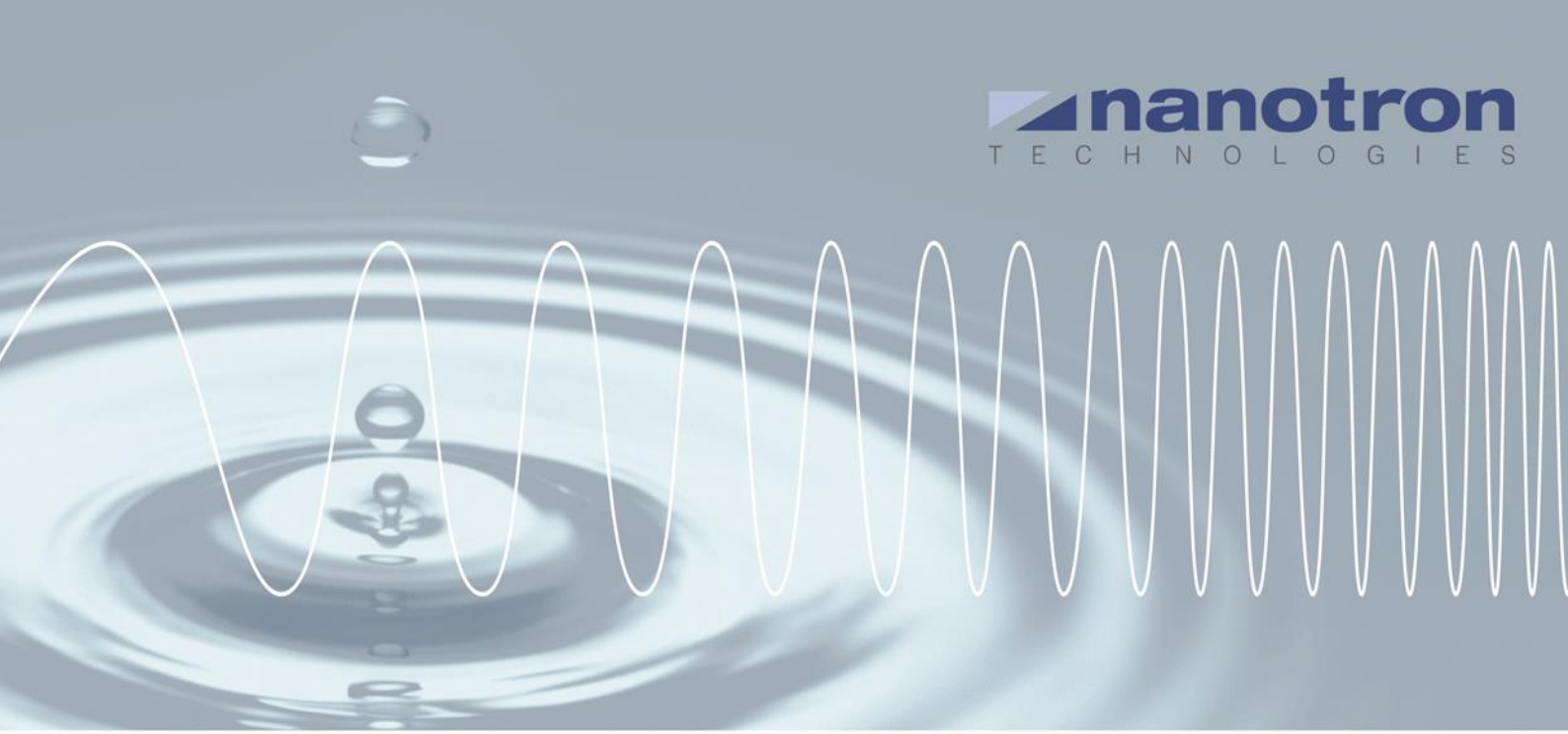

AN0519 - Transmission mechanism in the swarm bee LE

1.0

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Contents

1. Introduction

Any communication system needs to have some mechanism to interface with the transmission medium. In the case of wireless systems, the physical transmission medium is more vulnerable; thus the interface mechanisms often needs to ensure that the message arrives correctly at the receiver. All these mechanisms are normally transparent to the user. However, understanding them is important to understand why the same device does not always behave the same way. It also helps to predict how the environment can influence the behavior.

This document applies for the swarm bee LE products.

2. How do simple transmissions work?

When the radio chip, nanoLOC, needs to transmit a message, it does it immediately.

Every time a unicast message is sent, the transmitter device starts a timer (T_{ack} = ack-timeout). The transmitter expects to receive a hardware acknowledgement (ack) from the destination before the timer expires. If the T_{ack} timer expires and the ack has not arrived, the message will be retransmitted. To avoid falling into an infinite loop, the number of retransmissions is limited to 3; this means that the same packet can be transmitted a maximum of 4 times. If after the 3rd retransmission the device still does not receive any ack the transmitter aborts the operation.

The ack-timeout is 24us.

3. Transmissions with the CSMA mechanism

3.1. What is CSMA

The Carrier Sense Medium Access (CSMA) mechanism consist on avoiding packet collisions by listening to the medium before transmitting. After listening, the packet is transmitted only if the medium is free; i.e. no other device is transmitting. When the medium is detected as busy, the transmission of the packet is delayed. After a certain period of time, the device will check the channel again.
This mechanism avoids that different devices transmit at the same time causing collision and communication errors. It increases the success rate of the transmissions when the channel becomes busy.

3.2. How does CSMA work?

When a message is transmitted using the CSMA mechanism, it should also be acknowledged by the destination and, if not, retransmitted. This is done as explained in previous section.

In addition to the regular procedures, the CSMA mechanism is added:

Before transmitting or retransmitting a message the module listens to the channel, in this case the air. If the channel is free, the module transmits its message. If the channel is taken it waits for a short while (back-off time) and it listens again. It keeps on doing so until the channel is free. When this happens the device transmits its message. To avoid that the devices goes into an infinite loop of continuous listening and waiting, a timer (T_{CSMA} = csma-timeout) is initialized the first time that the device listens to the channel. The timer cancelled when the device is able to transmit the message. If the T_{CSMA} expires, the device stops trying and aborts the transmission.

The csma-timeout is equal to 15 ms.

The back-off time depends on the CSMA settings but always a multiple of 24us (time slot duration).

CSMA <M=1/2> <Duration>

CSMA <M=3/4> <Duration> <Threshold>

Fix back-off: M=2 or M=4, the parameter <Duration> is multiplied by 24 us.

Random back-off: M=1 and M=3, the parameter <Duration> is combined with the internal clock to obtain a random seed. The random seed will be used to generate an integer every time a back-of is required. The back-off time will be that integer multiplied by 24us. For the first back-off this integer will be a low number (lower than 10). The more times the device needs to back-off the longer the waiting time.

What does exactly mean 'the channel is occupied'?

The channel is occupied when another signal with the required characteristics is detected during the listening time. Said characteristics can be a symbol type or the signal energy higher than a certain threshold:

If M=1 or 2 (symbol detection mode) the listening device looks for a signal with similar modulation (CSS). It detects when another nanotron device is transmitting.

If M= 3 or 4 (energy detection mode) the listening device measures the strength of the radiated energy present in the channel. If that energy is higher than <threshold> it considers the channel is taken. The radiated energy could be caused by a nanotron device or by any other transmission device working in the same frequency band (WiFi…)

More information on how to set the CSMA can be found in [1]

3.3. Why should CSMA be used?

In scenarios where many devices are working simultaneously, it is highly probable that more than one transmission occurs at the same time. When this happens, the air messages involved will collide and a retransmission will be needed again. It is possible (but not probable) that the retransmissions collide again. The percentage of successful transmissions decreases dramatically when the number of devices working in the same area increases.

To avoid such situations the CSMA should be activated, so that the device avoids transmitting at the same time as other devices. Although at first sight it may seem that the CSMA mechanism increases the transmission time, its effect is the opposite. CSMA avoid packets collisions, increasing the success rate of the first transmission and reducing the number of retransmissions needed. As the number of retransmissions is limited to 3, the CSMA mechanism also reduces the rate of unsuccessful operations (transmission aborted).

Nanotron always recommends to use the CSMA mechanism in symbol detection mode with random back-off time (command CSMA 1 <Duration>). This is very appropriate for scenarios with multiple swarm devices.

In scenarios where other wireless systems working in the 2.4GHz ISM band exist. The CSMA 3 can be more appropriate.

4. Operations involving multiple transmissions → The ranging operation

The ranging process consist in exchanging multiple air messages to so that the device that started it can gather all the required information to estimate the distance to the other device. For each message both retransmissions and the CSMA mechanism, if active, apply.

Figure 4-1 depicts a complete ranging process. The upper yellowish line shows the pin /TX_RX status on device A, it indicates a transmission when it is low level. The lower blueish line shows the pin /TX_RX status on device B, it indicates a transmission when it is low level. Device A broadcast a blink, as it is a broadcast, it is never retransmitted. However, the CSMA mechanism is applied. When device B receives the blink it triggers a range request (RR) directed to device A. The RR, as well as ranging message 1 (R1) and ranging message 2 (R2) are unicast messages, thus a hardware acknowledgment is expected and retransmissions are implemented. This means that, every time a device sends a RR, that request should be acknowledged (ack) by the destination. That ack only means that the request has been received, independently of whether it will be accepted or not. When device B receives the ack it expects to receive the other two messages R1 and R2. Perhaps this other messages do not arrive due to communication problems or simply because device A does not agree to do the ranging. To avoid being blocked waiting, device B starts a timer $T_{ranging}$ = ranging-timeout immediately after it receives the ack to its RR. The value of the Raging timeout depends on the device settings:

CSMA off – Transmission mode 1 (SDAM 1) → Ranging Timeout = 7 ms
Transmission mode 2 (SDAM 2) → Ranging Timeout = 13 ms
CSMA on – Transmission mode 1 (SDAM 1) → Ranging Timeout = 7 ms + 15 ms
Transmission mode 2 (SDAM 2) → Ranging Timeout = 13 ms + 15 ms

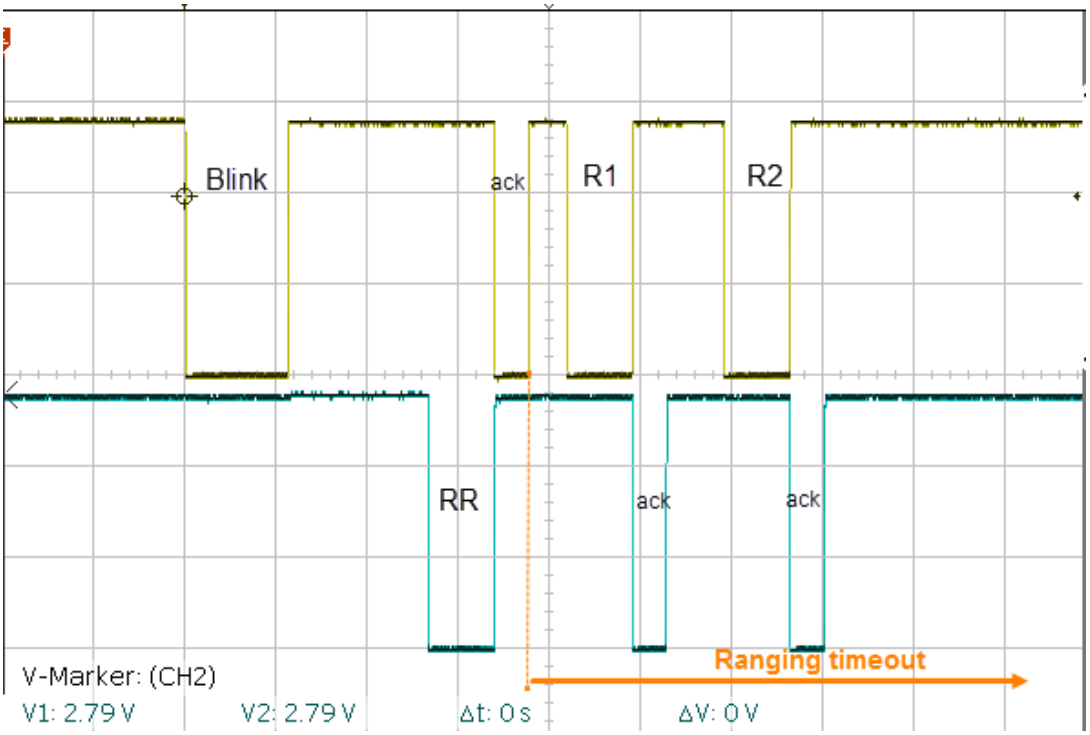

Figure 4-1 Ranging operation between two devices

In Figure 4-1 the ranging operation is successfully acomplished. Figure 4-2 depicts a situation where the ranging timer expires and now ranging information is available. The upper yellowish line shows the pin /TX_RX status on device A, it indicates a radio transmission state when it is low level. The middle blueish line shows the pin /TX_RX status on device B, it also indicates a radio transmission state when it is low level. And the lower pinkish shows the UART_TX pin on device B,used to transmit the range result notification to the controller. Device B detects a blink from A and reacts to it by sending a ranging request message. Device A receives the request and acknowledges its reception. However, as A is in privacy mode, it does not accept the request and in consequence it does not transmit R1 nor R2. When device B receives the acknowledgement it starts the ranging timer and waits for the ranging messages. After the ranging timeout, it transmits the ranging result notification with an error over the UART.

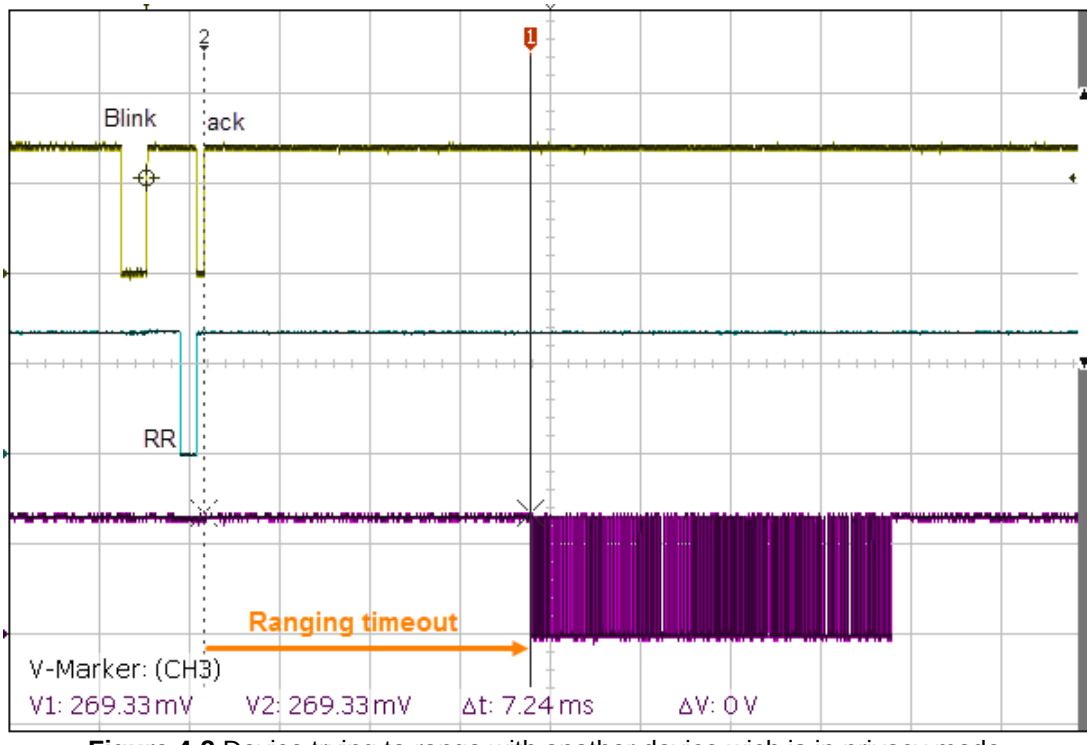

Figure 4-2 Device trying to range with another device wich is in privacy mode

5. Summary

The document describes how the swarm bee LE devices interface to the transmission medium and defines different parameters involved in the transmission process. These are listed below

ACK timeout → maximum time that a transmitting device waits after the transmission to receive the ack.

When this timer expires the device retransmits the message or, if a 3rd retransmission was already completed, it aborts the transmission.

Maximum number of packet retransmissions 3

Back-off time → time that a device waits after detecting the channel as occupied and before listening to the channel again.

CSMA timeout →maximum time that the device keeps on trying to find the channel free. It is initiated for every transmission when the device listens to the channel for the first time. If it expires the transmission is aborted.

Ranging timeout → maximum time that a device waits to have all the required data after its ranging request has been acknowledged. If the timer expires before all the ranging packages have been received the ranging operation is erroneous and no distance is returned.

6. References

[1] *swarm* bee API User Guide, v3.0.8, 2017

Document History

Date	Author	Version	Description
6-8-2017	MLA	1.0	Initial version

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Further Information

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