Wi-SUN module for B-Route, Enhanced HAN

BP35C0-J11 Protocol Stack Specification

This document describes the specifications of the protocol stack on Wi-SUN module BP35C0-J11.

Caution

- On the firmware
  - With respect to the firmware (hereinafter collectively “Software”) built into BP35C0-J11, agree to the following licensing prior to use.
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  - For customers who are verifying points relating to specific communication, please introduce Wi-SUN Enhanced HAN compatible packet capture. As a rule, support for communication-related content is conditional on the capture log being provided.
    Recommended capture: Keysight's PS-X30 W10121A Wi-SUN protocol catcher
    https://www.keysight.com/jp/ja/assets/7018-04443/flyers/5991-4654.pdf
- This document consists of the “j11_protocol_stack_specification” which is copyrighted by ISB Corporation, and ROHM has received permission from ISB Corporation for the publication of this document.

Wi-SUN Enhanced HAN
Plus Route-B Dual Stack
J11 Protocol Stack Specification

First Edition

English

ISB CORPORATION

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Document Convention

This document uses the following typographical convention:

Convention	Description
Initiate Route-B PANA Re-authentication	Words in bold with the first letter of each word capitalized indicate command names.

Revision History

Date	Description
March 19, 2020	First English edition of the Japanese original first edition Rev 1 (1.0)
June 1, 2020	Revision of the first English edition

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1. Introduction

1.1 Overview

This document describes functional specification of wireless modules (hereinafter referred to as the “Module”) compliant with Wi-SUN Profile for ECHONET Lite as the international wireless communications standards (hereinafter referred to as the “Wi-SUN”) for Route B and for Enhanced HAN (hereinafter referred to as the “HAN”) specified by “Wi-SUN Alliance”.

1.2 Scope of this document

This document describes the functional specification of the protocol stack implemented in the following Module configuration.

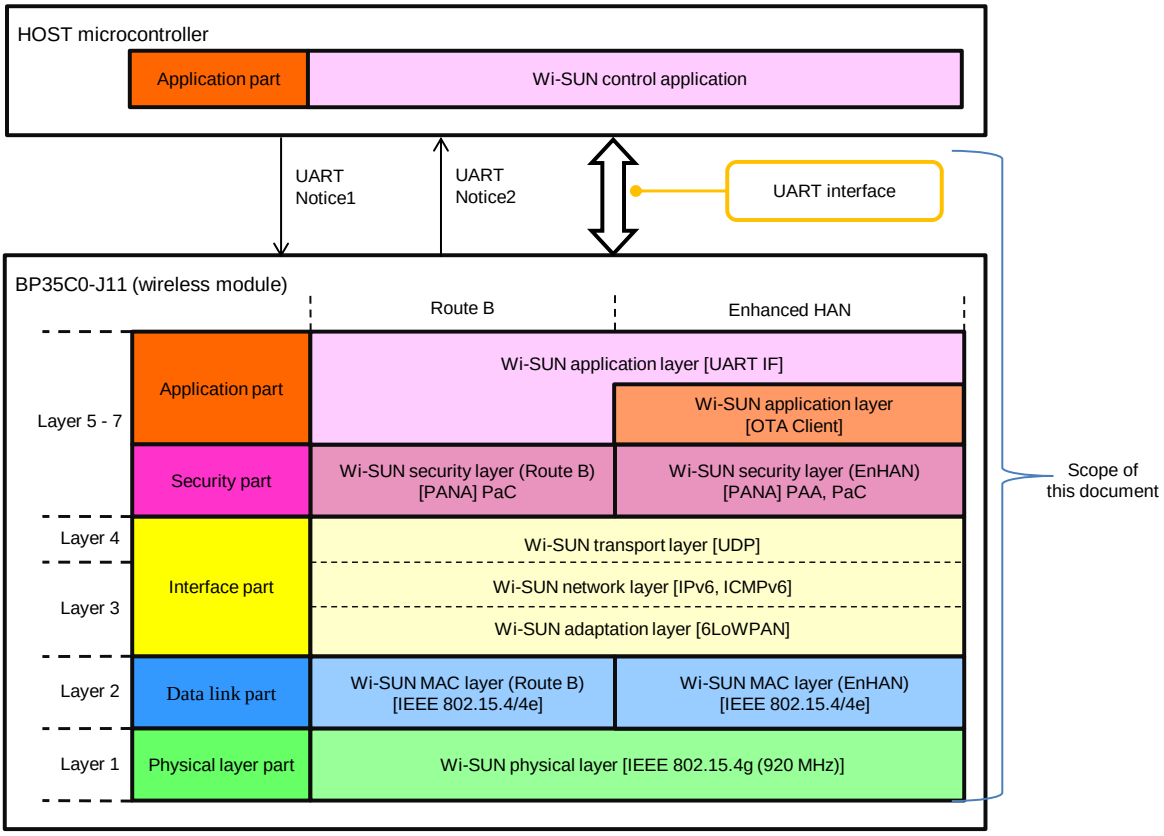

Fig. 1: Module configuration

1.3 Terms and definitions

The following table lists terms and definitions used in this document.

Table 1: Terms and definitions

Term	Definition
HEMS	Home Energy Management System
Route B	Wi-SUN profile for communications between smart meters and HEMS controllers
Enhanced HAN	Wi-SUN profile for communications between HEMS controllers and home electronics
ECHONET Lite	Communication protocols formulated by the ECHONET CONSORTIUM, including control protocols and sensor network protocols used for smart house
NS	Neighbor Solicitation
NA	Neighbor Advertisement
PANA	Protocol for carrying Authentication for Network Access
PAA	PANA Authentication Agent
PaC	PANA Client
OTA	Over The Air
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance

1.4 Reference documents

Table 2: Reference documents

No.	Document name
1	20160617-Wi-SUN-Echonet-Profile-2v08_clean.pdf
2	Guidelines for Operating HEMS / Smart Meters for Route B (Low-voltage Wattmeter) [Ver. 2.0]
3	Home network communication interface for JJ-300.10 ECHONET Lite (IEEE802.15.4/4g/4e 920 MHz-band Wireless)

2. Overview

2.1 Features of the protocol stack

- Compliant with Wi-SUN Profile for ECHONET Lite for Route B and for Enhanced HAN.
- Module can operate by changing its operation modes: master device (PAN coordinator), relay device (coordinator), slave device (end device) and sleeping slave device (sleeping end device) for Enhanced HAN.
- Module can operate in Dual mode in which the Route B and the PAN coordinator serving as the master device of the HAN are put into operation at a time
- Wireless communication range can be expanded by 1 hop rely via a relay device.
- Firmware OTA update function is supported.
- Robust and secured PANA authentication and AES encryption are supported.
- Use of 920 MHz wireless frequency band with well diffraction and ability to surmount obstacles.

2.2 HEMS service

This protocol stack has a high affinity with ECHONET Lite and provides appropriate communication for using an HEMS controller. The following figure shows a use case of a HEMS service to control home appliances and smart meters with this protocol stack implemented in home appliances and HEMS controllers.

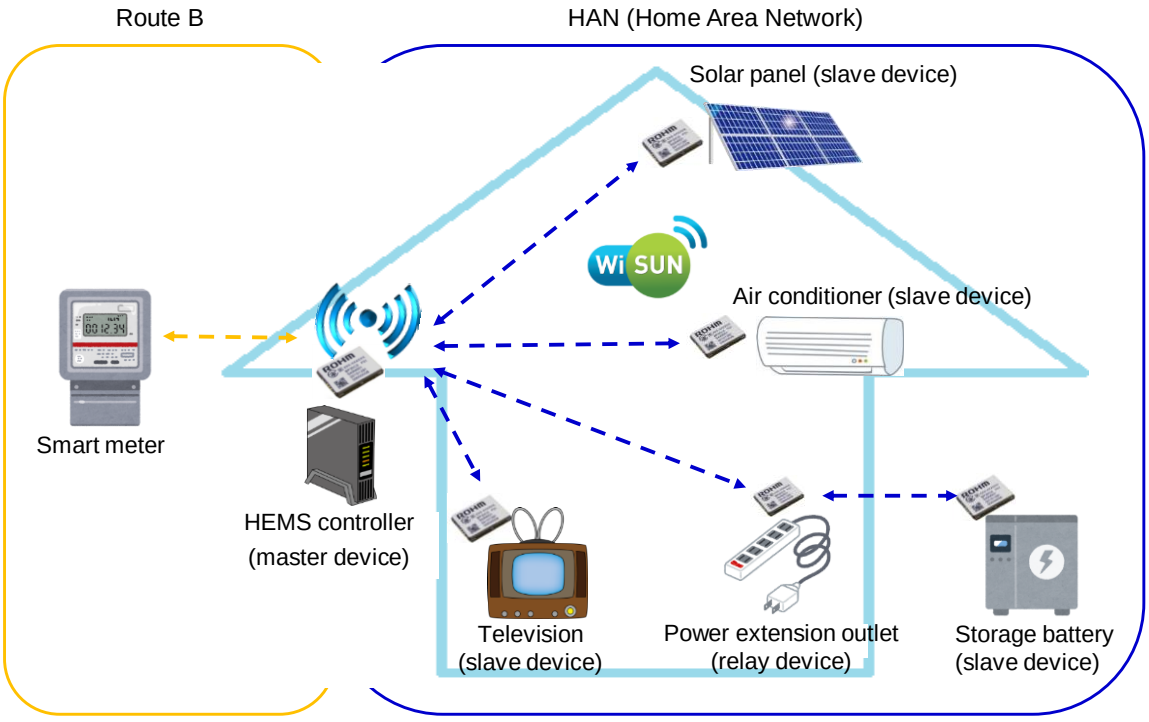

Fig. 2: Use case of HEMS service

2.3 Hardware configuration

This protocol stack is implemented in ROHM Module BP35C0-J11.

3. Protocol stack specification

This protocol stack is compliant with Wi-SUN Profile for ECHONET Lite. Parameters and operations to be used in the protocol stack are subject to the content described later in this document.

3.1 Network configuration

The maximum number of units of devices to be connected with the network is 17 units of devices.

The maximum number of hops in the network is 1 hop in the network.

In case of connection with a smart meter (Route B), up to 17 units of devices including one smart meter (Route B) and 16 units of HAN devices including up to 4 sleeping end device can be connected with the network. In case of no connection with a smart meter (Route B), up to 17 units of HAN devices can be connected.

The following figure shows an example of the network configuration.

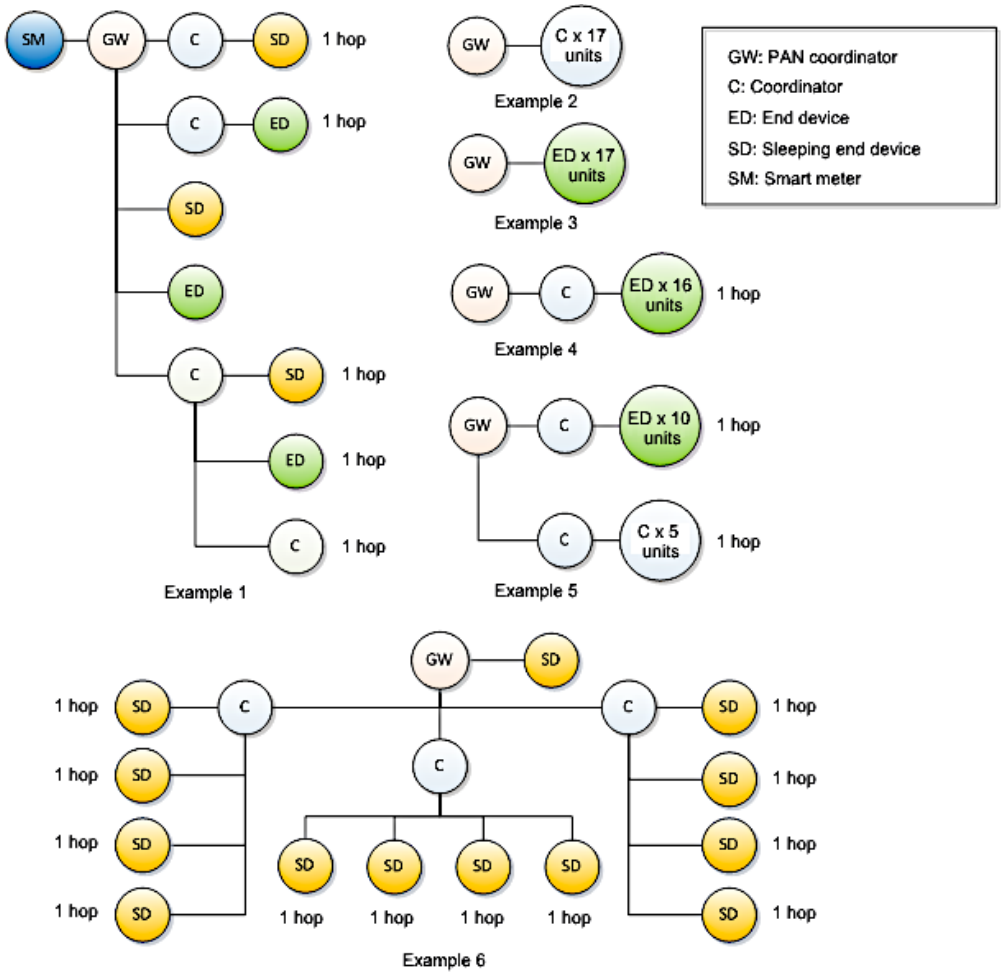

Fig. 3: Example of network configuration

3.1.1 Network connection specification

This protocol stack requires encryption communication with PANA authentication used.

PANA authentication should be executed immediately after connection in the MAC layer.

Non-encryption communication is used during connection in the MAC layer and before PANA authentication. 80 minutes after the terminal remains being connected in this status, the terminal will be automatically removed and disconnected from the network.

3.2 Wi-SUN physical layer (IEEE802.15.4g)

The Wi-SUN physical layer (IEEE802.15.4g) specification is subject to ARIB STD-T108 Specified low power radio station.

3.2.1 Transmission rate

100 kbps only is supported.

3.2.2 Transmission power

20 mW, 10 mW or 1 mW can be specified for the transmission power. The default is 20 mW.

3.2.3 Channels

The list of the available channels is listed below.

Table 3: Channels

Channel number	Center frequency (MHz)
4	922.5
5	922.9
6	923.3
7	923.7
8	924.1
9	924.5
10	924.9
11	925.3
12	925.7
13	926.1
14	926.5
15	926.9
16	927.3
17	927.7

3.2.4 Limitation on the sum of transmission data amount

Since the sum of transmission time per one hour (3600 seconds) must be 360 seconds or less according to 920 MHz range for ARIB standard, the sum of transmission time is calculated by the following method.

The amount of data to be transmitted per 360 seconds is used as the threshold to determine whether transmission is allowed.

The amount of data allowed to be transmitted at 100 kbps is 4,500,000 bytes.

When data transmission succeeded, the transmission size (amount of transmission data including preambles) is added to the sum of the transmission size. The sum of the transmission size is managed 60 times an hour (every minute).

Whenever data is transmitted, the amount of data to be transmitted is checked whether it exceeds 4,500,000 bytes (the amount of data allowed to be transmitted) by comparing with the total size of “the sum of the transmission size during the last 60 minutes” and “the amount of transmission data to be transmitted currently”.

When the amount exceeds the limitation on the sum of the transmission size, the transmission is not allowed.

When the amount does not exceed the limitation, the transmission via wireless is allowed within the sum of the transmission size.

3.3 Wi-SUN MAC layer (IEEE802.15.4/4e)

3.3.1 CSMA/CA communication method

The CSMA/CA communication method is used to prevent conflicting communication.

The CSMA/CA setting values for this protocol stack are shown below.

Table 4: CSMA/CA setting values

Setting value name	Recommended setting value	This protocol stack's setting value (default)
macMaxBE	8	5
macMinBE	8	3
macMaxCSMABackoffs	4	5
macMaxFrameRetries	3	4

The above values used for more stabled communication without delay on the basis of the result of multiple devices communication test are different from recommended values of Wi-SUN Profile for ECHONET Lite.

3.3.2 Relay

The MAC layer (Layer 2) provides 1 hop relay communication.

The maximum number of hops is 1 hop and a 2-hop connection is not allowed.

3.3.3 Selecting a device to connect with

Pairing ID is used for MAC layer connection.

When there are multiple units of device to connect with as candidates, the number of hops and reception RSSI are compared to connect with an appropriate device.

For example, if there are two candidates to connect with a PAN coordinator and coordinator as end devices and the RSSI of Enhanced Beacon received from the PAN coordinator exceeds -80 dBm, the PAN coordinator is connected; if not, the coordinator is connected.

3.3.4 Frame encryption

The frames are encrypted with AES-CCM by using keys exchanged during PANA authentication.

3.3.5 Indirect communication

When data is transmitted to a sleeping end device, the transmission data is queued and indirect communication is performed as appropriate. The number of sleeping end devices to be connected using indirect communication and this protocol stack is up to 4 units each of PAN coordinators and coordinators.

3.4 Wi-SUN adaptation layer (6LowPAN)

IPv6 packet compression and fragment are performed.

3.4.1 Fragment threshold

Fragment threshold varies with transmission packet header sizes with or without encryption and relay.

The table below provides the fragment threshold for transmitting unicast data with encryption and no relay via one-on-one communication.

Table 5: Fragment threshold with unicast and no relay

Number of fragments	Data size
1	1 to 185 bytes
2	186 to 360 bytes
3	361 to 544 bytes
4	545 to 728 bytes
5	729 to 912 bytes
6	913 to 1096 bytes
7	1097 to 1232 bytes

3.5 Wi-SUN network layer (IPv6, ICMPv6)

3.5.1 IPv6 address

This protocol stack uses an IPv6 address.

An IPv6 address is formed from a link local address prefix (FE80::0/64) and MAC address (EUI-64 address).

For example, when a MAC address is 001D1291000039BB, the IPv6 address is FE80000000000000 021D1291000039BB.

3.5.2 Multicast address

The table below provides multicast addresses for the receivers in all-nodes and solicited-node multicast groups.

Table 6: Multicast group

IPv6 multicast address	Addressing to	Scope
FF02::1	All-nodes address	Link local
FF02::1:FFxx:xxxx	Solicited-node address	Link local

3.5.3 Ping

Ping provides the reach ability check using Echo Request and Echo Reply.

3.5.4 Neighbor Discovery

Neighbor Discovery provides neighborhood search using Neighbor Solicitation and Neighbor Advertisement in the vicinity of a node.

3.6 Wi-SUN transport layer (UDP)

This protocol stack uses UDP for data transmission/reception.

UDP ports are used mainly for the purpose of the following description in the table below.

Table 7: UDP ports

Used for	Port number
PANA	716
PANA	19788
OTA update	31941
Echonet Lite	3610

3.7 Wi-SUN security layer (PANA)

Authentication using PANA can be used.

ID and password required for the authentication should be specified from a HOST via UART.

3.7.1 Concurrent authentication process

While PANA authentication is being performed for one device, authentication for other device is not acceptable.

Since concurrent PANA authentication is not supported, device authentication shall be executed from one after another.

3.7.2 PANA retry setting

The table below provides default values for PANA retry setting of this protocol stack.

Table 8: PANA retry setting

PANA retry setting	Recommended setting value	This protocol stack's setting value (default)
Number of times of retransmissions of HAN PaC PANA authentication initiation message	10	4
Number of times of retransmissions of PANA authentication message	10	1

This protocol stack does not support concurrent authentication. When the number of times of retransmissions is a high number, sequence duration takes long to cause delay in multiple devices connection. The above values used for more stabled communication without delay are different from recommended values of Wi-SUN Profile for ECHONET Lite.

The set values can be changed by a command.

3.7.3 Automated re-authentication of Route B

This protocol stack automatically re-authenticates the devices after successful Route-B PANA authentication.

Automated re-authentication is performed during PANA authentication when the time remaining of session life time notified by the smart meter is 80% of it. The HOST cannot change execution timing of automated re-authentication.

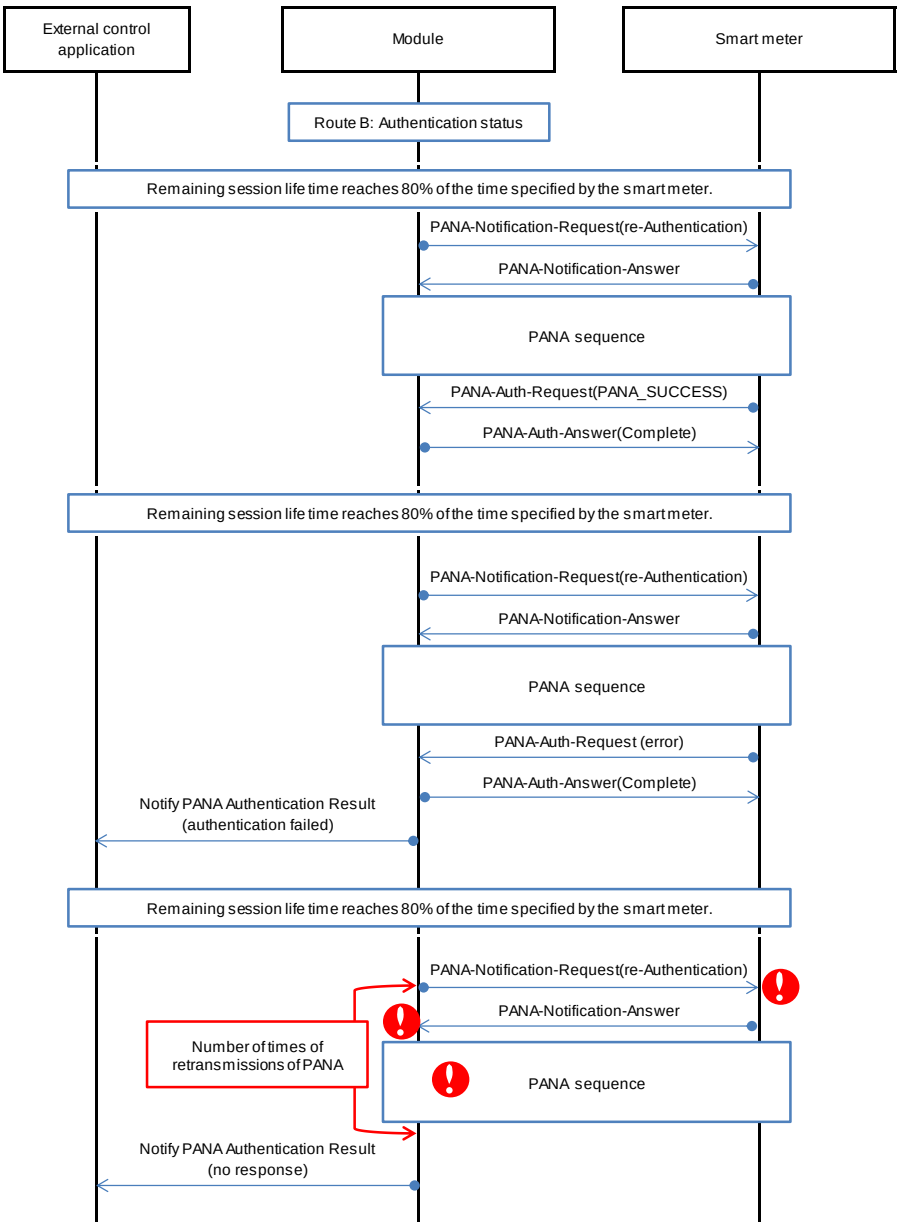

Fig. 4: Sequence of Route-B automated re-authentication

Success/failure of result of automated re-authentication triggers whether to notify the result.

Re-authentication succeeded: Does not notify the result.

Re-authentication failed: Notifies the results of PANA authentication

3.7.4 Automated update of HAN group key

This protocol stack automatically updates the HAN group key after HAN PANA authentication succeeds.

The key is automatically updated when the following conditions are met:

- Maximum validity period of the encryption key set in PAA is exceeded.
- PaC is re-connected and 255 of the authentication counter is exceeded.
- Transmission frame counter of each session is exceeded.
- Reception frame counter of each session is exceeded.

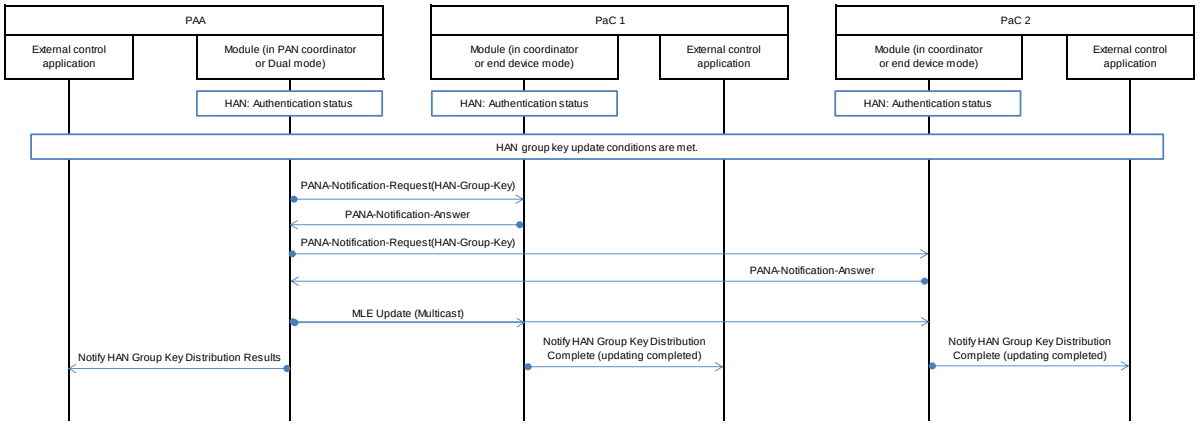

Fig. 5: Sequence of automated update of HAN group key

3.7.5 Encryption

The table below describes encryption trigger of this protocol stack.

Table 9: Encryption and key update trigger

<table>
<tr><th>Protocol</th><th>Route B</th><th colspan="4">HAN</th></tr>
<tr><td>Role</td><td>HEMS</td><td>PAN coordinator</td><td>Coordinator</td><td>Device</td><td>Sleeping end device</td></tr>
<tr><td>Encryption trigger</td><td>Successful PANA authentication with smart meter</td><td>Successful PANA authentication with the first unit of device</td><td colspan="3">Successful PANA authentication with PAN coordinator</td></tr>
<tr><td>Key update</td><td>Auto:
Automated Route-B re-authentication by session life time

Manual:
Initiate Route-B PANA Re-authentication command</td><td>Auto:
When one of the following conditions is met:
- Maximum validity period of the encryption key runs out.
- Authentication with one unit of device was executed 255 times.
- Packet was transmitted certain times.
- Packet was received certain times.

Manual:
Check HAN Group Key Update Request command</td><td colspan="3">Encryption key update cannot be performed from the coordinator, device and sleeping end device.</td></tr>
<tr><td>Items to be encrypted</td><td colspan="5">UDP except PANA messages (unicast/multicast)
ICMPv6 (unicast/multicast)</td></tr>
<tr><td>Items not to be encrypted</td><td colspan="5">UDP of PANA message
MLE</td></tr>
</table>

3.8 Wi-SUN application layer

3.8.1 UART IF command

This protocol stack supports control from UART interface.

For details, see the document “J11 UART IF Specification”.

3.8.2 OTA update

This protocol stack supports firmware update via wireless using Wi-SUN communication.

For details, see the document “J11 OTA Update Specification”.

4. HOST interface

The following terminals are used to notify the UART communication status between the HOST and Module.

UART Notice1: (21) GPIOA1

UART Notice2: (22) GPIOA3

4.1 UART Notice control

This control helps to grasp UART communication timing from the Module to the HOST.

HOST also can enter the deep sleep mode.

4.1.1 Enabling/disabling of UART Notice control

This Module determines enabling or disabling of UART Notice control by checking the UART Notice1 status immediately after the Module power-on.

- When low signal is detected successively 3 times over 10 ms cycle length, UART Notice control is enabled
- When high signal or Hi-Z is detected successively 3 times over 10 ms cycle length, UART Notice control is disabled.
- When UART Notice1 terminal is unconnected (open), UART Notice control is disabled.

After determination of enabling/disabling, HOST's UART communication status is indicated.

4.1.2 UART communication availability status

UART Notice1 indicates HOST's UART communication availability status and UART Notice2 indicates the Module's.

Table 10: UART Notice communication availability status

	Description	High/Low
UART Notice1	Indicates whether the HOST can receive UART communication.	High: UART communication can be received. Low: UART communication cannot be received.
UART Notice2	Indicates whether UART data that the Module transmits to the HOST exists.	High: UART transmission data exists. Low: UART transmission data does exist.

4.1.3 HOST-side control

When UART Notice (hereinafter referred to as the "UN") control is enabled, this Module expects the HOST to perform the operation described in the Table below.

Table 11: HOST-side control

	Description
UART Notice1	1. Only when high is set in UN1, the Module transmits UART to the HOST. When low, the Module does not transmit UART. (Note) 2. Module determines whether the HOST can receive data by checking UN1. When the HOST can receive data, set high in UN1.
UART Notice2	1. When the Module is in the Wakeup mode, UART communication from the HOST to the Module can be performed regardless of the UN2 status. 2. Note that UN2 does not indicate the Module in the deep sleep status. 3. HOST detects interrupt from low to high (high interrupt) in UN2 and sets high in UN1. 4. In case of the above 3, the Module makes attempt of UART communication with the HOST. If the HOST is in the deep sleep mode, change it into the Wakeup mode. 5. When UART data to be transmitted to the HOST do not exist, the Module sets low in UN2. When the HOST detects interrupt from high to low (low interrupt) in UN2, the HOST can transit to the deep sleep mode.

Note: Module has 4-kbyte data buffer. It continuously retains data in the buffer until the HOST can receive data. When data is added into the buffer and buffer overflow occurs, the data is discarded. This does not affect the data stored in the buffer.

4.1.4 Timing chart of UART Notice when HOST transmits

Transmission from the HOST to the Module can be performed regardless of the UART Notice status

4.1.5 Timing chart of UART Notice when HOST receives

4.1.5.1 Low in UART Notice1 and low in UART Notice2 when HOST receives

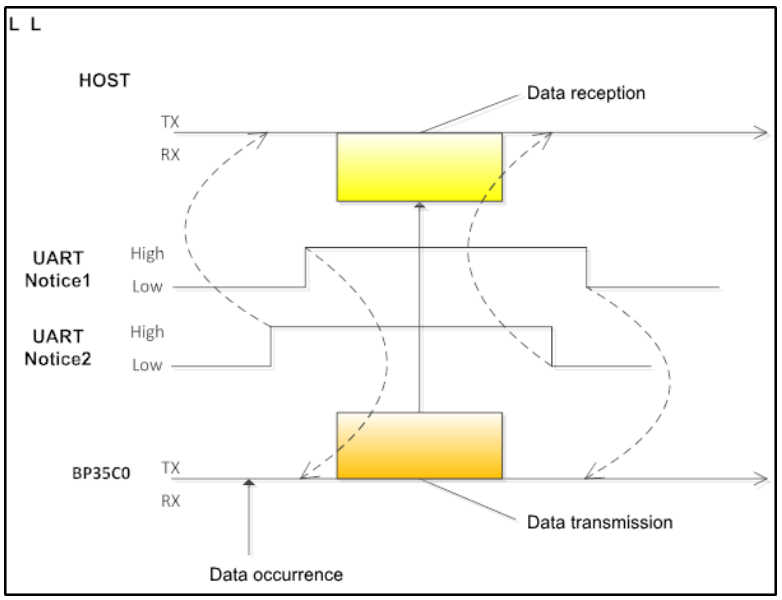

Fig. 6: Low in UART Notice1 and low in UART Notice2 when HOST receives

4.1.5.2 Low in UART Notice1 and high in UART Notice2 when HOST receives

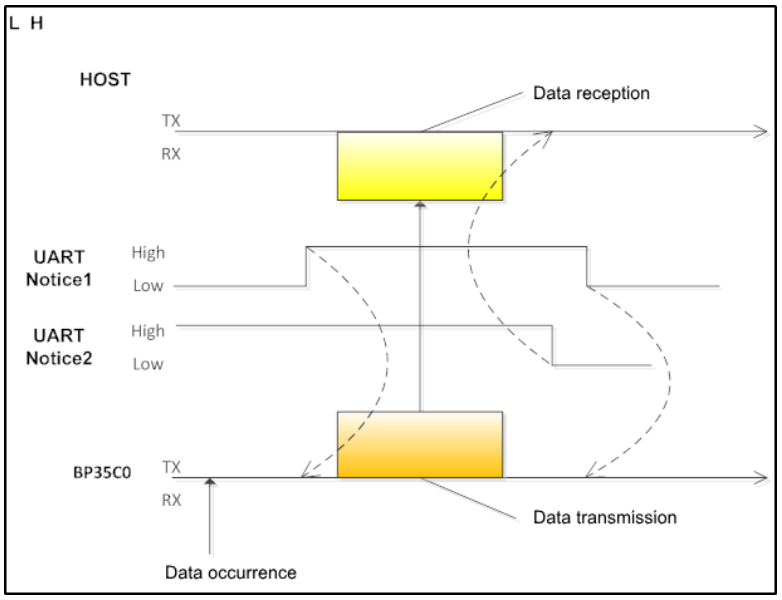

Fig. 7: Low in UART Notice1 and high in UART Notice2 when HOST receives

4.1.5.3 High in UART Notice1 and low in UART Notice2 when HOST receives

Even though high remains in UART Notice1, UART transmission data notification is performed by UART Notice2.

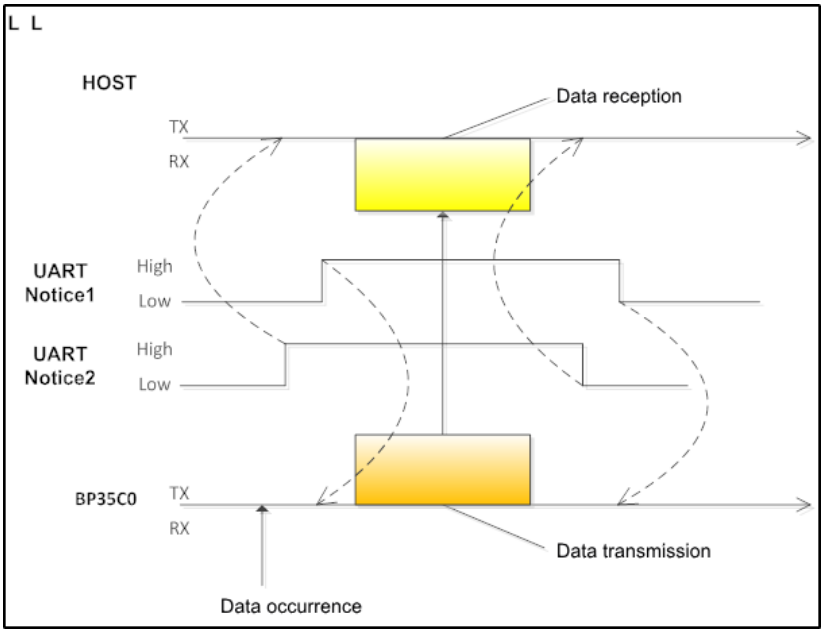

Fig. 8: High in UART Notice1 and low in UART Notice2 when HOST receives

4.1.5.4 High in UART Notice1 and high in UART Notice2 when HOST receives

This is not the case because completion of transmission from the Module to the HOST triggers to set low in UN2.

5. Power saving

This protocol stack's power saving controls power-on/off of the hardware deep sleep and RF.

5.1 Deep sleep control

Module deep sleep control is triggered by deep sleep request from the HOST.

Deep sleep control can be performed only when the operation mode is end device or sleeping end device, not when PAN coordinator or coordinator.

The HOST shall manage whether the Module enters to deep sleep mode as appropriate.

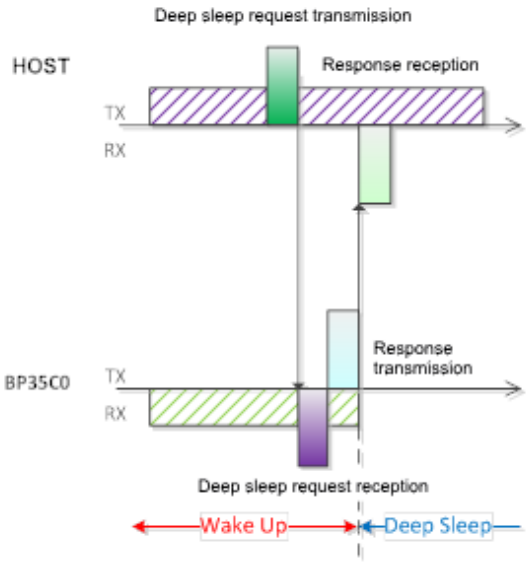

Fig. 9: Wakeup to deep sleep

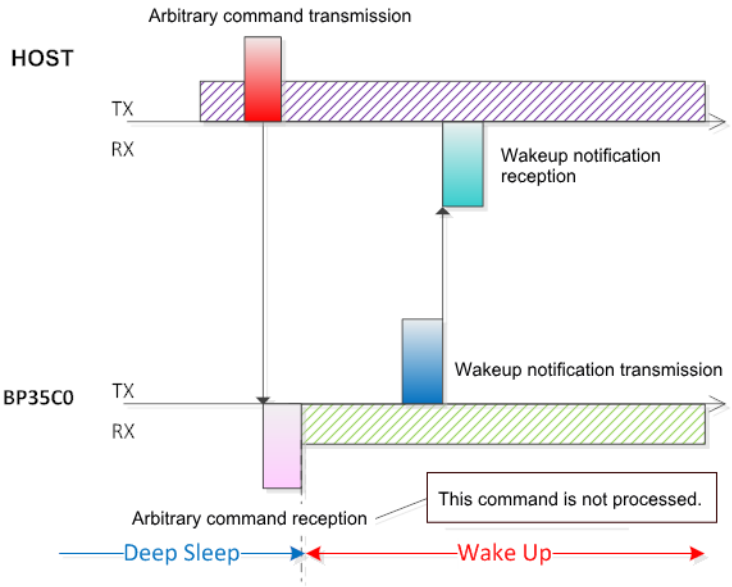

Fig. 10: Deep sleep to Wakeup

5.1.1 Deep sleep Wakeup trigger

The Module releases the deep sleep mode when detecting low in UART_TXD of the HOST; therefore, the deep sleep mode can be released by sending an arbitrary **Request** command from the user. When both the HOST and Module concurrently make the devices enter to the deep sleep mode, do not set low in UART_TXD of the HOST.

5.1.2 UART Break signal

Low is set in UART_TXD of the Module for power saving when the Module is the deep sleep mode.

The Module performs UART communication to respond to a deep sleep request and high is set in UART_TXD of the Module; therefore, this deep sleep operation triggers to set low in UART_TXD, which results in Break signal (0x00) in the HOST.

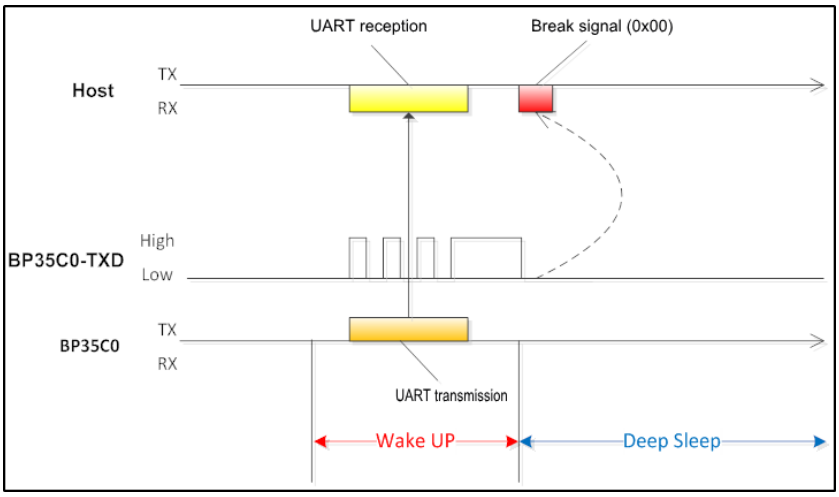

Fig. 11: Break signal by Module TXD control

5.2 RF control

This protocol stack controls power saving by turning off RF at normal times and turning on RF as needed.

RF power-on/off control is executed for sleeping end devices only.

RF power-on/off control is not executed for PAN coordinator, coordinator or end device.

5.2.1 Poll Request transmission - no queuing data

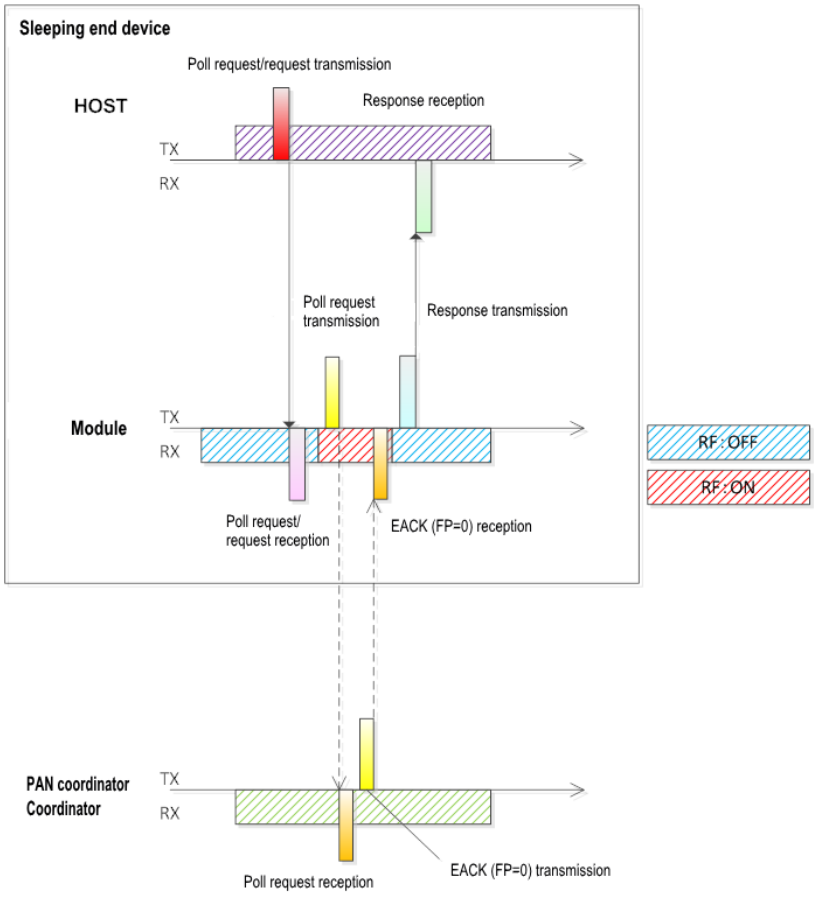

Fig. 12: Poll Request transmission - no queuing data

5.2.2 Poll Request transmission - queuing data reception

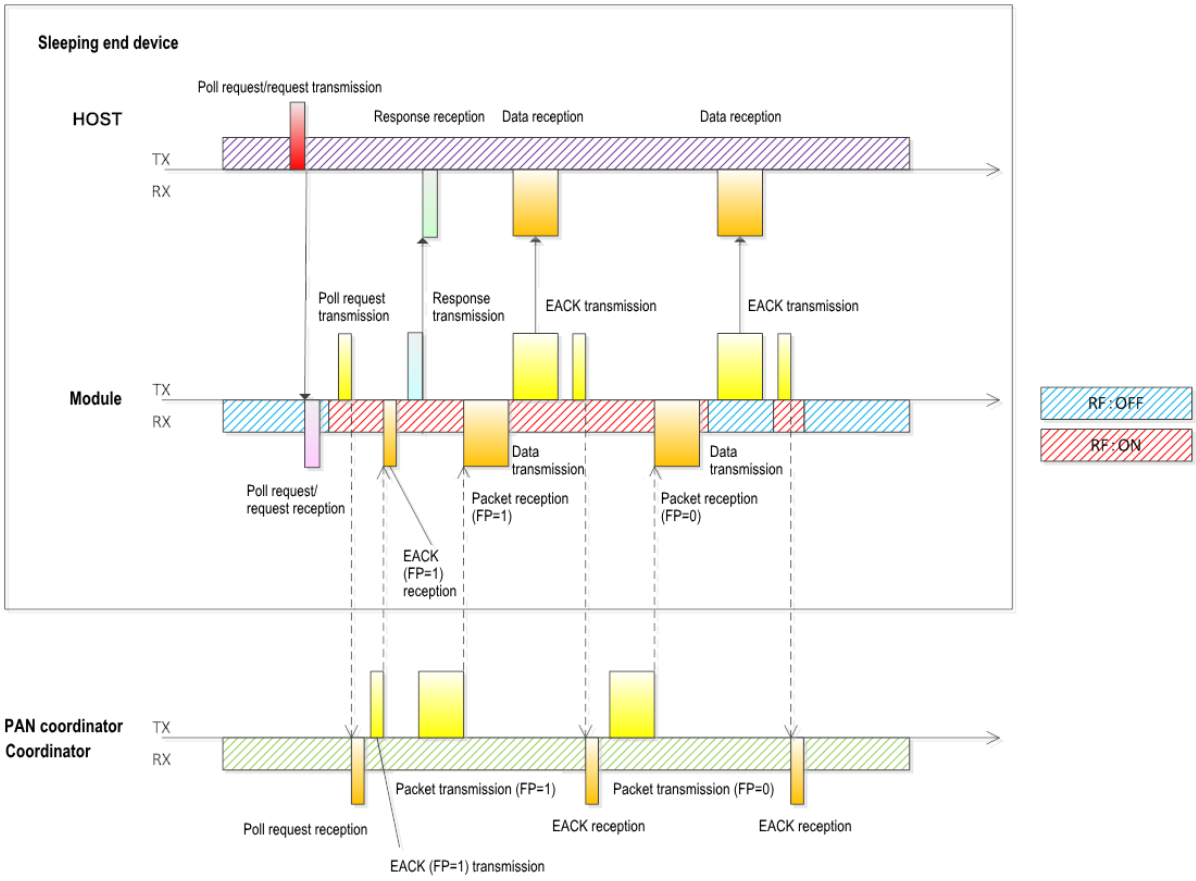

Fig. 13: Poll Request transmission - queuing data reception

5.2.3 Poll Request transmission - queuing data reception time-out

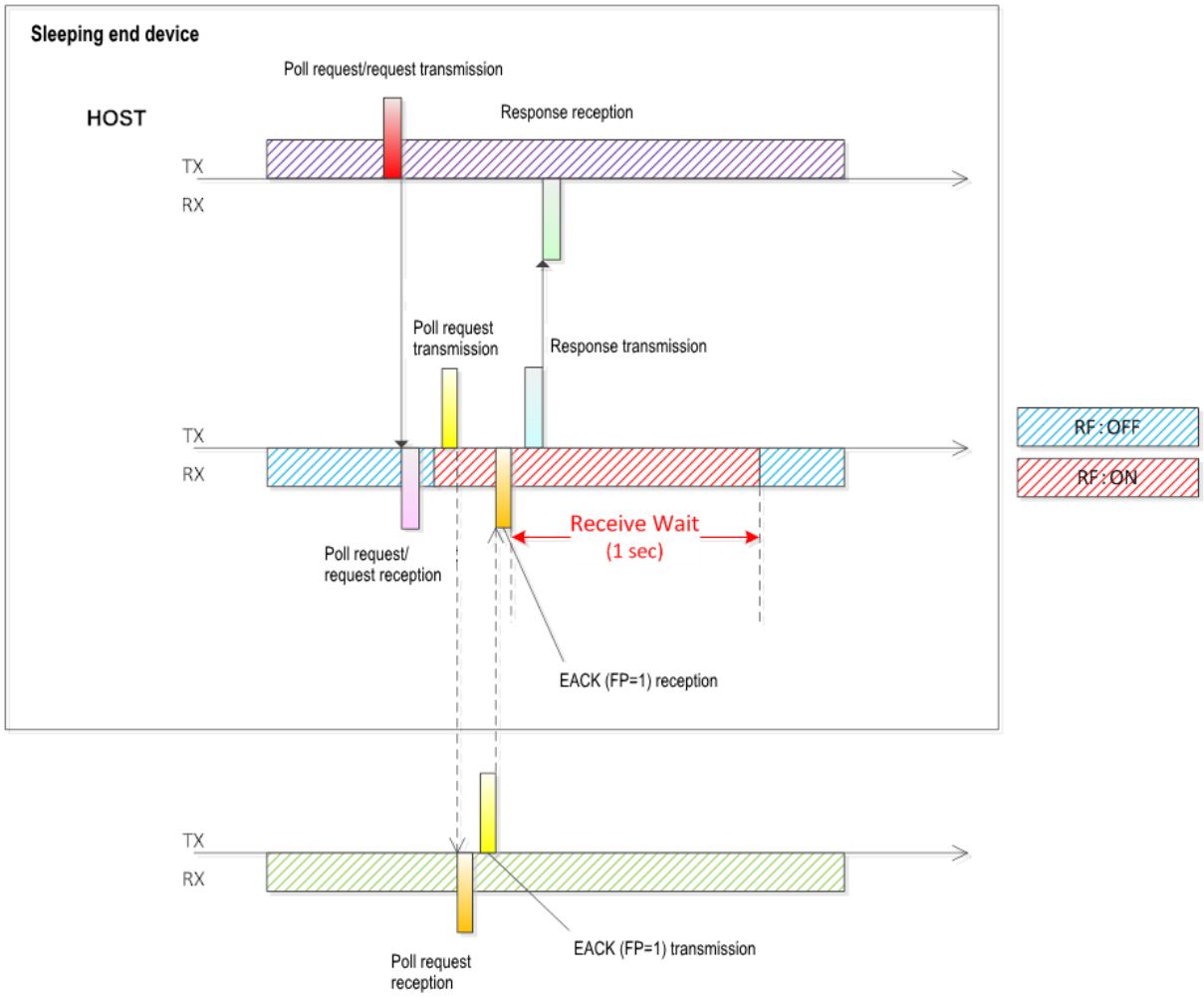

Fig. 14: Poll Request transmission - queuing data reception time-out

6. Watchdog timer

When an abnormal operation is exceptionally generated in this protocol stack, reset may be automatically executed by the watchdog timer.

7. Stack size

The size of the firmware implemented in BP35C0-J11 is described below.

ROM: 220K

RAM: 64K

8. Throughput

Throughput measurement with this protocol stack is provided below for reference purpose.

The following table describes the aggregated results of 500 times of one-way/two-way UDP data transmission of 1,232 bytes in multiple forms.

Throughput was measured 500 times of transmission during a 1-minute period.

Table 12: Throughput results

No.	Form	Data transmission direction	Data transmission success rate	Throughput (bps)
1	1 to 1	PAN coordinator to end device (one-way)	100%	23,654.4
2	1 to 1 to 1	PAN coordinator to coordinator to end device (one-way)	100%	13,141.3
3	1 to 1	PAN coordinator to end device (two-way)	100%	19,547.7
		End device to PAN coordinator (two-way)	100%	17,905.1
4	1 to 1 to 1	PAN coordinator to coordinator to end device (two-way)	99.2%	9,198.9
		End device to coordinator to PAN coordinator (two-way)	99.6%	8,706.1

Notes

1) The information contained herein is subject to change without notice.

2) Before you use our Products, please contact our sales representative and verify the latest specifications :

3) Although ROHM is continuously working to improve product reliability and quality, semiconductors can break down and malfunction due to various factors.
Therefore, in order to prevent personal injury or fire arising from failure, please take safety measures such as complying with the derating characteristics, implementing redundant and fire prevention designs, and utilizing backups and fail-safe procedures. ROHM shall have no responsibility for any damages arising out of the use of our Poducts beyond the rating specified by ROHM.

4) Examples of application circuits, circuit constants and any other information contained herein are provided only to illustrate the standard usage and operations of the Products. The peripheral conditions must be taken into account when designing circuits for mass production.

5) The technical information specified herein is intended only to show the typical functions of and examples of application circuits for the Products. ROHM does not grant you, explicitly or implicitly, any license to use or exercise intellectual property or other rights held by ROHM or any other parties. ROHM shall have no responsibility whatsoever for any dispute arising out of the use of such technical information.

6) The Products specified in this document are not designed to be radiation tolerant.

7) For use of our Products in applications requiring a high degree of reliability (as exemplified below), please contact and consult with a ROHM representative : transportation equipment (i.e. cars, ships, trains), primary communication equipment, traffic lights, fire/crime prevention, safety equipment, medical systems, servers, solar cells, and power transmission systems.

8) Do not use our Products in applications requiring extremely high reliability, such as aerospace equipment, nuclear power control systems, and submarine repeaters.

9) ROHM shall have no responsibility for any damages or injury arising from non-compliance with the recommended usage conditions and specifications contained herein.

10) ROHM has used reasonable care to ensure the accuracy of the information contained in this document. However, ROHM does not warrants that such information is error-free, and ROHM shall have no responsibility for any damages arising from any inaccuracy or misprint of such information.

11) Please use the Products in accordance with any applicable environmental laws and regulations, such as the RoHS Directive. For more details, including RoHS compatibility, please contact a ROHM sales office. ROHM shall have no responsibility for any damages or losses resulting non-compliance with any applicable laws or regulations.

12) When providing our Products and technologies contained in this document to other countries, you must abide by the procedures and provisions stipulated in all applicable export laws and regulations, including without limitation the US Export Administration Regulations and the Foreign Exchange and Foreign Trade Act.

13) This document, in part or in whole, may not be reprinted or reproduced without prior consent of ROHM.

ROHM SEMICONDUCTOR

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