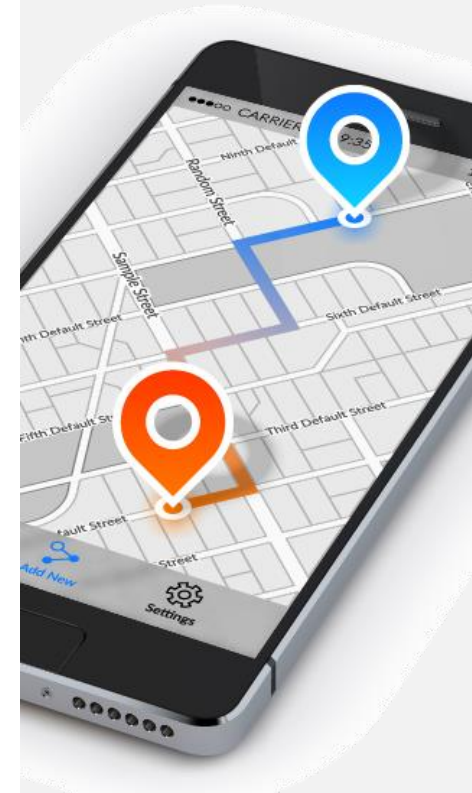
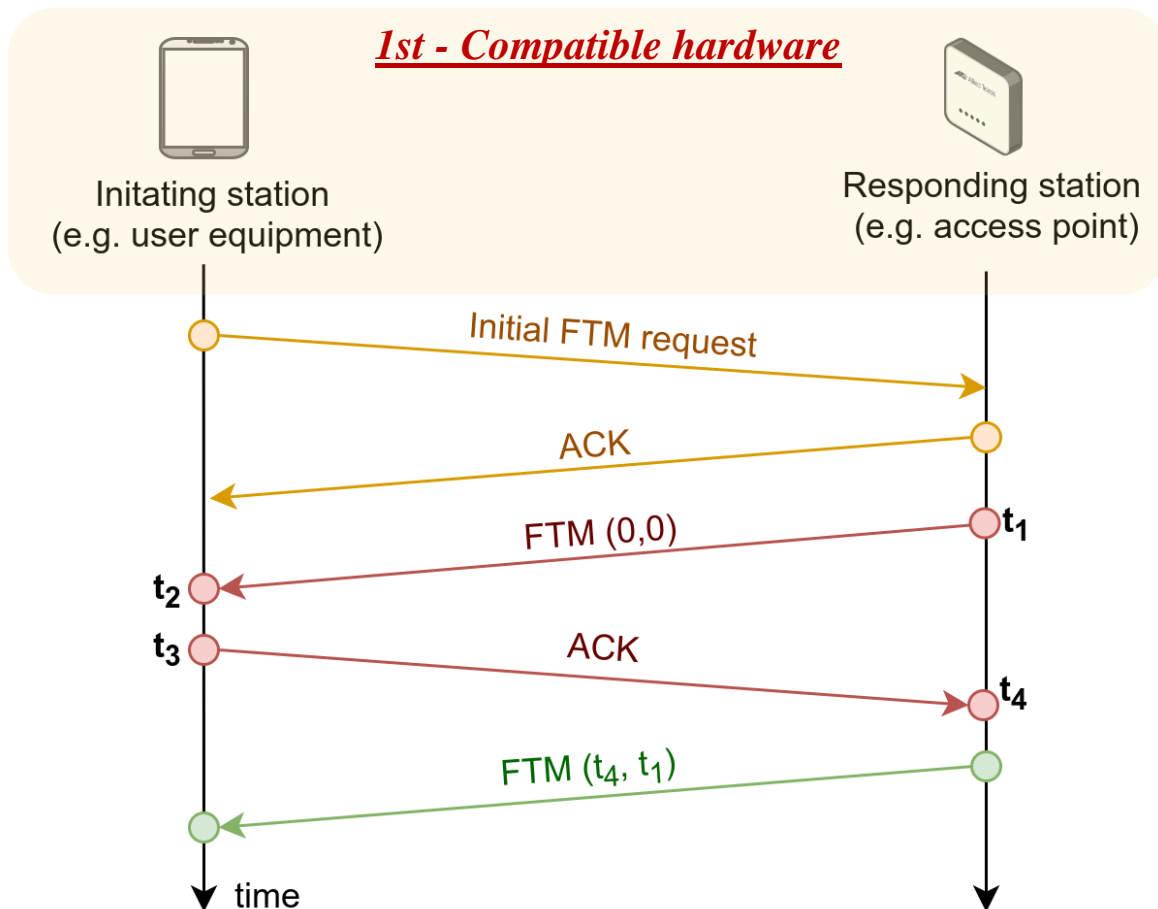


# AVAILABILITY AND PERFORMANCE ISSUES ON FTM HARDWARE

LBS demonstration  
 Carrer de Roc Boronat 117, 08018 Barcelona



How is the time of flight estimated?



$$TOF = \frac{1}{2}[(t_4 - t_1) - (t_3 - t_2)]$$

**2nd - System calibration**

*Two ways for access points to support the technology*

Announcers: announce 802.11mc capabilities



Compulabs WILD  
[COMPULABS, 2021]  
*Not recommended for new projects*



Google Nest Wi-Fi router  
[NEST-ROUTER, 2021]

Responders: capable of handling FTM frames



Google Wi-Fi AP  
[GOOGLE-AP, 2021]



Eero Mesh Wi-Fi  
[EERO, 2021]



Google Nest Wi-Fi Point  
[NEST-POINT, 2021]



StarLink Wi-Fi router  
[XLINK, 2021]



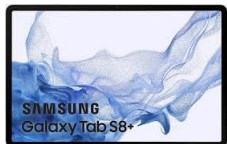
EE: ArubaOS 8.7 onwards

*Smartphones supporting the technology*

Brand	Models
Google	Pixel 1, 2, 2XL, 3, 3XL, 3a, 4, 4XL, 4a, 5, 5a, 6, 6a, 6 Pro
Xiaomi	Xiaomi 12 (Pro), Mi 11 (T, Pro), Mi 10 (T, Pro), Mi Note 10 (lite), Mi 9 (T) Redmi Note 9 (S, Pro), Redmi Mi 9T Pro, Redmi Note 8 (T), Redmi Note 5 Pro Redmi K20 (Pro), Xiaomi Redmi K30 Xiaomi Pad 5 (pro)
Samsung	Galaxy Note 10 (+, 5G, +5G), Galaxy S20 (+, 5G, +5G, Ultra 5G), Galaxy Tab S8, S8+, S8 Ultra
LG	G8X ThinQ, V50S ThinQ, V60 ThinQ, V30
Poco	X2, F3 (Pro), X3 NFC
Sharp	Aquos R3 SH-04L
Zebra	PS20, TC52/TC52HC, TC57, TC72, TC77, MC93, TC8300, VC8300, EC30, ET51, ET56, L10, CC600/CC6000, MC3300x, MC330x, TC52x, TC57x, EC50 (LAN, HC), EC55 (WAN), WT6300

*Smartphones supporting the technology*

- Hardware is ready, but is it software?
  - Any current device is potentially hardware compatible (firmware update)
  - Manufacturers decide **not enabling** the technology
  - Some devices lose capabilities on software upgrades (e.g. Redmi Note 9 series, Poco X3 NFC, Samsung Galaxy S20, etc.)
- Different manufacturers, models, bands... different range estimations
- Calibration is required to normalize RTT (or eventually range) estimations
  - Removing the bias according to the manufacturer/model and transmission band
  - Identify the artifacts introduced by each band

*Devices used for the experiment*

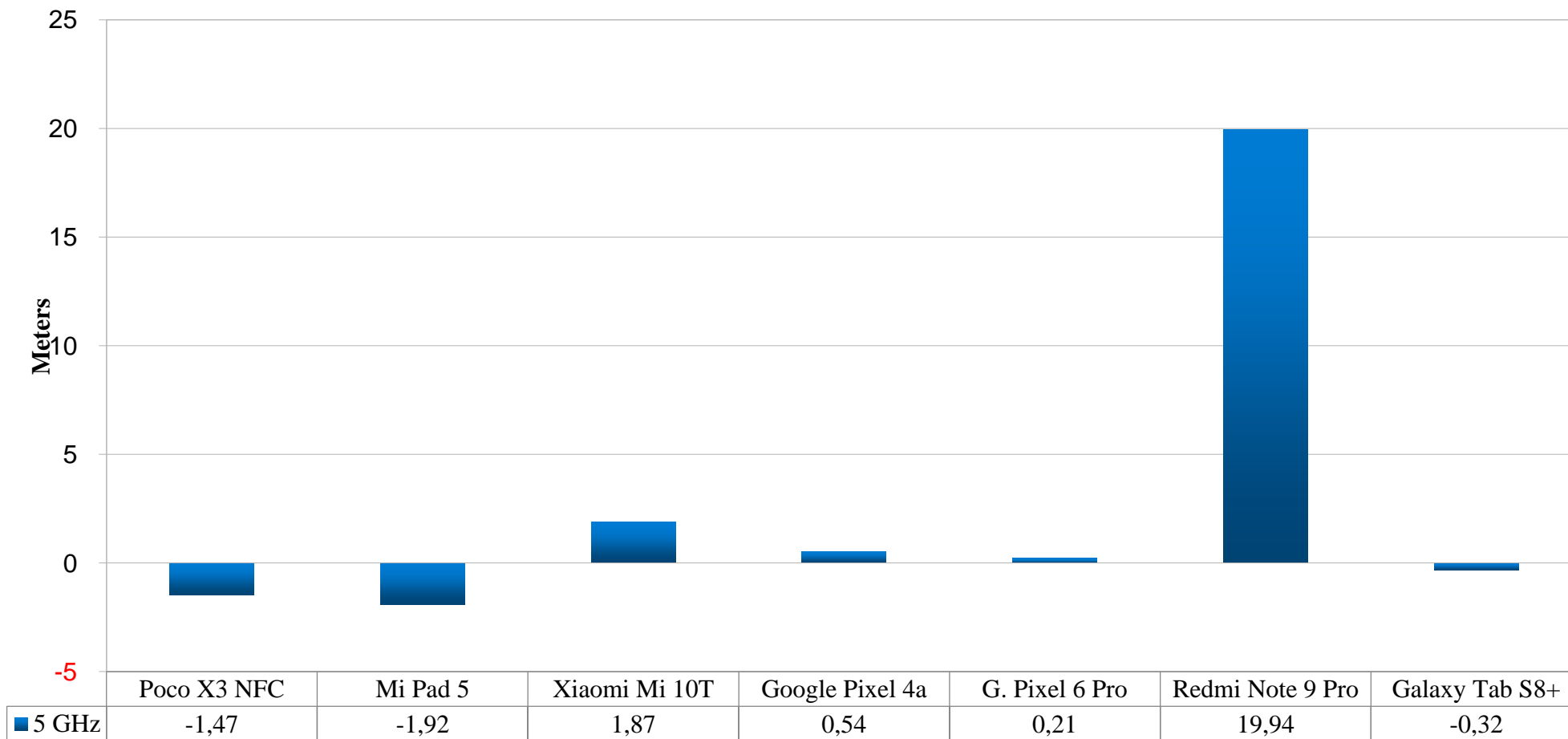
FTM estimation →



Parameter	Google Wi-Fi	Linksys Velop AC6600
Bans supporting positioning	5 GHz	2.4 and 5 GHz
5 GHz channel bandwidth	80 MHz	80 MHz
5 GHz channel number	42 (FCC-NII-1)	42 (FCC-NII-1) 106 (5.3 FCC-NII-2)

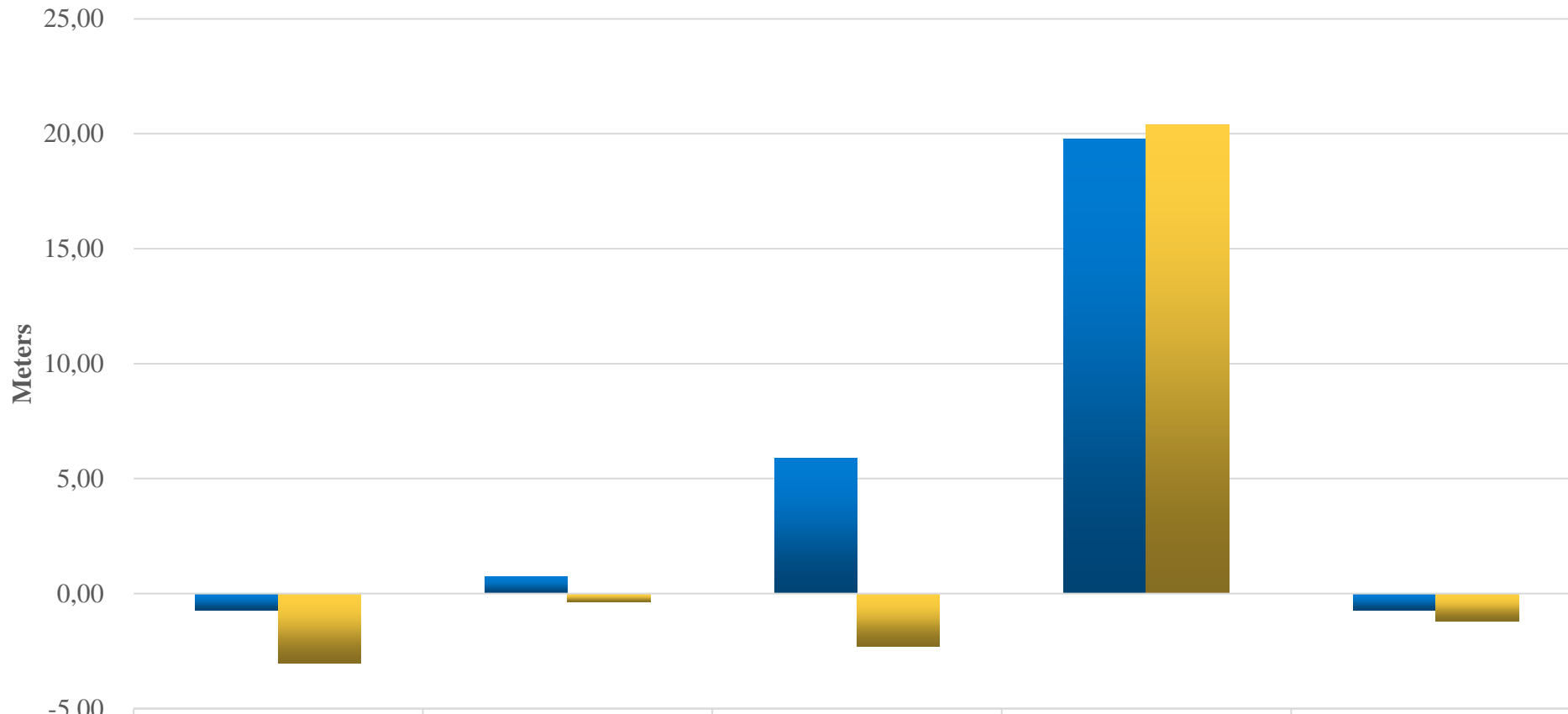
*Calibration figures*

## Google AP



*Calibration figures*

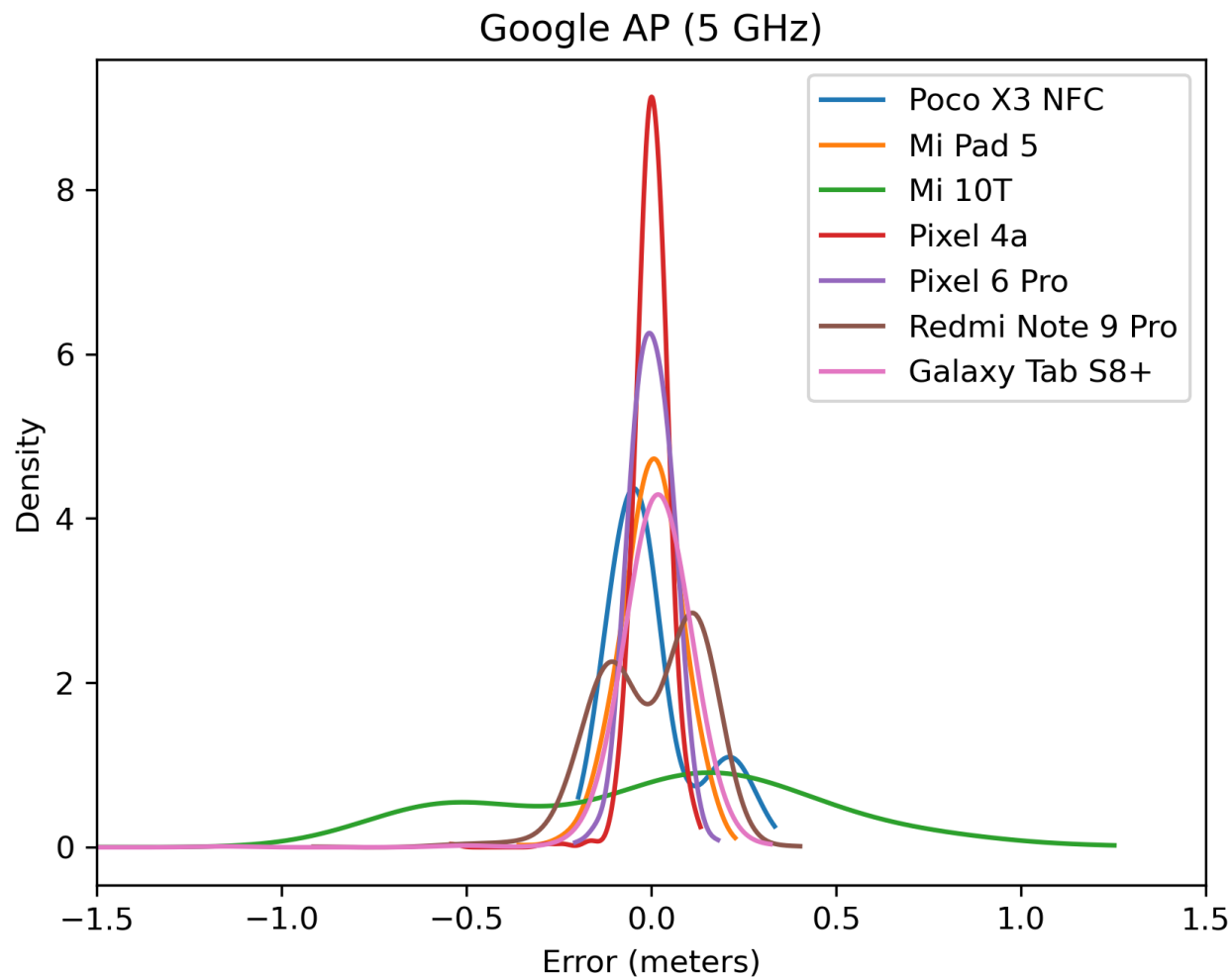
## Linksys AP



	Poco X3 NFC	Pixel 4a	Pixel 6 Pro	Redmi Note 9 Pro	Galaxy Tab S8+
■ Indoor	-0,72	0,73	5,89	19,76	-0,72
■ DFS	-3,02	-0,36	-2,31	20,39	-1,19

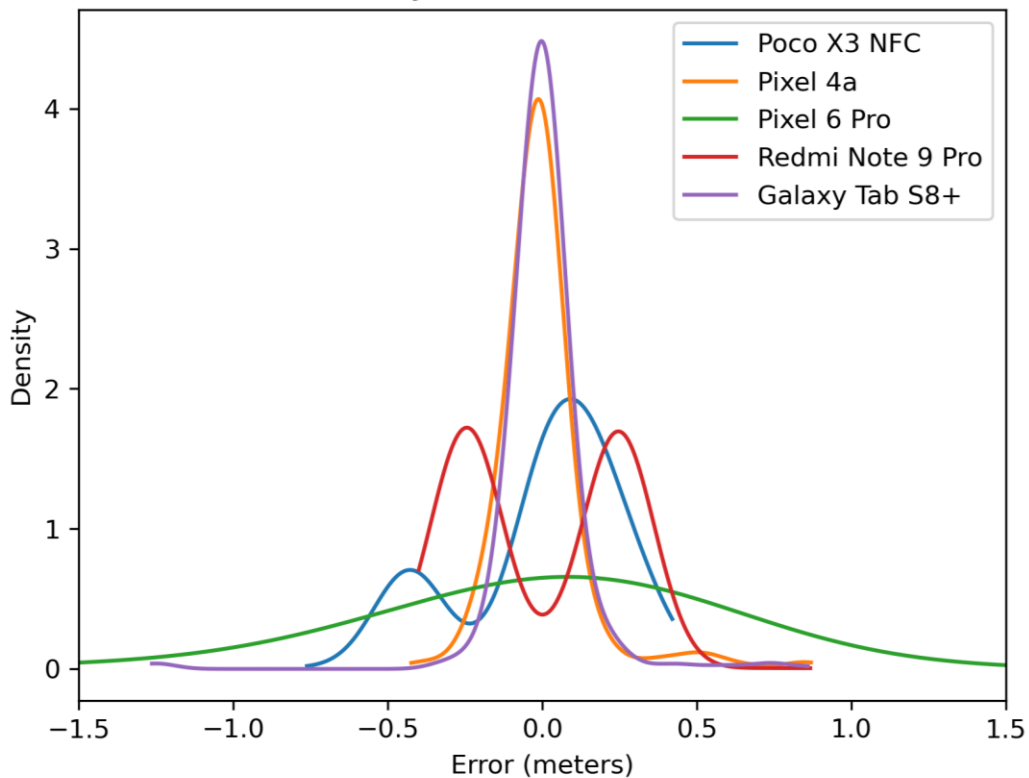


*Probability density function (once calibrated)*

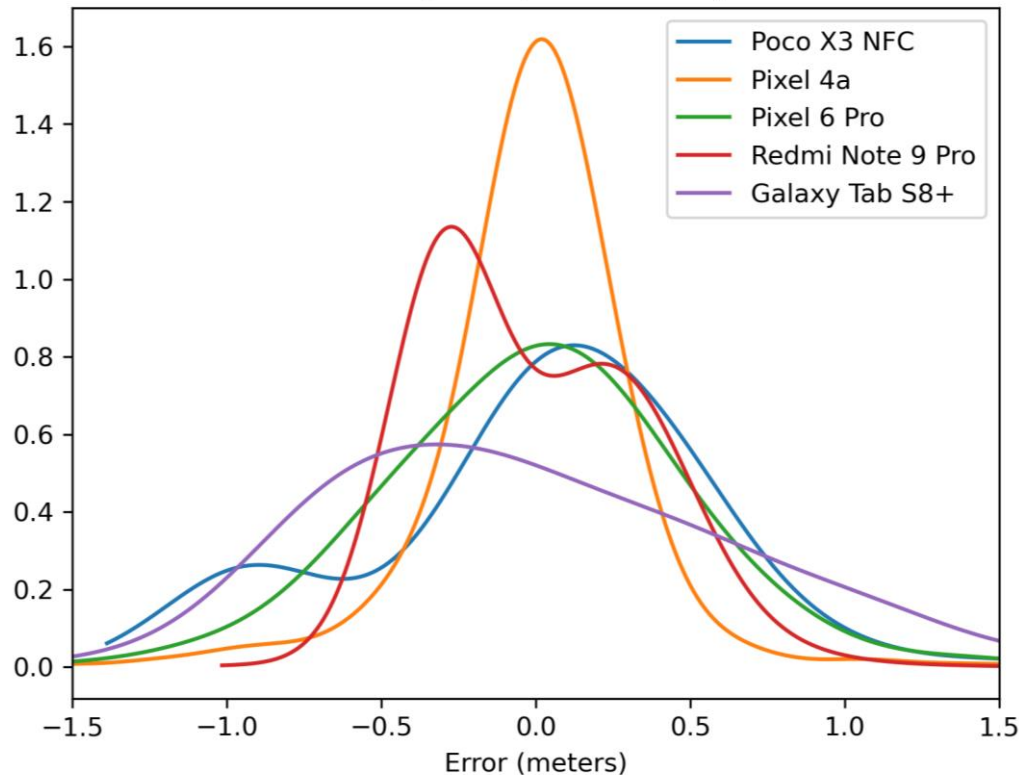


*Probability density function (once calibrated)*

Linksys AP (5 GHz - Indoor)



Linksys AP (5 GHz - DFS)



*What is the take away?*

- Hardware is already there.
- Only software support is often required.
- Calibration is required at a device and frequency band level

*Hardware threats*

*Hardware support*

*System calibration*

*Final remarks*

# THANK YOU

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