SISTEMAS DE POSICIONAMIENTO EN INTERIORES

(INDOOR POSITIONING SYSTEMS)

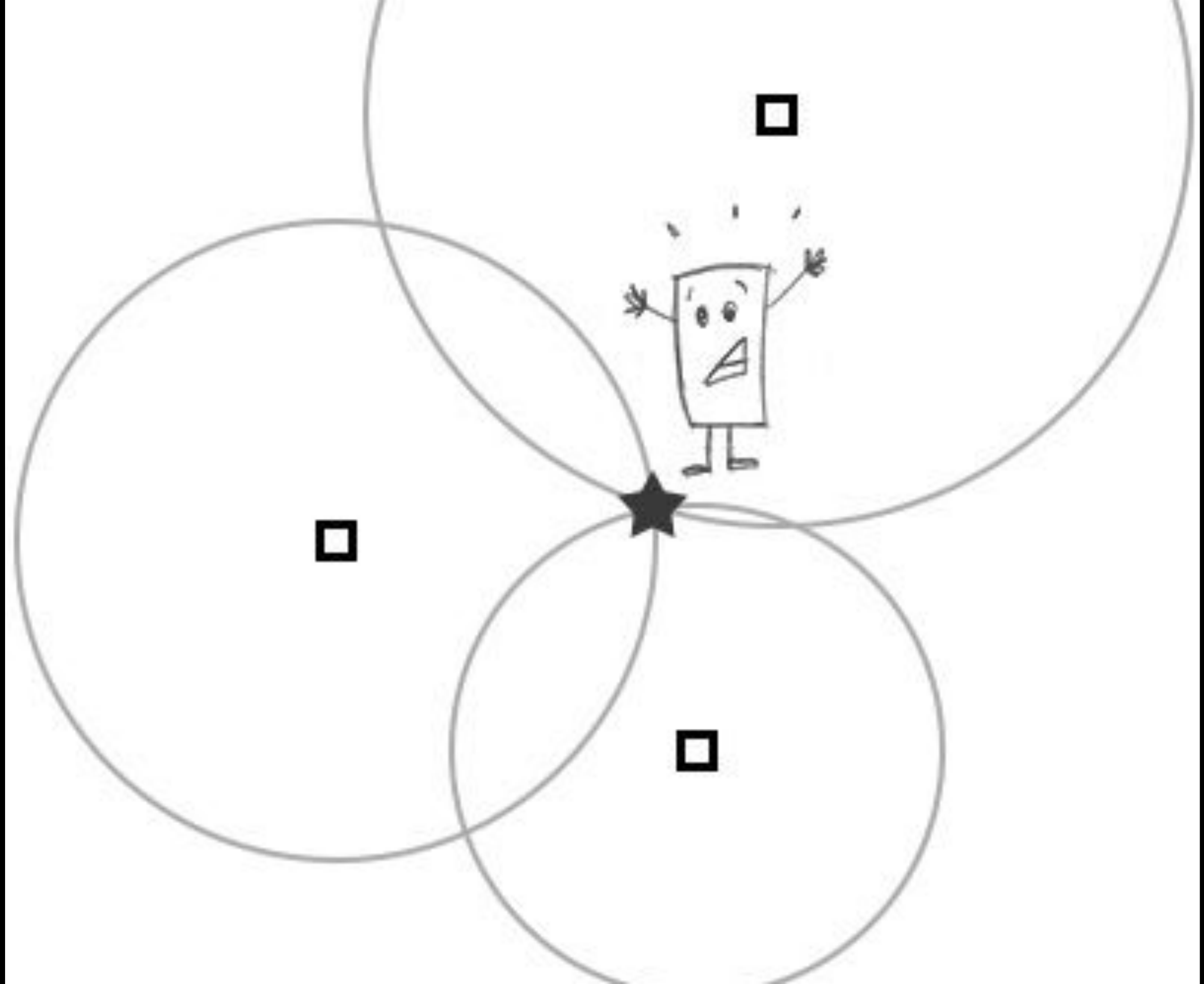
UWB

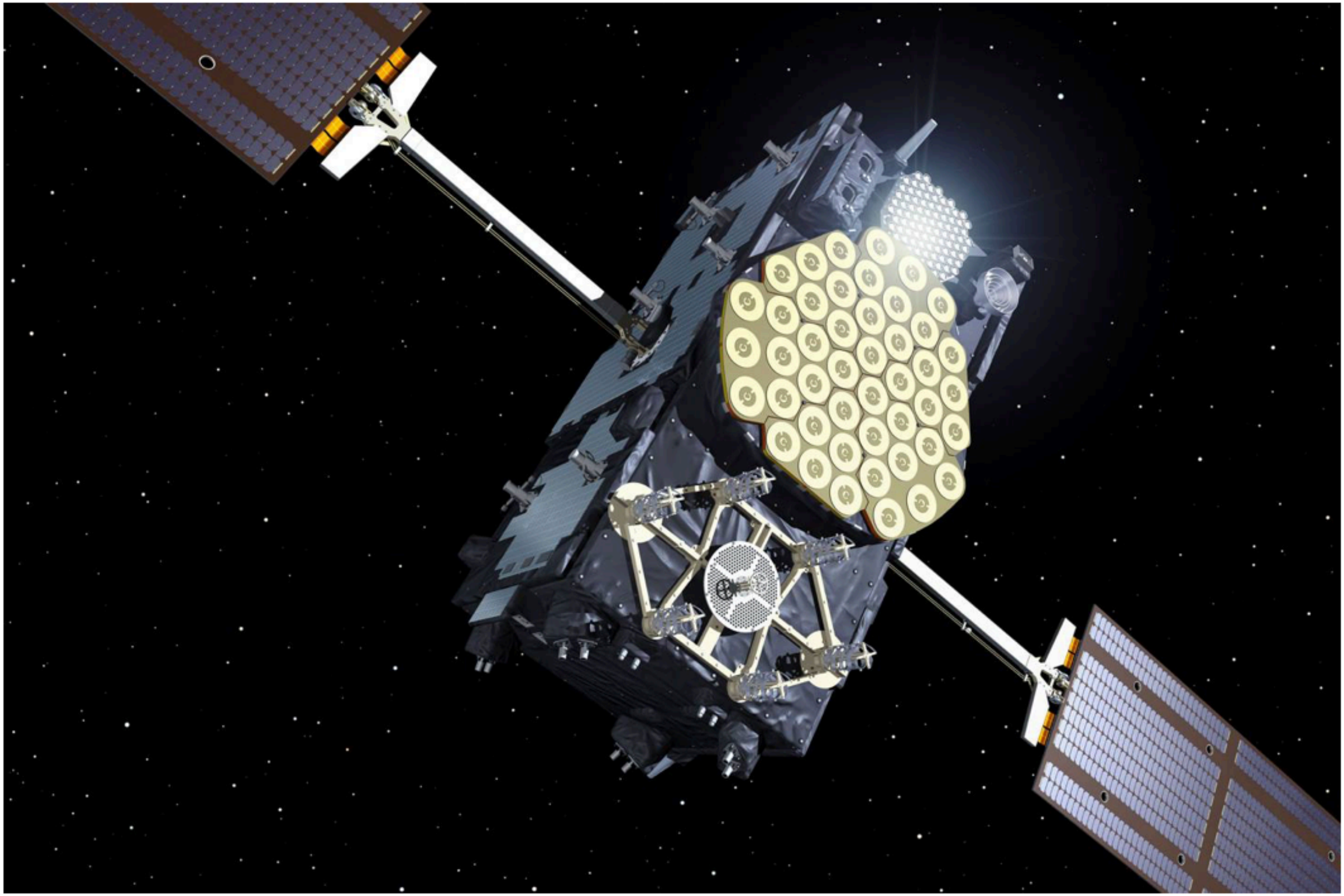
Manuel Prados
&
Pedro López

MEDIALAB PRADO

24/01/2020

ACAR PUIG MAYOR · EVA·7 · NO MAS ALLA





Europe's Galileo satellite system will be completed by 2020. The UK's involvement is currently up in the air

Credit **ESA/ P. Carril**

Range

Graphic by Rainer Mautz

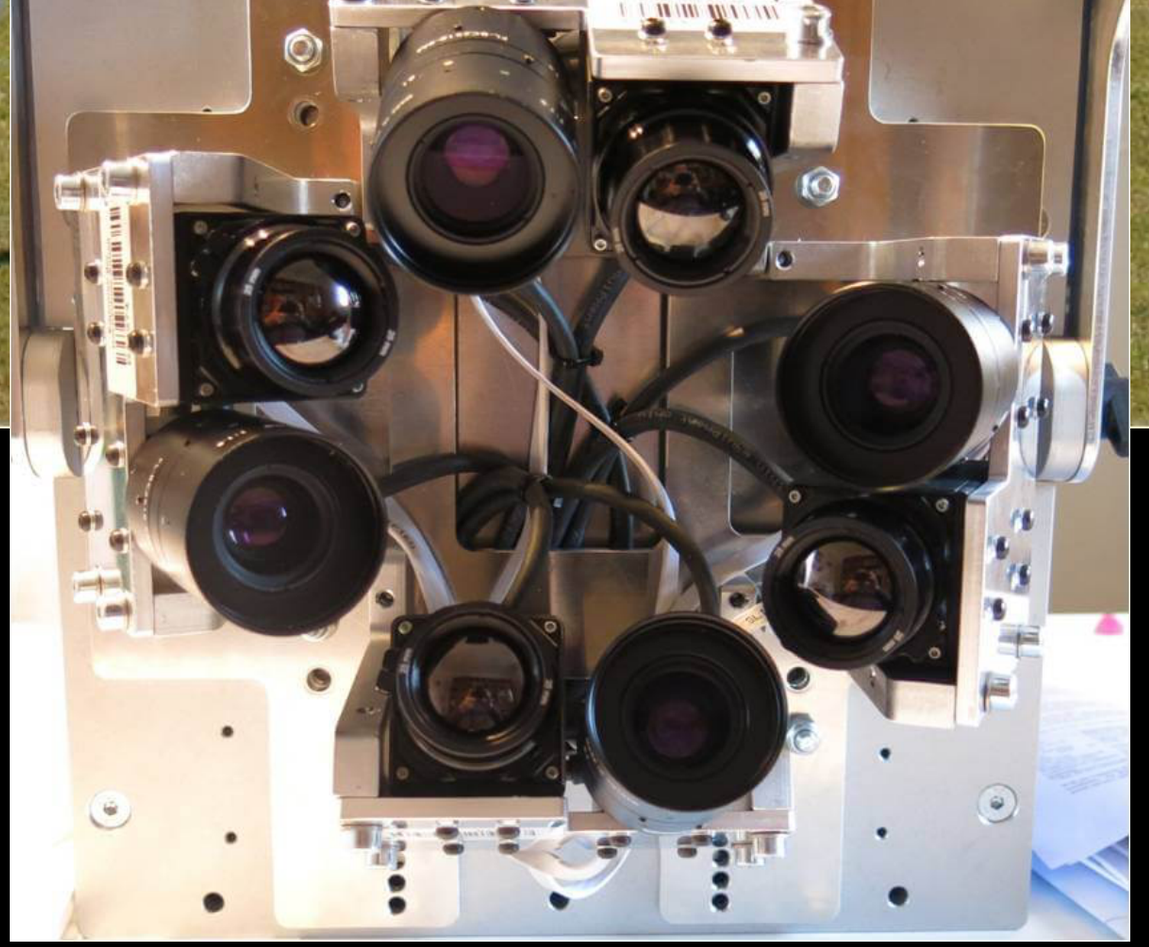
+ Sonidos y Ultrasonidos
+ Campos Magneticos
+ IMU - Inercial
+ Camaras

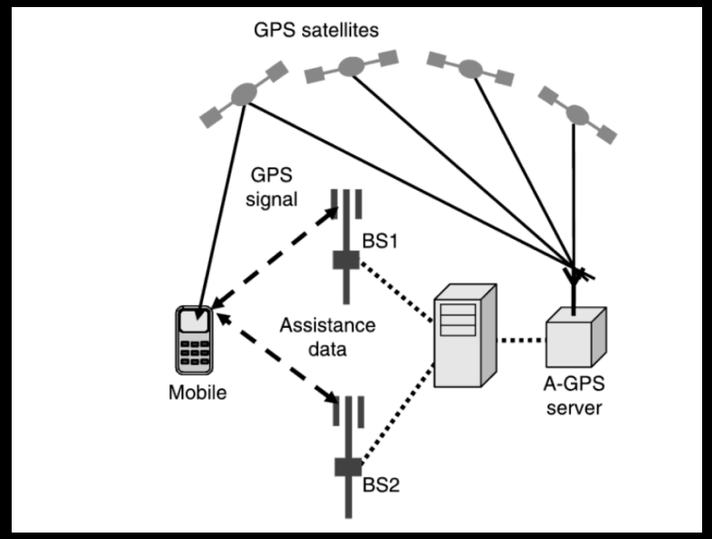
Outdoor
10 km
Remote
1 km
Rural
100 m
Urban
Indoor
10 m
Room
1 m
Sub-Room

Precision Level (1D)
Geodetic GNSS
Pseudolites
Locata
Novariant
Naviva
Radianse
Versus
DecaWave
Robostation (AndroTec)
Metris
iGPS
Laser Tracker
Rotational Laser (2D)
RF Distance Network
Active RFID
AGPS / Single GNSS Receiver
GSM
WLAN / Wi-Fi
CLIPS (ETHZ)
Totalstation
Ultrasound Systems
IR Laser
UWB
Coordinate Measuring Machine
Measuring Arm
Optical
ProCam (Aicon)
Active Bat
Cricket
DOLPHIN
Sonitor
NorthStar
TrackSense (ETHZ)
Ubisense
Sapphire DART
Ekahau RTLS
SIPS (ETHZ)
MagicMap
COMPASS

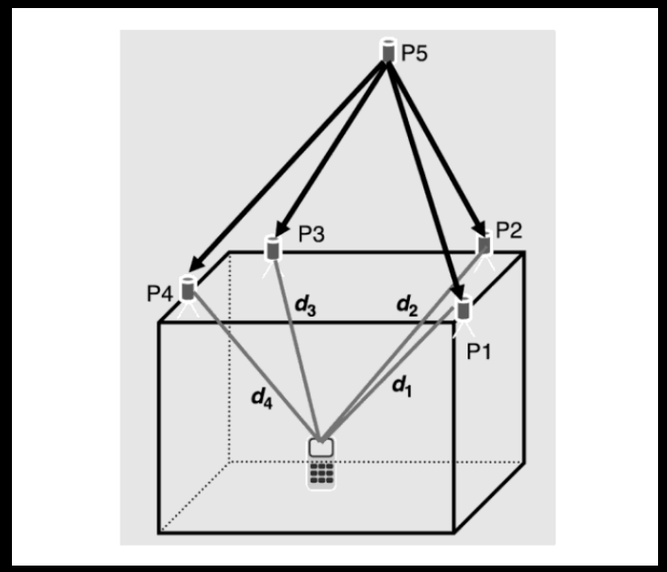
1 µm | 10 µm | 100 µm | 1 mm | 1 cm | 1 dm | 1 m | 10 m | 100 m
Accu

3D thermal imaging camera

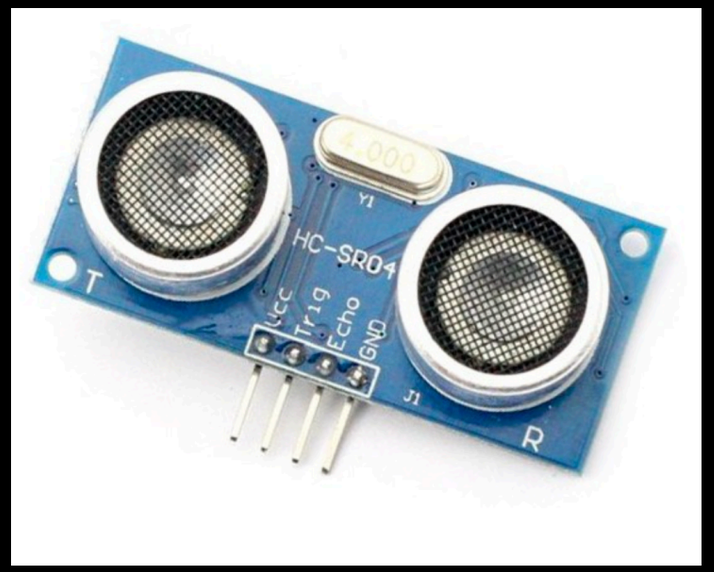




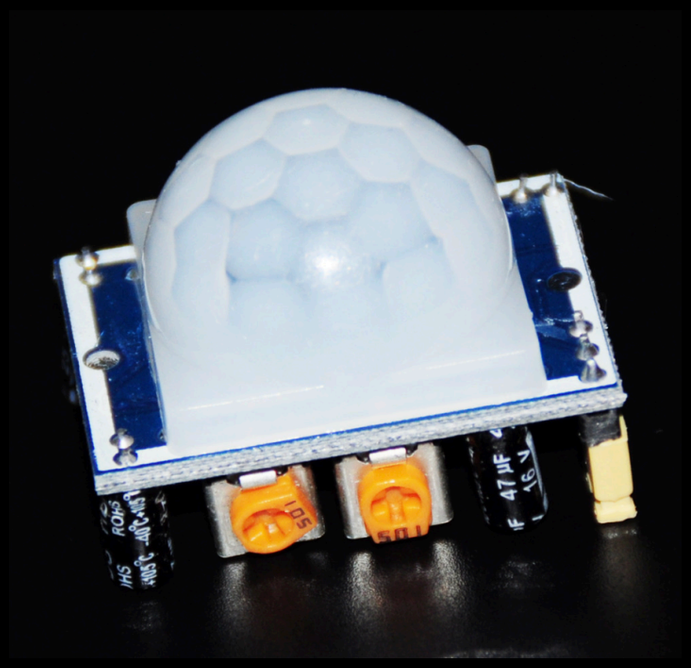
Global Navigation Satellite System



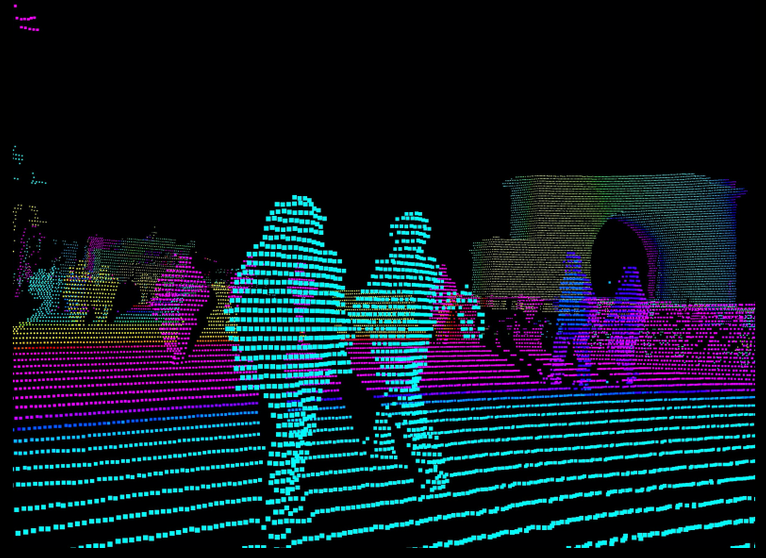
SEUDOLITES



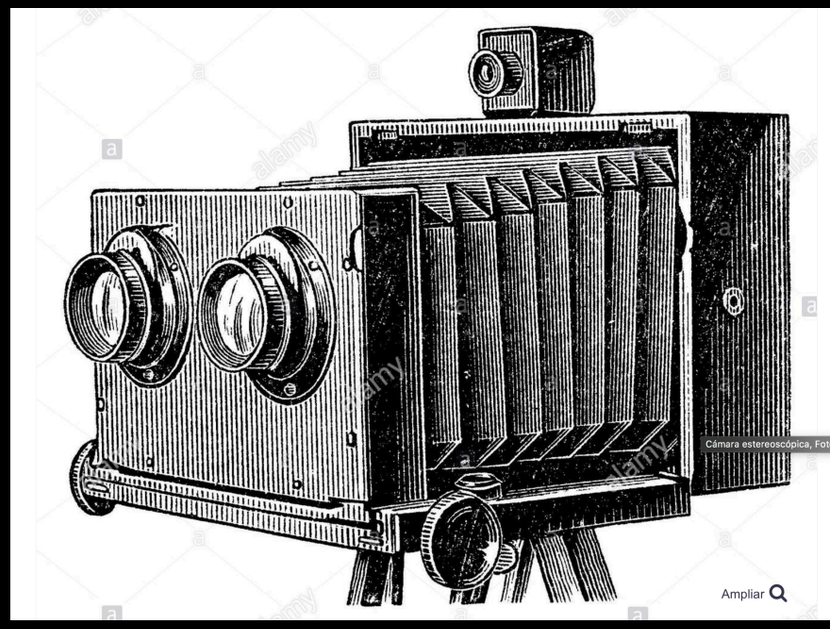
Utrasonidos



PIR



LIDAR



CAM Estereoscópicas

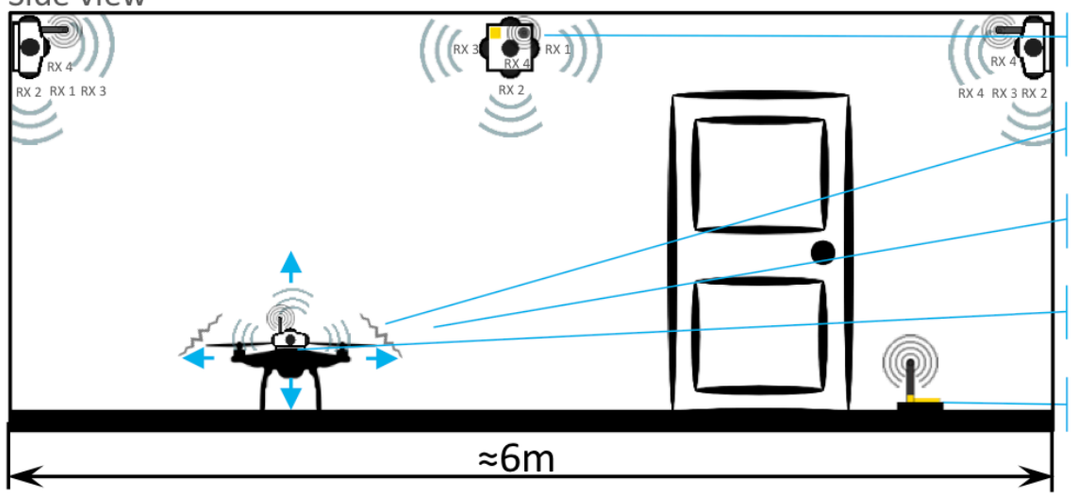
Indoor “GPS”

(with ±2cm precision)

Autonomous copter setting manual

Marvelmind robotics

Side view



Stationary beacon

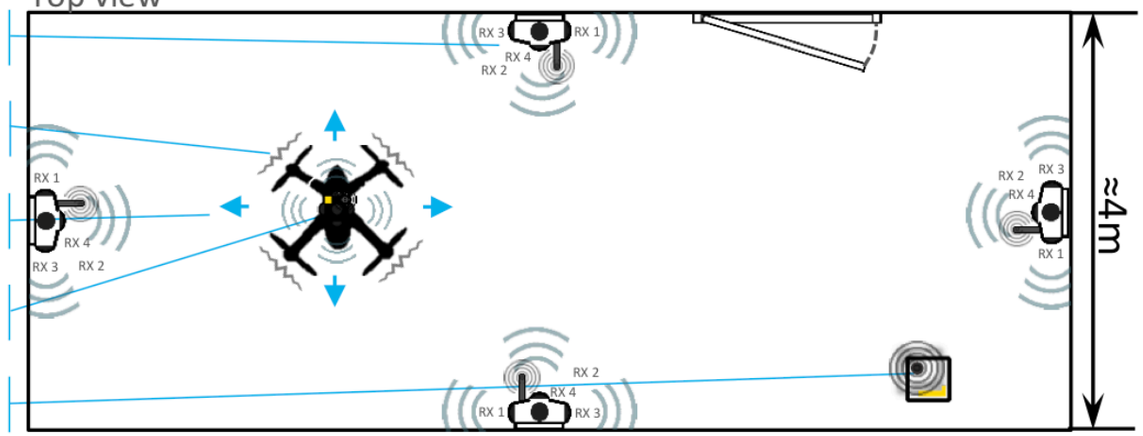
Noise

Copter

Mobile Beacon

Modem

Top view




Time since last flash: 5.35 ms
Delta t X 4.926 ms = 16.401 Deg
Delta t Y 5.173 ms = 21.733 Deg


htc
htc
htc
htc
VIVE
VIVE

LIFI

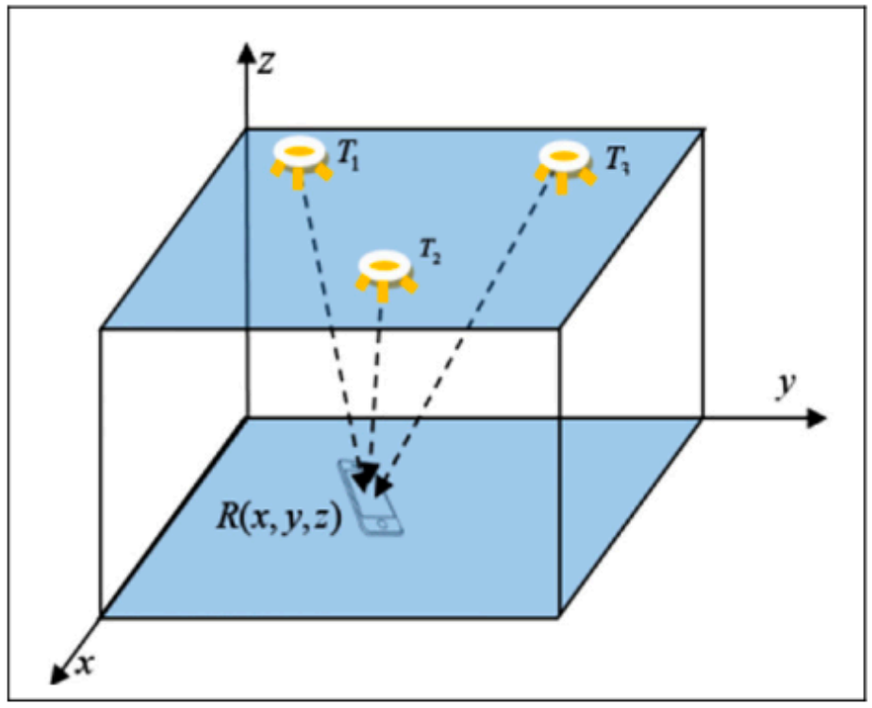


Figure 2. Visible light positioning.

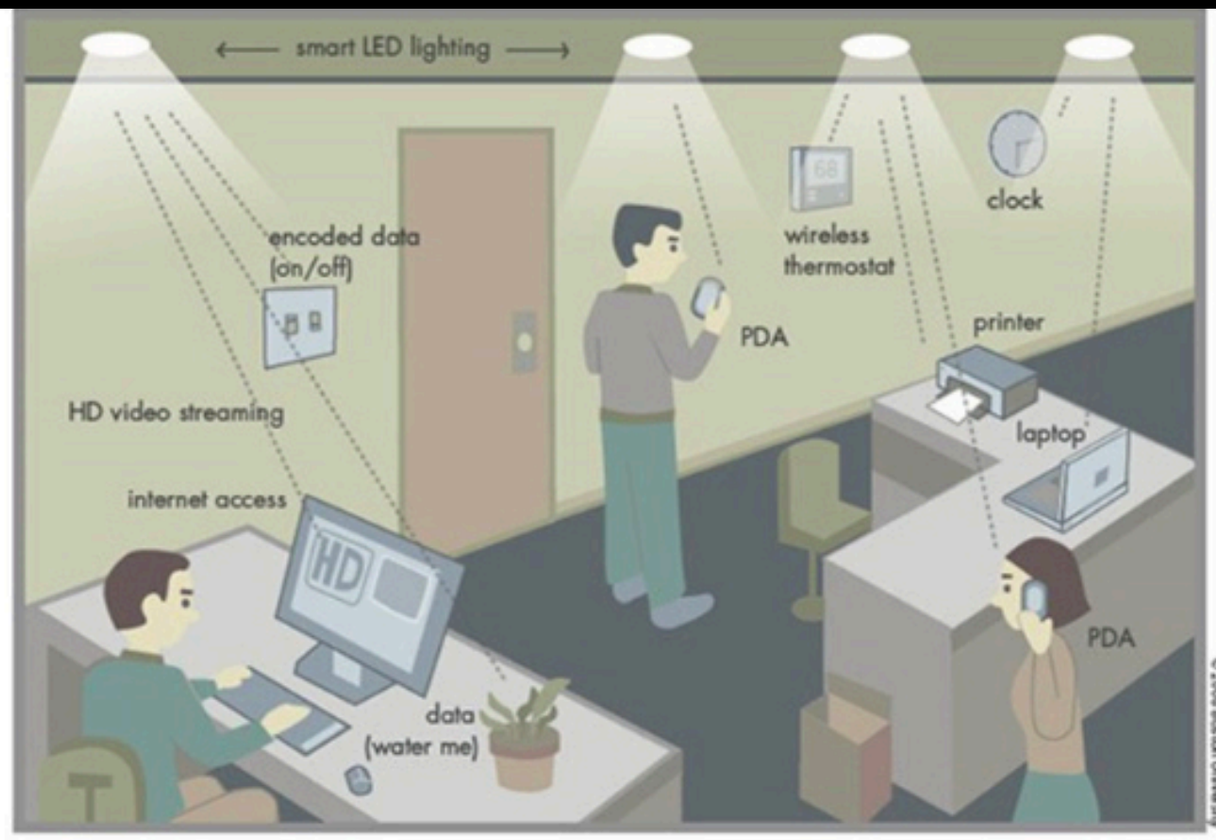


Fig. 3 LED communications [16]

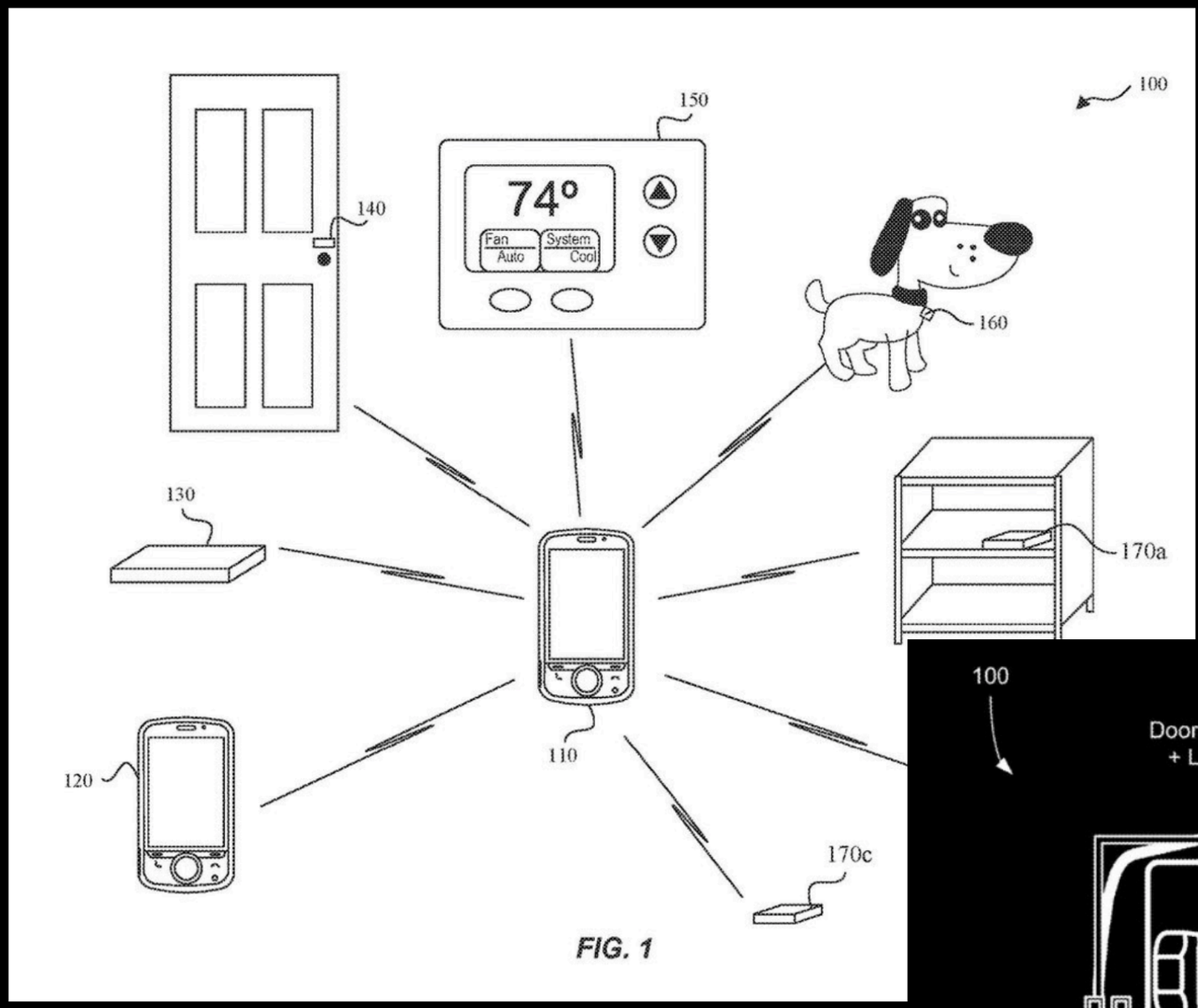
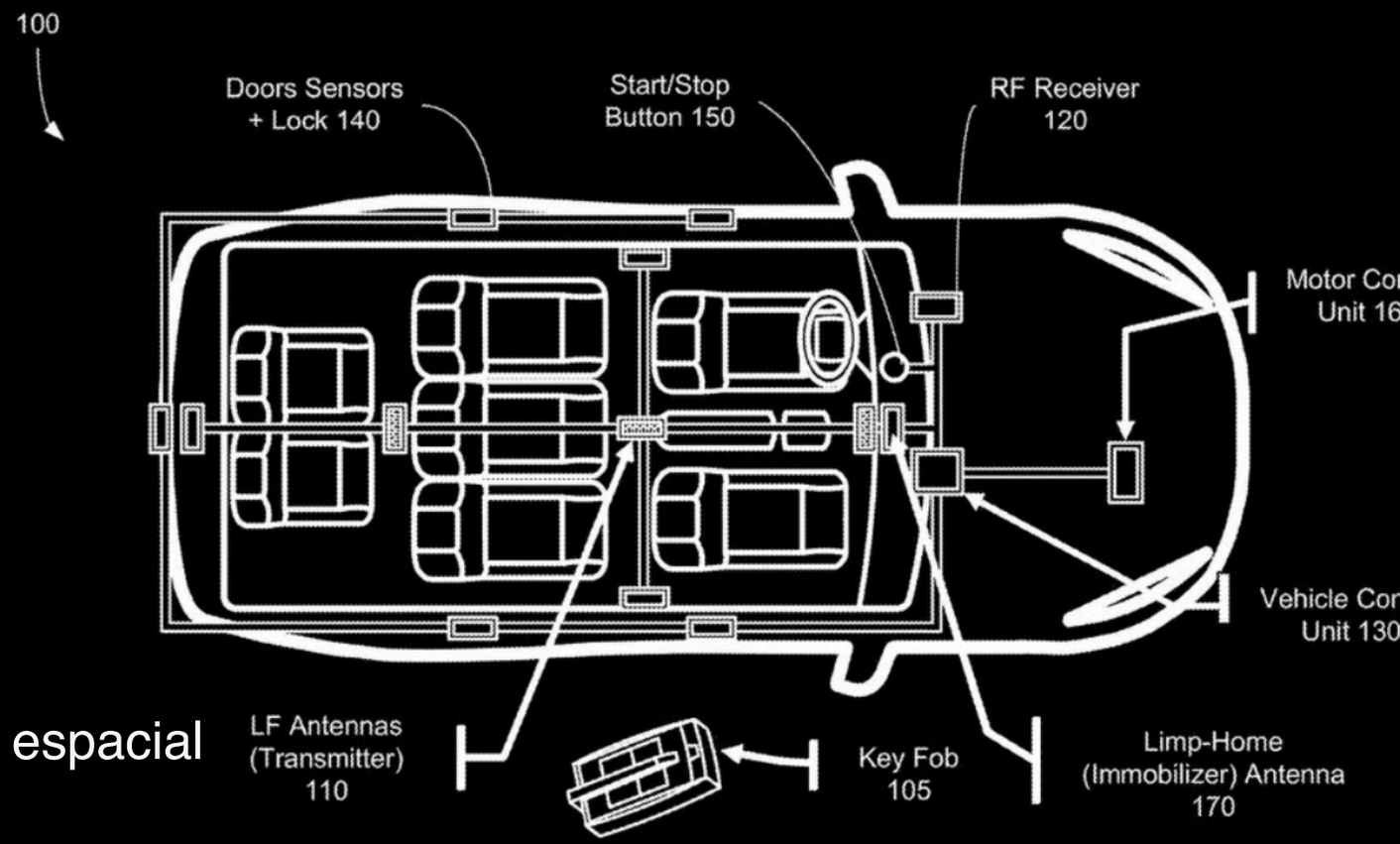


FIG. 1



Chip de **banda ultraancha** para la detección espacial

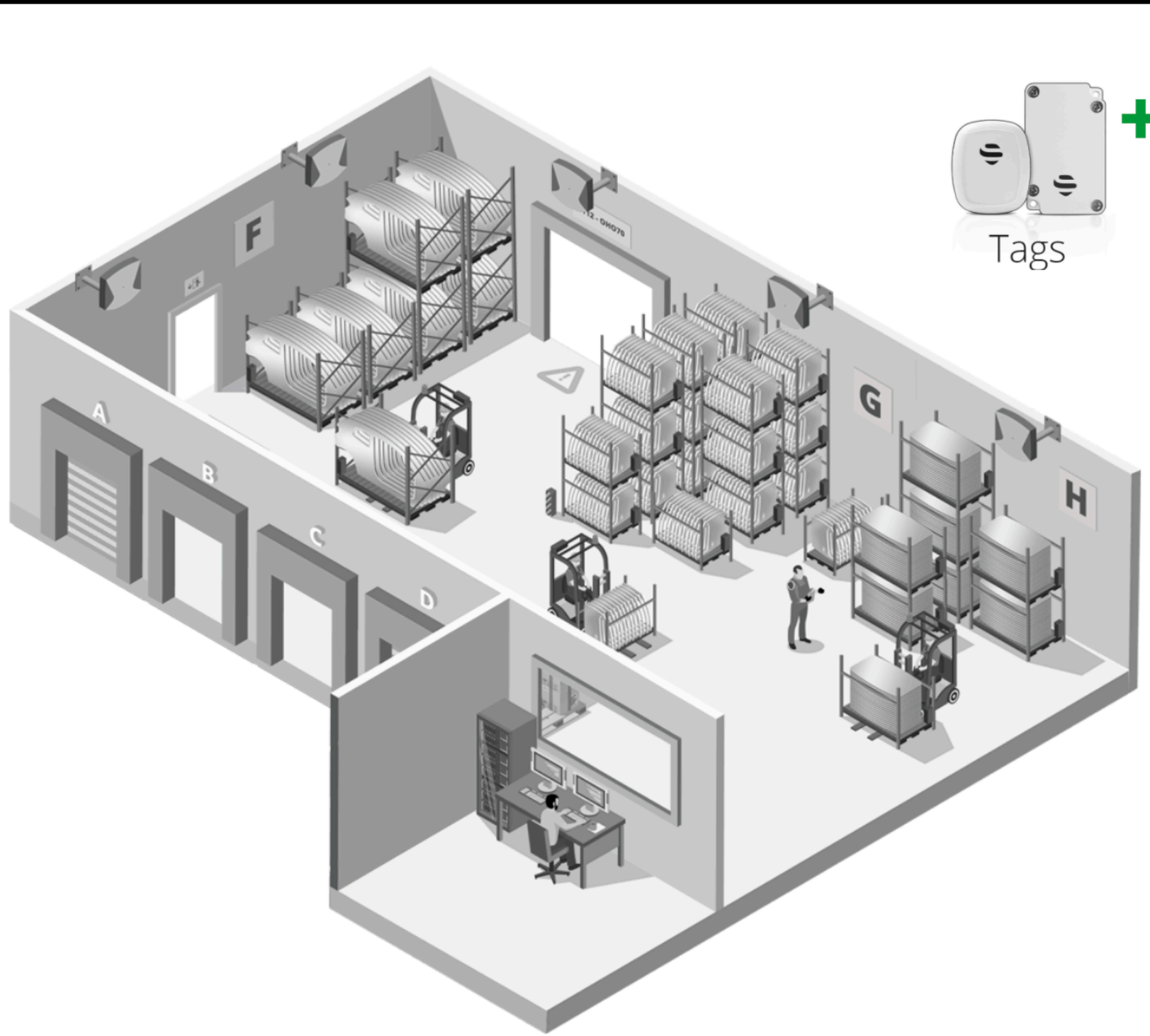
POZYX
0-10 cm

POSITIONING ERROR

BLUETOOTH, WIFI, ...
1-5 m

GPS
6-10 m

0 1 2 3 4 5 6 7 8 9 10


A
B
C
D
F
G
H


Tags
Anchors
Software
RTLS STUDIO

Principles of UWB

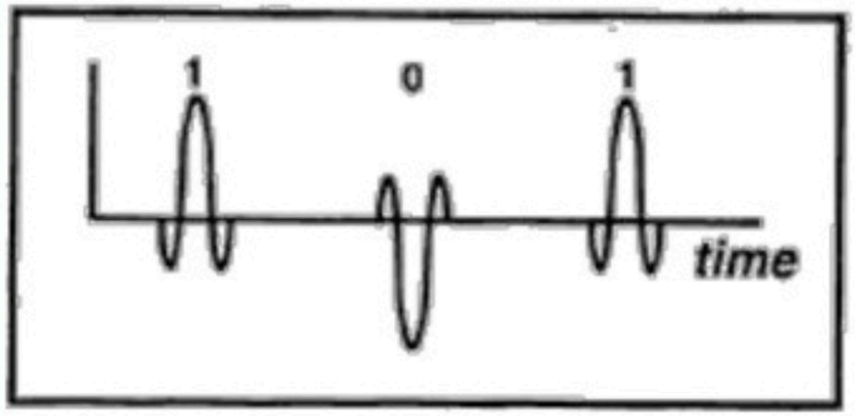
Time Domain

- Extremely short pulses
- Very low duty cycle

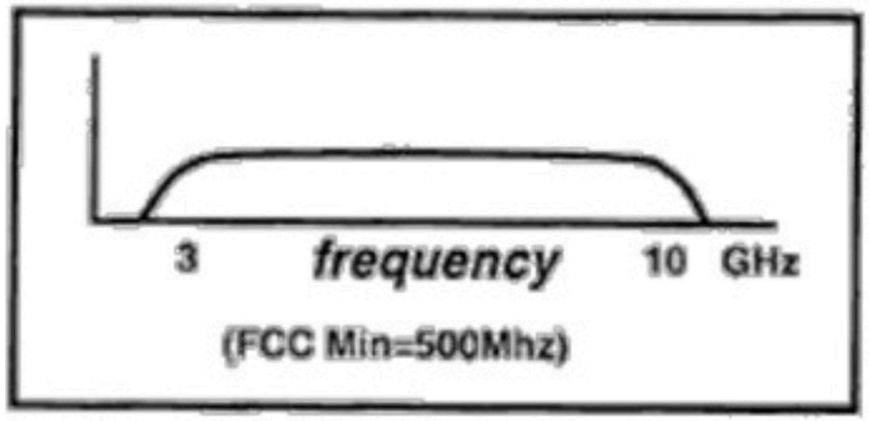
Frequency Domain

- Ultra wide spectrum
- Low power spectral density

Time-domain behavior

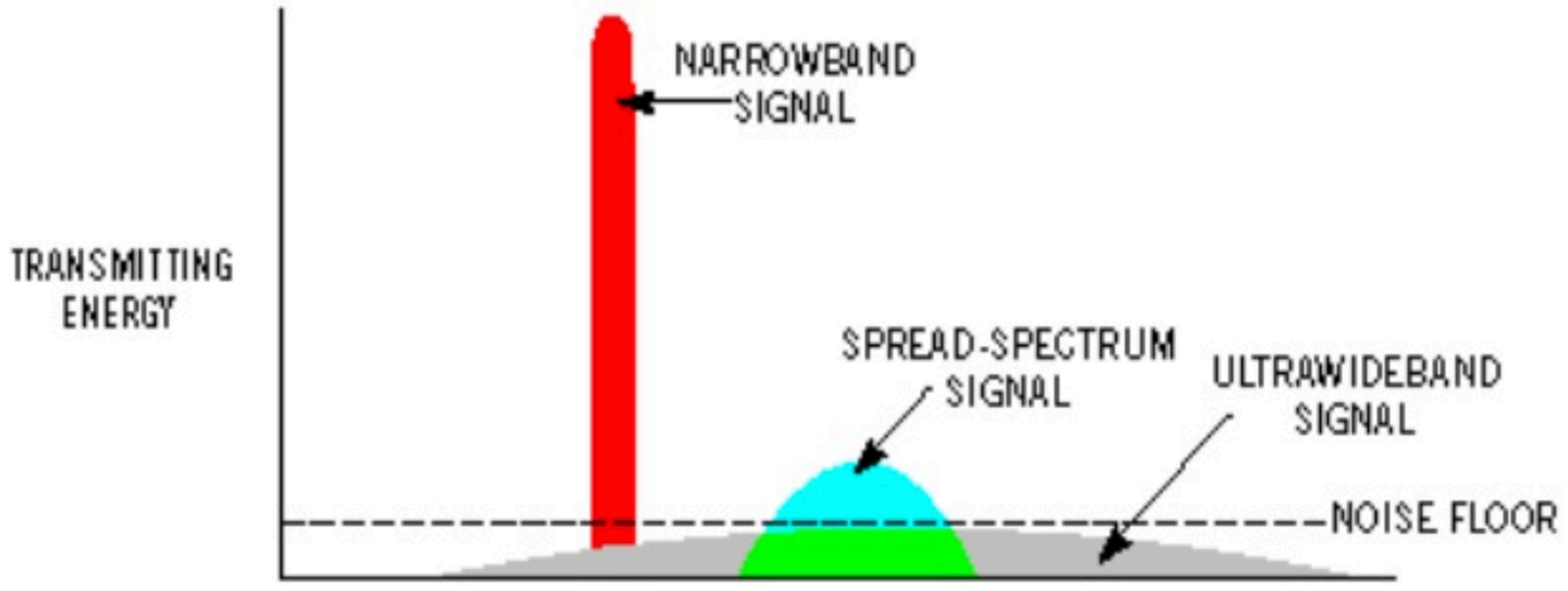


Frequency-domain behavior

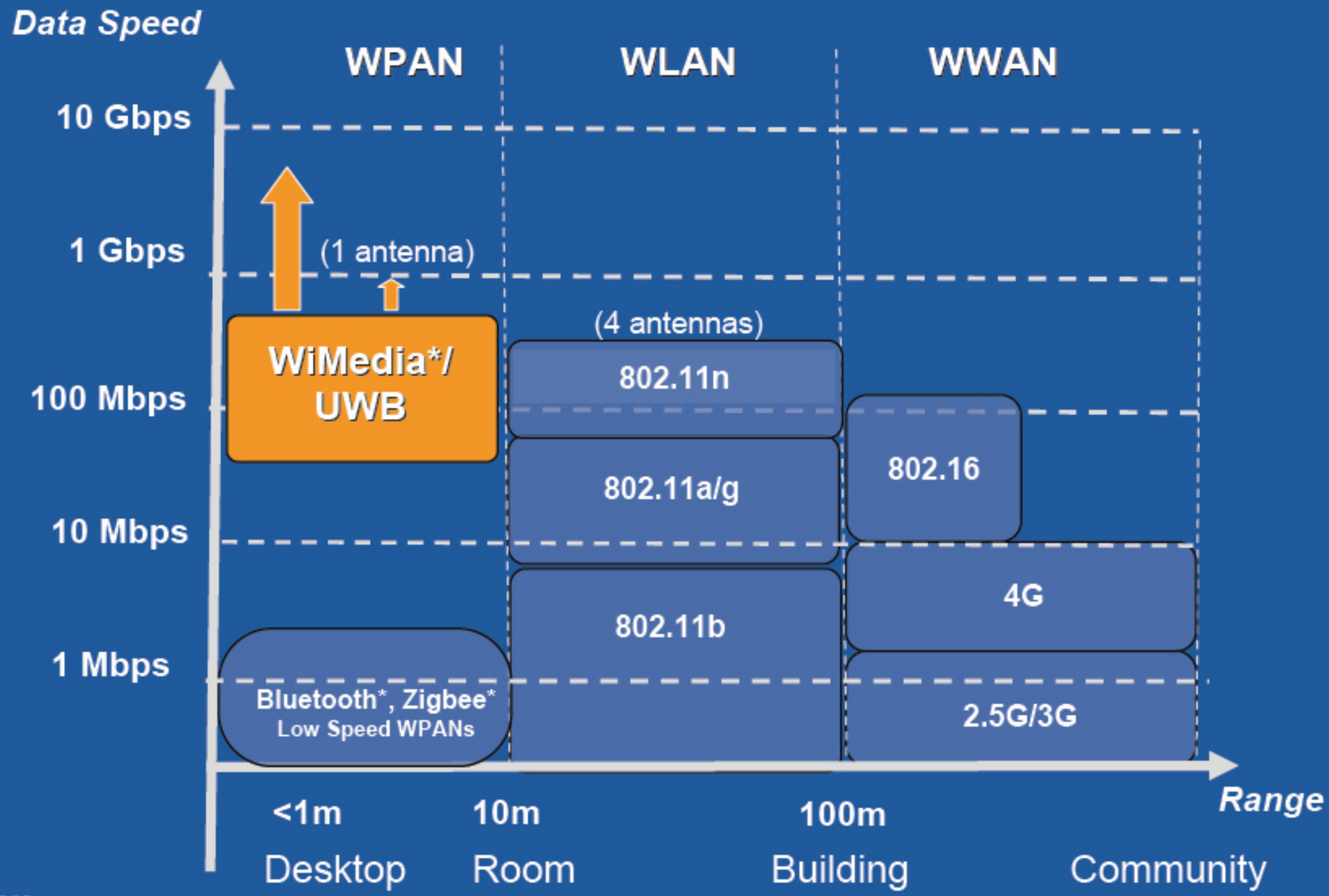


How UWB works

- Generation of extremely short digital pulses in the subnanosecond range.
- Uses and extremely wide band of RF spectrum to transmit data



UWB Fills a Speed-vs-Range Gap

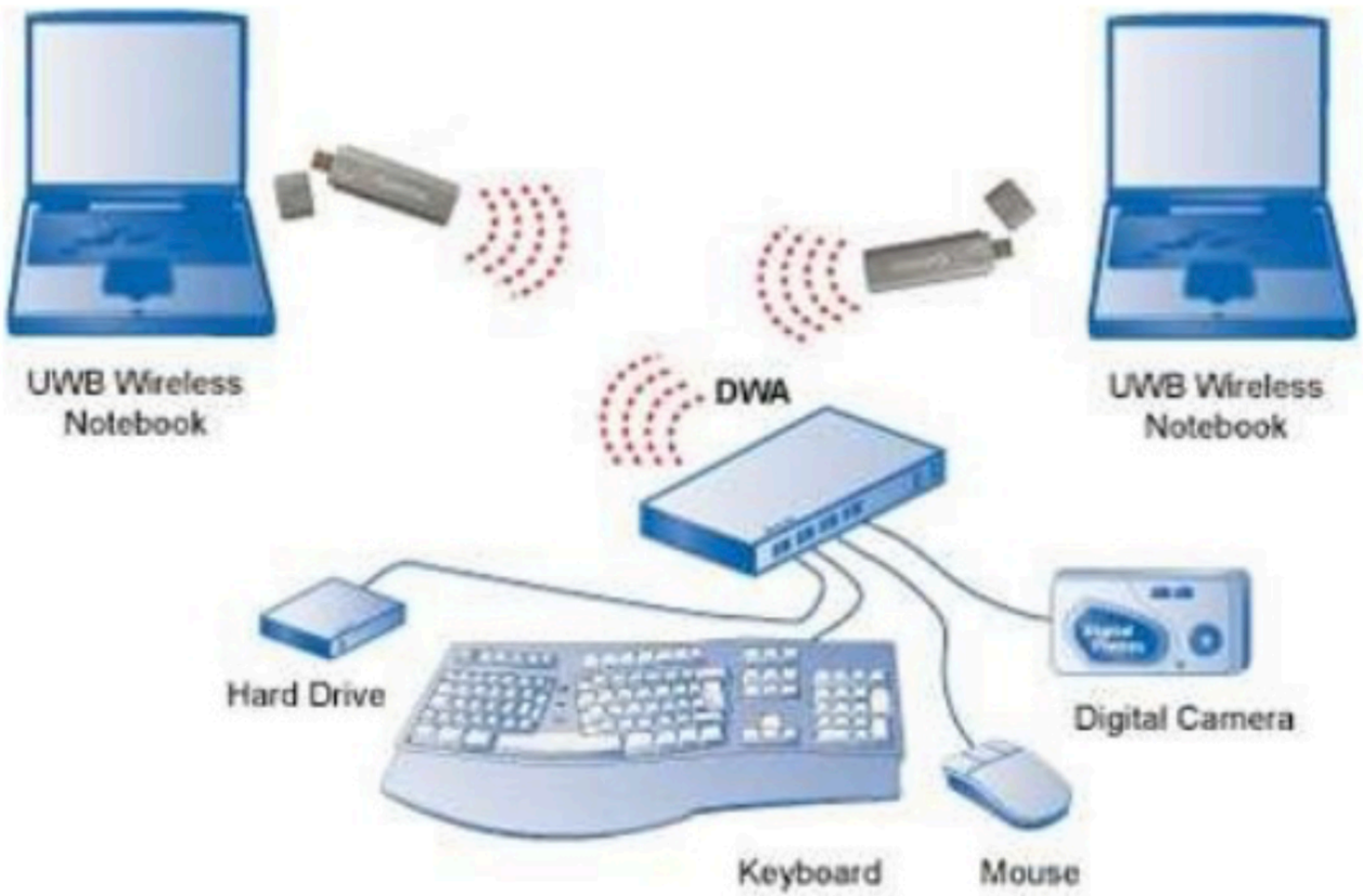


*Other names and brands may be claimed as the property of others

Future Scope

WIRELESS USB

- The next step for USB technology is wireless USB.
- WUSB will be high speed wireless interconnect technology to take advantage of USB



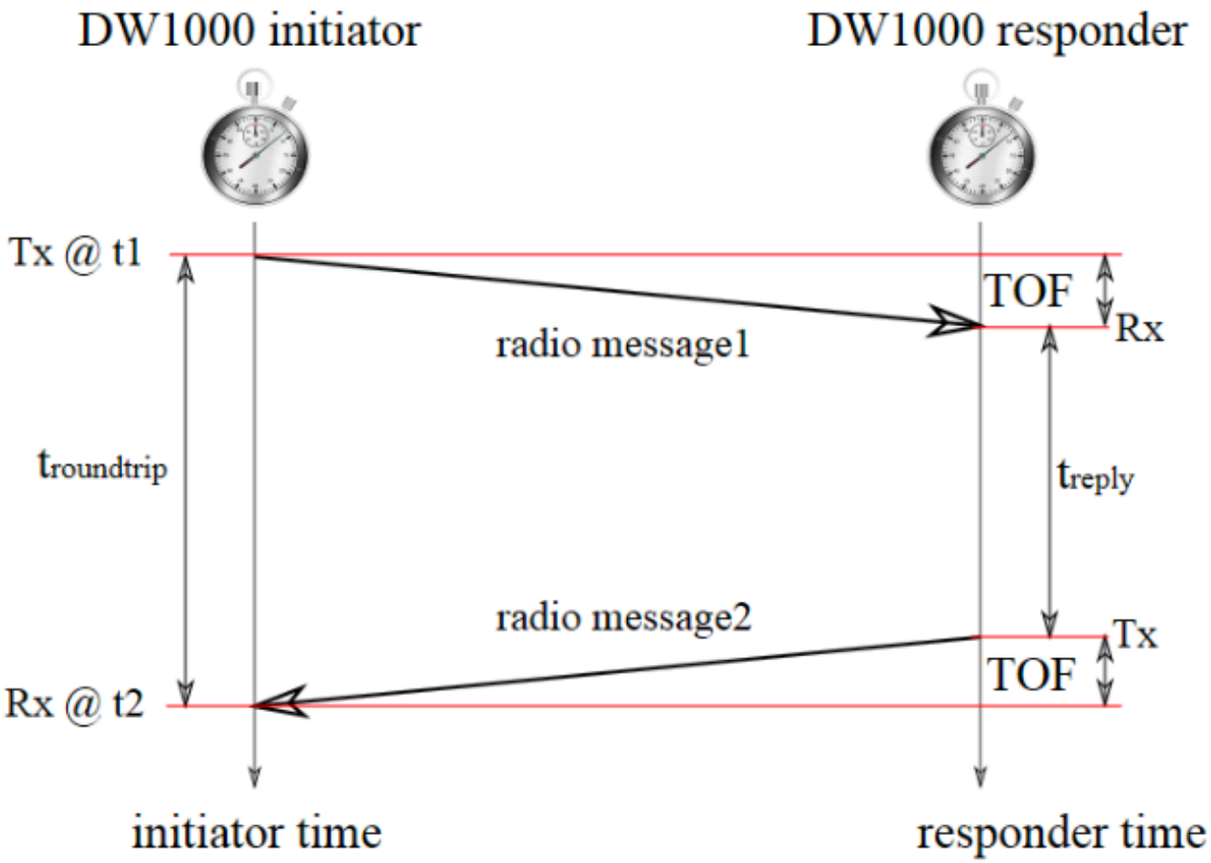
- With WUSB, a user can bring a hard disk in proximity to a PC, laptop and, once authentication and authorization are complete, files can be transferred onto the PC.

- Time of arrival (TOA)
- Angle of arrival (AOA)
- **Arrival time delay (TDOA)**
- Received signal strength (RSSI)
- Hybrid systems (mix of different physical principles related metrics)

¿ Como se mide la distancia ?

Radio faro VOR - Navegacion aerea

Single-sided Two-way Ranging (SS-TWR)



$$TOF = \frac{t_2 - t_1 - t_{reply}}{2}$$

Figure 1: Two-way ranging concept

```
/* Speed of light in air, in metres per second. */
#define SPEED_OF_LIGHT 299702547

//    1 us +- 300 m
//    1 ns +-  30 cm
// 100 ps +-   3 mm
```

Double-sided Two-way Ranging (DS-TWR)

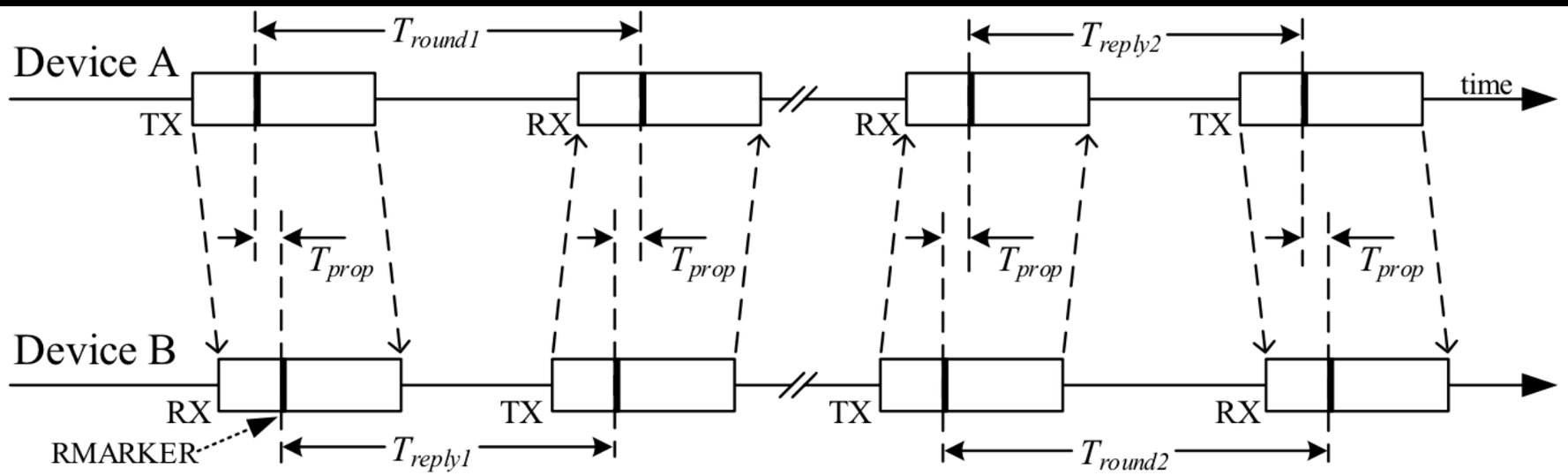


Figure 37: Double-sided two-way ranging with four messages

Double-sided Two-way Ranging (DS-TWR)

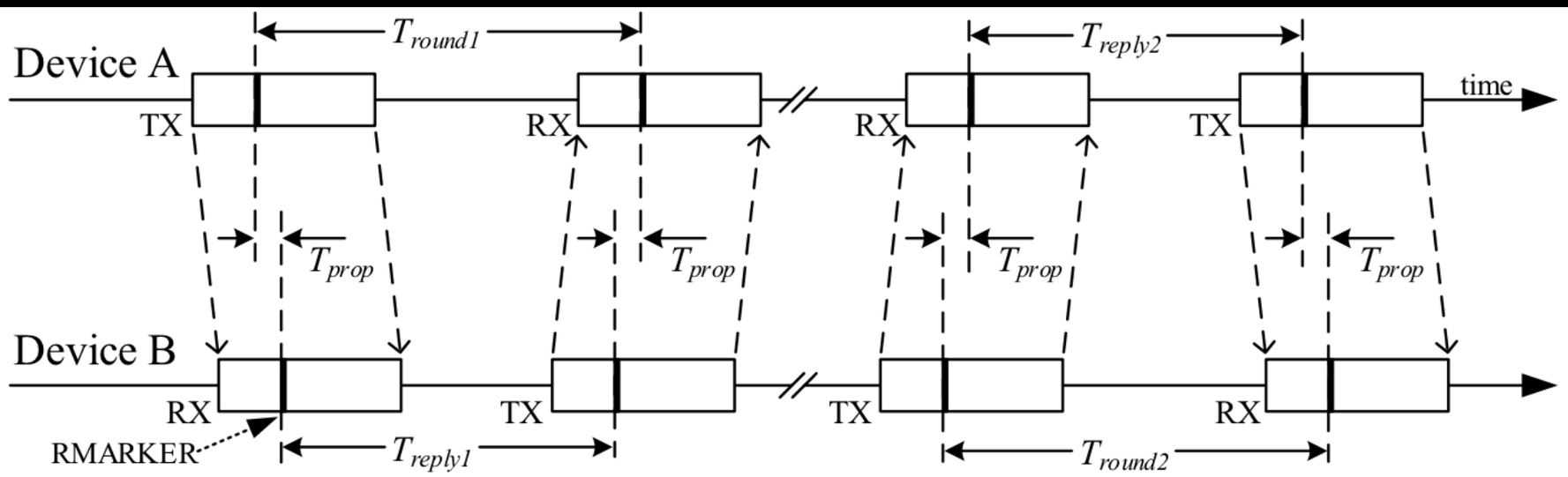


Figure 37: Double-sided two-way ranging with four messages

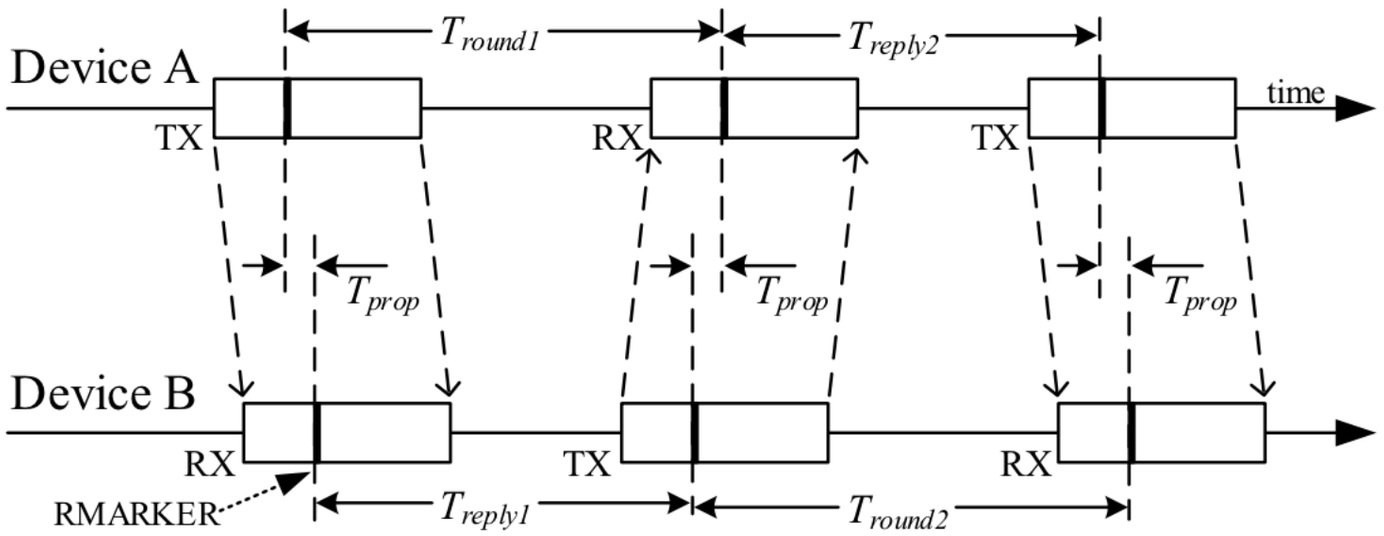
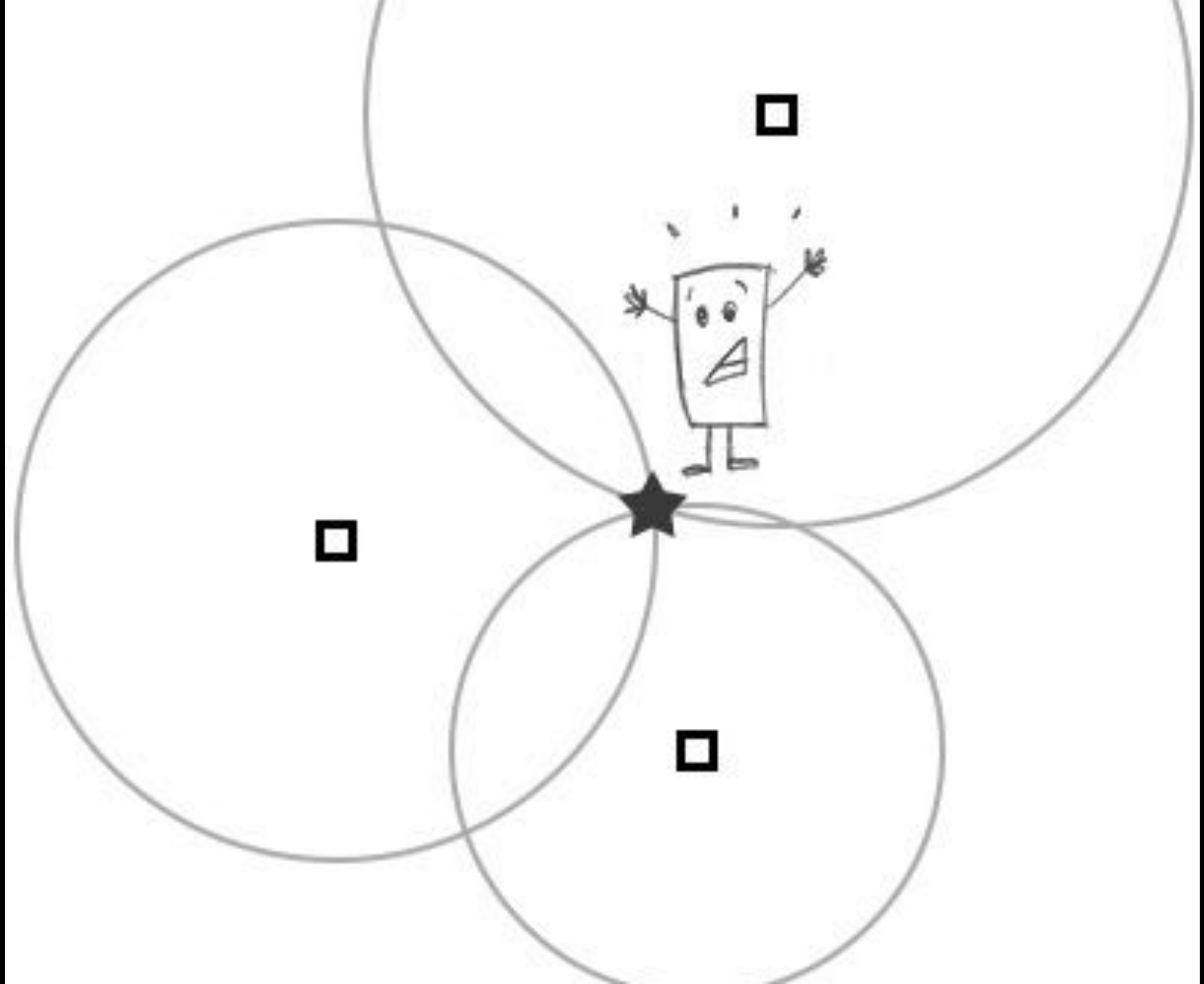
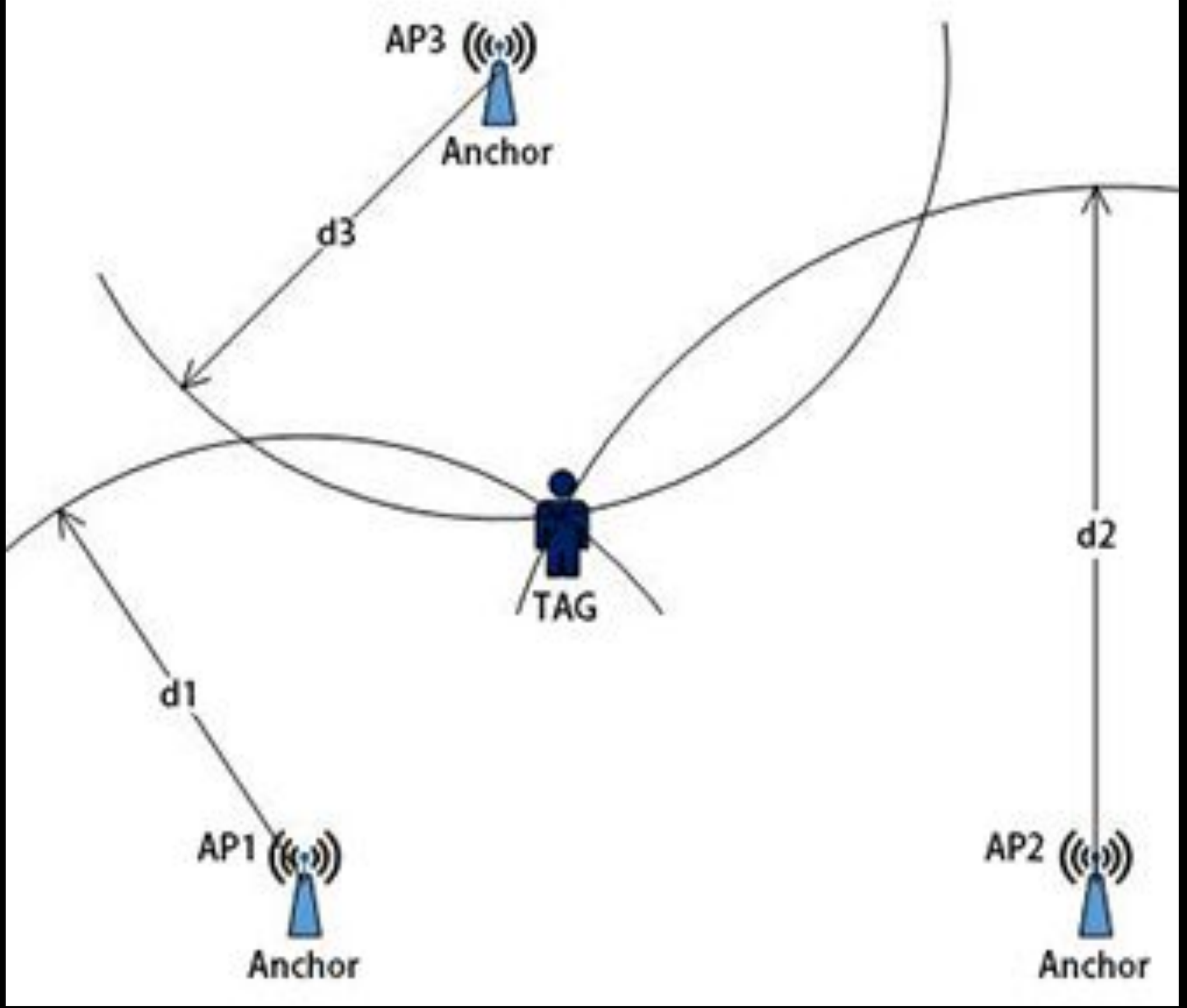
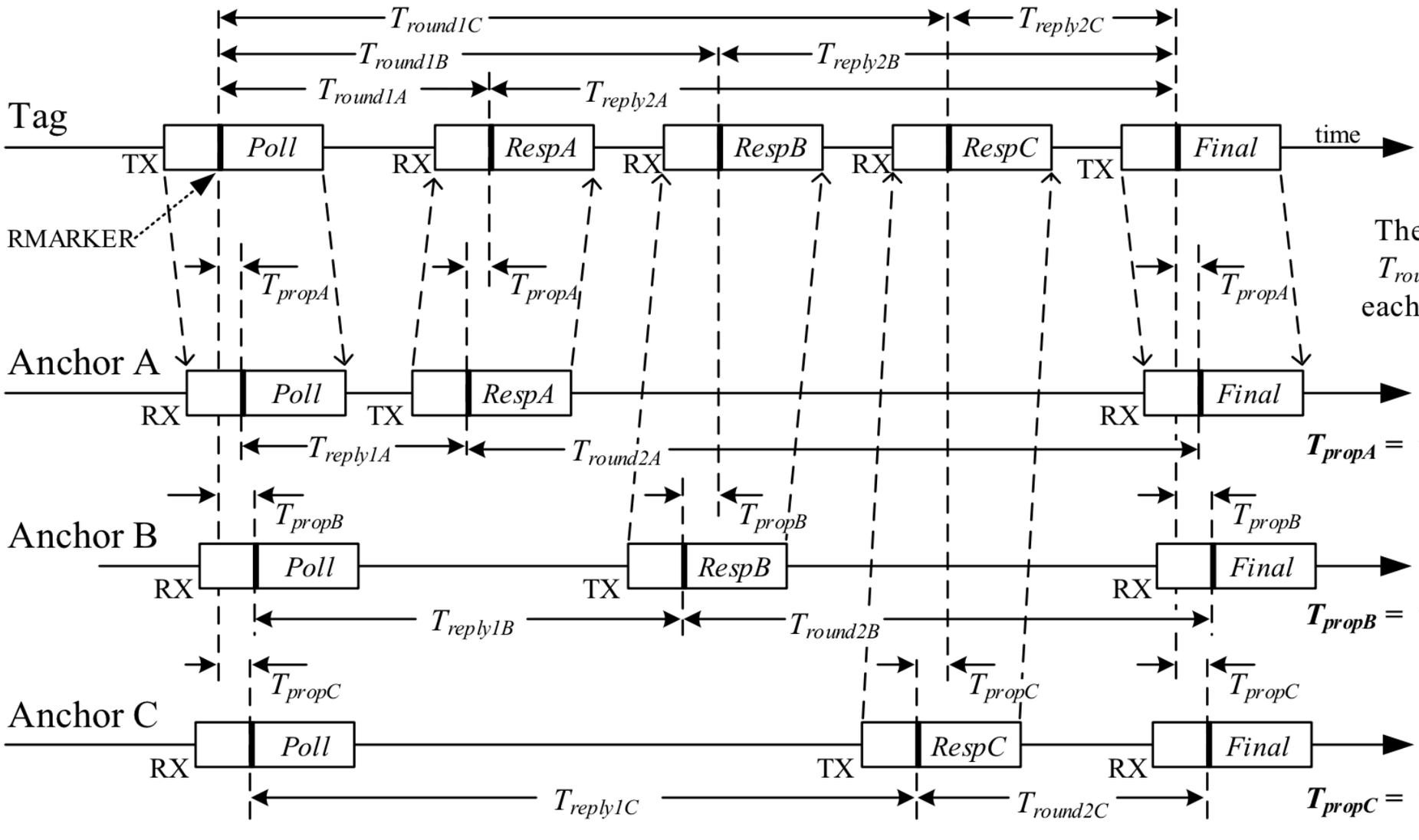


Figure 38: Double-sided Two-way ranging with three messages





Infraestructura - “ANCHORS”



The *Final* message communicates the tag's T_{round} and T_{reply} times to the anchors, which each calculate the range to the tag as follows.

$$T_{propA} = \frac{T_{round1A} \times T_{round2A} - T_{reply1A} \times T_{reply2A}}{T_{round1A} + T_{round2A} + T_{reply1A} + T_{reply2A}}$$

$$T_{propB} = \frac{T_{round1B} \times T_{round2B} - T_{reply1B} \times T_{reply2B}}{T_{round1B} + T_{round2B} + T_{reply1B} + T_{reply2B}}$$

$$T_{propC} = \frac{T_{round1C} \times T_{round2C} - T_{reply1C} \times T_{reply2C}}{T_{round1C} + T_{round2C} + T_{reply1C} + T_{reply2C}}$$

Figure 39: Ranging to 3 anchors with just 5 messages where each anchor calculates its own range result

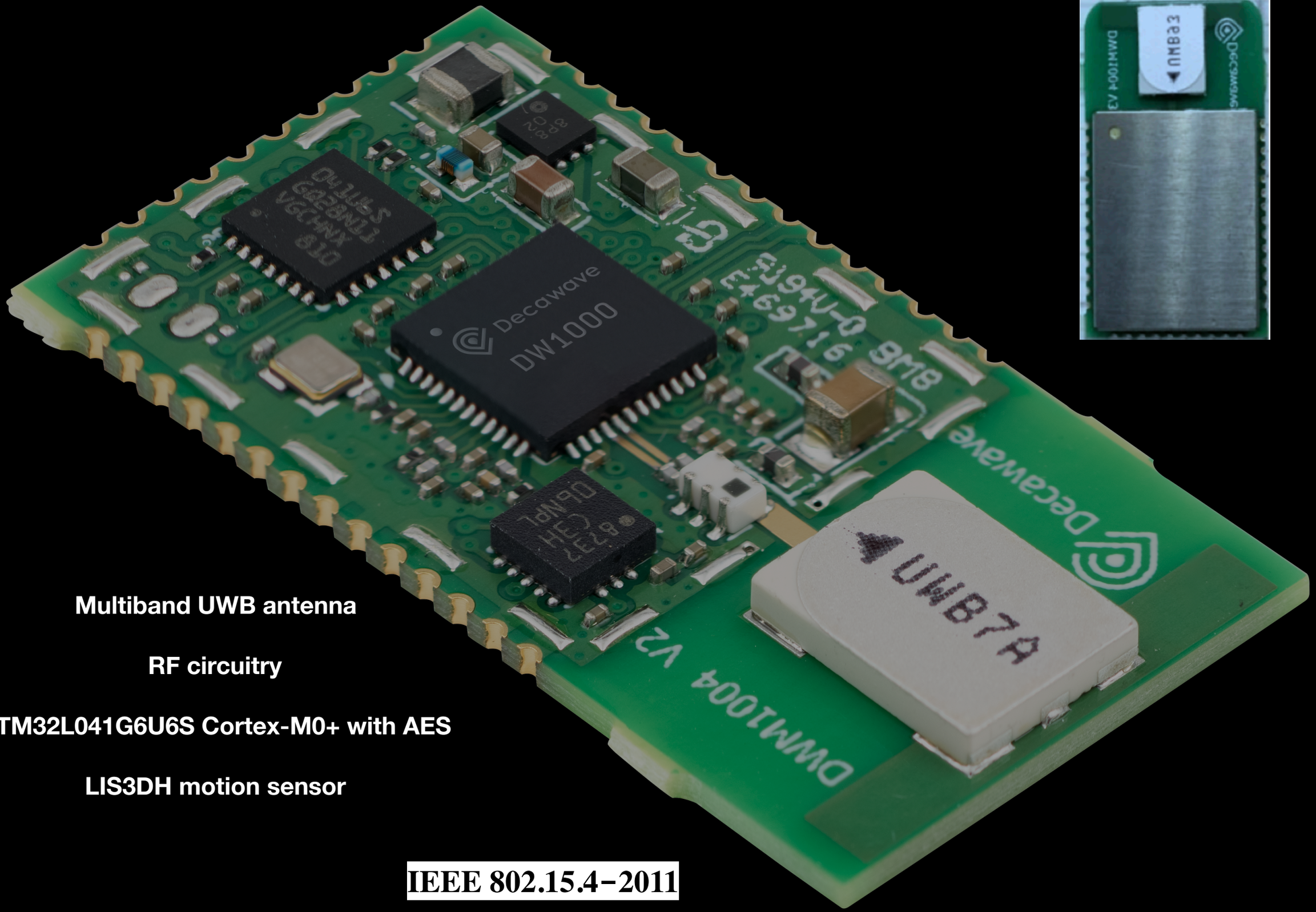
MAC Header (MHR)							MAC Payload	MAC Footer (MFR)
Frame Control	Sequence Number	Destination PAN Identifier	Destination Address	Source PAN Identifier	Source Address	Aux Security Header	Frame Payload	FCS
2 octets	1 octet	0 or 2 octets	0, 2 or 8 octets	0 or 2 octets	0, 2 or 8 octets	0, 5, 6 10 or 14 octets	Variable number of octets	2 octets

Figure 34: General MAC message format

```
static uint8 tx_poll_msg[] = {0x41, 0x88, 0, 0xCA, 0xDE, 'W', 'A', 'V', 'E', 0xE0, 0, 0};
static uint8 rx_resp_msg[] = {0x41, 0x88, 0, 0xCA, 0xDE, 'V', 'E', 'W', 'A', 0xE1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0};

   The first 10 bytes of those frame are common and are composed of the following fields:
*     - byte 0/1: frame control (0x8841 to indicate a data frame using 16-bit addressing).
*     - byte 2: sequence number, incremented for each new frame.
*     - byte 3/4: PAN ID (0xDECA).
*     - byte 5/6: destination address, see NOTE 2 below.
*     - byte 7/8: source address, see NOTE 2 below.
*     - byte 9: function code (specific values to indicate which message it is in the ranging process).
*    The remaining bytes are specific to each message as follows:
*    Poll message:
*     - no more data
*    Response message:
*      - byte 10 -> 13: poll message reception timestamp.
*      - byte 14 -> 17: response message transmission timestamp.
*    All messages end with a 2-byte checksum automatically set by DW1000.
```


Decawave
DW1000
DWM1004 V2
UWB7A



Multiband UWB antenna

RF circuitry

STM32L041G6U6S Cortex-M0+ with AES

LIS3DH motion sensor

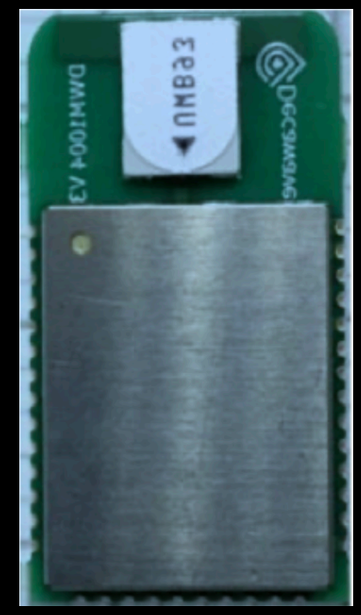
IEEE 802.15.4-2011

- Decawave **open source** TDoA Tag firmware (Keil and Eclipse) supporting configurable adaptive blink rate motion detection support

- Typical LoS range point-to-point: CH2 60m, CH5 40m

3.5 GHz to 6.5 GHz

BW Mhz 500 ~ > 900 , 6.8Mbps



- Sleep mode current < 2uA

- Battery life >2 years using 500mAh battery, TDoA blink @0.2Hz

- Recommended sale price is $9.95 in 10k quantities

Key Features

Bluetooth 5
2 Mbps

Bluetooth 5
Advertising Extensions

Bluetooth 5
CSA #2

M4F Cortex

FPU HW

AES encryption

512 KB Flash

64 KB RAM

+4 dBm

-96 dBm sensitivity

NFC Tag

Balun onboard

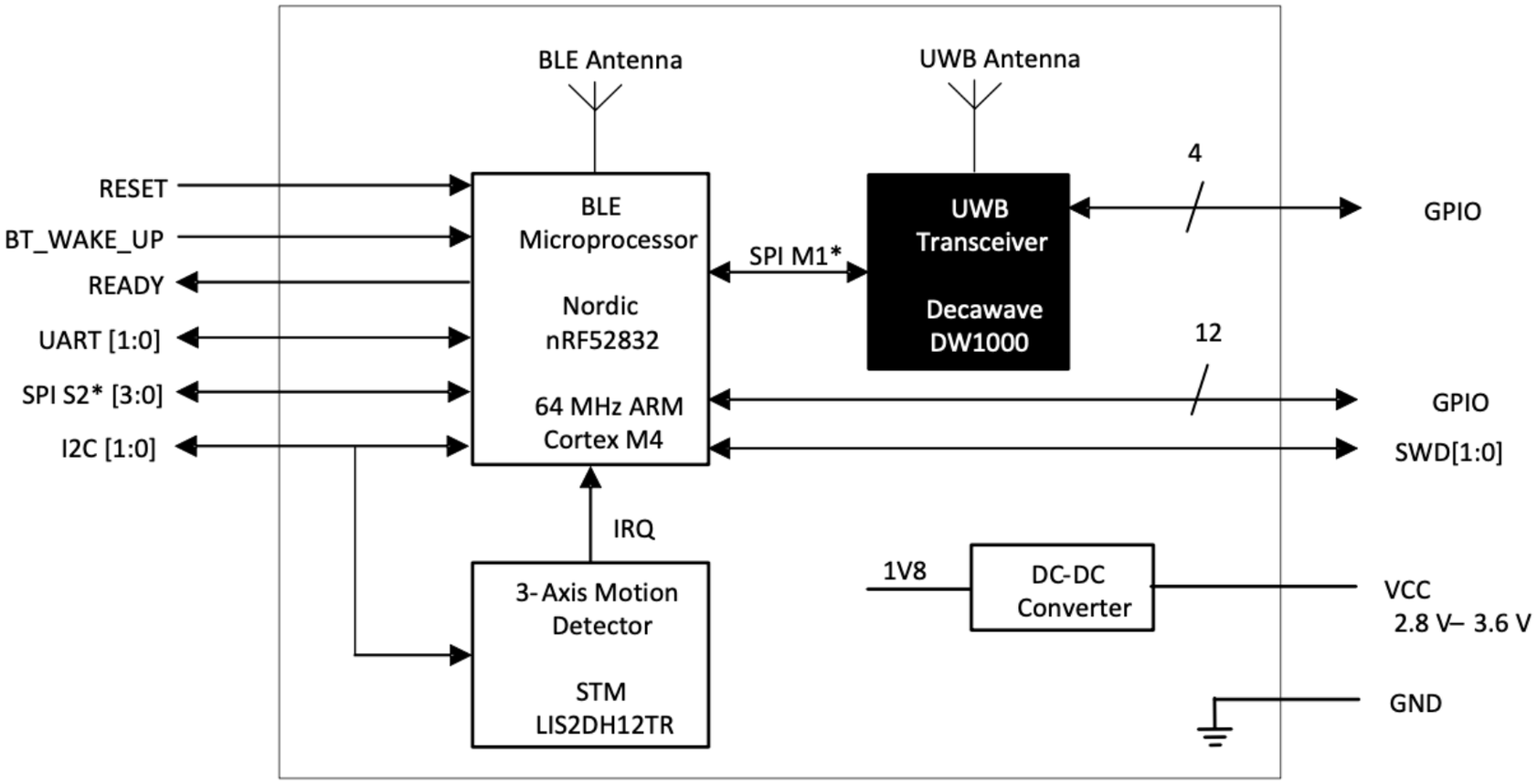
ANT support

12bit ADC

PDM interface

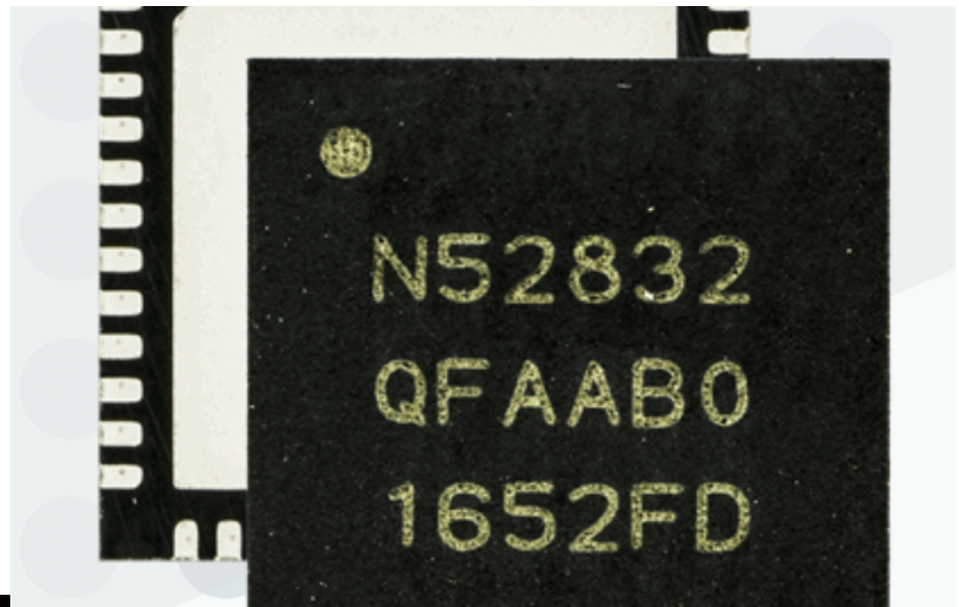
2 DWM1001 Module

Figure 5 shows a block diagram of the module. All major sections of the module are shown, along with the source of signals coming to the module's pins.



*SPI M1 is nRF52 SPI master 1, SPI S2 is SPI slave 2

Figure 5: Block diagram of DWM1001 module



MDEK1001 Development Kit

MDEK1001 provides customers interested in a scalable RTLS network solution, the necessary hardware, software and development environment to quickly evaluate its features and performance. The evaluation kit includes 12 encased development boards (DWM1001-DEV).

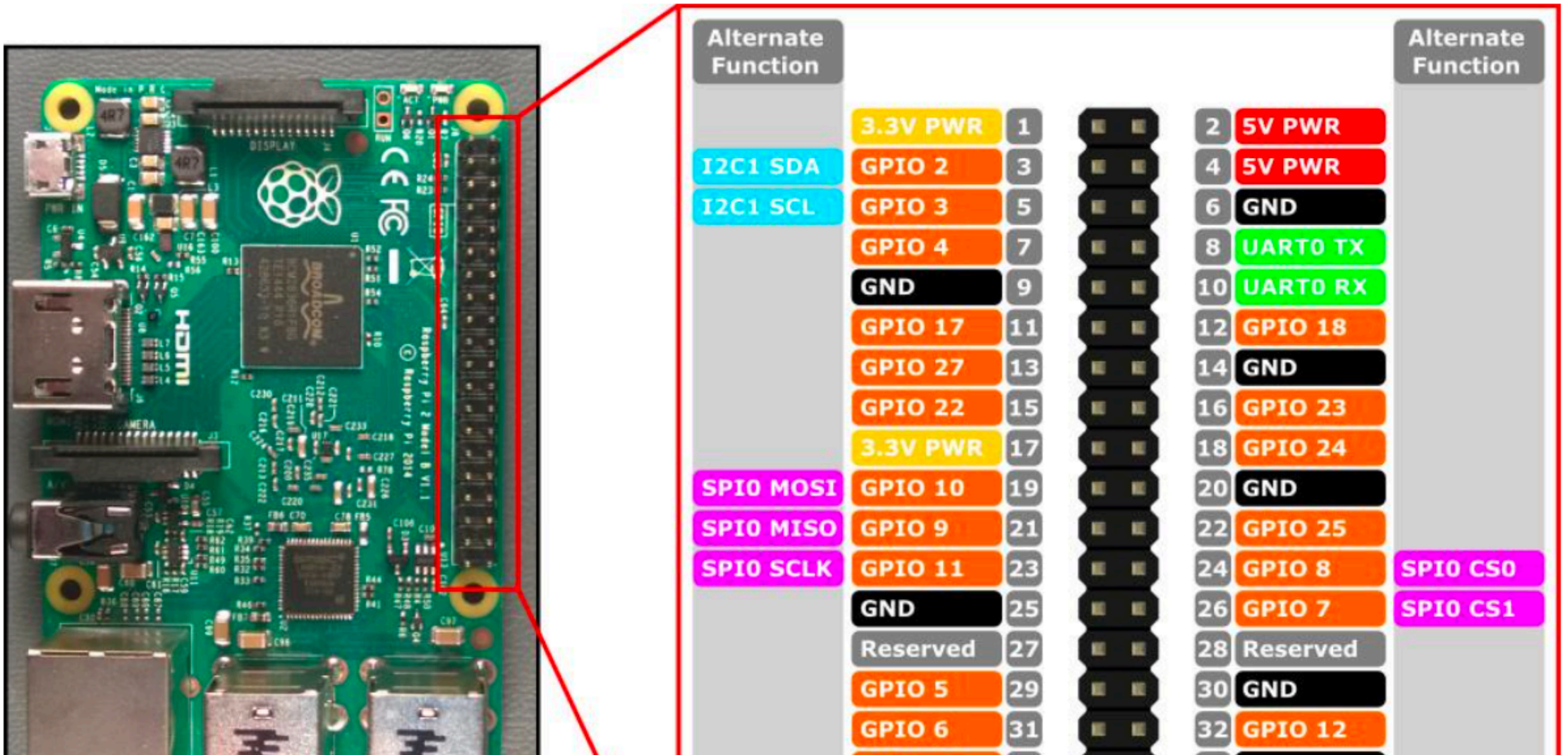
Kit Includes:

- 12 units based on DWM1001 module/development board
- Embedded location stack (binary)
- Gateway firmware, PC/Android app (in source code)

What You Can Do With This Kit:

- Out-of-the-box scalable RTLS network solution
  - Channel 5 - 6.8Mbps - 30m range
  - Up to 10Hz update rate for each individual tag
  - Up to 150 updates per second per cluster
  - Up to 30 anchors per cluster (requires 3 kits, minimum)
  - Backhaul over Raspberry Pi 3 (not included)
- Visualize and configure over Android/PC app
- Customize via APIs, re-flash boards over USB

Figure 10: Front View of the DWM1001-DEV Module Development Board



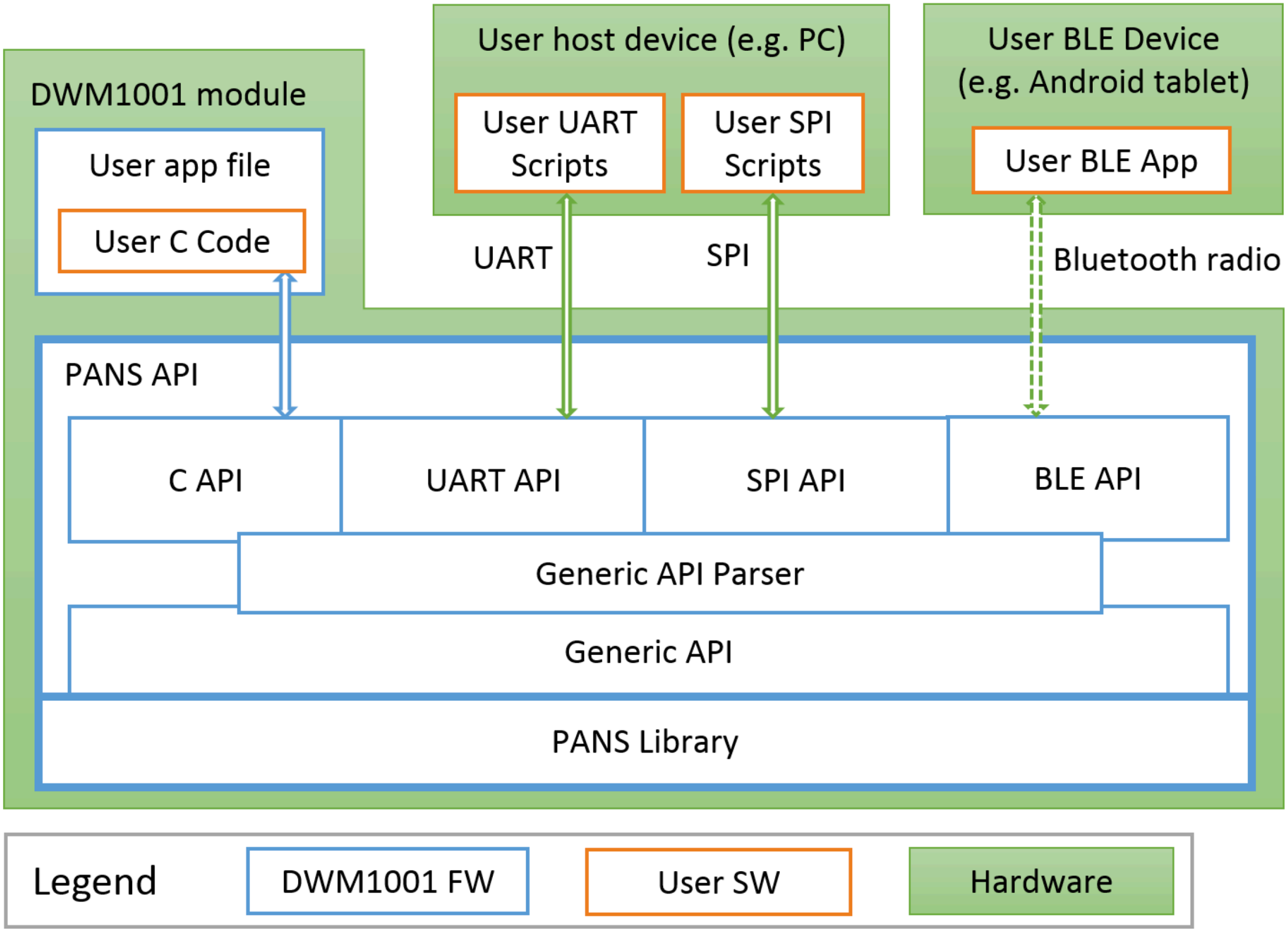
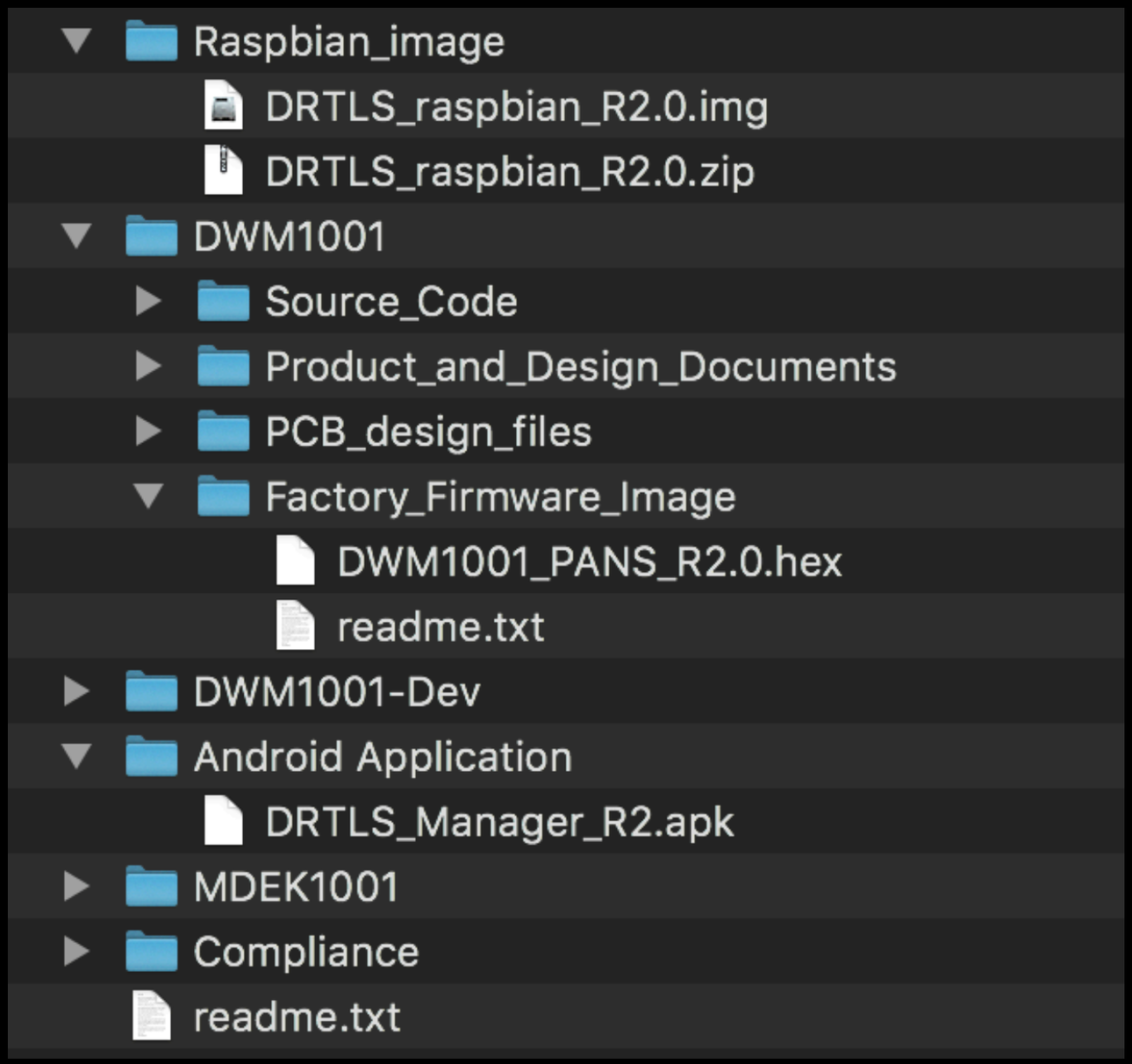


Figure 1 High-Level Architecture of DWM1001 Firmware vs. User Software

Herramientas y Firmware

DWM1001_DWM1001-DEV_MDEK1001_Sources_and_Docs_v9



DWM1001 Firmware User Guide
Based on DWM1001-DEV board
Version 1.3

Setup_EmbeddedStudio_ARM_v430c_macos_x64

License_SES_CPedro%Lopez%-%
%Personal%use_WNordic%Semi_
x3NfL9ygVdK+FXnz7dDhPLM+UC

l9eyewjlMtqjuYZUDFxm/
KE5R8d+pnC5lCNe/M=

JLINK

SEGGER Embedded Studio File Edit View Search Navigate Project Build Debug Target Tools Window Help

ss_twr_init_int - SEGGER Embedded Studio for ARM V4.30c - Licensed to Pedro Lopez - None - Personal use

Project Explorer

nrf52832_xxaa

Project Items	Code	Da
Solution 'ss_twr_init_int'		
Project 'ss_twr_init_int'	33.8K	
::CMSIS		
::Device		
Application 3 files	[1.5K]	
main.c	0.7K	
sdk_config.h		
ss_init_main.c	0.8K	
Board Definition 1 file		
Board Support 2 files		
Config 1 file		
Decadriver 3 files		
Freertos 12 files		
Internal Files 3 files		
nRF_Drivers 5 files		
nRF_Libraries 14 files	[5.2K]	
nRF_Log 6 files		
nRF_Segger_RTT 3 fil		
Uart 1 file		
Output Files		

main.c | ss_init_main.c

```
/*! ----------------------------------------------------------------------
*  @file    ss_init_main.c
*  @brief   Single-sided two-way ranging (SS TWR) initiator example cod
*
*           This is a simple code example which acts as the initiator i
*           frame (recording the TX time-stamp of the poll), after whic
*           code (companion to this application) to complete the exchan
*           RX, and response TX. With this data and the local time-stam
*           for the time-of-flight over-the-air and, thus, the estimate
*
*           Notes at the end of this file, expand on the inline comment
*
* @attention
*
* Copyright 2015 (c) Decawave Ltd, Dublin, Ireland.
*
* All rights reserved.
*
* @author Decawave
*/
#include <stdio.h>
#include <string.h>
#include "FreeRTOS.h"
#include "task.h"
#include "deca_device_api.h"
#include "deca_regs.h"
#include "port_platform.h"
#include "ss_init_main.h"

#define APP_NAME "SS TWR INIT v1.3"

/* Inter-ranging delay period, in milliseconds. */
```

Terminal Emulator

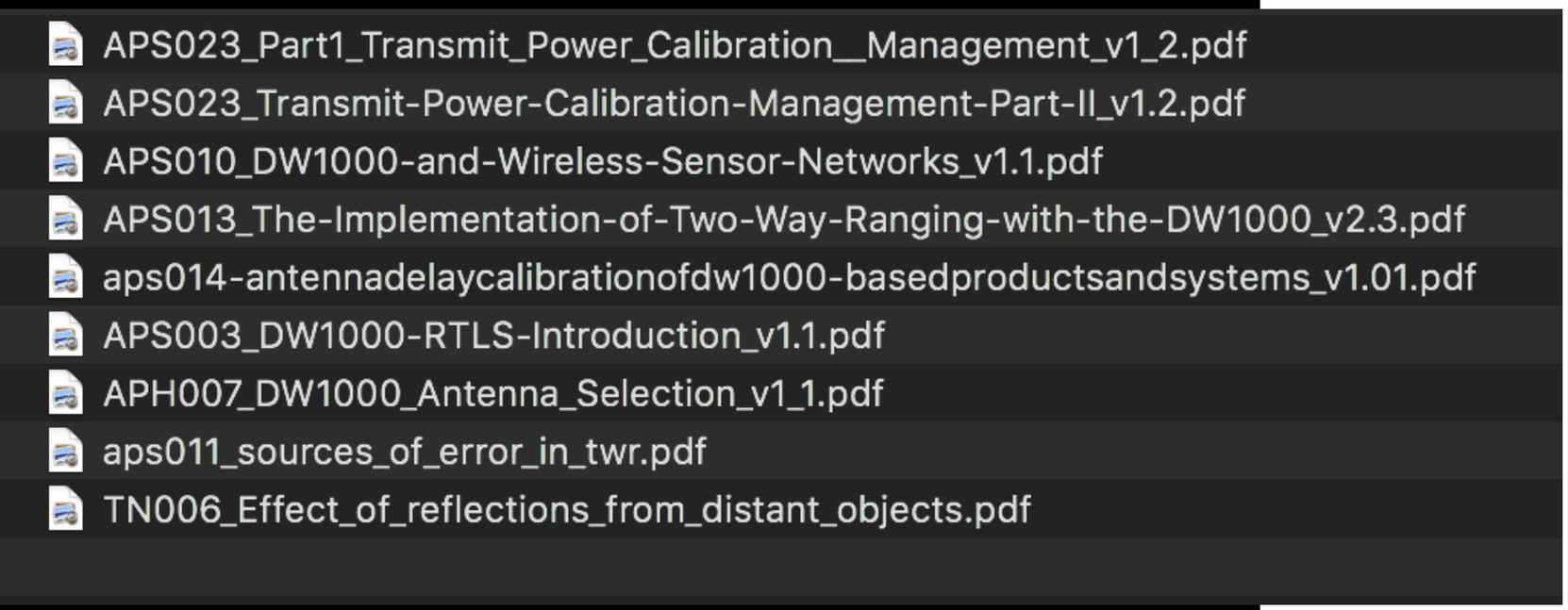
Source Navigator

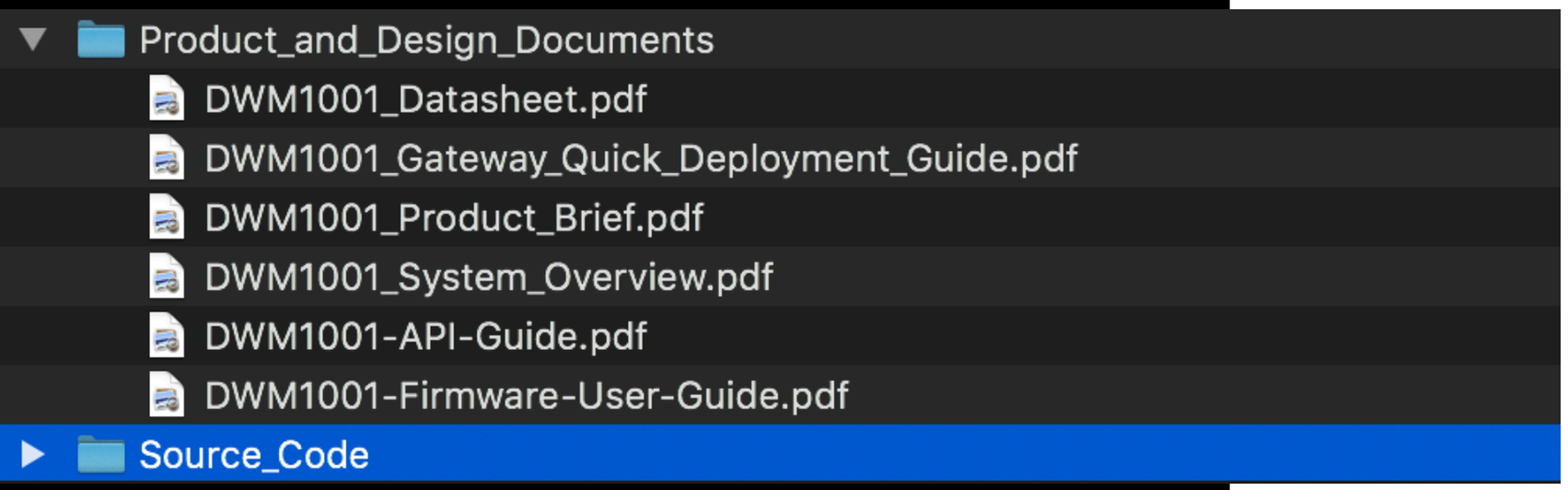
Search Symbols

Functions 830 functions

- __CLREX()
- __disable_fault_irq()
- __disable_irq()
- __DMB()
- __DSB()
- __enable_fault_irq()
- __enable_irq()
- __get_APSR()
- __get_BASEPRI()
- __get_CONTROL()
- __get_FAULTMASK()
- __get_FPSCR()
- __get_IPSR()
- __get_MSP()
- __get_PRIMASK()
- __get_PSP()
- __get_xPSR()
- __getchar(FILE *)
- __ISB()
- __LDRBT(volatile uint8_t *
- __LDREXB(volatile uint8_t
- __LDREXH(volatile uint16_
- __LDREXW(volatile uint32
- __LDRHT(volatile uint16_t
- __LDRT(volatile uint32_t *)
- __NVIC_ClearPendingIRQ
- __NVIC_DisableIRQ(IRQn_
- __NVIC_EnableIRQ(IRQn_
- __NVIC_GetActive(IRQn_T
- __NVIC_GetEnableIRQ(IR
- __NVIC_GetPendingIRQ(I
- __NVIC_GetPriority(IRQn_
- __NVIC_GetPriorityGroupi
- __NVIC_GetVector(IRQn_T
- __NVIC_SetPendingIRQ(I
- __NVIC_SetPriority(IRQn_
- __NVIC_SetPriorityGroupi
- __NVIC_SetVector(IRQn_T
- __NVIC_SystemReset()
- __putchar(int, __printf_tag
- __QADD(int32_t, int32_t)

Disconnected (J-Link) Built OK INS (No editor)





Decawave

APS013 APPLICATION NOTE

The implementation of two-way ranging with the DW1000

Version 2.3

This document is subject to change without notice