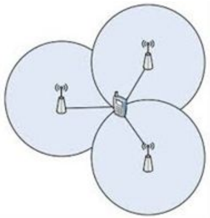
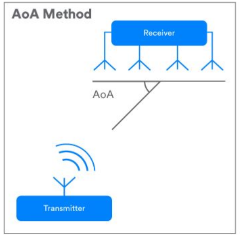
Localisation Technique

RF-based



Multi-Lateration

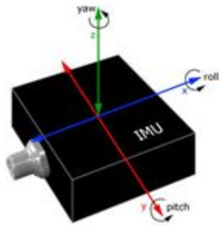
Pseudo-Ranging with Received Signal Strength Index (RSSI) or Round Trip Time (RTT)



Multi-Angulation

Angle of Arrival/ Angle of departure (AoA/AoD) with Bluetooth 5.1

IMU-based

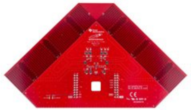


Pedestrian Dead Reckoning

Gyroscope, accelerometer and magnetometer

Comparison of Techniques

PDR	AoA/AoD	RSSI	RTT
• Very low-cost • Independent, low infrastructure support	• High accuracy • **0.25 m** Mean Absolute Error (MAE), with variance of **1.32 m** [1]	• Low-cost • Satisfactory accuracy MAE of ~**3 m** with user feedback[2]	• Low-cost • Less vulnerable to environmental factors • Potentially higher accuracy than RSSI
• Cumulative error • Knowledge of initial state	• Incompatibility (Bluetooth 5.1) • High cost • $150 array antenna	• Vulnerable to environmental factors • Accuracy can be improved	• High frequency clock required • Uncertainty in node internal processing time

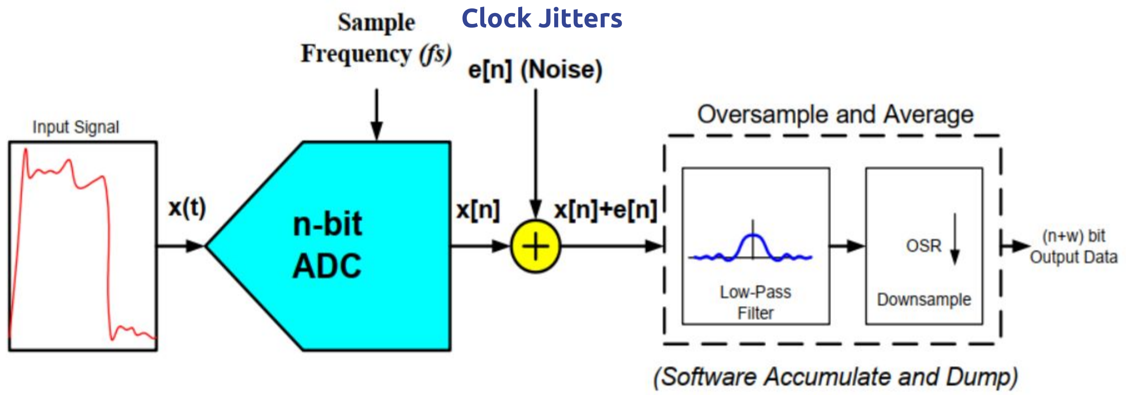


Oversampling and Averaging

- **Increase measurement resolution** [3]
- **Eliminate the need for expensive ADCs**
- **Reduce data throughput**
- **Applicable to system with ‘white noise’**

$$f_{os} = 4^{w} \cdot f_s$$

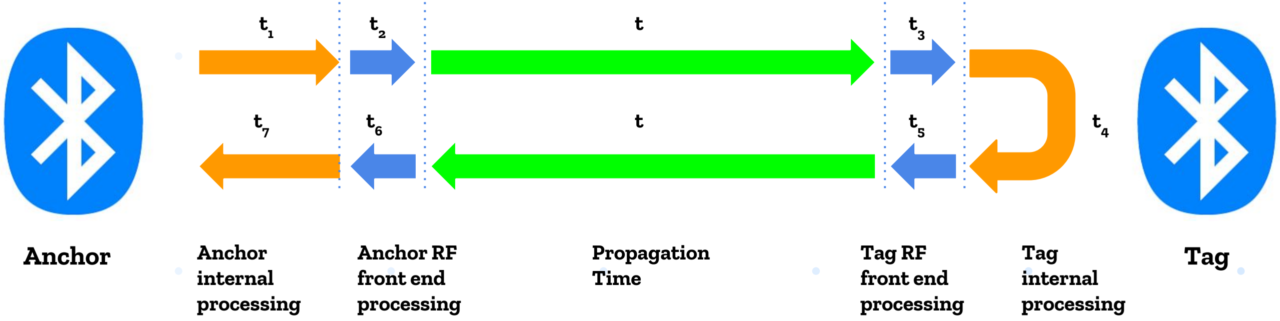
f_{os} : Oversampling frequency
W: Additional Bit of resolution
f_s : Sampling frequency



BLE RTT Ranging

$$RTT = 2*t$$

$$Delay = t_1 + t_2 + t_3 + t_4 + t_5 + t_6 + t_7$$



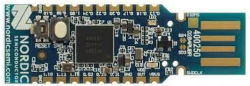
Key Limitations:

- Uncertainty in delay time
- System resolution

BLE RTT Ranging (Hardware Considerations)

Anchor Node
nRF52 Series DK

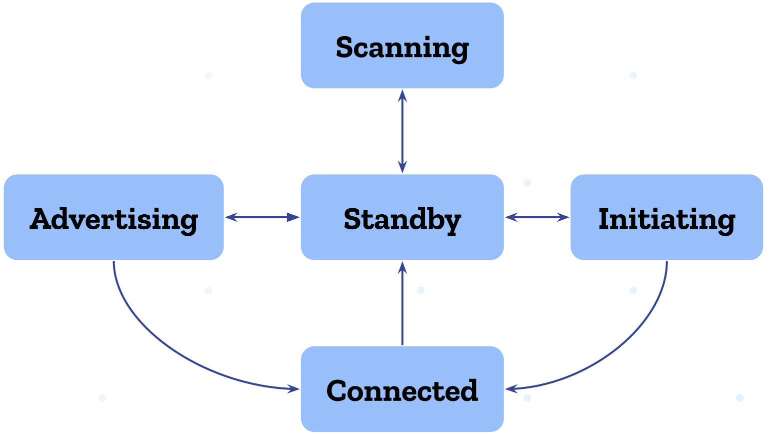
- **RADIO** peripheral to access into bluetooth low level state machine
- 16 MHz **TIMER** peripheral
- Programmable Peripheral Interconnect (**PPI**)

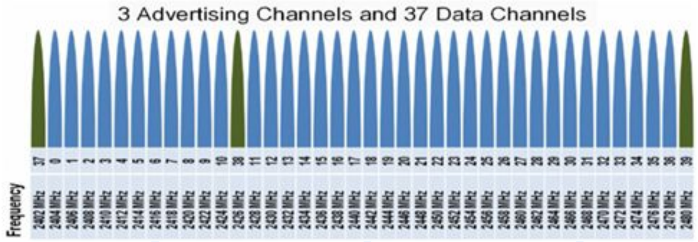


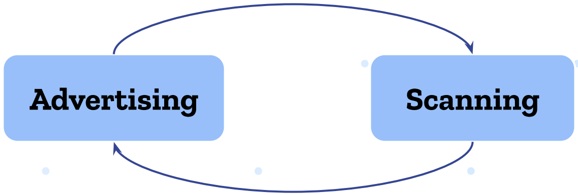
Tag Node
nRF52840 Dongle

- **Powerful**. Same features as nRF52840 DK
- **Compact**. 46.4 mm * 15.2 mm

BLE Link Layer State Machine

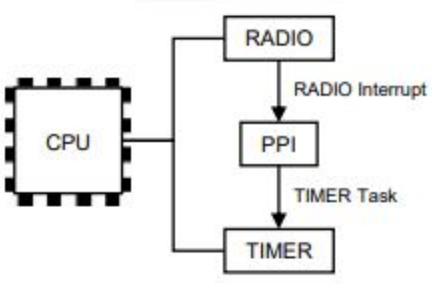




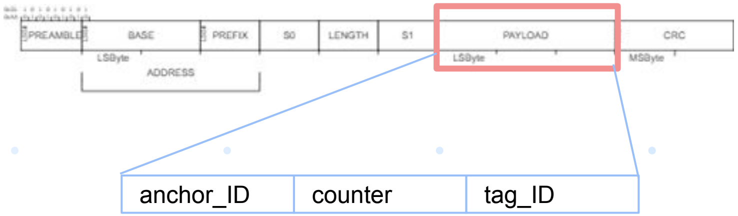


- Measure RTT without pairing
- Reduce processing time
- Increase sampling rate

Reducing Node Processing Time



Programmable Peripheral Interconnect (PPI)



Low Packet Size
Simple Logic at Tag

BLE RTT Ranging (System Resolution)

BLE Packet Propagation Speed:

3e8 m/s

TIMER peripheral frequency:

16 MHz

ToF resolution

3e8/ 16e6 = **18.75 m**

RTT resolution

(3e10/16e6)/2 = **9.375m**

$$f_{os} = 4^{w} \cdot f_{s}$$

Desired System resolution:

~ 1 m

Additional Bits:

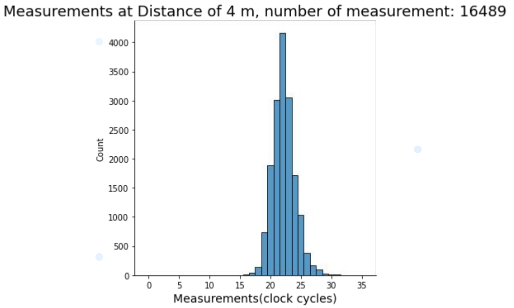
log2(9.375/1) =3.23

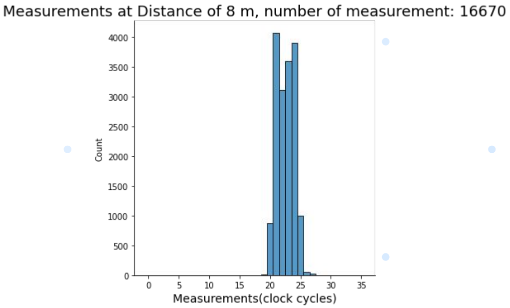
Oversampling Requirements:

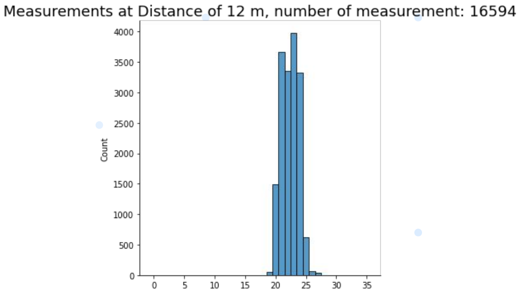
$4^{3.23}$ ~=**90 X**

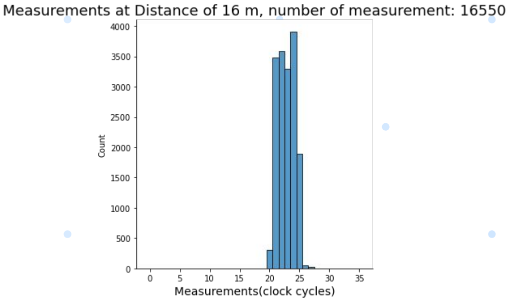
BLE RTT Ranging (test result)

NUS E1 Corridor





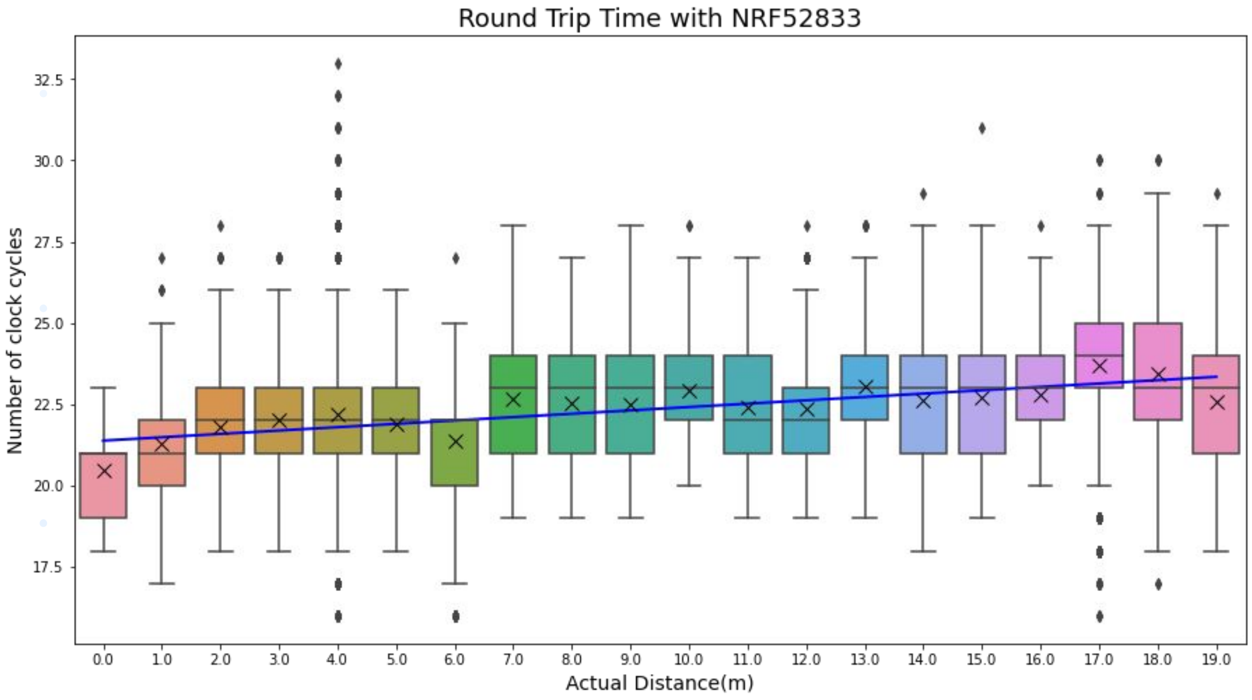




BLE RTT Ranging (test result)

$t = 0.1032*d - 21.386$

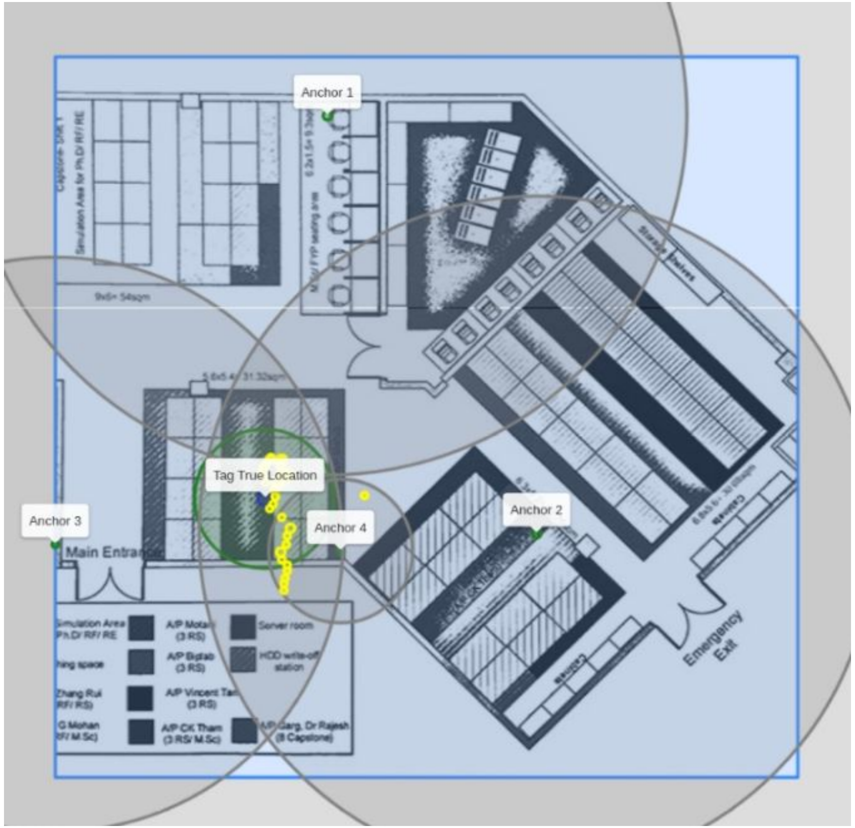
d : actual distance
t : clock cycle measured



Results

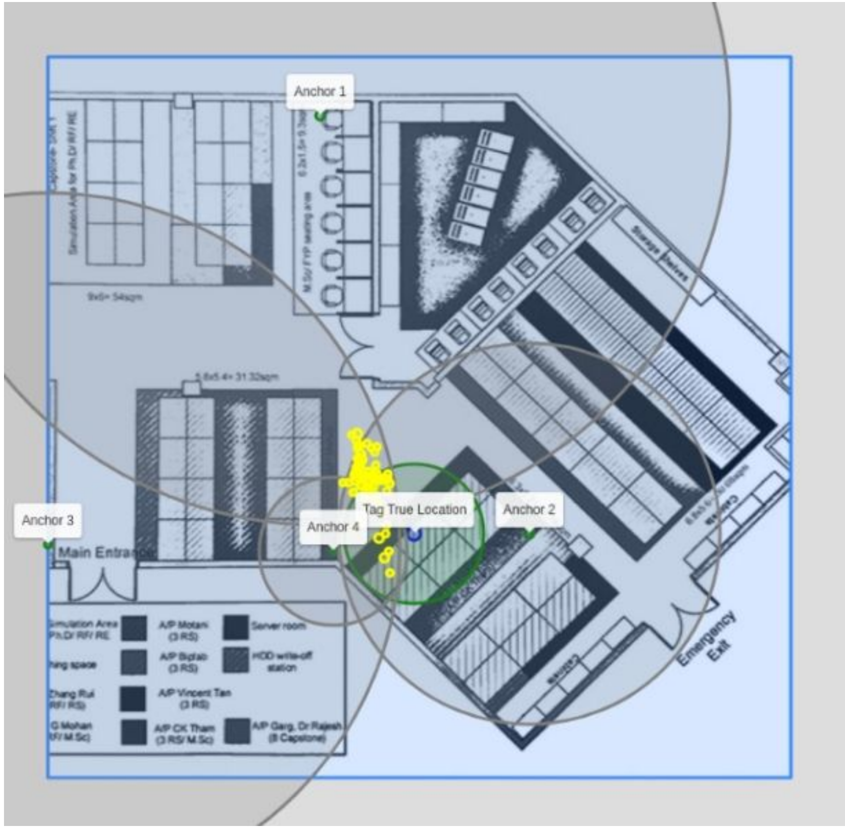
5

Results



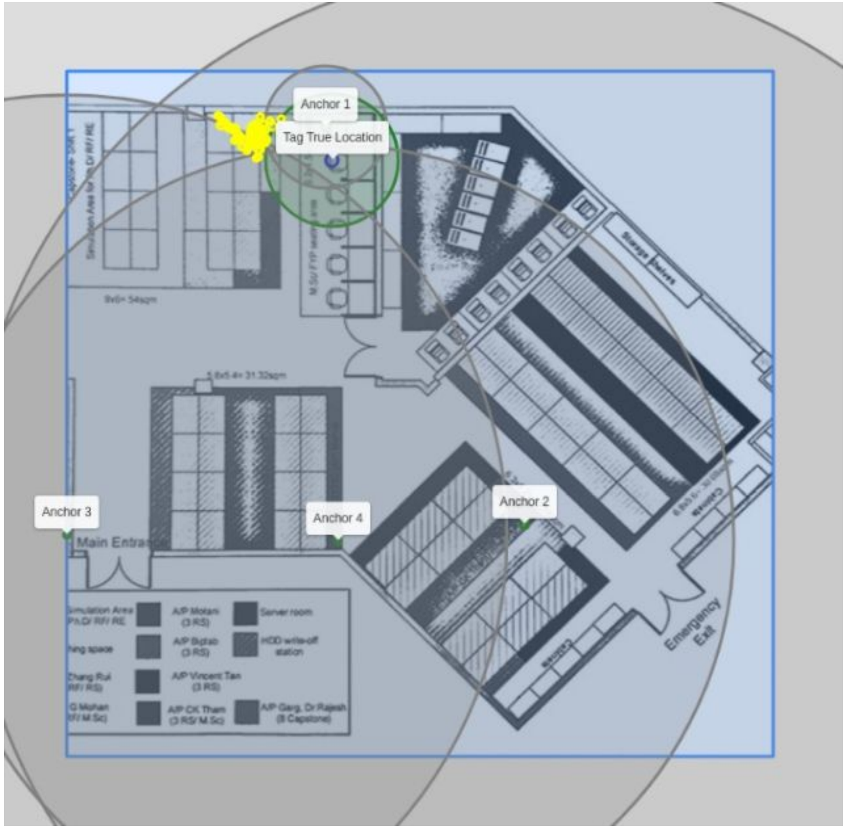
	x	y
truth	6	8
mean	6.451	8.162
var	0.167	1.138
mae		0.479

Results



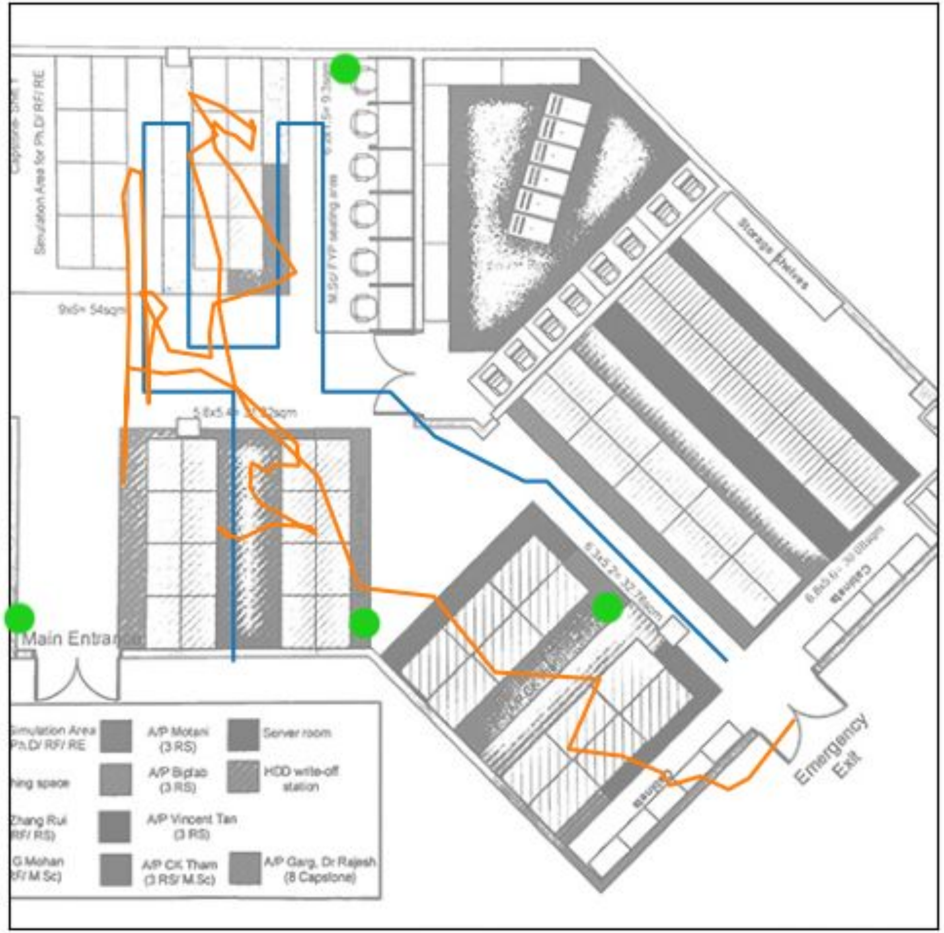
	x	y
truth	10	7.5
mean	9.242	8.479
var	0.132	0.737
mae		1.238

Results



	x	y
truth	8	18
mean	5.509	18.797
var	0.201	0.101
mae		2.615

Results


Main Entrance
Emergency Exit
Storage Shelves
Simulation Area Ph.D/ RF/ RE
A/P Motani (3 RS)
Server room
A/P Biplab (3 RS)
HDD write-off station
Zhang Rui RF/ RS)
A/P Vincent Tan (3 RS)
G Mohan RF/ M Sc)
A/P CK Tham (3 RS/ M.Sc)
A/P Garg, Dr Rajesh (8 Capstone)