Wireless locating with Chirp and UWB

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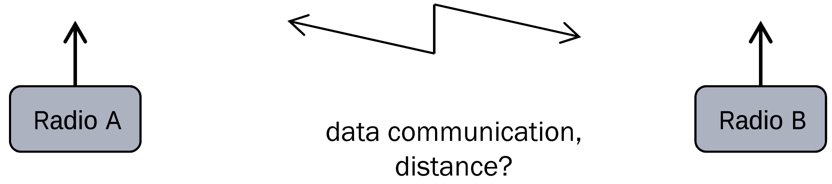
Orginal motivation:
Get the distance between two radio devices



- Use RSSI (Receive Signal Strength Indicator)

  ⇒very inaccurate because of high randomness radio channel

- Measure TOF (Time of Flight)

  ⇒requires accurate time stamps of TOD (time of departure) and TOA (time of arrival)

  ⇒ less impacted by randomness of radio channel

What does it need to achieve good time stamp accuracy?

- High effective signal bandwith (B_{eff})
- High Signal to Noise Ratio (SNR)

Radar theory states the relationship between standard deviation of time delay estimate, B_{eff} and SNR:

$$std(T_R) = \frac{1}{B_{eff}\sqrt{2\frac{E_s}{N_0}}} \qquad [1]$$

~ Bandwidth x Sqrt(P)

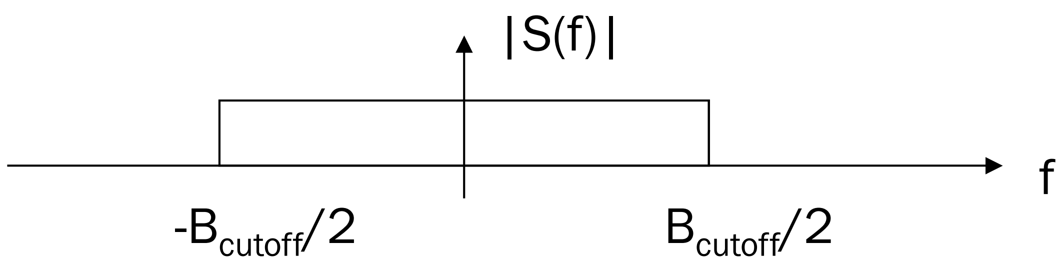
with

$$B_{eff}{}^2 = \frac{1}{E_s}\int_{-\infty}^{\infty}(2\pi f)^2 \, |S(f)|^2 \, df$$

where $S(f)$ is the spectral power density

Theoretical limit of time stamp accuracy

For a signal with a flat spectrum (e.g. chirp) the following numbers are obtained:



$$B_{eff} = \frac{\pi \cdot B_{cutoff}}{\sqrt{3}}$$

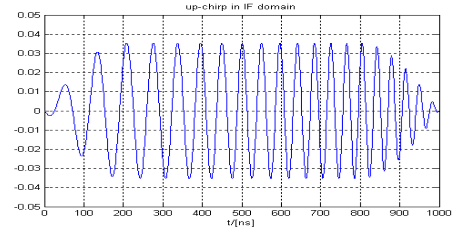
B_{cutoff}	B_{eff}	E_s/N_0=20 dB
20 MHz	36 Mrad/s	1.94 ns (0.584 m)
80 MHz	145 Mrad/s	0.487 ns (0.146 m)
500 MHz	907 Mrad/s	0.077 ns (0.023 m)

Two approaches: CSS and UWB

- Utilize given bandwidth and signal power within license free band

  => Chirp Spread Spectrum (CSS)

  - 80 MHz, 20 dBm



- Brute bandwith

  => UWB IR (Impulse Radio) [*since OFDM didn't make it*]

  - 500 MHz, -41dBm/MHz => -14dBm

$10*\log(B) + 0.5 * P_{dBm}$		
CSS_{20}	CSS_{80}	UWB
83	89	20

much higher Bandwidth x Sqrt(power) product

CSS and UWB found their way into international standards

- 2005 IEEE 802.15.4a Task Group started, intense participation of many companies
- 2007 IEEE 802.15.4a published [2] (UWB IR PHY, CSS PHY)
- 2007 CSS radio transceiver (nanoLOC by nanotron technologies) on the market
- 2011 ISO/IEC 24730-5 Information technology — Real-time locating systems (RTLS) — Part 5: Chirp spread spectrum (CSS) at 2,4 GHz air interface
- 2013 ISO/IEC 24730-62 Information technology — Real time locating systems (RTLS) — Part 62: High rate pulse repetition frequency Ultra Wide Band (UWB) air interface
- 2013 UWB transceiver (DW1000 by DecaWave) on the market
- 2018 Cooperation between nanotron technologies and DecaWave

Comparison

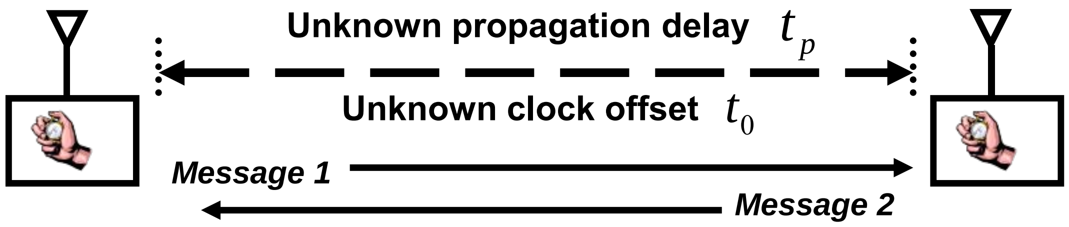
- CSS
  - limited bandwidth (80 MHz) -> good location precision (meter)
  - high Tx power (20 dBm, 2.4 GHz ISM) -> high range, risk of interference
  - world wide stable regulation

- UWB
  - high bandwidth (500 MHz) -> very good location precision (20 cm) **if Line of Sight (LOS) condition can be maintained**
  - very limited Tx power (-17…-14 dBm, 6.5 GHz band) -> poor range, lower risk of interference (currently)
  - changing regulatory (e.g. 6 GHz band has just been opened for unlicensed use by FCC)

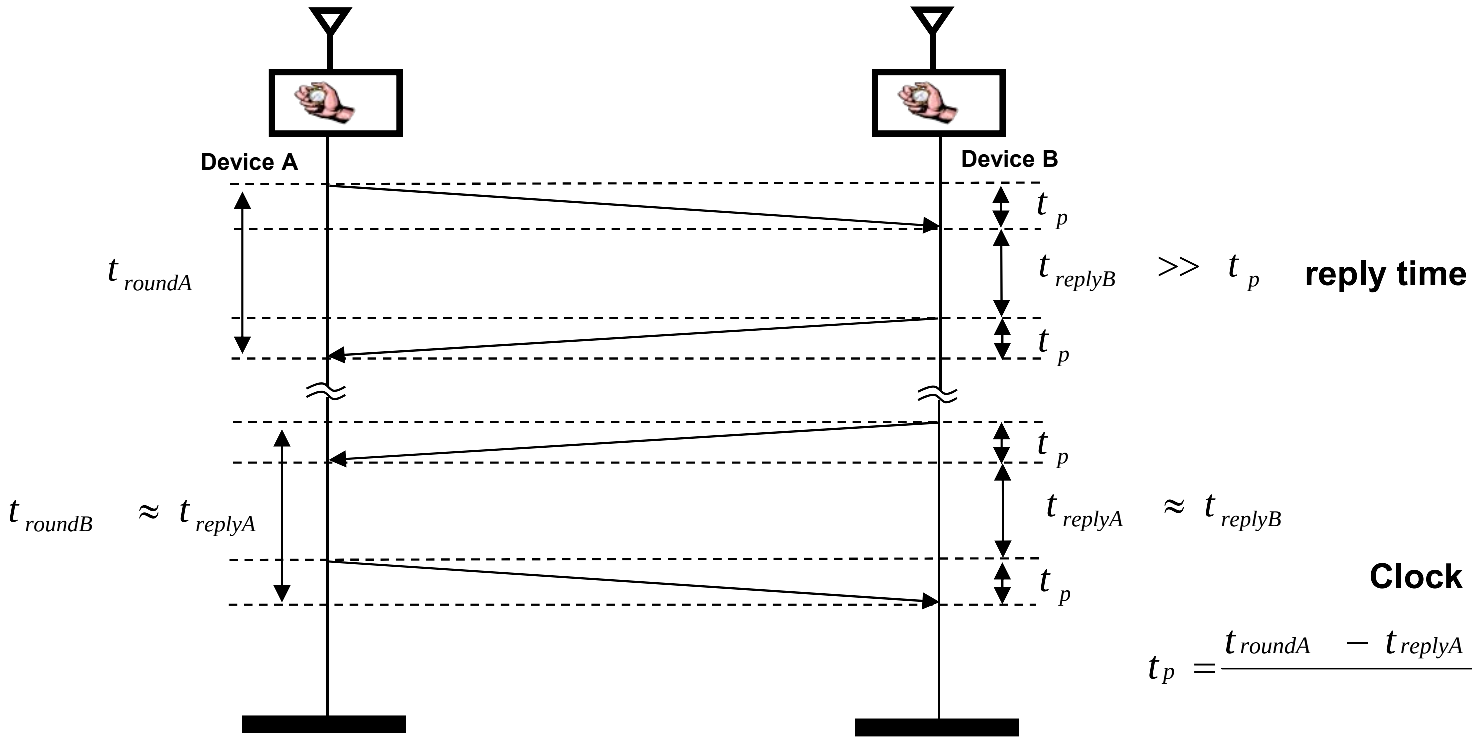
- Which on should be used?
  - Depends on the application
  - In some application you might need both simultanously

First step towards location: Round Trip Time of Flight

- Two Way Ranging
  - Issues: clock offset



- Solution: Symetrical Double Sided Two Way Ranging (SDS TWR) [2]



Clock offset is eliminated !

$$t_p = \frac{t_{roundA} - t_{replyA} + t_{roundB} - t_{replyB}}{4}$$

Limited application space for ranging

- Ranging consumes **air time** and **energy**

  => good for applications with limited number of nodes

  - E.g. Collision avoidance system (CAS) between vehicles in a mine

  ⇒Not good for large scale applications:

  ⇒locating & tracking thousands of battery powered devices within an infrastructure equipped environment

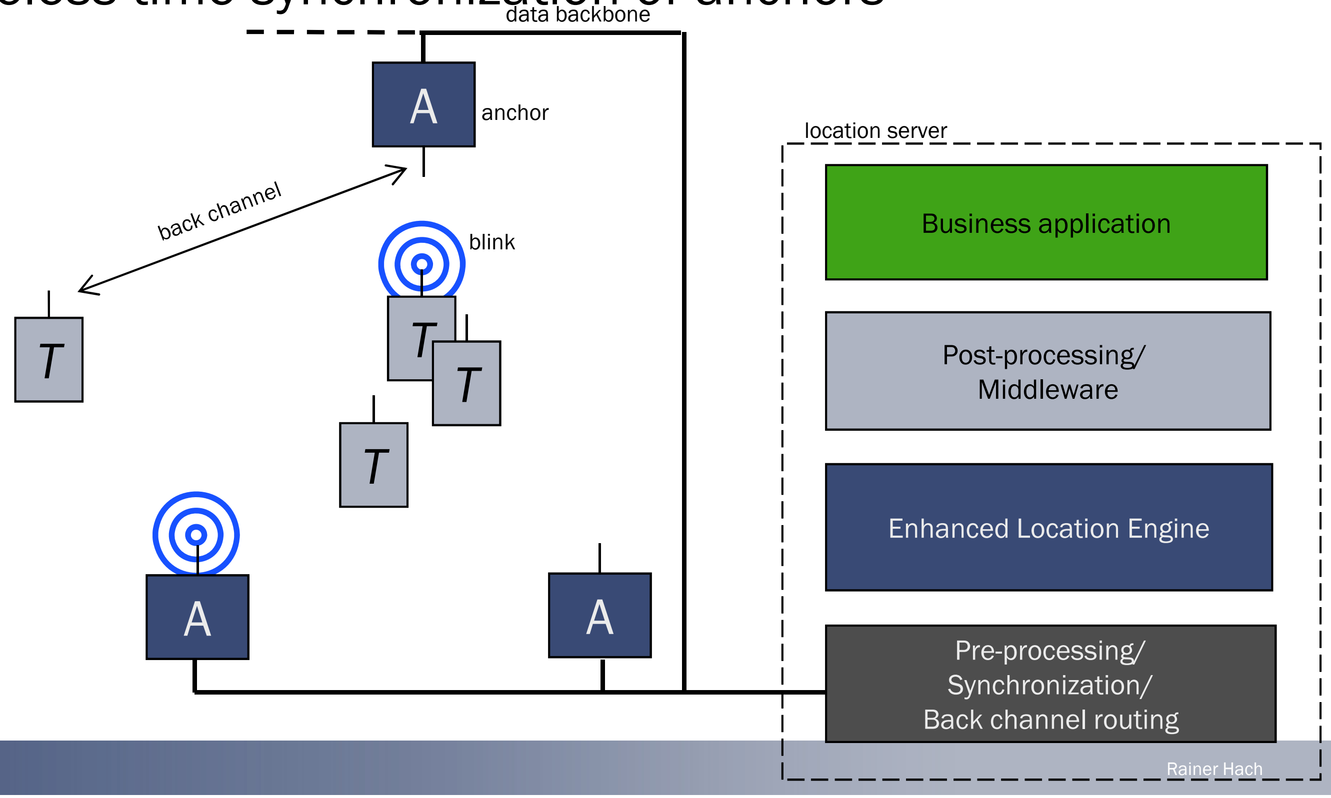
  ⇒E.g. Cattle in a barn

- *Example calculation: N tags, M anchors, N times M ranging exchanges*
  - *1000 tags, 10 anchors, 2.5 ms ranging duration -> 25 sec*

    Assume Channel utilization of 15 % -> several minutes on average until each tag has been located once

TDOA for large scale applications

- Hundreds of anchors, thousands of tags
- Infrastructure consisting of
  - Anchors,
  - Server SW: location engine, tools for administration and maintenance
- Tags: application specific, open Air interface, customizable payload
- Challenge: Wireless time synchronization of anchors



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Summary & Conclusions

- CSS and UWB are commercially available technologies for locating applications
- Theoretical achievable location accuracy of CSS and UWB has been shown
- Brief historical overview has been given
- How clock offset is removed in ranging with CSS or UWB has been mentioned
- TDOA architecture and components have been indicated
- Physical layer (CSS or UWB) is only small piece of location solution

Outlook

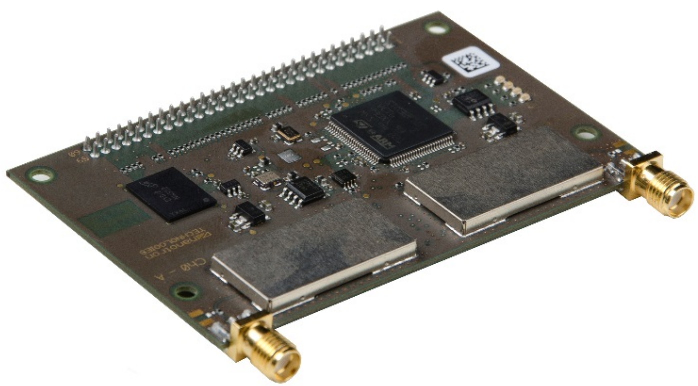
- For maximization of performance and reliability
  - Combine multiples technologies and sources of information

  e.g. CSS, UWB, inertial navigation units (IMU), map matching, …

- Make setup and maintenance of RTLS solution even easier

- Connect to cloud
- Provide event detection and Location Data Analytics as service to IoT

Questions, comments, feedback?



nanoANQ EM:
Credit-card size
anchor module
for fixed location
infrastructure.

Let us know!

Thank You!

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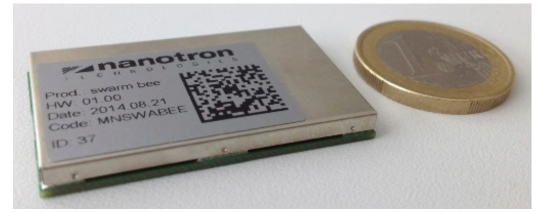


swarm bee module 24 x 40 x 3,5 mm^3
available with CSS and UWB

BACKUP

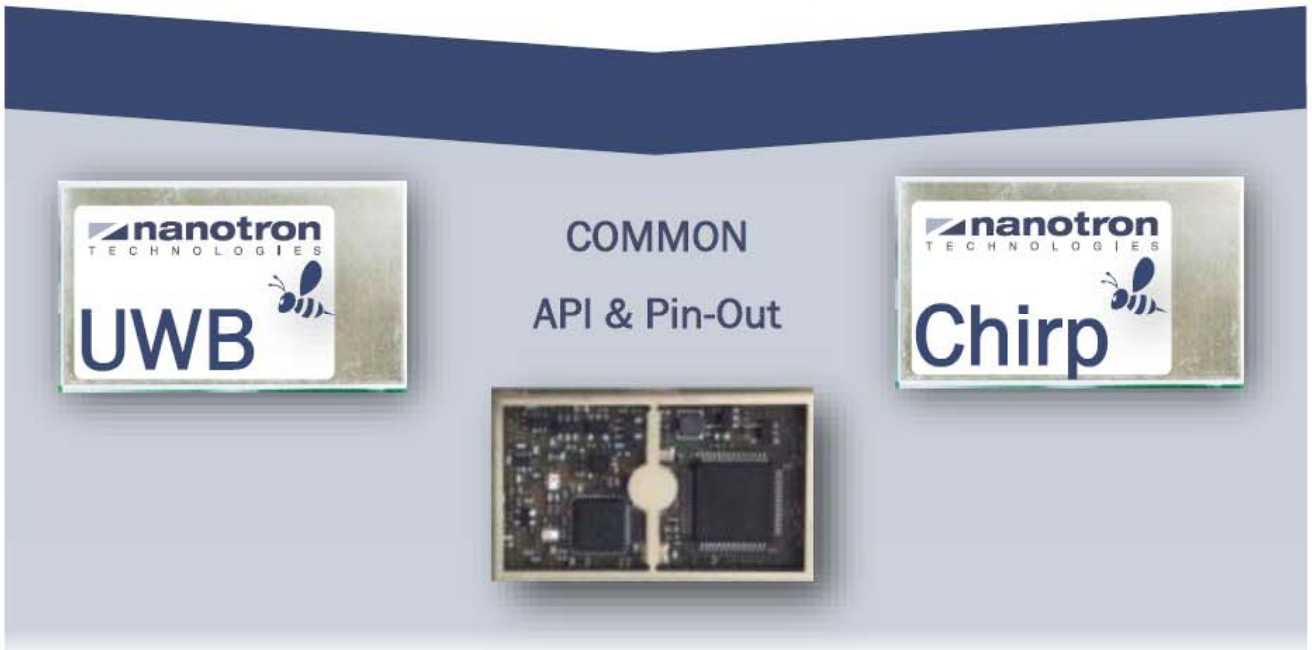
References

[1] Skolnik: Introduction to Radar Systems, Third Edition, p. 320

[2] *Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs), Amendment 1: Add Alternate PHYs, IEEE Std. 802.15.4a,* August 2007.

Nanotron Platform is RF-Technology Agnostic

Mix & Match



- **swarm bee** can do this!

protect and find

Today nanotron's *embedded location platform* delivers location-awareness for safety and productivity solutions across industrial and consumer markets. The platform consists of chips, modules and software that enable precise real-time positioning and concurrent wireless communication. The ubiquitous proliferation of interoperable location platforms is creating the location-aware Internet of Things.

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