15.4 compliant radios, that is why it states “Not feasible” for the non IEEE compliant HW)

Additional it also depends on whether a tested SW installer is available for the different combinations. This is especially important for the MSP430+CC2520 combination for TI-MAC and ZigBee, as there might be other MSP430s capable of handling the code then the few MSP430 versions mentioned above but for them the SW has not been fully tested and hence no installer is provided).

Low Power RF protocol - Topology

- Proprietary solutions can in principle support every topology
  - If one writes the code for it!
- SimpliciTI™ SW is not bound to a specific topology
  - Based on Peer2Peer communication and/or star
  - Uses Range Extender (Repeaters)
- IEEE 802.15.4 MAC provides a star topology
  - Beacon based (allows all nodes to be battery powered) & non-beacon based
- RemoTI™ SW is based on IEEE 802.15.4 point-to-point communication with additional NWK layer
  - Targeting applications that need "direct, point-to-point monitoring and control". A single controller can control multiple targets, but each link is still point-to-point.
- Z-Stack™ SW provides self forming and repairing mesh networking, robustness
  - Based on a NWK layer on top of the IEEE 802.15.4 MAC

    (combining non-beacon based Star Networks to one Mesh Network)

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Quick topology overview showing which topologies the different protocols support.

Regarding the topology one can have a look at the topology slides earlier in this presentation.

In the topology section there is a **SimpliciTI** example "Topology Combining Star and Peer2Peer using repeaters?"

There you can also find more info about the beacon mode in **TIMAC** on the slide "Topology Beacon-based vs. Non-Beacon-based"

RemoTI should be recommended if the application needs "direct, point-to-point monitoring and control". A single controller can control multiple targets, but each link is still point-to-point.

Low Power RF protocol overview

Parameter	ZigBee PRO	ZigBee RF4CE	TIMAC (802.15.4)	SimpliciTI
Radio Frequency	2.4 GHz DSSS IEEE 802.15.4	2.4 GHz DSSS IEEE 802.15.4	2.4 GHz DSSS IEEE 802.15.4	Sub 1GHz 2.4 GHz 15.4 and proprietary
LPRF Products	CC2520+MSP, CC253x, CC259x	CC253x	CC2520, CC253x, CC259x	CC11xx, CC24xx, CC25xx, CC430
Distance / Range	100-400m @+4.5 dBm	100-400m @+4.5 dBm	100-400m @+4.5 dBm	Various (HW dependent)
App Data Rate	10's kbps	10's kbps	10-100+ kbps	Various
Nodes Targeted	10's to 100's	2-10's	2-10's	2-10's
Security	AES-128 +	AES-128	None	XTEA (default)
Robustness	DSSS + freq agility	DSSS + freq agility	DSSS	Freq agility (option DSSS)
Certification	ZigBee Alliance	ZigBee Alliance	NTS	None
Topology	Mesh	Star / P2P	Star	Star+Repeater
Power Consumption	20-30mA (Rx / Tx)	20-30mA (Rx / Tx)	20-30mA (Rx / Tx)	10-30mA Various
Profiles	Smart Energy HA, (CBA, Telecom, PHHC)	CERC – Remote Control	Proprietary	Proprietary
Kits	CC2520DK, CC2530ZDK	RemoTI-CC2530DK	CC2520DK, CC2530DK	Various DK
Markets	Metering, Home Automation, Medical, WSN, …	Remote Control for Consumer Electronics	Various	Various

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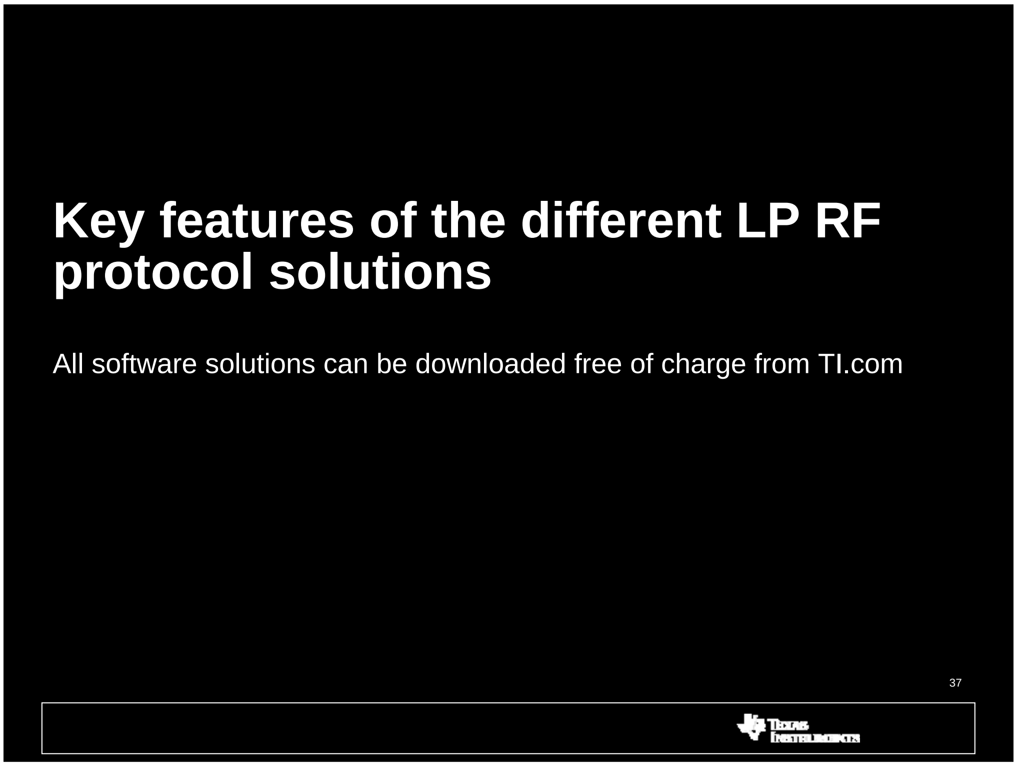
This table gives a quick comparison of the available TI Protocols.



In the following the key features for the different TI LPRF protocol offerings are listed…

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 TI LP RF HW
  except when using protocol specific NWK processors e.g. CC2480
- Only limitation given by regulations like FCC, ETSI, …

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Proprietary - Key features

SimpliciTI - Key features

- Simple
  - Utilizes a very basic core API
  - Protocol kit providing basic building blocks for building your own protocol
- Low Cost
  - Uses < 8K FLASH, 1K RAM depending on configuration due to small feature set
- Simple low-power RF network protocol aimed at small RF networks
  - Supports sleeping devices, frequency agility, acknowledgments, …
  - Typical for networks with battery operated devices that require long battery life, low data rate and low duty cycle
  - Flexible topology: simple star w/ extender and/or p2p communication
- Full source C - code
  - High design freedom
- Supports all TI LP RF HW solutions
  - Except protocol specific NWK processors (e.g. CC2480)

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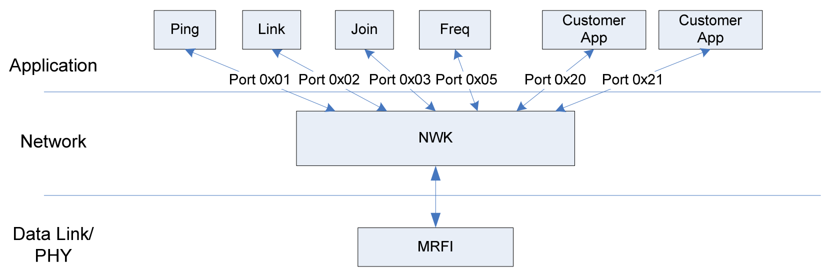
SimpliciTI - Key features (slide 1 of 2)

To see an example of the Flexible topology: simple star w/ extender and/or p2p communication see the Topology section "Topology Combining Star and Peer2Peer using repeaters?"

SimpliciTI - Key features

Layers

- Customer application
- Network application modules (e.g. frequency agility)
- Network (NWK)
- MRFI (“minimal RF interface”)



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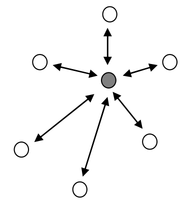
SimpliciTI - Key features (slide 2 of 2)

TI MAC - Key features

- Standardized HW & SW for battery-powered and/or mains powered nodes (IEEE 802.15.4 compliant)
  - DSSS included in the HW of the IEEE 802.15.4 compliant CC products
  - 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)
- Used in many end-products (also in RemoTI and Z-Stack)



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TIMAC - Key features

It is important to keep in mind that the TI-MAC is the only stack supporting beacon-based networks; see slide “Topology Beacon-based vs. Non-Beacon-based”

It is used in many applications/end-products and also in the RemoTI and ZigBee stack solutions.

RemoTI - Key features

- Based on standard initiated & driven by main players in the CE market:
- Standardized protocol/hardware
  - Off the shelf solutions
  - Provides protocol interoperability and one application profile
  - DSSS included in the HW of the IEEE 802.15.4 compliant CC products
- RemoTI Includes:
  - Frequency agility for multi-channel operation to avoid interference
  - Mechanism for secure transactions
  - Power save mechanism for power efficient implementations
  - Simple and intuitive pairing mechanism
- Targeting applications that need direct, point-to-point monitoring and control
  - A single controller can control multiple targets, but each link is still point-to-point
- Easy to deploy
- Code size (< 64 Kbyte)

The RF4CE industry consortium was formed to develop a new protocol that will further the adoption of radio frequency remote controls for audio visual devices.

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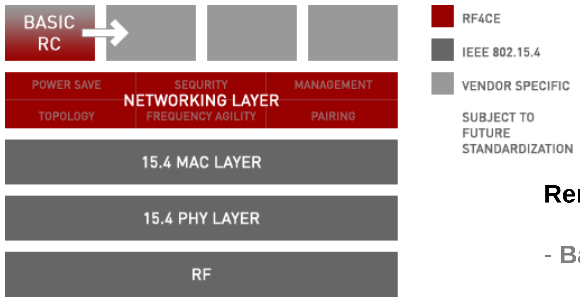
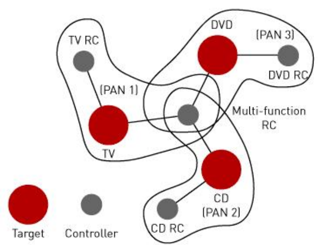
RemoTI - Key features (slide 1 of 2)

RemoTI - Key features



RemoTI protocol

- Based on IEEE 802.15.4
- Includes a thin NWK layer
- Command Set Interface
- A single controller can control multiple targets (each link is point-to-point)
- CERC interoperable profile



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RemoTI - Key features (slide 2 of 2)

Z-Stack - Key features

ZigBee® Alliance

- 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.)
- Supported on all IEEE 802.15.4 compliant platforms
  (e.g. CC2480, CC243X, CC2520+MSP430 and CC2530)
  DSSS included in the HW of the IEEE 802.15.4 compliant CC products

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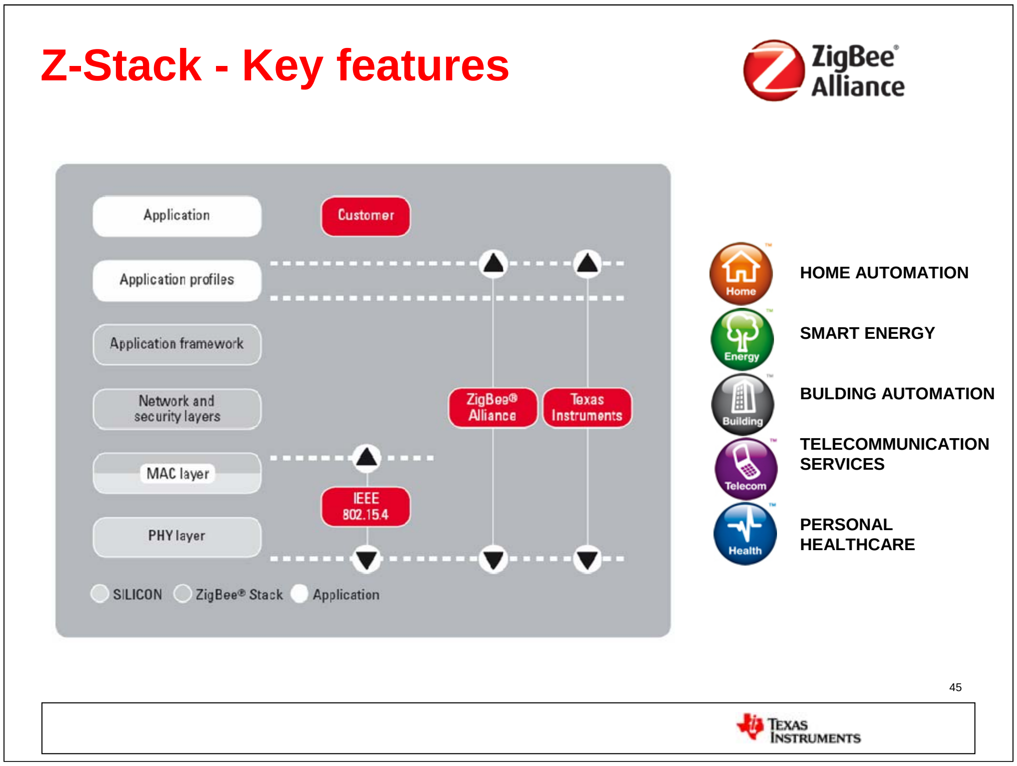
ZigBee - Key features (slide 1 of 2)



ZigBee - Key features (slide 2 of 2)

ZigBee supports so-called application profiles to allow 100% interoperability.

The ZigBee alliances is looking into many areas but the following areas are the "released ones" so far:

•HOME AUTOMATION

•SMART ENERGY

•BULDING AUTOMATION

•TELECOMMUNICATION SERVICES

•PERSONAL HEALTHCARE

Network protocol support from partners

SW offerings that are built on top of TI LP RF Hardware

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3rd parties provide SW (Wireless M-Bus, 6LoWPAN, SP100, WHART, …). that is built on top of TI LP RF Hardware.

Network protocol support from partners

Protocol	Target applications	Developer Network Partner	Compatible TI RF-ICs
Wireless M-Bus	Water, gas and e-meters to be connected inside house/apartment	**Radiocrafts**: Module with software stack **Amber Wireless**: Module with software stack	**CC1101 CC1110 CC430**
6LowPan	Metering infrastructure supporting a mesh network of meters	**Sensinode**: Software stack	**CC2430 CC2530**
SP100	Industrial Mesh Sensor infrastructure servicing difficult wireless environments	**Nivis**	**CC2430 CC2520 CC2530**
WHART	Wireless last 30M(100ft) extension of Wired Hart Protocol Industrial Buildings	**Nivis**	**CC2430 CC2530**

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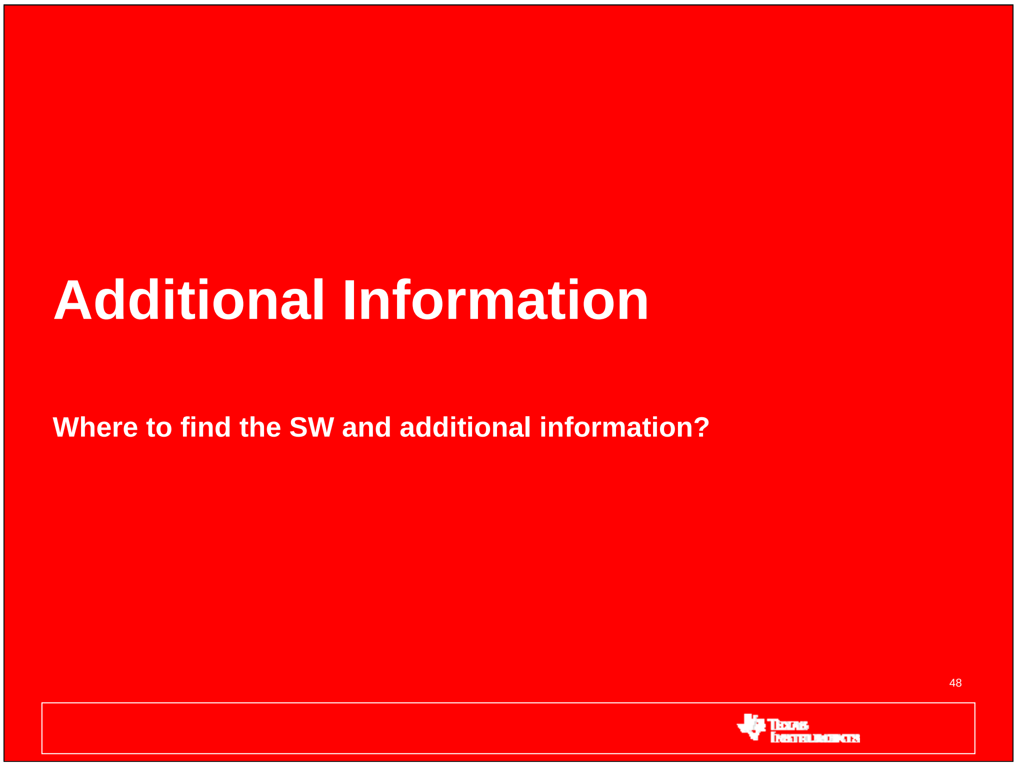
contact@nivis.com , http://www.nivis.com/technology/WirelessHART.aspx



This section guides the user to additional info

Additional Information

TI LPRF SW solutions (all free of charge!)

- **Z-Stack (ZigBee)**
  www.ti.com/zigbee
  www.ti.com/z-stack
- **RemoTI**
  www.ti.com/remoti
- **TI-MAC (IEEE 802.15.4 MAC)**
  www.ti.com/timac
- **SimpliciTI**
  www.ti.com/simpliciti

- **Proprietary code examples**
  See the chip product pages (Tools & Software section); some examples:
  CC2520 Software Examples (swrc090) : http://focus.ti.com/docs/prod/folders/print/cc2520.html
  CC1100 CC1101 CC2500 Examples Libraries (swrc021): http://focus.ti.com/docs/prod/folders/print/cc1100.html
  CC110x/CC2500 + MSP430 Examples(AN049, swra141): www.ti.com/ccmsplib

Links to the different protocols.

For the proprietary solution there is no single product, hence, no single product page. Instead the users can have a look at the available sample applications (e.g. PER test) and see how those can be used to write their own solutions. They can be found on the chip specific product page.

Additional Information

Where to find help & additional information:

- **TI Low Power RF website** – www.ti.com/lprf
  Where you can find a lot of information as the Developer Network
- **Customer Support**
  http://www.ti.com/support
  Email, Product Information Centers:
  Americas, EMEA, Japan, Asia

- **TI LP RF forum / E2E community**
  http://www.ti.com/lprf-forum

Where you can find FAQs, Videos, Design and Application Notes:
FAQs: https://community.ti.com/forums/51.aspx
DN: https://community.ti.com/search/SearchResults.aspx?tag=DN&orTags=0
AN: https://community.ti.com/search/SearchResults.aspx?tag=AN&orTags=0

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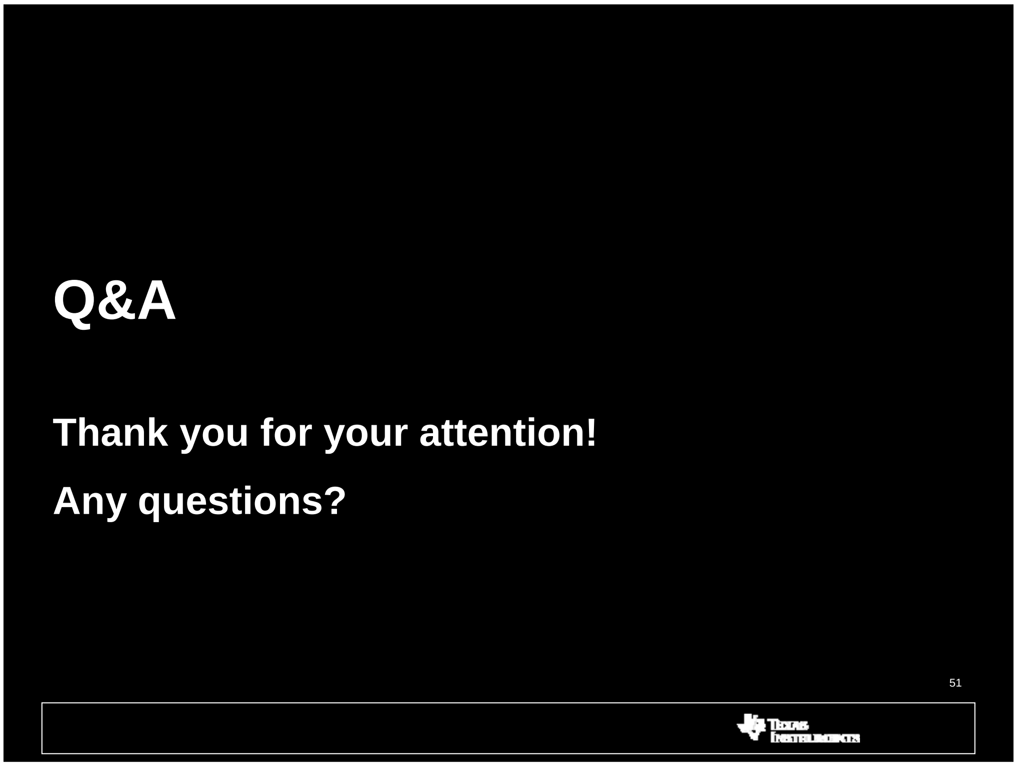
Links to other useful information & support



… time to take questions.

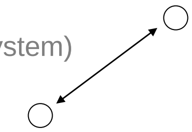
In the following you find use cases that can be used for further detailed illustration/discussion

Use case 1 – point-to-point connection

Use case (1)
Point-to-point connection for a remote control

Goal:

Designing a remote control for an air-conditioning (HVAC system)



Question:

Which technology/protocol would best fit the application?

- Proprietary
- SimpliciTI
- MAC 802.15.4
- RemoTI
- Z-Stack

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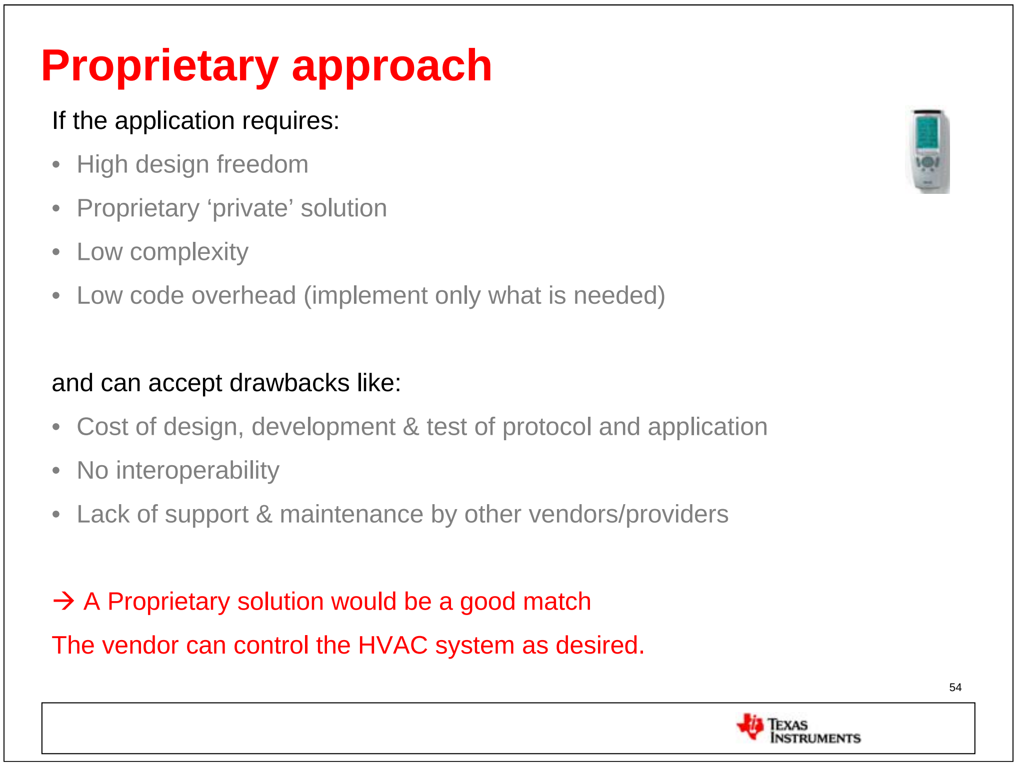
Use case 1 – Description/Intro



Use case 1 - Proprietary approach

When choosing the proprietary approach one will need good Embedded SW developers that can write all the code (as everything needs to be written almost from scratch as one can use code examples). Obviously this gives full freedom and one only implements what is needed; hence, does not need more flash, RAM than really needed (which then allows as well to use any of TI's RF HW solutions)

In principle one could of course add so many features that it also can handle some of the features the more advanced TI LPRF solutions offer; however, it requires a lot of work (especially on the testing and verification front). The other offerings are tested and used by many.

Proprietary approach using SimpliciTI

If the application requires:

- Freedom to design own higher layer protocol
- Lower cost on design & development than the pure proprietary solution
- Usage of available lower layer protocol to obtain easy implementation and deployment out-of-the-box
- Option of going for several TI RF platforms (such as the MSP430 family of low-power MCUs and the CC1XXX/CC25XX transceivers and SoCs) without big changes in the SW
- Avoidance of channel restrictions given by e.g. IEEE 802.15.4

and can accept drawbacks like:

- Design, development & test of higher layer protocol and application
- No interoperability

→ A proprietary solution using SimpliciTI would be a good match

The vendor can control the HVAC system as desired

At the same time SimpliciTI gives the freedom to select the best hardware for the solution since it supports both two chip solutions with the MSP430 MCU as well as System-on-Chip solutions such as CC1110 and CC2510. Additionally it makes it easy to upgrade to future generations of the TI RF platforms.

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Use case 1 - SimpliciTI approach

When choosing the proprietary approach based on SimpliciTI one still needs to write the higher layer protocol in case more advanced features are required.

So one would have to check the latest SimpliciTI release notes and then see how much is missing before knowing how much one still would have to add.

However, the big advantage here is that SimpliciTI comes in source code and has a very good low layer SW block (called MRFI layer) that also could be used (fully, partially) alone.

The source code allows the user to change all parts according to the application needs; i.e. add/change/remove features.

As for the pure proprietary solution one could in principle of course add so many features that it also can handle some of the features the more advanced TI LPRF solutions (TI-MAC, RemoTI, and Z-Stack) offer; however, it requires a lot of work (especially on the testing and verification front). The other offerings are tested and used by many.

SimpliciTI is smaller in code size than the more advanced TI LPRF solutions, but please remember that this is due to the fact that the others offer more features!

At the end the developer can then chose the best fitting HW (e.g. the best fitting MSP430 regarding flash/RAM)

As all TI RF HW solutions are supported by SimpliciTI one has a big variety of HW to chose from.

One is also not limited to the IEEE 802.15.4 compliant parts; i.e. one can use the CC1xxx (sub 1GHz) and the CC25xx transceivers and SoCs.

TI-MAC - IEEE 802.15.4 compliant approach

If the application requires:

- Standardized physical layer and lower layer protocol (IEEE 802.15.4)
- Freedom to design own higher layer protocol
- Free choice of different HW and lower layer SW vendors
- Interoperability on the physical and lower protocol layer
- Lower cost on design and development
- Support and maintenance by other vendors/providers

and can accept drawbacks like:

- Design, development & test of higher layer protocol and application, after understanding the IEEE 802.15.4 MAC functionality (development might be limited by the fact that the free TI-MAC code is not provided in full source code).
- Radio channel restrictions (to the channels specified in IEEE 802.15.4)

→ A TI-MAC IEEE 802.15.4 compliant solution would be a good match

The vendor can control the HVAC system as desired using a standardized HW platform.

One can pick from TI RF IEEE 802.15.4 compliant HW solutions (certain MSP430s with the CC2520 and the CC24xx SoCs). Using the TI-MAC makes it also easy to upgrade to future generations of the TI RF platforms.

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Use case 1 – TI-MAC approach

RemoTI - RF4CE compliant approach

If the application requires:

- Standardized physical layer and lower layer protocol (IEEE 802.15.4)
- Standardized higher layer protocol
- Minimal design and development effort (focusing on application only)
- Competition between support and maintenance vendors/providers

and can accept drawbacks like:

- Need to develop a HVAC specific profile as RemoTI per default only support the RF4CE type of profiles (TV, DVD, etc.)
- Code size (overhead of functionality one might not use)
- Radio channel restrictions (to the channels specified in IEEE 802.15.4)

→ An RemoTI based solution would be a good match

The vendor can control the HVAC system as desired (using a standardized HW & SW platform).

Additionally, one could also control other RF4CE compliant devices (if the corresponding application profiles are implemented)

Also one could buy complete/partial reference designs for the RF system (due to interoperability) or even better, buy an of-the-shelf reference design for the remote control where only the SW part needs to be modified to support the HVAC specific application.

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Use case 1 - RemoTI approach

Z-Stack - ZigBee compliant approach

If the application requires:

- Standardized physical layer and lower layer protocol (IEEE 802.15.4)
- Standardized higher layer protocol (providing e.g. mesh topology, multi-hop, …)
- Full interoperability; even up to the application layer (public profiles)
- Minimal design and development effort (focusing on application only)
- High competition between support and maintenance vendors/providers

and can accept drawbacks like:

- Code size (overhead of functionality one might not use)
- Cost for ZigBee Alliance membership
- Certification costs (not needed if not targeting a ZigBee compliant/certified product)
- Radio channel restrictions (to the channels specified in IEEE 802.15.4)

→ A ZigBee compliant solution would be a good match

The vendor can control the HVAC system as desired (using a standardized HW & SW platform).

Additionally, one could also control other devices (i.e. building a multi-functional remote control when using public application profiles like Home Automation (HA), Smart Energy (SE), etc.).

Also one could buy complete/partial reference designs for the RF system (due to interoperability) or even better, buy an of-the-shelf reference design for the remote control.

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TEXAS INSTRUMENTS

Use case 1 - ZigBee approach

Use case (2)

Multi node network

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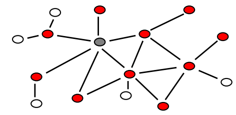
Use case 2 – multiple node network

Use case (2) - Multi node network to control the temperature and light in a house



Goal:

Install a wireless home control system (consisting of thermostats, controllers, air-conditioning, heaters, temperature sensors, lights, sun-blinds, etc.) to control the temperature and light in a house.

Question:

Which technology would best fit the application?

– Proprietary
– SimpliciTI
– MAC 802.15.4
– RemoTI
– Z-Stack

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Use case 2 – Description/Intro

Challenges that come with the multi node scenario:

-Topology to support the whole house

-Commissioning/Deployment

Proprietary approach

If the application requires:

- High design freedom
- Proprietary ‘private’ solution
- No additional complexity & code for features that are not needed for the specific application (implement only what’s needed)

  If the application requirements do not match any existing protocol offering.

and can accept drawbacks like:

- High cost of design, development & test of protocol and application starting from scratch
- Next to the application specific code one needs to
  - Define a network layer code to handle a large network topology/infrastructure
  - Resolve the deployment/commissioning challenge
- No interoperability; hence, lack of support & maintenance by other vendors/providers

→ A Proprietary solution would be a good match

However, one should be aware that it is a huge SW design, development & test task.

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Use case 2 - Proprietary approach

When choosing the proprietary approach one will need good Embedded SW developers that can write all the code (as everything needs to be written almost from scratch as one can use code examples). Obviously this gives full freedom and one only implements what is needed; hence, does not need more flash, RAM than really needed (which then allows as well to use any of TI’s RF HW solutions)

In this given use case one could argue that the functionality needed is already provided by protocols like ZigBee so why invest the huge design and development effort to “re-invent the wheel”.

It really only makes sense if the solution should be fully private and perfectly tailored for the application.

Proprietary approach using SimpliciTI

If the application requires:

- Freedom to design own higher layer protocol
- Lower cost on design, development & test than the pure proprietary solution
- Usage of available lower layer protocol to obtain easy implementation and deployment out-of-the-box
- Avoidance of channel restrictions given by e.g. IEEE 802.15.4

and can accept drawbacks like:

- Cost of design, development & test of higher layer protocol and application starting from scratch
- Next to the application specific code one needs to
  - Define a network layer code to handle a large network topology/infrastructure
  - Resolve the deployment/commissioning challenge
- No interoperability; hence, lack of support & maintenance by other vendors/providers

→ A proprietary solution using SimpliciTI would be a good match

However, one should be aware that it is still a huge SW design, development & test task as SimpliciTI is not targeting large networks (as a home automation system could/would be quite large).

At the same time SimpliciTI gives the freedom to select the best hardware for the solution since it supports both two chip solutions with the MSP430 MCU as well as System-on-Chip solutions such as CC1110 and CC2510. Additionally it makes it easy to upgrade to future generations of the TI RF platforms.

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Use case 2 - SimpliciTI approach

When choosing the proprietary approach based on SimpliciTI one still needs to write the higher layer protocol in case more advanced features are required.

So one would have to check the latest SimpliciTI release notes and then see how much is missing before knowing how much one still would have to add.

However, the big advantage here is that SimpliciTI comes in source code and has a very good low layer SW block (called MRFI layer) that also could be used (fully, partially) alone.

The source code allows the user to change all parts according to the application needs; i.e. add/change/remove features.

As for the pure proprietary solution one could in principle of course add so many features that it also can handle some of the features the more advanced TI LPRF solutions (TI-MAC, RemoTI, and Z-Stack) offer; however, it requires a lot of work (especially on the testing and verification front). The other offerings are tested and used by many.

SimpliciTI is smaller in code size than the more advanced TI LPRF solutions, but please remember that this is due to the fact that the others offer more features!

At the end the developer can then chose the best fitting HW (e.g. the best fitting MSP430 regarding flash/RAM)

As all TI RF HW solutions are supported by SimpliciTI one has a big variety of HW to chose from.

One is also not limited to the IEEE 802.15.4 compliant parts; i.e. one can use the CC1xxx (sub 1GHz) and the CC25xx transceivers and SoCs.

The SimpliciTI might not really be a good match as the cost of design, development & test of higher layer protocol and application is big.

TI-MAC - IEEE 802.15.4 compliant approach

If the application requires:

- Standardized physical layer and lower layer protocol (IEEE 802.15.4)
- Freedom to design own higher layer protocol
- Free choice of different HW and lower layer SW vendors
- Interoperability on the physical and lower protocol layer
- Lower cost on design and development
- Support and maintenance by other vendors/providers

and can accept drawbacks like:

- Cost of design, development & test of higher layer protocol and application, after understanding the IEEE 802.15.4 MAC functionality (development might be limited by the fact that the free TI-MAC code is not provided in full source code).
- Next to the application specific code one needs to
  - Define a network layer code to handle a large network topology/infrastructure
  - Resolve the deployment/commissioning challenge
- That the network topology (using 2.4 GHz) is targeting a star network, which is unlikely to cope with large multi room home automation systems.
- Radio channel restrictions (to the channels specified in IEEE 802.15.4)

→ A TI-MAC IEEE 802.15.4 compliant solution would be a good match

One can pick from TI RF IEEE 802.15.4 compliant HW solutions (certain MSP430s with the CC2520 and the CC24xx SoCs). Using the TI-MAC makes it also easy to upgrade to future generations of the TI RF platforms.

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Use case 2 - MAC approach

The MAC approach is not really a good match in this case as the Cost of design, development & test of higher layer protocol and application is big.

It might even not be possible due to the fact that the free TI-MAC code is not provided in full source code.

If one wants a TI-MAC - IEEE 802.15.4 compliant approach it would be a good idea to look at ZigBee for a large home automation system.

The MAC is targeting small star networks while ZigBee targets large networks like the one described here.

RemoTI - RF4CE compliant approach

If the application requires:

- Standardized physical layer and lower layer protocol (IEEE 802.15.4)
- Standardized higher layer protocol
- Low design and development effort (focusing on application and higher layer networking)
- Competition between support and maintenance vendors/providers

and can accept drawbacks like:

- Need to develop a Home Automation specific profile as RemoTI per default only support the RF4CE type of profiles (TV, DVD, etc.)
- Cost of design, development & test of higher layer protocol and application, after understanding the RemoTI functionality (development might be limited by the fact that the free RemoTI code is not provided in full source code).
- Next to the application specific code one needs to
  - Define a network layer code to handle a large network topology/infrastructure
  - Resolve the deployment/commissioning challenge
- RemoTI network topology (using 2.4 GHz) is designed for point-to-point communication; hence, it is not meant to be used to build a larger NWK topology on top; hence, it is unlikely to cope with large multi room home automation systems.
- Code size (overhead of functionality one might not use)
- Radio channel restrictions (to the channels specified in IEEE 802.15.4)

→ An RemoTI based solution would be a good match

Additionally, one could also control other RF4CE compliant devices (if the corresponding application profiles are implemented)

However, one should be aware that it is not a trivial and straight forward task to modify the RemoTI code to be able to cope with large networks (as a home automation system could/would be quite large).

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Use case 2 - RemoTI approach

The RemoTI approach is not really a good match as the Cost of design, development & test of higher layer protocol and application is big.

It might even not be possible due to the fact that the free RemoTI code is not provided in full source code.

If one wants a IEEE 802.15.4 compliant approach it would be a good idea to look at ZigBee for a large home automation system.

RemoTI should be recommended if the application needs "direct, point-to-point monitoring and control". A single controller can control multiple targets, but each link is still point-to-point.

RemoTI is targeting small topologies based on P2P connections, while ZigBee targets large networks like the one described here.

It is not the goal of RemoTI to support large networks with an application that is not using a pre-defined profile.

Z-Stack - ZigBee compliant approach

If the application requires:

- Standardized physical layer and lower layer protocol (IEEE 802.15.4)
- Standardized higher layer protocol (providing e.g. mesh topology, multi-hop, …)
- Full interoperability; even up to the application layer (public profiles)
- Minimal design and development effort (focusing on application only)
- High competition between support and maintenance vendors/providers
- A network layer code to handle a large network topology/infrastructure
- Help to resolve the deployment/commissioning challenge

and can accept drawbacks like:

- Code size (overhead of functionality one might not use)
- Cost for ZigBee Alliance membership
- Certification costs (not needed if not targeting a ZigBee compliant/certified product)
- Radio channel restrictions (to the channels specified in IEEE 802.15.4)

→ A ZigBee compliant solution would be a good match

ZigBee has been designed for these kind of application examples; hence, it is naturally the best fit as it provides a public application profile for Home Automation (HA), Smart Energy (SE), etc.

Also one could buy complete/partial reference designs/devices for a home automation system.

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Use case 2 - ZigBee approach

ZigBee has been designed for these kind of application examples; hence, it is naturally the best fit as it provides a public application profile for Home Automation (HA), Smart Energy (SE), etc.

Also one could buy complete/partial reference designs/devices for a home automation system.

Additionally it provides deployment/commissioning help.

Glossary

Abbreviations

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Use case 2 – multiple node network

Glossary

6LoWPAN	IPv6 over Low power Wireless Personal Area Networks
AFH	Adaptive Frequency Hopping
API	Application Programming Interface
CA	Collision Avoidance
CE	Consumer Electronics
CERC	Consumer Electronics Remote Control
CSMA	Carrier Sense Multiple Access
DSSS	Direct Sequence Spread Spectrum
E2E	Engineer to Engineer
FA	Frequency Agility
FH	Frequency Hopping
HA	Home Automation
HVAC	Heating, Ventilation and Air Conditioning
HW	Hardware
IC	Integrated Circuit
IEEE	Institute of Electrical and Electronics Engineers
IPv6	Internet Protocol Version 6
ISM	Industrial, Scientific and Medical
LNA	Low Noise Amplifier
LPRF	Low Power Radio Frequency
MAC	Medium Access Control
M-Bus	Meter-Bus
MCU	Micro Controller Unit
MRFI	Minimum RF interface
NWK	Network
OSI	Open Systems Interconnection
P2P	Peer to Peer
PA	Power Amplifier
QoS	Quality of Service
RAM	Random Access Memory
RC	Remote Control
RF4CE	RF for Consumer Electronics
RX	Receive
SE	Smart Energy
SoC	System on Chip
SRD	Short Range Device
SW	Software
TX	Transmit
WHART	Wireless Highway Addressable Remote Transducer
WLAN	Wireless Local Area Network

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