The ZigBee® RF4CE standard
New application scenarios

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Remote Controls: Past/Present/Future

- **Wireless remote controls exist for many decades**
- **Infrared technology is standard for consumer electronic devices since the 80‘s**
  - ... Nothing really new for more than 20 years?
- **RF technology available since a few years**
- **No real standard so far ...**

Remote Controls: Infrared

Infrared technology

- **is established and cheap**

But:

... has short range

... needs line-of-sight

... allows only one-way communication

... needs more energy

... is not secure

Remote Controls: ZigBee RF4CE

RF4CE technology

- **is a bit more complex and not low cost yet**

But:

... has long range and wall penetration

... needs no line-of-sight

... uses two-way communication

... has ultra-low power consumption

... offers 128-bit AES security

And:

- **is a certified standard supported by multiple vendors**

The ZigBee RF4CE Standard

- **RF4CE stands for „Radio frequency for consumer electronics“**
- **Based on initial specification from the RF4CE consortium:**
  - Panasonic, Philips, Samsung and Sony
- **Since early 2009 maintained by the ZigBee alliance**
- **Version 1.00 released in March 2009, downloadable from ZigBee alliance**
- **Certified end products will carry this logo:**

ZigBee RF4CE – device roles & topologies

- Consumer electronics primarily consist of a device that controls and one or more devices that are controlled.
- ZigBee RF4CE defines two primary roles:

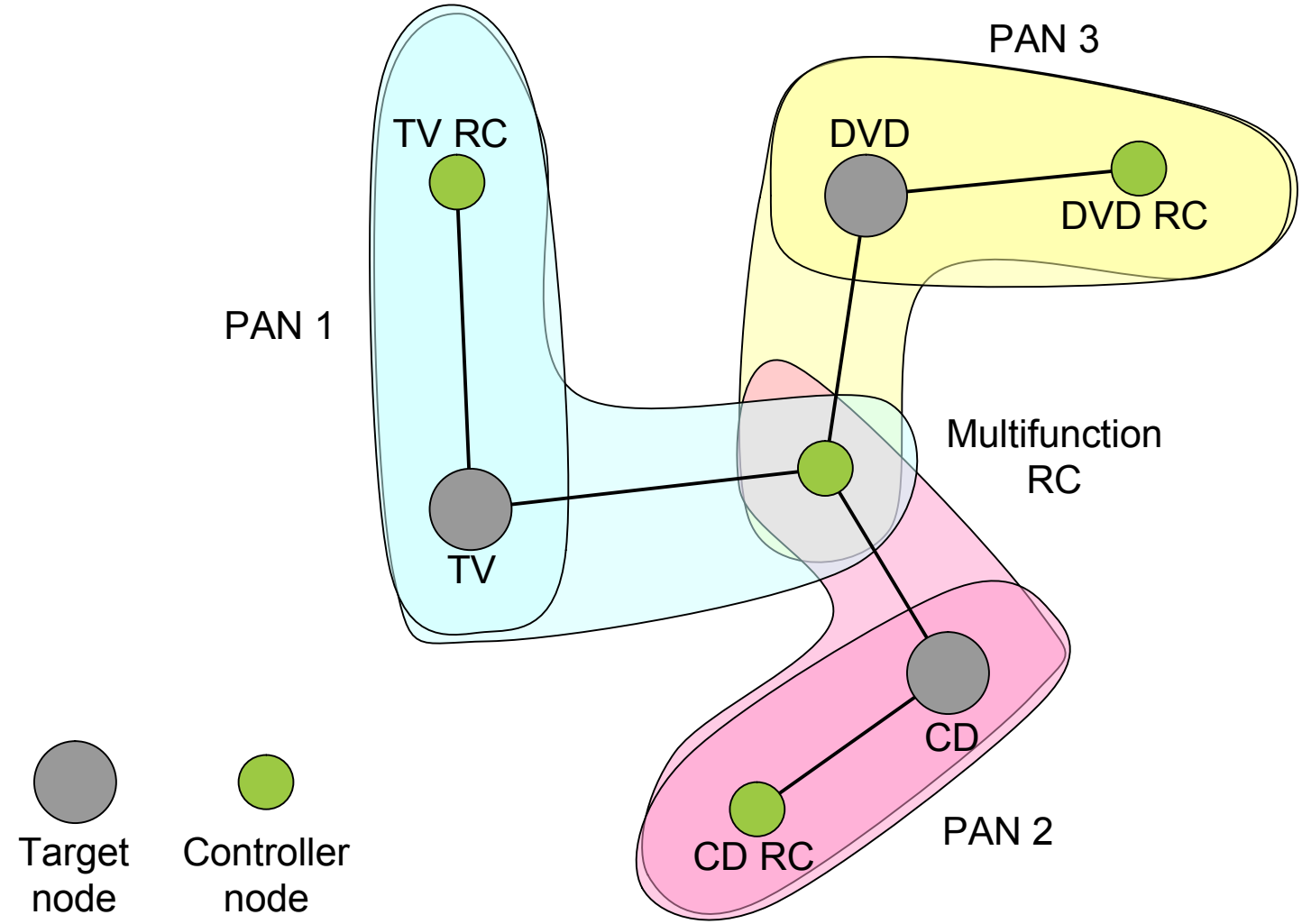
I. Target node

- PAN coordinator, defines network parameters, starts network
- Decides about pairing with other nodes
- Controls frequency agility

II. Controller node

- Initiates pairing and discovery process to Target Nodes
- Implements frequency agility
- On-demand communication

ZigBee RF4CE – example topology



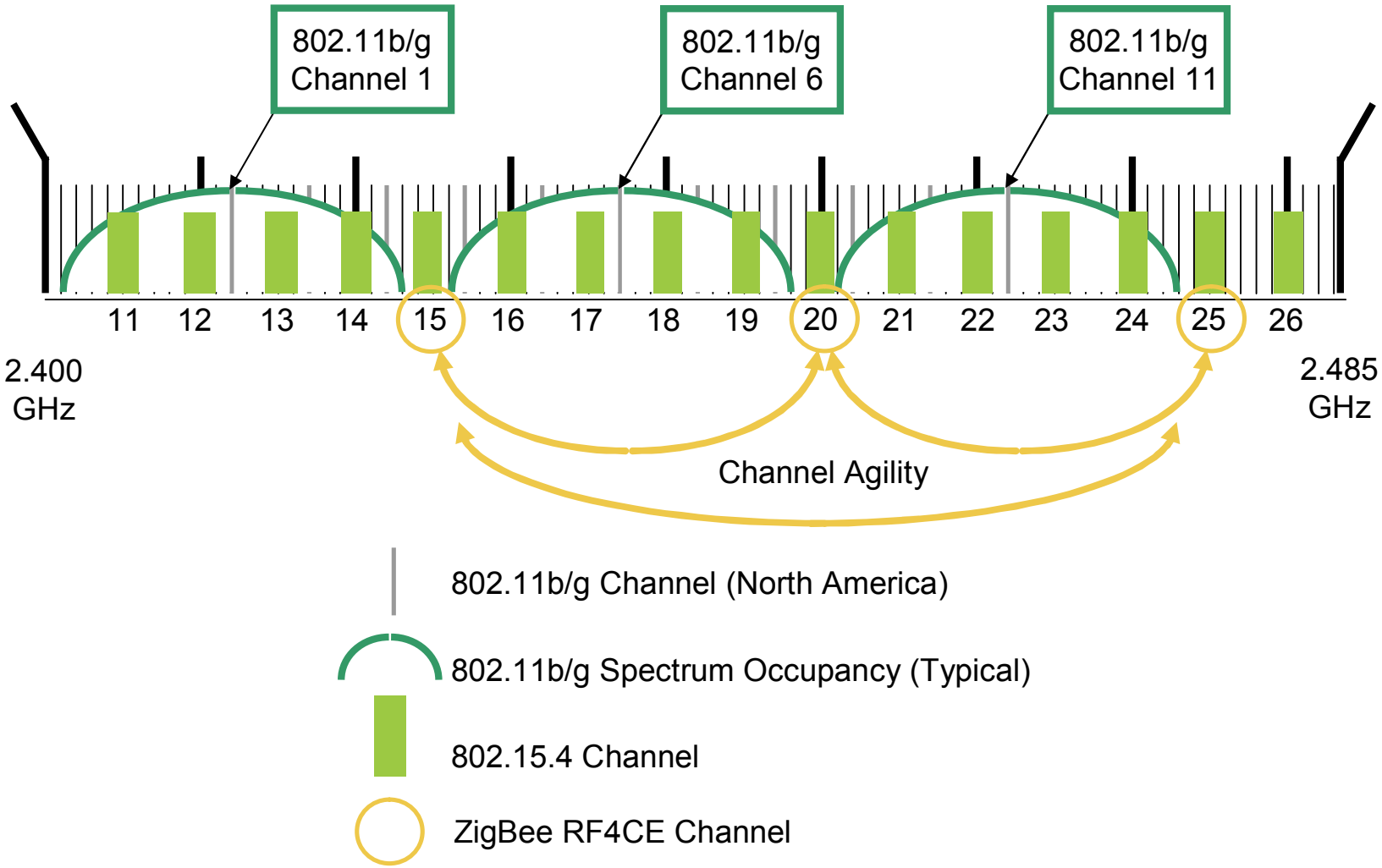
ZigBee RF4CE Mechanisms

- Channel agile solution operating over three channels
- Incorporates power management mechanism
- Discovery mechanism
- Pairing mechanism
- Multiple star topology with inter-PAN communication
- Various transmission options including unicast, broadcast, acknowledged, unacknowledged, secured and un-secured
- Security mechanism

ZigBee RF4CE Frequency Agility

- ZigBee RF4CE Networks operate on IEEE 802.15.4 channels 15, 20 & 25
  - Channel 15 – 2.425 GHz
  - Channel 20 – 2.450 GHz
  - Channel 25 – 2.475 GHz
- All node types support frequency agility
- Target specifies PAN base frequency
- Target can switch frequency on adverse channel conditions
- Other nodes know where the target ***was*** and attempt to transmit
- If target not found, nodes re-acquire by trying each frequency
  - Once found, new channel information is stored for future communications
  - Due to reduced number of channels in use this procedure is very fast

ZigBee RF4CE Frequency Agility

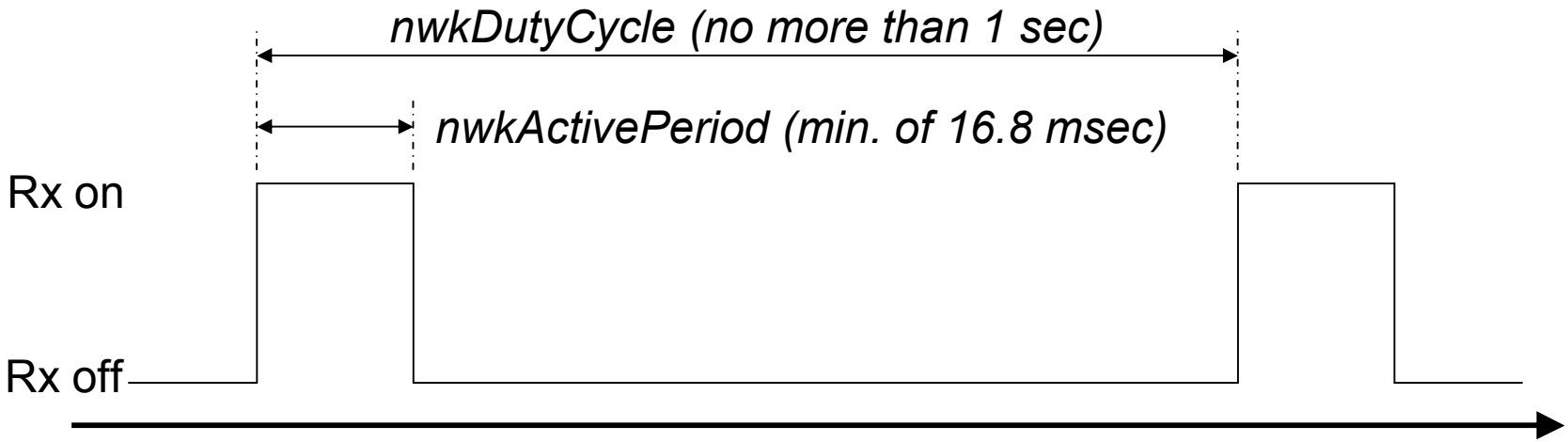


ZigBee RF4CE Power Saving

- **RF4CE relies on IEEE 802.15.4 devices with very low power consumption**
  - Example: **Atmel AT86RF231**
  - TX current
    - with +3dBm TX power : **14 mA**
    - with minimum TX power : **7.5 mA**
  - RX current:
    - at highest sensitivity of -101dBm : **12.3 mA**
    - at reduced sensitivity < -101dBm : **11.7 mA**
  - Sleep current: **20 nA**

ZigBee RF4CE Power Saving

- **Two states for Power Save: Active (until event or defined duration) & Standby**
- **Controllers simply turn off when no buttons are being pressed**
- **Targets must also use power save when in standby**
  - But must ensure a (human) reasonable reaction time
- **Power saving utilizes**
  - Active period during which the device wakes
  - Duty cycle at which device repeats active period

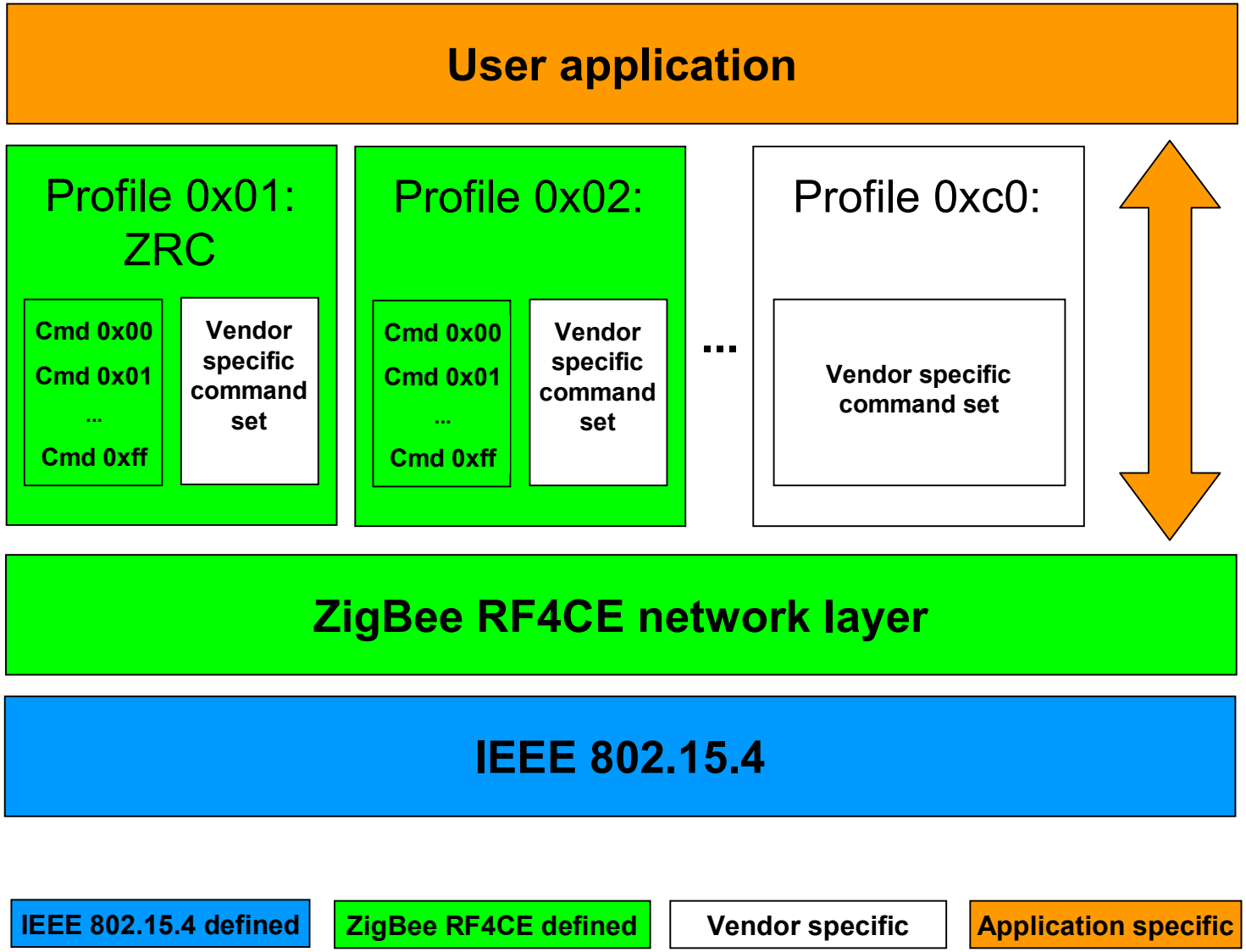


ZigBee RF4CE – security

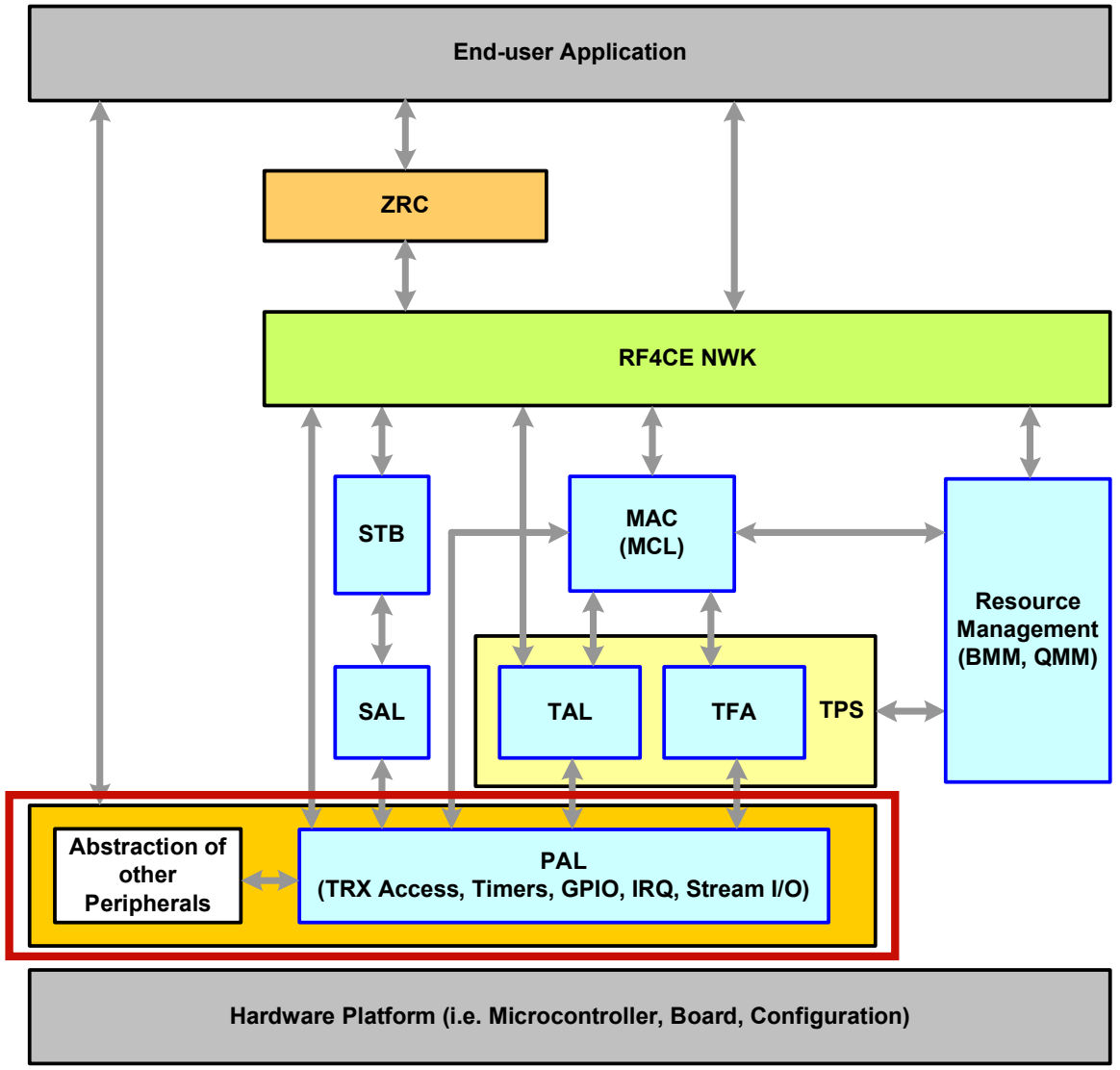
- **Security is established during pairing process**
- **Utilizes AES-128**
  - **Security mode: CCM* (ENC-MIC-32)**
    - Data confidentiality (via payload encryption)
    - Data authentication (via Message Integrity Code)
    - Replay protection (via frame counter)

- **Nodes use 128-bit link keys**
  - **Keys are generated automatically, if security is supported**
  - **Keys are stored in the pairing table**

ZigBee RF4CE stack architecture



Atmels RF4Control stack specifics



Atmels RF4Control stack specifics

- **Small footprint:**

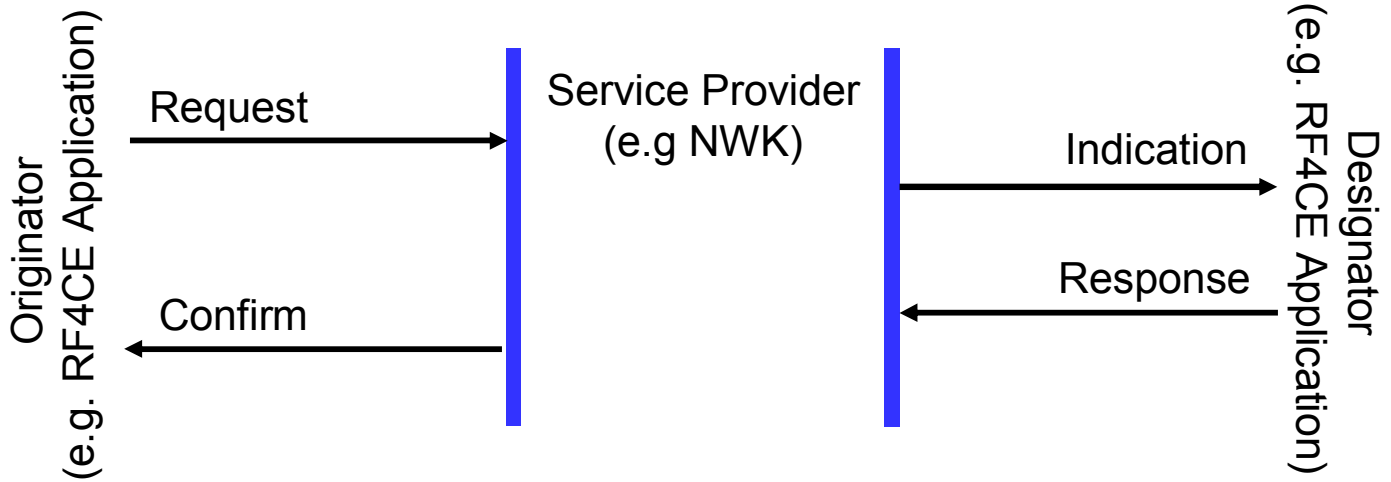
Build Configuration*		Stack	Basic Demo	Serial Interface	Key Remote Controller	Terminal Target
Controller	w/o security	**17.8 kB**	**+ 0.9 kB**	**+ 1.2 kB**	**+ 1.4 kB**	**-**
	w/ security	**20.8 kB**	**+ 0.9 kB**	**+ 1.3 kB**	**+ 1.5 kB**	**-**
Target	w/o security	**25.2 kB**	**+ 0.7 kB**	**+ 1.6 kB**	**-**	**+ 9.7 kB**
	w/ security	**29.2 kB**	**+ 0.8 kB**	**+ 1.6 kB**	**-**	**+ 9.8 kB**
Platform	w/ security	**29.6 kB**	**-**	**+ 1.6 kB**	**-**	**-**

*) Implementations leave room for further footprint optimization.

- **Stack packet also supports Atmels IEEE 802.15.4 transceiver AT86RF212**
  - **Allows development of RF remote controls with longer range and better wall penetration by using 780/868/915 MHz frequency bands**

ZigBee RF4CE - primitives

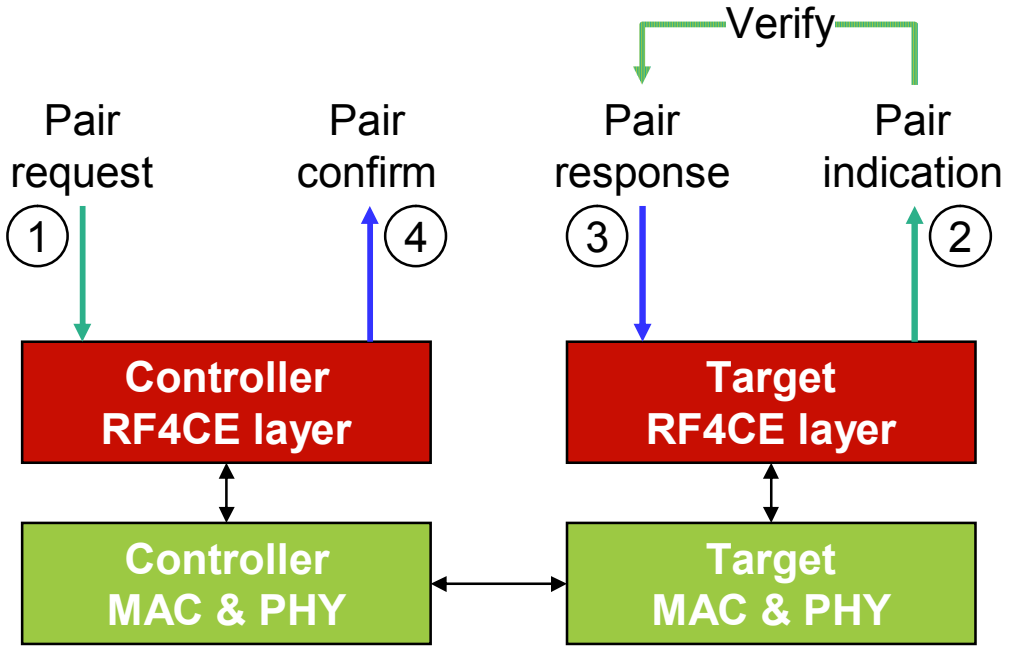
- **Concept of primitives**



Example for primitive use

Pairing with a target

- A device wants to pair with a target and asks the target for permission
- The target verifies that this particular controller is allowed to pair. If yes it will sends a positive confirmation.



ZigBee RF4CE - NLME primitves

- **primitives for network management:**

Name	Request	Indication	Response	Confirm
NLME-AUTO-DISCOVERY	3.1.2.1			3.1.2.2
NLME-COMM-STATUS		3.1.2.3		
NLME-DISCOVERY	3.1.2.4	3.1.2.5	3.1.2.6	3.1.2.7
NLME-GET	3.1.2.8			3.1.2.9
NLME-PAIR	3.1.2.10	3.1.2.11	3.1.2.12	3.1.2.13
NLME-RESET	3.1.2.14			3.1.2.15
NLME-RX-ENABLE	3.1.2.16			3.1.2.17
NLME-SET	3.1.2.18			3.1.2.19
NLME-START	3.1.2.20			3.1.2.21
NLME-UNPAIR	3.1.2.22	3.1.2.23	3.1.2.24	3.1.2.25
NLME-UPDATE-KEY	3.1.2.26			3.1.2.27

ZigBee RF4CE - NLDE primitives

- **primitives for data transfer:**

Name	Request	Indication	Confirm
NLDE-DATA	3.1.1.1	3.1.1.2	3.1.1.3

ZigBee RF4CE - basic operation steps

- Network start
- Discovery
- Pairing
- Data transfer

ZigBee RF4CE – Network start

- Node initiates & configures stack
- Target performs active scan to identify potentially occupied channels
- based on network parameters like PAN ID, base channel etc.
  - parameters are stored in network information base (NIB)
  - access to NIB with NLME-SET.request & NLME-GET.request

- Primitives:
  - NLME-RESET.request
    - resets RF4CE network layer
  - NLME-START.request
    - if device is configured as target (NIB) it initiates a active scan
    - defines PAN ID and operating channel

ZigBee RF4CE - Discovery

- **RF4CE devices use discovery procedure to find devices that they can be paired to**
- **Discovery requests sent by originating device (e.g. RC)**
  - Use broadcast, multi-channel service so multiple devices can respond
    - This allows a list of devices in the “RF vicinity” to be built
  - performed on all channels until discovery response is received
    - “Discovery trial“
  - Discovery request contains originator informations like:
    - Node capabilities
    - Vendor information (Vendor ID)
    - Application information (“User String”, supported & requested device types)
- **Recipient devices normally inform application of discovery information**
  - Application decides whether to respond
  - Discovery response only sent if application approves

ZigBee RF4CE - Discovery

- **Discovery response sent by recipient device (e.g. TV)**
  - Uses unicast service directly back to the originator (e.g. RC)
  - Discovery response contains recipient information
  - Targets can switch into automatic discovery response mode
    - only active for a certain timeframe
    - target automatically responds to discovery requests during that timeframe
- **Originator devices inform application of all discovery information**
  - Application decides whether to pair with a particular device
- **Primitives:**
  - **NLME-AUTO-DISCOVERY.request**
    - **requests automatic discovery response mode**
  - **NLME-DISCOVERY.request**
    - **sends discovery requests on all channels**
    - **switches to next channel after certain duration & can repeat whole procedure**

ZigBee RF4CE - Pairing

- **After successful discovery of a potential node to pair with the device initiates a pairing sequence**
- **During that the target and the controller establish a secured link**
- **after successful pairing target and controller create an entry in their pairing table**
  - Contains addressing information
  - Application uses this entry via a reference
- **Pairing information is stored in non-volatile memory**

- **Primitives:**
  - **NLME-PAIR.request**
    - **initiates the pairing sequence**

ZigBee RF4CE – data transmission

- Data transmission only between paired devices
  - can be acknowledged, unacknowledged, unicast, broadcast, single channel, multiple channel
- data can be encrypted or unencrypted

- Primitives:
  - NLDE-DATA.request
    - sends data to other node

New application scenarios

Paradigm change

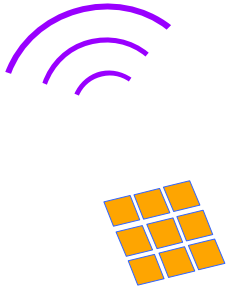
- **ZigBee RF4CE will change the way we see and use remote controls**
- **Technology that offers every device capable of handling user input to be used as control entity for consumer electronics**
- **Due to the standards interoperability new application scenarios for controlling TV's, DVD players, home audio systems possible**
- **Really „smart" remote controls:**
  - „RF4CE Apps" for Smartphones equipped with IEEE 802.15.4 radios can be provided and updated by the Vendor of the CE device
- **Security allows transmission of sensitive data (e.g. direct TV home shopping)**

➢ **A few RF4CE application scenarios that already exist or will become reality very soon:**

Smartphone „RF4CE Apps“

1. **Start RF4CE TV Control App**
   - **Use App to switch TV to channel 1**
2. **Start RF4CE DVD Player Control App**
   - **Use App to play DVD**

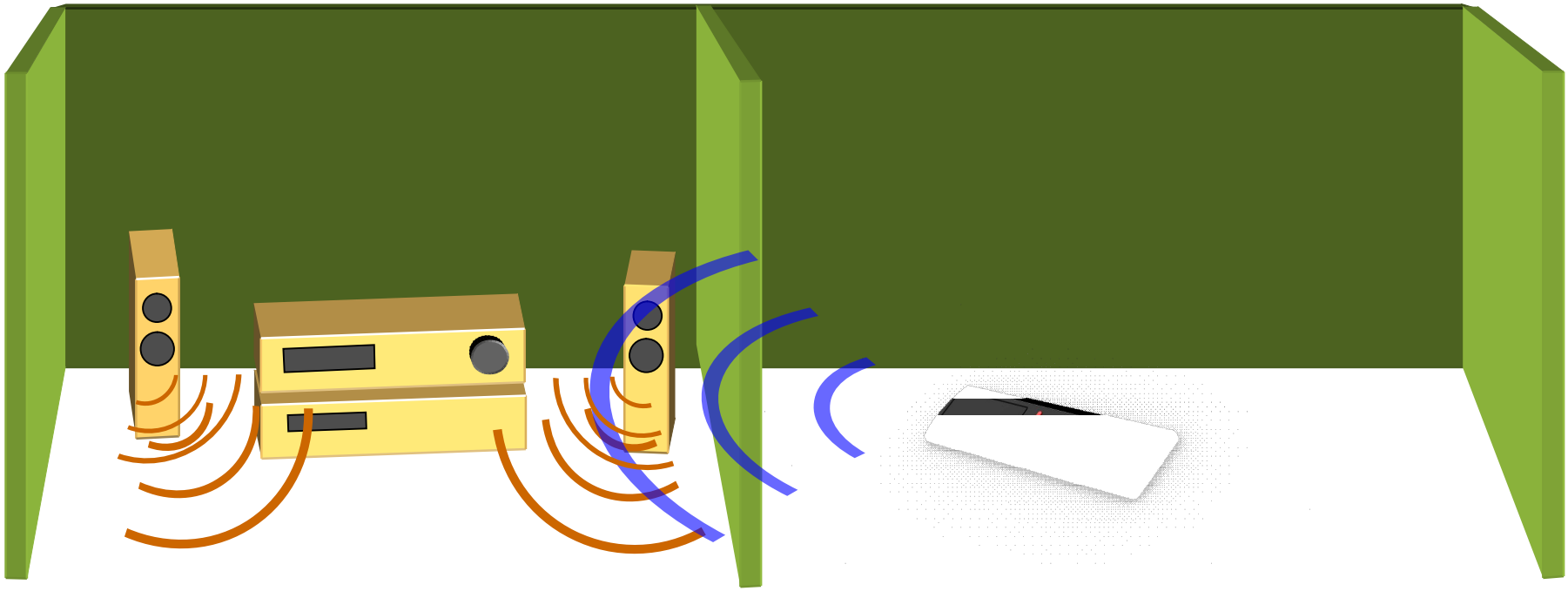
Proximity based applications



1. TV Control App started

2. Air Condition Control App started

Control devices from other rooms



...and many more !

- Vendors will come up with completely new application scenarios supported by ZigBee RF4CE
- You decide whats possible, RF4CE enables it

Thank you !

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