An Original Correction Method for Indoor Ultra Wide Band Ranging-based Localisation System

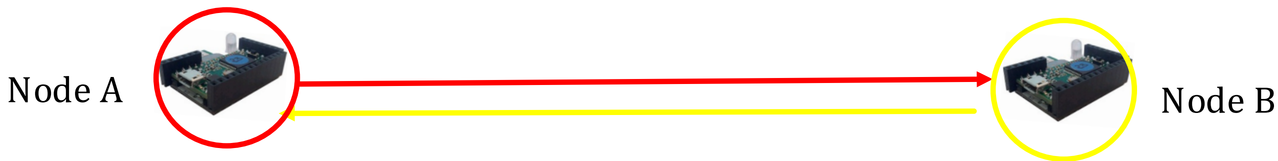
Nezo Ibrahim Fofana, Adrien van den Bossche, Réjane Dalcé, Thierry Val

IRIT, Université de Toulouse, Toulouse, France

Ad Hoc Now 2016

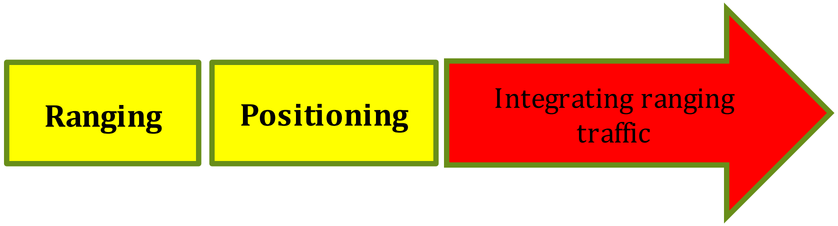
Context

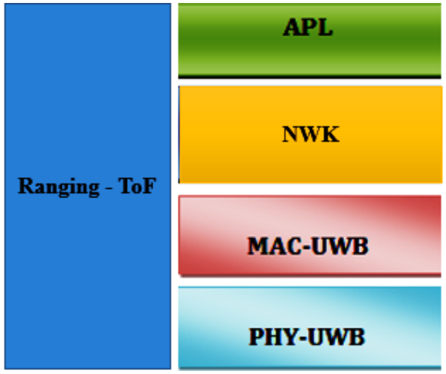
Objective: Indoor localisation of things

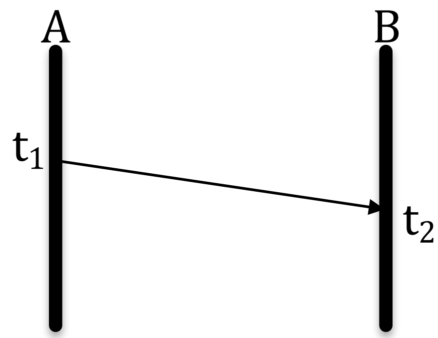


- **Ranging mechanism between nodes**

PHY UWB ➔ ToF







SUMMARY

I. Related work

II. Testbed description

III. Implementation results and comparison of TWR and SDS-TWR

IV. Artificial delays and TWR performance

V. Proposed error mitigation method

VI. Conclusion and future works

SUMMARY

I. Related work

II. Testbed description

III. Implementation results and comparison of TWR and SDS-TWR

IV. Artificial delays and TWR performance

V. Proposed error mitigation method

VI. Conclusion and future works

Related work

1. Std IEEE 802.15.4-2011 : Ultra Wide Band (UWB) PHY layer

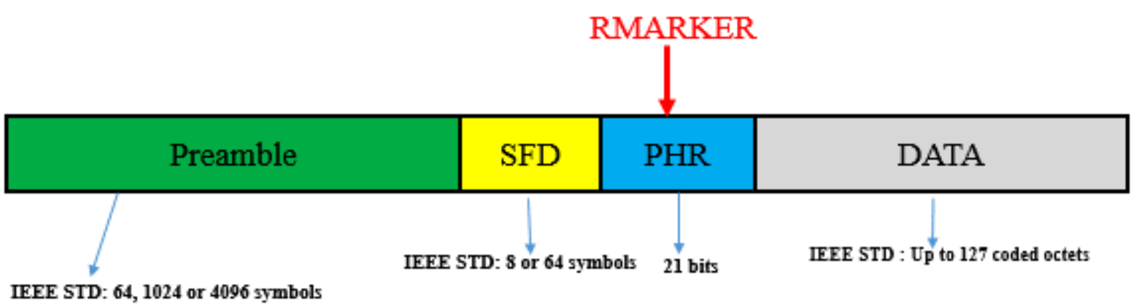
- Bandwidth: 500 MHz
- Frequency Band: 3,1-10 GHz
- Data Rates: 110 kb/s, 850 kb/s, 6.81 Mb/s, 27.24 Mb/s
- Power Spectral Density (PSD) : -41.3 dBm/MHz

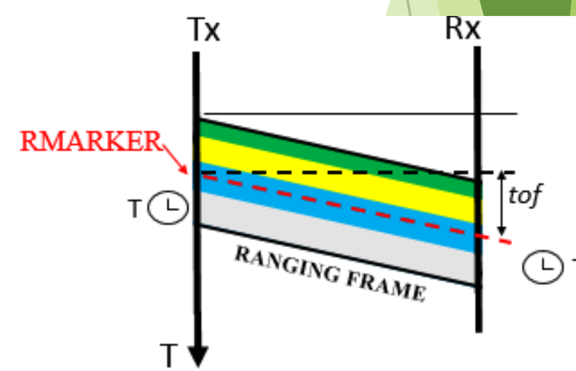
Very high temporal resolution

➔ Indoor localisation

➔ Time of Flight (ToF) measurement

RMARKER : Ranging Marker



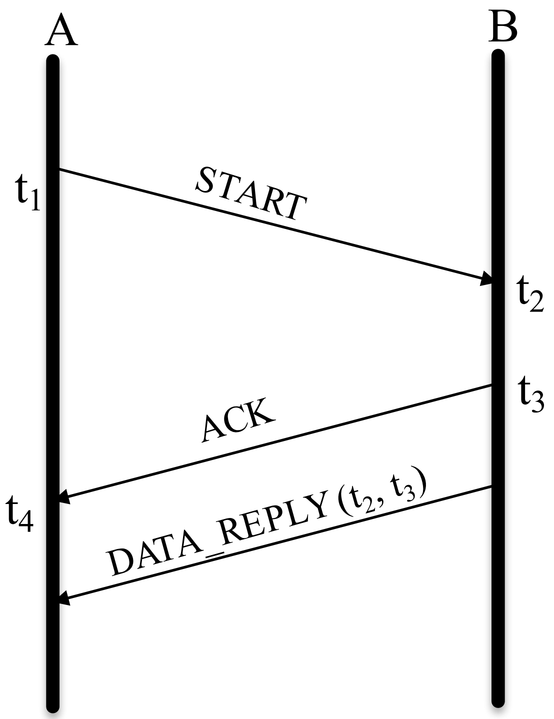


Use of UWB radio links to achieve an efficient ranging, based on ToF measurement

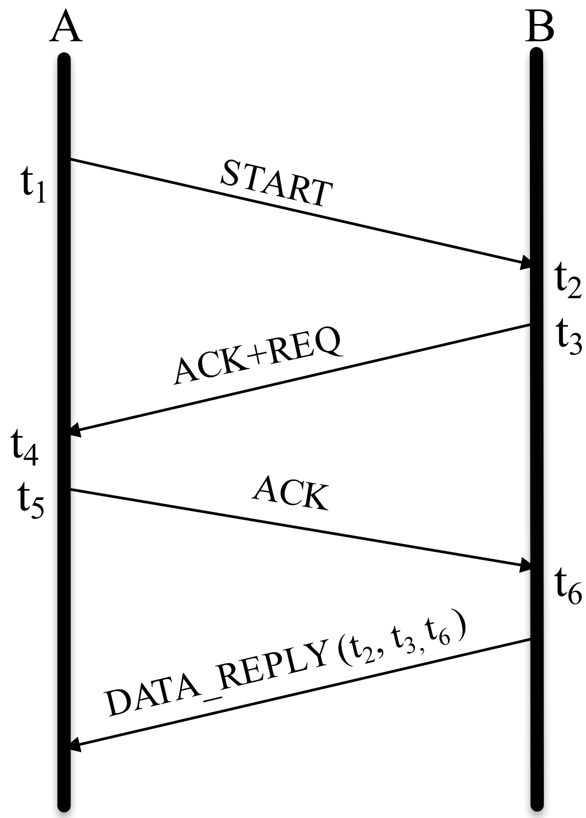
Related work

2. Ranging protocols

TWR (Two Way Ranging)



SDS-TWR (Symmetrical Double Sided -Two Way Ranging)



$$ToF_{TWR} = \frac{(t_4 - t_1) - (t_3 - t_2)}{2}$$

$$ToF_{SDS\text{-}TWR} = \frac{(t_4 - t_1) - (t_3 - t_2) + (t_6 - t_3) - (t_5 - t_4)}{4}$$

$$Distance = ToF * C$$

C: speed of light

Related work

2. Ranging protocols

First step:

Implementation of TWR and SDS-TWR

Proposal for improvement

Incorporate ranging traffic in the usual network traffic

SUMMARY

I. Related work

II. Testbed description

III. Implementation results and comparison of TWR and SDS-TWR

IV. Artificial delays and TWR performance

V. Proposed error mitigation method

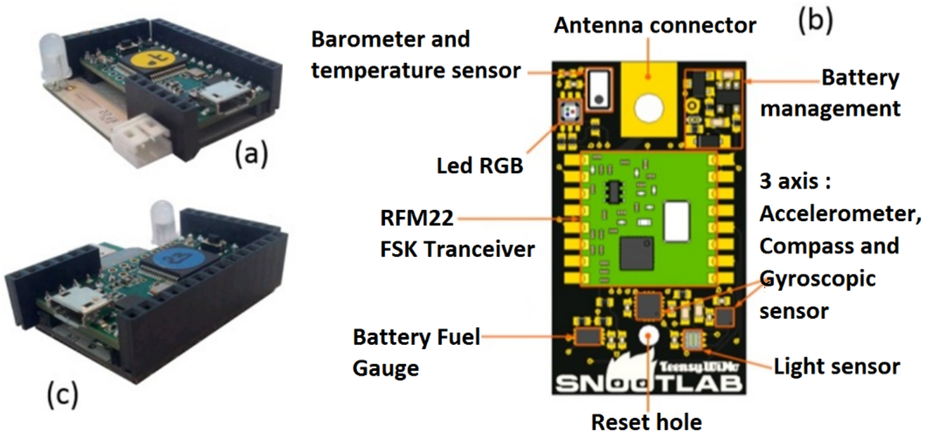
VI. Conclusion and future works

Tesbed description

OpenWino

Open source environnement for WSN

Used for prototyping of WiNo (Wireless Node) Nodes



The WiNos nodes

DecaWiNo

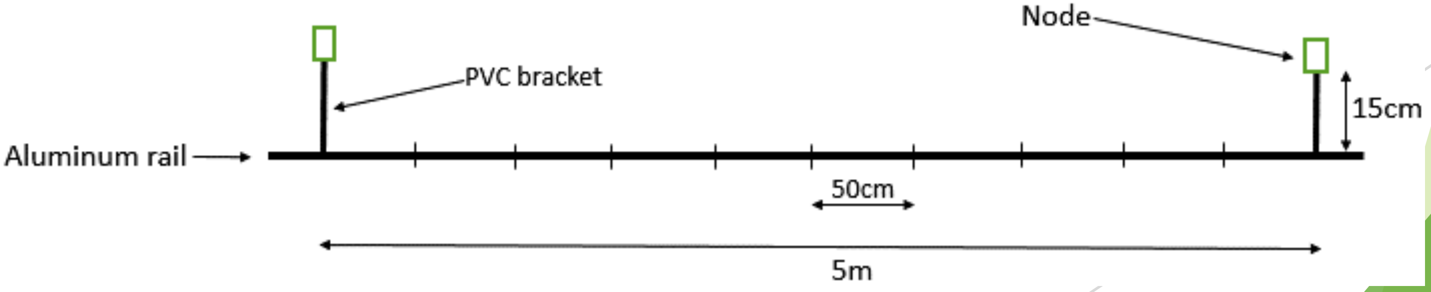
•WiNo built on UWB transceivers developed by DecaWave, compliant with the IEEE 805.15.4 2011

• Library DecaDuino available online [3]

[3] https://www.irit.fr/~Adrien.Van-Den-Bossche/DecaWiNo

Tesbed description

Context of distance measurements



SUMMARY

I. Related work

II. Testbed description

III. Implementation results and comparison of TWR and SDS-TWR

IV. Artificial delays and TWR performance

V. Proposed error mitigation method

VI. Conclusion and future works

Implementation results and comparison of TWR and SDS-TWR

Error Summary in TWR (in meters)

Actual distance	Dist. TWR	average error	max error	min error	standard deviation
0,5	0,339	-0,160	-0,11	-0,24	0,029745754
1	0,881	-0,118	-0,05	-0,17	0,02427616
1,5	1,417	-0,082	-0,03	-0,14	0,023683855
2	1,993	-0,006	0,05	-0,06	0,024150096
2,5	2,480	-0,019	0,03	-0,07	0,017567371
3,5	3,481	-0,018	0,03	-0,07	0,022417601
5	5,046	0,046	0,08	0	0,016043844

Error Summary in SDS-TWR (in meters)

Actual distance	Dist. SDS_TWR	average error	max error	min error	standard deviation
0,5	0,4	-0,099	-0,05	-0,15	0,02623868
1	0,942	-0,057	-0,02	-0,09	0,01638611
1,5	1,482	-0,017	0,03	-0,07	0,02390231
2	2,061	0,061	0,11	0,01	0,02122458
2,5	2,546	0,046	0,08	0,01	0,01724975
3	3,067	0,067	0,11	0,03	0,02023639
5	5,107	0,107	0,15	0,07	0,01559689

Implementation results and comparison of TWR and SDS-TWR

Ranging using TWR and SDS-TWR

Representation of SDS-TWR / TWR error in function of the distance

Error on both SDS-TWR and TWR < 16 cm

Low standard deviation (~ 0.02)

TWR possible

SUMMARY

I. Related work

II. Testbed description

III. Implementation results and comparison of TWR and SDS-TWR

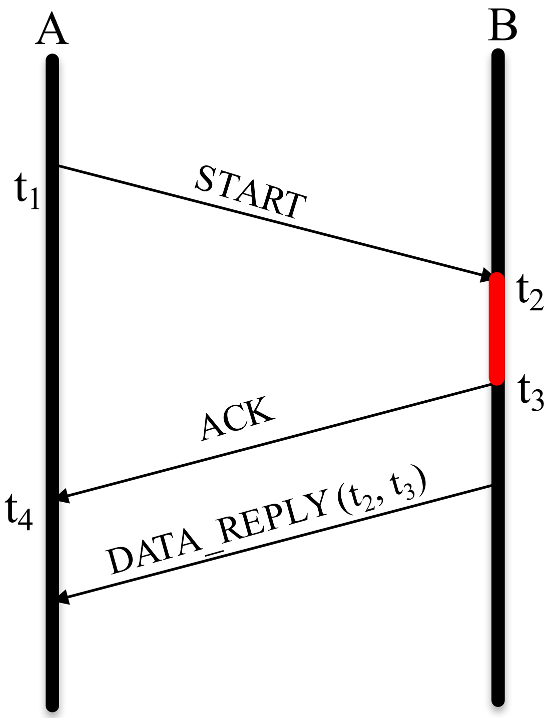
IV. Artificial delays and TWR performance

V. Proposed error mitigation method

VI. Conclusion and future works

Artificial delays and TWR performance

Context of measurements

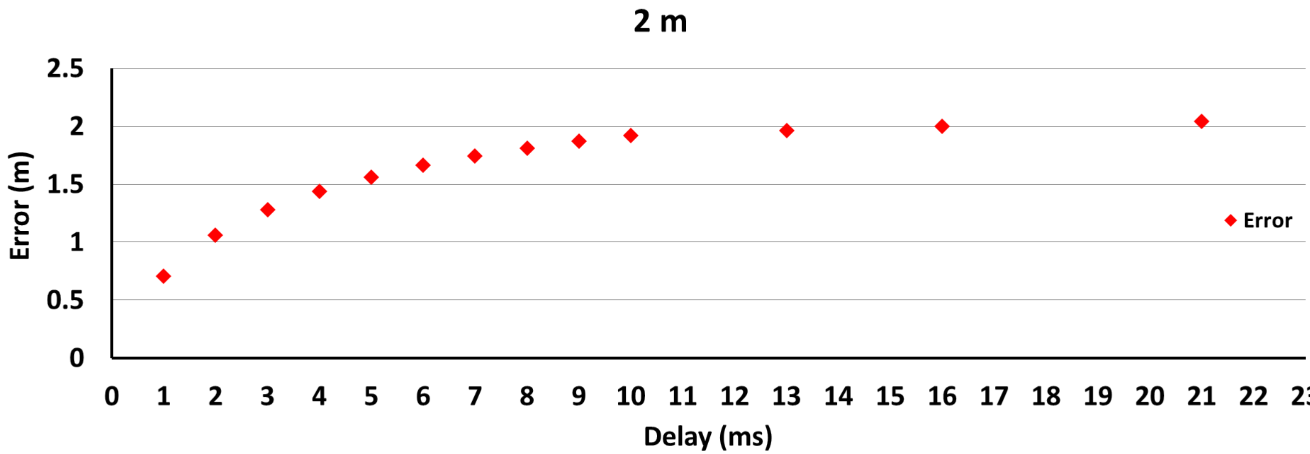


Delay 1, 2, 4, 5, ……..21 (ms)

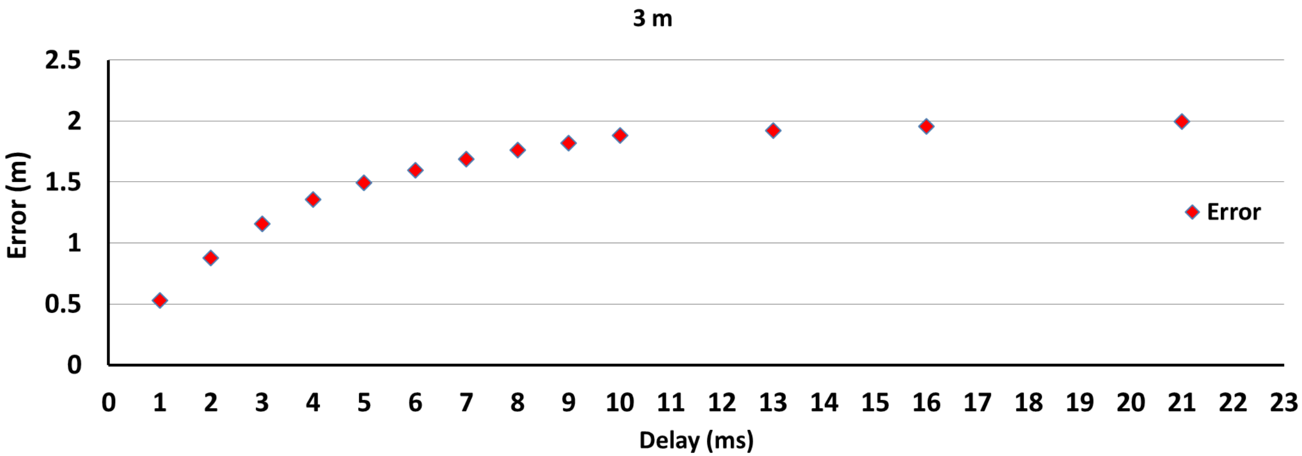
TWR with a delay between exchanges

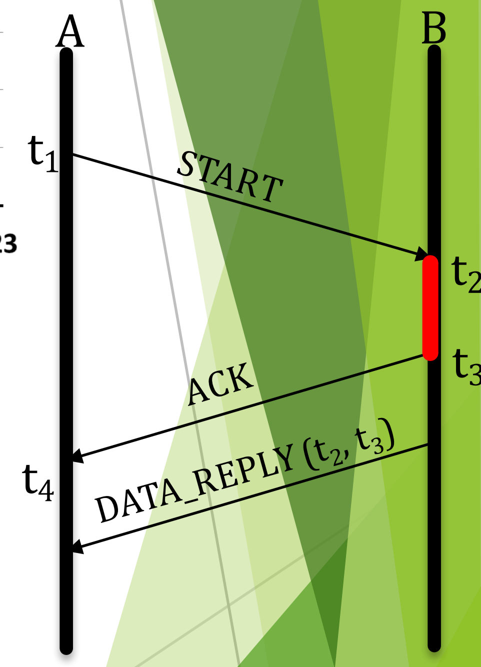
Artificial delays and TWR performance

Results with 2 and 3 m



Representation of the error in function of delay (TWR)



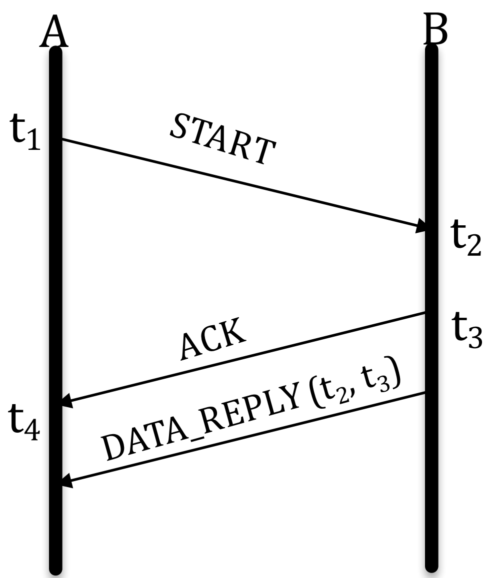


Representation of the error in function of delay (TWR)

SUMMARY

Proposed error mitigation method

Principle of the correction



TWR

Frequency f_A

Frequency f_B

- $$tof = \frac{t_4 - t_1 - (t_3 - t_2)}{2}$$
- $f_A = f_B$ ➔ *tof* very precise
- $k = \frac{f_B}{f_A}$ ou $k \approx 1$

➔ $$tof' = \frac{t_4 - t_1 - k * (t_3 - t_2)}{2}$$

ClockOffset➔ Skew (ppm, 10^{-6})

$$k = 1 + ClockOffset * 10^{-6}$$

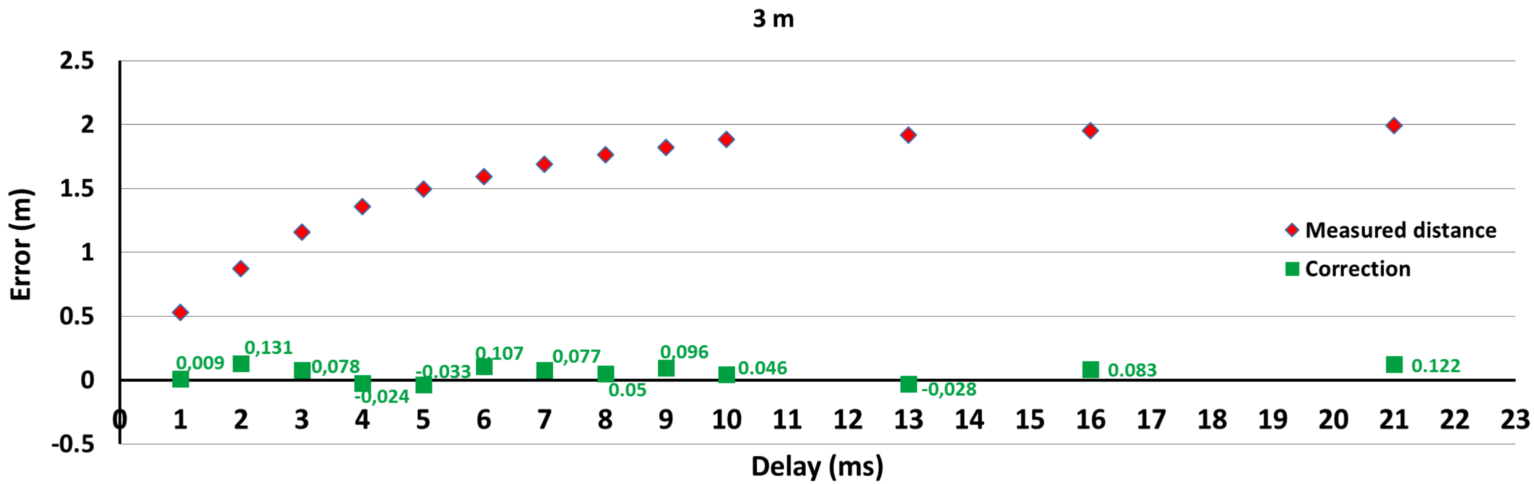
➔ $$tof' = \frac{t_4 - t_1 - (1 + ClockOffset * 10^{-6}) * (t_3 - t_2)}{2}$$

Proposed error mitigation method

Analysis and interpretation of results

Summary table of corrected distances

Delay \ Distance	0,5 m	1,5 m	2,5 m	3,5 m	4,5 m	5,5 m
1 ms	-0,26	0,06	0,15	0,06	0,24	0,23
2 ms	-0,32	-0,04	-0,01	0,04	0,21	0,31
3 ms	-0,29	-0,07	0,05	0,00	0,24	0,27
4 ms	-0,37	-0,02	0,17	0,02	0,22	0,38
5 ms	-0,17	-0,09	0,05	-0,10	0,36	0,17
6 ms	-0,30	-0,12	0,11	0,11	0,34	0,23
7 ms	-0,27	-0,04	0,03	0,05	0,04	0,24
8 ms	-0,23	-0,12	0,19	0,05	0,16	-0,01
13 ms	-0,16	0,06	0,24	0,12	0,32	0,06
16 ms	-0,11	0,04	0,27	0,18	0,38	-0,02
21 ms	-0,17	0,20	0,19	0,22	0,35	0,28



Representation of the error and correction in function of delay

SUMMARY

I. Related work

II. Testbed description

III. Implementation results and comparison of TWR and SDS-TWR

IV. Artificial delays and TWR performance

V. Proposed error mitigation method

VI. Conclusion and future works

Conclusion and future works

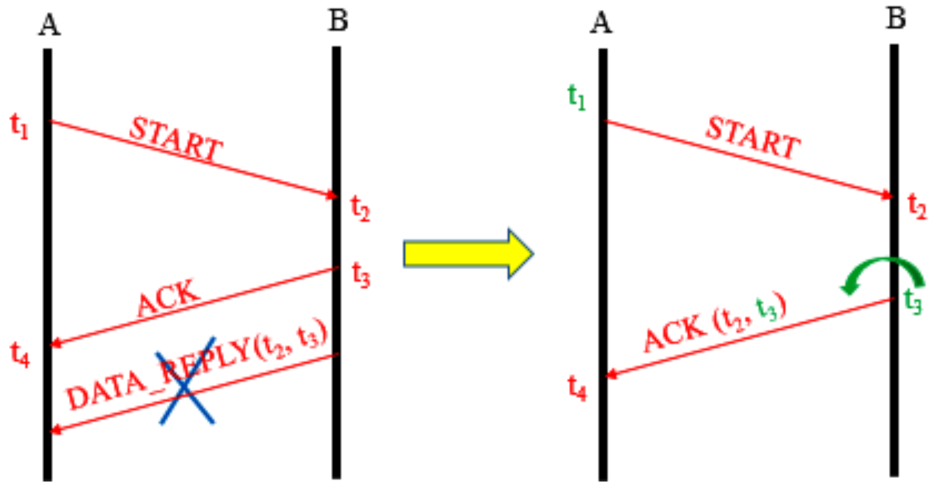
Conclusion

Proposition and implementation of an original correction on our testbed

With this correction, we obtained identical performances of TWR without delay

Another contribution

Improvement of the classic TWR protocol [4]



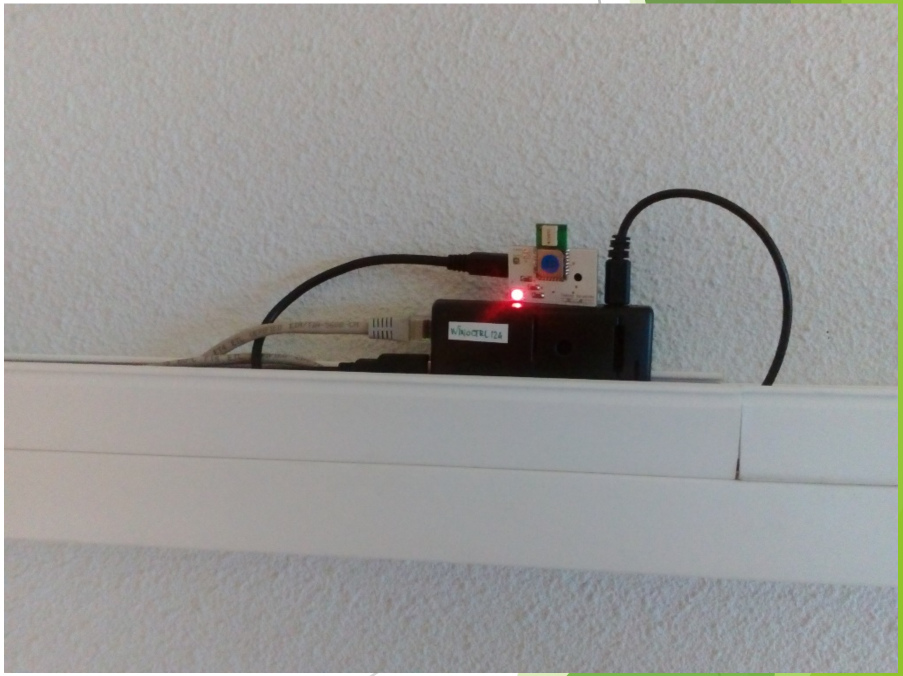
2M-TWR (2 Messages – TWR)

[4] A. van den Bossche, R. Dalcé, N.I. Fofana, T. Val, "DecaDuino: An Open Framework for Wireless Time-of-Flight Ranging Systems" In : Wireless Days, Toulouse (2016)

Conclusion and future works

Future works

Implementation of ranging protocol for localisation



Thank you for your attention