

Wireless Congress 2008, Munich
Systems & Applications



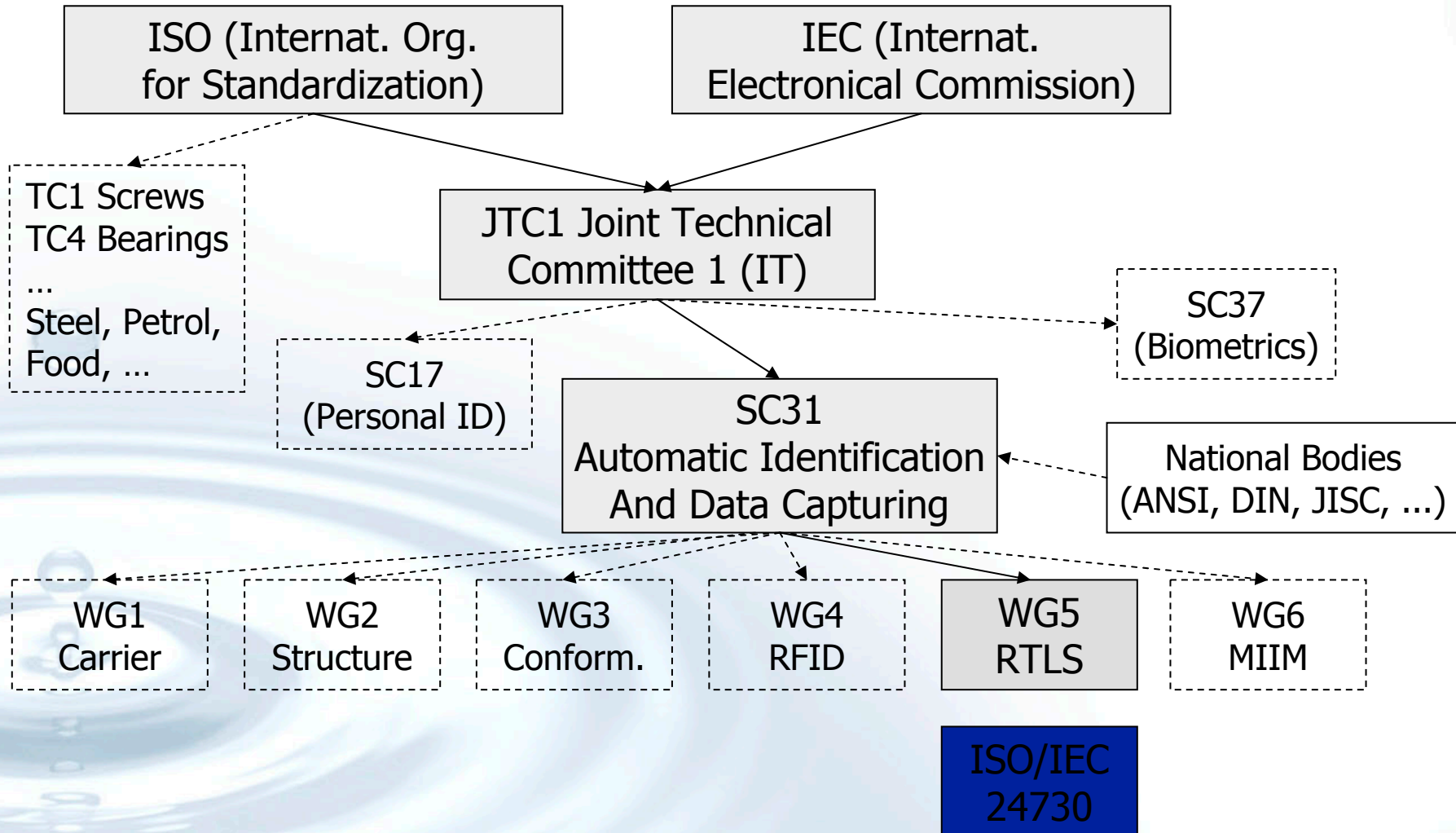
ISO compliant RTLS based on Chirp Spread Spectrum

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Agenda

- The ISO/IEC 24730 Standard
- The ISO/IEC 24730-5 Air Interface
- Example Systems based on 24730-5
- Status ISO/IEC 24730-5 Standardization Process
- Other RLTS Standards
- Forecast on future Developments and Opportunities

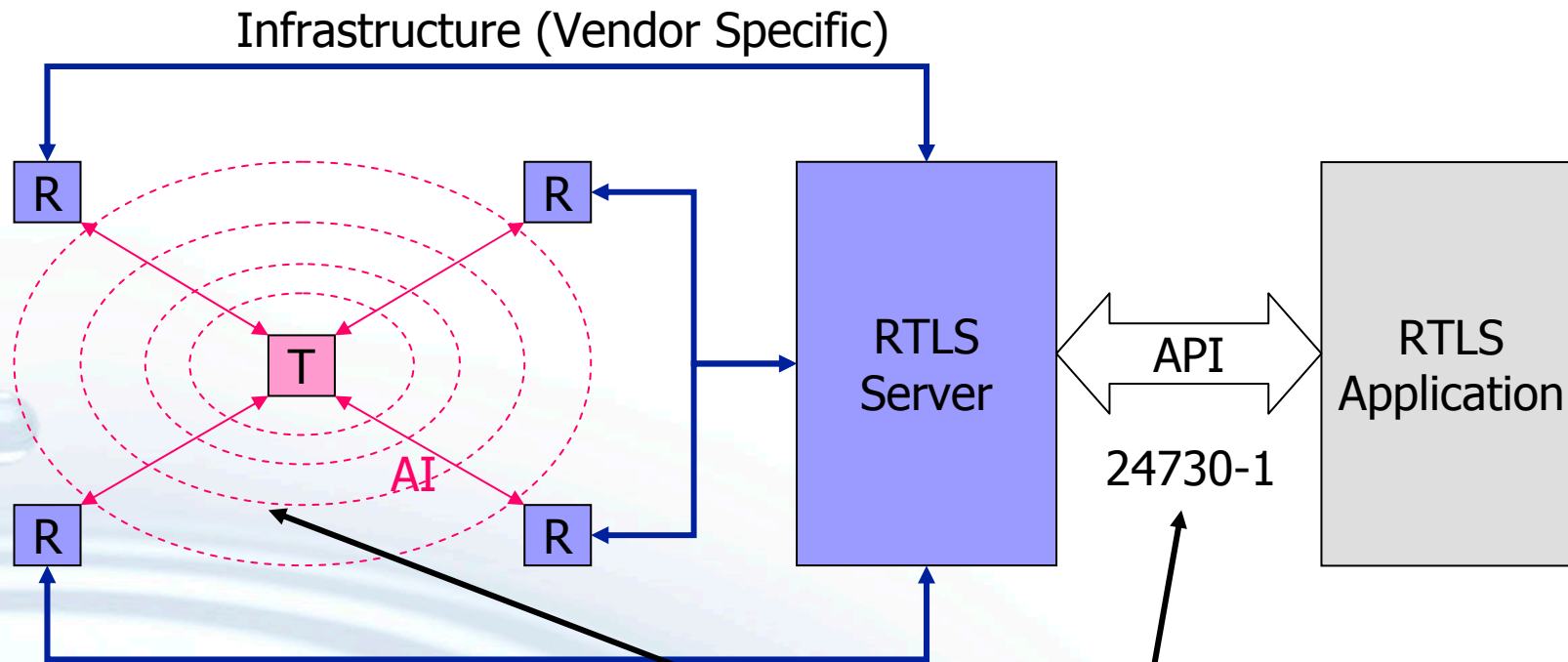
ISO/IEC JTC1 SC31 Landscape



ISO/IEC 24730 Standard Parts

- 24730 defines components of RTLS systems
 - 24730-1 Application Programming Interface (API)
 - 24730-2: 2.4 GHz Air Interface
 - 24730-3: 433 MHz proposal (withdrawn)
 - 24730-4: GLS GeoLocatingSystem via Satellite (withdrawn)
 - 24730-5: 2.4 GHz Personal Area Network (PAN) Air Interface
 - 24730-6 UWB (t.b.d.)

ISO/IEC 24730 System

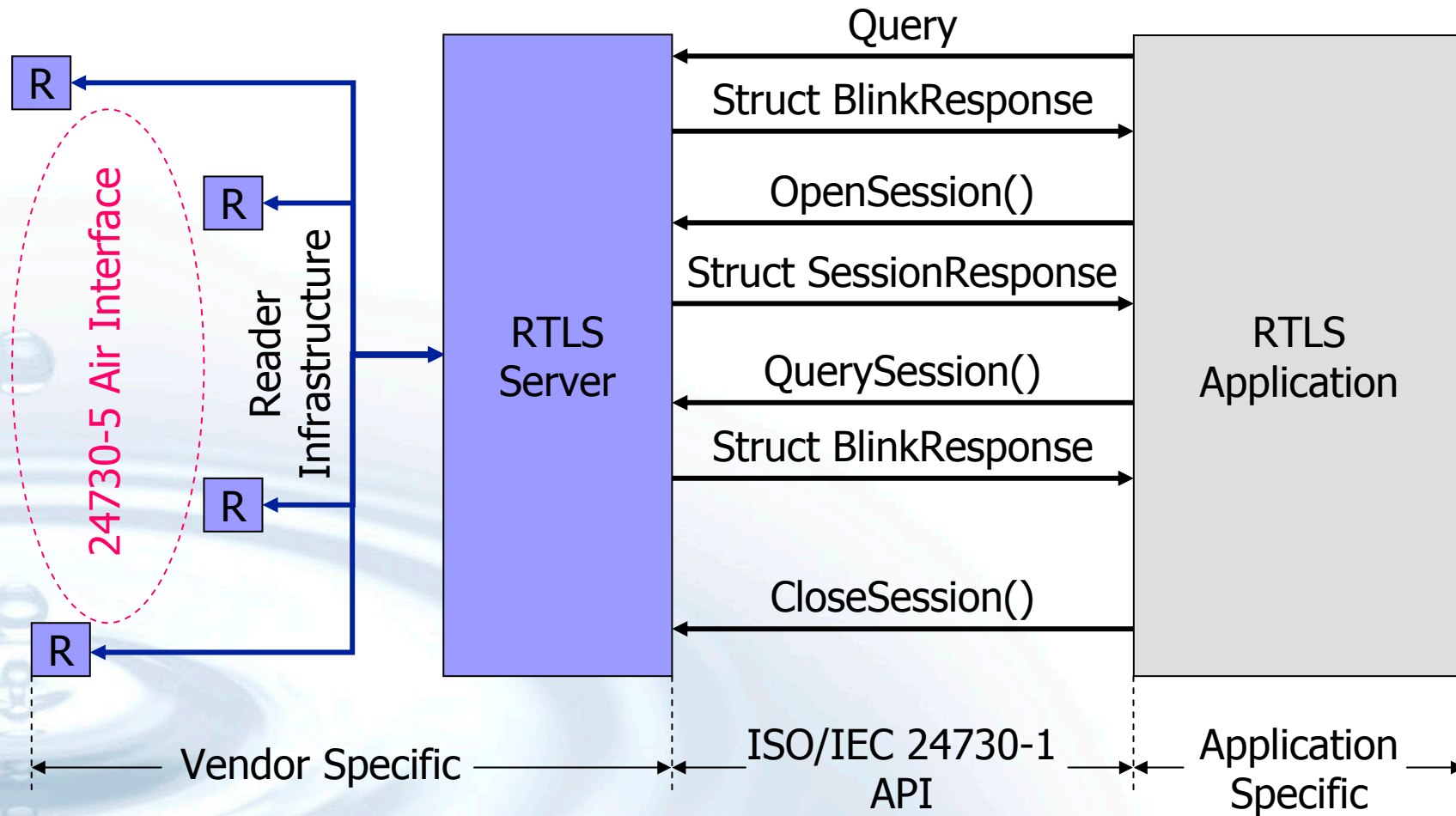


R Reader
T Tag (up to x 1000's)

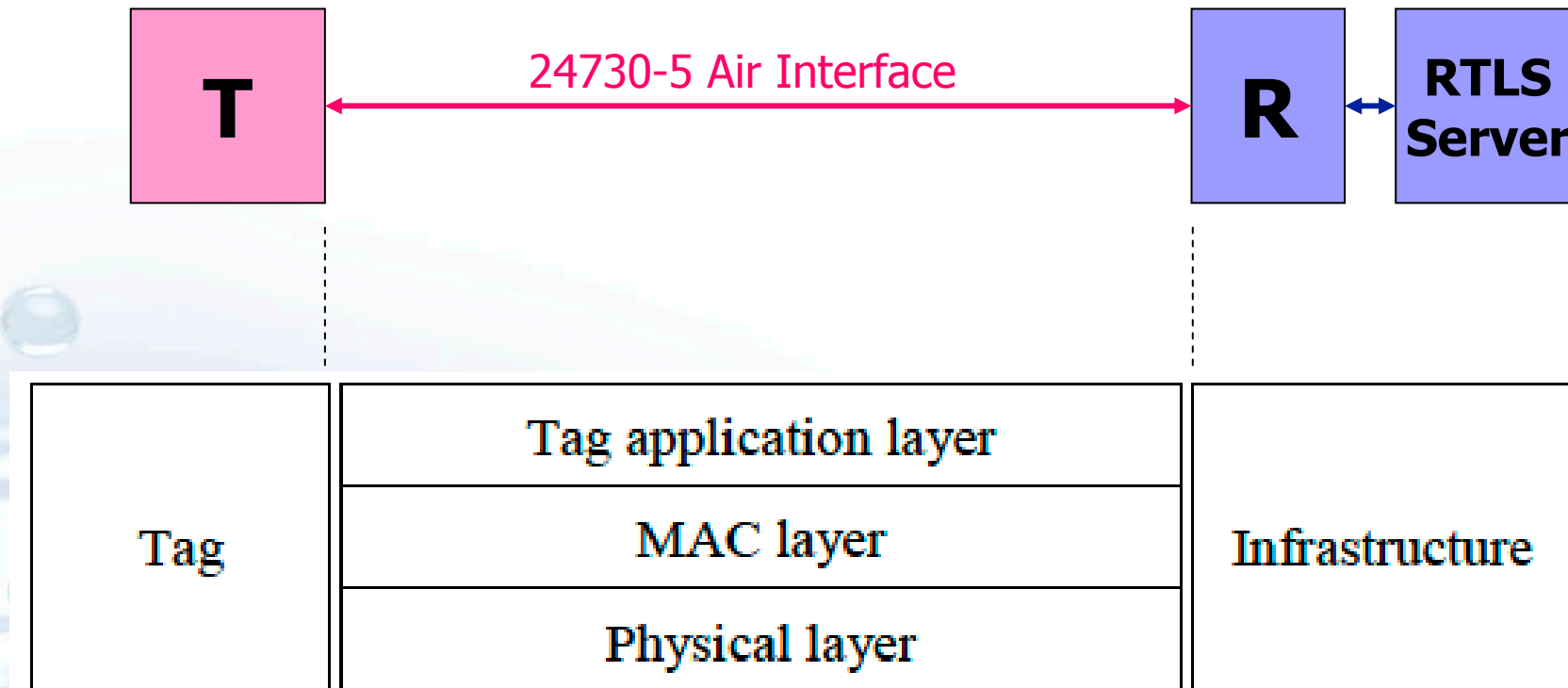
AI Air Interface (24730-2, 24730-5, ...)

- 24730 defines API and Air Interface
- Infrastructure is Vendor Specific (wired / wireless)

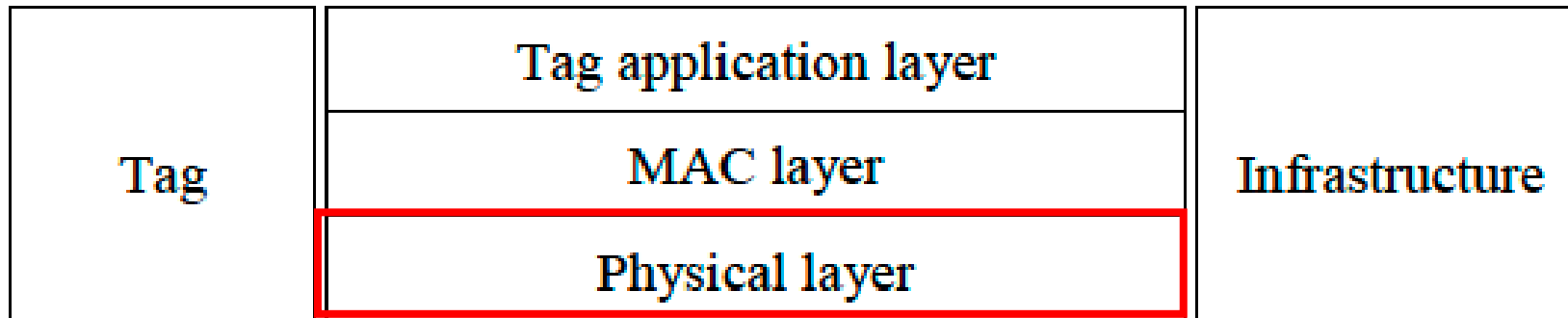
ISO/IEC 24730 API and Air IF



24730-5 Air Interface



24730-5 Physical Layer



■ Modulation

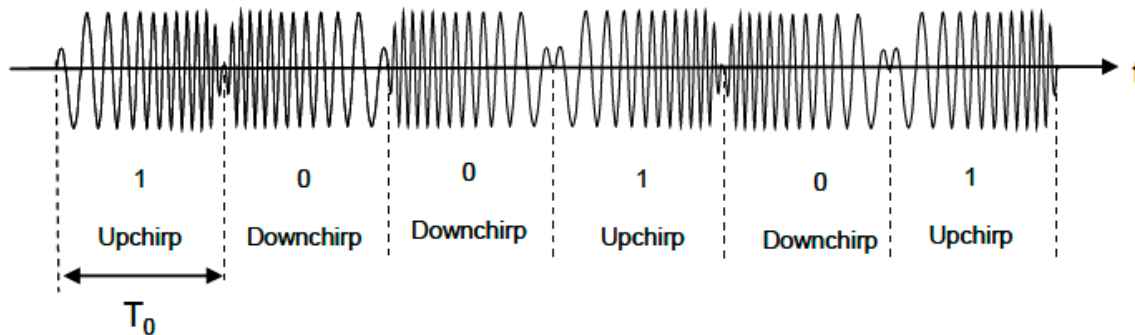
- 2-ary orthogonal CSS (mandatory)
 - 80/22 MHz Bandwidth, Center Frequency 2441.75 MHz
1 RF Channel
 - 22 MHz Bandwidth, Center Frequency 2412 - 2484 MHz, 14 RF Channels
- 8- or 64-ary orthogonal DQPSK-CSS (optional)
 - 22 MHz Bandwidth: Center Frequency 2412 - 2484, 14 Channels

■ Data Rates

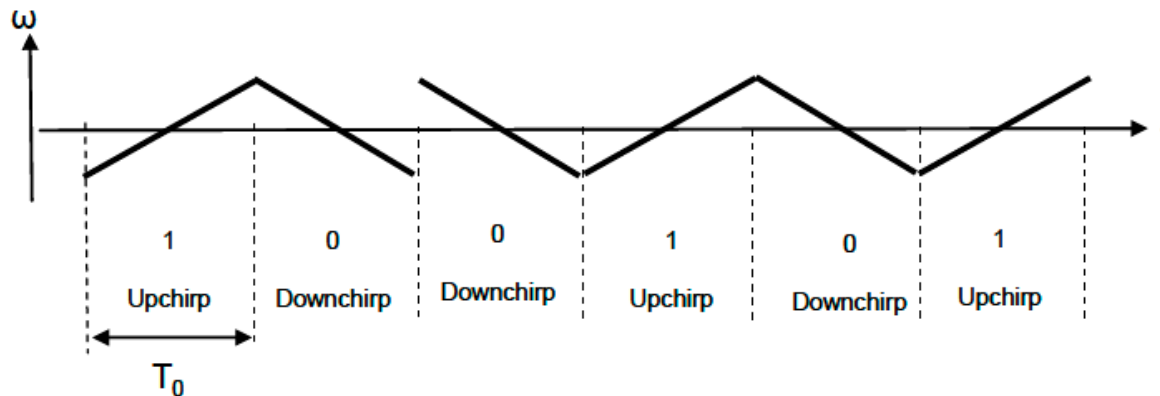
- 1 Mbit/s, 250 kbit/s

24730-5 Physical Layer

2-ary Orthogonal CSS Modulation



2-ary orthogonal CSS modulated bit sequence in passband domain



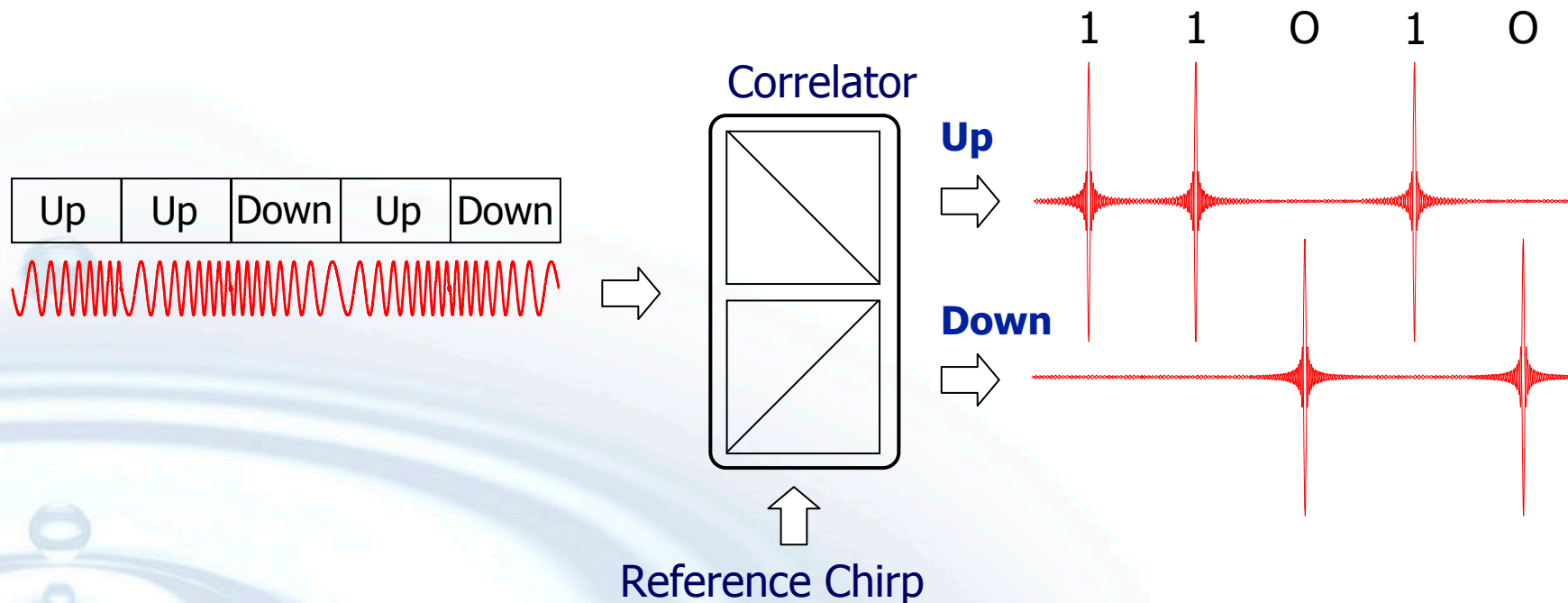
2-ary orthogonal CSS modulated bit sequence in time frequency domain

- Chirp BW 80 (22) MHz
- Bit Rate = Symbol Rate
 - 1E6 bit/s
 - 250 kbit/s
- Simple Coding
 - 0 = Downchirp
 - 1 = Upchirp

24730-5 Physical Layer

2-ary Orthogonal CSS Receiver

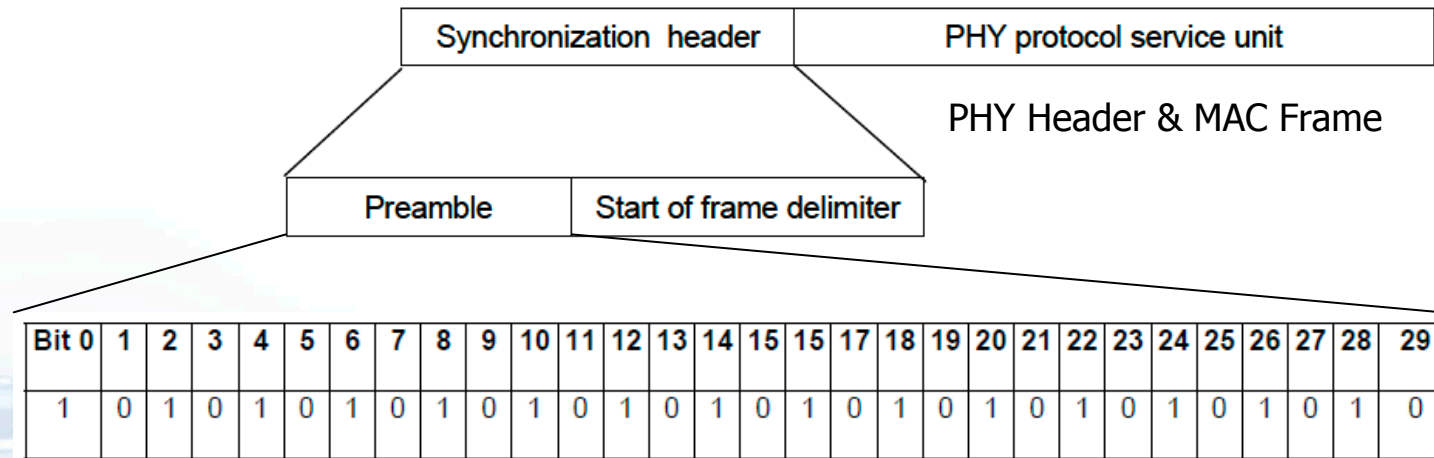
- Up-Chirp and Down-Chirp are orthogonal and easy to separate



- Ranging and Localization: Simple and precise TOA (Time of Arrival) evaluation

24730-5 Physical Layer

2-ary Orthogonal CSS PHY Packet Format



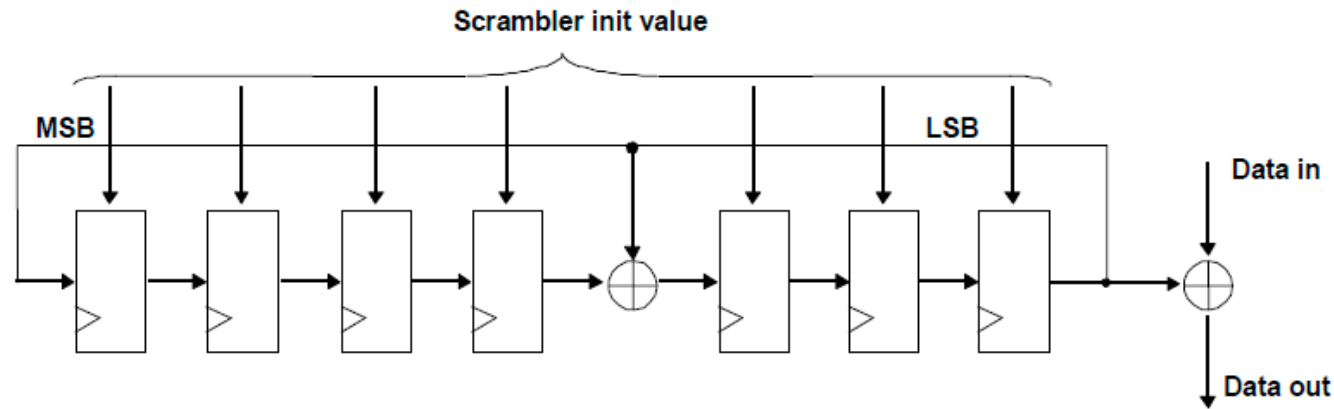
Preamble (30 alternating bits)

Octet 0	Octet 1	Octet 2	Octet 3	Octet 4	Octet 5	Octet 6	Octet 7
64h	52h	52h	9Ah	5Ah	4Bh	DBh	54h

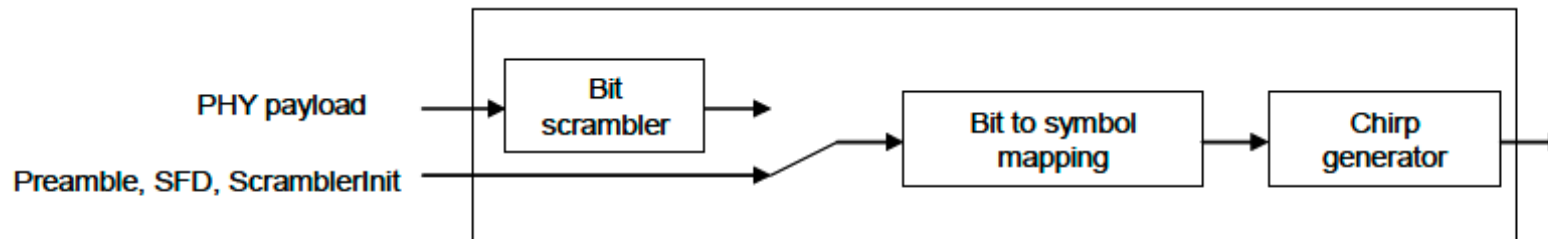
Start of Frame Delimiter (64 bits)

24730-5 Physical Layer

2-ary Orthogonal CSS PHY Packet Format



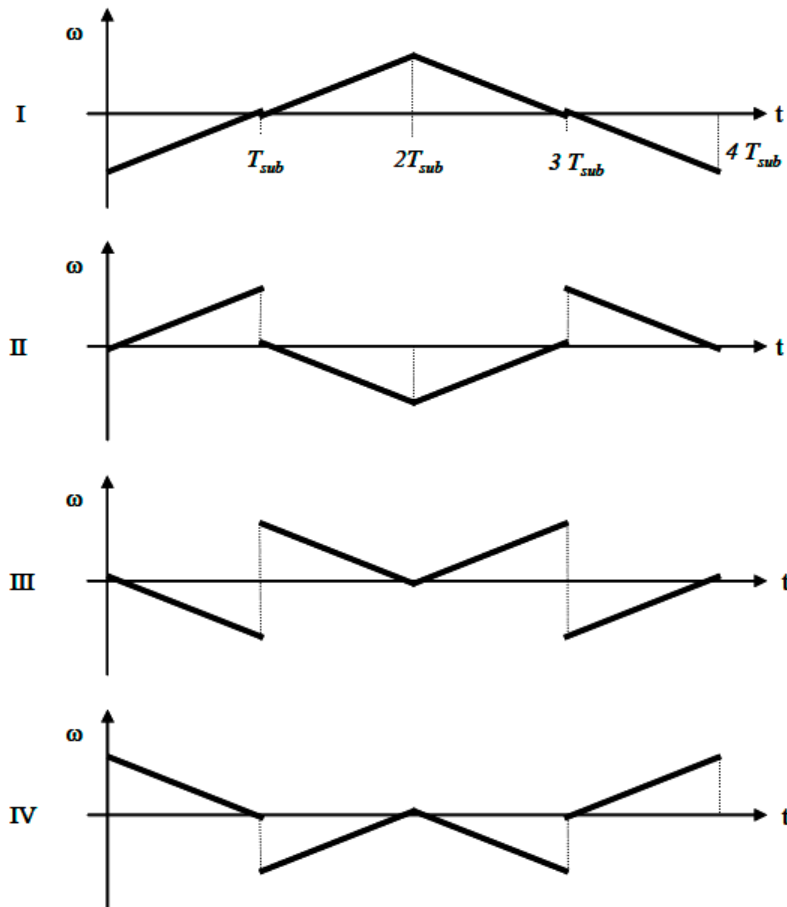
Scrambler Polynomial $g(D) = D^7 + D^4 + D^0$, EXORed with bit stream



Reference Modulator Diagram

24730-5 Physical Layer

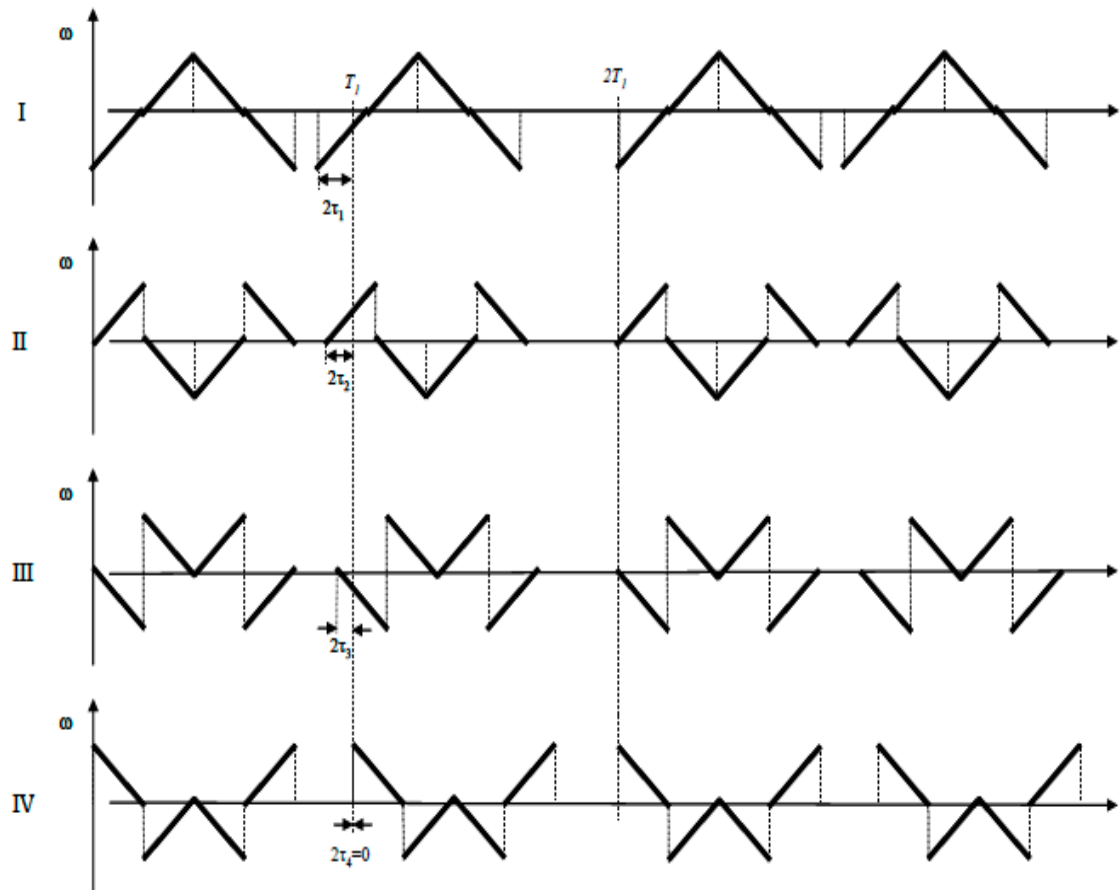
DQPSK-CSS Modulation



- Differential Quadrature Phase Shift Keying
- Band plan corresponds with 802.11b
- DQPSK-CSS approved in IEEE 802.15.4a
- Chirp BW 22 MHz, 14 RF Channels
- Sub-Chirp Freq. Offsets +/- 3.15 MHz
- 4 different Sub-Chirp Sequences: I, II, III, and IV (up to 4 x 14 channels)
- Provides sub-chirp sequence division AND frequency division
- Bit Rate
 - 1E6 bit/s (3/4 symbol mapping)
 - 250 kbit/s (6/32 symbol mapping)
- Symbol Rate
 - 166667 symbols/s

24730-5 Physical Layer

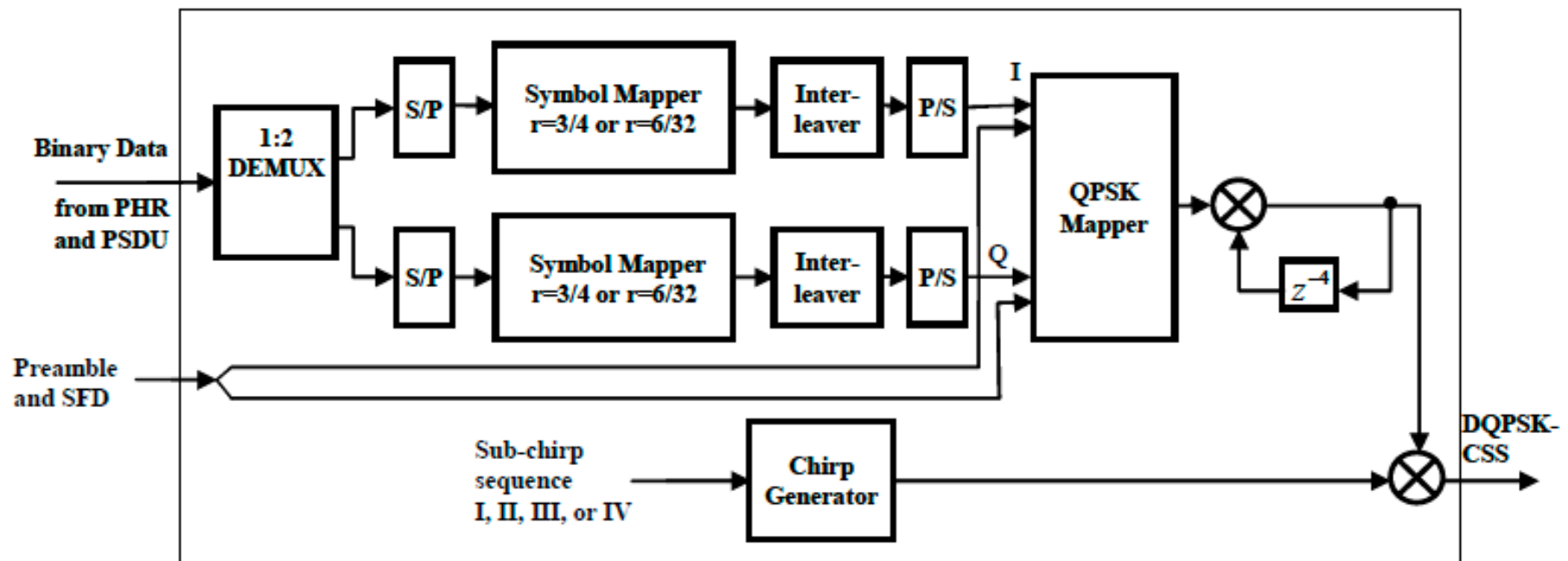
DQPSK-CSS Sub-Chirps and Time Gaps



- Pairs of Time Gaps defined
- Time Gaps applied alternately between subsequent chirp symbols
- Provides sharper orthogonality between chirp symbols

24730-5 Physical Layer

DQPSK-CSS Reference Modulator



DQPSK CSS reference modulator

24730-5 Physical Layer

DQPSK-CSS Symbol Mapping

- Data to 8-ary Bi-orthogonal Code Word Mapping ($r=3/4$)

(Decimal)	(Binary) ($b_0 b_1 b_2$)	($c_0 c_1 c_2 c_3$)
0	000	1 1 1 1
1	001	1 -1 1 -1
2	010	1 1 -1 -1
3	011	1 -1 -1 1
4	100	-1 -1 -1 -1
5	101	-1 1 -1 1
6	110	-1 -1 1 1
7	111	-1 1 1 -1

- 3-bit data symbol b_{0-2} is mapped to 4-chip bi-orthogonal code word c_{0-3}

- Data to 64-ary Bi-orthogonal Code Word Mapping ($r=6/32$)
For 250 kbit/s data rate, 6-bit data symbols are mapped to 32-chip bi-orthogonal code words

24730-5 Physical Layer

DQPSK-CSS Preamble and SFD

- Preamble

Data rate	Preamble Sequence
1 Mbit/s	ones(0:31)
250 kbit/s	ones(0:79)

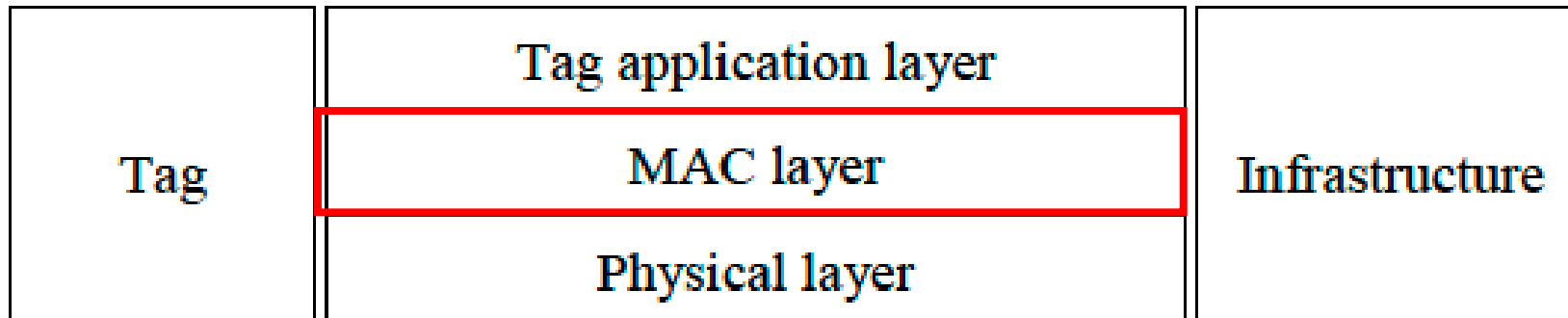
- SFD

Table 14 – SFDs for DQPSK-CSS

Data rate	Bit 0	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	Bit 9	Bit 10	Bit 11	Bit 12	Bit 13	Bit 14	Bit 15
1 Mbit/s	-1	1	1	1	-1	1	-1	-1	1	-1	-1	1	1	1	-1	-1
250 kbit/s	-1	1	1	1	1	-1	1	-1	-1	-1	1	-1	-1	-1	1	1

24730-5 MAC Layer

MAC Frame Types



Type	Name	Description
Data	Data	The MAC frame of a Data packet can contain up to 8192 octets of data payload.
Acknowledgement	ACK	Acknowledges the successful reception of a Data packet.
Broadcast	Broadcast	Transmits information to all stations in range
Request to Send	Req2S	Requests a frame transmission
Clear to Send	Clr2S	Confirms a requested frame transmission and indicates that a Data packet can be transmitted.

24730-5 MAC Layer

MAC Frame Formats

ACK

Reserved	Type	Dst	CRC1
4	4	48	16

Data

Reserved	Type	Dst	Src	Length	Ctrl	CRC1	MAC payload	CRC2
4	4	48	48	13	3	16	8...8*8192	16

Broadcast

Reserved	Type	Blink info	Src	Length	Ctrl	CRC1	MAC payload	CRC2
4	4	48	48	13	3	16	8...8*8192	16

Request to Send

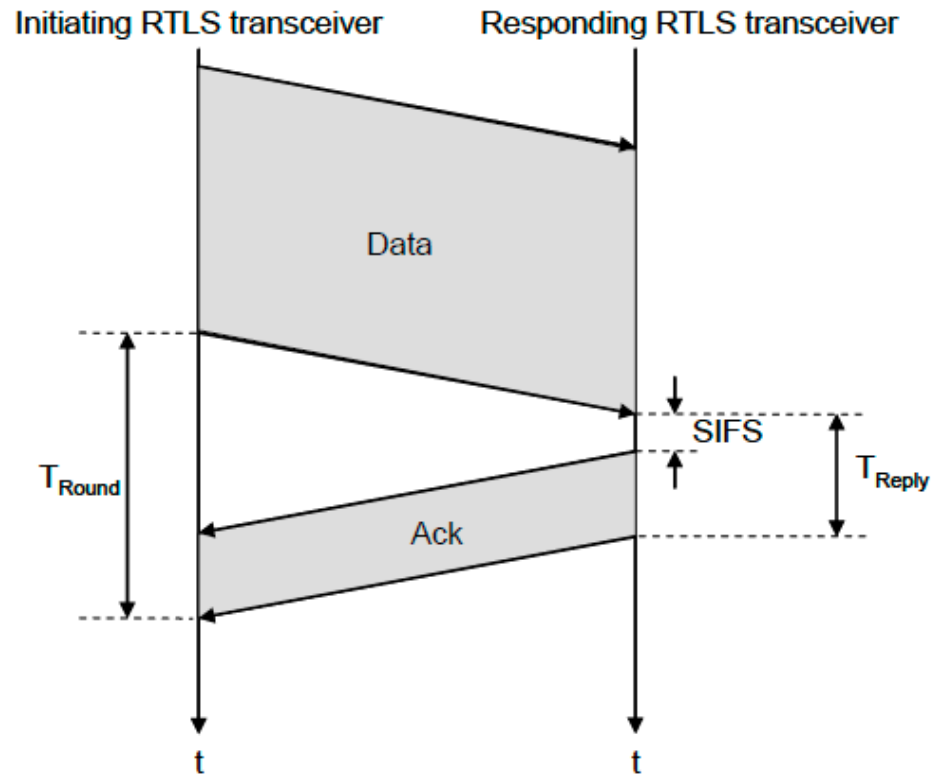
Reserved	Type	Dst	Src	Length	Ctrl	CRC1
4	4	48	48	13	3	16

Clear to Send

Reserved	Type	Dst	Length	Ctrl	CRC1
4	4	48	13	3	16

24730-5 MAC Layer

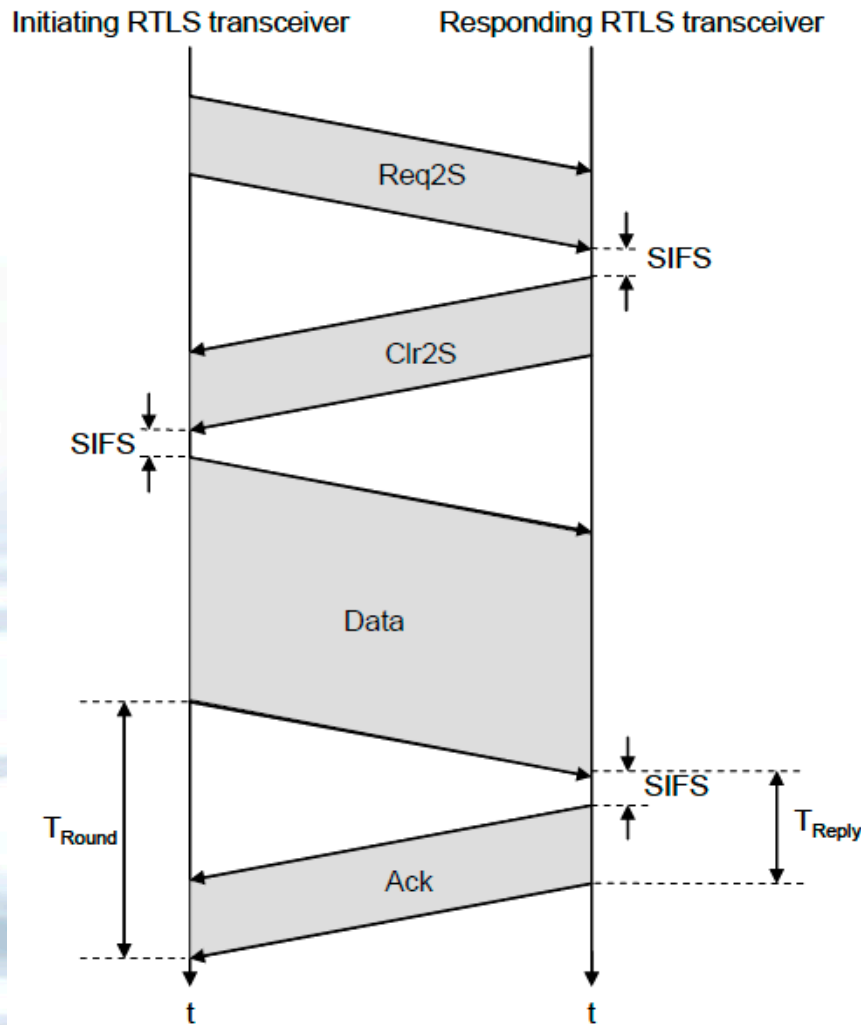
2-Way Handshake



- SIFS (Short Inter Frame Space) = $8 \mu\text{s}$
- T_{round} , T_{reply} measured for Ranging

24730-5 MAC Layer

3-Way Handshake



- 3-Way handshake initiates a Request-to-Send and waits for Clear-to-Send prior to data transmission
- Used to overcome hidden-node problem: used for virtual carrier sensing (see later)
- T_{round} , T_{reply} measured for Ranging

24730-5 MAC Layer

Media Access Methods

- ALOHA
 - Immediate Access w/o listening for any activity

- CSMA/CA
 - Energy detect
 - Average power sensing during CIFS period

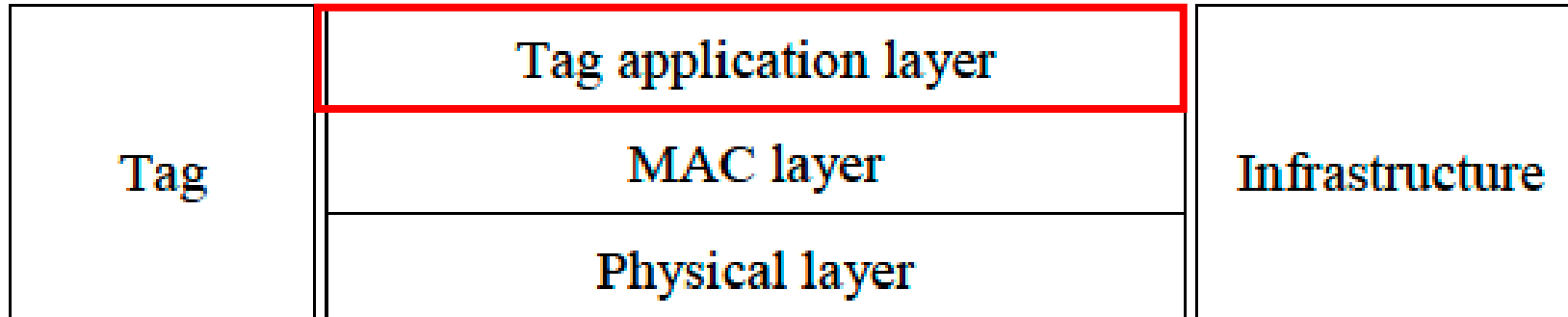
 - Physical carrier sense
 - Sense for CIFS duration on medium

 - Virtual carrier sense
 - Evaluating Type and Length fields of incoming traffic

 - For all 3 Methods above: Backoff when media is busy

24730-5 Tag Application Layer

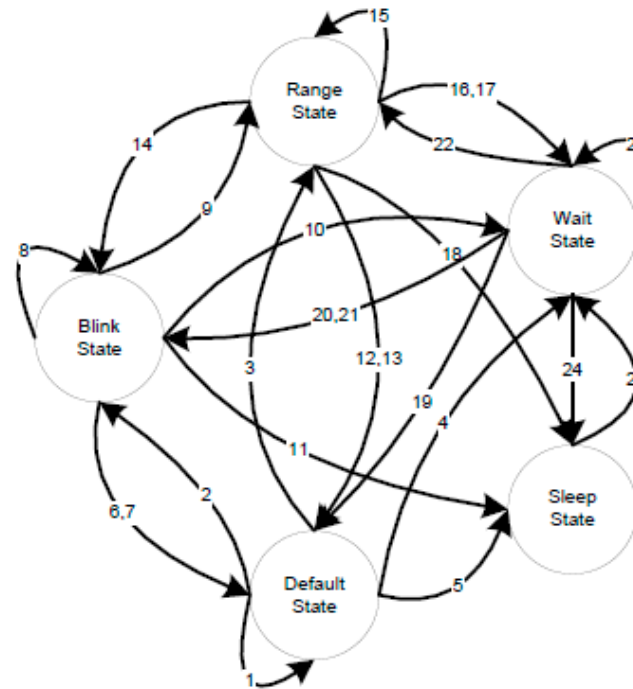
Tag Application Packet Types



- Four Types of Tag Application Packets
 - Command Packets
Used by infrastructure to transmit instructions to tags
 - Report Packets
Used by tags to transmit information to the infrastructure
 - Ranging Packets
Used for Ranging
 - Blink Packets
Broadcast packets transmitted by tags, e.g. for RTLS via TDOA

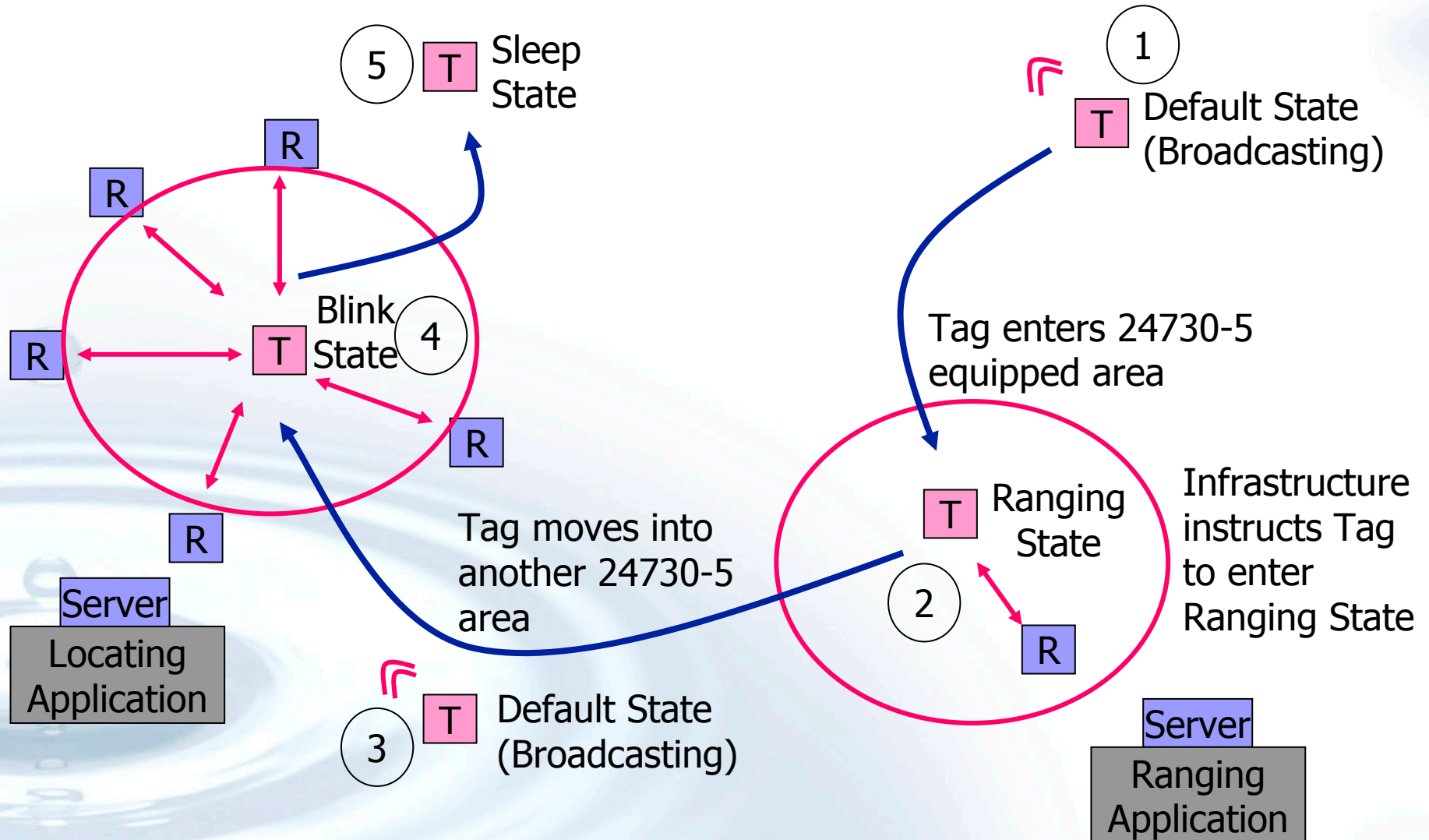
24730-5 Tag Application Layer

Tag Application States



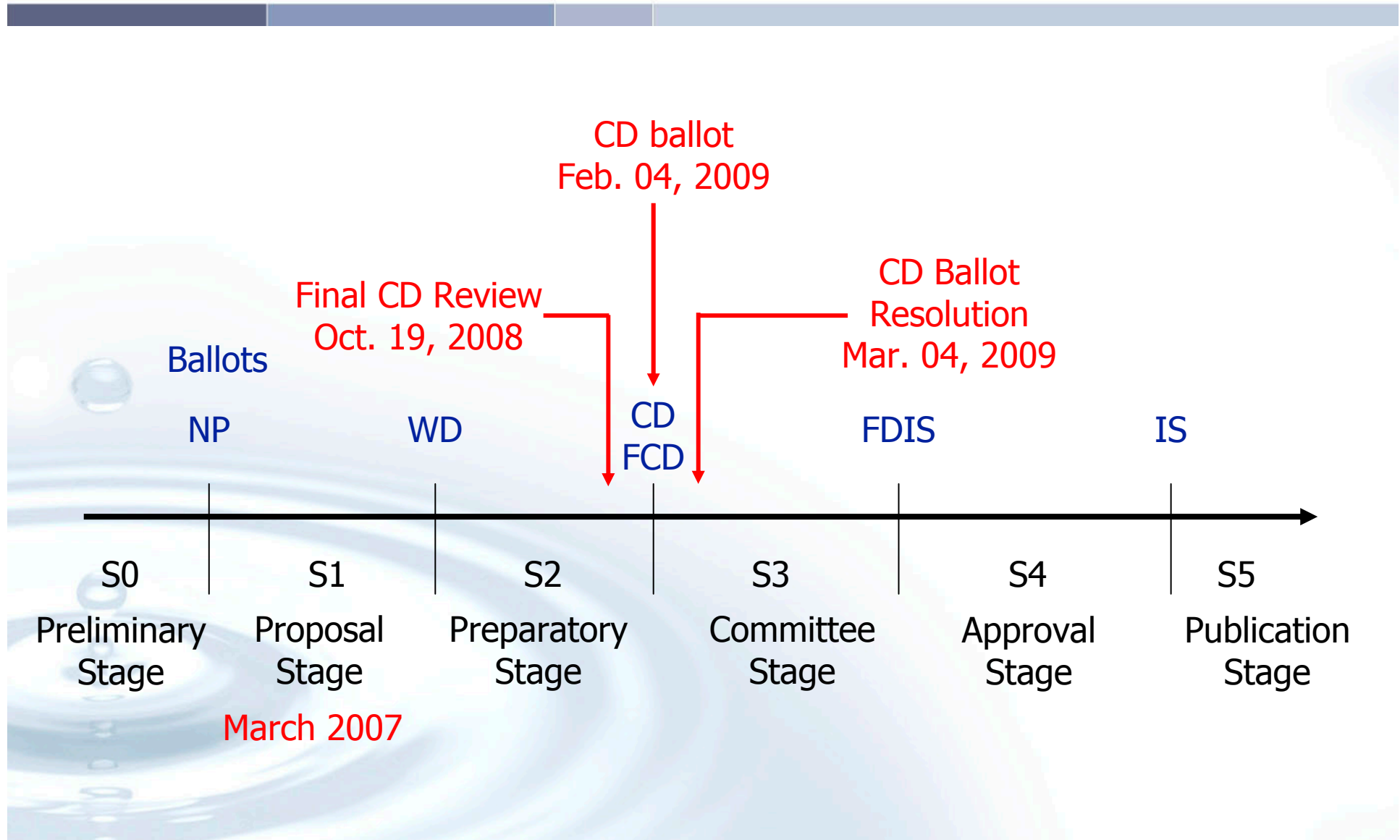
- 5 different Tag Application States
- Infrastructure can instruct the TAG application to go to desired states or to go through sequences of states

Example System



Standardization

Status of 24730-5



Standardization

Other RTLS Standards

- ISO/IEC 24730-1 (API, common for all Air Interfaces)
 - Stage 5 (IS) since Feb. 2006

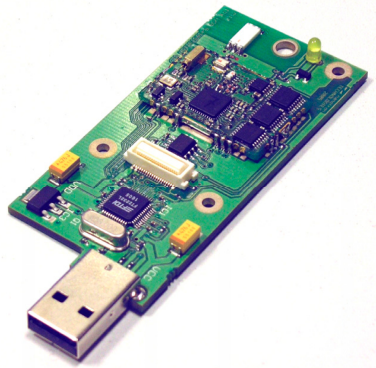
- ISO/IEC 24730-2
 - Stage 5 (IS) since Dec. 2006
 - BPSK DSSS (Direct Sequence Spread Spectrum) Modulation
 - Center freq. 2441,75 MHz, BW 60 MHz
 - Data rate: ~60 kbit/s
 - Packet length 56 - 152 bits
 - 2-Tone OOK/FSK Modulation
 - Center Freq. 2441,75 MHz, BW 60 MHz
 - Data rate ~20 kbit/s
 - Packet length 88 - 188 bits
 - Short Distance Magnetic Link (115 MHz, 127 MHz)
 - Data rate 2,048 kbit/s

Forecast, future Developments

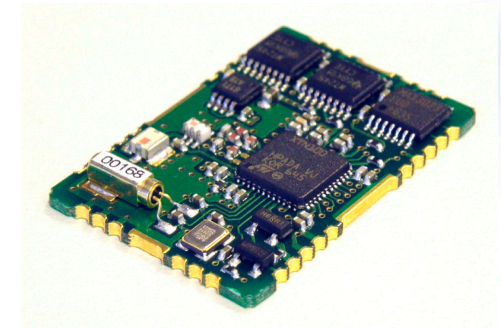
- ISO/IEC 24730-6 (UWB)
 - t.b.d.

- ISO/IEC 24730-5
 - Improvement of Ranging/Localization Accuracy
 - Improvement of Power Efficiency
 - Development of Application Software for Emerging Markets & Applications

For more information..



Please check Proceeding Papers



Thank You!

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